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PROPAGATION STUDY OF GSM FREQUENCIES THROUGH FOREST

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Abstract - This study investigates the attenuation characteristics of GSM (2G, 3G, and 4G) frequencies, which is important for the determination of coverage areas in the forest. Some theoretical models from the literature were studied and simulated. The loss and electrical field of the transmitted signal were measured in the woodland of Sakarya. Our results were compared with the literature and experimental datagood agreement was found.

Keywords - Attenuation, GSM, Propagation Models,Coverage areas.

I. INTRODUCTION

The increasing demand for clear communication in any situation and any environment leads people to find a better way to communicate. Nowadays, it is used in the field of military and civilian services such as; TV remote control, Wi-Fi, cell phones, power transfer, surveillance, etc. One of the hardest environments is forested areas. The presence of tree canopies can affect the ability of GSM signals through its way. Because of the physical extent of trees above the ground surface, they can reduce the signal. In order to find a better way to communicate, the propagation features of the environment should be known. The whole forest, a line of trees or a single tree canopy have major effects on the quality of the signal. As a general view, frequency, randomly settled leaves, branches, and the size and shape of trunks may cause attenuation on the received signal. The total fields in the medium are formed by coherent and diffuse parts. The coherent fields are the forward scatters which pass through the leaves or trunks, whereas the diffuse part is known as back scattering. During the propagation, coherent fields dominate at first, but absorption in leaves and trunks decrease its effect [1-7].
In this paper, we performed experiments on the complexity of forest environment at GSM signals. Tree species, distribution of leaves, geographical position, and many other aspects may change the experimental results.

II. BACKGROUND

Rogers[8] worked on radio propagation through vegetation with generic model of 1-60 GHz. His measurements were made at twelve locations in England, including eight species of trees, both in-leaf and out-of-leaf which includes different type of vegetation geometries. Narrowband measurements were made between 2 and 18 GHz (at 0.5 GHz intervals) and wideband measurements were made with 31 MHz bandwidth at 1.3, 2.0, 11.2 GHz and with 120MHz bandwidth at 2.2, 2.4, 37.5 and 61.5 GHz. The generic model combines the effects of three individual propagation modes: diffraction from the side and top of the foliage, ground reflection and direct (through vegetation) propagation. The direct (through vegetation) ray is modeled using the theory of Radiative Energy Transfer (RET) which accounts for both scattering and absorption. RET predicts the attenuation vs. foliage depth using parameters to describe the absorption and scatter cross-sections, albedo, and scatter function (phase function) of the vegetation.
Al-Basheir [9] work on propagation measurements which were carried out to investigate the excess attenuation of radio signal at 2.1 GHz through Date Palm trees in North of Abu Dhabi city, United Arab Emirates (UAE). The obtained experimental results have been used to evaluate some existing vegetation attenuation models, Exponential Decay (ED) and Maximum Attenuation (MA) models. The measured data is also used in further analysis to obtain the MA model parameters values given in the International Union Radio Recommendation (ITU-R). The results obtained by the present models are in good agreement with published results.
The excess vegetation attenuation due to the Date Palm trees has been investigated at 2.1 GHz in the North of Abu Dhabi city, UAE under typical semi-desert conditions. The measured data were used to evaluate the performance of the Exponential Decay (ED) and the ITU-R Maximum Attenuation (MA) models. The (ED) model gives an RMS error equal to 5.97 dB against the measured data. The ED model's parameters are modified, and the modified model gives an RMS error equals to 3.66 dB against the measured data. Furthermore, the measured data used to obtain the best ITU-R model (MA) parameters values related to semi-desert enlivenment. A comparison between the ITU-R model parameters values yield based on measurement carried in Brazil, France, and UAE shows an RMS equal to 10.60 dB for Brazil values, 4.37 dB for France values and 3.59 dB for UAE Data against the measured data.

Seker [10] investigated the forest with radio frequency propagation model. The forest is modeled using discrete method where incoherent waves dominate over coherent waves. Tree trunks, branches, and needles are characterized by randomly oriented, lossy dielectric cylinders. Leaves are characterized by dielectric discs. The scatterer orientation and distribution are prescribed. The biophysical input parameters to the model are gathered from an experimental site. Theoretical attenuation based upon the biophysical parameters of vegetation is compared with measured values for both horizontal and vertical polarization and excellent agreement is obtained. The forest is considered as an unbounded medium of randomly oriented and positioned homogeneous canonical scatterers representative of various vegetative components. For this case, a simple plane-wave solution to the mean-wave equation can be found. They found out that multiple component model allows a sophisticated and realistic representation of forest attenuation. Comparison with data from the Florida campaign, where all the required parameters were carefully measured, show the model performs well with good quality input data. The numerical results show that the intensity of incoherently scattered fields increases relative to that of the coherent (mean) field with increasing distance from the source and with increasing frequency. Thus, incoherent fields within the forest will be the dominant propagation mechanism at S-band and above. The rate of attenuation naturally varies with the density of the woods and the degree of undergrowth. It is greater for trees in full leaf than for bare trees and increases when foliage is wet. Around S-band, there is little difference in the loss rate between horizontally and vertically polarized waves. During experiments, we observed that increasing the antenna height generally reduces the propagation loss. This is particularly true, as expected, when the height of both antennas exceeds the height of the foliage.

