

Electronics Division Technical Note No. 200

Millimeter-Wave Feed Measurements Using the Green Bank Indoor Antenna Range

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Millimeter wavelength feed-pattern measurements have been planned ever since the Anechoic Chamber Antenna Range in Green Bank was first conceived in 1992. From 2003 (when the range was first used) to 2005, Orbit/FR positioners and software, and an Agilent 8530 range receiver, allowed operation from 2 to 50 GHz in a "standard" configuration from both the standpoint of Agilent and Orbit/FR. This technical note documents the additional work performed to outfit the range for measurements above 50 GHz and compares its first mm-wave feed measurements (68 to 92 GHz) with those taken at another facility.

Planning:

The original plans in 2001, during range design, were to use the HP/Agilent mm-wave test multipliers designed and built for use with both the 8530 range receiver and the 8510 network analyzer. A cost proposal from 1995 implied that G. Behrens intended the same when compiling an RE budget for equipping the chamber. When we were ready to submit to the vendors a Request for Quotes in 2001, discussions with engineers at other NRAO sites indicated a desire to implement the range as a turnkey system in order to have it available for use more rapidly. Bids were received for a full turnkey system, but the cost was too high to be considered. A modified approach, where the NRAO-GB would do the installation and Orbit/FR would do a qualification test after installation, seemed likely to meet cost requirements.

Green Bank had, at that time, placed an order for an Anritzu "Lightning" Network Analyzer. Roger Norrod suggested that the multiplier assemblies from Oleson Microwave (now OMI) that he had recently ordered for use with the network analyzer might be usable with the antenna range hardware for millimeter-wave coverage. Neither Agilent, nor Oleson, nor Orbit/FR supported this combination, although Oleson claimed they had reports from users who had used their modules successfully in this mode. Telephone calls to other antenna ranges verified this. Our analysis of information submitted by OMI also showed that the units should work. In fact, it was determined that they should be an improvement over the HP hardware, since they were designed to use lower multiplication factors, thereby reducing the chance of making a measurement on an incorrect harmonic. Therefore, it was decided to base all future mm-wave antenna measurements on the Oleson units.

Implementation/ Range Theory of Operation:

Drawing D10812K001 (attached) shows the Indoor Antenna Range block diagram for mm-wave operation.

Two sweepers supply the RF signal for the source and Antenna Under Test (AUT) side of the range. The Agilent 83651B sweeper supplies its output directly to the source antenna in low-frequency mode and to an Oleson TR module located at the source antenna in mm-wave mode. The generator output is multiplied in frequency in the Oleson head and connected to the source antenna to provide the transmit signal for the range. The Agilent 83621B sweeper supplies its output to the Agilent 85309A LO/IF Distribution Unit, where it is amplified and routed to two destinations. One path terminates in an Oleson Transmit module, located at the AUT, where the signal is multiplied and used as a local oscillator to downconvert the signal received by the AUT to 20 MHz (the center frequency of the 8530 range receiver). The other path ends at the Oleson T/R module (at the source antenna) where it is also used as a local oscillator, this time to mix a sample of the source RF signal for leveling at the Agilent 85309A.

A diplexer is required on the AUT side of the range to feed LO power to the converter and return an IF signal from the converter through a single coaxial line. The mm-wave measurement system designed by HP/Agilent uses lower-frequency signal generators and wideband multipliers that require a multiplication factor of 18 to 20 to operate at 100 GHz. This means that the diplexer supplied by HP/Agilent for their system (85326-60001) only needs to be operational from 10 MHz to 6 GHz in its designed use. I determined, during system design, that the manufacturer's diplexer was fully usable at frequencies up to 20 GHz. Thus, the HP/Agilent 85326 assemblies might be used for our application while preserving the capability to use HP modules in the future (they are the same as are used with the HP/Agilent 8510 Network Analyzer and are easily available). However, when setting up the system, we found that the frequency response of the LO detector in the 85326-60002 Reference Module (used on the Source side of the range) rolled off above 8 GHz or so. Therefore, an outboard 10 dB coupler and a detector supply a DC reference voltage to the 85309 LO/IF Distribution Unit for power leveling. An attenuator precedes the detector and is selected so that the DC voltage generated is the same for mm-wave operation as when the 85320B/H50 mixer module is used in the low-frequency mode (2-50 GHz). By proper selection of this attenuator, no readjustment of the 85309A is necessary when changing frequency ranges.

