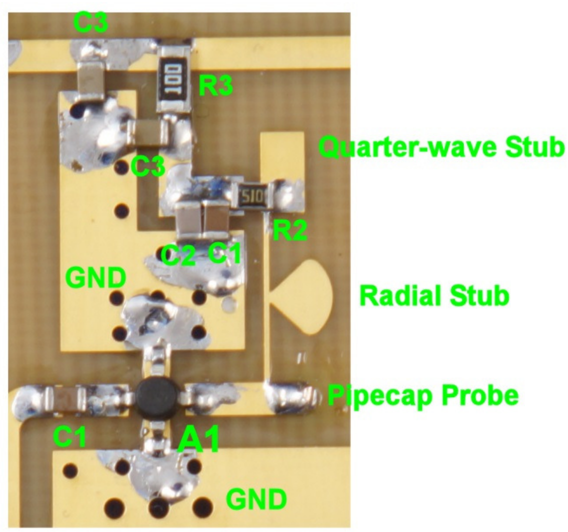
Update – Personal Beacons and LO multipliers for 10 GHz and Lower Bands

Paul Wade, W1GHZ ©2023 *updated 2026*
w1ghz@arrl.net

The 10 GHz Personal Beacon has gone through a couple of iterations and improvements since I first described it in 2010. It made the 10 GHz transverter possible, and has generated several variations: a 10 GHz LO multiplier and a lower frequency version, usable as an LO multiplier or personal beacon for 5760 MHz or 3400 MHz. These changes and variations have generated some confusion, so I get a number of questions. Perhaps we can tie up some loose ends.

The original Personal Beacon PC board used 1/16 inch thick FR-4 material, ordinary PC board. Following my basic design philosophy, **Gain is Cheap**, it was an experiment to see if 10 GHz was possible without exotic (expensive) PCB material. It worked better than expected; there was some radiation from the board, but that's OK in a beacon – radiation is what we want. What I learned was that 10 GHz is possible but thinner PC board is required.

After I got the 10 GHz transverter going (a real learning experience) using thinner 1/32 FR-4 PC material, I also switched the personal beacon to the thinner material and modified the layout slightly. All 10 GHz MMIC stages now use the same PC layout, including the 10 GHz LO multiplier, which is identical to the transmit chain in the transverter – three MMICs separated by two ½ inch pipecaps. A pipecap between stages adds a bit of loss, which increases amplifier stability. A MMIC between pipecaps prevents coupling between resonators, making tuning clean and smooth (this is called synchronous tuning, if you care to be fancy). The receive chain is also identical to the transmit chain. **Figure 1** shows one MMIC stage with parts identified.



A bit of explanation about the circuit, shown in the latest schematic diagram in Figure 2. In the center of the thin bias line from R2 to the MMIC is a Radial Stub; this acts as a quarter-wave stub over a fairly wide frequency range, so it presents an RF short circuit to the center of the bias line. The thin bias line (Zo~ 100 ohms) is a quarter wavelength long on each side of the radial stub, transforming the RF short circuit to an open circuit at the MMIC output transmission line so it does not affect RF performance. At the R2 end of the line is also an RF open circuit, which is bypassed by the rectangular quarter-wave stub. R2 and R3 set the MMIC current, and lower frequency decoupling over a wide range is provided by C1 (small value for microwaves), C2 (VHF), and C3 (HF). All this separates the MMICs from any lower frequency interaction or coupling between stages.

