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# A Brief Survey on Adaptive Modulation and Coding Over Time Varying Fading Channel

Rohit Khajuria[1], Aparna Sharma[2], Pankaj Anand[3], Akhil Gupta[4]
School of Electronics and Communication Engineering
Shri Mata Vaishno Devi University
Katra, Jammu and Kashmir, India

## ABSTRACT
Adaptive modulation and coding (AMC) refers to the choice of modulation, coding and other signal parameters according to the instantaneous conditions in the channel. This paper explains the potential of AMC in wireless communication over time-varying fading channel. By the use of rate adaptive transmission, the transmitted information rates are significantly increased provided accurate channel modelling and channel state estimation is done. An important performance measure discussed in this paper is spectral efficiency (Bits/sec/Hz). Also, since the channel states have to be estimated at the receiver, there would be a certain degradation of system performance compared to ideal case of perfect channel knowledge. The adaptive modulation provides various modulation scheme and modulation levels according to instantaneous channel conditions. When the received signal is not faded, the modulation mode having a higher data rate is selected to take advantages of good channel conditions and maximize throughput. When the received signal fades, the modulation level that decreases a data rate is selected. N-MSK modulation scheme is preferred in non-linear channel conditions and in communication systems where power sources are limited. N-QAM is used mostly in linear channels. OFDM modulation scheme is used for high data rate transmission over frequency selective fading channel. Good performance of these schemes requires accurate channel estimation at the receiver and a reliable and fast feedback path between estimator and the transmitter

## Keywords
Adaptive modulation, fading channel, spectral efficiency.

## 1. INTRODUCTION
In wireless communication, fading refers to the change in signal strength at the receiver due to variations in the channel attenuation during signal propagation. Fading varies with time, geographical conditions and the frequency of transmission. It is caused either due to multipath propagation (received signal is the vector sum of original transmitted signal and various replicas of the original signal) or due to shadowing caused by obstacles present in the propagation path. [1]. as the signal strength at the receiver is varying with time and other conditions, we need to use adaptive modulation at the transmitter.

Adaptive modulation and coding (AMC) refers to the choice of modulation, coding and other signal parameters according to the instantaneous conditions in the channel. It's a dynamic process. Adaptive transmission techniques such as adaptive modulation & coding, adaptive power control etc. generally require precise channel estimation & feedback of channel state information (CSI). [2] In time division duplex systems, this information can be acquired by assuming that the channel from the transmitter to receiver is the same as that from receiver to transmitter. Alternatively, we can estimate the channel conditions at the receiver and feedback this information to the transmitter. The feedback delay, overhead, channel estimation & CSI quantization errors & processing delay degrade the performance of adaptive modulation especially in rapidly time variant fading.[2] Adaptive modulation assigns a higher modulation order with higher code rate ,when receiver is close to the transmitter. In contrast, modulation order is decreased and so is the code rate, when the receiver is far away from the transmitter. Different order modulation uses more bits per symbol thus achieving higher throughput or we can say, higher spectral efficiency. Thus, different modulation schemes can be used in various communication scenarios to meet specific data rate performances.

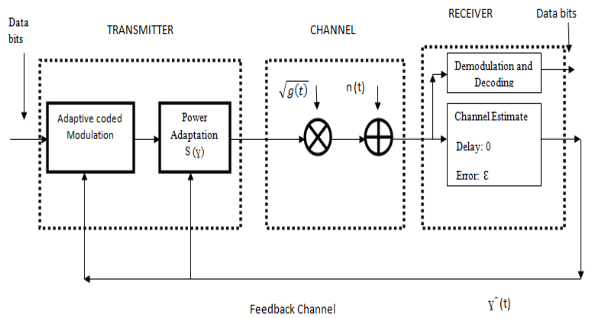


**Fig. 1 System Model**

System model is given in Fig. 1.We have assumed g(t) as the time varying channel gain, n(t) is the additive white Gaussian noise and S is the average transmitted signal power .We also assume that the estimation of channel gain g(t) is transmitted to the transmitter through a feedback channel without any delay.[3]

Adaptive modulation improves transmission rate, bit error rate (BER), spectral efficiency by using CSI present at the transmitter. In fading channels, where we model the wireless channel, AMC system give higher performance as compared to systems which do not calculate or use the channel state information at the transmitter.

## 2. Modulation Techniques

### 2.1 N-MSK
The N-MSK signal is the sum of N number of MSK signal components each having a different amplitude. The average energy of the N-MSK signal is normalized to one. If N=1 the

1-MSK signal is equal to a MSK signal and if N=2 the 2-MSK signal is usually called the MAMSK (multi-amplitude MSK signal). [n-msk.pdf] also, for N> 1, the N-MSK signals are having variable envelopes. It is the channel conditions that determine which type of N-MSK modulation is to be used. For instance, a 2-MSK signal is a combination of 1-MSK & 2-MSK signals. When the channel conditions are worse (such as a deep fade) 1-MSK signal is transmitted .On the other hand, when the channel conditions are good 2-MSK signal is sent out from the transmitter.3 MSK signal is not used in practice as it do not increase the throughput nor does it decrease the BER.

