Reduction of the Cross Polarization Component in the Quiet Zone of a Single Reflector CATR

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Abstract—A novel conjugate matched feed for standard single reflector Compact Antenna Test Ranges (CATR) has recently been presented [1]. Significant reduction of the cross polarization component in the Quiet Zone (QZ) can be achieved with a dual-polarization feed in a nominal 1.5:1 bandwidth. The feed is a standard hardware component, consisting of a 3-element array with integrated feeding network, suitable for upgrading any single reflector CATR. This concept has been verified previously by QZ probing of a side-fed CATR configuration using a proof-of-concept demonstrator with a limited bandwidth of 10 to 12.5 GHz.

In this paper, we report on the application of the proof-of-concept demonstrator for standard corner-fed CATR applications. The concept is validated by QZ probing. It is shown, that the spatial distribution of the cross polarization field of the QZ is significantly reduced and homogenized. Thus, the cross polarization received by an Antenna Under Test (AUT) is no longer dependent on AUT size or QZ location. The advantages of the new feed concept are further investigated by measurement of a low cross-polarized antenna at different QZ positions. For offset QZ measurements, it is shown that an improvement of 10 dB in cross-polar discrimination can be achieved.

I. Introduction

In a standard Compact Antenna Test Range (CATR) configuration, a feed antenna illuminates a reflector such that the amplitude and phase taper across the Quiet Zone (QZ) is minimal. In an offset CATR geometry, the feed is rotated with respect to reflector / world coordinate system towards about the center of the reflector. This causes a non-uniform polarization of the electric field over the QZ, i.e. the tilt angle of the polarization ellipse is a function of the position within the QZ. The tilting is "experienced" by an Antenna Under Test (AUT) mounted in the QZ as a variation of the cross-polarized component defined by the reflector coordinate system, thus limiting the achievable dynamic range of cross polarization measurements.

For measurements of small antennas, relative to the CATR reflector diameter, this effect is negligible as long as the AUT is well centered in the QZ. An antenna diameter to compact range focal length ratio threshold of 0.051 is proposed in [2] above which the cross-polar measurement accuracy is considered significantly degraded. Standard single reflector CATR geometries have focal length roughly twice the diameter of the reflector. Thus, a diameter at least 10 times the size of the AUT is necessary to meet this requirement. Consequently, the accurate measurement of cross-polar performance is rather difficult for physically large antennas, such as arrays or reflector antennas or antennas mechanically offset in the QZ, for example when mounted on a structure such as a satellite.

Other than reflector geometry adjustment, different options, spanning post-processing and hardware modifications have been presented in the literature to improve the cross-polar performance of the single reflector CATR. An overview of such technologies can be found in [1].

Compensation of the cross polarization using an array-feed based on the matched-feed concept has already shown good performance in a side-fed reflector CATR [1]. For a side-fed geometry, the feed is offset in one dimension. In this paper we will demonstrate that the compensation technique can be adapted to a single reflector, corner-fed CATR where the feed is offset in two dimensions. The experimental verification has been performed in the CATR at RWTH Aachen University, Germany. Besides verifying the reduced cross polarization level in the QZ by planar field probing, measurements of a large reference antenna with a cross-polar component below -50 dB were performed.

II. Proof-of-concept Demonstrator

The matched-feed concept consists of a feed with an aperture field that is conjugate matched to the incoming field in the focal-plane of the reflector when illuminated by a plane wave impinging from the QZ [3]. With this technique, high QZ polarization purity for both orthogonal polarizations can be achieved.

A limited scope conjugate matched feed has been implemented as proof-of-concept demonstrator as described in [1] and is shown in Figure 1. It consists of 3x1 antenna elements: A center element, which produces the co-polar illumination of the reflector and two cross-polarized side elements designed to create the conjugate field matching. This single polarization demonstrator has a relative bandwidth of 1.25:1, covering 10 to 12.5 GHz.

The array was dimensioned using a 3D full-wave simulation tool [4]. The simulated far-field pattern of each array element was used in a PO/MoM simulation calculating the resulting electric fields in the QZ, taking into account the effects of the serrated reflector [5]. Optimum complex array-feed excitation

Figure 1. The proof-of-concept demonstrator configured for a corner-fed single CATR

coefficients were determined by combining the simulated QZ cross-polar components generated by the side elements with those generated by the center element. Further details are given in [1]. The resulting dimensions are summarized in Table I.

