10 GHz Transverter and Pipe-Cap Filter Improvements

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Recently, while developing the QBeacon boards for Q65 beacons, Tom, WA1MBA found some nice pins from Mouser that are perfect input and output probes for the ½ inch pipe-cap filters. The Mill-Max pins, Mouser #575-5068000150000000, have a nail head so the head sits flat on the board for perfect alignment, and the diameter slips nicely into the plated-thru hole in the board. They are gold plated for easy soldering and the flat head also eliminates a solder bump over the probe that adds a bit of loss.

The new PC boards have a bit longer transmission lines in a couple of places, so I was able to chop one up with enough line to fit SMA connectors next to the pipe caps and make some filter bandwidth measurements. Figure 1 shows the bandwidth at 10 GHz for a range of probe lengths including the Mill-Max pins.

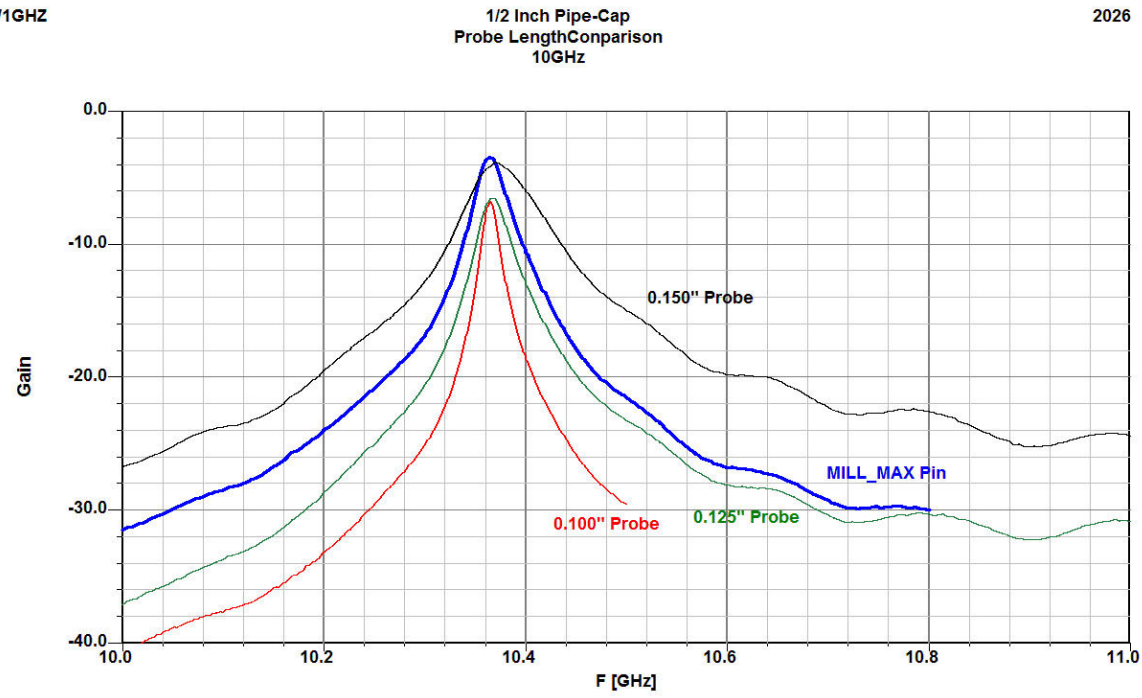

Figure 1 – ½ inch pipe-cap filter response with varying probe length at 10 GHz

The losses are probably a bit high since I was using cheap SMA connectors, but that shouldn't affect the bandwidth. Another factor is that the pipe-cap is only clamped to the scrap of PC board, with a chunk of foam on the circuit side for support. This arrangement allows for multiple pipe-caps tuned to different frequencies, and for easy changes of probe length by starting long and trimming – data was not taken in the order shown. Probe length was controlled

by taking a small pad of Post-It notes, removing pages until the pad was the desired thickness, then using the pad next to the pin as a spacer for flush-cutting wirecutters.

