2 Watts on 24 GHz
Using the Surplus mm-Tech Power Amplifiers

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INTRODUCTION

Activity and interest in the 24 GHz amateur band continues to grow. Many of those on 10 GHz narrowband are now migrating to 24 GHz using surplus modules such as the PCOM transmit/receiver units, as well as the DB6NT transverters. Noise figures are now on the order of 2 dB using PHEMTs.

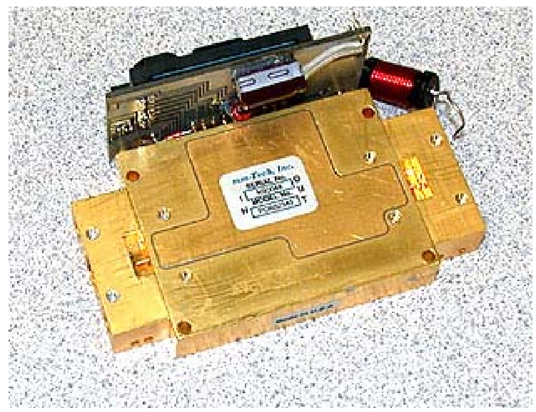
Solid state power at 24 GHz, however, has been slow in coming for the amateur enthusiast. For a number of years, most amateurs on 24 GHz ran bare mixers. A few individuals used the low noise packaged PHEMTs such as the NE324 to get to the 10-20 mW level. Very few amplifiers above the 100mW level were to be found on the surplus market. The only other choice for RF power at 24 GHz was the use of a TWTA, but even moderate power TWTA's capable of operation at 24 GHz are rare and costly. TWTA's don't easily lend themselves to portable work, either.

Then around 1998 or 1999, a number of ½ watt Milliwave amplifiers became available thanks to Will Jensby, W0EOM[1]. These were a big hit and quickly sold out! Somewhere in this same timeframe DB6NT offered a 1 watt amplifier for about $1200 USD. Then, a number of 1.4 watt PA's were designed and assembled over the last several years via the Pack Rat / Update 24 GHz Amplifier Project. These used MMIC die components that were wire bonded and packaged into a housing. A limited number of these amplifiers were built and made available at cost to those who were on the band or serious about getting on 24 GHz. The design of this amplifier was presented at Microwave Update 1999 in Dallas, Texas.[2] Unfortunately, the demand for the 1 watt PA's exceeded the group's available time and resources! [3]

Fortunately, for the amateur community, a number of additional surplus PA's have recently become available for 24 GHz! This paper describes one such amplifier and gives some operating suggestions. Many of the fundamental concepts may apply to other surplus millimeter wave amplifiers as well.

mm-TECH 24 GHz POWER AMPLIFIER

The mm-Tech PA shown in the photo was designed for highly linear service for one of the commercial LMDS bands. It uses MMIC chip and wire construction, and is housed with a bias board and WR42 waveguide at input/output.



mm-Tech 2 Watt PA

Unfortunately for the manufacturer (perhaps a *fortunate* event for amateurs) the LMDS broadband service never really took off and a number of these amplifiers have been found on the surplus market. The author was involved in the design of this and similar amplifiers from the above company, so this information has made it a bit easier to put these to use for amateur operation at 24 GHz!

One nice feature of this unit is that the amplifier's original operating frequency range was just above the 24.192 amateur allocation. What's more, the original application required an operating bandwidth of nearly 500 MHz, with a very flat gain response. In order to meet the tight gain spec, the amplifier's overall gain response (and impedance match) needed to be somewhat wider yet. So moving the amplifier down just a bit to the 24 GHz band is a fairly easy task! The input/output tuning is simply adjusted a bit and the unit works quite well for amateur use at 24.192.

