LDMOS SSPAs for 23 cm using the MRFE6S9160, with 500 W and 1.000 W output.

Project by F5JWF.

Elaborated by IK3GHY,IK3HHG,IU3CQP , IZ3VTH

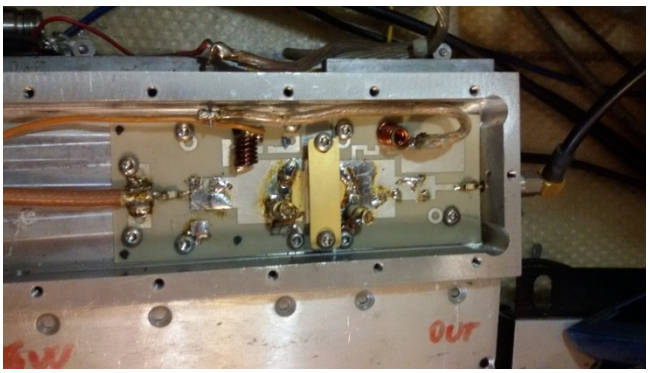
Introduction

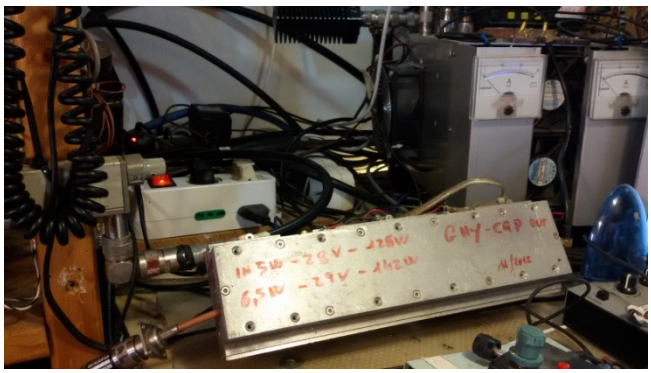
While we were working out our SSPAs for 23 cms , in 2012, Manuel (IU3CQP) was putting together an amplifier using the MRFE6S9160 MOSFet to be used as a driver for a previously designed and built 500 w . output SSPA using a group of 8 x MRF286.

http://www.ik3ghy.it/8_mrf.html

Results of the first SSPA with a single MRFE6s9160 (2012)

After some adjustments, the performance was excellent, with 140 watts output at 1 dB compression, with 6w drive,29 V.@11 A. supply, and an efficiency close to 43%.





Further results with SSPAs using 1 or 2 MRF6S9160

Three more single MOSFet amplifiers were built, with results closely approximating those of the pilot unit. We then tried to use two MOSFets in push-pull assembled on a single circuit, with input and output hybrids. Results were not satisfactory, with outputs from the two units built not exceeding 170 w. We then decided to abandon this project.

DF9IC project

In 2014 Henning,DF9IC published an excellent paper on his 1296 mHz SSPAs with single and double MOSFet. His results were outputs of 150/160 w. for the the single MOSFet project and 280/ 300 w @28 V for the double device project.

http://www.df9ic.de/doc/2015/mmrt_2015/mmrt_2015_1296MHz_PAs.pdf

Our experience with the DF9IC modules (2015)

Henning's results stimulated us to give the project a new try, his printed circuits were duplicated and assembled, and the single device unit had a good performance (140 w. out with 28 v., driven with about 5 watts). The double device unit, however, had an output never exceeding 180 w., no matter the changes we made to it. Roberto (IZ4BEH) has published a similar experience with his version.

http://www.iz4beh.net/SSPA_23.html

A new 4 devices project by Philippe, F5JWF

In late 2015,Philippe published a project for a 23 cm SSPA using 4 x MRFE6S9160 assembled on a single board (as we had tried to do with the MRF286), and reported success, with outputs easily reaching over 500 w.

