ExperimentalPropagationStudyfor 2G, 3G, and 4G Frequencies

Fulya Callialp Kunter[1,2], Saban Selim Seker[3], Elif Surmeli[3], Osman Cerezci[4]
[1](ElectricalandElectronicsEngineeringDepartment, Marmara University, Turkey)
[2](ElectricalEngineeringDepartment, ChulalongkornUniversity, Thailand (on sabbaticalleave))
[3](ElectricalandElectronicsEngineeringDepartment, BogaziciUniversity, Turkey)
[4](ElectricalandElectronicsEngineeringDepartment, Sakarya University, Turkey)

ABSTRACT : *Nowadays, there has been an increase and dependent items that affect the quality of the signals such as the properties of substances in the buildings, objects and humans' movements, electronic equipment. In this study, the effects of electromagnetic interference on the functional usage of mobile communications are examined. The indoor and outdoor attenuation characteristics of 2G, 3G and 4G frequency bands are investigated. Field strength measurements are conducted in university campusopenarea, along a corridorfield in a fivestoreyuniversitybuilding, in different floors, and rooms, where normal incidence on plane boundary is of main concern. This study investigates multilayer model for building structures. The evaluation of measured values together with the simulated results is compared with literature outcomes. In addition, dependency with the frequency, power of the waves and existence of trees on the transmission path are also discussed.*

KEYWORDS *-Attenuationcharacteristics, electromagneticpropagation, fieldstrengthmeasurement,transmissionpath.*

I. INTRODUCTION

Thegreatsuccess of mobile communications encouraged the researchers to study, either statistical or theoretical, on the indoor radio propagation, which was shown to be very complex and dependent on variousfactors, whichcauseinterference, attenuationandfluctuations in signalstrength [1-7]. Investigation of indoor propagation characteristics cover many situations in which they differ in the properties of construction materials, moving individuals, furnishings, architectural configurations etc. Therefore in order to provide services with good coverage and efficiency, the characteristics of indoor propagation for mobile communication must be investigated in different environments and conditions. For instance in the healthcare domain, the increase in the use of cellular developments prompt the researchers concern about the interference problems. Many studies reveal that 2G/3G/4G LTE cellular phones exposures effects the function and operation of medical devices [8-17]. In these publications they find out that the clear distinction between 2G , 3G and 4G cellular phones is that the peak power emitted by 3G and 4G cellular phones are much lower (max. 1 W) compared to the corresponding value issued by the 2G phones.

Propagationprediction has been an important subject for the design of mobile communications systems. In order to provide efficient and reliable coverage of services, understanding the factors that influence signal strength and determining the parameters of radio system is very important. ElgannasandKostanic [18] have studied the propagation characteristics for both indoors and outdoors at 850 MHz and 1900 MHz frequencies. The penetration loss of four different buildings are examined and concluded that building penetration loss may not be depend on the operating frequency. Evaluation and analysis of 3G network in Lagos, Nigeria has beenconductedbyAkinyemi et al. [19]. Receivedsignalcodepower, Ec/No service quality, speechqualityindex, transmittingpower and path loss are the parameters measured in the study. In 2016, RodriquezLarrad [20] analysisexploredthepenetration loss at normal incidence for the frequency range from 800 MHz up to 18 GHz for several modern constructions in comparison with an old building. From the measurement results, it is observed that the attenuation experienced in all the different scenarios is material dependent. A set of dedicatedmeasurementswereperformed along several corridors in shopping malls and modern and old constructions in order to characterize the different indoor propagation contributions. The attenuation from the indoor walls was found to present very small frequency dependence.

Subsequent studies showed that not only the existence of floors or the distance between the receiver and transmitter but also the existence of obstacles, features of construction materials, architectural configurations and many other factors had significant influence the path loss [7]. For this reason path loss models [21] have been modified multiple times and propagation parameters have been improved according to measurement data. Hence approximate numerical approaches based on theory have been of interest. In particular, ray tracing, which is a nice method for calculating radio signal strength, propagation parameters in an indoor environment, is based on Fresnel equations and uniform/general theory of diffraction. Inyears, manydifferent ray-tracingapproacheshavebeendevelopedformodelingindoorwavepropagationandpenetration [3, 22].

