

Simulation and Research of Single Sideband AM Signal Demodulation Circuit Based on Simulink

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Abstract: Single sideband communication is one of the important research fields of modern communication technology, and its purpose is to improve communication signal-to-noise ratio and spectrum utilization, so as to improve the reliability, stability and efficiency of signal transmission. In this paper, a single sideband AM signal demodulation circuit is designed based on Simulink, which shows and analyzes the modulation and demodulation process of single sideband AM signal concisely and intuitively. At the same time, the influence factors of noise are considered, and the influence of different variance and mean of Gaussian noise on the signal is studied. The simulation results show that the designed demodulation circuit can effectively demodulate the original information in the single sideband AM signal. On the basis of adjusting the mean and variance of Gaussian noise, it is concluded that larger mean and variance of Gaussian noise will lead to distortion of output signal.

Keywords: SSB; Modulation; Demodulation; Simulink; Simulision; Matlab

1. INTRODUCTION

The research of single side band modulation and demodulation technology is of great significance to the development of modern communication technology. As an important means of information transmission, wireless communication has higher and higher bandwidth requirements [1]. Single side band modulation technology breaks through the traditional communication bandwidth limitation, can better meet the needs of modern communication technology, and improve the efficiency and quality of signal transmission. In addition, single sideband modulation has better anti-noise ability, which can improve the signal-to-noise ratio and further improve the quality of signal transmission. Single-sideband demodulation technology can effectively recover the signal lost in the transmission process, improve the signal-to-noise ratio, and ensure the stability and reliability of the transmission signal [2].

In this paper, through the study and comparison of three methods of single side band modulation and demodulation principle, the filtering method is used to realize the single side band AM signal generation circuit, the coherent demodulation is used to design the single side band AM signal demodulation circuit, the single side band modulation and demodulation circuit is designed through Simulink, and their power spectrum is analyzed, and the influence of different mean and variance of Gaussian noise on the signal is studied.

2. Single sideband signal modulation

The principle of double-sideband modulation is that the original signal is amplitude modulated to obtain the modulated signal, which contains both side bands of the carrier frequency. Although the power efficiency of double-sideband modulation is effectively improved, it requires a wider spectrum range to transmit, which results in a decrease in the channel transmission rate. Therefore, its development has been greatly restricted in the limited frequency band range [3]. As a result, single sideband modulation techniques have emerged.

Single sideband signal contains only one side band and the information of the original signal, which is narrower than the

common modulation method and can be used to transmit more information. It is a more efficient modulation method, which can effectively reduce the signal bandwidth and improve the efficiency of signal transmission

2.1 Filtering method

Filtering is one of the most widely used modulation methods. Its working principle is to maintain the upper and lower frequency bands in a single sideband modulation signal at a lower frequency band through a band-pass filter. In the case of using the unilateral frequency band, all the information of the original signal can be retained in both the upper and lower side bands. Therefore, when transmitting the signal in this way, the efficient transmission and restoration of the signal can be achieved by retaining only the upper or lower sidebands.

This method can effectively reduce the demand for bandwidth, so that single sideband modulation has been widely used in radio communication and broadcast. Because the filtering method needs to use a low-pass filter or a high-pass filter to filter the upper sideband or the lower sideband, but because it is difficult to make a filter with steep cut-off characteristics in the hardware implementation, it is necessary to use multiple frequency shifting and multiple filtering in practice, which can increase the normalized value of the transition band. In other words, if the filter transition band is not so steep, good filtering effect can be obtained [4].

2.2 Phase shifting method

In the phase shifting method, the original signal is firstly transformed by Hilbert transform, so that the phase of the negative frequency part of the original signal is 90° different from the positive frequency part of the original signal. Then the transformed signal is multiplied with the original signal to obtain the signal containing only the positive frequency part. Finally, the negative frequency part is removed by the filter, and the single sideband modulated signal is obtained.

The phase-shifting method removes signals on both sides through clever phase shifting operations, so as to directly generate single-sideband modulation signals, making signal transmission simpler and more stable [5]. The phase-shifting method does not need a filter to suppress the carrier and

sideband frequencies, and only needs to phase shift the signal without additional frequency transformation, so it can reduce the complexity of the system and save the bandwidth of the cost frequency. In essence, the transfer function property of the Hilbert filter is used to filter out a sideband. The principle block diagram of single-sideband modulation with phase shifting method is shown in the following figure.

