

Cerys Versey RF Systems Assignment

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



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Abstract

The following report hopes to give the reader a comprehensive review of Amplitude modulation(AM) , double side band suppressed carrier (DSB SC) and single side band suppressed carrier (SSB SC) modulation as well as covering important concepts such as modulation index, SNR, noise tolerance and density. The report hopes to draw clear conclusion by following the full design, creation and analysis cycle.

Introduction

Task one will take the reader through the steps of creation of an AM modulation and demodulation as well as the effect critical, over and under modulation has on the carrier. There are a number of key terms the reader should be aware of before reading on.

Firstly carrier signal, this is the signal that is transmit and contains the message signal as well as the other signal that is used to modulate the signal. [1]

Another key concept to understand is a message signal as its name suggests this is the signal that contains the data that the user wants to send.

To be able to understand the different types of modulation you firstly need to understand what modulation does. Modulation is the 'process by which data is converted into electrical / digital signals for transferring over a medium' [2]. This is done by varying characteristics of the signal such as frequency, phase or amplitude [3].

Once modulation is understood the reader is able to understand the process of demodulation. This is the process by which data is converted back into its original form after being sent over a medium [4].

The final concept for the reader to be aware of before reading on is signal to noise ratio or SNR. SNR is a ratio of the amplitude of the message signal to that of the surrounding noise [5].

Task 1

Am modulation being where the carrier signal amplitude varies as the amplitude of the message varies. [6]

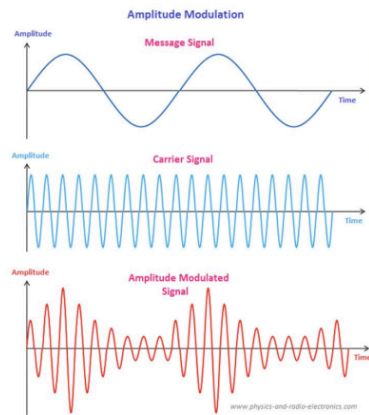


Figure 1 - Example of AM modulation (<https://www.physics-and-radio-electronics.com/blog/amplitude-modulation/>)

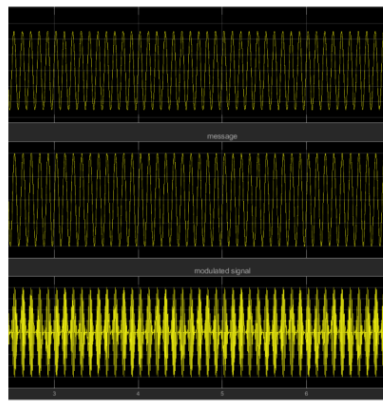


Figure 2 - Example of AM modulation made from a Simulink model

To create the initial AM modulation scheme, Simulink was used. The below diagram uses two colours to show the two parts of the transmission, transmit (in purple) which include the modulation and receive (in green) which includes the demodulation. Demodulation for AM signals can be done in two ways either by multiplying and then filtering or by using a peak detector in the below examples multiplication and filtering was chosen. To be able to check the accuracy of the modulation and demodulation a scope and spectrum analyser are used to compare the message signal before and after modulation and demodulation.

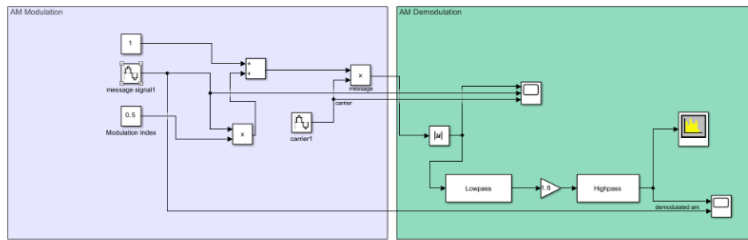


Figure 3 - AM Simulation model in Simulink

The modulation part of the model is designed using the expression for an amplitude modulated wave which is

$$VAM = Ac \sin \omega t (1 + m \sin \omega t) \quad [7]$$

$$VAM = Ac \sin \omega t (1 + m \sin \omega t)$$

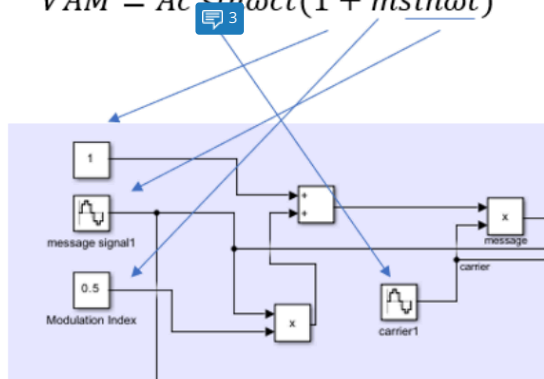


Figure 4 - Figure showing comparison between design and equation for AM modulation

You can directly relate different parts on the equation to parts of the model.

A signal that has been AM modulated has an associated modulation index. The modulation index is the ratio of the amplitude of the modulated signal to the amplitude of the carrier[8]. A modulation index less than one is considered under modulation, a modulation index of 1 is considered critical modulation this is where the amplitude of the carrier is equal to that of the modulated signal. When the modulation index is greater than one it is considered over modulation [9].

Initially a test was conducted using a modulation index of 0.8 (Last digit of student ID is 8) this is considered under modulation. The carrier frequency was 100 Hz and the message signal was at a frequency of 10 Hz.

