"BACKSCATTERING OF MICROWAVES BY CONCEALED CYLINDERS"

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The study of backscattering or reflection of microwaves from concealed objects is important to many applications such as detection and imaging of such objects. An inifinte cylinder is considered here since it resembles practical targets such as pipes and cables. Fig.1 shows an infinite cylinder of radius a, illuminated by a plane wave, linearly polarized at an angle θ, and propagating in the X- direction. The incident wave will be analyzed into a normal component Ey and a parallel one E_z;

$$\vec{E}^i = E^i_y \vec{a}_y + E^i_z \vec{a}_z = E_o \text{ Sin } \theta \vec{a}_y + E_o \text{Cos } \theta \vec{a}_z \quad \text{................(1)}$$

It has been shown(1) that each of the above components is scattered such that the magnitude of the ratio of the scattered wave to the incident one is given by:

$$S_1 = \left| \frac{E^s_y}{E^i_y} \right| = \tfrac{1}{2} (ka)^2 \sqrt{\lambda/\rho} \left| 1 - 2\text{Cos } \phi \right| \quad \text{................(2)}$$

$$S_2 = \left| \frac{E^s_z}{E^i_z} \right| = \sqrt{\lambda/\rho} \Big/ (2\log ka) \quad \text{................(3)}$$

where ρ and ϕ are cylinderical coordinates, k is the wave number and it is assumed that $ka \ll 1$ and $\rho \gg \lambda$.

Following the same analysis of Ref.(1), it can be shown that the phase of the scattered components with respect to the incident ones is given by:

$$\psi = \frac{3}{4} - k\rho(1 - \text{Cos } \phi) \quad \text{................(4)}$$

The total scattered field can now be found by a vector sum of E^s_y and E^s_z, i.e

$$\vec{E}^s = [S_1 \text{Sin } \theta \; \vec{a}_y + S_2 \text{ Cos } \theta \; \vec{a}_z] \; E_o \text{ Exp}(j\psi) \quad \text{...............(5)}$$

The depolarizing effect of the cylinder can be seen by analyzing the scattered field $\vec{E}_s$ into copolar E_{cp} andcross-polar E_{CR} components. With reference to Fig. 1 and using Eq.5, it can be shown that

$$E_{cp} = [S_1 \sin^2 \theta + S_2 \cos^2 \theta] \quad E_o \ \text{Exp}\ (j \psi) \qquad \ldots\ldots\ldots\ldots\ldots (6)$$

$$E_{CR} = 0.5 \ (S_1 - S_2) \sin 2\theta \quad E_o \ \text{Exp}\ (j \psi) \qquad \ldots\ldots\ldots\ldots\ldots (7)$$

It can be seen from Eq,. 7 that maximum depolarization occurs when $\theta = 45^o$ for which the two components are given by:

$$E_{CR} = 0.5 \ E_o \ (S_1 - S_2) \ \text{Exp}\ (j \psi)$$

$$E_{cp} = 0.5 \ E_o \ (S_1 + S_2) \ \text{Exp}\ (j \psi)$$

Variations of the relative strength of the backscattered E_{cR} and E_{cp} are shown in Fig.2 for $S_1 = 0.084$ and $S_2 = 0.706$. Experimental verification was performed at a frequency of 7GHz where an open-ended wave guides were used to illuminate and receive backscattered components from an Aluminum cylinder of radius = 0.4 cm and 40cm away. Good agreement with theoritical results can be seen.

The influence of concealing the cylinder by a large dielectric plate of a given ϵ_r and thickness d was studied experimentally. In Fig.3. the copolar reflected wave can be seen to have a constant term due to reflection from the plate. Using formulas of Ref.2, the reflection coefficients of the concealing plates were; 0.38, 0.53 and 0.56 respectively. In Fig.4, the cross-polarized reflected wave is seen to have almost the same sinusoidal variation with out the concealing plate, see Fig.2.

In conclusion, maximum cross-polar reflection occurs when the cylinder is at 45^o to the incident polarization. The concealing dielectric plate produces copolar reflection that can be exessive. However, the cross-polarized reflection is still due to the cylinder and thus can be exploited for easier detection of concealed cylinderical objects.

