O9-5	**RESONANT CHARACTERISTICS OF ELECTROMAGNETIC SCATTERING FROM PENETRABLE 2-D TARGETS**

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Formulation of the scattering problem

The scattering problem of a 2-D target has been considered in the past by several researchers [1 – 4]. In most of the cases TE or TM excitation from a source located somewhere in the space was used and the appropriate integral equation gave the induced currents and the scattered field.

In the present paper the resonant characteristics for the scattering field are studied. The EFIE formulation is used. Figure 1 shows the geometry of the problem. A line source parallel to the body excites the EM field. The total electric field $\overline{E}^{tot}$ at any point of the underground space can be expressed in the following form:

$$\overline{E}^{tot} = \overline{E}^{i} + \overline{E}^{r} + \overline{E}^{is} + \overline{E}^{rs} \tag{1}$$

$\overline{E}^{i}$ and $\overline{E}^{r}$ are the incident and the reflected on the interface electric field. Correspondingly, $\overline{E}^{is}$ and $\overline{E}^{rs}$ are the scattered from the incident and from the reflected field. By making use of the proper expressions of the field and substituting to equation (1) we have a 2nd kind Fredholm equation with unknown the polarization and the conducting current densities on the scatterer. It is

$$\mathrm{E^i} + \mathrm{E^r} = \frac{\mathrm{J_{eq}}(\mathrm{x},\mathrm{y})}{\mathrm{j}\omega(\varepsilon_2 - \varepsilon_1)} - \frac{jwm_0}{2p} \iint_{CS} J_{eq}(x',y') \left\{ K_0\left(g_2 \left| r - r' \right|\right) + \int_0^{\infty} \frac{R_\perp}{f} e^{-f(2d-x-x')} e^{-jg(y-y')} dg \right\} dx'dy' \tag{2}$$

$J_{eq}(x,y)$ is the equivalent current density placed at the position of the target. K_0 is the modified Bessel function, $R_\perp$ is the reflection at the interface coefficient, $g_2^2 = -w^2 m_2 e_2$, $e_2 = e_0\left(e_{r2} - j\frac{s_2}{we_0}\right)$ and $f^2 - g^2 = g_2^2$.

Solving (2) by using the Galerkin method we can find the $J_{eq}(x,y)$ and from this the scattering field. Our formulation is made in the frequency domain and could be extended in the time domain by using the FFT. In both domains the most interesting thing is the appearance of characteristic resonances. The resonances depend on the depth, the size and the electromagnetic characteristics of the target and the underground. It is obvious that such characteristic properties could help to recognize the geometry as well as the type of the underground targets and could be extremely useful in Applied Geophysics.

Numerical investigation and conclusion

The scattered field in a frequency range up to 500 MHz has been computed. Figure 2 shows the order of resonance as a function of the frequency multiplied by the target depth. For certain characteristics of the target and depth, it was found that there is a linear relation between the above quantities, of the form:

$$y = bn + a \tag{3}$$

where $y = f_0(d-a/2)$, f_0 is the resonant frequency and n is the order of resonace. For a rectangular target of 0.5x1 m with $\varepsilon_1 = 2$, $\sigma_1 = 0.0012$ mS/m, in the earth space with $\varepsilon_2 = 4$ and $\sigma_{21} = 0.003$ mS/m, parameters *a* and *b*, take the values -16.26 and 34.15, respectively.

Similar linear expression could be taken for any combination of target size and characteristics.

In the time domain and the corresponding frequency domain, a gaussian pulse is of the form:

$$v(t) = \exp\left[-a^2(t - t_{\max})^2\right], \quad V(f) = \frac{2\sqrt{p}}{a}\exp\left(-p^2\frac{f^2}{a^2} - jwt_{\max}\right) \tag{4}$$

Via IFFT one can find the response of the target.

The main characteristic in this case is that the response increases with the scatterer cross section and decreases with its depth. It was also found the inverse behaviour of the field, as the dielectric contrast between the earth and the body changes from a ratio less to a ratio more than one. Figure 3 gives in 3-D the normalized backscattered field as a function of the target dielectric constant, ε_1, and frequency. It is evident the dependence of the order of resonance from the frequency. Also, it is shown that the same order of resonance appears in lower frequencies as ε_1 increases.

Concluding, from the numerical computation it was found that the size, the depth and the contrast of the scatterer characteristics over the earth, give different frequency resonance and backscattering field response. Also the gaussian pulse response determines the size and the contrast of the dielectric characteristics of the problem. It is believed that the scattering field in the frequency and the time domain can help in the identification process of a target.

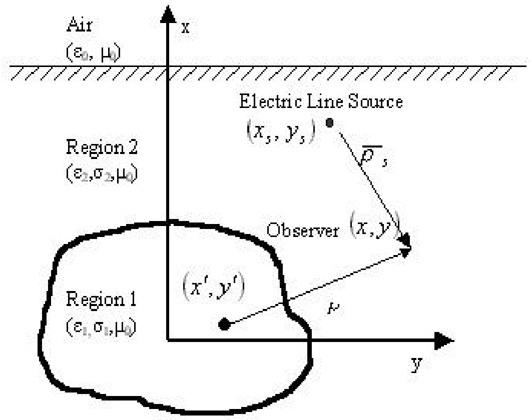

Fig. 1. Geometry of the problem.

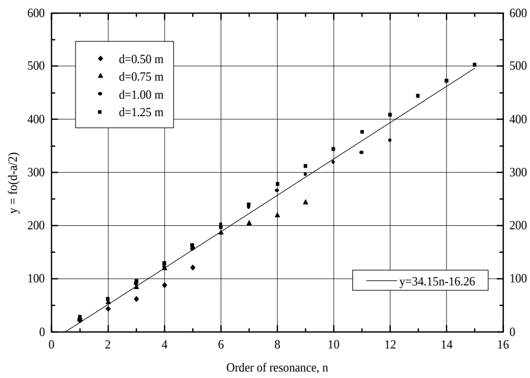

Fig. 2. Order of resonance as a function of frequency multiplied by the target depth.

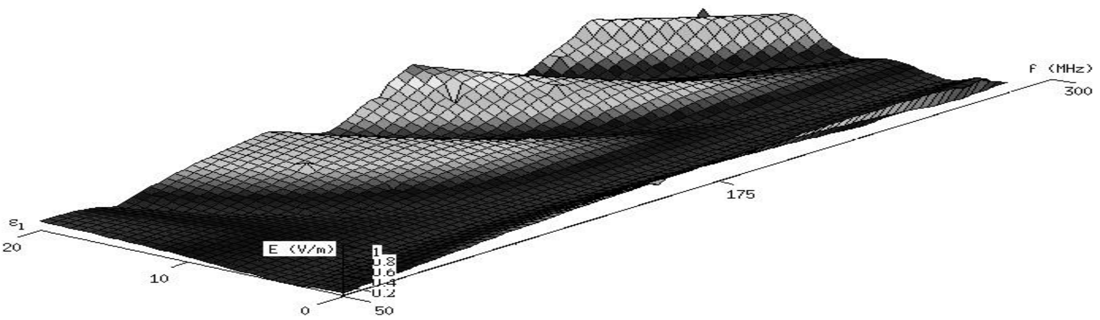

Fig. 3. Normalized backscattered field as a function of å$_1$ and frequency for a target of 0.5x1m with ó$_1$=0.0012mS/m in the earth space with $\varepsilon_2 = 4$, $\sigma_2 = 0.003$ mS/m, in a depth of d=0.5m. Line source is at x_s=d and y_s=0m.

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