# An Improved 2 x MRF286 Power Amplifier for 1296 MHz

## By Darrell Ward VE1ALQ

In recent years there has been a lot of amateur construction activity surrounding the Motorola MRF286 transistors on 1296 MHz. All of the known designs have been empirically derived and have produced some good results with approximately 150 W out and a gain of about 12-13 dB for a pair of transistors. Computer modeling has shown that a big improvement of output power is possible with a considerable improvement in input return loss. The modeling has shown that at these power levels great care has to be taken in the choice of materials in order to achieve the predicted results. The improvements have been confirmed experimentally

## Amplifier Design

I have been fortunate to have available an up- to- date copy of the Microwave Office software to analyze the MRF 286 designs. The software allows the complete analysis of the RF circuitry including the power, gain, frequency response, return losses, gain compression and harmonic content. Of course the circuit board layout is fundamental to the design of the circuit and can be exported directly.

The design work was stimulated by problems encountered while trying to build the W6PQL amplifier boards. There have been several versions of the boards released and I received the Version 7.2 which gave me problems. Similar problems have been experienced by Dominique HB9BBD, who has spent an extensive amount of time in modifying the Version 7.2 W6PQL boards to get them to work properly. Please refer to the write-up by HB9BBD elsewhere in the 2010 EME conference Proceedings, which describes the modifications he has made.

The problems with the Version 7.2 boards appear in several areas:

1. Input match to each device
2. Lack of balance in the hybrid couplers

### Input Match

The input section on the version 7.2 W6PQL boards is too short to complete the matching. Some improvement was achieved by replacement of the single turn trimmer with a 4.5 pF high Q multi-turn piston trimmer. The adjustment is very sharp.

### Hybrid Coupler

There is a problem with the design of the hybrid couplers in that all of the input and output ports should share a half each of the 35 and 50 Ohm legs of the hybrid. When they do not the hybrid balance of the output ports is upset. The design of these hybrids is not obviously different between different versions of the board, yet on an earlier version V7.11 used by VE4MA the hybrid balance was apparently not a problem and did meet Jim's specifications.

### Choice of Substrates

One of the fundamental choices to be made in the design is the choice of substrates. 1296 MHz is at a frequency where some of the lower frequency substrate choices are possible as well as the high frequency ones. Of course the amount of surface area is relatively large for almost any 1296 design which will have an impact on the production cost if the high frequency substrate is chosen. The substrate material chosen is Rogers 4003C (the same as W6PQL used) however others considered were Rogers RT-5889LZ and Taconic TLX-8-200.

The lower dielectric constant materials result in wider traces and subsequently larger circuit boards. With the high current density on these circuit boards, there is some RF efficiency gained by using larger traces, but at the cost of the larger board and cost of the material.

The modeling showed that there is also a significant disadvantage in the use of thicker 0.062 inch board material vs. the more common 0.020 or 0.032 inch material. The thicker substrate material, i.e. 32mil results in wider copper traces and radiation loss from the board is not so much of an issue. Please note however that with the high powers being used here the radiation hazard does exist for the eyes!

The final consideration is the thickness of the copper plating on the boards. The skin depth for copper at 1296 MHz is about 0.0006 inches (or 0.6mil) and the copper thickness for 1oz copper is 1.3779527559055mil and for 2oz copper is 2.75590551mil Therefore there is no advantage to the use of 2oz copper board material when using the RO4003C 32mil. The Hybrids and matching Pads are of sufficient width to handle the power capabilities of the active devices being used in this design.

**Sources of Transistors & Choice of mounting**

The MRF286 / XRF286 transistors are no longer in production by Motorola or its descendent company Freescale. These transistors are available by salvaging from surplus "PyroJoe" amplifier boards available on EBay but they are also being supplied from stock piles in China. It is a sad fact that copies of semiconductors are being produced in China that are cosmetically excellent but the RF (and other) characteristics may not match the original device performance. There is considerable variation of the input and output capacitance of some devices but this has not been correlated to RF performance. The effect of the capacitance changes should be negligible at 1296 MHz since the impedances are so low. There has been a concern with purchases made by several ham operators but it is not clear if the MRF286 devices being supplied are originals or copies and if there has been a problem with the devices supplied but as the old saying goes "Buyer Beware".

There are two (2) mounting choices for the MRF286, with the standard being the flanged package carrying the MRF286 designator and the flangeless package that is designated as the MRF 286S. The spacing of the Gate and Drain leads above the bottom of the package is the same for either version. The flangeless MRF286S must be soldered down to something that ultimately is intimately attached to the heat sink. In both cases some form of heat spreading plate is desirable and great care taken to mount the devices with the lowest thermal resistance possible, and greatest RF return path to the device Source. I do recommend the MRF286S over whose you see on eBay which are the MRF286F with flange mounting because the F version can only be secured with 4-40 bolts, unless you drilled the slot for 6-32. Then you only have something like Wakefield Thermal compound to conduct the device heat to the heat sink, and I found the device was hotter around each bolt than the spreader was. Whereas the S version is soldered to the heat spreader allowing heat to be more evenly dispersed.

I suggest if using the Flange mounting version of the MRF286 is to simply cut the bolting tabs off and solder the device directly to the copper heat spreader as you would with the RF286S version, this should eliminate any localized heating around the device and improve greatly the RF return path to the Device Source.

## Design Results

The designs were completed for several board materials but this report will concentrate on the .020 and .032 inch RO4003c substrates. The results with the 0.032 inch substrate were very interesting in that the best power output is 320W with 13.5 dB gain at the 1dB gain compression point! This result is shown in Figure 1, while Figure 2 shows a DC power efficiency of 58%. The gain and return loss vs. frequency are shown in Figure 3.

The results for the 0.020 inch substrate are similar except that the maximum output power at 1 dB gain compression is reduced to about 280 W. Nothing could be done to the design to improve the output power. Another big reason for using RO4003C 32mil material over the thinner 20mil substrate was that at 300+ Watts output the output Hybrid was heating and starting to shine like a Mirror and very certainly would have lifted from substrate over a period of time.

The modelling program also predicts the harmonic power levels and this is shown in Figure 4.

