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A Tracking Signal Generator for Use with a Spectrum Analyzer

It's ideal for any application that requires a sweeping signal generator.

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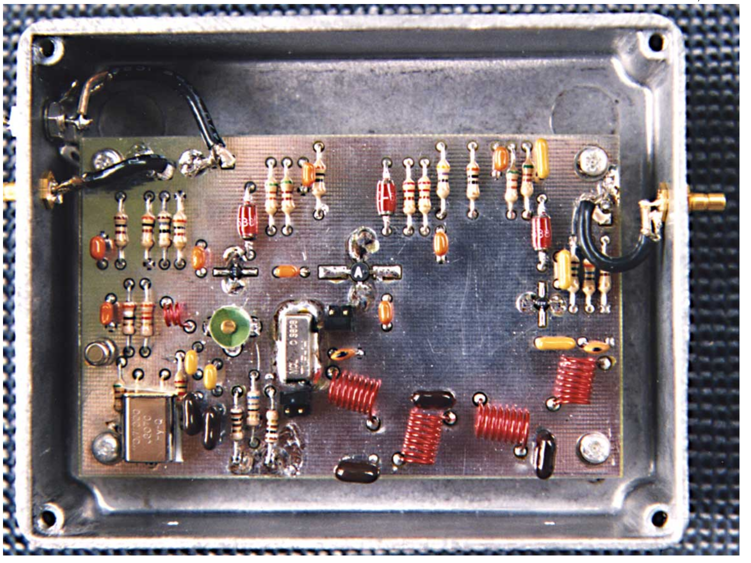


The tracking generator PC board is housed in a die-cast aluminum box (Hammond 1590BB; see Note 4). Careful board shielding is vital to trouble-free operation.

A spectrum analyzer is a receiver-like instrument that measures signals over a wide range of frequencies and amplitude. A tracking generator is a transmitter-like source of RF that tracks and sweeps with the spectrum analyzer to which it is attached. The circuitry needed to realize this function is the same as that used in an amateur transceiver and is based upon a shared oscillator. Unlike an amateur transceiver, however, a tracking generator functions in full duplex, emitting RF as the spectrum analyzer works.

The upper portion of Figure 1 shows a partial block diagram of our spectrum analyzer described last year in *QST*.[1] Input signals within a 0- to 70-MHz range are upconverted to a 110-MHz IF, where they are filtered and processed. Swept conversion is obtained from a 110- to 180-MHz voltage-controlled oscillator (VCO.) Our spectrum analyzer VCO circuit includes an auxiliary output for use with a tracking generator—like this one.

A block diagram of our tracking generator is shown at the bottom of Figure 1. A pair of monolithic amplifiers (U1 and U2) boost the VCO sample to a level of +17 dBm, providing local oscillator (LO) injection for a high-level mixer, U4. Q1, a 110-MHz crystal-controlled oscillator provides 0 dBm RF injection for the mixer. The mixer's output is low-pass filtered and amplified by U3 to provide a 0-dBm output.

