# DVB-S2 Communication Chain

## Modulation and coding

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# Contents

# Chapter 1

# Optimal communication chain over the ideal channel

## 1.1 Symbol mapping

The first step to implement the DVB-S2 communication system is to map the bit stream, that have to be sent to the receiver, with complex symbols. This consists of decomposing the data in chunks of data packets of fixed length (i.e the number of bits per symbol) and associate each chunk of bits to a given symbol in a constellation diagram using a specific modulation coding. The modulation codes supported by DVB-S2 systems are the following: BPSK, QPSK, 16QAM and 64QAM. To implement a communication chain, some trade-offs between data rate and noise sensitivity have to be made. For example, the higher the number of bits per symbol, the higher the information rate but the higher the bit error rate. Indeed the number of constellation symbols increases with the number of bits per symbol, however the constellations are closer one to each other, leading to a higher probability of corrupted symbol by noise. At the receiver side, the demapping bloc associates each corrupted symbol to the closest constellation point, following the maximum likelihood rule.

## 1.2 Nyquist filter

The second step of this first part is to implement the Nyquist filter. Indeed the Nyquist filter is necessary to avoid intersymbol interference (ISI). This is one of the two main properties of the Nyquist filter which are: the limited communication bandwidth and the cancellation of the inter-symbol interference. The cancellation property has been illustrated during the simulation and is depicted on Figure 1.1. One can notice on this figure the two characteristics that maintain zero ISI: the pulse is equal to 1 at $t = 0$ and is equal to 0 at all multiples of the symbol rate.

As specified in the project, the Nyquist filter must have specific parameters, a 1 MHz cutoff frequency and a 0.3 roll-off factor.

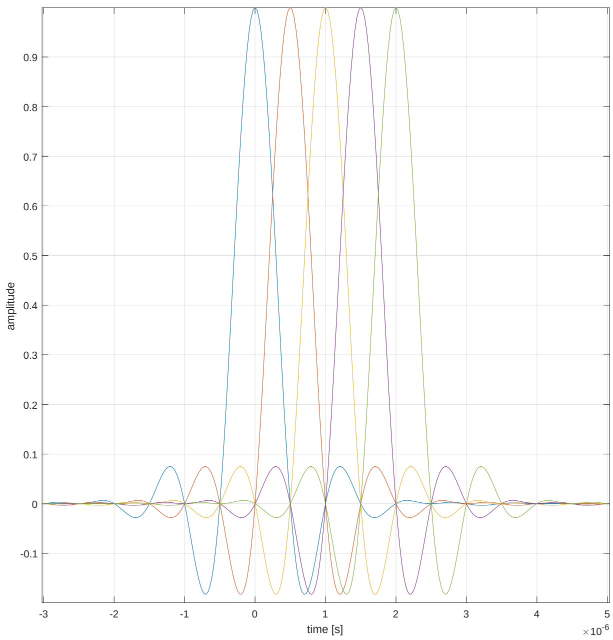


Figure 1.1: Cancellation of the inter-symbol interference ($Tsymb = 0.5\mu s$)

## 1.3 Noise addition

To implement the communication chain, the consideration of the AWGN is essential. The sent signals are expressed as there baseband equivalent. Therefore,the baseband model for the noise must be used.

The complex envelope of the noise n(t) is defined as:

$$n(t) = n_I(t) + jn_Q(t) \tag{1.1}$$

Where $n_I(t)$ is the in-phase lowpass component and $n_Q(t)$ is the quadratic lowpass component. The white noise is supposed to possess a mean equal to 0 and a PSD of value $N_0$. As a consequence, the real and imaginary part of the envelope have a mean equal to 0 and a PSD 2N0. This is due to the independent nature of the real and imaginary part. The power of the complex envelope is expressed as:

$$P_{N_0} = 2N_0F_s \tag{1.2}$$

The frequency shown is the sampling frequency. This is the frequency used to take all the frequency below this one into account. The PSD of the noise can be computed from the SNR per bit.

$$SNR = \frac{E_b}{N_0} \tag{1.3}$$

$E_b$ is the energy per bit. It is calculated by dividing the signal power P by the bit rate R.

$$E_b = \frac{P}{R} = \frac{\sum\limits_{i=-\infty}^{\infty} |s(kT_s)|^2}{N_{bits}/Ts} \tag{1.4}$$

The power of a bandpass signal is equal to the power of its complex envelope divided by two. The factor 0.5 has to be taken into account for the bit energy.

The power of the noise $P_{N0}$ can now be computed. The noise is added to the sent signal as a random variable of zero mean and variance $\sigma$. The variance is equal to $\sqrt{P_{N_0}/2}$. The power of the noise can be modified in the simulation by modifying the SNR. The BIt Error Rate can be computed to measure the impact of $E_b/N_0$.

