

RF_Systems_Laboratory_Report _Alistair_Lounds_2227990

by Alistair Lounds

Submission date: 05-Jan-2025 11:41PM (UTC+0000)

Submission ID: 247238732

File name:

43539_Alistair_Lounds_RF_Systems_Laboratory_Report_Alistair_Lounds_2227990_629023_1480906373.docx
(1.27M)

Word count: 2745

Character count: 15178



Investigating the Effect of Noise in SSB-SC and DSB- SC

By Alistair Lounds 2227990

Supervisor: Jenifer Prince Devaraj

Second Marker: Dr Stephen Mosey

Project submitted as part of the requirements for the award of
BEng (Hons) Embedded Electronic Systems Design

December 2024

Table of Contents

Introduction.....	3
Background Research & Literature Review	3
Circuit Design.....	3
Transmitter & Receiver Architectures	5
Examining the AM Signal.....	5
Varying Modulation Index for the AM Signal	6
Comparison of Modulated and Demodulated AM Signal.....	7
Implementation of the DSB-SC Modulator.....	7
Effect of AWGN on the DSB-SC Signal.....	8
Implementation of the SSB-SC Modulator	9
Effect of AWGN on the SSB-SC Signal.....	10
Simulated Outputs & Results.....	12
Simulation Results	12
Analysis of Results	12
Conclusion	13
Recommendations for Future Work.....	13
References.....	13

Table of Figures

Figure 1 – AM Simulink Block Diagram	4
Figure 2 - DSB-SC Simulink Block Diagram	4
Figure 3 - SSB-SC Simulink Block Diagram.....	5
Figure 4 – AM in the Time Domain	5
Figure 5 – AM in the Frequency Domain	6
Figure 6 – Modulation Index Formula [8]	6
Figure 7 – DSB-SC in the Time Domain	7
Figure 8 – DSB-SC in the Frequency Domain	8
Figure 9 – DSB-SC Simulink Block Diagram with AWGN.....	8
Figure 10 - SSB-SC in the Time Domain.....	10
Figure 11 – SSB-SC in the Frequency Domain.....	10
Figure 12 – SSB-SC Simulink Block Diagram with AWGN	11
Figure 13 – Power Density Measurement for AM, DSB-SC and SSB-SC Systems	12

Table of Tables

Table 1 – Signal Statistics of the AM Signals	7
Table 2 – Oscilloscope showing the Distorted DSB-SC Signal in the Time Domain	9
Table 3 - Power Density of Demodulated DSB-SC Signal in the Frequency Domain	9
Table 4 – Oscilloscope showing the Distorted SSB-SC Signal in the Time Domain	11
Table 5 – Power Density of Demodulated SSB-SC Signal in the Frequency Domain	12
Table 6 – Bandwidth Measurements for AM, DSB-SC, and SSB-SC Systems.....	12

Introduction

This report details the comparison of analogue modulation techniques and how the presence of Additive White Gaussian Noise (AWGN) effects the performance of Single-Sideband Suppressed-Carrier (SSB-SC) and Double-Sideband Suppressed-Carrier (DSB-SC) systems. This has been conducted by modelling and simulating these modulation techniques using MathWorks MATLAB Simulink R2023b Version 23.2.0. [1]

Background Research & Literature Review

In this report, the following analogue techniques have been investigated using data collected from models developed using MATLAB Simulink:

AM

Amplitude Modulation (AM) is an analogue modulation technique where the message signal is multiplied by the desired carrier signal, varying the amplitude of the transmitter signal. This encodes the data into the signal so it can be transmitted over different mediums. [2]

DSB-SC

Double-Sideband Suppressed-Carrier (DSB-SC) is an Amplitude Modulation technique where data is transmitted using two sidebands that are symmetrical, while the carrier signal does not appear in the transmission. [3]

SSB-SC

Single-Sideband Suppressed-Carrier (SSB-SC) is an Amplitude Modulation technique where data is transmitted using only one sideband, with the carrier signal not appearing in the received transmission. [4]

Literature Review

Experimentation surrounding the performance of AM, SSB-SC and DSB-SC can be found documented in existing literature and research. For example, in March 2017 by students of St. Vincent Pallotti College and Engineering and Technology Nagpur India, whom used MathWorks Simulink and their own source code to design and simulate models for DSB-SC and analyse the effect of introducing AWGN to the model, on the simulation results. [5] Similar research projects have also been conducted by students of the Maharaja Agrasen Institute of Technology and Delhi Technological University, all in which utilise Matlab Simulink. [6]

Circuit Design

MATLAB Simulink was used to design models for the simulation of AM, DSB-SC and SSB-SC individually, while enabling the introduction of AWGN to the system and vary variables such as modulation index. For each simulation conducted a time period of 50 seconds was used.

AM Model

Figure 1 shows the block diagram model produced to simulate AM using MATLAB Simulink R2023b.

