CHAPTER 8

Conclusion and Future Work

In this chapter, the conclusion made out of present work and limitations associated with the same, are presented in order to gain better understanding of the use and implementation of a GPR system for the land mine classifications based on neural network.

In addition future work to be carried out to overcome above limitations and to improve the operational aspects of GPR are also presented [17].

8.1 Conclusion

The appropriate frequency window for the GPR operation, extends from 2 MHz to 1 GHz, for the land mine identification was established using a generalized theoretical model. These results are also in agreement with the practical observations.

Estimating important system parameters of GPR are evaluated and the required peak voltage of the PMC signal for a detecting a land mine at a distance of 30 cm, is around 25 V. A technique for evaluating the buried distance of the object is presented.

By using an analytical approach it was shown that appropriate modulation technique for land mine detection is the PMC.

A GPR model which is capable of estimating received signal levels for a given soil attenuation, operating frequency, buried distance and dielectric properties of the buried object, was developed. By using this model, data for network training and simulation for the range of soil condition, were generated.

It has been shown by simulation that BPN can be used to classify Metal and Plastic land mines, subsequent to following proper training practices.

8.2 Future Work

The satisfactory operation of the GPR based on EM system, used for the target classifications, depends mainly on the presence of dielectric discontinuity between surrounding soil and the object. The system will fail to receive the target reflected signal when this discontinuity is absent.

In generating the data for network training and simulation, possible error variations were not treated. By carrying out network training and simulations with introducing error variations, more accurate results can be achieved.

In developing the GPR model, it was assumed that soil has uniform electrical and magnetic properties. In practice, soil properties varies with depth. To predict the received signal accurately in this situation, FDTD model is proposed.

The data generated by using above model is free from noise arising as result of discontinuities of the soil properties and the clutter effect. Therefore, to obtain the realistic results data generated by the FDTD model should be used for the BPN.

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APPENDIX A

Back Propagation Network

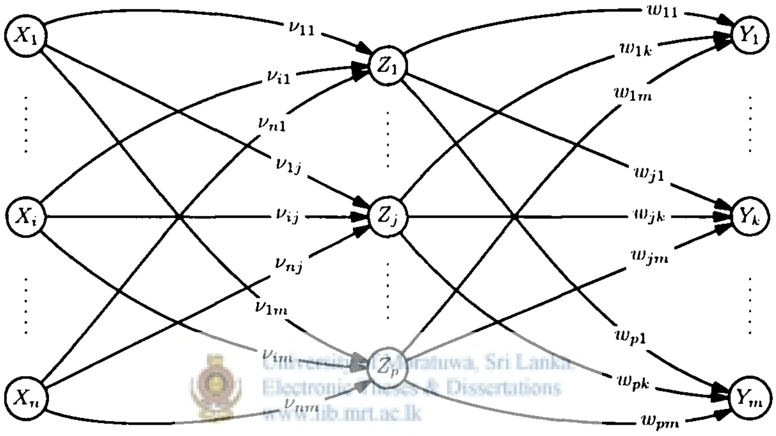

Figure A.1: Three layered BPN architecture

Figure A.1 shows a three layer back propagation network(BPN) architecture. It is a layered feed forward network that is fully interconnected by layers. Thus there is no feedback connection and no connection that bypass one layer to go to a latter layer [12].

The main desirable feature of this BPN is that the network can be trained for the predetermined set of input-output pairs by using a two phase propagate adapt cycle. When input pattern is applied to input layer of the input units, it propagates through each upper layer until output is generated. This output pattern is then compared to the desired output and an error signal is computed for each output units. These computed error signal are propagated backward and weights in each intermediate layers are adjusted such that error generated by each node of intermediate layers is minimum.

During the training process, the nodes in the intermediate layers organize themselves such that different nodes learn to recognize different features of the total input data patterns.

This trained BPN gives desirable output when new data which are not in training data space, presented to the network input.

APPENDIX B

Intrinsic Impedance and Skin Depth

B.1 Instrinsic Impedance η

For a lossy dielectric medium, the intrinsic impedance (η) is given by the equation (B.1) [8]:

$$\eta = \sqrt{\frac{\mu_0}{\epsilon_0}} \sqrt{\frac{\mu_r}{\epsilon_r \left[1 - j\frac{\rho}{(\omega\epsilon_0\epsilon_r)}\right]}}\ \Omega \tag{B.1}$$

The term $\sqrt{\frac{\mu_0}{\epsilon_0}}$ is known as the impedance of the free space and is equivalent to 377 Ω. Assuming soil is free from magnetic properties then μ_r can be taken as 1.

Then above equation(B.1) can be simplified as:

$$\eta = 377 \sqrt{\frac{1}{\epsilon_r \left[1 - \frac{j\rho}{2\pi f \epsilon_0 \epsilon_r}\right]}}\ \Omega \tag{B.2}$$

For a given frequency and known electrical and dielectric properties of the soil, equation (B.2) can be used to calculate the intrinsic impedance of the soil.

