# A 10-12.5 GHz in, 40-50 GHz out Quadrupler – Final Report

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## Background

Purpose – to increase amateur activity on the EHF bands by at least two means. Firstly, this device can be used directly as a beacon, albeit low power, when coupled with a signal source of +3 to +5 dBm at 11.77+ GHz it will output a signal at 47.088+ GHz at just under 20 milliwatts (about +12 dBm). This signal can be frequency modulated, keyed on and off, or continuous, and the device provides for external keying. There are other papers and talks in this Microwave Update meeting describing 47 GHz beacons and sectoral antennas for that purpose. Secondly, the device can be used on the bench as a ready source of EHF signals in the 40 to 50 GHz region at power levels +5 to +12 dBm for signal source needs. Although this level of signal is not quite high enough for use as an LO in some mixers, it can suffice in others.

Basic Requirements that were met with the final device are:

- operates with single power supply (6 to 13 VDC)
- provides for external keying of output with no leakage during "key up" periods
- uses standard SMA input and WR22 output
- requires +3dBm to +5dBm input to deliver +5 to +12.5 dBm output
- maximum output is at the 47 GHz amateur band

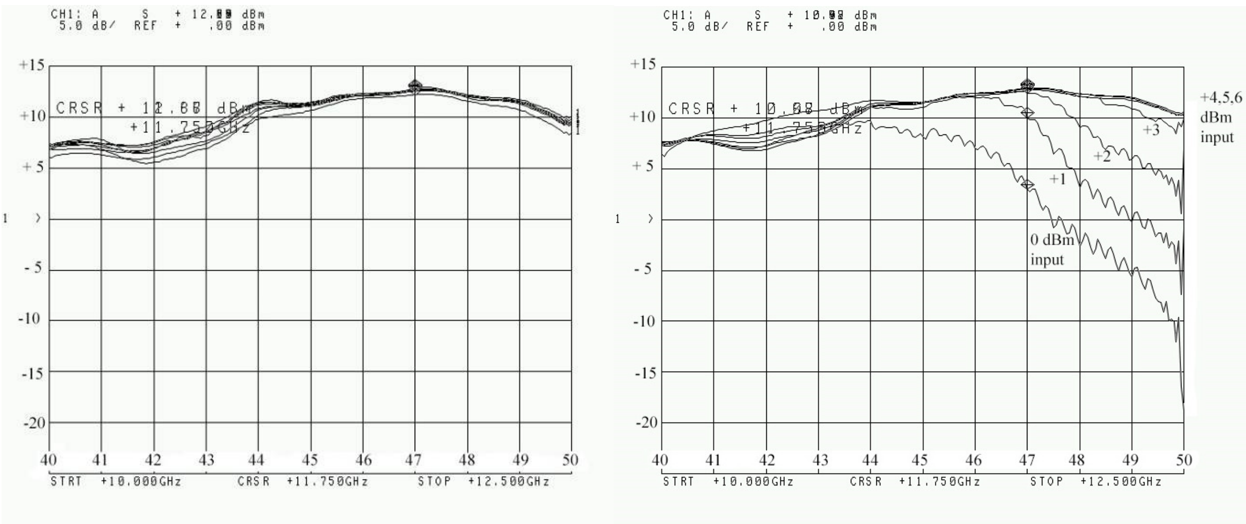
## History

The original design started in 2016 after hearing that the Cellular 5G band was going to include EHF bands with one adjacent to the Amateur 47 GHz allocation. A few of us hearing this decided that some kind of beacon for 47 GHz would be helpful to put signals on the air and could also be used for other purposes. Parts were selected in 2017 and a design for a block and a bias board was completed in 2018. That basic design proved to function as expected in a prototype unit. However, soon afterward the power supply IC selected was in short supply and essentially vanished. This required a re-design of the bias board in order to have the KEY signal pin grounded for the "on" condition.

The aluminum split-block design was submitted to two machine shops. One did an excellent job but at a price far too high for the project. Another was very busy with other business and did not respond for a while. Then the pandemic hit and progress on all fronts slowed or halted. In 2020 we added a few features to the block, and the fabrication of that was stalled. In 2021 the re-design of the bias board was completed, and tested on a breadboard. Also that year I decided to ask Mark Lewis, N0IO for block machining. His results in past millimeter-wave projects was excellent, and he took on the job for this project at a very reasonable cost.  During the year 2022 we had fabricated over 50 sets of blocks, had them plated, fabricated bias boards, RF circuit boards, and began assembly. MUD conference proceedings of the last few years describe circuits, RF ICs, etc. for this project.

