Reverse engineering on 3.4 GHz DJ6EP transverter

Release 1c
The last but not the least !

Introduction

-Beeing for a long time ago very interested by approaching this 9cm european band
-Even if french hams aren't yet allowed in transmitting on it, sure that authorized eur. Hams will be very interested by crossband QSO's like I do from the 4 meter band
But things may perhaps change here in the coming years

-Some solutions can be actually found on the market such as the DEMI or the DB6NT transverters
-DEMI with its 3.456 GHz solution in hairpin technology for the US band is also a cheaper alternative, but I didn't find any 2nd hand equipment on the US market yet
-There are other possibilities (OK2UKG, SP??? - -) but I don't have enough infos about them yet

-So I'd decide to buy this complete and relatively cheap transverter + OCXO (about DB6NT half-price)
- I'd take the profit of a good DL hamfriend who'd immediately order two complete equipments directly to SP9QZO

But despite of DB6NT or DEMI productions (with following data sheets and dedicated meases), it seems that this DJ6EP brand :
- is only a signature ! !
- isn't corresponding to an unique centered production in Poland, but done by «some non official polish subcontracters»
- SP9QZO seems to be one of them : both mounted/tested transverters were bought to him completely assembled / tested
- It can also be found on german ham meetings, but on very restricted quantities
- so these both present transverters were clearly **not built as proposed by the author elements!**

Introduction

And like I do with other sold equipments, I'd immediately begin its reverse engineering study and RF measurements
And focus was especially done on its reception conversion part

PS : many reverse engineering studies and RF meases from 28 MHz up to 26 GHz can be found on :
- Hyper.r-e-f.org (REF is our french ham buro)
- F1CHF.free.fr/F5DQK

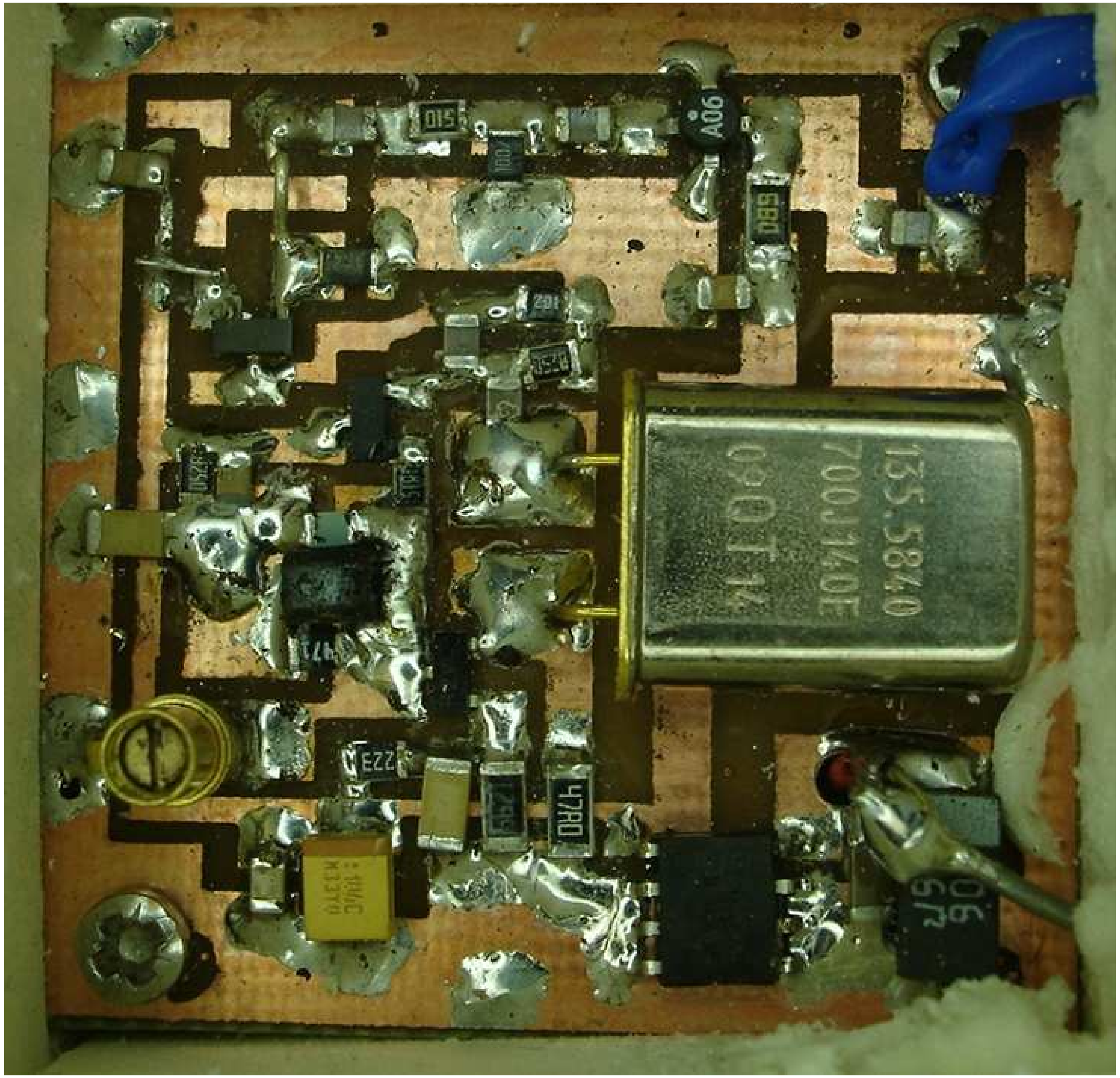
Suite à l'achat d'un ami Allemand de 2 transverters 3.4 GHz / 146 MHz en Pologne, neufs assemblés et théoriquement testés, la tentation fut grande d'en étudier un exemplaire plus en détails
Malheureusement avec son piètre gain de conversion Rx initial de seulement 13.5dB et la fréquence FI à gain maximal totalement décentrée, des investigations plus poussées ont alors permis de régler plusieurs problèmes (en particulier, de remplacement arbitraire de certains composants par rapport au design originel)

En fait il s'agit d'une copie conforme du transverter 3.4 GHz DB6NT réalisée exactement avec les mêmes éléments, mais adaptée sur du substrat verre-époxy FR4, plus abordable pécuniairement pour la clientèle polonaise

Plan

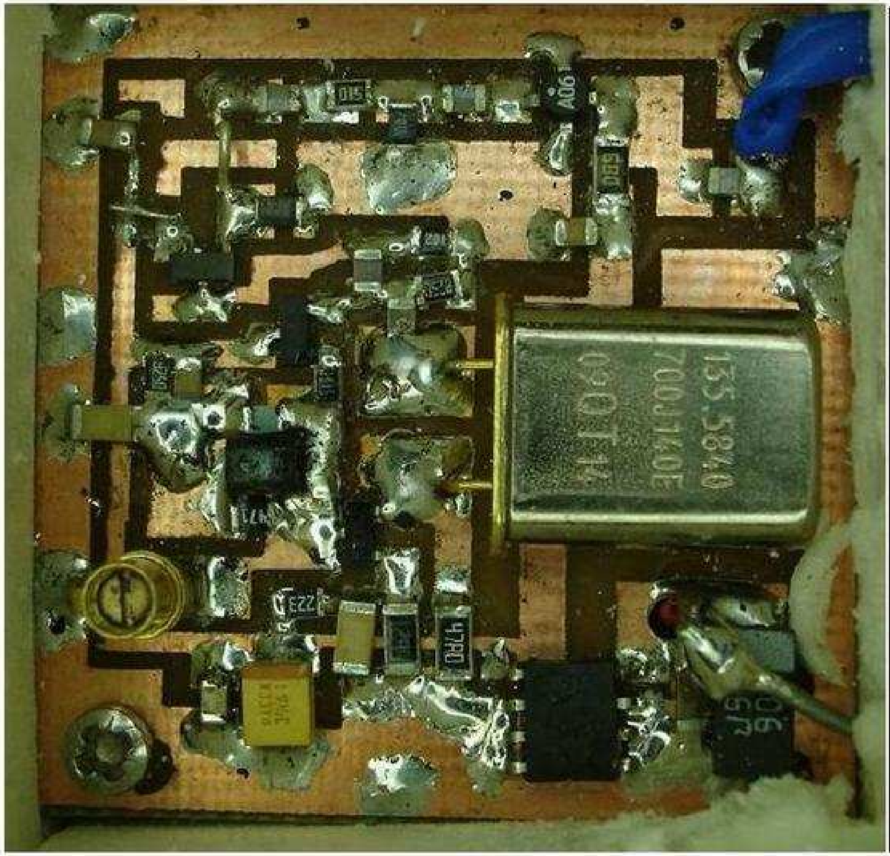
1- Meases on external OCXO

135.58 MHz OCXO internal structure

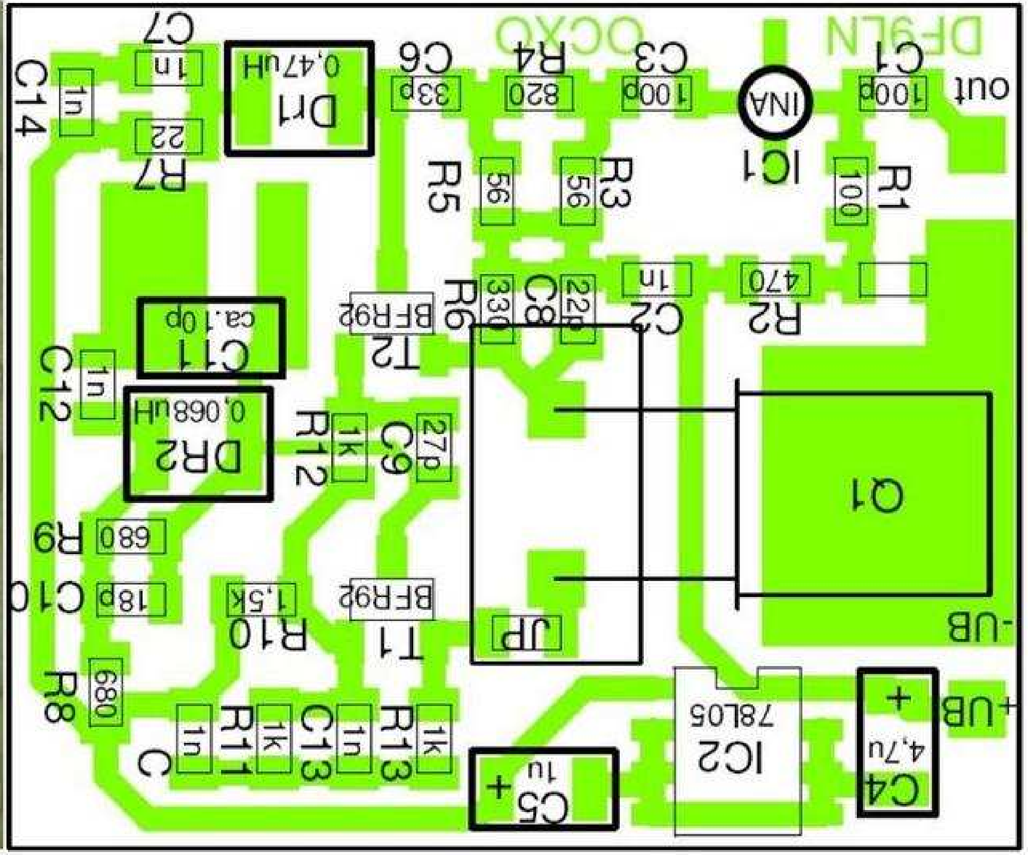


Comparaison between SP9QZO and DF9LN conception

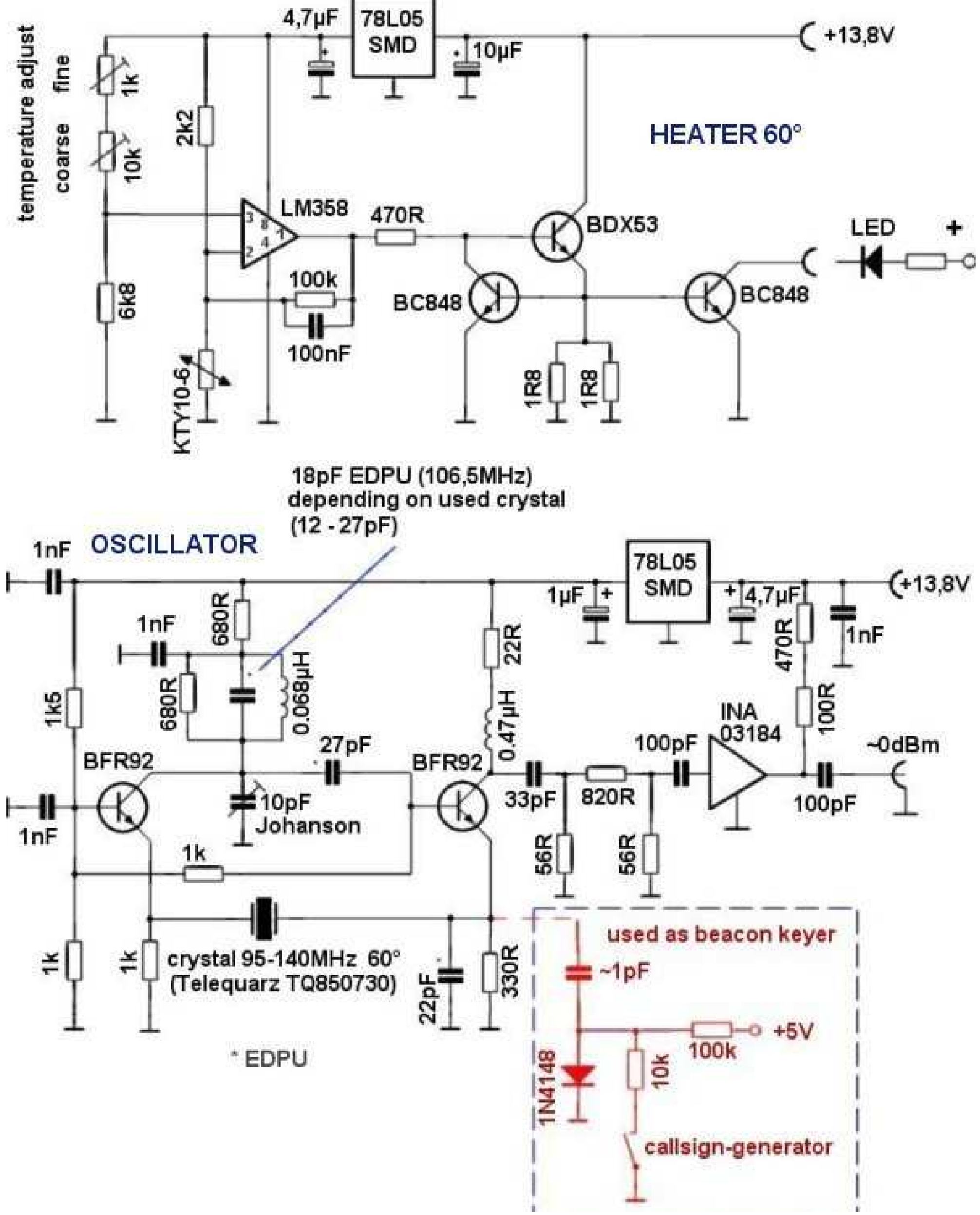
SP9QZO



DF9LN



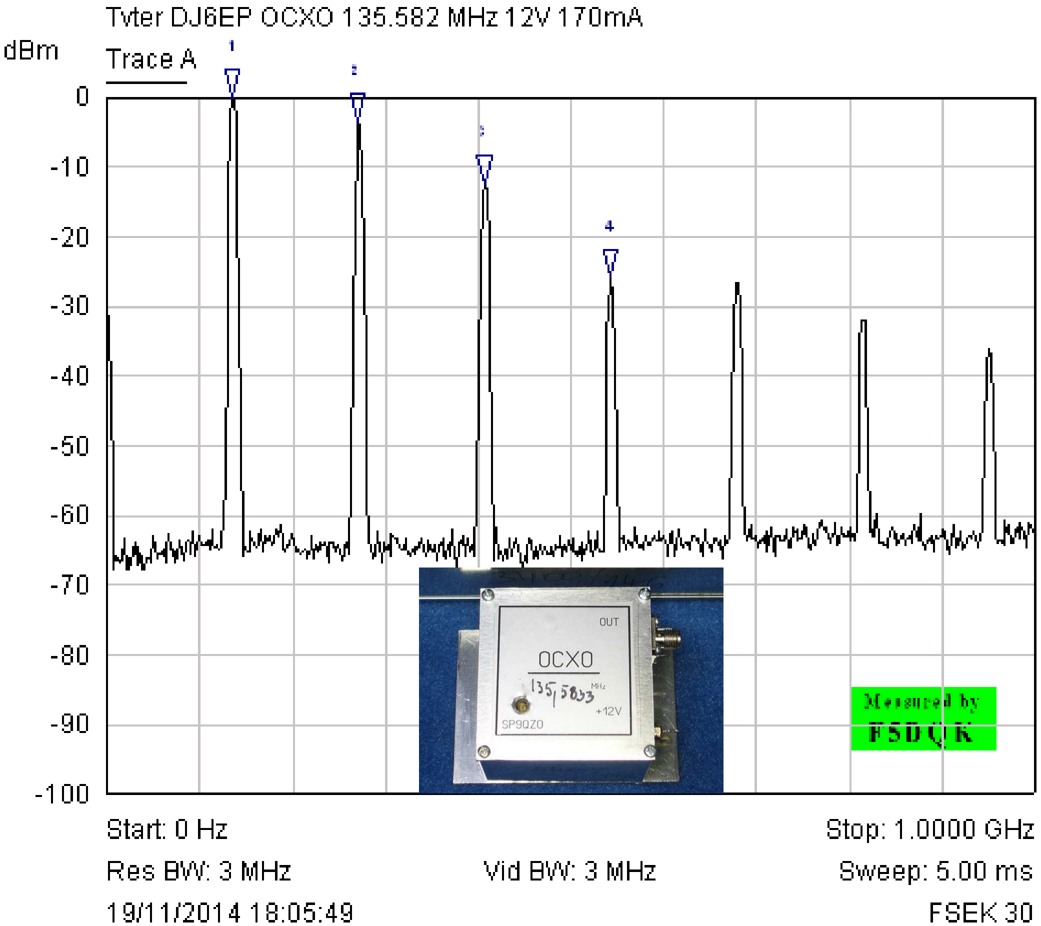
DF9LN schematic



Butler oscillator with far better phase/noise behaviour as if soldered inside the transverter

