24 GHz TWTA modifications

by Manfred Ploetz, **DL7YC**

Introduction

For 24 GHz EME communication it is necessary to use transmission power levels higher than 10 watts, otherwise it is not possible to detect own echos. This is true for CW and dish diameters of 2.4m.

Today SSPA solutions where possible and commercial 10 watt amplifier one can buy from (1). JA6CZD and LX1DB combine 4 x 10 watt SSPAs and Charlie Suckling, G3WDG, is working for a 20 watt amplifier, but all these solutions are expensive and complicated to achieve.

10 years ago, Ulli Mallwitz, DK3UC, presented a so called „quick and dirty“ solution to modify surplus 12 GHz TWTA tubes for 24 GHz amateur usage (2). It turned out, that SIEMENS or THOMSON TV-transmitters RW1127 (3) (or RW1135 / RW1136), constructed for 3.5 watt AM carrier levels (with very low IM3 distortion) can be easily modified into a VERY effective 24 GHz CW transmitter.

Ullis solution was published first by Brian Coleman, G4NNS, (3) in 2006. Brian modified his own tube and some more for local HAMs with great success.

Based on his publication and a lot of discussions with the originator DK3UC and Johannes, DF1OI, I modified a RW1127 TWTA tube by my own, but had the impression: this is not the PERFECT solution !!

Modifications

My modified RW1127 generated up to 40 watts RF @ 24048 MHz but I started to collect some more tubes and some more information about TWTAs. I wonder about the length of the center pin of the tubes helical connections in the published paper, penetrating the whole waveguide in Ulli`s and Brian`s tubes. Normally, well known from commercial WG-SMA transitions or feedhorn solutions, the radiating element having quarter wavelength dimensions!

Therefore, I personally forced a solution with a much shorter „antenna“-pin. I felt, this could be eventually the better way of coupling energy in and out of the helix. At the same time I compared all the ground path solutions I know from others with my own modification. I generated very high power at 24 GHz(compared to some other results I heard from) and was not sure: Is it a matter of my specific tube or is something different in my construction !!

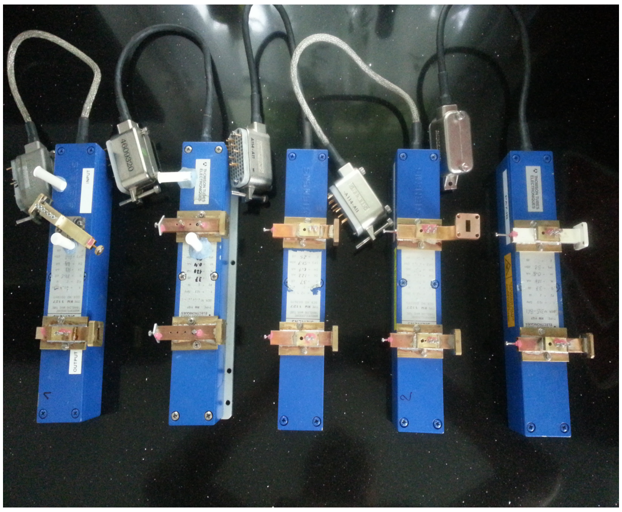
A good way to check out RW1127`s performance is, to let them run at 10368 MHz. All six tubes I tried, generated output power levels between 70-90 watts at 10 GHz !!

But to get these high output levels it is necessary to disconnect the IC1 overcurrent protection in the associated power supply, normally switch off the RWN 320/322P TWTA power supplies beyond >31mA IC1 current.

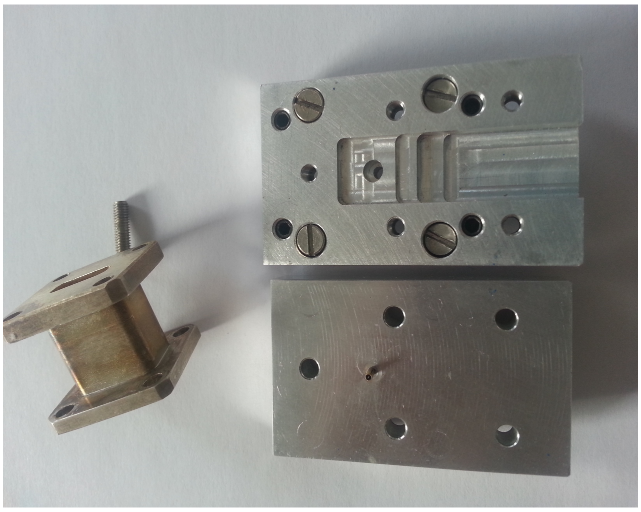
To remove the protection can be easily done by removing and secure the orange wire from the last small vertical PCB, just close to the TWTA high voltage connector. Beyond 22-23 watts of RF output at 10 GHz, the IC1 normally will exceed the „save level“ of 31 mA, climbing up to more than 100mA. This looks dangerous, but is tolerable for CW if sufficient cooling for the tube is present.