With the Mill-Max pins, the 3 dB bandwidth is roughly 35 MHz, and the LO rejection 144 MHz away is about 20 dB. Two pipe-caps surrounded by amplifier stages form a synchronous filter with twice as much rejection; 40 dB should be adequate for a transverter. The Qbeacon board has three pipe-caps surrounded by four amplifier stages for even more LO and image rejection.

While I was testing, I tried even shorter probes, shown in Figure 2. The filter gets even sharper, but loss goes up considerably. The Mill-Max pins seem to be near the sweet spot. Longer pins, not shown, provide wider bandwidth and very little LO rejection.

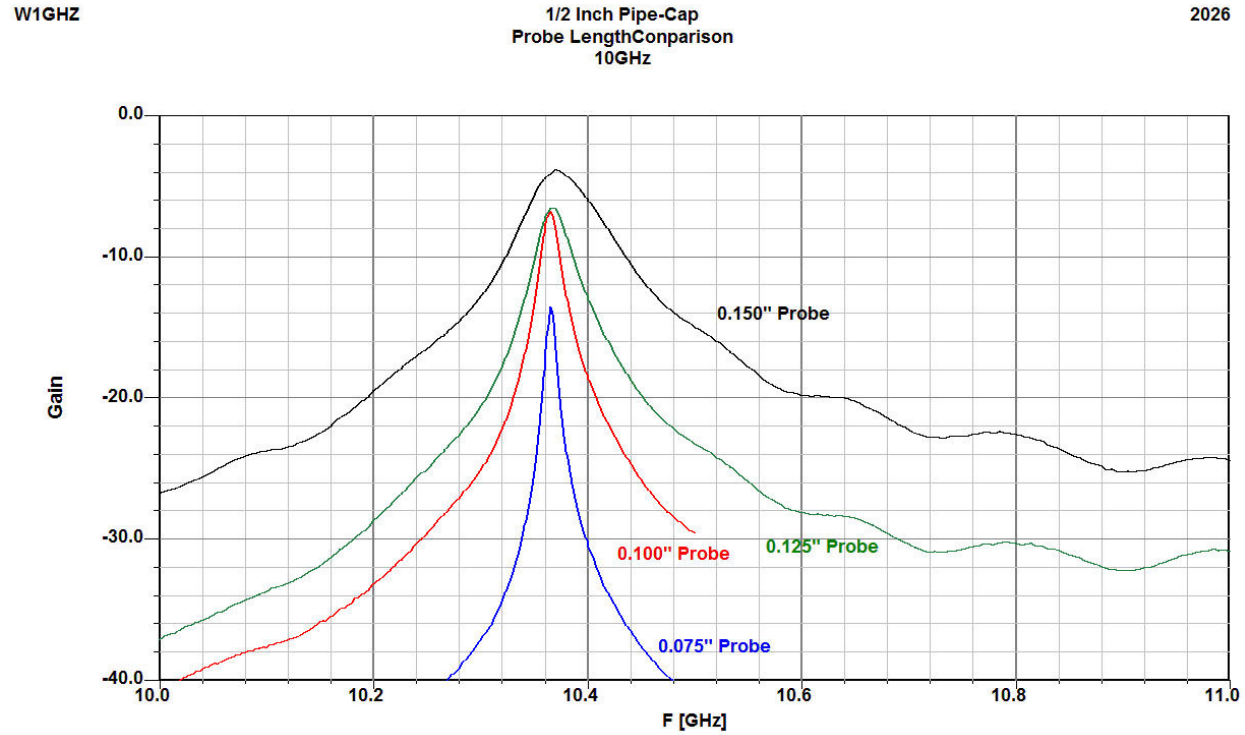

Figure 2 – ½ inch pipe-cap filter response with short probe lengths at 10 GHz

12 GHz

The Qbeacon board is intended for 24 and 47 GHz beacons as well, multiplying up from near 12 GHz, so the pipe-caps were retuned for 12 GHz and measured. Results in Figure 3 show the Mill-Max pins work well, with about 3 dB bandwidth of about 100 MHz. LO rejection is not good enough for a 2-meter IF, but fine for 432 MHz IF, which was Tom's goal.

