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Comparison of Bit Error Rate Performance of Multi Carrier DE-APSK Systems and Single Carrier DE-APSK in Presence of AWGN and Rician Fading Channels

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Abstract: We compared the simulated Bit Error Rate (BER) performance for the coherently differential detection of a single carrier differentially encoded 16 level amplitude/phase shift keying (16 DAPSK) in presence of Additive White Gaussian Noise (AWGN), flat fading and Rician fading channel with the BER rate performance for the coherently differential detection of multi carrier differentially encoded 16 level amplitude/phase shift keying (16 DE-APSK) in presence of Additive White Gaussian Noise (AWGN), flat fading and Rician fading channel. Differential detection comprises eight level Differential Phase Detection (DPD) and two Amplitude Ratio Detector (ARD). This study investigates the BER performance of differentially coherent demodulation in presence of AWGN, frequency flat and Rician fading channels for single carrier mode of 16 level DE-APSK and multi carriers mode of 16 level DE-APSK via Monte Carlo simulation. The BER performance is also compared with 16 DE-PSK. The results showed a large degradation system performance for both single and MC 16 level DE-APSK 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 and mobile communications, Rician fading channels, 16 level DAPSK, 16 DPSK multi carrier, AWGN

INTRODUCTION

Mobile radio system requires highly bandwidth efficient digital modulation schemes, because the available radio spectrum resources are limited. 16 DE-APSK is based on 16 star QAM that needs coherent detection[1-4]. 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 $k=\infty$, there is no fading at all and when $k=0$, this means to have Rayleigh fading. Figure 1 shows the simulation model for single mode of 16 level DAPSK system and channel and Fig. 2 shows the Rician fading with single mode of 16DE-APSK model.

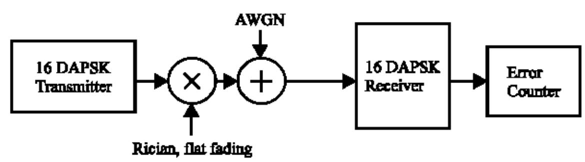

Fig. 1: Single mode of 16 DE-APSK system and channel

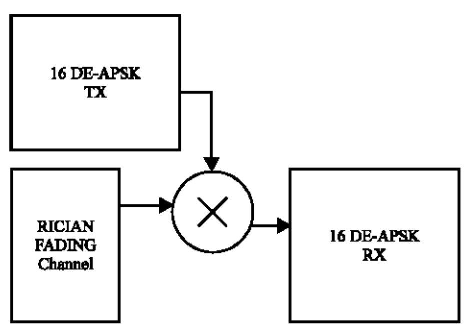

Fig. 2: Rician fading with 16 DE- APSK model

FLAT FADING CHANNELS

A typical channel model in land mobile radio is known as frequency flat Raleigh fading. Rician fading may

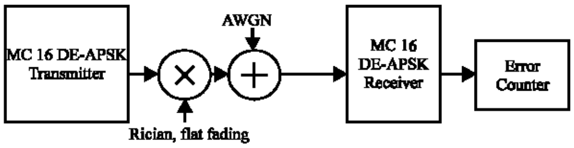

Fig. 3: Multi-carrier mode of 16 level DE-APSK system and channel

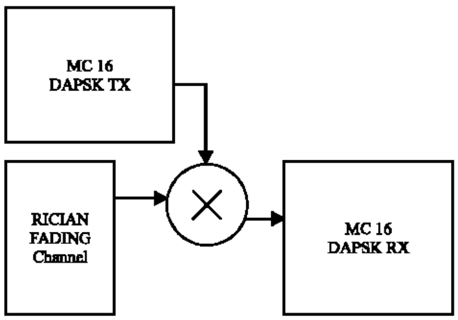

Fig. 4: Rician fading with multi-carrier mode of 16 DE-APSK model

be characterized by a factor which is defined as the power ratio of the specular (line of sight 'L.O.S' or direct path) component to the diffuse components. Figure 3 shows multi-carrier mode MC-16 DE-APSK system and channel. 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 MC symbol duration. For the considered simulations, the symbol duration is 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[5-7].

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 modeled 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 Inter-symbol Interference (ISI). In this model the first arriving path experiences Rician fading. In this study, the ratio k for the Rician fading path is equal to 15 for all the simulations. Figure 4. shows the simulation model

Fig. 5: Basic single mode of "16 DE-APSK" system simulation model

SYSTEM SIMULATION FOR SINGLE 16 LEVEL DE-APSK

A basic 16 DAPSK system can be simulated as shown in Fig. 5. Firstly the data symbols come from the serial data source to the 16 DE-APSK modulator. The output of the differentially encoded 16 level amplitude/phase shift keying (16 DE-APSK) modulator is fed to the channel. In this simulations the outputs of the channel are then differentially coherently demodulated to recover the data. Figure 5 shows the basic single mode of 16 DE-APSK system simulation model.

