MRS → for use in Control room

3/10/2K3

This contains SOP for running this program

E-Plane Omnidirectional RFI monitoring System

for

GMRT

[redacted]

Shubhendu Joardar

Introduction

Today Radio Astronomy needs support from the human community for RFI free zones to set up Radio-Telescopes. In spite of best support from the government, geographical site location and other sources, man made interference is growing. The Omnidirectional RFI monitoring system was made for studying the various effects of RFI on the GMRT data and also locate the possible RFI sources. It consists of Four log-periodic-antennas looking towards East, West, North and South directions in the E-plane at a height of 20 meters. The output from the antennas are spectrum analysed and stored in four files representing the four directions. The antennas are swithched in a cyclic fashion throughtout the time of observation. The 4-direction RFI data is thus made available for statistical and other analysis after the observation.

Acknowledgements

I am thankful to Shri Vikram Kharat (Graduate Trainee, GMRT) and Shri Shrinivas Rao (Project Student) for their contribution in the development of some of the hardware and software tools. I am also thankful to Shri S.Rajmohan and Shri H.S.Kale for his support in modification of antenna tower. Finally, I am thankful to Prof. S.Ananthakrishnan and Prof A.Pramesh Rao for their encouragement and support.

Contents

Part-I

BASIC SYSTEM AND SOFTWARES

****

(A) System Hardware details:

Fig.1 shows basic hardware of ORMS. The 4 antennas

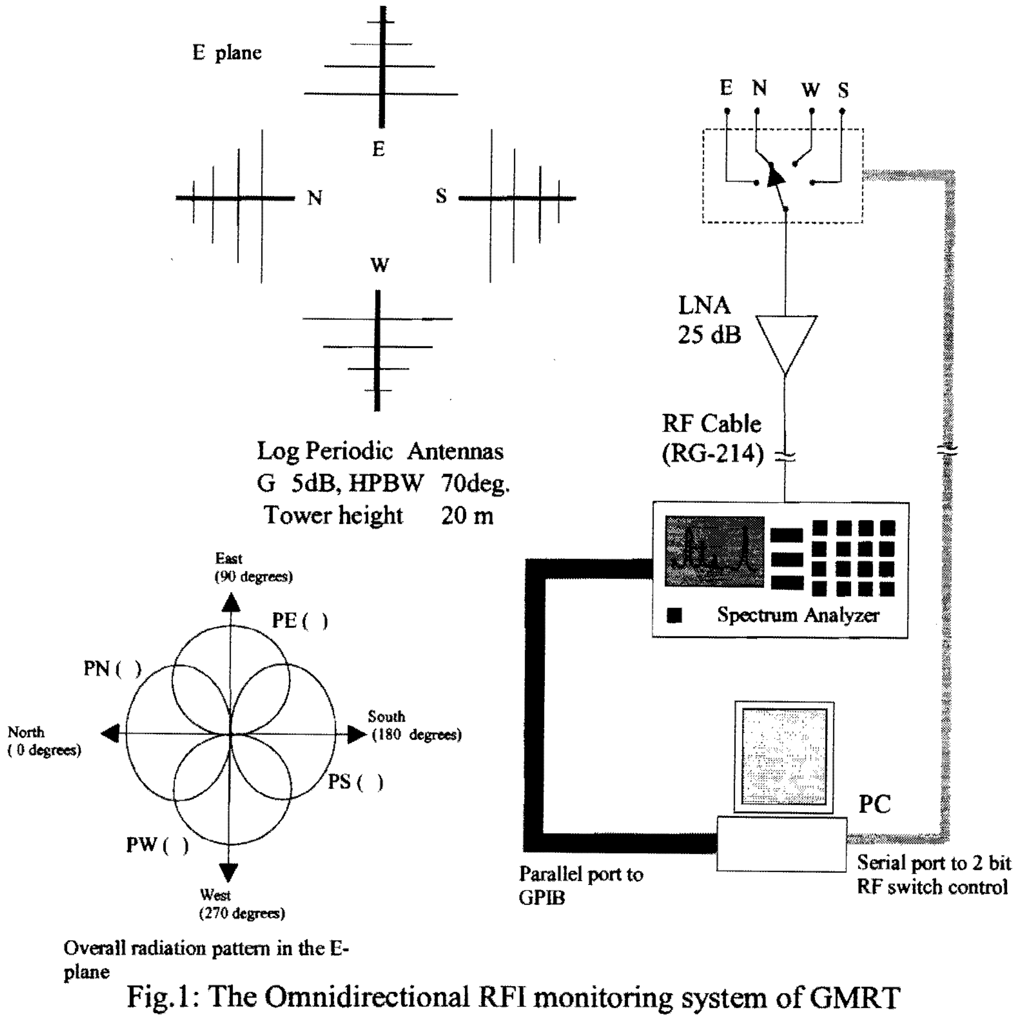


Fig.1: The Omnidirectional RFI monitoring system of GMRT

are placed in the E-plane in orthogonal directions, viz. East, West, North and South. The computer selects the antennas sequence of East-West-North-South using the SP4T switch. After each selection the incoming RFI power is amplified (LNA) followed by spectrum analysis and finally recorded in the corresponding direction file in the computer. This cyclic process is continued throughout the observation.The rest of the RF characteristics of the system are listed below:-

Antenna:

Frequency (MHz)	***150***	***233***	***327***	***610***
Gain (dB)	5.67	4.7	4.2	4.4

RF switch:

RF Switch type	***Manufacturer***	***Model no.***	***Insertion loss (dB)***
SP4T	Mini Circuits	ZSDR-425	1.1

LNA:

Model No.	***Manufacturer***	***Avg. Gain (dB)***	***Noise Fig. (dB)***
ZFL-1000LN	Mini Circuits	25	2.9

RF Cable: An RF cable (RG-214) of 100 m length is connected after the LNA to the spectrum analyzer (HP 8590 L). The cable loss is listed below:

Frequency(MHz)	***150***	***233***	***327***	***610***
Cable loss (dB)	1.4	2.2	2.9	6.1

System: The LNA receiver temperature is calculated as 754 K. 75% of the antenna beam faces the sky and the rest faces the ground.

Frequency (MHz)	***150***	***233***	***327***	***610***
Sky temperature (K)	308	99	40	10
Antenna temperature (K)	306	149.25	105	82.5
System temperature (K)	1062	903	859	836.5

Minimum resolution bandwidth = 300 Hz.

Minimum receptable signal by the spectrum analyzer = -125 dB

S = (4 Pin)/(G ^2) ....(1)

Pspec = (Pin Gamp)/(Lswitch Lcable) ....(2)

where,

S = Power flux density per unit area appearing at the antenna.

