DC to Daylight—*Part 2*

In the first installation of "DC to Daylight" in July 2003 *QST*, we reviewed the atmospheric absorption and modes of propagation for EHF. Remember that frequencies from 30 GHz to 300 GHz are called the EHF band, for extremely high frequency. Someday, we may also explore the vast range of frequencies spanning between 300 GHz and light at over 1000 times that frequency. For now, it is a big enough challenge to build equipment and operate in the EHF range. In this installment, we explore devices and circuits for these frequencies, and give some examples of successful ham radio communications in the rarified portions of our hobby.

Devices and Circuits for EHF

Figure 1 shows a very simple, and common transceiver for EHF.[1] Often, the use of multiplying mixers allows the use of a lower frequency (more easily generated) LO. For instance, to make a 145 GHz contact, one might use a 47 GHz (×3) or even a 11.8 GHz (×12) local oscillator and an appropriate mixer. The noise figure of the mixer increases (gets worse) both as the frequency goes up and as the multiple increases, so there is a penalty in using higher harmonic numbers. Typical harmonic mixer LO power levels are around +20 dBm maximum (100 mW) and transmit IF power of 0 dBm (1 mW).

If your approach will use wideband FM and thereby reduce the need for frequency stability it is possible to eliminate the IF/mixer and directly modulate a source, such as a Gunn diode oscillator. In a design where DX is being attempted, however, wide bandwidth costs too many dB.

Oscillators

Reasonably stable microwave oscillators start with a crystal or a synthesizer, and then through multiplication and phase locking of other oscillators, generate microwave energy. Oscillators that are locked this way include DRO (dielectric resonant oscillators), and cavity oscillators to produce energy in the 10 to 20 GHz range for further use. This kind of oscillator is often found at hamfests. Gunn oscillators can be made to work (and can be locked) up to about 100 GHz—but are much more difficult to find surplus, and the locking circuitry usually has to be developed by the builder.

Frequency Stability

Once locked, microwave oscillators behave very similarly to their locking sources (with error, stability and phase noise appropriately multiplied). For instance, if you use a crystal that is drifting ±10 Hz each hour, running at 100 MHz, which through various multiplication chains eventually is used to generate 145 GHz, then the multiple of 1450 will turn the 10 Hz/hour instability into 14.5 kHz/hour of drift. Ovenized crystals are likely to hold to within 1 Hz over several minutes (with absolutely perfect power supply and stable components in the oscillator). You do not want the additional burden of hunting for the frequency over one or two dozen kilohertz when trying to make a difficult EHF contact. High-stability OCXOs and rubidium standards found at hamfests need to be employed for successful narrowband DX EHF communication (where we typically use CW).

Power

Gunn diodes can be constructed to oscillate at frequencies across the entire microwave region, up to 100 GHz. They are capable of power over 200 mW, although the power capability drops somewhat as the frequency increases.

The Gunn can be frequency and phase locked by controlling bias (see Figure 2), and with some difficulty it can even be amplitude modulated. It has quite a bit of phase noise if it is not locked, and tends to drift with changes in temperature, cavity and age. A Gunn must be locked for narrowband EHF work in order to achieve acceptable stability and noise.

There are some commercially available transistors that will generate +20 dBm (100 mW) up to about 50 GHz. They are very expensive, and only available in die form. There are laboratory experimental amplifiers that have been tested to as high as 110 GHz, producing about 100 mW output, and although there is unlikely to be commercial availability for several years, 100 mW at 120 GHz is very QRO!

Finding Mixers

As mentioned above, mixers have more noise as the frequency increases and more noise as the harmonic multiple goes up. There are general-purpose multiplying mixers that are used to extend the frequency range of spectrum analyzers. A pair of these were used to make some of the first Amateur Radio EHF full duplex CW radios. Typical configurations have the subharmonic LO and IF on the same connection, so a diplexing filter is required for operation.

There are mixer circuits available from DB6NT as published in *DUBUS* and sold by Kuhne Electronic for 47, 145 and 245 GHz.[2] There are also mixers to be found in surplus and flea markets.

