low-cost spectrum analyzer
with kilobuck features

Build WA2PZO's useful instrument for operating position and lab bench

Although laboratory-grade spectrum analyzers cost $4500 or more, you can build a spectrum analyzer offering many features of its costlier cousins for about $50. How can such amazing capabilities be had at such incredibly low cost?

- *Through the use of a commercially mass-produced varactor tuned TV tuner that covers the VHF low, VHF high, and UHF TV bands.* It will tune down through the 2-meter and 6-meter Amateur bands without modification, with better than 1-microvolt sensitivity. By using a crystal-controlled converter and a narrower IF filter, any one of the HF Amateur bands could be viewed as well, by simply upconverting to a TV channel.
- *Through the use of consumer-grade integrated circuits in the oscillator/mixer, dual ceramic filter, IF amplifiers/detector, and audio amplifier (offering audio as well as scope output it is really a spectrum monitor).*
- *Through the use of your own oscilloscope.* Just about any scope may be used; I used a 1951 Heathkit Model OL-1 with its original cathode ray tube.

spectrum analyzer applications

Spectrum analyzers allow the user to observe in real time an adjustable/variable bandwidth of radio frequencies. One of the earliest spectrum analyzers for the ham bands was the "Panadaptor," manufactured by Hallicrafters in the early 1950s. I used one to check for F2 propagation 6-meter band openings in the mid-1950s and credit the panadaptor with my earning the IARU 6-meter WAC award (phone) issued by the ARRL.

The band of frequencies swept by the spectrum analyzer described in this article may be varied from zero up to about 38 MHz on VHF low TV = 50 MHz − 88 MHz, zero up to about 85 MHz on VHF high TV = 135 MHz − 220 MHz, and zero up to about 300 MHz on the UHF TV = 500 MHz − 800 MHz. When the sweep width is set at zero, each of these bands of frequencies may be manually tuned just as in a single-frequency receiver. Both wideband FM and narrowband FM signals, and surprisingly, even amplitude modulated signals are detected quite well by the FM IF amp/detector IC and amplified by the audio IC.

Figure 1 is a block diagram of this spectrum analyzer using a Sanyo varactor tuned TV tuner. A ten-turn, 10k pot with +35 VDC across it is used to adjust the center frequency of the tuner. A low varactor bias yields low frequency and a high varactor bias provides higher frequency on the TV band to which the tuner is set. The sawtooth sweep voltage that is capacitively coupled into the tuner's varactors is the horizontal sweep voltage from the oscilloscope. If your scope doesn't have the horizontal sweep output (the Heathkit OL-1 does not), just mount an RCA phono jack on the front of the scope and bring out the horizontal sweep from the scope's horizontal multivibrator to this point. The 100 kilohm load across the horizontal sweep output should have little or no effect on the scope's operation.

Besides the TV tuner and scope, the rest of the circuit consists of only three integrated circuits. The second mixer/oscillator chip is a Siemens SO42P. The ceramic filter is a Murata SFJ two-section filter at 10.7 MHz. The combination IF amp/detector/AGC amp is a National LM-3089N, and the 1/2-watt audio amp is a National LM-386N.

construction, testing, and alignment

Figure 2 is a schematic of the analyzer. A printed circuit board is available from WA2PZO; I recommend using this and WA2PZO parts kits. (Although the pots, S-meter, and speaker aren't furnished, most are available from Radio Shack.) **Figure 2A** shows the component layout on the WA2PZO printed circuit board (foil side down). Alternatively, you could use perfboard and point-to-point wiring.

Figure 3 is a schematic diagram of the interconnections between the Sanyo tuner, the three-IC printed circuit board, and the scope. Once everything is connected as shown in **fig. 3**, alignment can begin. (It should be easy, since there are only four adjustments,

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the ferrite cores in L1, L2, L3, and L4.)

With all the parts on hand — and assuming you're using the PCB — assembly time is at most an hour or two. I tuned up my unit using only a grid dip meter as a signal source in about 20 minutes.

