**The Importance of Polarization Purity**

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The polarization purity of an antenna system is an important characteristic, particularly in dual-polarized electronic systems, where depolarization can prevent the system's quality objectives from being achieved. High quality testing requires significantly higher polarisation purity, or lower cross-polarization, of the test system than the test object. Compact Antenna Test Ranges (CATR) provide convenient testing, directly in far-field conditions, of antenna systems placed in the test chamber Quiet Zone (QZ). Performance, in terms of polarization purity is often the reason that a more expensive, more complex, compensated dual reflector CATR is chosen, particularly for electrically large antennas. This expense and complexity has driven research to develop the capacity to obtain equivalent polarization performance in a single reflector CATR. Most recently, the CXR feed, a new, wide band, dual polarised feed, based on conjugate matching of the undesired cross-polar field in the QZ has been developed by MVG, significantly improving the cross-polar accuracy of standard single reflector CATR systems.

**Single Reflector Compact Antenna Test Ranges**

A Compact Antenna Test Range (CATR) is a facility used to provide convenient testing of antenna systems at frequencies where space for far-field testing is infeasible. The CATR uses a source antenna which radiates a spherical wavefront and one or more reflectors to transform the radiated spherical wave into a planar wave within the desired test zone. In standard, single reflector systems, a large reflector is illuminated by a feed to ensure that the amplitude and phase variation is minimal across the QZ. To avoid obstruction by the feed, it is offset, and the reflector illuminated at an angle. The offset geometry causes a variation of the polarisation tilt angle as a function of position in the QZ. This Geometrical Optics (GO) effect gives rise to cross-polarisation in the QZ.

Accurate testing of low cross-polar antennas in CATR requires a QZ with high polarization purity. It is well known, that such a condition is only achieved for testing scenarios, where the CATR reflector is at least 10 times the size of the Antenna Under Test (AUT) [1]. Unfortunately, this requirement makes the accurate measurement of cross-polar performance rather difficult for physically larger antennas, such as arrays or reflector antennas, or antennas naturally offset in the QZ since they are mounted on a structure, as is the case with satellite antennas.

When testing electrically large antennas and/or fitted to large platforms, the QZ cross-polar performance is often the reason that a more expensive, complex, compensated dual reflector CATR is chosen rather than a single reflector CATR. This complexity and cost deterrent is why much research has been done on minimizing the QZ cross-polarization of the single reflector CATR. Solutions such as reflector geometry adjustments, other hardware improvements and post-processing techniques have been proposed over the years but the drawback of these techniques have been a hindrance for their widespread use [2].

## CXR Feed

The CXR feed is a new plug-and-play component that performs cross-polar reduction, similarly to the second reflector in a dual compensated CATR. This novel feed concept is a breakthrough in CATR systems as it extends their measurement capabilities beyond the traditional limitations and at the affordable cost of a feed replacement. The CXR feed has been conceived to significantly improve the cross-polar accuracy of side/corner-fed single reflector systems but is equally suitable for dual cylindrical reflector systems. The concept behind the CXR feed is the cancellation of the Geometrical Optics (GO) cross-polar component induced by an offset reflector by means of an innovative architecture providing conjugate field matching in bandwidth of 1.5:1. The CXR was developed upon the concept of the conjugate-matched feed [3, 4].

## Cross-Polarization Compensation by Conjugate Matched Feed

A conjugate-matched feed has aperture fields that are conjugate matched to the focal-plane fields of the reflector when illuminated by a plane wave within the QZ. Such a feed effectively cancels the Geometrical Optics (GO) cross-polar component. This provides high QZ polarization purity in both orthogonal polarizations as well as unlimited bandwidth. Only secondary cross-polar sources remain, such as edge diffraction effects.

