ADAPTIVE MODULATION WITHOUT AMPLITUDE ESTIMATION

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ABSTRACT:

Channel estimation at the receiver side is essential to adaptive modulation schemes, prohibiting low complexity systems from using variable rate and/or variable power transmissions. Towards providing a solution to this problem, we introduce a variable-rate (*VR*) *M*-PSK modulation scheme, for communications over fading channels, in the absence of channel gain estimation at the receiver. The choice of the constellation size is based on the signal-plus-noise (*S*+*N*) sampling value rather than on the signal-to-noise ratio (*S/N*). It is analytically shown that *S*+*N* can serve as an attractive simpler criterion, alternative to *S/N*, for determining the modulation order in *VR* systems. In this way, low complexity transceivers can use *VR* transmissions in order to increase their spectral efficiency under an error performance constraint. As an application, we utilize the proposed *VR* modulation scheme in equal gain combining (EGC) diversity receivers

***Index Terms*—**Adaptive modulation, equal gain combining, fading channels..

1 INTRODUCTION:

A common technique for dealing with fading in wireless communications, is transmission or reception diversity , If a feedback link is available, the fading can be mitigated by allowing the receiver to monitor the channel conditions and request compensatory changes in certain parameters of the transmitted signal. This technique is called adaptive transmission. The basic concept is the real-time balancing of the link budget through adaptive variation of the transmitted power level, symbol transmission rate, constellation size, coding rate/scheme, or any combination of these parameters.

In many practical applications, the *VR* communication systems, we adapt the transmission parameters according to the instantaneous channel condition system with no channel gain cannot benefit the adaptation technique.

2 PROPOSED SYSTEM:

We propose a rate adaptation technique, which is based on the signal-plus-noise (*S*+*N*) samples, instead of the instantaneous *S/N*. They require no channel gain estimation. The *S*+*N* technique has been applied to selection diversity communication systems.

We introduce an $S+N$-based *VR M*-PSK modulation scheme that does not require any channel gain estimation. The *M*-PSK modulation schemes have some important advantages over QAM schemes

ADVANTAGES:

- Adjacent channel interference and Inter symbol interference is reduced.
- Feedback channel is provided to avoid the channel estimation.
- Adaptive modulation is used.
- Data rate is increased and the data are transferred in a proper way with the total bandwidth.

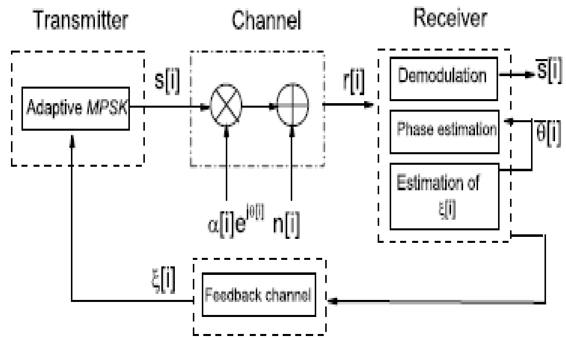
3. VARIABLE-RATE TECHNIQUES:

In variable-rate modulation the data rate is varied relative to the channel gain. This process is done by fixing the modulation scheme or by fixing the particular modulation scheme, then change the constellation size or symbol rate of the signal;

Symbol rate variation is difficult to implement in practice since a varying signal bandwidth is impractical and complicates bandwidth sharing. They are currently used in systems such as EGPRS for data transmission in GSM based cellular systems varies between 8PSK and GMSK modulation thus for GPRS data transmission. In IS-136 TDMA cellular systems can use 4, 8, and 16level PSK modulation.

3.1 MODE OF OPERATION:

We introduce a constant power, *VR M*-PSK modulation scheme, in which the decision on the modulation order is based on the $S+N$ values



The *VR* M-PSK modulation scheme.

An ideal coherent phase detection is available at the receiver at time instant, while no channel gain estimation is necessary. The receiver estimates the $S+N$ samples at time, the decision on the modulation order is sent back to the transmitter, transmitting bits through a feedback channel that does not introduce any errors. The elimination of the estimation errors can be assured by increasing its delay time and using an ARQ transmission protocol. Similarly to the *S/N* based adaptive modulation schemes, the estimation of the modulation order for the $S+N$ based schemes; require a closed-form formula that relates, the $S+N$ with the error probability. Because of the fact that such formulas are not available, *S/N* related formulas will be used instead. Moreover, formulas relating $S+N$ with the SER would be useless for the adaptation scheme, since the instantaneous noise components between two time instances are different. Therefore, for the case of the *M*-PSK we can use the approximation for the SER, i.e.

$$P_M = erfc\left(\sqrt{\gamma} sin\frac{\pi}{M}\right)$$

Therefore, the selected order will

$$M = M_j, if \begin{cases} M_j \leq M < M_{j+1} \\ \gamma_j \leq \frac{\left(a\sqrt{E_s}+n_I\right)^2}{N_0} < \gamma_j \end{cases}$$

The proposed scheme gives the ability to communications systems with no channel gain estimation capabilities to adapt high transmission rate, so that their spectral efficiency can be increased.

