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PRELIMINARY

On Dielectric Lenses

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In electromagnetic wave propagation in parallel-plane waveguides, one is confronted with the problem of launching the waves. When horns are used, they introduce fringing due to their side walls. For example, the electric field lines which are parallel to the walls (TE_{01} mode) are curved instead of being straight as they are supposed to be. A method of eliminating this difficulty is to use a dielectric lens.

The dielectric lens has been used to modify or correct the phase of an electromagnetic wave (1, 2) as shown in Figure 1. The phase front is usually spherical due to a point source, or circular due to a line source.

The shape of the lens is determined by the fact that the electrical distance travelled through the air plus that travelled through the lens is equal to the electrical equivalent of the constant distance R.

If the source is a horn as shown in Figure 2, a different situation arises. The flux plot is no longer perfectly circular, and consequently the problem of designing the lens must be handled graphically as well as analytically.

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From Figure 2, one can formulate the following

$$ds^2 = dx^2 + dy^2$$

$$s = \int_0^L \left[1 + g'^2(x) \right]^{1/2} dx$$

where s is the actual distance the wave travels, and $g'(x) = \frac{dy}{dx}$. The function g (x) is determined numerically at as many points as one likes for the desired accuracy. The shape of the lens is then determined by the imposed condition that the distance a wave front travels in an empty wave-guide plus the distance the same front travels in the dielectric filled portion

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1 S. Silver, editor, Microwave Antenna Theory and Design, McGraw-Hill Book Co., New York, (1949).

2 Kraus, J. D., Antennas, McGraw-Hill Book Company, New York, (1950).

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of the guide is equal to the constant electrical distance R. This condition is expressed by the following design equation.

$$\frac{1}{\lambda_g}\int_0^{X_o}\left[1+f'^2(x)\right]^{1/2}dx + \frac{1}{\lambda_d}(L-X_o) = \frac{1}{\lambda_g}R$$

where

$$\lambda_g = \frac{\lambda_o}{\sqrt{1-(f_c/f)^2}}$$

$$\lambda_d = \frac{\lambda_o}{\sqrt{\epsilon_r-(f_c/f)^2}}$$

f = operating frequency

λ_o = free space wavelength at f

f_c = cut-off frequency of the guides

ϵ_r = relative dielectric constant .

If $n = \frac{\lambda_g}{\lambda_d}$, the above equation becomes

$$\int_0^{X_o}\left[1+f'^2(x)\right]^{1/2}dx + n\,(L-X_o) = R$$

The position X_o is determined by trial and error such that the design equation is satisfied. The equation may be made frequency independent if dielectrics with relatively high dielectric constants are used.

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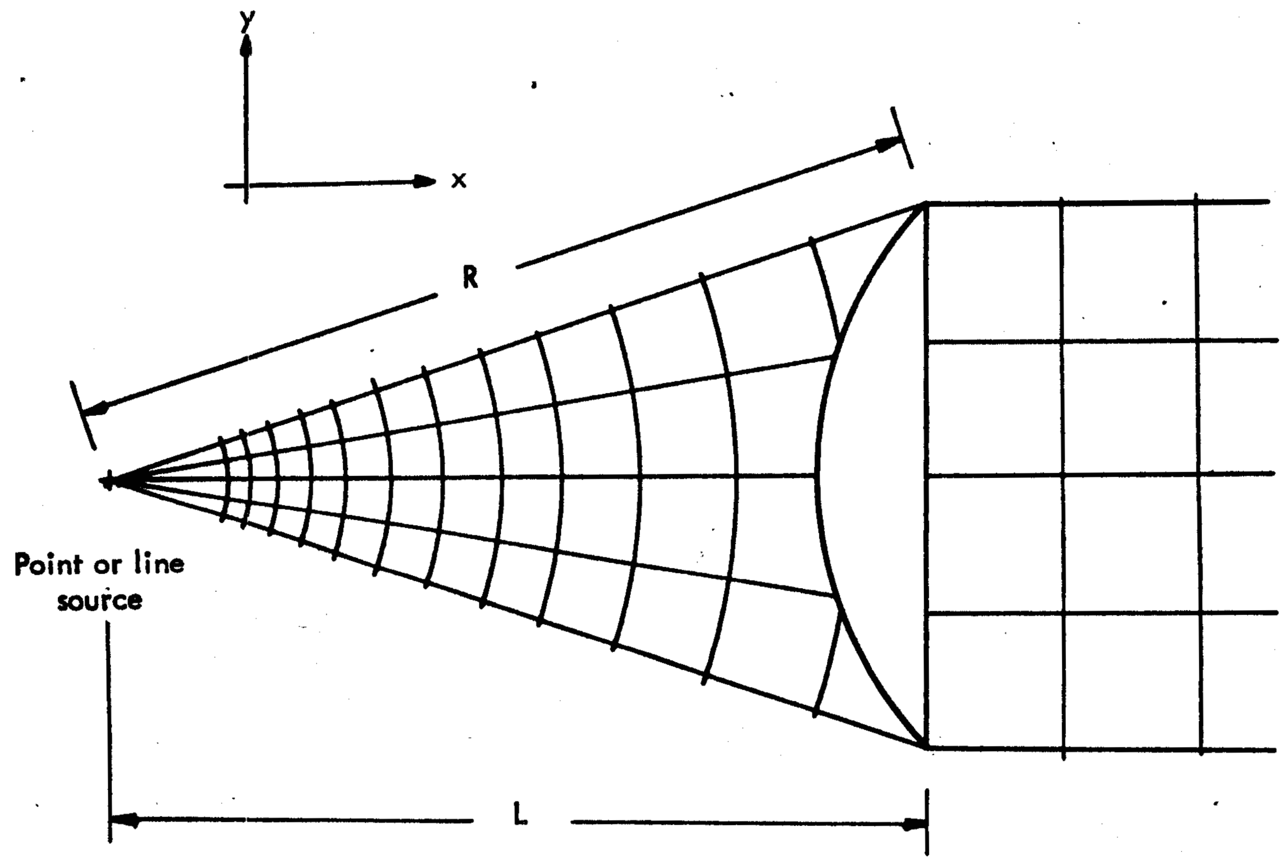