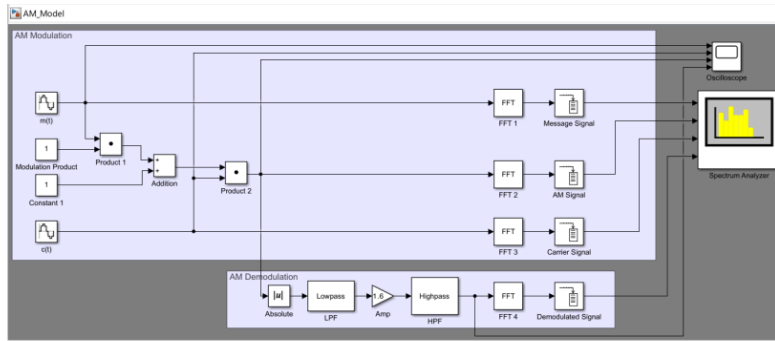


Figure 1 – AM Simulink Block Diagram

DSB-SC Model

Figure 2 shows the block diagram model produced to simulate DSB-SC using MATLAB Simulink R2023b.

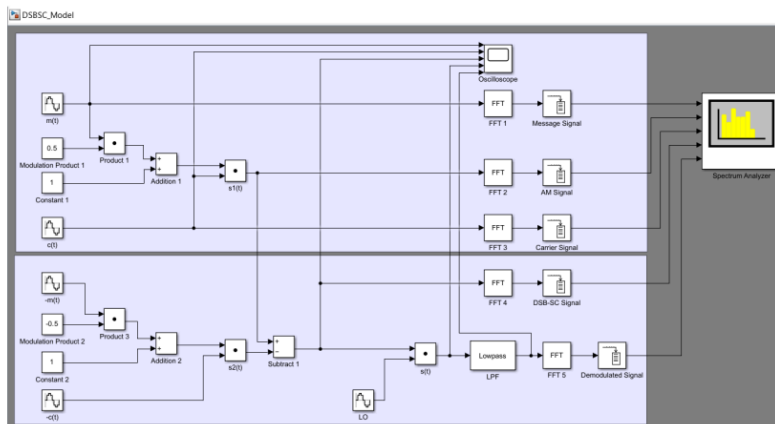


Figure 2 - DSB-SC Simulink Block Diagram

SSB-SC Model

Figure 3 shows the block diagram model produced to simulate SSB-SC using MATLAB Simulink R2023b.

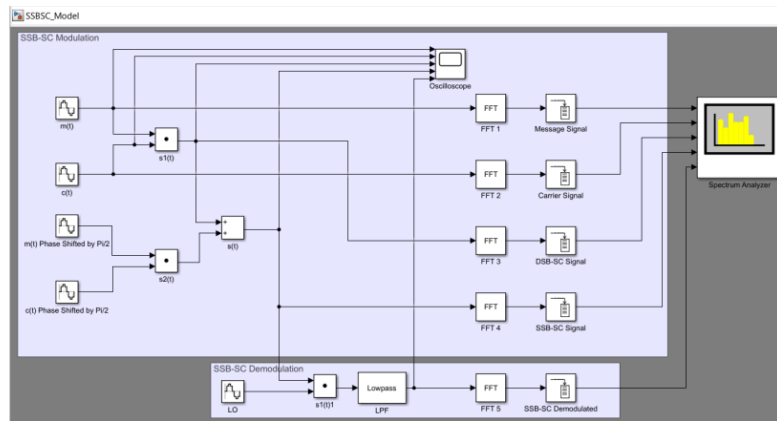


Figure 3 - SSB-SC Simulink Block Diagram

5

Transmitter & Receiver Architectures

Examining the AM Signal

In order to examine the AM signal, the angular frequency of the carrier signal (ω_c) was set as ' $2\pi(100)$ ' and the angular frequency of the message signal (ω_m) was set as ' $2\pi(10)$ '. This task required the use of the Modulation Index table stated in the assignment description. As the last digit of my student identification number is '0', a Modulation Index of 1 was used, therefore being Critical Modulated for this experiment.

6

Figure 4 shows the AM model in the Time Domain, using an oscilloscope.

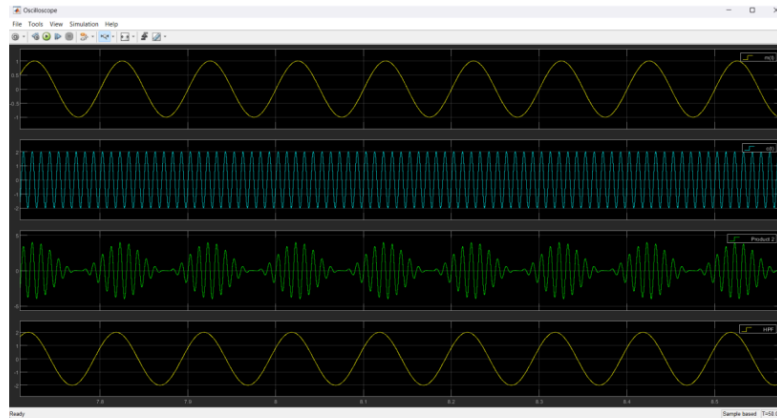


Figure 4 – AM in the Time Domain

Figure 5 shows the AM Model in the Frequency Domain using a spectrum analyser.

