Home-brew Spectrum Analyzer

Project for DXers and experimenters alike.

by Gregory R. McIntire KEØUV

If you've always wanted a spectrum analyzer, but figured it was way out of your budget, here's the answer! All the components required to build your own HF spectrum analyzer may be found in a well-stocked junk box. In the worst case, it'll run you less than ten dollars, as long as you already own an oscilloscope and an inexpensive, general coverage shortwave (SW) receiver.

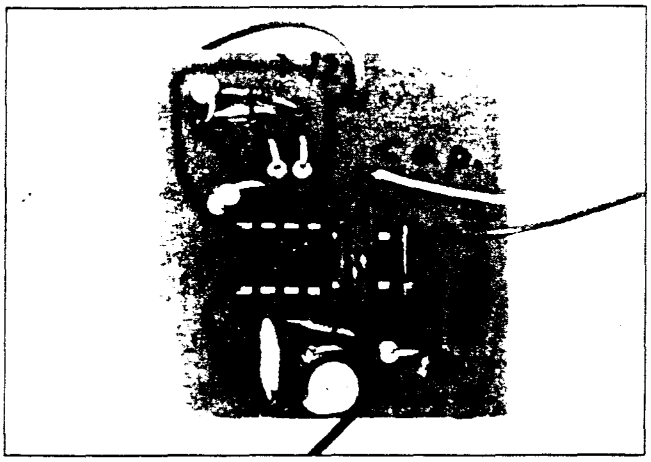


Photo A. Top view of the spectrum analyzer interface.

Overview

This system is surprisingly simple. Imagine a "scanning receiver" whose IF output is rectified into DC. This DC signal is then fed to the vertical input of an oscilloscope. The scope's trace beam scans the face of the CRT at exactly the same rate as that of the scanning receiver. Thus, whenever the receiver scans across a received signal, a DC voltage proportionate to the strength of the received signal causes the trace on the scope's CRT to deflect upward. As soon as the scanner passes by the signal, the trace deflects back down. If the scan rate is fast enough, a continuous trace appears on the CRT with vertical spikes or deflections of varying magnitude which correspond to the RF signals in the path of the scanner.

This spectrum analyzer interface contains its own HF receiver. Simply tune the SW receiver to the portion of the HF spectrum you want to view, or feed the antenna input of the SW receiver with the wideband IF signal of your HF transceiver. Using the latter system, any signal on the frequency to which your transceiver is tuned will show up in the center of the CRT. This signal, too, marks the middle of the spectrum range the analyzer is looking at.

The amount of spectrum you can view depends on the amount of bandwidth available at the IF (before the final IF filtering) of your transceiver. This also requires that the IF frequency be within the tuning range of the SW receiver. If your IF is 455 kHz, you can use a simple AM broadcast band receiver.

Theory and Construction

Since it's unlikely many of you have the same scope and SW receiver I use, I give relatively generalized instructions here. With a little care, however, you should be able to easily apply this idea to most models of SW receivers, and to almost any oscilloscope. If you have my particular setup, though, contact me for help on finding the specific connections on the DX-360. Please send an SASE.

First, obtain almost any simple, low-cost scope. I use a forty-dollar, 2 MHz, used scope.

Next, obtain a simple, LC tuned, shortwave receiver. My Radio Shack Realistic DX-360 works great. However, since I couldn't see the component side of the board, it was tough figuring out what was what. After a lot of trial and error, I found what I was looking for. It's easiest if one terminal of the tuning capacitor is connected directly to ground.

Now see the schematic in Figure 1. The receiver provides the signal (DC voltage) for the oscilloscope to display. All you have to build is a very simple device that will (1) cause the receiver to "scan" a portion of the HF spectrum and (2) provide a "sync" signal to the scope so it will also scan the CRT at the same rate.

