

2214885 Radio Frequency's final submit

by Joseph Gillespie

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2025

The Investigation of the Effect of Noise in SSB-SC and DSB-SC

RADIO FREQUENCY SYSTEMS (ACDA5019)
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Abstract

This report aims to show the effect that White Gaussian Noise (WGN) has on two different types of Amplitude Modulation (AM) methods. From these results, both modulation methods, Double Side Band Suppressed Carrier (DSB-SC) and Side Band Suppressed Carrier (SSB-SC), are then compared, proving that SSB-SC is the most efficient AM modulation method out of the two techniques.

The conclusion of this report was achieved via a test carried out on the software known as Matlab. Both DSB-SC and SSB-SC modulations and demodulation methods were constructed within the simulation with an added WGN block between the two sections. This WGN block value was changed to produce the results seen later in this report.

The following report structure will break down each AM method with a description, diagram explanation and results breakdown before coming together with a comparison and then the conclusion.

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Introduction

Communication plays a vital role in today's society, whether it is for personal use, entertainment or to allow the operation of electronic systems. It cannot be denied that it is needed in a variety of ways, but how is it achieved? Many systems and older methods of communication such as landline phones depended upon communication via wire, but as technology has advanced and the introduction of radios, wireless communication has become the favoured option.

This has brought into play the use of the radiofrequency segment of the electromagnetic spectrum which operates between 3kHz to 300GHz [1]. Within this frequency range are smaller divides such as Extremely Low Frequency (ELF), Medium Frequency (MF) and

Extremely High Frequency (EHF) [2] to name a few, which further categorise the transmission types and tailors the transmission to the respected receiver.

For an electronic transmission to be placed within one of these frequency categories, Amplitude Modulation (AM) has to be performed upon the transmitted signal. Three main types of AM can be chosen depending on the transmission requirements, this modulation types are Double Sideband-Suppressed Carrier (DSB-SC), Single Sideband Modulation Suppressed Carrier (SSB-SC), and Vestigial Sideband Modulation (VSB) [3].

It is within this report that only DSB-SC and SSB-SC will be investigated, comparing the two modulation techniques effectiveness in modulation and demodulation while under the effect of White Gaussian Noise (WGN). The report will be broken down into a description of each technique, their construction within the Matlab simulation software and the results of their simulated tests before finalising on a comparison of the two's performance.

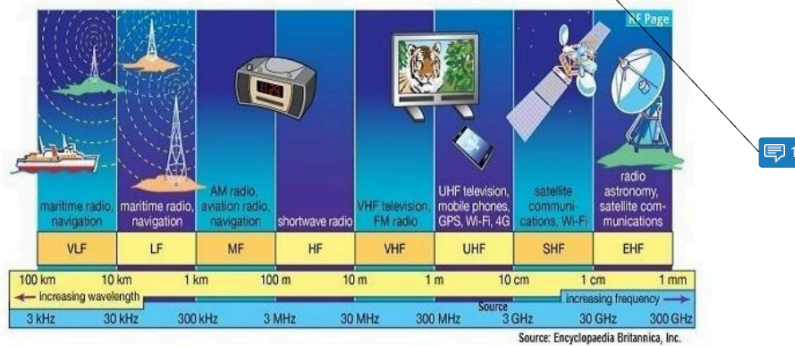


Figure 1, Radiofrequency segment of the Electromagnetic Spectrum [4]

(1:0) AM Systems

AM is the simplest and earliest method of modulation most commonly used within radio transmission [3]. It effectively transmits a consistent and reliable signal at long distances thou at the cost of its sound quality [5]. Alongside this, its demodulation process is far simpler than any other demodulation method, but this also makes its transmission/resaving signal much more susceptible to noise interference resulting in its poor sound quality.

The way in which AM works is by amplifying the amplitude of a message signal with the transmission signal before broadcasting it to the receiver. This modulation method only affects the amplitude of the message signal leaving the frequency the same. Due to this, discrete upper and lower sidebands are generated from the sum of the difference between the message signal and transmission signal [6].

