# 144MHz direct conversion receiver with I/Q outputs for use with Software Defined Radio.

## Overview

This design is a direct conversion receiver for 144MHz with quadrature outputs for use either with a software defined radio (Reference 1) or with additional audio phasing circuitry. Quadrature outputs, generated from two 90 degree shifted local oscillators, allow SSB reception by unwanted sideband cancellation as described in Reference 2.

The converter was designed with the primary aim of using it for the IF stage on microwave transverters, so a linear receiver was needed with no AGC, but a calibrated gain control to make accurate relative measurements of microwave beacons using a PC Soundcard based system for the actual level and Signal to Noise ration measurements. A straightforward gain calibration can then be used to convert these into absolute readings, making this a useful piece of test equipment for propagation studies.

There is nothing inherently narrowband in the design - filtering limits the RF bandwidth to around 8MHz to eliminate strong signals from broadcast and PMR, and audio bandwidth is kept to about 20kHz , wide enough for the normal maximum soundcard sampling rate of 44100Hz. Any subsequent audio filtering for actual listening purposes is performed by the SDR software, or in separate audio processing circuitry.

## Operation

The circuit diagram is shown in Figure 1.

In the RF path two modamps, a MAR-6 and a MAR-3 amplify the RF; there is a two stage bandpass filter between them with 10MHz bandwidth. The output feeds into two SRA-1 type DBMs via a resistive splitter, with the quadrature LO signal generated using a MiniCircuits PSCQ-2-160. This device guarantees less than 3 degrees phase error over 100 to 160MHz; as 144MHz is near the middle of the range we can expect a fair bit better performance here.

The local oscillator is an AD9851 DDS, currently clocked at 100MHz, generating 16 to 16.67MHz followed by a X9 RF multiplier. The DDS source is not described here, but the module in a basic form is described in Reference 3. The active stages in the multiplier consist of MAR-6 modamps configured as a pair of cascaded tuned X3 stages with a final MAR-6 as amplifier/limiter, this combination forming probably the simplest tuned RF multiplier possible! (There are a couple of CW spurii generated by the DDS, but I know where they are and can ignore them). All filtering is designed to allow the LO to tune over 144 to 150MHz to cover a bit wider than the normal 2MHz narrowband segments on the microwave bands, and allow for odd LO frequencies. Multiplier output level is +10dBm drive to the quadrature hybrid.
By using the internal X6 option in the AD9851 DDS Chip, the LO can be driven from a 10MHz frequency reference, producing a clock of 60MHz, but this has not been implemented yet. Hopefully spurious levels will be no worse, with none falling in the beacon bands at the lower clock frequency.

The mixer outputs drive a pair of identical NE5532 opamps with a voltage gain approaching 300 (exact value a bit uncertain due to internal impedance of the mixer IF port) No clever matching, just the mixer feeding the inverting input giving 800 ohms input resistance at audio, and low pass filtering to get rid of RF leakage. The I/Q outputs feed another pair of op-amps with precisely switchable gain from 0 to 40dB in 10dB steps. Audio bandwidth is not especially tailored, but rolls off gently from about 20kHz to allow for 44100Hz sampling rate in a soundcard.

The total system gain and dynamic range is based on 16 bit digitisation, and is sufficient at maximum (+40dB) to place its own thermal noise least 10dB above the quantisation noise pedestal. Strong signals and extra RF gain in transverters is catered for by backing off the audio gain. For signals too strong even for this (80db S/N in 20kHz) an external (calibrated) RF attenuator can be added

**Construction**

No attempt was made to put this on a proper PCB. The converter and audio stages were built birds-nest style on a piece of unetched copper clad PCB as can be seen in Photograph 1. Plenty of decoupling and short direct wires ensure stable performance. As there is a lot of gain - particularly at audio - the whole unit was built into a tinplate box for screening

Using parallel and series 1% resistors for the switchable gain stage, no especial trimming or adjustment was necessary, the traces looked well enough matched on a 'scope and as I was only after 20 - 25dB sideband rejection to make opposite sideband noise insignificant, tweaking wasn't necessary. 3 degrees phase error will give 25dB rejection, assuming amplitude is correct, which is about equivalent to 5% amplitude imbalance. So if I have a 'bit better' in each case the 20dB plus is easily achievable. All power rails are regulated and well filtered for operation off a portable 12V supply.

