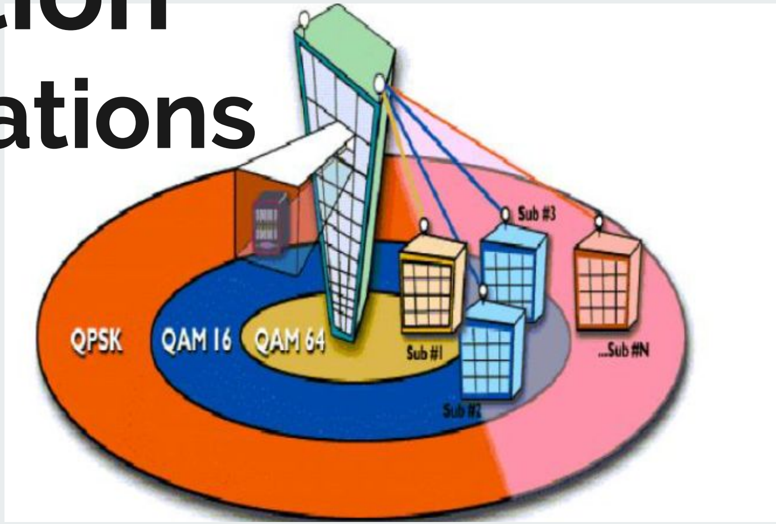
Adaptive Modulation Wireless Communications



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Adaptive Modulation (QPSK, QAM). Rao Farhat Masood, Member *IEEE*, MIE (Pak), PEC. National University of Sciences and Technology, *Pakistan*.

Outline

- What is Adaptive modulation? And why?
- Parameters to Adapt
- Optimisation Criteria
- Adaptive modulation Techniques
- Variable Rate-Variable Power MQAM
- Assumptions
- Adaptive Techniques in Combined and Fast Fading
- How it addresses Coding issues and Capacity
- Disadvantages
- Present Scenario
- Real-Life Examples
- Symbol duration Flex

What is Adaptive Modulation? And Why?

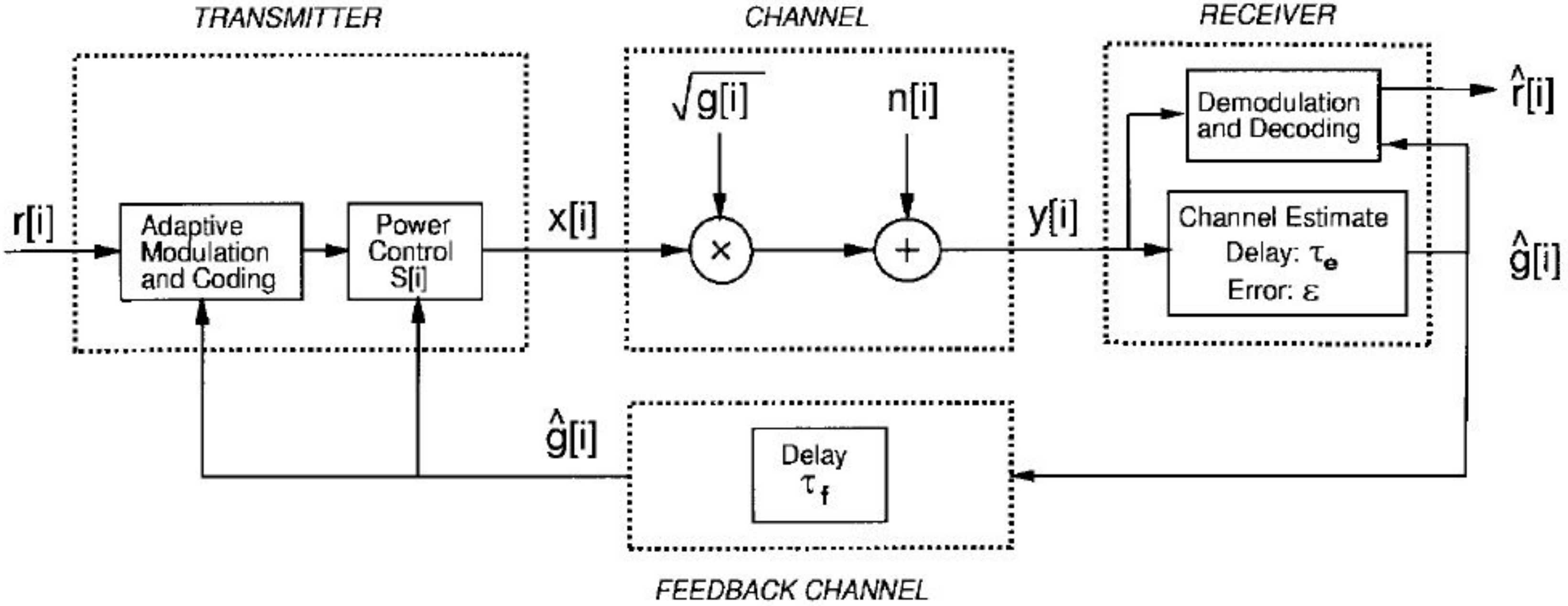
- Estimate the channel at the receiver and feed this estimate back to the transmitter
- Transmission scheme then adapts relative to the channel characteristics.
- Systems are effectively designed for the worst-case channel conditions
- Adapting to the channel fading can change
  - average throughput (reducing or increasing the data rate)
  - required transmit power (reducing or increasing power)
  - average probability of bit error

