Using the Elad FDM-DUO for Coherent Signalling

When operated with an external 10MHz frequency reference, such as a GPS, Rubidium or Caesium standard, the frequency conversion from RF to audio, including that involving the transceiver's internal soundcard, is completely coherent. However, the frequency tuning is done in steps of 1Hz and is subject to minor systematic but predictable errors. There is also a difference in errors between transmit and receive

Receive Tuning Errors

The receiver A/D samples at 122.88MHz and the centre frequency is selected using a Numerically Controlled Oscillator (NCO) within the FPGA firmware. The NCO uses a 32 bit tuning word N such that :

$$F_{TUNE} = 122.88\text{MHz} * N / 2^{32}$$

This means the frequency is set in steps of 122.88MHz / 2^{32} = 0.02861Hz so if any particular frequency is selected it could be in error by half this value above or below the nominal tuning point. Ie. a maximum error of ±0.0143Hz. For 'normal' listening use this will go completely unnoticed but if the receiver is used for coherent communications, as are now taking place on the 137kHz band using *EbNaut*, such a 'massive' tuning error is catastrophic. *EbNaut* relies on the absolute phase of an RF carrier remaining within less than 90 degrees over several hours of transmission which equates to a permitted frequency error at 137kHz of 0.000069Hz or 0.5 parts per billion. Most good standard references can manage this accuracy, but any inherent frequency setting error in the radio will negate it if not taken into account.

The actual tuning error can be determined by first calculating the value that will be used internally, then using this to calculate the exact generated frequency. For example, assume 137010 Hz is desired.

$$N = 137010 / 122.88\text{MHz} * 2^{32} = 4788846\ [.592]$$

Rounded to the nearest integer = 4788847.

Recalculate Fo from this integer value:

$$Fo = 122.88\text{MHz} * 4788847 / 2^{32} = 137010.0117\ \text{Hz}$$

Since this local Oscillator is 0.0117Hz <u>high</u>, using Upper Sideband tuning means the resulting tone output will be <u>low</u> by this same amount. Any self respecting coherent communications software should allow this offset to be entered manually.

Note that *The correction has to be calculated based on the FDM-DUO's tuned frequency – not the RF being received.*

'Sweet-Spot' Frequencies

There are certain frequencies that can be generated 'exactly' and occur at all multiples of a particular starting point, or base frequency. This base has to be an exact multiple of the tuning step, 1Hz, and must also be a binary submultiple of the clock. Binary submultiple means a value of 2^N such as 256, 2048, 65536 etc.

For F_S = 122.88MHz this criteria is met for 1875Hz which is clearly a multiple of 1Hz and is equal to 122.88MHz / 65536. So we can generate 136875Hz (73 times the base) exactly with N = 4784128. This is the only 1Hz step in the 137kHz band that can be generated exactly. If the receiver is tuned to this frequency, or to the next step below, 135000Hz, then any audio tone delivered to the decoder will be exactly equal the offset of the RF from this tuning point with no NCO rounding errors.

Transmission

Exactly the same rules apply to transmission except the situation is slightly worse. The Tx signal is generated in a 32 bit Direct Digital Synthesizer clocked at 368.64MHz, three times the receiver F_S. This means the Tx frequency resolution is 0.08583Hz giving a maximum error of ±0.0429Hz. The lowest common base frequency for 1Hz steps is 5625Hz and there is no 1Hz multiple within the 137kHz band that is a multiple of this.

However, 135000Hz does meet the exact criteria, so any tone fed into the transmitter in USB mode will be upconverted exactly from this tuning point and can be made to lie in band if a wide enough SSB Tx filter is used.

OR …

Designers of coherent links could just specify frequencies that can be generated exactly at each end of the link using their respective hardware.