The following equation is the method in how to calculate the upper (f_{USB}) and lower (f_{LSB}) sidebands:

$$f_{USB} = f_c + f_m$$

$$f_{LSB} = f_c - f_m$$

To calculate the Carrier Signal:

$$C(t) = C \sin(\omega_c t + \phi) \quad [7]$$

Where:

C = Carrier amplitude

ω_c = Carrier frequency in Hz

ϕ = Phase of the signal at the start

To Calculate the Modulating Signal:

$$m(t) = M \sin(\omega_m t + \phi) \quad [7]$$

Where:

M = Carrier amplitude

ϕ = Phase of the signal at the start

ω_m = Modulated signal Frequency in Hz 

(1:1) System Design

The block diagram shown in Figure 2 shows both AM and its demodulation counterpart. This Simulink diagram consists of several sections that make up the modulation stage of the transmission and is the source of the results seen in section 1:2.

The modulation starts with two sinewaves labelled m(t) and c(t). m(t) is the message signal, either voice or music, and is times with the modulation index which decides the change that occurs to the signal's amplitude. c(t) is the carrier signal, and this is times to the transmission signal just before broadcasting.

The second stage of m(t)'s modulation is to be added to a constant which prevents  the message signal from going negative. Once applied, the carrier signal is multiplied to the message signal and then broadcast to its receiver.

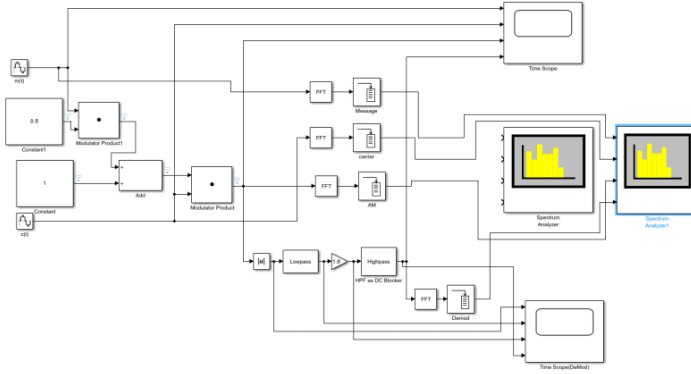


Figure 2, AM Modulation and Demodulation

The demodulation phase, seen at the bottom of Figure 2, primarily consists of two filters, starting with a low pass and followed by a high pass. Each filter is used to separate the transition from the message signal allowing for the message to be heard.

(1:2) Results

The following results show the effect that the modulation index has upon the transmission signal and how the demodulated signal compares to the original transmission. This was achieved simply by changing the constant value of the modulation index within the simulation and collecting the results via a spectrum analyser and oscilloscope giving two different views on the effects.

To begin the test, a modulation index of 1 was chosen to keep the change occurring to the message signal the same. This is the ideal state of the modulation index as it limits the effect of noise on the signal once its intended target receives it. By doing this, a clear standard was set to compare any differences to when the index was changed. A way of calculating the correct modulation index for a system is by the following formula:

$$\mu_a = A_m / A_c \quad [8]$$

Where:

A_m = Amplitude of the message Signal

A_c = Amplitude of the carrier Signal

Figure 3 shows both the frequency and time results of a steady modulation index. What is to note here, especially within the frequency measurement on the left of Figure 3, is that the carrier signal is the same power as the message signal. When looking at the results within the time domain, right side of Figure 3, the received message is higher than the transmitted message but is identical in its transmission.