Circuit Discussion and Adjustment

Figure 2 is the tracking-generator sche-

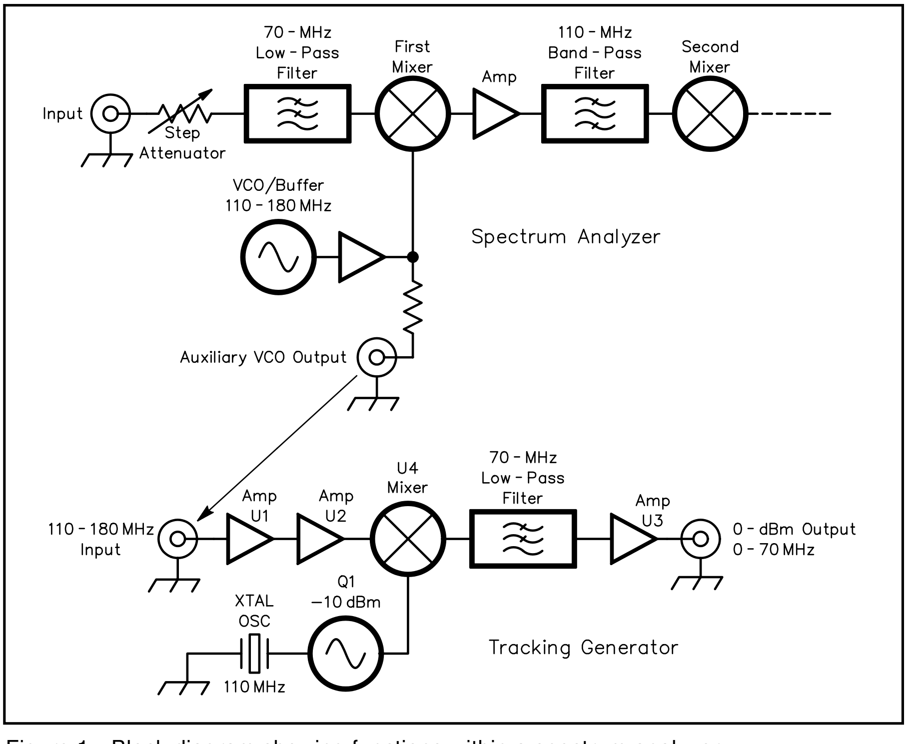


Figure 1—Block diagram showing functions within a spectrum analyzer front end and a tracking generator.

[1]Notes appear on page 52.