At this time, the greatest problem with the system is a physical one: the configuration of the Oleson heads. They are designed to rest on a table when used with a network analyzer; not to be attached to an external support(s) for either rotation or translation, as one wishes to do on an antenna range. Additionally, one wants to attach the AUT rigidly to the positioner system so that its position relative to the center of azimuth rotation can be known with precision when doing phase center measurements. Safely attaching an Oleson head to a rigidly-mounted feed with rigid waveguide is extremely difficult. (So far, flexible waveguide has been unavailable to us for mm-wave use.) Thus far, we have avoided these problems by physically supporting the units on tables and by using 45 and 90 degree waveguide twists to rotate polarization, as the test requires. Future measurements may require a more flexible system (no pun intended).

Please heed these warnings about the Oleson heads:

- 1: The multipliers contained in the heads are NOT wideband multipliers. When using them in "unconventional" modes, pay close attention to the notes Oleson supplies with the heads, and only expect them to work at the frequencies defined by their recommended multiplier number. Furthermore, keep in mind that the multiplier used when driving one of the coupled mixer/downconverters may not be the same for a given frequency as that specified for the multiplier/ "thru" path.
- 2: As supplied to NRAO-Green Bank, the power connections to the Oleson units DO NOT MATCH THE DOCUMENTATION. The basic Oleson heads were altered to allow their use with Anritzu network analyzers. Both the connector pin out and the specified voltage to be applied are different. I have documented the differences and added this to the Oleson manual in Green Bank.
- 3: From verbal discussions with OML, any part of the Oleson units may be operated with +12 or +15 volts, despite their documentation. We use a +12 volt supply to power all parts of the Oleson heads in the antenna range.

Test Data:

In 2003, S. Srikanth had the GBT W-Band feed patterns measured at the NASA/Goddard Space Flight Center in Greenbelt, Maryland. The feed was measured in their Scientific Atlanta 5706 compact range between the frequencies of 68 to 92 GHz. From that measurement, we have data taken at 1 degree increments in azimuth.

In the late spring of 2005, a feed of the same design (but not necessarily the same physical feed) was measured in Green Bank to determine its phase center location with respect to frequency (which was not determined at Goddard) and, incidentally, to verify the quality and performance of the range when making

millimeter-wave pattern measurements. Data was taken at 0.5 degree increments in azimuth. Distance between the source and AUT was 50 inches.

The graphs that follow show the Goddard data superimposed over the Green Bank data.

The comparison graphs (Figures 2 through 10) show excellent agreement in overall pattern shape between the two data sets. Figure 3 above, +50 degrees in azimuth, shows the largest deviation between the data sets. Excellent pattern symmetry in the Green Bank data set implies that the anomaly is an unwanted reflection within the chamber at Goddard.

The major difference is in signal-to-noise performance. The Green Bank data shows as much as 15 dB additional dynamic range. Note the lack of noise on the traces, even 60 dB down from boresight.

Note 1: Apparently, there was a boresighting error of as much as 3 degrees in the Goddard data. This was probably due to misalignment of the feed when mounting it on the range. The data has been plotted as recorded.

Note 2: None of the Goddard data files were normalized (set for a reference level of zero dB at boresight). E and H-plane amplitude data has been normalized manually and plotted. No co-polarized data in the 45-degree plane was available. The average of the E- and H-plane boresight amplitudes was used to normalize the cross-pol data.

Note 3: Cross-pol data was taken using waveguide twists to provide the desired polarization rotation. Thus, the resulting data depends on the accuracy of fabrication of the twist.

