

Radio p=freq systems

by Robbie Young

Submission date: 01-Dec-2023 02:35PM (UTC+0000)

Submission ID: 217538198

File name: 32858_Robbie_Young_Radio_p_freq_systems_538956_813073472.docx (676.58K)

Word count: 2168

Character count: 10652

Investigating the Effect of Noise in DSB- SC and FM Systems

Radio Frequency Systems (ACDA5019)

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Introduction

The aim of this investigation was to examine amplitude modulation and frequency modulation through a given time and determine the effect of noise when it is applied to different systems showing its effects and how it can change outcomes.

Task 1

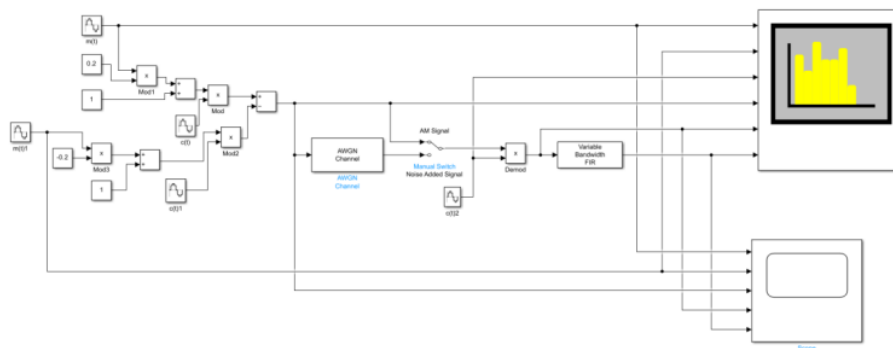
Introduction

For task one the aim of my design was to show amplitude and frequency modulation and how using different modulations from the index can affect how well a system performs and its purpose.

Background research

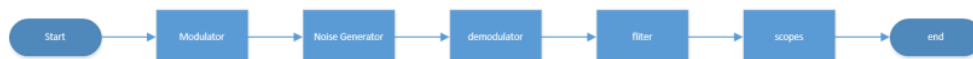
Whilst looking for information about what the modulation index is, I came across [1]. This site helped me understand what the modulation index is and the effects it had on amplitude modulation. It also helped explain that the optimal index is 0.5 and to get to this value you divide your message amplitude by your carrier amplitude, this means that your carrier should always double your message amplitude to get the optimal index. The sources also referenced some other books for radio systems such as [2] in which chapter 5 goes into depth into analogue modulation which includes both AM and FM.

Circuit design



The circuit I built for this task was a DSB SC modulator, as shown above. My student number ends in a 7 therefore I set my modulation index at 0.7. Due to this I set my information wave amplitude to 1.4, with a frequency of $2\pi \cdot 15$. For my carrier wave the amplitude was set at 2, with a frequency of $2\pi \cdot 60$. This way I could test both amplitude and frequency modulation at the same time.

Block diagram



My block diagram consists of 5 blocks, the first block is my modulation block, where my signal is combined with its carrier wave. Block 2 consists of a noise generator. Block 3 is the demodulator where the signal emulating the information wave. Block 4 is my lowpass filter removing errors and recreating the original wave. Block 5 is my scopes where I can read the outputs.

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Transmitter and receiver architectures

A DSB SC modulator works by modulating the amplitude of a signal to represent the unmodified wave, to achieve this you take your unmodified signal and multiply it by the carrier signal. By multiplying these 2 together you can send the information to your receiver, during the travel noise will be picked up in the signal, possibly corrupting the information, which you later filter out. However, before this you must demodulate your signal, which is done by multiplying your received signal, by the carrier wave then doing the filtering process, which is done by a lowpass filter smoothing out any disparities and making the signal as close to the original as possible, completing the transfer of data.