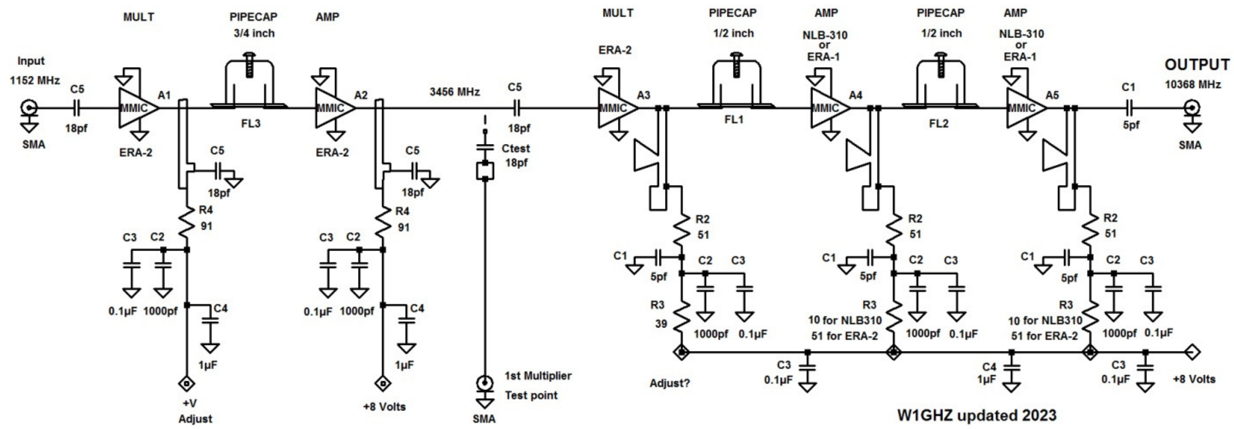


Figure 2 – Updated schematic diagram of 10 GHz Personal Beacon

The original personal beacon used Minicircuits ERA-1 MMICs at 10 GHz, the only MMIC that worked well at 10 GHz. Since then, the Qorvo NLB-310 has become available with a bit higher performance, but requires more current, so the bias resistor values are lower. Both these MMICs have pretty flat gain with frequency, while many others have much higher low-frequency gain, making circuits less stable at lower frequencies. If a better MMIC comes along, a different bias resistor will probably be required. However, the 4-lead MMIC package is not being used for many new devices, so layout changes might be necessary.

Before the 10 GHz section of the personal beacon, there is a multiplier from 1152 MHz to 3456 MHz, a ¾ inch pipe cap to filter the desired third harmonic, an amplifier, then another tripler from 3456 MHz to 10368 MHz. The triplers use ERA-2 MMICs; I believe the smaller devices generate harmonics better with lower drive than the NLB-310. Varying the MMIC multiplier current by adjusting the supply voltage to that stage may improve harmonic output. The board may also be used as an LO multiplier by tuning the pipe caps to the desired frequency.

The 3456 MHz stages use a simpler bias decoupling scheme: a quarter wavelength of thin, high impedance line and a wide low impedance line, so that the open circuit at the end of the wide line is transformed to an RF short circuit at the DC connection point, then transformed back to an RF open circuit at the MMIC output transmission line.

The completed personal beacon board is shown in Figure 3. The middle connector is the test point for the first tripler – it is connected by soldering C4 to the side transmission line as Ctest for tuning the first pipe cap, then moving the capacitor to its normal position before finishing tuneup. Tuning was smooth, and I measured almost 10 dBm at 3456 MHz at the test point. Screw depth is nearly the full height of the pipe cap.

Keying for CW ID is best accomplished by keying the voltage to the last two 10 GHz stages, A4 and A5.