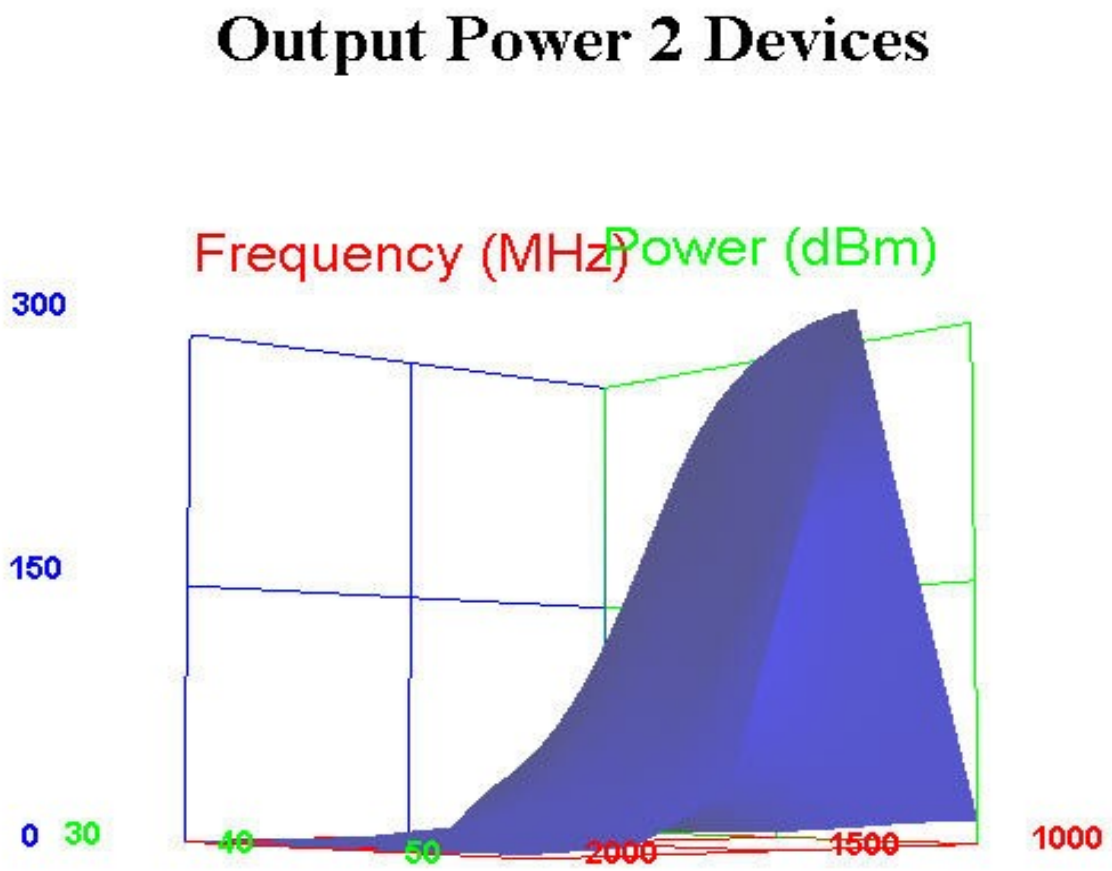



**Figure 1 DC and Power Added Efficiency vs. Drive for .032 inch RO4003C Substrate Amplifier**

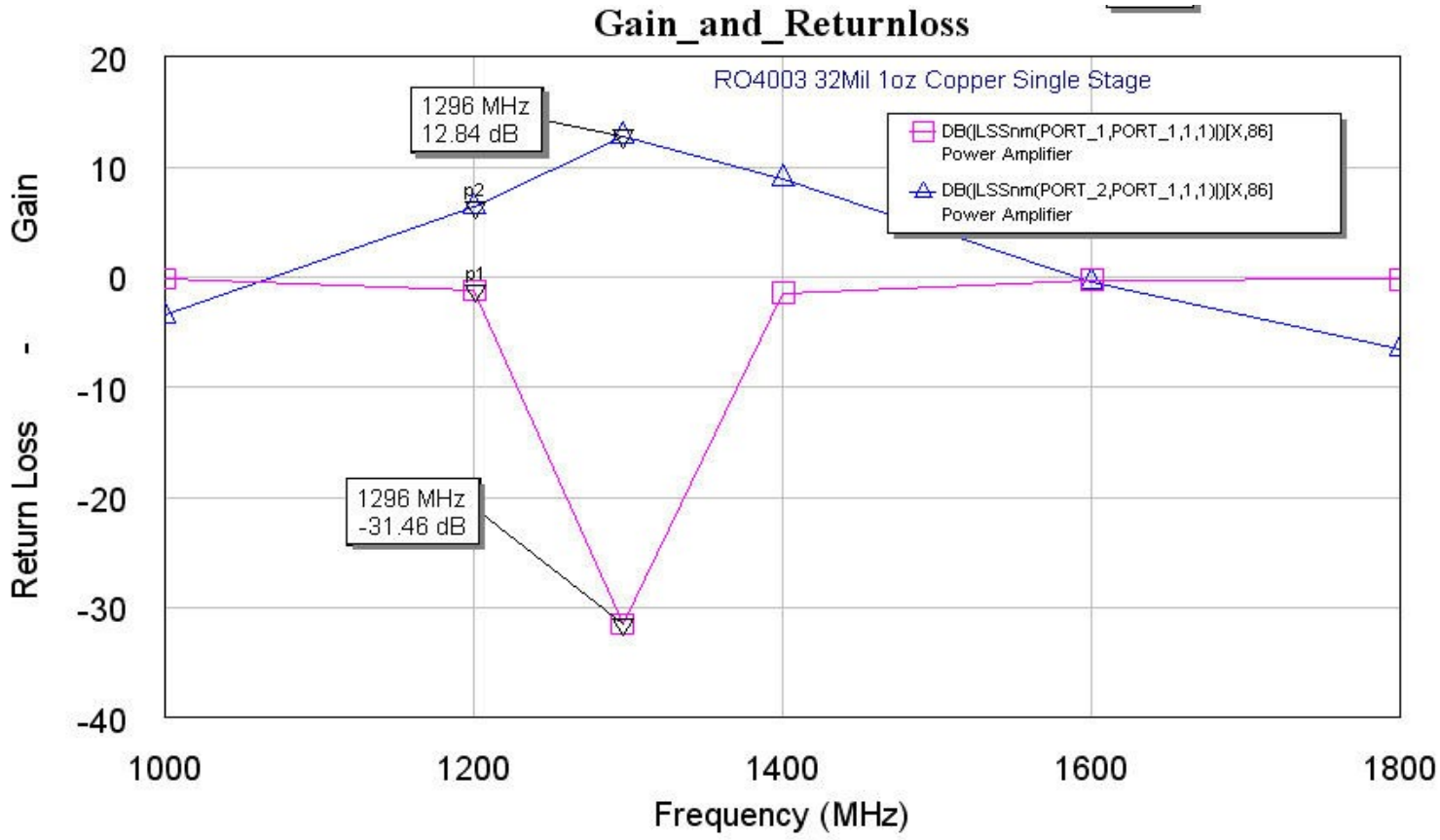



**Figure 2 Gain & Return Loss vs. Frequency**

## Final Circuit Board Design Layout & Schematic

I have no intentions of putting this board into production, but all Drawing and Gerber files will be made available to those who ask. I can also provide a source connection for the MRF268S Devices if needed. Similarly if anyone is interested in the board information for the 20 mil substrate design can be made available by asking me by email to ve1alq@ve1alq.com . Or check Web Site for more information: http://www.ve1alq.com Complete ZIP Package should be there soon.

