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Implementation of SSB Modulation/Demodulation using Hilbert Transform in MATLAB

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Abstract – To facilitate communication over large distances, modulation is the right key. Different parameters of the transmitted signal are varied as per the system requirement. Single Side Band (SSB) is the refined form of Amplitude Modulation providing bandwidth and power efficiencies. In this paper we analyze the SSB modulation scheme using Hilbert Transform approach. Hilbert Transform finds its applications in the field of signal processing because of its ability to maintain a phase shift of 90^0 between the carriers which is necessary for orthogonality. 5^{th} order low pass Butterworth filter is designed and applied at the receiver end for the recovery of data. All the simulations are performed by using MATLAB by Math works.

Keywords – Modulation; SSB; Hilbert Transform; Butterworth; MATLAB

1. Introduction

Modulation is a process in which information is transferred over a medium by changing its various parameters such as Amplitude, phase and frequency [1]. It is the process in which we convert the information so that it can be successfully transmitted over the medium. Three basic types of modulation exist including Amplitude, Frequency and Phase Modulation. Other hybrid techniques are evolved by combining these three basic techniques [5]. In all of the techniques any parameter of the sinusoid is varied and this is used to represent our data which has to be sent over the medium. Carrier signal is multiplied with the signal which contains required information [1] [4].

1.1 Single Side Band Modulation

In this type of modulation we transmit only one side band of our transmitted signal [6]. As compared to double side band single side band requires only half of the bandwidth as we are transmitting only half of our signal [2] [3].

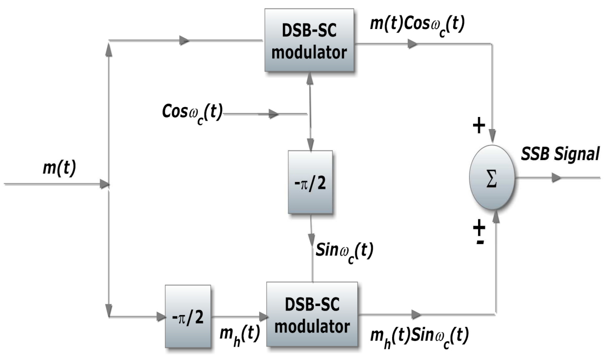

Figure 1. Single Side Band Modulator

Single side band modulation can be implemented as: The baseband signal shown in figure 1.

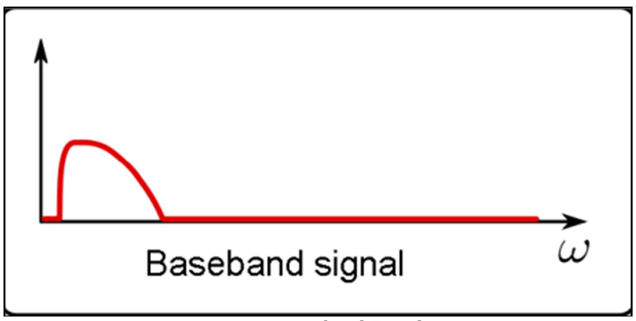

Figure 2. Baseband Signal

After modulation we received the signal which is shown in figure 2. Now we have to extract Upper side band and lower side band.

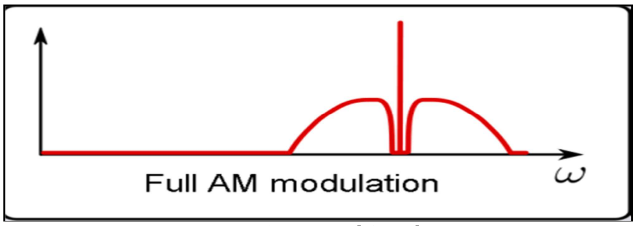

Figure 3. Received Signal

Upper side band can be calculated by the following equation.

$$\varphi_{USB}(t) = mt(t)\cos\omega_c t - m_h(t) sin\omega_c t$$

Figure 4 shows Upper side band of the AM modulated signal [8].

