DESIGN OF A RUGGED MILLIMETER-WAVE DOUBLER USING A SERIES VARACTOR CONFIGURATION

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ABSTRACT

An efficient planar microstrip doubler to 48 GHz employing a novel series varactor configuration has been developed.

The nominal conversion loss of the multiplier is 8 dB when driven by 200 mW. Measured performance over -60 to +100°C shows ±1 dB variation in the output power. Several units have been thoroughly tested under vibration with 100% survivability.

This design represents a very cost effective and simple planar doubler realization for application in future advanced EW systems.

INTRODUCTION

Many designs for millimeter-wave multiplier realizations in waveguide (using packaged or point contact varactors) have been previously reported. These multipliers do not exhibit mechanical characteristics which would allow them to survive harsh thermal or vibrational environments. In addition, they are costly to machine and require considerable assembly/tuning effort in order to achieve repeatability. They have, however, demonstrated low conversion loss and broadband performance in less demanding environments.

It is expected that planar technology would provide a mechanically rugged realization of the multiplier. One approach to this is to implement resistive devices [1], which generally result in lower efficiency and output power, or the use of monolithic techniques [2] in which engineering costs are high. A more practical approach is to apply hybrid microwave integrated circuitry utilizing a shunt [3] or series varactor diode. A series configuration using chip devices avoids the need for holes to be drilled in the substrate (required for shunt mounting) and utilizes only a single stitch bond. This results in better repeatability, ruggedness and reduced assembly costs. As a result, a planar microstrip multiplier with a series mounted varactor chip was the focal point of this design effort.

VARACTOR DEVICE

In general, varactors are selected based on their frequency of operation. A device with a high cut-off frequency will usually have a lower series resistance and junction capacitance. This will allow for higher frequency operation with reduced intrinsic conversion loss.

The breakdown voltage of the device must be closely matched to the driving voltage swing so that the device can be operated at maximum efficiency without the risk of device failure. The input power for a particular varactor operating at a specific frequency can be calculated from [4].

For this application, a varactor was selected with a cut-off frequency of greater than 900 GHz. The device exhibits a zero bias junction capacitance of 0.25 pF and a series resistance of less than 2 ohms. The breakdown voltage of the varactor was selected to be about 25 V. This breakdown voltage results in an input drive level of about 200 mW at 24 GHz [4].

MULTIPLIER DESIGN

The circuit layout for the doubler is shown in Figure 1. Isolation between the two ports of the multiplier is provided by the input lowpass filter and output stub filter. The impedance matches on the input and output sides of the diode are provided by quarter-wave impedance transformers and phasing of the rejection filters. The input and output impedances of the varactor were calculated in a straightforward manner using [4].

The input lowpass filter passes the input signal with less than 1 dB insertion loss and provides 40 dB rejection at 48 GHz. The output filter is a simple narrowband stub filter which passes the 48 GHz component and provides greater than 30 dB rejection at 24 GHz.

The filters are phased so as to provide the proper reactive termination at the diode for the 24 GHz and 48 GHz signals. Taking the effective bond wire inductance into account during simulation is difficult to do accurately. As a result, some alteration of the bond wire length was required to arrive at the final design.

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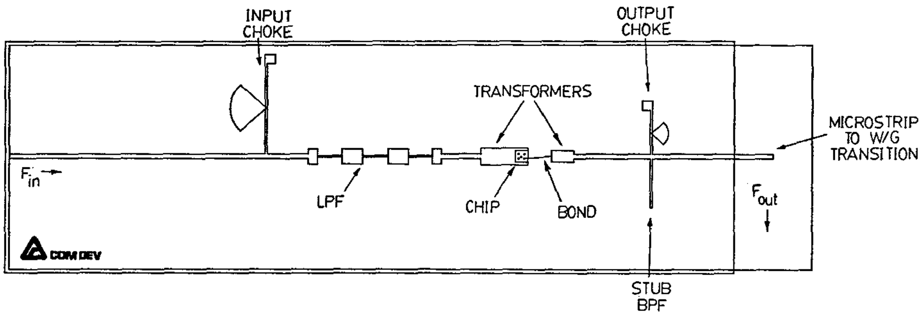

Figure 1 : Doubler Circuit Layout

The input signal enters the multiplier directly on the microstrip and the 48 GHz component is extracted through waveguide which is cut-off to the input signal frequency. The microstrip to waveguide transition is a simple narrowband transition which incorporates a 50 ohm probe half-way into the waveguide E-plane. As much of the substrate material (alumina in this case) was removed from the waveguide as possible to reduce the transition losses.