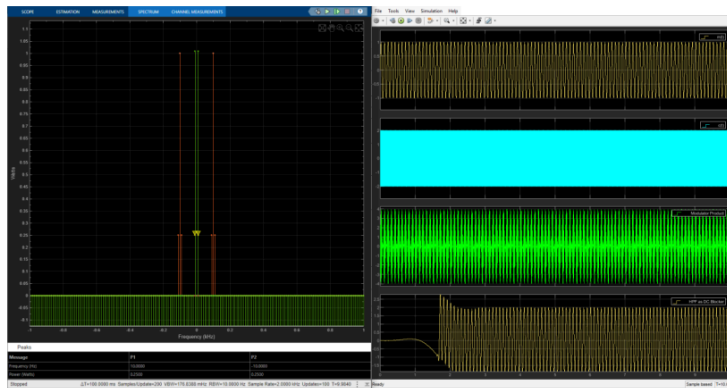


Figure 3, AM Modulation Transmission/Demodulation at 1 Modulation Index

When the modulation index is changed to 1.5, over modulation occurs. This results in the message signal becoming distorted on receiving due to the signal being cut during the demodulation phase. It can be seen in figure 4 quite clearly that the message signal has significantly more power than its transmission signal. There is also a secondary smaller message signal seen at the base of the message signal.

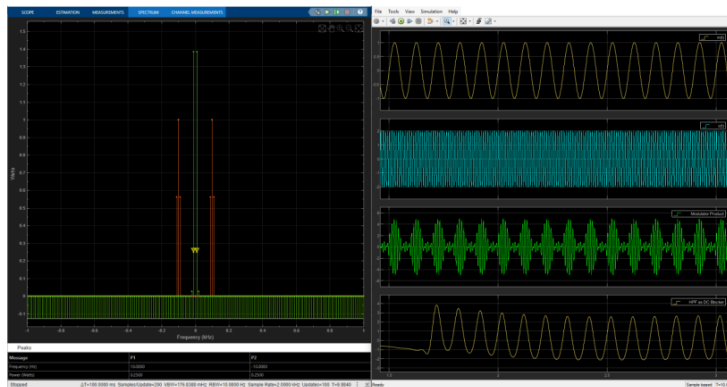


Figure 4, AM Over Modulation at Modulation Index 1.5

At a modulation index of 0.5, under modulation occurs. This is when the message signal is too small to efficiently effect the transmission signal resulting in parts of the message signal becoming filtered out during demodulation. It can be seen in the spectrum analyser readings in Figure 5 that the message signal, in green, is significantly less powered than the accompanying transmission signal.

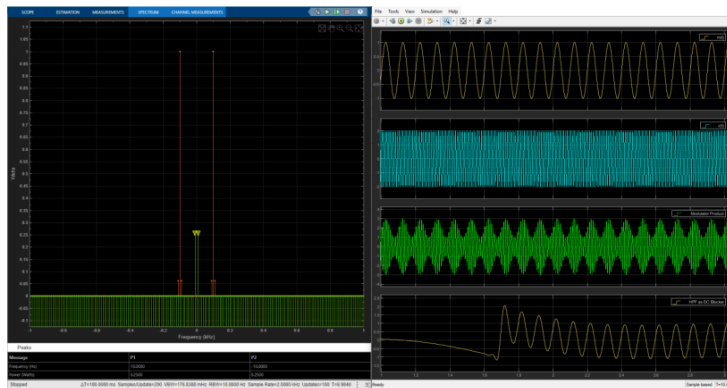


Figure 5, AM Under Modulation at Modulation Index 0.5

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(2:0) DSB-SC

As another way of transmitting audio signals at a much more power-effective way compared to AM. DSB-SC only utilises that of two sidebands, one being the upper and the other being lower, when transmitting a signal [9]. The purpose of these sidebands is to keep the message signal together and to aide in the demodulation of the message on receiving it.

The calculations for DSB-SC follow the same construction as AM with the following equations being additions to those seen in section 1:0. To begin with, to calculate the bandwidth of DSB-SC:

$$BW = f_c + f_m - (f_c - f_m) [10]$$

To calculate the power required for DSB-SC, the power of the sidebands needed to be identified. The following equations can be split to calculate both sideband's power but within this configuration gives the total DSB-SC power:

$$P_t = A_m^2 A_c^2 / 8R + A_m^2 A_c^2 / 8R [10]$$

9

Where:

A_m = amplitude of modulated signal

A_c = amplitude of the carrier signal

R = load resistance

(2:1) System Design

DSB-SC's modulation and demodulation method was created within MATLAB's Simulink, seen in Figure 6. What is instantly recognisable on the diagram is that there is two modulation stages that are combined right before transmission which is located at the adder

box labels S. Both of these modulation phases operate identically with the only difference being that of a constant which decided whether the location of the sideband is upper or lower. The structure of the modulation technique is also the same as the modulation of AM as seen in section 1:1.

