Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 5 (5): 841-845, 2005
ISSN 1812-5654

Bandwidth Efficient Differentially Encoded 16 Amplitude Phase Shift Keying (16DAPSK) Schemes for Rician Fading Channels

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Abstract: This study investigates the Bit Error Rate (BER) performance of 16DAPSK and differentially coherent demodulation in presence of AWGN, frequency flat and Rician fading channels via Monte Carlo simulation. The BER performance is also compared with 8DPSK and 16 DPSK. The results showed a large degradation system performance over Rician fading compared with Additive white Gaussian channel, this is due to the increase of the Doppler rate from 0.01 to 0.1 Hz.

Key words: Wireless mobile communications, fading channels, 16 star QAM, 16DAPSK, 16 DPSK

INTRODUCTION

Mobile radio system requires highly bandwidth efficient digital modulation schemes, because the available radio spectrum resources are limited. 16DAPSK is based on 16 star QAM that needs coherent detection[1-3]. However, since the performance of coherent detection is severely affected by fast multi path fading because of the tracking problem experienced by carrier recovery circuits in fast fading environments, differentially coherent detection is preferred.

Frequency flat Rayleigh fading is a typical channel model found in land mobile radio situations. This model is suitable for modelling urban areas that are characterized by many obstructions where a line of sight path does not exist between the transmitter and receiver. In suburban areas, a line of sight path may exist between the transmitter and receiver and this will give rise to Rician fading. Rician fading is characterized by a factor, which is expressed as the power ratio of the specular (line of sight or dominant path) component to the diffused components. This ratio, k, defines how near to Rayleigh statistics the channel is. In fact when $k = 0$, this means to have Rayleigh fading and there is no fading at all when $k = \infty$.

The rate of change of the fading is defined by the Doppler rate. The Doppler rate is proportional to the velocity of the mobile station and the frequency of operation. The normalized Doppler rate is given by $f_d T_s$ where, f_d is the maximum Doppler rate and T_s is the symbol duration. For our simulations, the symbol duration is assumed to be equal to one second so that the normalized Doppler rate is equal to the Doppler rate. In general, normalized Doppler rates less than 0.01 are applicable to most systems[1,2].

A more complex propagation model includes many discrete scatters, where each propagation path may have a different amplitude, propagation delay and Doppler shift. When the components of a signal are received with different delays, the phase difference between them is a function of the frequency of the components. Thus the transmitted signal will experience a channel with a non-flat frequency response, which also varies with time. This type of channel is said to be frequency selective and is usually modelled as a tapped delay line, where the number of taps is equal to the number of discrete delayed paths. Clearly, the effect of the tapped delay line is to introduce overlap between the transmitted symbols. This form of degradation is known as intersymbol interference (ISI). In this model the first arriving path experiences Rician fading. In this study, the ratio k for the Rician fading[4,5] path is equal to 15 for all the simulations. Figure 1 shows the simulation model for 16DAPSK system and channel.

The rate of change of the fading is defined by the Doppler rate. To enable comparison between systems we define a normalized Doppler rate given by, $f_{dn} = f_d T_S$[6]. Where, f_d is the maximum Doppler rate and T_s is the transmitted symbol duration. Figure 2 shows the Rician fading with 16DAPSK model.

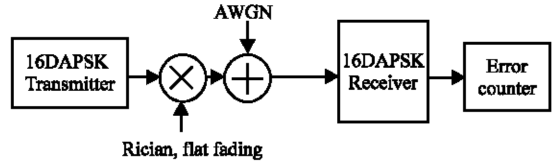

Fig. 1: 16DAPSK system and channel

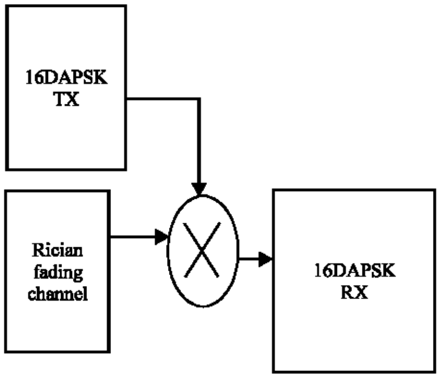

Fig. 2: Rician fading with 16DAPSK model

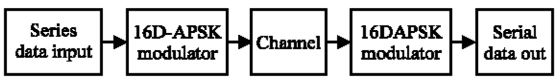

Fig. 3: Basic 16DAPSK system simulation model

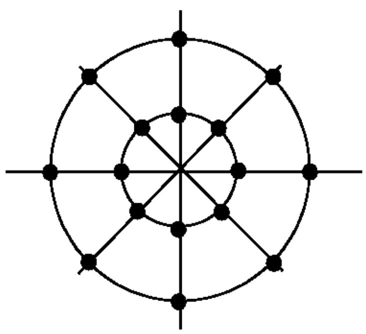

Fig. 4: 16 level star QAM constellation

SYSTEM SIMULATION

A basic 16DAPSK system can be simulated as shown in Fig. 3. Firstly the data symbols come from the serial data source to the 16DAPSK modulator . The output of the differentially encoded 16-level amplitude/phase shift keying (16DAPSK) modulator is fed to the channel

In this simulations the outputs of the channel are then differentially coherently demodulated to recover the data. Figure 3 shows the basic 16DAPSK system simulation model.