Pin = Power appearing at the antenna terminals.

G = gain of the antenna (frequency dependent).

Pspec = Power reaching the spectrum analyzer

Gamp = Gain of the LNA (almost constant over 30 – 1000 MHz).

Lswith = Insertion loss of the RF switch (nearly constant over 30 - 1000 MHz).

Lcable = Loss of the RF cable (frequency dependent).

Sensitivity: Minimum detectable signal flux density with 300 Hz resolution BW

Frequency (MHz)	*150*	*233*	*327*	*610*
S (dBW/Sqm)	> -185	> -180	> -175	> -170

Principle of Operation: For a particular incoming signal at a certain frequency and certain power, the output powers from the 4 antennas will be unique depending on their radiation patterns. If the signal lies in or near the E-plane of the antenna system, two of the antennas delivering the first and second largest power values determines the quadrant in which the signal lies. The exact angle of the RFI is found from the ratio plot using the software shown in Fig.2.

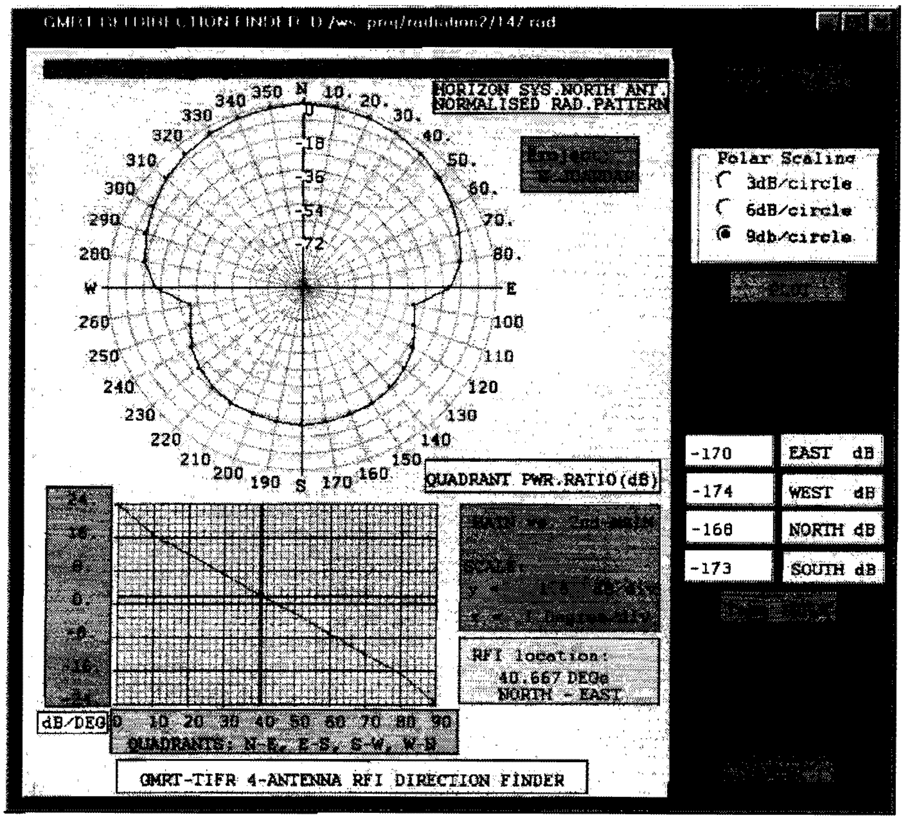


Fig2. Software for RFI direction finding

(a)Left Top: Radiation pattern at 147 MHz in E-plane

(b)Left Bottom: Ratio of radiation patterns of two orthogonal antennas & direction of incoming RFI . inputs given (see"(d)")

(c)Right Top: Radiation pattern file select & plotting scale

(d)Right Bottom: Input powers from 4 antennas to find direction of RFI

Softwares: The softwares can be categorised into three parts, viz. (a) System Operating Software, (b) Data Representation Software and (c) Data Analysis Software.

(a) System Operating Software: The output from the antennas are multiplexed using a computer controlled RF switch followed by an LNA and the signal is fed to the spectrum analyzer through an RF cable of 100m length. The spectrum analyzer is also controlled by the same PC using a printer-port to GPIB conversion software. The spectrum data is recorded in PC simultaneously in 4 files representing each antenna. There are two Port-driver softwares (described in next paragraphs) which are part of the system operating software. The overall functionality may be understood from Fig.3.

Printer port - GPIB communication driver software (Spectrum analyzer control through GPIB): Basically, this is a software mapping of the functionality of GPIB card on a printer-port (written in assembly). The 486 and upward versions of PCs use bidirectional printer port. The GPIB has 3 control bits which are connected to 3 control lines of the printer port. The 8 data lines of the GPIB are mapped 1:1 by the printer port data lines. The end or identify (EOI) line of the GPIB is connected to one of the five status lines of the printer port.

SP4T RF Switch driver (written in assembly): The SP4T switch requires two TTL inputs for port selection, viz.00-East, 01-West, 10-North, 11-South. The DTR (Data Terminal Ready) and RTS (Request to Send) bits in the modem control register of the UART of a serial communication port of a PC can be held in 0 or 1 positions. Since the output of a serial port is RS-232, the voltage levels are converted to TTL first before sending it to the switch.

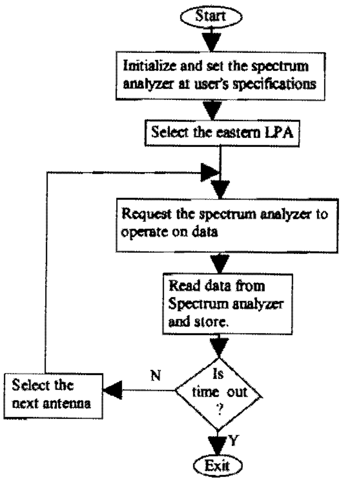


Fig 3. flow chart for system operation

The software can be operated by logging in from any terminal of GMRT or NCRA using the "export DISPLAY" command. The spectrum details from each antenna is sequentially displayed on the user terminal. The various windows of this software are shown in Fig.4. The top window forms are filled based on observation objectives and PROCEED is cliked. The spectrum analyzer is set whose details appear in the middle window. Click STORE to save details, then click START DUMP to begin observation. The bottom window now displays the spectrum of last observed data with antenna direction marked above. The process continues until timed out. The entire data can be found in 4 files each corresponds to an antenna.

