Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

6th International Conference
on Electrical Engineering
ICEENG 2008

A comparison of parallel and series transmission techniques with M-ary FSK.

By

Abdel-Rahman AlQawasmi* Ibrahim N. Abu-Isbeih*

Abstract:

In this paper a comparison between parallel and series transmissions is considered by calculating the bit rate, noise immunity and the power of transmitter of Digital Communication System (DCS). The use of Wide-band parallel transmission instead of series one in Broadband Digital Communication Systems (BBDCS) using Broadband Signals (BBS) causes an increasing of the bit rate and a decreasing in the noise immunity of the system, which can be compensated by increasing the power of the transmitter (signal –to- noise ratio, (SNR)). The effectiveness of parallel and series transmission is considered for M-ary Frequency Shift Keying (MFSK).

Keywords:

Broadband System, Parallel & Series Transmission, Power of Transmitter, Noise Immunity

---

* Department of Communication Engineering, Philadelphia University, Jordan

1. Introduction:

The BBDCSs differ from the narrowband digital communication systems by their extremely wideband which gives the wideband systems the ability to stand for noise, interference and fading caused by receiving multiple waves of the same transmitted signal from different paths. There are a number of modulation techniques such as FHSS and DSSS that have a wideband using the method of pseudonoise generation that depends on changing the frequency or code randomly to accomplish with the main propagation and receiving problems that can be occurred. In earlier works and literature [2], the main objective of using BBSs is oriented on the efficiency use of this wideband.

The signal is said to be broadband (complex) signal if it consists of number of elementary signals and it has a multiplicity factor much greater than 1 ($B = FT >> 1$), where F is the bandwidth of the used frequencies and T is the duration of one symbol (bit).

In DCSs the Information rate R_b=1/T. In BBDCSs the bandwidth is much greater than the bit rate $F >> R_b$ which means that the bandwidth of BBS is always greater than the bandwidth of the transmitted bandwidth.

In communication systems, we can form BBS from a large number of narrowband (elementary) signals. This technique differs from spread spectrum techniques, where the wideband has its deterministic frequencies that are not changing by the time. We can form a BBS by time summation of frequency sequences where every frequency sequence is considered as a basic elementary subsignal with narrowband width $B_e = F_e \tau_e \approx 1$. For example, we can use impulses with different shapes, or sinusoidal signals with different frequencies and modulations.

To get high noise immunity and greater bandwidth, usually MFSK signals are used, where the signal in this case consists of number of different frequency sequences with bandwidth equals difference between the maximum and minimum frequencies. One important issue should be explained here, the formed wideband signal with different frequencies represents only one digit or bit, where in traditional FSK, and each bit has its own frequency.

The two techniques have a practical value in free access digital systems where the number of users is limited and the requirements of noise immunity are not high. For example free access digital communication system for 121 users working in area with minimum security of information.

2. Problem formulation:

In this paper, we give an analytical comparison between two different transmission techniques. Using first technique, series transmission, the BBS is transmitted in series form, where the series transmission time T_s of frequency sequences is

$$T_s = n\tau_e \tag{1}$$

where n is the number of frequencies in the interval T_s. Using the second technique, parallel transmission, the BBS is transmitted in parallel form, where the parallel transmission time T_p of every frequency sequence equals to τ_e. The main steps of comparison analysis between the two techniques will be as follows:

- Calculate the probability of bit error P_B (symbol error) of the two techniques assuming the absence of interference from other signals from the same set or from the neighborhood.
- Calculate the bit rate (symbol rate) for the two techniques considering the same conditions as for P_B.
- Computing the used efficiency coefficients for the two techniques using different encoding (signaling) methods.
- The effect of orthogonality of BBS on the both techniques and its effect on reducing the number of users of the system.

3.Probability of error in ideal conditions:

The term ideal here is referred to the absence of mutual interference and the non-ideal construction of the electronic devices of the system. As usual in the communication systems, the idealized thermal noise (AWGN) with power spectral density N_0 will be used as the main source for occurring P_B.

