

Design and Simulation of GSM Received Signal Stabilizer for Improved Network Reception

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Abstract— The major problem of GSM users in heavy vegetation Areas like Nigeria is environment which is filled up with radio signal scatterers, reflectors, refractors etc, that creates multipath problems which is one of the root causes of poor network receptions of Global System of Mobile (GSM) signal. The effect of these factors are that at some locations in the network coverage area, a mobile station is not able to pick good network signals at some time, resulting in disruptions of conversations or such network problems. A slight change in the transmitting frequency in the network was found to stabilize receptions at such poor reception locations. In this work, a system that will monitor bad network receptions and select a frequency that will stabilize signal reception at that bad network reception location was designed to be incorporated in the mobile station and associated base station. The designed systems was simulated and the result shows a tremendous improvement in the stability of received GSM signal wherever and whenever there is a poor network reception in any GSM coverage area.

Index Terms— Multi path signal, Fading, Frequency Hopping

1.0 Introduction

In telecommunication systems such as GSM, radio mode of transmission is always prone to so many environmental factors like vegetation, weather and climate [1]. These factors create multiples of a transmitted signal as the signal propagates from its transmitting station to its receiving node (mobile station). The reception of these multiple signals degrades the received signal causing signal fade. This fade condition varies from one spot or location to another in the network coverage area.

The effect is that at some spots or locations, one may be on a call, suddenly the call will drop in the middle of the conversation. The call has to be re initiated if the conversation must continue. At some other times one may be on a call and suddenly either of the two parties will not be hearing the other person, suddenly they will start hearing themselves again only for the problem to occur again in a few seconds or minutes time. This type of problem also affects internet connectivity if one is at such a spot where this call problem is occurring. These leads to lots of frustration with effect that

network subscribers do not enjoy the services they paid for.

Research has shown that this phenomenon is being experienced in almost every part of Nigeria by GSM users and that the reason is simply our type of environment [2]. This problem is common with all the existing GSM network operators in Nigeria. One surprising thing about this phenomenon is that at a location where one network is being poorly received another network will be fully received there. And that is why many Nigerians carry two or more phones with different network operators with the belief that if one network is unsteady or not receiving at a point the other one may be receiving full network.

This therefore aims to design a system that will be incorporated in the mobile stations to ensure that GSM network subscribers receive good network signal that will enable them make and receive good calls and good internet services at all locations in their network coverage area. With that, the quality of GSM network signal will be improved tremendously for users so that those using more than one GSM networks because of network failures at some locations,

will no longer do that as they will be sure of good receptions with one network at all locations.

2.0 Literature Review

2.1 Multipath Signal

Studies have shown that the major cause of poor GSM network reception is multipath effect. In a multipath environment a single signal propagated from a transmitter arrives points of reception in multiple versions of that sent signal [3]. If the vector sum of the arriving multiple versions of that signal is constructive the received signal level will be good enough to sustain calls but if its destructive, the received signal level will not be able to sustain calls and it may lead to unsteady receptions or no reception at all.

In radio communication, the signal arriving at the receiver contains a large number of reflected, refracted and deflected versions of the transmitted signal. These arriving signals suffer time delay, amplitude differences and interference among each other resulting in significant degradation of the performance of the network. Multipath reception affect mobile user in so many ways: for an analog television signal, ghost images will be seen on the screen. For Satellite positioning systems strong delayed reflections which may cause a severe miscalculations of the distance between user and satellite. For a wideband (digital) signal, it will be dispersion and inter symbol interference. For fast moving mobile phone user, it will be rapid fluctuations of the signal amplitude and phase which will affect network quality of service. For a stationary mobile user it will be good reception at some locations, poor reception at some locations and no network reception at other locations.

According to [4], the received signal $s(t)$ in multipath environment is given as follows

$$s(t) = x(t) \exp(j\varphi_0) \exp(2\pi f_0 t) \quad (1)$$

Where

$$x(t) = \sum_{i=1}^k (a_o a_i(t) \exp[-j2\pi f_0 \tau_i(t)]) \quad (2)$$

$s(t)$ = received signal

$\chi(t)$ = received signal strength at any point in the network coverage area.

τ = received multipath signal

a_o = amplitude of the transmitted signal

a_i = attenuation constant of the received i^{th} multipath signal

f_o = operational frequency

τ_i = the i^{th} multipath received signal

k = the total number of arriving multipath signals

Considering the envelope ($\chi(t)$) of the received signal which contains the transmitted message, it will be seen that the received signal depends on the transmission frequency (f_0) and the number of multiples of the transmitted signal (τ) received at the location.