The multiplier was realized on 0.005" thick alumina mounted on a gold plated kovar carrier. The circuit dimensions are 0.65" x 0.24". A photograph of the assembled doubler is shown in Figure 2.

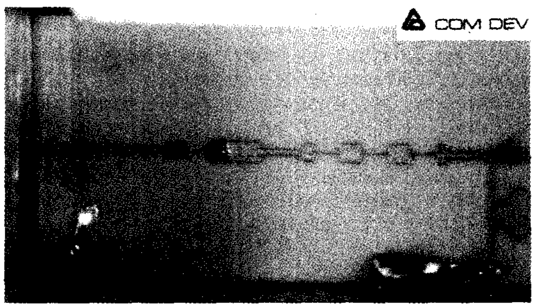

Figure 2 : Assembled Series Doubler in Test Jig

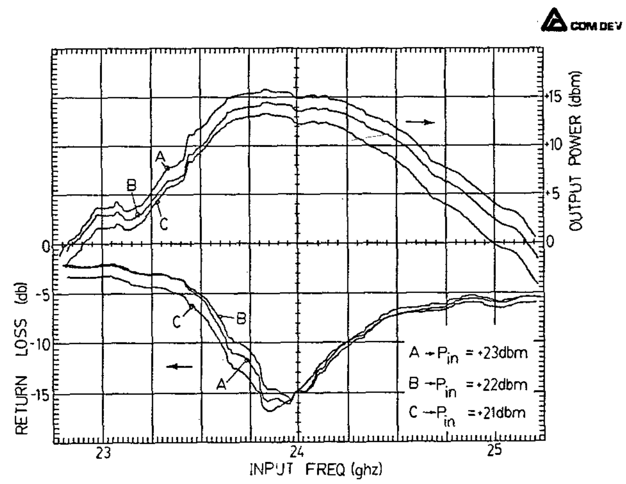

Figure 3 : Output Power and Input Return Loss Vs. Frequency (With Fixed Backshort)

RF PERFORMANCE

The output power of the doubler as a function of frequency for various drive levels was measured and is shown in Figure 3. This figure also shows the input return loss of the multiplier.

Four complete units were assembled and tuned to examine the overall repeatability of the design. These four units showed similar power output and input return loss characteristics. The maximum variation in output power between these four multipliers was ±1 dB at 24 GHz and ±4 dB in input return loss.

The levels of the pump signal and the third harmonic in the output spectrum are at least 30 dB lower than the desired second harmonic output signal.

ENVIRONMENTAL TESTING

The multiplier performance was measured over the -60 to +100°C range in a nitrogen environment. The output power dropped approximately linearly up to 1 dB at the high temperature extreme and increased approximately linearly up to 1 dB at the lower extreme.

In addition, several of the doublers have been tested for vibrational survivability. The tests involved X, Y and Z axis testing on a resonance free jig at levels of 30 g sine and 24 g rms random vibration for 30 minutes. All of the units tested to date have been fully operational after this testing.

CONCLUSIONS

A series diode microstrip doubler employing a commercially available varactor diode has been developed using hard substrate technology in Q-band.

The multiplier exhibited a conversion loss of less than 8 dB. Temperature testing over the -60 to +100°C range showed an output power variation of ±1 dB. In addition the design has exhibited its ability to withstand 30 g sine and 24 g rms vibration without failure.

In addition, the design is simple, cost effective to produce and repeatable in RF performance.

ACKNOWLEDGEMENTS

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