Investigation of Compact Antenna Test Range Symmetry Requirements

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Abstract: The optimal design of a compact antenna test range (CATR) is constrained by many factors including electrical performance, available space, and facility cost. This trade-off has implications for the location of certain critical components which include the reflector, antenna under test positioner, and feed positioner. This paper presents the results of a recent study that examined the effect on measurement accuracies of utilising three commonly used configurations for the CATR feed position, namely floor-, corner- and side-fed. Here, particular attention is paid to the effect of range symmetry on measured test antenna co- and cross-polar patterns.

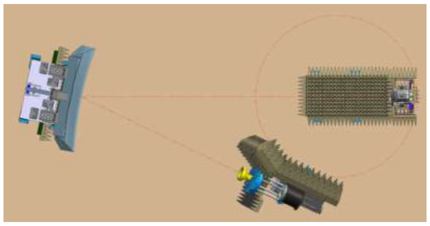
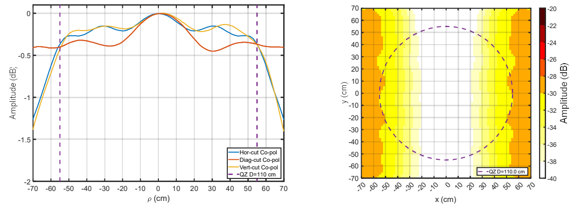


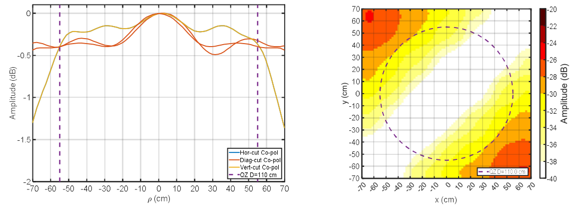
Figure 1. Layout of a corner fed CATR

While over the air (OTA) testing is performed almost exclusively in the direct far-field in the sub-6 GHz FR1 bands, the CATR has become the de facto standard test methodology for mm-wave massive multiple input multiple output (Massive MIMO) antennas for the 5G New Radio communication systems [1]. This is especially true for mm-wave, FR2, OTA test applications which have greatly intensified the demand for CATRs, and particularly those having small quiet zone (QZ) sizes, *e.g.* ranging from 0.3 to 0.6 m in diameter. This, coupled with the frequent need to collocate multiple test systems needed for production testing, has further increased the desire for highly space efficient designs. Here, the position of the feed within a CATR can be seen to be a particularly important factor in these considerations as, for example, corner-fed CATRs provide an easy way to reduce the overall length of the setup whilst incurring only a comparatively minimal impact on the width as is illustrated in Figure 1. Indeed each of the floor-, corner-, and side-fed CATR configurations place different constraints in terms of the physical envelope required by the respective systems, whilst also yielding subtly different properties of the resulting, collimated, pseudo plane-wave [2].

