EFFECT OF PARASITIC CURRENTS IN ANTENNAS OF UHF RADIO RANGES ON HORIZONTAL FIELD PATTERN

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CA INFORMATION AND STATISTICS

EFFECT OF PARASITIC CURRENTS IN ANTENNAS OF UHF RADIO RANGES ON HORIZONTAL FIELD PATTERN

INTRODUCTION

The term "parasitic currents" as used in this Note designates antenna currents excited by mutual coupling (through space) between two or more antennas. Specifically, the case of 3 loop antennas present in the UHF radio ranges is considered here. Of interest are the parasitic currents produced in the side antennas by current in the center antenna. The purpose of this Note is to furnish a qualitative picture of the effect of these parasitic currents on field strength, course sharpness, and clearance of the horizontal field pattern.

No attempt has been made to analyze the complex nature of the coupling between loop antennas, especially since it is simple to measure relative magnitude and phase of the parasitic currents.

As insufficient experimental data of the relationship between parasitic currents and their phase angle as a function of the tuning adjustments of the side antennas are available, a simple series circuit was assumed whose resistance is essentially the radiation resistance, and whose reactance is varied by antenna tuning.

THE FIELD PATTERN EQUATION

Consider 3 identical loop antennas, 1, 2, 3, in a horizontal plane, with centers in a straight line and spaced S degrees, as shown in figure 1.

Call the current in the center antenna k, and let the current in each side antenna, in the absence of parasitic currents, be unity. Superposed on unit currents in the side antennas assume a parasitic current p with phase angle δ with respect to current k. Figure 2 shows the vector diagram of these currents.

The relative instantaneous field intensity in the plane of the antennas, at distance r, in the direction θ (figure 1), is (for $r \gg \lambda$)

$$1)\quad E(t) = \cos \omega \left(t - \frac{r}{c}\right) \left[k + 2 \sin (S \sin \theta) \right] + \cos \left\{ \omega \left(t - \frac{r}{c}\right) + \delta \right\} 2p \cos (S \sin \theta)$$

The terms in the bracket give the contributions due to current k in the center antenna, and due to unit current in each side antenna whose phase angle is + and − 90 degrees, respectively, referred to the current in the center antenna.

The second member of equation 1 gives the contribution of the parasitic currents. It will be observed that the parasitic field is symmetrical to the course ($\theta = 0, \pi$). Therefore, the bean patterns with parasitic currents in the side antennas remain symmetrical to the course, but their shape is changed.

Phase δ and magnitude p of the parasitic currents can be varied, although not independently, by tuning adjustments of the side antennas. At resonance the parasitic current is p_0 and is in phase with the induced emf, let its phase angle, with respect to the current k in the center antenna, at resonance, be δ_0. Measurements have shown that for the usual antenna spacings, δ_0 is a positive angle in the first or second quadrant. At resonance the parasitic current is assumed to be limited by the radiation resistance plus r-f resistance of the antenna. The phase angle of the parasitic current can be reduced from δ_0 to δ by adjusting the antenna tuning such that it offers an inductive reactance to the parasitic emf. Call the angle between parasitic emf and parasitic current γ. In the absence of experimental information assume the relation

2) $p = p_o \cos \gamma$

where p is the parasitic current with the side antennas out of resonance Assume further that after detuning the side antennas the current in the center antenna be readjusted to its original value, i e , that the parasitic emf be constant

3) $\gamma = \delta_o - \delta$

Equations 1), 2), and 3) are illustrated in figure 3

Introducing equations 2 and 3 into equation 1 the relative amplitude of the field strength in a given direction θ, with parasitic currents p of phase angle δ (referred to the current in the center antenna), is found to be

$$4)\quad E = \left\{ \left[k + 2 \sin (S \sin \theta) \right]^2 + \left[2 p_o \cos (\delta_o - \delta) \cos (S \sin \theta) \right]^2 + 4 p_o \cos (\delta_o - \delta) \cos \delta \cos (S \sin \theta) \left[k + 2 \sin (S \sin \theta) \right] \right\}^{1/2}$$

