# vestigial sideband microtransmitter for amateur television

## Amateur television video bandwidth can be reduced by adapting commercial techniques

**To conserve spectrum space** commercial television uses a transmission mode known as vestigial sideband. A composite video signal, containing frequency components from dc to 4 MHz, is amplitude modulated onto a carrier. The resulting sum and difference frequencies (sidebands) occupy an 8-MHz bandwidth. Before transmission, the modulated signal is filtered. The upper sideband and carrier are transmitted, but most of the lower sideband is not (see **fig. 1**). Thus the video signal plus its audio can be transmitted in the 6-MHz TV-channel allocation.

As amateur television (ATV) activity expands in the 70-, 23- and 13-cm bands, it will become necessary for amateurs to adopt vestigial sideband as their operating mode to avoid interference with other communications services. A case in point is the possibility of interference with the 435.1-MHz OSCAR satellite telemetry beacon, which would result from the unfiltered lower sideband of an ATV station operating on the 439.25 MHz ATV calling frequency.

In commercial television, the modulated carrier is developed, and filtering performed, at the ultimate transmission frequency (**fig. 2**). A complicating factor, the need for frequency flexibility, makes such a system impractical for ATV. Imagine retuning a stagger-tuned string of over-coupled resonator pairs for sharp skirts and flat response over a 5-MHz band, then retuning it each time you need to shift your operating frequency!

One alternative is to generate a stable, well-filtered vestigial sideband video signal on a fixed frequency in the vhf spectrum, then heterodyne it to the desired uhf in a balanced mixer. The conversion stage local-oscillator chain, if made variable in frequency, will provide the system with the required frequency flexibility. **Fig. 3** is a block diagram of one such system, which I use for ATV transmission in the 70-cm band. The observant reader may note in **fig. 3** a pronounced similarity to the transceive converter for 1296-MHz ssb published in an earlier issue.[1] Obviously, the process of heterodyning a modulated signal into a higher frequency band for transmission is virtually the same, regardless of whether the original signal was modulated with a-m, fm, ssb, CW, or video.

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Many of the blocks in the local oscillator and rf strings of **fig. 3**, as well as the mixer, are either available commercially or may be adapted from equipment designs published previously. This article deals with the design and construction of the microtransmitter and vestigial sideband filter modules of the ATV system in **fig. 3** – building blocks toward clean, commercial-quality TV transmission.

## microtransmitter chip

The heart of the ATV transmitter is the LP-2000, a miraculous integrated circuit from Lithic Systems Inc., in Saratoga, California.* The outgrowth of a program to develop a microminiature aircraft crash-beacon transmitter, the LP-2000 is a complete transmitter system – oscillator, buffer, driver, power amplifier, modulator, preamplifier and regulator – all in a single 10-lead, TO-100 can. With the addition of a crystal, two tuned circuits, a battery, and a modulation source these ICs can generate as much as 100 mW of CW, or 50 mW of a-m or pulse-modulated output well into the vhf spectrum. **Figs. 4** and **5** indicate the very complex circuitry that can be built into a single monolithic microcircuit. A complete circuit description is available from the manufacturer in the form of an application note.[2]


**Heart of the ATV system is the LP-2000 IC next to the crystal.**

An appealing feature of the LP-2000 is that its modulator transistors (Q14 and Q16 in **fig. 5**) are dc-coupled to both the driver and power amplifier transistors, Q13 and Q15. Additionally, direct coupling is employed between all modulator stages. Thus the circuit lends itself well to video-modulated applications.

## frequency selection

The operating frequency chosen for the microtransmitter, 61.25 MHz, corresponds to the assigned video carrier frequency of commercial TV channel 3. This permits the basic microtransmitter module to be used for short-range, closed-circuit TV applications, there being no local channel 3 allocation in my area to interfere with such operation. Similarly, you may wish to select an operating frequency corresponding to the video carrier frequency for a locally unassigned lower vhf-band TV channel.

