Frequency-Measuring Tests Using a Product-Detector SSB Receiver

Costly frequency-measuring equipment preventing you from becoming an FMTer? Read how this author resolved the problem. Now he's really competing in the precision tests.

By Donald L. Upp,* WB8STQ

When I became acquainted with *QST* eight years ago, those reports on the quarterly frequency-measuring tests seemed rather dull and routine. The accomplishments appeared to be ones in a narrow field of interest. I wondered why anyone except those amateurs concerned with the official observing program would even become involved. After all, the FMT activities were established many years ago for the OOs and would-be observers. My attention to this section of *QST* was most casual. Little did I realize then that the future would bring about a surprising change of attitude.

What did not escape my attention was that two notable amateurs in my area consistently gained prominence on the FMT honor-roll listings. In time, as my general activity increased, I was most fortunate to meet both W8OK and W8CUJ. These two distinguished gentlemen readily impressed me as men of sincerity and character. Their warm friendship, interest and concern have shaped the course of my Amateur Radio life.

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A Start in Frequency Measuring

Conversations with W8OK and W8CUJ, as a natural course of events, aroused my curiosity about frequency measuring in general. I soon realized that I was giving more attention to the quarterly FMT reports. Other than these reports in *QST*, little additional written material seemed available on frequency-measuring activities. Perhaps the lack of information indicated that interest was not widespread. Nevertheless, W8OK and W8CUJ had motivated me to the point where I wanted to be part of the scene.

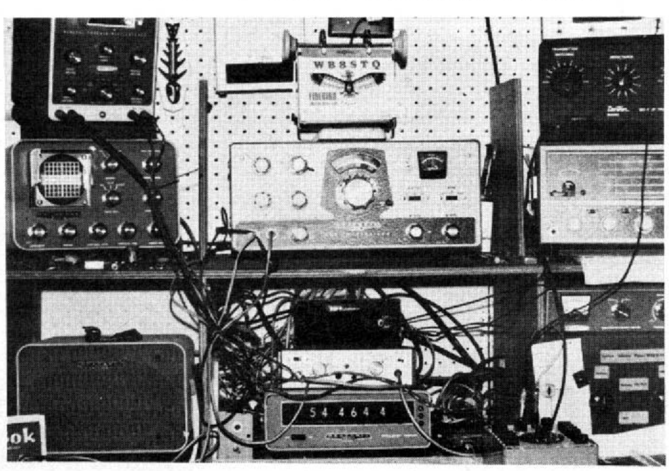
With a measure of impatience to get started, I launched my first attempts at frequency checking, limited by what little equipment I possessed. These efforts were crude and unreported. Yet they were the beginnings. While my station lacked the more refined equipment essential to precision measurements, inadequate reception clearly needed to be resolved. Could I really expect optimum performance from my HW-100 while depending on a ground-mounted vertical without radials? Those 80-meter signals, for instance, did little more than push the meter up to S3 at best. Performance on 40 meters was more decent, with S9 signals a common occurrence. But, on the negative side again, I was never able to bring in W1AW signals on 20 meters.

On Deck with the SB-650

Planned improvements for my installation included the acquisition of a Heath

WB8STQ during the November 1976 frequency-measuring tests.

The station setup at WB8STQ for FMT using divide-by-100 mode.



SB-650 frequency display. My reason for this particular choice is that it is compatible with the HW-100. This display operates with the Heath amateur receivers and five-band transceivers of the SB and HW series, covering the 3- to 30-MHz range. It calculates the received frequency to 1/10 kHz. The measured frequency is read out on six display devices.

Not long after the SB-650 went into service, I found that with a home-constructed, extremely narrow-band 750-Hz filter in the audio circuit, my equipment could measure the frequency of CHU (7,335,000 Hz) to within 25 Hz. But the final step in making the frequency check, admittedly, was done by ear and by "guesstimating" the relative length of the last-digit jitter. Satisfaction with this accomplishment was eventually overruled by a need to be honest with myself, admitting that 25 Hz was not good enough.

To make the honor roll in the FMT at the time I got started, 0.4 ppm was a requirement.* Results had to be better than 3 Hz (average) for all three frequencies used in the quarterly frequency-measuring tests.

