

Radio Frequency Systems

Henry Rennison

by Henry Rennison

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Effect of Noise in SSB-SC, DSB-SC and AM

Radio Frequency Systems (ACDA5019)

Henry Rennison 2218326

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Introduction

This report is structured to provide an understanding of the **principals** of AM (Amplitude Modulation), SSB-SC (Single Sideband Suppressed Carrier) and DSB-SC (Double Sideband Suppressed Carrier). This report will investigate these modulation schemes through tasks that are aimed at understanding their characteristics, performance and noise resilience. The simulations and modulation techniques were all done on Simulink. The report aims to provide a comprehensive understanding of the key modulation techniques.

Background Research

This part of the report will give definitions and examples of three modulation schemes:

- AM (Amplitude Modulation)
- SSB-SC (Single Sideband Suppressed Carrier)
- DSB-SC (Double Sideband Suppressed Carrier)

Amplitude Modulation (AM)

Amplitude modulation is a technique used in communication systems where the amplitude of a higher frequency carrier wave is changed in proportion to the information signal being transmitted, the frequency of the carrier will remain the same. [1]

Single Sideband Suppressed Carrier (SSB-SC)

Single sideband suppressed carrier is a type of amplitude modulation where only one of the sidebands is transmitted, while the carrier and the other sideband are removed. This is to save bandwidth and improve the power efficiency. [2]

Double Sideband Suppressed Carrier (DSB-SC)

Double sideband suppressed carrier is a type of amplitude modulation where both sidebands are transmitted, but the carrier is removed. This saves power since the carrier doesn't carry any useful information. [3] A common use case for DSB-SC is in FM radio and analogue television transmitters as they require more efficient power usage.

TASK 1

This task will look into the fundamentals of AM, it will look at the time and frequency domains whilst changing the modulation index. It will be tested at 0.6 and then it will be run three more times at under-modulation, over modulation and critical condition. This task will also compare the difference between modulated signals with the demodulated signals.

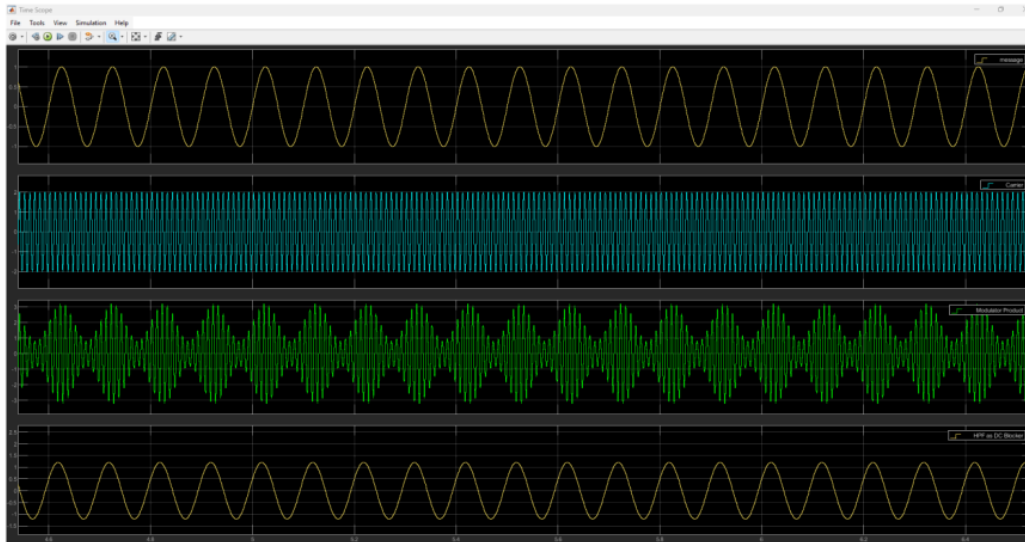


Figure 1 0.6 AM

In the above image you can see the top waveform represents the message signal which is the modulating signal. Its frequency is lower than the carrier signal which is what you would expect to see on a typical AM signal. The second waveform (blue) is the carrier signal, which is a higher frequency than the message signal. This is unmodulated signal and serves as the base for modulation. The third waveform (green) is the AM Modulated signal, the amplitude of the carrier varies according to the message signal, which then creates the AM signal. This waveform should mirror the message signal. The final plot shows the demodulated signal. In the above case the waveform resembles the message signal. This suggests a successful demodulation process.

