Research on S Band Broadband Frequency Agility

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Abstract

At present, the ultra high speed frequency hopping communication and frequency agility radar have not been fully developed. The main reason is that the frequency synthesizer is not required to meet the requirements of the frequency synthesizer. Therefore, it is important to study the frequency synthesis technology of wide frequency band and frequency agility, which has important application value in the improvement of electronic countermeasure, radar, guidance, remote sensing monitoring and millimeter wave communication.The analysis based on the theory of frequency synthesizer discussed several frequency hopping source synthesis scheme, according to different user needs, choose different hopping frequency synthesis technology, in the S-band developed three different time hopping frequency synthesizer, phase locked loop (PLL) technology were used, direct digital frequency synthesis (DDS) technology, and the combination of the and control of high speed FPGA device, give full play to their respective advantages to overcome the shortcomings of each single technique. In the study of frequency source, fast frequency hopping source PLL interpolation based on DDS, using the PLL interpolation scheme of DDS, 2710~3210MHz in the frequency bandwidth, realized within 100MHz stepping frequency conversion time is about 9us; high frequency source based on DSS technology, using DDS+DS program in the 2710~3210MHz frequency band, in order to realize the arbitrary step frequency conversion time of less than 4 us; PLL and DDS technology based on agile frequency source, using DDS and PLL ring mixing scheme, combined with high speed FPGA control circuit, the realization of the 2349~2954MHz frequency band, the arbitrary step frequency conversion time is less than 1.5 us. The above three sets of solutions, in solving the different frequency hopping time demand, both with spurious suppression is better than 60dBc and phase noise is better than -97dBc/Hz@1KHz, achieve the desired objectives of the project.

Keywords

frequency hopping source, broadband, frequency hopping time, frequency agility.

1. Frequency Synthesis Technology and The Development of Frequency Hopping Source

Frequency synthesis technology is the key technology of modern microwave system. Frequency synthesis technology is mainly used to synthesize a kind of high performance signal generator. A frequency synthesizer is a combination of system elements that produce one or more frequencies by one or more reference frequencies. With the progress of modern electronic technology, radar, wireless communications, electronic warfare and other indicators of the frequency of the source of the requirements are also getting higher and higher. The quality of an electronic system is greatly related to the source of the signal used in this system. Because of this, in the radar system, the low phase noise signal source can be the improvement of the moving target indication radar; in the communication system, due to the use of the high stability of the signal source can make full use of the frequency

resources, in the electronic warfare, electronic navigation system, the signal source of high quality will bring a good price, so as to provide reliable technical barrier for the system designer. Frequency hopping frequency source is derived from the spread spectrum communication, it is widely used in the field of electronic technology and its military communications. The advantage of the frequency hopping source is that it has strong anti-interference ability and wide frequency band. It is because of the large number of the modern electronic warfare and the information countermeasure. So it is of great value to study the synthesis technology of frequency hopping source in engineering.

In the field of microwave, frequency synthesizer can be referred to as the frequency hopping source, and the wide application of frequency hopping source makes many scholars at home and abroad have done a lot of research on frequency hopping source. Frequency hopping source study is a higher degree of difficulty of the frequency synthesis technology, the current in terms of the research status of this field all over the world, in the field of frequency hopping source of relatively good is Herley communications techniques company.

From a technical point of view, the modern frequency hopping source is based on the PLL technology and DDS technology. This is closely related to the two techniques to achieve frequency hopping control. Frequency hopping frequency synthesizer based on phase locked technology. Because of the existence of system feedback circuit, the output signal stability of the system requires a track locking process, it is difficult to realize the characteristics of frequency agility, generally in several microseconds to tens of microseconds above. All along, many scholars in many countries all over the world have made a lot of research on how to shorten the lock time of phase locked loop technology, and have achieved fruitful results in the technology. Which digital loop filter method, double loop structure, preset the DC voltage VCO, loop bandwidth, phase frequency detector phase method. These methods are summed up by a large number of research of relationship of frequency hopping time some methods. And in order to reduce the volume of the synthesizer, many technologies have been integrated in the chip. Method of variable loop bandwidth and phase discrimination. However, these methods are not ideal for the improvement of the frequency hopping time, such as National Semi-conductor Corporation introduced an integrated chip LMX2470, which integrates the fast lock circuit. The essence of this kind of circuit is to change the loop bandwidth in the phase locked loop. Theoretically, by changing the loop bandwidth, the frequency hopping source locking time is reduced to 1/4 of the original, and the actual test shows that the lock time is only about 50% of the improvement. The synthesis methods of modern frequency hopping source are mostly used in hybrid synthesis. In the frequency hopping source system, the phase locked technology and DDS technology are used in the system.

