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Sensitivity Profile of a Prototype Mobile Number Portability GSM Design Using Bit Error Rate (BER)

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Abstract
Mobile Number Portability (MNP) standards and its integration is still evolving. As part of the previous work where JAVA programming language was used to develop an integration front end for admin logs and audits (MNVSim Suite), this work further expanded the work by presenting a simulation prototype of a MNP GSM design. MATLAB Simulink was used to implement the design while showing the sensitivity profile of the end user GSM node using BER metric as a QoS standard. The reviewed works shows that BER is a vital metric in a communication system. For the conceptual design, the significance of Gaussian Minimum Shift Keying GMSK was outline. An insight into the performance of proposed MNP conceptual GSM design based on array transceiver of CDMA 2000-1x system, considered for the case of 614.4 Ksps image data service WCDMA mobile radios with uniform variation of 1 km/h to 150 km/h was considered.

1. Introduction

MNP scheme is a telecommunication service that grants mobile phone users the freedom of changing GSM operators while still retaining their original mobile phone numbers [1]. Today, poor Quality of Service (QoS) among the GSM operators explains the motivation for the introduction of Mobile Number Portability Scheme across the globe including Nigeria lately [1]. This was the shown in our earlier research in [2]. Various works on MNP have been carried out in [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], and [22]. Sensitivity profile of MNP has received little research attention. In this regard, Quality of services vis-à-vis MNP has been scarcely investigated.

BER is widely used to measure the performance of communication system. It is the ratio of number of bits detected with error to the total number of bits transmitted [23]. Sensitivity profile for MNP scheme explains the reliability of the system. In this case, BER is leveraged. To develop a prototype GSM module for MNP which demostrates a good BER perfomance depicting an excellent QoS results is a research area which has received little attention. In this paper, a simulation of a conceptual MNP GSM design based on integrated GSM network in MATLAB software will be carried out showing the sensitivity profile of the end user GSM node. The BER strategy was used to obtain the QoS dataset. BER was used as an important metric for evaluation. We used this to validate that a low BER is required for mobile SIM Network communication QoS.

The structure of this paper is as follows: Section II discussed the literature reviews; Section III presents the prototype designs. Section IV discussed the simulation implementation and results. Section V concludes the research work with future works and recommendations.

2. Literature Review

Bit-error rate (BER) performance of the proposed Rake receiver for asynchronous direct sequence code-division multiple access (DS-CDMA) downlink system was investigated in [24] by computer simulations. The work used zero-padding method for implemented of the transmitter output while the Gaussian approximation of the noise and interference are used on the receiver output to enhance the BER performance with Binary Phase-Shift Keying (BPSK) modulation in presence of Rayleigh Fading Channel.

In [25], the work focused on the calculation of the bit error rate of a CDMA in a multipath fading while modelling AWGN channels by a discrete set of Rayleigh faded paths. A performance comparison their system in multipath fading and additive white Gaussian noise (AWGN) channels was presented.

In [26], the authors opined that Ad hoc networks are formed on a dynamic basis, i.e. a number of users maywish to exchange information and services between each other on an ad hoc basis, in order to do this they will need to form an Ad Hoc network. In this case, multipath signal detection is done using BPSK for CDMA Extended for OFDM and the calculated BER while analysing the signal in Ad hoc Network. It was adduced that the performance of data transmission over wireless channels is well captured by observing the BER, which is a function of SNR at the receiver.

The paper in [27] gave an overview about the WiMAX standard and studied the performance of a WiMAX transmitter and receiver, covering the performance of the proposed wimax system using simulation approach. The proposed system was tested under AWGN, Rayleigh, Rician, AWGN+Rayleigh and AWGN+Rician channels. It is concluded from the results that the proposed modified WiMAX system provides good reduced BER, channel capacity, reliability and throughput as compared to the normal WiMAX system.Most works in literature, that worked on BER failed to discuss their prototype designs in the context of MNP and its sensitivity profile. We shall make attempt, address these issues.

3. System Design

In the prototype design, thebasic components associated with the GSM transmitter and receiver is shown in figure 2 which is discussed below. In the proposed model, the respective blocksare implemented in order to transmit and receive data traffic with the least possible number of errors and call drops measure in BER. The various subsystem blocks will be discussed in this work.This work used Minimum Shift Keying (MSK) for modeling the Peer to Peer communication (See figure 1a) since:

- GMSK is a spectrally efficient modulation scheme and is particularly attractive for use in mobile communication systems because of its possesses properties such as :
- It has constant envelope.
- It has good Spectral efficiency.
- It offers good BER performance.
- It has self-synchronizing capability.

3.1. GMSK Modulation

There are different forms of digital modulation in mobile communications. Modulation is the process of encoding information from a message source in a manner suitable for transmission. The ultimate goal of a modulation technique is to transport the SMS signal through a radio channel with the best possible quality while occupying the least amount of radio spectrum. Since voice is the main payload of cellular network, we consider the model described by Equ1

$$X[n] = S[n] + t[n] \quad (1)$$

Where, $x[n]$ is the noisy speech signal, $s[n]$ is the original call speech *and* $t[n]$ is the noise source. At micro-mobility, the noise reduction blocksis placed at the demodulator of the MS receiver of the peer to peer system.