If a given tube CANNOT generate these levels at 10 GHz, it is NOT worse to take over the modification process to 24 GHz with all its mechanical work !!

As I pointed out before, I modified six different RW1127 tubes in six major different mechanical ways of the waveguide connection to the prepared helical coaxial in-/output. They all having different mechanical center pin length (due to its height in respect to the transition dimensions) and most of them having different ground path connections.



5 of the different modified tubes



DC0LB`s milled solution

To guarantee a more scientific approach, I used the same power supply all the time and looked to the s11 and s22 values every time after a modification. Therefore I used a 12 GHz Vector Network Analyzer in connection with a active frequency doubler at the generators output. The return loss measurements where made by a WILTRON Autotester (RL bridge) having 40GHz bandwidth. The RL dynamic range was better than 40dB !!

Measurements

After the mechanical modification process of the first two tubes and the related four RL (return loss) measurements at the tubes input and output, I observed a strong dependency between tubes gain and maximum output in relation to the input/output RL. RW1127`s with the RL`s tuned to the best values one can achieve (mostly > 30-35 dB), having maximized overall performance at the same time.

This does NOT mean: they will have all the same output !?

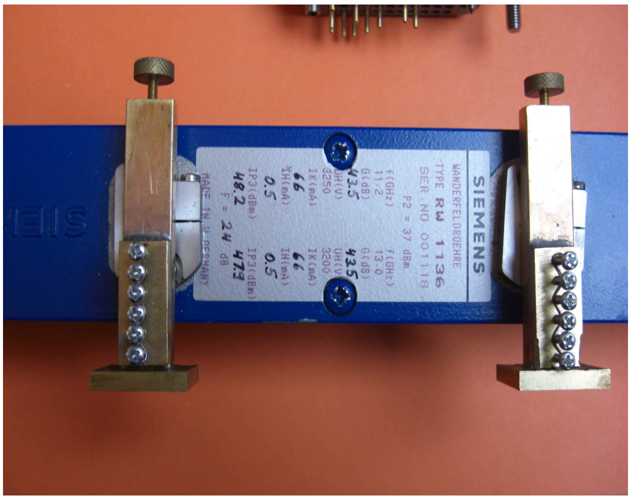
Something different must have some influence too ! During the mechanical coaxial helix / WG transition design process I found these tubes running best, having the shortest and tightest ground path connection. Therefore I tried very good ground connections in conjunction with a quarter wavelength center pin.

But due to a slight longer ground path length these versions did NOT perform better than different solutions.

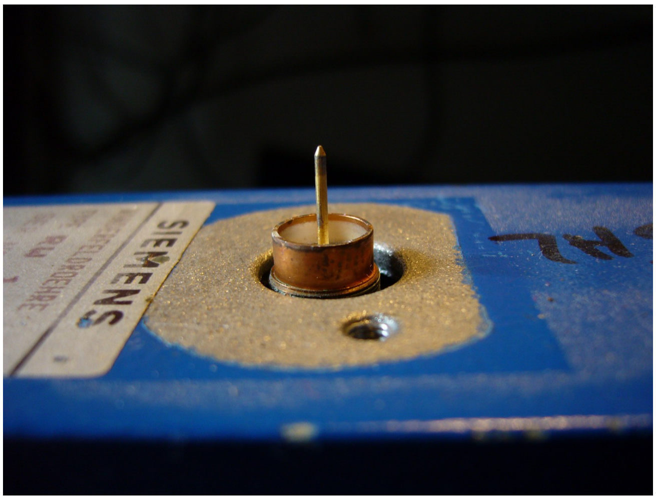
Armando, I3OPW, a well known Italian Microwaver, went for a much different way. I checked this solution too !!
He used a modified part of the former removed outer coaxial piece of the original SMA connector. This part he machined down, removing the SMA part, and soldered it into a standard WR-42 waveguide. This solution allowed a perfect smooth turning, downwards to the tubes body, for the best (in terms of RL) position of the untouched center pin. But the ground current flow gone over the thread.

