Gilbert Cell Multiplier Measurements
III: Response from 2-30 GHz

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1 Overview and summary

This note summarizes a set of measurements of Steve Maas' wideband Gilbert Cell multiplier over an extended frequency range of 2 to 30 GHz. It also includes an investigation of the effect of terminating the unused multiplier inputs on the chip instead of leaving them open circuits, as was the case for the 2–18.5 GHz results from the probe station. The basic results are that the multiplier response remains high to 27 GHz, and that the performance is slightly better with the unused inputs left open.

2 Setup

The test fixture is compact to allow short connections to external equipment. Its geometry also allows tests involving wire bonds on the MMIC surface. Figure 1 shows the fixture: a brass block with Amphenol 901-9804-1 SMA connectors and alumina microstrip lines to the chip. The chip and microstrip lines are epoxied to the block with Bondline 2900 conductive epoxy; the SMA center pin is a friction connection to the lines. Dual 1 mil diameter aluminum wire bonds, 22 mils long, connect the chip to the microstrip lines. These lines are 9.7 mil wide on 50 mil wide, 10 mil thick alumina substrates, 130 mils long. Further wire bonds between the chip and Metal Processing Co. Inc. model MP-1493 hermetic feedthroughs carry DC bias in and the IF signal out.

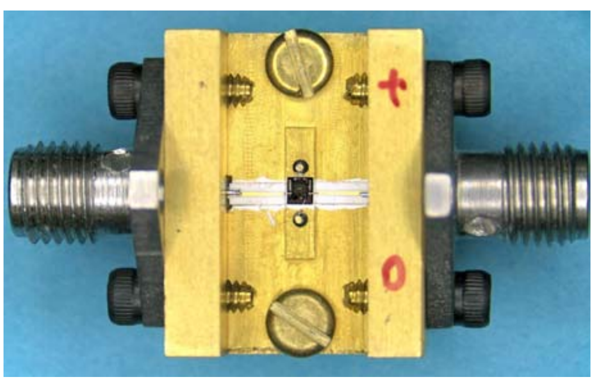

Figure 1: Top view of multiplier test block. The multiplier chip is the black square in the center.

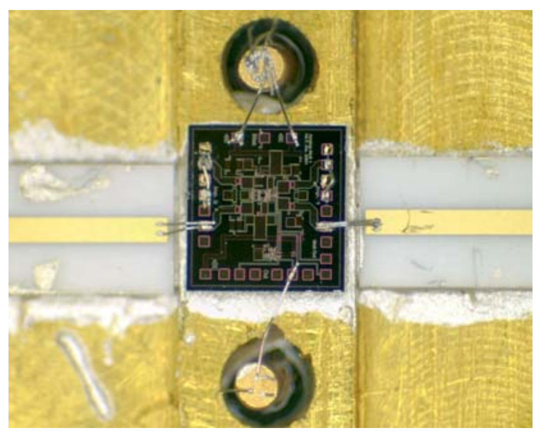

Figure 2: View of multiplier chip and bond connections.

This prototype block has minor machining and assembly errors, most notably a pilot hole (filled with epoxy) below the mixer chip, some stray epoxy on the microstrip substrate (Figure 2, left side), and wirebond tails that are a little long. The additional epoxy filling the pilot hole under the chip raised the chip above its design position by a few mils.

Figure 3 is an overview of the test assembly for measurements from 2 to 18 GHz. The doubler, 20 dB pad, and one SMA male-male transition were removed for measurements below 18 GHz. The cw output of an Agilent 8722D network analyzer provided input to one side of the multiplier. A signal from an HP 8671B 2–18.5 GHz synthesizer, doubled for frequencies above 18 GHz, provided the other input. An offset to synthesizer frequency produced a difference signal near 50 kHz. An SRS 770 spectrum analyzer provided an accurate measurement of the beat note amplitude.

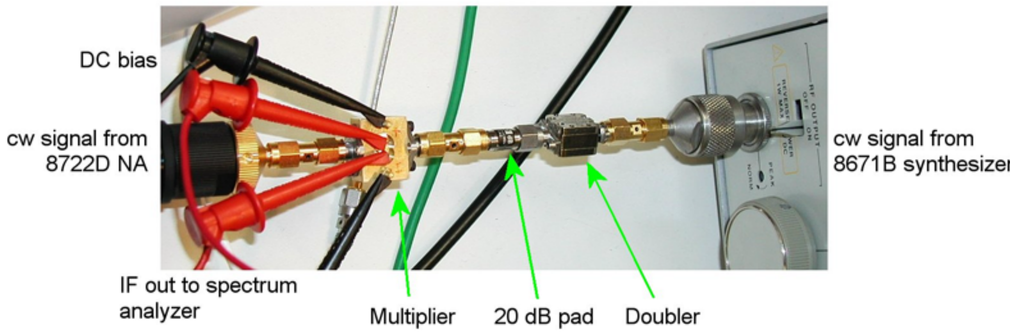

Figure 3: Test setup showing input and output signal connections.

