Comparative Analysis of Various Digital Modulation Techniques for FHSS-WCDMA over AWGN and Fading Channels

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Abstract - *CDMA will outperform GSM and TDMA due to bandwidth availability. CDMA operates over the frequency range of 800 MHz to 1.9 GHz and its channel is 1.23 MHz wide. Performance of CDMA depends on the type of modulation techniques used in CDMA. CDMA signal passes through different types of fading channels under different conditions. The suitability of digital modulation techniques to CDMA are tested under Rayleigh, Rician fading and AWGN channels. The modulation technique which gives less error is proposed. W-CDMA uses 5 MHz channel Bandwidth. So, it has a capacity of carrying 100 voice calls simultaneously. Frequency hopping spread spectrum (FHSS) uses less power compared to direct sequence spread spectrum (DSSS) in WCDMA. Different data rate modulation techniques are simulated with FHSS-WCDMA using MATLAB R2010a. Both low data rate modulation techniques and high data rate modulation techniques such as Quadrature amplitude modulation (QAM) are also analyzed with FHSS-WCDMA. The variants of QAM such as QAM-16, QAM-32, QAM-64 and QAM-128 are considered for FHSS-WCDMA signal analysis with Rayleigh, Rician fading and AWGN channels. High bandwidth efficiency in FHSS-WCDMA can be achieved with high data rate modulation techniques but the disadvantage is that, noise and interference will be high.*

Key Words: **W-CDMA, FHSS, AWGN, FADING, QAM, BER, SNR**

1. INTRODUCTION

CDMA is based on spread spectrum technique which spreads the data using a code. The code used can be either a PN sequence code or a Walsh code. At the receiver side, the same code is used to decipher the transmitted data. Spreading codes used in CDMA are specific to the user. If the user is not the designated one, than the signal will act as noise and it will be discarded. Spread spectrum signals are highly resistant to interference and are very difficult to intercept the signals. CDMA uses wider bandwidth which results in multiple user access and increased immunity to interference. The modulation techniques which give less data rate are not suitable for wideband CDMA (WCDMA) techniques. Some modulation techniques used with WCDMA will introduce noise in other channels which leads to the degradation in the performance of WCDMA. As the performance decreases, the power requirements in WCDMA increase. Frequency hopping spread spectrum (FHSS) technique uses less power compared to direct sequence spread spectrum technique (DSSS). In FHSS, the available frequency band is divided in to many sub-frequencies. Frequency hopping spread spectrum is a technique to switch from one frequency channel to the other by shifting the carrier. Different modulation techniques can be used with FHSS-WCDMA, but the suitability of modulation technique depends on the bit error rate performance. Bit error rate performance in FHSS-WCDMA decreases as the signal passes through different propagation channels. Some of the fading channels such as Rician and Rayleigh fading channels along with AWGN are used as propagation channels for FHSS-WCDMA. Fading deals with signal attenuation. Fading happens due to signal going through different paths called multipath fading and also due to obstacles which attenuates signal. In AWGN, the probability distribution of noise samples is Gaussian and it has uniform distribution of power across the whole frequency band. Bit error rate of FHSS-WCDMA with AWGN noise is always less compared to fading channels. Practically, FHSS-WCDMA signal passes through different fading channels other than AWGN. The performance of FHSS-WCDMA varies with different fading channels. In this work, different digital modulation techniques with FHSS-WCDMA are analyzed with fading channels and the modulation technique which produces less bit error rate is proposed.

Higher data rates are achieved using higher modulation techniques such as QAM. The variants of QAM are QAM 16, QAM 32, and QAM 64 and so on. The QAM signal varies with amplitude and phase. The constellation points are very close in higher order modulation techniques. Due to this, higher order modulation techniques are prone to noise. The suitability of these modulation techniques for FHSS-WCDMA along with lower data rate modulation techniques are analyzed using MATLAB R2010a. Lower order modulation techniques gives less data rate with acceptable noise. The modulation technique with good E_b/N_o gives fewer errors. The performance can be improved with an increase in E_b/N_o. Remaining sections of this paper discuss the details about the concepts of AWGN, fading channels, modulation techniques, frequency hopping spread spectrum techniques and the results obtained for FHSS-WCDMA under AWGN and different fading channels.

