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Author: Thomas O'Hara, W6ORG

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Practical Ideas for the ATV Enthusiast

BY THOMAS R. O'HARA,* W6ORG

Part II -- Transmitters, Modulators and Cameras

Transmitters

POWER LEVELS that can be generated in the uhf range economically with transistors are rather low, so the specialized modulation problems of solid-state TV transmitters will not be detailed here. For the ATV newcomer, several commercial tube-type uhf transceivers are now available at low cost on the surplus market and offer the simplest solution to the transmitter problem. The two important differences between TV and fm service should be kept in mind in choosing from the available surplus equipment. ATV bandwidth is stated in megahertz, whereas that of fm is in kilohertz. ATV modulation is a-m, so amplifier stages must be linear. The fm transmitter has no linearity requirements, so it is often designed with other objectives in mind.

The 2C39 grounded-grid triode amplifiers, such as in the Motorola T44 and GE Pre-Prog transceivers, are not well adapted to wide-band amplitude modulation. They have very low grid-drive impedance, which requires much more modulator power than grid-modulating tetrodes. These transmitters have built-in bypassing of the grid that limits the bandwidth to 2.5 MHz, or only about 200 lines of video resolution. This allows a fairly good black-and-white picture, but it will greatly attenuate fm and color subcarrier, if these are added later. The best available information on video-modulating the T44 is that given by WØMZL.[3] We deal in this section with grid-modulation of tetrode amplifiers of the surplus-rig and homebuilt high-power variety. Typical tube types include the 6939, 6252, 5894, and 6907, all dual tetrodes in the low- to medium-power range, and the 4X150A and other tubes of the same general type, used for medium and high-power applications. Preferred dual-tetrode transmitters are those in the RCA CMU-15 and the Motorola U44 line. The GE Progress Line is usable, although these GE units have high-*Q* plate lines which limit their bandwidth to about 3.5 MHz, not enough for the fm subcarrier described later.

Converting the CMU-15

The most readily converted of the uhf fm transmitters is the RCA Carfone, CMU-15. It will put out 15 watts, with high-resolution video, at moderate cost. The receiver is not used for ATV, but it can be made to serve as a monitor for any uhf calling frequency, such as 431.5 MHz used in Southern California. Details given refer specifically to the Carfone, but the ideas can be applied to other dual-tetrode amplifiers.

There are three chassis bolted together in the Carfone. Separate them, and cut connecting wires. Transmitter power requirements are 285 volts at 280 mA, 270 at 95 mA, 270 at 20 mA, 200 at 15 mA, and minus 15 at 25 mA. The first three can come from a single high-current source of 300 volts, with the 200 being obtained from the same point through a 7500-ohm 5-watt dropping resistor. A complete supply for the high voltage and bias is shown schematically in Fig. 4. Resist the temptation to try for higher output by running higher plate voltage. The 5894 and similar tubes go bad fairly soon if run at more than 50 watts input in the 420-MHz band. The long periods of operation with continuous modulation which are characteristic of ATV testing are rough on transmitting tubes. Cooling fans are not commonly used, but may be helpful in extending tube life.

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* 2522 S. Paxon Ln., Arcadia, CA 91006.

[3] McLeod, "ATV with the Motorola T44 UHF Transmitter," December, 1972 and February, 1973, *QST*. Condensation in *Special Communications Techniques for the Radio Amateur*," ARRL, 1975.

