PROJECT N:12 FINAL REPORT

BER Performance Analysis of Quantized and BFSK Modulated Audio Signals in AWGN Channels

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OBJECTIVE

The aim of this project is to examine in detail the performance of low bit rate processed audio signals, that is, downsampled audio signals, in the transmission process. Audio signals are first scaled to integer levels of coding by the required number of bits. In this way, 15 distinct levels are obtained. and then transferred to a transmission channel using BPSK and BFSK modulations. This process simulates various transmission conditions at different SNR (Signal-to-Noise Ratio) levels and by adding AWGN (Additive White Gaussian Noise). The analyzes aim to evaluate the reliability and performance of the transmission process through factors such as transmission error, SNR values and demodulation accuracy. This study aims to create a basis for transmission systems to be more effective and reliable by identifying possible error points and improvement opportunities in the transmission process in the real world. In summary, the performance of different steps in the transmission process of an audio signal is analyzed. The aim is to understand the impact of factors such as transmission error and SNR values during this analysis. In this way, it is aimed to obtain information about errors or performance improvements that may occur during the transmission process.

The project ensures these steps are achieved by performing the following steps:

1. Read File Path and Audio Data.
2. Downsampling is done.
3. Scaled to integer levels of coding by the required number of bits Quantization error is calculated.
4. By performing Binary Encoding, the data is converted into binary form.
5. BPSK and BFSK modulation is applied.

6. After the noise implementation simulated in the AWGN channel demo is performed, demodulation is applied with the AWGN channel.
7. DAC (Digital to Analog Conversion) is applied.
8. BER Analysis is applied.

BACKGROUND

As it has been introduced in the previous part what we have done so far can be explained in brief in sections as below.

Sampling step in the project proposal is changed in here as downsampling was a mimicking of sampling operation of a continuous signal where we keep the information in a good level and lowering the computational cost that will be spent on discrete data points in advancing part of the codes.

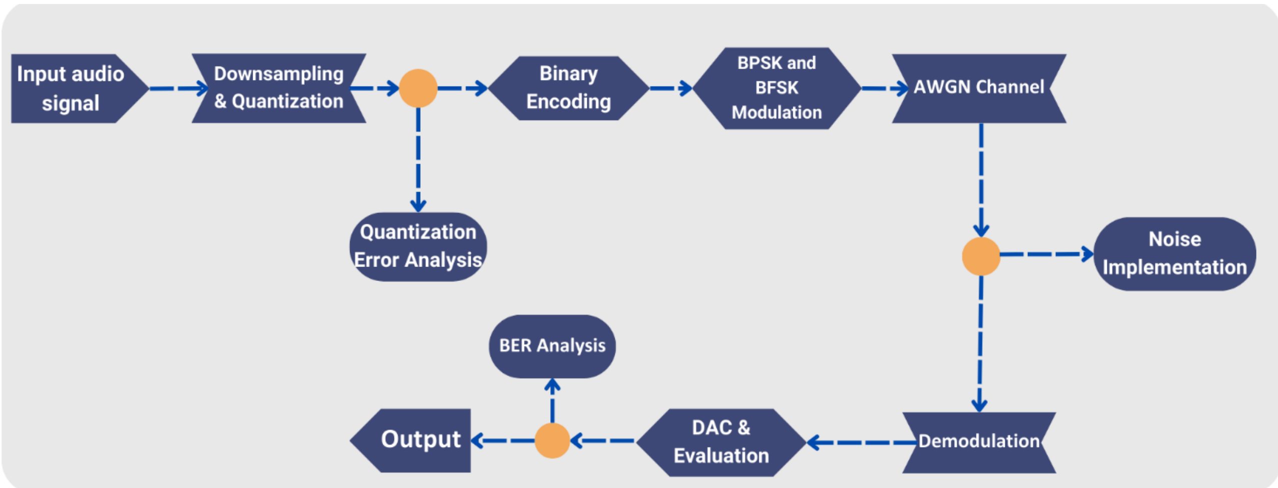
Quantization is a necessary pre-step in digital communication where we simply categorize or map the amplitude range of read signal to (2^n – 1) certain levels where n is the number of bits for each level. Number of bits also can be called as bit depth is an important parameter in order to perform necessities of the given task. Quantization error, we compute as mean square error between downsampled signal and quantized signal, depicts the quality of performed quantization in terms of intelligibility as we performed in presentation, but also for lesser number of bits quantization performs quick transmission process where the speed of transmission is a must requirement.

