END COUPLED PARASITIC MICROSTRIP ANTENNA

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ABSTRACT

A Parasitic Microstrip Antenna Array is discussed. The array consists of different lengths of microstrip radiating elements spaced apart in an end-to-end arrangement. Only one element is actively fed at its feedpoint, and energy emanating from the fed element is primarily coupled to parasitic elements by the electric field generated in the fed element. The radiating pattern is determined by the phase relationship and amplitude distribution between the excited fed element and the parasitic elements.

This antenna configuration exhibits higher end fire gain along the missile axis than obtained with arrays having elements individually fed.

INTRODUCTION

This microstrip parasitic fed antenna array has two or more radiating elements spaced apart in an end-to-end arrangement with only one element having a feedpoint. The two or more different microstrip radiating elements are positioned above a ground plane and separated by a dielectric substrate. The driven element is fed at its feedpoint via a coaxial cable. Energy emanating from the coaxially fed element is primarily electrically coupled end-to-end to the parasitic elements by the electric field generated in the fed element. Previously, it has been necessary to feed each of several microstrip elements with a separate coaxial connector to provide a high gain end fire antenna array. Delay lines were also required in the separate coaxial lines feeding each of the separately fed elements in order to obtain the proper phase relationship. This required more space and expense, and complicated the conformal arraying capability of such an antenna especially when it was to be flush mounted on an airfoil surface. It also was necessary to use many more excited elements to provide as high a gain as obtained with fewer elements of this antenna configuration.

The radiating pattern is determined by the phase relationship and amplitude distribution between the active element and the parasitic elements. These functions are governed by the separation between the coaxial fed and parasitic elements, and the length of the parasitic elements. The antenna impedance (i.e., the mutual coupling impedance and the input impedance of the excited element) is also governed by the end-to-end separation between the elements and the length of the parasitic elements. The phase relationship of the parasitic elements to the coaxial fed element is determined experimentally. Tests show that fairly high gains are obtained in the end fire mode even when the antenna is flush mounted on a missile body. When a thick dielectric substrate is used with parasitic arrays, an additional advantage in end fire configuration is obtained. This advantage is due to the monopole mode excited in the coaxially fed element. A monopole mode will exist in all coaxially fed elements and the greater the spacing between the radiating element and ground plane the greater will be the effect of the monopole mode. Coverage along the end fire direction is available from the present parasitic antennas with gains of 8 dbi or more being provided using several parasitic elements with large spacing between elements and ground plane. Whereas, in other microstrip antennas where each microstrip element is fed from a separate coaxial connector, less gain has been available along the end fire direction while using more elements than the present end-to-end coupled parasitic antenna.

DESCRIPTION

Fig. 1 shows a typical electrically end coupled parasitic microstrip antenna, having two radiating elements, and formed on a dielectric substrate which separates the radiating elements from the ground plane. One of the elements is actively excited and the second is parasitically excited. The active element is fed from a coaxial-to-microstrip adapter with the center pin of the adapter extending to the feedpoint of the element. Tabs at both ends of the active element are reactive loads which operate to effectively foreshorten the length of the radiating element. The parasitic element is excited with energy emanating from the active element by end-to-end electric field coupling of the electric fields generated in the active element. The length of the parasitic element is usually somewhat less than the length of the active element, and in antennas where more than one end-to-end coupled parasitic element is used the length of each successive parasitic element becomes progressively shorter. Asymmetric (1) feeding of the driven element is used in the embodiment shown in Fig. 1 in preference to other types of feeding (2, 3, 4, 5) since additional end fire gain is provided by using an asymmetrically fed microstrip element due to the surface wave launched as a result of the monopole effect of the coaxial connector pin in the cavity between the radiating element and the ground plane. This effect can be seen from the dashed line curve for a single element coaxially fed antenna in Fig. 2 which shown a tilting of the radiation pattern toward the forward direction.