References:-

1. HARRINGTON, R.F., "Time harmonic electromagnetic fields", Mc-Graw Hill, 1961, PP. 232-236.

2. CHENG, D.K., "Field and wave electromagnetics", Addison-Wesley, 1983, PP. 350.

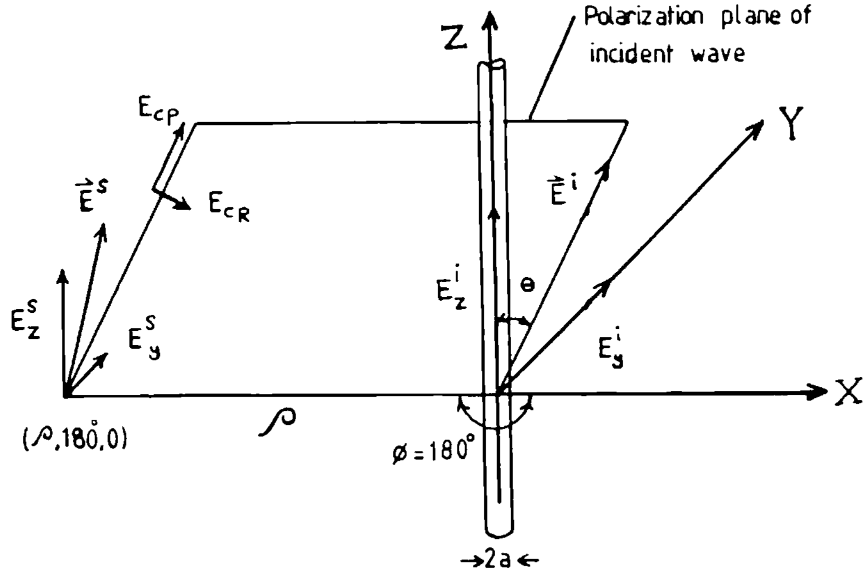

FIG. 1 Geometry of backscattering of a plane wave by a conducting cylinder