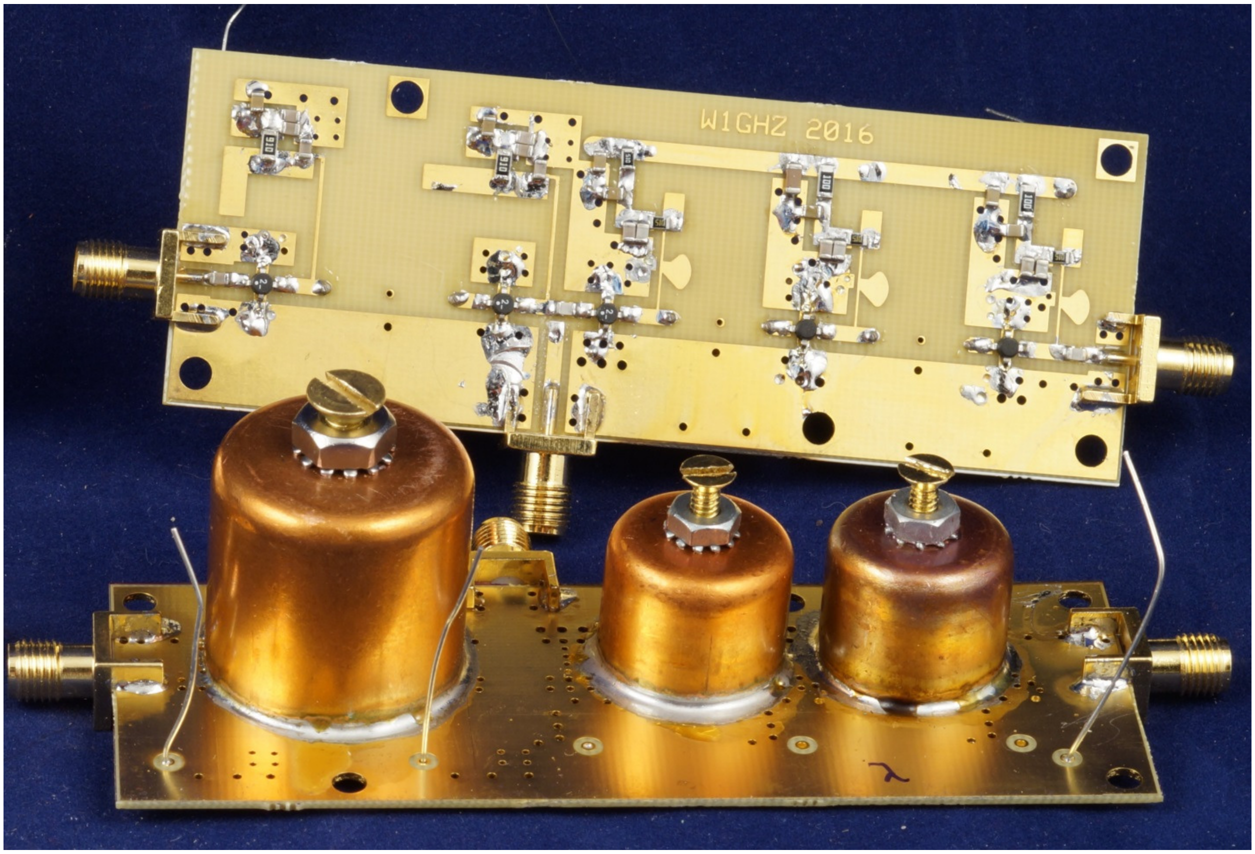


Figure 3 – Completed 10 GHz Personal Beacon board

LO Multiplier Board

The 10 GHz LO multiplier is identical to the transmit chain in the 10 GHz transverter – three MMICs separated by two ½ inch pipecaps. The schematic is shown in Figure 4. Frequency synthesizers good to 4 or 6 GHz with OK phase noise have become readily available in recent years. Only a simple frequency multiplier is needed to provide a local oscillator for a 10 GHz transverter. This board can multiply by four from 2880 MHz to 10224 MHz, by three from 3408 MHz, or by two from 5112 MHz. It can easily be tuned for other LO frequencies for different IF frequencies, or for other uses entirely. I recently tuned one as a tripler from 3924 MHz to 11772 MHz to drive a 47 GHz beacon. An ERA-2 MMIC might be better for the first stage, A3.