So to improve signal reception at that location one can either vary the number of the received multiples of the transmitted signal or the transmission frequency. Since the number of the multiples of the transmitted signal depends on the environment of the location which will be difficult to alter, one therefore has to rely on varying the transmitted frequency.

2.2 Fading in Multipath Environment

Fading in radio communication is the rapid fluctuations of the amplitude and phase of a radio signal over a short period of time or short travel distance. Fading is caused by interference between two or more versions of the transmitted signal which arrive at destination at slightly different times [5]. These waves, called multipath waves, combine at the receiving antenna to give a resultant signal which can vary widely in amplitude and phase, depending not only on the location of the receiving equipment but also on the distribution of the intensity and relative propagation time of the waves and the bandwidth of the transmitted signal. Fading can manifest itself basically in two forms vis-a-vis Large-scale fading and small-scale fading.

Large-scale fading is the long-term variations in the mean signal level of the received wave. Its effect is as a result of movement over distances

large enough to cause gross variations in the overall path between the transmitter and the receiver.

On the other hand small-scale fading is the short-term fluctuation in the received signal amplitude caused by the local multipath, and it can be observed over distances of about half a wavelength. The three most serious effects of small-scale fading are:

- Rapid changes in signal strength over a small travel distance or time interval.
- Random frequency modulation due to varying doppler shifts on different multipath signals.
- Time dispersion (echoes) caused by multipath propagation delays

Small-scale fading can be further classified as flat or frequency selective, and slow or fast see (Fig.1). A received signal is said to undergo flat

fading, if the mobile radio channel has a constant gain and a linear phase response over a bandwidth larger than the bandwidth of the transmitted signal. Under these conditions, the received signal has amplitude fluctuations due to the variations in the channel gain over time caused by multipath. However, the spectral characteristics of the transmitted signal remain intact at the receiver. On the other hand, if the mobile radio channel has a constant gain and linear phase response over a bandwidth (BW) smaller than that of the transmitted signal, the transmitted signal is said to undergo frequency selective fading. In this case, the received signal is distorted and dispersed, because it consists of multiple versions of the transmitted signal, attenuated and delayed in time. This leads to time dispersion of the transmitted symbols within the channel arising from these different time delays resulting in inter-symbol interference(ISI).

