Investigating the Extended Frequency Range of the WA1MBA Millimeter Wave Quadrupler

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Introduction

This brief paper discusses a qualitative investigation into the usable frequency range of the active millimeter wave quadrupler [1] produced by Tom Williams, WA1MBA. These quadruplers, the design and production of which were discussed at Microwave Update 2018 [2], and 2023 [3], are specified to operate with an input frequency range of 10 GHz to 12.5 GHz, and an output range of 40 GHz to 50 GHz. They may be used to construct beacons or CW transmitters in the 47 GHz amateur band. Other potential uses include local oscillators (LOs), test equipment, science experiments, and further multiplication to higher bands.

Having purchased a quadrupler, I ran some basic tests with a Kuhne MKU LO 8-13 PLL-2 synthesizer, a coaxial attenuator, a Hughes Q band power detector (45772H-11), and an HP 432A power meter. I was seemingly able to detect strong signals significantly outside the specified range of the device, although these measurements were also pushing beyond the specifications of the power detector, and were limited by the range of the signal source (which has a gap between 6.85 GHz and 8.4 GHz, and an upper limit of 13.6 GHz). Of course, none of this equipment was calibrated.

I was also unsure of what was being measured by the power head when running equipment out of specification: was it the expected output signal, or perhaps only mixing products or other spurious signals? Intrigued, I decided to try and characterize the full useful range of the quadrupler, drawing upon the resources of the local microwave community [4], and Ebay.

Quadrupler Overview

The WA1MBA quadrupler specifications are as follows:

Parameter	Minimum	Maximum	Notes
Input Frequency	10 GHz	12.5 GHz	
Output Frequency	40 GHz	50 GHz	
Input Level	3 dBm	8 dBm	5 dBm nominal.
Output Level	5 dBm	12.5 dBm	Peak in 47 GHz band.
Power Supply	6 VDC	13 VDC	Nominal 160 mA. Use 8 VDC if beacon.
Operating Temperature	-	40 C	25 C nominal.

There is typically some conversion gain: nearly 6 dB in the amateur 47 GHz band.

The device’s RF path consists of two active frequency doublers, as follows:

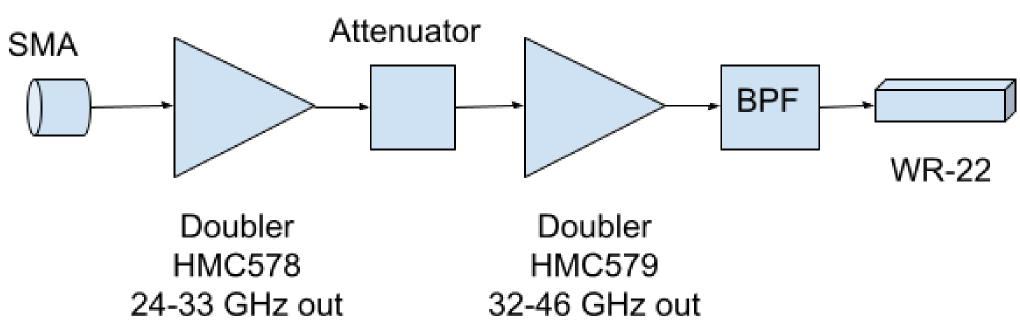


Fig. 1: RF block diagram.

Per the quadrupler design specification, source signals in the range 10-12.5 GHz are input via an SMA connector. These signals are then doubled to the 20-25 GHz range. An attenuator ensures the signal level is correct for the next stage, which doubles again to the 40-50 GHz range. For full implementation details, see the MUD 2018 presentation video [2]. Note that a BPF following the first doubler was disabled in the production version, which helped increase final output levels, according to an email discussion with Tom, WA1MBA. It is not included in the diagram above.

Both doubler chips operate significantly beyond their published descriptions. Testing by Tom indicates that the final version of the device provides a fairly consistent output from 40 to 50 GHz, around 10 dBm, when driven at 5 dBm, and with a peak at 47 GHz. The following is a chart from his MUD 2023 report [3], representing “an overlay of 8 typical units at +5 dBm input”.