Thanks to F6AJW for this info

135.58 MHz OCXO for 146 MHz IF

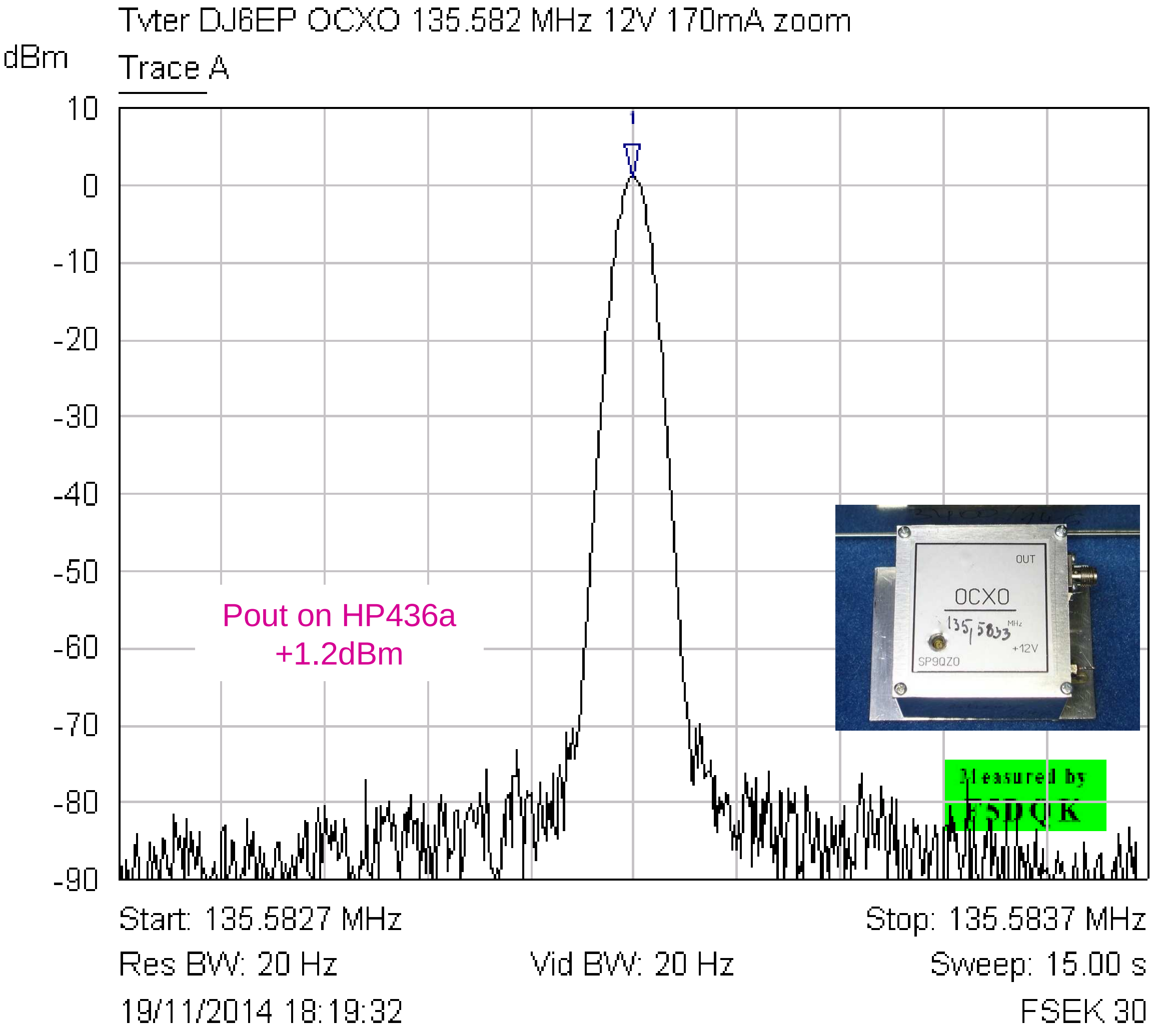


Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	134.2685 MHz	1.48 dBm	P_bolo +2.8dBm
2 ▽	Trace A	270.5411 MHz	-3.45 dBm	
3 ▽	Trace A	406.8136 MHz	-12.36 dBm	
4 ▽	Trace A	543.0862 MHz	-25.87 dBm	

Not filtered output and many harmonics with :
- H2 only 2dB down
- H3 only 10dB down

- The Marconi 2440 counter did immediately synchronise on its H1,
- The EIP 578 did only accept its H2 measurement ! !

135.58 MHz OCXO for 146 MHz IF



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	135.5832 MHz	1.17 dBm	FSEK piloté GPSDO

