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Green Bank Telescope 290 to 395 MHz Feed Analysis and Modification for Operation in the 140 to 175 MHz Band

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Green Bank Telescope 290 to 395 MHz Feed Analysis and Modification for Operation in the 140 to 175 MHz Band

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National Radio Astronomy Observatory

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ABSTRACT

A previously developed 290 to 395 MHz short backfire antenna feed for the Green Bank Telescope (GBT) has been modified for operation in the 140 to 175 MHz VHF band. The feed has been modeled with the Electromagnetic Surface Patch code, Version 5 (ESP5) software, developed at The Ohio State University (OSU) to predict the feed radiation patterns and with OSU SatCom Workbench software to predict the GBT radiation patterns. Measured feed radiation patterns are in good agreement with the electromagnetic model. This lower-frequency VHF feed is suitable for use as a receive antenna for the GBT.

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1. INTRODUCTION

The Green Bank Telescope (GBT) at the National Radio Astronomy Observatory (NRAO) site in Green Bank, West Virginia, is a 100 m diameter reflector antenna (shown in Figure 1) with prime-focus short-backfire antenna feeds within the bands 290 to 395 MHz, 385 to 520 MHz, and 510 to 690 MHz, and waveguide feeds at 680 to 920 MHz and 910 to 1230 MHz, see Reference [1]. The short-backfire antenna is described in the literature, see Reference [2]. Higher frequency operation (1.15 GHz to >100 GHz) of the GBT is accomplished with a Gregorian subreflector and feeds, see Reference [3].

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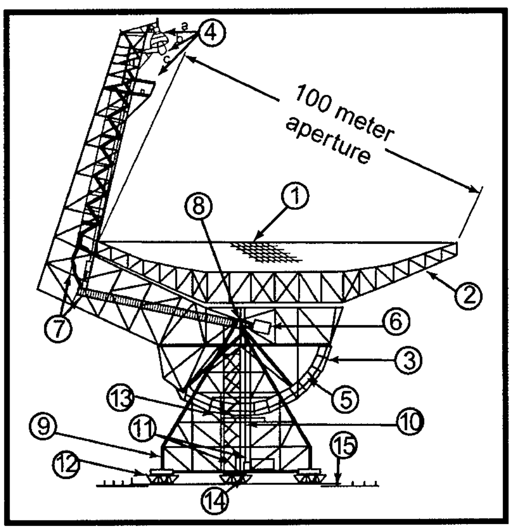
Key to Diagram

1. Primary reflector surface
2. Reflector support structure
3. Elevation wheel
4. Secondary reflector; (a) subreflector, (b) prime focus, and (c) receiver room
5. Counterweight
6. Active surface control room
7. Access way to focal point
8. Elevation bearing
9. Alidade
10. Elevator
11. Equipment room
12. Azimuth trucks and drives
13. Elevation drives
14. Pintle bearing
15. Azimuth track



Green Bank Telescope

Figure 1. Diagram and photograph of the 100 m diameter GBT located in Green Bank, West Virginia.

A recent requirement for VHF observations (140 to 175 MHz) at the GBT required a study to determine and implement the necessary antenna feed modifications or for new antenna design/hardware to support 140 to 175 MHz prime focus feed operation at the GBT.

2. FEED DESIGN MODIFICATIONS FOR 140 TO 175 MHz BAND

The primary design approach was to determine whether the existing 290 to 395 MHz short-backfire antenna (SBA) feed on the GBT, shown in Figure 2, could be modified for the 140 to 175 MHz band. The SBA feed shown in Figure 2 consisted of a crossed dipole antenna, with removable extension, mounted over a 72-inch diameter shaped ground plane along with two directors (one flat and one conical with a cylindrical rim) (see Figures A-1 through A-3). The main reflector had a central flat section with a diameter of 15.937 inches. The conical section had a tilt angle of 15° and terminated on a cylindrical rim with a height of 5.505 inches and diameter of 70.95 inches. One small, flat reflector (Reflector "B") with a diameter of 12.482 inches was located 26.639 inches above the main reflector. The other reflector (Reflector "A," shown in Figure A-3) was shaped with a central circular flat section of 6.339-inch diameter. This reflector had a conical section tilted down at a 15° angle toward the main reflector and had an outside diameter of 14.164 inches. This reflector is located at a distance of 23.129 inches above the main reflector. The antenna was excited between the main reflector and the shaped small reflector. The space between the two reflectors acted as an open resonant cavity radiating most of the energy from a virtual aperture in the plane surrounding the small reflector. The SBA was essentially a leaky cavity structure and, hence, relatively insensitive to the configuration of the exciting source. The exciting elements consisted of a resonant (one-half wavelength) crossed dipole antenna located at a distance of 13.414 inches above the main reflector. The dipoles were fed with a dual-line balun, and the desired impedance bandwidth was achieved with an open-sleeve configuration simulated with upper and lower sleeve plates.

The exciting elements of the existing GBT 290 to 395 MHz feed had removable dipole tubing extensions (outside diameter 1.18 inches, length 3.942 inches), and the total dipole length was 17.1 inches tip to tip. Thus, the 290 to 395 MHz dipole varied in electrical length from 0.42λ to 0.57λ. As will be shown, by replacing the 3.942-inch extension with a 12-inch extension the resonance of the dipole could be lowered to the 140 to 175 MHz band (new dipole length = 32.4 inches tip to tip). Thus, in the 140 to 175 MHz band the new dipole electrical length varied from 0.38λ to 0.48λ. The fixed balun length was approximately 12.8 inches, which represented an electrical length varying from 0.29λ at 290 MHz to 0.43λ at 395 MHz. Because the balun length was fixed (unless the entire feed was redesigned), the balun electrical length was 0.15λ and 0.19λ at 140 MHz and 175 MHz, respectively, which would be expected to provide adequate bandwidth performance.

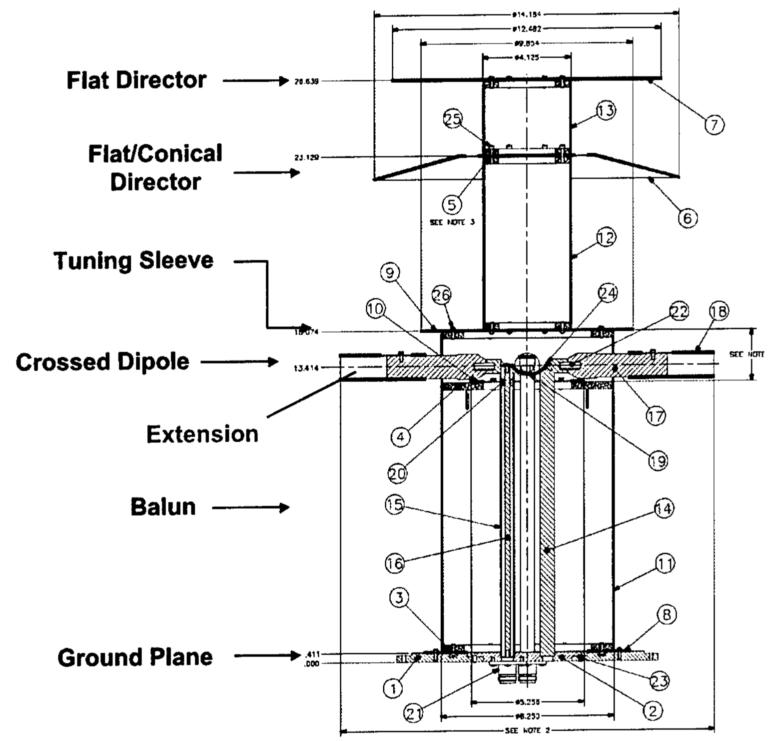


Figure 2. Drawing of GBT 290 to 395 MHz crossed-dipole with directors and ground plane.

For experimental purposes, three lengths of dipole extension tubing (8, 12, and 16 inches)[1], shown in Figure 3, were fabricated at MIT Lincoln Laboratory and shipped to NRAO for substitution and testing (return loss and radiation patterns) with the 290 to 395 MHz GBT feed. As will be shown, the 12-inch extension shown in Figure 4 provided good performance in the 140 to 175 MHz band.

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[1] Yarde Metals, www.yarde.com, 6061-T6 DT, aluminum round drawn tube, 1.25 inch OD × 0.083 inch wall, 0.3450 lbs/ft.

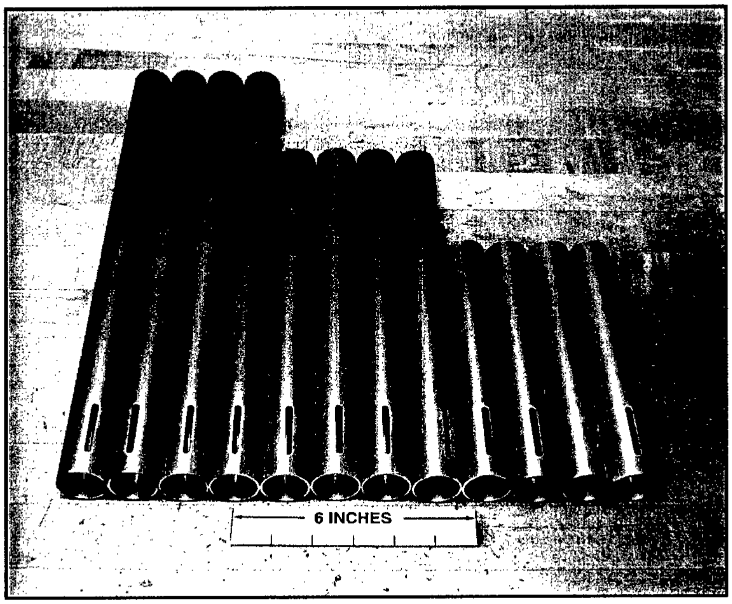

Figure 3. Photograph showing three different lengths of dipole tubing used in lowering the resonant frequency of the GBT 290 to 395 MHz feed antenna.

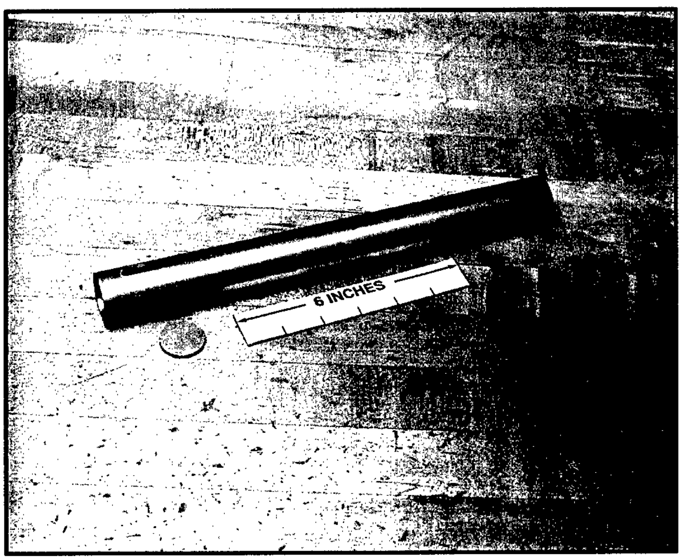

Figure 4. Photograph of the 12-inch extension used in the final configuration of the GBT 290 to 395 MHz feed antenna modified to operate in the 140 to 175 MHz band. The slot (left-hand side of the tube) was used in making a fine adjustment in length.

3. RESULTS

3.1 MEASURED RETURN LOSS

Figure 5 is a photograph of the GBT prime focus feed antenna showing the 12-inch dipole extension in the horizontal position, forming a 32.4-inch dipole for the 140 to 175 MHz band. The vertical dipole is the original dipole antenna element for the 290 to 395 MHz band. In this configuration, if the horizontal dipole antenna feed was rotated horizontally in azimuth, this would correspond to the antenna E-plane (E_θ component). When the dipole feed antenna was rotated to the vertical position and the antenna rotated horizontally in azimuth, this corresponds to the antenna H-plane (E_φ component).