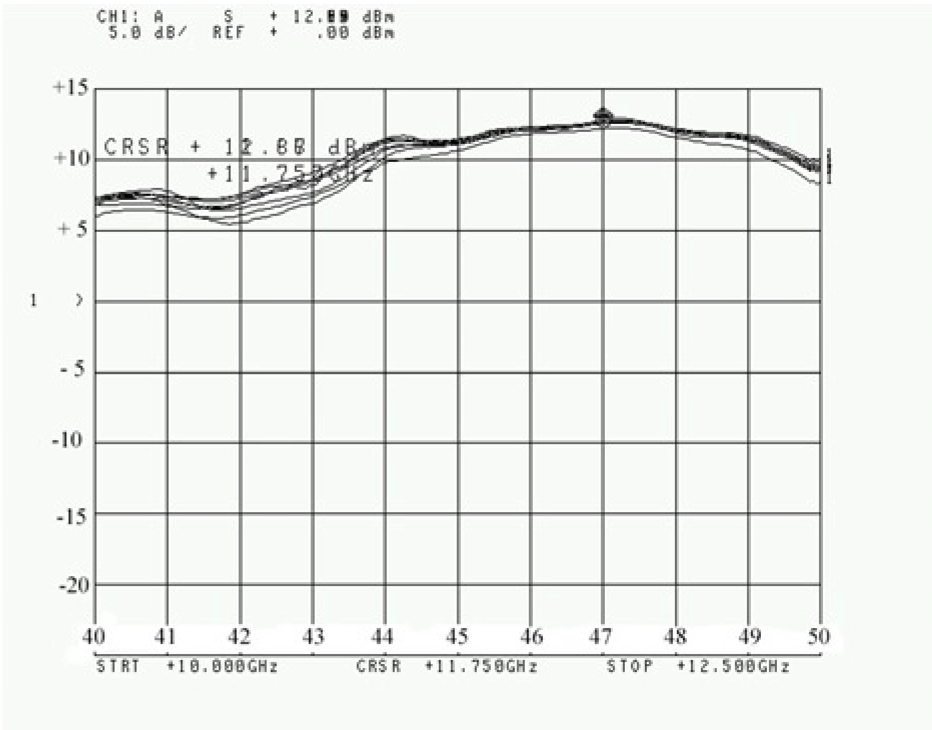


Fig. 2: Test results from WA1MBA.

Viewing this chart, I wondered how much further the range of the device might extend in each direction. The data sheet for the HMC579 chip [5] indicated some output reduction (see Fig. 3), with more at the lower end, but perhaps still useful for amateurs.

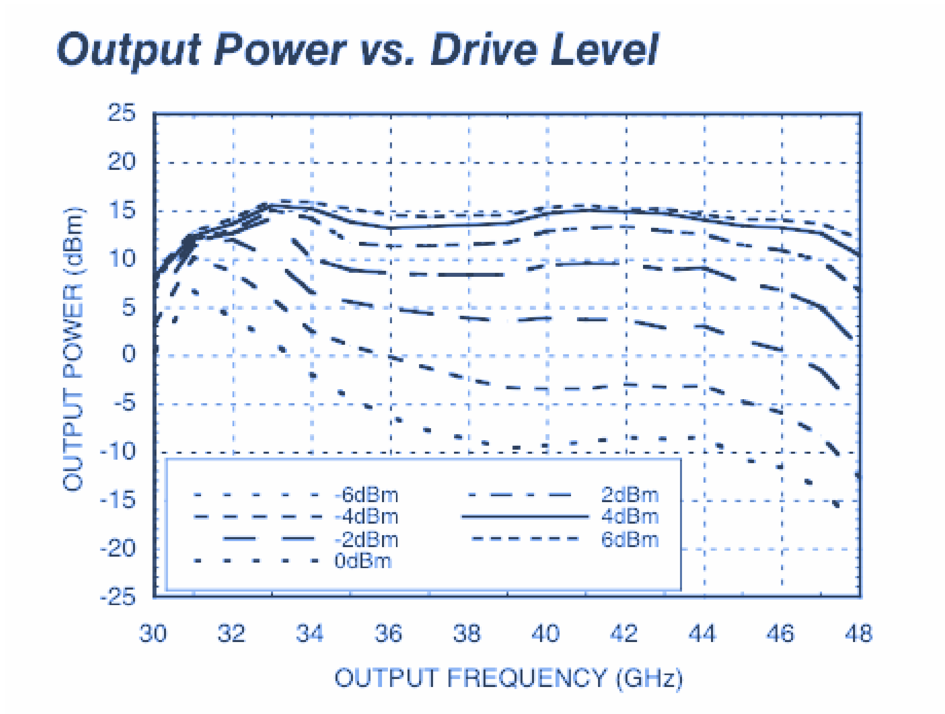


Fig. 3: HMC579 datasheet.

