

A Broadband T/R Front-End of Millimeter Wave Holographic Imaging

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Abstract

A broadband T/R front-end of active holographic imaging system is presented. Compact autodyne mode circuit structure front-end is adopted to achieve higher signal to noise ratio and higher reliability, which is beneficial to the after-end imaging. The factors that influence the dynamic range and the transverse resolution ratio of holographic imaging system have been analyzed. Wide-band oscillator, wide-band low noise amplifier and the tapered slot antennas are implemented to meet the requirements of the holographic imaging system. According to the measured results, the output power is uniform in the broadband working frequency. The sub-harmonic suppression is better than 25 dBc from the frequency of 28 GHz to 33 GHz. The isolation between antennas channel is greater than 20 dB. The experimental result shows that the performance of the front-end is good enough to meet the needs of active millimeter-wave holographic imaging system.

Keywords

Millimeter Wave, Broad-Band, T/R Front-End Module, Holographic Imaging

1. Introduction

With the development of millimeter wave technology, especially the decreasing cost and the elevating performance of millimeter wave devices, which have provided conditions to realize miniaturization, array and high reliability; and have laid the foundation for millimeter wave imaging system of commercial. Millimeter wave imaging has developed from the passive focal plane array imaging to more complex active imaging [1]. The change of the mechanism of the imaging makes the millimeter wave imaging resolution and field of view have much improved. Pacific Northwest Laboratory (PNNL) developed and authorized the L3 communications (L3-Communications) millimeter wave active imaging spectrometer has been greatly promoted the millimeter wave active imaging technology research and application [2]-[6].

The front-end T/R module’s performance plays the key role in the millimeter wave active holographic imaging system. This paper proposes a ka-band broadband T/R front-end of active holographic imaging system. Compact autodyne structure is adopted in order to achieve the higher signal to noise ratio and the higher reliability, which are beneficial to the after-end imaging. The MMIC chips on the front-end circuit include the frequency multiplier, the frequency mixer and the amplifier. The circuits are designed, and the simulating and experimental results are given in this paper. This front-end T/R module has the advantages of compact, good performance, convenient processing.

2. Design of the Ka-band T/R Front-End

The T/R front-end is mainly composed of a phase locked loop frequency synthesizer and frequency multiplier link circuit, broadband radiation antenna, MMIC mixer and millimeter wave low noise amplifier. Frequency synthesizer provides baseband signal to frequency multiplier link, then become broadband millimeter wave frequency synthesizer. The transmitting signal is divided into two channels by passing through the power divider, one channel is providing millimeter wave signal for transmitting branch, the other channel is the local frequency signal and is mixed with the signal from the receiving branch to obtain the IF signal, as in **Figure 1**.

2.1. The Broadband Millimeter Wave Frequency Synthesizer

The circuit link of the broadband millimeter wave frequency synthesizer is shown in **Figure 2**. The front-end frequency multiplier bandwidth is determined by the base-band signal, the reasonable frequency and the pass band of the filter, which will meet the need of the transverse resolution of the imaging system. The output power determines the dynamic range of the system. Three-grade frequency-doubled structure is adopted in this frequency multiplier circuit link. The input signal of the frequency synthesizer from 3.875 GHz to 4.5 GHz, which passes through the frequency multiplier, becomes a broadband frequency synthesizer with frequency bandwidth of 5 GHz, from 28 GHz to 33 GHz.

At the baseband frequency of 4 GHz, when the simulating input power $P_{in} = 2$ dBm, we can get the frequency multiplier output power, as is shown **Figure 3**. In the result figure, the output power amplitude is greater than 15 dBm and the spurious suppression is greater than 27 dBc, which meets the system requirements.

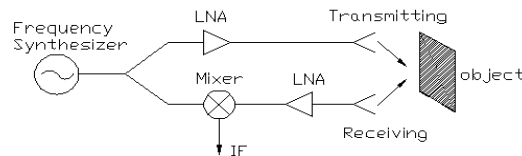


Figure 1. Diagrammatic layout of the autodyne mode circuit structure front-end.

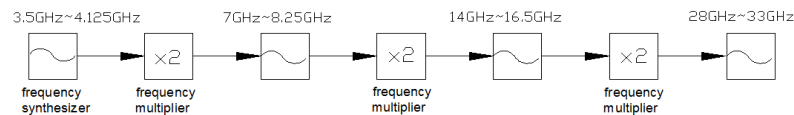


Figure 2. Circuit link of the broadband millimeter wave frequency synthesizer.

