The Dual Injection Converter

By Sam Jewell, G4DDK

Introduction

For many years the standard intermediate frequency (IF) for use with microwave receivers (converters/transverters) has been 144MHz. The reason for this is quite simple, 144MHz radios are quite common, reasonably cheap and provide a sufficiently high first IF for radios operating to 10 or even 24GHz. However, the phase noise performance of the local oscillators in the vast majority of 144MHz transceivers is quite poor. The notable exception is the ubiquitous ICOM IC202 with its mechanically tuned VXO local oscillator. Poor phase noise performance can lead to reciprocal mixing problems when strong off-channel signals are present. Unfortunately, the situation does not appear to be getting any better, with most manufacturers seeming to prefer to add yet more bells and whistles to their products rather than improving basic radio performance.

Many HF transceivers do have adequate performance in respect of phase noise and strong signal handling on the 28 to 29.7MHz (10m) band. Using 28MHz directly as the first IF of a 10GHz or even a 1.3GHz converter will lead to poor image signal rejection allowing both unwanted signals and noise at the 56MHz-spaced image to appear at the converter IF due to the closeness of the image frequency to the signal frequency.

There are three methods of improving image response:

1. Brute force filtering
2. Image rejection mixers
3. Multiple conversion

Brute force filtering requires critically tuned multi-pole filters that can be large and prone to performance drift with time, whereas image rejection mixers can be difficult to set up and even then provide limited rejection. Multiple conversion tends to be the preferred option, with dual and triple being the most commonly used conversions.

Dual injection can be as simple as two cascaded converters. For example, a 1296 to 144MHz converter followed by a 144 to 28MHz converter. Such an option is perfectly viable and is used by many operators. However, this approach suffers from several disadvantages including:

1. Poor gain distribution leading to possible poor signal handling capability
2. Two separate crystal oscillators with different frequency drift characteristics (what frequency are you tuned to?
3. Possible interaction between the two oscillators leading to unwanted spurious receive signals.
4. Pick up of signals at the first intermediate frequency, via the inter-converter connecting lead, especially if this happens to be a popular amateur band (144MHz?).
5. Two boxes to go wrong

A preferable method of multiple conversion is to use a single crystal oscillator source to feed two (or more) conversion stages in a single, well designed converter.

This converter would have a balanced gain distribution, selection of suitable Intermediate frequencies to avoid interference pick up and all frequencies determined by a single crystal oscillator source to reduce the chances of spurious signal reception.

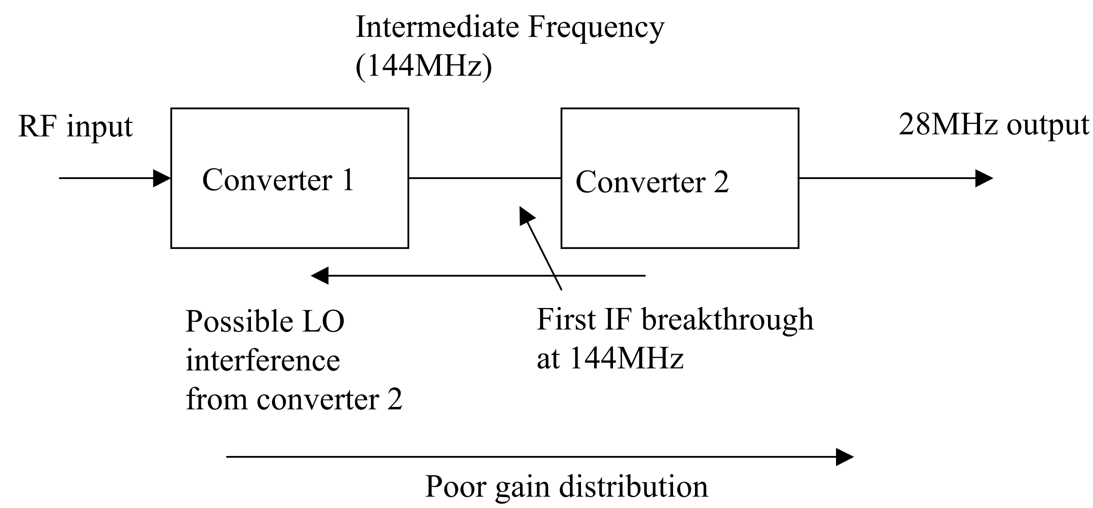

Fig 1 Cascaded converters and their disadvantages

<u>Designing a dual injection converter frequency scheme</u>
A scan of the available literature failed to produce any articles on designing dual injection converters. Determining the frequency conversion scheme is not immediately obvious. However, it is not difficult to work out the required frequencies once the required block schematic has been produced.

