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ACDA5019: Radio Frequency Systems Investigating the Effect of Noise in DSB- SC and FM Systems

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Introduction

The ability to transmit information, normally via a radio signal, requires the use of a carrier signal in a process known as modulation. This can take a number of forms, with this paper investigating Amplitude and Frequency Modulation (AM and FM).

Within this study an AM system will be designed within MathWorks Simulink and the modulation index adjusted to investigate the phenomenon of critical, over and under modulation then demodulate the signal and compare the original message and demodulated signal. This study will also investigate the modulation technique of Double Side Band – Suppressed Carrier and how DSB-SC can be a more energy efficient modulation technique.

Background research

Amplitude Modulation is the earliest known modulation technique, having been developed in the early 1900's by Roberto Landell de Moura and Reginald Fessenden [1] and was widely used for public radio broadcasting and radio telephony [2]. Traditional amplitude modulation was developed further, with techniques such as vestigial sideband transmission and Double Side Band Suppressed Carrier and Single Side Band Suppressed Carrier seeking higher levels of efficiency, greater signal power and bandwidth.

Amplitude Modulation is the simplest form of modulation, only requiring the (at it's simplest) the multiplication of a message signal and its carrier frequency; however this risks the resulting signal being under or over modulated to the point at which the original message is either very weak or distorted. [3] To avoid distortion or a weak signal, a weak message signal would need to be amplified while a larger signal might need to be attenuated; this can be achieved by adjusting the modulation index of the system.

Block Diagrams

Amplitude Modulation

The below system has been designed with a carrier signal of $c(t) = A_c \sin \omega_c t$ and a message signal of $m(t) = A_m \sin \omega_m t$ at a frequency of 10kHz and 1kHz respectively and a modulation index of 0.9.

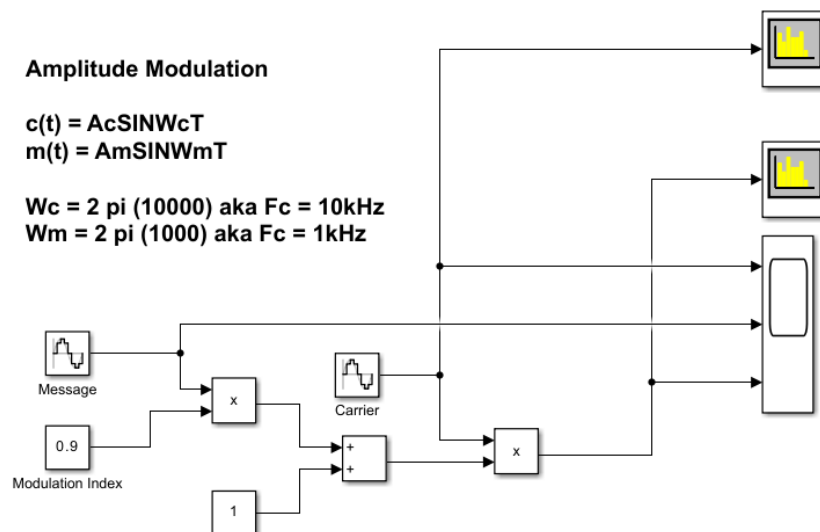


Figure 1 - Amplitude Modulation system modelled within MathWorks Simulink

It can be seen in Figure 2 the scope output of the Amplitude Modulation system, showing the Carrier signal in the first display, then the original message signal and outputted signal in the second view. The message signal has been raised up by 1 to allow a better comparison of the two signals. As can be seen, the original message signal closely follows the upper envelop of the modulated signal, clearly demonstrating how an AM signal works.

