Indian Committee for International Union of Radio Science (URSI)

National Report 2002–2005

For presentation at the
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Preface

This Indian national report summarises the work done in the field of Radio Science in India during the period 2002-2005. The report will be presented in the forthcoming URSI General Assembly being held in New Delhi, India during October 23-29, 2005. The reports are grouped under the various Commissions of URSI. Due to logisitic problems, it is regretted that the report from Commission B could not be got in time for the final compilation of the volume.

In the preparation of these reports, various commission members from India have been extremely helpful and have spent considerable time and energy in ensuring the completeness of the reports. However, the volume may not be complete in all respects. We apologise, in case any important work done during this period has been inadvertently left out.

It is a pleasure to thank Shri Annabhat Joshi, Ms. Sunita Barve and Prof. D.J. Saikia of the National Centre for Radio Astrophysics of TIFR, Pune for their valuable help in the compilation of the document. We would also like to thank the Indian National Science Academy for all the help provided. In view of the organisation of the URSI in India this year, the Local Organising Committee of URSI will be producing more than a thousand copies of this document in the form of CDs. We wish to express our sincere thanks to them for their help and cooperation.

The Commissions included in the report and the authors who compiled them are:

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Contents

Commission A: Electromagnetic Metrology in India during 2002-2005

In India, the activities related to Electromagnetic Metrology are mainly centered in National Physical Laboratory (NPL), New Delhi. NPL has been engaged in the realization, establishment, development and maintenance of SI unit (Time), Primary, National Standards of various electrical, electronic and magnetic parameters. The division has participated in many international intercomparisons organized by BIPM, APMP and bilateral comparison to establish international traceability. It has also coordinated various proficiency testing programme under MoU between NPL and NABL.

NPL-India signed BIPM-MRA in October 1999. The BIPM global Mutual Recognition Arrangement (global MRA) requires National Metrology Institutes (NMIs) to have in place a recognized Quality System in order to,

- Establish the mutual confidence in measurement and Calibration Certificates issued by the NMI, and
- Thereby provide governments and other parties with a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs.

Global MRA indicates the requirements for a *Quality System* to be recognized. It was left to the regional metrology organizations (RMOs) to develop guidelines for acceptable quality systems. In case of our laboratory RMO is Asia Pacific Metrology Program (APMP). In order for the APMP to accept a quality system of an NMI as satisfying the requirements of the global MRA, it requires evidence demonstrating.

i) The implementation of a Quality System satisfying ISO/IEC 17025

ii) Technical Competence to provide a calibration and measurement service that can deliver the uncertainties

The compliance could be demonstrated through one of the following three pathways:

a) Third party accreditation, or

b) Certification to ISO 9001 and attestation by technical peers, or

c) *Attestation by a team consisting of Quality System Experts and Technical Peers*

NPL India has chosen the pathway C. This division has successfully completed the International Peer Review for the following parameters as per ISO/IEC 17025: Time & Frequency, Quantum Hall Resistance, Josephson Voltage & DC Standards, AC Power & Energy, AC High Voltage and High Current, LF Impedance, LF & HF Voltage, Current and RF Power, RF Attenuation & Impedance and DC High Voltage.

For further details please refer Appendix-C of BIPM-MRA on BIPM Website: www.bipm.org.

Time & Frequency Standards

NPL maintains Indian Standard Time (IST) through a bank of Cesium Atomic Clocks. Time scale of NPL is continuously traceable to UTC of BIPM through GPS Network and has a stability of 6.4×10^{-13} for averaging over one day according to Circular T.

The study on the effect of scintillation on GPS Timing accuracy has been carried out for first time.

A Rubidium Frequency Standard in the section has been indigenously upgraded and further development of Coherent Population Trapping (CPT) based clocks is being planned.

NPL disseminates IST via INSAT known as STFS Service providing time transfer accuracy of the order of 1 ms and also through Telephone Network called Teleclock Service having accuracy of the order of 1 s. There are now more than 50 dedicated users of STFS time service located all over the country and more than 700 clocks are linked to the Teleclock service.

To further improve the stability and accuracy of primary clock, work on indigenous development of Laser Cooled Cesium Fountain Clock have started. For this purpose, ultra-low noise cavity stabilized X-band oscillator and Precision Temperature Controller with PID control have been developed. A 9.192 GHz microwave synthesizer for Cs-Fountain was completed and tested. A conjugate regenerative divider for low noise frequency synthesis was also designed and developed. Theoretical studies on the use of Squeezed vacuum to achieve higher cooling force in Cesium Fountain Clock were undertaken.

Quantum Hall Resistance Standards & Superconducting Devices

Quantum Hall Resistance Standard

NPL maintains primary standard of dc resistance based on integer quantum Hall effect that provides an invariable reference standard of resistance linked to the fundamental physical constants. The standard is used to calibrate a secondary 1 kW resistor regularly at different temperatures with combined expanded uncertainty (at coverage factor k=2) of 0.08 ppm.

High-T_c SQUID setup for measurement of magnetic fluctuations

High-T_c SQUID setup for measurement of magnetic noise in manganite/superconducting sample has been developed. The sensitivity of the high-T_c SQUID is 10^{-11}T/Ö Hz

Josephson Voltage and DC Current, Voltage & Resistance Standards

Josephson Voltage Standard

Josephson series array voltage standard is maintained at 1 volt level. The ‘National Standard’ of volt is being calibrated at regular interval of six months against the Josephson Voltage Standard (JVS).

DC Current, Voltage and Resistance Standards

An automated bank of Zener Reference Standard has been established as a ‘National Standard’ of DC Voltage with an uncertainty of £ ±1.2 ppm.

AC Power & Energy Standards

A Bialteral intercomparison was done during the technical Audit from 12th January to 16th January with PTB Geramny. The artifact was C-1/2 Wattconverter and was compared at 120 V, 5A for Unity power factor, 0.5PF (lag and lead) 0.25PF (lag & lead), 0.1PF (lag & lead) and 0.01PF(lag & lead). The values are in very close agreement and all the uncertainty bars of NPLI are overlapping over those of PTB Germany.

A five position Calibration Bench for energy meters have been installed with Uncertainty ± 100ppm related to Apparent power.

AC High Current & High Voltage Standards

This section is maintaining National Standards of AC High Current and High Voltage Ratios at power frequencies (50Hz) by using Reference Standard Current Transformers and Reference Standard Voltage Transformers.

The calibration facilities for the calibration of Current Transformer Testing Sets have been improved from ± 0.005% to ± 0.001% and all the Current Transformer related measurements are now traceable to International Standards.

The facility for the calibration of Voltage Transformers has been upgraded. The calibration range

of voltage ratios has been extended from 40 kV/100 V to 100 kV/100 V and from 3 kV/100 V down to 100 V/100V at 50 Hz. The voltage ratio measurements are traceable to International standards with an uncertainty of ± 0.005%.

LF and HF Impedance Standards

This Group is maintaining primary standards of capacitance, Calculable Cross Capacitance, based on Lampard-Thompson theorem. The unit of inductance, Henry, is realized from capacitance using Maxwell-Wien Bridge. The unit of resistance, Ohm, is also realized from capacitance using Quadrature Bridge and other precision ac bridges. The ac voltage ratio is derived through absolute calibration of Inductive Voltage Dividers. This activity also provides apex level calibration for the above parameters at low and high frequency, to various calibration laboratories and R & D organizations.

As primary standards of HF impedance, a set of high precision coaxial reference air lines with traceability to calculable cross capacitor has been set up.

DC High Voltage Standard

DC High Voltage Standards Laboratory up to 100 kV has been established kV, traceable to Josephson Voltage Standard, NPL, India.

In India, this is one of the first calibration facility for calibration of HV sources, kV meters, probes & dividers up to 100 kV using this facility. The uncertainty of measurement is as follows:

	Equipment	Range	Uncertainty
1.	HV sources	1-100kV	50 ppm
2.	HV probes/dividers	1-100kV	100 ppm
3.	kV meters	1-100kV	100 ppm

LF & HF Voltage, Current & RF Power Standards

As per the BIPM-MRA requirement we have participated in BIPM Key Comparison 'CCEM K6.c'. BIPM had provisionally accepted the results of this comparison in Key Comparison Data Base (KCDB) subject to final approval of its report by JCRB. In January 2005, JCRB has accepted the final report this Key Comparison and our results have been accepted for establishment of formal Equivalence of our ac-dc transfer standards in the frequency range 1 MHz to 100 MHz.

Frequency range of RF power measurement has been extended to 26 GHz from 18 GHz with traceability to PTB, Germany. RF Power level measurement range has also been extended to 30 watts from existing 100 mW in the frequency range 1MHz to 1000 MHz.

RF Attenuation and Impedance

The calibration facilities in attenuation and impedance parameters established in the frequency range 30 MHz to 40 GHz in 50 ohm coaxial system and 3.95 to 40 GHz in waveguide system (G-band, Xn-band, X-band, Ku-band, K-band and Ka-band) are being used for the calibration of transfer standards of attenuation and impedance of various user organizations

Magnetic Standards

NMR Gaussmeter, primary standard for the measurement of magnetic field was calibrated for frequency against the National Standard maintained by Time & Frequency Division.

The magnetic susceptibility of a small part of the F_2 class weight made by Austentitic stainless steel was measured in accordance with OIML recommendation R-111. This measurement is based on Guoy balance and susceptibility measured was 0.41 in SI unit.

Vibrating Sample Magnetometer (VSM) system, a new facility has been established for industrial use and R&D work in the area of magnetic materials.

R&D work on conducting polymer has been carried out on the behaviour of ferromagnetic dopants in polyaniline polymers matrix for electromagnetic interference (EMI) shielding.

NPL participates regularly in different Key-comparison campaigns organizes many Proficiency Testing (PT) programmes.

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Commission C: Signal and Systems

1-510

Signal processing is performing any operation on any signal by a system. Here we summarize the research carried out in India during the period of 2002-2005. The list is exhaustive but may not be complete.

Speech and Audio Processing

15, 26, 57, 60, 61, 66, 68, 104,105,143-146, 157,158,159, 173, 185, 186, 191, 201, 203,243-246, 251,256-283, 296, 311, 312, 315-31, 332, 336, 356-359, 372-379, 394, 408, 433-435, 439, 469, 471-473, 482, 488, 491, 494, 500

Researchers have experimented with different ways to convert text into speech. Individuality transformation is an important way to achieve personalized text-to-speech synthesis with small amount of training data. Voice fonts encompass a set of descriptors of speech individuality, such as, spectral envelope, pitch period, speaking rate, jitter, etc. All the voice fonts descriptors of a speaker are estimated from the speaker's speech corpus automatically to create the voice fonts of the speaker. The voice fonts descriptors of a speaker are independent of any source-target pair involved in the individuality transformation and thus a parallel speech corpus is not required to estimate these descriptors. These descriptors, therefore, can be used to transform the individuality of a speech utterance from the given speaker to any other speaker or vice versa.

Also frequency-warping function that separates the speaker dependencies from the inherent characterization of the sound has been obtained. Such functions allow the enunciations of different speakers to be transformed into each other. Speech processing for hearing aids has also been carried out.

Wireless Communication

13, 16,17,19,20,22,23,30,31,32,35,43,51-56, 67, 69-71, 74, 80-91, 93,94, 96-98, 102, 103, 106, 110-115, 119, 149-156, 160-166, 197, 198, 204, 208-224, 229-231, 247, 249, 254, 284, 288-290, 293. 295, 297, 303-306, 310, 313, 321-331, 341, 382-385, 388-393, 396, 397, 403, 406, 409, 415, 417, 418, 430, 432, 442-448, 452, 454, 456, 458, 460, 461-464, 468, 470, 475, 476, 492, 496-498, 510

Researchers have worked in mainly two areas; one is code design for wireless MIMO channels and second is the study and analysis of the performance of the complete system.

With the advancement in technology, a set of single transmitter and single receiver is replaced by a set of multiple transmitters and multiple receivers. This multiple transmitter and multiple receiver system (MIMO system) improve the performance of the communication system by increasing the spatial diversity.

Studies have been also been carried out on algebraic codes to cater for the requirement of MIMO system. A relation between Abelian codes and DFT (Discrete Fourier Transform) is established which has help in understanding this codes in better way. New classes of space-time-frequency block codes for multi-antenna orthogonal frequency division multiplexing (MIMO-OFDM) transmissions over frequency selective Rayleigh fading channels has also been studied. Also Space Time Trellis Code (STTC) was constructed using delay diversity. A sufficient condition for this STTC to achieve full-diversity, based on the delay diversity scheme is established.

The performance analysis of MIMO systems is of interest to many researchers. Various noise and signals scenarios under various channel conditions are simulated to study the performance of the designed codes. Different analytical tools for the performance analysis of coded communication system, on various kinds of channel is designed. Estimation of signal to noise ratio (SNR) in various channel and noise condition is performed. System through, channel capacity and other required system parameters have been calculated.

Text Processing

34, 58,76,196, 316, 335, 356, 357, 437

Text processing is always an interesting research area. Classification of text or conversion of text from one language to another is of interest to researchers. Schemes have been developed to translate unknown words (nouns, words of different language) that are used very frequently in our day-to-day life without expanding the dictionary. Different algorithms have been developed for translating the word-pairs that have opposing meanings and have same initial character, such as, segmentating and decompositing of Devanagari composite characters/symbols into their constituent symbols.

Medical signal processing

21, 78,79,182, 183, 194, 250, 255, 339, 366-370, 419-422, 426, 427

The Electroencephalogram (EEG) is a biological signal that represents the electrical activity of the brain. A commonly encountered problem in clinical practice during EEC recording is the 'blanking' of the EEC signal due to blinking of the user's eyes. Simple techniques for the detection and subsequent de-noising of these ocular artifacts using Haar wavelets of high orders have been suggested. Systems have been designed to monitor Anaesthesia and Pain using ECG signal only. Automatic detection and classification of cardiac arrhythmias using EGC signal has been suggested. Extraction of the fetal electrocardiogram (FECG) from maternal cutaneous electrode recordings is formulated. Multivariate techniques for visualizing gene regulatory networks using independent components analysis (ICA) techniques have been developed.

Image and Video Processing

25, 45, 47-50, 64, 129, 133-140, 147, 167-171, 184, 300, 302, 307-309, 343, 353-355, 371, 386, 395, 426-429, 455, 465, 467, 481, 502-509

Researchers have carried out estimation of motion from two successive frames of smeared images. The blurring system is modeled as temporal integration of instantaneous images and has been estimated using System Identification Theory. A very low bit rate video codec which achieves a bit rate of as low as about 25 Kbps for test sequences having frame rate of 7 fps and frame size of 256×256 pixels has been implemented.

To provide multimedia applications with new functionalities, such as content-based interactivity and scalability, the new video coding standard, MPEG-4 relies on content-based representation. A fast yet robust color segmentation algorithm based on DWT and k-means clustering is designed. The problem of simultaneous estimation of scene structure and restoration of images from blurred photometric measurements image retrieval scheme based on projectively invariant features has recently been addressed. A method for automatic transformation of the color planes to match the skin color model learnt for a fixed illumination has also been presented.

Wavelets

33, 73, 120-122, 125, 130, 169, 170,225, 257, 314, 320, 344, 352, 360, 362, 449, 455, 465

The theory of wavelets has been used quite extensively into many applications. A method for texture synthesis using angular wavelet frames (AWF) is suggested. Digital watermarking is carried out with the 3-band wavelet decomposition. A wavelet based detection technique for multiple single pixel dim targets in IR image sequence in the presence of clutter and noise, for fast image retrieval and video watermarking have been suggested. A single-frame, learning-based super-resolution image restoration technique by using the wavelet domain is also suggested. Some algorithms to detect and subsequent de-noise of the ocular artifacts in ECG recording using wavelets has been suggested.

Fuzzy logic and Neural network

24, 38, 41, 44, 46, 58, 65, 75, 129, 130, 137, 139-140, 142, 184, 195, 199, 200, 286, 287, 355, 363-366, 423-425, 457, 477, 495-501

A neural network based tracking algorithm, incorporating interacting multiple model to track both maneuvering and non-maneuvering targets simultaneously in the presence of dense clutter is suggested. The tracking algorithm based on interacting multiple model (MM) that exploits the genetic algorithm for data association. Many systems like load scheduling system, PID controller, fault classifier etc. have been designed using Fuzzy logic.

Networking

36, 42, 77, 95, 107, 117, 123, 124, 126, 127, 141, 148, 176, 181, 205, 206, 227, 232, 285, 298, 338, 340, 387, 398-405, 416, 436, 459, 489, 499

The comparison of the performance of APACE (Adaptive Prediction based Approach for Congestion Estimation) with other existing AQM (Active Queue Management) schemes in networks having both single and multiple bottleneck links is carried out.

Architecture for an IP address lookup engine based on programmable finite-state machines (FSMs) is suggested.

Mechanisms to obtain timely and consistency-preserving updates for dynamic data by pulling data from the source at strategically chosen points in time, providing Quality of Service (QoS) guarantees has been worked out.

Underwater Signal Processing

27, 28, 29, 62, 63, 87, 347-351, 366, 416

Sea has many acoustic sources. These sources act as noise source in underwater communication. The design of underwater communication is a step towards designing a reliable acoustic communication system. Sea Mammals have a very excellent communication system, an active study in performed to study these natural systems so that they can be used to improve the present system.

Underwater channel modeling is also under its way, this is quite interesting and challenging task because of dispersive nature..

Sensor Array Signal Processing

4-12, 132, 202, 207, 345, 347, 349-351, 360-362, 450

Several novel algorithms for DOA estimation and beamforming for different types of sources such as wideband, nearfield, spread and sources having non-zero mean has been developed. A "spatial-only" model for spread, broadband and broadband spread sources has been formulated to reformulate the problem of their DOA estimation in a simple and elegant way involving only one-dimensional search. Ambiguities present in the array designs have been studied.

Watermarking

131, 188-190, 228, 342

Watermarking is a way to hide information. Watermark is added to the cover-signal in order to convey the hidden data. Recently it has become an important research area. New and effective watermarker based on wavelets and other signal processing schemes are designed for audio, video, text and other kinds of signals. Designed water markers are analyzed for various conditions.

DSP Algorithms

2, 37, 38, 92, 100, 108, 118, 172, 236-238, 242, 299, 380, 391, 440, 441, 451, 453, 474, 479, 480

Digital signal processing is processing of digital signals. Sometimes the processing in one domain becomes difficult to perform or analyze then one defines transform to ease out the processing and to also bring out the hidden information. Implementing a algorithm in an efficient way always brings

down the implementation cost, hence always desired. Many efforts have been made for this purpose.

Classification and Detection

3, 14, 18, 39, 40, 72, 75, 101, 109-116, 128, 167, 174, 175, 199, 226, 233-235, 253, 256-283, 291, 292, 346, 348, 351, 427, 352, 481

Detecting and classifying signals into predetermined category is always of great interest to researchers. Signal may be voice signal for speaker identification or it may be ship radiated noise for detecting particular kind of ship or may be text signal to classify documents into its class. It requires finding the correct and optimal feature set and then designing the effecting classification algorithm.

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Commission D: R & D in Photonics in India during 2002-2005

The field of Photonics, which emerged with the invention of the laser in 1960, deals with generation, detection, transmission, storage, processing, etc. of photons (light). During the past four decades it has found and continues to find innumerable applications in communication, sensing, spectroscopy, metrology, basic sciences, etc. There are a number of Institutes in India where work in the general area of Photonics is being carried out. The present report is a compilation of the activities in some of the Institutes in the area of Photonics during the past three years.

The R & D work in Photonics can be broadly classified into the following areas:

1. Fiber optics
2. Optical communications and networking
3. Optoelectronic devices
4. Photonic crystals
5. Quantum optics
6. Integrated optics
7. Nonlinear optics
8. Adaptive optics
9. Lasers
10. Bio Photonics
11. Instrumentation
12. Miscellaneous

The report includes activities in the above areas carried out at the following institutes in India during the past three years:

Bhabha Atomic Research Center (BARC), Mumbai.
Center for Advanced Technology (CAT), Indore
Center for Development of Telematics (C-DoT), Delhi
Central Electronics Engineering Research Institute (CEERI), Pilani
Central Glass and Ceramics Research Institute (CGCRI), Kolkata
Cochin University of Science and Technology (CUSAT), Kochi
Indian Institute of Science (IISc), Bangalore
Indian Institute of Technology Bombay (IITB)
Indian Institute of Technology Delhi (IITD)
Indian Institute of Technology Kanpur (IITK)
Indian Institute of Technology Kharagpur (IITKgp)
Indian Institute of Technology Madras (IITM)
Instruments Research Development Establishment (IRDE), Dehradun
Jawaharlal Nehru University (JNU), Delhi
Laser Science and Technology Center (LASTEC), Delhi

1. Fiber optics

CGCRI: Optical amplifier for application in CATV has been developed in collaboration with NeST, Cochin. High concentration EDF developed at CGCRI has been used for developing the amplifiers. The amplifier is used to increase the distance between repeaters or nodes to 10-20 km vs. the 1-5 km usually obtained with coaxial metallic cable in a CATV network and to boost a signal before splitting it among many user nodes. The complete integration has been carried out at NeST and tested at CGCRI. After environmental testing, few amplifier units have been deployed in real CATV network at Indian Cable-Net Co. Ltd (RPG Netcom), and Cablecom, Kolkata and Incable, Mumbai for field trial and the performance of the amplifiers were certified as satisfactory to present industrial standard. C-band WDM amplifier is in the process of development at CGCRI and participation of BSNL is expected shortly during field trial. Radiation soft optical fibre for dosimetry application has been developed.Photosensitive fibres are now being fabricated on regular basis for developing FBGs using additional dopants for enhancing the photosensitivity.Apart from the above activites, institute has taken up programme for developing nano-photonic materials particularly through sol-gel routes.

CUSAT: Work in the field of fibre optics can be broadly divided into a) drawing of polymer optical fibre and its characterization b) development of various fibre optic sensors. A polymer optical fibre drawing facility has recently been set up at International School of Photonics . PMMA (Poly methyl metha acrylate) based fibre has been drawn successfully . One of the important advantages of the fibre drawing machine is that one can draw dye doped polymer optical fibre as well. Preliminary studies show gain in the dye doped polymer fibre and the same can be exploited to amplify weak coherent signals in the visible region. Dye doped planar wave guide structures show gain as well as selective excitation of modes. Sol gel technique was employed to fabricate polymer based Optical Integrated components . Fibre optic sensors to determine the contaminants in water and to measure the level of polluting gases have been developed based on evanescent wave absorption method. These sensors were observed to have very high dynamic range and extremely high sensitivity of the order of parts per billion. A class of fiber optic sensors based on side polished fibres show extremely good performance as sensitive refractometers as well as trace analyzers. Fiber optic sensors have also been developed to study the health of civil structures .Fibre optic sensors based on long period grating structures and microbends have also been developed in this laboratory.

IITB: The research work on the development of a WDM source for fiber-optic applications using the nonlinear optical properties of silica fiber was initiated for the first time in the country in 1999. The primary step of the design involves the amplification of a GHz frequency beat signal in a high-power Erbium-doped fiber amplifier (EDFA). This is followed by time-domain shaping to a train of picosecond duration pulses by passing the amplified beat signal through a combination of suitable fibers in an appropriate sequence for the effects of dispersion and nonlinearity to be utilized effectively. This results simultaneously in the spectral enrichment of the pulses. Multiple channels may be extracted from the spectral domain filtering process with a demultiplexer and subsequently modulated at the required rates for data transfer. The entire design of this source has been computationally modeled in-house. Hardware work on the high-power EDFA using a 980 nm pump laser and the spectral enrichment studies have yielded very satisfactory results. The utility of such a source for both synchronous and asynchronous data transfer applications have been analyzed. The main advantages of this source design are related to its scalability for data rates of 40 GHz and more, along with the capability to generate a throughput of hundreds of GHz, at a fraction of the cost of a conventional WDM source.

Design of flat gain broad band amplifier have been investigated. A Genetic Algorithm based optimization studies have been carried out for gain flatting of the Raman amplifier. Wavelengths and power levels of multiple pumps have been optimized to for broad bandwidth and low gain ripple in the Amplifier. Experimental studies also have been initiated on the Raman Amplifier.

IITD: The recent activities include work in the area of erbium doped fiber amplifiers (EDFA), Raman fiber amplifiers (RFA), studies on nonlinear effects in optical fiber, Photonics bandgap fibers,

dispersion compensating fibers, fiber Bragg gratings, all-fiber components, numerical modeling, etc. New fiber designs for intrinsically gain flattened EDFAs and RFAs operating with a single pump have been proposed. These involve the modification of the modal field profiles to achieve gain flattening and hence amplifiers built with such fibers need less optical components and hence should be cost effective especially for application in the metro networks area. Conventional EDFAs work in the C-band (1530 to 1565 nm) and L-band (1565-1610 nm). Recently there is a lot of interest in using the short wave band (S-band covering the region 1460-1530 nm) for communication. New designs of gain flattened EDFAs have been proposed which should make it possible to realize EDFAs for the S-, C- and L-bands. RFAs are evolving as important amplifiers since they can work in any wavelength band. Gain flattening in such amplifiers is usually accomplished by using multiple pumps. Recent work has shown that by designing fibers with having dual concentric cores or asymmetric twin cores, it is possible to achieve gain flattened amplification using a single pump. The interesting feature of the gain flattened Raman amplifier designs is that they have a large negative dispersion value and hence they act as lossless dispersion compensators thus integrating the amplification and the dispersion compensating features in a single unit. Work on thulium doped fiber amplifiers, dispersion compensation, long period gratings in optical fibers, and nonlinear pulse propagation have also been carried out.

Recent work also involves design of dispersion tailored Photonic Bandgap Bragg fibers for potential use in metro networks and also as a dispersion compensating fiber with ultra-high figure of merit. Both the designs were based on an air core surrounded by alternate layers of high and low index contrast layers, which leads to a photonic bandgap (in 1-D) akin to energy bandgap in electronic materials. Other fiber design work involved design of coaxial dual-core dispersion compensating silica fibers (DCF) for dispersion compensation in G.652 and G.655 fibers and also design of a partially doped DCF as a stand-alone module for zero-loss DCF.

All-fiber components have emerged in recent years as an important field of research for realizing a host of components for optical networks. Recent work in this area involved design and realization of gain flattened EDFA through use of a i) fiber loop mirror based on a conventional single-mode fiber, and ii) side polished fiber half-coupler loaded with a multimode planar wave guides, design and realization of flat-top wavelength interleavers tuned to ITU wavelength grids for DWDM transmission.

A simple and novel fiber optic sensor structure consisting of a parabolic core multimode (MM) fiber, spliced at both its ends with a single mode (SM) fiber having different modal spot size as compared of the fundamental mode of the MM fiber has been proposed and studied. It is shown that the power transmitted through such a structure is very sensitive to the relative phase difference accumulated between various modes of the MM fiber and hence such a structure can be used to measure physical parameters as temperature or longitudinal strain since they change the above mentioned relative phase difference.

Computational techniques for modeling wave propagation have gained importance, as more and more intricate device structures are required to be analyzed and designed. Conventional non-paraxial techniques solve the one-way wave equation and are iterative. Two different approaches namely the direct numerical solution, DNS and the split step non-paraxial method (SSNP) have recently been developed for solving directly the second order scalar wave equation. Both the methods are non-iterative, do not involve neglecting the backward propagating waves and are highly accurate. The problem of reflection from numerical boundaries is inherent in all numerical methods. This has been analyzed by proposing a new absorption profile for the perfectly matched layer (PML).

IITM: Fiber Bragg gratings (FBGs) are gaining wide acceptance in fiber optic communication systems and sensors primarily due to their narrowband (<1 nm) filtering characteristics with sharp roll-off. Efforts are focused on the design, fabrication and testing of FBGs. Specifically, FBGs have been fabricated in collaboration with IISc, Bangalore with reflectivities up to 95% and 3dB bandwidth of <0.4 nm @ 1550nm. A key achievement to date has been the demonstration of extremely narrowband

(3 GHz) transmission-type filters based on Fabry-Perot structures with finesse of 100 using FBGs.

2. Optical communication and networking

CDoT: A 32 Channel 100GHz Dense Wavelength Division Multiplexing (DWDM) system has been developed in accordance with the specifications made by TEC & ITU-T and is meant for the backbone transport application. The various subsystems in the DWDM system include Terminal Equipment (TE) with a maximum of 32, G.957 compliant optical STM-16 inputs from independent Synchronous Digital Hierarchy (SDH) Systems and launch into the fiber at the MPI-S point a G.692 and G.694 compliant composite optical signal, in-line amplifier to compensate for the span loss, optical add/drop multiplexer (OADM) to provide for adding/dropping of a maximum of 4 wavelengths (channels) in each direction. The salient features of the DWDM equipment include support for long Haul (22 dB span attenuation) and ultra-long Haul (28 dB span attenuation) point-to-point applications, integrated optical multiplexing and pre emphasis, in-line/in-service monitoring of individual optical channels (wavelengths), omni orderwire, STM 1/4/16 client side interface, 10 Mbps ethernet interface for EMS, a simple network management protocol (SNMP) based Network Management System, elaborate alarm reporting. C-DOT has already completed the design of the DWDM system and the same is undergoing TEC validation currently. Current activities include design of 8 Channel CWDM system for Metro core and Metro access network applications, following the guidelines of the TEC & ITU-T. Besides this, C-DOT has also completed the development of single channel optical amplifier system, STM-1 equipment, customer premises equipment and PDH OLTEs and MUX like 2/8Mbps OLTE, 2/34 Optimux etc.

IISc: Various novel ring structures are also being studied. In the area of networks work is presently focused on impairment based routing algorithms (IBRA) in wavelength routed optical networks incorporating the physical layers constraints in the RWA algorithms. These IBRA guarantees the signal quality at the destination, to be less than certain threshold. The impairments are both linear and non-linear.

IITB: Synchronous as well as asynchronous time domain OCDMA systems have been investigated. Specifically, the effect of dispersion and non-linearity are studied for binary and multi-level codes. Theoretical as well as experimental issues are investigated for the spectral domain OCDMA systems. Few channel Spectral domain OCDMA system using fiber Bragg gratings is under development at present. Also a study of dispersion effects on OCDMA systems using parametric process is under progress.

IITM: The objective is to design, build and test a low cost (< Rs. 1000) 10 Mbps optical wireless link over 100 meters. A Vertical Cavity Surface Emitting Laser (VCSEL) was chosen as light source for transmitter and silicon PIN diode as photo detector for receiver. An acrylic lens was used for laser transmitter optics and a low cost, large area (13cm X 9 cm) plastic Fresnel lens was chosen for the receiver optics to reduce the overall cost. A 10 Mbps link was successfully established and tested for 40 meters distance. Efforts are underway to extend this range to 100 meters and also to improve the power budget using coding techniques. An apparatus for simulating rain/fog has been put together and its effect on the link budget is currently being studied.

A testbed has been established to qualify physical and network layers of optical communications. The testbed consists of over 200km of optical fibre, Bit Error Rate Tester (BERT), Optical Spectrum Analyzer (OSA), Polarization Mode Dispersion (PMD) analyzer and the ability to run computer controlled experiments for as long as 8 hours. The setup will be used to test key technologies such as Quantum Key Distribution (QKD) being developed at the Centre for Intelligent Optical Networks

3. Optoelectronic devices

CAT: A Metal-Organic Vapor Phase Epitaxy (MOVPE) system (AIX200) has been commissioned in a class 10,000 clean room laboratory. MOVPE machine is used for the growth of epitaxial layers of conventional III-V semiconductor materials which can be utilized for the development of quantum well (QW) lasers, photodetectors, solar cells, high electro mobility transistors etc. At CAT, the main

emphasis is on the development of high power laser diodes.

CEERI: Development of some important optoelectronic components like need-specific photo-detectors based on III-V materials and fabrication of front-end / receiver modules for fiber-optic communication ranging from 8 Mbps to 2.48 Gbps have been carried out. These were successfully tested at CDOT, Delhi. InGaAs/AlGaAs based high power 980 nm pump laser devices have been developed, which were successfully incorporated in the EDFA module at CDOT, Delhi. A CATV amplifier has been developed jointly by CGCRI, Kolkata, CEERI, Pilani, and NeST, Cochin and showed quite encouraging results. The 980 nm laser modules developed at CEERI and Erbium doped fiber developed at CGCRI are being used in this development. M/s Optiwave, Hyderabad, has also been involved in this programme to promote the packaging of these laser chips indigenously. R&D efforts are also being made to improve the lifetime of the laser in the chip-form as well as in the packaged-form in order to make these modules suitable for system applications. Efforts are being made to create a base for Silicon optical bench technology and to demonstrate Silica on Silicon (SOS) based planar light-wave circuits like power splitter, AWG based MUX/DEMUX and tunable filters for different applications in optical communication.

IITB: Silicon based optically controlled microwave devices have been investigated theoretically and experimentally. Specifically, optically controlled phase shifters, attenuators, variable loads, photo-induced antennas have been the focus of the study.

IITM: Silicon-on-insulator (SoI) based devices have shown better performance compared to their Si-counterparts. A variable optical attenuator (VOI) using p-n junctions and ridge waveguieds on SoI wafers has been designed. The devices are expected to be capable of up to 15dB of attenuation. Device prototyping is ongoing.

NPL: Work in silicon and silicon devices include development of silicon photodiodes for use with scintillating crystals for detection of gamma rays, studies on temperature effect on various parameters of n+ - p - p+ solar cells, techniques for improving the characteristics of n+ - p - p+ silicon solar cells.

TIFR: A wide range of materials of photonics interest have been studied, including III-V semiconductors such as GaAs, InP based quantum structures (wells, wires and dots) and the group plans to move into nitride-based III-V material now. The compound semiconductor materials are grown on two MOVPE systems. Apart from crystalline materials, there is active interest in organic semiconductors, both small molecules and polymers. There is also work on anocomposite semicon-ductors and porous anodic alumina. The spectroscopy work has concentrated on novel techniques, usually based on modulation techniques to probe energy levels in semiconductor structures. These include a variety of modulated reflectance, and surface photovoltage spectroscopies, with recent work on magneto-optics in the quantum Hall regime.

In the devices area, work is concentrated on the growth of diode lasers, with a range of GaAs and InP-based devices from about 800-1600nm wavelengths. In addition, Quantum Well Infra-Red Photodetectors (QWIPs) at 8.5micron wavelength have been demonstrated. O-LEDs structures are used to address transport issues in the organic materials.

4. Photonic crystals

IITB: Research work on the photonic band gap properties of self-assembled inorganic and organic samples is being pursued. Sub-micron-size 3-dimensional ordering in fcc structure has been observed in structural and optical characterization studies. An exhaustive computer code for the calculation of transmission and reflection coefficients using the transfer matrix method has been developed to analyze different directions of propagation of the electromagnetic waves. A numerical code is under development for investigating the characteristics of a photonic crystal fiber. The code will help in investigating the sensitivity of the characteristics against the lattice parameters. Various 2-D photonic crystal devices will be studied using the code.

JNU: Photonic crystals hold a lot of promise for future development of optical networks. Photonic crystals exhibit a variety of interesting nonlinear optical phenomena. It has been shown that intense nonlinear processes can occur in photonic crystal structures built up from nonlinear materials. One such finite 1-d PC is a special Bragg reflector, where every alternate layer is a nonlinear medium and the number of periods is much higher than required for a highly reflecting Bragg mirror. Second-harmonic and subharmonic generation has been predicted and also observed in such structures. The advantages of these structures from the point of view of nonlinear interactions are because of (a) the high densities of local optical modes, (b) the localization of optical modes in confined regions of the structure, and (c) the ease of fulfilling of the phase-matching conditions of a given nonlinear process.

5. Quantum optics

BARC: Laser cooling of cesium atoms, for the first time in India, has been demonstrated in the laboratory using local expertise and technology. State of art facility for laser cooing consisting of magneto optic traps, dark trap, sophisticated diagnostic techniques for temperature and number density of cold cloud etc. exist in the laboratory. Routine cooling of cesium atoms to 100 mK and Rubidium to 200 mK for a variety of investigations including precision spectroscopy, collision physics and quantum optics have been carried out.

IISc:: Work of the Atomic and Optics group of Physics Department includes laser cooling of atoms and ions, magneto-optic trapping of atoms, optical tweezers etc. A ring cavity based frequency doubler for diode lasers, Grating based spectrometer, Michelson interferometer-based wave meter etc have been built for the experiments.

JNU: Two-mode lasers have found numerous applications in optical transmission and signal-processing systems. High-repetition rate optical pulse trains can be generated using a dual-wavelength light source, or two discrete laser diodes, where the beating of the two wavelengths generates a high-frequency sinusoidal signal. This signal can then be compressed into short optical pulses using, for example, nonlinearity and dispersion in a fiber. From the quantum optical point of view, a natural question then arises: what is the fundamental limit on the phase noise of a dual wavelength laser? In a treatment of the problem with a proper nonlinear description of the gain medium including self-saturation and cross-coupling between the two modes, the question: how does the cross-coupling affect the heterodyned fundamental linewidth of the laser has been probed. Following Lamb, our approach is based on the adiabatic elimination of the population inversion in the active medium, and hence the treatment applies rigorously only to class-A lasers (gas lasers) for which the inversion dynamics is sufficiently fast.

6. Integrated optics

IISc: The current work is focused on theoretical analysis of nonlinear ring resonator structures which are expected to have significant role in multiplexing and filtering applications especially for DWDM communication applications. In the area of optical MEMS analysis and design of guided wave optical MEMS (MOEM) based pressure and vibration sensor with Mach-Zehnder and directional coupler architectures has been carried out. MOEM pressure sensor work has been sponsored by National program on smart materials (NPSM), Govt, of India. It has been fabricated at SCL, Chandigargh and the characterization is in progress.

SAMEER: Activities include design and development of lithium niobate based directional coupler and optical switch, 2.4 GHz intensity modulator, variable optical attenuator, glass based passive optical splitters (1x2, 1x4, 1x8), and GaAs based laser diodes. Recent activities include packaging and environmental testing of optoelectronic devices and also in the area of polymer based optical devices, biophotonics for sensors, DWDM components and Nano-photonics.

7. Nonlinear optics

BARC: An intense laser beam, while propagating through any transparent, homogeneous and isotropic medium, may undergo changes in its spatial, spectral and temporal characteristics (for pulsed lasers) due to an intensity dependent non-linear susceptibility exhibited by the medium. Such non-linear propagation phenomena are important in several areas ranging from development of high power lasers to applications in material processing, remote sensing, and laser isotope separation. Knowledge of the nonlinear coefficient n2 is important in estimating non-linear propagation effects. In a recent study, the resonant enhancement of n2 in atomic vapour was successfully investigated using the Z-scan technique, commonly employed for measuring n2 in condensed matter. This investigation was undertaken primarily, to assess the applicability of the Z-scan technique for measurement of optical nonlinearity in atomic vapour and to determine the frequency regime in which the dielectric response of atomic vapour to a near resonant laser can be formulated using the adiabatic following model. Our experimental data on atomic Sodium is the first report on use of the Z-scan technique for determining resonant nonlinearity in atomic vapour.

In the area of optical parametric oscillators, operation at two widely different wavelengths have been demonstrated. Several techniques for reduction of threshold pump power requirement in OPOs have been investigated, including a new technique based on injection of an external, spectrally uniform dye laser beam into the OPO that resulted in ~33% reduction in the input power threshold. The wide wavelength tunability of the OPO was utilized to excite urnayl nitrate solution at ~ 430 nm and the resulting fluorescence spectrum was recorded showing the signature peaks of uranyl ion. In comparison to the conventional approach of using Nitrogen laser in uranium trace detection, use of wavelength tunable radiation will substantially improve the sensitivity and selectivity in ultra trace detection of several elements, including uranium, in process streams and effluents.

CUSAT: Third order optical nonlinear properties of phthalocyanine and their derivatives were studied extensively for the last two years using degenerate four wave mixing and Z-scan techniques. The metal pthalocyanines were found to be good optical limiters with comparatively high NLO coefficients. The optical limiting characteristics studies have helped to identify some of the special properties of pthalocyanine compounds like change over from excited state absorption to absorption saturation as the pump intensity is changed. Nonlinear optical properties of nano ZnO and nano silver colloids were also investigated using Z-scan technique. Recently discovered class of crystals of L-arginine tetrafluoroborate and L-histidine tetrafluorate with improved SHG efficiency and mechanical stability are also studied here. Another important study pursued is dual colour Z-scan spectroscopy which will help to record nonlinear optical spectra of materials.

IITKgp: Nonlinear optical characterization of materials for their use in all optical devices are being carried out. This includes second order nonlinear optical processes like efficient harmonic generation, optical parametric generation in bulk and quasi phase-matched structure while the Z-scan technique is used for third order nonlinear optical characterization. The study of second order cascaded nonlinear optical processes and, specially, cascaded process where both the processes simultaneously phase-matched is also being studied because of its potential for all optical devices. Indigenous development of diode pumped, all solid state, nonlinear mirror mode-locked lasers capable of generating sub picosecond pulses for their use in nonlinear optical characterization of materials has been carried out.

JNU: It has been experimentally demonstrated that the combination of a second-order process, namely phase-matched second-harmonic generation, and a third-order process results in a nonlinear mirror operation in a 1-d PC. Potential applications point to fast control of light-by-light (as in a nonlinear mirror and/or an optical switch) and all-optical signal processing. An efficient general scheme for the analysis of pulse propagation through a 1-d PC, taking into account the periodic patterns, the nonlinearity of the medium and the enhancement of the propagating pulses in the structure.has been recently proposed.

RRI: Work includes investigation of nonlinear optical properties of noble metal and alloy nano-

clusters, with particle sizes ranging from 1 nm to 60 nm. Other materials studied are conducting polymers, semi conducting nano-structures and ferro fluids. The present interest is in studying molecular clusters of metal nano-particles. Nonresonant feedback effects, and subsequent light amplification, have been examined in laser dyes doped with submicron-sized scatterers. Resulting phenomena like linewidth narrowing, gain enhancement have been experimentally studied and modeled. Lasing action in submean-free path sized samples has been explained in terms of rare scattering events being rendered important by virtue of the high gain of the system. The possible applications of random lasers in signal amplification in optic fibers and as optical diodes have been proposed and investigated.

8. Adaptive optics

IRDE: Work on the development of adaptive optics (AO) system for long range surveillance and missile imaging and tracking for ranges up to 50 km is being carried out. The work broadly involves experimental studies of atmospheric turbulence, design and development of AO sub-system consisting of wavefront sensor, tip/tilt mirror, deformable mirror and AO control system, design and fabrication of imaging telescope, stabilized gimbal and EO tracker, AO multi-conjugate technology and system integration and technical trials.

9. Lasers

BARC: The chemical oxygen iodine laser is a chemical laser that converts energy derived from chemical reactions into laser photons. The atomic iodine is energized to form an optical gain region and power is extracted with these optical resonators at the wavelength of 1315 nm. Keeping in view the stringent requirements with respect to the specifications of multilayer optical coatings for the resonator mirrors, successful design and development of these multilayer dielectric mirrors using refractory ZrO2 and SiO2 thin film optical materials and adopting a process control reactive electron beam deposition technique has been undertaken. For high reflecting feed back mirrors, a reflectivity value of 99.96% has been achieved by adopting a periodic 37-layer quarterwave design and a 29-layer periodic quarter wave design has been adopted to develop the output couplers that carry an optimized reflectivity value of 99.46% at the COIL wavelength.

The quality of optical components used in complex applications such as lasers, synchrotrons, analytical instruments and lithography systems is critically influenced by surface morphology and associated optical losses. Such losses also become more highlighted as the application wavelengths go below the ultraviolet spectral regions. Using process control multi-component co-deposition technique, superior morphology in certain composite gadolinia-silica (Gd2O3-SiO2) thin films have been demonstrated so as to minimize the RMS surface roughness. Composite films with different mixtures of Gd2O3 and SiO2 components have shown wide ranges in RMS roughness values. The best morphology and minimum RMS roughness parameters have been achieved for a composite film that caries a 70/30 composition ratio of Gd2O3:SiO2.

A new technique has been developed for spatial filtering of laser beams based on a saturable absorber that is free of lateral positioning accuracy, can handle high average power lasers, and can be tailored by changing the absorber concentration and length, as well as the beam focusing parameters. This technique has been successfully applied to reduce the divergence of laser beams from a high repetition rate Copper Vapour laser and a narrow band tunable dye laser, using circulating dye solution in a dye cell as a saturable absorber. A single longitudinal mode (SLM) pulsed dye laser in the Littrow configuration with a narrow time averaged linewidth ~600MHz, an excellent spatial mode (near TEM00), a broad tuning range (564 - 600nm), negligible amplified spontaneous emission (ASE) and efficiency of 5% has been demonstrated. The low output power from the (SLM) oscillator which has a good spectral and spatial content was boosted up in a pre-amplifier transversely pumped by the green beam of the Copper Vapor Laser with an extraction efficiency of 11%

Two color laser induced fluorescence spectrometer has also been developed using which several highly excited levels of samarium have been observed. The technique has great potential in atomic spectroscopy of highly excited levels.

CAT: An Nd Glass Table Top Terawatt Nd Glass Laser system (Pulse energy 1 J, Pulse duration 900 fs) has been developed in-house based on Chirped Pulse Amplification scheme. A crucial sub-system of this laser is injection Q-switched regenerative amplifier with a multi-pass (130) gain of 3 x 107 with a highly stable operation. Further, different types of novel optical autocorrelators have been set up and demonstrated for measuement of pulse duration, frequency chirp, pulse asymmetry, and pulse front tilt.