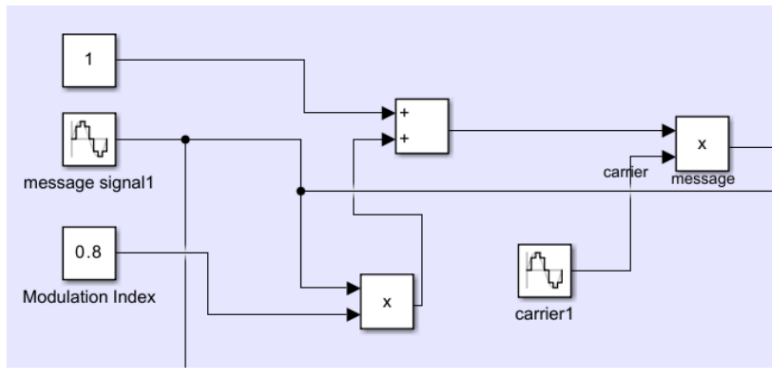


Figure 5 - AM modulation, modulation index of 0.8

5

This is considered under modulation, this causes the carrier to fall above zero but ultimately causes no distortion. As can be seen from the scope outputs. [10]

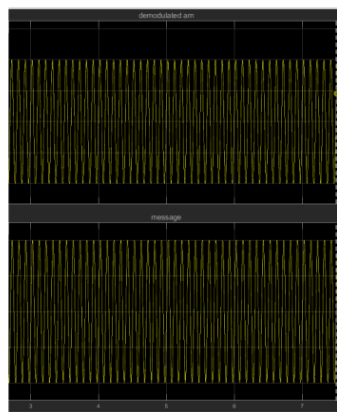


Figure 6 - Scope out from 0.8 AM modulation message and demodulated

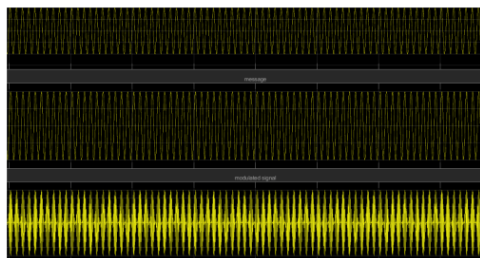


Figure 7 - Scope out from 0.8 modulation index message, modulated and demodulated

Critical modulation was then applied. This is where the modulation index is equal to 1. This is the ideal modulation index as the Amplitude of the carrier is equal to that of the message signal.

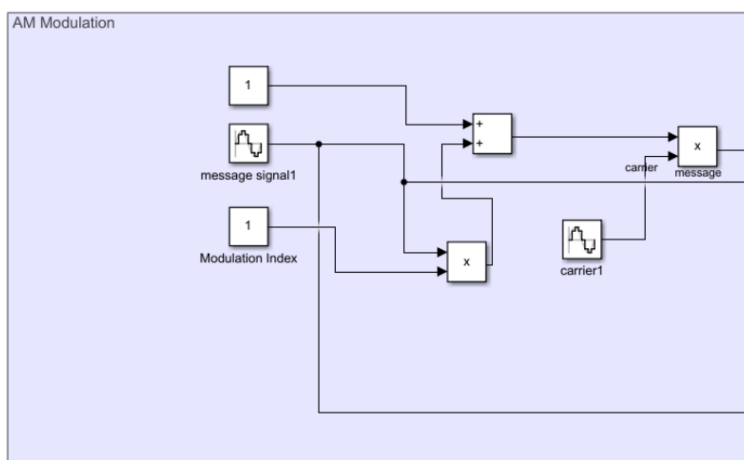


Figure 8 - AM modulation index of 1 (critical modulation)

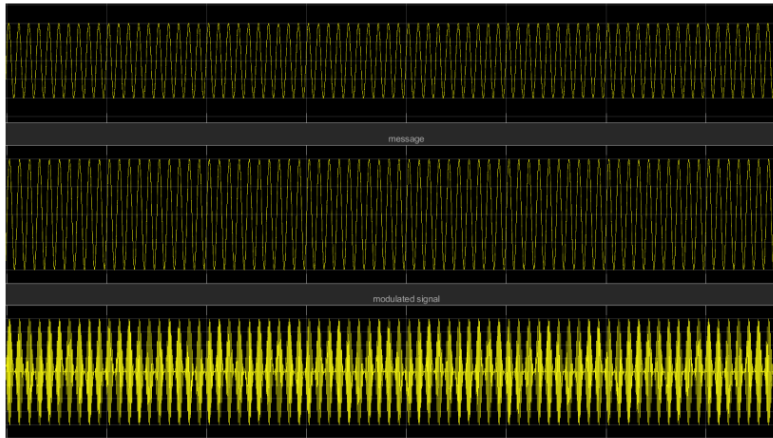


Figure 9 - scope output AM modulation critical modulation

As can be seen from the above scope trace this had no distortion affect on the signal at all.

Finally over modulation was tested. A value of 10 was chosen this is ten times the recommended modulation index, as can be seen from the below scope plots distortion has occurred.

