

RFS Report

by James Hunt

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RADIO FREQUENCY SYSTEMS

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Abstract

This report investigates the impact of noise on various Amplitude Modulation (AM) techniques, with a particular emphasis on Double Sideband Suppressed Carrier (DSB-SC) and Single Sideband Suppressed Carrier (SSB-SC). The study evaluates the performance of these modulation schemes in the presence of noise, which remains a significant challenge in communication systems. Through simulation outputs and comparative analysis, the report highlights the advantages and disadvantages of the techniques, focusing on bandwidth efficiency and noise tolerance. The findings underscore the importance of understanding these modulation techniques in optimising communication performance in noisy environments.

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Introduction

Since its discovery, radio has revolutionised communication, enabling the transmission of information over vast distances without the complexity of physical wiring. Early systems like those developed by Guglielmo Marconi relied on basic binary "on-off" signalling methods via spark gap transmitters. However, the dream to transmit more complex data, such as speech and music, saw the development of more advanced techniques.[1]

This progress led to the beginnings of radio modulation, which now forms the foundations of modern wireless communication. One of the earliest techniques is Amplitude Modulation (AM). This involves varying the amplitude of a high-frequency carrier wave in proportion to the amplitude of the information signal, enabling the transmission of voice wirelessly for the first time.

This report will explore the impact of noise on different AM techniques, focusing on how noise affects signal quality and demodulation performance. By looking at not only AM but also systems developed from the basic AM, such as Single Sideband Suppressed Carrier (SSB-SC) and Double Sideband Suppressed Carrier (DSB-SC), this study aims to compare their performance in terms of bandwidth efficiency, power consumption, and noise tolerance. The findings will help to understand the complexities faced by early radio engineers.

Background research

The development of radio modulation was a revolutionary leap in communication technology. One of the earliest and most widely employed modulation techniques is Amplitude Modulation (AM). This method uses a high-frequency carrier wave, typically a single-tone sine wave, which varies in amplitude in direct correlation with the amplitude of the information signal. This mixing results in a signal containing the carrier frequency and, more importantly, the data in two sidebands. This modulation was the first to deliver audio signals, such as voice and later music, over considerable distances.[1][1. 2]

However, as technology and understanding progressed, variations of AM were developed to address specific challenges and enhance the overall performance of communication systems. Two main modulations are Double-Sideband Suppressed Carrier (DSB-SC) and Single-Sideband Suppressed Carrier (SSB-SC).[2. [2. 3. [2. 3. 4]

Double Sideband Suppressed Carrier (DSB-SC) improves the power efficiency of the original AM by eliminating the carrier signal while retaining both sidebands. This improves energy efficiency while

maintaining the transmitted signal's integrity. This modulation is especially beneficial for a range of analogue communication applications, such as transmitting a stereo signal, with each sideband containing either the left or right channel of the signal.



Single Sideband Suppressed Carrier (SSB-SC) takes this further by transmitting only one of the two sidebands, which helps optimise bandwidth and energy efficiency. This allows for a greater transmission range, as it minimises the frequency spectrum required and reduces the effect of noise.

Despite the innovations represented by DSB-SC and SSB-SC, noise remains an inherent and persistent challenge in communication systems, especially analogue-based ones. Noise is created from various sources, including channel interference, thermal noise associated with the electronic components, and environmental factors. These elements can severely degrade signal quality and overall transmission performance. Therefore, evaluating how different amplitude modulation (AM) techniques perform in noisy environments is vital to ensure clear communication.



Literature Review

Amplitude modulation (AM) techniques have been widely used since the beginning of radio communications, and their efficiency under noisy channels has been studied and modelled. Communication texts have documented these concepts of AM, particularly Double-Sideband Suppressed Carrier (DSB-SC) and Single-Sideband Suppressed Carrier (SSB-SC).

Various studies have conducted a comparative analysis of DSB-SC and SSB-SC systems, demonstrating that SSB-SC provides better bandwidth efficiency by transmitting only one sideband, thus reducing redundancy.

Other studies have explored the impact of noise on AM systems. Their research showed that traditional AM systems with a carrier are more susceptible to noise because carrier and sidebands consume additional power without directly contributing to the information content. By contrast, DSB-SC and SSB-SC systems suppress the carrier and redundant sidebands, improving power efficiency and noise resilience. However, they also highlighted that coherent detection in these systems requires exact synchronisation of the carrier signal at the receiver, making them more prone to errors in practical scenarios. [5, [3, 5, [3, 5, 6]