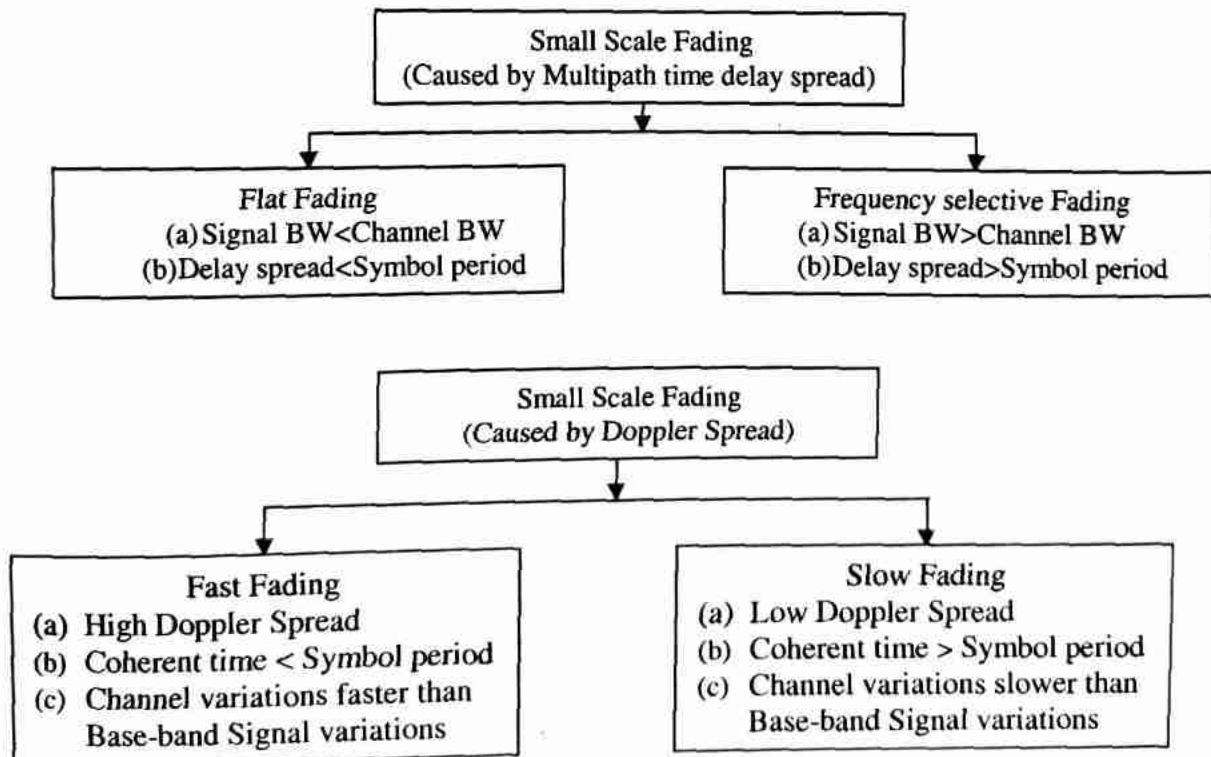


Fig.1: Classes of Small Scale Fading

When there is relative motion between the transmitter and the receiver, Doppler spread is introduced in the received signal spectrum causing frequency dispersion [6]. If the Doppler

spread is significant relative to the bandwidth of the transmitted signal, the received signal is said to undergo fast fading. This form of fading typically occurs for very low data rates. On the

other hand, if Doppler spread of the channel is much less than the bandwidth of the baseband signal, the signal is said to undergo slow fading.

Some of the physical factors in the radio propagation channel that influence small scale fading include:

Multipath Propagation – As earlier stated, the presence of reflecting objects and scatterers (like trees) in the channel creates a constantly changing environment that dissipates the signal energy in amplitude, phase, and time which results in multiple versions of the transmitted signal. It is this random phase and amplitude of the multiple versions that cause fluctuations in the received signal strength, thereby inducing small-scale fading, signal distortion, or both.

Movement of Surrounding Objects – In environments where some objects in the radio channel are in motion, they do induce time

2.3 Frequency Hopping

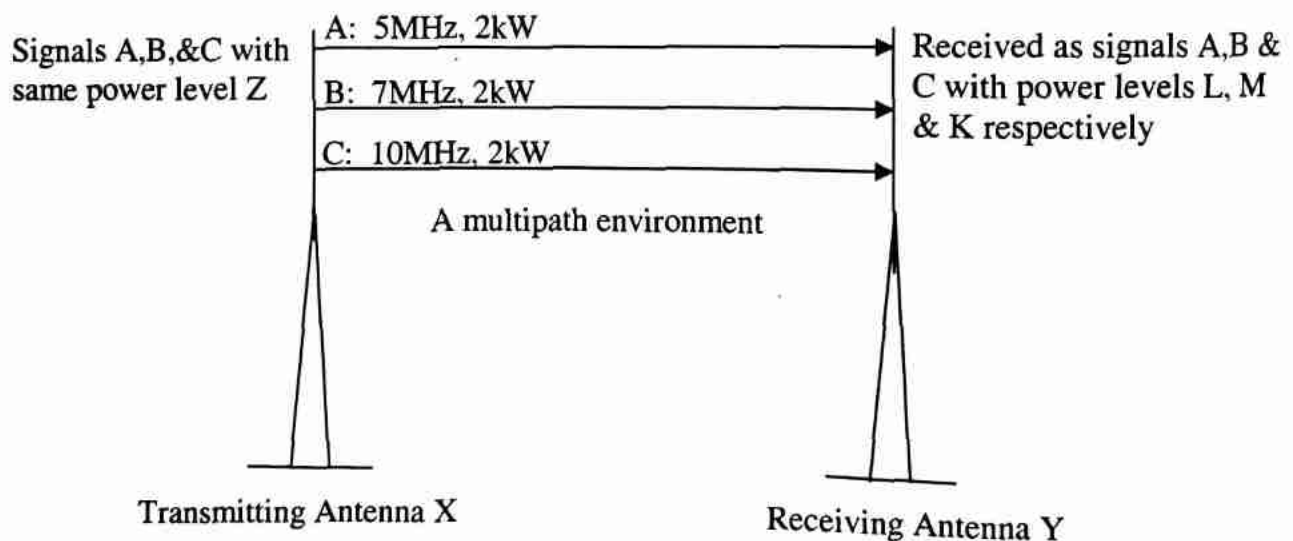


Fig.2: Diagram showing how a received signal is affected by the transmitting frequency

In radio communication, transmission is carried out by using a signal that changes with time called frequency. For effective radio communication, the frequency that must be used is located in the microwave band of the frequency spectrum. Different frequencies (operating frequencies) carrying the same message between the same distance and being transmitted with the same power level in a multipath environment arrive their destinations with different power levels. For example, in

varying Doppler shift on the multipath components.