This paper uses as an example how the frequency conversion scheme for the 2400MHz to 28MHz dual injection 'Gemini' [1, 2] receive converted was determined.

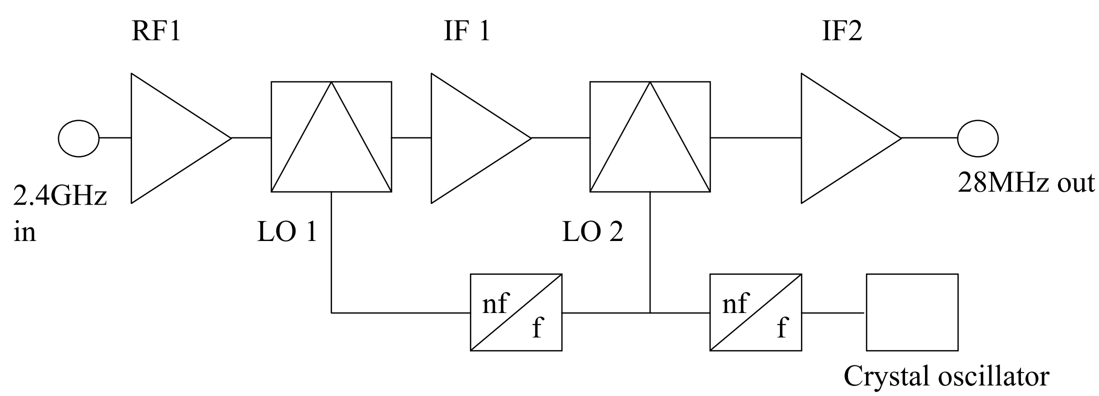

Fig 2 the basic design for a 2.4GHz to 28MHz converter

Initially the only frequencies we know are the RF1 input, IF2 output and that LO1 is an integer multiple of LO2. The integer value (frequency relationship) between LO2 and LO1 can be any convenient value. In this design a value of 4 was chosen i.e. LO2 = LO1/4

We also know:

IF1 = RF1 – LO1

and

IF1 = IF2 + LO2 (or LO1/4)

therefore

RF1 – LO1 = IF2 + LO1/4

transposing

RF1 – IF2 = LO1 + LO1/4

putting in some numbers

2400 – 28 = 1.25LO1

2372 = 1.25LO1

therefore

LO1 = 2372/1.25

= 1897.6MHz

from this

LO2 = 1897.6 / 4

= 474.8MHz

IF1 = 2400 – 1897.6

= 502.4MHz

A first IF of 502MHz was considered acceptable as a compromise between second image filtering and frequency stability. Commercial 502MHz helical filters are available from Toko etc, easing the requirements of tuning.

The image frequency with a 502MHz first IF is now over 1GHz below the 2.4GHz RF frequency, leading to excellent first image rejection for both signal and noise.

