VLB ARRAY MEMO No. 643

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AN OVERVIEW OF THE RFI MONITORING SYSTEM

FOR THE VLBA PROJECT

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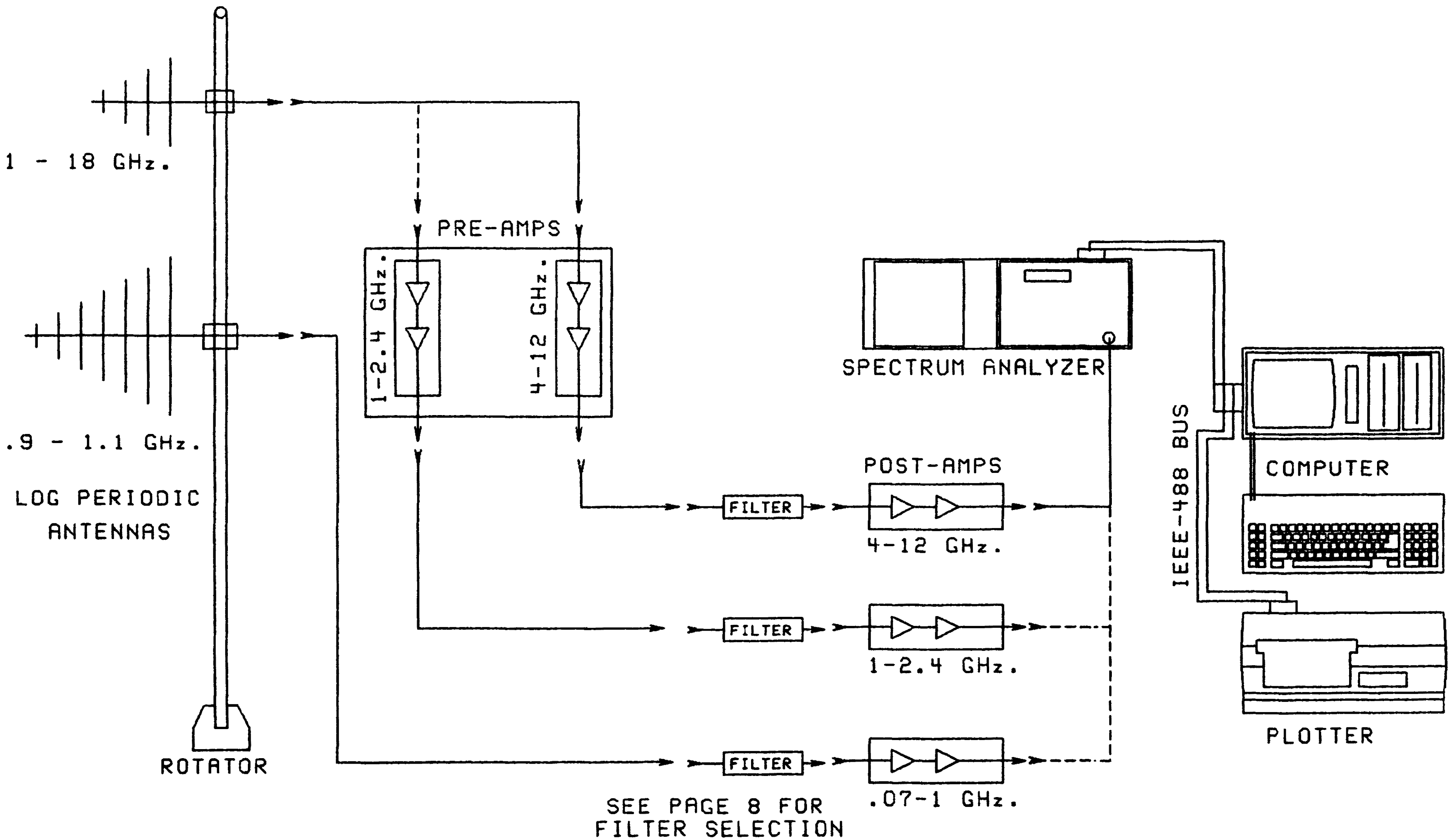
RFI MONITORING SYSTEM



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RFI MONITORING SYSTEM FOR VLBA

When the VLBA was in the planning stages, it was deemed necessary to make some type of RF measurements at the proposed antenna locations. These measurements would not only help avoid locations where the RF environment was severe, but also provide some measure of the actual RF environment at the various locations for equipment design criteria. A system had been developed for preliminary VLA site monitoring, however it was felt that to resurrect that system was not practical. A new system, modeled after the VLA system was put together and all ten proposed VLBA locations were surveyed. This report is an overview of the system.