With reference to figure 3 the locus of the end point of the parasitic current vector appearing in field strength equations 1 and 4 is a circle with center C With the side antennas resonated the contribution of the parasitic current is AE As inductive reactance is introduced in the side antennas by detuning, the parasitic current decreases, and the endpoint of the corresponding vector moves from E to D, B A. Keeping the current in the center antenna and the non-parasitic current in the side antennas constant (OA) it is apparent that for a particular phase angle δ' the field strength OD is maximum This condition is obtained if OCD is in a straight line, and is given by

$$5)\quad E_{max} = \left\{ \left[k + 2 \sin (S \sin \theta) \right]^2 + \left[p_o \cos (S \sin \theta) \right]^2 + 2 p_o \cos \delta_o \cos (S \sin \theta) \left[k + 2 \sin (S \sin \theta) \right] \right\}^{1/2} + p_o \cos (S \sin \theta)$$

Figure 4 shows the vector diagram of the currents appearing in the field strength equation for directions $\theta = 0°, \pm 30°, \pm 48\ 6°, \pm 90°$. In figures 5 and 6 the diagrams for field strength on-course and at right angles to the course are shown, assuming the same constants as for figure 4 The field strength on-course can either be increased or decreased by changing the parasitic currents from their resonance value AE in figure 5 Maximum and minimum values of field strength on course are OD and OD', respectively

At right angles to the course (figure 6) the minor lobe field strength is O'B, and the field strength at +90° is OB The clearance, therefore, is C(90°) = OB/O'B, with phase angle δ of the parasitic current It will be observed that the minor lobe field strength, with the constants chosen, is never zero Its minimum value is O'P with a phase angle δ of -14 2°, its maximum is O'Q

The maximum field strength on course ($\theta = 0$) is

$$6)\quad F_{max} = \left\{ k^2 + p_o^2 + 2 p_o k \cos \delta_o \right\}^{1/2} + p_o$$

In the absence of parasitic currents ($p_o = 0$) the field strength on course equals k However, in order to obtain a better comparison of the relative field strengths with parasitic currents, the curves in figure 7 are for constant radiated power in the horizontal plane This requires integration of the field patterns in all directions ($\theta = \pi$ to $\theta = -\pi$) and will be described in more detail in another note

The phase angle δ of the parasitic current giving maximum field strength in direction θ is found by maximizing equation 4 It is

$$7)\ \delta' = \frac{1}{2}\tan^{-1}\left[\frac{p_o \cos(S \sin\theta)\sin 2\delta_o + [k + 2\sin(S\sin\theta)]\sin\delta_o}{p_o\cos(S\sin\theta)\cos 2\delta_o + [k + 2\sin(S\sin\theta)]\cos\delta_o}\right]$$

On course $(\theta = 0)$ this simplifies to

$$8)\quad \delta' = \frac{1}{2}\tan^{-1}\left[\frac{p_o \sin 2\delta_o + k\sin\delta_o}{p_o\cos 2\delta_o + k\cos\delta_o}\right]$$

COURSE SHARPNESS WITH PARASITIC CURRENTS

Starting from equation 4 with parasitic currents p of phase angle δ , and calling $S \sin\theta = \frac{nS}{2}$ the course sharpness N_p is

$$9)\quad N_p = \left\{\frac{(k+nS)^2 + 4p^2 + 4p\cos\delta\,(k+nS)}{(k-nS)^2 + 4p^2 + 4p\cos\delta\,(k-nS)}\right\}^{1/2}$$

This compares with the course sharpness N in the absence of parasitic currents given by

$$10)\quad N = \frac{k+nS}{k-nS}$$

where $n = 0\ 915 \times 10^{-3}$

with spacing S in degrees

Parasitic currents in general reduce the clearance between two associated bean patterns, and the direction of maximum field strength and of the minor lobes is shifted

