

ACDA5019 – Radio Frequency Systems

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Introduction

This assignment investigates the effects of noise on a Double Side Band – Suppressed Carrier (DSB-SC) modulated transmission. DSB-SC is a modulation technique used to encode analogue data onto an analogue carrier signal. The performance of DSB-SC will also be compared to other modulation techniques such as AM and FM.

The investigation uses simulations of the modulation on the software called Simulink. Simulink is a simulation and model-based design tool part of the MATLAB environment. It is capable of simulating electronic circuits without having to design a low-level circuit or write any firmware [1].

These simulations will be able to provide realistic data on how the modulated signals are affected by noise and these results will be discussed and a conclusion formed.

Simulation Models

Each model consists of four sections: Modulation, Noise Insertion, Demodulation and Filtering. The Demodulation and Filtering sections are consistent throughout all models and simulation runs. The Noise Insertion section is the variable being changed during each simulation to observe the effect on the transmission. Finally, the Modulation is the main variable which determines what modulation technique is being used.

The demodulation technique being used in the models is a coherent detector. This method uses the same carrier signal used to modulate the signal to detect the encoded message signal. A Coherence detector is a simple method which uses only one block. The input modulated signal is multiplied by the carrier in a product block.

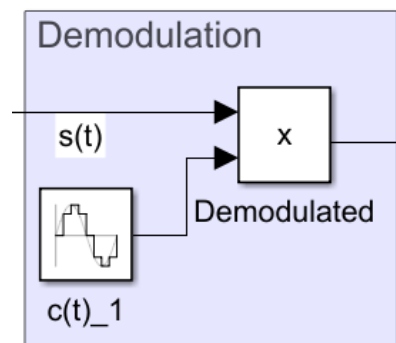


Figure 1. Simulink Demodulation Block [Own]

The filtering function is performed by an analogue filter design block set to act as a lowpass butterworth filter. The filter order is set to 22 and the passband is 10KHz, the frequency of the carrier wave.

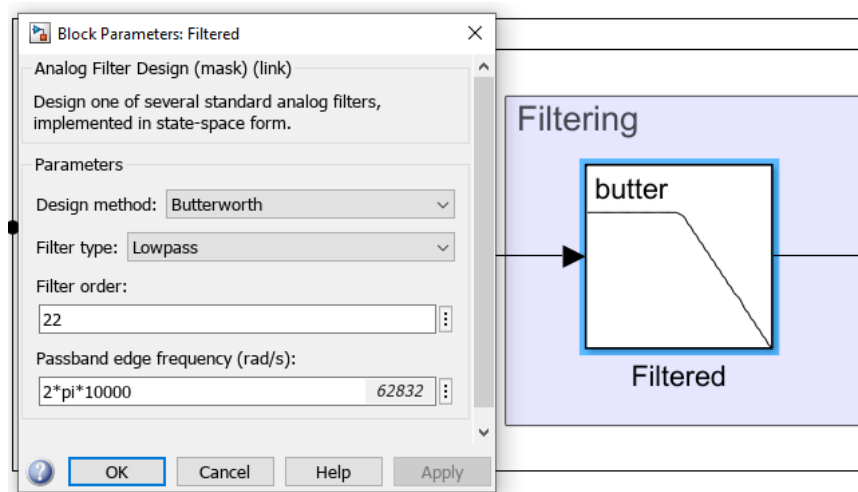


Figure 2. Simulink Filtering Block and parameters [Own]

Amplitude Modulation (AM)

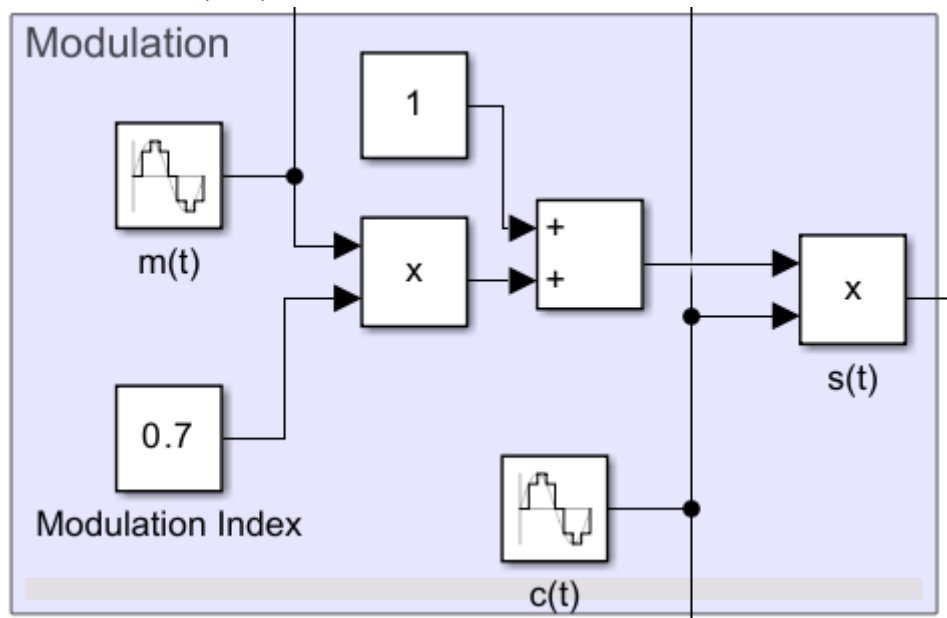


Figure 3. Simulink Amplitude Modulation [Own]

The AM modulator functions by multiplying the message signal by the carrier wave. There is also a modulation index prior to the modulation block to change the amplitude of the message signal.

The parameters for this model were 1V amplitude for all signals, 1KHz message frequency and 10KHz carrier frequency.