IITK: The present activity of laser group is centered around interest in Raman spectroscopic studies for smart material properties, biological tissues, semicoductors, and thin films for varied applications as electro-optic material; high resolution spectroscopy using single mode laser for Doppler free spectroscopic studies, laser physics for developing micro lasers based on ZnO, diode pumped Nd:YAG single crystal fiber laser and single crystal fibers of LiNbO3. Work on plasmas used for thin film deposition is towards understanding the dynamics of plumes and various reactions taking place in gaseous phase. Laser ablated plasma and shock waves studies are being carried out for development of functional materials for integrated optics for example ZnO and ZnO alloyed with MgO thin films to name a few. Laser ablation of calcified tissues like human tooth to identify carious tooth and spectroscopic work on biologically important molecules for disease diagnosis using noninvasive/ minimally invasive techniques based on polarized fluorescence spectroscopy, intrinsic fluorescence spectroscopy are in progress. The techniques are being developed to extract optical properties / intrinsic fluorescence from human breast tissues so as to get deeper insight into biochemical and morphological changes occurring inside the tissues during the progression of disease. Work on looking for non-linear dynamics of semiconductor diode lasers and secure communications has also started. The critical balanced combination of both (dynamics and communication) can result in its utilization for creation of optical chaos and message encoding, transmission and decoding. Other important areas include laser material processing around a commercial 1.5 KW CO2 laser and interferometric tomography to look for heat flux in fluids and gas liquid interface.

LASTEC: Work has been carried out on ring laser gyroscope for use in inertial navigation systems. Work on lasers include micro-chip laser with output power of 50mw, CO2 waveguide laser with output power of 20W for use in medical application.

10. Biophotonics

CAT: In the area of biophotonics, R&D on use of lasers for biomedical imaging, diagnosis, manipulation of microscopic objects (single cell or sub-cellular objects) and phototherapy is being pursued. The work involves i) development of novel laser micromanipulation techniques for controlled two and three-dimensional rotation of trapped microscopic objects and for acceleration and projection of microscopic objects using asymmetric transverse gradient force optical tweezers. The laser micromanipulation set up built at CAT has been used for a variety of studies which include first demonstrations of three-dimensional orientation of intracellular objects & optical binding of nanoparticles; guidance of neuronal growth cones with asymmetric transverse gradient force laser tweezers, laser assisted injection of genetic material or drugs in cells, and malaria diagnosis with laser tweezers. Current work involves study of fluorescence and elastic scattering from human tissues and on their use for diagnosis of cancer. It was demonstrated that angle resolved measurements on polarized component of fluorescence could be used for depth resolved fluorescence measurements in layered biological tissue. It was shown that the use of polarized autofluorescence measurements should help maximize the contrast and thus improve diagnosis. State of art statistical pattern recognition based diagnostic algorithms were developed and these led to significant improvement in detection of cancer using autofluorescence spectra acquired in-vivo. Optical coherence tomography system has been assembled and used to image various biological samples like a fish eye or a human finger pad with axial and lateral resolutions in of ~ 10 μm and 20 μm. The OCT images of fish eye are being used for estimation of corneal thickness, the anterior angle of cornea with iris, and other ocular parameters. For time gated optical imaging, the dependence of contrast of images on the anisotropy parameter and the scattering coefficient were examined. Studies on the effect of nitrogen laser irradiation on viability of clinical isolates of Mycobacterium tuberculosis have been carried out and analyzed.

TIFR: Two-photon excitation has provided visible wavelength images of biological cells using benign infrared wavelengths. Work to push this technique further, using three-photon excitation, to visualize some of the most important biological molecules that absorb only in the ultraviolet has been undertaken. The first multiphoton microscope capable of producing detailed images of serotonin (a neurotransmitter) in neurons has been constructed. Using single molecule detection and Fluorescence Correlation Spectroscopy (FCS), it has also been possible to break the barrier of resolution and to measure the sizes of sub-nm particles in solution. An FCS spectrometer has been built and a new data analysis methodology based on the Maximum Entropy Method, to be able to look at the aggregation of nm sized protein molecules has been developed. Characterization of these processes is throwing light on the pathological aggregations that take place in the brain giving rise to diseases such as Alzheimers and Parkinsons.

11. Instrumentation

BARC: The technology of fabrication and testing of precision optical components such as plane parallel plates, Fabry-Perot plates, concave spherical mirrors, lenses, prisms, beam splitters needed for various types of optical instruments, spectrometers and monochromators has been developed. The optical surfaces of diameter upto 200 mm in size can be fabricated with a surface accuracy of ./ 10. The plane surfaces of diameter 50 mm can be fabricated with surface accuracy of ./100. These precision Fabry-Perot plates have been used for the stabilization of wavelength in dye lasers required for isotope enrichment program of BARC.

IITM: An optical time domain reflectometer (OTDR) with a dynamic range of 32 dB at 1310nm and a spatial resolution capability of 5 m has been demonstrated on a compact board and integration with a LCD display is underway. Current efforts are focused at extending the dynamic range to 43 dB and shrinking the spatial resolution to 1 m using avalanche photodiodes and correlation techniques.

Optical coherence tomography (OCT) originates from the well-known principle of white light interferometry, also known as low coherence interferometry. We have constructed a fiber-based Michelson interferometer based on an EELED source with a coherence length of 16 m and is capable of sub m depth resolution. The set up is able to resolve the front and back surfaces of semi-reflective objects such as a glass slide and cellophane tape and scattering objects such as tissue samples with extremely low light levels (sub-nW). Currently our efforts are focused at improving the depth resolution and demonstrating tomography on tissue samples

12. Miscellaneous

Laser produced plasmas

CUSAT: Laser generated plasma from various solid targets were studied in detail. Temporal and spatial resolved studies of laser produced plasma provides answers to some of the problems related to plasma dynamics. A work recently taken up is the laser generated collision plasma. A special plasma chamber for such studies has been designed and fabricated.

Liquid crystals

NPL: In the area of liquid crystals various studies on a new type of ferroelectric liquid crystal, namely, distorted helix ferroelectric liquid crystal have been carried out. These have no inherent bistability, no inherent optical threshold voltage, etc. Work includes prediction of bistability effect, studies on electroclinic liquid crystals with nanosecond switching response, studies of dielectric behaviour by dielectric relaxation method and development of optically addressed spatial light modulator with improved characteristics.

Optical radiation standards:

NPL: In the area of optical radiation standards, Fourier transform Raman spectrometer studies for development of materials for IR reflectance / transmittance standards have been carried out. The R & D work includes effect of spatial coherence in optical measurements, improved technique for determination of optical source intensity profile, correlation induced spectral shift (Wolf effect), quantification of individual components of sugar in sugarcane juice, determination of moisture in

tobacco, variable-temperature FTIR spectroscopy studies for thermal denaturation and IR spectroscopic studies of polycyclic aromatic hydrocarbons. Theoretical and experimental study of generation of cross-spectrally pure light by two diffusers moving in opposite directions and determination of diffuser surface roughness have also been carried out.

Organic light emitting diodes

NPL: New materials are being studied which give blue, orange and red electro-luminescence. Device fabrication, characterization, optimization and encapsulation being carried out.

Thermo optic spectroscopy

CUSAT: Materials in solid, liquid and gaseous phases as well as thin film and bulk forms are studied using photoacoustic effect , photothermal deflection and thermal lens techniques. Optical and thermal properties of materials can be simultaneously studied. Availability of dual beam thermo optic effect set up will help us to study spectrally resolved nonradiative energy processes taking place in light matter interaction. An important class of material studied using this facility is low dimensional structures like quantum dots . Photothermal properties of a wide variety of materials like thin films of piezoelectric materials , ZnO, ceramics like Alumina-Zirconia were investigated using thermo optic effect. These techniques were also employed to study the absolute fluorescence quantum efficiencies of various laser dyes as well as other fluorescing compounds..

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Commission E: R & D activities on EMI/EMC in India

Electromagnetic Interference/Compatibility concerns with the ability of electronic and electrical equipment to work satisfactorily in the electromagnetic environment without introducing intolerable interference to the environment with particular to health hazards. The frequency range can cover from extra low frequency to very high frequency. That is why the study of EMI/EMC has become increasingly important in recent years because of wide ranging applications in industry and more general societal implications. And as a lot of work is being carried out in various organizations, like Indian Institute of Technology, Kharagpur, ADA Bangalore, SAC ISRO, Govt. of India, C-DOT, ERTL, ERDC, SAMEER, LRDE, DRDO, etc.

R & D activities at IIT, Kharagpur

The Electromagnetic Group of Department of E & ECE, I.I.T. Kharagpur has been engaged on the studies of different low and high frequency EMI sensors, EMI / EMC measurements and different EMI test sites. The increased use of electronic equipment in modern day technologies causes electromagnetic interference (EMI) with one another, which results the malfunction and even damage of different electronic components. To avoid this EMI related problems, different regulatory committees in different countries had specified some standards of electromagnetic emission. All the electronic devices must conform to these standards. The frequency range of conducted emission standards extends from 450 KHz to 30 MHz and that for radiated emissions begins at 30 MHz and extends up to 40 GHz. By measuring the radiated electric field due to that equipment, the compliance of the devices conforming to the standards of interference in this range is tested. To use sensors for this purpose, a calibration data is required relating the electric field at the aperture of the receiving antenna to the voltage at the 50 ohms matched detector. The ratio of incident electric field at the surface of the sensor to the received voltage at the antenna terminal is known as antenna factor. The EMI sensors in common use for frequency range upto 1GHz are dipoles or loop antennas (e.g. EMI probe kit 8611A, EMI probe MA 2601 B/C of Anritsu Corporation Japan, Anritsu dipole MP651A/B). For frequency above 2GHz, open–end of a rectangular waveguide can be used very effectively as an EMI sensor. The antenna factor of open-ended rectangular waveguide, window sensors in free space and different loaded and unloaded wire antennas have been theoretically evaluated using Method of Moments. The time-domain studies of different broadband antennas have also been performed.

The Gigahertz Transverse Electromagnetic (GTEM) Cell has been analyzed, designed and developed in the Department of E & ECE, I.I.T. Kharagpur. The GTEM Cell is considered as a suitable test environment for EMI radiated emission and susceptibility measurements. The GTEM Cell is basically a section of gradually flared rectangular coaxial transmission line terminated with a matched load. The inner conductor (SEPTUM) is vertically offset to create a larger usable test volume. The end termination consists of a combination of low- frequency circuit element 50 O load and a high-frequency absorber wall for absorbing the incident propagating wave, as in anechoic chamber. The advantages of GTEM Cell over other test facilities are less amount of required RF drive power in susceptibility tests and the compact size compared to anechoic chambers with same performance in field homogeneity. The GTEM Cell does not suffer from ambient like an Open Area Test Site (OATS), nor do we have to adjust the antennas.

Emissions

1. On the EMI Potential of Various Laser Types, Bhatia, M.S., and Kumar, G., BARC, Mumbai.

ABSTRACT: The electrical activity in any laser leads to EMI emissions, which needs to be controlled if the overall system is to exhibit compatibility. This paper lists the EMI potential of various

laser types and gives some reasons for origin of electrical noise.

2. Mapping of Radiation Field from a Discharge Laser Head, Bhatia, M.S., Madan, V.K., Dongare, A.S., Phulluke, R., Kumar, G., and Agarwal, V., BARC, Mumbai.

ABSTRACT: EMI radiation from a Laser head of a copper – vapour Laser (pulsed discharge Laser) are mapped in the near field with a characterized pick – up probe. This is followed by simulation of Laser head as a microstrip antenna and also as a loop antenna. The modification of radiation characteristics of these antennas by inclusion of metallic sheet with any shorts is studied with an aim to minimize radiated EMI. Shielding of the Laser head feed cable is also simulated.

3. Prediction and Measurement for EMI Pollution Generated by the Personal Computers, Rao, I.M., LRDE, Bangalore.

ABSTRACT: This paper reviews about the electromagnetic field pollution generated by the digital computers with their Benchmark Results. It is reviewed about the theoretical analysis and prediction for the generated pollution of Pc's, Further it is reviewed about the practical measurement carried out for a typical Compaq personal computer, in the shielded chamber to find the field strength at different frequency bands for the spectrum of the emission. It also covers about the Lan Emission measurements and how this analysis compatibility of the equipment for various sensitive receivers working around the Personal Computers.

4. Electromagnetic Interference by High Power Microwaves, Rao, V.G., Roy, A., Paithanker, A.S., and Ron, P.H., BARC, Mumbai.

ABSTRACT: High Power Microwave (HPM) radiation with frequency > 1GHz may penetrate the electronic system through front or backdoor openings and propagate like the genuine signal. Some times parasitic resonance may amplify the HPM signal and cause havoc to the systems. The surface caused buy HPM can also interfere with the normal signals and upset the functioning of the devices. The HPM incident upon the electronic components may damage them by the following mechanisms like adiabatic heating of the junction or punch – through of the depletion layer. High Power Microwave radiation generation studies were performed using the intense electron beam from the KALI- 1000 Pulse Accelerator by Virtual Cathode Oscillator method. Various axial resonant cavities were used to optimise the microwave emission. The maximum power of 500MW around 5GHz was generated by using a axial resonant cavity with a resonant frequency of 5GHz. The HPM was also used to study the effects on some electronic devices. The HPM caused damage to the op-amps and stopped the functioning of the personal computers. The HPM can also cause breakdown in the low-pressure devices like hydrogen thyratrons and cause spurious triggering in the control circuits that use them.

5. EMI Reduction in a Laser Pulse Switch out System, Krishnan, S., Asha Singh, Rama Chari, Bhatia, M.S., and Oak S.M., CAT, Indore, and BARC Mumbai.

Analysis and Simulation

1. Comparison of IE3D and Fidelity Simulations for Planer Circuit Design, Singh, Y.k., Ghosh, S., Chakrabarty, A., Sanyal S., and Sahoo, G., IIT, Kharagpur.

ABSTRACT: In this paper detailed investigations have been carried out through computer simulations on the reflection and transmission properties at the center frequency of 10GHz, of 3db Wilkinson power divider and Quadrature hybrid in microstrip form on 0.1mm GaAs substrate. The simulations have been performed using simulators based on MOM and FDTD techniques.

2. EMC Evaluation & Analysis of UPS, Chand, S., and Chawla, K., ERTL, New Delhi.

ABSTRACT: Computing devices are finding increasing importance day by day. Erratic power supplies pose a serious threat to the reliability & durability of data. The person working on system needs protection of data and UPA thus become a necessity. UPS Stores energy into batteries & converts back the stored DC into an AC supply. Switching techniques are used to convert Dc into AC. Switching of current generates electromagnetic Emission which effects

the nearby products. The emission generated from UPS may be of conducted type/ radiated type or both. Advance technologies of UPS are also sensitive & hence call for high immunity from Electromagnetic noises. Since the computer supply is taken from UPS, hence the UPS shall be immune to power noises / disturbances and shall not generate such noises as well. EMI / EMC evaluation of UPS thus becomes very essential to insure that system works satisfactorily in the intended environment. The paper discusses various available specifications for EMC evaluation of UPS and analyzes the working environment of UPS.IT also highlights probable EMI sources & suppression & immunity improvement techniques for compliance of UPS to national and international norms.

3. An Efficient Numerical Tool for Electromagnetic Field Problems, Patel, B.P., Ganapathi M., and Mohan Krishna, T., IAT, Pune.

ABSTRACT: The finite element method allows one to solve large – scale, complex electromagnetic problems. It is also highly amenable to automation. Here, a numerical solution based on third-order c1 triangular finite element is proposed for solving 2D electromagnetic field problems. The design of this new finite element involves field variable and its derivatives as degrees of freedom compared to the standard Lagrangian polynomial based finite element available in the literature. The performance/ effectiveness of the present method is studied against that of standard element. For almost same accuracy, the number of equations to be handled based on present formulation reduces to less than half of those of standard element, which, in turn, leads to significant saving in CPU time and memory requirements.

4. Analysis of Field in a Symmetric TEM Cell by FEM, Malathi, K., and Annapurna Das, Collage of Engineering, Anna University, Chennai.

ABSTRACT: The field distribution inside the symmetric Transverse Electromagnetic (TEM) Cell is analyzed by Finite Element Method (FEM). Poisson's equation is solved to obtain the potential distribution in the cross section. The Horizontal and vertical components of the electric field are computed from the gradient of the solution. The field variation below the septum are computed and their variations are plotted. The uniform region of the vertical component of electric field is found and isolation of the horizontal component of electric field is determined.. This proves that in the region below the septum the TEM cell supports uniform Transverse Electromagnetic (TEM) field, which is a requirement for testing the susceptibility levels of electronic equipment.

Standards and EMC Education

1. Comparison of Civilian EMC Immunity Standards with Automotive EMC Immunity Standards, Sakthivel, K.N., DAS, S.K., and Kini, K.R., SAMEER Centre for Electromagnetics, Chennai.

ABSTRACT: The paper discusses about a detailed comparative study between civilian EMC immunity standards, IEC 61000-4 series and automotive EMC immunity standards, SAE J 1113-series. The objective of this paper is to find out major differences between this two important EMC immunity standards and reasons behind them. Generally automotive EMC immunity standards (SAE J1113-series) are more stringent than civilian EMC Immunity Standards (IEC 61000-4-series), due to the direct human safety aspects involved in the usage of automotive. This is explained with more details in the paper. The paper highlights the important deviations in the text specification of the following civilian EMC immunity standards (IEC 61000-4-series) and automotive EMC immunity standards (SAE J1113-series).

2. CE Marking and EMC Directive, Sathyendra, M.G., and Brij Aggarwal, CSA International, Bangalore.

Transients

1. Computation of Lighting Induced Voltage on Telecommunication Subscriber lines, Kannu, P.D., and Thomas, J.M., KREC, Surathkal, and IISc, Bangalore.

ABSTRACT: The electric and magnetic fields produced by a lighting stroke in the vicinity of

a telecommunication line can illuminate the line and it can acquire in induced over voltages which may be detrimental to the equipment connected to the telecommunication line. The magnitude and waveshape of the electromagnetic fields produced by lightning as well as the induced voltage on telecommunication line are influenced by the finite conductivity of the ground. In this paper, the induced transient voltages on an overhead telecommunication subscriber line due to a nearby lightning stroke to the ground are computed. From the results it is seen that the induced voltage is bipolar for all the observation points except at the line midpoint for the lightning striking point location chosen in this study. It is also observed that the finite ground conductivity decreases the magnitude of the induced voltage at the line terminations where as it increases the induced voltage as the line mid point is approached. The results obtained in this study will be useful in evolving a suitable lightning protection scheme for the rural telephone exchanges which are interconnected using overhead lines instead of underground cables as in the case of urban exchanges. At the same time this rural telephone exchanges have become more vulnerable to transient over voltage as they are being converted into digital ones their susceptibility levels for transient over voltages being much lower than the old electromechanical exchanges.

2. Induced Voltage on Control Cables in a GIS Due to the Transient EM Fields Generated During Switching Events, Rao, M.N., Thomas, J.M., and Singh, B.P., BHEL, Hyderabad and IISc, Bangalore.

ABSTRACT: Very Fast Transient Overvoltages (VFTO) generated due to switching operation in Gas Insulated Substation (GIS) may propagate out into external environment through discontinuities like SF6 to air bushing, SF6 to cable termination, nonmetallic viewing ports and flanges etc. For the reliable operation of substation controls, it is essential that the transient electromagnetic (EM) fields radiated due to VFTO be within permissible levels. Since, these transient fields are having frequency components upto 200 MHz, it may induce currents on the metallic sheath of the shielded control cables. This in turn may induce undesired voltage on the central conductor of the cable depending on the transfer impedance of the cable.

3. Studies on the Failure of Semiconductor Components Due to Electrostatic Discharge, Lakshminarayanan, V., and Manoj Kumar, A.K., C- DOT, Bangalore.

ABSTRACT: Electrostatic Discharge (ESD) is a major cause of failure of semiconductor components. With the increasing complexity if devices and higher component densities, device geometries have been shrinking and susceptibility to ESD damage has increased in the recent years. This paper discusses the ESD induced failure mechanisms in electronic systems and techniques to minimize failure at various stages using different techniques. Examples based on case studied carried out are also presented.

EMC and Composites

1. EM Shielding Effectiveness of Metal Sandwiched Composites, Sudarshan, N., Chatterji, S.K., Suryanarayana, K., and Rao, G.V., CPDC, Hyderabad.

ABSTRACT: Thermoset polymer composite materials are finding a wide range of application in aerospace structural parts, due to many advantageous features. The most important feature is the reduction in weight of the structure component to other alternatives. Majority of the essential systems of this class with the exception of carbon fiber based composites, are also transparent to EM radiation.

There are applications where such structural composites should not transmit EM radiation while retaining the weight advantage.

2. Issues and Concerns in Using Composites for Spacecraft Structures, Nagesh, S.K., Shastry, S.V.K., Hariharan, V.K., and Katti, V.R., ISRO Satellite CENTRE, Bangalore.

ABSTRACT: Several problem areas that are associated with the use of composites in spacecraft structures have been highlighted. In particular, the problem of controlling static charge build- up on composites has been analyzed in some detail.

3. Shielding of Electromagnetic Interference Using Conducting Polymer Composites, Dhawan, S.K., Kamalasannan, M.N., and Bawa, S.S., New Delhi.

ABSTRACT: Conducting polyaniline composites can be used as shield material for the control of electromagnetic interference in ratio frequency range and at 101 GHz. The conducting composites can also be used for the dissipation of static charge. The conducting composites show a shielding effectiveness in the range of 20db to 60db depending upon the loading of the conducting polymer in the thermoplastic matrix. The characterization of the conducting polymer was carried by thermogravimetric analysis, spectroscopic techniques. A static decay time of 0.02 sec was observed on going down from 5000 volts to 500volts.

EMC in Communications -I

1. Channel Characterization of Mobile Signal at 11GHz, Ravindra, K., and Sarma, A.D., Osmania University, Hyderabad.

ABSTRACT: For effective mobile satellite communications system design, it is necessary to know quantitavely the channel characteristics such as signal fading due to multipath. Such characteristics can be studied by the statistical distribution of the received signal envelope. In this paper, polynomial model is proposed to estimate the path loss of the mobile signals at 11 GHz. Also, variability of the probability density function (pdf) of the received signal power on various parameters has been investigated. The polynomial model for path loss is agreeing well with the measured data. The investigations on the channel characterization estimate the pdf of the channel for a variety of statistical parameters, which are directly useful for the mobile system designers.

2. Electromagnetic Compatibility of Digital Communications for Naval Applications, Bhargava, A., Naval EMC Centre, Mumbai.

ABSTRACT: Digital communication has proliferated in a big way in the recent years. The advantages of digital communication are improved efficiency, better transmission accuracy, better noise immunity of lesser bandwidth, secrecy, and standardisation of transmission/reception equipment. Digital communication in a shipboard application is used for transmission of voice, data and picture between ships in a operational equipment where accuracy, secrecy and immunity to noise/interference is essential. The advent of latest equipment cable of advance signal processing techniques will result in prolific use of digital communication in shipboard applications.

The paper aims at bringing out various aspects of digital communication vis-à-vis the dense electromagnetic environment that exists on a naval platform and their compatibility. The use and application of source coding, digital modulation techniques, error control coding and data security in mitigating the electromagnetic interference in a ship borne environment are discussed. The various problems of co-channel/adjacent channel interference and the effect of random/burst noise on a digital communication system are also brought out. Achieving immunity of digital communication to interference by use of various spread spectrum techniques is also discussed.

3. Adaptive Techniques to Mitigate Ship Borne Co – located Interference Problems, Chandra, P., Naval EMC Centre, Mumbai.

ABSTRACT: A generic adaptive scheme for suppression of an undesired signal coupled from a Co- located transmitter to a receive antenna is presented. This adaptive interference cancellation scheme is customized for a Naval Ship to mitigate interference coupled from any of the HF transmit to any of the receive antennas.

EMC in Communication II

1. Performance Enhancement of TCP/IP Network in the Presence of Ingress Noise between Nodes, Sudarsan, S.D., Manaswini Rath, Ranjan, N., T.R., AND Pranesha, T.N., CRL – BEL, Bangalore.

ABSTRACT: The emerging scenario of convergence of mobile and fixed networks, civilian and tactical military networks as well as strategic networks is crating heterogeneous networks with different

link performances. The links may have a BER ranging from 10e-2 to 10e-12 and the type of link varies from radio to co-axial to fiber. Tactical communication networks are using COTS technology and civilian intermediate nodes. Collocation of equipments meant to operate in civilian environment along with other MIL standard equipments, electrical gadgets for surveillance and monitoring, weapon control systems, etc. create high level of EMI and hence degrade performance of TCP/IP networks ultimately resulting in congestion and choking. New mechanisms are needed to handle EMI vis-à-vis congestion. This paper describes emerging scenarios, possible BER between various types of links, new coding schemes for performance enhancement and possible solutions.

2. Effect of Inter – Channel Interference on IP Traffic over WDM Backbone Networks, Manaswini Rath, Ramamohan, T.R., Sudarsan, S.D., and Pranesha, T.N., CRL – BEL, Bangalore.

ABSTRACT: Convergence is forcing the network operation and switching speeds to Gigabit and more. WDM networks are becoming the de facto standards for IP backbone networks as they overcome the EMI issues associated with Em channels and switches. With its large bandwidth handling capabilities, the concept of IP traffic over optical WDM networks has become one of the most challenging topics to be considered. The issues arising out of mapping IP packets directly into WDM link using Point- t0-Point (PPP) encapsulation are discussed in this paper. While the magnitudes EMI problems reduce with WDM, it emerges in a different form, albeit with lesser magnitude. One such challenge is the Inter- Channel Interference (ICI), which is caused by nonlinear effects of fiber focuses on the Four-Wave Mixing (FWM) effect, which in turn affect the performance of the IP packet transmission. The characteristic of IP packet error is evaluated in terms of IP load, input light signal power and channel spacing. This paper suggests a possible solution to control the IP traffic load and improve channel spacing without affecting the overall network performance.

3. ATM Protocol Adaptation EMI/EMC Environment, Jain, M., Vidyasagar, L., Rajashekhar, N.H., and Rajashekhar, N.H., Ramamhohan, T.R., and Pranesha, T.N., CRL – BEL, Bangalore.

ABSTRACT: Traditionally telecommunication networks are primarily circuit based with variety of protocols developed specifically to have call control while computer networks and packet switching based with specific protocols for having traffic control and packet routing. In contrast, the next generation networks are being evolved as a convergence of communication and computer networking. These networks will be having distributed elements interconnected through broadband connecting media. The traffic carried over the networks will be circuit switch as well as packet switch but to support this in distributed processing environment control plane messages will also be transacted as overheads.

However in this contest of evolving high performance network as objective the assessment of the suitability of conventionally evolved protocol needs to be done. As user applications also will use this type of network infrastructure hence suitably adapted form of existing protocols are to be used by them. This will ensure compatibility with existing protocols at the same time will provide immunity against electromagnetic interference by interconnecting heterogeneous media.

The communication system at each end can be branched into classical 7 layers OSI model with transactions being done between peer entities. The electromagnetic interference in the interconnecting media directly affects the physical layer but indirectly all upper layers also. It causes different types of error patterns to be introduced in the physical layer bit analyzed to quantity their effect on the communication system. Various classical channel models viz., Poisson, Neymann Pearson, Pareto, Markov etc. can emulate various segments of the interconnecting media thereby giving failure good idea of error pattern behavior at physical layer. This information is useful in selecting suitable FEC with interleaver so as to have very less residual error out of physical layer at other end. Still upper layers are affected because of this residual error. The main objective of this paper is to focus on various issues concerning adaptation of ATM layers so that overall electromagnetic compatibility of the system can be achieved.

4. Artificial Intelligence Approach to Planning and Managing Communication Network, Sahebu, K.M., LRDE, Bangalore.

ABSTRACT: -Communication Networks in general face innumerable EMI problems. The problems come mainly from various emitters situated in the same network or from other networks in the vicinity of sensitive receivers. After the network is established and is working for some time, suddenly a new interference can crop up due to repair or change, of location of an existing system or induction of a new system in the network. In LRDE we have developed a package to address some of these problems. The paper highlights the existing features of this software tools, its GUI features, merits, shortcomings and the way AI features can be incorporated into this software for handling complex EMI situations in the network.

EMI Suppression Techniques – I

2. Spread Spectrum Clock- An EMC Solution for New Generation Portable Computers, Heredia, N.J., Naval EMC Centre, Mumbai.

ABSTRACT: Electronic equipment often generate radiated electromagnetic interference (EMI) that effects the operation of other electronic equipment. As more electronic systems operate at higher frequencies and bandwidths, more EMI gets generated. In a portable PC, the data bus and the clock are major EMI sources because the conduct high currents and from large loops. Due to lack of shielding, portable computers systems have come under increasing pressure to comply with strict EMI emission regulations, such as FCC and CISPR.

Traditional techniques to reduce attempt to contain or to reduce the amount of generated radiation. Coaxial wires and shielded cables are effective at containing radiation, but are expensive, bulky, and inflexible. Metal chassis with sealed seams are effective for reading EMI of desktop PCs, but portable PCs are kept light by using plastics. Toxic metal paints are sometimes sprayed on plastic housings for portable PCs to provide shielding. A newer technique to reduce EMI is to very or modulate the clock frequency in the Pc. This technique is known as spread spectrum clock, since the frequency spectrum of the clock is spread over a wider range of frequencies. The paper will focus on this method to reduce the peak EMI emissions of the clock and data signals for EM compatibility.

3. Overcoming Effects of Electromagnetic Interference in warships through Multi- sensor Data Fusion, Raghu, K.R., Naval EMC Centre Mumbai.

ABSTRACT: The sensors onboard a warship biz, the radar systems, the sonar systems, the communication systems and the Electronic Support Measures (ESM) system, are the eyes and ears o the strip. Operational availability of these systems is an unavoidable necessity for the success of a mission. It is equally unavoidable that varied kinds of interactions exist amongst these systems, which manifest as electromagnetic interference. The degrading and sometimes destroying affects of electromagnetic interference are caused not only due to onboard emissions, but also due to sources external to the ship. In either case, this results in scarcity of information and consequently, difficulty in decision making, sometimes with grave operational consequences. Therefore some kind of intelligent data/information processing would be required, to enable fast and accurate decision-making.

This paper explores the possibility of overcoming the pitfalls of information scarcity by fusion of sensor data, or Data Fusion, to yield reliable information even in the face of strong electromagnetic interference. Data fusion, by definition, is the process of combining diverse data from multiple sensors in such a way that the result provides more information than the result provides more information than the sum of the individual sensors. It employs the concepts of redundancy, diversity and complementarity of information to achieve reliability and reduce ambiguity in decision making.

4. Reduction of conducted EMI Levels in an Electrical Lighting Device to Meet Application Regulatory Limits, Dhar, V.k., ERTL (West), Mumbai.

ABSTRACT: Electromagnetic Interference (EMI) refers to the impairment of desired operation of equipment by electromagnetic disturbance. Miniaturization of equipment structures as well as increasing complexity of electronic circuitry, their integration & interconnections makes all electric installations &components vulnerable to such EMI disturbances. Conducted interference is one of forms

of subject EMI disturbances, which normally exists due to sharing of power bus between different circuits or systems or equipment. Such conducted EMI usually travel normal current paths of electronic equipment & can provide potential impact on its operational states. Often EMI currents are produced due to inadequate EMI design considerations within the equipment. Situations like these demand the control/reduction of such conducted EMI preferably at design stage. The eauthor in this paper desires to highlight non-compliance of lighting appliance (i.e. electronic ballast with load as Compact fluorescent lamp) with applicable conducted regulatory limits. Apart from analysis part, this paper also deals with remedial measures takes in appliance, which finally leads to compliance with conducted regulatory limits.

5. Minimizing EMI Problems with Chaos, Banerjee, S., Kastha, D., and SenGuptha, S., IIT, Khargpur.

ABSTRACT: All power electronic circuits with state feedback controlled switching can be described as nonlinear time – varying dynamical systems, and the occurrence of chaos – where the ripples become aperiodic – is common in such systems. It is shown here that this natural phenomenon can be effectively used in minimizing EMI problems in power electronic circuits, because controllers based on chaos spreads the spectrum of converters thereby reducing the interference power at any target frequency.

EMI Suppression Techniques II

1. Conducted Noise Complains through Good Filter Design, Chand, S., and Sachdeva, A., ERTL, New Delhi

ABSTRACT: Personal computer is becoming an important item for domestic and industrial sector. Computing Devices need good regulated power supplies. Power supply could be linear or switching. But due to certain advantages of SMPS, it is preferred for usage in all computing devices. Yet compared to linear power supply, SMPS generates higher EMI noises because of switching devices. This noise may affect the performance of products in the vicinity. To suppress these noises a low pass filter is used. The design of EMI filter for SMPS depends upon a lot of factors such as impedance of filter, frequency of emitted noise fundamental frequency and suppression requirements. This paper describes the techniques for design of filter for compliance purpose and throws light over comparison of the theoretical values with reference to practical suppression.

2. Conducted EMI Issues and the Design of EMI Filter for AC Power Supply Feeding a Copper Vapour Type Laser, Phulluke, R., Agrawal, V., Kumar, G., Bhatia, M.S., Madan, V.K., and Dongare, A.S., IIT, Mumbai and BARC, Mumbai.

ABSTRACT: The switching process of the various devices of the power supply feeding a copper vapour type Laser, leads to the generation of conducted EMI. The high speed switching action by thyratron operating at high voltage and current leads to conducted EMI. Simulation of the conducted EMI from a copper vapour Laser has been done using a powerful circuit simulator software SABER. Based on the results obtained by simulation and measurement, it is proposed to design filters that will reduce the conducted EMI to acceptable levels

3. Immunity Response of Fourth Order Input EMI Filter for DC/DC Converters of Spacecraft Systems, Kartikeyan, B., Shastry, S.V.K., Nageswara Rao, M., Prahlad Rao, N., ISAC, Bangalore.

ABSTRACT: Spacecraft subsystem level EMC tests have revealed that the conducted emissions at the input of DC/DC converters tend to go above the relevant MIL-STD-461/D/E limits. A low passes fourth order input filter is required at the input of DC/DC converter for reducing this conducted emission to a level that is below the MIL-STD limits. The filter is a bilateral network. It not only cuts of the noise emanating from the DC/DC converter but also enhances the immunity of the converter to input power line transients and other noise voltages on the bus. This paper present the immunity response characteristics of the forth order input EMI filter without and with parasitic elements. Simulation was done by the circuit simulator SPICE.

Test Facilities and Measurement

1. Susceptibility Testing Using GTEM Cell, Ghosh, S., Chakrabarty, A., Sanyal, S., Katti, V.R., and Shastry, S.V.K., IIT, Kharagpur and ISAC, Bangalore.

ABSTRACT: The GTEM cell has been found as a suitable test environment for radiated susceptibility testing of electronic equipment. In Microwave Measurement Laboratory, Department of E & ECE, IIT Kharagpur a GTEM cell with test volume (1m)3 and characteristic impedance of 50O has been fabricated [1],[2] and is being successfully used for radiated emission [3] and susceptibility testing. For susceptibility testing the device in intentionally put in the required amount of electric field. In this paper a method of moment based procedure is described to evaluate the field produce inside the cell due to certain amount of applied power. The theoretical value is in well agreement with the measured one. 2. Performance Improvement of an EMC Test Laboratory through key Measures of Quality Management System, Deepak Kumar, and Das, S.k., SAMEER Centre for Electromagnetics, Chennai.

ABSTRACT: The paper describes the significant role of ISO 9000 Certification even for those organizations who offer EMC Services to industry since such Certification provides benchmark of quality for EMC services. Quality System Certification serves as the foundation for quality and business improvements. It discuss that key issues of success for continuous improvement in both quality and business, which depends on how well quality system has been maintained and measured effectively. The paper also describes how the effectiveness of quality system as per ISO 9001: 1994 standards could be measured for performance improvement of an EMC Test Laboratory.

3. Low Cost Radiated Emission Package, Aravind, M.K., Parthasarathy, T., Rao, P.N.A.P., and Pande, D.C., ADA, Bangalore, and LRDE Bangalore.

ABSTRACT: The proliferation of electronic system by commercial / military users has resulted in electromagnetic pollution of frequency spectrum. This calls for ambient EMI survey of test side over a wide band with an EMI receiver. This is a prerequisite to ensure system EMC for normal functioning. Moreover EMI receiver can be used during and after design stages for RE / CE compliance checks. The EMI receivers currently available in the market are costly. If the product designer has a low cost EMI receiver, it can be used at various stages of design, development and precompliance checks. The authors have developed low cost solution for Emission testing by making use of low cost commercial receiver having RS-232 interface and developed software for control and compliance verification. The effectiveness of the system is enhanced due to use of software, which can be altered to incorporate many additional new features time to time.

4. Inter System EMC Tests on Indian Light Combat Aircraft, Aravind, M.K., Parthasarathy, T., Rao, P.N.A.P., and Pande, D.C., ADA, Bangalore, and LRDE Bangalore.

ABSTRACT: System Level EMI/EMC Tests were carried out on Indian Light Combat Aircraft (LCA) prior to its maiden flight. This paper discusses the various aspects of testing, execution and performance of the system level EMI/EMC tests on LCA.

5. EMC Issues of Rader Receiver – A Case Study, Surya Prasad, G., and Nirmala Shanmugam, LRDE, Bangalore.

ABSTRACT: Rader receiver subsystem is developed in 3 channel-monopulse, low noise front-end configurations. The receiver consists of three identical channels for sum, azimuth difference and elevation difference outputs of monopulse comparator and each of the channels has low noise amplifier in the front end. The functional requirements of the receiver, the subsystem design details with emphasis on EMC issues are described in this paper. The electromagnetic emissions and susceptibility characteristic of a typical Radar receiver are measured and the results are critically analyzed.

Antennas and Propagation

1. Studies on New and High Tapered Amplitude Distribution for Low EMI Applications, Bala Subrahmanyam, N., Raju, G.S.N., Gottumukkala, K.R., and Habibulla Khan, GVPCE, AUCE, Visakhapatnam and KLCCE, Vijayawada

ABSTRACT: It is evident from literature that no amplitude distribution is optimal in the generation of narrow beams. This is due to the opposite behaviour of sidelobe levels and beam width. In view of this some studies are made to propose a few tapered distributions, which are useful to produce narrow beams with low side lobes. The proposed distributions are mainly raised versions of distributions obtained using Taylor's method.

2. Modeling of Planar Spiral Antenna Mounted on a Rocket Shaped Structure Using Wedge Diffraction Analysis, Ramakrishna Rao, B., Murthy Sarma, N.S., Sarma, A.D., and Ravindra, K., Osmania University, Hyderabad.

ABSTRACT: The location of the antenna on an aircraft plays a major role in improving the system performance. It is essential to locate the antennas in such a way that their radiation characteristics will be least distorted even under the influence of surroundings and EMI/EMC problems due to other electronic systems already installed on the aircraft. To predict the distortion in the radiation pattern of a planar cavity backed spiral antenna on board airborne platform, a novel technique is used using wedge diffraction theory. The experimental measurements are carried out in an anechoic chamber. The results predicted in elevation plane is compared with experimental results and found to agree well.

Electromagnetic Hazards

1. Software for determining field Distribution Inside Bio – objects Using FDTD Method, Barnejee, S., Subhankar Ray, Singh, S.K., Goswami, K.K., RBC Collage and IGNOU, WB.

ABSTRACT : The electromagnetic fields may be transmitted inside bio-objects. The analytical results were obtained by applying FDTD method using software. The results were tabulated taking one, two and three dimensional approaches.

2. Analysis of Random Survey on Electromagnetic Radiation Hazards, Chowdhury, A.K., Ray, S., Singh, S.K., Banergee, S., Goswami, K.K., and Dey, T.K., RBC Collage, and IGNOU, WB.

ABSTRACT: A random survey on electromagnetic radiation hazards on bio-objects was undertaken on ten different places. The interdependence between suffering and electromagnetic fields is denoted by correlation. The cause (EM-fields) and effects (sufferings) are indicated by regression equations. A statistical analysis was done for finding out the association of long time exposure with radiating electromagnetic fields using frequency and proportion methods.

3. A Generalized Design of Shield for he Protection of Boi – objects, Singh, S.K., Ray, S., Banerjee, S., Goswami, K.K., and Dey, T.K., RBC Collage and IGNOU, WB.

ABSTRACT : This paper is related to a software for the design of shields to protect bio-objects from incident electric fields, magnetic fields, plane waves and ESD. An optimization is also taken in between required shielding effectiveness and weight carrying capacity by using dynamic programming method.

4. Estimation of Radiation Hazards Generated on Bio – objects by Electromagnetic fields, Ray, S., Sing, S.K., Banerjee, S., Goswami, K.K., and Dey, T.K, RBC Collage, and IGNOU, WB.

ABSTRACT: Considering bio-objects as antennas to electromagnetic fields of different frequencies from extra low frequency to hundreds of GHz, specific absorption rates (SAR) are calculated with the help of a specially design software. The increase in temperature and hence change in ratios of Na + and K + ions inside and outside of a membrane due to the energy absorbed are also estimated in this paper.

5. Test Instruments for Radiation Hazard Monitoring, Sathyamurthy, S., CVRDE, Chennai.

ABSTRACT: Scientific instruments well designed for specific applications are of paramount importance in respect of any critical measurement and more so to the controversial topic of “Radiation Hazard Monitoring”. A number of radiation monitoring situations are identified in this paper starting from general survey to home appliance like microwave oven leakage’s. Therefore, the need to measure specific radiation parameters necessarily requires the right choice of instruments for accurate results. Measurement parameters, measuring system and its relevance’s are touched in this paper. Also the general measurement requirements of non-ionized radiation and its effects are briefly mentioned.

6. Electromagnetic Pollution – The Causes and Concerns, Ashis Sanyal, and Behari, J., DOIT and JNU, New Delhi.

ABSTRACT: Electromagnetic pollution, caused by increasing human activity, in the area of utilization of electrical and electromagnetic energy, is slowly increasing without much appreciation of the consequential implications. While everyone is aware of the benefits derived from the high-tech electrical and electronic devices and systems, only few users are aware of the real or unsuspected dangers from them. In this paper it was intended to give a snap shot overview of this newer version of pollution by citing few examples.

7. Prediction of the effect of EMP on system’s health and performances: B. K. Sarkar and A Chakrabarty- IIT, Kharagpur.

ABSTRACT: General Properties of EMP are stated and their effects on systems are pointed out. Electromagnetic wave coupling to various structures by different ways is discussed. Need of extensive analysis and simulation, development of computational electromagnetic techniques and modeling of various EMP signatures are stressed. Knowledge base in this respect at IIT Kharagpur is briefly described.

8. Electrical power distribution: Innocently Ignored Impeding danger: B N Biswas, Academy of Technology – Invited lecture delivered at the Golden Jubilee Celebration of the West Bengal State Electricity Board on May 28, 2005.

ABSTRACT: Health hazards and its remedy due to high voltage LF transmission have been discussed, based on epidemiological report published all over the world. “The exposure of living organisms to abnormal electromagnetic fields results significant abnormalities in physiology and function.” It is concluded that EMFs could turn out to be a far worse environmental disaster, affecting far more people, than toxic waste, radiation or asbestos.

Commission F:

Introduction

In India the work related to propagation studies and Radio Remote Sensing has been done by universities and different research institutions. They are ISRO, CSIR, DRDO and universities. For the first time in our country a systematic propagation study was done at 13 and 18 GHz using ATS 6 by ISRO and later with the help of UNDP grant ISRO conducted for nearly two years the propagation studies at 13 GHz using five line of sight links and five radiometers located at different locations in the country. The data were collected round the clock for more than one year. The climatic zones in India for this purpose were redefined and the calculations for slant path attenuation was done for prediction of attenuation in the satellite to ground path.

Another highlight is in the field of Microwave Remote Sensing. The BHASKARA I & II satellites carried microwave payload known as SAMIR acronym for Satellite Microwave Radiometer. The radiometers were operating at 19, 22, and 31GHz. BHASKARA I was launched in 1979 and BHASKARA II in 1981 and India became THIRD country in the world to have put this microwave payload for remote sensing in space for applications in Oceanography Atmospheric sciences & Land Studies.

The scientific work related to commission F has been done as said earlier by different organizations. In this report the work related to Commission F done by different organizations in the country from 2002 – 2005 is reported.

Propagation studies at SAC

As far as the work on propagation is concerned here at SAC, we have planned to carry out a Ka band propagation experiment at 20.2 and 30.5 GHz. Our next GSAT satellite, viz. GSAT-4 will be carrying a Ka Band beacon at the mentioned frequencies. We are at present waiting for the launching of the GSAt-4 satellite.

In the meantime, we have carried out some literature survey. We have gone through the relevant ITU recommendations and papers on the works carried out in ACTS and OPEX experiments. We have also seen some COST reports and papers.

For further details please contact:- Dr. Rajat Acharya, Space Application Centre, Ahmedabad. Email rajat_acharya@sac.isro.gov.in

NMRF Experimental Facilities

Summary on the status of lower and middle atmospheric research using NMRF experimental facilities

National MST Radar Facility, a unique site of having MST Radar, LAWP, Lidars, disdrometer, ORG, AWS and dual frequency GPS receiver, has been operating all the instruments to study lower and middle atmospheric dynamics. These instruments have been operated in two modes: in a campaign mode and as per the requirements of the users. Several major campaigns have been organized in the recent past, namely, Equatorial atmospheric campaign, convection, dynamics of the tropical tropopause, gravity waves, MIDAS, etc. In addition to these national campaigns, NMRF took part in international campaigns such as Coupling Processes in the Equatorial Atmosphere (CPEA). The MST radar has been operated for more than 2000 hours per anum for the last 3 years to meet the requirements of user scientists' proposals and campaigns. Several interesting results have been brought out making use of the experimental facilities at NMRF. A total of 73 (60 international and 13 National) papers have been published in journals of high impact factor. Making use of the experimental facilities of NMRF, 20 research scholars have been awarded Ph.D. degrees by different universities and the result of 2 Ph.D theses are awaited. At present 25 students are working for their Ph.D degrees in several universities and institutes.

NMRF took an active role in formulating a network of radars operating in the tropical region – International Network of Tropical Atmosphere Radars (INTAR). With the large-scale dynamics, like Walker circulations, Madden Julian oscillations, equatorial waves, monsoon circulations, etc, as main objectives, an international colloquium was held in Tirupati during 20-22 January 2005. 21 eminent scientists from Australia, Japan, Taiwan, Indonesia, France, Germany, Norway, Peru and USA and 75 scientists from India took part in this colloquium. In addition to this international colloquium, NMRF has organized 4 winter schools on MST radars and 7 user scientists workshops so far. Very recently, NMRF has organized a workshop on GPS occultation techniques to motivate the young Indian scientists to take an active part in middle atmospheric studies using the data available from CHAMP and SAC-C.