Modulation schemes we used were binary phase and frequency shift keyings. As we encoded the levels nx(length of quantized signal) and transformed it into 1x(n times length of quantized signal), we introduced phase to the carrier signal for a 1 cycle of bit duration of binary data where it represent 1 and no phase for bit 0. As for BFSK we introduced additional frequency to the carrier frequency for bit 1 and no additional frequency for bit 0. BPSK being simple since it only needs a block of phase for modulating signal where BFSK being spectral efficient makes them suitable modulation schemes for task special situations.

Additive White Gaussian Noise is a simple form of noise introduced during transmission of data in real life. Deterministic parameter for any type of noise is it’s SNR, comparison metric between message and noise signal in terms of their power. In this work we performed BER Performance Analysis of Quantized and BFSK Modulated Audio Signals in

AWGN Channels, for SNR values in range of -30 to 30 and in addition quantization number of bits 3, 4, 5, 6 bits.

SYSTEM MODEL & METHODS



We can explain each step in the block diagram as follows:

Input Audio Signal: In this section, the audio file is read with audioread.

Downsampling & Quantization: In this part, we perform a downsampled the signal by 4 and process to reduce the data points, and then the coding is scaled to integer levels with the required number of bits. (Quantization). In this part, we first perform a quantization process with 16 levels between -8 and +7. And then we ensure that the minimum level is shifted to 0 and the integer levels are rearranged as 0 - 15. In this way, they are converted into 4-bit arrays.

Quantization Error Analysis: In this section, you can analyze the quantization error as 'q_err = sqrt(mean((original_signal- quantized_signal)^2));' We calculated it with the formula.

Binary Encoding: In this section, we converted the data into binary form with the 'dec2bin' function.

BPSK and BFSK Modulation: In this section, we applied BPSK (Binary Phase Shift Keying) modulation and BFSK (Binary Frequency Shift Keying) modulation. With BPSK, the phase of the carrier is shifted to represent binary data. For example, a phase shift of 180 degrees represents a binary "1", while no phase shift or a phase shift of 0 degrees represents a binary "0". With BFSK, the frequency of the carrier is changed according to the baseband digital input. In BFSK, binary "1" is represented with a high frequency, while binary "0" is represented with a low frequency.

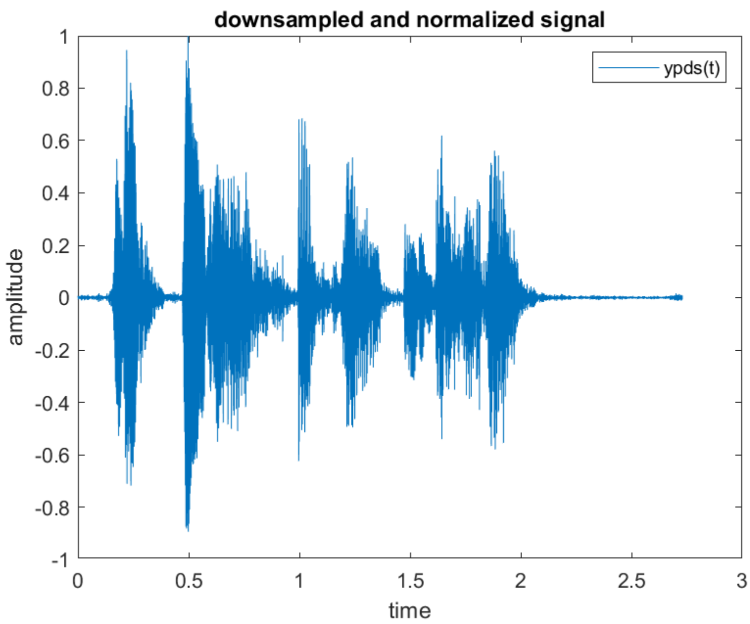
AWGN Channel & Noise Implementation: In this section, the noise simulated in the AWGN channel demo is implemented for different SNR levels.

Demodulation: In this section, demodulation is applied via the AWGN channel.

DAC & Evaluation: In this section, digital to analog conversion is applied. In this way, digital data is converted into analog data.

Ber Analysis: In this last part of the block diagram, the number of inter-bit errors is analyzed to calculate the bit error rate. The 'berawgn' function is used to calculate the theoretically expected bit error rate.

RESULTS & DISCUSSION



One of the audio signals' time domain reading, duration is approximately 2.8 seconds.

