Non-noisy communication using linear modulation

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Abstract

This report gives a brief look at the fundamental aspects of digital communication using linear modulation. Large parts of this project is ideal and a significant part of that is that the system is non-noisy. With this discovery the parameters and the required goal that were given turned out to be pretty simple to fulfill.

Contents

1. Problem statement

The task in this project is to design a system of digital communication in LabVIEW communications. To further complicate the problem there were given a set of requirements and goals for the system to achieve. The specific of these requirements is as follows:

- Signal should not exceed -20 dB beyond the bandwidth limit of 140 000 Hz.
- The physical channel attenuation is 0.5.
- The received power of the signal should be over 4300.

Another task to fulfill is to get more familiar and comfortable using LabVIEW and to put following concepts into practice:

- Power spectral density.
- Transmit and receiver filters.
- Pulse shaping.
- Bandwidth and power of signals.

LabVIEW is a graphical programming language where you place block and functions in a diagram instead of writing them in a text editor.

2. Theoretical solution

In order to make a functioning communication system with linear modulation you need to choose a modulation type and a type of filter for your pulse shaping filter. In addition to a pulse shaping filter in the transmitter side you need a matched filter at the receiver side. The receiver filter should have the complex conjugated coefficients as the one at the transmitter side. Figure 1 below shows a simple block diagram of how the system is realized.

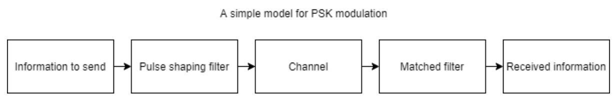

Figure 1: A simple block diagram of a communication system with PSK modulation

From figure 1 there is a block called pulse shaping filter, this is where the signal is modulated with a given modulation type. The modulation type that is being used for this communication system is phase-shift keying modulation, often referred to as PSK modulation. This is a digital modulation process where phase of a constant frequency (center frequency) is changed[1]. To further dive into the PSK, in this project we use a type called QPSK. With QPSK the center frequency is modulated between four different phases, encoding two bits per symbol. With this technology you can decide if you want to increase the data rate or occupy a smaller bandwidth.

The filter type that is used in this communication system is a raised cosine filter. The raised cosine filter is an implementation of a low-pass Nyquist filter [2] . The filter have a value called: the roll-of factor, which is a measure of excess bandwidth of the filter. Figure 2 shows the frequency response of raised-cosine filter with various roll-off factors and figure 3 shows the impulse response of raised-cosine filter with various roll-off factors.

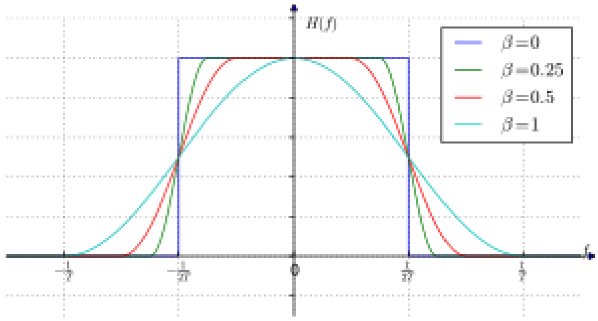

Figure 2: frequency response of raised-cosine filter with various roll-off factors.[2]

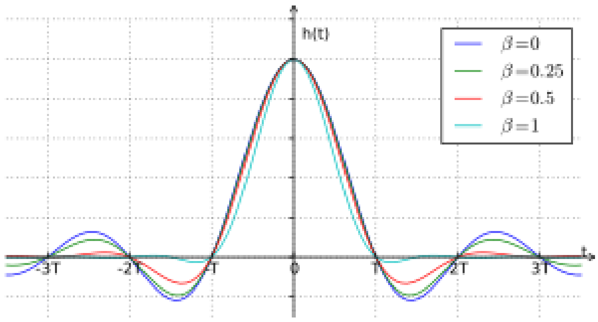

Figure 3: impulse response of raised-cosine filter with various roll-off factors [2].

From figure 2 and 3 we can see that if the roll-off factor is ideal in the frequency plot its not ideal in the time plot and vice versa. Therefore its important to find a balance that suits your needs.

If we compute the power density spectrum of a signal, we can find out which frequencies in the signal is strongest in amplitude and how large of a bandwidth is used. A bandwidth is given by the difference between the upper and lower frequencies in a continuous band of frequencies and is measured in hertz [Hz][3]. If a spectrum contains a window that is symmetric around 0 Hz the bandwidth is given by the window length divided by two. The power density spectrum is given by equation (1)

$$S_{xx}(\omega) = |x(f)|^2 \tag{1}$$

The signal power can be computed by equation (2)

$$P = \frac{E}{T} = \frac{1}{T} \cdot E[|a_k^2|] \tag{2}$$

where a_k is the symbol amplitude.

3. Realization and testing

The solution to the problem can be split into two parts: Making a functioning communication system and verifying the results and required goals. A overview screenshot of the whole communication system is attached in the appendix. The system was not built from scratch, and includes some predefined functions to simplify the task.

