1296-MHz transverter

Complete construction details for a simple, inexpensive transverter for ssb and CW that will make a noticeable dent on the 1296-MHz amateur band

Recent issues of *ham radio* and other amateur publications have contained a wealth of construction articles on equipment for 1296 MHz, indicating the growth of interest and activity on that band. Conspicuously absent from the literature, however, is a simple, inexpensive way of generating reasonable amounts of stable transmitter output power — greater than 1 watt — for serious CW and ssb work on 1296 MHz.

Most long-haul, narrow-band DX work is conducted at or just above 1296 MHz, leaving the lower part of the band for wideband modes. Traditional transmitting schemes for this band usually involve tripling from 432 MHz using planar triodes in a cavity or stripline arrangements, and more recently, varactor diodes. These approaches yield CW or fm signals, but they are obviously unsuitable for single sideband.

Recent solid-state mixer designs, although suitable for producing clean ssb and CW signals have one principal drawback: low power output, typically in the dozens of milliwatts range. This requires considerable linear amplification to approach reasonable power levels. The circuitry associated with uhf mixers is difficult for amateurs unfamiliar with these devices and expensive in terms of dollars invested per watt of outpuut power obtained.

In an effort to overcome these drawbacks with minimum circuit complexity and financial investment, a high-level mixer was developed which uses the popular 2C39/7289/3CX100A5 family of planar triodes. These tubes are abundantly available surplus at extremely reasonable prices. Depending on the plate voltage applied to the tube, this transverter will deliver from 5 to 15 watts of clean, stable CW and ssb power output on 1296 MHz. This is more than enough for routine contacts up to a 100 miles (160km) or more. My 1296-MHz signals are regularly copied at +20 dB over S-9 over a 50 mile (80km) path using the transverter stage alone; for more serious DX work the unit will drive a single 7289 to 100 watts ssb and CW output!

theory of operation

The 1296-MHz transverter operates like a receiving converter or mixer in reverse, and at much higher power levels. As shown in **fig. 1**, an ssb signal from the output of a high-frequency or vhf transmitter (here considered to be the *intermediate frequency* or i-f) is mixed with a higher frequency carrier (the local oscillator or LO) to produce sum and difference frequencies, of which one is the desired uhf ssb signal. The remaining, undesired signals are eliminated with a selective filter.

I used the output of a 50-MHz ssb transceiver for my i-f. Obviously, other ssb source frequencies could be used, but it is desirable to use as high an i-f as possible to separate the desired mixer product from the unwanted LO and difference frequencies as much as possible, making it easier to eliminate the unwanted signals by filtering. Intermediate frequencies as low as 21 or 28 MHz can be used with little difficulty.

Transceivers in the 10-20 watt class are ideal for driving this transverter. They should, however, be

By Joe M. Cadwallader, K6ZMW, Star Route 2, Bosse Road, Jackson, California 95642

isolated from the transverter by a simple 3 dB attenuator[1] (such as a suitable length of RG-58/U coaxial cable) to make sure the transceiver is terminated in a matched, resistive load. The output of transceivers in the 100-watt class should be attenuated down to about 10 watts; don't just turn down the DRIVE or MIC GAIN control.

The transverter requires about 5 watts of local oscillator injection at 1296 MHz plus or minus the i-f. This signal can be derived in a number of ways. In my case, withh a 50-MHz i-f, a LO of either 1246 or 1346 MHz was needed. A crystal-controlled signal source providing about 10 watts output at 415.333 MHz was built; this was used to drive a tripler stage to 1246 MHz with about 5 watts output.

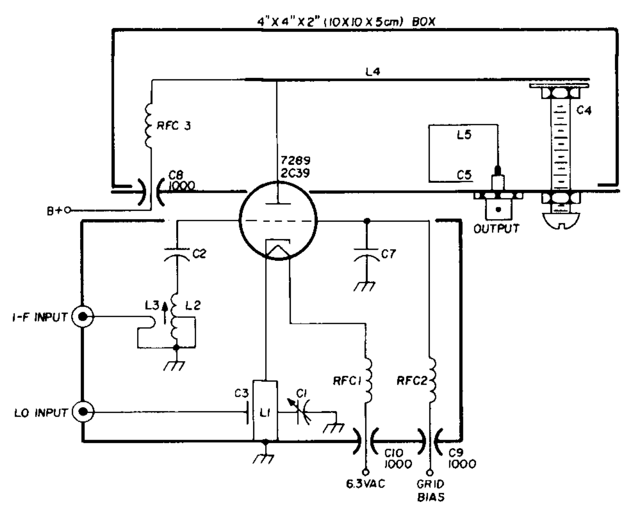
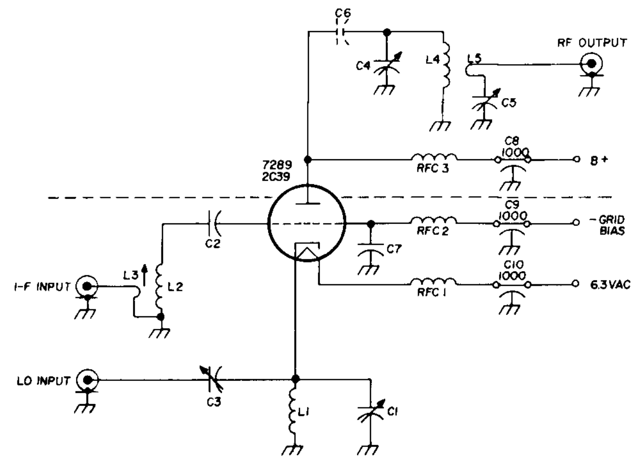


fig. 1. Circuit layout for the 1296-MHz transverter. Component details are listed under fig. 2.

