TECHNICAL NOTE

DATE :August 20, 1996

SUB : REPORT ON RFI SURVEY AT GMRT, JUNE - AUGUST 1996

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Abstract:

A systematic recording and analysis of the current status of RFI at GMRT site, Khodad, in the frequency range 125 - 1400 MHz was attempted during the period June 26, 1996 to August 8, 1996. The methodology of the recording and analysis procedures evolved as the experiments progressed. This note presents brief details of the hardware used, software developed for recording and analysis as well as preliminary results. The note concludes with a list of recommended direction for further work.

1.0 Introduction:

The RFI survey was started at antenna W2 on June 26, 1996, mainly because (a) It was the only antenna equipped with the final version of L-band front-end; (b) No RFI survey has been made in the L-band earlier; (c) The site is at a distance of about 2 kilometers from the Pune - Nasik National Highway as well as the Central Electronics Building (CEB) of GMRT; (d) The antenna had some alignment problem with elevation encoder and hence the probability of disruption of the survey (which was conceived in "Dish-to-Zenith and Feed-to-Horizon" mode and hence did not need any elevation motion) by some other user did not exist; (e) It was one of the sites with security personnel available round-the-clock and hence costly mobile equipment like spectrum analyzer, PC and diesel generator could be left behind at the site for prolonged periods.

The survey was continued at antenna C11 from July 26, 1996 till August 7, 1996 to make use of an experimental 750 MHz feed and front-end system available there. It was also simultaneously conducted at the terrace of CEB using a 200-1000 MHz log-periodic antenna and 100-200 MHz GMRT fat dipole with reflector, which were mounted on a home-made "Chowgule" stand, having facility for manual azimuth rotation.

2.0 Procedure for Data Acquisition:

The process of data collection consisted of:

(a) Using the GMRT dish in zenith position with the antenna stow-locked (so that high monsoon winds of July would not disrupt the experiments) and rotating the dish only in azimuth axis. The azimuth angle was cyclically changed from +180° to -180°, in steps of 45°, and dwell time in each step of 15 minutes. This "Cyclic Rotation" was done automatically through On-line system and the azimuth position was recorded every minute at CEB. The information was used during analysis for study of direction-dependent RFI.

(b) Selecting one among the two feeds pointed towards horizon and it's front-end system. The output of Channel 1 cable (corresponding to vertical polarization for L-band and Left-Circular polarization for other bands) from the prime focus to dish base was connected to a HP 8590L Spectrum Analyzer. The digital display storage of the spectrum analyzer facilitates obtaining a 401 pixel data of the screen display with a vertical axis resolution of 8000 pixels. Setting of the spectrum analyzer parameters and downloading the stored display was effected using a Personal Computer through General Purpose Interface Bus (GPIB).

(c) Two versions of hardware-dependent acquisition programs evolved as the recording progressed: Version 1, for use with Dynalog make PCL236 GPIB add-on card plugged into

a 286 type PC (used for recording done at W2 and C11) and Version 2, for use with PCL231 GPIB add-on card plugged into a 486 PC (used for recording done at CEB).

(d) The name of the data file is uniquely decided by the program, based on the start date of recording. The extension is frozen as ".rfa" for recordings done at antenna base and ".rfk" for acquisition done at CEB. The data from the spectrum analyzer is written to the file at the start of each minute in append mode so that there is no loss of data in the event of power failure. The actual data with 2 decimal point precision is rounded off and the data is written in integer format, which provides sufficient resolution for the current exercise.

A brief note on the acquisition program is given in Annexure 1.

(e) The experiment was originally conceived with recording in Peak-Hold mode of the Spectrum analyzer. While this was quite satisfactory for UHF and L-band, it was found that strong pulsed interference *(SOURCE TO BE IDENTIFIED)* in VHF bands were overriding and swamping the RFI from terrestrial transmissions. Satisfactory results were obtained when the spectrum analyzer was set to averaging mode.

3.0 Normalization of data recorded:

It is preferable to normalize the power of RFI signals and express in terms of Spectral Power density at the site in Watts/ m² collecting area/ Hz bandwidth, so that the results are independent of the test setup used. This can be achieved by defining an APC (Antenna gain, Pre-amplification, Cable loss) factor in dB, so that when one subtracts this number from the power of a signal displayed in the spectrum analyzer in dBm, the power density at the input terminals of the feed in dBm/ m² is obtained. Table 1 below computes the APC factor for GMRT antenna in various frequency bands.

The spectrum analyzer measures power levels in dBm in the resolution bandwidth (RBW) used. If the actual spectral width (SW) of a line is narrower than RBW setting, then the power read is same as the absolute power. If SW is wider than RBW, then the power read has to be corrected by SW/ RBW factor to arrive at the absolute power. If a proper correction for this factor is added, one would get the Spectral Power density in dBm/ m²/ Hz. The RBW setting used for the survey was typically 100 kHz, which is of the same order of magnitude as typical bandwidth of terrestrial transmissions.

It is also found convenient to define a unit called dBJy (with units of dBW/ m²/ Hz), which is the Spectral power density referred to 1 Jansky (= 10^{-26} Watts/ m²/ Hz).

Spectral power density (dBJy) = 260 + Power measured (dBm) - 30 - APC - 10 LOG (RBW)

Sl. No (1)	Feed (2)	Freq. (MHz) (3)	Gain (dB) (4)	Effective Area (m^2) (5)	Effective Area (dB-m^2) (6)	FE Gain (dB) (7)	Cable loss (dB) (8)	APC factor(dB) (9) (=7- 8 - 6)
1	150 MHz thick dipole pair	150	8.5	2.25	8.12	62	8	46
2	327 MHz Kildal	327	5.4	0.23	-14.6	65	11	69
3	233 MHz coax	233	7.7	0.78	-2.53	64	9	58
4	610 MHz coax	610	8.6	0.14	-19.7	61	15	66
5	L-band horn	1000	12.0	0.11	-21.8	76	21	77
6	L-band Horn	1200	12.8	0.09	-23.6	73	23	74
7	L-band horn	1400	9.6	0.03	-34	70	26	78

Note: Columns 2, 3 and 4: Data provided by Shankar based on measured 3 dB widths of the feeds;

Columns 7 and 8: Data provided by Praveen.

4.0 Data Analysis programs:

The recording could be analyzed by directly importing the ".rf?" data file as a file of numbers into any spread-sheet program capable of handling 405 columns and a number of rows, equal to the total minutes for which the recording was done. It could be also studied using text editor programs, which have a facility to display a line of about 3000 characters with out word wrap, like Norton Editor.

Two specific analysis programs named GSP1-3 and H2P1-1 evolved as the recording progressed for analysis of the data files. These programs produce output files with the original name preserved but with suitable extensions.

The salient features incorporated in GSP1-3 are:

(a) Finds the MAXIMUM and MINIMUM value of power for each of the 401 pixels forming the frequency axis (= frequency channel) from the start to end of experiment and displays the same on the PC screen. A typical display, at this stage of data analysis (for an experiment in 160 to 310 MHz band using the 233 MHz coax feed) is enclosed as Annexure 2. This data is also written to a file with extension ".mnx" .

(b) Produces an output file with extension ".bsp" where the minimum power in a frequency channel is codified as zero. Increasing power levels are coded as 1... 9, a...z, A...Z, to result in a single character representation of a maximum of 62 integer levels. Facility to replace characters below a certain threshold (user definable) by blank in the output file is available. The structure of the output file is similar to the input data file.

A print-out of a typical ".bsp" file (after font compression) with blanking done at 2 dB above minimum value for an experiment in 900 to 1400 MHz range using the L-band horn and with cyclic rotation of the antenna is enclosed as Annexure 3.