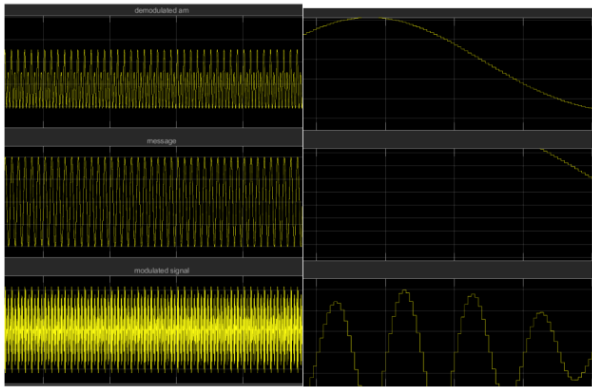


Figure 10 - am over modulation distortion

Figure 11 - scope out over modulation index of 10

This can be seen even clearer when comparing the message and demodulated signal which should look identical but has clear distortion.

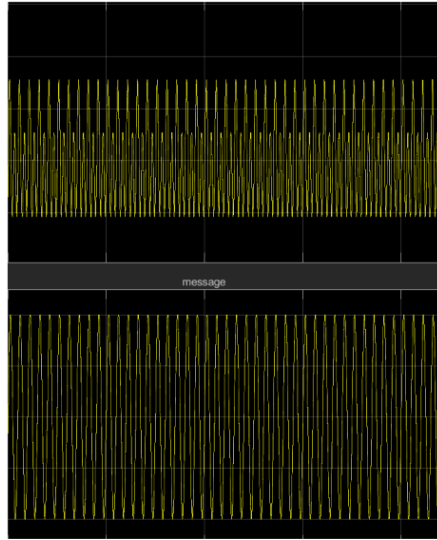


Figure 12 - AM modulation scope out message and demodulated

Task 2

Another type of modulation is Double side band suppressed carrier (DSB SC) modulation this is a form of AM modulation [12]. This is where the sidebands of the signal are transmitted and the carrier signal is suppressed. This can be seen in the figure below.

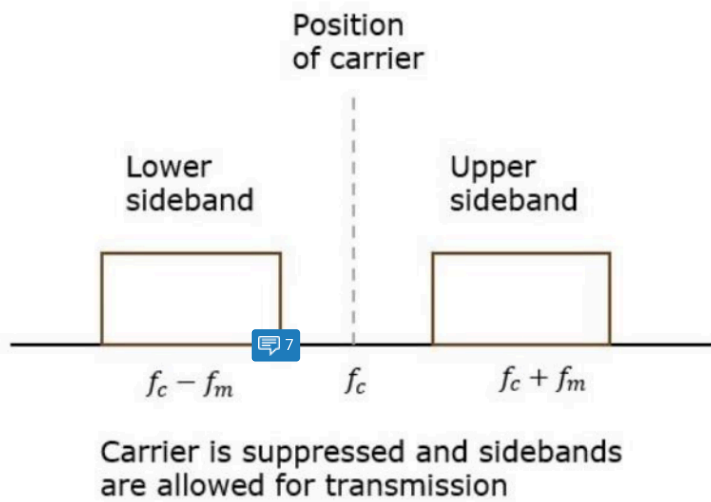


Figure 13 - Example of a DSB-SC transmission (Tutorials point)

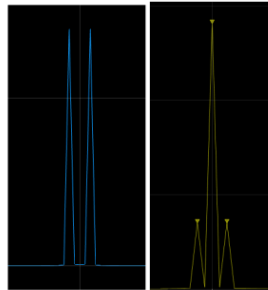


Figure 15 - Original message signal

Figure 14 - DSB SC Transmitted signal

This is done to improve efficiency to reduce the power loss as the carrier signal doesn't carry any data and so power is being conserved by not transmitting the carrier [13]. To do this the message signal is copied into two. One is the carrier plus the message and one is the carrier minus the message signal. This gives the double side band aspect of DSBSC [14].

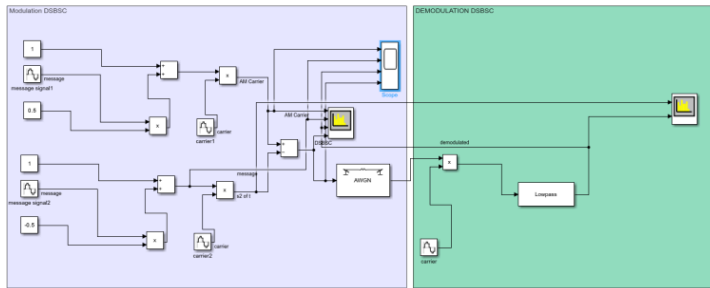


Figure 14 - DSBSC Simulink model NO AWGN modulation index 0.5

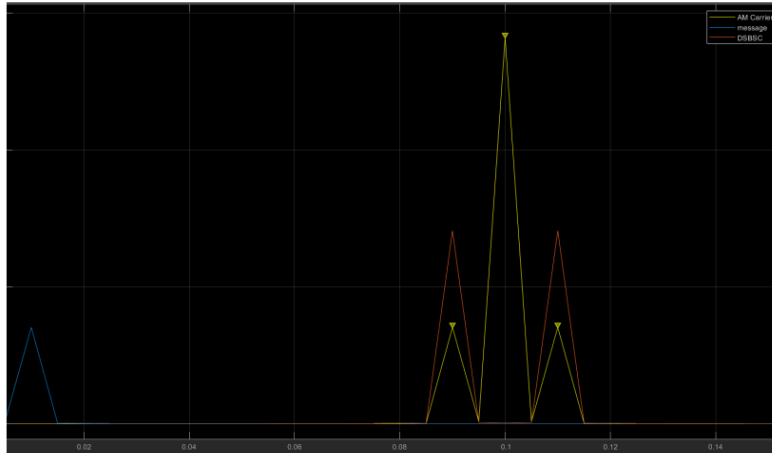


Figure 15 - DSBSC spectrum output Carrier, message, DSBSC

The above figure shows DSB-SC in the frequency domain, with a modulation index of 0.5. The message signal is at a frequency of 10 Hz and the carrier signal has a frequency of 100 Hz. This means the Side bands fall at 110 Hz ($CF + MF$) and 90 Hz ($CF - MF$) respectfully. This was done with no additive white Gaussian noise. As can be seen below the post modulation the message signal is the exact same frequency as initially transmitted.