The output of such a modulator can be seen in the scope output of the simulation below. Where the top signal is the message signal, the middle signal is the carrier wave, and the bottom signal is the modulated signal.

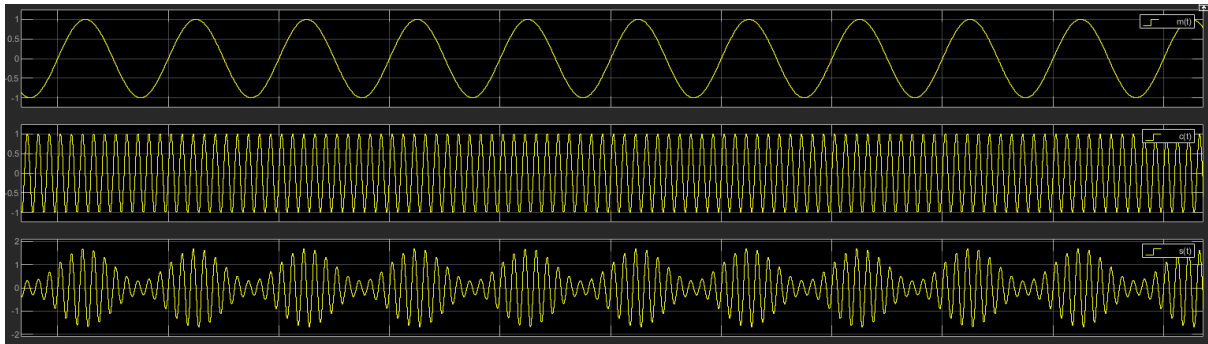


Figure 4. AM Modulator Output

The frequency response of the modulator can be seen in figure 5. A spectrum analyser block is used to view these signals. The yellow trace is the modulated transmission signal. The carrier response can be observed centrally at 10KHz, the two side bands at 9KHz and 11KHz are indicative of the 1KHz message signal frequency.

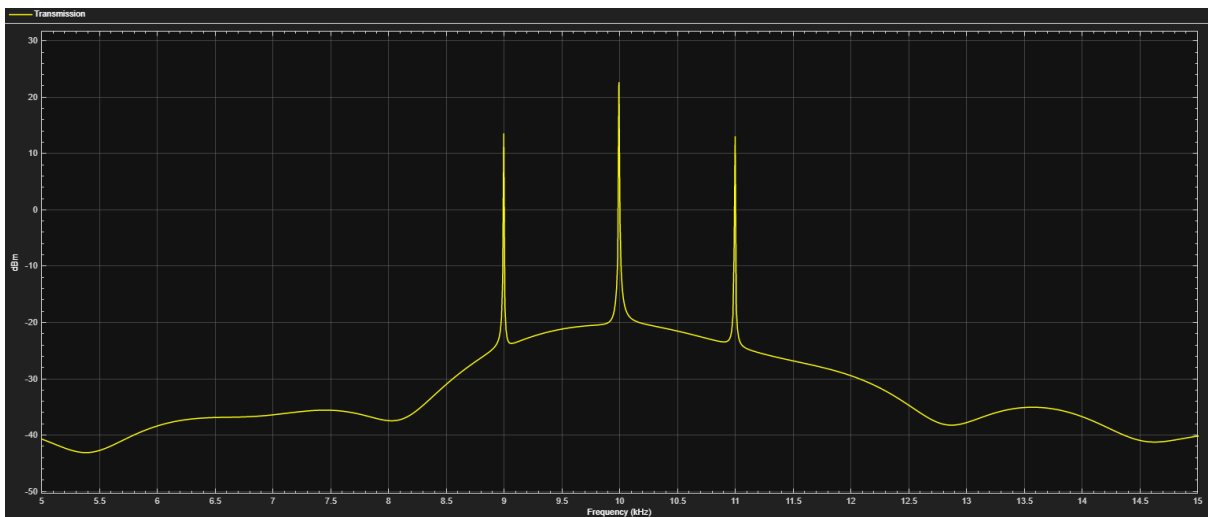


Figure 5. Simulink AM Spectrum Response [Own]

The full schematic for the AM model can be seen in figure 6 below. It includes the scope and spectrum analyser used for viewing the simulation outputs.

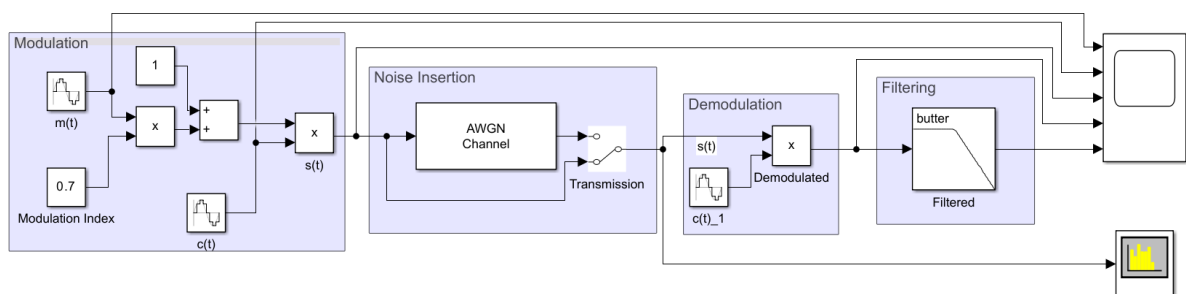


Figure 6. AM Simulink Model

Double Side Band – Suppressed Carrier (DSB-SC)

DSB-SC is a type of Amplitude Modulation where only the two side bands are transmitted, and the carrier is suppressed. This is advantageous because the carrier does not contain any of the data, therefore, it is a waste of energy [2].

The modulation technique consists of two regular amplitude modulation blocks. One is inverted to form a negative modulated signal. The difference is then obtained, and the output consists of the two sidebands without the carrier response. This type of modulator is called a Balanced Modulator. The modulation block in Simulink can be seen in figure 7.

