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Performance Evaluation of GSM Transmission over Different Modulation Schemes (BPSK,QPSK,GMSK)

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Abstract- This paper presents performance evaluation of the different Modulation Schemes (BPSK, QPSK, GMSK) in terms of Bit error rate (BER) in cellular mobile environment with GSM standard parameters. The main objective of this paper is to investigate the factors that go into selection of the particular modulation scheme in the wireless environment. To analyze the cellular mobile environment GSM standard is selected. There are a number of factors that enter into the choice of a modulation scheme for use in a wireless application. Performance of a cellular system is dependent on the efficiency of the modulation scheme in use. Gaussian channel model was used. The various modulation schemes like BPSK, QPSK, and GMSK will be simulated in SystemVue software. After simulation of the all this, BER was carried out. Then using these parameters, the various modulation techniques were compared.

Keywords–BPSK, QPSK, GMSK, BER, Gaussian channel, GSM standard parameters.

I. INTRODUCTION

Nowadays, GSM network is more important and more advanced in the world. It is necessary to analyze which modulation scheme is best suited for GSM network. There are a number of factors that enter into the choice of a modulation scheme for use in a wireless application. Performance of a cellular system is dependent on the efficiency of the modulation scheme in use. The main objective of this paper is to study the factors that go into selection of the particular modulation scheme in the wireless environment. The goal of a modulation technique is not only to transport a message signal through a radio channel, but to achieve this with the best quality, power efficiency, and the least amount of bandwidth possible. Linear and constant envelope modulation techniques, such as BPSK, QPSK, GMSK, etc…, were used to examine the features of the required modulation scheme. To study the cellular mobile environment GSM standard is selected. The work in this paper is to understand the modulation schemes and compare their performance in the wireless channel. BPSK, QPSK, and GMSK modulation schemes were simulated. After simulation of the all this BER parameters of each modulation scheme have been carried out. Then a comparison was made by using these parameters. Simulation work has been done by using SystemVue (Elanix software package).

II. PROPOSED SYSTEM

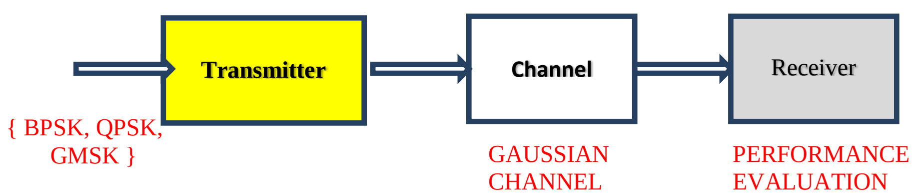

Figure1. System model

The system model we implemented is as shown in the figure 1. For the purpose of modulation BPSK, QPSK, and GMSK modulation techniques have been implemented. After modulation signal is passed through a channel where the channel can be modeled as Gaussian. In the Receiver, the standard minimum distance decoder logic was used. Then the BER of each modulation scheme will be observed in Gaussian channel model.

A. Binary Phase Shift Keying (BPSK)

In binary phase shift keying, the phase of a constant amplitude carrier signal is switched between two values according to the two possible signals corresponding to binary 1 and 0 respectively. Normally, the two phases are separated by 180 degrees. In a BPSK system the pair of signals S0(t) and S1(t) are used to represent binary symbol '1' and '0' respectively.

Eq (1)

$$S_0(t) = \sqrt{E_s}\cos(2\pi f_c\ t + 0) \dots\dots\dots 0 \le t \le T_b$$

$$S_0(t) = \sqrt{E_s}\cos(2\pi f_c\ t) \qquad \text{for symbol(1)} \qquad \text{Eq (2)}$$

$$S_1(t) = \sqrt{E_s}\cos(2\pi f_c\ t + \pi) \dots\dots\dots 0 \le t \le T_b \quad \text{for symbol(0)} \qquad \text{Eq (3)}$$

$$S_1(t) = -\sqrt{E_s}\cos(2\pi f_c\ t) \qquad Since\ cos(\theta + \pi) = -\cos(\theta) \qquad \text{Eq (4)}$$

