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Design of C-band Very Low Phase Noise Voltage Controlled Oscillator Based on Optimized Materials

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Abstract
Oscillator is a device that can automatically convert DC energy into periodic alternating energy without additional excitation signal. It is one of the main parts of many electronic systems and is widely used. However, with the continuous development of radar and wireless communication, the system puts forward higher and higher requirements for local oscillator. High current metal ion implantation (HIMI) is a new surface optimization technology for engineering materials, which has been successfully developed by the Institute of Low Energy Physics, Beijing Normal University. According to the existing application and related research of capillary permeable drainage zone, a new type of drainage material at home and abroad, and combined with the current situation that landfill drainage system is prone to blockage, a new application direction of capillary permeable drainage zone for domestic landfill leachate drainage system is proposed for the first time. A comparative indoor simulation experiment was carried out. The development trend and application prospect of these new revolutionary technologies are also analyzed. It proves that they have become the leading industries of high technology and the period of deterioration of productivity has come.

Key words: New Optimized Materials; Microelectronics Technology; Very Low Phase in C Band; Noise Voltage Controlled Oscillator

1. Introduction

With the development of CMOS technology, the production cost of integrated circuits is getting lower and lower, the speed is getting faster and faster, and the integration is getting higher and higher [1]. The entire oscillator circuit can be precisely designed by the computer using the S-parameter of the device. Firstly, the theory of coaxial dielectric resonator and the working principle of series feedback oscillator are analyzed, and then simulated and designed in high frequency electromagnetic simulation software HFSS and ADS [2]. In order to achieve electrical tuning, the varactor is reasonably added to the oscillator, and finally a C-band low phase noise coaxial dielectric voltage controlled oscillator is designed [3]. Device, but it has inherent defects in phase noise compared with iS-based transistors, which forces people to think about whether there is a better alternative [5]. Just after celebrating the 50th anniversary of the invention of transistors, people are facing the opportunity to cross the century. At this historic moment, it is of great significance to predict the development of microelectronics, which is the core technology of modern information society. A new surface optimization treatment technology for materials is to inject metal elements with certain energy, such as Qin, Chromium, Ni, Aluminum, Rare Earth and other elements into the surface of materials, so as to optimize the surface properties of materials. It can simultaneously improve various surface properties of materials, such as friction, wear, oxidation, corrosion and fatigue. It has shown a very attractive application prospect in the fields of metals, fine ceramics and polymers. Based on the existing research and engineering application of capillary permeable drainage belts at home and abroad, the experimental device was designed independently. Taking a new type of drainage material as the research object and combining with the existing structure of landfill drainage system, a new direction of using capillary permeable drainage belt to improve the drainage capacity of landfill leachate drainage system is proposed. The mainstream of microelectronics is naturally the first generation of Si semiconductor materials. Microelectronics industry is a basic industry, and microelectronics technology is the core technology of high-tech and information industry. Microelectronics technology has a strong penetration and rapid development. When combined with other disciplines, it will produce a series of new disciplines and major economic growth points, making great contributions to the development of science and technology and national economy. At higher frequencies, transistors biased to negative resistance operating points and cavity, transmission line or dielectric resonators are used to generate fundamental frequency signals up to 100 GHz [6]. With the continuous development of radar and wireless communication industry, the system has put forward higher and higher requirements for the performance of local oscillator. Seeking for low phase noise and high stability of local oscillator has become the main development trend.

Frequency source is the key of radar, communication, electronic countermeasures and other electronic systems to achieve high performance. Many modern electronic devices and system functions are directly dependent on the performance of the frequency source [7]. With the development of semiconductor technology,