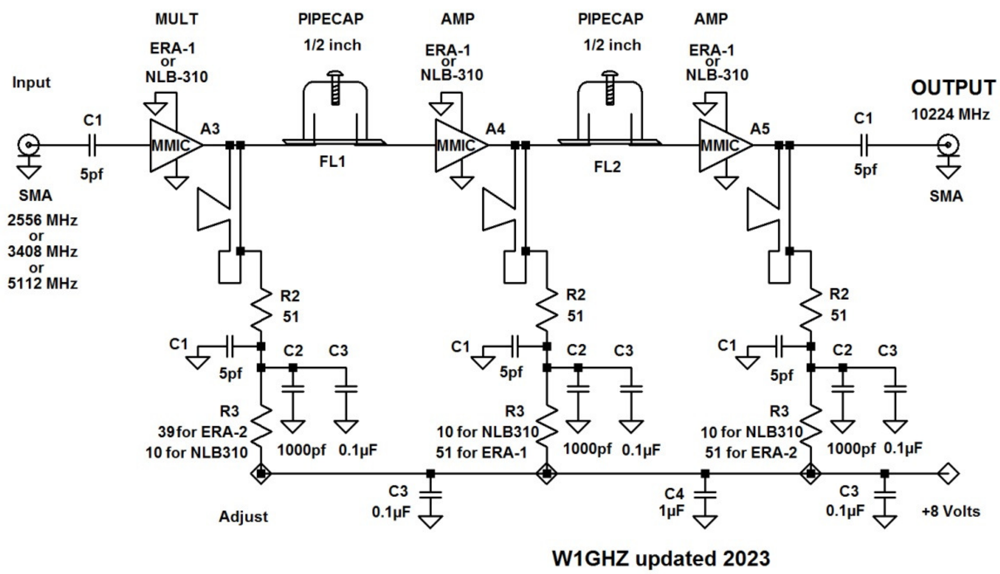


Figure 4 – Schematic Diagram of 10 GHz LO Multiplier

Note: change R3 to 62 ohms for ERA-1 or 2

A completed board is shown in Figure 5. Since both pipecaps are tuned to the output frequency near 10 GHz, the board can also be used as a tuned amplifier. If you have a signal source or VNA, the easiest way to tune one up is as a straight-thru amplifier.