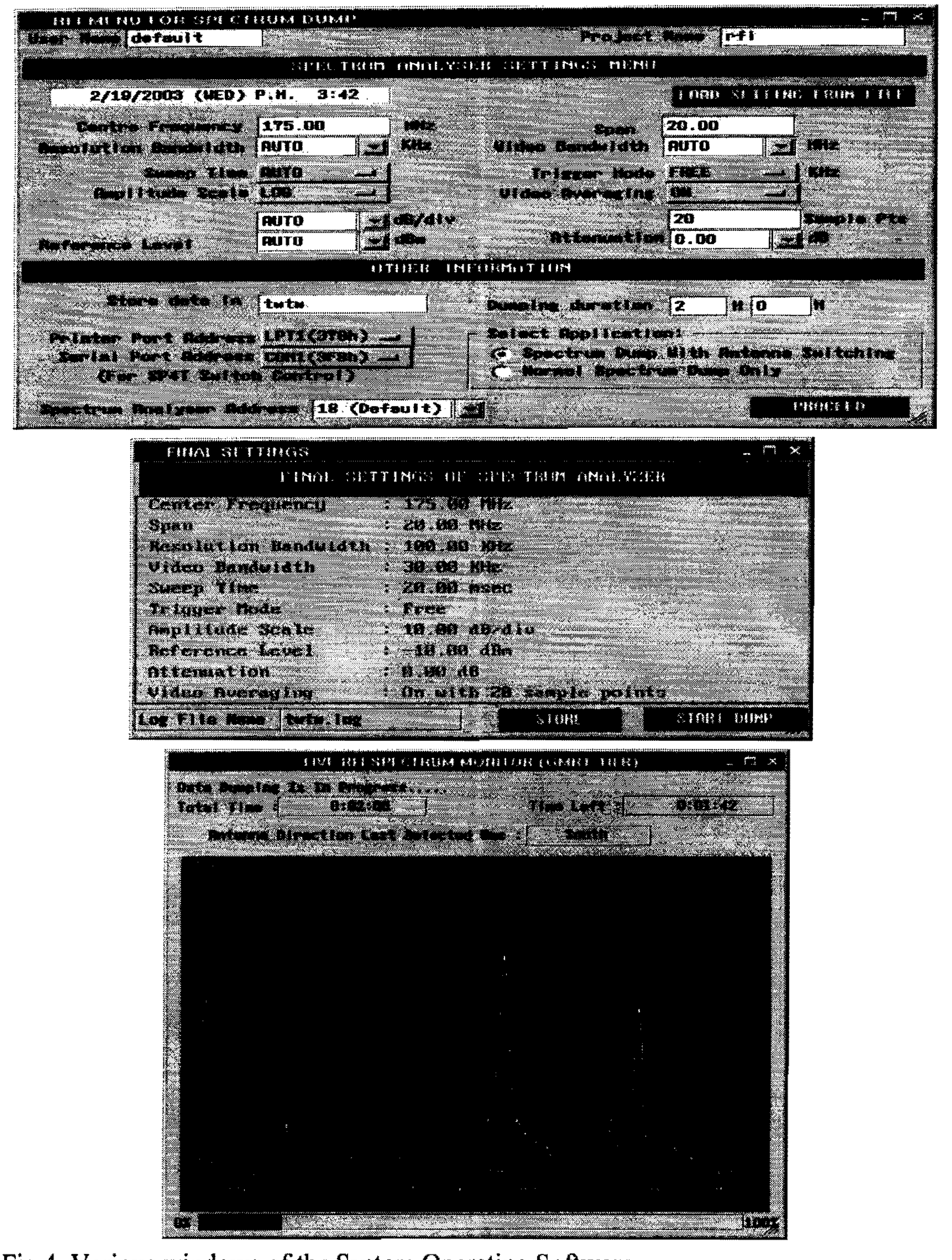


Fig.4. Various windows of the System Operating Software

(a) Top: Settings and duration of Observation (fill and click "Proceed")

(b) Middle: Accepted settings are displayed (click "Start Dump")

(c) Bottom: Spectrum dump for all directions (sequentially displayed)

(b) Data Representation Software: Fig.5 shows the basic flow chart of this software. Fig.6. Shows an actual data in gray (x axis: time, y axis: frequency, intensity: power level at the spectrum analyzer's input port).