While considering my intentions to achieve more accurate measurements, I did not fail to keep in mind the reception problem. Failure to hear even a whisper from W1AW on 20 meters was a significant loss, for the measurements on this band offered the greatest tolerance. Reception on 40 meters provided good signal strength but this was offset by heavy nighttime QRM that often makes activity on that band nearly a total loss. My frequency measuring seemed destined to be carried out on the 80-meter band where frequency checks had to be held within 1.8 Hz. Should the propagation produce a shift of 1/2 hertz and the umpire decided on the next higher (or lower) reading, all room for error would be lost — including any allowance for digital-display jiggle or line-voltage shifts. Tackling the reception problem, nevertheless, was not given top priority, all immediate effort being devoted to the electronic devices that perform the actual measurements.

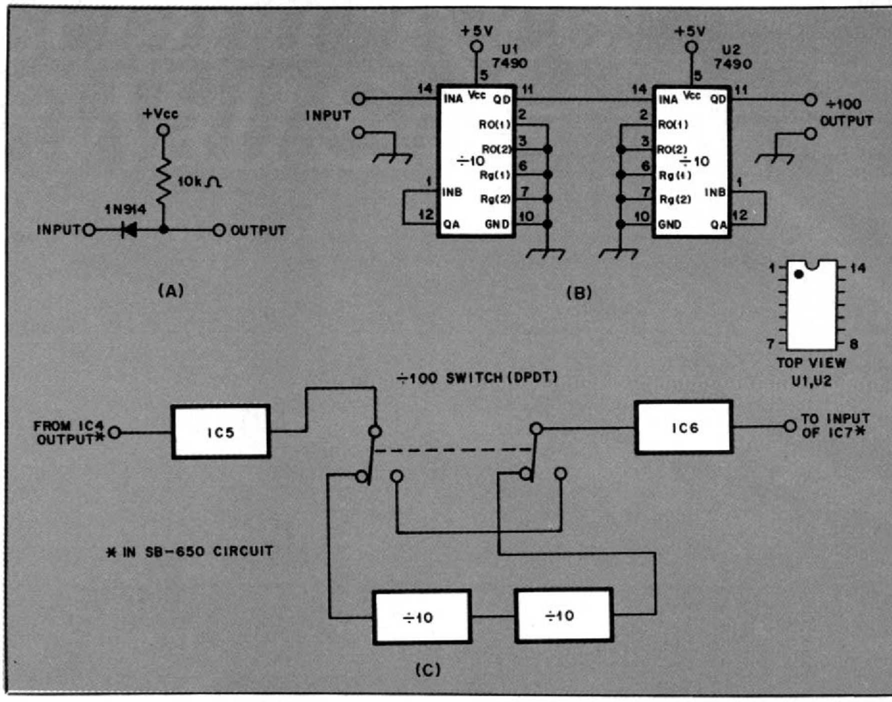
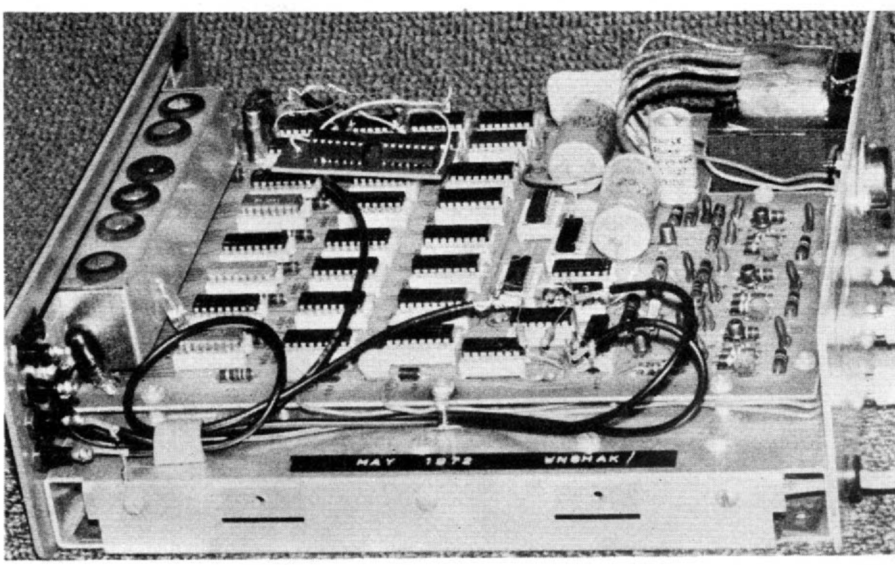


Fig. 1 — Circuits added in the modification of the Heath SB-650 frequency display. At A, a nonloading signal tap for TTL circuits using a high-speed switching diode. At B, details of the divide-by-100 circuit. Switching of the divide-by-100 system is illustrated at C. U1 and U2 are TTL decade-counter ICs. No connections are made to IC pins not shown in B.