TABLE I. CONJUGATE MATCHED FEED DIMENSIONS

Dimensions	Co-feed	Cx-feeds
Aperture inner diameter	21.0 mm	21.0 mm
Choke inner diameter	39.2 mm	-
Inter-element distance	-	90.0 mm

III. PROBING OF THE QUIET ZONE

The CATR at RWTH Aachen University (Figure 2.) is based on a corner-fed single reflector with a parabolic section of 1.7 m x 1.7 m and serrated edges. The resulting size of the cylindrical QZ is 1.1 m x 1.1 m. Currently, the operational frequency range spans from 2 to 75 GHz. The positioner system is configured as roll-over-azimuth with elevation squint and AUT pick-up, all mounted on a cross-range slide. RF-instrumentation is based on a ZVA24 Vector Network Analyzer with 85320 series external mixers. High-performance, linearly polarized, axisymmetric, corrugated horns are used. The feeds are mounted on a 4-axes positioner system. The range is housed in a shielded chamber of 9 m x 5 m x 5 m (L x W x H).

The QZ field probing measurements were performed using a linear field probe scanner in combination with the cross-range slide for 2D planar scanning with a spatial sampling of $\Delta_x, \Delta_y = 10 \text{ mm} \leq \lambda_{min}/2$ as shown in Figure 3.

As a field probe the standard single-linearly polarized CATR feed (Orbit/FR AL2309-10.0-SL) with medium gain and high polarization purity was used. The QZ field was first measured exciting only the center element of the demonstrator, which has a radiation characteristics very similar to a standard CATR feed horn, and was repeated with all elements of the conjugate matched feed. The QZ co-polar probing results are shown in Figure 4. and Figure 5. The measured co-polar field component in the QZ shows a peak-to-peak amplitude variation of less than 1 dB for both cases. The field difference between the two configurations is negligible with a maximum of 0.14 dB.

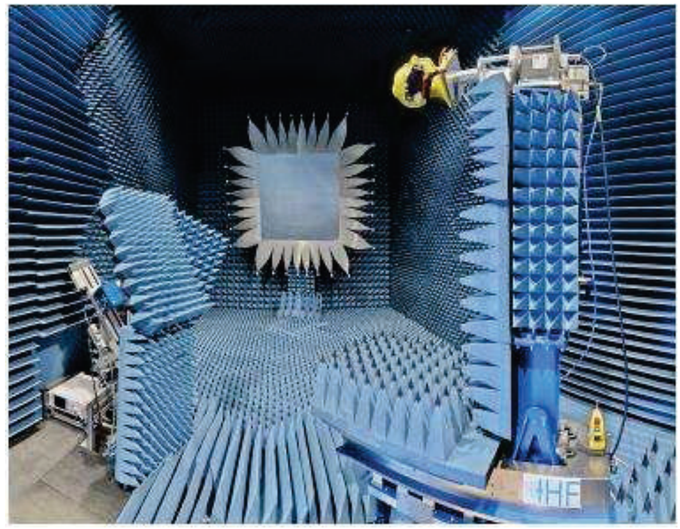

Figure 2. CATR at RWTH Aachen University

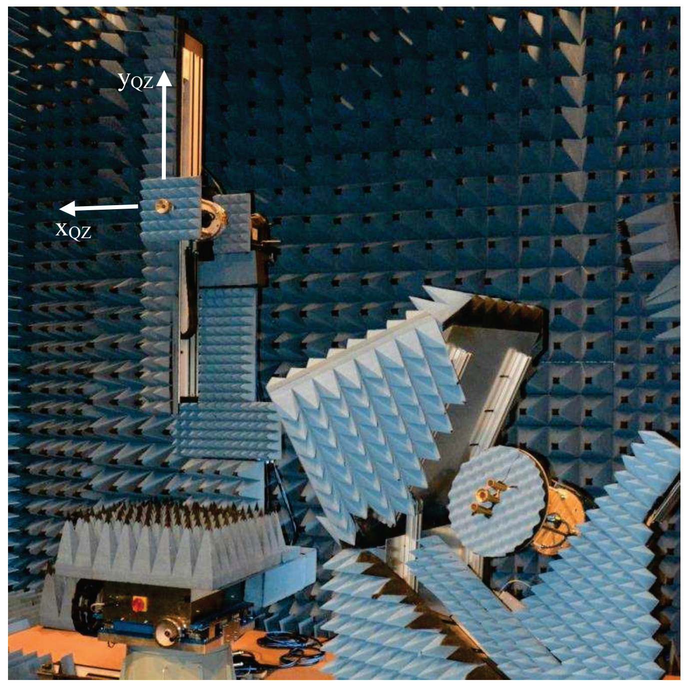

Figure 3. Field probe scanner (Left) and the conjugate matched feed (Right)

