The Elevator: A Simple 220-MHz FM Transverter

Going up... to 220-MHz FM? Try the Elevator! Add a low-cost 49-MHz hand-held transceiver, antenna, and you're there!

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I've always been thrilled by the opportunity to try out a new band or mode of operation! Some time ago, I became interested in getting on 220-MHz FM. Novices have voice privileges on that band—and I'm a Novice at heart. The cost of commercially made gear for 220 MHz initially dampened my enthusiasm, but not for long. An avid experimenter, I considered the home-brew alternative.

I wanted a 223-MHz FM transceiver that would allow me to make solid local contacts. The radio had to be reliable, easy to reproduce and tune up. It also had to comply with current FCC specifications for spectral purity and cost less than $100. The Elevator, an intermediate-level construction project, meets these design goals. Several Elevators have been in operation locally for over a year providing dependable communications.

Overview

Hand-held transceivers—such as the 49-MHz TRC-501 available from Radio Shack®—have become very popular for short-range, unlicensed communications. These inexpensive, crystal-controlled FM radios are stable; they also have a superhet receiver and use a modulation level that is compatible with existing amateur VHF FM standards. But how do you get the '501 to work on 223 MHz? Easy—you build a transverter!

A transverter is a combined transmit and receive converter. Transverters allow you to use a transceiver (or separate transmitter/receiver combination) on a band other than enclosures for both units. Ventilation holes are drilled in the top and bottom covers on the right-hand side. A small U-shaped metal bracket is attached to the back of the top cover at the left (Fig 1). The TRC-501 can be clipped to this bracket when carrying the unit.

The Elevator in Fig 1 is designed for dual-channel operation and has a small slide switch mounted on the bottom lip of the

Fig 1—An oblique view of a two-channel version of the Elevator. At the top rear of the case is a U-shaped clip to which the TRC-501 transceiver can be attached. Beneath the handle at the left is a frequency-selection switch for two-channel operation. Ventilation holes are drilled in the top and side of the case. The DIN PWR and BNC ANT Jack are mounted on the bottom lip of the box; a notch in the upper lip allows it to fit around the ANT jack.
Fig 2.—An inside view of an Elevator built for two-channel use (note the two crystals at the top middle of the board). The crystal-selection switch is mounted in the handle section of the plastic case. (This unit contains an experimental GaAsFET receiver preemphlizer on the foil side of the board. Therefore, some components are not visible in the area of Q8.) Refer to the parts overlay (Fig 7) for component placement. At the upper left, the DIN PWR connector can be seen; an in-line fuse holder (for F1) is immediately to the right of the connector. The cable at the top right of the board (near the crystal-selection switch) leads to the XCVR jack (J1) on the other side of the case. A voltage regulator U3 and its finned heat sink are below the DIN connector. An aluminum extension is attached to U3’s heat sink; beneath this extension are C17 and C18. Cylindrical heat sinks made from aluminum tubing fit tightly over Q2 (above the coaxial-cable jumper) and Q7 (left, foreground). L9 is the vertically mounted coil near Q7. The ANT connector (J2) is at the left just below U3.

plastic housing beneath the carrying handle. Because the unit in the title photo is designed for single-channel use, no switch is used, but a convenient location for this optional switch is identified by the label SWITCHES.

With the exception of the power transformer, power connectors and optional channel-selection switch, the Elevator is contained on a single PCB board. For operation from the home station, power for the Elevator can be supplied from a 9-V ac wall transformer. For portable, mobile or home-station operation, a 12- to 14-V dc supply can also be used. The transverter delivers between 1 and 1.5 W of RF output, has adequate noise performance, and can be used in RF-sensed TR switching and for five crystals.

Circuit Description

To give you an idea of how the transverter works, a brief circuit description is in order. Refer to the schematics in Figs 3 and 4.

Power Supply

Power for the Elevator is supplied through the DIN connector, J3. Fig 4 shows how to power the Elevator from an ac or dc power source. F1 and F2 are in-line fuse holders; F1 is installed within the Elevator’s case.

