Principles of Digital Communications Transmitter/Receiver Design

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***Abstract*—The aim of this project is to design a communication system that transmits and receives data with applied channel effects. The use of root-raised-cosine functions as a basis and the shift into different frequencies resulted in a very reliable and fast reconstruction.**

I. Introduction

This report is intended as an enhancement of the submitted code. It relates to the structure and approach of the project in the design of a communication system.

II. Structure of the Code

The code is structured in two main parts where in the first part the functionality of the transmitter is explained. The second part describes the structure of the receiver. A schematic design of the whole communication system can be seen in figure 1.

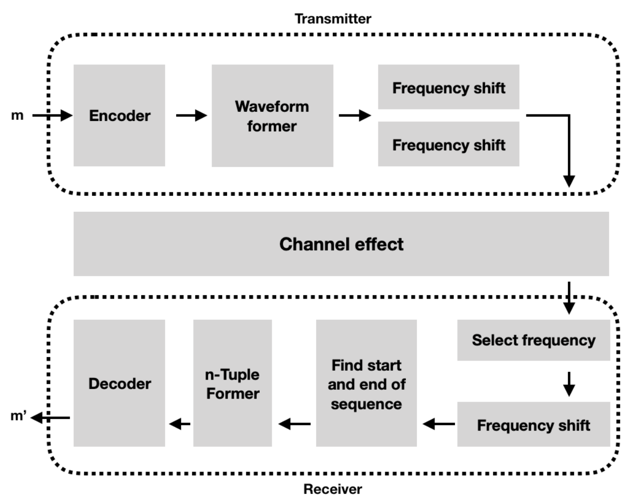

Fig. 1: schematic structure of the designed communication system

A. Transmitter

1) Encoder: In the encoder the text input is converted into a bitstream. We choose to convert each character in an 8-bit ASCII String and afterwards stack all 8-bit Strings together. Furthermore starting and end sequences are added for the purpose of synchronisation, which is described in the next section.

2) Waveform former: The waveform former takes the codewords as an input and creates a waveform based on a root raised cosine function. Furthermore each "0" value in the bitstream is replaced by "-1" in order to have a lower error probability. The root raised cosine can be seen in figure 2.

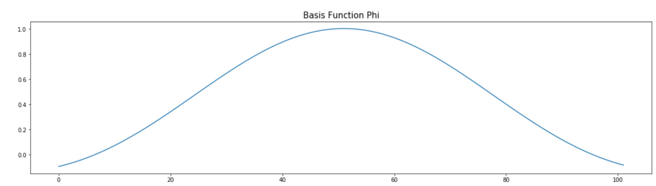

Fig. 2: Root-raised-cosine function with $\beta = 0.5$

3) Frequency shift: The fact that the channel only passes signals that are within a certain frequency, demands that the computed waveform has to be shifted in frequency. This is done in two different frequencies to prevent a frequency drop that will be described in the next section. An example of the modulated signal for 5 bits can be seen in figure 3. Afterwards the signal is send to a server that returns a noisy signal.

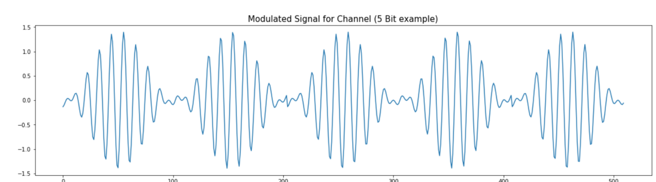

Fig. 3: Modulated signal for channel effect (2000Hz)

B. Receiver

1) Frequency shift: In this step the output of the server has to be shifted back in frequency for further computations. The frequency shift is done the same matter as in the transmitter.

2) Lowpass filtering: After the signal is shifted back in the zero frequency band, a lowpass filter is used in order to reduce the noise.

3) Inner Product: After reducing the noise, the inner product between the signal and the base function is computed in order to do matched filtering. Because the root-raised-cosine function is used as a basis which is applied on the ACSII encoding, a single matched filter can be used. The output is a bitstream that can be used in the next step for the decoding.

4) Decoding the signal: To decode the received output signal, the result of the inner product is split into 8 bit chunks. Afterwards each chunk is translated back into ASCII characters.

III. Dealing with channel filtering

As it turned out the channel applies a variety of effects on the signal. In order to overcome these effects the following methods were applied:

A. Frequency Drop

As described in the previous section, the channel randomly drops one of the frequency bands shown below in figure 5. To prevent the channel to drop the whole signal, the signal in the transmitter is shifted into two different frequency bands. These two signals are then stacked together and sent to the server that applies the channel effect. The receiver performs a convolution with two time shifted basis functions to detect which frequency has been erased. In figure 4 one can see that the 4000Hz frequency was dropped since the max value of the convolution in the second plot is much smaller than the one for the first one.

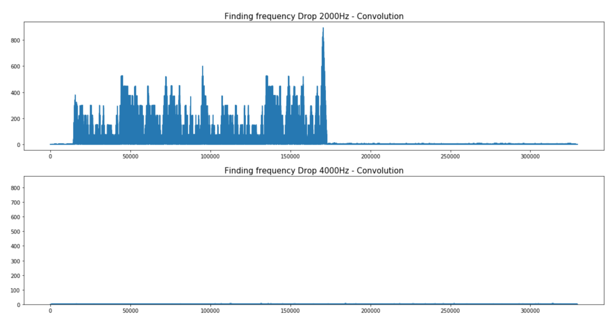

Fig. 4: 4000 Hz frequency drop

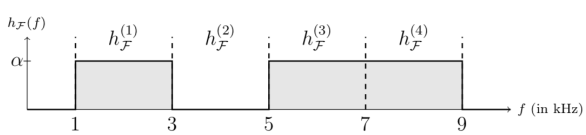

Fig. 5: frequency drop in the channel

B. Synchronisation

Because the channel effect adds a random delay on the signal it is hard to identify the beginning of the signal. Therefore a unique starting sequence, in form of a rectangular pulse, has been added to the beginning of the codeword that is both known by the receiver and the transmitter. Afterwards a convolution has been made that detects the beginning of the sequence. The same method has been used for finding the end of the signal. In this case a pattern of 24 Bit pulses of intensity 1 has been added. In figure 6 one can see this convolution and resulting peaks at indices 22.000 and 155.000.

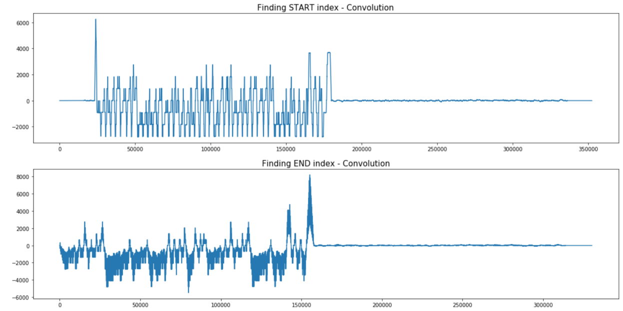

Fig. 6: convolution to find start and end index

IV. Conclusion

As a result the designed communication system is able to take a valid ASCII encodable text input and transmit the message over a channel that applies random noise, delay and frequency drop on the signal. All the parameters that were used can be found in table I.

Parameters of the communication system	
Sampling frequency	22050 Hz
Basis function Beta Samples per bit	Root raised cosine 0.5 102
Used frequency bands	2000Hz and 4000Hz
Starting pattern Ending pattern	rectangular pulse lengths 24-bits 24 encoded bits with intensity 1

TABLE I: Parameters of communication system