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# Adapt Your Equipment to Operate at Millimeter Waves up to 32 GHz

*Start exploring millimeter waves on a modest budget by adding a prescaler and doubler to your test equipment.*

The use of millimeter waves in wireless communications has a long history, evolving from over more than a century ago, when Guglielmo Marconi developed the first wireless telegraph communication systems in 1896 and when Father Roberto Landell de Moura publicly demonstrated a wireless broadcast of the human voice in 1900.

Today, research in radio communications is focused at frequencies above 10 GHz, mainly in SHF and EHF bands or millimeter-wave bands where the wavelength λ is between 1 and 30 mm. Amateur Radio frequency allocations in that range include 8 bands between 10 GHz and 241 GHz, and all above 275 GHz. I present two projects here. The first is a divide-by-4 prescaler circuit that operates in the 10 to 28 GHz range and can extend the upper frequency range of a frequency counter. The second is a frequency doubler with an output frequency range of 24 to 32 GHz. It extends the frequency range of an RF signal generator and has an output power of +21 dBm. Figure 1 shows the divide-by-4 prescaler (left) and the frequency doubler (right).


**Figure 1 — Prescaler (left) and multiplier (right).**

## The Prescaler

The heart of the divide-by-4 prescaler is the HMC447LC3 MMIC[1] from Analog Devices. The HMC447LC3 is a regenerative divider implemented in InGaP GaAs HBT (heterojunction bipolar transistor) technology that improves the noise and the ability to work in high frequencies. The HMC447LC3 is housed in a 3 mm by 3 mm leadless SMT package, and consumes just 96 mA from a single positive 5 V supply. It delivers a very flat output power across the rated bandwidth. Figure 2 shows the input