Parameters To Adapt

–Constellation size
–Transmit power
–Instantaneous BER
–Symbol time
–Coding rate/scheme

Optimisation Criteria

–Maximize throughput
–Minimize average power
–Minimize average BER



Total delay , $i_d = i_e + i_f$

The adaptive strategy may take into account the estimation error and delay in g[i] or it may treat g[i] as the true gain. In our case we consider to be true gain.

We assume that the feedback path does not introduce any errors.

https://ieeexplore.ieee.org/document/634685

Different modulations

- Variable rate (Bandwidth or Modulation Scheme)
- Variable Power (optimal power allocation similar to water filling)
- Variable Rate-Variable Power

Variable rate Variable power MQAM

- Continuous Rate Continuous Power
- Discrete Rate Continuous Power

Adaptive Transmission System (Assumptions)

Linear Modulation with symbol rate $Rs = 1/T_s$.

Ideal Nyquist data pulses ($sinc[t/T_s]$)

Bandwidth $B = 1/Ts$

SNR $\gamma[i] = S.g[i]/(N_0.B)$

S=average transmit power
g[i]=time varying gain of channel with distribution p(g)
AWGN n[i] with PSD $N_0/2$

Here g[i] is assumed to be stationary which implies that SNR is also independent of i and its distribution is given by p(γ)

Parameters to adapt are

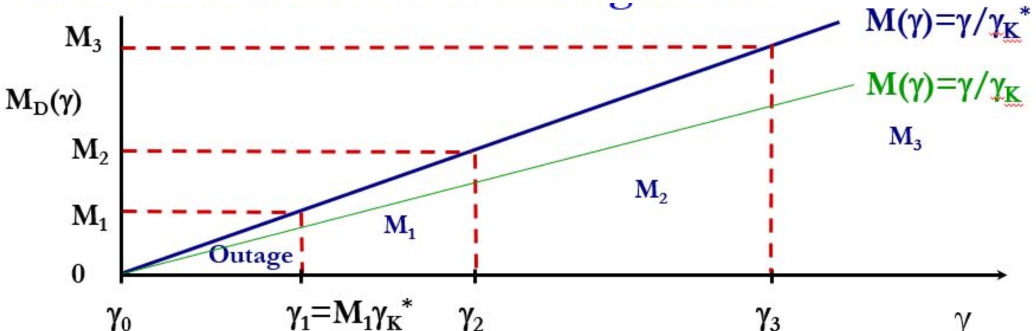
The data rate $R[i]=\log_2 M[i]/T_s = B\log_2 M[i]$ bps for M-ary modulation

Transmit power S[i]

Coding parameters C[i]