Research was conducted with a conjugate-matched feed implemented as a 3-element array: a central horn, which produces the co-polar illumination of the reflector and two cross-polarized side-elements, designed to create the conjugate field matching. In this case, the array element was optimized using a 3D full-wave simulation tool and the optimum complex array-feed excitation coefficients were determined by numerical simulation (PO/MoM) of the serrated reflector. The target minimum cross-polar discrimination of the QZ was 40dB, offering an improvement more than 10dB on the classical, single feed performance. The physical dimensions of such feed limit the realisable bandwidth to roughly 1.6:1 in dual simultaneous polarisation and for any offset reflector configuration [3-4]. In this example, the conjugate-matched feed concept was validated with a limited scope proof-of-concept CXR demonstrator (shown in Figure 1). The CXR demonstrator has been designed with a relative bandwidth of 1.25:1, covering 10GHz to 12.5GHz in single polarization.


Figure 1. The proof-of-concept CXR, conjugate matched feed demonstrator configured for corner-fed single reflector CATR geometry.

## Quiet Zone probing setup in a CATR

The CATR at RWTH Aachen University shown in Figure 2 is a typical example of a single reflector CATR. The compact range was manufactured by MVG-Orbit/FR and based on a corner-fed single reflector with a parabolic section of 1.7m x 1.7m and serrated edges [5]. The resulting size of the cylindrical QZ is 1.1m x 1.1m and the operational frequency range is 2GHz to 75GHz. The positioner system is configured as roll-over-azimuth with elevation squint and AUT pick-up; all mounted on a cross-range slide. The feeds are mounted on a 4-axes positioner system. An optimized- geometry absorber fence limits the direct leakage from the feeds towards the QZ. The range is housed in a shielded chamber of 9m x 5m x 5m (L x W x H).

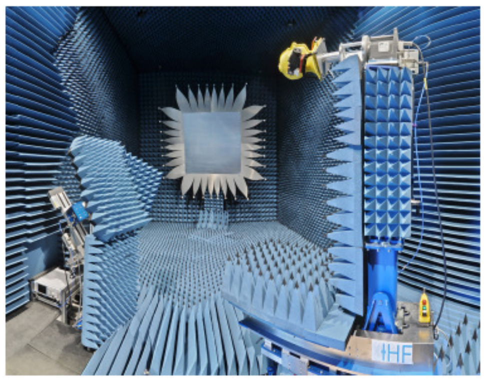

Figure 2. CATR at RWTH Aachen University

QZ field probing measurements were performed using a linear field probe scanner in combination with the cross-range slide for 2D planar scanning. As QZ probe, a standard single-linearly polarized CATR feed with medium gain and high polarization purity was used.

Figure 3. Field probe scanner with the Orbit/FR AL2309-AL-10.0-SL as probe (left). The CXR, conjugate matched feed demonstrator is mounted on the feed positioner (right)

## Validation of Proof-of-Concept Demonstrator by Quiet Zone Probing

The QZ field was measured with a traditional feed and the CXR, conjugate-matched feed at the centre frequency 10.7GHz as shown in Figures 4 and 5 respectively. In both configurations, the co-polar QZ presented appreciable co-polar field quality with maximum 1dB peak-to-peak amplitude variation, including ripple and taper effects. The field difference between the two configurations was negligible (max 0.03dB variation).

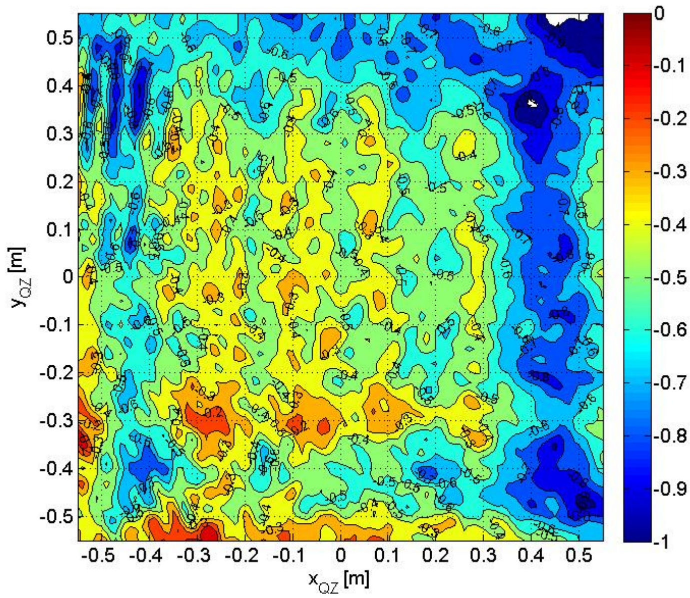


Figure 4. QZ field probing results. Contour plots of co-polarized field at 10.7 GHz using a traditional feed.