Making a functioning communication system: Figure 4 is an implementation of the transmitter.

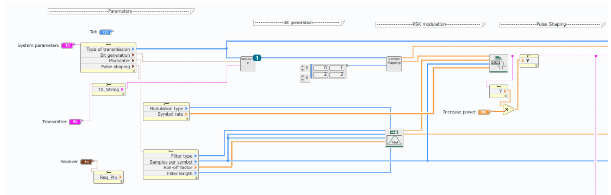

Figure 4: Screenshot of the transmission part of the communication system.

From figure 4 we can see that the implementation of the transmitter includes a lot of coefficients (Roll-off factor, symbol rate, filter length and many more) and mainly two LabVIEW functions(generate filter coefficients and apply pulse shaping filter.) The function (generate filter coefficients) creates two sets of filter coefficient, one set for the (apply pulse shaping filter)-function and one for the matched filter on the receiver side. The (apply pulse shaping filter)-function also takes in the information signal from the predefined (bit-to-symbol mapping)-function.

The modulated signal then travel through the channel as shown in figure 5.

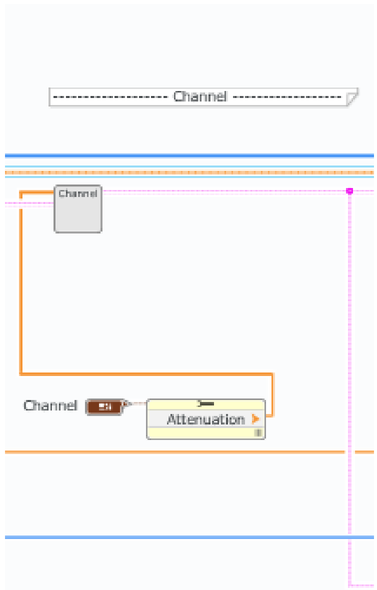

Figure 5: Screenshot of the channel of the communication system.

The (channel)-function takes in a coefficient named attenuation as shown in figure 5. This is where we fulfill the required physical channel attenuation requirement. Figure 6 shows how the different coefficients from the transmission and channel are configured.

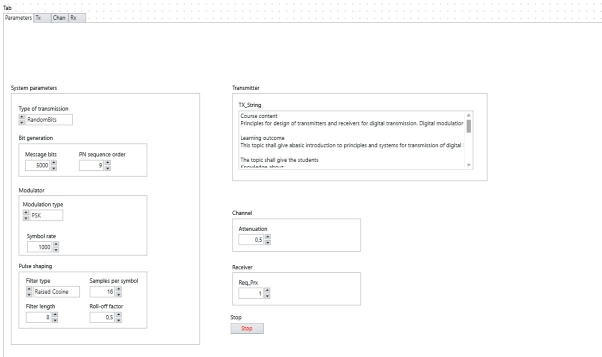

Figure 6: Screenshot of parameter selection.

As stated in the problem description the physical channel attenuation is set to 0.5 and figure 6 confirms how this is being done. The roll-off factor is set to 0.5 and the filter length is set to 8.

The last part of the communication system is the receiver and is implemented as shown in figure 7.

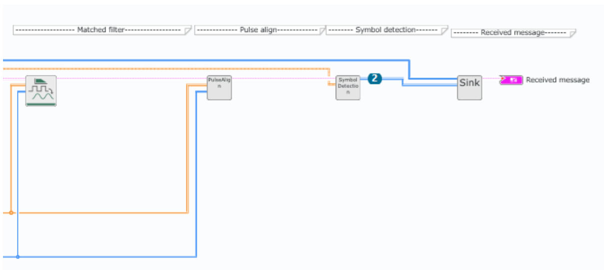

Figure 7: Screenshot of the receiver part of the communication system.

The main function in figure 7 is the (apply matched filter)-function, which takes the phase modulated signal from the channel and demodulates it along with the predefined (pulse align)-function, before the information is being deciphered with the predefined (symbol detection)-function.

Verifying the results and required goals: To check if the bandwidth requirement is fulfilled, the power density spectrum is found by implementing it like it is shown in figure 8.

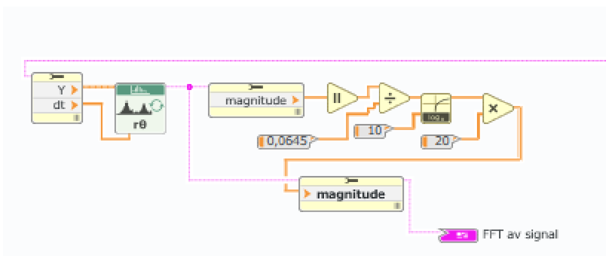

Figure 8: Screenshot of the implementation of the power density spectrum.

The implementation in figure 8 results in a plot of the spectra shown in figure figure 9. Its worth nothing that the magnitude of the frequency spectra is shown in a decibel scale, hence the extra implementation in figure 8. Another point to mention is that the signal is not to the power 2 as it was mentioned in the theoretical implementation, this is an error from the implementation.