There are a number of ways to generate the 415-MHz signal: the easiest is to modify and retune an existing transmitter which operates near this frequency. Many 432-MHz transmitters described in amateur publications can be easily retuned; transistorized transmitter kits advertised in amateur publications are very reasonably priced and should work well for this purpose.

Even old commercial 450-MHz fm transmitter strips, often available as junk, work nicely. If this approach is used, however, a few precautions are in order: turn the DEVIATION control off and, if possible, remove the speech-amplifier and phase-modulator tubes; substantially increase the power supply filtering to assure clean output with no ac hum which would otherwise appear on your transverter LO signal; voltage-regulate the oscillator and buffer stages with zener diodes or VR tubes to maintain oscillator stability; and use a good quality crystal with a low temperature coefficient in a temperature-controlled oven, or mount the crystal under the



C1, C3	part of cathode circuit (see fig. 5)
C2	150 pF silver-mica capacitor for 50-MHz i-f (three 47-pF dipped silver-mica capacitors in parallel)
C4	plate tuning capacitor (see fig. 7)
C5	part of L5 (see fig. 3) or 10 pF piston trimmers
C6	non-existent; represents dc open condition of this line configuration (see text)
C7	grid bypass capacitor (see fig. 4)
C8,C9,C10	1000 pF feedthrough capacitors. C8 must be rated for applied B + voltage
L1	part of cathode circuit (see fig. 5)
L2	4 turns no. 16 (1.3mm) enamelled copper wire on 1/4" (6.5mm) slug-tuned coil form (for 50-MHz i-f)
L3	1 turn no. 16 (1.3mm) around cold end of L2
L4	plate line (see fig. 6)
L5	1/4" (6.5mm) wide copper or brass strip, about 1/8" (3mm) away from plate line (see fig. 3)
RFC	15 turns no. 16 (1.3mm) copper wire, closewound on 1/16" (1.5mm) mandrel

fig. 2. Schematic diagram of the 1296-MHz transverter. The circuit layout is shown in fig. 1. Rf power output at 1296 MHz is 17 watts.

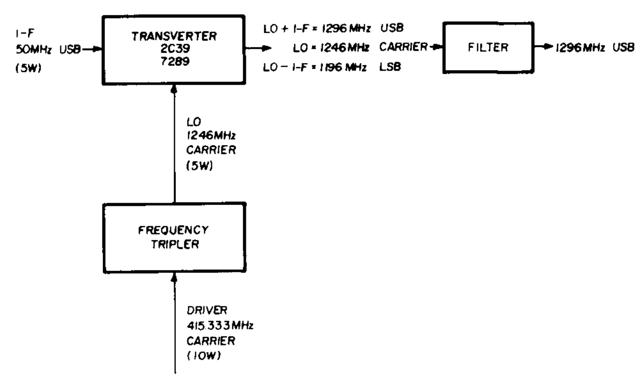
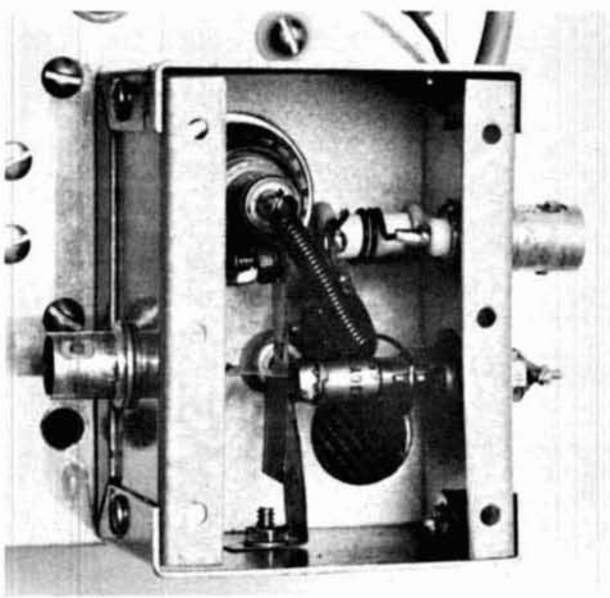


fig. 3. Block diagram of the 1296-MHz transverter system for CW and ssb operation. Although the author used a 50-MHz ssb/CW transmitter, 21 or 28 MHz could be used with equally good results. Frequencies below 21 MHz are not recommended because of the difficulty in separating the resulting mixer products.

chassis away from sources of heat, to reduce LO drift.