It is known that for proper matching, the feedpoint for an asymmetrically fed element is normally located at the 50 ohm point. In order to accomplish this and also maintain the proper phase relationship in the parasitic antenna, the fed element may need to be longer which would result in physically overlapping the adjacent parasitic element. By including tuning tabs (i.e., reactive loads) on the coaxially fed element, the fed element can be effectively elongated while not being physically elongated, thereby maintaining a proper phase relationship and proper match. In other words, tuning tabs can be used to foreshorten the fed element to provide proper spacing between the parasitic and the fed element and maintain a proper match. However, in antennas where there is sufficient spacing between the ground plane and the radiating element (e.g., a thicker substrate inherently allows use of a shorter element at the same frequency) foreshortening of the coaxial fed element by the use of tabs would not be necessary. The use of reactive load tuning tabs can also be used on parasitic elements, if necessary, whenever foreshortening of the parasitic elements is required (6).

Although other types of microstrip fed elements, which do not require a coaxial feed, can be used in a parasitic array to provide gain in the end fire direction, the additional benefit of the monopole effect, due to the connector pin, is not provided. Other types of microstrip elements which are coaxially fed, can benefit from the monopole effect provided by the connector pin when used in parasitic microstrip antennas.

The phase relationship and the amplitude relationship of the parasitic elements to the fed element is determined experimentally. This is accomplished by internal probing of the microstrip cavity, between each of the radiating elements and the ground plane, to determine the phase and the amplitude of the fed and the parasitic elements with relation to each other (i.e., provide relative amplitude and phase). In internal probing, a network analyzer, for example, along with a field probe, is used to determine the current distribution along the length of an element and the relative phase of the current at each measured point. At each measured point the current amplitude and its phase can be related to any other measured point on the same element or other element in the antenna array.

DESIGN EXAMPLE

As mentioned earlier there are no design equations for the microstrip parasitic antenna array. The design procedure entails using a combination of old proven array theory along with experimental results, i.e., doing an active array design and using the results to guide the parasitic array design.

In designing a parasitic microstrip end fire antenna array, a single element microstrip antenna is initially designed using previous design techniques (1), and a single element radiation pattern is obtained. The dotted line curve in Fig. 2, for example is a single element radiation pattern for such a single element antenna. Next, an active end fire array of two or more elements is analyzed, assuming an isotropic radiation pattern modified by the single element pattern of Fig. 1 and using conventional array design techniques. In the analysis for the active end fire array it is assumed that all elements are excited in the same manner (e.g., coaxially fed). Conventional analysis techniques are used for determining the current and phase required for each of the elements to provide end fire array design. This will give a first estimation of the required spacing between the elements of the parasitic antenna array.

Ideally, the energy in the end fire array should add maximally between the coupled elements in an end fire direction. For example, in an active two element array, where the radiating elements are spaced by one-half wavelength (1/2 λ), the phase difference or delay between the two elements should be approximately 180°. To design a typical parasitic antenna as in Fig. 1, a similar type of phasing is required. To accomplish this in a parasitic array, the inherent 90° phase difference between end-to-end coupled elements is used. Also the phase relationship between the fed element and the parasitic element can be changed by changing the length of the parasitic element to provide additional phase difference or delay. Changing the length of the parasitic element changes the phase of the energy from the fed element that is induced into the parasitic element. By making the parasitic element shorter, it is made more capacitive, effectively incurring a greater degree of phase delay in the parasitic element. While 180° phase delay and 1/2 λ spacing may be ideal, other phase delays and spacing can suffice assuming the signals maximally add in the end fire direction. Assuming that a 50° phase delay is provided by changing (i.e., shortening) the length of the parasitic element, a combination of the inherent 90° phase difference in end coupled elements along with the 50° phase delay due to the change in length of the parasitic element will provide a phase delay of 140°.

