By Chuck Houghton,* WB6IGP

Components for 10-GHz and Up Transceivers

Well, here we are. I never thought I would be talking about working 47-GHz using some sophisticated junk-box parts. However, surplus material is available, and with a diligent search of surplus outlets you can obtain components that can be assembled into a working transverter as will be described here. This was our first attempt. It's rather crude, but it works, which shows that the construction of a simple homemade mixer for 47 GHz is possible.

It was not an overnight collection binge that started the effort, but rather a slow process aimed in this direction. Collecting material for a project takes time, especially when you are not ready to sell the family farm to purchase the parts needed. Most of the material used in this project can be obtained in ready-made kit form, and the kits are quite good. However, that is costly. We chose another avenue, and that was to sit and wait for the parts to come our way. The idea was to slowly gather the components to construct a microwave transverter. All you need is some luck in locating key parts and the time to find the components needed. Take, for example, my first SSB transceiver for 10 GHz.

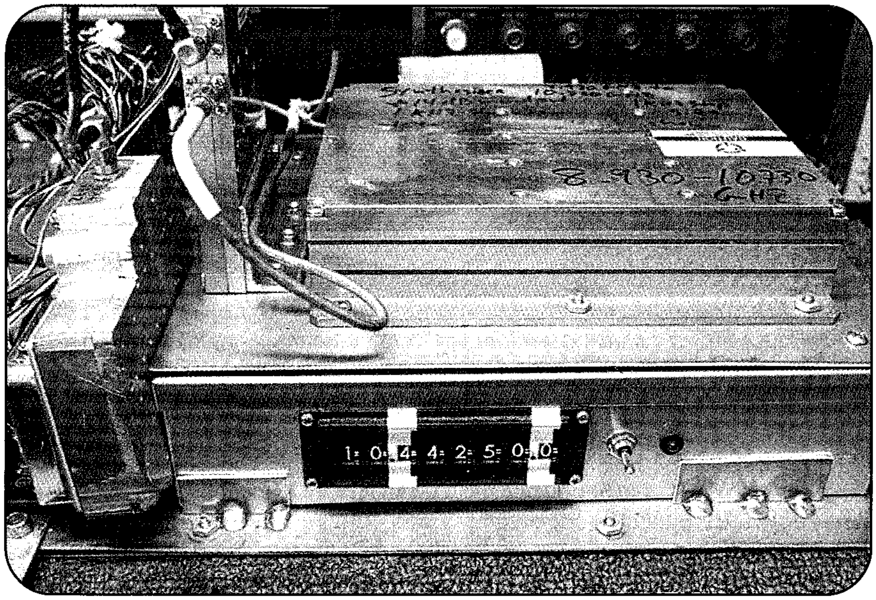

Photo A. Front view of 47-GHz rig. The synthesizer is at the top right, sitting on top of the BCD controller chassis. The synthesizer is capable of operation from 8930 to 10730 MHz with +14 dBm output. Frequencies in as fine as 1-kHz steps are set throughout the frequency range and are controlled by BCD switches on the front panel in conjunction with the 10-MHz internal clock oscillator. Close-in phase noise of the synthesizer is better than –90 dB.

An SSB Transceiver for 10 GHz

The SSB rig was assembled using a surplus TVRO RF preamp, a mixer found at a local swap meet, four SMA relays, and a Frequency West microwave "brick" oscillator. Additional material included a 10-watt TWT (traveling wave tube) power amp and TR switching control with time delay for transmit relays. The time-delay control board was the idea of Kerry, N6IZW, and he designed it with receiver protection circuitry, allowing the TX relays to be slow to operate and fast to release, with the reverse for the RX relays. This way the receive preamp was protected from the transmitter by switching times. It allowed the receive relay to release from the antenna before it operated the transmitter relay. This circuit was constructed dead-bug fashion, although I made a circuit board for it. I never installed it, though. The 10-GHz rig is still wired that way after ten years. I should have revamped the circuit with PC boards, making it more reliable and better looking as well.