Circuit design/Block Diagram/Transmitter and Receiver Architectures

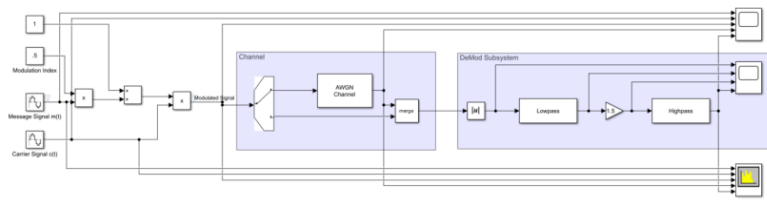


Figure 1 - AM Simulink Model

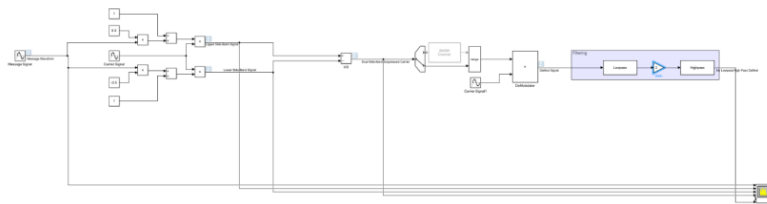


Figure 2 - Double Side Band - Suppressed Carrier

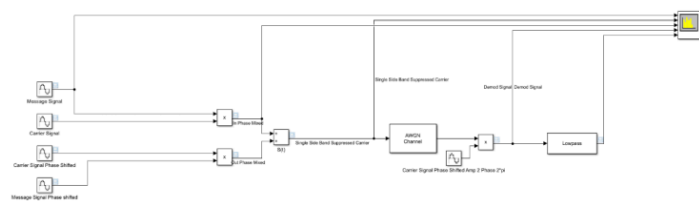


Figure 3 - Single Side Band - Suppressed Carrier

Simulated Outputs/ Results

Task One

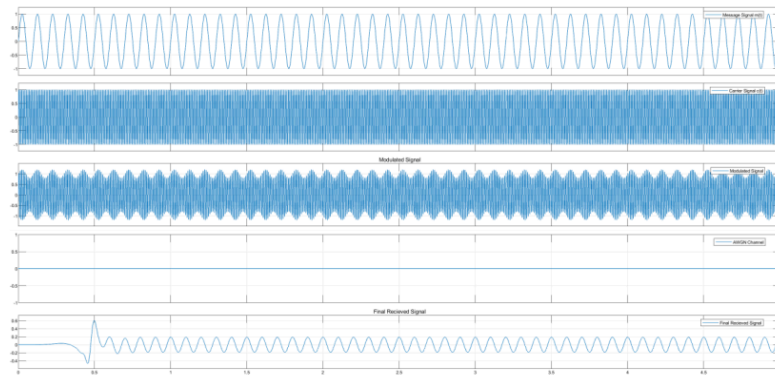


Figure 4 - Modulation Index 0.2 - Scope

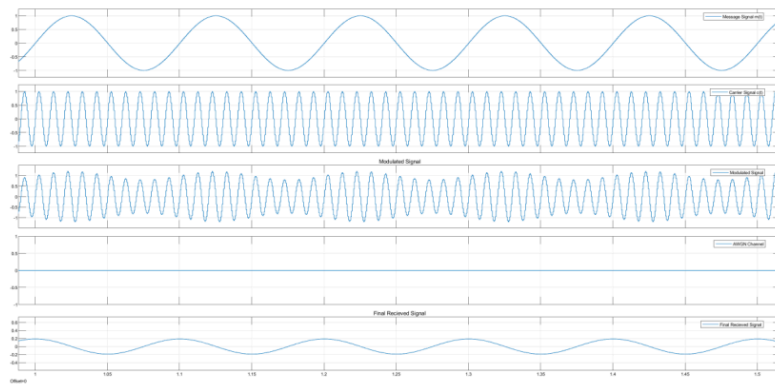


Figure 5 - Modulation Index 0.2 - Zoomed Scope

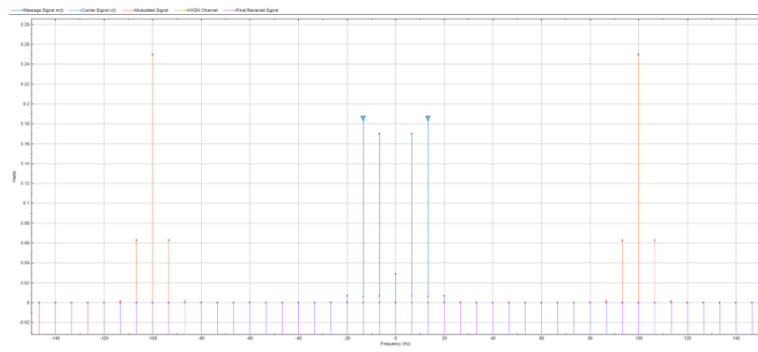


Figure 6 - Modulation Index 0.2 - Spectrum Analyser Output

Task One Continued

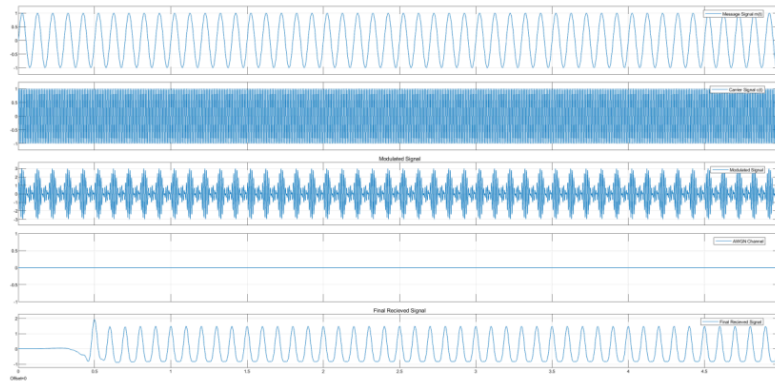


Figure 7 - Modulation Index 2 - Scope

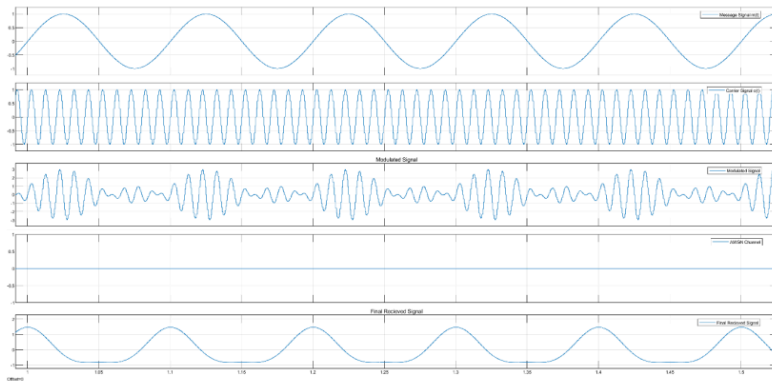


Figure 8 - Modulation Index 2 - Zoomed Scope

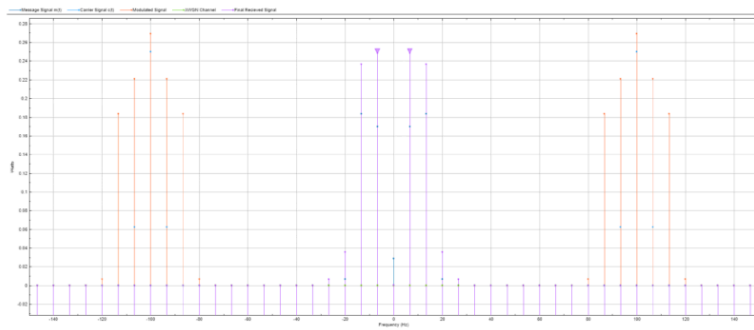


Figure 9 - Modulation Index 2 - Spectrum Analyser

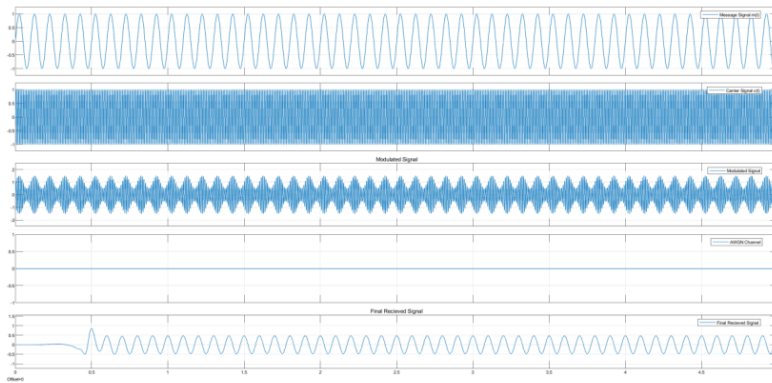