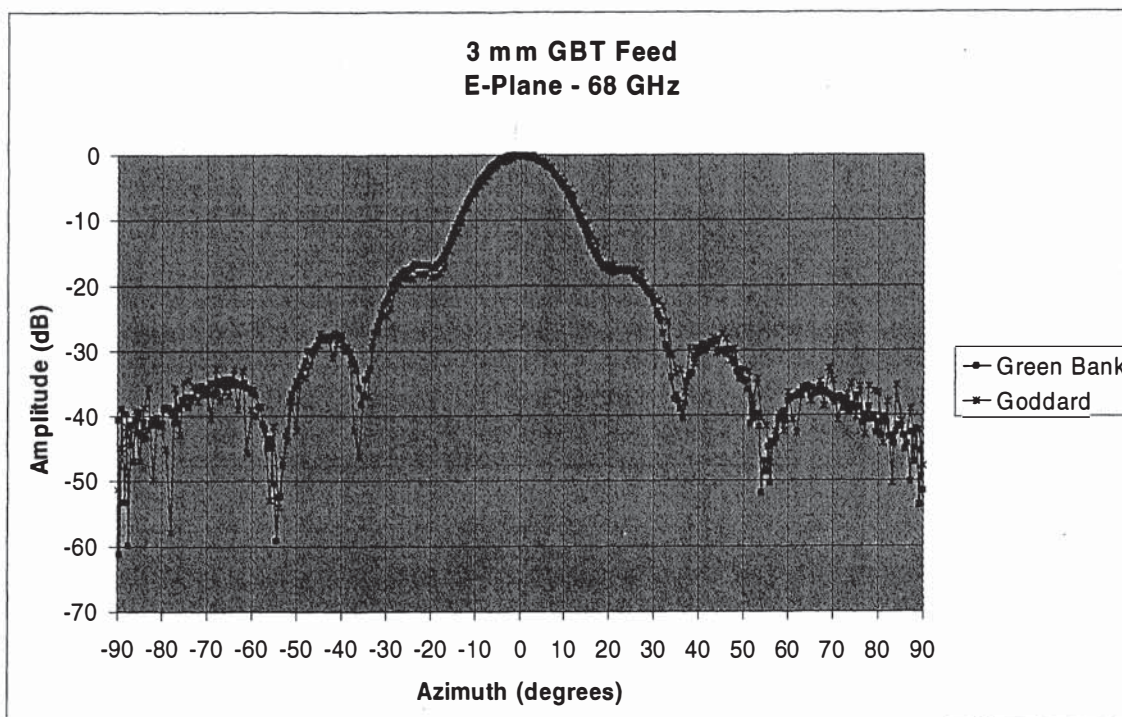


Figure 2

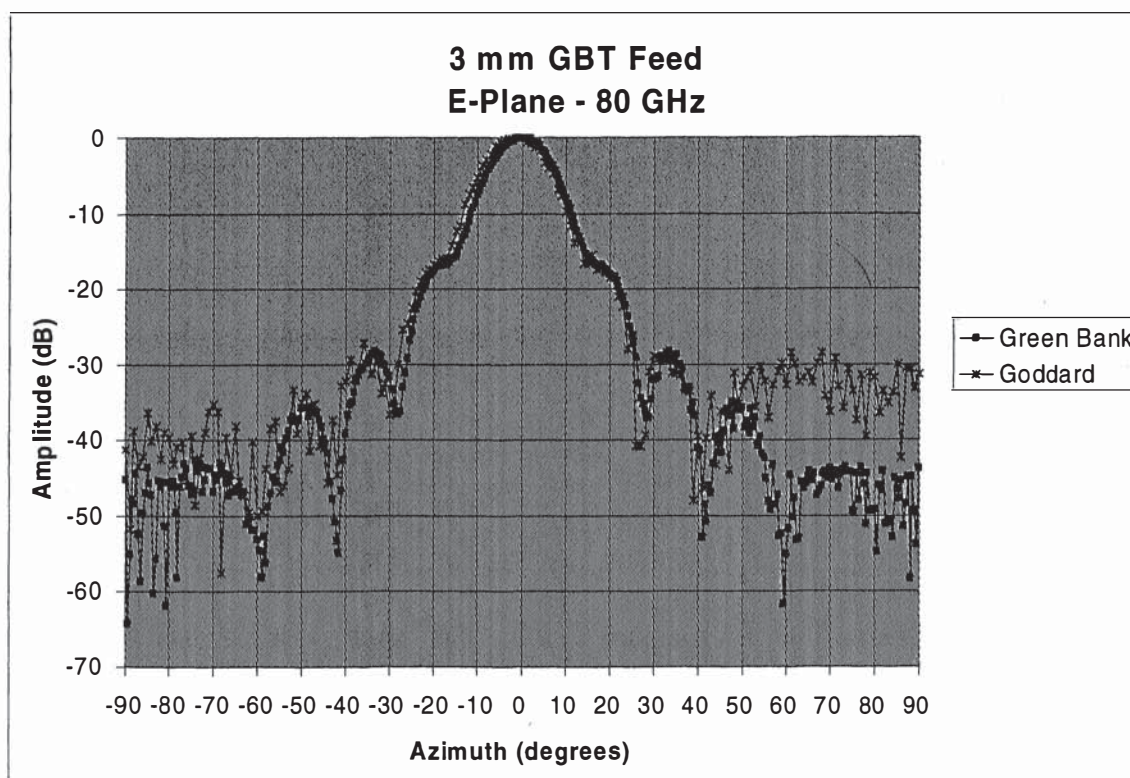


