RESEARCH ARTICLE OPEN ACCESS

Determination of Path Loss of GSM Signal Due to Buildings and Vegetation

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Abstract:

This paper is on Experimental study of the effects of obstacles on Global System for Mobile Communication (GSM) Signal in Buildings with Vegetation. The line of sight (LOS) power received over Buildings with Vegetation was measured in dBm at 952.2 MHz and 955.8 MHz for various distances: 20m, 50m, 100m, up to 700m away from the Base Transceiver Station (BTS) using spectrum analyser GSP 810. Obstruction densities were also determined. The results obtained from the experiment were analysed using MATLAB R2012b. The measured path losses compared with the ones predicted by the existing model due to building and vegetation (COST 231, COST 235, Early ITU and Weissberger) show some differences. However, COST 235 predicted better than other models because it values were relatively close to the measuredvalues.

Keywords: Global System for Mobile Communication, Line of Sight, Base Transceiver, spectrum analyser, Obstruction Density, MATLAB, Building and Vegetation.

1.Introduction

Global System for Mobile Communication (GSM) has attracted the interest of many researchers in recent time because it is the fastest and reliable means of communication between a person to person over a long distance. Reduction in signal strength of GSM signal (path loss), attenuation and fading of the signal as it propagates through space is caused by different factors such as the propagating medium, obstacles, atmospheric parameters. It could also be influenced by other factors such as the distance between the transmitter and the receiver, the height and location of the transmitting antenna [1-14]. But this researcher only focus on the effect of buildings with vegetation on GSM signals. In the present day scenario of communication, the path loss propagation models become an active area of research. Path loss can be defined as the attenuation of the radio-waves presented in the communication channel in between transmitter and receiver. Due to existing channel signal strength reduction that signal suffers when propagating from transmitter to receiver [13].

In wireless communication, the losses which occurred in between transmitter and receiver as the signal is propagated from the transmitter to the receiver is known as propagation path loss. Path loss is the unwanted reduction in power strength which is Transmitted [4].

It is important to estimate, with a high degree of confidence, the mean signal amplitude decay that would be received by individual subscribers located in various areas surrounding the site of a base station when planning any cellular wireless systems [3].

The rate at which Buildings affects signal propagation depends on their thickness, types of materials used in the construction of the buildings, nature and number of opening in the buildings. For example, signals will penetrate buildings with large and many opening than the ones with small and few openings.

Apart from buildings, vegetation, however is another significant feature, which affects radio wave propagation, trees and flowers planted at strategic places within residential environment or in offices to beautify the environment and at the same time maintain a greener environment. However, their presence may have adverse effects on telecommunication services as they may cause blockage to radio wave path by obstructing the line of sight between transmitter and receiver [2]. The signal follows different paths to the receiver due to obstructions and this situation leads to signal degradation.

However, removing all trees obstructing line of sight is not the solution as it may damage the ecosystem and contribute to global warming. Mounting many antennas within short intervals, fade mitigation techniques such as adaptive coding and path modulation, path diversity etc. can be adopted to mitigate the effect. So for radio planners whose aim is to achieve effective communication with high degree of reliability and good quality of service, the effect of buildings with vegetation has to be taken into consideration during the planning and design work.

The environment between (and around) the transmitting system and receiving system has a major influence on the quality of the transferred signal in a propagation system where antennas are used to transfer information [7, 9]. Buildings has more adverse effects on signal propagation but vegetation element such as trees and large bushes can also have some reducing effects, on the propagating radio signal.

Thus the study of the reduction in GSM Signal received within the office environmentcannot be carried out without considering the effect of vegetation because most offices and residentialenvironments have their building covered with trees and flowers. This study is therefore aimed at contributing to a better understanding of radio waves propagation in an office environment.

2.Theoretical Computations

Some of the propagation models that are relevant to this study were
Employed. And they are summarized as follows: [2].

COST 231 Model:

$$PL = 46.3+33.9\log(f)-13.82\log(h_t)-[1.1\log(f)-0.7]h_r+1.56\log(f)-0.8+[44.9-6.55\log(h_t)]\log(d)+C.\ dB \quad (1)$$

Where C = 0 dB for medium cities or suburban centre. C = 3 dB for metropolitan centres.

In equation (1), f is the resonance frequency in MHz d is the transmitter and receiver separation distance in kilometres (km) and h_t is the transmitting antenna height which is 30 and 200m, h_r is the receiving antenna height.

