15 Watts on 24GHz at reasonable price

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Most of the high power SSPA for the 24GHz amateur band are not affordable for a large part of OMs, the objective of this white paper and presentation is to show how it's possible to build a solid state amplifier for the 24GHz amateur radio band at a very reasonable cost using industrial MMIC devices and some parts you can found on the flea-market without having to spend too much money.

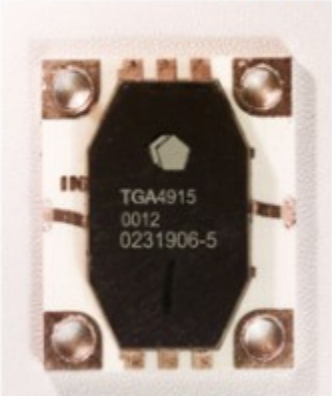
This project has been done in several phases:

1) First prototype single device – sma in ==> sma out
2) Single device - sma in ==> wr42 out
3) Dual devices first tentative - stripline coupling
4) Dual devices second tentative - wr42 output coupling

The device we used is the TGA4915-CP from TriQuint Semiconductor, initially a 7W packaged Power Amplifier designed for the Ka Band.

The TGA4915-CP is announced to have the following performances:

7 W Ka Band Packaged Power Amplifier



Key Features and Performance

- Frequency Range: 26 - 31 GHz
- 38 dBm Typical Psat @ Pin =21 dBm
- 22 dB Nominal Gain
- 15 dB Typical Return Loss
- 0.25µm pHEMT Technology
- Bias Conditions: Vd = 6V, Idq = 4.2 A
- Package Dimensions: 0.526 x 0.650 x 0.073 in

Although for this device the interconnects are to be gold bond-wires or gold ribbons we have been very successful in soldering the DC and RF instead of using bonding technology which is quite difficult to access for the ham radio community.

Another technique has been used successfully using conductive epoxy, to do so I recommend the Epotek 20 or the Chemtronics CW2400, this last is my favorite one.

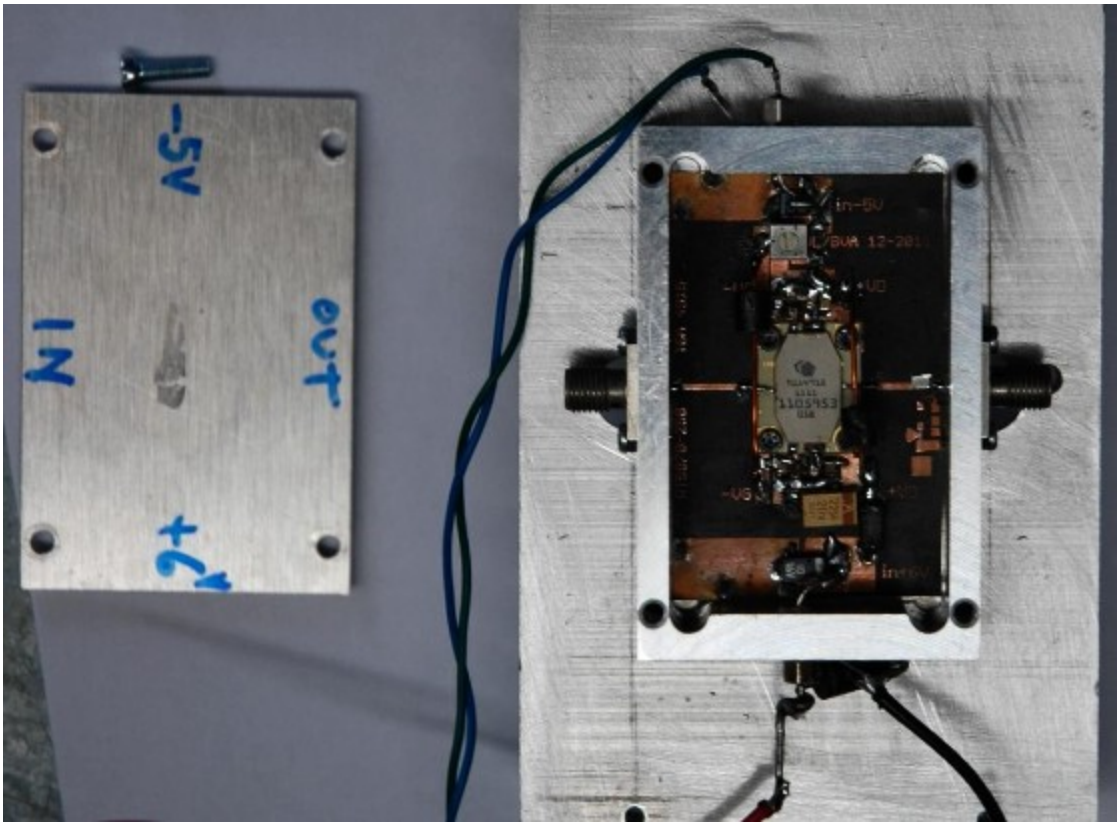
It's almost mandatory to use a binocular or a magnifying glass to solder or glue the RF in and out connections of the TGA4915-CP, if not you have a very good chance to ground them.