(c) Produces output files with extension ".gsp" and ".rsp", which are compatible for further processing in GNUPLOT or AIPS packages, for producing 3-D (Frequency-Power-Time) or gray scale plots. In the file with extension ".gsp", the slope across the spectrum because of band shape is removed by subtracting the minimum value of a frequency channel from the current value of that channel. IT SHOULD BE REMEMBERED THAT THIS PROCESS ALSO SUPPRESSES INFORMATION ON THE MINIMUM LEVEL OF RFI IN A FREQUENCY CHANNEL. No such data manipulation is done in the ".rsp" file.

A print-out of a typical gray scale plot for an experiment in 125 to 175 MHz band is enclosed as Annexure 4.

The salient features incorporated in H2P1-1 are:

(a) Study of the raw data file in time domain, for a particular frequency channel from start to end of recording. A typical screen where the behaviour with time of an RFI at 636 MHz was studied is presented as Annexure 5.

(b) Study of the raw data in Frequency domain, where the recording for a maximum of 81 consecutive minutes could be displayed either singly or in any consecutive combination. A typical screen is presented as Annexure 6.

5.0 Results of preliminary analysis:

Annexure 7 gives MiNmaX plot in all the bands of GMRT which were included in the experiments to give an idea of typical bandshape in various frequency bands as well as the RFI scenario at GMRT site during this epoch of time. It would be quite interesting to conduct similar experiments and compare results during the next Olympics!

The recording done could be divided into two classes:

(a) Experiments in 125 to 400 MHz band, using the 150 MHz thick dipole, 233 MHz coax, 327 MHz Kildal and 200-1000 MHz Log-periodic antenna at W2, C11 and CEB. Total period of recording: about 195 hours. Annexure 8 summarizes the results.

(b) Experiments in 510 to 1400 MHz band, using the 610 MHz coax feed, an experimental 750 MHz feed (which was available at C11) and L-band horn at W2. Total period of recording: about 115 hours. Annexure 9 summarizes the result.

6.0 Recommended Further Work:

(a) Source of the strong pulsed interference, especially in VHF bands has to be found out. *We should rule out the possibility that it is locally generated.* This may need simultaneous recording at two antenna locations and CEB.

(b) Efforts were made to record the antenna azimuth position along with the spectrum analyzer data in the PC at the antenna itself by tapping the information from the encoder but could not be completed. This feature, when added during the next phase of recording will ease data analysis for finding details of direction-dependent RFI to a great extent. *The rotation of the dish using the servo system must continue to be done by Telescope Operators from CEB using On-line for safety reasons.*

(c) Automatic setting of front-end parameters using MCMPRN program through the data acquisition PC is to be realized, so that the complete procedure could be planned with out the need for any operator intervention after a power failure at the telescope site.

(d) Study of RFI of other polarization, using Front-end Channel 2 cable is to be done.

(e) The acquisition and analysis programs are to be rewritten for use with Tektronix 2710 spectrum analyzer, for use if and when required.

(f) H2P1-1 is to be upgraded to include histogram.

Acknowledgment:

The help provided by all colleagues at Khodad who participated in the efforts to sustain the data recording in spite of interruptions due to power failure, more pressing demands for the spectrum analyzer and other reasons is thankfully acknowledged. The data acquisition program for PCL231 was developed independently by Naveen. Aba contributed in the efforts for obtaining the Gray scale plots using AIPS and in data analysis.

Annexure 1. A brief note on the Data Acquisition program

The flow of RFI Data Acquisition program is summarized in the following steps:

Step 1: Informs Observer about current PC date, time and free disk space available in the computer so that one can exit and correct the situation, if needed. (Note that program needs about 100KB disk space/ hour for writing the data).

Step 2: Asks name of the Observer.

Step 3: Reads in data regarding location of survey, type of feed, it's polarization, mounting arrangement for feed, direction towards which feed is pointed, details of spectrum analyzer (SA) used and APC factor from a Configuration file "CONFIG.RFI" and displays on screen. Gives a choice to Observer for exiting and editing the configuration file (using any standard text editor), if needed.

Step 4: Initializes SA through GPIB and sets start frequency, stop frequency, resolution bandwidth, video bandwidth, reference level and input attenuator as per value read in from CONFIG.RFI file. Sweep time is read back from SA and displayed on the screen.

Step 5: Asks observer's confirmation of the setting of the SA. Choice of confirming or exiting and editing the CONFIG.RFI file and start again or setting the parameters from front panel control of SA rests with the Observer. At this stage, the Observer can also study the bandshape displayed and get satisfied that the front-end has been set properly

Step 6: Puts SA in Local Lock-out mode and *disables all front-panel controls*. Reads current setting of all parameters listed in Step 4 and updates screen display.

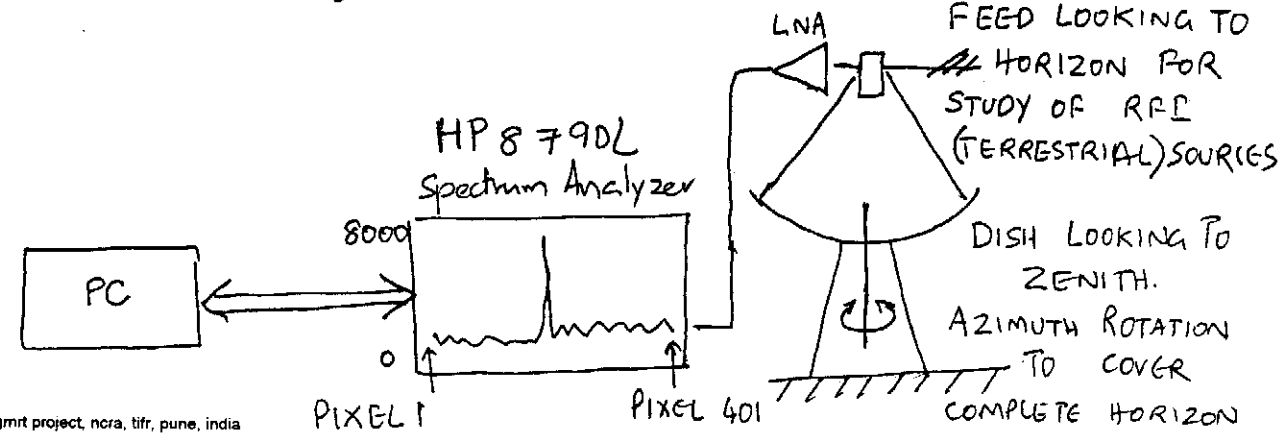
Step 7: Decides on output data file name, using the PC date for the first six characters of name field and "rfa" or "rfk" for extension. Chooses the 8th character of name field to result in a non-existent file name. Opens the output data file so named and writes a header giving all the final configuration information. Closes the data file.

Step 8: Waits for the computer clock to read NEXT minute to start the actual data acquisition, with Iteration set to 1.

Step 9: Clears SA Display Store and starts the display in Averaging mode, which continues till the start of NEXT minute.