Research work on lower and middle atmosphere using experimental facilities of NMRF can be broadly divided into different major groups as follows:

Boundary layer processes: Making use of continuous atmospheric boundary layer data obtained with LAWP, seasonal and diurnal evolution of boundary layer features have been studied. The characteristics of the low level jet, like the occurrence frequency, amplitude, etc, have also been studied. The links between the active and break monsoon spells and the low level jet are envisaged. Further, it has been shown that the trapped humidity layers, just above the boundary layer and the Kelvin-Helmholtz Instability (KHI) are very important for UHF radar backscattering.

Horizontal and vertical winds: The three dimensional wind velocities obtained with the MST radar have been used to study the tropospheric and lower stratospheric dynamics. The characteristics of Tropical Easterly Jet (TEJ) have been studied in detail with a special emphasis on the formation of turbulence layers near TEJ zone. It has been observed that at most of the times and at many heights, the vertical velocities are downward. It is well known that vertical velocities are positive in and around Indonesia, undergo a circulation and are negative over India and west of India forming the walker circulation. Though it is a known fact, the vertical velocities measured and studied by Indian MST radar is the first observational evidence.

Turbulence: Extensive studies have been carried out to quantify turbulence. The refractivity turbulence structure constant, eddy dissipation rate and eddy diffusivities are estimated using different methods and the variation of these parameters at different scales are investigated. The anisotropy of the turbulence in different weather conditions has been studied.

Temperature and Humidity profiling: VHF radars are known for their continuous measurements of wind. However, an attempt has been made to retrieve temperature and humidity profiles from MST radar measurements. First, temperature has been derived by identifying Brunt-Vaisala oscillation from vertical velocity fluctuations. The humidity profile has been retrieved using temperature and turbulence profiles (both provided by radar). The radar retrieved profiles compare well with those obtained with radiosonde.

Precipitating systems: Extensive studies have been carried out to understand the kinematics and the microphysics of precipitating cloud systems with a special emphasis on convective systems. A detailed scheme has been developed to classify precipitating clouds. Based on this classification scheme, Z-R relationships have been derived for different precipitating systems and also for the southwest and northeast monsoon systems. These relationships found direct application in operational meteorology and also in satellite meteorology. Dual wavelength algorithm has been developed to derive the drop size distribution (DSD). Variations of DSD with height as well as with time within the meso-scale convective systems are studied. The mass and momentum fluxes estimated during convection show an order of magnitude higher than those estimated during normal weather.

Waves: Making use of continuous measurements of MST radar and Lidar, a spectrum of waves starting from gravity waves to QBO has been studied. The sources, characteristics, and the propagation of these waves in the middle atmosphere have been studied in detail. Special emphasis is given to convectively generated gravity wave phenomena. Winds and temperature measured in the MST region

at Gadanki and SHAR have brought out the characteristics of equatorial waves and their interaction with the mean flow. The tidal wind variations also have been studied and it is found that they are much higher than the GSWM model. Further, the gravity wave activity is found to be maximum over here in the equinoxial (February-April and August-October) months. It is also seen that the middle atmospheric gravity waves are modulated remarkably by equatorial waves having periods of 4 days and 12 days.

QBO's have been studied using 8 years of wind measurements obtained with the Indian MST radar. A strong signal of QBO in the height range of 16-20 km with a periodicity of 25 months was observed. We are aware that QBO's are usually seen in stratospheric heights. But interestingly, QBO's are observed in the upper troposphere. More interestingly, the QBO seen in the upper troposphere in the year 1997 corresponds to the strongest El-Nino of the last century.

Theoretically it is postulated that 1.4 year oscillations in temperature can occur at upper stratospheric and mesospheric heights. Using the vertical profiles of temperature obtained with the Lidar at NMRF, strong 1.4 year oscillations in temperature at 40 km, 55 km, 65 km, and 79 km were observed. This is the first observational evidence of 1.4 year periodicity oscillations in temperature.

Mesospheric dynamics: Mesospheric mean winds and their seasonal variation are studied in detail using the data collected over 4 years. The features of semi annual oscillation and quasi-biennial oscillation observed in the zonal component are studied in detail. Coordinated MST radar and Nd:YAG lidar observations have been conducted to study the mesospheric structures and these observations show a one-to-one correspondence of the occurrence of MST radar echoes and temperature inversion. A detailed analysis shows that these processes are associated closely with gravity wave breaking.

CHAMP – Tropopause height, gravity waves: Occultation is a powerful technique and CHAMP makes use of this technique to derive vertical profiles of temperature and humidity with reasonable accuracy. CHAMP data has been used to study the global tropopause structure. It was believed that the tropopause height has a convex shape, ie., the tropopause height is maximum in the tropics and decreases with latitude. However, the cold point tropopause derived from CHAMP measurements show an increase in tropopause height as we move from equator to sub tropics and then decreases with latitude. This contrasting finding has to be investigated further to find out the reasons for this behavior and the impact of this feature on our existing hypothesis.

GPS radio occultation observations provide an opportunity to study global morphology of stratospheric gravity wave activity. The energy density Ep is a measure of gravity wave activity. The global distribution of Ep values in the height region of 20-25 km has been studied. It has been observed that at tropical and sub-tropical latitudes, Ep values are large in all the months, which is due to larger convection than expected and also partly due to equatorial waves. Significant enhancement of Ep has been observed over Antarctica during 2002, which is thought to be responsible for an unusual strong stratospheric warming observed during September-October 2002. Lidar observations at Gadanki have revealed stratospheric warming coincidence with the warming at high latitude.

Development of Lidars for atmospheric probing: Augmentation of the existing lidar has been made in order to make it capable of measuring temperature in the upper troposphere and lower stratosphere and water vapor in the troposphere using the vibrational rotational Raman scattering. An unmanned portable Micro-pulse Lidar system operating at 532 nm has been developed for monitoring atmospheric boundary layer features using aerosol as the tracers of atmospheric motion.

Recently, a resonance Lidar system has been developed for deriving the vertical profiles of atmospheric sodium in the height region of 80-110 km. These are the first atmospheric sodium measurements to be reported from India. Preliminary analysis of sodium density profiles reveals interesting features like wave modulations in the density profiles and sudden formation of a dense thin Na layer superimposed on background Na layer, etc.

NMRF took up several new projects to augment the existing instrumentation so as to enable the scientists to study several aspects of the middle atmosphere. The ongoing projects, include Spatial

Domain Interferrometry/Coherent Radar Imaging, development of a Doppler Lidar to measure stratospheric and lower mesospheric winds, electron density measurement using the coherent radar signals, development of Doppler Sodar, etc.

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Radio Propagation and Remote Sensing

There are four major areas in which work has been done: (i) Modelling of propagation at millimeter wavelengths, (ii) Rain dropsize distrbution, (iii) Retrieval of microphysical properties of cloud with dual-frequency radar observations, and (iv) Atmospheric sounding using satellite-based GPS occultation measurements, and

Modelling of propagation at millimeter wavelengths:

The modelling of rain attenuation has been carried out using the measurements of rain drop size distribution (DSD) at three locations namely, Calcutta, Deharadun and Guwahati in the frequency range 10-200 GHz (Maitra, 2004). The prevailing DSD in the Indian region can cause significant variability in the rain attenuation distribution emphasizing the need of long-term and extensive observation in

this region.

The propagation of wideband signal in the frequency range 10-200 GHz has been studied using the Liebe's propagation model under different propagation conditions (Maitra and Kundu, 2003). The dispersion and absorption can cause distortion of the propagated wideband signal having a bandwidth of a few GHz the severity of which depends on the frequency of the carrier signal, path length and rain rate. This distortion of wideband signal can affect the performance of links at millimeter wavelengths used for high rate data communication.

The measurement of rain attenuation over an earth-space path is being carried out since June 2004 by receiving a Ku-band satellite signal at Kolkata (22°34' N, 88°29' E) from the satellite NSS-6 (geostationary at longitude 95^0 E). An optical raingauge (ORG) is also operated at the receiver site. The distributions of rain rate and rain attenuation obtained with one year data indicate that the occurrences both rain rate and attenuation are higher than that given by the ITU-R model (Maitra and Chakravarty, 2005). The instantaneous rain attenuation is estimated from the measurement of the point rain rate using the simple attenuation model (SAM) and it is found that the model estimated value follow the measured attenuation below the rain rate of 20 mm/h. At higher rain rates, the model gives higher estimates than the measured values indicating that the sizes of the rain cells associated with the rain events are much smaller than that considered in the model.

Rain drop size distribution

An impact type disdrometer to measure rain DSD, which is collocated with an ORG, is being run at Kolkata since June 2004. During the evolution of raindrops during rain events, the DSD at the growing phase is biased for larger drops whereas smaller drops dominate at the decaying phase of the event for the identical rain rates (Maitra and Chakravarty, 2005). The variability of DSD is more at the low rain rates than that at the high rates, indicating that the precipitation processes responsible for low rain rates are more varied compared to that for high rain rates. The three parameters lognormal and gamma functions are fitted to the disdrometer data to model DSD at the present location for some rain events, and no definite preference has been indicated to any of the two functions. With the accumulation and analysis of more data a long term picture will emerge to give a firm indication about the suitability of a particular function to model DSD at the present location.

Retrieval of microphysical properties of cloud

A technique for obtaining the vertical profiles of effective particle size and liquid water content of low altitude water cloud by combining the backscatter measurements with 94 GHz radar and 905 nm lidar has been used to identify the different regions of low altitude water cloud (Maitra and Goddard, 2002). This technique involves obtaining a power law relation between the effective drop diameter and the ratio of radar-to-lidar backscatter coefficient, considering a three-parameter modified gamma distribution for cloud droplets. Case studies with experimental radar and lidar measurements made at the Rutherford Appleton Laboratory, UK, at Chilbolton, England (51.15^0 *N*, 1.44^0 *S*) indicate that the base region of Stratocumulus cloud is dominated by large drops and there is a distinct region of small droplets at higher altitudes.

Atmospheric sounding using satellite-based GPS occultation measurements

Refractivity profiles obtained from the radio occultation measurements of the CHAMP satellite using GPS signals have been compared with the radiosonde data in the Indian region to validate the occultation measurements (Maitra et al., 2005). A comparison between the temperature profiles from CHAMP and radiosonde observations indicates generally a good agreement above 10 km, and below 5 km the CHAMP-derived temperatures are considerably lower than the radiosonde measurements due to the significant presence of water vapour. The height and temperature of tropopause have been investigated in the Indian region using the CHAMP data on the basis the cold point tropopause (CPT). The tropopause height shows very little variation with latitude, whereas the tropopause temperature shows a noticeable increase with latitude.

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Ionosphere

The ionospheric group at IIG has been involved in studies of the evolution and dynamics of equatorial spread F (ESF) irregularities under different ambient conditions in the post-sunset equatorial ionosphere, using theory and observations of scintillations on VHF and higher frequency trans-ionospheric radio waves, which occur due to scattering of the radio waves by ESF irregularities. Some specific studies undertaken during this period are:

Space weather affects the distribution of plasma in the ionosphere and plasmasphere through which radio waves used for communication and navigation propagate. On some occasions, only large-scale (> 10 km) structures in the propagation medium are encountered by the radio waves, while at other times, small-scale variations in ionospheric electron density give rise to scintillations on transionospheric radio waves (Bhattacharyya and Basu, 2002).

Two different aspects of the effect of magnetic activity on the dynamics of ESF irregularities are studied using spaced receiver scintillation observations. The first one deals with the question of how magnetic activity affects the generation of ESF irregularities. For this, a parameter designated the "random velocity," which is a measure of random changes in the irregularity drift velocity, is evaluated from the data. In earlier studies, this parameter had been found to have large values in the early phase of evolution of ESF irregularities during the post-sunset period, with a steep decline to a low value by 22 LT. It is suggested that the random component of the irregularity drift velocity arises from the perturbation electric field associated with the generalized Rayleigh-Taylor (GRT) instability, which gives rise to the intermediate scale ESF irregularities responsible for the occurrence of the observed scintillations. The decline of the "random velocity" is therefore attributed to the decay of the perturbation electric field associated with the GRT instability, in agreement with results derived from computer simulation of the temporal evolution of the GRT instability in the post-sunset equatorial F region. This observation has led to the idea that the "random velocity" may be used as an indicator

of the “age” of the irregularities which produce the observed scintillations, because in the absence of this “random velocity”, ESF irregularities generated much earlier to the west of the observation point simply drift eastward with the background plasma, on to the path of the radio wave signal, to produce the observed scintillations. Therefore, estimation of the “age” of the irregularities is crucial for determining a cause-effect relationship between magnetic activity and generation of ESF irregularities. This idea has been used to determine when scintillation observations on magnetically active days are due to irregularities, which are freshly generated in the postmidnight period due to a reversal of the background electric field from westward to eastward, as a result of magnetic activity. The second aspect studied is the identification of magnetically disturbed background plasma drifts, which is generally possible only after 22 LT, when the estimated irregularity drift velocities are close to that of the background plasma. The monthly pattern of the estimated drift after 22 L T for magnetically quiet days with scintillations, is established in order to identify a slowly varying superimposed westward perturbation in the background plasma drift that is produced by a disturbance dynamo, which arises due to magnetic activity. The results are in broad ‘agreement with some of the recent empirical models of the evolution, with storm time, of equatorial disturbance dynamo electric fields (Bhattacharyya et aI., 2002).

A new method is developed for calculating the spatial correlation function of intensity scintillation patterns produced by the propagation of a radio wave signal through ionospheric irregularities using spaced receiver observations of such scintillations. This requires that random temporal variations of the irregularity drift speed be taken into account. It is seen from the results that the occurrence of strong scintillations on an L band signal requires the presence of short (~ 20 m) coherence scale lengths in the UHF scintillation pattern obtained in the plane of the receiver. This condition is satisfied near the crest of the equatorial ionization anomaly (EIA) region, but not near the dip equator. In the decay phase of L-band scintillations recorded near the crest of the EIA region, the maximum strength of these scintillations at any point in time is found to be correlated with the magnetic eastward drift speed of the pattern of intensity scintillations on an UHF signal recorded in this region, which is determined mainly by the magnetic eastward drift velocity of the ionospheric irregularities. Dependence of the corresponding strength of UHF scintillations on the drift speed indicates that toward the end of the decay phase of L-band scintillations, the irregularity power spectrum steepens, and the large scale irregularities that remain can cause the UHF signal to be focused in the plane of the receiver, yielding UHF S4-indices greater than one, while focusing of the UHF signal is less evident at earlier times when there is focusing of the L -band signal (Bhattacharyya et aI., 2003).

A theoretical model was developed to relate the spatial variations found in intensity scintillation patterns formed on the ground due to scattering of radio waves by equatorial ionospheric irregularities, with the spatial structure of these irregularities. As equatorial ionospheric irregularities are closely aligned with the geomagnetic field, they may be considered to constitute a two-dimensional dispersive random medium. A power law spectrum is assumed to characterize the electron density variations, which produce refractive index irregularities in the medium. A numerical solution of the equation satisfied by the fourth moment of intensity variations, in the plane of the receiver, is obtained using the split step method. The S4-index, which is the standard deviation of normalized intensity variations as well as spatial correlation function of intensity, is obtained by considering special cases of the fourth moment of intensity variations. Variation of S4-index with the standard deviation of phase fluctuations imposed by the ionospheric irregularities is studied for irregularities with different power spectral indices. Effect of varying phase fluctuations on the 50% de-correlation scale length is also studied fur weak as well as strong scintillations. The S4-index and spatial scale lengths in the ground scintillation pattern depend on parameters like thickness and height of the irregularity layer, background plasma density, standard deviation of electron density fluctuation and irregularity power spectrum. The theoretical model is used to understand the roles of these parameters in determining the S4-index and spatial correlation function of intensity in the ground scintillation pattern (Engavale and Bhattacharyya, 2005).

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NPL, New Delhi

The research efforts carried out at the National Physical Laboratory, New Delhi are broadly categorized into the areas such as Fixed, mobile and marine communication and Rain and cloud attenuation studies.

FIXED, MOBILE AND MARINE COMMUNICATION

The group at NPL has been involved on all aspects of work related to fixed, mobile and marine communication. Incase of fixed communication, both terrestrial and earth space path and wide range of frequency from VHF band to many giga hertz are covered. Some of the briefs on communication studies carried out are as follows.

LOS PROPAGATION STUDIES

In collaboration with Indian southern Railways, field strength measurements were made using several communication links situated in different locations of Indian southern region. The performance deterioration of such links operating at 7 GHz was investigated (Sarkar et al., 2002). The performance of the links is satisfactory when the signal level is equal to and greater than -74 dBm, which is the usual satisfactory level of the signal. The links performance start deteriorating when the signal level reduces to as low as around -75 dBm. The most problematic months and time during which the performance of each link was found not to be satisfactory was investigated. On the basis of low signal level, causes of deterioration in relation to meteorological conditions have been determined. In order to counter multipath fading, some remedial techniques also have been looked into. Results on carrier intensity of another microwave communication link belonging to Indian southern Railways situated between Raichur and Adoni having path length 60 km and affected by three atmospheric conditions viz. clear air, fog and cloud have been deduced (Sarkar et al, 2002). The low signals associated with deep fades were observed for large percentage of time during foggy and cloudy situations. It was seen that there is wide variation in signal level under foggy condition. The low signal associated with less than -70 dBm was found to occur for 74% under foggy situation. The change of meteorological situation (temperature or water vapour or liquid water content) from normal condition (level) leads to change in atmospheric condition and such change gives rise to change in signal level. For cloudy condition, the low signal £ -70 dBm has been found to occur for around 91%. The low signal characterized with fades as seen in cloudy condition can only be explained on the basis multipath propagation phenomena.

VHF PROPAGATION STUDIES

DOUBLE KNIFE EDGE DIFFRACTION PROPAGATION STUDIES OVER IRREGULAR TERRAIN:

Mountain cliffs constituting knife-edges influence radio wave propagating from VHF to microwave frequencies. The diffraction phenomena caused by these single or multiple knife edges are a dominant Propagation mechanism that has to be taken into account in planning TV,FM networks, cellular radio, microwave network etc., in mountainous regions. In order to investigate the above mechanism field strength measurements were conducted over five double knife-edge paths and the measured signal levels are compared with several prediction techniques. Four paths are around Mumbai TV transmitter and one path around Pune transmitter. These are Mumbai-Kasara, Mumbai-Karjat, Mumbai-Chauk, Mumbai-Bulsar, Pune-Mahabaleshwar. All these places are located in western India. It is seen that out of all the prediction methods Giovanelli' s method gives best agreement with the observed values. Detailed results can be seen in Prasad et.al [Prasad et al, 2004].

MOBILE COMMUNICATIONS

Characterization of mobile radio channel has been carried out by using narrow band measurements in a moving train in northern Indian and western India in urban, sub-urban and rural environments. In northern India this has been done using New Delhi, Ghaziabad, Meerut, Muzzafarnagar, and Saharanpur base stations. In western India the base stations utilized are Kurla, Kalyan, Vangani, Neral, Talegaon, Pangoli and Pune base stations. Various land mobile predictions methods like Hata, B lomquist-Ladell, Egli, Uniform theory of diffraction etc. have been tested with measured results. The suitabilities of various prediction methods, their deviations have been discussed (Prasad et.al 2002, 2005, Ravindra et al, 2005).

The effect of antenna tilting especially the transmitting one, on the performance of fixed and mobile communication systems has been investigated. Here, fixed systems correspond to transmitting antenna height of 100 m and mobile systems correspond to 30m. The path loss exponents deduced by us over the northern region have been utilized to deduce cell radii for various tilting angles ranging from 3 to 10 degrees. Apart from this COST 231 Hata and Walfisch Ikegami methods have been utilized to deduce path loss at cell boundary as a function of base station antenna height for various tilting angles at a PCS frequency of 1800 MHz. These results can of great help in optimizing tilting angles and cell radius Prasad et al, 2005).

MARINE COMMUNICATION

Work also has been carried out on evaporation duct over Indian seas both Bay of Bengal and Arabian Sea. Evaporation duct exits over sea on regular basis due to the excess evaporation of water vapour from seawater. Such evaporation ducts effect performance of microwave radio communication and radar propagation. Based on meteorological parameters evaporation duct height morphology over Indian seas have been prepared (Pasricha et al, 2002). In addition to, refractivity gradient statistics over different locations in Indian seas have also been deduced. Such results can be used for estimation performance of radio systems over seas. Based on evaporation duct characteristics, the vertical and horizontal coverage diagrams are generated under different systems configuration. The coverage diagrams indicated shadow zones on radio holes i.e., regions, which are not illuminated by radio rays.

RAIN AND CLOUD ATTENUATION

There is a shift in the focus of research studies as well as from the user point of view for satellite communications from C band to higher bands in India. Measurements of various precipitation parameters have been carried out over different geographical regions of India in recent years. The parameters, which affect the microwave communication and radar propagation, are mainly rain rate, horizontal extension of rain, rain height, rain drop size distribution, cloud characteristics. All these parameters are taken as input parameters for estimation performance of microwave communication systems. Several techniques such as rapid response rain gauge, conventional rain gauge, radar, radiosonde etc., are used to deduce such results. In addition to precipitation measurements, communication links operating in Ku and K bands are also monitored to investigate the effects of rain on the performance of communication systems. Such links should be monitored where heavy

rainfall occurs.

Results on raindrop size distribution (RDSD) at different rain intensities from radar reflectivity measurements were derived (Mali et al, 2003). To deduce RDSD, some Integral Rainfall Parameters (IRP) are used. The formulation obtained in terms of radar reflectivity factor and rain rate is quite simple. The well known equations, that relate radar reflectivity factor (Z) in dBz, effective radar reflectivity factor (Z_e) in mm^6 m^{-3}, rain rate (R) in mm/hr, rain drop diameter (D) in mm, drop size distribution N(D) in m^{-3} mm^{-1}, back scattering cross-section (s_b) in m^2, terminal velocity of rain drop (V) in m/s, dielectric constant of water (K_w) and the wavelength of the operating radar (l) in m were utilized to deduce N(D) over Kolkata.The most probable raindrop diameters at different radar reflectivity and rain rate have been estimated. It is seen in our study that the most probable raindrop diameter, D varies exponentially with radar reflectivity, dBz. The values of D vary from ~ 0.1 mm to 1.4 mm, while the radar reflectivity varies from 23 dBz to 58 dBz. The values of D have also been found to vary exponentially with rain rate. At higher rain rate of ~ 100 mm/hr, D is around ~ 1.25 mm. The values of N (D), at rain rates ~ 49 mm/hr and 75 mm/hr were also estimated. It was seen that the maximum number of drops is around ~ 1800 per m^3mm^1 and associated with most probable raindrop diameter around ~ 0.75 mm at 49 mm/hr. Significant number of rain drops is associated with diameters more than ~1.5 mm. Large numbers of small rain drops also have been observed at ~ 49 mm/hr. For rain rate ~ 75 mm/hr, the maximum number density, N(D) per m^3mm^1 was observed around ~ 640, while the maximum rain drop diameter was around ~ 3.9 mm. Considerable large number of rain drops with large diameter have also been observed at ~75 mm/hr. The number of drops [N(D)] per m^3mm^1 associated with rain drop diameter ~ 1 mm, 1.5 mm, 2 mm, 2.5 mm and 3 mm have been found to be ~ 630 , 530, 300 ,150 and 10 , respectively at ~ 75 mm/hr.

The statistical morphology of radar reflectivity as a function of horizontal and vertical extension of rain is of considerable interest to those assessing the possible interference between terrestrial links and earth-space satellite links. The horizontal and vertical extension of rain is also estimated from radar plan position indicator (PPI) and range height indicator (RHI) measurements (Sarkar et al., 2003). These results of rain extension are deduced as a function of radar reflectivity factor (dBz). The radar reflectivity factor is the measure of the strength of the scattering cross section of the rain cells. The radar reflectivity measurements taken by X-band radar over Kolkata have been utilized to deduce rain cells extension. Taking all PPI measurements, horizontal extension of rain has been derived. It has been seen that the horizontal extension varies from ~14 km to 4 km while the radar reflectivity varies from 28 dBz to 53 dBz. The large value of reflectivity is an indication of high rain rate and is associated with low horizontal extension of rain. The radar reflectivity of ~43 dBz (which is a measure of rain rate ~ 18 mm/hr), is associated with the horizontal extension of ~ 8 km, while the radar reflectivity of ~ 33 dBz (which is a measure of rain rate ~2.6 mm/hr) is associated with the horizontal extension of ~ 10 km. The low radar reflectivity is associated with large horizontal extension.

The results on the variation of vertical extension of rain with radar reflectivity suggest that the height from where the rain of different intensities starts occurring. It has been seen that the vertical extension of rain varies from 9 km to 5.75 km. These measurements were taken in monsoon months. It is seen that the low vertical extension of rain ~5.75-km is associated with the radar reflectivity of ~ 53 dBz when the rain intensity is ~ 74 mm/hr. The vertical extension of rain from 8 km to 9 km is found to be associated with 28 - 43 dBz and the rain rate varies from ~ 2.4 mm/hr to 18 mm/hr.

The rain height is important for attenuation estimation in satellite communication. It is well established that 0^OC isotherm height is taken as rain height. Detailed investigations of rain height have been made over India (Mondal and Sarkar 2003). The variation of rain height is appreciable over different locations in India particularly during winter months. It is seen that rain height decreases in winter as the latitude increases while in monsoon the variation is not substantial. The rain height is within 4.5 -5.5 km up to 30^oN. This is due to the fact that the rainfall during monsoon is more or less uniformly distributed throughout India irrespective of the station latitude. Over Srinagar H_I is around 0.25-1.60 km while over Minicoy, it is around 4.30-6.50 km and over Calcutta it is 3.20-

4.70 km during winter season. In the months of monsoon season, the variation of Hi is not substantial particularly over inland. Rain height depends on rain rates and since rain rates during monsoon over these stations are almost similar, no significant variation in rain height with respect to latitude is observed. As far as topographical dependence is concerned, it has been found that rain height does not depend very much on topographical features, but it depends more on seasons. Seasonal dependence has been observed almost over all the stations. The latitudinal dependence has also been observed particularly in winter months.

To see the effects of all such climatic parameters, commercial communication links having different hop length operating at 13 GHz and 18 GHz are monitored along with rapid response rain gauge measurements (Sarkar et al, 2003, 2004,2005).The attenuation results over two different paths at 13 GHz at different probability levels are deduced (Sarkar et al, 2003, 2005). It is seen that under normal condition when there is no precipitation the measured signal level is ~-44 dBm. The results on attenuation have been derived by taking the difference of the normal signal level ~ -44 dBm and the instantaneous signal level in dBm. If the observed signal level at a time is ~-54 dBm then the estimated attenuation is 10 dB. It is seen that the attenuation increases with rain rates. The observed attenuation is around ~ 6 dB at 20 mm/hr and it is 16 dB at 60 mm/hr. The attenuation ranging between ~ 15 dB and 27 dB is found to be associated with rain rate from 55 mm/hr to 145 mm/ hr. The results on attenuation at different rain rate have also been deduced from the ITU-R model, $A= .02515R^{1.164}$.The attenuation results deduced from ITU-R model particularly at higher level, intermediate level, show quite reasonable good agreement with the measured results. But at very high rain intensities the ITU-R model overestimates the attenuation results at 13 GHz.

The probability distribution of attenuation at 18 GHz (Sarkar et al, 2004) over the communication link situated over Kolkata having path length 8 km is deduced. It was observed that under normal condition when there is no precipitation the measured signal level is -48 dBm. It is seen that the observed attenuation is around 7 dB at 20 mm/hr and it is 18.6 dB at 60 mm/hr. There is not much increase in attenuation from 120 mm/hr to 180 mm/hr. It was seen that the attenuation is equal or more than 18 dB for 20% of the time. It was seen that the attenuation is ³ 18dB when the rain rate is ³ 64 mm/hr for 10% of time. The attenuation is around 30 dB for 1% of time when the rain rate is ³ 160 mm/hr for 1% of time.

Rain attenuation studies were also made at 11.7GHz by utilizing INSAT-2C satellite signals over southern India during rain events (Rao et al, 2002). The observed cumulative distribution functions were compared with prominent predicted models and found that Garcia-Lopez and Moupfouma methods fare better and ITU-R method deviates largely from the observed rain attenuation.

CLOUD CHARACTERISTICS AND CLOUD ATTENUATION

The effects of rain on radio wave are more than cloud but the occurrence of cloud is more prevalent than rain. The frequent presence of cloud causes some amount of link degradation for significant percentage of time over the tropical Indian subcontinent. The cloud morphology particularly in relation to radio wave propagation over different geographical region of India is very essential and important. In view of this, systematic studies on cloud occurrence morphology over different geographical locations in India have been undertaken. Recently, some results on cloud occurrence statistics and attenuation of radio wave due to cloud over selected stations located in different geographical regions were derived and reported (Sarkar et al, 2002, Sarkar et al, 2005). The cloud characteristics have been derived from the low cloud data. The cloud data was obtained from the India Meteorological Department. The cloud observations are taken four times during day and four times during night. The daytime observations are taken during 0830 hrs IST, 1130 hrs IST, 1430 hrs IST and 1730 hrs IST. The nighttime observations are taken during 2030 hrs IST and 0530 hrs IST. The low clouds are found to occur between 2 km and 6 km heights. The times of observations of clouds were chosen in such a way that four-day time observations and four night time observations are good enough to be representative conditions of day and night. More over the results on cloud statistics have been provided on monthly basis. Similarly, the daytime and nighttime average cloud statistics of a month can be the true representative of the daily cloud statistics in that month. The day time and night time results on cloud

derived from four observations in a day and night can again be said the true representative of cloud occurrence in any time of the day and night. In fact such type of statistics is good enough to radio communication engineers and radio researchers for estimation performance or prediction of field strength for satellite communication. It is seen from a recent study (Sarkar et al, 2005) that low cloud occurrence over Hyderabad is very significant and particularly during June, July, August and September. In the months of June, July, August and September the low clouds are found to occur for 29 days, 30 days, 30 days and 28 days and 28 nights, 28 nights, 31 nights and 28 nights respectively. In winter months, December, January and February, the clouds occur for 11 days, 10 days and 12 days and for 6 nights and 7 nights respectively. The specific attenuation of radiowave due to clouds at various frequencies ~ 10 GHz, 20 GHz, 30 GHz, 40 GHz, 50 GHz, 75 GHz and 100 GHz for summer and monsoon seasons has also been deduced. The specific attenuation of radio wave due to cloud at 30 GHz for liquid water content ~1g/m^3 is 0.88 dB/km while at 75 GHz the specific attenuation is ~ 5.55 dB/km.

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Double knife edge diffraction propagation studies over irregular terrain:

Mountain cliffs constituting knife-edges influence radio wave propagating from VHF to microwave frequencies . The diffraction phenomena caused by these single or multiple knife edges are a dominant

Propagation mechanism that has to be taken into account in planning TV,FM networks, cellular radio, microwave network etc., in mountainous regions. In order to investigate the above mechanism field strength measurements were conducted over five double knife-edge paths and the measured signal levels are compared with several prediction techniques. Four paths are around Mumbai TV transmitter and one path around Pune transmitter. These are Mumbai-Kasara, Mumbai-Karjat, Mumbai-Chauk, Mumbai-Bulsar, Pune-Mahabaleshwar. All these places are located in western India. It is seen that out of all the prediction methods Giovanelli' s method gives best agreement with the observed values. Detailed results can be seen in Prasad et.al [1].

Mobile communications:

Characterization of mobile radio channel has been carried out by using narrow band measurements in a moving train in northern Indian and western India in urban, sub-urban and rural

Environments. In northern India this has been done using New Delhi, Ghaziabad, Meerut, Muzzafarnagar, and Saharanpur base stations. In western India the base stations utilized are Kurla, Kalyan, Vangani, Neral, Talegaon, Pangoli and Pune base stations. Various land mobile predictions methods like Hata, B lomquist-Ladell, Egli, Uniform theory of diffraction etc. have been tested with measured results. The suitabilities of various prediction methods, their deviations have been discussed in publications Prasad et.al [2-5].

The effect of antenna tilting especially the transmitting one, on the performance of fixed and mobile communication systems has been investigated. Here, fixed systems correspond to transmitting antenna height of 100 m and mobile systems correspond to 30m. The path loss exponents deduced by us over the northern region have been utilized to deduce cell radii for various tilting angles ranging from 3 to 10 degrees. Apart from this COST 231 Hata and Walfisch Ikegami methods have been utilized to deduce path loss at cell boundary as a function of base station antenna height for various tilting angles at a PCS frequency of 1800 MHz. These results can of great help in optimizing tilting angles and cell radius.

The detailed results are seen in Prasad et.al [6]

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International Centre for Radio Science, Jodhpur

The Radio waves were first generated by Sir J.C. Bose in India about 100 years ago. At the same time Sir Marconi also demonstrated the communication in Europe. In last 100 years there has been phenomenal growth in the technology, Science and Application of Radio waves all over the world. In India also, after Sir J.C. Bose had done the pioneering work, the application-oriented research has picked up only in last fifty years. With the advent of Satellite Communication, Microwave Remote Sensing, Line of Sight Communication, Troposcatter Communications, the radio wave generation and its applications have been widely accepted. (In the world Industrial application of radio waves in Textile, Tea, Rubber and other industries where uniform heating is required the radio wave heating is used.) The diathermy equipment using Microwave heating is one of the Biomedical Application of Radio waves.

In January 1996 the formation of promoters group started and by June 1997 about 10 promoters signed for starting the International Centre for Radio Science as a registered society. Shri Laxmi Narain Calla Education foundation was the initial promoter and all the funds were being provided for initial work from Shri L.N.C.E. foundation. The ICRS was registered as society on 24th June 1997. The management committee was set up under the chairmanship of Prof. O.P.N. Calla who earlier in May 1996 was invited by Promoters to become the First Director (founder Director) of ICRS in the meeting held on 15th May 1996 at New Delhi. An “International Advisory Board was also set up with scientists from various important Laboratories, Research organizations, Government organizations and Academics. The management committee has scientists from Indian Research Institutes, Government Departments, Academics and prominent person in their field.

OBJECTIVES OF ICRS

It is basically intended to organize research activities and programs, which are in line with objectives of the Centre.

The importance of radio science in improving the quality of life for the mankind is beyond doubt. The interaction within the scientific community at research level has increased all over world mainly due to the generation of application oriented newer areas of science. Enhanced interaction between the scientists could further accelerate the research activities being carried out in many part of the world. Thus to have larger collaboration within scientists working in the field of radio science, International Centre for Radio Science (ICRS) is planned with the following objectives:

(a) The object of the International Centre for Radio Science is to conduct research and studies in the field of radio, telecommunications, electronics and information science and within these fields: to promote and organize research with national and international cooperation, and the

discussion and dissemination of the result of the research.

(b) To encourage the adoption of common methods of measurement, and intercomparison and standardization of measuring instruments used in scientific work.

(c) To stimulate and coordinate studies of:

· The scientific aspect and application of telecommunications using electromagnetic waves guided and unguided.

· The scientific aspect of applications in remote sensing using electromagnetic waves, guided and unguided.

· The generation and detection of these waves, and the processing of the signals embedded in them.

· To study the interaction of radio waves with matter. To find out the effects of radio waves on the living and nonliving.

· Studies and research and development in the area of non-conventional power generation methods.

(d) To create infrastructure commensurate with the need of well-defined programs as accepted and approved by the competent decision making body.

(e) To work in close coordination with concerned National organization working in the field of radio science.

(f) To collaborate within National as well as International institutions and organizations for hardware and software needs of the Centre and also with a view to exchange and share academic resources.

(g) To conduct short term and long term courses within the framework of the Centre. Also have training programs as well as other activities in line of the objectives of the Centre.

(h) To upgrade and augment available facilities required for research programs.

(i) To consider and implement at appropriate time, extension of facilities at the Centre in a form which should be suitable for furtherance of the aims and objectives of the Centre.

(j) To consider and, if found appropriate by competent body, allow utilization of available facilities to similar other professional bodies at terms and condition as may be decided from time to time by competent authority for causes which are in tune with the overall objectives of the Centre.

(k) To obtain grants, sanctions and take other appropriate steps conventional as well as innovative to make the Centre financially self-supporting.

(l) To purchase and sale the property including land building etc. As per the need and requirement of the institution either on lease, or with patta, or as gift / donation and also to take on rent as approved by competent decision-making body.

After registration on 24th June 1997, ICRS has been engaged in the research activities in many areas like studying the effect of Radio waves on Animals, planning to conduct literature survey for application of Microwaves in Industrial heating. The different areas in which ICRS is working and will work are as follows:

1. Electromagnetic Metrology
2. Field and waves
3. Signals and systems
4. Electronics and Photonics
5. Electromagnetic Noise and Interference

6. Wave propagation and Remote Sensing
7. Ionospheric Radio and Propagation of waves
8. Waves in plasma
9. Radio Astronomy
10. Electromagnetic in Biology and Medicine
11. Information Science and Technology
12. Computer Hardware and Software
13. Satellite Communications
14. Microwave Remote Sensing
15. Image Processing

ICRS has completed four projects for different organizations the description of the same is given below.

1. ICRS was given a project by Snow and Avalanche Study Establishment Defence Research Development Organization Chandigarh to prepare a **"Feasibility study report on use of Microwave Instruments for SNOW study (SASE)".** ICRS has prepared the report and has submitted final report to Director SASE.
2. ICRS was given a project by Interim Test Range, DRDO Chandipur; "**Propagation studies for Line of sight Link over sea (ITR)**". It was completed successfully by ICRS
3. ICRS was given a project by Electronics and Radar Development organization, DRDO Bangalore, "**Study of High Resolution Radar (LRDE)".** It was completed successfully by ICRS
4. ICRS was given a project by Research Centre Imarat, DRDO Hydrerabad "**Multipath Studies (RCI)**". It was completed successfully by ICRS

ICRS is presently doing the following projects

1. To study and establish methodology for measurement of complex dielectric constant of solid at microwave frequencies for radome application (rci)
2. Measurement of dielectric constant of dielectric materials at s-band (2.2 – 2.3 ghz) (rci)
3. Determination of surface and subsurface water content using microwave techniques (dtrl)

List indicating the No. of papers published in Journals, Proceedings of the conferences and papers presented in conferences from 2002 to 2005

S.N.	List of Papers	No. of papers
1.	Paper Published in Journals from 2002 - 2005	
	(A) National	08
	(B) International	00
2.	Papers Published in Proceedings of the Conferences from 2002-2005	
	(A) National	07
	(B) International	03
3.	Papers Presented in Conferences from 2002 - 2004	
	(A) National	00

(B) International	11
Total	**29**

ICRS has published 18 papers in Journals and proceedings of the conferences from 2002 to 2005 the list of the papers is given below.

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7. **Estimation of scattering Coefficient of Saline Soil for slightly rough Surface and undulating surface at Microwave Frequencies,** O P N Calla and Himadri Sekhar Kalita, Indian J. Radio & Space Phys, Vol. 33 December 2004 pp 405-410

8 **Estimation of Emissivity and Scattering Coefficient of the constituents of vegetation at Microwave Frequencies,** O P N Calla, Avdhesh Roop Rai, Pronnoy Mathur, Deepak Mathur and Dinesh Bohra, Indian J. Radio & Space Phys, Vol. 34 February 2005 pp 67-70

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B. National

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12. Study of rcs of different shapes at microwave frequencies, O.P.N. Calla, Amitesh Ranjan, Jitendra Singh Jaitawat, Paper presented in Asia Pacific Microwave Conference, December 15-18, 2004.

List of papers accepted for presentation in international conference in year 2005

1. Study Of Effect Of Rain And Dust On Propagation Of Radio Waves At Millimeter Wavelength, O.P.N. Calla And J.S. Purohit, Accepted for Oral presentation in Commission F in URSI GA, October 23-29, 2005.

2. Estimation Of Emissivity And Scattering Coefficient Of Vegetation From Measured Dielectric Constant At Microwave Frequencies, O.P.N. Calla And Dinesh Bohra, Accepted for Oral presentation in Commission F in URSI GA, October 23-29, 2005.

3. Estimation Of The Scattering Coefficient At Microwave Frequencies Of Dry And Wet Soils Of India Using Measured Values Of Dielectric Constant And Relating the Same With the Constituents of the Soil, O.P.N.Calla, O.P. Acharya, S.K. Mishra And K.C. Harit, Accepted for Post presentation in Commission F in URSI GA, October 23-29, 2005.

4. Comparison Of The Soil Moisture Obtained Directly From Radiometer And The Estimated Soil Moisture From Measured Dielectric Constant, O.P.N. Calla, S.K. Mishra And O.P. Acharya K. C. Harit, Accepted for Post presentation in Commission F in URSI GA, October 23-29, 2005.

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6. Study Of The Electrical Parameters Like Dielectric Constant, Emissivity And Scattering Coefficient Of Ice At Different Physical Temperatures At Microwave Frequencies, O.P.N. Calla, Dinesh Bohra And Rajesh Vyas, Accepted for Oral presentation in Commission F in URSI GA, October 23-29, 2005.

7. Measurement Of Dielectric Constant Of Saline Water And Estimation Ofemissivity And Scattering Coefficient At Different Physical Temperaturesat Microwave Frequencies, O.P.N. Calla, Dinesh Bohra And Rajesh Vyas, Accepted for Post presentation in Commission F in URSI GA, October 23-29, 2005.

List of papers accepted for presentation in national conference in year 2005

1. Development of a Low Cost Scatterometer, O.P.N. Calla, Md.S. Abbas, S. Bhattacharjee, B. Kalita, P.P. Saikai, Accepted for presentation in Indian Conference on “Microwaves, Antenna, Propagation and Remote Sensing”, 20th –22nd December 2005.

2. Antenna Systems for use in low-cost scatterometer to study the effect soil on scattering coefficient of metal targets, O.P.N. Calla, Md.S. Abbas, S. Bhattacharjee, B. Kalita, P.P. Saikai, Accepted for presentation in Indian Conference on “Microwaves, Antenna, Propagation and Remote Sensing”, 20th –22nd December 2005.

3. Effect of soil on the scattering coefficient of metal targets, O.P.N. Calla, Md.S. Abbas, S. Bhattacharjee, B. Kalita, P.P. Saikai, Accepted for presentation in Indian Conference on “Microwaves, Antenna, Propagation and Remote Sensing”, 20th –22nd December 2005.

4. Design and Development of Rectangular Microstrip Patch Antenna, O.P.N. Calla, M. Alam, D. Hazarika, L. Ramawat, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

5. Study of the Variability of Dielectric Donstant of dry Soil Irradiated by Microwaves, O P N Calla, M.Alam, D.Hazarika, L.Ramawat., Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

6. Effect of Microwave Radiation on the Electrical Parameters of Soil, O P N Calla, M.Alam, D.Hazarika, L.Ramawat., Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

7. Retrieval of Brightness Temperature at 6.6 GHz for Vertical Polarization from MSMR Data, O.P.N. Calla, Anil Kumar Soni, Sandeep Kumar, Sugandha Lohar, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

8. Study of Methodology for Image Generation Using Brightness Temperature Data, O.P.N. Calla, Anil Kumar Soni, Sandeep Kumar, Sugandha Lohar, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

9. Retrieval and Image Generation for Geophysical Applications using MSMR Data, O.P.N. Calla, Anil Kumar Soni, Sandeep Kumar, Sugandha Lohar, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

10. Measurement Of Dielectric Constant Of Saline Water Using Cavity Resonator Method At Different Microwave Frequencies, O P N Calla, Charu Sharma, Navin Bohra, Neha Gathania, Nitin Khandelwal, Paritosh Kalla & Saurabh Shukla, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

11. Design of a tunable cavity resonator at Microwave frequencies and the measurement of complex permittivity for low loss materials, O P N Calla, Charu Sharma, Navin Bohra, Neha Gathania, Nitin Khandelwal, Paritosh Kalla & Saurabh Shukla, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

12. Measurement of Dielectric Constant of Diesel at Microwave Frequencies, O P N Calla, Charu Sharma, Navin Bohra, Neha Gathania, Nitin Khandelwal, Paritosh Kalla & Saurabh Shukla, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

13. Study the effect of temperature on dielectric constant of water at microwave frequencies., OPN Calla, Dinesh Bohra, Rajesh Vyas, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

14. Study of the parameters which are responsible for providing High resolution in Radars, OPN Calla, Rajesh Vyas, K C Harit, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

15. Determination of soil moisture by measuring electrical parameters of soil., OPN Calla, K C Harit, Dinesh Bohra, Rajesh Vyas, Accepted for presentation in Indian Conference on "Microwaves, Antenna, Propagation and Remote Sensing", 20th –22nd December 2005.