Figure 3

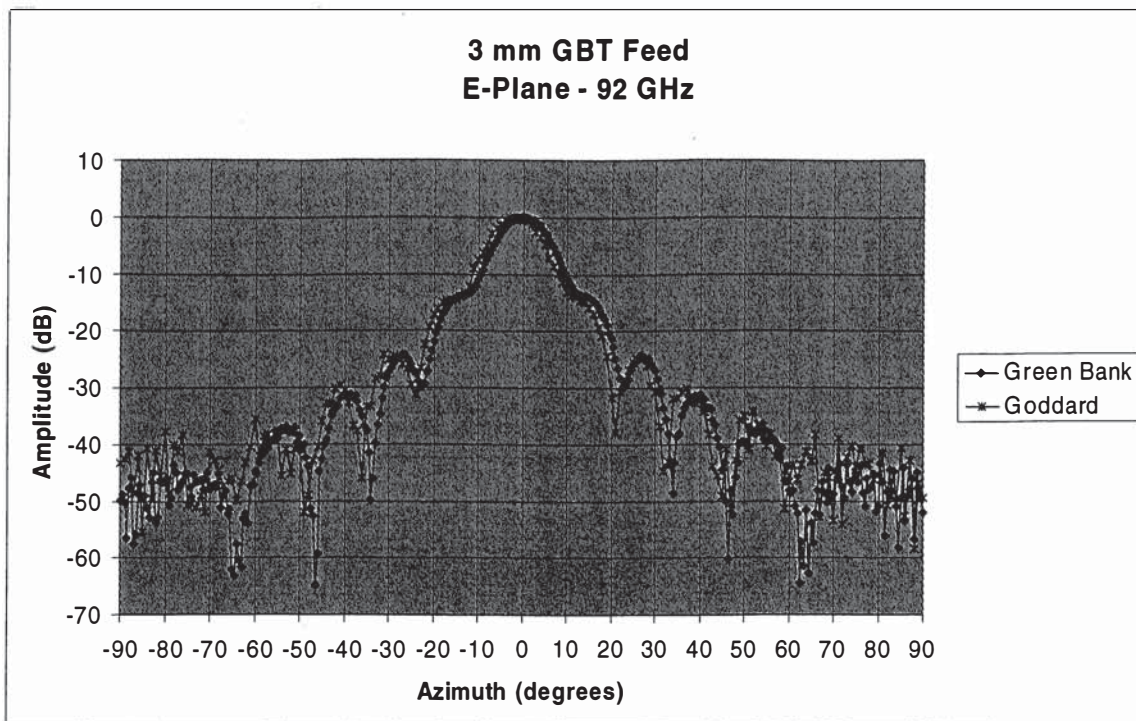


Figure 4

