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# Design of a 212 GHz LO Source Used in the Terahertz Radiometer Front-End

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**Abstract**—We introduce a 212 GHz LO source which could be used to drive sub-harmonic mixer in the radiometer front-end. It mainly includes a phase-locked dielectric resonator, a 71 GHz power source and a 212 GHz tripler. Actually, design of 212 GHz tripler is the key technology in the LO chain because the research on W band source is relatively mature. Based on our former research work, there is a great improvement in the design of 212 GHz tripler. At room temperature, the measured efficiency is more than 9% in 208 $\sim$ 218 GHz, and the maximum efficiency is about 14.5% at 215.5 GHz when being driven with 21.8 dBm of input power. Besides demand on the main technical specifications, the stability of each module is also extremely important since the front-end is designed to keep working for three months.

## 1. INTRODUCTION

In recent years, passive remote sensing technology at terahertz frequencies plays a key role in the global numerical weather prediction and climatology. Several radiometer systems have been launched on satellites such as the Ice Cloud Imager (ICI) onboard MetOp-SG, which provides a total number of 13 channels to exploit the ice clouds, covering the frequency range 183 GHz to 664 GHz [1–3].

In the terahertz receiver front-end, the antenna is followed by a mixer directly for lack of the terahertz low noise amplifier (LNA). Hence, the noise of the receiver is mainly decided by the mixer. Meanwhile, the LO source provides sufficient power to ensure the mixer work normally. A 424 GHz radiometer is designed by our research group, and the composition block diagram is shown in Fig. 1. In general, the system consists of horn, RF front-end, IF module (includes LNA and filter) and LF module (includes square-law detection, filter and integrator).

This paper will introduce the LO source used in the RF front-end. Furthermore, it is made up of three parts: phase-locked dielectric resonator (PLDRO), 71 GHz power source (includes a sextupler and a power amplifier) and 212 GHz tripler. The details of above-mentioned modules will be discussed in the following parts.

## 2. GENERAL SCHEME

Local oscillator source used in the terahertz receiver is based on cascaded frequency multipliers, which consists of a 212 GHz tripler fed by a sextupler as shown in Fig. 2. Actually, the reason of choosing a tripler as the last stage of the chain rather than a doubler is that W-band commercial chip is relatively mature. The sextupler employs commercially available GaAs MMIC chip fabricated by UMS Company, and the power amplifier uses the MMIC chip fabricated by Hittite Microwave Corporation, which converts 11.78 GHz signal to 70.68 GHz. Moreover, the PLDRO produces 11.78 GHz signal with low phase noise and low spurs.

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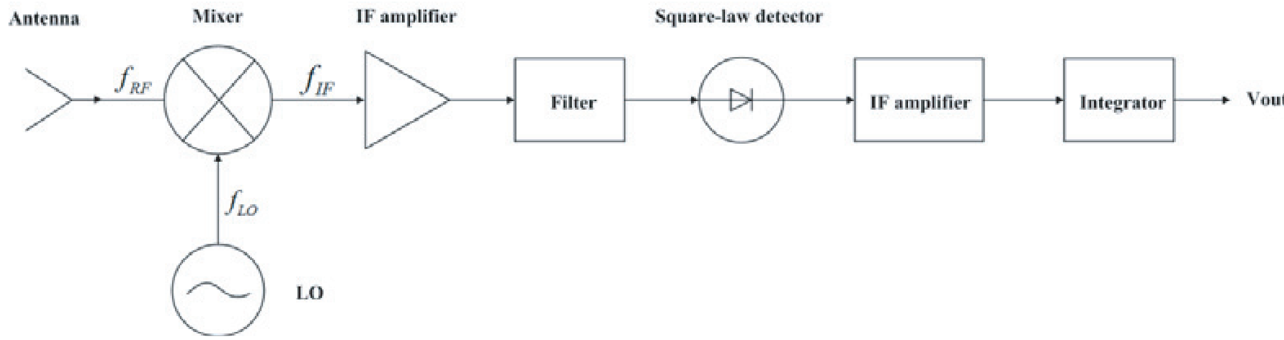