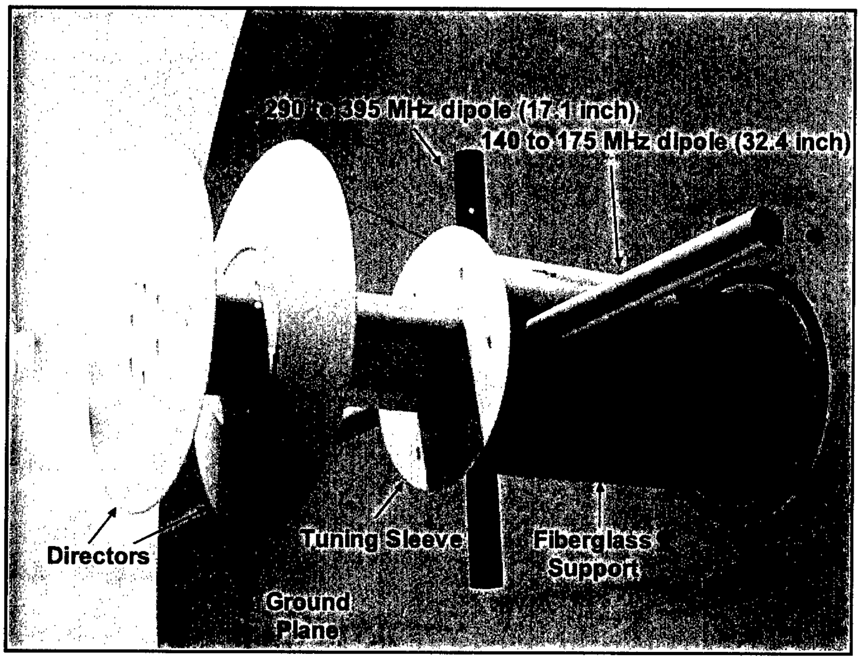

Figure 5. Photograph of GBT 290 to 395 MHz feed antenna with 12-inch dipole extension for 140 to 175 MHz band.

The measured return loss (–20 log R, where R is the reflection coefficient) for the modified feed over a 100 to 200 MHz (10 MHz per division) band, using a 32.4-inch dipole, is shown in Figure 6. Good performance over the 140 to 175 MHz band was demonstrated[2]. The impedance mismatch loss ($-10 \log (1-R^2)$), or gain loss due to mismatch, was less than 0.1 dB at 150 MHz and only 1.6 dB (corresponding to a 5 dB return loss) at the band edges. Because the return loss measurements of the 290 to 395 MHz feed antenna with 12-inch dipole extensions showed good performance over the 140 to 175 MHz band, the next step was to verify the antenna patterns.

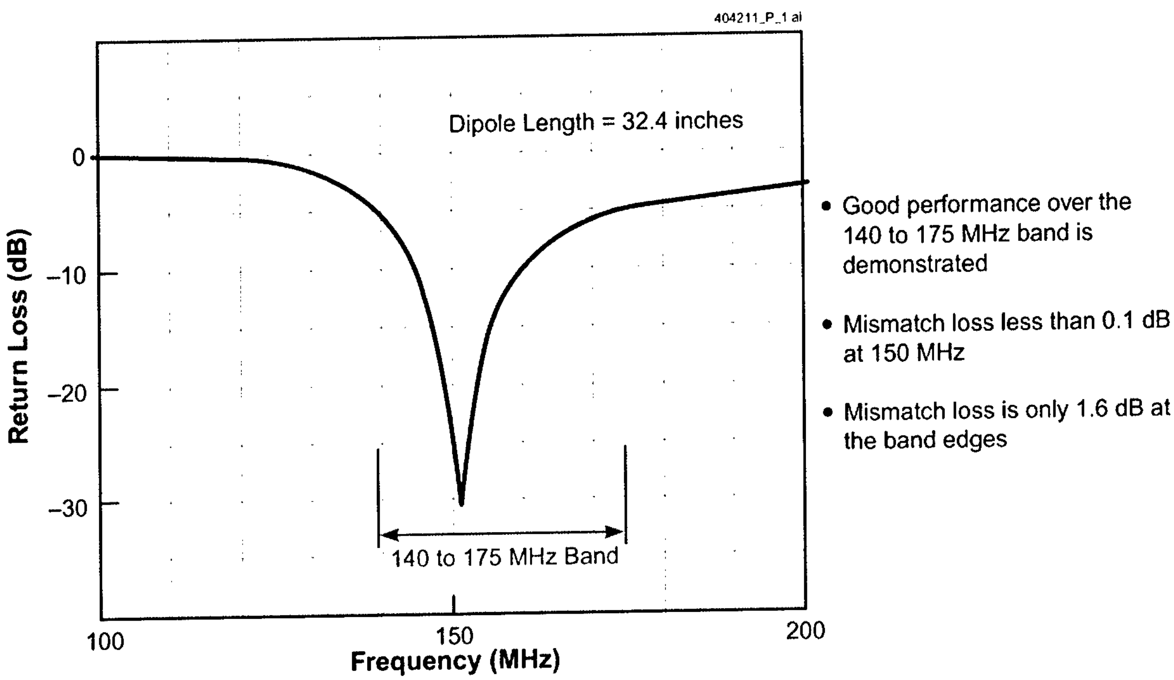

Figure 6. Measured return loss of GBT 290 to 395 MHz feed antenna with 12-inch dipole extension.

3.2 CALCULATED AND MEASURED RADIATION PATTERNS

Prior to radiation pattern measurements at Green Bank, a method of moments electromagnetic model (ASCII text data file) of the 290 to 395 MHz feed was developed at Lincoln Laboratory based on the drawings supplied by NRAO as documented in Appendix A. General-purpose moment method

[2] The dipole resonance can be moved to other frequencies by adjusting the dipole length. For example, with a total dipole length of 41.4", measurements show that the resonance is at 118 MHz with a 5 dB return loss bandwidth from 112.5 MHz to 128 MHz. Similarly, with a total dipole length of 27.8", the resonance is at 172 MHz with a 5 dB return loss bandwidth from 156 MHz to 206 MHz.

software, ESP5 (Electromagnetic Surface Patch code, Version 5) developed at the OSU ElectroScience Laboratory, was used to analyze both the existing 290 to 395 MHz feed and the new 140 to 175 MHz feed. Only radiation patterns and gain were considered; thus, only the principal structures of the feed impacting the radiation pattern were modeled (structures ignored included the balun, tuning sleeves, and fiberglass supports which would primarily affect the input impedance). Assumptions made for radiation pattern analysis were a single linear wire dipole was used to model the dipole radiator (the crossed dipole element was ignored), and the directors and ground plane were modeled using flat facets.

The ESP5 (method of moments) model of the GBT 290 to 395 MHz feed is shown in Figure 7. The feed was modeled as 2 wirè segments and 39 flat plates. The calculated antenna gain pattern for the 290 to 395 MHz feed at 342.5 MHz is shown in Figure 8 (E-plane) and Figure 9 (H-plane). The ESP5 calculated peak gain was approximately 15 dBi. The peak gain (theoretical value for a uniformly illuminated aperture of diameter D is $10 \log (\pi D/\lambda)^2$ with units of dBi) of a uniformly illuminated 72-inch aperture (size of ground plane) was 16.3 dBi. A comparison of the NRAO measured and ESP5 calculated E- and H-plane patterns is shown in Figure 10 and good agreement is observed.

The ESP5 model for the 140 to 175 MHz design is shown in Figure 11. This model consists of 2 wires for the dipole and 39 plates to model the directors and ground plane. The only change is the GBT 290 to 395 MHz dipole feed was extended to 32.4 inches. The ESP5 calculated antenna gain pattern for the 140 to 175 MHz feed at 150 MHz is shown in Figure 12 (E-plane) and Figure 13 (H-plane). The calculated peak gain was approximately 8.9 dBi. For a uniformly illuminated aperture with a 71-inch diameter, the theoretical maximum gain was 9.05 dBi.

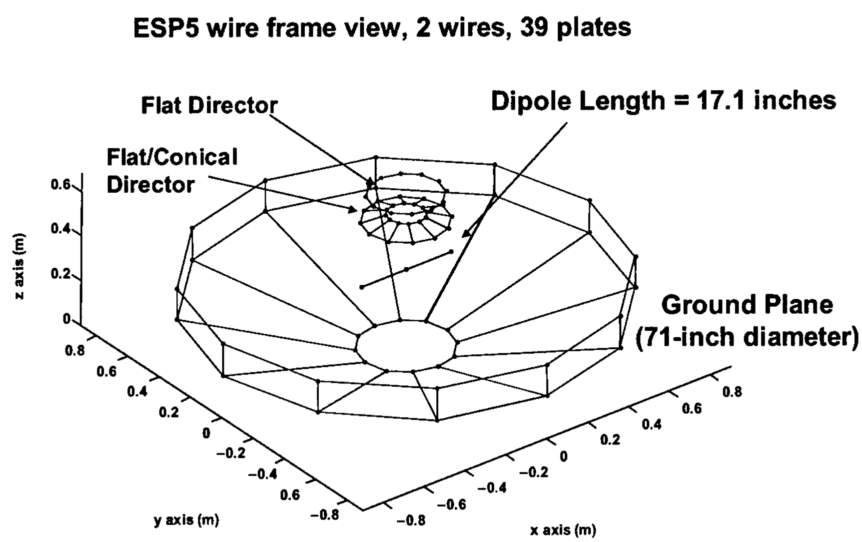

Figure 7. GBT 290 to 395 MHz feed antenna modeled with the ESP5 (methods of moments) software.

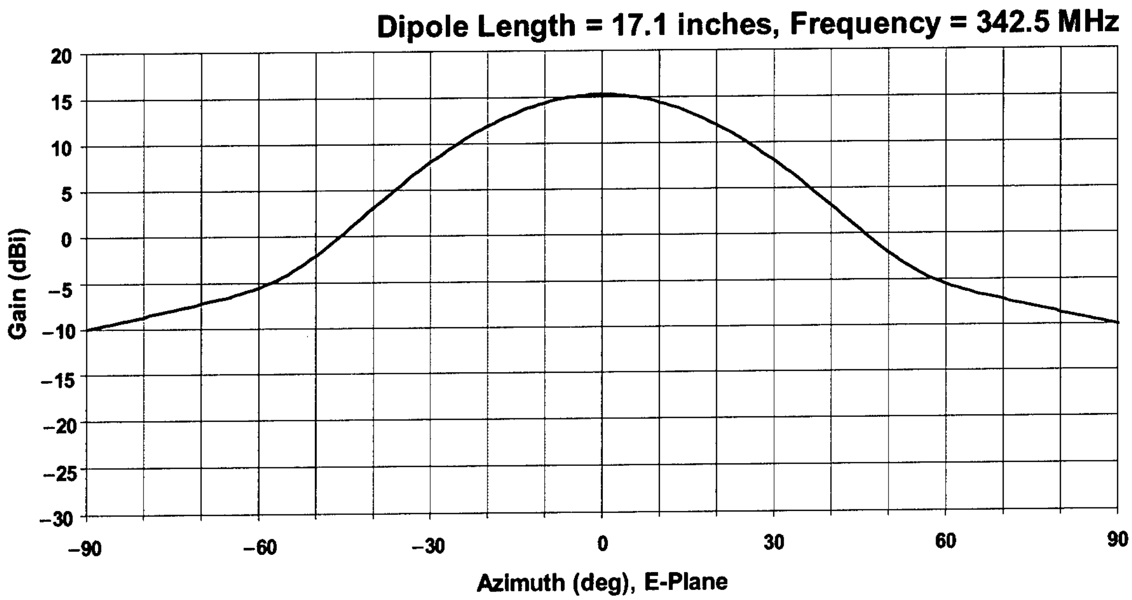

Figure 8. ESP5 calculated antenna gain pattern (E-plane) for the GBT 290 to 395 MHz feed antenna at 342.5 MHz.