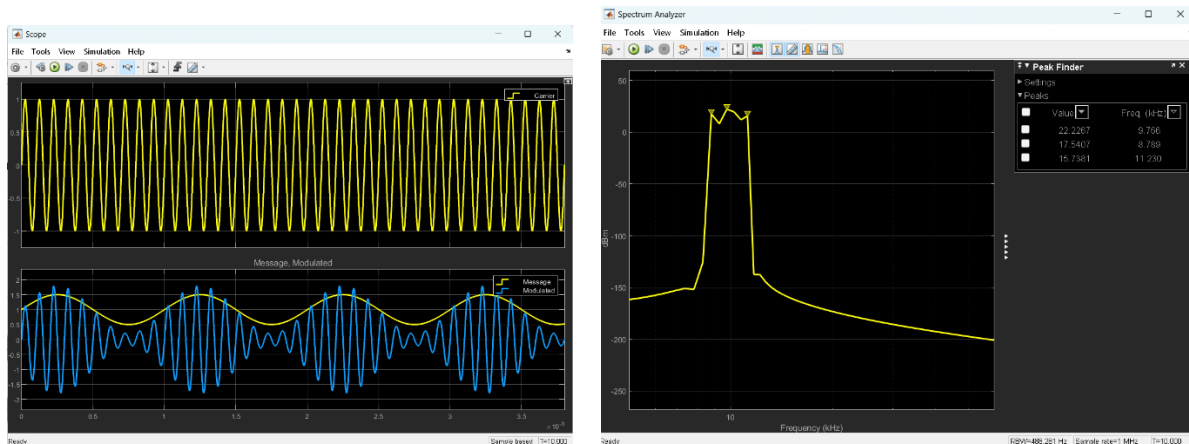


Figure 2 – LEFT - Scope output from Simulink showing the Message, Carrier and Modulated signal of an AM system
RIGHT – Spectrum Analyser output clearly showing the three peaks of the AM signal; the lower sideband, carrier and upper sideband.

Double Sideband – Suppressed Carrier

A model of a Double Sideband – Suppressed Carrier system can be seen below in Figure 3. DSB-SC benefits from not transmitting power in the carrier signal, resulting in a more efficient transmission

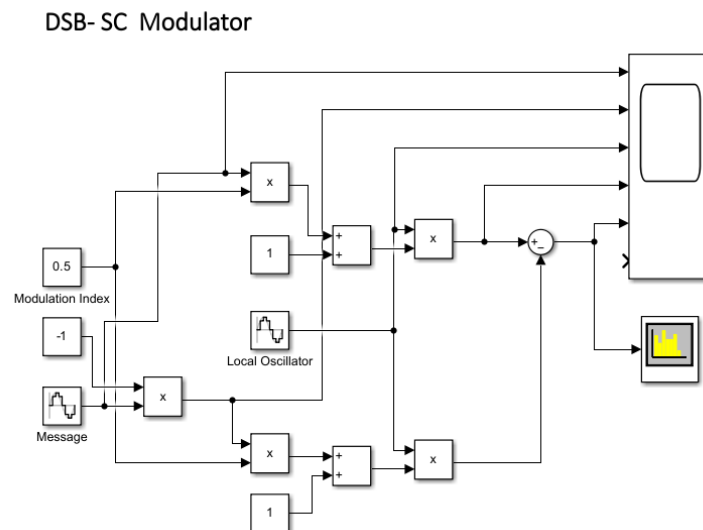


Figure 3 - Double SideBand Suppressed Carrier system modelled in MathWorks Simulink

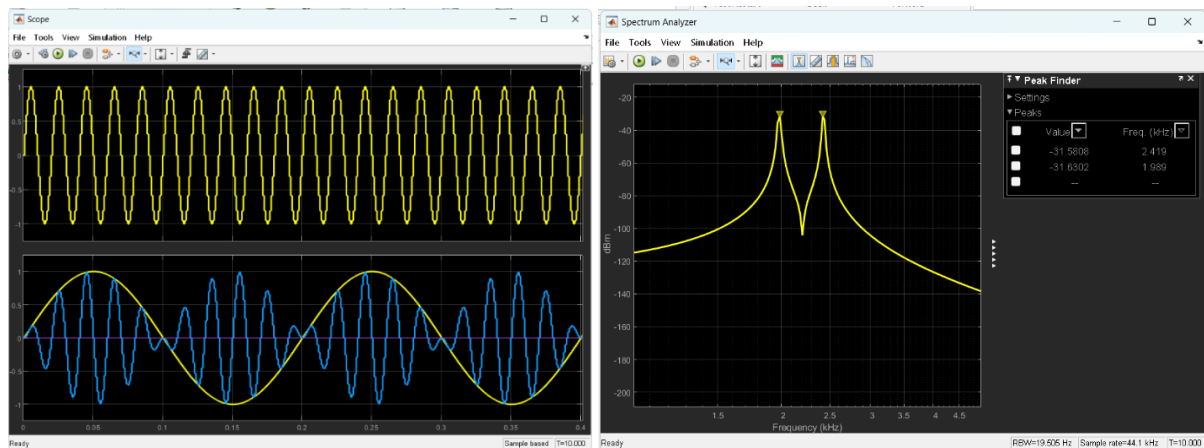


Figure 4 - LEFT - Scope output from MathWorks Simulink showing the Carrier Signal on the first display and the Message and Modulated signal on the second display.