Step 10: Freezes the display. Checks for any changes in SA parameters, done in spite of the local lock out. If so, aborts the experiment with a warning. Else, opens the data file in APPEND mode and writes iteration number, current hour, current minute and the integer value of the 401 pixels of the SA display as a single line of data. Change of time from 23 hours to 00 hours during mid-night is taken care while deciding on value for current hour, so that there would be no wrap-around while plotting. Closes the data file. Checks for an iteration value of 2880 (corresponding to 2 continuous days of recording) or a specific combination of key-board entry for shutting down the experiment. **Otherwise, increments iteration by 1 and goes to step 9.**

The Block diagram of the setup used is:-



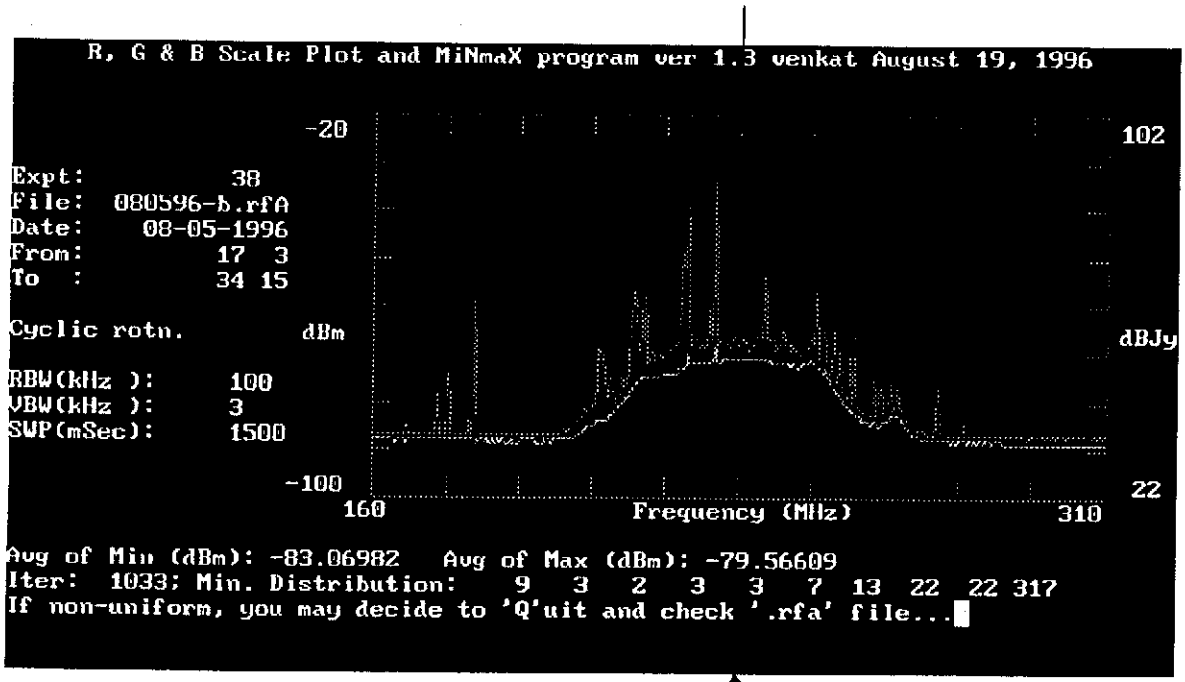
stores 1min data/ Av. 2 ~ 25 scans of SA

Annexure 2. Typical Screen display after computing Minimum and Maximum of data in GSP1-3 program

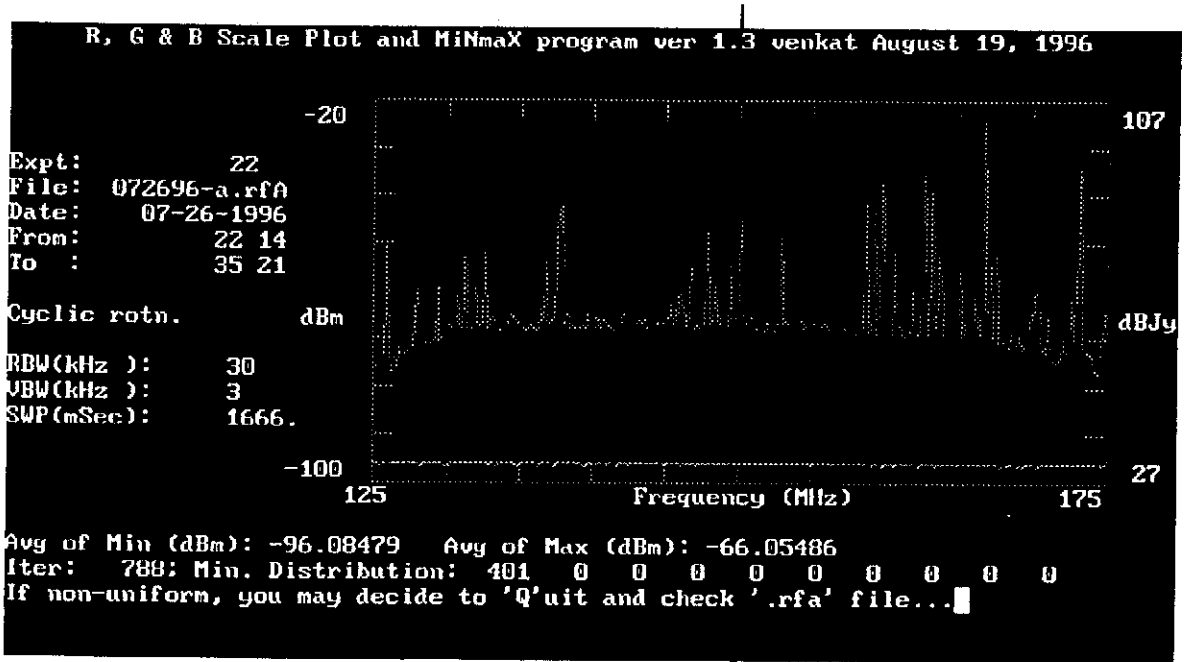
Visual inspection of the screen at this stage should help in deciding the quality of data recorded and whether to proceed with further analysis. If the minimum of data resembles the spectrum analyzer noise floor, it is probably because someone disconnected the input to the spectrum analyzer as the data acquisition was in progress! It is possible to purge such offending data recorded using EDI1-1 so that rest of the data can be re-analyzed.

The display also helps in making a judicious choice of blank limit for ".bsp" file.

The dBJy scale in the plot for experiment 22 below is in error. Also, the feed was facing East. The wrong entries is because of oversight in not editing the CONFIG.RFI file before starting the experiment.



