Mchf/Eagle Carrier suppression improvements

The mcHF/Eagle transceiver uses the “audio shift” technique both in transmission and in reception, this means that the frequency of the local oscillator is shifted by +/- 6khz or +/- 12khz compared to that of the band in use, and this is done to avoid problems with the dc component always present on the frequency of the local oscillator.
The technique of audio shift is very useful for signal reception, but perhaps a little less useful in transmission.
In transmission, the signals I and Q generated by the audio circuit (WM8731), after passing through a low-pass filter that cuts the harmonics of the WM8731 DAC, are sent to an integrated (TLV2474D) with four operational amplifiers that generate 4 phase-shifted signals (0°,90°,180°,270°).
These 4 modulated audio signals load the 22 nF sampling capacitors through the 47 ohm resistors.
The TX mixer is connected to the capacitors, which, taking them sequentially at the L.O. frequency, creates the RF signal and sends it to the T4 transformer (turn ratio 2: 1, impedance ratio 4:1) through two 47 ohm resistors.
In the theory everything perfect, in reality a little less.
The unbalancing of the I-Q signal level at the output of the audio generator creates a TX image signal which, thanks to the development of the UHSDR software, was eliminated with a linear interpolation algorithm.
The imperfections of the hardware cause a Carrier signal (L.O. leakage) to be generated, which unfortunately can not be eliminated by software and that in the mchf / Eagle has a level of about 30-35 dB less than the modulated signal in the highest band and that instead should be at least less than 43 db (see fig.1) .