Method: “If you can see them, you can work them”

I figured that amateur experiments in the millimeter bands, that being able to easily see a signal on a common spectrum analyzer would make a good test of whether the signal is *useful*.

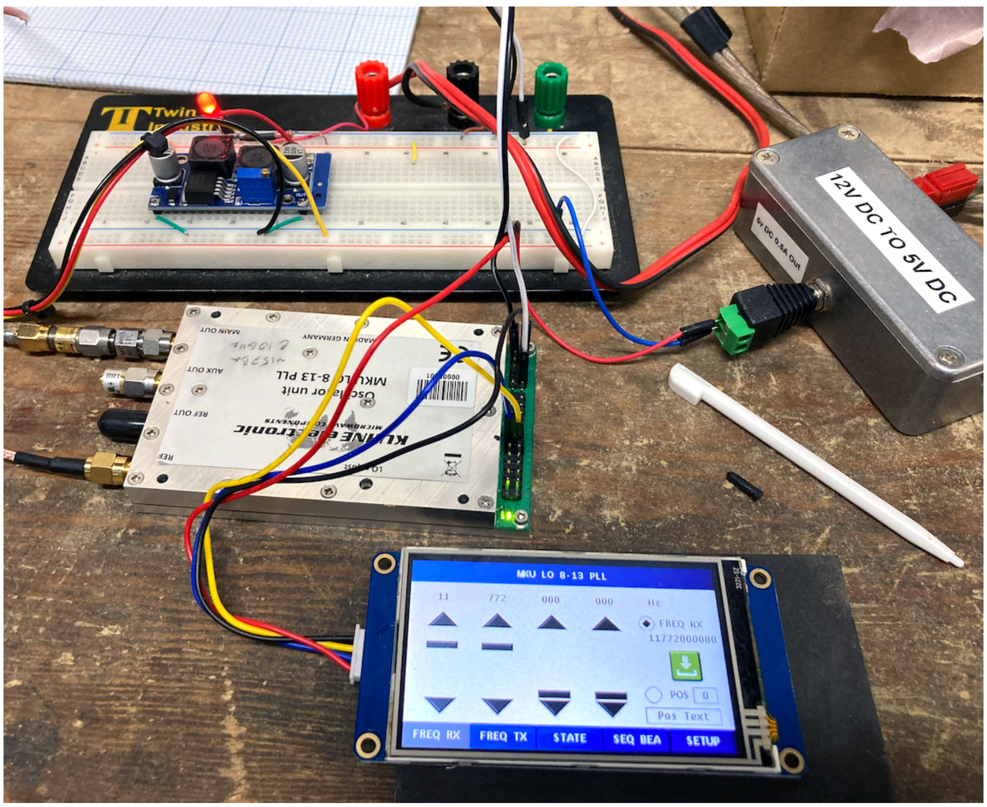
Presumably, if you can generate a signal and then receive it across the bench with a typically decades-old piece of test gear (as wonderful as it still is today), that you could conceivably communicate with another amateur over some distance, especially with gain antennas, weak signal modes, and modern LNAs. Such a signal, even if weak, might also be suitable for mixing and further multiplication or amplification, depending on the application.

With available technical resources, the idea was to vary the input signal in steps over a wide frequency range, and verify that the output signal, if present, was indeed what we were expecting at 4x the input frequency. We would employ Tektronix 49X spectrum analyzers with harmonic mixers to extend their ranges. These analyzers have an “Ident” function, which removes known spurious signals from the display, which we would utilize to validate that the observed output was not a mixing product or other spurious signal.

This experiment would be, of course, purely qualitative.