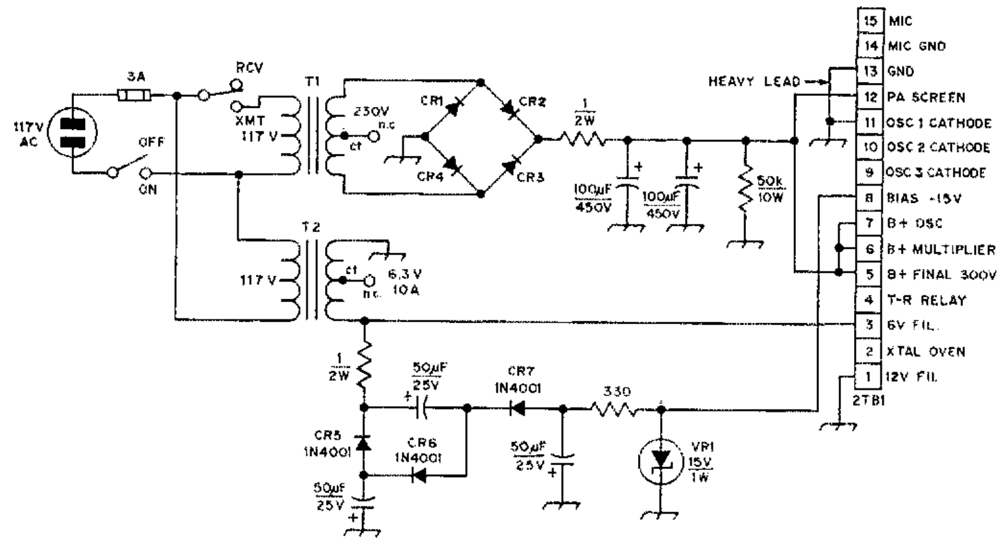


Fig. 4 — Schematic diagram and parts information for the CMU-15 power supply. Part numbers beginning with 2 indicate original CMU-15 components; e.g. 2TB1. All capacitors are electrolytic.
CR1 — CR4, incl. — 1000 PIV, 1 A (1N4007).
CR5 — CR7, incl. — 100 PIV, 1 A (1N4001).
VR1 — 15-V 1-W Zener diode (1N4744).
T1 — 150-VA isolation transformer, 235 and 117-volt windings (Essex-Stancor P-8622 or equiv.).
T2 — 6.3-V 10-A filament transformer (Triad F-21A or equiv).

The 150-VA isolation transformer, operated backward, with its 230-volt windings series connected to form the secondary as shown in Fig. 4, provides a relatively inexpensive solution to the transformer problem. The 400 mA at 300 volts may not be easily provided, otherwise. If one is willing to do some transformer work, the existing vibrator transformer in the Carfone can be stripped of its heavy primary and rewound with 350 turns of No. 22 enamel wire for 117-volt service. If this is done, only a 6.3-volt transformer capable of delivering 10 amperes for the heaters and bias supply is all that need be added, and the original power supply wiring can be left intact, other than in the primary circuit.

Test the transmitter and tune it up in the amateur band before trying video modulation. Divide the desired operating frequency by 36 to get the crystal frequency (427 MHz requires an 11.861-MHz crystal). The crystal oven is not needed, and inexpensive crystals are good enough. One thing that is *not* critical in ATV is frequency tolerance; the receiver can handle the 4.5-MHz sound subcarrier with frequency variations up to 300 kHz.

Remove the 12AX7 audio limiter tube. Some areas transmit fm sound on the a-m carrier, but the sync buzz will be heard under weak-signal conditions in the fm receiver, when the limiters go in and out of saturation with video a-m. Also, sync buzz may get into the high-impedance speech-amplifier circuits, and cause sync jitter in the picture.

Test the transmitter on a *good* dummy load — no light bulbs at this frequency! The metal strip along the side of the tripler-final cage is a low-pass filter. If off-frequency components are not a problem, removing the filter will eliminate its 1-dB insertion loss. Apply power, briefly at first, and tune the stages, starting with the first tripler, for maximum negative readings at the first four test points on the meter socket. Run no more than 30 seconds at a time, with two minutes off for cooling between adjustments, until optimum adjustment has been found. The following readings were taken with a high-impedance meter, 20,000 ohms-per-volt or higher: Test Point 1 (first tripler) 13V; 2 (first doubler) −29 V; 3 (second doubler) −76 V; 4 (second tripler) −62 V.