For operation from the ac mains, the 9-V ac input from the wall transformer is fed to a voltage doubler/rectifier (D6 and D7). The dc output is filtered by C17 and C18 and fed to regulator U3. D8-D10 are used to raise the regulated output of U3 to approximately 13.6 V. A jumper is connected between points A and D when an ac wall transformer is used.

For operation from a dc supply, the positive output of the power supply is connected to point D and the jumper between A and D is not used. D20 provides reverse polarity and transient-voltage protection. Dc operating voltage is applied continuously to TR switch detector U2, local oscillator (LO) Q1 and Q2, the power-amplifier (Q6 and Q7) collector circuits and the IF transceiver (the TRC-501) at J1.

Local Oscillator

The LO operates in the 86-MHz region. For 223.5-MHz operation with a 49.830-MHz IF (standard channel A on the TRC-501), an 86.835-MHz crystal is used at Y1. The crystal frequency required is determined by subtracting the channel frequency of the TRC-501 from the desired operating frequency and dividing the result by 2:

\[ F_\text{x} = (F_\text{op} - F_\text{IF}) \div 2 \quad \text{(Eq 1)} \]

Push-push doubler Q2 multiplies the oscillator output to 173.670 MHz, providing very clean LO energy to mixer U1.

Crystal Switching

DC voltage is also available at terminal B for selecting diode-switched crystals with an on-board jumper (W2) or an off-board switch for simplex operation. For half-duplex operation, terminals T and R are used. Jumper R to the crystal-select point (CS1-CS5) corresponding to the crystal to be used for the receive frequency. Likewise, point T goes to the desired crystal-select point for transmit. Any switching scheme can be used, provided that only one crystal-select input is high (+12 V) at a given time.
Fig 3—Schematic of the Elevator. The T, R and B terminals are connected to the crystal select (C6) terminals as described in the text. Here, W2 is shown between terminal B and C8 for simplicity. A finned heat sink is attached to U3. Q2 and Q7 have cylindrical heat sinks made of aluminum tubing. Parts suppliers are listed in Table 1.

C8, C9, C43, C44, C50—4-20 pF trimmer (Mouser 24AA022).
C35—3-12 pF trimmer (Mouser 24AA021).
D11—1N5268B, 3.3-V, 0.5-W Zener diode.
D12—1N5295, 5.1-V, 0.5-W Zener diode.
D17—MPS404 PIN diode (Circuit Specialists).
D20—1N4745, 16-V, 1-W Zener diode.
L1—5 turns, 5/32-in ID, 1/2 in long. (Note: All air-wound coils use no. 22 bare wire; the slant of a drill bit can be used as a winding jig.)
L2—8 turns, 5/32-in ID, 1/4 in long, tapped 2 turns from ground end.
L3—0.22-0.28 μH adjustable (Jameco CL-1).
L4—0.86-0.07 μH adjustable (Jameco CL-2).
L5—7 turns no. 24 enameled wire on a T-30-12 core; tapped two turns from D15/D16 end.
L6, L7—5 turns, 1/8 in ID, 1/2 in long.
L8—3½ turns, 5/32 in ID, 3/16 in long, 1/4 turn from C37 end.
L10—2½ turns, 3/16 ID, 3/16 in long.
L11—4½ turns, 3/16 ID, 3/16 in long.
L12, L13, L16—2½ turns, 5/32 ID, 5/32 in long. L12 is tapped 1 turn from ground end.
L14—3½ turns, 5/32 ID, 1/4 in long.
Q1, Q6—PN5179 (Mouser ME335-PN5179). Note: A 2N5179 has a different pin-out than that of a PN5179.
Q7—3N307 (RF Parts).
RFC1-RFC3—104 turns no. 28 enameled wire on an FB43-101 ferrite bead.
T1—Secondary: 8 bifilar turns no. 28 enameled wire on a T-35-12 core; primary: 3 turns no. 28 enameled wire wound over the middle of the secondary.
U1—Mini-Circuits SBL-1 mixer.
U2—MC1330 low-level video detector.
U4, U6—Mini-Circuits MAR-1 amplifier.
U5, U8—Mini-Circuits MAR-4 amplifier.
Y1-Y5—86-MHz, 5th-overtone, series resonance, HC-25U holder. Crystal Crys-
tals RHF-4 or equiv. The required crystal frequency is determined by subtracting the channel frequency used in the TRC-501 from the desired operating frequency and dividing the result by 2. (F2 = Fref - Fch + 2). See text.
Z1-Z7—FB43-101 ferrite bead.