First Experiment

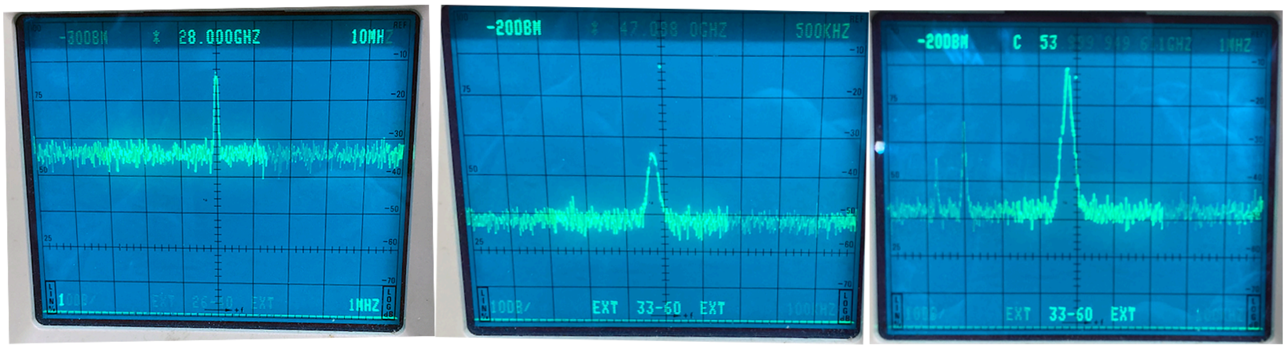
Lacking a suitable spectrum analyzer, I reached out to other members of the Pacific Northwest Microwave group [4], and Ray Cannon W7GLF volunteered to lug his Tektronix 494AP spectrum analyzer to a fortnightly build day. We set up the Kuhne synthesizer as the source, fed into a Philips harmonic mixer, then to the 494AP via a short length of WR-22 waveguide. Both the 494AP and the synthesizer were GPS locked. The quadrupler was supplied with 8 VDC, and the output of the synthesizer was attenuated to approximately 5 dBm.



Source signal setup.

Results

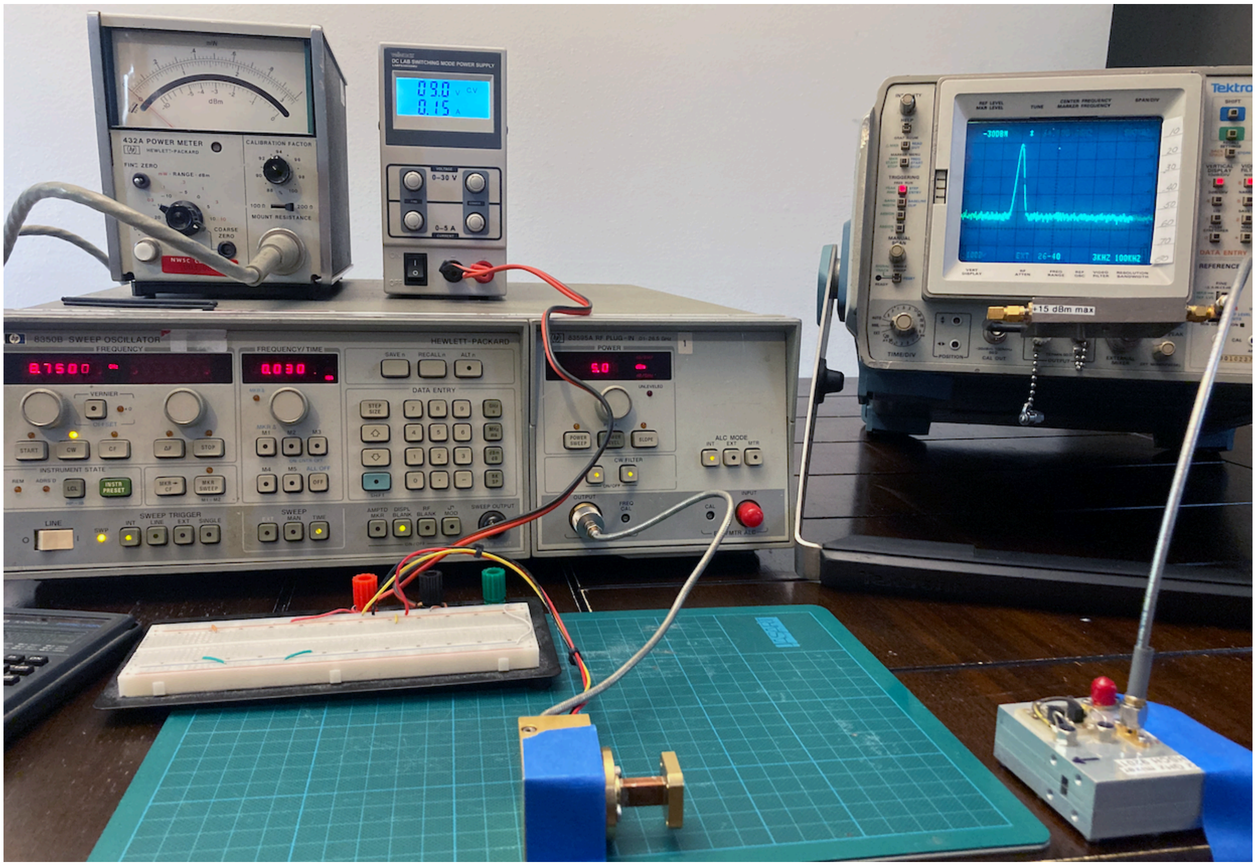
We observed a useful range of output signals from as low as 28 GHz and as high as 54 GHz, and determined that it would be worth repeating the attempt with a wider range of input frequencies. Note that the displayed power levels are relative to each other: we did not take into account conversion losses in the harmonic mixer. The actual output power level will be significantly higher in most cases.