The LO multiplier was made by cutting a 50 ohm microstrip line into a double sided PCB. To quickly make a 50 ohm line without etching, score two lines 2.8mm apart through the copper on the top face of the PCB for the full width, use a Stanley knife or similar making sure you penetrate the copper fully. 2.8mm width on normal 1.6mm thick fibreglass PBC gives about 50 ohms characteristic impedance. Then score two more lines about 1mm from each of these. Using a hot soldering iron, use this to soften the adhesive and with a pair of tweezers, lift up and remove the two 1mm wide strips, which will give a single 50 ohm line surrounded by copper groundplane. Drill a number of 0.8 to 1mm holes through the top ground plane to the underside and fit wire links to give a solid RF ground structure. Wire links are best fitted close to where grounding and decoupling components are connected.

Cut the 50 ohm line into segments with gaps for the modamps, DC blocking capacitors and filters. Other connections around the filters are made up birds nest style. When completed and aligned, coils can be held in place with glue (a hot glue gun is a useful accessory to have around) Photograph 2 shows the completed multiplier chain.

**Using the downconverter.**

For the standalone unit for use as a receiver in the field, a simple quadrature network and loudspeaker amp can be added to make a complete receiver. A high/low pass pair of all pass networks will give 15dB sideband rejection over 400Hz to 2kHz which is good enough for listening to beacon signals on hill tops. Alternatively, look at Reference 2 for phasing type SSB networks to give an improved SSB performance. A meter driven from the audio level via a precision rectifier circuit can be added to allow quite precise signal strength measurements to be made in conjunction with the calibrated attenuator. Alternatively, take at look at the Software Defined Radio software (Ref 1) from I2PHD for another solution