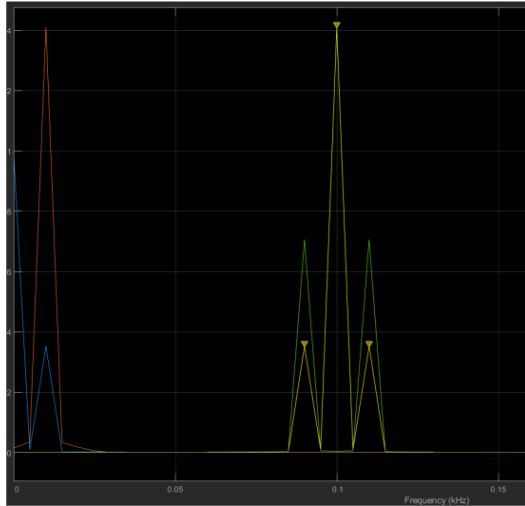


Figure 16 - Message, carrier, modulated and demodulated

This can also be seen from the scope output.

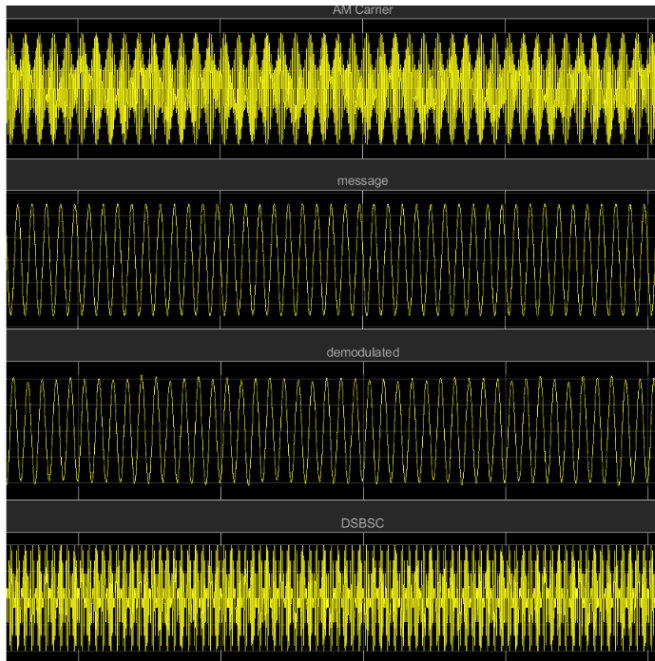


Figure 17 - DSB-SC scope output

AWGN was added this was done by changing the SNR [15].

Initially no noise was added as a control, then the SNR was changed to 0.1 this means the signal is a 10^{th} of the strength of the noise.



Figure 18 - DSBSC scope output message and demodulated signal noise (SNR 0.1)

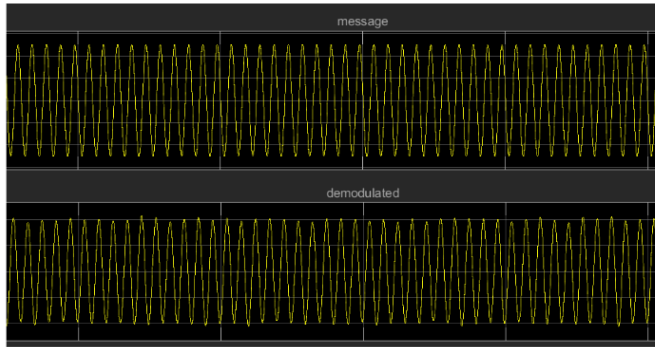


Figure 19 - DSB-SC No noise and modulation index 0.5

As can be seen from the above figure the demodulated signal now has significant anomalies compared to the original message signal. This is further emphasised when looking at the scope with no added noise. This shows that with an increased noise level causes anomaly in the demodulated message signal.

It is important to note that like AM modulation DSB-SC can also be mathematically represented. This helps the reader to draw direct links between the equation and the model. [16]

$$s(t) = A_c [m(t) \cos(2\pi f_c t) - 1/2 m(t) \cos(2\pi(f + f_c)t) + 1/2 m(t) \cos(2\pi(f - f_c)t)] \quad [11]$$

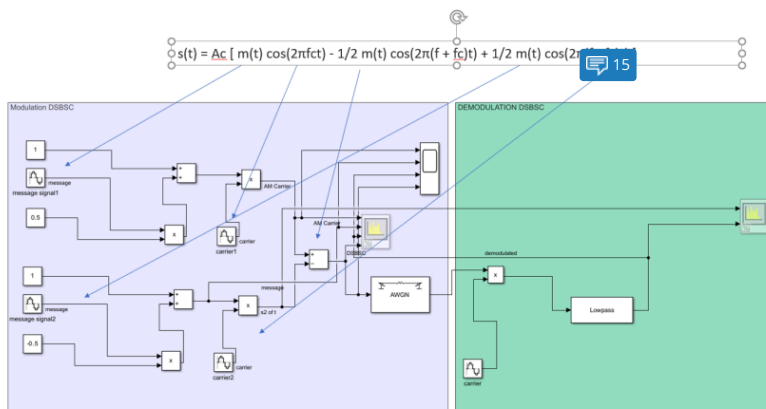


Figure 20 - DSBSC Model and equation

Task 3

Another type of AM modulation is SSB-SC or single side band suppressed carrier, this works the same as DSB-SC but with one side band not two.

