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SIMPLE, LOW-PROFILE, CIRCULARLY POLARIZED ARRAYS

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ABSTRACT

A low-profile, circularly polarized antenna can be made using an annular sector of strip conductor parallel to a closely spaced ground plane. This antenna has a very wide impedance bandwidth and is particularly well suited for use in series-fed arrays. Control of the excitation coefficients can be accomplished by a simple variation in the geometry of each element. Interconnection of the elements has been realized both in coaxial cable and in microstrip. Axial ratios less than 1 dB in the broadside direction are easily obtainable.

INTRODUCTION

Circular polarization (CP) is required to receive signals from satellite-borne transmitters. Antennas for a mobile platform are preferably low-profile. The attainment of desired pattern shape to provide adequate gain and coverage is made possible through array techniques. Acceptance of the system is dependent upon the total cost. All of these features are well met by a new type of antenna element [Drewniak and Mayes, 1987]. In addition, this element has a wide impedance bandwidth. Since the element is constructed from strip conductor in the shape of a sector of an annulus, it is basically a curved section of strip transmission line. We shall call it the ANSERLIN (ANnular SEctor Radiating LINe) antenna.

SINGLE ANSERLIN ELEMENTS

The configuration of the conducting strip is shown in Figure 1. A triangular section on each end of the annular sector is used for connection to the center conductor of a coaxial cable. The width-to-height ratio is maintained near constant in order to provide the same impedance through the antenna from one port to the other. Since the impedance does not change appreciably at any point along the structure, a wave that is initiated at either port will traverse to the other without producing any reflections. This traveling-wave operation of ANSERLIN antennas contrasts sharply with the resonant manner in which most microstrip patch antennas work. As a result,

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the impedance bandwidth of ANSERLIN elements is very much greater than that of patches. In fact, the variation of impedance is of no consideration in determining the operating bandwidth. Measured SWR less than 1.5 has been observed over bandwidths as great as 8:1. The Smith Chart of Figure 2 shows that the SWR can be held to even smaller values over a narrower band. However, the operating bandwidth is more likely to be based upon variation in power gain on boresight relative to a CP standard.

A single ANSERLIN element produces a beam of CP radiation which scans slowly with change in frequency. At the frequency where the traveling wave suffers a one degree change in phase for each degree of rotation in azimuth, the beam maximum occurs along the line perpendicular to the plane of the strip conductor. Near this frequency the radiation is very nearly CP over most of the beam; axial ratio less than 1 dB being routinely obtained near the beam maximum. A typical radiation pattern at a frequency where the above condition is very nearly realized is plotted in Figure 3. This pattern was measured in a rapidly rotating linearly polarized field to illustrate how little the polarization changes with angle. Either sense of CP can be produced depending upon the port which is excited.

Of course, achieving a single wave, traveling in the desired direction, is dependent upon maintaining the impedance match at the output port. Hence, that part of the input power that is not radiated before the wave reaches the output port must be absorbed by the matched termination. Although it is possible to increase the percentage of the input power that is radiated (by increasing the width of the strip conductor and, consequently, the height above the ground plane), even the maximum value (between 60 and 70 percent, so far) may not produce acceptable values of power gain. However, it is a relatively simple matter to combine ANSERLIN elements in a series-fed array. Then the power left at the output of the first element in the array can be delivered to the input of the next element, and so forth. In this way it is possible to radiate more than 90 percent of the incident power in an array with only a few elements.

LINEAR ARRAYS OF ANSERLIN ELEMENTS

The layout of a broadside array of six ANSERLIN elements is illustrated in Figure 4. A symmetric excitation is achieved by splitting the input power and feeding the two sides of the array at the two central elements. Further control of the excitation is provided by changing the widths of the annular sectors, using narrow strips near the input of the array and increasing the width of each succeeding element to increase the fraction of the power input to that element that is radiated. The impedance measured at the input of the power divider is plotted on the Smith Chart of Figure 5. The radiation pattern in the plane of the array measured with a spinning source antenna at 2.2 GHz is shown in Figure 6. The half-power beamwidth and sidelobe level are close to the expected values.

Fabrication of arrays of ANSERLIN elements could be facilitated, with resulting reduction in cost, by replacing the coaxial interconnections by a printed transmission medium. The upper diagram in Figure 7 shows an ANSERLIN element that is connected at both input and output ports to microstrip conductors. To maintain the required impedance, the thinner microstrip is closer to the ground plane than the annular sector. A six-element array with hybrid interconnections is shown in the lower part of Figure 7. This is an intermediate step in the development of an array with only microstrip interconnects. Although microstrip-to-ANSERLIN transitions occur at the input and output ports of each element, the interconnection and phasing of the elements are still accomplished with coaxial lines behind the ground plane. So far, the SWR realized with the microstrip feed at each port has not been as low as the best previously obtained with coaxial feeds. The impedance measured at the input of the power divider for the array of Figure 7 is shown in Figure 8. Improved pattern performance has been achieved with the microstrip-fed elements, however, as illustrated in Figure 9. This is primarily due to a better design technique.

