

S-Band and X-Band Feed Bandwidth Tests

Anna Castelaz

July 27, 2006

INTRODUCTION AND BACKGROUND INFORMATION

The goal of this project was to find the frequency limitations on the bandwidths of the feeds on loan from Green Bank, 85-2 and 85-3 on the two operating bands, the S and X bands. These feeds will be used in the new instrumentation system designed by PARSEC for the 85 meter telescopes at PARI. Bands of frequencies with low return loss are essential for astronomical observation. In addition, in order to use all four available polarizations at either the S-Band or X-Band as an interferometer; a common bandwidth must be selected. Even before observations may begin, in order to configure certain components of the system, the bandwidths must be known.

The feeds were used along with a third feed, 85-1, as an interferometer at Green Bank. In a 1992 IEE proceedings article, "Design and Implementation of a Low-Noise Prime-Focus S/X Receiver System for Radio Astronomy," Norrod describes that the feeds were designed for observations for measuring the earth's rotation for navigation and standardization of timing. He continues by noting that they were optimized to 25 dB of return loss for S-Band observations from 2.2 to 2.35 GHz and X-Band from 8.2 to 8.94 GHz. It is unknown whether modifications have been made to the feeds since these tests were completed. Different types and lengths of bolts used in the feeds and differing locations of certain components suggest that modifications may have been completed. In addition, in light of the feeds length of stage time at Green Bank, verification of these bandwidths becomes even more necessary.

To test bandwidth, a signal is transmitted from the feed either into empty space or absorbent material. The reflected signal is measured as return loss, or the signal which is reflected back from the instrumentation of the feed horn. If the return loss is measured by pointing the feed horn into space, it is pointed towards a region of space known to have little radio emission. Any possible sources of outside interference must be noted. The bandwidths may be limited by these outside sources of interference, but testing in this way best mimics the limitations of the feed once located in the telescope's feed box. Laboratory tests are done in chambers coated in absorbent materials. This ensures that no outside reflections are recorded.

INITIAL PROCEDURES

We initially tested the feed horns at the S-Band in the laboratory by transmitting a 2.3 GHz signal from the feed horn to an absorbent material and recording the return loss through our Network Analyzer. We chose to begin with the S-Band tests for two reasons. First, the S-Band is already split into two polarizations, and the X-Band is not. Secondly, we had a convenient wide bandwidth source available for S-Band frequencies.

We pointed our feed horns at a 4' by 4' wall of Eccosorb VHP-18 carbon loaded urethane very high performance broadband pyramidal absorber. We constructed this mobile wall from four sections of Eccosorb and plywood for laboratory testing of the

feeds. For angles of incidence up to 50 degrees, the Eccorsorb guarantees to reflect a maximum of 45 dB of a transmitted signal at 3 GHz¹. . The feed was placed on a rolling cart so that the lowest point of the edge of the horn was 9” above the ground. The half angle of the horn is 60 degrees, so the front edge of the feed must be placed within 5.2” of the tips of the absorbent cones in order to ensure that the entire area of the transmitted signal is absorbed by the Eccorsorb. This set up is depicted in Figure 1.

