THE LWM-3

- A BANDSWITCHING MOBILE SSB TRANSCEIVER

By W. C. Louden, W8LW, and A. F. Prescott, W8DLD

PART I — Design and Electrical Details

G-E HAM NEWS is proud to present a complete bandswitching SSB/CW transceiver which—though primarily designed for mobile service—is also well suited for operation from a fixed location too.

The LWM-3 tunes eleven 200-kilocycle wide segments in its over-all range of 3.5 to 30 megacycles. These ranges may be chosen by plugging the proper crystals into the high frequency section which is crystal controlled.

The LWM-3 is a project which the experienced radio amateur can construct and have the equivalent of fine commercial equipment in performance and operating convenience.

Design and electrical details of this 23-tube transceiver are covered in this issue, and the complete mechanical and construction details, and tuning information, are given in the January-February, 1962 issue of G-E HAM NEWS.

The LWM-3 is a MOBILE SSB and CW transceiver covering 3.5 to 30 megacycles, and delivering 5 watts PEP output. It was designed to drive an easy-to-drive linear amplifier.

It features:
1. Transceive operation — no zeroing of the transmitter to the received frequency;
2. 2.1-kilocycle filter for high selectivity — unwanted sideband down 40 decibels;
3. Double conversion circuit with good rejection of spurious signals;

Plus features include the following innovations:
1. Ultra stable VFO using Command Set transmitter tuning capacitor and packaged oscillator construction for rigidity;
2. Slug tuning unit from broadcast auto radio — modified for ganged exciter tuning control;
3. Custom made slow-tuning rate dial for VFO;
4. Cabinet which is inexpensive and easy to fabricate;
5. Balanced first mixer in transmitter featuring the inexpensive G-E 6AB6 beam-beam tube to minimize spurious frequencies;
6. Standard IF transformers — slightly modified to perform special tasks;
7. Mobile mount that facilitates “slip in—slip out” operation in the car;
8. Good ideas on circuit board component mounting.

W8LW DEMONSTRATES here the operation of his new LWM-3 transceiver in his automobile. The complete unit and mounting bracket were designed and built by him and A. F. Prescott, W8DLD. The LWM-3 is the latest in a series of projects described by these well-known authors in G-E HAM NEWS. W8LW drives a pair of GL-6021/4-152-A’s in a linear amplifier in his station wagon. Power is supplied by a 3-phase AC alternator system and high-voltage stepup transformers, as previously described in G-E HAM NEWS.

Basically the LWM-3 was designed for mobile operation. All the “most-used” controls were placed on the left side of the front panel to minimize the distance a driver must reach when tuning and operating the unit. The tubes and associated circuitry were positioned for this placement of the controls.

The size of the unit was reduced to a minimum to prevent using front seat leg room needed by passengers. In fact, three people can still sit in the front seat if the one in the center sits at an angle with his feet to the right of the transceiver. “VOX” has worked out well through the use of a close-talking reluctance microphone which minimizes background noise pickup.

The 5 watts peak power output is more than adequate to drive the “Mobile Linear Amplifier” even at 28 megacycles. An intermediate amplifier stage with higher power was not needed, and was not included to achieve higher over-all efficiency, which is of prime importance for mobile operation.

THE RECEIVER SECTION of the LWM-3 transceiver is shown in block diagram, Fig. 1. Several tubes and other key components in the circuit also function when the transceiver is operating as a transmitter. These dual-function stages are colored in red on the block diagram, with the signal paths on “transmit” also in red.

(continued on page 2)
A 6BZ6 remote-cutout pentode (Vr) serves the dual purpose of tuned RF amplifier for the receiver, and as the driver for the output amplifier on transmit. The amplified incoming signal is then mixed in a 6BA7 pentagrid converter (Vq) with the signal from the crystal oscillator (Vc1), a 6BZ6 pentode, resulting in an intermediate frequency signal between 2.955 and 3.155 megacycles.

This IF signal then passes through passband tuned circuits in T2 into a second 6BA7 pentagrid converter (Vq), where the signal is mixed with the 2.5 to 2.7-megacycle VFO signal from the tunable oscillator (Vq). The difference frequency in the output of the second mixer in the 450 to 460-kilocycle range, is then fed through the 2.1-kilocycle wide mechanical filter (F3). This second IF signal is amplified in two 6BA6 remote-cutoff pentodes (Vq and Vr).

