MILLIMETER-WAVE DOWNCONVERTER WITH SUBHARMONIC PUMP

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ABSTRACT

Hybrid integrated downconverters which are pumped at half the frequency needed in a conventional downconverter have shown a conversion loss of 3 dB and a SSB receiver noise figure of 6.7 dB at 50 GHz. Each downconverter circuit consists of a stripline conductor pattern, a novel transition from waveguide to stripline and a Schottky barrier diode pair. The circuits can be tuned over an RF bandwidth of 20 GHz, and they can be readily scaled to frequencies up to 100 GHz.

Introduction

A new subharmonically pumped downconverter has shown a conversion loss and an RF bandwidth which is superior to the performance of previously reported integrated converters[1,2] and of conventional waveguide downconverters. The converter has the following advantages:

1. The thin film stripline medium suppresses waveguide modes at harmonics of the pump frequency.
2. The mixer can be readily tuned for single sideband or double sideband operation.
3. The pump frequency is half that needed in conventional downconverters.
4. The circuit does not require a dc return path.
5. Separation of the signal and pump frequencies is readily obtained.
6. The local oscillator AM noise sidebands are suppressed[3].

Mixers have been built at 50 GHz and 100 GHz by linearly scaling the circuit dimensions of an optimized 5 GHz model.

Circuit Description

A block diagram of the new circuit is shown in Fig. 1, and a detailed view of the stripline conductor pattern is shown in Figures 2 and 3.

The circuit consists of a signal waveguide input section, a waveguide-to-stripline transition, a stripline conductor pattern with a pair of Schottky barrier diodes, and a transition from the pump waveguide to the stripline. The waveguide-to-stripline transition, illustrated in Figure 4, can be tuned such that the converter can be operated either as a single sideband or as a double sideband mixer by adjusting the E-plane and H-plane waveguide shorts.

The incoming signal is coupled to a pair of beam-leaded diodes which are shunt mounted with opposite polarities in the strip transmission line. The diodes have a typical series resistance of 3.5 ohms, a zero bias capacitance of 0.06 pF and a breakdown voltage of 7 V at a current of 10 μA. The corresponding zero bias cutoff frequency is 760 GHz.

Two low-pass filters are needed to separate the signal frequency ω_S, the pump frequency $\omega_P = 1/2\ (\omega_S - \omega_{IF})$, and the intermediate frequency ω_{IF}. The filter which is adjacent to the diode pair has a cutoff frequency of 33 GHz in order to reject the signal (47 to 67 GHz) while transmitting the pump (22.8 - 32.8 GHz) and the IF (1.4 GHz). The second low-pass filter rejects the pump and transmits the IF. The thin-film chromium-gold conductor patterns are deposited on fused quartz substrates using standard photolithographic processing techniques.

Performance

The measured conversion loss and the single sideband noise figure of the receiver including a 3.7 dB IF noise contribution are shown in Figure 5. A best conversion loss of 2.7 dB and a total SSB noise figure of 6.7 dB is obtained at 50 GHz. The conversion loss is determined by direct power measurements at 50 GHz and 1.4 GHz. The noise measurements are made with both a calibrated waveguide noise source and by standard hot-cold load techniques. The agreement is within 0.4 dB. The mixer noise ratio is given by[4]

$$N_R = 1 + \frac{F_{SSB} - LF_{IF}}{L} \qquad (1)$$

Where F_{SSB} is the total SSB noise figure, F_{IF} the IF noise figure and L the conversion loss of the mixer. The mixer noise ratio obtained at 50 GHz for a local oscillator pump level of +11 dBm is 1.17. The single sideband noise figure and the conversion loss as a function of frequency are plotted in Fig. 6. Each point is obtained by adjusting the position of the backshort in the pump waveguide for minimum noise figure.

The measured instantaneous IF bandwidth of the mixer, tuned for optimum noise figure, is 400 MHz for a total variation of 0.5 dB. The circuit is thus useful as a front end in digital communication systems with modulation rates of up to 300 Mbaud. The mixer also exhibits excellent pump-to-signal port isolation. The pump frequency is totally suppressed since it is below cutoff in the signal waveguide. The measured output power at the second harmonic of the pump frequency is 34 dB below the input power at the pump port. The third harmonic is suppressed by better than 28 dB.