Numerous studies include comparisons between the path losses from propagation measurements at various frequencies indoors and outdoors [5], however an extensive experimental propagation study on building structures for 2G, 3G and 4G frequencies have not been reported yet. This study presented in this paper describes detailed measurement conducted inside the university building and outside the building to characterize the propagation at 2G, 3G and 4G frequencies. This paper is organized as follows. The first step of the study addresses the locations where the experiments have been conducted. In the initial part of the study, the transmitter and the receiver configurations with the transmitter power is given for each setup areas at selected frequencies. Next section highlights the experiments which are conducted to provide the indoor and outdoor attenuation characteristics. In the conclusion, further analyses are given in details by means of simulations, and the future potential research directions that could help to extend the presented findings are introduced.

II. EXPERİMANTALSETUPAREAS

Each floor has 2.70 m height and 1.35 m concrete wall between floors. Transmitter was placed 2.4 m above the ground and receiver was held at 0.2 to 1.20 m above the floor. The ceiling has spot lightening and measurements were made close to the staircase. The measurements were performed outdoor and at different points in thecorridors, at differentfloorsanddifferentrooms in theBogaziciUniversity KB building. In each measurements, transmitter power was 2 W withpulsesignal, andthetransmitterfrequencywas900/2100/2450 MHz.

Freespacemeasurementsweremade in BogaziciUniversity North Campus in front of Abtullah Kuran library. The transmitter was placed 1.50 m above the ground and the receiver was held at 1.30 m height during experiment. Receiver was moved along the straight path with 3m displacement at each measurement. The panel antenna was vertically polarized and the receiver was an isotropic three axis antenna.

In the corridor, the transmitter was placed 1.20 m above the ground and the receiver was held at 1.2 m height during experiment.

Through floors, the transmitter was placed 2.40 m facing the ceiling. Receiver was held at points that were in the direction transmitter propagation.

Transmitter in the room measurements was placed on the desk and transmitter antenna 20 cm above the surface, 1.20 m above the ground. Thetransmittingantenna has 7±1 dBigainfor 900 MHz and 8 ±1 dBigainfor 2100 MHz and 2450 MHz. The transmitting antenna is a directional panel antenna which is vertically polarized and has dimensions 0.21 m x 0.18 m x 0.44 m. Thereceiverwiththree-axisantenna has gain 18.90 dBi, 13.8dBiand 15.5 dBifor 900 MHz, 2100 MHz and 2450 MHz respectively. It was held at 1.2 m height during measurements.

III. EXPERİMENTALINVESTİGATİON

3.1 Freespacepropagationresults

This model is based on Friisformula, whichgives the amount of power of an antenna which is received under ideal conditions from another antenna. This equation provides accurate results for far field, unobstructed free space and correct alignment and polarization of antennas.

Plane earth model takes into account the near ground effects in propagation and loss due to reflection from earth and other propagation mechanisms are included. The parameters can be defined empirically from the best fit to data [23].

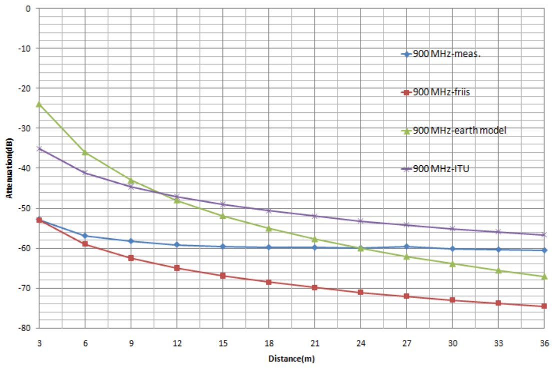

Figure 1. Attenuation(dB) vs. distance from transmitter in open area for 900 MHz

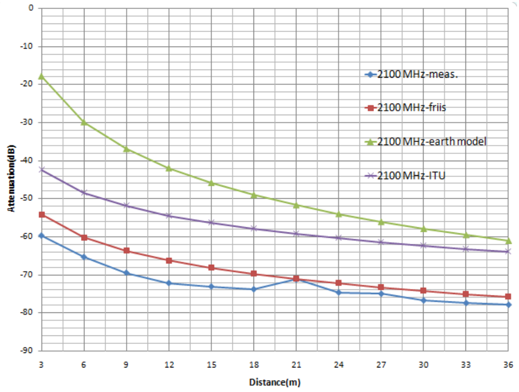

Figure 2. Attenuation(dB) vs. distance from transmitter in open area for 2100 MHz