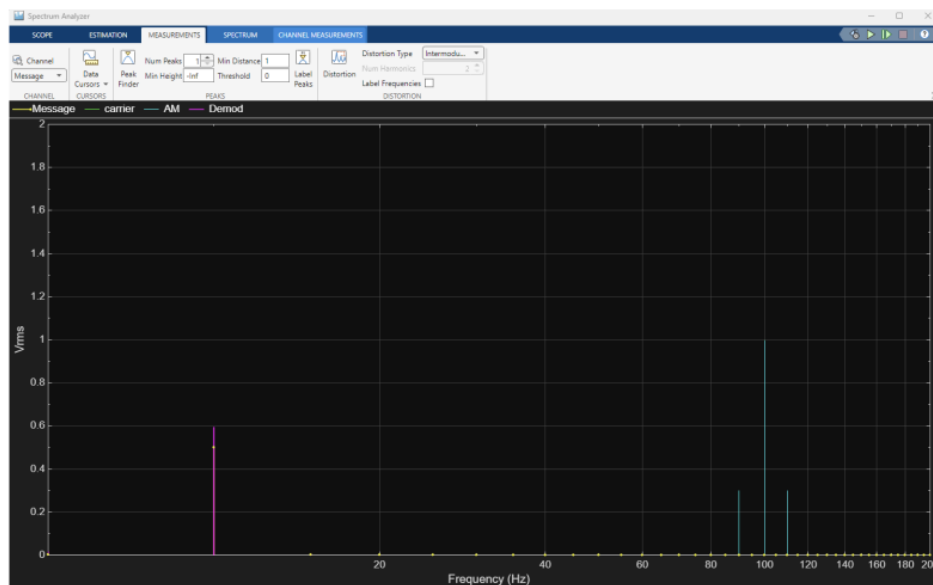


Figure 2 0.6 Spc Ar 9

Above is the screen shot of the spectrum analyser when the modulation index is set to 0.6. The spectrum shows a single peak at the message signal's frequency (10Hz) This is the low frequency component of the system. It also shows a sharp peak at the carrier signal frequency (100Hz) this is expected as it represents the unmodulated carrier used in AM. The AM spectrum (sidebands) are visible either side of the carrier signal at (90Hz and 110Hz) These two bands contain the modulated message signal.

10

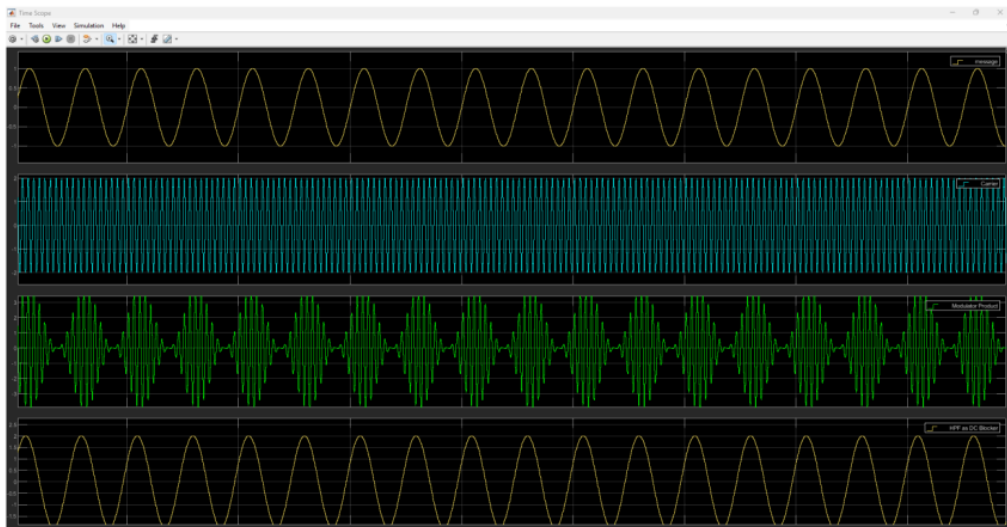


Figure 3 AM Crit

Above is the scope when running the modulation index at critical modulation, Critical modulation occurs when the modulation is exactly 1. When using critical modulation, the amplitude of the modulating signal is equal to the amplitude of the carrier signal. This is shown above as the modulated signal matches the shape of the message signal. The demodulated signal matches the original message signal very closely. [4]



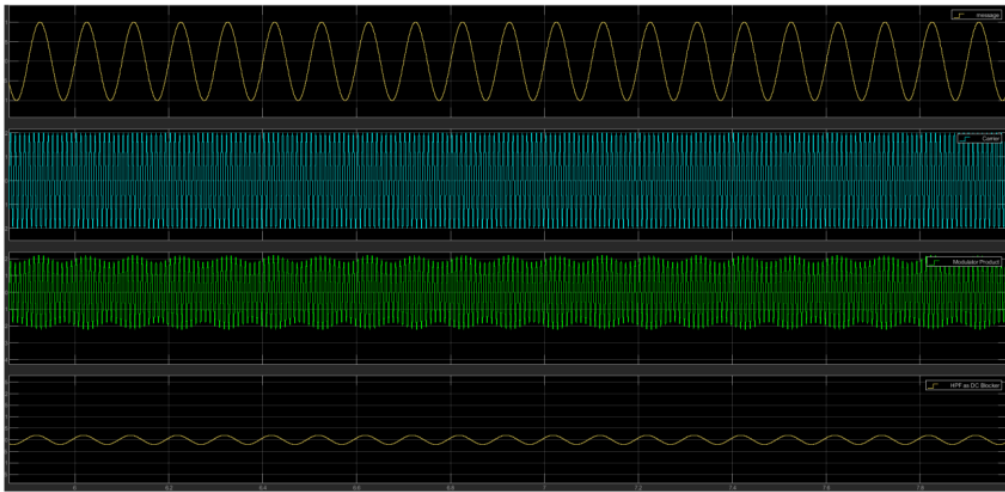


Figure 4 AM Under

The above image shows under modulation, under modulation occurs when the modulation index is less than 1. This means the amplitude of the modulating signal is smaller than the amplitude of the carrier signal as above. Since the carrier signal is stronger than needed it results in wasted power and reduced efficiency. [5]