This rig has withstood the test of time. It has even survived my grandsons' tinkering with it. I had mounted the 10-GHz rig in an old BC221 surplus WW II frequency-meter case in my grandsons' tree fort in our backyard, pointing it at a local mountain for reflection contacts on 10 GHz. With their sandbox under the fort, the kids filled the outdoor case with about 25 pounds of sand. Needless to say, some shaking out was needed and I thought it was a goner. It took a while to dump all the sand and vacuum it out, but it's still working just fine now, with a lock on the case. This little episode demonstrated certain reliability in construction even back then in my early years of putting surplus parts together. I still can imagine the effort it took to haul all that sand up into the tree fort and dump it carefully into the muffin-fan exhaust hole. There still is sand embedded in the RTV used to harden the circuit boards, using the RTV like a potting compound to protect the wiring and component parts. The rig is still switched by the original four SMA relays

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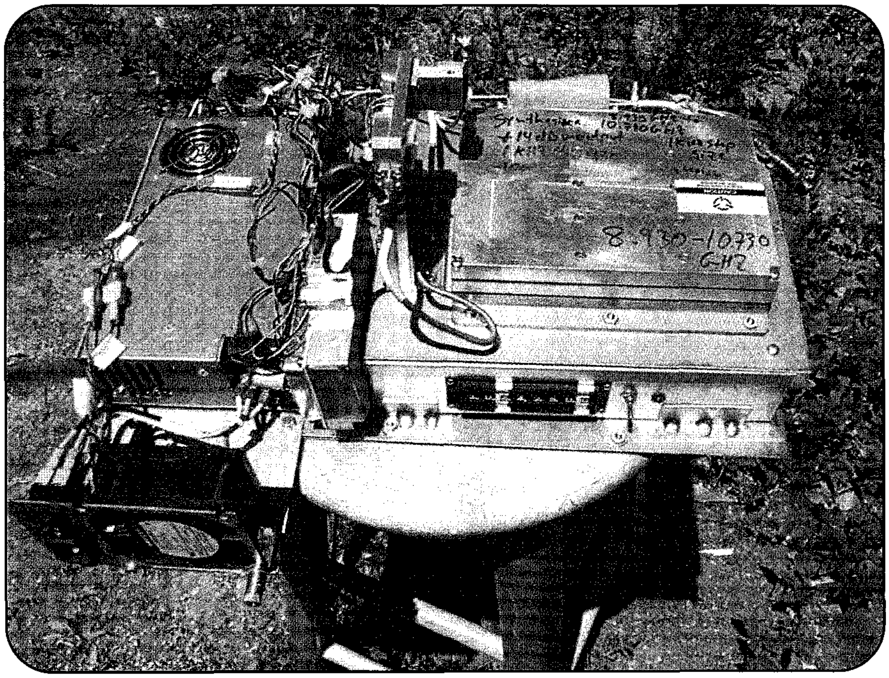

Photo B. Top view of the 47-GHz rig. The Verticom synthesizer is to the right. The 2640-MHz synthesizer is at the bottom left in the aluminum cutout shield compartment. The Pecom 23-GHz TX module is just above the 2640-MHz synthesizer. The switching regulated power supply is to the far left, with the cooling fan in front of the power supply.

controlling a TWT 10-watt amplifier and a series of two RF preamps (one preamp to drive the TWT).

The unit was a collection of quite a few components all scrounged from surplus dealers or swap meets and assembled over time.

The 24-GHz Transceiver

Establishing a station on 24-GHz SSB was quite unexpected, as my steady hands and eyesight are not that of my younger years. I put off that project until the time was right and waited to collect parts the economical way. However, a most unlikely set of circumstances presented itself in the form of a transverter that was sold as part of an estate sale. I could not turn down the offer of a complete transceiver fully modified from surplus. It was a 24-GHz Pecom unit modified by Sam Lutweiler, K6VLM (SK), of the San Bernardino Microwave Society (SBMS). Obtaining the completed transverter would help in tracing out his conversion details.