And finally if you decide solder the connections be careful not to heat lo much during a long time, or then you could destroy the golden connections on the ceramic substrate.

Phase 1 : First prototype single device – sma in ==> sma out

The design of this print have been made by our friend Michel F6BVA in his kitchen, and one of the first prototypes have been assembled and tested by Christian F1VL.This version was a sma in ==> sma out, the first tests where very promising with 5W@sat.

Here is the first baby:



However 5 Watts was far beyond our expectation so a new phase was decided.

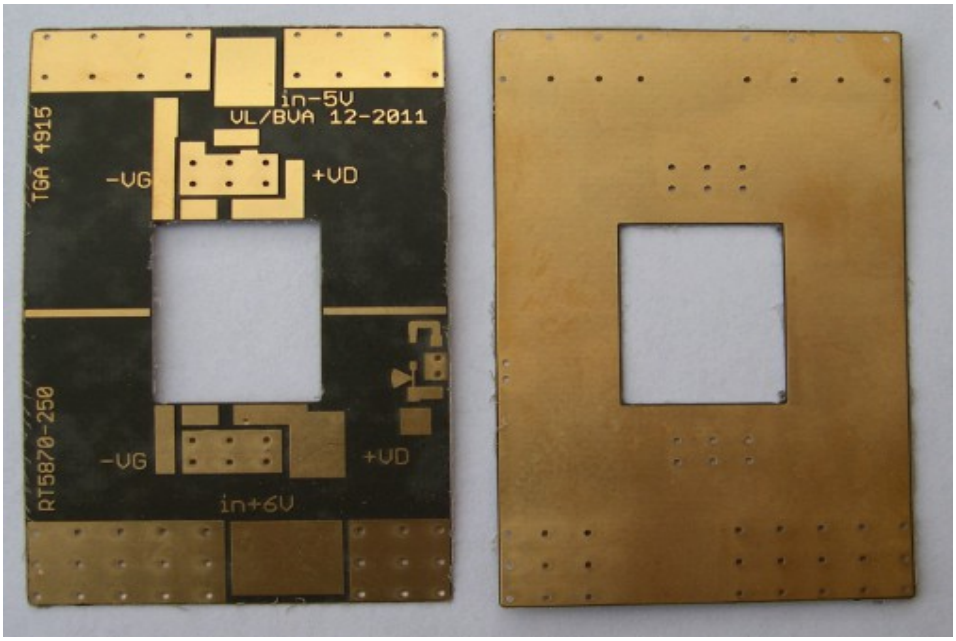
Phase 2 : Single device - sma in ==> wr42 out

It was decided to place orders for a large quantity of TGA's then it was decided to build a more consistent milled box with the sma out replaced with a wr42 probe to minimize the losses. Michel F6BVA worked with Philippe F8BTP and Philippe F6DPH to design a new milled box with this wr42