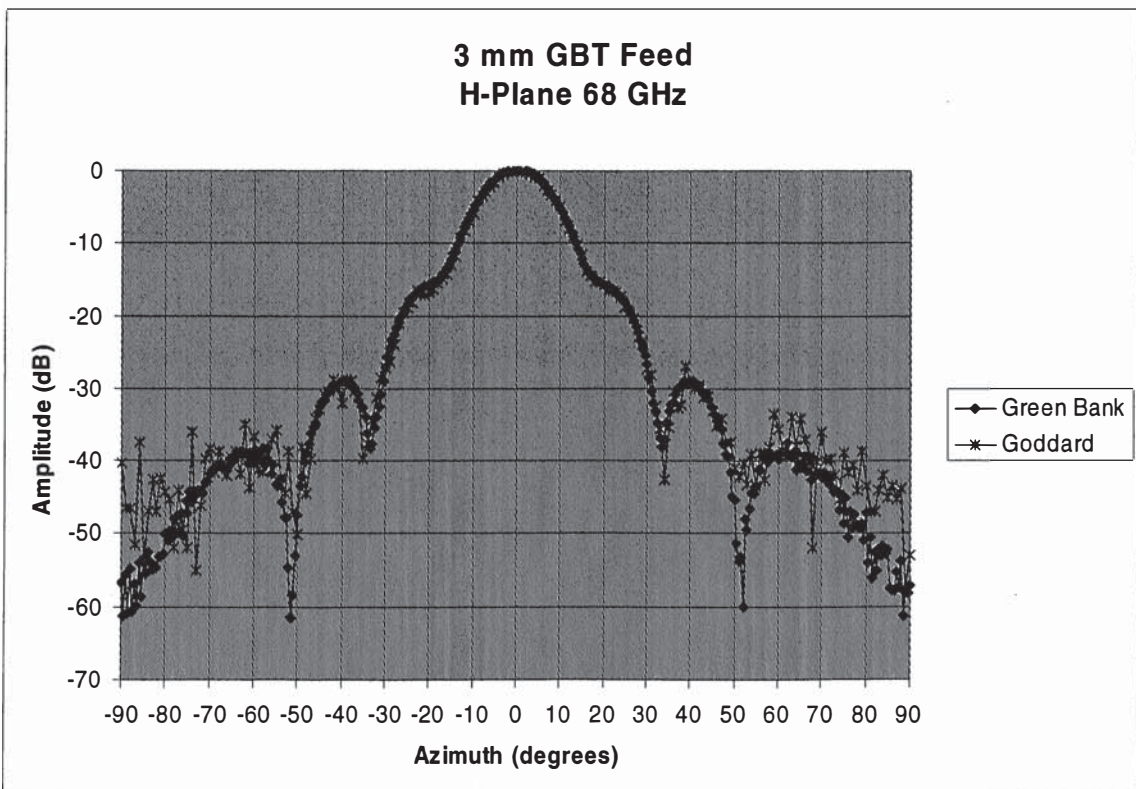


Figure 5

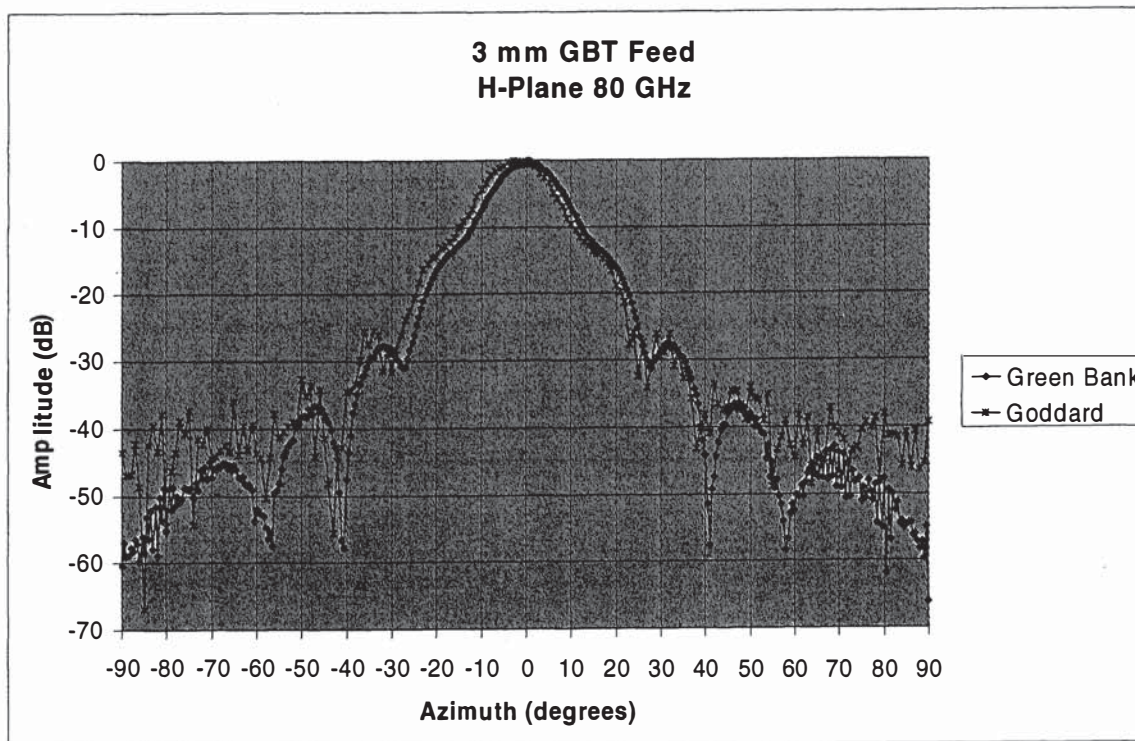