Construction of the PCB proceeds as follows:

1. Install the jumper at the lower edge of U3 as illustrated in **fig. 2A**.
2. Install the 11 resistors as shown in **fig. 2A**.
3. Install the 16 capacitors as indicated in **fig. 2A**. Since C6 and C7 are electrolytics, be sure to observe the polarity indicated in **fig. 2A**.
4. Install the Murata ceramic filter, FL1. Because it's symmetrical, it can be installed in either direction.
5. I recommend carefully installing sockets for U1 (16-pin DIP), U2 (8-pin DIP), and U3 (14-pin DIP).
6. Install L1 through L5, carefully bending the pins slightly so that they fit easily into the PCB's pre-drilled

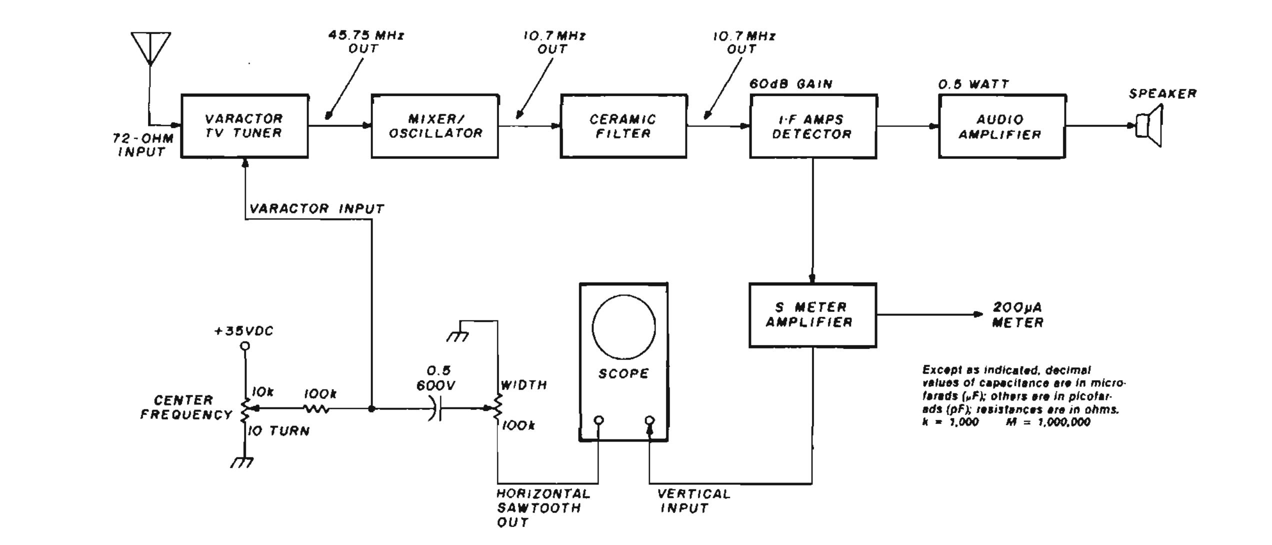


fig. 1. Block diagram of WA2PZO spectrum analyzer.