As shown in Figure 6. and Figure 7., the overall cross-polar field component in the QZ has been homogenized by using the conjugate matched feed. In particular, the maximum cross polarization level at the edges of the circular QZ region is reduced by about 10 dB. The maximum and mean value of the cross-polar component as a function of frequency is shown in Figure 8. A significant reduction throughout the QZ can be achieved by the conjugate matched feed. However, the improvement by the conjugate matched feed is not as large as expected from simulation (Figure 9.). This is probably due to deficiencies in the manufacturing of the limited scope demonstrator. It is believed that these cause also the slightly increased cross-polar level within the QZ center region in the contour plots.

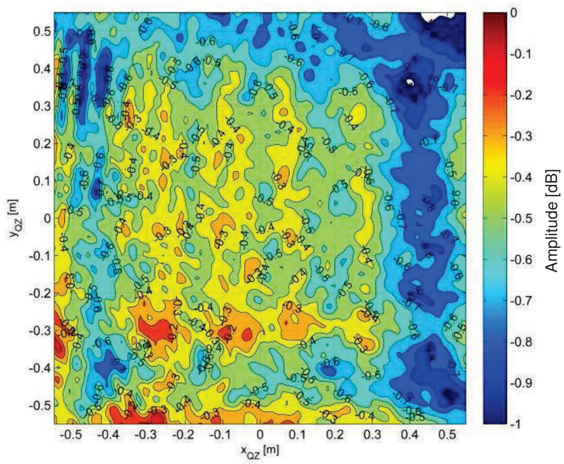

Figure 4. Contour plots of the QZ co-polarization at 10.7 GHz using the proof-of-concept demonstrator: Center element

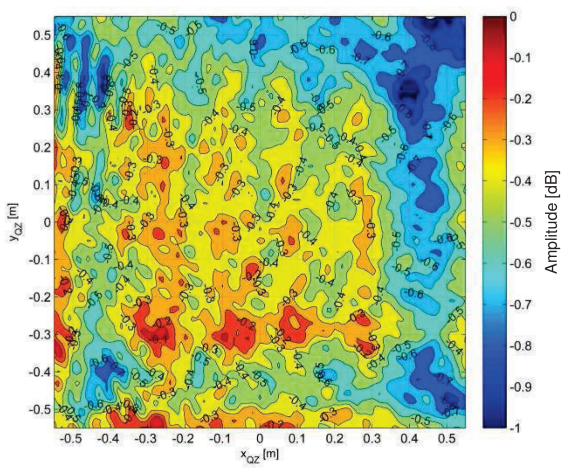

Figure 5. Contour plots of the QZ co-polarization at 10.7 GHz using the proof-of-concept demonstrator: Conjugate matched feed

IV. SR40-A Radiation Pattern Measurement

As a large reference antenna for the measurements, we choose the SR40-A [5] as shown in Figure 10. This antenna is a vertical linearly polarized, prime focus, super elliptical, offset reflector antenna (F/D = 0.5) with a wideband dual-ridge horn feed covering 4 to 40 GHz. The parabolic rim of this antenna is about 400 mm x 400 mm, thus the diameter-to-compact range focal length ratio is 0.09. In the context of this investigation the cross-polar component of the E-plane cut (coincident with the plane of symmetry of the AUT), is the most interesting, as it has the lowest cross-polar values. Figure 11. and Figure 12. show the simulated radiation pattern [6].

