1296MHz   JT65 Experimental Beacon

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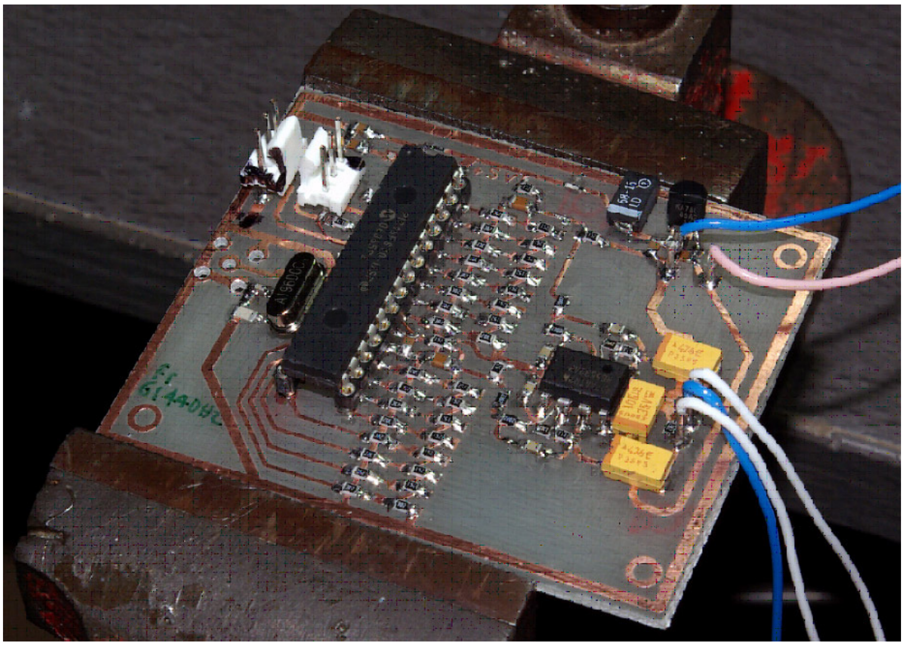
This is a description of the experimental beacon I've been running recently for transmitting WSJT modes, made up from a mixture of surplus bits and modern ICs with some DSP thrown in.

Background

The idea started after I developed a simple low frequency Direct Digital Synthesizer using a PIC and external R-2R ladder. By clocking the PIC with a 20MHz crystal, code for implementing a DDS allowed frequencies up to around 25kHz to be generated. The latest version of this PIC-DDS allows it to be programmed with a frequency word over a custom serial interface.   Another PIC was then programmed to generate WSJT modes (code exists for JT4, JT65 and WSPR) so any of these could be generated at carriers frequencies up to 25kHz.   All this was done with optical communications using 25kHz subcarriers in mind, and all works well up there.   Versions of the PIC code were developed that could operate free running, relying on the PIC crystal alone for maintaining timing, as well as versions taking in NMEA from a GPS receiver.   With a crystal set to within 10ppm of its nominal value, adequate timing for WSJT decoding could be maintained for a day or two

Then it occurred to me: I'd previously built a PIC based DDS designed for generating two 90 degree shifted audio tones, so the hardware already existed. A quick modification to the PIC code to add in the serial command protocol I'd developed for the optical comms one, and it was happily generating JT65 / JT4 / WSPR with IQ outputs, all ready for a quadrature upconverter. A photograph appears below. (File LF_IQ_DDS.JPG)

The maximum frequency wasn't as high as the single tone versions, 10kHz maximum is all the dual DDS can really achieve, but as I/Q upconversion is really a baseband process and wouldn't be used for subcarriers, not an issue...