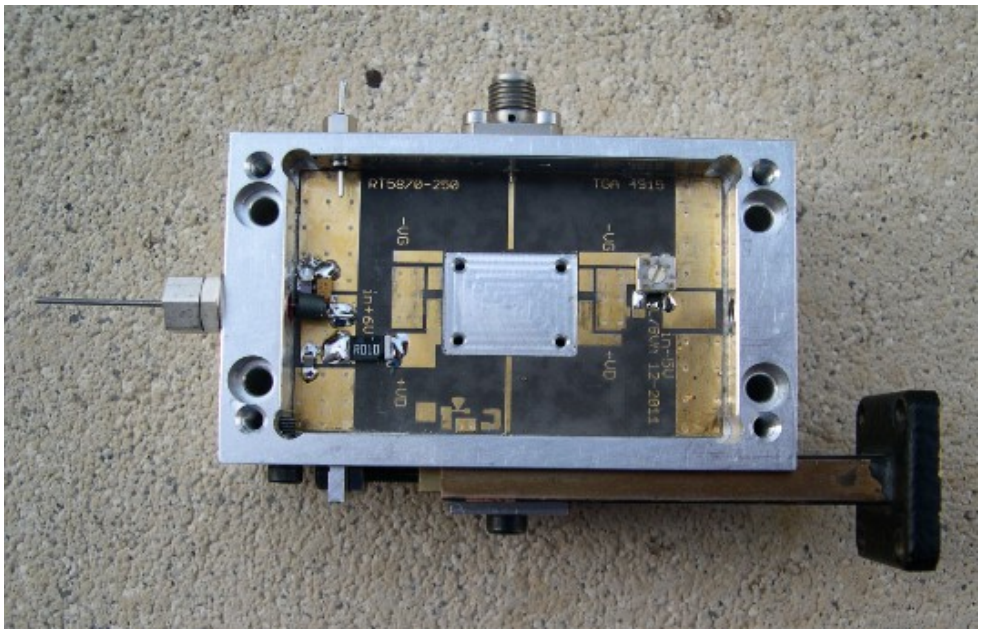
output. The drawings of this nice mechanic parts are available if needed and provided on the DVD with these proceedings. For this project a total of 77 devices where ordered, firstly by Andre F1PYR and then Guy F2CT. With so many SSPA to build it was decided to design a print “a la pro”, Michel could not produce so many prints in his kitchen, he certainly would not have had the permission from his authorities. So he made some modifications to his initial print to add vias, cutout in board, etc... to have a clean quasi professional printed circuit board.

This print is designed with the substrate Rogers RT5870 - Thickness 0.010” (0.254mm) / Copper Cladding 1 oz (35µm).

Here is the print:

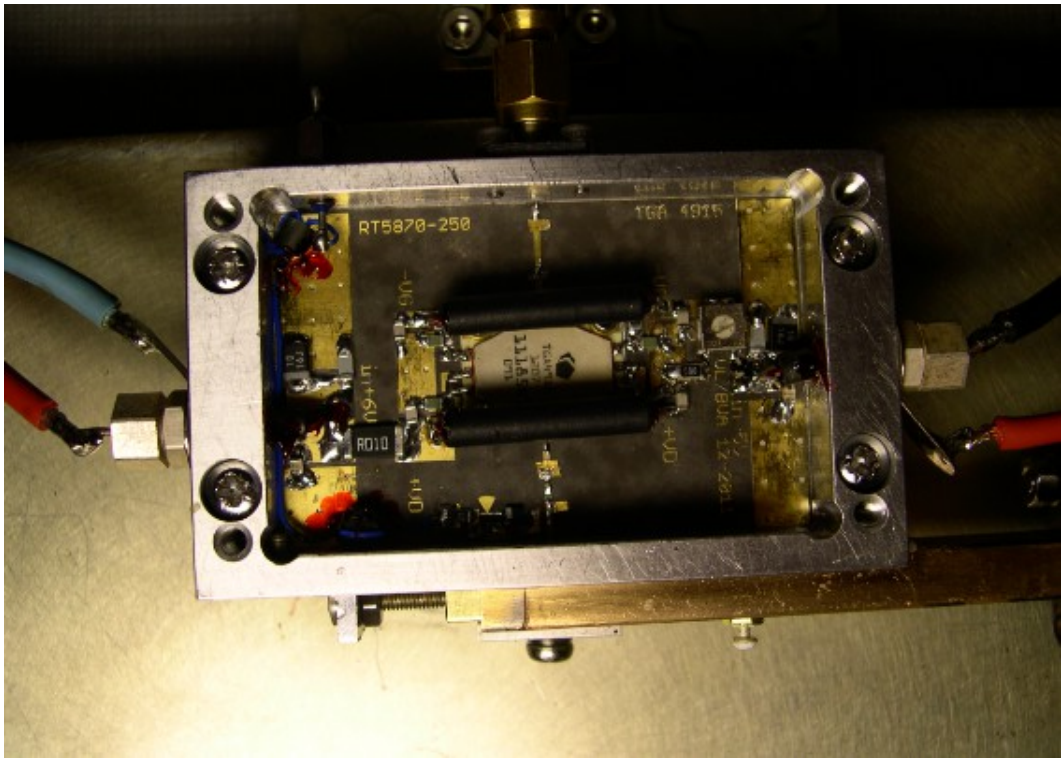


And the milled box:



The mechanical drawings of the milled box are provided on the DVD so if you have your own milling machine tool or access to a numerical machine you could reproduce it quite easily.

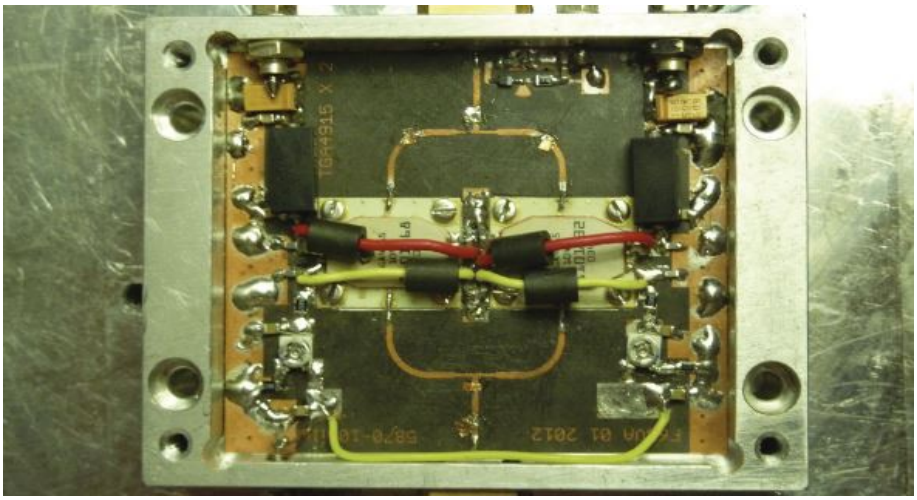
Here is the single device SSPA terminated:



I could obtain 8+ Watts at the saturation, this is better than the specs announced and has been verified on my 3 units.

Phase 3 : Dual devices first tentative - stripline coupling

8 Watts is nice at 24GHz, however the “Lunatics EMErs” where not satisfied enough so it was decided to build a dual devices SSPA, using strip-line coupling. Michel F6BVA made a new print and tempted to make it working, here is the design:



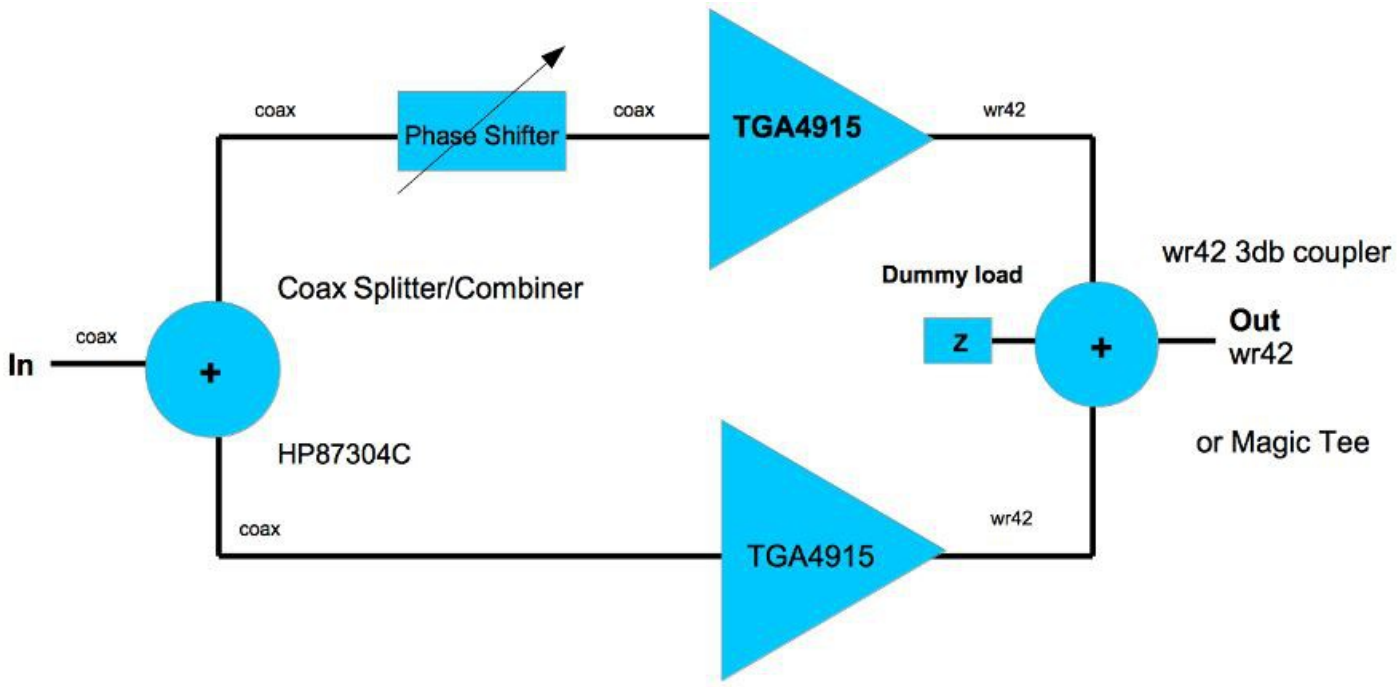
The performances were extremely poor, only 5 to 8 Watts could be achieved and Michel abandoned that project declaring he could not do more. All the group was very disappointed, however in this group there is one guy who like the challenge, it's me... So the adventure was going to continue... Lol...

Phase 4 : Dual devices second tentative - wr42 output coupling

I reminded my 70's microwave courses, our teacher always told us: “with waveguide technology you've zero losses”. I decided to try to do a dual devices SSPA using a waveguide coupling with a 3dB coupler or a Magic Tee. I started to find a 3dB coupler, and found one coupler coming from an old Alcatel refurbished stock (Thanks to Olivier F6HGQ).