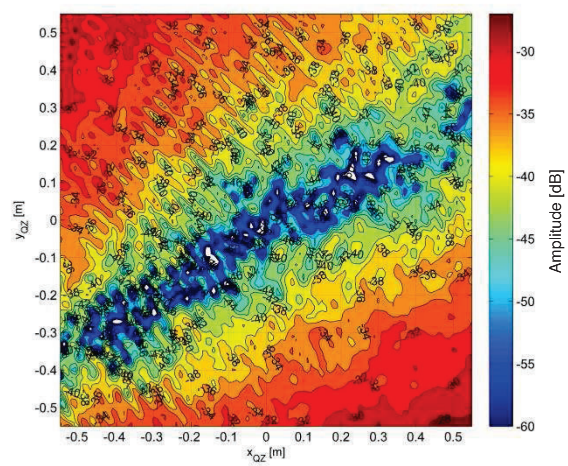

Figure 6. Contour plots of the QZ cross polarization at 10.7 GHz using the proof-of-concept demonstrator: Center element

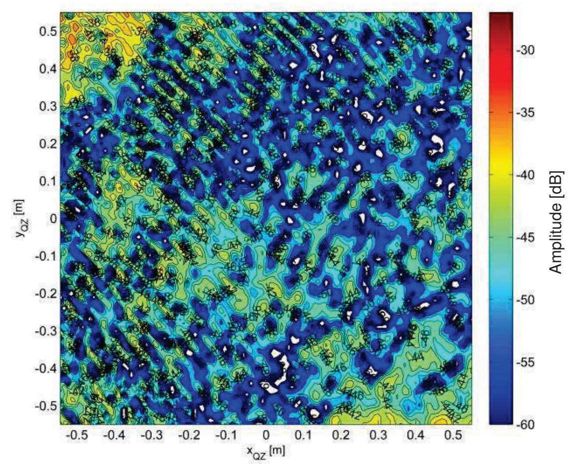

Figure 7. Contour plots of the QZ cross polarization at 10.7 GHz using the proof-of-concept demonstrator: Conjugate matched feed

To illustrate the impact of the matched-feed concept on the cross-polar measurement accuracy, the cross-polar pattern of this antenna was measured using both the conjugate matched feed and center element for comparison.

The AUT was furthermore placed at two different locations of the QZ: At its center and at an offset position of -0.3 m. This was done to simulate the measurement scenario in which the AUT is located in an area of the QZ with lower cross-polar discrimination. The displacement was achieved by using the cross-range slide, so that the complete positioner, hence the center of rotation, was displaced. The volume of the QZ occupied by the AUT during azimuthal rotation is therefore the same.

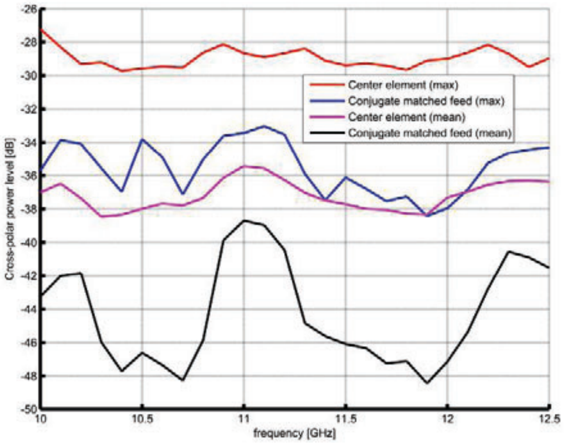

Figure 8. Measured mean and maximum QZ cross-polar level over the frequency band, using the center element and conjugate matched feed

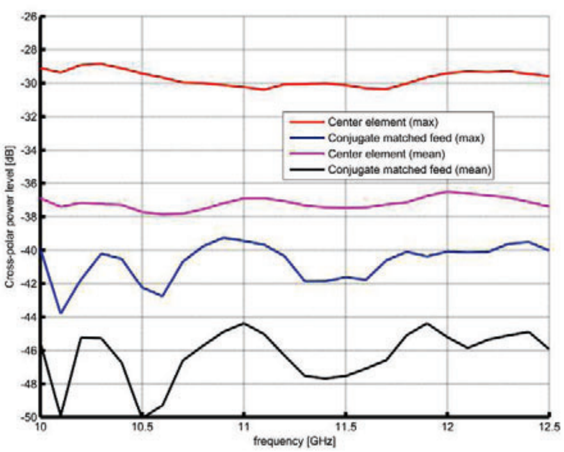

Figure 9. Simulated mean and maximum QZ cross-polar level over the frequency band, using the center element and conjugate matched feed

As shown in Figure 13., a high cross-polar discrimination of the AUT (> 50 dB) can be measured if the AUT is centered in the QZ.