Models due to vegetation are:

COST 235 Model:

$$PL = 1.56*f^{-0.009}*d^{0.2}.\ dB \quad (2)$$

Early ITU Model:

$$PL = 0.2*f^{0.3}*d^{0.5.}\ dB \quad (3)$$

In equations (3) and (4), f is in MHz and d is in meters (m).

Weissberger's Model:

$$PL = 1.33*f^{0.284}*d^{0.588.}\ dB \quad (4)$$

3.Experimental Procedure

The receiver system (spectrum analyser GSP-810) was mounted on a chair (Figure 1) which makes the height of its antenna to be 1.6m above the ground. The receiver system was used to monitor the signal power received at the two different frequencies as the separation distances were varied frombase transceiver station (Figure 2),along the possible line-of-sight.

The GSM signal power level received (Figure 3), were Measured at two different frequencies: 952.2MHz, and 955.8MHz as the distances between the base transceiver station (Figure 2), and the receiver system were varied from 20m, 50m 100m, 150, 200m up to 700m along the possible line-of-sight (LOS).

A generator (dynamo) was used as a source of electricity to the receiver system.

The obstruction densities were determined for the two frequencies as the distances between the base transceiver station (BTS) and the receiver system were varied from 20m up to 700m.

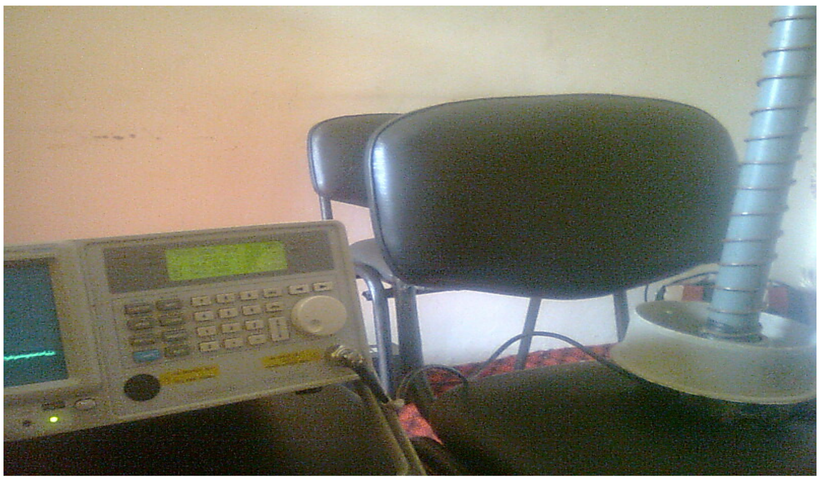

Figure 1 Experimental Set up

Figure 2 Base Transceiver Station (BTS)

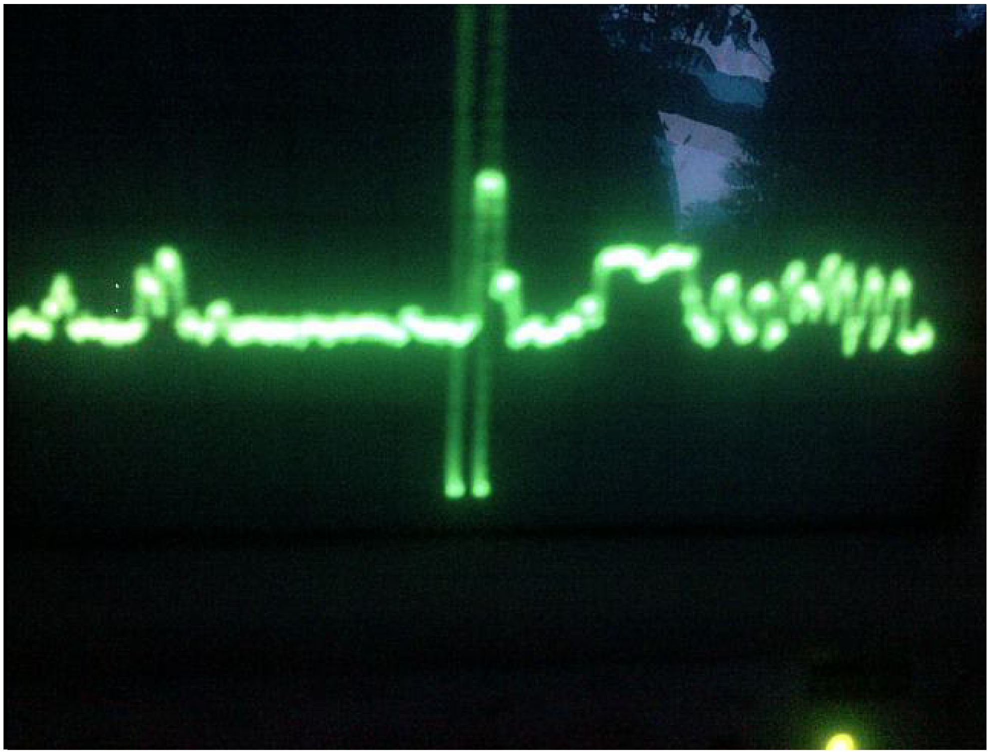

Figure 3Power Received Displayed on Spectrum Analyser at a Distance of 520m.