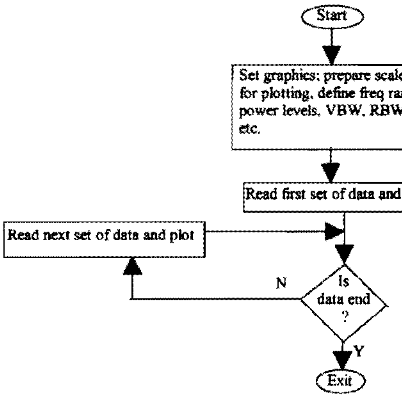


Fig 5. Flow chart of Data Representaion Software

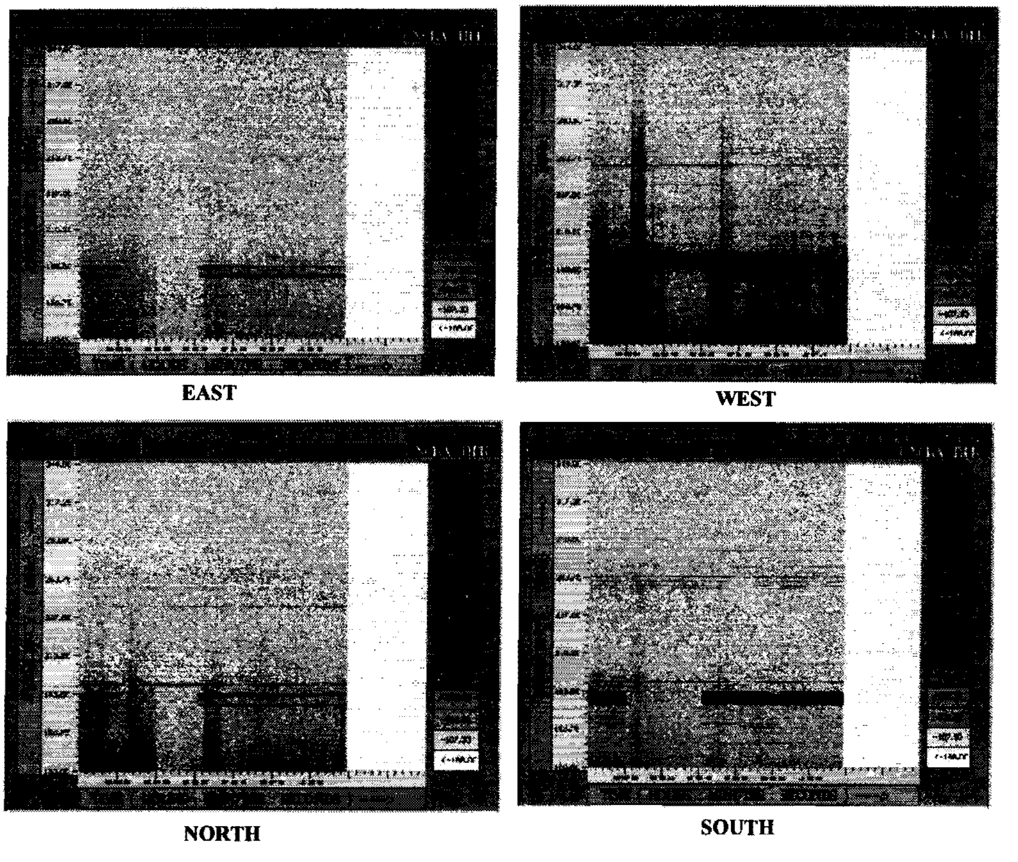


Fig 6:An actual data presented showing Power-line Interference (data taken at GMRT)

The data in Fig.6. is observed using this monitoring system. The vertical dark patches on the West, spread over wide frequency shows the power line interference from high tension ac lines in the W-N quadrant. There was a power failure between 2:35 to 5:30 hrs where the patches are absent. The two dark lines and some of their sister lines sitting near 175 MHz are due to a TV transmitter located towards South.

(c) <u>Data Analysis Software</u>: This can be categorised into two parts, viz. (1) Single RFI Direction finding software and (2) Overall RFI Analysis Software.

(1) <u>Single RFI Direction finding</u>: This is shown in Fig.2. For a single frequency one time observation, the actual direction of the incoming signal is obtained from some algorithms based on the radiation patterns. The entire azimuth angle can be divided into four quadrants, viz. N-E, E-S, S-W and W-N. The ratio of the radiation pattern of two adjacent antennas representing in a quadrant is expressed as a function of azimuth angle (0 to 90 Degrees).

The radiation pattern is selected for a frequency close or equal to the observed frequency. The various power levels from the same source (observed at different antennas) are given as input. The software first compares the power levels.. The antenna pair delivering largest and the second largest power signifies the azimuth quadrant of the incoming RFI. The direction angle corresponding to the ratio of largest power to second largest power is located from the ratio graph (cross wires in Fig.2).

(2) <u>Overall RFI Analysis Software</u>: This software has been recently completed and is currently under test. Given a set of data from all the four antennas over the period of observation, this software displays (i) the average flux densities from all four directions, (ii) a multiple dot-plot of RFI incoming directions for every set of data, (iii) a multiple plot for RFI incoming flux density, (iv) a plot for average RFI incoming flux density, (v) histogram for incoming RFI angles, (vi) histogram for incoming RFI frequencies and (vii) histogram for incoming RFI flux densities. I have written this software under MATLAB progamming. It is currently offline. The data files generated by the System Operating Software are translated to MATLAB format using another of my softwares shown in Fig.7.

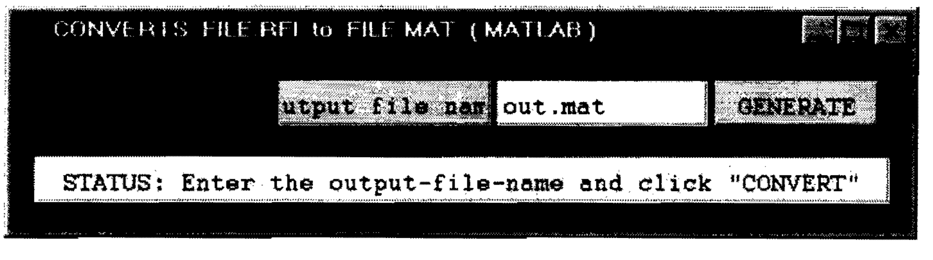


Fig.7. Data format translator software (from .RFI to .MAT format)

As an example, a set of data (file-names beginning with "test2") covering the Pune TV transmission frequency (~175-184 MHz) is analysed using this software. The data has been recorded continuously over an hour. The different results/graphs are shown in Fig.8.