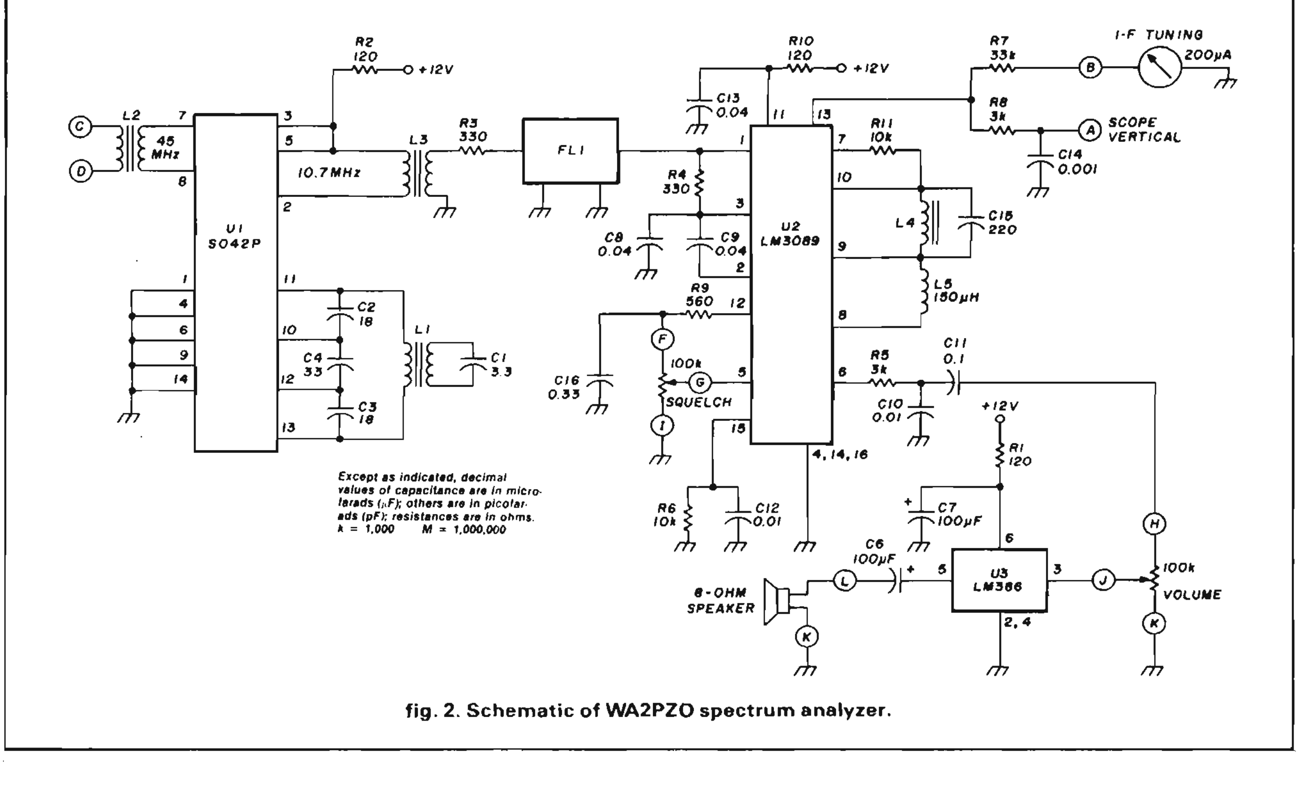


fig. 2. Schematic of WA2PZO spectrum analyzer.

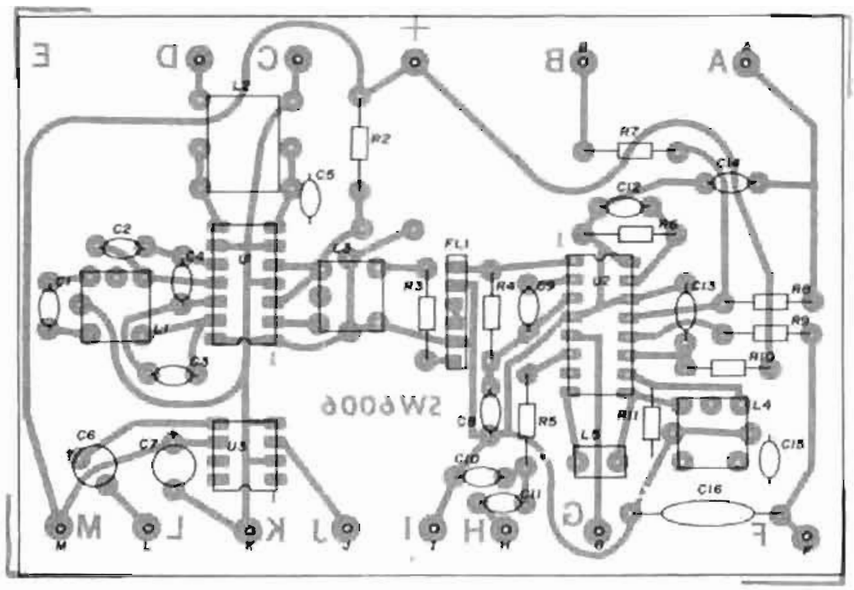


fig. 2A. Component layout on the WA2PZO printed circuit board (foil side down).