Bandwidth of the Propagated Signal - In situations where the bandwidth of the propagated signal is greater than that of the multipath channel, the received signal will be distorted, but the received signal strength will not fade much over a local area (i.e. small-scale fading will not be significant). But if the propagated signal has a narrow bandwidth as compared to the channel, the amplitude of the signal will change rapidly, but the signal will not be distorted in time [7]. This means that the statistics of small-scale signal strength and the likelihood of signal smearing appearing over small-scale distances are very much related to the specific amplitudes and delays of the multipath channel, as well as the bandwidth of the transmitted signal.

Fig.2, three signals A, B and C with different operating frequencies and carrying the same message are being transmitted from point X with 5MHz frequency and power level of 2kW, 7MHz 2kW, and 10MHz 2kW respectively. The three signals though with the same power level arrive their destination Y with different power levels (K-mW, L-mW and N-mW). These power levels depend on how each signal path is being affected by the environment (i.e. between X and

Y). This shows that received signal depends also on the transmitting frequency.

So in multipath environment, a number of frequencies can be used to transmit the same message. At the receiving end the frequency that gives the best signal level will be selected and used for subsequent transmissions. This phenomenon is called frequency hopping. With that, signal levels at poor reception points within the network can be improved.

3.0 System Design

A mobile station (M.S.) is the hand held equipment which enables mobile subscribers to communicate (voice or data) with one another in the network. It has been observed that in some locations in the network, some subscribers do receive fluctuating network signals resulting in their communication coming in an OFF and ON manner. This is not desirable in a good communication network. From the various reviewed literatures, the cause of this kind of situation is due to signal fading at such locations which can be very bad in some locations in the network coverage because of the environment of that location. The condition in such case is that the received signal level continues to vary and a mobile receiver at such location will be receiving a fluctuating signal. If the received level is below the threshold signal level of that network, the call will fail, but if the signal level comes up again, the signal level improves and the call will be restored. Efforts have been made by some researchers to improve the signal level at such locations - such as connecting the mobile station to a mounted antenna. But that has not been very effective even with its inconveniences. Hence this work aims at improving the quality of transmitted signals that experience such phenomenon.

The design of this system follows a different approach. Here the concept is that the mobile station will measure the incoming signal level (Fig.3). If the received signal level is below the network threshold level (low level reception) the system will select (from the available list of

frequencies for the network operator) the frequency that gives the best signal level based on the environment of the location.

Design Assumptions

1. The operating frequency bandwidth for the network of this system is 905 – 920 Mhz
2. The network has 75 channels for its Operations.
3. The base transmitting station (BST) for the mobile subscriber for this work is allocated 8 channels from 905Mhz
4. The reception frequency for the mobile station at the coverage area is 905.4Mhz
5. The mobile station can receive between 905.4-905.5Mhz.
6. This band is subdivided up to 20 frequencies called hopping frequencies in steps of .005Mhz so that the mobile station can hop it to find the best frequency for its receptions.
7. For every hopping frequency a code has been assigned. The list of these frequencies and their associated codes shown in Table 1, are available at both the mobile station and the base station transmitter.

The mobile station will then transmit the associated code for the selected frequency to its BST.

At the base station, the transmitted code will be detected and decoded to determine the appropriate frequency for that location. The variable frequency generator for the base station will be accordingly instructed on the frequency it will generate for the next cycle of transmission. The base station frequency generator will start generating that frequency which it will along with other set or sets of frequencies transmit after it has been mixed with the message signal to the network coverage area (Fig.4). When the mobile Station receives at that frequency the signal level will improve tremendously and ensuring that the received level at that location is always good as long as the base station continues to transmit with that frequency.

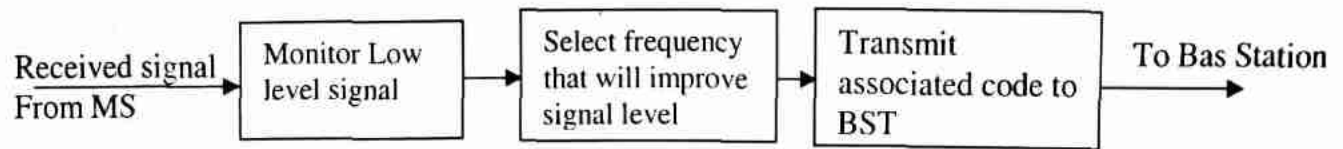


Fig. 3: Block diagram for incoming low level signal detector and frequency selection (at M. S.)