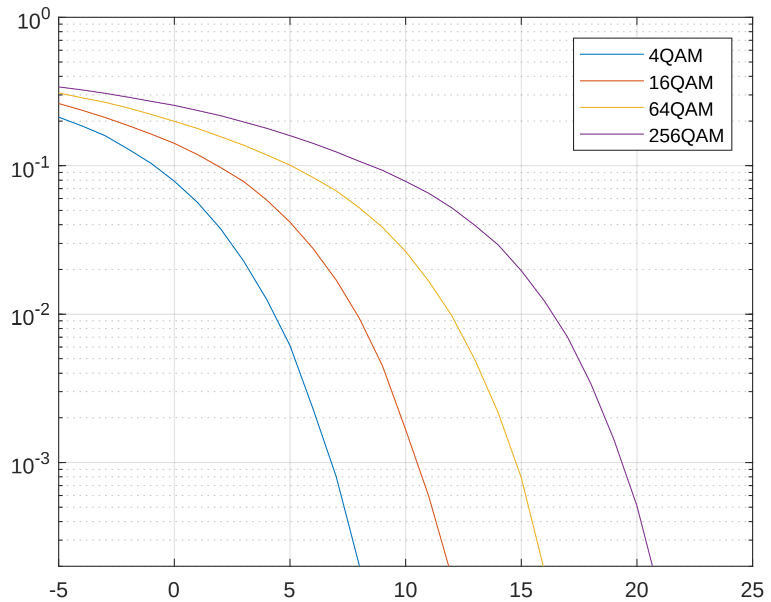


Figure 1.2: BER

## 1.4 Questions

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?**
Working with a bandpass implementation of the system would require a much higher sampling frequency since we are dealing with narrow-band signals: the carrier frequency is much higher than the bandwidth.

2. **How do you choose the sample rate in Matlab?**
The sampling rate is chosen following the Nyquist Criterion which ensures that aliasing effects can be avoided when the sampling rate is at least twice the symbol frequency. In practice, an oversampling factor is introduced in *MATLAB* in order to increase the filter resolution.

3. **How do you make sure you simulate the desired $\frac{E_b}{N_0}$ ratio?**
The SNR factor $\frac{E_b}{N_0}$ is imposed in the *MATLAB* code and the PSD of the noise $N_0$ is deduced from the SNR and the bit energy $E_b$ using the following relation:

$$N_0 = \frac{E_b}{E_b/N_0} \tag{1.5}$$

4. **How do you choose the number of transmitted data packets and their length?**
The number of bits sent to the communication channel has to be a multiple of the number of bits per symbol (i.e the data packet's length).

5. **Determine the supported (uncoded) bit rate as a function of the physical bandwidth.**
As the cut-off frequency $F_{cut}$ of the RRC filter is 1MHz, the symbol frequency $F_s$ is chosen as twice this frequency, namely 2 MHz. The bit rate $R$ can then be deduced as follows:

$$R = F_s * Nbps \tag{1.6}$$

6. **Explain the trade-off communication capacity/reliability achieved by varying the constellation size.** One can intuitively understand that working with a higher constellation will lead to a higher information rate but with also a higher bit error rate as shown on the Figure 1.2. This is expected since the number of constellation symbols increases with the number of bits per symbol, however the constellations are closer one to each other, leading to a higher probability of corrupted symbol by noise.

7. **Why do we choose the halfroot Nyquist filter to shape the complex symbols?**
In order to reduce the impact of the noise on the signal and maximize the SNR, matched filters are usually used. This is why the Nyquist filter has been split into two RRC. Also, the Nyquist filter allows to cancel out the inter-symbol interference and to limit the signal to the desired frequency spectrum.

8. **How do we implement the optimal demodulator? Give the optimisation criterion.**
The optimal demodulator is implemented by using the RRC filter at the transmitter and its matched filter at the receiver. It maximizes the SNR of the received signal by choosing the folded transmitted signal $s(t)$ as a filter: $h(t) = s(-t)$ $(H(f) = S^*(f)$ in the frequency domain). This can be intuitively understood by verifying that the response of the matched filter convolved with the received signal corresponds to the auto-correlation of the filter without delay, which reaches its maximum value at t=0.

9. **How do we implement the optimal detector? Give the optimisation criterion.**
The optimal detector is implemented using the maximum likelihood criterion:
$\underline{\tilde{s}}_m^{ML} = \max_{s_m} p(\underline{r}|\underline{s}_m)$ which corresponds to minimizing the Euclidian distance between the received symbols and the constellation vectors of a given modulation.