holes. Because L5, the 150 μH inductor, is symmetrical it can be installed in either direction.

7. Most important: lubricate the small ferrite cores of L1, L2, L3, and L4 with a drop or two of WD-40 *before* attempting adjustment. These cores are extremely brittle; use a plastic or nylon tuning tool matched to the width of the ferrite slots (using a metal one will guarantee their destruction).

8. If you're not using a 200-μA S-meter, install a jumper from 'A' to ground.

Testing and alignment proceed as follows:

1. Connect the TV tuner's VHF input to your 2-meter antenna.
2. Set the VHF/UHF switch to the VHF position.
3. Set the Hi/Lo switch to *Hi*.
4. Make sure the top of the ferrite core in L1 is exactly even with the top of its shielded housing.
5. Set the squelch control to zero and adjust the volume control for a slight hiss from the speaker with the gain control at maximum resistance (10 kilohms).
6. Set the width control (sawtooth sweep from scope) to zero.
7. Connect a voltmeter to pin 10 of the TV tuner (varactor input). Use the + 30-volt voltmeter range (adjust the center frequency 10k-turn pot so that varactor bias is below + 30 VDC).
8. Turn the center frequency pot slowly down (reducing varactor bias voltage) until a local TV video carrier is both heard on the speaker (buzz) and seen on the scope. If no TV stations are nearby, use a signal generator with modulated output or a grid dip meter.

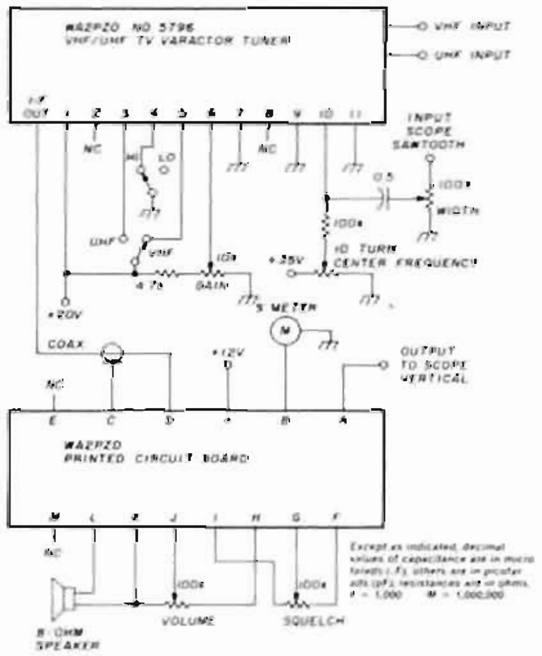


fig. 3. Schematic showing interconnections between tuner, printed circuit board, and oscilloscope. Note: + 35, + 20, and + 12 VDc sources are regulated supplies.

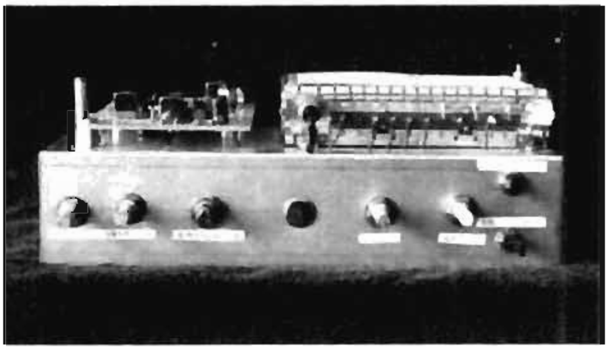
9. Peak the ferrite slugs in L2 and L3 for maximum signal output on the scope.