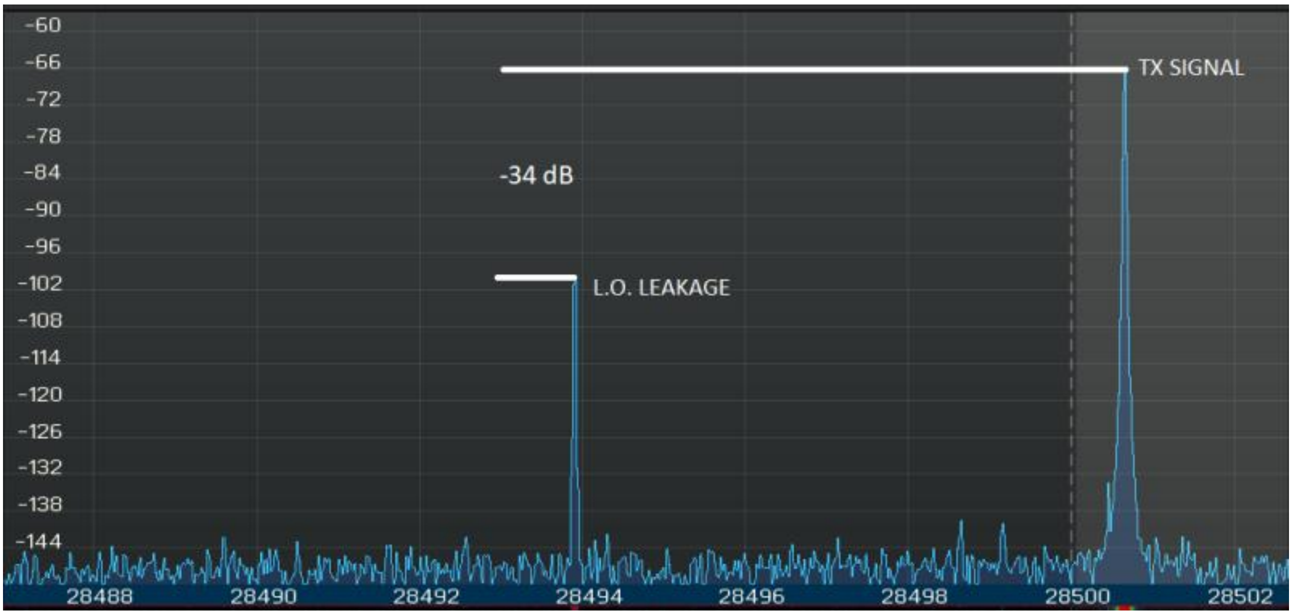


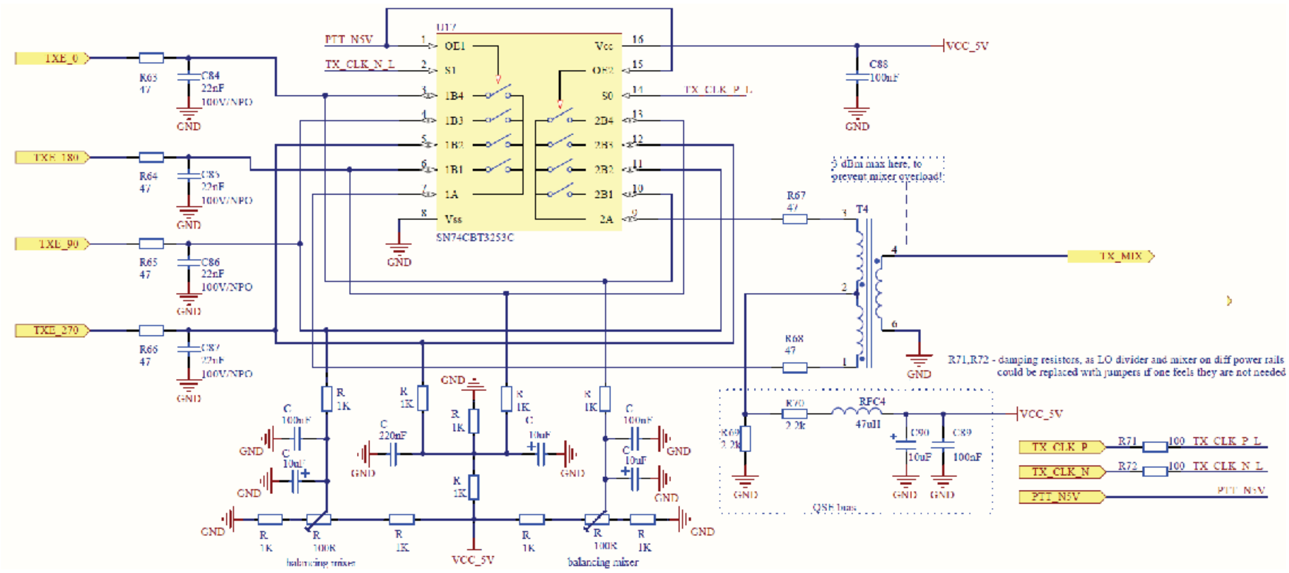
FIG.1

The causes of the Carrier signal, characteristic of all SDR Trasmitter are:

1) the difference of signal amplification of the 4 channels of the IQ to Quad amplifier (TLV 2464 CD) partly caused by the tolerance of the operational amplifiers and in other part by the tolerance of the R and C components
2) the capacity tolerance of the 4x22 nF sampling capacitors (C84-C85-C86-C87).
3) the capacity tolerance of the 4x10 uF tantalum capacitors (C100-C110-C111-C112)
4) The non-linearity of the Ron resistance of the TX Mixer (CBT 3253C) as a function of the signal voltage level (see fig.4)
5) The phase and amplitude unbalancing of the two primary windings of the transformer T4

