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Novel Ka-band low-noise down-converter assembly

Li Ming Li Xingguo

(Institute of Near-Sensing Technology with Millimeter-Wave and Optical-Wave,
Nanjing University of Science and Technology, Nanjing 210094, China)

Abstract: An efficient way to design a down-converter assembly for the Ka-band millimeter system is presented, in which dielectric resonators (DR's) are adopted in the Schottky barrier diode image recovery mixer and the local oscillator (LO). DR structures guarantee high frequency stability with an acceptable volume. The configurations of low noise amplifier, mixer and oscillator in the assembly are described and fabricated to estimate the chain performance. According to the verification results, the assembly exhibits the noise figure of less than 5 dB over 1 GHz frequency range, and the single-sideband phase noise (200 kHz offset from carrier frequency) of -70 dBc/Hz. Utilizing the DR structure, the frequency stability of the local oscillator is less than 60×10^{-6}/℃.

Key words: down-converter; dielectric resonator; noise figure; conversion loss

While the integration trend of microwave circuits extends to higher frequency, millimeter-wave circuits still adopt cavity technology. As a simple exemplification, the cavity millimeter-wave oscillator has high frequency stability, but its volume cannot be accepted in sensors. Although the integrated fin-line or microstrip mm-wave oscillator has suitable size, its frequency stability cannot satisfy the requirements if no stabilized frequency approach has been adopted.

Being an important microwave subsystem, the down-converter assembly, including the local oscillator (LO) and mixer, should be of rather small size and possess proper performance to meet the requirements for military purposes[1].

With the dielectric resonator applying at Ka-band frequency, it becomes a comprehensive consideration. In this paper, a compact converter with a dielectric resonator is developed. The main features in this assembly are as follows[2]:

1) Using a GaAs MMIC to design a 35 GHz low-noise amplifier in order to reduce the entire noise figure and achieve the required RF power level.

2) Adopting a mixer with a Schottky barrier mixer diode and a dielectric resonator. Considering a proper structure, reasonable noise figure and conversion loss are easily achieved.

3) Proposing a high-stabilized Ka-band oscillator with a dielectric resonator. It is stabilized by a DR to obtain greater frequency stability. The oscillator supplies several adjustable portions to adjust and optimize the oscillator frequency and power level.

Combining the above parts, the assembly can maintain a proper performance. The noise figure is less than 5 dB over the interested frequency range.

1 Configurations

The Ka-band low-noise down-converter assembly includes a low noise amplifier, local oscillator and mixer. The assembly is fed with an RF input of 34.8 to 35.6 GHz, thus generating an IF output of 200 to 400 MHz. The frequency of the local oscillator is 35.2 GHz.

In the system, the waveguide-to-MIC transition adopts an E-field probe structure, which is presented in Fig. 1(a). In the structure, a and c are the diameter and length of the probe connected with the microstrip line, respectively; b and d are the diameter and length of the probe inserted into the wave-guide, respectively; h is the distance between the probe and the wall of the

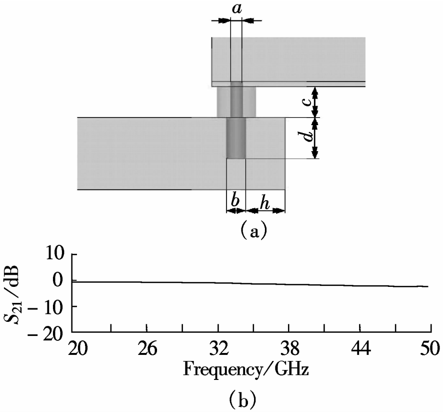

Fig. 1 Waveguide-to-MIC transition. (a) Schematic diagram; (b) S_{21} parameter

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Biographies: Li Ming (1979—), male, graduate; Li Xingguo (corresponding author), male, professor, njngguol@jlonline.com.

wave-guide. Applying the transition, Fig. 1 (b) shows that the insertion loss of a back-to-back cavity is about 1 dB. It means that the insertion loss of a single transition is about 0. 5 dB.

1. 1 Low noise amplifier

To be low cost and low noise, the chosen device is a GaAs MMIC LNA (HMC 263, Hittite). Its typical applicable frequency range is 24 to 36 GHz. Considering the feasibility and the possible parasitic susceptances, the MMIC in chip form is chosen[3].

Three 100 pF bypass capacitors are placed 0. 5 mm from the chip and the bonding wires adopt a 0. 076 mm × 0. 013 mm diameter ribbon bond, which is shown in Fig. 2(a).