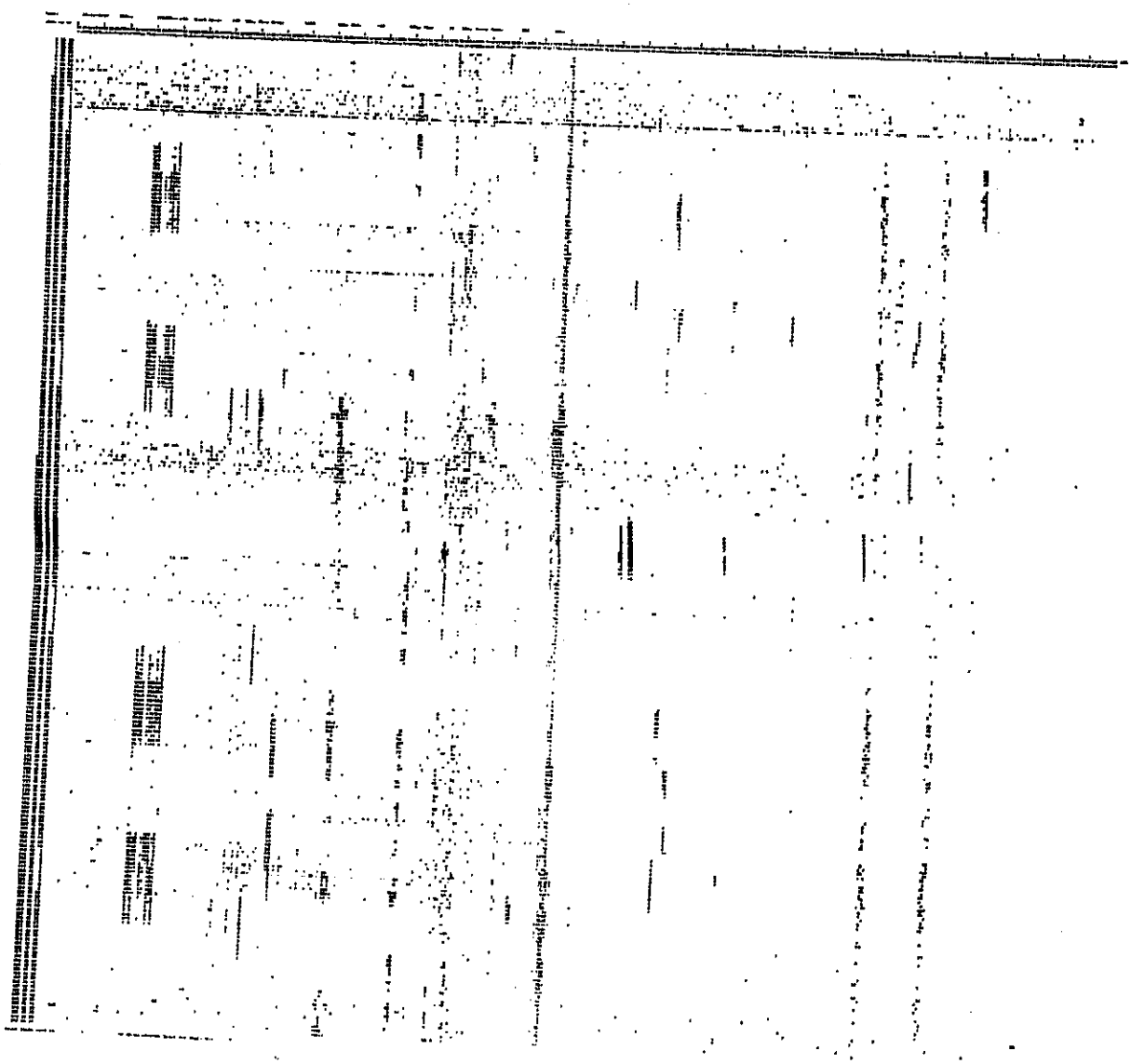
235 MHz



150

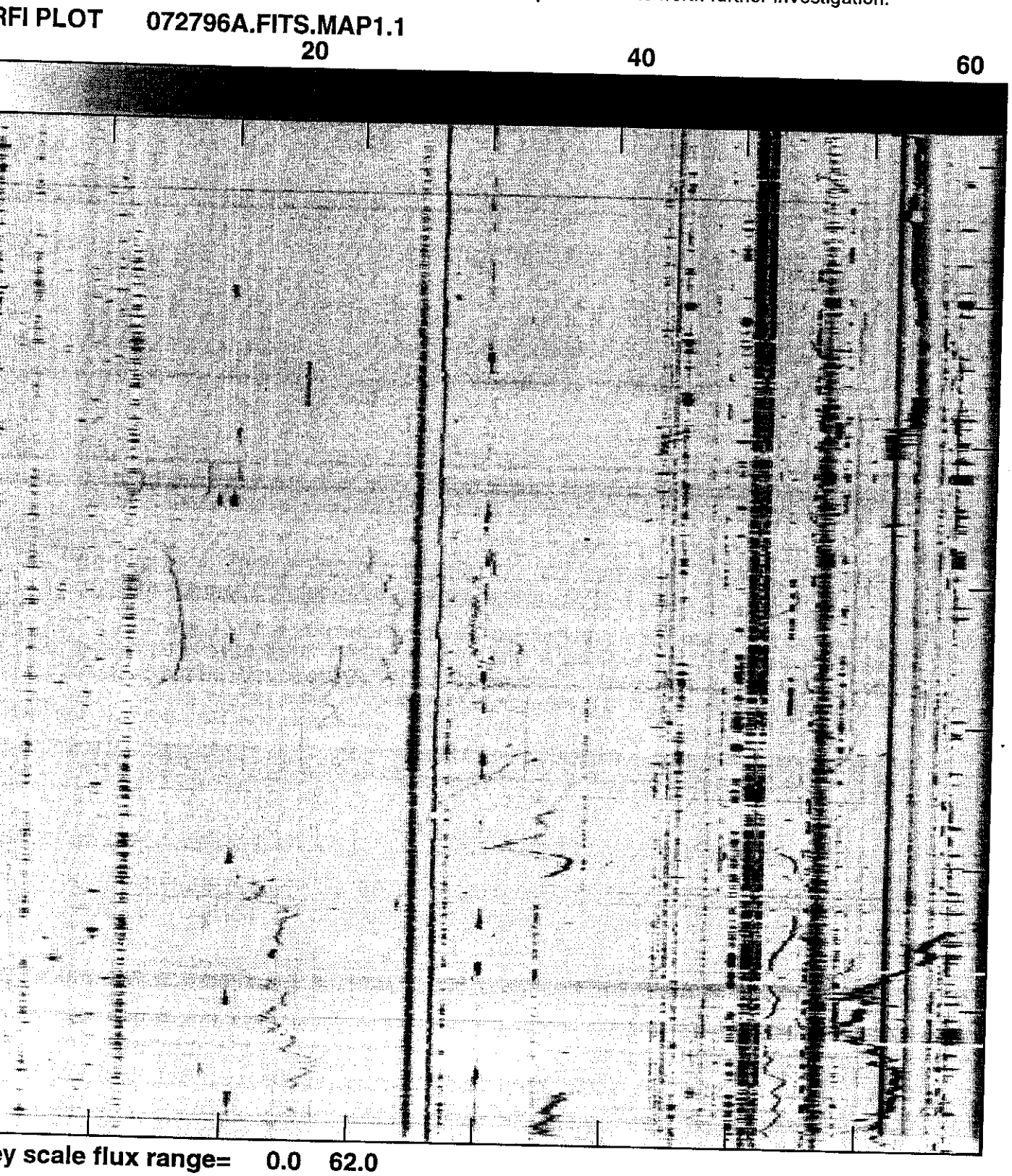
Annexure 3. Print out of a typical ".bsp" output file

The print-out of 070396-c.bsp, which is the result of analysis of a recording in 900 to 1400 MHz band with cyclic rotation of the antenna is presented below. The horizontal axis is frequency channel and vertical axis is time. The effect of cyclic rotation of the antenna can be clearly seen on some of the channels. The channels where the interference seems to be present for 100% of the time are prime suspects for locally generated RFI. The reason could also be that the minimum level received (by the back lobe of the feed) was higher than the blanking level set for the bsp-ing. Note that as the recording was done in Peak-hold mode.



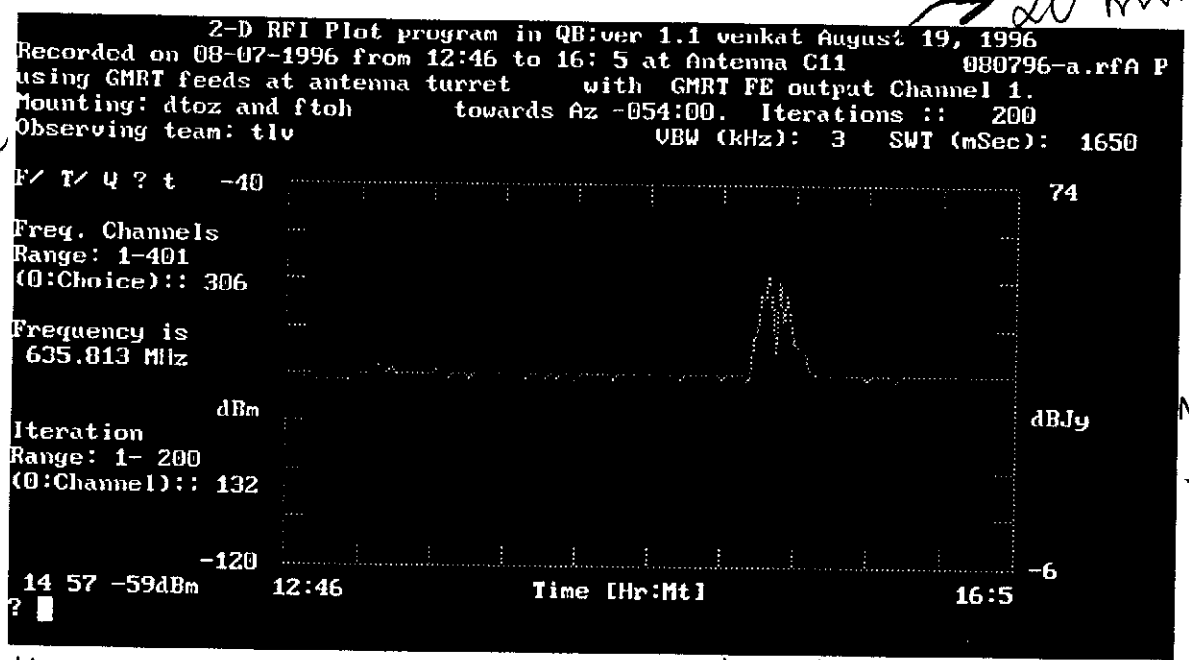
Annexure 4. Gray scale plot of a typical ".gsp" file