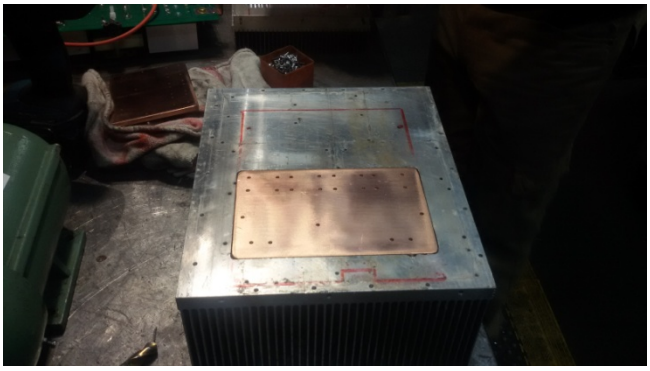
http://f5jwf.free.fr/PA_23cm_500W.htm

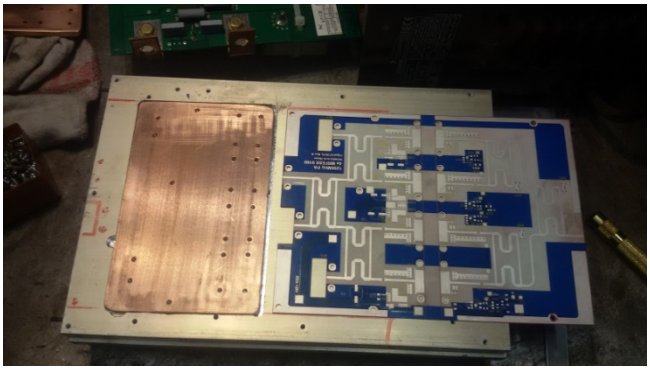
A new start

After reading the F5JWF publication, we contacted him and were told that some 4-unit printed circuits were available. It was then decided to buy from Philippe 3 of his RO4003 professionally made printed circuits.

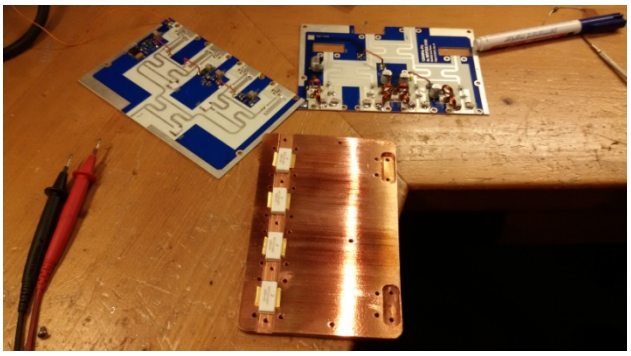
The assembly

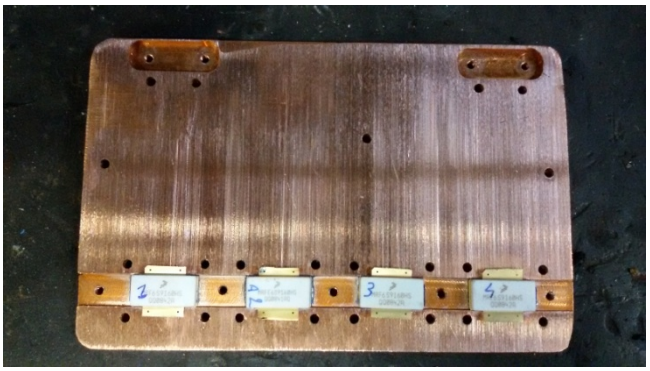
After receiving the F5JWF boards and getting the necessary components ,In early 2016 Frank Ik3hhg and Giorgio Ik3ghy assembled the first amplifier , starting with the heatsink , involving both aluminum and copper sections and needing machining for the various screws and bolts and devices' flange positions. After about a week of these preliminaries, the circuits were populated with the various supply components, the ceramic capacitors, the 50 ohm load resistors, etc.