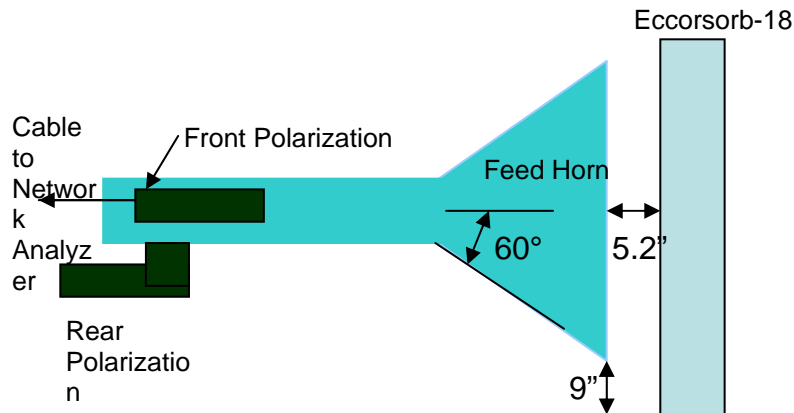


Figure 1. Testing Orientation

When completing observations, the tips of the absorbent foam cones were moved to within a few inches of the feed horn cone. This allowed for minimum reflections from sources other than the feed horn within the limitations of the feed horn’s mobility. It cannot easily be empirically tested whether any reflections were collected from the laboratory. For the following test, we have assumed that the entire reflected signal was reflected only from the feed and the entire transmitted signal absorbed by the foam.

After setting up the feed horn in front of the Eccorsorb wall, a signal was transmitted through the feed horn from the Network Analyzer. The Network analyzer transmits a broadband signal within the span necessary for 2.3 GHz analysis. In addition, it also receives and analyzes the return loss signal, producing a plot of the reflected power on a decibel scale.

When using the network analyzer, before attaching it to the feed, we calibrated it for the return loss of the cable connecting it to the feed. The analyzer internally calibrates itself to account for the return loss in the cable after we test the open cable, test a short and a 50 ohm load on the cable. We repeated this calibration process before each test.

TEST 1: Return Loss Observations at Each Polarization at 2.3 GHz

We hoped to locate an S-Band span of at least 150 MHz from which less than 1% of the transmitted signal was reflected back into the network analyzer from the feed horn at each polarization. We first wanted to verify that each polarization provided a large enough bandwidth with return loss of less than 10 dB, then hoped to verify that the

bandwidths of the polarization occurred at corresponding frequencies. This would allow us to use the telescopes as an interferometer.

The feed horn was oriented in front of the Eccosorb-18 absorbent and network analyzer calibrated as previously discussed. The return loss of the front and rear polarizations of both feed horns was measured at 2.3 GHz. The spectrum analyzer produced plots of the return loss on a decibel scale as a function of frequency. The bandwidths of these initial measurements appear in Table 1, and plots of the return loss across these spans are in Appendix 1.

FEED	POLARIZATION	START, GHz	END, GHz	SPAN, GHz
85-2	Front	1.8	3.0	1.2
85-2	Front	1.9	2.5	0.6
85-2	Front	2.05	2.55	0.5
85-2	Rear	1.8	3.0	1.2
85-2	Rear	1.9	2.5	0.6
85-2	Rear	2.05	2.5	0.5
85-3	Front	2.05	2.55	0.5
85-3	Rear	1.8	3.0	1.2
85-3	Rear	2.05	2.55	0.5
85-3	Rear	2.05	2.55	0.5

Table 1: Return Loss Measurements

For three of the four polarizations, a return loss of less than 10 dB, 1%, was recorded within significant spans of the plots. For the front polarization of 85-3, no discernable spans were recorded with return loss of less than 1%.

Ranging between approximately 2GHz and 2.5 GHz, a span with two features was apparent for the remaining three polarizations. The first feature of each was a span of about 80 MHz of a plateau region of return loss below 10dB. This was immediately followed by the second feature, a lower valley extending perhaps another 100-150 MHz. This initial assessment suggested similar S-Band bandwidths between these three polarizations, but further analysis was postponed until improvements upon 85-3's front polarization produced a similar pattern.

TEST 2: Modifications to Iris Plate Location for the front Polarization of 85-3

Next, we wanted to decrease the return loss collected by the front polarization of 85-3 at S-Band frequencies. We were able to modify the return loss pattern of the telescope by modifying the iris. Depicted in Figure 1, the iris is the width of the opening between the rectangular connection to the circular wave guide and the rectangular wave guide for each S-Band polarization. At each polarization, a spacer plate 6/32" thick with the iris opening is placed between the rectangular and circular wave guides. A thin plate 1/32" thick with a narrower open space may be used to modify the width of the iris, changing the bandwidth of the telescope. The configuration of the iris is shown in Figure 2.

