longer rise time and total duration compared to those of normal flares and the proton flares which produced sfes exhibit east-west asymmetry as regards their position on the solar disc. Similar observations were reported by Pinter[8,11] using Hurbanov magnetogram data. The range of values of αN suggest that the region of excess ionization is about 60-90 km.

The observation of relatively longer rise times for sfes associated with proton flares suggests that sfe is insensitive to changes in X-ray energy spectrum. In fact, Deshpande *et al*[16] noticed that the time profile of sfe follows that of the integrated X-ray flux level rather than the spectral hardening factor. This is understandable at least on a quantitative basis, in terms of the fact that the sfe is an integrated effect of enhanced conductivity over a region of the ionosphere from about 60 km upto and including the electrojet region, although the relative contribution to the observed variation on ground from different heights, is not known. More work is, therefore, necessary using time profiles of sfe X-ray bursts in different wavelength bands and microwave bursts; and also in the direction of estimating the relative contribution to sfe from enhanced ionization at different levels.

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Radiation from a V-shaped Antenna Array

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A theoretical analysis of the radiation pattern from a plane V-shaped antenna array of n discrete radiators is presented. The lines of the radiators form the two arms with an apex angle α. The horizontal and the vertical radiation patterns have been investigated for $\alpha=\pi/2$ when the phase difference between the successive excitations is 0 and π. The resulting radiation patterns have been plotted and discussed.

In recent years, the studies of radiation patterns from various types of antenna arrays, viz. circular and spiral arrays have been reported[1-4]. These investigators considered antenna arrays of geometries determined by an angular parameter for the purpose of 360° scanning and relative frequency independence, particularly for the spiral arrays. While some investigators have been busy in the studies of radiation and impedance characteristics of various arrays, others have concentrated on the radiation and scattering from continuous structures. V-shaped antennas and reflectors are interesting because of their high gain, low cost and simple geometry. A detailed study of optimization techniques and radiation patterns of V-antennas have been undertaken by several workers[5,6]. Missler[7] has described the applications, technical requirements, construction, radiation properties and measurements of V-antennas for high frequencies.

For high gain considerations, an antenna array is superior to the ordinary antenna. It is obvious that if the geometry of the V-shaped antenna is retained and the continuous structure is replaced by an array, there would be an additional advantage obtainable from the combined effects of the V-geometry and the array structure.

With this end in view, the authors in the present communication have reported a study of the radiation characteristics of a plane two-dimensional V-shaped antenna array with cophasal elements and uniform progressive phase shift of the radiators. The resulting horizontal and vertical radiation patterns have been theoretically obtained.

Consider a two-dimensional V-shaped antenna array of discrete radiators with an apex angle α (Fig. 1). For simplicity, the radiators are assumed to be point sources. The separation between the radiators, which are equispaced, are different for the different arms.

Assuming the array to be placed in the X-Y plane, the array factor $f(\theta, \phi)$ (i. e. the field pattern

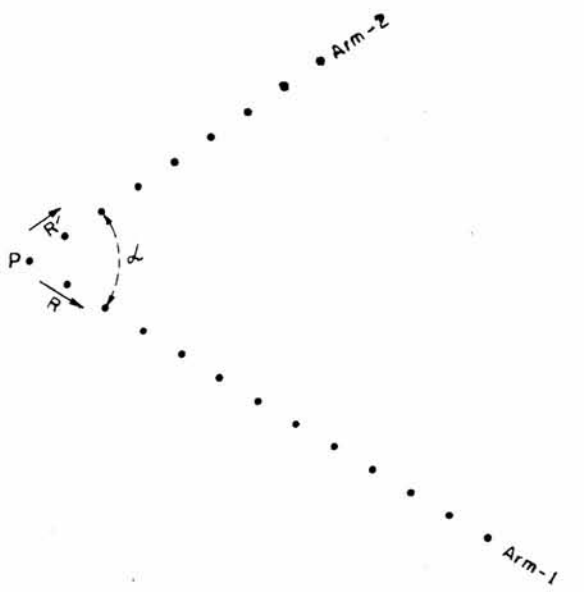

Fig. 1—Two dimensional V-shaped array of discrete radiators with apex angle α

as a function of θ and ϕ) for the first arm consisting of s_1 number of radiators is given by[8]

$$f(\theta, \phi) = \sum_{m=1}^{s_1} a_m \exp\left[jk_0 (m-1)\, \mathbf{R}.\mathbf{r}\right] \quad ...(1)$$