If the voltage indication does not go *through* a peak as a circuit is tuned, add 5 pF at a time until a definite voltage peak can be passed in adjustment of the tuning. The grid inductors of the tripler and final amplifier need more inductance for best operation. Remove the ribbon leads from the grid pins, and replace them with No. 14 copper wires 1/4 inch longer. Adjust the length until tuning peaks. Recheck all adjustments for maximum power output, as indicated by a wattmeter in the line to the load, or maximum reading (about minus 1.5 V) at pin 8 of the test socket.

Check the plate current, and adjust the screen voltage for 175 mA. There may be a control for screen voltage in the unit; if not, connect a suitable resistor between the B-plus line and pin 12 of the power terminal strip. A VOM can be connected between pins 6 and 7 to measure plate current, but remember the 300 volts dc is present here. With a 20,000 ohms-per-volt meter such as the Simpson 260, a reading of 1.1 on the 2.5-volt scale indicates 175 mA (volts × 160 = mA).

Bypassing of tube and circuit elements must be done with video characteristics in mind. Electrolytic bypass capacitors, 10 µF at 450 volts, were added to the 5894 screen and the high-voltage feed to the plate circuit, to prevent video distortion. At

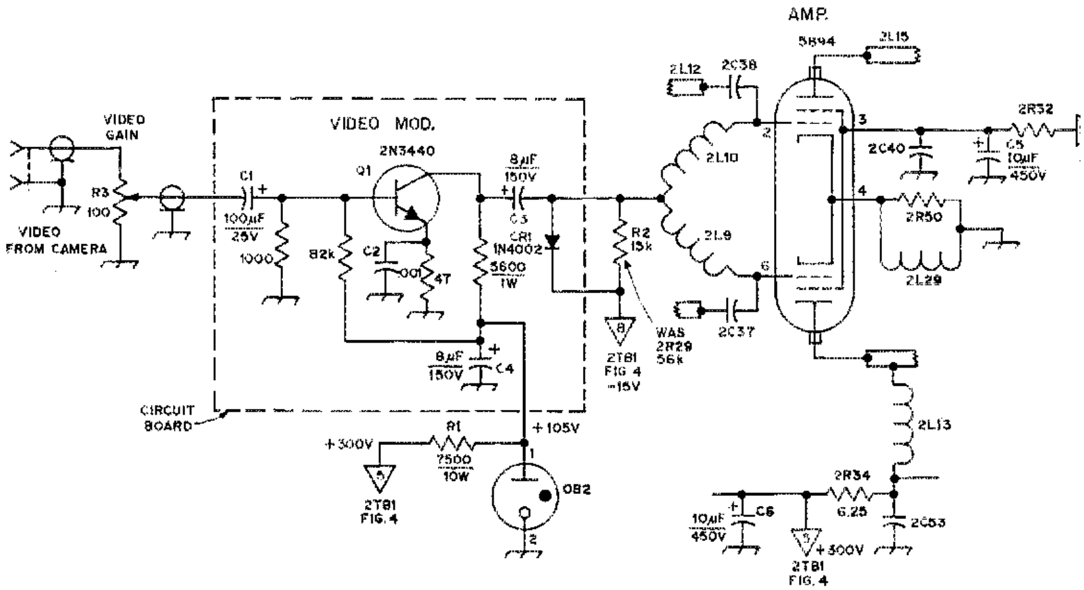


Fig. 5 — Schematic diagram of a one-transistor video modulator for use with the CMU-15 transmitter. Part numbers beginning with 2 indicate original CMU-15 components. Amplifier circuit is shown only in part, to indicate circuits where changes are made in adapting it to ATV service. Capacitors with polarity marked are electrolytic. The video gain control, R3, can be separated from the modulator by 2 feet or less, the connecting lead to be RG-59/U or other 75-ohm coax. The lead from the board to the junction of R2, 2L9 and 2L10 should be 2 inches or less in length.