In a further step, Frank (Ik3hhg) used an oxyacetilene flame to quickly solder the devices' source flanges to the copper part of the heatsink, using a low temperature (140 C.)solder paste. The end result was good with a total of 16 MOSFets (2 broken) installed on 3 amplfier circuits and 2 driver circuits





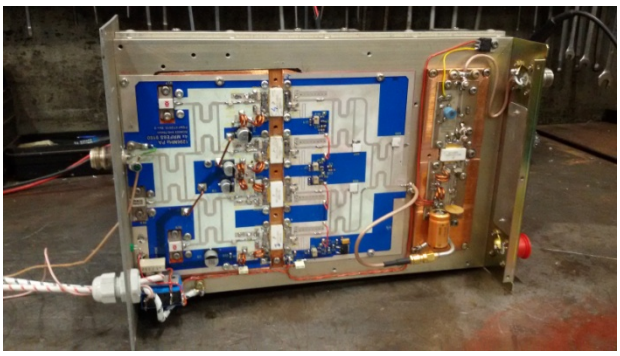
https://www.youtube.com/watch?v=V_zXBT5IocM

The amplifier was next assembled with special attention to the screws retaining the board and the heatsink, specially the copper section, looking to the best possible ground connection and placement of the MOSFets . Following Philippe's indications, every MOSFet was independently polarized until a resting current of 1.3 A.@ 28 V. was reached.

First test of a single board

initially with 24 V and 1 watt drive, the power output was in excess of 30 watts, a good sign! Increasing the drive also increased output, but not proportionately. As an example , with 10 watts drive, the PO was only 150 watts. Frank Ik3hhg suspected some RF feedback into one of the bias circuits, so some SMD bypass capacitors to ground were added, with the result that the output increased to about 300 watts

(@28 v.) with just 10 watts of drive. We had not optimized the position of the ATC capacitors on the input and output lines yet, so that was the next task. The power output was set at 200 watts to be on the safe side, then the capacitors' positions were patiently changed ,looking to the best output power.

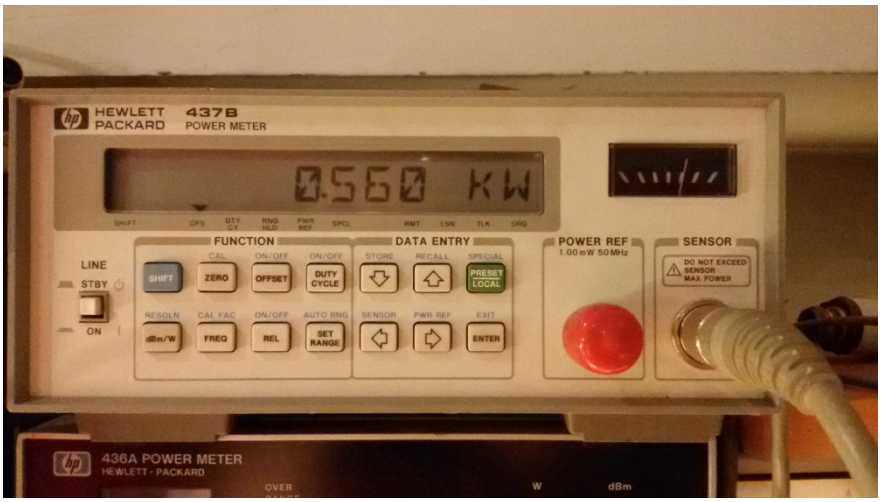


First single board amplifier results IK3HHG

The amplifier was run with 20 watts of drive at 28,5 V. and about 44 A. of peak current and the output reached up to 560 watts output. The circuit is very stable and spectrally clean on SSB ; in key-down cw conditions for 1 minute at a fixed output of 300 watts, the output only decreased by about 10%. As a sort of stress test, we drove it with 24 watts @30 V., easily running it up to 600 watts out.

This first version of the SSPA had been driven with a single device DF9IC style unit; this means that full output can be obtained with some 500 mW of drive to the driver stage. The large heatsink was additionally cooled with four muffin fans fed in parallel at 12 V. in reception and at 28 V. during transmission.