FIELD STRENGTH AND CLEARANCE AT RIGHT ANGLES TO COURSE WITH PARASITIC CURRENTS

Entering equation 4 with $\theta = \pi/2$ gives

$$11)\quad F_p(\pi/2) = \left\{(k + 2\sin S)^2 + (2p\cos S)^2 + 4p\cos\delta\cos S\,(k + 2\sin S)\right\}^{1/2}$$

In the case without parasitic currents we have

$$12)\quad F(\pi/2) = k + 2\sin S$$

For equal radiated power in the horizontal plane equation 12 has to be multiplied by a scale factor which is the ratio of the rms value of the horizontal field patterns integrated over 360°

With parasitic currents the clearance at 90° off course is

$$13)\quad C_p(\pi/2) = \left\{\frac{(k + 2\sin S)^2 + (2_p\cos S)^2 + 4_p\cos\delta\cos S\,(k + 2\sin S)}{(k - 2\sin S)^2 + (2_p\cos S)^2 + 4_p\cos\delta\cos S\,(k - 2\sin S)}\right\}^{1/2}$$

compared to

$$14)\quad C\ (\pi/2) = \frac{k + 2 \sin S}{k - 2 \sin S}$$

without parasitic currents

EXAMPLES

In figures 8, 9, and 10, horizontal field patterns are shown, with parasitic currents in the side antennas for antenna spacings $S = 120°$ and for the current ratio $k = 2$ With the side antennas in resonance the parasitic current $p_o = 1$ with phase angle $\delta_o = 60°$ is assumed The solid-line bean patterns in figure 8 apply for these constants The dashed pattern in the same figure is for the case of no parasitic currents. It will be noticed that parasitic currents increase the field strength on course, and that the clearance in general is decreased, especially at right angles to the course

In order to compare the two field patterns shown in figure 8 with the radiated power in the two cases equal, the dashed pattern has to be enlarged by a scale factor of 1 13

Figures 9 and 10 show the horizontal field patterns with the side antennas out of tune (inductively), whereby magnitude and phase of the parasitic current is reduced

In figure 7 the results of the previous drawings are summarized The phase angle δ is varied from $+60°$ at resonance to $-30°$ farthest off resonance (no parasitic current), and the corresponding parasitic current, course sharpness, 90° clearance and relative field strengths are shown

CONCLUSIONS

Caution must be exercised in making use of the parasitic currents in the side antennas of UHF radio ranges to modify the horizontal field pattern

The parasitic currents change the field strength on-course, magnitude and direction of maximum field strength and of minor lobes The directions of zero or minimum field strength are not changed, and the symmetry of two associated bean patterns with respect to the course is not affected by parasitic currents (i e , the course is not shifted)

The field strength on-course can be either increased or decreased over that obtained in the absence of parasitic currents by detuning the side antennas

If the side antennas are at resonance or detuned to offer an inductive reactance, signal strength on-course is increased and course sharpness decreased by the parasitic currents For certain capacitive tuning adjustments of the side antennas the field strength on-course in decreased and the course sharpness increased

The clearance can be either increased or decreased by parasitic currents, depending on side antenna tuning and on p_o, δ_o , k, θ For specific cases the vector diagrams can be drawn and studied regarding the effect of parasitic currents on clearance and course sharpness

It is believed that, in general, the advantage of increased signal strength on-course due to parasitic currents is lost by the decrease in course sharpness In special cases where course sharpness need not be high, the field strength on-course can be increased in the order of 50 per cent by using the parasitic currents in the side antennas