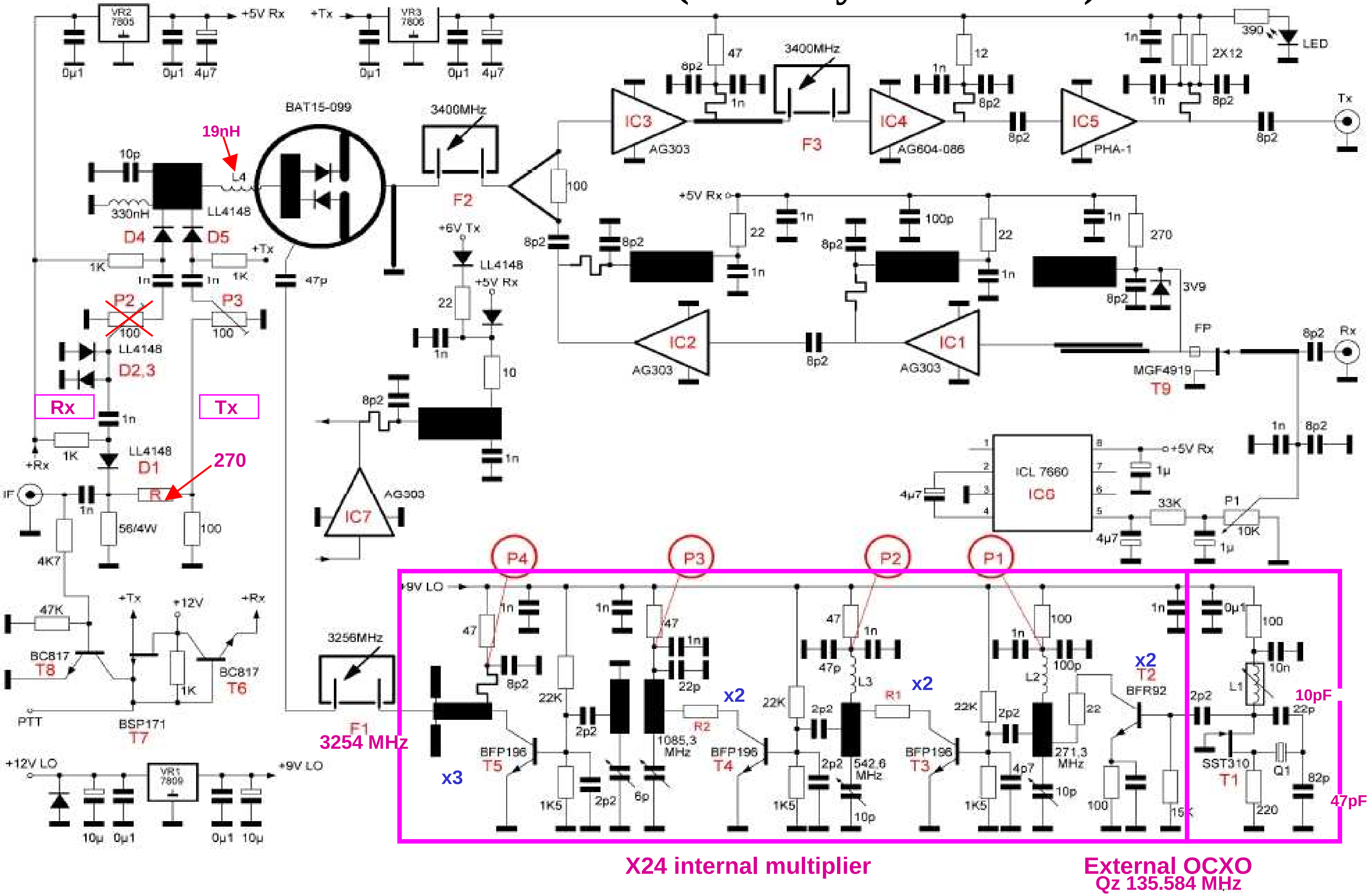
Not bad in spectral purity

12V, I_cold = 1.1A
I_stab after 5 minutes 150mA

2- 3.4 GHz transverter inside views

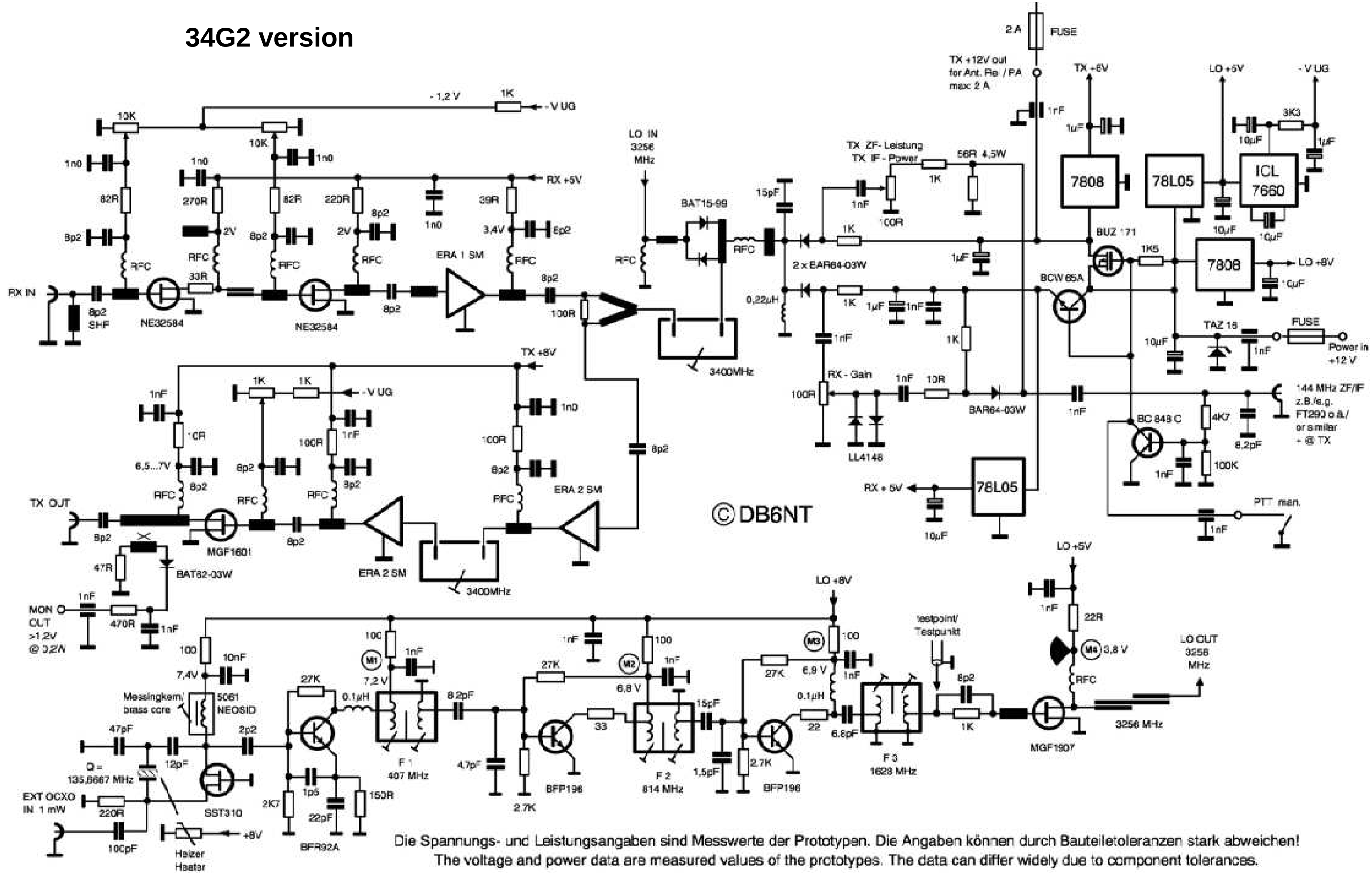
Internal dimensions 136x72, H=40

3.4 GHz schematic (courtesy of DH1VY)

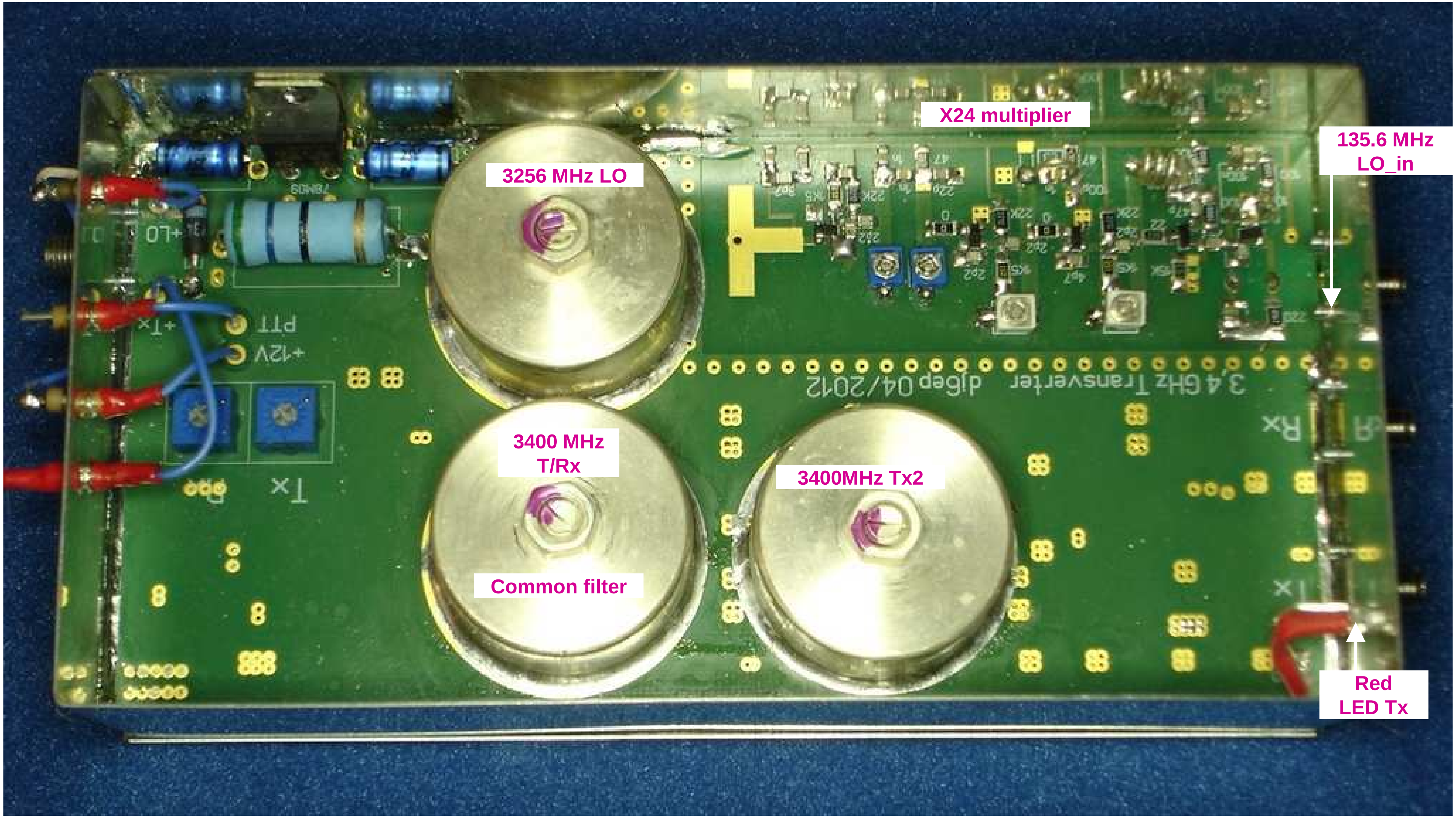


Direct comparaison with its 3.4 GHz DB6NT equivalent

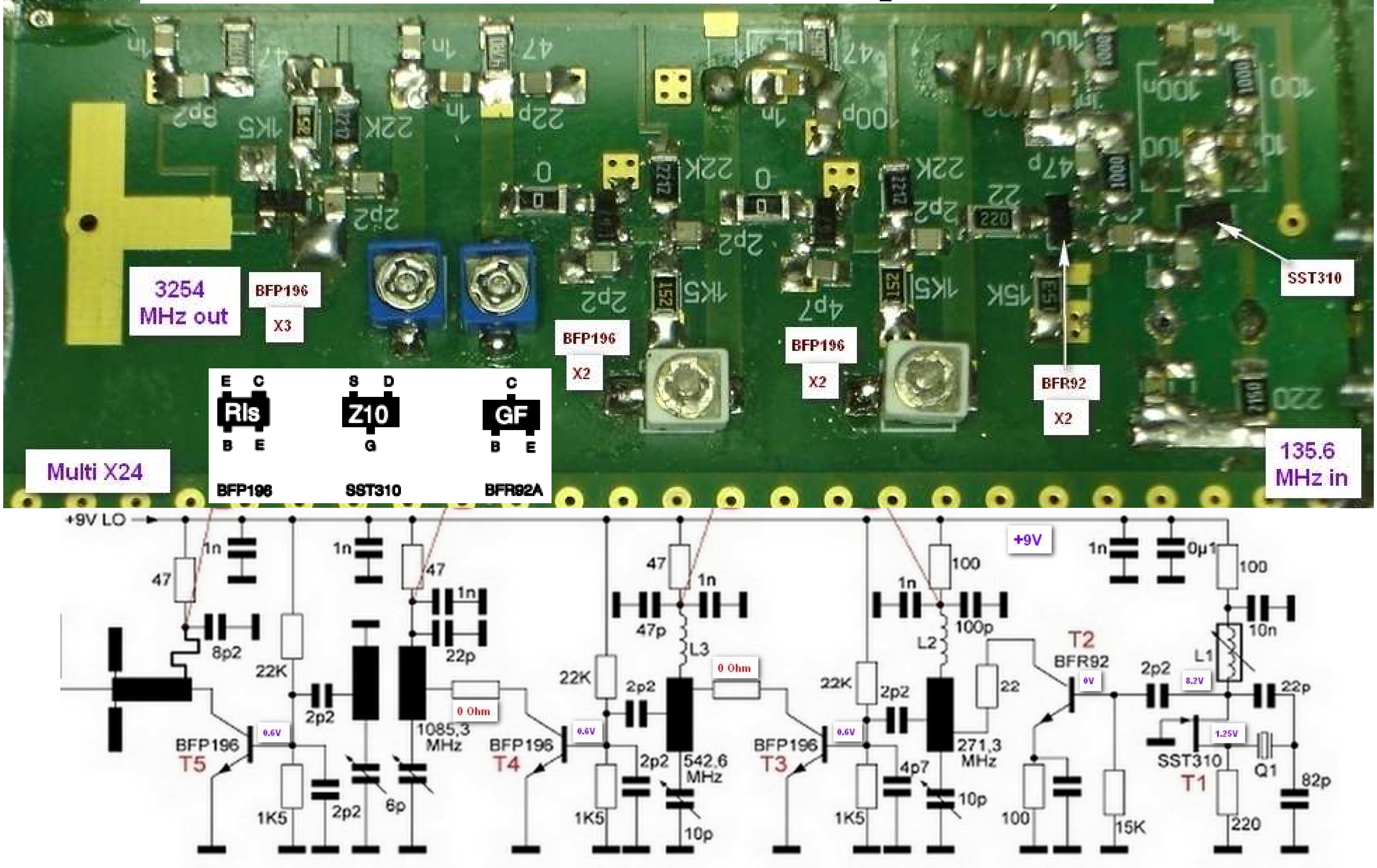
34G2 version



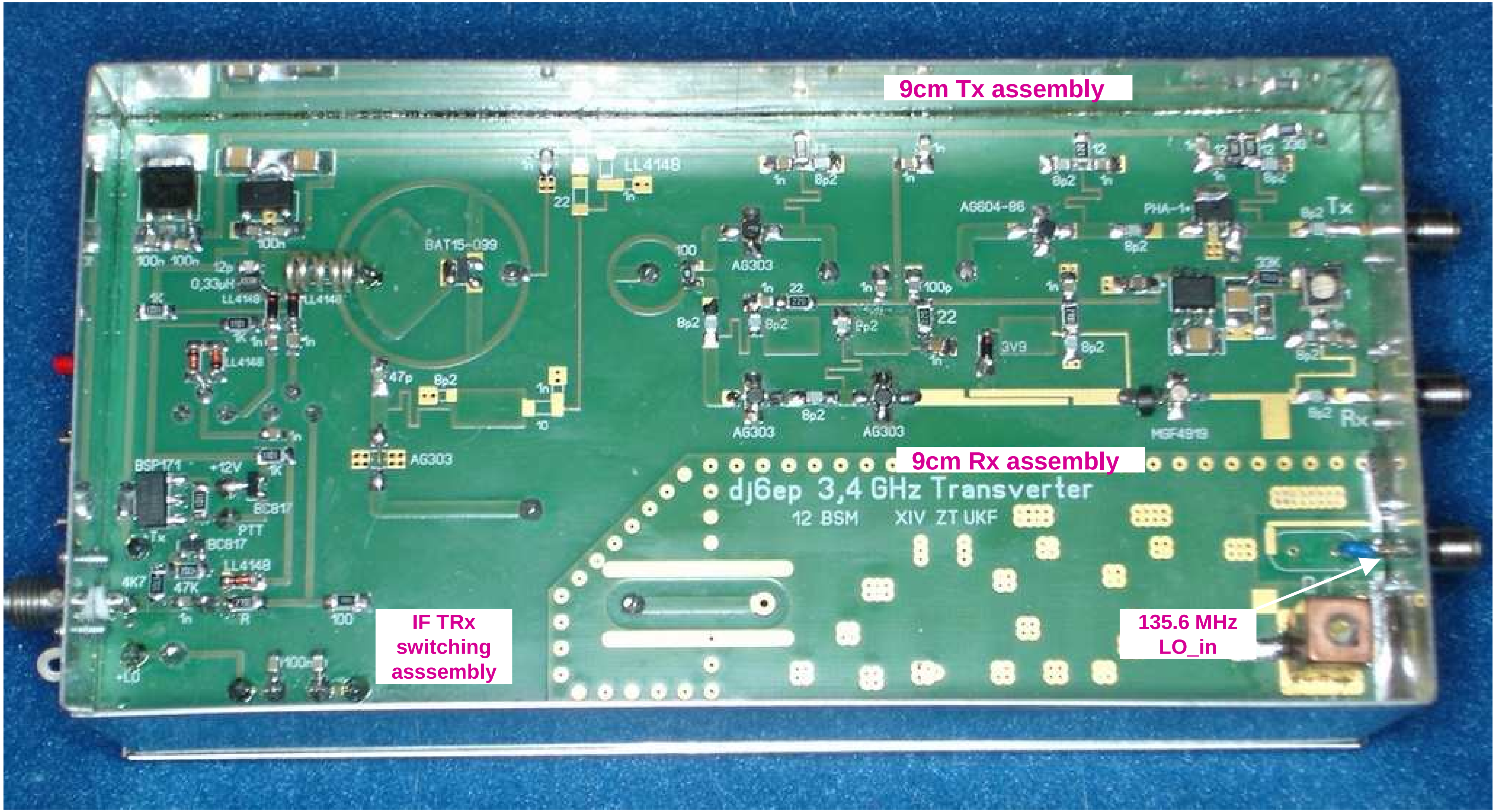
3.4 GHz transverter : upper side



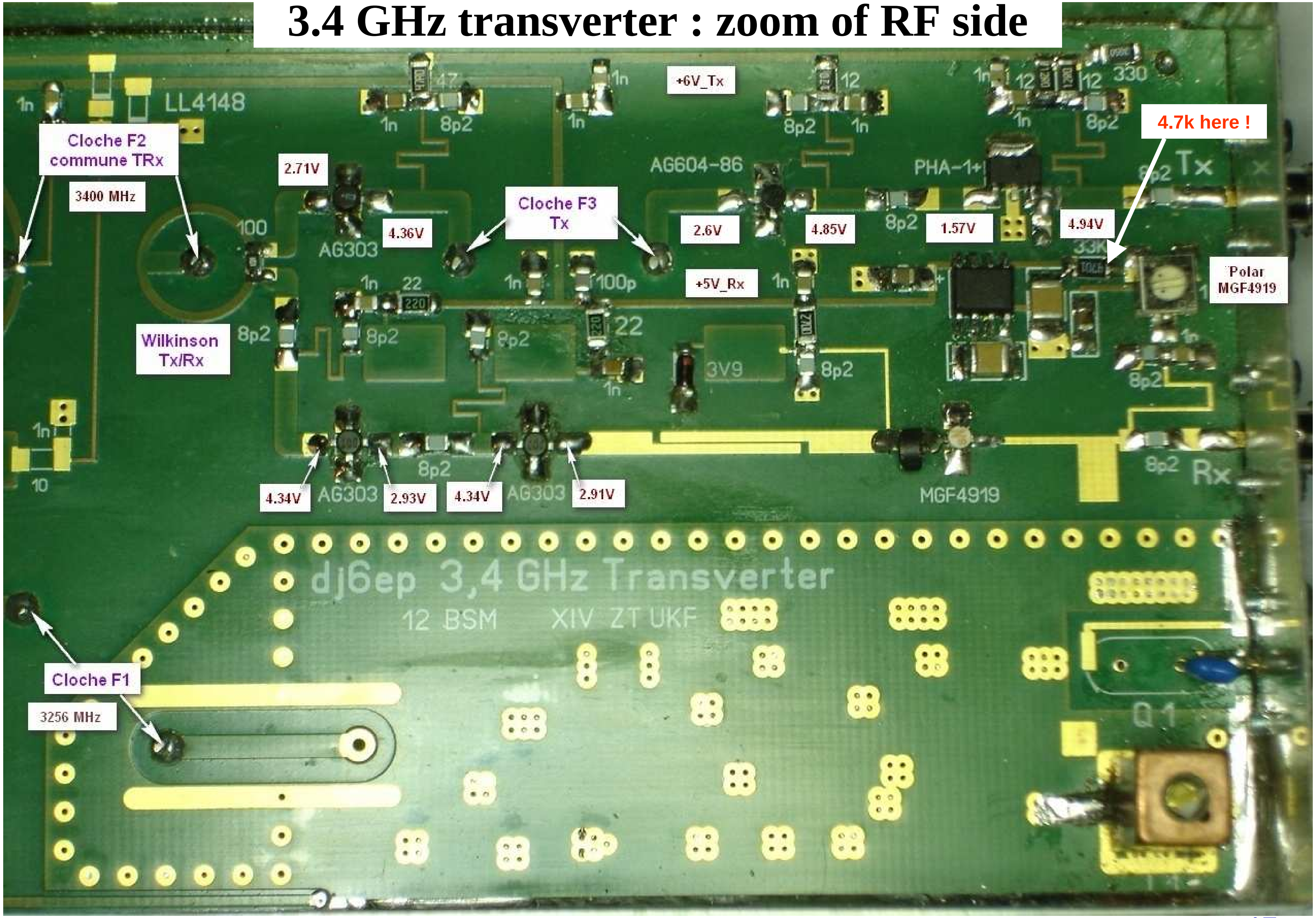
3.4 GHz transverter : LO multiplier zoom