Observed output frequency range on the 494AP.

Second Experiment

The author obtained an HP 8350B sweeper with an 84595A RF plug-in covering 10 MHz to 26.5 GHz. John Petrich W7FU then visited with his Tektronix 492A spectrum analyzer. This time, we utilized a different Philips harmonic mixer, and positioned the output of the quadrupler a short distance across the bench from the input of the mixer. Naturally, we were unable to characterize the losses here across the full range of the experiment, in addition to that of the harmonic mixer, which was operating out of specification. As discussed above, for amateur experimental purposes, this was adequate for qualitatively determining the useful range of the quadrupler.



Second setup, with HP sweeper.

In this experiment, neither the sweeper nor the spectrum analyzer were capable of being GPS locked. An initial frequency offset between the devices of approximately 40 MHz was observed. We defined the reading of the spectrum analyzer as the reference, as it had been used successfully in many previous situations and was in reasonable agreement with other, GPS locked, equipment. Manual offsets were calculated and entered into the sweeper, and we obtained an acceptable level of frequency accuracy for this qualitative investigation. We powered the quadrupler with 9 VDC and the RF drive was 5 dBm.

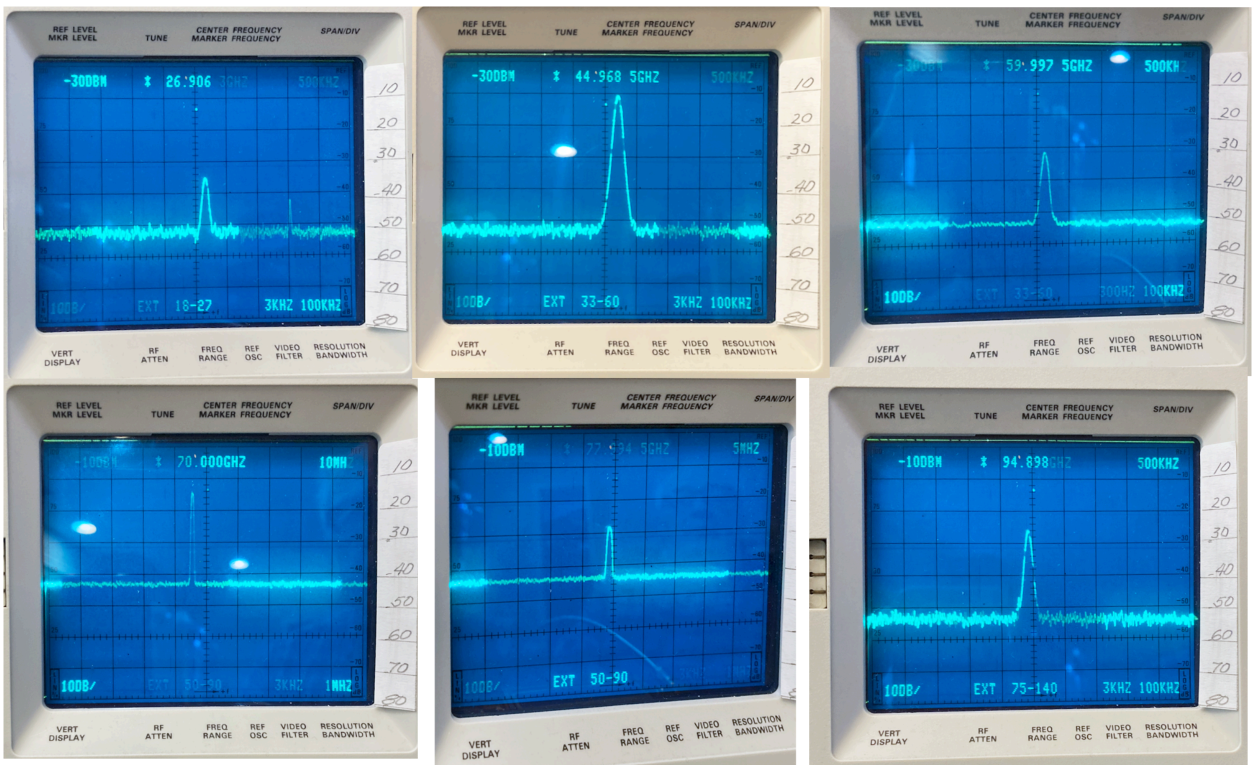
The output from the quadrupler is WR-22 waveguide, which has a cutoff frequency of 26.35 GHz (below which, no signal will propagate). Its recommended use is 33 to 50 Ghz, with the next mode cutoff at 52.69 GHz, beyond which higher-mode propagation can occur. The latter is not a concern in this experiment, as we use the spectrum analyzer to identify the signal of interest, rather than, say, a higher harmonic.

