LOW PHASE NOISE BROADBAND MICROWAVE FREQUENCY SYNTHESIZER

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Abstract: It has been discussed in this paper that low phase noise, broadband microwave frequency synthesizer consisted of low noise crystal oscillator, step recovery diode comb generator and switched filter bank. The paper illustrate the synthesizer block diagram and main circuit. The test results and test curve of 2cm band frequency synthesizer have been showed in this paper. The phase noise is about -105dBc at carrier offset 1 KHz in carrier frequency 12 GHz.

1 INTRODUCTIN

It is very important for development of modern radar system that design a high performance radar frequency synthesizer. In order to get target signal from sea clutter, the output spectrum of frequency synthesizer must have low phase noise and low spurious in low angle tracking radar system. It is also required that frequency synthesizer must have broad work band and very fast agile frequency in low angle tracking radar system. The frequency synthesizers can be divided into two types. One is direct synthesizer and another is indirect synthesizer. Direct synthesizer is usually used in agile frequency and high improve factor radar system because its fast agile time , low phase noise and low spurious. The frequency synthesizer discussed in this paper use high performance crystal oscillator and step recovery diode comb generator. A series comb spectrum that generated by step recovery diode comb generator is selected into every single signal by the filter and switch. After frequency upmix and frequency double, we can get low phase noise and broadband output signals of frequency synthesizer. The advantages of frequency synthesizer discussed in this paper are low phase noise and low spurious, broadband and fast agile in frequency.

2 DESIGN OF CIRCUITS

(1) Block Diagram

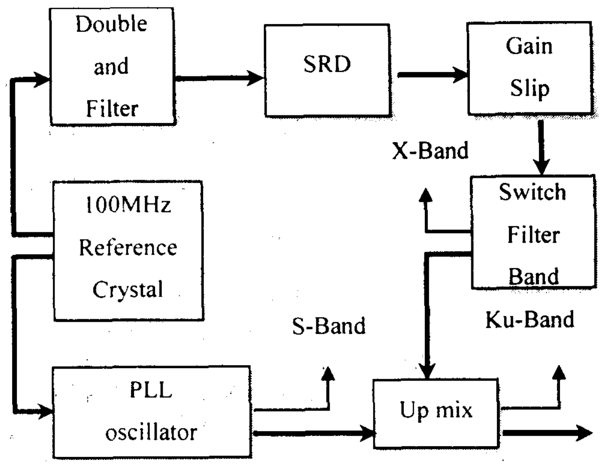

Fig 1

(2) Principle of Main Circuits

A. Reference Crystal Oscillator

In order to make the phase noise of frequency synthesizer less than -100dBc in 2cm frequency band, it is vary important to choose the reference crystal oscillator .To consider the reference frequency, phase noise and technology of crystal oscillator, it is reasonable to choose 100MHz crystal oscillator as reference oscillator. According to the function, the phase noise loss of multiplier is blow:

noise loss = 20lgN

where N is times of multiple

The ideal phase noise loss is 45dB when multiply 100MHz frequency to 2cm frequency band. To ensure the phase noise performance of frequency synthesizer with -100dBc, the phase noise of crystal oscillator that we chosen should be less than -150dBc.

The phase noise performance of reference crystal oscillator is as follows:

0-7803-4308-5/98/ $10.00 1998 IEEE

Carrier Offset(Hz)	10	100	1K	10K
Phase Noise(dBc)	-75	-125	-155	-165

The phase noise performance is achieved by using very high-Q crystal resonators with very small burst noise, a circuit topology that is in inherently low noise. An active device witch maintains good residual noise performance as an amplifier even while limiting, and by paying special attention to oscillator bias supply voltage.

B. Multiplier and amplifier model

a. Diode Bridge Squaring Circuit

100 MHz reference frequency is multiply to 300MHz with a 3X multiplier. The 3X multiplier is a diode bridge squaring circuit. Is is showed in fig 2.