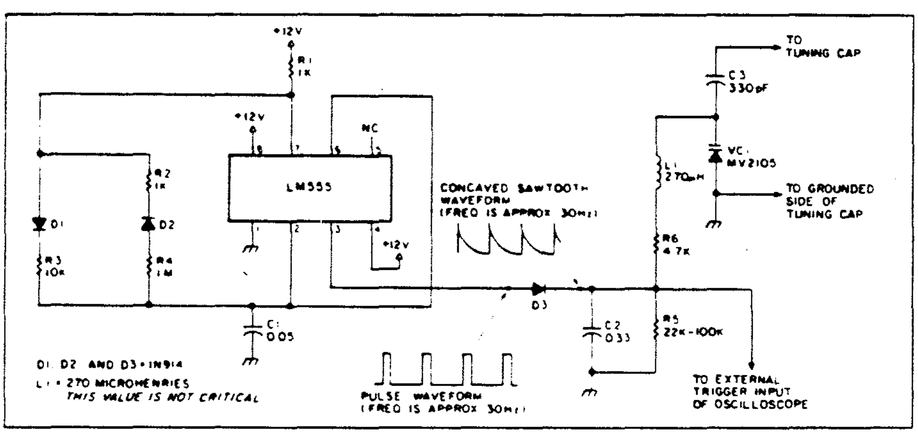


Figure 1. Schematic for the $10 or less home-brew spectrum analyzer.

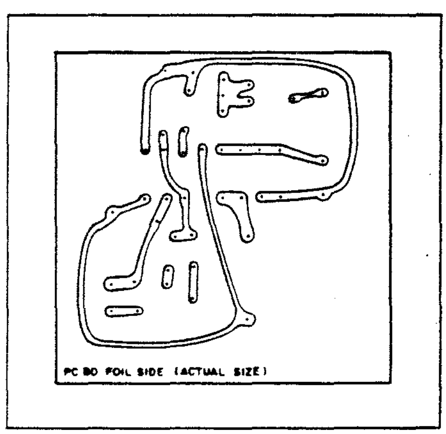


Figure 2. Foil side of board, actual size.

Two Birds With One Stone

The 555 timer IC takes care of both of the above. It is configured as a square wave generator, but with the ON part of the wave being very short relative to the OFF part. This is essentially a pulse wave. The pulse signal feeds a paralleled capacitor and resistor. The pulse charges the cap very rapidly, and then the resistor discharges the cap slowly. This creates a "concave" sawtooth waveform of about 25 Hz.

We need this waveform to create "linearity" of the scanning frequency of the SW receiver. The nonlinear characteristic of a varactor diode, and the nonlinear fashion in which the LC tuning circuit of the SW receiver operates, requires a nonlinear voltage to be fed to the varactor, but with its nonlinearity inverted in order to end up with *linear* tuning.

This DC voltage feeds a varactor diode (tuning diode) that is connected in parallel to the existing mechanical tuning capacitor of the shortwave receiver. The sawtooth wave is also fed to the scope's external trigger or sync terminal. (See below if your scope doesn't have an external trigger.)

Optimizing the Sawtooth Waveform

Select values of C2 and R5 to give a smooth concave sawtooth waveform as measured on the cathode of D3. This is a trial and error process. If R5 is too large, the scanning range is narrower and the minimum capacitance of VC1 will never be reached. The maximum capacitance range of the varactor—and thus the maximum possible spectrum scanning range—is never exploited since R5 will not be able to discharge C2 to zero volts. If R5 is too small, however, the scanning range will be at its maximum but will scan too fast. In this case, the waveform drops off very rapidly to zero volts before the cycle finishes.