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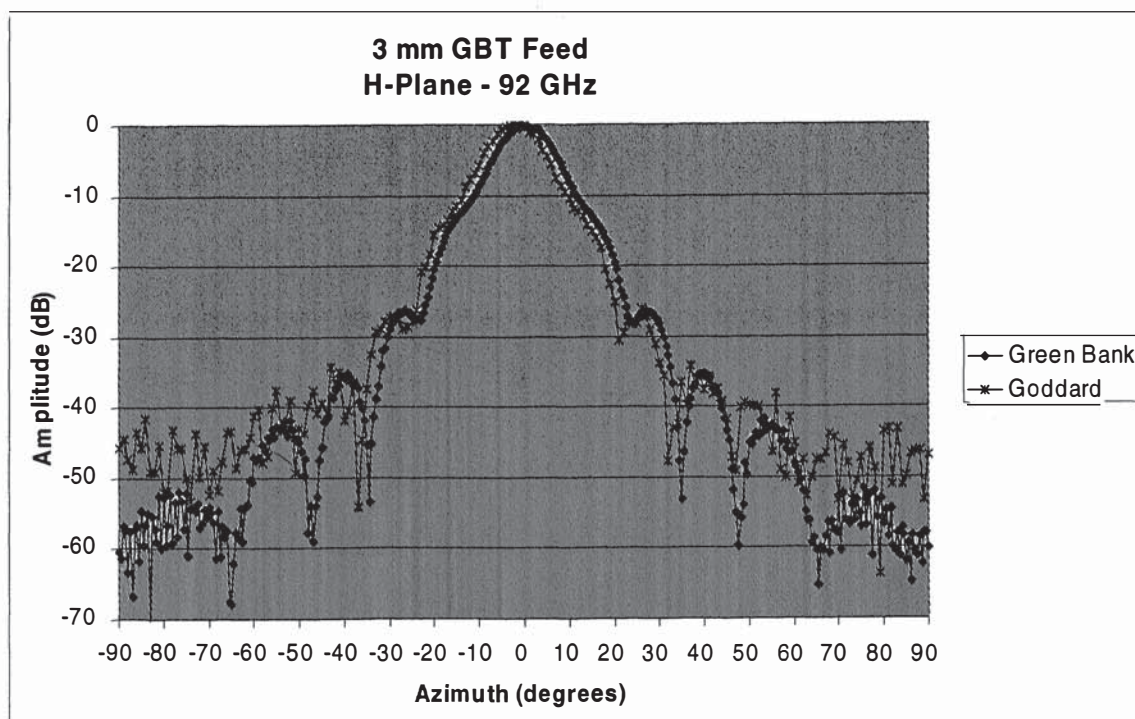