Now, for the GMSK modulator used, the mathematical model is derived below. Since the mobility baseband signals are generated at low rates, these signals are now modulated on an RF carrier for transmission. Thee baseband signal s(t) is a complex function represented by Equ 2

$$s(t) = a(t)e^{j\theta(t)} \quad (2)$$

Where $a(t)$ = Amplitude and $\theta(t)$ is the phase.

The fourier transform of$S(t)$ is give by Equ (3)

$$S(f) = \int_{-\infty}^{\infty} s(t)e^{-j2\pi ft}dt \quad (3)$$

A functional block diagram of a generic modulation procedure for signal $S(t)$ is given by

$$x(t) = \text{Real}\ \{s(t)\ A_c\ e^{ej2\pi fc^{t}}\} = A_c a(t)\text{Cos}[2\pi f_c t + \theta(t)] = A_c a(t)\text{Cos}\ \omega(t) \quad (4)$$

$$x(t) = A_c.a(t)\text{Cos}\theta(t)\cos(2\pi f_c t) - A_c.a(t)\text{Sin}\theta(t)\text{Sin}(2\pi f_c t) \quad (5)$$

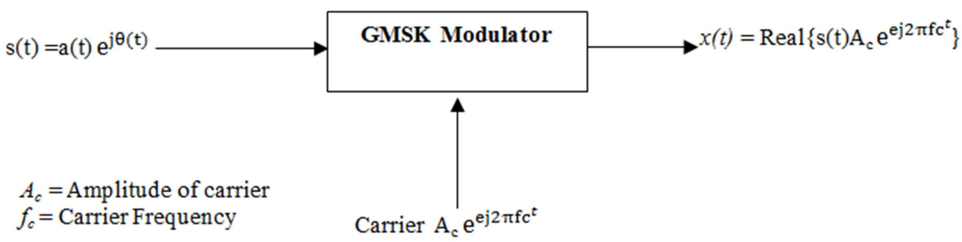

Figure 1a. *GMSK Modulation function for Peer to Peer Communication*

Now since GMSK is a constant envelop modulation, let's consider a data/voice stream

$\{a_k\}$ = 0,1, 2,

Where $a_k = \pm 1$ at a rate of $R = 1/T_b$ and T_b is the bit duration,

The in-phase and quadrature bit streams are:

$a_I(t) = a_0 \;\; a_2 \;\; a_4 \ldots\ldots\ldots$

$a_Q(t) = a_1 \;\; a_3 \;\; a_5 \ldots\ldots\ldots$

The rate of $a_I(t)$ and $a_Q(t)$ is $(0.5T_b)$ bit per second. Assuming the In-phase $a_I(t)$ and quadrature, $a_Q(t)$ signals are delayed by interval T_b from each other, the GMSK signal is defined by Equ 6

$$S(t) = a_I(t)\left[\cos\left(\frac{\pi(t-2nT_b)}{2T_b}\right)\right] \cos 2\pi f_c t + a_Q(t)\left[\sin\left(\frac{\pi(t-2nT_b)}{2T_b}\right)\right] \sin\,(2\pi f_c t) \qquad (6)$$

For filtration of the unacceptable adjacent channel interference so as to improve the spectrum of signal, is done by filtering the signal before modulation using gaussian filter which leads to bandwidth (B) of the filter in time-bandwidth product BT_b= 0.3.

The standard deviation σ of the impulse response is related to the filter bandwidth B byEqu 7

$$B = \frac{log_e{}^2}{\pi\sigma} = \frac{0.2206}{\sigma} \qquad (7)$$

Where the impulse response is given by Equ8

$$h(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{(-t^2)}/(2\sigma^2) \qquad (8)$$

The thread-off or price of the resulting improvement in bandwidth efficiency is a degradation in power efficiency. Hence, the BER is degraded due to inter-symbol interference (ISI) by the introduction of Gaussian filter.The BER performance of GMSK with coherent detection under AWGN conditions is given by Equ 9

$$P_e = \text{Xfc}\left(\sqrt{2\beta\frac{E_b}{N_0}}\right) \qquad (9)$$

Where β is a degradation factor due to pre-modulation filter. $\beta = 1$ correspondsto the performance of index of GMSK.

The BER under Rayleigh channel condition is given byEqu 10

$$P_e = 1 - \frac{1}{\sqrt{1+\frac{1}{\beta(E_0/N_0)_{avg}}}} \qquad (10)$$

Where (E_b/N_0)avg = Avg. Value.

Again, the burst message in a mobile portability scenario could be given by Equ 11

$$D(t) \rightarrow (t) = A\cos(wt+\theta) \rightarrow \text{Channel}. \qquad (11)$$

Where $D(t)$ is the message, $A\cos(wt+\theta)$ is the modulation. Modulation is done by varying the amplitude (A),phase(θ), or frequency (wt) of a high frequency carrier in accordance with the amplitude of the message signal.