I undertook this project, as I was involved in helping to obtain quite a large quantity of these surplus Pecom units. We obtained two different types of transverters that were what we call high side LO (local oscillator) injection and low side injection. The low side injection had a capability of operation at 23.525 GHz unmodified in the TX module. (This TX module will become a critical component of a rig for 47 GHz.) To put things in perspective, I was still tracing the circuitry of these units from our surplus haul at the time when Sam had already modified two Pecom transceivers for 24.192 GHz and had installed one on top of his roof for operation. We had a long phone call with Sam describing the modifications he developed. I tried to take notes and keep up with him. I wish I had used a tape recorder to record Sam's conversion technique, as the next I heard he had passed away. That left us to put together the hardware and notes to document his conversion.

Of primarily interest were the modification and construction techniques used by Sam in his conversion. Sam had accomplished this conversion with great success. As complicated as Sam's process seemed to me at the time, it demonstrated his deep understanding of conversion process for the Pecom units. We were fortunate enough to obtain a transceiver and a box of papers, which had some raw conversion details on procedures he had used in his modification process. For example, Sam's test sketch showed his scheme to mix two signal generators, one at 18 GHz and the other at 6 GHz, to align filters on the PC boards, as he did not have a 24-GHz generator.

Making a 47-GHz Transverter

In the meantime, Kerry, N6IZW, also was working out his conversion methods on the Pecom modules for a 24-GHz transceiver, and he observed another use for the TX module. He saw the relationship of the frequencies used in the unmodified 23-GHz transmit module. In its original configuration it was driven by a 9-GHz LO and had an IF frequency of nearly 3 GHz. This observation presented some interesting possibilities for its use on 47 GHz. With a 10.44250-GHz LO drive, which is doubled in the Pecom TX module mixer, and with IF drive of 2.640 GHz, an RF output of 23.525 GHz is produced. This method allows the Pecom TX module to operate nearly stock, driving a final output mixer, doubling the drive (23.525 GHz × 2 = 47.05 GHz). This was used with a 2-meter IF of 145 MHz, giving 47.195 used with the final mixer doubler circuit. (This mixer doubler is home constructed and nothing special, showing Kerry's thinking out of the box with this harmonic generator, or mixer.)

LO driving the two anti-parallel diodes attached to a section of 141 coax, or on the back of an SMA connector by themselves, makes a great harmonic multiplier. Adding the fine wire makes an RFC (radio frequency choke) to couple to the IF port of a mixer for an IF frequency used at 2 meters.

A little figuring revealed that by using components on hand the following could be constructed and given a try. Working backwards, if we used 47.05 GHz for an LO, that divided by 2 equaled 23.525 GHz (the Pecom TX unit driver output). We had 2.620-GHz Qualcomm DRO (dielectric resonant oscillator) synthesizers on hand, and we used a modified one for 2640 GHz to be the IF input driver on the Pecom TX converter. That meant that 23.525 GHz, the TX output, minus 2.640 GHz equaled 20.885 GHz, which is twice the input drive LO to the TX module. Dividing that by 2 equals 10.44250 GHz. Other frequencies are possible as well. It just depends on what you have on hand.

