BROADBAND, LOW SIDELOBE, ZERO HEIGHT, SLOTTED CIRCULAR DISK ANTENNA

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ABSTRACT

A rigorous mathematical theory for a rotationally symmetrical slotted circular disk antenna was developed. The theory applies the principle of "Gradient Invariance" of electromagnetic fields to determine the field components that are unique and single valued at any point in space.

To determine the radiation characteristics of the antenna in space, the field at the slot is taken as the secondary source radiation and the solution is carried out in a semi-spherical coordinate system. The expression obtained for the radiation pattern was programmed and the antenna patterns plotted.

The antenna was then constructed and, among others, its radiation patterns plotted.

Such an antenna can have wide ranging practical applications. It is interesting to note that the physical and geometrical constructions of such an antenna allow it to be conveniently mounted on different types of fast flying and/or moving objects without its characteristics being influenced by the strong wind resistances that may exist. In effect, it is a "zero height" antenna with respect to the object on which it is mounted.

ANALYSIS

The objective of this research was to develop a computer aided, rigorous mathematical theory for a rotationally symmetrical circular disk antenna of the type shown in Fig. 1 and experimental verification of the theory.

The theory applies the principle of "Gradient Invariance of Electromagnetic Fields" to determine field components that are unique and single valued at any point in space.

$$E = k^2\pi_z^e + \nabla\ \nabla.\pi_z^e - j\omega\mu\nabla \times \pi_z^m = TM + TE$$

$$H = (\sigma + j\omega\epsilon)\nabla \times \pi_z^e + k^2\pi_z^m + \nabla\nabla.\pi_z^m = TM + TE$$

