

RF Systems final handin

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Radio Frequency Systems
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Abstract

In this Report I will demonstrate three modulation techniques in simulink AM, DSBSC and SSBSC. I will demonstrate their noise tolerance power density and the spectrum usage to showcase what the the benefits and downsides of each modulation technique.

Introduction

This report will delve into the design of Simulink models for three modulation techniques: Amplitude Modulation (AM), Double Sideband Suppressed Carrier (DSB-SC), and Single Sideband Suppressed Carrier (SSBSC). A detailed description of each modulation method will be provided.

Robustness of the signal

To assess the noise robustness of DSB-SC, SSBSC systems and AM. Simulink simulations will be conducted for each model with the carrier and signals matched where they can be to make the modulation as close to each other as possible . By subjecting these systems to various noise levels, their performance degradation can be quantified and compared, In such a way that their benefits are made obvious to the reader.

Power density

I will compare the power density of each model will using the power density section in the spectrum analyser this will allow me to see the exact power of and where it lies on the transmission lines.

Frequency spectrum

I will look at the spectrum analyser and monitor the side bands of the signals to and where the power is placed to understand where other signals could possibly be placed in relation to the signal.

Background research

AM

Usage

AM was commonly used for radio stations and is currently used for point to point communication.

Fondation

It is the function of putting power on a single point and or small set of frequencies and changing the power level in relation to the data given this has been converted in more modern systems to a digital signal but it works with both analogue and digital data as its just multiplying the data onto a carrier signal.

Limitations of the system

As it is only looking at the power difference of a signal it is common for it to blend information on the same frequency depending on the strength this rarely happens with FM systems.

Dbsc

Usage

Commonly used by amateur radio hobbyists as it can be used effectively in high frequency bands and is relatively cost effective to make.

Fondation

Is a modulation technique for analogue modulation. It means double sideband suppressed carrier. It is an alteration of double side band full carrier that has both the side bands and the carrier in the transmission. The Dbsc only transmits the side bands without the carrier being transmitted or its transmitted at a low enough level that it's not relevant.

Limitations of the system

This system produces distortions in its demodulation unless specifically dealt with as such if this section is damaged or more commonly the distortion is more than it can deal with the user has to make do with what is likely garbage information

Ssbsc



Usage

Javapoint states "SSB is commonly used in the **long-distance transmission** of speech signals. The bandwidth of the speech signal lies in the range 300 Hz and 3400 Hz. The maximum space between the two channels in SSB can be 4000 Hz." [6]

Fondation

Single sideband suppressed carrier is a modulation technique that suppresses the carrier and one of the side bands this reduces its presence in the frequency domain as its a third of the size of the side bands and the carrier.

There are two demodulation systems possible "43000 Hz and 47000 Hz" [7] if the carrier is on the 45000 Hz point in real world terms this would vary by a few Hz as the crystals inside the device are only so precise 43000Hz is called lowside injection and 47000 Hz is called high side injection these side bands rely on the systems bandwidth some could be as small as 400Hz width but with high powers its easier to provide large gaps as it keeps the harmonics away and below the other sideband and carrier to avoid the receiver responding to the system. [7]

Limitations of the system

The limits of the system are related to its analogue nature as a copy of the signal is used to remove one of the side bands the system has a lower output than AM on its own.

System design

I designed an AM system in simulink this model multiplies the message signal by the modulation index and then adds 1 to it producing an effective amplification of the message signal before it is put back onto the

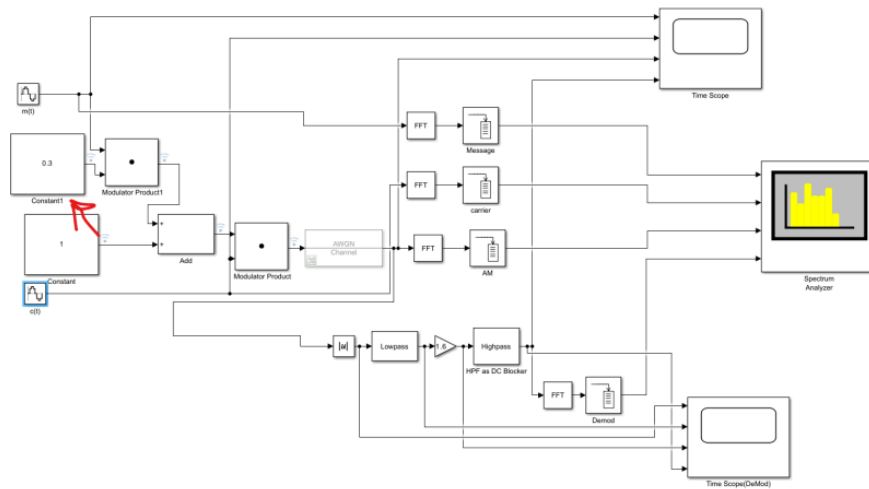


Figure 1: AM system diagram

The red arrow points at the modulation index; this is important for later tests.

Mt is the message signal to be modulated

Ct is the carrier wave i will use these two names in the other system designs

DSBSC

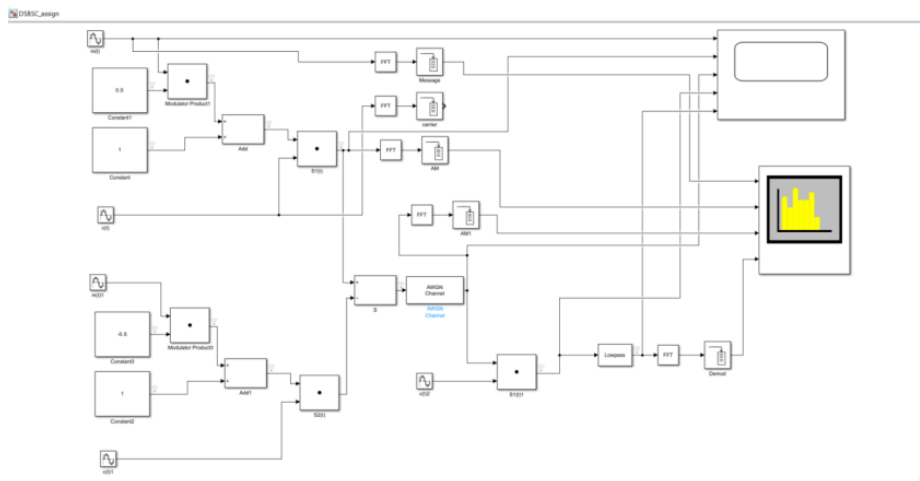


Figure 2: DSBSC System Diagram

The modulation index is negative on the negative side of the signal to ensure that it removes the positive when their finally combined giving you the signal without modulation

SSBSC

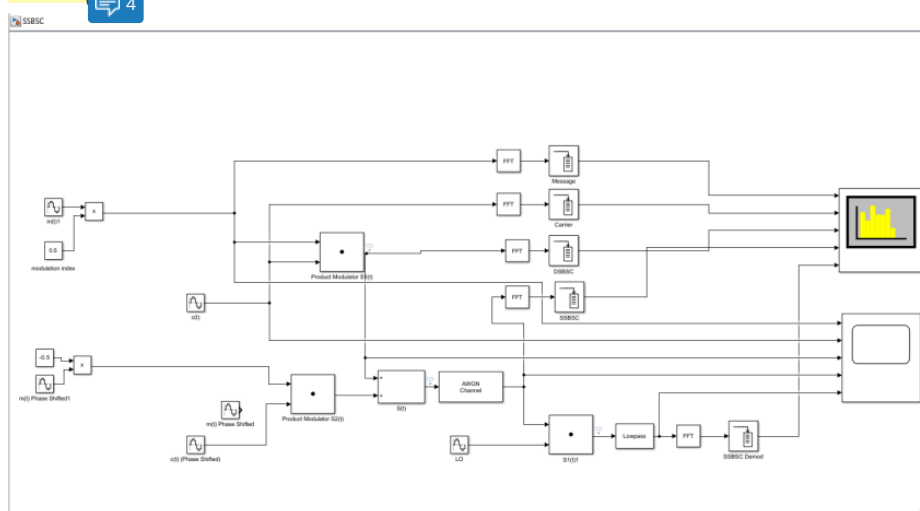


Figure 3: SSBSC System Diagram

The modulation index is negative on the negative side of the signal to ensure that it removes the positive when their finally combined giving you the signal without modulation i will not be

providing it further amplification as that would put it at an advantage over DSBSC and AM as such this is its limit.