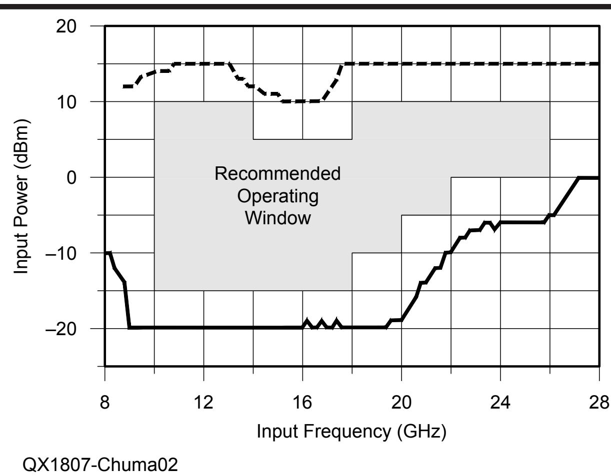


**Figure 2 — Input sensitivity window of the HMC447LC3.**

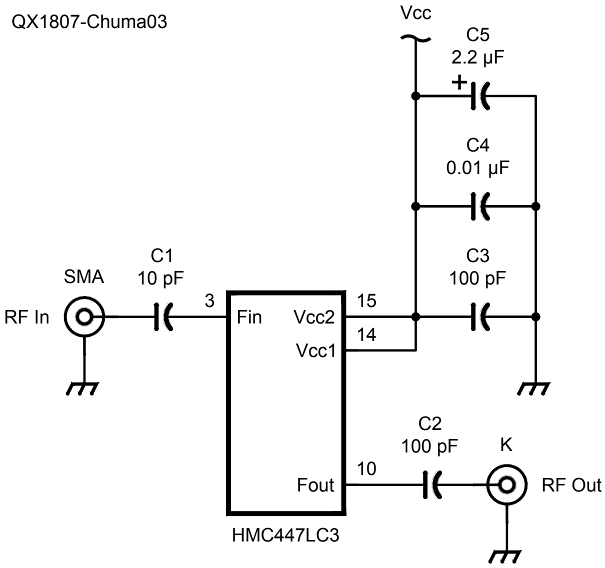


**Figure 3 — Schematic circuit of the prescaler using the HMC447LC3. The package base is ground.**

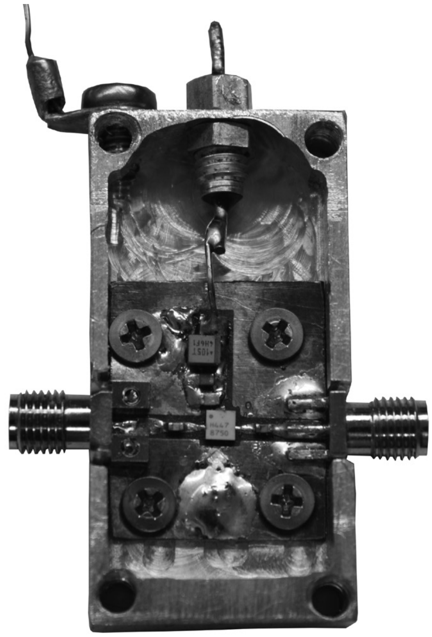

**Figure 6 — Assembled prescaler in a machined aluminum housing.**

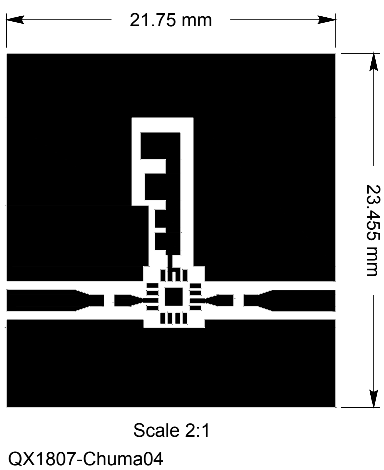


**Figure 4 — PCB layout of the prescaler.**

sensitivity window of the HMC447LC3.

Figure 3 shows the very simple schematic circuit needed to use the HMC447LC3. This apparent simplicity hides the physical difficulties in the assembly of the project. Special attention is needed with the PCB, which must have a very low loss dielectric material able to operate at these extremely high frequencies. I used[2] Rogers RT/duroid® 5870 with a thickness of 0.020 inches and 1/2 oz copper on both sides. It is very important to use proper microstrip line to connect the HMC447LC3 to the connectors. The PCB layout is shown in the Figure 4, note that the package base is ground.

Special attention also is necessary for the connectors on input and output of the circuit at these frequencies. I used a 2.92 mm (Figure 5) edge mount type connector, Hirose model[3] HK-LR-SR2. The 2.92 mm connector works up to 40 GHz. That is important because the input frequency of the prescaler operates up to 28 GHz. I used a common SMA edge mount connector at the output. It must operate up to 7 GHz.

I made the aluminum housings using a bench drill machine with end mill cutter, and exercised plenty of patience! I used a

**Figure 5 — This 2.92 mm connector can be used at higher frequencies (up to 40 GHz) than an SMA connector.**

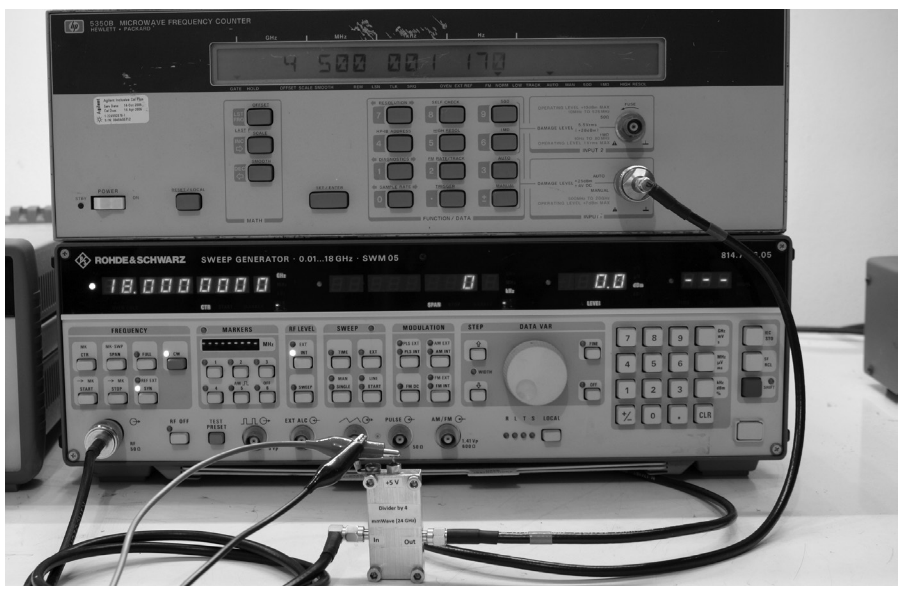


**Figure 7 — Testing the prescaler with 18 GHz input and 4.5 GHz output signals.**

feed-through by-pass capacitor in the $V_{CC}$ supply to control interference. Figure 6 shows the prescaler assembled in the aluminum housing. Figure 7 shows the prescaler being tested with an 18 GHz input signal (lower sweep generator display) and an output signal of 4.5 GHz (upper frequency counter display).

## The Multiplier/Doubler

I based the multiplier/doubler circuit on the HMC942LP4E from Analog Devices[4]. This device uses GaAs pHEMT technology. When driven by a +4 dBm signal, it provides output power of between +13 dBm and +20 dBm from 24 to 32 GHz. Figure 8 shows the output power, with +4 dBm drive level, *vs*. frequency at three temperatures.