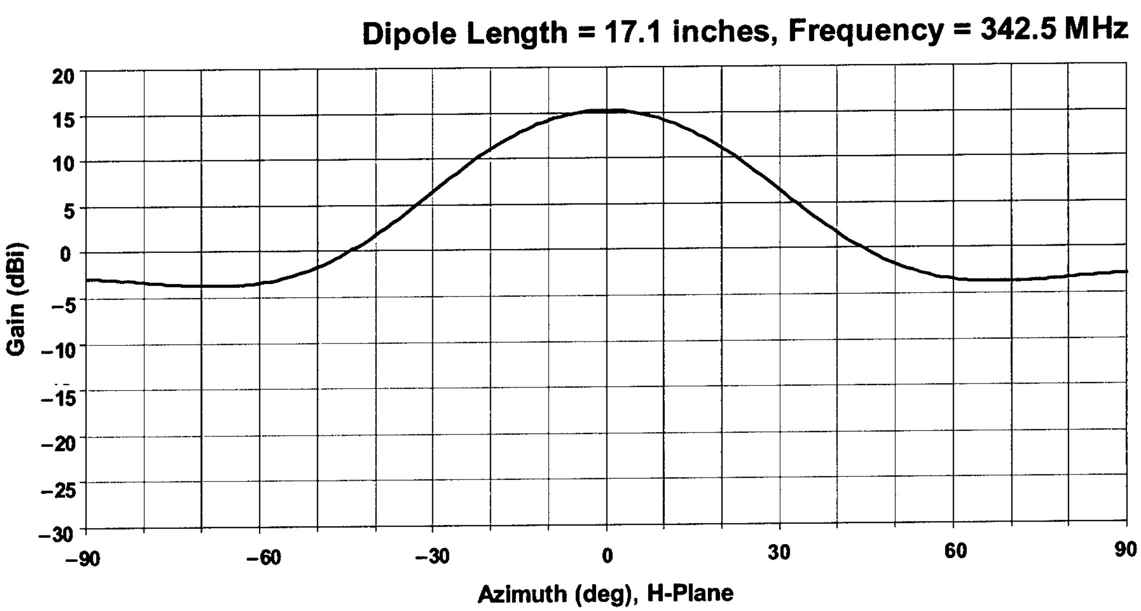

Figure 9. ESP5 calculated antenna gain pattern (H-plane) for the GBT 290 to 395 MHz feed antenna at 342.5 MHz.

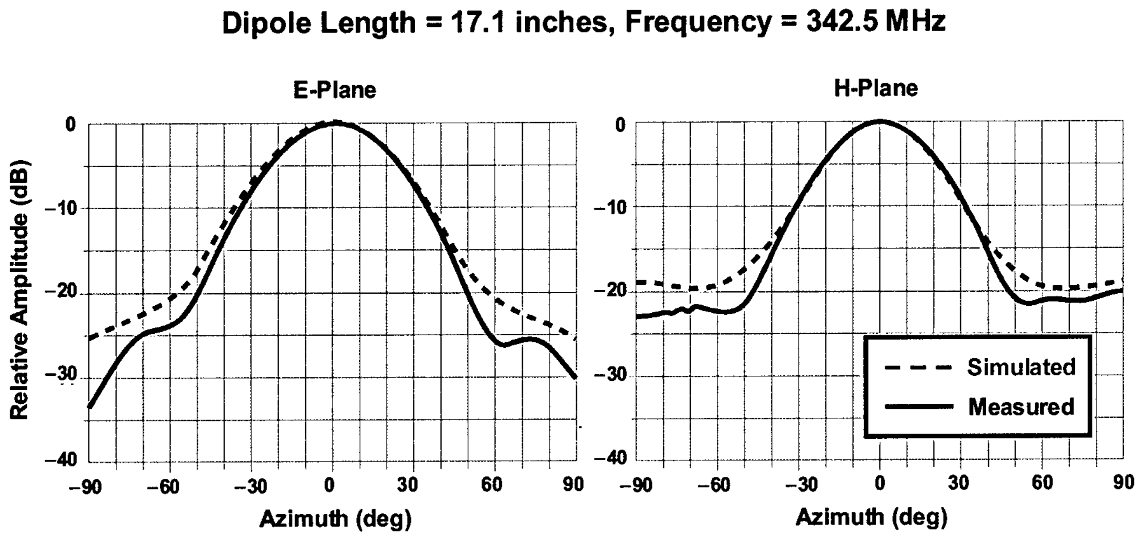

Figure 10. Comparison of measured and ESP5 calculated radiation patterns for the GBT 290 to 395 MHz feed antenna at 342.5 MHz.

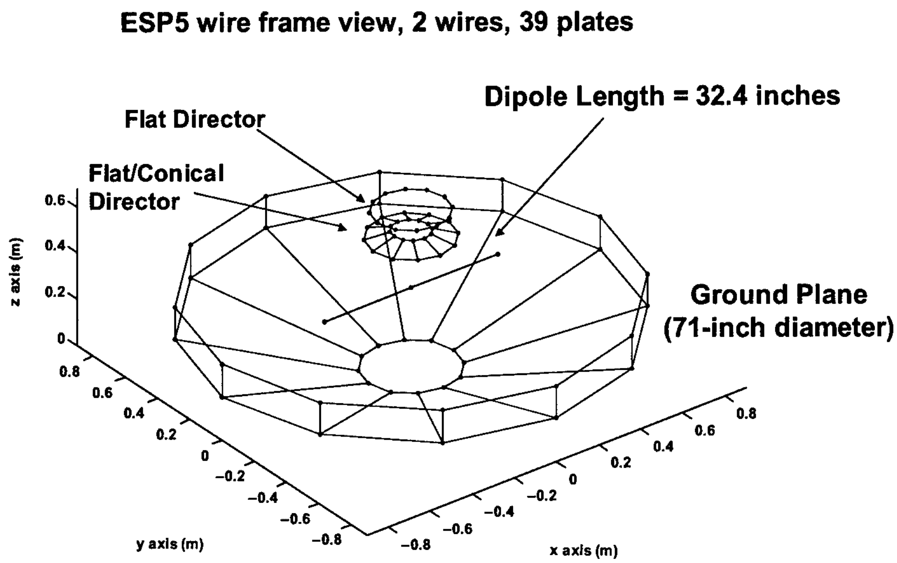

Figure 11. ESP5 (method of moments) model of the modified GBT 290 to 395 MHz feed antenna for operation in the 140 to 175 MHz band.

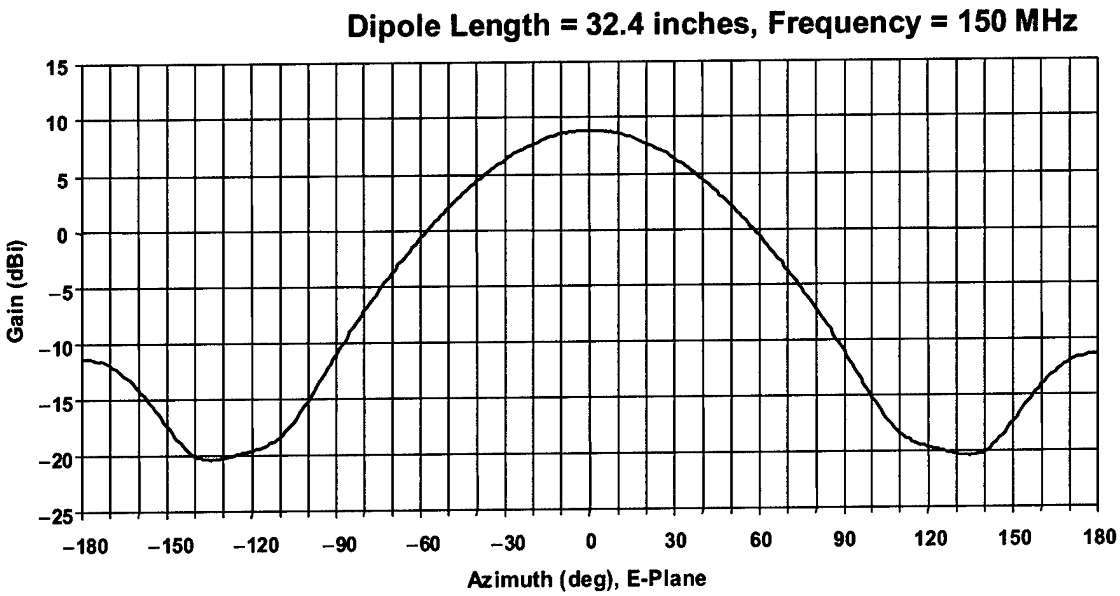

Figure 12. ESP5 calculated antenna gain pattern (E-plane) for the modified GBT 290 to 395 MHz feed antenna at 150 MHz.

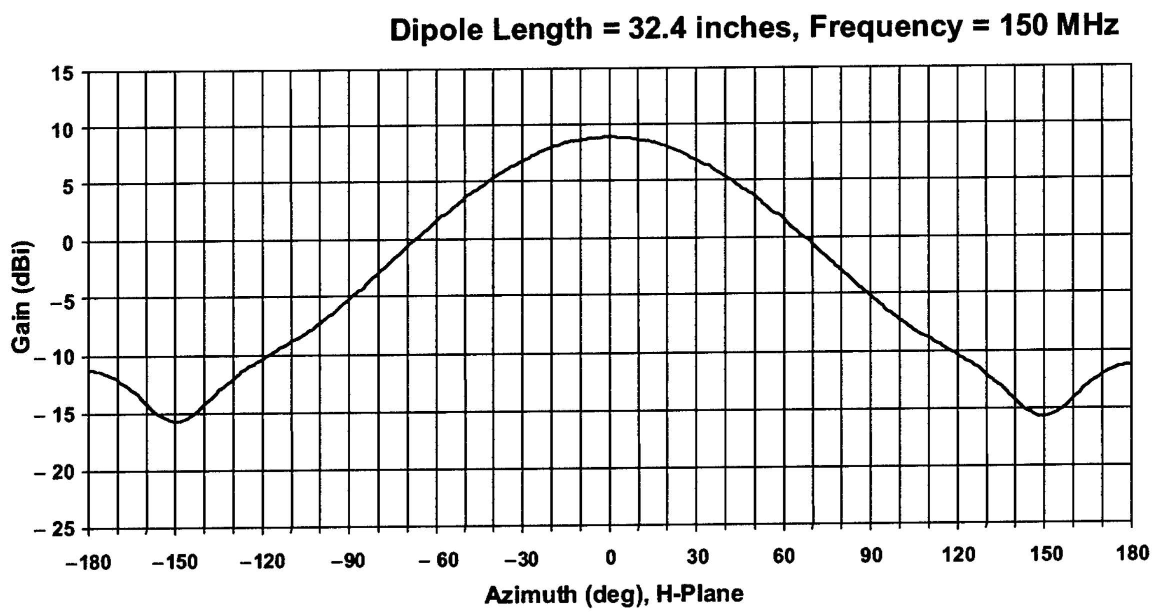

Figure 13. ESP5 calculated antenna gain pattern (H-plane) for the modified GBT 290 to 395 MHz feed antenna at 150 MHz.

Antenna pattern measurements were conducted at the NRAO outdoor antenna range in Green Bank, West Virginia, near the GBT. Figure 14 shows the GBT 290 to 395 MHz feed antenna mounted on a tower approximately 60 ft from a log-periodic source antenna. Antenna patterns were measured with the extended dipole for the 140 to 175 MHz operation. Figure 15 shows a close up of the GBT feed antenna, with the horizontal dipole extended for 140 to 175 MHz, with the GBT in the background. E- and H-plane pattern data at 140 MHz, 150 MHz, 160 MHz, and 175 MHz were recorded digitally.

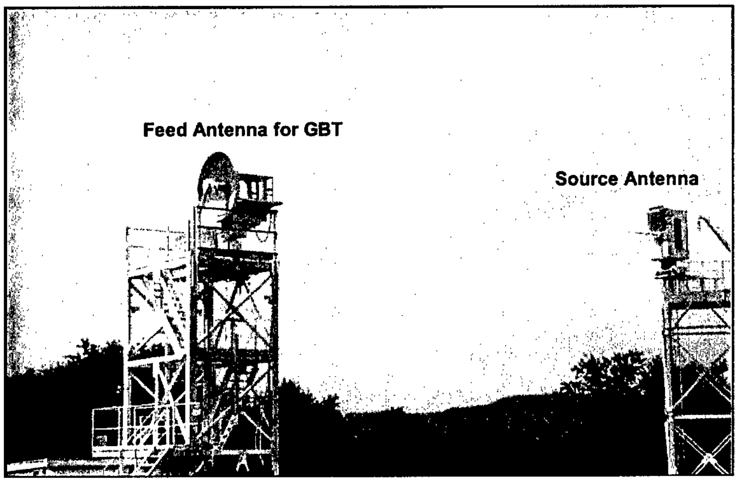

Figure 14. Photograph of antenna pattern measurements configuration at the NRAO outdoor antenna range.