MQAM - Discrete M

- We assume a set of square constellations of size $M_0 = 0$, $M_1 = 2$, and $M_j = 2^{2(j-1)}$, $j = 2, ..., N-1$ for some N. Constellation restricted to finite set $\{M_0 = 0, M_1, ., M_{N-1}\}$
- Let $M(\gamma)=\gamma/\gamma_K^*$, where γ_K^* is optimized for max rate
- Region boundaries are $g_j=M_j g_K^*$, $j=0,\ldots,N$
- Power control maintains target BER



https://slideplayer.com/slide/12680492/

Adaptive power

Fixed BER within each region

$E_s/N_0=(M_j-1)/K$

Channel inversion within a region

Requires power increase when increasing M

$$\frac{P_j(\gamma)}{P}=\begin{cases}(M_j-1)/(\gamma K) & \gamma_j \le \gamma < \gamma_{j+1}, j>0 \\ 0 & \gamma < \gamma_1\end{cases}$$

Adaptive Techniques in Combined Fast and Slow Fading

- We examine adaptive techniques for composite fading channels consisting of both fast and slow fading (shadowing).
- We assume the fast fading changes too quickly to accurately measure and feed back to the transmitter, so the transmitter only adapts to the slow fading.

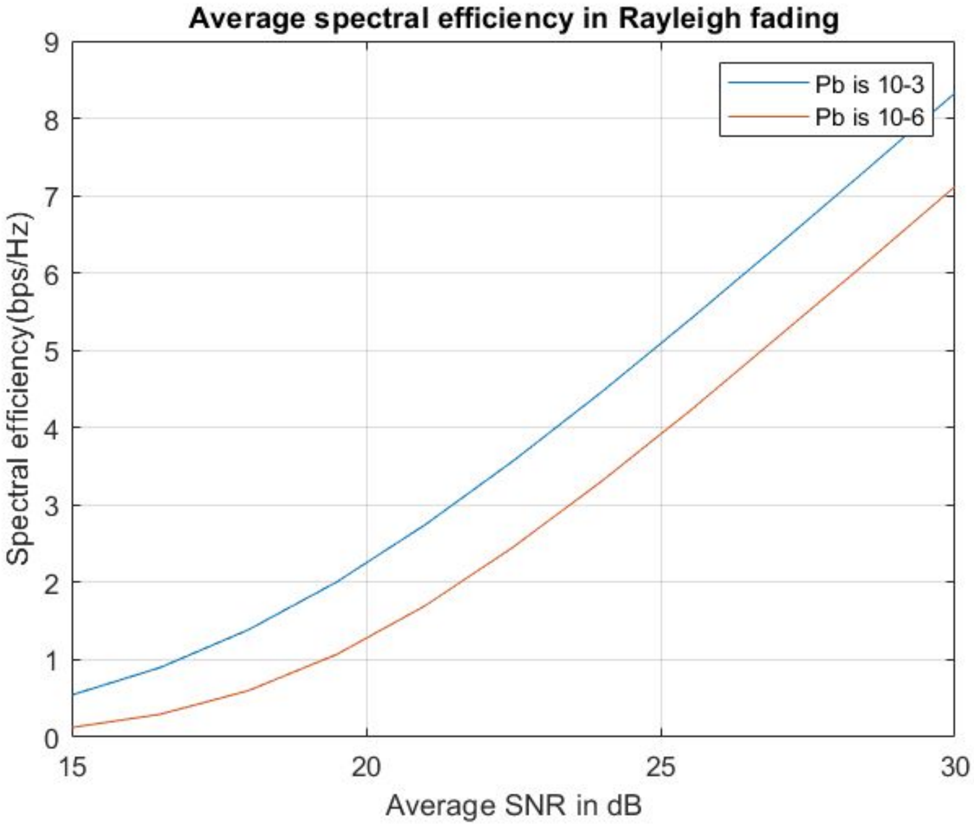
How adaptive modulation addresses coding Issues and Capacity?