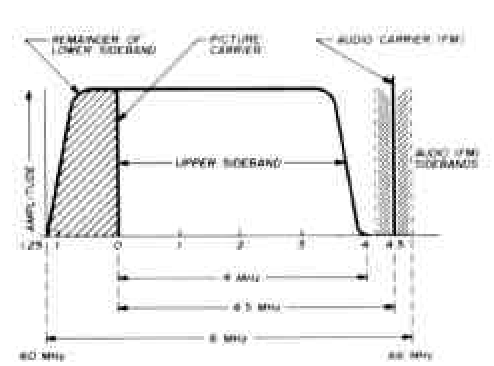



**fig. 1. Vestigial sideband transmission on monochrome television signals.**

The circuit I used on channel 3 (**fig. 6**) will cover TV channels 2 through 4 merely by substituting crystals and retuning the two trimmer capacitors. For operation on channels 5 and 6, it will be necessary to reduce L1 to 6 turns, L2 to 8 turns, and L3 to 2 turns. All other component values remain as in **fig. 6**. Similarly, the vestigial sideband filter shown in **fig. 7** may be tuned to cover TV channels 2 and 3. For operation on channels 4 through 6, L1 and L4 of **fig. 7** must be reduced to 3 turns, and L2 and L3 to 7 turns each. **Table 1** will serve as a guide in selecting crystal frequencies. When the microtransmitter operating frequency is increased, output power will begin to degrade as the upper frequency limit of the integrated circuit is approached.

## microtransmitter circuit

The basic circuit for generating 10 mW of stable double-sideband A5 with the LP-2000 microtransmitter IC is shown in **fig. 6**. The circuit is divided functionally into three sections. J1 is the video input connector, which is driven by the standard composite video output signal from a TV camera or video tape recorder (typically 1 volt peak into a 72-ohm impedance). This video

**table 1. Video-carrier frequencies of lower vhf television channels.**

| channel number | video carrier frequency (MHz) |
|---|---|
| 2 | 55.25 |
| 3 | 61.25 |
| 4 | 67.25 |
| 5 | 77.25 |
| 6 | 83.25 |

*An experimenter-grade version of this microcircuit, the NA2000, is available for $9.95 from NASEM, Box AI, Cupertino, California 95014.

drive level is more than adequate to overmodulate the microtransmitter, hence the pad-and-trimpot combination at J1, which simultaneously matches the relatively high video input impedance of the IC to 72 ohms and allows the appropriate video level to be set.

Because of the number of stages employed, the LP-2000 IC provides a considerable amount of rf gain in a rather confined space. Thus the circuit exhibits a strong tendency toward oscillations if precautions are not taken. It is advisable to let the physical arrangement of the schematic dictate the circuit board layout. As with all "hot" vhf circuits, short and direct wiring is a must. No printed-circuit artwork is provided, as the stray coupling between traces in a PC board would most likely lead to instability. I have achieved the greatest success by using a piece of PC stock only as a ground plane, positioning the components in space above it to minimize lead lengths. I call such a configuration a "breadspace," for breadboard suspended in space. (See the accompanying photographs.) This circuit would also lend itself well to isolated-pad construction, as described in recent articles.[3,4]

Parallel resonant circuits C1-L1 and C2-L2 tune the oscillator and amplifier stages respectively. Any coupling between them will obviously result in oscillations, or at least potential instability. Although the toroidal cores on which the inductors are wound tend to minimize stray coupling, the two inductors should nonetheless be