3.2 SPECTRAL EFFICIENCY:

The normalized spectral efficiency of the *S+N* based *VR M*-PSK scheme is obtained as

$$S_{S+N} = \frac{R}{B} = \sum_{j=1}^{N} log_2(M_j)\Pr\{\gamma_j \leq \varepsilon < \gamma_{j+1}\}$$

Where $f_Z(z)$ is the pdf of the random variable $z = a\sqrt{ES} + nI$, which is the sum of a Rayleigh and a Gaussian random variable, and is given by

$$\Pr\{\gamma_j \leq \varepsilon < \gamma_{j+1}\} = \Pr\{\sqrt{\gamma_j N_0} \leq a\sqrt{E_s} + n_I < \sqrt{\gamma_{j+1} N_0}\}$$

$$\Pr\{\gamma_j \leq \varepsilon < \gamma_{j+1}\} = \int_{\gamma_j}^{\gamma_{j+1}} f_z(z)dz$$

Thus

$$S_{S+N} = \sum_{j=1}^{N} log_2(M_j)[J(\gamma_{j+1}) - J(\gamma_j)]$$

The spectral efficiency of the *S/N* based *VR M*-PSK will be

$$S = \sum_{j=1}^{N} log_2(M_j)(e^{-\frac{\gamma_j}{J}} - e^{-\frac{\gamma_{j+1}}{J}})$$

3.3.1 APPLICATION OF EQUAL-GAIN COMBINING RECEIVERS:

Consider a multichannel diversity reception system with L branches operating in a discrete-time channel, in which the receiver employs symbol-by-symbol detection. The signal received over the kth diversity branch, at the time instant i can be expressed as

$$u[i] = \sum_{k=1}^{L} w_k[i]u_k[i]$$

where $ak[i]$ is the random magnitude, $\vartheta k[i]$ is the random phase of the kth diversity branch gain and $nk[i]$, represents the additive noise with $E\{nk[i]*nk[i]\} = Nk = 2\sigma 2 = N0$.Assuming that the random phase $\vartheta k[i]$ are known at the receiver, the received signals are co-phased and transferred to baseband so that the signal at the kth branch will be

$$r_k[i] = R\{|a_k[i]e^{j\theta_k[i]}s[i] + n_k[i]|\} = R\{R_k[i]\}, k = 1 \ldots L$$

At the combination stage the signals $uk[i]$ are weighted and a summed to produce the decision variable

$$u[i] = \sum_{k=1}^{1} w_k[i]u_k[i]$$

Where $wk[i]$ is the weight of the kth branch. Then, applying Maximum Likelihood Detection (MLD), the combiner's output is compared with all the known possible transmitted symbols in order to extract the decision metric.

The coherent equal-gain-combining (EGC) receiver co phases and equally weights each branch before combining and therefore does not require estimation of the channel (path) fading amplitudes, but only knowledge of the channel phase, in order the demodulator to undo the random phase shifts introduced on the diversity channels.

3.3.2 SYSTEM MODEL:

Consider a discrete-time channel, assuming that the fading amplitude $[i]$ follows a Rayleigh distribution with probability density function (pdf),

$$f_a(a) = \frac{2a}{\Omega} e^{-\frac{a^2}{\Omega}}$$

Where $\Omega = E\{a^2\}$

The received signal is:

$$r[i] = a[i]e^{j\theta[i]}\, s[i] + n[i]$$

Where r[i] = received signal,
a[i]= fading amplitude
ϴ[i]= phase of the signal
s[i]= transmitted signal
n[i]= noise component

The received S/N is

$$\gamma[i] = E_S \frac{a^2[i]}{BN_0}$$

Where Es= average signal energy
B= bandwidth of the signal
No= variance of the signal

3.4 RELATION BETWEEN S/N AND S+N:

The probability that both S/N and S+N determine the same constellation size, i.e.,

$$II_1 = P_r\left\{r_j \leq E_s \frac{a^2}{No} < r_{j+1} \cap r_j \leq \frac{(a\sqrt{E_s} + n_I)^2}{N_0} < r_{j+1}\right\}$$

Next deriving a closed-form solution for Π1.

