PERTURBATION OF MOBILE COMMUNICATIONS AND INTERFERENCE IN A ROCKY ENVIRONMENT

By

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ABSTRACT

Mobile Communication in Nigeria is plagued with unprecedented drop-calls, cross talks and service unavailability even when the subscribers are credit worthy. The reasons for such reprehensible observations are either due to natural courses, inadequate network infrastructure or due to poor network design parameters. This paper examines the perturbation of mobile communications. The various causes of impairment are examined. Different scenarios of mobile communications environment are presented. The rocky environment to which the likes of Abuja are subjected to is also examined.

Key words: *Mobile communication, mobile signal impairment, perturbation, signal fading, Multipath.*

1.0 INTRODUCTION

Performance of mobile communication systems often experiences a degree of degradation in a multi-service environment especially in geographical areas with preponderance of rocks, hills and valleys. It has been established that the received signal by a mobile station is prone to various degrees of attenuation due to path loss and fading, notable amongst which are Rayleigh, Rice and Nakagami fading (1,2,3). The issue of signal degradation due to path or multipath propagation loss was discussed in (1)] and this led to various models for predicting propagation loss. Even with the existence of the various models, mobile communications have continued to experience various level of perturbations leading to poor reception especially in rocky environment. Interference militates against wide area coverage of radio signals and capacity; and because wireless systems must coexist in extremely complicated signal environments as well as terrains, steps must be taken in the design stage to limit these influences.

In an attempt to address the ever mounting problems of perturbation and interference in mobile communications the world over, concerted efforts have been made with the sole aim of improving the capacity, coverage and content, commonly referred to as **(3Cs)**, for better service delivery. The 3Cs improvement

…e along with compatibility and roaming issues are responsible for mobile communication networks developmental stages over the last decade that is often called Next Generation Networks (NGN). Moreover, the adverse effects of many propagation media and limited availability of frequency broadcast spectrum, which has led to strict allocation of frequencies (2) has also not been helpful in addressing the various communications impairment. Despite these efforts, in Nigeria the signal reception of the GSM utilizing the TDMA frames as well as the CDMA based networks have been exhibiting uncomfortably high rate of fades in signal transmission with the constant report of 'network not available' even when the mobile station is known to be situated in locations contiguous to several sites.

Abuja the capital city of Nigeria, the crème of the nation, is situated in a rocky environment and densely accommodates many tall buildings. It has been observed that the capital city is known for high drop calls, crosstalks and poor receptions of wireless mobile communication signals. In order to understand this, it is important to appraise the contributions of these rocks that are predominant in the city. This gave the impetus for this work.

The prime design objective in a wireless mobile communications system is to provide a near-ubiquitous coverage of signal over a wide area of interest and make room for high traffic density while ensuring that an acceptable carrier-to-interference level is maintained (3). It is the contention of the authors that the levels of observed Abuja mobile communication impairments are very unusual, unacceptable and requires an immediate re-engineering. Fundamental to this is the need to understand the propagation characteristics of radio signals at frequencies of interest with respect to the propagating environment. This paper investigates the various types of perturbations and interferences affecting mobile communications networks in a rocky environment. In section 2 we discussed the various mobile communication scenarios with associated impairments. Section 3 examines various modes of perturbations to which the signals are prone and some of the models used to characterize them. Finally, we make observations and give conclusions.

2.0 MOBILE COMMUNICATION SCENARIO

Since mobile communications are essentially radio based, perturbations on the radio path constitute the major constraint to optimum reception. With the bandwidth constraints and in cases of multi-network environment, re-use rate of allocated frequencies is usually high leading to narrow safety margin and more often overlapping of carrier frequencies, especially in crowded urban centres. Thus, at a mobile terminal there is tendency to record in addition to signals from its ambient cells or cluster of cells, also signals from cells in other clusters presumably outside the reuse distance frequency values. This creates at the receiver, a multipath effect with its result being a weakening (or sometimes a strengthening) of the received signal. Where the reception from outside the cluster carries transmission from another terminal, additional noise/interference is recorded which is often due to the completely different terminal. Over rocky terrain there is a considerable increase in the number of rays arriving at the antenna due to the processes of multiple reflections, diffraction and dispersion. It is not unusual to have a second reflected wave when either the Mobile Station (MS) or the Base Station (BS) is situated on a hilltop and the other on a flatter terrain. The propagation model in this case can be represented as in figures 1 and 2 (1).