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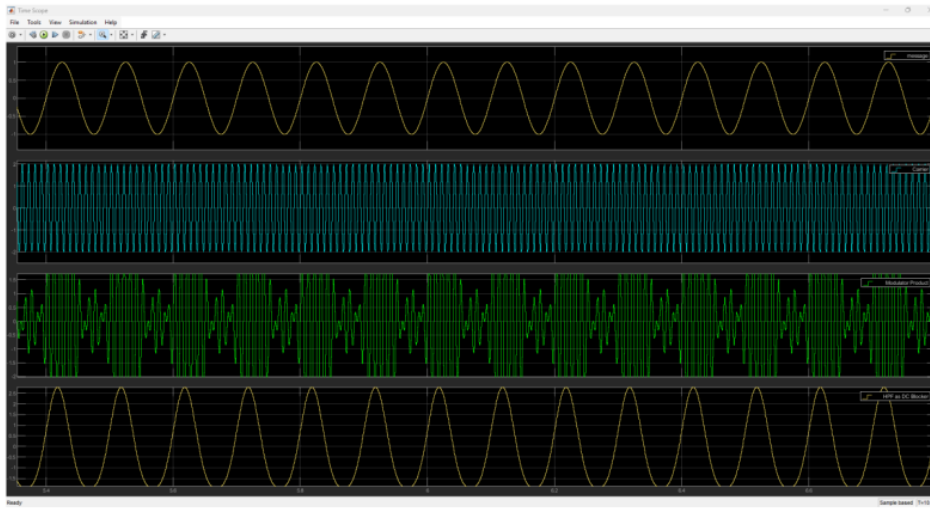


Figure 5 AM Over



The above image shows an example of over modulation, this occurs when the modulation index is set to greater than 1. This happens when the amplitude of the modulating signal is larger than the amplitude of the carrier. This can cause the introduction of additional frequency components into the spectrum, which can in turn make interference with adjacent signals. It also can lead to the original message be very difficult to recover accurately during demodulation. [6]

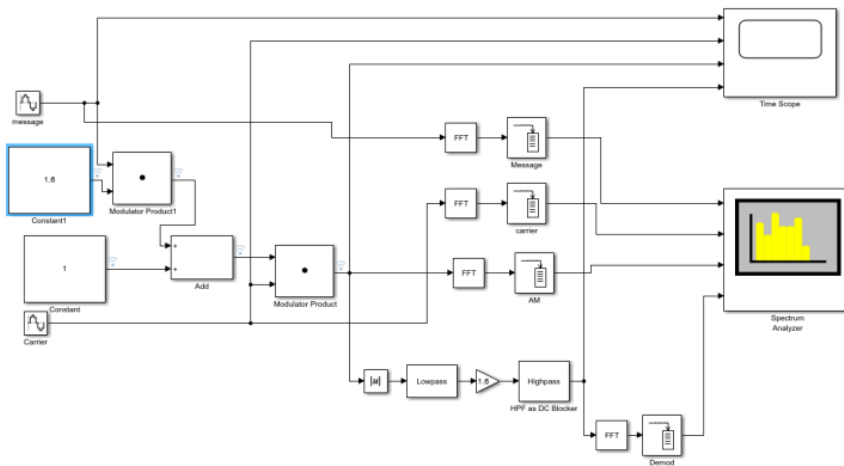


Figure 6 AM Simulink

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Task 2

This task focuses on the use of DSB-SC modulator. For the first tests the, modulation index was set to 0.5 to maintain a consistent level of modulation and to ensure optimal signal transmission. The demodulation process recovers the original signal and checks it in both the time and frequency views to ensure it matches accurately. The next part of this task was to add some random noise into the modulator. Then compare both sets of tests to see the effects that adding noise to the transmitted signal has had.