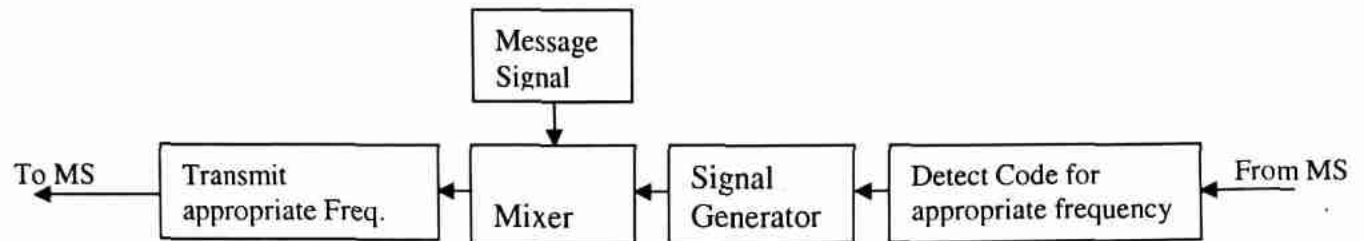


Figure 4: Block diagram of appropriate frequency code detector and frequency generator (at BS)

Following the concept, the design of this system was in two parts

1. Low level signal monitor and Appropriate Frequency Selector. This system will be embedded in the mobile station.
2. Appropriate Frequency Transmitter: To be located at the base station of the mobile station.

3.1 Design Parameters for Low Level Signal Monitor and Appropriate Frequency Selector

The received Low Level Signal Detector in a mobile station should be able to measure the incoming signal strength at the location of mobile station and decides whether the received signal strength is strong enough to sustain the calls. When the received signal level is not strong for calls (i.e. low level reception), the system selects an appropriate frequency from a list of frequencies that if transmitted will improve the received signal to a very appreciable level for calls. The associated code for this frequency will be transmitted by the mobile station to the base station.

Two systems are needed to perform this function: A signal strength measurement system and a frequency selector system.

(i) Received Signal Measurement System

This system has two units: Signal Level ($\chi(t)$) Measurement Meter (SLMM) and Low Level Detector (LLD). The signal level measurement meter module (Fig.5) will take a sample of the

received network signal at the location of the mobile station and send to the low level detector unit (LLD) which is the software aspect of the unit, to check if the signal is strong enough to carry communication transactions. From MTN handbook [2] if the received network signal level is equal to or above -91dBm ($\chi(t) \geq -91\text{dBm}$), that signal is strong enough to carry communication calls, but if that signal level is below -91dBm ($\chi(t) < -91\text{dBm}$), that level will likely result in intermittent call receptions, call failure or absent of network reception at that location depending on the level of the received signal. So for good reception, the received signal must be above -91dBm . The signal strength measurement system will therefore measure the received signal strength and determine if it is below -91dBm . If it is true it means that the call will very likely experience intermittent call reception or call failure. The signal needs to be boosted for smooth communication. The flowchart for the low level signal detector is given in Fig.6.

From the flowchart, the incoming network signal will be measured every second for 30 seconds. The average of the 30 seconds measurement will be taken ($\chi(t)$). If the level $\chi(t) \geq -91\text{dBm}$, it means that the received level is okay for the transmission. But if $\chi(t) < -91\text{dBm}$, it means that the level is low for the transmission. Such network receptions will cause intermittent call reception or no network

receptions, an undesirable condition. The signal level needs to be improved at that point. The signal will be sent to the appropriate frequency

selector to select the appropriate frequency that will likely boost the signal level at that location.