2. ADDITIVE WHITE GAUSSIAN NOISE (AWGN)

Additive white Gaussian noise (AWGN) is additive because it will add to any noise already present and is white because it has uniform power over all the frequencies. It follows normal distribution. It is a basic and generally accepted model for thermal noise in communication channels. This channel is used for wired channel analysis.

3 .FADING CHANNELS

3.1. Rayleigh Fading Channel

It is a communication channel having a fading envelope in the form of Rayleigh Probability Density Function. It is statistical model for the effect of a propagation environment on radio signals, such as that used by wireless devices. In Rayleigh fading channels the magnitude of the signal will fade according to Rayleigh distribution. Rayleigh fading is applicable when there is no dominant propagation along the line of sight between the transmitter and the receiver [1].

3.2 Rician Fading Channel

Rician fading or Ricean fading is a stochastic model for radio propagation. The signal arrives at the receiver by several different paths which cause multipath interference. Rician fading is applicable when there is a dominant propagation along the line of sight. In Rician fading, typically line of sight signal is much stronger than the signal coming from different paths [1].

4. QUADRATURE AMPLITUDE MODULATION (QAM)

QAM varies both amplitude and phase in order to increase spectral efficiency. The in-phase and quadrature phase components are orthogonal to each other. It is both the analog and digital modulation technique [3]. It is used for high speed data communications. With the increase in the order of QAM, more number of bits can be modulated per symbol. So, there will be an increase in the data rates. Constellation points in QAM are arranged in square grid with equal vertical and horizontal spacing. As the distance between the constellation points decreases with the increase in the order, the probability of error also increases.QAM is used in many applications from cellular phones to Wi-Fi. Some examples of communication systems that use QAM are Wi-Fi, cable modems, digital video broadcast (DVB) and WiMAX. QAM is suitable when data loss is acceptable, so it is mainly used in cable television. The QAM modulated signal is given by

$$y(t) = M_I(t)\cos\left(2\pi f_c t + \phi_c\right) + +M_Q(t)\sin\left(2\pi f_c t + \phi_c\right) \text{--- (1)}$$

f_c is the carrier frequency and ϕ_c is the initial phase (rad). Because the sine and cosine signals are orthogonal, the original signals can be recovered later using demodulation techniques [2]. QAM-16 signal corresponds to 16 states and therefore each symbol represents 4 bits. QAM-32 signal corresponds to 32 states and therefore each symbol represents 5 bits. Similarly QAM-64 signal corresponds to 64 states and therefore each symbol represents 6 bits. 64 QAM and 256 QAM are often used in digital cable television.

5. BINARY PHASE SHIFT KEYING (BPSK)

Modulation is achieved by changing the phase. For bit '1' the modulated signal can be represented as

$$S(t) = A_c \cos 2\pi f_c t, \quad 0 \le t \le T_b \quad \text{----- (2)}$$

For bit '0'the modulated signal can be represented as

$$S(t) = A_c \cos(2\pi f_c t + \pi), \quad 0 \le t \le T_b \quad \text{---- (3)}$$

Constellation points are 180 ^{0} apart. Only one bit per symbol is used in BPSK. So, data rate and error rates are very less. The probability of error for BPSK is given by

$$P_e = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right) \quad \text{----------- (4)}$$

Where 'Eb' is the bit energy 'N_o' is the noise spectral density.

