MMIC Amplifiers for 10 GHz

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The Simple and Cheap Transverter for 10 GHz has helped get more folks on 10 GHz. The San Diego Microwave Group did a group build. With a barefoot transverter, Drew, N7DA, reported making a rainscatter contact of several hundred kilometers. In Uruguay, one is being used for 10 GHz EME by Ric, CX2SC.

For serious operation, it still needs a bit of help – the Noise Figure is a bit high, and the power output is only a few milliwatts. An LNA for 10 GHz is more expensive than the transverter, and power amplifiers cost even more. I've been looking for inexpensive ways to increase performance. Power devices are available but still fairly expensive per watt and hard to find or hard to assemble at home. LNA MMICs are also rather expensive, starting at around $40, and they consider 2 dB NF to be low noise.

To see what could be done with available MMICs, I made a simple single-stage PC board on ordinary PC board, 0.8mm (1/32 inch) thick, and another on 0.6mm thick PC board, both shown in Figure 1. The gold board is 0.6mm thick.

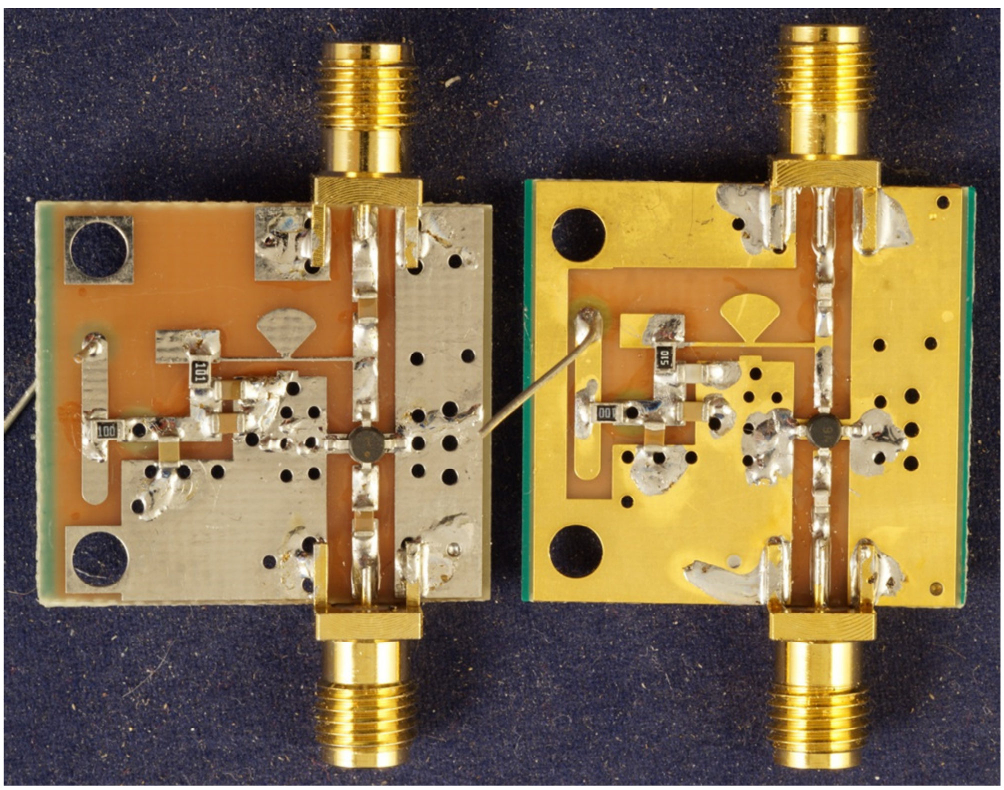
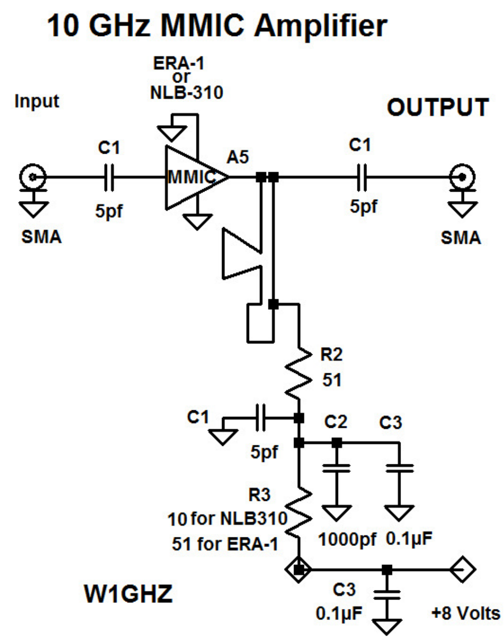


Figure 1 – MMIC Amplifiers for 10 GHz with NLB-310

The only commonly available MMICs in human-solderable packages with usable gain at 10 GHz are the Qorvo NLB-310, used in the 10 GHz transverter, the Minicircuits ERA-1, used in earlier versions, the Minicircuits GVA-123. I also tried the obsolete MGA-86576, since I had a few on hand; I also ordered a couple on ebay from seller rfextra, who appears to have part of a reel of old stock. The price is a bit high, but these were always more expensive parts. There are many offered from China, but fakes are common.

The circuit is the same as one stage of the 10 GHz transverter, with quarter-wave stubs for bias network, shown in Figure 2. There is no pipecap probe in the these MMIC amplifiers, just a blocking capacitor.