Figure 10 - Modulation Index 0.5 – Scope

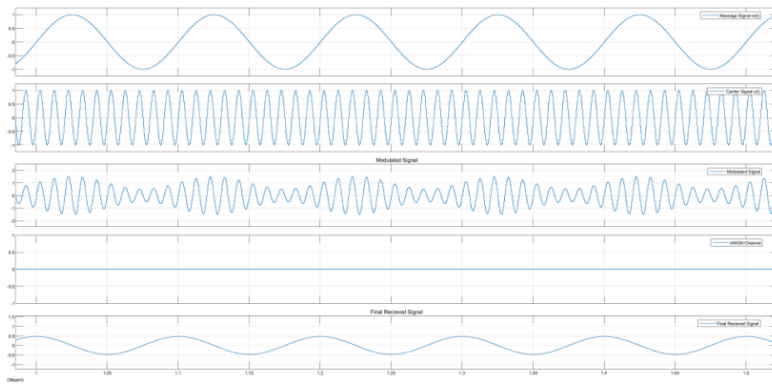


Figure 11 - Modulation Index 0.5 - Zoomed Scope

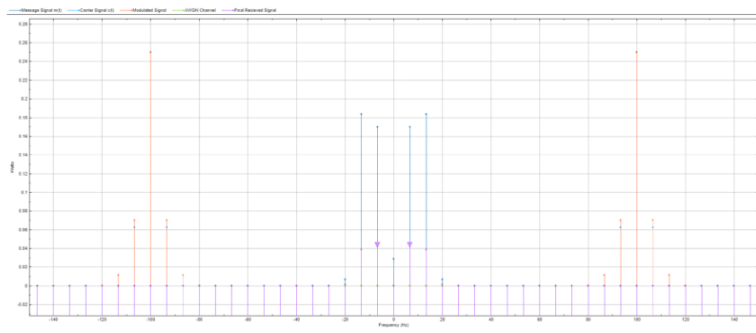


Figure 12 - Modulation Index 1 - Spectrum Analyser

Task Two

Part A

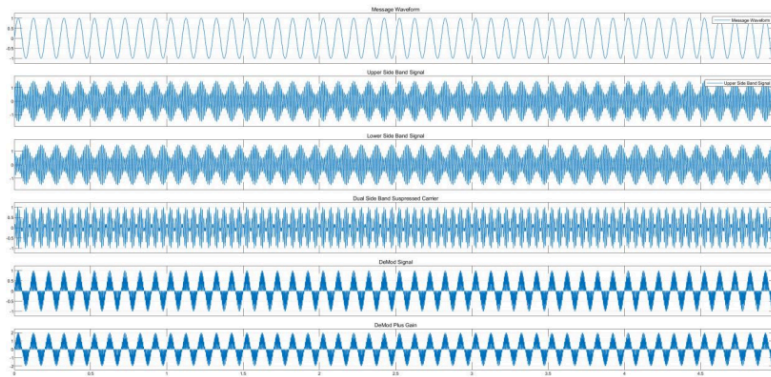


Figure 13 - DSB-SC - Modulation Index 0.5 – Scope

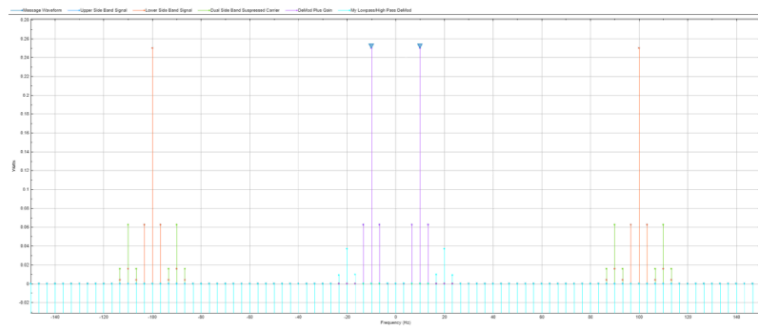


Figure 14 - DSB-SC - Modulation Index 0.5 -Spectrum Analyser

Part B

With AWGN SNR of zero IE, the same amount of noise as the signal

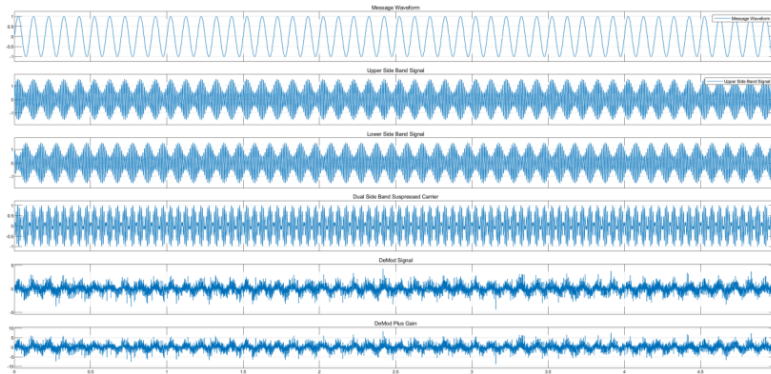


Figure 15 -DSB-SC - With AWGN at a SNR of 0 – Scope

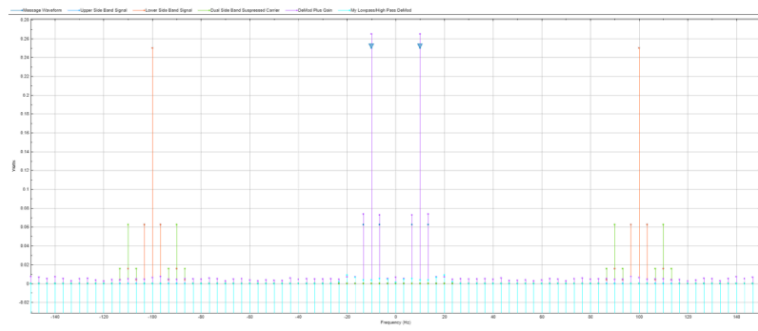


Figure 16 -DSB-SC - With AWGN at a SNR of 0- Spectrum Analyser

SNR AT -10

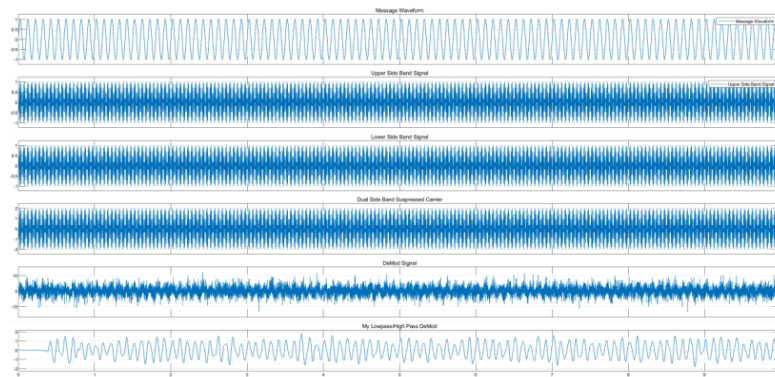


Figure 17 - -DSB-SC - With AWGN at a SNR of -10

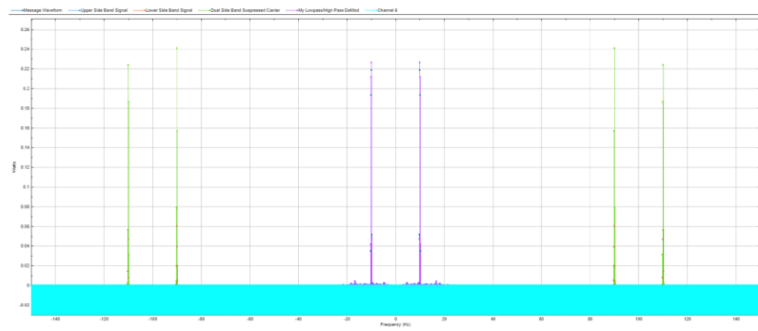


Figure 18 - DSB-SC - With AWGN at a SNR of 0

Task Three

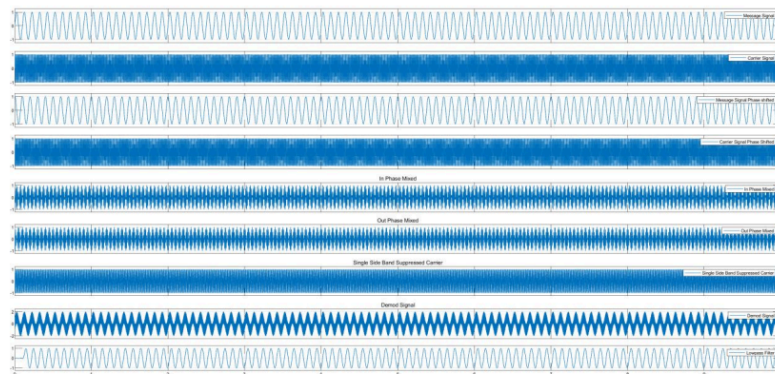