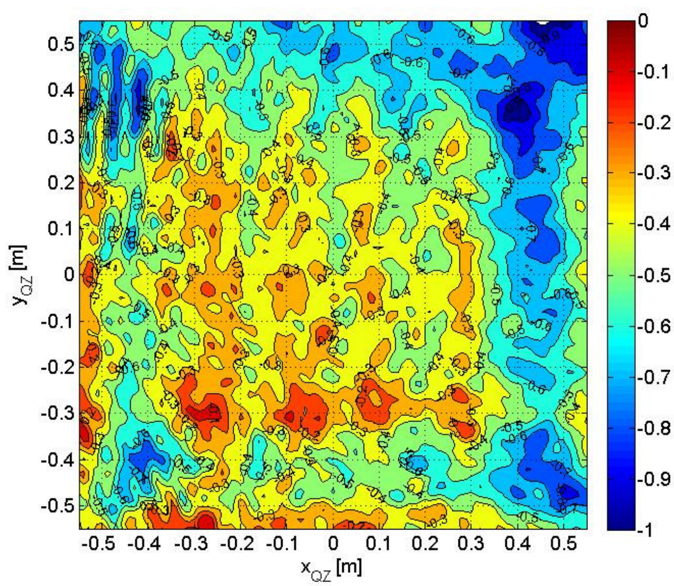


Figure 5. QZ field probing results. Contour plots of co-polarized field at 10.7 GHz using the proof-of-concept CXR, conjugate-matched feed.

The measured cross-polar QZ field components are shown in Figure 6 and Figure 7. The field levels have been homogenized by using the CXR, conjugate-matched feed. In particular, the worst-case cross-polarization level within the circular QZ region is reduced by more than 10 dB, proving the concept of the conjugate-matched feed.

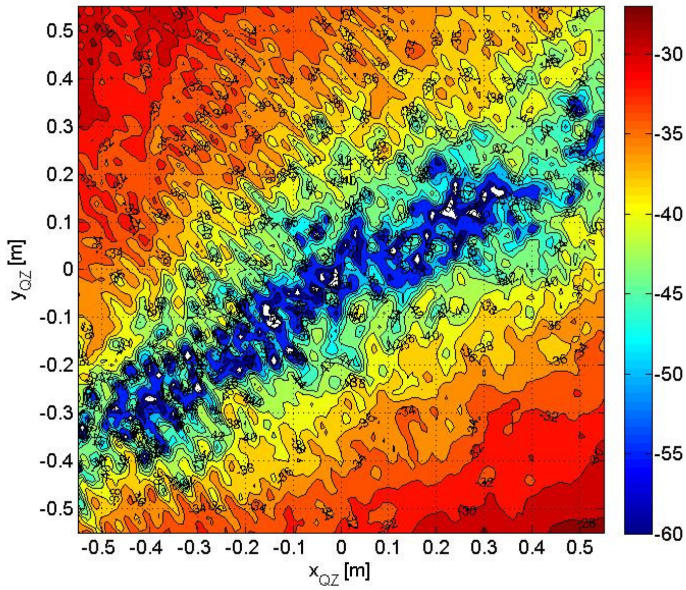


Figure 6. Contour plots of the measured QZ cross-polarization at 10.7 GHz using the using a traditional feed

