Comparison of Measurements Conducted at the NRAO Anechoic Chamber Antenna Range and MIT/Lincoln Laboratory Millimeter-Wave Chamber

S. Srikanth
National Radio Astronomy Observatory
25 September 2003

Introduction:

The NRAO anechoic chamber antenna range, located in the Jansky building addition in Green Bank, was complete in June 2003 with the exception of the receiver installation. At the same time, the personnel operating the range had not undergone the software training. A Ka-band feed covering the 26-40 GHz range, designed and fabricated for the GBT Ka-band receiver, was available for testing in the beginning of July 2003. Since the NRAO range was not quite ready at that time, an agreement was made with MIT/Lincoln Laboratory (MIT/LL) to measure the feed at their facility at the Hanscom Air Force Base. The Lincoln Laboratory millimeter-wave chamber is also a fairly new facility and only one feed, also at Ka-band, had been measured at that time. Measuring the NRAO feed provided an opportunity for them to better evaluate their chamber. After the measurement at the Lincoln Laboratory, the NRAO feed was also measured at the NRAO range. In this memo, both measurements are compared to theoretical results, and some conclusions presented.

NRAO Anechoic Chamber Antenna Range:

The NRAO chamber measures 37′x15′x15′. It has broadband pyramidal absorbers (8" in the center of the walls and 6" in other places) that are good down to about 2.0 GHz. The quiet zone of the chamber is a 2′ sphere located along the center axis of the chamber, equidistant from the rear and side walls (approximately 7′3″). The test antenna positioner has polarization rotation, translation along the feed boresight axis, translation orthogonal to the feed boresight axis and azimuth rotation. The transmit antenna positioner has polarization rotation and manual translation along the boresight axis. The base system at the receive end, covering the 2 to 50 GHz range, is an 8530A antenna range receiver from Agilent Technologies. Millimeter-wave heads from Oleson Microwave will be used to cover the 60 to 115 GHz range. The RF source is an 83650B synthesized sweeper. The positioner/controller hardware and software were purchased from ORBIT/FR. The range is equipped to make range measurements up to 115 GHz. The chamber was qualified by tests at 10, 20 and 40 GHz. By extrapolation with the measured data, the chamber was qualified up to 94 GHz.

MIT/LL Millimeter-Wave Chamber:

The MIT/LL chamber measures 30'x18'x18' with 9" unpainted absorbers in the middle of the walls, floor and ceiling and 6" absorbers everywhere else. The test antenna positioner has four axes of motion, namely, polarization rotation, elevation rotation, manual translation along the boresight axis and azimuth rotation. The transmit antenna is positioned in a cutout on the front wall of the chamber and currently does not have any positioners. The range of operation is from 2 to 50 GHz. The chamber was instrumented by MI Technologies as a turnkey system. This instrumentation includes an HP 8530A receiver, an HP 83620B signal generator, along with a Model 4190 position controller and MI-3000 software from MI Technologies.

Measurements:

Measurements at MIT/LL took place on 7-8 August 2003. These measurements covered the frequency range from 26 to 40 GHz at every 1-GHz step. Patterns were measured in the E-, H- and the 45°-planes from -120° to 120° with a 0.5° step. Patterns in the E-plane were measured first. The feed was positioned initially with the center of rotation at the theoretical phase center locations at 26, 34 and 40 GHz. At each of these frequencies, phase patterns were measured for various axial positions of the feed in the vicinity of the initial position until a relatively flat phase plot was obtained. This position corresponds to the phase center location. The phase center locations at 26, 34 and 40 GHz are, respectively, at 1.0", 2.1" and 2.6" behind the feed aperture. Amplitude and phase patterns were measured at all the frequencies with the feed set at each of the three locations. In the lateral direction, a plumb bob was used to align the center of the feed aperture with the center of rotation.

Figure 1a shows the measured E-plane, far-field pattern at 26 GHz laid on top of a theoretical pattern predicted with mode-matching software. The peak of the measured beam was offset in the positive direction by 1°. Figure 1b shows the measured pattern offset by 1° in the negative direction. The agreement with theory is excellent out to ± 40°. In all the subsequent figures showing the MIT/LL measurements, the pattern is offset by -1°. The measured sidelobes at 45° off boresight are symmetric. However, they are higher by about 3 to 4 dB compared to theory. The sidelobes at 70° are asymmetric.

Measurements at NRAO were carried out on 26-27 August 2003. Patterns in the E- and H-planes were measured. The azimuth angle interval used is 1°. Figure 2 shows the E-plane patterns at 26 and 40 GHz measured at NRAO before and after absorbers were placed at strategic locations. The initial measurement shows an offset of -1° in the peak of the beam. The feed was moved in the appropriate direction to correct for this. Absorbers placed around the feed on the mounting plate eliminated ripples on the pattern along boresight. In Figure 2a, ripples in the region between ± 30° and ± 50° were due to reflections from the back plate of the feed mounting bracket. Absorber wrapped around the mounting bracket smoothed the ripples. Beyond ± 50°, the ripples were due to a combination of reflections from the above-mentioned back plate and the sides of the polarization motor housing. Once again, absorbers placed on the housing reduced the level of the ripples. Below the -50 dB level, the ripples are due to low signal/noise ratio. Some of the ripples could be reduced by using an amplifier in the transmit signal path.

