Comments on Spectral Efficiency of VMSK

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Abstract— **This paper demonstrates that no ultra narrow band modulation method, which includes VMSK and VPSK, can have substantially greater efficiency than conventional methods, such as QAM, in transmission in the same frequency band.**

Keywords— **VMSK, VPSK, Ultra Narow Band Modulation, QAM**

I. Introduction

Recently the exceptional properties of a new modulation method named VMSK (Very Minimum Shift Keying) have been heavily advertised, especially on the internet. Two companies in particular are active in this area: AlphaCom Communications and Pegasus Data Systems. To quote only two of their most typical marketing statements: "What this means to the end user is data transmission speeds up to 1,000 times faster than present 56Kbps - with less distortion, at probably half the price of current monthly DSL and cable ISP rates." [1]; "VMSK modulation is a very unique modulation method for transmitting digital information that does not require a spreading of the bandwidth, therefore 20 to 50 times as many radio stations could be put on the dial." [2].

The story begins in 1997 with a paper by H R Walker [3], to which most of the advertising claims also refer. Although the same author later presented his idea at several places, e.g. [4]-[7], it is safe to say that the publication of the paper in IEEE Transactions on Broadcasting carried the greatest scientific weight and thus contributed the most to the creation of the illusion spread by VMSK proponents. It is thus appropriate that this illusion should be refuted in the same journal.

The purpose of this paper is not to conduct a precise analysis of the VMSK modulation method or to determine where the author went wrong in his rather vague presentation of the method. We wish merely to show that no modulation method can increase the efficiency of conventional modulation methods to the extent promised by VMSK proponents. The same conclusion thus applies to any ultra narrow band modulation (UNBM) which has appeared (or may yet appear) as a derivative of VMSK or its alternative.

II. Simple proof

The basic assertion made by VMSK proponents is that, in the ultra narrow frequency band occupied by VMSK, we can achieve a much greater information throughput (bits/s) than is possible using conventional methods.

To refute this claim, let us look at the reference system for the simple case of a linear distortion-free communications channel with additive white noise, as shown in Figure 1.

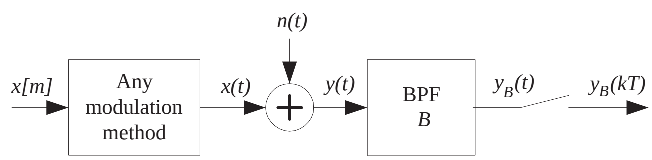

Fig. 1. Reference system

The assumptions of white noise and a distortion-free channel are reasonable, since UNMB involves an extremely narrow frequency band for transmission, so that the frequency characteristics of the channel and the noise in this band cannot change significantly.

We convert the information stream $x[n]$ into signal $x(t)$ in any way which enables the transmission of information in a narrow frequency band B, which means that the loss of frequency components outside this band do not result in loss of information. VMSK and VPSK should also have this property [8].

Signal $y(t)$ at the channel output is first filtered using an ideal filter of bandwidth B and then sampled at equidistant time intervals $T = 1/2B$.

We can now express the output symbol stream as

$$y_B(kT) = x_B(kT) + n_B(kT) \tag{1}$$

where $x_B(t)$ is a band-limited signal $x(t)$ and $n_B(t)$ is band-limited noise $n(t)$. Since we have assumed that the modulation method is such that all the information is in the frequency band B, the filtered signal $x_B(t)$ also contains all the information. The signal $x_B(t)$ is band-limited; it can be perfectly reconstructed from its samples $x_B(kT)$, which at the same time means that these samples also contain all the information.

Equation (1) represents a discrete additive white noise channel with symbol stream $x_B(kT)$ at the input and symbol stream $y_B(kT)$ at the output, wherein input stream $x_B(kT)$ is a loss-free encoded input stream $x[m]$, while the rate at which we transmit symbols is equal to $r = 2B$.

The alternative system shown in Figure 2 thus performs at least as well as the reference system shown in Figure 1, regardless of the modulation method used in the reference system. Although the reference system is not a practical solution, no practical system can have greater information throughput.

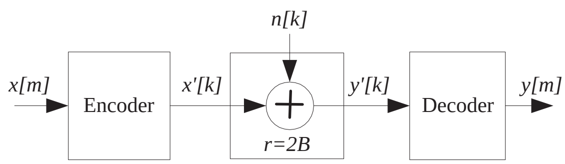

Fig. 2. Alternative system

The information throughput of the alternative system is limited by the capacity C of the channel. This depends on the variance of the imput stream $\sigma^2_{x_1}$, the variance of the noise σ^2_n, and the rate r, which in our case equals $2B$. In the particular case of additive white Gaussian noise $C$is given by the equation:

$$C = B\log_2(1 + \frac{\sigma^2_{x_B}}{\sigma^2_{n_B}}) \tag{2}$$

It is well known that, at least theoretically, we can transmit symbols without inter-symbol interference at a rate $r = 2B$ and it is also well known that practical systems using quadrature amplitude modulation (QAM) already closely approach this limit. How closely we approach the limit given by equation (2) depends solely on the quality of filters applied and the coding method used.

III. Conclusion

We have shown that, by introducing new UNBM methods such as VMSK and VPSK, we cannot exceed the efficiency of conventional QAM of the same bandwidth, at least if we accept that the sampling theorem and Nyquist's criteria for transmission without inter-symbol interference (not demonstrated here) hold true.

The division of the frequency band of transmission into narrow channels, which is equivalent to the use of multiple UNBM channels, can improve the signal-to-noise ratio in individual channels, but this fact has already been exploited by methods with multiple carriers, such as DMT, which normally use QAM modulation in an individual channel.

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