6. QUADRATURE PHASE SHIFT KEYING (QPSK)

QPSK is a type of phase modulation technique. QPSK is used to modulate 2 bits per symbol with four possible phase shifts with a phase difference of 90^0. So, with the same bandwidth the data rate is doubled compared to BPSK. So, Bandwidth efficiency is improved. QPSK modulated wave can be represented by

$$S_i\,(t) = \sqrt{\frac{2E}{T}} \cos\left[\left(2i-1\right)\frac{\pi}{4} + w_c t\right] \quad \text{------ (5)}$$

The average bit error rate, BER for QPSK is given by

$$\text{BER} = \frac{\text{No.of erroneous bits}}{\text{Total number of bits Transmitted}} \quad \text{------ (6)}$$

The probability of symbol error is given by

$$P_e = erfc\left(\sqrt{\frac{E}{2N_0}}\right) \quad \text{---------- (7)}$$

For QPSK, E= $2E_b$ ---------- (8)

E= Symbol energy

E_b =bit energy

$$P_e = erfc\left(\sqrt{\frac{E_b}{N_0}}\right) \quad \text{- - - - - - - - (9)}$$

So, probability of error is more than BPSK

7. FREQUENCY HOPPING SPREAD SPECTRUM (FHSS)

Frequency-hopping spread spectrum (FHSS) is a method of transmitting radio signals by rapidly switching a carrier among many frequency channels, using a pseudo random sequence known to both transmitter and receiver. It is used as a multiple access method in the frequency-hopping code division multiple access (FHSS-WCDMA) scheme. Frequency hopping spread spectrum (FHSS) uses less power compared to direct sequence spread spectrum (DSSS) in CDMA. So, FHSS is used in this analysis. The transmission frequencies are dependent on hopping sequence. Based on the hopping sequence, the receiver uses the same hopping sequence codes to decode the signal. FHSS is a robust technology with less effect from reflections and noise. DSSS also spreads the signal across wide channel but is more sucespatable to interference and noise. FHSS can be used where power requirements are less.

8. BLOCK DIAGRAM

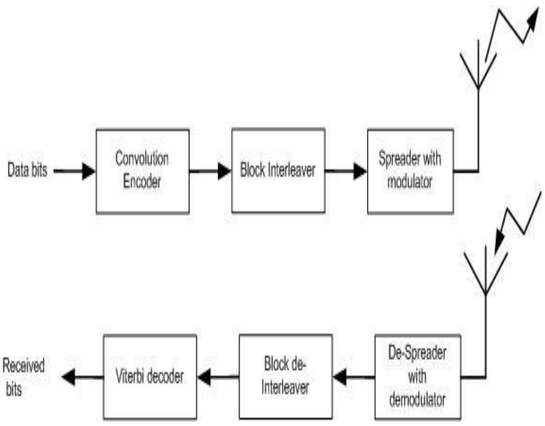

Figure 1: Block diagram of FHSS-WCDMA over fading channels

The random number generator will generate random numbers. These random numbers are the inputs to the convolution encoder. The convolutional encoder is a type error correcting code. Convolutional codes are characterized by encoder as [n, k, K]. Where 'n' is the input data rate and 'k' is the output symbol rate and 'K' is the constraint length. The code rate of the convolutional encoder is given by 'n/k'. Code rate used in this work is ¼. So, each bit generates four output bits. Constraint length used in this work is '5'. Convolutional encoder is a finite state machine which encodes the data for the given input. It performs convolution of the input stream with the impulse responses of the encoder. The Encoded bits interleaved using Block interleaving. Block interleaving is a technique used by mobile wireless systems to combat the effects of bit errors introduced during the transmission of frame [2]. The encoded bits are modulated using any one of the digital modulation technique. The modulated waveform is then spread using frequency hopping spread spectrum (FHSS) technique. Wireless channels can be modeled using different fading channels. The FHSS-WCDMA signal enters into wireless communication channel where it encounters fading according to different conditions. Along with AWGN, the fading channels used for analysis are Rayleigh and Rician. The faded signal is received at the receiver. At the receiver, first the signal is de-spread and demodulated to get data bits. For decoding the encoded data bits, Viterbi decoding algorithm is used. Viterbi decoding algorithm uses trellis diagram to decode the information. Trellis diagram uses different transitions from one state to another state for different inputs.