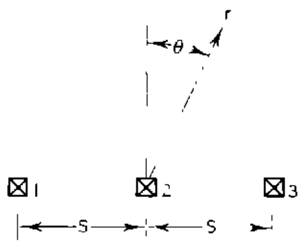

Figure 1 Antenna Layout

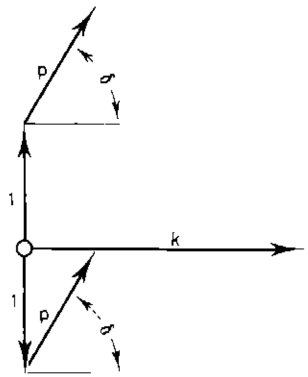

Figure 2 Vector Diagram of Antenna Currents

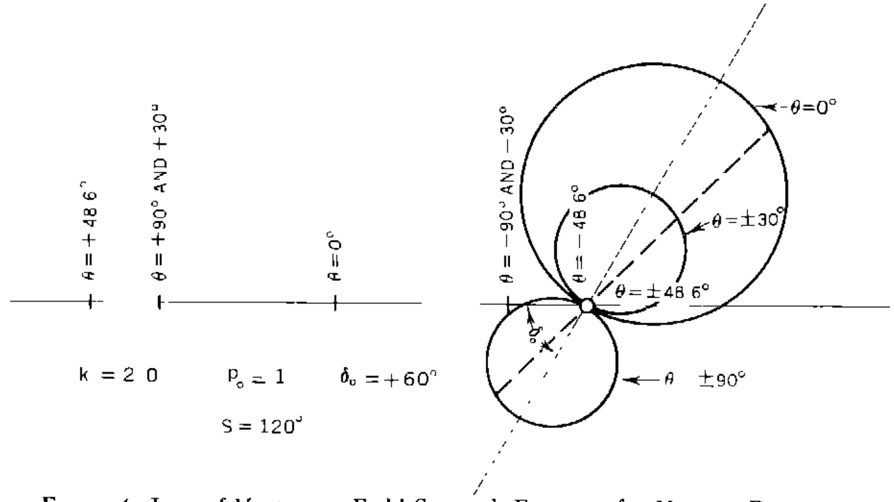

Figure 4 Loci of Vectors in Field Strength Equation for Various Directions θ

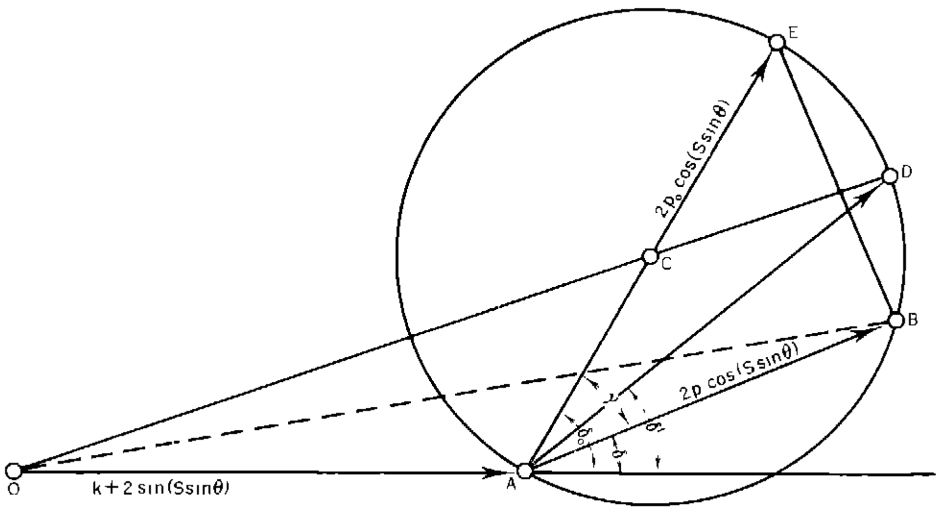

Figure 3 Vector Diagram of Currents Entering Field Strength Equation

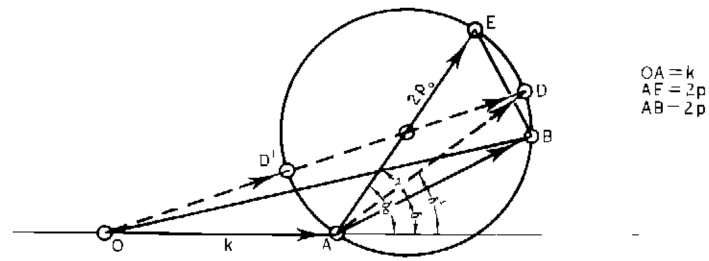