Demodulation of SSB signals is accomplished with a 12AU7-A triode (V1), which functions as a product detector. A 6A6 crystal controlled beat frequency (BFO) oscillator (V2) provides the inserted carrier for the product detector. Two crystals, V1 and V2, place the oscillator on the correct frequencies for selection and reception of upper or lower sidebands. After detection, the audio signal is amplified in the 6H6 first pentode, voltage amplifier (V7a), and a 6AK5 beam power audio output stage (V8).

**THE TRANSMITTER SECTION** of the LWM-3 utilizing the twin triode as two stages of audio amplification (V7a and V8) from a high-impedance microphone input (Jm). The audio signal is then fed into a balanced modulator (V2) to provide the 2.5 to 2.7-megacycle output through the triode section of a 6U8-A (V9) in a cathode follower circuit. The same BFO (V2) used for the receiver drives a 6US-A pentode section isolation amplifier (V3) to supply the carrier to the balanced modulator. Crystals Y1 and Y2 again provide selection of upper or lower sideband.

The output of the modulator is a double sideband suppressed carrier signal, the carrier having been balanced out in the modulator. This signal passes through the 2.1-kilocycle bandwidth mechanical filter (F3) at 455 kilocycles to remove one sideband. The resulting single sideband signal is then amplified in a 6BZ6 pentode (Vq) before being applied to a 6AK8 sheet beam tube (Vq).

The 6A8 mixes this SSB signal with the signal from the VFO (2.5 to 2.7 megacycles), resulting in a signal in the 2.955 to 3.155-megacycle range, depending upon the frequency to which the VFO is set. After passing through the bandpass filter (T1 and T2), the signal is mixed with the signal from the 6BZ6 pentode crystal oscillator (Vc) to arrive at the desired amateur band output signal frequency.

Then the signal is amplified by the 6BZ6 RF amplifier (V3), and this stage, in turn, drives the 12BY7-A beam pentode (V9) output amplifier. Thus, the RF amplifier, VFO, BFO, and the two oscillator tubes, plus the 2.1-kilocycle wide mechanical filter and the 2.955 to 3.155-megacycle bandpass filter, all serve dual purposes in the LWM-3 and function both for reception and transmitting.

Still other circuits in the LWM-3 transceiver include automatic volume control (AVC) (V9), and a 100-kilocycle crystal oscillator (Vc2) to provide essential frequency markers from which to adjust the tuning dial pointer.

Most of the circuit switching between receive and transmit is performed by applying a minus 65 volts — obtained from the external power supply — to the tubes which are unused in each function, biasing these stages to cutoff condition. This is similar to transferring such functions through relay contacts or other mechanical means.

The voice-controlled break-in (VOX) circuitry (V4, V5, and V6) acts three relays during transmit which apply and remove a minus 65 volts to appropriate circuits. Plate and screen voltage is applied to V6 and V5 only during transmit. One of the control relays also transfers the antenna from the input circuit of V5 to the output circuit of V6.

**FIG. 1. COMPLETE BLOCK DIAGRAM** of the LWM-3 transceiver. The diagram is color coded to show:

1. circuits which operate only on receive, and inoperative on transmit, are in solid black lines;
2. circuits which operate both on receive and transmit in solid black and red lines, which operate only on transmit in solid red lines. The schematic diagram number is marked next to each tube and component.

**THE SCHEMATIC DIAGRAMS** of the LWM-3 transceiver have been divided into sections according to major function to facilitate reference. Major components in the transceiver are identified in the photo on page 3.

The transmitter schematic diagram, Fig. 2, contains the circuits of the two key oscillators, the VFO (V6) and the high-frequency crystal oscillator (Vc). A description of these circuits follows.

The heart of any mobile communications unit is the tunable oscillator (VFO), and therefore the design of the LWM-3 was built around this unit. It was realized that stability was the prime objective and small size would necessarily be the second. From previous experience with mobile VFO's the LWM-3 VFO was designed to withstand shock and impact testing as well as vibration and thermal drift.