$$\Delta\pi_z^e + k^2\pi_z^e = \frac{J}{\sigma + j\omega\epsilon}$$

$$\Delta\pi_z^m + k^2\pi_z^m = -\frac{J}{\sigma + j\omega\epsilon}$$

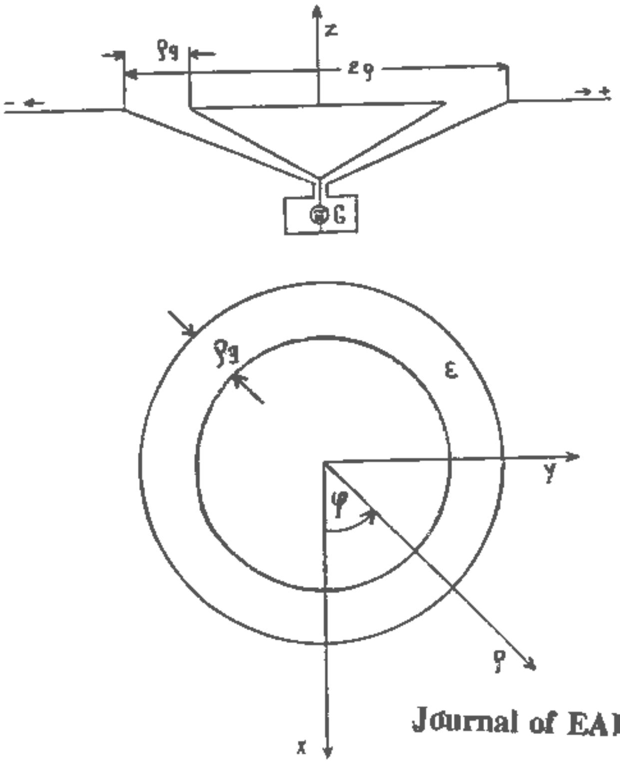

Figure 1

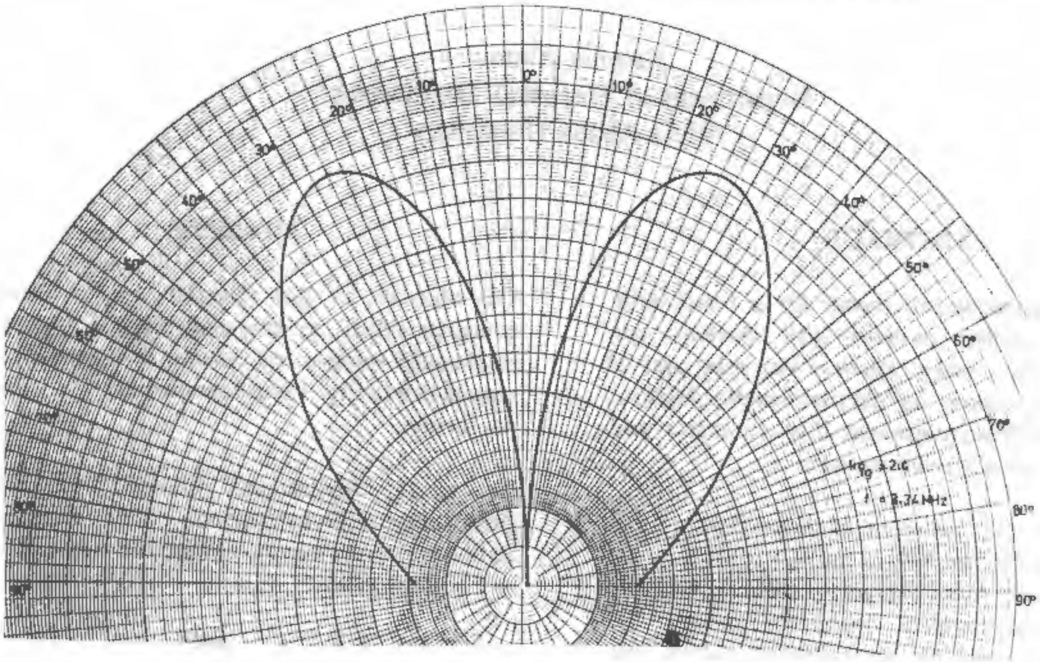

Figure 2

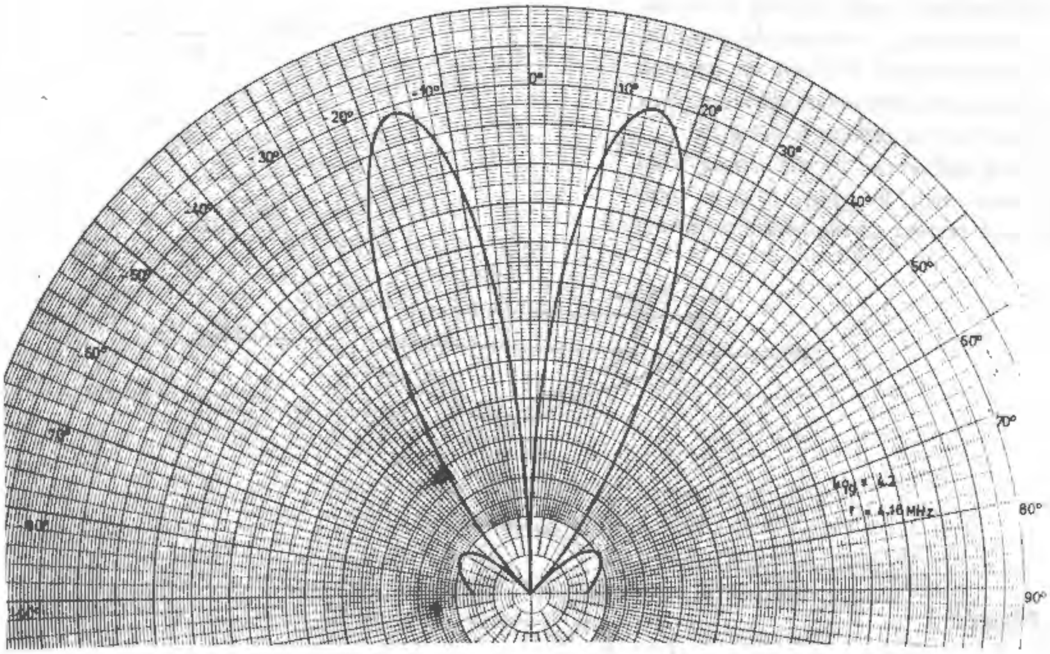

Figure 3

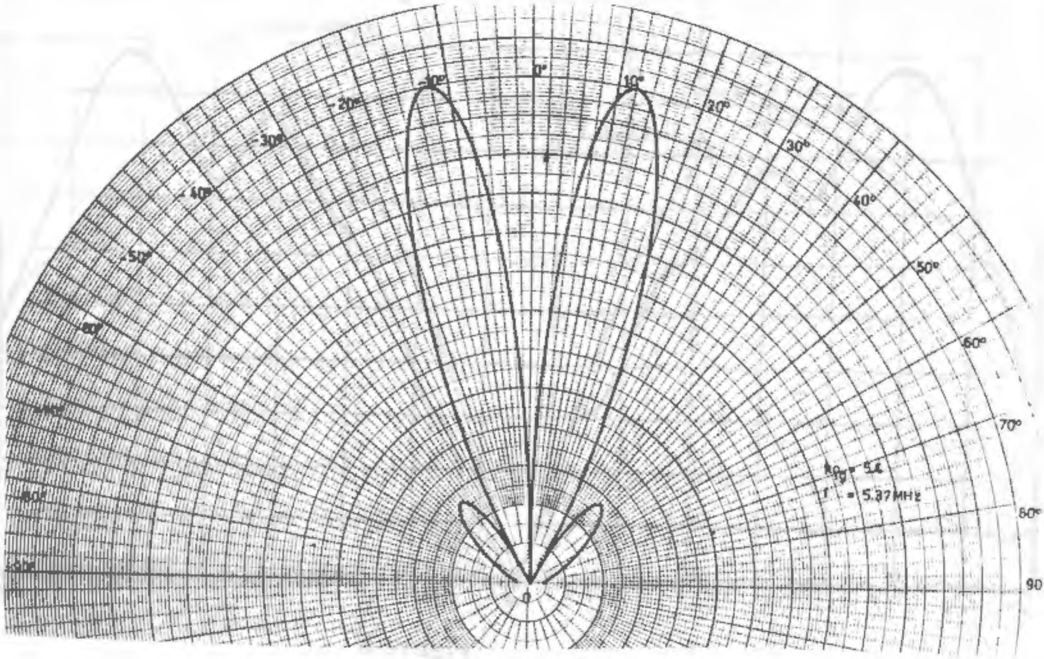

Figure 4

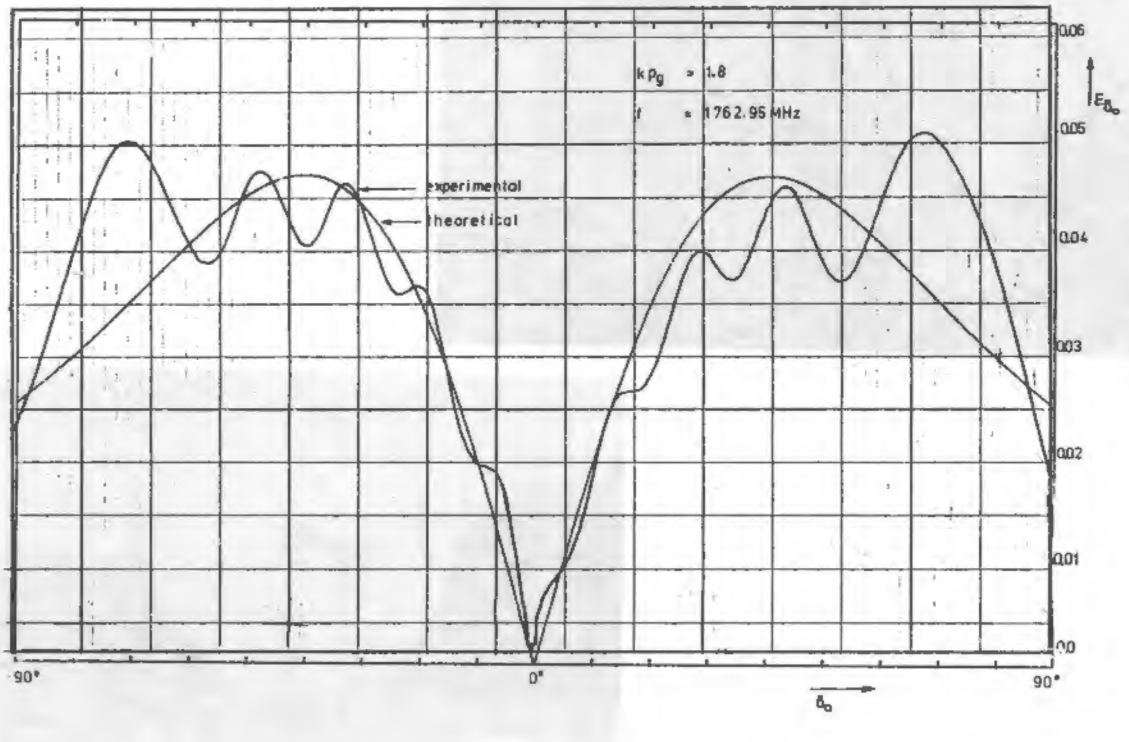

Figure 5

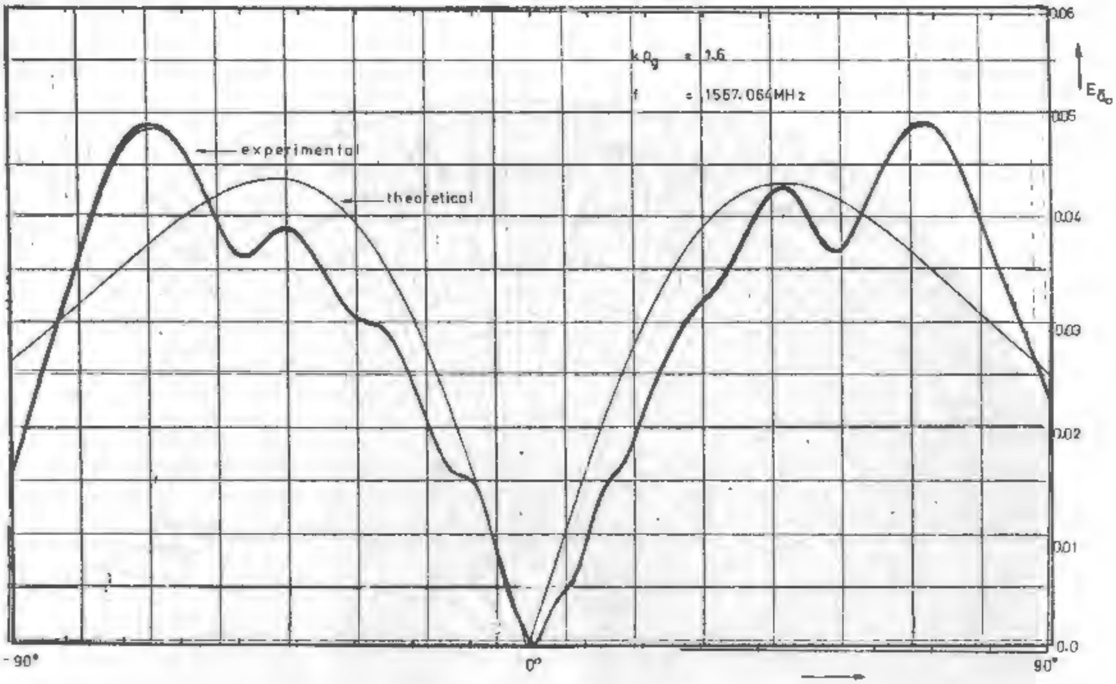

Figure 6

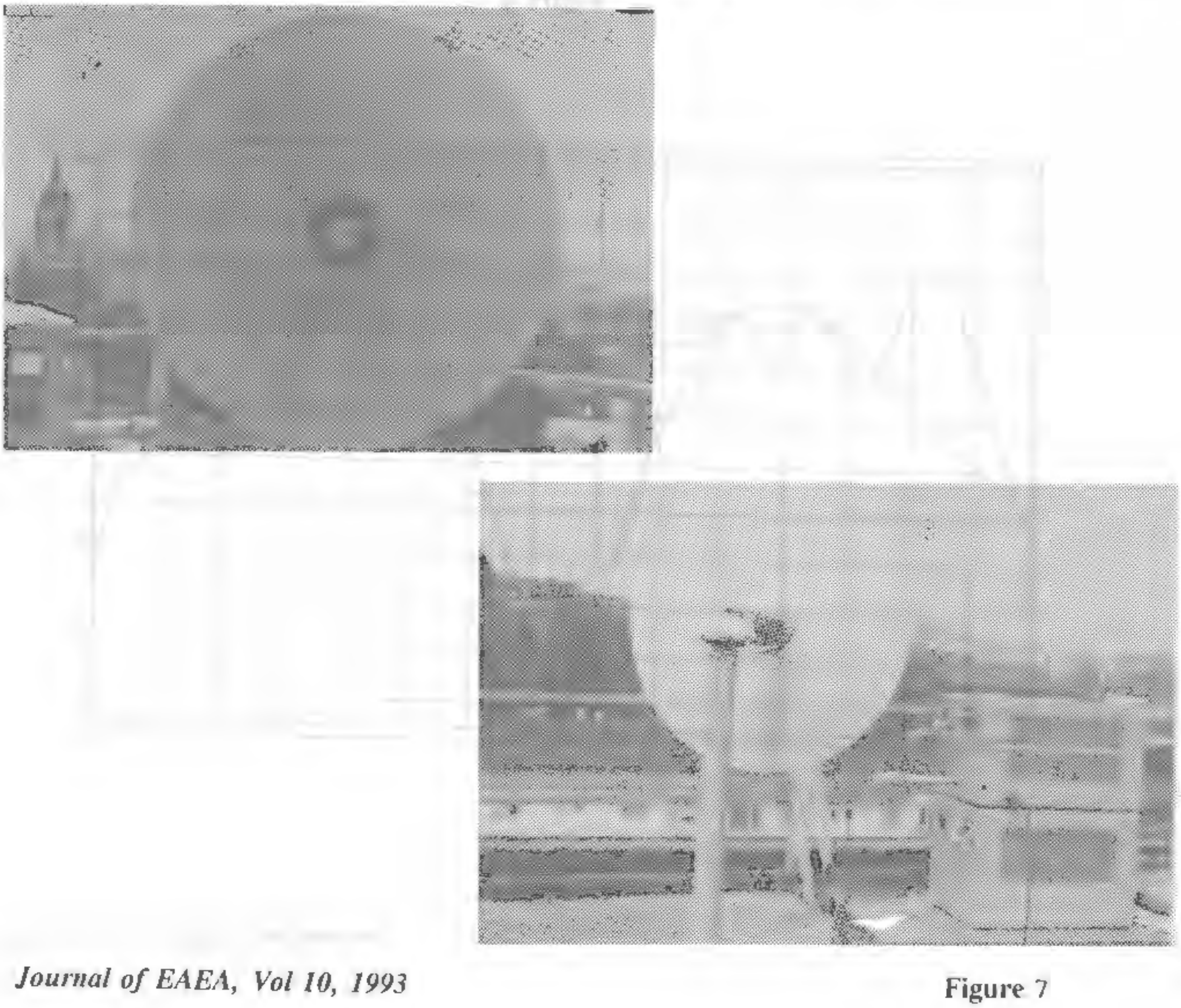

Figure 7

These wave equations are second order partial differential equations which could be solved by themethod of separation of variables in cylindrical coordinate systems. The solution result is given by

