André Jamet F9HX Gil Féraud F5CAU

Multiplication, division and addition of a 10MHz source to get a synthesised VHF signal

Here is an *original idea* to solve the frequency stability and repeatability problems encountered with crystal oscillators used as local oscillators for microwaves while getting a high quality spectrum close in and distant from the carrier.

1. Introduction

Contacts at quite long distances are currently made on SHF using SSB and CW. That implies a rather difficult frequency stability goal both for reception and transmission. The magnitude of the relative stability df/f is more difficult to achieve than on the 2m or 23cm bands. Moreover digital modes like JT44 require narrower bandwidths than the classical modes so they need an increased stability. Likewise transmitter spectrum width must be limited to mode requirements.

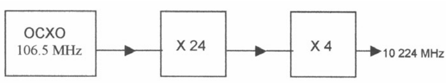

Fig 1: Block diagram of a local oscillator with a VHF OCXO source.

Local oscillator phase noise must be kept as low as possible in order to avoid any interference to week signals by strong adjacent signals.

2. Frequency stability and requirements

An SSB or CW link needs 50Hz stability for a ten minute contact in spite of a few tenths of a degree temperature variation. For a long QSO a 100Hz variation can be accepted while temperature variation can reach several degrees. Through a day, one kilohertz is acceptable with significant temperature changes for outside usage.

Another point is the repeatability problem, this means the ability to get the same frequency after a short or long break. One kilohertz drift is acceptable owing to the receiver bandwidth.

To summarise for 10 GHz we need:

- Short-term 10 minutes : 50Hz 5.10^{-9} (5 ppb)
- For an hour: 100Hz 10^{-8} (10 ppb)
- Long period : 1000Hz 10^{-7} (0.1 ppm)

For the following ambient conditions:

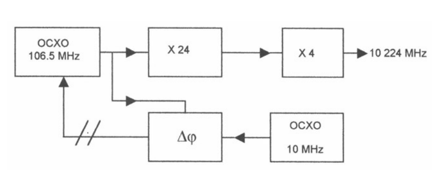

Fig 2: Block diagram of a local oscillator with VHF OCXO plus PLL with 10MHz reference.

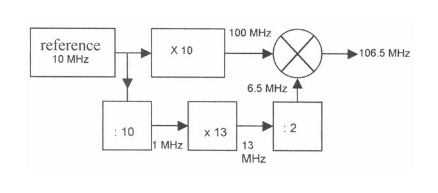

Fig 3: Block diagram of a local oscillator with a 10MHz reference.

- Temperature : - 10 to + 45 °C
- Humidity : 0 to 100 %
- Height above sea level: 0 to 2000 meters

These stability values must be bettered for modes other than SSB and CW although we can take advantage of more restrictive values for CW.

For the higher SHF bands we have a goal five times harder for the 47GHz one and a lot more for 241GHz!

3. Spectral purity

First we have to consider the close in noise, up to a few kilohertz due to amplitude and mainly to phase noises. Up to a megahertz we can have spurs, harmonics and mixing products. It is difficult to quantify the acceptable limits to the best of our ability and to measure them with amateur equipment. Measured values and results in the field will be covered later.

3.1. A well known solution: VHF OCXO

An example of that solution is given by in Fig 1 [1]. A VHF crystal oscillator drives several multiplier stages up to the wanted output frequency, for example 10,224MHz for a 10,368MHz transverter with a 144MHz intermediary frequency. The close in noise is good for a well designed oscillator. The phase noise is decreased when the crystal power is high but the ageing is worse, a compromise is required. That solution also needs a lack of spurious frequencies from the multiplier stages.

It is difficult using that solution to get the frequency stability needed. To put the XO into a constant temperature oven and using a crystal cut for 60°C allows a good stability in spite of the ambient temperature variations. But a repeatability effect gives a frequency shift after a break, worse when it is a long break. The only way to avoid that is to keep the power on the OCXO and get the ageing but not the repeatability problem.