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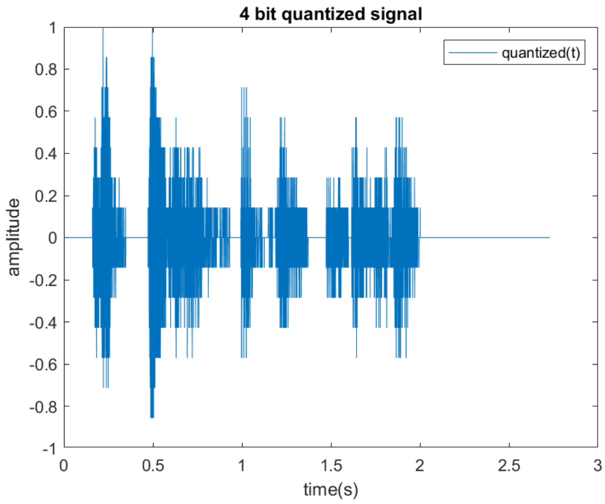
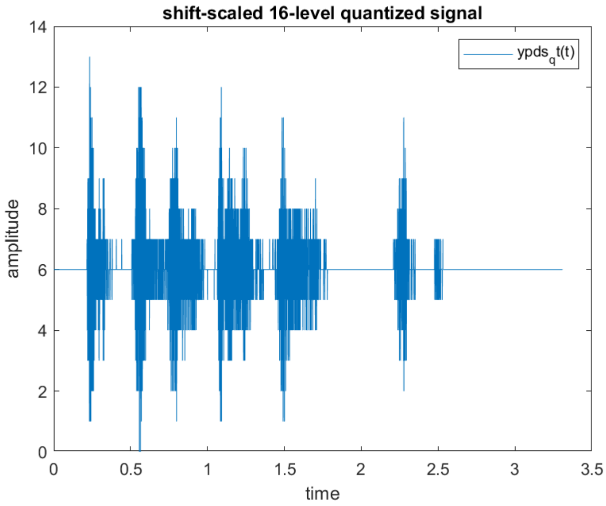
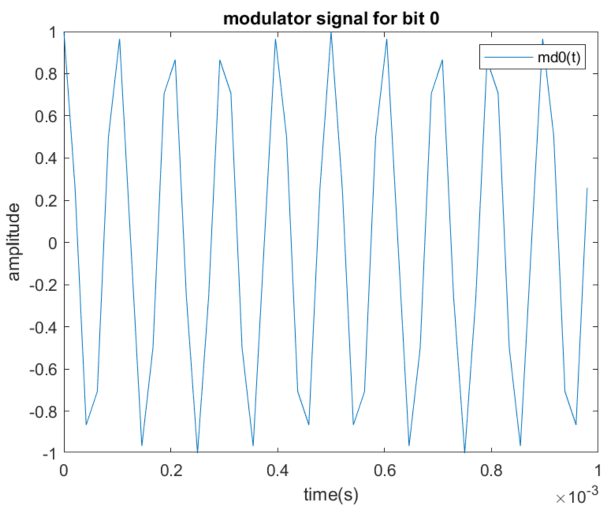
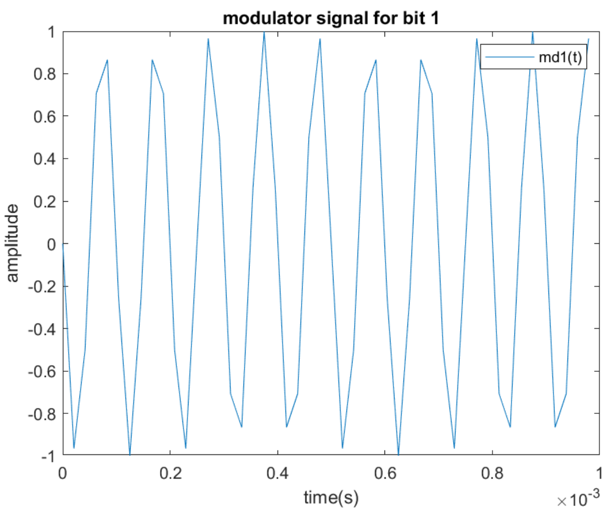




As we mentioned afore with the aid of working in MATLAB, we introduced a simple trick of "Shifting and Scaling to integer levels of according number of bits encoding" instead of mapping for every different number of bits encoding. With this trick we directly applied dec2bin built-in function in MATLAB and obtained a vector of nx(length of message vector), then transformed vector in a suitable form for modulation which is 1x(n times length of mt).