For the above models, this thesis used Minimum Shift Keying (MSK) for modeling the peer to peer system owing to the reasons stated above. GMSK Modulation, expression for the Modulated Signal $x(t)$ is illustrated in figure 1b. It uses the Gaussian frequency shaping filter.

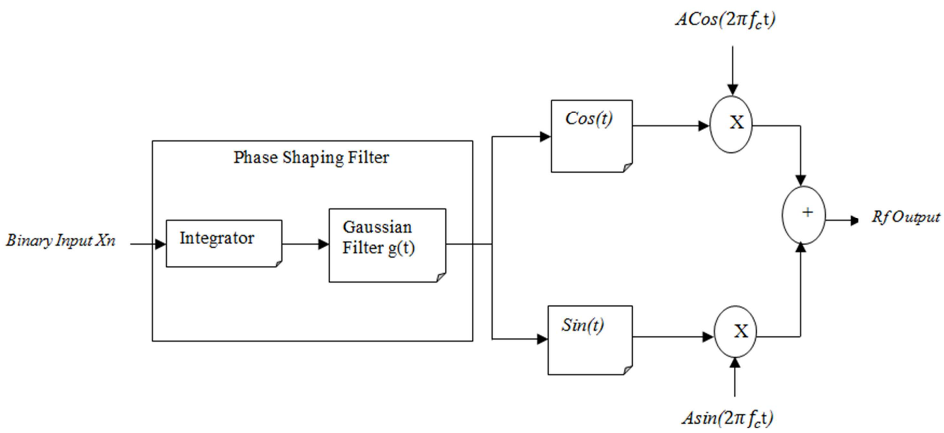

Figure 1b. *Peer to peer GSMK Modulator*

Granting that GMSK is a continuous phase modulation (CPM) signal with modulation index $h = 1/2$ which is defined by the continuous phase shift function θ(t), a modified complex baseband representation is given byEqu 12 [28]:

$$r_{transmit}(t) = Aexp(j\pi h \sum_n x_n \varphi(t - nT) + \varphi_0 \quad (12)$$

Where T is bit period, A is amplitude, $Xn = \pm$ is the sequence of binary alphabet symbols, θ_0 is random initial phase and θ(t) is the phase shift function. Constant envelop, continuous-phase modulation schemes are robust against signal fading as well as interference and have good spectral efficiency. The slower and smoother the phase changes, the better the spectral efficiency.The schematic diagram of a GSMK modulator is shown in figure 1b, where GSMK signal is generated by modulating and adding two quadrature carriers with the frequency f_c. Phase changes are smoothed by a filter having Gaussian impulse response [28].

$$g(t) = \frac{1}{2T}\left[Q\left(2\pi B\frac{t-T/2}{\sqrt{ln2}}\right)\right] - Q\left(2\pi B\frac{t+T/2}{\sqrt{ln2}}\right) \quad (13)$$

Where Q(t) is the Q-function given by Equ 14

$$Q(t) = \int_t^{\infty} \frac{1}{2\pi}\exp(-r^2/2)\mathrm{dr} \quad (14)$$

and the phase shift function $Q(t)$ in (1) is given by Equ 15

$$\varphi(t) = \int_{-\infty}^{t} g(t))dt \quad (15)$$

The key parameter in controlling both bandwidth and interference resistance is the 3-dB down filter bandwidth x bit interval product (BT) referred to as normalized bandwidth. GSM uses BT = 0.3, which corresponds to spreading the effect of 1bit over approximately 3bits intervals. The received signal in a mobile radio environment travels from the transmitter to the receiver over many paths. The signal fades in and out and undergoes distortion because of the multipath nature of the channel. For a transmitted signal as shown inEqu 4 and 12, the received signal, $r(t)$, is represented by Equ 16

$$r(t) = \sum_{i=0}^{n} x_i(t-\tau_i)\mathrm{a}(t-\tau_i)cos[\omega(t-\tau_i) + \theta(t-\tau_i)] + y_i(t-\tau_i)\mathrm{a}(t-\tau_i)sin[\omega(t-\tau_i) + \theta(t-\tau_i)] \quad (16)$$

From Equ3, we know that the received signal has Rayleigh fading statistics. But what are the characteristics of the $x_i(t)$ and $y_i(t)$ term in Equ16. If the transmitter signal is narrow enough compared to the multipath structure of the channel, then the individual fading components, $x_i(t)$ and $y_i(t)$ will also have Rayleigh statistics.

If a particular path is dominated by a reflection off a mountain, hill, building, or similar structure, then the statistics of that path may assumed to be the Rayleigh. If the τ_i(delay spread) is small compared to the bit interval, then a little distortion of the received signal occurs. If the τ_i is greater than the bit interval, then the transmissions from one bit will interfere with transmissions of another bit, resulting in inter-symbol interference (ISI). Spread spectrum systems use wide bandwidth signals and attempt to recover the signals in each of the paths and add them together in a diversity (Rake) receiver.