a kind of SiGe transistor developed in recent years can be considered as an active device of C-band oscillator [8]. It is found that the permeability coefficient of the gravel layer is much larger than that of the capillary permeable drainage zone by the experiment of the drainage performance of the new material. Therefore, in the experiment of adding or not adding capillary permeable drainage zone (drainage only through gravel layer), the effluent is very fast, basically achieving the effect of effluent equaling effluent. At present, this new material surface optimization technology has achieved remarkable results in the practical application of related industries. For example, in the application of high-speed steel metal cutting tools, the service life is prolonged by 3 to 20 times, and in the hot extrusion die of high-strength aluminium alloy profiles, the service life is prolonged by 3 times. Surface optimization effect of doubling and reducing extrusion force by 10% to 20%. The surface optimization effect of reducing energy consumption by more than 25% and improving wear resistance and prolonging service life has been achieved in the application of the pumping pump of the returnable satellite remote sensor and the military directional instrument. This circuit is a breakthrough in sinusoidal signal generation technology. It has a wider frequency range than before. It can change the frequency simply by changing the inductance or capacitance of the coil [9]. C-band is one of the main frequency bands of digital communication system, so it is very important to research and design low-phase noise oscillators working in C-band [10-12]. However, the lower supply voltage severely limits the output voltage swing of the VCO, which in turn degrades the phase noise [13]. With the rapid development of modern production and human civilization, many demands are the fundamental driving force for the emergence and development of new technology. The great achievements in the development of modern natural science have laid a theoretical foundation for the birth of new technologies. Another important factor that stimulates the emergence and development of new technologies is war and confrontation. Nowadays, all fields of society are inseparable from new technologies such as microelectronics, computer, communication and information, intelligent control and so on. Electronic technology is the foundation and pillar of these new technologies. The impact of the new technological revolution on human beings is not only economic, but also political, military, family and social life. The low noise amplifier and the power amplifier amplify the signal [14] when receiving and transmitting, respectively. Breaking the low voltage limit replaces the typical VCO' s tail current source with an inductor. This technique provides a way to improve phase noise by increasing the output voltage swing. In practical applications, dielectric resonators are generally classified into two types: cylindrical and coaxial dielectric resonators. For C-band to millimeter-wavelength oscillators, cylindrical dielectric resonators are generally used [15]. In the L to C band, since the volume of the cylindrical dielectric resonator is too large, a coaxial dielectric resonator is more used as a frequency stabilizing element of the low phase noise oscillator [16].

As an integral part of the dielectric oscillator, the cylindrical dielectric resonator needs to be adhered to the dielectric substrate with an adhesive, which brings hidden troubles to the stable operation of the dielectric oscillator [17]. The voltage controlled oscillator VCO is an indispensable component in the phase-locked loop circuit, and the demand for miniaturized VCOs operating at low voltages is increasing. Two bandpass filters in the receive and transmit paths are used to filter out signals outside the bandwidth [18-20]. Nanometer solid materials (nanometersizedmateria-s) have excellent properties which are not available in general crystalline materials and amorphous materials. The appearance of nanometersizedmateria-s has challenged the theory of condensed matter physics. Several developed countries in the world have invested a lot of efforts in the basic theoretical research and applied research of this material, which will play an important role in the scientific progress of the 21st century. With the development of science and technology and the demand of industry for materials, the progress of material science and technology has been very rapid in recent years. According to the book Material Science and Engineering in the 1990s published recently in the United States, the specific strength of materials has been greatly increased due to the emergence of composite materials, and the increase of working temperature of materials has greatly promoted the development of thermodynamic machinery. Due to changes in the external working environment, the dielectric resonator may fall off and the oscillator may be stopped, resulting in system failure [21]. Oscillator circuits became popular in transmitters and were soon used in World War I. With the size breaking through 0.1 micron, which was considered the physical limit 10 years ago, experts now predict that single-atom storage technology in nanoelectronics will be realized in 2010-2020. Along with nanoelectronics, silicon-based micro-electromechanical systems (MEMS) are considered as revolutionary new technologies in the 21st century, which will have a far-reaching impact on science and technology, production methods and human quality of life in the 21st century. This is the beginning of a new life for the first generation of semiconductor materials. At this time, both transmitter and receiver adopt this new oscillator circuit based on vacuum tube, which has a far-reaching impact on the innovation of oscillator circuit [22-24]. Microwave frequency source is a very important component in microwave system. Its stability directly affects the performance of the whole system. For example, as the local oscillator of radar receiver, it requires not only good long-term stability, but also good short-term stability, namely phase noise [25]. The dielectric resonator can improve the quality factor of the circuit, so as to improve the phase noise of the circuit. LCVCO can realize bandwidth output of the signal in the high frequency band. This paper proposes a series feedback connection scheme between dielectric resonator and LCVCO circuit,they complement each other.

