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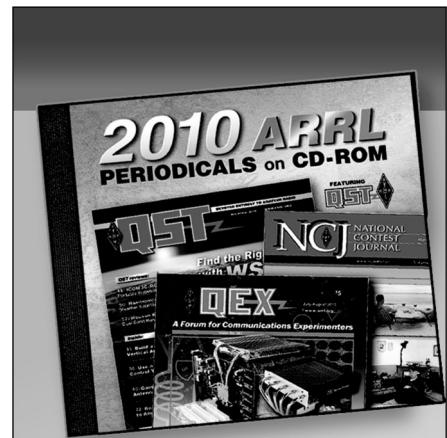
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MICROWAVE LENGTHS

The Transverter

Why is it that great DX happens much more readily with CW and SSB than with FM or television? It's a matter of bandwidth. If you communicate with less bandwidth, then the same equipment can communicate over greater distances. This is the driving force behind the growing popularity of microwave transverters. Over-the-horizon contacts, scattering signals off of rain and mountains, even doing moonbounce (EME) all depend on recovering a very weak signal.

Hams who want to get into microwaves build upon a HF or VHF multimode radio. What they need is a way of converting this into a microwave radio, while retaining frequency control, memories, bandwidth control, noise blanking and all those convenient features of a modern communication device. The transverter accomplishes just that by adding a frequency to the transmit signal and subtracting it from the receive signal. In a real sense, the HF or VHF radio is then relegated to operation at an intermediate frequency such as 28 or 144 MHz. Microwavers refer to their transceivers as "IF rigs."

Inside the transverter we see the workings of just about any super-heterodyne radio (Figure 1). One important component is a local oscillator (LO) that set to a frequency that is the difference between the transceiver's frequency and the desired microwave frequency. Another is a mixer, which will take two input frequencies and produce their sum and difference.

Q: How are microwave local oscillators made?

A: The LO in a microwave transverter must be quite stable to allow CW and SSB QSOs to proceed without significant retuning. The LO must also be almost exactly on a known frequency in order to expect to find the other station quickly. Above all other characteristics of a transverter that can make or break a con-

tact, having the LO on a known frequency and stable are probably the most critical. Fortunately, there are effective and affordable solutions to meet this need.

The two most common LO sources for transverters are the multiplied crystal oscillator and the phase-locked microwave oscillator. Both of these LO schemes derive their basic accuracy and stability from a crystal oscillator running in the 100 to 200 MHz range. When this oscillator is reasonably temperature stable, usually accomplished with a temperature stabilized miniature oven, the resulting microwave frequency is likewise stable. After warm-up, a simple ovenized 200 MHz oscillator stays within a few tenths of a hertz over the time that typical contacts are made. The 200-MHz oscillator is multiplied by approximately 50 to achieve an LO for a 10.386 GHz radio. One hertz of variation in the crystal oscillator will result in about 50 Hz change at 10 GHz, a noticeable but tolerable change. If the LO is to drive an 80 GHz or 145 GHz radio, the sensitivity is ten times more critical. LO techniques for Extremely High Frequency radios will be discussed in a future column.

A multiplier chain is the most common LO generation circuit in modern Amateur Radio transverters available as kits and ready-made systems. The multiplied crys-

tal oscillator is just what it sounds like. The example in Figure 2 shows the new trend in these designs. A 189.3334 MHz output from an ovenized crystal oscillator is multiplied by 6 to 1136 MHz, filtered and then multiplied by 3 and filtered again, resulting in 3408 MHz. A further $\times 3$ multiplier produces 10,224 MHz. Each stage requires filtering to remove the unwanted multiples and fundamental. Where large multiplication steps are taken in the multiplier chain, higher quality filtering is needed. Earlier designs used lower frequency crystals and more multiplication steps, requiring less stringent filters, but creating a more complicated circuit that requires more filters and can have more birdies.