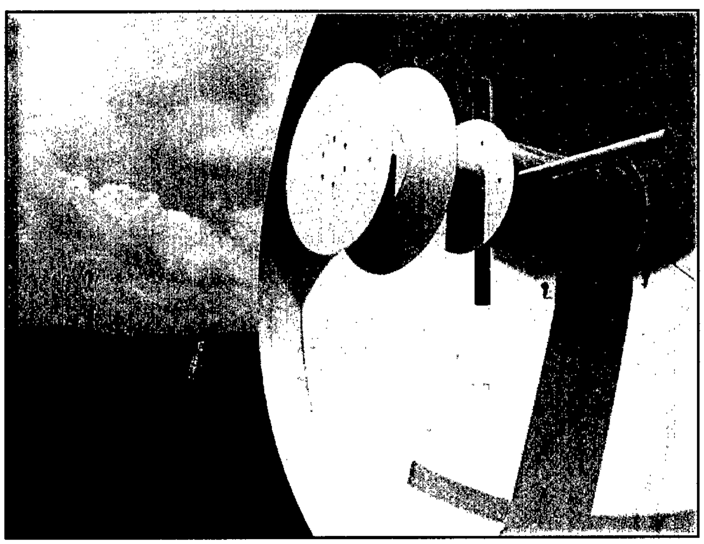

Figure 15. Photograph of the GBT 290 to 395 MHz feed antenna modified for the 140 to 175 MHz band.

A comparison of the measured and ESP5 calculated feed antenna patterns at 150 MHz is shown in Figure 16 and the agreement was good to about the –20 dB level for both the E- and H-plane patterns. Figure 17 shows the same comparison at 175 MHz and, again, the agreement is good to about the –20 dB level. The measured E- and H-plane patterns are summarized in Figures 18–25 over the 140 to 175 MHz band. Over the ±39° angle subtended by the GBT reflector, the feed pattern has good coverage indicating this feed design should produce good far field patterns for the 100 m GBT reflector—the feed edge taper varies from about 4 to 7 dB over the 140 to 175 MHz band for efficient illumination of the dish. Although not shown here, the E- and H-plane phase patterns calculated at 150 MHz using the ESP5 model indicate the phase center position is 17 inches above the ground plane. Thus, the phase center is located 3.6 inches above the dipole (shown in Figure A-1)[3].

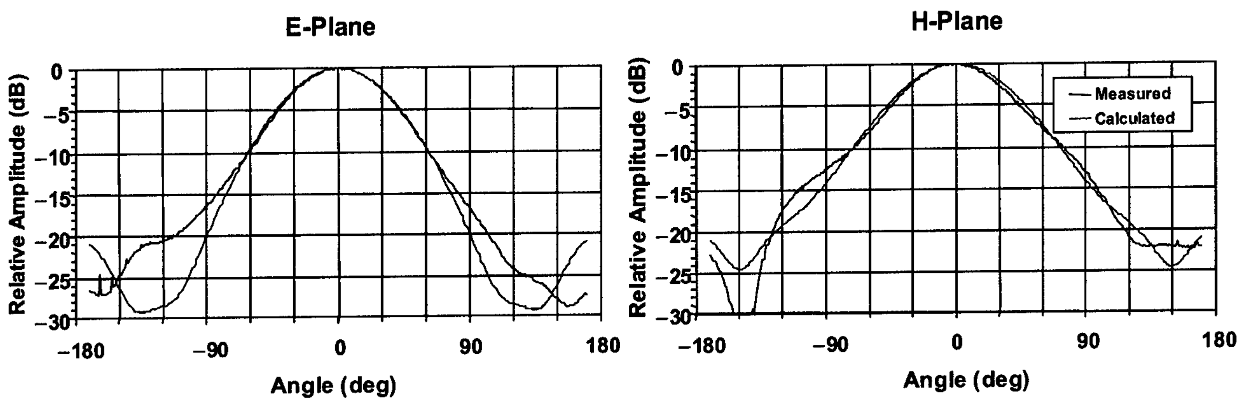

Figure 16. Comparison of measured and ESP5 calculated antenna patterns (E- and H-planes) for the modified 290 to 395 MHz GBT feed antenna at 150 MHz.

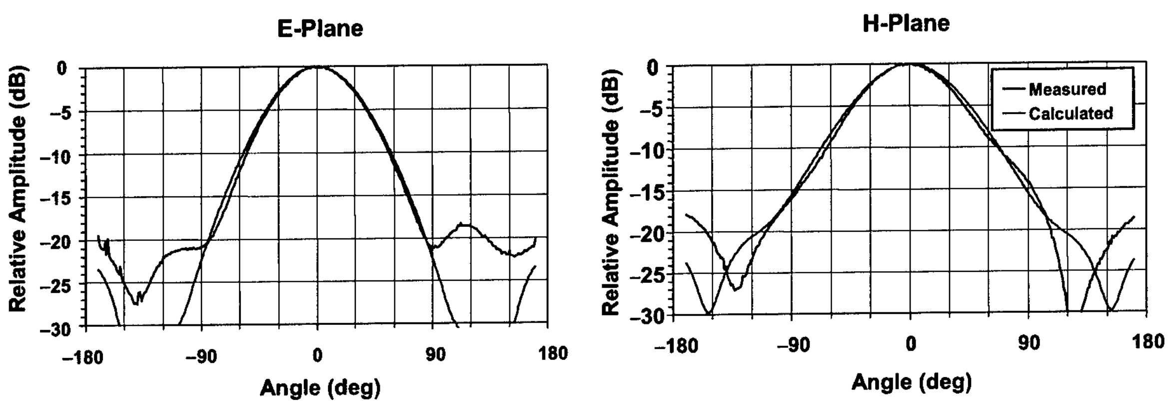

Figure 17. Comparison of measured and ESP5 calculated antenna patterns (E- and H-planes) for the modified 290 to 395 MHz GBT feed antenna at 175 MHz.

[3] In the measurements, the ground plane was mounted 2.25" behind the center of rotation.

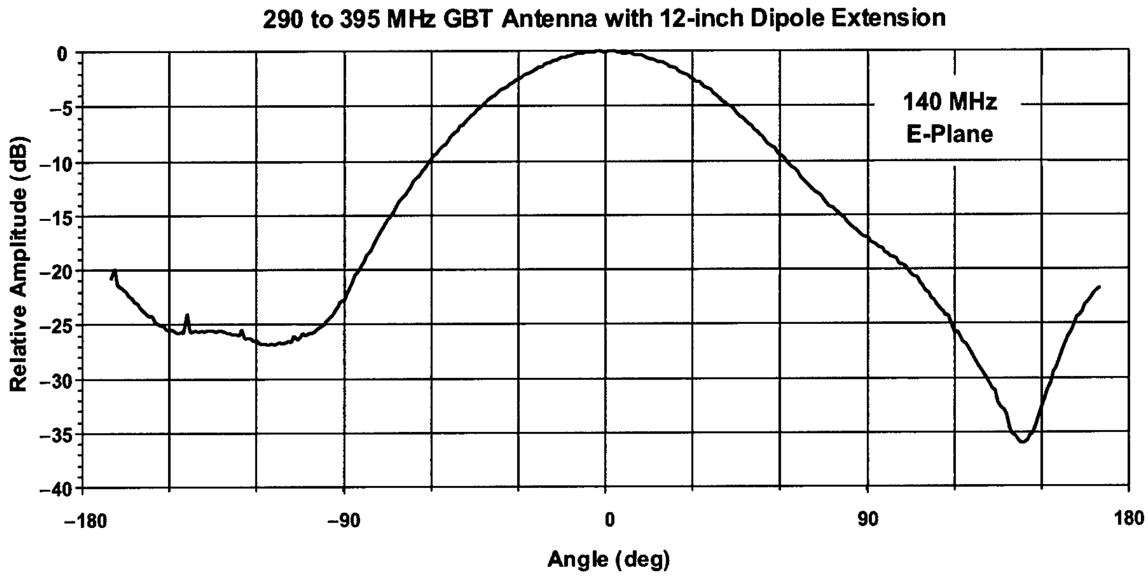

Figure 18. Measured E-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 140 MHz.

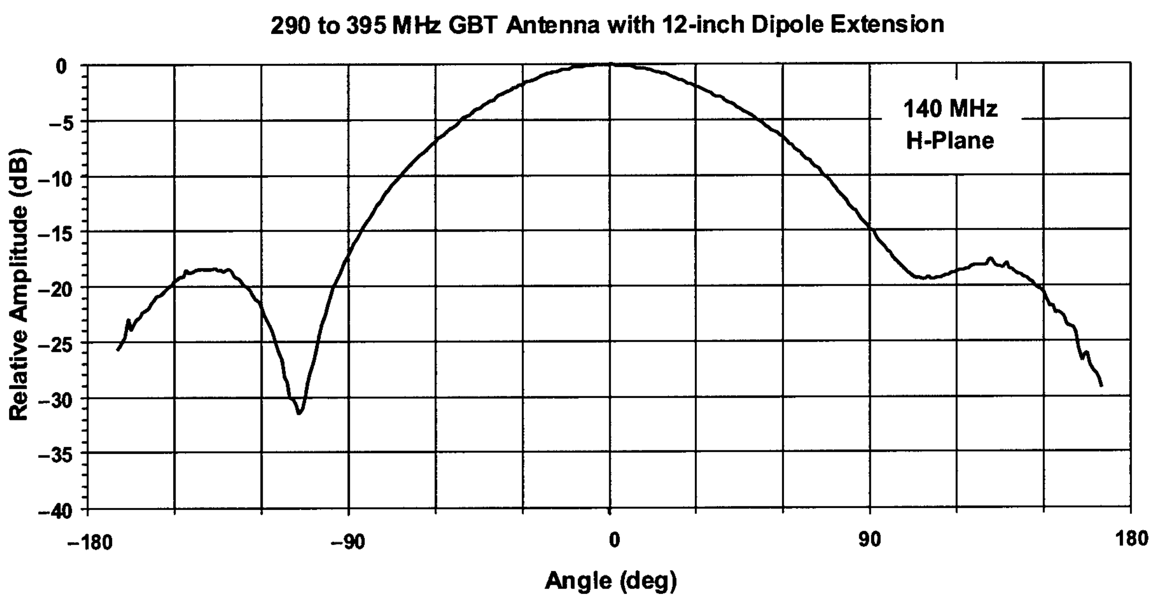

Figure 19. Measured H-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 140 MHz.

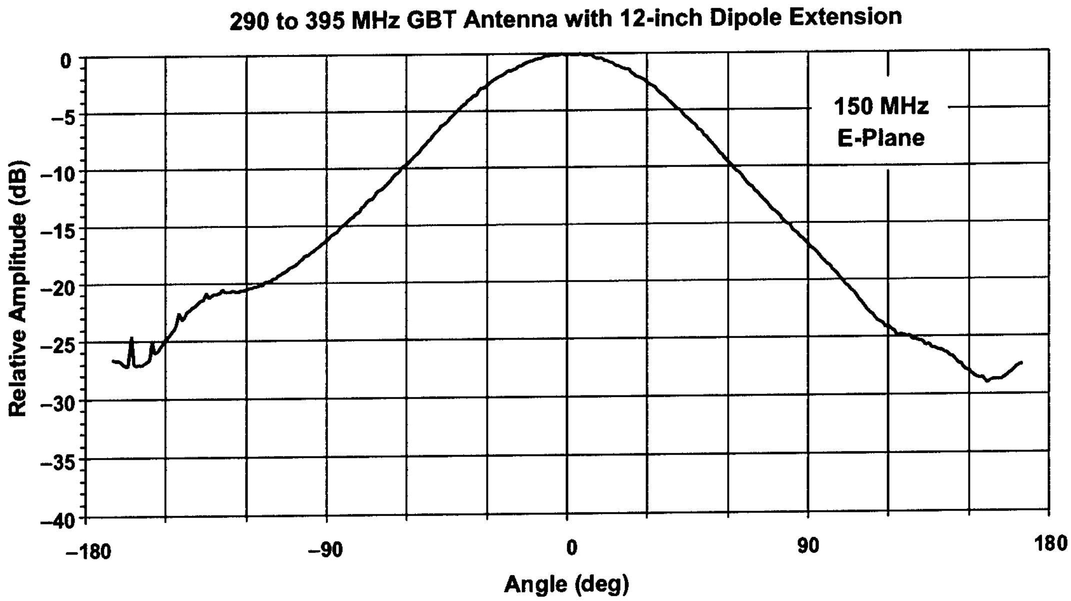

Figure 20. Measured E-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 150 MHz.

