DESIGN AND FABRICATION OF 77GHZ HEMT MIXER MODULES FOR AUTOMOTIVE APPLICATIONS USING EXPERIMENTALLY OPTIMIZED ANTIPODAL FINLINE TRANSITIONS

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77GHz PHEMT gate mixer module and resistive mixer module were fabricated for automotive applications using LG-CIT low noise PHEMT process and WR12-to-microstrip antipodal finline transitions. The finline transitions were experimentally optimised for wideband operation and low insertion loss by adjusting geometrical design parameters. The average insertion loss was measured to be 0.74dB per transition in 75~90GHz. The fabricated gate mixer module and the resistive mixer module showed very good conversion loss of 2dB and of 10.3dB, respectively, including finline transition loss and IF cable loss, which were very competitive performances.

1 Introduction

Car radars and sensors have been one of the most important and interesting areas in the microwave and millimeter wave applications over the past years. These are not only related to huge market of automotive industry but also play a key role in safety of intelligent cruise control in the future. Among the components of radars and sensors operating at 77GHz for short range and high resolution applications, mixer is one of the most important circuit elements that converts Doppler-shifted reflected signal to very low frequency signal below 1MHz.

In the millimeter wave region, coaxial-to-microstrip transition does not have good reproducibility and requires fine and accurate mechanical machining which leads to higher cost. As an alternative, direct waveguide-to-microstrip transition has been widely used. In case of antipodal finine transition among them, the advantages of wide bandwidth and assembly easiness can be utilized, and so finline transition was chosen for our works.

In this paper, we present the measured results of experimentally optimized WR-12 to microstrip transitions. And also we present the design, fabrication and measured results of 77GHz HEMT gate mixer module and resistive mixer module that were mounted on WR-12 waveguide jigs using these optimized finline transitions.

2 Waveguide-to-Microstrip Transition

The inserted antipodal finline substrate into rectangular waveguide makes the dominant mode TE_{10} of the waveguide rotate 90^{o} and form the electric field of the microstrip line [1]. This finline transition is not sensitive to mechanical machining and mechanical parameter variations. But the characteristics of the antipodal finline transition cannot be accurately predicted only by 3D electromagnetic field (EM) simulation. We optimized the structure of the finline transition by simultaneously performing FDTD (Finite Difference Time Domain) simulation and experimental optimization of the major structure design parameters. The major design parameters are as follows: the transfer length for low

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insertion loss (tp), the shape and length of ground semicircular pattern for in-band resonance removal (S, L), the alignment of top and bottom (signal and ground) patterns and so on, as shown in Fig.1. The serrated choke (W_1, W_2, W_3) was used for fragility prevention and reproducibility during the assembly. Impedance discontinuity between the waveguide and the microstrip was reduced using low dielectric constant quartz substrate whose ε_r is 2.2.

We found from our experiments that long transfer length showed relatively lower insertion loss than shorter one, semicircular pattern caused no remarkable half-wave resonance predicted from EM simulations but reduced the ripples of insertion loss, and the serrated choke worked well as ground plane in the wide frequency range. The optimized finline transition showed average insertion loss of 0.74dB per transition in the frequency range of 75~90GHz. Fig. 2 shows the measured results of back-to-back WR-12 to microstrip antipodal finline transitions.

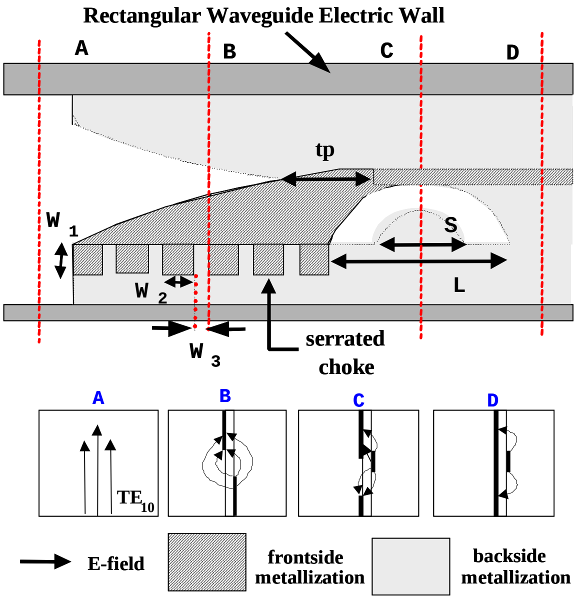

Fig. 1 The structure and design parameters of the antipodal finline transition. A, B, C and D show the field rotation as the wave propagates toward inserted transition.

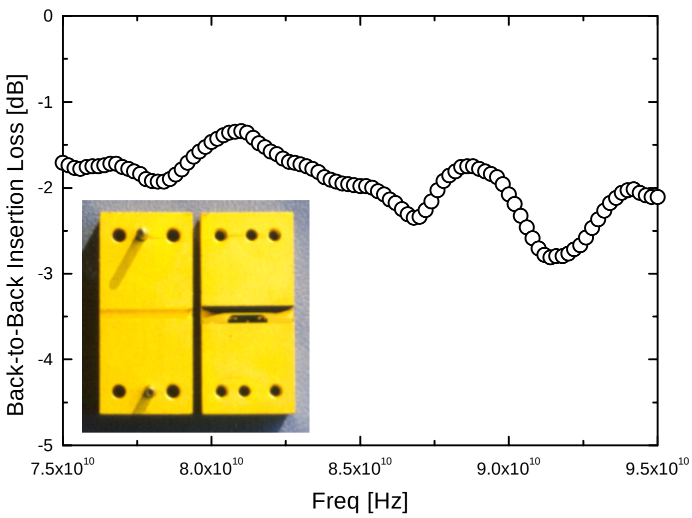

Fig. 2 The measured insertion loss of back-to-back antipodal finline transitions. The average insertion loss of 0.74dB per transition was obtained in the frequency range of 75~90GHz.