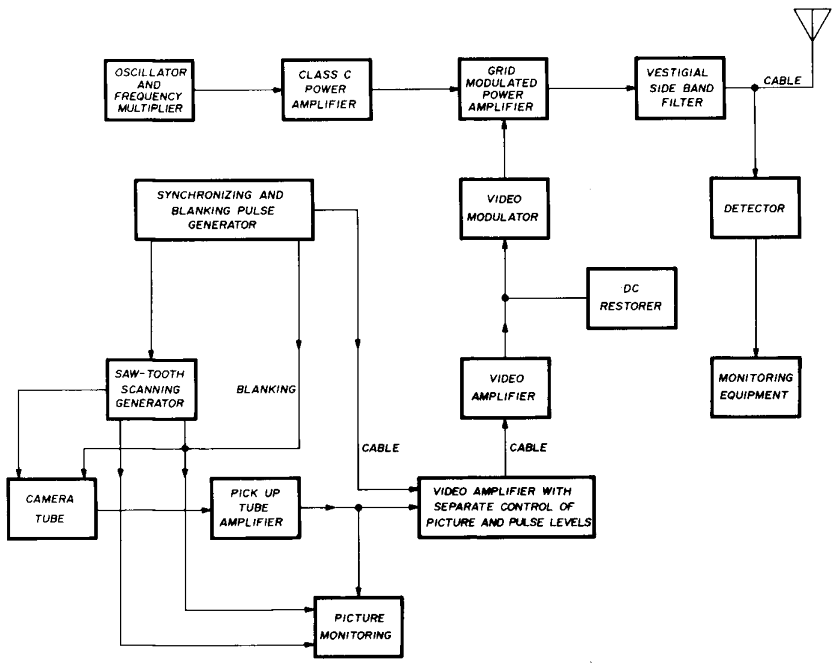



fig. 2. Simplified block diagram of a monochrome TV transmitter.

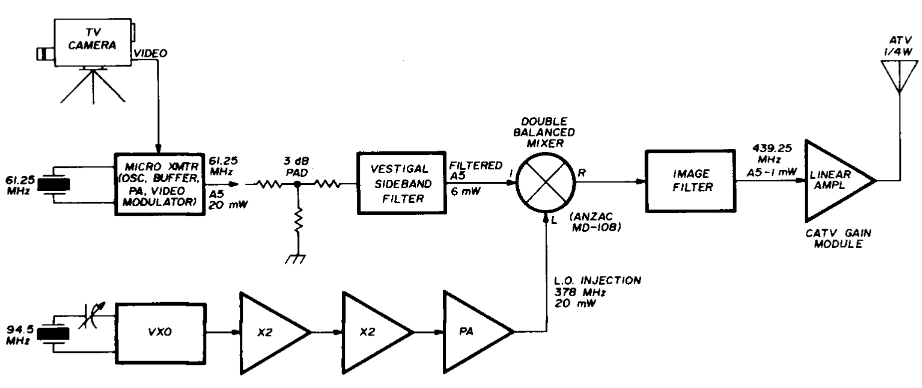
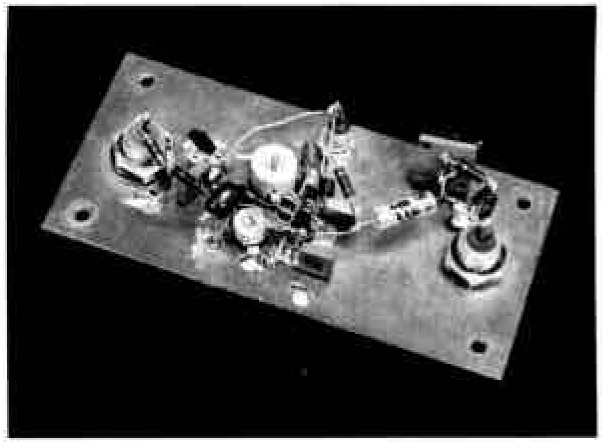



fig. 3. Block diagram of ATV transmitter for use in the 70-cm band.

oriented at right angles to one another as a precaution against oscillations. Although not attempted in the prototype unit, the use of shields positioned as shown by the dotted lines in **fig. 6** is a good idea. The 3-dB T pad between L3 and J2 not only keeps the power level within the requirements of the system but also provides a degree of isolation against instability that may occur from mismatching the output to its load.

## microtransmitter tuning

A common amateur practice in tuning transmitting equipment is to adjust all tuned circuits for maximum indicated output power. As this circuit is potentially unstable, such an approach would be disastrous if applied to the microtransmitter. The resulting output signal could well contain a multitude of frequency components. If some of the output energy did indeed fall on the desired video carrier frequency, it would only be by coincidence. The best way to tune this circuit is with a spectrum analyzer. Trimmers C1 and C2 are tuned for maximum output on the desired video carrier frequency consistent with minimum spurious output. Tuning should be accomplished with video input connector J1 terminated into a 75-ohm resistor. Some interaction between the tuning of C1 and C2 will be noticed; repeated adjustments may be necessary.