**Figure 1.** The block diagram of the terahertz radiometer.

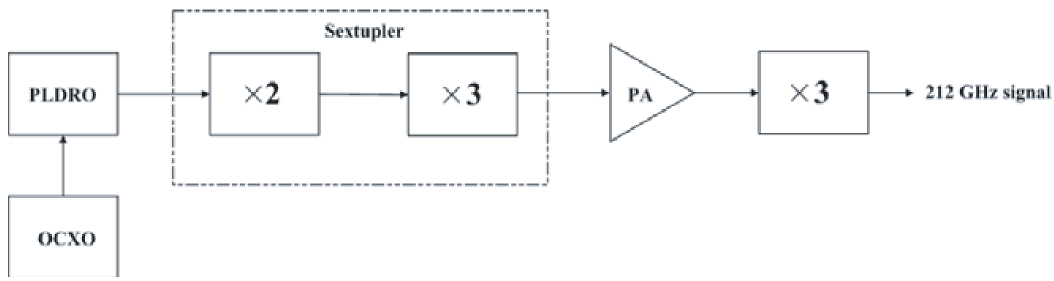



**Figure 2.** The block diagram of the local oscillator used to drive mixer.

## 3. DESIGN AND MEASUREMENT

Because the technology of W-band signal source is relatively mature [4–7], this section will especially introduce the terahertz tripler, which is a technical difficulty in the chain. Moreover, the LO source introduced in this article is aimed to work for three months as part of radiometer front-end carried by satellite. Hence, the stability of the source becomes important during the design progress.

### 3.1. Phase-Locked Dielectric Resonator Oscillator

For further improving the phase noise, it is desirable to phase lock the free running dielectric resonator oscillator (DRO) to a high stable crystal oscillator [6] such as oven controlled crystal oscillator (OCXO). The basic concept of conventional PLDRO is multiplying a crystal reference up to the carrier frequency via sampling phase detector (SPD) [7]. Then compare reference signal to the free running signal, and the error signal is fed back to the loop filter.

To some extent, the performance of mixer can be affected by the LO source. As the first stage of the LO chain, it is necessary to measure the stability of PLDRO. As depicted in Fig. 3, the measured working frequency of PLDRO is 11.7989 GHz and keeps invariant within 10 hours. In addition, the output power is about 7.5 dBm after stability.

### 3.2. Power Source

As the second stage of the LO chain, the function of power source is sextupling and amplifying the signal produced by PLDRO, and can be used to drive a 212 GHz tripler. It mainly includes a sextupler and a power amplifier that employ commercially available MMIC chips.

To avoid reducing the performance of Schottky diodes caused by heat accumulation, the driving power is limited to 100 mW. Fig. 4 shows the stability characteristic of power source, which makes clear that the power tends to be stable after a period of time. It is worth to explain that the output power can drop in a period of time until the devices reach heat balance.

