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Optimum Filter Design for Digitally Modulated Signal

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***Abstract*- Modern communication systems use modulations with high spectral efficiency to transmit information over limited bandwidth channels. Thus, quadrature amplitude modulation (QAM) is widely used but requires accurate synchronization between transmitter and receiver oscillators. Use of an equalizer with an adaptive algorithm is then necessary to correct inter- symbols interferences. When distortions, frequency offset and modulation level become important, a joint architecture is mandatory to allow carrier recovery and adaptive equalization algorithms to collaborate and work efficiently. Different type of filters suggested in this paper to low down the noise in communication channel.**

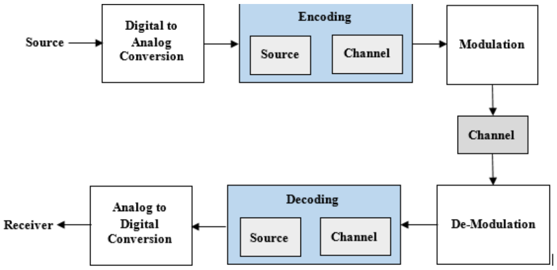
***Index Terms*- (QAM), AWGN Channel, RPF etc.**

I. INTRODUCTION

With these new requirements in terms of quantity of information and the constraints of availability of frequency bands, a new challenge has emerged and has taken a major importance in the design of communication systems. Indeed, the ability to transmit the maximum amount of data in a minimum of bandwidth, i.e. increased spectral efficiency [2], has become the determining factor and the guarantee of survival for wireless service providers. In fact, several communication systems use equalizers whose function is to identify the channel and to compensate for its effects on the transmitted signals (elimination of interferences between symbols). This part of the system employs, for the most part, training sequences which consist of a number of well-known bits, which are transmitted at the same time as the information bits. Without resorting to the use of drive sequences, more bits of information can be sent, which has the effect of increase the spectral efficiency.

II. DIGITAL TRANSMISSION SYSTEM

Every digital communication system is composed of a transmitter, a channel in which the information is transmitted and a receiver [3]. Depending on the communication chain and the level of abstraction of the description chosen, the representation of the system and the details of the operations performed may vary. Following are the general representation of Figure 1 below.



Introduction

In this example, the analog information provided by the source is first digitized. Then, two successive coding operations are performed in order to optimize and adapt the information to the transmission channel.

- Source encoding transforms binary information taken in a set 0.1 in one following values included in another set, depending on the selected code type (NRZ2, Bi-phase, and RZ). At this stage, the goal is to optimize the amount of information to be transmitted [4,5].
- Channel coding adds a number of control bits to the source encoder bit sequence. The objective is then to allow the receiver to correct the errors introduced by the channel [7, 8].

The next block will realize different types of digital modulation (QPSK3 and QAM) to group several bits in the same signal called symbol. The modulator also makes it possible to associate these symbols with an electrical signal and to transmit them, if necessary, on a carrier wave more adapted to the channel.

Digital Transmission Channel

In the baseband transmission, the signal is transmitted on the channel without the modulation operation that translates the signal spectrum to center it on a channel. Carrier frequency f_o. The schematic diagram of a baseband transmission system [7, 8]. On transmission, the signal to be transmitted is composed of binary numbers {an} codes into a set of data which modulates amplitude of the pulses s (t) at the transmission rate of the symbols R_s. The emission and reception optimize the signal-to-noise ratio and limit the signal bandwidth.

III. DIGITAL MODULATION SYSTEMS

Fundamental Notions

The modular process consists of converting digital information or a low-pass analog signal into an analog band-pass signal at a much higher frequency. In telecommunications, modular consists of varying one or more properties of a periodic signal, or carrier, with a modulating signal that contains the information to be transmitted. These properties vary between amplitude, frequency, phase, or a combination of two of them.

Modulation and Demodulation QAM

The 16-QAM [9] modulation is performed by consulting a transformation table, from which the values of the real and imaginary part of each subcarrier are obtained. This can be seen in Table 1.In

i_0/q_0	i_1/q_1	I/Q
0	0	−0, 948683298
0	1	−0, 316227766
1	0	0, 948683298
1	1	0, 316227766

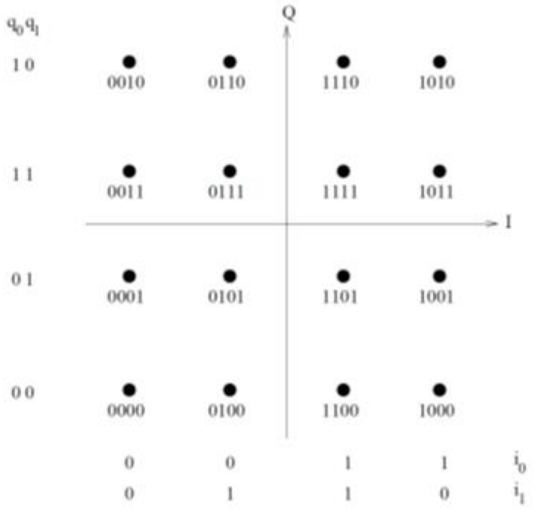


Figure 2: 16-QAM constellation used in the implementation

The data stream that enters the QAM mapping block is divided into 4-bit blocks, and these are assigned to the constellations according to equation (1):

$$\{i_0 i_1 q_0 q_1\} = \{b_3 b_2 b_1 b_0\} \quad (1)$$

Figure 2 shows the constellation of 16-QAM used in the project, where the order of the bits has been assigned according to the gray code. The assignment of each constellation point to each 4-bit combination is shown.