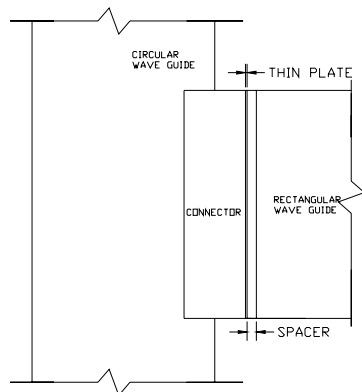


Figure 2. Iris Location: The thin plate is drawn inside of spacer plate.

This thin iris plate was located outside of the spacer plate for both polarizations of 85-2 and inside the plate for the rear polarization of 85-3. This thin plate was placed outside of the thicker plate for the front port of 85-3. The opening of the thin iris plate was narrower for each polarization than the iris width of the spacer plate, and was the same width for all of the polarizations.

We modified the location of the thin plate for the front polarization of 85-3. First we moved the thin plate from behind the spacer plate to the outside position; between the rectangular wave guide and spacer plate. Secondly, we removed the thin plate altogether.

The feed horn was oriented in front of the absorbent foam and network analyzer calibrated as previously discussed. The cable was connected to the rectangular feed guide of the 2.3 front and rear polarizations of 85-3. The S-Band signal was transmitted and return loss recorded. The network analyzer produced plots of the power on a decibel scale as a function of frequency. The bandwidths of these measurements appear in Table 2, and plots of the return loss across these spans appear in Appendix 1.

FRONT PLATE LOCATION	POLARIZATION	START, GHz	END, GHz	SPAN, GHz
Outside	Rear	1.8	2.5	0.7
Outside	Front	1.9	2.5	0.6
Outside	Front	1.9	2.5	0.6
Removed	Front	1.8	2.5	0.7
Removed	Rear	1.9	2.5	0.7

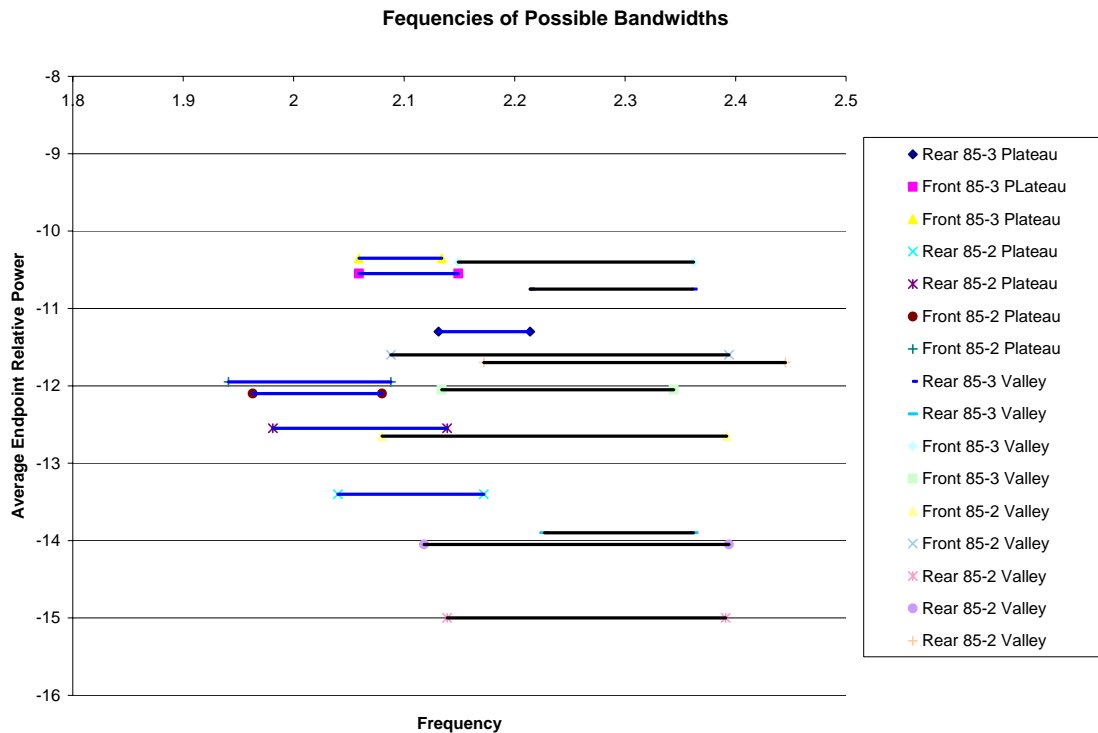
Table 2. Recorded Spans for new plate orientations

