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A Comparative Study of Different Amplitude Modulation Signals

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***Abstract*—**Analog Modulation refers to the process of transferring an analog baseband (low frequency) signal. In this paper we will compare different methods to transfer an analog baseband signal and will perform a comparative study. Also, we will be studying advantages, disadvantages applications and waveforms of different AM Signals. The different AM signals that have been studied here are - Normal AM, SSB-SC, DSB-SC and VSB.

Keywords*—Amplitude Modulation (AM), Single Side-Band Suppressed Carrier (SSB-SC) Modulation, Double Side-Band Suppressed Carrier (DSB-SC) Modulation, Vestigial Side-Band (VSB) Modulation*

I. INTRODUCTION

The process of converting information (i.e., the message) into a radio signal by adding it to a carrier signal is called modulation [1]. There are various types of modulation like Frequency modulation, Amplitude modulation, Phase modulation, Polarization modulation and Pulse-code modulation. Modulation helps a lot in transmission of data. In this paper, different types of Amplitude Modulations are studied like Single Sideband Modulation (SSB), Double Sideband-Suppressed Carrier Modulation (DSB-SC) and Vestigial Sideband Modulation with their waveforms, applications, advantages and disadvantages.

II. AMPLITUDE MODULATION

Amplitude modulation (AM) is a technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. AM works by varying the strength of the transmitted signal in relation to the information being sent [1]. It is a processIn which the carrier signal changes with respect to modulating signal. In this, the strength of amplitude of the carrier wave is given to the message signal. Also, the frequency of the carrier signal is much more than that of the message signal. From the sending end the message is carried by the carrier signal and at the receiving end the message is taken from the carrier signal. In this process the loss of information in the message signal is minimized. Following are the waveforms and equations for Amplitude Modulation.

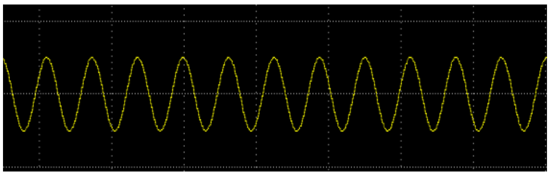

Figure1: Modulating Signal: $m(t)=\sin(Ш_M t)$

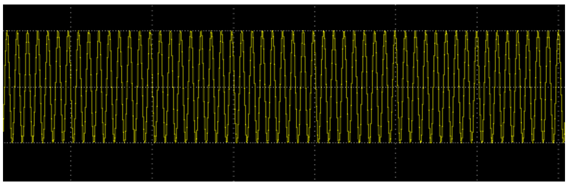

Figure 2: Carrier Signal: $c(t)=\sin(Ш_C t)$

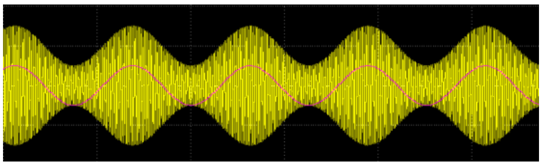

Figure 3: Amplitude Modulated Signal: $y(t)=A_C \sin Ш_C t + (A_C\mu/2)(\cos(Ш_c-Ш_m)t-(A_C\mu/2)(\cos(Ш_c+Ш_m)t$

Amplitude Modulated signal: -

$$y(t) = A' \sin(Ш_C t)$$
$$y(t) = (A_C+m(t))(\sin Ш_C t)$$
$$y(t) = (A_C+A_M \sin Ш_M t)(\sin Ш_C t)$$
$$y(t) = A_C(1+(A_M/ A_C)\sin Ш_M t)(\sin Ш_C t)$$