2. The Basic Theory of Frequency Synthesis Technology

Phase locked loop circuit is a special system to track the other system. It can track the phase, realize the synchronization of the output signal and the input signal. More precisely, the phase-locked loop is a circuit that causes the output signal to be generated by the oscillator and the reference signal or the input signal in frequency and phase. The phase difference between the oscillator output signal and the reference signal is zero, or a constant, when the synchronization is usually called a lock. If phase error occurs, a control mechanism is applied to the oscillator, and the phase error is reduced to the minimum. In such a control system, the phase of the actual output signal is locked to the phase of the reference signal. So we call it phase locked loop. Phase locked loop consists of three basic components, phase detector, loop filter and voltage controlled oscillator.

The structure of the direct digital frequency synthesizer DDS is as follows:

Its working principle is the frequency control word as input of the accumulator, per after one clock cycle, the output of the accumulator increases a frequency control word, input and then fed back to the accumulator. The accumulator output to input to the adder, and phase control word for an addition operation, also is a phase shift, so as to accomplish the phase control. The phase corresponds to an address in the ROM, through which the current digital signal value can be obtained. Finally, the signal sequence can be simulated by the D/A and the low pass filter.

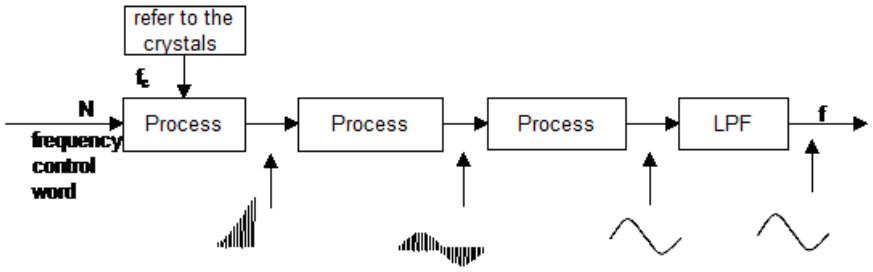

Fig.1 DDS Structure Block Diagram

The choice of frequency synthesizer design depends on the requirements of the system to the frequency synthesizer. When the technical indexes are determined, the frequency synthesizer scheme can be optimized according to the requirements. The technical indexes basically determine the cost, the volume, the weight and the difficulty of the realization of the frequency synthesizer. Working frequency is under the specific working condition, stable carrier frequency synthesizer which generates the nominal frequency value, usually with the actual measurement of the estimation value. The absolute value of the difference between the two frequencies of the frequency synthesizer is called the frequency hopping interval, which is called the frequency resolution. Usually expressed as the maximum frequency interval and the minimum frequency interval. Frequency synthesizer to meet the requirements of the work of frequency points called the number of points, also known as the number of channels. From the start of a frequency conversion instruction, the frequency conversion is completed, and the time required to enter the allowable phase error range is called the frequency conversion time. The switching time of the voltage controlled oscillator with variable capacitance tuning is ns order of magnitude. Direct frequency synthesizer conversion speed depending on the response time of each part of the circuit, amplifier, mixer, multiplier and divider circuit conversion speed is very fast, the main limitation from circuit filter and control circuit of the response time. In short, the direct frequency synthesizer frequency conversion time is easy to reach 2 ~ 1us. Harmonics is a signal that has a coherent relationship with the output signal. The integer times of the frequency of nf_0 in the spectrum reflects the signal frequency of f_0 single spectrum (n=2,3,4,..... The ratio of the harmonic power to the carrier power is called the harmonic suppression, and the unit is dBc. Spurious is a number of useless spectra of the relationship between the signal and the output signal. The spectrum shows the signal frequency of f_0 spectrum by discrete single spectrum of the non harmonic relationship exists. The amplitude of these spectral lines are generally higher than the noise. Spurious suppression is the ratio of the discrete spectral power and the carrier power, which is the frequency of the carrier and the carrier frequency. The unit is dBc. The long term frequency stability of the frequency synthesizer is the same as that of the reference standard source. The requirement for the frequency stability of the frequency synthesizer is related to the application occasion. Short term frequency stability is the main quality index of frequency synthesizer. The short-term frequency stability mainly refers to the instantaneous frequency or phase fluctuation caused by random noise.