3.2. Another well known solution: VHF OCXO + PLL with 10MHz reference

Several publications about this solution have been published in the amateur magazines [2]. The idea is to lock the VHF OCXO using a PLL to a very stable reference source (Fig 2). Stability and repeatability are the same as the reference that can be a professional or amateur 10MHz OCXO [3,4]. These devices do not suffer from the repeatability problems as much as VHF ones. After a break the frequency is within limits in a quarter

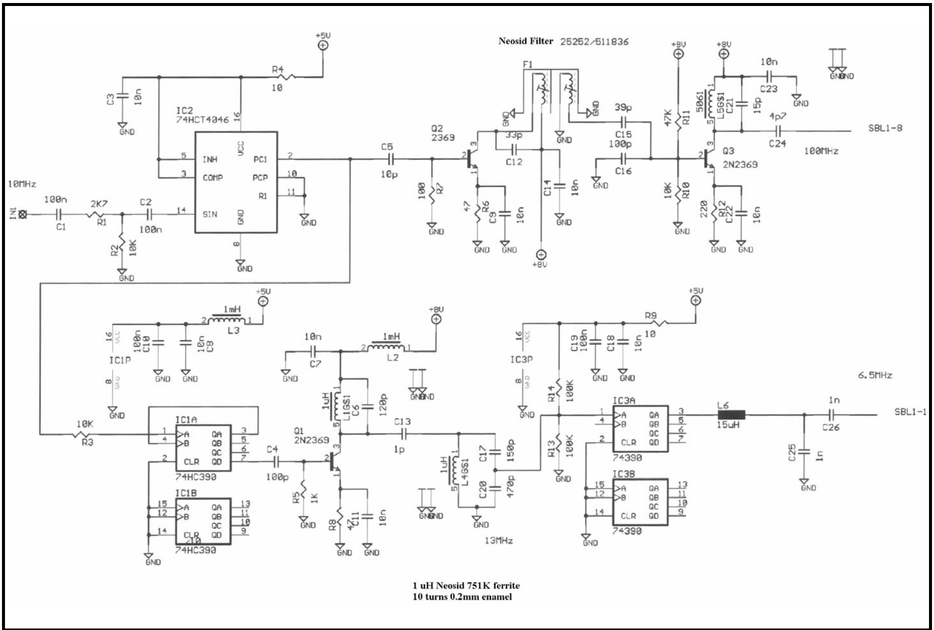

Fig 4a: Circuit diagram of local oscillator.

of an hour. We may also use a GPS signal, a standard radio frequency, a rubidium or a caesium source.

Since the frequency stability is achieved by the reference source we can increase the crystal power in order to improve the oscillator signal/noise ratio.

Unfortunately any noise or spurs on the control signal from the PLL to a varicap diode can spoil the spectrum of the

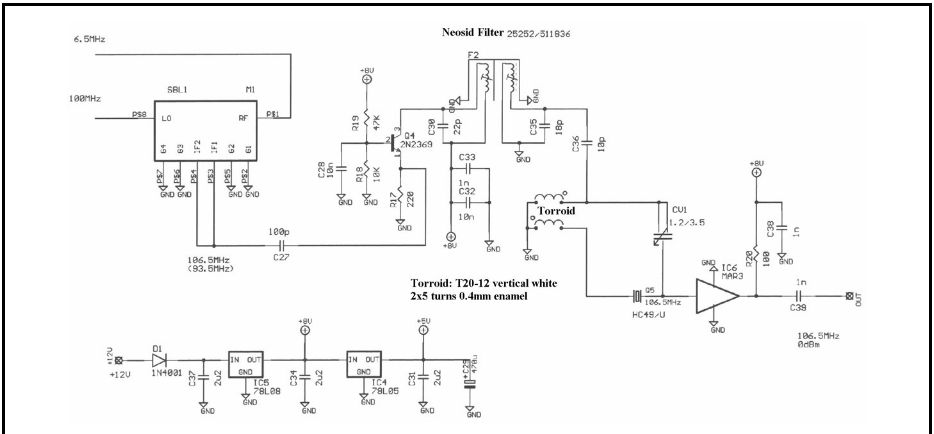

Fig 4b: Circuit diagram of local oscillator.