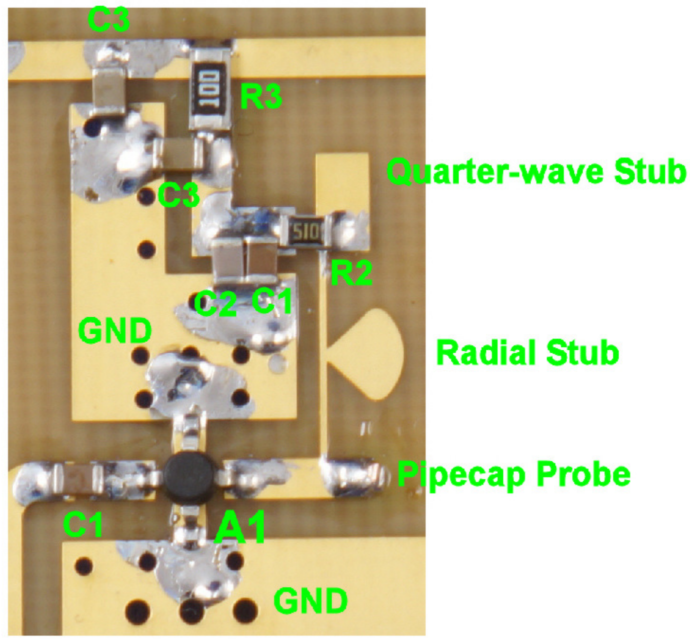


Figure 2 – Schematic diagram and layout of 10 GHz MMIC amplifier

MMIC Comparison

I had built some of the MMIC amplifiers previously, for various experiments. This spring I had access to a modern, calibrated noise figure instrument for a short period, so I started testing amplifiers and building new ones quickly to fill gaps in comparison. As a result, some of the comparisons may be apples-and-oranges, but close enough to be informative. And all configurations are one-off, so device to device variation may cloud comparisons.

The noise figure and gain of a representative sample of each type is shown plotted in Figures 3 and 4. Each device type with more samples will be discussed in detail later.

In Figure 3, the NLB-310 has a noise figure around 6 dB, corrected for second stage. The cheap and simple transverter using these devices would have a higher NF since the gain, in Figure 4, is not high enough to mask the similar NF of the second stage. The GVA-123 is perhaps 1 dB better, and might offer some improvement for the transverter front end. The ERA-1 is about a dB worse but could still be usable in the transverter. If you can find any, the MGA86576 is significantly better, about 3 dB NF; it's a shame they were discontinued.

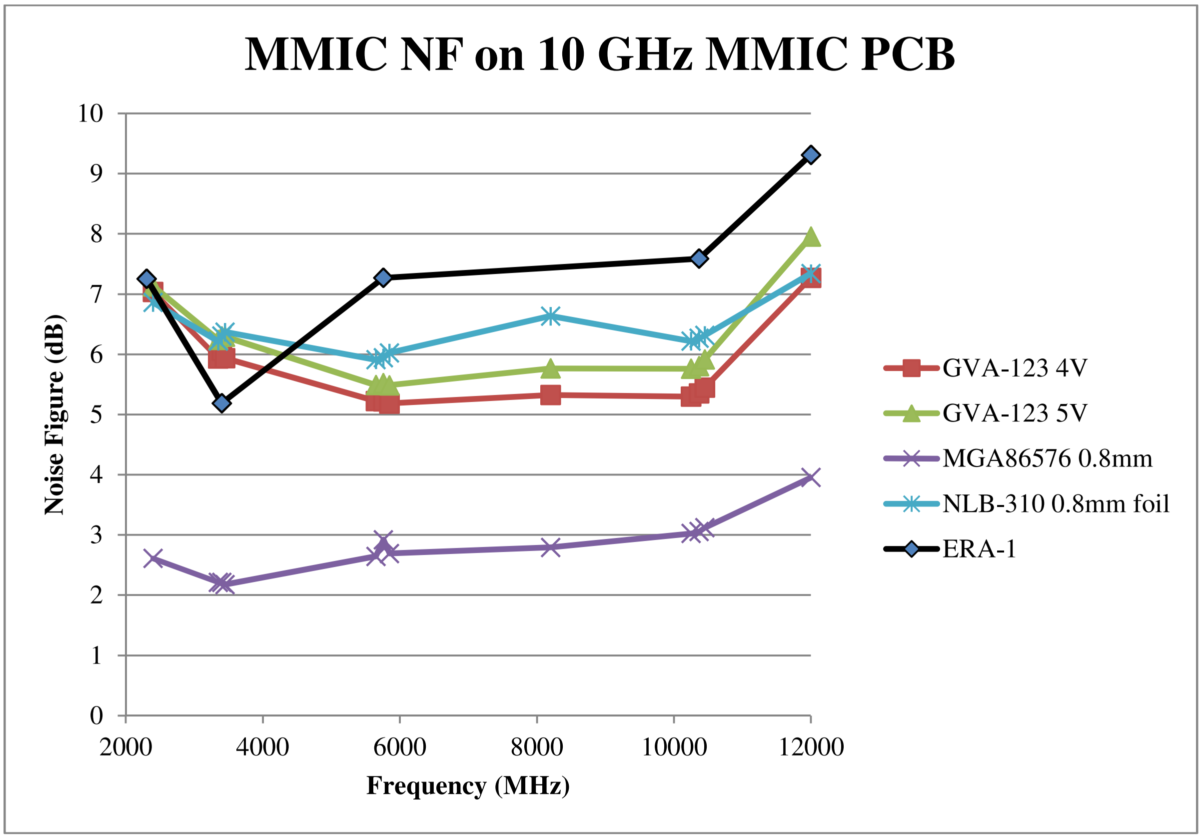


Figure 3 – 10 GHz MMIC amplifier Noise Figure comparison

Gain of the NLB-310, shown in Figure 4, is around 10 dB, which is quite usable, and the gain is good to 12 GHz. The GVA-123 has 1 or 2 dB more gain, but the gain falls off fast above 8 GHz and is lower at 12 GHZ. The ERA-1 gain is only around 6 dB, not really useful. And the MGA-86576 gain is around 11 dB but much higher at lower frequencies. Note the dips in gain of the amplifiers – the 10 GHz quarter-wave stubs have a resonance at half the frequency, reducing the gain.

