CROSS-POLARIZATION MEASUREMENT ACCURACY IMPROVEMENT ON A SINGLE REFLECTOR COMPACT RANGE

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ABSTRACT

Scientific-Atlanta has developed a new algorithm for obtaining high accuracy cross-polarization measurements from prime focus, single reflector, compact ranges. The algorithm reduces cross-polarization extraneous signals to levels that rival or exceed much more expensive dual reflector systems, but with the associated cost and simplicity of a single reflector system. This paper provides an overview of the new algorithm. It explains the limitations on conventional polarization measurements in single reflector systems and the methods for overcoming these limitations without error correction for some antennas. A method for determining if error correction is needed for a particular antenna is reviewed and the fundamentals of the error correction algorithm are explained. Preliminary test results are provided.

Keywords: Compact Range, Cross-polarization

1. INTRODUCTION

Accurate cross-polarization measurements require an incident field on the antenna-under-test (AUT) that has uniform amplitude and phase, as well as low cross-polarization content. Single reflector compact ranges are well suited to provide uniform amplitude and phase over a defined test zone. However, to obtain low cross-polarization content over the same region for which amplitude and phase are uniform has required costly dual reflector systems that theoretically produce low cross-polarization, but in practice, due to manufacturing tolerances, assembly and alignment inaccuracies, etc., produce cross-polarization extraneous signal levels only in the -40 to -45 dB range. Scientific-Atlanta has developed a new algorithm for obtaining high accuracy cross-polarization measurements for use with prime focus, single reflector, compact ranges. The algorithm reduces cross-polarization extraneous signals to levels that rival or exceed the much more expensive dual reflector systems, but with the associated cost and simplicity of a single reflector system

2. THE ECCA[1] SOLUTION

The Scientific-Atlanta Error Correction Code Algorithm (ECCA) is a powerful option available on the 2095 Microwave Measurement System. Not all antennas, measured in single reflector compact ranges, however, require cross-polarization error correction. In order to allow a wider class of antennas to be measured without correction, the 2095 measurement system with the optional ECCA software provides two compact range configurations to the user for making cross-polarization measurements.

The standard compact range configuration illuminates the compact range reflector such that the amplitude and phase taper in the quiet zone is negligible. Therefore, it is ideally suited for making copolarized antenna pattern measurements and should always be used when cross-polarization measurements are not required. However, due to the geometry of tilting the feed up so that the feed pattern compensates for the extra path loss at the top of the quiet zone, the electric field over the quiet zone is not uniformly polarized -- the tilt angle of the polarization is a slight function of the quiet zone location. For antennas having ratios of their diameters to the compact range focal length of less than 0.051 this induced cross-polarization is negligible and the standard configuration can be used to measure cross-polarization, so long as the antenna is measured with no lateral offset from the center of the quiet zone. However, for apertures either laterally offset from the center of the quiet zone, or for antennas with diameter-to-compact range focal length ratios larger than 0.051, the geometry induced cross-polarization in the quiet zone can introduce unacceptable errors.

The alternate configuration overcomes the geometry induced problem of cross-polarization in the quiet zone. By reorienting the feed so that it points horizontally at the vertex of the compact range reflector's parent paraboloid, the feed's high purity Huygens polarization is transformed into uniform linear polarization upon reflection by the compact range reflector, resulting in high purity, uniform polarization in the quiet zone. The negative consequence of redirecting the feed axis to the vertex of the reflector is that quiet zone amplitude taper is introduced. The energy at the bottom of the quiet zone is higher than at the upper edge of the quiet zone due to both higher path loss to the top of the quiet zone and slightly reduced feed pattern amplitude there.

However, for antenna diameter-to-compact range focal length ratios of less than 0.20, the taper in the field over the antenna aperture is small enough to be negligible. Therefore, cross-polarization for antennas having ratios less than 0.20 may be measured in the alternate configuration compact range without correction.

For antennas with diameter-to-compact range focal length ratios larger than 0.20 the amplitude taper in the quiet zone can introduce errors that may be unacceptable. To overcome this problem, data should be manipulated by ECCA to remove the effects of the amplitude taper.