Where DSB-SC separates itself away from AM is, excluding the two modulations but involving them, the combining of the two modulated signals which can be branded as positive (high) and negative (low). These two signals are the lower and high sidebands which can be seen in Figure 7.

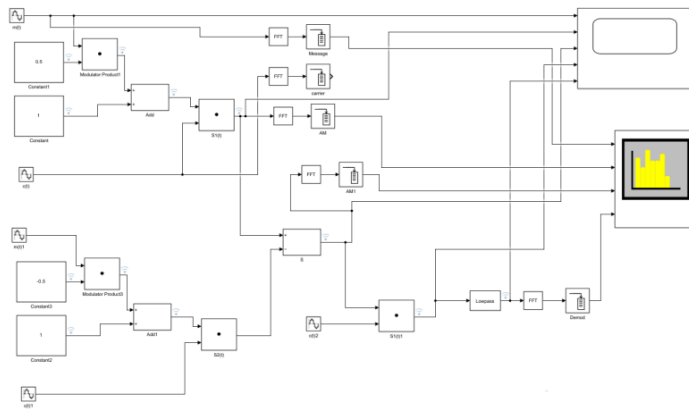


Figure 6, DSB-SC Modulation and Demodulation

As for the demodulation, the modulated signal is multiplied with the same carrier signal used within the modulation phase. Once this stage is completed, the signal is put through a lowpass filter where the message signal is extracted.

For the tests with results are shown in section 2:2, a WGN block was added between the end of the modulation signal and before demodulation. This is not shown within Figure 6.

(2:2) Results

What can be seen in Figure 7 is that of the unaffected transmission of DSB-SC. What should be noted is that of the two sidebands, in orange the spectrum analyser located to the left of the image. Figures 8 and 9 are the results of the spectrum analyser under the effect of WGN, interesting, the lower sideband is the first to become lost within the noise while the upper sideband rises slightly as the noise increases.

