Underground Radio Signal Attenuation at 109.8 MHz

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Abstract: Underground radio propagation measurement is an interesting work as its application very much helping on enabling radio through the earth (TTE) application. TTE enablesunderground work to communicate with people on surface. The ground consists of various materials rapidly degrading signal level. This paper performs an experiment to enable frequency of 109.8 MHz to be used as radio to the earth application. The mathematical model is used to predict the attenuation pattern. However, as model proposed by different measurement places, an experiment by measuring directly to ground attenuation is conducted to confirm the model precision. The measurement shows significant error up to 16.18%, which results some parameters adjustment on the model. By adjusting the earth parameter, error is reduced to 11.17%.

1 INTRODUCTION

Radio signal passes underground experiencing various scattering, absorption and signal dispersion which results significant signal attenuation.Signal attenuation is even worse when frequency is higher. Some underground applications employsvery high frequency (VHF) band as its attenuation is acceptable and capacity is permissible (Vuran, 2010). In order to predict attenuation level, mathematical model is employed. However, as model used in different location, experiment validation should be performed (Akyildiz, 2009). Despite the simplicity of experiment reported by this paper, TTE application for available 109.8 Band is not yet reported. This work is to make sure this frequency is suitable enough for the forthcoming TTE design.

The famous earth attenuation model was proposed by Friis (Fauzi and Maulana, 2017) as described by Equation 1. The higher frequency, the higher the loss. To obtain acceptable threshold level in the receiver, transmitting power should be high enough. In order to do so, loss signal should be correctly predicted. The correction factors which include earth dispersion, absorption and scattering are added (Equation 2) (Akyildiz, 2007).

$$L(dB) = 32{:}4 + 20\log(d) + 20\log(f) \quad (1)$$

$$L(dB) = 6.4 + 20\log(d)(m) + 20\log(\beta) + 8.69\,\alpha d \quad (2)$$

The attenuation parameter is represented by α, the shifting of signal phase is adjusted by using β. Both parameters are varied to the type of ground as the earth dielectric changes frequently depending the materials. The values are approximated by Peplinski using permittivity and permeability measured directly fromthe ground materials (Li, 2007).

$$\alpha = \omega\sqrt{\frac{\mu\epsilon'}{2}\left[\sqrt{1+\left(\frac{\epsilon''}{\epsilon'}\right)^2}-1\right]} \quad (3)$$

$$\beta = \omega\sqrt{\frac{\mu\epsilon'}{2}\left[\sqrt{1+\left(\frac{\epsilon''}{\epsilon'}\right)^2}+1\right]} \quad (4)$$

The permeability of the measured ground sample is relatively closed to μ_0.So the value of μ_0 is set to one (Mietzner, 2012).

2 EXPERIMENT DESIGN

The following is the experiment design to validate the Friss model that is used for predicting signal attenuation on TTE working on 109.8 MHz. Signal

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generator is devised by using a transistor performing an oscillating circuit as illustrated in Figure 1 (Mietzner, 2012).

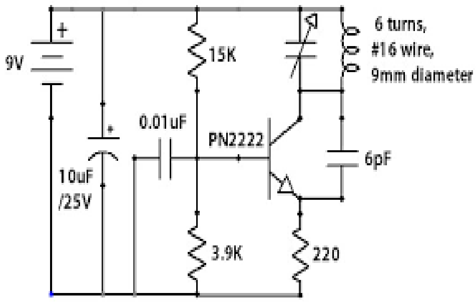

Figure 1. 109.8 MHzoscillator

The LC circuit tank consisting of C1 and L1 are combined to genera tesignal on 109.8MHz.By switching on the transistor Q1, the multifrequency signals is generated. The tuned circuit LC adjusts which frequency is feedbacked to the basis of the transistor.

This signal is repeatedly amplified until stability is obtained. The desired frequency has enough amplitude level to be radiated by a wire antenna that is connected inbetween inductor and capacitor.

To activate the signal generator, a two-diodes adaptor circuit is assembled as shown in Figure 2. To enable increasing transmitting power level, output voltagesare set to be adjustable from 6 volt to 9 Volt.

Figure 2. Transmitter and power supply modules

In order to analysis the received power, a vector network analyser that work as frequency spectrum analyser is used (Figure 3). A monopole wire antenna with length of 1/8 λ isconnected each to transmitter and to network analyser.

The total antennalength of 27.317 cm made by wire is devised as the system antennas. The measurement point is set as shown in Figure 4.

Figure 3. Network analyser

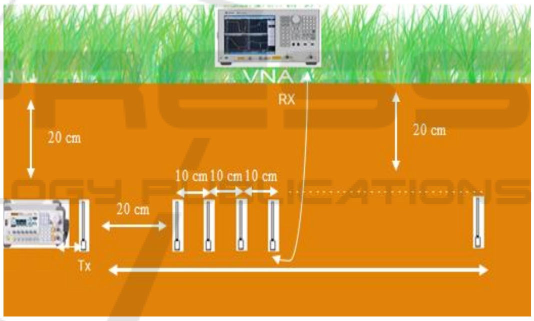

Figure 4. Measurement plan

The ground material samplesare rocky with small stones mixed with the dirty ground. The location of monitoring is in Electrical Engineering Building within Universitas Sumatera Utara.

For the analysis purpose, the dielectric parameters are approximated by employing those in Table 1 (Sadeghioon et al., 2017).