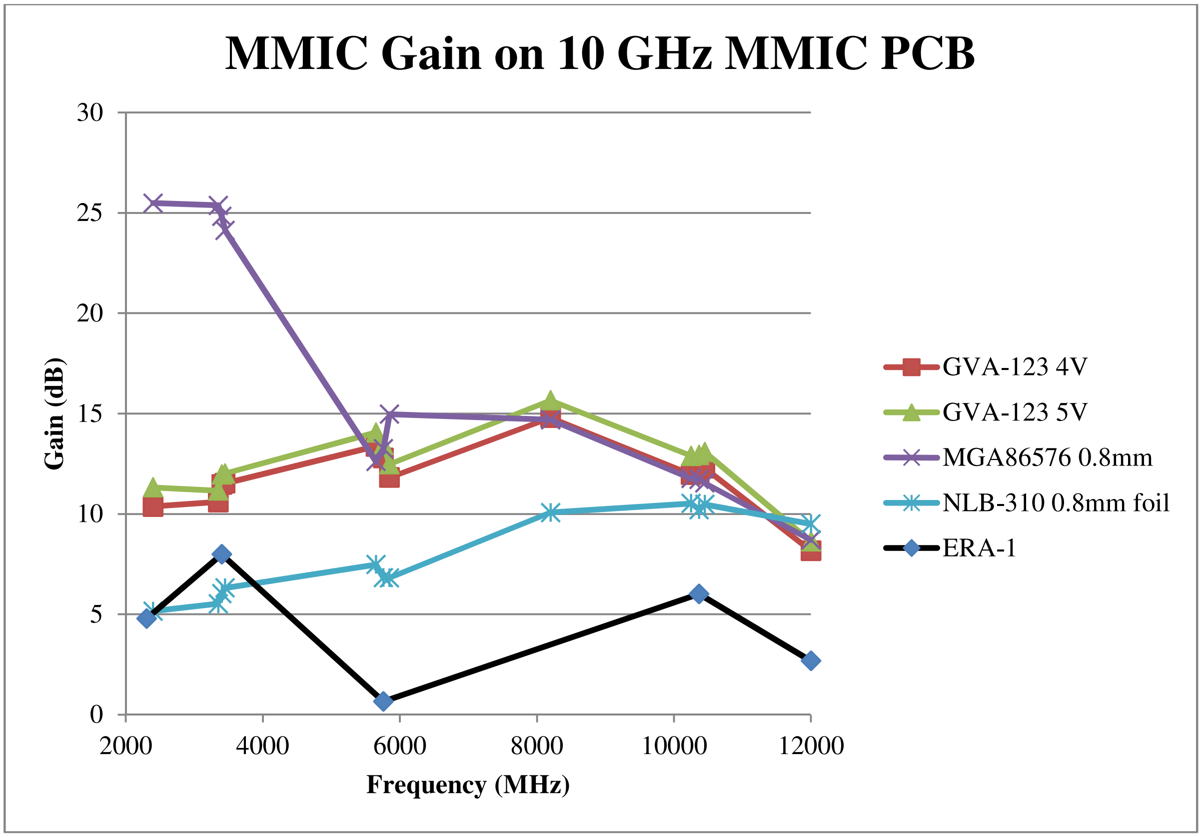


Figure 4 – 10 GHz MMIC amplifier Gain comparison

For the transverter, both the GVA-123 and the MGA856576 offer better gain and NF (at higher cost), so either would be an improvement for the receive side, but both are lower power devices, so the NLB-310 is probably still the best choice for the transmit side.

Connectors, Capacitors, and Packaging

Some of the earlier amplifiers were part of experiments to investigate connectors and packaging. From previous tests, Cheap SMA connectors from China are OK up to 6 GHz, but are at least 1 dB worse at 10 GHz than the better Taoglas ones used in the transverters. Good ATC capacitors are at least ½ dB better than ordinary 0805 or 0603 chip caps; bigger chip caps are far worse. For the 0.6mm thick PC boards which have narrower 50-ohm lines, I used ATC 600S series capacitors.

One connector experiment was to cut up a transverter board and make a single stage using the pipecap probe positions to attach semi-rigid cable out the back. This eliminates the blocking capacitors and connectors, relying on the internal bias tees of a VNA to block voltages. The results suggest that the blocking capacitor and connector might cost up to a dB at each end. But we can't leave out blocking capacitors unless there is no DC connection at the other end.

For the 0.6mm thick PC boards, I was able to locate a few SMA edge connectors but haven't tried them yet since I prefer not to use anything that is not readily available. Instead, I use the Taoglas edge connectors designed for 0.8mm (1/32 inch) thick boards and shim them on the back side with thin copper or brass. Soldering them with the shims proved tricky, so I use a razor blade as a temporary shim to hold the connector in place while soldering the top side, shown in Figure 5. The blade wedges the connector in place and solder doesn't easily stick to the steel. Once the top side is soldered, the razor blade is removed and the shim slid in and soldered in place.