Figure 5 Vector Diagram for Field Strength On Course

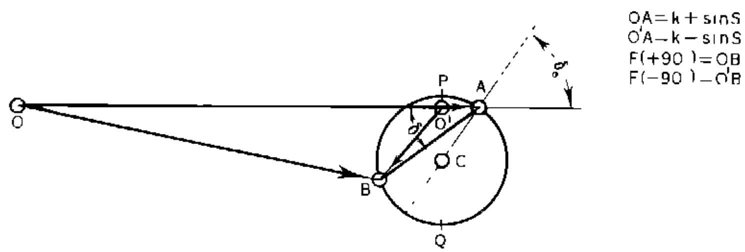

Figure 6 Vector Diagram for Field Strength at ± 90° Off Course

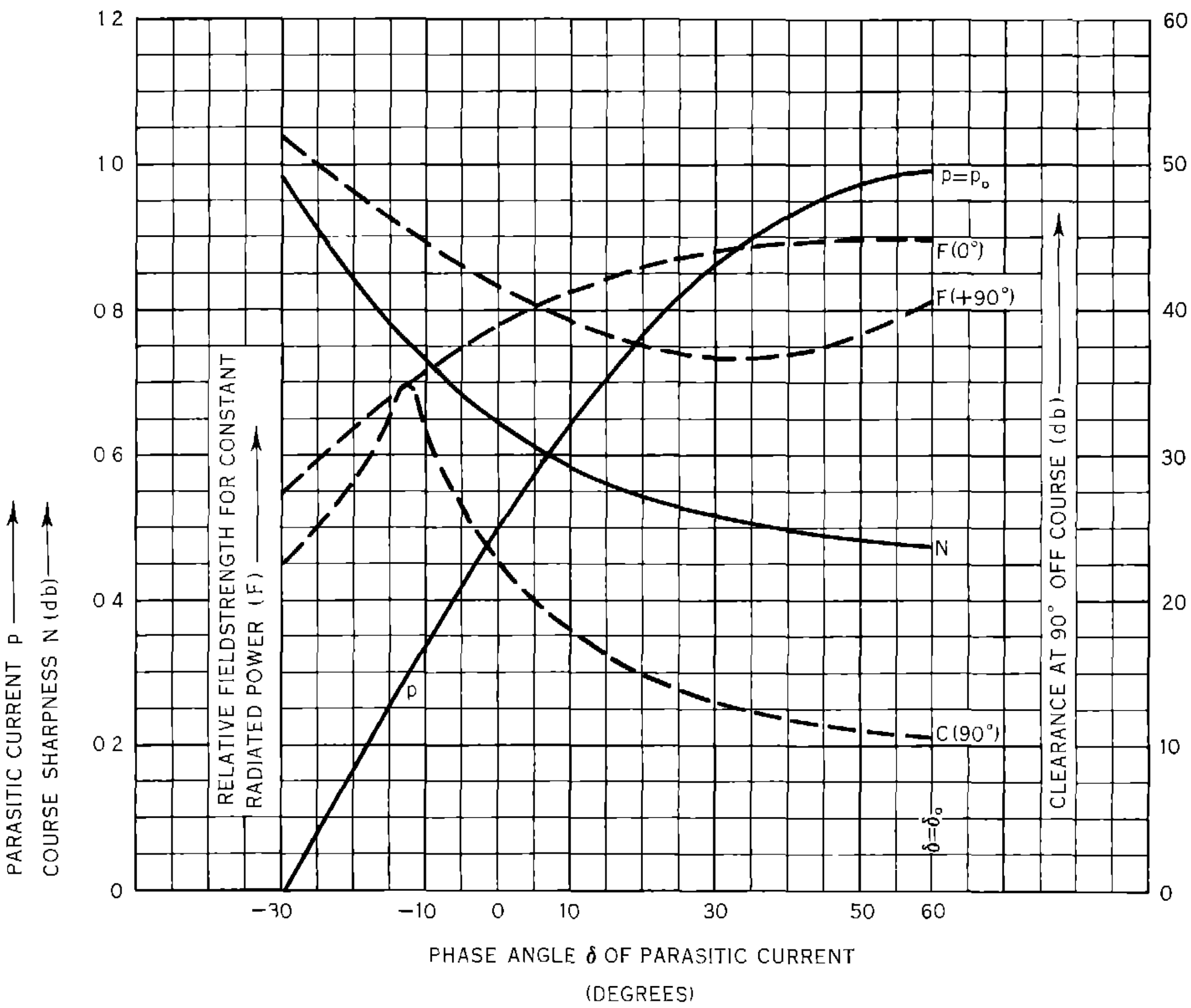

Figure 7 Effect of Parasitic Currents in Side Antennas of Magnitude p and Phase Angle δ On Course Sharpness N, Right Angle Clearance C (90°), Relative Field Strength On Course E (0°), and Relative Field Strength 90° Off Course E (+90°) for Constant Radiated Power