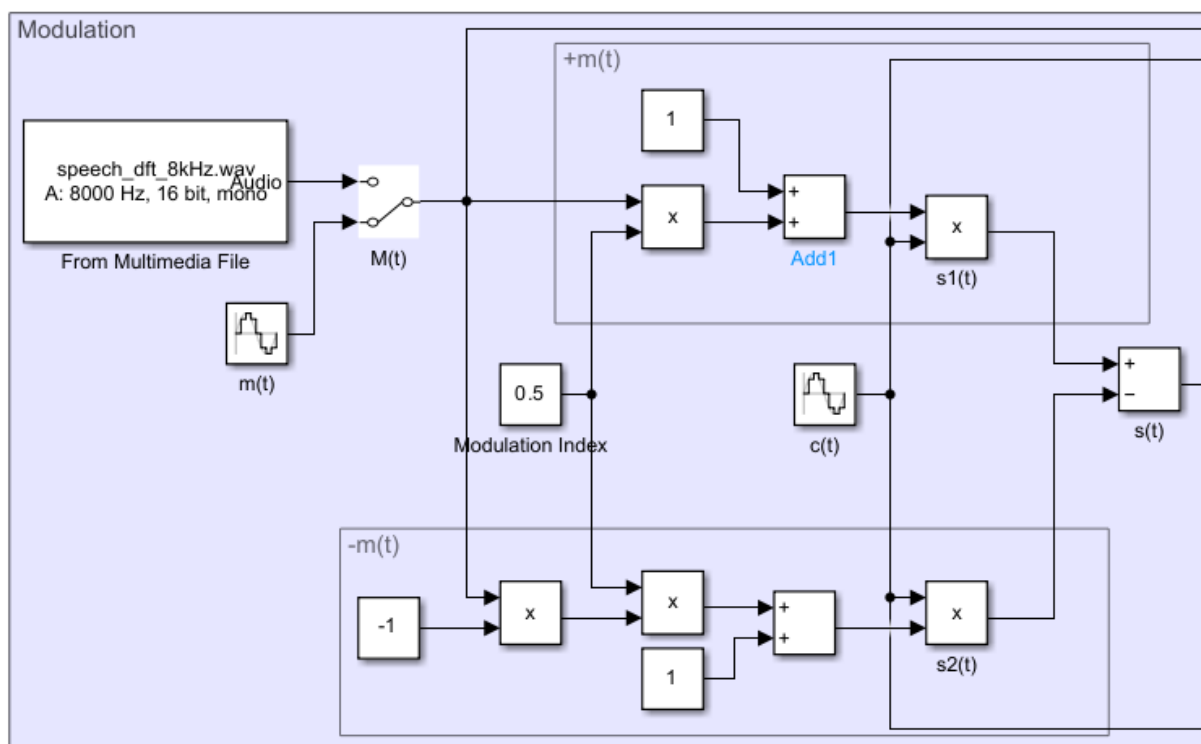


Figure 7. DSB-SC Simulink Modulation [Own]

The signals as seen in a scope and the frequency response of the transmission signal can be observed in figures 8 and 9.

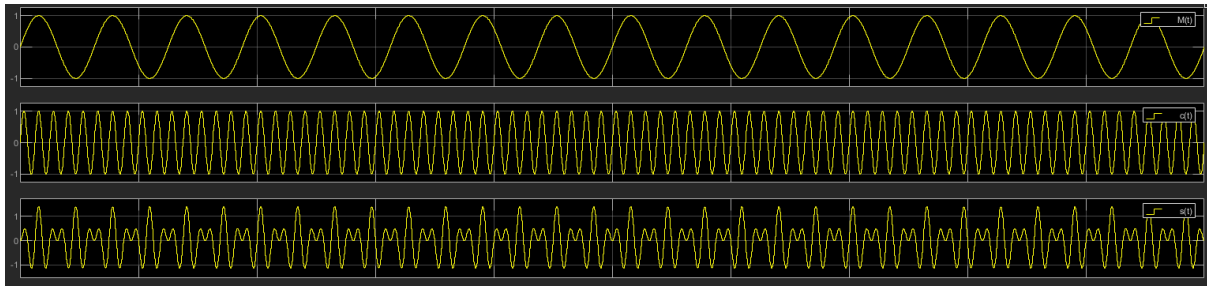


Figure 8. DSB-SC Simulink Scope Output [Own]