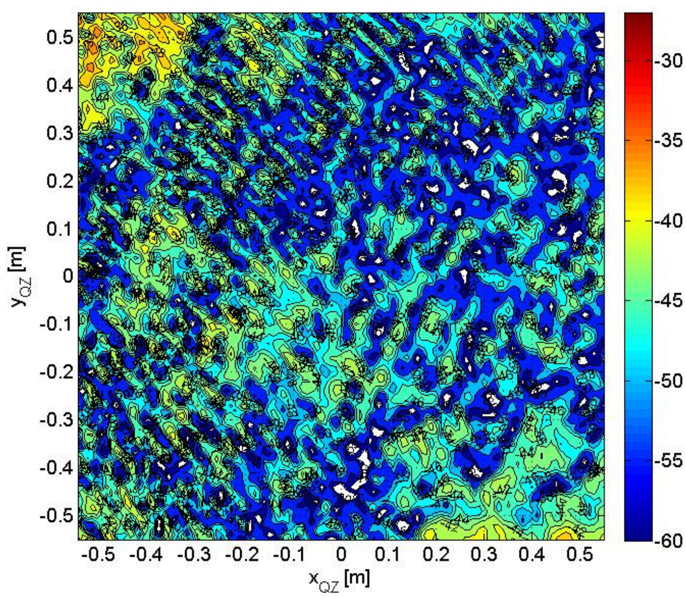


Figure 7. Contour plots of the measured QZ cross-polarization at 10.7 GHz using using the proof-of-concept CXR, conjugate matched feed.

**Application to Space Antenna Testing Scenarios**

As stated above, the CXR conjugate-matched feed is particularly valuable when testing electrically large antennas fitted to large platforms, such as a satellite bodies. The emulation of a space antenna testing scenario using the SR40-A reflector antenna by MVG [4] is shown in Figure 8. The antenna is a linearly polarized, super elliptical, offset reflector antenna (F/D = 0.5) with a wideband dual-ridge horn feed covering 4 to 40 GHz. This antenna has very low cross polar radiation in the symmetry plane and is therefore well–suited as a demanding test object.

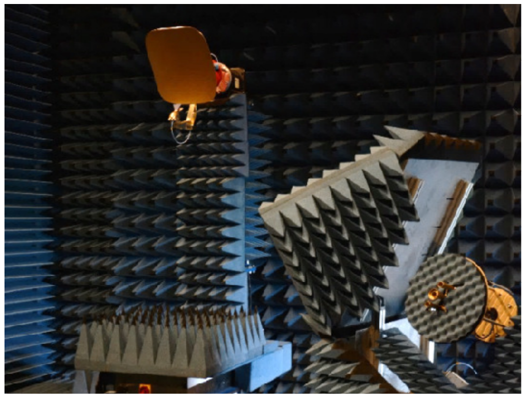

Figure 8. Reference antenna, Satimo SR40-A with SH4000 mounted on the AUT positioner (left). The CXR conjugate matched feed demonstrator is mounted on the feed positioner (*Right*).

**Emulated Space Antenna Testing Scenario Results**

In typical Telecom applications, two reflector antennas are often mounted on each side of the satellite body. In this scenario, both antennas would be situated in areas of the QZ with unsatisfactory, high cross-polar levels, as illustrated in Figure 9. The consequence of this placement can be quantified by comparing measurements of the SR-40 reflector antenna in both the QZ center and offset position. The measurement improvement by the conjugate-matched feed can be investigated by comparing to measurements with a traditional CATR feed.