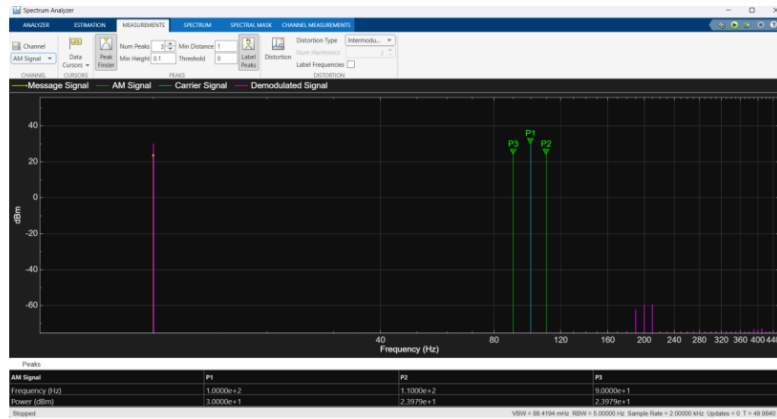


Figure 5 – AM in the Frequency Domain

Figure 4 shows that Modulated Carrier signal has a peak amplitude of 3.975, with its peak to peak value being 7.161; this was determined by using the signal statistics tool. Figure 5 shows the Carrier signal is transmitted alongside the Lower Sideband (LSB) and Upper Sideband (USB) of the AM signal. This varies from DSB-SC and SSB-SC as the carrier signal is not suppressed. The sidebands of the AM signal were observed to be lower in power than the Carrier signal, with both the LSB and USB having power of 23.979 dBm at 90 Hz and 110 Hz respectively. The spectrum analyser shows the Carrier power to be 30 dBm. From this we can also determine that there is a Total signal bandwidth of 20 Hz. Another observation is that the Demodulated signal produced has a power of 30.038 dBm, a value of 0.038 dBm greater than the carrier transmitted. This model is less representative of AM in the real world conditions due to lack of noise. This model could be more realistic with the addition of AWGN.

Varying Modulation Index for the AM Signal

By viewing the AM signal in the Time Domain, we can observe the effect of Modulation Index on the modulated carrier. Figure 6 shows the formula used to calculate modulation index for AM signals. Under-Modulation is where the Carrier Signal's amplitude is greater than Message Signal amplitude, giving a Modulation Index less than 1. Critical Modulation is where these are equal, having a Modulation Index of 1. Over-Modulation is where the Message Signal amplitude is greater than the Carrier Signal amplitude, giving a Modulation Index greater than 1. [7]

$$m = \frac{A_m}{A_c}$$

Where:

m – Modulation Index

A_m – Amplitude of Message Signal

A_c – Amplitude of Carrier Signal

Figure 6 – Modulation Index Formula [8]

Table 1 shows statistics for the AM signal across an array of Modulation Index values.

Modulation Index	Under-Modulated	Under-Modulated	Under-Modulated	Critical	Over-Modulated	Over-Modulated	Over-Modulated
	0.4	0.6	0.8	1	1.2	1.4	1.6
Max	2.790	3.185	3.580	3.975	4.370	4.766	5.161
Min	-2.790	-3.185	-3.580	-3.975	-4.370	-4.766	-5.161
Peak to Peak	5.580	6.370	7.161	7.951	8.741	9.531	10.320
RMS	1.485	1.537	1.625	1.763	1.855	1.990	2.135

Table 1 – Signal Statistics of the AM Signals

Table 1 shows that when the AM signal is Over-Modulated (across Modulation Index values 1.2 to 1.6) the amplitude of the signal is increased to a point in which signals become distorted; providing a poor/degraded signal quality. Therefore utilising power less efficiently. In comparison, when the AM signal is Under-Modulated (Modulation Index of 0.4 to 0.8) the amplitude of the signal reduces, indicating lower transmission output and quality. This could result in worse signal to noise ratios, with the transmission easily overcome by unwanted noise. Critical Modulation is said to be the optimal modulation level, as it provides the clearest transmissions, not causing distorting being more efficient than Under-Modulation. This was difficult to observe from the small dataset collected. [9]

10

Comparison of Modulated and Demodulated AM Signal

When observing the Modulated and Demodulated AM signal, we can see that the carrier signal, LSB and USB signals are present, while only the baseband message signal is present for the Demodulated signal. The modulated signal consists of a carrier signal that is varied in proportion to the message signal. Figure 5 shows that's the Demodulated AM signal is a lower frequency than the Modulated signal, being 10 Hz, while the Modulated signal has power distributed across the Upper Sideband at 110 Hz, the Lower Sideband at 90 Hz and the non suppressed carrier signal at 100 Hz. Therefore the Modulated signal require more bandwidth than the Demodulated signal.