By setting $y = a\sqrt{ES}$, can be equivalently rewritten as

$$II_1 = P_r\{\sqrt{N_0 r_j} \leq y < \sqrt{N_0 r_{j+1}} \cup \sqrt{N_0 r_j} - y \leq n_I < \sqrt{N_0 r_{j+1}} - y\}$$

$$\int_{\sqrt{N_0 r_j}}^{\sqrt{N_0 r_{j+1}}} P_r\left\{\sqrt{N_0 r_j} - y \leq n_I < \sqrt{N_0 r_{j+1}} - y\right\}$$

$$f_y(y) = \frac{1}{\sqrt{E_s}} f_a \frac{y}{\sqrt{E_s}} = \frac{2y}{\Omega E_s} e^{-\frac{y^2}{\Omega E_s}}$$

Moreover, the probability

$$P_r\left\{\sqrt{N_0 r_j} - y \leq n_I < \sqrt{N_0 r_{j+1}} - y\right\}$$

Involved in is the probability that the random Gaussian variable, nI, lies in a specific interval and it is directly related to the complementary error function erfc(·). Using the cumulative distribution function (cdf) of the zero-mean Gaussian random variable, x,

$$F_X(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{z^2}{2\sigma^2}}\, dz$$

and the definition of the erfc(·),

$$\text{erfc(x)} = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-z^2}\, dz$$

the probability can be calculated after some trivial manipulations as

$$P_r\left\{\sqrt{N_0 r_j} - y \leq n_I < \sqrt{N_0 r_{j+1}} - y\right\}$$

$$\frac{1}{2}\left[erfc\left(\frac{\sqrt{N_0 r_j} - y}{N_0}\right) - erfc\left(\frac{\sqrt{N_0 r_{j+1}} - y}{N_0}\right)\right]$$

Therefore, the probability, Π1, can be written as

$$II_1 = \frac{1}{2}\int_{\sqrt{N_0 r_j}}^{\sqrt{N_0 r_{j+1}}} \left[erfc\left(\frac{\sqrt{N_0 r_j} - y}{N_0}\right) - erfc\left(\frac{\sqrt{N_0 r_{j+1}} - y}{N_0}\right)\right] F_y(y)dy.$$

Now, in order to derive a closed-form expression for we have to solve integrals of the form

$$I = \mathrm{D}\int_{\mathrm{t}}^{\mathrm{y}} \mathrm{erfc}\left(\frac{\mathrm{E}-\mathrm{x}}{\sqrt{2}\mathrm{c}}\right)\mathrm{x}\mathrm{e}^{-\mathrm{D}\mathrm{x}^2}\,\mathrm{dx}$$

Finally, combining a closed-form solution to Π1, is derived as

$$II_1 = g\left(\sqrt{N_0 r_j}, \sqrt{N_0 r_{j+1}}\sqrt{\frac{N_0}{2}}, \frac{1}{E_s\Omega}, \sqrt{N_0 r_j}\right) - g\left(\sqrt{N_0 r_j}, \sqrt{N_0 r_{j+1}}\sqrt{\frac{N_0}{2}}, \frac{1}{E_s\Omega}, \sqrt{N_0 r_{j+1}}\right)$$

As a general comment regarding criterion 1, one can observe that Π1 may not be always indicative of the efficiency of *S+N* to replace *S/N*, since it involves also the probability that *S/N* leads to a modulation order, *M*. In other words, if the probability that *S/N* leads to the modulation order, *Mj*, is too low, then Π1 will be also too low, independently of whether *S+N* led to the same order, *Mj* or not. Towards this, a supplemental criterion for the efficiency of *S+N* is presented in the following.

4.1 ADAPTIVE MODULATION:

Adaptive Modulation provides efficient transmission over time varying channel. Modulation and Coding techniques that do not adapt to fading condition require a fixed margin to maintain acceptable performance when the quality of channel is poor. As Rayleigh fading causes a signal power loss of up to 30dB, adaptive modulation technique is followed for efficient usage of channel.

