# HORIZONTAL FIELD PATTERNS OF VERY-HIGH-FREQUENCY UNSYMMETRICAL LOCALIZER ANTENNA ARRAYS

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# HORIZONTAL FIELD PATTERNS OF VERY-HIGH-FREQUENCY UNSYMMETRICAL LOCALIZER ANTENNA ARRAYS


## SUMMARY

The properties of the horizontal field patterns of unsymmetrical linear antenna arrays consisting of from five to seven antennas are compared with those of the Civil Aeronautics Administration's standard 10-loop localizer array  Horizontal field patterns for the sideband frequencies and curves of cross-pointer instrument deflection versus azimuth angle for eight antenna arrays are shown  It is found that the best field patterns of the unsymmetrical arrays considered are not as good as the field pattern of the standard 10-loop array, although the course sharpness can be made the same for both types of arrays  For general use unsymmetrical arrays are not recommended  The effect of improper current phasing in one antenna on course bending was investigated and found to be small, but it was greater in unsymmetrical arrays than with the standard 10-loop localizer antenna array


## INTRODUCTION

Antenna arrays which produce field patterns having certain prescribed characteristics can be developed by two methods  In the first method the field patterns evolve from a large number of calculations in which antenna spacings and currents are systematically and judiciously varied until a practical and economical solution of the problem is obtained  The second method starts from the desired contour of the field pattern and makes use of Fourier analysis[1] to determine antenna currents and spacings giving a field pattern which approximates this contour

The present localizer antenna arrays of the CAA were developed by the "cut-and-try" method and have very satisfactory field patterns  It is realized, however, that theoretically the antenna arrays are not necessarily the best ones possible

The localizers operate at frequencies of approximately 110 megacycles and their antennas are horizontally polarized loops

As the function of the localizer is to give lateral guidance to the pilot making an instrument landing, we are interested primarily in the horizontal field pattern produced by the antenna array  The horizontal field patterns shown in the appended drawings are for free space and have an arbitrary scale

The purpose of this investigation is to examine the possibility of reducing the number of antennas of the standard 10-loop localizer array by using an unsymmetrical array without sacrificing the desired properties of the field pattern  An unsymmetrical array is one in which not all of the antennas are symmetrical with respect to the center of the array

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[1]Wolff, Irving, "Determination of the Radiating System which will Produce a Specified Directional Characteristic " Proceedings of the I R E , v 25, p 630, May 1937

## THE STANDARD 10-LOOP LOCALIZER ANTENNA ARRAY

Relative antenna currents and antenna spacings (measured from the center of the array) for the standard localizer are shown at the top of figure 1 and on figure 2 [2]. The latter drawing also shows the two conjugate sideband field patterns[3] and the carrier pattern which are marked by the frequencies ($f_c \pm 150\sim$), ($f_c \pm 90\sim$) and $f_c$.

The sideband field pattern equation is

$$E(\theta) \propto I_1 \cos(S_1 \sin\theta) \pm \sum_{n=2}^{5} (I_n \sin(S_n \sin\theta)) \qquad (1)$$

where $E(\theta)$ = field intensity in horizontal plane

$\theta$ = azimuth angle measured from course

$I_1$, $I_2$, etc = antenna sideband current amplitudes

The + and − sign in the equation distinguishes the conjugate field patterns

The carrier field pattern is given by

$$E_c(\theta) \propto I_c \cos(S_1 \sin\theta) \qquad (2)$$

where $I_c$ = amplitude of carrier current in each of the two center antennas

The pattern clearance is defined as the ratio in decibels of the field intensities of the conjugate field patterns in any azimuthal direction At 1 5° off course the clearance is called course sharpness (N)

$$N_{db} = 20 \log_{10} \left[ \frac{I_1 + \sum_{n=2}^{5} \left[ I_n \sin(0\ 0262\ S_n) \right]}{I_1 - \sum_{n=2}^{5} \left[ I_n \sin(0\ 0262\ S_n) \right]} \right] \qquad (3)$$

where $S_n$ is the antenna spacing of the $n^{th}$ antenna in degrees, measured from the center of the array, and $I_n$ the sideband current amplitude of the $n^{th}$ antenna $I_1$ is the current in each center antenna if there are two center antennas, or one-half of the current in the center antenna if there is but one center antenna

In good approximation equation (3) may be rewritten as

$$N_{db} = 20 \log_{10} \left[ \frac{I_1 + 4\ 57 \times 10^{-4} \sum_{n=2}^{5} (I_n S_n)}{I_1 - 4\ 57 \times 10^{-4} \sum_{n=2}^{5} (I_n S_n)} \right] \qquad (4)$$

From a practical point of view the course width is of great importance The course width W is defined as the horizontal angle, measured between two points symmetrical to the course, and the radiation center, at which full-scale deflection (4 dots to 4 dots) of the cross-pointer instrument occurs Within the service area in which the airplane receiver's automatic volume control is operative, the deflection of the cross-pointer instrument is substantially constant as the plane flies on a radial going through the center of the localizer array

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[2] Caporale, Peter, "Instrument Approach System", Radio News, v 29, p 121, June 1943

[3] The term "conjugate field patterns" means the two patterns of sideband frequencies produced by 90- and 150-cycle modulation, respectively

The course width is

$$W = K \sum_{n=2}^{5} \left[ I_n \sin (S_n \sin \theta) \right] \qquad (5)$$

where W is the course width in degrees and K is a constant which depends on the setting of the manual gain control in the receiver The receiver gain is adjusted to give a certain value of output voltage measured at the input of the 90- and 150-cycle filters A representative value of filter potential for a localizer course width of 5° (4 dots to 4 dots) is 30 volts, using a Western Electric Type 32-A receiver Values of localizer course width between 2 5° and 5° are satisfactory from a flying standpoint

Before discussing the merits of the various field patterns shown in the appended drawings, it is appropriate to state briefly the most important requirements for a satisfactory localizer field pattern These requirements are

1 The service area in a horizontal plane through the localizer antennas should have approximately the shape of an ellipse whose major axis coincides with the two reciprocal courses and whose minor axis is approximately one-third of the length of the major axis

2 The difference in the field intensities between the conjugate field patterns must rise rapidly from zero on course to a value sufficient for full-scale deflection of the cross-pointer instrument in the airplane, that is, the course sharpness must be sufficient to insure an instrument landing near the center line of the runway with proper allowance for normal flight deviations

3 The difference-field intensity must be sufficient to give full-scale deflection of the cross-pointer instrument in all azimuthal directions within the service area except near course

4 The difference-field intensity should not greatly exceed the value required to give full-scale deflection of the indicator within the service space This requirement assures, first, a minimum of interference effects from radiated power reflected by objects in the vicinity of the localizer and, second, the most economical use of radiated power

5 The size of the minor lobes of the field patterns should be as small as possible

6 The degree of modulation of the carrier should be high on and near the course

An obvious condition regarding the antenna array is that it should contain the least number of elements consistent with the above requirements for the field pattern

Inspection of figure 2 shows that the field pattern of the standard localizer fulfills these requirements to a high degree The maximum of radiation is near the course at approximately 8° and the ratio of field intensity on course to maximum field intensity is relatively large The minor lobes are small, giving a high minimum clearance, and the degree of modulation is high in any direction The relative scales of carrier and sideband field patterns are such that the maximum modulation equals but does not exceed 100 percent

