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A Performance Study of GSM and GSM/EDGE Systems for Different Multipath Fading Channels

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ABSTRACT

This study investigates the performance of GSM and Enhanced Data rate for GSM Evolution (EDGE) mobile communication systems operating in both Additive White Gaussian Noise (AWGN) channel and Rayleigh fading channels. This investigation presents the characteristics of the bit error rate (BER) for conventional GSM and GSM/EDGE MCS-1 and GSM/EDGE MCS-7 systems. These characteristics are compared for different models of fading channel in order to describe various environments. These fading channels are HT100, HT 50, TU 50, TU 3, EQ and SUI- 1. The investigation results indicate clearly that to achieve a bit error rate BER of 1×10^{-5} in additive white Gaussian Noise AWGN channel, the signal-to-noise ratio SNR should be 5.8, 4.9 and 13.9 dB when conventional GSM, MCS-1 EDGE (GMSK modulation), and MCS-7 EDGE (3π/8-8PSK modulation) systems are used, respectively. These values are to be compared with 11.3, 10.0 and 20.5 dB, respectively, for HT100-type fading channel. The MSC-1 EDGE system offers the best BER characteristics followed by conventional GSM system. The MCS-7 EDGE offers the worst BER characteristics among the three systems.

Keywords: BER, GMSK, GSM, EDGE, SNR.

1. INTRODUCTION

The introduction of global system for mobile communication (GSM) air interface has undoubtedly created a new area in telecommunications. In view of its extensive use in real world applications, it is highly desirable to further investigate the performance of the GSM system under different operating conditions and environments. Furthermore, there is increasing interest in using high-level modulation to provide enhanced data rate for GSM evolution EDGE [1]. This technique improves spectral efficiency by applying the modulation format 8-ary phase shift keying (8-PSK) instead of binary Gaussian minimum shift keying (GMSK) which is used in conventional GSM. By extending the signal space from 2 to 8, each symbol contains three times more information. Although EDGE reuses the GSM carrier bandwidth and time-slot structure, it can also be used with other cellular systems. It can be regarded as a generic air interface for efficiently providing high bit rates thereby facilitating the evaluation of cellular systems toward third–generation capabilities [2].

In 2002, an equalization concept for EDGE by which high performance can be obtained at moderate computational complexity has been shown [2]. It has been shown that delayed decision-feedback sequence estimation (DDFSE) and reduced-state sequence estimation (RSSE) are promising candidates. Lee and Chengshan [3] have proposed a new method for channel equalization and symbol detection of EDGE cellular system. The new algorithm is computationally efficient and can also be easily implemented into commercial signal processors. Simulation results comparing this method with the RSSE method, both with and without set partitioning have been presented. Isoard [4] has proposed a network simulator to test some protocols implementation and to validate the compliance of mobile phones with 3rd generation partnership project (3GPP) standard. Tang and Ding [5] have introduced a new and simple iterative equalization scheme for EDGE wireless system. Loat and Bidan [6] have introduced a low complexity receiver scheme where equalization and channel decoding are jointly optimized in an iterative process. Majeed [7] has introduced a new detection method with minimum computational complexity for the GSM/EGDE system. Many efforts have been extensively carried out including analysis and simulation to improve the performance of GSM/EGDE mobile communication system [8].

The aim of this study is to investigate the performance of conventional GSM and GSM/EDGE mobile communication systems operating in both Additive White Gaussian Noise (AWGN) channel and Rayleigh fading channels. The BER characteristics are studied for those channels.

2. SYSTEM DESCRIPTION

A. GSM System

Fig.1 shows the blocks of the GSM system, all the transmitter blocks are standard and they are certified by the European Telecommunication Standard Institute (ETSI) [9,10]. The first block in the transmitter is the channel encoder. When the data is received from the higher layers it must be encoded using both convolutional encoder and cyclic encoder to make it possible for the receiver to detect and correct some (or all) the errors that are introduced in the channel. This encoder reduces the probability of error and increases the probability of correct reception. After the channel encoder, the second block is the block interleaver which interleaves the convolutional data to increase its immunity to noise. When the data is encoded and interleaved, it will be arranged to form the transmitted frames by inserting the header bits and the training sequence bits (used for channel estimation). When the frame arrangement is completed, the frames are now modulated (mapped) into Gaussian minimum shift keying (GMSK) and then sent through the channel.