3. Based on The PLL Technology of Fast Frequency Hopping Source Design

100 MHz continuous wave signal output requirements phase noise less than 140 dBc/Hz@10KHz spurious suppression is better than-70dbc, output power of more than 0dbm, according to the requirement on the frequency stability of the frequency source, crystal oscillator frequency stability degree 1×10^{-7}. The technical index is determined by the outsourcing of the crystal oscillator. Crystal oscillator the choice to meet the first 100MH signal output index. Secondly, to meet the requirements of crystal oscillator the frequency hopping source, through the technical index of the phase noise, spurious, frequency stability to determine to buy suitable crystal oscillator.

The combination of direct digital frequency synthesis technology and phase lock technology has many advantages, which can solve many difficulties encountered in frequency synthesis in many projects. In the combination of the two schemes, the DDS excitation PLL scheme is very effective to solve the small

step frequency hopping source scheme. However, because of the large frequency hopping step in the project, the frequency switching time of the single loop phase locked technology can not meet the requirements of the project design, so we will not use this method.

PLL+DDS PLL frequency synthesizer is mainly composed of two phase locked loops, a step into the fc/R phase locked loop PLL1, and the other by the DDS and mixer loop PLL2. Frequency fc of crystal oscillator input, after r Reference Division get phase frequency of fc/R, VCO1 output frequency after N frequency procedure, and reference frequency discrimination phase. This through the first loop lock, to achieve a big step into the fc/R. The small step is provided by the DDS circuit. The main advantage of this scheme is that the output spectrum has lower phase noise and smaller resolution. But the output frequency of the DDS is small, and the mixer after mixing, a large number of cross fell in the output spectrum of the band, filter is difficult to remove, so that output spectrum of spurious suppression performance variation. When the output spectrum of the wide bandwidth, in order to improve spurious suppression system can be predicted by simulation to make the position of the adjusting component, by selecting the mixer input frequency to adjust the size of the component position, so as to improve the output frequency spectrum purity. The specific implementation of the project as shown in figure:

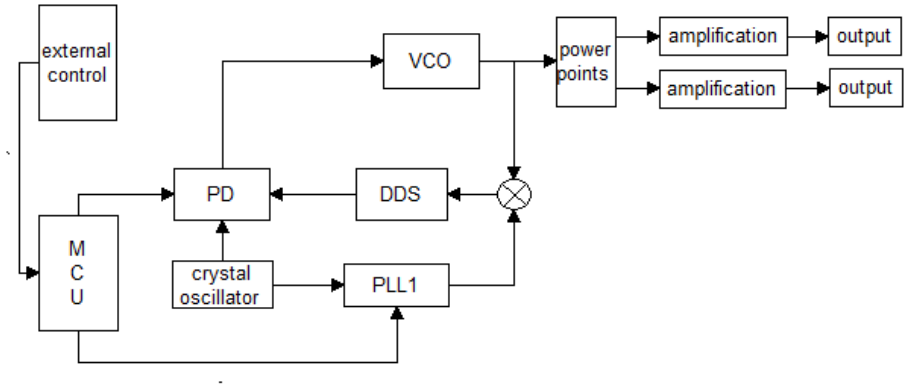

Fig.2 Synthesis scheme of frequency hopping source

4. Based on The DDS Technology of High Speed Frequency Hopping Source Design

The high speed frequency hopping frequency synthesizer based on DDS technology is developed in this project, and the expected target of project research is finally realized. Frequency hopping source mainly adopts the frequency synthesis technology of DDS technology +DS technology and more rapid PIC MCU control circuit, realize 2710~3210MHz 500MHz bandwidth in arbitrary step into a time hopping is less than 3.9us, narrow band spurious suppression is better than-70dbc, phase noise is better than -100 dBc/Hz@ 1kHz. In the scheme, the eighteen frequency doubling circuit is used to improve the phase noise of the output signal to a large extent. Debugging multiplying chain and filter the in band flatness is more complex, also because of the frequency doubling device of reflection, multiplying chain of amplifier is extremely easy to cause self, improve amplifier input output matching is also a focus on the actual experiment. The high speed single chip microcomputer control circuit is applied in the PIC Series MCU, which has the advantages of fast processing speed, simple hardware circuit and easy programming, which can effectively shorten the frequency hopping time of the frequency hopping source. Final system after the debugging effort, high speed frequency source based on DDS reached expected design specifications, so as to further validate the scheme to realize the feasibility of S band high speed frequency hopping source, is the study of frequency hopping source have more profound knowledge background.