Regardless of which approach is used to generate the LO signal, a small amount can also be coupled off for LO injection to the receiving converter, thus reducing the total system equipment requirement and yielding true transceive operation on 1296 MHz. In my case, a small amount of 415.333-MHz energy was inductively coupled from the PA grid circuit of a 10-watt transmitter strip used as the LO source and applied to the multiplier diode of a popular trough-line receiving converter.[2]

The task of tripling up to the transverter's required LO injection frequency can be readily accomplished in a varactor multiplier — either commercial* or homebrew[3] — or a stripline or cavity multiplier stage[4,5] can be built around a 2C39/7289 triode. It has been suggested that cavity assemblies from surplus uhf equipment such as the UPX-6 would serve this purpose well. As is, these beautiful cavities tune from roughly 1000 to 1200 MHz.

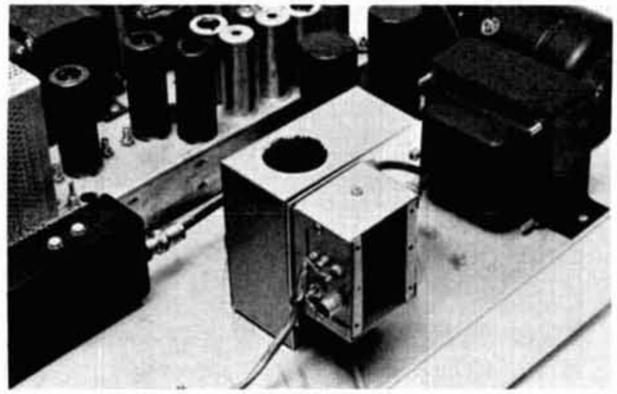


Close-up of the cathode compartment. The BNC connector on the left is used for the local oscillator input, while the one on the right is for the i-f input. The filament and grid voltages are brought into the compartment by feed-through capacitors.

Table 1 lists the required local-oscillator frequencies for various intermediate frequencies. Keep in mind that using an LO *above* 1296 MHz causes inversion of the sideband in the transverter: for example, a 1346-MHz LO minus a 50-MHz *upper* sideband signal equals 1296-MHz *lower* sideband.

Referring to the schematic diagram, **fig. 2**, the

*The MMv-1296 tripler available from Spectrum International, Box 1084, Concord, Massachusetts 01742.



The complete 1296-MHz ssb/CW transverter, mounted on a pressurized chassis. The local-oscillator chain is at the upper left, the varactor tripler is to the left, and the high-voltage power supply and blower are at the right.

transverter circuit is remarkably simple, using a 7289 (2C39) or equivalent in the familiar grounded-grid configuration. As is common practice in this application, the tube grid is not actually grounded directly but rather is bypassed, through capacitor C7 so the grid is grounded at the signal frequency while remaining above ground to dc. This provides a convenient way to apply grid bias through RFC2 and C9 without affecting the rf behavior of the grid circuit.

table 1. Possible i-f/local oscillator combinations for the 1296-MHz transverter. LO frequencies above 1296 MHz invert the sideband.

intermediate frequency	local oscillator	driver (LO ÷ 3)
21 MHz	1275 MHz	425.000 MHz
21 MHz	1317 MHz	439.000 MHz
28 MHz	1268 MHz	422.666 MHz
28 MHz	1324 MHz	441.333 MHz
50 MHz	1246 MHz	415.333 MHz
50 MHz	1346 MHz	448.666 MHz
144 MHz	1152 MHz	384.000 MHz
144 MHz	1440 MHz	480.000 MHz

The grid bypass capacitor, C7, consists of a flat, concentric brass or copper plate connected by finger stock to the tube's grid collar and insulated from the chassis with a thin mica or Teflon sheet. This type of bypass plate is standard equipment on military surplus vhf communications gear and can often be scavenged. The bypass plate can also be home built by soldering finger-stock material* around an appropriately sized hole centered on a flat brass or copper sheet (**fig. 4**). Thin mica for the dielectric material is available in most hardware or plumbing supply stores as replacement material for gas furnace pilot-light inspection holes. It can be easily cut with scissors or an *Exacto* knife.

The bypass plate is insulated from its mounting

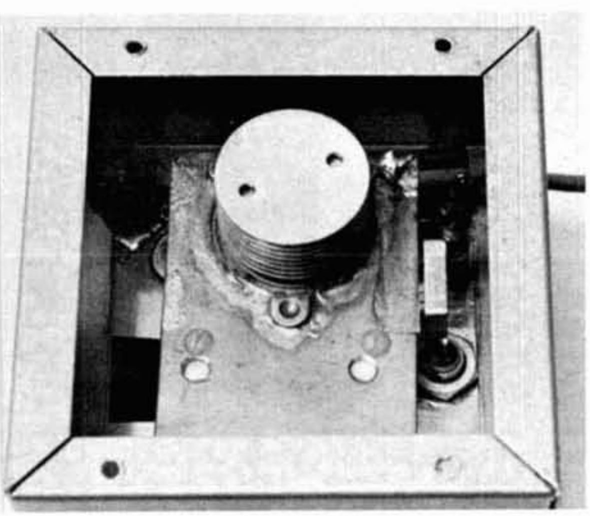
*Instrument Specialties Company, Little Falls, New Jersey 07424.

