A 902- to 144-MHz Receive Converter

Build this receive converter for your 2-meter rig and be among the first to listen in on our newest amateur band!

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ome years ago, when it was first rumored that the Amateur Service would get 902-928 MHz, I spent many hours developing equipment for that frequency. I have used techniques that evolved from that work in this project. This receive converter takes 902- to 906-MHz signals and converts them to 144 to 148 MHz so they may be heard on any 2-meter rig. The frequency range includes the weak-signal segment specified in the ARRL Interim 33-cm Band Plan. This is a complete project—you'll need just an antenna, 12-V power supply and 2-meter receiver to get started on 33 cm.

In designing this converter, I have tried to minimize the number of components that might be designated "difficult to obtain." Also, I attempted to keep the circuit design as simple as possible without impairing performance. The complete converter, including the GaAsFET front end, has a 1.3-dB noise figure and 25 dB of gain.

Fig. 1 shows the converter block diagram. The design is straightforward. LO energy is injected into a commercially available doubly balanced mixer. A GaAsFET preamplifier delivers the 902-MHz signal to the mixer input. The 144-MHz mixer output drives a dual-gate FET IF amplifier.

Rather than develop a printed-circuit board, I chose to build the unit as a prototype, on a $6\frac{1}{2}$ - \times 1-7/8-inch piece of single-sided 1/16-inch G-10 glass-epoxy circuit board. This keeps the construction

time and expense to a minimum. Modular construction is considered to be more desirable, but if the circuit board is constructed as described, each stage is readily accessible for testing, evaluating or troubleshooting. The finished unit may be mounted where convenient or put in a chassis box or other enclosure.

Circuit Description

A schematic diagram of the converter is shown in Fig. 2. The LO uses four inexpensive RF transistors to develop approximately 7 mW of 758-MHz power. The 2N5179 oscillator circuit (Q1) is a standard overtone configuration. I usually use a fifth-overtone crystal, even when using it as high as the eleventh overtone. Fifth-overtone crystals are generally much cheaper than higher-overtone crystals, and you often get faster delivery from the manufacturer. In this case, Y1 is a 90.2380-MHz fifth-overtone crystal that is operated on the

seventh overtone, 126.3334 MHz.

The oscillator is capacitively coupled to another 2N5179 (Q2) that triples the frequency to 379 MHz. The collector has a double-tuned circuit consisting of C9, L2, L3 and C11 that helps filter out some of the 126-MHz signal present in the output. C10, used between the two 379-MHz tuned circuits, is a "gimmick" type made by tightly twisting together two pieces of no. 26 plastic-covered hookup wire for a length of 5/16 inch. This produces a capacitance of approximately 0.7 pF. If desired, a ceramic chip capacitor of approximately that value may be used.

Another 2N5179 (Q3) is used as a doubler, producing the needed injection frequency of 758 MHz. Again, the collector uses a doubled-tuned circuit (C13, L4, L5, C15) to reduce the unwanted 126- and 379-MHz levels. C14, the coupling capacitor between the tuned circuits at this point, is a ceramic chip. A gimmick type

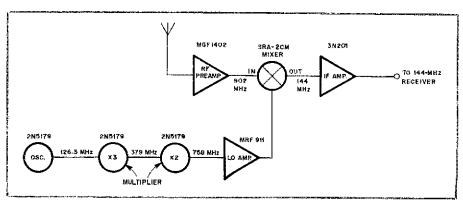


Fig. 1—Block diagram of the 902- to 144-MHz receive converter,

^{&#}x27;Albert D. Helfrick, "The 900-MHz Band—What's in Store for Amateurs," QST, Jan. 1984, pp. 27-30.