No noise Tests

DSBSC
No noise

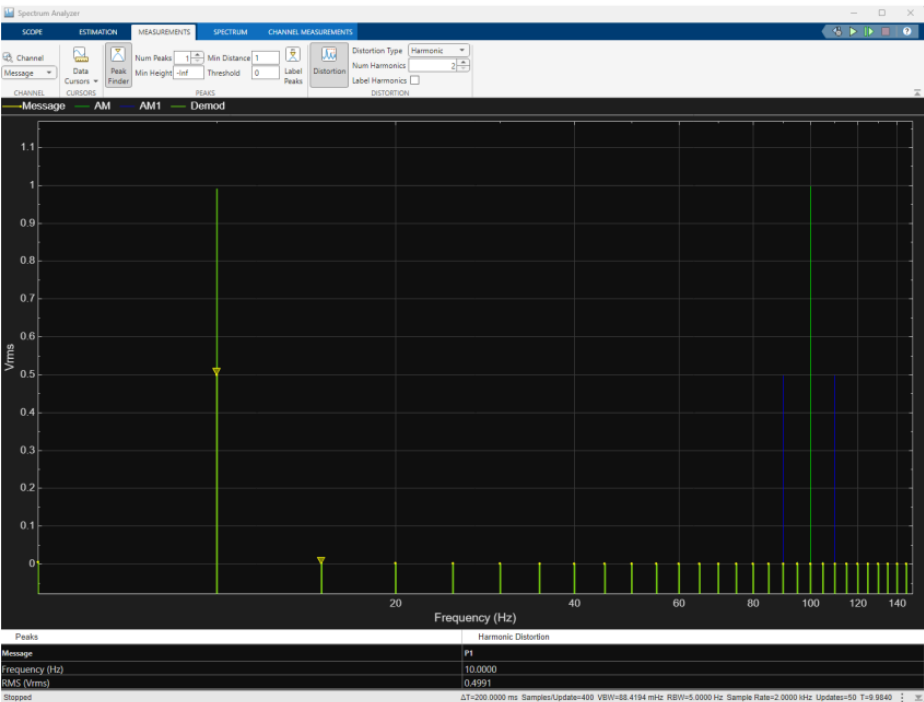


Figure 4: DSBSC all signals

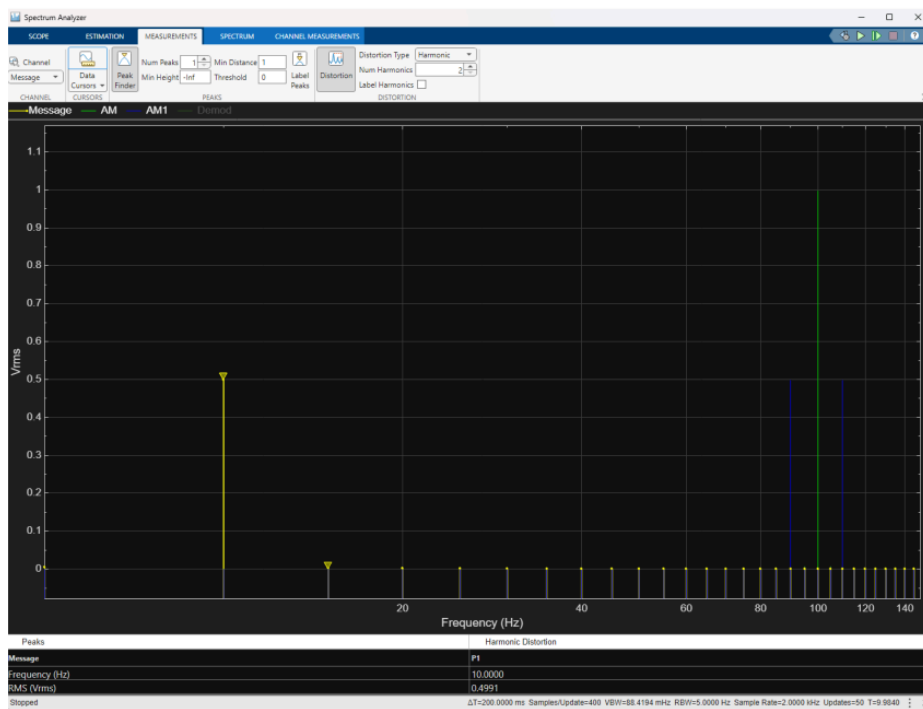


Figure 5: DSBSC no demod

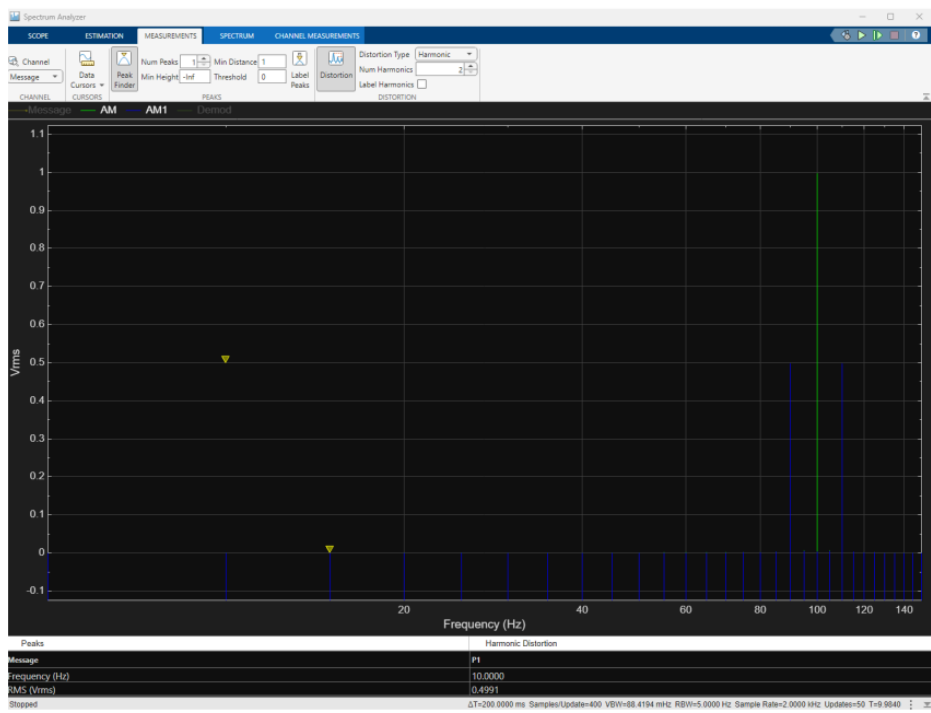
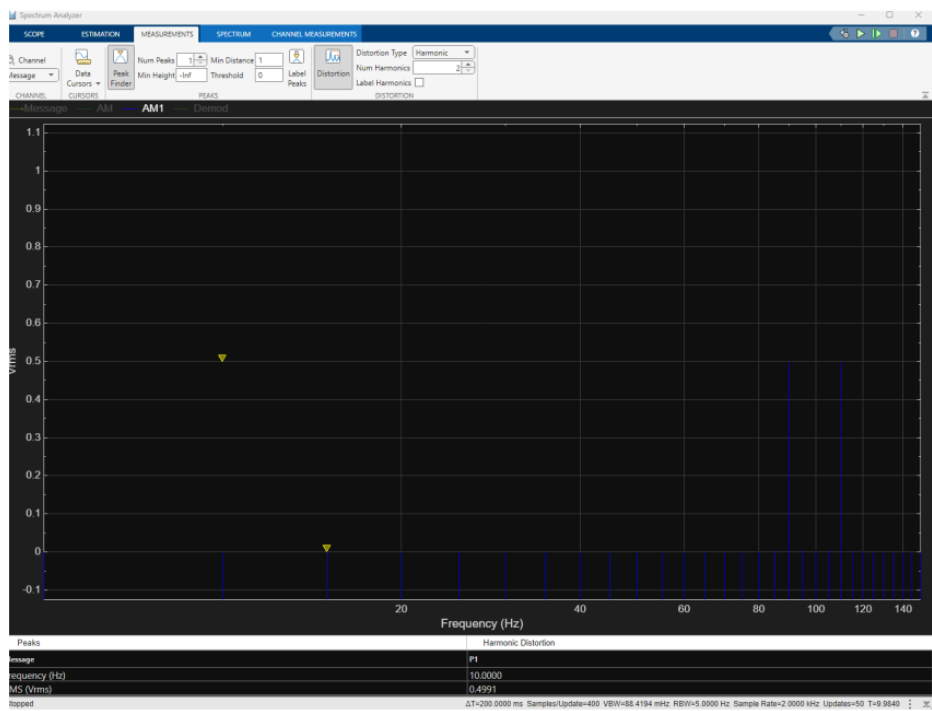


Figure 6: DSBSC no demod no carrier



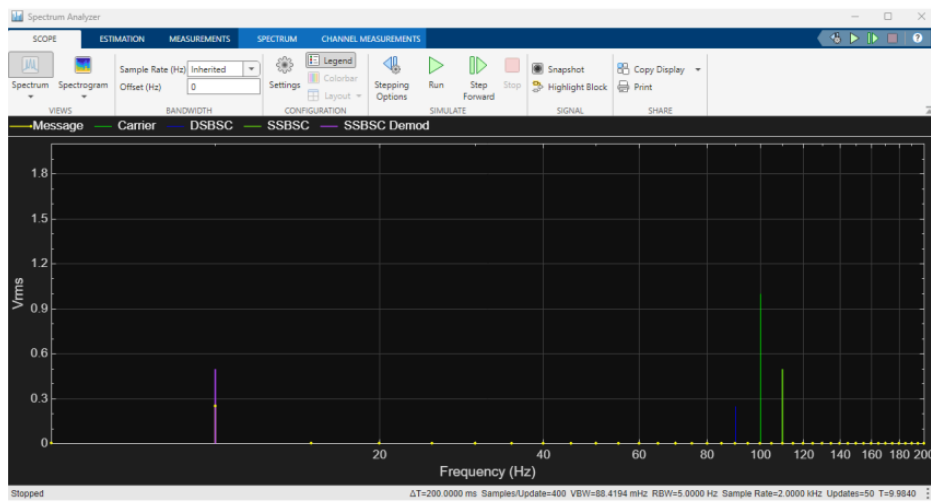


Figure 8: SSBSC all signals

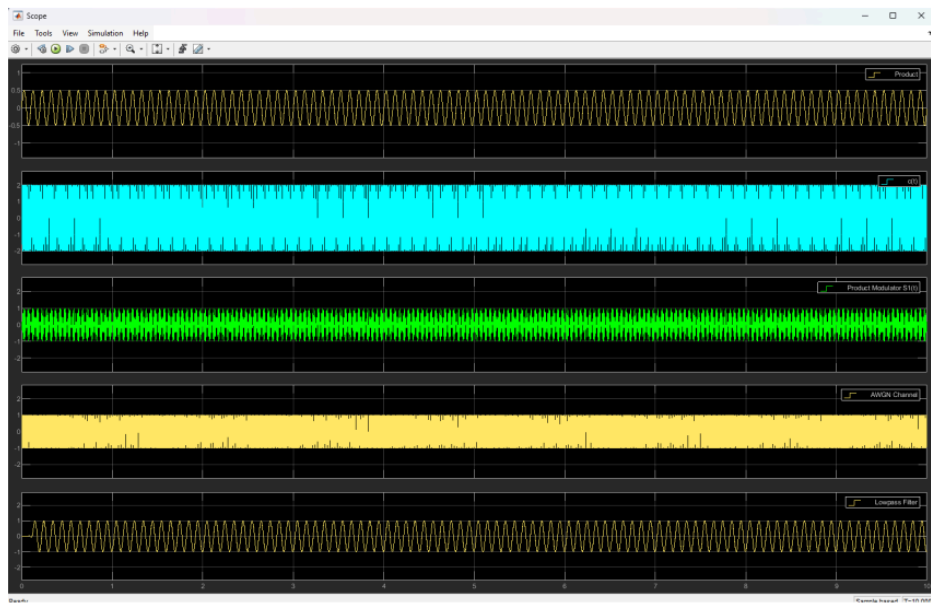


Figure 9: SSBSC Scope

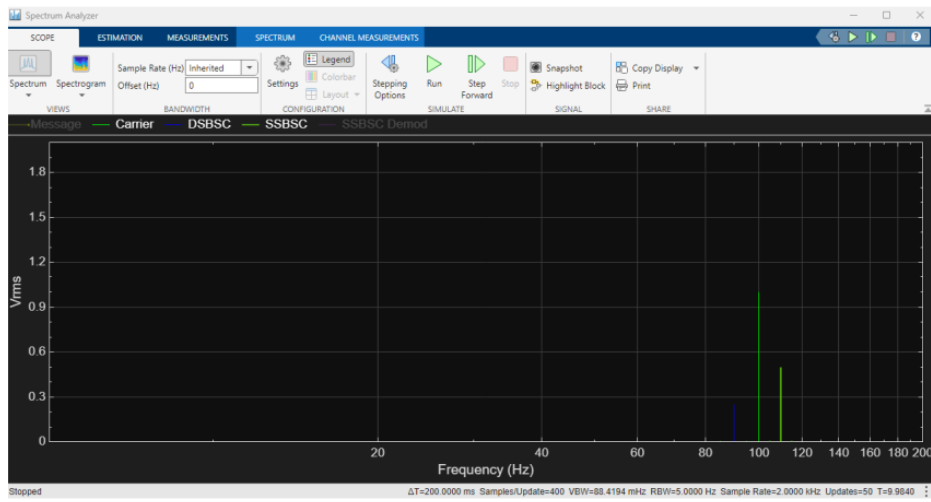


Figure 10: SSBSC No mesage no demod

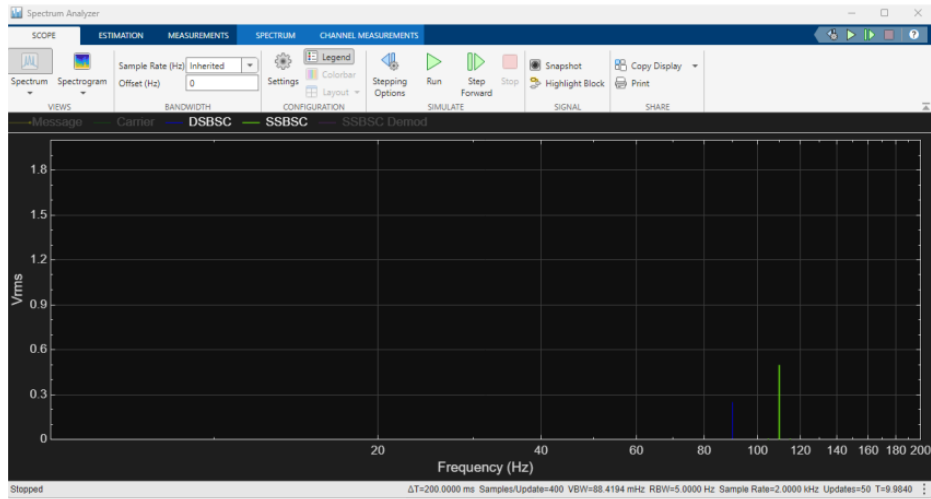


Figure 11: SSBSC DSBSC SSBSC

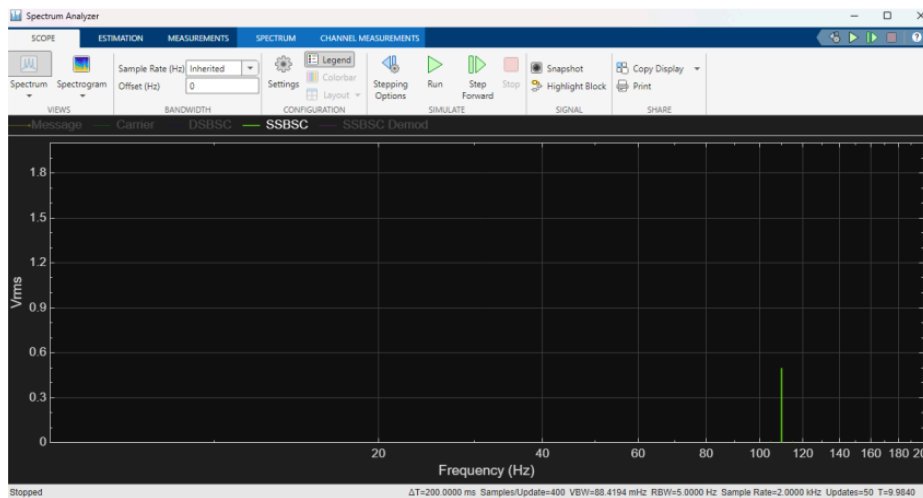


Figure 12: SSBSC only

Results

DSBSC

DSBSC shows a similar power level to AM which is what I expected as its not subtracting part of its signal with a copy of itself. Its constituent parts are higher than it in power since its half their power.