## Four Port Power Combiner Design

In my investigations it became apparent that 4 of these 330W modules could not be combined using a hybrid coupler made of even the 0.032 inch RO4003 substrate material. I did follow through with a design using 0.062 inch Taconite substrate (see Figures 6 & 7 below) which includes a directional coupler for forward and reflected power monitoring purposes. Once again those interested can contact me for Drawing and Gerber files.

A sub-set of this 4 Stage combiner was extracted in order to combine 2 amplifier modules. It is essencially the top 1/3$^{rd}$ of the 4 Stage Combiner (figure 6) and is shown in Figure 8. The Coupler coupling and isolation performance is shown in Figure 9. The excellent Port to Port Balance and very low insertion loss should be noted. Ports 1 & 2 would be the driven Ports, Port 3 is the Isolation Port and Port 4 the combined output port. Once again those interested can contact me for Drawing and Gerber files.

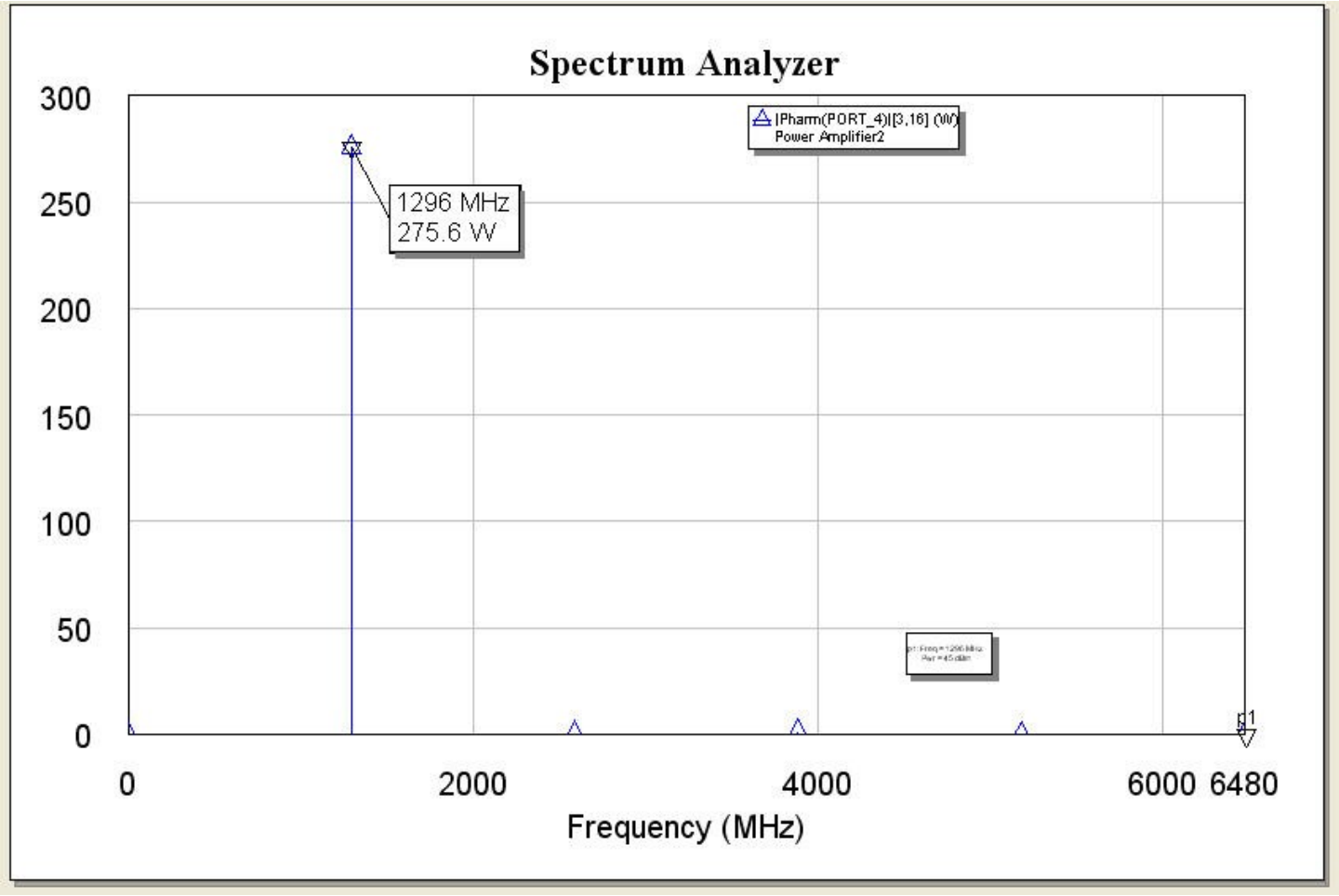



**Figure 3 Output Spectrum vs. Frequency @+41dBm Drive Level**

## Actual Results

The 2 stage amplifier design has been tested using the 0.020 inch Taconic's TLX substrate at a saturated power of 330 W. As further confirmation of the design, it has been checked and confirmed by Mr. Dane Collins, the CEO of AWR/ Microwave Office and his Support staff who provided excellent support and corrective pointers as the project developed.

This brings up a very IMPORTANT point: This board is not, nor will it be produce for profit by any one and I mean ANY ONE…….PERIOD, including myself or my temporary licence will be revoked. I am sure there will be someone who perhaps would like to see that happen, but in the spirit of Amateur Radio let's hope no one attempts to do it.