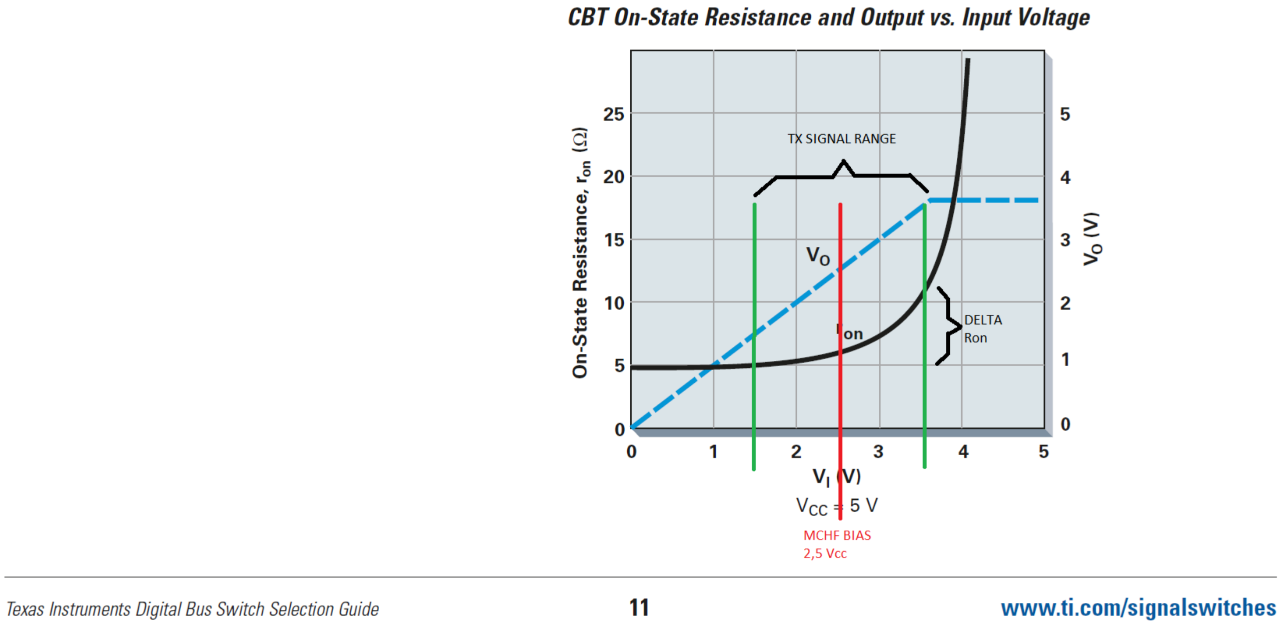
IMPROVEMENTS

The simplest improvement do to is to balance the mixer channels with resistance partitions and 2 potenziometers, as was done in the Eagle (see fig. 2), but its calibration is valid for one frequency only and does not solve the problem, as can be seen in fig. 3 in which the potenziometers has been calibrated to 7100 obtaining a suppression of the carrier of more than 60 db, but without significant improvements on the other bands (-32 db carrier suppression at 28500)



Eagle mixer balancing FIG.2

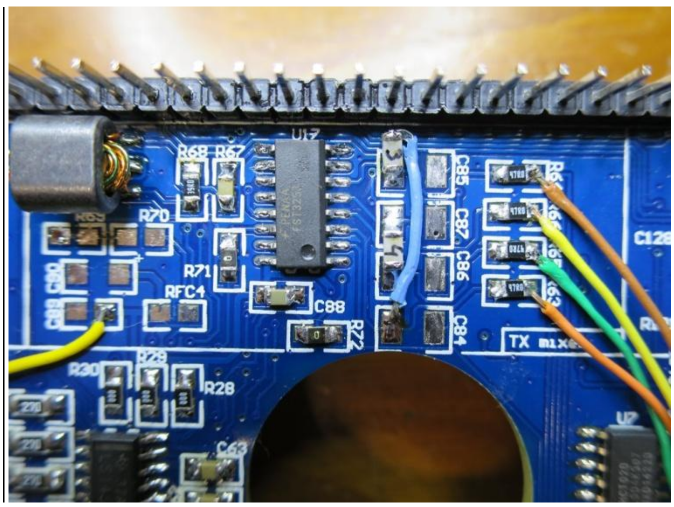
Eagle Balanced at 7100 FIG.3



CBT3253 Delta Ron vs Signal Voltage with BIAS 2,5 V FIG.4

A better approach is to try to remove the causes of the problem indicated in the five points of the list above:

1) Reduce the difference in the amplification of the 4 channels of the IQ to Quad amplifier signal by replacing the TLV2464CD with an OPA 4192 precision low offset voltage, low noise Op Amp, and then select the resistances of the circuit and the two 100 pF capacitors so that they have values that are as similar as possible to each other.
2) Replace the 4x22 nF sampling capacitors with the reference to ground in the mixer with only two capacitors the first between the 0°-180° channels and the second between the 90°270° channels a better result is obtained, since the circuit is already balanced; you just have to select two more similar capacitors as possible and connect them as indicated in the Schematics and in the fig 5 (mcHF) – fig 6 (Eagle).
3) Replace with a short the 4x10 uF tantalum capacitors (C100-C110-C111-C112)



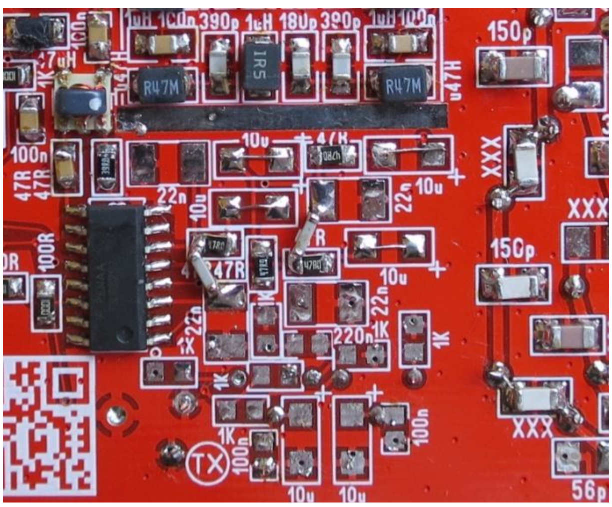
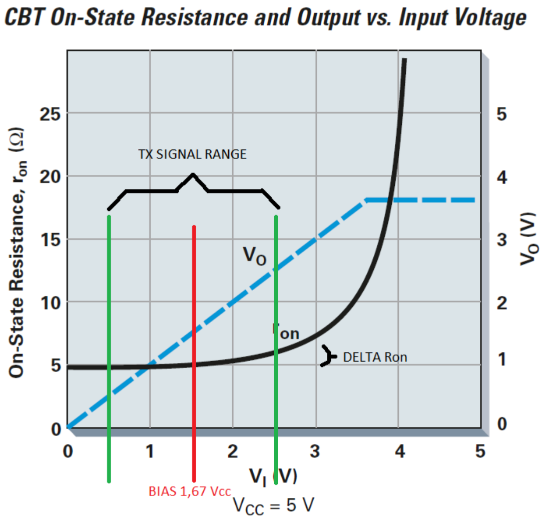