I3OPW: Prepared WR-14 waveguides

I3OPW: Machined former SMA connectors



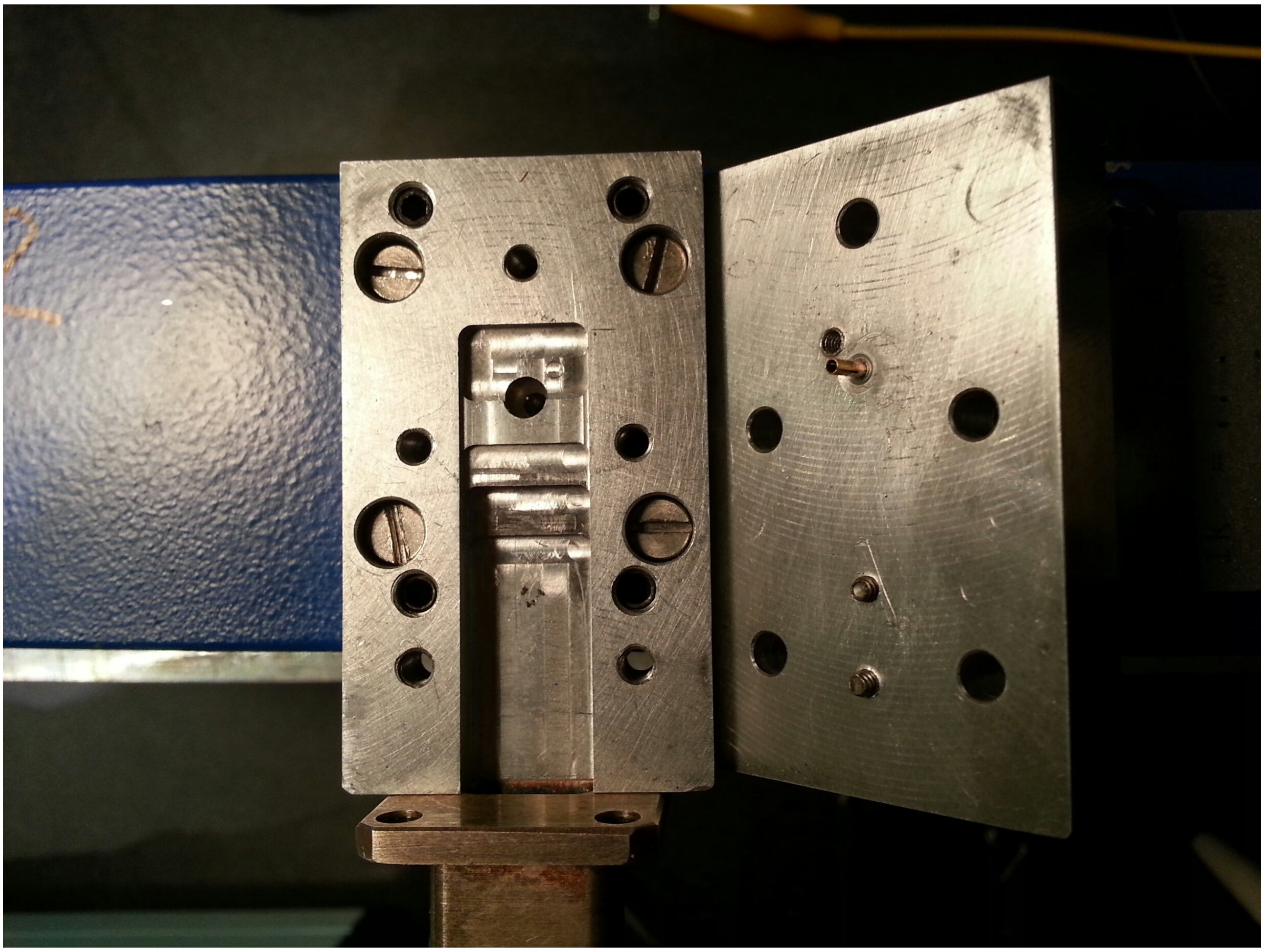
I3OPW solution ready to use
but draws the current by the thread



BETTER: End of the coaxial Helix system -
The WG must fit very tight to the outer dia

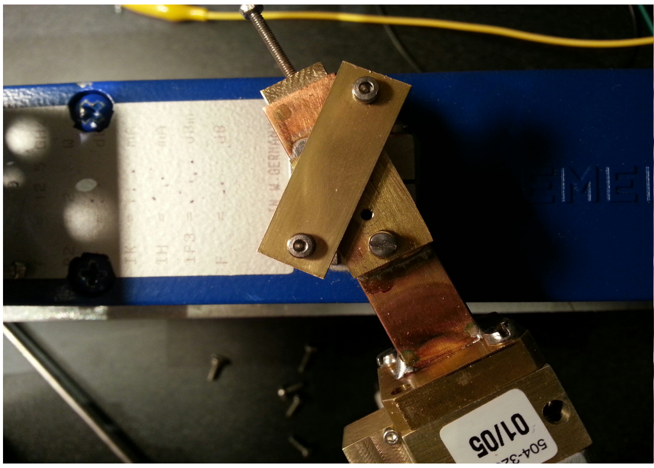
Again, the achievable RL result by the I3OPW way is very good but the ground path RF current had to pass the connection thread. This influenced the total gain and the output power and therefore, this solution was discarded.