By adapting channel fading:

- Increase average data rate
- Transmit power reduces
- Decreases average probability of bit error

Adaptive Modulation requires feedback path between the transmitter and receiver, which is not possible in some system. If the channel changes faster than the reliable estimation and feedback then adaptive technique will perform poorly. In multipath fading channel may change very quickly and in shadowing channel changes more slowly. Only slow variations can be tracked so to address the effect of multipath flat fading mitigation is needed. Adaptive Modulation varies the rate of data transmission relative to channel conditions. Average spectral efficiency of adaptive modulation under average power is maximized by setting data rate to be small or zero in poor channel. In delay constrained applications the adaptive modulation should be optimized outage probability for a fixed data rate.

4.2 ADAPTIVE TRANSMISSION SYSTEM:

- Model is the flat fading channel as a discrete-time channel where each channel use corresponds to one symbol time Ts.
- The channel has stationary and ergodic time varying gain g[i] that follows a given distribution p(g) and AWGN n[i], with power spectral density N0/2.
- Assumptions:
  - Linear Modulation where the adaptation takes place at multiple symbol rate Rs=1/Ts.
  - Ideal Nyquist data pulses (sinc[t/Ts]), so signal bandwidth B=1/Ts.
- Denotation:
  - S=Average transmit signal power.
  - B=1/Ts, received signal power.
  - G=Average channel gain.

- The instantaneous received SNR is then γ[i]=Sg[i]/(N0B), 0≤γ≤∞, and its expected value γ=Sg/N0B.
- In adaptive modulation we estimate power gain or received SNR at time I and adapt the modulation and coding parameter accordingly.
- Parameters:
  - Data rate: R[i]
  - Transmit power: S[i]
  - Coding parameters: C[i]

M-ary Modulation data rate:

R[i]=log2M[i]/Ts=Blog2M[i] bps.

Spectralefficiency: R[i]/B=log2M[i] bps/Hz.

SNR estimate: γ̂[i]= Ŝg[i]/N0B

Adaptive transmit power: Ŝ(γ[i])=S[i]

Received power: γ[i]S(γ̂[i])S

Data rate of Modulation: R(γ̂[i])=R[i]

Coding parameters: C(γ̂[i])=C[i]

We will omit [i] with respect to γ, S(γ), R(γ) and C(γ).

Channel information at transmitter allows it to adapt its transmission scheme relative to channel variation. Adaptive consider delay and error also. Assume feedback path does not introduce any errors. At low speed, shadowing is constant and multipath fading is slow so that it can be estimated and feedback to transmitter with an estimation error and delay that does not degrade performance. At high speeds the system cannot estimate effectively so shadowing is adapted.

4.3.1 Adjacent Channel Interference:

Adjacent Channel Interference is caused by extraneous power from a signal in an adjacent channel. It is caused by inadequate filtering, improper tuning or poor frequency control.

4.3.2 Intersymbol Interference:

A signal distortion in which one symbol interferes with other symbols. It is caused by multipath propagation. It introduces error in decision device at receiver. Adaptive equalization and error correcting codes reduces ISI.

4.4 DIVERSITY SCHEMES:

Diversity improves transmission performance by using faded version of transmitted signal.

It is used because:

- It is a powerful receiver technique.
- It is used to improve wireless link by reducing errors caused by fading.
- It is achieved at low cost.

4.5 DIVERSITY COMBINING TECHNIQUES:

- Selection Combining(SC)
- Equal Gain Combining(EGC)
- Maximal Ratio Combining(MRC)

4.5.1 Selection Diversity:

Among many branches of signal the received branch with highest instantaneous SNR will be fed to detector circuit.

$$g_k = \begin{cases} 1, if\ k = l \\ 0, if\ k \neq l \end{cases}$$

$$\gamma_{out} = max \frac{\alpha_{k/2}}{\bar{n}^2}$$

4.5.2 Maximal Ratio Combining:

Each replica of signals are weighted according to SNR and co phased and distortions are cancelled out. It is assumed and it is like taking an average of weight and hence noise is reduced.

$$g_k = \frac{\alpha_k e^{-j\phi_k}}{\overline{n_k}^2}, for\ k = 1,2,\dots,l$$

$$\gamma_{out} = \sum_{k=1}^{L} \frac{\alpha_k^2/2}{\overline{n_k^2}} = \frac{\frac{1}{2}\sum_{k=1}^{L}\alpha_k^2}{\bar{n}^2}$$