Simulations

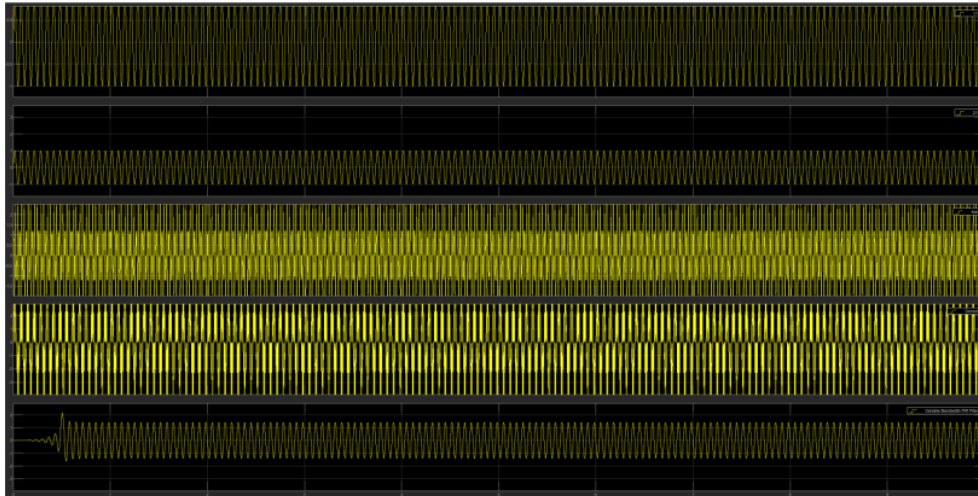


Image 1 shows the results on the scope, displaying the amplitude modulation, whilst using a modulation index of 0.7.

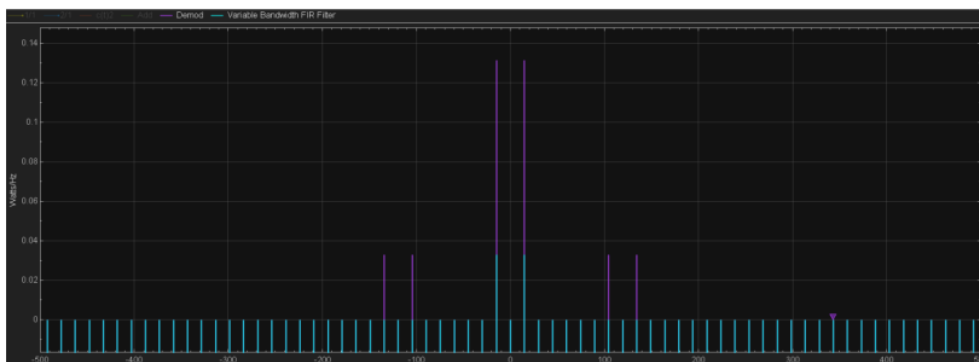


Image 2 shows frequency modulation by using the spectrum analyser.

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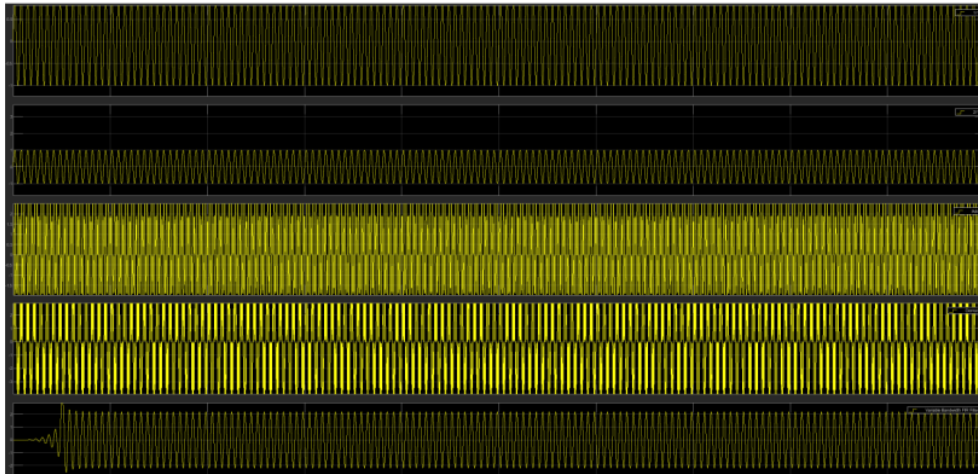


Image 3 is the scope, however the modulation index is set to 1.1.