Microwave LOs in commercial and scientific converters are usually Phase Locked Oscillators or PLOs. These items cost over a thousand dollars if purchased new. However, there have been many of these PLO "bricks" at flea markets and auction sources over the past decade because of the replacement of commercial microwave links with fiber-optic circuits. I have found surplus PLO bricks to range in price from \$50 down to \$5, and have had only about one failure out of ten purchased. There is not enough space in the column to describe the internal workings of these units. The negatives of using a surplus PLO include the effort to retune, acquisition of a special crystal, greater weight and the need for -20 V at 1 A of power that most of them require. The positives include excellent phase noise, great stability after warm up and low cost.

Q: Why do mixers need filters?

A: For receive, our mixer will take the 10,224 MHz of LO and the 10,368.1 MHz of the station calling us, and create $10,368.1 - 10,224 = 144.1$ MHz. By having the receiver in our VHF multimode radio tuned to 144.1 MHz we will hear the calling station. Likewise, when we need to respond, our 144.1 MHz trans-

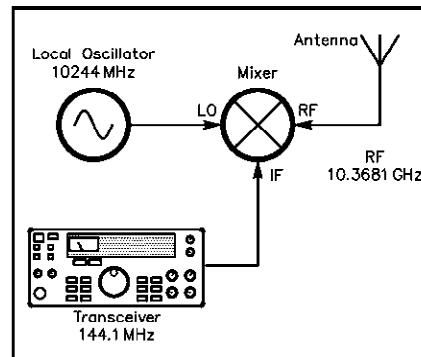


Figure 1—A simplified drawing of a transverter.

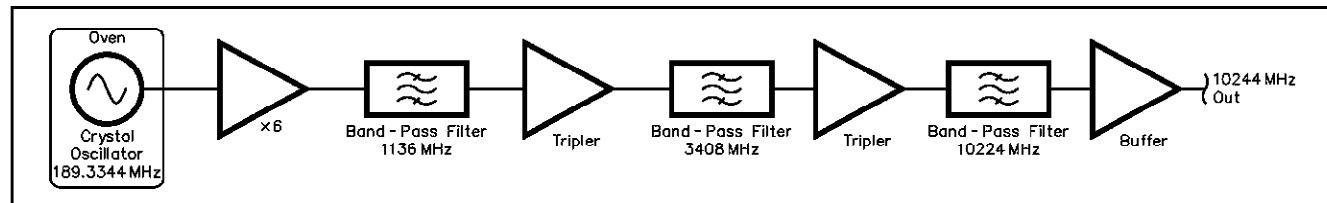


Figure 2—A local oscillator multiplier chain.

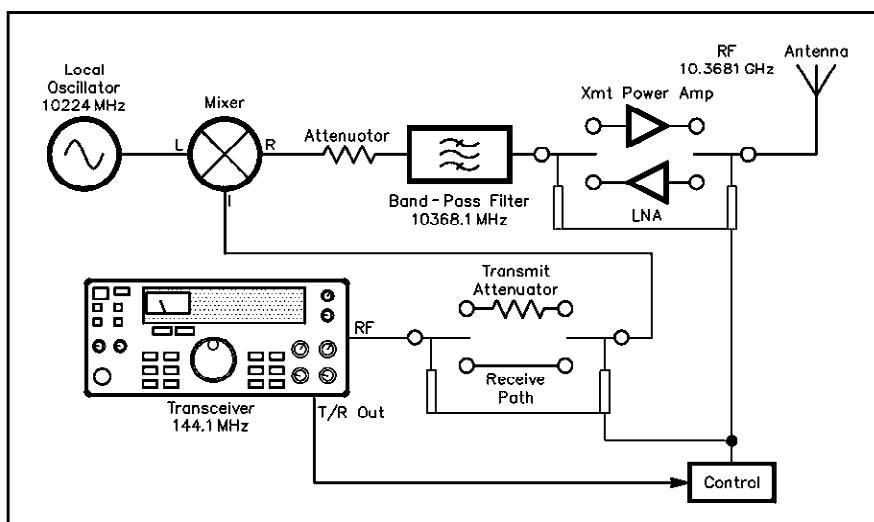


Figure 3—A more realistic transverter system.

mission will be mixed with the LO, so that $10,224 + 144.1 = 10,368.1$ MHz, will be produced and transmitted.