List indicating the No. of Undergraduate Students Trained at ICRS from different Institutions of

India From 2002 to 2005

S.N.	Name of the College	No. of Students
1.	Assam Engineering College Guwahati, Assam.	20
2.	Engineering College, Bikaner	01
3.	Hira Sugar Institute of Technology, Belgaum Karnataka	05
4.	IIT Roorkee	01
5.	Jaipur Engineering College, Kukas Jaipur. (Raj.)	01
6.	Malviya National Institute of Technology Jaipur	02
7.	Mahrishi Arvind Institute of Engineering & Technology Jaipur	01
8.	M.B.M. Engineering College, J.N.V.U, Jodhpur	01
9.	National Institute of Technology Hamirpur Himachal Pradesh	06
10.	National Institute of Technology, Sri Nagar, Kashmir	05
11.	Rajasthan Institute of Engg. & Tech. Jaipur,	02
12.	Shankara Institute of Technology, Kukas, Jaipur. (Raj.)	06
13.	Stani Memorial College Of Engineering & Tech. Phagi, Jaipur	01
14.	Rajasthan College of Engg. For Women, Jaipur	02
15.	Kautilya Inst. Of Technology & Engg. Jaipur	02
16.	Sri Balaji College of Engg. & Tech., Jaipur	01
17.	Mody Inst. Of Tech. & Science Lakshmangarh, sikar	01
	Total	58

List indicating the No. of M. E. Students have done their Thesis work at ICRS from different Institutions of India from 2002 - 2005

S.N.	Name of Colleges	No. of Student
1.	Tezpur University, Tezpur Assam	03
4.	National Institute of Science & Technology Berhampur, Orissa	02
	Total	05

List indicating the No. of PhD Students have registered for their PhD Thesis work at ICRS from different Institutions of India from 2002 - 2005

S.N.	Name of Colleges	No. of Student
1.	Jai Narain Vyas University, Jodhpur	02

List of M. Tech Thesis done at ICRS from 2002 -2005

S.N.	Name of Student	Title of Thesis	University	Year
1.	Bitupan Saikia	Measurement of dielectric constant and estimation of emissivity for pure and saline water and ICE at microwave frequencies	Dept. of electronics Tezpur University Tezpur	Dec. 2002

	and at different temperature.		
2. H.S. Kalita	Measurement of dielectric constant of saline soil and estimation of scattering coefficient of dry wet and saline soil for two type of surfaces and study of scatterometer	Dept. of electronics Tezpur University Tezpur	Dec. 2002
3 Shahin Perwez	Estimation of brightness temperature and design at radio meter for measurement of moisture content of different type of dry and wet soil.	Dept. of electronics Tezpur University Tezpur	Dec. 2002
4 O.P.Acharya	Characterization of soil for active Microwave remote sensing	Dept. of electronics & Communication NIT Berhampur Orissa	Jun-05
5 S. Kr. Mishra	Characterization of soil for passive Microwave remote sensing	Dept. of electronics & Communication NIT Berhampur Orissa	Jun-05

PhD Students at ICRS

S.N.	Name of Student	Title of Thesis	University	Year
1.	Mr. K C Harit	Study of electrical properties of natural materials for Microwave Remote Sensing	JNVU, Jodhpur	2005
2.	Mr. D. Bohra	Study of the Effect of Terrain on a Microwave Line of Sight Link	JNVU, Jodhpur	2005

List of B. E/B.Tech Projects done at ICRS from 2002 - 2005

S.N.	Name	Titel of Project	University	Year
1	MR Solanki	Measurement of dielectric constant of dry soil at microwave frequencies	E&C Dept, MBM Engineering College Jodhpur	Aug.2002
2	Waseem Hassan & H S Bali	Measurement of dielectric constant at the soil of Kashmir - 2	E&C Dept. REC Srinagar, Kashmir	Feb. 2003
3	V Ranjan, C Bohra, G L Naik	Measurement of dielectric constant of dry soil of Rajasthan - 2	Hira Sugar Rural Engineering college Belgaum, Karnataka	Mar-03
4	Anahita Vyas *P Chaudhary	Model generation for microwave communication link	Dept. CS Engg, Shankara Inst.of Tech. Kukas Jaipur, *Dept. of CSE, NIT Hamirpur	Jul-03

5	A R Rai, Deepak Mathur, *P Mathur	Microwave remote sensing of natural vegetation	Dept. IT, Shankara Inst.of Tech. Kukas Jaipur, *Dept. of E&C. Jaipur Engg.College Kukas Jaipur	Jul-03
6	M Mathur M Upadhayay *Ramesh Punia	Image generation for microwave remote sensing C++ and java	Dept. of CS&Engg Shankara Ins.of Tech. kukas, Jaipur, *Dept. of IT, Stani Memorial College of Engg & Tech Phagi, Jaipur	Jul-03
7	Ankur Baruah, Biswajit Das, K P Mishra, Manisha Kalita S S Hoque	Study of electrical properties of soil of northern India	Dept. E&T Assam Engg Col. Guwahati	Aug-03
8	N S Nagar	Study of various methods of measurement of dielectric constant of rocks at microwave frequencies.	AMIE Calcutta	Feb. 2004
9	S H Shah, B A Shah Z A Baba	Estimation of emissivity and scattering coefficient from measurement values of dielectric constant dry soil of Kashmir	NIT, Hazratbal Srinagar	Feb. 2004
10	C Bohra, Vivek Ranjan	Designing, testing and fabrication of various microwave antennas	Hira Sugar Rural Engineering College Belgaum, Karnataka	May-04
11	JS Jaitawat, Amitesh Ranjan	Study of scattering behavior of different target bodies and calibration of active remote sensor at microwave frequencies.	Dept. E&C M N IT Jaipur	Jun-04
12	A Das, P P Kanwar, Bhrigu Kumar, C Baruah Paromita Dutta	Measurement of dielectric constant and estimation of emissivity and scattering coefficient of dry and wet soil sample of Assam and the characterization of horn antennas at X band	Dept. E&T Assam Engineering College Guwahati	Aug-04
13	*A Jaiswal, A Agarwal, S Kr Toshipa	Indigenous development of CSAAS of ICRS for GIS application	*IIT Roorkee NIT Hamirpur	Jul-04
14	1M Upadhayay, 2S Jain, 3S Vyas, 4N Yadav, 5A Shrama	Image generation for microwave remote sensing and retrieval of data through C++ and java	1Shankara ITJaipur 2&3Rajasthan IET Bhakrota Jaipur 4Mahrishi Arvind IT of Jaipur, 5Bikaner Engg. College Bikaner	Jul-04

15	B Kalita, Md. S Abbas, PP Saikia, S Bhattacharjee	Measurement of Scattering Coefficient of Soil at Microwave Frequencies using Horn Antenna Design at ICRS	Dept. E&T Assam Engineering College Guwahati	Jul-05
16	D Hazarika, L Ramawat, M Alam	Study the effect of Microwave Radiation on the dielectric constant of soil and design and development of Patch Antenna	Dept. E&T Assam Engg. College Guwahati	Jul-05
17	*Charu Sharma *Neha Gathania, #Saurabh Shukla **Paritosh Kalla **N Khandelwal	Estimation of Emissivity and Scattering Coefficient of Saline Water and Saline Ice and Design and Development of Cylindrical Cavity for Measurement of Complex permittivity	*Dept E&C Raj. College of Engg. for Women, Jaipur #Dept. E&C, NIT Hamirpur, **Dept.of ECE, Kautilya Inst. Technology & Engg. Jaipur	Jul-05
18	Anil KrSoni, Sandeep Kumar, *S Lohar	Study of Methodology of retrieval and Image processing of Remote Sensing Satellite Data	Dept. CSE,NIT Hamirpur, *Dept E&C Mody Inst. Tech. & Science Lakshmangarh, Sikar	Jul-05

For further details please contact:- Prof. O P N Calla, Director, International Centre for Radio Science, "OMNIWAS" A – 23 Shastri Nagar, Jodhpur (Rajasthan) 342003. Fax No. :- 0291 -2626166, Tele No.:- 0291-2626166, 0291-2613123, 0291-2640063. Email :- opncalla@yahoo.co.in

Activities at the Indian Institute of Technology, Kanpur during 2000 – 2004

IIT Kanpur has a strong remote sensing group. Since last 25 years, remote sensing courses are taught at the undergraduate and postgraduate levels. The group is involved in theoretical, lab measurements, field studies and also data analysis. The group has carried out microwave remote sensing applications to numerous areas. For detailed information, please contact

Theoretical Studies

Extensive theoretical studies have been used to demonstrate the potentiality of VHF and microwave remote sensing data to map the water-logged and salt-affected coastal areas. It has been found the low microwave frequency (1-5 GHz) sensors can be very useful in mapping such areas in India. Detailed theoretical studies over various snow cover surfaces have shown the potentiality of microwave radiometers for characterizing snow cover areas, monitoring of onset of snow melt and quantification of snow water content**.**

Seasonal Variation of Brightness Temperature

Analysis of brightness temperature recorded by Special Sensor Microwave Imager (SSM/I) during 1987-2004 has been carried out for mapping of soil moisture, sea surface temperature, snow cover and its characterization, mapping of water vapor in the atmosphere. The analysis of data from August 1987-December 2004 have shown some interesting features over the Bay of Bengal compared to the Arabian ocean which have significant contribution to the International Geosphere and Biosphere program. The brightness temperature shows characteristic features of Indian terrain and these brightness temperatures are significantly found to be dependent on the month to month and season to season.

Development of Software for Processing SSM/I, ERS-I/II, MSMR Data

Numerous software packages have been developed to process brightness temperature data recorded by SSM/I and MSMR Sensors and also scattering coefficient data recorded by ERS 1/II sensors. These softwares run on windows environment. Using these softwares weekly, monthly and yearly analysis of brightness temperature and scattering coefficients over Indian and adjoining regions are being carried out. From these data various surface and atmospheric parameters are being retrieved.

Microwave remote sensing for study of the Atmosphere:

Total precipitable water vapor (TPW) over the oceanic regions surrounding the Indian sub-continent are retrieved using SSM/I (Special Sensor Microwave Imager) data at 19.35, 22 and 37 GHz frequency, which shows good correlation with the onset of monsoon in the Indian sub-continent. TPW in the $10\text{-}15^0$ N latitude zone attains its highest value 7-12 days prior to the onset of monsoon at Kerala coast of India.

TPW has also been found to show precursory anomaly prior to an impending earthquake, which is related to the enhanced Earth-atmosphere coupling due to the pre-earthquake release of electro-magnetic energy.

Microwave remote sensing for study of the surface parameters:

Microwave remote sensing is an efficient tool to monitor the surface emissivity and soil moisture globally. IRS P4 MSMR (Multi-frequency Scanning Microwave Radiometer) data have been used to study the spatio-temporal variability of emissivity and soil moisture over different geological terrains of the Indian sub-continent. Emissivity at 6 GHz frequency displays strong seasonal variability with maximum values in the summer, minimum during the winter season; whereas the soil moisture shows maximum values during the monsoon season. Soil moisture is found to be higher in the coastal regions and in the Gangetic basin compared to the other regions.

Microwave remote sensing of snow cover

IIT Kanpur in collaboration with the Snow Avalanche Establishment (SASE) carried out detailed analysis of SSM/I data and studied the characteristics of snow parameters and snow cover in the Himalayan region. Seasonal characteristics of snow cover thickness and also estimates of snow water equivalence were done using SSM/I data for the period 1988 – 2004. The snow water equivalence clearly show the flooding near the Manali region during 1994.

Publications related to Microwave Remote Sensing:

1. R. P. Singh, P. K. Sahoo and N. C. Mishra, **Seasonal variations of brightness temperature over India**, *Adv. Space Res.,* **26(7)**, 1081-1084, 2000.
2. N. C. Mishra, P. Dash and R. P. Singh, **Brightness temperature over Indian subcontinent, *J. Geol. Soc. India***, **55**, 541-551, 2000.
3. R. P. Singh, N.C. Mishra, A. Verma and J. Ramaprasad, **Total Precipitable Water over Arabian and Bay of Bengal using SSM/I Data**, *Int. J. Remote Sensing*, **21(12)**, 2497-2503, 2000.
4. N. C. Mishra, R. Kanwar, S. Sarkar, P. Dash and R. P. Singh, **Use of multi-sensor data for mapping of Thar Desert**, *Adv. Space Res.*, **29(1)**, 51-55, 2002.
5. R. and U. Narayan, **Extraction of MSMR Data for Windows and Linux Based Applications,** *Indian J. Remote Sensing***, 30,** no. 1& 2, 113-116, 2002.
6. D. R. Mishra, A. K. Sahoo, R. Kanwar and R. P. Singh, **Estimation of monthly rain rate over Indian Ocean region using MSMR data**, *Curr. Sci.,* **83(7)**, 877-880, 2002.
7. D. R. Mishra, A. K. Sahoo, R. Kanwar and R. P. Singh, **Rain rate over ocean surrounding the Indian sub-continent using MSMR data**, *Proceedings of the Pan Ocean Remote Sensing Conference (PORSEC 2002)*, Vol. II, P. 550 - 554.
8. S. Dey, S. Sarkar and R. P. Singh, **Anomalous changes in column water vapor after Gujarat earthquake**, *Adv. Space Res.*, **33(3)**, 274-278, 2004.

9. D. R. Mishra, S. Dey and R. P. Singh, **Emissivity of various geological terrains using IRS P4 MSMR data**, *J. Geol. Soc. India*, **63**, 453-457, 2004.

10. R. P. Singh, S. Dey, A. K. Sahoo and M. Kafatos, **Retrieval of water vapor using SSM/I and its relation with the onset of monsoon**, *Annales Geophysicae*, **22**, 3079-3083, 2004.

11. R. P. Singh, D. R. Mishra, A. K. Sahoo and S. Dey, **Spatial and temporal variability of soil moisture over India using IRS P4 MSMR data**, *Int. J. Remote Sensing*, **26(10)**, 2241-2247, 2005.

12. V.D. Mishra, P. Mathur and R.P. Singh, **Qualitative and Quantitative Analysis of Snow Parameters using Passive Microwave Remote Sensing**, *Indian J. Remote Sensing* (in press).

M. Tech Theses using Microwave Remote Sensing data:

1. **Relation between the Observed and Theoretical Brightness Temperature over Indian sub-continent using SSM/I data**, K. V. Raghav Reddy, 2000.
2. **Inter-annual variability of snow-covered regions using SSM/I data**, A. K. Sahoo, 2001.
3. **Retrieval of land and ocean parameters using IRS P4 MSMR data**, D. R. Mishra, 2002.
4. **Sediment yield study over Bhakra Nangal dam using remote sensing data**, Siddharth Yadav, 2004.
5. **Retrieval of soil wetness over Indian sub-continent using DMSP SSM/I data**, Rajneesh Kumar, 2005.

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Commission G

The Commission G of the URSI deals with the study of the ionosphere in order to provide the broad understanding necessary for radio communications . The main goal is to know the spatial and temporal structure of the ionosphere for various applications.The development of the required tools ground based as well as space based for this purpose forms an integral part of the aims of this commission.Several premier institutions from India such as the National Physical Laboratory, New Delhi, Indian Space Research Organization, Bangalore, Space Application Center, Ahemdabad are engaged in this pursuit.

Indian Space Research Organisation in collaboration with Airport Authority of India is planning to implement Satellite Navigation in India to meet the requirements of Category I precision landing for aircrafts. The technique to be used is the well known Wide Area Augmentation system (WAAS). In this technique, the existing GPS (Global Positioning System) satellite constellation will be augmented with a Regional Geostationary Satellite (GSO) and a suitable ground segment. The user aircraft carrying a WAAS receiver, can receive GPS as well as the GSO Satellite signals in L band, correct its pseudorange measurements and determine its position more accurately. Because of the corrections, the aircraft position accuracy improves from 100m to less than 5 m. It is an exciting and active area of research .

A brief account, by no means complete, of some of the work done in the ionospheric research during 2002-2005 in the country is given here.

Equatorial F region plasma dynamics

During the severe magnetic storm of July 15, 2000, an impulsive and remarkably large downward movement of F region occurred simultaneously at locations throughout the equatorial region (dip 0.3- 20 ^{0} N) in the Indian sector, in close association with episodes of rapid ring current intensification (decreases of SYM-H index, 59-94 nT/15 min) over the interval 1900-2100 UT (0030-0230 IST). The abnormal midnight descent of equatorial F region (maximum amplitude close to the magnetic equator, 215 km/hr) indicative of a short-lived, anomalously large westward electric field disturbance (peak amplitude » 4.6 mV/m) is interpreted as the signature of prompt penetration electric fields associated primarily with impulsive ring current injections. The westward electric field disturbance in the Indian (midnight) sector occurred near simultaneous with the eastward electric field disturbances in the dusk sector (Atlantic and Eastern Brazil), reported by *Basu et al* [2001a]. Moreover, the prompt electric field penetration to the magnetic equator both in the dusk and midnight sectors occurred in an environment already under the influence of ionospheric disturbance dynamo (IDD) electric fields, illustrating the profound manner in which the equatorial F region plasma dynamics can get modified globally during the main phase of severe magnetic storms [*Sastri et al*, 2002].

Field-aligned currents

The storm sudden commencement (ssc) of July 8, 1991 is characterized by a reduction (enhancement) of ground-level geomagnetic X-component at mid-latitudes in the noon (midnight) sector in the 1-h period after its start. This distinctive feature is seen even after accounting for the effects of the Chapman-Ferraro current. Evidence is obtained from HF Doppler radar measurements of F-region vertical plasma drift that over the same 1-hour period after the start of the ssc on July 8, 1991, an eastward electric (E) field disturbance (peak value 1.2 mV/m) grew up and decayed at the pre-midnight dip equator. The evidenced eastward E-field disturbance is interpreted as the signature of the penetration of the dawn-to-dusk E-field associated with an enhancement of region 1 currents field-aligned currents (FACs) driven by the solar wind. The negative disturbance in H/X component at mid-latitudes is explained as the magnetic effect of the FACs that carry the large-scale electric fields from the magnetosphere to the polar ionosphere as well as the disturbance of polar origin-type 2 ionospheric currents excited by the large-scale electric field. [*Sastri*, 2002].

Global magnetospheric- ionospheric oscillations

It is found that a major increase in the solar wind pressure is followed by long period (about 1-hour) global magnetospheric- ionospheric oscillations. When the magnetosphere is suddenly compressed, enhancements in energetic electron fluxes are simultaneously detected over a wide longitude range at geosynchronous orbit; the electron fluxes(energy range 55-225 Kev) showed periodic variations (period range 55-85 min.) which are identified as electron bunches circling the Earth. Periodic oscillations of ground level magnetic field occur from auroral to equatorial latitudes simultaneous with the variations in the magnetospheric parameters. It is interpreted that while the solar wind impulse plays a role in initiating the magnetosphric oscillations, the period of oscillations is determined by the magnetosphere itself and that the distubance electric fields associated with the magnetospheric oscillations penetrate to the ionosphere and cause ground level magnetic fluctuations. [*Huang et al.*, 2003].

Validation of IRI (International Reference Ionosphere) model using Digital Ionosonde measurements at NPL, New Delhi and Incoherent scatter radar measurements at Arecibo

Digital Ionosonde Measurements

(a) Using digital ionosonde measurements at NPL, the diurnal and seasonal variations of the critical frequency of the F2-region (foF2) for the period from August 2000 to July 2001 (a high solar activity period) have been examined. Bottomside electron density profiles using in-built POLAN software have been obtained and these profiles are then normalized individually to the peak height and density of the F2-region. These observations are used to assess the predictability of the IRI-2000 model. These results reveal that IRI model shows a good agreement during daytime for all the seasons, the percentage deviation of the IRI model with respect to observed values are less than 10 % during daytime for all the seasons, while during nighttime these deviations fluctuate between 10 to 25 %. Comparative studies of the normalized observed profiles with those obtained from the IRI model, reveals a better agreement with observations during all the seasons.

(b) The diurnal and seasonal variations of height of the peak density of the F2-layer (hmF2) are analyzed for the period from January 2001 to August 2002 using measurements from Digital Ionosonde at NPL, New Delhi. The observed hmF2 values are somewhat larger than those predicted by IRI-2001 model, during all the seasons and at all local times. Major discrepancies occur when the IRI underestimates the observed hmF2 for local times from about 1400 LT to 1800 LT and 0400 LT to 0500 LT during winter and equinox. In this time period, the percentage deviation of observed hmF2 values with respect to IRI model varies from 15 to 25%.

(c) Digital Ionosonde measurements at New Delhi, during the period from January 2001 to December 2003, are used to examine the seasonal and solar activity variations of Bottomside Total Electron Content (BTEC). Comparison of BTEC with those predicted by the IRI model during medium solar activity (2003) , show in general good agreement within 20 % during all the seasons except for post-sunset hours and around midnight. During high solar activity, (2001-02) , the IRI model in general, underestimates the BTEC during equinox and winter at all local times. However, the discrepancies are least during summer, and also no winter anomaly phenomenon is predicted by the IRI model during high solar activity, while the observations show the same. The peak content increases by a factor of around 2 during all seasons from moderate to high solar activity.

Incoherent scatter measurements at Arecibo

(a) High resolution measurements of incoherent scatter radar at Arecibo, are used to study the diurnal and seasonal variations of Total Electron Content (TEC) during high solar activity period (1989-90). Comparisons of diurnal variations of observed median values of TEC with those

predicted by the IRI model in general reveals similar trend during all the seasons and at all local times. Discrepancies between the IRI and the median values exceed 40 % during nighttime for winter and equinox, however, during daytime they are less than 20 % . The peak content increases by a factor of 4 from solar minimum (1975-76) to solar maximum (1989-90).

(b) Using electron density profiles from Arecibo incoherent scatter radar for the solar minimum and solar maximum periods, we have been able to establish the control of solar activity on the F2-peak height (hmF2) , which showed an increase of about 100 km during solar maximum as compared to solar minimum periods.

(c) With the availability of large data base of electron density and electron temperature from incoherent scatter radar at Arecibo for solar minimum and solar maximum conditions, we developed an exponential relations between heat flux and electron density in the topside ionosphere during both the solar activity periods. These functional relationships are then used to generate electron temperature profiles in topside ionosphere. We compared the temperature profile obtained from these model with experimental measurements at different locations and different solar cycle conditions and found reasonable agreement.

We have also studied the seasonal and solar activity variations in electron temperature for noontime conditions. Our studies show that average electron temperature profile for each season reveal distinct solar activity variations. Comparisons with IRI-95 and Truhlik et al., (2000) models show a reasonable agreement within one standard deviation of the measured values.

3. The evolution and dynamics of equatorial plasma bubbles: relationships to ExB drift, post-sunset total content enhancements and equatorial electrojet strength

The growth in latitude, and consequently in altitude, of equatorial plasma bubbles was monitored, using simultaneous recordings of VHF scintillation at five locations situated between 3^{o} and 23^{o}N magnetic latitudes along a common meridian in the Indian zone during February 1980. The onsets of the scintillation were mostly abrupt in character and their occurrence at higher latitudes was conditional on prior appearance at lower latitudes, indicating a causal link to irregularities associated with rising equatorial plasma bubbles. The day-to-day occurrence and the latitudinal, and effectively latitudinal, growths were examined in relation to: the pre-reversal enhancement in h'F and its rate of rise, the onset of a secondary maximum in total electron content at 21^{o}N, and equatorial electrojet strength variations. It was found that the bubble rise velocity over the magnetic equator maximized at heights in the 450 and 550 km range, with a subsequent decrease at higher altitude. The bubbles and associated irregularities reached the highest altitudes / latitudes on those days when h'F in the evening over the magnetic equator exceeded 500 km and had a growth rate of more than 30 ms^{-1}, though no relationship was found with the initial rise velocity. Scintillations were observed at the highest latitude only on those days when a secondary maximum in total electron content was also observed there. It was found that equatorial h'F and dh'F/dt are both positively correlated with day time (1100 LT) electrojet strength values, and consequently to the latitudinal / altitudinal extent of the plasma bubble and associated irregularities. It is concluded that, after the initial development of a bubble, the ExB drift and the post-sunset ionization anomaly play an important role in the subsequent growth and evolution, and that electrojet strength is a useful parameter for the prediction of the development.

Study of Mid-latitude NightTime Enhancement in F Region Electron Density using tomographic Images

Earlier nighttime enhancements in ionospheric electron content (IEC)/ various workers in the anomaly and mid latitude regions have studied peak electron density (NmF2). Such studies give an idea about their enhancement over that location only. In the present study tomographic images over UK, which gives a latitudinal versus height distributions of ionospheric electron density in a much wider area, have been used to study the anomalous increases in nighttime F region electron density at mid latitudes. From the analysis of four seasonal representative months (November 1997, March, June and October 1998) data it was noted that majority of the cases of night time enhancements

were observed after local midnight with a maximum between 0300-0400 hours LT (see figure 2a) in the month of November 1997. Enhancements were observed mostly between 45-50 N latitudes and their positions are not affected by magnetic activity (Kp) variations whereas the separation between mid-latitude trough and enhancement decreases with increases in magnetic activity. This shows that only the trough moves equator ward with the increase of magnetic activity. It is also noted that the electron density gradient from trough to enhancement increases with increase of Kp. Results are discussed in terms of down ward plasma transport from the protonosphere to the ionosphere and night-time the neutral winds.

Radio tomographic imaging as an aid to modeling of ionospheric electron density

Models of ionosphere, used in applications for the prediction or correction of propagation effects on practical radio systems, are often inadequate in their representation of the structure and development of large-scale features in the electron density. Over northern Europe characterization of the main trough present particular problems for such empirical models and hence for radio propagation forecasting and ionospheric mapping. Results are presented from a study aimed at investigating the possible role of radio tomographic imaging in adapting models to yield a better representation of the ionosphere over Europe. It is shown that use of radio tomography gives better agreement with actual ionosonde data than can be obtained from any of the models used alone. It is suggested that the technique may have a possible role in the mapping of ionospheric conditions in near-real time for future systems applications.

Studies by using an Indian satellite observations

Indian satellite SROSS-C2 launched in May 1994 carried Retarding Potential Analyzer (RPA) Experiment for the study of ionosphere/ thermosphere over the Indian region covering the latitudinal belt of 5°S to 40°N. The satellite was active till June 2001. Thus, half a solar cycle of data was collected starting from low activity period to the peak of 23 solar cycle. The parameters measured are electron and ion temperatures, ion density and suprathermal electron flux in the height region of 450 to 650 km.

Morphological studies:

Comparison of Ion & Electron parameters measurements from SROSS-C2 with IRI Model

Ion Temperature (Ti):

The diurnal and seasonal and latitudinal variation of ion temperature (Ti) measured by SROSS-C2 satellite at equatorial and low latitudes during the solar minimum period of January 1995 to December 1996 are investigated.

(i) The satellite covered a latitudinal belt of 31°S to 34°N, longitude range was 40° to 100°E and average altitude is ~500 km.

(ii) Measured Ti varies between 600 to 700K during nighttime (2000-0400Hrs LT)

(iii) Between 100 – 1100 K around noon

(iv) Enhancement in Ti up to ~3000 K at sunrise hours (0400-0600 Hrs)

(v) An afternoon increase of ~200 K over daytime value is observed between 1500- 1700 Hrs. LT in summer

(vi) Latitudinal gradients in Ti have been observed during the period of morning and afternoon enhancements.

(vii) The ion temperature exhibit large variability.

(viii) Comparison of observed and International Reference Ionosphere (IRI) predicted ion temperature reveals that IRI overestimates Ti at about all local times and latitudes except during the period of enhanced Ti

Electron Density (Ne):

(i)Diurnal variation of Ne at topside is similar to that observed at F-region peak

(ii) Electron density is minimum before sunrise and reaches the diurnal maximum in the afternoon hours.

(iii) A secondary enhancement is observed in the sunset hours during June solstice

(iv) The EIA is found to be asymmetric at the altitude traced by the satellite in this period of low solar activity (mean sunspot number = 13.9)

(v) The location of the crest of the anomaly varies with season

(vi) There is seasonal and latitudinal variation of Ne

(vii) Comparison of measured density with that predicted by IRI reveals IRI overestimates Ne at about all local times and all seasons.

(viii) The IRI also fails to produce the secondary enhancement of electron density.

Detection of Heavy Ions

During meteor shower events heavy metallic ions like iron, cobalt, magnesium and calcium were detected in the height region of 400 to 600 km. Although the number density of these ions are very small (about 100 cm^{-3}), the existence of these heavy elements at those altitudes is yet to be explained

Response of Equatorial and Low Latitude Ionosphere to Magnetic Storms

Latitudinal Ion density distribution during magnetic storms of May 1997, November 1998, October 1999 and April 2000 from Ion RPA data are studied along with the Ionosonde data from 5 stations (located right from magnetic equator to a station near to the peak of the ionization anomaly), the vertical component of the interplanetary magnetic field (IMF Bz), Auroral Electrojet Index (AE) and GPS observations.

The results of the present study demonstrate that

(i) The magnetospheric and high latitude electric fields do penetrate to low and equatorial latitudes and play a key role in ionization distribution at these latitudes by modifying the EXB drifts driving the equatorial fountain.

(ii) The latitudinal ion density distribution as observed using SROSS-C2 has provided clear evidence of the role of meridional wind also in storm time ionization distribution

(iii) During Northern summer month the equator ward wind tends to move the plasma from higher latitudes upward along the field lines and southward, thus adding to the ion density and also through reduction in loss rate.

(iv) During winter months the pole ward wind modulate the ion density distribution by moving the plasma northward and downward, thus causing a reduction in ionization and enhancing the loss rate.

VHF and L-band Scintillation studies

Studies on the characteristics of Ionospheric irregularities by the simultaneous observations of scintillations at VHF (244 MHz) and L-band (1.5 GHz) frequencies from two geo-stationary satellites, namely FLEETSAT (73^{o}E) and INMARSAT (65^{o}E) respectively have been carried out at Waltair (17.7^{o}N, 83.3^{o}E) along with a co-located digital Ionosonde system during this low and descending phase of solar activity period 2004-2005. A detailed study of scintillation events in terms of Fading rates, S4 indices, scintillation patch durations, their association with range/frequency type Spread-F, the irregularity zonal drift velocities, the East-West extent of irregularities and the spectral signatures suggests that these scintillations are mainly of two types namely Plasma Bubble Induced (PBI) and Bottom Side Sinusoidal (BSS). The occurrence of scintillations due to PBI type are predominantly higher during the post sunset hours of equinoctial months (March, April, September and October)

which are characterized by high intensity and fading rates and appears at both VHF and L-band frequencies. Whereas the BSS type events are mostly confined to the post-midnight hours of the summer solstice months (May, June, July and August) with relatively low intensity and fading rates at 244 MHz with practically no signatures at the L-band frequency. The amplitude spectra PBI scintillations exhibit large spectral slopes (p) and Fresnel break frequencies (f_B) due to the multiple scattering of radio waves from different scale sizes of irregularities embedded in plasma bubbles. Whereas, the BSS scintillation spectra shows relatively small spectral slopes and break frequencies indicating that the scattering is weak and results from a thin layer.

GPS-TEC and S4 index studies at L-band frequencies:

Studies on the spatial and temporal behaviour of the Total electron content and scintillations at the L-band frequency of 1.5GHz are being carried out using the data from a total of 18 dual frequency GPS receivers, which are deployed at different locations in the Indian equatorial and low latitude regions under the ISRO/GAGAN programme. The development and decay of the equatorial ionization anomaly is clearly observed, with anomaly peaks occurring in the latitude zones of 15 – 25^o geographic latitudes (8 to 15^o geomagnetic) maximizing around 1600 to 1700 hrs IST during the equinoxial months of March, April and September, October.

Temporal variation of the GPS L-band scintillations of this low sunspot activity (LSSA) year of 2004 shows that the occurrence of scintillations is mostly confined to the pre-midnight hours with maximum occurrence during the equinoxial months, with maximum activity confining to anomaly crest regions. The maximum occurrence of scintillations is found towards the equator with feeble intensities and occurrences at the equator, but with maximum intensities towards the crest region. Good correlation is found between the scintillations and the plasma (bubble) depletions observed from TEC data. It has been observed that the GPS receiver in most of the cases looses its lock whenever the scintillations intensity exceeds S4 >0.45 or >10 dB.

Characteristics in the occurrence of F3 layer over the Indian equatorial and low latitude sector:

Additional stratification in the ionospheric F-region called the F_3 layer was often observed in the vertical incidence ionograms at sub-tropical Indian station Waltair (17.7^{o}N, 83.3^{o}E). From a database of more than half a solar cycle (1997 to 2003) it was found that this layer stratifies more frequently during the summer solstice months of low solar activity periods and persisted for longer durations compared to equinox and winter solstice. The F_3 layer occurrence decreases with increase of solar activity, with a few cases of occurrence during the winter months of moderate and high solar activity years. The most probable duration for which it is seen is around 1-3 hours though in some cases it persisted for, as long as 6-7 hours, with best stratification between 10-12 hrs LT. The occurrence does not seem to depend on the magnetic activity. When F_3 is absent, the critical frequency of the F_2 layer almost matches the critical frequency of the F_3 layer when it is present, thisindicates that F_3 layer is not formed by additional production of ionization, but was a result of the redistribution of ionization. When the data from equatorial and crest locations ionosondes was examined for the effects of equatorial plasma dynamics on the occurrence of such events; the F_3 layer was rarely present at the equatorial station, Trivandrum, while it is totally absent at the anomaly crest station Ahmedabad.

Evolution and dynamics of equatorial spread F (ESF) irregularities

The ionospheric group at IIG has been involved in studies of the evolution and dynamics of equatorial spread F (ESF) irregularities under different ambient conditions in the post-sunset equatorial ionosphere, using theory and observations of scintillations on VHF and higher frequency trans-ionospheric radio waves, which occur due to scattering of the radio waves by ESF irregularities. Some specific studies undertaken during this period are:

Space weather affects the distribution of plasma in the ionosphere and plasmasphere through which radio waves used for communication and navigation propagate. On some occasions, only large-scale (> 10 km) structures in the propagation medium are encountered by the radio waves, while at other times, small-scale variations in ionospheric electron density give rise to scintillations on transionospheric radio waves (Bhattacharyya and Basu, 2002).

Two different aspects of the effect of magnetic activity on the dynamics of ESF irregularities are studied using spaced receiver scintillation observations. The first one deals with the question of how magnetic activity affects the generation of ESF irregularities. For this, a parameter designated the "random velocity," which is a measure of random changes in the irregularity drift velocity, is evaluated from the data. In earlier studies, this parameter had been found to have large values in the early phase of evolution of ESF irregularities during the post-sunset period, with a steep decline to a low value by 22 LT. It is suggested that the random component of the irregularity drift velocity arises from the perturbation electric field associated with the generalized Rayleigh-Taylor (GRT) instability, which gives rise to the intermediate scale ESF irregularities responsible for the occurrence of the observed scintillations. The decline of the "random velocity" is therefore attributed to the decay of the perturbation electric field associated with the GRT instability, in agreement with results derived from computer simulation of the temporal evolution of the GRT instability in the post-sunset equatorial F region. This observation has led to the idea that the "random velocity" may be used as an indicator of the "age" of the irregularities which produce the observed scintillations, because in the absence of this "random velocity", ESF irregularities generated much earlier to the west of the observation point simply drift eastward with the background plasma, on to the path of the radio wave signal, to produce the observed scintillations. Therefore, estimation of the "age" of the irregularities is crucial for determining a cause-effect relationship between magnetic activity and generation of ESF irregularities. This idea has been used to determine when scintillation observations on magnetically active days are due to irregularities, which are freshly generated in the postmidnight period due to a reversal of the background electric field from westward to eastward, as a result of magnetic activity. The second aspect studied is the identification of magnetically disturbed background plasma drifts, which is generally possible only after 22 LT, when the estimated irregularity drift velocities are close to that of the background plasma. The monthly pattern of the estimated drift after 22 LT for magnetically quiet days with scintillations, is established in order to identify a slowly varying superimposed westward perturbation in the background plasma drift that is produced by a disturbance dynamo, which arises due to magnetic activity. The results are in broad agreement with some of the recent empirical models of the evolution, with storm time, of equatorial disturbance dynamo electric fields (Bhattacharyya et al., 2002). A new method is developed for calculating the spatial correlation function of intensity scintillation patterns produced by the propagation of a radio wave signal through ionospheric irregularities using spaced receiver observations of such scintillations. This requires that random temporal variations of the irregularity drift speed be taken into account. It is seen from the results that the occurrence of strong scintillations on an L-band signal requires the presence of short (~ 20 m) coherence scale lengths in the UHF scintillation pattern obtained in the plane of the receiver. This condition is satisfied near the crest of the equatorial ionization anomaly (EIA) region, but not near the dip equator. In the decay phase of L-band scintillations recorded near the crest of the EIA region, the maximum strength of these scintillations at any point in time is found to be correlated with the magnetic eastward drift speed of the pattern of intensity scintillations on an UHF signal recorded in this region, which is determined mainly by the magnetic eastward drift velocity of the ionospheric irregularities. Dependence of the corresponding strength of UHF scintillations on the drift speed indicates that toward the end of the decay phase of L-band scintillations, the irregularity power spectrum steepens, and the large scale irregularities that remain can cause the UHF signal to be focused in the plane of the receiver, yielding UHF S_4-indices greater than one, while focusing of the UHF signal is less evident at earlier times when there is focusing of the L-band signal (Bhattacharyya et al., 2003).

The day-to-day variability in the occurrence and characteristics of ESF irregularities continues to pose a problem for ionospheric communications using radio waves. Although, the fact that occurrence of ESF irregularities is a post-sunset phenomenon, indicates the role of E-region conductivity in discharging the equatorial plasma bubbles, which arise due to growth of the GRT instability in the equatorial F region, the time required for the discharging process was never estimated. A transmission line analogy, which was used earlier in a linear theory for the development of equatorial plasma bubbles, is extended to study the effect of E region conductivity on non-linear evolution of the plasma bubbles. For this, a set of mode coupling equations are used to describe non-linear development of equatorial

plasma bubbles in the presence of field-aligned currents which couple the equatorial F region with conjugate E regions. For a three-mode system, these non-linear equations yield a condition for unstable fixed states. This condition shows that E region resistivity together with F region polarizability introduces another time scale in the non-linear evolution of equatorial bubbles, and this is the time scale for discharging the bubbles, which is estimated (Bhattacharyya, 2004).

A theoretical model was developed to relate the spatial variations found in intensity scintillation patterns formed on the ground due to scattering of radio waves by equatorial ionospheric irregularities, with the spatial structure of these irregularities. As equatorial ionospheric irregularities are closely aligned with the geomagnetic field, they may be considered to constitute a two-dimensional dispersive random medium. A power law spectrum is assumed to characterize the electron density variations, which produce refractive index irregularities in the medium. A numerical solution of the equation satisfied by the fourth moment of intensity variations, in the plane of the receiver, is obtained using the split step method. The S_4-index, which is the standard deviation of normalized intensity variations as well as spatial correlation function of intensity, is obtained by considering special cases of the fourth moment of intensity variations. Variation of S_4-index with the standard deviation of phase fluctuations imposed by the ionospheric irregularities is studied for irregularities with different power spectral indices. Effect of varying phase fluctuations on the 50% de-correlation scale length is also studied for weak as well as strong scintillations. The S_4-index and spatial scale lengths in the ground scintillation pattern depend on parameters like thickness and height of the irregularity layer, background plasma density, standard deviation of electron density fluctuation and irregularity power spectrum. The theoretical model is used to understand the roles of these parameters in determining the S_4-index and spatial correlation function of intensity in the ground scintillation pattern (Engavale and Bhattacharyya, 2005).

On the dependence of F layer movement on the nocturnal variations of 777.4 nm airglow intensity over low latitude

Ionospheric electron concentration near the F layer peak height has been shown to solely affect the intensity variation of the nocturnal thermospheric 777.4 nm airglow emission. It is also generally believed that the vertical movement of the F layer does not affect the 777.4 nm airglow emission. Therefore, the vertical redistribution of plasma is not expected to affect the total 777.4 nm emission. This is not the case with the 630.0 nm airglow emission. It is well-established that downward/upward movement of F layer enhances/reduces the 630.0nm emission intensity. In order to understand the development of ESF irregularities and also to evaluate the dependence of 777.4 nm airglow intensity variation with the movement of ionospheric F layer, simultanous VHF radar, ionosonde and airglow measurements are analyzed. The VHF radar and airglow measurements are obtained from Gadanki (13.5^{o}N, 79.2^{o}E, dip lat 6.3^{o}N). The ionosonde measurements are carried out from Sriharikota (SHAR), a station 100 km east of Gadanki.

The large scale intensity variations are observed on both the line emissions on almost all the nights while the small scale intensity variations, particularly in 630.0 nm, are observed either during ESF events or during geomagnetically disturbed periods. The similarities observed between the large scale intensity variations at 777.4 nm with those at 630.0 nm are remarkable on magnetically quiet nights when ESF events are not present (as confirmed by the VHF radar observations). The large scale 777.4 nm airglow intensity variations are also found to be anti-correlated (similar to 630.0 nm) with the F layer height variations in varying degrees. This indicates that the 777.4 nm airglow emission is not completely independent of the F layer height movement contrary to the existing belief.

Simultaneous VHF radar and narrow band optical observations on Equatorial Spread F structures

Co-ordinated campaigns have been conducted from Gadanki by operating simultaneously the Indian MST radar in ionospheric mode and by monitoring thermosphere airglow line emissions using a photometer during February-March, 2003 and 2004 and also during January 2005. Radar observations are made using a 3^o wide beam oriented orthogonal to Earth's magnetic field. Optical observations are obtained using a multi wavelength narrow band (0.3 nm) photometer whose field of view is chosen to coincide with the radar beam width. Airglow emissions at 630.0 nm (owing to the dissociative

recombination of O_2^+ with e^-) and 777.4 nm (radiative recombination of O^+ with e^-) emanating from bottomside of the F-region (~250km) and from the peak altitude of the F-region respectively were monitored in a bi-directional mode (zenith and east) during these campaigns.

Simultaneous radar and optical observations yielded complementary informations regarding the ESF structures (both "micro" and "macro"). Different types of ESF structures revealed by the VHF radar maps (for example, multiple plumes in the presence of wave like bottomside structure, presence of plumes in the absence of bottomside structures, confined bottomside wavelike and flat structures etc.) reveal distinctly different optical signatures. This helps to characterize the VHF radar structures by means of optical observations.

Evidence for the interplanetary electric field effects in the low latitude ionosphere during a space weather event

On the basis of co-ordinated optical and VHF radar observations made from Gadanki , it is reported that the small scale thermospheric airglow intensity variations during ESF events are generally associated with the plasma depletion or enhancement structures (revealed by VHF radar maps) (e.g. *Sekar et al., Ann. Geophysicae, 22, 3129-3136, 2004*). However, during a geomagnetically disturbed (12 February, 2004; A_p=30) and non-ESF night, the 630.0 nm airglow intensity variations revealed small scale (temporal), quasi-periodic intensity fluctuations. The small scale intensity fluctuations observed on 12 February, 2004, are found to vary in accordance with the time rate of changes of peak height of the F region observed over Thumba, a dip equatorial station (8.68^{o}N, 77.0^{o}E, dip lat 0.45^{o}N). Furthermore, these small scale intensity fluctuations have high degree of coherence with the interplanetary electric field variations (obtained using Advanced Composition Explorer satellite measurements) for the frequency component of ~2 cycles/hour. In addition to that, the variations in the nocturnal horizontal geomagnetic field over three low latitude stations are found to be anti-correlated with the above-mentioned small scale airglow intensity fluctuations. It is thus shown that the presence of such small scale intensity variations in the absence of ESF events on 12 February, 2004 are associated with the penetration of the storm time magnetospheric electric field into the low latitude ionosphere. Thus the storm time electric field alter the equatorial ionospheric electric field which, in turn, affects the thermospheric airglow intensity fluctuations.

Preferred modes of atmospheric gravity waves over low and equatorial latitudes during daytime

The propagation of gravity waves in the upper atmosphere can be inferred by studying the temporal variations of ionospheric parameters obtained by ionosonde and also by investigating the naturally occurring airglow intensity variations. In the present study, both the techniques are used to characterize the preferred modes of gravity waves over multiple stations separated in latitude in the Indian sub-continent.

The small-scale intensity fluctuations obtained from 56 days of observations of OI 630.0 nm dayglow emission intensities from Mount Abu (24.6^{o}N, 73.7^{o}E, dip latitude 19.09^{o}N), a station under the crest of equatorial ionization anomaly (EIA), have been subjected to harmonic analysis to unravel different modes of atmospheric gravity waves (AGW). Similar analysis is carried out for 26 days of dayglow intensity data recorded from Waltair (17.7^{o}N, 83.3^{o}E, dip latitude 10.09^{o}N), a low-latitude station, and for 8 days of available data from Thumba (8.68^{o}N, 77.0^{o}E, dip latitude 0.45^{o}N), an equatorial station with the same objective. The analysis reveals the relative dominance (''preferred mode'') of 0.5–1.0 hour periodic component over Mount Abu, 2.0–2.5 hour periodic component over Waltair, and 1.0–1.5 hour component over Thumba during geomagnetically quiet periods.

In order to compare the spectral information obtained from the experimentally measured dayglow data, a few days of simultaneous ionosonde data (h'F and f_oF_2) obtained from Ahmedabad, Waltair and Thumba are also used. Since the heights corresponding to the base and the peak of the F region differ, in general, from the centroid altitude of the OI 630.0 nm dayglow emission layer by a few tens of kilometers, simultaneous ionospheric parameters (h'F and f_oF_2) are first used to obtain empirical dayglow intensity variations by using a Barbier-type relationship [*Taori et al., Geophys. Res. Lett., Vol. 28, No. 7, 1387-1390, 2001*]. These empirically generated dayglow intensity variations are also

subjected to similar analysis discussed earlier. The analysis reveals the relative dominance of 0.75–1.25 hour periodic component over Ahmedabad and 2.5– 3.0 hour periodic component over Waltair which agree well with dayglow observations. However, for Thumba no specific preference is seen from the given data set.

Qualitative arguments have been propounded to explain the differences in the preferred modes over these places, and it is suggested that the source responsible for the preferred modes may lie in the lower atmosphere.

High resolution mesospheric layer structures over low latitude using MST Radar and rocket borne measurements

The MST radar facility located at Gadanki has been used to study the high resolution spatial structures of the mesospheric return echo power. It is shown that these structures are related to the dynamics and electron density irregularities of the region. Radar observations were made using narrow pulse lengths. The observations with high range resolution reveal the presence of scattering layers having width ~ 600 m. These layers are found to be embedded in a broad turbulence field which has a thickness of ~ 4-5 km at 75 km height region. Possible causative mechanism for the generation of these layers has been suggested. The percentage amplitudes of the 3 m electron density irregularity profile are reconstructed for 200 m height resolution from the past rocket borne results over SHAR, a site close to the radar site. At least two rocket results showed that apart from the considerable increase in percentage amplitudes of the 3 m size irregularities in 70-80 km height region, the presence of similar layers as observed by the VHF radar. These results are believed to have important implications to understand the mesospheric echoes using MST radar.