https://www.youtube.com/watch?v=7OHfpGVSpGQ



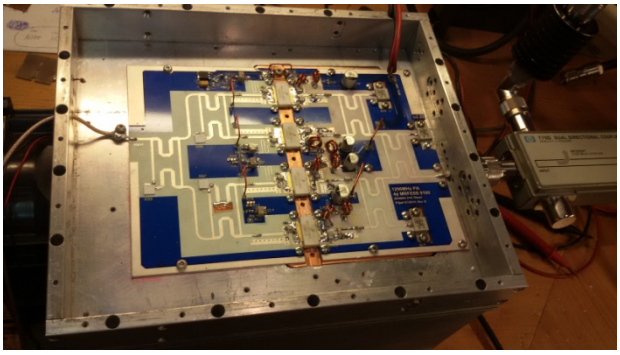
IK3HHG initial 4 devices SSPA results

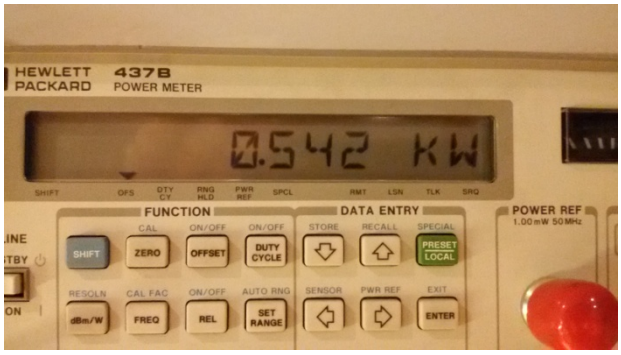
The 4 devices amplifier Frank has built, has been in operation for several months, feeding his 200 cm. dish, with excellent results and hardly any problem at a power output of 480 watts on cw and SSB, with good linearity. Frank has worked on EME HB9Q,for his first SSB EME QSO.

Second 4 devices SSPA assembly and results

This unit was assembled in a couple of days , taking advantage of the experience made with the first one. Results have been basically the same, 540 W. output with 20 W. drive. After some minor position adjustments of the input and output striplines capacitors, the output was close to 600 watts with 24 watts drive and 30 V. on the drains.

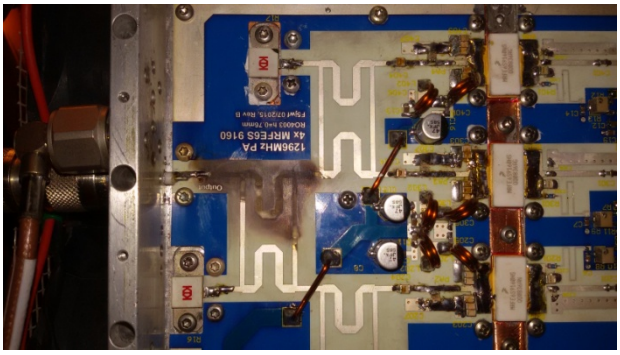
There was at this time some delay, as we had exhausted our supply of MRFE6S9160, and had therefore to wait for the next batch of devices to be delivered.





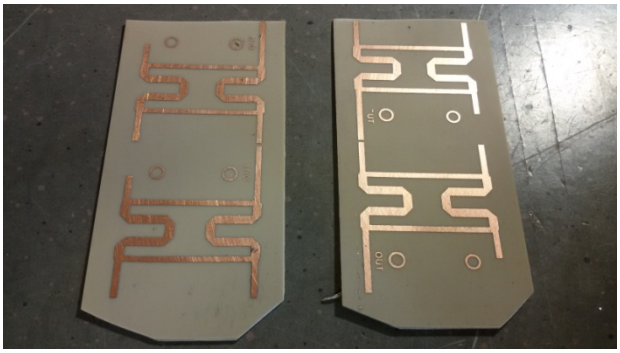
Third 4 devices SSPA ……. Disaster hits!

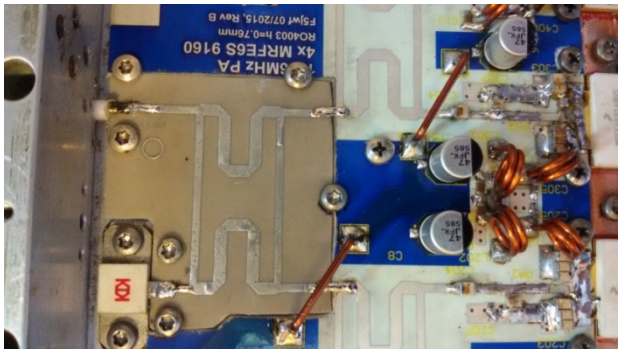
The third unit results immediately appeared to be unsatisfactory , as two devices failed, and an output hybrid coupler failed too, while the power output was being kept at a conservative 350 watts. An obvious cause for the hybrid coupler failure could not be established. As for the devices, one was probably defective and the second one had undergone a considerable amount of mechanical stress while repairs were being carried out.