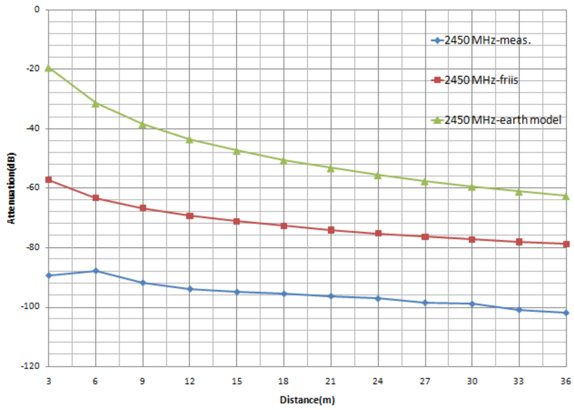

Figure 3. Attenuation(dB) vs. distancefromtransmitter in openareafor 2450 MHz

It is clear from the results that the ground effect shows itself after a certain distance and dominates the free space attenuation. When, the distance is small enough, the reflected signal cannot contribute to the measured signal. Finally the movement of people also might have caused the deviations in signal temporarily.

3.2 Corridorattenuation

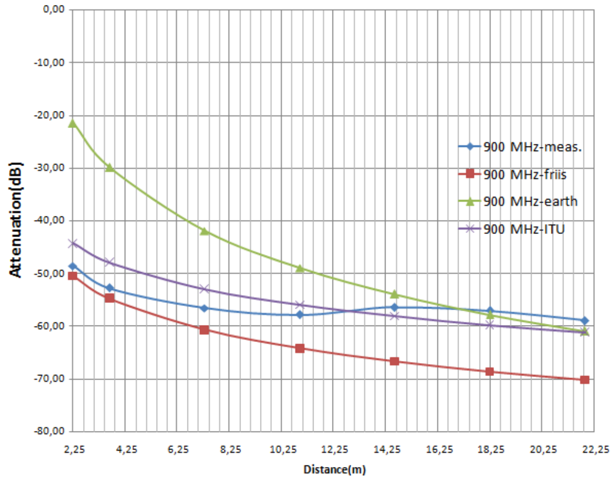

Figure 4. Attenuation(dB) vs. distance from transmitter along the corridor for 900 MHz

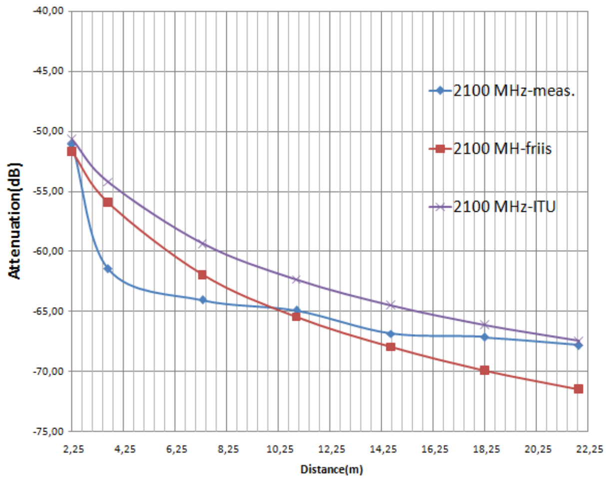

Figure 5. Attenuation(dB) vs. distance from transmitter along the corridor for 2100 MHz

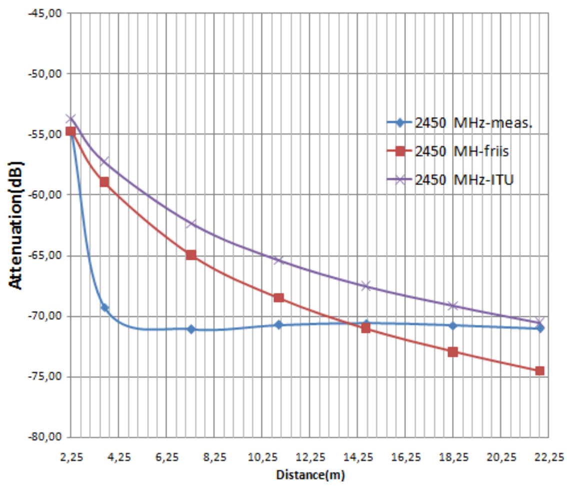

Figure 6. Attenuation(dB) vs. distancefromtransmitteralongthecorridorfor 2450 MHz

The results have shown that for the attenuation in corridors, the reflection from the floor affects the propagation after a certain distance which can be calculated from ground model. The deviations from theoretical and empirical results are due to the effect of opendoornearthetransmitter, thematerial of floor, theworkingWiFitransmitter on thewall. Moreover diffraction plays a role in saturation of signals after a certain distance from the transmitter. Hence the attenuation at the same distance is less than free space attenuation.