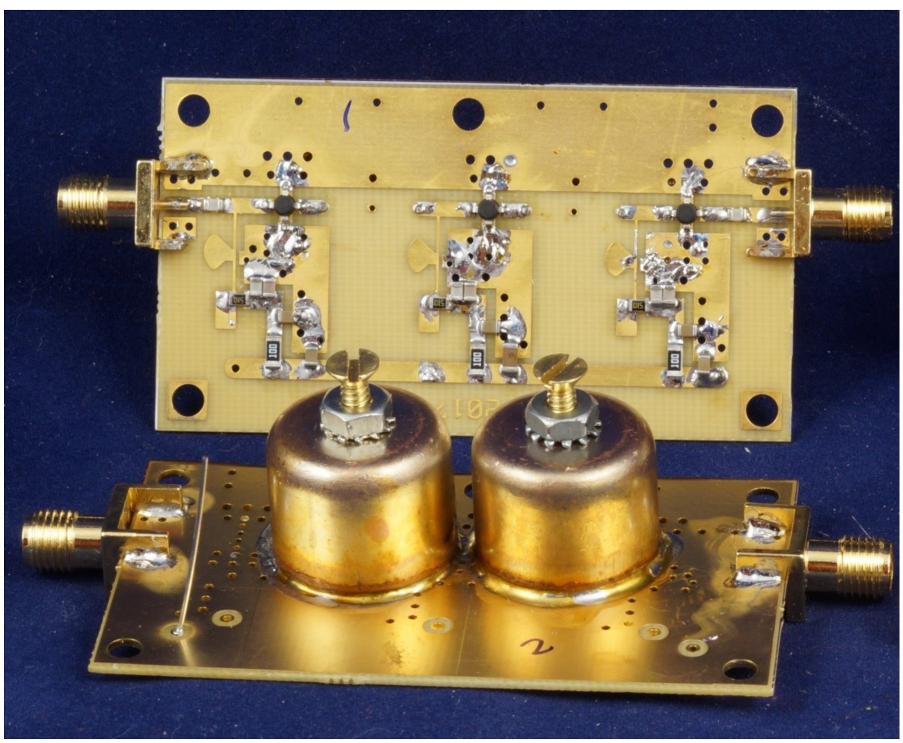


Figure 5 – Completed 10 GHz LO Multiplier board

5760 and 3400 MHz

At 5760 and lower frequencies, the 1/16 inch thick PC boards work fine. The thick boards are more rigid and easier to work with, so the transverters for 5760 and for 2 & 3 GHz, use this material. The LO multiplier or personal beacon which covers all these bands also uses the thicker material. The 5760 transverter and the LO multiplier or personal beacon both use the same lineup, three MMICs separated by two ¾ inch pipecaps. Less expensive MMICs in the SOT-89 package like the GVA-62 or GVA-63 may be used; more options and better heat-sinking are available in this package. Most operate from 5 volts with no required bias resistors.

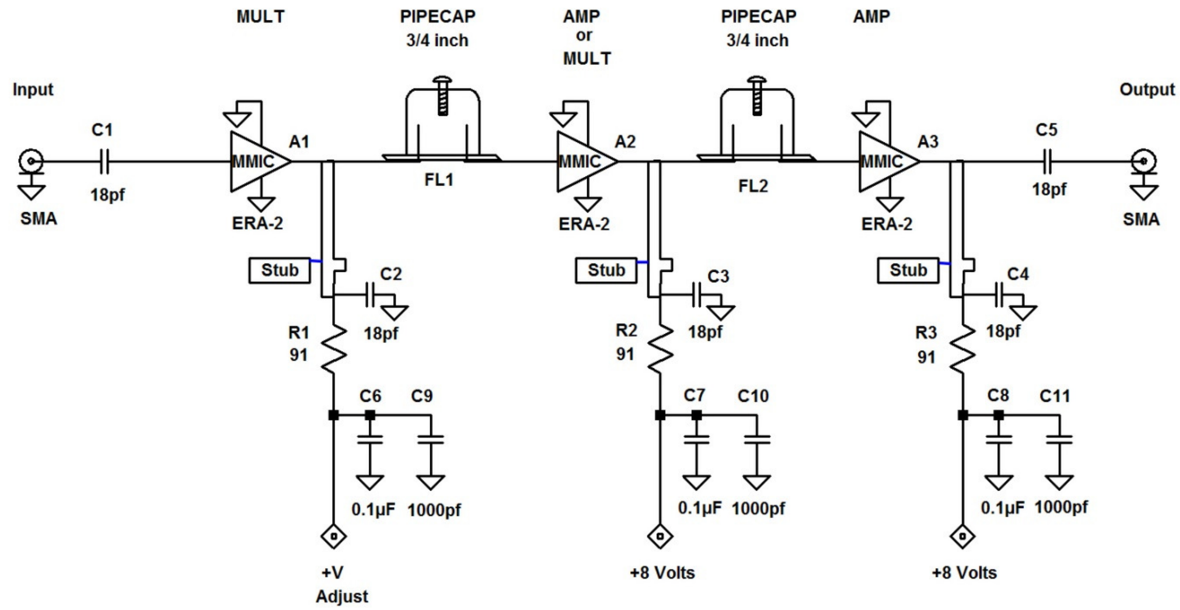


Figure 6 – Schematic of Personal Beacon or LO Multiplier for 5760 & 3400 MHz

Note: R1,2,& 3 should be 110 ohms

The 5760 transverter and LO multiplier uses a simpler bias decoupling scheme, shown in Figures 6 and 7: a quarter wavelength of thin, high impedance line and a wide low impedance line, so that the open circuit at the end of the wide line is transformed to an RF short circuit at the DC connection point, then transformed back to an RF open circuit at the MMIC output transmission line. Lower frequency decoupling over a wide range is provided by capacitors of different values in sequence like the 10 GHz decoupling.

The wide low-impedance stub for 5760 is connected by a short, thin line on the PC board. The prototype on Figure 7 did not have these lines, so connection was made with a bit of copper braid.