Figures 3a and 3b show the MIT/LL and NRAO measured E-plane patterns at 26 GHz laid on top of theoretical pattern. NRAO measurements agree well with theory down to -50 dB level. The first and the second sidelobes on the MIT/LL pattern are higher by about 3 dB. Figure 3c shows the measured phase patterns. In the case of the NRAO measurement, the phase pattern shown was measured with the feed aperture positioned 1.31″ in front of the center of rotation. The pattern is symmetric, showing good alignment of the feed axis with the boresight axis. The gradient on the MIT/LL phase pattern is due to the lateral shift of the feed from the boresight axis. Figure 4 shows measured and theoretical patterns at 26 GHz in the H-plane. Both NRAO and MIT/LL measurements agree well with theory.

Figures 5 and 6 show measurements at 34 GHz. In the case of the MIT/LL measurements, the E-plane pattern shows excellent agreement with theory up to the third sidelobe, while the H-plane pattern has good agreement with theory out to ± 42°. In the case of the NRAO measurements, agreement with theory is moderate in both planes. At 40 GHz, both NRAO and MIT/LL measured E-plane patterns (Figure 7) agree well with theory out to ± 22°. However, the sidelobes on the measured patterns are slightly higher. The measured H-plane patterns (Figure 8) follow theory very well down to - 50 dB level.

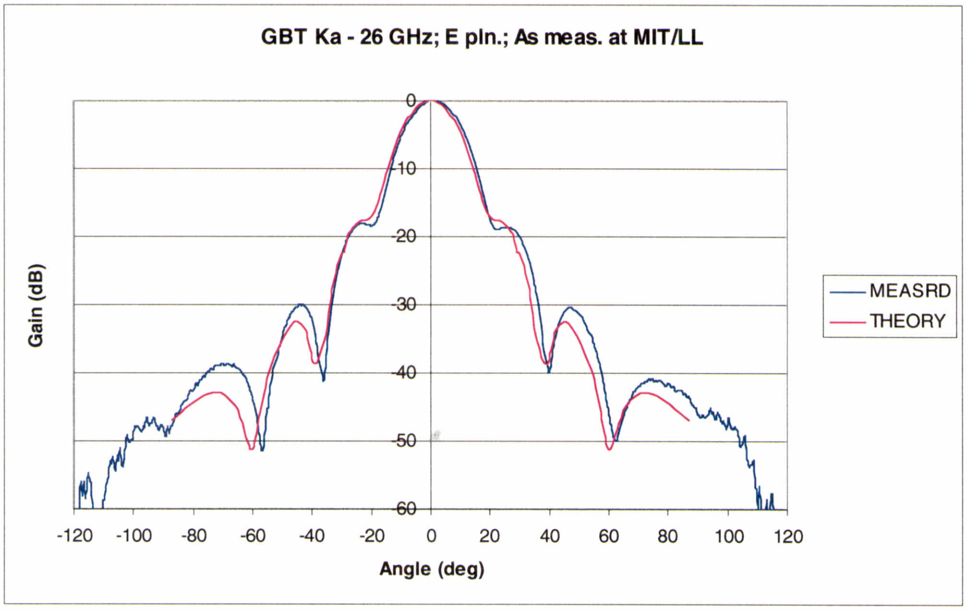
Conclusion:

In general, the NRAO measurements show some asymmetry below the -40 dB level and at angles greater than ± 60°. The absorbers placed on the motor housing and mounting bracket need to be tightly secured. Perhaps using velcro would keep the absorber in place during the measurements. It is recommended that the absorbers on the azimuth positioner, as well as on the motor housing, be left undisturbed. This would help in making measurements repeatable down to -50 dB level. The NRAO chamber is currently a shared facility used also for RFI/EMI testing. In order to ensure good symmetry and repeatability of measurements, it is recommended that the anechoic chamber be used solely for antenna range measurements. Using an amplifier in the signal path will lower the noise floor of the measurements. Measurements at MIT/LL indicated that the feed was not centered on boresight. The measurements will be repeated after this alignment. Except for some minor details, the performance of both chambers is good up to 40 GHz.