3.3 Floors

EM waves impinge upon a plane boundary obliquely will be partially reflected back to first medium and partially transmitted (refracted) in the second medium. Boundary conditions determine the direction of propagation and the amplitudes of these waves. The path loss in terms of reflection and transmission coefficients is calculated for TE polarization [2].

Commonbuildingmaterialsare non-magnetic and non-ionised so that only the dielectric properties of building materials will be considered. Mostbuildingmaterialsshowlossydielectriccharacteristics. Hence the wave impedance and the reflection/transmission coefficients include imaginary parts. We have calculated these coefficients referring the permittivity studies of building construction materials. Moreoveraccordingtothisattenuationperwallvaluewehavemodifiedthe Friisequationand in thefiguresbelowthevalueforFriisvaluesare not thepurefreespaceloss.

It can be seen that the free space formula with wall loss may not be inadequate to predict attenuation, due to existing a lot of environmental factors that contribute to signal level.

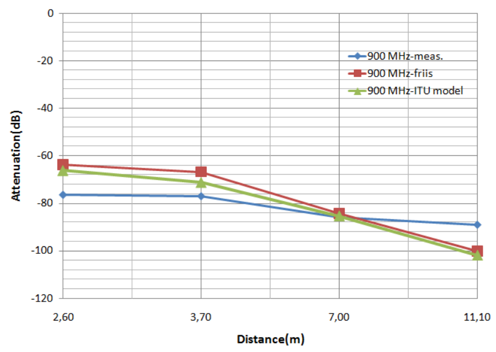

Figure 7. Attenuation(dB) vs. distance from transmitter on the floor for 900 MHz

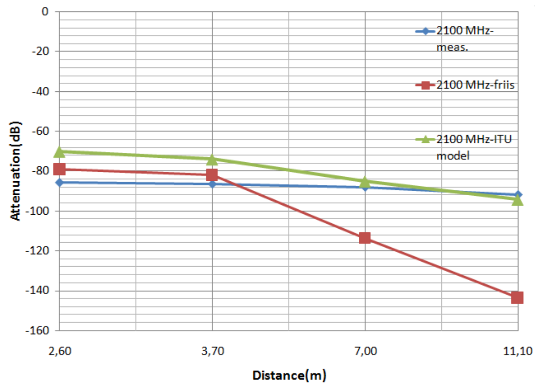

Figure 8. Attenuation(dB) vs. distance from transmitter on the floor for 2100 MHz

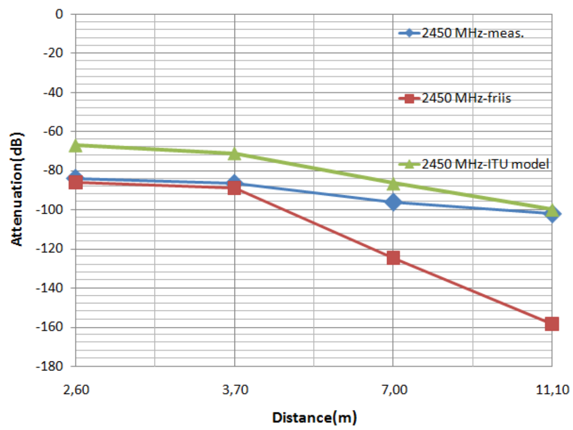

Figure 9. Attenuation(dB) vs. distance from transmitter on the floor for 2450 MHz

Measurements in different floors have shown that the effect of multipath components might affect the signal strength and coverage in the area strongly. Signals find new paths to propagate upper floors which cause less decrement through upper floors. Literature coincides with our results. ITU model is used for simulation. The results are quite similar with measurement data.

ITU model for attenuation in indoor environment includes different parameters which are tabulated for different frequencies. The ITU formulas are stated in [24, 25].

It is importanttonotethatthetransmittingWiFidevices in eachfloorcausedgreatinterference effect and resulted in divergence from theoretical and empirical expected values. Moreover the ceiling material and lightening caused reflections and variations in signal strength.

3.4 Rooms

WehavemodifiedtheFriisequationbyadding a wall loss component in the equation and the graphs are plotted according to these values. Hencethefriisvalues in thegraphsincludeattenuation by walls. Moreover the same formula for the corridors, the ITU model is used for simulating the data.