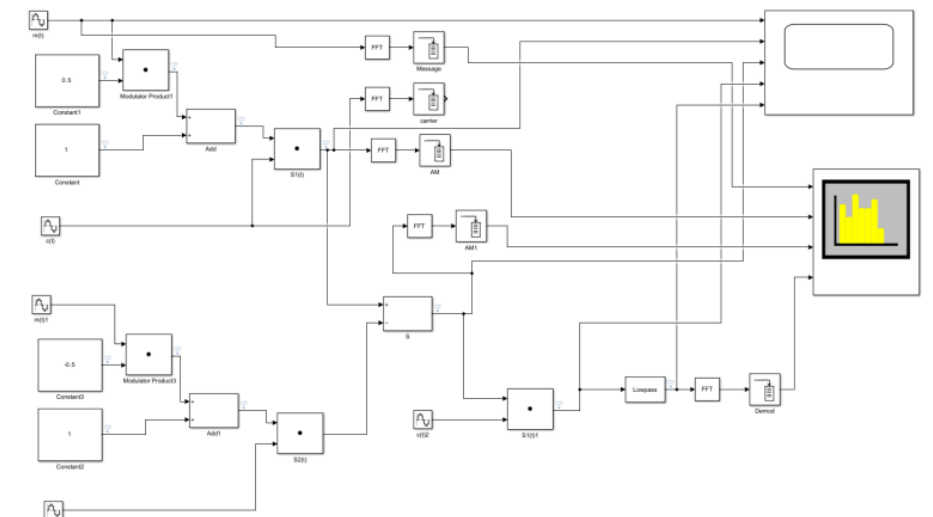


Figure 7 DSb-SC Simulink

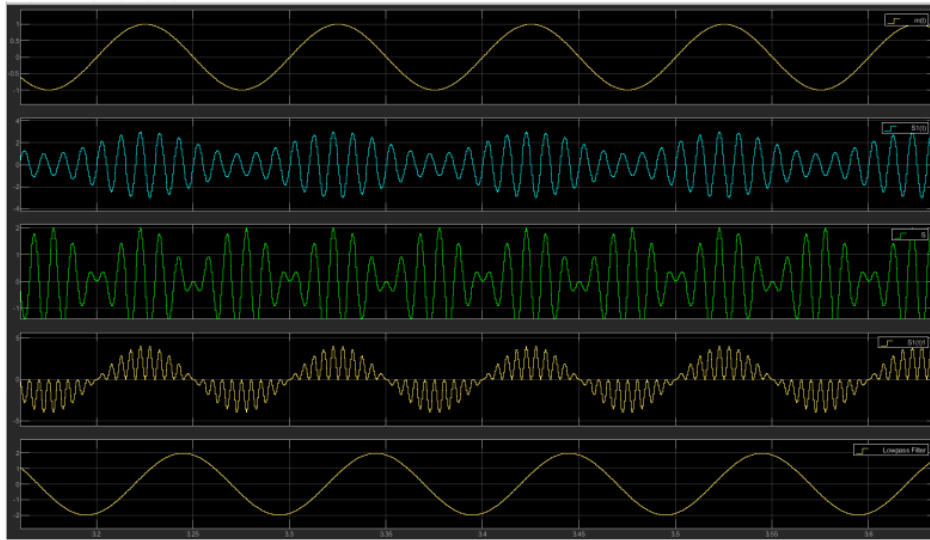


Figure 8 DSB-SC 0.5

The above image is of a DSB-SC modulator using a balanced modulator and then demodulating it. Its modulated signal has a high frequency sine wave where the amplitude varies according to the message signal. However, after demodulation the recovered signal does resemble the original message. Where the modulation index is set to 0.5 you would expect to the amplitude of the modulating signal to be half of the carrier signal.

16

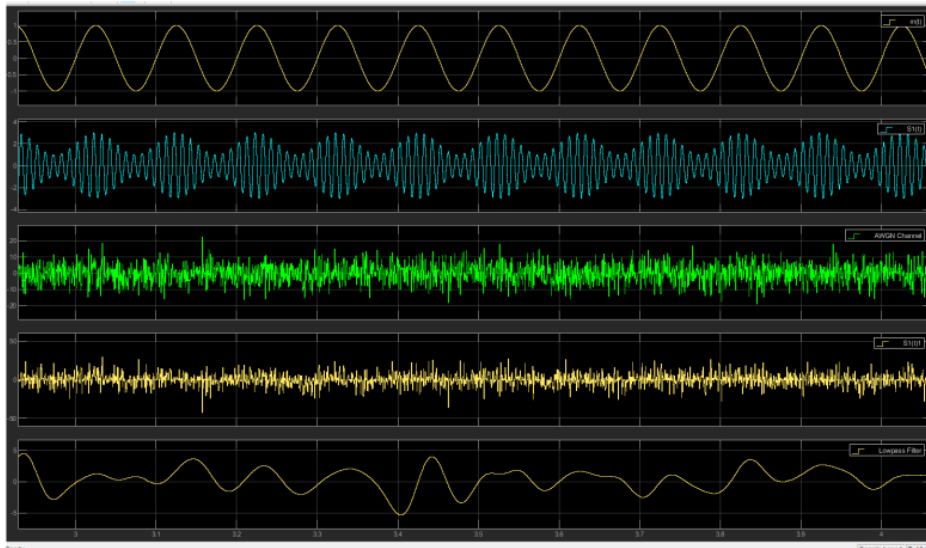


Figure 9 DSB-SC SNR-15

The above image is the DVB-SC with a modulation index of 0.5 and -15 SNR as can be seen the modulated signal now has random fluctuations on it its waveform due to the noise. The demodulated signal is very difficult to distinguish due to the noise. Overall there is greatly reduced clarity on both the modulated and demodulated signals, in this case the noise appears to be too strong for the signal as it has a great impact.