Modulator signals for BPSK modulation, they are used in cross correlation demodulation part for estimating a measurement for similarity. Carrier signal having frequency of 10kHz with the sampling frequency of 48kHz, but even if the Nyquist rate is not considered modulation and demodulation works somehow, for example carrier frequency of 80kHz.

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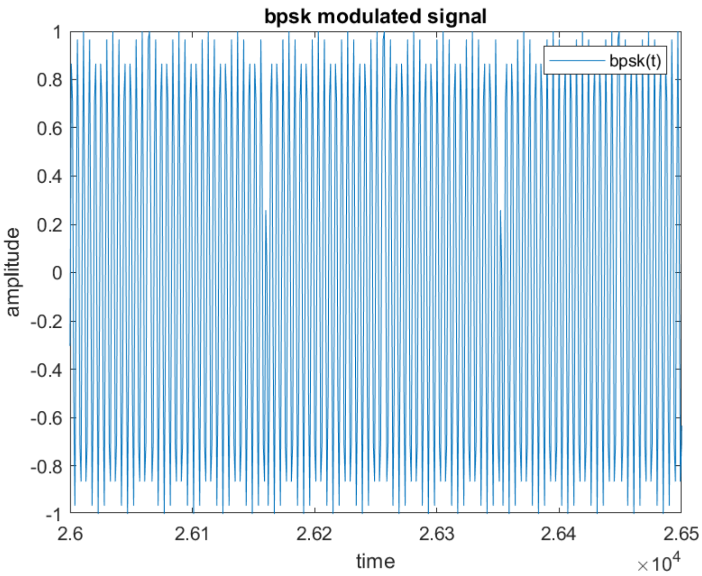
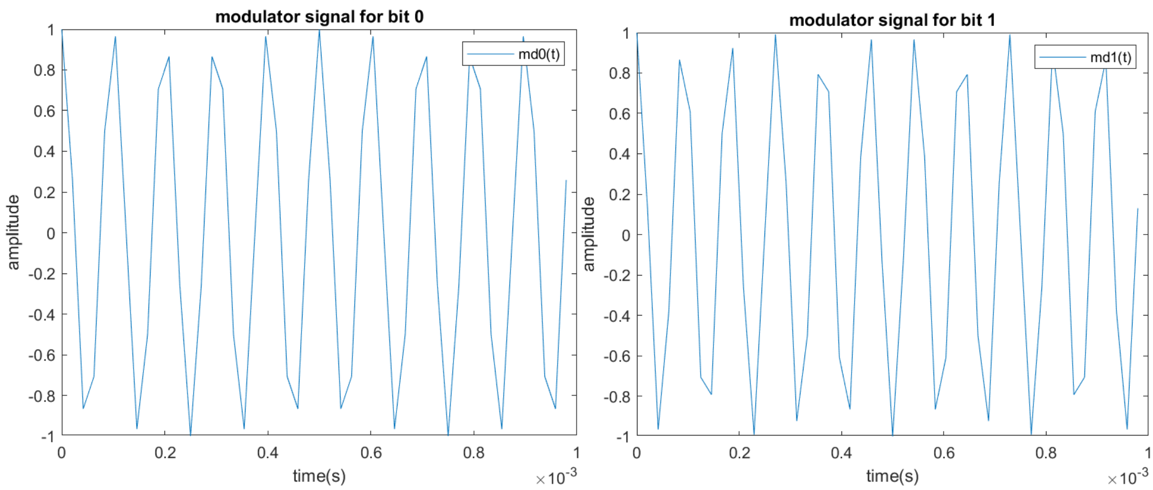


BPSK modulated window of bit stream equivalent of 1010101, when the gap occurs in down it’s a transition from 1 to 0 and when the gap occurs in above it’s a transition from 0 to 1.



Modulator signals for BFSK modulation, 0 bit having 10kHz carrier frequency and frequency difference is 1kHz.