N-MSK adaptive modulation schemes is preferred in nonlinear channels or where power sources are limited , over N-QAM adaptive modulation because the former is not seriously affected by the nonlinear amplification used in the transmitter , which distorts the signal in the later. Also, MAPCM (multi-amplitude pulse code modulation) signals demodulation is easy provided modulation index is 0.5.

When N-MSK signals are analyzed it is proved that if we can track the fading rate in the channel, the average number of transmitted bits is increased and the BER stays in the required range. The interval of the average carrier to noise ratio where the BER is nearly constant, is wider for the higher number of modulated signals combined in the adaptive modulation schemes. [4]

## 2.2 M-QAM

QAM is a combination of ASK and PSK where both the Phase and amplitude are changed .The receiver receives this modulated signal detects the shift and demodulates the signal back into the original form. The QAM constellation changes as the channel conditions vary. As the distance from the transmitter increases, lower order QAM is chosen i.e. QPSK While in close proximity of transmitter system utilizes higher order QAM .It increases the throughput.

Star-like constellation is adopted as it gives easy recovery of carrier and power efficiency. Differential coding is also applicable to the star-like constellation. For 1 bit/symbol M-QAM is same as BPSK; 2 bit/symbol is the same as QPSK; for 3bit/symbol, signal constellation is 8-point QAM. In the 8 point QAM, we add a phase shift 45 degrees for the outer circle. This keeps the Euclidean distance between on inner and outer circle to be the same. In the 16-level PAM-PSK constellation we double the phase points [5].

One of the proposed adaptive scheme for M-QAM, assuming a perfect channel CNR estimation .Also the data CNR range has been divided into N+1 fading regions and constellation size $M_n = 2^n$ , where n is the number of bits per MQAM symbol and N is the number of different constellation sizes .If the received data CNR is estimated in the nth region then constellation size $M_n$ is transmitted.

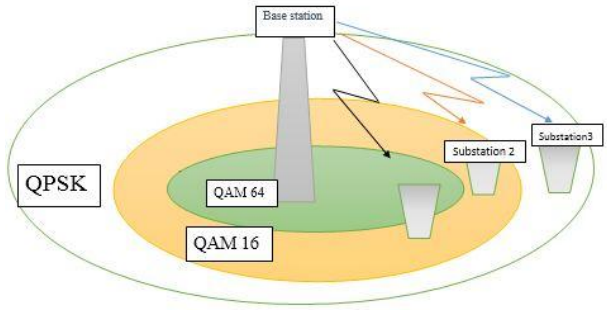


**Fig. 2. Variation in QAM w.r.t to distance from the transmitter**

## 2.3 OFDM

OFDM is Orthogonal Frequency Division Multiplexing. In this scheme the orthogonal sub-carrier signals are used. The data to be transmitted is carried on several parallel data channels. OFDM uses lower data rate on each of the subcarriers. Basically a single high rate data stream is divided in several low rate data streams. The each of data stream is modulated using the orthogonal sub- carrier. Because of this division of high data rate stream, OFDM is more resistant to frequency selective fading than single carrier systems. This results in low Inter Symbol Interference. Interference on one frequency results in interference on one sub-carrier only. Although the concept of OFDM is an old concept. It has recently been recognized and adopted as an effective technique for high speed bidirectional data transfer e.g. WI-MAX, DAB, DVB-T are some new emerging standards that use OFDM [6]

The main advantage of OFDM is that it provides excellent spectral efficiency and Bit Error rate is also reduced considerably. By selecting a special set of orthogonal carrier frequencies, high spectral efficiency is obtained because the spectra of the carriers overlap,while mutual interference among them is avoided [7, 8, 9].