Task 3 – SSB-SC

This task focuses on the use of SSB-SC modulator. For the first tests the modulation index was set to 0.5 to maintain a consistent level of modulation and to ensure optimal signal transmission. The demodulation process recovers the original signal and checks it in both the time and frequency views to ensure it matches accurately. The next part of this task was to add some random noise into the modulator. Then compare both sets of results to see the effects that adding noise to the transmitted signal has had.

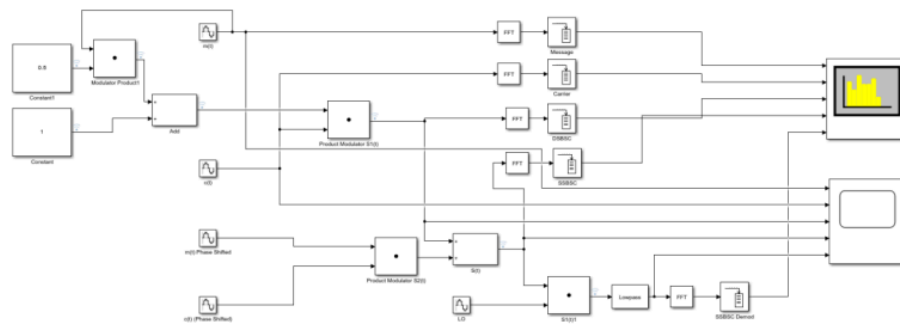


Figure 10 SSB-SC Simulink

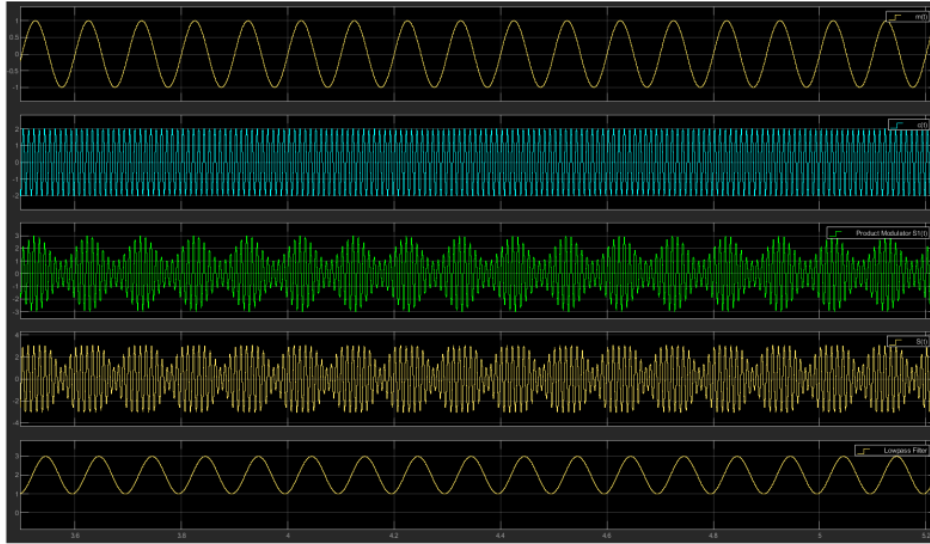


Figure 11 SSB-SC 0.5

21

The above image is of an SSB-SC modulator with a modulation index of 0.5. The waveform does resemble a high-frequency sine wave but its amplitude does vary according to the message signal. The recovered signal does look like the message signal and the demodulated signal has minimal distortion and does resemble the input. Bandwidth efficiency is visible as only half the bandwidth required. This image demonstrates the high bandwidth efficiency of SSB-SC and its ability to recover the original message with minimal distortion.

With noise -15

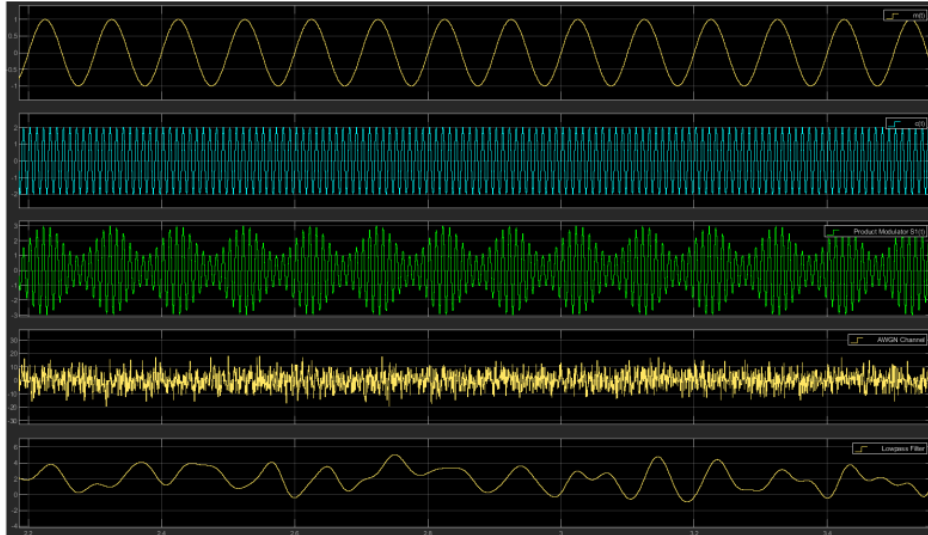


Figure 12 SSB-SC SNR-15

The above image is of a SSB-SC with a modulation index of 0.5 and a SNR of -15. The modulated signal does represent a modulated message however it is affected by the noise. The demodulated recovered signal does resemble the original message signal however it is not as clear. There are many distortions in the peaks and zero crossings making it look much less smooth.