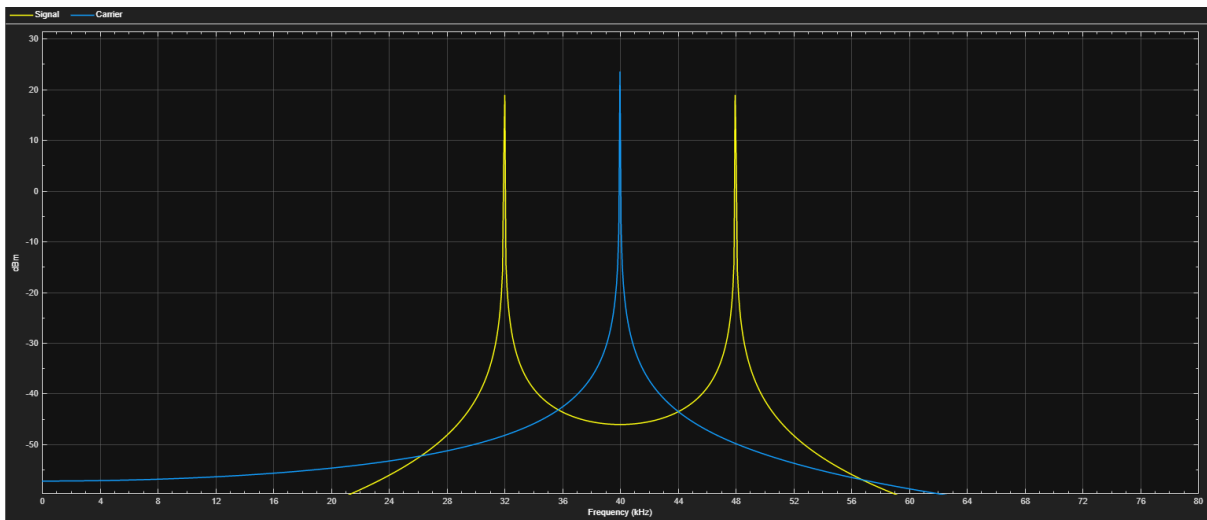


Figure 9. DSB-SC Simulink Frequency Response [Own]

In the spectrum analyser response, the yellow trace is the transmission signal, and the blue trace is the carrier signal. It can be observed that the transmission signal only contains the two sidebands and not the central carrier wave response. Furthermore, compared to the AM response, the dBm of the DSB-SC sidebands are greater. This means the transmission would be able to travel over a longer distance and be less susceptible to noise.

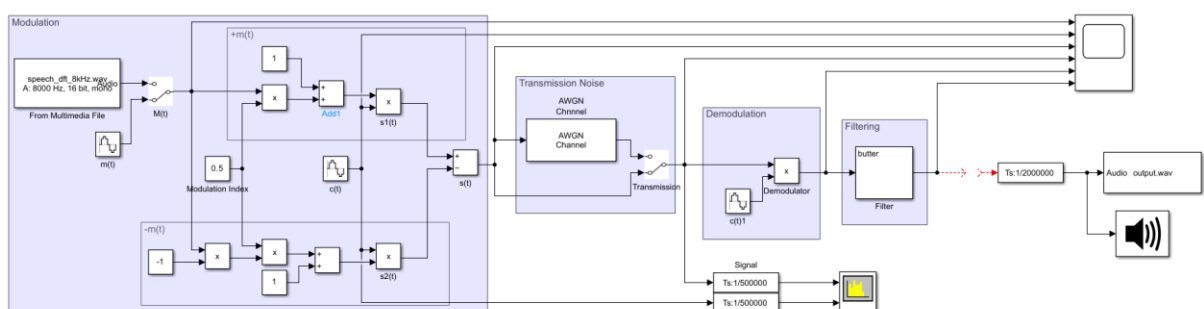


Figure 10. DSB-SC Simulink Schematic [Own]

The schematic also features the ability switch the input to an audio file. The audio file chosen is a 5 second clip of someone talking and is in the .wav format. Its sampling frequency is 8KHz to decrease the simulation time. There is also functionality to store the output signal stream into a .wav audio file. This then allows a comparison to be made from the original audio file and the audio files transmitted with an amount of noise.

Frequency Modulation (FM)

FM alters the frequency of the carrier wave rather than the amplitude [3]. In theory, FM should be much less susceptible to noise due to the fact that noise is a change in amplitude and does not affect a signal's frequency. However, this does not have much effect in practice. FM is actually more susceptible to noise, as observed in figure 12 and 13, where even with less noise than DSB-SC the message response is almost drowned out by the noise floor.

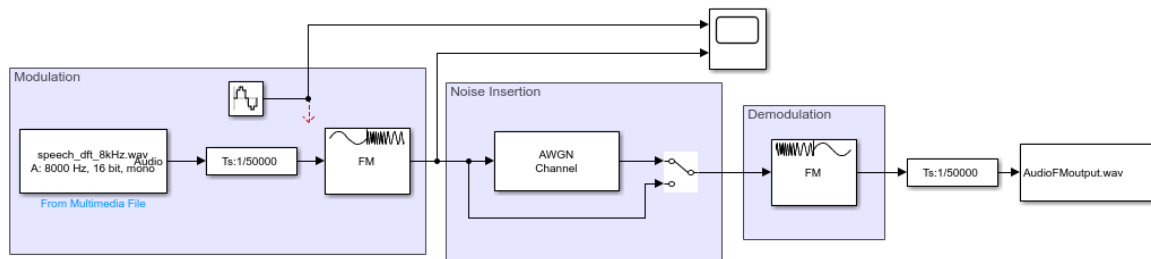


Figure 11. FM Simulink Model [Own]