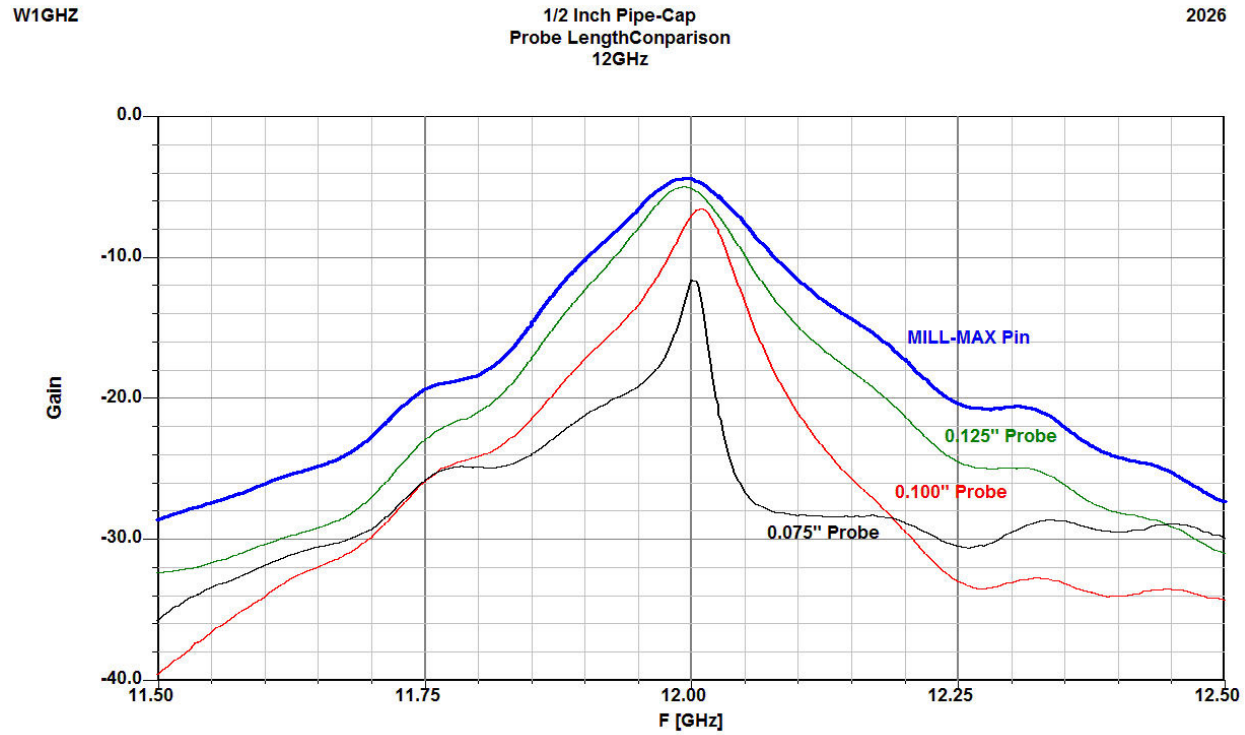

Figure 3 – ½ inch pipe-cap filter response with varying probe length at 12 GHz

5760 MHz

One of my 10 GHz transverter boards was retuned to 5760 MHz by Don, W1FKF, so I knew they could be tuned that low. I ran the screws way in one of the pipe caps and took data at 5760 with the longer probes – I started with long probes and trimmed them rather than changing them. Figure 4 shows the plots. The Mill-Max pins do a good job of LO and image rejection for a 144 MHz IF, but slightly longer ones have lower loss. At this frequency, cheaper MMICs that are readily available have good gain – *Gain is Cheap*.