THE HARDWARE

The monitoring system was designed around a Hewlett Packard Spectrum Analyzer Model HP8559A/HP853A. The HP8559A is a plug in unit that covers 0.01 - 21 GHz. and the HP853A Main Frame provides the display and IEEE Interface capability. Please see data sheet included with this report for more information.

Data is plotted on a Hewlett Packard two pen X-Y plotter Model HP7470A. This instrument is also equipped with the IEEE Interface Bus.

Two antennas were used to cover the frequency span of interest. These were both log periodic antennas with a gain of 8 dB. A low band antenna covered from 0.9 GHz. to 1.1 GHz. and a high band antenna covered from 1 GHz. to 18 GHz. A third antenna, a conical omni-directional with a frequency range of 1 - 18 GHz., was used on occasions when long term, non-directional monitoring was desired.

In order to increase the sensitivity and lower the noise figure of the spectrum analyzer, a combination of pre-amplifiers, filters, and post-amplifiers were use. For frequencies below 1.0 GHz., a single amplifier with a filter between the antenna and amplifier was used. The filter options are listed in an accompanying table. For frequencies above 1.0 GHz., a pre-amplifier was mounted at the antenna and a filter and post-amplifier were used at the input to the spectrum analyzer. Two amplifier selections were used. One for 1.0 - 2.5 GHz. and one for 4.0 - 12.0 GHz. Again the filter options are listed in an accompanying table.

Other various pieces of equipment were included such as a power meter and a signal generator for system calibration. An antenna rotator and control box were used to rotate the antenna. All the equipment was mounted in a 17 foot long travel trailer and towed from site to site. A 2 KW emergency generator was carried for operating where commercial power was not readily available.

THE COMPUTER

A Compaq portable computer was used to control the RF monitoring equipment. This computer is equipped with two floppy disks, expanded memory card (512K), clock and IEEE 488 interface card.

THE SOFTWARE

A software package was developed to run the system. This software was written in BASIC and after testing, it was compiled using a BASIC compiler to increase operating speed. The software allows variable length operating times without operator intervention which makes around the clock monitoring possible. The following short description explains how this software operates.

When the software was loaded, a screen allows the operator to select one of 13 standard operating modes. These modes include standard operating parameters such as antenna gain, amplifier gain, bandwidth, frequency ranges, and sweep times. Once a mode is selected, it is the operators responsibility to set the manual controls properly and connect the proper antenna, filter and amplifiers. The program calculates the run time of the program from the parameters selected. Once the program is started, data is plotted on the X - Y plotter and stored on a floppy disk. No more operator attention is required until the program ends.

During operation the following events happen. Under computer control, the spectrum analyzer makes a preliminary sweep. From this sweep the scaling for the plot is derived and the X - Y axis is drawn on the plotter. The data block for the plotter is also printed at this time. A file containing this information is created and stored on the floppy disk used for data storage. While the plotter is busy, the spectrum analyzer is scanning the frequency of interest for a preset number of times in the max hold mode. When the computer has completed the plotter tasks and the spectrum analyzer has completed the proper number of scans, data is dumped from the spectrum analyzer into the computer. This data consists of 481 numbers containing the amplitude information of the spectrum analyzer display. These numbers are converted to amplitude in dBm and stored in two arrays in the computer as peak and average value. Normally some number of these data dumps are processed before actually plotting the result in order to increase the survey time. A record is created from one of these arrays, usually the peak value, after the completion of the preselected number of scans and data dumps. This record is converted to Watts per Meter Squared and plotted as one line on the plotter. This record is also saved on the data floppy disk.

The spectrum analyzer continues to scan and save data for the next record. Each successive record is handled the same way but plotted with a slight offset to produce a three dimensional plot with time as the third axis. When all the records have been plotted and recorded, the program updates the information file and shuts down. It is then up to the operator to start up a new recording session. The plotter output is usually all that is used, however the data stored on the floppy disk can come in handy to reproduce lost or damaged plots. Other data manipulating can be accomplished from the recorded data to find absolute power levels and frequencies.

CONDUCTING A SURVEY

A standard routine was established for conducting a survey at a selected site. The first problem was finding a suitable location where the trailer could be set up and power was available. Fortunately, most of the selected sites were near an existing radio astronomy facility. All equipment was set up inside the trailer and the antennas were mounted on the mast and rotator. Mast mounted amplifiers and feed lines were connected. The system was checked for operation including a quick check of amplitude and frequency calibration. Once the station was operational the actual survey started.