This IF synthesizer is a surplus Qualcomm DRO PLL board and is available from the author, should the stock fre-

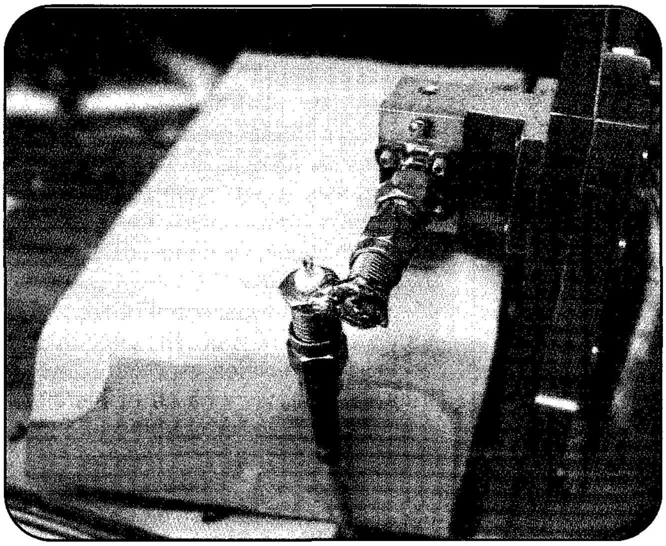

Photo C. Close-up of the 47-GHz system mixer showing the tiny diodes (you can barely see them) and IF cable (145 MHz) and SMA connector pointing downward in the original test configuration. This was the first design.

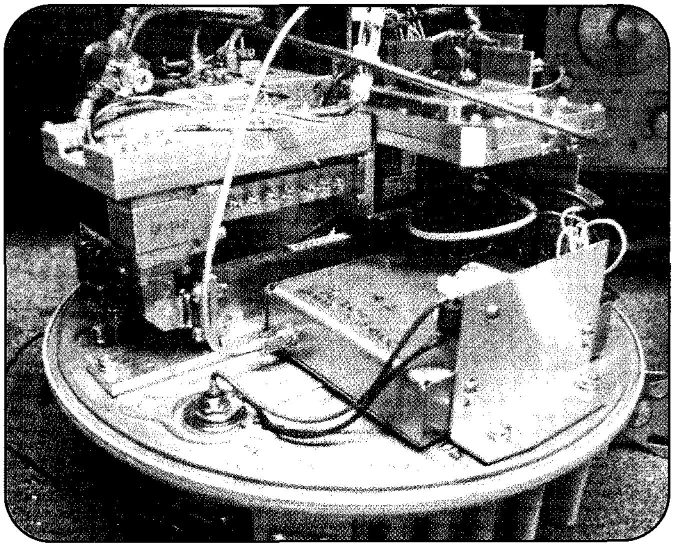

Photo D. Side view of the modified Pecom 24-GHz rig completed by Sam, K6VLM. In the center is same 23-GHz TX module used in 47-GHz rig. The module behind the TX unit on the multi-screw waveguide receive filter is the receiver module.

quency work out for your LO and IF drive requirements. Stock, it functions on 2.620 MHz and is quite easy to convert in the range of ±50 MHz of the original 2620-MHz frequency. As we needed 2640 MHz, it proved to be quite easy. With a DRO synthesizer, not every desired frequency is easy to modify to a new frequency. Some synthesizers are more flexible than others.

The DRO synthesizer was an easy fix for the IF drive required. However, the 10-GHz synthesizer we obtained from surplus was the crown jewel and could be termed unobtainable. It was manufactured by Verticom and is capable of 1-kHz parallel, simple BCD (board chip definition) switching of frequency from 8.3 GHz to 10.7 GHz in 1-kHz frequency steps (its Verticom part number is MTS-2000), a very lucky find. (Note that there have been many Verticom synthesizers on eBay, but all I have observed is model 1500, which has a 150-kHz step (or other unknown frequency steps, and they require suitable serial programming with a processor or stamp board). If you find an MTS-2000 synthesizer in a frequency range suitable for your rig, I suggest you grab it.