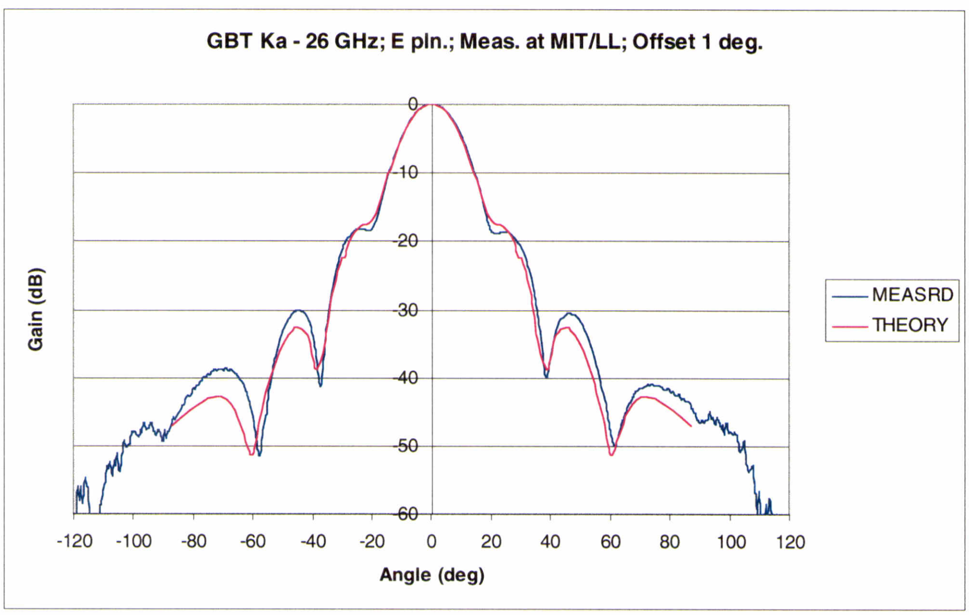
Since the measurement at MIT/LL yielded a phase pattern with a gradient, the phase center locations were not identified accurately. From the measurements conducted at NRAO, the phase centers at 26, 34 and 40 GHz are, respectively, at 1.31", 2.1" and 2.6" behind the aperture plane.

Acknowledgements:

Special thanks go to Alan Fenn of MIT/LL who arranged and coordinated the measurements, Bob Piccola who carried out the measurements and David Mooradd who arranged to send the data. George Behrens designed the NRAO anechoic chamber. Gary Anderson equipped and set up the chamber as an antenna range. Anderson and Jonah Bauserman set up the chamber to measure the Ka-band feed. The Green Bank machine shop did all the fabrication work, and Bill Porter and Ted Miller processed the necessary paperwork.