[1]Notes appear on page 89.

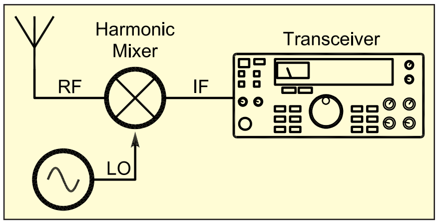

Figure 1—A narrow-band EHF radio consisting of a harmonic mixer, LO and transceiver.

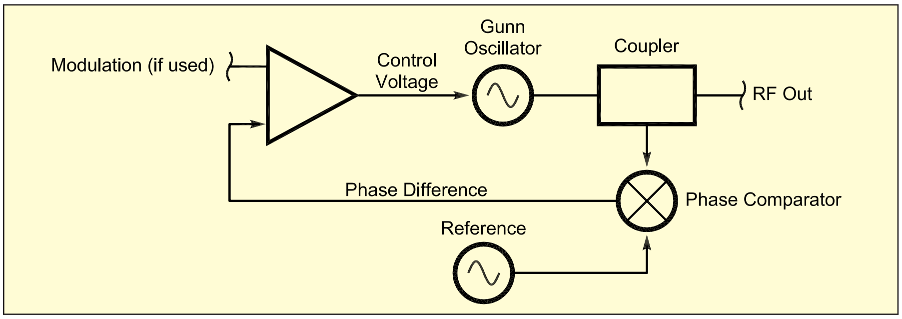

Figure 2—Voltage controlled locking can produce stability just as good as the reference.

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General Motors and others have established an automotive radar band at 76 GHz, and the FCC has moved amateur privileges in that band to accommodate the radar band. Someday there will be surplus parts in the junkyard! Although there is not a large need for low-noise in this application, development of affordable sources, receivers, transmitters and antennas is underway.

Dishes and Lenses

Antenna gains at these frequencies are pretty impressive. A properly designed and fed 18 inch dish (1/2 meter) at 245 GHz can provide nearly 60 dB of gain! This is enough to turn 1 µW into 1 W of ERP. Although multimillion dollar dishes have been built up to 13 meters in diameter that are effective to 300 GHz, most antennas for these frequencies are much smaller (less than a half meter). Unfortunately, dishes that maintain ±0.2 mm across their surface are not easy to find. It is possible that amateur telescope mirrors could be adapted. Their comparatively high f/D (they are exceedingly shallow) demands selection of appropriate feed horns.

Lenses are often used in millimeter wave applications for several reasons. They can be machined with relative ease (they are made of plastic), and can be fed with a horn from the back eliminating feed shadow, and placing the electronics right on the feed. Elimination of the large waveguide losses at these frequencies translates into higher performance.

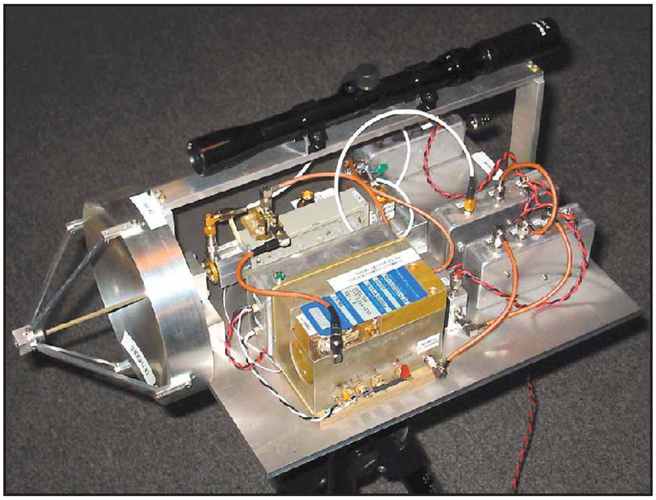

Figure 3—Here is WA1ZMS's 241 GHz radio. On top is a rifle scope for pointing.