In the next step of this example, a sample antenna is produced using a spacing between the fed and parasitic elements of approximately 140° (i.e., 0.389λ). Then the radiating elements are probed again at the middle of each element and the overall phase relationship is determined. However, moving the radiating elements closer together causes changes in the phase relationship and impedance due to mutual coupling providing a mutual impedance in the parasitic element. It was found by experiment, that the mutual impedance adds more capacitance to the parasitic element thereby incurring more phase delay in the parasitic element. Thus it is required that the parasitic element be moved further away from the coaxially fed element. The new spacing of the radiating elements and new probe measurements of the elements for phase and amplitude are used in new analysis calculations to provide values for further iteration in producing the parasitic antenna array. Several changes in spacing and probing of the radiating elements are usually required to provide an optimum parasitic antenna design. The experimental process is essentially the same when more than one parasitic element is used. Performance data for a two element parasitic array design at 3.3 Ghz are shown in Fig. 3, Fig. 4, and Fig. 5. Fig. 3 shows a pitch plane plot of the radiation pattern taken on a missile section. The plot shows good folding of the radiation pattern towards the end fire direction.

Fig. 6 shows a typical three element parasitic array design, and performance data for the three element design at 10.4Ghz are shown in Fig. 7, Fig. 8, and Fig. 9. Fig. 8 shows a pitch plane plot of the radiation pattern taken on a missile section. The gain along the missile axis shows a gain of approximately 8 dbi which is higher than obtained with individually fed elements. This phenomena is found to be peculiar to microstrip parasitic end fire arrays.

CONCLUSION

Although the design procedure for a parasitic array appears to be complicated, the reduced fabrication cost, and the higher gain along the missile axis more than compensates for the initial design complexity. The higher gain obtained in the parasitic array along the missile axis as compared to an active array is an unexplained phenomena.

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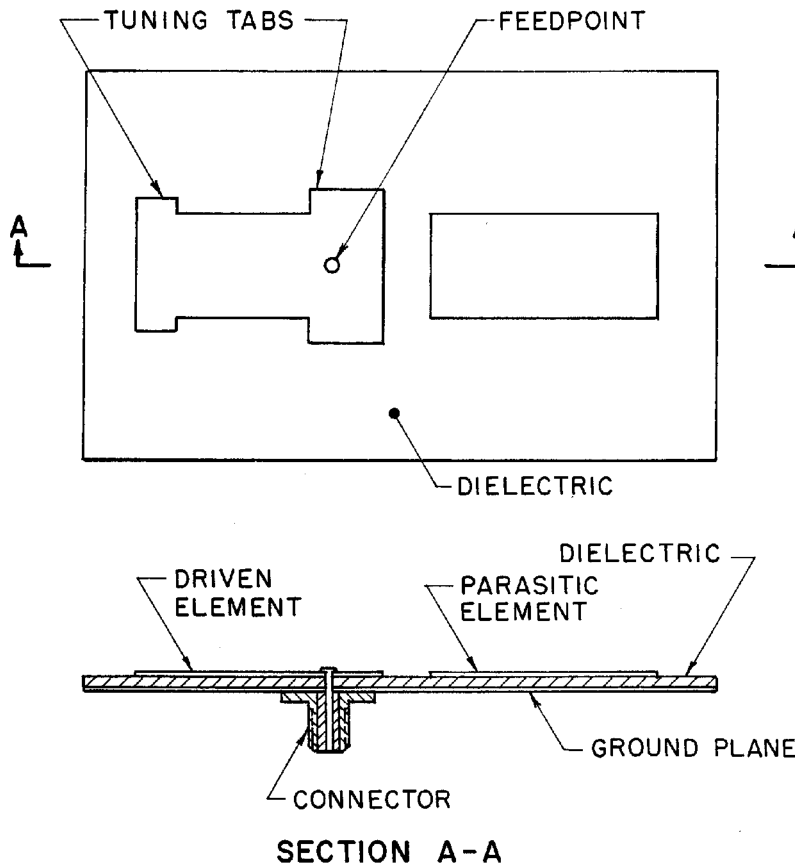