The measurement of the reference antenna in the QZ offset position is shown in Figure 14. As expected, the measured cross-polar pattern is degraded using the center element due to the unfavorable position of the AUT in the QZ. This can be seen by a 10 dB increase of the cross-polar component in boresight.

It can be further observed that the measurement using the conjugate matched feed is very similar to the measurement in the QZ center position. More detailed examination in the main beam direction (Figure 15.) shows that the measured cross-polar pattern is strongly affected by an AUT offset for the center feed configuration. In contrast, the effect is very small for the conjugate matched feed due to the homogeneous cross-polar distribution in the QZ.

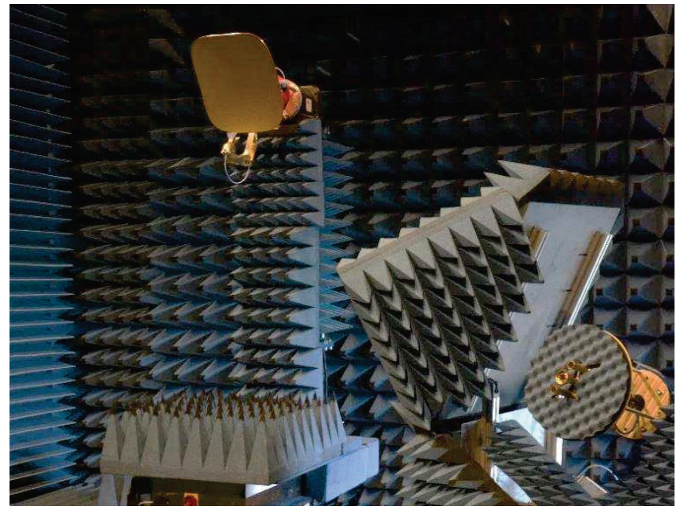

Figure 10. Reference antenna, Satimo SR40-A with SH4000 as feeder, and the conjugate matched feed

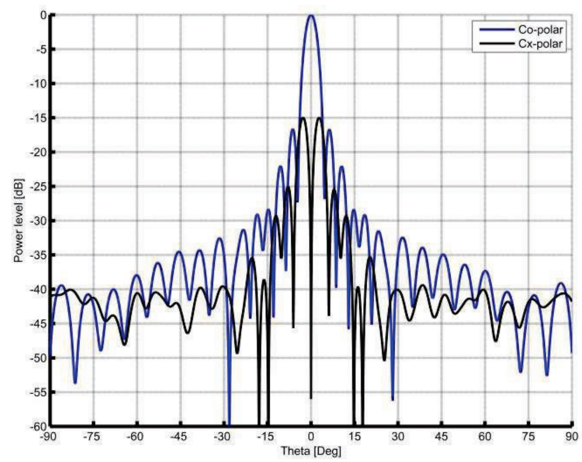

Figure 11. Simulated H-Plane pattern of the reference antenna at 10.7 GHz

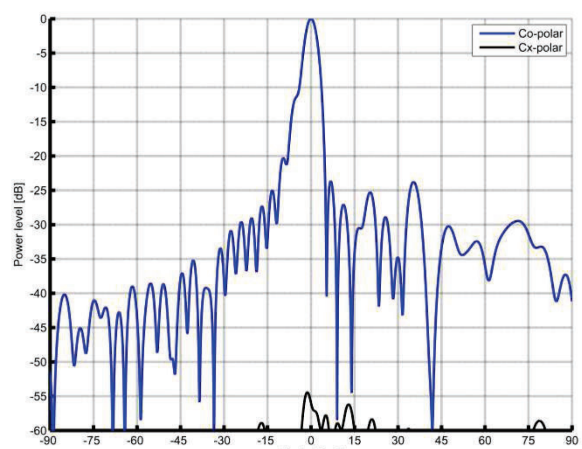

Figure 12. Simulated E-Plane pattern of the reference antenna at 10.7 GHz

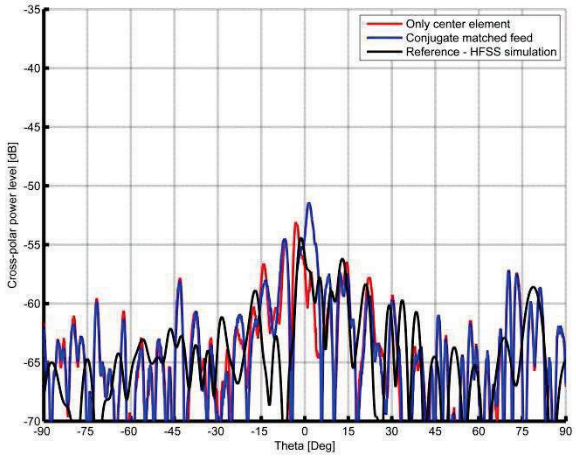

Figure 13. Measured and simulated cross-polar E-plane pattern at 10.7 GHz. AUT positioned in QZ center