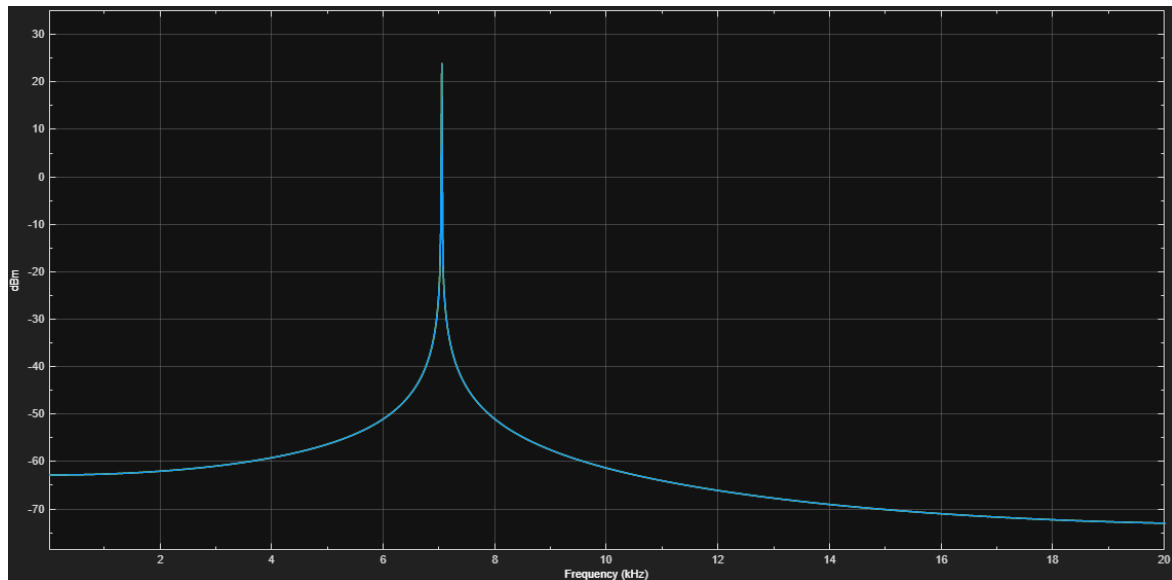


Figure 12. FM Spectrum Response No Noise [Own]

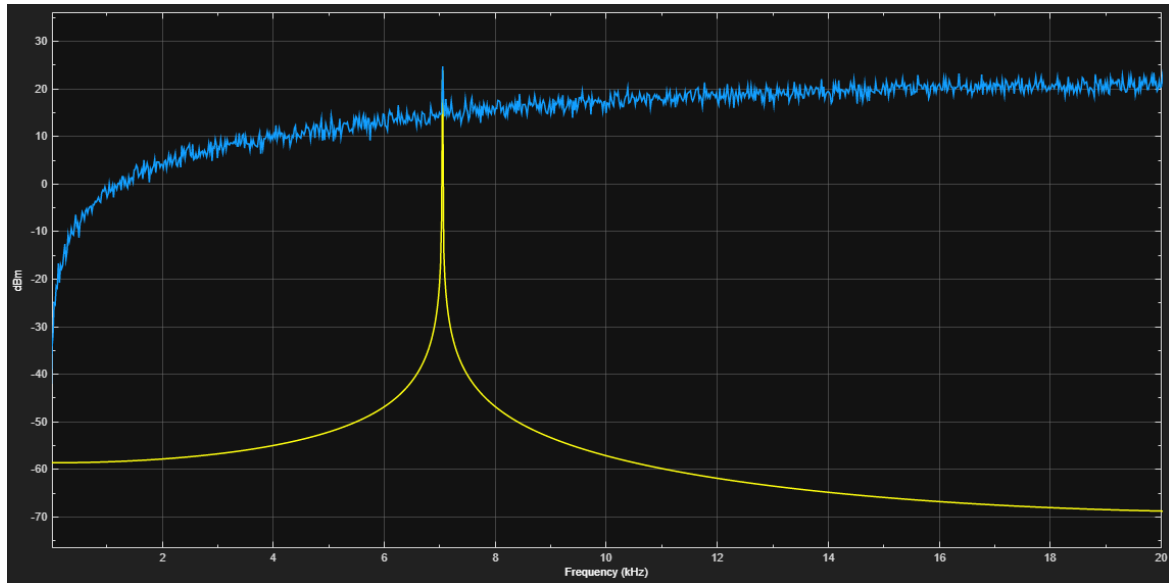


Figure 13. FM Spectrum Response 10 SNR [Own]

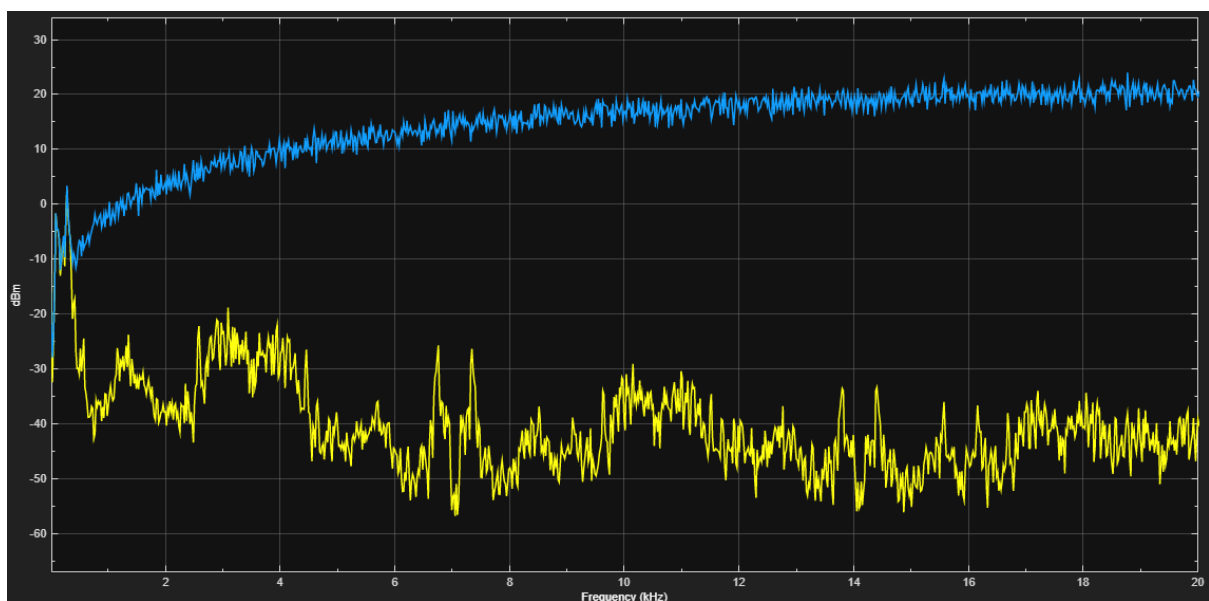


Figure 14. FM Audio File Response 10 SNR [Own]

This noise susceptibility is even more prevalent when using an audio file as an input. Figure 14 above shows how only a tiny portion of the message is greater than the noise floor. The audio file recorded from the output has very loud static distortion and the speech is very dulled.