SYSTEM SIMULATION OF MULTICARRIER TRANSMISSION (MCT) USING 16 LEVEL DE-APSK

A basic (MCT) system can be simulated as shown in Fig. 6. Firstly the data symbols from the (16 DE-APSK) modulator are converted from serial to parallel (S/P) format. In the simulations the output width of the converter is 16 symbols (comple x valued), which corresponds with the number of parallel carriers in the MCMT signal at the output of the Inverse Fast Fourier Transform (IFT) block. The output of IFT is the time domain MC signal which has 16 complex valued samples[10-12]. These samples are converted from parallel to serial format before being placed on to the channel. In the receiver, the incoming signal is converted back to a parallel format before being processed by the Fast Fourier Transform (FT) which implements the demodulator. The FT output represents the parallel demodulated symbols which are converted back into the original serial format. These symbols are then differentially coherently demodulated to recover the data[13,16]. The data formats employed at the input to the IFT block will be described where required.

In the presence of inter-symbol interference caused by the transmission channel, the properties of orthogonality between the carriers is no longer maintained[19,20]. However, by preceding each symbol by a guard period it is possible to absorb the inter-symbol

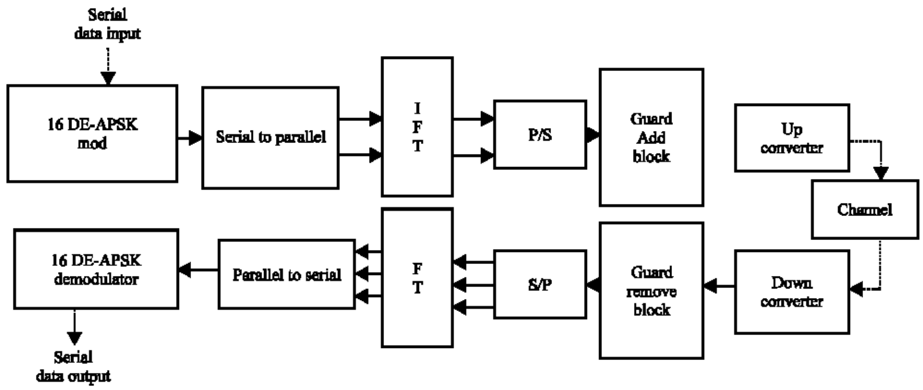

Fig. 6: Basic MCT mode of 16 level DE-APSK system simulation

interference. This is achieved using the optional guard period add block. This guard period is removed at the receiver by the complementary guard period remove block as shown in Fig. 6.

Comparison of the performance of multi carrier 16 level DE-APSK and single 16 DE-APSK in the presence of AWGN: We wish to establish benchmark AWGN for Multi carrier Differential encoded (DE. 16 DE-APSK and single 16 DE-APSK in the presence of AWGN with differentially coherent demodulation. In this study the BER performance of Multi carrier Differential encoded (DE. 16 DE-APSK and single 16 DE-APSK with a guard period disturbed by AWGN are compared. Figure 7 shows the BER results as a function of Signal to Noise Ratio (SNR)for both a single carrier and for an MC system using differential 16 DE-APSK encoding. Clearly the BER performances are not identical in AWGN. This is to be expected owing to the noisy phase reference used in the differential systems. Also Fig. 10. Compares the BER performance for Multi carrier 16 DE-APSK and single 16 level DE-APSK and single 16 level DE-PSK in the presence of AWGN.

For example the result of Comparison shows that the BER performance for Multi carrier mode of 16 level DE-APSK, single carrier mode of 16 level DE-APSK and single carrier mode of 16 level DPSK in the presence of AWGN are not the same as shown in Fig. 8. If we choose SNR ratio for instant 15 dB, then the BER performance for Multi carrier 16 DE-APSK is equal 10^{-7} and the BER performance for single carrier 16 level differential encoding phase shift keying 16 DE-PSK is equal 10^{-3}, but the BER performance for single carrier 16 level De-APSK is equal $8x10^{-5}$.

