Frequency Stability Calibration or Signal Sources

The frequency stability calibration of precision signal sources in the range from very low frequencies to 500 MHz has been announced as a regular service by the Radio Standards Laboratory (Boulder, Colo.). Previously, this service had been available only on a limited basis.

Equipment for frequency stability measurements, capable of accuracy of 1 part in 10^{10}, was developed by John H. Shoaf of the microwave calibration laboratory. Additional facilities will provide a similar calibration service to 1000 MHz, and it will be extended into the microwave region in the future. All measurements are made with reference to the U.S. Frequency Standard (cesium) which has a known accuracy of 1 part in 10^{11}.

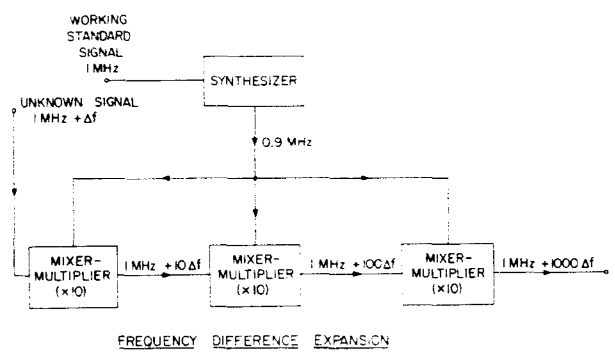
Signal sources submitted for calibration should provide a minimum power output of approximately 10 milliwatts (into a matched load) and have a frequency stability better than approximately 1 part in 10^{7}.

The calibration consists of measurements of both long-term (greater than one day) and short-term stability. The average frequency of the unknown signal source is determined for short intervals of time, and changes in these average-frequency values are observed. These changes are a measure of the frequency stability. Various techniques are employed in making the measurements, depending on the calibration required.

Direct counting of the number of cycles of the unknown frequency for an accurately known period of time is used. The unknown frequency usually is multiplied to a higher frequency value for greater accuracy. Electronic frequency counters, gated by a signal from an NBS working standard, are used for counting frequencies to 500 MHz.

Another approach compares the unknown frequency with an NBS working standard frequency by mixing the two frequencies in a nonlinear element and measuring the difference frequency obtained. The difference frequency is measured by the direct counting technique. When the difference frequency is very small, the accumulated phase of the difference frequency for a known period of time is measured. There are various techniques and equipment for doing this. An electronic frequency counter may be used, but in a manner essentially the reverse of the direct counting technique referred to above. The small difference frequency signal is applied to the portion of the counter that establishes the time-measurement function, and the working standard frequency signal is applied to the cycle-counting circuit. The result is a determination of the time required (in convenient units such as microseconds) for the phase accumulation of one or more complete cycles of the small difference frequency.

When the difference frequency is extremely small, the difference in phase between the unknown frequency and the working standard frequency may be recorded directly from phase-discriminating circuits, and the accumulated phase difference for a known period of time may be used to determine the difference frequency. Special circuits may be used to expand the difference frequency to a larger value before making a measurement. The difference frequency, Δf, can easily be expanded to a value of 1000 times the initial value.



Above: **Diagram of a technique for expanding the frequency difference between the unknown source and the working standard by a factor of 1000. The output signal frequency may be counted with a conventional 1-MHz counter.** ***Right:*** **John Shoaf examines a record from the frequency comparison equipment used to perform frequency stability calibrations for signal sources in the frequency range zero to 500 MHz. Shown are the phase comparison apparatus (left), electronic frequency counters and frequency difference expanders (center), and frequency multipliers (right).**