Figure 19 - SSB-SC - Scope

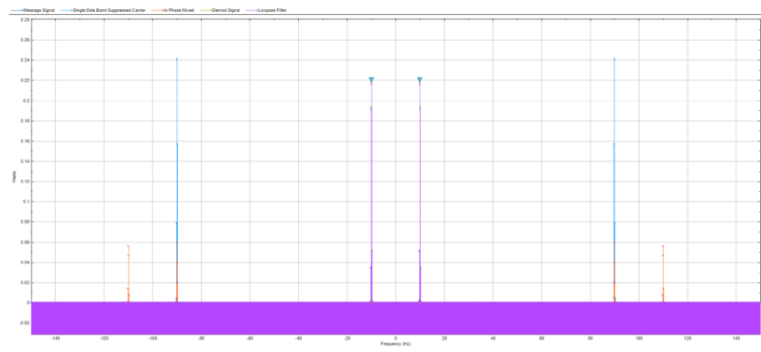


Figure 20 - SSB-SC - Spectrum Analyser

SNR at 0

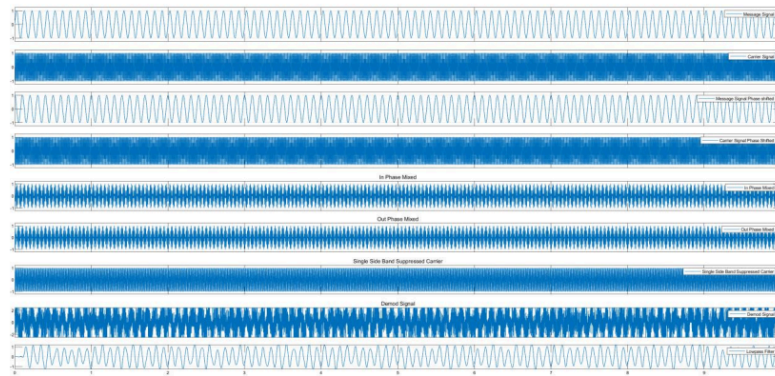


Figure 21 - SSB-SC - With AWGN at a SNR of 0 - Scope

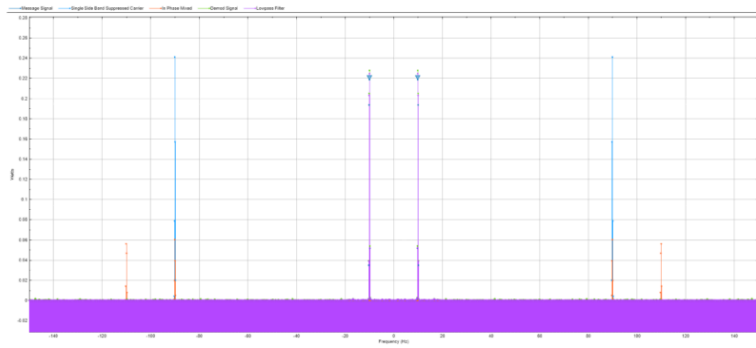


Figure 22 - SSB-SC - With AWGN at a SNR of 0 – Spectrum Analyser

SNR at -10

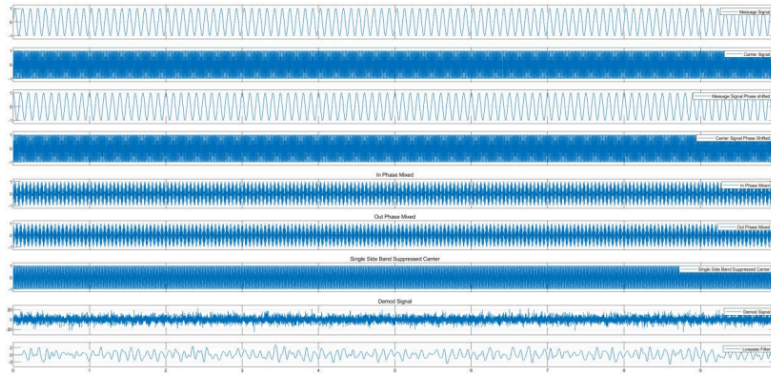


Figure 23 - SSB-SC - With AWGN at a SNR of -10 - Scope

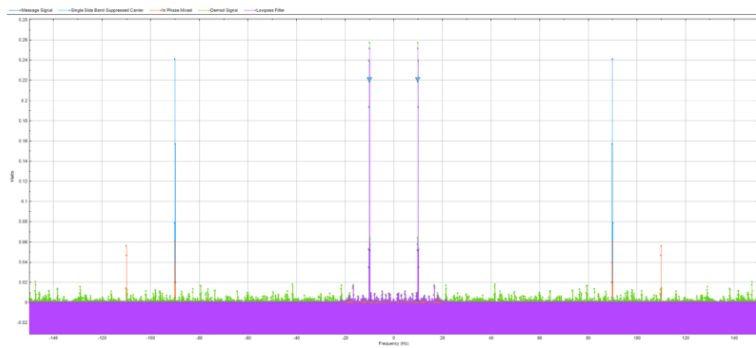


Figure 24 - SSB-SC - With AWGN at a SNR of -10 - Spectrum Analyser

Analysing the Results.

Task One

Using the last digit of the author's student ID (2, therefore 0.2) as the modulation index, the following is noticed in Figure 4—Modulation Index 0.2—Scope: The modulating signal only minimally affects the carrier signal. This produces only a weak modulation effect, i.e., minor amplitude variations to the carrier waveform. Therefore, this can be classed as under-modulated. While this can prevent distortion, it limits the strength of the transmitted signal, which impacts signal clarity and, therefore, demodulation is harder. [3. [3. 4. [2. 3. 4]