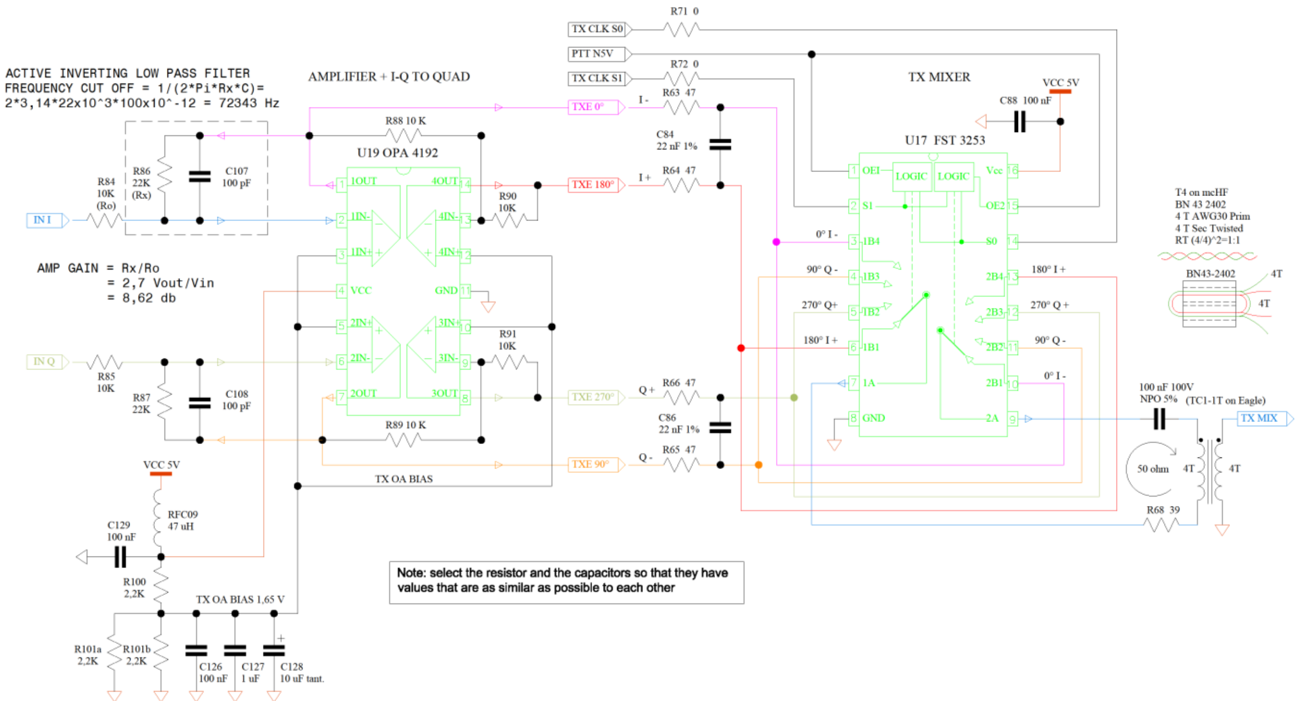
FIG.5 mcHF Fig.6 Eagle

4) Reduce the non-linearity range of the Ron resistance (CBT 3253C) as a function of the signal voltage level, lowering the bias voltage of the OPA4192 to 1.65 volts by welding a 2.2 kohm resistor in parallel with R101 (see fig. 7 and schematics fig.8)
5) Remove all the components of T4 transformer bias voltage (QSE bias). Wrap a new T4 1:1 transformer on a BN 43-2402 binocular nucleus with 4 + 4 twisted turns in the mcHF; replace the TC4-1T in the Eagle with a TC1-1T. Install a 39 ohm resistor instead of R68 and a 0.1 uF capacitor instead of R67 to electrically separate the two branches of the mixer.

