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Frequency Measurement by Sliding Harmonics

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Frequency Measurement by Sliding Harmonics*

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Summary—A method of measuring radio frequencies is described which uses an interpolating, or adjustable, frequency standard. Harmonics of this standard are caused to slide along the frequency scale until the one next below the frequency under measurement is brought up to match that frequency. The number of the used harmonic is readily determined from a simple calibration of the detector, heterodyne frequency meter, or receiver used to receive the frequency being measured. The positive increment in frequency of the used harmonic is determined from the control dial of the adjustable frequency standard. The use of wide-band receivers and interpolating equipment is avoided. Accuracy of measurement of the order of 10 parts per million is realized with the equipment described. If the interpolating frequency standard is treated as a highly stable heterodyne frequency meter, it may be used with many advantages in a conventional frequency-measuring system. The methods discussed are applicable to frequencies up to 1000 Mc.

A WIDELY USED, and generally very satisfactory, method of measuring frequencies up to several megacycles utilizes (1) a series of fixed standard-frequency harmonics of 10 kc, (2) a receiver or detector capable of accepting the frequency to be measured as well as the nearest 10-kc standard-frequency harmonic, and (3) an interpolation oscillator covering a range from zero to one-half the standard frequency (0–5 kc) with good stability and a highly expanded scale.

This method is very satisfactory for measuring the frequency of local oscillators or of transmitters having steady carrier frequencies. In cases of keyed or intermittent signals, an auxiliary oscillator (heterodyne frequency meter) is frequently required as a substitute signal source. Finally, unless an auxiliary oscillator is used, the system is not capable of producing a desired output frequency.

If the frequency f_x to be measured lies in the interval between a given standard-frequency harmonic nf_s, and a frequency $f_s/2$ above that harmonic, the beat-frequency difference obtained in the output of the receiver is considered positive. The frequency under measurement is then given by $f_x = nf_s + f_{b1}$. If the frequency to be measured lies above the given standard-frequency harmonic nf_s by more than $f_s/2$ but less than f_s, attention is shifted to the next higher standard-frequency harmonic $(n+1)f_s$, and the beat-frequency difference is considered negative. The frequency under measurement is then given by $f_x = (n+1)f_s - f_{b2}$. These conditions are illustrated in Fig. 1. Operating in this manner, the range of the interpolation oscillator needs to be only from 0 to $f_s/2$.

If, now, we propose to measure frequencies of a few hundred megacycles by this method, we find (1) that the standard frequency must be increased by 100 times, say, in order that the necessary harmonics can be generated with usable intensity and that the separation between successive harmonics be sufficient for ready identification; (2) that the pass band of the detector or receiver must correspondingly be increased by 100 times;

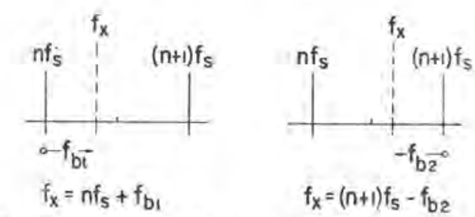

Fig. 1—Illustrating frequency measurement by conventional methods, with a fixed frequency standard.

and (3) that the range of the interpolation oscillator must also be increased by 100 times. It is apparent that the beat-frequency difference obtained in the output of the receiver will range far beyond audible limits, thereby requiring means of indication other than headphones or loudspeakers. With the extended range required of the interpolation oscillator, decreased accuracy of reading results. While it is by no means impossible to set up a frequency-measuring system on this basis, such a system is neither convenient or simple to use.

Some improvement is possible by utilizing the *higher* of the two beat frequencies produced by beating the frequency to be measured with adjacent standard-frequency harmonics and using an interpolation oscillator covering the range from $f_s/2$ to f_s (instead of from 0 to $f_s/2$), but the basic difficulties remain.[1]

A search for a more rapid procedure leads to the following: Consider a frequency standard combined with an interpolator so as to produce an *adjustable* standard frequency, of stability and accuracy approaching that of a fixed standard. It is then evident that a multiple of the adjustable standard frequency can be slid along the frequency scale and be matched to a frequency under measurement by simple zero-beating in any convenient detector or receiver. Under these conditions no wide-band receivers or wide-range interpolation oscillators are required.[2]

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[1] S. Sabaroff, "An ultra-high-frequency measuring assembly," Proc. I.R.E., vol. 27, pp. 208–213; March, 1939.

[2] J. K. Clapp, "Continuous interpolation methods," *General Radio Experimenter*, vols. 8 and 9, pp. 4–8 and 3–8; January and February, 1944.