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Research Article

Design of Passive Components in Quadruple Sub-harmonic Image Rejection Mixer

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Abstract: The design of passive components in quadruple Sub-harmonic image rejection mixer is presented in this study. The passive components include double-balun and Lange coupler. With the help of ADS, a Balun with magnitude imbalance degree less than 0.2 dB and phase imbalance degree less than 1° is achieved in the range of 7.9 9.5 GHz. The insertion loss is about 7.3 dB at the center frequency of 8.7 GHz. A Lange coupler with magnitude imbalance degree in the range less than 0.3 dB and phase imbalance degree less than 1° is realized over the 30~40 GHz measurement band. The insertion loss is about 3.25 dB at the center frequency of 35 GHz. Satisfactory results have been reached in the simulation of double-balun and Lange coupler, which makes a significant foundation to the realization of the monolithic quadruple Sub-harmonic image rejection mixer.

Keywords: Double-balun, insertion loss, lange coupler, magnitude imbalance degree, phase imbalance degree

INTRODUCTION

Mixer, as one of the main components of the receiver, not only takes the role of frequency conversion, but also has an image signal suppression function (Bahl and Bhartia, 2006). Image rejection technology is now an electronic countermeasures and electronic interference.

This study introduces the design of the passive parts of the monolithic quadruple sub-harmonic image rejection mixer. Nowadays, local oscillator with high quality is hard to achieve and Sub-harmonic mixer can be used as local oscillator with frequency of one Nth of the RF frequency. Therefore, with the use of Sub-harmonic mixer, requirement of the millimeter wave system can be easily met.

The passive parts include double-Balun and Lange coupler. The magnitude of the image rejection depends directly on the magnitude balance degree and phase balance degree of the Balun and the Lange coupler. Therefore, the passive parts are significantly important in the design of the entire monolithic circuit. This design is simulated using the simulation kit from UMS Corporation of France. The substrate is GaAs with dielectric constant of 12.8 and the height of the substrate is 100 um.

IMPLEMENT OF SUB-HARMONIC IMAGE REJECTION MIXER

Sub-harmonic image rejection mixer has not been extensively investigated over millimeter wave band in recent years. Only Sub-harmonic mixer or image rejection mixer was researched. Research on both two is rare.

Figure 1 is the implementation schematic of quadruple Sub-harmonic image rejection mixer (the function of this mixer is to reject lower-sideband signal, which is referred as the image signal). What is framed by dash line is on-chip integrated part. LO signal is fed in through double-Balun while RF signal is fed in through Lange coupler. Then the IF signals transmit through two-way low-pass filters and 90° phase shifter. Finally, IF signal can be got through power combiner. RF signal is 33-37 GHz and IF signal ranges from 0-2 GHz.

DESIGN AND SIMULATION OF DOUBLE-BALUN AND LANGE COUPLER

Design of double-balun: This study presents the design of balun by using Marchand Balun with operation frequency 7.9~9.5 GHz. The length of λ/4 is 3000 um at the center frequency of 8.7 GHz. The coupled line is shortened to 600 um after loading capacitance, resulting in a decrease of the size of Balun. However, with the loading capacitance, insertion loss of balun increases. The simulation layout of balun is shown in Fig. 2.

The final simulation results are exhibited in Fig. 3 and 4. As shown in Fig. 3, magnitude imbalance less than 0.2 dB within 7.9~9.5 GHz is achieved and insertion loss is 7.269 dB (one double Balun is separated to four ways). The theoretical value of

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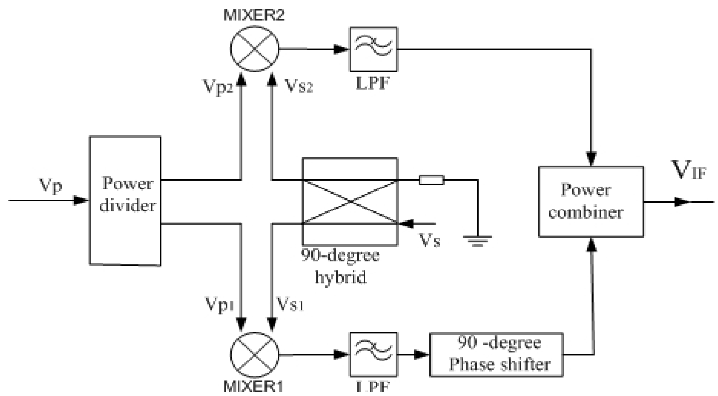