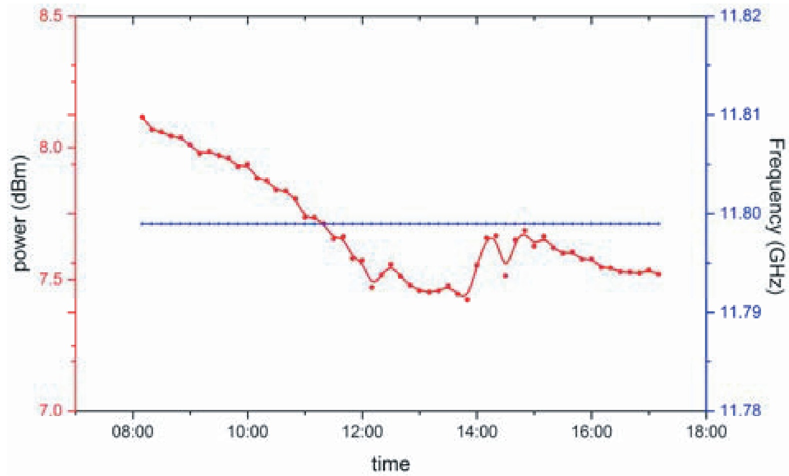



**Figure 3.** Stability test: Output power and frequency of PLDRO vs. time.

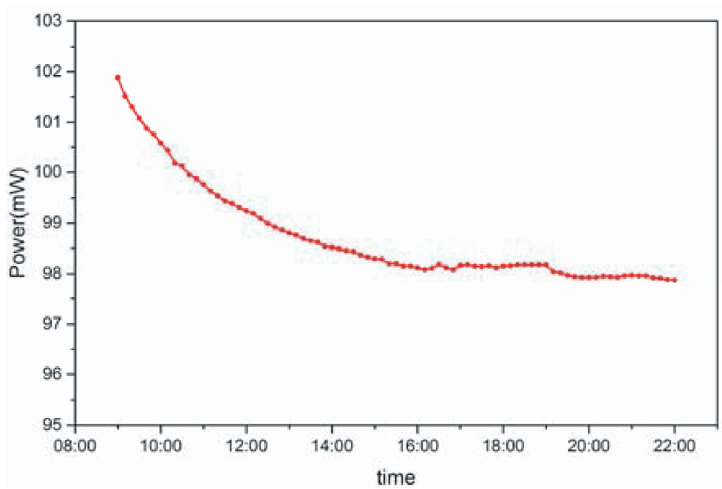
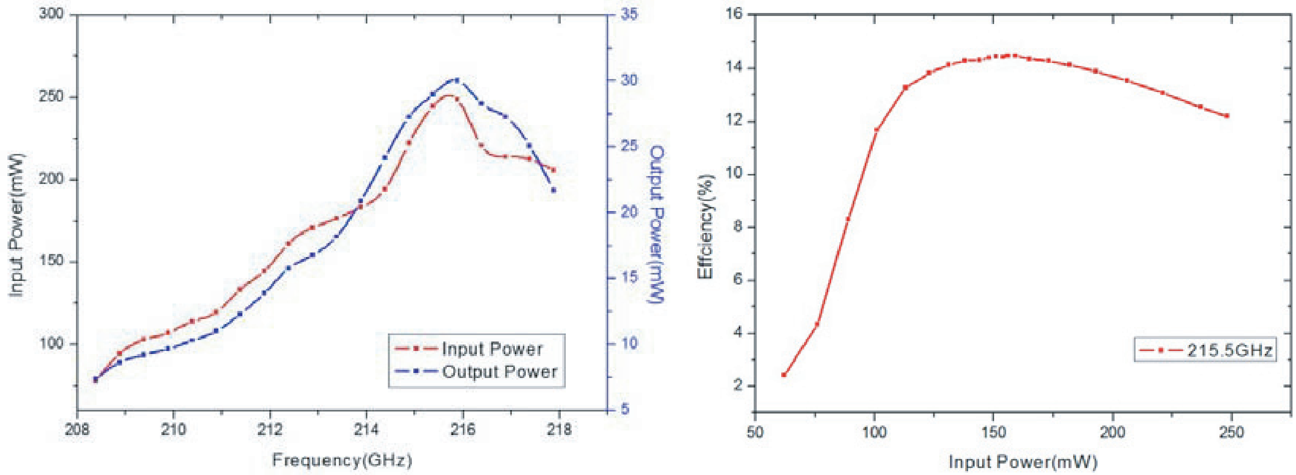



**Figure 4.** Stability test: Output power of power source vs. time.

### 3.3. 212 GHz Tripler

The 212 GHz tripler is the most critical component in the LO chain. In consideration of thermal dissipation, it is necessary to design a tripler with high efficiency to reduce requirement for high output power of the former source. In fact, the tripler based on unbalanced structure has been studied in our former research work, and the measured results show that the highest efficiency is 7.3% [8]. Compared with it, the performance of the 212 GHz tripler designed in this paper improves greatly. Before the tripler is fixed in the 212 GHz LO system, it has been measured comprehensively with high output power source, and the measured results are shown in Fig. 5. It can be found that the conversion efficiency is more than 9% in 208 $\sim$ 218 GHz, and the maximum efficiency is about 14.5% at 215.5 GHz when being driven with 21.8 dBm of input power at room temperature. Fig. 7(a) shows a photo of the assembled 212 GHz tripler block. There is a simple comparison between the performance of other frequency triplers above 200 GHz and this work (as shown in Table 1) [9–12]. Thus, it can be seen that the performance (efficiency and output power) of the 212 GHz tripler in this work comes up to internal leading level.

The reasons for improving performance are as follows. Firstly, the dimension of Schottky diode' model is further modified to make simulated results match with the measured results of tripler, which was designed in our former research. It mainly includes the thickness of each layer, diameter of Schottky

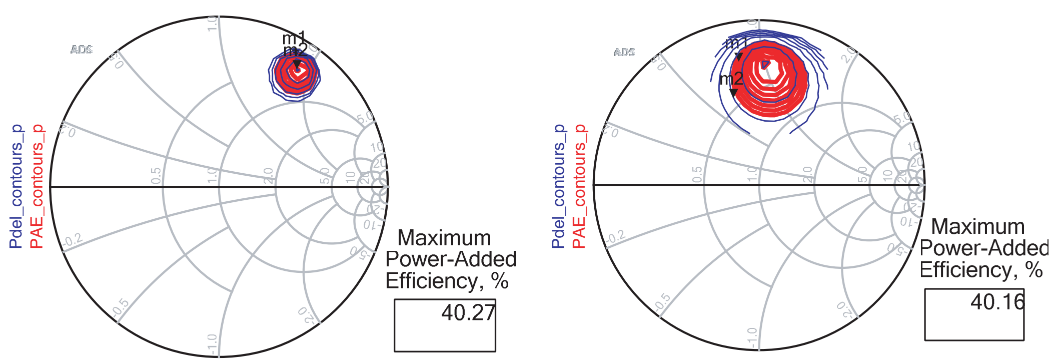



(a) (b)

**Figure 5.** (a) Measured input power and corresponding output power. (b) Efficiency vs. input power (taking a fixed frequency point 215.5 GHz for example).