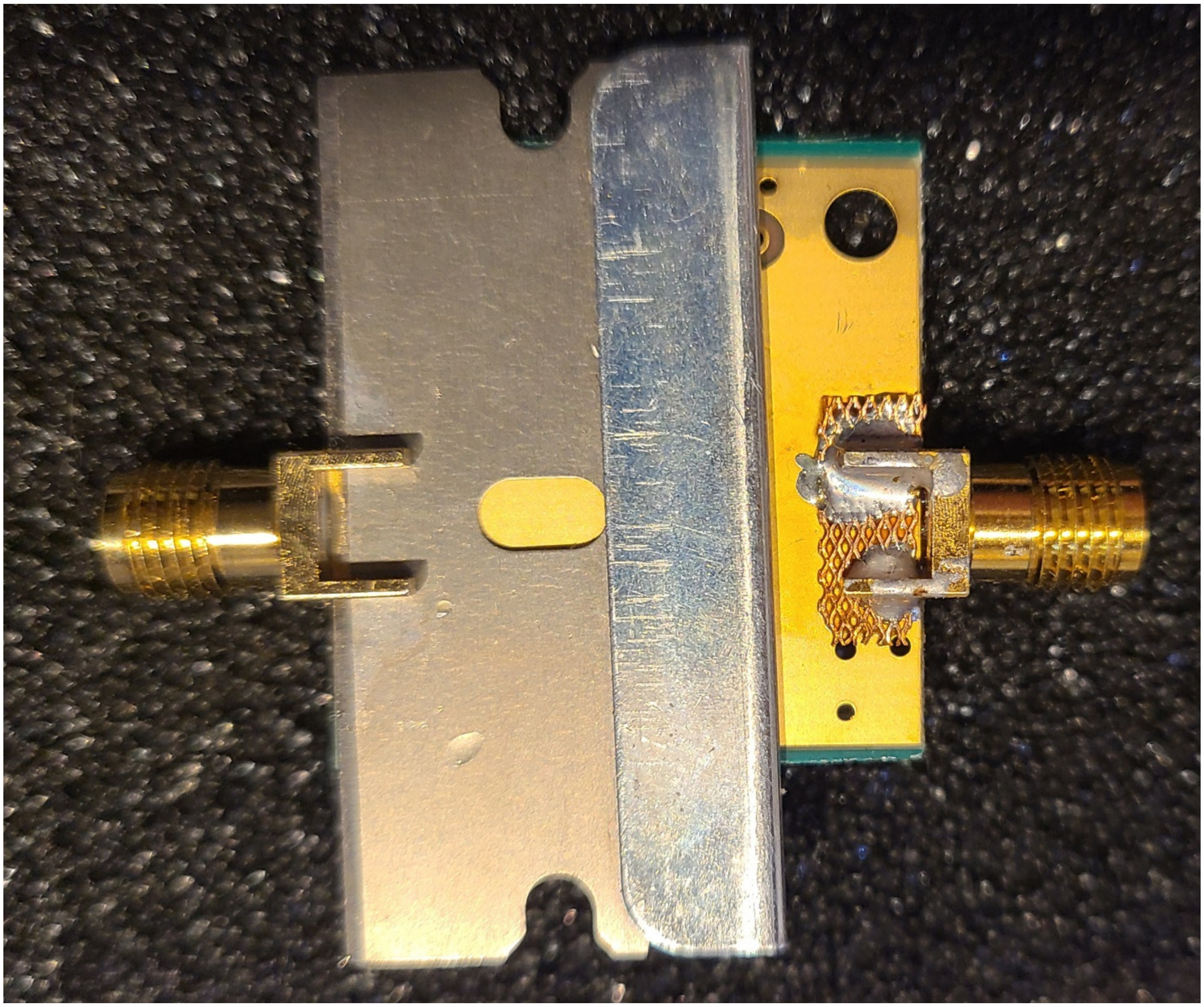


Figure 5 – Shimming for soldering SMA edge connectors on very thin PC board

This construction is quick and easy for experimenting. However, even with the shims, these amplifiers aren't very robust. We are probably going to connect them with semi-rigid coax and put some stress flexing the then PC board. One solution I have used for thin small boards is to mill out an aluminum clamshell package like Figure 6. The slots for the SMA connectors are very slightly undersize so that the connector is clamped behind the threads and the PC board is suspended inside, isolated from stress from cables. Great if you have a milling machine.

