HISTORICAL BACKGROUND ON THE USE OF EQUIVALENT STRAY SIGNAL IN COMPARISON OF ANTENNA PATTERNS

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Abstract

It has become of current interest to understand how best to draw conclusions as to the effects of sources of error upon the accuracy of measured antenna patterns.[1] In particular, when for a particular antenna, two pattern measurements made under slightly or somewhat different conditions are compared, how might one arrive at a conclusion as to which is the more nearly correct or the least uncertain pattern result ? Before attempting to address this question, it is important to realize that the method used to compare patterns must be examined for any anomalous artifacts. Here in this presentation I provide some background on how the equivalent stray signal method of pattern comparison came to be used in assessment of pattern accuracy and goodness of pattern result.

Before digital techniques came into common usage for storage of pattern data, antenna patterns were recorded on chart paper; it was possible to create pattern overlays by retracing the plots with small changes made to the conditions of the antenna between two successive plots. Often it was in this way that the antenna development engineer proceeded to refine the design of an antenna. It was also noticed that a change in the test conditions as set up on a particular range could equally well produce a discrepant pattern; such modifications as small alteration in the range length, a rotation of the range source by 180 deg or a rotation of the test antenna about its aperture normal could produce a discrepant pattern. Thus developed the practice of antenna range evaluation by systematically conducting such tests and looking for pattern discrepancies. (Two methods of range evaluation came to be used -- aperture field probing or free-space VSWR and antenna pattern comparison. [2],[3])

It was realized that most of the discrepancies were caused by range imperfections consisting of spurious reflections. And, the dominant measure of the quality of the range came to be its suppression of reflected extraneous signals. Suppression of range reflections came to be thought of as equivalent to achievement of pattern measurement accuracy. Quantifying the level of suppression by quoting the equivalent stray signal level for a ranges became the usual practice.

The analysis of antenna pattern comparisons was described in an article published in the IEEE AP-S Newsletter.[4] In that article it was also pointed out that the method might be useful in comparing two different antenna measurement techniques. By overlaying two patterns made on the same antenna by two different methods, one could gain a quantitative measure of the degree to which two techniques gave measurement results consistent with the equivalent stray signal suppression for each type of range. This was important at the time because the antenna community was moving toward acceptance of the measurement methods we know as the near-field scanning and compact range methods. Just as equivalent stray signal was used as a figure of merit to characterize or compare two different far-field ranges, it was suggested that it might also be used to characterize or compare two different measurement techniques.

Included in this presentation also will be examples showing how the concept of equivalent stray signal has been applied to evaluation of compact antenna ranges and to comparison of compact range patterns to near-field scanning patterns.

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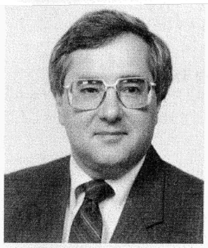
The Measurements Column



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In this edition of The Measurements Column, I consider a method of quantifying the discrepancies, between patterns measured for a single antenna, which are measured under similar but not identical conditions. This method yields the notion of an "equivalent array signal," which is useful in stating a figure of merit for a pattern measurement.

Correction: "stray"

Antenna engineers have often experienced a situation where a measured pattern cut cannot be reproduced exactly. For example, rotating a [symmetrical] antenna by 180 degrees about its main beam axis should ideally leave the antenna in an orientation with the same principal-plane pattern as before the rotation. Often the patterns taken before and after this rotation process have a discrepancy, because of stray signals present on the range, due to unwanted reflections. (This can be a useful process in evaluating an antenna range.) A standard method of analyzing the pair of disagreeing patterns is shown below. It yields the true pattern level and the apparent stray signal, at a particular angle, by assuming that the stray signal adds in phase with the direct signal to produce the higher pattern level, and out of phase to produce the weaker pattern level.

The pattern discrepancy can be quantified in a way meaningful to the antenna engineer by the apparent stray signal level. This is a useful concept, because it permits a comparison between measurements with a discrepancy in terms of the most common cause of discrepancies: extraneous or stray signals.