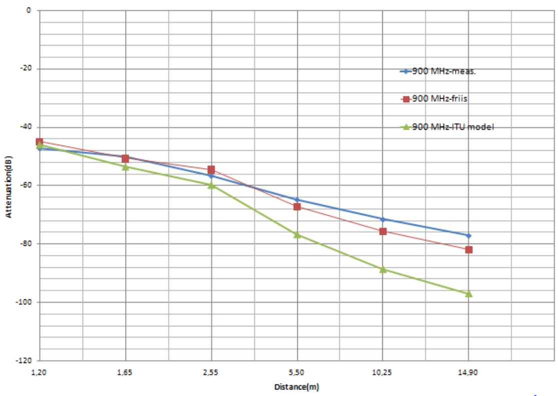

Figure 10. Attenuation(dB) vs. distancefromtransmitter in theroomfor 900 MHz

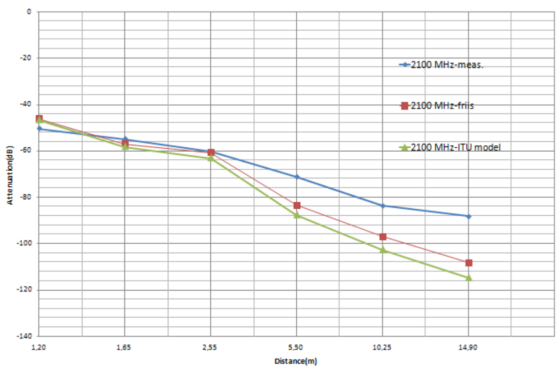

Figure 11. Attenuation(dB) vs. distance from transmitter in the room for 2100 MHz

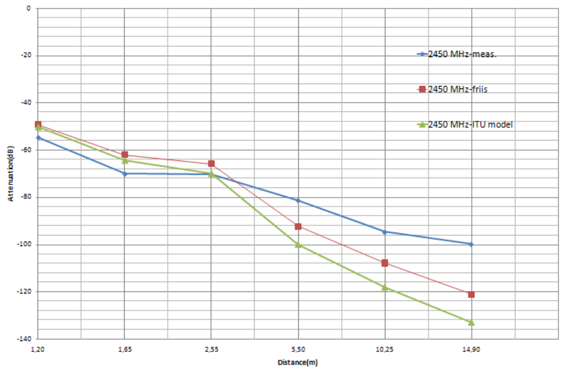

Figure 12. Attenuation(dB) vs. distance from transmitter in the room for 2450 MHz

TheresultsfromfiguresshowthattheempiricalmodificationtoFriisequationimprovesthepredictio n of propagation and gives closer results to measurement data. The differences between the measured data and the models are caused by the metallic book shelves, the boards on the walls and other furniture as obstructions. It can easily be seen that as the power is getting higher, the signal strength is more deviating. Moreover, rise in frequency is positively correlated with loss through obstacles; in addition diffracted signals contribute less to the received power. On the contrary, leading to lower loss, the Fresnel region is limited obstructed at higher frequencies. However, the genuine path loss is counted on these opposing mechanisms.

IV. CONCLUSİON

The results in our experiment mostly comply with EM wave theory. The outcomes of the project can be discussed as follows:

1-Free space measurements have shown that transmitter must be placed high enough in order to reduce and avoid earth effect on signal strength. It can be also seen that measured values converge to plane earth model values after a distance and this threshold is determined by heights of the transmitter, receiver and frequency of signal [2].

2-Measurements along the corridor have shown that again in order to reduce reflection from the ground the transmitter must be placed high enough, actually it is recommended to place the transmitter antenna as close as possible to ceiling in order to assure LOS propagation [24].

3-In different floors an analysis based on electromagnetic (EM) wave theory would be very complex, since the multipath phenomena cause variations and emergence of signals in unexpected points. However basically, the attenuation is due to material separating the floors and adding the attenuation due to wall transmission and free space loss gives quite good results. In different floors measurements for 900 and 2100 MHz gavereasonableoutcomes, whereas 2450 MHz signalstrengthsometimesincreaseduetoWiFitransmitters at eachfloornearmeasurement point. Moreover the lightening spots on the ceiling effects the attenuation with 15-30 dB magnitude.

4-Measurements in rooms have shown that the effect of the furniture, electrical properties of materials, dimensions of building structures [25]. This indicates that diffractions and reflections may vary the signal strength dramatically.

The theoretical or empirical results are not the same as the measurements due to environmental conditions. Moreover different factors that affect measured signal level have also been investigated. It is reported that the user's head and body affect the received signal level. In future the measurement data may be used for characterization studies of building materials, investigation of compliance with electromagnetic safety rules, design of local area networks and communication systems. Furthermore a new empirical prediction model based on the measurement data can be developedandused in ordertoimprovecoverage of WiFi, etc.

V. Acknowledgements

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