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THE COUPLING BETWEEN TWO HORNS WITH SQUARE APERTURES ON COMMOM METALIC FLANGE

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Now systems of the horn irradiators of mirrow antennas find a wide application in television space tie. To get acceptable values of coupling between neighbour channels it is interesting to know the coupling between the horn irradiators, as well as the optimal size and mutual disposition when the value of such a coupling achieves its minimum.

Let us consider the system of two wedge-shaped horns with square apertures on common metalic flange which size is more larger than wavelength in free air λ_0. The displacement of the horns with respect to each other is $(\Delta x, \Delta y)$, as shown in Fig. 1. Each horn is joined with the standart rectangular waveguide 23 x 10 mm, which is fed by the electromagnetic wave of the main mode H_{10}, so that E-vector is parallel to the axe y, and H-vector to the axe x. The problem was solved by the integral equations method. Let us consider in common form the electric field distribution $\vec{E}(x,y)$ on the horn's apertures. It determines the distribution of magnetic current $\vec{j}^m$ using well known formula

$$\vec{j}^m = [\vec{E}, \vec{n}], \tag{1}$$

where $\vec{n}$ is the external normal. Then the vector potential $\vec{A}^m$ on the surfaces S1 and S2 can be calculated as follows:

$$\vec{A}^m = \frac{1}{4\pi} \int_{S1+S2} \vec{j}^m \frac{e^{ikr}}{r} ds. \tag{2}$$

In [1] it was shown that the condition of the large conductive flange allows to exclude the electric currents $\vec{j}^e$ from consideration, with magnetic currents $\vec{j}^m$ redoubling. Magnetic field $\vec{H}(x,y)$ can be found on S1 and S2 outside of horns as

$$\vec{H} = i\omega\varepsilon\vec{A}^m + \frac{i}{\omega\mu} \operatorname{grad} \operatorname{div} \vec{A}^m. \tag{3}$$

The boundary condition of the tangential component of magnetic field continuity gives the H-field distribution inside of the horns. Utilization of the eigen waves allows to calculate the electric field distribution inside of the horns by the given distribution of field $\vec{H}$. Dividing the surfaces S1 and S2 into the finite elements we obtain the system of linear algebraical equations with the integral coefficients. Such an approach to the waveguide problems solving was expounded in detail in [2] and applied to different problems. The main trouble is that unlike rectangular and circularwaveguides as well as pyramidal and sectorial horns it is rather difficult to construct exactly the eigen modes of the wedge-shaped horn. In the solving of this problem there were used the approximate numerical values for eigen waves of wedge-shaped horn, based

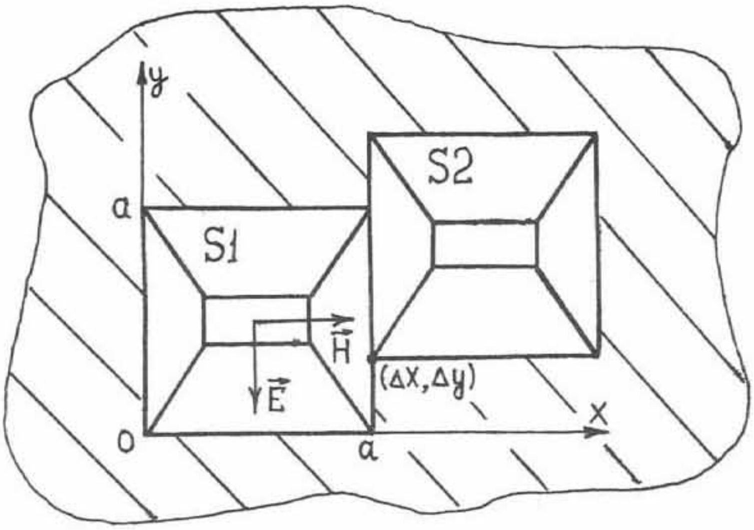

Fig.1. The system of two horns.

upon the analogy between rectangular waveguide and horn; it was shown in [3,4] that when $kr >> 1$, that is far from the horn's nesk, such an analogy was acceptable and rather useful.