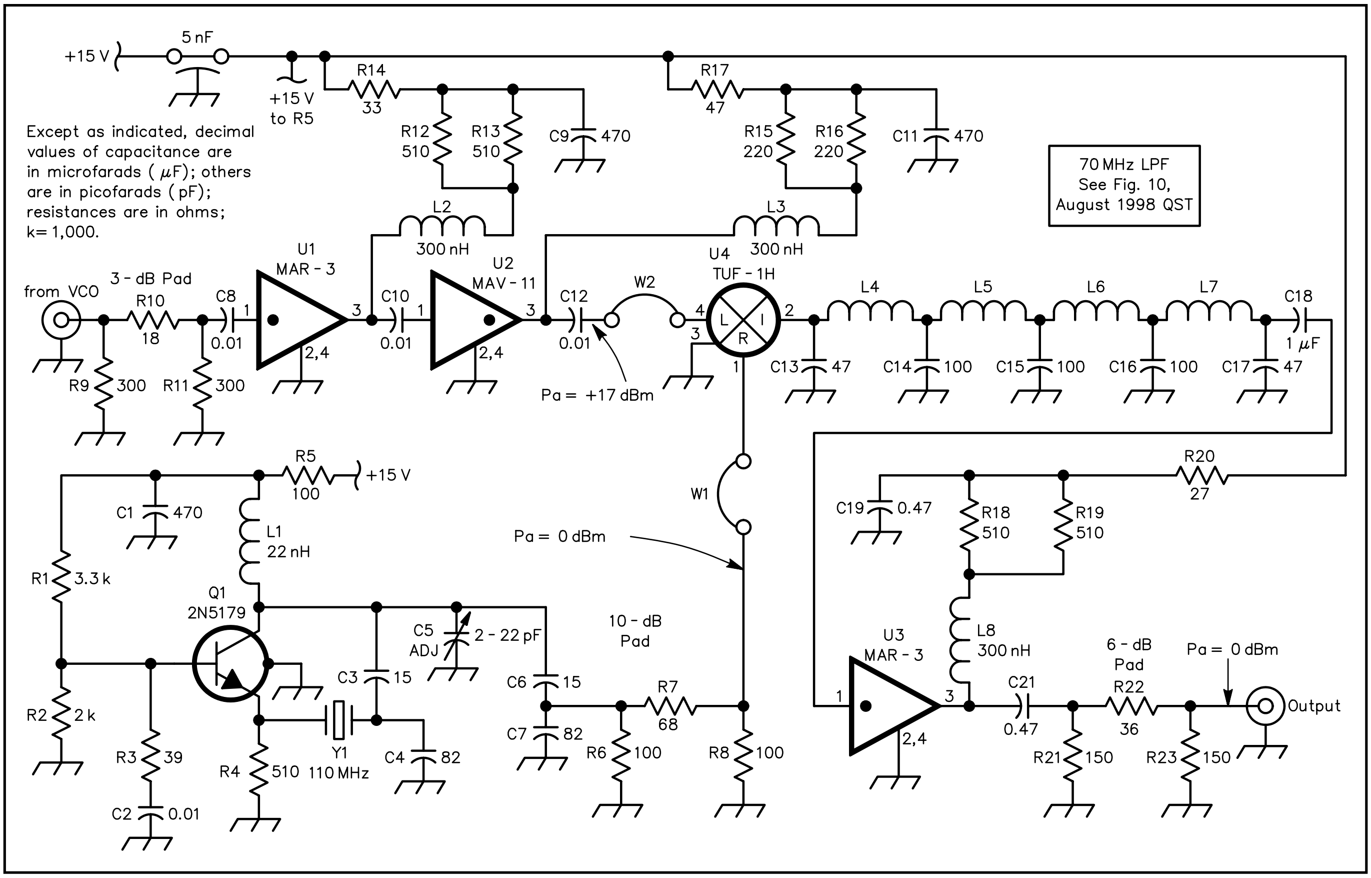


Figure 2—The tracking-generator schematic. Unless otherwise specified, resistors are 1/4-W, 5%-tolerance carbon-composition or film units. Equivalent parts can be substituted; n.c. indicates no connection. The low-pass filter is identical to that used in the original spectrum analyzer (see Note 1).

L1—22 nH, 2.5 turns #28 wound in the threads of a #6-32 machine screw as form; see text.
L2, L3, L8—1-µH molded RFC, any value from 100 nH to 2.7 µH will suffice.
L4-L7—8 turns #22 wound in 1/4-20 bolt threads as form. Use bare or enamel-covered wire.
Q1—2N5179 NPN VHF transistor
U1, U3—Mini-Circuits MAR-3 amplifier
U2—Mini-Circuits MAV-11 amplifier
U4—Mini-Circuits TUF 1-H mixer
Y1—Fifth-overtone crystal at first IF; see text and Note 2.

matic. Before doing anything else, determine *exactly* the center frequency of your spectrum analyzer's first IF. In our analyzer, this is the second LO frequency (usually 100 MHz) plus the second IF, 10 MHz in our analyzer. (Other spectrum-analyzer builders have used slightly different frequency combinations.) The measurement is best done by injecting a signal from a generator into the first IF, while measuring the generator signal using a frequency counter. Once the first IF is determined (using the narrowest-resolution bandwidth position), you can order an appropriate crystal.[2] By determining the proper frequency for Y1 early on, there is no need for crystal-oscillator frequency adjustment. Some tuning might be needed if a much narrower bandwidth is available.

The tracking-generator's crystal oscillator, Q1, is nearly identical to that of the spectrum analyzer's second LO. L1, the collector inductor, consists of 2.5 turns of #28 wire wound in the threads of a #6-32 machine screw (2.5 mm ID, 1.26 turns/mm), removed after winding. Temporarily remove jumpers W1 and W2. Then, using a 50-Ω-impedance power meter, measure the crystal-oscillator power output and the mixer LO injection. Confirm the output power of U3. Attenuator-pad values in all paths may be adjusted as needed.[3]

When installing the Mini-Circuits amplifiers use care, for the dot position changes with amplifier types! Careful shielding is mandatory when the generator