When tuned for 24.192 GHz, the mm-Tech PA has the following characteristics:

Small signal gain	55-60 dB
Input Return Loss	>15 dB
Output Return Loss	>15 dB
P_{1dB}	+30 dBm
Psat	> +33 dBm
NF	5 dB
Voltage	8 to 15 VDC
Current	1.3 A @ 12 VDC @ full power output

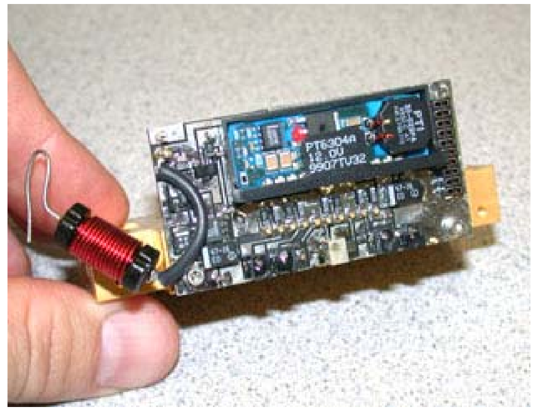
This amplifier produces over 2 W of RF output by combining two power MMIC's as the last stage. Incidentally, these are the TI/Triquint TGA9070 MMIC's[4], the same device that Charlie Suckling, G3WDG[5] presented, and the same device used in the aforementioned project amplifier.

RF INPUT / OUTPUT

When the amplifier is oriented as shown in the figure, the WR-42 RF input is on the left side, and the RF output is on the right. 4-40 tapped holes are provided for mounting into a waveguide system. Wave guide may be mounted to the amplifier using 4-40 x ¼" or ½" screws, depending on your wave guide flange thickness. Be VERY careful not to bottom out the screws, or you may strip the tapped holes. Waveguide should be mounted tightly against the amplifier so that there are no gaps at the flange interface.

OPERATING VOLTAGE

The amplifier includes a bias board mounted to its side, which supplies the necessary gate and drain voltages, with the proper sequencing. A DC-DC converter is included at the board's input (large rectangular module towards the top of the board) which allows for a wide range of operating voltages. Nominal input voltage is +12 VDC; however, the amplifier will work with an input range of +8 to +15 VDC.



Bias Board View

This supply range is advantageous in portable battery powered operation where voltages can vary over time. The DC current drain is a function of supply voltage, and since the output devices are somewhat class AB, current will also increase slightly when the amplifier is driven to full output power. At 12 VDC the small signal current will be under 900 mA. With full RF drive, however, the PA will draw approximately 1.3 A. With the DC-DC converter, current draw is inversely proportional to supply voltage, so if the input voltage is lowered, the input current will increase.

Note that increasing the input voltage will NOT increase the RF output power.

A regulated 12 VDC supply is recommended for operating the amplifier. Do not exceed +15 VDC.

APPLYING VOLTAGE

Most of the surplus amplifiers have a wire dangling from the bias board at the DC input (see above photo). If your unit does NOT have this, locate two small PC board solder terminal on the upper left side of the bias board. The lower terminal is the positive input. Solder a +12 VDC supply lead here, and if desired, a ground lead may be soldered to the top terminal.

SEQUENCE of OPERATION

The amplifier bias board automatically sequences the MMIC gate and drain voltages, so there are no special precautions necessary in that regard. As with any solid state PA, care must be exercised in using the amplifier in a system. The PA has a tremendous amount of gain! If left un-terminated, oscillation may occur. For this reason (and to limit self heating) it is recommended that voltage ONLY be applied during the transmit cycle. Additionally, the PA should always be operated into a good load, preferably less than a 2:1 VSWR.

The following sequence of operation is recommended for the PA:

1. Output of amplifier connected to antenna
2. Voltage applied
3. RF drive applied
4. RF drive removed
5. Voltage removed
6. Antenna switched to receive position.

Use your favorite sequencing method!

PA HEATSINK REQUIRED

The die MMICs used in this amplifier need to be run at moderate junction temperatures for reliable operation. The PA generates nearly 16 W of DC power in the form of heat, which must be dissipated. It's no fun chiseling out a blown MMIC die and trying to replace it! More importantly, there are no spare replacement devices available! You'll want to be able to run the amplifier key down for an extended period of time to "work the weak ones"[6] and never have to worry, so again heatsinking is vital.

Lots of us like to mount modules to a transverter chassis for mechanical support and heatsinking. If the amplifier is mounted to a large aluminum panel (at least say 8 x 8 inch) of sufficient mass, this may suffice. As a test, mount the amplifier to the panel with the holes provided, put a WR-42 load on the output, and simply apply DC power to the amplifier. If after five minutes it gets more than warm to the touch, you need more heat sinking! Keep in mind too, that inside a transverter enclosure the ambient temperature will likely rise, which directly adds to the amplifier's ambient operating temperature, so it's best to use a larger heatsink arrangement and err on the side of caution.