I am attempting to locate a PCB Manufacture who will be able to produce the board at a reasonable price for those who do not wish to produce their own boards using either the Positive Sense, or Negative Sense approach, and will advise all who that will be.

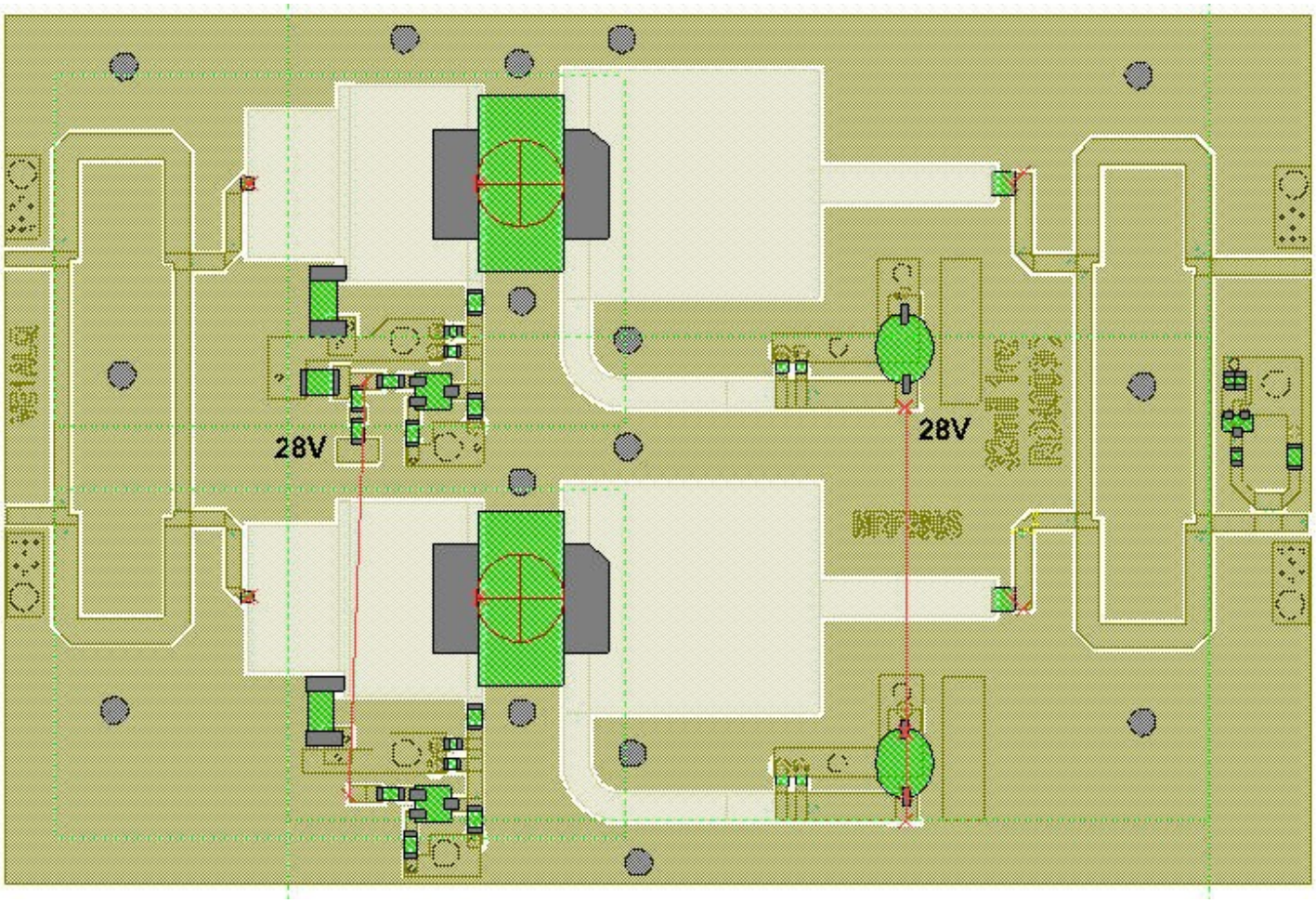



**Figure 4 Circuit Board Layout for 0.032 inch RO4003C Substrate**

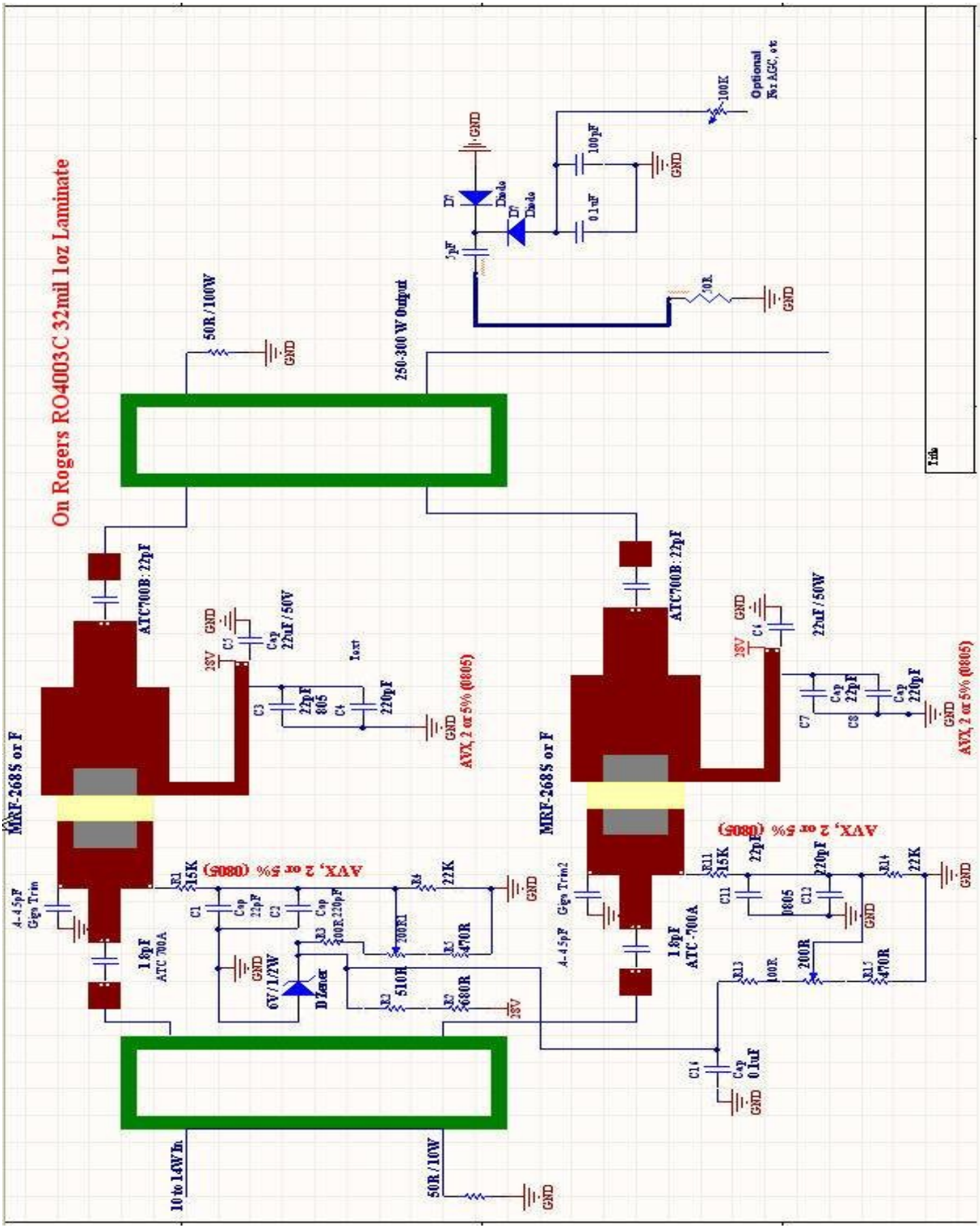