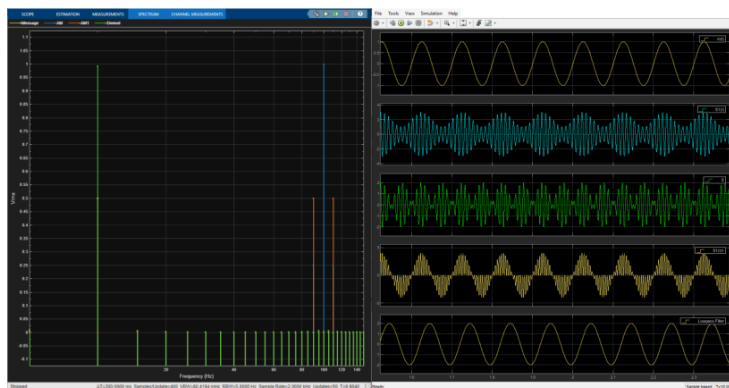


Figure 7, DSB-SC Modulation/Demodulation with No Noise Effect

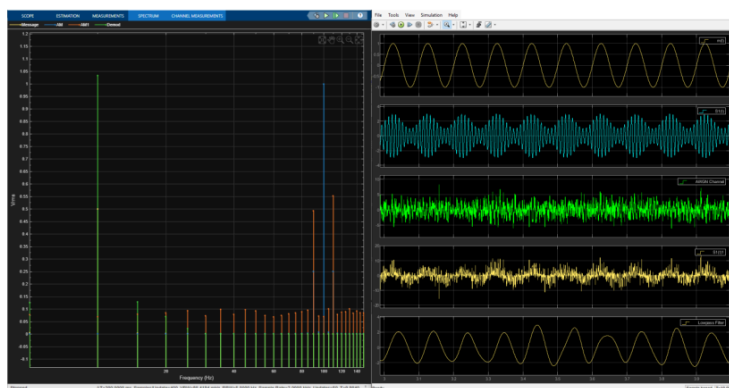


Figure 8, DSB-SC Modulation/Demodulation at -5dB of WGN

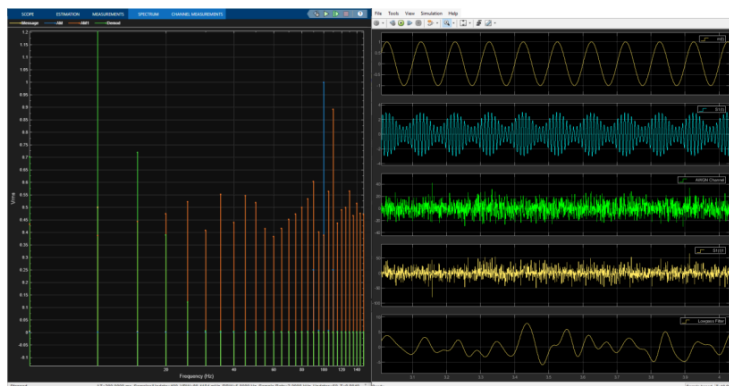


Figure 9, DSB-SC Modulation/Demodulation Failure at -20dB WGN

(3:0) SSB-SC

Popular in the amateur radio field and often used within military communication systems [11], SSB-SC utilizes that of a single sideband, either high or lower, when transmitting. This modulation method drastically reduces the bandwidth of the transmitted signal, subsequently reducing the power required for transmission. This also allows for many more transitions to take part within the given frequency band due to the limited channel space taken up [12].

To calculate the bandwidth of the modulated wave of SSB-SC:

$$BW = 2f_m/2 \text{ [13]}$$

Where:

f_m = Is aver the upper or lower sideband.

To calculate the power of SSB-SC:

$$P_t = \frac{A_m^2 A_c^2}{8R} \text{ [12]}$$

(3:1) System Design

SSB-SC takes a much simpler approach to its modulation method as seen in Figure 10. To begin with, the message signal $m(t)$ is multiplied directly to the carrier signal $c(t)$. While this is happening, a 90° phase shifted copy of both the carrier and message signal are also multiplied together. Once both signals are combined, the phase shifted copy, and the original signal are added together at block $s(t)$ and then transmitted.



(3:2) Results

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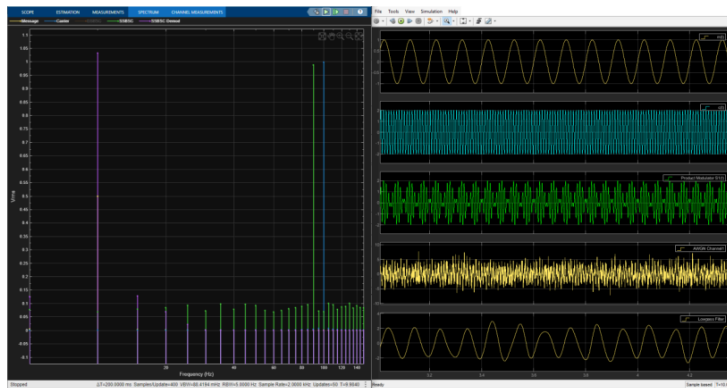


