A Family of Q, V and W-Band Monolithic Resistive Mixers

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***Abstract* — This paper presents the design, fabrication, and testing results of Q, V, and W-band monolithic broadband resistive mixers for measurement instruments. Low conversion loss and good flatness of the frequency response across a wide frequency range were achieved using InGaP/InGaAs HEMT biased in the resistive mode. Three mixers in Q, V, and W-band show similar excellent measured performance. Q and V-band mixers were designed using two Lange couplers. The Q-band mixer exhibits a conversion loss of 11.7 dB and a loss flatness of 1.2 dB for 11 GHz IF frequency over 42-56 GHz RF frequency band. The V-band mixer exhibits a conversion loss of 12.8 dB and a loss flatness of 1.0 dB for 18 GHz IF frequency over 56-72 GHz RF frequency band. On the other hand, the W-band mixer using a 180-degree balun, shows a conversion loss of 10.6 dB and a loss flatness of 1.2 dB for 30 GHz IF frequency over 72-84 GHz RF frequency band.**

I. INTRODUCTION

Recently, the demand of the millimeter wave radio communication applications such as LMDS, LMCS, ITS and various kinds of W-LAN, which are high frequency broadband wireless, are increasing day by day. The useful measurement instruments for such millimeter wave applications will promise to extend business market of millimeter wave radio communication systems. In order for the millimeter wave applications to further develop, measurement equipments to analyze millimeter wave signals with high-bit-rate are strongly required nowadays. To realize such measurement instruments, 1st mixers implemented in front end are most important key devices. HEMT process is popular for millimeter wave MMIC fabrication, so many types of millimeter wave mixer based on HEMT process have been investigated. Balanced resistive mixers have many attractive performances of wide band operation, low IMD, low LO leakage with no drain bias and low LO power [1] [2]. So far, many studies on millimeter wave resistive mixers have been reported. However, most conventional resistive mixers were designed for low IF frequency operation [1]-[6]. We developed Q, V and W-band MMIC resistive mixers, which have a high IF frequency operation performance for measurement instruments. To the best of the authors' knowledge, the mixers presented in this paper are the first mixers among wide band millimeter wave resistive mixers reported so far, which produce an excellent flatness of the frequency response across Q to W-band with high IF frequency operation.

II. CIRCUIT DESIGN

A. Q, V-band Resistive Mixer

In order to achieve enough rejection of the even order spurious signals, good return loss for the RF, LO ports and isolation between the RF and LO ports across a wide frequency range, the single-balanced circuit configuration shown in Figure 1 was chosen for Q and V-band mixers. The mixer circuit consists of two Lange couplers for the RF and LO ports, two 0.15 x 80 um InGaP/InGaAs HEMTs for mixing elements, and a pair of diplexer circuits. The LO and RF signals are fed to the gate and drain. As high IF frequency is difficult to separate from RF, it should be careful design of diplexer which is a combination of RF-BPF and IF-LPF. A quarter wave length microstrip coupled line is used for RF-BPF to achieve low insertion loss and sufficient IF rejection easily. L-C-L type LPF consists of two microstrip high impedance lines and a MIM capacitor for IF signal filtered out from the drain. Design parameters of two Lange couplers such as finger width and finger spacing must be optimally characterized in order to achieve good return losses at RF and LO band. One shorted stub for gate bias works as a simplified reflective match network for the input of the single-ended circuit. To operate in resistive mode, HEMT devices are biased near pinch-off and no drain voltage.

