60-GHz-band MHMIC Frequency Multiplier Module for Multi-port Interferometer Receivers

Mansoor Dashti Ardakani *[1], Reza Karimian [2], and Serioja O. Tatu [1]
[1] Institut National de la Recherche Scientifique (INRS – EMT), Université du Québec, Montréal, QC, Canada.
[2] Electrical and Computer Engineering Department, The George Washington University, Washington D.C., USA.
* mansoor.dashti@gmail.com

***Abstract*— In this paper, a 60-GHz-band miniaturized LO frequency multiplier module is presented. The ×4 frequency multiplier is appropriately designed as a LO chain to cover the entire band and provide enough power for mm-wave multiport receivers. To obtain a high suppression harmonic parameter, two compact bandpass filters are designed and placed after each multiplier. The miniaturized module with competitive parameters is fabricated and tested successfully through an MHMIC structure layout design.**

I. Introduction

The Federal Communications Commission (FCC) has assigned a 7 GHz spectrum bandwidth (from 57 to 64 GHz) in the V-band for unlicensed short-range applications [1]. The millimeter-wave (mm-wave) technology at this frequency range, has the potential to revolutionize wireless communications, radar, and imaging systems [2]. Lots of networks have been proposed for mm-wave communication especially in the 60-GHz band [3]. Six-port interferometer receivers, which are based on multi-port technology, have outstanding benefits such as low cost, easy fabrication, and operating with low power local oscillator (LO) signal (comparing to conventional mixers) in a wide frequency range [4]. In a homodyne six-port receiver, the existence of a reference signal (LO) at the same frequency of the received signal (RF) is essential. One of the most common methods to reach this high frequency from typical RF oscillators is to employ frequency multipliers/doublers [5] to produce output signals at integer multiples of the input signal frequency.

A miniature hybrid microwave integrated circuit (MHMIC) is a circuit that its passive components have been printed onto the surface of a substrate, and the active elements are joined to the circuit individually by wire bonds. MHMIC technology provides a wide range of options for active components and the miniaturization of the circuit by reducing the number of used elements [6]. In this manuscript, a small size, low-spur wideband LO chain module using MHMIC technology is presented, which covers the whole unlicensed 60-GHz band.

II. Frequency Multiplier Design

For a direct down-conversion procedure, a reference signal with the same frequency as the received RF signal (V-band) is required. By a reduced LO power, thanks to its unique characteristics, the six-port interferometer represents the vector correlation between the received millimeter-wave RF signal and its own LO, the reference signal. In millimeter-wave designs, the lower LO power is an outstanding development because high power levels are more challenging and costly to generate. To achieve this high-frequency signal from a conventional RF generator, designing a frequency multiplier module is a must.

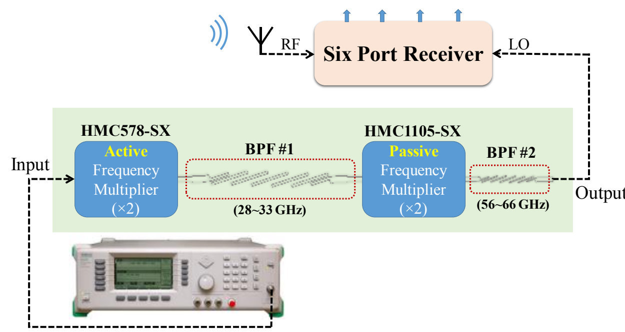
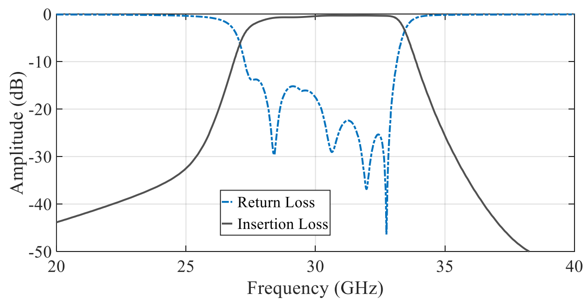


Fig. 1. Block diagram of the proposed LO chain module used for six-port receivers.