ARRAY WITH TILTED BEAM

The coverage area of the linear arrays of ANSERLIN elements can be changed by taking advantage of the tendency of the element patterns to scan with frequency. This effect could be used to reduce the tilt angle that would be required to cover elevation angles near the horizon. Figures 10 and 11 show radiation patterns measured for the array of Figure 4 at 2.6 GHz. Excess phase shift in the wave traveling around the element causes the beam maximum to occur off the perpendicular. The pattern in the plane of the array shows lower sidelobe level since the beam and lobe maxima are no longer located in the plane of the measurement. The pattern in the orthogonal plane displays the beam tilt, the maximum occurring almost 20 degrees away from the perpendicular to the array surface. Between 10 dB points the beam is still very nearly CP.

CONCLUSIONS

Many of the requirements for a mobile, earth-based antenna for satellite communications can be easily met with an array of ANSERLIN elements. Additional efforts in interconnection technology, pattern synthesis, and construction techniques could well provide a low-cost, high performance array that is very well suited for this service.

REFERENCES

Drewniak, J., and P. E. Mayes 1987. Broadband, circularly polarized, radiating line antennas with an application to a series-fed array. Electromagnetics Laboratory Report No. 87-4. (Urbana, Illinois: University of Illinois).

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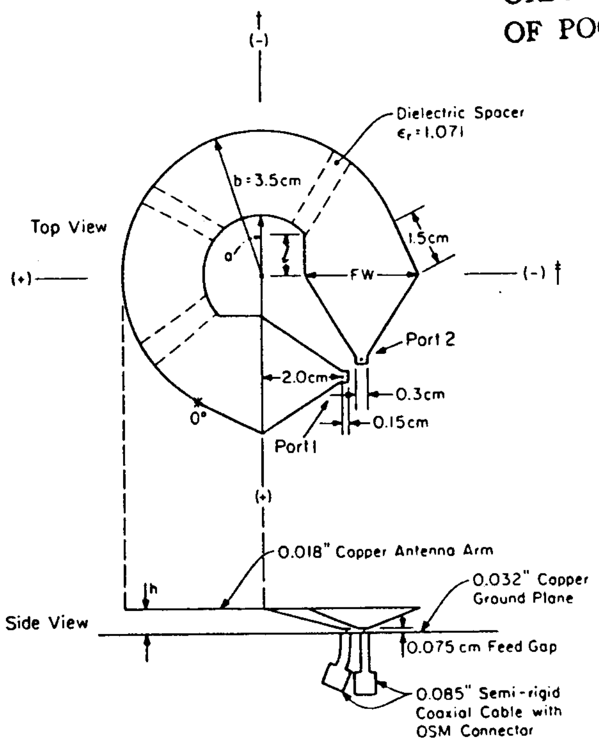


Fig. 1. An ANSERLIN element.

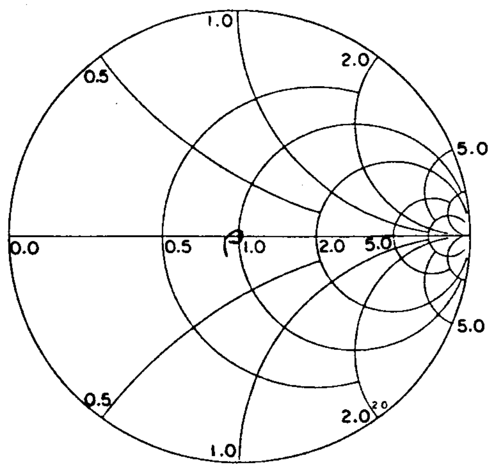
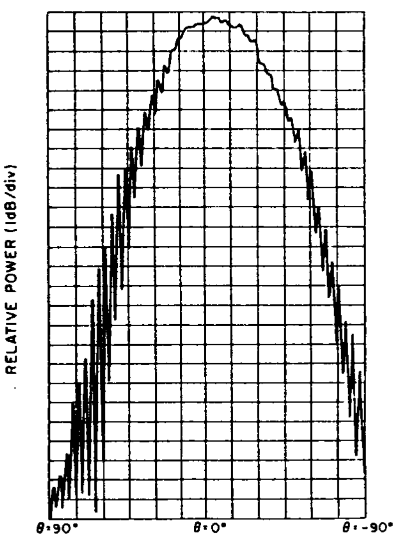


Fig. 2. Input impedance, 2-3 GHz.