The Figure 1 shows a Mobile Station (MS) scenario where MS is situated on the Hill and the BS on a flat terrain. On the other hand, in figure 2 the BS is situated on top of a hill and the MS on the flat terrain. The diagram of figure 3 depicts another scenario, where there are identifiable dominant reflectors and a number of scatterers. The diagram shows a rock and a skyscraper that are dominant reflectors. The directed arrow represents a signal to the mobile station. The dotted lines show multiple signals that were reflected by various signal scatterers.

The urban, rocky environment can be assumed to have the same effects on radio wave propagation as in an environment with tall buildings (skyscrapers) presenting themselves as obstructions to the propagating radio signal. These skyscrapers act as reflectors on the wireless signals in such a manner as to produce interferences- multipath effects, shadowing, etc (12).

Consider a given wireless communication cell in a typical rocky urban city like Abuja as shown in fig.4, which is made up of base station (BS), user terminal (MS) and the associated obstructions in the propagating environment. This particular environment can be modeled as comprising of skyscrapers obstructing, reflecting, diffracting, refracting, absorbing, etc the transmitted signals from the Base station to the User terminal (fig.4).

3.0 THE OVERVIEW OF MOBILE PERTURBATION PROBLEMS

There are two fundamental sources of problems in the mobile communications:

- Design error of Frequency Re-use
- Impairments Due to Mobility

Frequencies allocated to operators are often insufficient to meet service and capacity demands. Efficient use of available frequencies is therefore inevitable and as a result hosts of techniques (4) have been designed to optimize capacity and frequency re-use. Some of the techniques are cell splitting, cell sectorisation, antenna array, etc. Generally, frequency re-use design must depend on (1) the power of transmitted signal, (2) The terrain over which the signal is sent, (3) the height of antenna, (4) the type of antenna used, (5) weather and the frequency used. Inadequate design of the frequency re-use by an operator would lead to crosstalk, serious fading of signal such that at times a mobile station is reported as unavailable when it is actually available and also congestion. The diagram in the figure 5 shows a mobile communications architecture with seven-cell site clusters. Each cell site is represented with a hexagon and there are 7 cells in a cluster. A line is also drawn from one cell cluster labeled 7 to another cluster. The line shows the cell re-useable distance. The re-useable distance must be properly and optimally calculated to avoid serious degradation due to co-channel interference, which is interference between cells. Moreover, the channel must be properly planed in order to avoid channel interference, which also refers to interference from channels within a cell.

The variability introduced by the mobility of the User and the wide range of environment that may be encountered results into such adverse effects as Doppler spread, multipath propagation, delay spread and penetration loss, which significantly affect system performance.

3.1 Multipath Propagation

Multipath occurs as objects in the propagating environment and it creates reflected signal paths between the base station and the user terminal. It could therefore be said that multipath propagation occurs due to multiple replicas of the same signal arriving with different arrival times at the receiver. The reflected signals arrive at the receiver with random amplitudes and phase shifts because of the different paths followed by the arriving signals. In dense urban environment where multipath propagations occur, the range of times of arrival of the "replica signals" can be very significant (5, 6).

Multipath propagation consists of the direct dominant signal and a Raleigh distribution of the reflected signals with various amplitudes and phase shifts (fig.3). This results to random signal fades as some of the reflected signals destructively cancel the others while some constructively add to the others over brief periods. The degree of cancellations (called fading) depends on the Delay Spread of the reflected signals. The components of Multipath phenomenon can result into the following effects that can lead to signal impairment.

3.1.1 Fading

Fading occurs because of the reflected signals that arrive from different paths out of phase at the receiver. These out of phase signals, depending on their arrival times, randomly cancel or add to each other. The fading due to multipath can be frequency selective in which case the channel must have introduced time dispersion resulting in the delay spread exceeding the symbol period. Flat fading can also occur and in such case, there is no time dispersion and the delay spread is less than the symbol period.

Fading signal amplitude is statistically described as Rayleigh or Ricean [1]. Rayleigh fades are due to No-Line-of- Sight (NLOS) signal component present in the received signal. When there is the presence of Line-of-Sight (LOS) signal component in the received signal, the fading is regarded as Ricean (1). Generally, if there is no LOS path to mobile station because of its mobility, the fading in mobile is therefore Rayleigh.

3.1.2 Delay Spread or Time Spread

The arrival times of the multiple reflected signals at the receiver are different, and this can result to Inter-Symbol Interference (ISI) where energy from one symbol could spill over into another symbol leading to high Bit Error Rate (BER) and consequently the degradation in the quality of received signal.