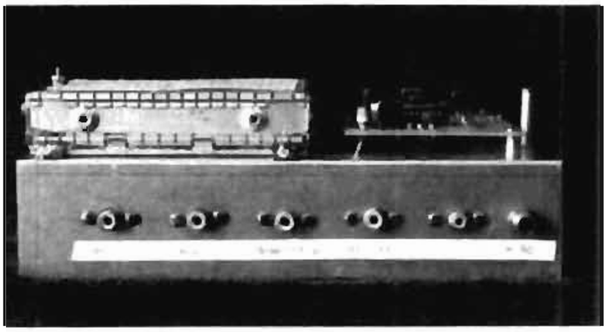
10. Continue tuning the center frequency pot until a TV audio signal is found, then adjust L4 for maximum

audio output and minimum background noise from the speaker.

11. Though each varactor tuned TV tuner will have somewhat different voltage versus frequency response, see **fig. 10** to see the response we obtained using a Sanyo varactor tuned TV tuner.

Figure 4 is a photo of our finished spectrum analyzer. The tuner and PCB are mounted on top of a 2 x 5 x 9-inch (5 x 13 x 23 cm) aluminum chassis. The PCB is mounted on 1/2-inch (1.3 cm) threaded standoffs. Left to right, the five pots are: volume, squelch, center frequency, sweep width, and tuner gain. The two mini-toggle switches on the right of **fig. 4** are VHF-UHF (top) and VHF LOW – VHF HIGH (bottom). On the rear of the chassis are six RCA phono jacks: +35 VDC for tuner center frequency; +20 VDC for tuner; +12 VDC for oscillator/mixer, second IF amps, U3 audio amp; horizontal sweep from scope; vertical output to scope; and audio output to the 8-ohm speaker.





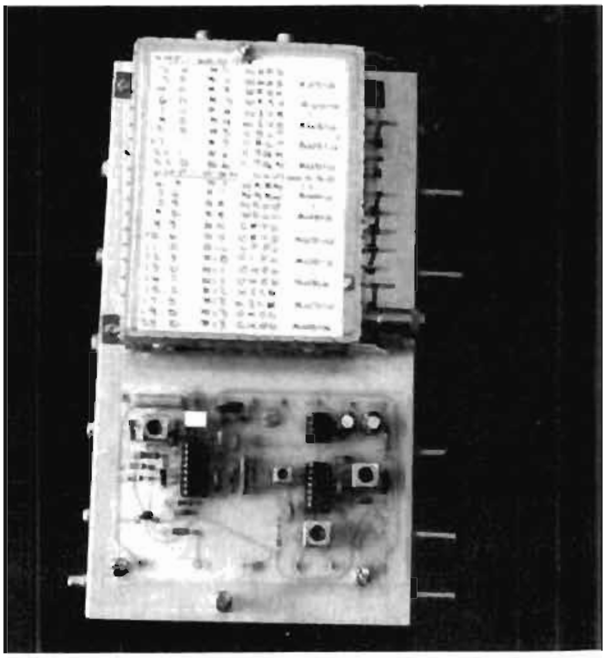


fig 4. Completed spectrum analyzer: (A) front, (B) rear, (C) top.

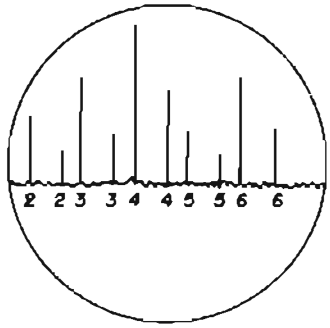


fig. 5. VHF low TV band with horizontal sweep amplitude set to maximum.