Task 4 Comparison of Modulation Techniques

This part of the report will cover the performance evaluation of modulation techniques which is a critical part of analogue communication system design. It will compare and look into their efficiency and robustness under varying conditions. All three of the systems (AM, DSB-SC, SSB-SC) will be analysed to identify their strengths and limitations. .

SSB-SC with noise

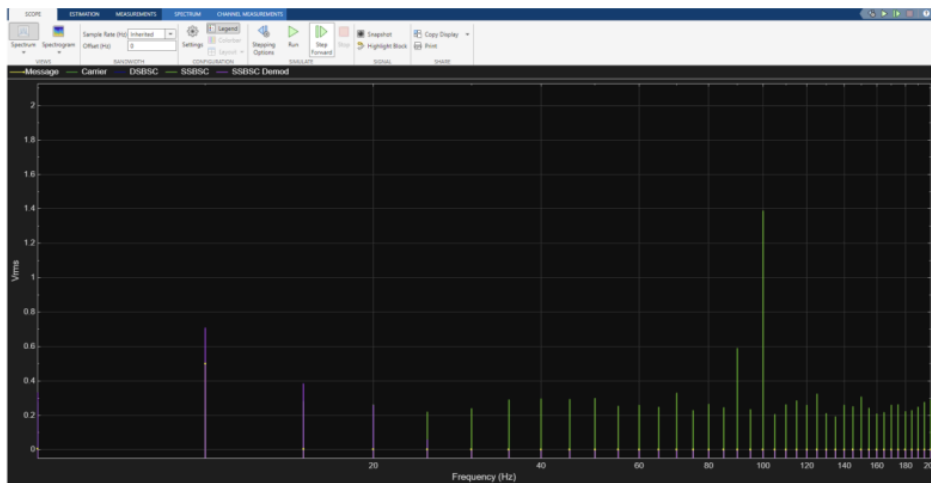


Figure 13 SSB-SC Spec

DVB-SC with noise

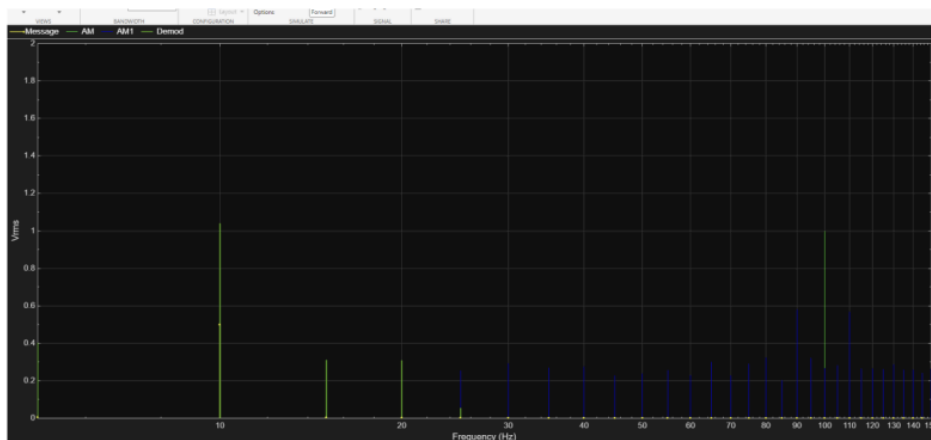


Figure 14 DVB- SC Spec

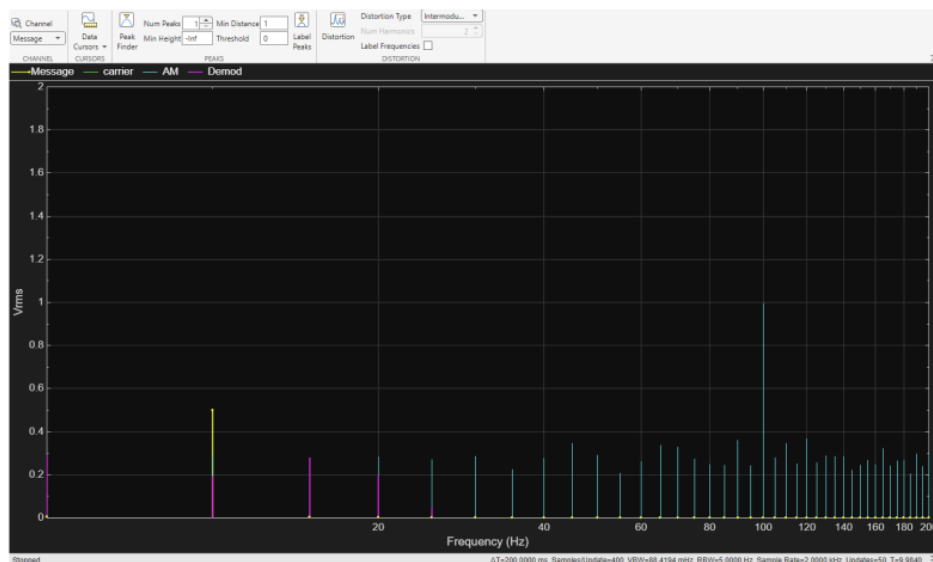


Figure 15 AM SPEC AN

Spectrum analysis

AM: the spectrum shows the carrier frequency and two sidebands which increases the bandwidth usage.