4.Results

The results obtained from the experiment conducted with the spectrum analyser GPS 810 along the choosing line of sight, the reduction in the power received (path loss) as the separation distance between the BTS and the receiver system increases were calculated using equation (5), and the values obtained were presented in table 1 and table 2.

$PL = 10\log_{10}(\text{Power Transmitted}/\text{Power Received})$ dB (5)

TABLE I
Power Received (W) and Path Loss (dB) at 955.8MHz

Transmitter Receiver Separation Distance (m)	Power Received (w)	Path Loss (dB)
20	5.8884E-9	88.3
50	6.7608E-9	87.7
100	3.8019E-9	90.2
150	1.2589E-9	95.0
200	6.0256E-11	108.2
220	4.8978E-10	99.1
270	2.0893E-10	102.8
320	1.4125E-10	104.5
370	1.0E-10	106.0
420	2.3988E-10	102.2
470	2.0893E-10	102.8
520	2.0893E-10	102.8
570	1.9498E-10	103.1
620	1.0E-10	106.0
670	8.1283E-11	106.9
700	1.479E-10	104.3

TABLE II
Power Received (W) and Path Loss (dB) at 952.2MHz

Transmitter Receiver Separation distance (m)	Power Received (w)	Path Loss (dB)
20	5.8884E-9	88.3
50	6.7608E-9	87.7
100	1.2882E-9	94.9
150	1.5488E-9	94.1
200	6.7608E-9	87.7
220	1.2589E-9	95.0
270	1.9498E-10	103.1
320	9.7724E-10	96.1
370	2.3988E-10	102.2
420	7.7625E-9	87.1
470	1.4125E-9	94.5
520	2.8184E-9	91.5
570	4.3652E-9	89.6
620	1.2303E-10	105.1
670	1.0715E-10	105.7
700	2.4547E-10	102.1

The obstruction densities were also determined as the separation distance between the Base Transceiver Station and the receiving system increases along the possible line of site as shown in table 3.

TABLE III
Obstruction Density (km^{-1})

Distance (km)	Obstruction Density (km^{-1})
0.001 to 0.020	0
0.001 to 0.050	0
0.001 to 0.100	10
0.001 to 0.150	6
0.001 to 0.200	5
0.001 to 0.220	18
0.001 to 0.270	33
0.001 to 0.320	44
0.001 to 0.370	41
0.001 to 0.420	36
0.001 to 0.470	51
0.001 to o.520	46
0.001 to 0.570	42
0.001 to 0.620	40
0.001 to 0.670	39
0.001 to 0.700	37

The graphs of path loss against transmitter receiver separation distance (Figure 4 a and b), for the two frequencies considered, path loss against obstruction density were also plotted (Figure 5a and b)for the two frequencies considered.