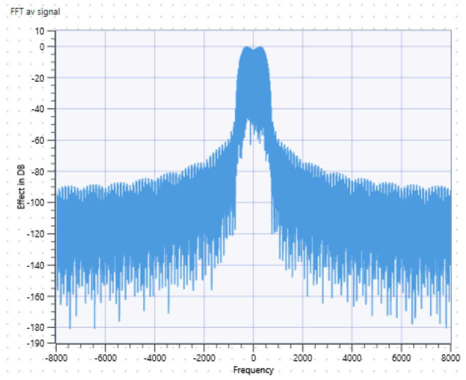

Figure 9: Screenshot of the graph of the power density spectrum.

From figure 9 we can see that the signal does not exceed -20 dB beyond the bandwidth limit of 140 000 Hz and the requirement is well fulfilled.

The calculation of the signal power is implemented in figure 10.

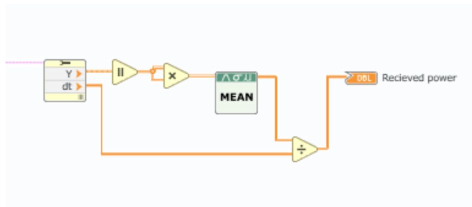

Figure 10: Screenshot of the implementation of the signal power.

The implementation depicted by figure 10 is used both on the received and transmitted signal to check how much you should multiply the transmitted signal to receive the required transmitted power. This resulted in the values calculated in figure 11.

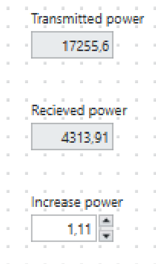

Figure 11: Screenshot of results from the signal power.

From figure 11 we can see that transmitted signal is multiplied by a factor of 1.11 to reach the required transmitted power of at least 4300. Its worth noting that the multiplication of the transmitted signal was performed before the channel. This was based on the decision to not amplify the noise that will be generated from the physical channel.

4. Conclusion

- The channel attenuation requirement was relatively easy to implement, and is essentially just scaling the transmitted signal by a factor of 0.5.
- The bandwidth requirement was fulfilled because the end of the spectrum were no way near 140 000 Hz, although the power density spectrum were not graphed correctly.
- The signal power requirement was fulfilled when the transmitted signal were multiplied by a factor of 1.11.
- Knowledge about LabVIEW and fundamental concepts of digital communication were improved.

The requirements were rather easy to fulfill, some were almost impossible not to (The bandwidth requirement). Although the roll-off factor and the filter length could be changed to receive a different power density spectrum, there was no point, so the standard values were used. This was a ideal system with no noise, so the placement of the signal multiplier was not important.

5. Acknowledgements

The software LABVIEW can freeze quite easily, so its important to save your work often. I would also like to thank fellow students Simen Berg, Tobias Kristensen and the student assistant Torstein Langan for a good discussion and input on the project.

References

[1] Phase-shift keying. Wikipedia Accessed 27.09.2020 *https://en.wikipedia.org/wiki/Phase-shift*$_k$*eying*

[2] Raised-cosine filter. Wikipedia Accessed 27.09.2020 *https://en.wikipedia.org/wiki/Raised-cosine*$_f$*ilter*,

[3] Bandwidth. Wikipedia Accessed 27.09.2020 *https://en.wikipedia.org/wiki/Bandwidth*$_($*signal*$_p$*rocessing*),

A. Figures

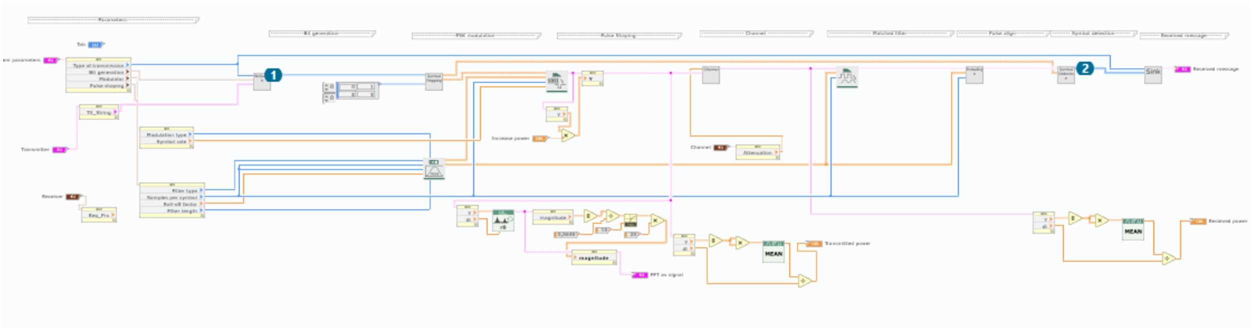

Figure A.12: A screenshot of the full system: from the transmitter, through the channel and to the reciever.