3. OVERVIEW OF ECCA

ECCA is based on both the Fourier transform relation between the far-field and aperture fields of aperture type antennas, and on the generalization of the reaction theorem presented by Richmond[2]. Richmond's generalization of the reaction theorem shows that the voltage response, V, of the antenna under test to the fields generated by the compact range can be expressed by

$$V \propto \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\left[\mathbf{E}_{\mathbf{aut}}(\xi,\eta)\times\mathbf{H}_{\mathbf{cr}}(\xi,\eta) - \mathbf{E}_{\mathbf{cr}}(\xi,\eta)\times\mathbf{H}_{\mathbf{aut}}(\xi,\eta)\right]\cdot\mathbf{n}\,d\xi\,d\eta \qquad \mathbf{1}$$

where ξ and η are aperture plane coordinates, $\mathbf{E}_{\mathbf{aut}}$ and $\mathbf{H}_{\mathbf{aut}}$ are the electric and magnetic fields, respectively, in the antenna aperture plane when the antenna transmits into free space, $\mathbf{E}_{\mathbf{cr}}$ and $\mathbf{H}_{\mathbf{cr}}$ are the electric and magnetic fields, respectively, generated by the compact range that are incident on the antenna aperture plane when V is recorded, and $\mathbf{n}$ is the outward unit normal vector to the antenna aperture plane. Using the high frequency approximations applicable to aperture type antennas made by Silver[3] in the development of the Fourier transform relation between antenna aperture fields and the resulting far-fields, and the additional constraint that the compact range incident field be nearly normal to the aperture plane, Equation 1 may be simplified to

$$V(k_x,k_y) \propto \int_{-\infty}^{\infty}\int_{\infty}^{\infty} E_{aut}(\xi,\eta)E_{cr}(\xi,\eta)\,e^{j2\pi\left(k_x\xi+k_y\eta\right)}d\xi\,d\eta \qquad \mathbf{2}$$

where $k_x = \dfrac{\sin\theta\cos\phi}{\lambda}$ and $k_y = \dfrac{\sin\theta\sin\phi}{\lambda}$. We recognize Equation 2 as the Fourier transform of the scalar multiplication of the antenna aperture fields and the scalar compact range fields at each point in the aperture plane.

If we can measure V over a sufficiently large region of the far-field, we can calculate the inverse of Equation 2 to determine the antenna aperture distribution with adequate resolution:

$$E_{aut}(x,y) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} V\left(k_x,k_y\right)e^{-j2\pi\left(k_x x+k_y y\right)}dk_x\,dk_y}{E_{cr}\left(x,y\right)} \qquad \mathbf{3}$$

Equation 3 is valid so long as $E_{cr}(x,y)$ is not a function of k_x and k_y. In order to meet this criteria, the solid angle measurements can not be made by rotating the antenna with respect to the compact range incident field. Therefore, the measurement is made with a raster scan by scanning azimuth and stepping elevation in an elevation over azimuth positioner system. Further, the compact range incident field must be kept nearly normal to the aperture plane. Therefore, scan angles must be kept small.

The Fourier transform used in ECCA is a Fast Fourier Transform (FFT). The sample spacing in the far-field k space is a maximum of one-tenth of the null-to-null beamwidth of the far-field pattern. The period in the far-field k space is twice the far-field extent processed by the FFT, which exceeds the Nyquist criteria. The sample spacing in the aperture plane is one-hundredth of the aperture dimension. The period in the aperture plane is five times the aperture dimension, again exceeding the Nyquist criteria.

The finite extent over which the far-field is collected in k space defines the aperture plane resolution. The maximum number of resolution cells across a major axis of the antenna aperture is limited by ECCA to 25. The minimum number of cells recommended for ECCA processing is eight. Figure 1 shows the relationship between frequency and antenna diameter required to achieve eight resolution cells with the 20 degree maximum scan angles allowed by ECCA. For antenna/frequency combinations above and to the right of the curve, scan angles may be considerably smaller than 20 degrees when the maximum of 25 cells of aperture resolution allowed by ECCA is reached. Antennas to the left of the vertical line do not require ECCA processing due to their small size.

Complete polarization characterization of an antenna may be made by measuring the response of the antenna to two orthogonal polarizations. Therefore, ECCA requires that the antenna response to both vertical and horizontal polarization be acquired by the 2095 system. This may be done by time multiplexed, automatic switching of the compact range dual polarized feed during the raster-scan collection of the far-field data, or two raster scans may be measured.

These measurements are corrupted by the amplitude taper of the alternate configuration compact range incident field. With proper book-keeping to account for measurement-scenario-induced phase and polarization errors, ECCA calculates the aperture fields responsible for the measured horizontally and vertically polarized far-fields and removes the effects of amplitude taper from the aperture fields by using Equation 3. ECCA calculates the corrected horizontally and vertically polarized far-fields associated with the corrected aperture distributions using the inverse Fourier transform of the corrected aperture distributions. These two orthogonally polarized far-field patterns then completely describe the polarization of the antenna under test.

4. SETTING UP FOR ECCA

The 2095 measurement system with the ECCA option provides the user with an interactive ECCA Antenna Definition Menu that makes selection of the proper measurement configuration simple. The Menu is shown in Figure 2.