11

Implementation of the DSB-SC Modulator

Figure 7 shows the implementation of the DSB-SC modulator using the Balanced Modulator technique and the demodulated signal. This is shown in the Time Domain using an oscilloscope, where Modulation Index has been set to 0.5.

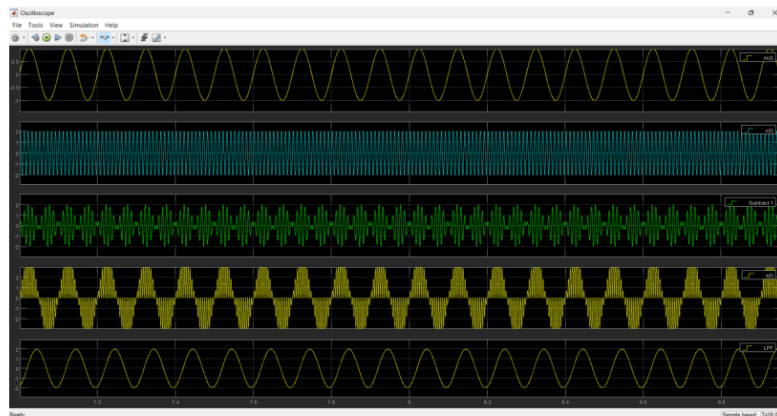


Figure 7 – DSB-SC in the Time Domain

Figure 8 shows the implementation of the DSB-SC modulator and the demodulated signal in the Frequency Domain using a Spectrum Analyser, where Modulation Index has been set to 0.5.

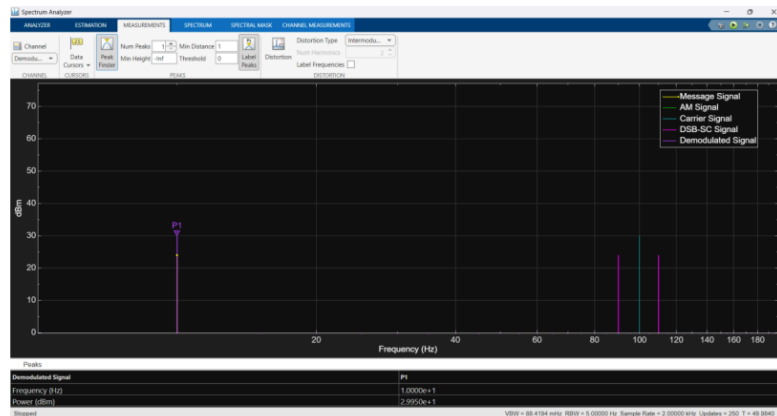


Figure 8 – DSB-SC in the Frequency Domain

Effect of AWGN on the DSB-SC Signal

Figure 9 shows that random noise has been introduced to the DSB-SC model using an AWGN block.

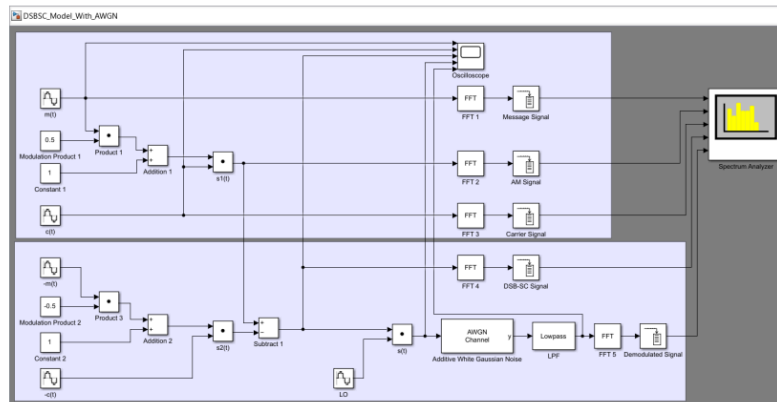


Figure 9 – DSB-SC Simulink Block Diagram with AWGN

Random noise was introduced to the DSB-SC model by adjusting the AWGN. Signal to Noise Ratio (SNR) levels of 0 dB, -10 dB, -20 dB and -30 dB respectively. As the noise power surpasses that of the wanted signal, the signal becomes distorted. This can be visually observed from Table 2. This can be compared to Figure 8 where the original transmitter signal is not distorted.

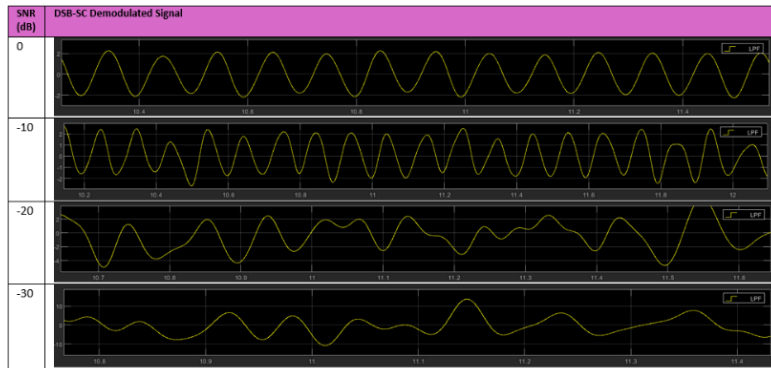


Table 2 – Oscilloscope showing the Distorted DSB-SC Signal in the Time Domain

The AWGN distorts the sidebands, resulting in a varied amplitude in the demodulated signal. This is shown by the increase in maximum amplitude as noise increases. When SNR is -30 dB the maximum amplitude of the DSB-SC signal is 13.58 compared to, 5.33 at -20 dB and 1.3 at -10 dB.