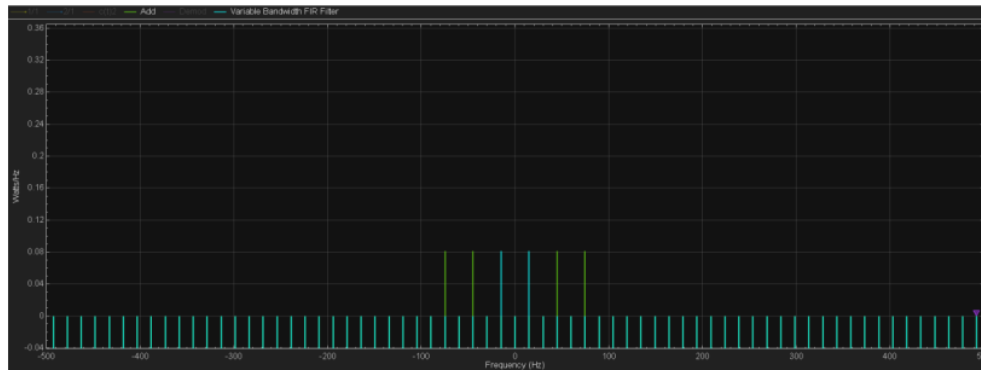


Image 4 is the spectrum analyser with a modulation index set to 1.1.

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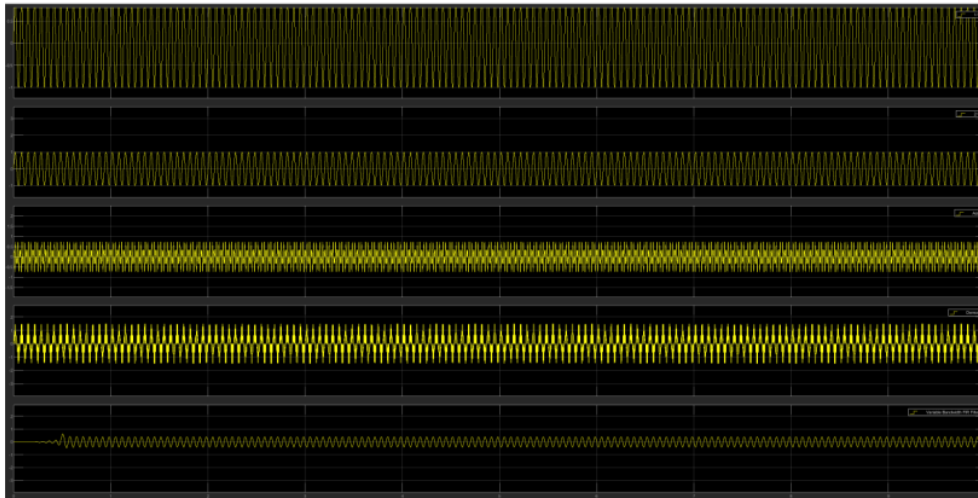


Image 5 is the scope, however the modulation index is set to 0.2.