Fig. 1: Block diagram of quadruple sub-harmonic image rejection mixer

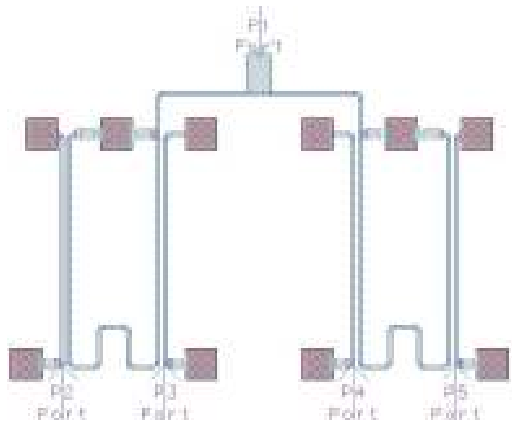

Fig. 2: Layout of double-balun

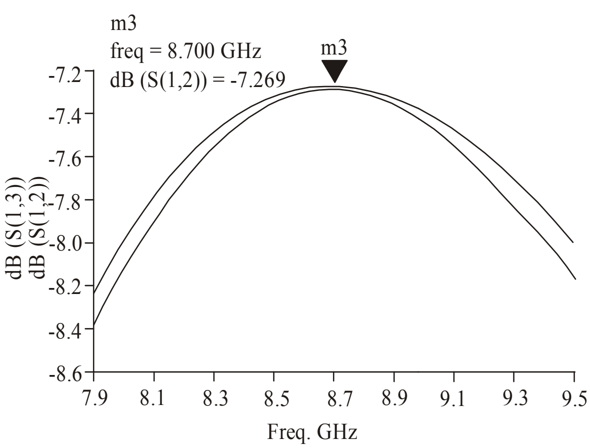

Fig. 3: Magnitude imbalance of double-balun

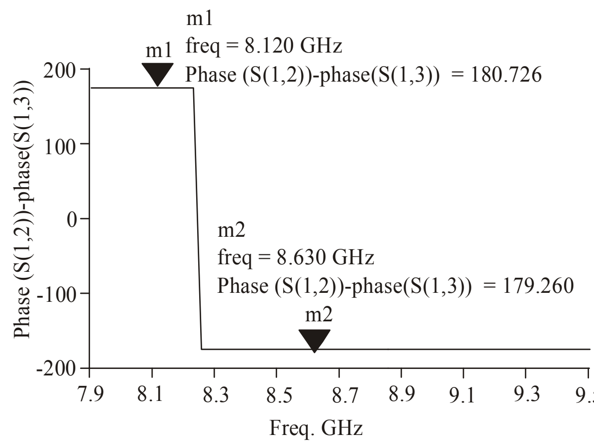

Fig. 4: Phase deference of double-balun

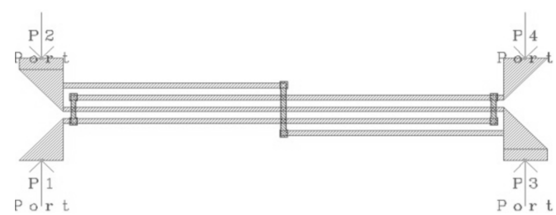

Fig. 5: Layout of lange coupler

insertion loss is 6 dB at the center frequency; Phase deference between two ports reaches 180° fairly well. Phase imbalance is less than 1°. Simulation results should be the same between port 4/5 and port 2/3 since the structure of Balun is absolutely symmetric, so only the simulation result of output of port 2 and port 3 is given. A good performance of the double-Balun has been achieved according to the simulation result.

Design of lange coupler: Lange coupler has been researched a lot in the research of monolithic microwave integrated circuit (Ang and Robertson, 2001; Ang *et al*., 2003; Fathelbab and Steer, 2005). It's widely used in circuits like balanced mixer, balanced amplifier and phase shifter. Two output signals of equal magnitude and 90° phase deference can be realized with one way input signal in a wide band. Figure 5 is the structure of layout for simulation.