FIG. 1 TWO ELEMENT PARASITIC ARRAY

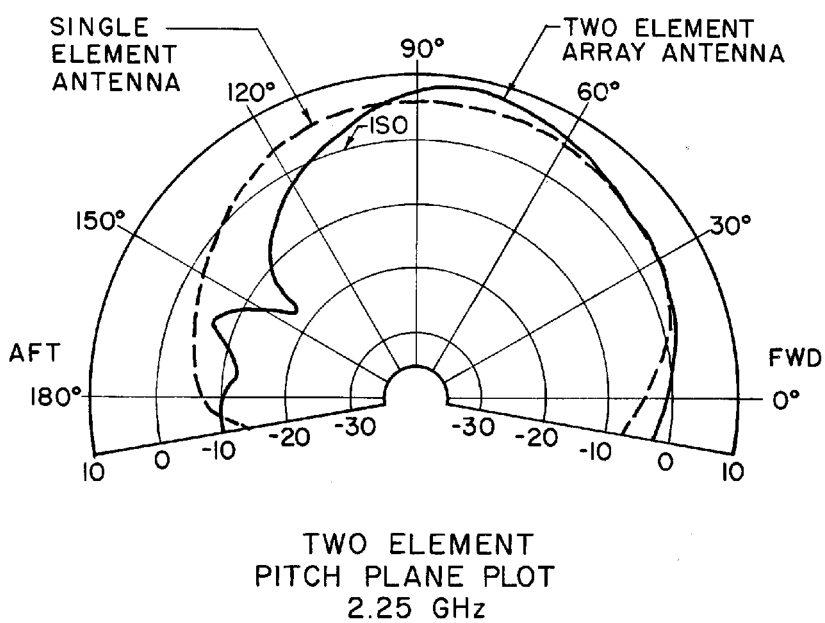

FIG. 2 RADIATION PATTERN COMPARISON BETWEEN A SINGLE ELEMENT AND A TWO ELEMENT ARRAY

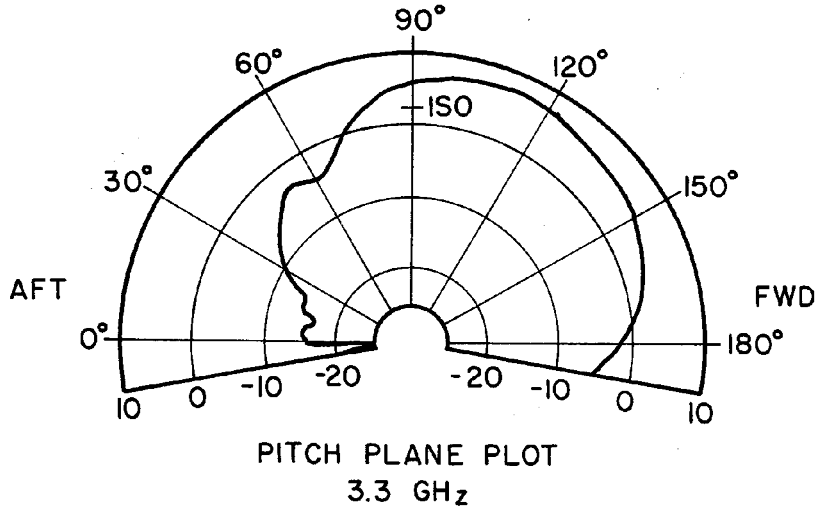

