An Integrated Frequency Doubler

Alexander Chenakin, Yi Fu, and Dongwook Lee

Nextec Microwave & RF, Inc.

2255-E Martin Ave., Santa Clara, CA 95050, USA

Phone: 408-727-1189, Fax: 408-727-5915

Abstract: **This paper describes a balanced frequency doubler utilizing a matched pair of Schottky diodes fed in antiphase with two 90^0 Lange couplers. The module design and performance is presented. The doubler, being integrated with additional amplifying and filtering modules, demonstrates +21 dBm output power over 24-30 GHz frequency range. The fundamental frequency and third harmonic rejection is 45 and 56 dBc respectively.**

Key words: **frequency multiplier, integrated circuit, doubler**

1. Introduction

Doublers are key components in frequency generation and control circuits. Various doubler types have been extensively used [1], [2], however, the most practical circuits employ resistive diode multiplication. The resistive diode doublers exhibit broadband stable performance, favorably distinguished from varactor and transistor multipliers.

The diode doublers are usually built in a balanced or doubly balanced configuration [3], [4]. They utilize a full-wave rectifier circuit, which features odd-order harmonic cancellation in input and output baluns. Since matched GaAs Schottky diodes are readily available, the circuit performance is mostly limited by balun characteristics. We use two 90^0 Lange couplers to feed the diodes with 180^0 overall phase shift in a wide frequency range. The feeding circuit is essentially a Marchand balun version described in [5]. This structure is planar and can be easily integrated with conventional hybrid and monolithic technologies. The doubler module realization and performance are described in the following section. Further sections report on design and measurement of a practical integrated unit employing the developed doubler module and additional amplifying and filtering circuitry.

2. Doubler Module

The doubler module is designed in a singly balanced configuration as shown schematically in Fig. 1. The circuit is a full-wave rectifier that utilizes a balun in place of the output transformer. This approach eliminates the input balun that should be dimensioned at fundamental frequency and usually occupies significant space. The circuit utilizes a diode pair in a series tee configuration. The diodes are fed in antiphase with two 90^0 Lange couplers. The structure is essentially a Marchand balun [5] divided in two branches. The couplers together provide the overall 180^0 phase shift between the upper and lower branches in order to switch the diodes every half cycle. This configuration effectively generates the second harmonic of the incoming signal rejecting odd-order components, specifically the fundamental frequency and third harmonic.

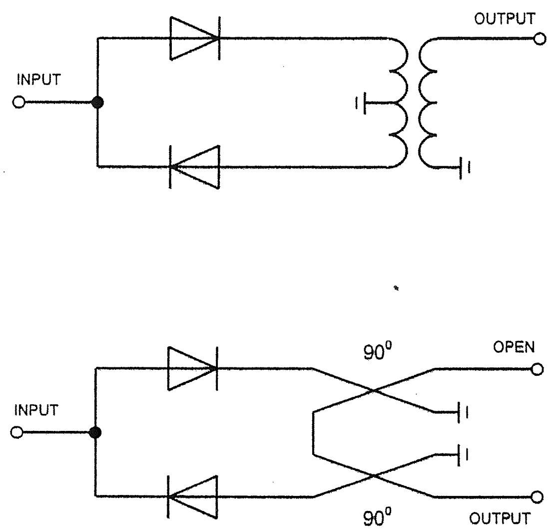

Fig. 1 Doubler module configuration: a full-wave rectifier circuit and its microwave realization

The use of separate couplers simplifies the circuit design and layout. The design procedure is straightforward. First, microstrip Lange couplers are synthesized. Then, the couplers as well as input and output matching circuits are optimized using a non-linear simulator. We use an HSCH-9501 GaAs Schottky diode chip containing a series pair tee available from Agilent. The diodes exhibit low junction capacitance and series resistance of 0.04 pF and 3 Ω respectively. Moreover, since the diodes are fabricated in a common technological process, their characteristics are internally matched.

The Lange couplers and matching circuits are printed on 10 mil alumina substrates using conventional thin-film technology. The diode chip and substrates are attached to a kovar carrier and wired with 0.7 mil gold wires.

An assembled module is placed in a test fixture and characterized at +13 dBm input power. Its performance is shown in Fig. 2.