Both by moving the plate location from behind the spacer plate to the front position and by removing the plate we observed regions of low return loss for S-Band frequencies. We observed that moving the thin plate to the outside location produced low return loss a span from approximately 2.05 to 2.35 GHz. This was roughly the same span

as the other three polarizations. In addition, the plateaus and valley features noted on the other polarizations appeared in the return loss of the front polarization of 85-3 after the plate was moved to the outside location. When removing the front polarization's thin plate the span of low return loss shifted approximately 0.2 GHz lower. In addition, the plateau region was less discernable.

FURTHER ANALYSIS AND CONCLUSIONS

We decided to leave the thin in the outside position. This provided return loss for the fourth polarization with a similar span and features of the return loss for the other polarizations. Because of the two apparent features of the return loss plots, we decided to explore two possible bands of operation for each polarization. For each plot listed in Table 1, the endpoints of each plateau and valley were estimated, these endpoint frequencies were recorded, and the return loss measured at each endpoint averaged for each plateau or valley region. This data is recorded in Appendix 2, and each region is plotted at its averaged endpoint return loss in Plot 1. Note that the each measurement provided a plateau and valley region within the S-Band with between 10 dB and 15 dB of return loss.



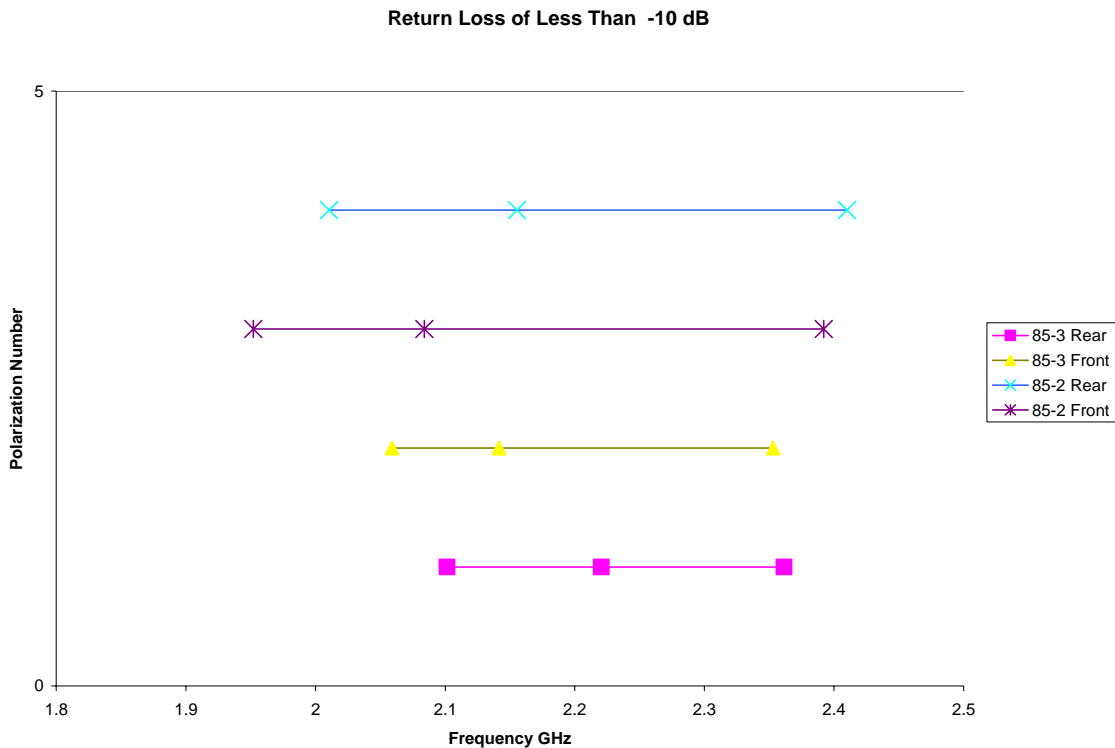
Plot 1: Frequencies of Possible Bandwidths