Rocket and ground-based Measurements of Mesospheric Turbulence

An experimental program was conducted to understand the generation mechanism of mesospheric turbulence and the role of turbulence and stratification in producing the scattering mechanisms of the MST radar echoes. Simultaneous measurement of winds and electron/ion density and fluctuations were made in the mesosphere and lower thermosphere using rocket and MST radar for the first time in the Indian region. Two RH-300 Mk-II rockets instrumented with fixed bias Langmuir probe and Spherical probe were successfully launched from SHAR when strong mesospheric echoes were observed by the MST radar at Gadanki. The Langmuir probe and MST radar data showed presence of small-scale irregularities in 75-77 km region Detailed analyses are being made to examine the turbulence parameters from radar and rocket data.

All Sky Imaging of Plasma Depletions Over Indian Zone During Solar Maximum

PRL's all sky imaging system was operated from Kavalur (12:56 N; 78:8 E), India during February-April 2002 to observe plasma depletions through 630.0 nm, 557.7 nm and 777.4 nm airglow emissions. These observations showed the occurrence of plasma depletions continuously for several nights. This is the first time such continuous occurrence of plasma depletions for such a long duration has been observed. In addition, simultaneous occurrence of plasma depletions was observed in 630.0 nm, 557.7 nm and 777.4 nm images on many nights.

Study of Gravity waves through All sky Optical Imaging

PRL's all sky optical imaging system was modified to make it more suitable for detection of gravity waves. An observational campaign was conducted from Kavalur (12.5°N, 78.8°E) in January 2003 to image 557.7 nm airglow emissions. Very prominent band like structures were seen in these images and these are believed to be the manifestations of the gravity wave modulations. These band structures were present for 20 min and unlike plasma depletions, these were not aligned with the geomagnetic field direction.

Geomagnetic Storms and their F2-Region Response over Equatorial Anomaly region

Geomagnetic storms (~102 events) that occurred during the period of 1997 to 2001 showed that the onset time and the intensity of storm occurrence were highly correlated with the onset time and intensity of the southward component of the interplanetary magnetic field. The storm-time effects in the ionospheric F_2-region during 51 magnetic storms over Ahmedabad (23.2^{o}N, 72.4^{o}E, dip angle 30.7^o

at sub-ionospheric points) were also studied. The prompt penetration of high-latitude electric fields and the electric fields generated by the disturbance dynamo can play important role in F_2-region response during the magnetic storm, at low latitude.

Geomagnetic Storms and their Ionospheric Effects

The storm-time effects in the ionospheric F_2-region during the periods of 1989–1991 and 1999–2001 and VHF scintillations at Ahmedabad during 1999–2001 were studied. Ionosonde data show both positive and negative effects in f_oF_2, the negative storm effects are more pronounced with a maximum occurrence in the post-midnight period. A decrease in f_oF_2, due to storm-induced circulation that brings high latitude gas with depleted $[O]/[N_2]$ ratio to low and equatorial latitudes, dominates an increase in f_oF_2 due to an increase in h'F and results in a net decrease in f_oF_2 in the post-midnight period. The probability of occurrence of scintillations in the post-midnight sector is enhanced for storms in which D_{st} <75 nT occurs in the post midnight to dawn sector. Reversal of the equatorial ionospheric electric field due to the penetration of storm time magnetospheric electric fields explains the occurrence of such scintillations.

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Commision H

The research on Waves in Plasmas, a topic relevant to Commission H of URSI, is carried out in India at several National Institutions as well as Universities. This report is based on the inputs received from the following Institutions and Universities:

Indian Institute of Geomagnetism, Mumbai -IIG

Space Physics Laboratory, VSSC, Trivandrum --SPL

Physical Research Laboratory, Ahmedabad -PRL

National MST Radar Facility, Tirupati -- NMRF

Indian Institute of Technology, Delhi --IITD

Physics Department, Bundelkhand University, Jhansi --BU

R. B. S. College, Agra -- RBSC

Physics Department, Guru Nanak Dev University, Amritsar --GNDU

Space Science Laboratory, Department of Physics, Barkatullah University, Bhopal--SSL

Indian Institute of Astsrophysics, Bangalore - IIA

Some Laboratories/Departments either did not respond to our request to send their inputs on URSI Commission H activities carried out by them or their inputs were received too late; therefore, their work could not be included. During 2002-2005, Indian scientist have been active conducting observational campaigns for the ionospheric irregularities and other Commission H activities, pursuing experimental research with ground-based as well as satellite borne experiments, data analysis, and theoretical research with analytical and simulation techniques. Several national and international conferences and workshops on the URSI Commission H themes were organized in the country. Highlights of these activities are given in this report.

Indian Institute of Geomagnetism, Mumbai

1. Wave phenomena in the Ionospheric

1.1 Ionospheric Irregularities due to Rayleigh-Taylor Instability

Collisional Rayleigh-Taylor (RT) instability is studied in the bottom side of the equatorial F-region. It is shown that for an applied shear flow in equilibrium, the growth of the instability is considerably reduced. The relevance of the results to the observations of long-lived irregularities at the bottom side of the F-layer is discussed.

1.2 Nonlinear Evolution of Plasma Bubble

A transmission line analogy, which has been used earlier in a linear theory for the development of equatorial plasma bubbles, is extended to study the effect of E region conductivity on non-linear evolution of the plasma bubbles. For this, a set of mode coupling equations are used to describe non-linear development of equatorial plasma bubbles in the presence of field-aligned currents which couple the equatorial F region with conjugate E regions. For a three-mode system, these non-linear equations yield a condition for unstable fixed states. This condition shows that E region resistivity together with F region polarizability introduces another time scale in the non-linear evolution of equatorial bubbles, and this is the time scale for discharging the bubbles.

2. Wave phenomena in the Magnetosphere

2.1 Boundary Layer Waves

The magnetopause low latitude boundary layer (LLBL) is a region where solar wind momentum and energy is transferred to the magnetosphere. Wave-particle interactions, with focus on cross-diffusion

rates and the contributions of such interactions toward the formation of the boundary layer are reviewed. It is shown from the numerous magnetopause boundary layer events that all have a common signature: on onset of electric bipolar pulses, the formation of ion conics, an onset of electron (isotropic) heating, and the presence of Kinetic Alfve'n waves. The origin of bipolar pulses, the relationship to ion and electron heating and to low frequency Alfve'n waves is discussed.

Polar high-resolution wave data shows "magnetic noise bursts" and three types of intense electric signals, namely, solitary bipolar pulses, lower hybrid waves, and narrow-band waves near electron plasma frequency in the polar cap boundary layer/cusp. Status of the theoretical models put forward to explain the fine structures of the boundary layer waves are reviewed with emphasis on the new results. Future direction towards the development of suitable theoretical models in view of new high resolution results coming from Cluster are discussed.

The low latitude boundary layer (LLBL) is a region where solar wind momentum and energy is transferred to the magnetosphere. The wave-particle interactions were reviewed, with focus on cross-diffusion rates and the contributions of such interactions toward the formation of the boundary layer. It is speculated that all planetary magnetospheres will have boundary layers and that they will be characterized by similar currents and plasma wave modes.

Two magnetic hole events observed by Polar on 20 May 1996 when it was in the polar cap/ polar cusp boundary layer are studied. It is shown that low-frequency waves can provide free energy to drive some high frequency instabilities which saturate by trapping electrons, thus, leading to the generation of electron holes.

Cross-field diffusion of magnetosheath plasma occurs through resonant interaction with magnetopause boundary layer plasma waves. The formulation for this physical process was developed and applied for the magnetopauses of the Earth and Jupiter. Similar physical processes may occur at all planetary magnetospheres. The consequences of the waves for the polar aurora were discussed. POLAR plasma wave data was used to determine the local time dependences, the interplanetary control and the exact nature of the waves.

A report is presented on recent measurements of solitary waves made by the Wideband Plasma Wave Receiver located on each of the four Cluster spacecraft at 4.5-6.5RE (well above the auroral acceleration region) as they cross field lines that map to the auroral zones. These solitary waves are observed in the Wideband data as isolated bipolar and tripolar waveforms. A discussion of the importance of these solitary waves in magnetospheric processes and their possible generation mechanisms, through electron beam instabilities and turbulence, is provided.

2.2 Solitary structures on Auroral Zone Field Lines

Solitary electrostatic structures have been observed in and around auroral zone field lines at various altitudes ranging from close to the ionosphere, to the magnetopause low-latitude boundary layer (LLBL) and cusp on the dayside, and to the plasma sheet boundary layer on the night-side. Various models based on solitons/double layers and BGK modes or phase space holes are discussed in order to explain the characteristics of these solitary structures.

The nonlinear evolution of low frequency electrostatic waves in magnetized plasma is investigated for parameters characteristic of the auroral acceleration region. The model consists of Boltzmann electrons and warm ions. Numerical solutions show the existence of sinusoidal, sawtooth or bipolar waveforms.

The presence of dynamic, large amplitude solitary waves in the auroral regions of space are well known. A weakly nonlinear analysis is found to be inadequate to explain the width--amplitude variation pattern of such a large amplitude solitary wave whereas a comprehensive fully nonlinear theory is yet to be established. A fully nonlinear analysis based on Sagdeev pseudopotential technique has been adopted for two-electron temperature magnetized plasma. The width-amplitude variation profile of the resulting solitary wave solutions has been compared with the recent POLAR spacecraft observations,

which shows a good qualitative agreement.

The study of multi-dimensional localized structures has recently attracted a lot of attention due to their potential applications in nonlinear optical media and as a higher dimensional generalization of solitonic studies. Dromions are one such class of nonlinear structures that occur as exact solutions of a large class of two-dimensional partial differential equations. They have localized structures with an exponential decay in both space dimensions and are driven by time dependent boundary conditions. While solitons have been used extensively to model coherent wave phenomena in plasmas, dromion solutions have not received as much attention. A possible paradigm for modeling the rich variety of two-dimensional potential structures observed in space as well as laboratory plasmas is discussed.

2.3 Plasma Waves and Instabilities in Storm Time Ring Current

Quasi-electrostatic instabilities driven by the anisotropic oxygen ions are investigated during the storms/substorms in the three-component ring current plasma consisting of electrons, protons and energetic oxygen ions having loss cone distribution. Obliquely propagating modes with frequencies below as well as near the harmonics of oxygen ion cyclotron frequency are found to become unstable due to pressure anisotropy of the energetic oxygen ions. The results are applied to storm-time ring current region parameters.

2.4 Shear Flow modes in the Magnetotail

Shear flow instability is studied in the plasma sheet region in three-component cold plasma consisting of electrons, protons and oxygen ions. It is found that low-frequency waves could become unstable due to the velocity shear of the O+ ion beam in the near earth plasma sheet region.

Low frequency instabilities driven by ionospheric oxygen ion beam are studied in the plasma sheet region. In three component cold and uniform plasma consisting of electrons, protons and oxygen ions, the linear dispersion relation is derived with velocity shear in each component. It is found that uniform oxygen ion beam can excite the low frequency instabilities provided the Mach number exceeds a critical value. These low frequency waves may be responsible for the low frequency turbulence observed in the plasma sheet region.

2.5 Response of field line oscillations to pressure pulses

The response of transverse field line oscillations to changes in the magnetic field has been brought out in perfectly reflecting ionospheric conditions. The analysis clearly shows that the fundamental toroidal modes are dominant in the dawn and the dusk sectors as revealed by the statistical studies of pulsations observed by the satellite AMPTE/CCE. The analysis shows that the dominance of fundamental toroidal modes in the dawn and dusk sectors can also be explained in terms of response to impressed pressure impulses without invoking K-H instability and poloidal modes do not exhibit any longitudinal structures. These results are consistent with the observations.

3.0 Wave phenomena in the Interplanetary Medium

3.1 Plasma waves in Magnetic Holes and Magnetic Deceases

Solar wind protons detected within Magnetic Holes (MHs) and Magnetic Decreases (MDs) are found to be preferentially heated perpendicular to Bo. Ponderomotive Force (PF), a phenomenon due to wave pressure gradients is examined. It is shown that for this plasma regime and for phase-steepened Alfve'n waves, the PF proton acceleration/energization will primarily be orthogonal to Bo. It is suggested that accelerated ions create the MHs/MDs by a diamagnetic effect.

Nonlinear transverse Alfvén waves propagating in a medium with gradients, can lead to wave phase steepening and wave damping. One damping process is perpendicular heating of ions through the Ponderomotive Force and the creation of local large magnetic field decreases (called MDs) through the diamagnetic effect. Thus in this case, evolution of transverse waves leads to power law and compressive "spectra". An analytical expression for nonresonant particle interactions with MDs is given. Energetic charged particles can diffuse across magnetic field lines at a rate almost equal to the Bohm

rate through this process. The cross-field diffusion rate for a resonant wave-particle interaction mechanism is also given. The latter is applicable in cases where plasma instabilities are taking place.

3.2 Waves in Dusty Plasmas

The influence of non-thermal ions on linear dust acoustic waves is studied in unmagnetized plasma consisting of ions, which have a non-thermal velocity distribution, Boltzmann-distributed electrons and streaming dust particles. A detailed examination is conducted of the dependence of the real frequency and growth rate of the excited instability on the dust drift speed, temperature, particle densities and the parameter a, which determines the non-thermal nature of the energetic ions. Comparisons with approximate analytical solutions are also made.

Nonlinear propagation of electrostatic solitary structures in unmagnetized multispecies plasmas are studied in the wave frame, where they are stationary, via the recently developed McKenzie approach, as an alternative to the more usual Sagdeev pseudopotential method. This way of looking at the problem brings out the gas-dynamic aspects, which then allow a straightforward characterization of the solitary wave possibilities in terms of the species' own sonic points and of the global charge neutral points. A qualitative discussion of ion-, dust- and electron-acoustic solitary waves is given in terms of these concepts and the results are contrasted with those obtained by other methods. Beam-plasmas can also be studied, as in the electron-acoustic solitary wave model for the spiky structures of the broadband electrostatic noise observed in the auroral regions of Earth's magnetosphere.

4. International Workshop on Nonlinear Waves and Chaos in Space Plasmas

The Fifth International Workshop on Nonlinear Waves and Chaos in Space Plasmas (NWW-2003) was organized by the Indian Institute of Geomagnetism (IIG) at Taj President in Mumbai during March 2-7, 2003. The previous four workshops in this series were held in Kyoto, Japan (1994); Köln, Germany (1997); Carlsbad, California, USA (1999); and Tromso, Norway (2001). The convenors of NWW-2003 were Professor Gurbax Lakhina, Director, IIG, Dr. Bruce Tsurutani of the Jet Propulsion Laboratory, U.S.A., and Dr. Surjalal Sharma of the University of Maryland, U.S.A. The Workshop was attended by 15 foreign scientists and 13 Indian Scientists, who presented 27 papers dealing with the topic of nonlinear waves and chaos from the points of view of new experimental observations, theory and simulation techniques. The presentations and subsequent discussions contributed significantly towards the understanding of various nonlinear phenomena such as coherent structures, anomalous transport, solitons, turbulence and chaos etc., which are observed in space plasmas. The workshop was a part of the yearlong celebration of the centenary of the world renowned Alibag Magnetic Observatory, run by IIG. The Local Organizing Committee of NWW-2003 had also organized a visit to the Alibag Magnetic Observatory by the participants of NWW-2003.

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1. Ionosphere-Thermosphere Studies

1.1 Study on the plausible Linkage of thermospheric meridional winds with the Equatorial Spread

Some of the characteristic features of thermospheric meridional winds during equinoctial period associated with Equatorial Spread F (ESF) and their possible role in the triggering of ESF were studied through case studies of observational events under different geophysical conditions that essentially control the post sunset F layer (h'F) rise. The study has brought out an important result that the polarity and magnitude of the meridional winds become significant with the equatorward wind being present when the h'F is below a critical height for the Rayleigh-Taylor plasma instability to get triggered leading to the onset of ESF.

Detailed investigations have been carried out on the occurrence of bottomside ESF and thermospheric meridional wind characteristics just before the onset of ESF using ground based ionospheric data from Trivandrum (8.5 N; 77 E; dip 0.5 N) and Sriharikota ((13.7 N; 80.2 E; dip 10 N) in the Indian longitudes corresponding to the equinoctial periods of 1993-1998. Information on the F region base height (h'F) at the time of triggering of ESF and the polarity of the meridional winds showed that if the h'F is above a certain level ESF occurred under both equatorward and poleward wind conditions. Below that level, ESF occurred only when equatorward winds were present implying that the equatorward winds must somehow be able to offset the reduced growth rate of the plasma instability responsible for ESF. This study has thus enabled the identification of a threshold height

(h'F)c for the meridional wind to play a deterministic role in the bottom side equatorial spread F and a solar activity dependence for the same.

A plausible explanation linking Equatorial Ionization Anomaly (EIA) and equatorial temperature and wind Anomaly (ETWA), and the consequent neutral dynamics effectively enabling the instability event at lower height, has been offered. The threshold height (h'F)c has been found to bear a linear relation to the solar activity and sheds height on the enigmatic short and long term variability of ESF.

2. Radar Studies on Equatorial E&F Regions of the Ionosphere

2.1 Simultaneous Observations of the Electrojet plasma irregularities of 8.3m and 2.7m scale size using HF and VHF radars

Simultaneous observational studies on electrojet plasma irregularities of 8.3m and 2.7m scale sizes using the collocated HF (18 MHz) and VHF (54.95 MHz) radars over the magnetic equatorial location of Trivandrum have brought out a new and interesting aspect of the presence of a significant anisotropy in the nature of 8.3m scale size irregularities in the plane perpendicular to the earth's magnetic field in contrast to that normally observed for 2.7m scale size irregularities (Fig.1). The velocities of type II irregularities at these scale sizes have been found to be quite close to each other only below the electrojet peak altitude of 102 km, whereas the velocities of 8.3m scale sizes are less than those of 2.7m above this altitude. The spectral widths are also remarkably different at the two scale sizes.

2.2 Study of the east-west asymmetry in the 8.3m scale size E-region irregularities observed at Trivandrum

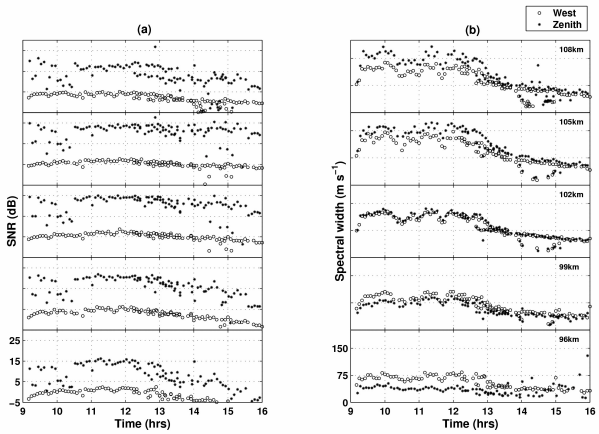

Fig.1 Temporal variations of (a) SNR and (b) spectral width observed in the zenith and 30 west beam of the 18 MHz radar are shown with symbols star and open circles respectively in the altitude region of 96-108 km .

East-west asymmetry in the electrojet irregularities refers to the dissimilarity in the Observed Doppler Spectral parameters of the backscattered radar signals as observed by west and east pointing radar beams. A detailed study on the east west asymmetry in the 8.3m scale size electrojet irregularities using 30 W and 30 E (from the zenith) beams of the 18 MHz radar at Trivandrum has indicated significant level of asymmetry in the Doppler Spectral parameters like (i) signal-to-noise ratio (SNR); (ii) irregularity phase velocity and (iii) spectral width, all as a function of height. The westward observed SNR is found to be more than that of the eastward and it decreases with increase in the electrojet height.

2.3 Study on the role of vertical electron density gradients in the generation of type II irregularities associated with blanketing ES (ESb) during Counter electrojet events.

The characteristics of different types of Sporadic E (Es) layers and the associated plasma density irregularities over the magnetic equatorial location of Trivandrum have been studied in a campaign mode using data from VHF radar, digital ionosonde and magnetometer. The presence of blanketing type ES (ESb) in the ionograms with varying intensity and duration were observed in association with afternoon counter electrojet events. ESb was associated with intense backscatter returns in the 54.95 MHz VHF radar and with either very low zonal electric field and/or with distortions present in the altitude profile of the drift velocity of the type II irregularities. The results of the study indicates the possible role of vertical electron density gradients in ESb layers in addition to providing evidence for the local winds to be responsible for the vertical gradients themselves..

2.4 18 MHz HF radar studies on Spread F irregularities

Simultaneous radar observations of 2.8m and 8.3m scale size Spread F irregularities using the 18 MHz radar at the equatorial location of Trivandrum and the 53 MHz MST radar of Gadanki (at the magnetic latitude of 6.5 N) have shown the occurrence of Spread F irregularities for a longer duration at Gadanki in comparison to that over Trivandrum. Further it is has been observed that: (i) the Spread F structures seen in the height time intensity maps at Gadanki are characterised by multiple periodic plumes in contrast to a more or less simple plume structure observed at Trivandrum; (ii) the Doppler velocities associated with the Spread F irregularities at both the locations are largely different with their range being -100 to -150 ms-1 in Trivandrum and -100 to -250 ms-1 at Gadanki and (iii) the Doppler spectral widths are less than 100 ms-1 in Trivandrum in contrast to that observed at Gadanki with values as high as 300 ms-1. The above aspects are illustrated in the height-time intensity and height time velocity plots of radar signals for both locations.

3. Study on the Equatorial ionospheric Response to the severe Geomagnetic disturbances of October-November 2003

During October-November 2003, two major geomagnetic storms occurred with Dst as low as ~500 nT. The equatorial ionosphere-thermosphere system response to these storm periods were manifested by the changes in the ionospheric parameters like foF2 and h'F. The storm features were studied using the magnetometer data of Trivandrum and the ionospheric data of Trivandrum and Sriharikota (SHAR). A significant anomaly in the general behavioural pattern of the equatorial and low latitude ionosphere during the period has been observed as characterised by changes in F-layer height (h'F) and in foF2 at these locations. Significantly the day time equatorial E and F region responses were marked by the periodic appearance and disappearance of E and F layers in tune with the storm time features. The features of perturbed thermospheric meridional winds during night time in relation to the occurrence/non occurrence of Equatorial Spread F during this period of the storm were also interesting.

4. Dayglow studies on equatorial middle and upper atmosphere

4.1Study on causative mechanisms for the variabilities exhibited by O'D 630.nm dayglow through coordinated optical and radar measurements

The equatorial electrojet parameters are known to have their imprint on the thermospheric O'D 630 nm dayglow intensity through electro-dynamical coupling. The EIA is the process that links the changes of measured dayglow intensity to the equatorial electro dynamics. In addition to the modulation of the quiet time electro dynamical processes, O'D 630.0 nm airglow is controlled by photochemistry and also by the large and small-scale neutral dynamical processes. The apportionment due to these processes under different geophysical conditions is extremely important in the investigation of the thermosphere-ionosphere system. Studies on the variabilities in the day time thermospheric air glow vis-à-vis the evolution and growth of EIA and equatorial electrojet under varying geophysical conditions were made using coordinated measurements with Multiwavelenth Dayglow Photometer, VHF/HF radars, ground magnetometer and ionosonde at Trivandrum. Day-to-day changes in the observed delay between the time EEJ current peaks and the maximum in the thermospheric airglow at 630.0 nm are being investigated to bring out the relative importance of various neutral and electrodynamical processes in terms of their manifestations in the temporal variation of the thermospheric airglow.

4.2 Investigation of the mesopause energetics and its possible implications on the mesosphere-lower thermosphere-Ionosphere (MLTI) processes through coordinated daytime airglow and radar measurements

Investigations based on daytime thermospheric and mesospheric airglow i.e. O'D 630 nm and OH (8-3). Meinel band intensity measurements from India have led to some new insight to the coupling processes of the mesosphere, thermosphere and ionosphere (MTI) over the equatorial latitudes. Coordinated air glow and radar studies have shown that planetary waves have a significant impact on the mesopause dynamics. In this context, coordinated measurements of various neutral and plasma parameter have been done using Multiwavelength dayglow photometer, VHF/HF radars, ground magnetometer and ionosonde at Trivandrum.

5. Coherent Radio Beacon studies of the low and equatorial ionosphere over India - CRABEX Program

A meridional network of very sensitive coherent receivers has been established in India comprising of locations Trivandrum, Bangalore, Hyderabad, Bhopal, Delhi and Nainital for receiving 150 MHz and 400 MHz Coherent radio beacon transmissions from the LEOS type of satellites. The chain has been fully operationalized to get the Total Electron Content (TEC) variation corresponding to each pass of the LEOS satellites at each of the above receiver locations. The simultaneous TEC data from these stations have been used to reconstruct the electron density distribution along this meridian. An in-house developed tomographic inversion algorithm is being used to develop the tomograms under different geophysical conditions. A tomographic reconstruction using five station data is shown in figure 2. Simulation studies have been undertaken to optimise the receiver network and sensitivity of the inversion algorithm to various errors in the data. The single station TEC data is used to understand the manifestation of some of the unique features of equatorial/low latitude ionosphere in the latitudinal profile of TEC. The presence of ionization ledges in the topside ionosphere has shown a clear signature in the measured slant TEC.

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1. Ionospheric Irregularities

1.1 Nonlinear development of Rayleigh-Taylor mode in the presence of molecular ion

It is rather well established that the plasma fluid type Rayleigh-Taylor (RT) mode is responsible for the generation of large scale irregularities in the nighttime equatorial F region to give rise to the equatorial spread F (ESF) phenomenon. Earlier investigations were essentially based on the assumption that the atomic ion (O+) is the dominant ion in the F-region. However, the rocket flight experiment conducted at the onset time of ESF by PRL group (Sridharan et al., J. Atmos. Terr. Phys. 59, 2051, 1997) revealed the presence of molecular ion (NO+) till the apogee (~300 km) of the rocket. Based on this result, the growth of the RT mode was examined using a linear analysis which revealed that the growth rate not only depends on the mass but also on the number densities of both (O+ and NO+) the ions (Sekar and Kherani, J. Atmos. Terr. Phys, 61, 399, 1999). This is in contrast to a single ionic constituent wherein the growth rate is independent of mass and number densities. In order to understand the earlier satellite observations by others which revealed the presence of molecular ion (NO+) even in the topside ionosphere the evolutionary characteristic of RT mode in the presence of molecular ion was investigated. The satellite observation also revealed enhancement in NO+ which were found to be collocated with the depletions in atomic oxygen ion.

The presence of short-lived molecular ions at higher altitude was an enigmatic problem. The nonlinear numerical simulation model developed in PRL (Sekar et al., J. Geophys.Res, 99, 2205, 1994) was suitably altered to include the presence of molecular ions. The investigation revealed the presence of collocated depletion in O+ and enhancement in NO+ similar to the satellite observations. Further investigation revealed that owing to the increased life time of molecular ion inside a plasma bubble, the plasma transport process associated with O+ depletions brings the molecular ion from the base of the F-region to the higher altitude (Sekar and Kherani, J.Geophys, Res., 107, A7, 10.1029/ 2001JA000167, 2002).

1.2 Evidence for sub-meter plasma waves during Leonid meteor storms:

Leonid meteor shower associated with comet Tempel-Tuttle occurs every year during 17-18 November. However, strong (order of magnitudes) meteor events occurs once in 33 years which is normally referred as Leonid meteor storm. During one such occasion, in-situ probe measurements of plasma parameters were carried out on 18th and 20th November 1999 from Sriharikota, India, a low-latitude rocket launching station to investigate the effect of a Leonid meteor storm. The high frequency Langmuir probe measurement provided an evidence for the presence of a new plasma wave (Gupta et. al., Current Sci., 84, 1340, 2003) which is classified as sub-meter plasma wave over low latitude ionosphere. Evidences are also shown that these plasma waves are not associated with the conventional two stream over equator and gradient drift waves over low latitude region. Further, the altitude profiles of the amplitudes of these plasma waves reveal that the maximum amplitudes are observed around

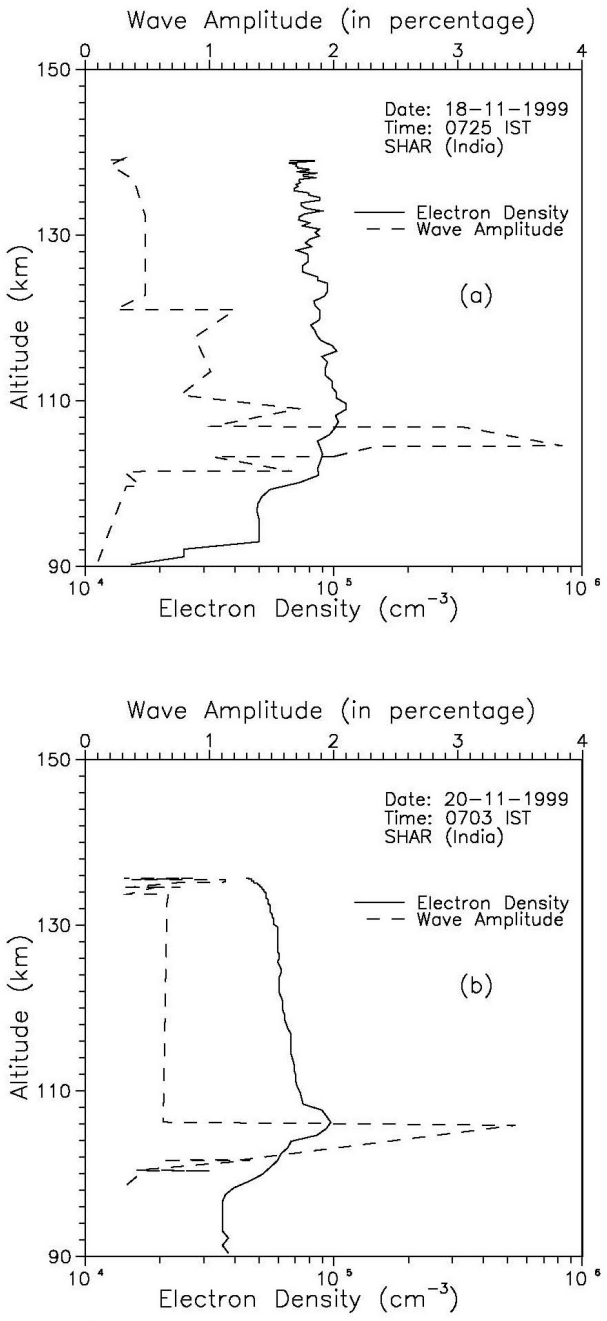

Figure 2: Altitude profiles of amplitude of plasma waves along with electron densities observed on 18 November 1999 and 20 November, 1999

105 km altitude (see figure1). These waves extend only over a limited altitude region on a day (20th Nov 1999) when the meteoric activity had fallen to one-third of its peak value corresponding to 18th November 1999. The association between sub-meter plasma waves and the meteoric activity, was also brought out by comparing the data set obtained during non-meteoric days (Gupta et al., Annales Geophysicae, 22, 2033, 2004).

1.3 Development of an analytical method for the nonlinear growth of Rayleigh-Taylor mode associated with equatorial spread F

The nonlinear development of plasma irregularities in the night time equatorial F region is usually addressed by means of numerical simulation models (Ossakow, J. Atmos. Terr. Phys., 43, 437, 1981; Sekar et al., J. Geophys. Res., 99, 2205, 1994). A few attempts have been made by others (B.Basu, Phys. plasmas 5, 2022, 1998) to study the nonlinear development of RT mode using analytical approach. However, comparison between their method and simulation model was not done. An analytical method is developed using the time and spatial domain characteristic method and the results obtained by this method are compared with the results obtained from the ESF simulation model developed in PRL. The analytical method is found to be consistent with the features, such as steep structure, which are normally described by the nonlinear simulation model. Further, the analytical method reproduces the dynamics of the structures associated with ESF (Sekar and Kherani, Physics of Plasmas, 9, 2754, 2002).

1.4 Evidence for Plasma enhancements in the VHF radar observation associated with equatorial Spread F:

The Rayleigh-Taylor mode associated with the equatorial spread F nonlinearly develops into a plasma depletion in general. However, the nonlinear simulation developed in PRL (Sekar et al., J. Geophys. Res., 106, 24,765, 2001) reveals the development of plasma enhancement in addition to plasma depletions in the presence of initial perturbations with more than one wavelength modes. The VHF radars have been extensively used to investigate the structures and dynamics of equatorial spread-F (ESF) irregularities. However, unambiguous identification on the nature of the structures in terms of plasma depletion or enhancement requires other technique as the return echo measured by VHF radar is proportional to the square of the variations in electron densities fluctuations. In order to address this issue, co-ordinated radar and airglow measurements were carried out during March, 2003 from the Indian MST radar site at Gadanki.. Temporal variations of 630.0 nm and 777.4 nm emission intensities reveal large-scale (macro) and small scale (micro) variations (figure2) during the period of observation. The micro variations are absent on non-ESF nights while the macro variations are present on both ESF and non-ESF nights. The macro variations are found to be anti-correlated with F-region layer movements. The micro variations corroborate- well with the ""plume" structures obtained by VHF radar. Apart from the signatures of commonly observed up-drafting depletions, the micro variations

also register the signatures of down drafting plasma enhancements as predicted by the numerical modeling studies revealing the importance of interaction of more than one modes.

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1. E- Region Irregularities and Instabilities

1.1 Electrojet plasma irregularities

Radar studies of the electrojet irregularities using the three radars (54.95 MHz, 18 MHz and 9 MHz radars) located at TERLS have been carried out. These radars are sensitive to 2.7 m, 8.3 m and 16.6 m irregularities respectively. These studies brought out several new aspects of the meter scale irregularities of the electrojet.

The important findings are (1) significant zonal anisotropy of the 8.3 m electrojet irregularities in contrast to that known as isotropic for 3 m; (2) East-West asymmetry of the 8.3 m electrojet type-II plasma waves and (3) significant difference in velocity and spectral width observed at 2.7 m and 8.3 m for the electrojet irregularities. It may be mentioned that the zonal anisotropy of the electrojet waves at 8.3 m is observed for the first time in the field of radar studies of electrojet irregularities. The observed difference in velocity and spectral width at the two scale sizes are attributed to the effects of anomalous collision of electrons caused by the large-scale turbulence present in the electrojet. 9 MHz radar observations of the electrojet plasma irregularities also have been studied and evaluated in the context of 18 MHz radar observations. While, no type-I waves are observed at 9 MHz conforming the theoretical understanding, the type-II plasma waves seen by 9 MHz show remarkable difference as compared to that of 18 MHz as well as 54.95 MHz.

1.2 Low-latitude off-electrojet E region plasma

Several new scientific results have been made on the low-latitude off-electrojet E region plasma irregularities using the Gadanki MST radar. They are given below.

Characteristics of the low-latitude E region irregularities

Although several interesting and new aspects of the low-latitude E region have been uncovered, a comprehensive picture of the low-latitude irregularities was missing. Using the entire database gathered so far on the E region observations at Gadanki, a comprehensive study has been made to characterize the low latitude irregularities and to provide the statistical behaviors. It is shown that (1) the echoes are observed during day and night, with the nighttime echoes being more intense and

covering a greater height extent than during the day. The most probable echo occurrence times are just after sunrise (95%) and just before sunset (80%), when the echoing regions are centered around 95 km and 100 km respectively. The lowest probability of echo occurrence is found to be during noon hours. This particular observation is important in view of the fact that when the electrojet is the strongest, the occurrence of low-latitude echoes is the lowest. This diurnal behavior needs to be understood fully in terms of the electrojet current system as well as the other governing factors viz., blanketing Es and winds.

Association of low latitude E region irregularities and Es

To examine the relationship of the irregularities with Es activities, an attempt has been made based on the common ionosonde data available at SHAR. The results show that the irregularities are better correlated with ftEs and fbEs during the night as compared to that during the day. Further, they are well correlated with (ftEs - fbEs) during the day and very poorly correlated during the night. The observed poor correlation during night is remarkable and is in contrast to that observed over midlatitude.

Kilometer-scale wave structures in the lower E region

Kilometer-scale wave structures have been detected in the collision dominated lower E region over Gadanki. These waves have been observed to occur in a narrow altitude range of 92-97 km and vertical wavelength of 0.5 km and wave periods of ~ 40 s resembling the characteristics of kilometer scale gradient drift waves. These observations are significant in view of the fact that they have not been observed in the electrojet and also have not been predicted by theory. These have been interpreted in terms of large- scale gradient drift instability occurring on very sharp thin ionization layers possibly generated by tidal winds.

Daytime QP echoes

Quasi-Periodic (QP) echoes are known to occur during the night and their occurrence is not known during the day. We have observed the daytime QP structures with descending slopes and periods of 1-3 min. in association with a descending irregularity structure whose descent rate is 0.3 m s-1. More importantly, these echoes were confined to the lower altitudes. It may be mentioned that these periods fall neither in the category of gravity waves (> 5 min.) nor in the kilometer scale gradient drift waves (usually 10s of seconds). Using the dispersion relation and assuming the collisional properties of the charge particles, meridional wind and wind shear were estimated. It is shown that shear is remarkably high to become unstable in a Richardson number sense. Accordingly, it is shown that KH instability acting on a tidal ion layer is the generation mechanism for the observed daytime QP structures.

Nighttime upper E region irregularities

The first observations of the upper E region irregularities, resembling the characteristics of intermediate layers observed by the Arecibo incoherent radar, have been made. The most interesting and important aspect in this is their occurrence at altitudes as high as 160 km, which requires an interpretation in terms of their source mechanism. It may be mentioned that at that height, the efficiency of the conventional Hall current driven gradient drift instability is extremely low. It has been shown that extremely stringent conditions are required for explaining the observations if we were to use the existing theories. Intermediate layers similar to that of midlatitudes are proposed to be essential.

Daytime 150 km echoes

For the first time low-latitude daytime 150 km echoes have been reported from Gadanki observations. The characteristics are quite similar to that reported over the equator. These results are puzzling in view of the fact that their occurrence was believed to confined to the magnetic equator.

Lower E region irregularities (< 95 km)

An outstanding problem of the E region plasma irregularities is the interpretation of the low

altitude (<95 km) irregularities, since the electric field driven gradient drift instability is heavily damped due to collisional effects. A critical computation based on the past rocket observations show that their occurrence is critical. When suitable neutral wind is included, it is shown that it is indeed possible for the instability to grow. To explain the low altitude (<95 km) echoes observed by the Gadanki radar, a proposal based on wind driven instability has been suggested. It is also proposed that this wind system is the same that is responsible for the low altitude ion layer (observed in terms of irregularity layer at Gadanki).

Theoretical and simulation studies

On the noon-time disappearance of E region irregularities over Gadanki

Different wind conditions were incorporated in the electrojet model and it has been shown that positive wind shear (eastward wind increasing with altitude) produces whorls of westward currents and downward vertical electric field, whereas negative wind shear engenders whorls of eastward currents and upward electric fields at dip latitudes centring around 6o. It is shown that it is the equatorial zonal wind field that modifies the current system at off the equator and control the growth rate of the irregularities resulting in the noontime disappearance of the irregularities a Gadanki.

On the VHF radar echoes from the lower part of the electrojet (< 95 km)

In the collision dominated lower part of the electrojet (< 95 km), often the radar observations are attributed to different processes due to the diminishing growth of the electric field driven gradient drift instability. It is shown that the lower E region echoes extending down to 90 km can be explained using the gradient drift instability if the neutral wind is taken into consideration. It is shown that the inclusion of neutral wind in the growth rate of the gradient drift instability is capable of explaining the day-to-day variability in the occurrence of the low altitude irregularities. This also explains low value of Doppler velocity and unusual velocity reversal (not counter-electrojet) observed by the radars at the lower altitudes.

2. Equatorial spread F irregularities

A number of new aspects have been addressed on spread F through simultaneous observations made using the 18 MHz radar at Trivandrum, MST radar at Gadanki and airglow measurements at Gadanki.

2.1 18 MHz radar observations of equatorial spread F irregularities

18 MHz radar observations on equatorial spread F irregularities show remarkably different results in contrast to that made extensively at 50 MHz. The Doppler velocities are found to be much less than that observed in the American sector. This is attributed to the prevalent lower value of electric field in the Indian sector as compared to American sector. More importantly, the spectral widths observed at 18 MHz are remarkably less that that observed at 50 MHz.

2.2 Simultaneous observations of spread F from Trivandrum and Gadanki

Observations made using the MST radar from Gadanki and 18 MHz radar observations from Trivandrum show that spread F structures observed at Gadanki have multiple plumes in contrast to limited number of plumes observed over Trivandrum. Remarkably, the Doppler velocities and spectral width observed to be remarkably more at 53 MHz as compared to that at 18 MHz.

2.3 E and F region coupling

Simultaneous observations of E and F region irregularities made at Gadanki show that the E region echoes weaken or disappear during the growth phase of the topside F region irregularities. Unlike Jicamarca observations, no valley region echoes are observed during this phase. It is shown that the weakening and disappearance of E region signals are not directly coupled with the F region irregularities just overhead, but linked with the instability processes over the magnetic equator through the magnetic field lines. It is proposed that the fringe fields present in the valley region in association with the equatorial plasma bubble, in the presence of appropriate background electric field conditions,

are responsible candidates. It is shown that these fringe fields and the electric fields associated with the irregularities in the valley region can map to the low latitude E region and thereby inhibit the growth of the E region instability processes.

2.4 Coordinated measurements of radar backscatter and airglow intensity during spread F

Coordinated measurements of radar backscatter and airglow intensity were made to unambiguously identify the nature of the structures observed in the radar observed intensity map in terms of plasma depletion or enhancement. Temporal variations of 630 nm and 777.4 nm emission intensities reveal small-scale ('micro') and large scale ('macro') variations during the period of observation. The micro variations are absent on non-spread F nights while the macro variations are present on both spread F and non-spread F nights. The micro variations in the airglow intensities are associated with large-scale irregular plasma structures and found to be in correspondence with the plume structures obtained by VHF radar. In addition to the commonly observed depletions with upward movement, the observation unequivocally reveals the presence of plasma enhancements, which move downwards. The observation of 777.4 nm airglow intensity, which is characterized as plasma enhancement, provides an experimental verification of the earlier prediction.

3.0 Numerical Simulation of Equatorial spread F

In order to understand the evolution of equatorial spread F structures and their dynamics an investigation was carried out with the perturbation consisting of a single wavelength mode and superposition of two modes. The investigation revealed that the depleted region always moves upward with a single wavelength mode, while the superposition of two modes gives rise to low-level plasma depletion which moves downward even when the ambient plasma motion is upward, in addition to well-developed upward moving plasma bubbles and downdrafting enhancements with varying degrees of development. Using this simulation it was possible to understand the downdrafting plasma structures observed by the MST radar.

4.0 New experiments for ionospheric research at NMRF

4.1 Faraday rotation of coherent scatter

This project is meant to estimate electron density profile by measuring the Faraday rotation of coherent scattered signals from the ionosphere. It is proposed to transmit 53 MHz signal from Gadanki using the entire MST radar and receive at a location about 200 km south of Gadanki in a bi-static radar mode. Once made operational, this will provide continuous profile of electron density and hence will provide opportunity to study the temporal variability of electron density with different time scale. Simultaneous observations of the field-aligned irregularities will provide better insight on the plasma instability processes.

4.2 Coherent Radar Imaging

This experiment will be used to study the ionosphere through interferometry, spaced antenna and imaging techniques. These techniques will provide insight of the plasma irregularity structures unresolved by a simple radar technique and turbulent plasma flow field and hence an over all understanding of the instability process at work.

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Indian Institute of Technology, Delhi

The plasma wave research at the Indian Institute of Technology is being carried out at its Physics Department and at Center for Energy studies. In space plasma motivation is to study the Alfve´n wave filamentation in the context of the solar wind turbulence and the coronal heating. While in laboratory plasma, the main concern is related to laser plasma interaction at high powers of laser flux with an application to laser induced fusion and laser based particle acceleration schemes.

1. Space plasmas

Alfve´n waves are found to play very important role in space and laboratory plasmas. The large amplitude Alfve´n waves have been observed in the solar wind and in other space and astrophysical plasmas. Existence of the large amplitude Alfve´n waves accompanying the fast solar wind have been shown by Helios 2 data and recently by Ulysses observations. The first observation of an Alfve´n wave was in mercury. Many laboratory experiments with Alfve´n waves are now conducted in tokamak devices also. With improved diagnostics laboratory experiments can scale phenomena that occur in space. In fusion physics, Alfve´n waves have been used in various heating schemes for both ions and electrons.

In order to study the transverse focusing, an equation of kinetic Alfve´n waves (KAWs) in the presence of ponderomotive and nonlinear electron heating driven nonlinearity modification in the

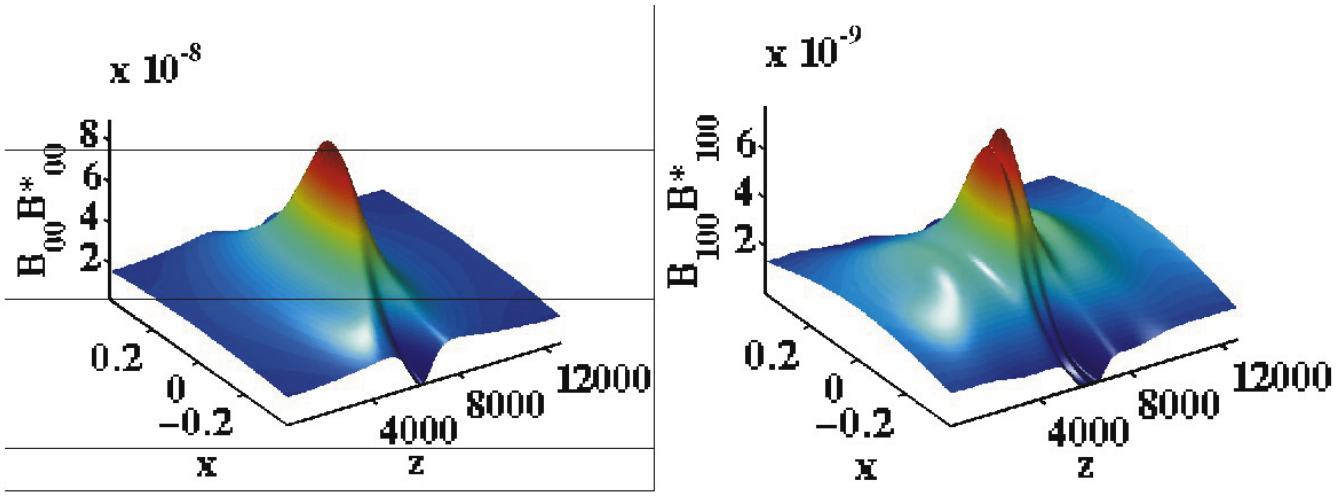
background density has been derived .This was done using the steady state model. It has been found that the KAW breaks up into filamentary structures with high intensity magnetic energy. These filaments are separated from each other by a distance of the order of 1 AU in the case of solar winds while it is of the order of 0.6 AU in the case of coronal heating. The relevance of these investigations has been discussed for the solar wind plasmas and coronal heating. In the case of the solar corona, rough estimates for additional heating have been made by assuming that the energy of the KAW is dumped to particles by wave particle interaction

In another work, the mutual nonlinear interaction between two small but finite amplitude KAWs was studied using two fluid models when the of the plasma is less than unity (for high- case one has to use the Boltzmann equation). The source of non-linearity is the nonlinear electron heating and ponderomotive force-driven nonlinear modification in the background density. The solution of model equations has been obtained by using analytical and numerical methods to study the effect of their mutual interaction on filament (hot spot) formation. It was concluded that the threshold field required for filament formation and their critical size is significantly affected by the mutual nonlinear interaction. Its effect on solar wind turbulence and coronal heating is also pointed out.