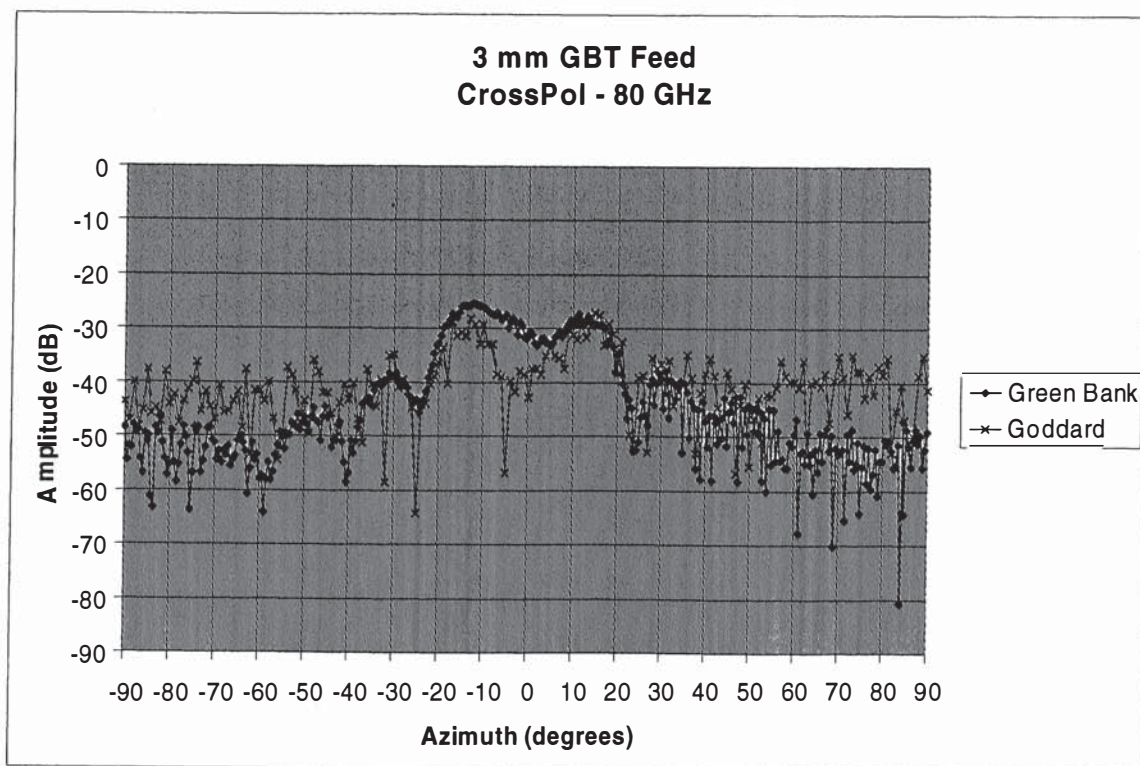
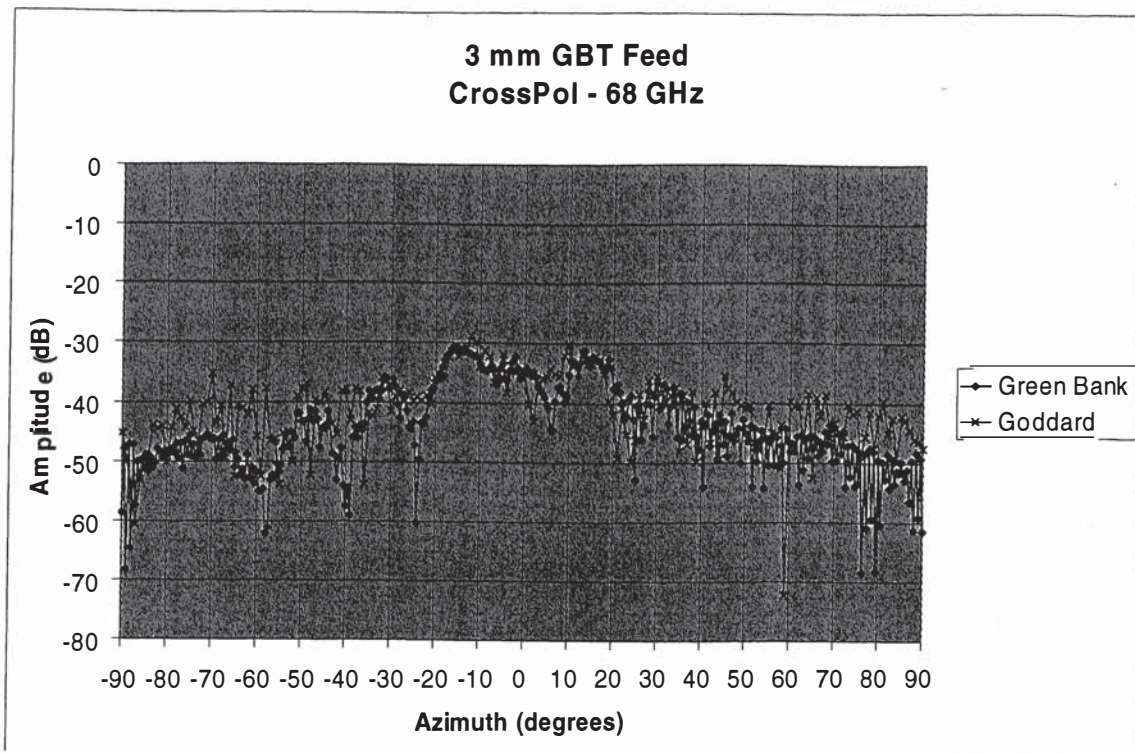