The user initially provides the requested data in the "Antenna Parameters" and the "Aperture Center Parameters" sections of the Antenna Definition Menu. The X and Y inputs under the "Antenna Extent in Quiet Zone" section are the horizontal and vertical dimensions, respectively, of the antenna when mounted in the quiet zone. The X and Y offsets from the roll axis requested in the "Aperture Center Parameters" section are the horizontal and vertical offsets, respectively, of the aperture center from the center of the quiet zone. As a double check to assure that ECCA is not used when cross-polarization measurements are not required, the user must select the "Cross-Polarization Measurement Required" button.

When the user has input these required parameters, selecting the button "Calculate Test Parameters" causes the section titled "Antenna Test Parameters" to be updated. The updated menu tells the user whether the antenna is a candidate for ECCA correction, the number of resolution cells that will be available to ECCA in the aperture plane, and which feed angle (range configuration) the user should use. Finally, If ECCA correction is recommended, the user will be prompted with the correct start, stop and increment values for the scan (azimuth) and step (elevation) measurement axes in the sections labeled "Scan (Azimuth) Parameters," and "Step (Elevation) Parameters," respectively.

ECCA requires five more inputs in order to perform the correction process. The user inputs four of these parameters under the section titled "Antenna Mounting Parameters." Three of these are the horizontal (X) offset of the antenna phase center from the test positioner roll axis, the vertical (Y) offset of the phase center from the roll axis, and the longitudinal (Z) offset of the phase center from the azimuth axis. The fourth parameter is the elevation axis offset from the azimuth axis. The allowable error on these parameters are ± 6 cm, ± 6, cm ± 20 cm, and ± 1 cm, respectively. These four parameters are required in order for ECCA to remove measurement phase errors associated with the antenna sweeping through the quiet zone on a moment arm during the measurement process.

The final test parameter the user must enter is the model number and frequency band of the feed used during the test. This is selected from a pop-down menu provided when the "Feed Model" menu button is selected. This allows ECCA to calculate the compact range field incident on the test antenna that must be deembedded from the test antenna aperture.

Finally, the user supplies a file name for the "Antenna Definition File" into which all of the user inputs are stored for subsequent use by ECCA processing.

The user exits the ECCA Antenna Definition Menu and uses the 2095 automatic measurement system to collect the antenna far-field response to vertical and horizontal polarization using the parameters supplied by the ECCA Antenna Definition Menu.

After the vertical and horizontal patterns are collected, the user enters the ECCA Correction Analysis Menu to process the measured data. The menu is shown in Figure 3. The user inputs the name of the Antenna Definition File that contains the measurement parameters, the name of the file(s) that contain the vertical and horizontal polarization measured data, the first bin (column) number containing the measured data, the name of the output file(s) to generate for the corrected data, and which frequency is to be corrected (files can contain multiple frequencies).

5. ECCA RESULTS

The co- and cross-polarized response of a "golden antenna" was characterized using a Scientific Atlanta spherical near-field (SNF) measurement system. The antenna is a linearly polarized, prime focus paraboloid 0.63 meters in diameter with characteristics given in Figure 4.

The golden antenna was characterized at 13 GHz in a Scientific-Atlanta 5704 compact range with a focal length of 3.66 meters and a 1.22 meter (H) x 1.83 meter (W) x 1.83 meter (L) quiet zone. The antenna diameter-to-compact range focal length for this antenna is 0.172, which falls in the ECCA Suitability Chart at the location shown by the "X" in Figure 1. Note that this antenna is to the left of the vertical line so it is small enough that ECCA is not actually required. Also note that it has near the minimum number of resolution cells recommended for ECCA processing. This antenna provides valuable insight into the behavior of ECCA at the lower limits of its applicability. Another, larger, antenna is currently being calibrated for ECCA evaluation in the near future.

The antenna was placed at the front edge of the quiet zone in two different locations of interest - centered, and 0.3 meters laterally offset from the quiet zone center. The ECCA corrected data was then compared to the SNF data to determine the extraneous signal level, where extraneous signal level is defined as the difference between the voltage response of the golden antenna as measured in the SNF facility and the voltage response of the golden antenna as measured in a 5704 compact range.

Figure 5 shows the solid angle cross-polarized SNF antenna pattern of the golden antenna. The four cross polarization lobes are clearly visible with principal plane null troughs running between them. This data was used as the reference to generate the extraneous signal level plots of the 5704 compact range measured data.

The next Figures show images of extraneous signal levels. The level in dB is shown in the grey scale at the end of the series. The contours shown in the plots are at the -30 dB level of the SNF cross-pol plot of Figure 5. The contour lines serve to show the locations of the four cross-polarization lobes.

The data shown in Figure 6 and Figure 7 measured in the center of the quiet zone show that the standard configuration and the alternate configuration, respectively, have worst case extraneous signal levels between -39 and -43 dB in the high slope regions near the null troughs of the cross-polarization lobes, and levels $\leq$-45 dB everywhere else, including the cross-polarization lobe peaks. The standard configuration has the best extraneous signal level due the high degree of circular symmetry of the antenna canceling the excellent odd symmetry of the cross-polarization in the center of the quiet zone. As expected, ECCA correction made an insignificant difference due to the diameter-to-focal length ratio < 0.20.