here $AM/ A_C=Ǔ$

Ǔ is modulation index

so ,

$$y(t) = A_C(1+Ǔ\sin Ш_M t)(\sin Ш_C t)$$
$$y(t) = A_C \sin Ш_C t +A_C Ǔ(\sin(Ш_M t)\sin(Ш_C t)$$
$$y(t) = A_C \sin Ш_C t +(A_C Ǔ)[\sin(Ш_M t)\sin(Ш_C t)]/2$$
$$y(t) = A_C \sin Ш_C t +(A_C Ǔ)[\cos(Ш_C-Ш_M)t-os(Ш_C+Ш_M)]/2$$
$$y(t) = A_C \sin Ш_C t+ [(A_C Ǔ)/2][\cos(Ш_C-Ш_M)t]-[(A_C Ǔ)/2][\cos(Ш_C+Ш_M)]$$

y(t) signal has three frequency components: -
(i) $Ш_C$
(ii) $Ш_C-Ш_M$
(iii) $Ш_C+Ш_M$

Where $Ш_C$ is carrier signal frequency, $Ш_C-Ш_M$ is one of the side-band, and $Ш_C+Ш_M$ is the other sideband amplitude of sidebands is,

$(A_C Ǔ)/2$
$(A_C (A_M/ A_C))/2$
$A_C/2$

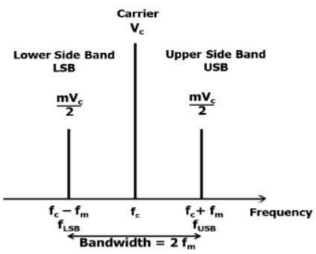

Figure 4: Frequency response of AM signal

In the Figure 4 we can clearly see that Carrier frequency (Ш_C) does not contain any information only modulating frequency (Ш_M) does and we can clearly see that carrier frequency consumes a major power so that leads to power loss. Also, the bandwidth of amplitude modulation signal is higher than the message signal (modulating signal).

III. SINGLE SIDEBAND SUPPRESSED CARRIER (SSB-SC)

A single side suppressed carrier is a special type of amplitude modulation in which instead of two side-bands only a single sideband is there. An external component is added to the system that removes one side of the side-band, this external component is called a bandpass filter. The bandpass filter is used to remove the lower part of the signal and the output from the bandpass filter is transmitted. This removal of a single side is done at the sender's end and then the information is transmitted. At the receiver end, a local carrier signal is added back to the signal before the processing. In SSB-SC, the doubling factor of DSB-SC is avoided and only a single sideband is transmitted through the channel. SSB-SC is superior to DSB-SC in terms of BW. In SSB-SC bandwidth is reduced by half after eliminating duplicate sidebands. Also, bandwidth is equal to FM, where FM is the maximum modulating frequency. This allows SSB-SC to add more channels by reducing the bandwidth transmitted within the same frequency band. Efficiency is improved drastically, efficiency is power in sideband divided by the total power, one may argue that efficiency is 100% as we are only transmitting single-sideband information. Theoretically, it may seem as if efficiency is 100% but practically it comes out to be 80%-95% as there are losses in electrical and electronic circuits and antennas [2].

It is a type of AM signal,

$$y(t)= A_C\sin\text{Ш}_Ct + [(A_C\check{U})/2][\cos(\text{Ш}_C-\text{Ш}_M)t]-[(A_C\check{U})/2][\cos(\text{Ш}_C+\text{Ш}_M)]$$

W-here Ш_C is carrier signal frequency, $\text{Ш}_C-\text{Ш}_M$ is the lower side-band, and $\text{Ш}_C+\text{Ш}_M$ is upper side band. In DSB-SC signal the Upper side band characteristic and the Lower side band characteristics are symmetric with respect to carrier signal so it is not compulsory to send both Upper sideband and Lower sideband ,one of the two can be extracted from the other, Bandwidth in SSB-SC signal is $f_{M,}$ whereas bandwidth in AM and DSB-SC signal is 2 $f_{M,}$ so a large portion of Bandwidth is being wasted as we are using double the amount of Bandwidth when compared to original signal,

Transmitted power (P_T) = ($\check{U}^2$ P_C)/4

The problem while using SSB-SC is that the Band Pass filter should be very sharp as some information of LSB may enter in USB (if USB is being extracted). Filtration of BPF depends on quality factor of BPF, it should have sharp edge, otherwise information of USB will get into LSB if LSB is being extracted or information of LSB may get into USB when USB is being extracted, to solve this problem we provide guard band.