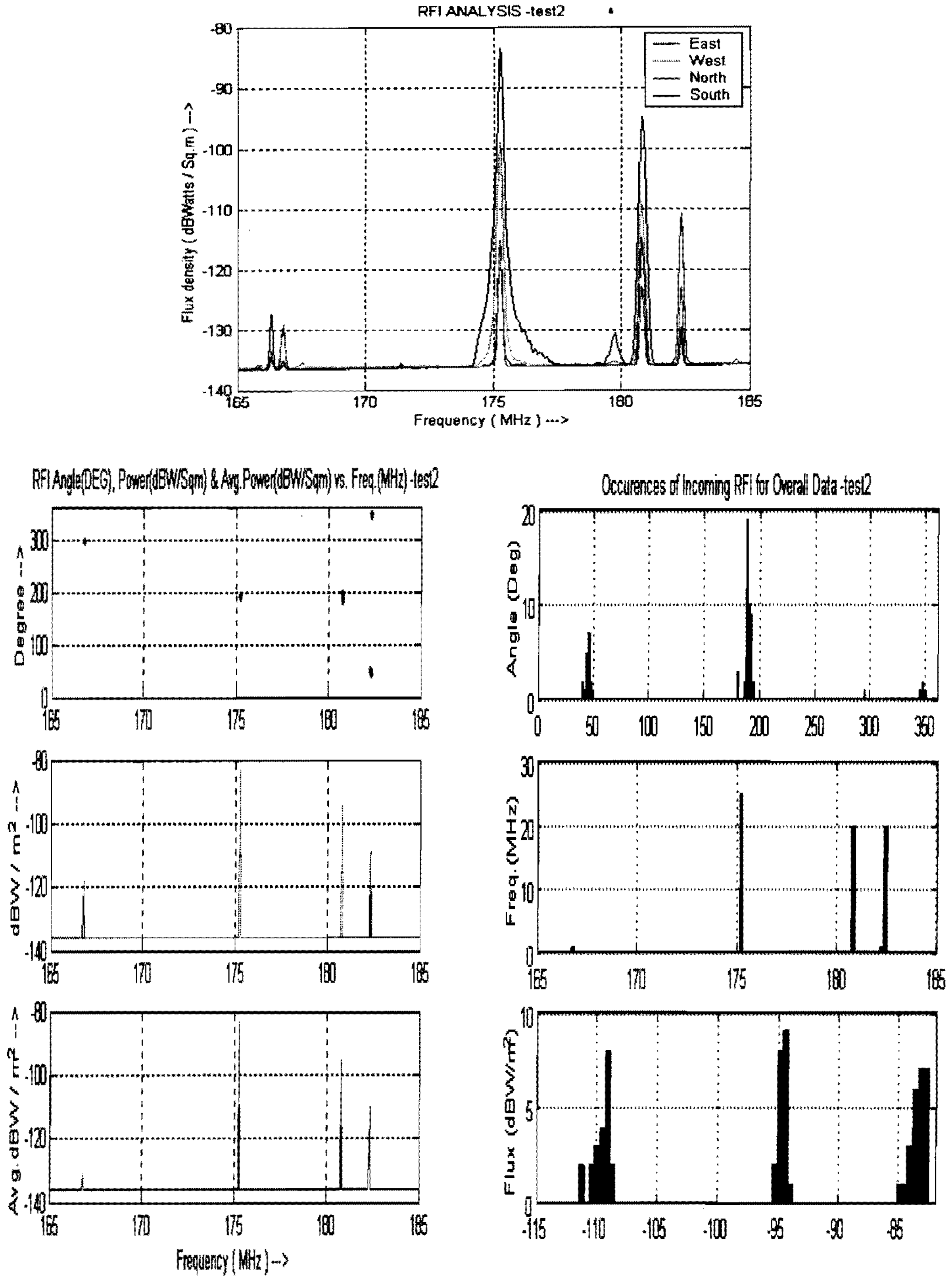
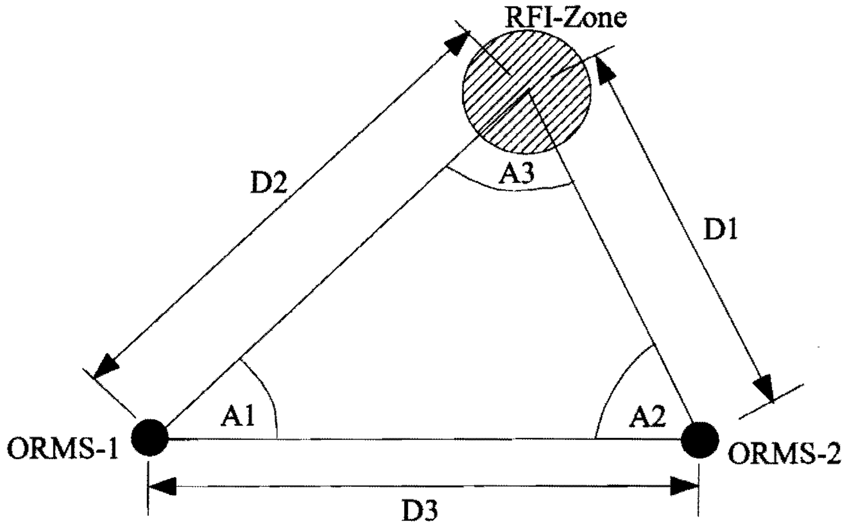


Fig.8. Analysed RFI data (file names: test2e, test2w, test2n, & test2s)

(B)Future Developments:

By adding extra number of antennas to the system, the H-plane polarised signals and RFI generated by the satellites in the astronomical observation could also be monitored. Also three ORMS in a triangle could possibly locate the RFI-zones (Fig.9).

Having reached these zones, hand held RFI detection instruments could be used to trace down the transmitters. Experiments will shortly begin.



$$\sin(A1)/D1 = \sin(A2)/D2 = \sin(A3)/D3$$

Fig9. Locating an RFI zone using two ORMS

(C) <u>Future hardware and software plans (simultaneous observation):</u>

If samples are taken simultaneously from the 4 antennas very short time RFI (less than 1 minute) can be observed. The following scheme shows the block diagram of the front end. Four different RF tuners are locked to a common tuning voltage set by the PC. The voltages from 4 antennas are sampled parallely (with respect to the Clock) and stored into the Register-Matrix. This is read by the PC and further analysis can be done in software.

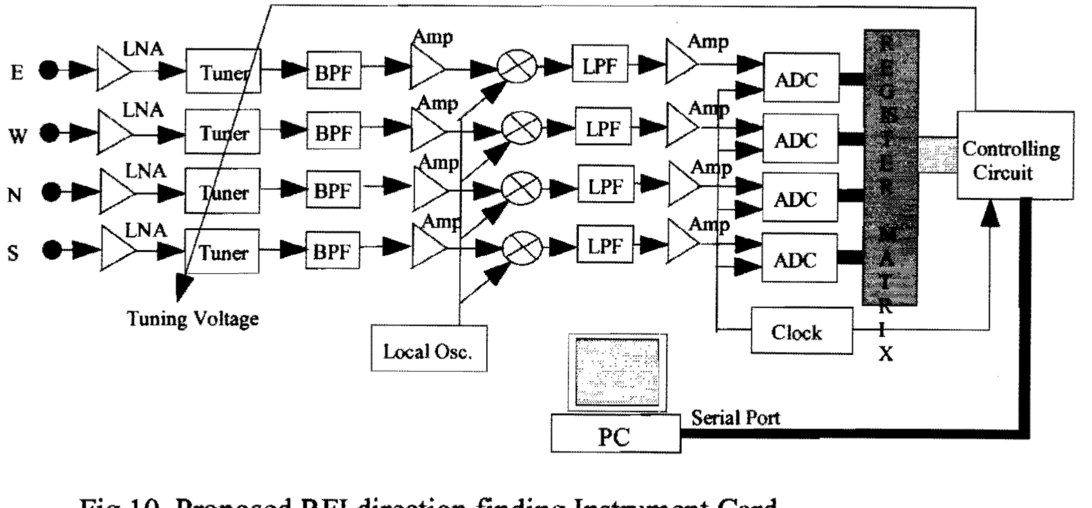


Fig.10. Proposed RFI direction finding Instrument Card

It is possible for a Pentium-4 PC with 512 MB RAM and > 1.4 GHz clock speed to run the system with live data analysis. All the softwares are likely to be combined.

Conclusions: Radio direction finding has been a major issue in communications. Most of the present day direction finders are narrow band type and are less immune to noise owing to phase measurement. For radio astronomy's aid such direction finders are less preferable since the former is interested in the information regarding very low powered non-astronomical interfering signals. The radio astronomers might also be interested in using a band (not officially alloted for radio astronomy) whose feasibility of usage is very much dependent on the prior information about its likelyhood of being RFI-free at the time of usage. Such predictions can be given to the astronomer beforehand from statistical analysis of RFI. The radio astronomy data when processed may also be aided with the corresponding RFI data to reduce errors. Setting of RFI mitigation techniques in radio-astronomy also requires a statistical base for selecting the bands. All these require a sensitive and wide band direction finder which our instrument is likely to fulfill. Apart from this it may find applications in military and police departments.