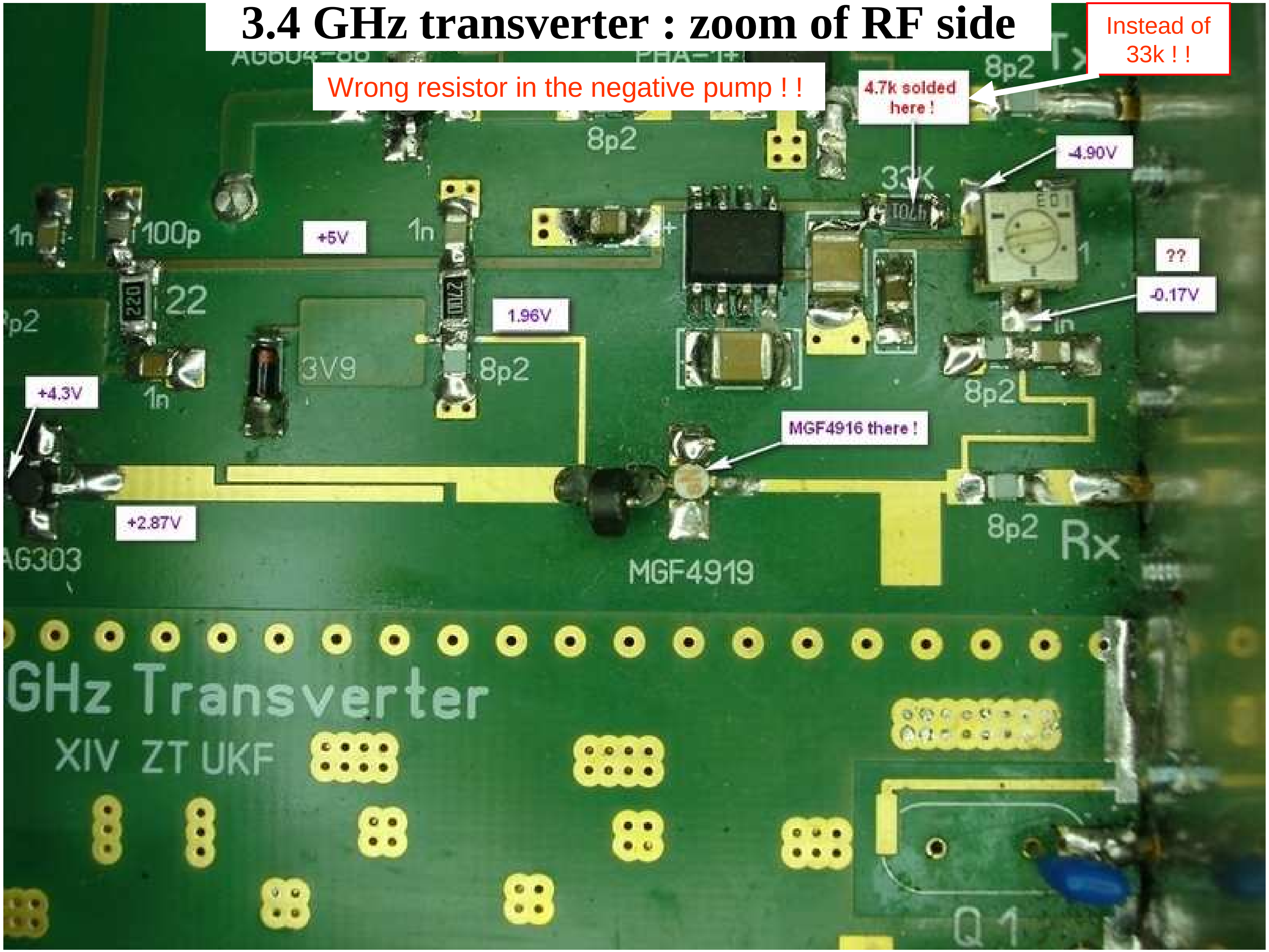
3.4 GHz transverter : RF side



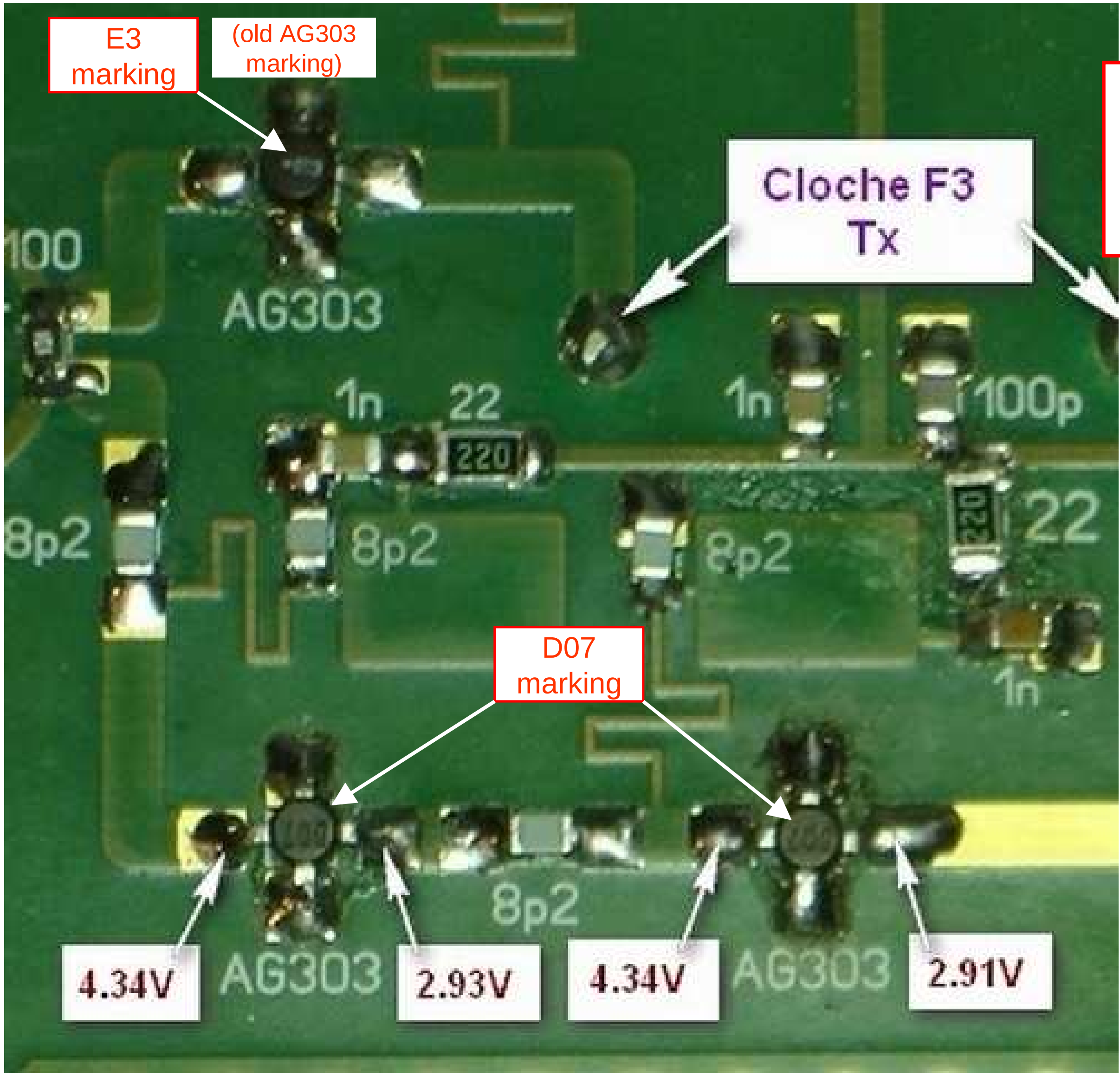
3.4 GHz transverter : zoom of RF side



3.4 GHz transverter : zoom of RF side



3.4 GHz transverter : zoom of RF side

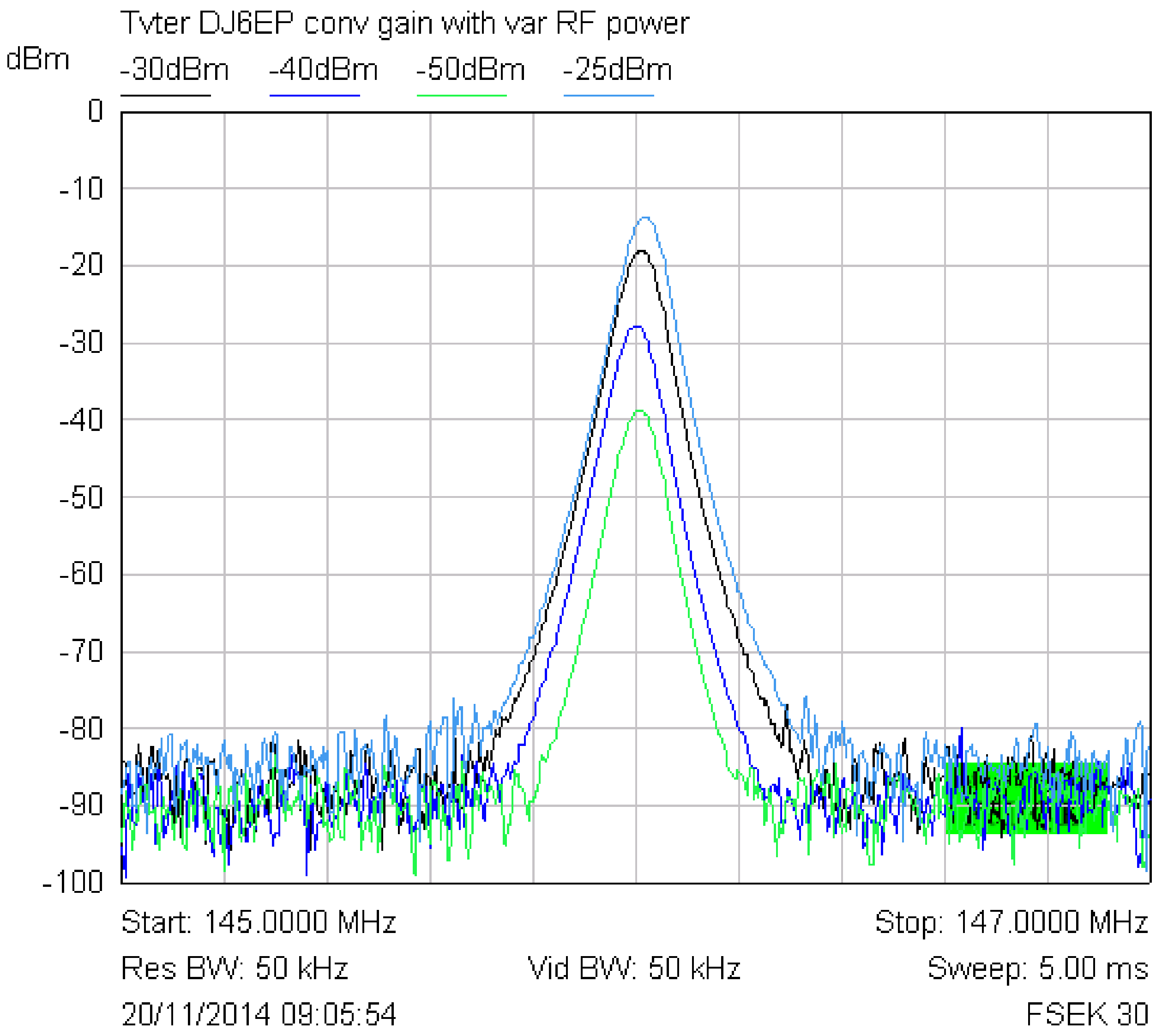


These 3 same MMIC devices have 2 different markings, who is the right one ?

Sure that D07 is the wrong one !

3- Whole Rx converter measurements

Rx measurement with RF variable input power

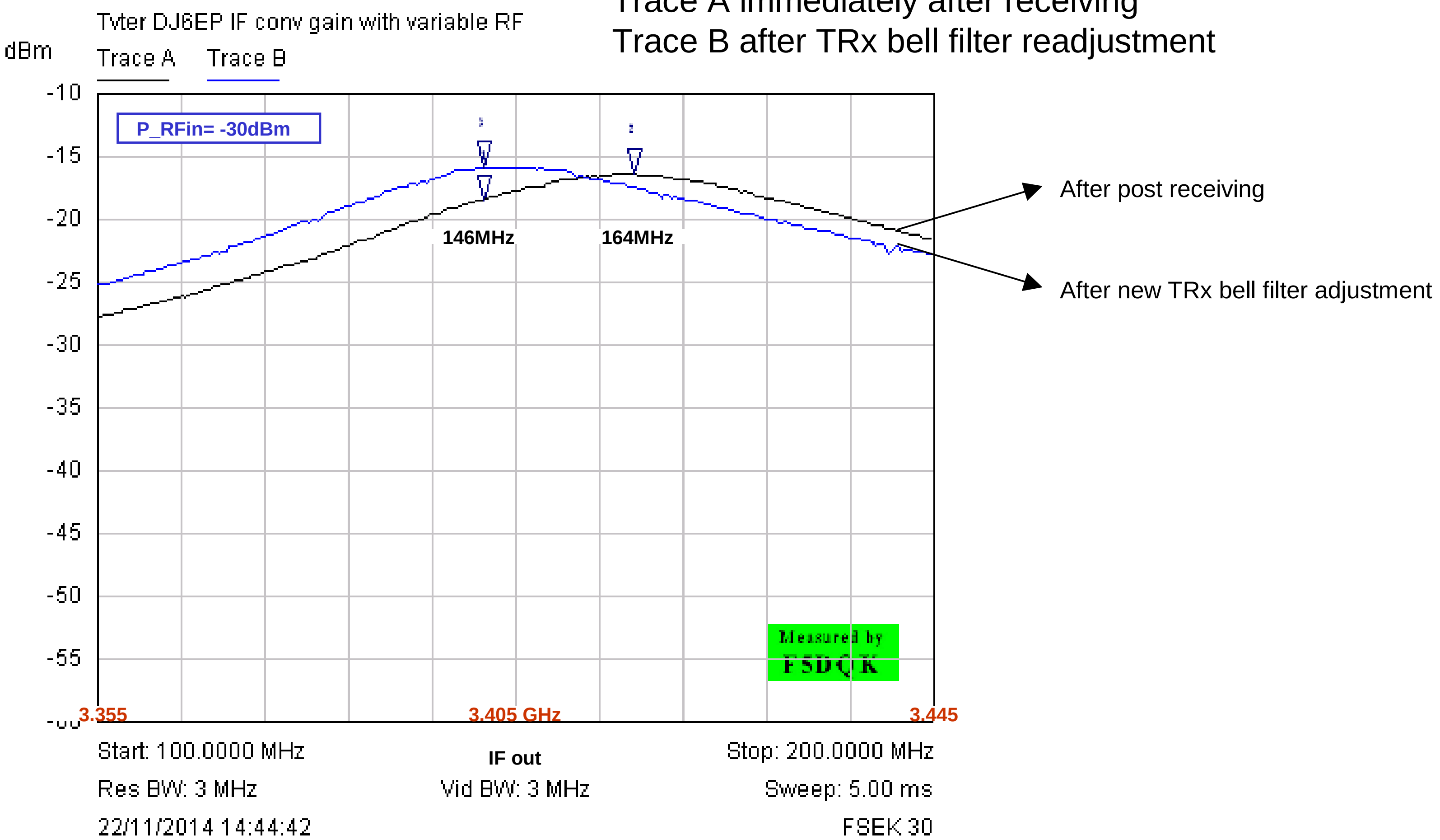


Rx 12V 130mA without OCXO

Conversion gain <u>only about 12 to 14dB</u>
RF_in saturating with about –25dBm

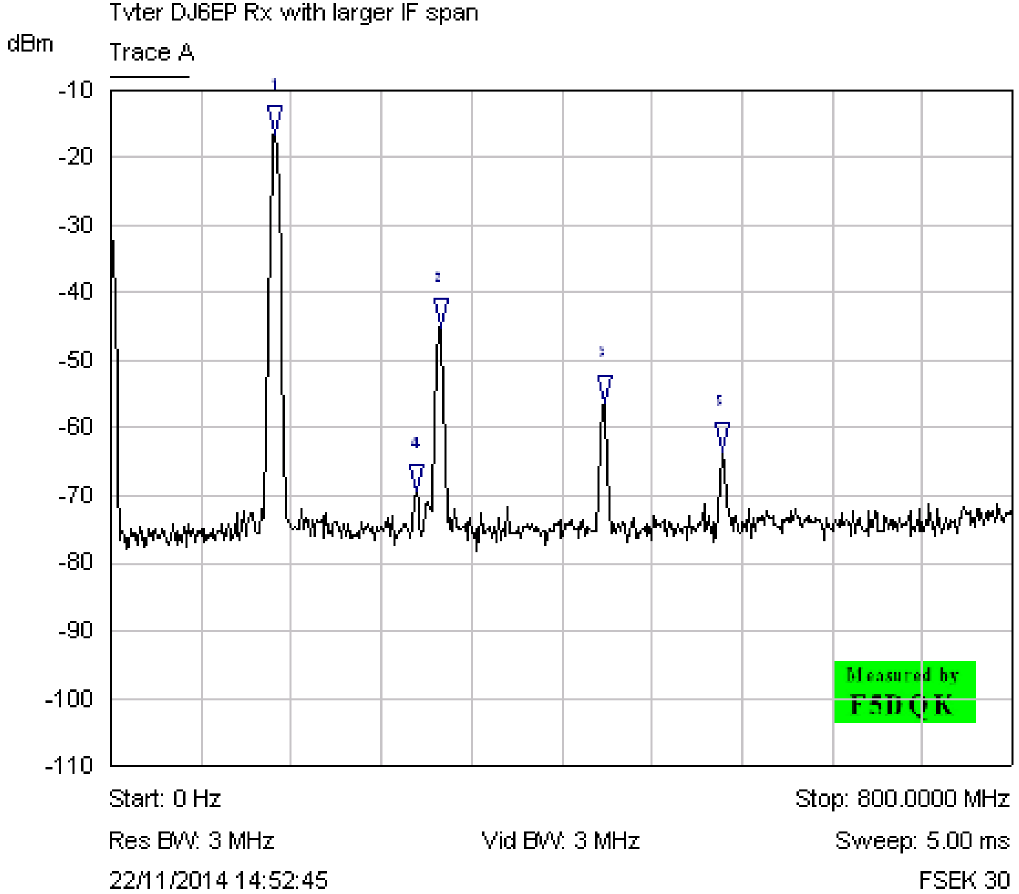
Max IF frequency gain versus variable RF frequency

Trace A immediately after receiving
Trace B after TRx bell filter readjustment



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	146.1924 MHz	-18.47 dBm	RF_in = -30dBm
2 ∇	Trace A	164.2285 MHz	-16.39 dBm	
3 ∇	Trace B	146.2004 MHz	-15.92 dBm	readjusted TRx bell filter

Surrounding IF measurements with large span



Mkr	Trace	X-Axis	Value	Notes
1 ▽	Trace A	145.8918 MHz	-16.53 dBm	Normal IF
2 ▽	Trace A	291.7836 MHz	-44.96 dBm	= 2*IF
3 ▽	Trace A	437.6754 MHz	-56.18 dBm	= 3*IF
4 ▽	Trace A	270.9419 MHz	-69.39 dBm	=2* LO
5 ▽	Trace A	543.4870 MHz	-63.32 dBm	=4* LO

Rx measurement with HP 8970b NGA (+ ext. OCXO)

LO = 135 MHz delivered OCXO
-HP 8970b NGA
-HP346B noise source with corrected ENR

U_Rx = 12V
I transverter alone = 130mA
I transverter + OCXO after 5 minutes = 220mA

A/ P1 pot adjust did show that it is initially well tuned at Nf_min

only (just after purchase) **? ?** → very frustrating !

best compromise found à 164 MHz instead of 146 MHz !

B/ TRx common bell filter adjusting (vy hard to do)

best values got after 10 minutes adjusting on spectrum analyser with 1dB scale → very sharp to do
Now about 2.6dB better gain, and centered à 146 MHz

But very frustrating because I'd expect a conversion gain of minimum 20dB !
And better gain is absolutely impossible to get !