## UNSYMMETRICAL LOCALIZER ANTENNA ARRAYS

As no mechanical means (such as the machine described by Williams[4]) for obtaining the horizontal sideband field patterns were available, the number of antenna combinations analyzed, of necessity had to be small The patterns selected for presentation are produced by the arrays shown on figure 1 It will be observed that the spacings of the standard 10-loop localizer array have been kept intact except in Cases 2 and 3 where a single center antenna instead of a pair was used, and in Case 7 which has a side antenna with a very large spacing In Case 9 the antenna spacings of a portable CAA localizer array mounted on the roof of a trailer are used in conjunction with a single unsymmetrical antenna This antenna raises the course sharpness of the portable localizer from 2 9 db to 4.8 db

The first thought in arriving at the unsymmetrical antenna arrays was to omit one of the radiators in each equispaced pair of the symmetrical array, alternating from one side of the center to the other (Cases 3 and 4) As the field patterns thus obtained are unsatisfactory, antenna arrays having two and three symmetrical pairs, respectively, in addition to unsymmetrical antennas have been calculated (Cases 5, 6, and 7)

To derive the field pattern equations for the unsymmetrical arrays, the retarded potentials due to each radiator are set up and the terms in time phase and in quadrature phase with the radiation from the center antenna(s) are collected (E' and E") The amplitude of the total intensity then is

$$E = \sqrt{E'^2 + E''^2}$$

For example, the equation of the field pattern for Case 6 is given by

$$E \propto \left[ \left[ 2 I_1 \cos (S_1 \sin \theta) \pm 2 I_2 \sin (S_2 \sin \theta) \pm I_3 \sin (S_3 \sin \theta) \pm I_4 \sin (S_4 \sin \theta) \pm I_5 \sin (S_5 \sin \theta) \right]^2 + \left[ I_3 \cos (S_3 \sin \theta) - I_4 \cos (S_4 \sin \theta) + I_5 \cos (S_5 \sin \theta) \right]^2 \right]^{\frac{1}{2}} \qquad (6)$$

Inspection of equation (6) shows that the terms in the first bracket are similar to those for the symmetrical array, equation (1), except that the members representing the unsymmetrical antennas lack the factor 2 (In equation (1) the factors 2 are omitted to simplify the equation ) Doubling of currents $I_3$, $I_4$, and $I_5$ relative to the values of the symmetrical antenna array makes the first bracket identical with equation (1) The "disturbing function" in the second bracket is symmetrical to the course and its members have alternating signs

Two methods are available for reducing the effect of the disturbing function on the field pattern on course and near the course

(a) Choosing the currents so that $I_3 - I_4 + I_5 = 0$.

(b) Moving antenna No 5 to the other side of the center line of the array (Case 5), which will make the sign of the $I_5$ term in the second bracket of equation (6) negative without changing its sign in the first bracket

As the antenna currents decrease with antenna spacing, method (b) readily lends itself to satisfy the equation $I_3 - I_4 - I_5 = 0$ While the effect of the disturbing

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[4] Williams, H. P , "A Machine for Calculating the Polar Diagram of an Antenna System," Electrical Communications v. 21, No 2, p 103, 1943

function on the field pattern near the course can be controlled, the disturbing function will reduce the clearance between the two conjugate field patterns in all other directions of the horizontal plane

In order to give a clearer appreciation of the properties of the field patterns as they affect the cross-pointer instrument, the relative deflection of this instrument versus the azimuth angle is shown on figure 11 for the nine antenna arrays of figure 1

As the cross-pointer instrument is in a direct-current bridge circuit in which the rectified 90-cycle and 150-cycle voltages buck each other, the deflection of the zero-center instrument is proportional to the difference in intensity of the conjugate sideband field patterns for the particular azimuth angle If the carrier field pattern is not circular but is constricted on the sides, it is necessary to take into account the automatic volume control characteristic of the receiver which tends to keep the receiver output constant regardless of carrier field intensity This has been done in figure 11 for Case 1 and Cases 4 to 8, inclusive The patterns shown in figure 11, with the exception of Case 9, are drawn to such a scale that at 1 5° off course they have the same ordinate

From previous discussion on the field pattern requirements, it follows that the ideal deflection curve would be a horizontal line as shown dotted for Case 1 The position of the horizontal line will be shifted up or down by the gain control setting of the receiver It is apparent that if in all but the ideal case the course width is made very broad, there will be certain azimuth angles where the instrument needle will have less than full-scale deflection Such a condition must be avoided since it may give a pilot who is circling the localizer station the impression that he is approaching the course when he actually is not

Any practical curves of cross-pointer indicator deflection versus azimuth angle (figure 11) will have minima limiting the maximum course width which can be accommodated by a given field pattern In table I maximum course widths for the nine cases considered are given The maximum course width for the standard 10-loop localizer is 5°

The following simple graphic method may be used to determine the maximum possible course width The curve of cross-pointer instrument deflection versus azimuth angle corrected for the automatic volume control action of the receiver is plotted The minimum of this curve is determined (disregarding the value zero on course) and a horizontal line drawn tangent to the minimum The azimuth angle at which this horizontal tangent intersects the curve as it rises from zero on course to the first maximum is determined and multiplied by two to find the maximum possible course width

## DISCUSSION OF FIELD PATTERNS

The field patterns shown in figures 2 to 9, inclusive, have been drawn to such a scale that the field intensity on course is approximately the same for all cases, varying from 2 0 to 2 04 units Examining the field pattern drawings, figure 11 and table I, it appears that the standard 10-loop localizer antenna gives a field pattern with the best over-all characteristics (Case 1) Good field patterns are also shown in figures 8 and 9 Figure 8, Case 7 shows the best pattern of the unsymmetrical localizer arrays considered The principal disadvantage of the array of Case 7 is the large antenna spacing (3000°) of the unsymmetrical antenna.

Figure 9, Case 8 holds for a symmetrical 8-loop localizer array This field pattern has approximately the same merits as that of figure 8 with the added advantage that the total length of its array is but 2200°

Figure 3, Case 2 shows the field pattern obtained if the standard 10-loop array is adapted to a 9-loop array with a single center antenna The chief drawback

TABLE I

DATA ON FIELD PATTERNS

| Case Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Figure Number | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Number of Antennas | 10 | 9 | 5 | 6 | 7 | 7 | 7 | 8 | 6 |
| Max Field Intensity | 4.55 | 4 9 | 4 5 | 4 45 | 4 9 | 4 6 | 4 75 | 5 0 | 4 25 |
| At Azimuth Angle in Degrees | 8 | 10 | 7 5 | 7.5 | 7.5 | 7 5 | 15 | 10 | 22 |
| E On Course | 2 0 | 2 01 | 2 0 | 2 0 | 2.01 | 2 01 | 2 04 | 2 0 | 1 84 |
| $\frac{\text{E On Course}}{E_{max}}$ in Percent | 44 | 41 | 45 | 45 | 41 4 | 44 | 43 | 40 | 43 |
| Min. Field Intensity | 1 37 | 2 88 | 2 66 | 1 85 | 1 77 | 1 39 | 1 13 | 0 84 | 2 58 |
| At Azimuth Angle in Degrees | 90 | 35 | 60 | 90 | 60 | 90 | 90 | 90 | 55 |
| Max Minor Lobe | 0 5 | 1 14 | 3 32 | 3 32 | 1.63 | 1 75 | 0 96 | 1 11 | 1 05 |
| At Azimuth Angle in Degrees | 8 | 35 | 45 | 45 | 20 | 45 | 15 | 10 | 55 |
| Course Sharpness at 1 5 Degree in db | 7 5 | 7 9 | 5.4 | 5 4 | 7 8 | 6.8 | 7 85 | 7 2 | 4 8 |
| Min Clearance in db | 12 4 | 8 1 | 2 4 | 1 7 | 3 3 | 4 7 | 10 8 | 10 9 | 7 8 |
| At Azimuth Angle in Degrees | 60 | 35 | 45 | 45 | 90 | 40 | 60 | 25 | 55 |
| Clearance at 90° in db | 55 | 8 7 | 4 2 | 2 5 | 3 3 | 8 9 | 10 9 | 14 4 | 22 8 |
| Azimuth of Min Cross-pointer Deflection in Degrees | 60 | 35 | 60 | 60 | 90 | 40 | 70<br>90 | 25 | 55 |
| Maximum Course Width in Degrees | 5 | 3 2 | 2 0 | 2 6 | 3 4 | 3 8 | 6.0 | 4 5 | 4 8 |
| Percent Modulation on Course | 78 | 70 | 52 | 35 | 40 | 54 | 56 | 63 | 74 |
| 100 Percent Modulation at Azimuth in Degrees | 10 | 10 | 45 | 45 | 90 | 45 | 60 | 65 | 22 |

of this field pattern is the small maximum course width which it can accommodate (see table I) and the somewhat low minimum clearance