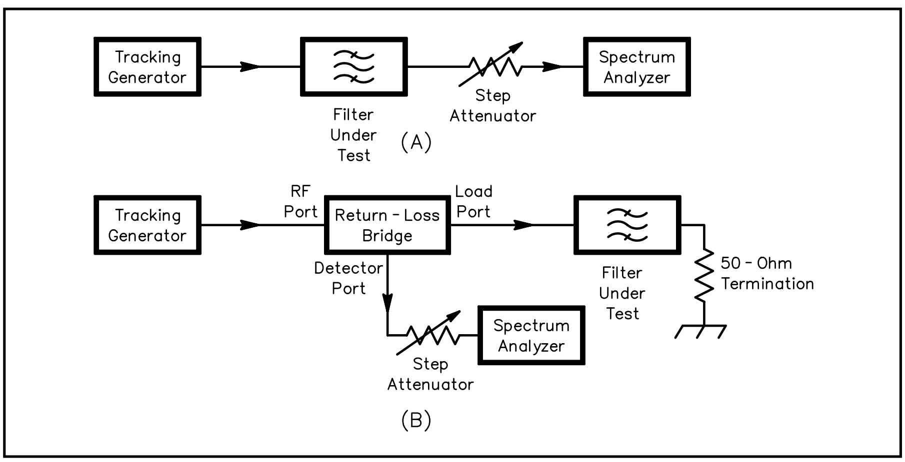
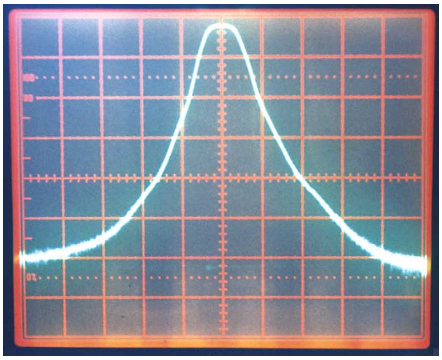
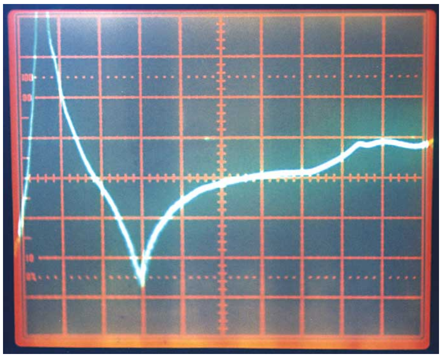


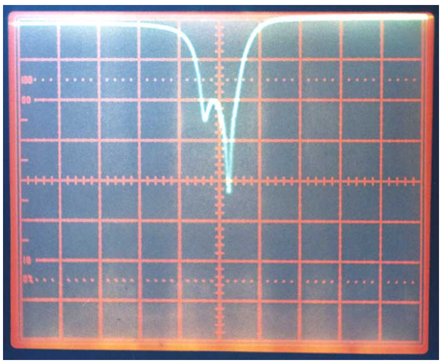
Figure 3—Application block diagrams for the spectrum-analyzer/tracking-generator combination. If a good return-loss bridge is not available, you can use a Mini-Circuits ZFSC-2-2, but with severely degraded directivity.



(A)



(B)



(C)

Figure 4—Filter measurement with the spectrum-analyzer/tracking-generator combination. Under test is a 7.15-MHz, three-pole LC bandpass filter with a 300-kHz bandwidth. At A, the nominal filter response including a 2-dB insertion loss. At B, all attenuation is removed, resulting in a peak filter response 30 dB above the reference level. This allows detail in the filter stopband to be seen. At C, the return loss at the filter input.

output frequency is the same as the analyzer input. The tracking-generator board (see the accompanying photo) fits a Hammond 1590BB die-cast box, slightly larger than the 1590B boxes used for most of the spectrum analyzer subcircuits.[4] Check our Web site for more tracking-generator and spectrum-analyzer details.[5] Also, see the Kanga USA site for board prices and availability.[6]

Applications

A tracking generator can be used in any application where a signal generator is needed and when it is useful to have the generator sweep. A spectrum-analyzer/tracking-generator combination is much more effective than using a swept oscillator with a wideband display. The combination affords enhanced dynamic range, the result of the detector's narrow bandwidth, a function performed by the spectrum analyzer.