2. Methodology

VCO can also be used in clock and data recovery unit circuits for high-speed data transmission. However, the disadvantage is that all VCO structures need additional inductance LS besides the resonant inductance LTANK of LC resonant circuit. LS increases the area of circuit chip and increases the cost of circuit fabrication. The coaxial dielectric resonator is directly welded in the circuit board, and its reliability and stability have been greatly improved. Microelectronics is a new technology developed with the development of integrated circuits, especially VLSI. Microelectronics technology includes a series of special technologies, such as system circuit design, device physics, process technology, material preparation, automatic testing, packaging and assembly. Microelectronics technology is the sum of all process technologies in microelectronics. Microelectronics technology is a high-tech electronic technology based on various semiconductor devices with integrated circuits as the core. The quality of traditional materials and labor productivity are constantly improving. For example, the reduction of impurity content and the adoption of controlled rolling process can obviously improve the properties of steel. With the introduction of new technology, new technology and new process, the productivity of Dian Hour Steel per worker has increased six times than in the 1920s, and the organic macromolecule and inorganic non-metallic materials are more prominent. The former has been growing at a rate of more than 10 pieces in the past 20 years. At present, the volume of organic macromolecule materials has exceeded that of steel. Ceramic materials are facing breakthroughs and have become the focus of modern scientific research. It is characterized by small size, light weight, high reliability and fast working speed. Microelectronics technology has a tremendous impact on the information age. Nowadays, the research trend in the industry is to use coaxial dielectric VCO combined with frequency doubling technology to gradually replace the C-band or even higher-band cylindrical dielectric oscillator. That is, in the general phase-locked loop design, the low phase noise characteristics of the crystal oscillator are not fully utilized and exerted. With the advancement of radio technology, many innovations have been made in the oscillating circuit technology. Engineers invented countless coils, variable capacitors, feedback techniques, and vacuum tubes to implement oscillators and frequency conversion circuits. For this reason, it is necessary to design a high-performance frequency source to meet its technical performance requirements.

Firstly, this paper will analyze the effect of varactor, capacitance and inductance in LC VCO on circuit performance. As shown in Figure 1, the capacitance of varactor diodes decreases with the increase of bias voltage.

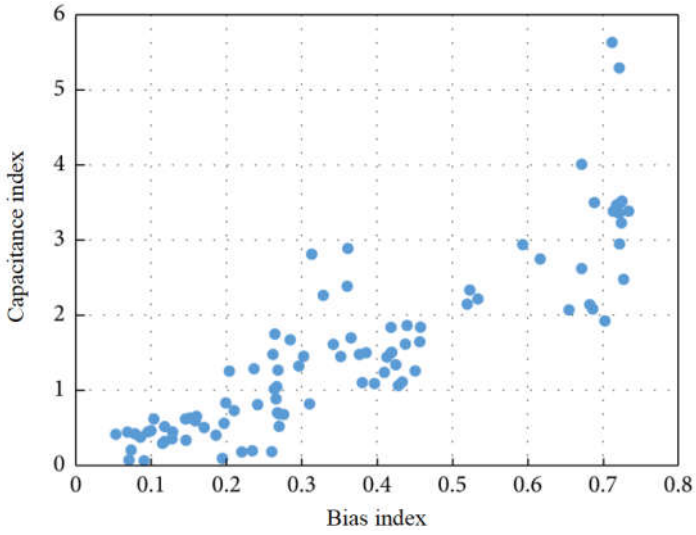

Figure 1. Effect of Bias Voltage on the Performance of Cumulative MOS Varistors

The characteristics of four kinds of junction varactor are shown in Table 1. It can be seen that the varactor with P+/N well structure has the best performance.