4.5.3 Equal Gain Combining:

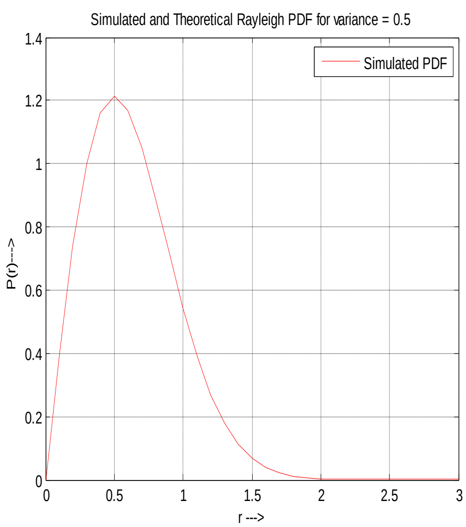
Signals are co phased and are equally weighted by their amplitude. Branching weights are all set to unity.

$$g_k = e^{-j\phi_{ki}}, for\ k = 1,2,\dots\dots,L$$

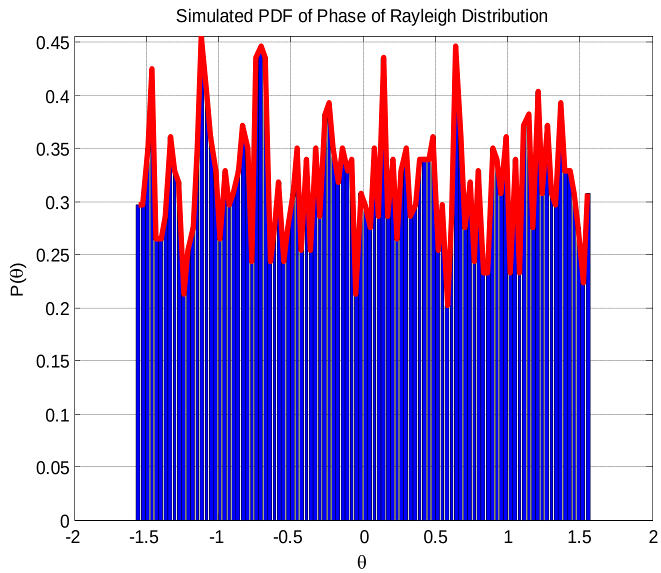
$$\gamma_{out} = \frac{\frac{1}{2}\left(\sum_{k=1}^{L}\alpha_k\right)^2}{\overline{L_n^2}}$$

presented in the following

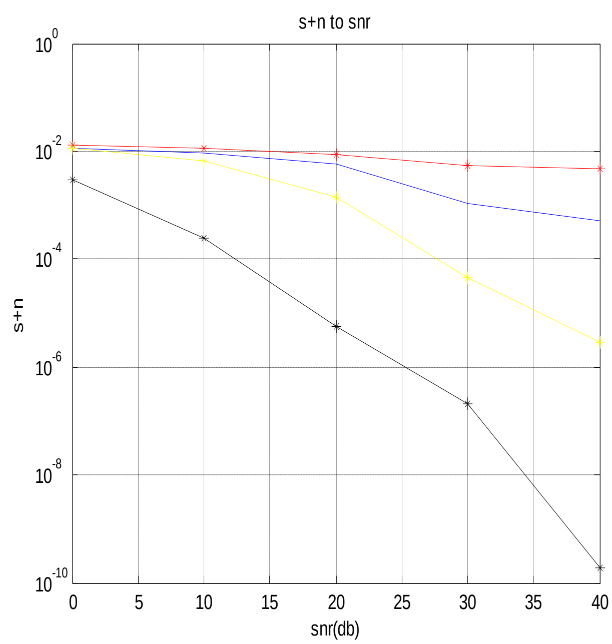
5.1 FADING AMPLITUDE:



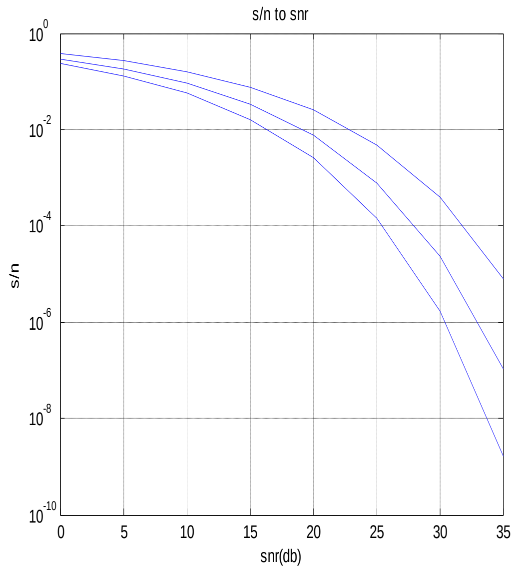
5.2 FADING PHASE:



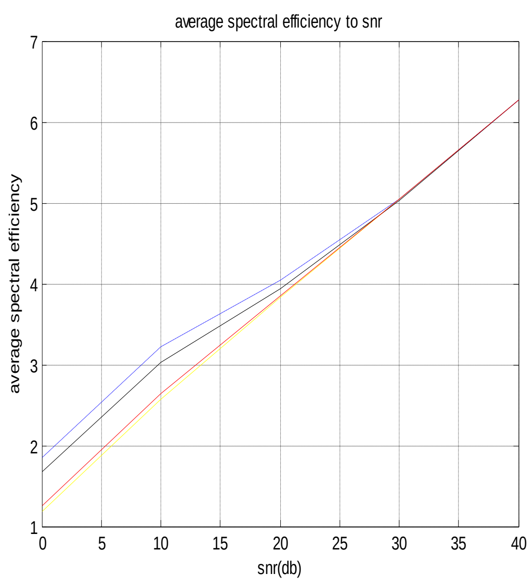
5.3 THE PROBABILITY, Π1, FOR A VR M-PSK MODULATION SCHEME. THEORETICAL (SOLID LINES) AND SIMULATION (SYMBOLS) RESULTS:



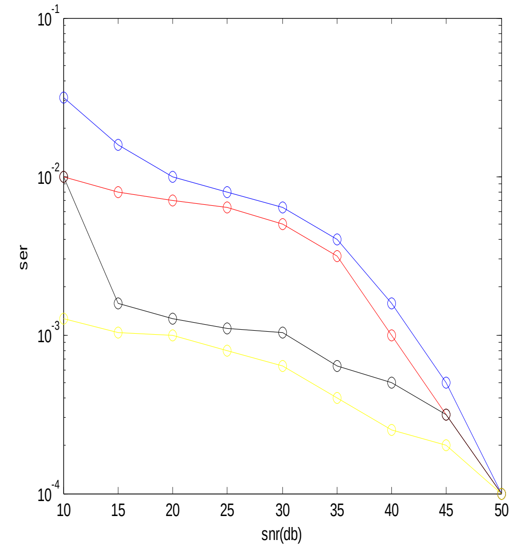
5.4 THE PROBABILITY, Π2, FOR A VR M-PSK MODULATION SCHEME. THEORETICAL (SOLID LINES) AND SIMULATION (SYMBOLS) RESULTS:



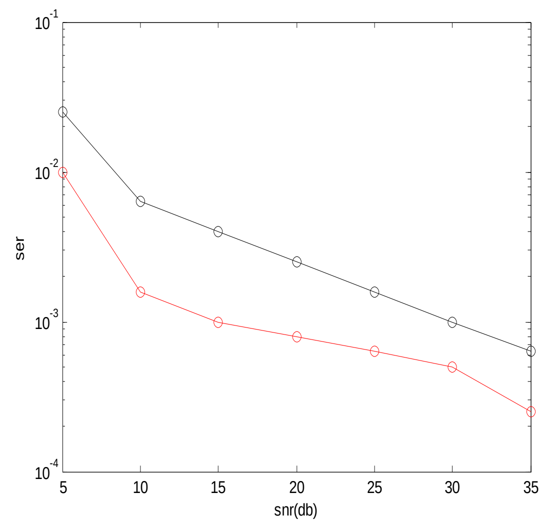
5.5 THE SPECTRAL EFFICIENCY OF VR M-PSK SCHEMES, FOR DIFFERENT SER RATES:



5.6 THE SER OF VR M-PSK SCHEMES, FOR DIFFERENT SER TARGETS:



5.8 THE SER OF EGC WITH VR M-PSK SCHEMES, FOR DIFFERENT SER TARGETS:



6. CONCLUSION:

- A VR M-PSK modulation scheme was introduced for wireless communication systems, where channel gain estimation is not available. VR M-PSK requires no channel gain estimation and increases the spectral efficiency of M-PSK systems under the instantaneous error rate requirement. The choice of the modulation order is not based on the S/N samples, but rather on the S+N ones.
- It was analytically shown that the S+N criterion is an attractive alternative to S/N for choosing the appropriate modulation order in VR communication systems, the same spectral efficiency can be achieved, when either S/N or S+N is used. Moreover, the proposed adaptive modulation scheme was applied to EGC receivers, enabling low-complexity diversity systems to increase their spectral efficiency.

7. REFERENCE:

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