screws with the same type of nylon bushings which are used to mount and insulate power transistors. Once assembled, a typical value for this bypass capacitor is about 100 pF; this represents about 1 ohm of capacitive reactance — essentially a dead short — at 1296 MHz, and effectively grounds the grid at that frequency. However, at lower frequencies the grid is definitely *not* at rf ground: at 50 MHz the reactance of the grid bypass is about 30 ohms, and at 28 MHz it is about 55 ohms. Thus, the grid can be driven by the low-frequency ssb i-f signal while the cathode is driven by the high frequency LO signal: the sum and difference of these two signals appear in the plate circuit.

This simple approach can be applied to numerous uhf tubes in various grounded-grid configurations, stripline or cavity, commercial or military surplus, with equally good results.

The cathode circuit, **fig. 5**, driven at the LO frequency of 1246 MHz in my case, consists of a shorted quarter-wave line section L1, made of thin brass or copper sheet 1/4 inch (6.5mm) wide, wrapped around the tube cathode sleeve and running 1-3/4 inch (44mm) to chassis ground. The line is tuned with C1 which may be a low loss, high quality glass or ceramic piston trimmer or, better yet, a metal tab bent up near the line, or a brass machine screw with a brass disc about 1/2 inch (13mm) in diameter soldered to its end (similar to C4). The LO energy is capacitively coupled to the middle of this line by C3, a small brass or copper tab soldered to the LO input connector and bent up near the cathode line. Spacing can be adjusted for maximum LO drive.

The ssb i-f signal is coupled to the grid circuit by L3, a one-turn link wound around the cold end of L2. The L2-C2 circuit must resonate at the intermediate frequency. Since this circuit will be driven with about



The plate-line enclosure for the 1296-MHz transverter. The output coupling network, L5-C5, is to the right.

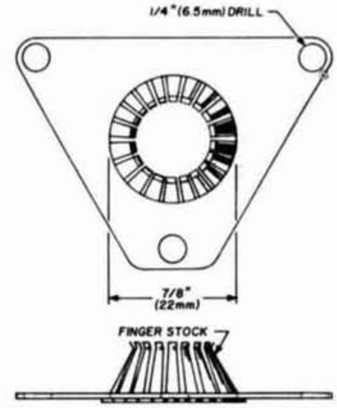
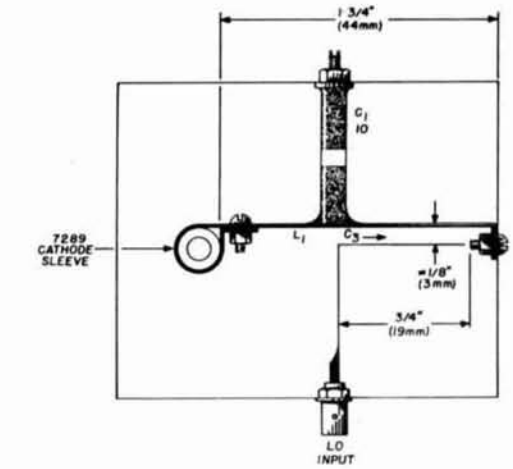


fig. 4. Construction of the grid bypass capacitor, C7.

5 watts, these coils should be either air-core or wound on a low-loss slug-tuned ceramic coil form of moderate diameter (1/4 inch [6.5mm] minimum, larger preferred) using no. 14 (1.6mm) to no. 18 (1mm) enameled copper wire. C2 should be a good quality mica or silver-mica capacitor to minimize losses. Two or three capacitors may be paralleled to handle the required rf current and still resonate with L2 at the i-f. The C2-L2 combination should be pre-

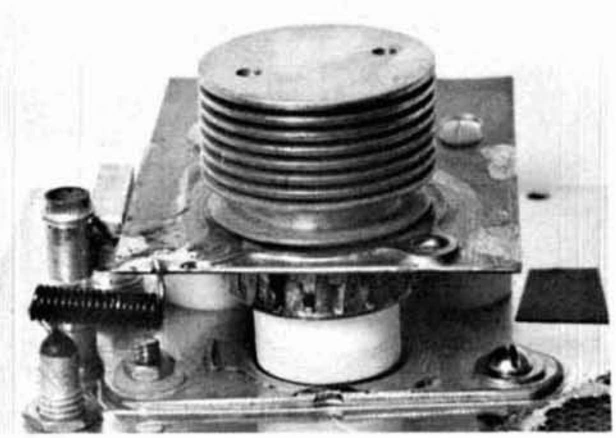


C2	10 pF piston trimmer capacitor or built as C4 (fig. 7)
C3	1/4" (6.5mm) wide copper or brass strap
L1	1/4" (6.5mm) wide copper or brass strap

fig. 5. Construction of the cathode circuit for the 1296-MHz transverter. This circuit is installed in a small aluminum minibox which is mounted on the plate enclosure (see fig. 1 and the photographs).