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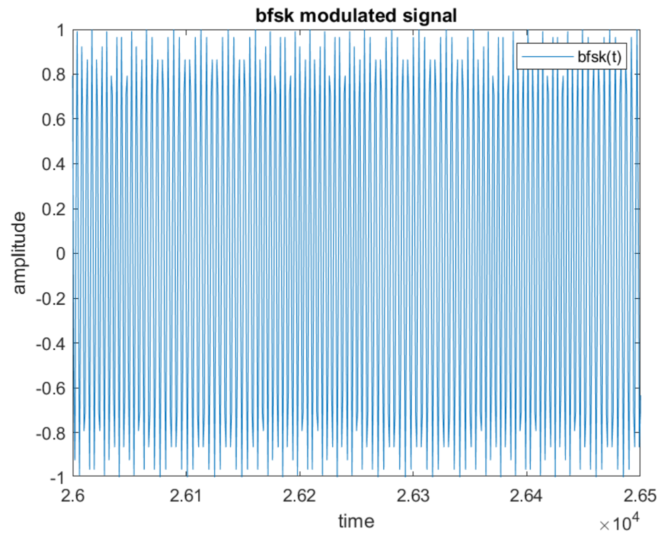
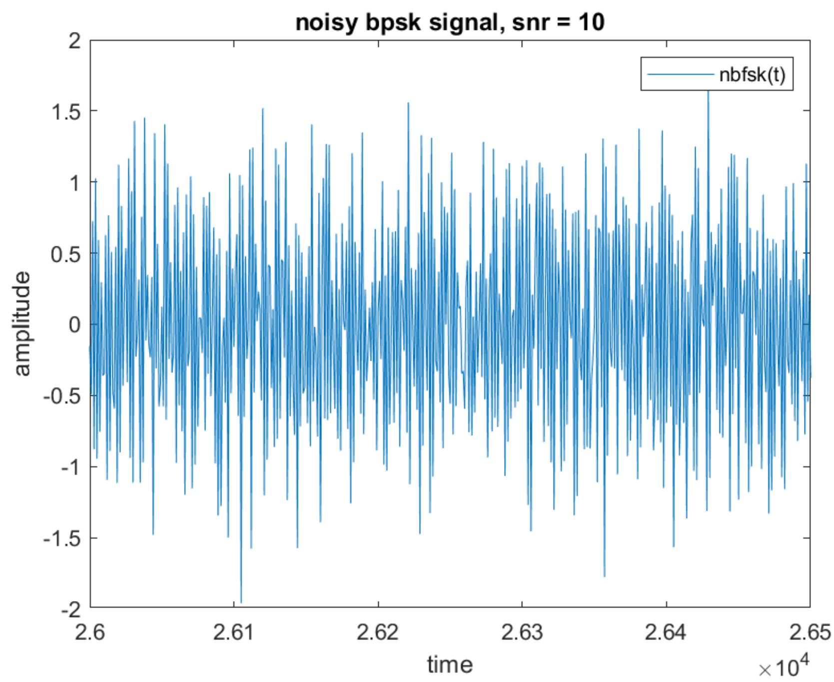
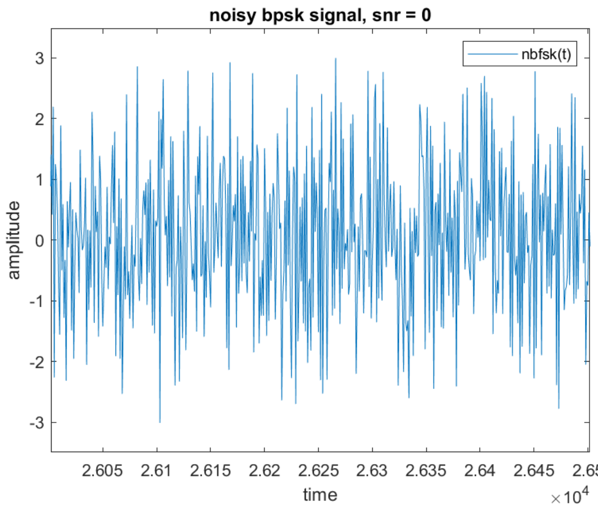
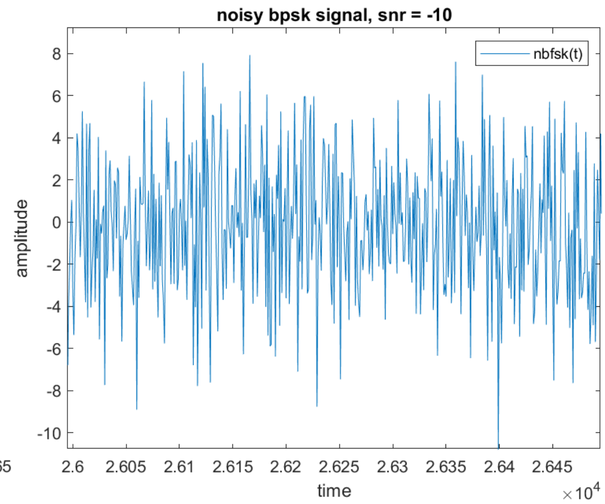