Ref:

[1]S.Joardar "The Omnidirectional RFI monitoring System of GMRT", Summer School on Spectrum Management, Green Bank, NRAO.
Site: www.iucaf.org/sschool/joardar/orms.pdf

[2]S.Joardar "The Omnidirectional RFI monitoring System of GMRT", NEC-2003
9th January 2003 report. GMRT & NCRA libraries.

Note: RfiServer works fine; the two other programs viz. RfiLiveClient
RfiAvgClient are not available currently ...
26.10.'03

Part-II

STANDARD OPERATING PROCEDURE

****

Note: Although operating the system is simple (user friendly), if you are a new user, please read the following sections carefully, specially the introduction part before you operate the RFI monitoring system. In case of any difficulty, please contact the author.

Introduction: To record the RFI that might enter into the GMRT observation, the instrument has to be set in the GMRT-observation band with duration of observation matching that of the GMRT. The system can be used to capture RFI that lies between 70MHz to 1GHz. However, as the observing bandwidth is increased the sweeping time increases. The narrower the resolution bandwidth, the slower is the system. A similar phenomenon takes place with resolution bandwidth. The number of averages taken also increases the time difference in switching the antennas. However, the number of averages also increases the sensitivity of the system. Care must be taken to observe the short duration RFI. Please refer to the HP-8590L spectrum analyser reference manual for better understanding of the settings. A typical setting for a fast RFI appearing at 314 MHz with high power flux density (-120 dB-Watt per square-meter):

CF (center frequency) = 314 MHz
SP (span frequencie) = 10 MHz
RB (resolution bandwidth) = 30 KHz
VB (video bandwidth) = 30 KHz
AT (attenuation) = 0 dB
RL (reference level) = -35 dBm
VAVG (video averages) = 1
AUNITS (amplitude units) = dB
LG (log scale) = 10 dB/unit
TM (trigger mode) = free

The above data is available is in a file called "314RFI.set" given as an example. Provision is made for the system to be directly set from the "xxx.set" files. In order to make your own settings for observation, please copy the "314RFI.set" file into a new file with extension "set". Edit the file and replace the values of the parameters like LG, VB, AT etc. with your choice. Save the file. This is your new file for setting the system. You may also set the system manually by filling the various fields appearing from the software run. **Always operate with video average "on" and never set the VAVG < 1** (the HBIB/GPIB port sometimes sends wrong data when operated fast which may terminate the system software; this is the problem of the HP-8590L spectrum analyzer). **It is advisable to use the system for RFIs that remain stable (power) for more than a minute.** Otherwise informations required for direction finding and power flux density of the incoming signal may not be adequate since we are multiplexing the antennas. But the other informations like frequency number of occurences etc. may exist in the data. These inconsistencies can however be understood and filtered later during offline data analysis.

<u>Where from to set and run the system?:</u> The system can be set from any terminal connected to the GMRT network. The best use would be to run this system parallely with the Astronomical Observation. Hence it is preferable to operate it from the control room of GMRT. However, once the system is set, the live data (spectrum analyzer screen with antenna direction marked) can be seen from any location in the network because of the socket programming.

<u>What and when to set and or run?:</u> The softwares can be classified into three groups, viz. *System operating and live data visualization software* (binary executable filename: **RfiServer**), *Online data visualization software* for any number of clients sitting on the same network working on different terminals (binary executable filename: **RfiLiveClient**), and *Offline data analysis software* (binary executable filename: **RfiAvgClient**). Please note that the *Offline data analysis software* are of many types as explained in Part-I. For the present we are only providing a *data averaging software* which should be used for averaging the RFI data after observation is complete to find the dominant RFIs along each directions over the total observed time. <u>The **RfiServer** should be run first followed by **RfiLiveClient** (optional) and finally only after the observation is complete, **RfiAvgClient** may be run.</u> The following sections describes the different steps of the operating procedure.

<u>Steps to set and run the system (RfiServer):</u>
Assuming that your terminal is 158.144.18.remote, execute the following commands from you area:

Execute this: /home/rfiuser/RfiServer <26.10.'03 status>

a. From your terminal please give the following commands: login = rfiuser pswd: .rfiuser

[your area]# xhost + 158.144.18.remote
[your area]# telnet 158.144.18.77 (password: rfiuser)

Now you are in the rfiuser directory. Issue the following commands:

[/home/joardar/rfiuser]# export DISPLAY=158.144.18.remote:0.0
[/home/joardar/rfiuser]# cd server

Now you are in the following area:

[/home/joardar/rfiuser/server]#

Not applicable ...

b. Create a "mysetup.set" by copying the 314RFI.set as mysetup.set using the following command:

[/home/joardar/rfiuser/server]# cp 314RFI.set mysetup.set

Edit the "mysetup.set" with your settings using the following commands:

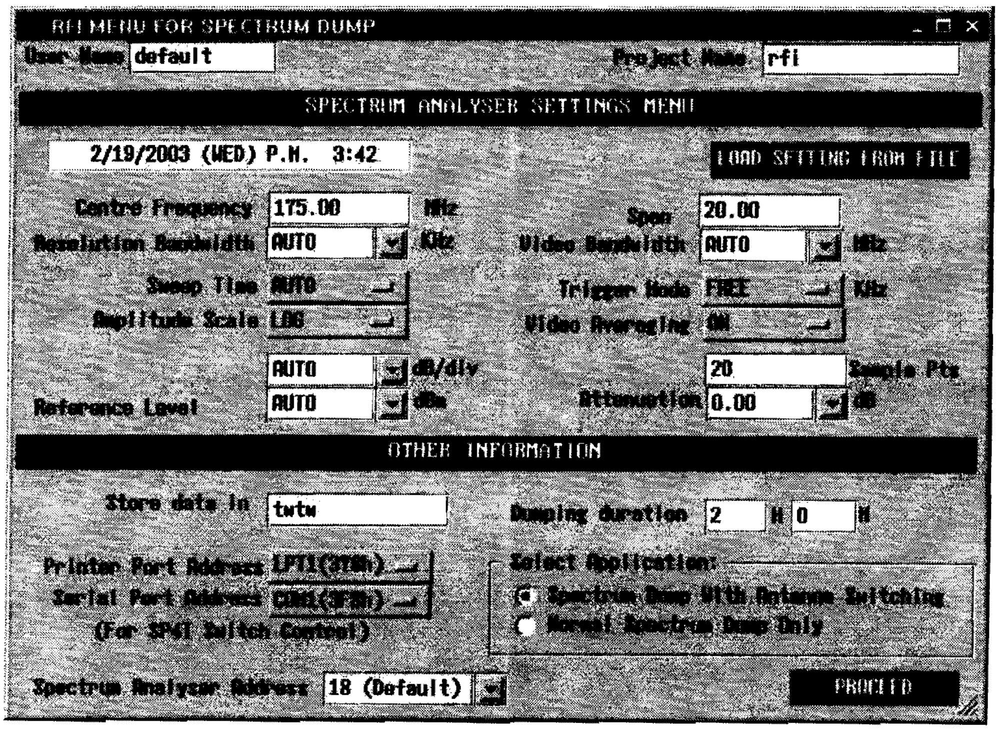
[/home/joardar/rfiuser/server]# gedit mysetup.set

Assign your setup values to CF, SP, RB, VB.... and save the file and exit. Your setup file "mysetup.set" is ready for use.