A series-tuned Colpitts (Clapp) circuit using a Harrington XL1 coil (L200) and a Command Set transmitter tuning capacitor (C205) resulted in the desired frequency stability after a series of preliminary tests. All major frequency determining components were bolted directly to the capacitor frame to eliminate relative movement of parts. V., temperature compensating capacitor (C204) in conjunction with thermistor drift (C209) is used to compensate the VFO for the temperature rise within the transceiver cabinet during operation.

The oscillator output is divided by a 470-microhenry coil (L202) in series.
with a 12-microhenry RF coil (L203), to provide between 1.2 and 1.5 volts RF for the first transmitter mixer (V1) and second receiver mixer (V2).

The crystal oscillator is a standard electron coupled Pierce circuit which uses fundamental crystals. The output circuit is tuned to the marked frequency of crystals in the range from 3.5 to 12 megacycles. Above this the second harmonic of the crystal is obtained in the oscillator plate circuit, pretuned to each crystal that is selected by the bandswitch (R8). The plate coil, L212, could be gang tuned with the RF amplifier and possibly eliminate some of the trimmer capacitors selected by R8. The series plate resistor (R225) can be adjusted so that the oscillator will provide 2.0 volts RF for the transmitter second mixer (V3), and the receiver first mixer (V4). The value of 4700 ohms for R225 gave the correct voltage in this unit.

The 6ARS sheet beam tube (V1) in the transmitter first mixer has the RF signal from the VFO applied to the control grid, and the 455-kilocycle SSB signal from the generator section applied to one beam deflection plate (see "D"). No balancing voltage controls were found necessary for the deflection electrodes of the 6ARS to obtain satisfactory rejection of the VFO signal in the output. Several 6ARS tubes with unbalance were substituted in the circuit to confirm this fact.

A Miller type 6205 4.5-megacycle ratio detector transformer was used for the balanced output transformer. This transformer has a tertiary winding which must be disconnected by unsoldering its connection to pin 6. An additional transformer (T4), a Miller type 6205 4.5-megacycle IF transformer, is used to obtain the desired bandwidth to cover 3.155 to 2.955 megacycles with high attenuation outside this range. The secondary of T4 is used as a parallel tuned trap to help attenuate unwanted frequencies.

The output of the bandpass IF amplifiers is connected to a second balanced mixer — a 12AT7 (V4) twin triode — of conventional design. Both mixers are biased to cutoff when the transmitter is in the receive function.

The grid and plate circuits of the 6EZ6 pentode RF amplifier (V3) are slug-tuned circuits with various capacitors switched in parallel to resonate at the various amateur band segments selected by the bandswitch. The plate circuit is also the grid circuit of the 12BY7-A pentode final amplifier (V5). Bridge neutralization is used and a Pi-type output network with 50-ohm output impedance is band switched in the plate circuit.

Since the 12BY7-A is operating class A, a Pi output tank is quite inefficient but it is a simple unit to switch, and provides sufficient RF output to drive W8WBF's mobile linear amplifier. A 1N34A diode (C5), voltmeter circuit is provided across the 50-ohm output to facilitate tuning procedures.

THE RECEIVER SECTION schematic diagram is shown in Fig. 3. This diagram contains the AVC, "S" meter and crystal calibrator functions. The 6EZ6 pentode RF amplifier for the receiver (See V, in Fig. 2) — also the RF driver stage in the transmitter — receives the signal from the antenna through connection "W" and the antenna transfers contacts on relay K1, in the VOX AND CONTROL CIRCUITS schematic diagram, Fig. 5. The plate circuit of V4 then runs to the 6IAT pentagrid first receiver mixer (V3) in Fig. 3 through connection "U."
TABLE 1 — COIL TABLE

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Turn spacing decreases from 1/2 inch to 1/32 inch at lower end (similar to Collins Radio No. 544-3135-002). Lumen...3.0-uh, 5 turns, No. 20 tinned wire, 1/2-inch diameter, 0.75-inch long, 16 TPI (B & W 3003 Miniductor). Lumen...0.8 — 1.5-uh slug tuned coil; 10 turns No. 24 Formex wire close wound on 1/32-inch diameter ceramic form (Cambion L5-8-6). Lumen...0.6-uh, 8 turns, No. 20 tinned wire, 1/2-inch diameter, 1/2-inch long, 16 TPI (B & W 3003 Miniductor). Lumen...12-uh total, 64 turns No. 24 tinned wire, 1/2-inch diameter, 2 inches long, 32 TPI, tapped at 9 (16 Mf), 18 (14 Mf), and 32 (7 Mf) turns from Lumen and (B & W 3004 Miniductor). Lumen...33-uh RF coil (J. W. Miller No. 4628-E). Lumen...1.2-uh, 12 turns No. 24 Formex wire close wound on 1/32-inch diameter ferrite core.

