ABSTRACT

Earlier measurement results are reviewed to understand the result that cross-polarized patterns agree well when compared between a point-source compact range and spherical near-field scanning. By taking account of the symmetry of the aperture distribution, one can see how the cross-polarized pattern can be affected only moderately by the classic polarization feature of an offset reflector geometry.

Keywords: Compact Ranges, Cross-Polarization, Antenna Measurements.

1. INTRODUCTION

Conventional compact range antenna pattern measurements with a point-source compact range have been shown by means of inter-range comparisons to give excellent accuracy in general (1),(2). Users have been well satisfied with the results and the compact range technique has been fully accepted by the measurement community.

However, in spite of this success, the dependability of the compact range for measurements of cross-polarized patterns has been deemed uncertain. In recent years subreflectors have been used to improve the polarization purity of the test zone fields (3),(4). This has added to the expense of compact range construction. And, it has added difficulty to the problem of creating a layout that is free of unwanted stray signals. Another way of correcting compact range polarization is the matched polarization filter (5). This is less obtrusive of the layout but nevertheless imposes additional expense.

In general excellent cross-polarization in the compact range field requires excellent polarization purity in the feed horn. Subreflectors will eliminate the cross-polarized component assignable to the reflector layout, but not the component assignable to the primary feed pattern. Thus, resources expended to improve the reflector portion are wasted unless one also expends resources for an excellent feed. Often this is not practical because of the narrow range of frequencies achievable. Thus it would appear attractive to utilize a point-source compact range when a moderately well polarized feed is to be employed.

In reviewing earlier measurement results comparing compact range patterns and spherical near-field patterns, we have come to conclude that point-source compact range measurements can in fact be quite accurate for cross-polarized pattern measurements. This is true in spite of the well known polarization property of offset reflectors. In the sections that follow we show how one can understand this phenomenon. We illustrate the case by exhibiting some typical comparison results.

2. COMPACT RANGE APERTURE DISTRIBUTION

The basic purpose of a compact range is to provide a uniform planar wave-front of electromagnetic radiation that illuminates an object under test. For the purpose of this discussion we will consider the object to be a receiving antenna whose pattern is to be measured. The region where the object is located is termed the test zone of the compact range. The test zone is appropriately described as a cylinder with a horizontal axis that is parallel to
the direction of propagation of the wave-front. The cylinder forms the boundary of the test zone.

The test zone is described by an amplitude taper (or roll-off). In directions perpendicular to the cylindrical axis, the amplitude distribution diminishes by the amount of taper or roll-off. The amplitude distribution is a maximum along the axis of the cylinder. The test zone is also described by the amount of phase variation in the oscillating wave over a planar aperture. (The aperture is a planar surface perpendicular to the direction of propagation of the illuminating wave-front.)

The compact range produces an illuminating electromagnetic field distributed over the aperture A typical compact range will possess between 0.5 and 1.0 dB of amplitude taper and 5 to 10 degrees of phase variation over the circular or elliptical area that forms the aperture of the range. In the next section we consider the polarization of the electromagnetic wave-front.

3. DESCRIPTION OF AN IDEALLY POLARIZED FIELD

The electromagnetic field is fundamentally a vector field, which means that at each point in space it is described by more than just a single component quantity. A propagating field far away from its source is described by the magnitude and phase of each of two components along directions in space perpendicular to the direction of propagation. These components are most readily thought of as two orthogonal linear components that correspond to fixed directions perpendicular to the direction of propagation and perpendicular to each other. In this case the components are termed horizontal and vertical.

Alternatively, the two components of the electromagnetic field at a point can be thought of as continuously rotating. This is equivalent to linear components. The senses of rotation of the two are opposite to each other. They rotate in a plane perpendicular to the direction of propagation. These components of circular polarization are termed right-hand and left-hand.

Polarization of a wave can vary over the wave front. To describe the polarization of a wave, one must describe the polarization of the field at each point on the wave front. Correspondingly, one describes the polarization of the compact range by giving a description of the two components at every point in the aperture.

Polarization is a way of describing the vector property of the electromagnetic field. One can do this giving the amplitude and oscillation phase of both components at a point in space. More appropriately, one typically gives the complex polarization ratio between the two component phasor quantities. Alternatively, one can describe the relationship between the two components by stating the tilt angle and axial ratio of the polarization ellipse that is formed by superposition of the two components. This later form is the most common.

The specification of polarization of a compact range field is often stated in terms of the suppression level of the unwanted component relative to the wanted or desired component. For example, suppose that the desired component is vertical linear polarization and that the unwanted component is horizontal polarization. See Figure 1 for illustration. The unwanted component is ideally zero amplitude and the cross-polar level therefore vanishes everywhere in the test zone. Expressed in dB, the cross-polar field is -∞ dB, since the logarithm of a vanishingly small quantity approaches negative infinity.

Unfortunately, a field polarized in such a manner is not achievable in practice. One always has a cross-polar level that is non-zero. It may be spatially uniform and systematically produced by the source of radiation. Or, it may be spatially random and produced by uncontrolled reflections from within an anechoic chamber.