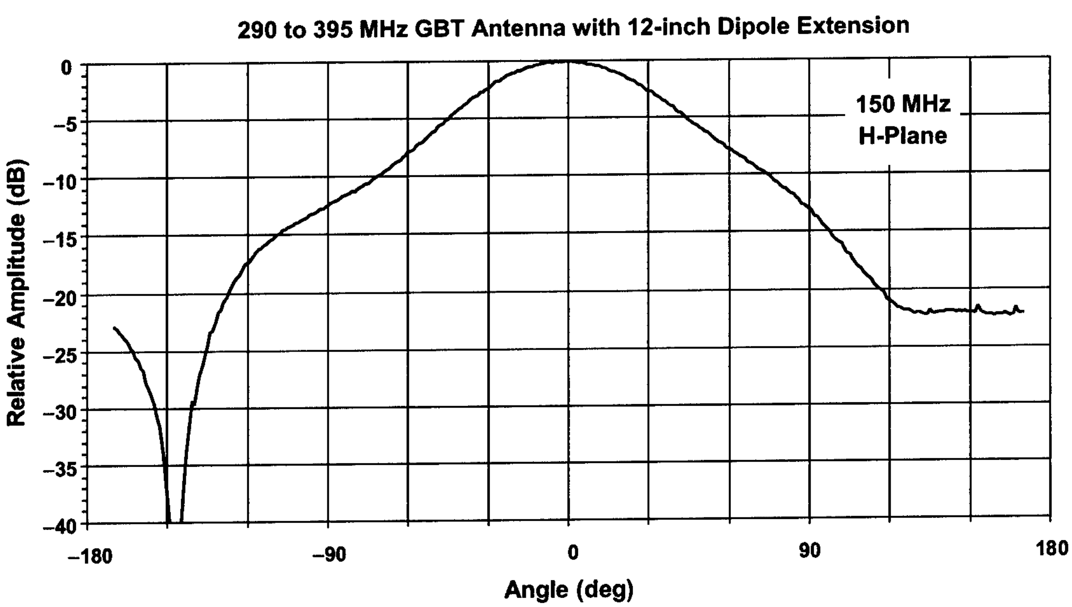

Figure 21. Measured H-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 150 MHz.

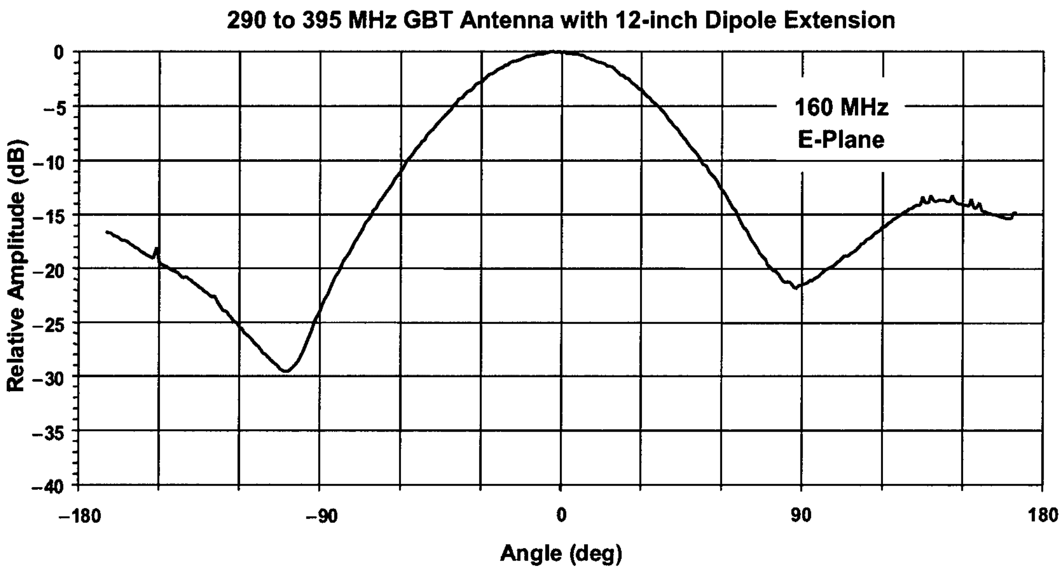

Figure 22. Measured E-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 160 MHz.

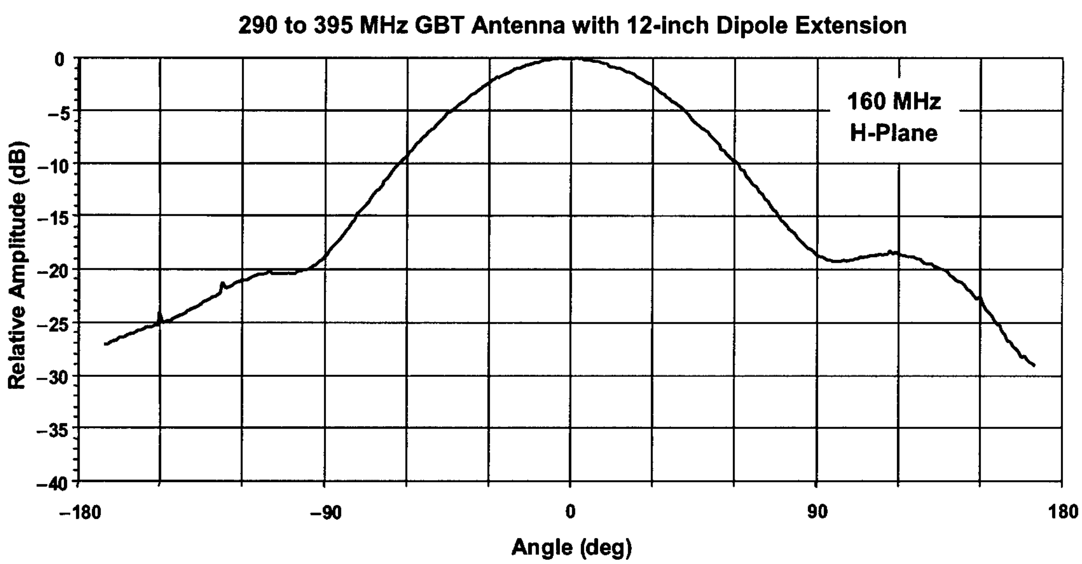

Figure 23. Measured H-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 160 MHz.

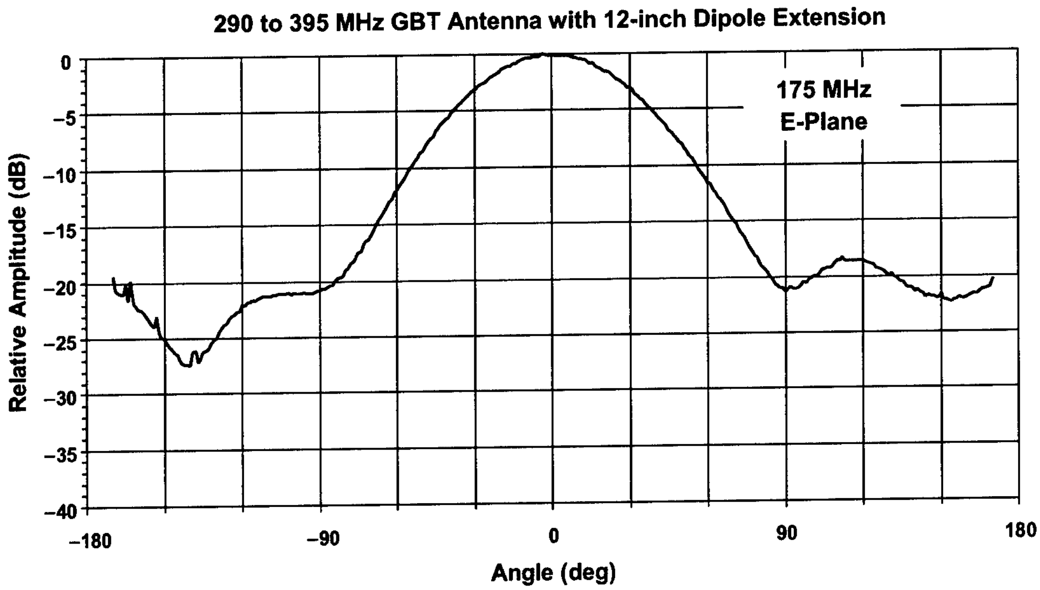

Figure 24. Measured E-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 175 MHz.

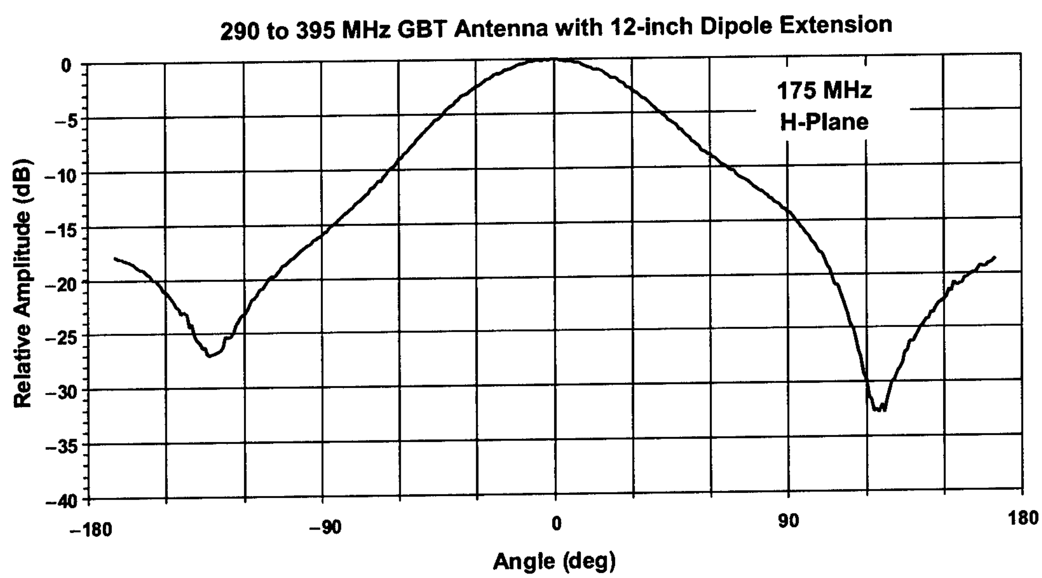

Figure 25. Measured H-plane pattern of the modified 290 to 395 MHz GBT feed antenna at 175 MHz.