Filamentation process in the presence of the perturbation present on the main Alfve´n wave was studied in low (<<me/mi) and high (>>me/mi) cases. Main beam was assumed to be having plain wave front while the perturbation present on it was taken to be having Gaussian wave front. Using the analytical and numerical techniques dynamical equation for the perturbation has been obtained and critical field value was calculated. Filamentation process was studied in detail for solar wind and solar corona parameters.

Using analytical and numerical methods the critical size of the filaments had been obtained in compressible hall MHD case, and the coupling between the two modes may be so effective that the formation of periodic filaments, separated by a distance of the order of 900 kms and a transverse size of the order of 2.3 105 kms, can be predicted for typical solar wind parameters. The effect of coupling on Faraday rotation and ellipticity was also studied. Its effect on solar wind turbulence was pointed out.

It was shown that even in a simple non-compressible MHD system filamentation is possible. In this work a uniform plain Alfve´n wave with a Gaussian perturbation on it was considered. The physical mechanism of the filament formation was discussed in detail with the applications to the solar wind turbulence and the coronal heating. The dependence of the critical field of the perturbation, its critical transverse size and the formation of filaments, on the plasma , main Alfve´n field and other parameters had been studied in detail.



The variation of the magnetic field intensity (normalized to background field intensity) of the main KAW, with x and normalized distance of propagation z/Rd0 (z, in the figures), for the high (= 0.02) solar corona for different initial (viz. at z=0) values of B00 and B00 = 4.1 10-4 G; Figure 2:The variation of magnetic field intensity of the perturbation (normalized to background magnetic field intensity) , with x and normalized distance of propagation, z/Rd0 (z, in the figures) for high (= 0.02) coronal holes for different initial (viz. at z=0) of B00 and B100: (a) B00 = 4.1 10-4 G and B100 = 13.8 10-5 G

The filamentation process, when both the main kinetic Alfve´n wave and the perturbation present on it have Gaussian wavefront in low and high cases was studied. It was found that because of the non-linear coupling of the main beam and the perturbation, secondary filaments (low intensity filaments) are also formed along with the primary filaments. These filamentary structures can act as a source for the particle acceleration by wave particle interaction because the KAW are mixed modes and Landau damping is possible. Especially, in the solar corona, the low and the high cases could correspond to the coronal holes and the helmet streamer. The presence of the primary and the secondary filaments of the perturbation may change the spectrum of the Alfve´nic turbulence in the solar wind. Typical figures for the filaments of the main beam and the perturbation is shown in Figure (3a) and Figure (3b).

2. Laser Plasma

Since the invention of first laser in 1960, the development of its peak power and focusing ability are steadily improved, laser-plasma interaction has been an important subject for worldwide research. Plasma is an ideal medium for optics nonlinearity studies, since high power lasers cannot damage it, and varying its density can control the plasma wave frequency. Intense laser pulse propagating through plasmas can reveal various novel nonlinear phenomena including the excitation of plasma wave, self-focusing/ defocusing, filamentation, self-modulation, growth and saturation of various parametric instabilities, particle acceleration, harmonic generation and others.

The effect of cross focusing of the two laser beams on the growth of laser ripple in plasma, when the nonlinearity is due to relativistic mass variation of plasma electrons, depending on the intensity of both laser beams has been studied. Because of the relativistic nonlinearity, the dynamical equation governing the intensity of the laser ripple depends upon the total intensity of both lasers. Therefore, by changing the intensity of the second laser, one can control the growth of the ripple in the plasmas. One can also obtain the optimum intensity of the second laser beam, so that the growth rate of the ripple can be decreased. If we know the dynamics of a single ripple in the presence of second laser beam, the PBWE process can be studied in each single intense hot spot and by averaging over the hot spot intensity distribution, one can obtain the correct amplitude of the excited plasma wave and hence the acceleration of the particles .

The task for the next study is to make an investigation of self-similarity in a self-focusing laser beam both theoretically and numerically using graphical user interface based interactive computer simulation model in MATLAB (matrix laboratory) software in the presence of saturating ponderomotive force based and relativistic electron quiver based plasma nonlinearities. The corresponding eigenvalue problem is solved analytically using the standard eikonal formalism and the underlying dynamics of self-focusing is dictated by the corrected paraxial theory for slow self-focusing. The results are also compared with computer simulation of self-focusing by the direct fast Fourier transform based spectral methods. It is found that the self-similar solution obtained analytically oscillates around the true numerical solution equating it at regular intervals. The simulation results are the main ones although a feasible semianalytical theory under many assumptions is given to understand the process. The self-similar profiles are called as self-organized profiles (not in a strict sense), which are found to be close to Laguerre-Gaussian curves for all the modes, the shape being conserved. This terminology is chosen because it has already been shown from a phase space analysis that the width of an initially Gaussian beam undergoes periodic oscillations that are damped when any absorption is added in the model, i.e., the beam width converges to a constant value. The research paper also tabulates the specific values of the normalized phase shift for solutions decaying to zero at large transverse distances for first three modes which can, however, be extended to higher order modes.

Nonlinear evolution of modulational instability by using the nonlinear Schrödinger equation in one dimension reveals a periodic reoccurrence of initial conditions. The nonlinear Schrödinger equation is the adiabatic limit of Zakharov equations, which couples the electrostatic electron plasma wave and ion-acoustic wave propagation. In the next research work, nonlinear evolution of modulational instability is investigated by using one-dimensional Zakharov equations numerically. A simplified model is predicted that establishes the fact that the effect of relaxing the condition of adiabaticity is drastic

on the nonlinear evolution patterns of modulational instability. These evolutions are quite sensitive to initial conditions, Fermi-Pasta-Ulam recurrence is broken up and a chaotic state develops. Next, quantitative methods like calculation of Lyapunov exponents and their variation with wave number is used to study spatial and temporally chaotic behavior. It is shown that regular patterns with a periodic sequence in space and time and spatiotemporal chaos with irregular localized patterns are formed in different regions of unstable wave numbers.

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Physics Department, Bundelkhand University, Jhansi

1. Research Activities

Bundelkhand University, Jhansi is an emerging seat of higher learning in the central part (Bundelkhand region) of the country. Department of Physics is a newly established and a premier department of the University giving teaching inputs to many other departments of the University. Apart from teaching, department is also engaged in high quality research in the field of Plasmas, Condensed matter, Neutrino theory and other areas.

Department of Physics, Bundelkhand University Jhansi is a relatively new group involved in the scientific research of the Space Plasma related problems, viz. Ionospheric Magnetospheric studies, Atmosphere-ionosphere-magnetosphere couplings, Lightning associated phenomena and identified problems related with Space Weather.The transport of energy from one region to the other region is being investigated. It is clearly observed that the Earth's near environment is electro-dynamically coupled and perturbation introduced at one place is effectively communicated to the remote places and alters the electrical properties of the whole system.

Another problem being tackled is the lightning associated phenomena in the Ionosphere. Lightning can interact with the ionosphere, directly or indirectly, by electron precipitation following transverse cyclotron resonance with counter streaming electron. In the past, lightning production, duct formation, ducted whistler mode propagation and optical waves were treated fairly isolated problems but recent results suggest that these problems are all related and required a more comprehensive solution. A

fuller understanding of lightning and the global circuit may yield a better understanding of all the lightning associated phenomena including discharges to and from the ionosphere.

Space Weather can have significant impacts on economic and scientific endeavors globally. Sometimes, it has been proved a hazard to our technological infrastructure. The Department is involved in studies related to the factors controlling the space weather and their effects on the day-to-day life of mankind. Several areas in which advances are required for scientific understanding of the causes have been identified. Good progress is being made in models dealing with the prediction of hazardous effects of space weather environment.

2. National Symposium

Department of Physics, Bundelkhand University successfully organized the 19th National Symposium on Plasma Science and Technology (PLASMA-2004) during December 07-10, 2004 and Dr. A. K. Singh convened the meeting.

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R. B. S. College, Agra

1. Research in the field of whistlers and VLF emissions

1.1 Low latitude whistlers

Agra station is well known for its research contribution in the field of low latitude whistlers and VLF emissions. We have not only recorded these events on a routine basis at our station by employing crossed loop and vertical antennas but also found the direction of arrival and polarization of some unusual whistlers and emissions. Recently, we have made a very useful contribution by shorting out the problem of whistler propagation in the low latitude ionosphere and their transmission to ground. We have examined the merits of ducted and non-ducted propagation critically in the light of work done mostly in the Asian countries, India, China, and Japan since 1965. We have shown that a growing consensus is found in favour of non-ducted pro-longitudinal mode of propagation

for nighttime whistlers and ducted mode of propagation in the presence of equatorial anomaly for daytime whistlers. However, controversy still exists about the propagation mechanism of echo trains of whistlers observed at very low latitudes. We have suggested an alternative mechanism involving nighttime features of the equatorial anomaly. We have also discussed some very unusual events observed at our station which include whistler triplets and temporal and frequency fine structures of whistlers.

A new experimental set up for recording and analysis of whistlers and VLF emissions has been developed at Agra which is less expensive , automatic , and time saving in comparison to earlier experimental set up being used at different whistler stations in India. The new experimental set up employs a crossed loop antenna, amplifiers, low pass filter, a sound card, and PC with specially designed software for recording and analysis of the data.

1.2 VLF emissions

VLF emissions of the hiss type have been recorded and analysed extensively at low and high latitude ground stations. We, at Agra, have recorded these emissions for the first time in side the ground using a borehole antenna and the same experimental set up usually employed for whistler recording. The only difference in the experimental set was that we recorded the signal at a fixed frequency of 3 kHz and used a DC ink chart recorder for the purpose. A thorough analysis of the data has shown occasional occurrence of large amplitudes, long duration (5~ 6 hours or more) noise bursts which showed seasonal, storm time and diurnal variations similar to those of low latitude magnetospheric hiss observed on the ground. Some aspects of these emissions was found to have positive correlation with the variation of 10 cm flux which was interpreted in terms of secondary electromagnetic radiations from the night side of the ionosphere as a result of excitation by high - energy short wavelength radiations from the solar flares.

1.3 Atmospheric science

With the establishment of a new high resolution picture transmission(HRPT) reception system at IMD, New Delhi, the real time data from microwave sounding instrument onboard the NOAA-K,L,M and N series of the satellites has also become available. The raw HRPT data is being interfaced with the recently aquired new ATVOS and AVHRR Processing package to perform temperature and moisture retrievals from AMSU data of NOAA-16 satellite using two separate schemes: Inversion Coupled Imager(ICI) and Neural Network (NN) approach. The results based on the analysis of the data for the month of January, 2002 shows that ICI approach yields better results for all atmospheric levels as the RMS errors in temperature profiles are found to be less than 4deg and RMS errors in relative humidity are less than 20% at all pressure levels.

2. Research in the field of Seismo- Electromagnetism

Electromagnetic emissions in wide frequency range from ultra low frequency (ULF) to high frequency (HF) have been observed prior to the occurrence of severe and devastating earthquakes not only on the ground but also in the ionosphere and magnetosphere. The phenomena of association of electromagnetic emissions with seismic activities is known as "Seismo-Electromagnetism" and the technique of its monitoring is popularly known as "Seismo-Electromagnetic technique". On account of technical convenience and reliability in monitoring electromagnetic precursors of earthquakes, this technique has been employed widely for earthquake prediction studies for the last two decades.

The research work based on this technique was started in India first at R.B.S.College, Agra at its Bichpuri campus in February, 1998 under a research grant from the Seismicity Division of the Department of Science & Technology, Government of India, New Delhi. In what follows, we describe briefly the different experimental facilities that have been developed recently at this center, and some interesting results obtained.

2.1 New facilities for research in the field of Seismo- Electromagnetics

2.1.1 Measurement of vertical electric field using a borehole antenna

A borehole antenna of 120 m height has been installed at our Bichpuri , Agra campus in

rural area about 12 Km west of Agra city to reduce electric and electromagnetic disturbances. The induced voltages in the antenna are amplified, filtered at the VLF frequency of 3 kHz, peak detected, and recorded on a DC ink chart recorder. Now the analog recording has been replaced by digital recording using PCL 206 ADC and LABTECH software.. A terrestrial vertical antenna of 20 m height is also operated in conjunction with the borehole antenna for the study of Lithosphere- Atmosphere coupling of the seismo-electromagnetic signals. The results have shown large enhancements in the occurrence of signal bursts prior to Chamoli and other earthquakes. A block diagram of the experimental; arrangement is shown below.

2.1.2 Phase and amplitude measurements using AbsPAL receiver.

A data logger for Absolute Phase and Amplitude measurements of fixed frequency transmitter signals passing over Indian longitudes through earth- ionosphere waveguide mode propagation has been installed at our center and continuous data collection at 3 frequencies of 19.8 kHz (NWC, Australia), 21.4 kHz (NPM, Hawaii) and 24 kHz (NAA, Cutler, Maine) has been in progress for the last one year. This experiment is expected to provide information over the ionospheric perturbation caused by earthquakes and energetic particle precipitation resulting from wave-particle interactions.

2.1.3 Measurement of ULF magnetic field emissions using 3-component Search Coil Magnetometers

Recently, Search coil magnetometers have been installed at our centre to monitor the 3-components Bx, By, and Bz of the magnetic field emissions associated with seismic activities in the frequency range of 0.01 to 10 H, study of magnetic field emissions of ionospheric origin and Schumann resonances.

2.2 Some useful results

(a) Results using borehole antenna

Employing the technique using borehole antenna mentioned above, vertical electric field components of the seismo-electromagnetic emissions have been monitored at the frequency of 3 kHz at our center since February, 1998. Some of the interesting results are mentioned as follows;

(i)The electromagnetic emissions occurred in the form of noise bursts with varying amplitude and duration associated with major earthquakes that occurred in India and around. In about 60% cases the emissions occurred 1 hour to 2.3 days before the occurrence of earthquakes.

(ii) In the case of Chamoli earthquake of 29 March, 1999, the emissions started appearing 16 days before the occurrence of main shock and continued till 18 April,1999 untill the seismic activities stopped fully. This result showed a clear association of electromagnetic emissions with earthquakes and also their precursory characteristics.

(iii) In order to study the Lithosphere - Atmosphere coupling of such emissions, a terrestrial antenna has been operated simultaneously in conjunction with the borehole antenna. Three kinds of data were collected (i) emissions observed by borehole antenna only (ii) emissions observed by terrestrial antenna only and (iii) emissions observed by both the antennas. A high positive correlation of 62 % was found between the first kind of data and number of earthquakes (M> 4.5) that occurred in the country during the period of observations. The level of Null hypothesis was determined which was found to be nearly rejected. The results also indicated a possible coupling of the emissions with atmosphere which was interpreted in terms of propagation through seismic faults.

(b) Ionospheric perturbation

The effects of six major earthquakes that occurred in India during the last 13 years between 1988 to 2001 at locations of Bihar - Nepal border, Uttarkashi, Latur, Jabalpur, Chamoli, and Bhuj are examined on the ionosphere. The results show that the critical frequency of the F2 layer is reduced by 20 % to 48% in morning hours, 2 to 7 days before the occurrence of main shocks in the above

cases and the effect continues for a number of days after the earthquakes. These results are not influenced by magnetic storms as they are observed during quiet periods. These results are also supported by the statistical analysis of the data.

The available ionospheric data for foEs changes corresponding to three earthquakes of the above namely, Bihar-Nepal, Latur, and Jabalpur show foEs enhancements 3 to 20 days before the main shocks

(c) Initial results of ULF measurements

The monitoring of the 3- components of ULF magnetic field emissions associated with seismic activities has been started at our center since 27 August, 2002. The emissions were monitored initially during nighttime (2300 - 0600 hrs, IST) for the sake of avoiding artificial and man- made noises which existed predominantly during daytime, but later on the observations were extended for both night and day hours.. The observations are being taken in the ULF band of 0 - 30 Hz from which data at different frequency bands of 0.01 - 0.1, 0.1 - 1 Hz etc can be separated. The initial results show that normally the amplitudes of the 3 components are low in the range of 0.03 - 0.7 nT, but they are occasionally enhanced to large values between 0.3 - 5 nT. The six month data between September, 2002 and February, 2003 have been analysed and two cases of abnormally large enhancements are selected. These cases correspond to 23 November, 2002 and 5-6 February, 2003. These unusual enhancements are examined in the light of micropulsations and earthquakes. It is found that the enhancements are most probably caused by the ULF magnetic field emissions generated during moderate earthquakes that occurred in India and neighbouring Pakistan successively within ± 1 day.

(d) Phase and amplitude measurements of fixed frequency VLF transmitter signals

This experiment has been in regular operation since 1 October, 2001. The observations were initially taken during daytime for 2 hours each in the morning between 0600- 0800 hrs, in midday hours between 1200- 1400 hrs, and in the evening hours between 1700 - 1900 hrs. However, recently we have started the observations round the clock except 2 hour break between 1200 - 1400hrs. The preliminary results of day to day variation in the amplitude of 19.8 kHz VLF signals transmitted from NWC, Australia and monitored at Bichpuri , Agra show the decreases in the amplitude from normal nighttime daily averages on six occasions over the whole period of observations between 1 August, 2002 and 30 April, 2003. It is shown that these amplitude decreases are caused by moderate earthquakes that occurred along the great circle path (GCP) between the transmitter and receiver.

The results of ULF data analysis for the same period of observations show that the magnetic field amplitudes of the three components are enhanced to the range of 0.26 - 0.96 nT either on the same days or within ±2 days of the decrease in amplitude of the VLF signal.

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Plasma, the most dominant constituent of universe, can support a wide variety of plasma waves. In a unmagnetized plasma, three types of waves viz. ion-acoustic, electron plasma and light waves exist. However, plasma immersed magnetic field can support a wide variety of natural modes, since the cyclotron motion of the particle motion is brought in the picture. Electric polarization of wave w. r. t. applied magnetic field plays an important role in characterizing the types of waves plasma can support, e.g., lower hybrid (LH) wave, ion cyclotron wave etc. as well as electromagnetic waves like extraordinary waves, left and right circularly polarized waves. Similarly with MHD description of the plasma, we obtain low frequency modes as Alfven waves, Magnetosonic waves etc. In case of inhomogeneous plasma, we have natural modes like drift waves.

All these linear waves can continue to propagate with constant amplitude or grow/decay in its amplitude temporally at all points of space as they propagate in space. When growing, amplitude of these waves become large, assumption of linearity breaks down and the most of the disturbance ends up in nonlinear state. Because of their self-consistent motions, plasma are rampant with instabilities, chaosity and nonlinearity. Nonlinearity is fundamental to wave plasma interaction because the equations of plasma dynamics are themselves nonlinear. The most important role of nonlinear effect is to causes steepening of the leading edge of the wave. However, it is frequently found that dispersion effects become significant as the steepness of the front increases. Nonlinear structures are beautiful manifestation of nature resulting from the interaction of nonlinearity, dispersion and dissipation. Since unmagnetized and magnetized plasmas exhibit a number of linear modes, their growth with time leading to nonlinear stage in the number of ways, cannot be ignored. The resulting nonlinear structures like solitons, double-layers, shock waves etc. have been observed both in laboratory plasma

as well as space environment.

The Physics Department at the Guru Nanak Dev University is involved with the study of linear and nonlinear waves in the laboratory (laser) plasmas, dusty plasmas and space plasmas.

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Space Science Laboratory, Department of Physics, Barkatullah University, Bhopal

The Space Science Laboratory of the Department of Physics is involved in several programmes dealing with the study of ionospheric tomography by CRABEX and the Global Positioning System (GPS), study of seismo-electromagnetic signals associated with earthquake precursors, Space Weather Programme at Antarctica, Ionospheric perturbations linked to seismic activity, and World Wide Lightning Location Programme. The Space Science Laboratory has ongoing collaborations under Indo-Russian and Indo-French bilateral agreements.

1. GPS studies

Dual frequency GPS receiver is installed at low latitude station Bhopal permanently and a mobile receiver is installed at Indian Antarctic region Matri for monitoring TEC and GHz scintillation. The primary purpose of the GSV4004A GISTM is to collect ionospheric scintillation and TEC data for all visible GPS satellites (up to 11). It measures phase and amplitude (at 50-Hz rate) and code/carrier divergence (at 1-Hz rate) for each satellite being tracked on L1 and computes TEC from combined L1 and L2 pseudorange and carrier phase measurements. The 12th channel is configured as an SBAS satellite-tracking channel, and to measure a noise floor for C/N0 and S4 correction computations. The ionospheric variability as represented by percentage standard deviation from the monthly median values of TEC has diurnal, seasonal and solar activity dependence giving structure and dynamics of the polar ionosphere. Comparison of Scintillation and TEC data at different latitudes will suggest the morphology of the ionosphere.

Installation of ELF/VLF experiments in the Polar Regions for detecting seismo- electromagnetic signals. Long duration measurements of ELF/VLF wave related to seismo-electromagnetic signals could enable us promising tools for earthquake prediction. Ionospheric Scintillation and TEC data from dual frequency GPS receiver is available from December 2003 to till date.

2. Space Weather Programme at Antarctica

The GSV4004A was installed at MAITRI station which, consists of three major components GPS antenna (NovAtel's model 503 GPS antenna) mounted on the roof of the Nandadevi Hut (Summer Station). GPS receiver (NovAtel's 3951R GPSCard) installed in a computer located inside the hut. The GPStation4E houses the GPS receiver and a low phase noise oven controlled crystal oscillation (OCXO) that is required for monitoring phase scintillation

A continuous data on Total Electron Contents, Scintillation, Ionospheric delay and Tropospheric delay was collected from 2nd January to 8th March 2005.

Total Electron Contents, Scintillation, Ionospheric delay and Tropospheric delay studies of ocean surface were also carried out during onward and return voyages with a separation of about three months using two GPS systems GSV4004A and Trimble 4000SSI. Initially, during the onward journey only a single GPS, "GSV4004A" was used but on the return journey two different systems, GSV4004A and Trimble 4000SSI were used in order to check for the accuracy and fine tune the results

VLF recording setup

Triangular Loop Antenna (TLA) was installed on a 24 meter base and with a height of 12 meters. This is a base driven antenna designed with a seven ply copper wire of 22 gauge. TLA had two components; North-South and East-West components. T-type VLF antenna was installed at a vertical height of 16 meters and with each arm being 12 meters. Data recording was carried out with Digital DAT system "SONY PCM300" at a sampling frequency of 48 KHz.

Relationships of geomagnetic parameters were studied with the help of Indian Institute of Geomagnetism observatory at Maitri. Data is available from 1 January 2005 to 9 March 2005

3. The micro-satellite DEMETER

The Laboratory is participating in DEMETER, a French small satellite mission investigate the ionospheric perturbations due to seismic activity. DEMETER will measure electromagnetic waves from DC up to 4 MHz, and plasma parameters. Among these plasma parameters, DEMETER will measure with a Langmuir probe the local electron density and temperature at the altitude of the satellite (~800 km). There are two modes for the scientific payload, a survey mode to record low bit rate data all around the Earth, and a burst mode to record high bit rate data above seismic regions

4. Coherent Radiation Beam Experiment (CRABEX): Ionospheric Tomography

The ionospheric tomography is one of the important techniques for probing the ionosphere in two dimensions (latitude and altitude) and it has been successfully applied at high and mid latitude regions. The Coherent Radio Beacon Experiment (CRABEX) is the Indian tomography programme, to reconstruct a two dimensional (Latitude and Altitude) electron density profile of low latitude ionosphere. The National Programme was proposed by Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram, ISRO, Government of India for tomographic study of ionosphere.

This project envisages the investigation as well as evaluation of small and large-scale irregularities on the basis of the TEC data collected from the chain of CRABEX receivers. The experiment mainly focuses on the tomographic imaging of the two-dimensional ionospheric electron density distribution over the Indian sub continent by measuring TEC, using a reasonably good number of receivers at the suitable locations. These receivers record the TEC data from Low Earth Orbiting Satellites, which is useful to study the various phenomenon of Low latitude ionosphere. The data is available from 25 November 2003 to till date

5. Coordinated Study of Precursory ULF/VLF Associated with Earthquakes

The vertical electric fields and the horizontal components of magnetic fields of VLF waves of natural and man made origins will be recorded using suitable vertical and cross loop antenna systems, audio amplifier and magnetic tape recorders, both in the analog and the digital form. Using these measurements location of source, path of propagation, etc. will be derived . ULF wave magnetic field component will be measured using the three component search coil magnetometer. Seismic component

will be derived from the recorded data.

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Indian Institute of Astrophysics, Bangalore

Turbulence is as ubiquitous in nature as it is elusive.The fact, that it is not meer randomness, merits more exploration.Coherent structures, correlated motions and well-defined patterns are observed on a variety of spatial and temporal scales in otherwise turbulent media. Organized states of matter and motion can be seen in, convection cells,cloud complexes, tornados, cyclones,zonal flows on planetary surfaces, the RedSpot of Jupiter, solar and stellar granulation, spiral patterns of galaxies and perhaps ourselves! The universality of its (turbulence) existence has inspiredthe investigators to look for universal characteristics such as the large Reynolds Number, a consequence of the large

nonlinearity.The dimensional arguments of a la Kolmogoroff to delineate the spectral distributions has proved to be another rewarding route to pursue this otherwise forbidding field. TheTaylor Relaxation hypothesis is a further attempt to understand the evolution ofany nonlinear system in terms of its global properties such as the invariants.The macroscopic turbulence is often modeled using ideal magnetohydrodynamics. We determine the spectra of the velocity and the magnetic field fluctuations within the framework of the two fluid picture including specifically the Hall effect. It is shown that the Hall magnetohydrodynamics (HMHD) supports three quadratic invariants viz the total energy, the magnetic helicity and the generalizedhelicity. The nonlinear states depart fundamentally from the Alfvenic state challenging the much believed concept of the equipartition of the kinetic and the magnetic energy densities. Using the dimensional arguments "a la Kolmogoroff", we derive the spectral energy distributions corresponding to thethree invariants. These distributions are stringed together by invoking thehypothesis of the selective dissipation which has proved its efficacy in thetwo- dimensional hydrodynamic turbulence. We apply the results to three different situations namely: (1) the solar wind spectra, (2) the solar atmospheric turbulence, the solar granulation and (3) the laboratory experiments.

The model reproduces in the inertial range the three branches of the observed solar wind magnetic fluctuation spectrum - the Kolmogorov branch $f^{-5/3}$ steepening to f^{α} with $\alpha \sim 3–4$ on the high frequencyside and flattening to f^{-1} on the low frequency side. These fluctuations are found to be associated with the nonlinear Hall-MHD Shear Alfven waves. The spectrum of the concomitant whistler type fluctuations is very different from the observed one. Perhaps the relatively stronger damping of the whistler fluctuations may cause their unobservability.

The additional structure imparted to the spectral laws (by the inclusion of the generalized helicity) allows us to reproduce, remarkably well, the essentials as well as the details of the observed spectra of the motions and the magnetic fields of the solar atmosphere on the scales of a few thousand Km.

In a recent study, the properties of the large scale turbulence have been investigated theoretically and experimentally concluding that the kinetic energy spectrum goes as k1/3 at large spatial scales and citing a few examples for the existence of such a spectrum in natural systems. We show that the 1/3 spectrum for the kinetic energy is a direct consequence of the magnetic helicity invariant of the Hall- MHD turbulence. We present the simultaneous kinetic and magnetic energy spectra and propose the verification of the latter in the laboratory and natural systems.

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Commission J: Radio Astronomy

Research in radio astronomy is carried out in several institutions in India, whose inputs are given below:

Inputs from NCRA–TIFR, Pune

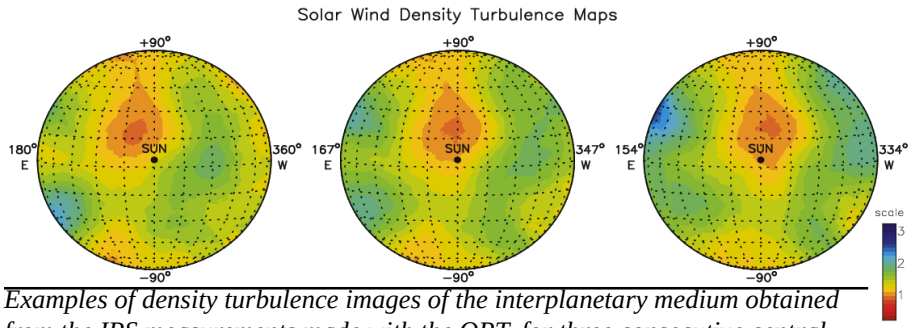
1. Sun, Solar System and Solar Wind

The first observations of a solar flare with the Giant Metrewave Radio Telescope (GMRT, Ananthakrishnan & Rao, 2002), at 1060 MHz were made on November 17, 2001. This was associated with a prominence and the initiation of a fast partial halo Coronal Mass Ejection event. Subramanian et al. (2003) found evidence for reconnection above the prominence, while Kundu et al. (2004) found that the filament eruption shows a gradual onset and then a rapid acceleration phase, which they found to be tied close to the impulsive phase of the flare.

IPS observations of the solar wind during the period around May 11, 1999 when the earth was engulfed by a region of low density, low velocity solar wind, were analyzed. Unlike the single point measurements given by satellites in space (like ACE), the IPS has probed the entire southern inner heliosphere and shows that solar wind densities and velocities were globally diminished during the period May 3-17, 1999 for which data were available from the Ooty Radio telescope. The IPS data also reveal a small subset of closely spaced sources to the west of the Sun that show a steep drop in the inferred densities to an immeasurably low value around May 11, 1999. This morphology has been shown to be a "void-within-a-void". It has been pointed out that the magnetic field on the Sun which was reversing during this period may have played a major role in generating the subsidence event [Balasubramanian, et al., 2003]

Fifteen coronal mass ejections were analyzed using Ooty IPS and SOHO LASCO data to study their evolution in the inner heliosphere. The additional data points on the speed of the CME at distances >50 R obtained from the IPS measurements have provided a better understanding of the propagation of CMEs. The results on the radial dependence of CME speed have been used to empirically predict the arrival of CME at 1 AU. Arrival times of a set of 32 LASCO CMEs have been compared with the predictions and a good agreement has been seen. The results on the CME travel time confirm that the IPS technique detects the sheath between the shock and the CME [Manoharan, 2003].

Ninety one interplanetary (IP) shocks associated with CMEs were studied, within about 30° in longitude and latitude from the center of the Sun during 1997–2002. These CMEs cover initial speeds of about 120 to 2400 kms^{-1} and they also include a special population of 25 interacting CMEs. This study provides the characteristics of propagation effects of more number of high-speed CMEs (V_{CME}>1500 kms-1) than the data used in earlier studies. The results on comparison of IP shock speed and transit time at 1 AU suggest that the shock transit time is not controlled by its final speed, but is primarily determined by the initial speed of the CME and effects encountered by it during the propagation. It is found that the CME interaction tends to slow the shock and associated CME. The deviations of shock arrival times from the empirical model are large for slow (V_{CME}<300 kms^{-1}) and fast (V_{CME}>800 kms-1) CMEs. Results show that the slow and fast CMEs experience stronger effective acceleration [Gopalswamy, Manoharan and Yashiro, 2003].



Examples of density turbulence images of the interplanetary medium obtained from the IPS measurements made with the ORT, for three consecutive central meridian days, March 4, 5, and 6, 2005.

CME Arrival Prediction: An empirical model to predict the 1-AU arrival time of halo CMEs was made considering the effective acceleration of ~100 CMEs in the Sun-Earth distance. The accuracy of the prediction was improved by considering the distance of acceleration cessation dependent on initial speed of the CME. The model was also examined for each CME's initial speed in space as well as in the projected sky-plane. The results suggested that a correct acceleration profile was crucial for the accurate estimation of 1-AU arrival times of halo CMEs. The study showed average errors of 9 and 11 hours for space and sky-plane initial speeds, respectively.

Magnetic field Configuration and Properties of CMEs: Solar active regions #9393 and #9415 produced a large number of intense flares and associated CMEs which were responsible for a number of severe geomagnetic storms. The characteristics of these mass ejections were studied using data from the Large Angle and Spectrometric Coronagraph on board SOHO and IPS measurements obtained from the ORT. These CMEs showed large variations in size, speed, acceleration, and in the radial dependence. A detail comparison of magnetic field observations of the active regions with the corresponding 'latitude-longitude' maps of the solar wind speed and density fluctuations obtained from Ooty measurements showed that the energy involved in the mass ejection was controlled by the magnetic configuration at and near the mass ejection site [Manoharan and Kundu, 2005].

Galactic Astronomy

Seven giant radio pulses were recorded from the millisecond pulsar PSR B1937+21 during 8.1 minutes observation by the Ooty Radio Telescope (ORT) at 326.5 MHz. Although sparse, these observations support most of the giant pulse behavior reported at higher radio frequencies (430 to 2380 MHz). Within the main component of the integrated profile, they are emitted only in a narrow ($\leq$ 47μs) window of pulse phase, close to its peak. This has important implications for doing super-high precision timing of PSR B1937+21 at low radio frequencies [Vivekanand, 2002]

Pravdo et al. claimed that the phase resolved X-ray spectrum in Crab pulsar (PSR BV0531+21) shows a spectral hardening at the leading edge of the first peak of its integrated profile; this was a new and unexpected result. Their data were reanalyzed and it was argued that the spectrum is as likely to be unvarying i.e., neither hardening nor softening [Vivekanand, 2002].

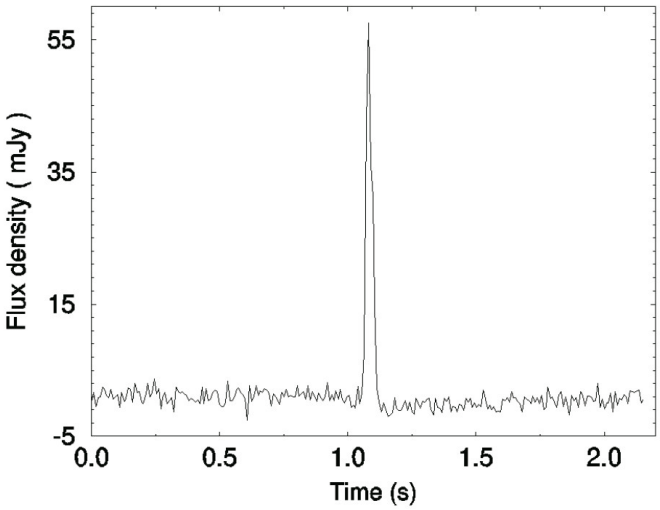
Emission Geometry of Radio Pulsars: Though a lot is known about the properties of the observed radio radiation from pulsars, there are still unanswered questions about the exact location and geometry of the regions in the pulsar magnetosphere that produce this radiation. A new technique for identifying emission components using single pulse data had been developed in an earlier work (Gangadhara and Gupta, 2001, ApJ, 555) and a novel interpretation of the locations of the conal emission components had been developed for estimating the height and magnetic field line location of the emission cones in the pulsar magnetosphere. These techniques of analysis and interpretation have been applied to several more pulsars for which high quality single pulse data was taken using the GMRT in the 325 MHz band. The results from this work (Gupta and Gangadhara, 2003) support the initial conclusions, that there is clear evidence for the following (i) pulsars with multi-component profiles have multiple (two to three) concentric, hollow cones of emission (ii) the typical emission heights for these cones in the pulsar magnetosphere range from ~ 100 to ~ 1000 km (iii) emission height for a given cone is a function of the radio frequency, being lower for the higher frequencies (iv) the magnetic field lines associated with these emitting cones are not located at the edge of the open field line region, but lie in the range ~ 0.2 to 0.7 of this boundary (v) there is some evidence that the wider cones originate on further out field lines.

Understanding the remarkable pulsar B0826-34: Pulsars that exhibit drifting sub-pulses in their single pulse data provide valuable insight into the emission mechanism of radio pulsars. In this context, PSR B0826-34 is remarkable, as it has a very wide pulse with emission seen over most of the pulsar period, implying an almost aligned rotator geometry, i.e. rotation and magnetic axes almost parallel. Furthermore, the single pulses show a remarkable and complex pattern of drifting sub-pulses, including significant variations in the drift rate and even reversals of the sign of the drift, which are apparently in disagreement with popular models like the Ruderman and Sutherland model that attempt to explain

the basic phenomenon of drifting sub-pulses. A detailed study of this pulsar has been started, using high quality single pulse data taken with the GMRT. The initial analysis of the drift behaviour at 318 MHz has revealed evidence for the presence of as many as 7 sets of drifting pulses within the pulse window, with significant variations of the drift rate, including apparent reversals, that are correlated across all the sets. It appears that the observed drift rate is not the real one, but is an aliased version, produced because of inadequate sampling (of once per pulsar rotation period) of the underlying sub-pulse drift pheonmena. The drift rate variations, including the reversals, can then be explained as small (~ few percent) changes of the true drift rate on the polar cap, which could be caused by minute fluctuations of the neutron star's surface temperature. The geometrical parameters for this pulsar have been derived and the distribution of the emission regions modeled as 14 or 15 sparks circulating in a ring around the magnetic axis, at 0.44 of the radius of the polar cap [Gupta, et al., 2004].

Study of pulsar dispersion measure (DM): Accurate estimates of the dispersion measures of pulsars using multi-frequency observations show that pulsar DMs can be estimated with an accuracy of 1 part in 10000 or better. This will allow monitoring minute changes in the DMs with time that are produced by random fluctuations of plasma density in the inter-stellar medium of our Galaxy, and hence probe the nature and physics of these fluctuations [Ahuja, et al., 2002].

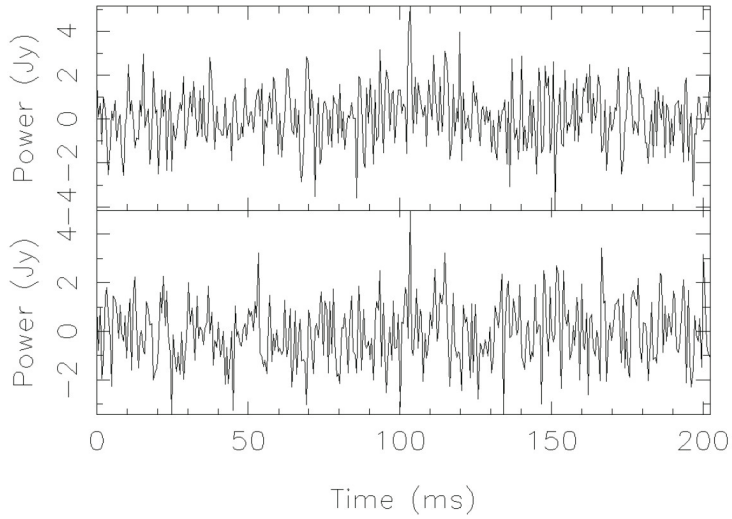
Parkes high Galactic latitude multibeam search: The observed spatial distribution of milli-second pulsars (MSPs) is nearly isotropic and many such pulsars have been observed at high Galactic latitudes. A new survey with Parkes radio tele-scope using the 20 cm multibeam receiver was started in November 2000 to search such pulsars. The survey covered a region around the southern Galactic plane between longitudes 220^o and 260^o and latitudes |b|< 60^o. The observations for the survey were completed in December 2002 and 36 pulsars, which include 14 new pulsars, have been discovered in the data analyzed so far. Four of the new pulsars are MSPs, which is consistent with the expected number. Three of these are binary pulsars [Joshi et al. 2002a].



The figure shows integrated profiles for the first pulsar, PSR J0818–3233, in Parkes high Galactic latitude survey.

Rotational instabilities in pulsars: A few pulsars occasionally exhibit a sudden increase in the rotation rate called pulsar glitch. These are useful probes to study the internal structure of the neutron stars. About 76 glitches in 25 pulsars have been reported to date. A massive glitch in PSR J1806-2125 was detected in the data on a large sample of pulsars, being timed at Jodrell Bank for several years. The magnitude of this glitch was ~2.5 times greater than any previously observed glitch and 16 times greater than the mean glitch size. In addition, a further 14 glitches were detected in 9 pulsars, 6 of which have glitched for the first time. This includes the third largest glitch in PSR B1930+22 and four recent glitches in PSR B1737-30, which continues to exhibit frequent glitches. A database of more than 100 glitches is currently being compiled for statistical studies [Joshi el al., 2002b, Krawczyk et al., 2003, Hobbs et al. 2002].

Search for Giant pulses in millisecond pulsars: Giant pulses, which are occasional individual pulses with intensity typically 100 times the average intensity, have been seen in three pulsars to date and their origin is not well understood. Eight millisecond pulsars (MSPs) were observed using GMRT to search for Giant pulse emission. Giant pulses at very high signal to noise ratio were detected in PSR B0531+21 and their distribution at 610 MHz was obtained. Large amplitude pulses were also detected for the first time in PSR J0218+4232 and B1957+20. Both these pulsars have a high strength of magnetic field at light cylinder. These data, together with the previously reported Giant pulses in PSR B0531+21, PSR B1937+21 and PSR J1821-64, suggest a connection between the strength of



A large amplitude pulsar (LAP) in PSR J0218+4232. The upper plot shows the dedispersed single puse data in 610.0 – 618.0 MHz subband and the lower plot for those in 618.0 – 626.0 MHz. The LAP, observed in both bands, has an intensity approximately 50 times the mean intensity.

magnetic field at light cylinder and the existence of giant pulses in MSPs [Joshi, B.C., et al., 2004a].

The discovery of the first pulsar with the GMRT: During February 2003, phased array pulsar mode observations were made with the GMRT of a selected list of 16 globular clusters in our Galaxy, with the primary aim of searching for as yet undiscovered pulsars in these dense and massive stellar condensates. In November 2003, analysis of the data from the globular cluster NGC1851 revealed the presence of a new 4.99-millisecond period pulsar. Follow-up observations at the GMRT in December 2003 confirmed the discovery of this pulsar. This is the first pulsar discovered in the cluster NGC1851, and the first new pulsar discovery using the GMRT. Furthermore, the follow-up observations showed that this is a binary pulsar, and that too in a very unusual binary orbit. The data are best fit by an orbital period of 18.785 days and an orbital eccentricity of 0.889 - the highest known for any pulsar binary system. The minimum mass of the companion is 0.9 of the Sun's mass. The parameters of this system have significant implications for theories of formation of binary pulsar systems. Using simultaneous recording of the interferometric data, a radio map of the globular cluster was also made to pin-point the location of the pulsar as being fairly close (within 0.1 arcminute) to the centre of the cluster [Freire, P.C.C., et al, 2004].

Multi-frequency observations (MFO) of pulsars: Simultaneous multi-frequency multi-observatory pulsar observations are powerful tools for studying the pulsar emission mechanism. New results were obtained from an ongoing program of analysis of MFO data taken with the GMRT, Jodrell Bank and Effelsberg telescopes. Flux density measurements of individual pulses simultaneously observed at four different frequencies for pulsars B0329+54 and B1133+16 have been used to derive the Flux density spectra of individual pulses, for the first time for any pulsar [Kramer, M. etl al., 2003].

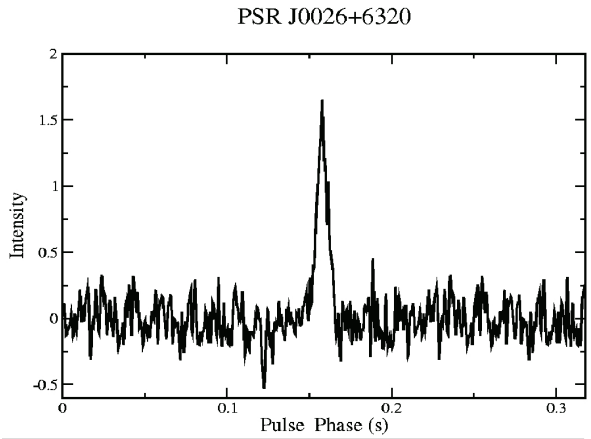
Frequency dependence of interstellar pulse broadening of pulsar signals: Final results were obtained from the study of interstellar pulse broadening of pulsar signals carried out using the GMRT during 2002-2003. This project was carried out with the aim of understanding the frequency dependence of the scatter broadening time scale, for a selected set of medium dispersion measure (DM) pulsars. Multi-frequency observations were carried out with the GMRT at 243, 325 and 610 MHz. The results show that the frequency dependence of the scattering is consistent with the Kolmogorov spectrum of electron density fluctuations in the interstellar medium, as is found to be true for the low DM pulsars. This implies that the anomalous frequency dependence seen for the pulsars with high DMs is likely to be due to special scattering conditions along lines-of-sight probing the regions of the inner Galaxy. These results have been submitted for publication [Gupta, Y.,].

The two pulsars in the binary system J0737-3039 were discovered in the above survey. A 22-ms pulsar was discovered in April 2003. in a 2.4 hour binary system with another neutron star as companion. The system is the most relativistic binary system known and the relativistic advance of the periastron was soon measured. The estimated time of its merger (85 Myr) and shorter life-span implied an increase in the double neutron star merger rate by at least a factor of 10, significantly improving the chances of the detection of gravitational waves by earth based detectors such as LIGO. These findings were published in Nature by Burgay et al. in December, 2003 [Burgay, et al., 2003].