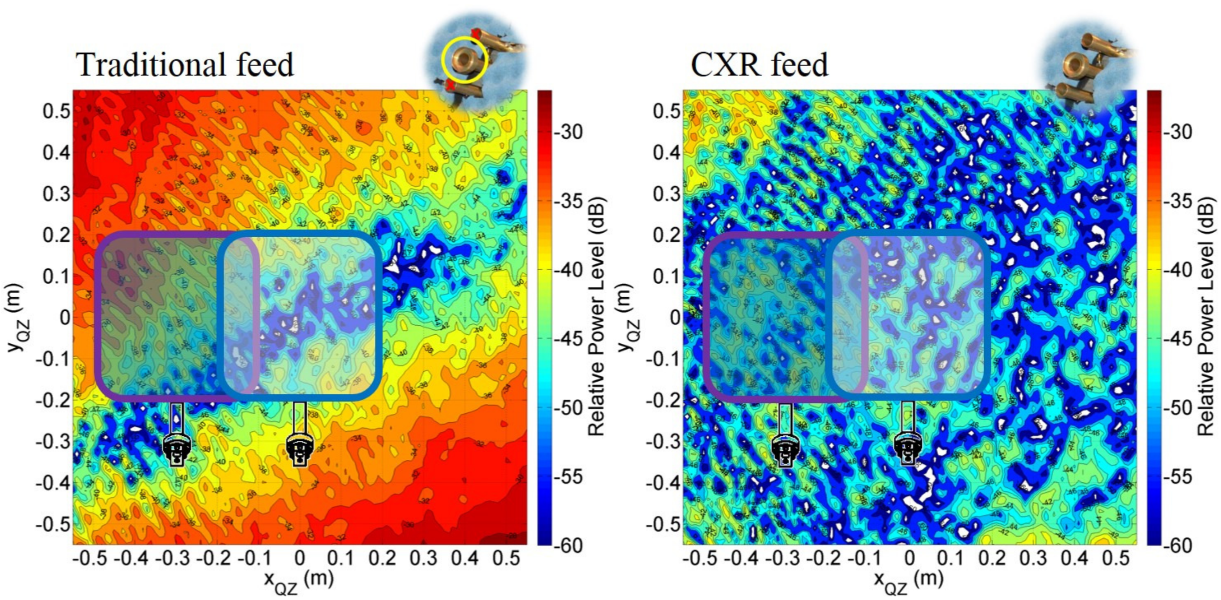

Figure 9. QZ cross-polar discrimination for centered and offset measurement of SR-40 reflector antenna with traditional CATR feed (left) and with the CXR, conjugate-matched feed (right).

The parabolic rim of the SR-40 antenna of 400mm x 400mm is about 5 times less than the CATR reflector diameter and enough to qualify the centered SR-40 measurement as reference for cross-polar performance. As shown in Figure 10, the measured cross-polar performance of the AUT positioned at the QZ center is very good with a cross-polar discrimination of better than 50dB. The correlation of the measured pattern is excellent when compared to the simulated reference pattern, for both configurations [7].

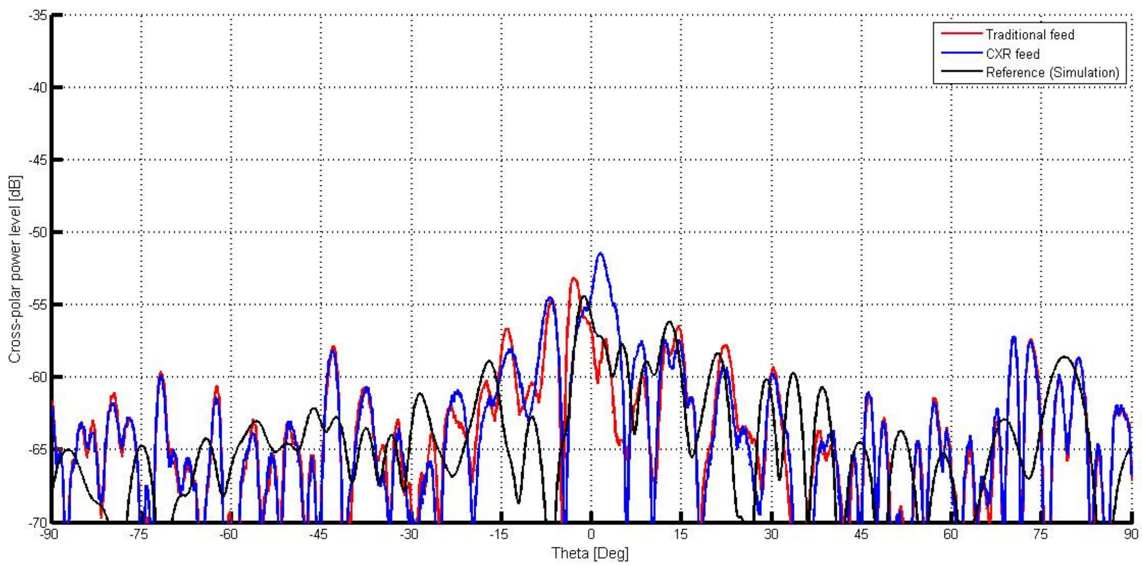


Figure 10. AUT positioned in QZ center. Comparison of measured and simulated cross-polarization E-plane pattern of the SR40-A at 10.7 GHz. Traditional feed (R*ed*). CXR, conjugate matched feed (*Blue*).