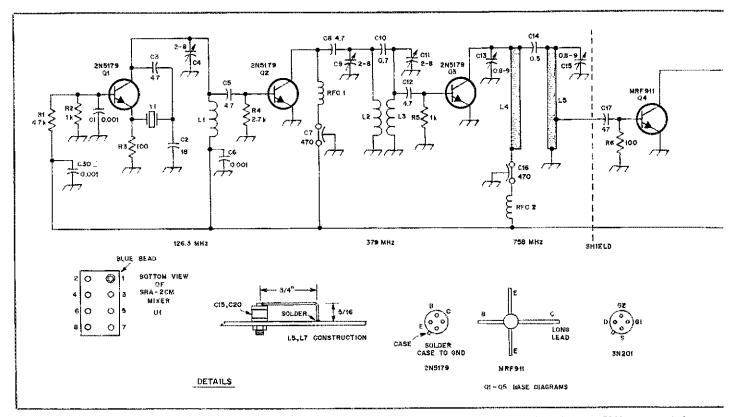


Fig. 2.—Schematic diagram of the 902- to 144-MHz receive converter. All resistors are ¼-W carbon composition. Capacitors are 50-V epoxy-coated miniature ceramic types unless otherwise noted.

- C4, C9, C11, C22, C25—2-8 pF adjustable ceramic trimmer capacitor.
- C7, C16, C19—470-pF ceramic or mica button or feedthrough capacitor, solder-in type (see text).
- C10—0.7 pF gimmick or ceramic chip capacitor (see text).
- C13, C15, C18, C20—0.8-9 pF ceramic piston trimmer capacitor (Voltronics EQT9 or equiv. See text).
- C14—0.5-pF ceramic chip capacitor (see text).
 C28—470-pF solder-in feedthrough capacitor.
 J1, J2—Chassis-mount female BNC connector
 (UG-1094 or equiv.).
- L1, L3—5t no. 24 enam. wire, 0.190-in ID (no. 11 drill), closewound.
- L2-3t no. 22 tinned wire, 0.190-in ID, spaced 1 wire dia.
- L4—Piece of no. 18 tinned wire, 11/16-in long (see Fig. 4).
- L5, L7—Piece of no. 18 tinned wire

might work here also, but I haven't tried one. Another alternative is a 0.3-3 pF miniature ceramic piston trimmer adjusted for the proper value.

LO output at this point is adequate to drive the mixer. The spurious components, however, are unacceptably high. Losses involved in adequate filtering would reduce the output level, so an MRF911 (Q4) is used to amplify and filter the LO signal even more. This stage is not "biased up" as are most amplifier circuits because only a small amount of gain is desired. The collector has a double-tuned circuit (C18, L6, L7, C20) to further reduce spurious responses in the output signal.

The output level at this point is approximately +20 dBm (100 mW), which is much higher than the +7 dBm required for the mixer, so a pi attenuator (R7, R8 and R9) is used. It requires more than passing care to make an attenuator from standard ¼-W carbon resistors that is usable at 750 MHz. Lead lengths must be as close to zero as possible. I used a 9-dB pad and ended up with approximately 8 mW. You may have to experiment with the resistor values depending on how much power you get from the MRF911 and on the tolerance of

your resistors. All spurious responses at this point are at least -33 dBc, a level adequate for most applications. If a cleaner LO is required, this part of the converter could be boxed separately and a suitable filter used to obtain the required spectral purity.

There is another plus to be gained by the use of the additional amplifier stage. A two-port power splitter may be added at the

output, providing an isolated output to drive a transmit mixer. Fig. 3 details one way to accomplish this. The three 50-ohm attenuators shown adjust signal levels for optimum in addition to providing proper termination for the power splitter. Attenuator values will depend on the amount of LO power available and the requirements of the mixers. Once you