**Figure 5 MRF286 Amplifier Schematic**

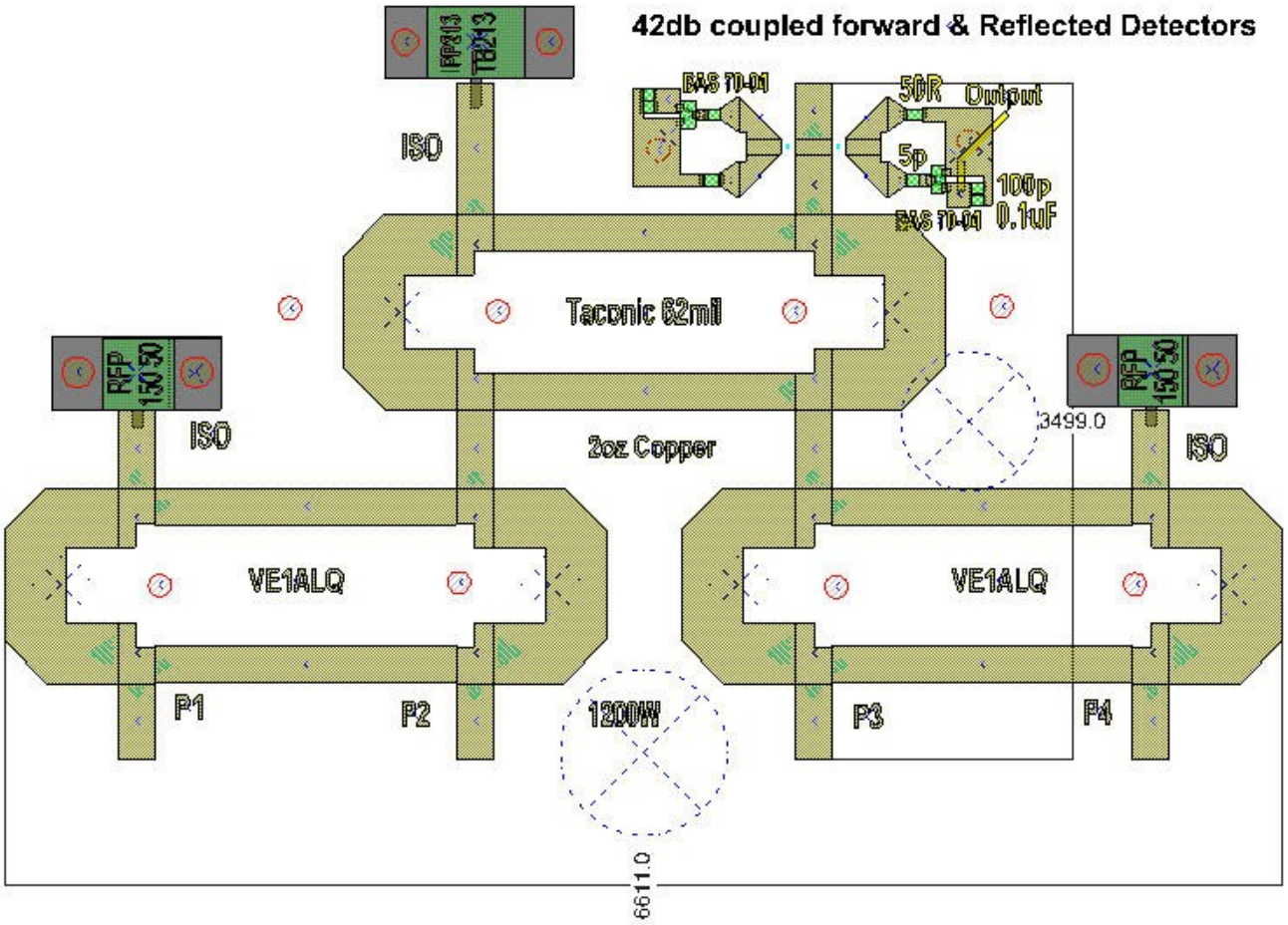



**Figure 6  4 Port Power Combiner Layout**

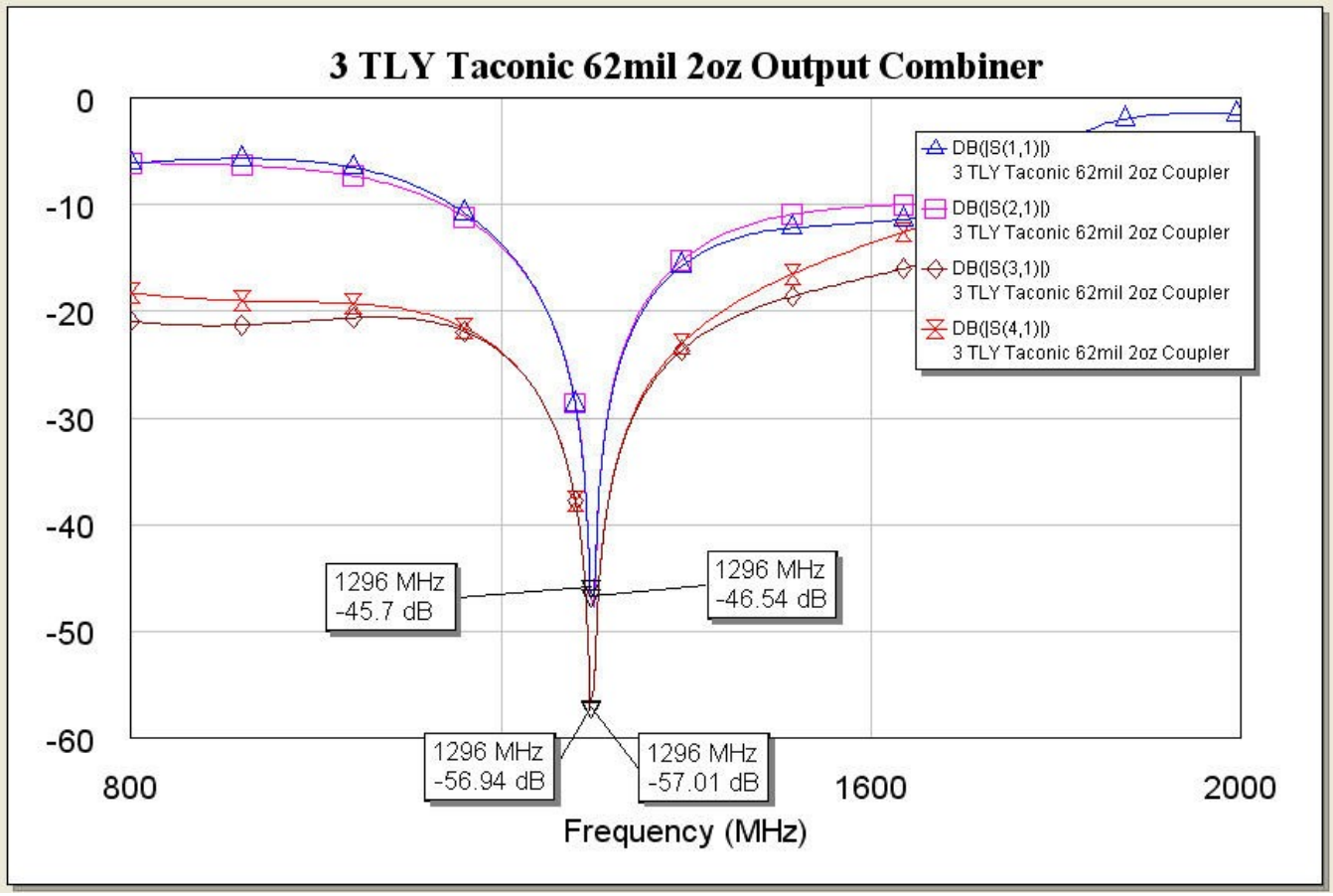



**Figure 7 Isolation & Coupling Response of 4 