Repair

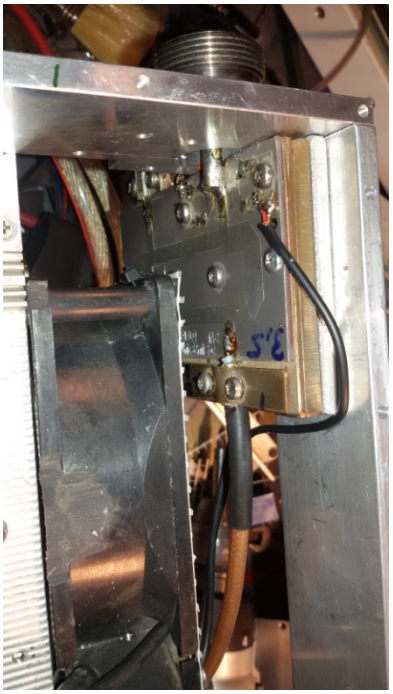
Manuel Iu3cqp designed and built four new hybrid couplers(some extra ones can always be useful as spares) on Arlon 25 substrate in place of the RO4003 (not always obtainable in small amounts). The burnt out hybrid was then removed from the board, and one of the new ones patiently substituted. After this ,the third SSPA was started again. Carefully applying drive up to 20 watts, peak output was about 480 watts and would go no higher, same as the total drain current. This unit , at 30 V. on drains, only outputs a little over 500 watts. The cause of this is probably to be found in some of the devices being defective as shipped.

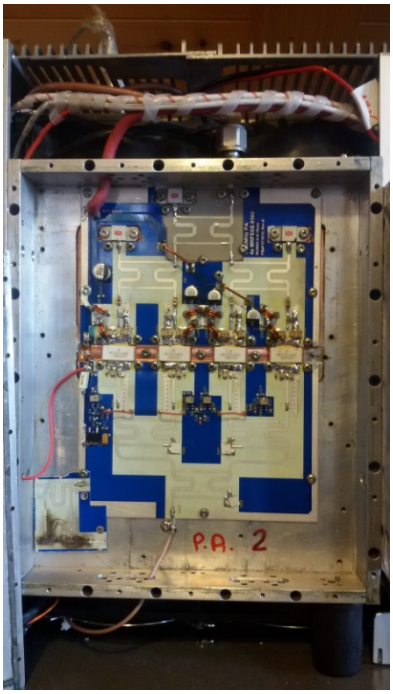




Our final goal

At this point we were trying to duplicate Henning's results with two PC boards and a total of 8 devices. Alessandro Iz3vth assembled a control board for the relays , the fan speed , the PTT and bias circuits, the ammeters (shunts included), the input and output power and the drain voltage.





The hybrid used at the input was an older unit built by Manuel Iu3cqp on FR4 substrate. For the output stage , several rings were tested , either metallic three dimensional or built on substrate. We finally opted for a Taconic 2 oz. copper substrate unit , better fitted to the available room and certified for power up to 1 Kw by VE1ALQ.