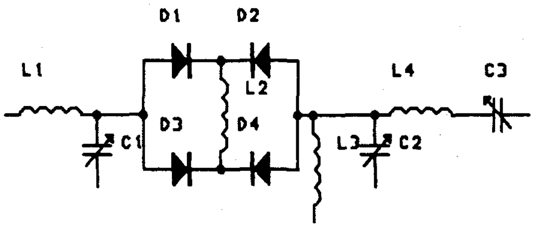

Fig 2

It is based on the harmonic content of a square wave. It theoretical efficiency is as follows:

efficiency (dB) = 20 lg1/N

where N is the desired harmonic

For example, if n=3 then efficiency=-9.5(dB). The 3X multiplier works by first impedance transforming the 100MHz input signal to about 300 ohm. This is done so that the input voltage is large enough to switch the 20V Schottky diodes. The impedance transformer output capacitor is also a low impedance for the desired third harmonic. It is important to note that the current in the inductor across the bridge flows in the same direction in both "+" and "-". Since an inductor will not allow its current flow to change instantaneously, the inductor supplies the voltage necessary to switch the diodes fast. The fast switching of the diodes produces a square wave very rich in odd harmonics.

b. 300 MHz Power Amplifier

The 300 MHz power amplifier is a high gain, high efficiency, class A 1 watt amplifier designed to provide broadband power in low noise power applications. This hybrid amplifier uses silicon bipolar technology and incorporates input/output blocking capacitors, bias network and is matched to 50 ohm. The amplifier's typical residual phase noise performances:

Carrier Offset(Hz)	10	100	1K	10K
Phase Noise(dBc)	-75	-125	-155	-165

c. 300 MHz Bandpass Filter

The 300MHz filter reduces the broadband reference noise down to the thermal noise floor at carrier offsets greater than 12 MHz This is necessary to prevent 30 MHz noise sidebands from being induced on each of the microwave comb line frequencies by the SDR comb generator. The step-recovery-diode (SDR) comb generator has a bias network resonance at 30 MHz which will cause parametric amplification of any 30 MHz sideband energy present on the 300 MHz reference. The filter is a six-section bandpass filter, with a center frequency of 300 MHz, and less than 2dB of insertion loss. The stopband loss relative to loss at center frequency is 40dB minimum from DC to 270MHz and from 330 MHz to 1600 MHz. The VSWR in the passband is 1.3:1 or better, input and output at 300 MHz.

C. Step Recovery Diode (SRD) Comb Generator

The circuit of SRD is in fig 3.

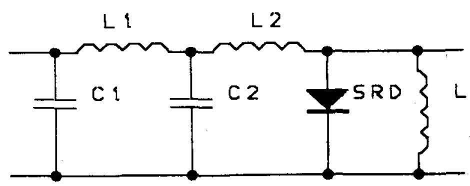

Fig 3

The SRD is a step recovery diode with an input level of +27 dBm to 30 dBm. The comb generator generates voltage impulse with rise time on the order of 65 ps. This fast rise time is rich in harmonic energy. The individual comb frequency power is distributed as a sin X/X function, where X is proportional to the pulse rise time. The usable out put frequency range is

3000 MHz to 12 GHz. The output level is greater than -10 dBm between 8 GHz to 12 GHz bandwidth when the input levels is greater than +27 dBm.

The SRD's typical residual phase noise performance is:

Carrier Offset(Hz)	100	1K	10K	100K
Phase Noise(dBc)	-150	-160	-168	-172

D. Switched Filter Bank

It is necessary to remove unwanted comb frequencies before the desired signal is amplified to prevent amplifier output saturation. The power in all the comb line frequencies together is about +23 dBm to 27 dBm although any individual comb frequency is no more than +3dBm. There are two methods can be used to do this. One is YIG-tuned-filter and another is switched filter bank. The advantages of YIG-tuned-filter is simple in circuit and structure, less in equipment, but its frequency agile time is about 10 ms. It can't satisfy the need of modem radar system.. the switched filter bank is suit for frequency agile radar system. The advantage of switch filter bank is higher frequency agile time and low spurious. The switched filter bank consist of fast microwave switches and high Q resonating filter. there are 7 high Q resonant cavity in every filter. The switcher is SP8T PIN diode switcher. Its switching time is less than 65 ns. The isolation of switcher between two ways is more than 70dB.The switched filter bank performance is as flows.

Frequency Rang	X Band
Insertion loss	<8 dB
Pass band	>20 MHz
Stop band	<150 MHz
Stopband Isolation	>70 dB
Switch Time	<65 ns
VSWR	1.5:1

E. gain sloping network

The amplitude of wave of SRD out is about 10 dB in X band. We can use a gain sloping network to slop the output amplitude of SRD. The basic schematic of a two section gain sloping network is show in fig 4.