The normal mode of operation was to work through the VLBA operational bands, staying on each band long enough to ensure that intermittent signals were not missed. Several hours of monitoring with the antenna pointing in one direction usually was sufficient. Four plots of each band were normally made with the antenna pointed in four different directions. If signals were present, the approximate direction was determined and noted on the plot. A few more hours were usually spent looking around each band for unusual activity and identifying observed signals. An occasional long duration plot, up to 24 hours, was made when station was left unattended for extended periods.

The length of time required to conduct a complete survey is somewhat arbitrary but usually lasted about three weeks. At several of the proposed VLBA locations, alternate sites were looked at briefly. These mini surveys were completed in a few days but only included a quick look at each of the bands.

COMMENTS

This is only a brief overview of the RF monitoring system used at the proposed VLBA sites. Included are several pertinent tables and a sample of a complete survey. These survey results are available from the numbered VLB ARRAY MEMO series.

VLBA OPERATING FREQUENCIES
(From Project Book, Version 7)

VLBA Specification Summary
1989 January 1

FREQUENCIES

Band Designation *1*			Frequency Range [GHz]	Aperture Efficiency *2*	Noise Temp. [K] *3* Rcvr.	System
330	P		.312 - .342	.50	30	104
610			.580 - .640	.49	30	64
1.5	L	*4*	1.35 - 1.75	.63	7	25
2.3	S		2.15 - 2.35	.70	8	28
4.8	C	*4*	4.6 - 5.1	.72	10	25
6.1		*5*	5.9 - 6.4	.72	12	32
8.4	X		8.0 - 8.8	.71	16	37
10.7		*5*	10.2 - 11.2	.71	20	36
15	U		14.4 - 15.4	.69	30	48
23	K	*4*	21.7 - 24.1	.66	60	87
43	Q		42.3 - 43.5	.51	90	125
89	W	*5*	86? - 92?	.18	?	?

Notes: *1* MHz/GHz frequency, to 2(+) significant figures; Conventional radio (and VLA) letter codes.
2 Total aperture efficiency, including all known effects.
3 Receiver noise temperature based on lab measurements; Estimated system temperature, including all effects.
4 Initial complement, installed as antenna is completed; All standard VLBA bands except 43 GHz installed at PT.
5 Optional receivers, not included in basic Array budget. (6.1-GHz receiver would share 4.8-GHz feed; one 10.7-GHz receiver already installed at PT.)

FILTER SELECTION

These filters were used in the RF path before the final (post) amplifier. In most cases, this filter was required to reduce intermodulation from strong RF sources outside the band of interest.

FREQUENCY	FILTER
1. 73 - 75 MHz.	BP 75/5%
2. 300 - 350 MHz.	BP 325/50
3. 550 - 650 MHz.	BP 600/100
4. 1.35 - 1.75 GHz.	BP 1500/1000 or HP 1000
5. 2.15 - 2.35 GHz.	HP 2000
6. 4.6 - 5.2 GHz.	HP 4000
7. 5.9 - 6.4 GHz.	HP 4000
8. 7.9 - 11.2 GHz.	HP 6000

TABLE OF HARMFUL INTERFERENCE LEVELS

TABLE II
HARMFUL INTERFERENCE LEVELS

VLBA TUNNING RANGE	HARMFUL INTERFERENCE LEVELS (Note 1)	RFI MEASURED THRESHOLD (Note 2 & 3)	FLUX DENSITY FOR 1% COMP. (Note 4)
50 - 100 MHz.	*	-142 dBW/m^2	#
310 - 340 MHz.	-151 dBW/m^2	-149 dBW/m^2	-72 dBW/m^2
580 - 640 MHz.	-146 dBW/m^2	-143 dBW/m^2	-67 dBW/m^2
1.35 - 1.75 GHz.	-135 dBW/m^2	-140 dBW/m^2	-59 dBW/m^2
2.175 - 2.425 GHz.	*	-138 dBW/m^2	-55 dDW/m^2
4.6 - 5.1 GHz.	-120 dBW/m^2	-128 dBW/m^2	-49 dBW/m^2
4.99 - 5.0 GHz. (Sub-band)	-127 dBW/m^2	-128 dBW/m^2	-49 dBW/m^2
5.9 - 6.4 GHz.	-120 dBW/m^2	-126 dBW/m^2	-47 dBW/m^2
8.0 - 8.8 GHz.	*	-119 dBW/m^2	-44 dBW/m^2
10.2 - 11.2 GHz.	-110 dBW/m^2	-115 dBW/m^2	-42 dBW/m^2

Note 1: These levels, from VLB Array Memo No. 81, are increased by 10 dB since ground based RFI is likely to enter the antenna through 0 dBI sidelobes rather than the +10 dBI sidelobes assumed in Memo 81.