However, the data measured in the laterally offset case shows that the loss of symmetry of the cross-polarization content of the quiet zone across the laterally offset antenna drastically degrades the measured cross-polarization extraneous signal level of the standard configuration near the null trough, as shown in Figure 8. Note the island of extraneous signal level in the trough is worse than -34 dB. The alternate configuration data is better, as shown in Figure 9, with extraneous signal levels in the trough of < -38 dB. The ECCA corrected data, shown in Figure 10, shows improvement of the extraneous signal level in the trough to nearly -40 dB, but because of its small size, not much correction due to amplitude taper is needed. Extraneous signal levels elsewhere are $\leq$45 dB, including the cross-polarization lobe peaks.

6. SUMMARY

Scientific-Atlanta has developed a new algorithm and associated software available on the 2095 Microwave Measurement System for obtaining high accuracy cross-polarization measurements from Scientific-Atlanta prime focus, single reflector, compact ranges. The algorithm is based on the generalized reaction theorem of Richmond and on the Fourier transform relation between the far- and aperture fields of an antenna. The algorithm software provides user interactive menus for ease of use.

Preliminary test results confirm that single reflector compact ranges are capable of cross-polarization measurements having maximum extraneous signal levels near -40 dB in the cross-polarization null troughs and ≤ -45 dB elsewhere, including the peaks of the cross-polarization lobes.

New test data on a physically and electrically larger antenna is anticipated in the near future to further validate the error correction code algorithm.

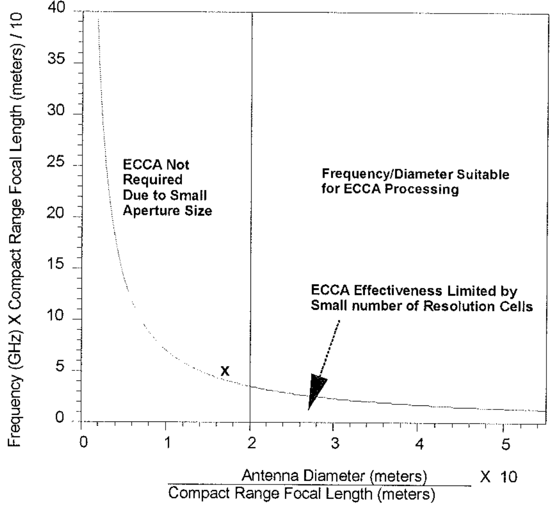
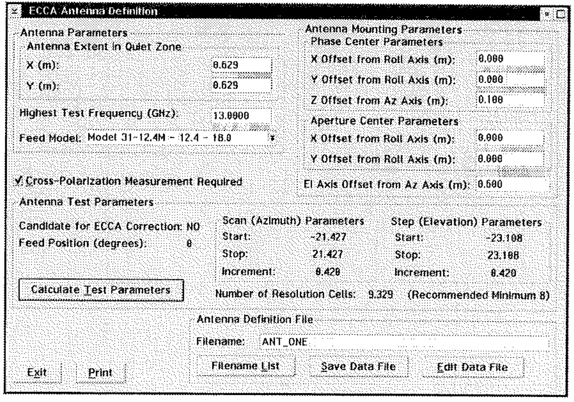
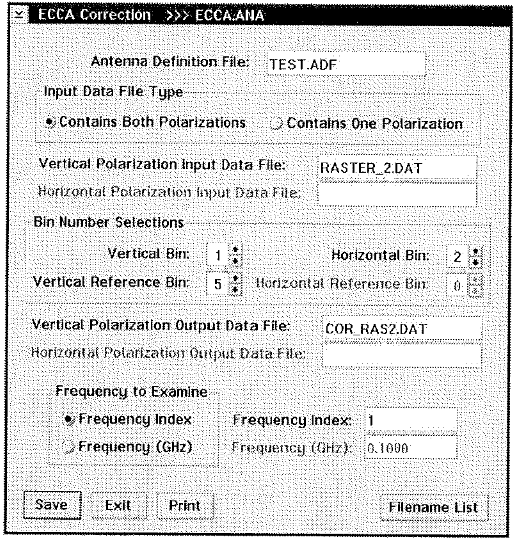


Figure 1. ECCA Suitability Chart Showing the Suitability of ECCA Processing forVarious Antenna Diameter/Frequency Combinations.