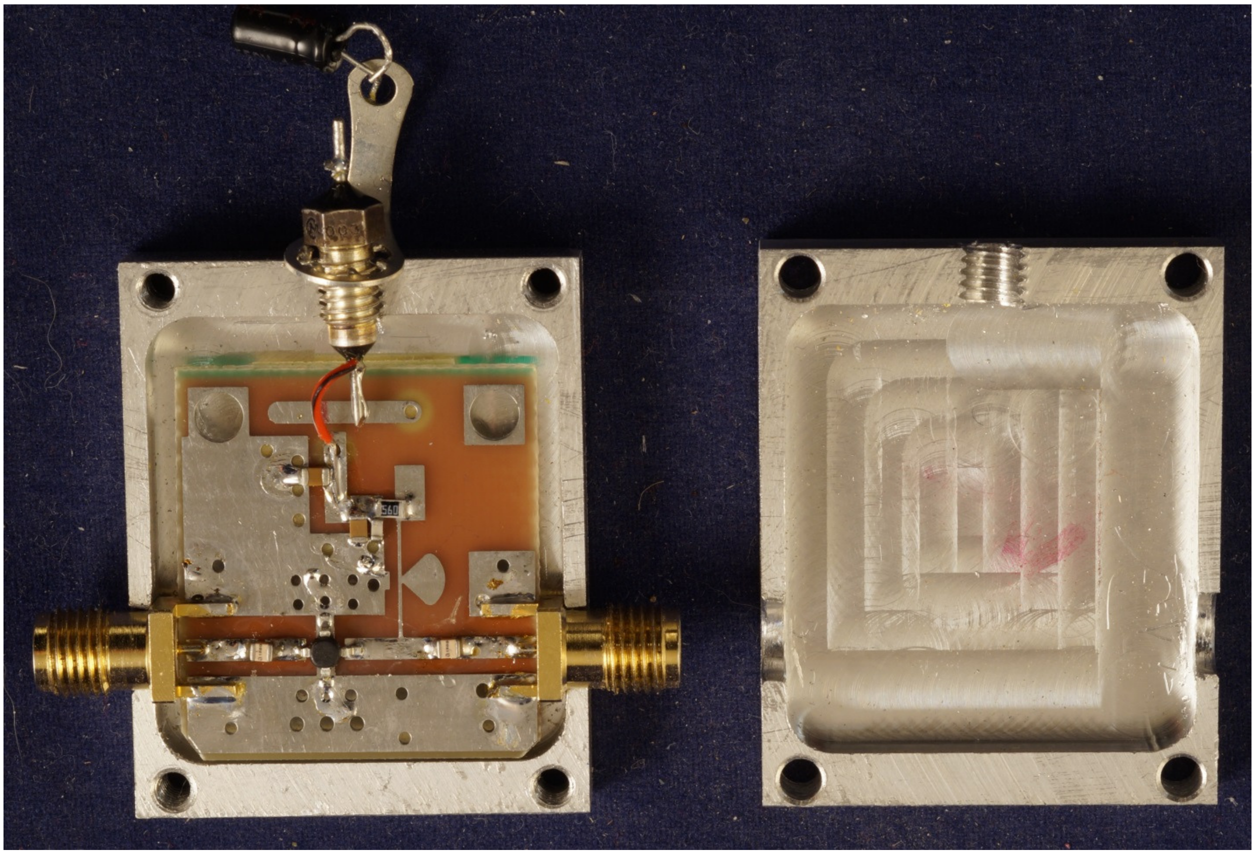


Figure 6 – Clamshell housing to reduce stress and flexing of thin PC board

Another more robust assembly technique that seems easier for building with hand tools is wrapping copper foil under the SMA connector, as Down East Microwave uses for the 3-watt amplifier. Thin foil (1/2 mil copper) is soldered to the bottom of the PC board near the connectors and folded down over a thick base plate. The PC board is clamped between a thick base plate under the board and a square ring pushing down the outer rim of the board with clearance slots for the SMA pins. The assembly, shown in Figure 7, is held together by 4-hole SMA connectors and screws which go through holes poked in the foil and into threaded holes in the base plate. The top ring is clamped in place during assembly and held in place by the top two screws for the SMA connector. I made the PC boards one inch square. At the hardware store, I found ¼ by 1 inch aluminum bar and 1-inch square aluminum tubing with 1/16 inch wall; 4 feet of each will make a lot of amplifiers. Either PC board thickness is accommodated by adjusting the hole positions.

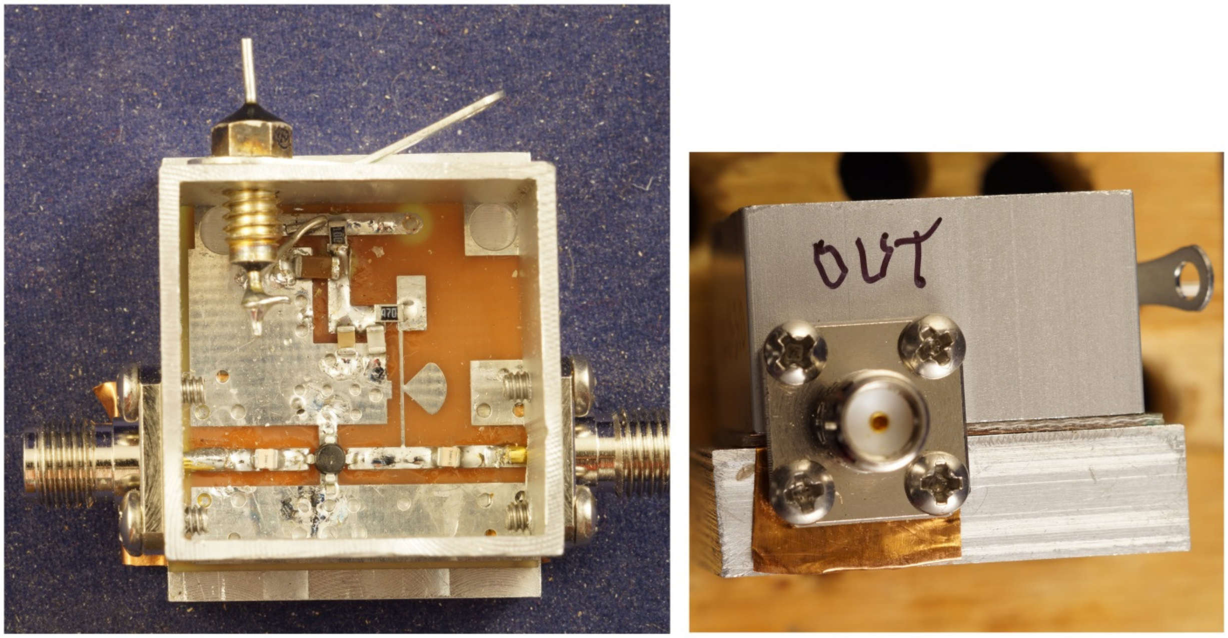


Figure 7

Another assembly technique that microwaves have been using for years is to wrap the PC board with thin brass and solder the perimeter of the board. An old Zack Lau preamp using this technique is shown in Figure 8. It works fine, but I find it takes a lot of heat and flux to assemble, and a lot of cleaning to get the flux out of the box.