A. The series form of MFSK

As shown in figure 1, every interval T_s uses number of frequency sequences N where the number of different sequences depends on total number of different symbols M in MFSK. The total number of symbols can be defined as

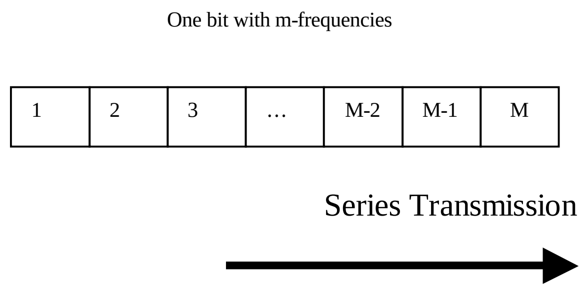
$$M = 2^k \tag{2}$$

where k is one of bits per symbol. The bit rate in this case is[2]:

$$R_B(series) = \log_2 M / T_s = k / T_s \tag{3}$$

and the symbol rate depends only on T_s, that is

$$R_s(series) = R_B / k = 1/T_s \tag{4}$$



Figure(1): *Series transmission of MFSK*

The number of frequency sequences N depends on the number of frequencies n in every symbol

$$N = n! \tag{5}$$

where the minimum number of frequencies should satisfy the following condition

$$N \geq M \tag{6}$$

Using the equations (1-6) the time duration of each frequency τ_e and k have the relation $k \leq \log_2(n!)$ then the bit rate

$$R_B \leq \log_2(n!)/T_s \tag{7}$$

The noise immunity of non-coherent detection of one information symbol transmitted by signals with (MFSK) and the effect of Gaussian noise can be described in ideal case (P_S^I) for series transmission for $N = M$ and $n \geq 1$ as:

$$P_S^I(M) < \frac{2^{\log_2(n!)} - 1}{2} \exp(-ME_B / 2N_0) \tag{8}$$

where $h_m = \frac{E_B}{N_0}$ is the signal-to-noise (SNR)of one symbol (bit), E_B is the energy of one bit . Because the probability of error as maximum value =1, then

$$n! < \left[\frac{2\log_2(e)}{\log_2(\frac{-ME_B}{2N_0})} + 1 \right] \tag{9}$$

where $\log_2(\frac{-ME_B}{2N_0}) \neq 0$

In the case of binary system (k=1, M=2) the probability of error is given by:

$$P_S^I(M) = \frac{1}{2}\exp(-E_B / 2N_0) \tag{10}$$

Figure (2) shows the ideal probability of error as a function of number of bits per symbol P_S^I for different symbol energies, considering the effect of AWGN. The term ideal refers to neglected effect of destabilizing factors of the demodulator of broadband and also neglecting the effect of noise in subchannels.

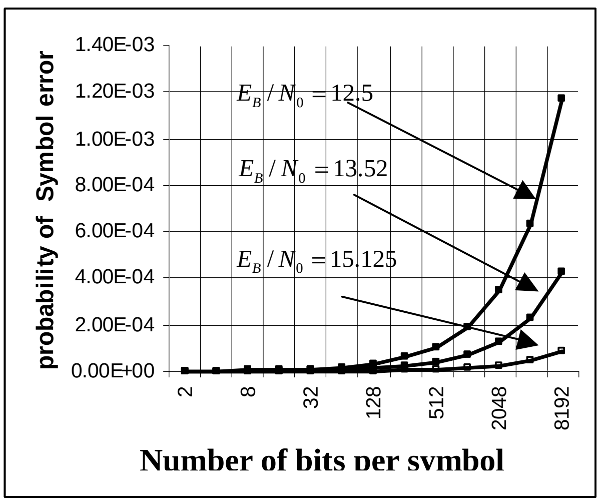


Figure (2): *Ideal probability of error* $P_S^I(M)$.

From figure 2, it is clearly shown that the noise immunity of the TDMA transmission can be high if the number of bits per symbol is small.

B. The Parallel form of MFSK

In this form, the n frequency sequences I each symbol is transmitted in parallel form. In each group one of symbols M is used as shown in fig.3. The symbol rate in this case is:

$$R_B(parallel) = \log_2 nM / T_s = nk / T_s \tag{11}$$

and the symbol rate depends only on T_s, that is

$$R_s(parallel) = R_B / k = n / T_s \tag{12}$$

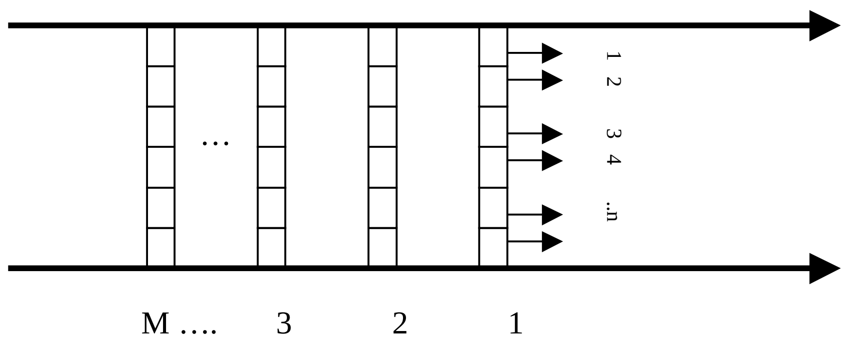


Figure (3): *Parallel transmission of FSK.*

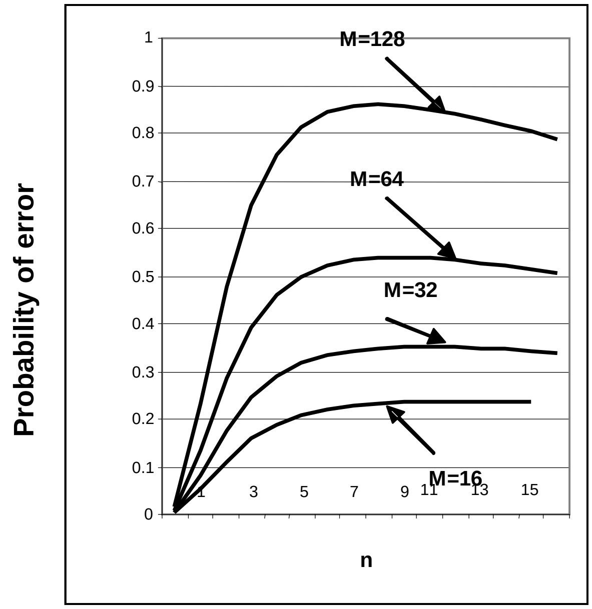
The noise immunity of non-coherent detection of one information bit transmitted using parallel transmission with (MFM) and the effect of Gaussian noise can be ideally described by:

$$P_P^I < \frac{M/2-1}{2\log_2(M/n)} \exp(-ME_B/2N_0) \tag{13}$$

As shown in figure (4), the probability of error in the case of parallel form is much higher than the series one. From (8) & (12), the symbol rate can be obtained as

$$R = \frac{R_s(parallel)}{R_s(series)} = n \tag{14}$$

where R is the increased data rate by n times.



Figure(4): *Probability of error* $P_P^I(n)$

4.The effectiveness of parallel transmission in Real conditions using orthogonal signals:

To estimate the efficiency of BB signals we calculate the used coefficient of channel bandwidth and the used coefficients of signal power as [2, 3]

$$\gamma = \frac{\log_2 M}{FT} = \frac{\log_2 M}{B} \tag{15}$$

and

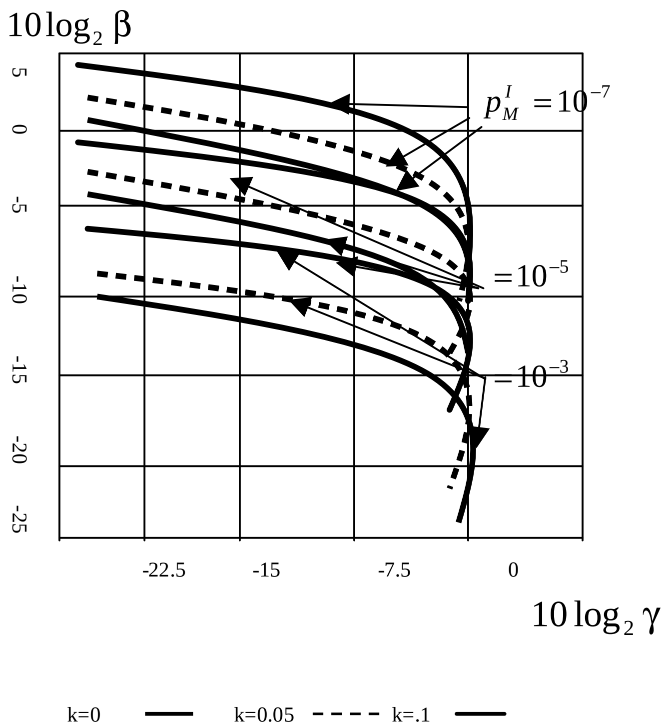
$$\beta = \frac{\log_2 M}{Bh_m^2} \tag{16}$$