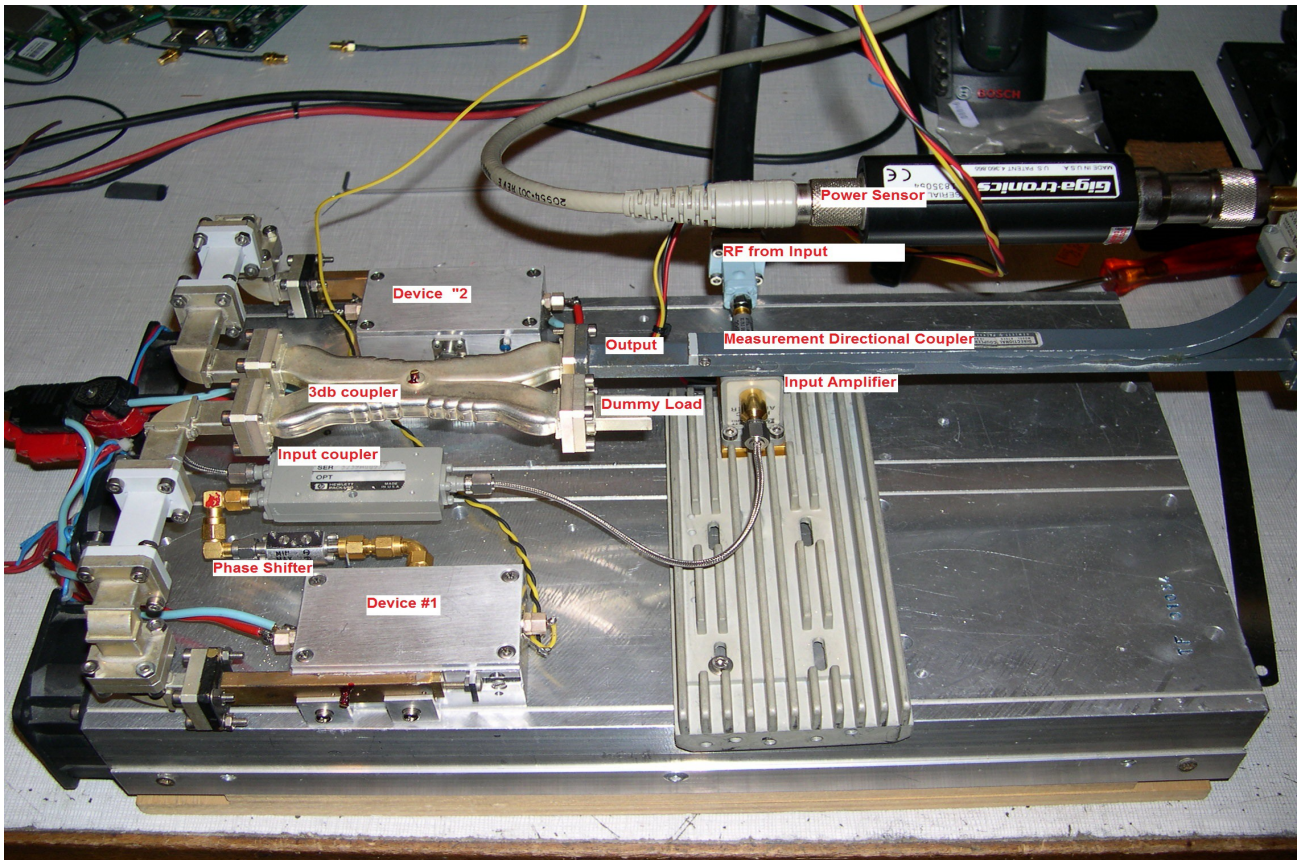
Coupling two devices together seemed to me not a real problem, my main interrogation was the concern of the phases of each devices, then I decided to introduce a phase shifter device into one branch to be able to adjust easily the phasing.