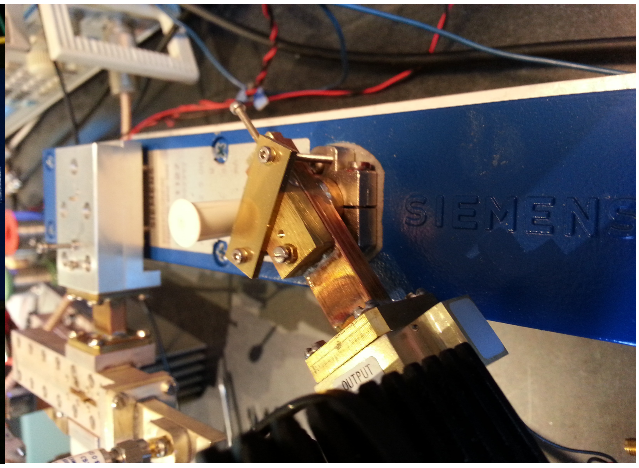
A different solution was created by DC0LB, a member of the DL0SHF group. His son calculated a milled waveguide solution with many tapered parts and a galvanic connection of the center pin to the waveguide inner wall. After manufacturing this transition, it shows a good RL, after slight tuning correction. But again, the ground connection to the helix was the weak point of this wonderful construction.



This problem is underestimated by every solution I observed, including my own ones.

Knowing now some problems regarding the RF path, I constructed a mechanical solution with ground connections like an SMA or 3.5mm connector. This part worked good, but is complicated and difficult to assemble and I did not follow the idea longer more.

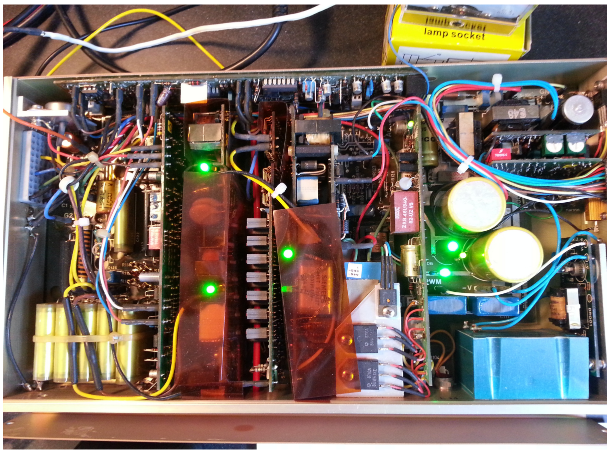




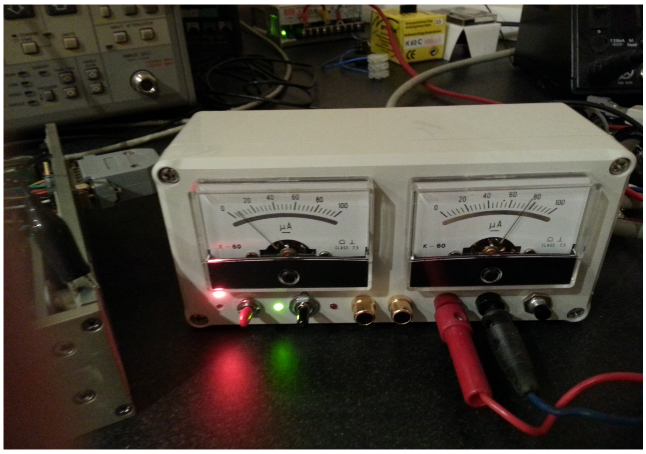
At the end it turned out that the favored DK3UC method provided with the best results and was only improve with respect to the execution.

TWTA modifications – Step by step guideline

1. Check 10 GHz performance of the tube. Therefore disconnect and secure the „YELLOW“ IC1 overcurrent protection wire from (left most) the helix-control-board inside the RWN 320/322P power supply. (Identity the board by 3 multiturn pots)



RWN 320P TWTA power supply open



Left: Helix 0-3mA Right: Cathode 0-150mA

2. Turn the RED G2 voltage knob max. counterclockwise. Do not touch at that time any other pots !!!

3. Connect the tube to the PSU – Connect the RWN PSU with a 48Volts (min 28Volts) DC power supply (6 A max)

4. Mount the tubes body to a very good heat sink with blower. A big fan additional on top of the top is not the worst decision.