Table 1. Summary of the Characteristics of Four PN Junction Varistors

PN Junction Varactor Type	Most Carriers	Port constraint	Quality factor
P+/N well	Electronics	Nothing	Optimum
N+/P sub	Hole	Anode grounding	Secondary
N+/P well	Hole	Nothing	Secondary
N well/P sub	Electrons/Holes	Anode grounding	Worst

The quality factor of inductance is defined from the bandwidth of the circuit and the frequency stability of the oscillator with a simplified tunable filter as examples (1), pp. (2), pp.

$$\psi\left(x,t\right)=0 \tag{1}$$

$$T\dot{\psi}+\psi=0 \tag{2}$$

Substrate shielding technology is to insert a grounded low barrier layer between inductor and substrate, which separates inductor from substrate, thus reducing the loss of substrate. When there is no ground shield layer, the loss in the substrate is as follows:

$$P_{ac}=G_i\left(a_1+a_2G_i+a_3\log\left(G_i\right)\right)\left(1+a_4\left(\Delta T\right)\right) \tag{3}$$

When the grounding shielding layer technology is adopted, the corresponding loss becomes as follows:

$$r=\frac{ac^3u^2 2}{2fe^2} \tag{4}$$

Quality factor is a parameter to measure the performance of devices from the angle of energy storage and energy consumption. The most common definition is:

$$J=J_0\left(\exp\left(\frac{q\left(V-R_sJ\right)}{nk_BT}\right)-1\right)+\frac{V-R_sJ}{R_{sh}}-J_{ph} \tag{5}$$

When the varactor operates far from its resonant frequency, the energy is almost stored in the capacitor, while the energy stored in the parasitic inductance can be neglected, so the above formula can be equivalent to:

$$r_c=y_cG_c=\frac{\Delta x}{\Delta y}G_c=\frac{u_{cm}\left(x\right)-u_{cs}\left(x\right)}{t_c}\cdot G_c \tag{6}$$

If the capacitance of the varactor is I and the voltage amplitude at both ends is U, the maximum energy stored by the varactor is:

$$I=I_{PV}-\sum_{i=1}^{2}I_{0i}\left[\exp\left(\frac{U+IR_s}{a_iV_{Ti}}\right)-1\right]-\left(\frac{U+IR_s}{R_{sh}}\right) \tag{7}$$

As the core part of microwave frequency source, microwave oscillator plays an important role. Many exquisite and elegant design schemes can tune the oscillator frequency accurately and qualitatively through the mechanical dial outside the wireless device. In general phase-locked loop circuit design, the output signal of crystal oscillator is often used directly as the reference of phase-locked loop. The use of electronic devices has promoted the development of electronic technology. The era of microelectronics began with the development of VLSI in 1978. Microelectronics technology refers to the fabrication of more than 100,000 transistors on several mm2 semiconductor materials and the assembly of these circuits into various microelectronic devices. In recent years, the broad sense of microelectronics technology refers to integrated circuits and their applications and products. The new technology saves materials, energy, space and labor, and has the characteristics of high efficiency and less environmental pollution. Because of its high stability and high purity, the normalized phase noise of crystal oscillator is much better than the normalized noise base of phase discriminator, so the influence of crystal oscillator is often neglected when calculating the phase noise of PLL output signal. In order to introduce a dielectric resonator into a microwave integrated circuit to perform its functions, there are two methods generally used in engineering: one is to add a dielectric resonator to a known oscillator to stabilize the frequency. The other is to use a dielectric resonator as part of the oscillator design to form the oscillator's pre-set frequency components. Because of the insurmountable shortcomings of single material, such as brittleness of ceramics and low modulus of organic materials, if different materials are compounded, new materials with better properties than the original components can often be obtained. Therefore, it has become an important trend in the development of structural materials. In fact, the development of composite materials is very early, such as the first generation of composite materials FRP, the second generation of carbon fiber reinforced resin matrix composites and so on. Ceramics, metal-based and carbon-carbon composites are currently being developed. Ceramic matrix is for toughening; metal matrix is for strengthening and increasing stiffness. Carbon-based materials are designed to quench and heat without bursting. In order to reduce the directional column, the

