Simulation Design and Research of Superheterodyne AM Receiver based on Multisim

Siqi Zhang
Department of Communication Engineering
Shandong University of Technology
Zibo, China

Abstract:- Information, as a resource, can only promote people's communication and cooperation through extensive dissemination and exchange. The dissemination and exchange of information rely on communication systems, and receiving equipment is a part of the communication system. A superheterodyne AM receiver consists of six modules: high-frequency small signal amplifier, local oscillator, mixer, intermediate frequency amplifier, envelope detector, and low-frequency amplifier. This article uses Multisim software to conduct the simulation research of the system, which can help us better understand and master the principles and components of each module of the AM receiver circuit.

Keywords:- *Multisim Simulation, Superheterodyne Receiver, Communication Electronic Circuit.*

I. INTRODUCTION

The Superheterodyne AM receiver is mainly composed of a high frequency small signal amplifier circuit, mixing circuit, local oscillator, intermediate frequency amplifier,detection circuit,and low frequency amplification circuit as shown in the overall system block diagram in Fig. 1[2].

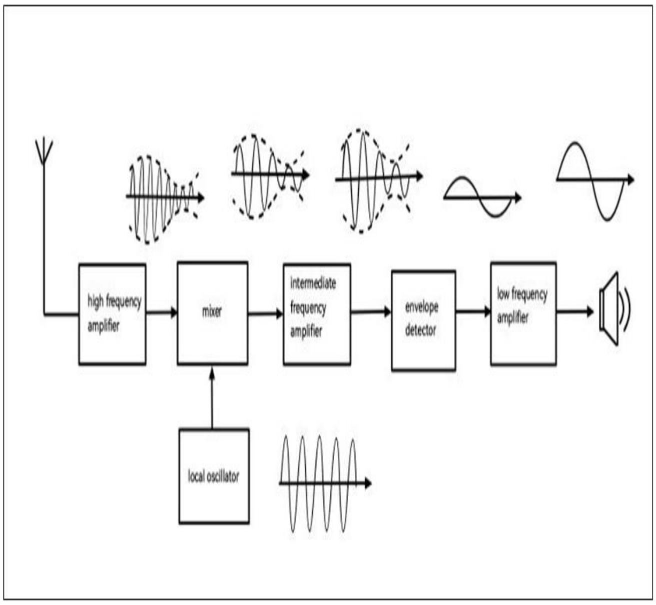


Fig 1 Super Heterodyne AM Receiver System Block Diagram AM

The radio wave is first received by the receiving antenna, then input to the high frequency small signal amplifier circuit. On the back end of the high frequency small signal amplifier circuit is a selective network, which allows the amplified signal to meet the frequency requirements of the subsequent circuit. After the signal is amplified, it can be processed and directly input to the mixer. The local oscillator of the superheterodyne receiver can generate a heterodyne signal. The frequency of the heterodyne signal should always differ from the received signal frequency by a fixed frequency, which is called the intermediate frequency[3]. Since the carrier frequency after frequency conversion is fixed, the resonance circuit of the intermediate frequency amplifier does not need to be adjusted all the time. No matter how the signal frequency changes, the intermediate frequency is always constant, and the selectivity is easy to do well[4]. This is also the advantage of the superheterodyne receiver. The intermediate frequency signal obtained by the frequency conversion is amplified by the intermediate frequency amplifier. It can be input into the detection circuit for detection, and the original sound signal can be obtained. However, the intensity of this signal is not large enough, and then the whole signal is processed by the low frequency amplifier. Finally, the speaker is driven by the electrical signal.

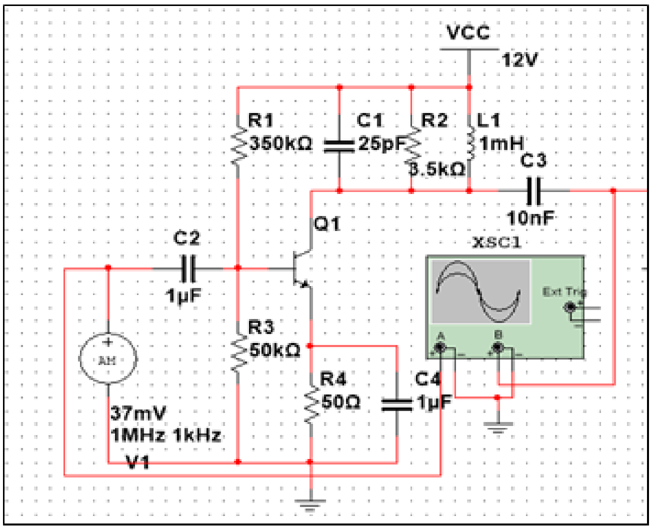
II. INTRODUCTION TO MULTISIM SIMULATION SOFTWARE