OCXO. A compromise is always needed between the loop stability of the PLL and any filter on the control signal.

4. The original idea

It is based on multiplication, division and addition of a 10MHz source to get the VHF signal. If the frequency required is an integer of 10MHz, we only need multiplier stages. But to get 106.5MHz is not simple. Fig 3 shows the block diagram of the proposed device. It can seem complicated but you can't get away from it without a DDS.

The major difficulty is to get a pure VHF signal free from close in noise and spurs. Filters are included at each stage, single or coupled circuits and a *crystal filter* at 106.5MHz in the final stage. In fact that is achieved using a standard overtone 5 or 7 crystal as used in VHF OCXOs. That filter allows a very clean signal without too much loss of amplitude.

4.1. Description

Figs 4a and 4b give the complete circuit diagram. First of all, the source sine wave 10MHz signal is squared to a CMOS level. Followed by transistor harmonic multiplier stages with a strict selection of the harmonic needed. Divider stages work with digital signals. Adding the 100 and 6.5MHz signals is carried out by a mixer.

The crystal filter comprises an adjustable capacitor to compensate the inter electrodes and the case capacitance. The setting is quite tricky and we can see the spectacular effect on the screen of a spectrum analyser.

5. Construction

The double side PCB is fitted in a 148 x 74 millimetres tined box. Components are SMD where available. Using the drawing, the construction is not difficult for a reasonably skilled OM.

6. Set up

Cores and capacitor adjustment require some measuring equipment to avoid misleading tuning. It is valuable to follow the signal along the stages similar to tuning a multistage transmitter. A spectrum analyser and a 30MHz oscilloscope are quite useful or maybe a calibrated grid dip meter

The recommended sequence is as follows:

- Output of the 10MHz source: sine wave - 10dBm or square wave 5V p-p
- Output IC1: 10MHz square wave 5V p-p
- Output IC2A: 1MHz square wave 5V p-p
- Setting of F1 and L3: sine wave on SBL1 at 100MHz (not 90 nor 110MHz !)
- Setting of L1 and L2: sine wave on pin 1 of IC3 at 13MHz (not at 12 or 14MHz)
- Output IC3A: 13MHz square wave 5V p-p
- Output IC3B: 6.5MHz square wave 5V p-p
- Input SBL1 mixer: 6.5MHz sine wave 300mV p-p
- Output mixer: 93.5, 100 and 106.5MHz