The demodulated data in DSBSC over powers the carrier because the side bands are not half or less than half the carrier such when added together they provide a very effective signal.

SSBSC

Shows a low power level when its on its own this demonstrates why it gets further amplification in most commonly used applications as such. And since you're adding an amplifier anyway the signal can be boosted to provide significant range compared to AM signals.

The carrier is higher in both SSBSC and DSBSC this is because they are products of the carrier not individual signals themselves.

AM modulation comparison of modulation index

Below is the settings used in the am modulator design

14

carrier

$$c(t) = A_c \sin \omega_c t$$

Modulating wave

$$m(t) = A_m \sin \omega_m t$$

$$\omega_c = 2\pi(100) \text{ or } f_c = 100 \text{ Hz}$$

$$W_c = 628.318531$$

15

$$\omega_m = 2\pi(10) \text{ or } f_m = 10 \text{ Hz}$$

$$W_m = 62.83185307179586$$

Modulation Index	1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Last Digit of Your ID	0	1	2	3	4	5	6	7	8	9

I will showcase the difference between 0.3 and 0.6

0.6 is chosen as my student number's final number is 6 and 0.3 is the corresponding half of my student number providing what I believe will be an easily visible difference modulation scheme.

16

AM in the time domain

AM in the time domain looks as follows.

0.3

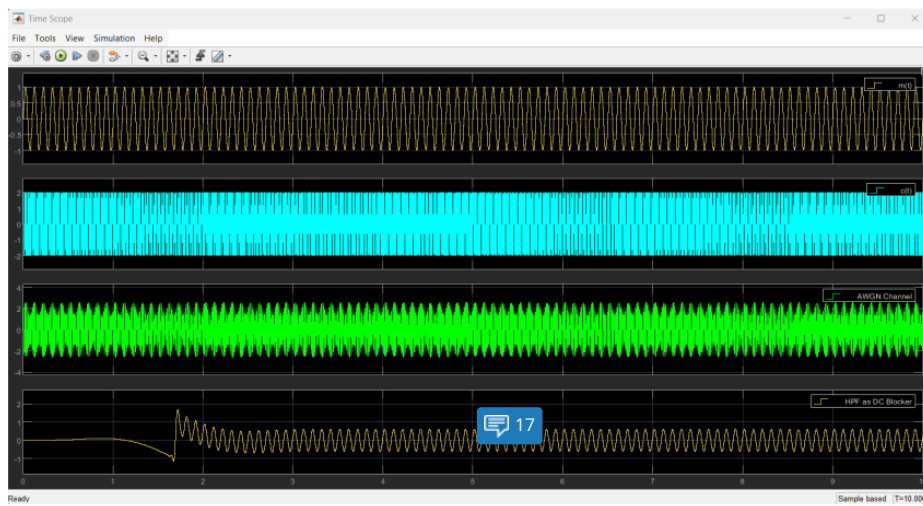


Figure 13: Modulation index scope

0.6

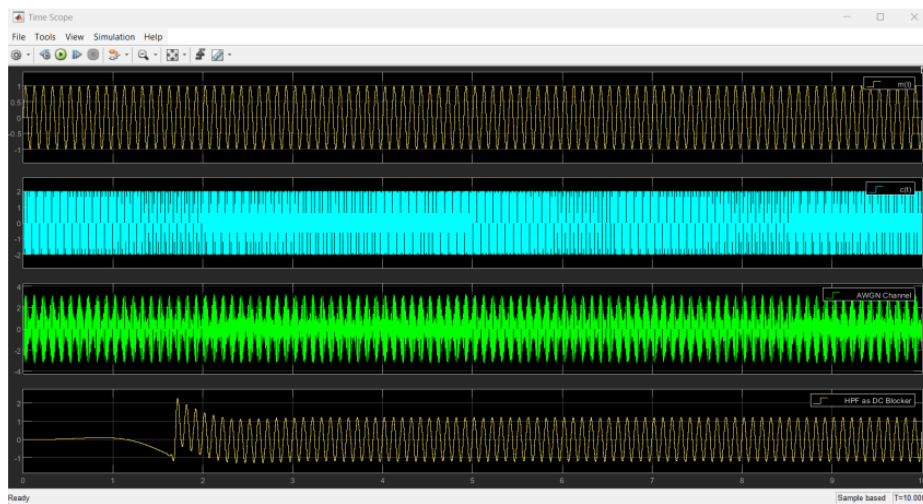


Figure 14: Modulation index scope 2

This was obtained from a scope in simulink.

AM the in frequency domain

AM the in frequency domain looks as follows.
0.3 modulation index

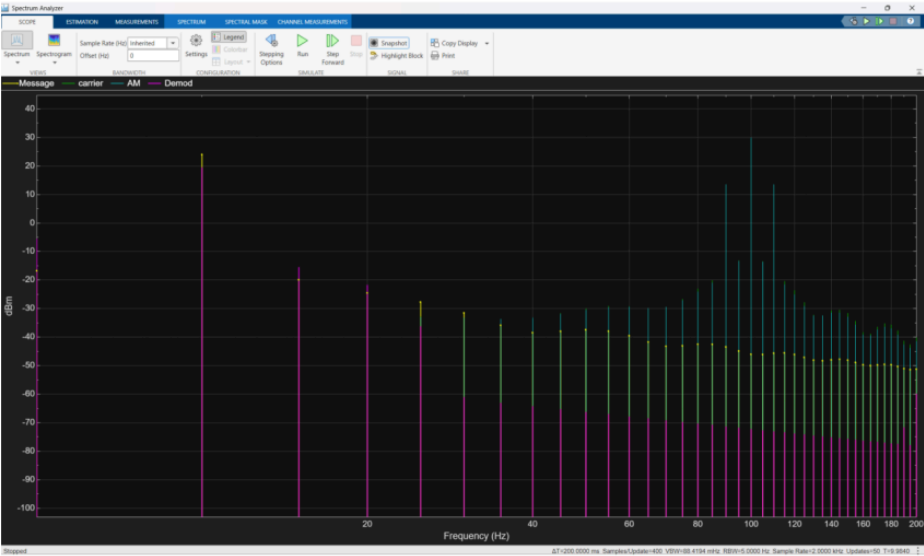


Figure 15: AM modulation index 0.3

0.6 modulation index

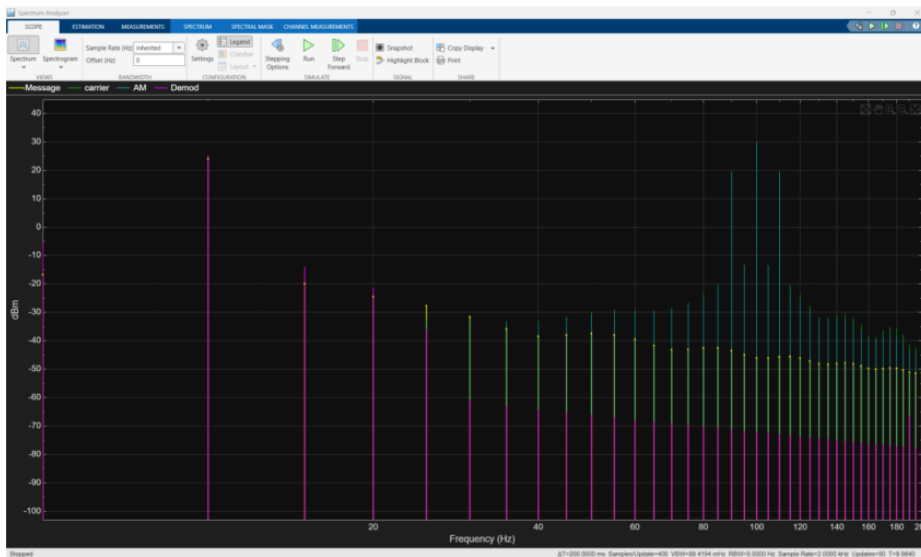


Figure 16: AM modulation index 0.6

This was obtained from a spectrum analyser in simulink.

The modulation index relates to the how much power is in the message signal before being combined
 19 the carrier signal this makes it easier to asses the amplification needed to produce a good
 demodulation