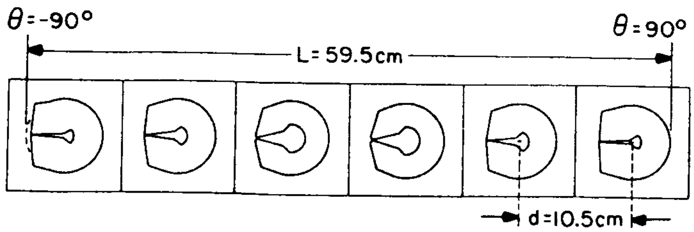


Fig. 4. Six-element array.

Fig. 3. Elevation-plane pattern, 2.2 GHz.

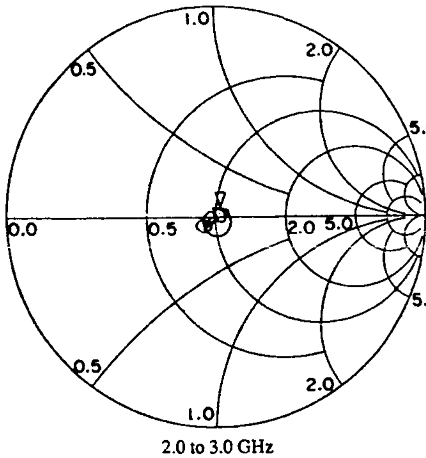


Fig. 5. Input impedance of array of Fig. 4.

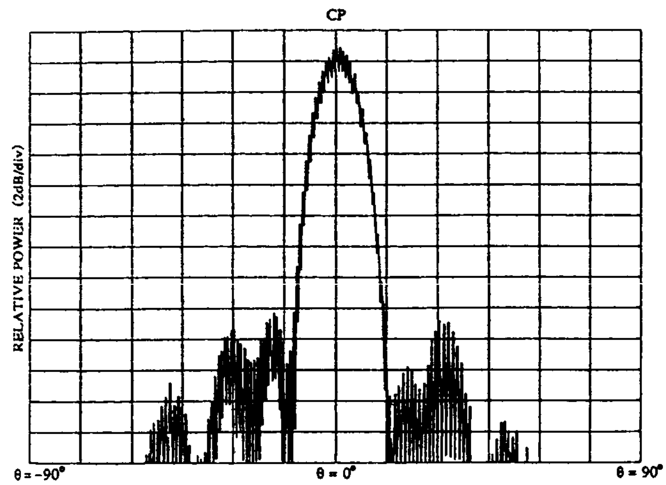
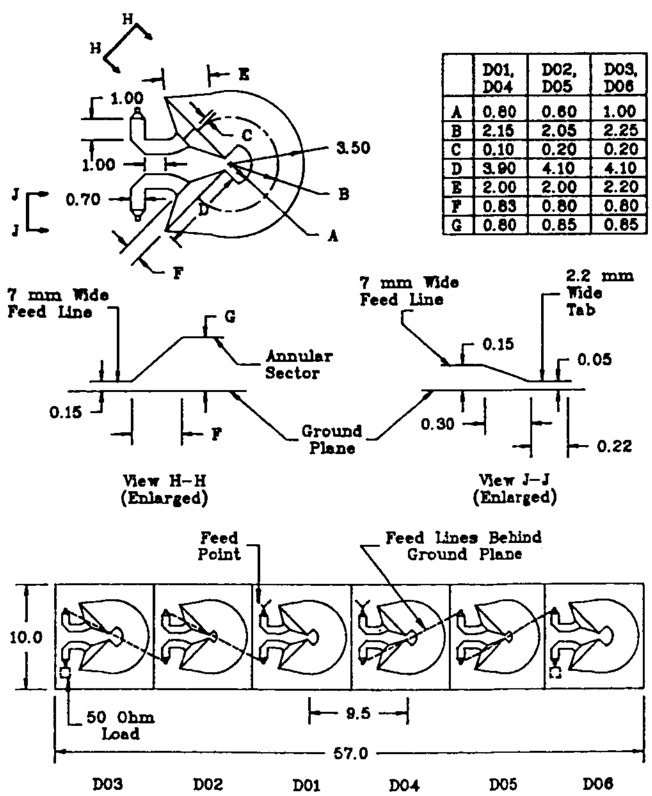


Fig. 6. Elevation-plane pattern through the plane of the array.



	D01, D04	D02, D05	D03, D06
A	0.80	0.60	1.00
B	2.15	2.05	2.25
C	0.10	0.20	0.20
D	3.90	4.10	4.10
E	2.00	2.00	2.20
F	0.83	0.80	0.80
G	0.80	0.85	0.85

Fig. 7. Microstrip-fed ANSERLIN elment and array (dimensions in cm unless stated).