Multisim is a Windows-based simulation tool launched by National Instruments Corporation in the United States. It is suitable for the design of board-level analog/digital circuit boards, and it includes graphical input of circuit schematics, hardware description language input, which rich simulation analysis capabilities[1].

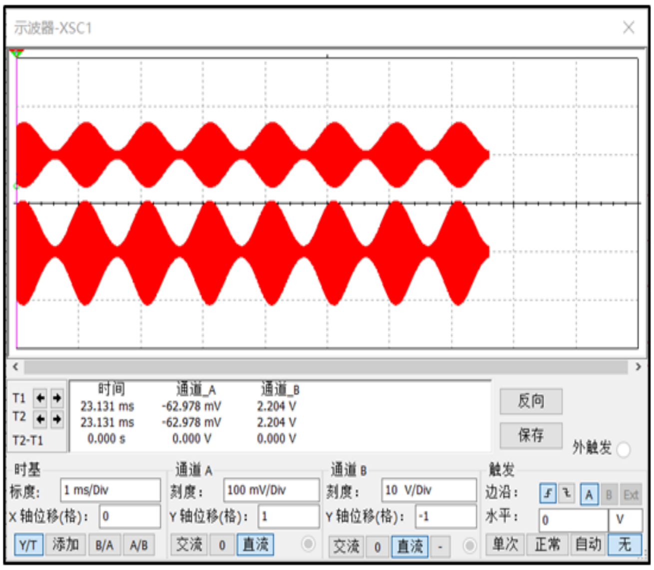
III. THE DESIGN AND SIMULATION ANALYSIS OF THE SYSTEM MODULES

A. High Frequency Small Signal Amplification Module

This simulation takes a common AM modulation signal with an amplitude of 37mV, a carrier frequency of 1MHz, and a baseband frequency of 1KHz as an example. The high-frequency small signal amplification circuit is used to amplify the received high-frequency weak signals. Fig. 2(a) shows a typical single-pole single-tuned amplification circuit, which consists of a parallel resonant network with $C_1 = 25PF, L_1 = 1mH, R_2 = 3.5K\Omega$ resonating at a frequency of 1MHz. This network acts as a selective filtering for the signal, and the amplified signal is output to the next stage through a coupling capacitor. In Fig. 2(b), channel A shows the input waveform and channel B shows the output waveform. It can be observed from the simulation graph that this circuit has achieved amplification.



(a)High-Frequency Small Signal Amplification Simulation Circuit



	时间	通道_A	通道_B
T1	23.131 ms	-62.978 mV	2.204 V
T2	23.131 ms	-62.978 mV	2.204 V
T2-T1	0.000 s	0.000 V	0.000 V

时基
标度: 1 ms/Div
X 轴位移(格): 0

通道 A
刻度: 100 mV/Div
Y 轴位移(格): 1

通道 B
刻度: 10 V/Div
Y 轴位移(格): -1

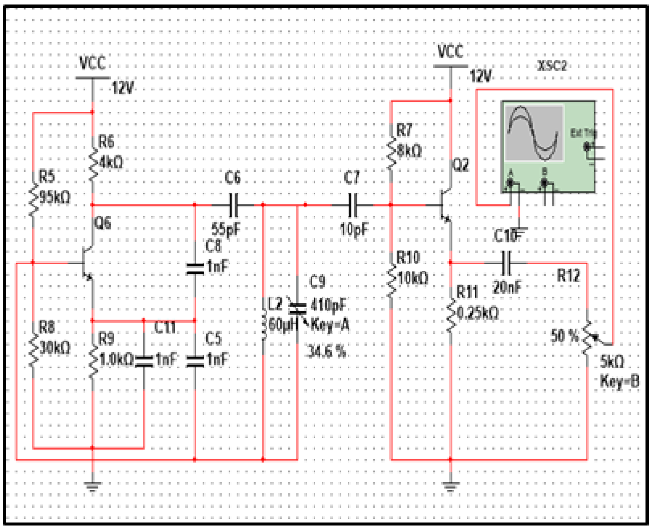
触发
边沿: A
水平: 0 V

(b) Waveform Diagram of High-Frequency Small Signal Amplification Circuit

Fig 2 High-Frequency Small-Signal Amplification Simulation Circuit and Waveform Diagram