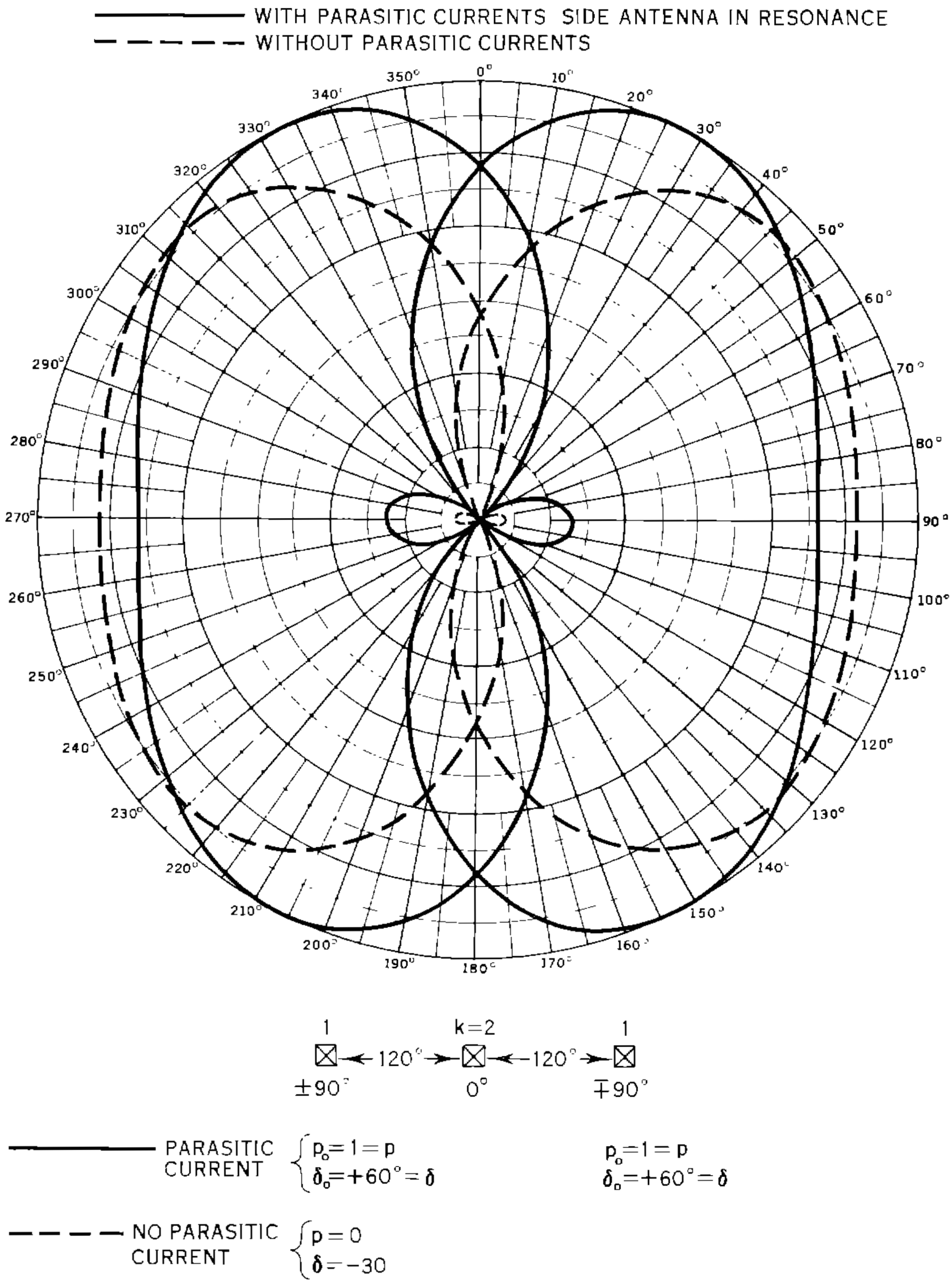

Figure 8 Effect of Parasitic Currents in Side Antennas on Horizontal Field Pattern

