LOW CROSS-POLARIZED COMPACT RANGE FEEDS

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Abstract

Compact antenna test ranges intended for low cross-polarization antenna measurements require the use of feeds with polarization ratios typically greater than 40 dB across the included angle of the quiet zone as well as across the frequency band of interest. The design for a series of circular corrugated aperture feeds to meet these requirements is presented. The feeds are based on a circular waveguide OMT covering a full waveguide frequency band with interchangeable corrugated apertures to cover three sub-bands. In order to validate the design of this series of scalar feeds, high accuracy cross-polarization data was collected. The primary limiting factor in the measurement of the polarization ratio was the finite polarization ratio of the source antennas. A technique for correcting for the polarization ratio of the source is presented along with measured data on the feeds. The technique begins with the accurate characterization of the linear polarization ratio of the standard gain horns using a three antenna technique, followed by pattern measurements of the feeds, and ends with the removal of the polarization error due to the source antenna from the measured data. Measured data on these feeds is presented before and after data correction along with data predicted using the CHAMP® moment method software.

Keywords: Cross-Polarization, Compact Range, Measurement Systems

1. Introduction:

Conventional compact ranges are limited by the geometry induced cross-polarization errors associated with an offset feed to cross-polarization measurements of about -30 dB for large test apertures. To collect high-accuracy cross-polarization measurements in a compact range, either a dual-reflector compact range configuration or a unique single reflector with a post processing technique such as the ECCA technique [1,2] must be used.

In these types of geometry systems and assuming the reflector(s) are properly aligned, the cross-polarization discrimination of the compact range feed becomes the dominant factor. Feeds used for single reflector compact ranges typically are designed to only have -35 dB of cross-polarization on-axis and -25 dB across the quiet zone since the cross-polarization induced by the feed tilt angle will dominate the quiet zone. In order to support low cross-polarization compact range systems, a new design requirement has been placed upon the antenna used to feed these ranges.

The requirement for this new feed is that it must possess a linear polarization ratio greater than the desired measurement levels across the full projected aperture of the quiet zone as illustrated in Figure 1. A further requirement that the feed operate across the bandwidth of the system further complicates the design.

For the geometry shown in Figure 1, where the primary feed axis is pointed at the vertex of the compact range reflector, this translates into a linear polarization requirement within about a 40-degree cone about the feed axis. To support high accuracy compact range measurements utilizing the geometry shown in Figure 1, the cross-polarization introduced by the source should be on the order of -43 dB.

2. Feed Configuration

The feed configuration chosen to meet these design requirements is a corrugated circular aperture similar to the prime-focus waveguide feeds shown in Olver, et al[3]. These new feeds, however, use a corrugation design with stepped rings, and a reduced aperture to widen the beamwidth of the feed and to equalize the E and H plane beamwidths. The aperture design of one of these feeds is shown in Figure 2.