The field patterns shown in figures 4 to 7 inclusive, (Cases 3 to 6) are illustrative of what may be expected from "highly unsymmetrical" antenna arrays While course sharpness is normal or fair, minimum clearance, percent modulation, and maximum course width are too low for practical use

Figure 10 is the field pattern of the CAA's portable localizer with an unsymmetrical antenna added to increase the course sharpness from 2.9 db to 4 8 db

## COURSE BENDING WITH LOCALIZER ANTENNA ARRAYS

It is of interest to examine what happens to the course alignment for both symmetrical and unsymmetrical localizer antenna arrays if the magnitude or phase of the current in the individual antennas is changed This is done by setting up the equations for the conjugate horizontal field patterns $E_1$ and $E_2$ and letting $|E_1| = |E_2|$ The last equation then should be solved for the azimuth angle ($\theta$) While this is impractical, the equation can be solved for the phasing error $\phi$

The results of the analysis show that changes of the magnitude of the antenna currents do not produce course bending or course shifting[5] if the phase of the currents is correct If the phase angle of the current of an individual antenna is incorrect, course bending will occur The course-bending angle will increase as the spacing of the particular antenna from the radiation center is decreased and when the current is increased

A special case of improper phasing which will apply to symmetrical antenna arrays must be considered, namely, when a symmetrical antenna pair has currents of equal magnitude and of equal phasing error in the same direction Under this condition no course bending occurs

The course-bending angle $\theta$ versus phasing error $\phi$ has been calculated for Cases 1 and 7 and is plotted on figure 12, one antenna of the array being improperly phased in each case

It will be observed that the curves resemble sine curves and have a horizontal tangent at the maximum course-bending angle If the phasing error increases beyond the value corresponding to the maximum course-bending angle, the course disappears

For illustrative purposes, equation (7) giving $\phi$ versus $\theta$ for the standard 10-loop localizer field pattern (Case 1) with antenna 5 out of phase is shown below, as well as equation (8) which holds for Case 7 with antenna 4 improperly phased

$$\phi_5 = S_5 \sin\theta + \sin^{-1}\left[\frac{2I_2}{I_5}\sin(S_2\sin\theta) + \frac{2I_3}{I_5}\sin(S_3\sin\theta) + \frac{2I_4}{I_5}\sin(S_4\sin\theta) + \sin(S_5\sin\theta)\right] \qquad (7)$$

$$\phi_4 = S_4 \sin\theta + \sin^{-1}\left[\frac{2I_2}{I_4}\sin(S_2\sin\theta) + \frac{2I_3}{I_4}\sin(S_3\sin\theta)\right] \qquad (8)$$

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[5] The term "course bending" designates the condition in which front and rear courses are displaced by an angle $\theta$ in opposite direction, thus having the azimuths $\theta$ and $(180^\circ - \theta)$ "Course shifting" occurs if the above displacements are in the same direction giving the azimuth angles of the courses as $\theta$ and $(180^\circ + \theta)$

Consideration of the equations indicates that the maximum course-bending angle is obtained when the value of the square bracket is unity It follows that the maximum phasing error at which the course just disappears is greater than 90°

It may be stated that a large phasing error in an individual antenna of a symmetrical or an unsymmetrical array produces but a small course-bending angle In general, the course-bending angle produced by a given phasing error will be greater for unsymmetrical arrays than for symmetrical ones

The adverse effect of improper phasing of an antenna of a localizer array on course sharpness and on pattern clearance is much more pronounced than the effect on course bending

Of academic interest is the effect of improper current phasing in an individual antenna of an array on harmonic distortion of the received signal

For the purpose of discussion assume an unsymmetrical antenna array of 7 loops (Case 7) with the phase angle of loop 4 having an error $-\phi$

This produces a phase shift $\delta$ between carrier and sidebands as follows

$$\delta = \tan^{-1}\left[\frac{I_4 \cos (S_4 \sin (\theta) - \phi)}{2I_1 \cos(S_1 \sin\theta) \pm 2I_2 \sin(S_2 \sin\theta) \pm 2I_3 \sin(S_3 \sin\theta) \pm I_4 \sin(S_4 \sin(\theta) - \phi)}\right] \tag{9}$$

The $\pm$ signs in equation (9) again distinguish the conjugate field patterns It will be observed that the phase shift $\delta$ varies with the azimuth angle and that it is small on the side of the major lobes of the field pattern On the side of the minor lobes of the field pattern the angle $\delta$ becomes larger In the directions where the denominator of equation (9) becomes zero, $\delta$ is 90°, and where the denominator becomes negative, $\delta$ is greater than 90°

It can be shown that improper phasing between carrier and sidebands causes second harmonic distortion in the receiver output using either linear or square law detection As the second harmonic amplitude is proportional to the square of the modulation factor of the signal, it follows that little harmonic distortion will be experienced in any azimuthal direction even if the unsymmetrical side antenna has an appreciable phasing error

## CONCLUSIONS

As a result of this study it is concluded that

1 The best field pattern among those considered in this Note is that of the standard 10-loop localizer antenna array

2 It is possible to obtain an equally high course sharpness with both symmetrical and unsymmetrical localizer antenna arrays, keeping the ratio of field intensity on course to maximum field intensity approximately constant

3 It is not possible, as far as this investigation has shown, to have as high a minimum clearance, maximum course width, and degree of modulation with an unsymmetrical antenna array as with a symmetrical antenna array if the number of antennas in the unsymmetrical array is appreciably smaller than that of the symmetrical array.

4. It is possible to obtain as good a curve of cross-pointer instrument deflection versus azimuth angle with 7 antennas (Case 7) as with the standard localizer array of Case 1.

5. If overmodulation of the carrier in any azimuthal direction is avoided, the average degree of modulation for the standard 10-loop localizer field pattern is appreciably greater than that of the best unsymmetrical patterns considered.

6. It is apparent that unsymmetrical antenna arrays having more than one unsymmetrical antenna will not give satisfactory localizer field patterns. For general use in localizer antenna installations, unsymmetrical arrays are not recommended.

7. In special cases - for example, when it is desired to reduce radiation of the array in a particular direction, such as toward a reflecting object - an unsymmetrical antenna may be added to advantage, although the ensuing scalloping of the field pattern will reduce the maximum course width and the pattern clearance.

8. The course-bending angle produced by a phasing error in an individual antenna is, under comparable conditions, greater for an unsymmetrical array than for a symmetrical one.