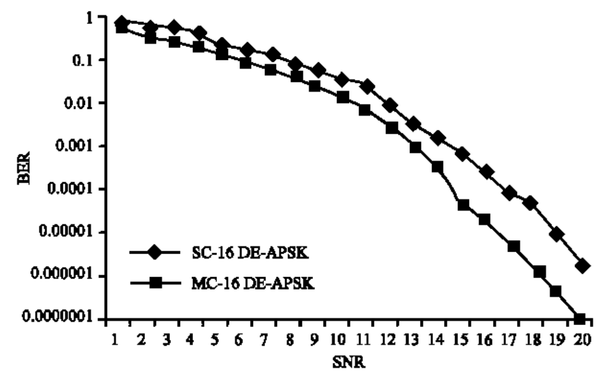

Fig. 7: Multi carrier mode of 16 DE-APSK and single carrier mode of 16 DE-APSK in the presence of AWGN

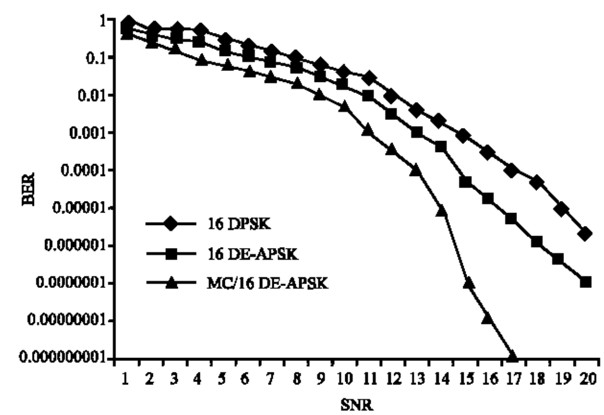

Fig. 8: BER performance for Multi carrier mode of 16 DE-APSK, single carrier mode of 16 DE-APSK and single carrier mode of 16DE-PSK in the presence of AWGN

Comparison of multi carrier mode of 16 DE-APSK and single carrier 16 level DE-APSK in the AWGN and Rician fading channel: The BER performances presented in Fig. 9 compares Multi carrier mode of 16 DE-APSK in

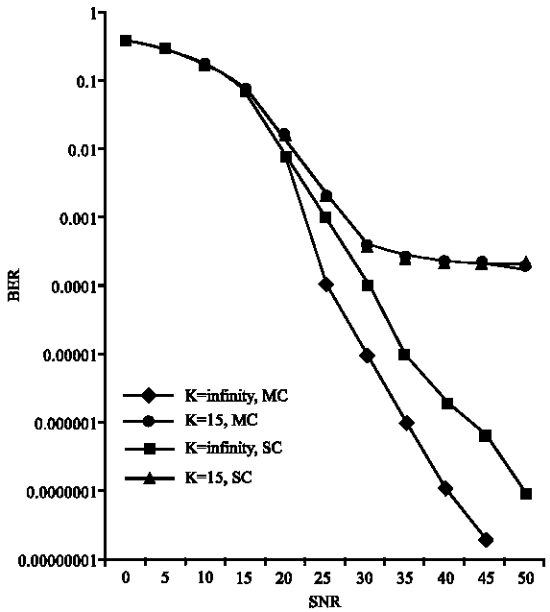

Fig. 9: Comparison of multi carrier mode of 16 DE -APSK and single carrier mode of 16 DE -APSK in the Gaussian channel (k =∞) and the Rician fading power ratio (k=15) and a Doppler rate of f_d=0.1 Hz

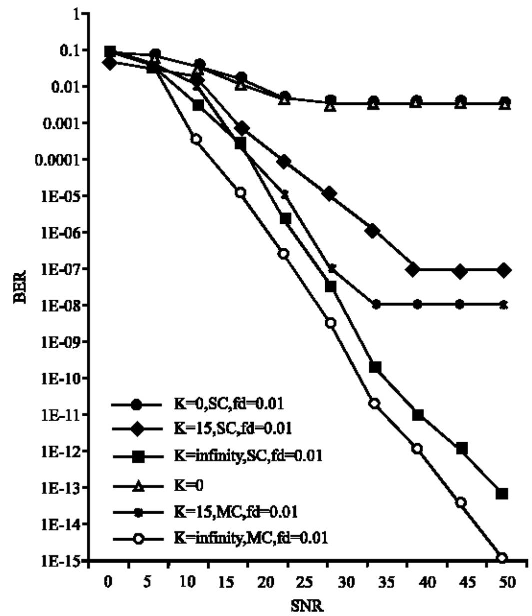

Fig. 11: Comparison of multi carrier mode of 16 DE-APSK and single carrier mode of 16 DE-APSK in the Gaussian channel (k=∞) and the various Rician fading power ratio and a Doppler rate of f_d=0.01 Hz