Figure 7



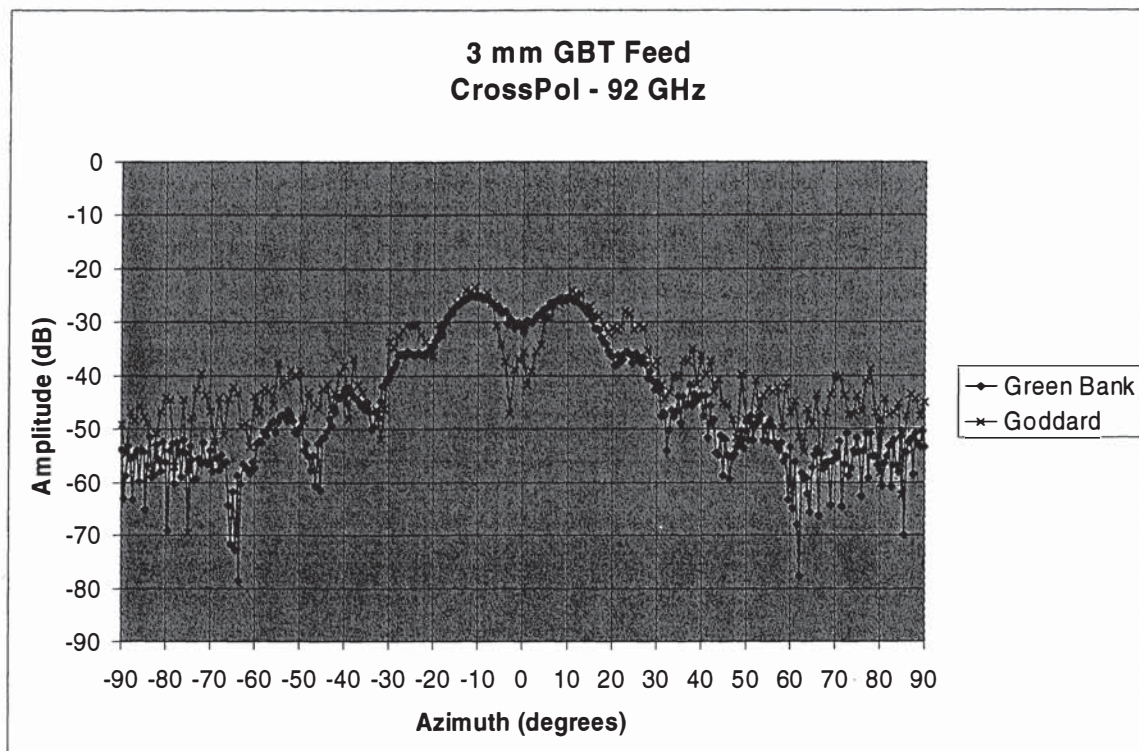


Figure 10

Acknowledgements:

To S. "Sri" Srikanth, for his training and advice.

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