Rx measurement with HP 8970b NGA (+ext Syntheziser)

LO = Marconi 2031 synthesizer
-HP 8970b NGA
-HP346B noise source with corrected ENR

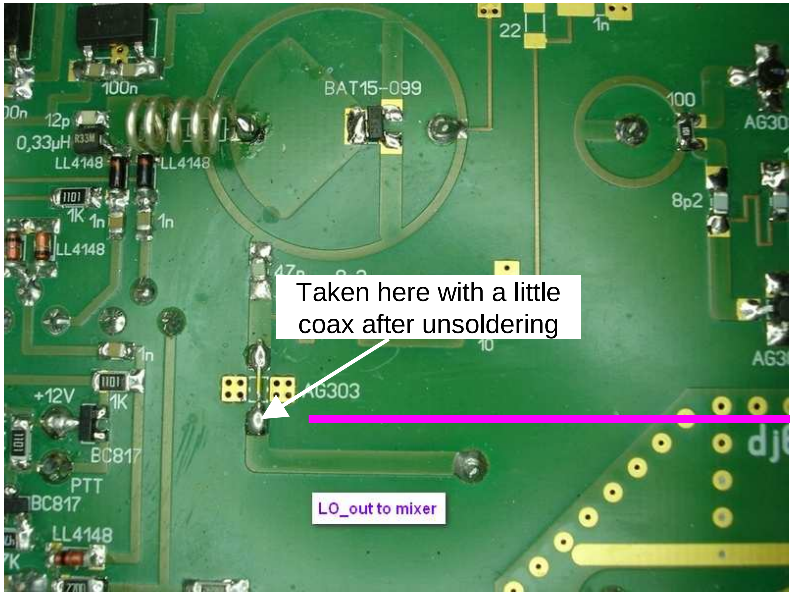
Exactly same gain/Nf meases were found, also à P_LO = +1dBm

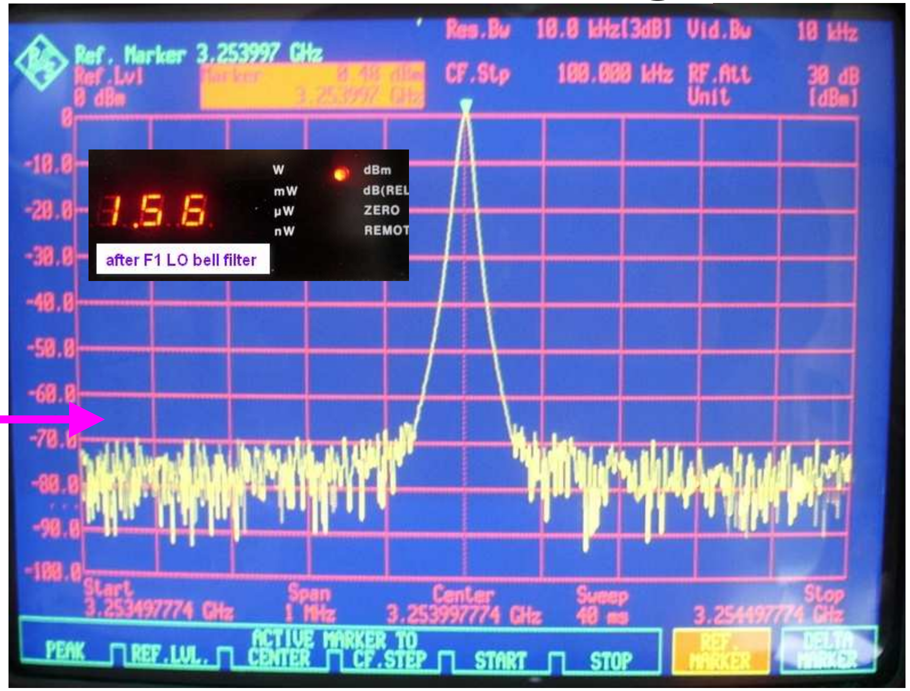
Now with variable LO power :
- down to P_LO = -2dBm : stable gain
- P_LO <= -5dBm : gain unlocking

LO measurement alone, after about 5 minutes heating

4- Meases on LO alone

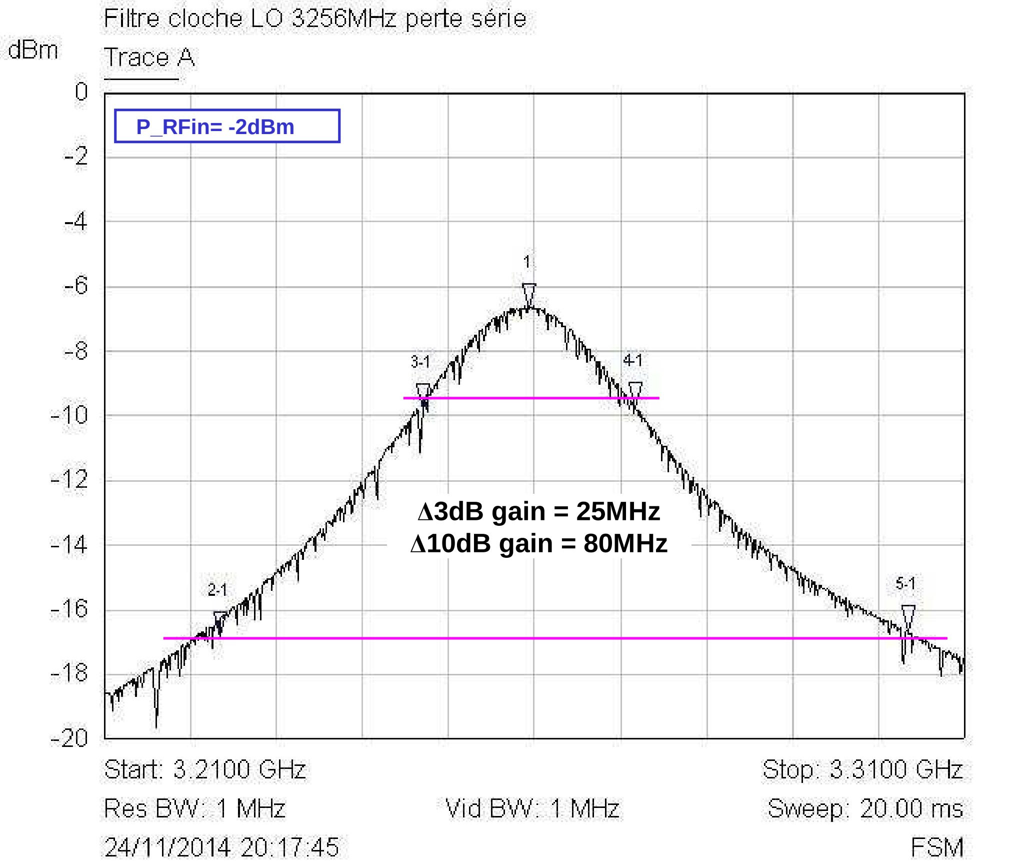
LO measurement alone, after about 5 minutes heating





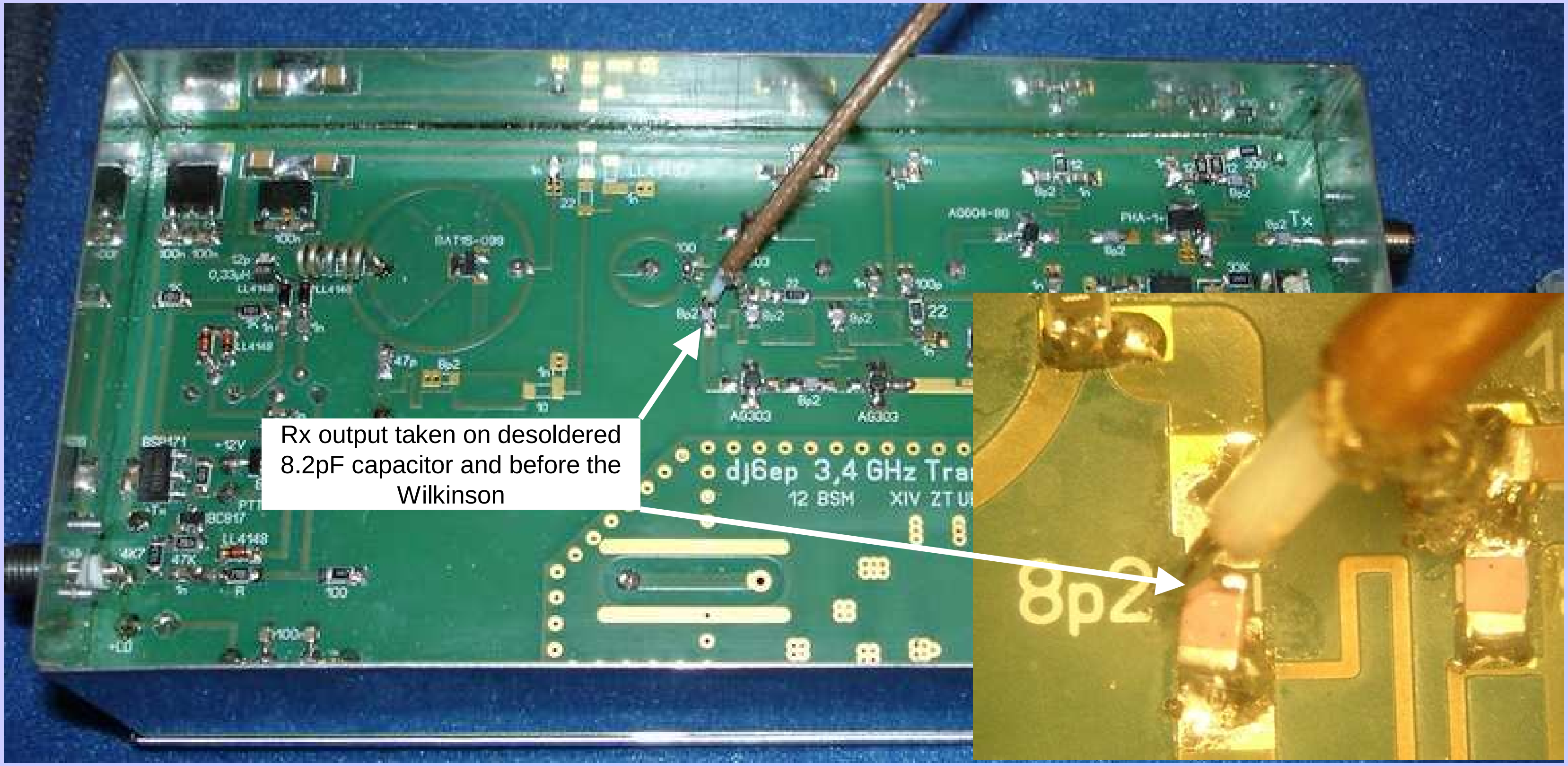
Why this difference on both same complete sold transverters ? ?

Losses of LO bell filter alone

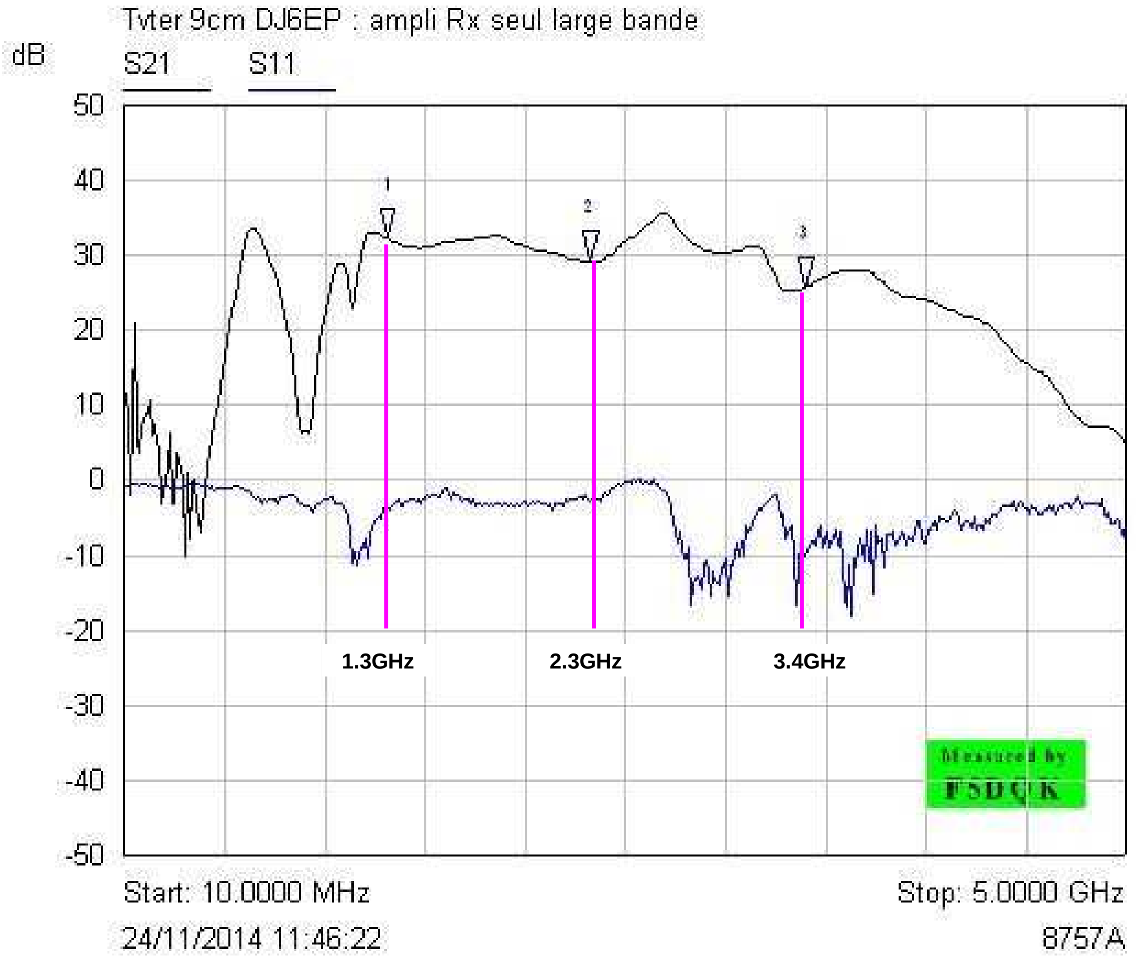


Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	3.2593 GHz	-6.70 dBm	best = 4.7dB losses
2-1 ∇	Trace A	-35.8889 MHz	-10.16 dB	
3-1 ∇	Trace A	-12.3333 MHz	-3.12 dB	
4-1 ∇	Trace A	12.4444 MHz	-3.05 dB	
5-1 ∇	Trace A	44.1111 MHz	-10.01 dB	

4- Meases on 3.4 GHz Rx chain only

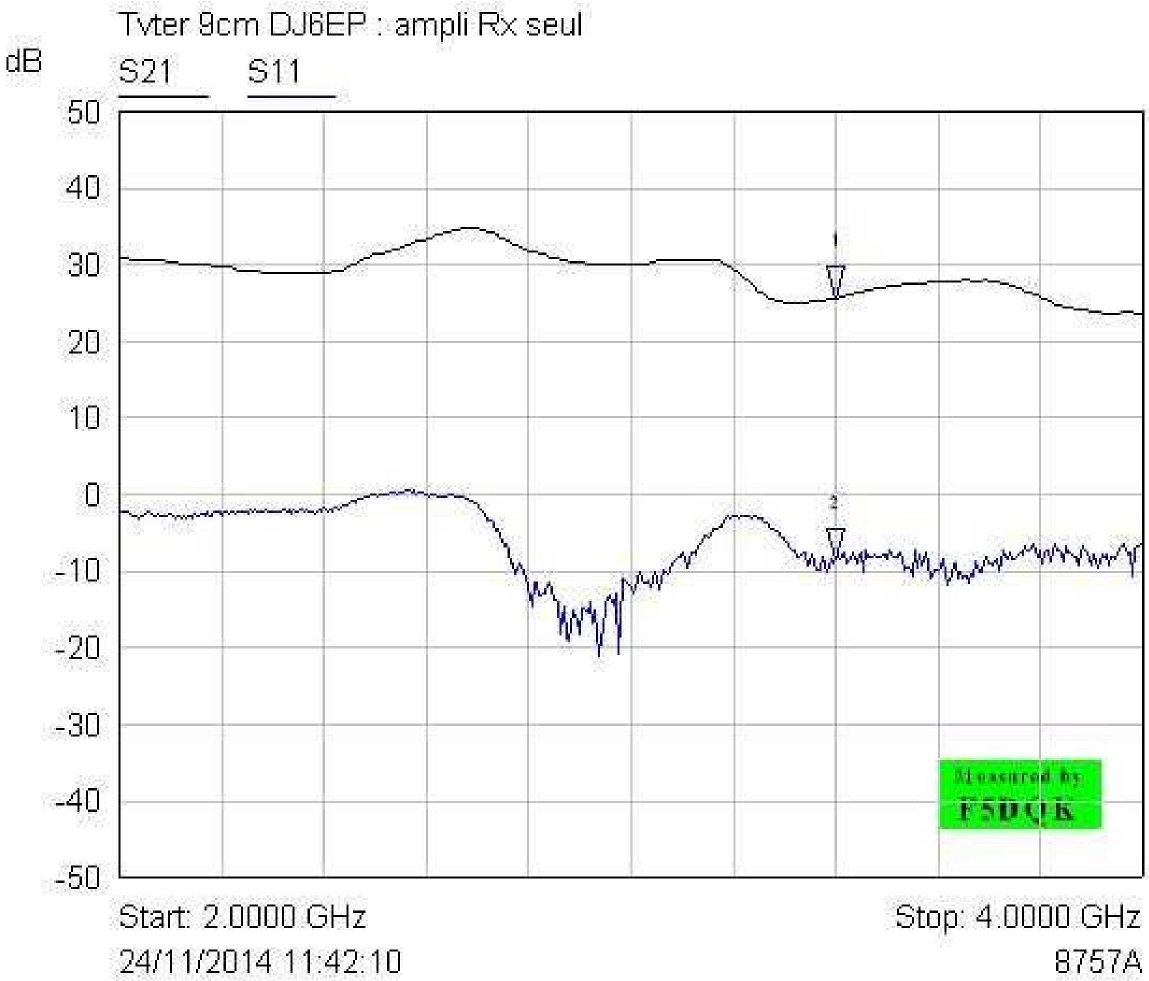


Broadband scalar meas on 3.4 GHz Rx part only



Mkr	Trace	X-Axis	Value	Notes
1 ∇	S21	1.3199 GHz	32.09 dB	
2 ∇	S21	2.3304 GHz	29.14 dB	
3 ∇	S21	3.4032 GHz	25.66 dB	