In the discussion so far, the MNP GSM devices can be transmitting narrowband signals, while the multipath signals are interference to the desired signal. We need a receiver that removes the effects of the multipath signal or cancels the undesired multipath.

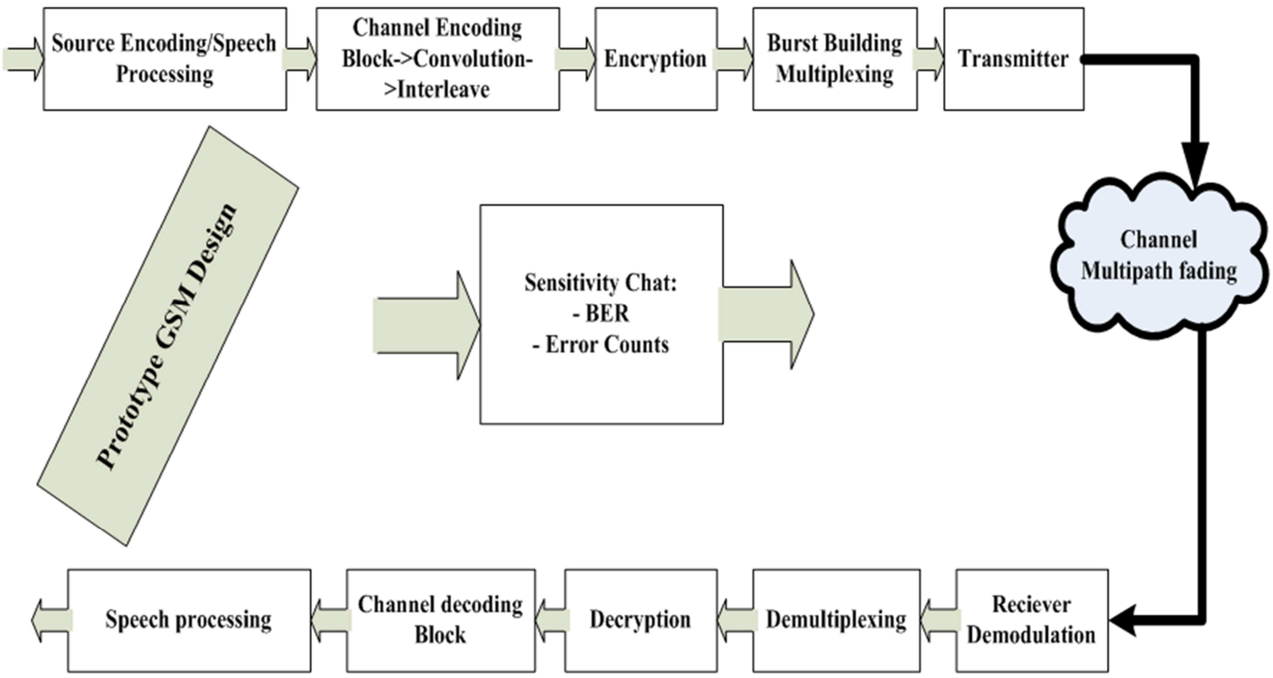

Figure 2. *Architecture of the Proposed Prototype GSM Design*

3.2. The Transmitter Block

From figure 2, the MNP GSM encoder implements source encoding. The channel encoding adds redundancy to the data stream in order to enable detection and correction of transmission errors. The encoder does block coding, both convolutional and interleaving, for error protection and correction. This comprises of the general cyclic redundancy check generator, encoder tail bits (pad), puncture, block interleaver, etc. This generates the modulation symbols for the next stage. The transmitter component of the GSM system has

- The smart antennas- This captures the modulation symbol from the encoder. It has the long code scrambler (mask) which performs long code scrambling, power control and signal point mapping for forward traffic channel. The spreading is the Non-TD mode which performs orthogonal spreading using a real-values quasi-orthogonal function and quadrature spreading using a complex-value pseudo number PN sequence.
- The Baseband Filter- This carries out RC filtering role for the channel. It unsample input signal by an integer factor and the apply an FIR filter.

3.3. The GSM Channel

This was capture with the multipath fading channel link with its optimal parameters for the receiver decoupling.

3.4. The GSM Receiver

The RC filter (Receiver baseband filter) picks the call signal from the channel via a rake receiver with four different fingers. Each finger down samples and decorates pilot bits of voice call using the corresponding sequence.

- The pilot bits are then sent to the channel estimator whose output is the used to detrotate the received signal for demodulation.
- The long code descrambler performs long code descrambling and power control extraction for forward voice traffic channel. In this case, the transmit diversity mode is the Non-TD mode. From the device receiver, the behaviour of the voice signal after the rake and derotation is captured.
- For the traffic decoder, a viterbi decoder was used to decode convolutionally encoded input data. Error correction with CRC detector is done while allowing for frame quality indicator process output.

Both the receiver channel bits and the transmitter channel bits are summed in the error rate calculation with recommended delays.

The model ends the receiver interface with a BER/Error estimator. The BER is computed by adding the source generated data with the demodulator output.