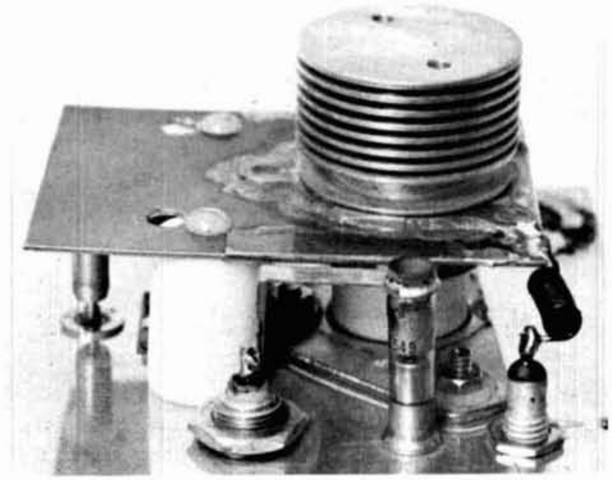
tuned to the intermediate frequency with a grid-dipper before installation.

The plate circuit (**fig. 1**) consists of an open half-wave line section, L4, tuned to 1296 MHz by capacitor C4. The line section is made of sheet copper or brass with finger stock connections to the tube anode ring and supported by insulating columns of Teflon, Rexolite, ceramic, or other good uhf dielec-



Construction details of the plate line, output network, and mounting of the grid-bypass capacitor, capacitor C7. Note that the mounting screw on the left is connected to the grid bypass plate for grid bias (from the cathode enclosure, below).

tric. The anode finger stock assembly can be found in the same military surplus vhf communication gear as the grid bypass assembly. Alternatively, commercial finger stock may be formed to the appropriate size and soldered around a hole in one end of the



Another view of the plate line showing the grid bypass capacitor, C7; output link, L5-C5; plate rf choke, RFC3; and bypass capacitor, C8.

plate line, L4, large enough to accommodate the tube anode ring as shown in **fig. 6**.

Capacitor C6 does not really exist, but merely represents the dc-open condition of this line configuration. In fact, the entire line and tube anode have B+ applied through RFC3 and C8. This feedthrough bypass capacitor must be rated to withstand the B+ voltage applied to the tube. If a commercial or surplus bulkhead capacitor cannot be found, this capacitor can be home-made using a 1-1/2-inch (38mm) square of sheet metal and sheet mica.

The plate tuning capacitor, C4, requires about 10 pF and must not break down at full applied B+. A low loss, high quality glass or ceramic piston trimmer (rated accordingly) would do nicely, or this capacitor may be constructed using 3/4-inch (19mm) wide, sheet brass strap bent up near the plate line for about 3/4 inch (19mm) and insulated from it with a layer or two of sheet mica (see **fig. 7**). The spacing between this tab and the plate line can be varied by any convenient mechanical means to tune the line. An alternate approach is to drill and tap the transverter topplate to pass a no. 8 or no. 10 (M4-M5) brass machine screw with captive lock nut. Cut the screw so it is just short of touching the plate line (by at least 1/16 inch or 1.5mm) and solder a 3/4 inch (19mm) diameter brass disc to its end. Insulate the disc from the plate line with mica sheet.

Output power is inductively coupled from the plate line via L5 which is made from 1/4-inch (6.5mm) wide copper or brass strap soldered to the output connector (N or BNC type) and run parallel to the plate line about 1/8 inch (3mm) away. The end of this strap can then be run down to, and parallel with, the chassis to form the matching capacitor C5. A low-loss glass or ceramic piston trimmer of about 10 pF capable of handling some moderately large rf currents, could also be used.

construction

The grid i-f and cathode LO circuitry plus filament and grid bias wiring are all contained within (and shielded by) a small aluminum minibox mounted on top of the plate line enclosure. This minibox is secured by the same hardware which is used to mount the grid bypass plate, C7. Two screws are insulated with nylon bushings from this grid bypass plate; the third screw makes contact with C7 but is still insulated from the chassis by nylon bushings. Bias and i-f connections are then made to this screw.

The plate circuitry and output coupling loop are

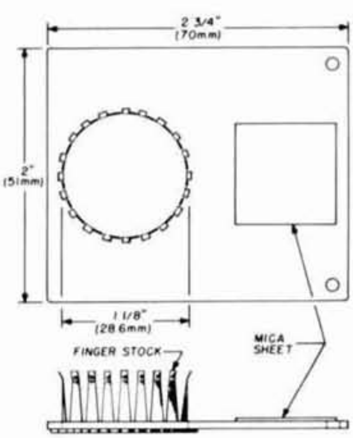
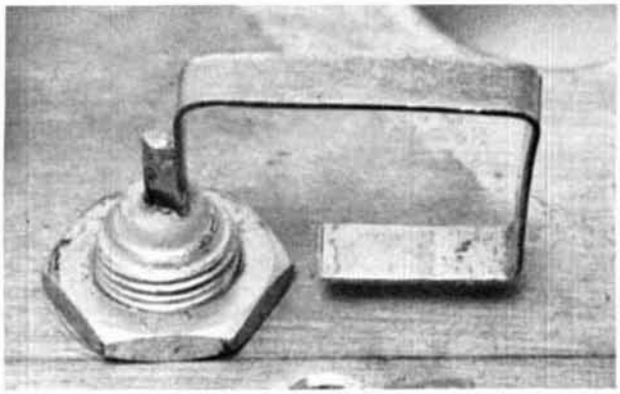


fig. 6. Plate line (L4 in figs. 1 and 2) for the 1296-MHz transverter. Finger stock can be obtained from Instrument Specialties, Little Falls, New Jersey.



