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A Robust Solution to Unreliable 900MHz GSM Communication Services during Rainfall

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Abstract

This paper presents an insight into network performance evaluation and quality of service (QoS) improvement of GSM cellular system services during rainfall. The components of QoS and mechanisms of analyzing and evaluating them are discussed. The paper also identifies the important key performance indicators (KPIs) for QoS evaluation which are used in evaluating the poor GSM network during rainfall. Five assessment parameters (i.e. network accessibility, service reliability, connection quality, and radio propagation and rain attenuation) for evaluating QoS on the network were employed. Prior to the development of this research, result shows that QoS of GSM system in the country is unreliable. It is also found that GSM network accessibility and reliability in the country are unsatisfactory during rainfall. The paper is concluded with recommendations which include the GSM link budget that incorporated the rain attenuation factor that would definitely improve the QoS of poor GSM network services in order to enhance effective and efficient telecommunication system in the country.

Keywords: GSM networks, Key performance indicators, Rain attenuation factor, GSM link budget, Assessment parameters. Rainfall

1.0 Introduction

In recent years with the rapid growth and need for high quality and high capacity GSM networks, estimation coverage accurately has become extremely important. The generic RF propagation predictions based on computer databases give only approximate coverage, and are not suitable for detailed network design. To more accurately design the coverage of modern cellular networks, signal strength measurements must be taken in the service area using a test transmitter. Taking signal strength measurements is an expensive and a time consuming task. It is well known that the accuracy of coverage estimation increases with the distance of the signal strength measurement drive route. Given today's demand for high quality wireless networks, it is more important than ever before to understand how the accuracy of coverage estimates depends on the amount of drive testing.

This research work analyzes the dependence of the coverage estimate on the number of measurements, presents a technique to improve the coverage estimation when only a limited number of signal strength measurements are available, and also presents a technique to design
networks for any required reliability depending on the distance of signal strength measurement drive route. This research work addresses the issue of estimating coverage from a finite number of signal strength measurements. First, the accuracy of the cell radius estimate on the number of 5 measurements for different propagation characteristics is shown. Secondly, the signal strength measurement drive route distance needed to obtain a desired reliability of coverage estimate is established. Thirdly, it is shown that cell radius is not very sensitive to the propagation slope and that in cases with limited signal strength measurements better results are obtained using a fixed propagation slope. Finally, the rain attenuation factor is proposed which depends on the desired reliability to compensate for abnormal and insufficiency of signal strength during rainfall [1]. This factor also compensates for the increased intrinsic characteristic impedance of the heterogeneous medium of propagation of r-f signal in GSM communication services during rainfall. Section 2.0 of this paper briefly discussed some the concept of propagation losses in GSM communication. The effects of rainfall on radio wave propagation in GSM communication services were explained in section 3.0. Section 4.0 narrates the method of determining rain attenuation factor using the updated ITU Model and section 5.0 shows the detail GSM link budget results. Finally, the conclusions were enumerated in section 6.0.

2.0 Concept of Propagation Losses in GSM Communication

An understanding of the radio propagation is an essential part of its operation, design and analysis of any radio system, whether it is for cellular mobile phones, for radio paging or for mobile satellite systems.

The architecture of a generic communication system always has an information source (e.g. a person speaking, a video camera or a computer sending data) which attempts to send information to a sink (e.g. a person listening, a video monitor or a computer receiving data). The data is converted into a signal suitable for sending by the transmitter and is then sent through a channel. The channel itself modifies the signal in ways which may be more or less unpredictable to the receiver, so the receiver must be designed to overcome these modifications and hence to deliver the information to its final destination without errors or distortions as possible. This representation applies to the generic communication system, whether radio or otherwise [2].

An example of the three fading processes is illustrated below which shows a simulated results, but nevertheless realistic signal received by a mobile receiver moving away from a base transceiver station. The path loss leads to an overall decrease in signal strength as the distance between the transmitter and the receiver increases. The physical processes which cause it are the outward spreading of waves from the transmit antenna and the obstructing effects of trees, buildings, hills and rain attenuation. A typical system may involve variations in path loss of around 150 dB over its designed coverage area. Superimposed on the path loss is the shadowing, which changes more rapidly, with significant variations over distances of hundreds of meters and generally involving variations up to around 20 dB. Shadowing arises due to the varying nature of the particular obstructions between the base and the mobile, such as pocket of particular tall buildings or dense woods. Fast fading involves variations on the scale of a half wavelength (50 cm at 300 MHz, 17 cm at 900 MHz) and frequently introduces variations as large as 35–40 dB. It results from the constructive and destructive interference between multiple waves reaching the mobile from the transceiver base station [3].This is clearly described in Fig. 1 below.