Q-factor of Band pass filter must be between 1000-2000.We don't use SSB-SC for broadcasting, as SSB-SC. As SSB-SC requires high frequency stability, which is really hard to achieve because we do not use high-quality Band-pass Filter as it is not cost effective [3].

Two Stage SSB-SC Modulator-When we have one stage SSB-SC modulator, The complexity of circuit is based on Band Pass Filter, so it is very difficult to design BPF and if frequency is very high and we use one stage SSB-SC modulator, then cost will increase and so will the complexity. So, we Dissect the modulation process in two parts as shown in the Figure 5.

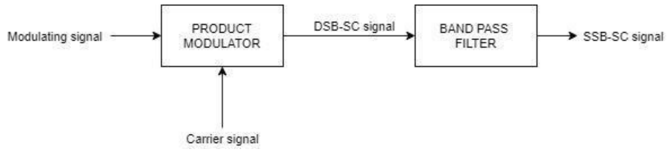

Figure 5:Block Diagram of SSB-SC

Applications of SSB-SC

- Two-way radio communication is done using SSB.
- It is used in marine's high frequency two-point communication using radio waves and is used in the military as well.
- SSB is mostly used where low bandwidth and power saving is required.

Advantages of SSB-SC

- Multiple signals can transmit in SSB
- SSB technique requires less bandwidth as compared to DSB technique. In comparison to DSB it requires less bandwidth.
- SSB consumes less power.
- In SSB high power signals can also be transmitted easily.
- Because of less bandwidth it gets less noise interference.

Disadvantages of SSB-SC

- SSB is more complex to set up.
- SSB costs more than other modulations.
- The transmitter and receiver used in SSB modulation must be highly frequency stable as a slight change will lead to degraded quality signal.

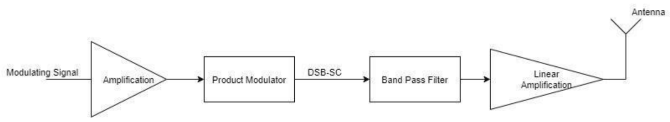

Figure 6: Filtration Method

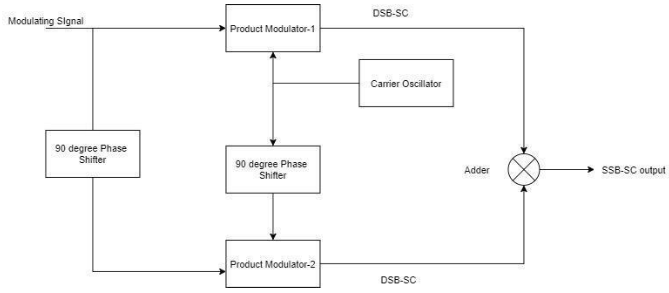

Figure 7: Phase shift method

Table 1: Comparison between Filtration Method and Phase shift method

Parameter	Filtration Method	Phase-Shift Method
Side Band Cancellation	By using Filter	By using 90^O Phase Shifter
SSB Frequency Range	Frequency must be high	Can be used for any frequency range
Linear Amplification	As signal strength is low, we use linear	Not Needed

	amplification before giving it to antenna	
Up Conversion	Needed	Not Needed
System Designing	It is based on the design of the filter, which depends on stability and size of Filter	Phase shifter and the Product Modulator must be symmetric