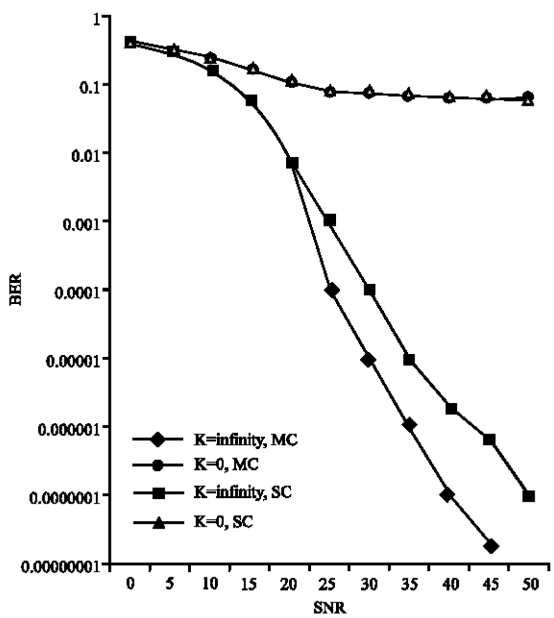

Fig. 10: Comparison of multi carrier 16 DE-APSK and single carrier 16 DE-APSK in the Gaussian channel (k=∞) and the Rician fading power ratio (k=0) and a Doppler rate of f_d=0.1 Hz

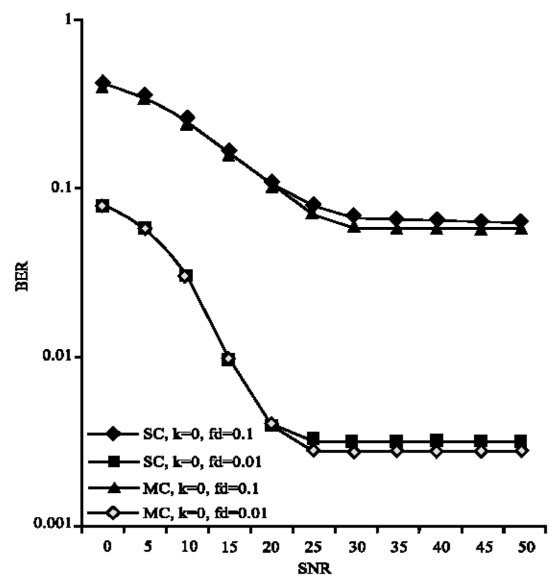

Fig. 12: Comparison of multi carrier 16 level DE-APSK and single carrier 16 level DE-APSK in the Gaussian channel (k=∞) and the Rician fading power ratio(k=0) and various Doppler rate of f_d=0.01 Hz and f_d=0.1 Hz

the Gaussian channel (k=∞) and the Rician fading power ratio (k=15) with a Doppler rate of f_d=0.1 Hz. It can be observed that the Rician channel degrades the SNR performance of the MC systems by about 5 dB compared with that achieved over the Gaussian channel at a BER of 1×10^{-3}. Also the simulation results for k=15, shows that the BER are coin side, but if we increase the power ratio "k" the error decreases especially when k=∞. When the SNR equal 35 dB, the BER is 5×10^{-4} for single carrier mode

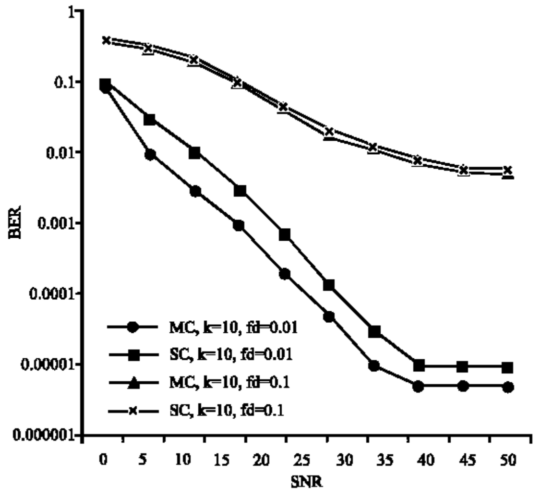

Fig. 13: Comparison of multi carrier 16 level DE-APSK and single carrier 16 DE -APSK in the Gaussian channel (k=∞) and the Rician fading power ratio (k=10) and Doppler rate of f_d=0.01 Hz