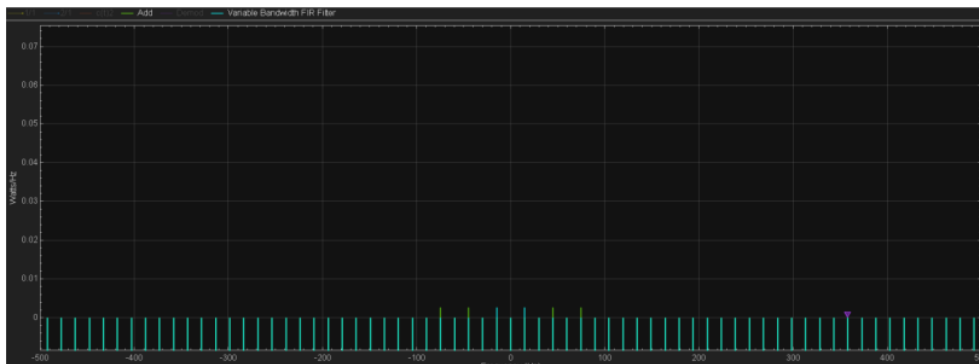


Image 6 is the spectrum analyser with a modulation index set to 0.2.

Analysis

Using the results of the graph it can be determined that the modulation index has a significant effect on how effective my system was able to produce the same output signal as was inputted, before combining with the carrier wave. As evidenced by images 1 and 3 the effect of modulation index is apparent. When set to 0.7 the carrier signal doesn't exceed the threshold of over modulating, this means the signal is modulated correctly and doesn't have any artifacts present meaning it can be demodulated correctly. However, when the index is set at 1.1, over modulation occurs, this makes the signal overlap, leaving artifacts that shouldn't be in the carried signal, this is created due to the amplitude of the carrier wave being less than the modulated signal, therefore it can't reach the same amplitude as the modulated signal, meaning all the information above that will be brought down to the peak, lowering the trough meaning information is lost. This means when demodulating, the original unmodified signal it's no longer present creating losses. Under modulation is showing in image 5, this is where the carrier signals amplitude is over four times the modulated signal, creating under modulating waves. Under modulated waves peaks and troughs can only be around 50% of the

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levels where no modulation is present. Therefore missing 50% of the information compared to the original inputted signal.

Conclusion

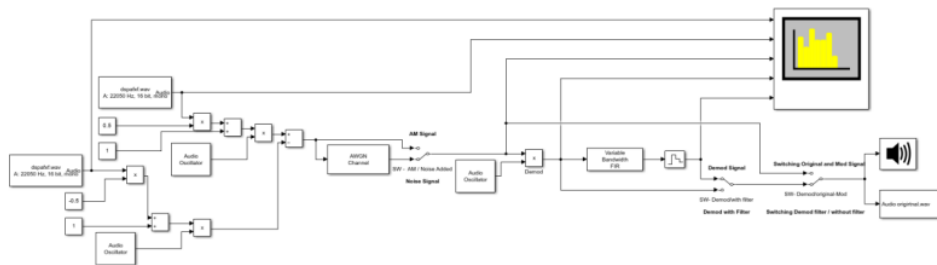
Over all I'm happy with the way my first task went, I feel that my results line up with my background research and demonstrated the effects of modulation index and how that effects AM modulation.

Task 2

Introduction

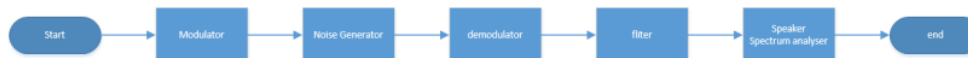
Task 2 is to modify task one so that audio can be transmitted, then later add noise. To test the performance of the DSB SC demonstrating, the effect of noise within a circuit.

Circuit design



For the circuit design of task 2, I modified task 1 by changing all the sine blocks, the 2 information waves were changed to digital audio files. The carrier waves were change to audio oscillators which act the same but have different values. Other changes included adding a speaker and an audio receiver.

Block diagram



The block design for task 2 shares the same base functions as task 1, however the inputs and outputs are changed. The inputs have been changed from basic sine functions to audio files and outputs have changed from the scope to a speaker and audio saver.

Transmitter and receiver architectures

In principle task 2's modulation and demodulation works the same as task 1. However, the carrier wave is different, and the modulation index is set 0.5, meaning the modulation is as good as possible making the transmission as clear as it can be before it is affected by noise.