Joshi [5] did his Near-ground channel measurement over line-of-sight and forest path. Near-ground radio-wave propagation is of interest for emerging military applications such as battlefield sensor networks and for wireless communication between dismounted soldiers. Narrowband and wideband channel measurement results at 300 and 1900MHz are presented for near-ground propagation, characterizing the effect of antenna heights, radiation patterns and foliage environments. An additional set of channel measurements was performed to study the effect of rain on near-ground propagation at 1900MHz in a forest environment. Measured power–delay profiles indicate significant multipath propagation with the multipath components becoming stronger relative to the direct path for decreasing antenna heights. In the LOS measurements, the RMS delay spread decreased with the use of directional antennas and increasing antenna heights, and increased with distance. This effect was not evident in the forest measurements, suggesting a larger angle spread of the multi paths. Foliage effects are more significant at 1900MHz than 300MHz Results from near-ground sensor measurements demonstrate that path loss varies inversely with the square of the receiving antenna height, as in the plane-Earth and Egli models [11].

III. EMPRICAL MODELS

At VHF and lower frequencies, a vegetative medium can be considered as a homogenous slab because wavelengths are large compared with the scattering elements, and the effects of the scatterers are averaged or smoothed to approximate a homogenous medium. However, this is not true for the electromagnetic waves in the frequency range of UHF and above. Thus, it appears that any agreement obtained between experimental results and predictions of a theory with the forest as a homogenous medium at frequencies above 400 MHz could be coincidental.

3.1. Models

There are many models to characterize foliage loss which is conducted at microwave and millimeter waves. Here are some propagation models;

3.1.1. Weissberger Model

Weissberger's model is a path loss estimation method that occurs from the presence of one or more trees. The model is useful between 230 MHz and 95 GHz with a foliage depth of 400m.

$$L_{\mathrm{W}}(\mathrm{dB}) = \begin{cases} 1.33 f^{0.284} d^{0.588}, & 14\text{ m} < d \le 400\text{ m} \\ 0.45 f^{0.284} d, & 0 \le d < 14\text{ m} \end{cases} \quad (1)$$

where L_{W} is the vegetation loss in dB, $f$is the frequency in GHz, and d is the depth of the trees in meter. This model is generally used in microwave transmission. There has to be an obstacle between the Tx and Rx. The model is useful where the path is blocked by dense, dry, and leafy trees [2,9].

3.1.2. ITU-R Model

$$L_{\mathrm{ITU\text{-}R}}(\mathrm{dB}) = 0.2 f^{0.3} d^{0.6} \quad (2)$$

where f is the frequency in MHz This model is useful for UHFs and d< 400m so that majority of the signal propagates through trees [9].

3.1.3. COST 235 Model

$$L_{\mathrm{COST}}(\mathrm{dB}) = \begin{cases} 26.6 f^{-0.2} d^{0.5}, & \text{out of leaf} \\ 15.6 f^{-0.009} d^{0.26}, & \text{in leaf} \end{cases} \quad (3)$$

This model is useful at 9.6GHz to 56.7GHz (millimeter wave frequencies) with d< 200m, f is the frequency in MHz. In this model, measurements should be done in two seasons which the trees with leaf and without leaf [9].

3.1.4. FITU-R Model

$$L_{\text{FITU-R}}(\text{dB}) = \begin{cases} 0.37 f^{0.18} d^{0.59}, & \text{out of leaf} \\ 0.39 f^{0.39} d^{0.25}, & \text{in leaf} \end{cases} \quad (4)$$

This model is appropriate the frequencies at 11.2 and 20GHz with d<120m, f is the frequency in MHz.

3.1.5. Free Space Attenuation Model

From Friis equation (2) we get;

$$L_f(\text{dB}) = G_t(\text{dB}) + G_r(\text{dB}) + 147.56 - 20\log(f \cdot d) \quad (5)$$

where G_t and G_r are gain of the antennas in dBi, f is Hz and $d$is in m. This is loss of signal in free space without obstacle.