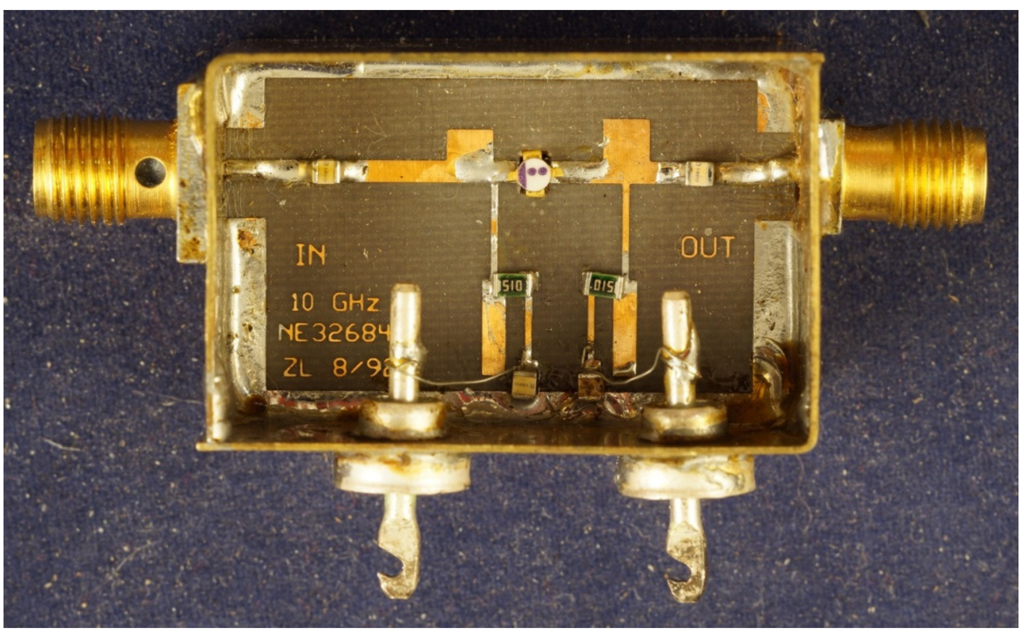


Figure 8 – Amplifier assembly wrapping thin brass around PC board and soldering perimeter

MMIC Data

NLB-310 – Noise figure of the 10 GHz MMIC amplifiers is about 6.5 dB from 2 to 10.368 GHz with all three construction techniques, the 0.6mm PCB with shim, the 0.8mm in clamshell case from Figure 6, and the 0.8mm with foil wrapping from Figure 7. The 0.8mm line with higher noise figure is the amplifier on the left in Figure 1, with ordinary chip capacitors and cheap connectors. Gain is about 10 dB at 10.368 GHz, peaking where the printed bias stubs are tuned. A utility board with RF chokes has similar performance at lower frequencies but falls off above 6 GHz.