Table 1. Dielectric parameters

Type	ε'	ε''
Ground with mud and stone	6.53	1.88

3 RESULTS

The results of attenuation measurement in dBm are depicted in Figure 5. The signal received by the VNA degrades as distance increases. Signal decreases from about -35 dBm at 20 cm to -80 dBm at 2 m This means that signal attenuation is about 20dBm/m.

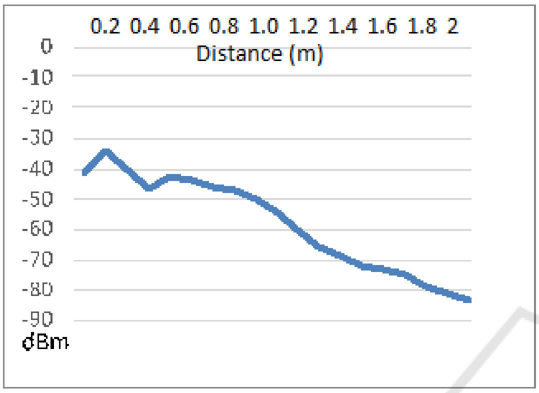

Figure 5. Measurement data

By applying Friss mode using the aforementioned equations and the ground parameters of α = 0,000503548 and β = 0,002038259, the attenuation is plotted as in Figure 6.

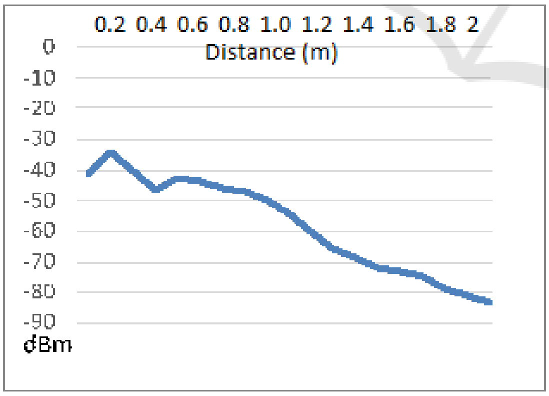

Figure 6. Mathematical analysis

Both results show the same pattern, decreasing signals to increasing distance. The values are then compared as shown in Figure 7. The average error obtained from the experiment and the model is quite high, 16.18%. This pattern error is primarily caused by the error on the earth parameters.

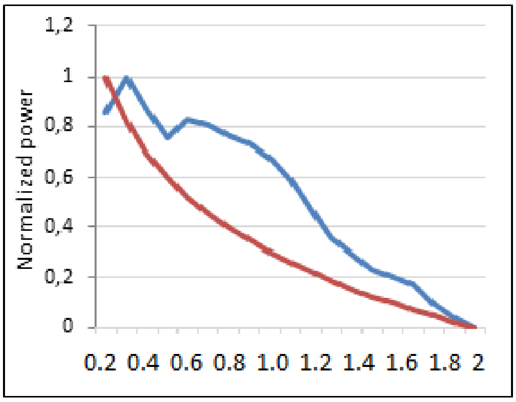

Figure 7. Pattern comparisons

By adjusting the parameters of ground dielectric from 20 (Figure 8a), 30 (Figure 8b) and 50 (Figure 8c), error can be minimized up to 11.17%.

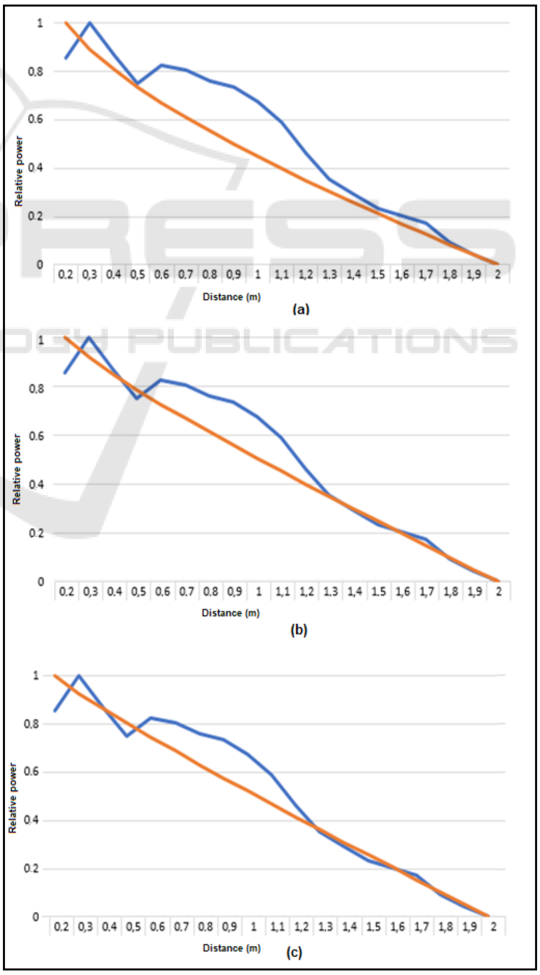

Figure 8. Adjustment results

4 CONCLUSIONS

This articleexamined signal attenuation by the earth by means of measurement and mathematical model. Signal attenuates as distance increases. In average, signal degradation is about 20dB/m. After evaluating the model by using direct measurement, the error of both model and measurement is 16.18% in average. Error can be decreased up to 11.17% by adjusting the ground dielectric parameter, which is the most important thing to get the precise model.

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