Next, for each polarization, the endpoints and averaged relative power of each return loss feature were averaged to create an average plateau band and valley band for each of the four polarizations. These averaged plateaus appear in Table 3 as Band 1 and the valleys as Band 2.

	Band 1			Band 2		
	Limit 1	Limit 2		Limit 1	Limit 2	
	Freq GHz	Freq GHz	Avg Power dB	Freq GHz	Freq GHz	Avg Power dB
85-3 Rear	2.102	2.221	-12.375	2.221	2.362	-12.325
85-3 Front	2.059	2.142	-10.450	2.142	2.353	-11.225
85-2 Front	1.952	2.084	-12.025	2.077	2.392	-12.383
85-2 Rear	2.011	2.156	-12.975	2.143	2.410	-13.583

Table 3: Averaged bandwidths

The spans of the averaged bandwidths in Table 3 are plotted in Plot 2. For each polarization, the first portion of the horizontal plot corresponds to the plateau region and second portion to the valley region. Notice that 85-2 has a slightly wider bandwidth than 85-3.



Plot 2: Averaged Bandwidths

It becomes questionable whether the current return loss will allow for two separate bandwidths for the telescopes, split by the plateau and valley regions of the return loss plots. Note that the plateau regions of 85-3 appear at significantly lower

frequencies than those of 85-2. The plateau regions of 85-3 rear polarization and 85-2 front polarization only overlap for frequencies spanning 0.04 GHz. One possible configuration, limited by the lower limit of 85-3 rear and upper limit of 85-3 is a single S-Band within the span of 2.10 GHz and 2.35 GHz.

RECOMMENDATIONS FOR FUTURE WORK

First, it will be necessary to complete return loss testing at 8.4 GHz. We will need to split the polarizations for the X-Band for both feed horns and obtain a source of wide X-Band frequencies before doing this.

For the S-Band, by changing the iris width it may be possible to move the spans of low return loss for 85-3 to slightly higher frequencies, aligning the peaks and valleys of all four polarizations. Further experimentations would include changing the return loss of 85-3 by modifying the iris diameter of the thin plate.

Moving the feeds to an outside location pointing into space may reduce reflections from outside sources in the laboratory. These measurements would be useful at both the S and X-Bands, and may be completed for the S-Band as soon as the feeds are more mobile. In addition, measuring the return loss once modifications are completed in the iris widths and the feeds are placed in the feed box will provide the best approximation of the operating spans of the feeds at the S-Bands and X-Bands.

REFERENCES

Norrod, Roger D., G. Behrezens, F. Ghigo, B. Levin. "Design and Implementation of a Low-Noise Prime-Focus S/X Receiver System for Radio Astronomy," IEEE Proceeding, May 1992.

Technical bulletin, Eccosorb VHP-NRL, "Very High Performance Broadband Pyramidal Absorber", Emerson & Cumming, Number EB-100, www.eccsorb.com, 26 July 2006.