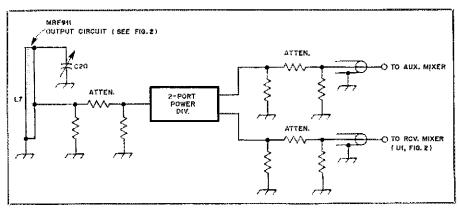
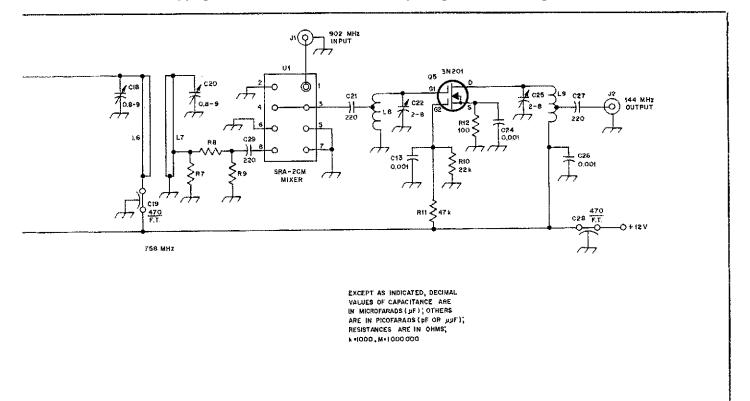


Fig. 3—The LO provides enough power to drive the receive converter mixer and an auxiliary mixer for a transmit converter, if desired. See text for details.



(see detail).

L6—Piece of no. 18 tinned wire, 5/8-in long.

L8, L9—6t no. 18 tinned wire, 0.25-in ID, spaced 1 wire dia, tapped 134t from ground.

Q1, Q2, Q3—2N5179 transistor.

Q4—MRF911 transistor.

calculate the power levels necessary and the amount of attenuation required, resistor values may be obtained from Chapter 25 of *The 1985 ARRL Handbook*. If more LO power is required, Q4 may be "biased up" by adding a 2.2-k Ω resistor from the base to +12 V. Properly biased, Q4 is capable

of delivering 150-200 mW. The two-port power splitter may be one of the type typically used for television service, such as Radio Shack part no. 15-1141. Remove the toroid from the metal container, replace the 150- Ω power resistor with a 100- Ω resistor, and you have a small 50- Ω power splitter. Mini-Circuits (see the section on obtaining components) also sells a line of suitable power splitters.

The Mini-Circuits SRA-2CM doubly balanced mixer was selected because of its good performance, moderate price and reasonable delivery time. It is housed in a compact 8-pin package and is rated for use through 1 GHz.

The 144-MHz IF amplifier, Q5, is necessary to maintain converter noise figure. The design uses a dual-gate VHF FET in a circuit similar to one that might be used as a preamplifier ahead of a 2-meter converter or receiver. Although I used a 3N201, almost any dual-gate VHF FET will work here. Common devices include the 3N204, 3N211 and 3SK51. Typically, the noise figure of such a circuit

Q5—Dual-gate FET (3N201, 3N204, 3N211, 3SK51 or equiv.).
RFC1—22t no. 30 enam. wire, 0.076-in ID (no. 48 drill), closewound.
RFC2—3t no. 24 wire, 0.082-in ID (no. 45 drill), spaced 2-wire dia.

will be approximately 3 dB or better.

The mixer conversion loss can be as high as 8 dB. This, added to the noise figure of the IF preamplifier, yields a typical converter noise figure of 10-11 dB. The noise figure of my prototype measured 9.25 dB. Although a noise figure this high can be considered adequate for many applications, a UHF enthusiast considers it to be unacceptably high. The solution, of course, calls for a low-noise preamplifier at the input frequency. Such a unit is described later in this article.

Component Layout

Unless you have had considerable UHF layout experience, you should follow the general layout scheme in Figs. 4 and 5. I usually build the oscillator first and then the succeeding multiplier stages, and so on. This way, the oscillator can be checked for performance, then the first multiplier and so on down the line.

All components except the mixer and BNC connectors are mounted on the foil side of the board. Ground connections are made directly to the copper ground plane. All parts are soldered together except Y1, which is mounted in a socket that is cemented to the board. Parts are supported by their leads above the ground plane where necessary. Keep all leads as short as possible.

U1—Mini-Circuits SRA-2CM doubly balanced mixer.

Y1—Fifth-overtone crystal, 90.238 MHz, or seventh-overtone crystal, 126.3334 MHz, HC-25/U holder (see text).