multi-direction braiding of fibers is adopted. Microelectronics technology can produce microelectronic structure modules with high reliability and accuracy at low cost and in large quantities. The development of microelectronics technology has brought great changes to people's production and life. Typical examples of successful integration with microelectronics are micro-electronics and biochips. The micro-electro-mechanical system makes the product small in size, less energy consumption and flexible in movement. Biochip is the combination of microelectronics and Bioengineering technology. Scientists have been discussing the possibility of implanting microchip memory circuits into everyone's brain to treat Alzheimer's disease, or to increase people's memory. Integrated circuit chips made of microelectronics technology have developed into GSI era. The most typical are memory and processor, which are widely used. The replacement of computers depends on the scale of integrated circuits. The best way to achieve low phase noise is to select a low-noise device that operates at low currents and high voltages and adds power to achieve the required output power. However, due to the inherent limitations of the process, there are some difficulties in implementing the process implementation circuit. The final oscillating circuit still needs manual adjustment to achieve the required technical performance. The oscillator circuit board and the substrate are integrally soldered with solder, the DC circuit board is fastened with the dowel and the bottom plate, and the low frequency component is potted with silicone rubber. All fasteners are tightened with a fixed torque.

The variation of the quality factor of the varactor diode with the frequency is shown in Figure 2. It can be seen that the quality factor reaches the maximum value at 5.5GHz-6GHz, which is also the working frequency range of VCO. It can be seen that the quality factor of varactor diode is much smaller than that of dielectric resonator.

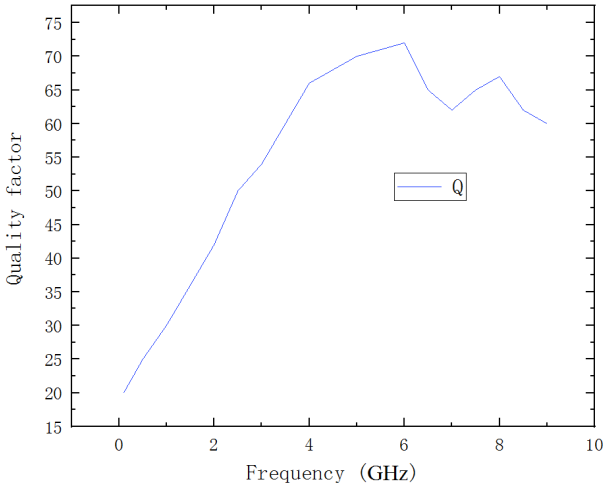

Figure 2. Effect of operating frequency on quality factors of PN junction varactor

In the process, the inductance in the LCVCO circuit is much larger than the capacitance, so the loss in the circuit mainly depends on the loss of the integrated inductance. The basic guidelines for low power optimization design are shown in Table 1.

Table 1. LC VCO Low Power Optimum Design Principle

Parameter	Trend	Limit
L	Maximization	Chip Area, Coordination Scope, Manufacturing
C	Minimize	Tuning Range, Manufacturing
R	Minimize	Metal
Range	Minimize	Phase Noise and Circuit Structure

The basic guidelines for optimum design of low phase noise are shown in Table 2.

Table 2. Optimum Design Principle of LC VCO with Low Phase Noise

Parameter	Trend	Limit
L	Maximization	Chip area, tuning range, fabrication
C	Minimize	Coordination Scope, Manufacturing
R	Minimize	Metal
Range	Maximization	Work Number, Reliability

Based on the previous analysis, a general approach to designing low power, low phase noise LC VCOs is presented, summarized in Table 3.