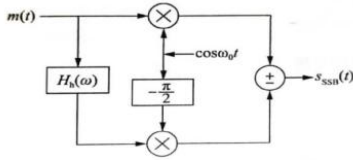


Figure. 1 Schematic diagram of the phase shift method

2.3 Dimensional embedding

Dimensional method is also called hybrid method. It has the advantages of filtering method and phase-shift method. At the same time, it avoids the high cut-off frequency of ideal filter in filtering method and the precise phase-shift of all frequency components in phase-shift method, and is easy to be realized by practical circuits.

The principle block diagram of dimensional method is shown in Figure 2. A pair of orthogonal carriers collapse the sideband of the lower side, and the sideband of the upper side is eliminated by the low-pass filter. Then another pair of orthogonal carriers moves the spectrum to the appropriate position, and the two signals are added or subtracted to obtain the single-sideband signal[6]. The circuit includes four multipliers, two 90 degree carrier phase shift circuits, two less demanding low-pass filters and adders and subtractors.

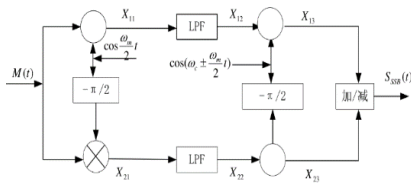


Figure. 2 Schematic diagram of the volt method

In summary, the single-sideband modulation method based on the filtering method is a relatively simple and common modulation method, and its implementation is simple, and the high-frequency part can be filtered out through the low-pass filter to obtain the demodulated baseband signal. The phase shift method and dimension volt method need higher precision digital signal processor and phase-locked loop devices, and the system complexity is higher[7]. When designing the simulation, the complexity of the simulation model should be increased accordingly, and the influence of device parameters on the simulation accuracy should be considered. Therefore, the filtering method is relatively simple and feasible choice.

3. Single sideband signal demodulation

Demodulation and modulation are, in essence, mobile spectrum. Modulation is to shift the spectrum of the baseband signal to the carrier frequency and multiply it with the carrier using a multiplier. Demodulation is the inverse process of modulation, that is, the spectrum of the modulated signal at the carrier position is moved back to the original baseband position [8]. Single-sideband signal demodulation is to filter out the carrier of the received SSB signal and restore the useful information needed before transmitting.

3.1 Coherent demodulation method

Coherent demodulation is also called synchronous detection. Firstly, the received SSB signal needs to be demodulated by the local demodulated carrier signal, which needs to have the same frequency, the same phase and the same amplitude as the received signal. The resulting locally demodulated carrier signal is then multiplied with the received SSB signal to obtain the mixing signal. Finally, the original baseband signal was obtained by filtering out the high frequency part of the mixed signal through a low-pass filter.

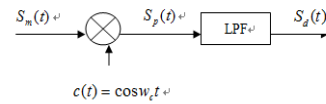


Figure. 3 Schematic diagram of coherent demodulation

3.2 Envelope detection method

The envelope detection method is a simple and economical demodulation technique, and it is also a common demodulation method in the demodulation of single sideband modulation. It is usually composed of a half-wave or full-wave rectifier and a low-pass filter, which does not need a coherent carrier, but only needs to extract the envelope of the input signal and restore it to the original signal. The specific steps are as follows: the received SSB signal is amplitude modulated to convert the high frequency component of the signal into the low frequency component. The envelope of the amplitude modulation signal is detected to obtain the restored baseband signal, which is the demodulated output.

The envelope detection method has advantages in simple implementation and no phase synchronization problem, but its accuracy is not as high as that of the coherent demodulation method. Therefore, coherent demodulation is a more common demodulation technique in some fields with high accuracy requirements, such as radio communication and broadcast.

In summary, compared with the envelope detection method, the coherent demodulation method can recover the phase information of the original signal. In the demodulation of single-sideband signals, phase information is very important, because different phases and angles will lead to different demodulation information. The coherent demodulation method can accurately recover the phase information of the original signal, and has better suppression effect on noise and multipath interference, so that the demodulation accuracy is higher. Therefore, the coherent demodulation method can obtain more accurate and stable demodulation results.

4. Simulation experiment and analysis

4.1 Single sideband demodulation with Gaussian noise

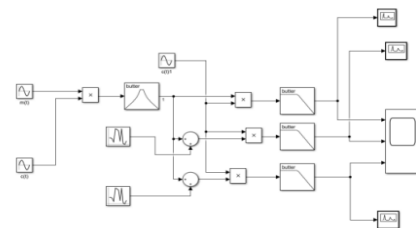


Figure 4 System model after adding noise

Gaussian noise is a kind of noise whose probability density function follows Gaussian distribution[9]. In order to simulate the Gaussian noise to the ideal channel, a Gaussian noise module can be added under the Simulink noise source to study the effect of different mean and variance of Gaussian noise on signal transmission. This method can help to determine the applicability and stability of the demodulation circuit for single sideband AM signals in different Gaussian noise environments.