The width of the coupled line of the Lange coupler is 8 um and the gap is 10 um. Jumpers Between lines are implemented using air bridge. Port 1 is input port. Port 3 is isolation port. Port 2 and port 4 are output ports. Final simulation results are exhibited in Fig. 6 and 7.

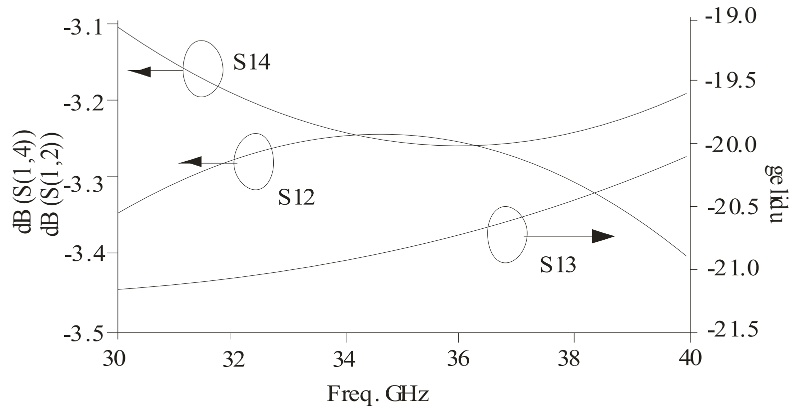

Fig. 6: Magnitude imbalance and isolation of lange coupler

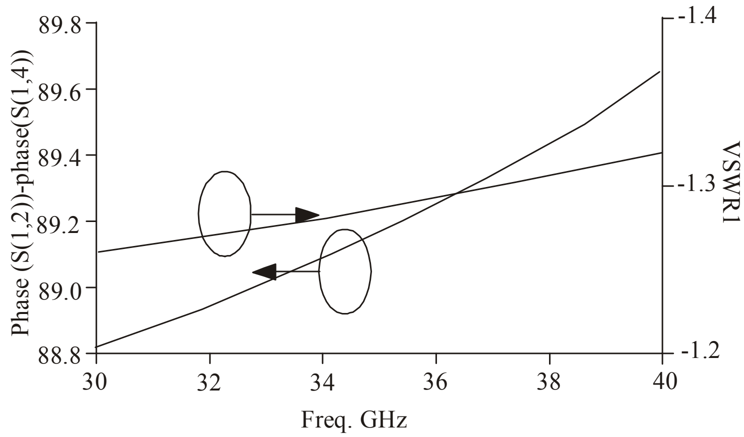

Fig. 7: Phase deference of lange coupler and VSWR of port 1

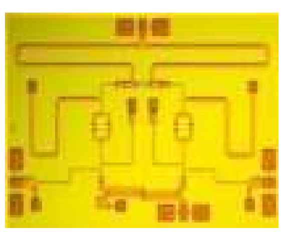

Fig. 8: Phase deference of lange coupler and VSWR of port 1

As shown in Fig. 6, magnitude imbalance degree is less than 0.2 dB within 30~40 GHz. Insertion losses is 7.269 dB at the center frequency of 35 GHz; Isolation between port 1 and port 2 is better than -20 dB. According to Fig. 7, Phase deference between port 2 and port 4 reaches 90°. Phase imbalance is less than 1 degree over the whole working frequency. The VSWR is better than 1.32. A good performance of the Lange coupler has been achieved according to the simulation result.

Applications: The Lange coupler has been applied in a fourth harmonic image rejection mixer with the commercial 0.15 um pseudomorphic High Electron Mobility Transistor (pHEMT) process as shown in Fig. 8. The results show that less than 20 dB Conversion Loss (CL) in 33-37 GHz, more than 20 dB Image Rejection Ration (IRR), can be achieved by the proposed configuration. The chip size is minimized to 2.5×1.5 mm.

CONCLUSION

The design of balun and lange coupler has always been important and difficult in the design of Monolithic integrated circuit (Marsh, 2006; Robertson, 2007). This study achieves a favorable simulation result using ADS. The design with highly quality of passive components will lay a significant foundation for the quadruple Sub-harmonic image rejection mixer.

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