B. GSM/EDGE System

The GSM/EDGE system uses eight Phase Shift Keying (8-PSK) modulations with filter in addition to GMSK. This means that three bits are sent for every symbol instead of only one single bit. Therefore, three times higher bit rates are theoretically possible. EDGE supports transmission rates ranging from 8.8 kbps to 59.2 kbps per channel. GMSK modulation can still be used when a more robust modulation is needed. One idea is to use 8PSK/GMSK for downlink communication, where the demand for high bit rates is larger, and use only GMSK for uplink communication, which results in less complex transmitters in the terminals [11]. To optimize the throughput for all radio conditions link quality control (LQC) is used to dynamically adapt the modulation and code rate with respect to the current link quality. EDGE has nine different Modulation and Coding Schemes MCS, (MCS-1 to MCS-9) as shown in Table 1.

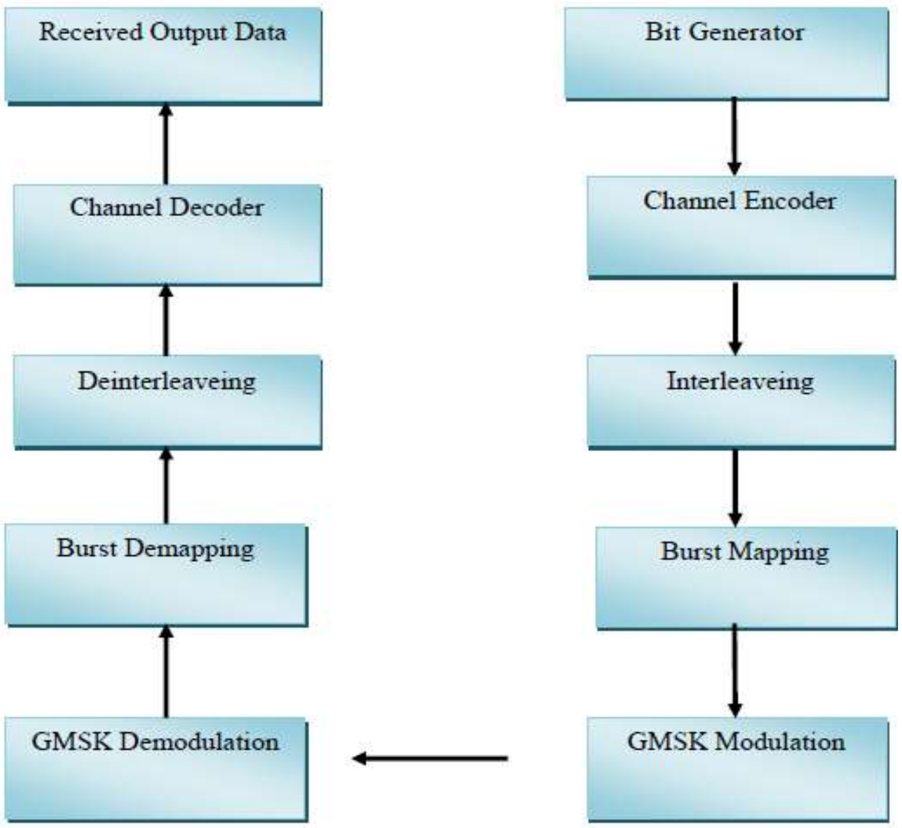


Fig. 1: A schematic block diagram for GSM system

Table 1: Coding parameters for the EDGE coding schemes.

Data rate kb/sec.	Raw data within one block	Scheme	Modulation
59.2	148	MCS-9	8-PSK
54.4	136	MCS-8	
44.8	112	MCS-7	
29.6	74	MCS-6	
22.4	56	MCS-5	
17.6	44	MCS-4	GMSK
14.8	37	MCS-3	
11.2	28	MCS-2	
8.8	22	MCS-1	

The first four use traditional GMSK and the last five used the new 8PSK modulation scheme. The MCS's also have different code rates and are therefore suitable for different radio conditions. If the conditions are very good, no coding is necessary and high bit rates can be achieved. Bad conditions require more robust coding, which results in less payload and lower bit rate [10]. Fig. 2 shows the blocks of the EDGE system. All the transmitter blocks are standard and they are certified by the ETSI [9, 10]. The first block in the transmitter is the convolutional encoder, which is the same for all the modulation and coding schemes (MCS's) (except for MCS-9, no coding is used). When the data is received from the higher layers it must be encoded using the convolutional encoder to make it possible for the receiver to detect and correct some (or all) the errors that are introduced in the channel. After the convolutional encoder, the encoded data is passed through a puncturing block. This block deletes some of the coded bits from transmission and this increases the throughput and also reduces the complexity of the decoder. The puncturing block structure depends on the used MCS.