Using (2)-(5) after transformations instead of (16) ,the power signal coefficient can be written as

$$\beta = \frac{\log_2 M}{2\ln \dfrac{M(2^{\log_2 M} - 1)}{4P_M^R q_M^R 2^{\log_2 M - 1}}} \tag{17}$$

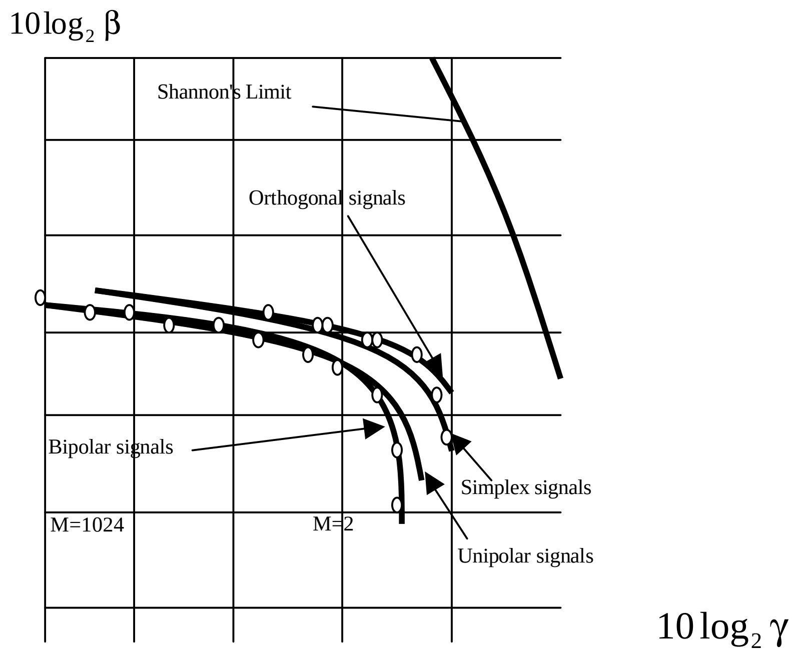
where q_m^R shows the ratio of the real noise immunity to the ideal noise immunity of the detector.

Using (9)→(17), the efficiency of broadband communication systems is considered and is shown in the figure (5) for the relationship $10\log_2 \beta = f(10\log_2 \gamma)$.



Figure(5): *Effectiveness of orthogonal signals*

Figure (5) shows the effectiveness of orthogonal signals for three values $P_m^I = \{10^{-3}, 10^{-5}, 10^{-7}\}$ with different types of signals (Orthogonal, Simplex, Unipolar and Bipolar}.



Figure(6): *Effectiveness of BBDCS for* $P_M^I = 10^{-5}$

The analysis of these figures for different k= {0, 0.05, and 0.1} shows that for a large number of M, the used coefficient of power β has the same values for different types of signals and different k values.

For different values P_M^I and ($h_m^2 = const$), the used coefficient of power β increases. This result can be explained as follows: the effect of destabilizing factors and time-frequency mismatching assuming that the energy of transmitter is constant would decrease the used coefficient of power. This means that we should compensate this loss by increasing the transmitter energy.

The loss in the used coefficient of power β is the result of the effect of k. (assuming that P_M^I =const and $h_m^2 \neq const$).

5. Conclusions:

From above work, the following results and remarks are concluded:

1- For systems with high noise immunity ($P_M^I \leq 10^{-5}$), the orthogonality can be well achieved and the effect of destabilizing factors shall not affect the BBDCSs if the value of time-frequency mismatching $k(\tau, \Omega) \geq 0.1$.

2- The results have practical value and they give analysis and technical formulation for BBDCSs with orthogonal signals.

3- The comparison between series transmission of BBS and the parallel transmission for data rate and noise immunity is presented.

References:

[1] Zuko A.G., *Noise immunity and effectiveness of communication systems*, Radio and Communication, P.360, 1985.

[2] Zuko A.G., *Noise immunity and effectiveness of communication systems*, Radio and Communication, P.360, 1985.

[3] Varakin L. E., *Theory of complex signals*, Radio & Communications, P.376, 1985. A. J. Viterbi, Wireless Digital Communication, *A View Based on Three Lessons Learned*, IEEE Comm. Mag., PP. 33-36, September 1991.