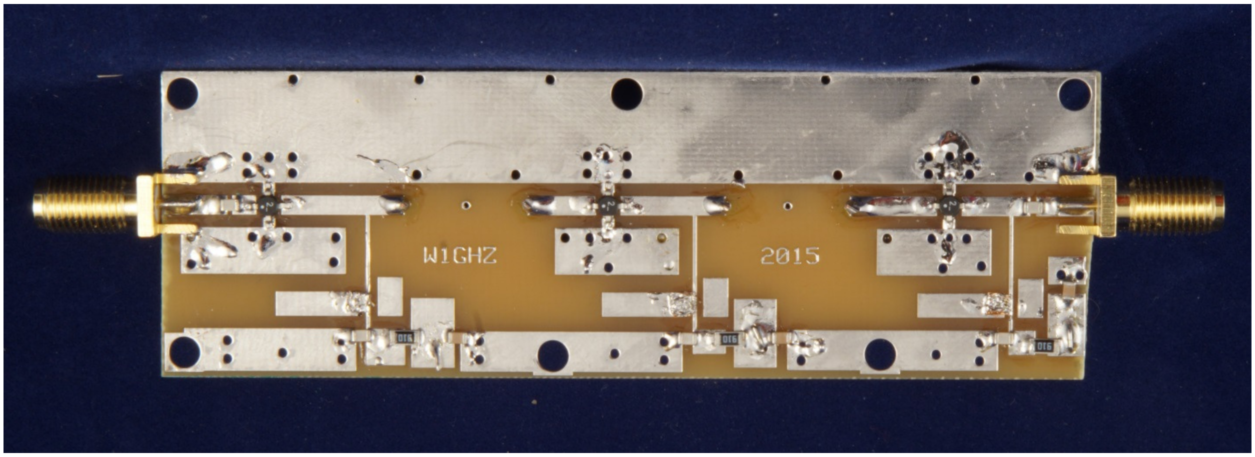


Figure 7 – Personal Beacon or LO Multiplier board prototype for 5760 MHz

3400 MHz

The 5760 LO multiplier can also be used as a personal beacon or LO multiplier for 3400 MHz. Just a matter of tuning the pipe-cap filters to the lower frequencies, and perhaps a bit longer probes in the pipe caps. The taller version of the ¾ inch pipe caps is recommended to allow for a longer tuning screw.

Decoupling for this band needs an RF capacitor to ground at the end of the bias line; I use 18 pf. The wide low-impedance stub for 5760 is connected by a short, thin line on the PC board. I had intended to cut this short line to the stub for operation on the lower bands so that the longer length is a quarter wavelength at 3.4 GHz, but I don't think it matters. The prototype in Figure 8 does not have this line, so the stub is not connected.