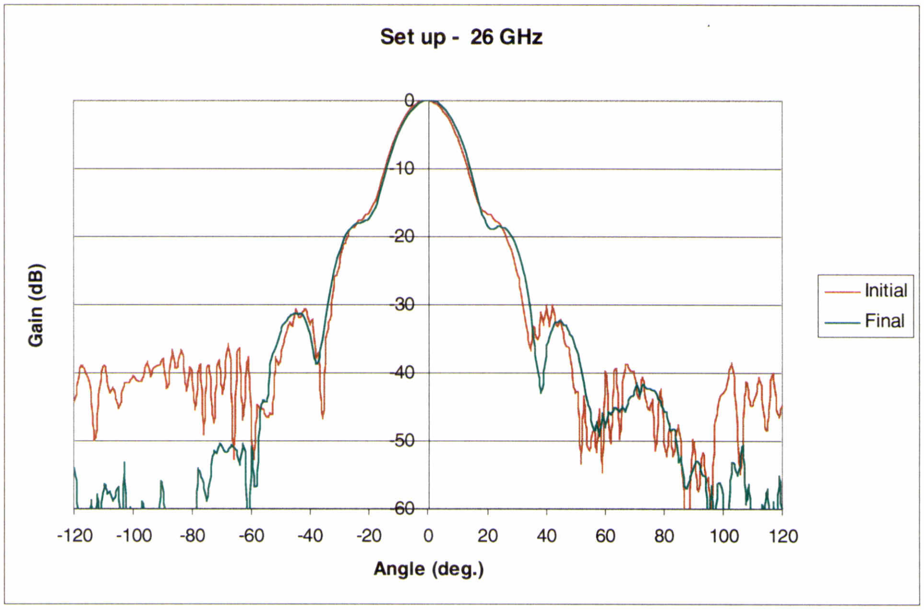


(a) Measured pattern - as measured

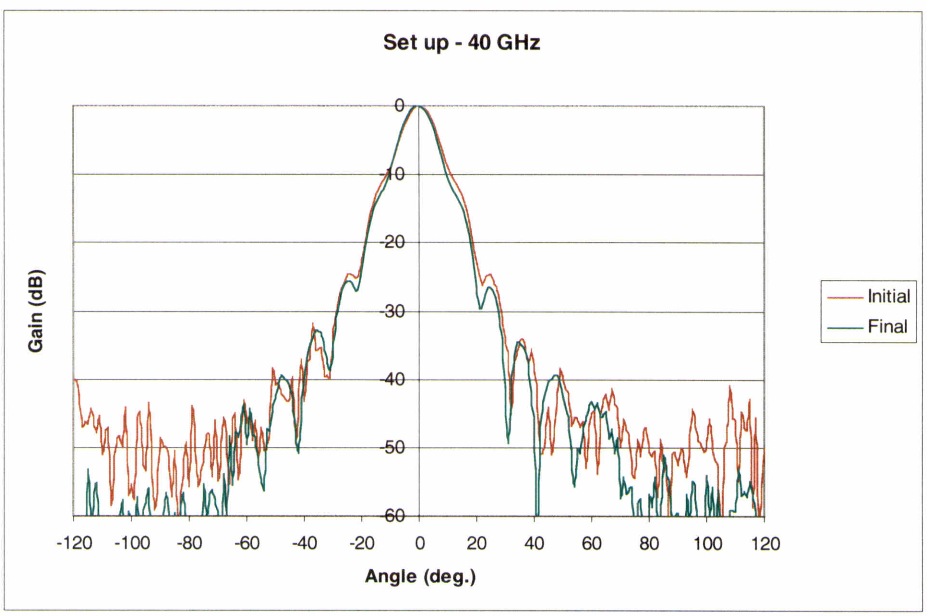


(b) Measured pattern - offset by -1°

Figure 1. Measured (MIT/LL) E-plane patterns at 26 GHz.

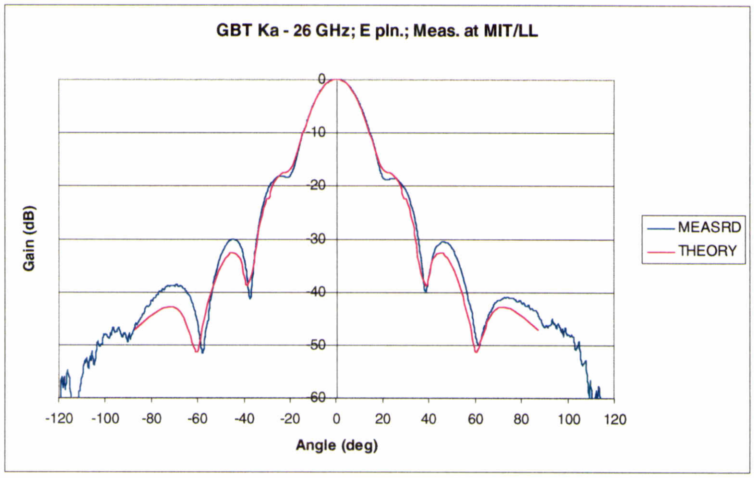


(a) Before and after setup at 26 GHz

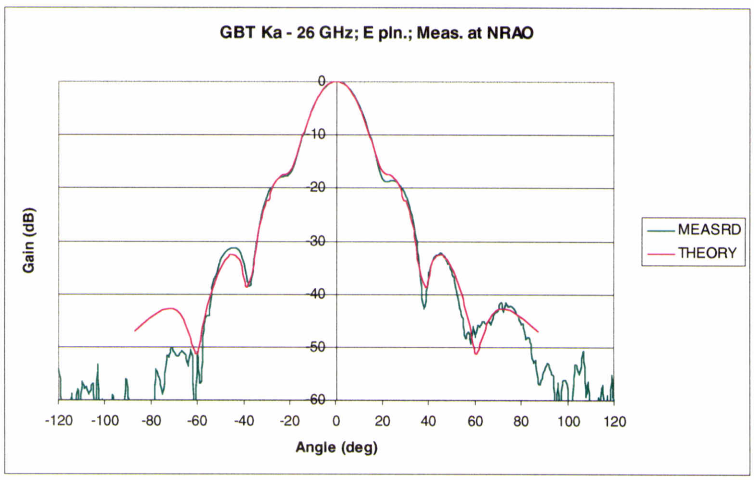


(b) Before and after setup at 40 GHz

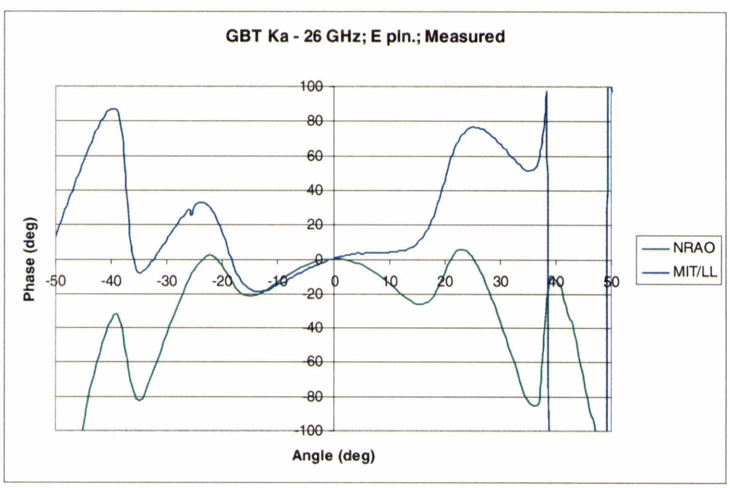
Figure 2. Measured (NRAO) E-plane patterns.