9. SIMULATION RESULTS

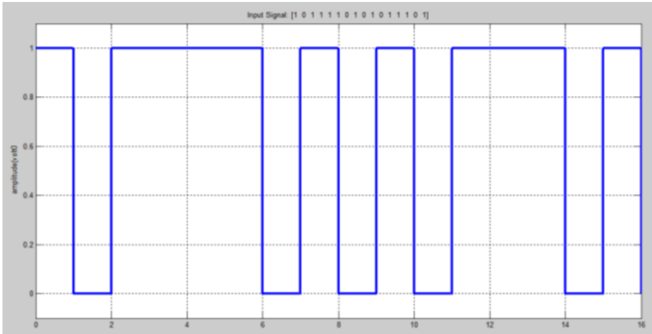

Figure 2:NRZ plot of Input data[101111010101101]

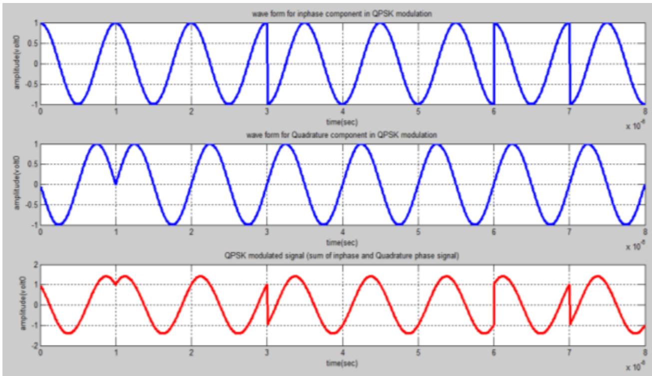

Figure 3: QPSK modulated signal for Input data [101111010101101]

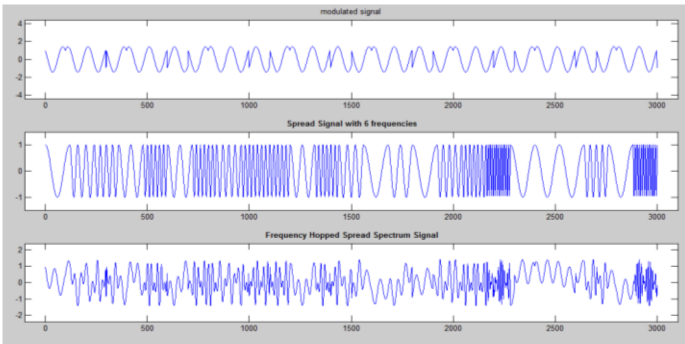

Figure 4: QPSK modulated signal spread with 6 frequencies(FHSS-WCDMA signal for QPSK modulated signal)

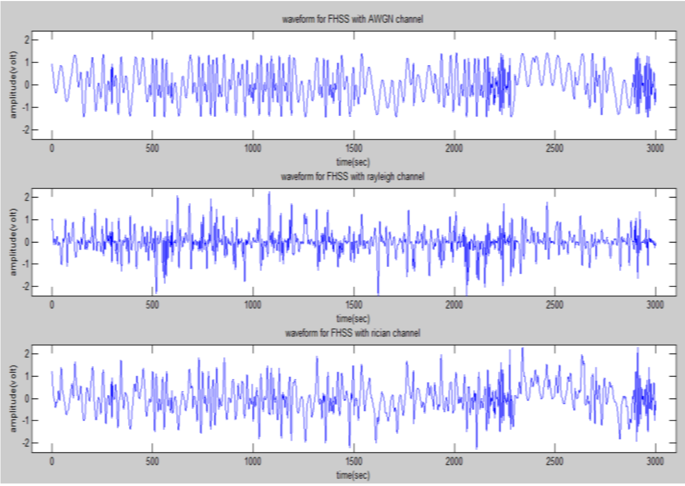

Figure 5: FHSS-WCDMA signal for QPSK modulated signal over AWGN, Rayleigh and Rician channels