Scalar meas more zoomed on 3.4 GHz Rx part only



Mkr	Trace	X-Axis	Value	Notes
1 ∇	S21	3.4000 GHz	25.59 dB	
2 ∇	S11	3.4000 GHz	-8.43 dB	

Broadband gain/Nf meases on 3.4 GHz Rx part only

It seems that it is a real Rx broadband amplifier (Gain>= 30dB up to 3.0 GHz)
But à F>3GHz, the curve monotony doesn't stay constant
A 3.4 GHz the 7dB less gain can perhaps play on the whole Rx chain target of 20 dB

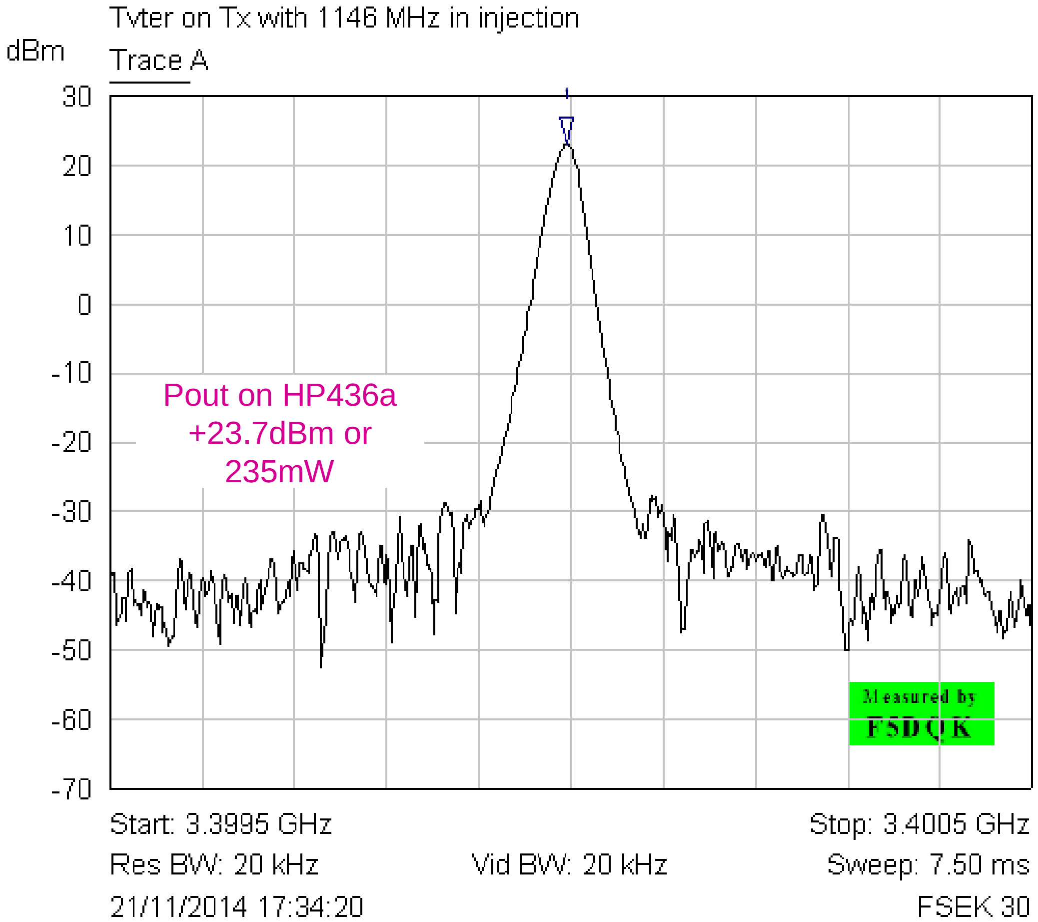
Mkr	Trace	X-Axis	Value	Notes
1	Nf (dB)	1.3000 GHz	1.61 dB	
2	Nf (dB)	2.3000 GHz	1.94 dB	
3	Nf (dB)	3.4000 GHz	1.08 dB	
4	Gain (dB)	3.4000 GHz	23.76 dB	

Nf not bad but gain variation beginning near 3.4 GHz perhaps not favorable for the hoped whole chain gain ?

6- Tx measurements

Tx measurement with FSEK spectrum analyser

U_Tx = 12V
I transverter alone in Tx = 330mA
(without OCXO)

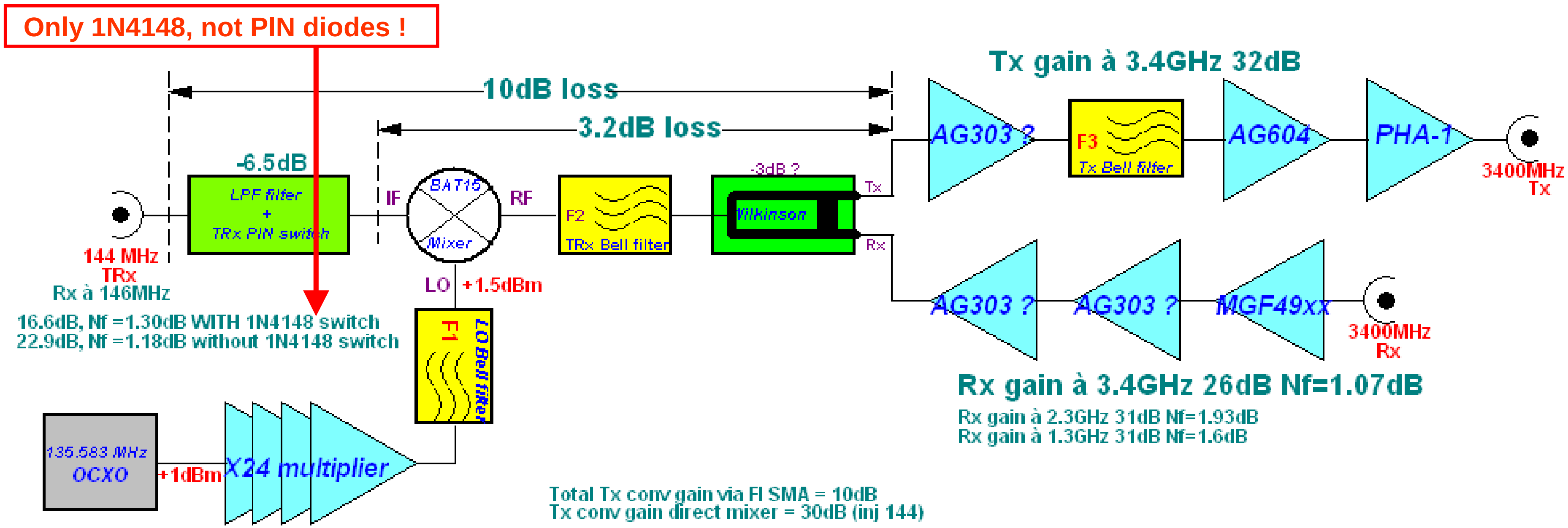


Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	3.4000 GHz	23.02 dBm	

NB :
- its Tx_DC switching is a very good idea
- and also its red Tx LED

7- Balance-sheet Tx and Rx

Balance-sheet Tx and Rx



18.6dB, Nf =1.27dB without 56 Ohm 4W
20.1dB, Nf =1.23dB without 100 Ohm Rx pot
18.1dB, Nf =1.23dB with 56 Ohm 4W again

In the IF part :

1N4148 diodes instead of PIN diodes BAR64-03 ! !

This actual IF diode switching system is far too lossy : -6.5dB
The 50R/4W takes 2dB loss (but no other possibilty because alway present)
The 100R pot takes 1.5dB more loss

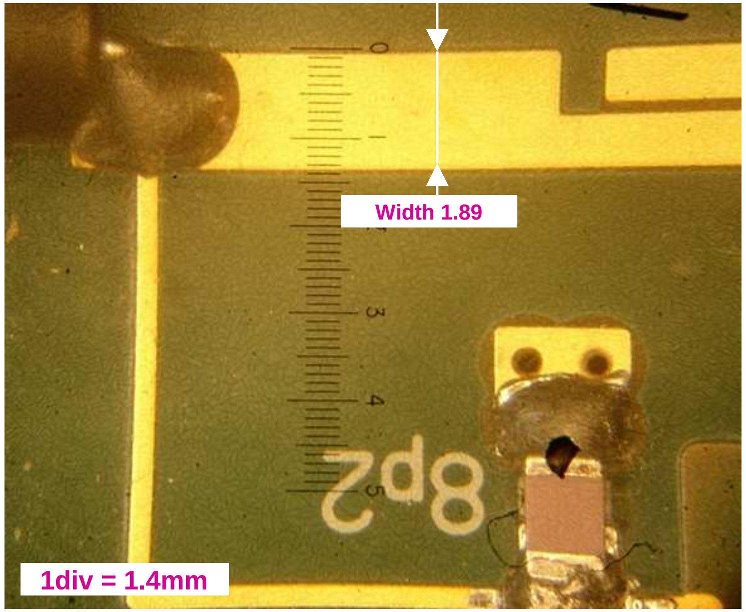
With the lack of gain after purchase, every dB is good to take !

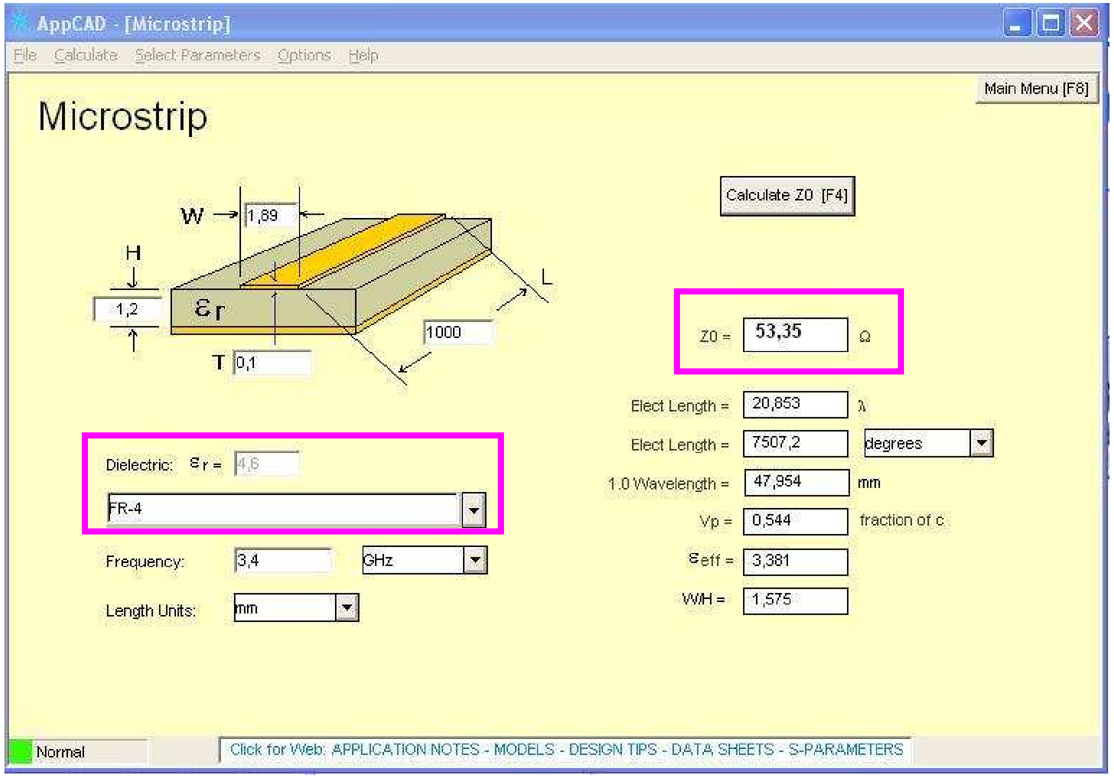
And taking a normal relay instead of this diode switching:
- decreases the IF losses to nil
- gives the possibility of also a 432 MHz IF possibility

PS : all IF bindings on the substrate between IF_SMA connector and diode mixer aren't dimensionned in 50 Ohm !

8- Substrate investigation

50 Ω line width meas and substrate possibility ?





According to :
- its 50 Ω line measured width
- The easiest thickness heigth found on the market 1.2mm)
- and the immediate AppCAD calculation done

It seems that the susbtrate is only common Epoxyglass or FR4

If it is the fact (and it seems so, because I also didn't get any answer from the builder), **it is a very bad substrate choice for F>2.0GHz, and principally à 3.4 GHz**
It can also explain the 3 stages preamp gain curve irregularities if F> 2.5 GHz
An RO4001 or 4003 substrate would be a far better choice at these frequencies

9- Back to the DJ6EP explanation PDF

About the DJ6EP explanation PDF

Principally relating about the 2.3 and 3.4 GHz transverter construction :

- only written in Polish, it is very frustrating to understand it clearly (no german or english, as largely prefered languages) ! !
- no clear separation is done between both 13 and 9cm versions (going from one subject to the other, and vice-versa)
- no pages numbering found under each of them

- only about 4 pages found on the 3.4 GHz printboard version in it middle part, with only kit details
- but no expected Rx and Tx resumed specs found for each 13 or 9cm version
- *the measurement picture of gain=20dB Nf=1.07dB Rx corresponds only to the 2.3 GHz version !*

So now about that its improvement solutions that every ham could expect ASAP :
- an only dedicated PDF for this 3.4 GHz transverter and totally separated from the 2.3 GHz one
- also **directly written in english or german**
- and also with a resumed data sheet with all Tx and Rx expected values (actually seriously missing)

3.4 GHz / 146 MHz DJ6EP transverter rapid data sheet

To be improved in a nearest future ? ?

Transverter alone à IF = 146 MHz :

I_Rx at 12V	130mA	
Gain/Nf (dB)	13.6/1.5	**Too less gain →** gain not reaching 20dB !
Readjust Gain/Nf	18.03/1.28	Now best compromise, but <20dB (IF diode switching gives 6.5dB losses)
		With normal relay switching, gain'll largely reach over 20dB ! !
I_Tx à 12V	330mA	
Tx power	+23.7 dBm	Or 234mW ***(Web forecasted P_output spec found +22.5dBm or 180mW)***

External OCXO :

I at 12V	1.1A→150mA	
F (MHz)	135.5833	Many high harmonics H2, H3, etc… but working OK
Pout	+2.5 dBm	

This is the actual Rx situation measured on end of november 2014

10- Conclusion

Conclusion – and suggestion proposals 1/3

These both present transverters were clearly **not built as proposed by the initial author elements !**

1- This design corresponds exactly to a strict copy/paste of the 9cm DB6NT transverter with all exactly same hardware, excepted that it was totally redesigned for low-cost Epoxyglass FR4 substrate.
- Only difference seen : in order to compensate for more FR-4 losses, every Rx and Tx chain have now 3 stages instead of 2 ones
-Sure that DJ6EP did a previous great adaptation work and must be thanked about it.
-But until now I have sincerely to regret his serious lack of helping cooperation by giving me a minimum / minimorum of infos (also a total blackout from SP9QZO)
- And the external LO_OCXO also beeing a direct copy/paste of the DF9LN design, isn't really of strong necessity

2- About its cover etiquette confusion :
As similar DB6NT or DEMI etiquettes, the middle DJ6EP title in great characters is seriously confusing the potential buyer, because introducing in his mind the fact that :
- it was directly done by DJ6EP
- some elements were subcontracted to SP9QZO

- in fact this transverter was build by SP9QZO with the DJ6EP concept, so both cover etiquettes have to be reversed
- after that, no more doubt could be introduced in the mind of every future potential buyer (SP9 or not) !

3- About its polish inner restricted market only :
This transverter design was 1st intended to promote the 9cm polish new band with a low-cost possibility
It can theroretically be bought only inside Poland, but can also be found as brand new design in very restricted number on some Ham-expositions in Germany, and also in Croatia ! !