As the carrier signal is suppressed this makes it more challenging for the receiver to synchronise the local oscillator with the transmitted signal. As coherent detection is required (having the receiver synchronised with the transmitter in both frequency and phase) this makes it harder to recover the original transmitted message, introducing errors therefore resulting in a higher Bit Error Rate (BER).

Power Density of DSB-SC in the Frequency Domain				
SNR (dB)	0	-10	-20	-30
Power Density (dBm/Hz) (4sf)	22.95	22.88	23.08	28.05

Table 3 - Power Density of Demodulated DSB-SC Signal in the Frequency Domain

Table 3 shows the Distorted DSB-SC signals Power Density. These are comparative to the Power Density value of 22.96 dBm/Hz when there is no noise. Power Density decreases as AWGN increases until the SNR of -20 dB.

Implementation of the SSB-SC Modulator

Figure 10 shows the implementation of the SSB-SC modulator using the Phase Discriminator technique and the demodulated signal. This is shown in the Time Domain using an oscilloscope, where Modulation Index has been set to 0.5.

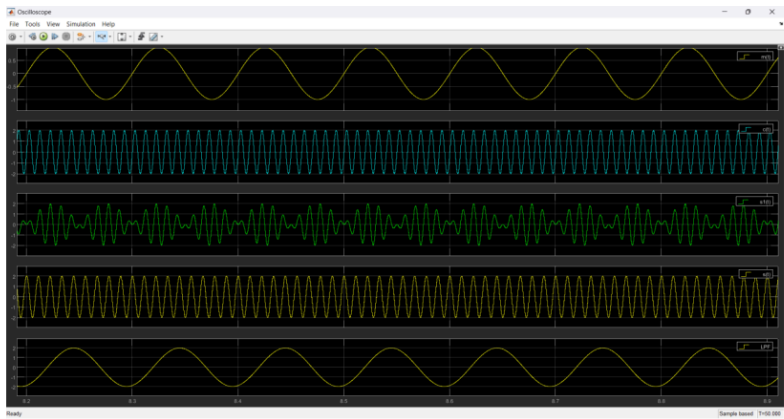


Figure 10 - SSB-SC in the Time Domain

Figure 11 shows the implementation of the SSB-SC modulator and the demodulated signal in the Frequency Domain using a spectrum analyser, where Modulation Index has been set to 0.5

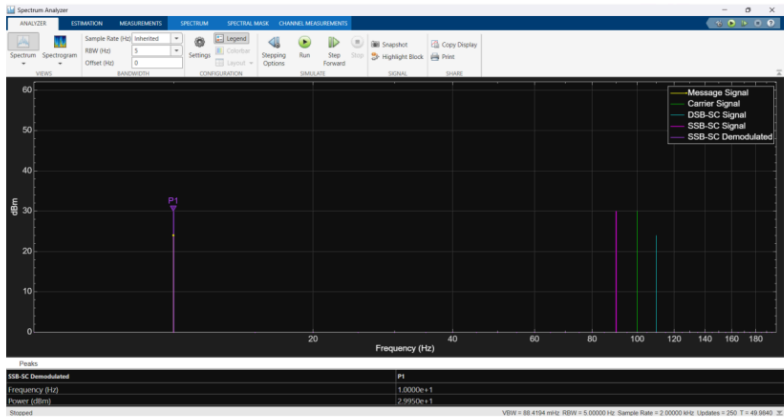


Figure 11 – SSB-SC in the Frequency Domain

Effect of AWGN on the SSB-SC Signal

16

Figure 12 shows that random noise has been introduced to the SSB-SC model using a AWGN block.