4. DESCRIPTION OF A UNIFORMLY CROSS-POLARIZED APERTURE FIELD

The most easily described case of non-ideal cross-polar field impurity in a test zone is the case of a uniform cross-polar field. This is often appropriate for describing the case of a far-field range. It is also appropriate for describing a compact range field whose feed is imperfectly polarized.
Consider the illustration of Figure 2 which shows a uniform vertically polarized field contaminated by a uniformly distributed cross-polar component. The effect of the cross-polar signal, assumed to be arriving in the same phase as the co-polar signal, is to change the tilt angle to be non-ideal. The field is no longer perfectly vertical.

The cross-polar field is the same everywhere in the test zone. A single quantity is adequate to characterize the level of the cross-polar signal everywhere over the aperture.

When a perfectly linearly polarized test antenna is mounted in the test zone, and oriented first to be vertically polarized and then horizontally polarized, it will respond in direct proportion to the amplitudes of the two linear components.

5. DESCRIPTION OF A RANDOMLY CROSS-POLARIZED FIELD

A randomly cross-polarized field is an easily understood case where the cross-polarized field is not uniformly distributed over the aperture of the test zone. Refer to Figure 3 for illustration of the case. Such a description might be appropriate for describing the fields associated with chamber reflections of the same frequency as the compact range field.

When a randomly distributed cross-polarized field is added to the desired vertical component, a distribution of tilt angles appears in the total field. The total field is only approximately vertical. (In fact, in general the total field can become elliptical, if the phases of the cross-polarized component are truly random.)

The cross-polar component is not the same everywhere in the test zone; a typical and a worst-case quantity might be used to describe the cross-polar levels.

When a perfectly linearly polarized test antenna is mounted in the test zone and oriented first to be vertically and then horizontally polarized, it will respond by summing the field distributions of the two components over the aperture. The response in horizontal orientation will be much lower than the worst-case level would imply because of the random distribution of phases.

6. DESCRIPTION OF AN ANTISYMMETRIC CROSS-POLARIZED FIELD

An offset paraboloidal reflector that is fed with a point source of radiation yields a cross-polar field that is not uniform. Refer to Figure 4 for illustration. The form of the cross-polar field is such that it vanishes in the vertical center plane of the test zone and has opposite sense on either side of the center plane. That is, it has odd-type symmetry with respect to the vertical center-plane. The more distant a point in the test zone is from the center plane, the higher the amplitude of the cross-polar signal will be. The effect of this odd-symmetry cross-polar field is to alter the tilt angle distribution of the field in the test zone. The tilt angle will be offset on either side of the center plane with opposite sense.

As with the case of a randomly cross-polarized field, either a worst-case or a typical cross-polarization value might be used to characterize the non-ideal polarization. Cross-polar levels quoted for point-source compact ranges are usually -25 dB worst case and -30 dB typical values for the test zone field.

When a perfectly linearly polarized test antenna is mounted in the test zone and oriented first to be vertically and then horizontally polarized, it will respond by summing the field distributions of the two components. Again, as with the case of randomly distributed cross polarization, the response in horizontal orientation will be much lower than the worst-case or the typical level of the test zone field implies. This is because of the opposite senses of the cross-polar fields on either side of the vertical center plane. A test antenna aperture will directly sum the opposite sense cross-polar fields to a low value. In fact, a symmetrically distributed antenna aperture will produce a null response in the cross-polar orientation for this case of the antisymmetric cross-polar test zone field.

This conclusion might be considered surprising in view of the current approach toward consideration of the issue of compact range cross-polar levels. However, examination of the data from inter-range comparisons supports this concept.
7. MEASUREMENT RESULTS FOR A POINT SOURCE COMPACT RANGE

It is well known from measured data that a point source compact range yields very accurate patterns on the co-polarized case. An example of these results is shown in Figure 5. To obtain this comparison, a particular test antenna was measured by two different techniques: First a spherical near-field scanning measurement was made and then the measurement was repeated with a point-source compact range. The two patterns from the two types of measurement are plotted overlaid as shown in Figure 5. When the cross-polarized cases are plotted and overlaid, the result appears as shown in Figure 6. Notice the excellent comparison.

For this particular antenna, the pattern discrepancy can be characterized by an equivalent stray signal of -50 dB. This is far better than an estimate based on either the worst-case (-27 dB) or the typical (-30 dB) cross-polar levels of the test zone field would yield. The explanation for this "surprising" result is that the integration over the aperture of the compact range test zone performed by the test antenna inherently suppresses the antisymmetric cross-polar signal.

8. SUMMARY AND CONCLUSION

Conventional worst-case descriptions of cross-polar levels do not appropriately characterize the cross-polar measurement accuracy of a point source compact range for aperture antennas. Comparison to spherical near-field results indicate that a point-source compact range can provide excellent cross-polar measurements for many antennas. It is important to recognize that cross-polar performance of compact ranges is governed not only by range geometry but also by feed polarization purity and by extraneous stray signal effects as well.

9. REFERENCES


Figure 1. Linearly Polarized Test Zone Field with Zero Cross-Polarization

172
Figure 2. Linearly Polarized Field with Uniform Cross-Polar Component

Figure 3. Linearly Polarized Field with Random Cross-Polar Component

Figure 4. Linearly Polarized Field with an Asymmetric Cross-Polar Component
Figure 5. Comparison of Spherical Near-Field and Point-Source Compact Range Measurements, Co-Polarized Patterns. Vertical Scale 80 dB, and Horizontal Scale ±180°.

Figure 6. Comparison of Spherical Near-Field and Point-Source Compact Range Measurements, Cross-Polarized Patterns. Vertical Scale 80 dB, and Horizontal Scale ±180°.