IQ+ XT

144Mhz SDR-RF Exciter
(preliminar v0.1)

INTRODUCTION

Since the IQ+ receiver was introduced one year ago several people ask if I have plans to produce an IQ+ transmitter. Initially I didn't plan that evolution but the constant demand from IQ+ receivers users force me to jump on my bench and design a properly Software Define Radio Exciter, the IQ+ XT.

For decades EME operators use HF transceivers to produce the RF needed for EME communications, this way is very expensive and normally demand a big amount of money in traditional multiband transmitters.

The present document describe what would be inside the IQ+ XT, I will explore the traditional way to generate RF with standard SDR techniques and finally I will propose a different way to create a transmitter with the lowest impact on the spectrum (in terms of TX Image rejection, Carrier suppression and undesired signals on your pass band). This is a preliminary approach and some things could change during the next months but essentially the technique I decide to use is the basis of my design and I would be explain here with some practical examples.

WHAT IS DONE UNTIL NOW

A SDR transmitter essentially is compose by HW and SW, exist different ways to generate RF but mainly the "Audio Shifting" is the most popular. The HW is mainly a modulator who receives the I and Q signals generated by an audio card in your PC, the TX software is responsible to generate a stereo audio signal (I and Q) with 90 degrees offset and "shift" the audio within your pass band to create a RF signal in different frequencies. Several SDR transmitters use this technique and mainly all software with TX capabilities shift the audio from an starting point: your carrier (defined by your local oscillator)

I will explain with practical numbers what is "audio shifting":

In conventional SDR transmitters your Local oscillator is fix, means you define a fix frequency (normally the center of your pass band for RX) and from that frequency you will move (shift your audio) to reach the TX frequency you want.

Let's said your LO is fix on 144.1 MHz, your RX pass band will be from 144.055 to 144.145 MHz (96 KHz, but in the practice like in MAP65 will be only 90KHz).
If you want to transmit in 144.130 your local oscillator will remain fix in 144.1 BUT your audio will "shift up" 30KHz, then the signal will appears in 144.130 MHz The coverage will be defined by the sample capability on your audio card. The

modulation, for example a JT tones, will appears aprox. 1.272 KHz UP from your desired frequency (144.130 MHz) and a CW signal just 600 or 700 Hz up.

The "audio shift" technique demand a very good audio card and software routines to shift the audio within your pass band without creating unwanted signals but everybody knows this is possible with some level of compromise. The software will need a very good code to do a "TX Image rejection" calibration and the HW will need to have a very good design to reduce the carrier or LO leakage in your pass band.

Most of the software with TX capabilities has TX Image rejection calibration routines but unfortunate this code is properly done for a single frequency, is a well know behavior when you do a TX Image rejection calibration in a specific frequency just moving few KHz from that frequency show a different level of results, traditional SDR transmitter HW reach aprox only -40dB TX Image rejection and this is not enough when you transmit with 1KW RF, probably is adequate for terrestrial communication and for power levels below 200 watts. the same phenomena is observed on SDR receivers, when you implement RX Image rejection works fine for one single frequency but as soon you move your signal the Image rejection becomes worst several dB's.

The only software I know who manage the RX Image rejection in a very clever way is Linrad, to do the calibration you sweep your entire pass band and Linrad create a table with amplitude and phase corrections every step, then this calibration table is applied and the corrections is almost perfect within your entire pass band. But this is done by Linrad for RX, I hope will be the same for the TX part when Leif decide to continue the TX capability in Linrad.

The reason why a single point of TX Image rejection doesn't work properly is based on your audio card mainly. inside the audio card the phase shift and is not constant within the pass band, the amplitude either, a very small change in phase and amplitude will represent several dB's of difference in the attenuation, this behavior is easy to observe on SDR receivers (and is the same for SDR transmitters), just calibrate RX Image rejection (probably you will reach a respectable 70 or 80 dB attenuation) then move your signal few KHz without changing the level and you will see a degradation of several dB's when you move away from the original calibration point, and several times if you back to the original frequency the calibration is not the same any more.