Simulations

Dsbsc
 100

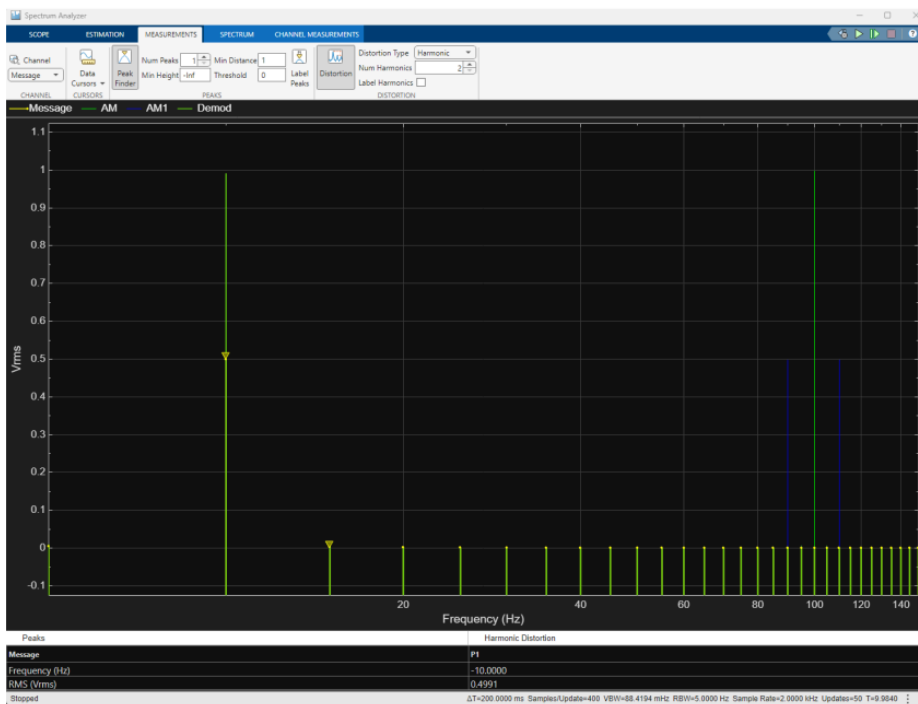


Figure 17: DSBSC SNR100

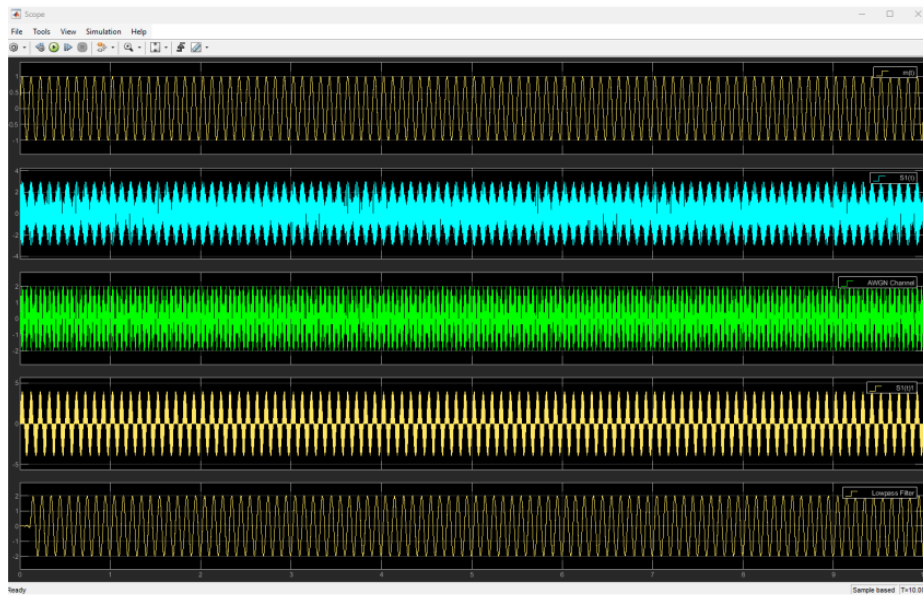


Figure 18: DSBSC Scope 100

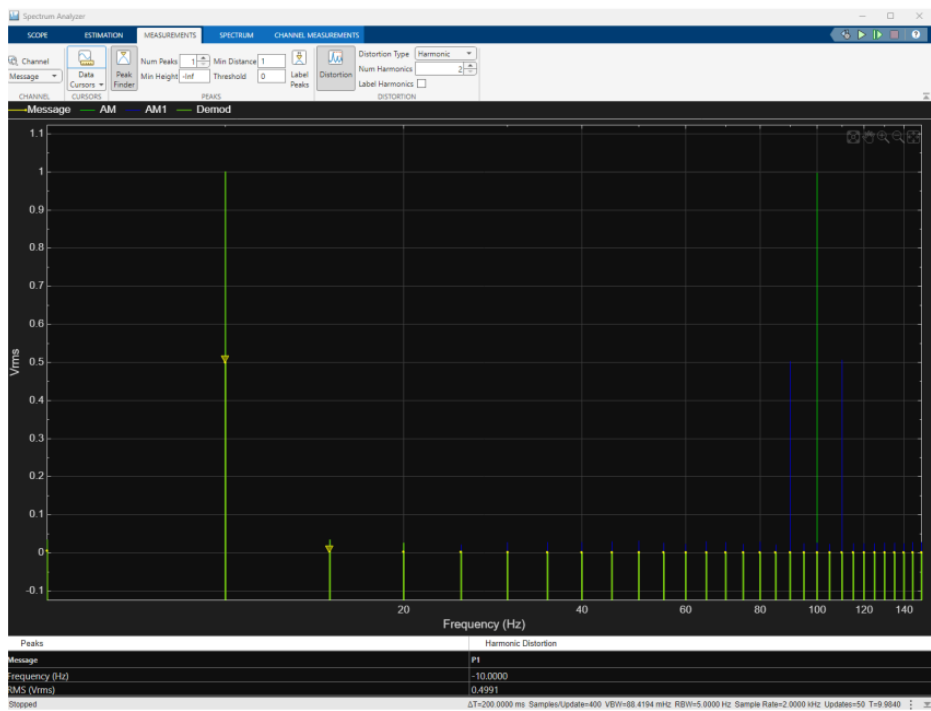


Figure 19: DSBSC SNR 5

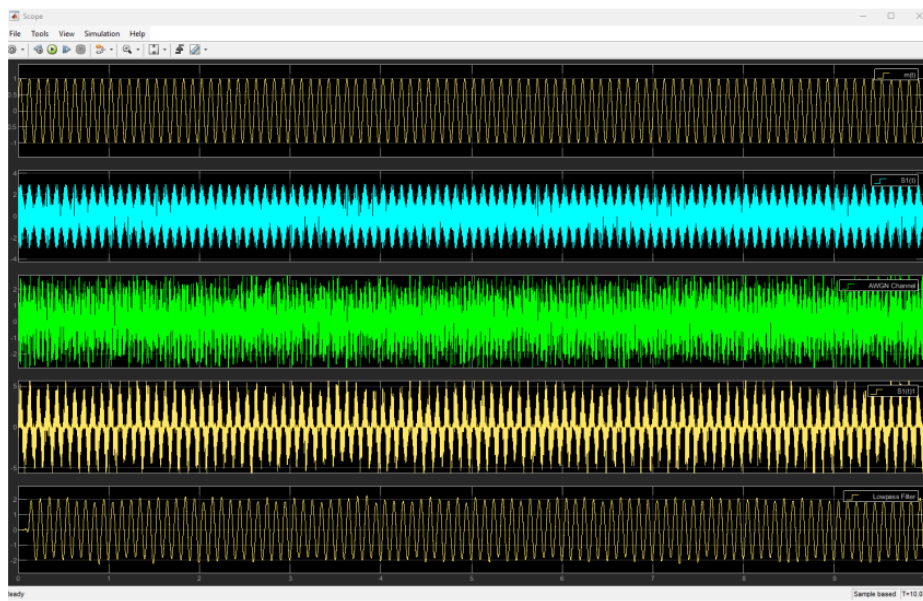


Figure 20: DSBSC Scope 5

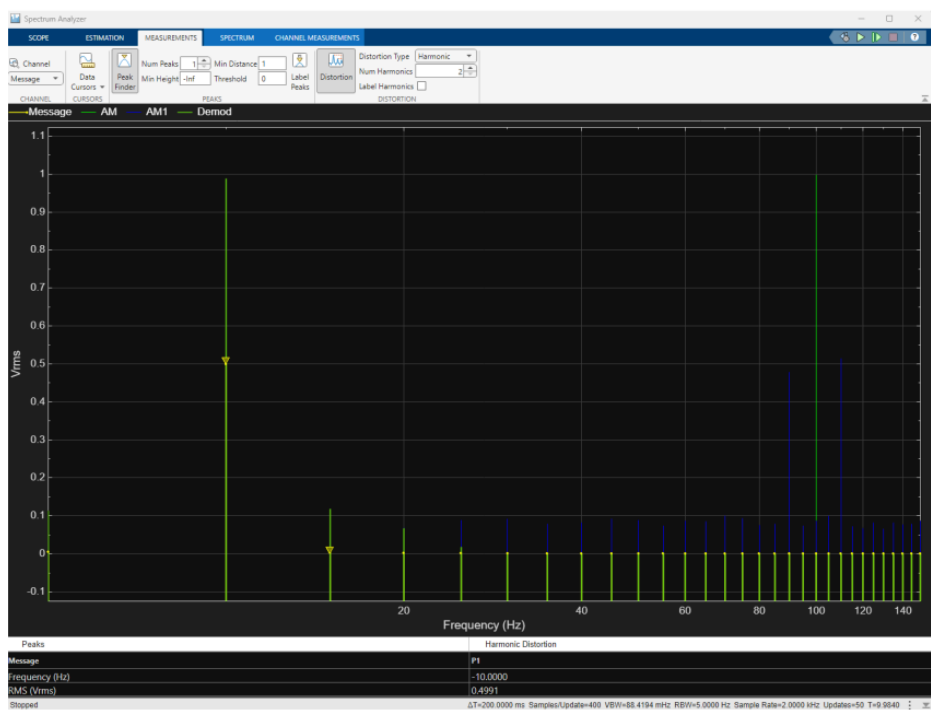


Figure 21: DSBSC SNR -5

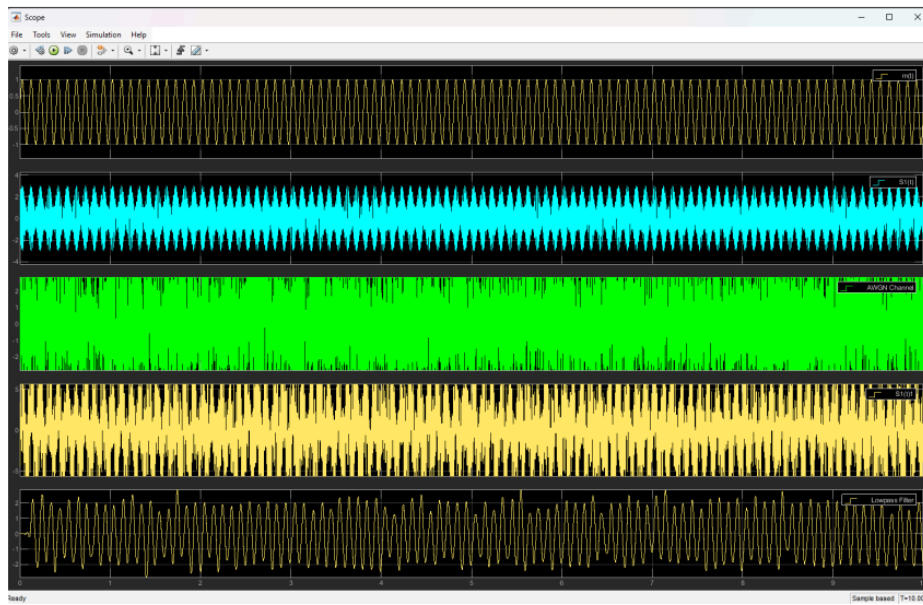


Figure 22: DSBSC Scope -5

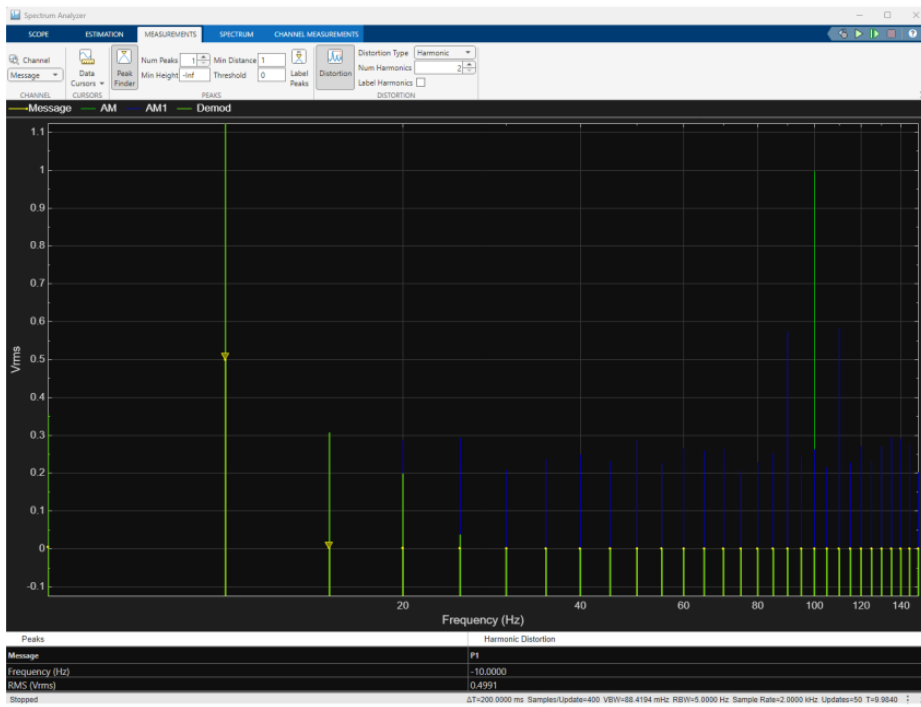


Figure 23: DSBSC SNR -15

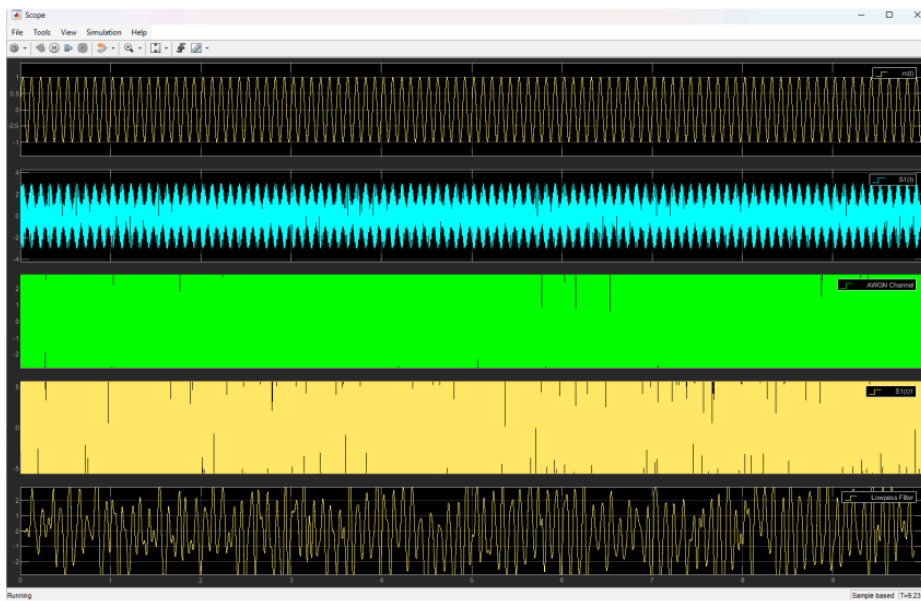


Figure 24: DSBSC Scope -15