5. Connect instruments (3) to the RWN PSU to measure Ih and Ik (3mA max. and 150mA max.). Connect PTT and the RESET button to the PSU.

6. Connect a sufficient 10 GHz load and a power meter to the tube`s output and switch ON the PSU. Wait for 1min warmup at least. If you watch out excessive Ih, exceed the warmup period once to several hours / days !

7. Switch on the PTT and observe Ik. Turn the red knob to 130mA -135 mA if I helix stays below 1mA. Keep Ih as low as possible by optimizing Ik to higher values. Switch off the PTT control !!

8. Connect 10 GHz / 500mW drive power to the RW1127 input by a step attenuator.

9. Switch on PTT for power measurement and switch on reduced drive power for 1(one) second. Read output power. If below 80-90 watts, increase drive power for the next measurement cycle. **NEVER USE A CARRIER (KEY DOWN) LONGER THAN ONE SECOND !**

10. If you have a real electronic keyer, use dashes and dots ! In CW mode the tube can run for more than ten minutes at this power level and sufficient cooling. A steady carrier will kill the RW1127 in a short time !!

11. You can increase drive power and cathode current (red G2 knob !!) until Ih did not exceed 1mA in idle mode and 3mA under CW keying.

12. Under idle condition, normally the electronic beam will travel from the cathode through the helix and collector 1 to collector 2. IC2 current is the same like the cathode current when idle. Under heavy RF output most electrons of the beam never reaches the second collector – the electrons where most collected by IC1. But IC1 is a small disc only and it is difficult to transfer heat to the outside world. Therefore a optimized cooling process is necessary and a longer carrier is not possible. If you decide to stay below 25 watts output power @ 10GHz – forget everything what you read before.

A positive „10 GHz tested" tube is a good source to be a 24 GHz candidate. Follow the guideline to modify the tube for 1.2cm usage:

1. Fix the tubes body flat on a table in front of you.

2. Remove the clamps supporting the SMA barrels at the input and output to provide better access.

3. Remove the SMA assemblies by unscrewing them counterclockwise with minimal force. But they are held with Loctite. To avoid the use of undue force which will destroy the tube, the SMA barrels should be heated with a hot air gun until they turn with minimal force. Use a hot airgun from time to time to only to „melt" the glue between the upper SMA part and the thread of the helix coaxial part.

4. Use pliers to loosen the SMA connectors.

5. Next, the most delicate operation, is to remove the matching disks from the input and output pins. The discs are held in place by (usually two) spot welds on the vertical, tube like, section of the disc. These are filed or ground away to free and remove the disks. If access to the welds is not possible with a file, a small grinding tool or a multitool such as DREMEL can be used. However you do this, great care must be taken not to damage the pin or the ceramic. NEVER TRY TO CUT THE PIN. THIS WILL DAMAGE THE TUBE IMMEDIATELY !! A small square file could be the best tool for the job. It may be necessary to file or grind away any small obstructions on the pin itself which stop the disc from sliding off easily. The pin will protrude right through the waveguide. Take great care !

6. Next, two sections of WR42 are prepared. The lengths are not much critical. Chose lengths so that the input and output flanges would clear the body of the tubes sidewall. Note that there is an precise 8mm hole on the side nearest the tube and a 3mm hole on the other side. Start with drilling a 3 mm hole first and open the hole at the bottom side of the waveguide very careful in steps to 7.9mm. The last work to 8.00mm should be done by a sharp mechanical 8H reamer.

7. **This is the most important work and guarantees a perfect ground path and a**

good current flow later.

8. The probe, which should not be cut, passes right through the waveguide and protrudes into the 3mm hole.

9. Before mounting the adapters base plate to the tube´s body, make sure the max outer part of the helix coaxial system is below the blue top cover. Otherwise the 8mm hole must be opened to 10mm a few tenth of a mm from the bottom side. If done, do not push the input or output downwards by much pressure, the fragile metal/ceramic construction cannot tolerate much stress in vertical or horizontal directions!

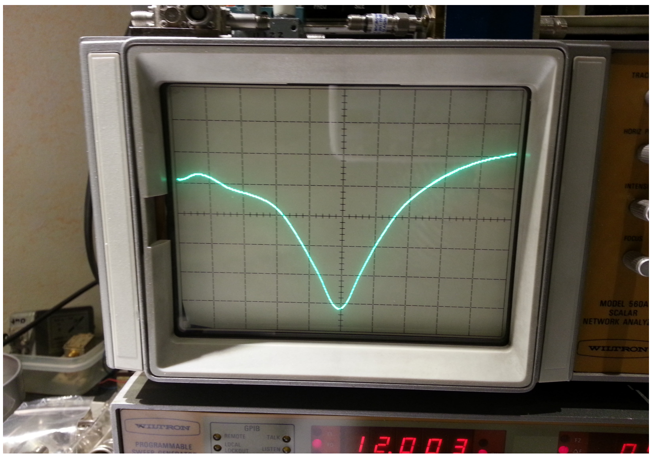
10. When ready, one can test the fit over the outer coaxial helix connection very careful, using some lubricant in between. The 8mm fit must be **very tight** but just barely movable by turning the ground plate a bit left and right parallel to the blue tube surface until the plate touches the tube case.