X (m): 0.629
Y (m): 0.629
Highest Test Frequency (GHz): 13.0000
Feed Model: Model 31-12.4M - 12.4 - 18.0
☑ Cross-Polarization Measurement Required
X Offset from Roll Axis (m): 0.000
Y Offset from Roll Axis (m): 0.000
Z Offset from Az Axis (m): 0.100
X Offset from Roll Axis (m): 0.000
Y Offset from Roll Axis (m): 0.000
El Axis Offset from Az Axis (m): 0.600
Candidate for ECCA Correction: NO
Feed Position (degrees): 0
Scan (Azimuth) Parameters: Start: -21.427 Stop: 21.427 Increment: 0.420
Step (Elevation) Parameters: Start: -23.108 Stop: 23.108 Increment: 0.420
Number of Resolution Cells: 9.329 (Recommended Minimum 8)
Filename: ANT_ONE

Figure 2. ECCA Antenna Definition Menu.



Antenna Definition File: TEST.ADF
● Contains Both Polarizations ○ Contains One Polarization
Vertical Polarization Input Data File: RASTER_2.DAT
Horizontal Polarization Input Data File:
Vertical Bin: 1
Horizontal Bin: 2
Vertical Reference Bin: 5
Horizontal Reference Bin: 0
Vertical Polarization Output Data File: COR_RAS2.DAT
Horizontal Polarization Output Data File:
● Frequency Index ○ Frequency (GHz)
Frequency Index: 1
Frequency (GHz): 0.1000

Figure 3. ECCA Correction Analysis Menu.

- **Frequency: 12.4 - 18 GHz, Tested at 13 GHz**
- **Polarization: Linear**
- **Diameter: .6287 meters (24.75 inches)**
- **Focal Length: .2286 meters (9 inches)**
- **Feed Blockage: .1016 meters (4 inches)**
- **Number of spars: Three, equally spaced**
- **Spar Diameter: .0191 meters (.75 inches)**
- **Number of Resolution Cells: 9.3**

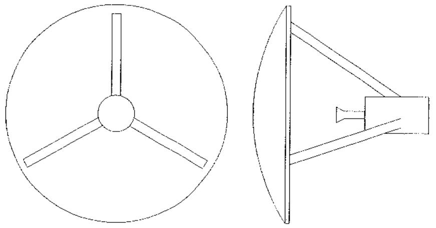


Figure 4. Golden Antenna Characteristics.

Figure 5. Solid Angle Cross-Polarized SNF Antenna Pattern of the Golden Antenna.

Figure 6. Standard Configuration Golden Antenna Extraneous Signal Level at the Quiet Zone Center.

Figure 7. Alternate Configuration Golden Antenna Extraneous Signal Level at the Quiet Zone Center.

Figure 8. Standard Configuratoin Golden Antenna ESL Laterally Offset from the Quiet Zone Center.

Figure 9. Alternate Configuration Golden Antenna ESL Laterally Offset from the Quiet Zone Center.

Figure 10. ECCA Corrected Golden Antenna ESL Laterally Offset from the Quiet Zone Center.

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[1] Patent Pending, "Apparatus and Method to Measure Co- and Cross-Polarization Properties of an Antenna," U.S. Patent Application: 08/627,972.

[2] J. H. Richmond, "A Reaction Theorem and Its Application to Antenna Impedance Calculations," *IRE Trans. on Antennas and Propagat.*, AP-9 (November 1961), 515-520.

[3] S. Silver, Ed., *Microwave Antenna Theory and Design*, M.I.T. Rad. Lab. Ser., vol 12 (New York: McGraw-Hill Book Co., Inc., 1949; repr., London: Peter Peregrinus Ltd, 1984), 80-83, 158-160, 164-166, 169-175.

the Error correction code algorithm

The block diagram of the ECCA process is shown in Figure 1.

After reading the files containing the antenna response to the horizontally and vertically polarized incident fields, ECCA converts the corrupted far-field patterns from the *az-el* measurement space to *kx-ky* space in preparation for the Fourier transformation to the aperture plane from the far field. ECCA then corrects for the phase errors associated with the antenna travelling through the quiet zone on the moment arm defined by the "Phase Center Parameters" values and the "El Axis Offset from Az Axis" value form the Antenna Definition File.

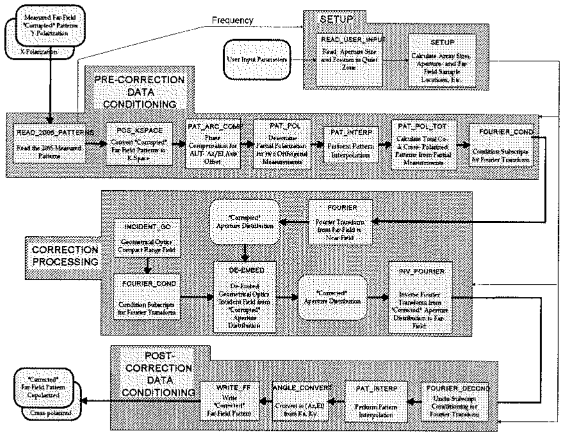


Figure 1. ECCA block diagram

Figure 3 a and b show the measured far-field phase response of a 0.6 meter (2 feet) antenna at 13 GHz mounted on a 0.3 meter (1 foot) moment arm as it sweeps through the quiet zone both before and after, respectively, the phase correction is applied by ECCA. The aperture distribution calculated from the Fourier transform of Figure 3 a without correcting for phase errors would be in error.