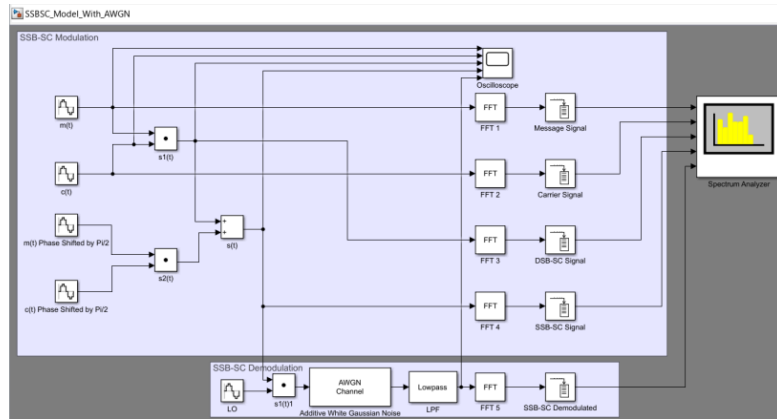


Figure 12 – SSB-SC Simulink Block Diagram with AWGN

Random noise was introduced to the SSB-SC model by adjusting the AWGN. Signal to Noise Ratio (SNR) levels of 0 dB, -10 dB, -20 dB and -30 dB respectively. As the noise power surpasses that of the wanted signal, the signal becomes distorted. This can be visually observed from Table 4. This can be compared to Figure 10 where the original transmitter signal is not distorted.

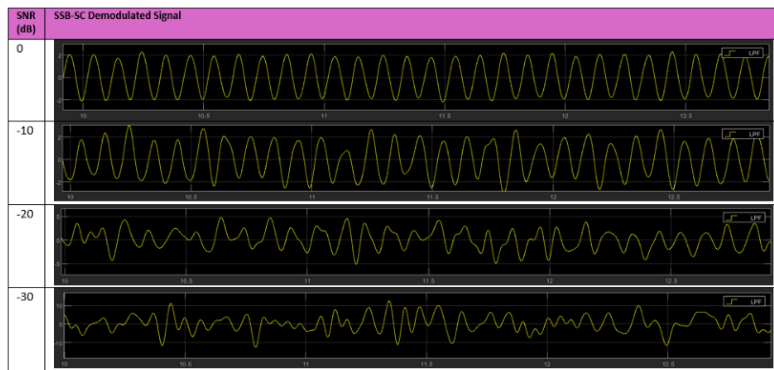


Table 4 – Oscilloscope showing the Distorted SSB-SC Signal in the Time Domain

The absence of the carrier in SSB-SC makes the signal more susceptible to noise. This noise makes can cause frequency and phase variations, causing demodulation to become more difficult. Therefore the AWGN distorts the signal, resulting in a varied amplitude in the demodulated signal. This is shown by the increase in minimum and maximum amplitude as noise increases. When SNR is -30 dB the maximum amplitude of the signal is 12.4 compared to 4.873 at -20 dB, and 3.007 at -10 dB.

Power Density of SSB-SC in the Frequency Domain				
SNR (dB)	0	-10	-20	-30
Power Density (dBm/Hz) (4sf)	22.92	22.81	22.46	28.41

Table 5 – Power Density of Demodulated SSB-SC Signal in the Frequency Domain

Table 5 shows the Distorted SSB-SC signals Power Density. These are comparative to the Power Density value of 22.96 dBm/Hz when there is no noise. This shows that as AWGN noise increases the power density of the signal decreases, with the signal becoming less efficient as it is distorted. However at an SNR of -30 dB Power Density increased.

18

Simulated Outputs & Results

Simulation Results

Figure 13 shows Power Density as AWGN is increased for the simulated AM, DSB-SC and SSB-SC models. This was determined in the frequency domain using the spectrum analyser, when modulation index is set to 0.5

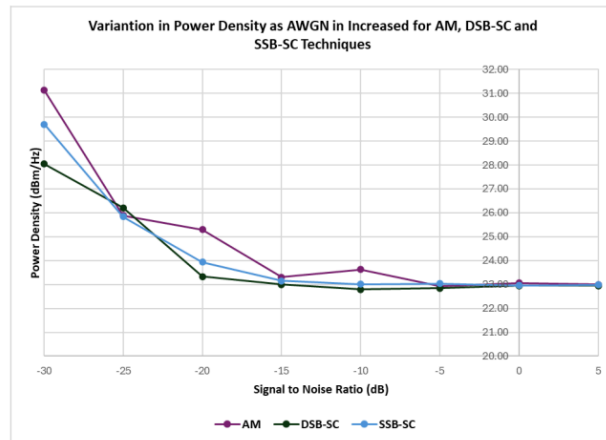


Figure 13 – Power Density Measurement for AM, DSB-SC and SSB-SC Systems

Table 6 shows the Bandwidth of the AM, DSB-SC and SSB-SC signals simulated.

Modulation Technique	AM	DSB-SC	SSB-SC
Bandwidth (Hz)	20	20	10

Table 6 – Bandwidth Measurements for AM, DSB-SC, and SSB-SC Systems

Analysis of Results

Table 6 shows us that AM and DSB-SC require double the bandwidth of SSB-SC signals. This suggests that SSB-SC provides greater bandwidth/spectral efficiency than DSB-SC and AM as it allows for information to be transferred with 50% less bandwidth use. However, it has not determine whether DSB-SC has greater bandwidth efficiency than AM.

Figure 13 shows that SSB-SC has higher power density than DSB-SC for all tested values of AWGN, accept for when SNR was -25 dB. Therefore this shows that SSB-SC has a higher total power output, therefore resulting in increased signal strength, and indicates higher performance. This is also an indication of higher efficiency in

power utilisation. Figure 13 also shows AM to have higher power density than the SSB-SC system, however there is less certainty in this data due to the high variance in results produced by the AM simulation.