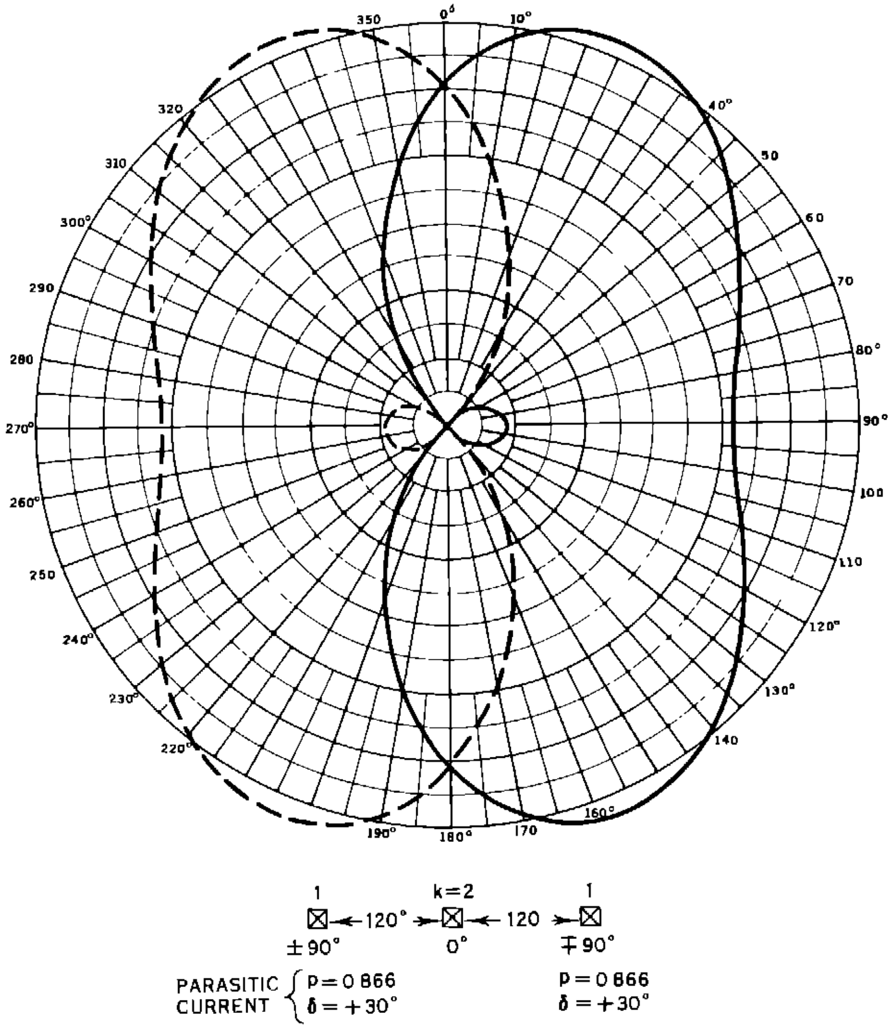

Figure 9 Effect of Parasitic Currents in Side Antennas on Horizontal Field Pattern