Results

To assess the effects of noise on these transmission methods the Additive White Gaussian Noise (AWGN) block is used. This block inserts random gaussian noise to the waveform and simulates the transmission travelling in a medium with background noise. The amount of noise inserted to the signal is determined by the selected Signal to Noise Ratio (SNR) the lower the SNR, the greater the amount of noise. The amount of noise used in these tests was zero noise, 5 SNR and 1 SNR.

DSB-SC

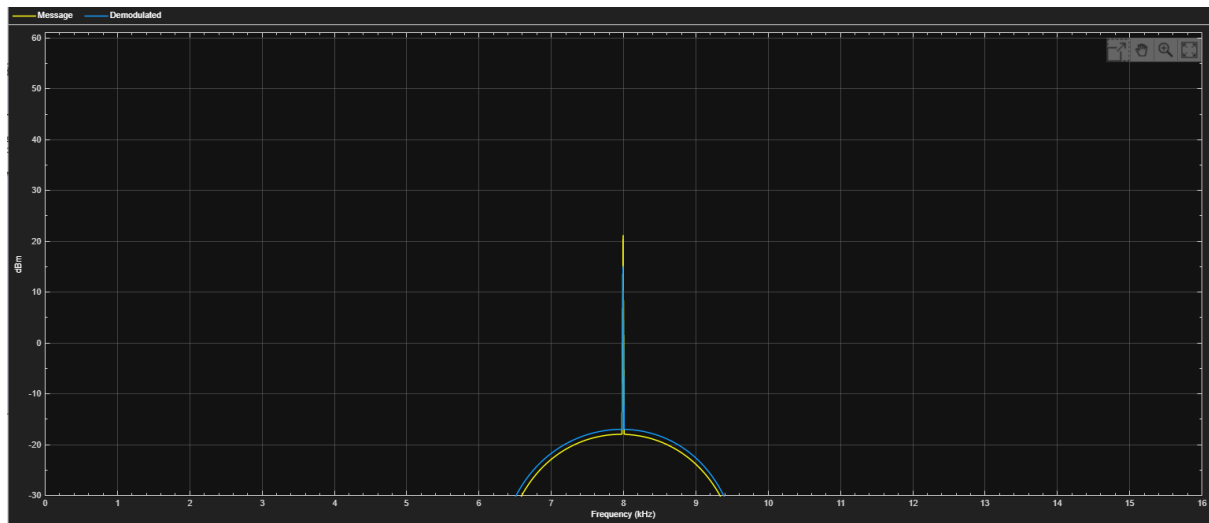


Figure 15. DSB-SC Zero Noise Results

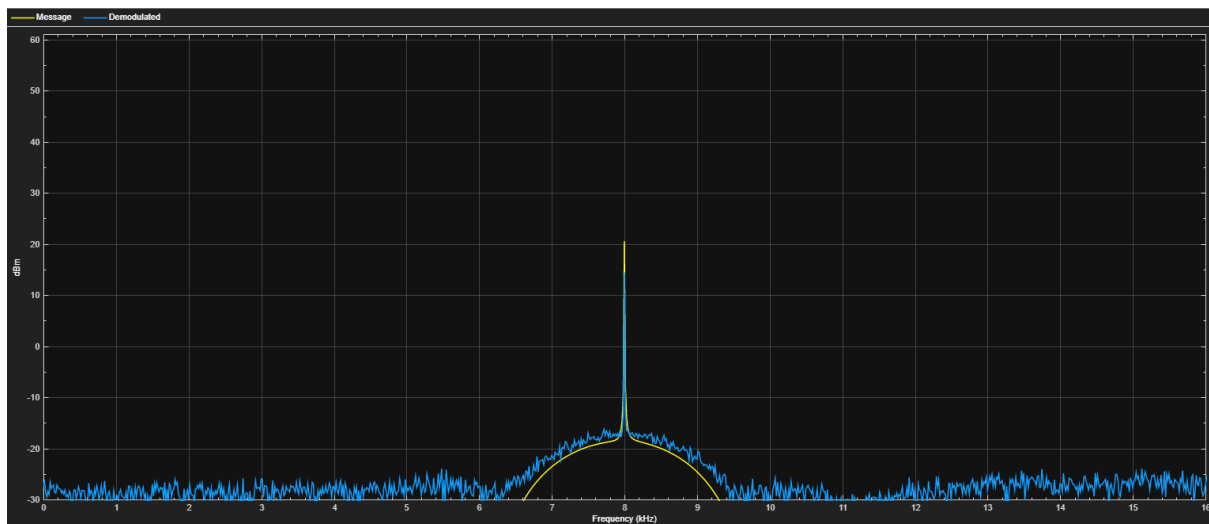


Figure 16. DSB-SC 1 SNR Results

The above figures 11 and 12 showcase the difference between the message signal and the demodulated signal after filtering. With zero noise in figure 11 it can be observed that the signals are identical except for a slight loss of power due to the transmission and filtering processes. The output with 1 SNR of noise in figure 12 is very similar except for the presence of a noise floor across all frequencies.

