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SIGNAL FADING IN MOBILE COMMUNICATION: A REVIEW

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ABSTRACT

For six years of introduction of mobile communication in Nigeria though highly celebrated but has led to frustration on the part of customers/subscribers. These arise from myriads of poor interconnectivity to the signal fading. According to Alberto et al., (2002) the ultimate goal of any communication (e.g. mobile) system is to provide error-free communication. This paper reviews different causes of signal fading experienced in mobile communication and how these problems can be combated in order to achieve reliable and effective information transfers. The review highlighted different methods in solving problems of fading in mobile communication. In this work, special focus on space diversity techniques was applied to combat fading in Nigeria. The exposition of this technique as well as different theories and calculations on path loss propagation and antenna spacing prediction were presented.

Keywords: Fading, Communication, Diversity, Transmitter, Receiver, Antenna.

Introduction

In 1887, the wireless means of communication through radio was discovered and Marconi demonstrated it in 1887 through its wireless telegraphy. From that point on, the exchange of information took a great leap forward with wireless communication systems nearly replacing wire line systems. By this development, communication system had been revolutionized and has made mobile radio communication system almost indispensable for all members of society as well as the public.

In spite of improvement in which wireless communication has over the traditional means of communication, Chinthananda et al., (2001) reported that the performance of wireless communication is still being degraded by many transmission impairments including fading, co-channel interference and noise. Among these impairments, the fundamental one that makes reliable wireless transmission difficult to achieve is fading. He reported that fading is the major phenomenon which makes wireless transmission a challenge when compared to fibre, coaxial cable, line of sight microwave or even satellite transmission.

Fading according to Data Communication Dictionary is defined as the fluctuation in intensity of any or all components of a received radio signal due to changes in the characteristics of the propagation path. Akbar and Behnaam (1999) reported that fading is the primary cause of the performance degradation in wireless systems and the central among other challenges facing the radio engineer. Therefore, it demands a lot of attention from communication system designers.

The goal of any communication system is to provide to the receiver, a signal that is strong enough to overcome all forms of interference as well as to ensure that the received signal is free from distortion and fading. Unfortunately, the wireless mobile channel has made it difficult to achieve these goals. This is because, unlike the fixed channel, the wireless channel or mobile system usually experiences fading which normally results in fluctuation of signal to noise ratios (SNRs) which do leads to poor voice quality, slow link speed and dropped calls Alberto, et al., (2002). Hence, a lot of attention should be given to fading. This is the motivation behind this work because being able to combat it will contribute greatly towards moving the communication industry forward.

Causes of Radio Signal Fading in Mobile Environment

There are various factors responsible for radio *signal fading in mobile environment. They are:-*

(a) Multipath

Radio energy do arrive the receiver via several paths simultaneously. A situation whereby various incoming radio waves arrive from different directions with different time delays gives rise to multipath propagation as shown in Fig. 1. The incoming radio waves now combine vectorially at the receiving antenna to give a resultant signal, which can be constructive or destructive in nature depending on the distribution angles or phases among the component waves.

In mobile environment, the multipath phenomenon may occur as a result of hills, trees, buildings etc. between the transmitter and the receiver. In the process, the amplitude and phase of the reflected path may differ from direct path. In the extreme case where the two signals are of equal amplitude but of opposite phases, they will cancel and there will be no received signal. The situation is referred to as total or complete fading. Whereas when they are the destructive vectoral summation types, it results in signal fluctuation or fading at the receiver.

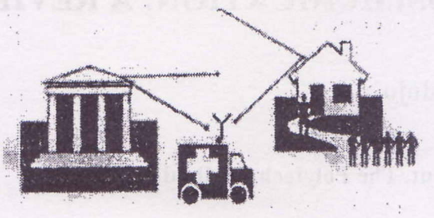

Fig. 1.0 Multipath Propagation

(b) Receiver Antenna Size

Receiver antenna height of the mobile terminal is another cause of fading in mobile communication. This is usually very small, typically less than a few meters. As a result of this small size, the antenna is expected to have very little clearance so that obstacles and reflecting surfaces in the vicinity of the antenna have a substantial influence on the propagation path.