The construction of such "eigen waves" is as follows. In the consideration there are the optimum horns, having fase difference in the vector E plane (that is between the central point C of the aperture and point D in Fig. 2) 1/4 of the wavelength. This condition determines the position of the point A - the horn vertex in the vector E plane, then from the square aperture horn joining with the standart waveguide the horn vertex in the vector H plane - point O - is found. After that the fields in the horn can be detemined as a combination of two cilindrical waves propagating respectively from the points A and O.

Now the horn is to be considered as rectangular waveguide with changing cross-section and "eigen waves" of the wedge-shaped horn are obtained from the eigen waves of rectangular waveguide after multiplying for amplitude and fase factors expressing respectively the attenuation due to spherical divergence and fase increase which depend upon the position of the point on the horn's aperture.

It is clear that the field components of such waves are not parallel to the horn's aperture plane because of the wave front bending and the projections of this components to this plane are to be considered when using the boundary conditions of continuity of the tangential components of $\vec{H}$ and $\vec{E}$ fields. It is known that electric as well as magnetic modes with the same indexes as in rectangular waveguide exist in the horn [4]. Wave resistances are calculated using the type, index of the mode involved and the length of the wave front; evidently wave resistance of each "eigen wave" is not constant for the cross-sections parallel to the horn aperture.

Constructed in such a way the "eigen" waves of wedge-formed horn constitute the full system owing to using analogy between horn and waveguide, but there is no orthogonality of this system on cross-sections parallel to the aperture, and that's why

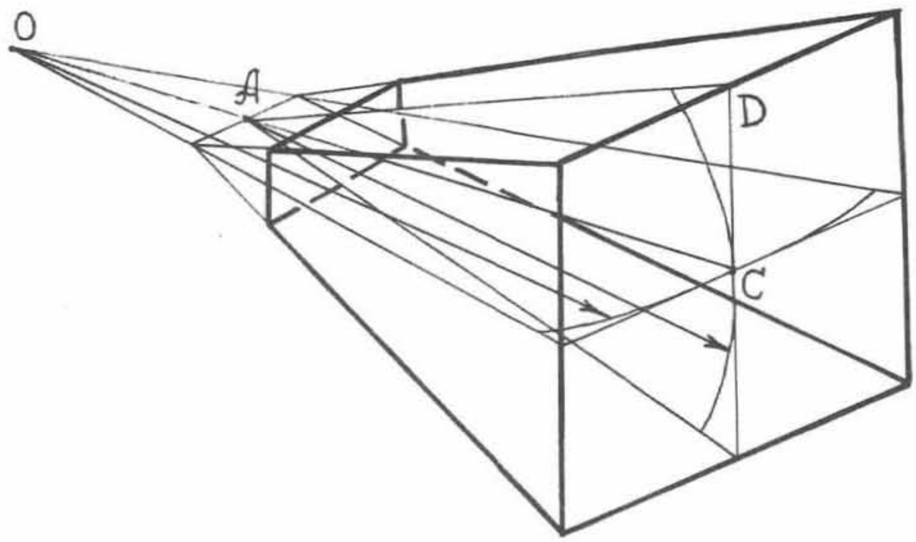

Fig.2. The construction of horn's eigen waves.

to expand electromagnetic fields in terms of this waves we must solve the finite system of linear equations to find the amplitudes of all "eigen waves" in consideration, rather than to utilize the usual Fourier-expanding algorithm as it takes place in waveguide problems with waves orthogonality. The dimension of this system is equal to the full number of "eigen waves" used and the elements of matrix are the scalar products of the components of field of the different "modes" on horn's aperture; column of the system consists of the scalar products of field obtained by formula (3) and the fields of "eigen waves". In the matrix of this system of equations only the diagonal elements differ essentially from zero, and all others which determine inorthogonality of the waves are equal to zero as for example the scalar product of "modes" H_{10} and H_{01} or near to zero.

In [4] it was shown that the field reflection coefficient of H_{10} mode in waveguide - horn joint in the worst case was less than 1%, it implies that the energy of H_{10} mode in the waveguide completely transforms to the energy of the proper horn "mode" and vice versa. All other horn's "eigen waves" are not essentially contribute in the amplitude of guide H_{10} mode because of small nondiagonal coefficients of matrix mentioned above. Wavelength is chosen so that all guide modes excepting H_{10} attenuate in the horn's neck and the amplitude of "H_{10} wave" in receiving horn gives immediatly the value of coupling between transmitting and receiving horns.