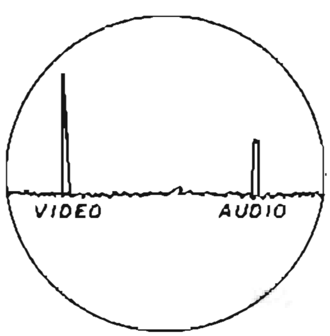


fig. 6. 8-MHz horizontal sweep width, with channel 2 video signal at left and channel 2 audio at right.

operation

Now the fun really begins. For antennas, I used my two 23-element Cushcraft 2-meter "Boomers." (No, I don't bounce signals off the moon with them, but I can work into 2-meter repeaters in Toronto, some 125 miles away. My QTH is on the south shore of Chautauqua Lake, some 65 miles southwest of Buffalo; because of this distance, and the presence of a range of hills about 300 feet (90 meters) high between Buffalo and Chautauqua, TV signals aren't par-

ticularly strong. Nevertheless, all the TV channels on both the VHF low TV and VHF high TV bands were displayed on the first try. Both the vestigial sideband video signal and its accompanying FM audio signal were clearly displayed for each channel.

Figures 5 through **10** are sketches of the oscilloscope display in the noted modes of operation. (Oscilloscope cameras cost about $300; I chose not to add one to my $39.95 Heathkit scope.)

Figure 5 shows the VHF low TV band with the horizontal sweep amplitude set to maximum. Each TV channel pair displayed (video and audio) is noted. The height of each signal is proportional to signal strength; some Canadian TV stations really pack a wallop even though they're 125 miles away.

Figure 6 illustrates about 8 MHz horizontal sweep width (left side of CRT to right side of CRT) with the video signal of Channel 2 on the left and the audio from Channel 2 on the right side.

Figure 7 displays the sweep width reduced to about 2 or 3 MHz with the center frequency set to Channel 2's video carrier. Note the blanking and vertical sync pulse riding on top of the carrier.

Figure 8 is the Channel 2 video carrier with the horizontal sweep set to zero. The blanking pulse with the vertical sync pulse on top is on the left side. The eight squiggles to the right of the vertical sync pulse on top of the blanking pulse are the color burst; all the hazy, wavy signals to the right are the video information. The top of the vertical sync pulse represents 100 percent modulation and the bottom ot the video information represents the white level of video at about 15 percent modulation.

Although some scope photos or sketches show 100 percent modulation at the bottom, I prefer it at the top. If you insist on having it at the bottom, simply turn the figure upside down and view it in a mirror.

Figure 9 illustrates the 2-meter band with horizontal sweep representing about 3 MHz. The left side of the CRT is at 145 MHz and the right side of the CRT is at 148 MHz. Spread between 146 and 148 MHz, we can see about six 2-meter repeaters located in the Buffalo and Toronto areas.

Figure 10 is a plot of varactor tuning voltage versus frequency on my Sanyo TV tuner. The 10-turn, 10-ohm pot used for setting the varactor voltage is an absolute "must" for fine tuning.

By reducing the sweep width to zero and single-signal tuning across each band, I was able to copy the audio on the VHF TV low band from the following stations: WGRZ-TV (Channel 2, Buffalo) WPSX-TV (Channel 3, Rochester), WIVB-TV (Channel 4, Buffalo), CBLT-TV (Channel 5, Canada), and CTGN-TV, (Channel 6, Canada). On the VHF TV high band we copied audio from air-to-ground and air traffic control stations; 2-meter repeaters in western New York and the Toronto area; commercial FM pagers; Toronto Coast Guard marine weather on 161.775 MHz; the Erie, Pennsylvania, weather bureau on 162.40 MHz; the Buffalo, New York, weather bureau on 162.55 MHz; WKBW-TV (Channel 7, Buffalo); WROC-TV (Channel 8, Rochester); CFTO-TV (Channel 9, Canada); CFPL-TV (Channel 10, Canada); CHCH-TV (Channel 11, Canada); WICU-TV, (Channel 12, Erie); and CKCO-TV (Channel 13, Canada). On the UHF TV

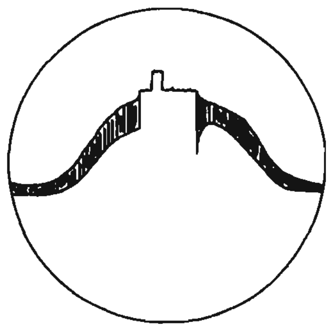


fig. 7. Sweep width reduced to about 2 or 3 MHz with center frequency set to channel 2's video carrier.