You may want to make slight variations on

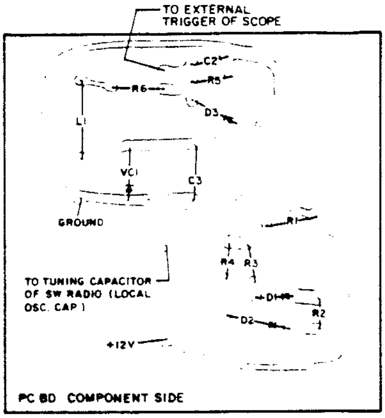


Figure 3. Parts placement on foil, enlarged. The 8-pin IC is in a 16-pin dip socket with pin 1 at 1 in the drawing. Leave pin 5 position undrilled to avoid breaking the trace from pin 4 to +12 volts. Note that C3 and VC1 plug into the 16-pin DIP socket for easy removal for experimentation. C3 and VC1 can also each be paralleled with other values via the unfilled DIP socket holes.

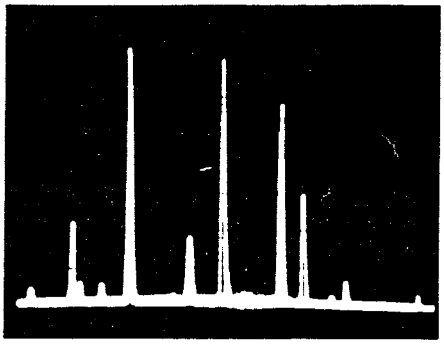


Photo B. The o'scope CRT showing signals in a 150 kHz piece of spectrum on 20m.

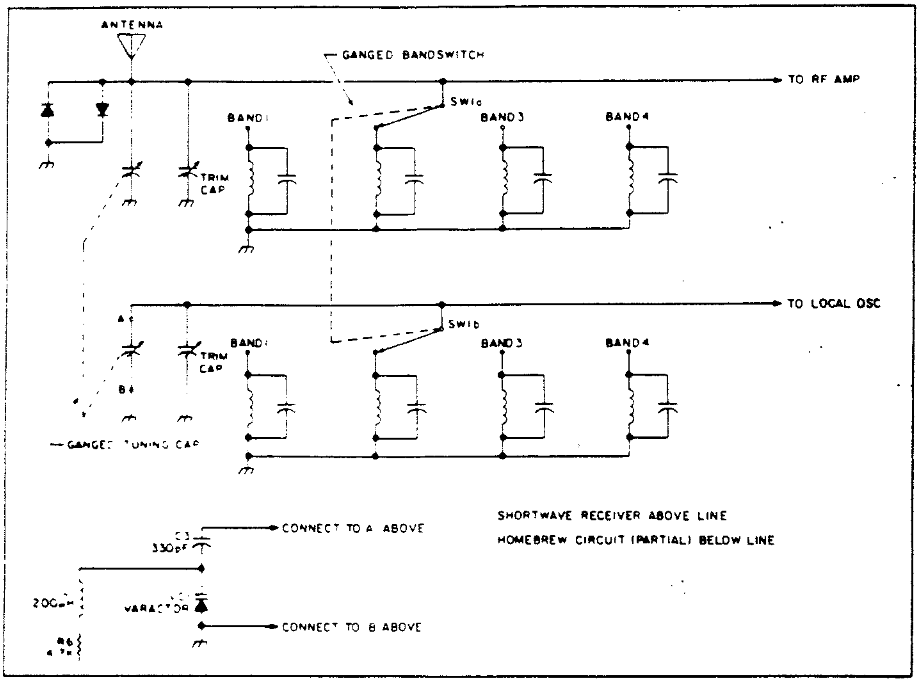
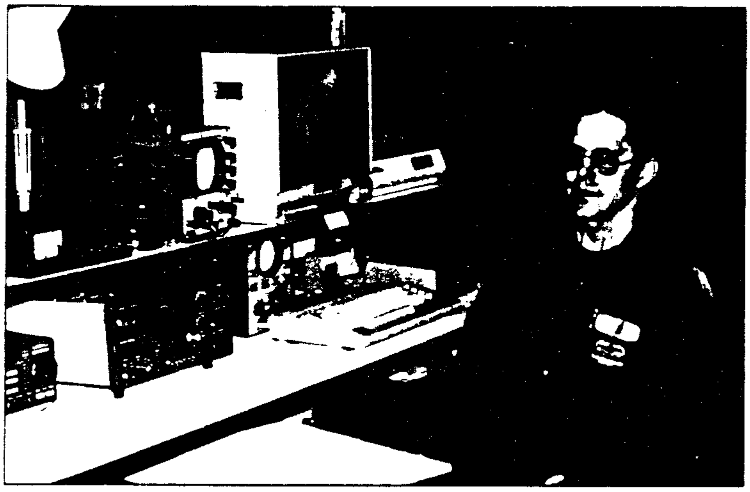
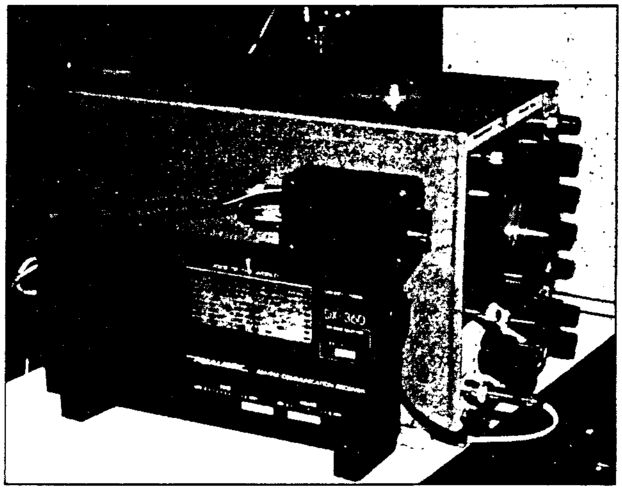