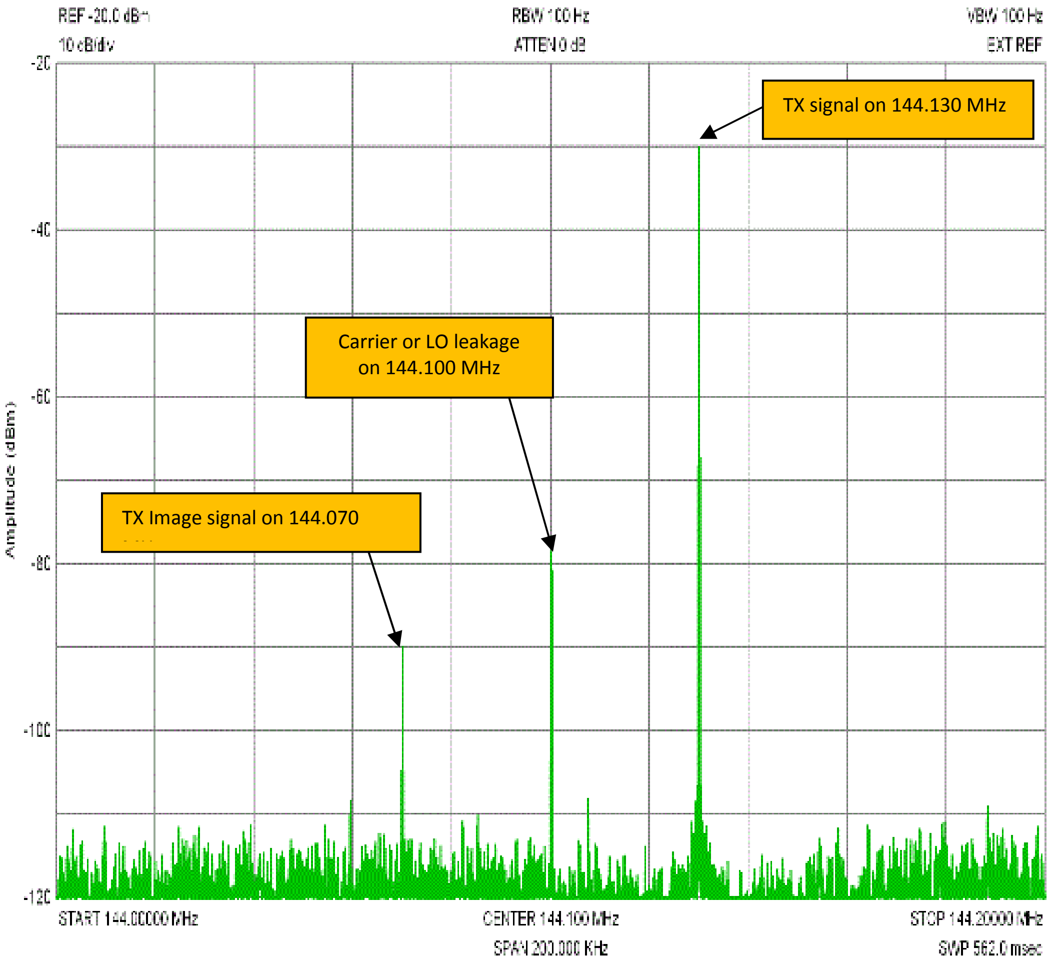
The jitter inside the audio cards is responsible of this phase changes but also the thermal stability, high values of Image rejection (90dB or more) are reachable but don't remain on time, few minutes after the calibration you will see worst numbers and is more critical in cheap audio cards like the embedded in your PC. This "jitter" is present even on the most respectable and expensive audio cards.

Audio Shift transmitters works fine when the RF level is not high, then the undesired signals created by the transmitter will be very low but with a standard EME station with 1KW output (I'm conservative in that point, is well know a lot of people use much more power than the legal permitted) the undesired signals injected in a high gain antenna system could create very strong signals in your pass band.