3.1.6. Plane Earth Model

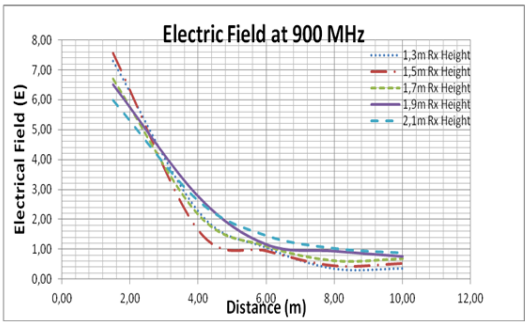
Modification of the Friis Eq. gives the Plane EarthPropagation model;

$$L_{\text{PE}}(\text{dB}) = G_t(\text{dB}) + G_r(\text{dB}) + 20\log(h_r h_t) - 40\log(d) \quad (6)$$

where h_r and h_t are heights of the transmitter and receiver from the ground in meters d is the distance between transmitter and receiver in m and G_r and G_t are gain of the transmitter and receiver antennas in dBi with respect to isotropic antenna.

IV. NUMERICAL AND EXPERIMENTAL STUDIES

The numerical simulations are done according to models that we mentioned in section 3. Distance between transmitter and receiver antenna is taken from 0m to 12m for each GSM(2G, 3G,4G) frequencies. MATLAB simulation program is used to simulate the models. The experiment took place in the woodland of the Sakarya. The experimental area has the trees with short and thin trunk and high amount of leaves so that we had multilayer of leaf obstacles. The 5 samples are taken within 10m distance and 5 different Rx height. To avoid ground effect as much as we could, Tx is located at 1.5m height from the ground. The day was sunny and clear, but days before the test were rainy so the leaves, trunks and ground was wet which may affect the results.