The user can choose if they want to use the upper or lower side band.

As shown above modulation schemes can be expressed as equations, which can help the user to create the model. Depending on the which side band the user has chosen the middle block will be ++ or +-. In the below example it is ++ showing the upper side band was chosen[17].

$$s(t) = \frac{A_m A_c}{2} \cos[2\pi(f_c + f_m)t] \quad \text{for the upper sideband}$$

$$s(t) = \frac{A_m A_c}{2} \cos[2\pi(f_c - f_m)t] \quad \text{for the lower sideband}$$

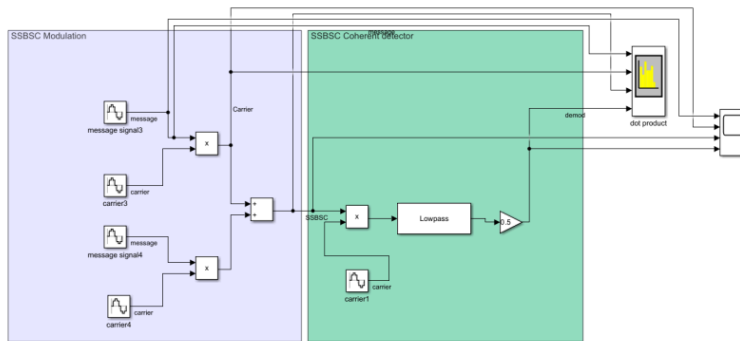


Figure 21 - SSB SC model and equation

When no noise is present the output in both the time and frequency domain is clear and distortion free.

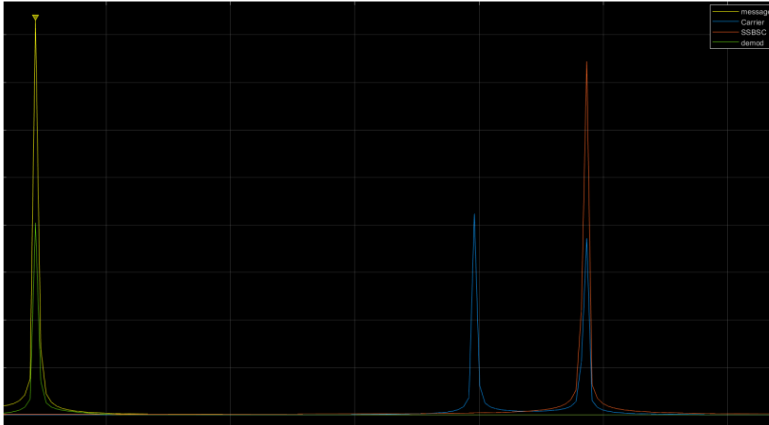


Figure 22 - SSB SC spectrum output

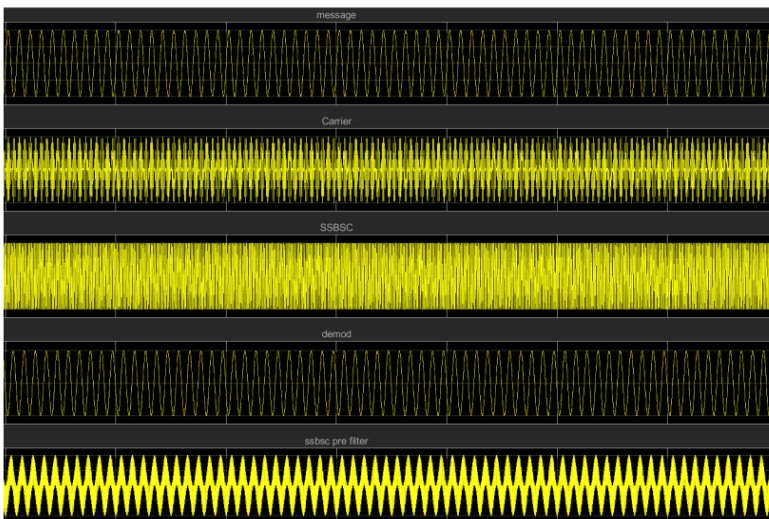


Figure 23 - SSB SC scope output

This is especially clear when you compare the message and the demodulated signal directly.

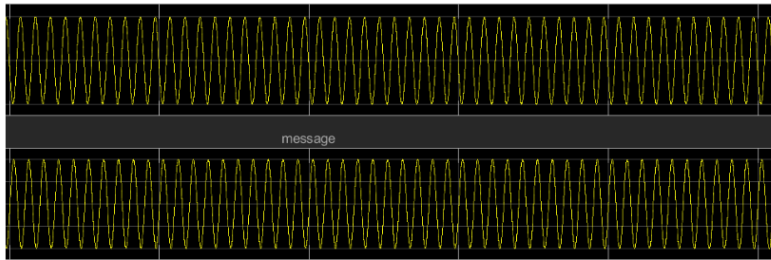


Figure 24 - SSB SC scope Message and Demodulated signal

Noise was then added to the SSB-SC scheme to see how it is affected by noise. This was done by adding an AWGN channel to be able to change the SNR.