Compare this under modulation to the Figure 7 - Modulation Index 2 - Scope where the modulation index is greater than 1, i.e. the message signal amplitude is greater than that of the carrier frequency amplitude. This causes the mixed signal to invert during lulls in the carrier, resulting in severe distortion, known as "envelope clipping," making the signal difficult or impossible to demodulate accurately using envelope detection. [3. [3. 4. [2. 3. 4]. Overmodulation of a signal leads to a complete loss of signal integrity.

Finally, Critical Modulation is shown in Figure 10 - Modulation Index 0.5 - Scope. This shows an optimal balance where the carrier amplitude is modulated sufficiently but without distortion. The mixed waveform is clean and symmetric, allowing for envelope detection when demodulating. This is the ideal scenario in AM systems to achieve efficient transmission and reception.

Task Two

Part A DSB-SC Modulation and Demodulation Without AGWN

To begin with let's focus on viewing in the time domain using Figure 13 - DSB-SC - Modulation Index 0.5 - Scope. The mixed signal is visible as a high-frequency waveform oscillating at the carrier frequency (100 Hz). As with, basic AM the amplitude of the waveform varies in proportion to the modulating signal. This also continues as the envelope of the modulated signal reflects the shape of the modulating signal as with basic AM.

It is with the frequency domain Figure 14 - DSB-SC - Modulation Index 0.5 - Spectrum Analyser, that differences are apparent. Once again, there are similarities with the basic AM as the spectrum exhibits the same two sidebands, the Upper Sideband (USB) at 110 Hz and the Lower Sideband (LSB)

at 90 Hz. However, the carrier frequency will not be visible with this modulation scheme, as it is suppressed.