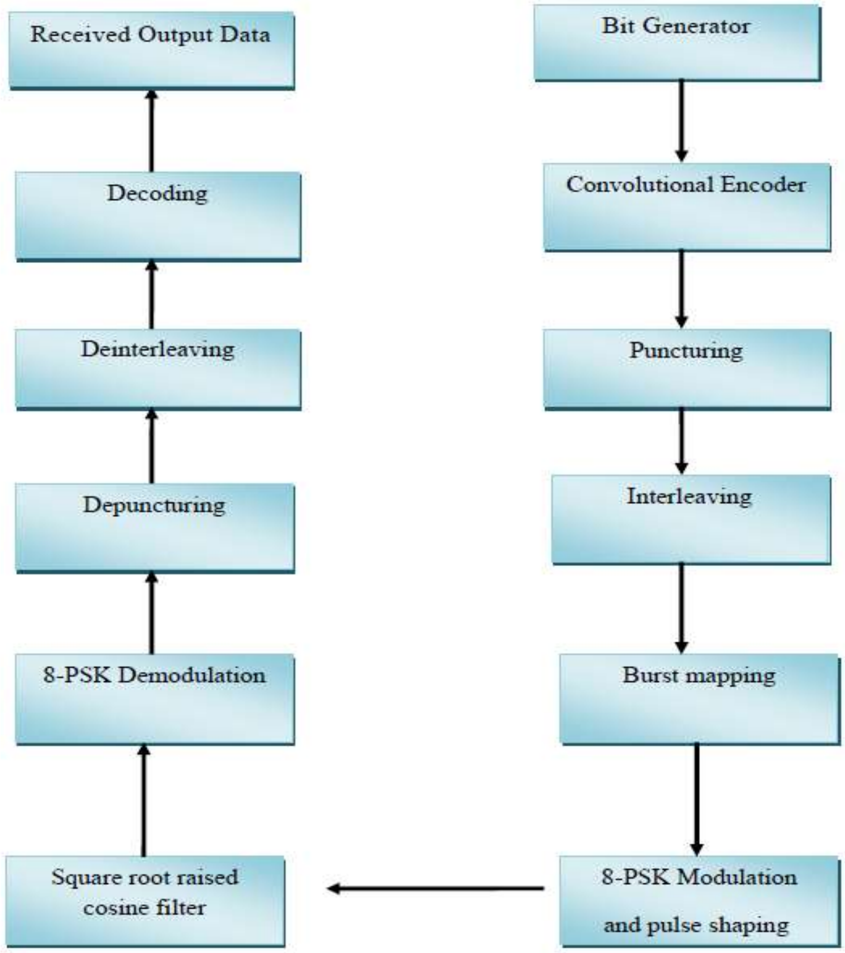


Fig.2: A schematic block diagram for EDGE system

The third block is the interleaver which interleaves the punctured data to increase its immunity to noise. This block also has different structures depending on the MCS used. When the data are encoded and interleaved, it will be arranged to form the transmitted frames, by inserting the header bits and the training sequence bits (used for channel estimation). All the MCS's have the same number of bits in each frame, but each MCS has a special frame arrangement. When the frame arrangement is completed, the frames are now modulated (mapped) into either GMSK (for MCS-1 to MCS-4) or 8-PSK (for MCS-5 to MCS-9). After the modulation, and before the transmission, a transmitter filter is used to limit the bandwidth of the transmission. For EDGE system a Gaussian filter is used to limit the bandwidth of the transmitted signal, and make it fit in the same bandwidth specified for GSM.

3. SYSTEM SIMULATION

This investigation has used a developed package of MATLAB software. This software package has been based on modeling and simulating extensively the EDGE system given in [8]. The modeling has taken into account channel coding, modulation type, interleaving and burst building, multipath channel effect, channel estimation, and detection process. Both MCS-1 and MCS-7 modulation coding schemes are considered for the EDGE system. In the present study, only the downlink is considered, i.e., the data transmission from BTS to the MS, where high data rates are needed, unlike the uplink where low data rates are sufficient for its needs.

4. RESULTS AND DISCUSSION

A. System Eye Diagrams

- **GSM system:** Fig. 3 shows the eye diagram of the transmitted signal. Note that the GMSK signal carries the information mostly in its phase. In fact the ideal FSK system is characterized by a constant envelope signaling where the information in is completely confined in the phase. The presence of the Gaussian filter adds a slight phase to intensity conversion due to its limited bandwidth.
  Fig. 4 shows the eye diagrams of the received signal simulated in AWGN and for different values of SNR.