The measured S_{21} parameter is presented in Fig. 2 (b), in which the flatness of the gain is satisfactory in the range of 34. 8 to 35. 7 GHz. The test results of the LNA present a gain of 13 dB and a noise figure of 2 dB at around 35 GHz.

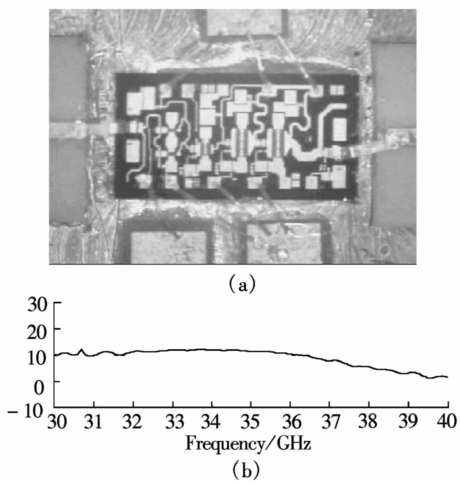

Fig. 2 LNA chip. (a) Bonding structure; (b) S_{21} parameter

1. 2 Mixer

An image frequency recovery mixer with DR configuration is adopted, in which DR's are close to the diodes[4-5]. The Ka-band image frequency recovery mixer with DR's is shown in Fig. 3.

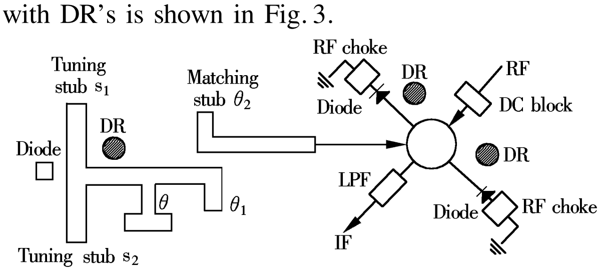

Fig. 3 Layout of mixer-LO assembly

The key point is that the distance between the center of DR and diode should be 1/2 wavelength in order to obtain the maximum output power level. Meanwhile, the certain distance l between DR and the closer microstrip line must be constant in order to obtain the expected attenuation value at the image frequency. In the design, the distance l is set as 0. 5 mm[6].

In the verification, the input signal is 35. 6 GHz, the local oscillator frequency 35. 2 GHz, and the image frequency 34. 8 GHz; consequentially, the output IF signal is 400 MHz.

The conversion loss and noise figure of the mixer are presented in Fig. 4. The conversion loss is about −5 dB, and the noise figure is about −4. 8 dB.

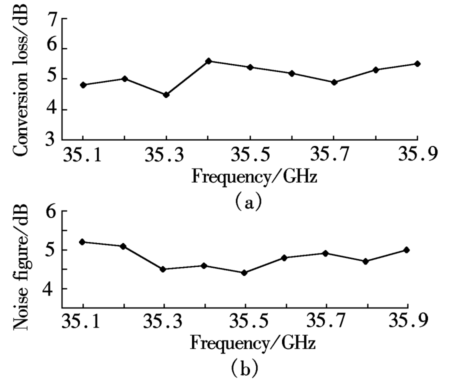

Fig. 4 Conversion loss and noise figure of mixer. (a) Conversion loss; (b) Noise figure

Meanwhile, in Fig. 5, around wanted frequency (offset frequency 1 GHz), the isolation between LO-RF is about 20 dB. Fig. 6 presents the spurious at IF resulting from the RF input at image frequency, the power level is −20 dBm (In the case, the power level of RF input is 0 dBm).

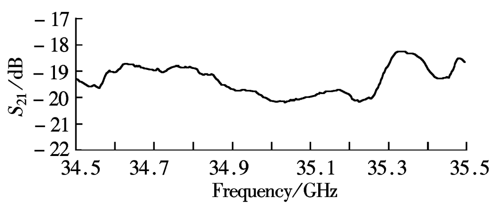

Fig. 5 LO-RF isolation

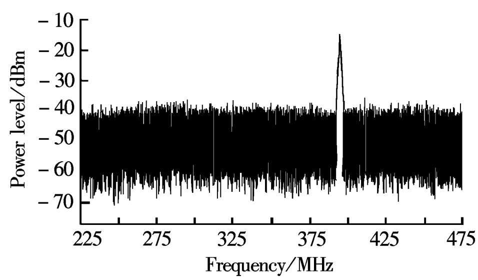

Fig. 6 IF resulting from image frequency (VBW, RBW = 100 kHz)

1. 3 Local oscillator

The local oscillator requires high frequency stability and low phase noise[3]. The configuration of the LO is also shown in Fig. 3. The DRO circuit is designed to stress specifically mounting DR structure to realize a high Q factor[7-8].