Note 2: These levels are threshold levels from Table I plots.

Note 3: These values may vary slightly from survey to survey because of minor equipment changes.
Note 4: These levels are from VLBA Electronics Memo No. 39.

* These frequency bands not included in memo 81.
# These frequency bands not included in memo 39.

Table 1-1. Model 8559A Spectrum Analyzer/180-Series Display Specifications (1 of 3)

SPECIFICATIONS

FREQUENCY SPECIFICATIONS

FREQUENCY RANGE

0.01—21 GHz

Covered in six ranges selectable by Frequency Band GHz pushbuttons (in GHz): .01-3, 6-9, 3-9, 9-15, 6-15, 12.1-21.

Tuning Accuracy

The overall tuning accuracy of the digital Frequency GHz readout in any span mode:

0.01—3 GHz < ±1 MHz ±0.3% of center frequency

3—21 GHz < ±5 MHz ±0.2% of center frequency

Digital readout resolution (included in tuning accuracy):
1 MHz

FREQUENCY SPANS (on a 10 division CRT horizontal axis)

"F" (Full Band)

Displays spectrum of entire Frequency Band selected. Tuning marker displayed in Full Band mode (becomes center frequency when Per Division mode is selected). Marker frequency is given on the digital display.

Per Division

Twenty calibrated spans from 10 kHz/Div to 200 MHz/Div in a 1, 2, 5, sequence.

Span width accuracy

Frequency error between any two points on the display is less than ±5% of the indicated frequency separation.

Center Frequency

The center frequency represented by the CRT is indicated in GHz by the digital Frequency GHz display on the front panel.

"O" (Zero Span)

Analyzer becomes a manually tuned receiver (for the time domain display of signal modulation) set to the frequency indicated in GHz by the digital Frequency GHz display.

SPECTRAL RESOLUTION AND STABILITY

Resolution Bandwidths

Resolution (3 dB) Bandwidths from 1 kHz to 3 MHz in a 1, 3 sequence. Bandwidth may be varied independently or coupled to Frequency Span/Div control. Optimum coupling (best ratio of Frequency Span/Div to Resolution Bandwidth) is indicated by alignment of markers (►◄) on both controls.

Uncoupled, the controls for Frequency Span/Div and Resolution Bandwidth may be independently set so any resolution bandwidth (3 MHz to 1 kHz) may be used with any span width (F and 200 MHz to 10 kHz/Div.).

Resolution Bandwidth Accuracy

Individual resolution bandwidth 3 dB points < ±15%, except for 3 MHz bandwidth; < ±30%

Selectivity: (60 dB/3 dB bandwidth ratio) < 15:1 for bandwidths 1 kHz to 3 MHz.

Stability (fundamental mixing; bands .01—3 and 6—9 GHz)

Residual FM: less than 1 kHz p-p for a time interval ⩽ .01 sec, 100/120 line voltages; less than 2 kHz p-p, 220/240 line voltages.

Noise sidebands: At least 70 dB down, greater than 30 kHz from center of CW signal when set to a 1 kHz Resolution Bandwidth and full video filtering (not in detent).

Video Filter

Post detection low-pass filter used to average displayed noise for a smooth trace. In the MAX position, provides a noise averaging filter with a bandwidth of approximately 1.5 Hz.

AMPLITUDE SPECIFICATIONS

AMPLITUDE RANGE

Maximum Input Levels

Total Power: +30 dBm with ≥10 dB of input attenuation
+20 dBm at 0 dB input attenuator setting

dc: ±7.1V

ac: ±10V peak

Gain Compression

Gain Compression is less than ½ dB for 0 dBm input level with 0 dB attenuation.

Average noise level:

Sensitivity (minimum discernible signal) is given by the signal level which is equal to the average noise level, causing approximately a 3 dB peak above the noise. Maximum average noise level with 1 kHz Resolution Bandwidth and 0 dB attenuation is given in the table below.