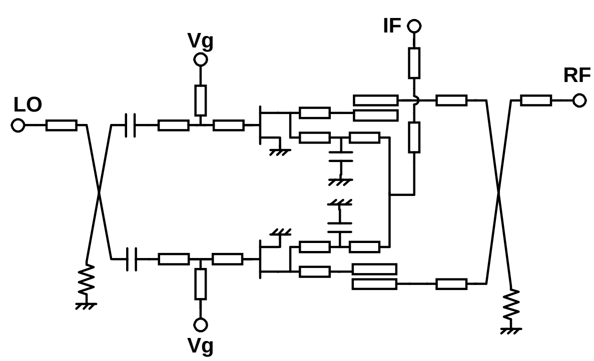

Fig. 1. Schematic of balanced mixer for Q, V-band

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B. W-band Resistive Mixer

Since, at W-band, insertion loss and frequency flatness of Lange coupler degrade, W-band mixer was designed using a 180-degree balun for LO port and a power divider for RF port instead of Lange couplers. Figure 2 illustrates a circuit schematic of the W-band mixer. The W-band mixer employs a 180-degree balun, two 0.15 x 60 um HEMTs, a pair of diplexer circuits to separate IF from RF, and a half wavelength microstrip line for IF to be combined in phase at IF port. A pair of diplexers is realized by the combination of two identical IF-LPF and one power divider. The power divider is composed of two quarter wavelength microstrip lines for IF. In Figure 2, a characteristic of the 180-degree balun is most important for the mixer. The balun is composed of two microstrip asymmetric side coupled lines and two via holes. The side coupled line is approximately a quarter wavelength at the center frequency of LO. 3D electromagnetic field simulation was used to optimize the final line width and spacing of the coupled lines in order to achieve an adequate bandwidth and balanced output impedance. The bias condition of HEMTs is similar to Q, V-band mixers.

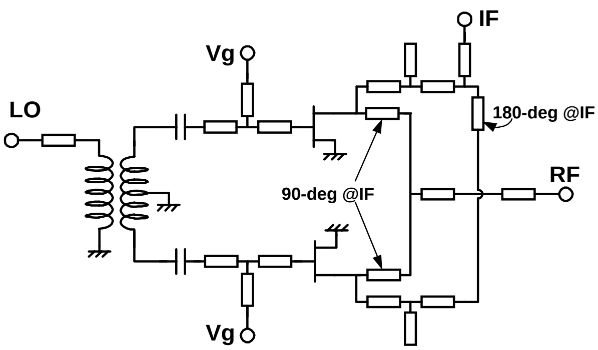

Fig. 2. Schematic of W-band balanced mixer

III. FABRICATION

The mixer circuits were fabricated on an MBE-grown wafer with an InGaP/InGaAs hetero-structure. The 0.15 um gate HEMTs, which provide a cutoff frequency of 65 GHz and a maximum oscillation frequency of 120 GHz for an 80 um gate width were used for this work. Figure 3 illustrates the device structure. T-shaped gate metal was formed using electron-beam lithography. After the wafer was thinned down to 70 um, etching of via holes and backside metalization were added for grounding.

The circuit layouts of mixers are shown in Figure 4 through Figure 6. The circuit size is 1.8 x 2.2 mm^2 for the Q-band mixer, 1.8 x 2.0 mm^2 for the V-band mixer and 1.8 x 2.4 mm^2 for the W-band mixer, respectively.