$$\pi_z^e = \frac{C_1}{N_n(\Gamma r_0)}[J_n(\Gamma r)N_n(\Gamma r_0) - J_n(\Gamma r_0)N_n(\Gamma r)] \cos n\phi[C_3 e^{j\gamma z} + C_4 e^{j\gamma z}]$$

where $J_n(\Gamma r)$ is the Bessel function of the n^{th} order of argument Γr, $Nn(\Gamma r)$ is the Neumann function of the n^{th} order of argument Γr where $k^2 = j\omega\mu(\sigma+j\omega)$ and $\gamma^2 + \Gamma^2 = k^2$, γ is the propagation constant, and Γ is real constant of the cross-section.

Having determined the Hertzian vector, the electromagnetic field distribution at the slot of the antenna can be obtained by substituting π'_z back into the field equations. The results are given by the following equations:

$$E_r = \underbrace{-jC_2\gamma\Gamma Z_n'(\Gamma r, \Gamma r_0)\cos n\phi e^{-j\gamma z}}_{\text{TM contribution}} + \underbrace{\frac{jC_2 w\mu n}{r} Z_n(\Gamma r, \Gamma r_0)\sin n\phi e^{-j\gamma z}}_{\text{TE contribution}} - \underbrace{\frac{jkC_1 e^{-jkz}}{r}}_{\text{TEM contribution}}$$

$$E_\phi = \underbrace{\frac{jC_2\gamma n}{r} Z_n(\Gamma r, \Gamma r_0)\sin n\phi e^{-j\gamma z}}_{\text{TM contribution}} + \underbrace{jC_2\omega\mu\Gamma Z_n'(\Gamma r, \Gamma r_0)\cos n\phi e^{-j\gamma z}}_{\text{TE contribution}}$$

$$E_z = \underbrace{C_2\Gamma^2 Z_n(\Gamma r, \Gamma r_0)\cos n\phi e^{-j\gamma z}}_{\text{TM contribution}}$$

$$Z_n(\Gamma r, \Gamma r_0) = J_n(\Gamma r)N_n(\Gamma r_0) - J_n(\Gamma r_0)N_n(\Gamma r)$$

where $Z'_N(\Gamma r,\Gamma ro)$ is the derivative of Z_n with respect to r.

To determine the radiation characteristics of the antenna in free space, the field at the slot is taken as the secondary source of radiation and the solution carried out in a semi-spherical coordinate system, and the following result was obtained.

The expression obtained for the radiation pattern was then programmed and the antenna patterns plotted in Figs. 2, 3, and 4.

RESULTS

The antenna was then constructed and, among others, its radiation patterns measured and compared with those predicted by the theory. These are given in Figs. 5, 6, and 7, respectively.

REFERENCES

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