Conclusion – and suggestion proposals 2/3

4- Now directly about this transverter build by SP9QZO :
Just after buying, a great frustrating Rx gain lack conversion was immediately pointed (only 13.6 dB / Nf= 1.5dB)
In fact in place of both real AG303's preconised by DJ6EP, 2 ersatz substitutes *(with D07 printing)* were sold at same place
So, **tremendous thanks must be done to SP2IPT Jakub Kulczynski**, who'd immediately put his finger on the wrong problem *(the total opposite of DJ6EP comportment - - or said in less words like also from SP9QZO - - strictly helpless) ! !*

Even the IF diode switching with 6.5dB losses isn't copied right because the initial DB6NT one is a PIN design with two BAR64 PIN diodes or equivalent

5- Internal or external OCXO ?
- the actual external one can be perhaps more stable than an inside Quarz equipped with DB6NT 40 degrees socket (not really sure), but takes an amount of subsidiary place
- an internal 40 or more 50°C Quarz wrapped in a regulated heating socket (à la DB6NT Strumpf) will practically do the same work in far less place
- and more better, a 3256MHz +2dBm DF9NP LO PLL (for 144 MHz_IF) put inside will directly :
  avoid the multiplier chain
  avoid all actual add spurious found on both Tx and Rx spectral views
  give directly a fiable frequency and seriously simplify the design

6- About the transverter explanation PDF (only in polish):
- separate totally 13 and 9cm versions
- write it also in English and in German (because these transverters are also sold in germany) ! !
- add on it serious target Rx and Tx specs on every band

7- And now for any new design in a nearest future :
- if this FR4 substrate is conserved, **need only exact hardware proposed in the DJ6EP schematic** (and absolutely no ersatz ones)

Next steps coming ASAP - 3/3

1- Internal Rx preamp alone :
- substitution of the T03 marked things with real AG303 ones
- broadband meases of it alone, compared to the actual chain, and also Nf meases
-Then, gain/Nf meas of the whole conversion à 146 MHz

2- IF diode switching :
-substitution of 2 x 1N4148 by good BAR64 PIN diodes and resulting observed improvements

Then and only if both measurements'll give enough improvements :

3- final improvements :
- study of also a 432 MHz IF possibility – sure without this diode switching by coming back to a conventional relay one
- if 432 MHz IF OK, then :
    definitive choice for an UHF intermediate frequency
    purchase of an adequate DF9NP PLL synth locked to an internal10 MHz reference → far less spuries than actually

Final thanks

Especially for the tremendous help and contribution of **SP2IPT Jakub Kulczynski**

But unfortunately, absolutely no other ham help coming either from the builder SP9QZO or its initial conceptor DJ6EP (thanks again to them for their real great ham spirit) ! !

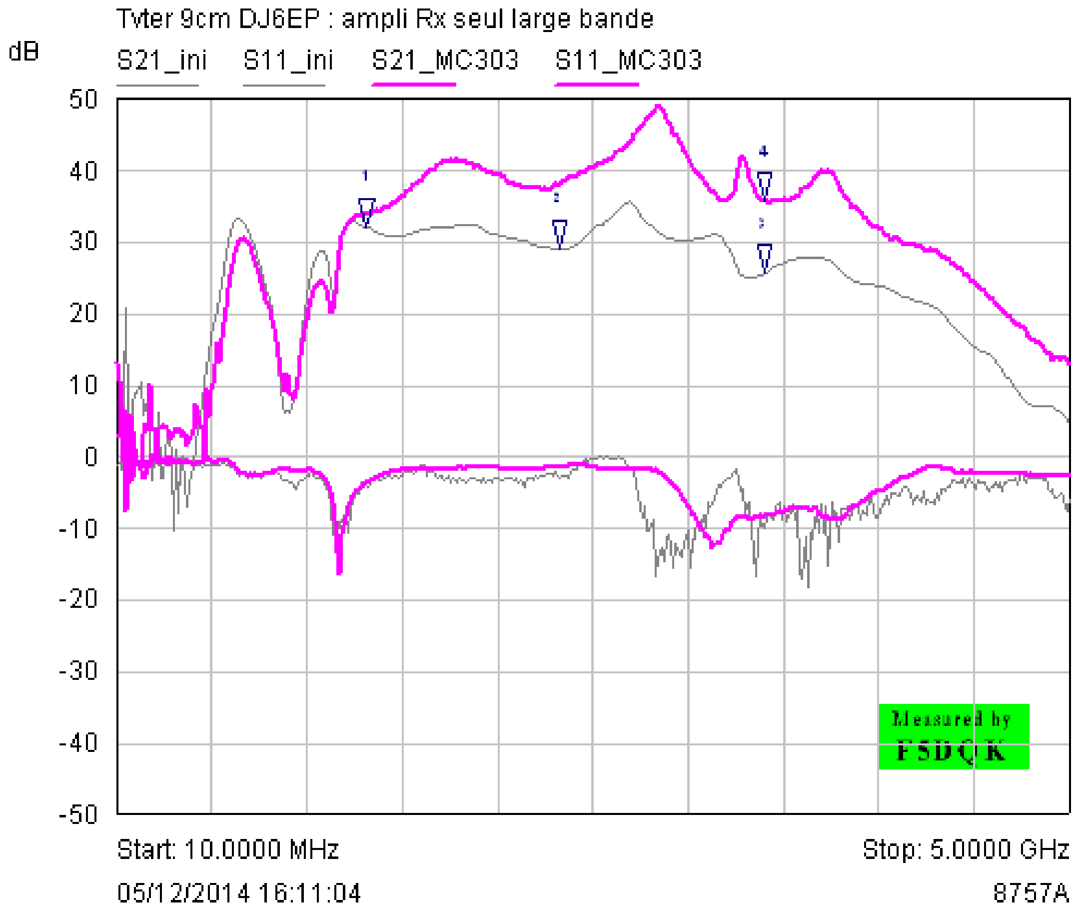
And before buying this finished transverter to SP9QZO, every new potential buyer must absolutely take in account this important factor (very important) :
- At a first glance, sure that this transverter costs only half the price of a DB6NT one !
- But if you get this exactly same finished product, you have to take in account its further time amount of transformations & modifications
- And especially if you have yourself absolutely no RF measurement possibilities ! !

So before taking the choice of buying this finished transverter to SP9QZO, first ask him for its specific data sheet, and especially for its <u>measured gain/Nf conversion</u> ! !

11- Added Post-improvements

- Rx preamp alone : now good AG303's instead of curious «D07» → effect on Rx conversion beahviour
- 432 MHz study with external variable LO
- Quartz soldered inside the transverter
- Direct LO with a DF9NP PLL synthetiser → new gain/Nf meases

Rx preamp alone : now good AG303’s instead of curious «D07»



Mkr	Trace	X-Axis	Value	Notes
1	S21_ini	1.3199 GHz	32.09 dB	
2	S21_ini	2.3304 GHz	29.14 dB	
3	S21_ini	3.4032 GHz	25.66 dB	
4	S21_MC303	3.4032 GHz	35.71 dB	+10dB more gain !

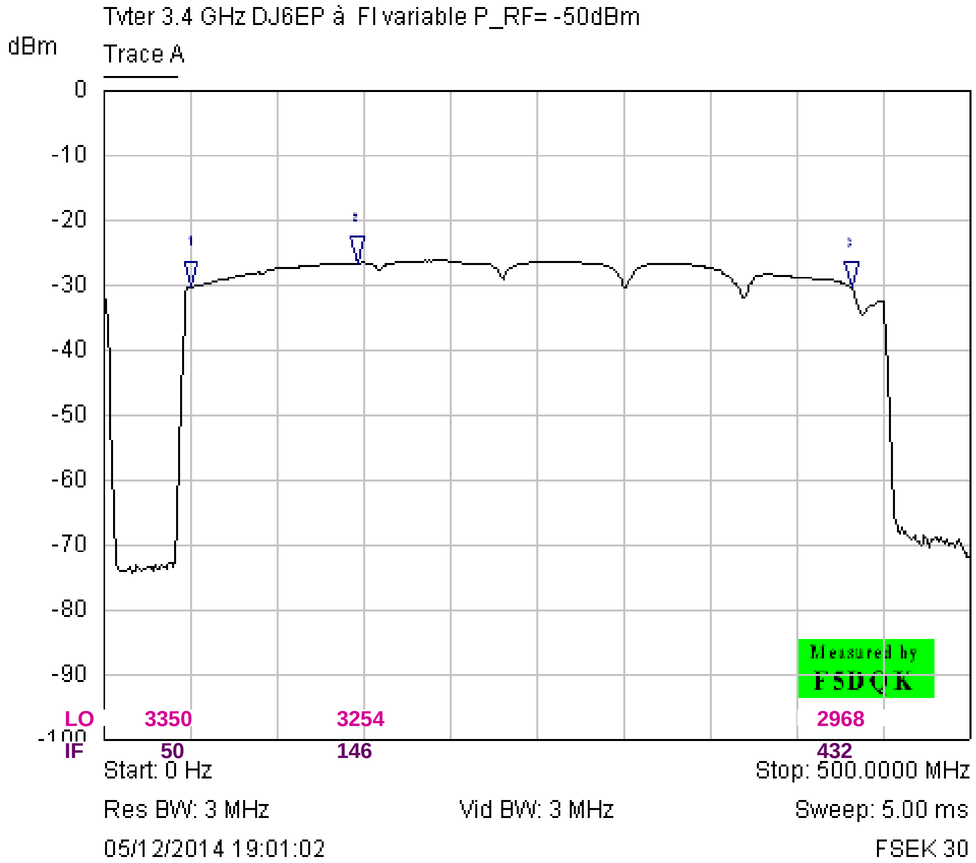
As predicted by Jakub SP2IPT at all very first time (again great thanks to him), the substitution of the previous «D07» Ersatz MMIC’s with real AG303-86 (labelised P15), in the **Rx preamp alone** does immediately give **10dB more gain**

Whole Rx final conversion chain

- About **5.7dB more Rx conversion gain**
- Now enough to reach the Rx conversion target gain >20dB

PIN diodes BAR64 aren't improving its conv. gain !
So keep the initial switching with 1N4148 diodes

432 MHz IF or 144 MHz (with external variable LO) ?

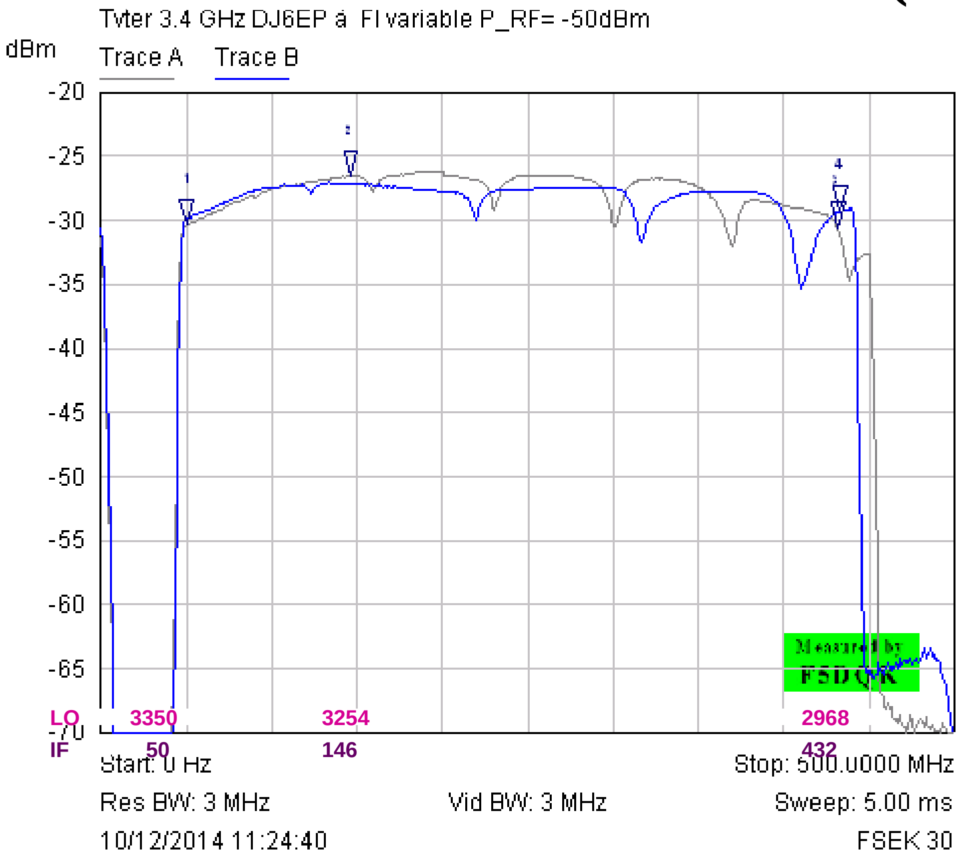


Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	50.1002 MHz	-30.35 dBm	Gain 19.7dB
2 ∇	Trace A	146.2926 MHz	-26.61 dBm	Gain 23.4dB
3 ∇	Trace A	431.8637 MHz	-30.57 dBm	Gain 19.4dB

Rx conversion gain 4 dB less than on VHF

With RF=3.4 GHz, this is the IF conversion gain as function of LO variable frequency (with initial IF diode switching)
LO sweeping from 2950 to 3350 MHz
P_LO = +2dBm

432 MHz IF or 144 MHz (with external variable LO) ?



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Trace A	50.1002 MHz	-30.35 dBm	Gain 19.7dB
2 ∇	Trace A	146.2926 MHz	-26.61 dBm	Gain 23.4dB
3 ∇	Trace A	431.8637 MHz	-30.57 dBm	Gain 19.4dB
4 ∇	Trace B	432.8657 MHz	-29.28 dBm	Gain 20.7dB sans 10pF en //

It can be also used with an UHF IF but its gain/Nf performance is more optimised at 144 MHz
But if used with a front-end LNA directly beside the antenna, either VHF or UHF IF can be taken

Now 135.583 MHz Quartz soldered inside the transverter

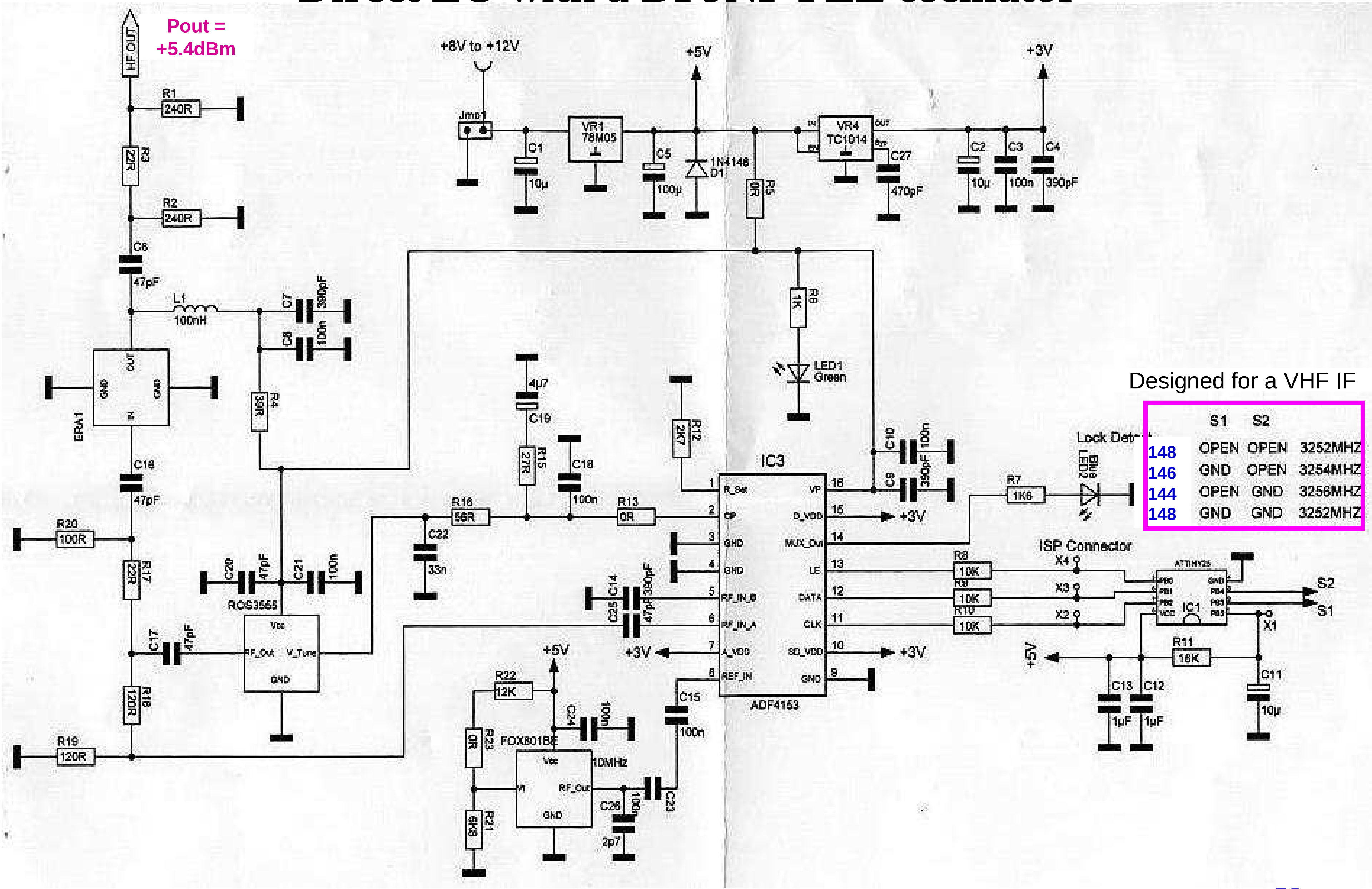
In order to «see how it is reacting» I'd desoder the Quartz from the external Butler oscillator, then solder it in the internal side of the transverter :

- immediate oscillation, but at **IF <25 kHz than expected** (T=22°C)
- so 3400 MHz is now converted to 145.985 MHz instead of 146.0 MHz ! !
- Action on the L1 brass kern → only +-2.5kHz (and only 3 turns possible for oscillation)