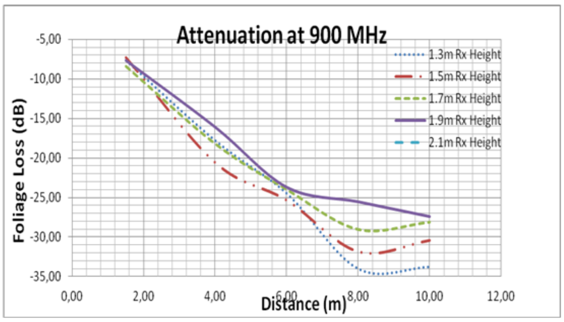


Figure 1 (Top) electrical field and (bottom) attenuation at 900MHz

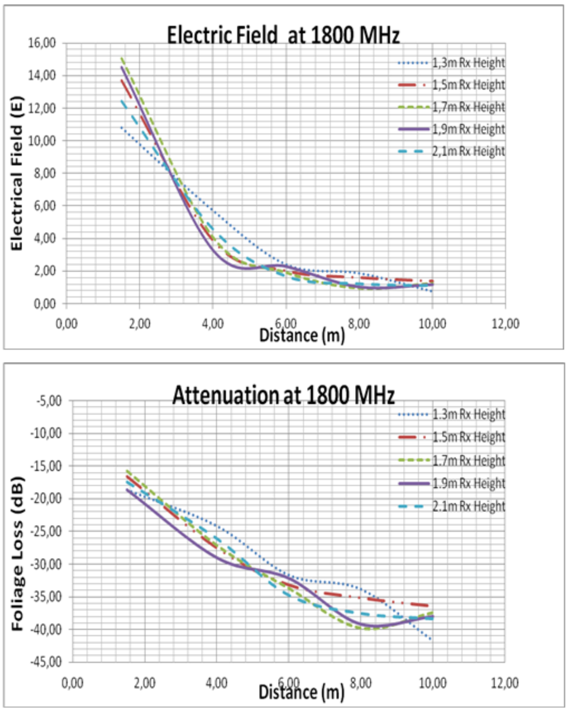


Figure 2 (Top) electrical field and (bottom) attenuation at 1800MHz

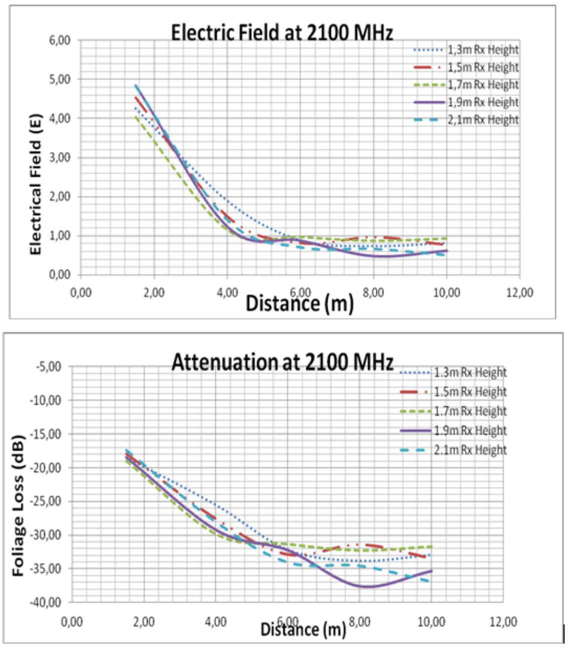


Figure 3 (Top) electrical field and (bottom) attenuation at 2100MHz

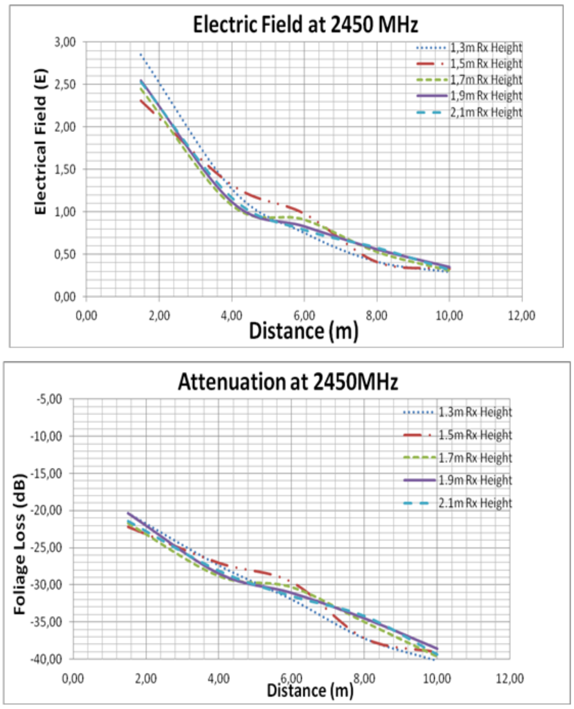


Figure 4 (Top) electrical field and (bottom) attenuation at 2450MHz

CONCLUSIONS

As it is seen in the Fig.5, the results of this work are compared with introduced models and literature data from Al-Basheir [9]. COST-235 Model is the most accurate one among the introduced models. Also, the literature data is a bit different since the parameters are totally different. My test area doesnot fit with other models in terms of environment, frequency and distance. Also, external effects are important in the outcome. For comparison with the model, Root Mean Square Error In our results, ITU-R RMSE = 26.2 dB, COST-235 RMSE = 7.56 dB, Weissberger RMSE = 28.7 dB, and FITU-R RMSE = 19.5 dB. So, it seen here that only the COST-235 Model is within the range. On the other hand, PE RMSE = 7.11 dB and Friis RMSE = 4.23 which fit RMSE range.

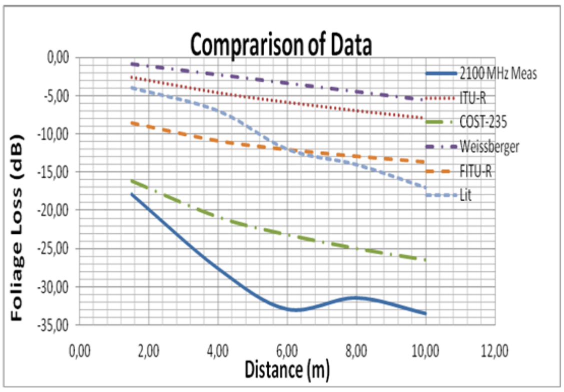


Figure 5 Comparison with models and literature

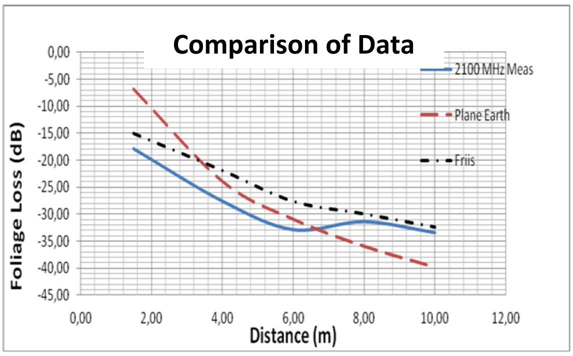


Figure 6 Comparison with Models

In Fig.6, our results were compared with Friis Equation and Plane Earth Model. As it is seen, earth effect dominates the field since our equipment were close to the ground. The ground was soil and it was wet, but some parts of the ground had leaves. Therefore, it is hard to make conclusion on PE model. To observe the propagation better, there should be more distance and Tx-Rx heights so that reflection or attenuation on the ground will be observed more clearly. As it is said, the test scenario was changed due to seasonal change and weather conditions. Therefore, there are some jumps in the results since the leaves were too intense in some parts of trees but not the other parts. Also, leaves and soil were a bit wet due to rain a day before which is an important effect on propagation. The literature outcomes and our work do not match some points due to various reasons like; humidity, leaf distribution, tree types, leaf intensity, terrain effect, and so on.

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