Actually SDR transmitters reach only -30 to -40 dB's TX image rejection (without software correction) and normally -40dB carrier suppression (the FCC demand at least -43dB carrier suppression). when your power is only 100 watts this values are ok as I already said not for high power stations.

The main problem with conventional SDR transmitters is for each desired signal you put on the pass band you create two additional signals: the Image signal and the carrier or LO leakage but spread in your pass band.

FIG1: Spectrum of a conventional SDR Transmitter with "audio shifting" with the undesired signals present:



- Carrier suppression or LO leakage : -50dB
- TX Image rejection : -60dB

You can see here how the two undesired signals are present and spread in your pass band and respect from the frequency you select. Assuming you are transmitting with 1000 watts the Carrier will be down -50dB means the carrier will reach your high gain antenna with 10mW power, assuming your high gain antenna are 4 long yagis (20dBd) your ERP (effective radiated power) will be 0.9 watts, enough to be present very strong in several kilometers around your antenna system.

Same for your TX image suppression: with a level of -60dB your image will be spread by the same antenna with a level of 100mW, again this is a undesired strong signal present in your pass band and far away from your desired frequency (144.130 MHz)

All this values are optimistic but in the real practice are worst, most of the SDR Transmitters don't reach even -40dB carrier suppression and the TX Image rejection becomes worst as soon you move from the calibration point, associated with high level transmitters (with more than 1000 watts) the mess is guarantee.

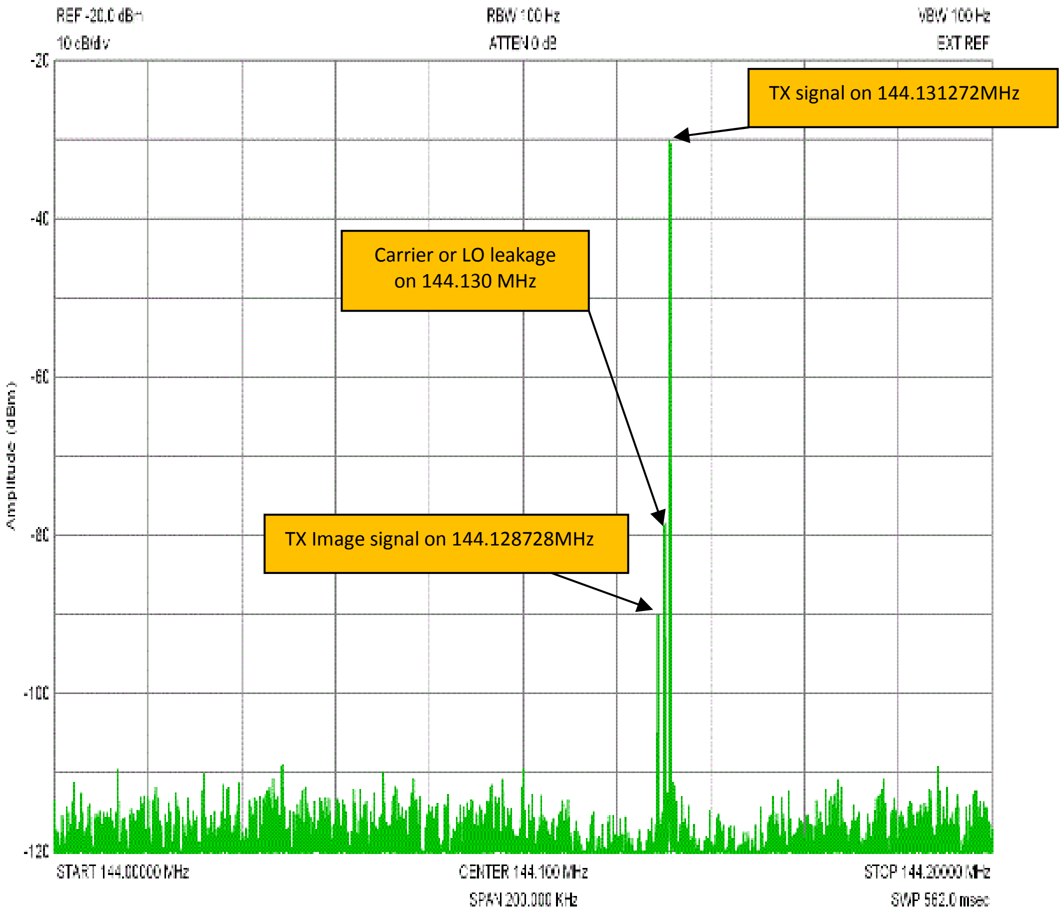
Just if you TX with 2000 watts in the same example your Carrier will be present with an ERP of 2 watts, tremendous undesired signal level!!.