The block diagram of Figure 3 shows how to evaluate an LC filter using the spectrum-analyzer/tracking-generator test set. At A, the scheme used to measure the usual filter response. Remove the filter from the system, replace it with a through connector or cable to calibrate the system for a reference level (top-screen) response. Install the filter and measure the response. Figure 4A shows the response of a 7-MHz bandpass filter measured with this approach. The response peak is below the top of the screen, indicating a 2-dB insertion loss. Figure 4B resembles 4A; however, the span is increased to show the response from about 5 to 50 MHz, and attenuation is removed so that the response peak is now 30 dB *above* the top of the screen. Although the response drops to –90 dBc at about 15 MHz, it comes back up. Shielding within the filter is needed to fix the degraded stopband performance.

Figure 3B shows the method used to measure the filter's input-impedance match. A return-loss bridge is employed. First, remove the filter and disconnect the 50-Ω termination, allowing the attenuator to be set for a top-screen response with an open-circuit termination at the load port. With the filter now terminated at the other end, insert it and measure the return loss. As seen in Figure 4C, it's a reasonable match (RL > 20 dB) over the filter passband.

The return-loss measurement approach is wonderful when used with an antenna. Figure 5 shows the result of checking a low, 20-meter dipole. Prior to attaching the return-loss bridge, the analyzer was tuned to place 14 MHz exactly at screen center. Measuring the antenna shows that its resonance is below the band with a return loss of about 15 dB (SWR = 1.43:1).

The reported measurements used no attenuation in the tracking-generator output, which provides an output power of 0 dBm. This power level is fine when checking an antenna or an LC filter. However, it is generally too high for the input of a receiver or amplifier. So, insert an attenuator at the tracking-generator output to establish a proper power level. The term *proper level* is, of course, relative. However, you now have the instruments needed to make such a determination for yourself. Unless you need the full 1-mW output of the tracking generator, using a fixed value of attenuation at its output forces a cleaner tracking-generator output impedance.

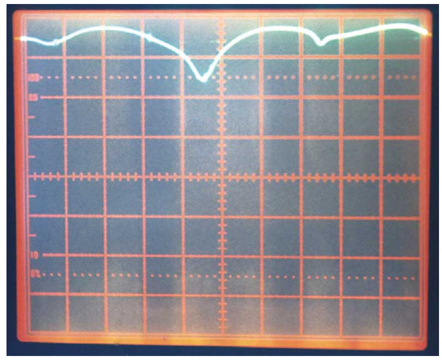


Figure 5—Input match for a low, 20-meter dipole antenna. The dip is slightly below 14 MHz indicating the need of a little trimming (or use of a Transmatch).

Concluding Thoughts

The spectrum-analyzer/tracking-generator combination is ideal for checking filters, amplifiers and antenna systems. Although this system is well suited to investigating LC filters, it lacks the stability and phase-noise qualifications for examining narrower crystal filters. This spectrum analyzer/tracking generator combination is capable of all measurements normally performed by a scalar network analyzer.

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Notes

[1]Wes Hayward, W7ZOI, and Terry White, K7TAU, "A Spectrum Analyzer for the Radio Amateur," *QST*, Aug and Sep 1998.

[2]The fifth-overtone crystal used in our analyzer was ordered from Hy-Q International, 1438 Cox Ave, Erlanger, KY 41018-3166, **www.hyqusa.com**. The board layout accepts an HC-49/U holder. The crystal type is JG07C.

[3]Attenuator-pad component values are found in Wes Hayward, W7ZOI, and Doug DeMaw, W1FB, *Solid-State Design for the Radio Amateur* (Newington: ARRL, 1977), p 151.

[4]Hammond boxes are available from Digi-Key Corp, 701 Brooks Ave S, Thief River Falls, MN 56701-0677; tel 800-344-4539, 218-681-6674, fax 218-681-3380; **http://www.digikey.com** and Mouser Electronics, 958 N Main St, Mansfield, TX 76063-4827; tel 800-346-6873, 817-483-4422, fax 817-483-0931; **sales@mouser.com**; **http://www.mouser.com**.

[5]**http://www.teleport.com/~w7zoi**

[6]Kanga USA, 3521 Spring Lake Dr, Findlay, OH 45840; **www.bright.net/~kanga/kanga**. QST