(c) Doppler Effect

This is the effect that occurs as a result of the relative motion existing between the transmitter and the receiver. Whenever this situation occurs there is an apparent shift in the frequency of the received signal (Parson, 1989). This in essence causes the receiver to experience continuous or random fluctuation i.e. fading at the receiver.

(d) Some other Causes of Signal Fading

These are changes in the state of polarization produced by the earth's magnetic field. In addition long term variation or fading could be as a result of radio wave absorption due to rain, fog, or smog (Morris, 1983).

Cure for Signal Fading

In an attempt to combat the adverse effects of fading, there have been a lot of approaches both theoretically and practically. Theoretically, the most effective technique to combat fading in wireless channel is transmitter power control. This occurs if the channel conditions as experienced by the receiver on one side and on links are known at the other side, the transmitter could predistot the signal in order to overcome the effect of the channel at the receiver.

However, there are two fundamental problems with this theoretical approach. The first problem which in fact is the major problem with this approach is the required transmitter dynamic range. This is because for the transmitter to overcome a certain level of fading, it must increase its power by the same level in which in most cases is not practicable. This is because of radiation power limitations, the size and the cost of the amplifier. The second problem is that transmitter does not have any knowledge of the channel experienced by the receiver. Hence the channel information has to be fedback from the receiver to the transmitter, which results in output degradation and considerable added complexity to both the transmitter and the receiver.

However, there is a practical approach that can be applied to combat fading effect in wireless channel. This is by application of diversity scheme. Diversity may be employed either at the transmitter or the receiver (Fossehini and Gans 1998, Chinthanada et al., 2001 and Liu et al., 2002). They reported that diversity schemes either transmission or reception diversity has been observed as a classical powerful technique that provides wireless link improvement at relatively low cost. In mobile radio systems, it is generally most practicable to employ diversity at the base station rather than at the mobile unit, this is because a base station has the ability to serve hundreds to thousands of remote or mobile units. It is therefore more economical to add equipment to base stations rather than remote or mobile units. So, in transmitting from the mobile to the base station, diversity is achieved through a multiple receive antenna– "received diversity" while in transmitting from base station to the mobile, diversity is achieved through a multiple element transmit antenna— "transmit diversity" (Fossehini, 1996).

Diversity Scheme

By definition, diversity is a method of transmission and/or reception where a single received signal is derived from combining a group of signals in an attempt to gain decibel (dB) or improve the signal strength (Data Communication Dictionary, 1976).

There are many types of diversity scheme used in wireless communication systems. Among them are space diversity, frequency diversity, time diversity, directional (angle) diversity and path diversity. Table 1 shows their features.

Table 1: Features of each Diversity

Diversity scheme	Merits	Demerits
Space Diversity	– Easy to design – Any number (N) of diversity branches is selected. – Neither extra power nor bandwidth is necessary or required. – Applicable to microscopic diversity	– Hardware size could be large depends on device technologies – Large antenna spacing is necessary for microscopic diversity at the base station.
Frequency Diversity	– Any number of diversity branches (N) are selectable.	– N times more power and spectrum are necessary
Polarization Diversity	– No space is necessary. – No extra bandwidth is necessary.	– Only two branch diversity schemes are possible. – 3dB more power is necessary
Time Diversity	– No space is necessary. – Any number of diversity branches (N) is selectable. – Hardware is very simple.	– N times more spectrums are necessary. – Large better memory is necessary especially when the delay constant is small.
Path Diversity	– No space is necessary. – Neither extra power nor bandwidth is necessary.	– Diversity gain depends on the delay profile
Directional (Angle) Diversity	– Doppler spread is reducible	– Diversity gain depends on the obstacles around the terminal. – Applicable only to be receiver or terminal unit.

In this paper, the space diversity was chosen to combat fading in mobile communication in Nigeria because of its outstanding advantages compared to others. Although large antenna spacing is required, this disadvantage can be taken care of as the conventional horizontal space diversity approach can now be replaced with the newly introduced vertical one (Signal Wireless Technologies, 2001). By this approach the scheme can now be applied in all parts of this country i.e. in both the urban and rural areas without necessarily in need of large space.

Space Diversity Reception Method

Generally there are three types of combining or switching techniques that are normally used. They are (i) Selection method (ii) Feed back or Switching Method and (iii) Maximal Radio Combing Method.