The GBT primary reflector and 140 to 175 MHz feed were modeled using the OSU SatCom Workbench reflector software made available to MIT Lincoln Laboratory through consortium participation. Figure 26 shows the direct-fed reflector option used to model the GBT offset reflector parameters, shown in Figure 27. A front and side view of the OSU SatCom Workbench model of the GBT and prime focus feed is shown in Figure 28. An analytic feed pattern shown in Figure 29 was used to model the GBT 140 to 175 MHz feed at 150 MHz. The SatCom Workbench input data file for the GBT prime focus analysis at 150 MHz is included in Appendix B. A comparison of the analytic feed pattern and the measured E- and H-plane patterns at 150 MHz are shown in Figure 30 and good agreement is observed. A Gaussian beam (fast) electromagnetic analysis was selected as one of the SatCom Workbench options, and the calculated 100 m reflector pattern at 150 MHz is shown in Figure 31. The peak gain is 41.7 dBi, the 3 dB beamwidth is 1.25°, and the first sidelobes are down by 21.7 dB. A uniformly illuminated 100 m aperture at 150 MHz had a peak gain of 43.9 dBi; therefore, the efficiency (due to taper and spillover) is −2.2 dB (60% efficiency). The GBT reflector peak gain can thus be modeled in the 140 to 175 MHz band approximately as 10 log $(0.6(\pi D/\lambda)^2)$—the mismatch loss of the feed would also need to be taken into account for a more accurate estimate of the GBT gain. For a 100 m aperture at 150 MHz (50 wavelength aperture), the calculated 1.25° half-power beamwidth fits a mathematical model of approximately $62/(D/\lambda)°$.

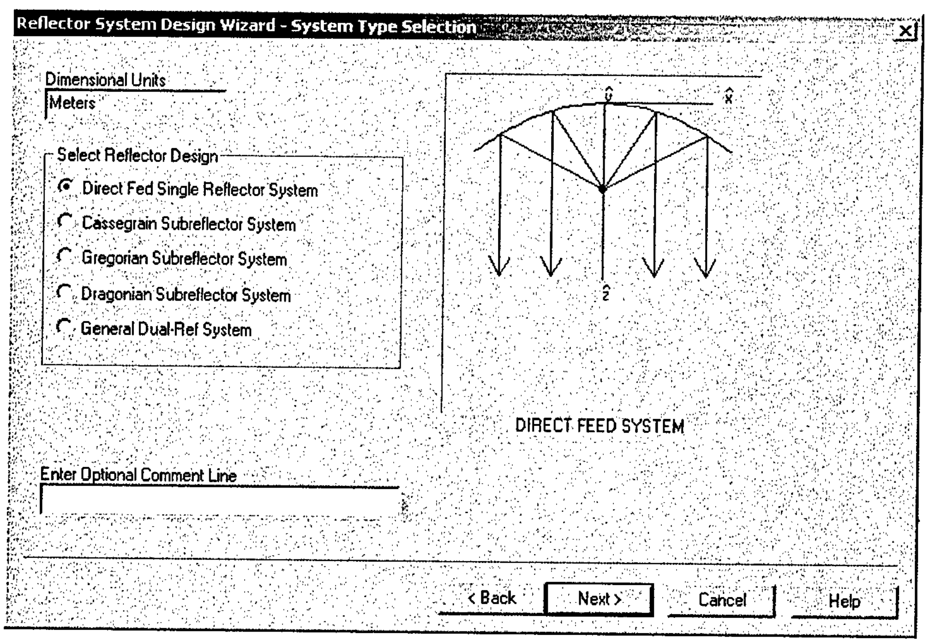

Figure 26. The OSU SatCom Workbench graphic user interface software used to calculate the antenna gain pattern of the modified GBT 290 to 395 MHz feed antenna at 150 MHz.

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Main Reflector Configuration:

Shape: Offset paraboloid

Projected diameter (*D*), m	100.0
Parent ref. diameter (D_p), m	208.0
Focal length (*F*), m	60.0
Offset of reflector center (H), m	54.0

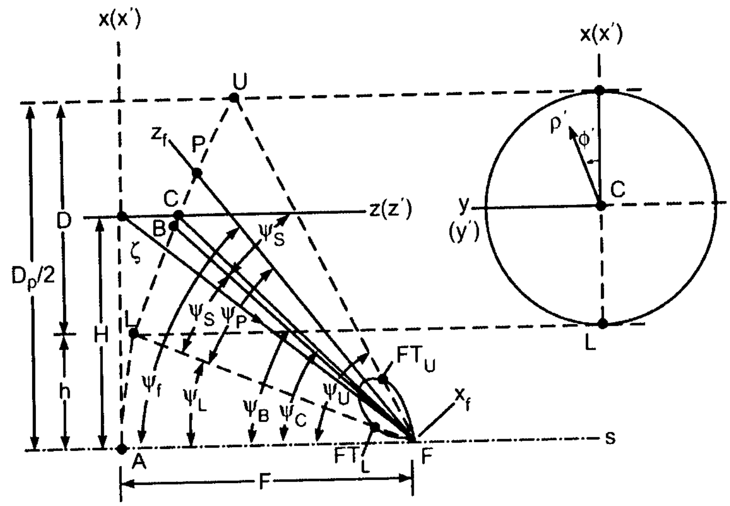

Figure 27. GBT parameters as depicted in an article by Terada and Stuzman, see Reference [4].

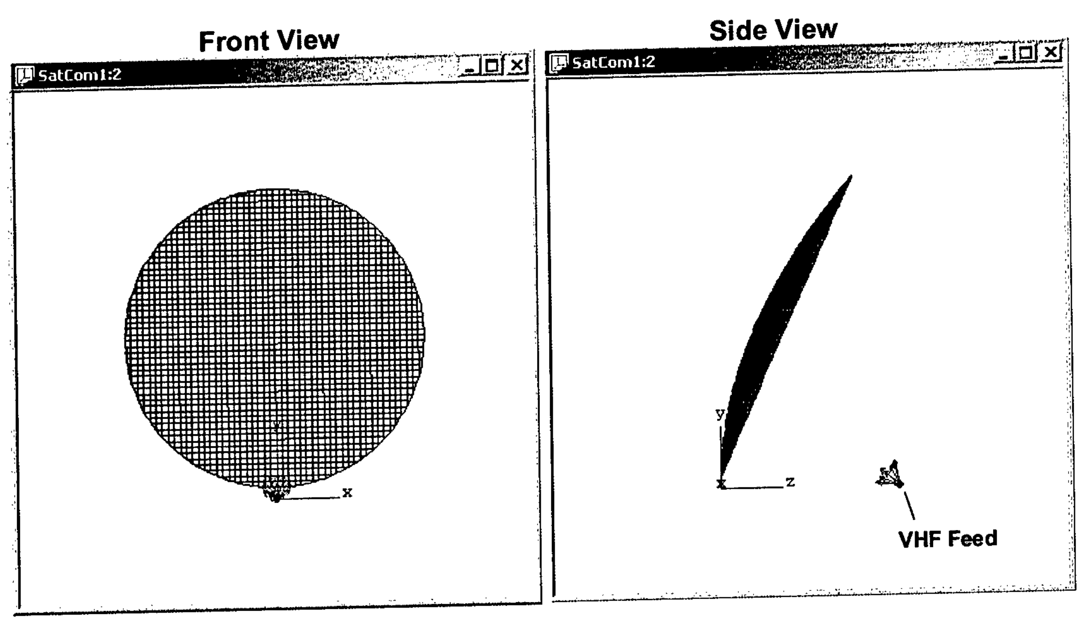

Figure 28. Screen displays for front and side views of the GBT reflector using the OSU SatCom Workbench software.

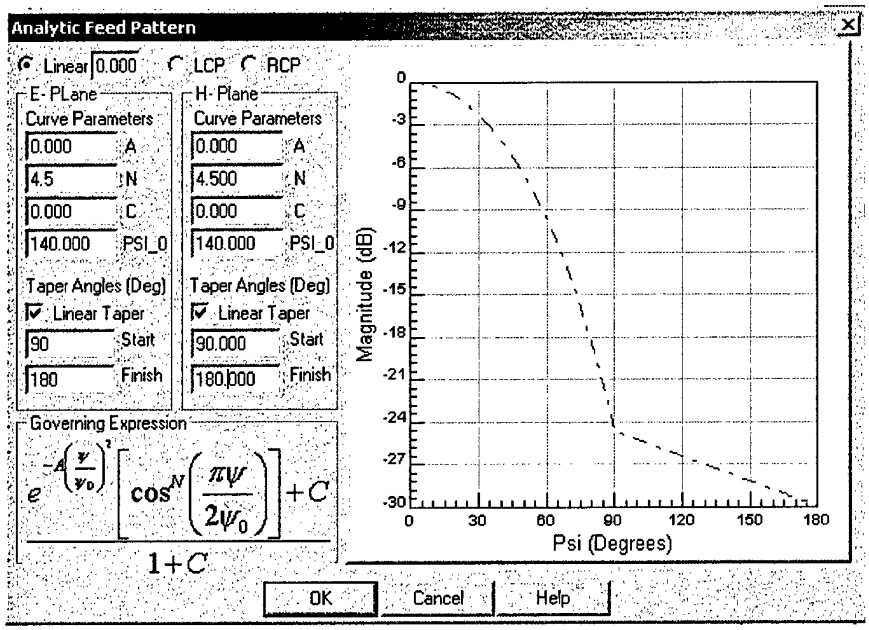

Figure 29. Screen display of the analytic radiation pattern model for the GBT 140 to 175 MHz feed antenna at 150 MHz. ψ is the angle from broadside.

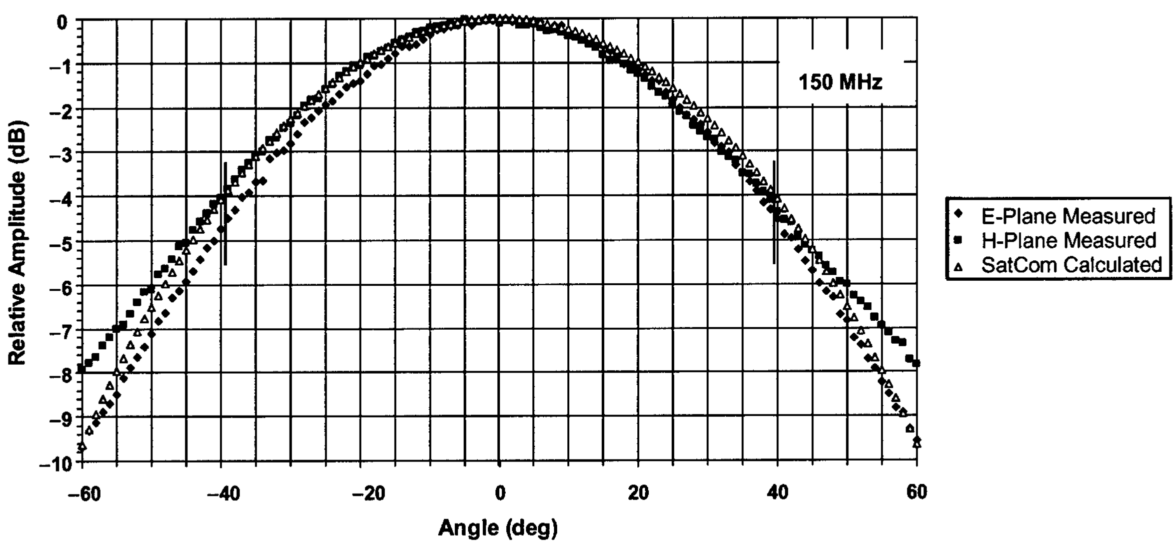

Figure 30. Comparison of measured E- and H-plane patterns with the SatCom Workbench analytic feed pattern for analysis of the GBT prime focus reflector gain patterns at 150 MHz. The vertical red lines indicate the edges of the GBT.

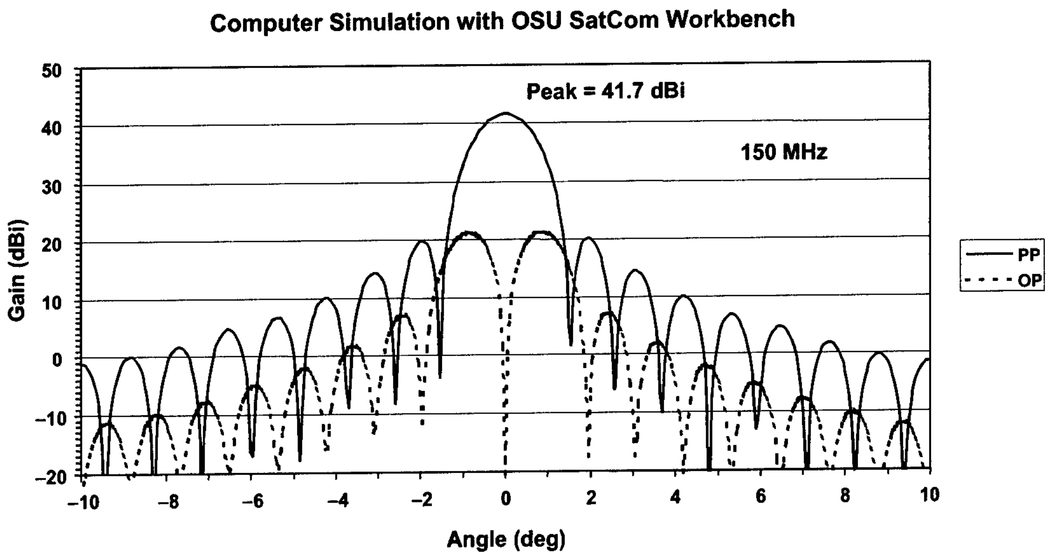

Figure 31. Calculated GBT gain pattern at 150 MHz for the modified GBT feed antenna. Principal polarization is denoted PP, orthogonal polarization is denoted OP.