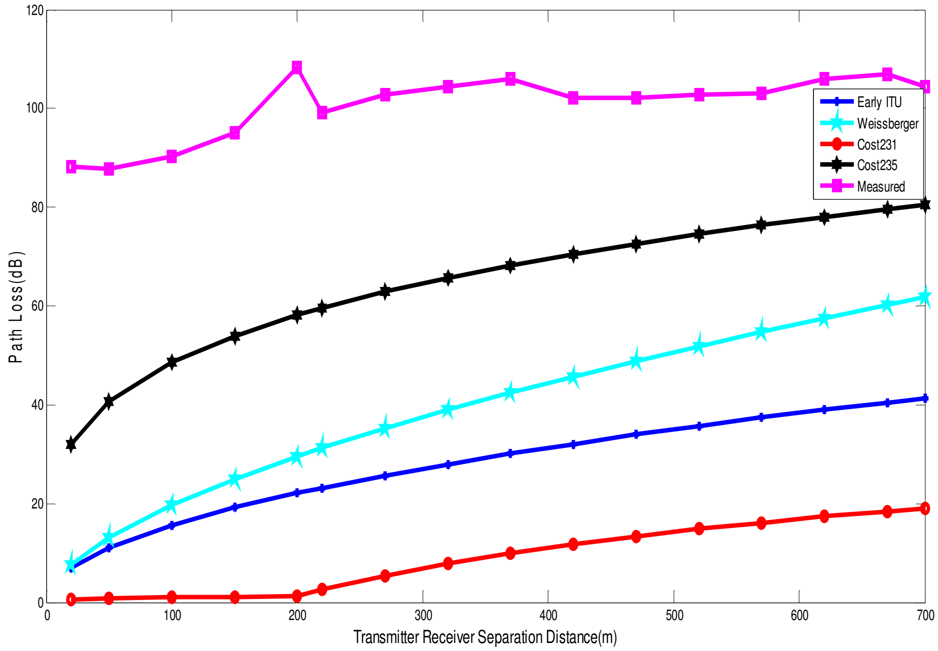

Figure 4a Path loss against Transmitter Receiver Separation Distance for952.2MHz.

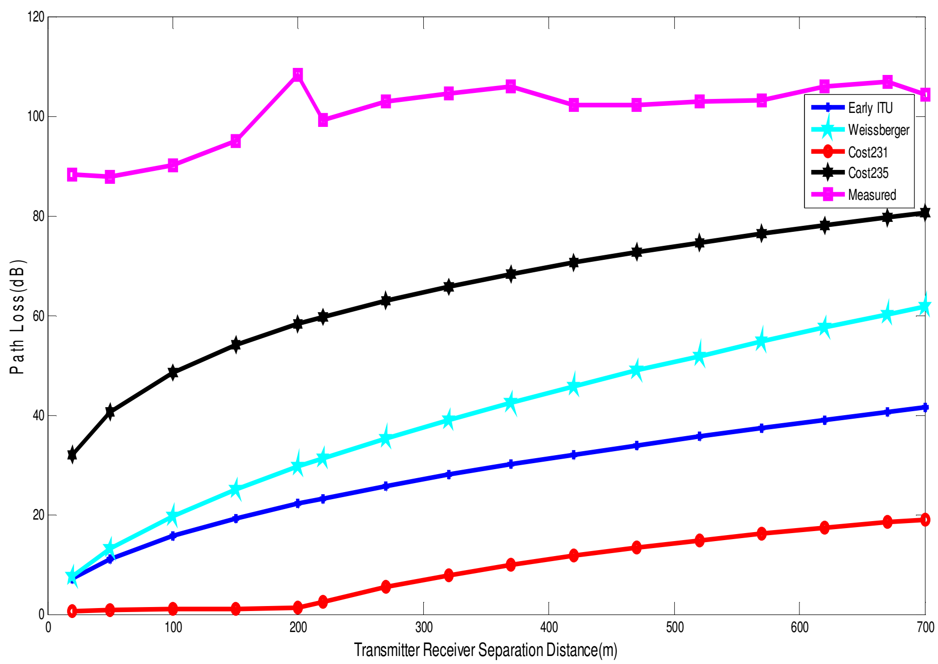

Figure 4b Path loss against Transmitter Receiver Separation Distance for955.8 MHz.