Part B DSB-SC Modulation and Demodulation With AGWN

Within the time domain shown in Figure 15 -DSB-SC - With AWGN at a SNR of 0 – Scope, AWGN is used to represent random noise with the channel on the DSB-SC signal. This causes the waveform to appear irregular, with random fluctuations in both amplitude and phase. As a result, the envelope that represents the modulating signal becomes increasingly difficult to distinguish.

When viewed in the frequency domain Figure 16 -DSB-SC - With AWGN at a SNR of 0- Spectrum Analyser and Figure 18 - -DSB-SC - With AWGN at a SNR of 0, the spectrum displays the original sidebands but also additional noise components spread across the frequency range. This noise creates a "fuzzy" floor around the sidebands, which could mask weaker signal components.

This leads to the demodulated signal being distorted due to the presence of the noise. The random fluctuations in amplitude makes it harder to recognise the recovered signal, particularly when the signal-to-noise ratio (SNR) is low.



Task Three

Part A SSB-SC Modulation and Demodulation Without Noise

When viewing the SSB-SC signal within the time domain Figure 19 - SSB-SC – Scope. The signal matches both the AM and DSB-SC on the scope. Once again, differences are visible only in the frequency domain Figure 20 - SSB-SC - Spectrum Analyser. This time, the spectrum displays only one sideband. The absence of the carrier and the other sideband confirms the suppression of redundant components, leading to more efficient bandwidth usage. [3. [3. 4. [2. 3. 4]

Part B SSB-SC Modulation and Demodulation With Noise

When viewed in the time domain Figure 21 - SSB-SC - With AWGN at a SNR of 0 - Scope, The SSB-SC signal exhibits random fluctuations due to the noise superimposed on the modulated waveform, showing similarities to both the AM and DSB-SC results. This similarity continues when viewed in the frequency domain Figure 22 - SSB-SC - With AWGN at a SNR of 0 – Spectrum Analyser. The spectrum displays the single sideband with additional noise spread across the frequency range. This noise adds small, random spectral components around the frequency of the original signal.

When demodulating the signal with noise, as with the previous modulations, the recovered signal is distorted, showing random fluctuations that include amplitude clipping or smoothing due to noise interference. By increasing the noise level, the original signal is unrecognisable. Figure 23 - SSB-SC - With AWGN at a SNR of -10 - Scope

Task Four

As previously discussed, the differences in the systems are clear within the frequency domain. The basic AM is dominated by its carrier frequency, which has the highest peak power. However, the power and spectral efficiency are poor because this carrier does not contain any of the desired message signals (the message is in the sidebands).

DSB-SC improves on this by suppressing the superfluous carrier, leaving the two side bands.



Although this improves power consumption, its spectral usage is still the same as the basic AM. However, this can be used to its advantage if, rather than both sidebands containing the same data, the sidebands are used to transmit parallel data, i.e., stereo audio. [7]

SSB-SC is the most efficient system investigated in this report, as both the carrier and one of the sidebands are suppressed. This allows all the power to be focused on transmitting the required data. It also improves the spectral efficiency by reducing the bandwidth to only that of the sideband.

However, this efficiency does come at a cost. Successful demodulation depends on accurate phase and frequency synchronisation. Noise can affect both factors, so SSB-SC is not ideally suited for high-noise environments. In these environments, DSB-SC would be a better choice. Although it is not as efficient, when the same data is transmitted on both side bands, it leads to a degree of redundancy that assists in demodulating. Basic AM, again, is slightly more tolerant to noise due to its simplicity in demodulating the received signal.

Conclusion

In conclusion, Double-Sideband Suppressed Carrier (DSB-SC) and Single-Sideband Suppressed Carrier (SSB-SC) modulation and demodulation analysis highlight their performance under various noise conditions.

Without noise, both DSB-SC and SSB-SC effectively transmit the modulated signal. DSB-SC features two sidebands around the carrier frequency, offering an improvement over AM but still requiring the same bandwidth. In contrast, SSB-SC transmits only one sideband, improving bandwidth efficiency while maintaining signal intelligibility.

However, noise impacts both schemes differently. DSB-SC is susceptible to distortion, particularly at lower signal-to-noise ratios (SNRs), leading to degraded signal quality. SSB-SC is also affected by noise, and the complexity of demodulating it can hamper receiving clean data.

These findings emphasise the importance of SNR in communication systems and the need to choose the appropriate modulation technique based on the environment. While DSB-SC may be suitable for less noisy applications, SSB-SC is preferable when bandwidth efficiency and noise resistance are critical. Understanding these differences can guide professionals in selecting the proper modulation method for their needs.

References

- [1] S. J. Potter, *The wireless world : global histories of international radio broadcasting*, Oxford: Oxford University Press, 2022.
- [2] M. A. Bhagyaveni, *Introduction to Analog and Digital Communication*, 1st Ed. United Kingdom: River Publishers, 2016.
- [3] M. S. Alencar, *Modulation Theory*, 1st Ed. New York: River Publishers, 2022.
- [4] S. Stevenson, *Analog Modulation and Digital Modulation*, World Technologies, 2014. [Online]. Available: <https://www.perlego.com/book/1240624/analog-modulation-and-digital-modulation-pdf>
- [5] R. E. Blahut, *Modem theory : an introduction to telecommunications*, 1st Ed. Cambridge, UK :: Cambridge University Press, 2010.
- [6] A. K. Nandi and E. E. Azzouz, "Automatic analogue modulation recognition," *Signal Process*, vol. 46, no. 2, pp.211–222, 1995. doi: 10.1016/0165-1684(95)00083-P.