A three-pole, four-position switch will handle all the crystal-switching possibilities (except for five simplex channels—an unlikely need).

Receive Circuits
During receive, the voltage present at U2, pin 4, is about 5. This positive voltage turns Q3 and Q4 on, and turns Q5 off. Q4 applies 12 V to the receive bus (12R). Incoming signals pass through D19 to Q8, a ground-de-
gate JFET preamplifier. Broadband ampli-
ifier U6 provides additional gain. Received-
signal flow proceeds through D16 and the 223-MHz bandpass filter L4/L5, arriving at mixer U1 where the desired signal is con-
verted to the 49-MHz region for delivery to the IF transceiver attached to J1.

TR Detector
The RF output of the 501 transceiver is very low, so an ultra-sensitive detector (U2) is required for TR sensing. During transmit, RF applied through C12 forces pin 4 of U2 to 0 V. This turns off Q3 and Q4, disabling the receive section. Q5 turns on, applying power to the transmit bus (12T).

Transmit
When the transmitter goes into transmit mode, the 49-MHz output signal from the transceiver is converted to 223 MHz in U1. Bandpass filter L4/L5 selects the desired mixer product. The 223-MHz signal is routed through D15 to broadband amplifiers U4 and U5. Interstage networks C25/L6 and C27/L7 narrow the 223-MHz response while maintaining the no-tune advantage. Additional signal amplification is provided by driver Q6 and final power amplifier Q7. PIN diode D17 passes the transmit signal to ANTenna connector J2 via a low-pass filter. The voltage developed across R36 by the current through D17 keeps D19 cut off, preventing transmitter RF entry into the receiver preamplifier, Q8.

Modification and Construction Information
Detailed Elevator construction and trans-
ceiver modification information is available from the author or from ARRL HQ. I'll describe the more important points here.

Transceiver Modifications
To interconnect the transmitter and the Elevator, the transmitter's telescoping whip antenna is removed and replaced by a short (approximately four-foot) length of RG-58 coaxial cable. Place a grommet in the trans-
ceiver-case hole vacated by the antenna, and feed the cable through it.

Ordinarily, the TRC-501 transceiver is powered by its own internal 9-V battery. But as shown in Figs 3 and 5, J1 of the Elevator can carry both RF and dc to the transceiver. The supply used to power the Elevator can also power the transceiver through the interconnecting coax. The voltage fed to the transceiver is regulated at about 9 V by the circuit shown in Fig 5. This regulator can be built on a piece of perf board about the size of a 9-V battery. Make sure that you connect the wires to the battery clip correctly to ensure proper supply polarity for the transceiver.

The center conductor of the interconnecting coaxial cable ties to the transmitter antenna lead that originally connected to the base of the whip antenna. The 0.001-μF disk capacitor connected to the coaxial cable center conductor prevents dc voltage from being applied to the transceiver's antenna-input circuit. The coax shield is tied to the transceiver's PC-board ground foil.

Elevator Construction
Unless you've an experienced VHF-circuit builder, I recommend using the PC-board layout shown in Fig 6; it's been "road tested." Parts-placement information is provided in Fig 7.