4. CONCLUSIONS

A previously developed 290 to 395 MHz short-backfire antenna feed for the Green Bank Telescope was modified for operation in the 140 to 175 MHz VHF band. The modified feed replaced (if desired) the existing 290 to 395 MHz dipole extensions with a longer (12 inch) extension to tune the antenna for 140 to 175 MHz operation. In practice, the feed can be used for either 140 to 175 MHz or 290 to 395 MHz frequency coverage with dual linear polarization or circular polarization, or for simultaneous linearly polarized 140 to 175 MHz and 290 to 395 MHz frequency coverage. Additional frequency bands can readily be achieved by using different lengths of dipole extensions.

The short backfire antenna feed was modeled with OSU ESP5 software to predict the feed radiation patterns and with OSU SatCom Workbench software to predict the GBT radiation patterns. The ESP5 calculated feed radiation patterns were in good agreement with measurements at VHF and at UHF. The SatCom Workbench calculated reflector gain patterns indicated the 140 to 175 MHz feed can be used as a receive antenna for the GBT.

APPENDIX A
ESP5 GBT 140 TO 175 MHz FEED MODEL, FEED DRAWINGS, AND COMMAND FILE

Feed Model (geometry file)

REM: Auxiliary Command File: GB_VHF_geom.txt

REM: Green Bank VHF Feed Model

REM: Dimensions are in meters (x, y, z)

REM: Model generated by Alan J. Fenn, MIT Lincoln Laboratory

REM: 11 July 2003, from drawings supplied by NRAO (Figures A-1, A-2, and A-3)

REM: central section of main reflector, GB 290 to 395 MHz feed

PLC: Coor. of Central Polygonal Flat Plate No. 1

```
 12
  0.2024   0.0000  0.0
  0.1753   0.1012  0.0
  0.1012   0.1753  0.0
  0.0000   0.2024  0.0
 −0.1012   0.1753  0.0
 −0.1753   0.1012  0.0
 −0.2024   0.0000  0.0
 −0.1753  −0.1012  0.0
 −0.1012  −0.1753  0.0
  0.0000  −0.2024  0.0
  0.1012  −0.1753  0.0
  0.1753  −0.1012  0.0
```

REM: validated tilted main reflector, Green Bank 290 to 395 MHz feed

PLC: Coor. of Plate No. 2

4

0.2024	0.0000	0.0000
0.9011	0.0000	0.1872
0.7804	0.4506	0.1872
0.1753	0.1012	0.0000

PLC: Coor. of Plate No. 3

4

0.1753	0.1012	0.0000
0.7804	0.4506	0.1872
0.4506	0.7804	0.1872
0.1012	0.1753	0.0000

PLC: Coor. of Plate No. 4

4

0.1012	0.1753	0.0000
0.4506	0.7804	0.1872
0.0000	0.9011	0.1872
0.0000	0.2024	0.0000

PLC: Coor. of Plate No. 5

4

−0.1012	0.1753	0.0000
−0.4506	0.7804	0.1872
0.0000	0.9011	0.1872
0.0000	0.2024	0.0000

PLC: Coor. of Plate No. 6 = -x image of No. 3

4

−0.1753	0.1012	0.0000
−0.7804	0.4506	0.1872
−0.4506	0.7804	0.1872
−0.1012	0.1753	0.0000

PLC: Coor. of Plate No. 7 = -x image of No. 2

4

–0.2024	0.0000	0.0000
–0.9011	0.0000	0.1872
–0.7804	0.4506	0.1872
–0.1753	0.1012	0.0000

PLC: Coor. of Plate No. 8 = -y image of No. 7

4

–0.2024	0.0000	0.0000
–0.9011	0.0000	0.1872
–0.7804	–0.4506	0.1872
–0.1753	–0.1012	0.0000

PLC: Coor. of Plate No. 9 = -y image of No. 6

4

–0.1753	–0.1012	0.0000
–0.7804	–0.4506	0.1872
–0.4506	–0.7804	0.1872
–0.1012	–0.1753	0.0000

PLC: Coor. of Plate No. 10 = -y image of No. 5

4

–0.1012	–0.1753	0.0000
–0.4506	–0.7804	0.1872
0.0000	–0.9011	0.1872
0.0000	–0.2024	0.0000

PLC: Coor. of Plate No. 11 = -x image of No. 10

4

0.1012	–0.1753	0.0000
0.4506	–0.7804	0.1872
0.0000	–0.9011	0.1872
0.0000	–0.2024	0.0000

PLC: Coor. of Plate No. 12 = -x image of No. 9

4

0.1753 –0.1012 0.0000
0.7804 –0.4506 0.1872
0.4506 –0.7804 0.1872
0.1012 –0.1753 0.0000

PLC: Coor. of Plate No. 13 = -x image of No. 8

4

0.2024 0.0000 0.0000
0.9011 0.0000 0.1872
0.7804 –0.4506 0.1872
0.1753 –0.1012 0.0000

REM: rim of tilted main reflector, Green Bank 290 to 395 MHz feed

REM: plates go counterclockwise beginning with No. 14

REM: with edge at phi = 0, rim has height of 5.505 inches (0.1398 m)

PLC: Coor. of Plate No. 14

4

0.9011 0.0000 0.1872
0.9011 0.0000 0.3270
0.7804 0.4506 0.3270
0.7804 0.4506 0.1872

PLC: Coor. of Plate No. 15

4

0.7804 0.4506 0.1872
0.7804 0.4506 0.3270
0.4506 0.7804 0.3270
0.4506 0.7804 0.1872

PLC: Coor. of Plate No. 16

4

0.4506 0.7804 0.1872
0.4506 0.7804 0.3270
0.0000 0.9011 0.3270
0.0000 0.9011 0.1872

PLC: Coor. of Plate No. 17 = -x image of No. 16
4

−0.4506	0.7804	0.1872
−0.4506	0.7804	0.3270
0.0000	0.9011	0.3270
0.0000	0.9011	0.1872

PLC: Coor. of Plate No. 18 = -x image of No. 15

4

−0.7804	0.4506	0.1872
−0.7804	0.4506	0.3270
−0.4506	0.7804	0.3270
−0.4506	0.7804	0.1872

PLC: Coor. of Plate No. 19 = -x image of No. 14

4

−0.9011	0.0000	0.1872
−0.9011	0.0000	0.3270
−0.7804	0.4506	0.3270
−0.7804	0.4506	0.1872

PLC: Coor. of Plate No. 20 = -y image of No. 19

4

−0.9011	−0.0000	0.1872
−0.9011	−0.0000	0.3270
−0.7804	−0.4506	0.3270
−0.7804	−0.4506	0.1872

PLC: Coor. of Plate No. 21 = -y image of No. 18

4

−0.7804	−0.4506	0.1872
−0.7804	−0.4506	0.3270
−0.4506	−0.7804	0.3270
−0.4506	−0.7804	0.1872

PLC: Coor. of Plate No. 22 = -y image of No. 17

4

−0.4506	−0.7804	0.1872
−0.4506	−0.7804	0.3270
0.0000	−0.9011	0.3270
0.0000	−0.9011	0.1872

PLC: Coor. of Plate No. 23 = -x image of No. 22

4

0.4506	−0.7804	0.1872
0.4506	−0.7804	0.3270
0.0000	−0.9011	0.3270
0.0000	−0.9011	0.1872

PLC: Coor. of Plate No. 24 = -x image of No. 21

4

0.7804	−0.4506	0.1872
0.7804	−0.4506	0.3270
0.4506	−0.7804	0.3270
0.4506	−0.7804	0.1872

PLC: Coor. of Plate No. 25 = -x image of No. 20

4

0.9011	−0.0000	0.1872
0.9011	−0.0000	0.3270
0.7804	−0.4506	0.3270
0.7804	−0.4506	0.1872

REM: Central section of Green Bank 290 to 395 MHz Reflector “A”

REM: This plate is No. 26

PLC: Coor. of Central Polygonal Flat Plate No. 1 for Reflector "A"

12

0.0805	0.0000	0.5875
0.0697	0.0403	0.5875
0.0403	0.0697	0.5875
0.0000	0.0805	0.5875
−0.0403	0.0697	0.5875
−0.0697	0.0403	0.5875
−0.0805	0.0000	0.5875
−0.0697	−0.0403	0.5875
−0.0403	−0.0697	0.5875
0.0000	−0.0805	0.5875
0.0403	−0.0697	0.5875
0.0697	−0.0403	0.5875

REM: Tilted down section of Reflector "A", Green Bank 290 to 395 MHz feed

REM: Plates are numbered 27 to 38

PLC: Coor. of Plate No. 2

4

0.0805	0.0000	0.5875
0.1799	0.0000	0.5609
0.1558	0.0900	0.5609
0.0697	0.0403	0.5875

PLC: Coor. of Plate No. 3

4

0.0697	0.0403	0.5875
0.1558	0.0900	0.5609
0.0900	0.1558	0.5609
0.0403	0.0697	0.5875

PLC: Coor. of Plate No. 4

4

0.0403	0.0697	0.5875
0.0900	0.1558	0.5609
0.0000	0.1799	0.5609
0.0000	0.0805	0.5875

PLC: Coor. of Plate No. 5 = -x image of No. 4

4

−0.0403	0.0697	0.5875
−0.0900	0.1558	0.5609
0.0000	0.1799	0.5609
0.0000	0.0805	0.5875

PLC: Coor. of Plate No. 6 = -x image of No. 3

4

−0.0697	0.0403	0.5875
−0.1558	0.0900	0.5609
−0.0900	0.1558	0.5609
−0.0403	0.0697	0.5875

PLC: Coor. of Plate No. 7 = -x image of No. 2

4

−0.0805	0.0000	0.5875
−0.1799	0.0000	0.5609
−0.1558	0.0900	0.5609
−0.0697	0.0403	0.5875

PLC: Coor. of Plate No. 8 = -y image of No. 7

4

−0.0805	0.0000	0.5875
−0.1799	0.0000	0.5609
−0.1558	−0.0900	0.5609
−0.0697	−0.0403	0.5875

PLC: Coor. of Plate No. 9 = -y image of No. 6

4

−0.0697	−0.0403	0.5875
−0.1558	−0.0900	0.5609
−0.0900	−0.1558	0.5609
−0.0403	−0.0697	0.5875

PLC: Coor. of Plate No. 10 = -y image of No. 5

4

−0.0403	−0.0697	0.5875
−0.0900	−0.1558	0.5609
0.0000	−0.1799	0.5609
0.0000	−0.0805	0.5875

PLC: Coor. of Plate No. 11 = -x image of No. 10

4

0.0403	−0.0697	0.5875
0.0900	−0.1558	0.5609
0.0000	−0.1799	0.5609
0.0000	−0.0805	0.5875

PLC: Coor. of Plate No. 12 = -x image of No. 9

4

0.0697	−0.0403	0.5875
0.1558	−0.0900	0.5609
0.0900	−0.1558	0.5609
0.0403	−0.0697	0.5875

PLC: Coor. of Plate No. 13 = -x image of No. 8

4

0.0805	0.0000	0.5875
0.1799	0.0000	0.5609
0.1558	−0.0900	0.5609
0.0697	−0.0403	0.5875

REM: Central section of Green Bank 290 to 395 MHz Reflector “B”

REM: This plate is number No. 39

PLC: Coor. of Central Polygonal Flat Plate No. 1 for Reflector "B"

12

0.1585	0.0000	0.6766
0.1373	0.0793	0.6766
0.0793	0.1373	0.6766
0.0000	0.1585	0.6766
–0.0793	0.1373	0.6766
–0.1373	0.0793	0.6766
–0.1585	0.0000	0.6766
–0.1373	–0.0793	0.6766
–0.0793	–0.1373	0.6766
0.0000	–0.1585	0.6766
0.0793	–0.1373	0.6766
0.1373	–0.0793	0.6766

WRR: Wire Radius and Conductivity

0.01524 –1

WRC: Coor. of Wire No. 1 (left half of dipole)

–0.4115 0.0 0.3406
0.0000 0.0 0.3406

WRC: Coor. of Wire No. 2 (right half of dipole)

0.0000 0.0 0.3406
0.4115 0.0 0.3406

WRG: Wire Generator (position index, amp, phase deg)

1 1.0 0.0

The move command "MOV" was used to move the entire feed geometry $\Delta z = -0.4318$ m such that the phase center was positioned at the origin. The MOV command was placed before the first plate command "PLC," and an "MVX" command was placed after the "WRG" command data.