Port Power Combiner**

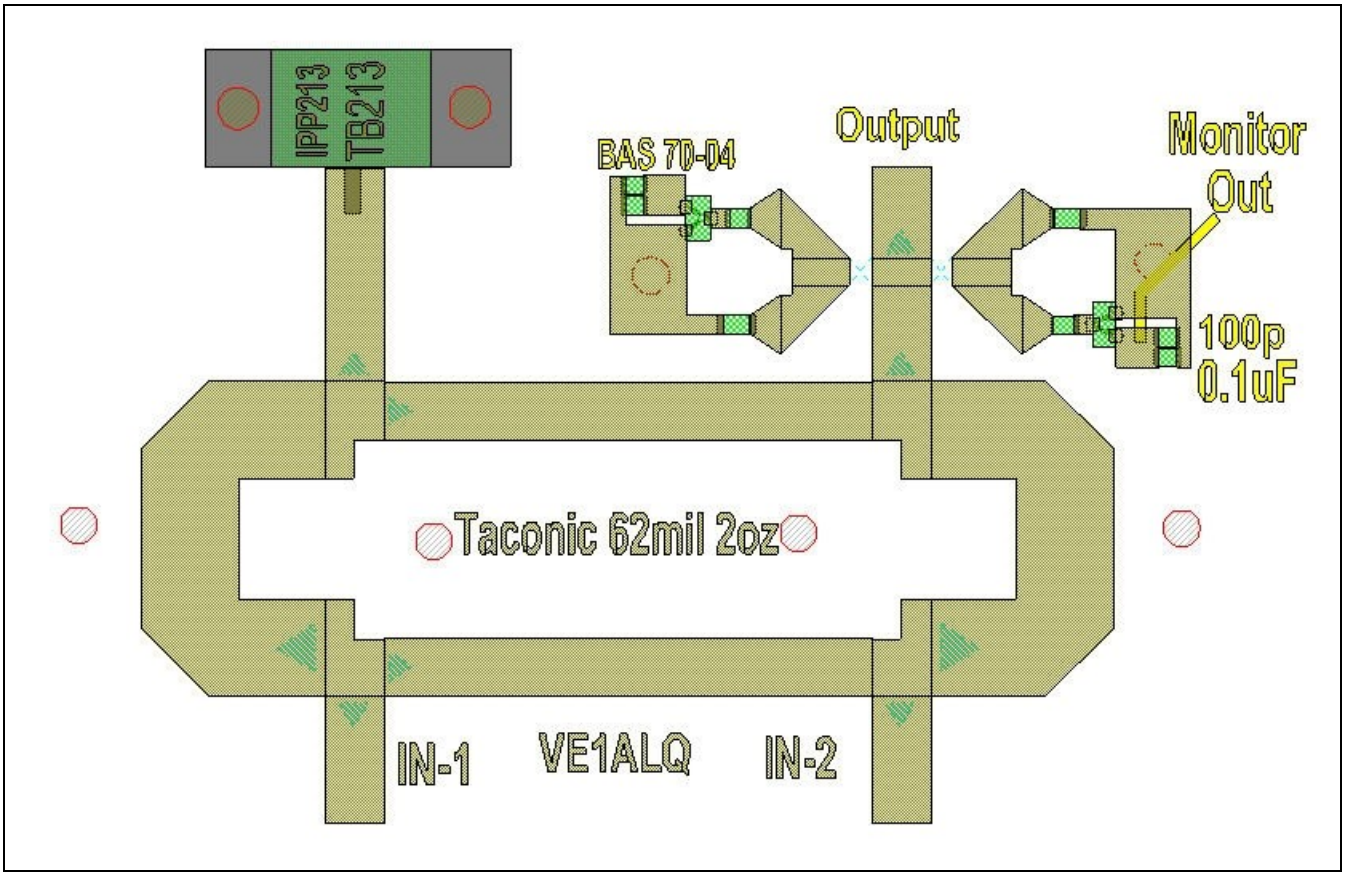



**Figure 8 High Power Output Combiner for 2 Amplifiers**

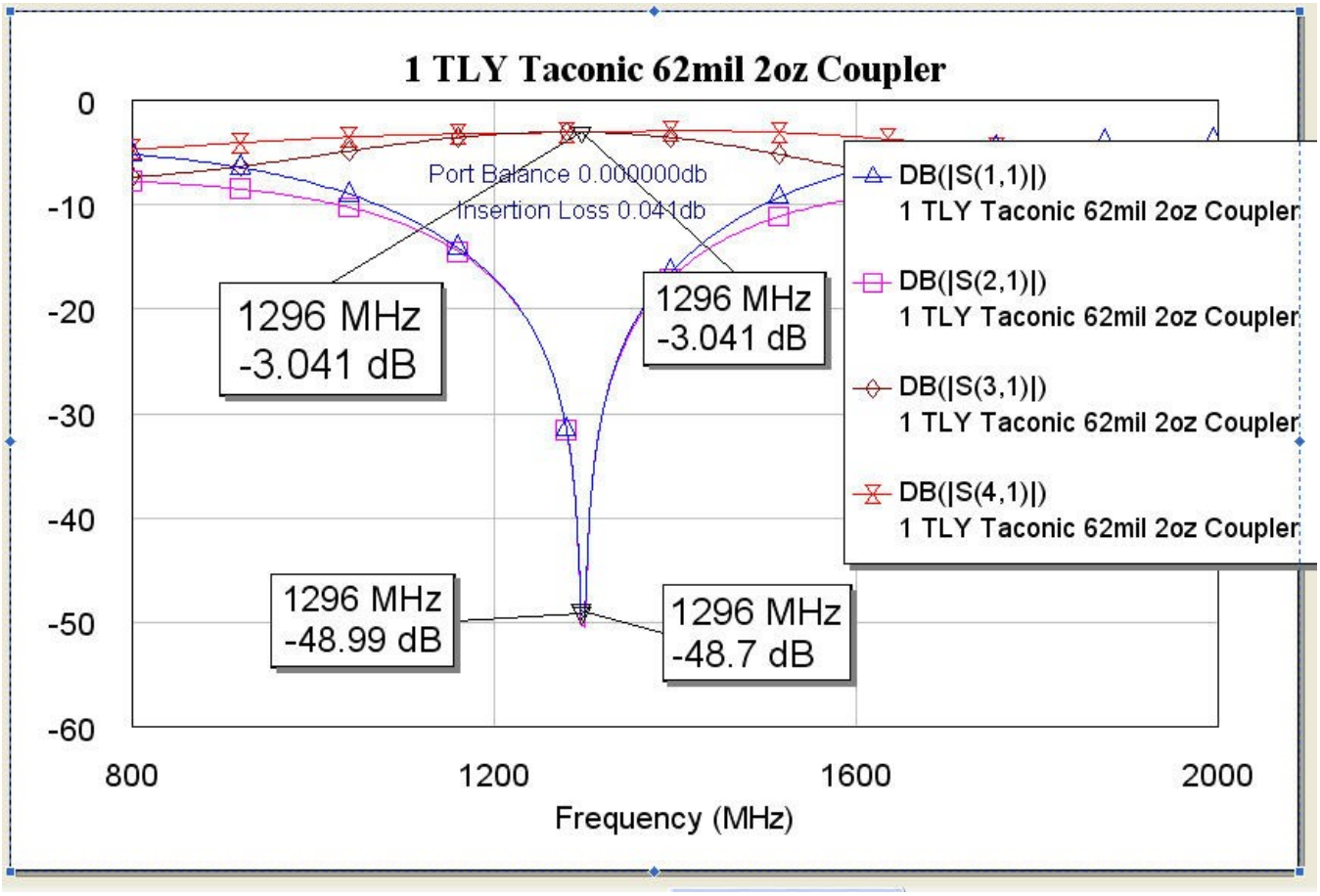
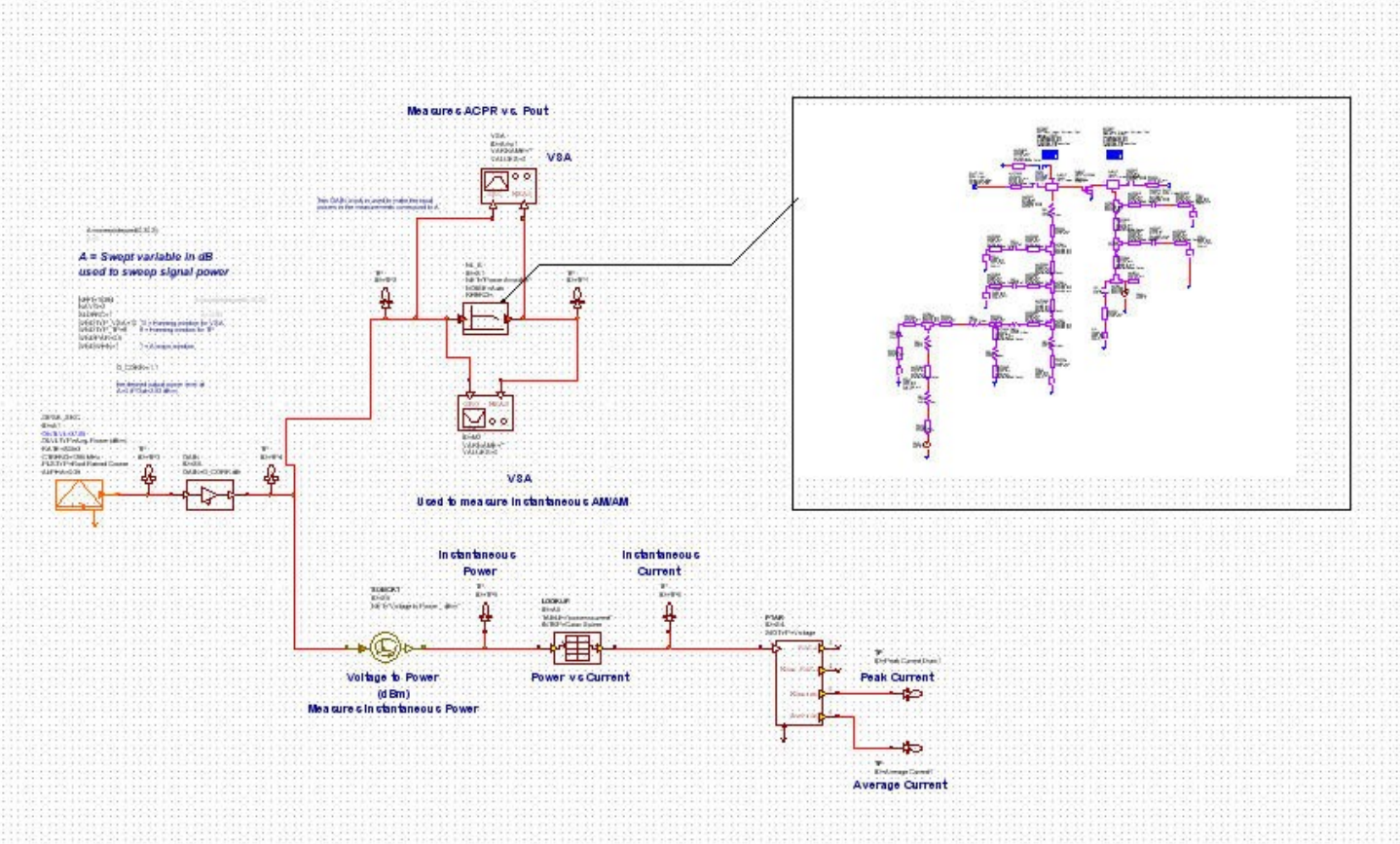