**Table 1.** Summary of the performance of previous triplers and this work.

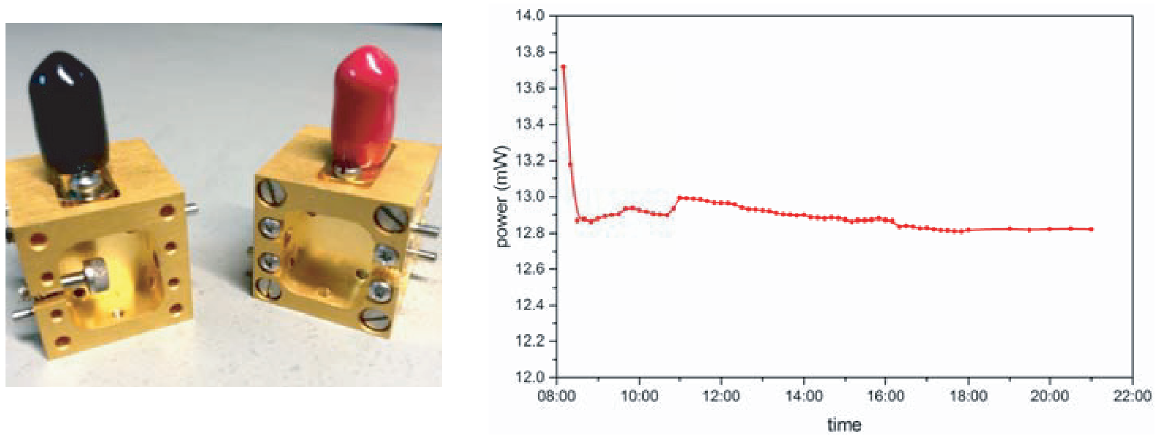
| Paper | 9 | 10 | 11 | 12 | This work |
|---|---|---|---|---|---|
| Research institute | UESTC | UESTC | UPMC | VDI | NSSC |
| Nationality | China | China | France | USA | China |
| Output Frequency (GHz) | 220–228 | 223.5–237 | 260–340 | 200–235 | 208–218 |
| Maximum output Power (dBm) | 8 | 2.3 | — | 13.6 | 14.7 |
| Conversion Efficiency | Highest 5% | Highest 1.78% | 1.5%–7.5% | Highest 16% | Highest 14.5% |




(a) (b)

**Figure 6.** The PAE and delivered power contours of the load pull and the source pull. (a) Source pull. (b) Load pull.

junction and length of the finger. Secondly, the method of load pull and source pull are adopted in calculating the optimum input and output impedance of diode cell, and the ideal conversion efficiency reaches 40%. Fig. 6 shows the PAE and delivered power contours of the load pull and source pull. Moreover, a five order stepped impedance lowpass filter is used to prevent the third harmonic leaking.




(a) (b)

**Figure 7.** (a) Photo of the assembled 212 GHz tripler block. (b) Stability test: Output power of 212 GHz tripler vs. time.

Besides, it can play a role as matching circuit. The dimension of microstrip line closest to the diode cell is further optimized to a better match. Finally, a combination of random and gradient method is adopted in the circuit optimization progress. The random method obtains a new parameter value by picking a number at random within a range, and the gradient method finds the gradient of the network's error function. At first, the random method is used to get close to the goal, and then the gradient method is used to converge at local range. The combined method can improve the speed of optimization and avoid the gradient analysis getting stuck in a local minimum which is not the optimal error function.

Similarly, there is a stability test of the 212 GHz tripler as shown in Fig. 7(b). The output power of the tripler is about 12.8 mW when the devices enter the steady state. The above experiments prove that the 212 GHz LO source can drive the mixer for long-term stable operation.

## 4. CONCLUSION

A 212 GHz LO source based on cascaded frequency multipliers is designed and tested in this paper. Furthermore, the terahertz receiver front-end passes the heat cycling test and mechanical test that has been carried by satellite successfully. The above mentioned work has an important reference value to the study on nationalization of terahertz receiver front-end. Our future work is mainly focused on assembly technique of terahertz device.

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