*Firm wire for Lumen and Lumen are impregnated paper fiber, 0.354-inch outside diameter, 0.260-inch inside diameter, 1/8 inches long, turned with 1/32-inch diameter ferrite slugs 11/4 inches long with flexible drive rod (similar to Collins Radio Part No. 288-2509-00). Coil forms and tuning slugs are available from Jeff-Tronics, Unlimited, 4722 Memphis Avenue, Cleveland 9, Ohio.

FIG. 2, "TRANSMITTER" SECTION schematic diagram, showing the tunable oscillator (V1, VFO), high-frequency crystal controlled oscillator (V3, VFO, and RF amplifier (V3) circuits which operate both in receive and transmit. The two transmitter mixer (V4, V5) and the final amplifier (V5) operate only in transmit. The BANDSWITCH (S5) is shown in the highest frequency position.

IN ALL SCHEMATIC DIAGRAMS, resistances are in ohms, tolerance 10 percent, 1/2-watt power rating, unless otherwise noted. Capacitances marked "UF" are in microfarads, disc ceramic type unless otherwise described in the PARTS LIST. Capacitances marked "MF" are in micro-microfarads (mmf), and mica type unless otherwise noted. Inductances are in microhenries unless otherwise described in PARTS LIST. Connections which run between schematic diagrams Figs. 2, 3, 4, and 5 are coded with letters "A" through "H" where they enter and leave each diagram. Only two inter-diagram connections are coded with each letter, except code letters in circles, which have three or more connection points. Components connected to panel controls are identified with the control title in a rectangular box.
A signal from the high-frequency crystal oscillator ($V_o$ on Fig. 2) through connection "T" is mixed with the received signal to obtain a signal in the bandpass first IF range, 2.555 to 3.150 megacycles. This IF signal then runs back through connection "Y" to Fig. 2 and through transformer $T_o$. From $T_o$, the signal runs back through connection "E" to Fig. 3 — transformer $T_i$ is not used for reception — to the signal grid of the 6BA7 second mixer ($V_i$). The VFO signal from $V_i$ in Fig. 2 is fed into $V_i$, through connection "Z", converting the first IF signal down to approximately 455 kilocycles. This signal then exits to Fig. 4 through connection "II" to the 455-kilocycle mechanical filter ($F_{1,2}$). From $F_{1,2}$, the signal returns to Fig. 3 through connection "II" and runs through a conventional two-stage IF amplifier.

At the output of the 455-kilocycle IF strip, the full output voltage is applied to the GAT twi diode AVC Rectifier ($V_u$). Through a capacitive voltage divider made up of C451 and C452, part of the IF voltage is applied to the 12AU7-A twin triode product detector ($V_l$). A conventional first audio — 68Hz pentode section ($V_m$), and 5AQ5 second audio amplifier ($V_u$) is used. A 12AU7-A twin triode ($V_u$) in a balanced VTM circuit is used with a 0.1 milliamperes ($M_a$) to read the AVC voltage on receive or ALC voltage on transmit. The same meter is used as an output meter on transmit through a DPDT slide switch (S6) on the front panel. A 6AU6-A pentode ($V_u$) tube in a 100-kilocycle crystal oscillator is used to calibrate the receiver.

The SSB GENERATOR section, including the audio circuits, is shown in the schematic diagram of Fig. 4. Connections which run from one schematic diagram to another are identified with the same code letter where they leave one diagram and enter the other. Input from a high-impedance microphone ($I_m$) runs through a two-stage audio amplifier using a 12AX7 twin triode ($V_l$). A cathode follower stage — the triode section of a 6UG8-A ($V_u$) — feeds the audio signal into a diode balanced modulator. The audio stages have coupling and shunting capacitors which shape the frequency response to the 300-3,000-cycle speech range.