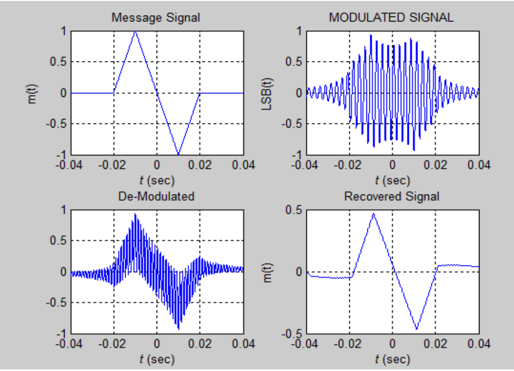

Figure 8: Waveform of SSB signal

III. DOUBLE SIDEBAND SUPPRESSED CARRIER (DSB-SC)

Double Side Band Suppressed Carrier also known as DSB-SC is an AM wave transmission scheme. In DSB-SC only sidebands are transmitted, a carrier wave is not transmitted, it is suppressed, as the name suggests. As the carrier does not contain any information and transmitting it leads to loss of power, so only sidebands are transmitted, thus saving power, this saved power can be consumed by the two sidebands, hence ensuring stronger signals that can travel longer distances with less attenuation loss [4].AM waves consist of both carrier waves and two sidebands, sidebands are a band of lower and high frequencies of the carrier frequency. Transmission of a signal in which there is a carrier along the two sidebands is called a Double Sideband Full Carrier (DSB-FC).

In an AM signal,

$$y(t) = A_C \sin Ш_C t + [(A_C Ǔ)/2][\cos(Ш_C - Ш_M)t] - [(A_C Ǔ)/2][\cos(Ш_C + Ш_M)]$$

or

$$y(t) = A_C \cos Ш Ct + [(A_C Ǔ)/2][\cos(Ш_C - Ш_M)t] - [(A_C Ǔ)/2][\cos(Ш_C + Ш_M)]$$

$$y(t) = A_C(1+Ǔt)\cos(Ш_C t)$$

$$y(t) = A_C \cos(Ш_C t) + A_C\, Ǔt\cos(Ш_C t)$$

where $A_C\cos(Ш_C t)$ is the carrier signal and $A_C\ Ǔt\cos(Ш_C t)$ is the side band, here only the side bands contain the information, Whereas a DSB-SC signal has two sidebands and has no carrier signal Power Transmission of AM is,

$P_T = P_C + P_S$
$P_T = (Ǔ^2 P_C)/2 + P_C$

Whereas in DSB-SC signal has power transmission of $P_T = P_S$, we can clearly see that we save a lot of power in DSB-SC signal. If Ǔ=1, then

$P_T = P_C + P_S$
$P_T = P_C + (Ǔ^2 P_C)/2$

$P_T = P_C + 0.5P_C$, We can clearly see that P_S is almost 33.3% of P_T and P_C is almost 66.6% of P_T by using DSB-SC we save almost 66.6% power .