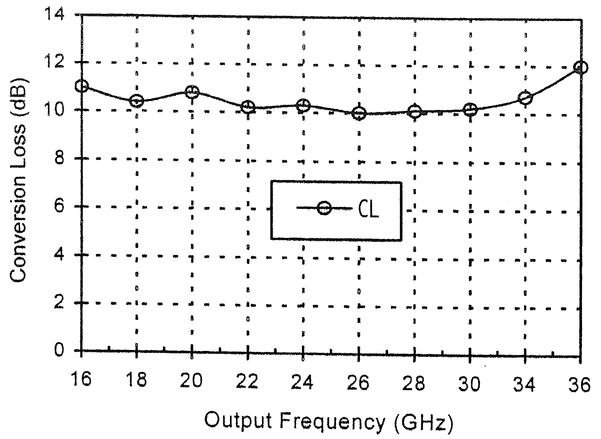

Fig. 2 Doubler conversion loss

The module demonstrates 10 to 12 dB conversion loss over 16-36 GHz output frequency range that is in good agreement with simulation results. The circuit shows good repeatability and is well-suited for integration with conventional hybrid and monolithic technologies.

3. Integrated Assembly

The doubler module is integrated with additional amplifying and filtering components as depicted in Fig. 3. The input signal is amplified with Agilent HMMC-5618 MMIC used as a buffer amplifier. The amplifier provides a sufficient power level to drive the doubler following the amplifier. The doubler output spectrum is further refined with a microstrip edge-coupled band-pass filter and then amplified by CHA3093c power amplifier MMIC available from UMS. The power amplifier is saturated to keep constant output power level over a wide range of input power. A low-pass filter removes high-order harmonics generated by the output amplifier.

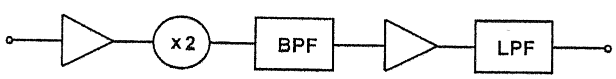

Fig. 3 Integrated frequency doubler containing additional amplifying and filtering modules

The integrated unit also incorporates voltage regulators and bias conditioning circuitry.

The modules are built on separate carriers using the thin-film technology mentioned above. They are placed into a metal housing interfacing input and output K-connectors. A photograph of the assembled frequency doubler is shown below.

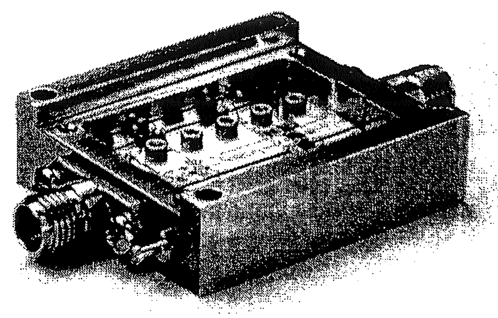

Fig. 4 Assembled frequency doubler

The longest tuning effort is applied to adjust MMIC biases as well as to tune transitions between the external connectors and microstrip environment. Special attention should be addressed to the mechanical design in order to prevent undesirable signal leakages.

4. Experimental Results

The measured output power of the integrated unit is shown in Fig. 5. The unit demonstrates very flat power response in 24 to 30 GHz frequency range.

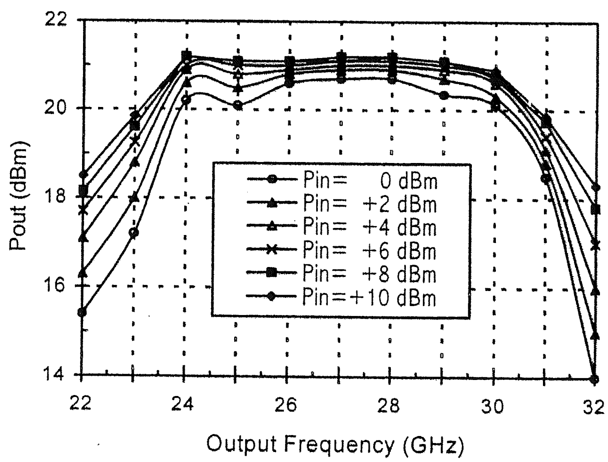

Fig. 5 Output power versus frequency and input power level

The power remains constant in 1 dB window over 0 to +10 dBm input drive level. The unit works at lower input power. However, in this case, the output power follows the input drive, since the output amplifier is not saturated. The maximum input power level is limited by absolute maximum ratings of the used devices. The frequency bandwidth is limited by the internal band-pass filter rather than the doubler module itself.