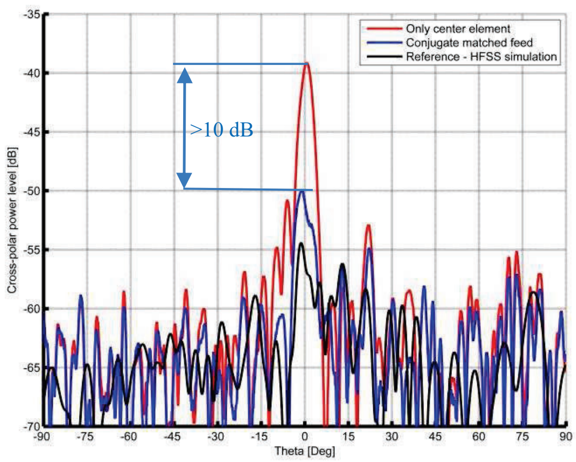

Figure 14. Measured and simulated cross-polar E-plane at 10.7 GHz. AUT offset by -0.3 m

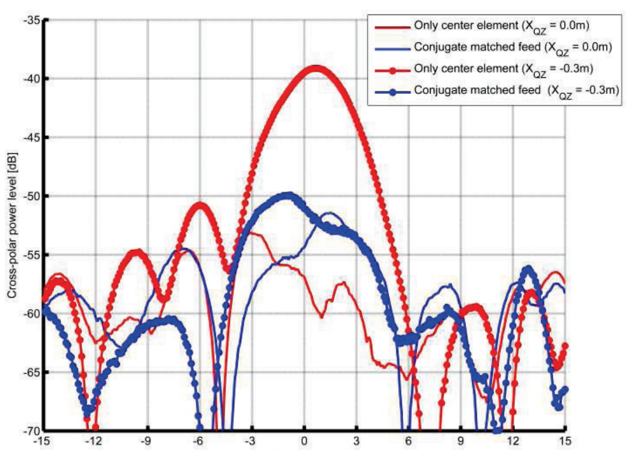

Figure 15. Measured and simulated cross-polar E-plane at 10.7 GHz. Center element (Red) and conjugate matched feed (Blue). AUT centered and offset by -0.3 m

V. Summary and Conclusion

The cross polarization reduction property of a conjugate matched feed for a corner-fed CATR has been investigated. The cross-polar accuracy improvement with the new feed concept has been verified by QZ probing and measurement of a low cross-polarized antenna in different QZ positions. The QZ probing shows no co-polar degradation of the QZ field as compared to a standard CATR feed. Further, a homogenization of the cross-polar QZ field has been achieved with no significant degradation in the center, compared to the center element. With the new concept, the cross polarization measurement accuracy is no longer dependent on the AUT size or position in the QZ. Consequently, the full QZ has become available for accurate cross-polar characterization of antennas in single reflector CATR. This is a significant improvement for the measurements of physically large antennas, such as arrays or reflector antennas or antennas mechanically offset in the QZ, for example when mounted on a structure such as a satellite. The performance of the conjugate matched feed was further investigated by measurement of a low cross-polarized (-50 dB) antenna at different QZ positions. For offset QZ measurement, an improvement in cross-polar discrimination of more than 10 dB has been achieved.

The actual demonstrator reported in this paper is a limited scope conjugate matched feed with relative bandwidth of 1.25:1. The feed covers 10 to 12.5 GHz in single linear polarization. Based on the findings in this paper, a new version of the conjugated matched feed has been designed by MVG and is currently being manufactured. The new feed provides simultaneous cross polarization cancellation in both orthogonal polarization in the full achievable 1.5:1 bandwidth and is easily reconfigurable for side and corner fed CATRs. Future activities include testing and verification of the new feed.

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