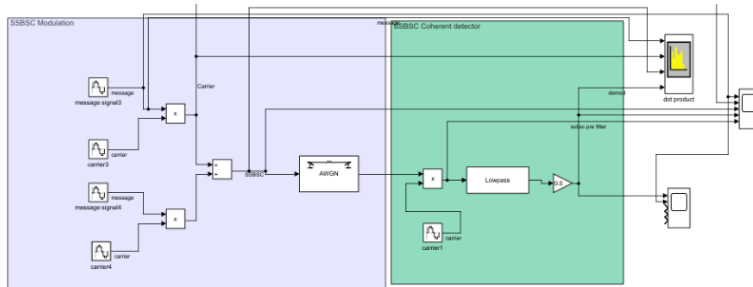


Figure 25 - SSB SC model

As done previously a test was done with no noise to have a set of control data the test was then reran with a SNR of 0.1, a 10th of the previous power to compare the effect noise has.



Figure 26 - message and demod SSBSC

As can be seen from the above schematic the noise increase had a significant effect to accuracy and quality of the demodulated message signal. Especially when compared to the demodulated output of the signal with no noise [18].

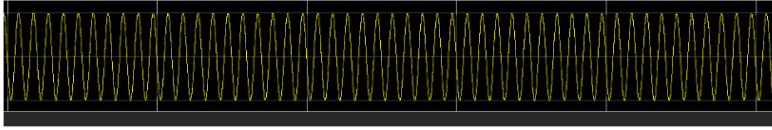


Figure 27 - SSBSC Demod no noise

Task 4

There are a number of ways to assess a modulation scheme, with the use of a spectrum analyser the user can review power levels, frequency shifts as well as any harmonics. With the use of a time scope the user can review distortion or delays in the signal. The signals can also be assessed using noise tolerance and power density. Bandwidth efficiency, power utilization and noise resistance are all key parameters that help the user to compare and contrast different modulation types for use in real world transmission [19].

AM, SSB-SC and DSB-SC will be reviewed in the above criteria to show the reader the performance of each modulation type, to help the reader select the correct option for there use case.

First each modulation scheme was review under a spectrum analyser.