SSB-SC: only one sideband is present which in turn saves bandwidth.

DSB-SC: Both sidebands are present without the carrier, this does reduce power consumption but in turn requires more bandwidth.

Power Efficiency

AM: probably the least power efficient of all the modulators in question. This is partly down to a large portion is used on the carrier.

SSB-SC: Easily the most power efficient due to the suppression of the carrier and one sideband.

DSB-SC: Somewhere between SSB-SC and AM in terms power efficiency as it does use carrier suppression but it does transmit both sidebands.

Noise Tolerance

AM: Very susceptible to noise especially in the carrier and both the sidebands.

SSB-SC: Much better noise tolerance than AM mostly due to the reduced bandwidth but will still be affected under strong noise conditions.

DSB-SC: Again, very much in between the other two modulation techniques, fairly good noise tolerance as the noise affects both sidebands but the absence of a carrier improves the overall resistance.

Bandwidth Efficiency

AM: Requires twice the bandwidth of the modulating signal.

SSB-SC: Requires the same bandwidth as the modulating signal, which makes SSB-SC the most bandwidth efficient.

DSB-SC: Requires twice the bandwidth of the modulating signal, similar to the AM but without the carrier.

Overall Assessment

AM: Is best suited for applications where simplicity is more critical than efficiency.

SSB-SC: The most efficient method for scenarios requiring higher bandwidth and greater power efficiency.

DSB-SC: Very much a middle ground between SSB-SC and AM. But still has many use cases.

After going through all the modulation schemes and looking at multiple factors, it would appear that SSB-SC comes out as the most overall efficient technique in terms of bandwidth and power. However, can be quite complex so DSB-SC is a perfectly viable alternative for less strict applications. That being said AM still remains a practical choice for older systems and ones with a simple implementation.



Conclusion

This report as covered three key modulation techniques AM, SSB-SC and DSB-SC. This was done through simulations on Simulink and theoretical analysis. The findings were as follows:

Amplitude Modulation

While being the simplest of the three to implement and create on Simulink it has large inefficiencies in power and bandwidth utilisation. It is also very susceptible to noise making it more useful for legacy systems such as radio broadcasting.

Single Sideband Suppressed Carrier

SSB-SC appears to be the most efficient of the three when it comes to bandwidth and power, this makes it the best choice for applications which require minimal resource usage. It is however one of the more complex to implement.

Double Sideband Suppressed Carrier

DSB-SC offers a balance between the other two techniques and Offers a viable alternative when the SSB-SC complexity can be restricting. It can also be useful if the AM inefficiencies aren't suitable for the specific use case.



Future Work

Ideas for future work could be to test all the modulation techniques under varying SNRs or different noise types. This could help provide a deeper understanding of how all the techniques respond and help make more informed decision. Another possible line of testing could be to test the modulation schemes against digital alternatives such as QAM and PSK, this could be helpful to understand the trade offs between digital and analogue. Another good test could be to perform the test on hardware using an SDR as this would help to validate the findings in a real-world scenario. Finally, a good test would be to compare the modulation schemes against a specific modern application (satellite communication or 5G).

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[5]

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Radio Frequency Systems Henry Rennison

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

56/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

 **Comment 1**
spelling

 **Comment 2**
no comment

 **Comment 3**
Well said.

PAGE 5

 **Comment 4**
what is measured here by giving different modulation index?

 **Comment 5**
Message

 **Comment 6** |  Knowledge & Understanding (20)
Not only in AM but in all Modulation ideas



Comment 7

The signal you are mentioning is the Amplitude Modulated Signal which not the mirror of the message signal.



Comment 8

Yes.

PAGE 6



Comment 9 | Transferable skills (20)

It is recommended to provide a clear and descriptive caption for the figure.



Comment 10 | Knowledge & Understanding (20)

Keen observation!

PAGE 7



Comment 11 | Cognitive skills (20)

Good findings. It could be better to explain the process of demodulation than explain it very briefly. Example: Envelope detection process at demodulator.

PAGE 8



Comment 12 | Cognitive skills (20)

Well Said!

PAGE 9



Comment 13

Descriptive caption for the figure is recommended.

PAGE 10



Comment 14

Figure 6: AM Simulink : When considering the over Modulation.

PAGE 11



Comment 15 | Knowledge & Understanding (20)

Observations are clearly made. It is also required to explain the concept and the working principle of balance modulator.

PAGE 12



Comment 16 | Transferable skills (20)

The explanation is good but incorrect terminology is used. The carrier is suppressed, so the statement about the modulating signal being 'half of the carrier' is inaccurate."