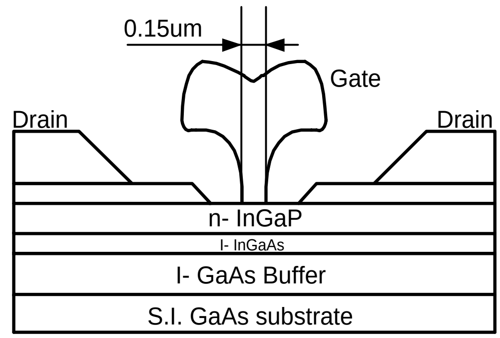

Fig. 3. Cross section of 0.15 um gate InGaP/InGaAs HEMT

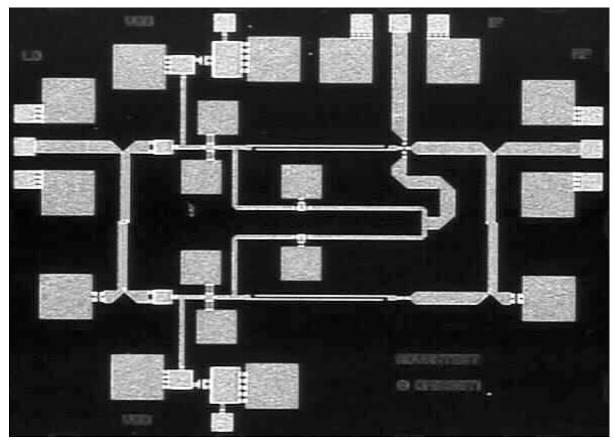

Fig. 4. Circuit layout of Q-band mixer

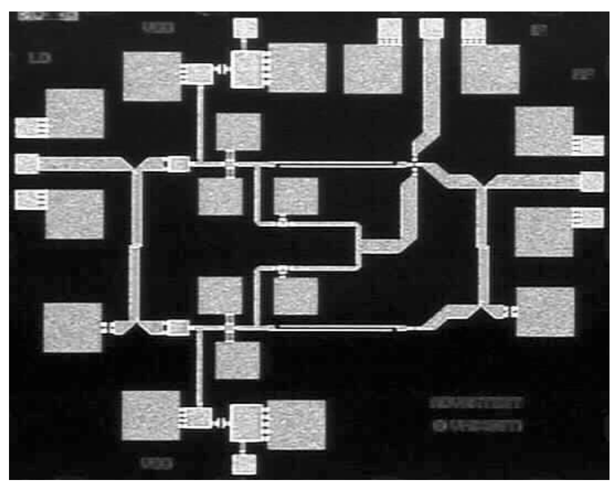

Fig. 5. Circuit layout of V-band mixer

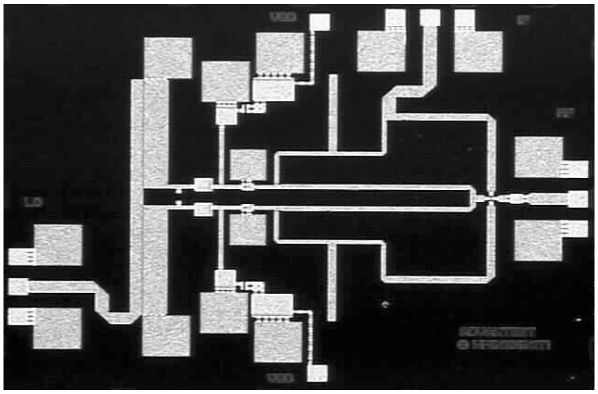

Fig. 6. Circuit layout of W-band mixer

IV. Measured Performance Of Mixers

Measured conversion loss and spurious signal rejection characteristics, including LO leakage power at IF port are plotted in Figure 7 through Figure 12. A LO drive power of 5 dBm was used for the measurements. The Q-band mixer exhibits a conversion loss of 11.7±0.6 dB, the LO signal isolation between LO and IF ports of more than 23.0 dB for a 42-56 GHz RF frequency with 11 GHz IF frequency. The V-band mixer demonstrates a conversion loss of 12.8±0.5 dB, a LO signal isolation of more than 18.0 dB for a 56-72 GHz RF frequency with 18 GHz IF frequency. On the other hand, a conversion loss of 10.6±0.6 dB, and a LO signal isolation of more than 14.0 dB are achieved for a 72-84 GHz RF frequency range with 30 GHz IF for the W-band mixer. Spurious signal rejection against RF input signals are -35 dB for Q and V-band mixers, and -30 dB for the W-band mixers. The equivalent RF input power at the 1 dB gain compression point were 4 dBm at 50 GHz for the Q-band mixer, 2 dBm at 60 GHz for the V-band mixer and –2 dBm at 77 GHz for the W-band mixer, respectively.