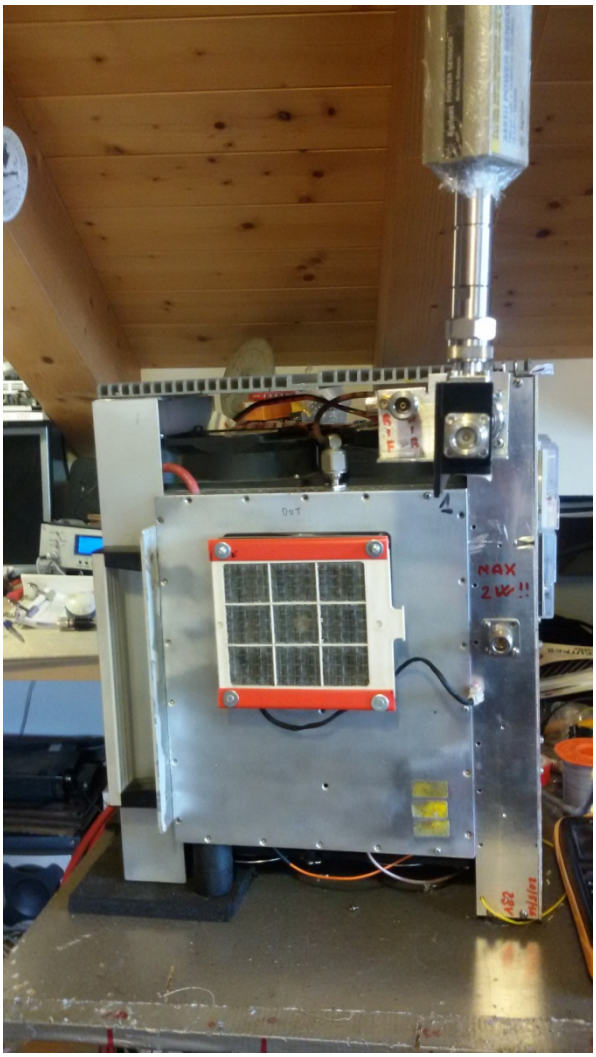
Initial tests with an 8 devices, 2 circuits unit IK3GHY

After assembly and various checks, the amplifier was tested with about 25 watts of drive and a 71 A. power supply, and it appeared to be satisfactory, even if the 71 A. available PS was unable to supply 28 V, because of some additional loads on it (driver and services). 28 V were obtained after reducing the drive to about 20 watts; under these conditions and with a peak current of 63 A., the output was 740 watts, quite acceptable.

Final results of the 8 devices 2 circuits unit;

The test were carried out with an available current of 140 A.. @28.5 V.(2 power supplies Ascom 3000 W modified) . Instrumentation was as follows: a Kathrein 28,58 dB directional coupler, an Andrew 19.9 dB directional coupler, and an HP 20 dB directional coupler, along with 435A,436A and 437B HP power meters and relative power sensors. An Agilent E4408B spectrum analyzer was available to check for unwanted emissions; the dummy loads in use were a 300 watts Bird, a Diconex 600 watt unit and a TV surplus 1500 watt unit.

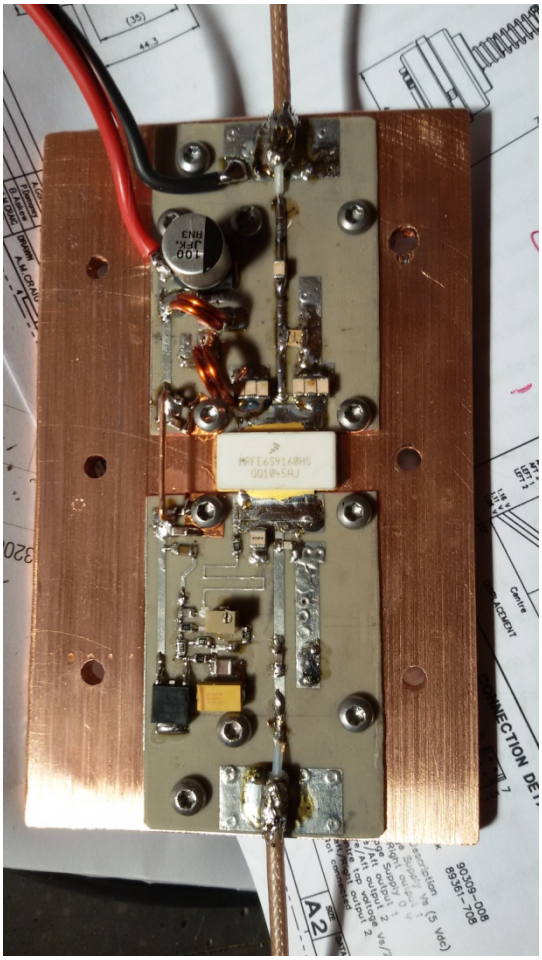
With some misgivings, the amplifier was energized and driven to the previously reached 700 watts out. The drive was then increased to about 40 watts (20 watts per circuit).With this amount of drive and a current of 79A. @28 V. , an output of between 895 and 930 watts (readings obtained with the different directional couplers available) was reached. A power output of 900 watts at the 7/16 output connector requires about 2.2 Kw DC, of which an estimated 1300 watts must be dissipated as heat ; the efficiency is therefore about 41%. At full drive there is, with time, some decrease in output.