(a) Amplitude -MIT/LL

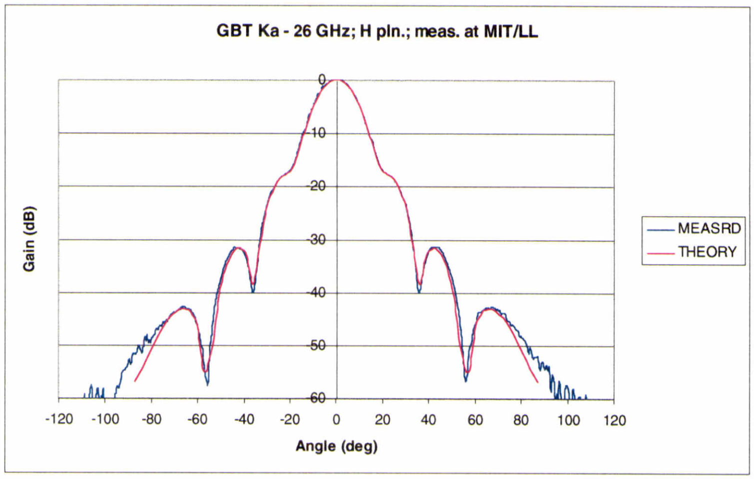


(b) Amplitude - NRAO

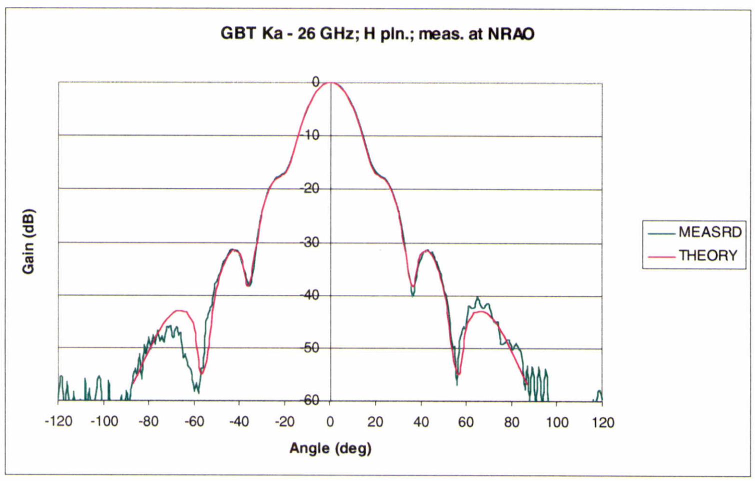


(c) Phase - MIT/LL, NRAO

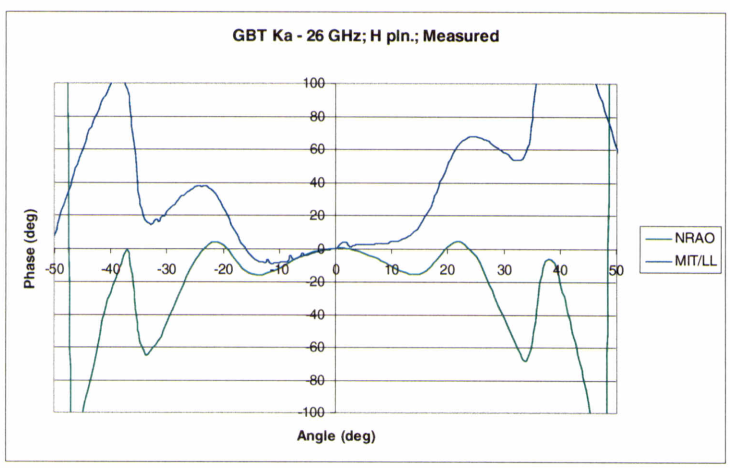
Figure 3. Measured & theoretical E-plane patterns at 26 GHz.