The synopsis of the SSPA



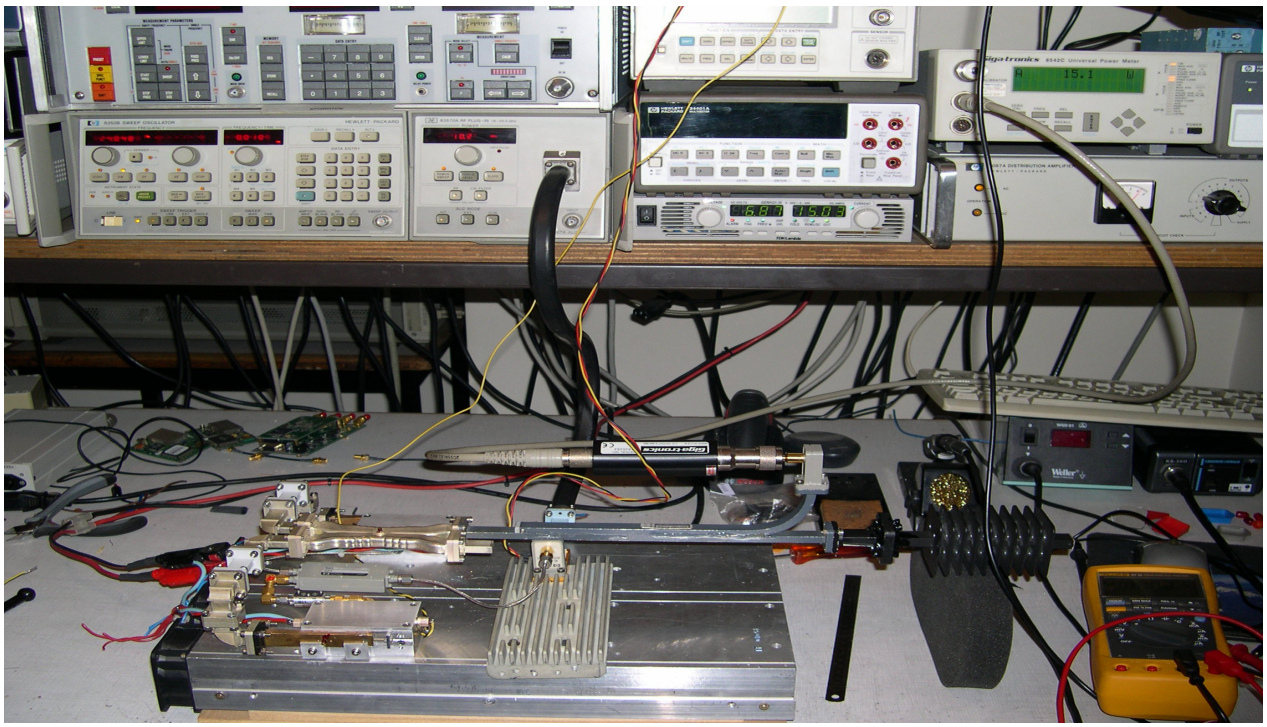
As a 26GHz phase shifter couldn’t be found I used a 18GHz one; as it is a passive component, it is working fine at 24GHz except it has a little bit more losses. It's not a real problem if at the input you have enough dBm to drive the TGAs.

The final SSPA on the bench



The reasonable performances achieved are more than 15 Watts (41.5 dBm) at the saturation, for approximatively 340 mW (~25 dBm) at the input. Each TGA needs 21 to 22 dBm in, plus the insertion losses in each input branch which are around 2.5db (insertion loss is in addition to 3 dB coupling loss).

The Test bench



For the fun I could obtain much more power than the 15 Watts but I do not recommend such a unreasonable work unless you're rich enough and have mounted a barrel to replace the TGAs.

Budget evaluation of the project:

For the pricing evaluation of this project there are two components which are mandatory for your purse unless you have a good friend working at TriQuint (please let me know I'm interested... Lol...), these are the two TGA4915-CP. The price is around $300 to $330 each at Mouser (quote is requested).

Budget evaluation

Components	Source	Qty	Max$	min$
TGA4915-CP	TriQuint (Mouser)	2	600	600
Milled box	various – your choice	2	140	0
Pcb	F5BQP or other	2	50	50
Output coupler	Ebay or other	1	250	0
Input coupler	Ebay or other	1	100	0
Phase Shifter	Ebay or other	1	150	0
Radiator	Ebay or other	1	50	0
Various components	Ebay or other	–	50	0
Total			1390	650

The final budget of this project should be in between, in that range, depending of your effort on the construction and the bargain you have in your garage. I've not described the power supply, it would have been another article, it has been done by our friend Joël F6CSX, it's described on his site.

Conclusion:

1 - It's very easy to build a single device SSPA using high power modern Ku band devices

2 - It's difficult for hams to build Dual (or more) SSPA using strip-line technology at 24GHz

3 - It's extremely easy to couple dual or multiple devices using fully matched waveguide couplers

4 - The same technique have been used to couple two commercial 10W SSPA from Kuhne DB6NT, this is the amplifier from our friend Andre F1PYR, and we obtained almost 20 Watts (see annexe 1)