Differential 16 star QAM (16DAPSK): The majority of this work concerning QAM for mobile radio applications has utilized square QAM constellations. In general 16 QAM (square) requires coherent detection. However, since the performance of coherent detection is

Table 1: Amplitude bit change

Information symbol, (a_n)	Amplitude change
0	No
1	Yes

Table 2: 16 Star QAM phase change

000	0
001	$\pi/4$
011	$\pi/2$
111	$3\pi/4$
101	π
100	$5\pi/4$
110	$3\pi/2$
010	$7\pi/4$

severely affected by multipath fading, (mainly because of carrier recovery issues), the 16 Star QAM constellation shown in Fig. 4 combined with differentially coherent detection is preferred[4,7].

Modulator structure for 16DAPSK: The modulator structure for 16DAPSK is shown in Fig. 5. The random data source gives a binary sequence, which is formed into four bit symbols namely, a_n,b_n,c_n,d_n. The carrier is differentially phase modulated by the last three bit, b_n, c_n, d_n and differentially amplitude modulated by the first bit a_n. The first bit a_n is used to determine the transmitted signal amplitude as follows. If the incoming bit a_n is a binary '1' the amplitude level of the transmitted signal is changed to the other amplitude level. However, if the incoming bit a_n is a binary '0' the amplitude level of the transmitted signal remains the same as shown in Table 1. The remaining three bits, b_n, c_n, d_n are Gray encoded to give the phase changes shown in Table 2. Consequently it can be seen that a differential 16 star QAM is a combination of independent 8DPSK[8] and 2DASK.

For example, suppose that the current input bits $\{b_n,c_n,d_n\}$ are "000 " and the previous transmitted phase is 0°, it can be seen from Table 2 that the required phase change is zero degrees giving a transmitted phase of 0°.

Detection of a differential 16APSK: Differential detection of a 16APSK signal can be split into two stages: first the Differential Phase Detector (DPD) for the eight PSK signal and second the Differential Amplitude Ratio Detection (DARD) of the two level amplitude signal[1]. The DPD and DARD detectors detect the phase difference and amplitude ratio of the two successive received signals, respectively, as shown in Fig. 6 and their respective outputs are given by:

$$\Delta\Psi_n = \arg z_n . z_{n-1}^* \qquad (1)$$

where, * denote the complex conjugate and

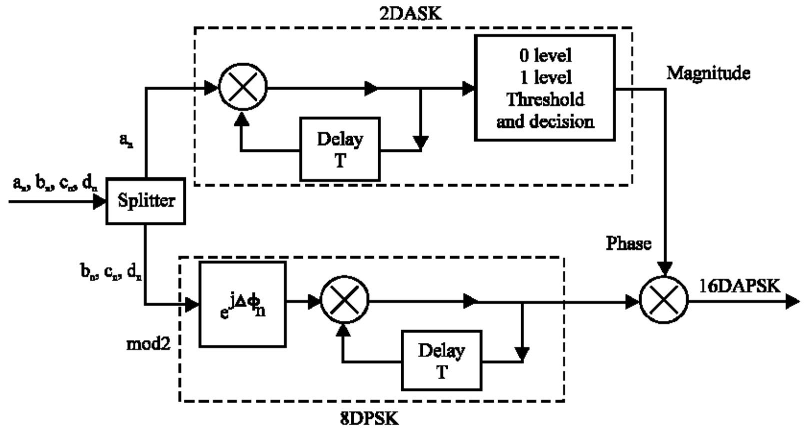

Fig. 5: Modulator structure for 16DAPSK

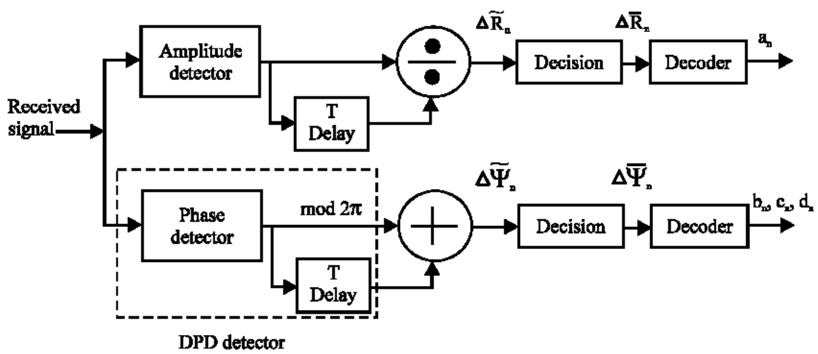

Fig. 6: Demodulator structure for 16DAPSK

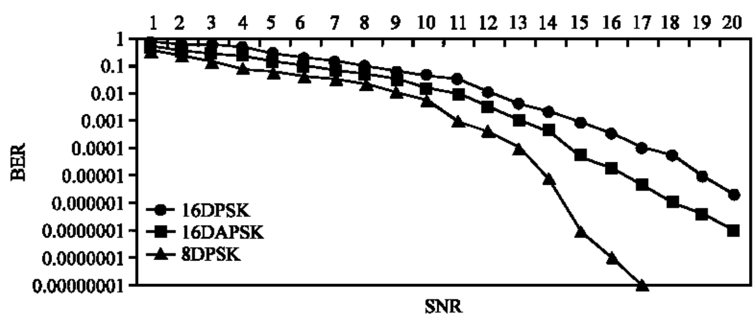

Fig. 7: The BER results as a function of signal to noise ratio (SNR) for 16DPSK and 8DPSK and 16DAPSK system in AWGN

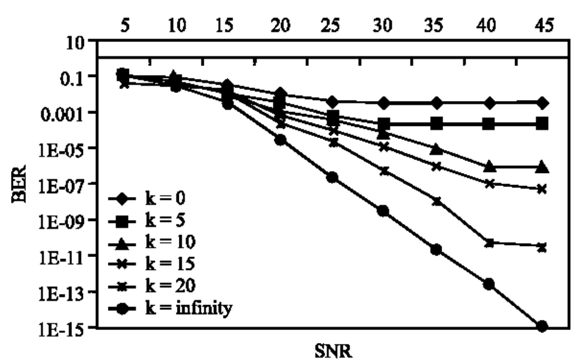

Fig. 8: BER performance of 16DAPSK in the presence of AWGN with various Rician fading channels and a Doppler rate of 0.01 Hz

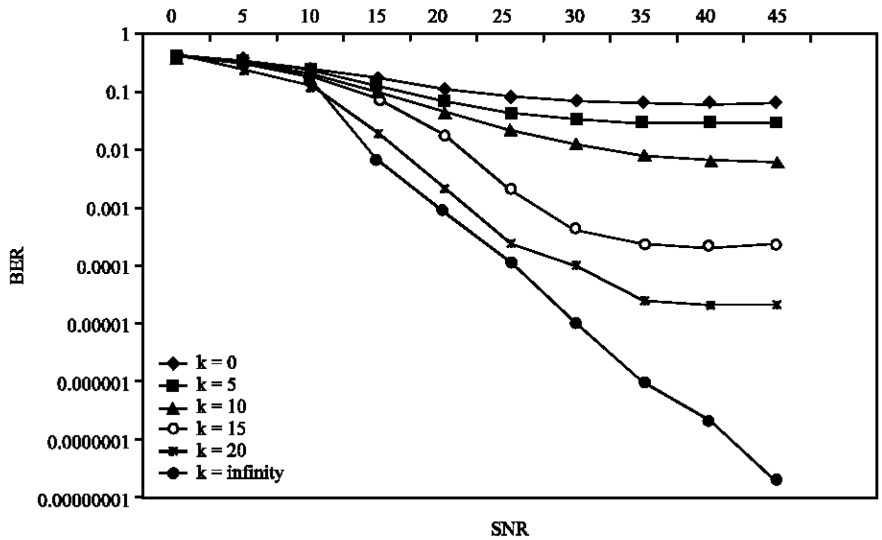

Fig. 9: BER performance of 16DAPSK in the presence of AWGN with various Rician fading channels and a Doppler rate of 0.1 Hz

$$\Delta\tilde{R}_n = \frac{|z_n|}{|z_{n+1}|} \qquad (2)$$

The decision rule is to find

$$\Delta\Phi_n, \text{from} : (m\pi l4, m = 0-7)$$

where, $\Delta\Phi_n$ is $-$ closest $-$ to $-$ $\Delta\Psi_n$

Which is chosen from:

$$(K^{-1}, 1, K)$$

$$\Delta\bar{R}_n = 1, \text{if} \Delta R_{11} \le \Delta\tilde{R}_n \le \Delta R_{12} \qquad (3)$$

$$\Delta\bar{R}_n = K, \text{if } \Delta R_{12} \angle \Delta\tilde{R}_n \qquad (4)$$

$$\Delta R_{L1} = \frac{1+K^{-1}}{2} \text{ and } \Delta R_{12} = \frac{1+K}{2} \qquad (5)$$

where, ΔRL_1 and ΔRL_{12} are the decision thresholds for low level and high level of the signal, respectively.