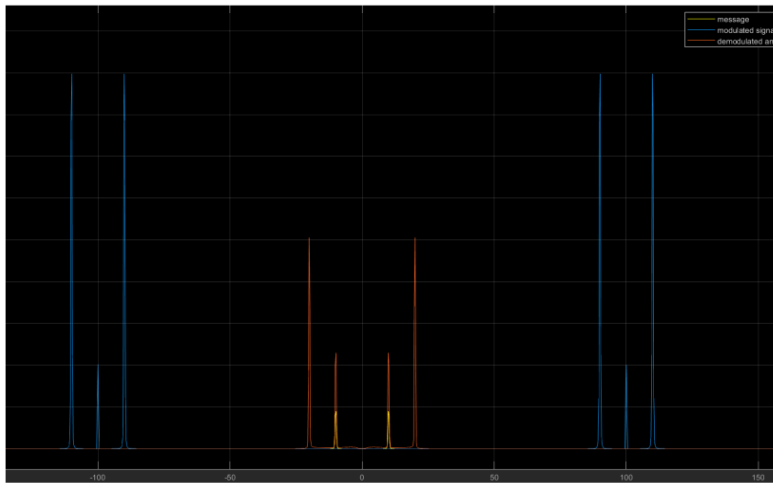


Figure 28 - AM Modulation, Message and Demodulation spectrum capture

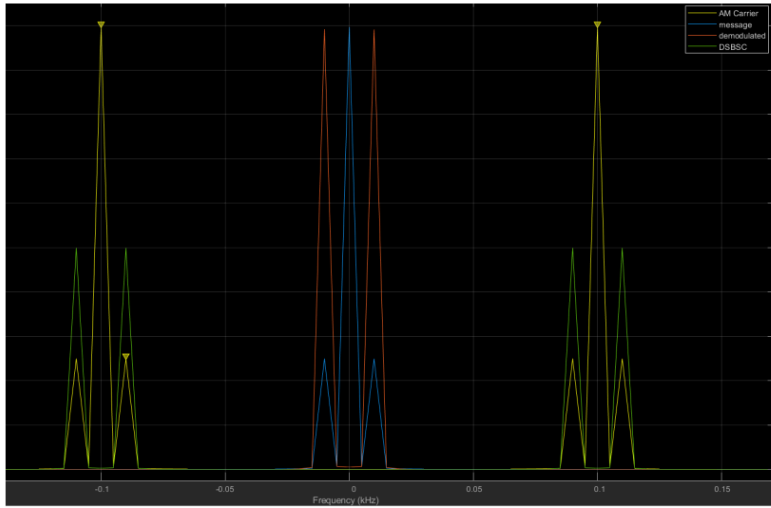


Figure 29- DSB-SC Modulation, Carrier, Message and Demodulation

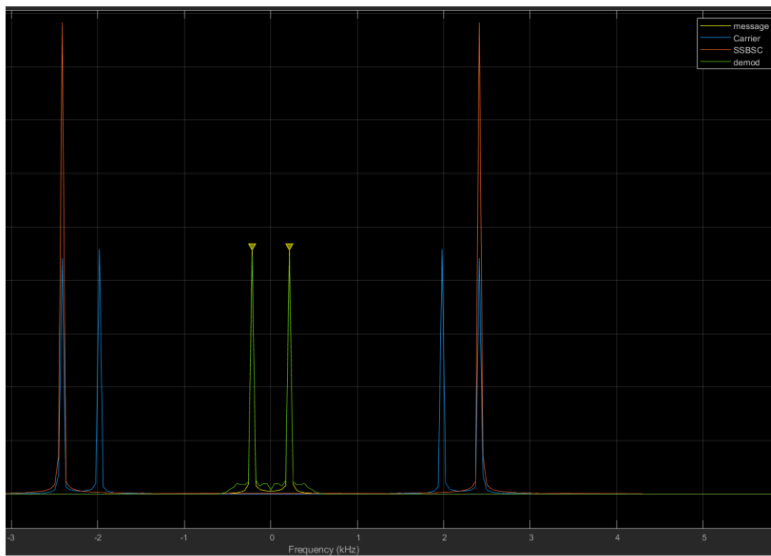


Figure 30 - SSB-SC Modulation, Carrier, Message and Demodulation

By viewing each modulation scheme with a spectrum analyser, you can first check each part of the modulation scheme is behaving as expected but can also use the features of the spectrum analyser to make power readings which can be used to calculate total power as well as power efficiency.

Power of signal power is half of the original message signal after modulation [19].

$$P_s = \frac{1}{2} P_m$$

$$P_s = 1 \times 1 / 2 = 0.5 \text{ W}$$

Carrier power is equal to that of the carrier and side bands and can be written as

$$P_c = \frac{1}{2} A^2$$

$$P_c = \frac{1}{2} \times 2^2 = 2 \text{ W}$$

This means the total power is the power of the message signal and the carrier and side bands.

$$\text{total power} = P_c + P_s \text{ [20]}$$

$$\text{Total power} = 0.5 + 2 = 2.5 \text{ W}$$

Useful power is the message signal power after modulation.

$$\text{Useful power} = 0.5$$

Power efficiency is the proportion of useful power over total power

$$\text{Power Efficiency} = \frac{P_s}{(P_c + P_s)}$$

Power efficiency for the AM modulated signal

$$\text{Power efficiency} = 0.5 / 2.5 = 0.2$$

$$\text{Power efficiency for DSBSC} = 0.5 / 2.5$$

$$\text{Power for SSB SC} = 0.5 / 2.5$$

The power efficiency values above suggest that the power efficiency is all the same however this is incorrect. SSB SC is the most power efficient as it only uses half that of DSBSC, whereas DSBSC uses less than SSB SC, ultimately making SSB SC the most power and spectrally efficient form of modulation.

Another value we can compare is SNR values we can also calculate the figure of merit. The figure of merit is the SNR of the demodulated output to the SNR of that at the receiver input.

$$\text{Figure of merit} = \frac{SNR_o}{SNR_c}$$

$$SNR_c = \frac{\text{Average power at receiver input}}{\text{average noise power at the receiver input}}$$

$$SNR_c = \frac{AC^2(1 + KA^2)P}{2WN_0}$$

A_c = amplitude of the carrier

P = power of the message signal

$K_a = m = 0.5$

$P_{\text{noise}} = N_0 \times W$

W = message bandwidth

$$SNR_o = \frac{\text{Average power of demodulated message signal}}{\text{Average power of noise demodulated output}}$$

$$SNR_o = \frac{A_c^2 K_a^2 P}{2W N_0} [21]$$

Figure of merit



For AM AWGN (SNR₀)

SNR₀ = 0.3080583 / 0.0190788

SNR_C = 1.01076 / 0.00919122

Figure of merit = 16.14667348 / 109.97061672 = 0.14682

For SSB SC AWGN (SNR₀)

SNR₀ = 0.445949 / 0.020484

SNR_C = 0.872419 / 0.0405286

Figure of merit = 21.77060145 / 215.2600879 = 0.10113626559

For DSB SC AWGN (SNR₀)

SNR₀ = 1.01332 / 0.0572615

SNR_C = 0.515108 / 0.060541

Figure of merit = 17.69635794 / 8.508415784 = 2.079865205

For AM AWGN (SNR_{0.1})

SNR₀ = 0.382214 / 0.195462

SNR_C = 1.01608 / 0.0191556

Figure of merit = 1.955438909 / 85.27337364 = 0.02293141253

For SSB SC AWGN (SNR_{0.1})

SNR₀ = 0.446038 / 0.0202635

SNR_C = 0.872532 / 0.0400662

Figure of merit = 22.01189331 / 21.77725864 = 1.010774298



For DSB SC AWGN (SNR 0.1)

$$\text{SNR O} = 0.993363 / 0.0662247 = 14.9988675$$

$$\text{SNR C} = 0.514914 / 0.59848 = 8.60369603$$

$$\text{Figure of merit} = 1.743423605$$

For AM AWGN (SNR 0.01)

$$\text{SNR O} = 0.380746 / 0.0356199 = 10.68913725$$

$$\text{SNR C} = 1.01075 / 0.234147 = 4.316732651$$

$$\text{Figure of merit} = 2.47621016$$

For SSB SC AWGN (SNR 0.01)

$$\text{SNR O} = 0.445958 / 0.0204621 = 21.79434173$$

$$\text{SNR C} = 0.87243 / 0.0404821 = 21.55100649$$

$$\text{Figure of merit} = 1.011290072$$

For DSB SC AWGN (SNR 0.01)

$$\text{SNR O} = 1.0133 / 0.066903$$

$$\text{SNR C} = 0.515089 / 0.0604713$$

$$\text{Figure of merit} = 15.14580811 / 8.517906842 = 1.778113936$$

(SNR)	0	0.1	0.01
AM	0.14682	0.02293141253	2.47621016
SSB SC	0.10113626559	1.010774298	1.011290072
DSBSC	2.079865205	1.743423605	1.778113936

As can be seen from the figure of merits above DSB SC always has a higher Figure of merit, this is twice that of SSB SC and almost ten times that of AM modulation.