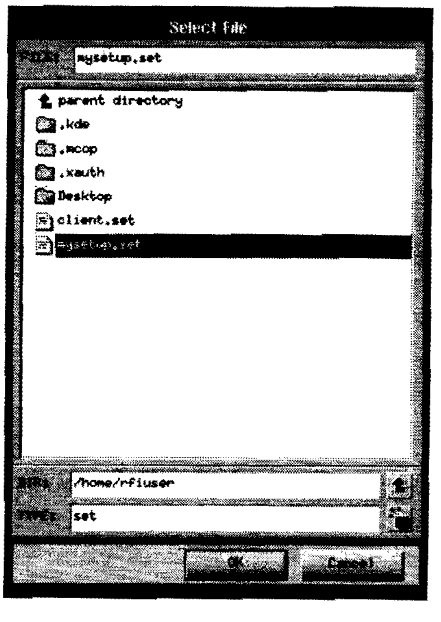
c. To start the system (main server) execute the following commands:

[/home/joardar/rfiuser/server]# RfiServer

Four windows appear with one displaying this file in Xpdf window. If you are an expert operator, you may close this window otherwise read it. Now take a look at the remaining windows. Select the window having a title bar "RFI MENU FOR SPECTRUM DUMP" using your mouse. It is shown below. Most of the fields will be empty. Fill the "User Name" field with your name (it records the observer's name in the data files). Now press the blue button marked "LOAD SETTING FROM FILE". Immediately, another window pops up with a directory tree as shown at the bottom of this page. Using the mouse locate your "mysetup.set" file and press the button marked "OK". You are back !

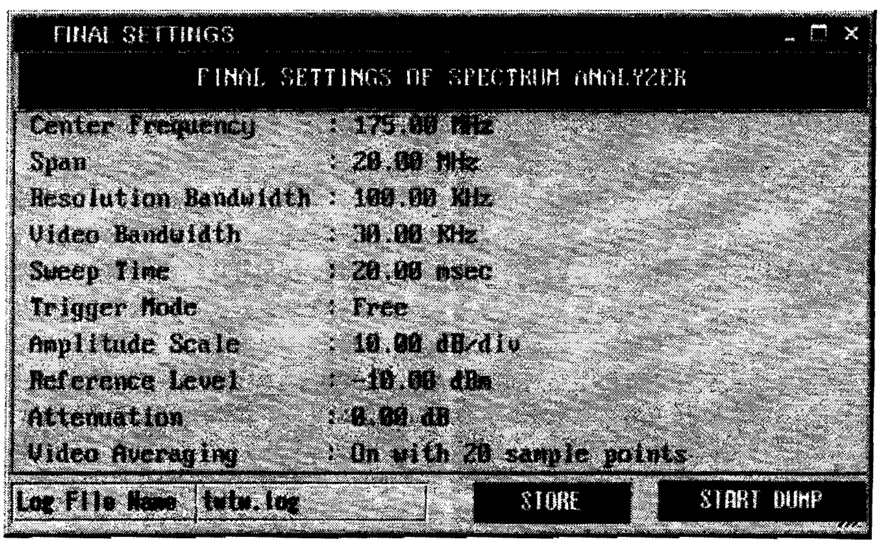


↑ This window can be accessed to pass-on many parameters .... or For initial-runs, one does not require .set file .

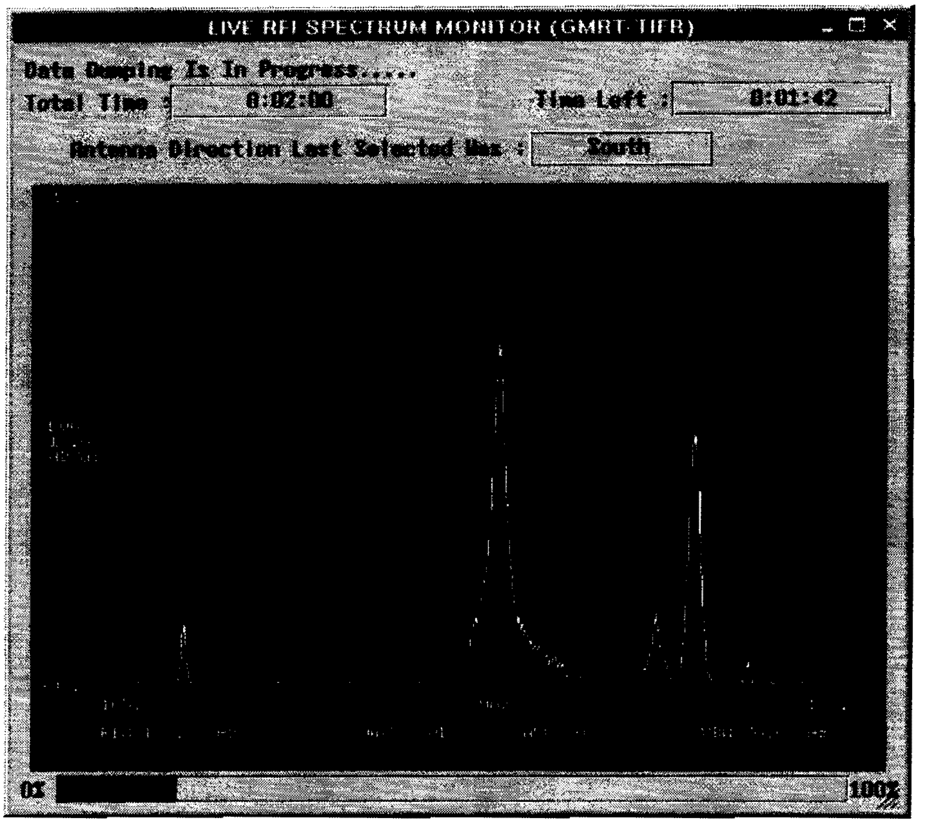


Look carefully into the "RFI MENU FOR SPECTRUM DUMP" window. You will find most of the fields are filled with your setup. Fillup the field called "Store data in" with the **filename** of your choice. Data will be stored in files called **filename_E.rfi**, **filename_W.rfi**, **filename_N.rfi** and **filename_S.rfi** respectively from the East, West, North and South antennas. In addition, another file with name **filenameAVG.rfi** containing all the four datas together will be formed, and its size will be approximately equal to total sum of the the previous files. Now fill the fields marked "Dumping duration" in hours (**H**) and minutes (**M**) depending on your observation duration. You can also make some changes in all other setting fields if you like.