Other than the power supplies, dish antenna, synthesizer, or source of a local oscillator and a mixer for 47-GHz, this rig could be constructed with the major item being the TX module from the 23-GHz Pecom transmitter. Using a flexible synthesizer that can be set up in 1-kHz steps made the main LO task simple. A Frequency West brick or other LO could be used here. We used the Agile Verticom Synthesizer, as it was in the junk box and it operated from 8.930 GHz to 10.700 GHz—just right for the required 10,442.50-MHz LO drive. Used with the Qualcomm 2.620-GHz synthesizer (now modified to 2.640 GHz; Pecom IF In/Out) it gave an output at 23.525 GHz right in the normal operation range of the TX module. With 100-mw (+20 dBm) drive (Pecom output) at 23.525 GHz to inject into the LO port of a home-built mixer constructed from two anti-parallel diodes (doubler), this gave us 47.05 GHz.

Using a 145-MHz multimode transceiver as the IF RX/TX source produced an operational frequency of 47.195 GHz. The 2-meter transceiver was set to 250 mw output, 1/4 watt, and an 8-dB attenuator was attached between the transceiver and the microwave mixer. This reduced the transmit power to +7 dBm output drive to the IF mixer port. Total mixer power being used was the LO at +20 dBm; IF drive on transmit of +7 dBm seemed a little high, but we went for the gusto and when tested it seemed to function very well. Besides, we had replacement diodes in the form of PC boards from surplus material to obtain new mixer diodes should that be needed.

A trial at Kerry's QTH during the San Diego Microwave Group's monthly meeting was our show-and-tell portion of the system check. It was a "go for the gold" effort. The first test on the workbench at 2 feet initially showed that something was very wrong. We were receiving signals every 25 kHz up and down the band. A check with the spectrum analyzer traced it to my 2-GHz synthesizer DC power supply 10-volt line. It seems that the 7810 10-volt voltage regulator was oscillating and needed better filter cap action. Replacing the 10-mFd bypass cap with a 100-mFd cap removed the offending ripple on the DC feed and greatly cleaned up the synthesizer output.

Testing the transverter over this 3-foot path proved simple and produced a great note for CW, almost as good as you can get. As a simple test we tried SSB on Kerry's 2-meter multimode IF driver. I switched to SSB on my Yaesu FT-817 and clarity was just as good as 40 meters during the best of times.

This was a contact on 47 GHz, and what fun it was. It was like putting together your first crystal-detector set.

Just for added fun we decided to increase the distance, as we were using AC power supplies for the rigs. We patched in a 75-foot extension cord and walked out of the garage and down the driveway still operating SSB between Kerry and myself. Signal levels were still in the S8+ region. Moving the 10-GHz synthesizer 10 kHz in frequency (it is multiplied by 4 in the rig) moved the IF frequency 40 kHz, as expected.

Also, later that evening Kerry placed a 40-GHz waveguide in the system to

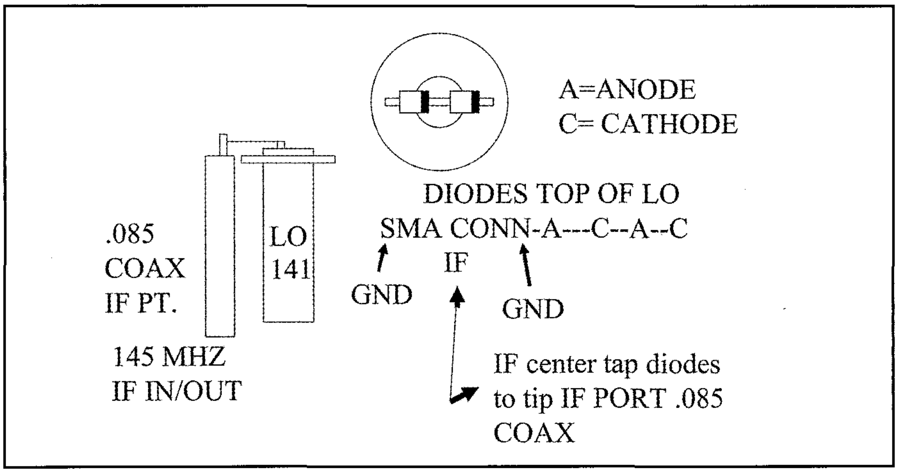

Figure 1. Mixer construction /placement of microwave diodes on the back of the SMA bulkhead connector. Use the shortest possible lengths. We used a bare mixer for a short SSB contact on 47-GHz at a meeting of the San Diego Microwave Group. This mixer, while not an optimum design, is shown here to demonstrate how simple a mixer can be. It's just a starting point in design and it worked.