Ideally, the amplifier should have a finned heatsink attached to its bottom side. My recommendation is to use a heatsink with ½" to ¾" fins measuring at least 2 x 2.5" (the same size as the amplifier housing). This method may also allow you to mount the amplifier in any convenient spot within your transverter enclosure. Assembling a lineup often becomes a three dimensional problem since surplus waveguide and various RF modules are used. By having a separate heatsink attached to the amplifier, you're not limited to mounting the unit directly to a mounting plate.

Before installing your heatsink, make sure there are no burrs on the amplifier's bottom surface, especially around the 4-40 thru-holes. A *small* amount of thermal compound is a good idea. Use sparingly.

RF INPUT DRIVE LEVELS

The typical PA has a lot of gain… 55-60 dB! Think of this as a solid state TWTA! With 60 dB of gain, for instance, this means that 1 W output power is attained with only –30 dBm RF drive. Most systems will require an attenuator at the amplifier's input to avoid overdrive and possible damage.

As long as the amplifier is operated in it's *linear* region, below its 1 dB compression point, the nominal gain figures will be observed. But most of us are more interested in generating as much power as possible, and this amplifier may be driven to saturation for better than 2 W of output. Note that the *apparent* gain will change when the amplifier is driven into saturation.

The typical PA saturates with –20 dBm RF input. Increasing the input level beyond this point will NOT give any additional output power. **Never exceed –15 dBm RF input, or permanent damage may occur.** Care should be exercised when setting up a transverter system. Use a power meter and attenuation, as required, so that a safe drive level is obtained. The proper place for an attenuator is usually on the mixer's RF side, just after the BPF.

As a side note, one possible benefit for an amplifier having this much gain may be with subharmonic mixers. Since a Ka Band local oscillator is difficult to generate, a subharmonic mixer requiring a lower frequency LO starts to look attractive. The problem is that most subharmonic mixers are very lossy… on the order of 20 to 25 dB conversion loss! There have been a number of connectorized sub-harmonic mixers showing up on ebay lately. This amplifier likely has enough gain to overcome the high losses of these mixers and still be driven to full output without the need for an additional driver amplifier.

LO LEAKAGE

Another precaution arises when using broadband, high gain power amplifiers in a transmit line-up. These amplifiers also tend to amplify any mixer LO leakage very nicely! Most of the mixers that I've tested at 24 GHz have rather poor LO isolation characteristics, and there may be quite a bit of LO energy at the mixer's output. Unless a BPF is used, this energy can cause the amplifier to produce undesired RF energy, and in some cases, be driven into saturation with just the LO! A proper BPF following the mixer is a must.

LOAD VSWR

The amplifier is designed to work into a decent load impedance. Most antennas that are matched at 24 GHz will be fine, but never operate the PA into a VSWR of greater than 2:1. Again, observe sequencing. With improper sequencing, it may be possible for the PA to be transmitting while the T/R switch is changing states, allowing the PA to transmit into a short circuit. This will result in permanent damage!

If all of the above operating conditions are met, an isolator at the output is un-necessary. If you have a WR42 isolator in your junk box though, use it… it's cheap insurance!

CONCLUSION

A number of amateurs are now using these units on 24.192 GHz. All of the surplus units I've tested will do better than 2 W saturated. A few have done almost 3 Watts! Your mileage may vary. At 2 watts output power level, the surplus mm-Tech PA's have filled the gap for those who are getting on the band or upgrading their existing stations. Hopefully, many more of us will benefit due to increased 24 GHz activity levels and the possibility of greater DX contacts. The author is always interested in skeds for 24 GHz!

73, Paul Drexler W2PED

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[1] See article by Peter Day, G3PHO at www.g3pho.free-online.co.uk.

[2] Paul Drexler, W2PED and John Sortor KB3XG, "A 1 Watt Power Amplifier for 24 GHz," Proceedings of the 1999 Microwave Update.

[3] Paul Drexler, W2PED and Tom Whitted, WA8WZG, "The 24 GHz Amplifier Project Delivers!" Proceedings of the 2002 Microwave Update.

[4] www.triquint.com

[5] Charlie Suckling, G3WDG, Presented at 1998 Microwave Update.

[6] A famous quote from the author's Pack Rat friend David Hackford, N3CX, now deceased.