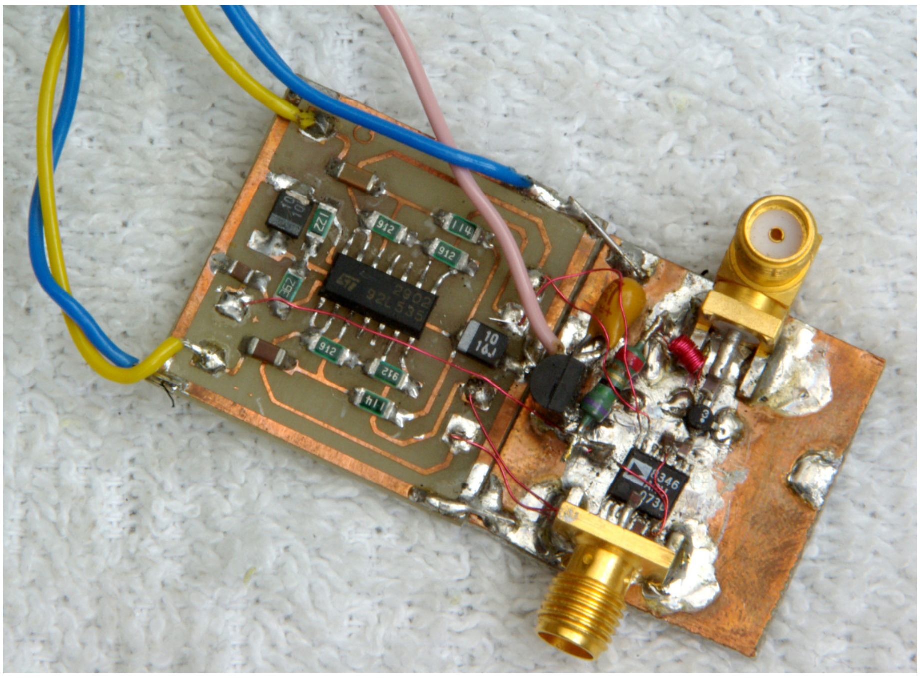
I also realised that by sending it the codes for negative frequencies (sending the twos-complement codes for the frequency to be generated) being an IQ source, it really would generate a negative frequency.

If the concept of negative frequency makes your head spin, it just means the phase of the I/Q outputs is swapped over, so after quadrature upconversion the output is now below the carrier. This ability to generate negative frequencies is an essential part of the IQ baseband to RF direct conversion process.