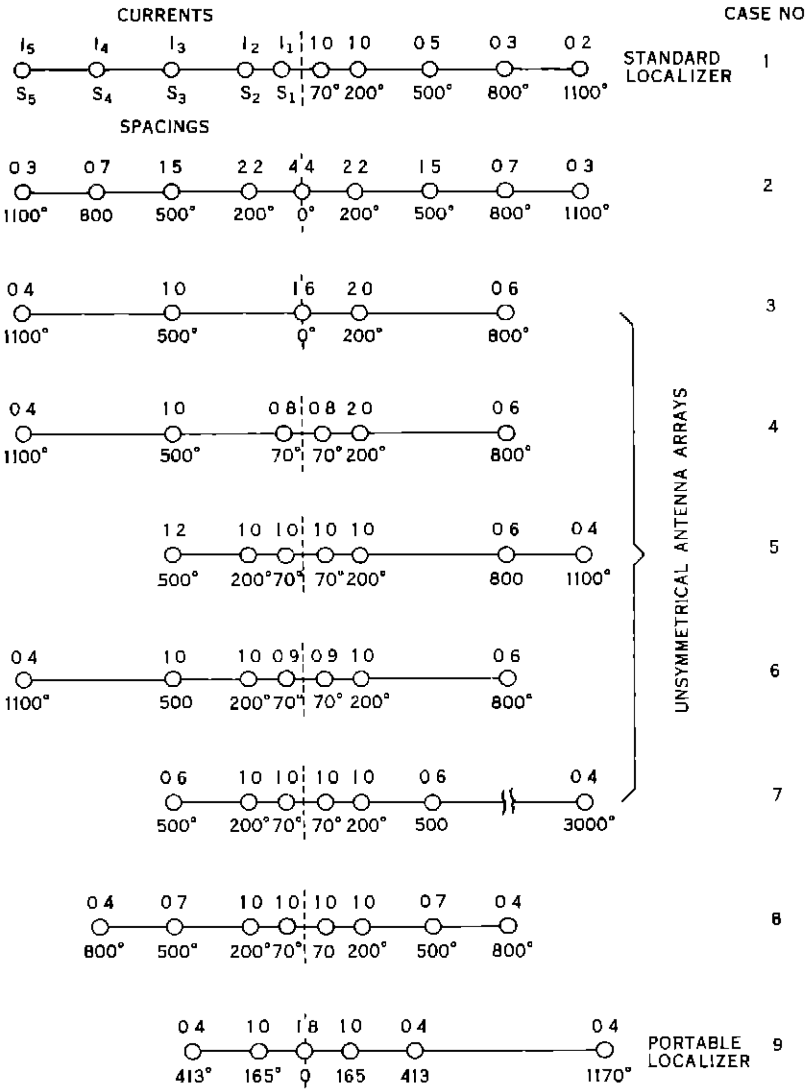



Figure 1 Antenna Arrays for which Field Patterns are Shown

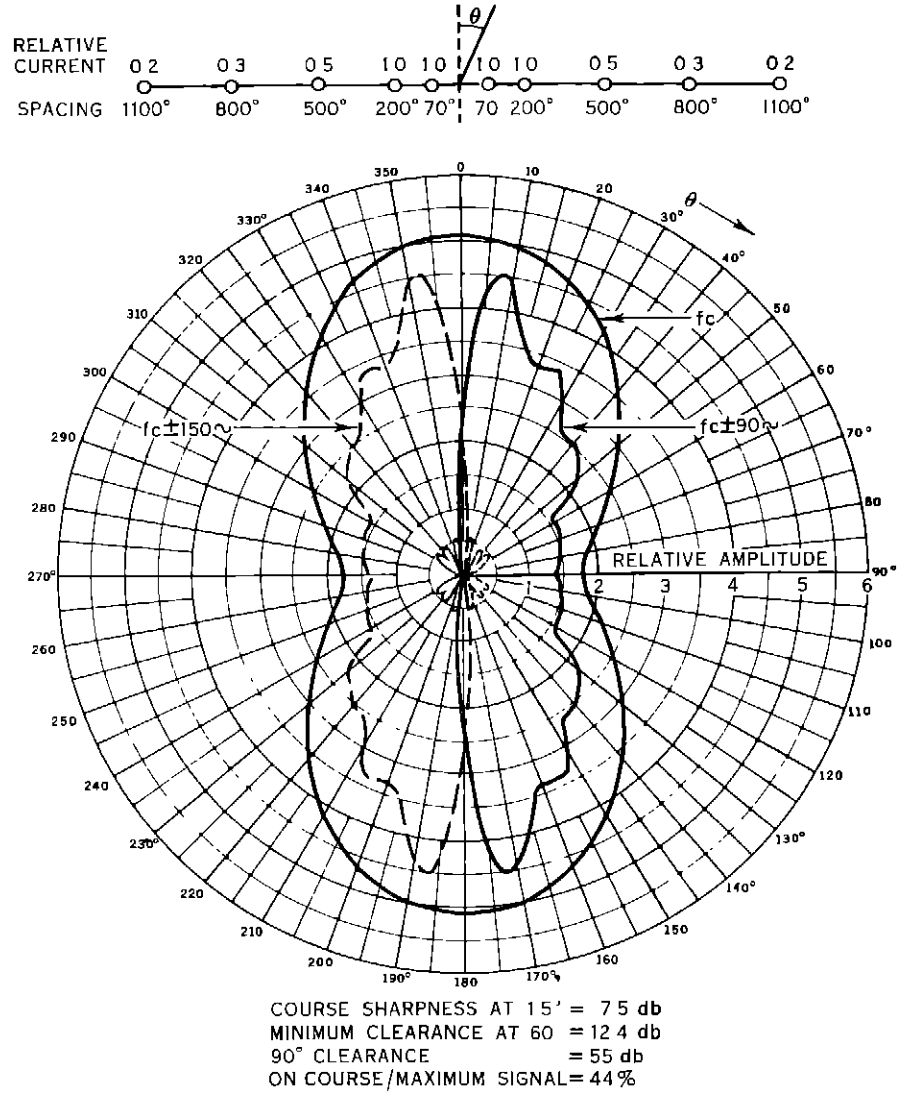
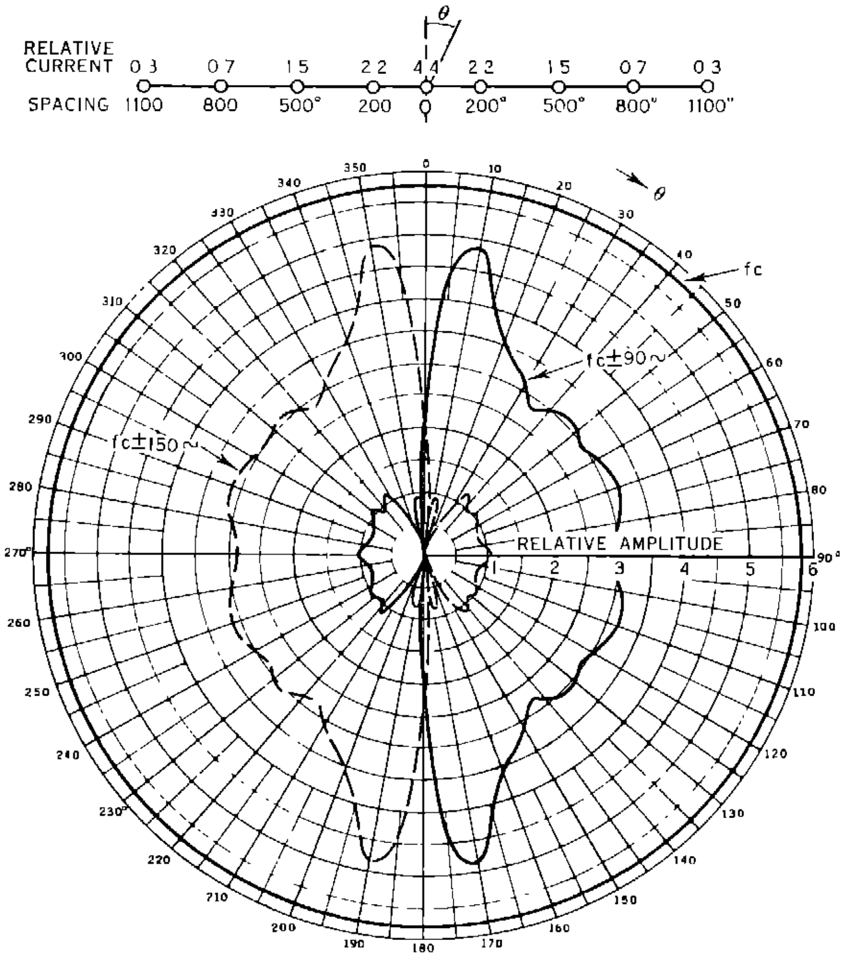
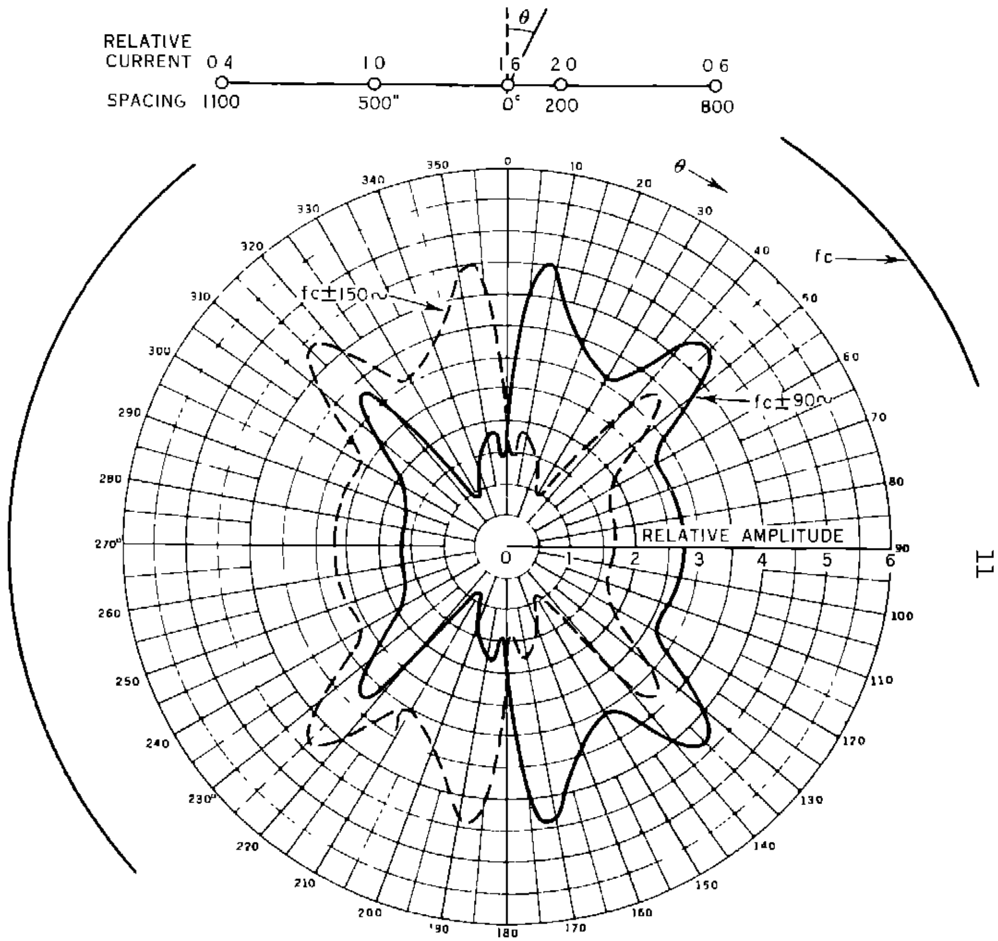