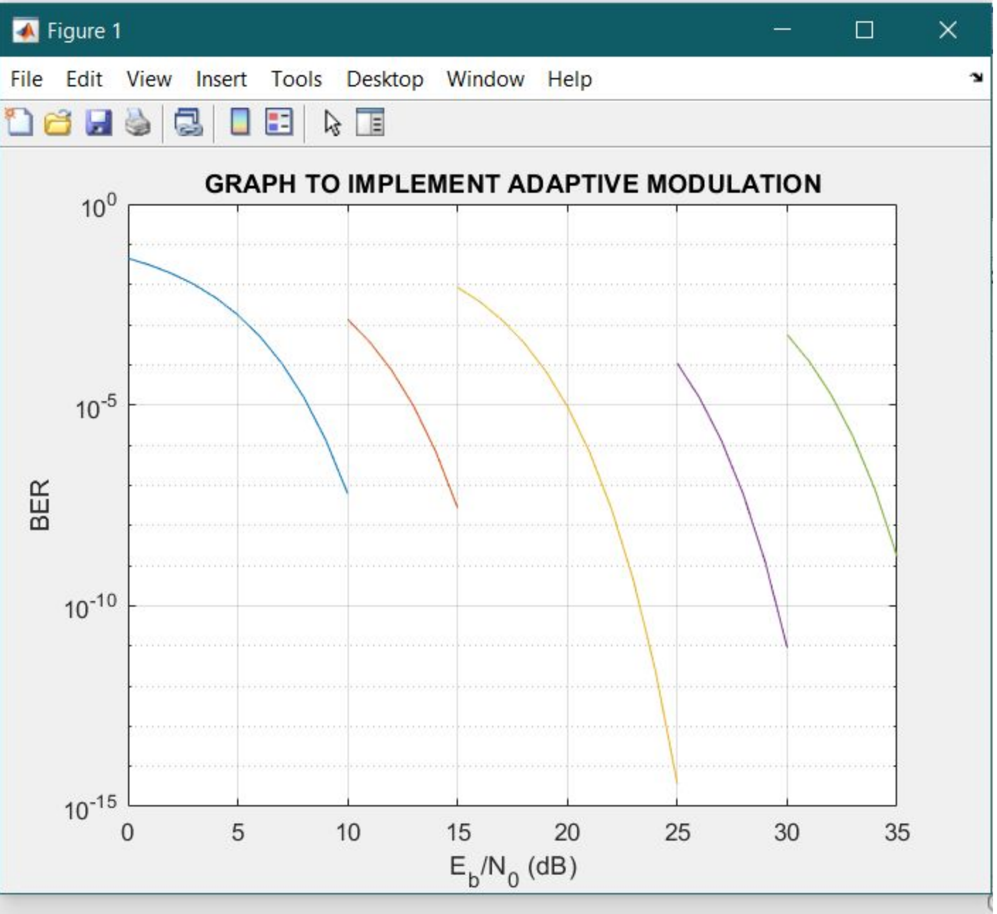
- Adaptive modulation schemes take channel conditions into account at both the transmitter and receiver end.
- It enables to easily multiply the available capacity of links, without requiring any hardware changes, without having to increase the antenna size.