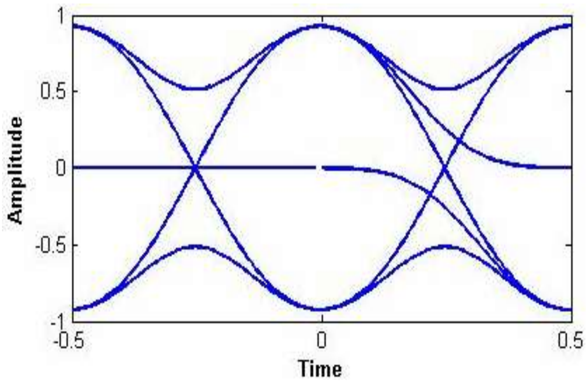
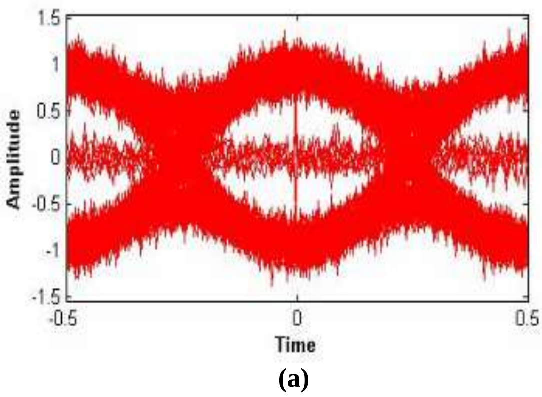
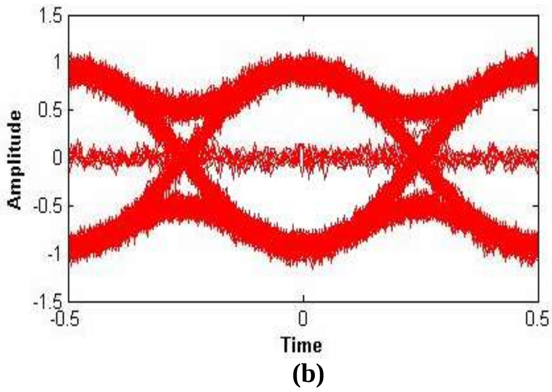


Fig. 3: GSM system eye diagram of the transmitted signal

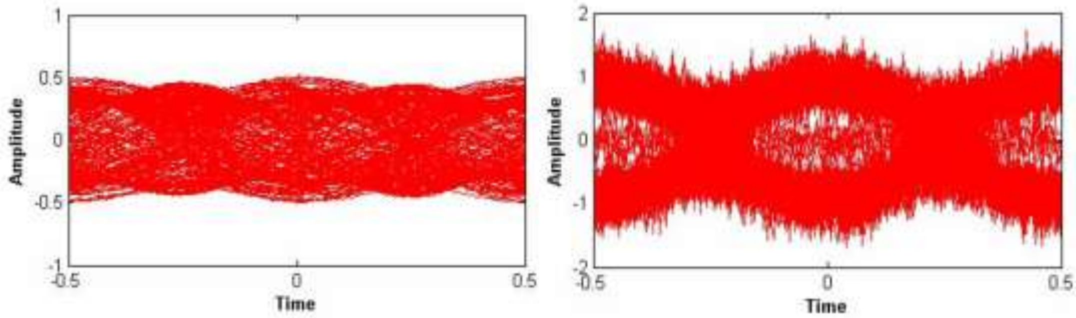


(a)



(b)

Fig. 4: Eye diagrams of the received signal for GSM system assuming AWGN channel at (a) SNR= 10 dB and (b) SNR=15dB



(a) **(b)**

Fig. 5: Eye diagrams of the received signal for GSM system assuming Rayleigh fading channel (a) SNR= 10 dB and (b) SNR=15 dB

The calculations are repeated for a 6-path Rayleigh fading channel and the results are depicted in Fig. 5. The parameter values of the fading channel are listed in Table 2 [8]. Investigating the results displayed in Figs. 4 and 5 reveals that the eye opening decreases as the SNR decreases and this effect is more pronounced in the presence of fading channels.

Table 2: Parameters values used to simulate the 6-path fading channels

path	Delay vector (μs)	Gain vector (dB)
1	0	-3
2	0.2	0
3	0.5	-2
4	1.6	-6
5	2.3	-8
6	16	-10

- **3π /8 – 8 PSK EDGE System:** This section presents simulation results related to MCS-7 of the EGDE/GSM system. This MCS uses 8PSK modulation format with 3π/8 phase rotator and operates with 44.8 kbps data rate. Fig. 6 shows the eye diagram of the modulated signal observed at the output of Gaussian pulse shaping filter. Note that in 3π/8 – 8-PSK signalling, the information contained completely in the signal phase, whereas both the signal amplitude and phase carry information at the output of the Gaussian pulse shaping filter. Fig. 7 (a and b) illustrates, respectively, the eye diagrams of the received signal assuming AWGN channel having a signal to noise ratio (SNR) of 10 and 15 dB. As the SNR increases, the eye opening increases.