11. Carefully drill M3 holes into the tubes body and tighten the WG base plate to the tube by using M3 screws. Do not drill much deep ! Just pierce the surface of the lid straight and not pierce the sealing compound inside.

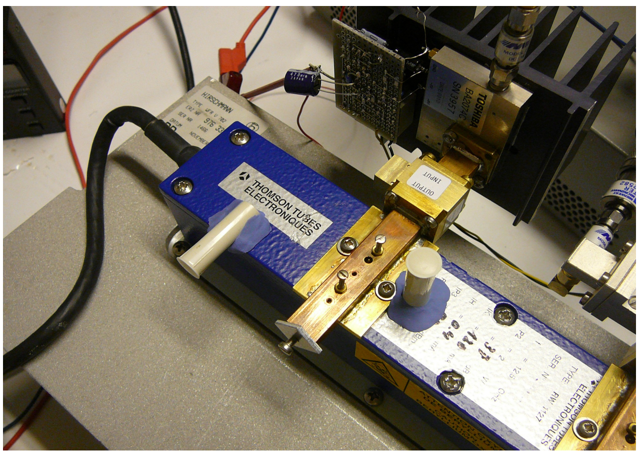
12. Tight fitting plugs (sliding shorts) are fitted to the end of the waveguide nearest the probe and flanges are fitted to the other ends. The plugs were machined very slightly over size and then lapped carefully on fine abrasive paper until they were a very tight (IMPORTANT: hardly sliding) fit in the waveguide.

13. Use 30mm long M2 screws at the rear side of the plugs together with a M2 nut and a **3mm** washer. (see picture) During the tuning procedure „hammer“ in the plugs **a bit** more close to the coupling pin and use the nut in front of a 3.5mm washer to move very slow backwards.

14. Connect the WR-42 input or output to the previously calibrated VNA and adjust the short-slide at 24048 MHz to minimum RL . Use the M2 adjustment screws on top of the WG to optimize the result. RL`s should be reachable between -30dB and -40dB. Secure the positions with sealing paint. (i.e., nail polish).

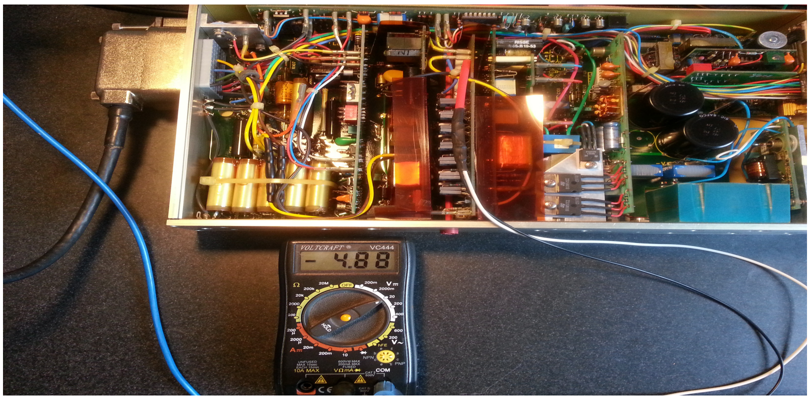


24048 MHz +/- 500 MHz … 5dB/Div



Washer or small disc for smooth adjustment

15. Use the same electrical tuning procedure as pointed out for 10 GHz (Step1 – Step7)



….. but re-adjust the Helix voltage to 4.88kV (refer pic for HV tip) This voltage can be varied by turning the middle multiturn pot at the helix-control-board`s left side.

16. Switch on PTT for power measurement and switch on reduced drive power for 1(one) second. Read output power. If below 20 watts, increase drive power for the next measurement cycle. **NEVER USE A CARRIER (KEY DOWN) LONGER THAN ONE SECOND !**

17. If you have a real electronic keyer, use dashes and dots ! In CW mode the tube can run for more than ten minutes at this power level. A steady carrier will kill the RW1127 in a short time !!