References

Some useful URL :

http://f6bva.pagesperso-orange.fr/24Ghz/PA%2024%20TGA4915%20mono.pdf

http://www.triquint.com/products/p/TGA4915-CP

http://f6csx.free.fr/PROJETS/BUCK/buck_6v_20a/buck_6v_20A.htm

Some useful components for the project (these are just some example) :

http://www.pasternack.com/phase-trimmers-category.aspx (still working at 24GHz)

http://www.nardamicrowave.com/east/index.php?m=Products&e=list&categoryId=217 (work at 24GHz)

http://www.minibend.com/catalog_viewitem.asp?pid=925

http://www.minibend.com/catalog_viewitem.asp?pid=711

http://www.home.agilent.com/en/pd-1000002276%3Aepsg%3Apro-pn-87304C/hybrid-power-divider-2-ghz-to-265-ghz

Many thanks to :

F6BVA for the initial design of the single device SSPA

F1PYR for the initial TGAs purchase order

F1VL for the single device SSPA prototype validation

F8BTP & F6DPH for the mechanics

F2CT for the second TGAs purchase order

All the others I've forgotten

And Ebay our second mother offering us so many toys not only for Christmas...

If you need to contact me :

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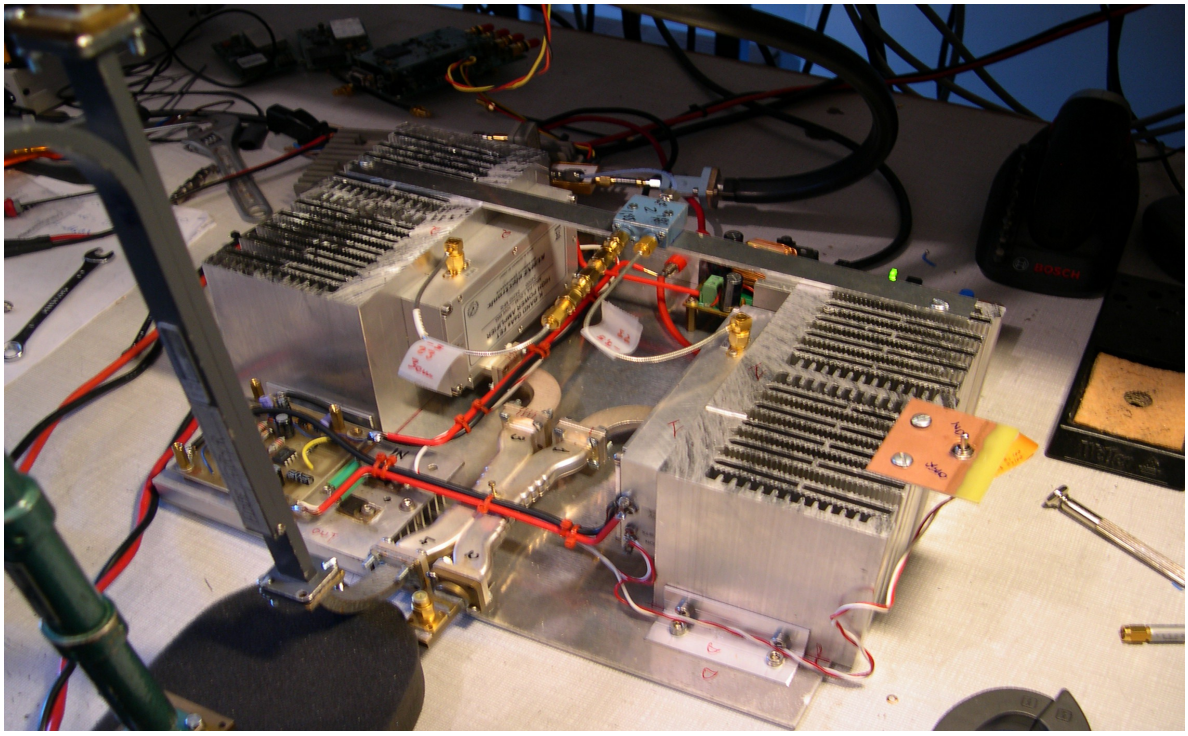
Annexe

The F1PYR amplifier on the bench:



And its output power