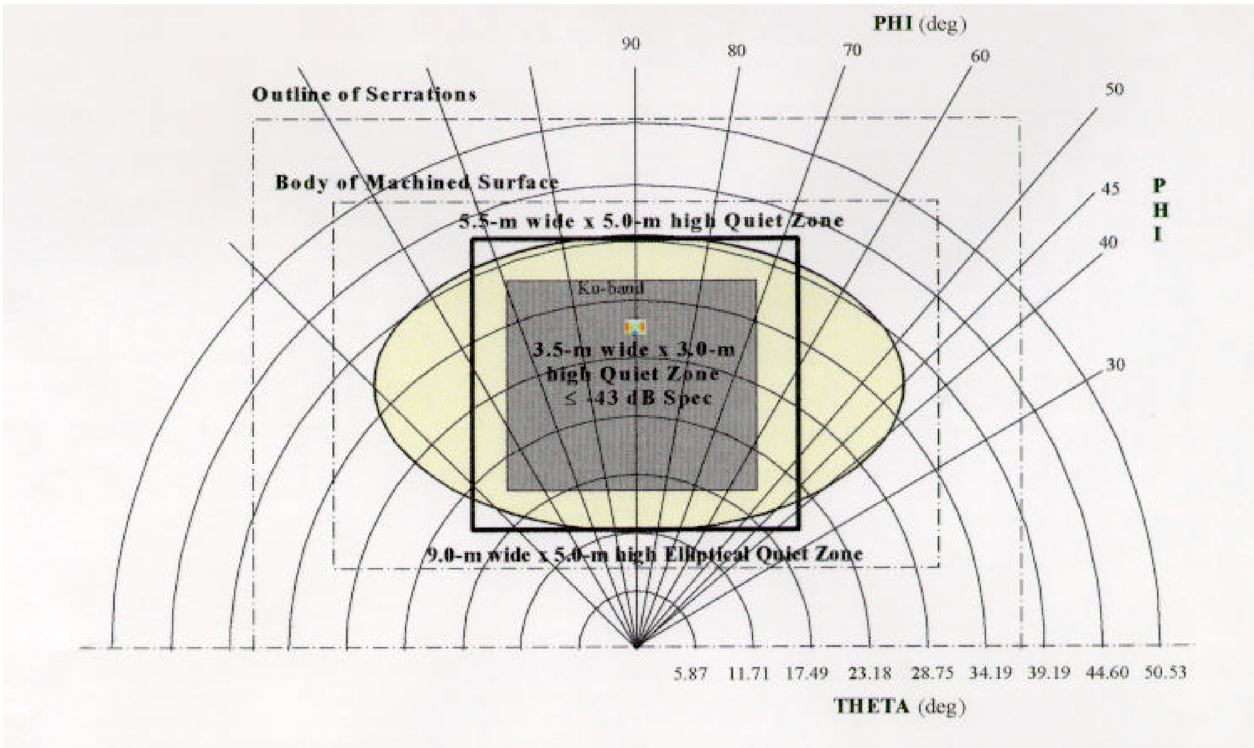


Figure 1: Compact Range Feed pointing angles overlaid on the Layout of the Quiet Zone of a MI Technologies Model 5712 Compact Antenna Range Reflector.

These feeds were designed to support either single polarization or switchable dual linear polarization. In designing these feeds further requirements were placed on the compact range feed system to support an operational band of frequencies from 1.1 GHz through 40 GHz.

This operational band is covered by the MI Technologies Model 31[4] and 33 series of compact range feeds. Each of these feeds covers a typical waveguide band of frequencies. In order to meet the cross-polarization requirements across each waveguide band, the bands were broken down into three subbands of approximately 23% bandwidth based on the wavelength of the feed in the waveguide according to the following equation.

$$BW_p = \frac{\lambda_{g1} - \lambda_{g2}}{\lambda_{g1} + \lambda_{g2}} * 100\% \qquad (1)$$

Where,

λ_{g1} = wavelength in the aperture at the high end of the band

λ_{g2} = wavelength in the aperture at the low end of the band

BW_p = Percentage bandwidth.

Each of these subbands are covered by a separate removable aperture section.

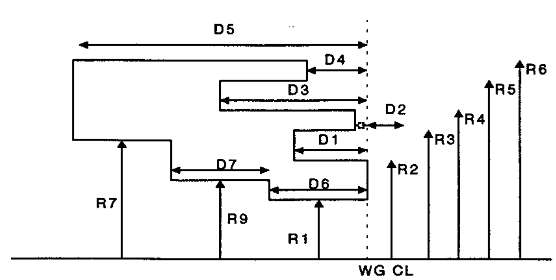


Figure 2: Cross Section of the Low-Cross Polarization Compact Range Feed Aperture.

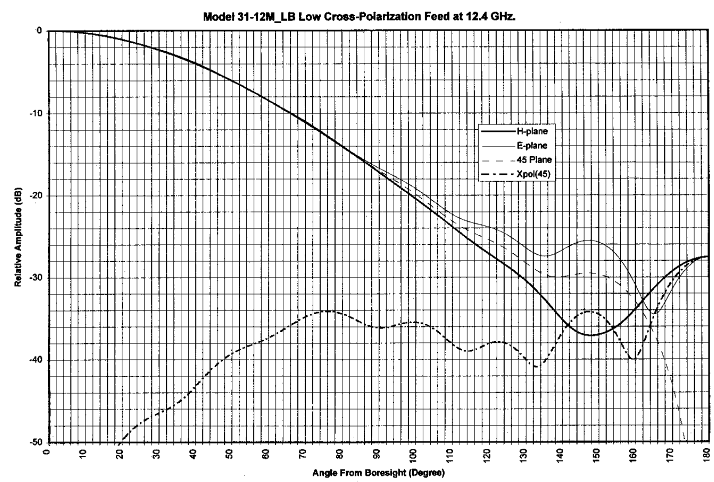


Figure 3: E-plane, H-plane, and intercardinal plane primary polarization, and intercardinal plane cross-polarization for the Model 31-12M_LB at 12.4 GHz.

3. Predicted Results

This series of feeds was designed with the aid of the "Corrugated Horn Analysis by Moment Method Program," (CHAMP) code.