(a) Amplitude - MIT/LL

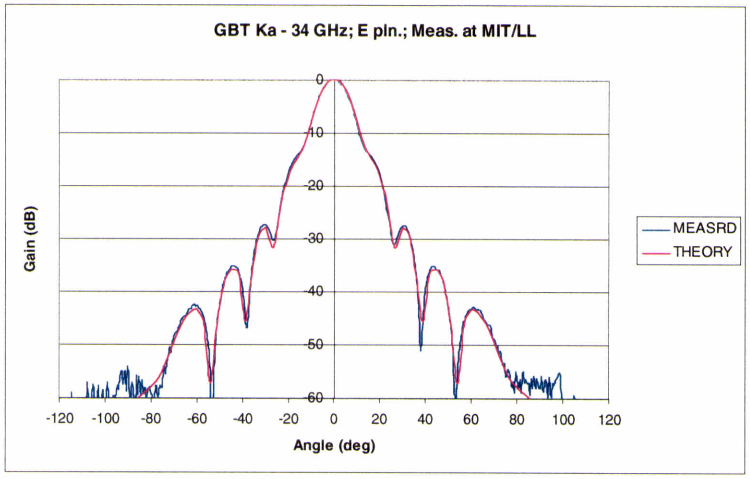


(b) Amplitude - NRAO

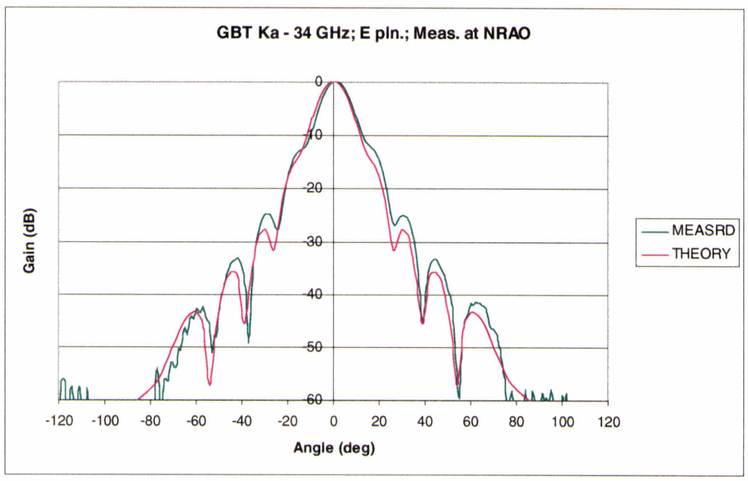


(c) Phase - MIT/LL, NRAO

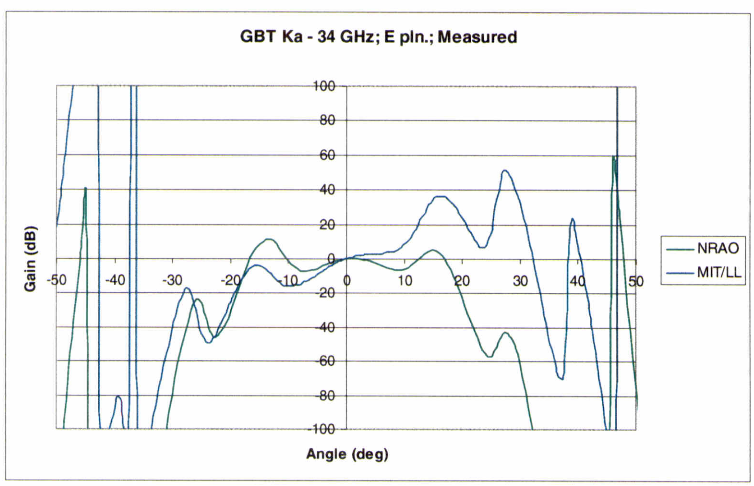
Figure 4. Measured & theoretical H-plane patterns at 26 GHz.