Where,

$\sqrt{E_s}$ is the peak amplitude of the modulated sinusoidal carrier

B. Quadrature Phase Shift Keying (QPSK)

Quadrature phase shift keying has twice the bandwidth efficiency of BPSK, since two bits are transmitted in a single modulation signal. The phase of the carrier takes on one of four equally spaced values such as 45deg, 135deg, -45deg , and -135 deg, where each value of phase corresponds to a unique pair of message bits. The QPSK signal for this set of symbol states may be defined as

$$S_{00}(t) = \sqrt{E_s}\cos(2\pi f_c\ t + \frac{3\pi}{4}), \qquad \text{Eq (5)}$$

$$S_{01}(t) = \sqrt{E_s}\cos(2\pi f_c\ t - \frac{3\pi}{4}), \qquad \text{Eq (6)}$$

$$S_{10}(t) = \sqrt{E_s}\cos(2\pi f_c\ t + \frac{\pi}{4}), \qquad \text{Eq (7)}$$

$$S_{11}(t) = \sqrt{E_s}\cos(2\pi f_c\ t - \frac{\pi}{4}), \qquad \text{Eq (8)}$$

Using the identity: cos(a+b)=cos(a)cos(b) - sin(a)sin(b),

$$S_{00}(t) = -\frac{\sqrt{2E_s}}{2}\cos(2\pi f_c\ t) - \frac{\sqrt{2E_s}}{2}\sin(2\pi f_c t), \qquad \text{Eq (9)}$$

$$S_{01}(t) = -\frac{\sqrt{2E_s}}{2}\cos(2\pi f_c\ t) + \frac{\sqrt{2E_s}}{2}\sin(2\pi f_c t), \qquad \text{Eq (10)}$$

$$S_{10}(t) = \frac{\sqrt{2E_s}}{2}\cos(2\pi f_c\ t) - \frac{\sqrt{2E_s}}{2}\sin(2\pi f_c t), \qquad \text{Eq (11)}$$

$$S_{11}(t) = \frac{\sqrt{2E_s}}{2}\cos(2\pi f_c\ t) + \frac{\sqrt{2E_s}}{2}\sin(2\pi f_c t), \qquad \text{Eq (12)}$$

C. Gaussian Minimum Shift Keying

MSK with a gaussian filter is termed as GMSK.GMSK is a simple binary modulation scheme which may be viewed as a derivative of MSK. In the GMSK, the sidelobe levels of the spectrum are further reduced. In GMSK, the digital signal is first passed through a premodulation Gaussian pulse shaping filter and the filter generates a signal which is used to shift the carrier phase. This has the effects of considerably reducing the sidelobes levels in the transmitted spectrum. Premodulation Gaussian filter converts the full response message signal into a partial response scheme where each transmitted symbol spans several bit periods. GMSK is most attractive for its excellent power efficiency and its excellent spectral efficiency. The Gaussian filter impulse response given by,

$$h_g(t) = \frac{\sqrt{\pi}}{\alpha}\ exp\left[-\frac{\pi^2}{\alpha^2}\ t^2\right] \qquad \text{Eq (13)}$$

and transfer function given by

$$H_g(f) = exp(-\alpha^2 f^2) \qquad \text{Eq (14)}$$

The parameter α is related to B, the 3dB baseband bandwidth of $H_g(f)$, by

$$\alpha = \frac{\sqrt{ln(2)}}{\sqrt{2}\ B} = \frac{0.5887}{B} \qquad \text{Eq (15)}$$

The GMSK filter can be completely described by the bandwidth B and the baseband symbol duration T. It is customary to defined GMSK by its BT product.

D. Gaussian Channel

In Additive White Gaussian Noise channel model as the name indicates, Gaussian noise gets directly added with the signal and information signal gets converted into the noise. In this mode, scattering and fading of the information is not considered. When transmitted signal, white Gaussian noise, and received signal are s(t), n(t), r(t), the received signal is

r(t) = s(t) + n(t) Eq (16)

E. Bit Error Rate or Bit Error Ratio (BER)

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The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unitless performance measure, often expressed as a percentage.

In a communication system, the receiver side BER may be affected by transmission channel noise, interference, distortion, bit synchronization, problems, attenuation, wireless multipath fading, etc.

The BER may be improved by choosing a strong signal strength (unless this causes cross-talk and more bit errors), by choosing a slow and robust modulation scheme.

The **bit error probability** (pe) is the expectation value of the BER. The BER can be considered as an approximate estimate of the bit error probability. The bit error probability (pe) is proportional to $Eb/N0$ which is a form of signal-to-noise ratio. The energy per bit, can be determined by dividing the carrier power by the bit rate. has the unit of joules. $N0$ is in power (joules per second) per Hz (seconds).