ensure that it was not 23-GHz overload of the receive mixer and that signals were still functional, proving to our satisfaction that we really were on 47 GHz. After all, we had to use these procedures, as we did not have 47-GHz test equipment and an alternate method had to be used to demonstrate what was going on.

It took time and effort, but the transceiver was assembled all from surplus parts. Several issues still remain, though. Small dish antennas are needed to allow greater operating range. DC power supplies should be added to make the rigs portable. The AC switching power supplies initially were used because they supplied +5 volts, in addition to +15 volts, and these were adjusted to 5.2 volts and 15.6 volts on the +15-volt supply for the YIG (yttrium iron garnet) synthesizer requirements. A bank of voltage regulators for –5 volts, and +10 and +12 volts DC for other circuit requirements, was derived off the switching power supply's + and – 15-volt output taps. It's a little crazy to use a switching power supply capable of 40 amps at 5 volts, but it is good for our power needs and it was in the junk box.

This multi-voltage output power supply made the power-supply issue only a matter of connectors and a slight voltage readjustment to up the 5- and 15-volt lines a few tenths of a volt for synthesizer requirements. Other changes might be to remove the synthesizer control BCD switch box and hard wire the YIG synthesizer control circuitry, greatly reducing the size of the rig. There are lots of possibilities, as there are still other junk boxes to check or we just might find what we are looking for if we sit back and wait for it to land in our lap.

The power supply, like most other items, was obtained surplus from a local scrap-metal junkyard. The Pecom transceiver was obtained surplus for $20 from another scrap-metal yard in the Sunnyvale, California area. The Verticom synthesizer was obtained surplus as well, a find about which I am still amazed. I feel very lucky that we were able to obtain it for our microwave group. Like all rare items, it was one of several key items used in the construction of the converter for 47 GHz—easier than a Frequency West brick.

I forgot to mention the dish reflector we first used. It was a flashlight reflector from a RadioShack lantern. Later reflectors used were stoplight reflectors of the 6- to 8-inch variety, and the latest is a Pecom 39-GHz commercial reflector about 12 inches in size.

One of the photos shows the synthesizer sitting on top of the BCD switch controller for the parallel input control to the synthesizer programming data lines. Inside the controller is an external 10-MHz OCXO (oven-controlled crystal oscillator) reference oscillator. Next to the muffin fan on the bottom left is the Qualcomm DRO synthesizer set to a fixed 2640 MHz. The module standing on its edge is the Pecom TX transmitter module for 23 GHz.

The 47-GHz mixer is the part of the system that was home built. The mixer consists of two SMA bulkhead coax connectors, one modified to accept two microwave diodes on its back face and the other to serve as 145-MHz IF port. The diodes used were scrap from Qualcomm transceivers for 14-GHz. Using a heat gun, we removed the diodes from the original PC-board 14-GHz mixer. The performance at 47 GHz, while not the very best, was quite good in this frequency application, especially considering the cost. As with all of the other material we picked up for this project, the diodes for the mixer were surplus.

Mixer Modification

The bulkhead SMA connector's Teflon® is cut off flush with the back of the SMA flange. Also, the center conductor of the SMA connector is cut off nearly flush with the back of the connector. Next a second SMA connector is soldered to the first connector to make the structure rigid. Use .141 hardline to support both connectors and form the mixer towards the focus point of a small dish.