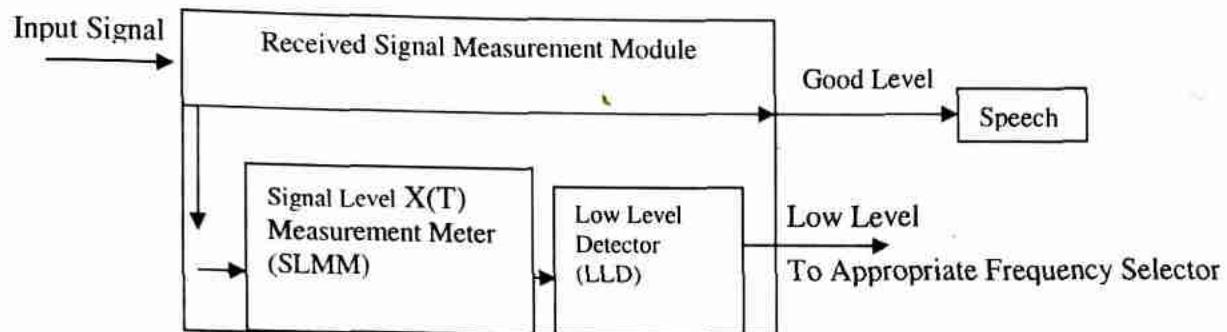


Figure 5: Received Signal measurement module

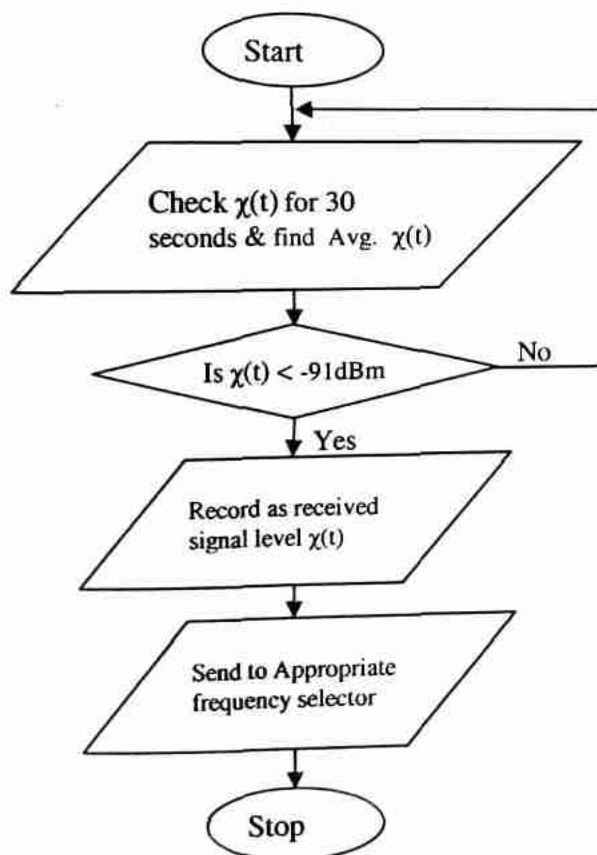


Figure 6: Flowchart for Low Level Signal Detector

3.3 Appropriate Frequency Selector

If $\chi(t) < -91\text{dBm}$, it means that the received signal is not good, because network connections with that signal level will experience network problems such as call interruptions or sometime

call drop. For good connection at such location the signal level needs to be improved. Signal level at any location in a mobile network depends majorly on two factors which includes path loss and multipath fading already explained.

Also as explained, the cause of signal level failures at isolated location in a network coverage area is mostly due to multipath problems.

3.4 Selecting the appropriate frequency that will improve the received signal level at that location

With the help of (2), two steps will be taken

- Since the operating frequency (f_0) is known and the received signal level ($\chi(t)$) for that location is also known by measurement, then the number of multipath signals at that location will first be determined.
- Now having known the number of arriving multipath signal at that location, each of the frequencies in the frequency list (Table 1) was tested in (2) to find the one that gives the best signal level.

From the flowchart of Fig. 7, the signal level ($\chi(t)$) from the received signal measurement module is read. With that level and using (2), the number of the multipath signal (τ) at that location would be calculated. Then a check was

made if the calculated multipath signal indicated that the receiver was within the coverage area of the network operator. If the (τ) is greater than 150, it means that the mobile unit is within the coverage area ($\tau > 150$), otherwise ($\tau < 150$) it is not within the coverage area of the Network and the system would prompt "Location not within the network coverage area", [2]. If the mobile unit is within the coverage area, using (2) also, all the frequencies in the list would be tested to find the frequency that gives the best signal level. The frequency that gives the best signal level would then be transmitted to the base transceiver station as the appropriate frequency for that location.

From the flowchart the signal level ($\chi(t)$) from the received signal measurement module is read. With that level and using equation 2, the number of the multipath signal (τ) at that location will be calculated. Then a check will be made if the calculated multipath signal indicates that the receiver is within the coverage area of the network operator. If the (τ) is greater than 150 [2] it means that the mobile unit is within the coverage area ($\tau > 150$), otherwise ($\tau < 150$) it is not within the coverage area of the Network and the system will prompt 'Location not within the network coverage area'. If the mobile unit is within the coverage area, using (2) also, all the frequencies in the list will be tested to find the frequency that gives the best signal level. The associated code for that frequency will then be transmitted to the base station as the appropriate frequency for that location. The mobile station will then be set to receive that frequency from the base station.

3.5 Appropriate Frequency Monitor

At the base station transmitter as shown in Fig :

1. The code receiver unit will decode the coded signal and select the appropriate frequency from the list as determined at the mobile station.
 2. The parameters for the generation of that frequency will be extended to the variable frequency generator of the base station transmitter.
 3. The variable frequency generator will then generate that frequency for transmission after it has been mixed with the message signal.
- Once the mobile station picks the signal with that frequency the signal level will greatly improve and network reception at that location will remain good

The flowchart for monitoring (at the BS) the coded signal and selecting the appropriate frequency from the list by matching in figure 8 below