Gather the components that mount through the board. These include Q1, Q2, Q3, Q5, C7, C13, C15, C16, C18, C19, C20, J1, J2 and U1. Using Fig. 5 as a guide, mark and drill the proper size mounting hole for each part. Q1, Q2, Q3 and Q5 fit snugly in 0.190-inch-diameter holes. After drilling the holes, mount the other components. Refer to Figs. 4 and 5 for an idea of the relationships between the various parts. Troubleshooting will be easier if you build and test each stage in succession.

Standard 3/8-inch-diameter, 2-8 pF ceramic trimmer capacitors (C4, C9 and C11) are used to tune the oscillator and first multiplier collector circuits. Two more ceramic trimmers, C22 and C25, are used in the IF amplifier. These trimmers are relatively inexpensive compared to the piston trimmer capacitors (C13, C15, C18 and C20) that are used to tune the collector circuits of the final two stages of the injection chain. Ceramic piston capacitors are preferred because they don't break as easily as the glass variety.

The solder-in button-type bypass capacitors, C7, C16 and C19, should be ceramic or mica types with good VHF characteristics. Feedthrough types may be used, then the power wiring could be done on top of the unit. Undesired interstage coupling could be further reduced. The wiring method shown in

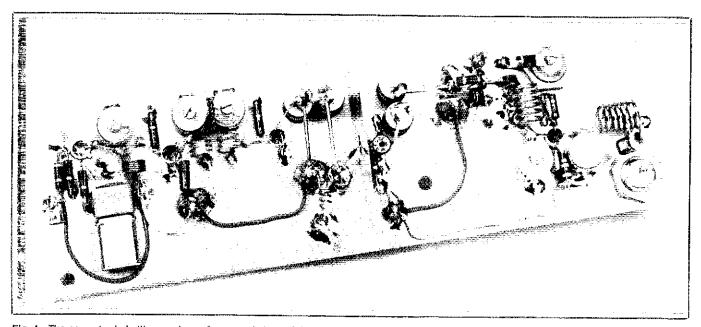


Fig. 4—The converter is built on a piece of copper-clad circuit-board material. Component leads are soldered together; lead lengths are as short as possible. Study this photo and Fig. 5 when you lay out your version.

Fig. 4 works fine, however.

With the exception of C10 and C14, the other capacitors are miniature, epoxycoated, ceramic monolithic capacitors. Small, silver-mica types would work as well. C10 is a gimmick capacitor that was described earlier, and C14 is a ceramic chip.

Carbon ¼-W resistors are used throughout the converter. Avoid using metal-film types in the RF circuits; their associated inductance can make a big difference in the performance of VHF and UHF devices.

When you mount U1, make sure pin 1 is located in the right position. Pin 1 has a blue insulating bead for identification purposes. Fig. 2 denotes the mixer connections.

The shield between Q3 and Q4 is necessary for stable operation. This shield can be fashioned from a piece of sheet brass or copper, or from a piece of double-sided PC-board material. The two stages are coupled by C14, which is mounted in a small hole drilled in the shield.

Adjustment Procedures

Most amateurs who build VHF gear have their own way of tuning up a multiplier string. I will offer a few comments for those who may not be familiar with these techniques.

First, use C4 to adjust the oscillator for output at 126.3 MHz. C4 tuning is fairly critical for reliable, stable operation. Next, adjust C9 and C10 in the first multiplier stage for maximum output at 379 MHz. Then adjust C13 and C15 in the second multiplier stage for maximum output at 758 MHz. After the multiplier stages are tuned for stable operation, tune C18 and C20 in the O4 collector circuit.

LO tuning is relatively easy if you have

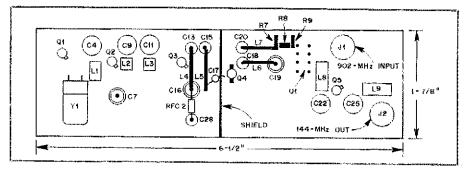


Fig. 5—Suggested parts placement for the converter board. Follow this placement guide carefully for best results. Refer to the text and Fig. 3 for additional details.

access to a spectrum analyzer, but it can be accomplished with a dip meter capable of tuning these frequencies. Another alternative is to use a receiver capable of tuning the necessary frequencies.