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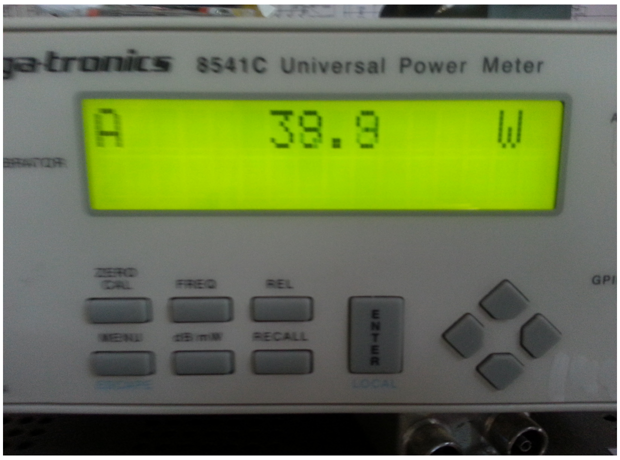


Example of output power from different modified RW1127 TWTA`s

Results

As pointed out before, six RW1127 were modified according to the latest findings and matched with the aid of a Vector Network Analyzer to best RL and the inputs and outputs.

The measurements were made in each case without connection to the RWN power supply, since only the helix is involved. Due to the electron flow later (under power) the return loss values of the helix are only slightly affected.

TUBE	Manufac-turer	Collector Current	Helix Current	Helix Voltage	Input RF Power	Output RF Power	Rel. Power
# 3670	SIEMENS			4.85kV	**1.2 W !**	<24 W kalt (18.5 W)	
# 3670	SIEMENS	141 mA	1.3 >>1.8	4.89kV	1.6 W	33 W	34 units
315-861	Thomson	130mA	1mA		**1.2 W !**	30.3 W kalt	32 (31.5)
315-861	Thomson		I3OPW		1.8 W	20 W peak (17W)	I3OPW
315-861	Thomson	130 mA	1.2 mA	4.85kV	1.8 W	42.6 W kalt	38 units
315-682	Thomson	130 mA	1.0>>2.0	4.88kV	1.7 W	>40 W (39 W)	
Serial # JB 3	Thomson		**Unstable >3mA peak**	4.88kV	1.8 W	(40 W) has to be more observed	
Serial # JB 3	Thomson	139 mA			**1.2 W !**	30 W (28.5 W)	
316-514	Thomson	138 mA	1.3>>2.0	4.88kV	1.8 W	43 W	37 units
# 002393	SIEMENS		I3OPW		1.8 W	18-19 W	I3OPW
# 002393	SIEMENS		I3OPW transition @ input		1.8 W	30 W	DC0LB milled transition
# 002393	SIEMENS	126 mA	0.8-0.9	4.88kV	1.8 W	<32 (30 W)	33 units

It was compared to the solution of I3OPW both at the input and at the output with the DK3UC solution. Likewise, a new DL7YC solution and the milled WG of DC0LB with the favored solution was compared.

It was found that later no further improvement could be made by readjustment. If you have the possibility of access to a 24 GHz VNA, one should always choose this path first. So you can be sure that you have reached the optimum!

Some of the “non favorite” solutions having good performances too, but they are more complicated to produce. If one have a very good ground contact between the waveguides and the Helix system, the power is best transported in and out of the RW1127. But due to the variations in the individual tube system and its magnetic balance, the achievable output power at 24GHz varies between 32-43 watts. (from at 10 GHz tested tubes !!)

These values were exclusive peak values and apply only to COLD tubes, a relatively short switching time from STBY to TX and return and 500 msec key down only. But they make excellent from what is achievable in the CW pulse mode. The short pauses between each character give enough time to the TWTA `s to be able to constantly operate at least 85% of peak levels in practical operation. WSJT at full power therefore is excluded from the previously mentioned reasons. **Also very good cooling is strongly recommended !**

Conclusions

Most of the findings previously listed are not really new or unknown. But in recent years, many discussions (personally and by email) regarding the input and output coupling of RW1127 TWTA `s been carried out.

During the complete design process, I made hundreds of power measurements with six different RW 1127 tubes and many different mechanical Coaxial/WG transitions, as pointed out before.

And at the end it turned out.....