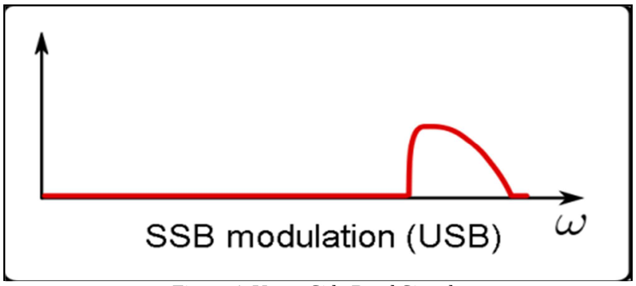

Figure 4. Upper Side Band Signal

Next step is to calculate Lower side band which is calculated using following equation [9].

$$\varphi_{LSB}(t) = mt(t)\cos\omega_c t + m_h(t) sin\omega_c t$$

Figure 5 shows the Lower side band of AM modulated signal [7].

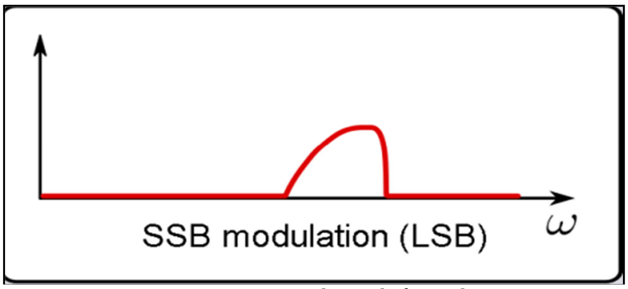

Figure 5. Lower Side Band of Signal

2. Algorithm implementation

Audio file is used as data source for the implementation of algorithm. Matlab is used for the implementation of algorithm. Audio data file is read using Matlab. Samples are plotted in time domain. Fourier transform of signal is taken in order to obtain the sampling frequency of signal. Carrier signal of frequency 5500 Hz is generated. Hilbert transform of message signal and carrier is performed. Hilbert transform takes a function $u\ (t)$ and returns a signal $H\ (u)\ (t)$ with the same domain. Hilbert Transform is given by the following equation.

$$m_h(t) = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{m(\alpha)}{t-\alpha}\, d\alpha$$

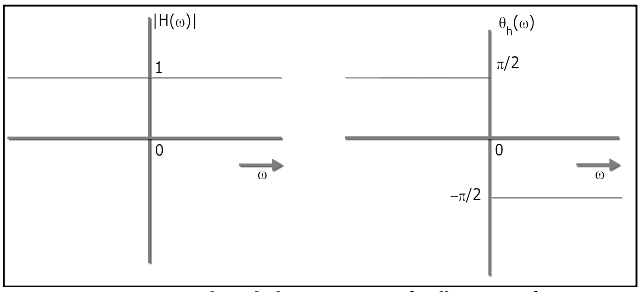

Figure 6. Magnitude and Phase response of Hilbert Transform

After this carrier signal is multiplied with the audio message signal and Hilbert of carrier signal is multiplied with Hilbert of audio message signal. We get our modulated signal here which is ready to be transmitted.

At the demodulator end Upper side band is extracted by subtracting the sample values of product of Hilbert of message signal with Hilbert of carrier signal from the product of audio message signal and carrier. Lower side band is obtained by the addition of both of these sample values. Carrier signal is multiplied with both the upper and lower side bands. Both of these are added to get the complete signal. This signal is then passed through Butterworth low pass filter with cut off frequency of 8000Hz.The order of filter is 5 in order to get good results. Retrieved signal after passing it through low pass filter is compared with the original signal to check the errors.