Conclusions

It has been demonstrated that mixers with very low noise figures can be fabricated using a combination waveguide-stripline thin film circuit. These mixers have shown better performance than microstrip mixers and conventional waveguide downconverters. The circuits can be readily scaled to other frequency bands. Preliminary measurements on a mixer built for a signal frequency of 87 GHz have resulted in a conversion loss of 4.3 dB.

Acknowledgment

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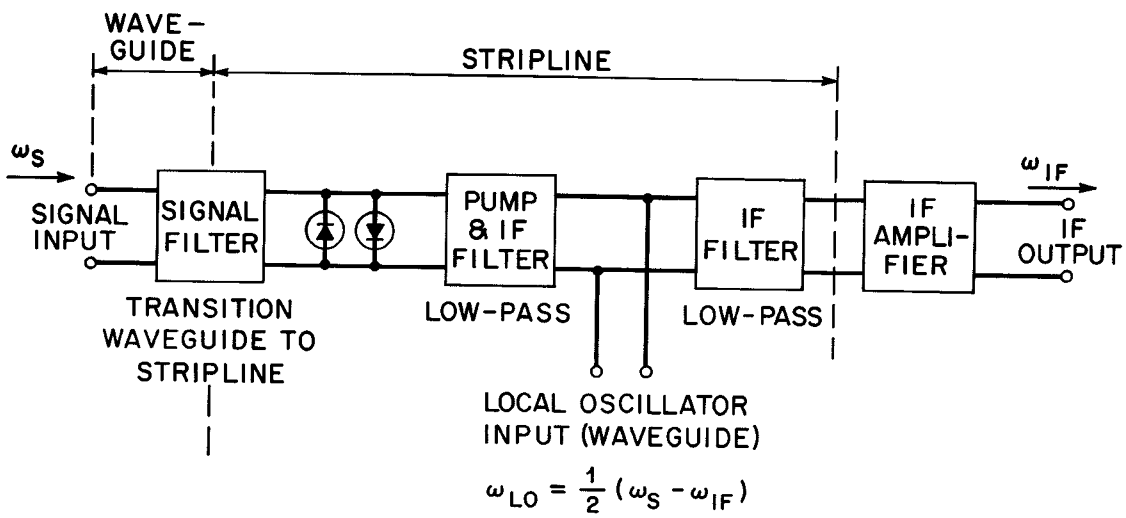

Figure 1: Block diagram of the receiver. The signal filter is a special transition from waveguide to stripline shown in Fig. 4. The stripline circuit includes two low-pass filters and a pair of Schottky barrier diodes. The pump is coupled to the stripline from a waveguide input as shown in Fig. 2.

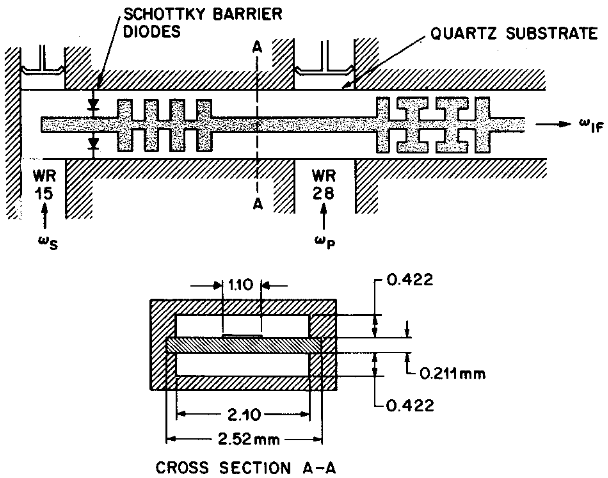

Figure 2: Top view and cross-sectional view of stripline circuit with signal and pump waveguide input ports.