FIG. 3 TWO ELEMENT PARASITIC ARRAY RADIATION PATTERN

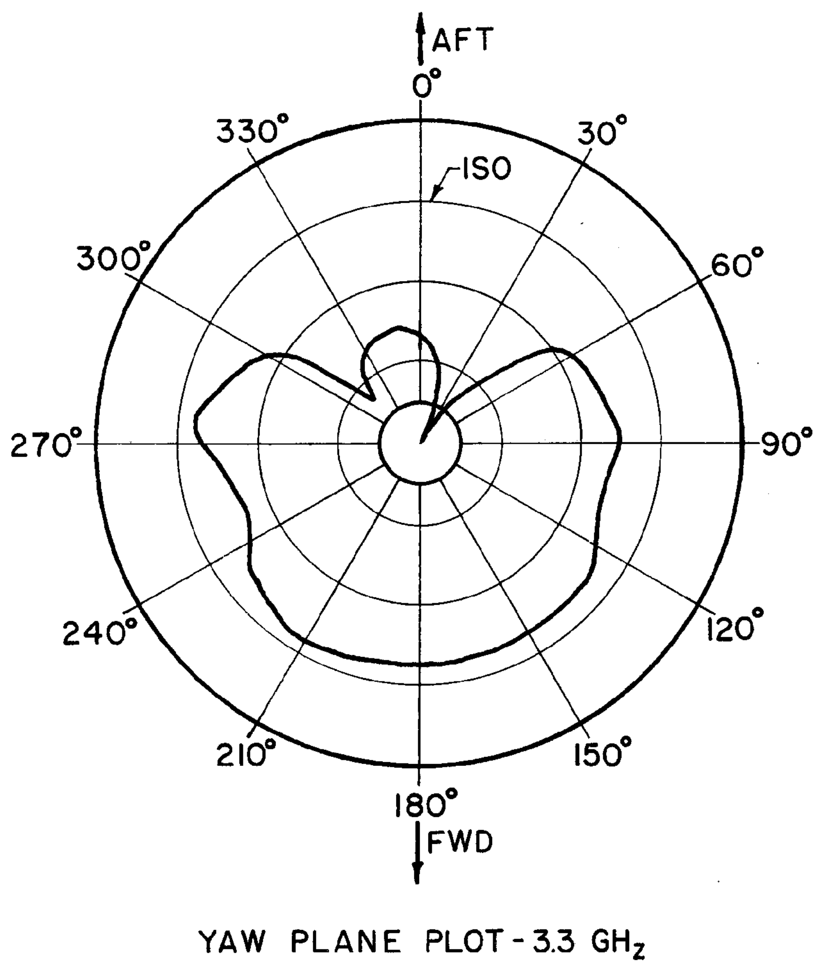

FIG. 4 TWO ELEMENT PARASITIC ARRAY RADIATION PATTERN

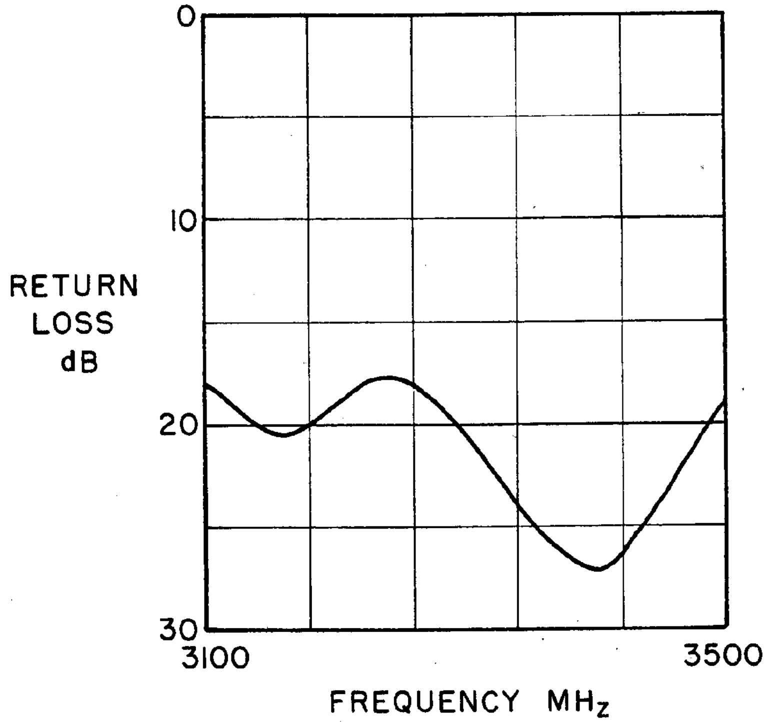