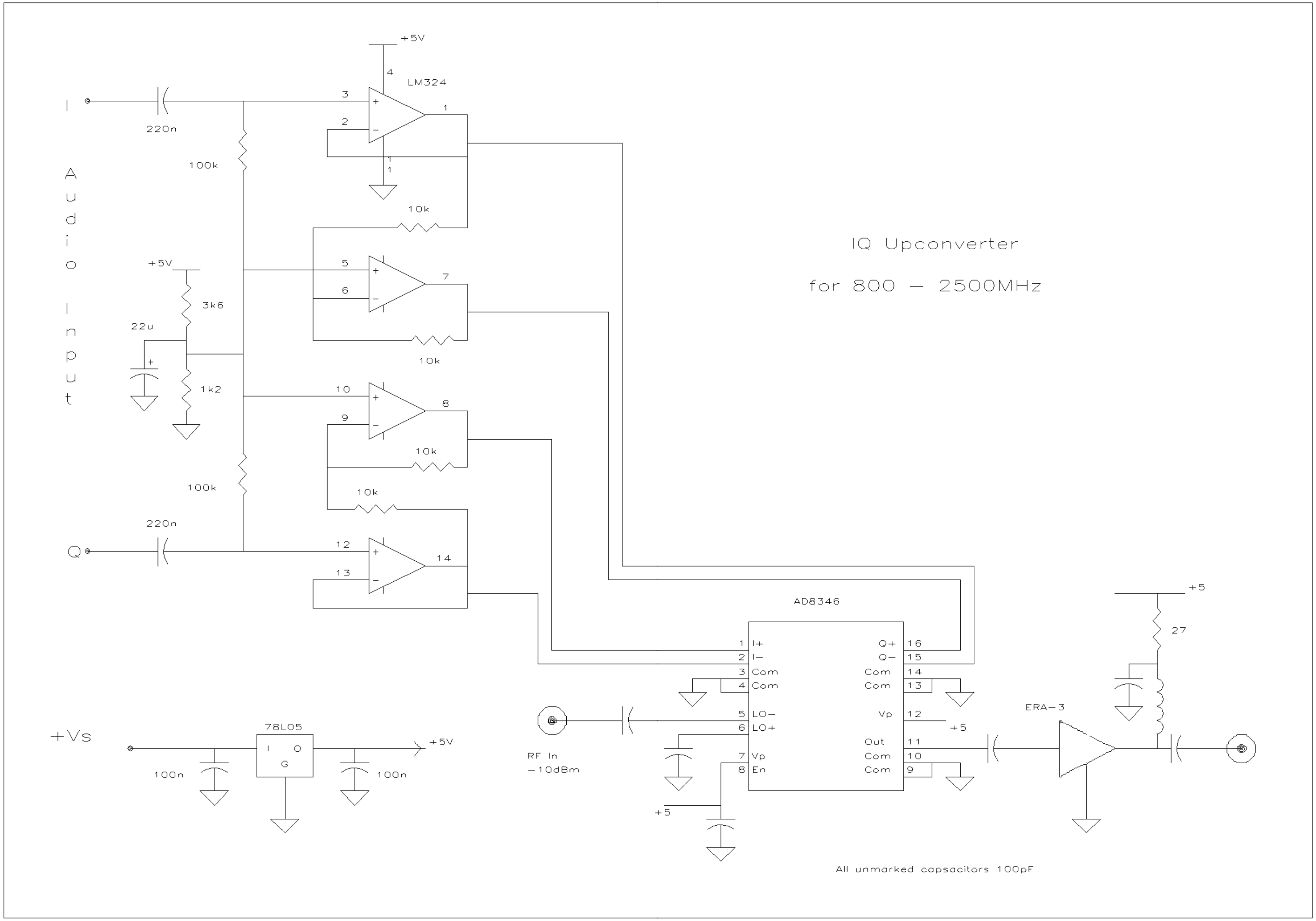
Full details of the low frequency DDS can be found at http://www.g4jnt.com/OpticalComms/LF_DDS_Beacon_Source.pdf with the download archive including all PIC code and design utilities at http://www.g4jnt.com/LF_DDS_Beacon.zip There is a bit more in *RadCom Design Notes, April 2011*

Microwave Version

The Analog Devices AD8346 is a quadrature upconverter designed for operation over 800MHz to 2400MHz The data sheet can be found at http://www.analog.com/en/index.html (search for AD8346) An RF input at the wanted carrier is supplied, optimally at a level of -15dBm, and dual differential baseband (audio type) signals have to be supplied at a level not exceeding 1.3V Pk-Pk. I'd made up a breadboard converter previously that was languishing on a shelf, (*RadCom, Short Circuits, Nov 2009*) so put it into a homebrew tinplate box for a bit of screening. A photo of the original before boxing-up is shown below. (File AD8346_Breadboard.jpg) An ERA-3 raises the output level from the AD8346 to around +10dBm