Digital Modulation Technique	**Error Probability(p_e)**
BPSK	$P_{e,BPSK} = \frac{1}{2}\, erfc\sqrt{\left[\frac{E_b}{N_0}\right]}$
QPSK	$P_{e,QPSK} = \frac{1}{2}\, erfc\sqrt{\left[\frac{E_b}{N_0}\right]}$
GMSK	$P_{e,GMSK} = Q\left(\sqrt{\frac{2\alpha E_b}{N_0}}\right)$

Where,

erfc is the error function,
Eb is the energy in one bit and
$N0$ is the noise power spectral density
Q= Q-function
α=constant related to BTb

III. SIMULATION RESULTS

Here are the BER simulations for the various modulation schemes for Gaussian channel models. The results are of BER is as shown below.

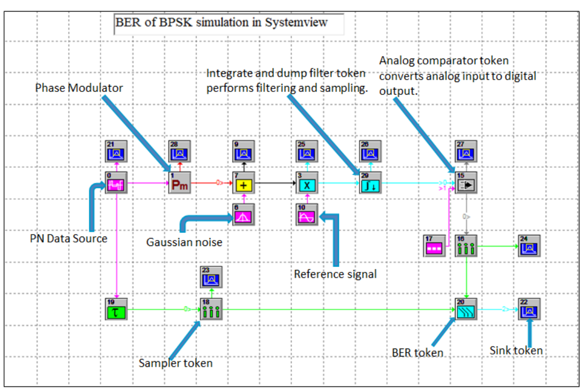

Fig.1 A BPSK coherent digital communication system with BER analysis in SystemView