Figure 4. A typical SW receiver RF and local oscillator tuning circuit. The lead from C3 from the spectrum analyzer attaches to point A; the other spectrum analyzer lead (from VC1) attaches to point B.





Photos C,D. Greg KE0UV getting ready to to spot some DX on 10m using the $10 Spectrum Analyzer. Photo D is a close-up of the system, comprised of the o'scope, the scanning receiver (the DX-360) and the interface, which sits atop the DX-360.

these two values if the finished spectrum analyzer's display has wider spikes on one side of the CRT than the other. You'll likely need alter only R5's value.

If your scope does not have an external trigger input, you may be able to tap into the linear sawtooth wave inside the scope. In this case, you can eliminate the 555 timer circuit. Simply feed this sawtooth, which may need to be voltage divided, to obtain a level of around 0–12 volts, to the varactor. Couple the sawtooth to L1 through a capacitor. (Experiment to find the proper value of this cap—0.001 µF is a good starting point.) This will create the concave sawtooth waveform suitable for driving the varactor.

Setting the "Viewed" Bandwidth

The varactor tuning diode (VC1) I use is rated at 15 pF, but this can vary according to your system. You may need to change this value, and/or the value of C3, depending on how much scanning range or bandwidth you want. A 33 pF varactor gave too much tuning range; too much of the spectrum was displayed on the CRT, which caused a loss of resolution and melding of the displayed signals. I suggest using a 16-pin DIP package for the 555, so that you can use the extra eight sockets to try out different VC1/C3 combos. Remember that VC1 and C3 are simply two capacitors in series, so you can calculate what amounts of change will have what affects on the total capacitance, using the standard series capacitance formula: C1 x C2/C1 + C2.

If you are tuned to the high end of the dial of the SW receiver, you will want a small varactor, and vice versa. The values I chose give a display of about 325 kHz wide. The wideband IF of my Yaesu FT-101ZD is also about this wide, so this means I can view about 150 kHz of spectrum on both sides of the frequency to which the Yaesu is tuned.

Connect C3 and VC1, in series, across the *local oscillator (LO)* tuning capacitor in the SW receiver. Since we are tuning only a relatively small part of the spectrum, we don't need to tune the RF tank circuit. See Figures 4 and 5.