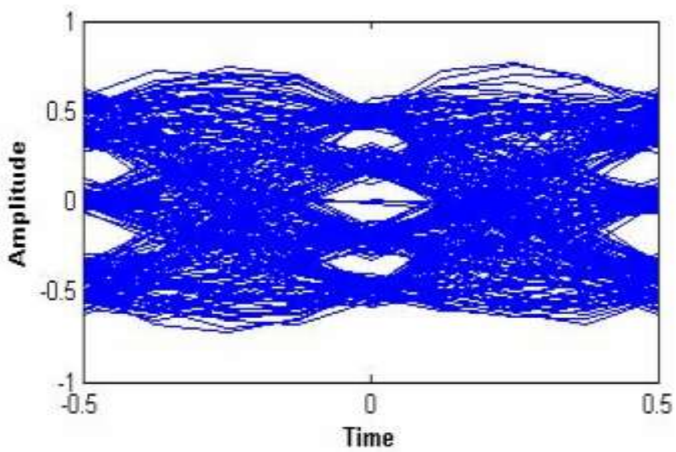
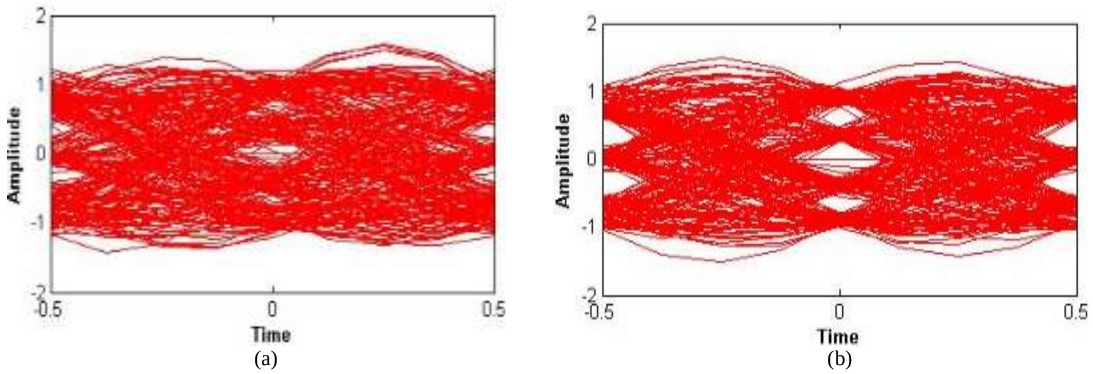


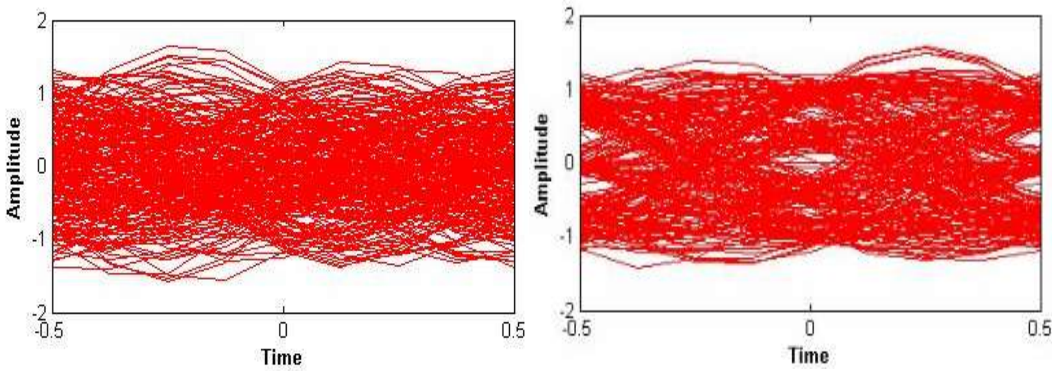
Fig. 6: Eye diagrams observed at the output of the Gaussian pulse shaping filter.



(a) (b)

Fig. 7:. Eye diagrams of the received signal of MCS-7 assuming AWGN channel (a) SNR=10 dB (b) SNR=15 dB

The calculations in Figs. 6 and 7 are repeated for a Rayleigh fading channel and the results are displayed in Figs. 8. The results are reported for a 6-path channel having the parameters values listed in Table 2 and assuming perfect channel estimation is performed at the receiver. It is observed that the presence of fading reduces the eye opening. SNR values that needed to obtain the same eye diagram for the received and the transmitted signals at different channels are listed in Table 4.