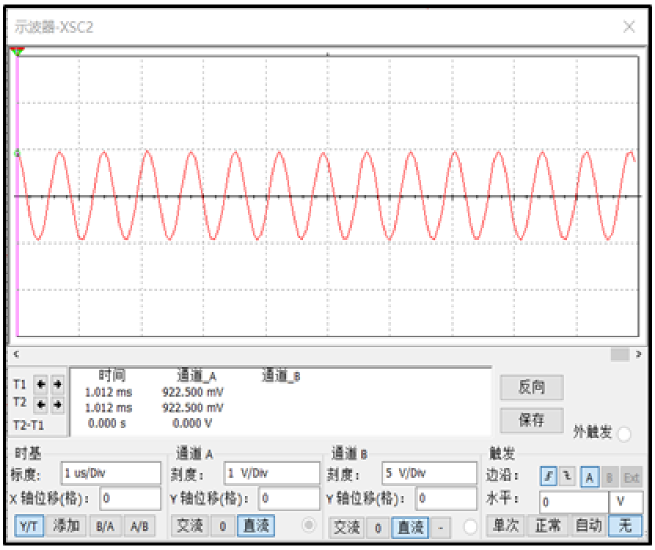
B. *Local Oscillator Module*

The parallel improved capacitor three-terminal oscillator, also known as the schiller circuit, with its simulation circuit shown in Fig. 3(a), is designed for a general carrier frequency range of 535—1605kHz[3], and an intermediate frequency of 465kHz. Therefore, the signal frequency produced by the local oscillator should be in the range of 1MHz—2.07MHz. Let $C_8 = C_5 = 1nF$, $C_6 = 55pF$, $L_2 = 60\mu H$ and C_9 be the adjustable capacitor with a maximum value of 410pF.Thus,the total capacitance value $C \approx C_6 + C_9$ yields the minimum oscillation frequency f_{0min}=952.8kHz, which is less than 1MHz, and the maximum oscillation frequency can exceed 2.07MHz. Adjust and test the parameters of each component to ensure the signal frequency reaches between 1MHz and 2.07MHz. The value of C_9 should be in the range of 10.6%-89.55% of C_{9max} .



(a) Local Oscillation Simulation Circuit Diagram

Since the simulation carrier frequency is 1MHz, the resonance frequency of the local oscillator network should be set to 1465KHz. Calculations indicate C_9 should be set to 142pF, making the variable capacitance indicator 34.6%. Conduct simulation experiments, and Fig. 3(b) shows the simulated waveform output.



	时间	通道_A	通道_B
T1	1.012 ms	922.500 mV	
T2	1.012 ms	922.500 mV	
T2-T1	0.000 s	0.000 V	