Later, re-analysis of PSR J0737-3039A data revealed occasional strong pulsations at a period

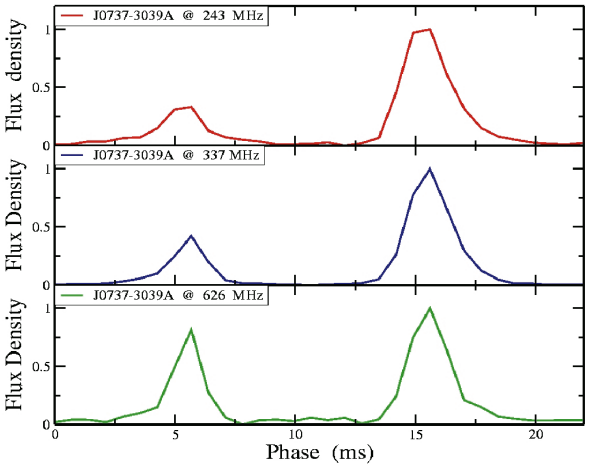
of 2.8 s. The second pulsar had the same dispersion measure as PSR J0737-3039A and an opposite Doppler variation of the period, confirming that this system is a double pulsar system - the first such system found to-date. The second pulsar is visible for two brief periods of 10 minute each and this pattern of visibility is essentially identical at all observing frequencies. Careful analysis of data also revealed a short eclipse of PSR J0737-3039A of about 20 s. The timing solutions for the two pulsars and the eclipse confirm the edge-on viewing geometry of the system. The mass of the two neutron stars were measured with unprecedented accuracy to be 1.33 $M_{\odot}$ and 1.25 $M_{\odot}$, the latter being the smallest known mass for a neutron star [Lyne, et al., 2004].

A 610-MHz pilot survey, covering about 40 square degree of sky near the Galactic plane, was carried out using GMRT to discover new long-period pulsars, or pulsars with periods longer than 3 seconds. Finding more of these pulsars is important to provide constraints on the pulsar emission mechanism and to understand the relationship between radio pulsars and high-energy "magnetars". A new pulsar, PSR J0026+6320, was discovered in this survey and 3 known pulsars were re-detected. Pulsar timing observations, being carried out for PSR J0026+6320 at GMRT and Jodrell Bank observatory, indicate a period 318 ms, a distance of about 8 kpc and a moderate magnetic field. The profile of this pulsar is shown in Figure. This is the second pulsar discovered using GMRT.

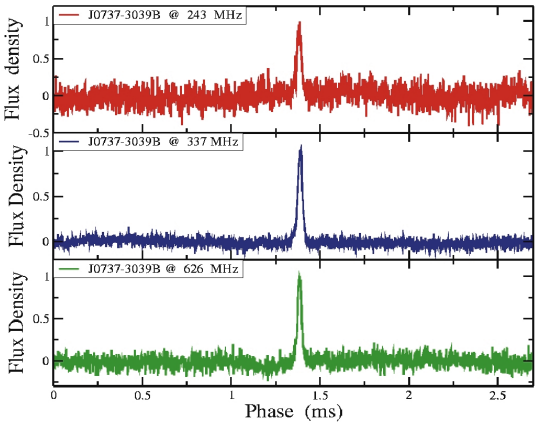


The average profile of the second GMRT pulsar PSR 0026+6320.

The follow-up studies of Double pulsar system PSR J0737-3039: In Double Pulsar system, PSR J0737-3039, the line of sight to the millisecond pulsar passes through the magnetosphere of the long period pulsar giving a unique probe of the pulsar magnetosphere. The relatively small separation between the two pulsars, a 17 per year advance in its angle of periastron and a mild eccentricity leads to a varying interaction between the pulsars, observed as a rich phenomenology in their emission. Follow-up studies of this system, since its discovery in 2003, have revealed peculiar modulation of the pulsed emission of the long period pulsar, PSR J0737-3039B (or B) with orbital phase. Observations with Parkes, Green Bank Telescopes and GMRT led to detection of drifting subpulses in one of the two bright phases of this pulsar with a fluctuation frequency of 0.196 cycles per period, indicating a direct influence of J0737-3039A's 44-Hz electromagnetic radiation on PSR B's magnetosphere. Later multi-epoch observations with GMRT at 325 MHz and Parkes Telescope at 1400 MHz indicated a change in the separation and intensities of the two bright phases



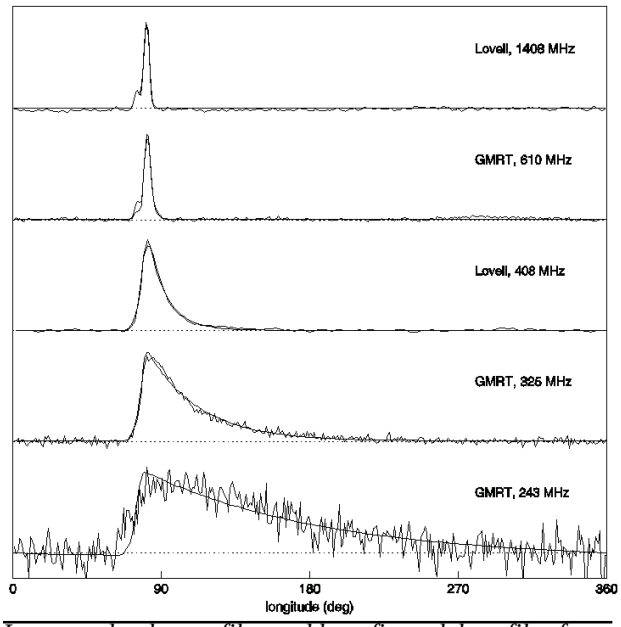
The average profiles of PSR J0737-3039B obtained with GMRT at 243, 337 and 626 MHz.



The average profiles of PSR J0737-3039A obtained with GMRT at 243, 337 and 626 MHz.

of B, probably due to geodetic precession of B. Future measurements will provide new tests of relativity as well as constrain theories of pulsar emission. In contrast, the follow up observation with Parkes radio telescope show no evidence for significant changes in the pulse profile for PSR A, the millisecond pulsar in the system contrary to expectation of large changes due to geodetic precession. These results conclusively rule out a recent geometrical model proposed for the system and imply that the misalignment angle between the rotation axis and the orbit normal is less than 60°. Due to the edge on orbit of the system, PSR A is eclipsed for about 30 s. Analysis of data from Green Bank Telescope indicated that the pulsed flux density at eclipse is strongly modulated with the periodicity of 2.8 s pulsar and the eclipse is due to synchrotron absorption by the shocked plasma around B. The system was observed at 626, 337 and 243 MHz with GMRT this year to study the multi-frequency behaviour of its low frequency emission. The multi frequency profiles of the two pulsars, obtained in these observations, are shown in Figure and indicate a differential spectral evolution for the two pulsars as well as for the components in their average profiles [Joshi et al., 2004b, Mchaughlin, et al., 2004a, Mchaughlin, et al., 2004b, Manchester, et al., 2005].

The frequency evolution of interstellar pulse broadening from radio pulsars: Scattering of pulsed signal from pulsars has been used as excellent probes to study the properties of the electron density fluctuations in the interstellar medium (ISM). The characteristic time scale sc, known as the scatter broadening time, scales with frequency and has a spectral index =4.4 for a pure Kolmogorov spectrum of irregularities in the ISM. Thus it is of interest to find sc for pulsars along various lines of sight in the ISM as it throws light on the ISM properties of our Galaxy. In this work we have done multi-frequency measurements of scatter broadening times sc for nine medium dispersion measure (DM ˜ 150-400 pc cm-3) pulsars observed over a wide frequency range. The low frequency data at 243, 325 and 610 MHz are new observations done with the Giant Metrewave Radio Telescope (GMRT). The frequency dependence of sc for all but one (PSR B1933+16) of our sources is consistent with the Kolmogorov spectrum of electron density fluctuations in a turbulent medium. PSR B1933+16, however, shows a very flat spectrum as previously observed for high DM pulsars. Our observations combined with earlier published results enable us to study for the first time the spectral index of sc over the whole observed DM range. While the spectral properties are generally consistent with a Kolmogorov spectrum, pulsars seen along line-of-sights towards the inner Galaxy or complex regions often show deviations from this expected behaviour. Figure shows the variation of the integrated pulse profile of PSR B1831-03 with frequency as an example of the effect of scattering over a wide range of radio frequencies [Lohmer, M., et al., 2004]

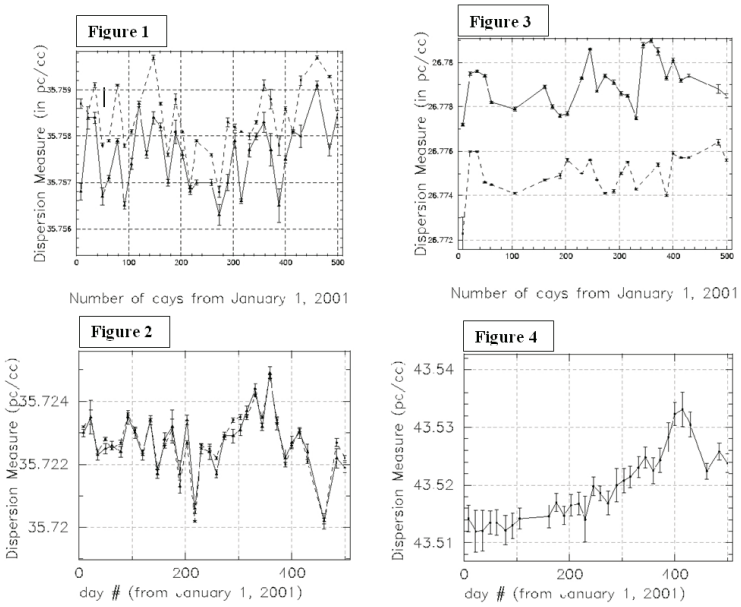


Integrated pulse profiles and best-fit model profiles for PSR B1831–03 at different frequencies. The profiles at 243, 325 and 610 were observed with the GMRT, whereas the 408 and 1408 MHz profiles were taken from the European Pulsar Network database (Lovell observations). The alignment of the profiles for different frequencies was done with respect to the peak of the main pulse.

Sub pulse drifting in wide profile pulsars: Such wide profile pulsars can be interpreted as emission coming from one magnetic pole of a highly aligned pulsar i.e. magnetic axis almost parallel to rotation axis). In such a case, the line of sight is very close to both the rotation and the magnetic axes, and consequently we can sample a large region of the polar cap. Studies of wide profile pulsars can probe detailed distribution of the emission regions in the pulsar magnetosphere. PSR B0826-34, in which emission occurs for nearly 350° of longitude, is a unique pulsar. It exhibits remarkable drifting including simultaneous multiple drift bands and sign reversals of drift rate [Gupta, Y., et al., 2004].

A novel experiment for the estimation of pulsar dispersion measure (DM) along the line of sight to a sample pulsar has been carried out using the Giant

Meter-wave Radio Telescope (GMRT). This involved simultaneous dual frequency pulsar observations of a sample of twelve pulsars using the GMRT over a period of more than one year. GMRT is an ideal instrument for such an experiment. This is the first time that pulsar DMs have been measured from dual frequency, single epoch, by using the cross-spectrum signal processing technique. This way we have managed to calculate DM to accuracies of 1 part in 104 and better. In Figure we show the measured DM's for 4 pulsars and its temporal variation. See figure caption for more details. [Ahuja, 2002]



Variation of DM (3s error bars) with time for pulsars B1642-03 (observed at 325+610 MHz) (Firure 1), B1642-03 (Observed at 243+325 MHz) (Figure 2), B0329+54 (Figure 3), and B2217+47 (Figure 4) over the interval 08 January 2001 to 14 May 2002, as a function of day number. The continuous lines show the results from average profile and the dashed one from the single pulse method.

Galactic Centre observations with GMRT: From the GMRT 610 MHz observations, the emission from the central compact object known as the Sgr A* has been detected, which is the lowest frequency detection of this object. There is an HII region Sgr A West seen along the same line of sight as the Sgr A*, which is shown to be optically thick at 620 MHz. The detection of Sgr A* indicates that it is located in front of the Sgr A West. Based on earlier 960 MHz observations, it was expected that the emission from the Sgr A* below about 800 MHz gets absorbed due to the free-free process. However, detection at 610 MHz clearly shows that this is not so and their estimated flux density at 960 MHz is a factor of 2 lower than what is measured at 610 MHz with the GMRT. This discrepancy cannot be explained by its spectrum. Refractive Interstellar Scintillation over the last 25 years could have caused this discrepency. [Roy & Rao, 2003].

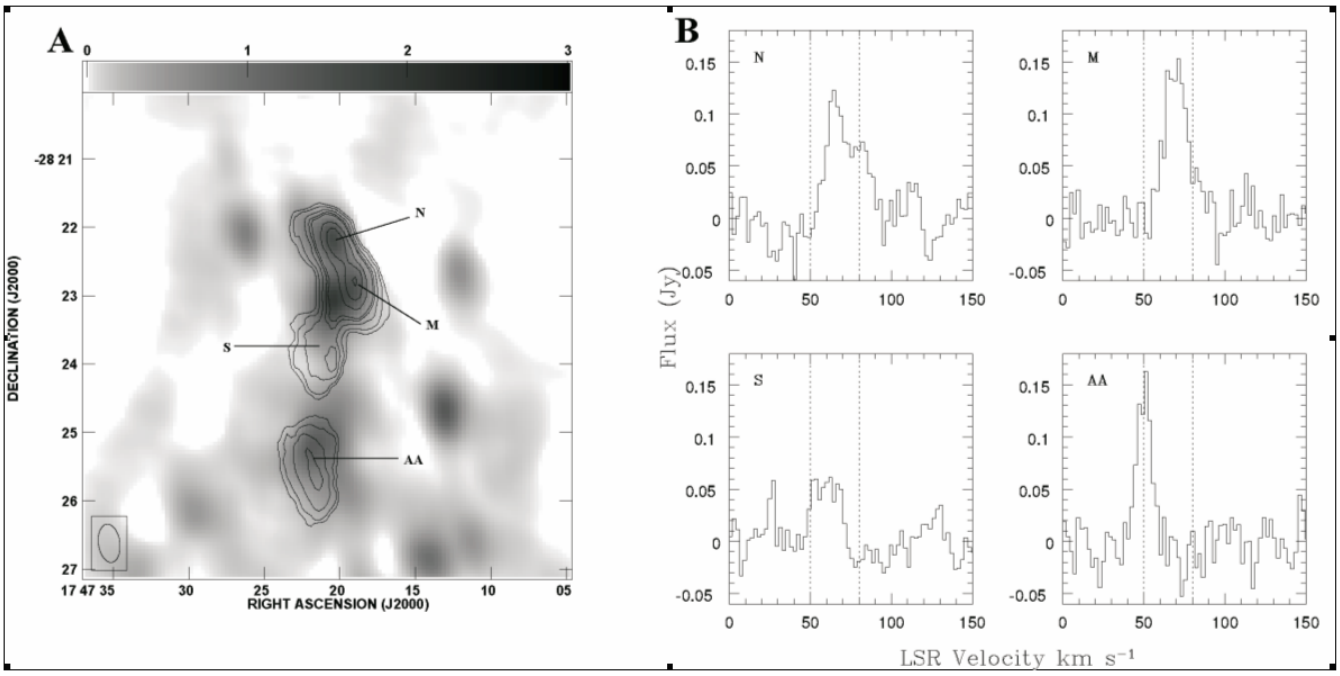
Magnetic field near the Galactic Centre: Rotation Measure observations of extragalactic sources: Except the central 200 pc of the Galaxy, the magnetic field in the inner 5 kpc region of our Galaxy has not been measured in the past. Concentration of the primordial magnetic field is believed to generate the bi-symmetric spiral configuration of the magnetic field seen in some galaxies. The estimated volume filling factor of the plasma responsible for the RM is about 10^{-5}, which indicates that the plasma is arranged in the form of dense clumps, whose sizes are ~35 pc and electron desnsity ~20/cm^3. These ionised clouds are likely to be the ionised outer envelope of the molecular clouds in the region. The estimated physical parameters of the clouds matches quite well with what was postulated earlier to explain the detection of the Galactic ridge Radio Recombination line in the inner Galaxy. The Faraday screen sampled by these observations has an outer scale 30', which is much larger than the scale size of 10" observed near the Non-thermal filaments in the Galactic Centre. Therefore, in the last few years, observations have been carried out to constrain the line-of-sight magnetic field of the central 2 kpc region ($354° \leq l \leq 6$, $-1.8° \leq b \leq 1.8°$) by estimating the Faraday Rotation Measure (RM) towards a large number (65) of suspected background extragalactic sources. Out of 65 sources, 60 were inferred to be extragalactic, which increases the number of known extragalactic sources seen through the region by an order of magnitude. Out of 65 sources observed, polarised emission were detected from 42 sources. The Faraday rotation measures (RM) towards most of these sources are found to be positive and large (~500 rad m^{-2}). Based on the typical electron density in the region, the line of sight component of this magnetic field is estimated to be 0.7 μG. This large scale magnetic field around the GC is consistent with a bisymmetric spiral configuration of magnetic fields in the Galaxy. The outer scale of the RM fluctuation is about 30 pc. With certain assumptions, the probability of encountering the ionised material responsible for the Faraday rotation and scattering in the central 2 kpc of the Galaxy is estimated to be 0.02, which indicates that the plasma is arranged in the form

of dense clumps, with sizes ~35 pc and electron density ~20 cm-3. These are likely to be the ionised outer envelope of HII regions. The estimated upper limit on the line of sight magnetic field in the central 300 pc of the Galaxy is 60 G, thereby suggesting the milliGauss magnetic field estimated near the NTFs are localised and does not pervade the central 300 pc of the Galaxy. [Roy, Rao & Subrahamanyan, 2003].

Radio continuum images of three Galactic HII regions, S201, S206, and S209 near 232, 327, and 610 MHz were obtained using GMRT. Since the GMRT has a mix of short and long baselines, therefore, even though the data have high spatial resolution, the maps are still sensitive to diffuse extended emission. All three HII regions have bright cores surrounded by diffuse envelopes. The high resolution data was used to estimate the electron temperatures and emission measures of the compact cores of these HII regions. These estimates of electron temperatures are consistent with a linear increase of electron temperature with Galacto-centric distance for distances up to 18 kpc (the distance to the most distant HII region in the sample). [Omar, et al., 2002]

Imaging the distribution of Acetaldehyde toward the Galactic Center: Giant Meterwave Radio Telescope images of the 1065 MHz emission from the $1_{10} \rightarrow 1_{11}$ rotational transition of acetaldehyde in the molecular cloud complex Sgr B2 were obtained. The observations are unique in that they have a high spatial resolution (~ 4), while still being sensitive to large-scale emission. Most complex organic molecules in this cloud (e.g. acetone, methyl formate, acetic acid) are concentrated in a very small core, ~0.1 pc across. In contrast, acetaldehyde is found to be spread over a region at least 100 times larger in extent. The line emission is confined to regions with radio continuum emission and correlates well (in both position and velocity) with formaldehyde absorption towards this continuum; this is consistent with earlier single dish results suggesting that it is likely to be weakly mased. The observations also suggest that grain mantle destruction by shocks plays an important role in the observed gas phase abundance of acetaldehyde in Sgr B2. [Chengalur and Kanekar, 2003a].

Timing Properties of Cygnus X-3: The binary corrected X-ray light curve of Cygnus X-3 using the RXTE-ASM (All Sky Monitor) data and RXTE-PCA data were studied and found that the X-ray template derived from the EXOSAT observations adequately explains the binary variations. Using the recently determined quadratic binary ephemeris we corrected the RXTE-PCA light-curve and obtained the power spectrum which shows distinct features of shifting towards the low frequency regime



[A] Integrated Acetaldehyde emission towards SGR B2 (contours) overlaid on the 1065~MHz continuum emission (greyscale). [B] Acetaldehyde emission spectra towards the four regions marked in panel [A] The dotted lines are at LSR velocities of 50 kms and 80 kms.

vis-à-vis the Galactic X-ray binaries. The power spectrum doesn't vary from the hard to the soft state. We also obtained the binary corrected RXTE-ASM monitoring light-curve and examined the previously obtained correlation between soft X-ray (2 - 12 keV from RXTE ASM), hard X-ray (20 - 100 keV from CGRO - BATSE) and radio (2.2 GHz from GBI) (Choudhury, et al., 2002) after the binary correction and found that the correlation time scale is less than a day [Choudhury, et al. 2004d].

The lagged anti-correlation of hard X-rays in Cyg X-3 and GRC 1915+105: Continuing the study of the anti-correlation of the hard X-ray vis-à-vis the soft X-rays (Choudhury et al., 2003), we used the binary corrected light-curve in the two bands to obtain the time scale of the anti-correlation to be of the order of few hundred to thousand seconds. This lagged anti-correlation of the hard X-rays gives rise to the pivoting feature in the spectral evolution of the source. The lag time scale may be attributed to the viscous time scale of flow of matter in the accretion disk (Choudhury, M., et al, 2004) . This suggests the geometrical picture of a truncated accretion disc with a Compton cloud inside the disc, the relative sizes of which determine the spectral shape. Any change in the disc structure will take place in a viscous time scale, with corresponding anti-correlated change in the Compton cloud. [Choudhury, et al., 2005].

Multifrequency study of the nova remnant GK Persei: Multifrequency radio continuum observations using GMRT, optical observations using the HCT and archival VLA data at higher radio frequencies have shown interesting results. We find that the radio continuum spectrum at frequencies lower than about 1 GHz is steeper with an index -0.85 whereas the higher frequencies the spectral index is -0.7. Moreover we find, for the first time in this nova remnant, that the spectrum above about 1 GHz shows a annual secular decrease of 2.1% in the flux density, which can be explained by adiabatic expansion of the remnant, and which is absent at the lower frequencies. We argue that there are at least two electron populations which give rise to the observed radio emission and which peaks at different frequencies. We conclude that the remnant of GK Per is similar to supernova remnants, in particular Cas A. (Anupama & Kantharia, 2005) The observed global spectrum of GK Parsei over 3 epochs is analysed using acceleration synchrotron losses and adiabatic losses. The evolution can be explained if the acceleration balances losses for electron energies greater than a critical energy Ec (corresponding to radio frequency 1 GHz) whereas synchrotron losses dominate at lower energies [Kantharia, et al., 2005].

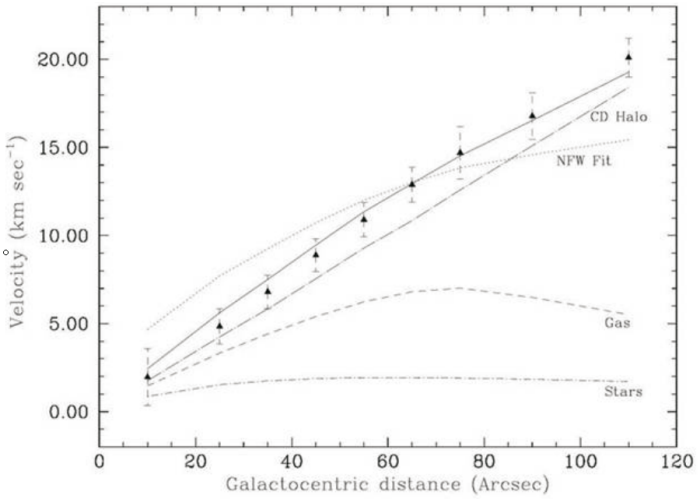
Extragalactic Astronomy, Intergalactic Medium and Cosmology

Nearby Galaxies

To understand relationships between gas inflow processes and circumnuclear star formation, the grand-design spiral NGC6951 was studied at radio wavelengths. These observations reveal a circumnuclear ring, consisting of discrete components which are possibly a mixture of both supernova remnants and HII regions. The estimated supernova rate is ~0.07 yr^{-1}. The lower-resolution radio image shows two peaks. The published CO(1-0) emission shows a twin-peak morphology which could be due to orbit crowding near the outer ILR. The HCN observations of Kohno et al. also show this dense gas to have twin peaks, but these are offset from the CO peaks and appear to be closely related to the radio peaks, which are identified with the regions of massive star formation [Saikia et al., 2002].

Radio continuum observations of the edge-on spiral galaxy NGC 5775 at 617 MHz with GMRT and at 850 μm with the Sub-millimetre Common-User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope (JCMT) have been made. These observations have shown the existence of dust at high latitudes, extending to about 5 kpc from the disc of the galaxy, and spurs of non-thermal radio emission. The 617 MHz and 850 μm distributions are compared with one another and a strong correlation has been found between metre wavelength radio emission and sub-millimetre emission in the disc and at high latitudes. This suggests that there may be a more fundamental relationship between cold dust and synchrotron radiation other than the link via star formation [Brar, Irwin and Saikia, 2003].

GMRT data at a couple of frequencies towards two galaxies UGC4961 and UGC11909 were



Mass models for Camelopardalis B obtained using GMRT observations. Camelopardalis B is the faintest galaxy for which such a model has been applied. The points are the observationally derived rotation curve. The total mass of gaseous disk (dashed line) is 6.6×10^6 M .The stellar disk (short dash dot line) has a stellar mass of 0.7×10^6 M . The best fit total rotation curve for the constant density halo model is shown as a solid line, while the contribution of the halo itself is shown as a long dash dot line (the halo density is 13.7×10^{-3} M /pc^{-3}). The best fit total rotation curve for an NFW type halo (for c=1.0) and is shown as a dotted line. The data clearly favour a constant density halo over the theoretically predicted NFW type halo.

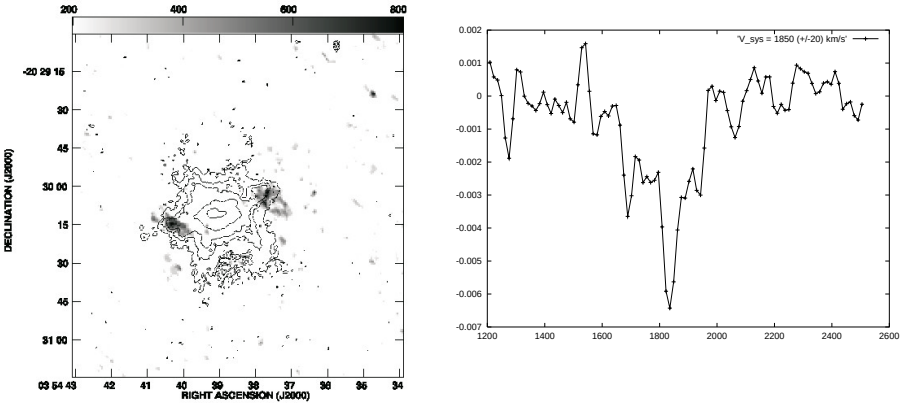
analyzed. A bridge of emission connecting a small group of galaxies near UGC4961 earlier seen at 1465 MHz was clearly detected at 325 MHz. [Ananthakrishnan, et al., 2004].

Deep, high velocity resolution (~ 1.6 km/ sec) Giant Meterwave Radio Telescope HI 21cm synthesis images were obtained, as well as optical broad band images, for the faint (M_B ≅ 10.9) dwarf irregular galaxy Camelopardalis B. It is found that the HI in the galaxy has a regular velocity field, consistent with rotational motion. Further, the implied kinematical major axis is well aligned with the major axis of both the HI flux distribution as well as that of the optical emission. Camelopardalis B is the faintest known galaxy with such relatively well behaved kinematics. From the HI velocity field a rotation curve for the galaxy is derived. The rotation curve can be measured out to galactocentric distances > 4 times the optical scale length. The peak (inclination corrected) rotation velocity vo was only ~ 7 km/sec — the high velocity resolution of our observations was hence critical to measuring the rotation curve. Further, the peak rotational velocity was comparable to the random velocity vr of the gas, i.e. v_o/v_r ~ 1. This made it crucial to correct the observed rotation velocities for random motions before trying to use the kinematics to construct mass models for the galaxy. After applying this correction a corrected peak rotation velocity of ~ 20 km/sec was found. On fitting mass models to the corrected rotation curve a good fit for a constant density halo with a density of ρ_0 ~ 12 M /pc3 was obtained. This density is well determined, i.e. it has a very weak dependence on the assumed mass to light ratio of the stellar disk. It was also found that the corrected rotation curve cannot be fit with an NFW halo regardless of the assumed mass to light ratio [Begum, et al., 2003].

GMRT observations at three frequencies (326, 615 and 1281 MHz) of the radio lobe spiral galaxy, NGC 3079 have been presented. These observations are consistent with previous data obtained at other telescopes and reveal the structure of the nuclear radio lobes in exquisite detail. In addition, new features are observed, some with HI counterparts, showing broad scale radio continuum emission and extensions. The galaxy is surrounded by a radio halo that is at least 4.8 kpc in height. Two giant radio extensions/loops are seen on either side of the galaxy out to ~11 kpc from the major axis, only slightly offset from the direction of the smaller nuclear radio lobes. If these are associated with the nuclear outflow, then the galaxy has experienced episodic nuclear activity. Emission along the southern major axis suggests motion through a local IGM (not yet detected) and it may be that NGC 3079 is itself creating this local intergalactic gas via outflows. Maps of the minimum energy parameters for this galaxy, including cosmic ray energy density, electron diffusion length, magnetic field strength, particle lifetime, and power are also presented [Irwin and Saikia, 2003a].

Synthesis maps of HI of the edge-on starburst NGC 5433 and its environment have been obtained with the VLA in its C and D configurations. The observations and spectral model residuals of the main disc emission in NGC 5433 reveal 3 extraplanar features. Two of these features are associated with coherent extraplanar extensions across multiple spectral channels in the data, including a complete loop in position-velocity space. Interpreting the latter as an expanding shell a corresponding input energy of 2×10^{54} ergs are derived, comparable to that for the largest supershells found in the Galaxy

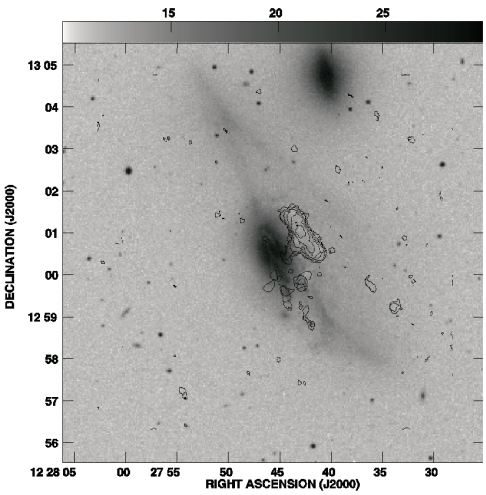
and those in other edge-on systems. NGC 5433 is in a richer environment than previously thought. It is confirmed that KUG 1359+326 is a physical companion to NGC 5433 and find two new faint companions, both with Minnesota Automated Plate Scanner identifications, SIS-1 and SIS-2. Including the more distant IC 4357, NGC 5433 is the dominant member of a group of at least 5 galaxies, spanning over 750 kpc in a filamentary structure. A variety of evidence suggests that interactions are occurring in this group. While a number of underlying mechanisms are consistent with the morphology of the high-latitude features in NGC 5433, it is argued that environmental effects may play a role in their generation [Spekkens, Irwin, and Saikia, 2004].



Left panel: H I total-intensity shown in grey with an angular resolution of 6.95×5.17 arcsec along PA of 34° superimposed on an optical H image. Right panel: The H I absorption spectrum towards the central continuum source with an angular resolution of 2.96×2.01 arcsec along PA of 25°. The heliocentric radial velocities are shown. The optical heliocentric systemic velocity of 1850±20 km s^{-1}.

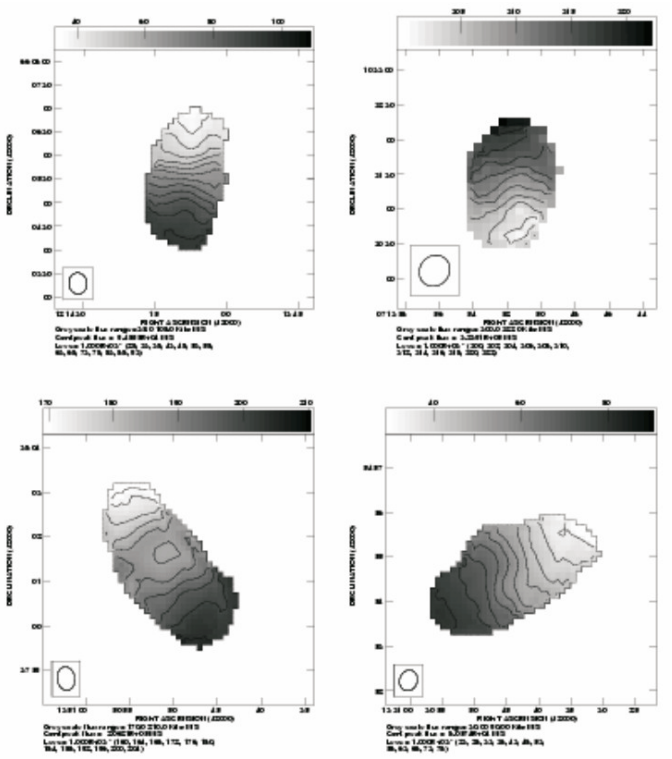
A multi-frequency radio continuum as well as HI study of the superwind galaxy NGC1482 with both the GMRT and the VLA has been made. This galaxy has a remarkable hourglass-shaped optical emission line outflow as well as bi-polar soft X-rays bubbles on opposite sides of the galactic disk. The low-frequency, lower-resolution radio observations show a smooth structure, while the high-frequency, high-resolution radio images of the central starburst region which is at the base of the superwind bi-cone shows one prominent peak of emission, possibly associated with the centre of the galaxy, and more extended emission. The HI observations with the GMRT show two blobs of emission on opposite sides of the central region, located at ~2 kpc from the centre and rotating about it. In addition, these observations also reveal a multi-component HI-absorption profile against the central region of the radio source. The absorption profile shows kinematics effects of the starburst on the cool HI gas [Hota and Saikia, 2005].

The barred spiral galaxy NGC6764 with an active nucleus and a starburst in the nuclear region and a multi-phase superwind, has been studied in radio continuum as well as HI using both the GMRT and the VLA. The HI emission appears depleted in the nuclear region, possibly due to ionization by the central starburst. HI emission is seen in both ends of the stellar-bar, close to the regions of enhanced H emission. The high resolution 8 and 5 GHz VLA A-array images shows somewhat conical-shaped regions of radio-emitting plasma along the major axis on both sides of the nucleus while the 1.4 GHz VLA A-array image also shows radio-emitting bubbles along the minor axis of this galaxy. H emitting gas with filamentary structures and X-ray emitting hot gas appear to be related to the radio bubbles [Hota, Saikia and Irwin, 2005].



The GMRT total-intensity HI contour-map of NGC4438 superimposed on the DSS blue-band image

NGC4438: This Virgo cluster galaxy has a distorted morphology due to its interaction with a companion. The radio continuum and HI observations have been made with the GMRT. The radio continuum observations show the central emission as well as the faint diffuse emission to the west of the thin stellar disk. The HI-observations with the GMRT show an elongated structure in HI-emission residing on the same western side and nearly 5 kpc away from the main disk and roughly parallal to the nearly edge on stellar disk. The mass of this elongated structure is nearly 200 million solar mass. Diffuse emission on the western side has also been seen in



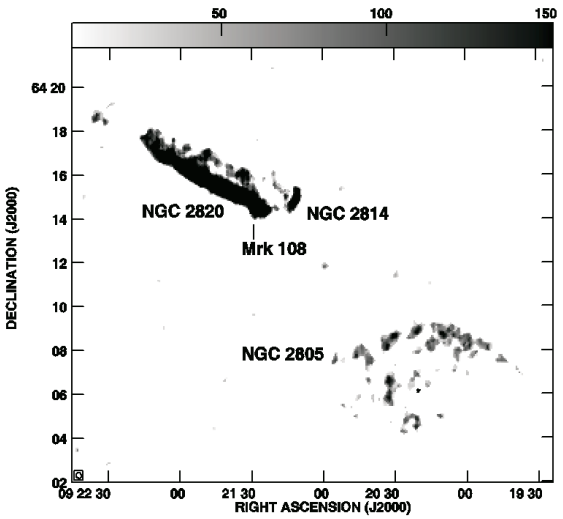
Velocity field of some faint dwarf irregular galaxies observed in HI emission with the GMRT

H_alpha and soft X-ray emission. Most plausible interpretation of these features is ram pressure stripping by the cluster medium. [Hota, Saikia, Irwin, 2005].

Deep, high velocity resolution GMRT HI 21cm synthesis images of two faint dwarf galaxies DDO210 and GR8 were obtained. For both galaxies, the velocity field is quite regular. DD0210's velocity field is consistent with rotational motion and the derived rotation curve has a peak rotation velocity of only ~8 km sec^{-1}, comparable to the random motions in the HI gas. After correcting for the dynamical support provided by random motion (the "asymmetric drift" correction), it is found that the corrected peak rotation velocity is ~16.0 km sec^{-1}. Mass modeling shows that the kinematics of DDO210 can be well fit with either a modified isothermal or an NFW halo (although in the case of an NFW halo the fit parameters are differ considerably from those expected from numerical simulations). For GR8 it is found that neither pure rotation, nor pure radial motion alone can fit the observed velocity field; however a combination of radial and circular motions can provide a reasonable fit. The most natural interpretation is that the neutral ISM, in addition to rotating about the center, is also expanding outwards, as a result of energy input from the ongoing star formation in the galaxy. Support for this interpretation comes from the fact that the pressure in the HII regions in the galaxy is known to be substantially (~55 times) more than the average pressure in the gas disk. Several theoretical models also predict expulsion of the ISM in dwarf galaxies due to energy input from star formation [Begum and Chengalur, 2003b].

GMRT 21 cm images of a nearby dwarf irregular galaxy NGC3741 (MB~-13.13) have been obtained. These show it to have a gas disk that extends to ~8.3 times its Holmberg radius. This makes it probably the most extended gas disk known. Rotation curve of this galaxy has been derived. NGC3741 has a dynamical mass to light ratio of ~107 and is one of the darkest irregular galaxies know. [Begum, Chengalur and Karachentsev, 2005a].

Tidal interaction or Ram pressure in Ho 124: Analysis of multi-frequency GMRT radio and HI 21 cm observations of the poor group of four galaxies called Holmberg 124 have yielded interesting results. Various tidal features like a steep spectrum radio continuum bridge, a streamer, a tail were detected in the four members of the group. Moreover, we detect several features like a large HI loop to the north of NGC 2820 (see Figure) with no ionized counterpart, a smooth boundary to HI distribution in NGC 2820 and NGC 2814 and enhanced star formation in NGC 2805 which we propose are likely due to the effect of ram pressure of the intra-group medium on the interstellar medium of the galaxies. We thus suggest that this group of late type galaxies has been subjected to both tidal interaction and ram pressure due to the motion of the member galaxies in an intra-group medium [Kantharia,



HI emission from the poor group Holmberg 124. Note the smooth boundary to the south of NGC 2820 and the large HI loop to its north. Also note the sharp cutoff to the north of NC 2814.

et al. 2005b].

Radio Galaxies, Quasars

Compact steep-spectrum (CSS) radio sources are believed to be young sources which evolve into the standard double-lobed radio sources. The CSS sources were proposed to evolve in an environment which is dense and highly asymmetric on opposite sides of the nucleus possibly due to the infalling clouds of gas. This has also been seen in new sample of radio sources selected from the S4 survey at 5 GHz [Saikia et al. 2003a].

To investigate the evolution of asymmetry of CSSs, a sample of weak B2 radio sources have been observed. A comparison of their flux density asymmetry with a sample of B3 sources and the 3CR sample show that about 25 per cent of the CSS objects are highly asymmetric compared to only about 5 per cent for the larger sources. The inferred sizes of the clouds with which the jets could be interacting are about 3 to 10 kpc, which is typical of dwarf galaxies [Saikia et al., 2002b].

A sample of CSS objects is also being studied with the Very Long Baseline Array (VLBA) to determine their rotation measures and probe the physical conditions in the nuclear regions of these young radio sources. The results on two of these sources, 0548+165 and 1524-136, show a rotation measure of ~104 rad m^{-2} and highly distorted structures suggestive of interaction of the radio jets with a dense external environment. [Mantovani et al., 2003a].

Polarization observations of a sample of CSS sources have been presented and these have been combined with information available in the literature, to show that CSS sources are more asymmetric in the polarization of the outer lobes compared with the more extended ones. This could be possibly due to interaction of the jets with infalling material, which fuels the radio source. A possible dependence of the polarization asymmetry of the lobes on redshift has also been investigated, since this might be affected by more interactions and mergers in the past. No such dependence is found for the CSS sources, suggesting that the environments on the CSS scales are similar at different redshifts. However, the polarization asymmetry of the oppositely-directed lobes is larger at higher redshifts for the more extended sources, possibly reflecting the higher incidence of interactions in the past [Saikia and Gupta, 2003b].

The role of radio polarimetric observations in understanding the nature and evolution of CSS and GPS sources has been explored and reviewed. The principal conclusions include: (i) the GPS objects do not appear to be a single homogeneous class of objects; (ii) Faraday depth effects are very strong in the inner 3 kpc of GPS and CSS objects; (iii) there is evidence of increased ionization near bends in some CSS objects probably due to jet-ISM interaction [Cotton, et al., 2003a].

Radio observations of the CSS QSOs 3C43 and 3C454 have been made with the VLA, MERLIN and VLBA at 2, 6 and 18 cm to examine the Faraday rotation in these highly bent sources. 3C43 is weakly polarized at 18cm at mas resolution and has a large rotation measure near the bend in the jet. This result is interpreted as indicating jet-ISM interaction. 3C454 is relatively strongly polarised and has high rotation measure along the jet visible in the high-resolution 18cm images. There is no brightening of the jet near the bend to the west indicating that it is not caused by a jet-cloud collision, and may simply be a hydrodynamic instability magnified by a small angle to the line of sight. However, there are clear differences in the sign and magnitude of the Faraday rotation measured at long and short wavelengths. This is interpreted as being due to thermal plasma mixed with the jet. Likely detection of circular polarization at 18cm supports this interpretation [Cotton, et al. 2003b].

Multifrequency radio observations of the radio galaxy 3C459 using MERLIN, VLA and the EVN, and an optical HST image using the F702W filter have been presented. The galaxy has a very asymmetric radio structure, a high infrared luminosity and a young stellar population. The eastern component of the double-lobed structure is brighter, much closer to the nucleus and is significantly less polarized than the western one. This is consistent with the jet on the eastern side interacting with dense gas, which could be due to a merged companion or dense cloud of gas. The HST image of the galaxy presented here exhibits filamentary structures, and is compared with the MERLIN 5-

GHz radio map. EVN observations of the prominent central component, which has a steep radio spectrum, show a strongly curved structure suggesting a bent or helical radio jet. The radio structure of 3C459 is compared with other highly asymmetric, Fanaroff-Riley II radio sources, which are also good candidates for studying jet-cloud interactions. Such sources are usually of small linear size and it is possible that the jets are interacting with clouds of infalling gas which are fuelling the radio source [Thomasson, Saikia and Muxlow, 2003].

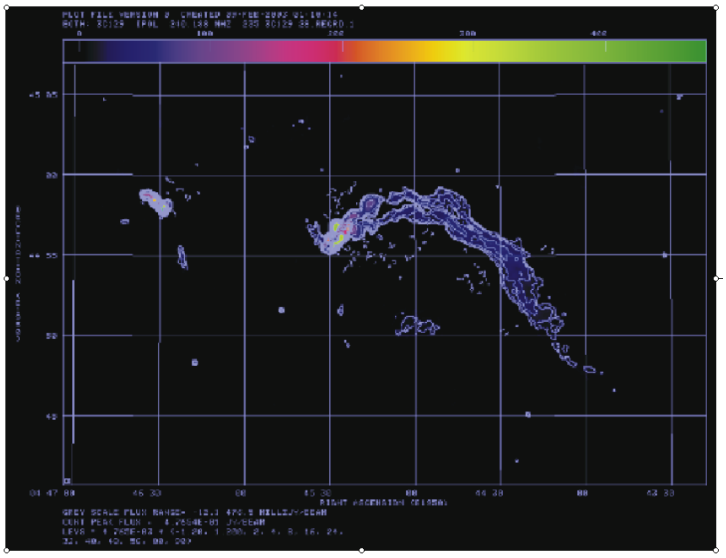
As CSSs have been shown to be more asymmetrical than larger sources of similar powers, there is a high probability that they interact with an asymmetric medium in the central regions of the host elliptical galaxy. A simple analytical model of the propagation of radio jets through a reasonable asymmetric environment has been considered and shown that they can yield the range of arm-length and luminosity asymmetries that have been observed. This has been generalized to allow for the effects of orientation, and quantify the substantial enhancements of the asymmetries that can be produced in this fashion. Two-dimensional and three-dimensional simulations of jets propagating through multi-phase media have been presented and shown that the results from the simulations are also broadly consistent with the observations [Jeyakumar et al., 2005].

MERLIN, global VLBI and VLBA observations have been reported of the high-luminosity, compact steep-spectrum quasar B1524-136 at cm wavelengths. These observations reveal well-defined radio jets on both sides of the active nucleus, a situation which is almost unique amongst high-luminosity radio quasars. However, the radio jets on opposite sides are very dissimilar, and the overall radio structure appears highly distorted. A possible scenario for explaining these observations and its implications have been explored [Mantovani, F., et al., 2003a].

Low-frequency GMRT observations at 333 and 617 MHz of the most-distant giant quasar J1432+158, which is at a redshift of 1.005, have been presented. The radio source has a total angular extent of 168 arcsec, corresponding to a projected linear size of 1.35 Mpc. This makes it presently the largest single object observed beyond a redshift of one. The objectives of the GMRT observations were to investigate the possibility of detecting a bridge of emission at low frequencies, which may be suppressed due to inverse-Compton losses against the cosmic microwave background radiation. A jet-like structure has been detected connecting the core to the western hotspot, while the eastern hotspot is found to be largely tail-less with no significant bridge emission. The estimated life-time for the radiating electrons in the tail of the western lobe appears smaller than the travel time of the radiating particles from the hotspot, suggesting either in-situ acceleration or dissipation of energy by the jet at this location. The pressure of the intergalactic medium at z~1 estimated from the minimum energy density calculations appears to be marginally lower than the value extrapolated from nearby giant radio galaxies [Singal, et al. 2004].