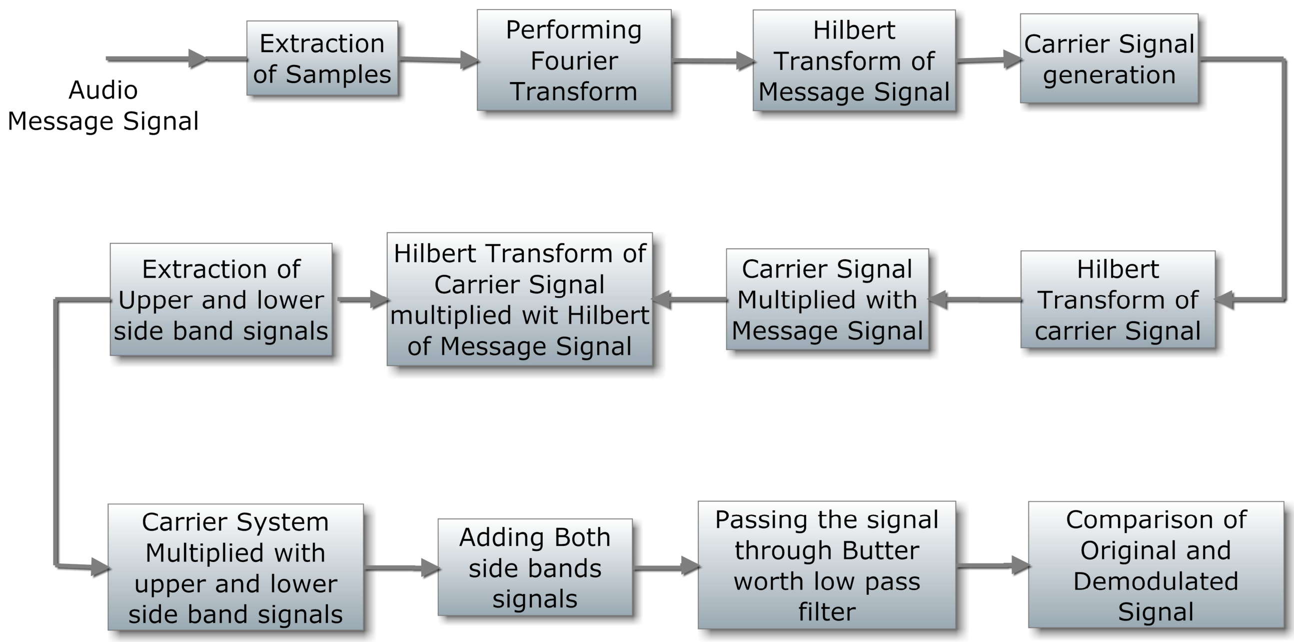

Figure 7. Algorithm of complete modulation and demodulation

3. Simulation Results

Figure8 shows the Frequency spectrum of Audio Signal. The peaks in plot demonstrate that it is sampled at 25050 Hz.

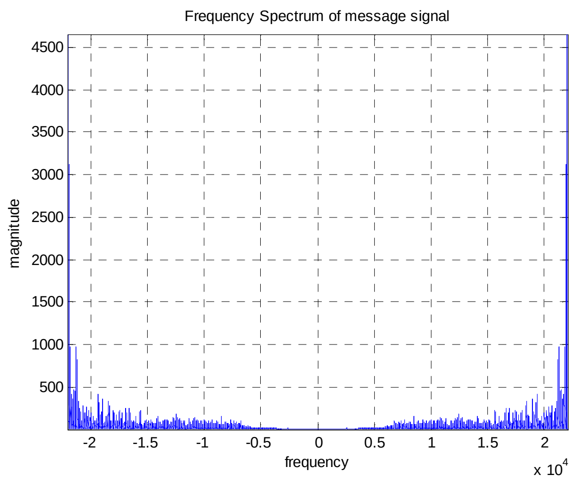

Figure 8. Frequency Spectrum of Audio Message signal

A carrier signal is a basically transmitted pulse or wave at a base frequency of alternation on which information can be imposed by increasing signal strength, varying the base frequency. The figure 9 explains the frequency spectrum of the carrier signal sampled at 5500Hz, as we have peaks at corresponding frequency.

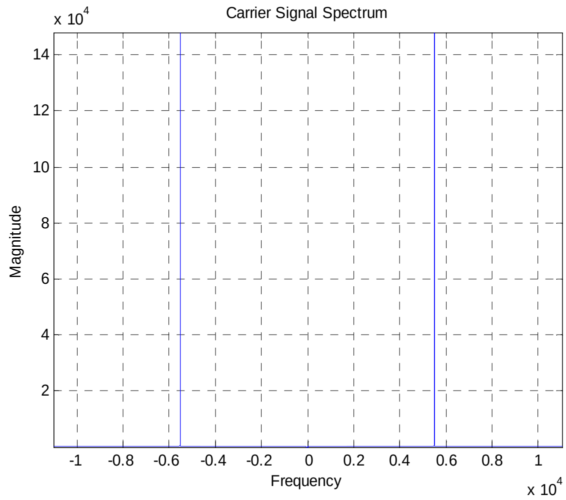

Figure 9. Frequency Spectrum of Carrier signal

The Original audio signal that contains information i.e. showed in Fig 8 is multiplied with the carrier signal i.e. shown in Fig 9 the original is transferred to low frequency i.e. 5500Hz which is shown in figure 10. The peaks show that original signal is transferred from 25050 Hz to 5500 Hz. This process is called Modulation and the signal is called modulated signal.