In a similar way, the array factor $f'(\theta, \phi)$ for the second arm of s_2 number of radiators is given by

$$f'(\theta, \phi) = \sum_{n=2}^{s_2} a_n \exp\left[jk_0 (n-1)\, \mathbf{R}'.\mathbf{r}\right] \quad ...(2)$$

In the above equations,

$$\left.\begin{aligned} \mathbf{R} &= d\,\mathbf{x} \\ \mathbf{R}' &= (d' \cos\alpha)\,\mathbf{x} + (d' \sin\alpha)\,\mathbf{y} \\ \text{and} \quad \mathbf{r} &= (\sin\theta \cos\phi)\,\mathbf{x} + \sin\theta \sin\phi\,\mathbf{y} + \cos\theta\,\mathbf{z} \end{aligned}\right\} \quad ...(3)$$

where $\mathbf{x}$, $\mathbf{y}$, $\mathbf{z}$ are the unit vectors in their respective directions, $\mathbf{r}$ is the polar unit vector in Cartesian coordinate system, d and d' are the distances between radiators in the first and second arm, respectively, which are shown vectorially by $\mathbf{R}$ and $\mathbf{R}'$, a_m and a_n are the excitation coefficients and $k_0 = 2\pi/\lambda$, where λ is the operating wavelength. In Eq. (2), summation is made for the field pattern from the contribution of second radiator onwards since the first radiator has already been included in the first arm. It may be pointed out that in Eqs. (1) and (2), m and n are dummies ranging from 1 to s_1 and 2 to s_2, respectively. Henceforth, n will be replaced by m.

The resultant radiation pattern due to the V-shaped antenna array is obtained by adding Eqs. (1) and (2) vectorially. We thus obtain

$$F(\theta, \phi) = \sum_{m=1}^{s_1} a_m \exp\left[jk_0 (m-1)\, d \sin\theta \cos\phi\right]$$
$$+ \sum_{m=2}^{s_2} a_m \exp\left[jk_0 (m-1)\{d' \cos\alpha \sin\theta \cos\phi + d' \sin\alpha \sin\theta \sin\phi\}\right] \quad ...(4)$$

It is to be noted that the array factor depends only on the excitation coefficients a_m and the relative position of the elements. Assuming that the excitation coefficients a_m in the individual elements have the same absolute value and the phase difference Ψ between the excitation coefficients of successive radiators are constant, the complex excitation coefficient can be written as

$$a_m = A \exp\left[j(m-1)\Psi\right] \quad ...(5)$$

where

$m = 1, 2, 3 ...... s$ radiators.

In Eq. (5), it is imagined that the reference radiator is at the centre and the current in the element is equally distributed to all the radiators. Using Eq. (5), for the complex excitation coefficient, the resultant radiation pattern can finally be written as

$$F(\theta, \phi) = \sum_{m=1}^{s_1} A \exp\left[j(m-1)\{\Psi + k_0 d \sin\theta \cos\phi\}\right]$$
$$+ \sum_{m=2}^{s_2} A \exp\left[j(m-1)\{\Psi + k_0 d' (\cos\alpha \sin\theta \cos\phi + \sin\alpha \sin\theta \sin\phi)\}\right] \quad ...(6)$$

Now from Eq. (6), the horizontal and the vertical radiation patterns can be obtained for suitable choice of array dimension and wavelength used.

For computational purposes, we have chosen a particular case for which the distance of separation between the radiators for both the arms are identical, i. e. $d = d'$ and the apex angle $\alpha = \pi/2$. Further, we assume the number of radiators in both the arms to be the same, i. e. $s_1 = s_2 = s$ so that we can identify m with n. For simplicity in numerical computations, the total number of radiators in both the arms are taken as four excluding the one which is common to both the arms. With the above specifications, Eq. (6) reduces to

$$F(\theta, \phi) = A\left[1 + \sum_{m=2}^{5}\left\{\exp\left[j(m-1)(\Psi + k_0 d \sin\theta \cos\phi)\right] + \exp\left[j(m-1)\{\Psi + k_0 d \sin\theta \cos(\phi - \alpha)\}\right]\right\}\right] \quad ...(7)$$