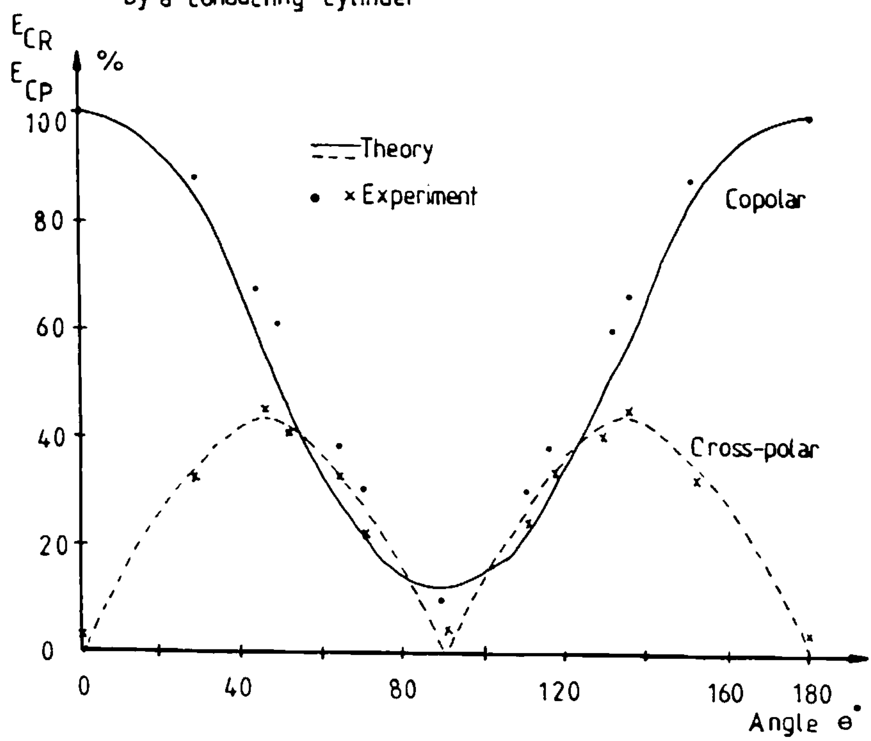

FIG. 2 Variation of the relative strength of the backscattered components

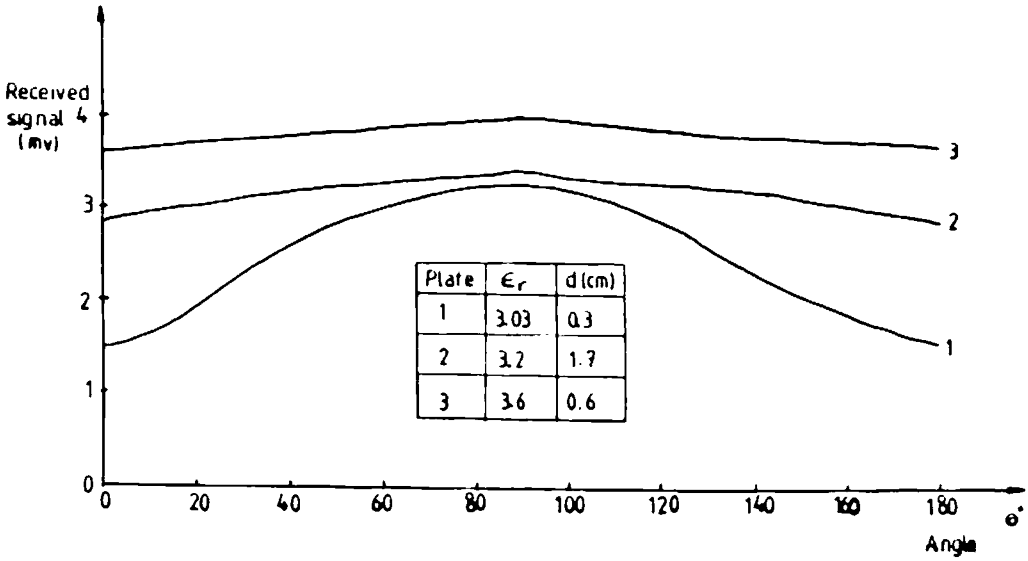

FIG. 3 Variation of the co-polar return from the concealed cylinder

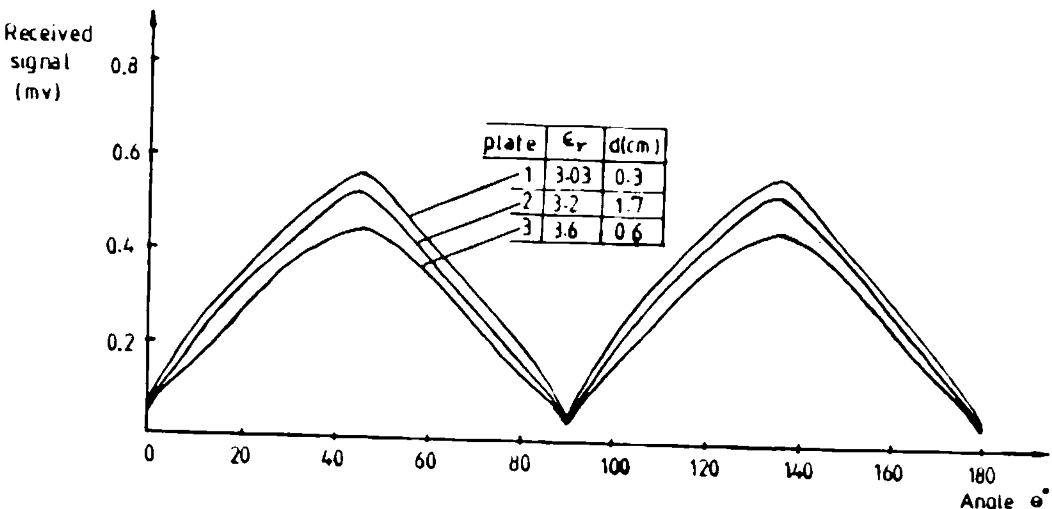

FIG.4 Variation of the cross-polar return from the concealed cylinder