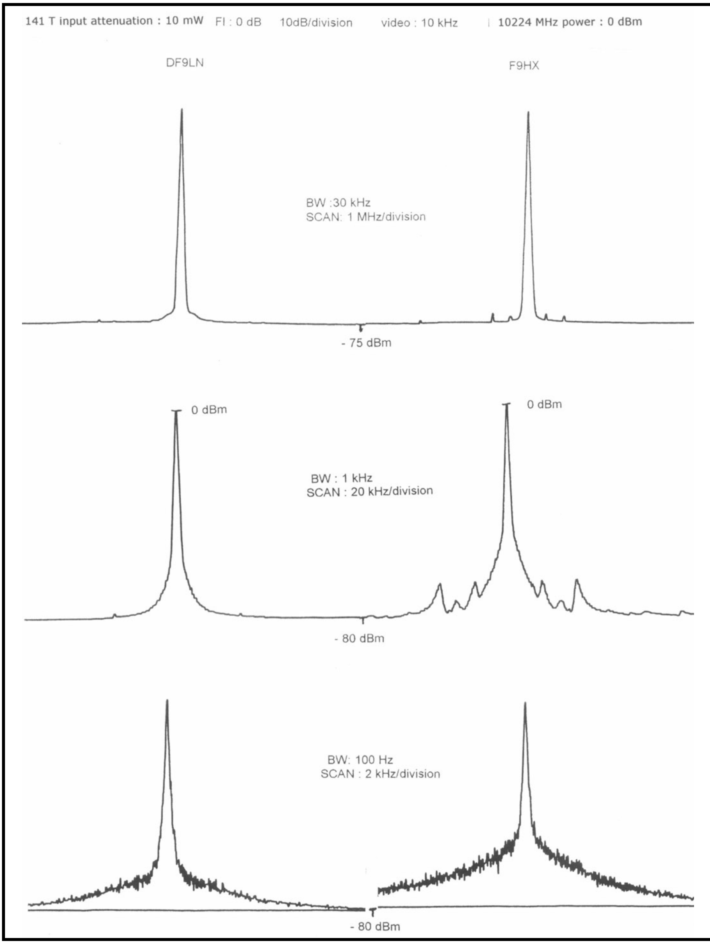

Fig 5: The 10,224MHz Spectrum.

- Setting of F2: 106.5MHz sine wave (not 93.5 or 100MHz)
- Setting of the adjustable capacitor to cancel all signals except 106.5MHz
- Power measurement on 50ohm load: + 0dBm 640mV p-p

7. Results

Several 10MHz sources as TCXO, OCXO, synthesiser, have shown similar results in spite of their different spectrum grades owing to the crystal filter action.

The spectrum at 10,224MHz is shown in Fig 5. In the field tests do not show spurs on receive or transmit on the 3cm band.

No frequency stability test have been done as the 10MHz source is only responsible for that. In practice with a standard 10GHz OCXO we can reach a 108 stability i.e. 100Hz at 10GHz. Temperature tests from 0 up to 46°C showed a few dB of output amplitude variations which is acceptable for the following multiplier stages.

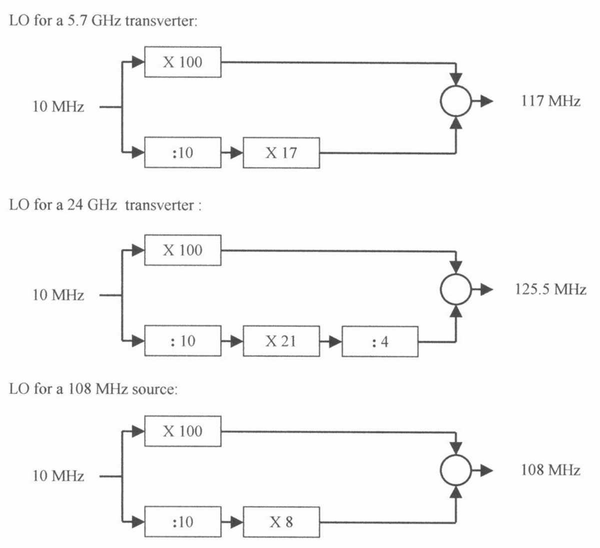

Fig 6: Local oscillator arrangemants for several applications.

8.

For other frequencies

Others SHF bands need different output frequencies. So we need to calculate which operations are required to get the right frequency always starting from 10MHz. Examples are given for some SHF bands in Fig 7.

Each time we have to use a custom cut crystal at the output frequency [6,7].

9.

Conclusion

The tests showed that this method is able to solve our frequency stability requirement at SHF with the availability of a high grade 10MHz source. This can be used for several outputs one for each SHF band.

10.

References

[1] Oven-Stabilised XO for VHF, DF9LN, DUBUS 3/1997

[2] Universal Microwave PLL System, WA6CGR http://ham-radio.com/wa6cgr/mwpll.html

The G8ACE Transverter for 76 GHz wa6cgr@ham-radio.com

PLL for Microwave Local Oscillators, VK5KK vk5kk@qsl.net

[3] DC9UP@germany.com

[4] A High Stability 10MHz Reference Oscillator, F9HX, Microwave Newsletter, May 1999