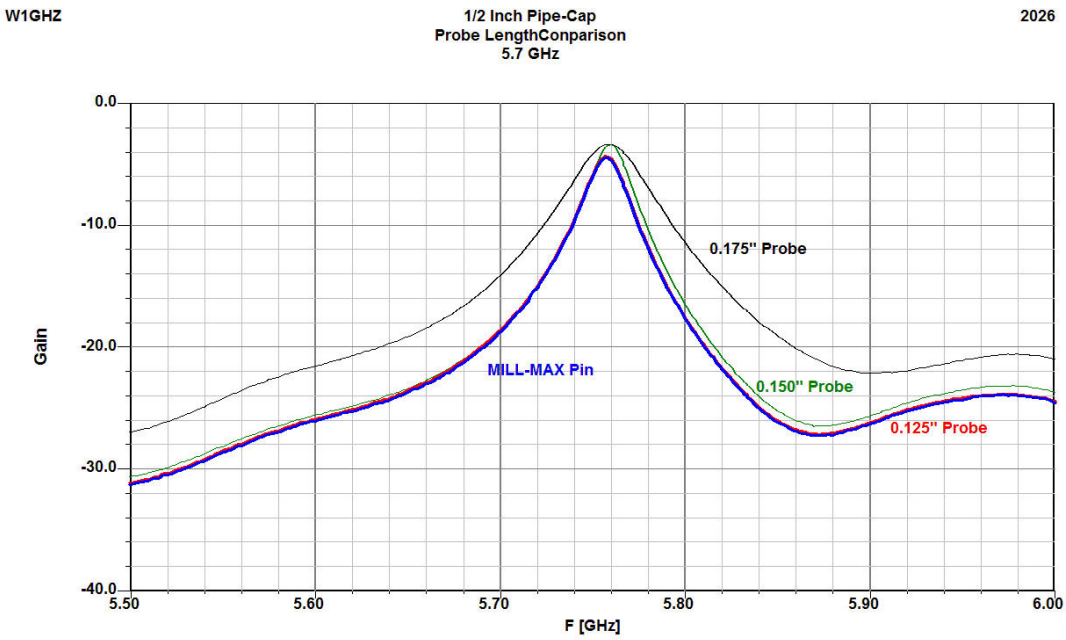

Figure 4 – ½ inch pipe-cap filter response with varying probe length at 5760 MHz

8.2 GHz

While tuning down to 5760, it occurred to me that the 10 GHz transverter can be used as a receive-only converter for 8.2 GHz space communications. Freddy, ON6UG, has received the NASA MARS orbiter on a 1-meter dish. So pipe-cap data at 8.2 GHz in Figure 5 might be useful:

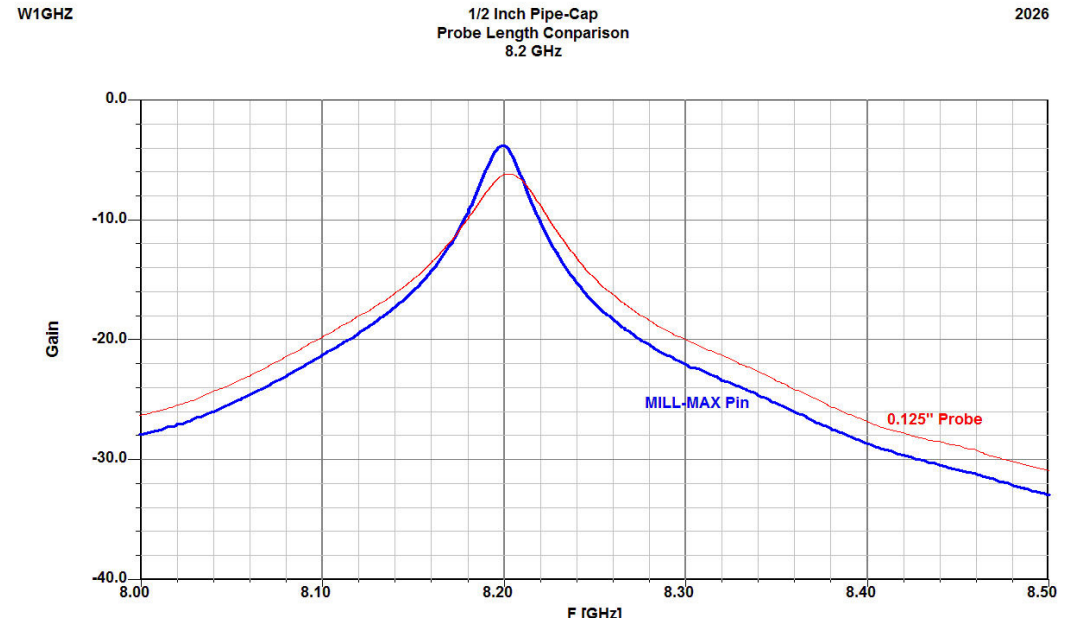

Figure 5 – ½ inch pipe-cap filter response with varying probe length at 8.2 GHz

Upper Frequency Limit

Finally, Zack, W9SZ, wondered how high in frequency the ½" pipe-cap would work. Just a matter of turning the screw out. The highest frequency curve, just below 14 GHz, is with the tuning screw removed completely.

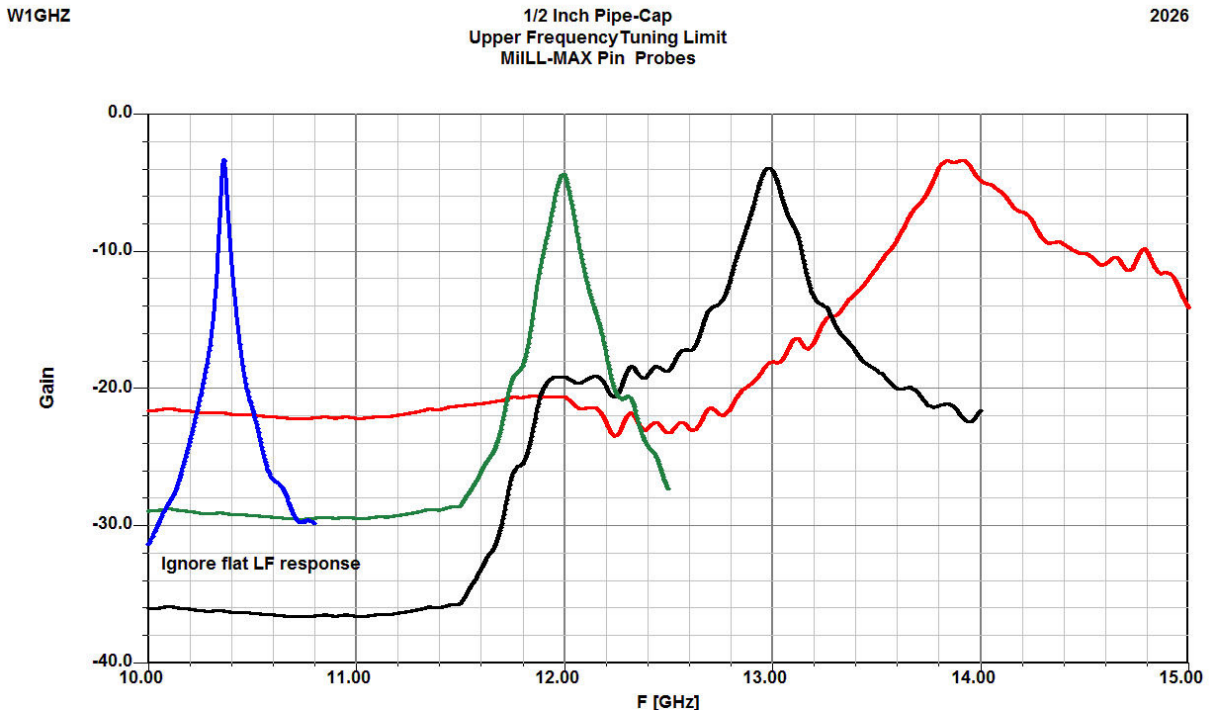

Figure 6 – ½ inch pipe-cap filter response at higher frequencies

Pre-tuning the pipe-cap filters

The pipe-cap filters are quarter-wave resonators, with the tuning screws acting as the resonator. Setting the tuning screws in the pipe-cap filters to approximately the right depth will make transverter tuneup easier. I recorded the following screw lengths inside the pipe-cap. Then setting the screws is just adjusting the length outside the cap to the screw length minus the inside length and wall thickness.