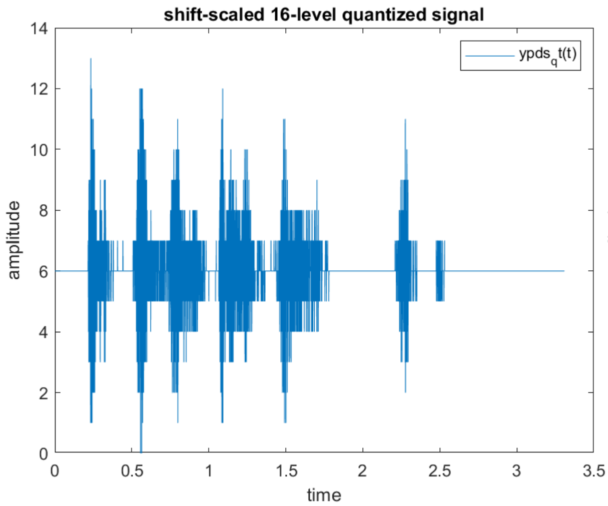
BFSK modulated window of bit stream. It’s hard to distinguish transitions but as in BPSK modulation its 101010 encoded bit stream window.

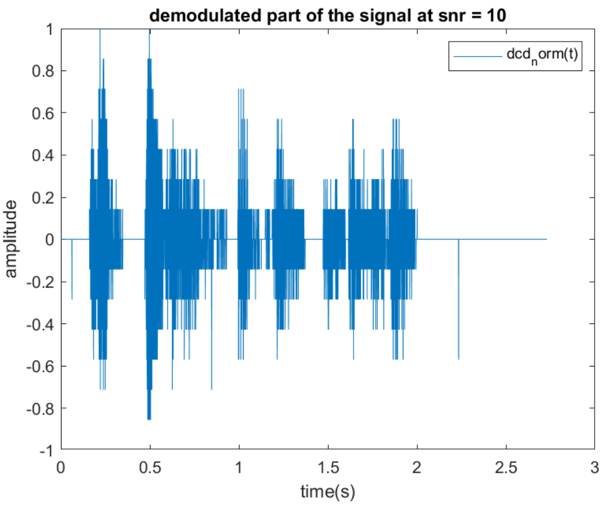






Transmitted modulated signal through AWGN channel having various SNR values in the above figures. Observer can notice that SNR value is a logarithmic metric that does determines power as can be seen in amplitude levels and not negativity.





After cross correlate demodulate the received signal we put the demodulated bit stream in a form that bin2dec built-in function can read and transform. As we shift scaled the message signal output was also obtained as shift scaled so we subtract the mean value and divided to absolute maximum of the message signal.

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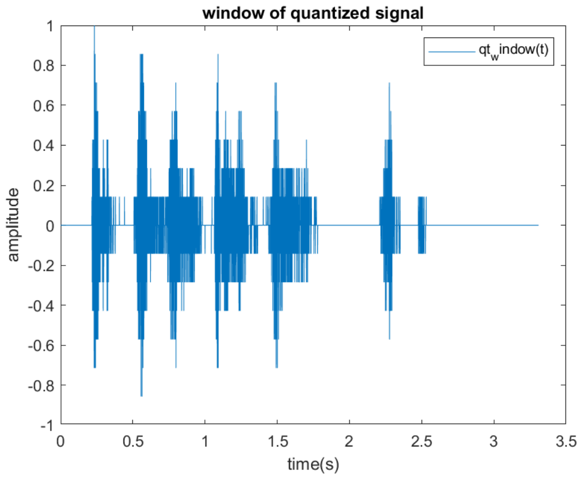

