W1GHZ

MICROWAVELENGTHS

What Frequency am I On?

Our last column discussed dish pointing and how important it is to have both stations pointed at each other. The other part of finding each other is to be on the same frequency — a challenge at microwave frequencies.

For most common electrical parameters, like voltage, frequency, and resistance, a 1% tolerance is considered quite accurate. Frequency, on the other hand, must be much more accurate for narrowband communications to take place — a signal must fall within the passband of the receiver, with a bandwidth of less than 3 kHz, regardless of the operating frequency. For good quality SSB, we must inject a BFO within about 50 Hz of the original carrier frequency, and our oscillators must be stable enough to maintain the frequency for the duration of a contact.

We rely on quartz crystals for frequency control. Good crystals have a tolerance of 100 ppm (parts per million), or 0.01%, and the best tolerance ordinarily available is 25 ppm. This will only get us within 50 Hz for SSB up to 2 MHz, yet we operate SSB on all bands, not just 160 meters. Of course, we may have to tune slightly at the higher bands — that's why the radio has a big knob on the front. Judging by the amount of tuning I've noticed over a number of VHF contests, the typical VHF or UHF transceiver or transverter is within about 40 ppm.

Calibrate for Accuracy

To get closer to a desired frequency, most oscillator circuits have a provision for trimming the frequency. But the frequency still does not stay put — crystals age with time, drift with temperature, and start up at a slightly different frequency each time they are turned off and on again. Yet hams expect their rig to be exactly on frequency, especially if it has a digital readout. I've even heard of hams sending a rig back to the manufacturer because the frequency was off. If you have test equipment good enough to measure the frequency accurately, just adjust the oscillator. Even laboratory equipment must be calibrated periodically to maintain accuracy.

For microwaves, the problem becomes more difficult — 40 ppm at 10 GHz is 400 kHz — much too far to tune randomly. We must get closer to have any chance of finding a signal. In practice, it isn't this bad — the most common microwave transverters include a small crystal heater to improve stability. This seems to maintain the frequency within perhaps 20 kHz over a day of portable operation, close enough for most operating, once we find the nominal calling frequency so we know where to start tuning.

When both stations are within range of a beacon, then life is easy. Exact frequency doesn't matter when we have a common reference — "Let's go 50 kHz below the beacon." DX contacts are more difficult. If there is an intermediate station that both can hear, he can be a temporary frequency reference. Otherwise, we must calibrate our frequency as accurately as we can.

The standard calling frequencies for all the microwave bands from 2.3 GHz through 24 GHz are multiples of 1152 MHz, plus 100 kHz. Many microwave operators take advantage of this by having a frequency marker at 1152 MHz, listening to the harmonics as a local frequency reference, and then tuning up 100 kHz to the calling frequency. Figure 1 shows a unit from Down East Microwave (**www.downeastmicrowave.com**) that

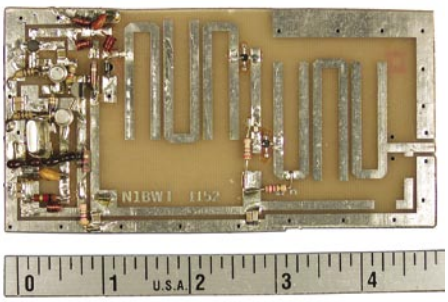

Figure 1 — 1152 MHz marker board from Down East Microwave.

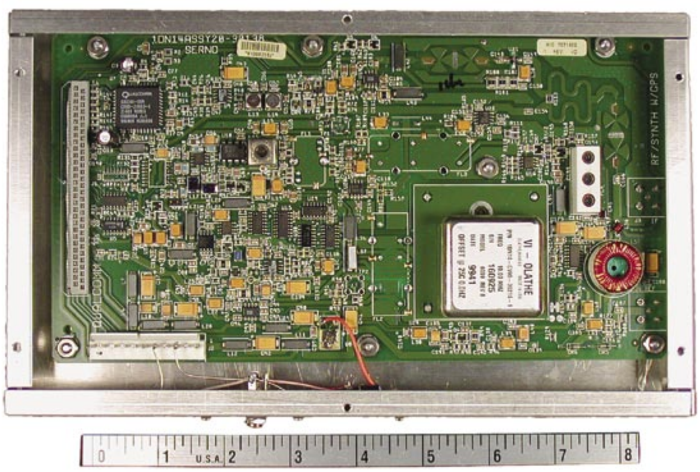

Figure 2 — 1152 MHz frequency synthesizer, modified and packaged up.