(i) **Selection Method:** This method works by selecting the signal with the highest signal strength at the receiver as shown in Fig 2a. The major advantage of this method is its simplicity to implement. However, this method cannot function on a truly instantaneous basis.

(ii) **Feedback or Scanning Method:** This is very similar to selection method except that instead of always using the best of M signals as in selection method, the M signals are scanned in a fixed sequence until one is found to be above the predetermined threshold. This signal is then received until it falls below the threshold and the scanning process is again initiated. This method is simple to implement though the result from it is not as accurate as results from other methods. This is shown in Fig. 2b.

(iii) **Maximal Ratio Combing Method:** This is as shown in Fig 2c. Here all the incoming signal from all the M branches are weighted according to their individual signal to noise power ratios, and then scanned. All the individual signals must be co-phased before being summed. This requires an individual receiver circuitry and phasing circuit for each antenna element. Although this method requires a complicated circuitry when compared with others. It is the only method produces an acceptable signal to noise ratio (SNR).

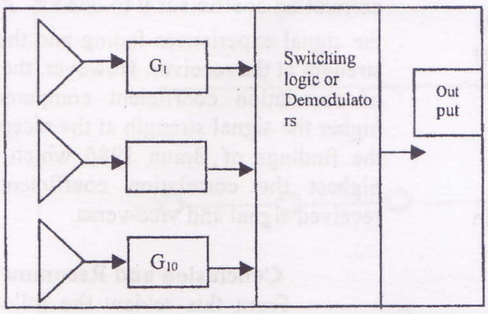

Fig. 2(a): Block representation for Selection Method

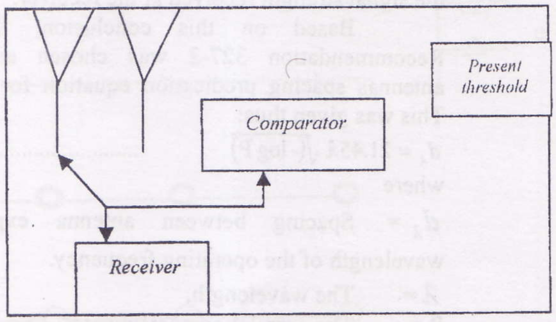

Fig. 2(b): Block representation for Feedback or Scanning Method

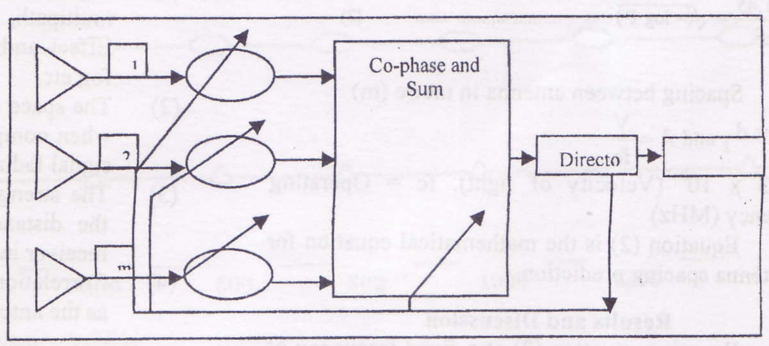

Fig. 2(c): Block representation for Maximal Ratio Combing

Analysis and Calculation of Path Loss Predication and Antenna Spacing

(a) Predication Path Loss for Microcell

Several empirical path loss models have been determined for microcells. One of such models is outlined below namely: Hata's model which was based on empirical data from measurements in Tokyo, Japan and has been claimed to give an accurate estimate of path loss to within 1.0 dB when compared with actual measurement (Lee, 1982). The model is useful for the following scenario.