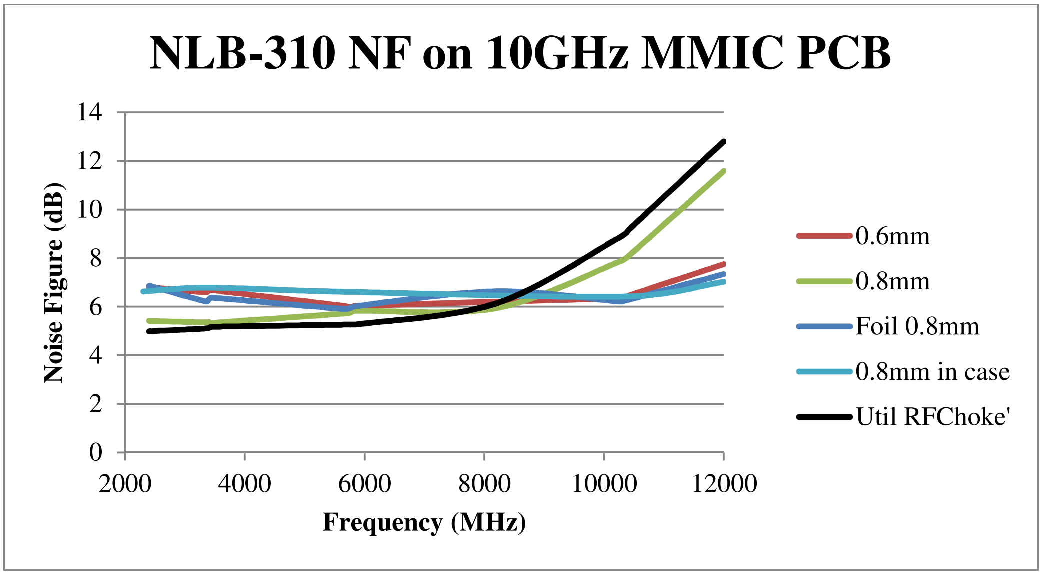


Figure 9 - Noise figure of NLB-310 MMIC amplifiers

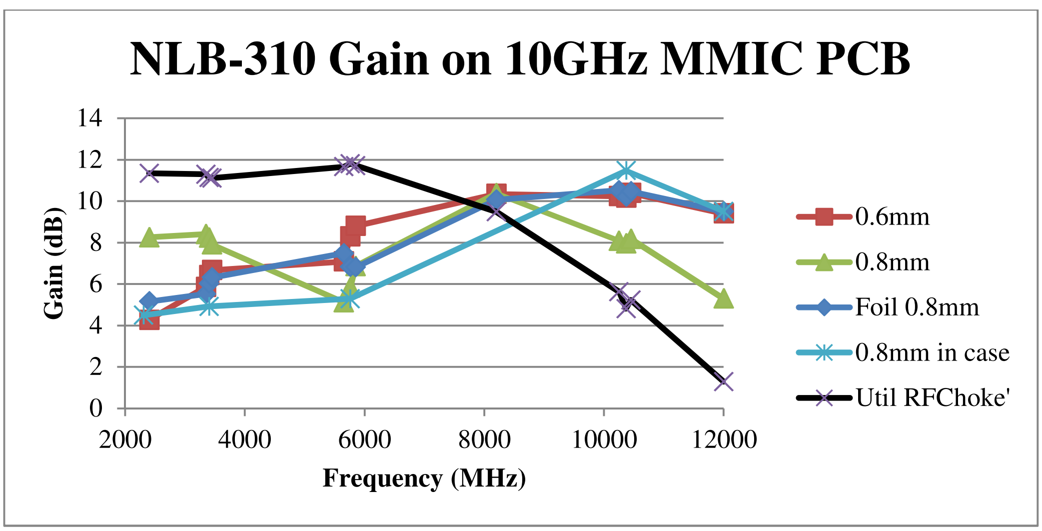


Figure 10 – Gain of NLB-310 MMIC amplifiers

GVA-123 – Noise Figure of the 10 GHz MMIC amplifier on 0.8mm PC board is under 6 dB at 10.368 GHz and goes down slightly at lower voltage but increases above 11 GHz. Gain is about 12 dB with 5V at 10.368 GHz but decreases a bit with lower voltage. Gain peaks at around 8 GHz, where the bias stubs are still effective, then falls off at lower frequencies, and falls off above 11 GHz. (The GVA-93 is similar to the GVA-123 but does not seem to work as well at 10 GHz.)

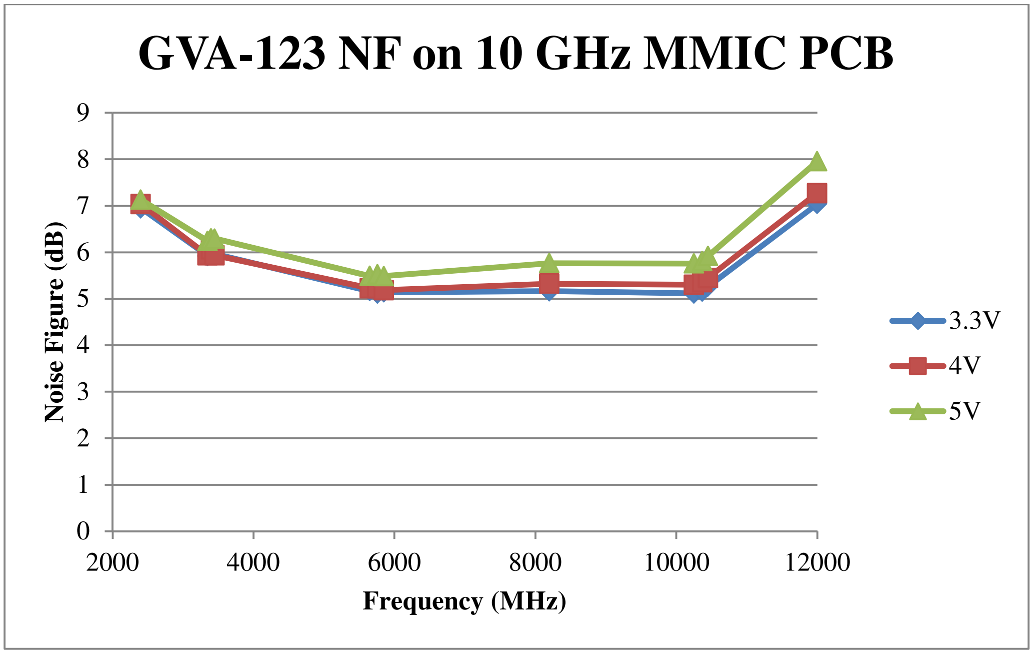


Figure 11 – Noise figure of GVA-123 MMIC amplifier

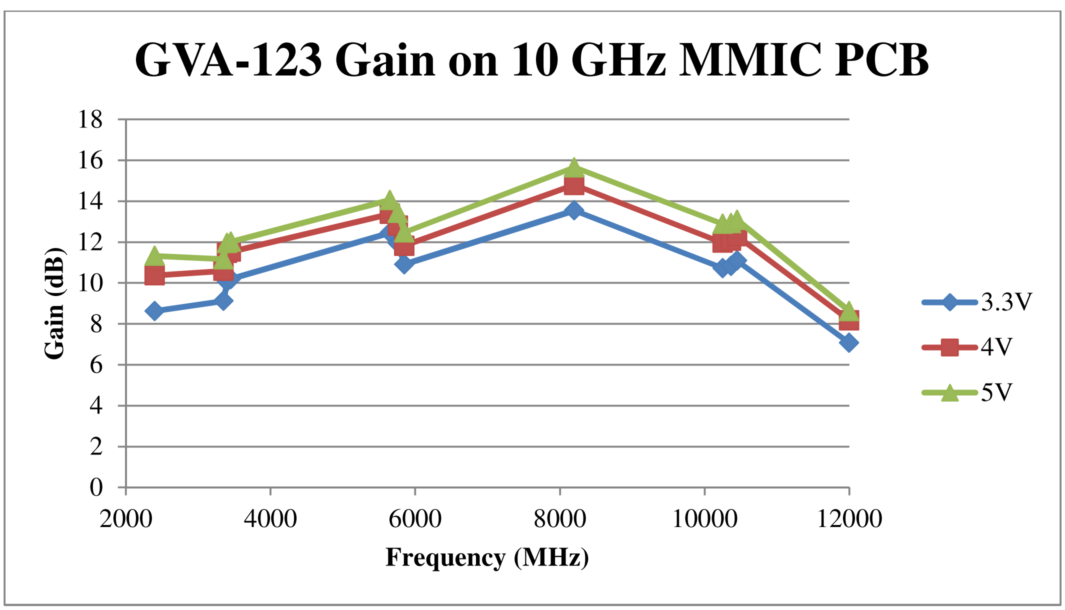


Figure 12 – Gain of GVA-123 MMIC amplifier

MGA-86576 – Noise Figure of the 10 GHz MMIC amplifier was similar on both 0.6mm and 0.8mm thick PC boards, about 3 dB at 10.368 GHz and slightly lower at lower frequencies. Gain is about 12 dB at 10.368 GHz, and much higher at lower frequencies, with bias stub resonances having significant impact. Increasing the voltage (by accident) had no significant effect on performance. A PC board with no bias stubs, just a ¼ watt 51 ohm resistor, works just as well up to 8 GHz.