Multi-frequency observations with the GMRT and the VLA of a sample of seventeen largely giant radio sources (GRSs) have been presented. These observations have either helped clarify the radio structures or provided new information at a different frequency. The broad line radio galaxy, J0313+413, has an asymmetric, curved radio jet and a variable radio core, consistent with a moderate angle of inclination to the line of sight. The lobes of emission in J0139+399 and J0200+408 may be due to an earlier cycle of nuclear activity. Inverse-Compton losses with the cosmic microwave background radiation dominate over synchrotron radiative losses in the lobes of all the sources, consistent with earlier studies. The prominence of the bridge emission decreases with redshift, possibly due to inverse-Compton losses. This could affect the appearance and identification of GRSs at large redshifts [Konar, et al., 2004].

Head-tail radio sources, which are almost always associated with clusters of galaxies, are characterised by a highly elongated radio structure with the associated optical (usually giant elliptical) galaxy at one end. A classical example of this class is 3C 129 which, along with its companion 3C 129.1 (a wide-angle-tail), is a member of the X-ray cluster 4U 0446+44 (z=0.021) that happens to lie in the galactic plane. A variety of models have been proposed to explain the morphology and spectral index distribution of the head-tail sources and 3C 129. The main result is that the radio

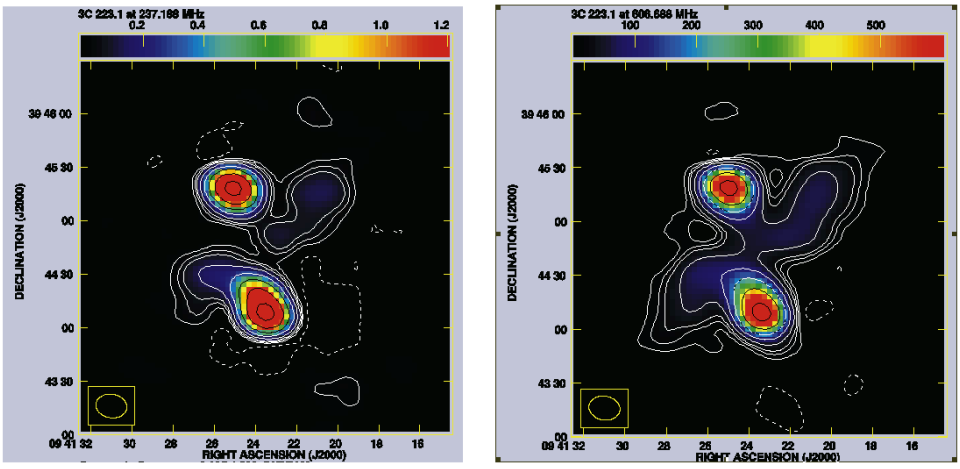


spectrum has been found to steepen with distance along the tail of 3C 129, and has been interpreted in terms of ageing of electron population. The radio map of 3C129 (Lal and Rao) using GMRT is presented alongside. The morphology of the source and the distribution of spectral index over the object have been studied in detail. Large-scale spectral steepening is found along the jet away from the core. Using synchrotron spectral ageing theory, the age (time since particle acceleration) of electrons at various locations along the jet is inferred to be ~200 Myr to 3C 129. It is also found that the "Crosspiece" has a spectral index of ~-1, similar to the jet, which is not consistent with the suggestion by Lane et al. (2002) that it could be a radio relic [Lal and Rao, 2004a].

X-shaped radio sources

A class of radio sources, "winged" or "X-type" are characterised by two low-surface-brightness lobes (the "wings") oriented at an angle to the "active", or high-surface-brightness radio lobes, giving the total source an 'X' shape; both sets of lobes pass symmetrically through the centre of the associated elliptical galaxy. The existence of such sources was recognized almost three decades ago. Many authors have attempted to explain the unusual structure in X-shaped sources; first attempt suggested that the jet direction processes due to a realignment caused by the accretion of gas with respect to the central BH axis. All the models known currently, can be grouped into the following four formation scenarios: (A) backflow from the active lobes into the wings, (B) slow, conical precession of the jet axis, (C) reorientation of the jet axis during which the flow continues, and (D) as model (C), but with the jet turned off or at greatly reduced power during the change of direction. Another recent model identifies the winged or X-type radio sources to be the candidates where super-massive BH are produced by galactic mergers. We have mapped the sample of such X-shaped sources with the GMRT with an aim to study radio morphology and spectral index gradients in the X-shaped sources. The radio map of X-shaped source, 3C 223.1 at 240 and 610 MHz using GMRT is shown alongside. These observations provide for the first time high sensitivity radio images of them [Lal and Rao, 2004, 2005].

A Z-symmetric distortion was detected in the rare class of radio galaxies whose X-shaped radio lobes are suspected to result from the coalescence of two super-massive black holes (SMBH) situated at the nuclei of two large galaxies prior to their merger. This results in the spin-flip of the radio jet producing SMBH, accompanied by the emission of gravitational radiation. The newly found Z-symmetry of the older radio lobe pair is a tracer of the orbital rotation of the infalling SMBH, prior to the merger. This finding goes to support the SMBH merger model for the X-shaped radio galaxies and, at the same time, considerably diminishes the appeal of the otherwise attractive alternative model that invokes a diversion of the back flowing plasma in the radio lobes [Gopal-Krishna et al., 2003a].



Giant radio sources: A detailed spectral ageing analysis for the giant radio sources, J0912+3510, has been done using observations at 330 and 600 MHz with the GMRT and at 4860 MHz using the VLA. Using the SYNAGE software developed by M. Murgia, the injection spectra have been estimated to be 0.56 and 0.63 for the northern and southern lobes respectively. There appears to be some evidence of a decrease in the spectral age with increasing separation from the hotspots before appearing to increase as it approaches closer to the core. This decrease is possibly due to in situ acceleration near the hotspot regions. The maximum age detected is about 30 Myr and the mean velocity is estimated to be ~0.1c [Konar et al., 2005].

It was argued that the maximum attainable brightness temperature of the superluminal radio knots of quasars may be considerably suppressed due to the low energy cut-off in the relativistic electron population, which is found to occur near 0.1 GeV in some well known particle acceleration models. This could explain the faster superluminal motion found in the VLBI surveys at higher frequencies, as well the apparent inability of most radio cores to even attain the brightness temperatures consistent with the equipartition condition. This mechanism may also play a significant role in causing X-ray variability of the kiloparsec-scale relativistic jets, and influence their detectability at higher redshifts, in spite of a much stronger cosmic microwave background [Gopal-Krishna et al., 2004a].

A theoretical framework has been proposed for quasar jets, incorporating a pair plasma flow convecting Poynting flux. Conditions for the formation, stable propagation and termination of such ExB drift jets are examined and it is inferred that they are likely to be extremely relativistic mono-energetic pair-plasma jets. Observational evidence and some observational implications of this model are pointed out in the context of AGN and the evolved/young stellar systems in our galaxy [Kundt and Gopal-Krishna, 2004].

A strong associated HI absorption line has been observed with the GMRT in 3C268.3 which is a Compact Steep Spectrum (CSS) Radio Galaxy. The optical depth of the peak absorption feature is about 0.13 and its redshift is 0.371. This feature is redshifted with respect to the [0III] emission line of the optical galaxy by about 500 km/s and seems to indicate that HI absorption arises due to an in falling gas cloud [Swarup and Sarkar, 2002].

In a study undertaken to assess the possible role of radio galaxies in the global star-formation peak in the young universe (in the aftermath of the so called `quasar era' at z ~ 2.5), latest models for the temporal and cosmological evolution of radio galaxies were considered. It was thus argued that during the quasar era the cosmic filaments containing most galaxies, clusters and baryonic material were probably permeated by lobes of radio galaxies. This idea has far-reaching implications for the basic issues of galaxy formation and the magnetization of galaxies and clusters of galaxies in the young universe. This proposal, which is a radical revision of the hitherto prevailing view, provides a unifying conceptual link between the cosmological evolutions of the normal galaxy population and the radio galaxy population [Gopal-Krishna et al., 2003b]

The long-term observational programme of studying comparative intra-night optical variability of different AGN classes, using the 1 metre telescope at Naini Tal, is concluded. Under this programme, a total of 26 AGNs matched in luminosity-redshift plane and representing blazars, radio-loud and radio-quiet quasars were monitored in the R-band for a minimum of 3 nights per object and each time for a continuous stretch of 5 to 8 hours. A total of 100 nights were devoted to this monitoring programme during 1999-2002 and a variability detection threshold of order of 1% was typically achieved using the CCD as a N-star photometer. Intra-night micro-variabilty was detected in all the above AGN classes and a detailed comparison for the different AGN classes is presented based on this high precision database [Stalin, et al, 2004].

The extra-ordinarily dense temporal sampling and high sensitivity attained in this program have led to a number of new results of direct relevance to the theories of the 'Central engine' of AGN. Firstly, it could be convincingly demonstrated for the first time that, like blazars, radio-quiet quasars (RQQs) also exhibit intra-night optical variation on hour-like time scale, albeit the variations are several times less pronounced both in amplitude (upto 3%) and duty cycle (~15%). The clear detection of

rapid optical variability of RQQs provides a strong clue that the central engines of RQQs are also capable of ejecting powerful relativistic jets of synchrotron plasma, but these jets are probably 'snuffed out' due to severe inverse-Compton losses while traversing out to parsec scale where they can become transparent to their radio emission. Thus, the oft-postulated `fundamental difference' between the central engines of radio-loud and radio-quiet quasars is NOT supported. It is further shown that the intranight variability of RQQs is much less pronounced simply because of the expected modest misalignment of their jets from the line-of-sight. It is also established for the first time that similarly mild intra-night variability and small duty cycle characterize the radio-loud quasars (excepting blazars) and therefore radio-loudness is far from being a sufficient condition for rapid optical variability, even for radio core-dominated quasars. Instead, optical polarization is shown to be the main factor. [Stalin, et al., 2004].

The GMRT was used to map HI 21cm emission from the lowest redshift (z = 0.009) damped Lyman- absorber (DLA), towards the quasar HS 1543+5921. The extremely low redshift of the absorber made it possible to make, for the first time, spatially resolved images of the 21cm emission; besides the HI mass, this also enabled a determination of the velocity field of the galaxy and, hence, an estimate of its dynamical mass. A total HI mass of ~ 1.4×10^9 $M_\odot$ was obtained, considerably smaller than the value of MHI* determined from blind 21cm emission surveys. This continues the trend of low HI mass in all low redshift DLAs for which HI emission observations have been attempted. The QSO is found to lie behind a region of low local HI column density in the foreground galaxy. This is interesting in view of suggestions that DLA samples are biased against high HI column density systems. Finally, the dynamical mass of the galaxy was found to be Mdyn = 5×10^9 $M_\odot$. [Chengalur and Kanekar, 2002]

The GMRT was used to detect redshifted 21-cm absorption from the z=0.437 metal line absorption system towards PKS 1243-072. Detection of 21-cm absorption indicates that the absorber has an HI column density large enough to be classified as a damped Lyman- system. Follow up ground based optical imaging and spectroscopy allowed the identification of the absorber with an L ~ L_* galaxy at an impact parameter of ~9.8 kpc from the line of sight to the QSO. The absorbing galaxy is extremely unusual in that it has bright emission lines. It is presently not possible to uniquely classify the galaxy since its emission line ratios lie in the transition region between starburst and Seyfert II type spectra [Kanekar, et al., 2002].

GMRT was used to search for OH in absorption in three intermediate redshift molecular absorbers, B3 1504+377 (z ~ 0.673), B 0218+357 (z = 0.685) and PKS 1413+135 (z ~ 0.247). The 1665 and 1667 MHz lines were detected in all three absorbers, all of which also give rise to well studied millimeter wavelength molecular line absorption from a host of molecules, including HCO^+. A comparison of the OH data with these millimetre line transitions showed that the linear correlation between NOH and N_{HCO}+ found in molecular clouds in the Milky Way persists out to z ~ 1. It has been earlier suggested that OH is a good tracer of H_2, with $N_{H_2} / N_{OH} \approx 10^7$ under a variety of physical conditions. This relationship was used to estimate N_{H_2} in these absorbers. The estimated N_{H_2} is $\geq 10^{22}$ in all four cases and substantially different from estimates based on CO observations. The new estimates also allow the explanation of some hitherto puzzling earlier results on the three absorption systems [Kanekar, N., et al. 2003].

Deep GMRT 21cm absorption spectra of 10 damped Lyman-alpha systems (DLAs), of which 8 are at redshifts z > 1.3 were obtained. HI absorption was detected in only one DLA, the z = 0.5318 absorber toward PKS1629+12. This absorber has been identified with a luminous spiral galaxy; the spin temperature limit (Ts < 310K) derived from these observations continued the trend of DLAs associated with bright spirals having low spin temperatures. In seven of the remaining 9 systems, the observations placed strong lower limits on the spin temperature of the HI gas. This sample was combined with data taken from the literature to study the properties of all known DLAs with 21cm absorption studies. This sample of 31 DLAs have Ts estimates available in 24 cases; of these, 16 are at z < 2 and 8 at z > 2, with 11 (all at z < 1) having optical identifications. For the latter 11

DLAs, it is found that all of the low Ts DLAs have been identified with large, luminous galaxies, while all the DLAs with high spin temperature (Ts > 1000K) have been identified either with LSBs or dwarfs. Further, no correlation was found between impact parameter and spin temperature; it is thus unlikely that the high measured Ts values for DLAs arise from lines of sight passing through the outskirts of large disk galaxies. Instead, the spin temperature of DLAs appears to correlate with the host galaxy type. The trend (noted earlier by Chengalur & Kanekar 2000) that low z DLAs exhibit both high and low Ts values while high redshift (z > 3) DLAs only show high spin temperatures is present in this expanded data set. Based on this difference in spin temperatures, the Gehan test rules out the hypothesis that DLAs at z > 2 and DLAs at z < 2 are drawn from the same parent population at 99% confidence level. Finally, the new GMRT spectra was used along with 2 spectra from the literature to estimate upper limits on the fraction of cold HI, f_{CNM}, in DLAs at z ≈ 3. For local spirals, f_{CNM} ~ 0.5; in contrast, it is found that f_{CNM} < 0.3 in all 7 high z absorbers, and f_{CNM} < 0.1 in 5 of the 7 cases [Kanekar & Chengalur, 2003b].

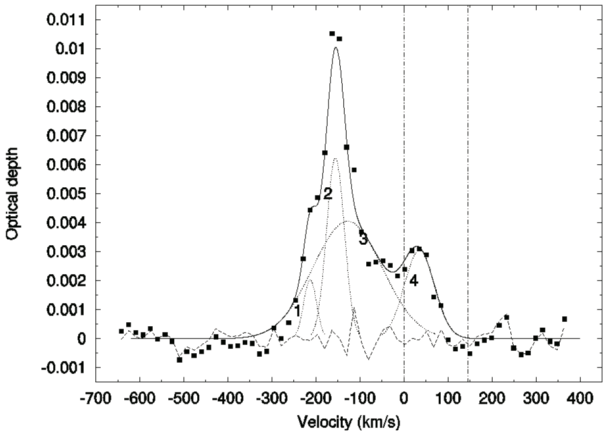
A new technique to estimate variations in the fundamental constants using observations of the 18cm OH absorption lines was devised. In conjunction with observations of one additional transition (for example, an HCO+ line), it is possible to simultaneously measure changes in α, g_p and y defined as m_e/m_p. The existing observations of these line redshifts were used in conjunction with GMRT observations of the OH 18 cm main lines in a gravitational lens at z~0.68 to constrain changes in the above three parameters over the redshift range 0 < z < 0.68 [Chengalur and Kanekar, 2003b].

A deep search for HI 21cm emission from the z=0.00632 sub-DLA toward PG1216+069 with the Giant Metrewave Radio Telescope is reported. No emission was detected and the 5σ upper limit on the mass of any associated galaxy is $M_{HI} \approx 10^7 M_\odot$ nearly 3 orders of magnitude less than M_{HI}^*. The z~0.006 absorber is thus the most extreme known deviation from the standard paradigm in which high column density quasar absorption lines arise in the disks of gas-rich galaxies [Kanekar, et al., 2005].

HI 21 cm-line absorption in red quasars: The study of redshifted HI 21 cm-line absorption at high-redshifts would provide interesting and important information regarding the distribution and kinematics of neutral hydrogen. A program has been started to search for HI 21 cm-line absorption in a sample of high-redshift (z > 1) radio loud 'red' quasars and galaxies with the Giant Metrewave Radio Telescope. HI 21 cm-line absorption has been detected in one of the red quasar 3C 190 at a redshift of 1.1946 (see figure). The absorption is broad and complex and most of the absorption is blue-shifted with respect to the systemic velocity. The core of 3C 190 is self-absorbed at this frequency, therefore the absorption is towards the hotspots. Comparison of the radio and deep optical images reveal linear filaments in optical, overlapping with the south-west radio jet. The blue-shifted HI absorption appears to be due to the gas shocked by the advance of the south-west jet [Ishwara-Chandra, and Dwarakanath, 2003].

Compact Steep Spectrum (CSS) sources are a subclass of FRII radio sources having both linear sizes of less than 20 kpc and steep high frequency radio spectra. Observational evidence implies that these objects are young, and asymmetrically distributed gas is found close to their nuclei. Previous investigations have shown a high incidence of HI absorption from within their host galaxies against the CSS continuum emission. Implied HI column densities are of the order of 10^{20} cm^{-2}. A few CSSs have also been detected in CO and these objects offer the potential for investigating atomic and molecular gas at intermediate and high redshifts. In a search for HI absorption and OH emission or absorption against a sample of CSS and larger sources using both the GMRT and the the Arecibo 305-m telescope, there has been one new detection of a complex multi-component HI absorption system towards the radio source 3C258, and new or improved upper limits for the other sources. The astrophysical implications of the results are being explored [Gupta et al. 2005].

High-resolution radio observations of a sample of 65 radio sources at low Galactic latitudes have been presented. The sources were all observed at 5 GHz with the VLA A-array. MERLIN observations at 5 GHz of the ultracompact HII region G34.26 + 0.15 and one of the extragalactic sources, B1857-



000, have also been presented, as well as GMRT observations of HI in the direction of three sources, B1801-203, B1802-196 and B1938+229. These observations were made with the objectives of (i) finding compact components suitable for studying the effects of interstellar scattering at lower frequencies, (ii) identifying high surface-brightness lobes of background radio sources to probe the Galactic magnetic field on different scales via polarization observations, and (iii) searching for young supernova remnants. The nature of the sources found to have shell or shell-like structure and exhibiting both thermal and non-thermal spectra have been discussed. Of the remaining sources, B1749-281 is coincident within the positional errors of a known pulsar, not detected earlier at 5 GHz. The rest are likely to be background extragalactic objects. [Saikia et al., 2004].

X-ray binaries are the brightest X-ray sources in the sky, and exhibit a wide variety of phenomena like rapid variability and outbursts. A small fraction of the X-ray binaries also show strong radio emission. The basic phenomena of radio emission from X-ray binaries are similar to that of quasars, both in morphology and physics; hence these are known as microquasars. The microquasar GRS1915+105 has been observed at low radio frequencies, viz, 610 and 235 MHz in June 2003. Analysis shows that GRS1915+105 is brighter at these frequencies than expected from naive application of synchrotron self-absorption model for compact jets [Ishwara-Chandra et al., 2005].

High spectral resolution Australia Telescope Compact Array HI 21cm observations were obtained towards two extragalactic radio sources. The two lines of sight were selected on the basis of the simplicity of their absorption profiles and the strength of the background sources; the high velocity resolution of the spectra then enabled us to estimate the kinetic temperatures of the absorbing gas by fitting multiple Gaussians to the absorption profiles. Four separate components were detected toward the two sources, with estimated kinetic temperatures of T_k = 3127±300 K, 3694±1595 K, 3500±1354 K and 2165±608 K respectively. All four components were thus found to have temperatures in the thermally unstable range 500 < T_k < 5000 K; this suggests that thermal equilibrium has not been reached throughout the WNM [Chengalur, et al., 2003c].

GMRT HI data from the redshifted system 0902+34 in the 325 MHz band was analysed. A deep narrow component is detected but no broad component, reported earlier by others, is detected. No emission feature, reported by others, is detected to the north of the above object. Thus, only a narrow HI feature is associated with the system [Chandra, P., et al. 2004].

Outflowing material in the CSS quasar 3C48: The detection of a zabs=0.3654 associated, absorption-line system in the ultraviolet spectrum of the CSS quasar 3C48 has been reported. The absorbing material is blueshifted with respect to the quasar emission-line redshift, zem=0.370, suggesting an outflow velocity of ~1000 km s^{-1}. Absorption lines have been detected over a range of ionization states from Lyβ, Lyγ, CIV, NIV, SIV to OIV and possibly NeVIII. The kinematical properties of the absorption-line system are similar to the blue-shifted emission line gas seen in [OIII]λ5007, which is believed to have interacted with the radio jet. The properties of the absorbing material have been studied using CLOUDY and it has been found that photoionization models with the Solar abundance ratios (with overall metallicity in the range $0.1 \leq Z / Z_{\odot} \leq 1.3$) are enough to explain the observed column densities of all the species except Ne VIII, detection of which requires confirmation. Because the cooling and recombination time for the gas is ~10^5 yr, the consistency with the photoionization models suggests that the jet-cloud interaction with the absorbing material must have taken place before ~10^5 yr. The abundance ratio of nitrogen to carbon is close to Solar values, unlike in the case of most quasars, especially at high redshifts, which have super-Solar values. 3C48 has been observed several times with the GMRT to search for redshifted 21cm H I absorption. However, no significant feature has been detected; the 3 upper limit to the optical depth has been

estimated to be 0.001-0.003. However, due to the diffuse nature of the radio source optical depths as high as 0.1 towards individual knots or compact components cannot be ruled out. [Gupta, Saikia and Srianand, 2005b].

Gamma Ray Bursts:

The GRB030329 was observed, shortly (within two days) after the burst, and then nearly once a month for about a year. The GRB was detected with GMRT with a flux density of 0.25 mJy at 1280 MHz within a day of the burst. The flux density at this frequency increased steadily for a few months and decayed slowly. Subsequently GRB030329 was also observed at 610 MHz, and the flux density at this frequency was found consistent with the model. [Resmi, et al., 2005]

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Inputs from TIFR, Mumbai

Radio Observations of X-ray Sources

Evidence of Synchrotron Bubbles from GRS 1915+105 : GMRT observations of the Galactic micro quasar GRS 1915X105 at 1.28 Ghz for 8 days from 2001 June 18, to July 1 were conducted. Several isolated radio flares of varying magnitudes (20 50 mJy) and durations (6 35 min) were seen and were modeled as due to adiabatically expanding synchrotron emitting clouds (synchrotron bubbles) ejected from the accretion disk. By applying this model, a new method was provided to estimate the electron power-law index p, hence the spectral index, from single frequency radio observations. Using estimated value of p and simultaneous multiwavelength data from literature, the time of ejection of the synchrotron plasma was calculated and compared withthe available X-ray light curve. The value of p was similar for the flares of different strength and durations suggesting that the spectral index does not change significantly during the radio baby jets frequently observed in GRS 1915+105. (Ishwara Chandra, et al. 2002)

Search for Compact Radio Jets in X-ray Binaries with GMRT

X-ray binary systems have now been established as sources of radio emission, which can be highly variable in intensity and also in spatial structure. Radio jets have been detected from an increasing number of these sources, with synchrotron radiation being the likely source mechanism. It has been suggested that galactic jet sources fall into two broad categories. In the first, of which SS433 is a famous example, the radio emission is characterized by coherent synchrotron emission in an optically thin medium. This category usually exhibits extended jets. The second category is characterized by incoherent synchrotron emission in an optically thick medium, and importantly from the point of view of this application, a flat or inverted spectral index. These jets are usually compact as seen in GRS 1915+105. GMRT is a very powerful telescope to map a region, in the 21-200 cm wavelengths. A programme has been initiated to study the Jet sources at various frequencies to measure their spectral indices. Observations were made on 15 targets including IE1740-2942, SS433, GRO J1655-40, GRS 1758-258, GRS 1915+105, XTE 1748-288 and G54.1+03; on July 9,10, and 11, 2001 using 28 antennas operating at 1420 MHz. Further observations at multiple frequencies are planned during 2002 (Ishwara-Chandra et al. 2005).

High angular resolution radio study of Galactic star forming regions from GMRT^M^MA programme was undertaken to supplement the balloon borne far infrared astronomy programme of TIFR (Study of Galactic Star Forming Regions) by relevant radio observations feasible within the frequency bands available in the Giant Metrewave Radio Telescope (GMRT), Pune (India). The radio continuum emission from the HII regions associated with the Galactic star forming regions would complement the far infrared continuum measurements by providing formation about the ionized gas. During the past one year, as a part of the pilot programme several star forming regions (viz. IRAS 02593+6016, IRAS 06061+2151,IRAS 17233-3606, IRAS 18507+0121, IRAS 19111+1048, IRAS

20555+3712) were mapped at 610 and 1420 Mhz continuum using the GMRT array. These regions were earlier mapped (resolution of 1 simultaneously in 130 and 210 micron bands in the far infrared during the balloon flights. A very rich structure in radio maps can be seen at 610 and 1420 MHz. (Ojha, et al. 2004)

Supernovae and Pulsars

Multifrequency radio studies of Supernovae : Two radio bright supernovae of the core collapse variety (type I, SN 1993J) and SN1979C were studied with the Giant Metrewave Radio Telescope (GMRT). Their radio light curves traced the evolution of the mass loss in the stellar wind before the parent star exploded in a supernova. Multifrequency spectrum of SN 1993J in the 1420, 610, 325 and 235 MHz bands showed a turnover below 325 MHz and indicated that radio emission was affected by synchrotron self absorption in the magnetized plasma of the interaction region of the outgoing shock with the circumstella medium. (Chandra, et al. 2002)

Hypernova Observations

The nature of hypernovae without the Gamma Ray Burst counterparts: Interest in highly energetic type Ib/Ic supernovae (also called hypernovae) has been intense after the temporal and positional near-coincidence of GRB980425 with the type Ic SN 1998bw (and subsequently that of GRB030329 with SN 2004dh) These imply a possible GRB-SNe connection for long duration GRBs. There are, however, SNe classified as hypernovae, mainly on the basis of high velocity eject, but also on the overall energetics, which do not show a GRB counterpart-notable among which was type Ic SN2002ap. Being one of the closest SNe at 7.3 Mpc, it was also one of the earliest detections in multiple bands of electromagnetic radiation. While the early X-ray emission (XMM Newton)from this supernova is consistent with inverse Compton boosting of optical and UV photons by energetic electrons produced by shock passage through the stellar envelope, a comparison of the radio spectra (from VLA and GMRT) between SN 2002ap, SN1998bw and SN1993J (a type IIB) revealed significant differences between hypernovae themselves as well as across type classifications. Notable among these is the speed at which the radio photosphere appears to move out between hypernovae associated with GRBs and those without a GRB counterpart. We also considered the possible candidates for the progenitors of type Ic SNe, such as massive Wolf-Rayet stars and interacting binaries. The optical depth for photons to be scattered upto high energies and the electron temperatures responsible for up-scattering as constrained from the multiwaveband studies of SN 2002ap, however, would still allow both sets of scenarios as possible progenitors. (Sutaria et al. 2003)

Spectral properties of radio bright supernova SN 1993J

SN 1993J was continued to be observed with GMRT in radio band at existing GMRT frequencies. Three spectra at different epochs were achieved. The spectra were fitted using free-free absorption model as well as synchrotron self absorption (SSA) model. Both give satisfactory fits to data. The radius of the radiosphere, as obtained from the spectral data with the assumptions of synchrotron self absorption model and equipartition of magnetic and relativistic particle energy densities, were compared with SN sizes measured directly by Very Long Baseline Interferometry (VLBI). Base on these comparisons, it is found that the SSA model alone cannot account fully for the low frequency absorption of radio emission. Magnetic field and mass loss rates from these fits were estimated. Magnetic field is an order of magnitude lower than that claimed by a few authors, but matches well with the magnetic fields obtained using VLBI observations.(Chandra et al. 2004).

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Inputs from Physical Research Laboratory, Ahmedabad

1) Flow Sources and Formation Laws of Solar Wind Streams: The large-scale stream structure of the solar wind flow was studied in the main acceleration zone from 10 to 40 solar radii from the Sun. Three independent sets of experimental data were used: radio astronomical observations of radio wave scattering using the large radio telescopes of the Lebedev Physical Institute; dual-frequency Doppler solar wind speed measurements from the Ulysses Solar Corona Experiment during the spacecrafts two solar conjunctions in summer 1991 and winter 1995; solar magnetic field strength and configuration computed from Wilcox Solar Observatory data. Both the experimental data on the position of the transonic region of the solar wind flow and the solar wind speed estimates were used as parameters reflecting the intensity of the solar wind acceleration process. Correlation studies of these data with the magnetic field strength in the solar corona revealed several types of solar wind flow differing in their velocities and the location of their primary acceleration region.

2) Fine Structure of the Solar Wind Turbulence Inferred from Simultaneous Radio Occultation Observations at Widely-Spaced Ground Statuions: Coronal radio sounding experimets with the Ulysses spacecraft at superior conjunction provided numerous opportunities for simultaneous observations of the downlink signals at two widely spaced ground stations (i.e. the Deep Space Network (DSN). In some instances the duration of these observations extended for up to four hours, thereby allowing one to track solar wind turbulence dynamics at spatial scales comparable with the corona-projected distance between ground stations (a few thousand km). The frequency and phase fluctuations produced by electron density inhomogeneities are normally quite well correlated on these scales. Whereas the mean frequency fluctuation intensity sigma_f was found to change only slightly over the duration of the observations, the spectral index of the temporal frequency fluctuation spectra varied over a wide range. The cross-correlation coefficient reached maximal values (~ 0.5) when the spectral index was high (~1), but no correlation could be detected when the spectral index became small (< 0.4). Similar behavior in many of the data sets implies that this is a common, if not permanent, feature of the solar wind. Possible reasons for the fluctuation decorrelation are analysed. The decorrelation at heliocentric distances of ~10 Rsun most likely results from continual deformation of the solar wind density irregularities during their motion across the radio ray paths.

3) IPS Observations of the Solar WInd Disappearance Event of May 1999: Resolving the Enigmatic Solar Wind Disappearance Event of 11 May 1999. Extensive interplanetary scintillation (IPS) observations of the solar wind during the period centered around 11 May 1999, when the Earth was engulfed by a region of solar wind with unusually low densities and velocities were carried out at the Ooty Radio Telescope and the 4 station IPS observatory at STEL, Japan. The ORT observations showed that the actual morphology of the subsidence event was that of a void-within-a-void. The role of the polar magnetic field reversal that was taking place between Carrington rotations 19471954, which may have played a key role in generating the subsidence event, is also examined. Some possible signatures of high energy strahl electrons were also recorded in this period.

IPS observations from STEL were used to make tomographic velocity maps to identify and delineate the extent and morphology of the stable solar wind flows, during CR1949, in the vicinity of the earth. Combined with in-situ measurements of the interplanetary magnetic field (IMF), potential field computations of the solar magnetic fields in the period and HeI 10830 A observations of coronal

hole boundaries during CR1949 we have identified the source region of the unusual flows and have shown that the flow responsible for the disappearance event was a stable uni-polar flow originating in the vicinity of a large mid-latitude active region AR8525, located at ~18. N and between heliographic longitudes 280 and 300 deg Earlier workers have speculated that such events may be caused by the large-scale restructuring of the solar magnetic field at the maximum of each solar cycle. However, by identifying the solar source and nature of this event we believe that at least in this particular case, the association with global, large-scale solar phenomena like the periodic 11 year solar polar field reversal is most likely to be co-incidental.

4) Giant Meter Wave Radio Telescope Observations of an M2.8 Flare: Insights into the Initiation of a Flare-Coronal Mass Ejection Event: We have used GMRT observations at 1060 MHz in conjunction with data from the NoRH, the Hiraiso solar observatory and LASCO to investigate the onset mechanism of a flareCME event on 17 November 2001. We find evidence for reconnection above the erupting arcade that could be construed as evidence in favor of the magnetic breakout model. We find evidence for the formation of a vertical current sheet below the erupting prominence. An abrupt increase in the velocity of the top of the vertical current sheet is accompanied by the M2.8 X-ray flare and the prominence eruption. The features associated with the formation of the vertical current sheet are consistent with the predictions of several variants of flux rope CME initiation models, as well as the magnetic breakout model. These were the first GMRT observations of a solar flare.

5) Radio Observations of Rapid Acceleration in a Slow Filament Eruption/Fast CME Event: A filament eruption/coronal mass ejection (CME) event associated with a flare of GOES class M2.8 that occurred on 2001 November 17 was observed by the Nobeyama Radio Heliograph (NoRH) at 17 and 34 GHz. The high cadence of the radio data allows us to follow the motion of the filament at high time resolution to a height of more than half a solar radius. The filament eruption shows a very gradual onset and then a rapid acceleration phase coincident with the launch of a fast halo CME. Soft X-ray and extreme-ultraviolet (EUV) images show heating in a long loop underneath the filament prior to the flare. The NoRH height-time plot of the filament shows a roughly constant gradual acceleration for 1 hr, followed by a very abrupt acceleration coincident with the impulsive phase of the associated flare, and then a phase of constant velocity or much slower acceleration.

6) The Solar Wind and Interplanetary Disturbances.

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1. We made several interesting observations of solar radio emissions using Brazilian Solar Spectrograph (BSS). BSS was operated in the frequency range of 1200-1700 MHz with the time resolution of 50 ms and frequency resolution of 5 MHz. We made a preliminary classification of about one hundred events, mostly on the basis of morphological features of the events e.g. fine

structures, chromospheric evaporation, isolated dots, chain of dots, bursts (like type III) emission, radio noise etc. A catalogue of these events has been prepared and related data from other observatories are being obtained. The analysis of spikes shows that spikes could have duration as low as 50 ms and the brightness temperature ~ 1015 K. Detailed investigations using this database is going on.

2. As self-similar temporal variability and power-laws are the fundamental conditions for the characterization of criticality in solar active regions, we computed wavelet transforms and frequency distribution of two solar observations: (a) a metric noise storm at 164 MHz and (b) a radio pulsation at 1.6 GHz for these investigations. The observations were made by Nancay Radio heliograph and by Brazilian Solar Spectrograph respectively. The frequency distributions provide slope exponents as -1.65 and -2.1 respectively for these two observations. Whereas the global wavelet spectral slopes are positive as 0.56 and 0.57 respectively. It means that there is a strong self-similarity in temporal variability of the two observations, confirming the occurrence of small spikes before each big spike in the whole series. This indicates that the solar magnetic field in msec scale could be in critical state, which leads to avalanches of many small intermittent particle acceleration events.

3. Interplanetary Scintillation (IPS) observations of three events April 2000, May 1999 and May 1997. April 2000 observations were the interplanetary consequences of the processes on Sun. The May 1999 event is termed as solar wind disappearance event, it appears to be due the passage of large void. The May 1997 event is that due to a Earth directed CME and the IPS observations of a radio source 3C48 show that the interplanetary disturbance due to this CME had density ~4 times more than the ambient, moved slower than the ambient medium.

4. Using SOHO/VIRGO data an attempt was made to investigate the short and long term variation of total solar irradiance during 1996- 2001. The correlograms of 1996 and 1998 show that there is clear and strong evidence of solar rotational modulation. The rotational modulation is more in 1998 than that in 1996, however, the data of 1998 shows a splitting the modulation peak. The synodic rotation period is estimated to be about 27 days. The variation of rotational modulation is independent of solar activity and it is found to be drastically different than other solar emission e.g. solar Lyman-Alpha, radio emission etc. There exists a large yearly variation in the correlograms having periodic and aperiodic peaks.

5. The calculations of the gradient of coronal rotation with altitude were performed using model of the electron density in the solar corona and the radio measurements of the solar coronal rotation. The magnitude of the gradient reduces if the emission is at higher harmonics of the plasma frequency. This work points to the possibility of reducing difference in the radio and optical measurements of the coronal rotation.

6. On 12 th June 2000, three homologous flares from the active region NOAA 9033 were observed in H-alpha at ARIES Nanital. The spectral analysis of the event indicated 26.7 minute periodicity in the intensity which supports the Quadra polar reconnection scenario as the possible mechanism for the event.

7. A detailed study of the various heliospheric aspects of CME of 4 April 2000 was undertaken. A comprehensive scenario of the event history was prepared in perspective of space weather covering observations of interplanetary scintillation, radio and optical measurements of the polar and equatorial ionosphere and geomagnetic consequences of the solar activity. Such studies would help in the near real time predictions of space weather.

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Inputs from the Centre for Space Physics, Kolkata

The Centre for Space Physics (CSP) is involved in Radio observations of the compact objects in our galaxy. One of the major works that was done was a Multi-wavelength campaign to observe the enigmatic source SS433 involving five telescopes: GMRT(Pune) for radio, 1 Meter optical telescope at ARIES, 1 Meter IR Telescope at Mt. Abu (PRL), 2.3 Meter Optical telescope at Kavalur and RXTE satellite for X-rays. Among other things, we discover that in all the wavelengths there are distinct signatures of variabilities in time-scales of minutes. We also report a two day time lag between the Infra-red and Radio emission regions, thereby clearly giving a length scale of around 1.e+15cm at which radio jets originate. We also detected short time scale flares from this system in all the wavelengths and interpreted them to be due to bullet-like ejections observed so far only in optical emissions. We observed X-rays with line emissions originating from the red and blue-shifted jets. The Doppler shifts are consistent with a jet velocity of 0.26c and the kinematic model of Abel and Margon.

Another object A0620-00 was observed in quiescent state. We observed a clear radio flare and from the emission rate at which the energy is lost we derived the accretion rate for a given choice of the mass and the distance. This rate matched with that estimated from X-ray observations.

Several objects, such as GRS 1915+105, Cyg X-1, Cyg X-3 etc. have been observed and the results are awaiting proper analysis.

A few papers published from GMRT observations are:-

1. SANDIP K. CHAKRABARTI, S. PAL, A. NANDI, B.G. ANANDARAO, SOUMEN MONDAL, Photometric Evidence of Ejection of Bullets in the Black Hole Candidate SS433, 2003, ApJ Letters, 595, L45
2. S. PAL and S. K. CHAKRABARTI, Mass Accretion Rate of the Galactic Black Hole A0620-00 in its Quiescent State, 2004, Astron. Astrophys. 421, 13
3. S. K. CHAKRABARTI, B.G. ANANDARAO, S. PAL, S. MONDAL, A. NANDI, A. BHATTACHARYYA, S. MANDAL, RAM SAGAR, J. C. PANDEY, A. PATI and S.K. SAHA, 2005, SS 433: Results of a Recent Multi-wavelength Campaign, MNRAS, 362, 957
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7. S. PAL & S.K. CHAKRABARTI, 2003, SS433 - A Puzzling Cosmic gun in `Recent Trends in Astro and Plasma Physics in India', S.K. Chakrabarti, S. Das, M. Khan and B. Basu (Eds.), p. 108, (CSP:India).

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Inputs from the Raman Research Institute, Bangalore

The implications of the recent GMRT detection of HI 21 cm-line absorption in the red quasar 3C 190 at a redshift of 1.1946 were investigated. Most of the absorption is blue-shifted with respect to the systemic velocity. It is suggested that the HI 21 cm line absorption could be occurring in the atomic gas shocked by the south-west jet in 3C 190. [Ishwara-Chandra et al. 2003].

Observation of two giant radio galaxies J0114-476 and B1545-321 were carried out using the Australian Telescope Compact Array (ATCA). The source J0114-476 gave the first clear observational evidence for recurrent activity in a radio galaxy. Furthermore, PKS B1545-321 is a rare opportunity for examining the development of restarted beams within a relic synchrotron plasma cocoon.[Saripalli et al. 2002, 2003].

Observations of Radio Afterglows of Gamma Ray Bursts and X-ray flares are being carried out from the GMRT since 2003. The afterglow of GRB 030329 has been detected and followed up for more than two years at two frequency bands, 1280 MHz and 610 MHz (Rao, A.P. et al 2003, GCN circular 2073 and 2268; Resmi, L. et al 2005, A&A, in press). Upper limits to the emission at 1GHz has been placed for XRF040812 (Ishwara Chandra et al. 2004, GCN circular 2653) and GRB050416A (Ishwara Chandra et al. 2005, GCN circular 3369).

Sky Survey

A steradian of the southern sky at 151.6 MHz was imaged using the Mauritius Radio Telescope with a resolution of 4' x 4' and a sensitivity of ~ 150 mJy, resulting in a catalogue of ~ 3000 radio sources. Detailed analysis of images including studies of spectral properties of sources is under progress as well as the imaging of the remaining regions. A low frequency survey of the sky is being undertaken with the Gauribidanur Radio Telescope by recording the direct voltage pattern (about 1 MHz bandwidth). Although it is primarily intended for pulsar search, the archived data can be used for a variety of investigations. [Oozeer and Udaya Shankar 2002; Pandey et al. 2002; Somanah and Udaya Shanakr 2002; Udaya Shankar et al. 2002].

Instrumentation and Signal Processing

An experimental setup is being built around the 1.4 GHz receiver system of the 10.4m telescope using locally available components. The 1.4 GHz frequency band of the telescope is contaminated by man made radio frequency interference (RFI). A reference antenna system was built which will be used to receive the RFI. Digitized voltages over about 1 MHz bandwidth from the reference antenna and the telescope will be recorded for further comparison and RFI mitigation.

A broad-band intermediate frequency (8-18 GHz) system is being developed as part of a wide Q-band (40-50 GHz) receiver for the 10.4m telescope. The receiver is expected to give competitive continuum sensitivity and capability to observe many molecular transitions in this band simultaneously. [Riya et al. 2004].

A new design has been proposed for building a submillimeterwave class telescope with cylinders. A prototype of a 3m telescope is under construction. [Ramesh 2004].

A 12m telescope using the concept of preloaded parabolic dish (PPD) is being built to operate in the frequency range 0.6 - 8 GHz. The dish has been built in-house and a contract has been awarded for the fabrication of the mount and its erection at Gauribidanur (about 80 km north of Bangalore). The dish with its mount and the receiver system are expected to be in place by the end of 2005. A commercially available off the shelf controller (Programmable Multi Axes Controller) has been adapted as a controller for the radio telescope. To improve the robustness of the control system, an alternate control path with a Linux based PC is also under development. In the first phase, the telescope will be equipped with a 4-8 GHz front end in a Cassegrain focus and 0.6-1.6 GHz receivers with a broad-band prime focus feed. Design and development of a cryogenic system based on pulse-cooled cryocoolers to cool the front-end electronics at the prime focus of the dish has been initiated.

A programme has been initiated for indigenous technology development for VLBI and frequency transfer on a geosynchronous satellite. A high stability frequency reference has been established on Insat 3A in collaboration with Insat Master Control Facility (MCF), Hassan. VSAT-based frequency dissemination units have been commissioned at MCF, RRI and at the GMRT site. The relative stability of the 25 MHz reference disseminated at these stations exceeds that of commercial cesium standards and is adequate for VLBI observations at centimetre wavelengths. Currently, the system is being used for making simultaneous measurements of distance to the satellite and its time derivative from these stations to improve the orbit estimate for a satellite. The measurement are being carried out using re-programmable data acquisition system based on a field programmable gate arrays. [Abhyankar et al. 2004].

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Commission K

Non-ionizing radiation has a significant and positive impact on modern society through a number of uses. There has been a growing concern among the public regarding the potential human health hazard of exposure to these frequencies by these appliances. These radiations affect different cellular activities either through enzymes or hormones which are responsible for the regulation of the body functions. Electromagnetic field is also found to influence the cellular proliferation, which leads to tumor promotion in the process of carcinogenesis. Earlier epidemiological reports suggest that the effect of this radiation have remarkable effects in biological system. The investigations relate mainly due to exposure to the low level field effects.

Effect of microwave radiation

Developing rats were exposed to 16.5 GHZ and 50 GHz separately for 2 h/day for 35 days. After the exposure period biochemical assays were performed.

Resent studies carried out in brain cells on DNA strand exposed to above mentioned radiation. A significant increase in the tail length of DNA was observed. These result indicate that the exposure increases the DNA damage in the brain cells.

Similarly PKC assay was performed in whole brain and hippocampus and there was a significant decrease in the activity of PKC in the hippocampus compared to the control and to the brain samples with hippocampus removed.

Another group was exposed to 2.45 GHz for 2 hrs/day for 35 days at pulse modulated field (power density, 0.344 mW/cm^2). A significant decrease in calcium dependent protein kinase (PKC) activity was observed.

Treatment of bone osteoporosis by modulated RF field

It is widely accepted that bone remodeling is dependent on electrical stimulation. Pulsed electric stimulation (carried frequency 14 MHz modulated at 16 Hz of amplitude 10 V peak to peak), coupled capacitively to the induced osteoporotic rat bone was carried out. We observed that the electric stimulation significantly increased the calcium, phosphosoursa and carbon content compared to contra lateral sham exposed limb bone.

A group of scientists in IIT Rookie are working on development of RF shield for the mobile handset to reduce absorption of EM energy in the human body.

In India the activity in the area of Bioelectromagnetics is taking shape. To create an awareness among the scientific community and general population national level seminars were conducted.

Also sessions were organized on the related subject in the following conferences/seminars:

1. INCURSI-’ 2003, “National conference on Radio Science in India November 27-29, 2003, National Physical Laboratory, New Delhi
2. Organised national symposium on Microwave Applications (Dec 3 2003)
3. National workshop cum symposium on Microwave Applications: Medicine, Remote Sensing and Industry, Feb 20-21, 2004. New Delhi.
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