this point we call attention to the method of identifying the parts shown in Fig. 5, to distinguish between original equipment in the CMU-15 and those parts changed or added in the conversion process. Original components have the numeral 2 before the letter in their number. New parts used are numbered in the conventional manner. Thus, the screen bypass, above, is marked C5. It is in parallel with the original part, 2C40. The grid resistor, R2, 15 kΩ, replaces original 2R29, 56 kΩ. It is well to go through the tune-up procedure outlined above before the purely video changes are made, so that if trouble should develop along the line the worker will know when it started.

If the grid circuit has isolation resistors in place of the rf chokes, 2L9 and 2L10 in Fig. 5, replace them with Ohmite Z-460 or other uhf rf chokes when installing the new grid resistor, R2. If the transmitter is now operating normally, proceed with installation of the video modulator.

Video Modulation

A one-transistor video modulator suitable for use with dual-tetrode transmitters of moderate power is shown schematically in Fig. 5. A two-transistor unit of similar design for use with high-power tetrode amplifiers, such as the K2RIW kilowatt amplifier[4] is shown in Fig. 6. Constructed on circuit board, this modulator is shown in one of the photographs, attached to the back of the kW amplifier.

The modulators can be built on perforated boards or printed-circuit boards of simple design. Layout is not critical, except that high-impedance video leads should be short. For example, either modulator should be positioned so that the lead between the modulator output and the point of connection to the grid circuit should be no more than about 2 inches long. There is room for the CMU-15 modulator under the transmitter chassis. The 100-ohm gain control, R3, can be up to two feet from either modulator. The lead from its arm to the modulator input should be 75-ohm coax. The control acts as a termination for the low-impedance line from the camera, in conjunction with the modulator input impedance. As in rf lines, reflections on a video line can cause ghosts and sync instability. Monitors can be tapped on at any point, so long as the monitor input impedance is greater than 1000 ohms.

The diode, CR1, acts to charge up the coupling capacitor, C3, for dc restoration, to insure maximum rf power output at the sync tips, regardless of average white-to-black ratio. This means that the picture will have a high contrast with varying scenes, and will insure a constant sync power level, for stable agc and sync triggering. It makes about a 3-dB improvement in weak-signal reception, because the receiver will be better able to lock up with a weak signal.

[4] Knadle, "A Strip-Line Kilowatt Amplifier for 432 MHz," *QST*, April and May, 1972. Condensed version in *The Radio Amateur's VHF Manual*, Edition 3, Chapter 13.