The SB-650 with case removed. Pin jacks used in frequency reading are at the lower left. The divide-by-100 circuit board is at the upper left.

An Oscilloscope and a Frequency Counter

The Dayton Hamvention flea market furnished me with the next addition to my equipment inventory. After a $20 bill changed hands, I owned a second-hand oscilloscope which became a useful adjunct to an inexpensive but very stable Southwest Technical Products signal generator I'd recently constructed. Upon calibrating the generator against the 60-Hz power-line frequency, my equipment had the capability of measuring down to the 1.5- to 2.0-ppm range.

Progress is seldom achieved without some disappointment, and so it was with a frequency counter I built which did not increase the accuracy of my measurements. What the device did offer was an instantaneous readout of the frequency being checked. Work continued as I responded to an inner voice that kept saying, "Just have to get closer results!" The efforts produced a modest improvement with the range being lowered to the 0.8- to 1.5-ppm region.

Refer to the photograph of the SB-650 with the cover removed. The front-panel jacks, which you see from a side view, are for the buffered outputs of the HFO, BFO and VFO in addition to the 1-MHz crystal time base.

By going "down stream" one stage

*[Editor's Note: The procedure for the ARRL-sponsored FMT has been changed since Mr. Upp wrote his article. No longer is ppm used for measurement tolerances. Instead measurements are made now in terms of hertz. In order to qualify for Class I OO the new requirement stipulates that the frequency check must be within 100 Hz. In order to make the honor roll, the requirement is 5 Hz. Both tolerances, of course, must be within the umpire's readings. See page 76, May 1978 *QST*. At the time Mr. Upp made his frequency checks, the degree of precision under the 0.4-ppm requirement was 1.4 Hz at 3.5 MHz.]

from the inputs, a square-wave-conditioned signal can be taken off by means of a 10-kΩ resistor and a 1N914 switching diode (Fig. 1A). This arrangement allows the BFO and the HFO signal to be read with a frequency counter just prior to and just after the measurement run. Alternate readings of the audio beat frequency and the VFO frequency can then be taken rapidly.

This procedure is fine, provided that the line voltage does not change. A 1-volt displacement can induce a 2-Hz error. In my area, for instance, the line voltage may vary substantially during the late reading periods. Perhaps with a little practice I might have been able to obtain measurements within the 0.4-ppm limit, but I was convinced I'd find a better way.

Many of the dedicated FMTers might have volunteered the question, "Why not use a stable signal with 5- or 10-kHz points and just measure the beat note?" Surely that's a time-honored way, except that if one has a product-detector receiver in which the BFO cannot be turned off, there will be *two* beat notes. This simply means that by locking on one beat note, a product detector will provide two frequencies. Picking the right one could be troublesome, as in my case. Something up my sleeve resolved the difficulty: a number of SN7490Ns I had in stock. I jokingly tagged them "Destination SB-650," feeling quite certain that the search for a better way had ended.

Adding a Divide-by-100 Step

The digital modification of the Heath frequency display that followed paved the way to the real game of FMT. My plan involved the addition of a divide-by-100 step to the time chain with connections made at the output of IC4 (pin 11) and the input of IC5 (pin 14). See Fig. 1B. Going any further down the chain than the IC6 to IC7 stages would change the up-down counter time relationships. The board layout is shown in Fig. 2, and you may see the board positioned in the upper left of the uncovered SB-650. The picture does not include the dpdt switch which I added later and appears in Fig. 1C.

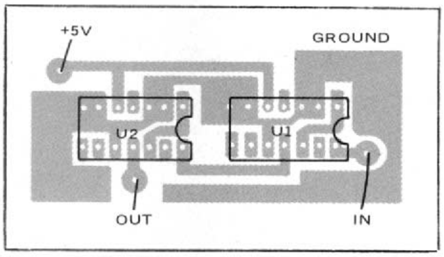


Fig. 2 — Parts placement guide for the WB8STQ divide-by-100 circuit. The shaded area represents an X-ray view of the copper pattern, the ICs being placed on the nonfoil side. The etching pattern for this board appears in the "Hints and Kinks" section of this issue.