When comparing Table 2 and Table 4, we observe that the SSB-SC system is more resilient to noise than the DSB-SC system. As AWGN is increased the DSB-SC system experiences greater distortion than the SSB-SC system. Therefore SSB-SC is preferable for use in environments where noise is high. The AM system is the most susceptible to noise experiencing distortion when SNR is at -5 dB and lower.

Therefore SSB-SC has the highest performance in terms of bandwidth efficiency, power utilisation and noise resistance; being closely followed by the DSB-SC. AM offers the poorest performance.

Conclusion

In this experiment, it has been determined that the SSB-SC has higher bandwidth efficiency than DSB-SC and AM. It also has a higher efficiency in power utilisation than DSB-SC. The SSB-SC system is the most resistant to noise; and DSB-SC is more resistant to noise than AM. As the level of AWGN increases DSB-SC and SSB-SC signals experience increased distortion, resulting in degraded signal quality.

21

20

Recommendations for Future Work

This experiment could be further improved by conducting more test serials at increased resolution to obtain larger datasets for the AM, SSB-SC and DSB-SC systems. This would reduce uncertainty in the data collected and enable a more detailed comparison of system performance. Scripting could be used to automate Simulink for more time efficient analysis of data.

References

- [1] The MathWorks, Inc, "R2023b Release Highlights - MATLAB and Simulink" Massachusetts: United States, Sep. 2023, [Online] Available: https://uk.mathworks.com/products/new_products/release2023b.html [accessed Dec 15. 2024]
- [2] Rohde & Schwarz. "Amplitude Modulation Technology", Munich: Germany, 2018, [Online] Available: https://www.rohde-schwarz.com/us/technologies/terrestrial-broadcast/am/am-technology/am-technology_55750.html [accessed Jan 3. 2025]
- [3] S. Hafizovic, Zurich Instruments AG, "Double-Sideband Suppressed-Carrier Modulation", Zurich: Switzerland, Aug. 2013, [Online] Available: <https://www.zhinst.com/europe/en/blogs/double-sideband-suppressed-carrier-modulation> [accessed Jan 3. 2025]
- [4] Rohini College of Engineering and Technology, "Single -sideband suppressed-carrier transmission (SSB-SC)" in "EC8491 Communication Theory", 2022, [Online] Available: https://www.rcet.org.in/uploads/academics/rohini_67750572916.pdf [accessed Jan 3. 2025]
- [5] S. Raut, S. Umredkar, Prof. K Wagh, "Design and Simulation of Double Side Band Suppressed Carrier Model using MATLAB Simulink Tool and Effect of Noise on Simulation Results using MATLAB Coding", Nagpur: India, Mar. 2017, [Online] Available: <https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.wjert.org/download/article/19032017/1490608556.pdf&ved=2ahUKewi2Kbxj92KAXUnTKEAHYUMGAUQFnoECBUQAQ&usg=AOvVaw1P7FJvKxP-inGMuZrc7d0p> [accessed Dec 19. 2024]
- [6] S. Bharadwaj, R. Sharma, "III. Single Sideband Suppressed Carrier (SSB-SC)" in "A Comparative Study of Different Amplitude Modulation Signals", Delhi: India, Aug. 2021, [Online] Available: <https://www.ijtrd.com/papers/UTRD22710.pdf> [accessed Dec 19. 2024]
- [7] D. Freeman, Massachusetts Institute of Technology Open Courseware, "Lecture 23: Modulation, Part 1" in "Signals and Systems", Cambridge, Massachusetts: United States, Oct. 2011, [Online] Available:

<https://ocw.mit.edu/courses/6-003-signals-and-systems-fall-2011/resources/lecture-23-modulation-part-1/>
[accessed Jan 2. 2025]

[8] Tutorials Point, "Modulation Index" in "Amplitude Modulation", Hyderabad: India, 2024, [Online] Available:
https://www.tutorialspoint.com/analog_communication/analog_communication_amplitude_modulation.htm
[accessed Jan 2. 2025]

[9] I.K. Ndungu, Strathmore University, "AM - Modulation", Nairobi, Kenya, Aug. 2024, [Online] Available:
<https://www.researchgate.net/profile/lk-Ndungu> [accessed Jan 2. 2025]

75/100

PAGE 1

PAGE 2

PAGE 3



Comment 1 | Engagement with literature(10)

The descriptions are very basic and lack technical depth, failing to explore the advantages, disadvantages, or practical applications of these techniques.



Comment 2 | Engagement with literature(10)

It is appreciable that citations are provided for each definition.



Comment 3 | Engagement with literature(10)

Referring the reader to external sources shifts the responsibility of explanation, which is not appropriate.



Comment 4 | Engagement with literature(10)

The cited works should be summarised and critically evaluated to demonstrate understanding and provide context.