With this book-keeping completed, ECCA determines the co- and cross-polarization responses of the AUT with respect to Ludwig's third definition (Huygens source polarization) from the measured responses of the antenna to both horizontal and vertical polarizations. This results in four partial polarization files: co- and cross-polarization files for the AUT vertical polarization response, and co- and cross-polarization files for the measured horiziontal response. In both cases, *co* refers to a nominally vertically polarized Huygens source. This step is necessary because the definition of co- and cross-polarization for an *az*-over-*el* antenna positioner is shown in Figure 2 a and b, respectively. ECCA desires the Huygens source polarization of Figure 2 c and d before transformation to the aperture plane. Utilizing a Huygens source polarization results in pure, uniform linear polarization when transformed to the aperture plane..

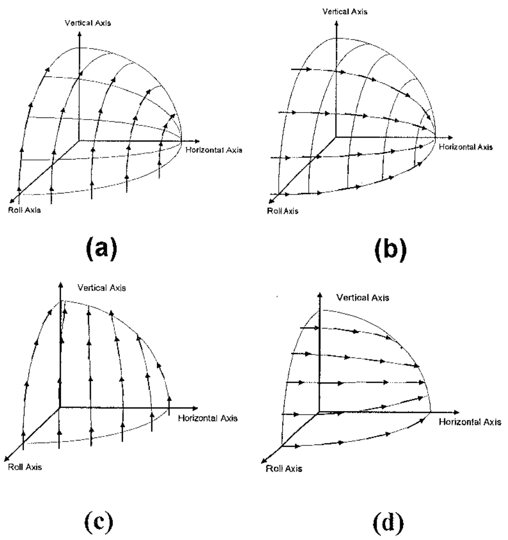


Figure 2. The polarization measured using an *el*-over-*az* positioning system (a) copolarized with respect to vertical, and (b) cross-polarized with respect to vertical. Figures (c) and (d) are the Huygens copolarization and cross-polarization, respectively, measured using Ludwig's third definition with respect to vertical.

ECCA then interpolates the data in each of the four files onto a regular, rectangular lattice of points required by the FFT and determined from the user inputs to the Antenna Definiton Menu. The four partial polarization files are then combined into two total polarization files, one file containing the total copolarized response of the AUT, and the other containing the total cross-polarized response, both with respect to a nominally vertically polarized Huygens source.

To this point, the measured far-field data collected by the user has been corrected for phase errors, transformed to *kx-ky* space, interpolated onto a regular, rectangular grid, and broken into the total co- and cross-polarized response based on a nominally vertically polarized Huygens source. Next, ECCA computes the forward Fourier transform of both polarizations via the FFT to obtain the co- and cross-polarized aperture distributions of the AUT. These aperture distributions are corrupted by the tapered compact range incident field. By a knowledge of the compact range optics, and knowing the radiation pattern of the compact range feed input by the user in the Antenna Definition Menu, ECCA calculates the amplitude of the incident field generated by the compact range at each point in the co- and cross-polarized apetures. At each point in the antenna aperture, the antenna aperture field is devided by the normalized magnitude of the compact range incident field to remove the incident field taper.

The corrected far-field is calculated by the inverse FFT of the corrected co- and cross-polarized apertures, yielding our desired results. Some booking keeping is again required at this point in order to put the calculated far-fields in a useable format. Interpolation is performed to supply the corrected patterns at points corresponding to the original measurement locations, and the data is converted from *kx-ky* space back to *az-el* space. The solid angle data files are then available for processing on the 2095 standard software.

ECCA

The Scientific-Atlanta Error Correction Code Algorithm (ECCA) utilizes microwave holography to obtain the aperture plane fields of the AUT. The known quiet zone amplitude taper is then removed from the AUT aperture fields to obtain the aperture plane fields due to a uniform plane wave. Finally, the far-field is calculated from the corrected far-field.

S-A DEVELOPED THE COMPACT RANGE

Compact ranges were developed by Scientific Atlanta in the 1970's in order to allow indoor testing of the far-field characteristics of antennas. The compact range creates a plane wave over a local "quiet zone" region in which the antenna-under-test (AUT) is placed for evaluation. .

ECCA

This new microwave holography technique involves the measurement of the AUT response over a solid angular region to two orthogonal, linear polarizations. The holography algorithm manipulates these measurements to obtain the co- and cross-polarized aperture field distributions of the AUT. The known amplitude taper of the compact range incident field is removed from the co- and cross-polarized aperture distributions and the corrected co- and cross-polarized far-field patterns are calculated from the corrected aperture distributions.