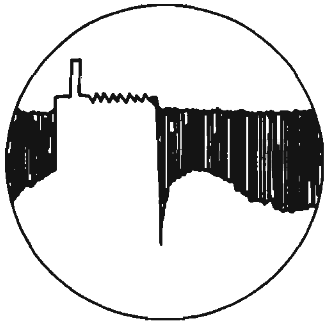


fig. 8. Channel 2 video carrier with horizontal sweep set to zero.

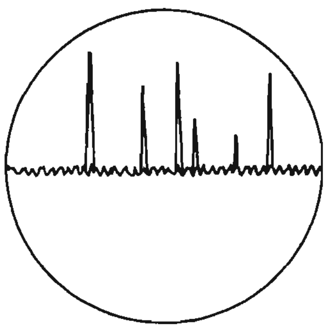


fig. 9. 2-meter band with horizontal sweep representing about 3 MHz.

Fig. 10. Varactor voltage versus frequency (will vary from tuner to tuner).

voltage	frequency MHz
	VHF low band
0.5	50.00 6-meter band
2.0	55.25 channel 2 video
3.5	59.75 channel 2 audio
4.0	61.25 channel 3 video
6.0	65.75 channel 3 audio
7.0	67.25 channel 4 video
9.5	71.75 channel 4 audio
13.5	77.55 channel 5 video
17.1	81.75 channel 5 audio
20.1	83.25 channel 6 video
34.8	87.75 channel 6 audio
	VHF high band
0.5	135.00 air to ground
1.0	144.00 2-meter band
2.0	148.20 commercial paging
4.0	162.55 Buffalo weather
6.5	175.25 channel 7 video
7.6	179.75 channel 7 audio
7.9	181.25 channel 8 video
9.0	185.75 channel 8 audio
9.3	187.25 channel 9 video
10.6	191.75 channel 9 audio
11.0	193.25 channel 10 video
12.3	197.75 channel 10 audio
13.0	199.25 channel 11 video
14.7	203.75 channel 11 audio
15.2	205.25 channel 12 video
17.5	209.75 channel 12 audio
19.0	211.25 channel 13 video
25.5	215.75 channel 13 audio

band we copied about six TV stations from Channel 17 through Channel 26, including a French language Canadian TV station. The Sanyo TV tuner is one super little box with excellent sensitivity — i.e., much better than 1 microvolt. All these stations were copied using only 2-meter antennas.

other uses

Once you become accustomed to using it, the spectrum analyzer is probably the greatest trouble-shooting aid since Volta invented the voltmeter. With the proper probes, attenuators, and converters it can be used as an RF voltmeter; as a signal tracer in transmitters and receivers; and for transmitter alignment, harmonic measurement, deviation measurement, oscillator injection measurement, IF alignment, and spurious radiation measurement, to name but a few of its applications. If you want to dig deeper, Cushman Electronics (2450 North First Street, San Jose, California 95131) publishes a neat little book entitled *Using The Spectrum Monitor* Priced at $7.25 (postpaid), it's easily understood by the average Radio Amateur.

acknowledgement

I wish I could claim authorship for this unique design, but credit goes entirely to my friend, Murray Barlowe, WA2PZO, who not only created the design but has generously made a partial kit of parts, TV tuner, and printed circuit board available to Amateurs at virtually his cost.

For more information send an SASE to Murray Barlowe, WA2PZO, P.O. Box 393, Bethpage, New York 11714. Once you try it, you'll never understand how you got along without it. **ham radio**