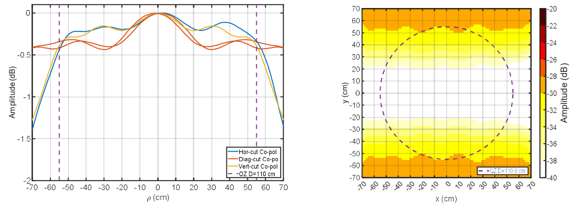
In this paper, we compare and contrast the electrical performances of these three commonly employed range configurations by means of an accurate numerical simulation that provides the "measured" antenna pattern for a known CATR and AUT pair. Details of the simulation technique together with its verification are left to the open literature [3, 4, 5] A floor fed blended rolled edge (BRE) single offset parabolic reflector with a 4 m focal length was designed and optimised using the techniques developed in [6, 7, 8, 9]. The CATR design was then fed from the floor, corner, and side with the edge treatments being kept consistent between three cases with the CATR quiet-zone (QZ) field distribution being predicted at 5 GHz for each. Here, a frequency towards the bottom of the operational frequency of this design was chosen as this is the region in which the QZ will have the largest differences as here the reflector is electrically smallest. These can be seen presented in Figure 2. While the symmetry of the copolar field distribution is more easily derived from the one-dimensional line plots (a), (c) and (e), the overall cross-polar pattern and its symmetry is more discernible from the two-dimensional false colour checkerboard plots (b), (d),and (f). Inside the QZ field, two different simulated test antennas are considered. The first antenna is a WR187 pyramidal horn which was placed with its aperture at the centre of the QZ and centre of rotation of the φ over θ positioner. This represents a very simple case and provides a good baseline for further evaluation of the algorithm, however here only a small and typically optimal portion of the QZ is occupied by the antenna during an acquisition. The "second" antenna comprised the same pyramidal horn, only here its aperture was displaced by 0.25 m in the positive z-direction away from the positioner rotation origin which means the antenna traverses across a larger portion of the QZ during its measurement as the AUT is rotated from -90° to +90° in azimuth. This is the most commonly used acquisition mode, with even a conventional "model tower" ϕ over θ type positioning system utilising the same horizontal motion [3]. Then, for each of the three CATR configurations, the RMS dB difference level was calculated between the ideal "reference" far-field pattern of the AUT and the simulated "measured" pattern to provide a single quantitative measure of similarity [3]. A further test involved performing a "flip test" on each of the patterns to obtain a measure of symmetry within the measurement, which replicates a test that is often performed in antenna test system validation campaigns [3]. Finally, the lower bound sensitivity for the simulation, which was found to be at circa -88 dB for the copolar pattern and significantly lower for the cross-polar pattern, was determined by illuminating the AUT with a perfect plane wave, and then comparing this with the reference far-field pattern. Here, the sensitivity of the simulation technique was established as more than 20 dB below the pattern level for all cases considered.



(a) Copolar floor fed (b) Cross-polar floor fed



(c) Copolar corner fed (d) Cross-polar corner fed



(e) Copolar side fed (f) Cross-polar side fed

Figure 2. BRE CATR Quiet-Zone Field Distribution.

In Table 1 the RMS dB difference levels are shown for comparison of the various configurations. Here it can be seen that the pattern accuracy of the offset pyramidal horn has degraded by *circa* 10 dB from the centred horn, which is caused by the larger part of the QZ that the offset horn traverses through during the measurement. However, more interesting is that the differences between the CATR setups remains within 2 dB for all three cases, and is largely independent of the position of the horn. Further investigation of Table 1 shows that for the offset horn case, the accuracy of the measured copolar patterns is very similar, even though the flip test clearly shows a much greater degree of symmetry for the floor fed case. In essence, this just means that the left and right hand sides of the pattern will have the exact same error. Lastly, while looking at the furthest right column of Table 1, it shows that as expected from the field distribution presented in Figure 2, the floor fed case performs the worst in terms of cross-polar accuracy, and the side-fed case shows the best performance for antenna centred in the QZ and φ over θ positioner. It should be noted here that this will only be true for an azimuth scanning, which as noted above, is the most commonly used setup, including using a conventional "model tower" ϕ over θ type positioner.

RMS difference (dB)	Centred Pyramidal Horn	Offset Pyramidal Horn		
	Co-Pol.	Co-Pol.	Co-Pol. Flip	Cx-Pol.
Floor Fed	-63	-53	-139	-59
Corner Fed	-61	-54	-56	-62
Side Fed	-60	-54	-54	-130

Table 1: Measurement accuracy presented as RMS dB difference levels.

In summary, this paper has used an end-to-end measurement simulation to compare the measurement accuracies of several common CATR feed configurations. It was shown that the expected measurement error between the three configurations is comparable, where range symmetry is only expected to result in a symmetric constellation of said errors. Thus, we have established that conventional flip tests can yield unduly optimistic estimations of accuracy if not interpreted correctly. This paper has been able to confirm that the best cross-polar accuracies can be obtained when using a side fed CATR arrangement when the AUT is not located at the origin of the measurement coordinate system.

References

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