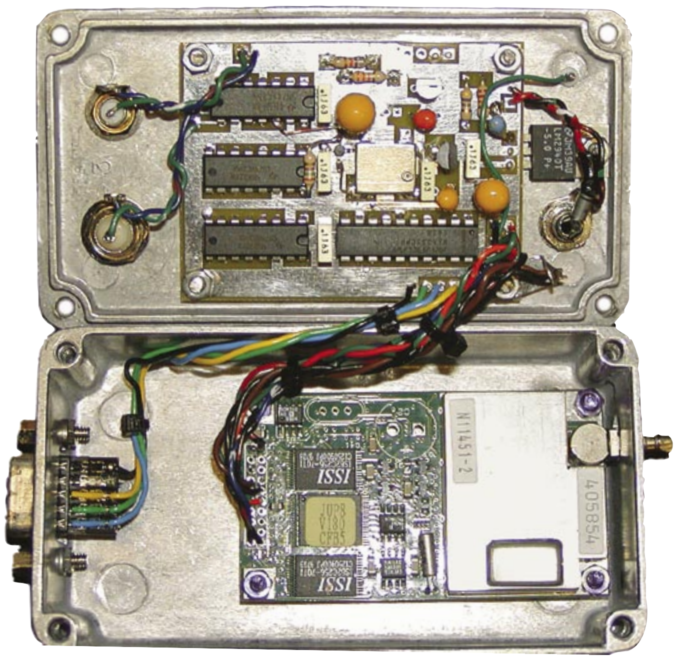

Figure 3 — N1JEZ GPS stabilized 10 MHz oscillator (the GPS engine is in the bottom half).

Paul Wade, W1GHZ ♦ 161 Center Rd, Shirley, MA 01464 ♦ w1ghz@arrl.org

uses an ordinary crystal as the frequency source, and Figure 2 is a surplus unit that uses a frequency synthesizer to generate 1152 MHz from a 10 MHz TCXO (Temperature Compensated Crystal Oscillator). These units are quite stable when run continuously in the shack — I have had one like Figure 2 running for more than 5 years, and the harmonic at 10.368 GHz is about 4 kHz high, but it does not vary by more than a kHz. Using this, I can always get my frequency close enough to find a signal.

However, when we take these simple frequency references out in the field, with varying temperature and voltage, they are not as stable, and the frequency uncertainty increases.

We need a more accurate frequency source that can tolerate mountaintop conditions and abuse.

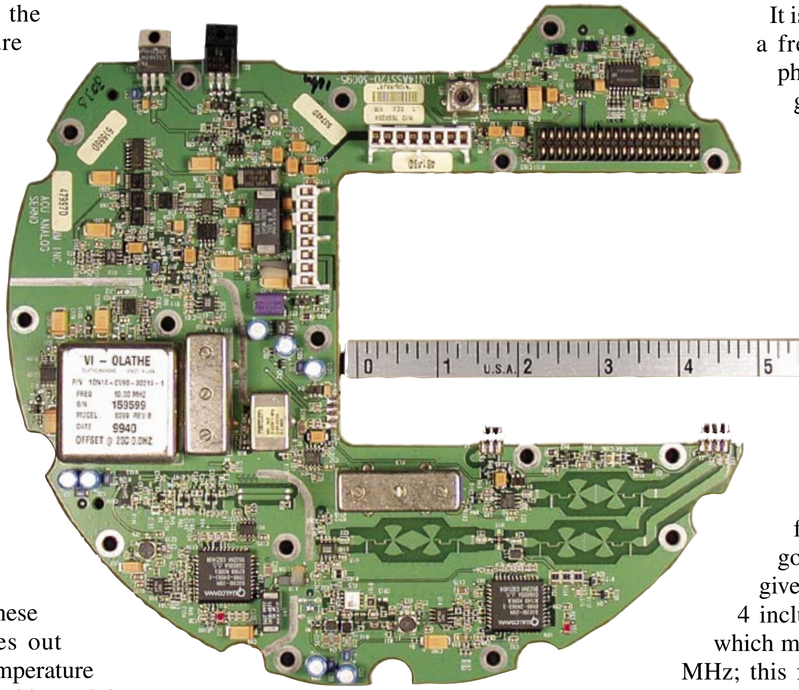

Figure 4 — Surplus frequency synthesizer from Microwave Group of San Diego, ready for conversion.