FIG. 5 TWO ELEMENT PARASITIC ARRAY RETURN LOSS VS FREQUENCY

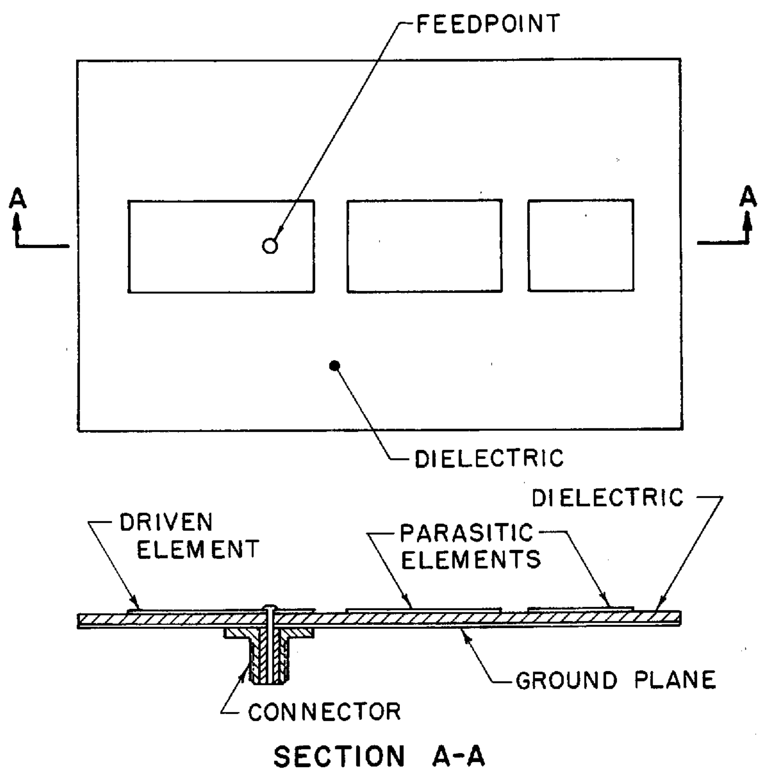

FIG. 6 THREE ELEMENT PARASITIC ARRAY

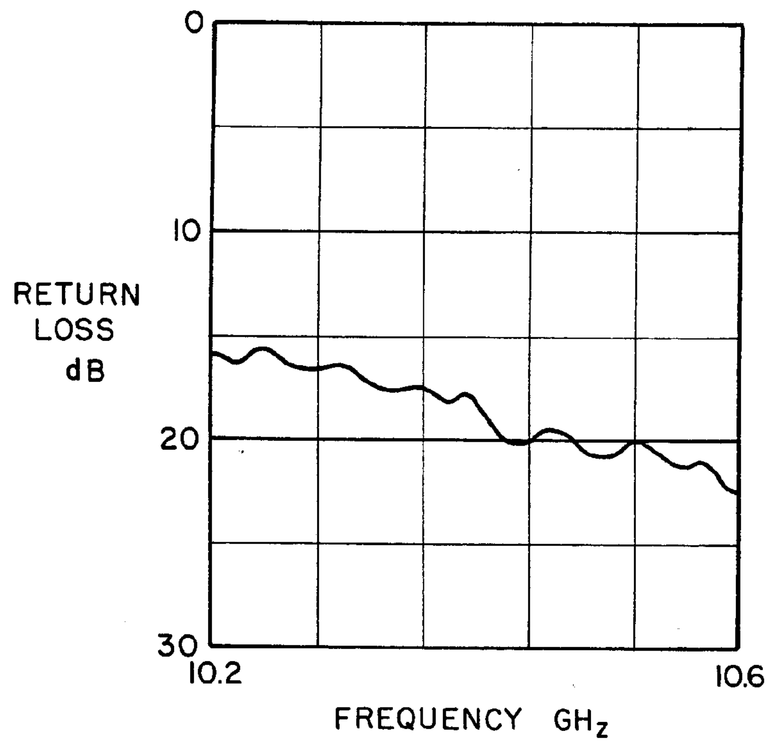

FIG. 7 THREE ELEMENT PARASITIC ARRAY RETURN LOSS VS FREQUENCY