From Brian Justin, WA1ZMS

After phase-locking the Gunns to 100 MHz homebrew 60 deg OCXOs, W4WWQ and I did 3.8, 6.1, 7.3 and finally 11.4 km.

WX at time of 11 km QSO was: 3/11/02 0225Z, Temp 5.6°C, Dew Pt –15°C, RH 21%. Calculated loss of 0.647 dB/km.

Each QSO was done on a slightly drier day than the last. I kept the OCXOs running the entire winter season by battery power when away from the QTH and with a dc supply when not out making QSOs. The goal was to age the crystals and keep the things as stable as possible.

Except for trying new sites at night only to find later in the day that a tree branch was in the path 500 ft away, we were able to make just about every QSO we've tried to do. About an 80% success rate! To me, this just proves the Leibe model. Most of the times that we didn't make a QSO, it was due to a tree that we didn't see because it was nighttime or equipment trouble like a PLL that wouldn't lock when it was really cold outside. The gear problems can be fixed by letting the equipment sit outside on a winter's night unpowered and see if it will operate after being ice cold for several hours. If it doesn't work, it's not worth taking out roving for DX records!

This same gear was used for my 1.4 km QSO on 322 GHz by tuning the RX IF to what would be the result by having the diode multipliers run in 4th harmonic mode.

Operating

Just a few years ago, getting on the upper bands meant building two complete stations because there was no one else on. Now it is common to make contacts on 47 GHz on the national calling frequency of 47,088.100 MHz. The higher bands, however, are still only workable with prior arrangement. As of this writing, there is no agreement in the US on a calling frequency for the 78, 120 or 241 GHz bands. A recent conversation on one of the microwave e-mail reflectors came up with no fewer than five calling frequencies in use on the 78 GHz band. Every suggested frequency made good sense. The best bet is to find out who is on in your area and agree to use their frequency. Eventually, there will be enough activity to settle into a good calling frequency.

There are plenty of records to be made and to extend. Since most QSOs on the amateur millimeter wave frequencies are done with line-of-sight paths, much future work lies ahead for exploring non-traditional modes of propagation. When the author made the world's first valid amateur contacts on 120 GHz and 145 GHz in the early 1990s, the distance race had begun. It seems that just about every season, all of the EHF records are extended. The first VUCC has been awarded in North America for both the 47 and 78 GHz bands.

One of the operators/builders who has extended and holds several records is Brian Justin, WA1ZMS. His 241 GHz radio is shown in Figure 3. This radio is based on a phase locked 40 mW, 80 GHz Gunn oscillator and an X3 GaAs Schottky diode multiplier. A very high stability 10 MHz OCXO is used as the PLL frequency reference. With dc bias changes, the multiplier also serves as a receive harmonic mixer. The multiplier produces 1 mW of transmit power and as of this writing has been used in a QSO with a similar radio at a distance of over 11 km. The antenna used with the radio is a homebrew 150 mm diameter parabolic reflector with a Cassegrain feed. A telescope slow-motion control head was used to help aim the <0.6° beamwidth antenna. A 432 MHz rig serves as the IF radio.[3] The complete radio is designed to operate on a 12 V dc battery supply and is easy to transport to high, snow covered mountaintops during the winter where the best "mm-wave weather" is found.

Interested in EHF?

All it takes to get on is two hams who want to put in the effort and dig around for parts. EHF is one of the wide open areas for ham radio experimentation, records setting and serious technical challenges. Have fun.

I want to thank Brian Justin, WA1ZMS, for his help with this column. Next time we will return to SHF as we take a closer look at building a 24 GHz station.

Notes

[1]Williams, T. and J. Mead, "Contacts in the Upper EHF Bands," *Proceedings of Microwave Update 1993* (Newington: ARRL, 1993).

[2]Kuhne Electronic GmbH can be found at **www.kuhne-electronic.com/**.

[3]Audio recording of a portion of the 11 km, 241 GHz QSO can be found at **www.mgef.org/audio/241GHz_record_11_4km.wav**.