It is desirable to separate the two processes of tuning (adjustment of signal frequency) and matching (adjustment of the impedance presented by the circuit to the microwave diode).

The tuning network, generally consisting of two open-ended stubs, provides a reactive impedance component across the diode terminals. Adjustment of this reactive component, by trimming off the stub lengths, serves to adjust the frequency of the signal: the oscillation occurs at the frequency at which the susceptances of the diode and that of the outside circuit just cancel each other out[9].

The remaining real part of the generator impedance is different from that of the line impedance, chosen at the value of 50 Ω. Then, a certain transformer is necessary to connect the generator with the load. The reactively terminated coupled line here behaves as an adjustable transformer, which can be adjusted by modifying the electrical length of the matching stub.

The diode is located at the T-junction, fitting in a hole drilled through the substrate between the upper conductor and the ground plane. The lengths of the two open-ended stubs s_1 and s_2 are adjusted for oscillation at the design frequency of 35.2 GHz.

A half-wavelength section of line between the diode and the coupler input severs to avoid interference between the stubs. The length of stub θ_2 is adjusted for appropriate output power[10].

As shown in Fig. 7(a), the output power level of the oscillator is 5 dBm. The frequency stability of LO is less than $60 \times 10^{-6}/℃$.

Fig. 7(b) presents the phase noise of −70 dBc/Hz at 200 kHz offset from the carrier frequency. Some spuriousness is observed, but the levels are rather low, which will not overly influence the performance.

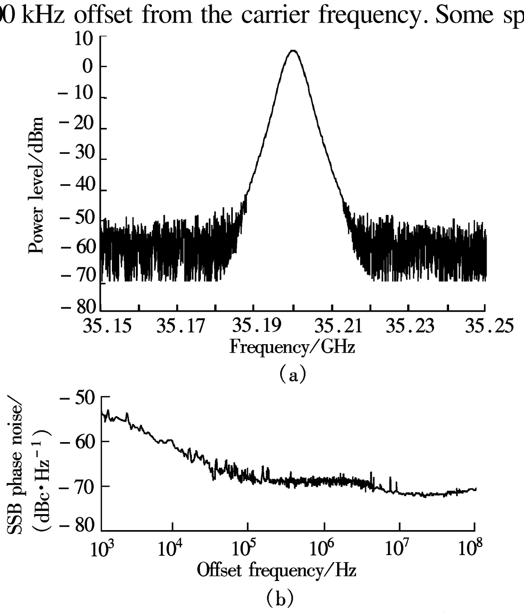

Fig. 7 Frequency spectrum and phase noise of LO. (a) Frequency spectrum (VBW, RBW = 3 MHz); (b) Phase noise

2 Assembly

Combining the above validated parts, the entire down-converter is assembled. After verification and calibration, a conversion loss of less than −5 dB is obtained, shown in Fig. 8.

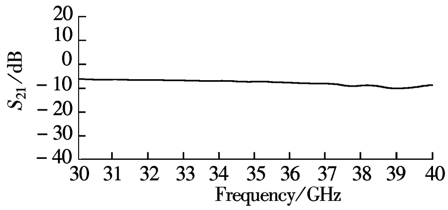

Fig. 8 Conversion loss of down-converter

3 Conclusion

A down-converter assembly at Ka-band is developed using the MIC technology replacing the cavity structure. As a result, a novel mixer with DR's achieves rather low noise figure and conversion loss. A local oscillator with DR's obtains low frequency drift and low phase noise. The converter assembly can be used in the ongoing research of a millimeter-wave sensor.

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一种 Ka 波段低噪声下变频器组件

李 鸣 李兴国

(南京理工大学毫米波光波近感技术研究所,南京 210094)

摘要:介绍了一种用于毫米波系统的下变频器,其中混频器采用了肖特基二极管镜频回收混频结构,振荡器采用了 DRO(dielectric resonator oscillator)结构以提高系统性能,以保证在合适的体积内实现较高的频率稳定度.描述了系统中低噪声放大器、混频器、振荡器的性能,用于评估系统链路性能,最后合并制作在单个基片上.根据测试结果,该下变频器的噪声系数在 35 GHz 处 1 GHz 频率范围内小于 5 dB,单边带相位噪声系数在偏离载波 200 kHz 处达到 -70 dBc/Hz.由于采用了介质谐振结构,本振的频率稳定度小于 60×10^{-6}/℃.

关键词:下混频器;介质谐振器;噪声系数;变频损耗

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