It is obvious that any polarization impurity in the quiet zone will contribute to the cross-polarization ESL.

The algorithm requires that a high purity Huygens polarized compact range feed be oriented for optimum cross-polarization performance. The effects of the resultant induced amplitude taper on the measured far-field patterns of the AUTare then removed by the use of a new algorithm developed by Scientific-Atlanta based on the Fourier transform property between aperture- and far-fields of the AUT.

In this paper, the new, Scientific-Atlanta holographic technique for removing the effects of known amplitude tapers from the measured far-field patterns of an AUT is outlined and explained. The applicability of the process to antennas of various geomteries and sizes is presented. The limitations of the algorithm and constraints on the measured data imposed by the Fourier transform are presented. Measured and analytical data is also presented that demonstrate the algorithm's performance in accurately measuring the cross-polarization response of typical, low cross-polarization antennas.

EXTRANEOUS SIGNAL LEVEL

The concept of extraneous signal level (ESL) is introduced as a quantitative measure of the quality of the quiet zone. The definition of cross-polarization ESL is simple. At a given pattern angle, an antenna under test (AUT) has a particular voltage response to an incident uniform plane wave that is cross-polarized. To the extent that the quiet zone field deviates from a uniform plane wave (in polarization, amplitude, or phase), the measured response of the AUT in the quiet zone will be in error. The cross-polarization ESL of an AUT measurement is defined as the difference between the voltage response of the AUT to a uniform, cross-polarized, plane wave and the measured voltage response of the AUT in the cross-polarized quiet zone.

NO NEED FOR ECCA WHEN SYMMETRY IS RIGHT

Figure 1 shows the electric field in the quiet zone of a single reflector compact range with the feed tilted up to optimize amplitude uniformity[i]. The tilt angle is greatly exagerted compared to a typical compact range in order to more easily see the cross-polarization. Note that the cross-polarizaiton content has odd symmetry about the vertical plane through the center of the quiet zone. It is possible to define a reduced size quiet zone in which the cross-polarization is neglible. Further, cross-polarization measurements of AUT's with circular symmetry made in the center of a much larger zone often have very little error. This is due to the integrated effect of the odd cross-polarization being zero. Measured results at Scientific-Atlanta have demonstrated both of these phenomenon. In general, however, reducing the size of the quiet zone is not a practical solution for antennas without circular symmetry or for large antennas.

CONFLICT BETWEEN AMPLITUDE AND POLARIZATION

The far-field polarization of a compact range feed is very nearly the same as that defined by Ludwig's third defintion of polarization[ii]. With a feed having this polarization located at the reflector focus and pointed directly at the reflector's parent paraboloid vertex, no cross-polarization is generated in the quiet zone[iii]. The further the feed is moved from this orientation, the smaller the quiet zone becomes for measuring cross-polarization. Unfortunately, in order to minimize the amplitude taper in the quiet zone, the compact range feed must be tilted up from the optimum polarization orientation so that the pattern factor of the feed offsets the unequal path loss to different portions of the quiet zone.

DUAL REFLECTOR SYSTEMS

Dual reflector compact ranges provide an additional degree of freedom to allow proper positioning of the feed for good amplitude taper while adjusting the tilt angle of one of the reflectors to cancel the induced cross-polarization. Dual reflector compact ranges, however, have serious dissadvantages. The additional alignment and manufacturing tolerances associated with the dual reflector system, along with the limited polarization purity obtainable from a compact range feed realistically limit the cross-polarization extraneous signal level performance to the -40 to -45 dB range. Further, dual reflector compact ranges must be operated in a pulsed, time-gated mode in order to remove the effects of the high direct radiation from the feed that enters the quiet zone. The most serious disadvantage, however, is that dual reflector compact ranges are expensive. Most of the extra cost is tied up in the second, large reflector. Additional, non-trivial cost is associated with the pulsing and gating hardware and the larger test facility required to house the additional reflector.

MORE ECCA JUNK

By pointing the feed at the compact range reflector's parent parabola, the constraint on the quiet zone size due to geometry induced cross-polarization goes away. Instead, the quiet zone size is constrained by the resulting amplitude taper. For larger antenna sizes, it is desirable to provide correction for the amplitude taper inroduced by the vertex-oriented feed. The process of correcting for amplitude taper is referred to as "error-correction." Error correction is possible because the compact range amplitude taper due to the vertex-oriented feed is well known.

The aperture distribution responsible for the far-field pattern of the AUT measured in the compact range, which includes the effect of the tapered incident field from the compact range, can be calculated via the Fourier transform. The interaction of the amplitude taper in the compact range with the AUT aperture distribution is algebraic at each point in the aperture and can therefore be removed from the AUT aperture distrubution. Finally, the far-field of the aperture distribution can be determined via the inverse Fourier transform. Figure xx shows the block diagram of the process.