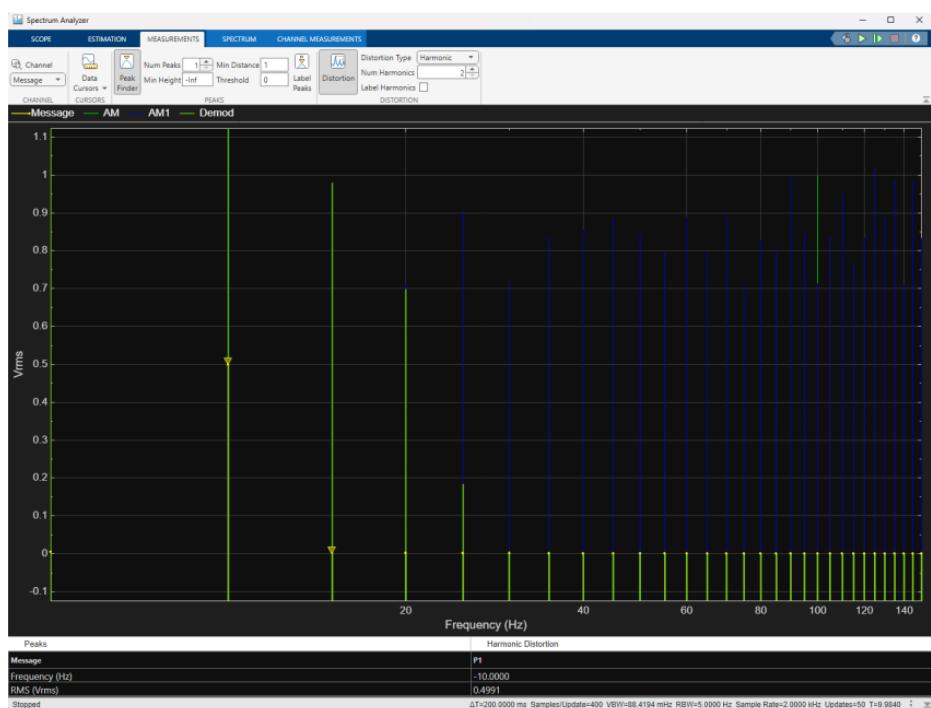


Figure 25: DSBSC SNR -25

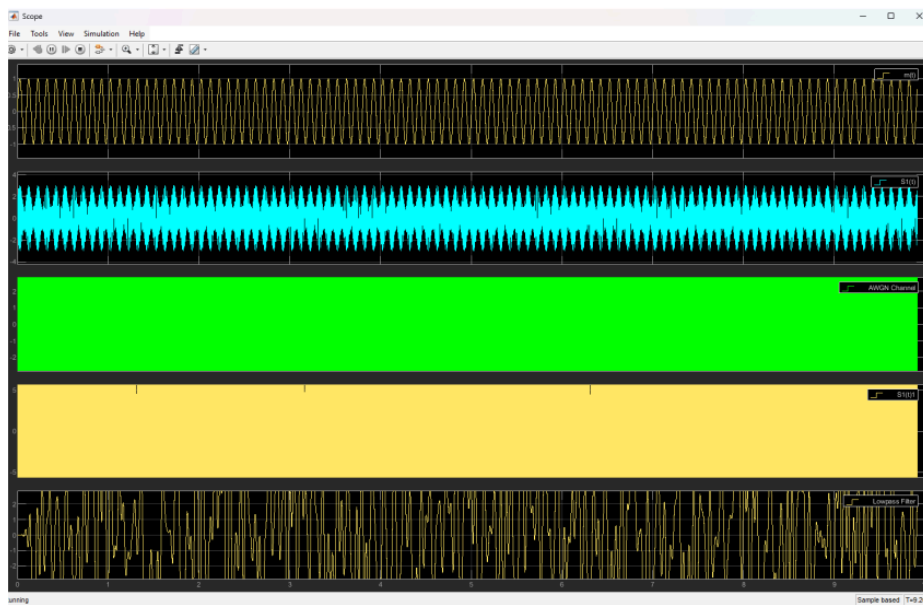


Figure 26: DSBSC Scope -25

Sbsc
100

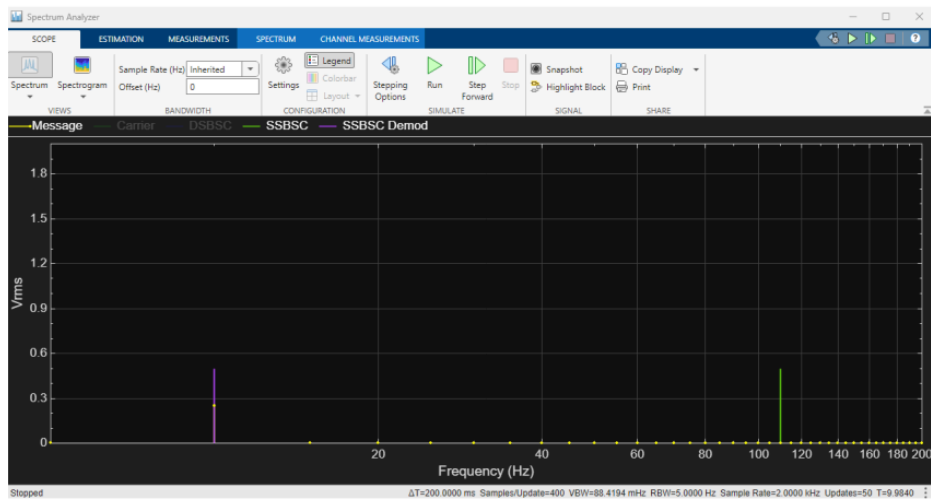


Figure 27: SSBSC SNR 100

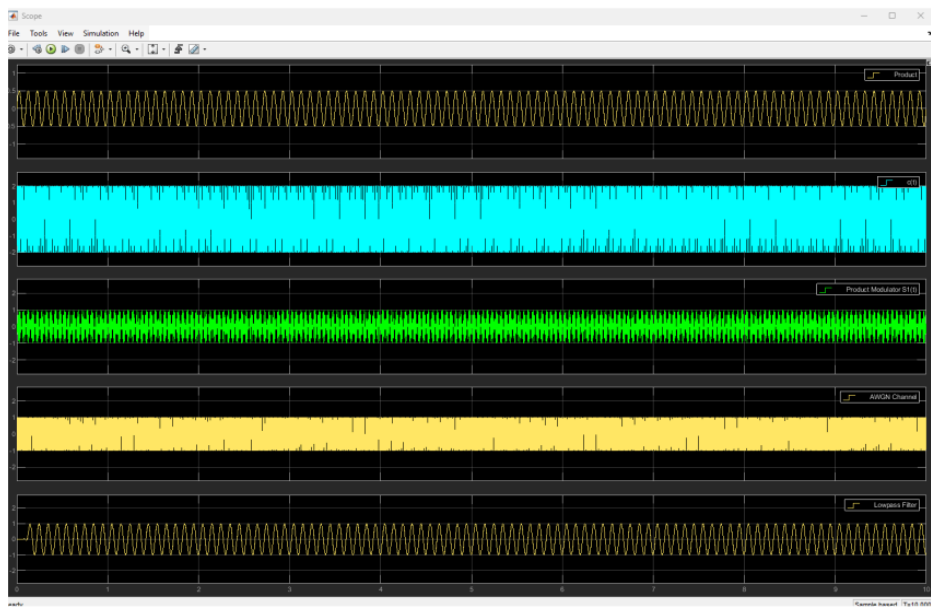


Figure 28: SSBSC Scope 100

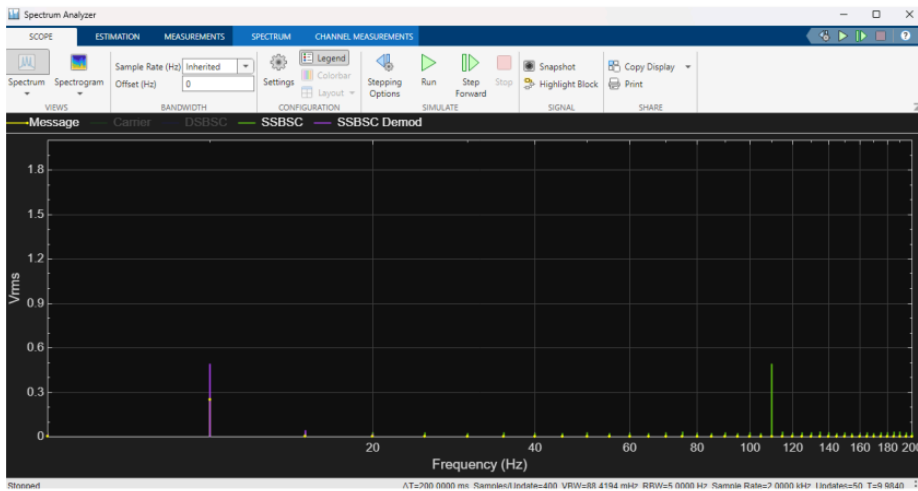


Figure 29: SSBSC SNR 5

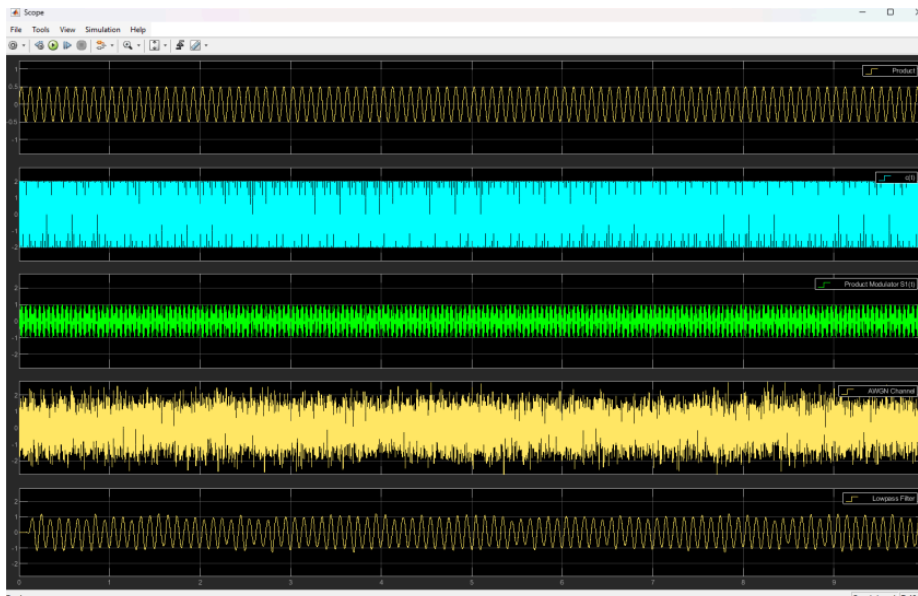


Figure 30: SSBSC Scope 5

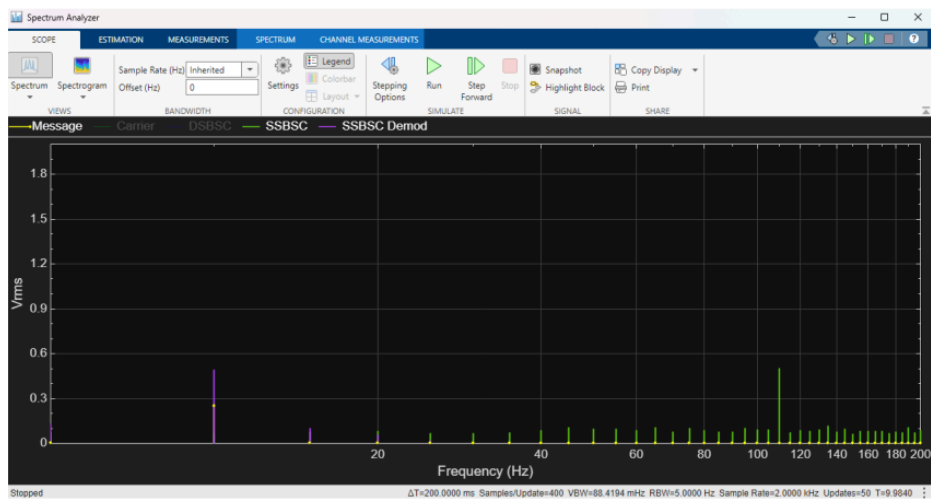


Figure 31: SSBSC SNR -5

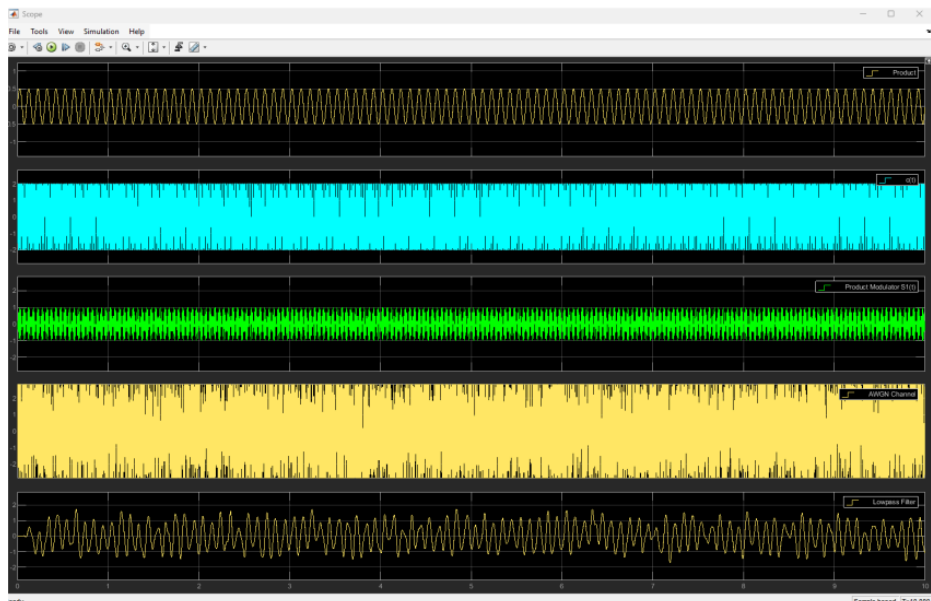


Figure 32: SSBSC Scope -5

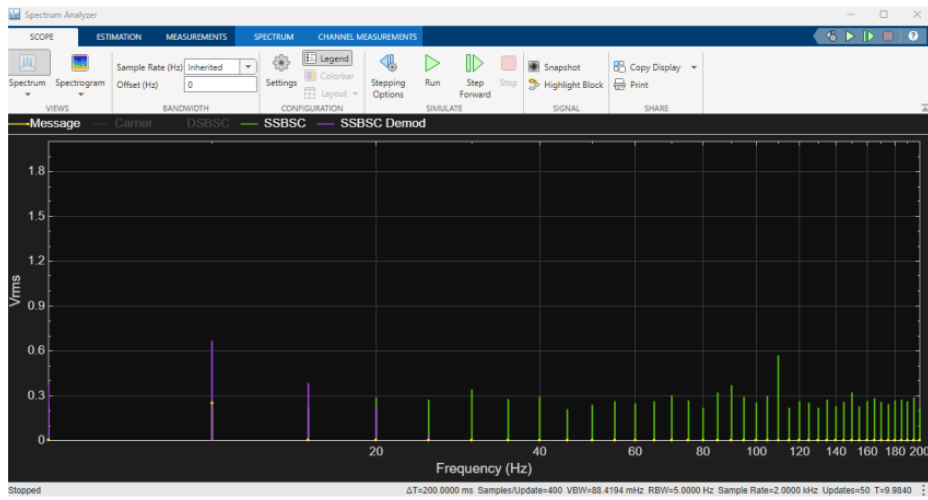