4. System Simulation Design/Results

Figure 2 summarizes the design prototype of figure 1 with table 1 showing the simulation parameters. MATLAB Simulink software [29] was applied in realizing the conceptual model.Simulink is a graphical extension to MATLAB for the modelling and simulation of systems. In Simulink, systems are drawn on screen as block diagrams. Many elements of block diagrams are available (such as transfer functions, summing junctions, etc.), as well as virtual input devices and output devices. Simulink is integrated with MATLAB and data can be easily transferred between the programs.

Table 1.*GSM Model Interface Specifications*

Simulation Parameters	Specifications
Channel Type	Forward fundamental radio configuration 3
Data rates	614.4Ksps
Propagation Model	Space Diversity:
Transmit diversity Mode	Non-TD
Channel Profile	Multipath fading
Channel bandwidth	3.5MHz
Receiver Type	Rake Receiver
Number of Simulations	100
Traffic Model	Infinite Buffer

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted. Equ 17 defines the BER.

$$\text{BER} = (\text{Bits in Error}) / (\text{Total bits received}) \tag{17}$$

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is a unit less Performance measure, often expressed as a percentage.

Figure 3 shows the implementation input in the MATLAB environment. The input to the source encoder in context is the voice stream. The output of the source encoder is a stream of bits mapped into the channel encoder. This streams of bits was passed through different blocks shown in figure 3. Some output was obtained at the output of the channel decoder block. The input and output was compared in order to check the validity of the results via BER monitor.

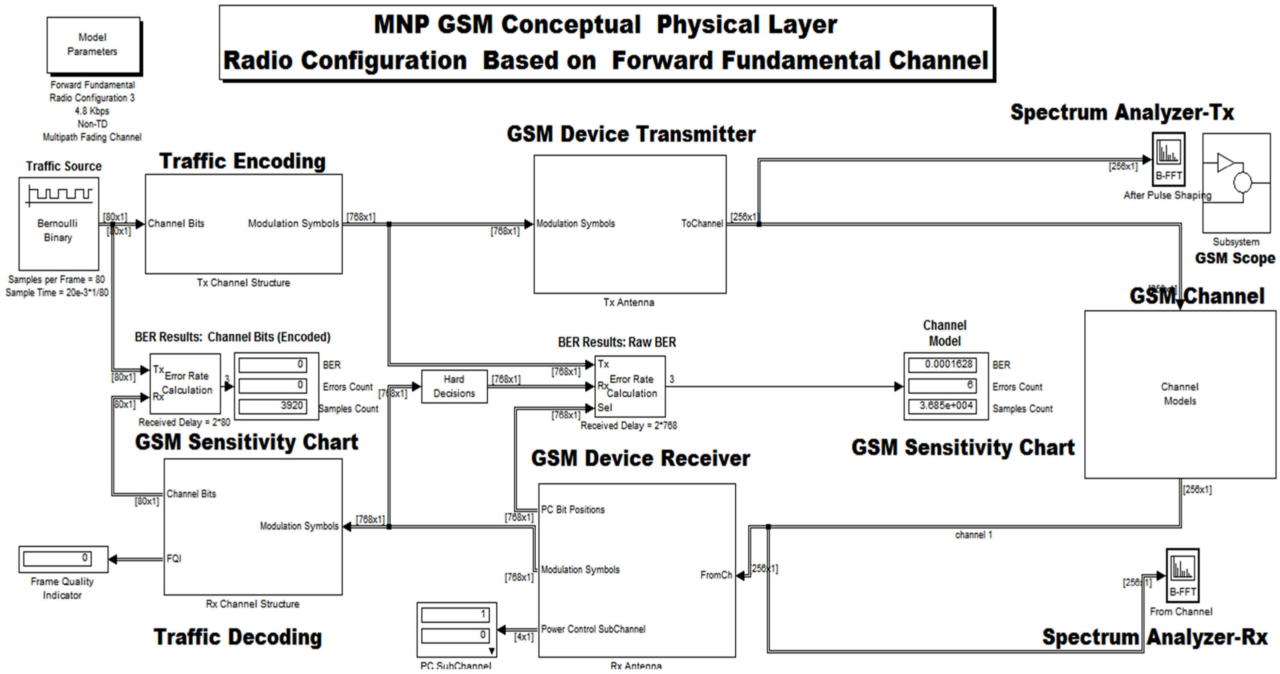

Figure 3. *MATLAB Implementation for Prototype MNP GSM Model*

Finally, the BER, Error counts and sample counts are monitored. For a simulation of 1sec, this work showed a BER of 0.001628 as shown in figure 4, which is very satisfactory for call drop analysis. In realizing a stable but sensitive system, the base BER of 0.001628 which is less than 1 achieves a good reliability.