In specific operation, different mean and variance of Gaussian noise can be set to simulate different Gaussian noise environments respectively, and then the simulation results are analyzed and compared to find the optimal model parameters and system design scheme. Here, the amplitude and frequency of the modulation signal $m(t)$ are set to 2 and 1, the amplitude and frequency of the carrier signal $c(t)$ are set to 2 and 10, the filter order of the low-pass filter is set to 8, and the passband cutoff frequency is set to 10.

4.2 Results Analysis

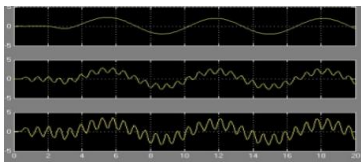


Figure 5 Influence of noise with the same variance and different means on the signal

The first one is the coherent demodulation signal waveform under the ideal channel, the second one is the output signal waveform when the Gaussian noise with mean value 0.5 and variance 0 is added, and the third one is the output signal waveform when the Gaussian noise with mean value 1 and variance 0 is added. The score is analyzed by the simulation results, adding Gaussian noise variance is the same, the larger the mean value, the larger the distortion after demodulation. The following figure shows the signal power spectrum of each process after adding different Gaussian noise in the coherent demodulation module.

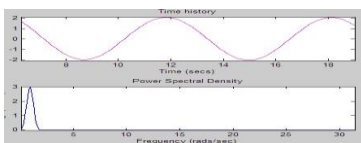


Figure 6 Output signal power spectrum under ideal channel

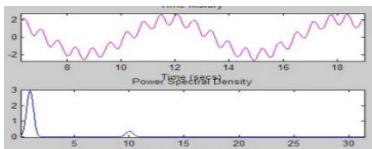


Figure 7 Power spectrum of output signal with Gaussian noise mean 0.5 and variance 0

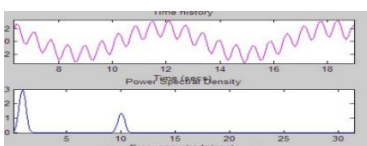


Figure 8 Power spectrum of output signal with Gaussian noise with mean 1 and variance 0

From the simulation results, it can be seen that compared with the output waveform under the ideal channel, when the Gaussian noise mean is 0.5 and variance is 0, the output signal waveform has a small distortion. A small component is generated on the power spectrum. When the Gaussian noise has mean 1 and variance 0, the output signal waveform has a large distortion. A large component is generated in the power spectrum. Gradually increasing the mean of the Gaussian noise, it is found that when the mean of the Gaussian noise is greater than 2, the waveform is almost completely distorted, creating a component in the power spectrum that is larger than the original signal power. The analysis shows that as the mean of Gaussian noise increases, the output signal distortion increases.

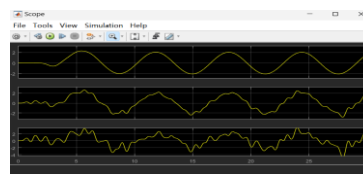


Figure 9 Influence of the same mean, different variance noise on the signal

In the same way, the relationship between waveform distortion and Gaussian noise variance is studied. The simulation results show that when the mean of Gaussian noise is 0 and the variance is 0.1, the waveform of the output signal has a small distortion. When the mean of Gaussian noise is 0 and the variance is 1, the waveform of the output signal appears obvious distortion. By increasing the variance of Gaussian noise, it is found that when the noise variance is greater than 2, the output waveform is almost completely distorted, and there are many clutter components in the power spectrum, and the power of these clutter components is higher than that of the original signal. The analysis shows that as the variance of Gaussian noise increases, the output signal distortion increases.

5. CONCLUSION

The research of single side band modulation and demodulation technology is of great significance to the development of modern communication technology. As an important means of information transmission, wireless communication has higher and higher bandwidth requirements. Single side band modulation technology breaks through the traditional communication bandwidth limit, and can better meet the needs of modern communication technology, improve the efficiency and quality of signal transmission. This paper designs single side band AM signal demodulation circuit through Simulink and analyzes their spectrum. The simulation results show that the distortion of the signal increases with the increase of the mean and variance of the Gaussian noise.

6. REFERENCES

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