The nominal input signal level was near –25 dBm for all measurements. The Marki Microwave D-0515 doubler is specified for operation with a +10 dBm input level; with an 11 dB specification on insertion loss (Figure 4), a 20 dB pad brought the signal level to about -21 dBm. The pad is specified for use to 18 GHz, but a quick check on the network analyzer showed that S_{21} is still flat to at least 24 GHz. Earlier measurements showed that the output power levels from the synthesizer and network analyzer were flat within ±0.5 dB to 18 GHz. Rather than continue the calibration beyond the power head's frequency range, it seemed better to rely on the doubler's specifications (Figure 4) and align the two measurement sets with a constant factor derived from data taken both with and without the doubler every 2 GHz from 12 to 18 GHz.

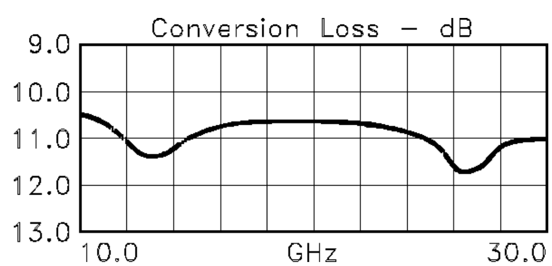

Figure 4: Conversion loss from Marki D-0515 doubler data sheet.

3 Results

Figure 5 shows all of the data, with a 2.45 dB correction factor between the doubler data with the low frequency data. This factor is the average ratio of measurements with and without the doubler between 12 and 18 GHz for the chip with one of the differential inputs on each side left open (square points). With a set of measurements over the full band in hand, I then bonded wires between the open inputs and the termination pad on the chip (round points in Figure 5; also Figure 2). There is not a large difference between the two cases, but the configuration with open unused inputs has somewhat less gain variation with frequency. The multipliers continue to work well to about 26 or 27 GHz, and then the gain drops rapidly. Most of the gain shape is a slope that could conceivably be removed with a gain equalizer.

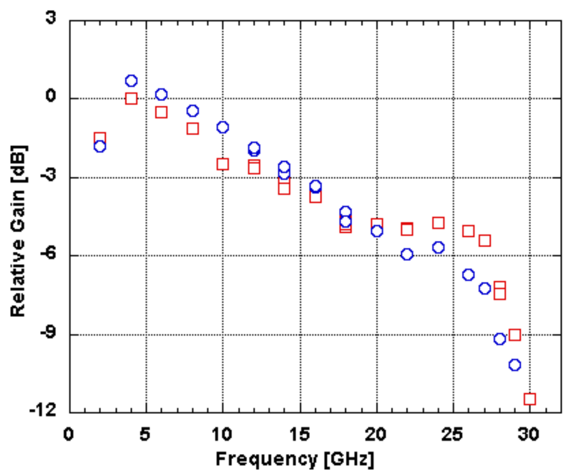

Figure 5: Multiplier responsivity versus frequency. All scaling factors are fixed for these measurements. Squares denote open unused inputs; circles are inputs terminated on the chip. Dual data points from 12 to 18 GHz point show the accuracy of a constant scaling factor.

The chips seem to work better with the unused inputs just left open, or at least not terminated as I did it (it was hard to get the wire to loop up over the ground pad on one side, so there may be more fringing capacitance to ground than there should be). The response up to 18 GHz looks the same as it did in the probe station, so there are probably no gross errors in fixturing. Line lengths were short enough that transmission losses will be small, and the overall calibration is probably good to ±1 dB or better, adequate for this measurement. Relative calibration between the two curves is better than that.

A measurement of output noise with only the power supply and spectrum analyzer connected gave 395 $nV_{rms}/\sqrt{Hz}$, lower by a factor of 0.57 from the mean value reported in the Multipliers II note. It is possible that this is a better value for the noise since the grounds are cleaner in the test fixture than in the probe station. The responsivity was also low, by a factor of 0.77 of the mean. Since responsivity and noise scale together, the drop in noise is not quite as large as it might first appear, but it is possible that the intrinsic multiplier noise is closer to 520 $nV_{rms}/\sqrt{Hz}$ than to 700 $nV_{rms}/\sqrt{Hz}$, about a 1 dB gain in dynamic range.