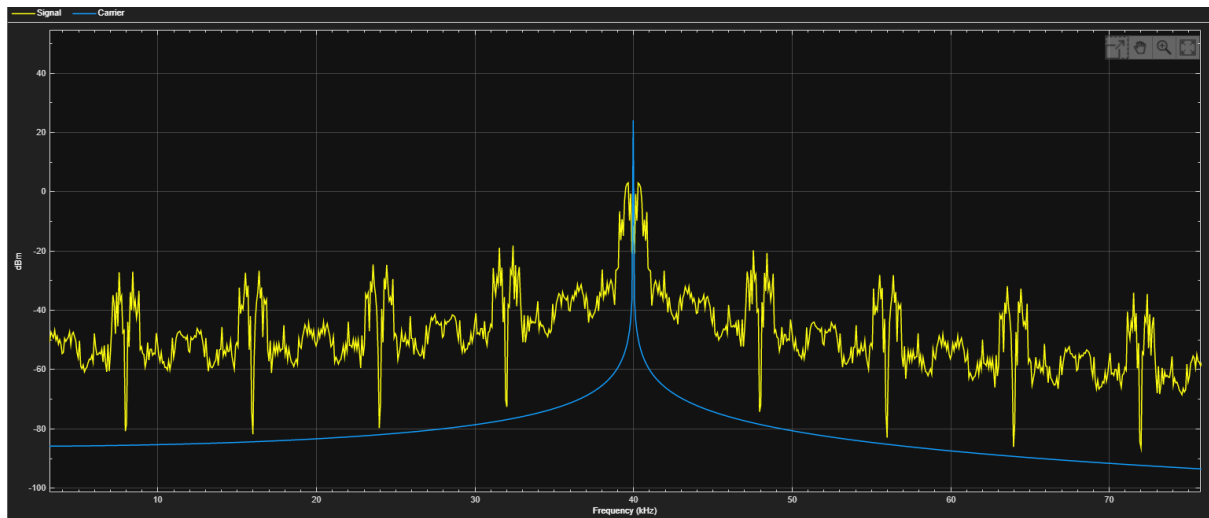


Figure 17. DSB-SC Audio File Zero Noise [Own]

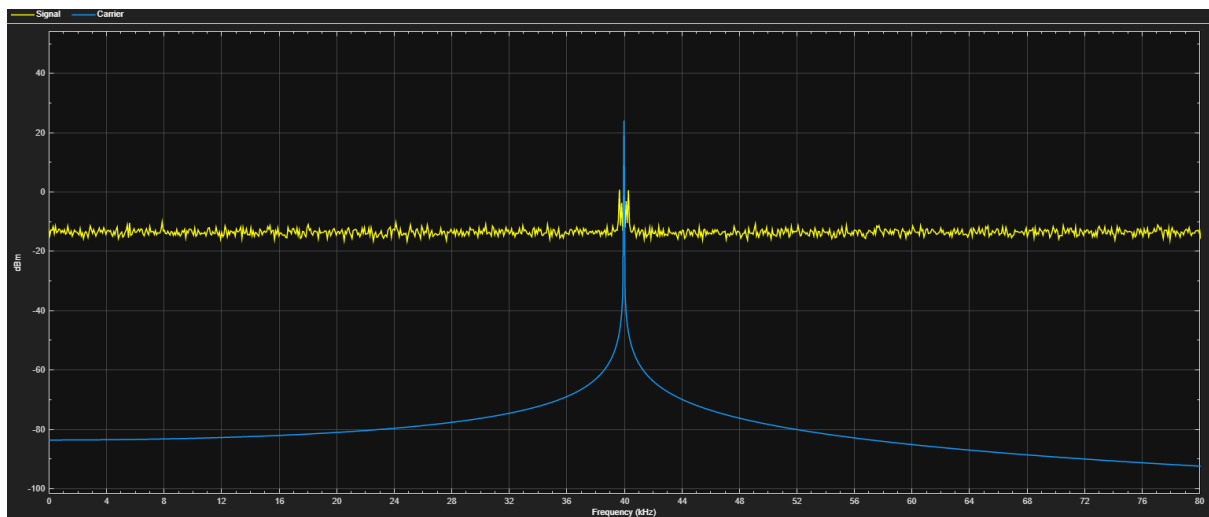


Figure 18. DSB-SC Audio File 5 SNR [Own]

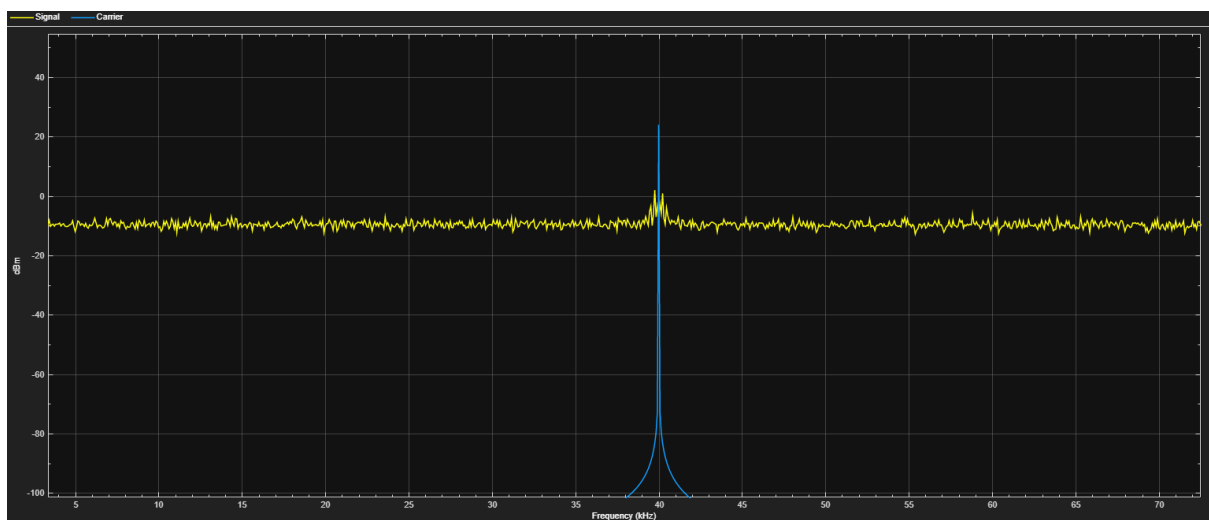


Figure 19. DSB-SC Audio File 1 SNR [Own]

The above figures 13 through 15 shows a snapshot of a transmission of the audio file viewed in the spectrum analyser. These figures clearly showcase the concept of a noise floor, the lower the SNR the

greater the noise floor. This noise floor has the effect of drowning out anything below it such as all the harmonics observed in figure 13. This has the practical effect of dulling out the speech and introducing a level of static noise in the background of the audio file. Accompanying this report is 3 audio files demonstrating these differences.