Figure 33: SSBSC SNR -15

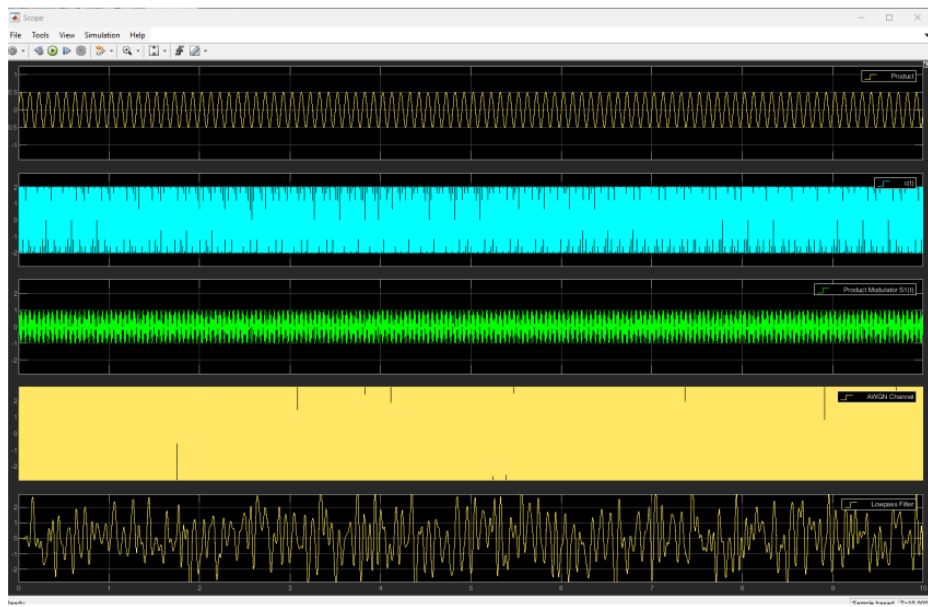


Figure 34: SSBSC Scope -15

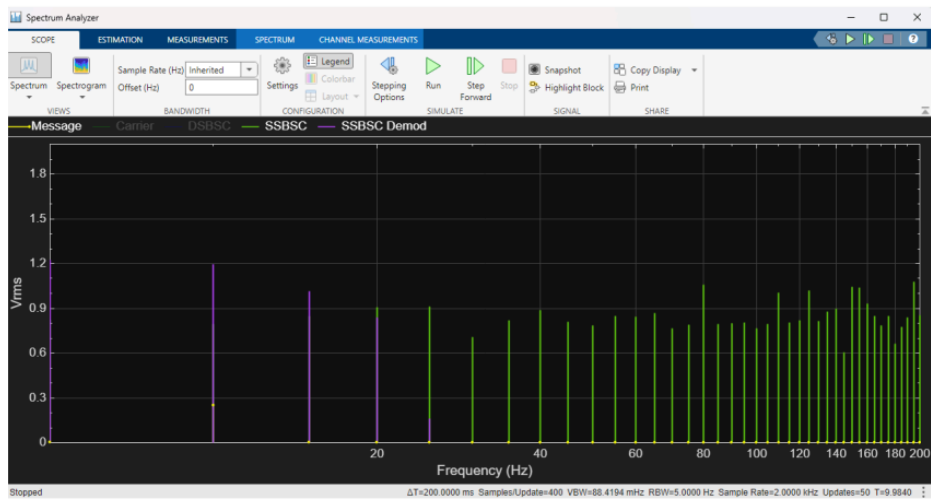


Figure 35: SSBSC SNR -25

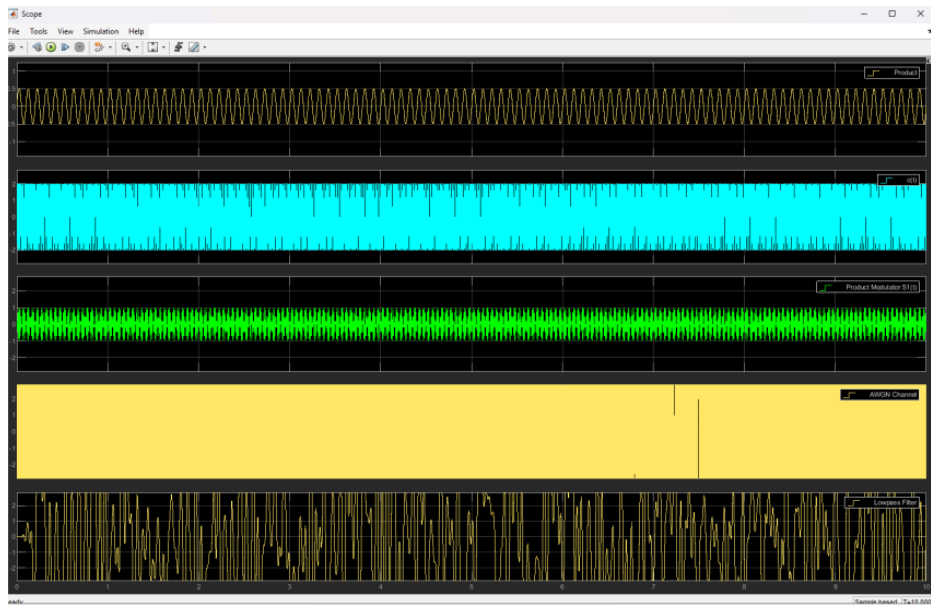


Figure 36: SSBSC Scope -25

AM

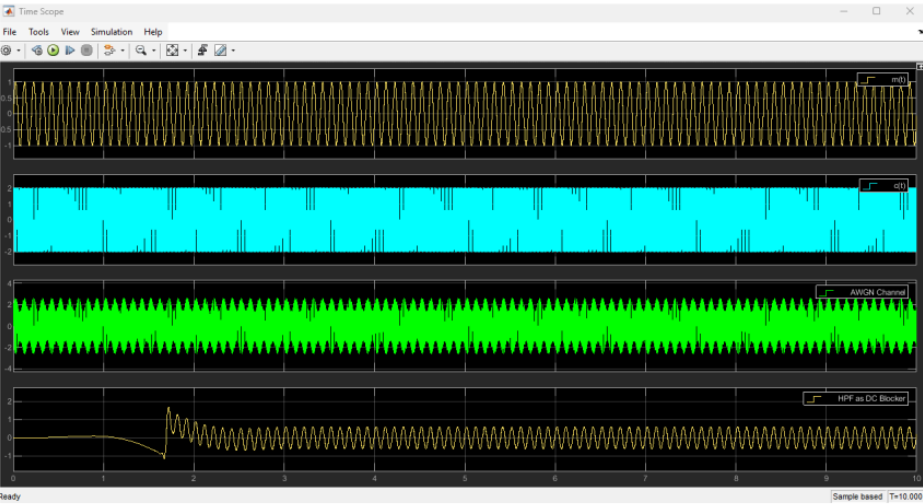


Figure 37: AM SNR 100

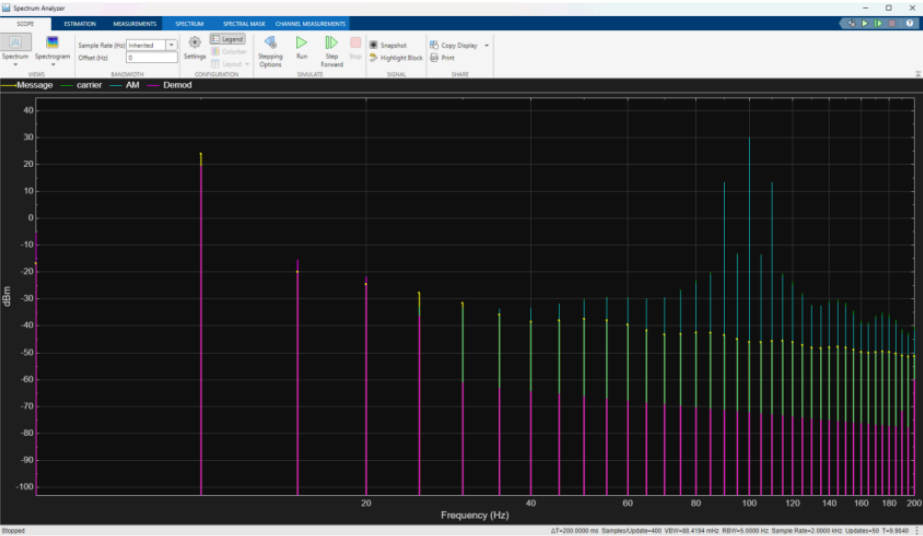


Figure 38: AM Scope100

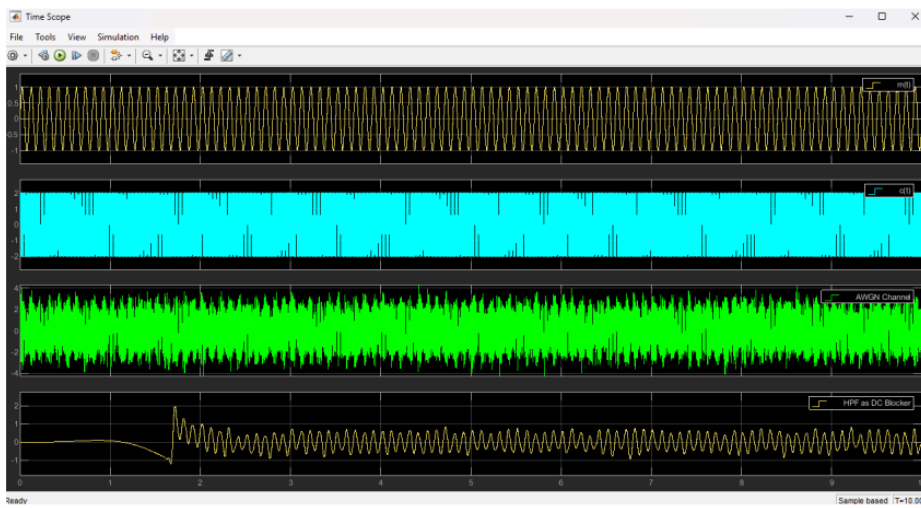


Figure 39: AM scope 5

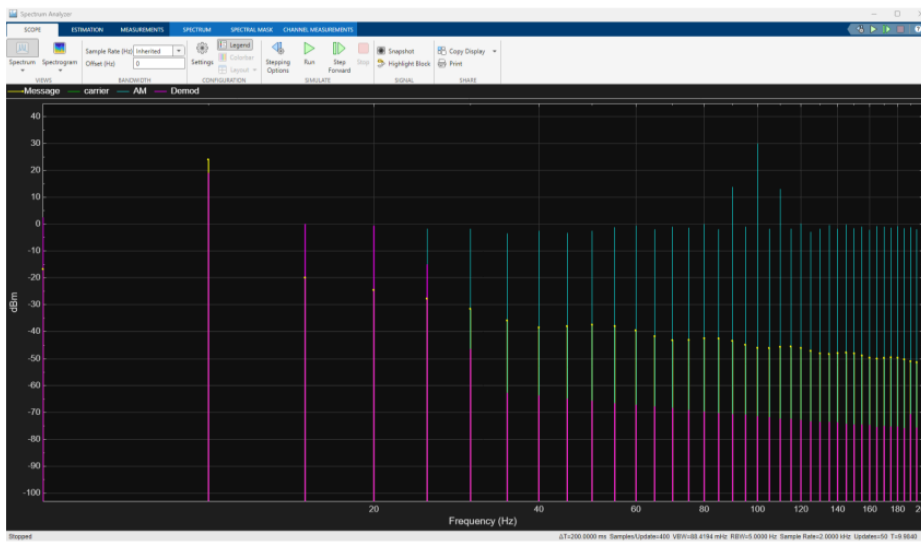


Figure 40: AM SNR 5

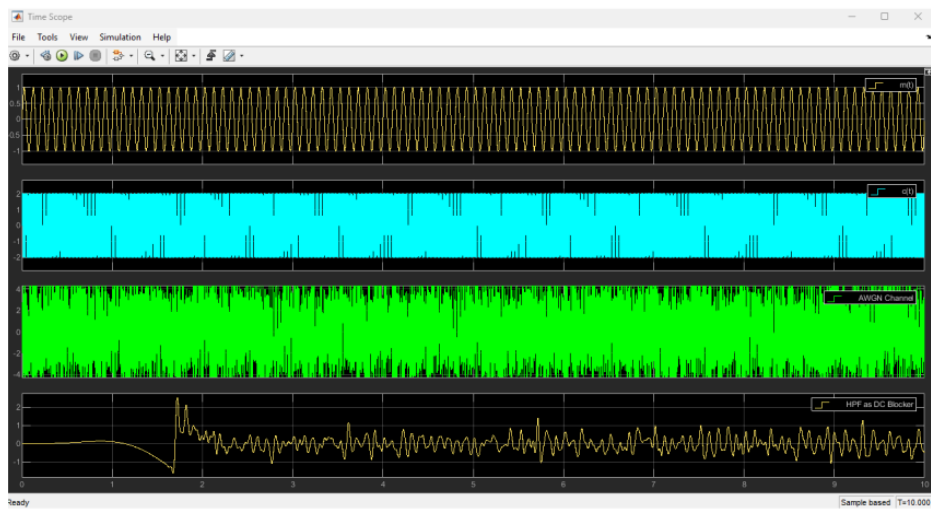


Figure 41: AM Scope -5