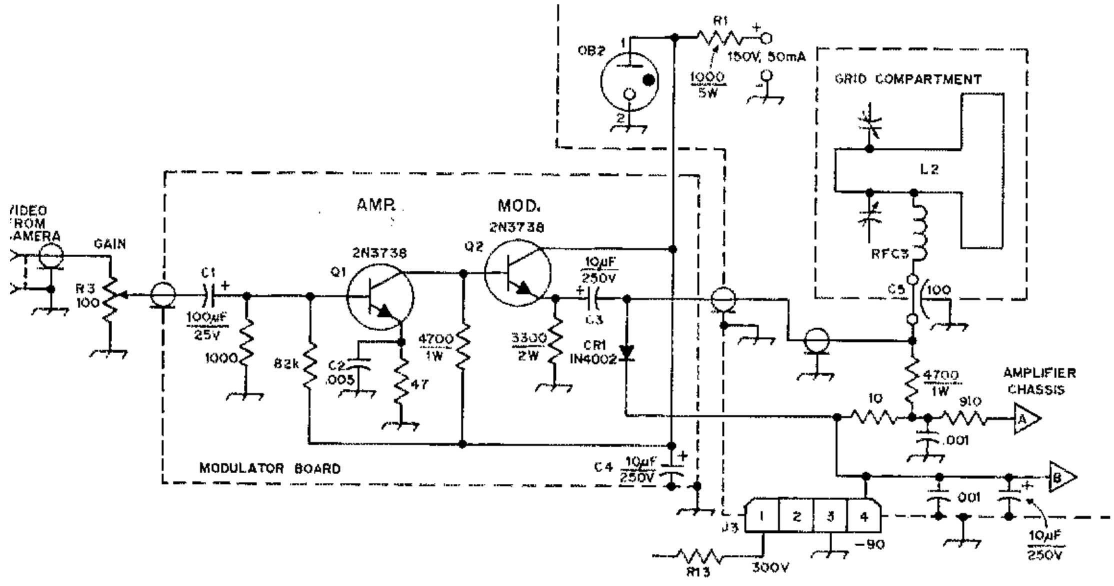


Fig. 6 — Schematic diagram of a two-transistor modulator, for use with the K2RIW kilowatt amplifier or similar high-power stages. Regulated voltage may be obtained from the screen supply, if it is capable of handling the extra load. Adjust value of R1 to suit source voltage. Basic amplifier components, where unchanged, are numbered as in the original article, Fig. 1, April, 1972, *QST*.

Adjusting for Picture Quality

With the modulator connected and the gain at minimum, apply power and check the output level. Then turn the gain up slowly until the output power decreases by one-third. Video modulation with dc restoration acts like downward modulation sometimes observed with a-m transmitters having low grid drive, but it is normal in this case. If everything seems to be working well, try to get another station, preferably a few miles away, to "talk your picture in." Adjusting the camera and modulation while monitoring the signal yourself will give false indications, because of overloading of your receiver. Low modulation will look fine on your monitor, but the signal received at a distance will lack contrast. Have the other fellow describe the appearance of the picture as you make adjustments. Transmitting a detailed test pattern is recommended for this.

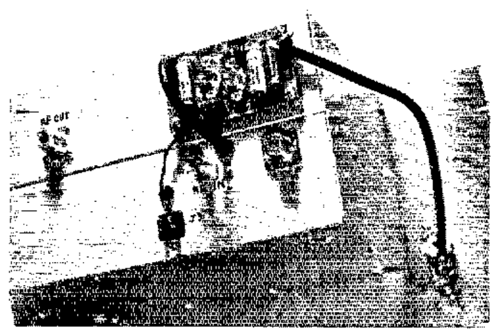
The final stage of a high-powered ATV rig can be run as a linear amplifier, driven by a CMU-15 or something comparable. In general, however, final-stage modulation makes for easier adjustment, and with grid modulation it adds little to the modulator complexity. Linearity never comes easily, and there is the extra problem in ATV of loss of bandwidth by the extra stages and tuned circuits.

Linear operation with transistors presents special problems. Often circuits must be heavily bypassed to prevent hf oscillation, and such bypassing may impose video bandwidth limitations. Useful application notes on simple uhf broadband amplifiers are available from several transistor manufacturers.[5]

FM Sound Subcarrier

Audio can be added at the camera input to the

[5] *RF Power Devices* (SSD-205B), RCA Solid-State Division, Box 3200, Somerville, NJ 08876; *MX-12 Power Modules*, TRW Semiconductor Products, Inc., 14520 Aviation Blvd, Lawndale, CA 90260; Motorola Semiconductor Products, Inc., 5005 McDowell Road, Phoenix, AZ 85008; *Wide-band UHF Land Mobile Power Amplifiers*, (Note 2186B), CTC, 301 Industrial Way, San Carlos, CA 94070.



Two-transistor video modulator of Fig. 6, mounted on the back of a kilowatt amplifier built from the popular *QST* article by K2RIW. Only minor changes were required to adapt the amplifier to video service.