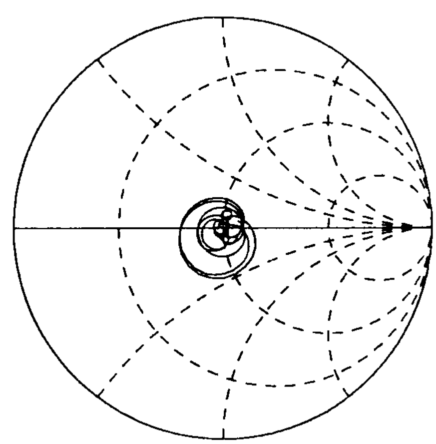


Fig. 8. Input impedance of array of microstrip-fed elements.

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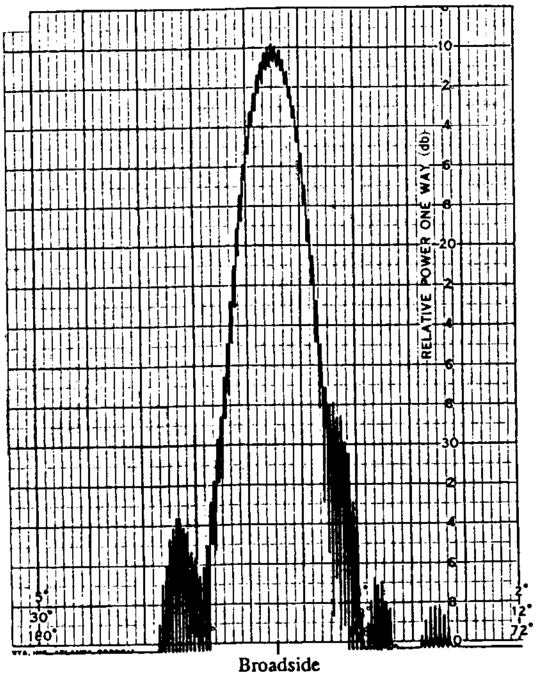

Fig. 9. Elevation-plane pattern of array of microstrip-fed elements.

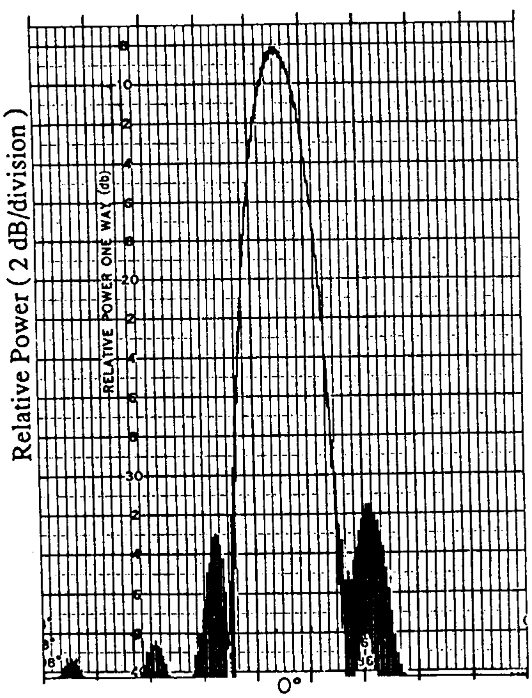

Fig. 10. Elevation-plane pattern through plane of array of Fig. 4 at 2.6 GHz.

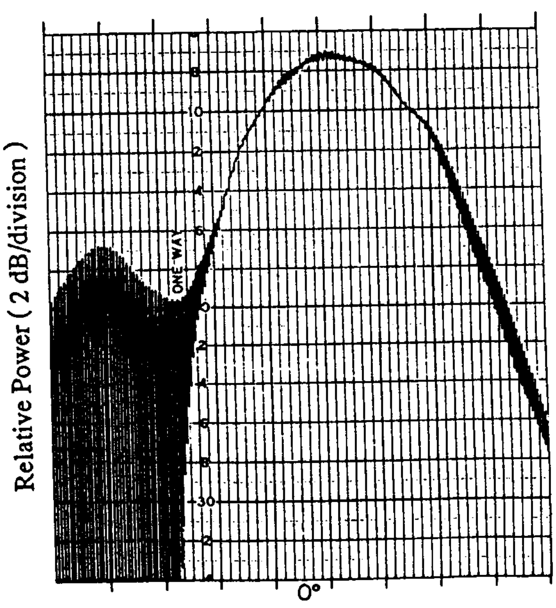

Fig. 11. Elevation-plane pattern in plane perpendicular to plane of the array of Fig. 4 at 2.6 GHz.

(20 degrees per major division)