3 77 GHz Gate Mixer Module and Resistive Mixer Module

We designed and fabricated hybrid gate mixer in which the mixing operation was mainly caused by nonlinearity of transconductance of active device, PHEMT. The matching circuits at RF and LO frequencies were fabricated on 5mil quartz substrate with waveguide transitions. The photograph of the gate mixer module and its measured conversion loss are shown in Fig. 3. The measured result shows very good conversion loss of 2dB with RF power of –25.45dBm at 76.878GHz and LO power of 11.93dBm at 76.495GHz. The measured data included the RF loss of the waveguide-to-microstrip antipodal finline transition and the IF loss of bias tee and SMA cable.

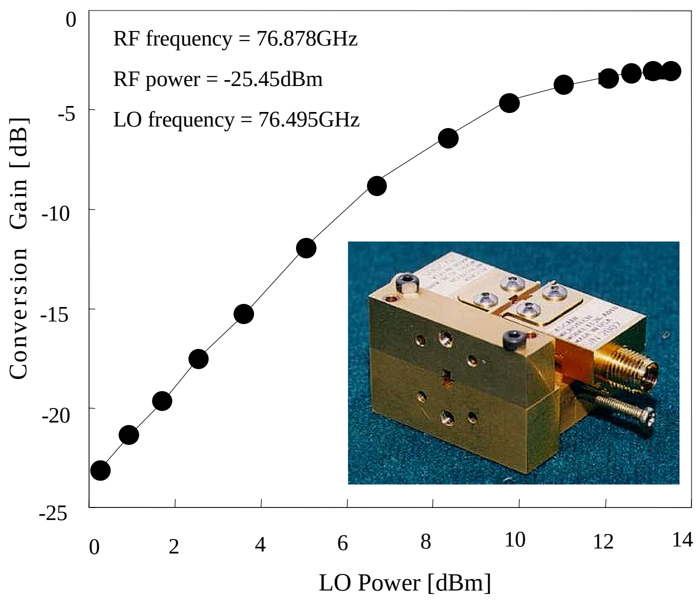

Fig. 3 The photograph and measured conversion gain of 77GHz HEMT gate mixer module with optimized finline transitions.

We also fabricated 77GHz HEMT resistive MMIC mixer on 3” GaAs semi-insulating substrate that had single hetero-epitaxial P-HEMT layers grown by MBE (Molecular Beam Epitaxy). We utilized double exposure-double develop technique [2] to improve uniformity and reproducibility of T-gate process which was a requisite for high speed and high frequency operation. The HEMT resistive mixer was designed using the Root model [3] of LG-CIT low noise PHEMT. The photograph of the fabricated resistive mixer module and its measured conversion loss are presented in Fig. 4. The fabricated MMIC size is 1.2mm × 1.0mm. The MMIC mixer chip is indicated by small box and arrow line. The relatively large bias SMA port and IF SMA port were used for test convenience. The measurements were done using Gunn oscillator as signal source and WR-12 waveguide accessories such as variable attenuator, harmonic mixer, directional coupler, and so on. As shown in Fig. 4, the measured conversion loss of the mixer module with LO power of 7dBm at 76.6955GHz and RF power of –15dBm at 76.6690GHz was about 10.3dB that was very competitive performance. This was in good agreement with the simulation result.

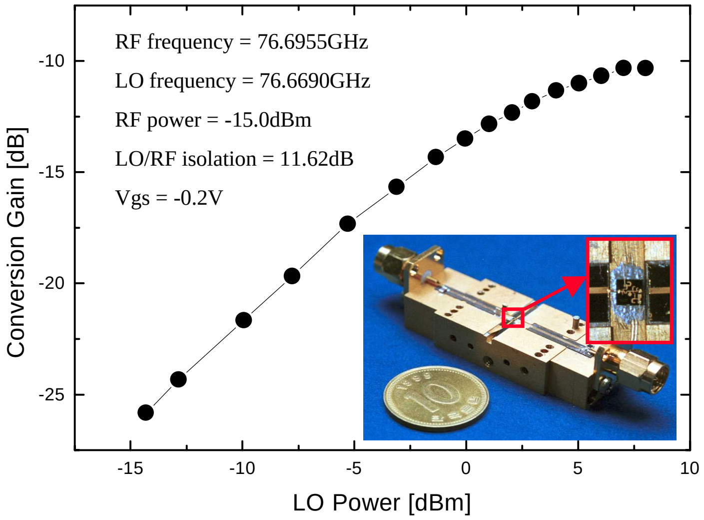

Fig. 4 The photograph and measured conversion gain of 77GHz HEMT resistive mixer module with optimized finline transitions.

4 Conclusions

The waveguide-to-microstrip antipodal finline structure was fabricated on 5mil quartz substrate and was experimentally optimised for wideband module applications. Its measured result showed the average insertion loss of 0.74dB per transition in 75~90GHz. Using these transitions, we designed, fabricated and measured 77GHz PHEMT gate mixer module and resistive mixer module. The measured results of the gate mixer module presented very good conversion loss of about 2dB with RF power of –25.45dBm at 76.878GHz and LO power of 11.93dBm at 76.495GHz. And the results of the resistive mixer module showed the very competitive conversion loss of 10.3dB with RF power of –15.0dBm at 76.6955GHz and LO power of 7dBm at 76.6690GHz including the loss of finline transitions. Both modules were successfully fabricated and tested using experimentally optimised WR-12 to microstrip antipodal finline transitions on 5mil quartz substrate.

References

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