The mixer, of course, is a broadband device and requires no tuning. The 1F amplifier may be tuned up using either a 2-meter signal source or a 902-MHz signal injected into the mixer input. Most VHFers have preferred procedures for making all of these adjustments.

A GaAsFET Preamplifier

A low-noise preamplifier for 902 MHz is necessary to bring the noise figure of the converter down to a level acceptable for UHF weak-signal work. Some years ago, Bob Sutherland, W6PO, developed GaAsFET preamplifiers for 902 and 1296 MHz. The amplifier described here is an adaptation of these designs. It has a gain of approximately 17 dB and a noise figure of 0.75 dB as measured on a Hewlett Packard 8970A noise-figure meter with the

HP 346A noise source.

Fig. 6 is a schematic diagram of the preamp. The input circuit consists of a tiny inductor, L1, and a section of $50-\Omega$ transmission line, L2. Q1 is a low-noise GaAsFET device. The drain circuit is a simple stub match made from two more sections of transmission line.

Rather than design an etched circuit board with microstriplines, I chose to build the preamp prototype style on an unetched piece of single-sided G-10 PC-board material. All components are mounted to the board, and all ground connections are made to the ground plane. I chose to make the enclosure from circuit-board material. It measures $3/4 \times 2 \times 3-3/8$ inches (HWD). Fig. 7 details the component placement, and Fig. 8 is a photograph of the finished unit.

L2, L3 and L4 are made from 0.141-in miniature semi-rigid coaxial cable (such as RG-402). This material is copper jacketed, has Teflon® dielectric and a silver-plated, solid center conductor. If you cut this cable

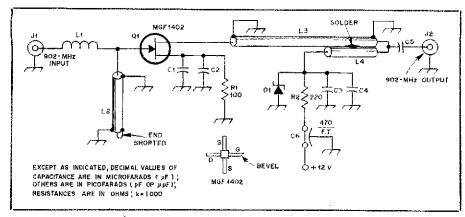


Fig. 6—Schematic diagram of the 902-MHz GaAsFET preamplifier. All resistors are 1/4-W carbon types,

- C1, C2—470-pF button or ceramic chip capacitor.
- C3-470-pF ceramic chip capacitor.
- C4-0.1-µF miniature disc-ceramic capacitor.
- C5—220-pF ceramic chip or miniature discceramic capacitor.
- C6—470-pF solder-in feedthrough capacitor. D1—3.6-V, 500-mW Zener diode (1N5227 or equiv.).
- J1, J2—Chassis-mount female BNC connector (UG-1094 or equiv.).
- L1-4t no. 30, 0.095-in ID (no. 41 drill), spaced 1 wire diam.
- L2—2.3-in length of 0.141 50-Ω semi-rigid coax. L3—1.6-in length of 0.141 50-Ω semi-rigid coax.
- L3—1.5-in length of 0.141 50- Ω semi-rigid coal L4—0.465-in length of 0.141 50- Ω semi-rigid
- Q1-GaAsFET (MGF 1402, DXL2501 or equiv.).

SOLDER SOLDER

Fig. 7—Suggested parts placement for the 902-MHz preamplifier. Follow this layout carefully and keep all leads as short as possible. Good grounding is important for proper performance. See text and Fig. 8 for further details.

jacket cracks and breaks neatly where you scored it. Remove the unwanted jacket and use your knife to cut through the dielectric. Be careful not to nick the center conductor. Remove the dielectric and trim the center conductor to the desired length. Repeat this process for the other end of the cable.

Follow the parts placement in Fig. 7 carefully. Arrange the parts in the order they will be placed on the board and mark any holes. (Caution: GaAsFETs are static-sensitive devices. Leave Q1 in its protective package until you are ready to solder it in place.) You will have to drill a hole for the

feedthrough, C6. If you use button instead of chip capacitors for C1 and C2, you will need to drill holes for these, too.