The Fourier transform relation between far-fields constrained within a small angular region about the electrical axis of an antenna and the aperture fields associated with the antenna is very accurate when the spacial variation of the aperture fields is small over a distance comparable to a wavelength. This approximation has been used successfully in many microwave holography applications.

The user begins the ECCA process by collecting a solid angle far-field pattern of the antenna under test by scanning the azimuth axis and stepping the elevation axis of an elevation over azimuth positioning system. In keeping with the Fourier requirement that the far-fields be constrained over a small angular region about the electrical axis of the aperture, the measurements are collected with movement of ± 20 degrees in both the elevation and azimuth axes, centered on the apeture electrical axis. For scanned beams of phased array antennas, the electrical axis is the peak of the scanned beam.

The test antenna mounting bracket must be shimmed so that the antenna boresight is

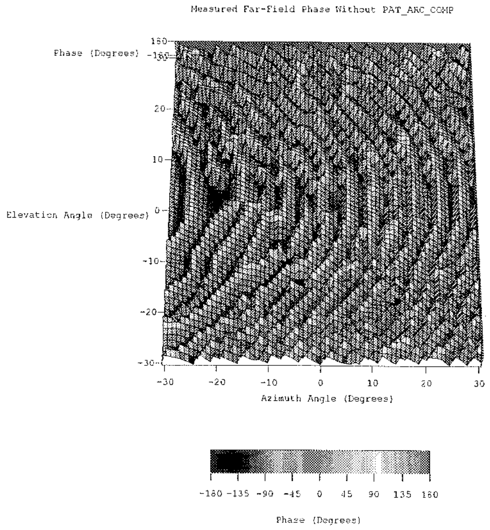
REQUIREMENTS ON THE MEASURED DATA COLLECTED FOR ECCA PROCESSING

.The Fourier transform is implement by a Fast Fourier Transform (FFT) peformed on sampled data. The sampling of the data must be done in a very specific way in order for the Nyquist and other criteria to be met. The specific parameters required for the measurement are provided to the user by a user-interactive menu called the ECCA Antenna Definition Menu, shown in Figure XX. Based on the antenna extent parameters and the highest test frequency input by the user, the Antenna Definition Menu automatically tells the user the start, stop and increment values for both the scan and step axes in order to meet the Nyquist and other requirements.

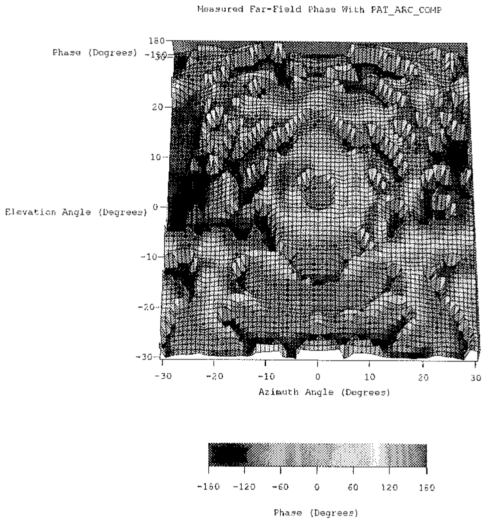
Data to be processed by ECCA is collected over a solid angle centered on the antenna electrical axis. The requirements on the measured data to be processed by ECCA are:

- The data must be collected having the scan (azimuth) and step (elevation) parameters as specified by the Antenna Definition Menu for the specific antenna, mounting, and measurement characteristics entered by the user.
- The response of the antenna to both vertical and horizontal polarization must be measured.
- The compact range feed specified in the Antenna Definition Menu must be used during the measurement.
- The antenna mounting bracket must be shimmed so that the antenna electrical axis is aligned with the antenna positioner roll axis.
- The location of the AUT phase center must be know within the tolerances shown in Table XX.
- The distance between the the elevation and azimuth axes of the antenna test positioner must be known within the tolerance in Table XX.
- The position of the center of the antenna extent rectangle must be know within the tolerances specified in Table XX.
-

The two configurations are known as the “standard” and the “alternate” configurations. The only difference between the two is the direction the compact range feed points. In the standard configuration, the compact range feed is tilted up so that the feed pattern compensates for the extra path loss at the top o f the quiet zone. The feed points up roughly toward the projection of the center of the quiet zone onto the reflector. In the alternate configuration, the feed points horizontally at the vertex of the compact range reflector.



(a)



(b)

Figure 3. Phase of the far-field of a 0.6 meter antenna at 13 GHz measured on a 0.3 meter (1 foot) moment arm without (a) and with (b) phase correction applied by ECCA.