In conclusion SSBSC has the lowest overall bandwidth requirement with it being equal to that of the message frequency whereas the DSB SC has a bandwidth of twice the message frequency. SSB SC saves the most power as it has the least to transmit. However, SSB SC can easily be affected by noise as seen previously, however this does also apply to the other modulation schemes too. Despite using less power SSB SC and DSBSC both struggle with power efficiency but are overall both low power and low cost options.

Ultimately the best modulation scheme choice comes down to the requirements of the user and the priorities they have, if the user is looking for power efficiency AM is the best choice however if the user is more concerned with overall bandwidth then SSB SC is the best choice.

To help the user make a more informed decision it is recommended the user runs tests using all 3 types of modulates with a variety of noise and power levels and compares against their key criteria to further help the user understand the options available.

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Cerys Versey RF Systems Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

76/100

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Comment 1 | Knowledge & Understanding (20)

The demodulation process in AM mentions the coherent detector and peak detector, but it would be more comprehensive if further details were added.



Comment 2 | Knowledge & Understanding (20)

The basic concepts of AM are well captured, but a more detailed explanation is essential, covering aspects such as how it operates, how the message signal is carried, and the modulation process itself.

PAGE 4



Comment 3 | Cognitive skills (20)

The use of relevant mathematical expressions to explain the working of Simulink blocks is commendable, as it demonstrates a clear understanding of the concepts.



Comment 4 | Knowledge & Understanding (20)

The definitions of critical, under, and over-modulation are well covered.

PAGE 5



Comment 5 | Practical Application (30)

The block representations are effectively captured, which is evident from the attached screenshots.

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

When comparing different modulation index values, the written explanation is appreciated, but including numerical values such as signal distortion levels, amplitude variations, and power changes would improve clarity.

**Comment 7** | Knowledge & Understanding (20)

The diagrams are relevant and effectively represent the depth of understanding.

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

Avoid starting a paragraph with "This," as it may cause confusion.

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

The aspect of DSB-SC is mentioned, but further clarity in writing is needed.

**Comment 10** | Cognitive skills (20)

"CF
- MF" is not relevant when USB is mentioned as 110 Hz; this should be corrected to "+".

**Comment 11** | Knowledge & Understanding (20)

The notation "CF - MF" could be represented in a more effective way, such as fc-fm

**Comment 12** | Cognitive skills (20)

Modifying the values within a range of -10, -20, 0, 10, etc., would provide a more in-depth analysis.

**Comment 13** | Cognitive skills (20)

The SNR value for DSB-SC and SSB-SC is too low.

**Comment 14** | Practical Application (30)

The scope outputs are well captured.

**Comment 15** | Knowledge & Understanding (20)

There is a good understanding of linking mathematical expressions with system blocks, which is appreciable.

**Comment 16** | Knowledge & Understanding (20)

The concepts of SSB-SC are well explained, but adding a brief explanation of the phase discriminator and how it satisfies SSB-SC principles would further enhance the study.

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

The scope outputs are neatly captured, showing valid observations. As noted for DSB-SC, the SNR values in SSB-SC should also be increased to better analyse signal distortion.

**Comment 18** | Engagement with literature(10)

Well done on performing the power calculations theoretically for the message signal, but it is not clearly stated for which type of modulation the values are calculated.

**Comment 19** | Engagement with literature(10)

The formula applied here is for conventional AM, where the transmitted power includes both carrier and message power.

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

The conventional formula for Power cannot be applied to DSB-SC and SSB-SC, as their carrier power is zero.

**Comment 21** | Knowledge & Understanding (20)

The steps taken to derive FOM are commendable, and correct formulas have been used.

**Comment 22**

no comment

**Comment 23** | Cognitive skills (20)

The results seem contradictory, as higher FOM values (>1) indicate greater efficiency with less noise, but in this case, the results suggest otherwise.

**Comment 24** | Transferable skills (20)

The report is well-researched, with many references and properly cited sources. The overall structure and organisation make it easily understandable for the reader.

GRADING FORM: RF_UPDATED_2025

CERY'S VERSEY

75.60**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.



A good understanding of modulation techniques is shown, with correct references to theoretical principles. The discussion on noise impact and modulation index is strong, but adding more detail could improve it further.

7.4

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

15.9

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 the calculation for SNR(in/Out), FOM, Power to compare with practical value is missing.

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 comparison is basic and misses clarity in bandwidth and power utilisation analysis.

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.

12.6

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.

Task 3 (a) & (b): The modulation and demodulation processes for SSBSC are clear but could include more detail.

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): Excellent modulation of index variations with accurate insights into carrier behaviour. Demonstrates strong skill and clarity.

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 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): Basic understanding of practical setup.

24.7

Observations are adequate but lack depth with theory.

Task 4 (b): Comparisons are done explaining the references.

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.

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