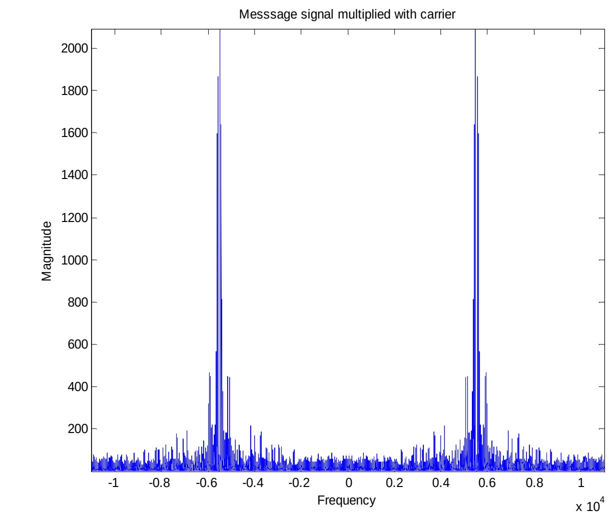

Figure 10. Frequency Spectrum of Message Signal after Multiplying with Carrier Signal

The lower side band of modulated signal which is extracted at the demodulator end is shown in figure 11. Lower side band is extracted by the subtraction of signals obtained after multiplying with the Hilbert transform of original and carrier signals.

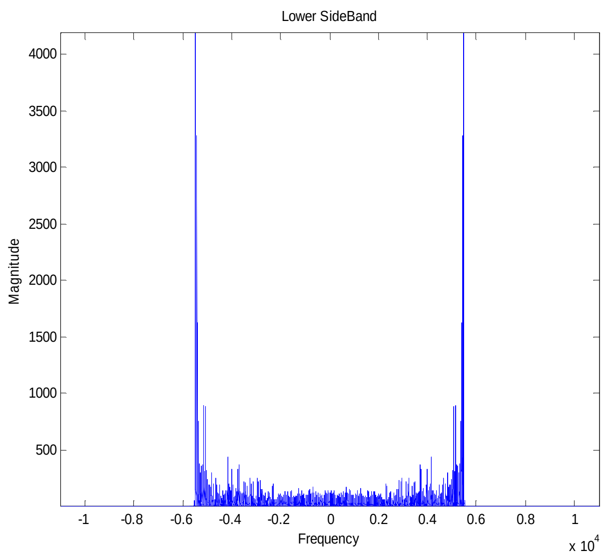

Figure 11. Lower Side band of Modulated Signal

The figure 12 shows the upper side band of modulated signal which is extracted at the demodulator end. Lower side band is extracted by the addition of signals obtained after multiplying with the Hilbert transform of original and carrier signals.

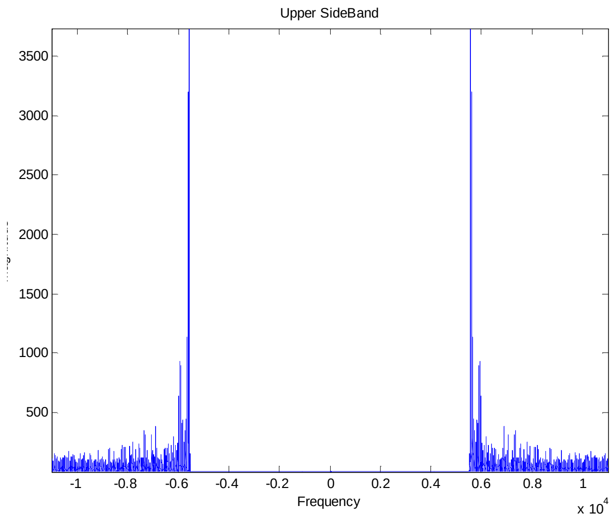

Figure 12. Upper Side Band of Modulated Signal

Upper sideband and lower side bands are combined to get the demodulated signals. The demodulated signal after the combination of both side bands is shown in figure 13.