Table1: Hopping Frequencies and their associated codes

Freq. (Mhz)	Code	Freq. (Mhz)	Code
905.405	00000	905.455	01010
905.410	00001	905.460	01011
905.415	00010	905.465	01100
905.420	00011	905.470	01101
905.425	00100	905.475	01110
905.430	00101	905.480	01111
905.435	00110	905.485	10000
905.440	00111	905.490	10010
905.445	01000	905.495	10011
905.450	01001	905.500	10100

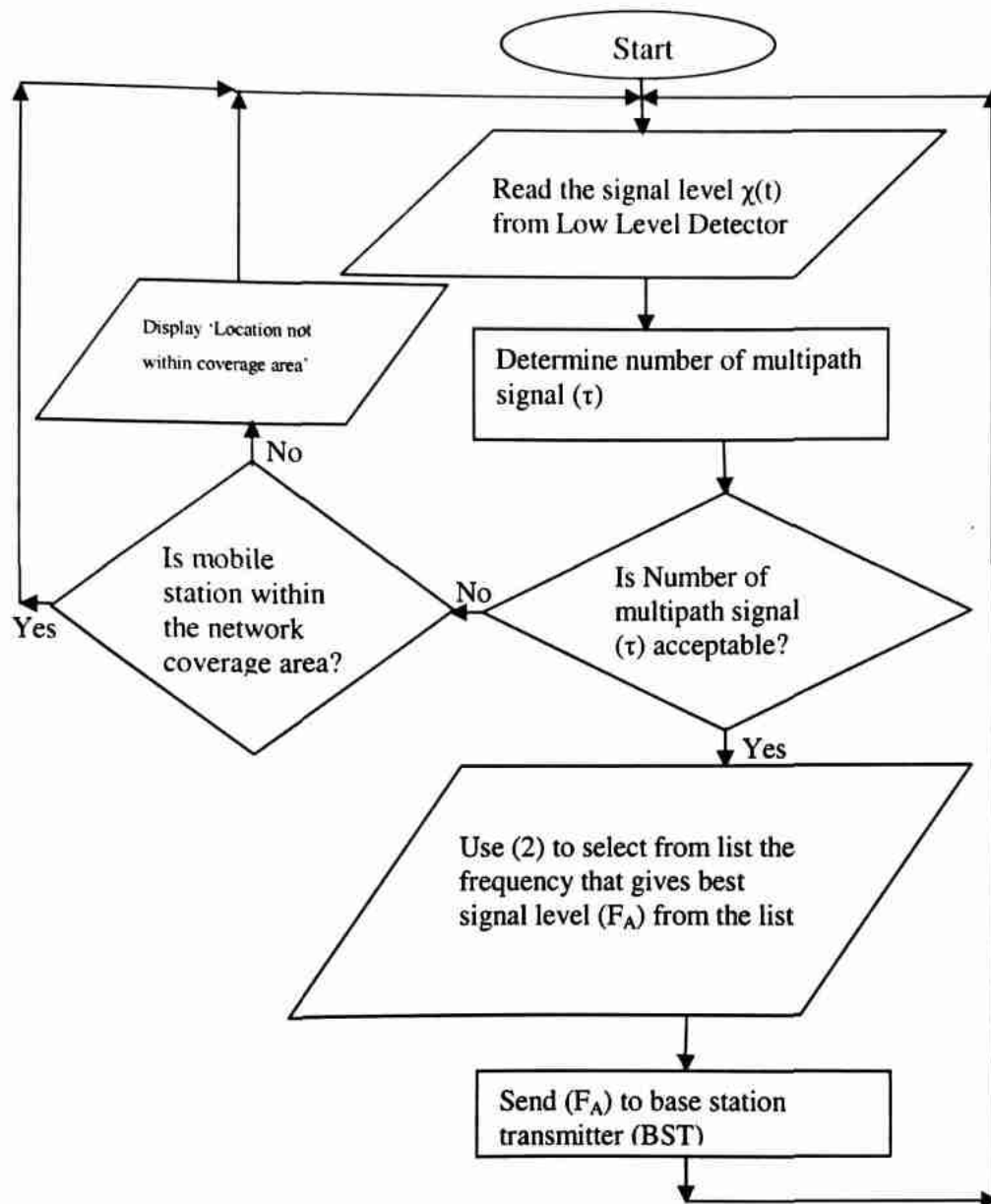


Figure 7: Flowchart for selecting appropriate frequency from list of frequencies

The frequency monitor at the Base Station Transceiver (BTS) detects the selected frequency based environment of the Mobile Station (MS). This detection is always done by matching the received frequency with the list of frequencies for the network. If there is a match, the system extends the parameters for generating

that frequency to the frequency generator at the BTS. The frequency then generates the frequency that will be mixed with the message signal and transmitted. Once the MS picks the signal with that frequency, the signal level will greatly improve and network reception at that location remains good (see Fig. 8).