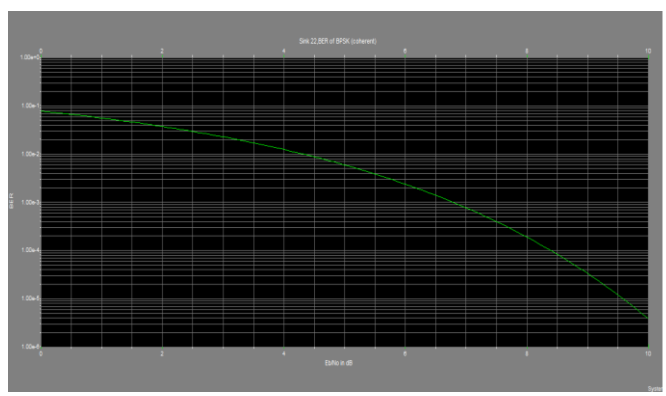

Fig.2 BER curve of BPSK

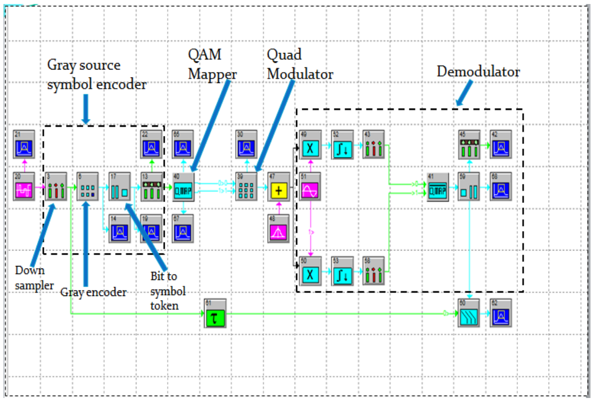

Fig.3 QPSK coherent digital communication system with BER analysis in SystemView

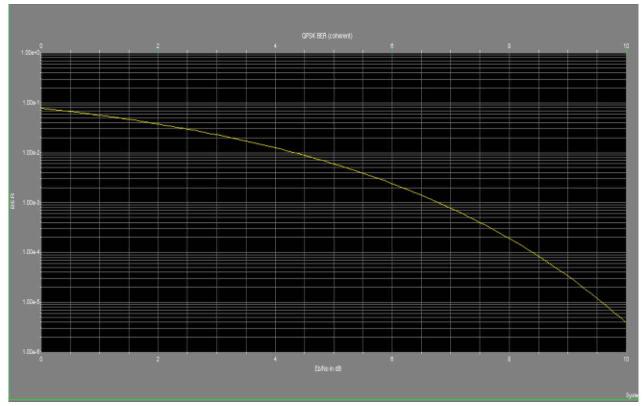

Fig.4 BER curve of QPSK

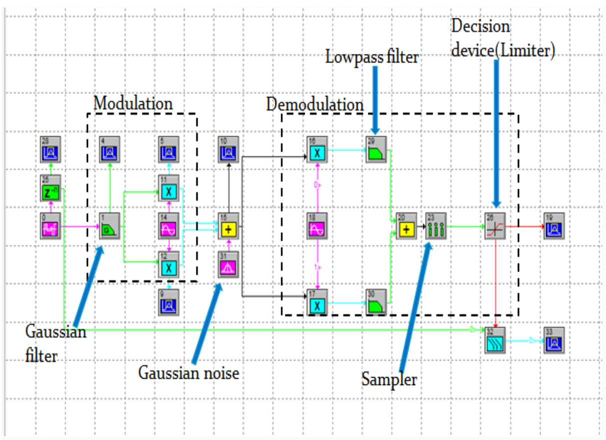

Fig.5 GMSK coherent digital communication system with BER analysis in SystemView

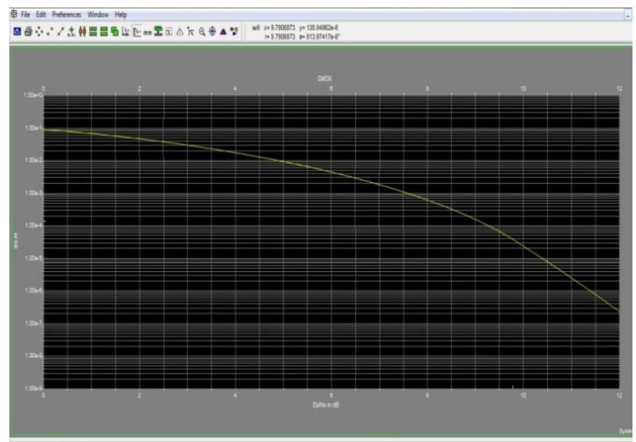

Fig.6 BER curve of GMSK

These tables show the comparisons of simulated BER and theoretical probability of error (p_e) of BPSK, QPSK, and GMSK.

Table.1 Simulated BER and Theoretical Probability Error (pe) of BPSK

$\frac{E_b}{N_0}$(dB)	BER	p_e
∞	0	0
0	0	4.05×10^{-6}
8	2×10^{-4}	2.06×10^{-4}
6	2.9×10^{-3}	2.41×10^{-3}
4	1.24×10^{-2}	1.25×10^{-2}
2	3.77×10^{-2}	3.75×10^{-2}
0	8.02×10^{-2}	7.93×10^{-2}

Table.2 Simulated BER and Theoretical Probability Error (pe) of QPSK

$\frac{E_b}{N_0}$(dB)	BER	p_e
∞	0	0
12	0	$\approx 10^{-8}$
10	3.87×10^{-6}	$\approx 10^{-6}$
8	2.9×10^{-4}	$\approx 10^{-4}$
6	4.2×10^{-3}	2.41×10^{-3}
4	1.46×10^{-2}	1.25×10^{-2}
2	3.69×10^{-2}	3.75×10^{-2}
0	7.72×10^{-2}	7.93×10^{-2}

Table.3 Simulated BER and Theoretical Probability of Error (p_e) of GMSK

$\frac{E_b}{N_0}$(dB)	BER	p_e
∞	0	0
12	2.03×10^{-7}	2.209×10^{-7}
10	2.35×10^{-5}	2.561×10^{-5}
8	6.23×10^{-4}	6.871×10^{-4}
6	5.14×10^{-3}	5.386×10^{-3}
4	1.94×10^{-2}	2.018×10^{-2}
2	5.21×10^{-2}	5.479×10^{-2}
0	8.93×10^{-2}	9.68×10^{-2}

IV. CONCLUSION

In comparing the performance of the three PSK based transmission over the same channel, BPSK and QPSK obtained similar result. Comparing their theoretical BER for AWGN equation, the simulated results are acceptable. Even so, it can be observed that BPSK requires less signal power to obtain a 0 BER. GMSK BER performance is significantly higher than BPSK. This might be due to the Gaussian filtering. The results above indicate that there is no one prominent modulation scheme between linear and constant envelope modulation methods. BPSK, QPSK, and GMSK have their own strong features that provide a desirable cellular environment. When it comes to any one particular application, it is important to look at the tradeoffs involved. Most mobile products are designed with Class C power amplifiers, which offer the highest power efficiency, yet because they are nonlinear, require the amplified signal to have a constant envelope. This reduces the desirability of implementing QPSK in this situation. However, QPSK effectively utilizes bandwidth; whereas, GMSK requires more bandwidth to effectively recover the carrier. Furthermore, due to its frequency modulating characteristic, GMSK shows a greater immunity to signal fluctuations. QPSK and GMSK each provide beneficial features, and although neither dominates the other, both contribute to the advancement of wireless telecommunication systems.

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