时基
标度: 1 us/Div
X 轴位移(格): 0

通道 A
刻度: 1 V/Div
Y 轴位移(格): 0

通道 B
刻度: 5 V/Div
Y 轴位移(格): 0

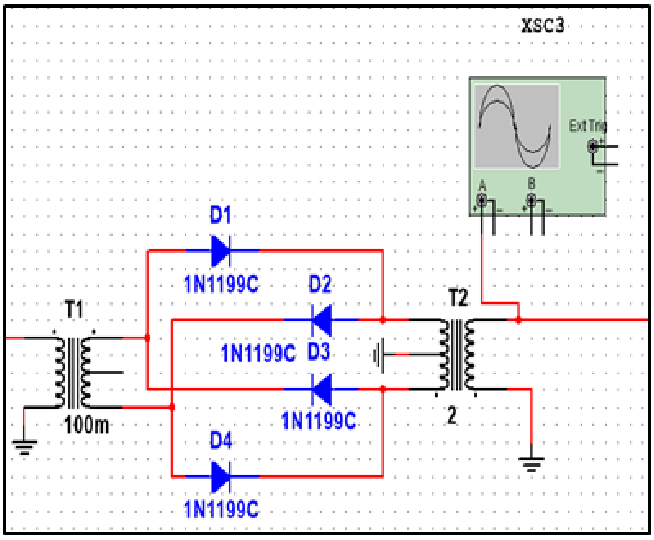
触发
边沿: A
水平: 0 V

(b) Output Waveform Diagram of Local Oscillation Circuit

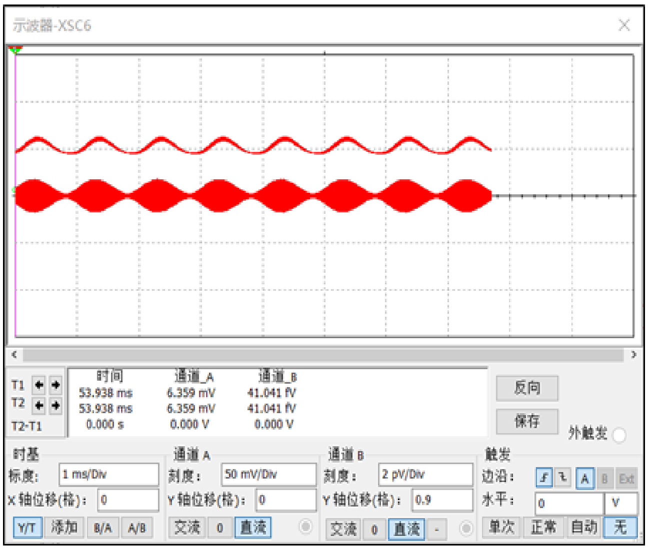
Fig 3 Local Oscillation Simulation Circuit and Output Waveform

C. *Frequency Mixer Module*

The balanced mixer can adopt a diode ring mixer, whose main advantage is that the output intermediate frequency signal is twice that of a balanced mixer, and it cancels out certain combination frequency components in the output current, thereby reducing the combination frequency interference inherent in the mixer. The simulation circuit diagram is shown in Fig. 4(a). The local oscillator voltage is added from the center tap of the input and output transformers. In the positive half cycle of the local oscillator voltage, diodes D_1 and D_3 conduct, while D_2 and D_4 cut off. In the negative half cycle of the local oscillator voltage, diodes D_2 and D_4 conduct while D_1 and D_3 are cut-off. In the end, we obtain terms such as $\omega_0 \pm \omega_s$、 $3\omega_0 \pm \omega_s$、 and $5\omega_0 + \omega_s$,What we need is $\omega_0 - \omega_s$, and the other frequency terms will be suppressed. For this design, 4 1N1199C diodes and 2 transformers are used, with the turns ratio of T_1 and T_2 being 0.1 and 2, respectively. The output waveform of the mixing circuit is shown in Fig. 4(b).



(a) Mixer Simulation Circuit Diagram



	时间	通道_A	通道_B
T1	53.938 ms	6.359 mV	41.041 fV
T2	53.938 ms	6.359 mV	41.041 fV
T2-T1	0.000 s	0.000 V	0.000 V