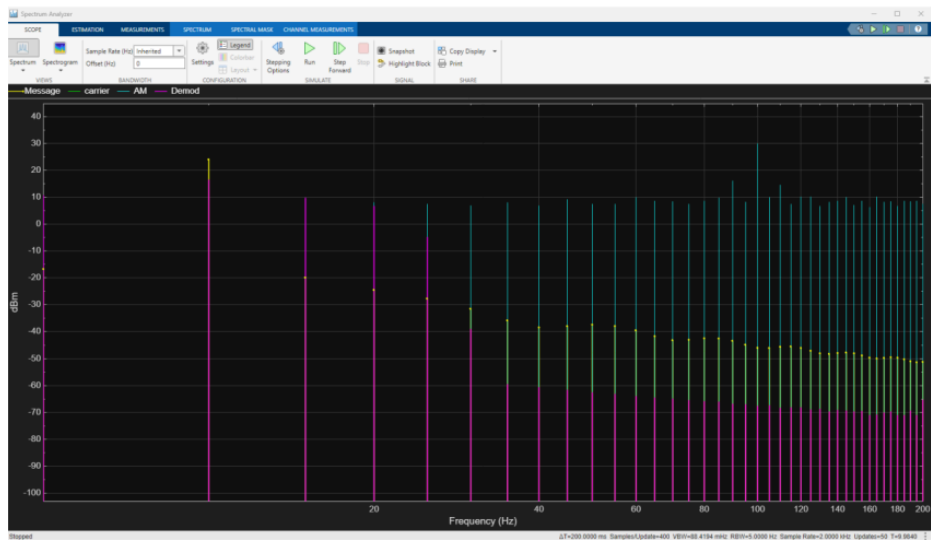


Figure 42: AM SNR -5

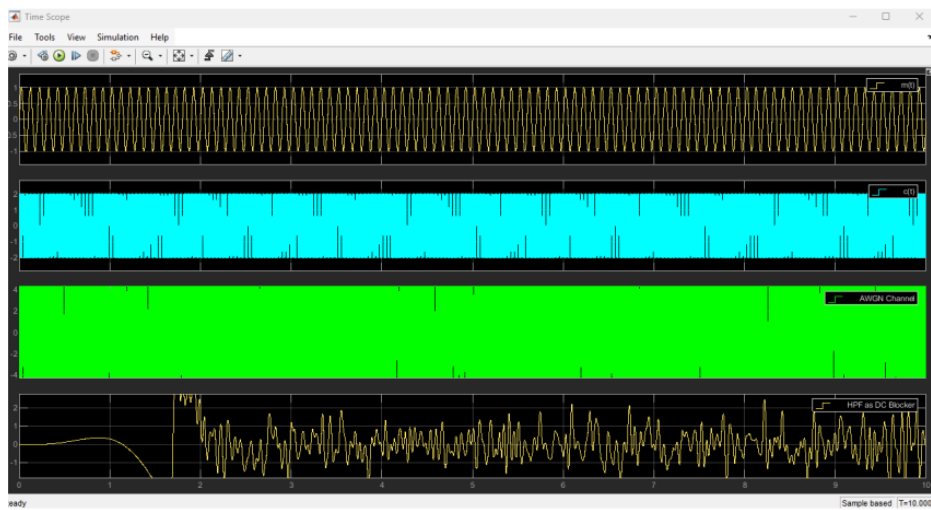


Figure 43: AM Scope -15

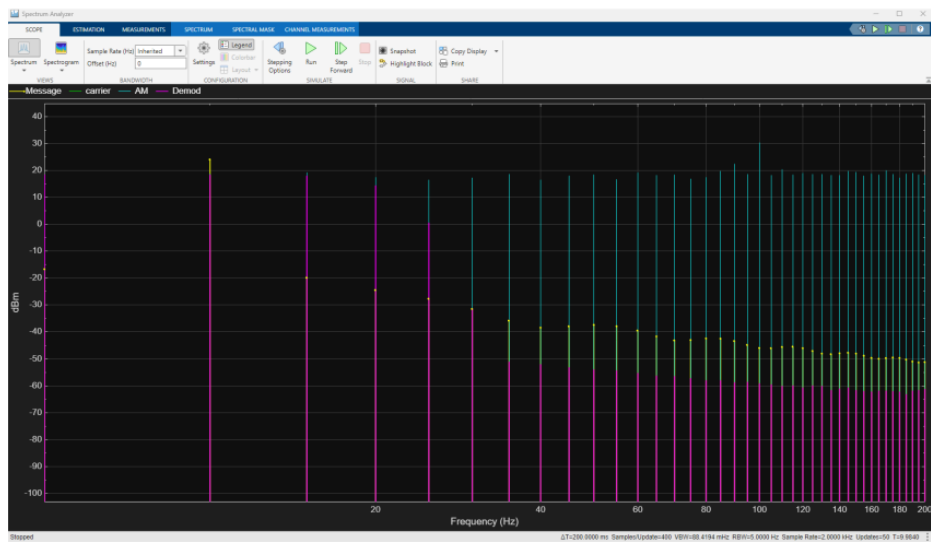


Figure 44: AM SNR -15

-25

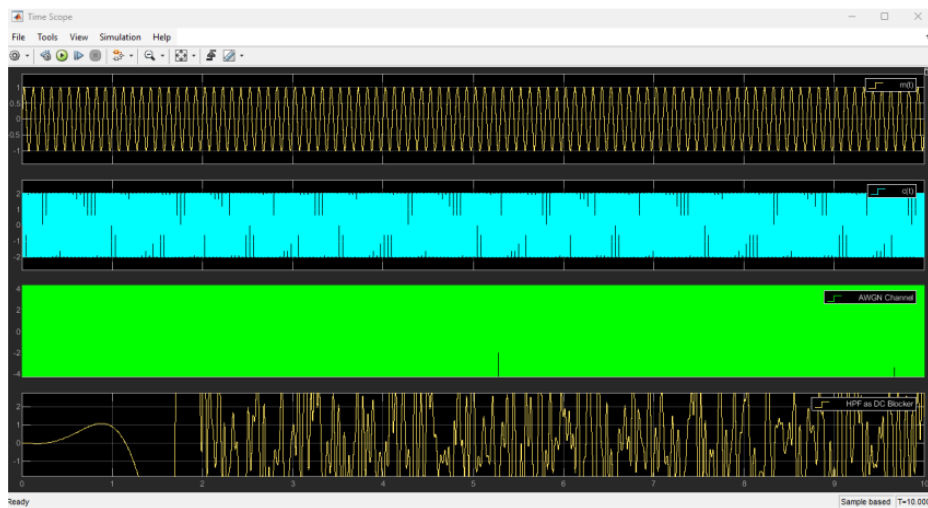


Figure 45: AM Scope -25

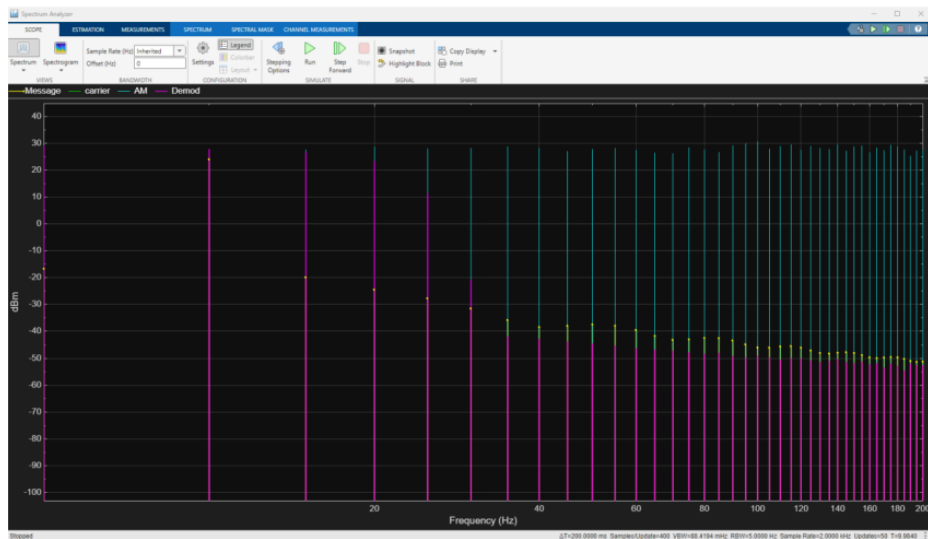


Figure 46: AM SNR -25

Results

These results will be the average of the three tests I have run for each noise level.

I will perform tests at 5 different SNR values 100 to ensure that the modulator is working and give a baseline 5 to start the test -5 - 15 - 25.