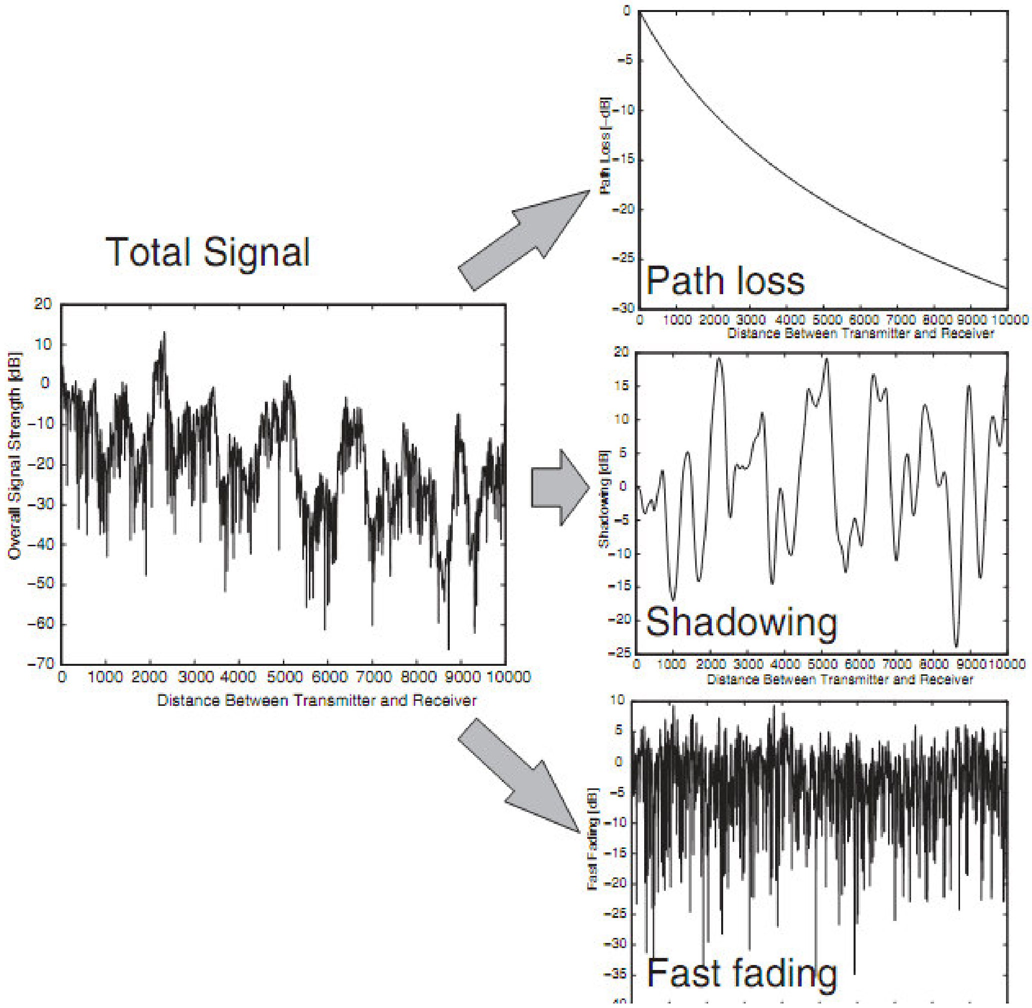

Fig. 1: Propagation Losses in GSM Communication

A radio signal while travelling between two stations in mobile communication passes through the earth's atmosphere and this can introduce certain impairments, as shown in the Table 1.0 in [4] below:

Table 1: R-F Propagation Impairments and Causes

Propagation Impairment	**Physical Cause**	**Prime Importance**
Attenuation and Sky Noise	Atmospheric gain ,cloud ,increase rain	Frequencies' above about 10 GHz
Signal Depolarization	Rain, ice crystal	Dual-polarization system depending on system configuration.
Refraction Atmospheric Multipath	Atmospheric gases	Communication and tracking at low elevation angles.
Signal Scintillations	Tropospheric refractivity fluctuation	Tropospheric at frequencies above 10 GHz and low elevation angles.
Reflection multipath, Blockage	Tropospheric	Mobile GSM & Satellite Services
Propagation Delays, Variations	Ducting scatter	Precise timing and location system, TDMA systems
Intersystem Interference	Diffraction	Mainly C-Band at present; rain scatter may be significant at higher frequencies

In the above mentioned factors, rain and water plays significant role in the attenuation of the radio waves, in GSM especially during rainfall.