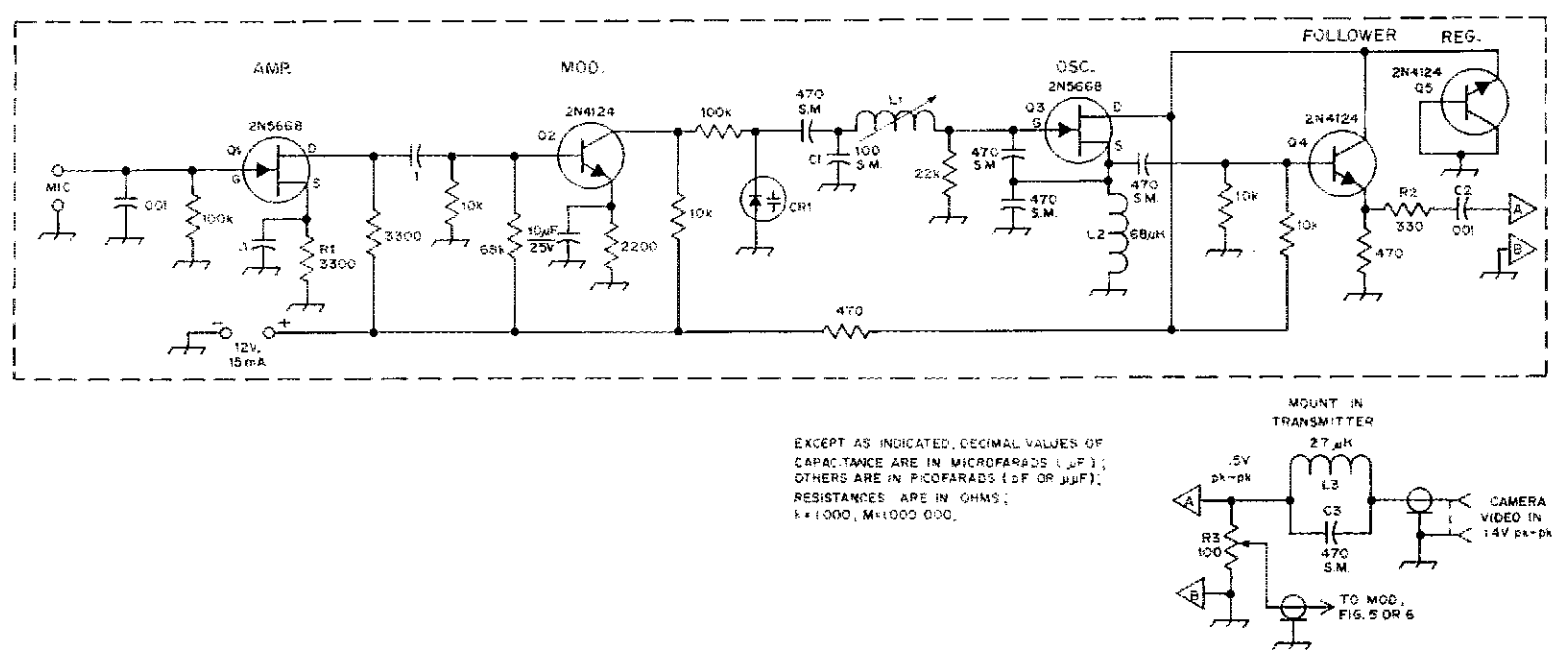


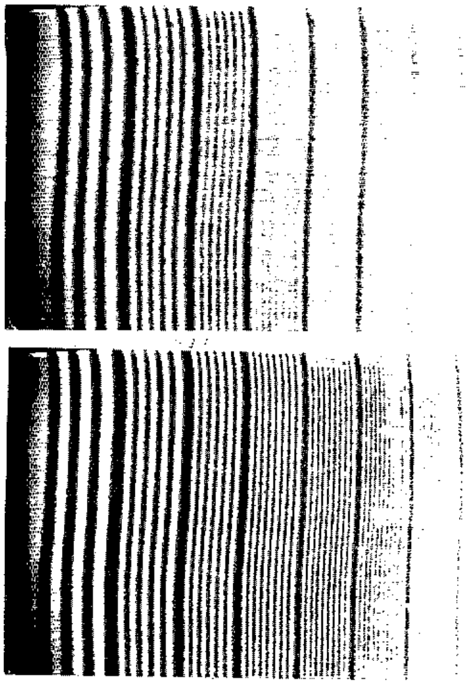
Fig. 7 — Schematic diagram of the 4.5-MHz fm sound subcarrier generator. Values for R1, R2, and C1 are nominal and may have to be varied when equipment is tested. See text. Lead from C2 to R3 should be less than 3 inches. Parts not described are numbered for text reference.

CR1 — Voltage-variable capacitance diode (Motorola MV2108).

L1 — 12-μH slug-tuned inductor (Miller 23A105RPC).

L2 — 68-μH rf choke (Miller 9210-68).

L3 — 2.7-μH rf choke (Miller 9230-30).



The effects of limited bandwidth are clearly apparent from these two views of a test signal. Even the broad lines at the left are a bit hazy in the upper picture, and vertical line detail is practically lost by the middle of the screen. Clear, sharp lines are plainly visible in the lower view, out to almost the right side. The same TV set and the same signal were used for both, except that a filter that limited the bandwidth to 2.5 MHz was in the circuit when the top picture was taken. Definition differences would be still more marked in direct viewing of the picture.

video modulator in the form of a frequency-modulated 4.5-MHz subcarrier, if the modulator and transmitter are capable of passing the 4.5-MHz signal. The CMU-15 and the K2RIW kilowatt amplifier do a good job. The Motorola T44 will not handle this bandwidth, and the GE progress Line transmitter is marginal. Its plate circuit may be capable of modification for lower Q, to increase bandwidth, but this has not been tried. The output filter has a bandwidth of about 8 MHz, so it is not the culprit.