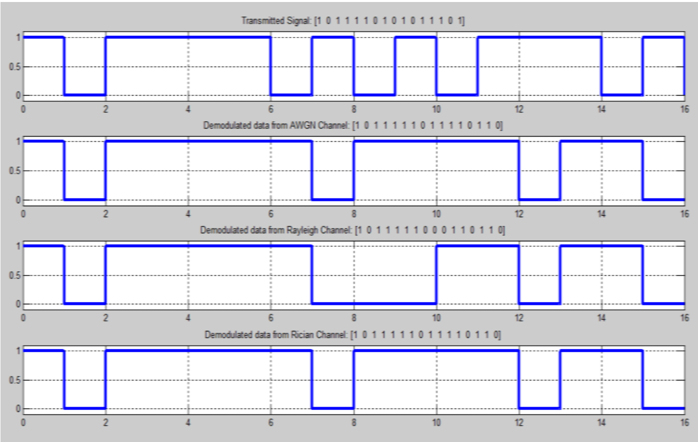

Figure 6: Demodulated data of FHSS-WCDMA with QPSK over AWGN and fading channels

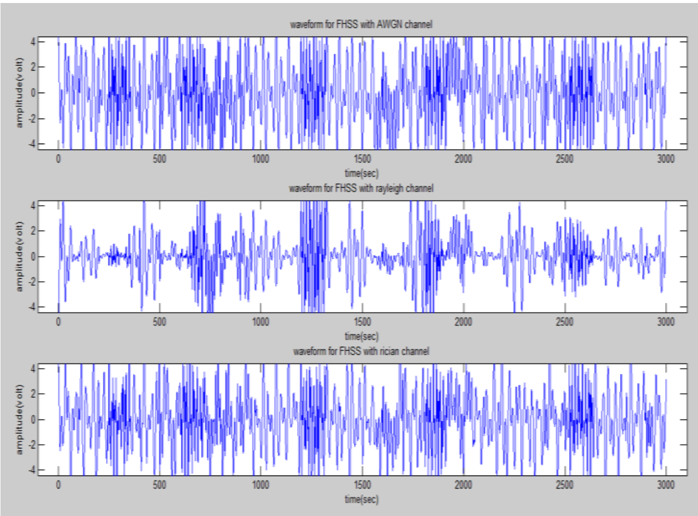

Figure 7: FHSS-CDMA signal for BPSK modulated signal over AWGN, Rayleigh and Rician channels

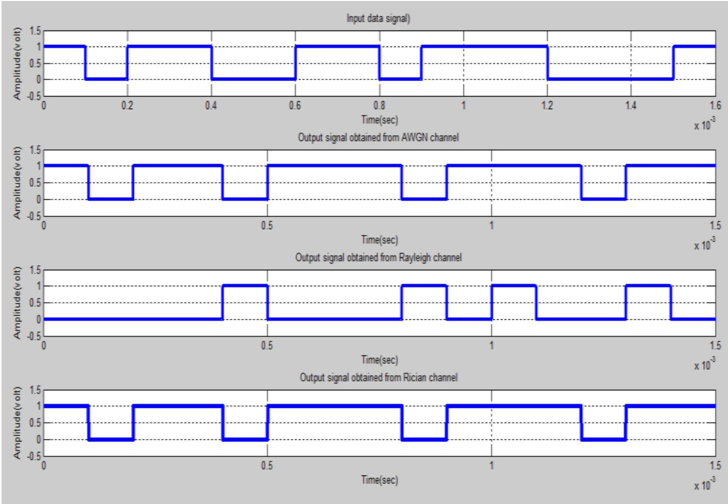

Figure 8: Demodulated data of FHSS-CDMA with BPSK over AWGN and fading channels

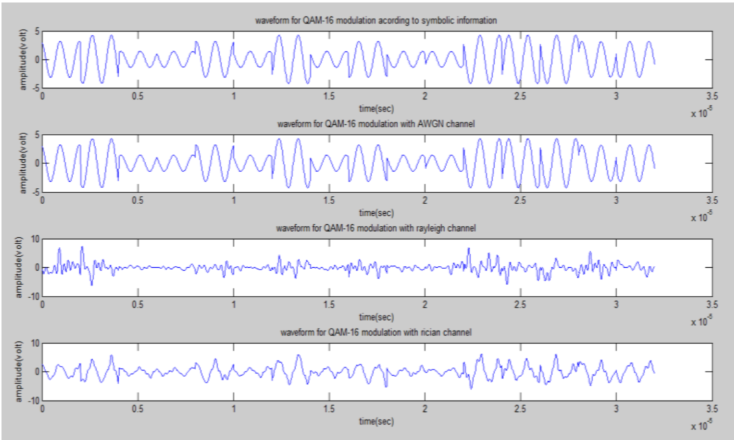

Figure 9: FHSS-WCDMA signal for QAM-16 modulated signal over AWGN, Rayleigh and Rician channels