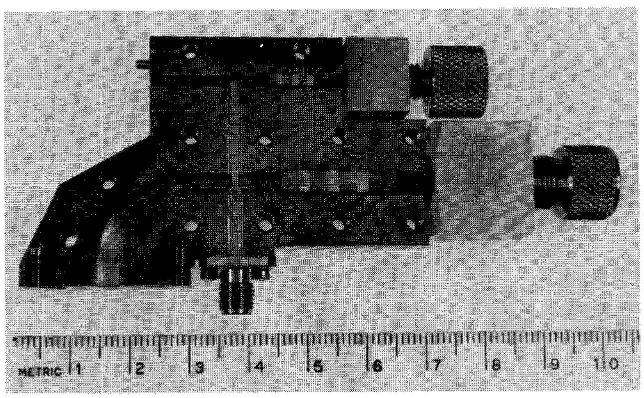

Figure 3: Photograph of downconverter. The top cover of the housing is removed to show the conductor pattern on the quartz substrate.

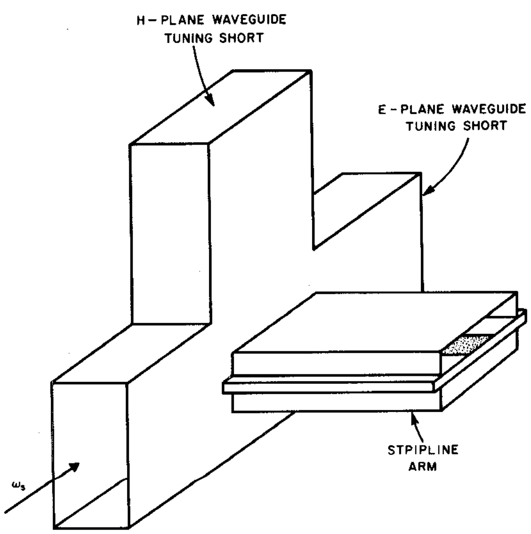

Figure 4: Transition from signal waveguide to stripline circuit with an E-plane and an H-plane tunable short for matching the signal and rejecting the image frequency.

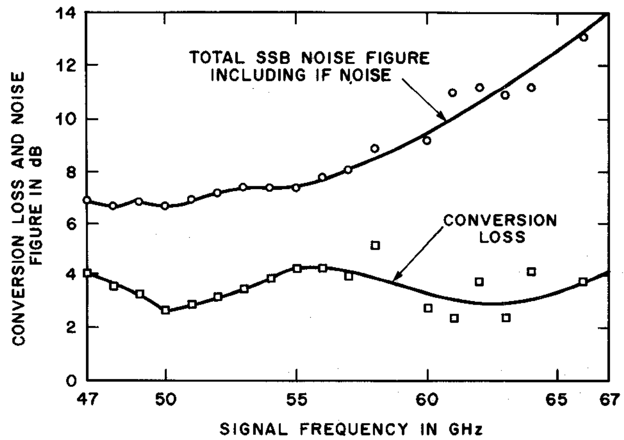

Figure 5: Total single sideband noise figure including a 3.7 dB IF noise contribution, and conversion loss of the downconverter as a function of frequency from 47 to 67 GHz. The data points are obtained by adjusting the tunable shorts for optimum noise figure at each frequency.

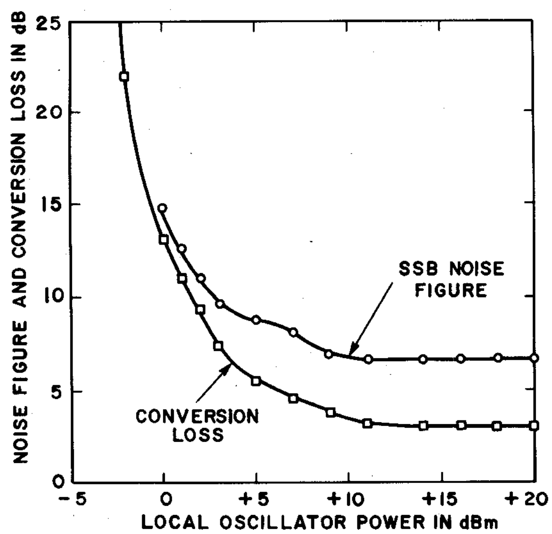

Figure 6: Conversion loss and SSB noise figure of the downconverter at 50 GHz as a function of the pump power of the subharmonic local oscillator. The conversion loss at a pump power of +11 dBm is 2.7 dB.