An alternate arrangement for the output circuit, L5-C5.

contained within a 4 x 4 x 2 inch (10x10x5cm) minibox which serves as the chassis base. Screened air holes provide a path for forced air cooling of the tube anode structure, which is absolutely essential at reasonable power levels. These holes must be rf tight, so the shielding screen must be well grounded around its periphery.

Copper screen can be soldered to the aluminum

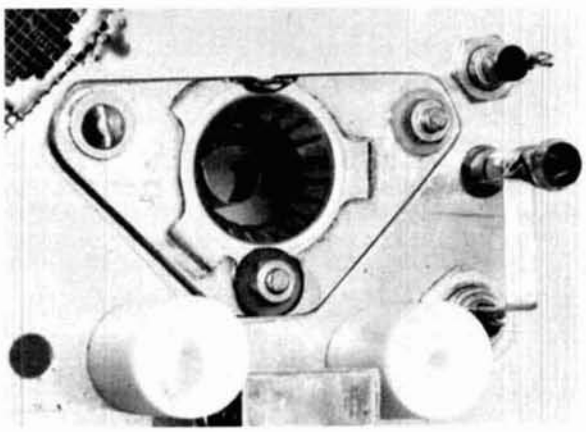


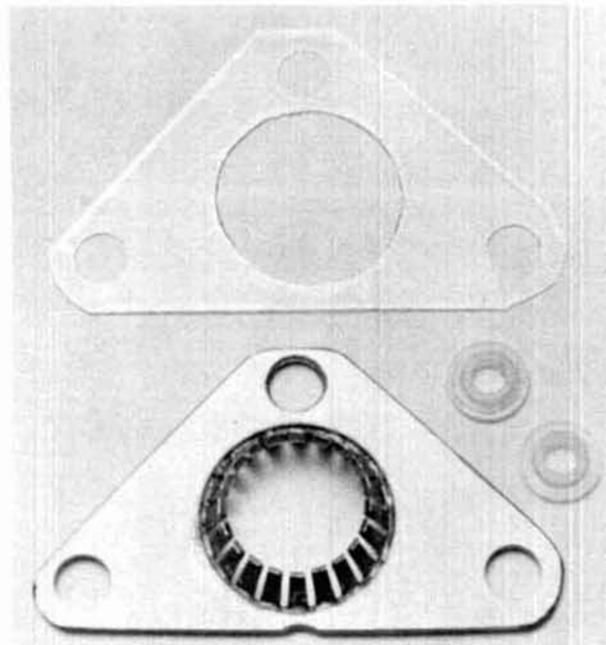
Plate line removed to show grid bypass plate. The plate line is mounted on the two Teflon pillars at bottom.

chassis by first tinning the aluminum with a large soldering gun or iron. Generously coat the periphery of the air hole with a heavy oil (clean auto engine oil works fine) to keep the aluminum from being exposed to air, then sand the surface clean using ordinary sandpaper or emery paper. Once cleaned, a hot iron (200 watts minimum) and rosin-core solder will tin the area beautifully. Then the copper screen can be soldered to the aluminum chassis. Practice this procedure first on some small aluminum scrap!

A convenient way to provide cooling air is to mount the transverter on edge on a large, air-tight pressurized chassis. The air hole in the transverter plate-line enclosure should be placed over an equal-sized hole in the pressurized chassis.

This chassis can also serve as a mounting platform and air source for the power supplies and LO chain components.

Common vhf construction practice should be followed throughout including short component leads, quality component selection, and rigid mechanical assembly. In one case, a 1/16-inch (1.5mm) thick, 4-inch (10cm) square brass plate was



Construction details of the grid bypass plate showing the sheet mica insulator cut out with an Exacto knife, and the insulating washers.

used as the top plate of the plate line enclosure with good results. It is a good idea to sand bare the adjoining surfaces of the plate line enclosure, top plate, and bottom plate, and use additional screws to assemble the top and bottom to assure good

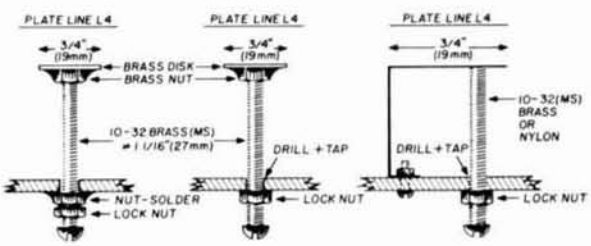


fig. 7. Three methods for building the plate tuning capacitor, C4.