**Figure 9 Isolation & Coupling Response of High Power Output Combiner for 2 Amplifiers**

**Part of MWO VSS-EVM Design System.** **Schematic implanted**




**A completed dual Device using Taconic TLX 20mil 1oz, this produced in excess of 300W when drive into compression. Those Coils or chokes were not needed and later removed with same results.**

**This is Old, but all I had for Picture until I assemble a another one**

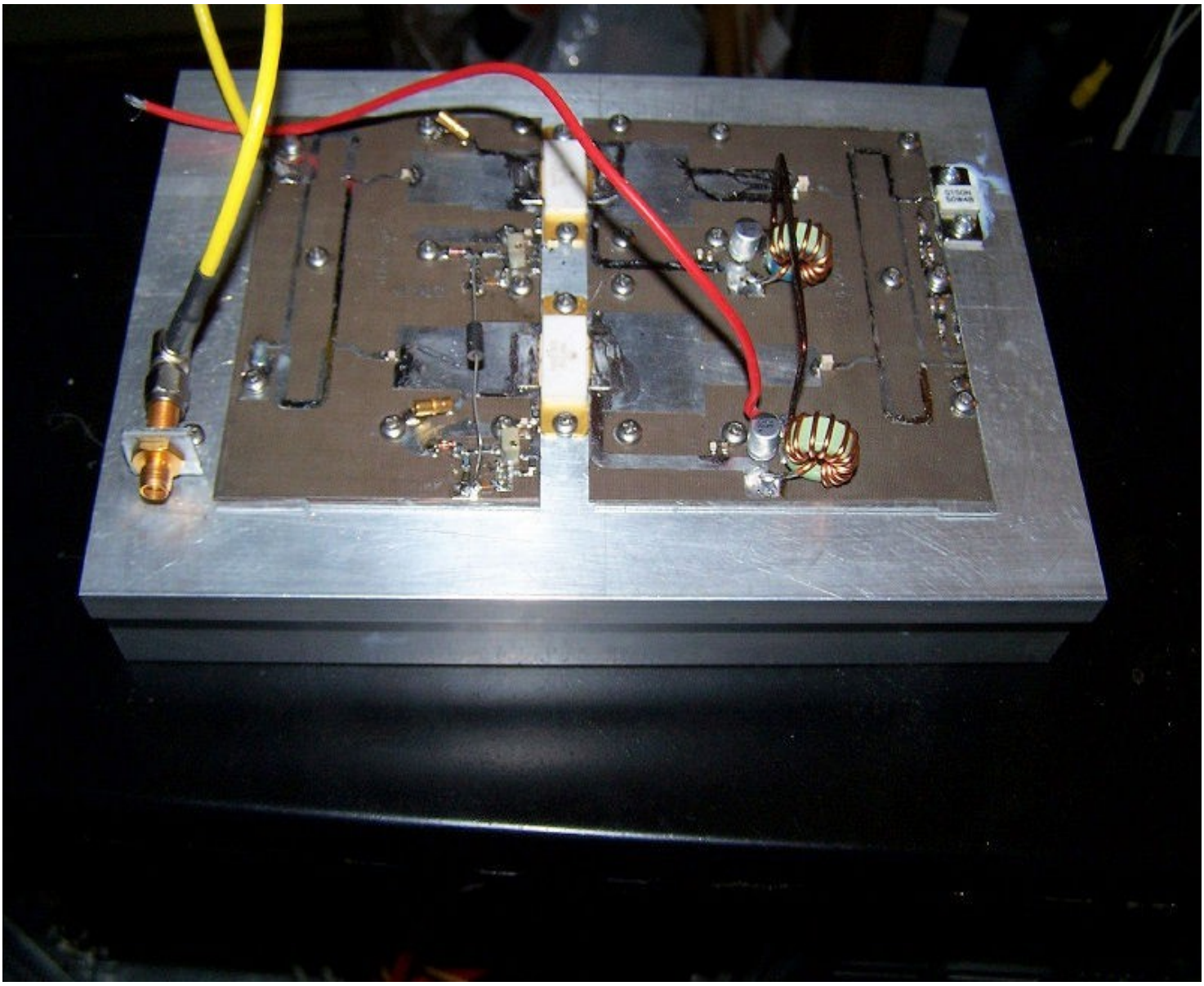


**Figure 10**

**This Image above was made from Taconic 20mil and without the Flanges on the Devices removed and as a result generated higher heating around the Machine bolts (4-40's) which was all the flange mount would allow. Solder the device in rather than bolting in would allow much better heat disturbing to the heat spreader, or heat sink.**