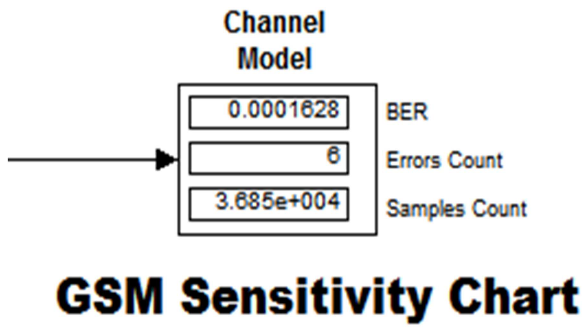

Figure 4. *Prototype GSM BER Sensitivity Response*

In a MNP environment, a mobile station will receive one direct signal from the base station and multiple signals which are reflected from obstructions like buildings and towers as shown in figure6 after the channel derotation. Each signal would have travelled a different length and would be displaced in time. Due to this, when they are combined at the mobile handset, it will cause interference resulting in poor signal quality. This is known as fading as shown in figure 5. This problem is handled in a very good way in CDMA from practical experience. Here, the phase of the multiple signals is modified such that only positive interference (addition) takes place and the overall signal strength. A receiver that implements the above principle is known as rake receiver as shown in figure 6. Convolutional coding and Quadrature modulation shown in figure 5 shows BER for a channel. The signal which is having highest receiving power and better BER that signal is considered (output signal from figure 5) and used to transmit the signal over ad hoc Network and shortest path algorithm is used to transmit the signal from source to destination. Figure 6 shows the Channel fading response before the receiver. Figure 7 shows the Channel fading response after derotation at the receiver. Figure 9 shows Channel response under multipath fading while Figure 8 shows the Channel fading response after rake receiver processing.