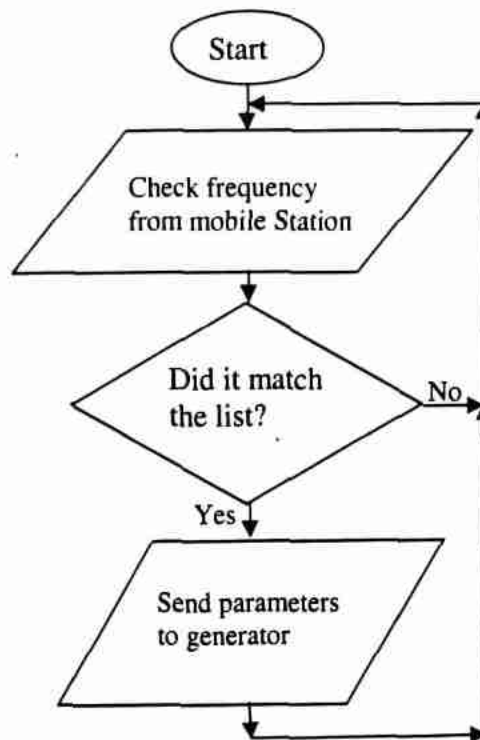


Figure 8: Flowchart for monitoring the selected frequency from mobile stations

The complete diagram for the propose GSM signal booster is shown in Fig. 9 below

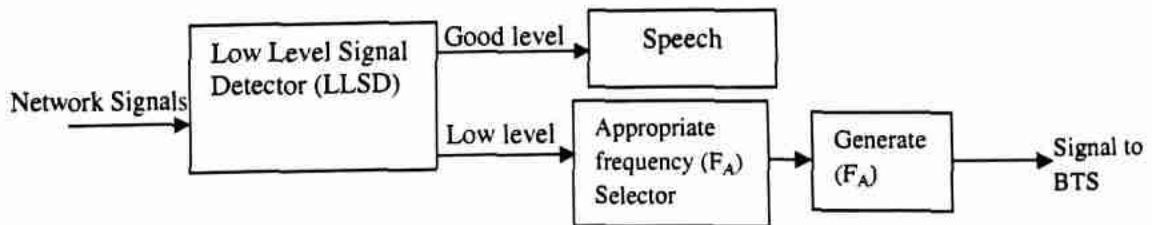


Figure 9: Low level signal detector and appropriate frequency (F_A) Selector (MS)

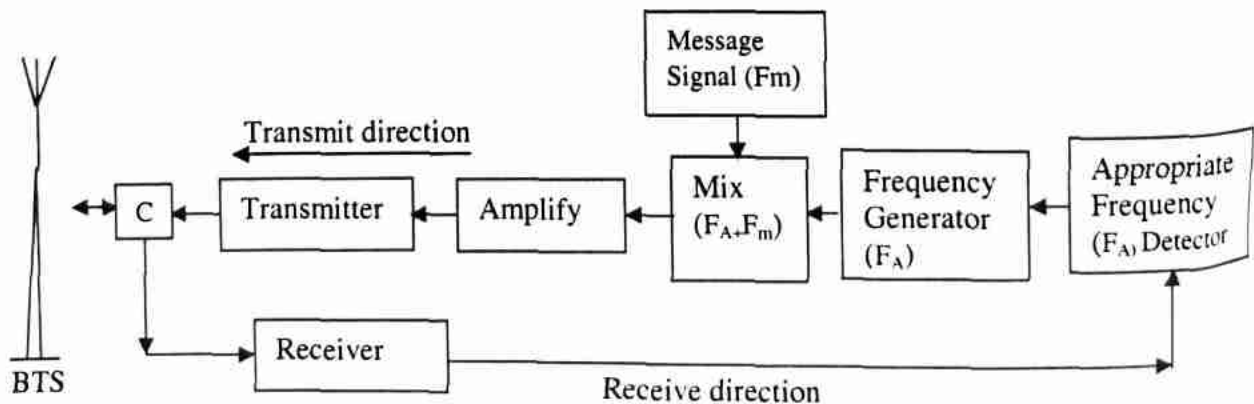


Figure 10: Appropriate frequency transmitter (Base station)

4.0 Conclusion

The simulation test for this design shows that the system is very reliable. It's easy to install, cost effective and can work in all networks and mobile devices. The system will be very good for environments where there are lots of obstructions and scattering of radio signals like Nigeria. With this, network receptions in GSM systems will be stabilized. Subscribers will now drop alternative lines and will be able to enjoy services anywhere in their network coverage area.

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