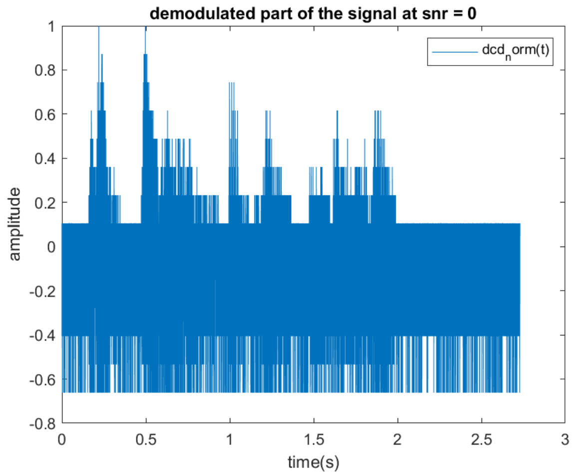

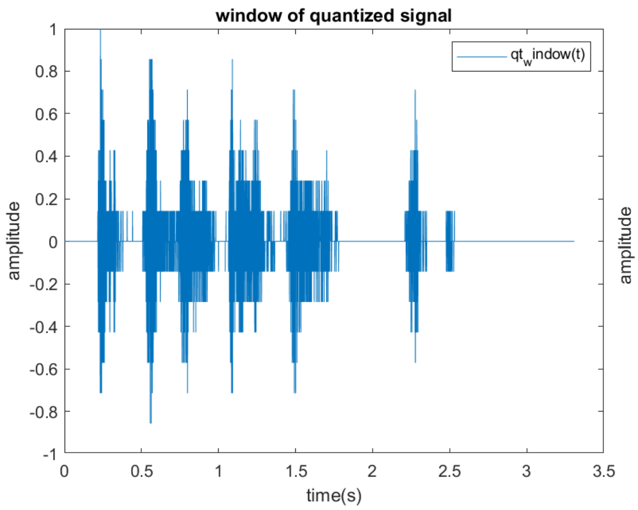

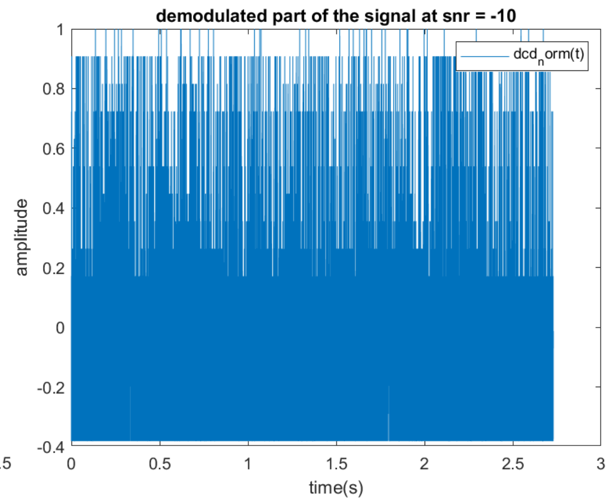

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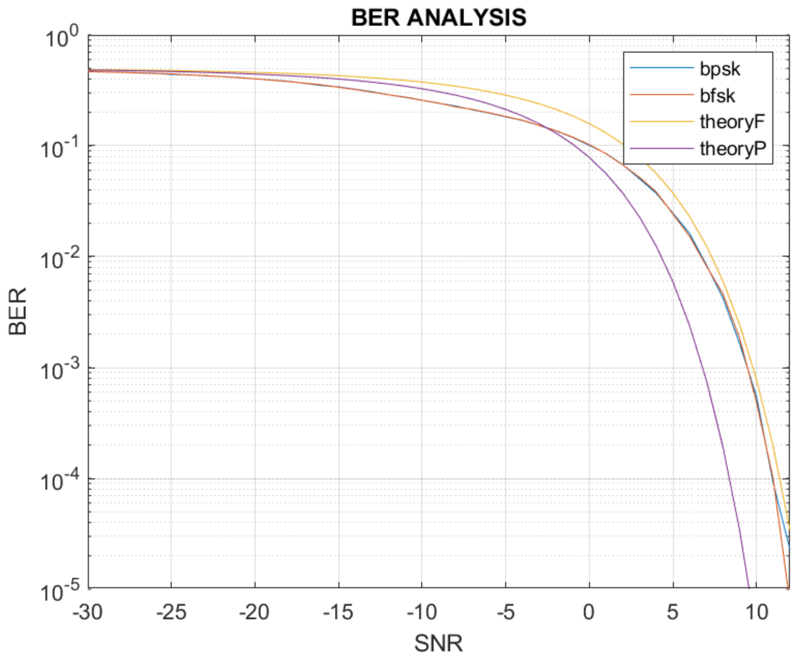
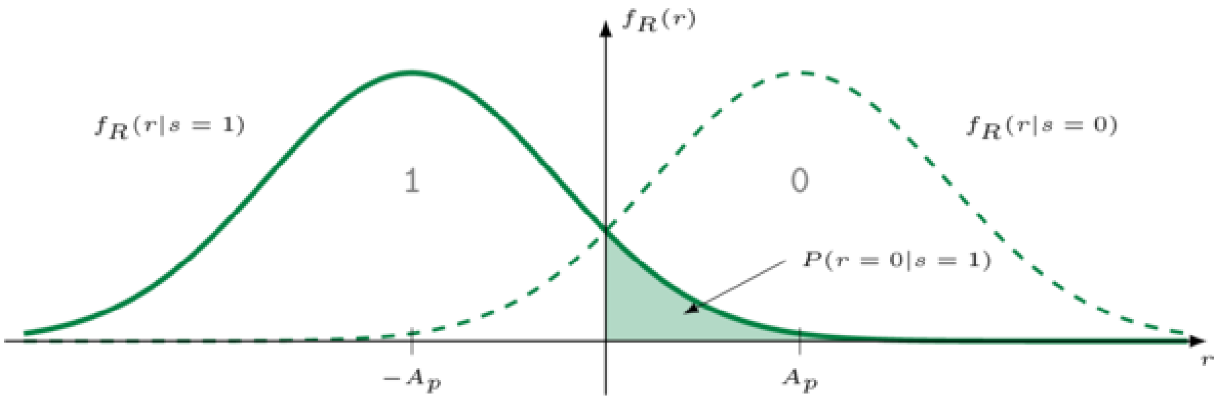