3.0 Effects of Rainfall on Radio Wave Propagation in GSM Communication Services

A. Rain Scattering

Scattering of the radio signal into different direction by the rain droplets is known as rain scattering. This rain scattering is a function of the wavelength of the radio wave and the size of the scattering particle.

Rain drops are not truly spherical, which results in differently polarized waves to suffer different attenuation (i.e. scattering and absorption by rain drops). Hence, rain scattering depends on the polarization of the radio waves. A horizontally polarized wave would be scattered forward or backward, in case of forward scattering the propagation range increases by 800 km. A vertically polarized wave suffers sideways scattering.

B. Rain Attenuation

Rain plays a significant role in the undesired absorption of the radio wave in the lower atmosphere. Such absorption cause variation in signal strengths and hence, results in the attenuation of the signal.

Rain Attenuation is a function of rain rate and the size of droplets. Rain Rate (RR) is the amount of precipitation occurring in a unit of time; generally expressed in millimeter per hour. In the calculation of radio wave rain attenuation, the rain rate is measured in millimeters per hour which is acceptable by standard RF communication writings [5].

4.0 Determination of Rain Attenuation Using Updated ITU Model

The standard approved relation governing rain attenuation in every country of the world is clearly written in the proceedings of the ITU. The rain rate attenuation measured in dB is expressed below:

$\text{Attenuation}_{(0.01)} = k.RR^{\alpha}dr$ (dB)

Where: RR = The 99.9% Rain Rate for the rain region (mm/hour). $K.RR^{\alpha}$ = This is the specific rain attenuation (dB/km) d = This is the link distance (km)

r = This is the distance factor given as $1/1 + (d/d_o) = 0.998$

d_o = This is the effective path length (km)

$d_o = 35e^{-0.015RR}$ (km)

$k = 0.324$, $RR = 95$, $\alpha = 0.95$ and d =?

The value of k and α is gotten from two ITU Publications page 838.1 and page 837.1 respectively. However, the value of d is assumed to be 7.2 km. [6], [7], [8], [9], [10], [11], [12] & [13]

Now calculating the rain attenuation for Lagos metropolis as a case study of this paper, we have

$\text{Attenuation}_{0.01} = 0.324 \times (95)^{0.95} \times 7.2 \times 0.998 = 176.135$ (dB) [14]

In this paper, we have considered the r-f wave propagation model designed by Airtel Nigeria Plc. The overview of the model is illustrated in Table 2 and Fig 2 below.

Table 2: R-F Propagation Model Designed for Airtel

Airtel	Site ID	Station ID or IP Address	Magazine Type	Modem Type	Mounting Pole	TX Rack
Far-End	LG0217		RTN900	AGILE	1	-
Near-End	LG0055		RTN900	AGILE	1	-
Link Configuration	1+0	Link ID	KG0217- KG0055		Polarization	Vertical

In the event of poor GSM network services during rainfall, the rain attenuation factor has been incorporated into the Link Budget designed. The new link budget is shown in Table 3.below.