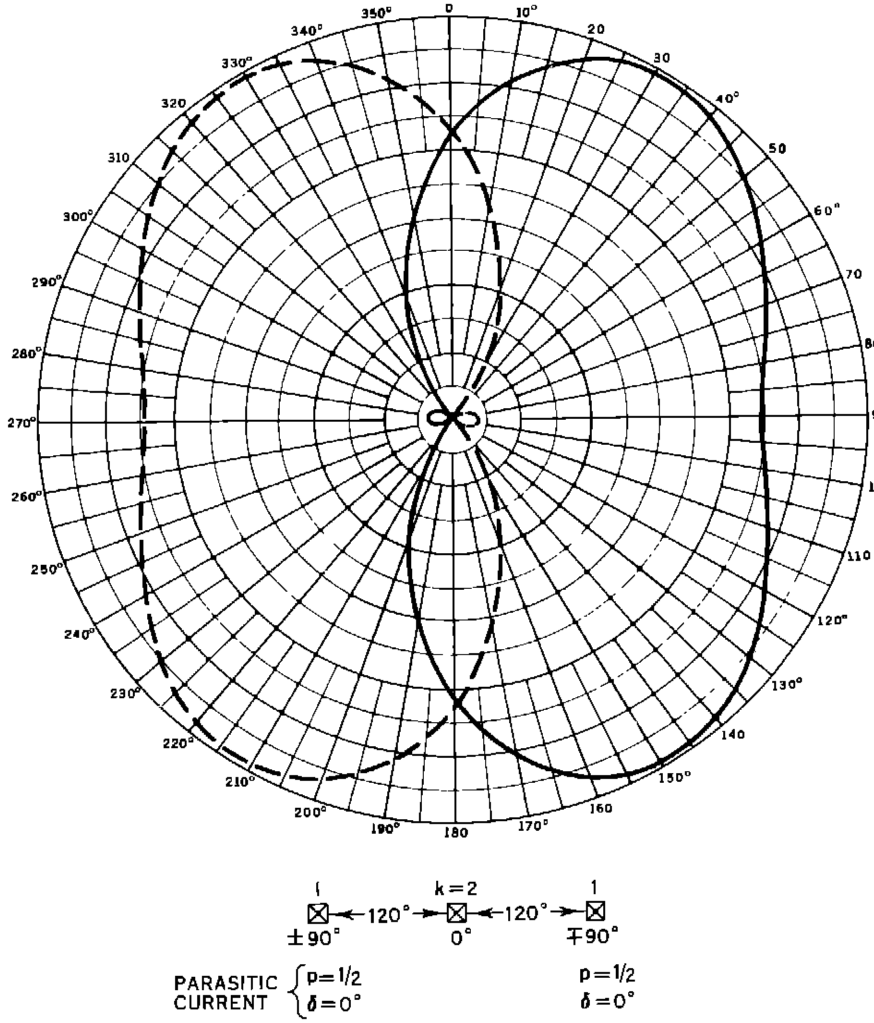

Figure 10 Effect of Parasitic Currents in Side Antennas on Horizontal Field Pattern