MODULATION AND CODING PROJECT

SATELLITE COMMUNICATION : DVB-S2

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1 Questions : Optimal communication chain over the ideal channel

1.1 Regarding the simulation :

1. **It is proposed to use the baseband equivalent model of the AWGN channel. Would it be possible to live with a bandpass implementation of the system ?**

   The baseband equivalent model is used to avoid the need of the carrier frequency. Hence, the envelop of the signal is independent of it. If the model stay in the bandpass equivalent, the sampling frequency will be very high and it will be difficult or impossible to implement.

2. **How do you choose the sample rate in Matlab ?**

   The sampling frequency must be greater than twice the symbol frequency to avoid aliasing. The choice of the upsampling factor M increases the sampling frequency for this reason.

   $$F_{samp} = F_{symb} * M \tag{1}$$

   Where M = 2,...

3. **How do you make sure you simulate the desired $Eb/N0$ ratio ?**

   First the signal spectral energy has to be computed, $\varepsilon_s = \int_{-\infty}^{+\infty} \frac{|s(t)|^2}{f_{sampling}} dt$, so the bit energy can be deduced by dividing ε_s by two times the total number of bits sent. The factor 2 comes from the fact that the power of a bandpass signal is equal to the power of its complex envelope divided by 2. Since we know that the PSD of the noise is $N_0/2$ we know that the added noise has the form $\sqrt{N_0/2}(\mathcal{N}(0,1) + i\mathcal{N}(0,1))$.
   We can adjust E_b/N_0 to obtain the desired SNR.

4. **How do you choose the number of transmitted data packets and their length ?**

   The BER computation quality is given by the relation $CL = 1 - e^{-BER.Nbits}$ where CL is the confidence level. In general we want to achieve a confidence level of 0.95 which gives us q relation between the BER and the number of transmitted packets.
   The total number of bits should be divisible by the number of bits per symbol.

1.2 Regarding the communication system :

1. **Determine the supported (uncoded) bit rate as a function of the physical bandwidth.**

   The bit rate is defined by :

   $$R = \frac{log_2(N)}{T_{symbol}} \tag{2}$$

where N is the number of words (symbol) and T_{symbol} is the symbol duration.
The Nyquist criterion states that to avoid inter-symbol interference, the minimum bandwidth (Nyquist bandwidth) is defined as :

$$B = \frac{2}{T_{symbol}} \tag{3}$$

where B is an ideal Nyquist Bandwidth.
The supported (uncoded) bit rate can be expressed as a function of the bandwith as :

$$R = \frac{B * log_2(N)}{2} \tag{4}$$

2. **Explain the trade-off communication capacity/reliability achieved by varying the constellation size.**

   The constellation size is determined by the number of bits for each symbol. The relation is : $size = 2^N$ where N is the number of bits per symbol. If the constellation size is increased, the minimum euclidian distance decreased between two consecutive symbols. This distance dominates the bit error rate. In other words, to have the same BER for each modulation, the energy of a bit must increased consequently. The capacity of a channel (number of bits per symbol) induced less reliability (more errors) at the receiver if the energy of a bit is the same for each modulation.

3. **Why do we choose the halfroot Nyquist filter to shape the complex symbols ?**

   The halfroot Nyquist is more efficient than the rectangular pulse which causes bigger side lobes and can interfere with adjacent channels. Moreover, the halfroot Nyquist avoid the inter-symbol interference and limit the bandwidth (limit the effect of the noise).

4. **How do we implement the optimal demodulator ? Give the optimisation criterion.**

   It is a bank of K filters matched to the basis functions which optimisation criterion is the maximisation of the SNR. It is maximides when $h(t) = ks(-t)$. This gives us the basis functions for the filter $h_i(t) = ks_i(-t)$.

5. **How do we implement the optimal detector ? Give the optimisation criterion.**

   It is a system that projects the received signal onto each of the M possible transmitted signals and make a decision according to which predetermined signal fits the best.
   There are two optimisation criteria :

   — Maximum a posteriori (MAP) : "The MAP criterion maximizes the probability of a correct decision, or equivalently minimizes the probability of making an error (bit error rate)". It is given by :

$$\tilde{\underline{s}}_m^{MAP} = \max_{\underline{s}_m} p(\underline{r}|\underline{s}_m)p(\underline{s}_m) \tag{5}$$

— Maximum likelihood (ML) : "The ML criterion reduces to finding the signal $\underline{s}_m$ that is closest in distance to the received vector $\underline{r}$ (minimum Euclidian distance)"

$$\tilde{\underline{s}}_m^{ML} = \min_{\underline{s}_m}(\sum_{k=1}^{K}(r_k - s_{mk})^2) \tag{6}$$

Références