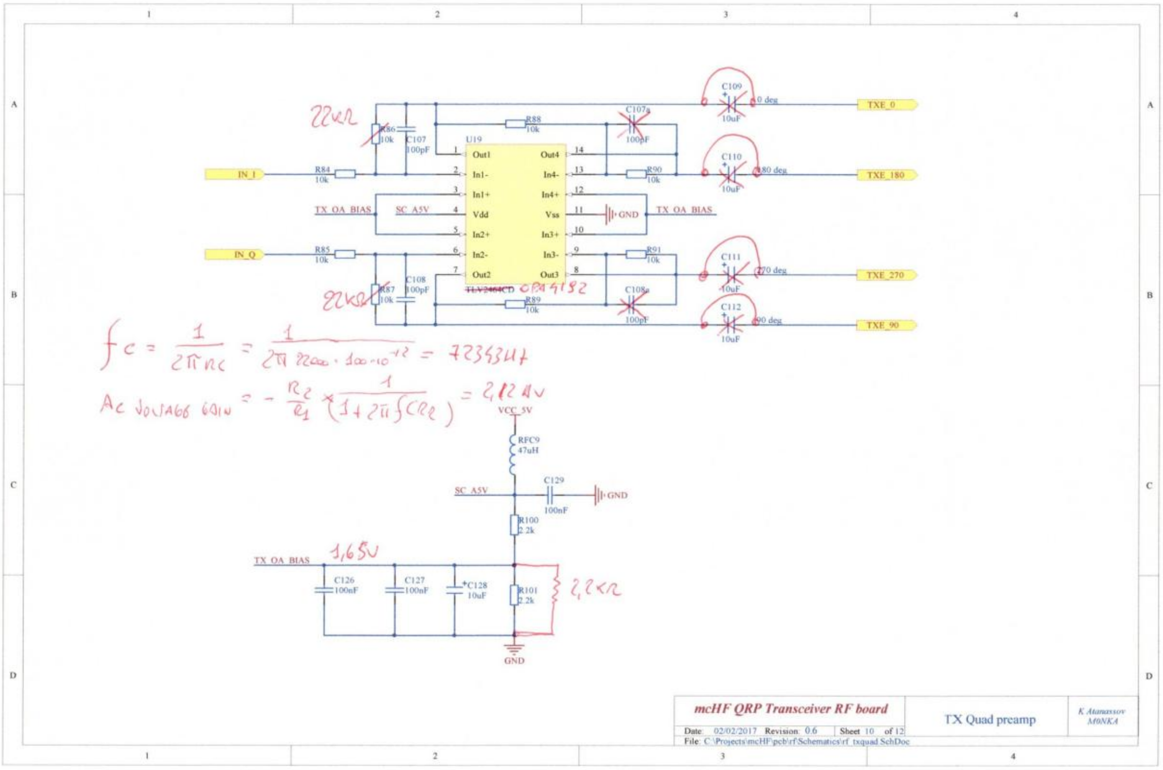


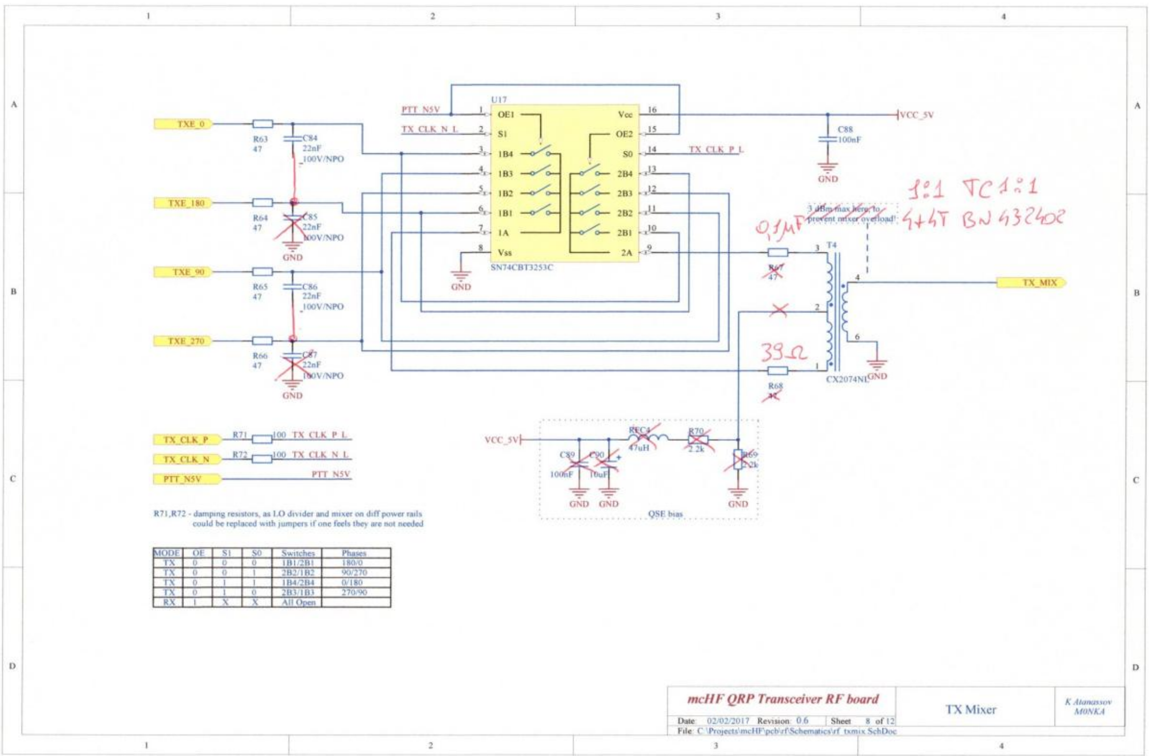
Texas Instruments Digital Bus Switch Selection Guide 11 www.ti.com/signalswitches