3.1.3 Phase Cancellation

This result from reflected signals that arrive 180° out of phase at the receiver, thus canceling each other. However, most air interface standards are very resilient to phase cancellations. Thus, a call can be sustained for certain period of time (8).

3.1.4 Co channel Interference

This occurs when the same carrier frequency reaches the same receiver from two separate transmitters. As it is well known, antennas scatter signals across widely disperse areas and signals intended for a particular location/user can stray to another; thus becoming interferer for the user on the same frequency in the same cell (4).

3.2 Doppler Spread

This explains the random changes in the channel due to mobility of mobile wireless user and the relative motions of objects in the channel. Doppler has the effect of shifting or spreading the frequency components of a signal. The Doppler spread is higher for urban environment where users are relatively mobile compared with rural communities. As the mobile moves through spatial locations with different field strengths, each multipath component of the received signal are subject to a Doppler shift in frequency and a slower change in the relative delay (5).

The coherence of the channel, that is the inverse of the Doppler Spread, determines the rate of fading due to Doppler effect. When the rate of change of the channel is higher than the modulated rate, fast fading results. However, when the rate is slower, slow fading occurs.

For a CDMA signal not subject to data modulation, the maximum Doppler frequency, f_m, is proportional to the maximum relative velocity of the vehicle, $\mathbf{V_m}$, given in (5) as:

$f_m = V_m / \lambda$, where $\boldsymbol{\lambda}$ is the carrier wavelength.

3.3 Path Loss

This describes the loss encountered as a result of the separation distance between the transmitter and the receiver. The spatial distribution of power (**P**) transmitted to a receiver separated from the transmitter by a distance, **d**, is related by the distance power law function of the form (7):

$P = 1/d^m$, and for free space, **m=2**.

Alexander (9,10) established that **m** varies according to building materials encountered between the transmitter and the receiver. Smulders et al (11) showed that path loss varies also with frequency as well as the penetration loss; increasing as the frequencies increase. At millimeter wavelength, the radio wave cannot penetrate some materials such as concrete, blocks, bricks, etc. Consequently, millimeter waveband are good for providing broadband services in a high-capacity frequency reuse areas (11).

3.4 Penetration Loss

As already known, the propagations of radio signals are affected by the presence of obstacles, such as buildings, rocks, vehicles, etc. The usage of mobile wireless communications system in both indoor and outdoor environments encounters losses as a result of some of the signals trying to penetrate into the walls/windows of buildings, vehicles, etc. Penetration loss therefore is one of the critical considerations in the design of radio systems in terms of coverage.

It has not been easy to characterize penetration loss for different buildings because of much variability in building materials, structures, etc. For in-vehicle coverage, the penetration loss varies differently according to whether it is car or a van (12). In all these a high penetration loss is assumed in the design so as to ensure good quality of service. However for the environment under consideration, the dominant penetrations to be considered are the building and the in-vehicle penetration loss.

4.0 Observations and Conclusions

Abuja the capital city of Nigeria experiences unprecedented cross talk and drop calls more than Lagos and some other urban cities in Nigeria. One would have expected the reverse to be the case and that was the reason the authors embarked upon this research. The paper discusses the various perturbations and interferences that the operators would have to exploit and optimize in order to ensure reasonable level of services to the consumers.

Several models have been proposed to optimize mobile communications with reference to the perturbations identified. Chang and Su (13) presented a method based on nonlinear regression channel models on the local time-frequency domain. This model was shown to achieve an excellent BER performance that is not far from the theoretical lower bound. Kang et al (14) investigated the efficiency of cellular mobile radio systems with smart antennas. Specifically, the work presented expressions for the situations when the signal is subject to Rice and Rayleigh type fading. Negi et al. [15] reported the performance of space-time coding scheme combined with beam forming strategy in smart antennas to reduce Frame Error Rate (FER) in a multiple-input, multi-output (MIMO) wireless system.