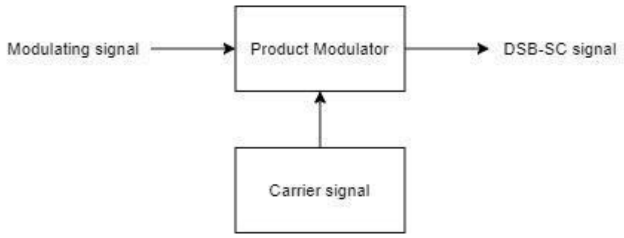

Figure 9: Block Diagram of DSB-SC

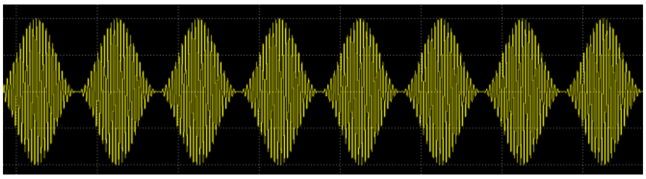

Figure 10: Waveform of DSB-SC

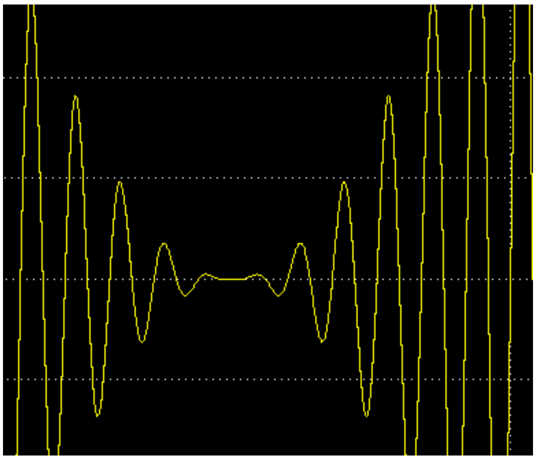

Figure 11: Frequency Response of DSB-SC

DSB-SC Generation - There are mainly three methods for DSB-SC generation (Modulation) -Ring/Chopper Modulator, Balanced Modulator (using Field Emission Transistor), Balanced Modulator (using a Non-Linear device).

DSB-SC Detection- There are mainly two methods for DSB-SC detection (Demodulation)-Coherent Detection and Costas Loop Receiver.

Applications of DSB-SC

- The phase shift key methods use DSB-SC during the transmission of binary data.
- It is also used in Television and FM broadcasting to transmit 2 channel stereo signals.

Advantages of SSB-SC

- The modulation efficiency for DSB-SC is 100%.
- Consumes less power because of suppressed carriers.
- DSB-SC gives a larger bandwidth.

Disadvantages of DSB-SC

- The detection process for DSC-SC is complex.
- The recovery of signals at the receiver end is difficult sometimes.
- The demodulation of DSB-SC is an expensive technique.

IV. VESTIGIAL SIDEBAND (VSB)

Vestigial Side Band also known as VSB is a modulation technique, which allows transmission of a single sideband along with a part or vestige of the other. It is a compromise between DSB-SC and SSB modulation. It was introduced to overcome the drawbacks and limitations of the SSB modulation technique. As in SSB, it requires an accurate frequency response of the filter to transmit only one sideband. Thus, by using VSB one can simplify the design of the filter to a great extent. Also, VSB overcomes the limitations of SSB, that SSB does not allow the transmission of extremely low frequency accurately. VSB technique is mostly used in TV transmission as television signals are extremely low in frequency.

In Vestigial Side Band (VSB), The Product modulator receives two inputs one is modulating signal and the other is carrier signal and it gives DSB-SC signal as output which is given to a VSB filter and then to a Linear amplifier and then to transmitting antenna.

Output of the product modulator: $y(t) = X(t).c(t)$

In terms of frequency $y(f) = A_C[X(F_C-F_o) - X(F_c+F_o)$

As we can see Total Bandwidth (BW) = $B + F_V$ [5].

We pass the weak VSB signal to a linear amplifier and then we send it to a transmitting antenna to transmit the VSB signal.

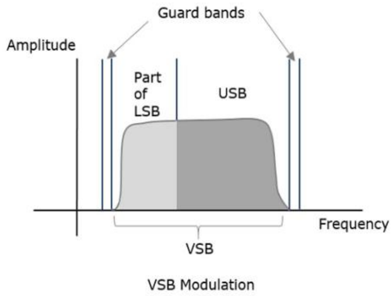

Figure 12: VSB Modulation

Vestigial sideband is about 25% to 33% of one sideband.it is used in various applications like in Television transmission, in Television transmission we send audio and video signal, Bandwidth of video is about 4.2 MHz, If we send a television signal with DSB-SC it will be 2 times the video signal's bandwidth which is almost 8.4 MHz plus we will have to send guard signals and audio band too, that will almost become 9 MHz whereas if we use VSB in TV transmission we will save around 3 MHz per channel VSB Demodulation [6].