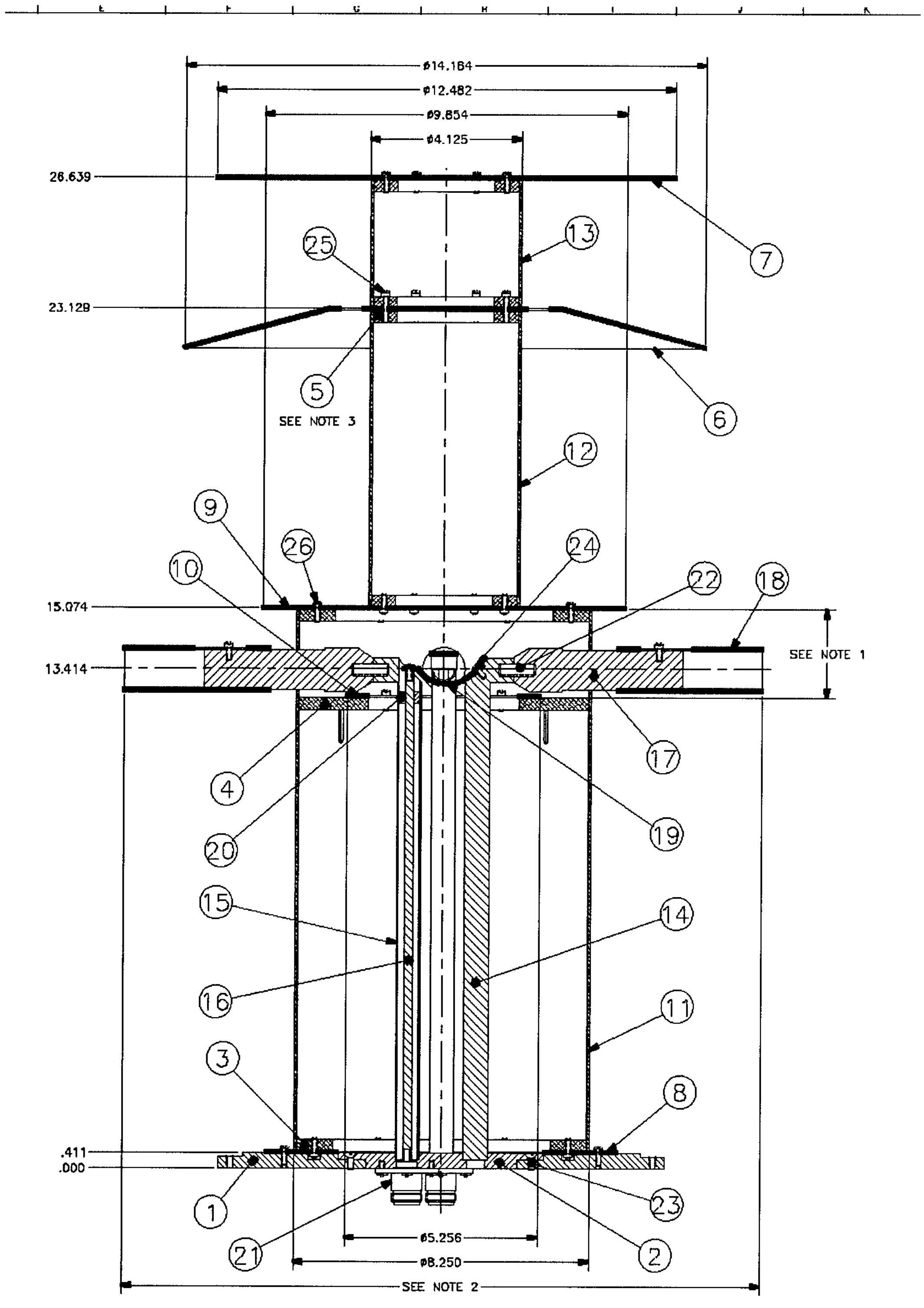

Figure A-1. Drawing of GBT 290 to 395 MHz feed. Dimensions are in inches. From NRAO Drawing D35241A012.

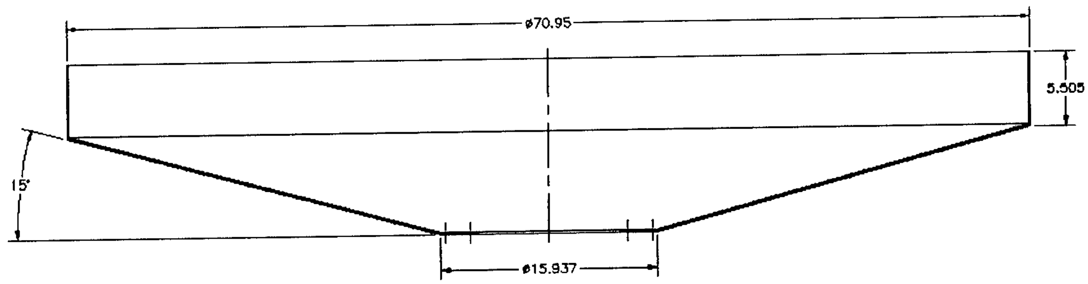

Figure A-2. Drawing of the GBT 290 to 395 MHz feed ground plane. From NRAO Drawing D35241M096.

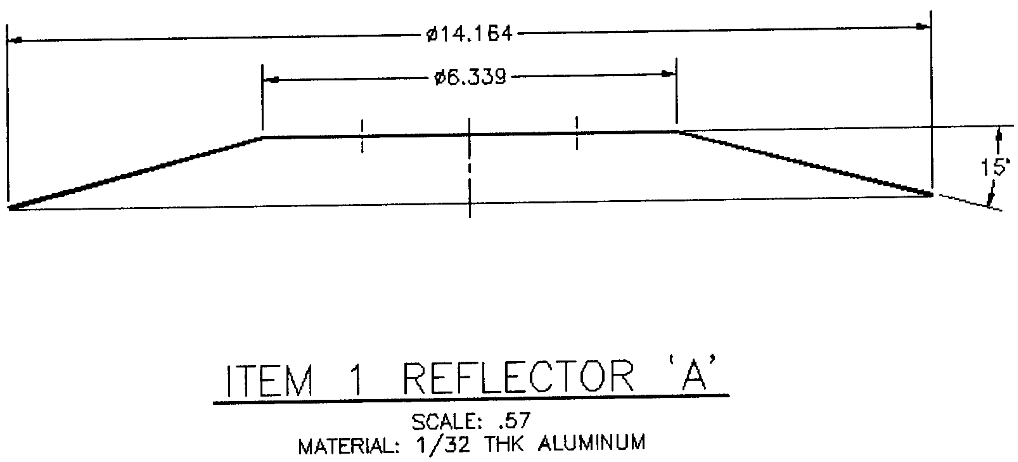

Figure A-3. Drawing of GBT 290 to 395 MHz reflector "A." From NRAO Drawing D35241M095, sheet 2 of 4.

ESP5 Command File

REM: Green Bank VHF Feed input file: GB_VHF.inp

REM: Alan J. Fenn, MIT Lincoln Laboratory

REM: 11 July 2003

REM:

OTF: Output File

GB_VHF_output.txt

PCM: Print Commands

RUN: Full Run

PRI: Print Indicators

3 2 2 2

1 0 0

SGX: Max. MM Segment Sizes (wavelengths)

0.15 0.2 0.2

TTL: Print Title

1

ESP5 MoM analysis of Green Bank VHF Feed

REM: The Green Bank VHF Feed geometry is contained in file

REM: GB_VHF_geom.txt

MTL: Define Location of MATLAB exe

C:\MATLAB6p5\bin\win32\matlab.exe

REM: could execute Execute MATLAB Mfile xxxgeom.m

REM: to generate feed geometry, but not done here.

ACF: Read Auxiliary Command File generated manually

GB_VHF_geom.txt

PGM: Plot Wireframe Geometry

1

RAD: Radiation Scan 1 - E-Plane Elevation pattern phi = 0° at 150 MHz

```
  150.0  150.0   1
-180.0  180.0   1.0
    0.0      0.0   0.0
```

RAD: Radiation Scan 1—H-Plane Elevation pattern phi = 90° at 150 MHz

```
  150.0  150.0   1
-180.0  180.0   1.0
   90.0    90.0   0.0
```

END: End of ESP5 Command Input File

APPENDIX B

SatCom WORKBENCH GBT 150 MHZ PATTERN COMPUTATION FILE

SatCom Workbench (input file)

```
UN:
1
FR: Green Bank Telescope, VHF
0.150000
RW:
1, 0, 0, 1, 0, 1, 0, 5
"bcifile"
RWMAINREF
0, 0, 0
0, 0, 0, -999
1, 1, 0
60, 3.33333, 3.33333, 100, 0
0, 54, 0
RWFEEDRR
0, 0, 60
137.176, 90, 0, -999
RWFEED0
0, 0, 0
0, 0, 0, -999
0, 0, 10, 30
1, 0
0, 4.5, 0, 140, 1, 90, 180
0, 4.5, 0, 140, 1, 90, 180
AW:
1, 5
0.150000, 0.150000, 1.00000
1
0, 0
0.000000, 4.50000, 0.000000, 140.000, 1, 90.0000, 180.000
0.000000, 4.50000, 0.000000, 140.000, 1, 90.0000, 180.000
0, 0.000000
4, 2, 2, 2
0.250000, 0.250000, 0.250000
1, 0, 0, 1
-10.0000, 10.0000, 0.0500000
0.000000, 0.000000, 1.00000
0, 0.000000
0
0
0
1, 0, 0, 0, 0, 0, 0
0
XQ:
```

To open the SatCom Workbench interactive graphic user interface (GUI), double-click on the reflector in the wire frame view, or double-click on the “RW:” line in the above SatCom Workbench input file (ASCII file). Either action will launch the Reflector Wizard and load the pages with the current parameter values.

REFERENCES

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3. S. Srikanth, R. Norrod, L. King, and D. Parker, “An Overview of the Green Bank Telescope,” *IEEE MTT 1999 Symposium Digest*, Vol. 3, 11–16 July 1999, pp 1548–1551.

4. M.A.B. Terada and W.L. Stutzman, “A Performance Assessment of the Green Bank Radio Telescope,” Proc. of the SBMO/IEEE MTT-S IMOC’97 (1997), pp 571–576.

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13. ABSTRACT (*Maximum 200 words*)

A previously developed 290 to 395 MHz short backfire antenna feed for the Green Bank Telescope (GBT) has been modified for operation in the 140 to 175 MHz VHF band. The feed has been modeled with the Electromagnetic Surface Patch code, Version 5 (ESP5) software, developed at Ohio State University (OSU) to predict the feed radiation patterns and with OSU SatCom Workbench software to predict the GBT radiation patterns. Measured feed radiation patterns are in good agreement with the electromagnetic model. This lower-frequency VHF feed is suitable for use as a receive antenna for the GBT.

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