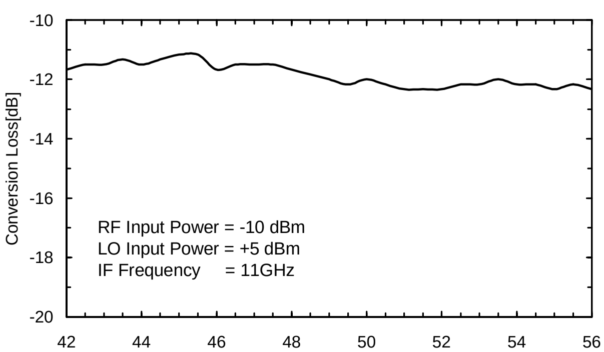

Fig. 7. Conversion loss of Q-band mixer

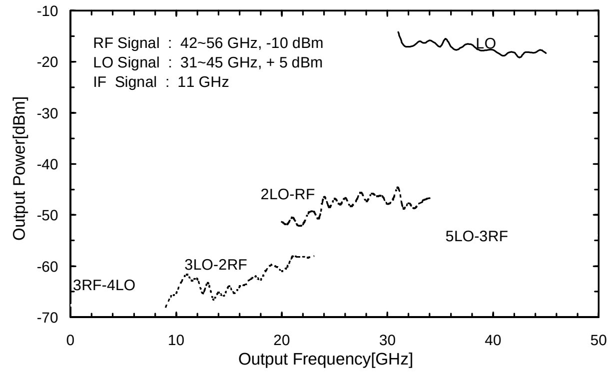

Fig. 8. Spurious and LO leakage output at IF port of Q-band mixer

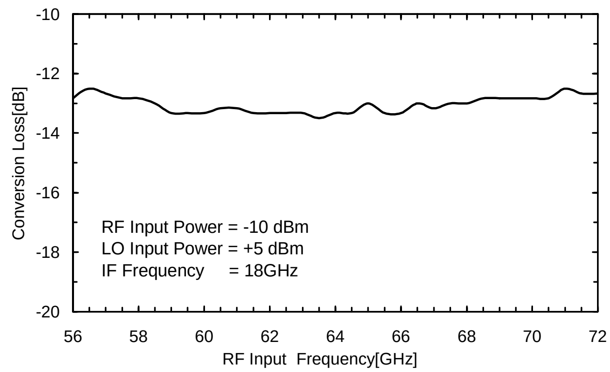

Fig. 9. Conversion loss of V-band mixer

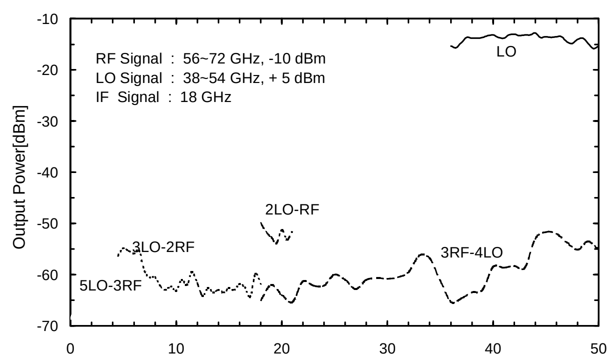

Fig. 10. Spurious and LO leakage output at IF port of V-band mixer

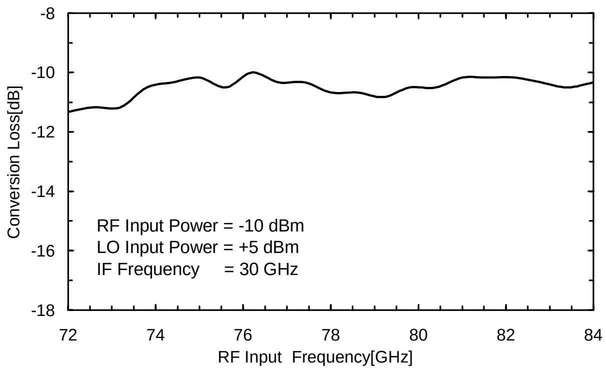

Fig. 11. Conversion loss of W-band mixer

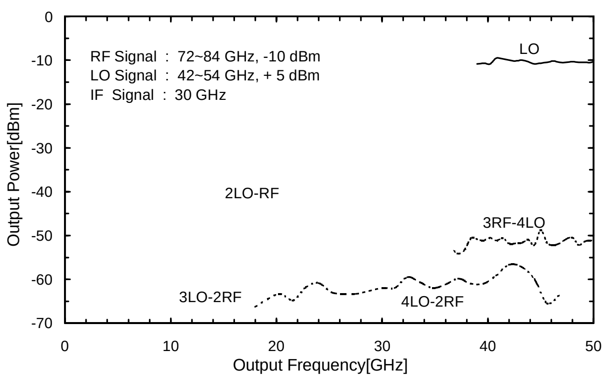

Fig. 12. Spurious and LO leakage at IF port of W-band mixer

V. CONCLUSION

We have developed Q and V-band mixers using Lange couplers, and W-band mixer using a 180-degree balun. These resistive mixers exhibit similar good performances at low LO power level with high IF frequency. These mixers are suitable for use as front end mixers of millimeter wave measurement instruments across Q to W-band.

ACKNOWLEDGEMENTS

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