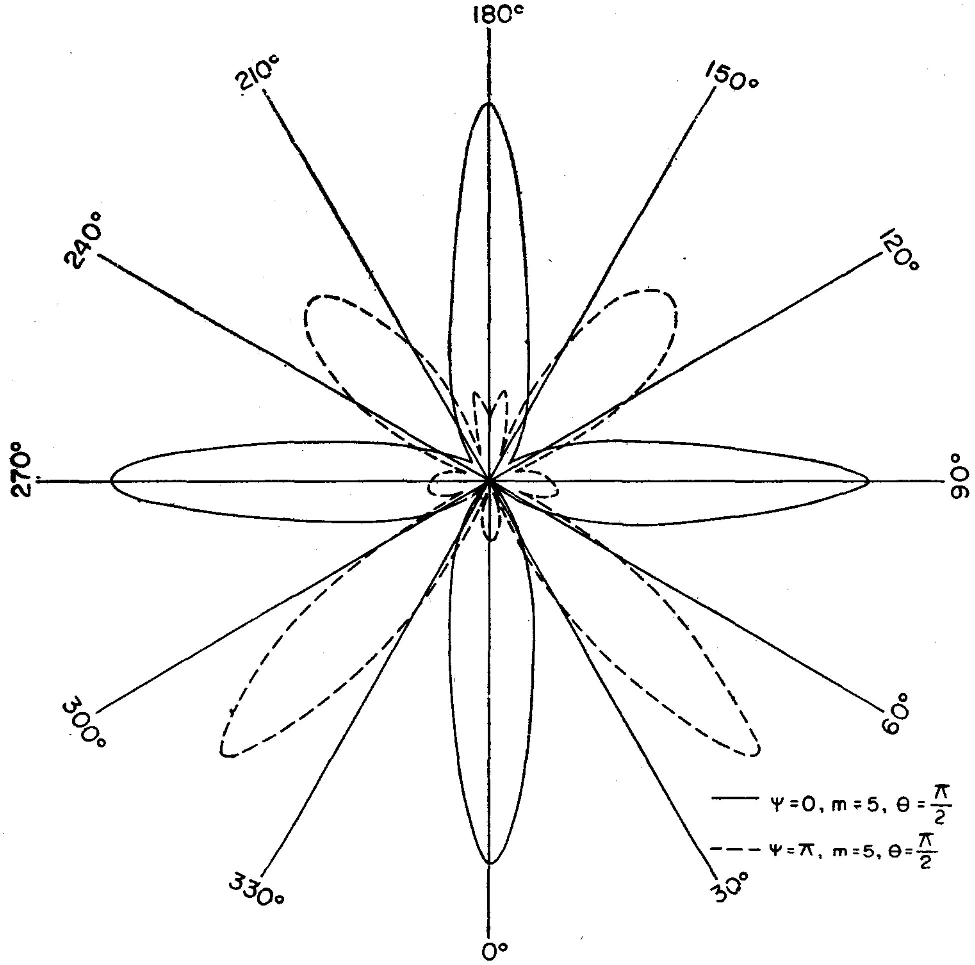

Fig. 2—Horizontal radiation patterns for two different values of Ψ as 0 and π

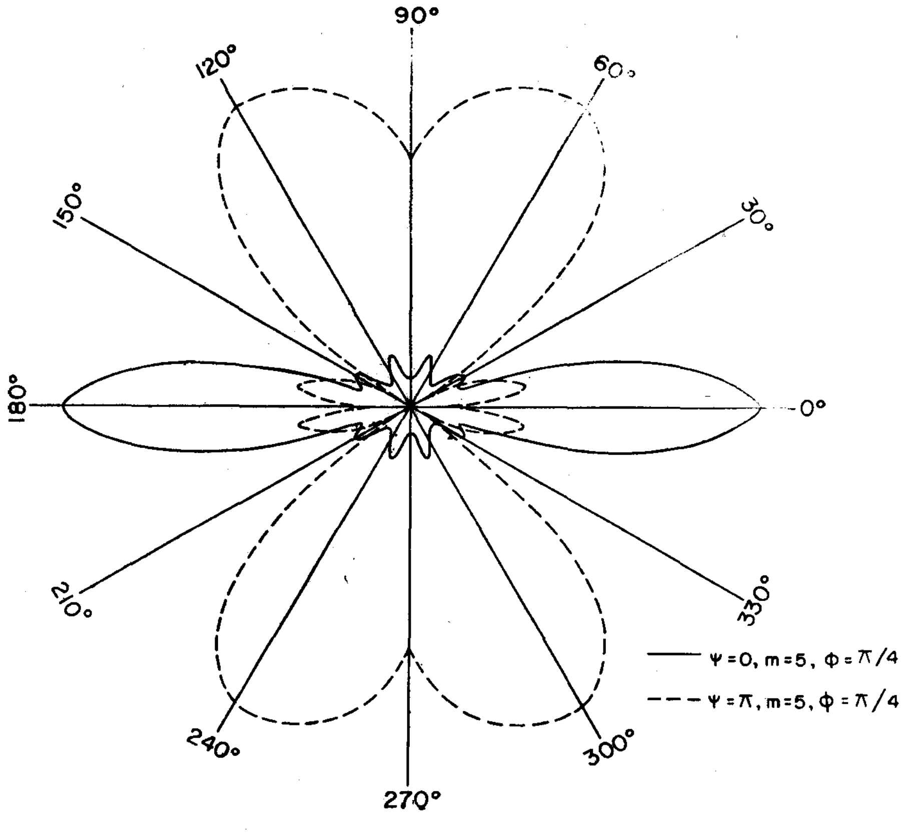

Fig. 3 — Vertical radiation patterns for two different values of Ψ as 0 and π

The array dimension is taken as $k_0 d = 5$ such that the array may be operative in the range from 6 to 300 MHz.

Using Eq. (7), the horizontal radiation pattern is obtained for $\theta = \pi/2$ and is given by

$$F\left(\frac{\pi}{2}, \phi\right) = A\left[1 + \sum_{m=2}^{5}\left\{\exp[j(m-1)(\Psi + k_0 d \cos\phi)]\right.\right.$$

$$\left.\left. + \exp[j(m-1)\{\Psi + k_0 d \cos(\phi - \alpha)\}]\right\}\right] \quad ...(8)$$

The horizontal radiation patterns showing the variation of $F(\pi/2, \phi)$ with ϕ for two different values of Ψ angles 0 and π are shown in Fig. 2.

For the study of the vertical radiation patterns, we have chosen the angle $\phi = \alpha/2 = \pi/4$ as a particular case. Substituting the above values, the expression for the vertical radiation pattern reduces to

$$F\left(\theta, \frac{\pi}{4}\right) = A\left[1 + 2\sum_{m=2}^{5} \exp j(m-1)\{\Psi + k_0 d \times \cos\frac{\alpha}{2}\sin\theta\}\right] \quad ...(9)$$

The variation of $F(\theta, \pi/4)$ with θ is shown in Fig. 3 for two values of Ψ as 0 and π.

In Fig. 2 which shows the variation of $F(\pi/2, \phi)$ with ϕ in the horizontal plane, a mirror symmetry about 180° is observed. For $\Psi = 0$, highly directive beams are obtained along 0° and 90° and due to mirror symmetry, also along 180° and 270° with half-power beam-width angle of 12°. It is interesting to note that no side-lobes appear and the minima occur at 45° and 135°. However, for $\Psi = \pi$, the maximum occurs along 45° with the half-power beam-width angle of 15°. Further, it may be observed that a secondary lobe with field-intensity of 67% of the main lobe and a few other minor lobes of low field-intensities also appear.