Enter GPS

One very accurate frequency reference that is widely available is GPS — each Global Positioning Satellite carries a set of atomic clocks. Some GPS engines (the guts of a GPS receiver) have a reference output at 10 kHz or 1 Hz. G3RUH has published a simple circuit[1] to discipline a 10 MHz crystal oscillator with the output so that its frequency is nearly as accurate as the GPS standard. N1JEZ fit the GPS engine and stabilized oscillator board in the compact box shown in Figure 3, and he has made oscillator interface circuit boards available.[2]

How can we make use of our accurate 10 MHz? Many of the microwavers in New England are using it with a frequency synthesizer like Figure 2 in place of the TCXO to make a very accurate frequency marker at 1152 MHz rich in harmonics, providing frequency markers for all the calling frequencies up to at least 24,192 MHz. Another version of the frequency synthesizer is shown in Figure 4. A limited number of these are available from the Microwave Group of San Diego.[3]

But why not just use the frequency synthesizer to generate an accurate local oscillator directly? Unfortunately, fractional-frequency synthesizers generate non-harmonically related frequencies with internal digital dividers which generate significant phase noise. Phase noise is insidious — it doesn't sound any different than any other noise. If your receiver local oscillator has large phase noise, it will mask weak signals without being noticed. The phase noise from some synthesizers is obvious to the ear, providing a musical note (if you call a circular saw musical!) that differentiates the marker from a random "birdie."

It is certainly possible to make a frequency synthesizer with phase noise nearly as low as a good crystal oscillator, but I do not know of any readily available units that I would use for weak signal work. Part of the problem is that it is very difficult to measure phase noise, so it is hard to know whether there is a problem. Perhaps I am overly cautious, since some of my best contacts are only a few dB out of the noise, but many stations on the West Coast use frequency synthesizers with good results. If you'd like to give it a try, the unit in Figure 4 includes a second synthesizer, which may be programmed to 2556 MHz; this frequency multiplied by 4 makes a good LO for 10 GHz.

REFLOCK

For minimum phase noise, we are better off using harmonics of a good crystal oscillator to generate our local oscillator. Periodic adjustment may be required to keep it on frequency. Even better, we can automate the adjustment — CT1DMK developed a "REFLOCK" circuit that gently corrects the crystal frequency to an accurate reference frequency.[4] By keeping the adjustment range very small and correcting very slowly, the phase noise of the crystal is not degraded. Luis integrated the circuitry into a small programmable CPLD chip, and VE1ALQ has the chips and circuit boards available at reasonable cost.[5]

The REFLOCK board may be used with the crystal oscillator in any of the commercially available microwave transverters, or with the oscillator of a surplus "brick" oscillator such as that shown in Figure 5. These units use a phase-locked loop to generate a signal at a harmonic of the crystal oscillator, providing a signal that is quite clean and stable.

Using at least one of these techniques, we can be confident that we are listening close to the desired frequency (but don't be afraid to tune a bit). The final part of coordination is to decide when each station transmits — if both stations are listening, neither will hear anything!

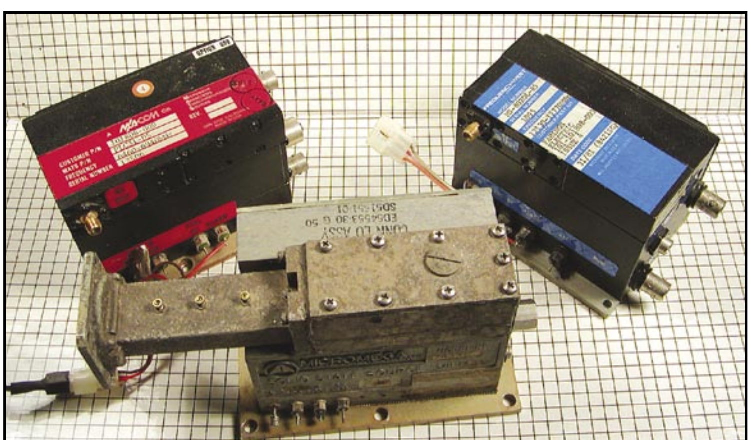

Figure 5 — Surplus microwave phase-locked oscillator "bricks."

[1]"*Simple* GPS Stabilised 10 MHz Oscillator," **www.jrmiller.demon.co.uk/projects/ministd/frqstd.htm**.

[2]**mysite.verizon.net/n1jez/**.

[3]C. L. Houghton, WB6IGP, 6345 Badger Lake Ave, San Diego CA 92119; **clhough@pacbell.net**.

[4]**gref.cfn.ist.utl.pt/cupido/reflock.html**.

[5]**www.ve1alq.com/cpldpll/cpldpll.htm**.