RIGHT – Spectrum Analyser output from MathWorks Simulink clearly showing the two peaks of the upper and lower sidebands, but missing the central peak of the carrier.

Simulated Outputs and results

Amplitude Modulation

The level of modulation is vital to ensuring the best quality signal is transmitted and then demodulated by the receiver. The value used to describe the level of modulation required is the modulation index. With a modulation index value of less than 1, the resulting signal will be under-modulated with the resulting audio being quiet and difficult to hear. However a modulation index of greater than 1 will result in over modulation, the phenomenon where distortion will be present on the demodulated signal, potentially making the original message unreadable.

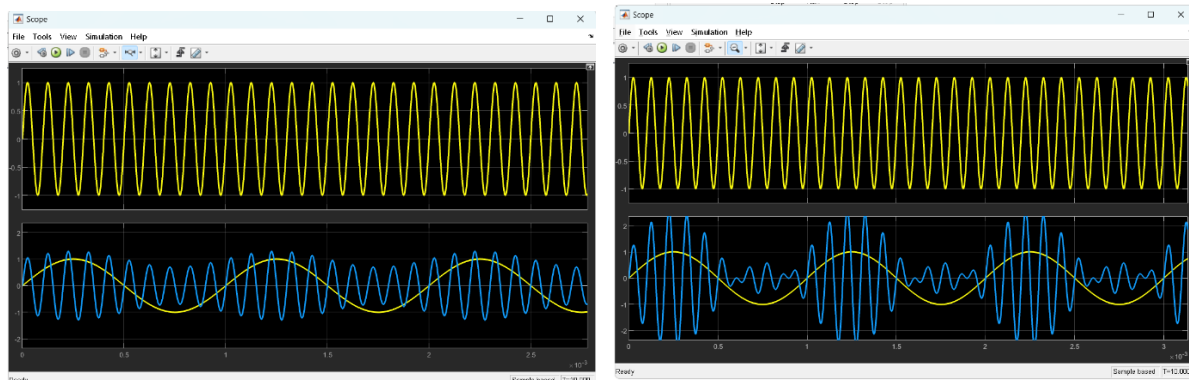


Figure 5 - LEFT - An example of under-modulation, where the Modulation Index was set at 0.3.

RIGHT – An example of over-modulation where the Modulation Index was set at 1.6.

Analysis of Results

When adjusting the modulation index we can observe a change in the level of modulation of the outputted signal. Its not just the modulation index that affects the level of modulation, the amplitude of the original message can also affect the level of modulation, however by increasing the amplitude there is then a risk of clipping the signal and introducing distortion as seen in Figure 6.

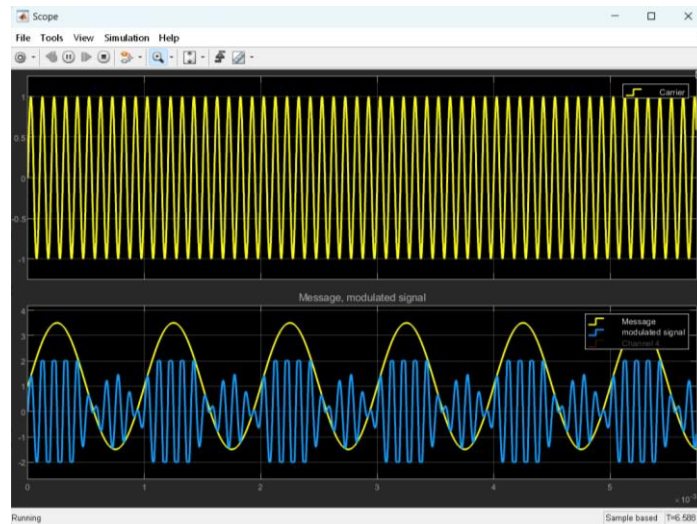


Figure 6 - Scope output from Simulink demonstrating possibility of clipping

Bibliography

- [1] "Wikipedia- Amplitude Modulation," 1 12 2023. [Online]. Available: https://en.wikipedia.org/wiki/Amplitude_modulation.
- [2] F.R.Connor, "Modulation," in *Introductory topics in electronics and telecommunication*, London, Edward Arnold (Publishers) Ltd, 1977, p. 1.
- [3] "Electronic-Notes.com," [Online]. Available: <https://www.electronic-notes.com/articles/radio/modulation/amplitude-modulation-am-index-depth.php>. [Accessed 1 12 2023].