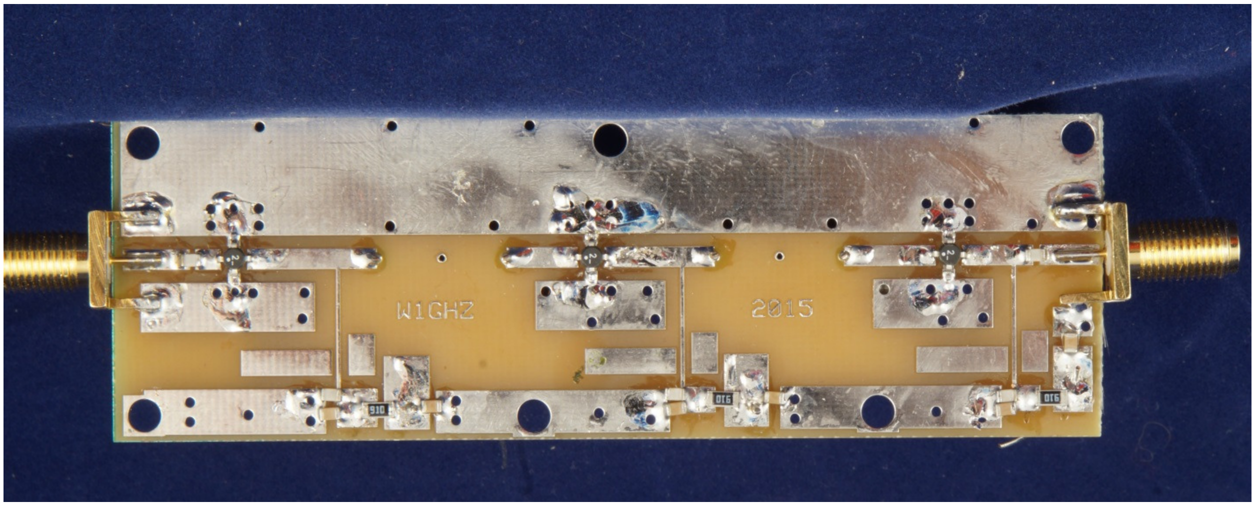


Figure 8 - Personal Beacon or LO Multiplier board prototype for 3400 MHz

Pipe Cap Filters

The pipe-cap filters are not cavity resonators, as some imagine. They are simply quarter-wave resonators – the screw is almost a quarter wavelength long, resonating with capacitance to the PC board. The probes provide capacitive coupling in and out. For more details, see: http://w1ghz.org/filter/Pipe-cap_Filters_Revisited.pdf .

The ½ and ¾ inch pipe caps are USA copper plumbing sizes. The rest of the world uses metric dimensions, and a frequent question concerns the actual dimensions of the pipe caps so that metric equivalents may be located. The dimensions are given in the link, but the important dimension is the height, so that the screw is a quarter-wavelength long.

In some areas, copper plumbing is no longer used. Hams in these countries have found that air-conditioning fittings are still made of copper and can be used.

Pipe Cap Assembly

The first step in assembly is to solder the pipe caps to the board, after drilling and tapping the screw holes in the top of the caps. Each pipe-cap location on the PC board has a hole at the center, halfway between the probe locations. I scribe lines on the bare board half the pipe cap diameter away from the center hole, making a square to line up each pipe cap. Then I put a bit of paste flux on the rim of each cap, place the caps in position, and put a ring of wire solder (63-37, preferably with no-clean flux) around the base of each cap. I solder the caps one at a time, holding the one being soldered in position with a screwdriver while heating the top of the cap with a hot air gun, aimed away from the other pipe caps to avoid heating them. The copper conducts the heat down to the board; when the joint reaches temperature, the ring of solder melts and flows around the base of the cap, without overheating the board. As soon as the solder flows, remove the heat, let it cool until the solder solidifies, then move on to the next cap. A torch could also be used, but tends to oxidize the copper, and might damage the thin PC board.

A note on pipe caps. I have found three different brands at local stores and any of them should work fine. What they all have in common is that the open end is not very uniform, so sanding on a flat surface with 220 grit Wet-or-dry sandpaper may be needed to make them sit level and solder cleanly. About 20% of them are so bad that too much sanding is required, so I toss them.

Brass screws are preferred for pipe-cap tuning, with a lockwasher. Even better are stainless KEP nuts, with an attached lockwasher – they can be partially tightend and make tuning much smoother. The probes are just bits of wire – I keep them straight and the desired length by using leads from an ordinary disc capacitor, as shown in Figure 9. Measure the full lead length, then insert it until the desired length is inside, and allow another 0.8 mm for the board thickness. The probe length inside the pipe cap is about 4.5 mm for the 10 GHz transverter. Probe length for the personal beacon or multiplier can be a bit longer, since harmonics are widely spaced . Since it is hard to get the length exact, slightly longer is probably better than too short, which would be lossy.