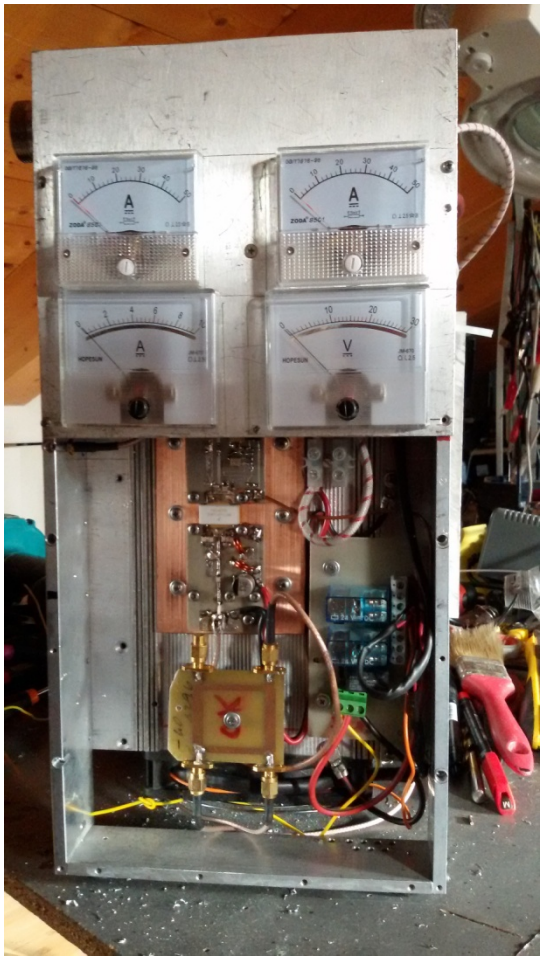


Looking to one KW output

A different driver was developed, using a single MRFE6S9160 on Arlon substrate (Iu3cqp) and installed on the same large heatsink. This unit delivers 50 watts output