Now press proceed and wait to see the changes in window having title bar "FINAL SETTINGS". After around 10 seconds, you will see it as follows except that instead of "twtw.log" you will see "filename.log". Now press the button marked "STORE". Immediately two new files will be created in **/home/joardar/rfiuser/server/** with names **filename.log** and **filename.set**. These will hold your final settings details as history. You may use the **filename.set** later for a future observation on identical settings.



If everything goes well, press the button marked "START DUMP" and watch the window with title bar "LIVE SPECTRUM MONITOR (GMRT-TIFR)". After some time (between 10 to 100 seconds), depending upon your settings, the live data (spectrum ananlyzer screen) will appear there with the "Total time", "Time left" and "Antenna Direction Last Selected Was" fields filled with latest status. All these along with the live data and progress bar keeps updating from time to time. You may minimise the "RFI MENU FQR SPECTRUM DUMP" and "FINAL SETTINGS" windows but leave the "RFI SPECTRUM MONITOR (GMRT-TIFR) which appears as shown next.



After observation is timed out, the system kills itself but the data remains in the files.

<u>Steps to set and run the Online Data Visualization software (RfiLiveClient):</u>
Assuming that your terminal is 158.144.18.remote, execute the following commands from you area:

a. From your terminal please give the following commands:

[your area]# xhost + 158.144.18.remote

[your area]# telnet 158.144.18.77 (password: rfiuser)

Now you are in the rfiuser directory. Issue the following commands:

[/home/joardar/rfiuser]# export DISPLAY=158.144.18.remote:0.0

b. Just execute the "RfiLiveClient" from the prompt:

[/home/joardar/rfiuser/server]# RfiLiveClient

Please be sure thet server software i.e. "RfiServer" is running before doing this, otherwise the client will not run. The RfiLiveClient gets the date from RfiServer via TCP/IP sockets.

The window is shown below:

c. To start getting the data, you will just have to click on "Start Plotting" button. The program will start plotting the RFI data on the screen. If it doesn't, then you will see a message on the prompt saying "Cannot Connect", which means that the server (RfiServer) is not running. This message occurs because the RfiLiveClient is not able to connect to the Servers socket.

All the datas keep upgrading and you can see dynamic change on the screen depending on the antenna switching frequency. After observation is timed out, the program automatically closes.

Steps to set and run the Offline data analysis software (RfiAvgClient):

Assuming that your terminal is 158.144.18.remote, execute the following commands from you area:

a. From your terminal please give the following commands:

[your area]# xhost + 158.144.18.remote

[your area]# telnet 158.144.18.77 (password: rfiuser)

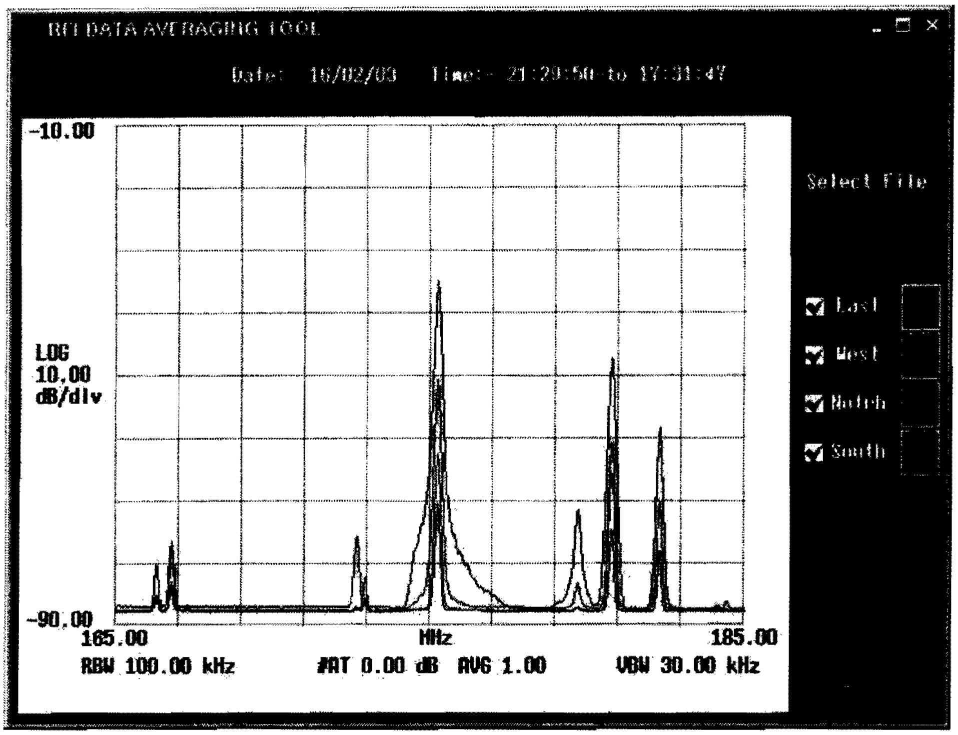
Now you are in the rfiuser directory. Issue the following commands:

[/home/joardar/rfiuser]# export DISPLAY=158.144.18.remote:0.0

b. Just execute the "RfiAvgClient" from the prompt:

[/home/joardar/rfiuser/server]# RfiAvgClient

You will see the RfiAvgClient window as shown next:



c. To see the averaged data of some observation, click on the "Select File" button. A file selection menu will appear, just select the filename which you created while running the server program.

Assuming that you created a file with "abcd" as filename, then the file which you should open is "abcdAVG.rfi". This file will contain the data from all the four files. After selecting the file, click on the four direction buttons to see the averaged data of that direction.

Note: The program may take time to show the average data on the graph. This is because of the size of the file. According to our test, a file created after 20 Hrs observation has a size of about 30Mb. So it may take 10-15 seconds to see the average of that direction.

I hope you enjoyed using the system. In case of any difficulty please let me know and send feed backs from time to time. A lot more stuff for analysing the data like direction finding, statical prediction etc. are coming up soon. I am testing these softwares and about to release.

Finally I thank all of you.

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