You may have to mount a trimmer capacitor, set at approximately the same value as the varactor diode (VC1), across the RF section. of the main tuning capacitor of the shortwave receiver. This is because the LO "scans" a slightly lower range of frequencies than the RF section of the tuning cap is centered on. I tried it without a trimcap and it worked, but I get higher AGC voltage to the vertical input of the o'scope with this trimmer installed, and thus taller spikes on the CRT display.

If room permits, mount C3, VC1 and L1 inside the receiver cabinet, as close as possible to the LO tuning cap. There is very little room inside my DX-360, so I simply soldered wires to each terminal of the tuning cap, (one of these wires is the receiver's ground) and brought the two wires to the outside of the radio via a ⅛" stereo phone jack. I used the third conductor of the stereo jack to bring out the AGC voltage of the receiver to feed the scope's vertical input.

Optimizing the Sync Frequency

I selected the frequency of the 555 timer circuit to give a smooth, sharp display on the CRT. It should generate pulses in the 20–30 Hertz range. Much below 20 Hz gives a flickering CRT display. Much above 30 Hz widens and smears the displayed signals, probably due to the SW receiver's AGC response time.

Make the connection to the AGC circuit of the SW receiver at a point before this AGC voltage is acted upon by any "timed decay" circuitry. If your SW receiver has an S-meter, try tapping into the AGC voltage there. Connect your scope to the S-meter, then manually tune the receiver across some shortwave signals and determine how fast the AGC voltage rises and falls. It should be *very* fast. If it is not, then work backwards from the S-meter till you get to a point where the AGC voltage is fast.

There's a point just after the IF filter where a portion of the IF is rectified. This is the AGC voltage. You may also be able to tap into the AGC voltage at the same point that it is fed back to the RF amp.

The aim is to probe around with the scope until you find a point where you get a DC voltage proportionate to the strength of a received signal with instantaneous response as you tune. When you find it, connect a wire to it. Bring the wire out of the receiver's cabinet and connect it to the vertical input of the scope.

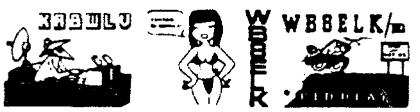
The IF filter of the scanning receiver limits the width of each displayed signal. The narrower the filter, the better. I temporarily inserted in cascade (series) a 4 kHz filter with the 6–8 kHz wide filters in my DX-360, and got much narrower spikes on the CRT display. A 2 to 3 kHz filter would be ideal.

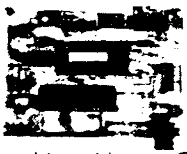
I recommend using a metal enclosure to keep out stray RF. Also, use shielded cable from the IF of the transceiver to the antenna input of the shortwave receiver, to keep everything *but* the IF out of the SW receiver.

Parts List

R1,R2	1k	¼ W
R3	10k	¼ W
R4	1 Meg	¼ W
R5	47k	(may be 22k–100k) ¼ W
R6	4.7k	¼ W
C1	0.05	disc ceramic
C2	0.33µF	electrolytic (any temp stable cap)
C3	330pF	mica or any stable cap (other values may be substituted, depending on desired scan range)
VC1	15pF	varactor diode MV2105
L1	150 to 300 µH inductor 43LS154 or 43LS564	
D1,D2, D3	1N914 or any small signal silicon diode	
U1	LM555 or NE555 timer IC	

DC Electronics, PO Box 3203, Scottsdale AZ 85257, (800-423-0070) has all the parts for this project. Since they require a minimum $15 order, you may want to get several values of varactor diodes.





Let the Fun Begin!

After constructing the simple interface, power it up with a 12 volt supply and listen to the audio of the SW receiver. It should have a buzzing sound as it very rapidly scans. Tune the receiver to a busy shortwave band. You'll note that the added capacitance of the varactor diode caused the dial calibration on the receiver to be a bit inaccurate, and that you will have to tune the receiver higher than normal.