The HMC942LP4E is housed in a 4 mm by 4 mm leadless SMT package. Figure 9 shows the schematic circuit to use the HMC942LP4E. Figure 10 shows the PCB layout including the microstrip lines to connect the HMC942LP4E to the connectors.

The multiplier/doubler is very similar to prescaler in the construction details. This PCB also uses the Rogers RT/duroid 5870 with a thickness of 0.020 inches and 1/2 oz copper on both sides. The input connector is a common edge mount SMA and the output connector is the 2.92 mm edge mount connector HK-LR-SR2 from Hirose. The assembled multiplier in its milled aluminum housing can be seen in Figure 11. Figure 12 shows the multiplier with an input signal of 13 GHz (lower display) and an output signal of 26 GHz (upper display).

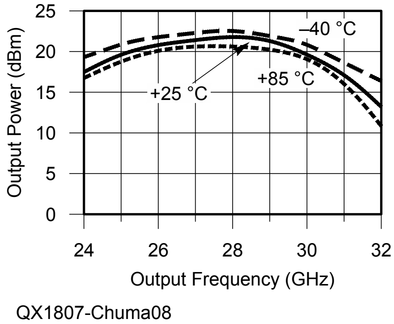


**Figure 8 — Output power *vs.* frequency and temperature with +4 dBm drive level to the HMC942LP4E.**

## Next Steps

I now have the capability to generate and measure signals up to 32 GHz, so my next steps are to develop high pass filters to pass only signals above 18 GHz, and finally develop a harmonic mixer capable of operating above 18 GHz to couple to the spectrum analyzer. I've reached 32 GHz, and my next challenges are at 40 GHz, 50 GHz, 60 GHz and beyond.

*Euclides Lourenço Chuma, PY2EAJ, earned a degree in mathematics from UNICAMP in 2003, a graduate degree in Network and Telecommunication Systems from INATEL in 2015, and MSc in Electrical*