CBT3253 Delta Ron vs Signal Voltage with BIAS 1,65 V FIG.7



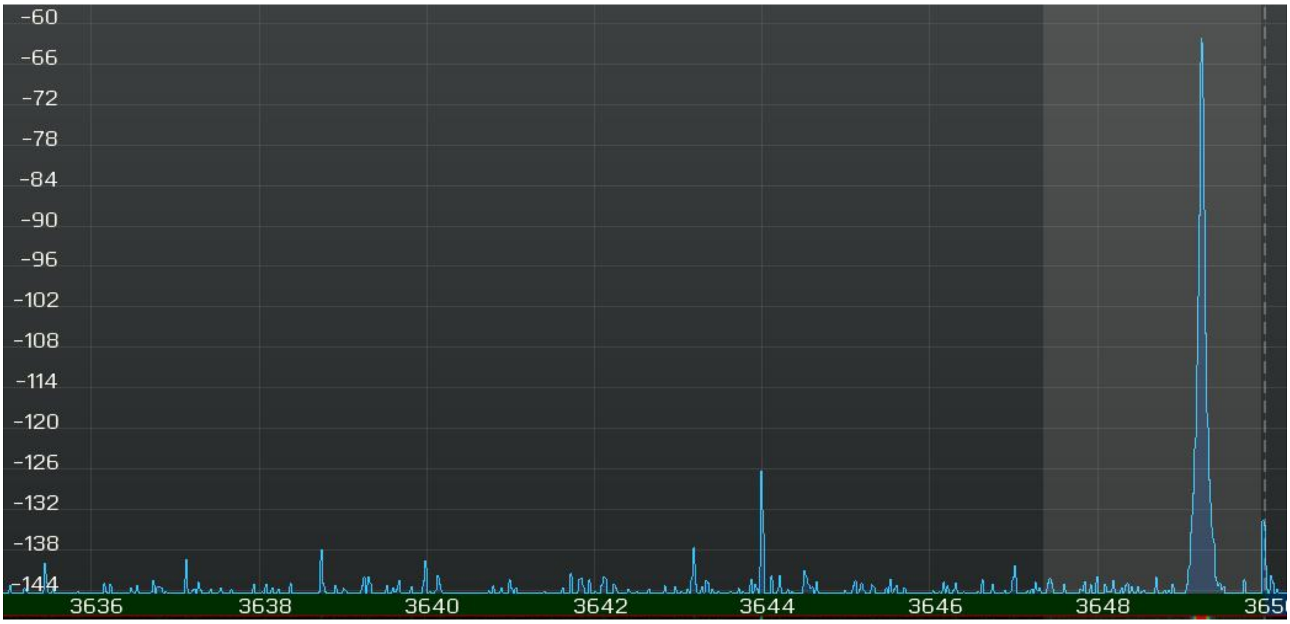
SCHEMATICS FIG. 8



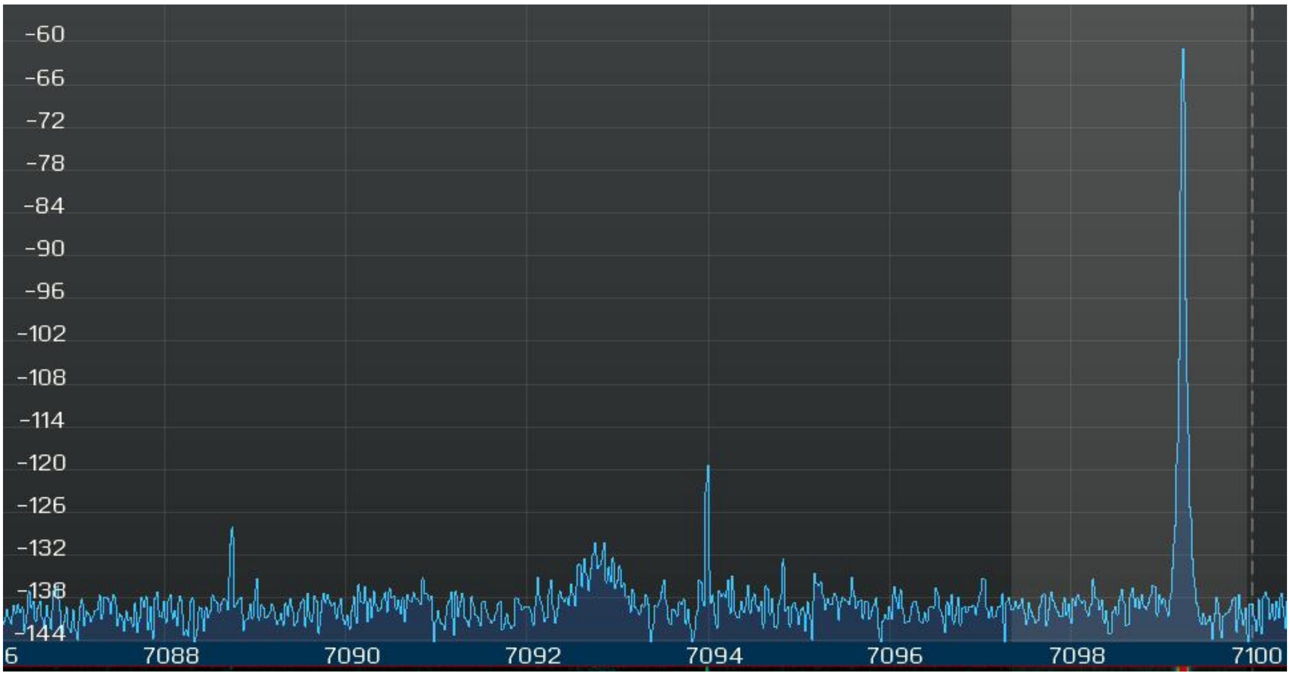


MODE	OE	S1	S0	Switches	Phases
TX	0	0	0	1B1/2B1	180/0
TX	0	0	1	2B2/1B2	90/270
TX	0	1	1	1B4/2B4	0/180
TX	0	1	0	2B3/1B3	270/90
RX	1	X	X	All Open	

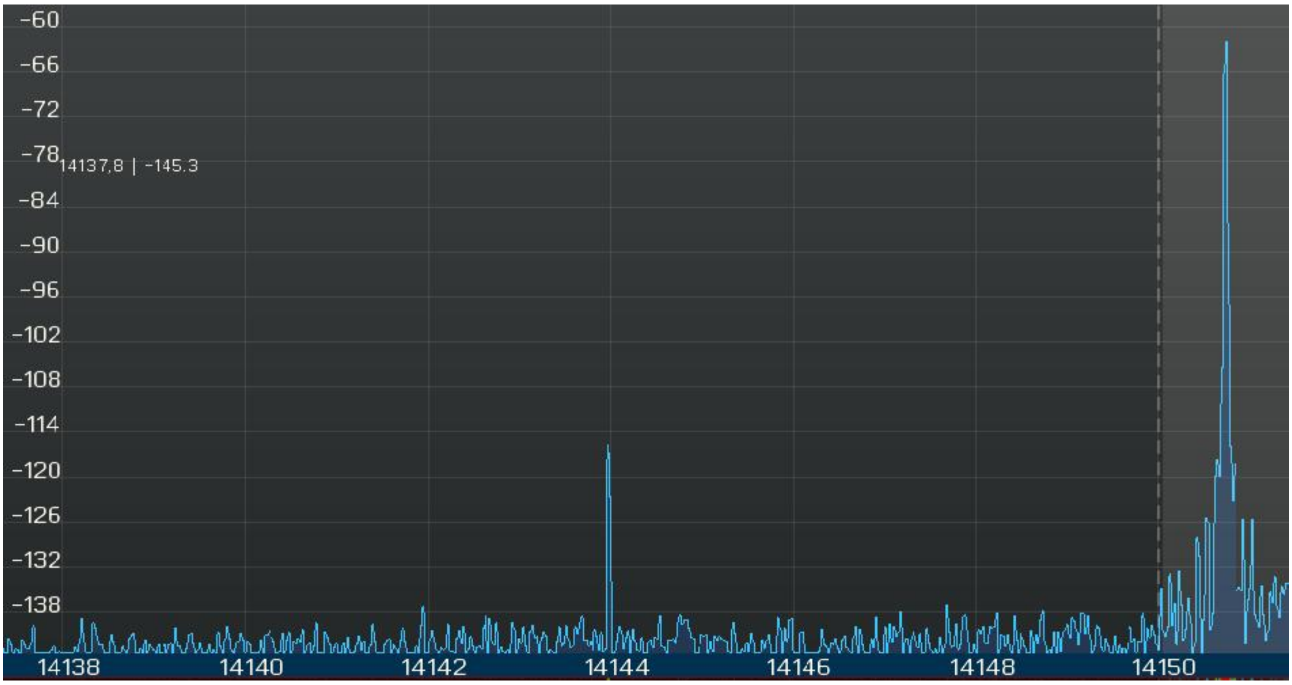
After making the changes it is necessary to repeat all the TX PA calibrations described at https://github.com/df8oe/UHSDR/wiki/Adjustment-and-Configuration-Manual#pa-power-calibration.
Making the measurements again what you are going to get should be very similar to what is reported in the fig. 9-10-11-12 with a carrier suppression that goes from -64 db at 3500 khz to rise to -51 db at 28500 khz.