Coil winding is easier done than said. The length of each air-wound coil is set by its PC-board mounting holes; winding lengths are provided in the parts list. The turns count starts when the wire enters the
Fig 5—The supply used to power the Elevator can also power the transceiver by use of the simple regulator circuit shown here. This circuit can be built on a small piece of perf board and installed in the transceiver’s battery compartment. The 0.001-µF capacitor connected to the coaxial-cable center conductor keeps dc voltage present at J1 from reaching the transceiver’s antenna input circuit (see text).

cylindrical domain of the coil and ends when it departs. For toroids and ferrite beads, one turn is counted each time the wire goes through the core hole. For L5, distribute the turns over 60 to 70% of the core. To form the bifilar secondary winding of T1, first twist together two pieces of no. 28 enameled wire (about 8 twists per inch). Wind this twisted pair to occupy 75% of the core with 8 turns of the twisted wire. Make the center tap by connecting the end of one wire to the beginning of the other, keeping the lead lengths short.

One lead of C49 connects directly to L13, as does one lead of network C51/R39. The top lead of L9 (mounted vertically) connects directly to L8 at only ¼ turn from the C37 end.

Be sure to correctly orient each transistor; make note of the position of the flat side or tab. Q7 (in a special emitter-to-case package) mounts flush with the PC board. Q2 and Q7 require heat sinks; I made mine from short lengths of aluminum tubing. Q2’s heat sink is about ½ inch long and Q7’s heat sink is 1 inch long. U3 requires a finned heat sink and an additional 1-square inch radiator made from scrap aluminum sheet (see photos).

Monolithic amplifiers U4, U5 and U6 are installed on the foil side of the PC board;

Fig 6—Circuit-board etching pattern for the Elevator. The pattern is shown full-size from the foil side of the board. Black areas represent unetched copper foil.
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the color dot on each device denotes its input lead. The leads of each of these devices must be trimmed somewhat. Before installing U4-U6, it’s helpful to pre-tin four target solder areas for each device’s leads.

A coaxial-cable jumper is required between D16 and C56. Use RG-174 or RG-58 for this purpose.

The ANT jack (J2) mounts directly on the PC board. Solder lugs on the flange of J2 permit easy soldering to the perimeter ground foil. The center pin of J2 connects to the PC board at the junction of L16 and C67. J1 (XCVR) is mounted on the case wall opposite J2 (see photos).

How you house the transverter PC board is up to you. I chose to use a nifty plastic pencil case available at a local drug store. The case costs less than the shipping charge for a metal cabinet, and it works great.

Tune-Up

Connect the TRC-501 to J1 and attach a VHF wattmeter and dummy load to J2. (A dummy load can be fabricated by paralleling three 150-Ω, 1/2-W carbon resistors.) Relative RF output can be read by monitoring the dc voltage at TP2.

Reset the slug in L3 to a depth of about 7/16 inch from the top of the form; set L4’s slug at 5/16 inch from the top of the coil form. Set all the variable capacitors at midrange. Attach a voltmeter set to read 5 V dc between TP3 (U2, pin 4) and ground. Turn on the power supply; D13, the green LED, should light. Turn on the TRC-501 and press the PTT switch. The red LED (D14) should illuminate. Adjust L3 to obtain 0 V at TP3. Release the PTT switch.

Verify the transverter’s crystal oscillator operation by probing with a frequency counter near T1, or by using an FM broadcast-band receiver to tune in the oscillator’s signal below the FM broadcast band. If necessary, experiment with the turns spacing on T1 and/or the value of C3 to achieve oscillation.

Use a wavemeter near L2, a public-service-band radio equipped with an S meter, or a spectrum analyzer to monitor the doubler signal (near 173 MHz). Adjust C8 and C9 for a maximum signal indication at twice the crystal-oscillator frequency. With a voltmeter connected between TP1 and ground, key the transceiver and adjust L4, then C8 and C9 for a maximum indication; typically 0.15 V dc.

With the exception of the adjustment of L3, the foregoing preliminary tune-up steps can be made using a received signal. Adjust C8, C9, L4 and C50 for maximum quieting of the received signal. If this is done, be sure to reconnect the dummy load to the Elevator for the next step: power-amplifier tune-up.