(a) Amplitude - MIT/LL

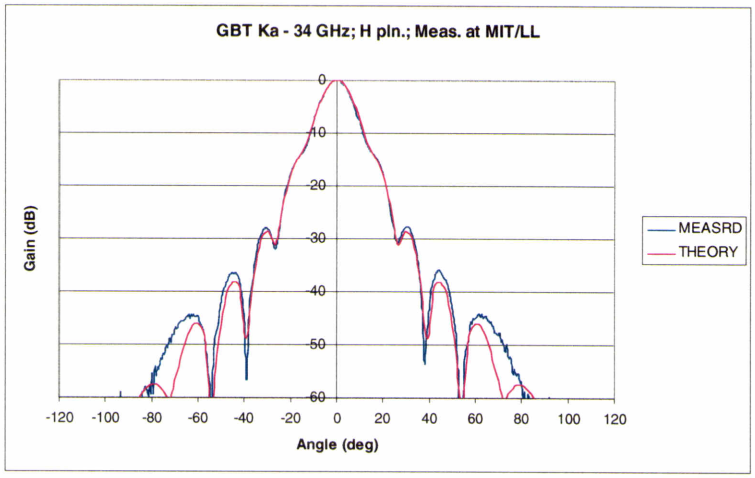


(b) Amplitude - NRAO

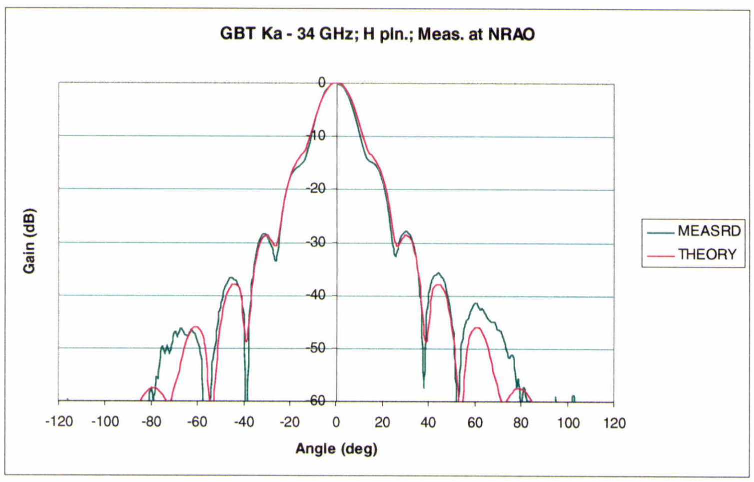


(c) Phase - MIT/LL, NRAO

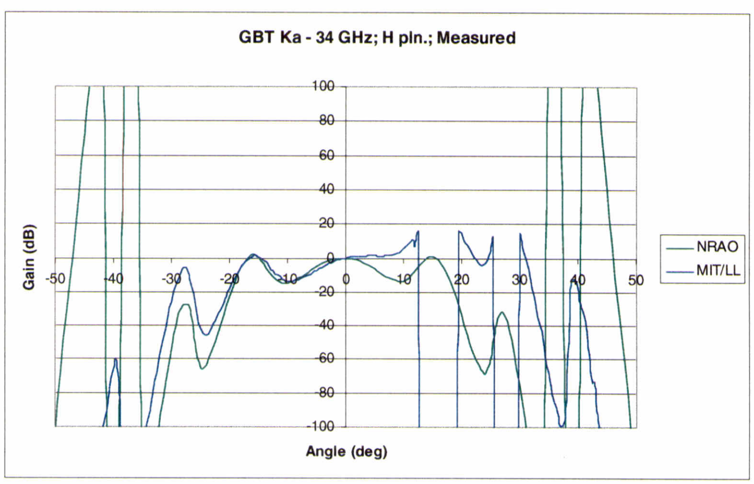
Figure 5. Measured & theoretical E-plane patterns at 34 GHz.