Table 3. Design strategy for low power, low phase noise LC VCO

Parameter	Low power consumption	Low phase noise
Ls/Rs	Maximize	Maximize
Ls/C	Maximize	Maximize
Amplitude	Minimize	Maximize

3. Result Analysis and Discussion

In this paper, the tuning voltage and output frequency range of VCO are obtained through simulation and experiment. 0-0.5v is selected as the tuning voltage range, and the output signal voltage amplitude is increased by increasing the supply voltage, so as to determine the supply voltage VDD of the circuit. The phase noise of VCO is greatly improved by adding dielectric resonator and increasing output voltage swing. With the development of integrated circuits. The key problem in composite materials is the interface matching between different materials. Because of the difference of modulus between matrix and hardening component, when deformation occurs, they will separate from each other because of the different strain, and because of the different expansion coefficient, they will also separate from each other because of the change of temperature. So we have to use the intermediate transition layer to improve it. At present, there is a lot of research work in this area. Another problem with composites is their use at high temperatures. The strengthening effect is invalid due to the diffusion between matrix and strengthening component. Composite materials as structural parts, there is also a welding or joining problem. From the material point of view, besides silicon semiconductor, compound semiconductor, such as GaAs, has been paid more and more attention, because its operation speed is several times faster than silicon. More importantly, it has optoelectronic effect, which makes it possible for different functions of information generation, processing, detection and storage to be accomplished on the same integrated circuit. In addition, the combination of Optics and microelectronics has become an optoelectronic technology, known as the cutting edge of the cutting edge, for the further development of microelectronics technology. Microelectronics technology is also widely used in military communications, fire control, intelligence reconnaissance, pre-detection and electronic warfare. It has made the appearance and performance of weapon equipment change qualitatively. It is also the foundation and core technology of realizing the informatization of weapon equipment nowadays. It is also an important driving force for the renewal of weapon equipment. At present, domestic digital TV is divided into standard definition and high definition. The resolution of standard definition is 720 *576 pixels, while the resolution of high definition can reach 1920 *1080 pixels. The core technology and the whole market of digital high-definition video chips in China have been monopolized by European and American enterprises for a long time.

Figure 3 shows the test results of the oscillation frequency of the VCO as a function of the tuning voltage. When the VCO without dielectric resonator, the oscillation frequency is 5.7 to 6.3 GHz when the tuning voltage changes from 0V to 0.5V,while the VCO frequency tuning range with dielectric resonator is 5.9GHz-6.1GHz.This is because the dielectric resonator has a high quality factor, and energy is concentrated in the dielectric resonator when the circuit works, so the output frequency range of VCO becomes narrow.

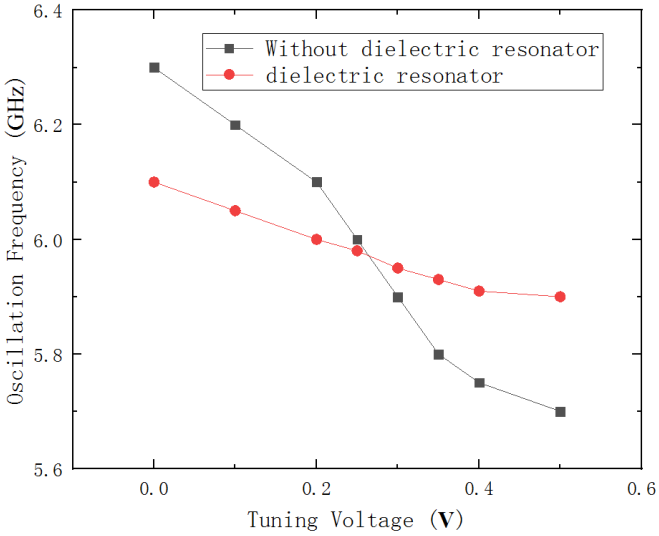

Figure 3. VCO phase noise test results

It can be seen from Figure 4 that the voltage output amplitude of VCO can be improved by increasing the supply voltage, so as to improve its phase noise. However, excessive supply voltage will also increase the power consumption of the circuit. Therefore, the supply voltage of the circuit designed in this paper is 1V.

