AN AMPLITUDE SCANNING ANTENNA

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Abstract:

A new electronic scanning antenna is proposed which may be called as an amplitude scanning antenna. The antenna utilised a cylindrical microwave ferrite post at the junction made by two similar antennas and a common waveguide feed. To bias the ferrite a d.c. electromagnet was employed. The scanning is achieved by changing the ratio of the power fed to the two antennas. A theory has been developed and its validity is verified by experimental investigations carried out with the developed antenna for 30° & 60° space angles. It has been found that the maximum obtainable scanning is equal to the space angle between the two antennas. The maximum scanning is obtained in E-plane which is equal to the space angle between the two antenna elements. In H-plane the maximum scanning angle is equal to the half of the space-angle between the two antennas. In any case the scanning angle with the proposed antenna is limited to 90° only.

Introduction:

In recent years the growing need for radars to provide longer detection range and faster data rates and accommodate increased target densities has resulted in new approaches to radar designs. Most promising of these approaches is electronic scanning. With electronic scanning, it is possible to obtain practically instantaneous slewing of an antenna beam to any position in a designated sector. It may be mentioned that reflectors have a limited scan angle and the pattern degrades as the beam is steered off axis [1] whereas the lens antenna [2,3] are associated with reflection and transmission losses which reduce the efficiency and cause mismatching at the feed. Moreover, scanning of arrays [4,5] involve large number of phaseshifters while frequency scanning [6,7,8] requires a large frequency band to achieve the objective. It is therefore, important to design and develope some antenna [9] in which such complexity and high cost could be avoided. In view of this, an attempt has been made to design and develope an amplitude scanning antenna.

Theoretical considerations:

Fig. 1 shows a schematic diagram for two antenna elements in the same plane but inclined by an angle δ to each other. The point

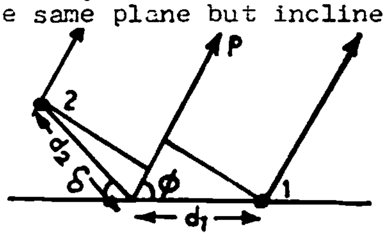

Fig.1 Schematic Diagram of Two Antenna Elements in the Same Plane.

P which is at large distance (r) from the antenna, receives power from both elements. If

$$E_1(\phi) = |E_1(\phi)| \angle f_1(\phi) \quad \ldots (1)$$

$$E_2(\phi) = |E_2(\phi)| \angle F_2(\phi) \quad \ldots (2)$$

be the electric field at point P due to antenna element 1 and 2 respectively then the resultant field at P is given as

$$|E(\phi)|^2 = |E_1(\phi)|^2 + |E_2(\phi)|^2 + 2|E_1(\phi)||E_2(\phi)| \cos\{f_1(\phi) - f_2(\phi) + \alpha\} \quad \ldots (3)$$

where α is the phase lead of radiated field of antenna 1 with respect to antenna 2 due to path difference.

$$\alpha = \beta[d_1 \cos\phi - d_2 \cos\{180 - \phi - \delta\}] \quad \ldots (4)$$

where β = phase constant infree-space = $2\pi/\lambda$ ... (5)

and d_1, d_2 are distances from the origin to the phase centre of antenna 2.

Since the two antennas are similar, we have

$$|E_2(\phi)| = a|E_1(\phi + \delta)| \quad \ldots (6)$$

$$F_2(\phi) = f_1(\phi + \delta) \quad \ldots (7)$$

where a is the ratio of maximum power amplitude of antenna 2 with respect to antenna 1. Substituting these values in Eq. 3 one gets

$$|E_R(\phi)|^2 = |E_1(\phi)|^2 + a^2|E_1(\phi)|^2 + 2a|E_1(\phi)|^2 \cos\psi \quad \ldots (8)$$

where $\psi = f_1(\phi) - f_2(\phi) + \beta[d_1 \cos\phi + d_2 \cos(\phi + \delta)$ ... (9)

Eqn. (8) gives us a good reason to expect that by changing the ratio of the field of source 2 to that of source 1, the radiation pattern can be rotated in space between two extreme positions. These two extreme positions are:

(i) when $a=0; E_2=0$. Thus the resultant pattern in this case is the same as that of the source (antenna)1. This has maximum radiation at $\phi = \phi_{mo}$.

ii) when $a=\infty$; $E_1=0$. In this case the radiation pattern is the same as that of source (antenna)2. This pattern has the same shape as that of the source 1 but shifted by an angle δ. Thus the maximum radiation in this case is at $\phi = \phi_{mo} - \delta$.

For values of a between these two extemes, if the value of δ, d1,d2 were properly chosen, the beam will have its maximum radiation at an angle ϕ_m such that

$$\phi_{mo} - \delta < \phi_m < \phi_{mo} \quad \ldots (10)$$

This relation shows that the maximum scanning angle is equal to the space angle between the two sources (antennas). Thus with the same sources the system can be designed for various scan angles. However, angle δ can not be increased as one wishes because for relatively larger value of δ, the two fields radiated from sources 1 and 2 will be widely separated so that continuous scanning of the resultant radiation beam would be impossible. Theoretically, the maximum value of δ will be limited to 90°.