Disadvantages

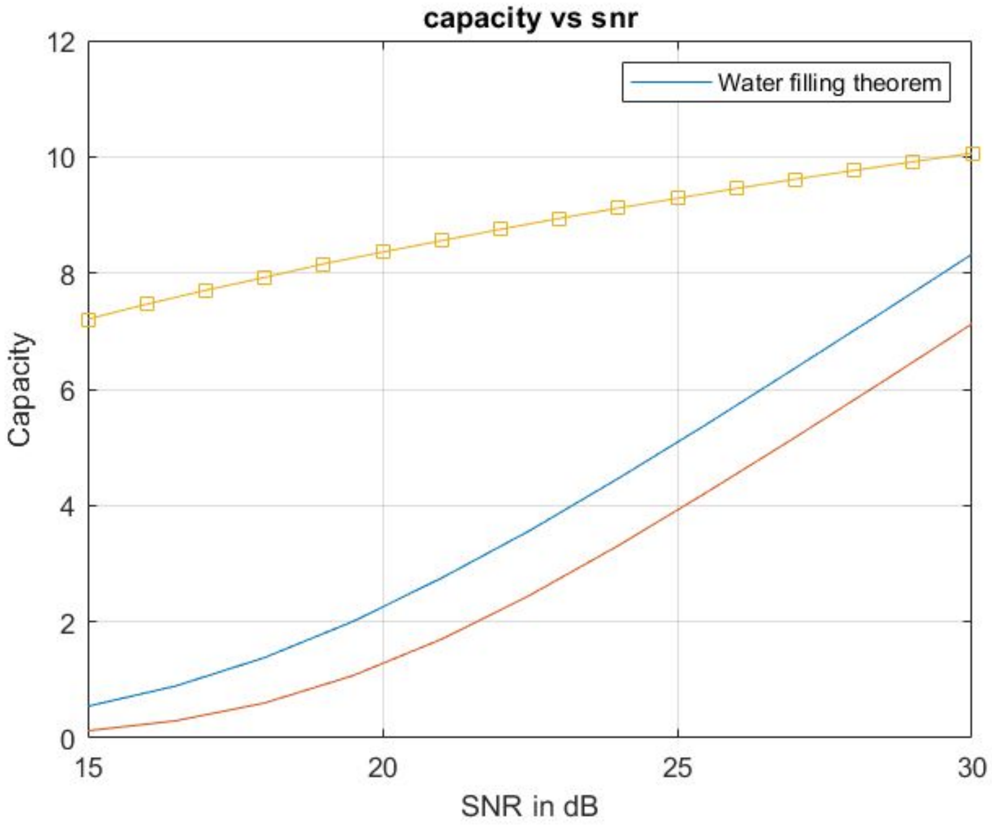
- Interaction between forward and reverse links, effect of delay, effect of errors in the feedback messages
- Hardware constraints may dictate how often the transmitter can change its rate and/or power,and this may limit the performance gains possible with adaptive modulation.
- Requires a feedback path between the transmitter and receiver, which may not be feasible for some systems.
- Fixed-rate applications with hard delay constraints such as voice or video- Quality compromised.

Simulations


Average spectral efficiency in Rayleigh fading
Spectral efficiency(bps/Hz)
Average SNR in dB
Pb is 10-3
Pb is 10-6
0
1
2
3
4
5
6
7
8
9
15
20
25
30