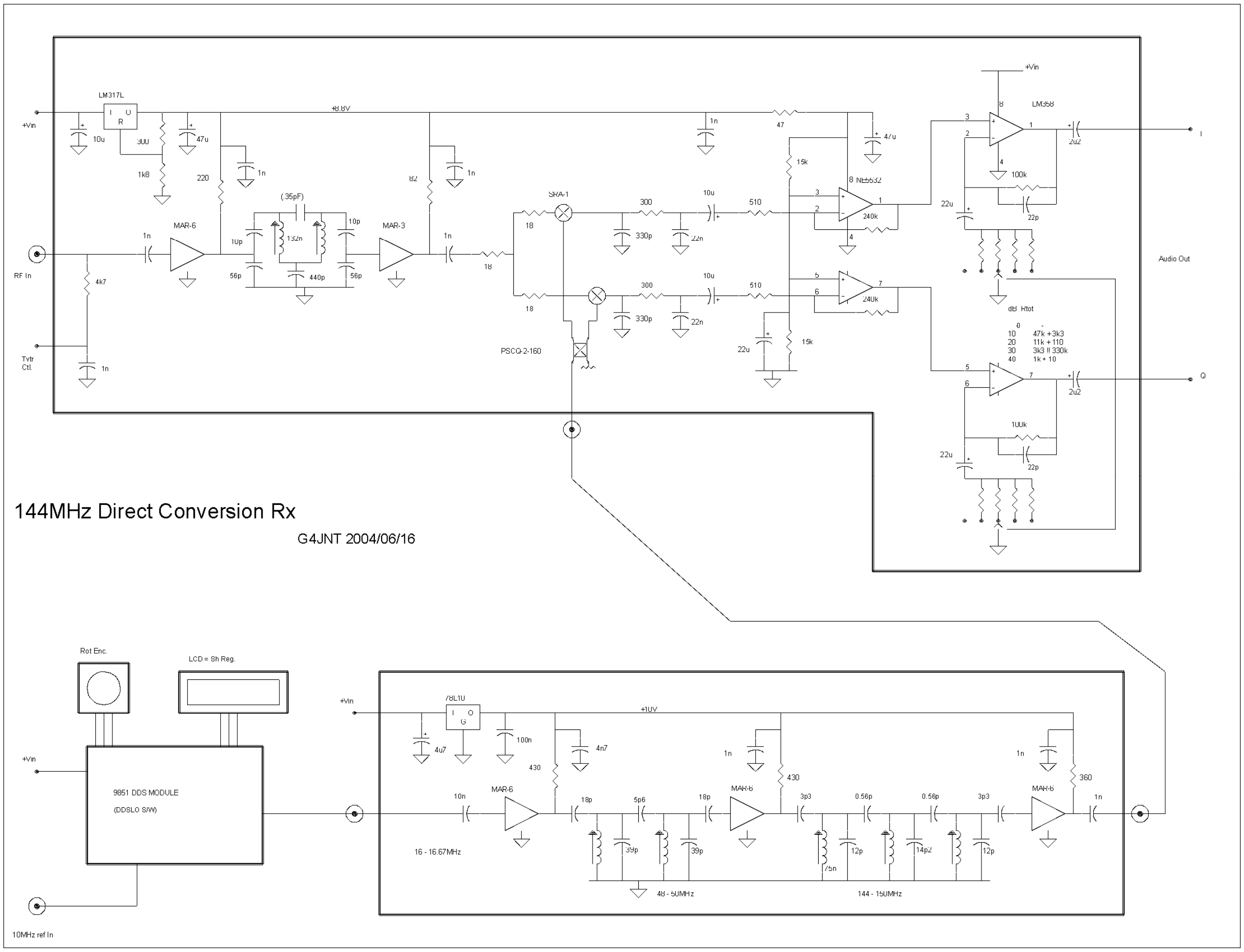
**LO Source**

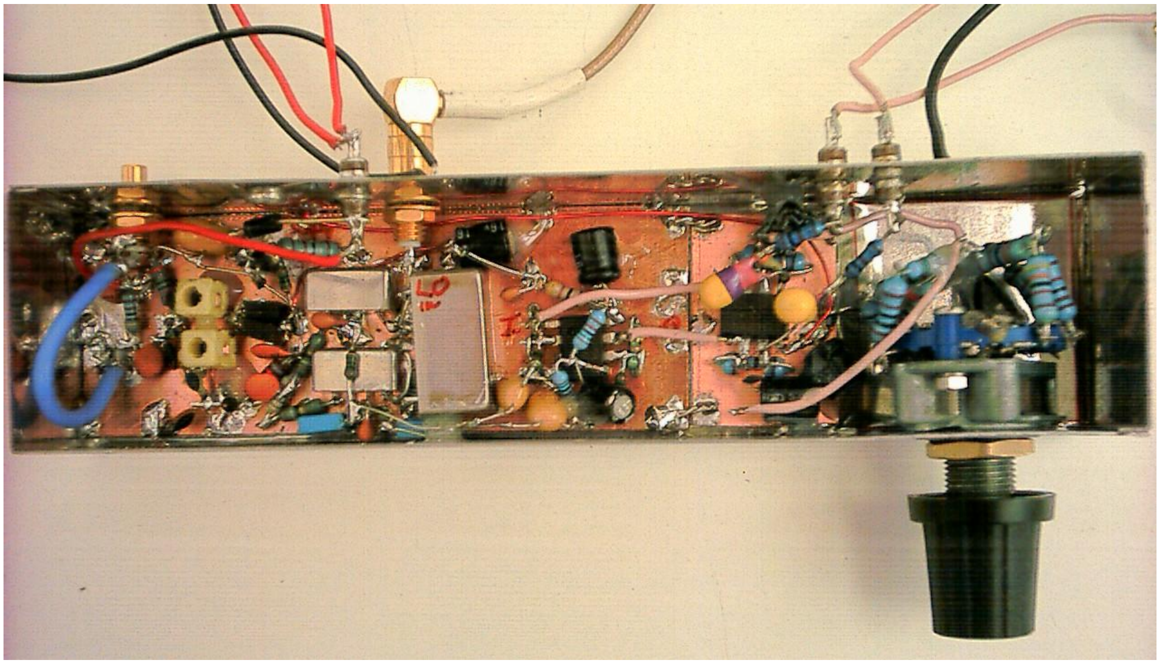
The DDS module as described in Ref. 3 has new PIC software, along with a rotary encoder and LCD display to give a user friendly interface. For anyone who has the original DDS board I can supply PIC software for this modification. However, the AD9850 and '9851 chips are in short supply now - they have been replaced in most cases by larger, faster, new devices in a different package.