<u>Typical Observations and Discussion of Results:</u>

All the measurements for the amplitude scanning antenna were made at 10.2 GHz. The space angles between two antenna elements that were subjected to experimental investigation, were 30° and 60°. Both E-plane and H-Plane radiation patterns were taken. However, the radiation pattern for 60° space angle between the two

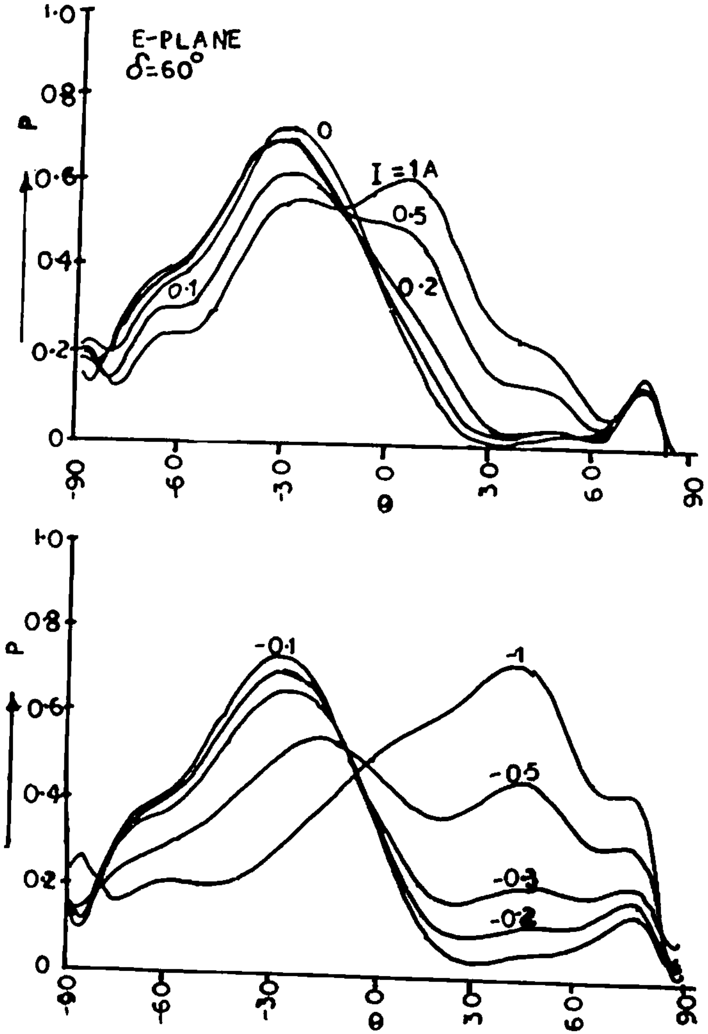

Fig.2. E-Plane Radiation Pattern for 60° Amplitude Scanning Antenna.

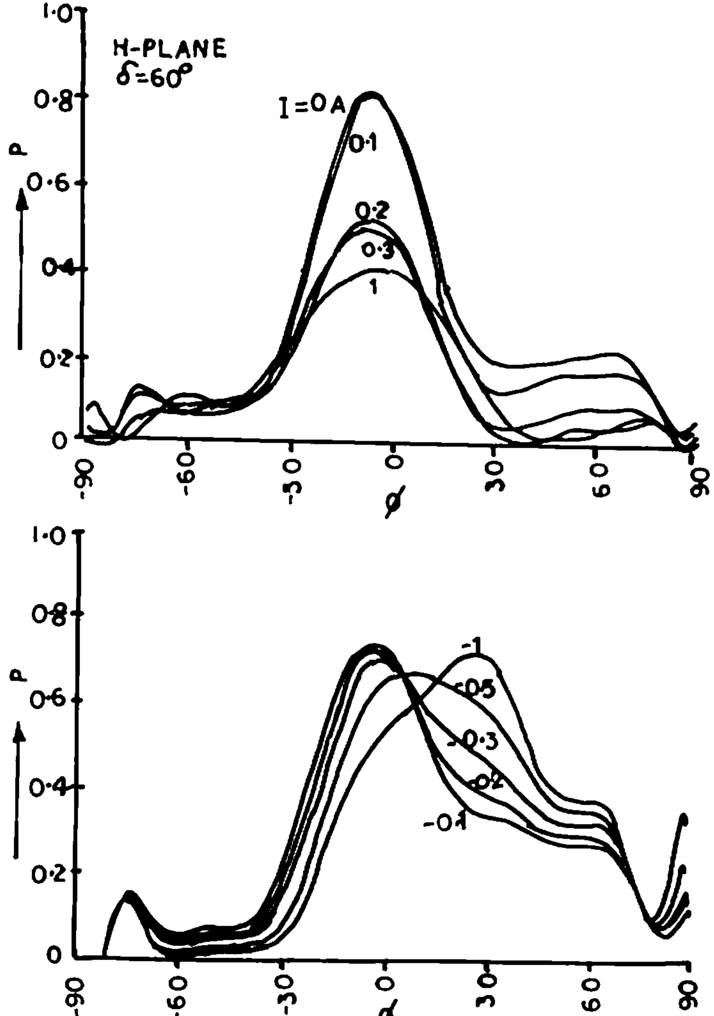

Fig.3. H-Plane Radiation Pattern for 60° Amplitude Scanning Antenna.

sources are only given (Figs 2,3). The variation in the magnet current allowed the variation in the ratio of powers fed to the two antennas. The observed radiation patterns for the amplitude scanning antenna clearly indicate that:

i) the maximum obtainable scanning angle is approximately equal to the space angle between the two antenna elements which is in accordance with the theory developed,
ii) the maximum scanning angle is obtained in the E-plane which is equal to the space angle (δ) between the two antenna elements,
iii) in H-plane the maximum scanning angle is equal to half of the space angle between the two sources. This may be attributed to the fact that in H-plane the separation between the two antenna elements is large as compared to the E-plane,
iv) the radiation pattern in the E-plane is comparatively better than that in the H-plane,
v) in E-plane the variation in the radiated power level is very low,
vi) scanning is found to be almost continuous in the E-plane while in H-plane continuous scanning is very limited.

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