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Simulations

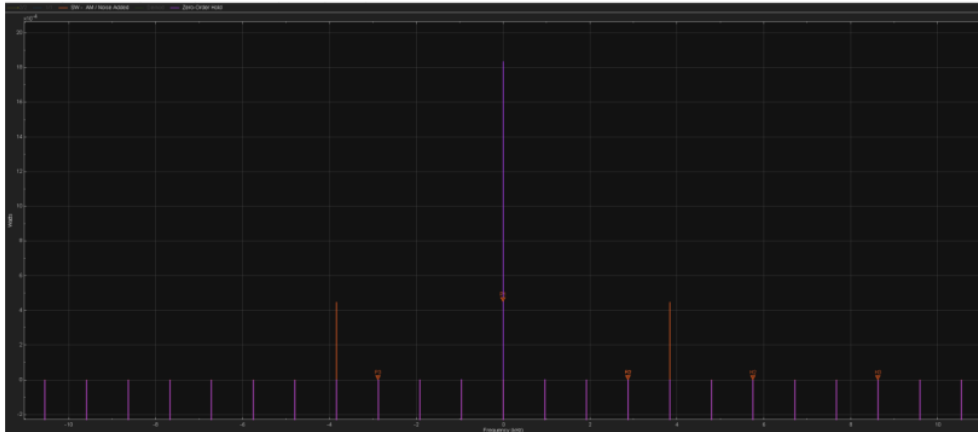


Image 1 shows the spectrum analyser whilst the system is running without noise present. Whilst this was running the audio is very clear and no white noise could be heard.



Image 2 shows the spectrum analyser whilst the system is running with a signal to noise ratio of 10, meaning the signal is 10 times stronger than the noise. Whilst listening to this the audio was relatively clear, however, there was a lot of static white noise in the background this can be seen by the purple lines which can be heard, this could be filtered out, making the audio clearer.

Analysis

After running the simulations with increasing noise levels, I could determine the effect of noise in my circuit. From image x above it can be seen the noise levels on the spectrum analyser. Whilst noise levels are limited, the audio is very clear and sounds very close to the original. However, as seen from image 2, where noise levels are much higher, the sound gets distorted more. This in turn has an effect on the quality of the audio. When listening back there is a lot of static noise present, making it unpleasant to listen to. This can be corrected by tuning filter and using amplifiers to correct the sound. Potential interference that could create this effect include solar rays, other signals being sent in a similar bandwidth and combining the waves. For the example of solar rays, white noise is

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generated by the solar ray colliding with the audio wave this in turn induces a power spike, which usually can be heard, because the audio cuts out for a brief moment, due to the amplifiers cut of point is lower than the power surge, therefore no noise is heard. On the other hand, most static white noise is generated by other waves combining with the signal. This distorts the audio creating a static sound which can be heard if incorrectly filter out, subsequently be heard by the end user.

Conclusion

To improve my system another filter could have been used, this however would make the audio a lot quieter, therefore needing an amplifier to boost the sound to the correct levels. This in turn if built rather than simulated would cost more. Otherwise I thought task 2 was successful as I got clear audio when no noise was present, allowing me to demonstrate the effect of noise.

Task 3

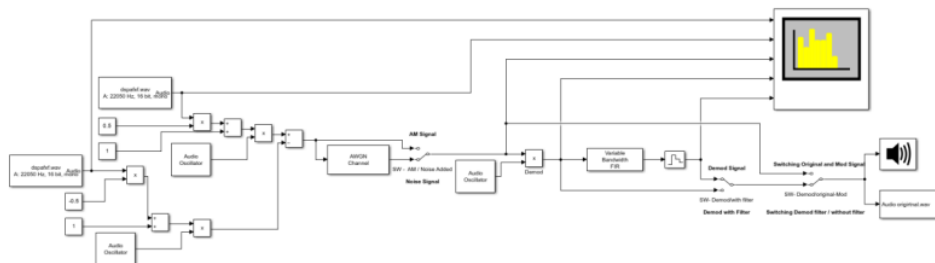
Introduction

For task 3 I have produced a FM modulator that is able to transmit audio, enabling me to test the effect of noise and how it distorts the output.