The improvement of this project is mainly to eliminate the self excitation of the amplifier in the frequency multiplication chain, and improve the stability of the module. The self excitation of the amplifier makes the system of the stray suppression of frequency hopping source worse. In order to improve this shortcoming, we can insert a circulator at the input end of a frequency doubling device,

making reflection signal of a frequency doubling device into the earth, before and after the amplifier reserved debug amplifier input and output matching position, convenient debugging work late, so as to effectively improve the amplification device of the self. The introduction of double frequency chain is also an increase in power consumption, which can solve this problem. It can improve the module power consumption by selecting the frequency doubling device, reducing the insertion loss of the filter and so on. Will DDS technology and DS combined effectively to improve the module's output signal frequency and the spectral bandwidth, which overcomes the difficulty of the DDS output frequency low, makes full use of the AD9912 spurious suppression system, high resolution advantages. The design process and debugging of the program is simple and convenient, which provides a favorable and reliable design basis for the design of the frequency hopping source.

5. S Band Broadband Frequency Agility Source Rresearch

This system uses the hybrid frequency synthesis technology, combined with the high-speed controller FPGA, to achieve a frequency hopping time of less than 2 us of the low spurious frequency conversion rate. The frequency hopping time, bandwidth, high spurious suppression is the advantage of agility is the main source of frequency hopping. Jump time is mainly determined by the configuration of the AD9912 frequency control word time. The DDS frequency switching time is ideal, according to Datasheet shows that the frequency of AD9912 switching time can reach 10ns. Influence of system frequency switching time and system in microwave switch, the modern high-speed microwave switch switching response time can reach several tens of nanoseconds and if the discussion of time hopping, DDS and its control time overlap, so it can be disregarded. So the frequency conversion time and frequency hopping time of the whole system are decided by the time of the system configuration DDS. In order to solve this problem, we selected FPGA to achieve high speed control of DDS, thus greatly reducing the time spent on the control of DDS. In fact, using AD9912 as the core chip of the DDS circuit, the main consideration is the whole system of stray suppression index. This is the time to change the system to bring worse, but we improve the system through the FPGA frequency hopping time this indicator. The whole system output signal of the suppression of the spurious suppression, and the entire system design is closely related to the design of the system. The DDS output filter, frequency segment filtering, and the mixing way to achieve spectrum shifting, RF signal again segmented to filter these methods are on the whole system of stray suppression of great help.

The improvement of the project is mainly to suppress the leakage of the local oscillator, and a series of signal. For this we can improve the disadvantage by increasing the degree of isolation of the switch. Three phase locked loop brings the space leakage, as well as the volume of the large frequency agile frequency source system needs to be improved. Space leakage can be solved by reasonable electromagnetic compatibility technology, such as reasonable sub cavity, strengthen the shielding. The large size of the vibration source can be taken into consideration. This system design process, the experiment process as well as the system insufficiency has left us the precious experience and is worth to draw lessons from the improvement method.

6. Summary

In order to develop the S band frequency hopping frequency source, this paper makes a detailed study on the problem of frequency synthesizer in frequency synthesizer. A careful analysis of the subject of the indicators, refer to the relevant information, basic theory of PLL and DDS frequency synthesis technology of a simple summary, based on PLL technology to the design of fast frequency hopping synthesizers, based on DDS technology, the design of high speed frequency hopping synthesizer and S-band broadband Jie frequently frequency synthesizer. The research and design of the modern high speed control circuit. Familiar with the modern frequency synthesizer of analysis and design method, and puts forward some design need to pay attention to matters. It is very convenient for the design of future development.; through the design of the project development process is a combination of

frequency synthesis theory, the frequency synthesis theory have further understanding, it also has his own views on this field.

In the frequency hopping frequency source design and debugging of the late, we also found that some areas need to be improved after. Based on PLL fast frequency hopping technology design, due to the simplicity of the hopping frequency synthesizer scheme can by improved scheme to improve system of frequency hopping time and enhance the practicability of this scheme, which simplifies the design of the complex. S-band broadband frequency hopping frequency synthesizer, the agile frequency source synthesis scheme slightly more complex, synthesis of hopping frequency synthesizer is stable, good inhibition stray, hopping time is short, but the structure of the whole system is relatively complex, large amount of control. To improve this, first of all for the complex structure, we modified the synthetic protocol with minor, if the introduction of fast frequency switching time of the vibration signal, remove three phase-locked loop can greatly reduce the system volume.

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