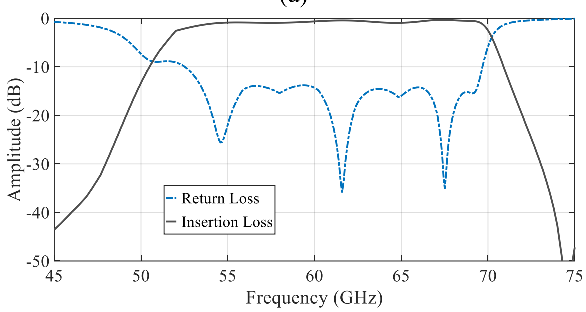
The block diagram of the designed frequency multiplier is displayed in Fig. 1. Two stages of GaAs MMIC ×2 frequency multipliers from Analog Devices Inc. are considered to have a 56–66 GHz output signal as the LO (reference) for the multiport receiver. The generated input frequency signal is in the range of 14 to 16 GHz. The first multiplier (HMC578-SX) is selected as an active MMIC to have enough output power as a driver, while the second one (HMC1105-SX) is a passive element. To drive the first frequency multiplier, a +5V DC power supply is provided. Both multipliers have good isolation (more than 25 dBc) between the output desired signal (second harmonic $2f_o$) and other unwanted signals (i.e. fundamental harmonic f_o or third harmonic $3f_o$). To have an ideal harmonic suppression (more than 70 dBc), two fifth-order coupled-line bandpass filters are designed to be placed after each stage of the multiplier.

III. Results and Discussion

Two fifth-order coupled-line bandpass filters have been designed individually in ADS software. The considered substrate is a thin ceramic (ε_r 9.9, thickness 10 mil) selected for its very low dielectric loss tangent at high frequencies and its great potential to be used as MHMIC technology. In the simulation, the bandwidth of the filters is considered to be wider than the desired value of design, to cover the possible discrepancy between the fabrication and simulation results. The simulation results of insertion and return losses for designed



(a)



(b)

Fig. 2. The simulation S-parameters of (a) the first BPF (BW: 28 to 33 GHz), (b) the second BPF (BW: 56 to 66 GHz).

bandpass filters are shown in Fig. 2 (a) and (b). The results indicate that both filters have excellent passband features (insertion loss less than 1 dB) and a wide stopband to reject undesired generated signals. Both bandpass filters meet module necessities.

Figure 3 is a photo of the V-band ×4 frequency multiplier module that is manufactured on a ceramic substrate (relative permittivity 9.9, thickness 10 mil). The size of this module is 4 cm × 4 cm. The input signal is fed by an RF signal generator (i.e. 68347B Anritsu) through an SMA connector, and the output signal exits through a microstrip to WR12 Rectangular Waveguide transition with the minimum insertion loss (0.7 dB at 66 GHz) [7]. The measurement results of the output signal are obtained by a V-band waveguide Power Sensor and shown in Fig. 4. The average output power is around +2 dBm, which is a great LO power for a six-port interferometer receiver. Table 1 illustrates all the functional parameters of the module. It is concluded that the final product can compete with similar developments in the market.

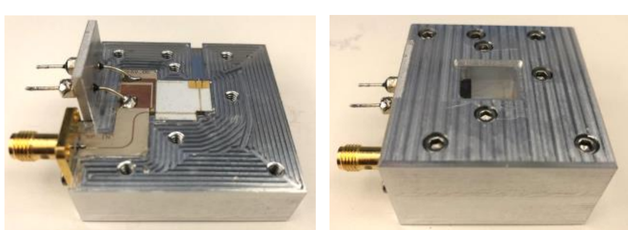


Fig. 3. The assembled frequency multiplier module based on MHMIC technology (left), and with aluminum case (right).

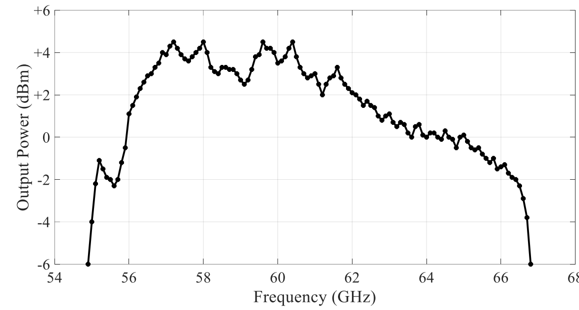


Fig. 4. The measured output signal of the fabricated LO chain module.

TABLE I. THE PARAMETERS OF THE IMPLEMENTED MODULE

Module Parameter	Typical Ratings	Unit
Input Frequency	14 ~ 16.5	GHz
Input Power	0 ~ +5 (optional)	dBm
Output Frequency	56 ~ 66	GHz
Output Power	0 ~ +4	dBm
Harmonic Rejection	> 70	dBc
Operating Voltage	+5	V
Conversion Loss	0	dB

IV. CONCLUSION

A compact ×4 frequency multiplier with high power output is presented in this paper. Two microstrip coupled-line bandpass filters are integrated with two MMIC to reduce the spurious undesired frequencies. The measurement results show a better than 70 dBc harmonic rejection and better than 0 dBm output power, make this proposed ×4 frequency multiplier a great candidate for interferometer receivers' applications as a LO chain module.

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