**Vestigial ATV system uses point-to-point wiring on PC chassis.**

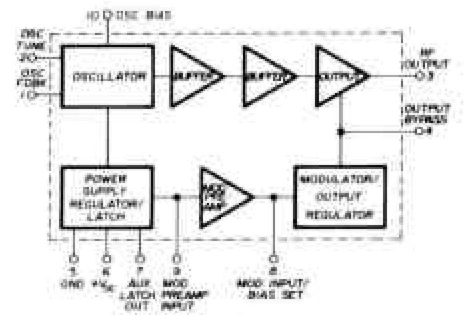



**fig. 4. Block diagram of the LP-2000 transmitter IC.**

Since few amateurs have access to a spectrum analyzer, two alternative tuning methods are proposed. The first involves the use of a high-selectivity absorption wavemeter (or grid-dip oscillator in the absorption mode), *loosely* coupled to J2. Adjust C1 and C2 repeatedly for maximum indicated output on the desired video carrier frequency, then tune the wavemeter over its *total* frequency excursion to ensure absence of parasitic oscillations.

Those lacking an absorption wavemeter will probably have difficulty in adjusting this circuit. Nonetheless, a "last resort" tuning method may be attempted. Loosely couple J2 output into a TV receiver that is adjusted for reception at the channel for which the microtransmitter was built. Tune C1 and C2 until the resulting video carrier blanks the TV receiver screen. Now tune the receiver to all adjacent channels to detect any parasitic oscilla-

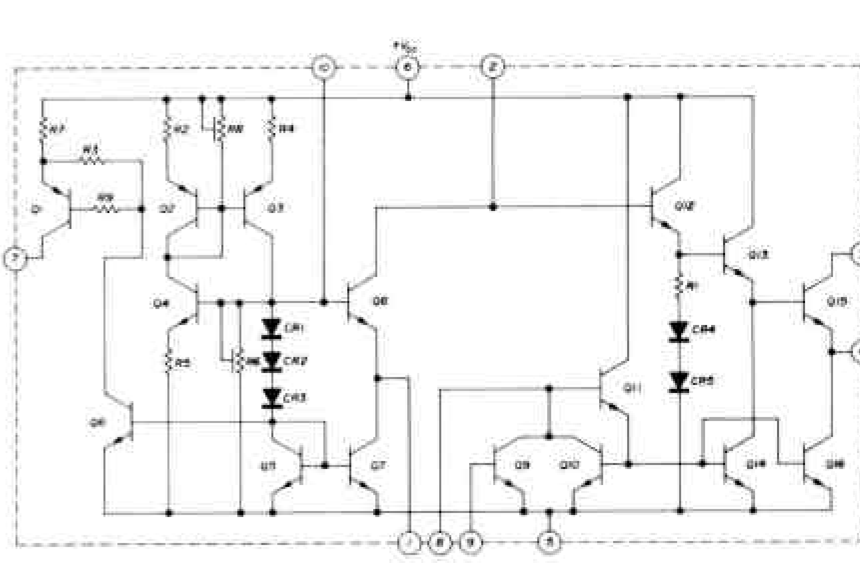


**fig. 5. LP-2000 IC schematic.**

tion. If any other channel is blanked, try again until output is noticed *only* on the desired channel.

The video level setting is best accomplished visually. After the rf adjustments are completed, loosely couple the rf output into a TV receiver. Connect a TV camera to J1 and scan a scene containing bright white level (a test pattern is ideal). Tearing of the horizontal synchronization will occur with the trimpot set for maximum video modulation. Back off on the video level until a stable sync is obtained, which will put the transmitter very close to the standard 12.5% ±2.5% modulation level for bright white. If the camera is properly adjusted, the 75% ±2.5% blanking level will fall into line automatically.

### vestigial sideband filter circuit

The filter depicted in **fig. 7**, consisting of two critically coupled parallel resonant circuits with link coupling in and out, is the absolute minimum in circuit complexity considered adequate for amateur vestigial sideband transmission. Attenuation of frequency components 2 MHz below the video carrier frequency, as seen in **fig. 8**, is 11 dB referenced to the passband midpoint. Similarly, the −3 MHz component is attenuated by 13.5 dB. If high-power ATV operation is anticipated, a greater degree of lower-sideband attenuation may be desirable, and two or more sets of resonator pairs may be cascaded. If multiple stages are used, stagger tuning may be necessary to maintain the required passband bandwidth.