Frequency Band (GHz)	Harmonic Mode	Average Noise Level (dBm)
.01 — 3	1 −	−111
6 — 9	1 +	−108
3 — 9	2 −	−103
9 — 15	2 +	−98
6 — 15	3 −	−93
12.1 — 18	3 +	−92
18 — 21	3 +	90

Alternate IF

Regular IF [illegible] 0075 GHz. Alternate IF is available at 2.9925 GHz for all frequency bands (minimum frequency: 25 MHz).

Table 1-1. Model 8559A Spectrum Analyzer/180-Series Display Specifications (2 of 3)

Reference Level

Reference Level range: +60 dBm[1] to −112 dBm in 10 dB steps and continuous 0 to −12 dB calibrated vernier.

Reference Level accuracy: With Sweep Time/Division control in Auto setting, the optimum sweep rate is selected automatically for any combination of Frequency Span/Div, Resolution Bandwidth and Video Filter settings. Thus, the Auto Sweep setting insures a calibrated amplitude display within the following limits[2]:

Calibrator Output Accuracy
−10 dBm ±0.3 dB
35 MHz ± 400 kHz

Reference Level variation (Input Attenuator at 0 dB). 10 dB Steps: <±0.5 dB (−10 to −80 dBm)
<±1.0 dB (−10 to −100 dBm)

Vernier (0 to −12 dB) continuous: Maximum error <±0.5 dB, when read from Reference Level Fine control.

Input Attenuator (70 dB range in 10 dB steps)

Step size variation (for steps from 0 to 60 dB):
< ±1.0 dB .01 to 18 GHz

Maximum cumulative Error (from 0 to 60 dB):
< ±2.4 dB 01 to 18 GHz

Frequency Response (with 0 to 10 dB of Input Attenuation) Frequency response includes input attenuator and mixer frequency response plus mixing mode gain variation (band to band).

Frequency Band GHz	Frequency Response (± dB MAX.)
.01 — 3	1.0
6 — 9	1.0
3 — 9	1.5
9 — 15	1.8
6 — 15	2.1
12.1 — 18	2.3
18 — 21	3.0

Switching between bandwidths:[3] 3 MHz to 300 kHz, ±0.5 dB; 3 MHz to 1 kHz, ±1.0 dB.

Calibrated Display Range

Log: Expanded from reference level down:
70 dB with 10 dB/Div scale factor
8 db with 1 dB/Div scale factor

Linear: Full scale from 0.56 microvolt (−112 dBm across 50 ohms) to 224 volts (+60 dBm)[1] in 10 dB steps and continuous 0 to −12 dB vernier. Full scale signals in linear translate to approximately full scale signals in the log modes.

Display Accuracy

Log: < ±0.1 dB/dB but not more than ±1.5 dB over full 70 dB display range.

Linear: < ±0.1 division over full 8 division deflection.

Residual Responses (no signal present at input):
With 0 dB input attenuation on fundamental mixing (0.01 to 3.0 GHz) < **−90 dBm.**

Signal Identifier: A signal indentifier is provided over entire Frequency Range and in all Frequency Span/Div settings. Correct response is a 1 MHz shift to the left of the signal and approximately 6 dB lower amplitude.

SWEEP SPECIFICATIONS

SWEEP TIME

Auto: Sweep time is automatically controlled by Frequency Span/Div, Resolution Bandwidth and Video Filter controls to maintain an absolute amplitude calibrated display.

Calibrated Sweep times: 20 internal sweep times from 2 μsec/Div to 10 sec/Div in 1, 2, 5, 10 sequence.* Sweep time accuracy ±10% except for 5, and 10 sec/Div which are ±20%. Swept frequency modes use sweep times 2 msec/Div through 10 sec/Div. When operated as a fixed tuned receiver (Zero Span) the full range of sweep times (2 μsec to 10 sec/Div) may be used to display modulation waveforms.
*Except 2 sec/Div.

GENERAL SPECIFICATIONS

TEMPERATURE RANGE:

Operating: 0 °C to +55 °C
Storage: −40 °C to +75 °C.

HUMIDITY RANGE (Operating):

<95% R.H. 0 °C to +40 °C.

EMI:

Conducted and radiated interference is within the requirements of methods CE03 and RE02 of MIL STD 461A, VDE 0871 and CISPR pub'n 1, 2, and 4.

[1] Input level not to exceed +30 dBm/+20 dBm Maximum Input Levels.

[2] When switching to or from the Alternate IF, the REF LEVEL CAL should be readjusted. Without readjustment, a reference level error of approximately 1 dB may result.

[3] 30 kHz and 100 kHz bandwidth switching uncertainty figures only applicable ≤80% relative humidity.