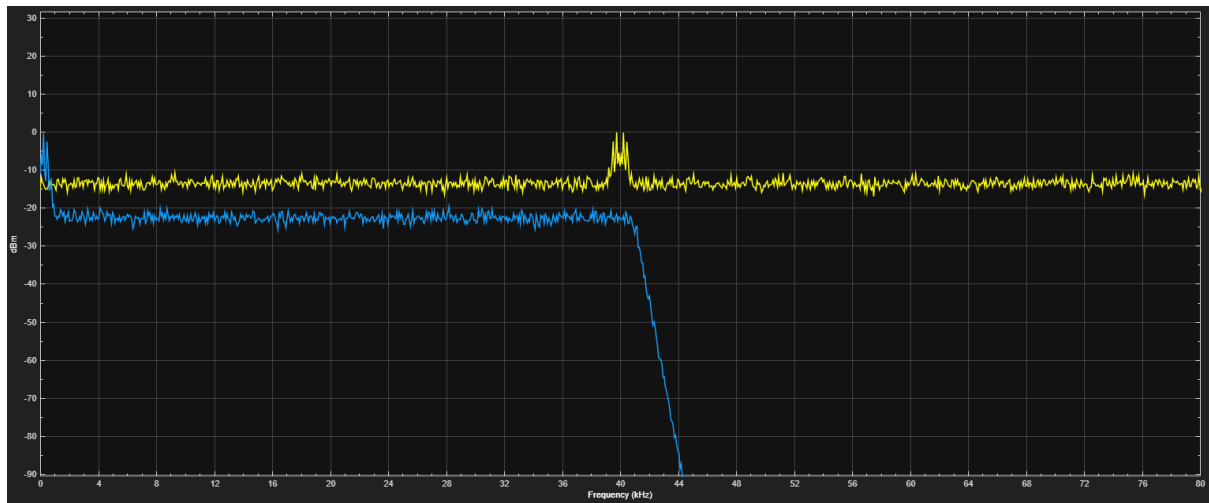


Figure 20. DSB-SC Audio File Demodulated 5 SNR [Own]

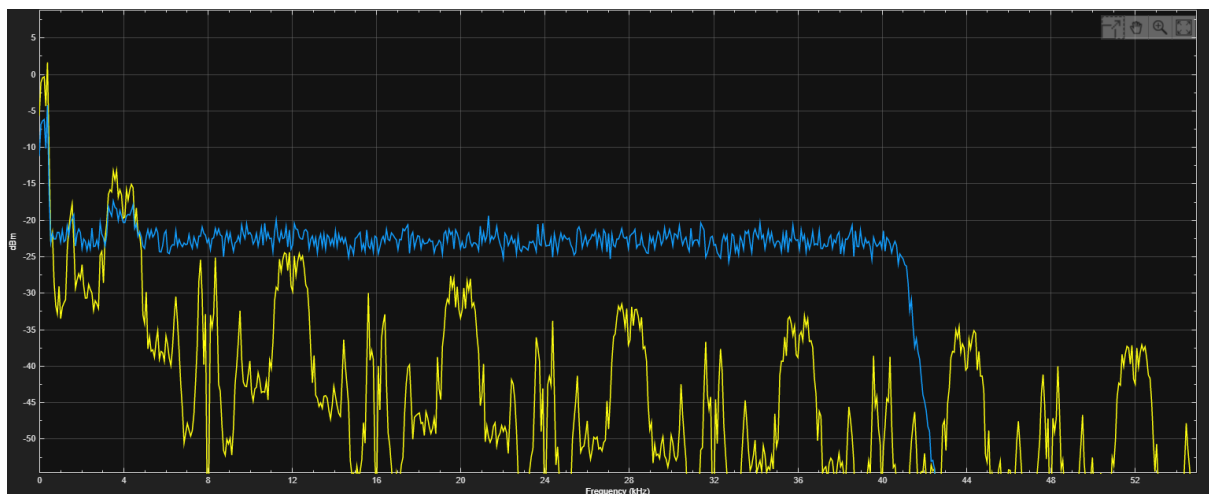


Figure 21. DSB-SC Audio File Original and Demodulated at 5 SNR [Own]

Figure 20 shows the modulated signal as a yellow trace and the demodulated, filtered output as a blue trace. The passband edge frequency of 41KHz can be observed, anything greater than 41KHz has significant attenuation. The yellow trace in figure 21 is the original, unmodulated signal from the audio file. This showcases once again the noise floor in the demodulated output and how the meaning full responses are attenuated slightly.

Conclusion

In conclusion, it is evident that analogue modulation and demodulation techniques without advanced noise filtering are very susceptible to noise. Frequency modulation is the greatest affected out of regular amplitude modulation and double side band – suppressed carrier modulation.

References

- [1] Mathworks, "Simulink," [Online]. Available: <https://uk.mathworks.com/products/simulink.html>.
- [2] Electronics Coach, "Double Sideband Suppressed Carrier (DSB-SC) Modulation," [Online]. Available: <https://electronicscoach.com/double-sideband-suppressed-carrier-modulation.html>.
- [3] Heavy.AI, "What is Frequency Modulation?," [Online]. Available: <https://www.heavy.ai/technical-glossary/frequency-modulation>.