I prefer to first mount all the components except the GaAsFET. For best results, clean the circuit-board foil and the 0.141 cable jackets until they are bright and shiny. Make all component leads as short as possible. Q1 will be supported above the ground plane by its source leads. C1 and C2 are soldered to the ground plane, and then the Q1 source leads are soldered to the pads on top of these capacitors. See Fig. 7. Cut off the center pin on J1 so there is just enough contact left to solder L1 to. Remember to solder the jacket of L4 to the jacket of L3 and to solder the jackets of L2 and L3 to the ground plane at each end. Solder the enclosure sides to the ground plane along the entire length of the seams.

After all other components are soldered in place, remove the GaAsFET from its package. These devices should be handled carefully to avoid damage by static buildup. Quickly solder the device in place using a cordless or grounded soldering iron. If you don't have a grounded iron, unplug your hot iron from the outlet before soldering. Tweezers may come in handy.

As can be seen, there are no tuning adjustments on the RF amplifier. If noise performance measuring equipment is available, it may be possible to optimize the noise figure by adjusting the spacing between the turns of L1 at the input connector. The improvements are very small however, and the performance is excellent with no adjustments.

This type of amplifier is inherently broadband. If this unit is to be used in an area where there is significant RF pollution in the portion of the spectrum above 500 MHz (such as UHF television signals), it

carefully to the dimensions given, you will have no trouble reproducing the preamp. These dimensions are for the section of the line that is inside the copper jacket, so remember that you'll need 1/4 inch or so on each end to make your connections.

Use the following procedure to cut the sections of the 0.141 cable. Measure the desired length and mark the copper jacket. Lay the cable on a flat surface and score the copper jacket around its circumference with a sharp knife. You'll get the best results if you hold the knife blade stationary on the mark you measured and exert moderate pressure on the jacket while rolling the cable under the blade. Next, hold the cable tight in one hand and grip the section of copper jacket to be removed with a pair of pliers. Gently rock the section to be removed back and forth until the

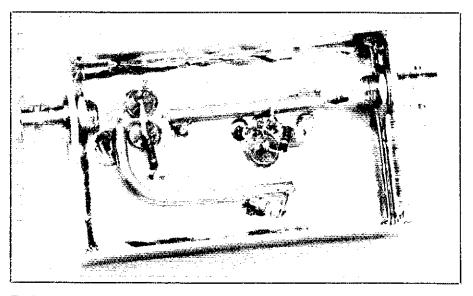


Fig. 8—The 902-MHz GaAsFET preamplifier is built on a piece of copper-clad circuit-board material. Follow the layout shown here and in Fig. 7 for best performance. The GaAsFET device, which is suspended from the source bypass capacitors, should be handled carefully and soldered in last. See text for details.

might be desirable to use a bandpass filter in front of the amplifier. Remember, however, that a filter will introduce some loss and will degrade the system noise figure.

Power Supply

Usually a 12-V regulated power source is available in most ham shacks. If you desire to build a separate power supply for this unit, a suitable one is shown in Fig. 9. This supply may, of course, power both the converter and preamplifier. It is a simple circuit using a full-wave bridge rectifier and 3-terminal 12-V regulator. The secondary voltage of T1 may be anywhere between 12 and 18 volts.

C2 and C3 should be mounted as close to the regulator pins as possible for best regulator stability. U1 should be mounted on a small heat sink. The parts for this unit are all available at any Radio Shack store.

Obtaining Components

Although I have tried to minimize the number of specialized components, there are a few that some constructors may have difficulty obtaining, such as the ceramic piston trimmers. 1 used Voltronics type EQT9 trimmers for this project. They are available in single-lot quantities from Voltronics Corporation, P.O. Box 366, E. Hanover, NJ 07936. A similar piston trimmer is sold by Trim-Tronics, Inc., 67 Albany St., Cazenovia, NY 13035 (part no. 60-0720-1501-000). Johanson is another manufacturer of several piston trimmer capacitors suitable for this project: these capacitors are available from most major parts houses. A source for adjustable ceramic capacitors is Stettner Electronics, Inc., P.O. Box 21947, Chattanooga, TN 37421.