The fm sound generator circuit is given in Fig. 7. Note the low-Q trap circuit, C3-L3, at the camera input. This trap keeps the long coaxial line to the camera from loading the 4.5-MHz generator capacitively. The value of the resistor, R2, in series with the generator output, is selected by experiment to give 0.5 V pk-pk, when everything is connected and operating, but with the camera switched off. R1, in the source lead of Q1, should be of such value that there will be 4 to 5.5 volts at the drain of Q1.

The oscillator, Q3, can be adjusted to 4.5 MHz by listening for it in a general-coverage communications receiver. Frequency tolerance is plus-or-minus 50 kHz. If adjusting L1 will not bring the frequency to 4.5 MHz, adjust the value of C1 as required. Do not try to tune the oscillator by listening to your own TV receiver. As with the TV picture, have a distant operator check the signal.

The only drawback with this system is that the power put into the subcarrier is taken from the video, which decreases the picture power by about 2 dB. This is a negligible difference with all but the weakest signals. The alternative is to use a separate fm transceiver 4.5 MHz above the video carrier, running on another antenna. This unit can also double as a secondary ATV calling-frequency setup, as shown in Fig. 1.

Cameras

The TV camera is usually the greatest expense in putting ATV on the air, and a primary reason that some potential enthusiasts never quite make it. The problem is not insurmountable, thanks to the boom in closed-circuit TV usage. Any closed-circuit vidicon camera with free-running sync will give very good pictures. New-camera prices start around $200. Kits such as from ATV Research[6] run up from $125. Used but serviceable cameras are increasingly appearing in pawn shops, camera-equipment exchanges, and so on, as firms that have used closed-circuit TV for security purposes go out of business or progress to more elaborate equipment. Prices generally range from $35 to $100.