Plot below shows the result of an observation in 125-175 MHz band from 11:53 to 23:50 hrs. on July 27, 1996 at antenna C11 with feed pointing towards South. X-axis of the plot corresponds to the 401 frequency channels and Y-axis, to time. Data has been presented on an "as-is" basis. When biased for 3 dB above minimum power level, about 90% of the plot area turned from gray to white. The "wandering" of some of the RFI lines with time *BY A FEW MHz* (see bottom right-hand corner) was unexpected and is worth further investigation.



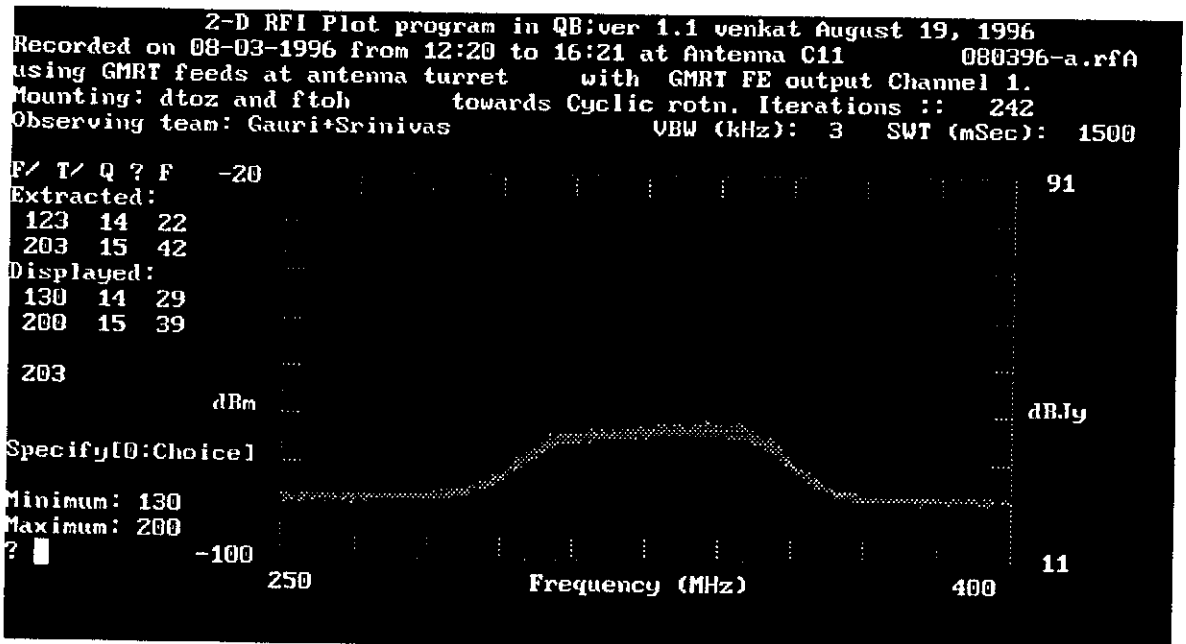
Annexure 5. Typical screen display during time domain analysis of a frequency channel, using H2P1-1

The data file 080796-a.rfa, (510-675 MHz using 610 MHz coax feed) had 1510 minutes of data, from 12:46 hrs of Aug. 7, 96 to 14:55 hrs of Aug. 8, 96. The analysis showed RFI in frequency channel 306, corresponding to 636 MHz, for about 20 minutes, from 14:51 to 15:11 hrs on Aug. 7, 96. The file was purged to select data for the first 200 minutes using EDI1-1, which was then analyzed using H2P1-1. The screen dump shown below illustrates the behaviour with time of the RFI signal. Note that the frequency channels 305 and 307 were absolutely clean!



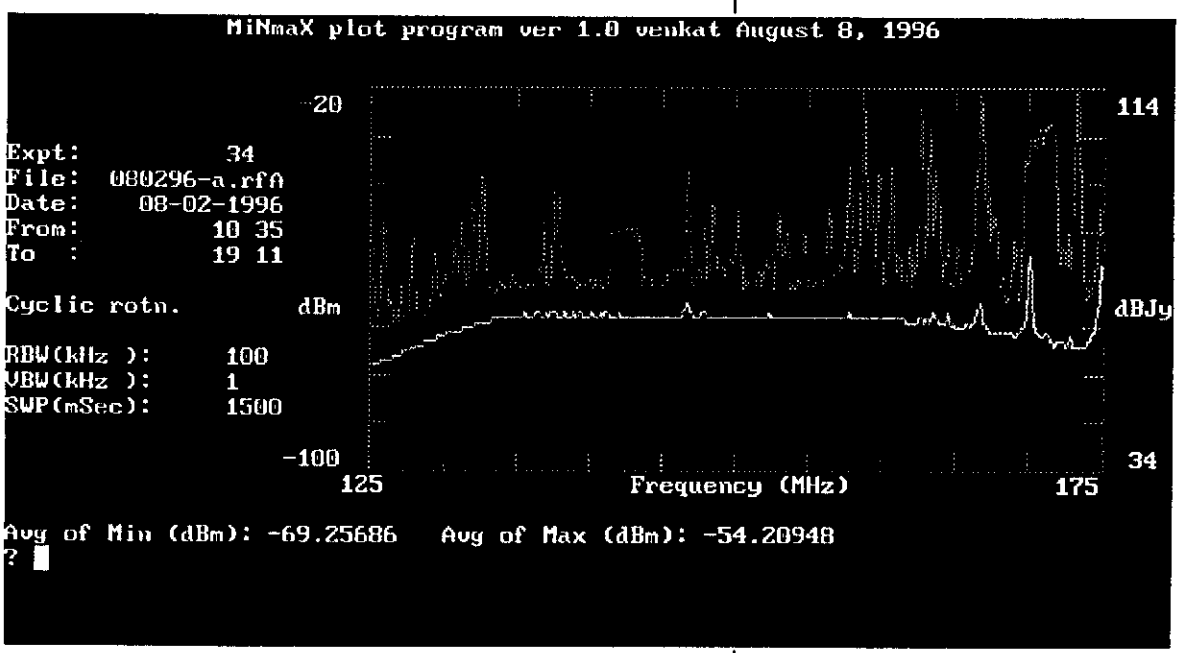
Annexure 6. Typical screen display during frequency domain analysis of Seventy-one consecutive frames, using H2P1-1

The screen dump below shows the PC display, with the spectrum for 71 successive minutes (from 14:29 hrs to 15:30 hrs) superposed. A maximum of 81 successive frames could be thus extracted and studied. The magic number 81 is because of memory limitation while defining the data array. Note that ANY combination of 81 frames, from the start to end of recording could be thus studied.