Carrier frequency $150MHz \le Fe \le 1500MHz$

Base Station Antenna Height: $30m \le ht \le 200m$

Mobile Station Antenna Height: $1m \le ht \le 10m$

Distance between base station and mobile: $1km \le d \le 20km$

$$Lp(dB) = \begin{cases} A + B\log_{10} d \ \text{for urban areas} \\ A + B\log_{10} d - C \ \text{for suburban areas} \\ A + B\log d - D \ \text{for open or rural areas} \ \ldots\ldots\ldots \ \ldots\ldots C \end{cases}$$

Where

Lp = Path Loss Model

$A = 69.55 + 26.16 \log_{10} f_c - 13.82 \log_{10} ht - 9(ht)$

$B = 44.9 - 6.55 \log_{10} ht$

$$C = 5.4 + 2\log_{10}\left(\frac{fe}{28}\right)$$

$$D = 40.94 + 4.78\,[\mathrm{Log}_{10} F_c^{\,2} - 18.33 \log_{10} F_c] \text{ And}$$

$$a(h_r) = \begin{cases} [1.1\log_{10} Fc - 0.7]h_r - 1.56\log F_c - 0.8 \text{ for medium or small city} \\ 8.28[\log_{10} 1.5h_r]^2 - 1.1 \text{ for large city and } F_C \le 200\text{MHz} \\ 3.2[\log_{10} 11.75h_r]^2 - 4.97 \text{ for large city and } F_C \ge 400\text{MHz} \end{cases}$$

This Hata's model is general and since the carrier frequency range for it include the frequency range for mobile communication in Nigeria, its model is recommended in this paper.

(b) Antenna Spacing Prediction

There is a need to obtain mathematical equation that can predict the distance between the antennas. With space diversity operation, the distance between antennas decides the correlation coefficient attainable (Braun, 1986). When a signal is subjected to fading (when there is no diversity) its correlation coefficient (P) is equal to one i.e. P = 1. With diversity, correlation coefficient must be sufficiently small i.e. P <<1 in this case, the smaller the value of P, the higher the signal strength received at the receiver.

Based on this conclusion, the CCIR-Recommendation 327-2 was chosen as the best antennas spacing predication equation for this work. This was given thus:

$$d_\lambda = 21.45\lambda\sqrt{(-\log P)} \quad \text{.........................} \quad (1)$$

where

d_λ = Spacing between antenna expressed in wavelength of the operating frequency.

λ = The wavelength,

P = The correlation coefficient

Equation (1) was reviewed as

$$ds = \frac{21.45}{fc} = \sqrt{(-\log P)} \quad \text{.........................} \quad (2)$$

where

ds = Spacing between antenna in metre (m)

i.e. ds = d_λ and $\lambda = \frac{V}{fc}$

V = 3 x 10^8 (Velocity of light), fc = Operating Frequency (MHz)

Equation (2) is the mathematical equation for the antenna spacing prediction.

Results and Discussion

By using equation (2) at a fixed frequency of 400MHz antenna height of 30m, the antenna spacing ds is obtained by varying the correlation coefficient (P) as shown in table 2.

Table 2:

Correlation Coefficient P	Antenna Spacing ds (Metre)
1	0
0.8	4.96
0.7	6.27
0.6	7.50
0.5	8.75
0.4	10.04
0.2	13.32

From table 2 and figure 3, it was observed that when antenna spacing is zero i.e. when there is no diversity scheme being used, the corresponding correlation coefficient value is one. This is an indication that signal fading is experienced. It was also observed that as the antenna distance is increasing (i.e. ds) the correlation coefficient value decreases. This further buttresses the fact that the wider the distance between the antennas, the better the signal reception at the receiving end.

Figure 4 also shows the signal strengths at different correlation coefficient values. From this figure, it was observed that the closer the values of correlation coefficient P to one i.e. $P \rightarrow 1$, the more the signal experiences fading and the lower the signal strength at the receiver. However, the smaller the value of correlation coefficient compared with one, the higher the signal strength at the receiver. This supports the findings of Braun 1986 which reported that the highest the correlation coefficient the lower the received signal and vice-versa.

Conclusion and Recommendation

From this review the following conclusions should be drawn.

(1) Signal fading in mobile environment is due to multipath, size of mobile receiver, Doppler Effect and radio wave absorption due to rain, fog etc.

(2) The space diversity technique gives better result when compared to other methods in combating signal fading.

(3) The strength of the signal can be improved as the distance between the transmitter and the receiver increases when diversity was applied.

(4) Correlation coefficient (P) decreases from one as the antenna spacing distance increases.