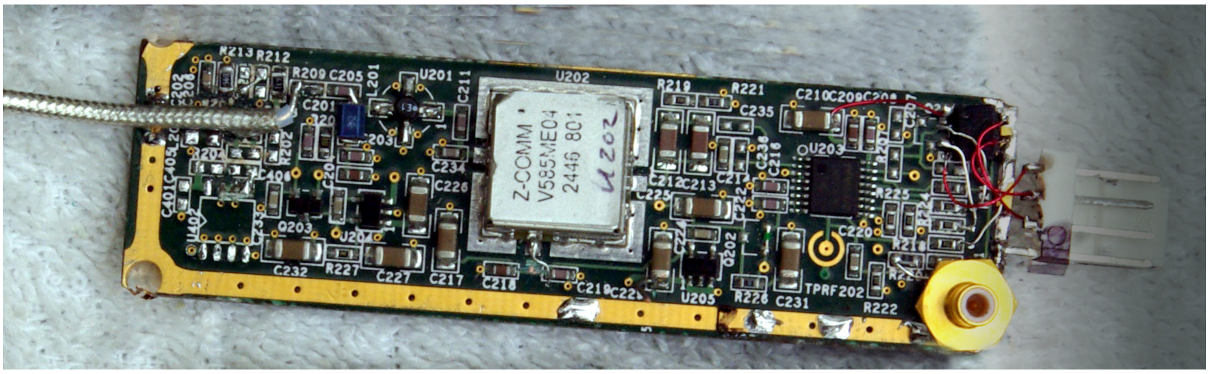


The differential audio comes from a quad opamp arrangement. The full circuit diagram of the upconverter is shown in Figure 1. (File IQUpconv.gif) As the LF-DDS arrangement delivers 2.8V peak to peak, the I and Q outputs have to be divided down to get to the maximum 1.3V permitted for this chip.


IQ Upconverter
for 800 – 2500MHz
I
Audio Input
Q
+Vs
220n
100k
+5V
3k6
22u
1k2
LM324
10k
AD8346
I+
I–
Com
LO–
LO+
Vp
En
Q+
Q–
Out
+5
27
ERA–3
RF In
–10dBm
78L05
100n
All unmarked capsacitors 100pF

RF Source

In the past I'd dismantled an old cell phone type of module that had had three LMX2346 synthesizers built onto it. I'd (literally) hacksawed off each module, added a small PIC to decode commands sent via an RS232 serial interface, then put them aside after testing. (One of these covered 2.3GHz and was subsequently used for GB3SCS. That conversion is detailed at http://www.scrbg.org/TheNewGB3SCS.htm) Another module covered 1.3GHz, and photo of that is shown below. (File Recovered_Synth.jpg) This module was also put into a tinplate screened housing



The output level from the synth at +15dBm was far too high for the AD8436, so 30dB of attenuation had to be added to bring it down to the drive level needed by that chip.

Frequency Setting

The synthesizer module was configured for comparison frequencies in the 500kHz region, and I didn't want to change loop filter components on this ready-to-go module, so was forced to choose only a limited range of frequencies in the narrowband 1296 segment. With a 10MHz reference input from the 'ZAZ GPS locked source, and after playing with a few numbers, I finally settled on R = 18 and N = 2333 for a generated frequency of 1296.11111MHz with a reference of 555.555kHz.

Now this is where being able to programme negative frequency is useful. It would be nice to have a round number of kHz as the reference tuning point for the signal. I'd intended to use JT65B and C waveforms for transmission (JT4 is old-hat, all uWave beacons run that now) and these are 350 and 700Hz wide respectively. Both are based on a reference sync tone that has to be tuned to come out at 1270Hz at audio. So the nearest ideal tuning points were 1296.110 or 1296.109MHz to keep the tones generated by the DDS as low in frequency as possible. Using .109 as the SSB carrier tuning reference, meant the audio tone needed for the JT65 sync at 1270Hz had to be at a frequency of 1296.109MHz (Wanted carrier) - 1296.1111 (From the synth) + 1270Hz (JT65 sync) which is [minus] -840Hz. JT65C generation inside the PIC increases this to -90Hz maximum. (Had I selected an SSB carrier tuning point of 1296.110MHz, the respective tone frequencies would +159 to +860Hz for JT65C, but I wanted negative frequencies for the challenge!)