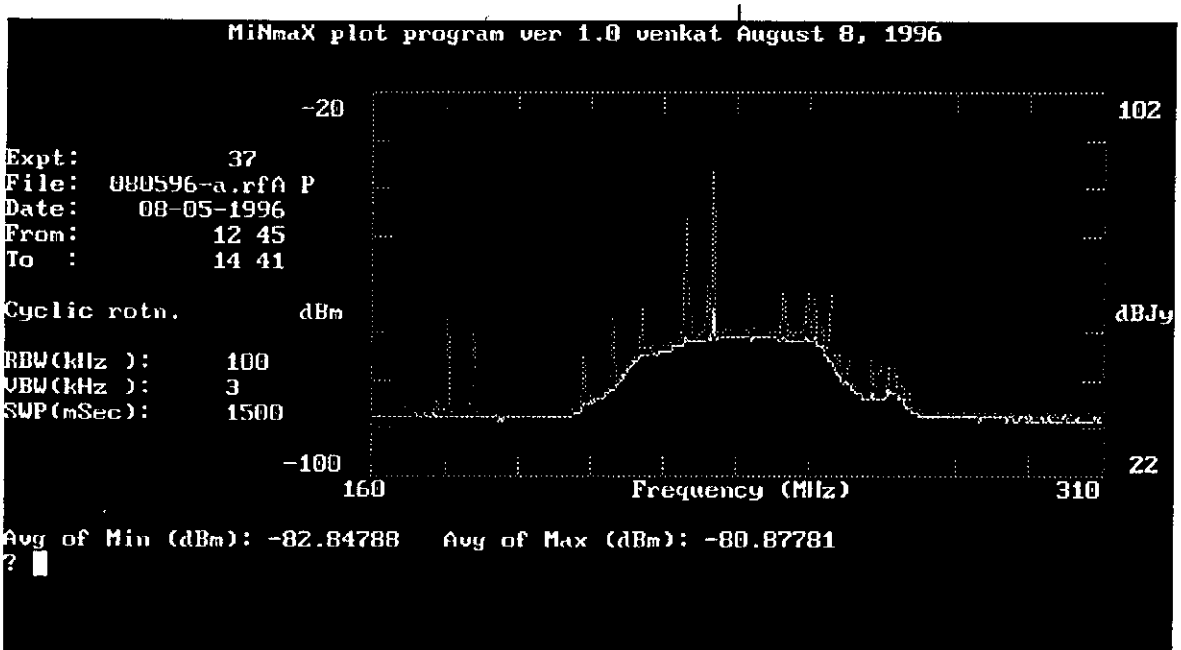
Annexure 7. MiNmaX plot at all RF frequency bands of GMRT

(a) 125 - 175 MHz band: The worst-case plot, during morning hours, with cyclic rotation of antenna is shown below. Note that the scenario was highly dependant on direction. There were quite a few 'Silent Valleys' when the feed was pointed towards East or North. It should be possible to use GMRT in this band, with a bandwidth of 6 MHz, atleast for a few more years!



150 MHz

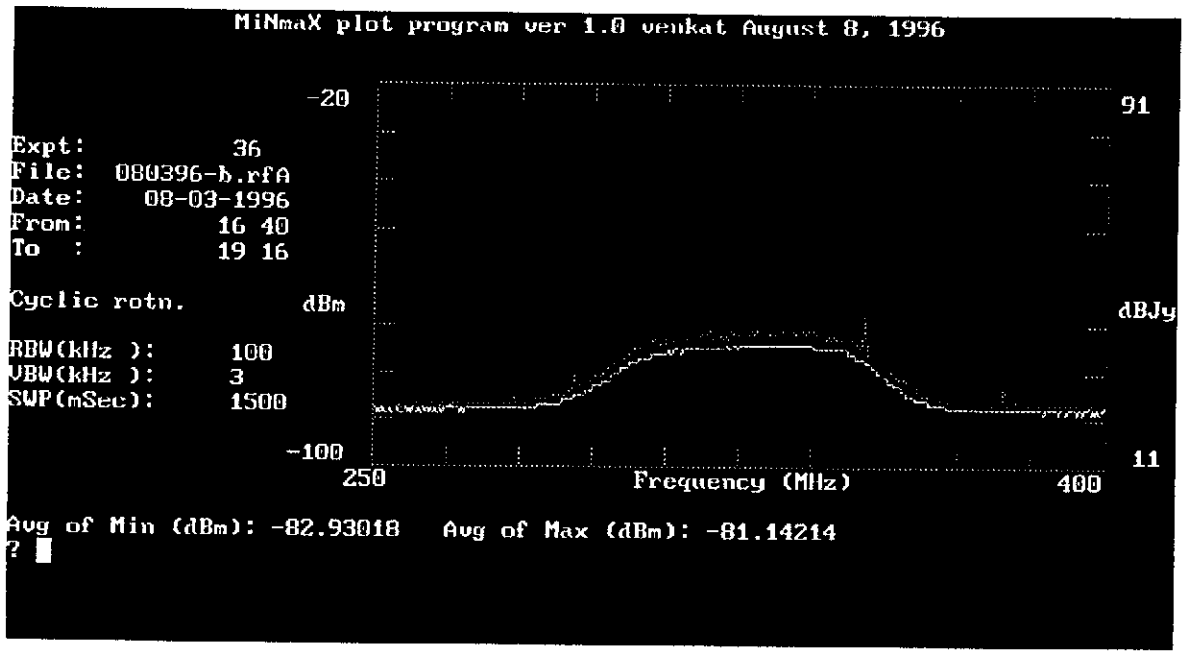
(b) 160 - 310 MHz band: The true picture of the scenario in 160-210 MHz range has not been faithfully brought out below because of rejection by the front-end system. However, the band in 230-250 MHz range is quite clean, except for a few strong lines, which should be studied in more detail for co-ordination with User Agencies. If we can move down the VHF TV transmission from Junnar (a city about 20 kilometers away), from Band 12 to say, Band 8, it should be possible to get useful observations with 16 MHz bandwidths in this band.



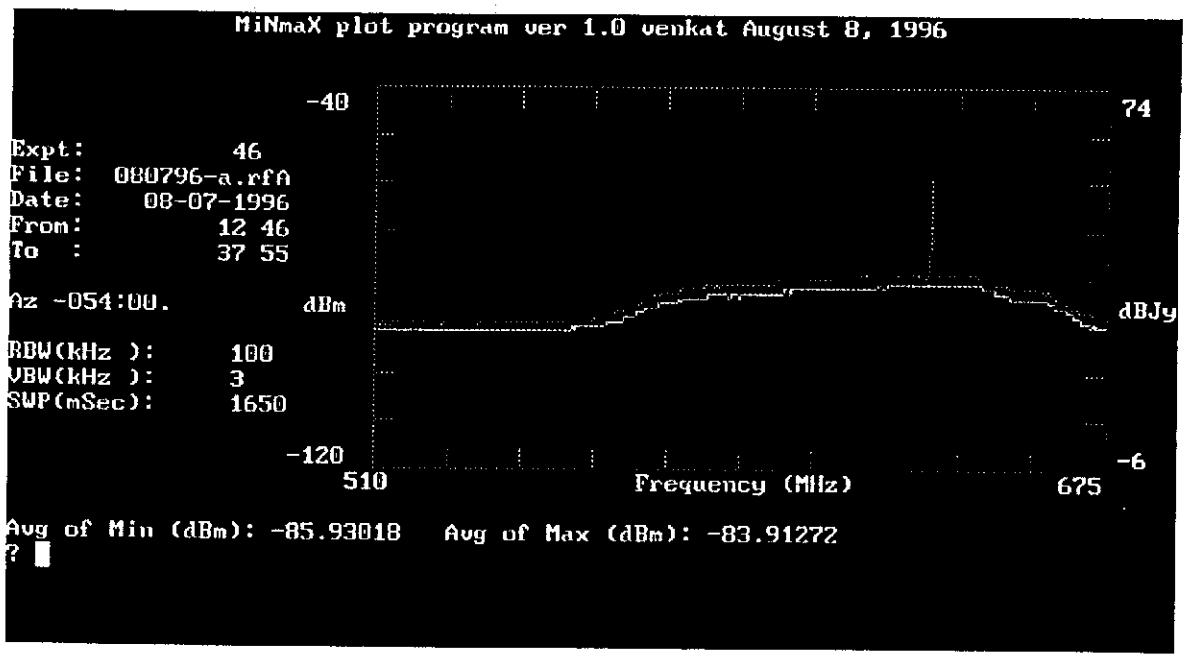
235 MHz

Annexure 7 (contd). MiNmaX plot at all RF frequency bands of GMRT

(c) 250 - 400 MHz band: It must be acknowledged that the time allotted for study in this band was a paltry 400 minutes. Part of the reason was our (hopefully!) full understanding of the band, having worked in this range for the past 25 years.