Figure 3 shows E-plane, H-plane, and intercardinal plane primary polarization along with the cross-polarization in the intercardinal plane for the Model 31-12M_LB operating at 12.4 GHz. Note that over the 40-degree cone about the feed axis, the highest cross-polarization level is -43 dB and occurs in the intercardinal plane.

Figure 4 shows the predicted performance of the Model 31-1.7M-HB feed at the low and high operating frequencies across the quiet zone of the feed/reflector system.

4. Measurement Technique

In order to verify the cross-polarization levels predicted using the CHAMP moment method software, a set of feeds was constructed and tested. This test program was constrained by the difficulties of making cross-polarization measurements on the order of -40 to -50 dB. After most sources of errors in the measurement were accounted for, the error associated with the linear polarization ratio of the source antenna was the most significant.

A measurement program was undertaken to characterize a number of standard gain horns to be able to select the one with the lowest cross-polarization. This program utilized the three-antenna polarization characterization technique outlined by Newell [5].

Using the complex linear polarization ratio and tilt angle determined by the three-antenna method, the source antenna cross-polarization contribution to the measurement was removed using equation 7.

Equation 7 is derived from the reaction equations as follows:

$$D'_{AS} = X_A * X_S - Y_A * Y_S \quad (2)$$

$$D''_{AS} = X_A * X_S + Y_A * Y_S \quad (3)$$

Where;

D'_{AS} = Co-polarized measurement

D''_{AS} = Cross-Polarized Measurement

X, Y = complex components of the elliptically polarized wave. A, S represent the AUT and Source respectively.

Taking the ratio of equations 2 and 3 and substituting;

$$p_A = \frac{X_A}{Y_A} \quad (4)$$

$$p_S = \frac{X_S}{Y_S} \quad (5)$$

Yields the ratio of the co-polarized to the cross-polarized measurement Q_{AS},

$$Q_{AS} = \frac{p_A + p_S}{p_A * p_S - 1} \quad (6)$$

Finally, solving for p_A gives the corrected AUT linear polarization ratio.

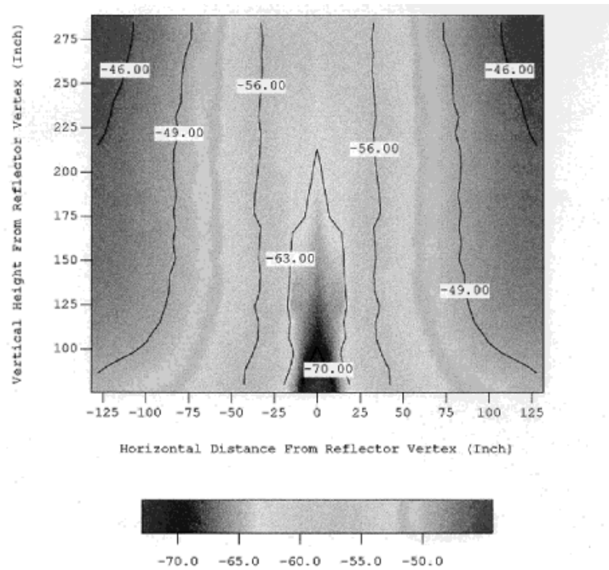
$$p_A = \frac{p_S + Q_{AS}}{Q_{AS} - 1} \quad (7)$$

5. Measured Data

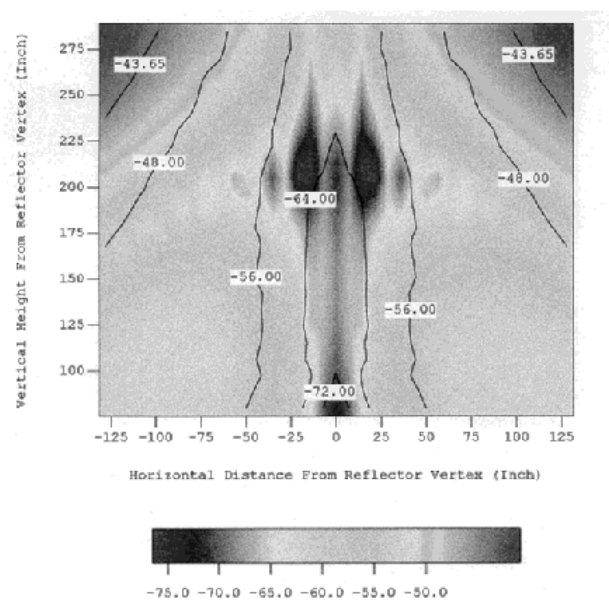
The cross-polarization required by these feeds is -43 dB over a 40-degree cone about the centerline of the feed. The maximum cross-polarization from a scalar feed occurs in the intercardinal planes (±45 degrees). The intercardinal plane patterns for the Model 31-12M-LB is shown in Figures 5a and 5b for the low and high ends of its operational band. For each plot presented, 5 traces are shown; the measured and predicted co-polarized patterns, and measured, predicted and corrected cross-polarized patterns. The corrected cross-polarized patterns are corrected for the error introduced by the standard gain horn's linear polarization ratio using the method outlined in Section 4.