We would expect the upper range of the quadrupler to be limited by the characteristics of its doubler chips, the output BPF, and its physical construction (which was optimized for 47 GHz). We would also expect widely varying losses due to the placement of the quadrupler and the mixer, as well as from the mixer itself.

Thus, the planned output frequency range to explore was 26.5 GHz to somewhere above 54 GHz (which was the limit of the first experiment).

Results

We observed and validated output signals **from 26.9 GHz through to 95 GHz**.



Selected screen photos from 2nd experiment.

The signal at the lower end was rapidly declining in this range. At the upper end, it was becoming challenging to identify the signal, which was varying significantly in strength at different frequencies. We did a quick check at 105 GHz and did not detect any signal. We did not attempt to look between 95 and 105 GHz, as the level of uncertainty was already very high.

Confirmation at 78 GHz

While reviewing this document, WA1MBA verified -39 dBm output at 78.1921 GHz with 19.548012 GHz input, using a “somewhat calibrated” setup. He also added a section of WR-10 waveguide to the quadrupler output to act as a high pass filter above its cutoff frequency of 59.015 GHz.

Conclusions

In summary, in these experiments we demonstrated that the WA1MBA quadrupler is capable of generating signals well outside of its design specification. Designed to operate with an output range of 40 - 50 GHz, it can output readily observable signals from approximately 26.9 GHz to at least 95 GHz, using surplus test equipment as commonly used by amateur microwave experimenters.

Our experiments were highly qualitative in nature, as most equipment was operating out of specification and none of it was calibrated. We thus view these results as a proof of concept, and as a starting point for further experimentation and characterization with more sophisticated equipment. For example, utilization of a calibrated SNA with detectors and interconnects specified for the full output range would allow for accurate measurement of output power, gain, return loss, and VSWR.

Next Steps

The author intends to utilize the quadrupler as a signal source in the 47 GHz band (for which it was designed), and explore its potential use directly in the 76 GHz band. Other future applications may include extending the range of test equipment from microwave to millimeter bands, and further multiplication to higher bands.

Acknowledgements

I would like to express my appreciation to Tom WA1MBA for creating and funding the quadrupler project, answering my questions on the topic, and confirming the experiment at 78 GHz. Many thanks also to Paul Wade W1GHZ, Ray Cannon W7GLF, John Petrich W7FU, and Frank Kromann AG6QV.

References

1. “WA1MBA 10 to 12.5 in, 40 to 50 GHz out Quadrupler”, http://www.wa1mba.org/Quad.htm

2. “Progress on a Quadrupler for 47GHz”, WA1MBA, Tom Williams - MUD 2018, https://archive.microwaveupdate.org/archive.php (paper), https://www.youtube.com/watch?v=egZHcSTFtXU (video).

3. “A 10-12.5 GHz in, 40-50 GHz out Quadrupler – Final Report”, Tom Williams, WA1MBA, Microwave Update/ Eastern VHF Conference, 2023.

4. “Pacific Northwest Microwave”, https://pnw-microwave.com/

5. “HMC Datasheet and Product Info”, https://www.analog.com/en/products/hmc579.html