(a) Amplitude - MIT/LL

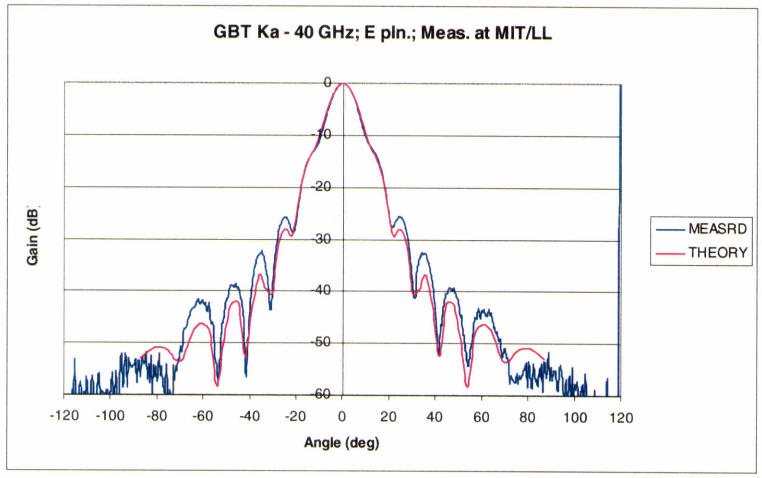


(b) Amplitude - NRAO

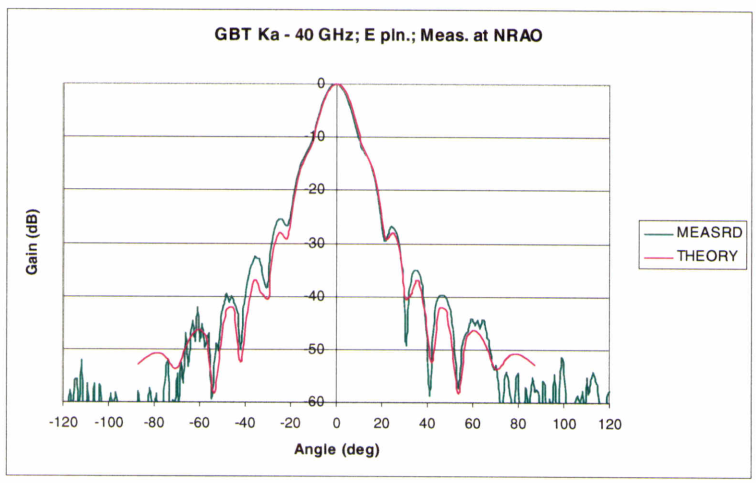


(c) Phase - MIT/LL, NRAO

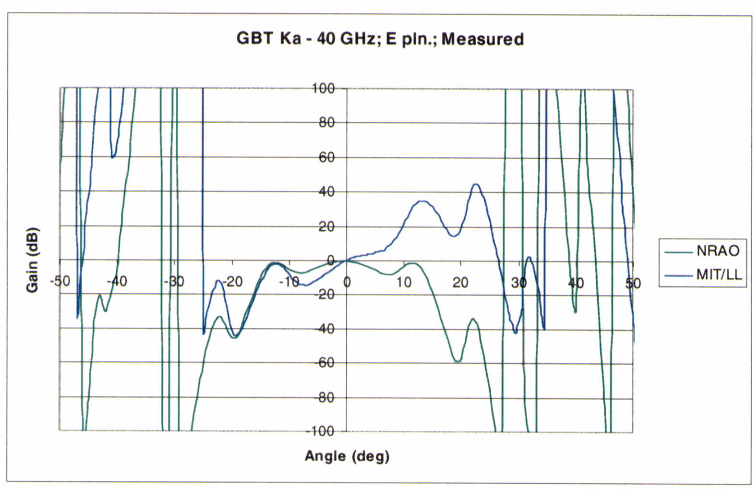
Figure 6. Measured & theoretical H-plane patterns at 34 GHz.



(a) Amplitude - MIT/LL

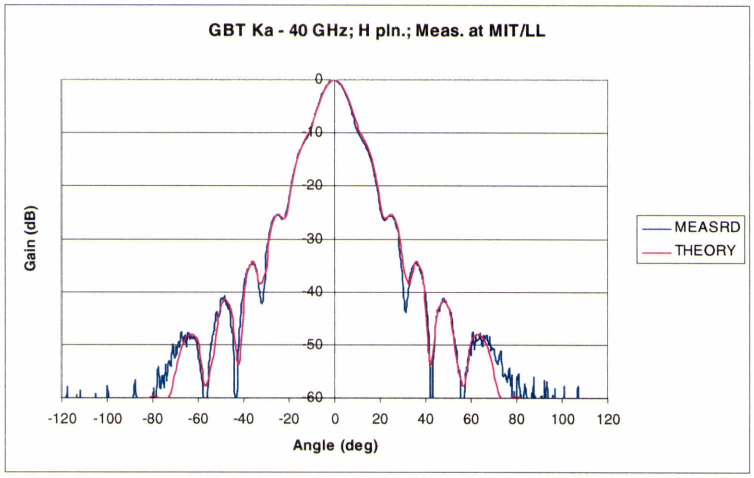


(b) Amplitude - NRAO

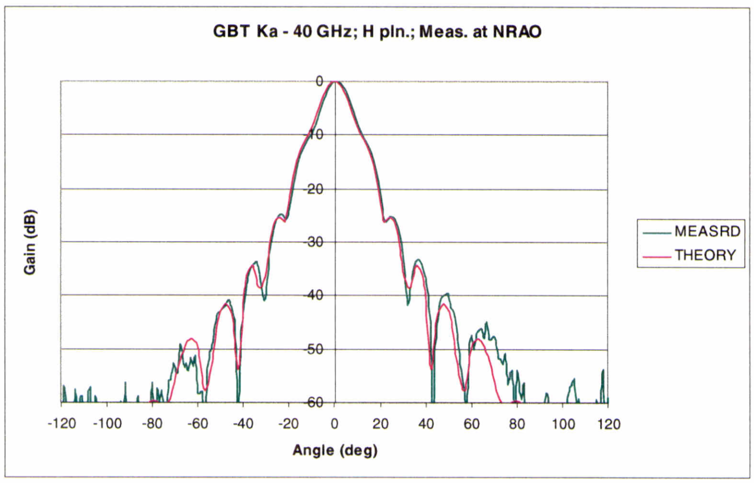


(c) Phase - MIT/LL, NRAO

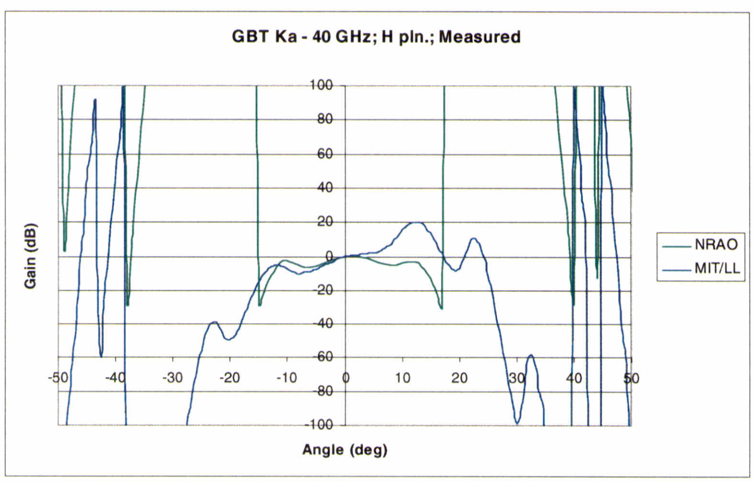
Figure 7. Measured & theoretical E-plane patterns at 40 GHz.



(a) Amplitude -MIT/LL



(b) Amplitude - NRAO



(c) Phase - MIT/LL, NRAO

Figure 8. Measured & theoretical H-plane patterns at 40 GHz.