Background research

Whilst looking for the differences in AM and FM and trying the pros and cons sources [3] was found. It has a great table of information into the differences between them, however it does get its sources from Wikipedia, so could be unreliable. To verify the information, I went to [4] which is a training course for am/fm systems and this was useful in verifying the table produced by [3].

Circuit design



Task 3 has the same design as task 2, however it has been modified so it works by changing the frequency, rather than the amplitude. To achieve this I changed the carries frequency and made sure the amplitude was the same as the sent signal.

Block diagram



Although the block diagram is the same as task 2 the principles inside the block have changed from am AM modulator to an FM modulator, this is the same for the demodulator. Although these appear to be minor, they actually have a large impact on how the system works.

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Transmitter and receiver architectures

FM transmission works by changing the frequency rather than changing the amplitude, like AM does. Expanding on source [3] This comes with pros and con's. The pros of using an FM system are its less prone to interference resulting in a better sound quality. The reason its less susceptible to interference than AM is because its harder for interference to change a frequency where the information is carried, compared to susceptibility of having information carried in the amplitude of the wave. The cons to FM is it requires a higher bandwidth meaning less communication channels can be used. The mean problem for FM transmission is it cost more to set up and more to maintain because there's limited frequencies.

Simulations

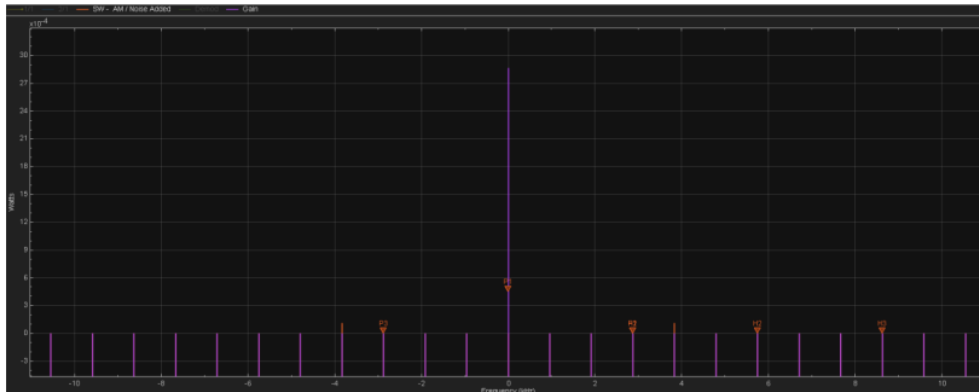


Image 1 is the spectrum analyser with no noise.

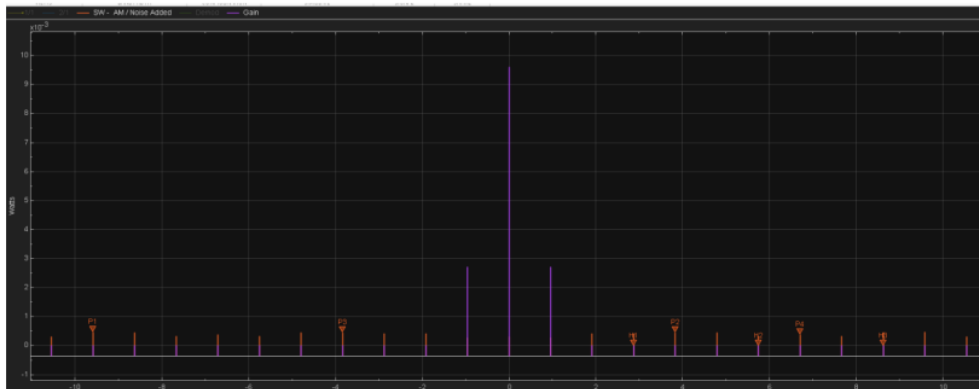


Image 2 is the spectrum analyser with a signal to noise ratio of 20.