The harmonic performance at +2 dBm input power level is shown in Fig. 6.

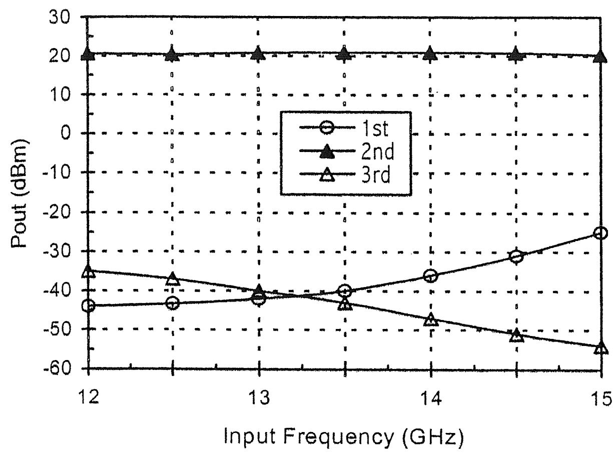

Fig. 6 Harmonic performance measured at +2 dBm input power level

We measured the worst-case rejection of 45 and 56 dBc (relative to the output signal) for the fundamental frequency and third harmonic respectively. The frequency variations are mostly due to the band-pass filter response.

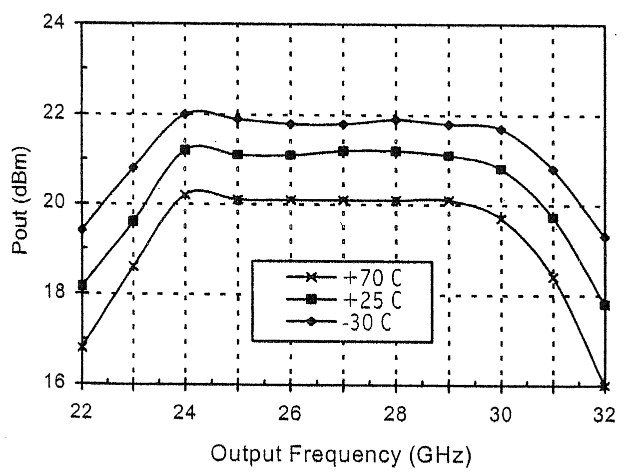

Fig. 7 Output power over temperature at +8 dBm input level

The unit keeps its performance over -30 to +70 ^{0}C temperature range with slight variations in output power as shown in Fig. 7. No temperature compensation circuit is applied.

5. Conclusion

We have designed a balanced doubler module utilizing a pair of Schottky diodes and 90^{0} Lange couplers used as a broadband output balun. The conversion loss of 10 to 12 dB is measured in excess of an octave band. The circuit demonstrates good repeatability and is well-suited for integration with conventional hybrid and monolithic technologies.

The doubler, being integrated with additional amplifying and filtering modules, demonstrates +21 dBm output power over 24-30 GHz frequency range. The power remains constant in 1 dB window over 0 to +10 dBm input drive level. The fundamental frequency and third harmonic rejection is 45 and 56 dBc respectively.

References

[1] S. Maas, The RF and Microwave Circuit Design Cookbook, Artech House, Norwood, MA, 1998.

[2] M. Faber, J. Chramiec, and M. Adamski, Microwave and Millimeter-Wave Diode Frequency Multipliers, Artech House, Norwood, MA, 1995.

[3] R. Bitzer, "Planar Broadband MIC Balanced Frequency Doublers," in IEEE MTT-S Digest, 1991, pp. 273-276.

[4] S. Maas, "A Broadband, Planar, Monolithic Resistive Frequency Doubler," in IEEE Microwave and Millimeter-Wave Monolithic Circuits Symp. Digest, 1994, pp. 175-178.

[5] M. Tsai, "A New Compact Wideband Balun," in IEEE MTT-S Digest, 1993, pp. 141-143.