Alternatively, emulate the venerable IC202 transceiver and build a VCXO to supply the signal to the multiplier. Or use a VFO/mixer, or a synthesizer - the choice is yours!

Ref 1 [http://www.sdradio.org](http://www.sdradio.org)
Ref 2 RadCom series on phasing networks Feb to June 2004.
Ref 3 AD9850 DDS Module RadCom, November 2000

Figure 1 Circuit Diagram
Photo 1 RF and Audio stages.
Photo 2 Local Oscillator multiplier

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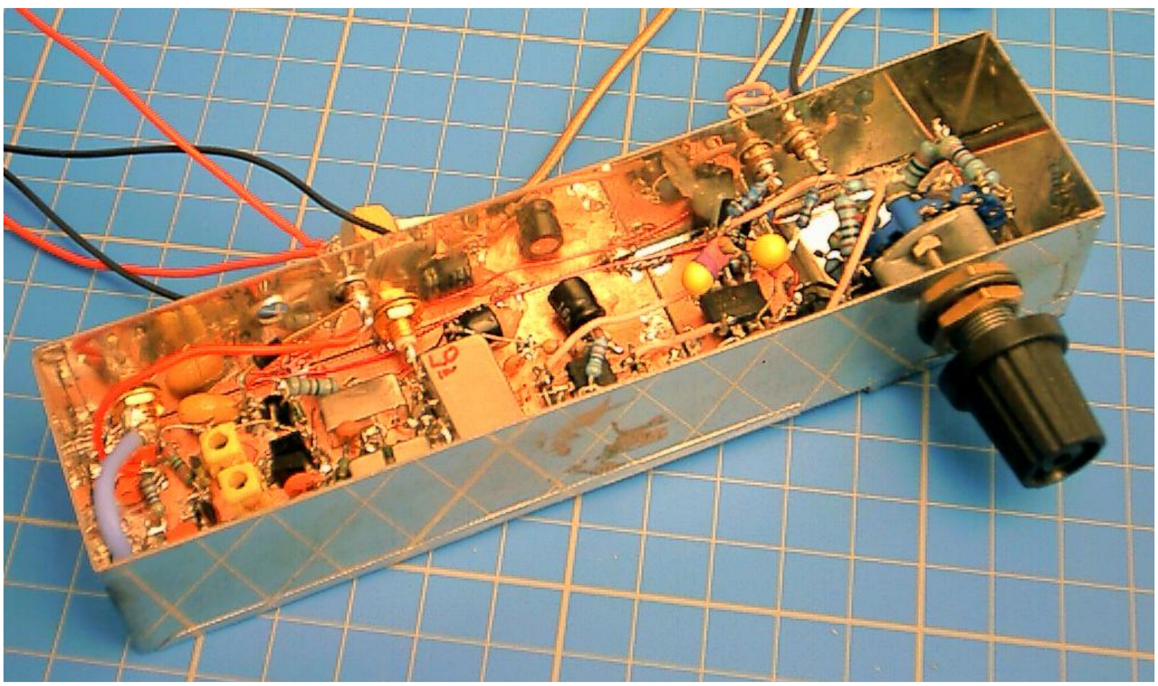
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