PAGE 13



Comment 17

DSBSC



Comment 18 | Cognitive skills (20)

Good Observation!



Comment 19

True

PAGE 14



Comment 20

no comment

PAGE 15



Comment 21 | Knowledge & Understanding (20)

Observations are clearly made. It is also required to explain the concept and the working principle of Phase discriminator in SSBSC.

PAGE 16

PAGE 17

PAGE 18

PAGE 19



Comment 22 | Cognitive skills (20)

The comparisons and the selection of the better-performing option are made only by looking at the graph in the spectrum analysis, without using calculations for factors such as F, SNR, and efficiency. Adding these calculations would give a more detailed evaluation.

PAGE 20



Comment 23 | Practical Application (30)

The conclusion gives a clear comparison of AM, SSB-SC, and DSB-SC, highlighting their strengths and weaknesses. Adding quantitative data like power efficiency or bandwidth utilisation would make it more detailed.

**Comment 24** | Engagement with literature(10)

The literature review covers a good range of sources but needs more critical analysis and better connection to the report's context. Including recent academic sources and summarising key points would make it more detailed and relevant.

GRADING FORM: RF_UPDATED_2025

HENRY RENNISON**55.75****ENGAGEMENT WITH LITERATURE(10)**

Demonstrated understanding of AM, DSB-SC, and SSB-SC techniques by referencing key theoretical principles. Discussed noise impact, modulation index, and performance metrics using scholarly resources.



The understanding of AM, DSB-SC, and SSB-SC techniques is clear, but the references to theoretical principles are not detailed enough. The discussion on noise impact and performance metrics is limited and lacks deeper analysis.

6.5**KNOWLEDGE & UNDERSTANDING (20)**

Explored modulation systems in time and frequency domains, analysing critical, over, and under modulation. Applied modulation index and signal design to understand carrier signal variations and noise effects.



Task 1: (a) (i) Shows basic understanding of AM principles. Explanation is fine but misses some key details.

Task 1: (a) (ii) Describes critical, over, and under

9.75

modulation with minimal detail. Observations lack clarity.

Task 1: (b) Explains demodulation at a basic level, but clear and precise comparisons are needed.

Task 2: (a) Task demonstrates clear explanation of DSB SC modulation and demodulation but lacks more examples and detailed reasoning for noise impact.

Task 2: (b) Noise effects in DSB SC demodulation are limited.

Task 3: (a) Task 3 (a) SSB SC modulation and demodulation are well explained but need more depth in noise analysis.

Task 3: (b) Noise effects in SSB SC demodulation are less explained.

Task 4: (a) Spectrum and power density are briefly discussed. Noise tolerance is poorly addressed.

Task 4: (b) Fails to compare modulation techniques. Bandwidth and power utilisation are not addressed.

COGNITIVE SKILLS (20)

Analysed and compared demodulated signals with original modulating signals. Evaluated system performance metrics, including spectrum, power density, and noise resistance, to assess modulation techniques.



Task 1 (a): The analysis lacks clarity. Comparisons are vague, with little use of spectrum, time scope, or modulation indices.

Task 1 (b): The demodulation process needs more explanation. Comparisons are vague. The analysis is very limited and lacks reasoning.

Task 2 (a) & (b): The modulation and demodulation processes are seen but needs more understanding. Observations are done, with little innovation.

Task 3 (a) & (b): The modulation and demodulation

8.6

processes for SSBSC are seen but needs more understanding. Observations are done, with little innovation.

Task 4 (a) & (b): Performance metrics, comparisons, and graphs are missing. No conclusions are drawn based on theoretical and observed value calculations.

PRACTICAL APPLICATION (30)

Implemented AM, DSB-SC, and SSB-SC modulation and demodulation using time scopes and spectrum analysers. Introduced random noise to evaluate distortion effects and conducted real-world performance measurements.



Task 1 (a) (i): Strong skills in tool usage but lacks minor details in demonstration clarity.

Task 1 (a) (ii): Modulation variations are demonstrated with minimal carrier insights.

Task 1 (b): Thorough explanation of AM demodulation. Results are accurate, with proper comparisons and strong theoretical alignment.

Task 2 (a): Demonstrates accurate DSB-SC modulation. Observations are precise, and tools are used effectively. Block diagrams are well-designed, and relevant screenshots are included to support the explanation.

Task 2 (b): Minimal noise analysis with less clarity and incomplete results.

Successfully implements SSB-SC modulation with accurate signal analysis using phase discriminator.

Task 3 (b): Weak analysis of noise effects with incomplete observations.

Task 4 (a): Practical setup is done with unclear observations. Measurements are missing.

Task 4 (b): Limited comparisons with fragmented analysis and unsupported conclusions.

18.9

TRANSFERABLE SKILLS (20)

Demonstrated systematic reporting skills through performance analysis and practical communication challenges. Showcased effective communication, clear organisation, and time management in a well-structured, standard-compliant report.



Transferable skills are adequate, with basic communication skills, acceptable organisation, and systematic reporting.

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