$$\Delta\bar{R}_n = k^{-1}, \text{ if, } \Delta\tilde{R}_n \angle \Delta R_{11} \qquad (6)$$

The transmitted four bits $a_n b_n c_n d_n$ is recovered from $\Delta\bar{\Phi}_n$ and $\Delta\bar{R}_n$

$$SNR = S/\sigma^2 + D/\sigma^2 = (1+k)\, D/\sigma^2 \qquad (7)$$

k = S/D Where, k is so called " k " factor of Rician fading, S is the power of the specular component and D is the power of the defuse component and σ^2 is the variance

SIMULATION RESULTS

Performance of Differential Encoded (DE) 16DAPSK IN AWGN: The BER performance of 16DAPSK disturbed by AWGN are compared with 16DPSK and 8DPSK. Figure 7 shows the BER results as a function of Signal To Noise Ratio (SNR) for 16DPSK, 8DPSK and 16DAPSK system, respectively. Clearly the BER performances are not Identical in AWGN.

Performance of 16 Star 16DAPSK in the rician fading channel: The BER performances presented in Fig. 8 compare the sixteen differential amplitude, phase shift keying (16DAPSK) in the Gaussian channel (k =∞) and with various Rician channel with a normalised Doppler rate of 0.01 Hz. The worse results when k = 0. This is because the channel is Rayleigh. However, when we increase k to become k = 20 (Rician channel), the performance of the system becomes better, for the same Doppler rate from 0.01 Hz.

Figure 9 shows the BER performance of 16DAPSK in the presence of AWGN with various Rician fading channels and a Doppler rate of 0.1 Hz. The results shows that the performance of the system is worse than the results shown in Fig. 8, this is due to the increase of the Doppler rate from 0.01 to 0.1 Hz.

CONCLUSIONS

In this study, the performance of 16DAPSK has been investigated in AWGN, flat Rayleigh/Rician fading channels. With a specular (k = 20) Rician channel at a normalised Doppler rate of 0.01, the degradation decreases for AWGN performance at a BER of 0.0000001, though a Rayleigh channel (k= 0) gives rise to an unacceptable irreducible BER of about 0.01. However, for the indoor or microcellular environment a direct path is likely to lead to less hostile channels than flat Rayleigh fading. This will improve the performance of the differentially coherent demodulator, especially for 8DPSK system.

REFERENCES

1. Qatawneh, I.A.Z., 1997. The use of Orthogonal Frequency Division Multiplexing (OFDM) techniques in mobile broadband applications. Ph.D. Thesis, University of Huddersfield.
2. Webb, W.T., L. Hanzo and R. Steele, 1991. Bandwidth efficient QAM schemes for Rayleigh fading channels. IEE Proceedings-I, 138: 168-175.
3. Botaro, H., S. Hasegawa and A. Sabato, 1986. Advanced groupband data modem using orthogonally multiplexed QAM techniques. IEEE Transactions on Communications, 34: 587-592
4. Webb, W.T., L. Hanzo and R. Steele, 1991. Bandwidth efficient QAM schemes for Rayleigh fading channels. IEE Proceedings-I, 138: 168-175.
5. Qatawneh, I.A.Z., 2002. Bit error rate performance of Orthogonal Frequency Division Multiplexing (OFDM) utilizing differentially encoded 16 star Quadrature Amplitude Modulation (QAM) with differentially coherent demodulation in AWGN, frequency flat and two path fading channels. Mansoura Engineering Journal (MEJ), Faculty of Engineering , Mansoura University, 27: 37-48.
6. Carlson, A.B., P.B. Crilly and J.C. Rutledge, 2002. Communication Systems. An Introduction to Signal and Noise in Electrical Communications. (Ed.) Carlson, A.B., McGraw-hill International.
7. Proakis, J.G., 1995. Digital Communications, 3rd Edn. New York, McGraw Hill.
8. Alert, C.M. Lee and Peter J. McLane, 1990. Convolutionally interleaved PSK and DPSK trelliscode for shadowed, fast fading mobile communication channel. IEEE Transactions on Vehicular Technol., 39: 378-386.