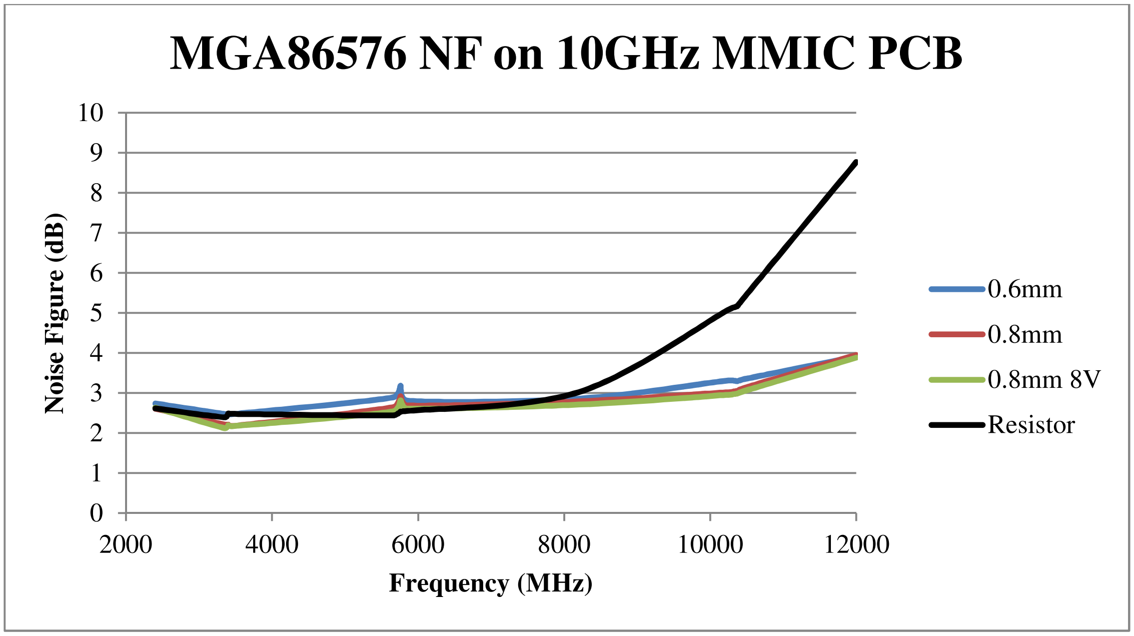


Figure 13 – Noise figure of MGA-86576 MMIC amplifier

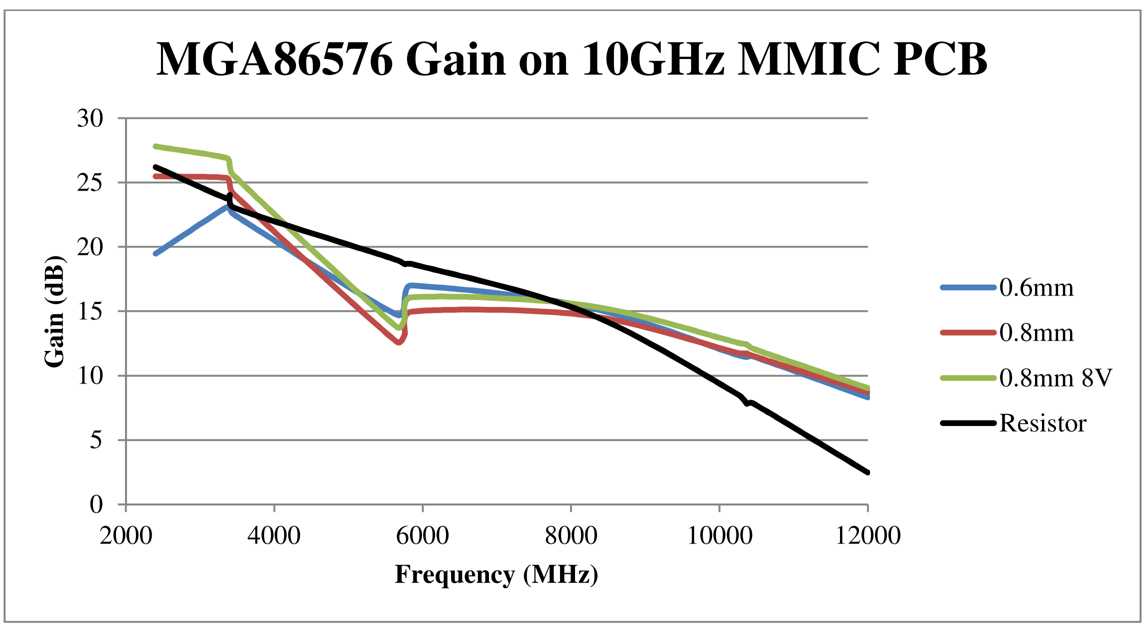


Figure 14 – Gain of MGA-86576 MMIC amplifier

Summary

These MMIC amplifiers can provide useful gain at 10 GHz and even up to 12 GHz. Only the MGA-86576, if you can find good ones, can significantly improve the noise figure of the basic simple and cheap transverter. If there are others available, please let me know. PC boards for the MMIC amplifier are available.

I am working on a simple and cheap GaAsFET preamp. The packaging alternatives explored here will prove useful. More to come…

If there are any power amplifier devices for 10 GHz that a human can assemble and a ham can afford, that would be another good project.