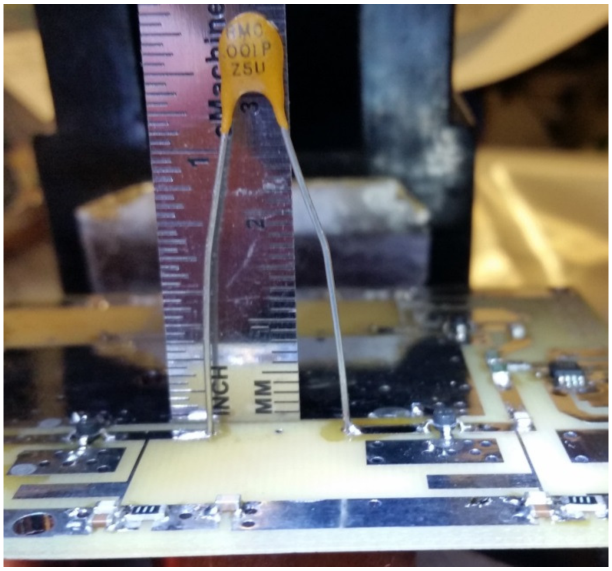


Figure 9 – Probe Assembly

Even better than the disc capacitors are larger capacitors with the right lead spacing, like the ones in Figure 10. I found a bunch of these being used for soldering practice. The probe length can be eyeballed with a scale as shown in Figure 9, or you could make a gauge block to make them more uniform.

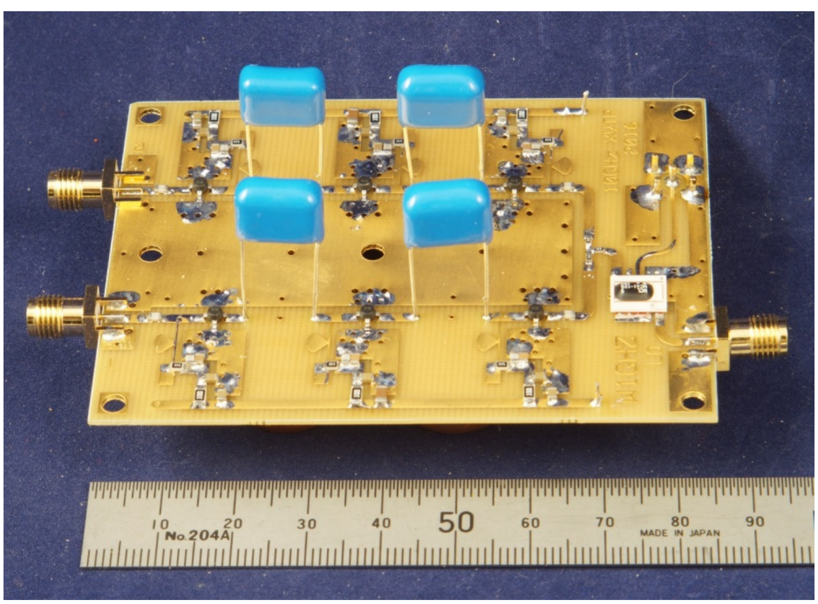


Figure 10 – Capacitors with perfect lead spacing make probe assembly easier

All the other parts are surface mount are easily soldered with a fine-tip iron and thin solder. The RF chip capacitors and resistors are the medium 0805 size, while the DC resistors and 0.1 µF bypasses can be the larger 1206 size.

Critical parts are at the 10 GHz output: the blocking capacitor and the SMA connecter. Oversize capacitors will reduce output. A high quality capacitor, like ATC, might buy a dB, but a cheap SMA connector will cost several dB. Finally, avoid solder blobs anywhere in the RF line, on capacitors, connectors, or pipecap probes – the added capacitance detunes the transmission line, and the extra height may increase radiation loss.

The other components are added after the pipe caps and probes are in place. Referring back to Figure 1, I usually start with R2 and work around the bias components in order. The plan is that the second solder joint on each component leaves a nice solder pad for the next component – sometimes it works. Then I add the MMICs and finish up with the SMA connectors. In some areas, the pipe-caps act as a heat sink and a larger soldering iron is needed to properly flow the ground connections.

Summary

I hope this update clarifies the description of these boards and makes assembly easier. If there is still any confusion, please let me know and I will add appropriate explanations.

These boards are not limited in application – the 10 GHz boards can be used from about 6 to 12 GHz, and the lower frequency one from 6 GHz down to about 2.7 GHz. Don't hesitate to cut them up to try something – they are cheap and more are available.