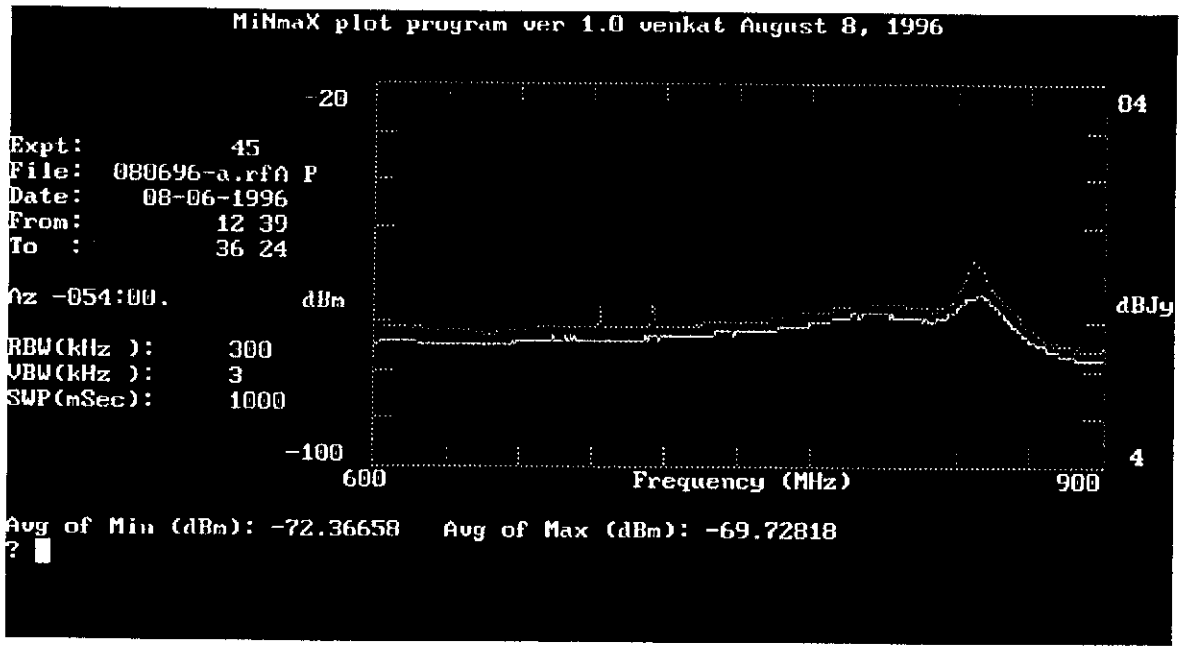


(d) 510 - 675 MHz band: As was explained in Annexure 5, the single RFI line at 636 MHz, which lasted for about 1.3% of the duration of the experiment spoiled the near-ideal picture in this band!



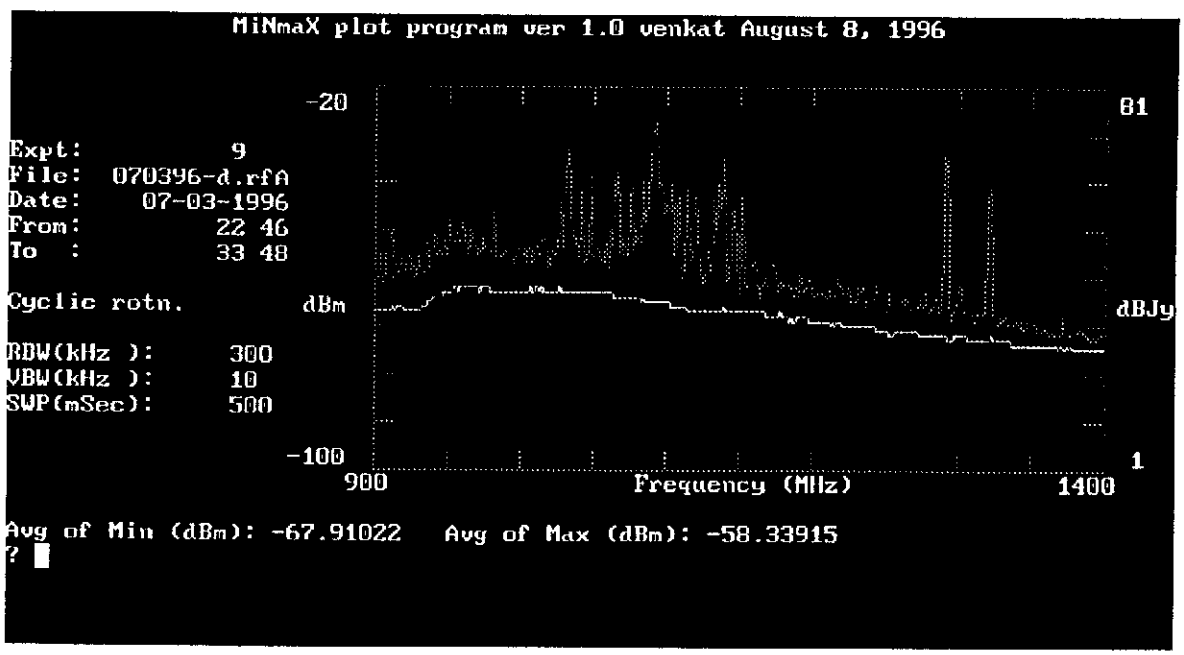
Annexure 7 (contd.) MiNmaX plot at all RF frequency bands of GMRT

(e) 600 - 900 MHz band: This band was a "Bonus" available at antenna C11 where it was installed in place of the L-band feed for a specific observation plan. There was no front-end filter to limit the band. The dBJy scale is to be read with caution, as it may be off by ± 5 dB.