(a) **(b)**

Fig. 8: Eye diagrams of the received signal of MCS-7 assuming Rayleigh fading channel (a) SNR=10 dB (b) SNR=15 dB

Table 4: SNR values needed for obtaining same eye diagrams for transmitted and received signals

channel	GSM	MCS-7 EDGE
AWGN	45 dB	60 dB
Rayleigh fading	40 dB	60 dB

B. BER Characteristics

This section presents the characteristics of the bit error rate (BER) for GSM/EDGE MCS-1system and GSM/EDGE MCS-7 system. These characteristics are compared with those of conventional GSM system. The results are obtained for both additive white Gaussian noise (AWGN) channel and Rayleigh fading channels. Different types of fading channel are considered (the parameters values used in different channels are given in Tables 5-8 and are usually used to examine the GSM [10] and WiMAX [12] systems. These channels simulate the following environments:

- HT100 channel, Hilly Terrain with moderate to heavy tree density The number concatenated to the channel type represents the speed (measured in km/h) of the mobile station which affects the Doppler frequency and hence the Rayleigh fading of each path of the channel model. For example, data transmission through channel HT100 is simulated using the HT profile and the mobile station speed is assumed to be 100 km/h.
- HT 50 channel: Hilly Terrain with light tree density or flat terrain with moderate to heavy tree density.

- TU 50 channel: Typical Urban (TU) that is used in the city and the data transmission through channel. The TU 50 is simulated using the TU profile and the mobile station speed is assumed to be 50 km/h.
- TU 3 channel: Typical Urban that is used in the city when the body is walking. The data transmission is through channel. The TU 3 is simulated using the TU profile and the mobile station speed is assumed to be 3 km/h.
- EQ channel: Equalization Test whose values are set by the ETSI. The worse case is set and has the longest impulse response as compared to the other channels.
- SUI 1 channel: Mostly flat terrain with light tree densities.

Table 5: Parameters values used for Equalization EQ50

Path	Relative time (μs)	Average relative power (dB)
1	0	0
2	3.2	0
3	6.4	0
4	9.6	0
5	12.8	0
6	16.0	0

Table 6: Parameters values used for Typical Urban(TU)

Path	Relative time (μs)	Average relative power (dB)
1	0	-3
2	0.2	0
3	0.5	-2
4	1.6	-6
5	2.3	-8
6	5	-10

Table 7: Parameters values used forHilly Terrain (HT)

Path	Relative time (μs)	Average relative power (dB)
1	0.0	0.0
2	0.1	-1.5
3	0.3	-4.5
4	0.5	-7.5
5	15.0	-8.0
6	17.2	-17.7

Table 8: Parameters values used for SUI-1

Path	Relative time (μs)	Average relative power (dB)
1	0.1	0
2	0.2	-15
3	0.3	-20

Fig. 9 shows the BER characteristics of the three systems when they are operating under AWGN channel. The MCS-1 system gives the best BER performance while the MCS-7 system gives the worst performance. The BER for the 8-PSK is higher than the BER for GMSK, this is because the 8-PSK transmits eight different symbol values in the transmission channel while the GMSK transmits only two values. When the number of the transmitted symbol values increases the noise immunity of the system decreases, but it will increase the transmission bit rate. For 8-PSK, each transmitted symbol represents three bits while for GMSK each transmitted symbol represents only one bit. At the receiver when a new symbol is received the receiver will compare this received symbol with a threshold level to detect the transmitted symbol value. When the number of the transmitted symbol values increases the number of the threshold levels increases too. This will also increase the probability of wrong detection and this will increase the BER. To achieve a BER= 1x10-5, the SNR should be 4.5 dB, 5.9 dB and 14 dB for MCS-1, GSM and MCS-7 systems, respectively.

Figs. 10a-f illustrate the BER performance of the three systems for the six types of Rayleigh fading channels. These results are used to deduce the value of SNR required achieving BER = 1x10-4 and 1x10-5 for different channels (see Table 9).