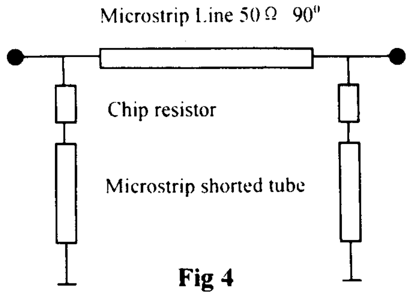

Fig 4

This network is designed to be implemented in line at the 50 ohm input to the stage whose gain slop is being compensated. The first section of the gain sloping network consists of a chip resistor in series with a microstrip shorted stub. The microstrip shorted stub is designed to have an electrical length of 90 degrees at the frequency where the output has lowest amplitude. At this frequency, the short is transformed to an open at the chip resistor. An ideal resistor in series with an open circuit. will dissipate no power, therefore this shunt section will not introduce any attenuation into the overall network at this frequency. As the frequency is changed, the microstrip shorted stub electrical length will change and the chip resistor will be in series with a complex impedance instead of an open circuit. This will allow power to be dissipated in the chip resistor, therefore introducing attenuation into the overall network and decreasing the output amplitude. This has the effect of decreasing the overall gain of the system at the higher gain frequencies.

At the frequencies in which the first section is dissipating power, this first section introduces a mismatch condition to the circuit causing power to be reflected towards the source. To compensate for this mismatch, an identical second section is separated from the network. The second section is added to the net work. This second section is separated from the first section by a 50 ohm microstrip transmission line with an electrical length of 90 degrees at midband. The power reflected from the second section will be 180 degrees phase shifted from the power being reflected from the first section, and it will therefore cancel a significant portion of the reflected power. The value of the chip resistor and the characteristic impedance of the microstrip shorted stub can be optimized to give the desired gain sloping compensation.

3. THE MEURMENT AND TEST

The phase noise and spurious of synthesizer have been tested with HP3048 phase noise test system and HP 8563E spectrum analyzer separately. The performance of phase noise at frequency 12.3 GHz is showed flow:

Carrier Offset(Hz)	100	1K	10K	100K
Phase Noise(dBc)	-82	-106	-117	-119

The curve of phase noise and spurious are showed in fig 5 and fig 6.

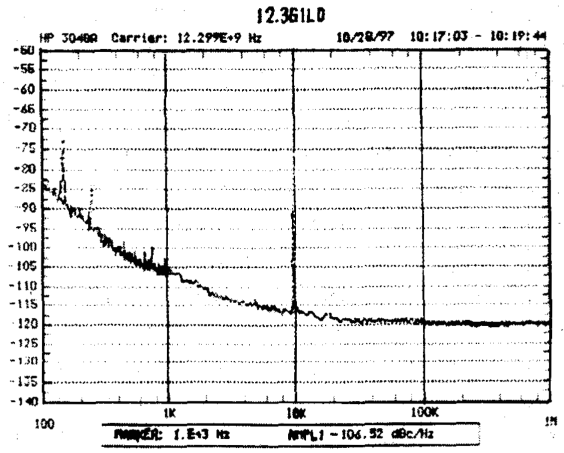

Fig.5

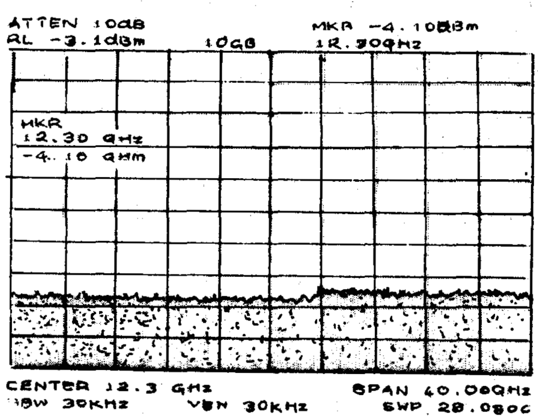

Fig.6

4. CONCLUSIONTED

It has been present in this paper that a microwave frequency synthesizer consisted of low phase noise crystal oscillator, step recover diode comb generator and microwave switched filter bank. The paper discussed the design principle of main circuits. The result of test and measurement illustrate the low phase noise and low spurious performance of this microwave synthesizer. The synthesizer can be used to high improve factor and broadband radar system.

References

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