Modification of the SB-650 was a rewarding effort. After a warm-up period of two hours, for stability, calibration against the frequency of CHU disclosed that at last my equipment had the capability of meeting those tight frequency-measuring requirements. With only 15 minutes of warming the error appeared better than 1 ppm. Following the more thorough warm-up the error remained constant and could be factored in any reading.

The Performance Report

My total score in the February 1977 FMT was 0.24 ppm. On the late 80-meter reading, I had five measurements that were exactly on the umpire's reported frequency. My other readings were plus or minus 1 Hz. A typical series in which the usb mode was used, so that all readings add, is as follows:

Band switch at 3.5 MHz.

SB-650 reading — 543561.

Audio to lock a single O on the oscilloscope — 882 Hz.

Calibration correction — add 3 Hz.

To apply the above information, add the numbers in this manner: 3.543561 MHz + 882 Hz + 3 Hz = 3544446 Hz.

By using the usb mode and adding the mathematical components, except possibly the correction factor, the chance for error at a sleepy-eyed 1 A.M. is minimized.

"Where did the variable error correction originate?" you might ask. The variation is mostly drift in the SB-650. The unit was not intended for this type of application, and thus has only a minimum of frequency stabilization. Furthermore, adjusting the time base to within 3-Hz error is nearly impossible, even on a short-time measurement using CHU as a standard. Because of the circuit delays and the timing/counting arrangement, the time base on mine must be set at 1000002.7 Hz to even be *that* close. But any error in ppm is virtually constant on the 80-, 40- and 20-meter bands. The short-time stability accounts for this feasibility. The poorest reading I obtained occurred in the early 80-meter run. My measurement was 0.57 ppm off that of the umpire, a difference of only 2 Hz. Therefore, you may appreciate what I mean about the need for close measurements.

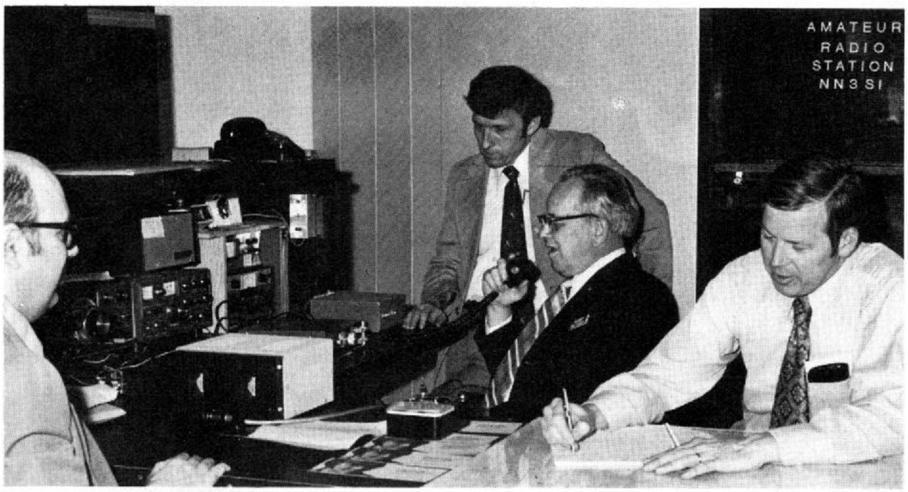
If the high price of equipment for frequency checking has discouraged you from participation in the FMT, I trust that these alternatives just outlined will renew your interest. I enjoy the challenge and also enjoy making equipment modifications to suit various needs, and I'm sure you will, too. As for modifying the antenna system, that too is in the works, with full anticipation of catching that elusive 20-meter signal from W1AW. So, in the months to come, you may see more of "STQ" in *QST*.

Strays

$5 FILTER SOLVES OSCAR MODE J DESENSE PROBLEM

☐ If your 435-MHz receive system is sensitive enough to get desense from your 2-meter uplink, this filter should solve the problem. The filter, developed by ARRL's Club and Training Department, can be built from simple materials for less than $5.

To receive the description and drawing of this filter send a self-addressed, stamped envelope to ARRL C&TD Filter, 225 Main St., Newington, CT 06111. — *W9KDR*



More than 250 science educators from around the U.S. "met" OSCAR at the ARRL booth at the NSTA Annual Convention in Washington, DC. Jim Jipping, W8MRR, science teacher at Holland (MI) Christian HS, gave an excellent presentation on his classroom OSCAR work. At the Smithsonian's NN3SI, an OSCAR 7 demo was given by (l-r) K3RJA, AA4BE, WA4DMF and AA4SI.