Figure 2 Horizontal Field Pattern for Standard 10 Loop Antenna Array (Case 1)



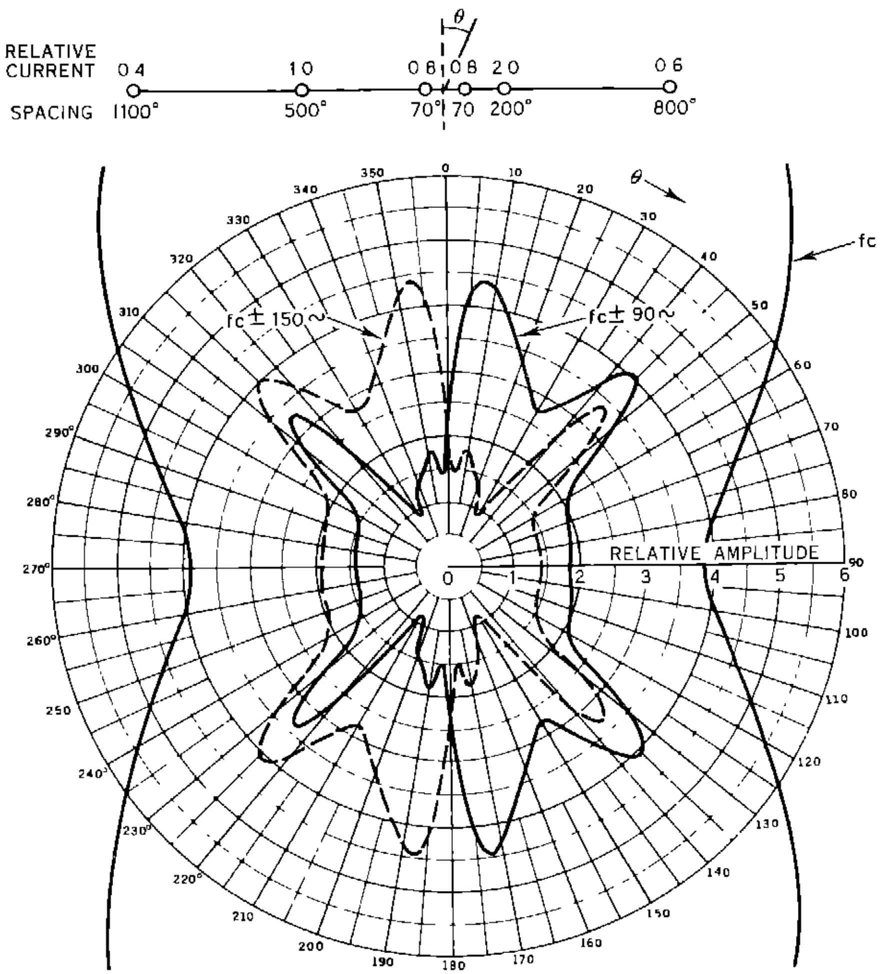

COURSE SHARPNESS AT 1 5° = 7 9 db
MINIMUM CLEARANCE AT 35° = 8 1 db
90 CLEARANCE = 8 7 db
ON COURSE/MAXIMUM SIGNAL = 41 %

Figure 3 Horizontal Field Pattern for 9-Loop Antenna Array (Case 2)