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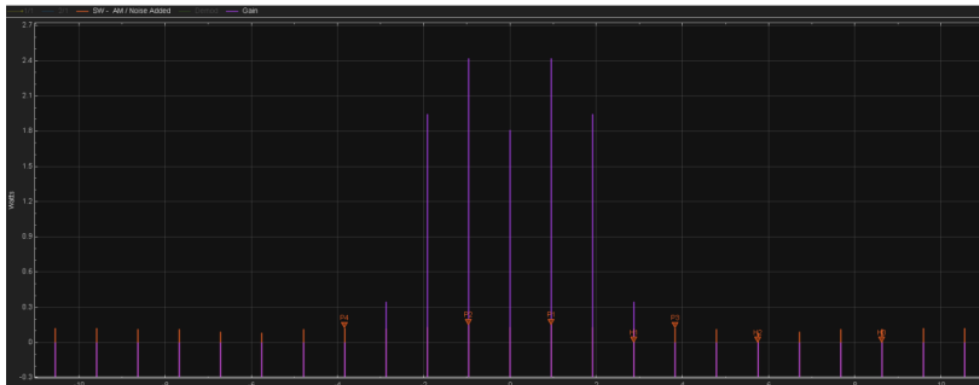


Image 3 is the spectrum analyser with a signal to noise ratio of -5.

Analysis

Whilst investigating the effect of noise in frequency modulator I was able to conclude that a frequency modulator was better equipped to filter out the sound, subsequently producing a better sound quality than an amplitude modulation system. To back up my analyses I can use images 1 through 3, to demonstrate how much noise was able to pass through my filter, to be heard by the end user. Image 1 is with added noise, as seen from the spectrum analyser (in red,) there are slight spikes in the noise level around the 3KHz, this is to be expected as a normal speaking range is around this value, as would be static noise picked up from the background of the recording. However, as seen from the purple lines, it has successfully filtered out and isn't heard when sound is playing.

Image 2 confirms my analyses as seen by the purple lines in the spectrum analyser which is the output of my filter. As seen in red the noise is very much more apparent, this in turn is passing through the filter and can be heard from the speaker as a static buzz.

In image 3 it becomes even more apparent the effect that noise has on the system as demonstrated by the purple lines. My filter is not correctly filtering out the static noise around the 1 KHz and 2KHz mark, which again is heard as a buzzing sound and makes the message incoherent.

Conclusion

To conclude although noise was present and could be heard the overall message could still be heard, although this is still much better than an amplitude modulator, as the AMs message was very distant and incoherent, proving the point that FM is better equipped to deal with noise than AM, making the overall listening experience much more comfortable.

Conclusion

I believe I successfully demonstrated the effects of noise on both an AM and FM system and shown why Fm systems are more popular as they filter out noise making it a better experience for listeners.

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Sources

- [1] Notes, E. (no date) Amplitude Modulation, AM Index & Modulation Depth, Electronics Notes. Available at: <https://www.electronics-notes.com/articles/radio/modulation/amplitude-modulation-am-index-depth.php> (Accessed: 01 December 2023).
- [2] Ellingson, S.W. (2016) 'chapter 5', in Radio Systems Engineering. Cambridge, United Kingdom: Cambridge University Press.
- [3] AM VS FM (no date) Diffen. Available at: https://www.diffen.com/difference/AM_vs_FM (Accessed: 01 December 2023).
- [4] Schools, M.M. (2023) Understanding how AM/FM Radio Works (part 1 & 2), Be On Air. Available at: <https://beonair.com/understanding-how-am-fm-radio-works#:~:text=Radio%20is%20a%20technology%20that,connection%2C%20often%20over%20significant%20distances>. (Accessed: 01 December 2023).