If all checks out so far, turn off the power and connect the AGC wire to the scope's vertical input. Set the triggering function of the scope to *external* and connect the external trigger or sync input of the scope to either the concave sawtooth waveform, or to the pulsed wave directly from pin 3 of the 555 IC. Turn the power back on and adjust the scope's input attenuator until you get a display on the screen. Now set the scope's sweep speed until it sweeps the entire CRT at a rate slightly faster than the 555's frequency. I set my scope's timebase at 1 millisecond per division and use the variable sweep control to slow it down.

> *"All the components required to build your own HF spectrum analyzer may be found in a well-stocked junk box."*

Now disconnect the antenna from the SW receiver, and connect the antenna input of the receiver to the wideband IF output of your transceiver. If your transceiver does not have an IF output jack, look for a source of wideband IF immediately before the IF filter, and bring it out via a wire. This signal is used only to feed the antenna input of the shortwave scanning receiver, so you can loosely couple it to the antenna input, with a resistor in line. Choose a resistance that will give maximum IF signal to the scanning receiver without overloading its front end. You may first want to use a pot with a known range to determine this, and then replace it with a fixed resistor with the appropriate value. I used a 100k resistor for the DX-360's input.

The last IF frequency of my Yaesu FT-101ZD is 8.9 MHz, so I simply tune the SW receiver slightly above that setting on its dial. Then I tune the Yaesu to a *strong* CW station and watch the spikes on the CRT until I identify the one that I am hearing. Next, I tune the SW receiver until that particular spike is in the center of the CRT display.

Now, as I tune the Yaesu, the signals on the display move left or right in such a manner that the signal I'm tuned to is always displayed in the *center* of the CRT screen.

If the IF of your transceiver is 455 kHz, replace the SW receiver with a simple AM broadcast band receiver. Tune the AM receiver to the low end of the dial, and you may have to use a 100 pF or higher varactor diode. (Simply parallel two or more varactors to get higher values.)

Of course, you can analyze chunks of spectrum the SW receiver itself tunes through. Just unhook the transceiver from the setup, and replace the SW receiver's original antenna (or something with higher gain.) Tune the receiver to the band of interest and view the activity on the scope CRT. One disadvantage of this is that, to maintain the same spectrum viewing width, you would have to swap in and out different values of VC1 for the lower, middle, and upper sections of the dial on the SW receiver.

So Now That You've Built It...

...what do you use your spectrum analyzer for? Imagine sitting in front of your rig in the wee hours of the morning, hoping to work some rare DX. As you sit and listen, slowly tuning across a seemingly dead band (which you know will soon be opening!), you have your eyes focused on the CRT. You see a small *pip* about three-fourths of an inch to the left of center; you watch it for a moment, just to be sure it isn't noise. Sure enough, it has the rhythm of a CW signal! Quickly, you tune downward and watch as it moves to the right. As it becomes centered on the CRT, you hear it. While working this station, you see another signal appear on the CRT. You quickly make your QSL info exchange and tune till this new signal is centered.

It's also useful for those who take an explorer's interest in what goes on on the E-M wave spectrum. For example, I am fascinated at watching and trying to analyze the myriad of sweepers, or "runners," on 10 meters as they go racing left and right across the CRT. As they pass the center, you hear a *peep*. A lot of strange stuff goes on on this band! If you are a birdwatcher, the only place you will ever SEE the woodpecker is on your spectrum analyzer. (And the woodpecker is indeed a strange bird to see!)

Conclusion

The most time consuming part of this project usually is trying to locate the AGC circuit and the local oscillator LC tank circuit of the SW receiver. Construction technique isn't critical, although the varactor should not be located too far from the LC circuit. I breadboarded this circuit using 12-inch long connecting wires, and it worked just fine. For display stability, however, keep connecting lengths as short as possible.

Now, you can build from the junkbox a feature for which avid DXers spend additional thousands of dollars in commercial amateur gear! 73

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