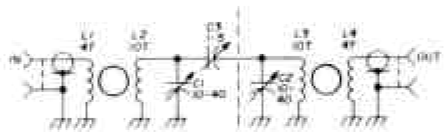
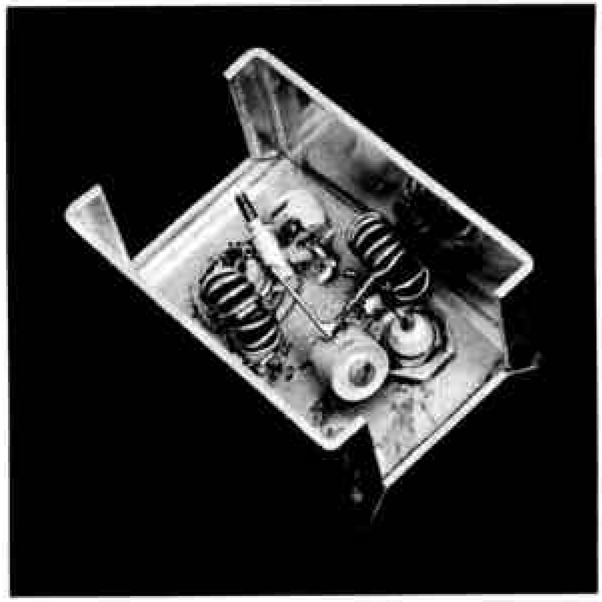


**fig. 7. Vestigial sideband filter schematic for TV channels 2-3. All coils are wound with no. 18 (1mm) on Amidon T50-10 toroids. L1 is 4 turns; L2 is 10 turns; L3 is 4 turns; L4 is 4 turns. See text for coil data for channels 4-6.**

As mentioned previously, the vestigial sideband filter may be modified for operation at different video carrier frequencies by modifying the number of turns on the toroids. As a general rule, skirt selectivity can be expected to degrade as operating frequency increases (due to a decrease in loaded Q). This suggests that cascaded resonator pairs should be considered for operation at TV channels 5 and 6.



**Construction of the vestigial sideband filter. All coils are wound on Amidon T50-10 toroid cores.**

Construction of the vestigal sideband filter is far less critical than that of the microtransmitter module. The only precaution to be observed is adequate shielding of the filter assembly to prevent lower video sideband components from leaking around the filter and being radiated into following stages.

### vestigial sideband filter tuning

As in the case of adjusting the microtransmitter module for optimum rejection of spurious output, properly tuning the vestigial sideband filter requires equipment not often available to the ATV experimenter. Thus

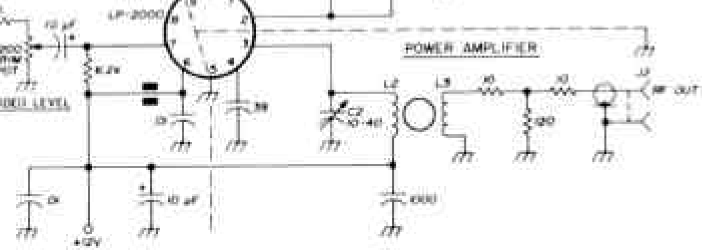



**fig. 6. Microtransmitter module schematic. Coil forms are Amidon T25-10 toroids. For TV channels 2-4, L1 is 8 turns no. 20 (0.8mm); L2 is 10 turns no. 28 (0.3mm); L3 is 3 turns no. 28 (0.3mm) wound opposite L2. See text for coil data for higher channels.**