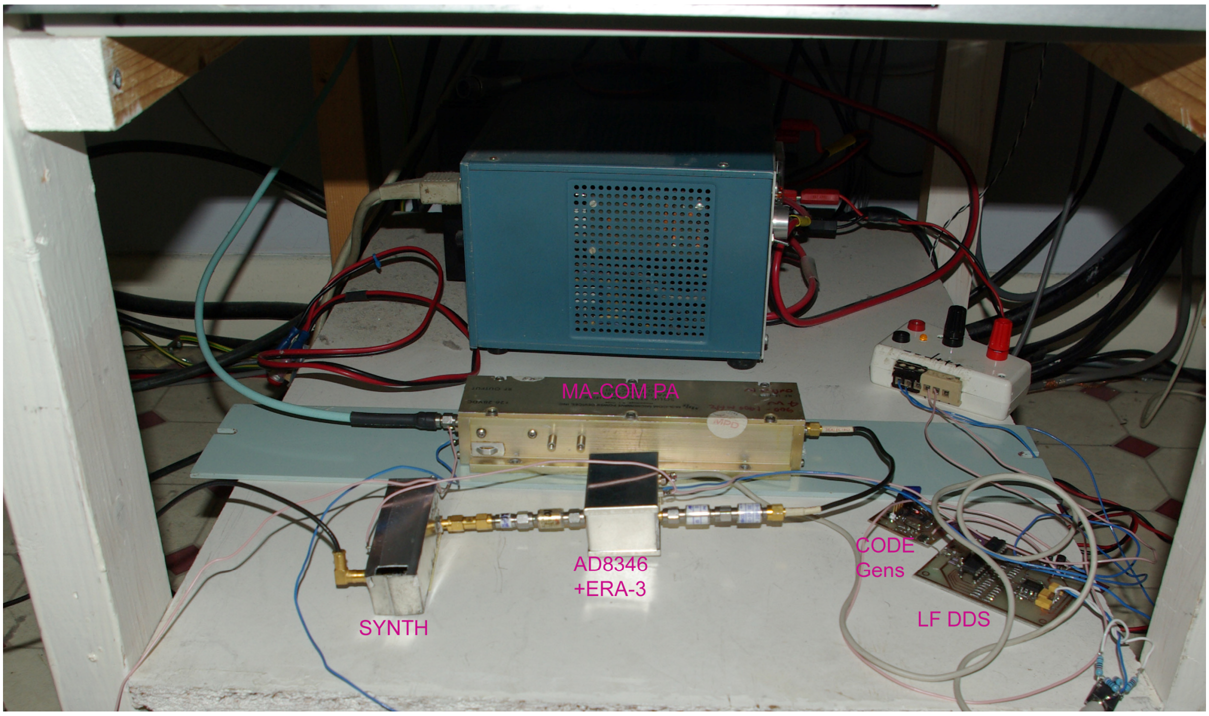
Calculating the values for the frequency codes to be sent from the code generator to the LF DDS, together with all details of programming the JT65 code generator are all covered in the references given.

Amplifier and Antenna

A surplus 900 – 1400MHz MA-Com unit was to hand, an ancient module running in class A that consumed over 1A from a 26V supply, but it did deliver a clean 5 Watts at 1296MHz. Optimum drive level was 0dBm so further attenuation had to be added on the upconverter output.

John G0API had loaned me a 1.3GHz Alford slot in a waterproof housing – it has been originally intended for an ATV repeater in the Bournemouth / Poole area that didn't happen) and this on top of the mast fed with 12m of LDF450 ensures an EIRP in the region of 11dBW.

The photo below (File 1296_Beacon.jpg) shows the breadboard combination connected up and going.



Conclusions

At the time of writing the beacon has been up and running for a couple of days, with reports from as far away as Wakefield (319km) QRM from Doppler shifted Aircraft scattering appears to suggest JT65C has the edge over the B version, and it ought to be possible to get successful decodes from the stronger aircraft reflections, as only 20s of the complete 48 second transmission sequence is needed for decoding, provided the that 20s is of good quality.

Carrier leakage at 1296.5111MHz which looks like a spurious tone at 2111Hz is at a level of -40dBc. With a properly laid out PCB intead of the rats-nest breadboard, an even better isolation should be possible. Other spurious tones in the -50 to -60dB region are also present. These come from a combination of the lkow 8-bit resolution of the LF DDS D/A converter, I/Q sideband cancellation etc etc.