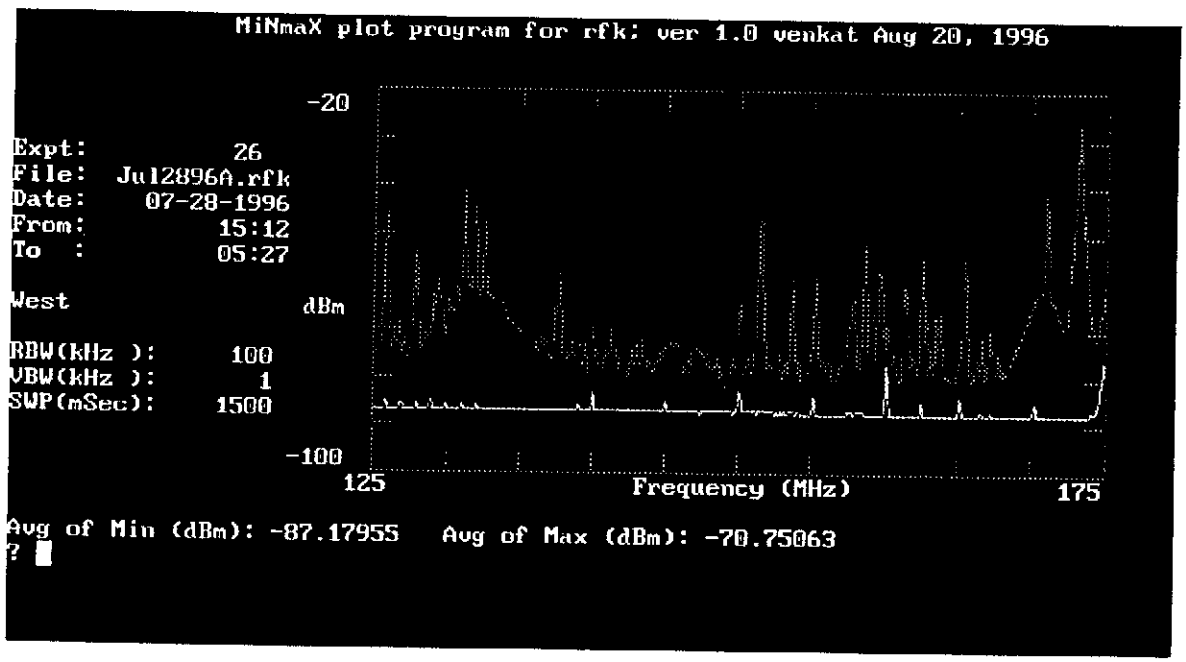
(f) 900 - 1400 MHz band: It should be remembered that the result seen below is with the spectrum analyzer in Peak-hold mode while the rest of the plots in Annexure 9 are in avaraging mode. I would not be surprised if many of the apparant lines seen below and also the relatively large difference between minimum and maximum are due to short-interval spikes at the site and will disappear if the recording is repeated in averaging mode.

The blame for not extending the upper limit of recording to atleast 1427 MHz rests solely with the author.

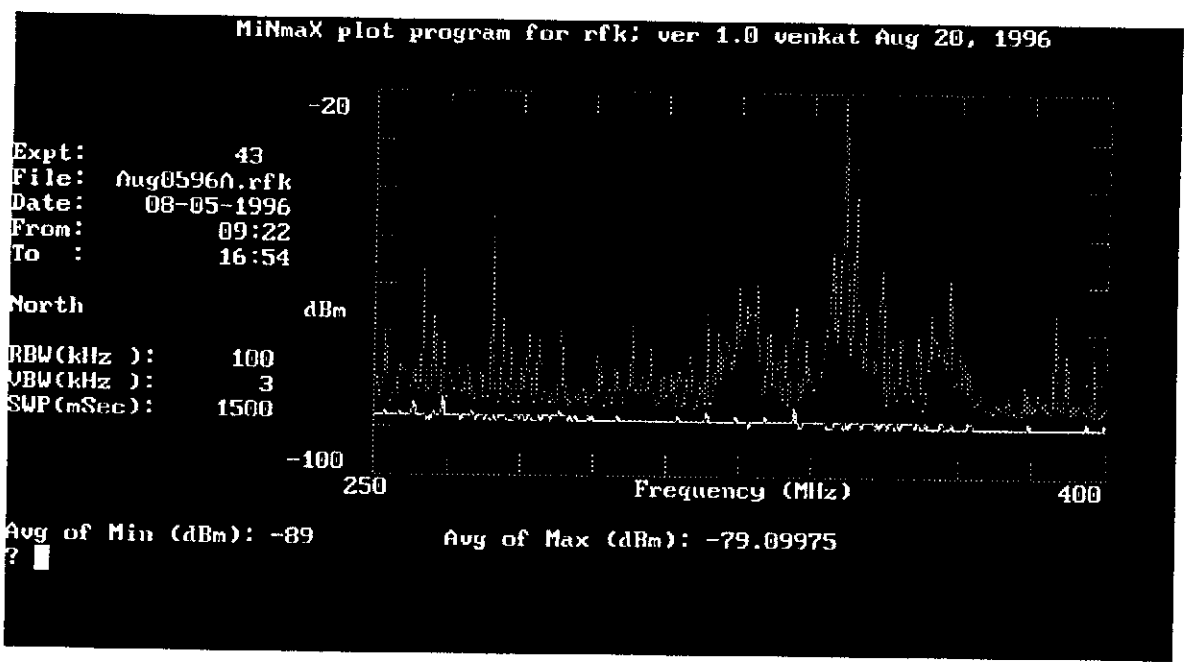


Annexure 7 (contd.) MiNmaX plot at CEB:

(g) The MiNmaX plot for an experiment conducted at the terrace of CEB in 125 to 175 MHz band, with a 2-stage MAR-6 broad-band amplifier (with out any band-limiting filter) connected to a single GMRT thick dipole is given below for comparison with similar plots on Page 6 of this report. An analysis of such simultaneous experiments will help in identifying self-produced RFI pollution.



(h) Similar plot in the frequency range 250 to 400 MHz using a 200-1000 MHz log-periodic antenna instead of the thick dipole in the above setup produced results as shown below. comparison with plot on Page 11 leads to the tentative conclusion that there is need for a LOT of cleaning up at CEB!

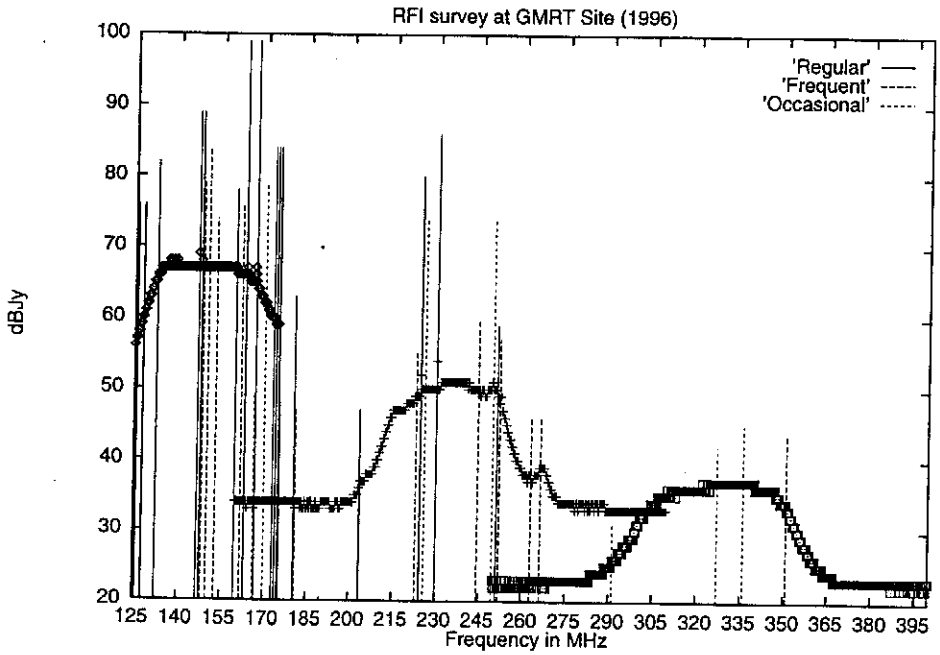


Annexure 8. Summary of the recording totaling 195 hours during June 26, 1996 to August 8, 1996 in the frequency band 125 to 400 MHz.

The grand summary of all the experiments conducted at W2 and C11 is presented with the power level normalised in all RF bands observed to dBJy. The bandshape across the frequency range is also shown by plotting the minimum power level recorded in MiNmaX file. The duration of occurrence of the RFI for each of the lines has been codified as under:

> 75% of the time: Continous line; Between 30% and 75%: Dotted line; < 30%: Dashed line.

(Regular) (Frequent) (Occasional)



Annexure 9. Summary of the recording totaling 115 hours during June 26, 1996 to August 8, 1996 in the frequency band 510 to 1400 MHz.