Frequency	Length inside
5.76 GHz	0.375 inch
10.368	0.165
12	0.150

Absorber

All microstrip transmission lines have some radiation. When they are enclosed in a metal enclosure, this creates coupling between stages, so that the filters are not as effective and LO and image rejection is not as good. Most of the effect is from the metal surface above the transmission lines. Tom tried putting expensive microwave absorber material on all surfaces of a metal box with good results. Looking for an available affordable alternative, he found some EMI Absorber material on ebay from TOJOIN. The stuff has adhesive backing, and adding it on just the metal surface above the transmission lines is as effective as doing the whole box. Two sheets of 2mm thick absorber for about $20 should last most of us a lifetime.

Summary

Using the Mill-Max pins as probes makes assembly easier and better controlled, with more predictable performance, and pre-tuning should make tuneup easier, particularly for those hams without extensive test equipment. Adding some absorber improves performance. Let's get them on the air.

Longer Pins

The Mill-Max pins are too short to use at 5760 MHz with the ½ inch pipe-caps – tuning is too sharp and critical. Lower frequencies and larger pipe-caps also need longer pins, though the length is probably less critical. I use capacitor leads as longer probes, ideally with the same lead spacing as the hole spacing for the probes. To set the length, I measure the distance needed from the capacitor body to the PC board that would produce the desired probe length, and use a drill bit of that diameter to set that distance, as shown in Figure 7.

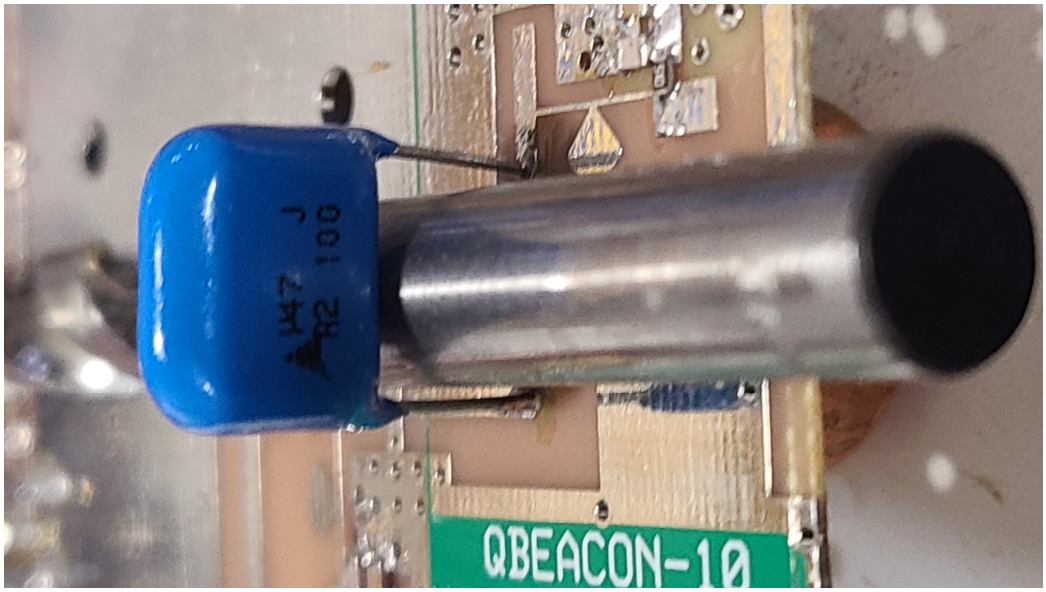

Figure 7 - Setting probe depth by using a drill bit as precision spacer