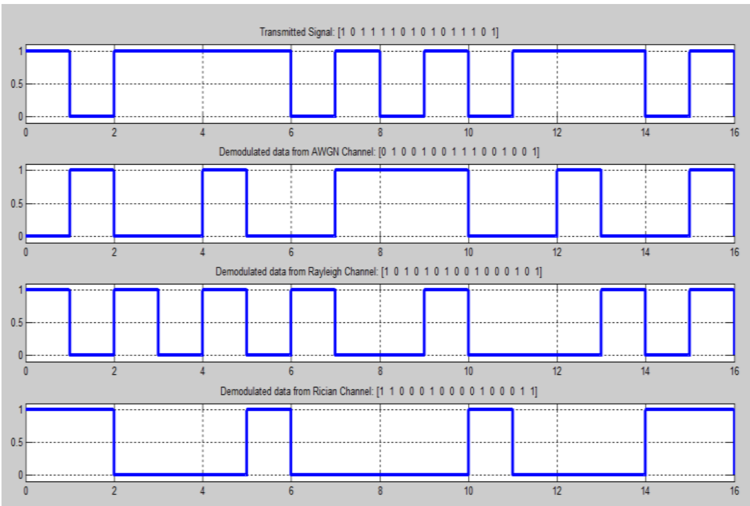

Figure 10: Demodulated data of FHSS-WCDMA with QAM-16 over AWGN and fading channels

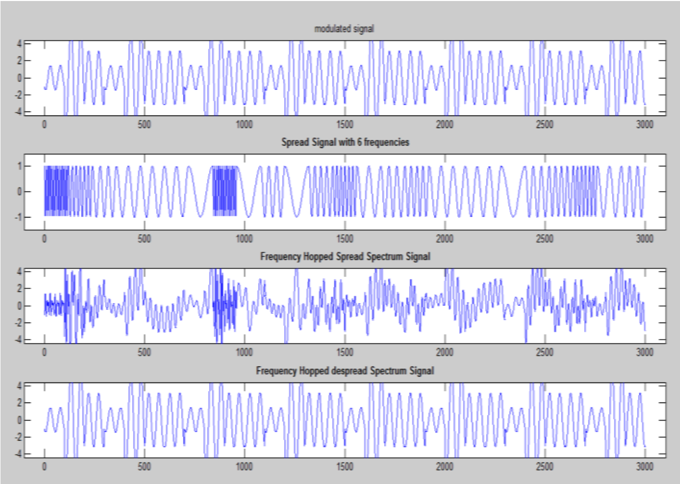

Figure 11: FHSS-WCDMA spread and de-spread signal for QAM-32 modulation technique

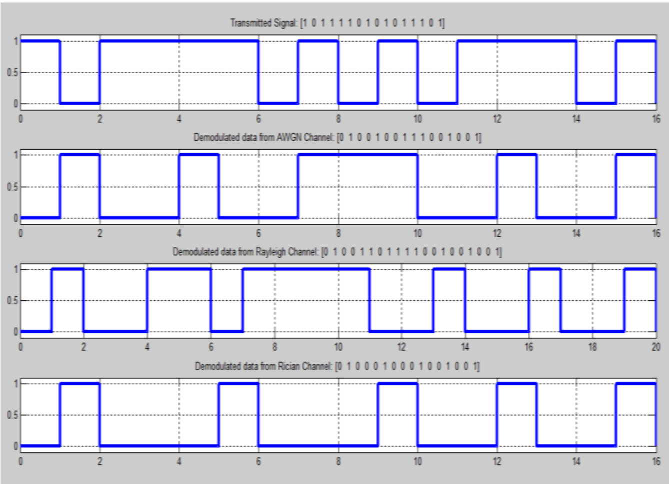

Figure 12: Demodulated data of FHSS-WCDMA with QAM-32 over AWGN and fading channels