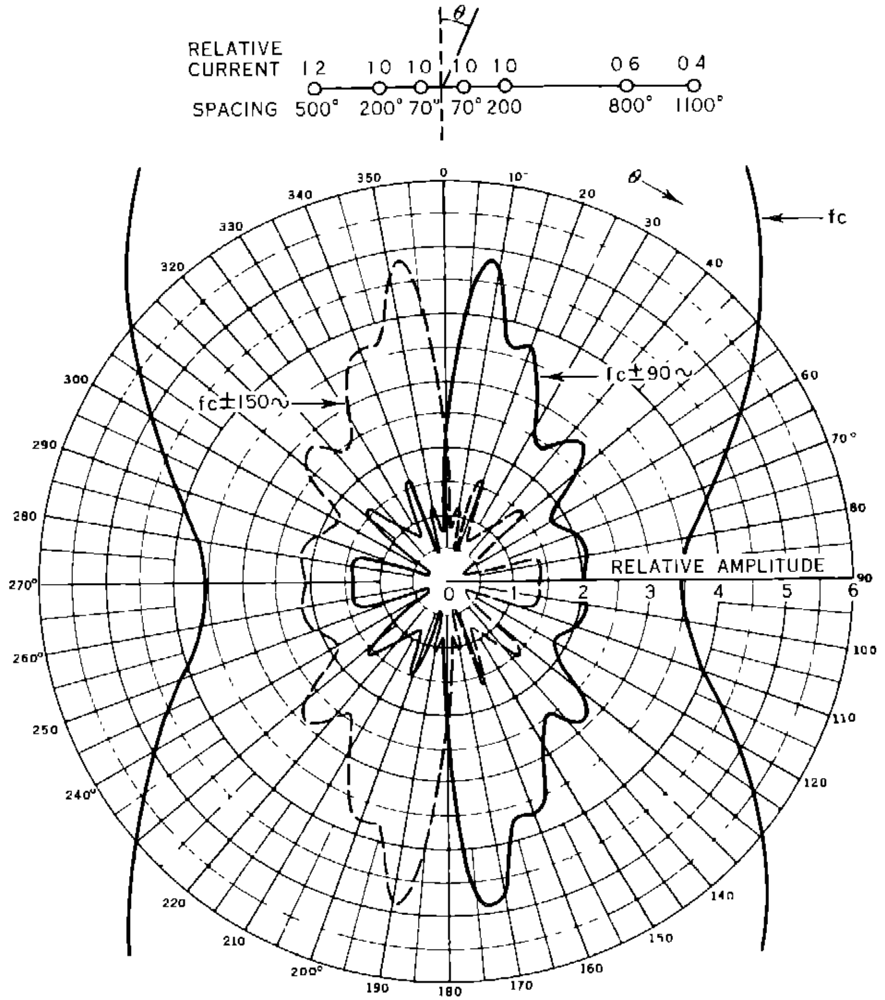

COURSE SHARPNESS AT 1 5 = 5 4 db
MINIMUM CLEARANCE AT 45° = 2 4 db
90° CLEARANCE = 4 2 db
ON COURSE/MAXIMUM SIGNAL = 45 5 %

Figure 4 Horizontal Field Pattern for Unsymmetrical Antenna Array (Case 3)




COURSE SHARPNESS AT 1 5 = 5 4 db
MINIMUM CLEARANCE AT 45 = 1 73 db
90 CLEARANCE = 2 48 db
ON COURSE/MAXIMUM SIGNAL = 45 %

Figure 5 Horizontal Field Pattern for Unsymmetrical Antenna Array (Case 4)




COURSE SHARPNESS AT 1 5 = 7 8 db
MINIMUM CLEARANCE AT 90° = 3 3 db
ON COURSE/MAXIMUM SIGNAL = 41 4 %

Figure 6 Horizontal Field Pattern for Unsymmetrical Antenna Array (Case 5)

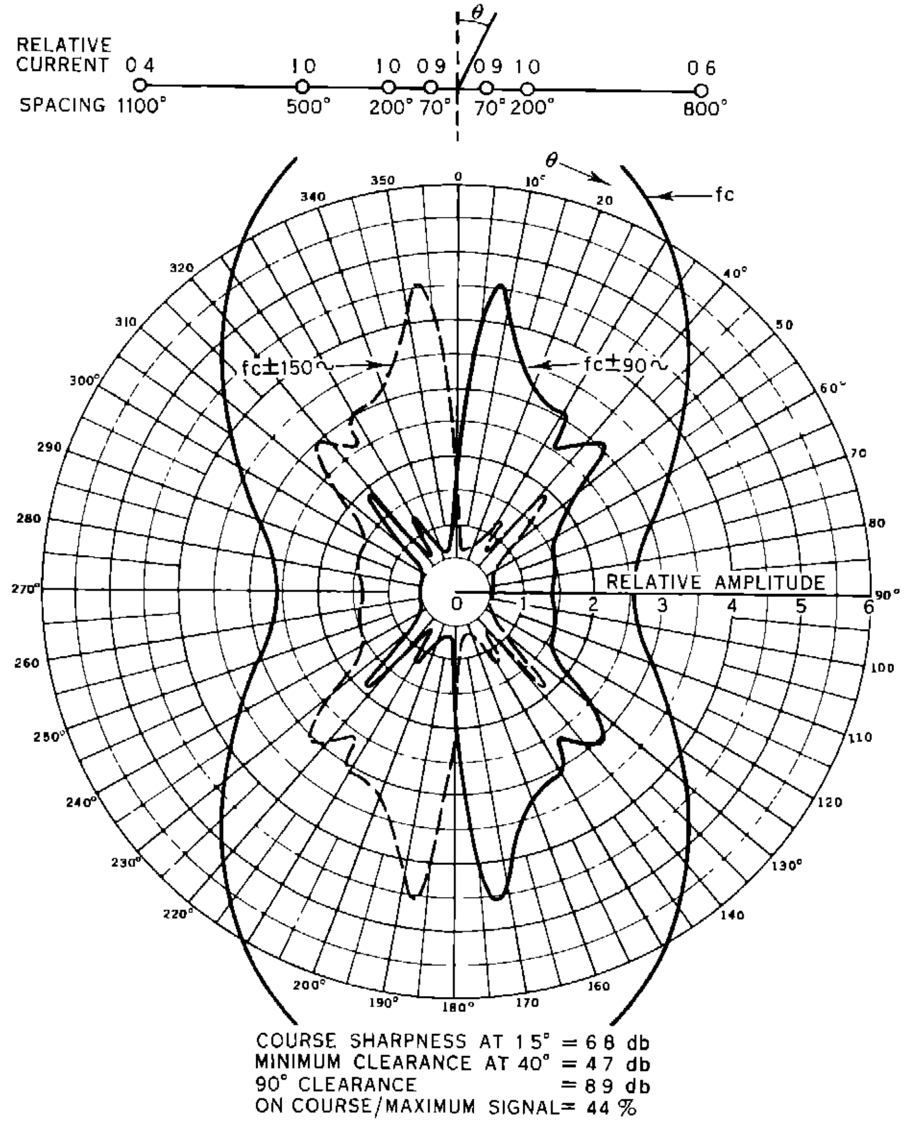



Figure 7 Horizontal Field Pattern for Unsymmetrical Antenna Array (Case 6)