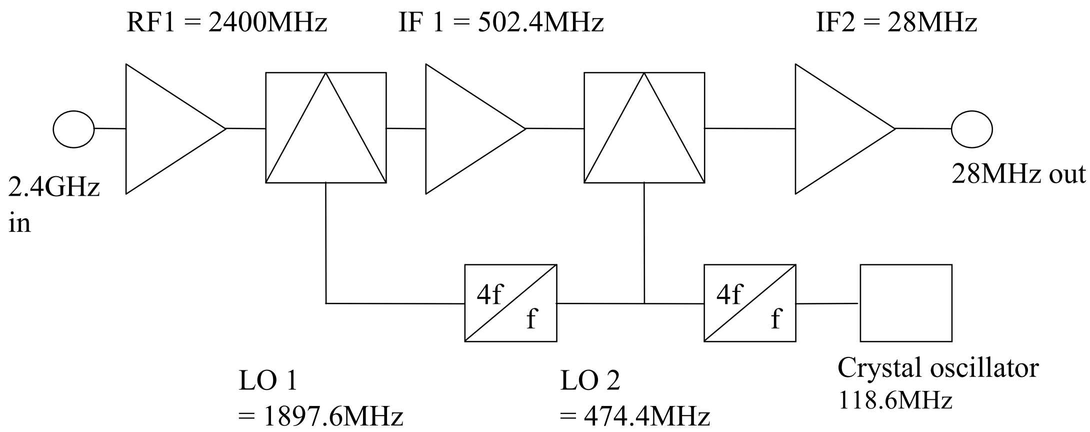

Fig 3 Block schematic of the final dual injection receive converter for 2400 to 28MHz

More on the dual injection converter

It may not be obvious at first sight, but the dual injection converter frequency stability error is not as straightforward as for a single conversion design.

Consider that the crystal drifts 1 kHz at 118.6MHz (hopefully this is an extreme example). LO1 is 16 times higher than the crystal frequency so that if the crystal drifts up by 1kHz at 118.6MHz, then it will have drifted up by 16kHz at 1897.6MHz. The result is that a signal received at exactly 2400MHz will produce a first IF of:

2400 – 1897.616MHz = 502.384MHz

This is 16kHz below the frequency at which it should be received.

The same crystal oscillator derived LO2 is now injected into mixer 2. LO2 is only 4 times the crystal frequency, therefore the injection is 4kHz high, i.e. 474.404MHz
The resulting IF2 is:

502.384 – 474.404 = 27.980MHz rather than the expected 28.000MHz

Note that the result is the addition of the drift at LO1 plus the drift at LO2.

However, if the conversion from 2400MHz to 28MHz was performed in a single stage then the 118.600MHz crystal would have been multiplied by 20 to reach 2372MHz, leading to the same drift characteristic so there is no disadvantage to the dual conversion scheme even though first examination seems to suggest a bigger drift than expected.

Don’t forget, when measuring this converter on the HP 8790 type noise figure meter to enter 2400 – 28 = 2372MHz as the local oscillator frequency!

Design for 1296MHz

Using the same assumptions as for the 2.4GHz converter, then table 1 shows some of the various frequencies that could be used.

Signal frequency	First IF (MHz)	First LO (MHz)	Second LO (MHz)	Crystal freq (MHz)	Comments
1296MHz	281.6	1014.4	253.6	84.544444	Option 1. Crystal x3 and then x4
1296MHz	344.7622	951.23781	237.809	118.9047	Option 2 Crystal x2 and then x4
1296MHz	450.6667	845.3333	422.6667	105.66667	Option 3 Crystal x4 and then x2
1296MHz	662.0	634.000	105.6667	105.66667	Option 4 Crystal x 6 (x2, x3)

Option 4 looks interesting as the local oscillator chain is quite simple, requiring just a times 6 multiplication to LO1. However, the drift is double this as the same LO1 frequency is injected twice. Image rejection might be a problem with the first IF as high as 662MHz.

Summary

In this paper I have presented a method of determining the frequencies to use in a dual injection frequency converter such that you can use your high quality HF transceiver as a 28MHz IF for your microwave radio. Using the formulae in the paper it should be possible to calculate the required frequencies to produce a high quality dual injection receive converter, suitable for use on any of the lower or middle microwave bands.

I have been using my Gemini 2.4GHz converter on Oscar 40 in conjunction with my FT847. Whilst the FT847 doesn't have much better, if any, phase noise performance on 28MHz compared with 144MHz, it has now freed-up 144MHz for use with my 1268/9MHz transmit up-converter and I still have all the advantages of the FT847 satellite facilities available. When using the Gemini converter with an ICOM IC735 the signal from AO40, subjectively, sounds cleaner on receive than with the FT847.

References:

[1] Gemini, A dual conversion 2.4GHz to 28MHz receive converter for satellite operation. Jointly developed by G4DDK and G0MRF. Dayton Hamvention Microwave Forum, 2002

[2] Gemini – a dual conversion S Band to 10m receive converter. David Bowman, G0MRF and Sam Jewell, G4DDK. Proceedings of the 17th Amsat-UK Colloquium, University of Surrey, July 2002