IMAGING OF BURIED OBJECTS BY MICROWAVE TOMOGRAPHY METHOD IN CONDITIONS OF LOW REFLECTION ON SURFACE MEDIUM

A.A. VERTIY\(^{(1,2)}\), S.GAVRILOV\(^{(1,2)}\), S. AKSOY\(^{(1,3)}\)

1. TUBITAK-MRC, Turkish-Ukrainian Joint Research Laboratory
   P.O. Box 21, 41470, Gebze, Kocaeli, TURKEY
   alex@yunus.mam.gov.tr, sergy@yunus.mam.gov.tr
2. IRE, National Academy of Sciences of Ukranie, 12 Acad. Proskura St.,
   Kharkov, UKRAINE
3. GIT, Gebze Institute of Technology, 41470, Gebze, Kocaeli, TURKEY
   Saksoy@penta.gute.edu.tr

ABSTRACT

One of the most important problems for imaging of buried objects by microwave tomography method is to reflection from surface. Experiments show that the level of surface reflection is very big. Because of this big reflection from surface, it is very hard to get images from weakly scattered objects like mine etc. if they are buried close to surface. This paper shows that if incident wave is arranged at Brewster angle, surface reflection is decreased and the imaging by microwave tomography method of buried weakly scattered objects like mine etc. are better than at non Brewster angle[1].

TOMOGRAPHIC ALGORITHM

In this part we will briefly consider our approach [2] to the image processing in subsurface the diffraction tomography. The scattered field \( \psi(x, y_i) \) at line \( y = y_i \) (1-D case, Fig.1) can be represented in the form of Fourier integral

\[
\psi(x, y_i) = \int_{-\infty}^{\infty} \hat{\psi}(\nu, y_i) \exp(2\pi \nu \nu) d\nu
\]

where \( \hat{\psi}(\nu, y_i) \) the Fourier image of \( \psi(x, y_i) \) and it is defined as

\[
\hat{\psi}(\nu, y_i) = \phi(\nu) \exp\left[-i \nu \sqrt{k^2 - (2\pi \nu)^2}\right] = \phi(\nu) \exp(-i \nu, y_i);
\]
\( \gamma_1 = \sqrt{k^2 - (2\pi\nu)^2} \); \( k = (\omega/c) \) is wave number of plane wave in free space; \( \omega \) is cyclic frequency; \( c \) is velocity of light. Function \( \varphi(\nu) \) can be written as

\[
\varphi(\nu) = c_1(\nu)c_2(\nu)
\]  
(3)

where

\[
c_1(\nu) = \frac{ik^2 T}{\gamma_1 + \gamma_2};
\]  
(4)

\( T \) is Fresnel transmittance of the boundary between two media with dielectric permittivities \( \varepsilon_i = \varepsilon_{0} \) (air) and \( \varepsilon_2 = \varepsilon_{r2}\varepsilon_{0} \) (\( \varepsilon_{r2} \) is relative dielectric permittivity); \( \gamma_j^2 = k_j^2 - 4\pi^2\nu^2 \); \( k_j = \omega^2 \varepsilon_j \mu_0 + i\omega\mu_0\sigma_j \), \( j = 1,2 \); \( \varepsilon_2, \sigma_2 \) are electrodynamical parameters characterising medium where cylindrical dielectric objects under investigation are embedded; \( \varepsilon_2 \) is dielectric permittivity; \( \sigma_2 \) is conductivity. Function \( c_2(\nu) \) may be written in the integral form

\[
c_2(\nu) = \int[K(x', y')\exp\left[-2\pi i(\alpha x' + \beta y')dx', dy'\right]
\]  
(5)

where

\[
\begin{align*}
\alpha &= \nu - \frac{1}{c} \frac{1}{2\pi} \sin \theta_1; \\
-2\pi\beta &= \sqrt{\left(\frac{\omega}{c}\right)^2 \varepsilon_{r2} - 4\pi^2\nu^2} + i\frac{\omega}{c} 120\pi \sigma_2 + \frac{\omega}{c} \sqrt{(\varepsilon_{r2} - \sin^2 \theta_1)} + i\frac{c}{\omega} 120\pi \sigma_2;
\end{align*}
\]  
(6)

\( \theta_1 \) is an angle of incidence; symbol \( S \) denotes that integration is over the cross section \( S \) of object under investigation; function \( K(x', y') \) represents normalised the polarisation current which is sought for.

Thus desired function \( K(x', y') \) is found by means of inverse Fourier transformation and by function \( \tilde{\varphi}(\nu(\alpha, \beta), y_j) \).

**THE THEORY OF BREVSTER ANGLE**

![Figure 2. Plane wave incident on a dielectric interface](image)

Reflection coefficient between two medium with relative dielectric constans \( \varepsilon_0, \varepsilon_r \) in figure 2 for the case of parallel polarization are introduced according to the following equation,
\[ \eta = \frac{(\varepsilon_r - \sin^2 \alpha_1)^{1/2} - \varepsilon_r \cos \alpha_1}{(\varepsilon_r - \sin^2 \alpha_1)^{1/2} + \varepsilon_r \cos \alpha} \]  

(8)

An important feature of \( \eta \) is that it vanishes for an angle of incidence \( \alpha_i = \alpha_b \), called Brewster Angle, where from reflection coefficient equation, can be found as follow,

\[ \alpha_b = \arcsin \left( \frac{\varepsilon_r}{\varepsilon_r + 1} \right)^{1/2} \]  

(9)

At this particular angle of incidence all the incidence power is transmitted into the dielectric medium. In fig 3, the reflection coefficient \( \eta \) is plotted as a function of \( \alpha_i \) for polystyrene, for which \( \varepsilon_r = 2.56 \).

![Figure 3. Modulus of reflection coefficient \(|\eta|\) dependence on incidence angle on a dielectric interface for \( \varepsilon_r = 2.56 \).](image)

EXPERIMENTAL SETUP.

In our case, objects such that different kinds of mines, metals etc. are buried in sand and general viewing of this subsurface experimental setup are given in figure 4.

![Figure 4. Experimental setup for the investigations of buried objects.](image)

According to figure 3, receiving and transmitting antennas are moved by scanner to get scattered field data for diffraction tomography processing. In our case, transmitting antenna is arranged at Brewster
angle, which is obtained 50 degree experimentally for soil. Brewster angle of soil is calculated theoretically and drawn graphics in figure 5.

![Brewster Angle Measurement](image)

Figure 5. Brewster angle calculation for soil (theoretically).

EXPERIMENTAL RESULTS

Two experimental results are given in fig.6 and fig.7. Fig 6. shows the image of buried mine at 60 degree which is not Brewster angle for sand. Fig 7. Shows the image of buried mine at 50 degree which is Brewster angle for sand. If one compares these results, it is clear that at Brewster angle, reflection from surface is decreased and reflection from object is increased according to non-Brewster angle.

![Reflection](image)

Fig. 6. The image of buried mine at 60 degree (non Brewster angle)

![Reflection](image)

Fig. 7. The image of buried mine at 50 degree (Brewster angle)

REFERENCE


2. Vertyi A.A., Gavrilov S.P., "Microwave imaging of cylindirical inhomogeneties by using a plane wave spectrum of diffracted field", Second International Conference the detection of abandoned land mines, Conference publication No: 458, pp. 91-95, IEE 1998, Edinburg, UK