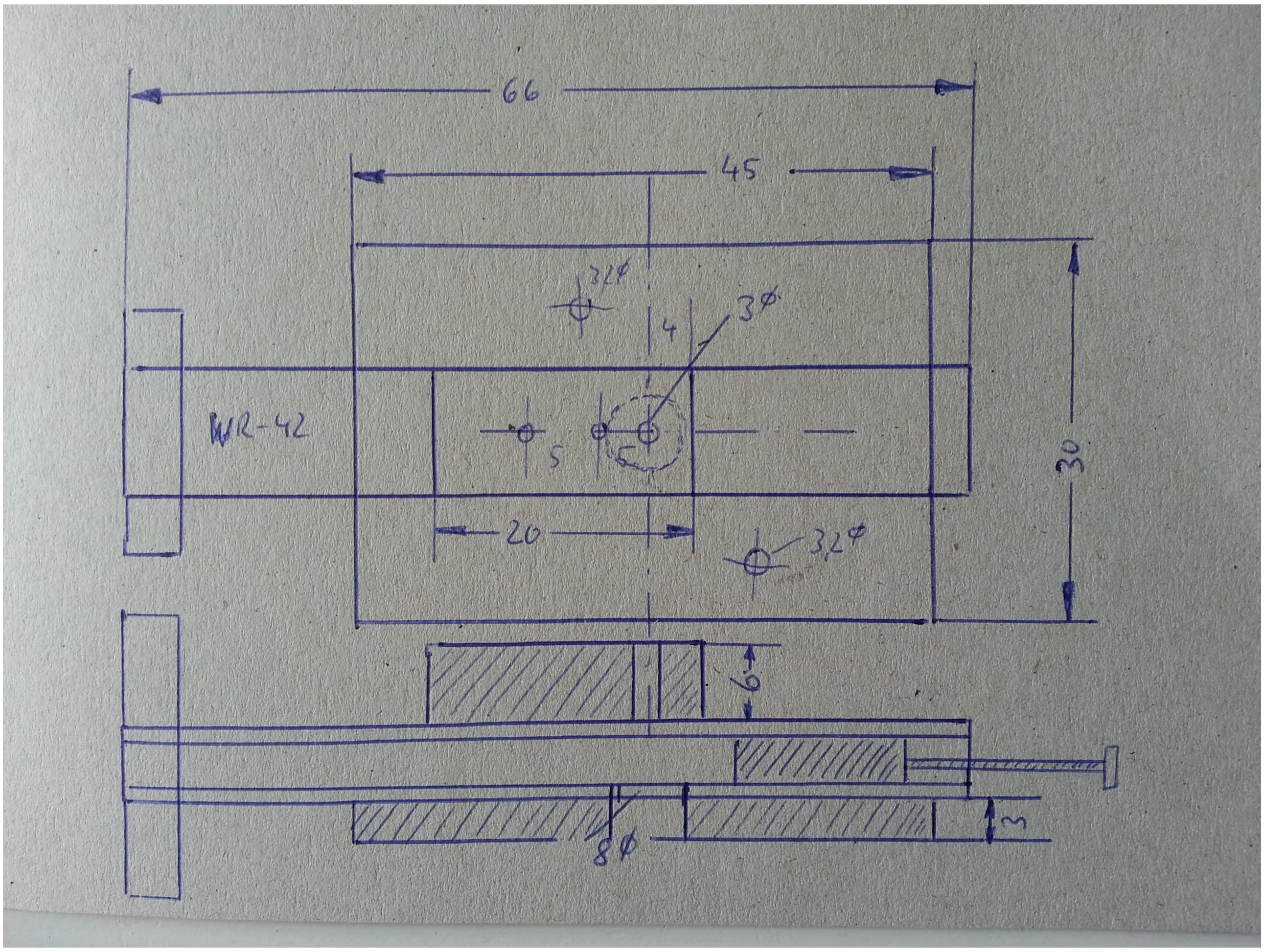
1.The most important feature of a good helix/WG transition is a good ground path connection of the transition.

2. The next important step is the pretuning of a „cold" RW1127, tuned to the best input and output RL with help of a Network Analyzer, resulting for best gain and output power later. After that, in practical operation, no further action in this matter are longer necessary. One can only focus settings on the DC and does not need in a "multi-dimensional matrix" playing around - with the constant risk of a irriversible overload of the tube !

I think, I have tested the most possible connections between the outside world and the helix – much more than listed above. From the various cases – some will work better, some more worse. But, what a wonder, the first presented „quick and dirty" solution, with slight modifications, transfers the power best.

The advantage of this solution is the cheap and easy way to create a high power 24 GHz transmitter – the biggest disadvantage is the need of a 24 GHz VNA for the optimized tuning procedure. The tuning can be made without, but it is much more complicated !!

I have to thank Ulli, DK3UC, for hundreds of discussions; Johannes, DF1OI, for many comments regarding TWTA`s and Brian, G4NNS, for his basic article regarding a RW1127 modification.



Mechanical dimension of the tested 24 GHz WG transition for RW1127 tubes

References:

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2. Modifying the RW1127 and similar TWTs for 24GHz
Some notes by Brian G4NNS updated after the EME conference. Issue 1.04

3. http://www.qsl.net/n3fti/Siemens%201987%20TWT%20Databook.pdf