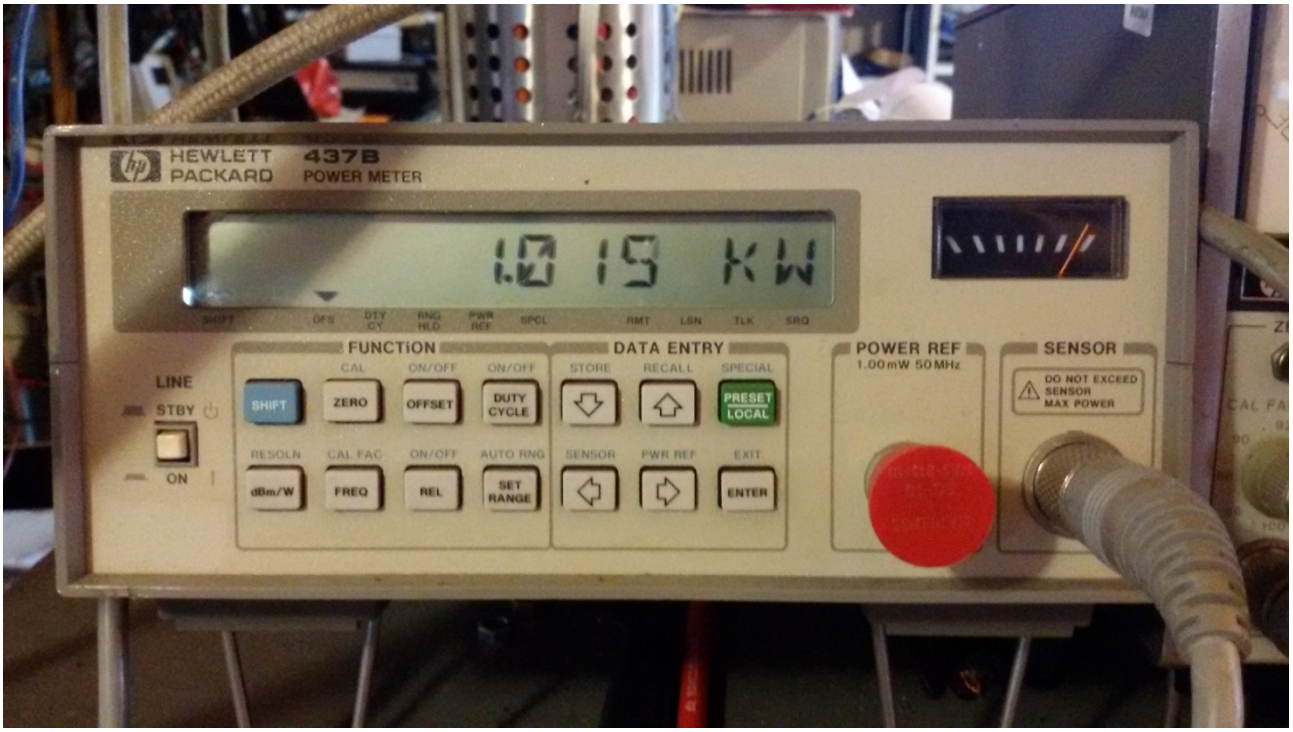
with just 2 watts input, sufficient to drive the large SSPA to compression; an input power of 1 watt results in an output of over 750 watts.





Pushing the amplifier into compression with 50 watts drive and a total current of over 90 A.(driver and services included) and increasing the drain voltage to 30 V., an output of 1035 watts has been obtained. At this power level, some signs of thermal drift become obvious; this probably calls for a more efficient liquid cooling system, as described by F5JWF for his 500 watt unit.

Some longer term power tests have also been carried out with outputs in the order of 750/800 watts (1 dB down from full output),and on JT65 with 500 watts out(3 dB down), after 60 seconds the output decreases by about ½ dB and stabilizes.



The cooling system

This is an aluminum block with 2 independent flats and a large, finned central tunnel. This is associated with a total of 7 fans (6 for the amplfier proper and 1 for the driver) run at low voltage (12 v). on standby and at a full 28 v. while transmitting.

IK3GHY Results of the 2 circuits unit

This has been tested in contest at about 750 watts out, without any problems . It has also been tested on EME at full power , using a 240 cm dish and linear polarization the CW echos were clearly audible in the best EME conditions .

Final comments

Philippe's (F5JWF) project is an excellent one, even if it requires a good level of experience to build and tune,and because of the relatively high DC current and power output associated with it. As an example, great care is needed in choosing the bias resistor values in order to keep the resting current of all of the devices taken singularly, as close as possible to 1 A. from the start.

One more problem we encountered was that of unwanted RF currents to ground between the two boards, close to the bridge at 28 V , resulting in the circuits running unbalanced.

The unsolved question remains that of the devices' efficiency. There is no way to tell beforehand how they will behave when energized. Apparently there are significant diversities among even the devices shipped in the same batch,with some of them singularly having outputs around 110/120 watts and others of 150/160 watts for no apparent reason. One of the MOSFets even had a resting current of 1,2 A. with 2,6 V. bias, but, when driven, only delivered a few watts.

As a conclusion, we were happy with the results, having been able to attain 500/600 watts from a single four devices amplifier, as per F5JWF, reaching then up to 1000 watts output from the eight devices configuration, as reported by Henning,DF9IC .

Thanks for reading .

73 Giorgio Ik3ghy, Francesco Ik3hhg, Manuel Iu3cqp, Ale Iz3vth.

Venice 02 May 2016