AM modulator

Power density

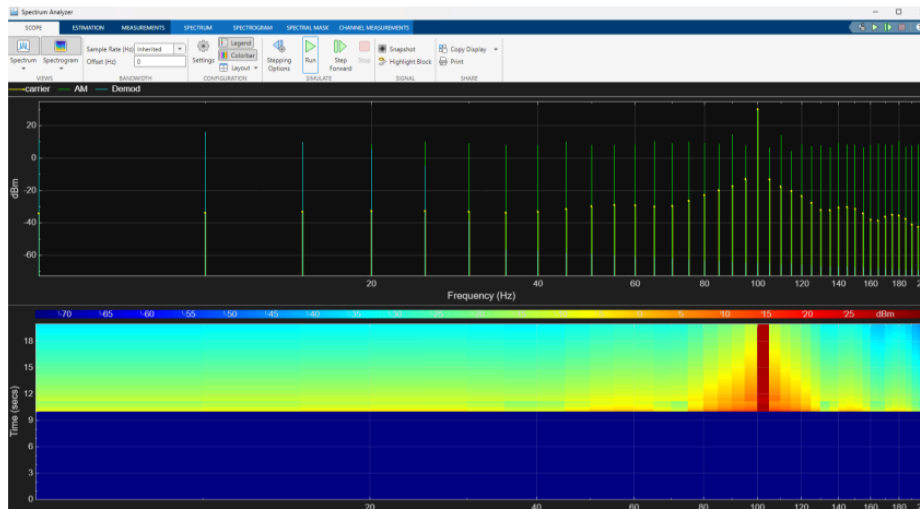


Figure 47: AM Power density

The power is all placed on the carrier with power placed around the carrier but much lower down

The max power outputted by this signal is 25dbm placed on the carrier with the area around it decreasing to 3 at the lowest before it enters the noise floor of this system

Noise tolerance

This is harder to measure but based on the simulations above the AM signal is unreadable at -15 and barely readable at -5 due to this I will place the noise tolerance of AM at -5 dbm as this is where the signal is last visible in my tests although this is likely not visible to a rf system

Spectrum usage

Am uses very little spectrum if its filtered correctly as it only transmits at one frequency this makes it able to have many channels in the spectrum area if filtered correctly. AM harmonics due to powers involved in AM transmission can be very large and could cover a weaker AM signal

Dsbsc

Power Density

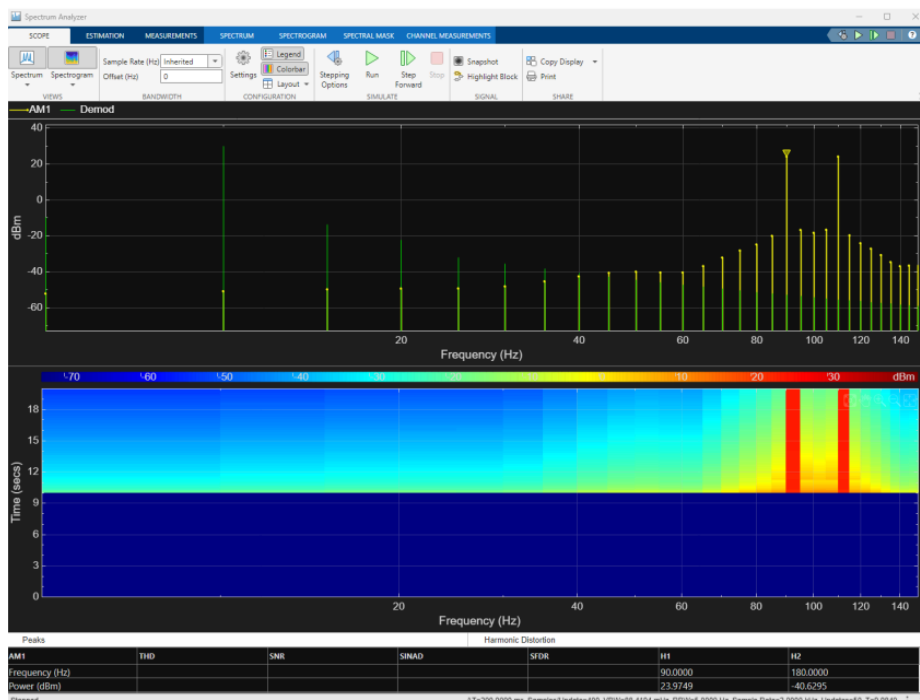


Figure 48: DSBSC Power density

DSBSC places all the power around the two side bands of the am signal as shown above. I have removed the carrier to get a better understanding of power the max power of this signal is 24

Noise Tolerance

As shown in the above images the DSBSC signal has a very high noise tolerance considering its an analogue the last time i can discern the signal from the noise is -15.

Spectrum usage

This uses about 20 hz of spectrum usage as such its not the smallest but its still very small

Sbsc

Power Density

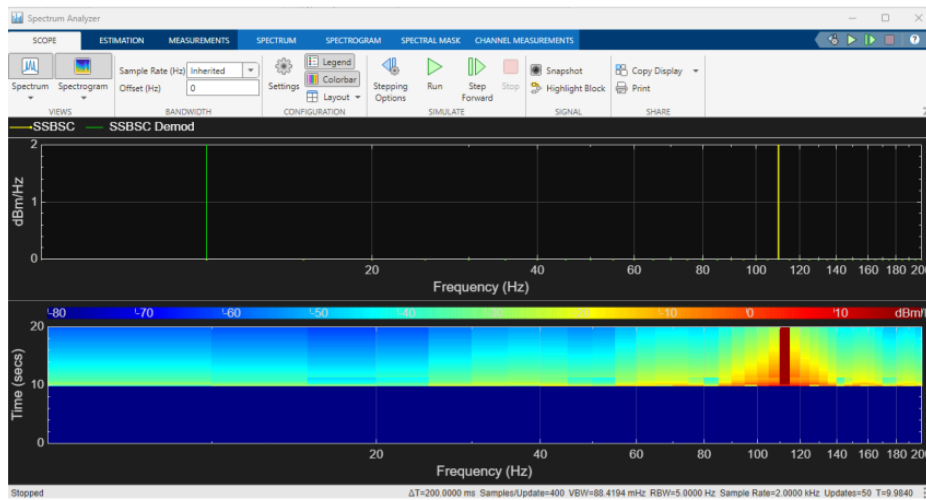


Figure 49: SSBSC Power density

The power is all placed around the transmitted sideband and not anywhere else this makes it very power efficient and capable of

Noise Tolerance

Ssbosc is

Spectrum usage

Ssbosc uses around 1hz of spectrum up to 20 depending on what is required to find the signal. As the message is only transmitted on the side band the actual data only takes up to 2 hz in width.

Discussion

Positives and negatives of the modulation techniques

AM

Has the lowest noise rejection of all but its the most simple to implement and the smallest in frequency spectrum as such in an open rural area AM is likely a more effective standard as it will be cheaper to implement than DSBSC or SSBSC and you can have more channels in the same area given good filters are present on the transmitters.

DSBSC

Has a higher Noise tolerance than both AM and SSBSC And a Higher power level than SSBSC due to not cancelling one of its side band signals this increases DSBSC signal strength significantly compared to SSBSC. Although it has a much larger Spectrum usage compared to AM or SSBSC.



SSBSC

Has Reduced spectrum usage compared to DSBSC and higher noise tolerance than AM make this effective in more applications than AM as it can be found in more noise. It has less noise tolerance than DSBSC And DSBSC can be more easily be seen at -15dbm than SSBSC but DSBSC takes up more frequency space than SSBSC as such their are less channels available in the spectrum for when using DSBSC.



SSBSC has a lower power output so its noise tolerance may increase within amplification but it also may make it take up more spectrum space as such their may be increases to come from a higher amplification.

Conclusion

In conclusion I believe SSBSC and DSBSC can be used for similar work depending on if the area has more noise or needs more channels. This is due to DSBSC having such a more capable noise rejection than SSBSC.

In a rural low noise environment AM is likely more effective as it should be cheaper to implement than SSBSC and DSBSC and the benefits of both are reduced compared to a urban environment as rural environments normally have less rf noise and would prefer the ability to have more device channels to communicate on separate channels.

Future

In future tests i would automate the data capture so that its more consistent and run more tests as this would enable me to get a more accurate representation of the system i would also increase the number of SNR values as the values chosen made it difficult to spot when the modulation types too noisy to see for a better setup i should go down in 5 dbm intervals and then when the noise becomes to much go back up in 1dbm increments to find when its truly lost.

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[1]

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[3]

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RF Systems final handin

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

44/100

PAGE 1

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PAGE 5



Comment 1

no comment

PAGE 6



Comment 2

All in caps

PAGE 7



Comment 3 | Transferable skills (20)

It is better to use consistent terms throughout the report for better clarity and understanding.

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Comment 4 | Knowledge & Understanding (20)

is this sentence talks about DSBSC or SSBSC?



Comment 5 | Knowledge & Understanding (20)

The term "negative modulation index" likely refers to polarity inversion or signal cancellation in balanced modulation, but this needs clarification as it is not a standard term in modulation theory.

PAGE 9

**Comment 6** | Transferable skills (20)

Could be placed before.

**Comment 7** | Transferable skills (20)

Including too many screen dumps seems unnecessary, as Figure 4 already effectively shows all the signals without noise.

**Comment 8** | Cognitive skills (20)

Parameter values like power, SNR, and figure of merit should be considered, to make the results more accurate.

**Comment 9** | Knowledge & Understanding (20)

The explanation provides a general understanding but contains some conceptual inaccuracies.

For instance, DSBSC is more power-efficient than AM due to carrier suppression, which is not clearly conveyed.

**Comment 10**

how?

**Comment 11**

signal

**Comment 12** | Practical Application (30)

The description of sidebands in DSBSC and the power levels in SSBSC needs clarification, as SSBSC focuses power on a single sideband, making it highly efficient.

**Comment 13** | Practical Application (30)

The mention of the carrier being "higher" in both systems is misleading, as both DSBSC and SSBSC suppress the carrier.

**Comment 14**

using notations should be consistent.



Comment 15

?



Comment 16

Good

PAGE 17



Comment 17 | Cognitive skills (20)

The scopes focus on AM, but it is important to observe and analyse the changes that occur during modulation with varying inputs of the modulation index.

PAGE 18



Comment 18 | Cognitive skills (20)

Different modulation index vales are applied to the design but failed to cover the concept of critical, over and under modulation index and how does it affects the signal strength.

PAGE 19



Comment 19

which values gives you the better results?

PAGE 20

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PAGE 22



Comment 20 | Practical Application (30)

A clear writing should be given to explain about specifying different values to SNR and what results and analysis are made.

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Comment 21

?

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Comment 22 | Cognitive skills (20)

The analysis includes some observations but would benefit from clearer explanations, stronger connection to theory or practical outcomes, and additional context to support the results. Providing more technical depth on power distribution and harmonics would make it more valuable.

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Comment 23

Provide numerical values or references to support claims about power, noise tolerance, and spectrum usage for AM, DSBSC, and SSBSC.



Comment 24 | Cognitive skills (20)

The claim that AM is simple and cost-effective in rural areas is valid, but the statement about using the smallest spectrum is inaccurate and needs clarification.

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Comment 25

Higher noise tolerance and power levels in DSBSC are correct but need supporting data.

The impact on spectrum efficiency compared to SSBSC should be clarified.



Comment 26

GRADING FORM: RF_UPDATED_2025

ALEXANDER GRAVATT

45.53

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 weak, and references to theoretical principles are very limited. The discussion on noise impact and performance metrics is unclear and lacks proper detail.

4

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) Limited understanding of AM principles. Examples are missing, and the explanation is not clear.

Task 1: (a) (ii) Fails to describe critical, over, and under modulation. Observations are absent.

Task 1: (b) Explains demodulation at a basic level, but comparisons are unclear.

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

7.73

impact.

Task 2: (b) Fails to describe noise effects in DSB SC demodulation.

Task 3: (a) 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 poorly explained and lack detail.

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

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. Use of spectrum time scopes are seen.

Task 1 (b): The demodulation process is seen but lacks to explain the concept with evident values. Comparisons are minimal. The analysis is shallow with satisfactory points.

Task 2 (a) & (b): The modulation and demodulation processes are seen and evident in screendumps but observations are minimal, with no innovative ideas.

Task 3 (a) & (b): The modulation and demodulation processes for SSBSC are seen but the observations are minimal, with no innovative thinking.

Task 4 (a) & (b): Performance metrics are incomplete. Comparisons and graphs are minimal, and no meaningful conclusion is drawn.

7

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.

17.8



Task 1 (a) (i): Basic understanding of tools is demonstrated but lacks clarity in signal demonstration.

Task 1 (a) (ii): Modulation variations are weakly explained with no clear carrier insights.

Task 1 (b): Limited explanation of AM demodulation. Screen dumps are clear.

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 poor clarity and incomplete results.

Task 3 (a): Implements SSB-SC modulation well but lacks strong theoretical alignment. Observations are clear, and block diagrams are included.

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

Task 4 (a): No evidence of practical setup or meaningful observations. Fails to demonstrate understanding of processes.

Task 4 (b): Insufficient comparison of modulation techniques, with no analysis.

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.



Minimal transferable skills, with limited communication skills, and organisation needs to be improved.

9