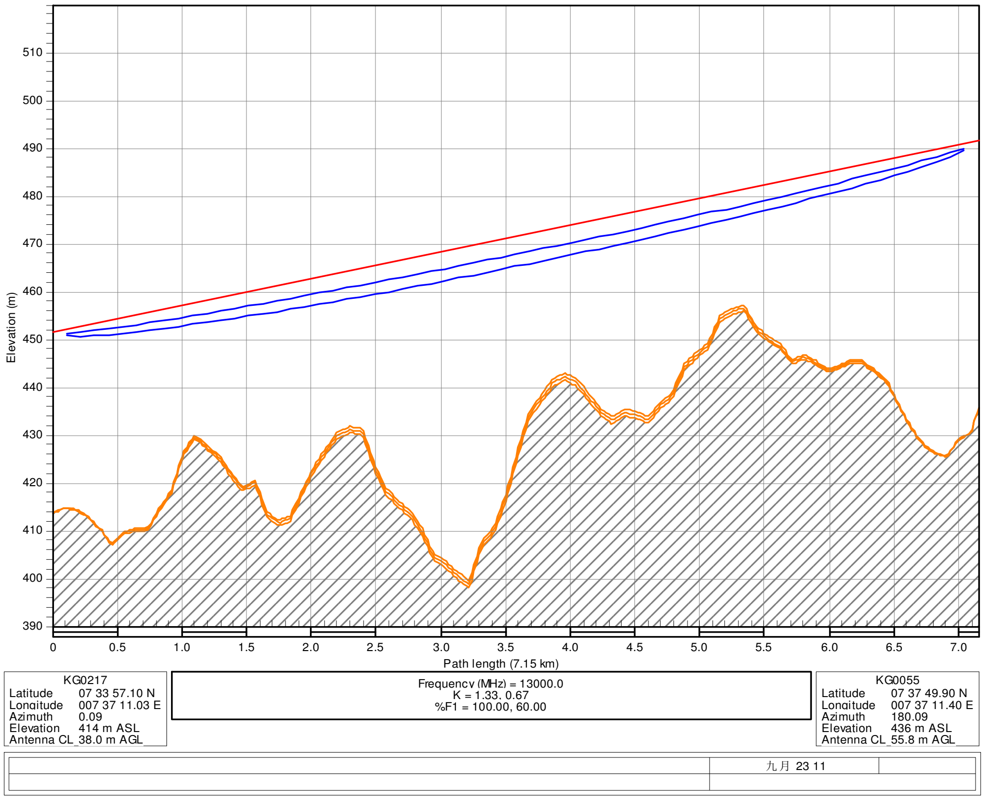

Fig 2: Propagation Model Performance Graph Designed for Airtel

5.0 GSM Link Budget Results

The result of the rain attenuation factor of 176.135dB is incorporated into the new link budget shown in table 3.0 below. This appears to be the only missing parameter in the old link budget. With the new values of Uplink-KG0217 and Downlink-KG0055 total power, a redesign of the Base Transceiver Station (BTS) and Mobile Switching Center (MSC) becomes inevitable. This is a robust method for achieving an effective GSM communication services during rainfall.

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Table 3: The New GSM Link Budget Incorporated with Rain Attenuation Factor

	KG0217	KG0055
Elevation (m)	413.68	435.72
Latitude	07 33 57.10 N	07 37 49.90 N
Longitude	007 37 11.03 E	007 37 11.40 E
True azimuth (?	0.09	180.09
Vertical angle (?	0.30	-0.34
Antenna model	A13S06HAC	A13S06HAC
Antenna height (m)	38.00	55.81
Antenna gain (dBi)	35.60	35.60
Radome loss (dB)	1.00	1.00
Frequency (MHz)	900.00	
Polarization	Verticall	
Path length (km)	7.15	
Free space loss (dB)	131.83	
Atmospheric absorption loss (dB)	0.15	
Field margin (dB)	1.00	
Net path loss (dB)	63.78	63.78
Radio model	13G_XMC2_16Q_7M_21M	13G_XMC2_16Q_7M_21M
TX power (watts)	0.16	0.16
TX power (dBm)	22.00	22.00
EIRP (dBm)	56.60	56.60
Emission designator	7M0D7W	7M0D7W
TX Channels	13B7-3L 12880.5000V	13B7-3H 13146.5000V
RX threshold criteria	BER 10-6	BER 10-6
RX threshold level (dBm)	-86.00	-86.00
RX signal (dBm)	-41.78	-41.78
Thermal fade margin (dB)	44.22	44.22
Geoclimatic factor	3.53E-04	
Path inclination (mr)	5.57	
Fade occurrence factor (Po)	2.95E-03	
Average annual temperature (?)	29.00	
Worst month - multipath (%)	99.99999	99.99999
(sec)	0.30	0.30
Annual - multipath (%)	100.00000	100.00000
(sec)	1.35	1.35
(% - sec)	99.99999 - 2.69	
Rain region	ITU Region N	
0.01% rain rate (mm/hr)	99.90	
Flat fade margin - rain (dB)	44.2	
Rain rate (mm/hr)	95	
Rain attenuation (dB)	176.135	
Annual rain (%-sec)	99.99739 - 822.15	
Annual multipath + rain (%-sec)	99.99738 - 824.84	

25 - 02 - 2013
KG0217-KG0055.
Reliability Method - ITU-R P.530
Rain - ITU-R P837.1-838.1

6.0 **Conclusion**

This paper has presented the results of rain rate analysis and rain attenuation factor for improved link budget in GSM communications. The incorporation of the updated ITU rain attenuation data into the link budget is a factor that will definitely improve GSM network services during rainfall. This implies that there is need for a complete redesign of GSM base transceiver stations (BTS) and mobile switching centers (MSC) in terms of their total output power in dB. This is a robust solution to the ineffective and unreliable GSM communication services during rainfall.

However, the relationship between effective specific attenuation and ITU-R predicted one was investigated and proved to be most appropriate for improved GSM communication link during rainfall.

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