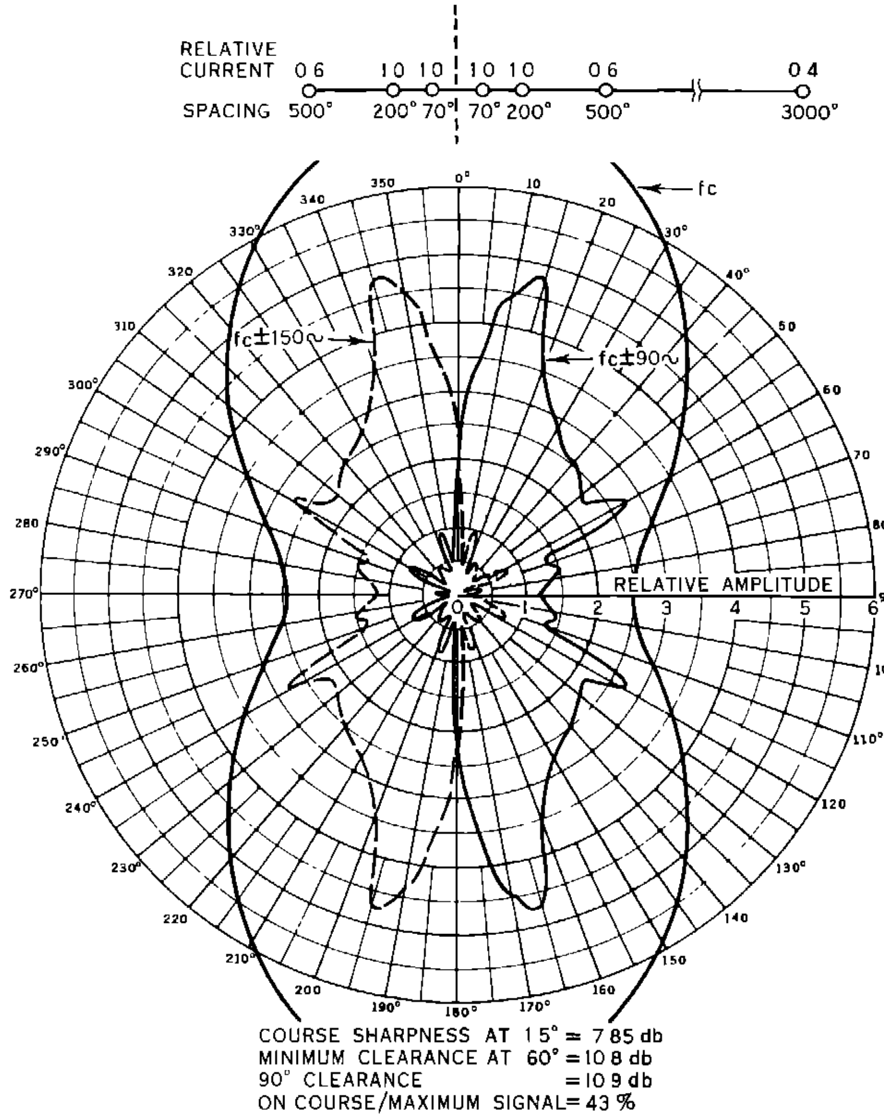
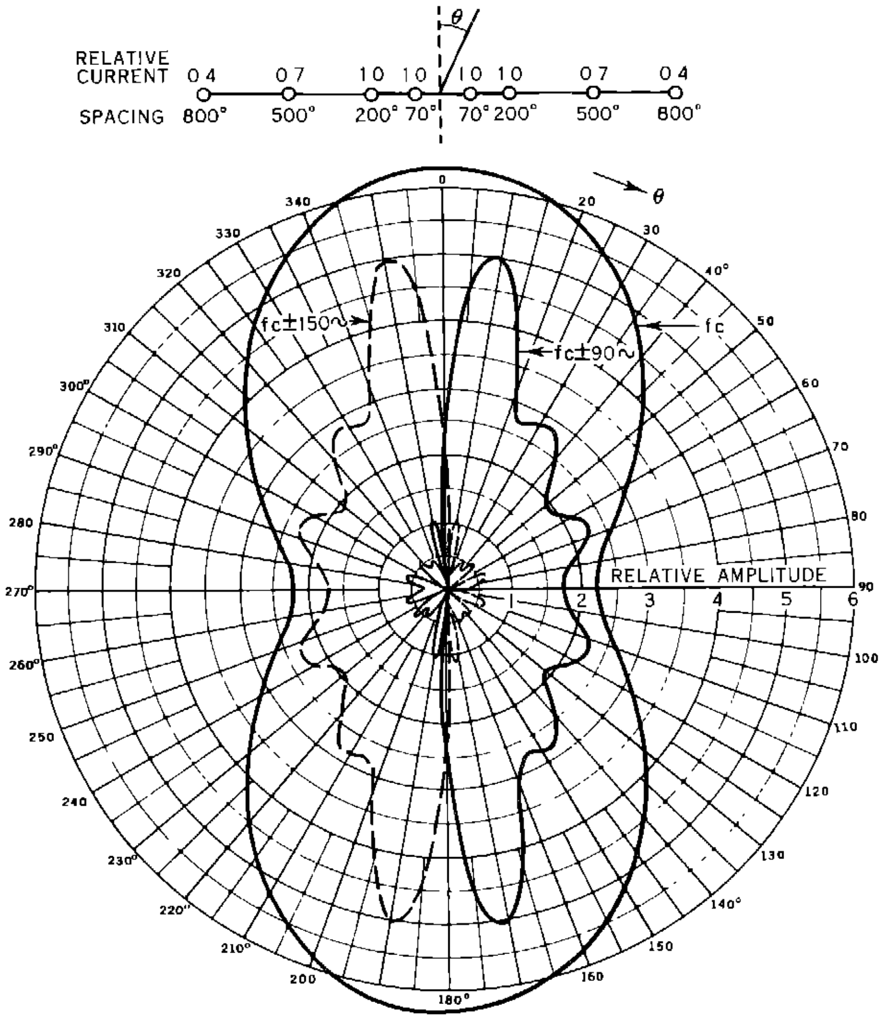
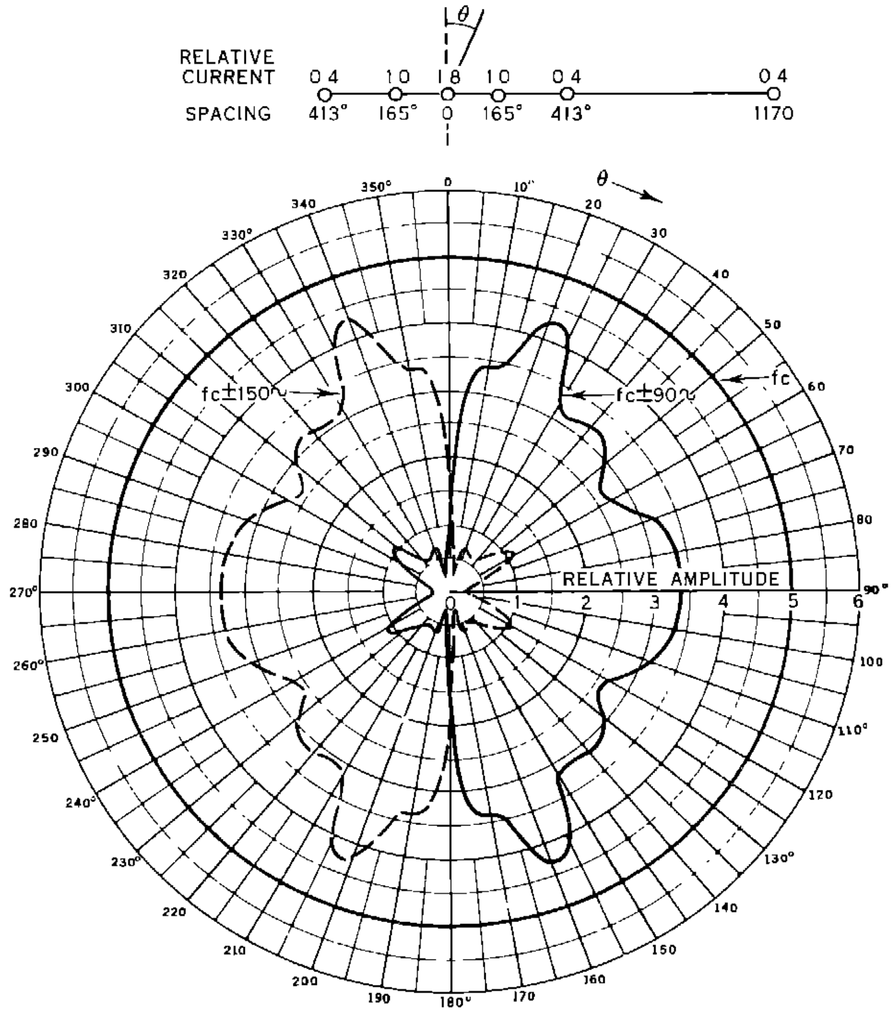