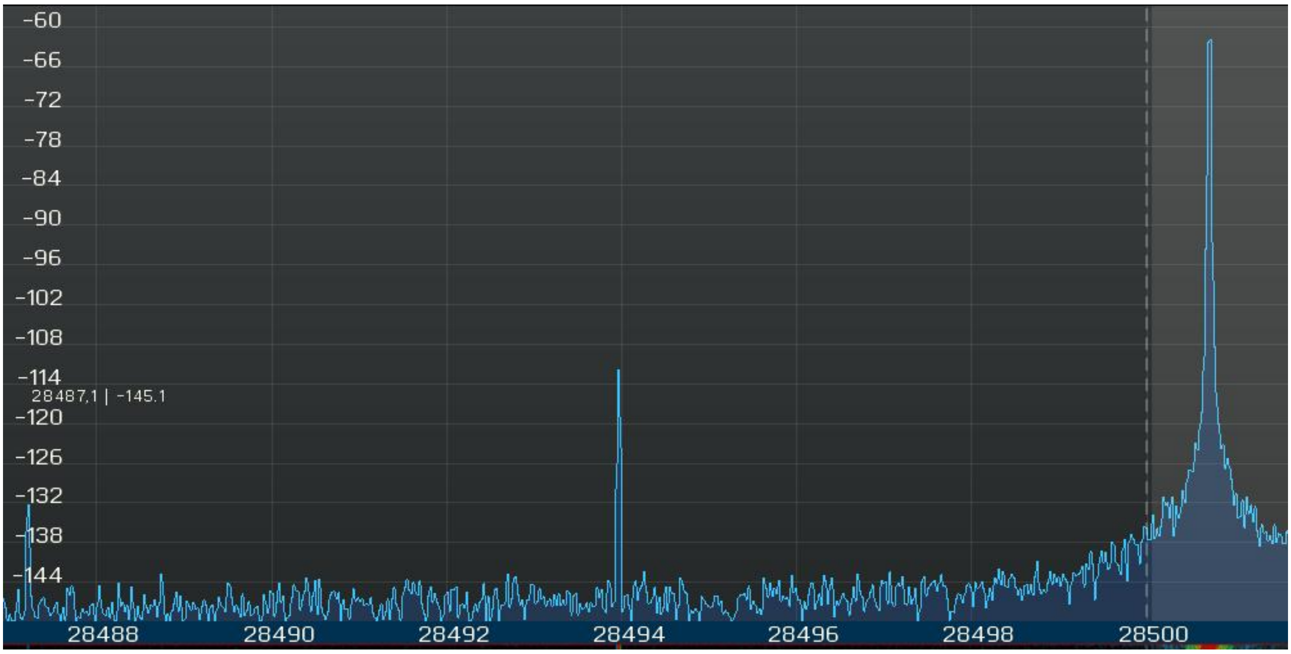
3500 kHz Carrier Suppression -64 db FIG9



7100 kHz Carrier Suppression -57 db FIG10



14500 kHz Carrier Suppression -54 db FIG11



28500 kHz Carrier Suppression -51 db FIG12

Is it possible to do even better?
Yes: it is possible to modify the UHSDR firmware so that when the radio is in transmission the frequency Xlate (+/- 6khz or +/- 12 khz) is set equal to 0 and at the same time the frequency of the local oscillator is shifted by the same value of the frequency Xlate to make the LO carrier signal superimposed on the modulated signal.
This is explained more clearly on pages 5 and 6 in the article of HB9DRI
(http://www.linkrf.ch/files/IQ+%20XT_previous.pdf)

My mcHF – Eagle TRX

’73 de IZ6MAF L’Aquila 2018_06_13