To see how the analysis is begun, consider the pattern comparison of Figure 1, where two pattern cuts with a discrepancy are overlaid. At a particular angle θ there are two sidelobe levels, d1 and d2, related to the two sidelobe signals, E1 and E2, by the logarithmic equations

$$d1 = -20 \log \frac{E1}{E0} \qquad (1)$$

and

$$d2 = -20 \log \frac{E2}{E0} \qquad (2)$$

where E0 is the signal level to which all other signals are referred. The pattern discrepancy in decibels is

$$\Delta = d2 - d1 = 20 \log \frac{E1}{E2} \qquad (3)$$

The extraneous signal, Ex, which causes the higher apparent sidelobe, E1, will be assumed to have added in phase with the direct signal, Ed, so that

$$E1 = Ed + Ex \qquad (4)$$

On the other hand, if this same signal arrives out of phase, then the lower apparent sidelobe will occur, and it will have an amplitude

$$E2 = Ed - Ex \qquad (5)$$

The true relative sidelobe level, d, which should appear on the pattern for an ideal range, with no reflections, lies between d1 and d2, and is given by

$$d = -20 \log \frac{Ed}{Epk}$$

[where Epk is the peak value; see Figure 1]. It can be shown that d can be expressed in terms of d1, Δ, and E0. These quantities can be easily read off of a pattern overlay. The result is

$$-d = -d1 + 20 \log\left[\frac{1 + 10^{-\Delta/20}}{2}\right] - 20 \log \frac{Epk}{E0} \qquad (6)$$

As an example, suppose that a pattern comparison overlay shows a sidelobe at -20 dB with a discrepancy of 1 dB. Suppose that the higher level is d1 = 20 dB, and that the peak of the pattern occurs at Epk = E0 (i.e., 0 dB). Then the true sidelobe level is

$$d = 20 \text{ dB} + 0.49 \text{ dB} + 0 \text{ dB} = 20.49 \text{ dB} \qquad (7)$$

The equivalent stray signal, Ex, which might have caused the discrepancy is given by

Correction: "-"

$$20 \log \frac{Ex}{Epk} = -d1 + 20 \log\left[\frac{1 + 10^{-\Delta/20}}{2}\right] - 20 \log \frac{Epk}{E0}$$

$$= -20 \text{ dB} - 25.3 \text{ dB} - 0 \text{ dB} \qquad (8)$$

$$= -45.3 \text{ dB}$$

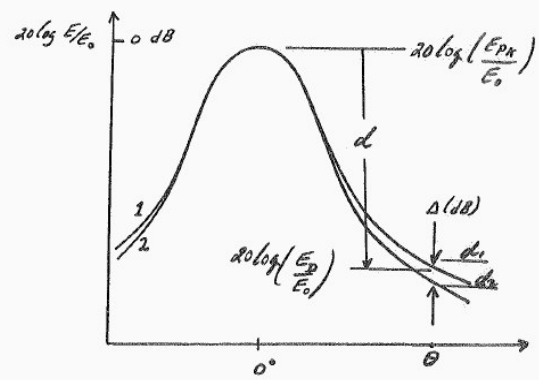

Figure 1. Two patterns with a discrepancy overlaid. The discrepancy between patterns 1 and 2 at angle θ is considered to be due to an apparent stray signal Ex which adds in phase with Ed to produce level E1, and out of phase with Ed to produce level E2.

Thus, the equivalent stray signal is at least 45 dB below the peak signal, for the particular pattern angle chosen.

A pattern comparison is usually analyzed at a large number of pattern angles, and the worst and typical case values identified. The typical value might derive from plotting a histogram of the equivalent stray signals. Note that equivalent stray signals depend on the antenna under test.

The analysis and the corresponding histogram can be expanded to include other pattern cuts at other polarizations and other frequencies. The discrepancies can also be studied for other antennas. The result is an accumulation of experience that yields information on the pattern accuracy and on the pattern range.

Quoting the result of the evaluation in terms of the worst case and typical equivalent stray signals is a useful method of stating a figure of merit for a set of measurements with discrepancies.

A low value for the equivalent stray signal level corresponding to the comparison between patterns has historically been taken as meaning that the antenna range has a good stray signal suppression. When extended to comparison among patterns made on different ranges and by different methods, a low value for the equivalent stray signal level can imply a small discrepancy and accurate measurement technique.