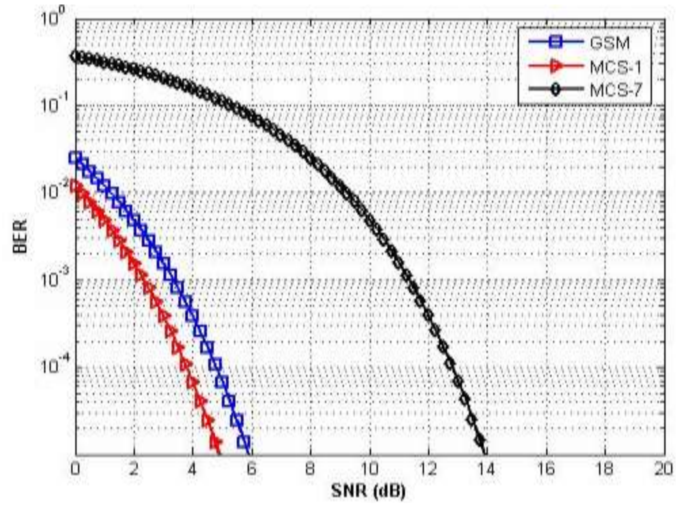
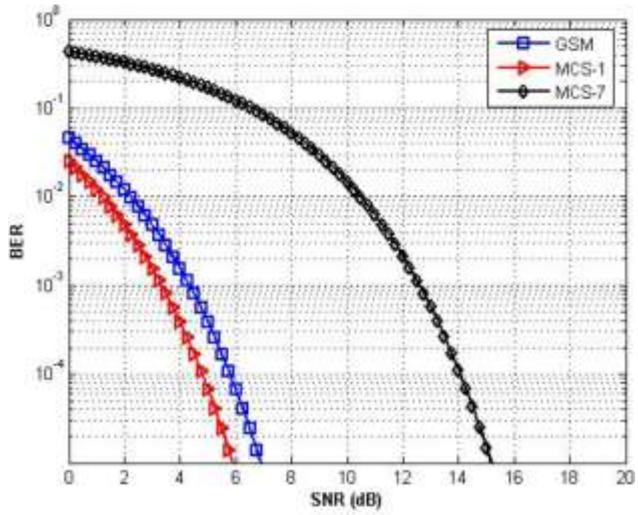
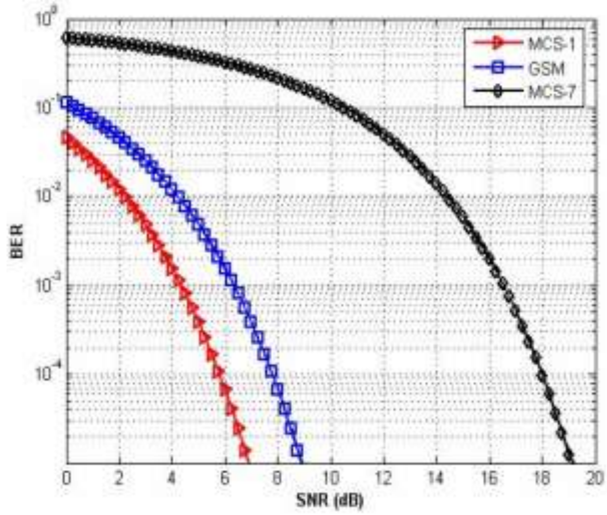


Fig. 9: BER Characteristics of GSM, MCS-1 and MCS-7 system in AWGN channel



(a)



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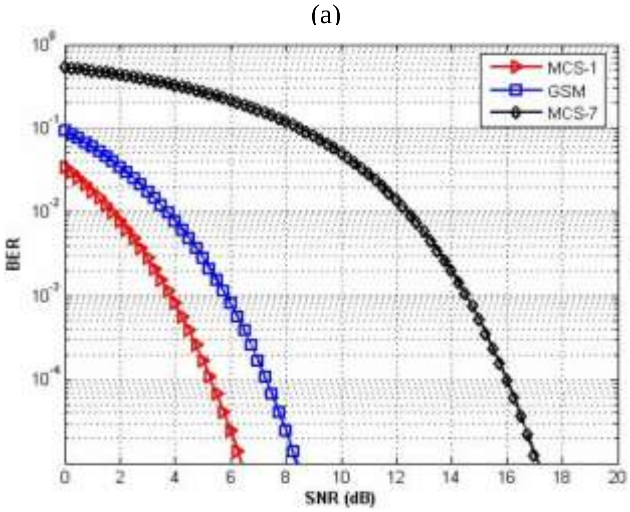

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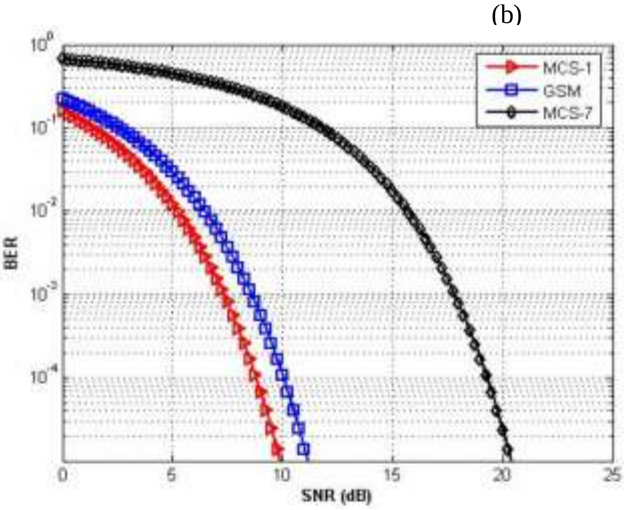