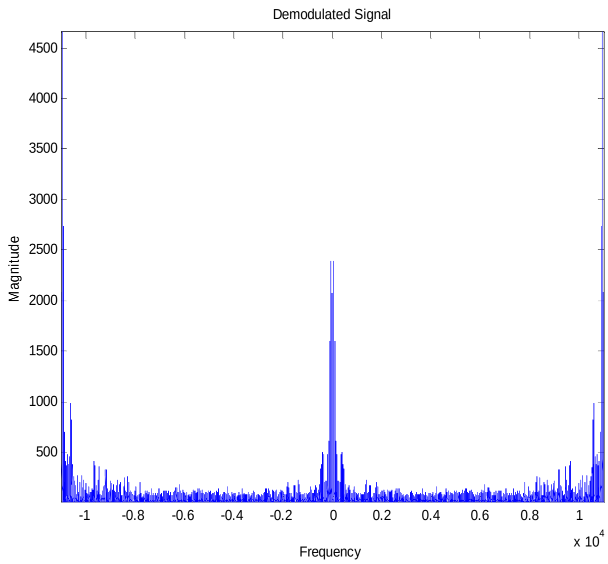

Figure 13. Frequency Spectrum of Demodulated Signal

The magnitude and phase response of 5^{th}order low pass Butterworth filter is demonstrated in figure 14. Suppressing frequency is 8000Hz as clearly shown in the magnitude plot of the filter.

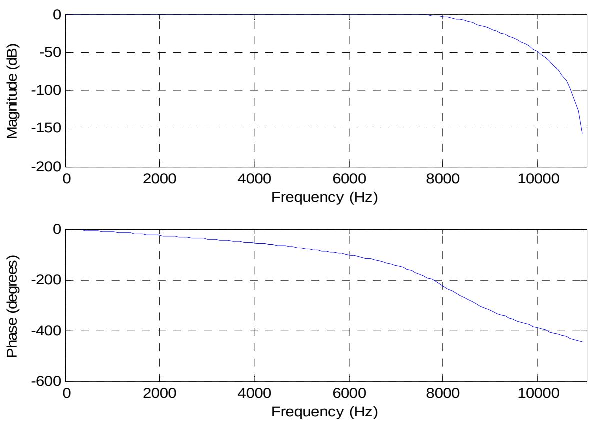

Figure 14. Magnitude/Phase response of 5th order Butterworth LPF

Figure 15 shows the demodulated signal received after passing it through the designed low pass filter. The signal obtained is almost the same that is transferred. Comparison of both transferred and demodulated signals is performed and it is found that there is almost very little difference in both the signals.

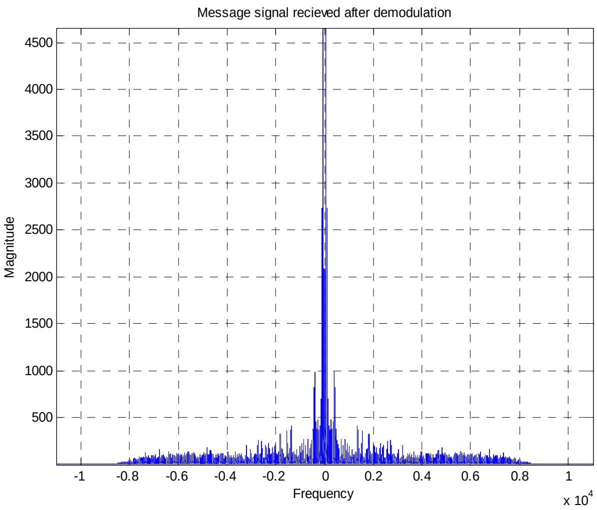

Figure 15. Demodulated Signal after LPF

4. Conclusion

SSB Modulation/Demodulation is performed and analyzed graphically. It can be seen that SSB is bandwidth efficient because of the use of single side bands at a time, but this comes at the cost of more complexity. SSB spans over the half bandwidth as compared to AM, thus enables us to increase the coverage area as the same amount of energy will be distribute over a small portion. Hilbert Transform is best suited for SSB systems due to its advantages of maintaining orthogonality. Filter design is an important parameter in the design of any communication system and with the help of proper filtering we can recover our transmitted signal successfully.

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Vitae

Abdul Basit, Waqar Aziz and Farhan Zafar is students of B.E Electrical Engineering at Institute of Space Technology, Islamabad, Pakistan. Currently they are working on their Final Year Projects and they done work on this paper as their semester project.