The mixer is not difficult to construct. Two diodes are required. One diode is soldered one end to ground and the other end to the nub of the center conductor of the SMA connector centered about a straight line from 9 o'clock to the center pin (anode to ground, cathode to the center pin). The second diode is soldered anode to center pin in line from the center pin to 3 o'clock and cathode grounded. Leads should be kept as short as possible, with the diode lying flat against the flange back of the SMA connector.

To test to see if the diodes survived the handling and soldering, measure with a VOM on diode check or use the X10 scale of a VOM. Measure from center pin to ground and you should see a diode junction forward resistance. Reverse the meter leads and you should see the same junction resistance to ground on the second diode, which is connected in an anti-parallel configuration. Now with the two diodes connected and testing good, make the IF port by connecting a single strand of the finest gauge wire you can find. I used a single strand of 110-volt AC lamp cord and soldered one end of this single strand to the diode center connector. The other end was soldered to the IF port, which is constructed out of .085 hardline. Make connection to the center conductor of the .085 hardline coax IF port. The other end of the .085 coax has a SMA connector for IF connection. This is the 2-meter IF port. The drive from the Pecom TX module output at 23.525 GHz is the input LO port of the mixer.

The RF port is somewhat unconventional. It is focused, the RF mixer diodes and IF port all directed to a small reflector dish for testing. On Kerry's rig he had a 4-inch dish, and he pointed the mixer diodes into the focus point of the dish for testing. The diodes and SMA connectors were supported by .141 coax hardline, positioning the mixer diodes to the focus point of the dish. This was the first-cut design and has been improved through the great efforts of Don Nelson, NØUGY.

The improved design consisted of drilling a hole in the LO SMA connector to couple the IF port out. The circular waveguide was placed over the diodes and soldered to the top of the LO SMA connector to create a rigid structure, coupling to a circular waveguide and small 47-GHz splash plate at focus. For full details on this improved mixer, look on the web at <http://www.ham-radio.com/sbms/sd/projindx.htm>.

The mixer also has harmonic-generating possibilities. Driving it at much lower frequencies into a single or even two diode arrangement works very well. This mixer has been shown to have great harmonic-generating capabilities. Frequency markers from lower frequency oscillators have been observed as high at 10 GHz and low at 24 GHz. The diodes used were "fly spec" size diodes (quite small). They were used in commercial applications for 14 GHz, so they already exhibited great microwave capabilities and were in a Stripline package, which permitted us to solder them to the back of a SMA connector.

This was the simplest test and evaluation. The next test came from Don, N0UGY, who put quite a bit of time into improving the mixer and making a mixer waveguide output to cut off the 24-GHz LO feed and only pass the 47-GHz signal-mix product from this simple mixer.

The waveguide was .188 ID diameter hobby brass tubing telescoped into a second section of brass tube stock. This slightly larger brass tube stock fit the OD diameter of the .188 ID stock and was soldered around the diode mixer and SMA connector rear, enclosing the mixer diodes in a launch sort of short section of brass tubing. The end of the .188 diameter tubing was a long section of tube length, and two slots were cut into the tube end. A very small splash plate was soldered onto the far end of the small tubing. The splash plate was placed at the dish focus point in a more conventional design.

My thanks to Don for his efforts in making this great improvement to Kerry's original mixer design. I don't want to cover all the design notes Don provided, but rather I'll let him release his improved design.

Kerry and I have made contacts over 1 km during the 10 GHz ARRL contest with lots of signal to spare. Improvements have been made, incorporating 8-inch stoplight reflectors with greater distance capabilities, and plans are in the works to adapt a better dish antenna from a 39-GHz Pecom system that we have on hand. The junk box delivers again.

Summary

Even though we made use of some sophisticated components, I hope we have shown that a project can be successfully and inexpensively completed using surplus components, items in a junk box or two, and homebrew construction. As always, if you any questions, please e-mail me at <clhough@pacbell.net>.

73, Chuck, WB6IGP