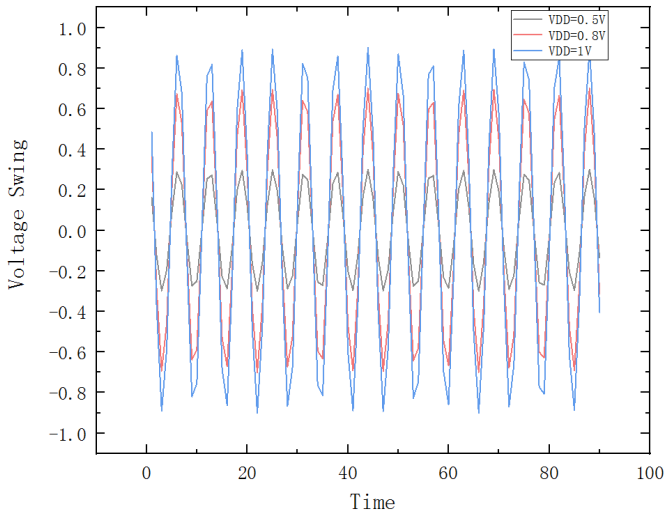

Figure 4. VCO output voltage swing under different supply voltage

The experimental result of LC VCO phase noise is examined, as shown in Table 4. It can be seen that the effect of output voltage swing on phase noise of VCO circuit. The phase noise of the circuit is greatly improved by adding dielectric resonator.

Table 4. Experimental result of LC VCO phase noise

Phase noise and Supply voltage	Output frequency=6GHz		
	(dBc/Hz@1MHz)	(dBc/Hz@100kHz)	(dBc/Hz@100Hz)
VDD=1V	-134.7~-136.4	-121.9~-126.1	-115.6~-119.4
VDD=0.8V	-128.3~-130.6	-117.6~-121.5	-109.3~-113.6
VDD=0.5V	-115.5~-124.5	-108.2~-113.7	-98.9~-102.2

4. Conclusions

The VCO designed in this paper can achieve 5.9GHz-6.1GHz tuning bandwidth in C band. At 6GHz, the lowest phase noise of the circuit is-134.7~-136.4 dBc/Hz@1MHz.At this time, the supply voltage is 1V. This paper realizes the design of local oscillator circuit with low phase noise, low power consumption and wide bandwidth. Thus, it can be seen that selecting the appropriate supply voltage of VCO circuit, maximizing the output voltage swing, and combining the dielectric resonator with high quality factor can obtain satisfactory phase noise. Microelectronics technology is one of the most typical products that can embody the characteristics of knowledge economy in the world today. Strictly speaking, many kinds of materials belong to non-equilibrium material, steel is one of them. The non-equilibrium materials referred to here are more unstable materials with special properties, such as supersaturated solid solution or amorphous state, which are formed under special conditions, such as rapid cooling, ion implantation and so on. The stability and brittleness of oxide superconducting materials are more difficult to solve, and more efforts are needed. At the same time, the possibility of room temperature superconductors should be explored, because working at liquid nitrogen temperature is inconvenient and expensive. Thin film high temperature superconducting materials have recently reached the stage of application because their current density has reached 10^6A/cm^2, and the brittleness of materials will not be an obstacle to application in such small parts. Many countries attach great importance to the development of microelectronics technology. Japan has put it at the height of electronic statehood. The United States regards microelectronics as its strategic industry. Thus, microelectronics technology is the core competitiveness of today's information society and era. New technologies such as computer, communication and information, bioelectronics, intelligence and control based on microelectronics technology are unparalleled in the past. They can be said to be a worldwide and all-round new technological revolution. It has infiltrated into people's life and all production activities, and has become the main pillar of modern production and life, and the leading role of high-tech industries. It has radically changed people's life and work, and the period of qualitative change in productivity has come. In this paper, the dielectric resonator and LCVCO are connected in series

feedback mode. Dielectric resonator can make the LC VCO do not add additional inductance, reduce its power consumption, and high quality factor can achieve lower phase noise.

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