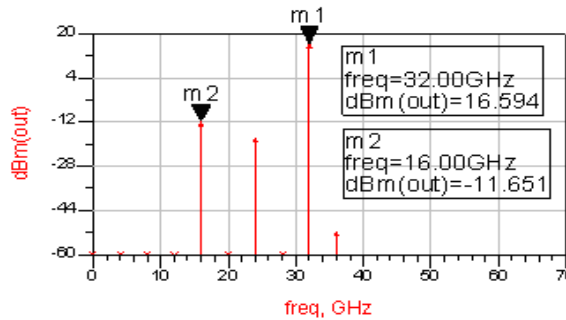


Figure 3. Simulating result of the output frequency multiplier spectrum.

2.2. Transmitting Circuit and Receiving Circuit

The transmitting signal of the antennas is sent from the Wilkinson power divider and the amplifier. The tapered slot antenna array is adopted for the requirements of the broadband radiation angle and the broadband frequency bandwidth, as is shown in **Figure 4**. The tapered slot antenna is end-fire transmitting radiating, which has the property of broadband radiation, and it is easy to be integrated with the front-end circuit. The performance of the antenna is shown in **Table 1**.

The receiving circuit is consisting of low-noise-amplifier, MMIC I/Q mixer and the antenna array. The receiving sensitivity of the front-end depends on the noise factor of the receiving circuit. The front-end circuit uses the ka-band MMIC low noise amplifier (LNA) which is produced by 0.25 μm GaAs pHEMT technology, with the noise factor is less than 3.5 dB and the gain is greater than 15 dB. Two LNA chips cascade connection is used to increase the sensitivity of the receiving circuit. The MMIC mixer needs have high isolation between the Lo port and the RF port, which can improve the dynamic range of the system. The measured result of the isolation between Lo and RF port is 50 dB. The receiving antenna array is as the same as the transmitting antenna, which has broadband radiation and frequency bandwidth.

2.3. Integrating and Measuring of the Ka-Band T/R Front-End

The RF integrated circuit is made by the substrate of Rogers 4350B with dielectric constant of 3.48 and thickness of 10 mil. The power supply circuit is operated by using feeding-through capacitors, which can keep the electromagnetic shielding between the circuit branches. The structure of the T/R front-end is shown in **Figure 5**.

As the output power amplitude of the frequency synthesizer is -10 dBm, the measuring result of the transmitting power of the front-end is as **Figure 6**. It can be seen that the working frequency bandwidth has uniformity output amplitude from 0 dBm to 5 dBm.

The isolation between the transmitting channels and the receiving channels are shown as **Figure 7** and **Figure 8**. It can be seen that the isolation data between channels are both greater than 20 dB.

At the frequency of 30 GHz, the supplying input RF signal power is -50 dBm, which mixing with the LO baseband signal frequency is at 3.9 GHz, then the IF frequency spectrum is obtained as is shown in **Figure 9**. The

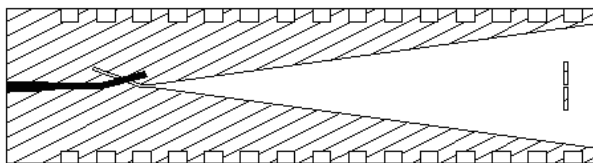


Figure 4. Structure of the antenna.

Table 1. Performance of the antenna.

Frequency	28 - 33 GHz
S11	<-10 dB
3 dB beamwidth	35°
Gain	11 dBi



Figure 5. Structure of the T/R Front-end.

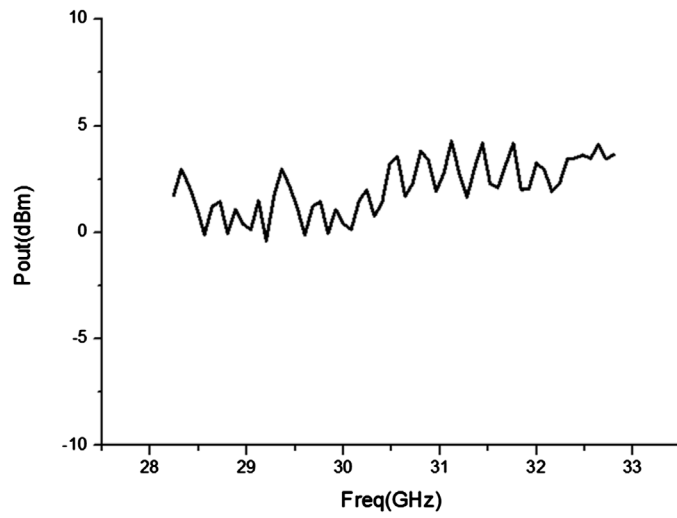


Figure 6. The output power measurement result.

