Not for the experts, but for those who haven't attempted it,

TRY THE FMT!!!

BY CHARLES L. WOOD,* W2VMX

You can try the FMT, and it's fun! The letters FMT signify Frequency Measuring Test. Twice each year, in February and September, and two additional times for those serving the fraternity as Official Observers, ARRL headquarters station W1AW provides a service to the amateur world by transmitting signals for FMT purposes. On each test these signals go out on the 80, 40- and 20-meter bands, at two different times in the evening, spaced three hours apart. With this diversity of signals to copy, almost every amateur can make at least two measurements, and some can measure all six different frequencies.

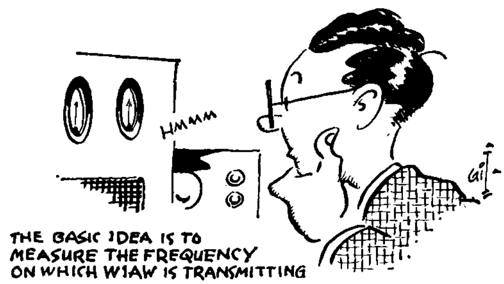
What is the purpose of FMT? The object is to provide for you an index of your skill in measuring the frequency on which W1AW is transmitting for the special test period. The familiar bulletin and code practice frequencies are not used for this purpose. Instead, "unknown" frequencies are transmitted. *QST* carries a listing of the approximate frequencies to be transmitted during the two FMTs each year which are open to all interested persons.

What do you do? You simply tune to W1AW, on or near the announced spot, and then make a measurement — as accurately as you can — of the transmitted frequency. Then, you mail your findings to ARRL. At headquarters, your data are compared with those supplied to ARRL by an independent laboratory. You will receive, by direct mail from ARRL headquarters, the results of your personal readings. The individual report on the ARRL Frequency Measuring Test tabulates the official reading, the submitted reading, the difference in cycles per second, the percentage error and the error in parts per million. At W2VMX there is a file of these FMT reports going back to 1955. Based on the many observations accumulated through the years, the following hints are offered to those who would like to take part in the sport.

The basic idea, as we have said, is to measure the frequency on which W1AW is transmitting. The best way to do this is to proceed from some *known* frequency or measuring point. There are a number of different ways of doing this, some much more accurate than others.

The Simplest Way

In the beginning, an FMT may be attempted with no more equipment than a simple crystal oscillator and a medium-grade receiver. Suppose W1AW is to transmit on or near 7090 kc. In your crystal box you find that you have two units, one labelled 7108 and the other stamped 7084. One of these is above the unknown frequency, the other below it. The evening of FMT, turn your gear on well ahead of time, to minimize errors due to warm-up. Tune in, and listen for W1AW, and suppose that you hear the signal somewhere around 7090. Looking at the seldom-used *logging* scale (most general-coverage receivers have something of this kind), you note that it reads 53. Now, you key the 7084 crystal in your oscillator and note the logging-scale point on your receiver. Let's say it is 49. The 7108 signal comes in at 61. The two crystals are 12 logging-scale units apart, and they are marked for frequencies 24 kc. apart. The logical conclusion is that for this portion of this particular band, each unit on your logging scale signifies a 2-kc. step in frequency. Since W1AW was heard 4 units above the lower crystal, then W1AW frequency must be 4 × 2 or 8 kc. above the 7084 point, or 7092 kc.



In actual practice, it would be rare for each division on a logging scale to represent exactly 2 kilocycles, or any other whole number of kilocycles. It would be very rare indeed for three signals to each be heard right on the scale division marks. The numbers in the illustration were set up simply to illustrate the basic process, called interpolation, by which an unknown signal between two known points can be mathematically computed. It also illustrates the point that FMT *can* be done with very simple equipment.

At W2VMX, we actually did three FMTs with nothing more complicated than an HQ129X and a boxful of crystals. Each of the three FMT's included 80- 40- and 20-meter readings. For the series of nine measurements the mean

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error was 315.7 parts per million, within the requirements for Class II in the Official Observer program.

Stepping Up The Accuracy

If you find that you have been bitten by the measuring bug, be assured that there is no antidote: you will have the disease for a long time to come! One symptom is a strong urge to acquire the next logical piece of equipment, a secondary frequency standard. That's a fancy name for a device which will provide you with reliable and valid signals[1] at known intervals throughout your receiver range. You already know that if you key your rig with a 3525 crystal in it, you can readily hear signals in your receiver at such places as 7050, 14,100, and so on. Suppose you had a crystal of 1,000 kc. . . . you'd then be able to find a marker signal every megacycle along the dial. Useful, but not too much so. It would be better if the marker signals appeared every 100 kc., or even every 10 kc. A 100-kc. crystal oscillator is available commercially as an optional accessory with many receivers. A suitable unit, with a 10 kc. multivibrator, was described in a fairly recent issue of *QST*.[2] Every such device should be equipped with some provision for varying the frequency of the crystal. This is true because a 100-kc. crystal seldom just happens to vibrate at 100.000 kc. The frequency depends upon temperature, voltages, and other circuit constants. A typical solution to this problem is a small trimmer capacitor which permits you to zero-beat the signal with WWV. *Always* zero-beat with the *highest* available WWV signal; any error you may make in this process at, say, 2.5 Mc., is magnified about six times on the 20-meter band.