The first plot in Figure 5 is taken on the lowband aperture at 12.4 GHz. The corrected cross-polarization meets the required specification over a ±45° range and agrees well with the predicted data. The standard gain horn used for this measurement had a linear polarization ratio of -48 dB. The second plot, Figure 5(b), was taken using a standard gain horn with a measured linear polarization ratio of greater than -72 dB. Therefore this source horn did not introduce much error into the cross-polarization measurement. This plot shows excellent agreement between the measured and predicted cross-polarization.

The final design requirement to test is the return loss for the feed. Figure 5(c) shows the return loss for the Model 12M-LB for 12.4 GHz to 18.0 GHz although the actual operating band for this feed is only 12.4 to 14.0 GHz. The worst case return is -13.5 dB across the operating band.



(a)



(b)

Figure 4: Cross-Polarization across the quiet zone shown in Figure 1 for the Model 31-1.1M-HB. (a) 1.5 GHz (b) 1.7 GHz

6. Summary

A series of circular corrugated aperture feeds to meet the requirements for testing low cross-polarized antennas in compact ranges has been presented. This series of very low, wide bandwidth feeds have been developed to cover a frequency band from 1.1 to 40.0 GHz based on the MI Technologies' Model 31 waveguide OMT and Model 33 feeds. Individually each feed aperture covers a bandwidth of approximately 23% with 3 apertures per full waveguide band. These feeds have been developed, tested and shown to exhibit a cross-polarization greater than 43 dB across a full 40° cone about the centerline of the aperture.

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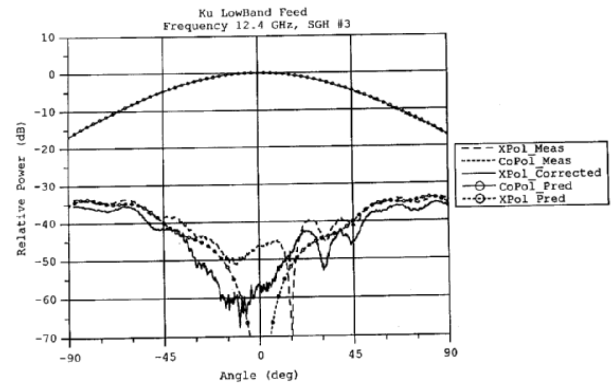
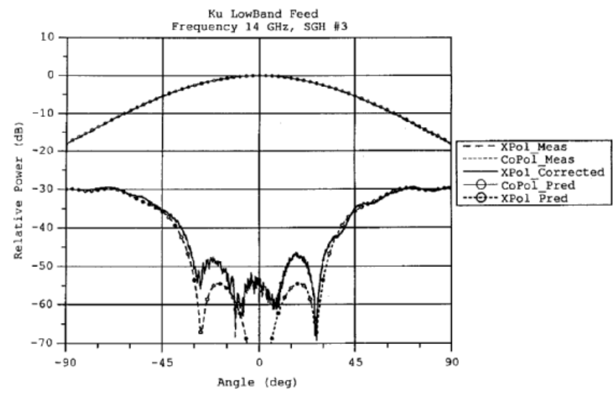
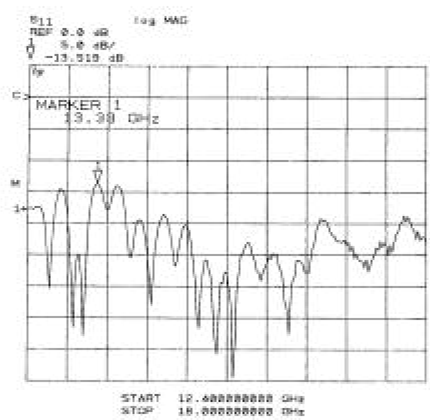


(a)



(b)



(c)

Figure 5: Performance Data for the Model 31M-12-LB feed. (a) Pattern data at 12.4 GHz. (b) Pattern data at 14.0 GHz. (c) Return Loss data vs. the full waveguide bandwidth of the Model 31 Feed.