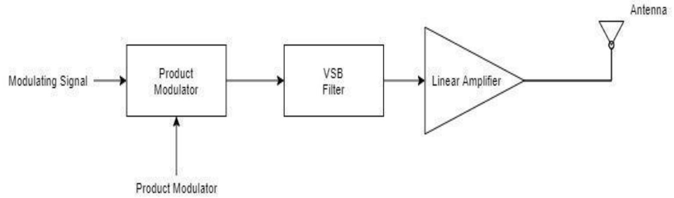

Figure 13: Block Diagram of VSB

Output of product modulator is: $V(t) = S(t).c(t)$

$V(t)=S(t)[A_C\cos(2\pi F_c t)$

In frequency domain

$V(t) = A_C^{'}[S(F-F_C) + S(F+F_C)]/2$

$V(t) = A_C^{'}S(F-F_C)/2+A_C^{'}S(F+F_C)/2$

$V(t) = A_C^{'}[A_C(m(F-F_C+F_C) + m(F-F_C-F_C)H(F-F_C)]/2 + A_C(m(F-F_C+F_C)+m(F-F_C-F_C)H(F+F_C)]/2$

after passing it through Low pass filter (LPF)

$$V(t)=A_C^{'}A_C[H(F-F_C) + H(F+F_C)]m(F) /4 + A_C^{'}A_C[H(F-F_C)]m(F-2F_C)/4 + A_C^{'}A_C[H(F+F_C)]m(F+2F_C) /4$$

All the high frequency components will be removed by the Low Pass Filter

so, $V_o(t) = A_C^{'}A_C[H(F-F_C) + H(F+F_C)]m(F) /4$

Applications of VSB

- For television signal transmission it is widely used as there is a need for transmission of both video and audio signals simultaneously.
- VSB is the most suitable technique where the usage of bandwidth is considered.

Advantages of VSB

- The efficiency of VSB modulation is high.
- The bandwidth utilization is reduced in VSB.
- The design is simple as there is no need to be highly accurate in filter characteristics.
- VSB has good phase characteristics and easily transmits low frequency components.
- To improve the SNR of the SSB scheme the proposed unequal sideband based VSB scheme can be a suitable scheme which balances both the SNR [7].

Disadvantages of VSB

- The bandwidth required is higher than SSB, because of the presence of vestige.
- It has a complex demodulation process at the receiver end.

CONCLUSION

In this paper, different types of Amplitude Modulation techniques have been studied. The authors concluded that every Modulation Technique has its advantages and disadvantages, and it would not be wise to say one is better than the other. Every technique has its use and can be used in various fields and sectors and a combination of all possible techniques for different purpose will bring the best result in the communication transfer. Inthis paper, different types of Amplitude Modulation techniques have been studied. The authors concluded that every Modulation Technique has its advantages and disadvantages, and it would not be wise to say one is better than the other. Every technique has its use and can be used in various fields and sectors and a combination of all possible techniques for different purpose will bring the best result in the communication transfer.

Table 2: Comparison of SSB, DSB-SC and VSB on different parameters

Parameters	SSB	DSB-SC	VSB
Carrier Suppression	Carrier is suppressed	Carrier is suppressed	No carrier is sent, so no carrier is suppressed
Side-band Suppression	One side band is suppressed	No suppression	One side is partially suppressed
Bandwidth	F_M	$2F_M$	$F_M + F_v$
Transmission Efficiency	It has best efficiency	Better than DSB-FC	Lower than SSB more than DSB-SC
Applications	Used in point-to-point communication	Used in Broadcasting	Used in Television (TV) transmission

Power Transmission	P_{LSB} or P_{USB}	$P_{LSB} + P_{USB}$	$P_{LSB} + P_V$ or $P_{USB} + P_V$
Complexity	Most Complex	Simple	Less complex than SSB but more complex than DSB-SC

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