- [7] "Double Sideband Suppressed Carrier (DSB-SC) Modulation | Communication System - Electronics and Communication Engineering (ECE) PDF Download."
<https://edurev.in/t/245349/Double-Sideband-Suppressed-Carrier--DSB-SC--Modula>
(accessed Jan 2).

RFS Report

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

61 /100

PAGE 1

PAGE 2

PAGE 3



Comment 1 | Knowledge & Understanding (20)

The evolution of radio is well explained.



Comment 2 | Engagement with literature(10)

Avoid citation inaccuracies

PAGE 4



Comment 3 | Engagement with literature(10)

The example provided for DSB-SC is well-appreciated, but adding more example would enhance clarity.



Comment 4 | Knowledge & Understanding (20)

Mentioning about noise in modulation is seen.



Comment 5 | Engagement with literature(10)

Critically analyse previous research, identifying gaps and limitations.



Comment 6 | Engagement with literature(10)

The discussion on noise impact in AM systems is clear and well-structured, effectively addressing power efficiency

PAGE 5



Comment 7 | Practical Application (30)

The Simulink blocks are well-captured and clearly presented.

PAGE 6

PAGE 7



Comment 8 | Knowledge & Understanding (20)

The outputs align well with the expected results, demonstrating a strong understanding of the AM modulation processes.

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Comment 9 | Practical Application (30)

The use of different modulation index values to distinguish under, critical, and overmodulation is well-executed, with time and frequency scope neatly captured.



Comment 10 | Practical Application (30)

The effect of distortion is noted, but analysing how variations in modulation index impact amplitude and power in signals.



Comment 11 | Knowledge & Understanding (20)

The technical explanation of balanced modulation for DSB-SC is not included.

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Comment 12 | Cognitive skills (20)

Analysing different SNR level with respect to the amplitude, Power levels are essential to compare deviations caused by different random noise levels.



Comment 13 | Cognitive skills (20)

The signal analysis values are essential to prove this statement.

PAGE 19



Comment 14 | Knowledge & Understanding (20)

More explanation is needed to explain how carrier suppression is achieved in SSB-SC using phase discriminator.



Comment 15 | Practical Application (30)

The block construction and scope screenshots for DSB-SC are well-presented, but a brief explanation of carrier suppression through balanced modulation would be better.



Comment 16 | Cognitive skills (20)

Observing power, frequency, and SNR variations and their impact on amplitude and power would add depth to the study.



Comment 17 | Transferable skills (20)

Transferable skills such as technical knowledge contributing to a structured and good presentation.



Comment 18 | Cognitive skills (20)

To effectively analyse and compare the results of all modulation techniques, it is important to theoretically calculate power, SNR, and Figure of Merit. Ensuring these calculations align with practical results would strengthen the conclusions.

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GRADING FORM: RF_UPDATED_2025

JAMES HUNT

61.18

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 needs is limited.

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 modulation with minimal detail. Observations lack

10.9

clarity.

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

Task 2: (a) Task explains basic concepts of DSB SC modulation but lacks depth and clear connection to theory.

Task 2: (b) Noise effects are explained well but it is necessary to calculate the theoretical values of SNR(in/Out), Figure of Merit, Power to compare with the values obtained after simulation.

Task 3: (a) describes SSB SC modulation with minimal detail, and noise analysis is lacking.

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

Task 4: (a) Spectrum and power density are weakly analysed. Noise tolerance is barely mentioned.

Task 4: (b) Comparison of modulation techniques is minimal and misses important aspects like power/noise resistance

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 is explained but has gaps. Comparisons are basic, and metrics like spectrum, time scope, or the effect of modulation indices are not well discussed.

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 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.

8.88

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 use of tools and clear demonstration of signals with a deep understanding of the working.
Task 1 (a) (ii): Demonstrates modulation variations but lacks detailed insights into carrier impact.
Task 1 (b): Thorough explanation of AM demodulation. Results are accurate and strong theoretical alignment. Block diagrams are well-designed and correctly represent the process.
Task 2 (a): Demonstrates accurate DSB-SC modulation. Observations are precise, and tools are used effectively.
Task 2 (b): Noise analysis is thorough and aligns with theoretical expectations. Observations are well-documented.
Task 3 (a): Successfully implements SSB-SC modulation with accurate signal analysis using phase discriminator. Task 3 (b): Noise analysis is comprehensive, with clear and precise documentation of observations.
Task 4 (a): Limited understanding of the processes, with observations that are vague or poorly aligned with theory.
Task 4 (b): Comparisons are only with the references

21.9

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.

13