This paper is only intended to study and analyze the problems associated with the observed poor quality of mobile services; probable solutions would be proffered later. Abuja experiences more communication degradation and this is an area of concern to the authors. It was discovered that the differences between Abuja and many other cities observed is its rocky environmental attributes. The examination of the impact of the rocky environment in Abuja, while it is expected to contribute to communications impairment, it is also not expected to be much different from other major cities with several skyscrapers. In fact, it is our contention that the multipath due to the rocky environment around Abuja could be exploited by operators for better communication services. It is equally our belief that the poor quality of mobile services in Abuja and most cities could be more of a design issue. The frequency re-use distance and the cell radius need proper examination and re-engineering by the operators. We pointed out earlier that the frequency re-use design should take into consideration the power of transmitted signal, the terrain over which the mobile signal is sent, the height of mobile antenna, the type of antenna used, the weather condition and the frequency used. However, comparing Abuja to other cities like Lagos, it is our belief that the coverage radius and re-use distance needs to be optimized by the operators concerned. There are techniques to compute the distance and radius along with the other variables in mind and it is recommended that the operators exploit the optimization techniques.

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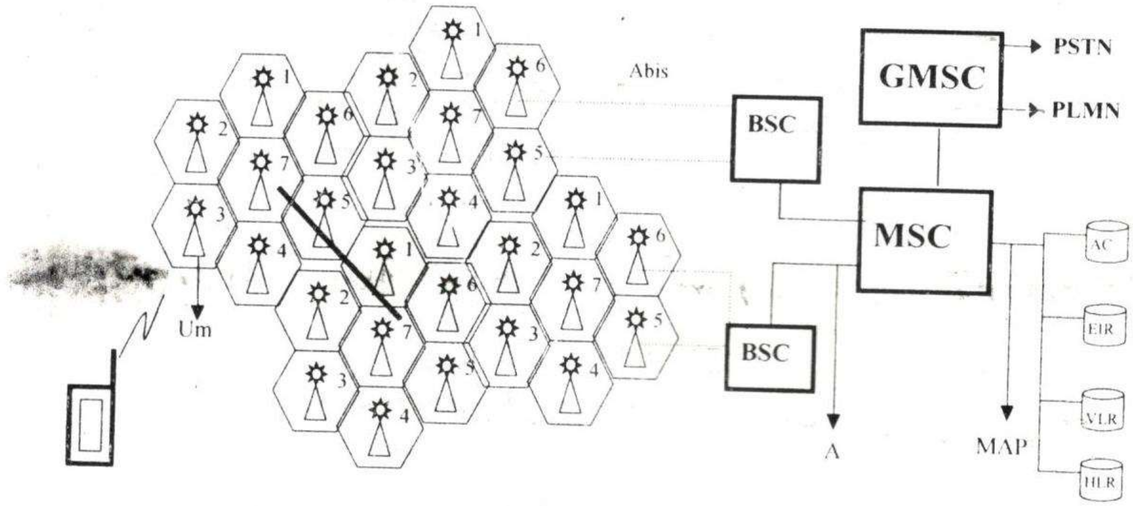
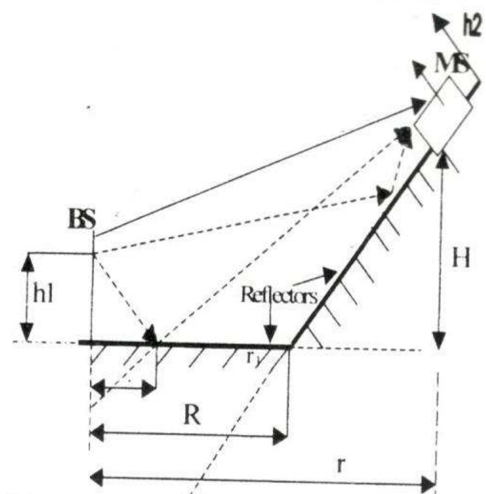


Figure 1: Model for multi-reflected wave and MS on the Hills



R = distance over which terrain is flat
r = total distance between BS and MS antenna
h_1 = height of BS above ground level
h_2 = height of MS antenna above ground level
H = difference in height between flat terrain and elevated terrain.