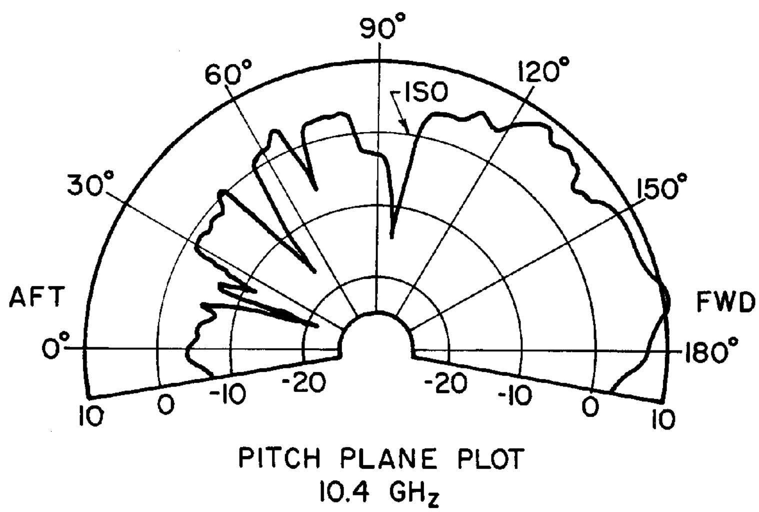

FIG. 8 THREE ELEMENT PARASITIC ARRAY RADIATION PATTERN

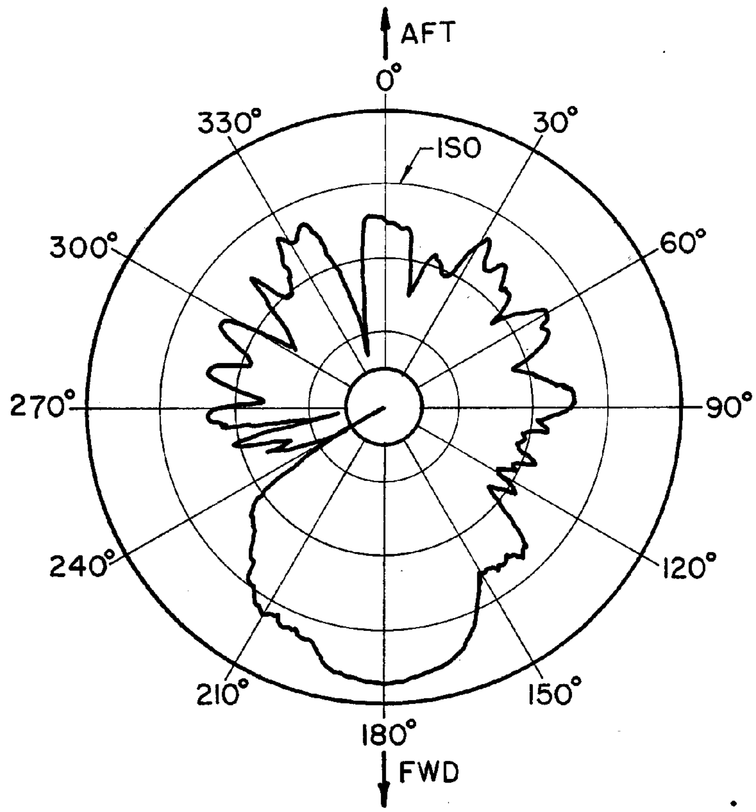

FIG. 9 THREE ELEMENT PARASITIC ARRAY RADIATION PATTERN