PAGE 4

PAGE 5



Comment 5 | Practical Application (30)

The Simulink blocks are well-captured and clearly presented.



Comment 6 | Practical Application (30)

The inclusion of key parameter settings, such as angular frequency of carrier and message frequency, modulation index adds clarity and demonstrates a thorough understanding of the simulation setup.

PAGE 6



Comment 7 | Practical Application (30)

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



Comment 8 | Cognitive skills (20)

Well Done! Keen Observation.



Comment 9 | Knowledge & Understanding (20)

The formula for the modulation index is clearly stated providing a solid foundation for understanding the concept.

PAGE 7



Comment 10 | Cognitive skills (20)

The provided ranges for modulation index values adds clarity and relevance to the discussion.



Comment 11 | Cognitive skills (20)

The demodulated signal should be clearly mentioned as having the same frequency as the message signal (10 Hz) used during the modulation process.

Ensure the explanation is straightforward and highlights the accurate recovery of the baseband signal.

PAGE 8



Comment 12 | Cognitive skills (20)

Comparison between the distorted and undistorted signals is well stated, linking the effect of noise to the observations seen in the tables.

PAGE 9



Comment 13 | Cognitive skills (20)

This needs clarity: The statement incorrectly suggests that signal amplitude increases with noise. The rise at -30 dB SNR (13.58) compared to -20 dB (5.33) and -10 dB (2.657) is due to noise peaks. As noise decreases at higher SNRs, amplitude distortion reduces, resulting in a clearer signal.



Comment 14 | Knowledge & Understanding (20)

Well said! This clearly highlights the challenges of carrier suppression and its impact on BER, providing a good understanding.



Comment 15 | Cognitive skills (20)

Consider specifying that the increase in power density at lower SNR is likely due to the noise dominating the signal power.

PAGE 10



Comment 16 | Practical Application (30)

The spectrum screen dump is well-presented and demonstrates the expected results effectively.

PAGE 11



Comment 17 | Cognitive skills (20)

The statement needs clarity. For instance, as the SNR value decreases, noise increases, leading to an apparent rise in amplitude.

PAGE 12



Comment 18 | Practical Application (30)

Likely to be same as it it mentioned in DSBSC 'Consider specifying that the increase in power density at lower SNR is likely due to the noise dominating the signal power. '



Comment 19 | Cognitive skills (20)

The explanation aligns well with the graph and clearly highlights the variations in power density for all techniques.

PAGE 13



Comment 20

The explanations are clear and precise, supported by many screen dumps and analysis, showcasing strong communication and well organised reporting skills.



Comment 21 | Cognitive skills (20)

It is also necessary to compare and analyse by evaluating parameters such as SNR(In, Out), noise power, figure of merit, and their values in comparison with the obtained practical results.

PAGE 14

GRADING FORM: RF_UPDATED_2025

ALISTAIR LOUNDS

75.30

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

6

theoretical principles needs is limited.

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) Good understanding of AM principles. scope analysis, and signal definitions are accurate.

Task 1: (a) (ii) Shows strong understanding of modulation index variations.

Task 1: (b) Demonstrates excellent understanding of AM demodulation.

Task 2: (a) Task demonstrates clear explanation of DSB SC modulation and demodulation.

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

Task 3: (b) : covers noise effects in SSB SC demodulation but it is necessary to calculate the theoretical values,

Task 4: (a) Task has good analysis of spectrum and power density but needs more detailed reasoning for noise tolerance.

Task 4: (b) Task demonstrates comparison, but analysis of bandwidth and noise resistance could be better.

15.4

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 very clear and detailed. Comparisons are insightful, using metrics like spectrum, time scope, and the effect of different

18

modulation indices on signal transfer efficiency.

Task 1 (b): The demodulation process is very clear and detailed. Comparisons are meaningful and insightful, showing key differences and similarities. The analysis is deep and well-supported with strong reasoning.

Task 2 (a) & (b): The modulation and demodulation processes for DSBSC are very clear. Observations are insightful and show a strong understanding of balanced modulation, with innovative ideas.

Task 3 (a) & (b): The modulation and demodulation processes for SSBSC are very clear and well-explained. Observations are highly insightful and demonstrate a strong understanding of phase discrimination. Innovative ideas are evident and applied effectively.

Task 4 (a) & (b): Performance metrics are clear with accurate values. Comparisons are insightful, and conclusions are strongly supported

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 strong skill and clarity, but theoretical calculations and practical values need to be included to clearly relate the analysis to the expected outcomes.

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.

Task 2 (b): Noise analysis is good and Observations are well-documented.

Task 3 (a): Successfully implements SSB-SC modulation with accurate signal analysis.

22.9

Task 3 (b): Noise analysis is comprehensive, with clear and precise documentation of observations.
Task 4 (a): Basic understanding of practical setup. Observations are adequate but lack depth with theory.
Task 4 (b): Provides basic comparisons but limited observations and conclusions.

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 evident with effective communication, good organisation, and clear reporting.

13