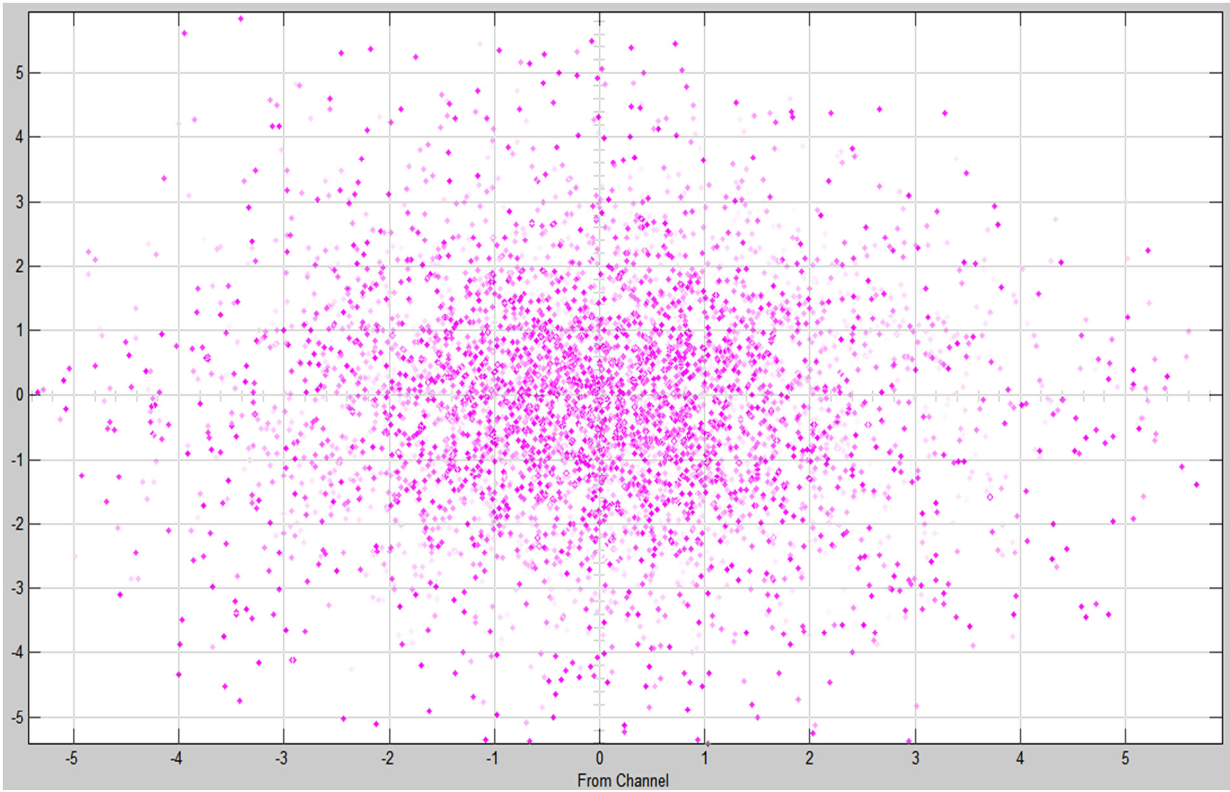

Figure 5. *Channel fading response before the Receiver*

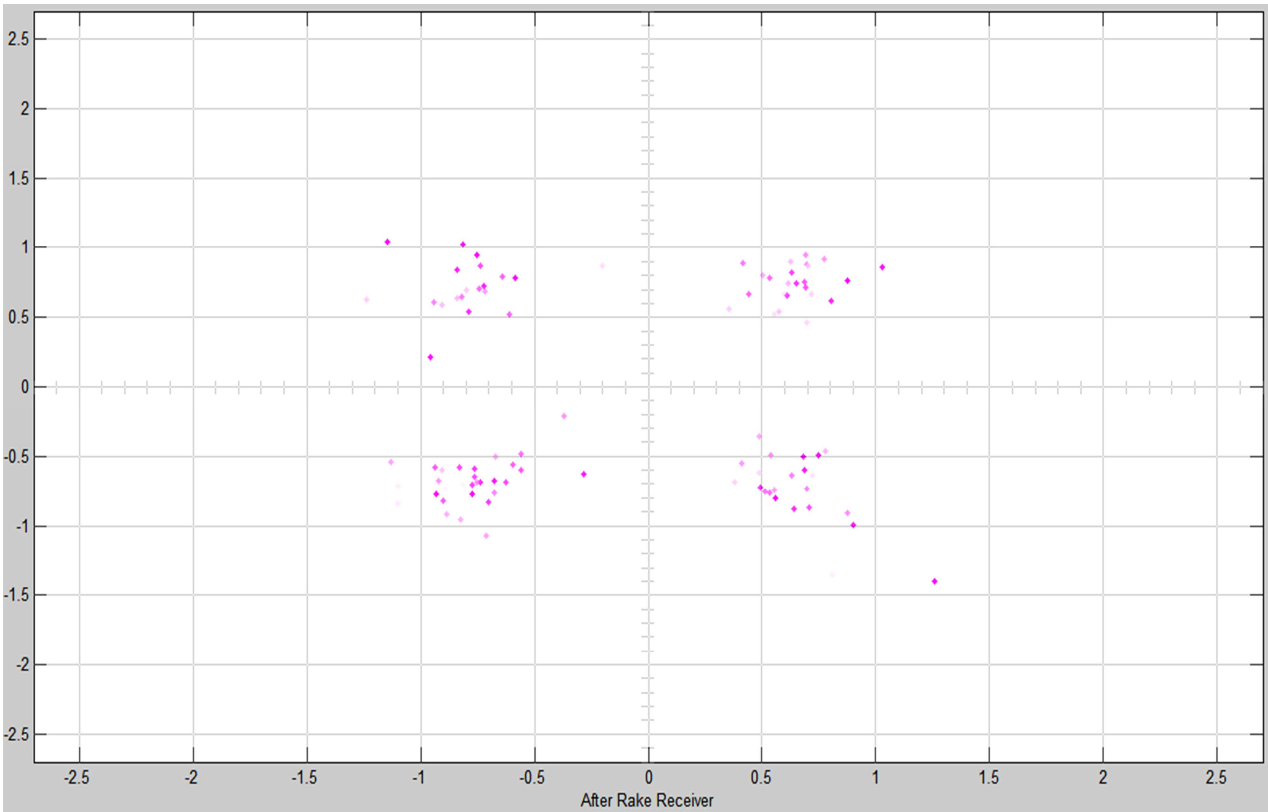

Figure 6. *Channel fading response after the Receiver*

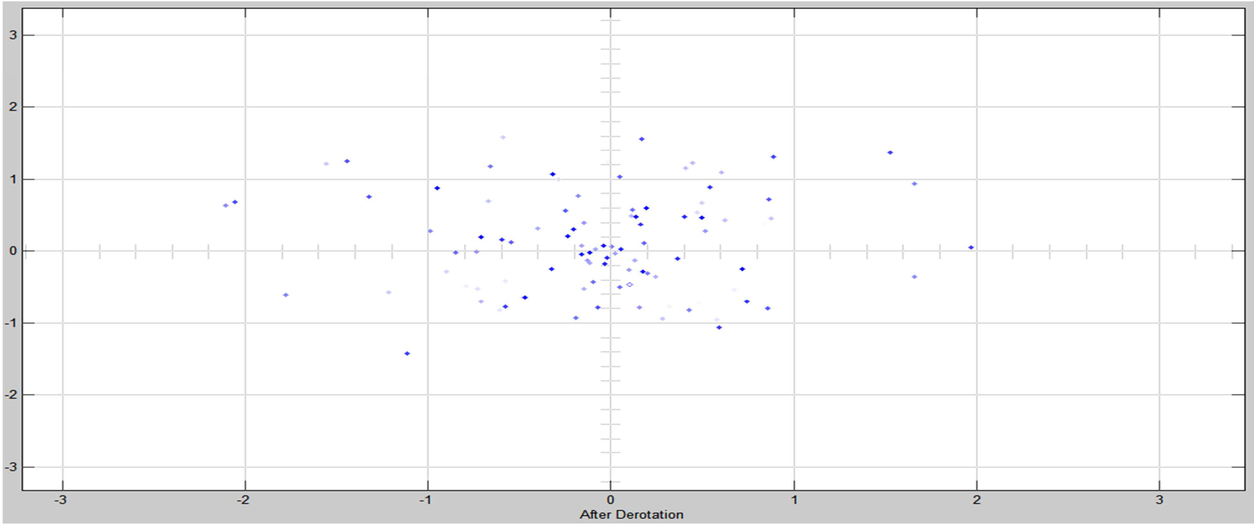

Figure 7. *Channel fading response after derotation at the receiver*

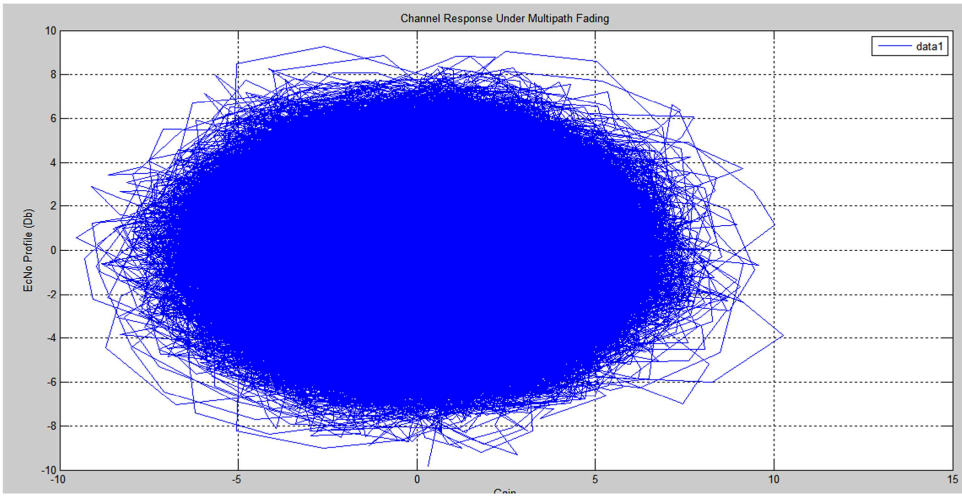

Figure 8. *Channel fading response after rake receiver processing*

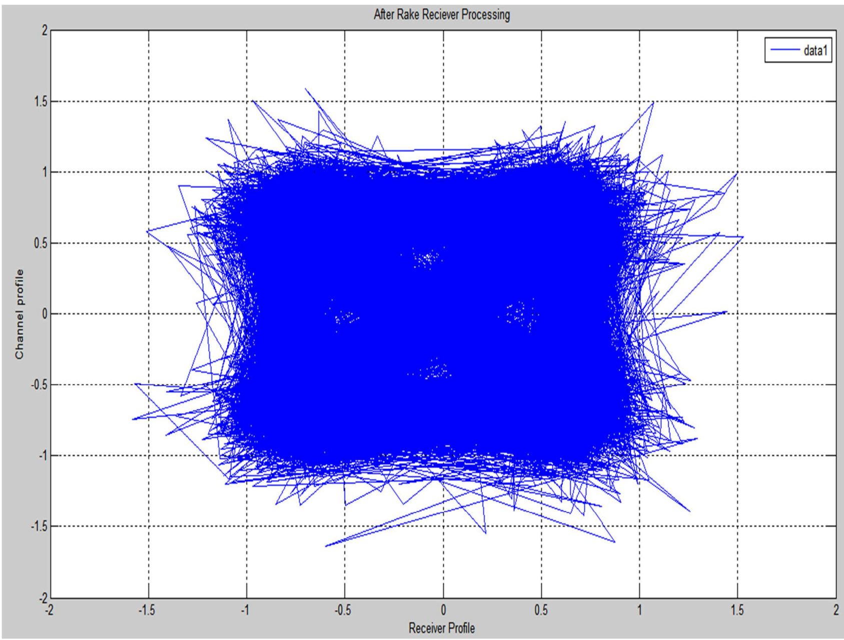

Figure 9. *Channel response under multipath fading*

5. Conclusion and Recommendations

In this paper, we tried to get an insight into performance of proposed MNP conceptual GSM design based on array transceiver of CDMA 2000-1x system, considered for the case of 614.4 Ksps image data service WCDMA mobile radios with uniform variation of 1 km/h to 150 km/h. To attain significant performance improvement, sensitivity profile channel estimation for BER was developed considering the conventional beamformer-RAKE schemes. It has been shown that improved MNP GSM array design is possible and system employing a smart base station transceiver structure can sustain significant co-channel interference and multipath fading suppression capability while maintaining low bit error performance at the mobile broadband image data service applications. The mathematical analysis of prototype design were presented, but the QoS processing time will be studied in the future

Throughout the previous research, this work has made following contributions viz:

1. To develop a MNSuite showing the scenario migration processes for end users [1].
2. Carried out a exhaustive literature survey on GSM QoS and KPI target analysis for possible improvements [2].
3. Developed a fuzzy integrated GSM network for decision rule management, using Mamdani Inference engine [30].

Furthermore, a prototype GSM module that is compliant with the proposed QoS model was achieved showing a satisfactory BER results. A low Bit Error Rate model with a call drop rate of <1 was achieved in the integration framework.Finally, this paper now developed a prototype GSM model for BER sensistivity with MATLAB Simulink.

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