So I'd decide to inspect more the 22pF/82pF capacitor divider directly near the quartz
After desoldering + each capacitor meas, both weren't 22 + 82pF, but **exactly 10pF + 47pF - exactly the same values as in the DBNT schematic ! !**
A 10pF replacement by à 12pF one → no more oscillation possible, so an initial carefull choice of the capacitor diviser values seems mandatory

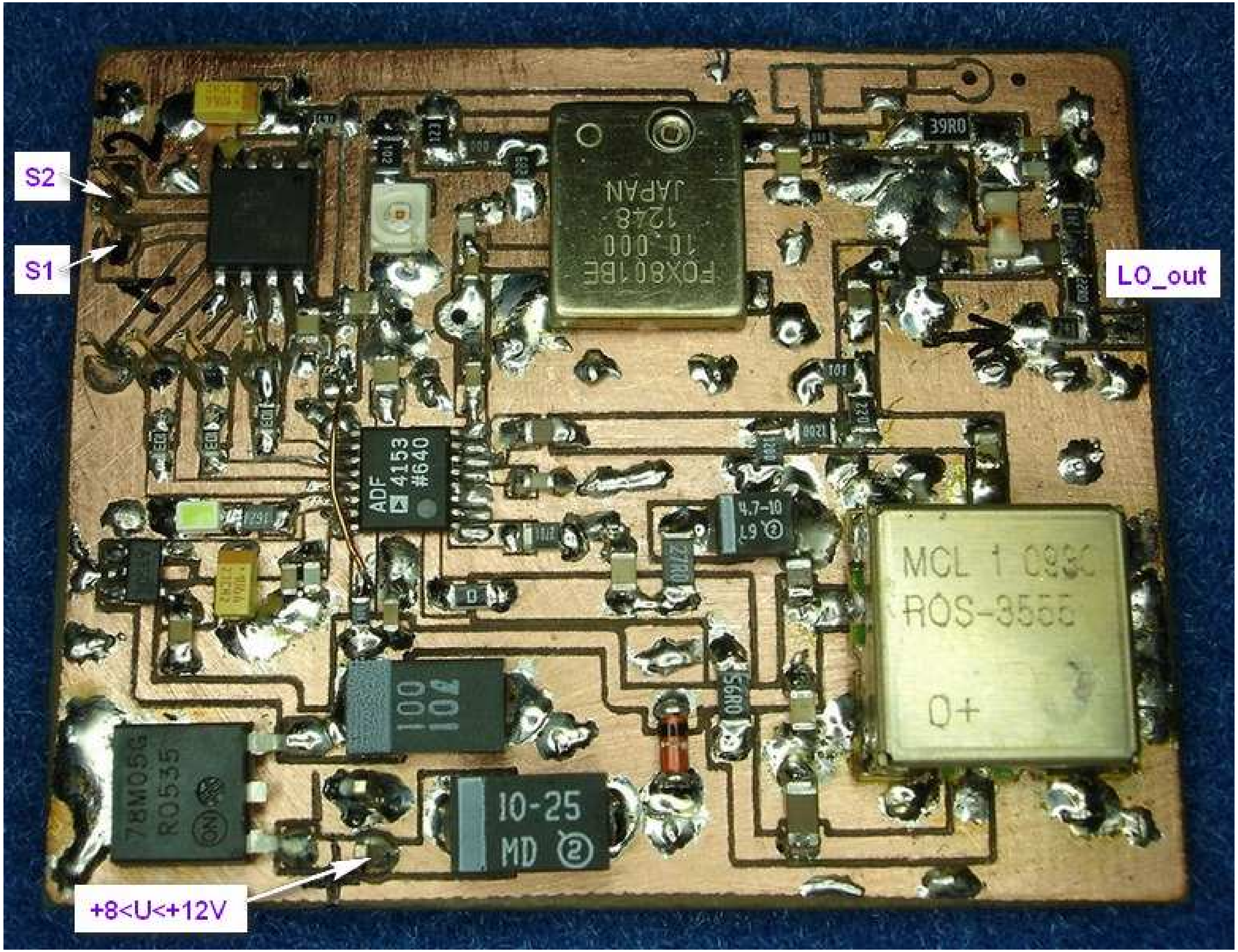
So I understand now better why SP9QZO didn't directly use the Quartz mounted inside the transverter but **did place it in an outside separate Butler oscillator**

Direct LO with a DF9NP PLL oscillator

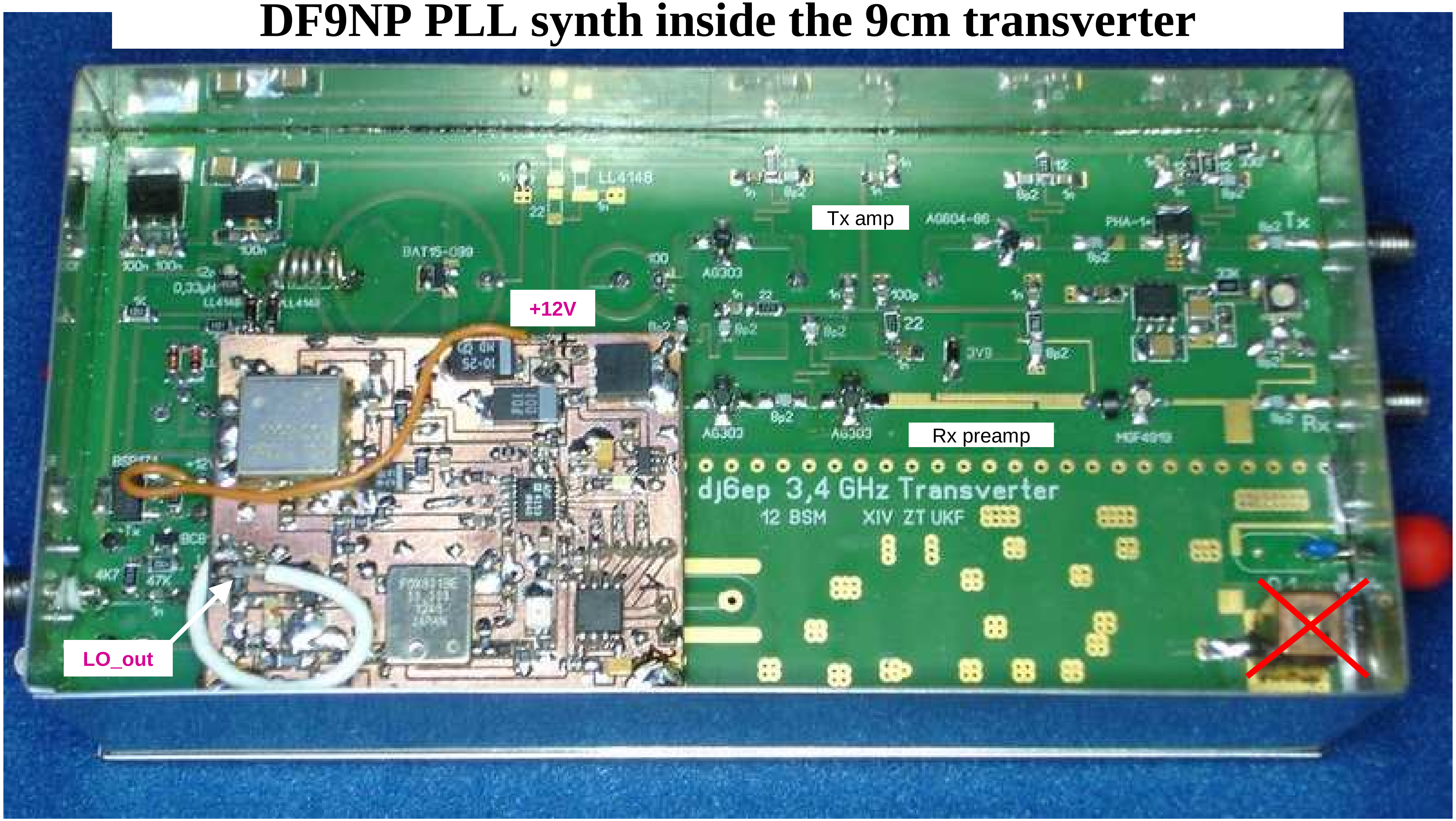


	S1	S2	
148	OPEN	OPEN	3252MHZ
146	GND	OPEN	3254MHZ
144	OPEN	GND	3256MHZ
148	GND	GND	3252MHZ

Direct LO with a DF9NP PLL synth

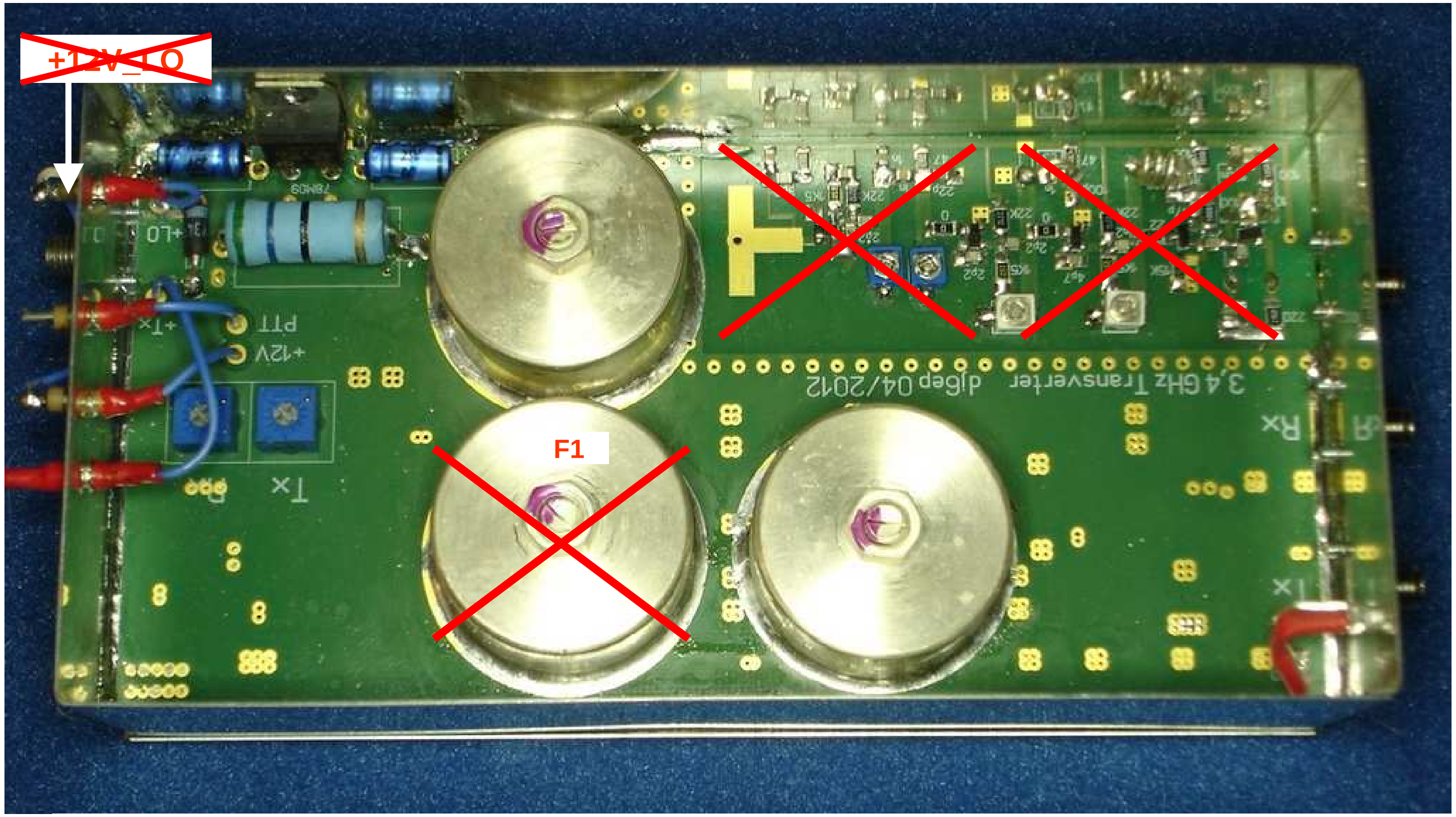


DF9NP PLL synth inside the 9cm transverter



The DF9NP LO output is soldered after the strap desoldering (page 27)

And no more need of all this hardware ! !



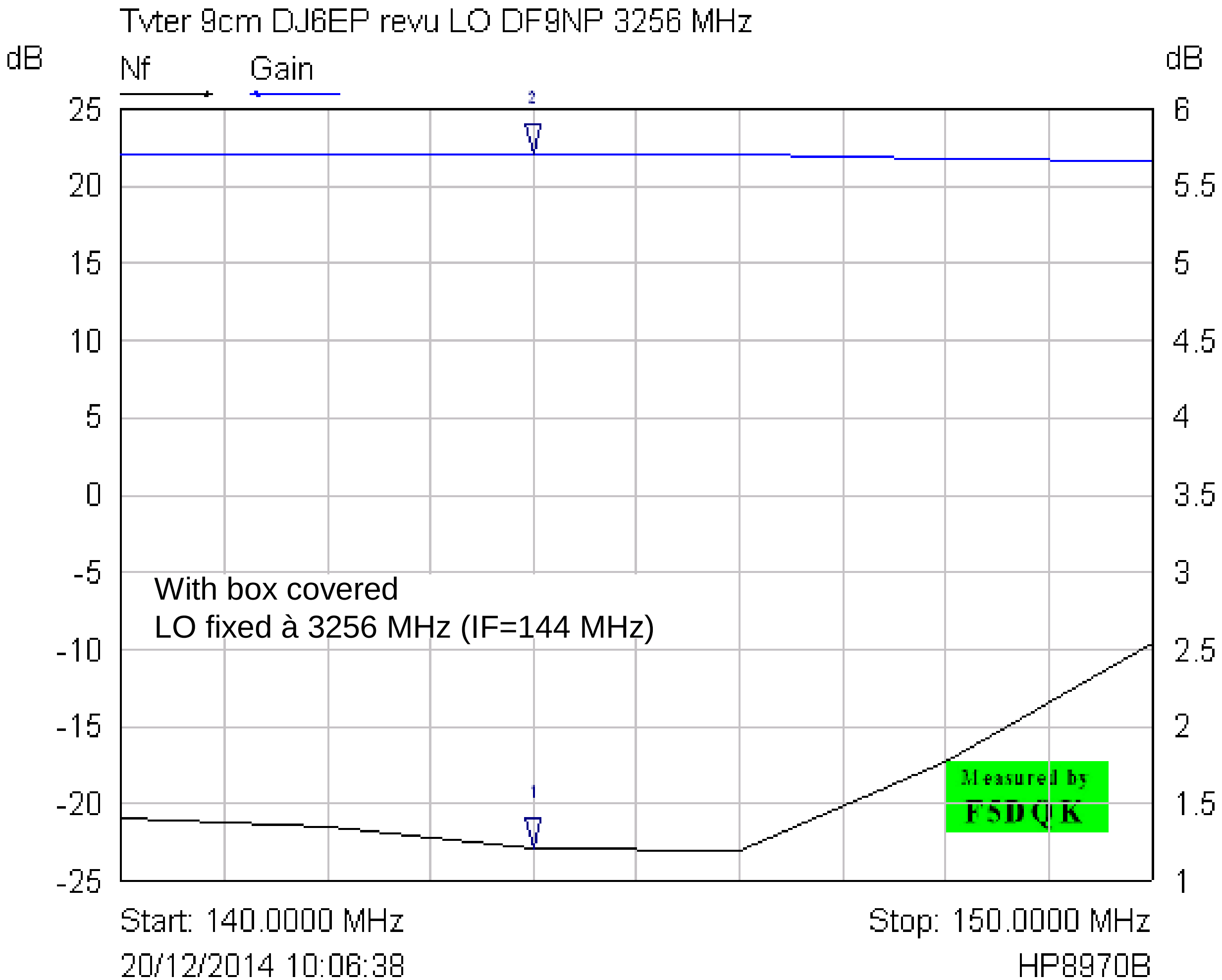
So these following elements are becoming now totally obsolete :

- 2nd separate +12V input power pin outside the transverter (only reserved for the initial LO chain)
- All the Quarz oscillator + L1 coil + multiplier chain
- Also the F1 bell-filter (to take in account for a totally new transverter project !)
- And principally this outside DF9LN Butler Oscillator

That's an important parameter to take in account for a brand new design !

And then, perhaps a more modern design with a SYM-4350 Mixer and a TRx common interdigital filter + Wilkinson splitter ? ?

Rx gain/Nf meases with the DF9NP PLL synth



Mkr	Trace	X-Axis	Value	Notes
1 ∇	Nf	144.0000 MHz	1.21 dB	
2 ∇	Gain	144.0000 MHz	22.03 dB	

With box opened

3.4 Ghz RF from the the Marconi 2031 gives now a pure 144.0 MHz tone, and stable versus time

With +12V :
I_Rx = 270mA
I_Tx = 420mA