Figure 12, SSB-SC Modulation/Demodulation with Added WGN at -5dB

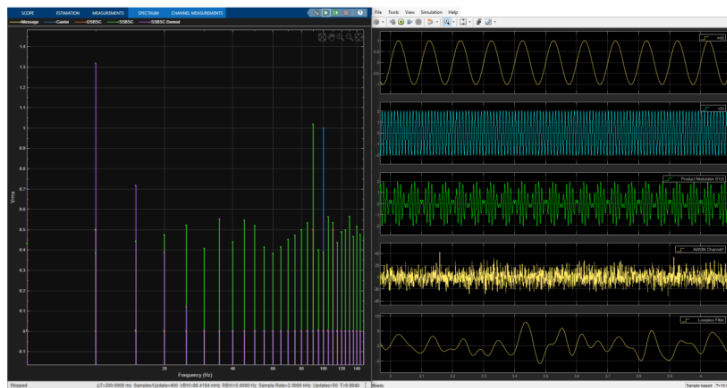


Figure 13, SSB-SC Modulation/Demodulation Failure at -20dB of WGN

(4:0) System Comparison

Each of the modulation techniques explored within this report have their advantages and disadvantages when operating in their respected systems. Unfortunately, due to the performance capabilities of both DSB-SC and SSB-SC while under the effect of WGN being almost identical in their results, as shown in sections 2:2 and 3:2. This section will look into the characteristics of their capabilities such as power usage and channel consumption.

As the most basic of all the modulation types examined in this report, AM is by far the most simplistic in its construction, resulting in it being the cheapest in manufacturing. It is capable of transmitting over long distances and sustaining a constant message while doing so but is extremely susceptible to noise resulting in its sound quality being poor. The methods in which it transmits is also inefficient taking up a large portion of the frequency channel due to its two side bands, it requires high amounts of power [14].

In comparison, DSB-SC operates as a much more reliable and efficient modulation technique than AM. Its use of purely two sidebands results in the prevention of noise interference effecting the transmission signal, but it is due to these sidebands where DSB-SC can be seen as a failure. The power is increased due to the sidebands and the frequency channels taken up are increased, resulting in lesser communications taking part within that frequency range.

These issues are rectified with the use of SSB-SC as the modulation method. Since SSB-SC only uses a singular side band, the power levels are decreased drastically and the frequency channels required for broadcasting are limited. This allows for several more transmission styles to be used within the same frequency range [11]. The effect of noise on SSB-SC is like that seen on DSB-SC resulting in the power requirements and frequency consumption the only difference between the two. All the better, the construction of SSB-SC is complex and if done incorrectly at both the transmitter and receiving ends, can result in poor transmission quality.

Conclusion

In conclusion, SSB-SC is the better modulation technique when it comes to long distances and strict frequency regulations which most transmission systems must abide by today. All though DSB-SC and AM still have a place depending on the application.

In terms of results gathered in this report, they show a rather inconclusive comparison causing the conclusion to be formed primarily from research rather than testing. As the results under the effect of WGN almost look identical to each other.

On a repeat of the experiment carried out within this report, more test points will be added when conducting the WGN effect upon the transmission demodulation. This will improve results and show a much clearer point of failure for both SSB-SC and DSB-SC while making the visual evidence within the report much more supporting.

A follow-up experiment with physical modulation devices forming the same test within a reverberation chamber would further extend this. This would give a real-world visual of the effects of modulation outside of a simulated environment.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

74

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Comment 1 | Knowledge & Understanding (20)

The fundamental concepts of communication systems are well presented, providing the reader with a strong understanding of the basics.



Comment 2 | Engagement with literature(10)

The citations are appropriately included, and the concepts of AM are clearly explained.

PAGE 6



Comment 3 | Knowledge & Understanding (20)

The inclusion of AM calculations is commendable, demonstrating a clear application of mathematical concepts to the blocks.



Comment 4 | Cognitive skills (20)

The connection between mathematical expressions and system blocks is well done.

PAGE 7



Comment 5 | Knowledge & Understanding (20)

It would be better to provide more details on the demodulation process, particularly on how envelope detection works.

PAGE 8



Comment 6 | Cognitive skills (20)

When comparing different modulation index values, the comparison of power signals is appreciated, but capturing numerical values would improve clarity.

PAGE 9



Comment 7 | Practical Application (30)

The scope findings are clear and the screen shots are well captured.