A SDR transmitter based on "audio shifting" could give better numbers if the HW and SW allow better attenuation for the undesired signals but this design will lack on the fact the undesired signal will be always spread on your pass band.

CARRIER SHIFT INSTEAD OF AUDIO SHIFT: THE IQ+ XT APROACH:

To resolve or at least to reduce this problem I decide to build the IQ+ XT with a "carrier shift" technique instead of "audio shift". Essentially the numbers are similar but instead of spread the main two undesired signals (carrier and TX Image) within your pass band the IQ+ XT concentrate all signals he produce in a very reduced portion of your pass band.

FIG2: Spectrum of the IQ+ XT SDR exciter with "carrier shifting" with the undesired signals present (LO is in 144.100 MHz during RX and shift to 144.130 MHz in TX):



In this example the values are the same, in the real practice the IQ+ XT will have a Carrier suppression in the order of -55dB and a TX Image rejection of -50dB (with software correction the TX Image rejection will be around -80dB)

Let's use the same example I did with the previous SDR transmitter with audio shifting but now we are using Carrier shift:

The IQ+ XT will not have a fix LO, every time you select a new TX frequency the LO will change to that frequency AND THE UNTOUCHED AUDIO WILL BE APPLIED TO THAT FREQUENCY.

Based on the fact the IQ+ receptor has a extraordinary LO with a very low phase noise and extreme agility (1Hz resolution) I decide not to build a new local oscillator, I will use the local oscillator embedded on the IQ+ receptor, the operation will be very simple, during RX the LO will be fix on the center pass band you select, as soon the software change to TX will "shift" the carrier to the desired frequency during TX and will return to the previous LO frequency defined as a center of your pass band on RX.

On FIG 2 the IQ+ XT is associated with a IQ+ revB receiver, the LO from the IQ+ receiver is shared with the IQ+ XT, the receiver has the LO on 144.100 MHz and this frequency define the center of my pass band for RX, as soon I select 144.130 as my TX frequency when the software go in TX the internal code will change the LO to 144.130 Mhz, this TX LO frequency is now my Carrier, as I said before I "shift the carrier" respect to my center frequency used for RX.

Now assuming we are transmitting JT with MAP65; in JT the sync tone is around 1.272 KHz, having my carrier in 144.130 will produce my main desired signal (RF modulated) on 144.130 MHz + 1.272 KHz = 144.131272 MHz and my desired transmission will be just 1.272 KHz up from the carrier, the TX Image signal will appears on 144.130 MHz - 1.272 KHz = 144.128728 MHz, just 2.544 Khz bandwidth.

As you can see on the Spectrum on FIG2 instead of spread all signals within the pass band the "carrier shift" technique allow us to concentrate ALL signals (desired signal, carrier and TX Image signal) in a extremely reduced portion of the pass band with similar band width than a conventional SSB voice channel.

Due the fact the two undesired signals (carrier and TX Image) will be extremely close to my main signal; MY TRANSMISSION will "hidden and mask" the undesired signals making impossible any kind of interference originated by this undesired signals because my main signal will dominate that small portion of the pass band.

Undesired signals will remain there but my strong desired signal and his very close proximity would make this undesired signal harmless.

Because my audio frequency remain untouched (only my LO frequency change) my TX Image Rejection calibration will be extremely effective due the fact will be done for a one single audio frequency.