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The 16-QAM demodulation is carried out by means of a soft decision. The method used is very simple, and is based on the bit distribution used in the QAM constellation. At the output of this demodulator, soft bits are obtained, where a positive value corresponds to a "1", while a negative value corresponds to a "0". The absolute value of the soft bit is equivalent to its reliability: the larger this amount is, the more reliable the bit is.

The main objective of this stage is to obtain a nibble of soft bits $\{b_3 b_2 b_1 b_0\}$ from each subcarrier. The two most significant bits are linked to the real part of the subcarrier, while the two least significant bits are linked to the imaginary part (See equation (1)).

In this way, to obtain the most significant bits, it was used (See Figure 2):

$$b_3 = \lceil \Re\{\hat{D}_{k,m}\} \rceil \quad (2)$$

$$b_2 = K + \Re\{\hat{D}_{k,m}\} \qquad b_3 < 0 \quad (3)$$

$$b_2 = K - \Re\{\hat{D}_{k,m}\} \qquad b_3 \geq 0 \quad (4)$$

To obtain the least significant bits, we use:

$$b_1 = \lceil \Im\{\hat{D}_{k,m}\} \rceil \quad (5)$$

$$b_0 = K + \Im\{\hat{D}_{k,m}\} \qquad b_1 < 0 \quad (6)$$

$$b_2 = K - \Im\{\hat{D}_{k,m}\} \qquad b_1 \geq 0 \quad (7)$$

Where $\lceil . \rceil$ corresponds to a saturation function, which limits the absolute maximum value of the soft bits (this was necessary for the correct functioning of the Viterbi algorithm). The constant K corresponds to a decision value, which can be seen in Figure 3. To calculate K, it is taken into account that the data is transmitted with half the amplitude of the pilot subcarriers. In addition, the equalizer normalizes the amplitude of the pilot subcarriers. With this in mind, the decision value K is obtained in the following way:

$$K = \frac{2}{3}.\frac{K_{DATA}}{K_{PILOTS}}.K_{MAXQAM}$$

$$K = \frac{2}{3}.\frac{1}{2}.0.948683298$$

$K = 0.316227766$ (8)

Where K_{MAXQAM} corresponds to the maximum amplitude per channel of the QAM constellation.

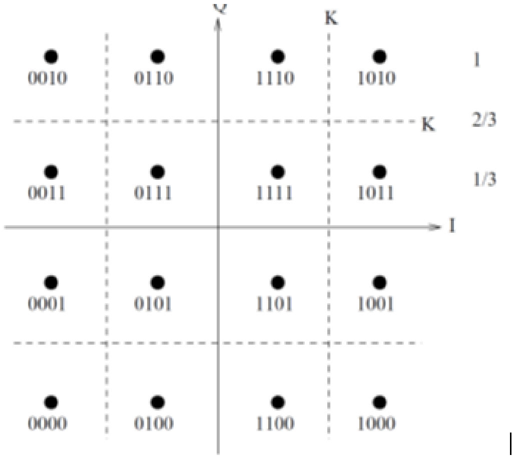

Figure 3: Decision threshold for the QAM demodulator

Pulse Formation and Filtering

To improve the spectral efficiency of the transmitted pulses and limit the ISI, modern communication systems change the waveform of these. This process is usually carried out after online coding and modulation. There are 3 pulse shaping filters that are used frequently:

Sinc Filter

Although it is an unrealizable filter because it is non-causal, it constitutes the ideal low-pass filter with relatively slow decay extremes. Its Fourier transform is a square of bandwidth$\frac{R_b}{2}$, defined by the function:

$$P(f) = \frac{1}{R_b}\prod\left(\frac{f}{R_b}\right)$$

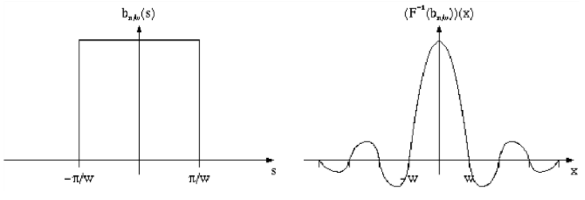

Figure 4: Sinc pulse shaping filter and its spectrum

Convolution Codes

The second family of codes differs from the block codes in that the encoder output is a continuous flow of data according to the elements of the current messages to be transmitted, as well as the previous elements, considering themselves up to K previous instants, depending on the encoder in use. Given its nature, the description of a convolutional code [10] conv (n, k, K) is performed in the domain of delays, or domain D, where the convolution becomes multiplication so the sequences can be expressed in polynomial form, but in the domain of delays and not in time as in the case of cyclic codes, so a message m = (m0, m1, m2, ...) can be represented as

$m(D) = m_0 + m_1D + m_2D + \cdots$ (10)

Where retrace D has the same interpretation as z-1 in the Z transform.

Every convolutional code can be described by the impulse response associated with each of the outputs. In this way the sequence of output $i - e$ is determined by the discrete convolution-module-2 between the message and the generating sequence,

$c(i) = m * g(i)$ (11)

Here it is extremely useful to use the description in domain D, where it is enough to multiply the polynomials,

$C(D) = M(D)\,G(D)$ (12)

IV. CONCLUSION

The proposed communication system model incorporate 16 QAM modulation and demodulation .AWGN channel model is considered to incorporate the noise frame. 5 dB noise is considered as reference for filters. There are different filter RPF, RRCF, used for noise filtration and a proposed hybrid model has been implemented with RRCF the proposed model outperformed with normal filtering technique.

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