shielding. When assembly is complete, a close visual inspection and a VOM continuity check should reveal any obvious problems before applying power.

tuneup and adjustment

Initial testing can best be done using variable-

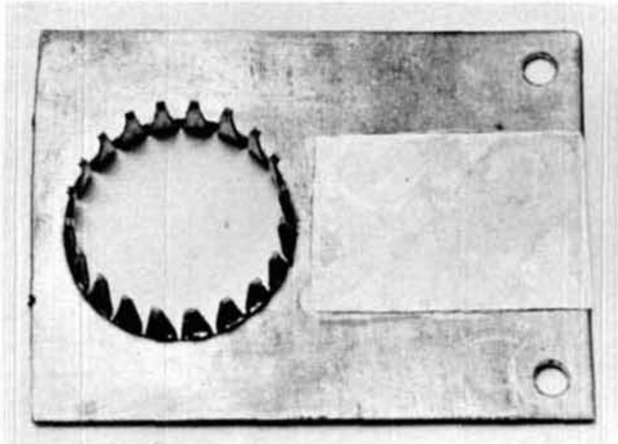


Plate line showing the plate collet (finger stock) and sheet mica insulator, right.

voltage power supplies to provide the plate voltage and grid bias. Since the grid will typically draw more than 50 mA, *the bias supply must have a low impedance and be capable of maintaining constant output voltage under fluctuating load conditions.* Apply filament voltage and cooling air, and after adequate filament warmup, gradually apply B+ while watching the plate current. Plate current should rise gradually, indicating normal tube conduction. Increase grid bias to reduce plate current until a plate voltage of about 300 volts can be applied with sufficient grid bias to limit plate current to about 20 mA.

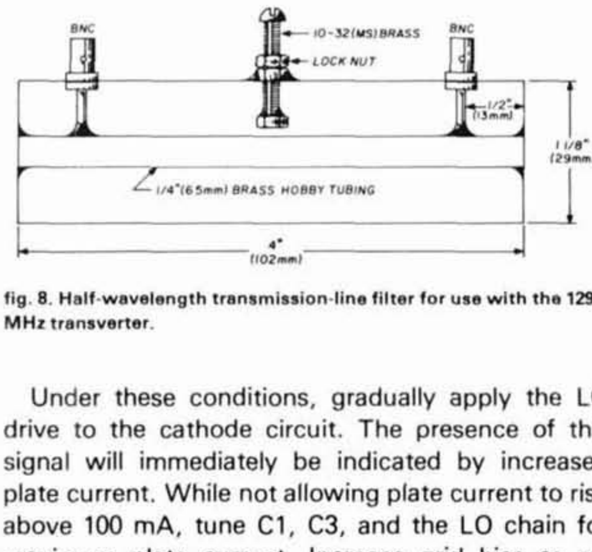


fig. 8. Half-wavelength transmission-line filter for use with the 1296-MHz transverter.

Under these conditions, gradually apply the LO drive to the cathode circuit. The presence of this signal will immediately be indicated by increased plate current. While not allowing plate current to rise above 100 mA, tune C1, C3, and the LO chain for maximum plate current. Increase grid bias as required to limit plate current to a safe value.

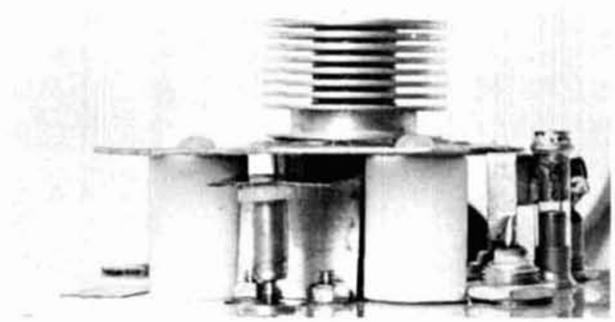
At this point, depending on your LO frequency, you *might* be able to resonate the plate circuit to the LO frequency by adjusting C4. Thus the unit operates as an amplifier to verify the behavior of the plate and output circuitry. If your LO is above 1296 MHz, tune toward minimum capacitance; if your LO is below 1296, tune toward maximum capacitance. Adjust C4, and the position of L5 and C5 for maximum indicated output power at the LO frequency.

Once cathode-line tuneup at the LO frequency has been accomplished and optimized, increase grid bias to reduce plate current to near cutoff — about 10 to 20 mA. Leave this grid bias at this value; the objective of this procedure is to bias the tube at or near cutoff (class AB or B) with plate voltage and LO drive applied but no i-f signal present. Now gradually apply a carrier at the i-f input and tune L2 for maximum plate current. Again, the presence of the i-f signal should immediately be indicated by increased plate current.