Comment 8 | Cognitive skills (20)

There is clear evidence of keen analysis using various modulation index values, though it would be beneficial to calculate signal distortion to strengthen the evaluation.



Comment 9 | Practical Application (30)

The expressions used for DSB-SC are relevant, but incorporating fundamental expressions and derivations would enhance the theoretical discussion.

PAGE 10



Comment 10 | Practical Application (30)

The concepts of DSB-SC and SSB-SC are well presented, demonstrating a good understanding of the working of blocks.



Comment 11 | Cognitive skills (20)

The use of colour to represent signals is appreciated, but noting and analysing numerical values later would add more depth to the discussion.

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PAGE 12



Comment 12 | Knowledge & Understanding (20)

It is appreciable that the some of the formulas are captured.



Comment 13 | Knowledge & Understanding (20)

The discussion on theoretical parameters and practical values should further highlight how the signal degrades with noise or how performance is affected, which would enhance the report.



Comment 14 | Practical Application (30)

Demonstrating a good understanding of the working of blocks.



Comment 15 | Knowledge & Understanding (20)

It is important to discuss the role of balanced modulators and phase discriminators.

**Comment 16** | Practical Application (30)

The noise effects in DSB-SC and SSBSC are observed for -5 dB and -20 dB, which is good, but including some positive SNR values would make the analysis more comprehensive.

**Comment 17** | Transferable skills (20)

The advantages of AM and its limitations are well captured. While power efficiency is generally discussed using spectrum scope outputs, it is essential to perform calculations for a more precise analysis.

**Comment 18** | Cognitive skills (20)

The calculation of power spectral density, efficiency, performance, and figure of merit is needed to fully analyse signals in both DSB-SC and SSB-SC, which is currently missing.

**Comment 19** | Transferable skills (20)

The use of references is evident and well-structured, which is commendable. The report maintains a logical flow and structured approach, making it easy for the reader to connect with the concepts effectively.

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JOSEPH GILLESPIE

74.40**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 work shows excellent understanding of AM, DSB-SC, and SSB-SC techniques. The theoretical principles are properly referenced, and the discussion on noise impact, modulation index, and

8.5

performance metrics is detailed and supported by scholarly sources.

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 excellent understanding of AM principles. All calculations, time and frequency analysis, and signal definitions are accurate and complete.

Task 1: (a) (ii) Task shows meaningful observations for modulation types but misses depth in certain areas.

Task 1: (b) Explains AM demodulation clearly but lacks depth in comparing original and modulated signals.

Task 2: (a) Detailed 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. 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 is missing.

15.8

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 clear but could have more detail. Comparisons are relevant but lack depth. Metrics like spectrum, time scope, and modulation indices are used but not fully explored.

13

Task 1 (b): The demodulation process is clear but could have more detail. Comparisons are relevant but lack depth. The analysis is good but could explore more points.

Task 2 (a) & (b): The modulation and demodulation processes for DSBSC are clear but need more detail. Observations are meaningful but lack depth, and innovative thinking is limited.

Task 3 (a) & (b): The modulation and demodulation processes for SSBSC are clear but could include more detail. Observations are meaningful but lack full depth. Some innovative thinking is present but not fully developed.

Task 4 (a) & (b): Performance metrics are explained but have gaps. Comparisons are basic, and conclusions are only partly supported by theory. Spectrum and noise tolerance are briefly mentioned but not well-integrated with the values.

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): Exceptional use of tools and clear demonstration of signals with a deep understanding of behaviour.

Task 1 (a) (ii): Good application of modulation index variations. 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): Clear explanation of AM demodulation with accurate results. Comparisons are present but lack some depth.

Task 2 (a): Demonstrates accurate DSB-SC modulation. Observations are precise, and tools are used effectively.

Task 3 (b): Noise analysis is comprehensive, with clear and precise documentation of observations.

Task 4 (a): Weak understanding of processes, with incomplete observations.

Task 4 (b): Comparisons are done explaining the references but not with the analysis.

22.1

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.

15