Because I shift the carrier (and not the audio) the undesired signals will be always on the same place respect to my carrier (LO during TX), the audio don't change, only the LO frequency.

Carrier shift allow us to produce a very clean transmission compare with the "audio shifting" SDR transmitters.

IQ+ XT HW ACHITECTURE

The IQ+ XT have his own DAC, just a USB cable is needed and the DAC is showed under audio devices, no more audio cards for TX, the DAC has extraordinary low jitter and will produce a very clean audio

The audio generated by the DAC is injected in a pre-modulator board to convert each channel (I and Q) from single to differential output.

The IQ modulator is the LTC5598 from Linear, this Direct Quadrature Modulator has extraordinary performance, capable to run from 5Mhz to 1.6GHz but in the IQ+ XT will be limited to 144Mhz only. The IQ modulator give -55dB Carrier suppression and -50dB TX Image rejection (without software correction)

The RF output from the IQ modulator is around +1.5dBm, this will be the IQ+ XT RF output level (I will explain later why?)

The LO signal will be extracted from the IQ+ receiver (revA and B), due the fact the request comes mainly from IQ+ users I decide to reduce costs using the same LO from the IQ+ receiver. A small kit need to be installed on the receivers to split the LO signal.

IQ+ XT SOFTWARE REQUERIMENTS

Using "carrier shifting" instead of audio shifting demand special characteristics on the software, actually no software is available for the IQ+ XT but after talk with Joe Taylor K1JT he confirm he will adapt MAP65 to support the IQ+ XT with "Carrier Shifting" capability. As soon a functional prototype is finish he will receive one unit to do the properly modifications in MAP65.

For CW I don't have any contact with those who produce software like for example HDSDR but I'm open to do that if the demand for CW exist.

WHY IQ+ XT (exciter) AND NOT IQ+ TX (transmitter) ?

The IQ+ XT has +1.5dBm RF power output, to use properly the user need to install a external amplifier (like a mmic to elevate to +20dBm) and then use a small brick amplifier to jump in 5 to 10 watts. The rest is trivial to reach more power. The main reason for that is related with government regulations.

Governmental Agencies don't like SDR transmitters because, as I demonstrate previous, too much undesired signals could reach the antenna out of control. The homologation process is very long and expensive and could have a big impact on the commercial price. Keep the IQ+ XT as low power exciter trespass the responsibility to "TX a clean signal" to each ham radio operator if you decide to amplified that signal.

As a holder of a valid ham radio license we are allowed to build our own equipments following the properly standards about spurious and undesired signals.
The IQ+ XT at +1.5dBm RF output will have extraordinary performance and will accomplish in excess most of the local regulation, amplified that signal avoiding over modulation and keeping undesired signal under control will be and individual responsibility.
An homologation process will cost thousands of dollars and the cost need to be spread in a limited number of radios, elevating the cost dramatically.

Final price is not yet define, for sure much less than the IQ+ receiver, the LO is the most expensive part and is already embedded on the IQ+ receptors, I hope to reduce the price to a half of a IQ+ receiver cost but is not yet define.

HOW MUCH EFFORT AND COST TO PRODUCE MORE RF OUTPUT:

The IQ+ XT has +1.5dBm output, you will need a small mmic amplifier, like GALI74, PHA-1+, PGA-103 etc to move into +15 to +20dBm, this small amplifier cost no more than 50.00 USD, then I recommend the kit from MINI-KITS based on the module RA08H1317MPA, this small PA produce up to 8 Watts but I push up to 5 watts to keep clean signal, the cost of this is less than 70 dollars, DEMI has also very good option up to 60 watts I think.

AVAILABILITY

I think 3/4 2013, the HW proto is running very good, now I need to build a usable device and send to Joe Taylor K1JT to extend the MAP65 support. As soon the new MAP65 with support for the IQ+ XT is ready I will test the final configuration in HB9Q system and if after that numbers are ok I will decide for the production path. The IQ+ receptor is taking almost all my free time, if everything go ok I will build IQ+ XT radios in limited number, is a matter of free time.

73 de Alex, HB9DRI