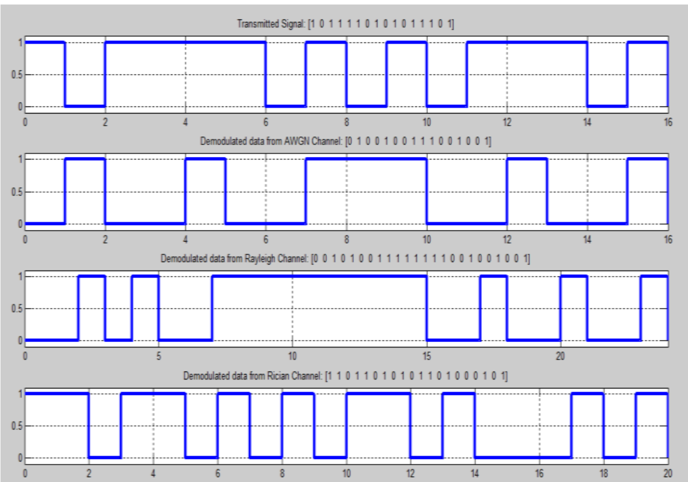

Figure 13: Demodulated data of FHSS-WCDMA with QAM-64 over AWGN and fading channels

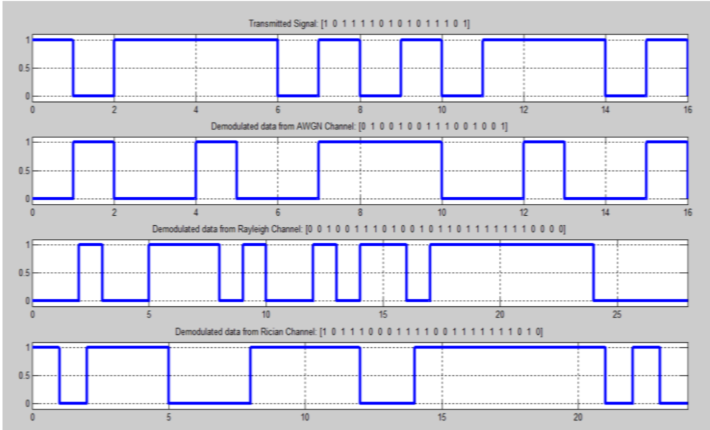

Figure 14: Demodulated data of FHSS-WCDMA with QAM -128 over AWGN and fading channels

The input for all the modulation techniques is shown in the Figure 2. Figure 3 to figure 6 shows the results of FHSS-WCDMA using QPSK modulation technique over AWGN, Rayleigh and Rician fading channels. Figure 7 & figure 8 shows the results of FHSS-CDMA using BPSK modulation technique for different fading channels. Figure 9 to figure 12 shows the results for QAM-16 and QAM-32 modulation techniques. Figure 13 and figure 14 shows the results of demodulated data of FHSS-WCDMA with QAM -64 and QAM-128 over AWGN and fading channels. From the results the following conclusions are drawn.

10. CONCLUSION

FHSS-WCDMA signal over AWGN and fading channels with different modulation techniques is developed and analyzed. From the results we can conclude that Rician fading channel outperforms Rayleigh fading channel in all modulation techniques due to the presence of dominant line of sight in it. From the results we can observe that in AWGN & Rician fading channels, BPSK modulation outperforms other modulation techniques with respect to bit error rate performance. So, BPSK can be used with FHSS-CDMA. As the data rate is very less, BPSK is not suitable for FHSS-WCDMA. So, we will go for higher modulation techniques which give less bit errors with improved data rate. From the results we can also observe that, for Rayleigh fading channel, QPSK and QAM-16 performs better than other modulation techniques. The results also show that, QPSK and QAM-16 perform well compared to other higher modulation techniques. So, QPSK and QAM-16 modulation techniques are suitable for FHSS-WCDMA.

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BIOGRAPHIES

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