Figure 8 Horizontal Field Pattern for Unsymmetrical Antenna Array (Case 7)




COURSE SHARPNESS AT 1 5° = 7 2 db
MINIMUM CLEARANCE AT 25° = 10 9 db
90° CLEARANCE = 14 4 db
ON COURSE/MAXIMUM SIGNAL = 40 %

Figure 9 Horizontal Field Pattern for 8 Loop Antenna Array (Case 8)




COURSE SHARPNESS AT 1 5° = 4 8 db
MINIMUM CLEARANCE AT 55° = 7 8 db
90° CLEARANCE = 22 8 db
ON COURSE/MAXIMUM SIGNAL = 43 %

Figure 10 Horizontal Field Pattern for Portable Localizer Antenna Array (Case 9)

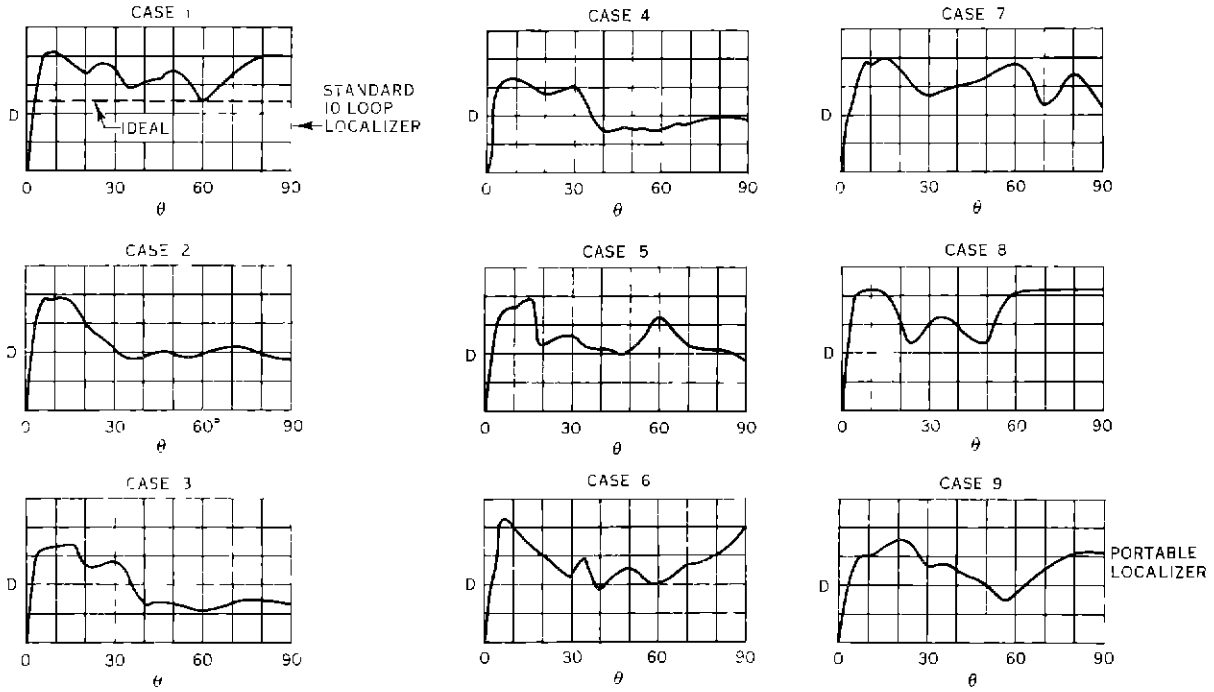
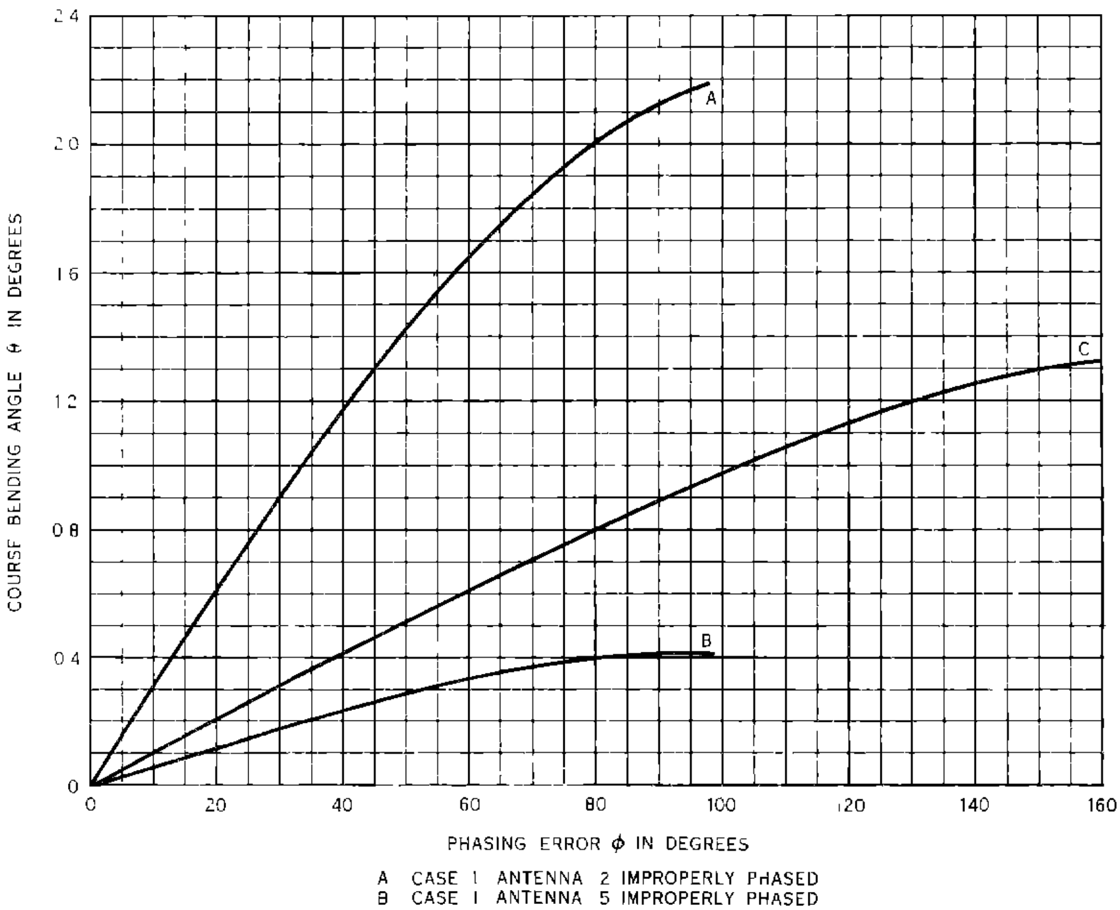



Figure 11 Cross-Pointer Instrument Deflection Vs Azimuth Angle




A CASE 1 ANTENNA 2 IMPROPERLY PHASED
B CASE 1 ANTENNA 5 IMPROPERLY PHASED
C CASE 7 ANTENNA 4 IMPROPERLY PHASED

Figure 12 Course Bending Angle Vs Phasing Error