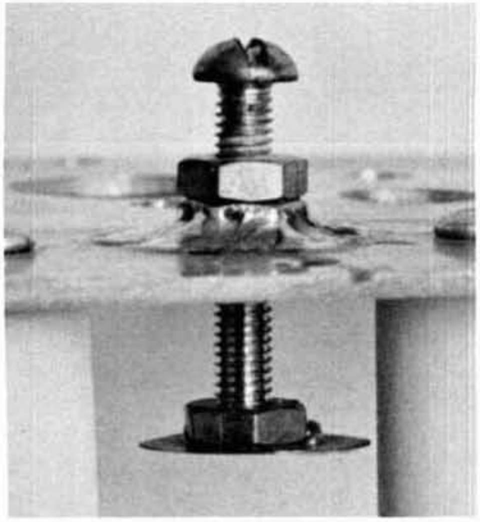
If all's well at this point, the LO and i-f signals are present in the tube's plate line; all that remains is to tune the plate line to the desired mixer product with C4. This process can be greatly simplified by placing a low loss filter tuned to 1296 MHz at the output of the transverter. An example filter of simple construction is shown in **fig. 8.**[6]

The filter can be pre-tuned to 1296 MHz by placing it in series with your 1296-MHz receiving system and tuning for maximum received signal from a nearby 1296-MHz transmitter, the third-harmonic of a 432-MHz transmitter, the 9th harmonic from a 144-MHz transmitter, or any other convenient rf signal source. This assures that any transverter output observed with the filter present will be on the desired signal frequency, and that power measurements will represent true power at the desired signal frequency, not the sum of the power contained in all the transverter's mixer products!

It is wise to leave the bandpass filter in the system to assure clean output. If, as is usually the case, your LO is *lower* than the desired mixer product on 1296 MHz, simply back out C4, (tuning toward minimum capacitance or higher frequency) while watching the output of the transverter for a peak. Once this peak is found, tune all screws for maximum output power. It may require a fair amount of time and patience to get the feel for the effects of each adjustment, and may even require repeating the entire procedure with a



The plate tuning capacitor, C4, is mounted under the plate line between the two Teflon pillars.



Construction of the home-made plate tuning capacitor, C4.

number of available tubes — some fly and some don't!

Once tuneup under reduced power conditions has been accomplished, full B+ may be applied; values from 500 to 1000 volts have been used successfully, but with lots of forced air cooling! The tube must then be re-biased for an idling plate current of 10 to 20 mA *with* LO but *no* i-f signal applied. Then increase CW i-f drive power up to the point of saturation (transverter output no longer increases with increasing amounts of i-f drive) and tune all adjustments for maximum output power. In the ssb mode, talk the transverter output up to an average of about half the maximum CW power output. Typical stage operating parameters are shown in **table 2**. The low efficiency is typical for this type of mixer circuit.

The half-wave, bandpass filter can also be used to transform a 50-ohm transmitter output impedance to 75 ohms to match the impedance of inexpensive,

table 2. Typical operating parameters for the 1296-MHz transverter. Output power was measured at the output of the bandpass filter with a calibrated Bird wattmeter and 50E slug.

Local-oscillator power	3 watts carrier
I-f power	4 watts CW
Plate voltage	+800 Vdc
Plate current	150 mA
Rf power input	120 watts
Grid bias	−35 Vdc
Grid current	50 mA
Rf power output	17 watts
Efficiency	14%

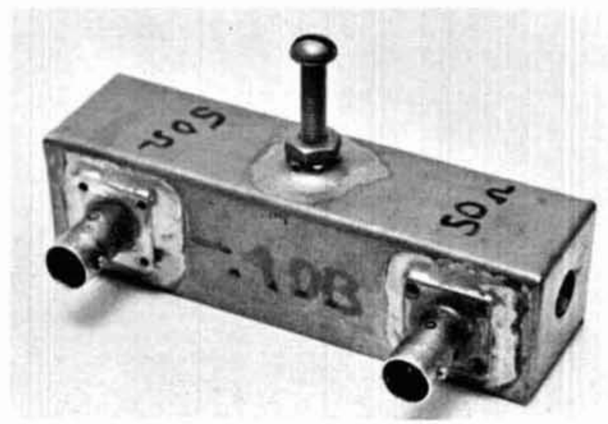
low-loss CATV coax. For 75 ohms simply space the tap 5/8 inch (16mm) from the line end.

conclusion

It is the intent of this article to describe a relatively simple and inexpensive method for the average amateur to get on 1296 MHz with enough power to make himself heard. Hopefully the ease with which this system can be put together will encourage more activity on the band and finally put to rest the myth that "you can't get there from here on 1296!" I am waiting now to hear from some hard-working and dedicated uhf buffs in Hawaii who would be interested in destroying the current 1296-MHz terrestrial record once and for all! How about it out there, any takers?

acknowledgements

Sincerest thanks are in order to the many people who contributed to this effort: notably to Bill Jungwirth, WA6NRV, for the beautiful construction of the first working prototype model of the transverter; to Tom Staller, WB6QHF, for the contribution of a commercial varactor tripler; and to the



Half-wavelength transmission-line filter for 1296 MHz. Loss of the filter shown here is 0.4 dB. Dimensions are shown in fig. 8.

West Coast's "Father of 1296," Bill Troetschel, K6UQH, who provided much good advice and encouragement amongst many good ribbings! Photo credits go to Alan Monie. Special thanks go to my wife, Jean, for typing the manuscript.

references

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