Figure 1: Field plot for a point or a line source

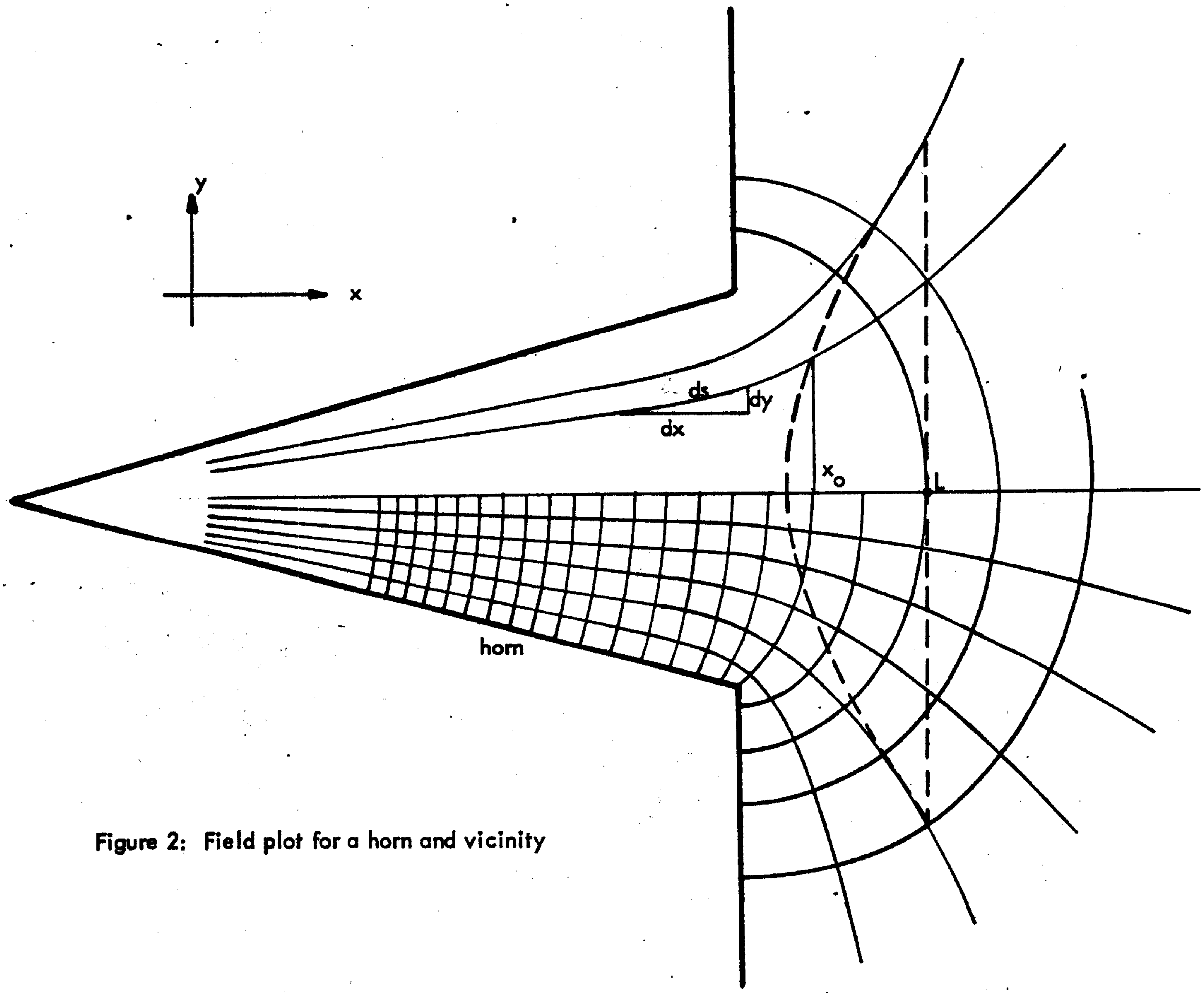

Figure 2: Field plot for a horn and vicinity