B.2 Skin Depth D_s

The propagation of EM signal in a lossy dielectric medium is characterized by the equation(B.3) [8].

$$E = E_0 e^{-\alpha z} e^{j(\beta z - \omega t)} \tag{B.3}$$

Where:

E	Instantaneous signal strength (V/m)
E_0	Incident signal strength (V/m)
β	Phase shift coefficient (rad/m)
z	Distance travelled by the wave (m)

The skin depth D_s as defined in Section (2.2.2), is given by the equation (B.4).

$$D_s = \frac{1}{\alpha} \tag{B.4}$$

α can be expressed by the expression [8] (B.4).

$$\alpha = 2\pi f \sqrt{\frac{\mu\epsilon'}{2}\left[\sqrt{1+\left\{\frac{\epsilon''}{\epsilon'}\right\}^2}-1\right]} \tag{B.5}$$

Where, $\epsilon' = \frac{\rho}{\omega}$ and $\epsilon'' = \frac{\rho}{\omega}$

Substituting for α, the equation (B.4) yields:

$$D_s = \frac{1}{2\pi f}\left[\frac{\mu_r\mu_0\epsilon_r}{2}\left[\sqrt{1+\left(\frac{\rho}{2\pi f\epsilon_0\epsilon_r}\right)^2}-1\right]\right]^{-\frac{1}{2}}. \tag{B.6}$$

The equation (B.6) can be used to find the skin depth for a given frequency and electrical and dielectric properties of the soil.

APPENDIX C

Mathematical Analysis of GPR

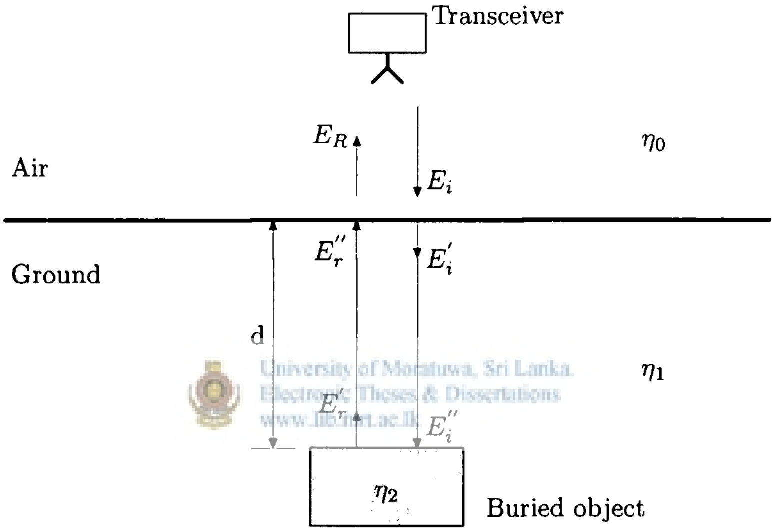

Figure C.1: Propagation of signal in GPR at a presence of a buried object

Figure (C.1) depicts propagation of RF signal in soil at the presence of a buried object. The transceiver transmits a RF signal having a intensity of E_0 towards the ground.

The propagation of the RF signal through the dielectric medium [8] (pp.326) is characterized by the equation (C.1).

$$E = E_0 e^{-\alpha z} \tag{C.1}$$

Where,

E	Instantaneous signal strength (V)
E_0	Transmitted signal strength (V)
z	Distance travelled by the EM wave (m)

The signal attenuation through the air is negligible. Then incident signal level E_i on the ground can be approximated as E_0.

At the air-ground interface the signal is subjected to both transmission as well as reflections. The signal strength of the transmitted signal E_i towards the ground, is given by the expression(C.2).

$$E_i^{'} = \tau E_i \tag{C.2}$$

Where τ is transmission coefficient from air to ground interface. The τ is characterized by the equation (C.3).

$$\tau = \frac{2\eta_1}{\eta_0 + \eta_1} \tag{C.3}$$

This signal propagates towards the buried object. Using the equations (C.1), (C.2) and (C.3), the incident signal on the buried object $E_i^{''}$ can be expressed by the equation (C.4).

$$E_i^{''} = E_0 e^{\alpha d} \left[\frac{2\eta_1}{\eta_0 + \eta_1} \right] \tag{C.4}$$

This signal is again subjected to the reflection at the surface of the buried object. The reflection coefficient ρ for ground - surface of the object is given by the equation (C.5).

$$\rho = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \tag{C.5}$$

Then the reflected signal by the object E_r^{1} can be expressed as:

$$E_r^{'} = E_0 e^{-\alpha d} \left[\frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \right] \tag{C.6}$$

This signal propagates towards the air-ground interface with travelling the distance x. The incident signal strength on the ground-air interface $E_r^{''}$ is given by the equation (C.7).

$$E_r^{''} = \rho E''_r \tag{C.7}$$

Substituting from equations (C.5) and (C.6), equation (C.7) becomes as:

$$E_r^{''} = E_o{}^{-2\alpha d} \left[\frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \right] \left[\frac{2\eta_1}{\eta_0 + \eta_1} \right] \tag{C.8}$$

At the ground-air interface, signal is again subject to transmission as well as reflections. The transmission coefficient for ground-air interface ρ^{1} is given by the equation (C.9).

$$\rho^{'} = \frac{2\eta_0}{\eta_0 + \eta_1} \tag{C.9}$$

The transmitted signal towards the ground E_R is given by the equation (C.10).

$$E_R = \rho^{'} E_r^{''} \tag{C.10}$$

Substituting for $\rho^{'}$ and $E_r^{''}$ equation (C.10) yields

$$E_R = E_0 e^{-2\alpha d} \left[\frac{2\eta_1}{\eta_1 + \eta_2} \right] \left[\frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \right] \left[\frac{2\eta}{\eta_0 + \eta_1} \right] \tag{C.11}$$

The equation (C.11) helps to find the signal strength of the target reflected signal.