For all possible mutual positions of two horns the numerical calculations were made, that is for $\Delta y = a$ and Δx changing from 0 to a, $\Delta x = a$ and Δy changing from a to 0 where a is the size of horn's aperture. The results of this calcu-

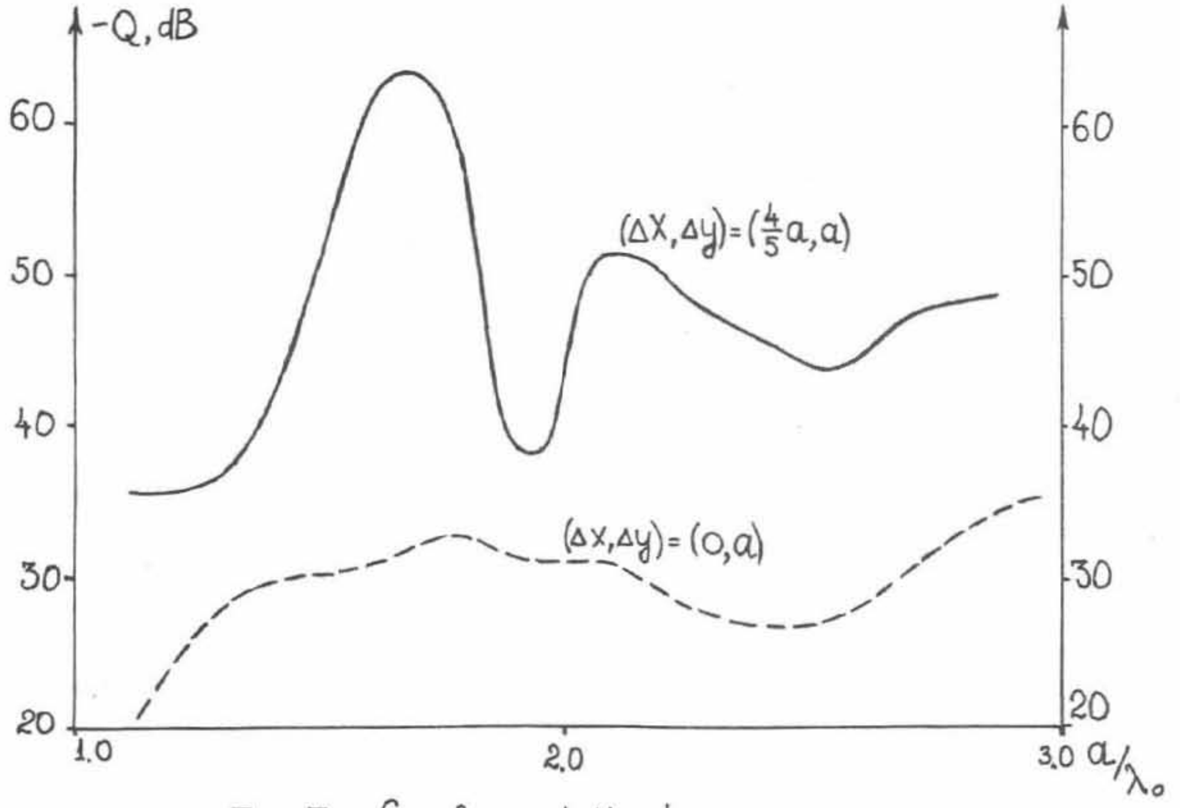

Fig. 3. Coupling of the horns.

lations for two dispositions are shown in Fig. 3. Ordinate axe is the value of coupling expressed in decibels and absciss axe is the size of horn with respect to wavelength. The size was changed from λ_0 to $3\lambda_0$. The curve of coupling in the case of displacement in the vector E plane, when $(\Delta x, \Delta y) = (0, a)$ and the coupling between horns achieves its maximum is presented in Fig. 3 as a dotted line. Solid line presents the case when $(\Delta x, \Delta y) = (4/5a, a)$ in which the coupling is minimum. The system reaches its coupling minimum when horns still touch each other by their ardent edges rather than by diagonal. The size a in this case is approximately equal to $1.65\lambda_0$.

Though the calculations were made without taking into account of the crosspolarization arisen due to spherical form of the wave front, its results can be usefull when choosing optimal size and mutual position of irradiators.

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