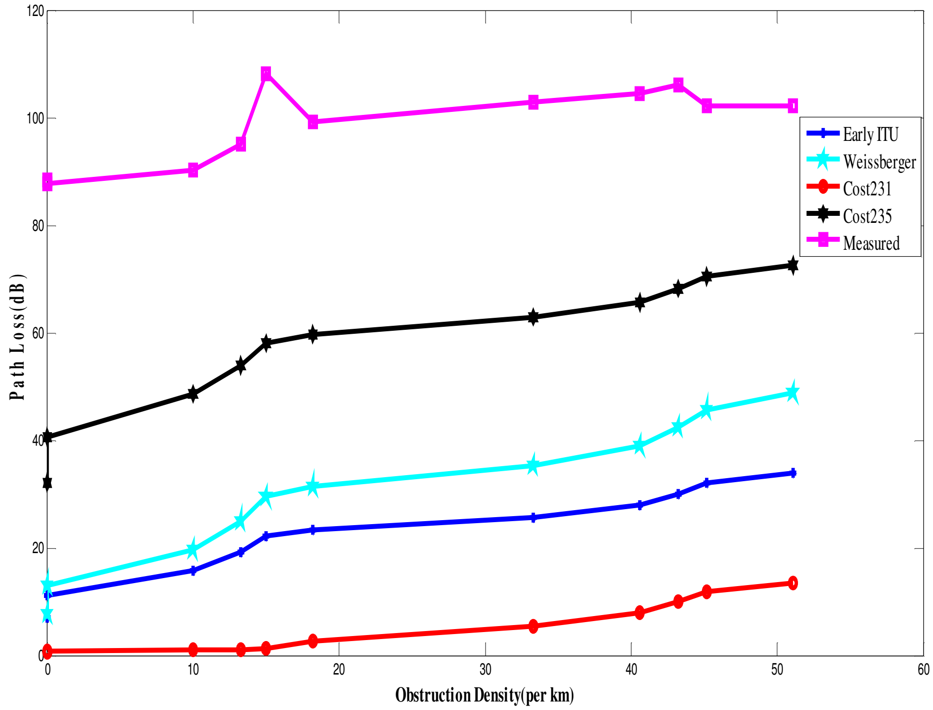

Figure 5a Path loss against Obstruction Density for 952.2MHz

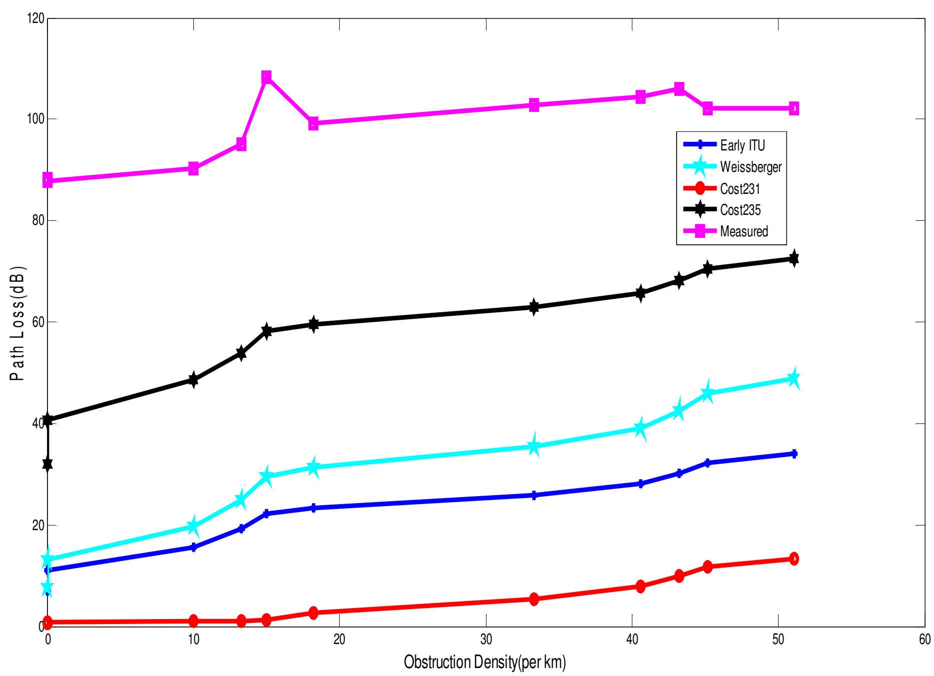

Figure 5bPath loss against Obstruction Density for 955.8 MHz.

5. Result Discussion

From table (1 and 2), it is shown that the power received at 20m is high because the wave has not encountered any obstacle. The power reduces due to obstacles encountered and increases in the Transmitter Receiver Separation Distance. There is no uniformity in the power received because in an area with relatively few obstacles or no obstacle at all (free space), the signal received will be high and low in an area with large number of obstacles as shown in table 1 and 2, for the two frequencies investigated.

The obstruction density increase with the distance between the transmitter and the receiving system, and has low value due to free space and increase in the distance between the transmitter and the receiving system as shown in table 3.

The path loss is also high at 200m because the signal is obstructed by a building in between the base transceiver station and the receiver system. It value is low at points with few obstructions and high at points with large number of obstructions as indicated in table 1 and table 2.

Figure (4 a and b) and Figure (5 a and b), shows that COST 235 is below the measured, Weissberger is next beneath COST 235, followed by Early ITU and COST 231 is the lowest. This implies that COST 235 predicted better than any other model reviewed in this research.

6.Conclusion

From the research, it is shown that obstacles are the major factors affecting GSM signal propagation in a built up environment. The rate at which obstacle affect signal propagation depends on the nature of the obstacle. The frequency at which the wave is propagating determine how far the signal will travel in a particular environment before it is totally lost or attenuated. Also the Transmitter Receiver Separation Distance affects signal reception. The longer the distance, the weaker the signal received and the shorter the distance the stronger the signal received. The values obtained from the measurement were compared with the existing models due to vegetation and building, and it is shown that COST 235 model predicted better than other models.

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