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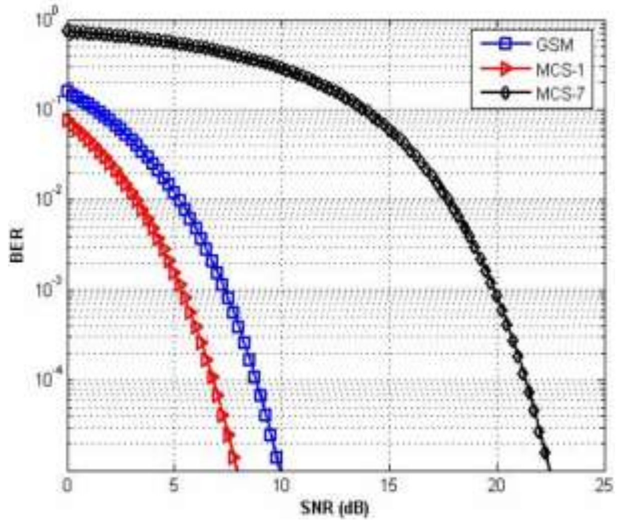
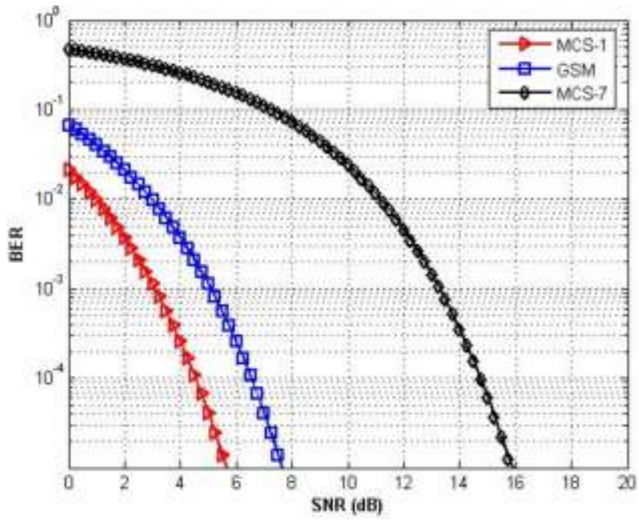


(e)



(f)

Fig 10: BER Characteristics of GSM, MCS-1 and MCS-7 systems operating with Rayleigh fading channel (a) TU3 (b) TU50 (c) HT50 (d) HT100 (e) EQ50 (f) SUI1

Table 9: Comparison of BER characteristics among different mobile channels

Channel	SNR (dB)					
	$BER = 10^{-4}$			$BER = 10^{-5}$		
	MCS-1	GSM	MCS-7	MCS-1	GSM	MCS-7
AWGN	3.8	5.0	12.5	4.9	5.9	13.9
TU3	4.8	5.9	14.0	5.9	6.9	15.3
HT50	5.3	7.5	16.0	6.5	8.5	17.3
TU50	5.8	7.8	18.0	6.9	8.9	19.3
HT100	8.9	10.0	17.6	10.0	11.3	20.5
EQ50	6.8	8.5	21.3	7.9	10.0	22.6
SUI1	4.5	6.5	14.8	5.6	7.6	15.8

Investigation into the results in Figs. 10a-f and Table 9 reveals the following facts:

(i) To achieve a specific value of BER, MCS-7 system requires the highest SNR, followed by the GSM system.
(ii) At $BER = 10^{-5}$, the required SNR increases by 1-2 dB as one moves from MCS-1 system to GSM system for all channels.
(iii) At BER= 1x10-5, the required SNR increases by 8-12.6 dB as one moves from GSM system to MCS-7 system for all channels.
(iv) The worst performance occurs when the GSM and MCS-1 systems operate in HT100 channel and MCS-7 system operates in EQ50 channel.

5. CONCLUSIONS

Comprehensive system simulations have been carried out for GSM and GSM/EDGE systems. Simulation results have been presented to compare the performance of GSM and GSM/ EDGE systems operating under various models of Rayleigh fading channels. The main conclusions drawn from this study are:

(i) The eye opening of the received signal decreases as the SNR decreases and this effect is more pronounced in the presence of fading channel

(ii) The worst performance occurs when MCS-1 systems operate in HT100 channel, and MCS-7 system operates in EQ50 channel.

(iii) At BER= 1×10^{-5}, the MCS-1 system offers SNR gains of 1-2 dB over conventional GSM system while the GSM system offers SNR gains of 8-12.6 dB over MCS-7 system for all channels.

(iv) The MSC-1 system offers the best BER characteristics followed by GSM system. The MCS-7 offers the worst BER characteristics among the three systems.

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BIOGRAPHY

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