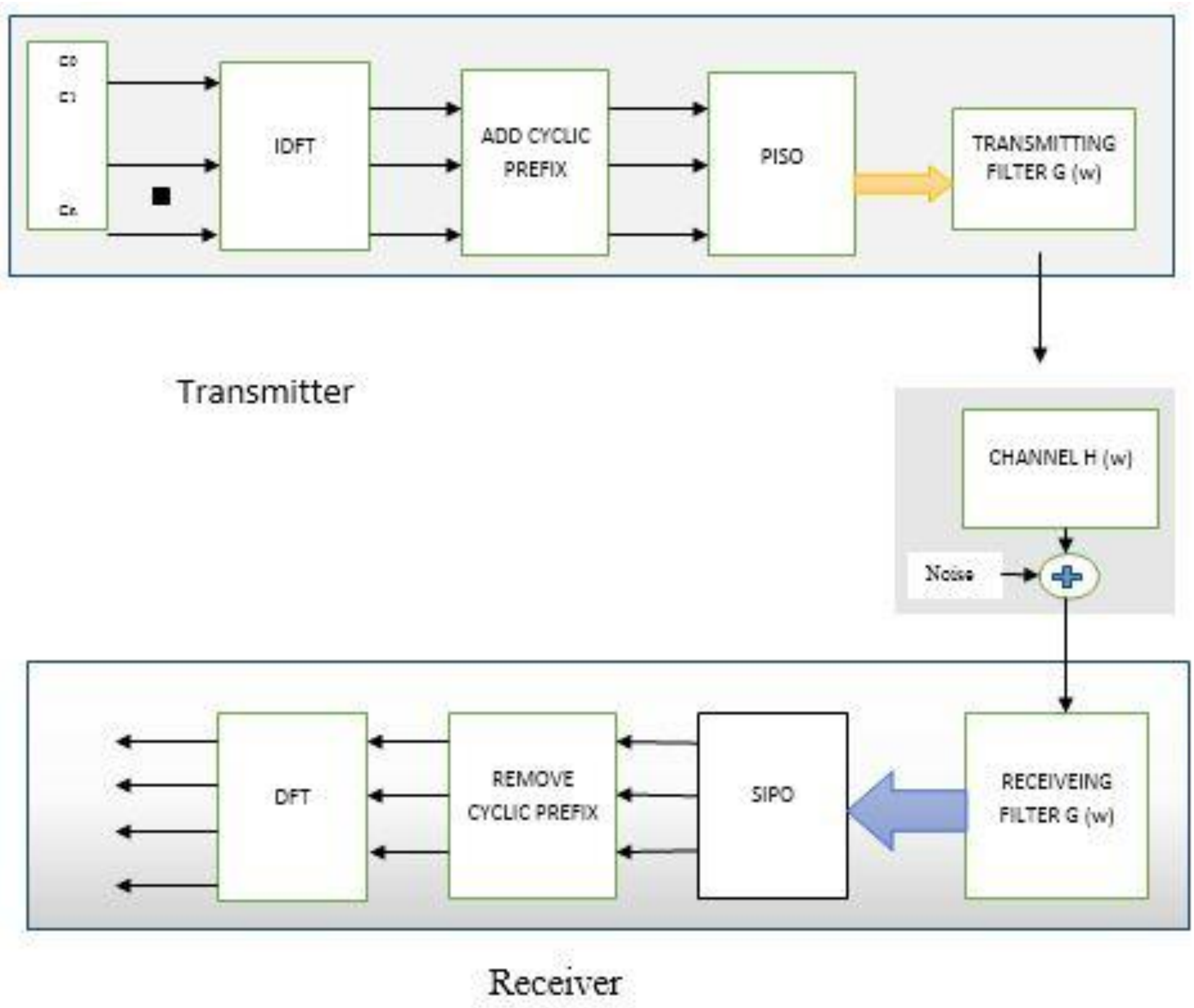


**Fig. 3. Block Diagram of a Typical OFDM system.**

**Table 1. Spectral Efficiency for Various Digital Modulation Method**

| Types of Modulation | Spectral Efficiency(Bits/Sec/Hz) |
|---|---|
| FSK | <1(depends on modulation index) |
| N-MSK | >1 & <1.35 |
| GMSK | 1.35 |
| BPSK | 1 |
| QPSK | 2 |
| 16 QAM | 4 |
| 64 QAM | 6 |

# 3. CONCLUSION

From table 1 we can see that N-MSK has the least spectral efficiency whereas OFDM has the highest spectral efficiency. Although, QAM increases the efficiency of transmission for radio communication, it is more susceptible to noise and as it contains an amplitude content, we need to use linear amplifiers at the transmitter side which are less efficient and consume more power. N-MSK adaptive modulation schemes is preferred where power sources are limited , over N-QAM adaptive modulation because the former is not seriously affected by the non-linear amplification used in the transmitter , which distorts the signal in the later. OFDM systems make the maximum efficient use of the available spectrum by allowing overlap, by dividing the channel into narrowband flat fading sub-channels

## Future Scope of Adaptive Modulation

Adaptive modulation can be used in rate adaptive optical trans-receivers used in optical networks .They exploit the available resources to the maximum limit in optical communication where different links yield different signal qualities .Use of rate adaptive coded modulation in fiber optic communication improves the spectral efficiency over a wide range of transparent reaches, approximately an improvement over 1 dB compared to existing methods.

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