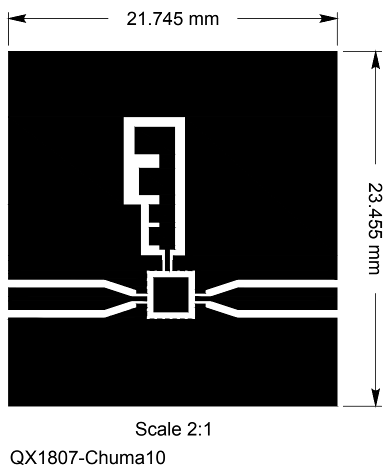


**Figure 10 — PCB layout of the multiplier.**

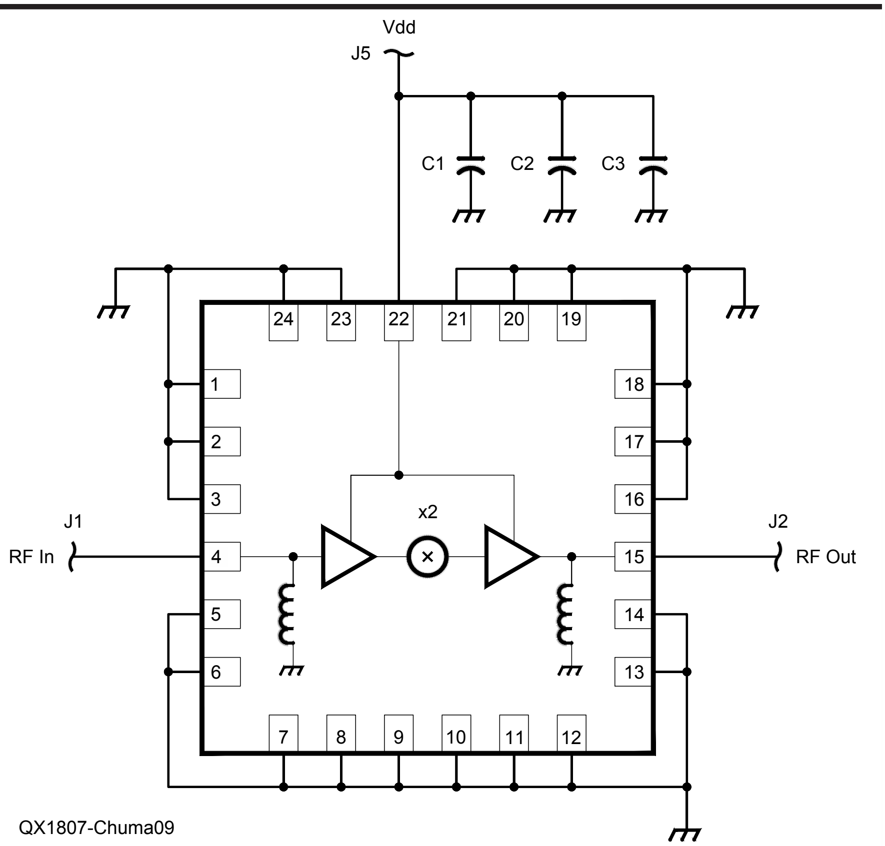


**Figure 9 — Schematic circuit of the multiplier using the HMC942LP4E. C1 is 100 pF, C2 is 1000 pF and C3 is 4.7 µF**

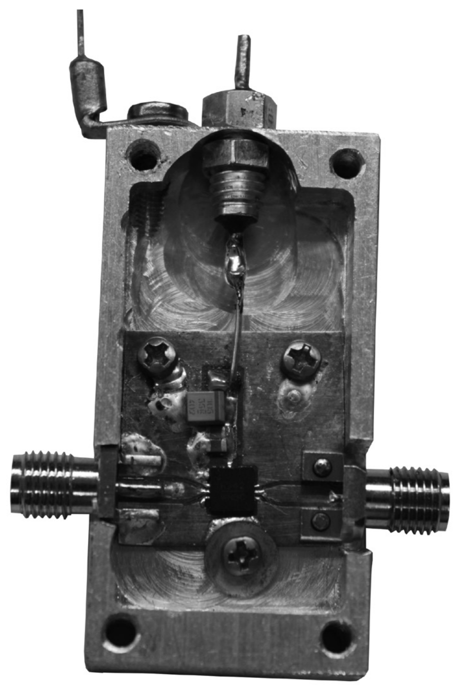

**Figure 11 — Assembled multiplier/doubler in a machined aluminum housing.**

*Engineering from UNICAMP in 2017. He is currently a PhD Candidate in Electrical Engineering at UNICAMP, SP-Brazil. His research interests are antennas, microwave, millimeter-waves, wireless power transfer, software defined radio and cognitive radio.*

## Notes

[1]Analog Devices HMC447LC3 datasheet, **www.analog.com/media/en/technical-documentation/data-sheets/hmc447.pdf**.

[2]Rogers RT/duroid 5870 datasheet, **https://www.rogerscorp.com/documents/606/acm/RT-duroid-5870-5880-Data-Sheet.pdf**.

[3]Hirose HK-LR-SR2 datasheet, **https://www.hirose.com/product/en/products/2.92mm/HK-LR-SR2**.

[4]Analog Devices HMC942LP4E datasheet, **www.analog.com/media/en/technical-documentation/data-sheets/hmc942.pdf**.

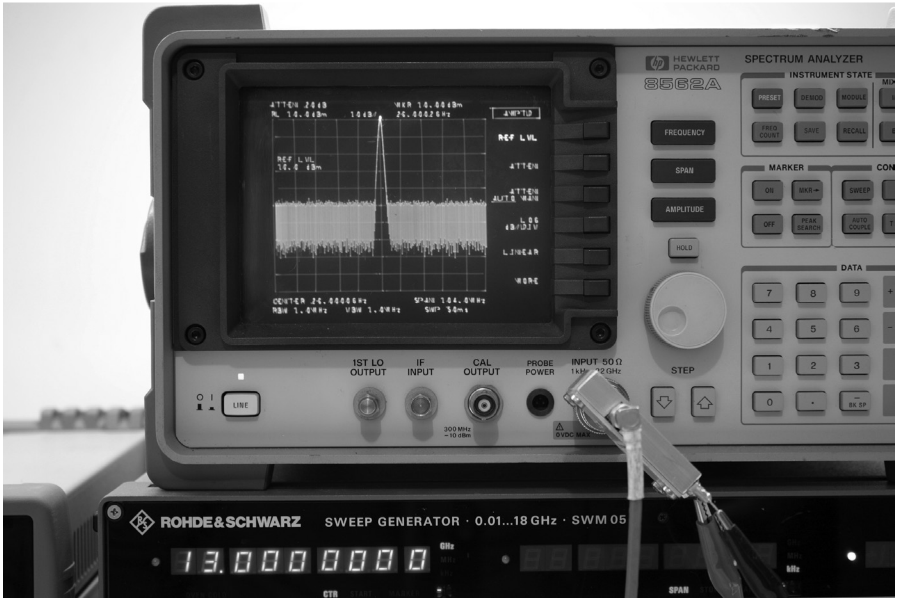


**Figure 12 — Testing the multiplier shows13 GHz input and 26 GHz output signals.**