Figure 2: Model for multi-reflected wave and BS on the Hills

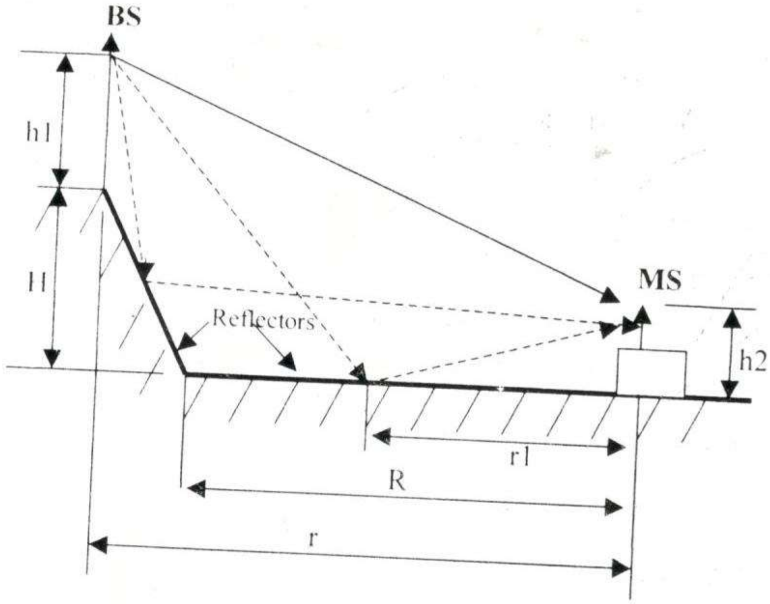
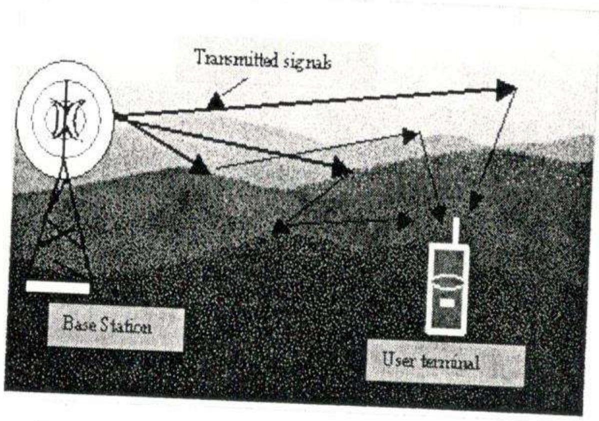


Figure 3: Multipath signal arrival model



Propagating Rocky Environment for Mobile Communications

Figure 4: Rocky Environment with no Line of Site

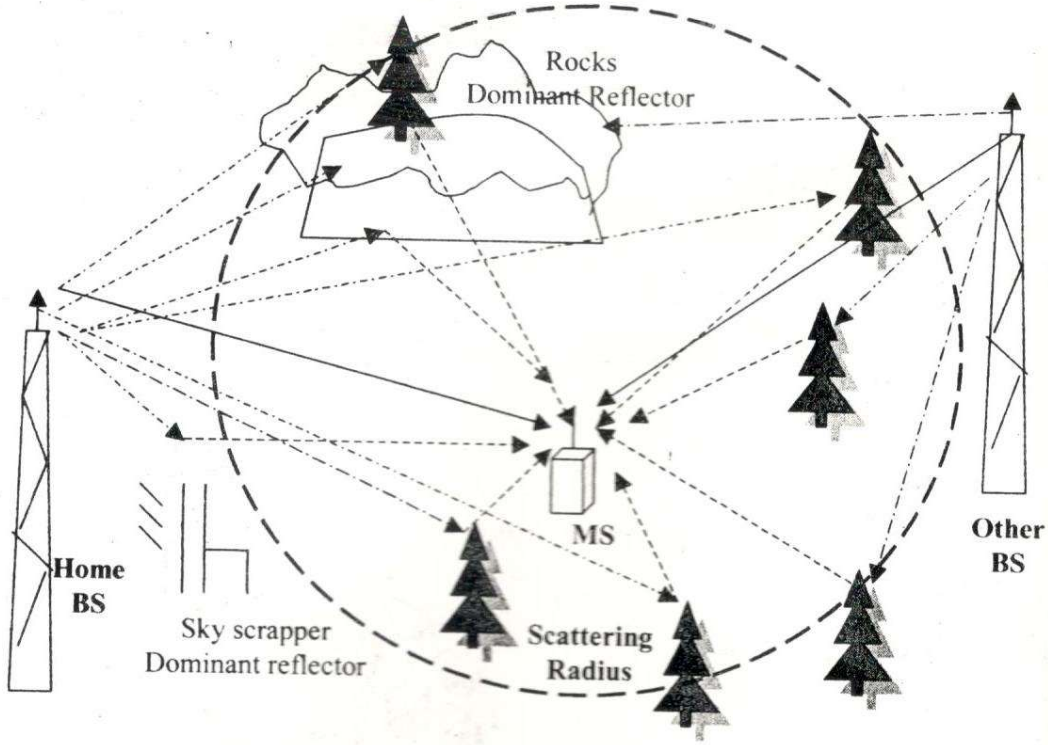


Figure 5: A Simple Mobile Architecture with Cell Sites