The measurement of the reference antenna in the QZ offset position is shown in Figure 11. As expected, the measured cross-polar pattern degrades by more than 10dB when using a standard feed due to the unfavourable position of the AUT in the QZ. It can be further observed that the measurement using the conjugate-matched feed is very similar to the measurement in the QZ center position. This proves that the full QZ has become available for demanding cross-polar measurements using the conjugate matched feed.

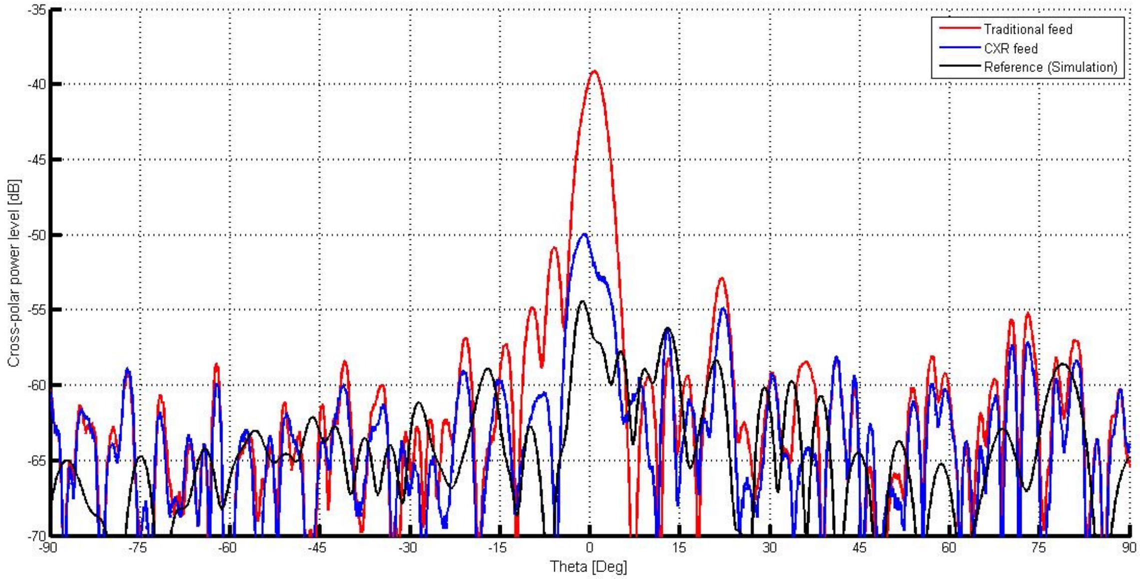


Figure 11. AUT offset -0.3m in QZ. Comparison of measured and simulated cross-polarization E-plane pattern of the SR40-A at 10.7 GHz. Traditional feed (R*ed*). CXR, conjugate matched feed (*Blue*).

**Evolution of the Conjugate Matched Feed**

Although of limited scope, the conjugate-matched feed demonstrator reported in this article, has nevertheless successfully proven this innovative concept. The development of the conjugate-matched feeds is a breakthrough for Compact Antenna Test Ranges as it extends their measurement capabilities way beyond the traditional polarization limitations at the limited cost of a new feed.

The new CXR feed is an add-on component of both side and corner-fed single reflector CATR systems. It is equally suitable for dual cylindrical reflector systems that have similar QZ cross polarisation issues. Based on the findings in this article, the conjugate-matched feeding concept has been further developed by MVG and implemented in the CXR feed. The final CXR feed provides simultaneous cross-polarization cancellation in both orthogonal polarizations on a full 1.5:1 bandwidth. Together, the dual polarization and wide bandwidth of the CXR improves measurement accuracy, facilitate the measurement process and reduce the overall measurement time.

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