After running for SNR values in range -30 to 30 we computed the simulation result as given in legends “bpsk” and “bfsk” in comparison to coherent BFSK and nodiff BPSK theoretical values. We observe that bpsk outperformed theoretical values where bfsk stayed in the boundary of near theoretical values. Intelligibility is lost near 0 SNR value and the reason we couldn’t compute any BER under 10^-7 is minimum possible error for our case, 4 bit binary encoded vector having length of near 10^7 and assuming the minimum possible error is obtained and mistake happened in 1 bit resultant error will be equal to 1/10^7 = 10^-7, which rolls to zero after a certain SNR.



In addition to the reconstructed signal’s shape, one can observe that most of the mistakes happened in bottom half of the mean value which includes more 0’s meaning that we shifted the threshold a little to the bit 0’s benefit, can be arranged if wanted.

CONCLUSION

In this project, we examined the performance of processed audio signals with low bit rates during the transmission process. Initially, we scaled the audio signals to integer levels up to the required number of bits. Through our work, we found that the most optimal error rate was obtained with 15 different levels after this process. Subsequently, we transmitted these levels using BPSK and BFSK modulations through a transmission channel. Simulating various transmission conditions at different SNR levels, we added AWGN (Additive White Gaussian Noise) to mimic real-world conditions. Adding AWGN at different SNR levels was an essential step to evaluate the performance of transmission systems and ensure real-world simulation.

We evaluated the performance of the transmission process based on factors such as reliability, error rates, and demodulation accuracy. During demodulation, we observed more peaks toward lower values due to a higher occurrence of '0.' Through this study, simulating real-world transmission systems allowed us to identify error points and improvement opportunities, aiming to make these systems more effective and reliable.

The steps involved in this simulation included reading the audio file, sampling, scaling to integer levels, error calculations, binary encodings, modulations, noise simulations, demodulations, and digital-to-analog conversions.

As a result of these steps, we extensively observed the effects of transmission errors and SNR values on the transmission process. Our mentor responsible for the project advised us to work within the [-30, 30] SNR range. We observed that the audio became unintelligible after -5, and we limited our analysis to 15 instead of going up to 30 due to the signal reaching zero at this point.

The outcomes particularly shed light on the relationship between SNR levels and transmission errors, as well as their impact on demodulation accuracy. This allowed us to conduct studies that could aid in optimizing real-world transmission systems.

In conclusion, this study aimed to thoroughly examine the performance of processed audio signals with low bit rates during transmission, identifying points of error and improvement opportunities. We conducted Bit Error Rate (BER) analysis after both BFSK and BPSK modulation processes. We worked on the assumption of a negative linear relationship between SNR and BER. That is, as SNR increases, the signal becomes stronger relative to the noise in the transmission channel, leading to a decrease in BER. While plotting the BER calculations based on this assumption, we observed that the theoretical BER graph generated using the 'berawgn()' function differed from the BER graphs of the modulated signals. This observation indicated a distinction between the actual performance in the transmission process and theoretical expectations, suggesting that the simulation conducted may not perfectly align with real-world applications or the model's accuracy might be limited under certain conditions. After conducting BER calculations and comparing the output audio signal with the input audio signal for analysis, we successfully completed our project.

REFERENCES

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