Recommendation

With this little review of signal fading in mobile environment, I wish to suggest that if the aforementioned method is used in our mobile communication industries i.e. space diversity technique, all the irregularities and our inadequacy as regards fading experienced in our mobile communication will be reduced. Not only that many advantages will also be derived. Firstly, it will bring about long desiring rural area development. Secondly, mass migration of people from rural areas will be reduced. Lastly, it will enable people in the rural area to reach people in urban area easily and vice-versa.

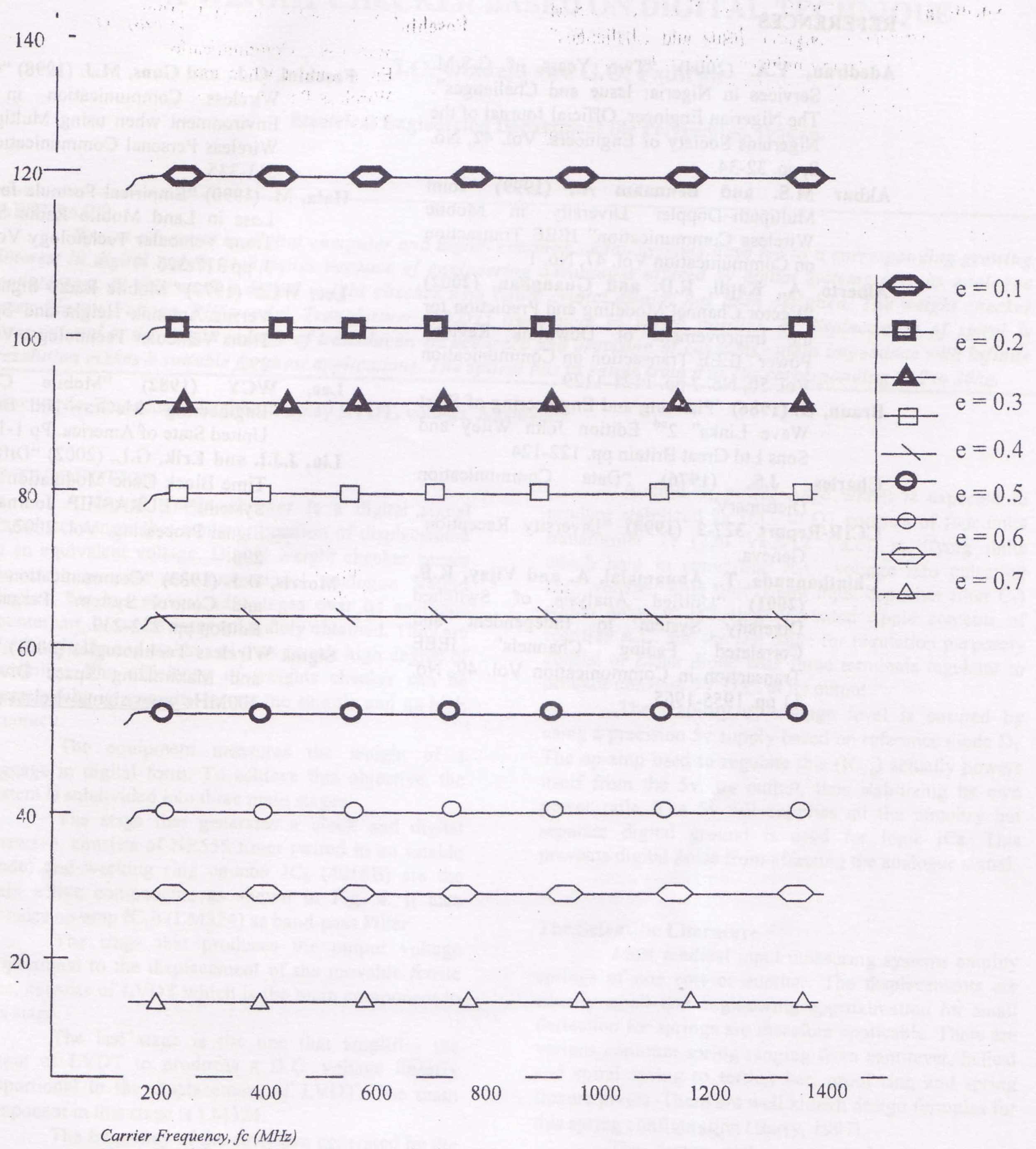

Fig. 4: Signal Gains at different Correlation Coefficient Values

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