The SRA-2CM mixer is available directly from the manufacturer, Mini-Circuits,

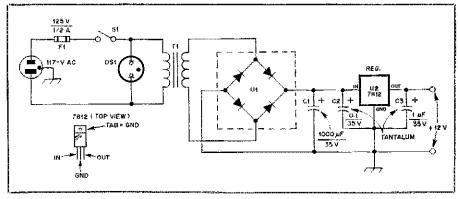


Fig. 9—Schematic diagram of a power supply suitable for both converter and preamplifier. C1— $1000 \cdot \mu F$, 35-V electrolytic capacitor. T1—Primary, 117-V ac; secondary, 12-18 V, C2— $0.1 \cdot \mu F$, 35-V tantalum capacitor. U1—50-PIV, 1-A bridge rectifier module. DS1—117-V neon pilot lamp. U2—12-V, 1.5-A 3-terminal regulator (LM7812 or equiv.).

2625 East 14th St., Brooklyn, NY 11235. The crystal I used was obtained from Jan Crystals, 2400 Crystal Dr., Ft. Meyers, FL 33906. Order a 90.2380 MHz, seriesresonant, 0.005%, non-oven, HC-25/U crystal.

S1-SPST toggle switch, 125 V.

Small pieces of 0.141 copper-jacketed coax used in the preamp may prove difficult for some to obtain. J. Smith and Assoc., Inc., 3540 N Academy Blvd., Suite 113, Colorado Springs, CO 80907 sells this cable in foot lengths.

The GaAsFET may be obtained from Advanced Receiver Research, P.O. Box 1242, Burlington, CT 06013. Applied Invention, RD 2, Rte 21, Box 21, Hillsdale, NY 12529, sells piston trimmers, chip capacitors and feedthrough capacitors. Yet another source for trimmer capacitors, chip capacitors, feedthrough capacitors, GaAsFETs and related parts is Microwave

Components of Michigan, 11216 Cape Cod, Taylor, MI 48010.

Most of the other components can be acquired from many parts houses. One such company that deals in small quantities is Mouser Electronics, 11433 Woodside Ave., Santee, CA 92071. A catalog is available on request.

In Summary

The receive converter described here is a high-performance project that can be built from available parts. Although some test equipment is desirable for alignment, it is not absolutely necessary. If you follow the guidelines I have established, you should have no trouble duplicating the project and being among the first to tune into our newest amateur band. A companion 902-MHz loop Yagi will be described in another article.

New Products

SOLARTS MINIATURE SOLAR PANELS

☐ Three new miniature solar panels capable of generating 20 V at 250-500 mA have been announced by Solarts. These strong, lightweight, high-efficiency units use rec-

tangular cells and high-density packaging for a high power-to-size ratio. Each panel contains 36 cells, each generating 0.55 V, on the average, compared to the usual 0.45 V (see Table 1). Open-circuit panel voltage is usually over 20 V. Encapsulated aluminum substrate construction makes them shockproof, weatherproof and ultra thin—only 3/16 inch thick. The largest model offered weighs less than 1 lb.

Included with each panel are a cigarettelighter adapter with a 4-ft cord, two 12-inlong hookup wires with spade lugs, two wire nuts, a suction cup for temporary mounting and complete instructions.

For more information, contact Dick Smith Electronics, P.O. Box 2249, Redwood City, CA 94063, tel. 415-368-8844.

—Bruce O. Williams, WA6IVC

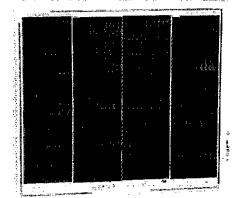


Table 1 Specifications

No. ot	Output		Size (HWD)	Weight
Cells	٧	mΑ	(in)	(OZ)
36	20	250	7 × 8 × 3/16	91/2
36	20	400	$8 \times 10\frac{1}{2} \times 3/16$	14
36	20	500	$9\frac{1}{2} \times 10\frac{1}{2} \times 3\frac{1}{6}$	16
	Cells 36 36	Gells V 36 20 36 20	Gells V mA 36 20 250 36 20 400	Cells V mA (in) 36 20 250 7 × 8 × 3/16 36 20 400 8 × 10½ × 3/16