Most cameras have both video- and rf-modulated outputs. The video is run to the modulator on a coaxial line, which must have a low-impedance termination at the modulator end. The gain control, R3 in Figs. 5, 6, and 7, provides this termination, as well as for adjustment of the level to the modulator. The camera output is usually an open emitter-follower requiring a dc path to ground, so do not couple it capacitively. If the camera has an rf output it can be run to a TV receiver to be used as a video monitor, by tuning the receiver to an unused channel between 2 and 6. For best resolution a separate monitor is preferred, tapped in as shown in Fig. 8. It is best to get a manual or Fotofact sheet on the TV receiver before going into it in this way.

Checking Picture Resolution

Most closed-circuit cameras are capable of 400- to 600-line resolution. The number of lines you can see determines the ability to see the video signal change from black to white. Test patterns with converging lines or groups of parallel lines of diminishing width are helpful in measuring the effect of linearity and bandwidth adjustments. A rule of thumb is 75 lines per megahertz of receiver bandwidth. ATVers soon develop a fondness for complimentary horizontal-resolution reports, in the manner of the DXer gloating over 40-over-9 reports from the rarest countries.

An excellent package of test patterns, with information on their use, is available from ATV

[6] ATV Research, Box 453, Dakota City, NE 68731.

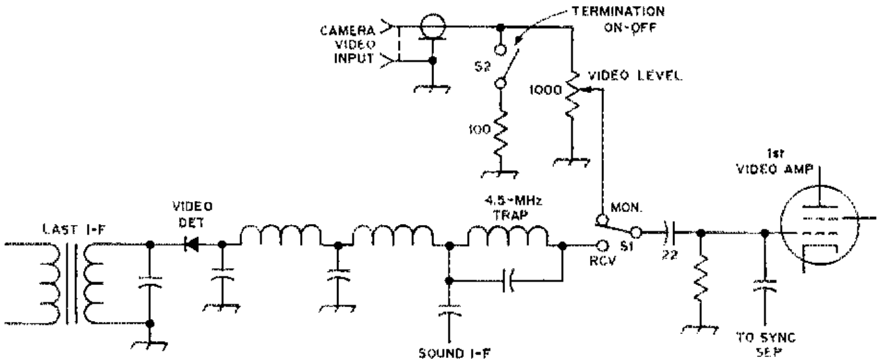


Fig. 8 — Circuit diagram of modifications made to a typical TV receiver, to use it as a video monitor. Parts with no values given are part of the original receiver.

Research. Servicing information, such as Sams, *Servicing Closed-Circuit Television*, is helpful. Many adjustments interact, making it difficult for the inexperienced ATV worker to obtain good resolution, video-to-sync ratio and contrast, without such aids.

Most cameras generate the vertical sync from the ac line frequency, and the horizontal from a free-running oscillator. The internal sync is helpful where more than one camera is used, as all will be running from the same sync source (the power line) and this will prevent picture jumping when cameras are switched.

ATV Horizons

Amateur television offers opportunity for expansion and development, limited only by the operator's imagination and technical skill. As an example, the Southern California ATV Club, WA6EVQ, participated in the Pasadena Rose Parade some years ago. A converted CMU-15 was installed in a helicopter of the Los Angeles County Sheriff's Office, to cover traffic situations. The police now have their own TV system, amateur radio having demonstrated convincingly the advantages of a real-time view of developing traffic problems, rather than relying solely on voice descriptions. Almost anyone entering the ATV field will quickly sense its potential for novel and challenging communication.

Information given here emphasizes simple and inexpensive approaches to ATV. By utilizing surplus components the newcomer can put a good ATV station on the air for $200 or less, with hardly more difficulty than is usually encountered in converting a commercial fm transceiver to amateur service. Current ATV activity and techniques are detailed in *A5 Magazine*, published six times yearly by Ron Cohen, K3ZKO, Box 6512, Philadelphia, PA 19138.

A complete bibliography of *QST* amateur television articles, both fast and slow scan, is available from ARRL, Newington, CT 06111. Send stamped self-addressed business-size envelope. QST

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