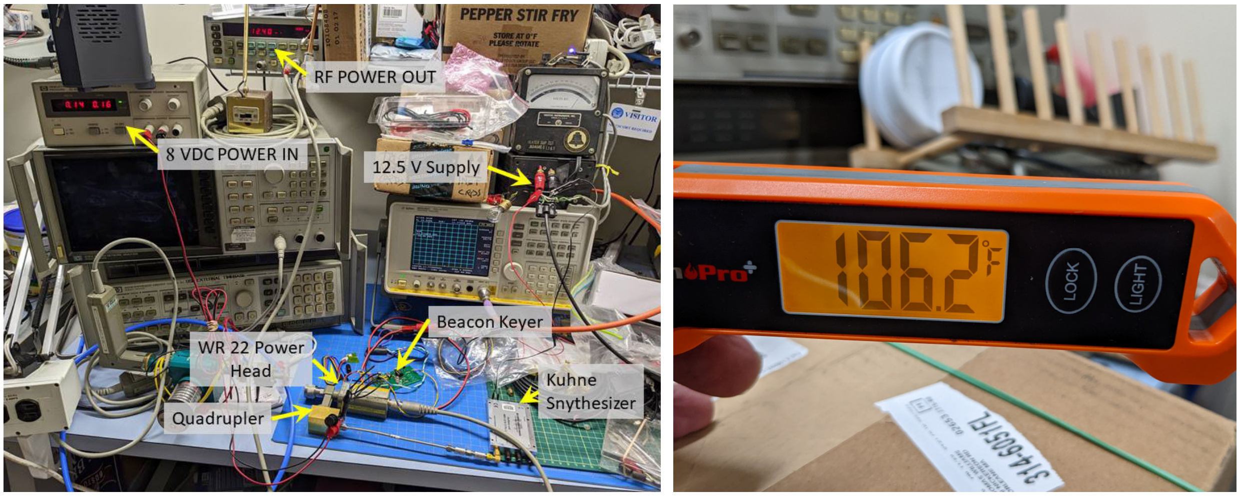
## Assembly and Test

Our initial 16 units yield was 50% pass both DC and RF test. Troubleshooting and fixing those units taught our assembler what to do differently, and the yields improved. Our limited materials, plus the purchase of some additional RF ICs to replace some which were damaged, yielded 43 working units. All working units were then swept and the results scrutinized. With only one exception, all units were within 1 dB of the same 47 GHz output power when 4 dBm was applied to the input. More than 85% reached their maximum power at 47-48 GHz with just 3 dBm input, and the others did so at 4 dBm in.



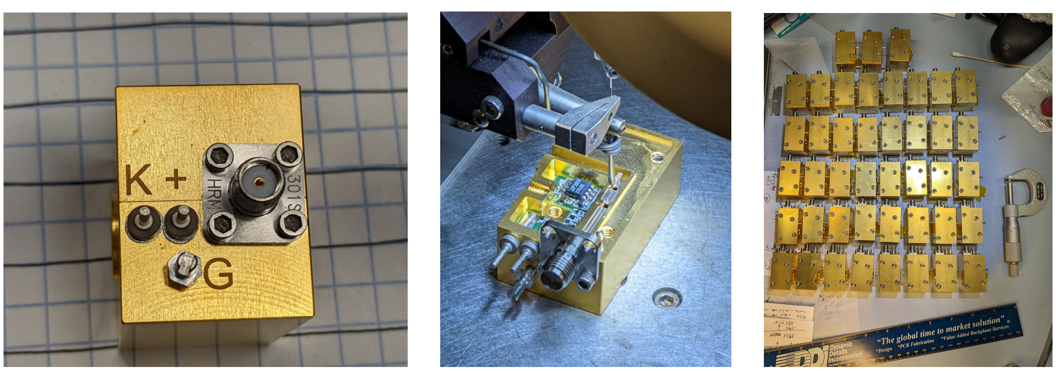

Sweep plots. The vertical scale is output power at 5 dB/, the horizontal is output frequency at 1 GHz/. On the left are overlays of 7 different units all at +4 dBm input giving an overall idea of how similar they are. On the right is an overlay of the same unit run a different input power levels.

Concerned about fragility and long-term use as beacons, I followed the advice of NEWS club President Dick Frey W2AAU and with some advice from Brian Justin WA1ZMS performed some life tests. Both tests were run with +4 dBm applied at 11.77 GHz (Kuhne 8-13 Synthesizer with power splitter), and a keyer was attached sending a 30 second beacon sequence, some 20 seconds of which was a continuous key down. Each had a WR22 power head connected to a dual input HP-438A power meter for quick checking a few times a day. One was operated in a benign environment, where DC bias was sourced at 8V, and the unit was in a room where the temperature varied from 63 to 66 degrees F. The second unit was operated at +12.5 VDC, and put into a box with plastic foam insulation and a 5 watt power resistor dissipating over 2 W, resulting in a continuous air and block temperature at or above 106 degrees F (41 C). See photos of the test setup.




<u>Photos of Life Test Setup.</u> On the left, prior to adding the high temperature stress test, the equipment and values are labeled. On the right, the box containing the stressed unit with a temp measurement.

The first unit (8V, room temp) functioned consistently well for 100 days continuously. At that point it was shut down. The second unit (being run at a higher voltage and temperature) failed after 9 days and 2 hours of continuous operation. The power regulator IC had failed, and replacing it fixed the unit. The consequence of this test requires that I inform users to be careful when operating them as continuous beacons. In such circumstances they should be run on reduced voltage (anywhere from 6 to 8V) and preferably by keying the ~11GHz source signal rather than keying the quadrupler. Also, if possible the ambient temperature should be kept below 100F if practical. As a bench signal source, at room temperature, running it at a reduced voltage (8V) is still recommended. If used as a source (such as an LO) in a portable station, a reduced voltage (8V) is also recommended.




<u>Photos</u> On left is the Input side of the unit, including Key, Power, and Ground pins and the RF input SMA. The middle photo is a unit in the ribbon bonder being assembled, and on the right is all the units after final assembly and testing.

## Post Script

The final cost to build (design time was not charged) came out to just over $400. All functioning units have been swept and a copy of that performance curve will be included with the unit. Please contact the author - tomw at wa1mba dawt org