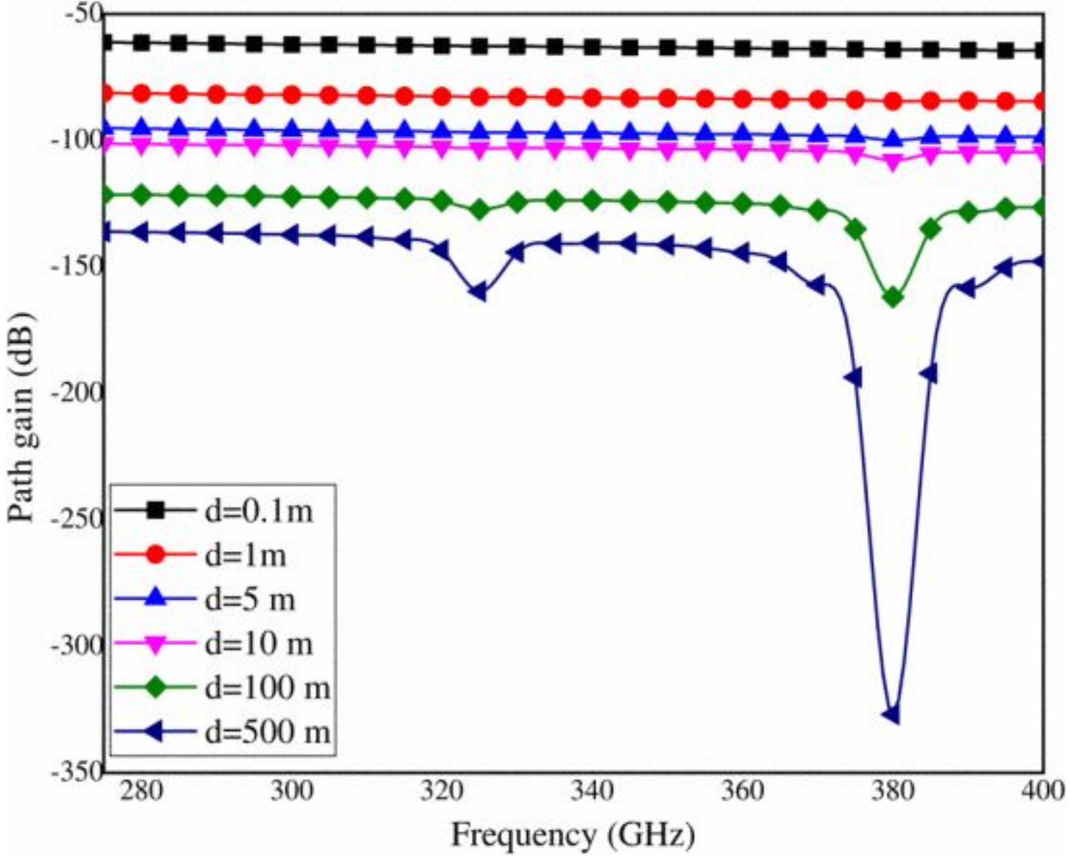


MODULATION SCHEMES
SIGNAL TO NOISE RATIO (EbNo)
BPSK 7.50 (0-12.30)
QPSK/4QAM 12.30 (12.30-20.00)
16QAM 20.00 (20.00-26.10)
64QAM 26.10 (26.10-32.50)


capacity vs snr
Water filling theorem
Capacity
SNR in dB
0
2
4
6
8
10
12
15
20
25
30

Present Scenario

- The increased data rates demand, in the beyond fifth generation (5G) wireless systems,
- Spectral efficiency approaching fundamental limits
- Higher frequency bands(Tz) that offer interference-free and abundance of communication bandwidth
- Severe pathloss attenuation
- Conventional modulation schemes cannot fully benefit from the properties of the THz regime



https://ieeexplore.ieee.org/document/8445864

Distance and bandwidth dependent adaptive Modulation

- Available transmission bandwidth is determined
- bandwidth of the subcarrier and the total number of subcarriers
- Virtual subcarriers
- Power is allocated to the non-virtual subcarriers, based on the water filling principle
- Modulation order

Real-Life examples

- GSM cellular systems varies between 8PSK and GMSK modulation
- TDMA cellular systems can use 4, 8, and 16 level PSK modulation, although the 16 level modulation has yet to be standardized
- GSM and CDMA cellular systems as well as wireless LANs, are using or planning to use adaptive transmission techniques

Symbol Duration Flex

- The Law of Large Numbers Interpretation:average of noisy samples converges to the true average (without any noise), as the number of samples approaches infinity.
- Reliability Vs. Goodput
- The Energy/Bit Interpretation

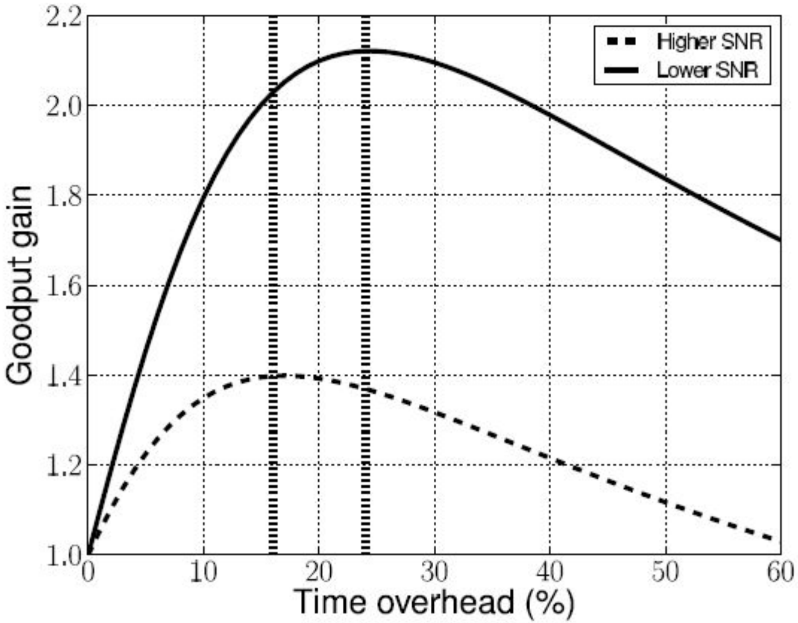


Fig. 1. Time overhead due to symbol duration extension vs gain in goodput. Extending symbol duration, beyond a threshold, does not improve goodput.