With a 10-kc. signal accurately zeroed in on WWV, you can read accurately any signal which happens to be an exact multiple of 10 kc. In the above example, it would be clear to you where 7090 and 7100 signals would appear on your dial. To compute the frequency of W1AW, you need only to note the logging scale readings for 7090, the unknown, and 7100. The arithmetic is the same as before. Here at W2VMX, using nothing more than a 1000/100/10 kc. marker, the logging scale, and a slide rule, we have made more than 75 observations over a period exceeding ten years, and we have never lost our Class I status in the Official Observer program.

An ideal addition to the station at this point would be an audio oscillator, calibrated in cycles per second and reading from the lower limit of hearing to 5000 cycles.[3] There would be no need for an oscillator calibrated above 5000 cycles, for it is not possible for any unknown frequency to be more than 5 kc. from a known point when the 10 kc. multivibrator is running. In using the audio generator, the amateur zero-beats either the marker signal or the W1AW signal, and then uses the tone oscillator to match the resulting beat note as heard on the receiver. You must use care so that you subtract and add when the particular process is appropriate! Returning to the above example, let us say that you zero-beat 7090 and hear a note of about 2000 cycles in your receiver. Using the calibrated audio oscillator you find a reading of 2535 cycles, and you *add* this to 7090, for an indicated reading of 7092.535 kc. because the unknown was *above* 7090 on the dial. W1AW frequencies which are more than 5000 cycles above the marker (e.g., 7096, 7098, etc.) would call for subtraction from the *next higher* marker, 7100 kc. in this case.[4]

Simple tone oscillators of the kind used for code practice can be built and calibrated for this purpose. If you have difficulty matching tones by ear, you can connect both the oscillator output and the receiver output to an oscilloscope (one to the horizontal, one to the vertical) and attempt to make a circle — which tells you that the frequencies are exactly matched. If the tone is high in pitch, and your oscillator calibrations are very close to one another at that point, try creating Lissajous patterns[5] and making the necessary mathematical computations to find the unknown frequency.

Sometimes, you can use your imagination in obtaining readings on an unknown signal. One way to do this is to measure up from the lower 10-kc. marker, then down from above, averaging the readings. Sometimes you will uncover major interpolation errors in that way. An interesting, if inexact, interpolation device used at W2VMX for one FMT was a tape recording made at the parish hall piano. The tape consisted of a series of announcements like, "F-5", "F#-5," "G-5" followed by striking the appropriate note on the piano. These notes were compared with the received notes from W1AW, and frequencies were read from a table of musical tone frequencies. Did it work? Well, returns showed that our mean error was 247 cycles. Quite probably, not all of our error was in the audio department . . . but at any rate our mean error in p.p.m. was 43.2 parts per million, well within the required 71.43 p.p.m. for Class I OO. The lack of a continuously-variable tone source precluded any capital-P precision with this method, but it stands as one more in a long line of ex-

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[1] The criterion of *reliability* refers to the fact that the marker signal will always be in the same place, and relatively constant with regard to its accuracy. The criterion of *validity* refers to the fact that a properly zero-beated 100 kc. marker will be heard every 100.000 kc. up the dial, not 100.004 or 99.996, or some other approximation of 100 kc.

[2] Hall, "The KH6EGL Frequency Standard," *QST*, May, 1965. This circuit also includes a 1-kc. multivibrator, which will provide still closer-spaced markers for trapping the unknown frequency. It may, however, be omitted if only 10-kc. markers are wanted.

[3] A suitable oscillator was described by Lange, "25 to 25,000 Cycles," *QST*, July, 1967. It has three ranges, the first two covering 25–250 and 250–2500 cycles per second, respectively.

[4] In this system, the absolute error tends to be rather constant. This means that the p.p.m. error is lowest on 14 Mc., roughly double at 7 Mc., and much greater at 3.5 Mc. This is in contrast to errors obtained through the use of tunable oscillators such as the BC-221, in which absolute error is proportional to the frequency being measured.

[5] See chapter on measurements in the *Handbook*.

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amples of the kind of make-do ingenuity which hams have been known for for years. And it worked.

Take a moment to try *your* best with the next open FMT from W1AW. With repeated practice, you, too, will gradually approach the limits of the accuracy permitted by your equipment. You'll find it a fascinating challenge.

The September 14, 1968 (GMT) test will be open to all. Full rules will appear in August 1968 *QST* Operating News.

Good luck! QST