Theophone signal from $V_u$ feeds into a ring type diode balanced modulator with four 1N34A germanium diodes. These were selected to have nearly identical forward resistance using the method suggested by WNMP. Some juggling of C121 may be necessary to make the modulator null out the carrier within the adjustment range of C122. A miniature Bourns Trinit, 10 turn potentiometer (R122) was found to provide good carrier null and to hold its adjustment with mobile vibration.

The 6AU6-A BFO crystal oscillator ($V_s$) provides a signal of either 455.9 or 458.4 kilocycles, depending upon whether crystal $Y_i$ or $Y_s$ is connected, through a 6U8-A pentode section ($V_o$) isolation amplifier to the balanced modulator. The output of the modulator, a pure 455-kilocycle DSB signal, is connected to the 2.1-kilocycle bandwidth mechanical filter.

Output of the filter is amplified by a 6Z6G pentode ($V_i$) to increase the level to several volts RP for the 6A28 balanced mixer ($V_o$). The signal patch to $V_i$ runs through connection "D" to the left side of Fig. 2.

The VOX and other control functions in the LWM-3 transceiver are combined in one schematic diagram, Fig. 5. The audio signal from the microphone, amplified by $V_i$ in Fig. 4, is transferred to the VOX circuit through connection "E." This signal is further amplified in a 6UG8-A triode section ($V_u$). It is applied to one diode of a 6AL5 ($V_u$), rectified and charged capacitor $C_u$ positive. This positive charge causes the 68Hz triode section ($V_m$) relay actuator stage to conduct more plate current, energizing relay $R_k$. In the absence of audio signal, $C_u$ discharges slowly through $R_m$ and $R_k$, causing $V_m$ to conduct less current and de-energizing $R_k$.

An anti-rip circuit to prevent speaker noise from triggering the VOX circuit obtains an audio signal from 6AQ5 audio amplifier ($V_u$) in Fig. 4 through connection "BB." This signal is rectified in diode $V_m$ and develops a negative voltage which counteracts the positive voltage developed when noise from the speaker is picked up by the microphone, and which otherwise would actuate the VOX circuit.

An Automatic Lead Control (ALC) circuit is incorporated into the transceiver by which an RP voltage from an external linear amplifier is fed into...
a time constant network and \( V_p \) through \( J_1 \). This voltage is applied to the 6B6Z driver amplifier (\( V \)) in Fig. 3), and the 6B6Z 450-kilocycle IF amplifier (\( V_1 \)).

One set of SPDT contacts on relay \( K \), in the LWM-3 transceiver transfers the antenna from the receiver to the transmitter when it is energized. The antenna connection from \( K \) to the receiver also runs through a set of SPDT contacts on \( K \). These contacts remove the antenna from the receiver and ground its input during transmit.

No external antenna transfer relay or T-E switch is thus required when the LWM-3 is operated directly into an antenna suitable for transmitting. However, when the LWM-3 is used to drive a linear amplifier, a coaxial cable should be run from the receiver connection on the antenna transfer relay or T-E switch for the linear to \( J_1 \) in Fig. 5. Or, if a separate receiving antenna is used, connect it to \( J_1 \).

**MOST EXTERNAL CONNECTIONS**

From the LWM-3 run through a 24-pin plug (\( P_{RA} \)) on the rear of the chassis. In addition to the power connections on pins 1 through 5, provision has been made to control some external functions from within the LWM-3. The connections from pins 9 through 16 run through a section of the bandswitch (\( S_{9t} \)). This circuit can be used to control external functions — linear amplifiers, etc. — for each band.

Pins 16, 17 and 22 connect to SPDT contacts on \( K_1 \), permitting control of an external function on either transmit or receive. Also, pins 23 and 24 connect to another set of SPDT contacts on \( K_1 \), which have the movable contact arm grounded, permitting external circuitry to be grounded in either position of \( K_1 \). All pins on \( P_{RA} \) are bypassed to the chassis by capacitors \( C_{m} \) to \( C_m \), and \( C_{m} \) to \( C_{m} \) to prevent RF leakage outside the LWM-3 enclosure.

The LWM-3 requires 265 volts DC (not less than 240, or over 275 volts is recommended) at about 200 milliamperes, and minus 65 volts at 10 milliampere for bias. The tube heaters are arranged in a series-parallel circuit for either 6.3 or 12.6-volt operation. A 12.6-volt, 4-ampere source can be connected to pins 2 and 5 on \( P_{RA} \); or, a 6.3-volt 8-ampere source should be connected to pins 2 and 4, and pin 5 should be connected back to pin 2, thus placing all heaters in parallel.