时基
标度: 1 ms/Div
X 轴位移(格): 0

通道 A
刻度: 50 mV/Div
Y 轴位移(格): 0

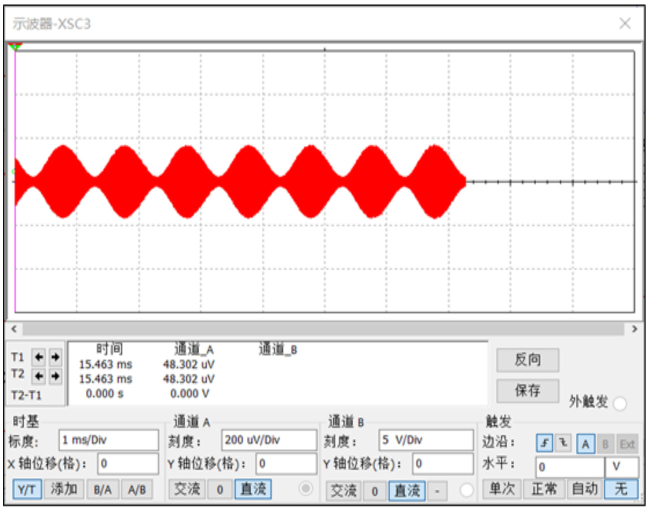
通道 B
刻度: 2 pV/Div
Y 轴位移(格): 0.9

触发
边沿: A
水平: 0 V

(b) Output Waveform Diagram of Mixing Circuit
Fig 4 Mixer Simulation Circuit and Output Waveform

D. Envelope Detection Module

Amplitude demodulation is the reverse process of amplitude modulation, usually referred to as detection. Its function is to recover the original modulated signal from the modulated high-frequency oscillation. In this design, a series-connected diode envelope detection circuit is used, and its circuit schematic is shown in Fig. 5(a). Let $C_{12} = 110nF$, and consider it as a short circuit for high frequency. The selected diode has a very small forward resistance $R_d \ll R$, so the charging time constant is small, making the charging process very fast. The discharge time constant $R_1C_1$is relatively large, making the discharge process very slow. In addition, given m_a=0.8, to avoid negative peak distortion, take $R_{21} = 15K\Omega, R_{19} = 0.7k\Omega$. In Fig. 5(b), Channel A is the intermediate frequency amplification output waveform, and Channel B is the output waveform after detection. From the output, it can be seen that this detection circuit completely detects the envelope of the AM modulated signal.



	时间	通道_A	通道_B
T1	15.463 ms	48.302 uV	
T2	15.463 ms	48.302 uV	
T2-T1	0.000 s	0.000 V	

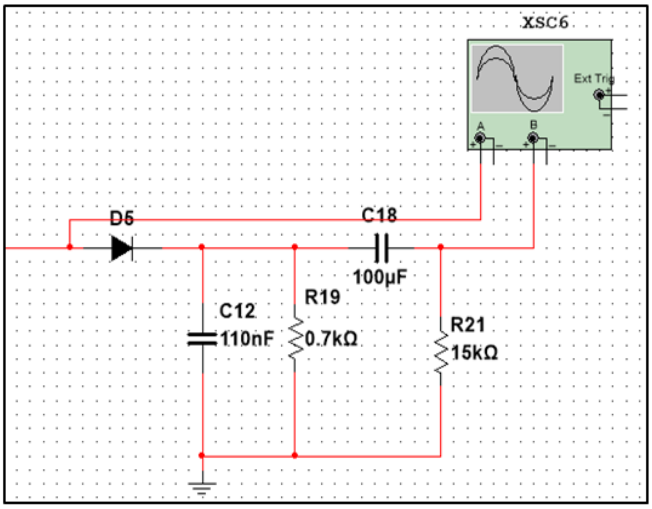
时基
标度: 1 ms/Div
X 轴位移(格): 0

通道 A
刻度: 200 uV/Div
Y 轴位移(格): 0

通道 B
刻度: 5 V/Div
Y 轴位移(格): 0

触发
边沿: A
水平: 0 V

(a) Simulation Circuit Diagram of Envelope Detection



(b) Envelope Detection Output Waveform Diagram
Fig. 5 Envelope Detection Simulation Circuit and Input-Output Waveform Diagram

IV. CONCLUSION

This article presents the working process of the superheterodyne AM receiver system and the simulated circuit diagrams of some modules. The working process can be summarized as follows: the antenna receives weak high-frequency signals, which are then amplified by the high-frequency small-signal amplifier. The signal is then mixed with the local oscillator frequency f_0 by the mixer to obtain the sum and difference of these two frequencies[6]. The intermediate frequency signal of $f_i = 465\mathrm{k}Hz$ is selected from it through the detector, and the restored signal is obtained by detector detection. Finally, the signal is amplified by the low-frequency amplifier, converted into audio signals by the speaker. The core modules in the article are the high-frequency resonant small-signal amplification circuit, parallel-type improved capacitance three-point oscillation circuit, diode double-balanced mixing circuit, and envelope detection module. The circuit is simulated and analyzed using Multisim, which is intuitive and easy to understand.

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