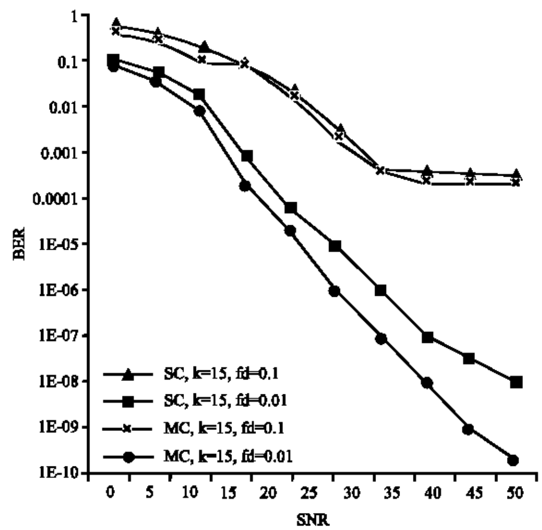

Fig. 14: Comparison of multi carrier 16 level DE -APSK and single carrier 16 DE -APSK in the Gaussian channel (k=∞) and the Rician fading power ratio (k=15) and various Doppler rate of f_d=0.01 Hz and f_d=0.1 Hz

and multi carrier mode are coin sine (where k=15), but the BER for multi carrier mode is 10^{-6} and the BER for single carrier mode is $1x10^{-5}$ where, k=∞ for both cases. The single carrier mode system performance is some 3 dB worse than the multi carrier mode system at the same BER in the Rician channel. The irreducible BER is also higher for the single carrier mode system.

The simulation results presented in Fig. 10. Compares1 the performance of Multi carrier 16 DE-APSK and single carrier 16 DE-APSK in the Gaussian channel (k=∞) and the Rician fading power ratio (k=0) with a Doppler rate of f_d=0.1 Hz. with differentially coherent demodulation It can be seen that the BER become irreducible for all the simulated values of k except for the AWGN case of k=∞.

The simulation results presented in Fig. 11. Compares the performance of Multi carrier 16 DE-APSK and single 16 DE-APSK in presence of Gaussian channel (k=∞) and for various values of the Rician fading power ratio (k) with a Doppler rate of f_d=0.01 Hz, with differentially coherent demodulation. It can be seen that the BER is $5x10^{-3}$ with k=0, for Multi carrier mode 16 DE-APSK and single carrier mode 16 DE-APSK. But, if we choose k =15 and SNR =35 dB we get a great improvement in the BER, which is equal $1x10^{-6}$ and $1x10^{-8}$ for single carrier mode of 16 DE-APSK and Multi carrier mode of 16 DE-APSK, respectively.

The simulation results presented in Fig. 12. Compares the performance of Multi carrier 16 level DE-APSK and single carrier 16 level DE-APSK performance in presence of Gaussian channel (k=∞) and for the Rician fading power ratio (k=0) and for various values of Doppler rate of f_d with differentially coherent demodulation. It can be seen that the BER for MC 16 levels DE-APSK improves when we change the Doppler rate from f_d=0.1Hz to f_d=0.01Hz

The simulation results presented in Fig. 13. Compare the performance of Multi carrier mode of 16 DE-APSK and single carrier mode 16 level DE-APSK performance in presence of Gaussian channel (k=∞) and for the Rician fading power ratio (k=10) and for various values of Doppler rate of f_d with differentially coherent demodulation. It can be seen that the BER for MC 16 levels DE-APSK improves when we change the Doppler rate from f_d=0.1 to f_d=0.01Hz.

The simulation results presented in Fig. 14. compare the performance of Multi carrier 16 DE-APSK and single carrier 16 DE-APSK performance in presence of Gaussian channel (k=∞) and for the Rician fading power ratio (k=15) and for various values of Doppler rate of f_d with differentially coherent demodulation It can be seen that the BER for MC 16 levels DE-APSK improves and becomes better, for the Doppler rate 0.01Hz.

CONCLUSIONS

The comparison of the BER performance of Multi carrier mode using 16 level DE-APSK and single carrier mode of 16 level DE-APSK with differentially coherent demodulation in the presence of AWGN is considered. The BER performance was presented for various values of k power factor and With different values of Doppler rate (0.1 Hz and 0.01 Hz). The simulation results shows that the BER performance improves as k factor increases (specular components becomes stronger) when specular component at (k=15), the required value of signal to noise ratio (SNR) is 35 dB at BER=$1x10^{-7}$ and $6x10^{-4}$ for Doppler rate 0.01 Hz and 0.1 Hz, respectively.

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