Information on an AC power supply for the LWM-3 will be covered in PART II in the next issue. This supply — or a mobile power supply — can be turned on and off through connection to pins 6 and 8 on \( P_{RA} \). These connections run through "GG" and "II" to Fig. 3, the receiver diagram, where they terminate in \( R_m \), a switch mounted on potentiometer \( R_m \), the AF GAIN control.

**CRYSTAL LATTICE FILTER**

Although the LWM-3 transceiver is designed, described and constructed using a Collins 4-455ZI mechanical filter, it is possible to substitute a crystal lattice filter for it. The crystal lattice filter usually will not have the sharp selectivity of the mechanical filter, and thus the selectivity on transmit, and unwanted sideband attenuation on transmit, will not be as good.

A representative circuit for a full lattice filter is shown in Fig. 6. Inexpensive war surplus type FT-241-A crystals can be used in a 450-kilocycle filter of this type. Refer to the "Filter System" chapters in the sideband handbooks for complete information on circuits, construction and, most important, proper alignment of crystal lattice filters.

**MECHANICAL DETAILS**

Complete mechanical and constructional details on the LWM-3 will be published in PART II of this article in the January-February, 1962 issue of G-E HAM NEWS.

Now that you've covered the design and electrical details, start collecting parts and be ready to start construction when the next issue is out!
Nominating letters for the 1961 Edison Radio Amateur Award must be postmarked not later than January 3, 1962.

Please remember that the judges will consider only candidates whose names are submitted in writing by you and others. There is no other source for Edison Award nominations.

Therefore, between now and January 3, canvass in your mind the activities of amateurs you know, in order to make sure no deserving OM or YL fails to be represented. If you uncover such a candidate, by all means send in his name promptly.

Write to Edison Award Committee, General Electric Co., Electronic Components Division, Owensboro, Ky.

HERE ARE TYPICAL ACTIVITIES THAT CAN QUALIFY FOR THE AWARD:

- Emergency communications work in a disaster, such as a flood, hurricane, tornado, or explosion.
- Helping amateurs and others with their specialized problems, through professional or amateur advice and experience.
- Community service in organizing mobile and fixed communications to promote the success of fund drives and other public events.
- Helping disabled or physically handicapped persons.
- Relaying messages from remote points for the benefit of isolated servicemen and civilians.
- Designing and constructing radio equipment for use by persons in remote parts of the world, who do not have access to regular commercial communication channels.
- Civil-defense organization work; weather reporting; radio assistance to state or local traffic and police authorities; cooperation in forest-fire prevention and control.
- Teaching basic electronics to young people.

RULES OF THE AWARD

WHO IS ELIGIBLE? Any man or woman holding a radio amateur's license issued by the F.C.C., Washington, D.C., who in 1961 performed a meritorious public service in behalf of an individual or group. The service must have been performed while the candidate was pursuing his hobby as an amateur within the limits of the United States.

RECIPIENT OF THE AWARD will receive the Edison trophy in a public ceremony in Washington, D.C. Expenses of his trip to that city will be paid.

$500 GIFT. Recipient will be presented with a check for this amount in recognition of the public service which he has rendered as a radio amateur.

WHO CAN NOMINATE? Any individual, club, or association familiar with the public service performed.

HOW TO NOMINATE. Include in a letter a full description of the service performed, as well as the candidate’s name, address, and call letters. Your letter of nomination must be postmarked not later than January 3, 1962.

BASIS FOR JUDGING. All entries will be reviewed by a group of distinguished and impartial judges. Their decisions will be based on (1) the greatest benefit to an individual or group, (2) the amount of ingenuity and sacrifice displayed in performing the service.


ROSEL H. HYDE, Commissioner, Federal Communications Committee.

GOODWIN L. DOLAND, President, American Radio Relay League.

Recipient of the Award will be announced on or before Thomas A. Edison’s birthday, February 11, 1962.

Employees of the General Electric Company may nominate candidates for the Edison Radio Amateur Award, but are not permitted to receive the Award.

Season's Greetings to All!

Lighthouse Larry