Connect a voltmeter between TP2 and ground, key the transceiver and adjust C35, C43 and C44 for a maximum voltage indication at TP2 (typically, 3 to 4 V dc). The adjustments of C43 and C44 interact, so you should make the adjustments a few times to ensure you’ve achieved a maximum indication. Allow some time between tune-up periods to allow Q7 and the dummy load to cool off. Experiment by compressing and expanding the turns of L9 to achieve maximum RF output. Lacking a receive signal to peak on, C50 can be adjusted during transmit for a very small dip in the

Fig 7—Parts-placement guide for the Elevator. Except for U4, US and U6, parts are placed on the nonfoil side of the board; the shaded area represents an X-ray view of the copper pattern. U4, U5 and U6 are soldered to the foil side of the board. The dots near U4, U5 and U6 identify the input lead of each device. Although only one crystal is shown installed on this board, five crystals can be accommodated. (For the purposes of this write-up, I’ve chosen to use the five crystals that were available with existing author-supplied materials; a departure from QST style is made in the identification of D13 and D14; normally, LEDs are identified with DS designators. Also, ferrite beads—here identified as Z1-Z7—usually have FB designators.)

Output indicated at TP2. If you have access to a spectrum analyzer, you can check for spectral purity.4

Operation

Connect the antenna feed line in place of the dummy load used during testing. If you’re using a wattmeter, leave it in the line. (Alternatively, you can monitor the dc-voltage amplitude at TP2 for a relative-output indication.) Turn on the power supply, press the transceiver PTT switch and touch up C3 and C44 for maximum output. If a weak-signal source is available, peak C50 for best reception. That done, you’re on the air! I recommend close-talking the mike for full modulation. RV1 in the TRC-501 transceiver provides some control of the deviation.

Activity on 220-MHz FM is mainly on repeaters, and simplex activity varies greatly around the country. Here in north-central Ohio, 223.5 MHz (the national simplex channel) is very quiet. I’ve mainly been working Elevator-equipped locals, such as N8AHK and WB8TCZ, for reliability testing. Late one evening, dozing in the shack, I was startled as the speaker came to life: “N8EDV listening.” After a short QSO with Dave, I checked the map. Wow! 82 miles... and I wasn’t even wearing Elevator shoes!

Mike Asgent was first licensed in 1966 and got his Extra Class ticket in 1969. He served six years in the US Navy as a Radar/Electronic Navigation Aids Technician and eight years in the US Merchant Marine as a ship’s Radio Officer. Mike is currently employed in the marine-electronics field. Two of Mike’s four brothers are hams: Dave, K4QY, and Jim, N2BB. Jim was an operator at K66DC of 160-m fame.

Notes

1. The Elevator is available in kit form from LECTROKIT, 401 W Bogert Rd, Stow, OH 44224 (a telephone number is not available). PC board only and detailed manual, $15; XV223-49 Elevator transverter kit, $88. All prices are post-paid in the US; Ohio residents add 6.5%. The kit includes a drifted PC board, parts, case, connectors, TRC-501 modification kit, detailed assembly manual and a 9-V wall transformer (unused surplus or new). TRC-501 transceiver, crystal(s) and antennae are not supplied. A 220-MHz crystal for use with the TRC-501 channel A (49.830 MHz) XTAL-A is $9. To determine the crystal frequency required for other channels, refer to the text and the parts list. Send a business-size SASE for latest information. The ARRL and QST in no way warrant this offer.

2. To order from the ARRL please send your request to the Technical Department Secretary, 226 Main St, Newington, 06111 and ask for the Elevator Template Package. Include $5 to cover photocopying and postage costs.

3. The Deluxe School Courses are sold by W. T. Rogers Co, 225 Main St, Riceville, IA 52179/6, tel 808-657-2227. Case part numbers are 510707 (black), 510808 (red) and 510912 (yellow). (These cases can be purchased in single-lot quantities from the manufacturer. Ed.)

4. Two Elevators checked in the ARRL Lab met FCC requirements for spectral purity. After the initial measurements were made, one unit was detuned to the starting points specified in the tune-up instructions and retuned according to the supplied procedure. Upon completion of the tune-up, all data were nominally the same as measured initially.