There are some problems that have been overlooked in this simple example. Because mixers both add and subtract frequencies, our example receiver mixer will also perform $10,224 - 10,079.9 = 144.1$ MHz. This means that any signal at 10,079.9 MHz will also be received within the same passband at 144.1 MHz. Although there may be no signals at that frequency, there is always noise, and to have the best sensitivity this noise (and potential interference) must be filterer out. Without the filter, 3 dB of unwanted noise will be added to the received signal. Unfortunately, if a filter is connected directly to a mixer the filter reflects the unwanted products (frequencies) back into the mixer, and those products are re-mixed causing other products and distortion. Therefore, an isolation amplifier or an attenuator is placed on every port of a mixer that has filtering. Another solution is to use a constant impedance (diplexing) filter, but they are difficult to construct at 10 GHz.

Although simply connecting the input of the mixer to the antenna will produce usable results on receive, low-noise amplifiers are available that will improve the signal to noise ratio, and so LNAs are usually placed between the receive antenna and mixer at all but the very highest microwave frequencies.

A similar frequency image problem exists on the transmit side, where $10,244 - 144.1 = 10,079.9$ MHz is produced at the same signal level as the desired product. A filter with the same characteristics (in our design, the same filter) can be used to remove this unwanted product. In some cases, this product might be outside the ham bands, and therefore not legal. The other reason to filter is that any subsequent (ex-

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pensive) power amplification will be wasting half of its power capability amplifying an unwanted frequency. This equates to an effective loss of 3 dB of average output power, and up to 6 dB PEP, if filtering is not used prior to the amplifier. Also, there is some leakage of the LO through the mixer, so it is good practice to filter out the LO frequency as well.

As with most RF circuits, there are variations on the theme. In one scheme separate transmit and receive mixers are used, and the LO power is either divided into each mixer or a relay is used to switch the LO between them. Although two filters are needed, the two coaxial relays simplify to SPDT rather than DPDT types (Figure 3).

Q: How are filters and mixers constructed?

A: Microstripline and cavity filters are most often used in amateur microwave

transverters. Microstripline filters consist of patterns of printed circuits that are frequency selective. Cavity filters are usually constructed from small plumbing parts that are soldered to circuit boards and then tuned with setscrews. Waveguide filters are also used, most notably at 10 GHz and higher. These consist of a piece of waveguide with metal rods and irises inserted. Tuning is performed with screws.

A mixer consists of diodes and transformers. At microwave frequencies the transformers are usually printed circuits. There are packaged mixers with connectors available new for about \$300 and surplus for about \$40. Some transverter designs implement mixers directly on the printed circuit board along with other transverter components. Such mixers cost only as much as the diodes, a few dollars.

A: One of the difficulties in interfacing transceivers to transverters is to get all circuits switched in the proper order so that sensitive components are not damaged. Most transceivers have a single antenna connection and produce 10 W or more of RF, whereas most transverter designs inherently have separate transmit and receive circuits and need only 1 *milliwatt* of RF drive.

To connect the transceiver to the transverter, an attenuator needs to absorb excess transmit RF and control must be provided for internal relays and amplifiers. Usually, some auxiliary T/R output from the transceiver is used. In a permanent shack installation, microwavers often employ a sequencer as the master controller of all transverters and auxiliary equipment. For a mountain-topping microwave rig, a single transceiver needs to be interfaced to a single transverter.¹ Most commercially available kits and transverters have interfacing circuits or available external sequencers to make this work well. Each transceiver has its own quirks, so it's a good idea to get a design that has proven to work well.

In the next issue we will be looking at microwave antennas. We will explore how dishes and horns work, and take a brief look at waveguide.

I wish to thank Steve Kostro, N2CEI, for assisting in review of the column this month. Steve designs and makes practical microwave systems for amateurs. He owns and operates Down East Microwave, one of the steady sources of transverters and other components for amateurs interested in microwaves.

¹Paul Wade, W1GHZ, "A Fool Resistant Sequenced Controller and IF Switch for Microwave Transverters," *QEX*, May 1996. 