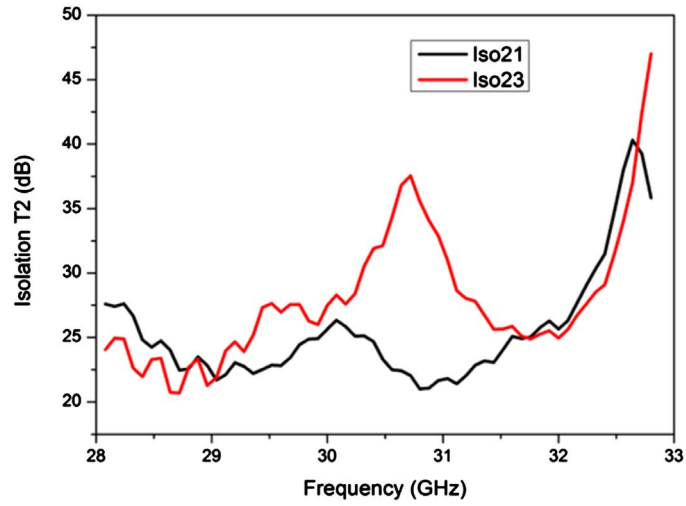


Figure 7. Isolation between the transmitting channels.

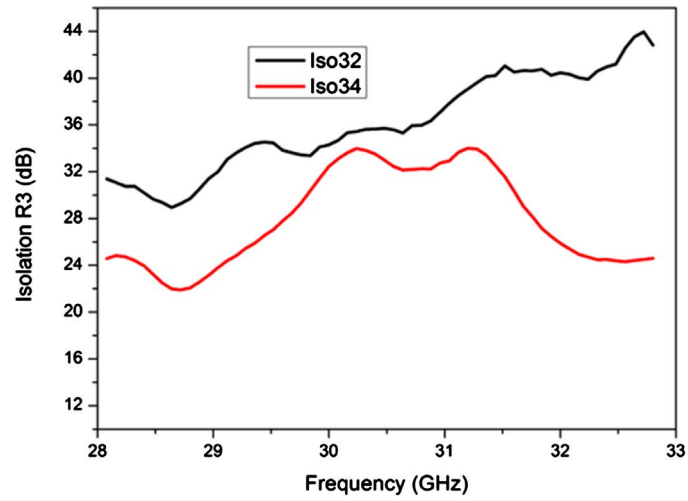


Figure 8. Isolation between the receiving channels.

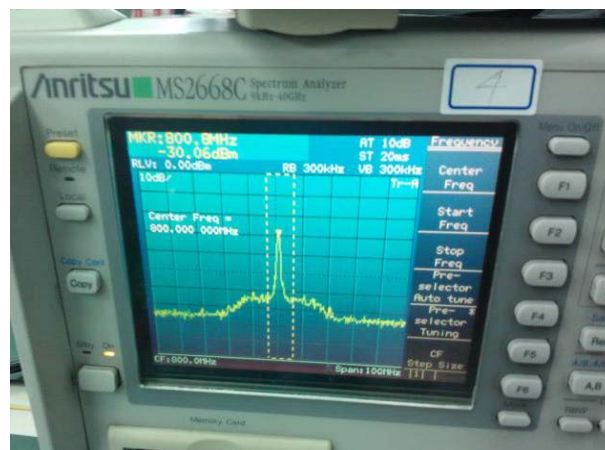


Figure 9. The output IF frequency spectrum.

experimental result displays that the conversion gain is greater than 20 dB at the IF frequency of 800 MHz. At the frequency bandwidth of 28 GHz to 33 GHz, the conversion gain is uniform, which meet the need of the broadband T/R front-end module.

3. Conclusion

In this paper, a broadband ka-band T/R front-end of millimeter wave active holographic imaging system is presented. Design methods of the broadband transmitting and receiving circuits have been displayed. The experimental performance is given, which is good enough to be used in the active holographic imaging system.

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