The vertical radiation patterns shown in Fig. 3 also exhibit a mirror symmetry about 180°. The field pattern for $\Psi = 0$ is found to be sufficiently directive. The half-power beam-width angle of the main lobe is about 20°. The maxima occur along 0° and 180° with small secondary lobes appearing along 30°, 70°, 110° and 150°. However, for $\Psi = \pi$, the central direction of the main lobe is shifted by 90° where it is bifurcated. The maximum intensities are at 60° and 120°. The half-power beam-width angle of the bifurcated main beam is as large as 84°. There occur side-lobes with intensity reaching upto 33% of that of the main lobe.

Although the same scale has been chosen for plotting the curves for $\Psi = 0$ and $\Psi = \pi$, it must be mentioned that only the relative intensities are depicted and in particular, the absolute maximum field intensity in the case $\Psi = 0$ is much greater than in the case $\Psi = \pi$.

For the chosen array dimension of the V-shaped array, the radiation patterns are highly directive in the horizontal plane both for $\Psi = 0$ and $\Psi = \pi$ and also in the vertical plane for $\Psi = 0$.

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Mutual Impedance of a Dipole Antenna in Magnetoplasma*

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The mutual impedance of a dipole antenna in an anisotropic plasma has been calculated following the quasi-static approximation method.

IN AN anisotropic media the self impedance and the mutual impedance of an antenna are different. Self impedance of a dipole antenna in an anisotropic plasma has been studied by several investigators[1]. The importance of the study of the mutual impedance of a dipole antenna in an anisotropic plasma has been discussed by Miyazaki[2]. The purpose of the present communication is to calculate the mutual impedance of the dipole antenna in an anisotropic plasma following the quasi-static approximation method.

*This work was done by the author when he was at the Department of Electrical Engineering, Tohoku University, Sendai, Japan.