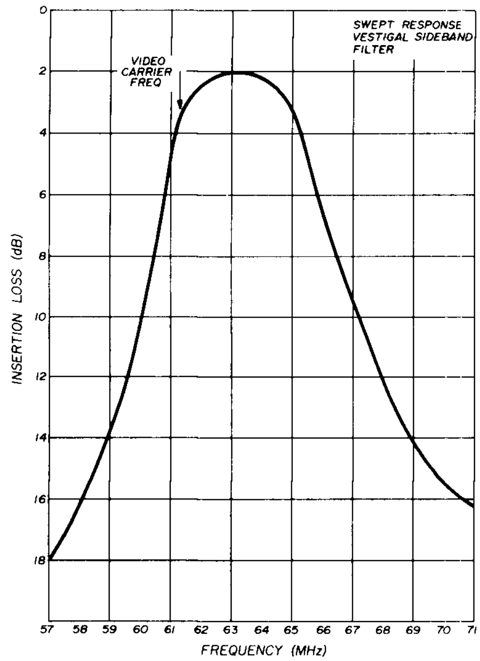



**fig. 8. Vestigial sideband filter swept-frequency response.**

in addition to the ideal approach, a compromise adjustment method will be outlined. Ideally, the filter should be adjusted on an rf sweep setup, as indicated in **fig. 9.** The procedure consists merely of adjusting C1, C2 and C3 of **fig. 7** repeatedly until the desired frequency response (that of **fig. 8**) is displayed on the CRT. The goals are a 5-MHz bandwidth, minimum passband ripple, and steepest possible lower-skirt selectivity with the video carrier frequency falling just at the knee of the lower-skirt rolloff. An application note from Hewlett-Packard[5] describes swept attenuation measurements in detail.

The filter passband can be adjusted manually using a stable rf signal generator, a vtvm with rf probe, and a 50-ohm coaxial feedthrough. Equipment is connected as in **fig. 10.** The signal generator is adjusted to 2 MHz above the desired video carrier frequency, coupling capacitor C3 adjusted to minimum capacitance, and C1 and C2 adjusted for a maximum indication on the vtvm. The filter will now be adjusted for minimum coupling (thus maximum Q) and will be resonant near the center of its passband. Next readjust the signal generator frequency to coincide with the video carrier frequency. The vtvm indication should drop off markedly because of the high selectivity and narrow bandwidth of the under-coupled resonators. The filter passband will widen if C3 capacitance is increased (because of tighter coupling), which will bring the video carrier within the lower skirt.

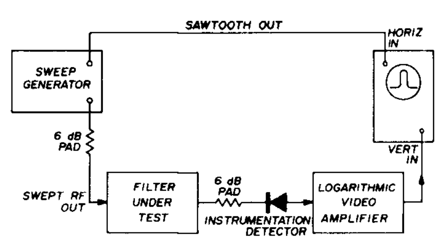



**fig. 9. Setup for swept-frequency response measurement of filters.**

The carrier-frequency attenuation, relative to mid-band power level, will be 1 to 2 dB when the voltage produced at the video carrier frequency (measured on the vtvm) equals 80 to 90% of the voltage indicated at mid passband. Acceptable vestigial sideband filtering will result under such conditions. Passband ripple and skirt selectivity can be examined readily by sweeping the signal generator manually in frequency and observing the vtvm.

## conclusions

As rf spectrum space becomes increasingly scarce, vestigial sideband transmission will become the standard for ATV. A high degree of frequency flexibility can be maintained by generating a stable vhf television signal, filtering it to roll off the lower sideband, then heterodyning the resulting vestigial sideband signal to the transmission frequency. I hope the equipment described will be the first of numerous approaches to apply commercial standards to amateur television transmission.

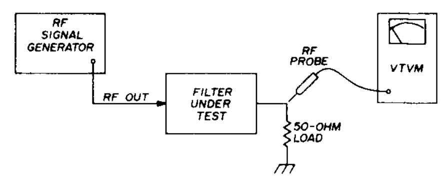



**fig. 10. Setup for manual-frequency response measurement of filters.**

## acknowledgements

I wish to express my appreciation to Bob Hirschfeld, W6DNS, president of Lithic Systems, for his interest in developing amateur applications for his products. Thanks also go to Cliff Buttschardt, W6HDO, for encouraging me to try the LP-2000 even though, in his words, "it's a squirrelly chip." Once tamed, I found the device to be a fine choice indeed.

### references

1. H. Paul Shuch, WA6UAM, "1296-MHz SSB Transceiver," *ham radio*, September, 1974, page 8.
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3. Ted Swift, W6CMQ, "Low-Cost Instant Printed-Circuit Boards," *ham radio*, August, 1971, page 44.
4. Alfred F. Stahler, W6AGX, "Isolated-Pad Circuit-Board Construction," *QST*, May, 1973, page 44.
5. "Swept Frequency Techniques," Application Note 65, Hewlett-Packard Company, 1501 Page Mill Road, Palo Alto, California, August, 1965.

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