31 MARCH 1961

THE INSTITUTE OF RADIO ENGINEERS, INC.
1 East 79th Street, New York 21, N. Y.

61 IRE 15. C
Re: 61 IRE 15. PS1

TO: Members of the Standards Committee and Chairmen of all Measurements Subcommittees

FROM: J. G. Kreer, Jr., Measurements Coordinator

SUBJECT: Proposed IRE Standards on Radio Transmitters: Methods of Measurement of Single Sideband Radio Communication Transmitters, 1961

The enclosed Proposed IRE Standards on Radio Transmitters: Methods of Measurement of Single Sideband Radio Communication Transmitters, 1961, is forwarded to you for comment. Additional copies are available for Committee and Subcommittee members, upon request to the Technical Secretary, IRE, L. G. Cumming, 1 East 79th Street, New York 21, New York.

It is urgently requested that this Proposed Standard be given careful consideration by the Measurements Subcommittees and that written comments be forwarded not later than May 5, 1961.

Comments should be sent to the following:

Mr. Stuart M. Morrison
2034 Fourth Ave., S.E.
Cedar Rapids, Iowa

with a copy to:

Mr. J. G. Kreer, Jr.
Bell Telephone Laboratories, Inc.
Whippany, New Jersey

If no comments are received by May 5, 1961, it will be assumed that the Proposed Standard is satisfactory and it will be submitted for approval by the IRE Standards Committee.

J. G. Kreer, Jr.
Measurements Coordinator

Enclosure
cc: Radio Transmitters Committee

THE INSTITUTE OF RADIO ENGINEERS, INC.
1 East 79th Street, New York 21, N. Y.

61 IRE 15. PS1
March, 1961

PROPOSED STANDARDS

SINGLE SIDEBAND RADIO COMMUNICATION TRANSMITTERS

DEFINITIONS OF TERMS

METHODS OF MEASUREMENT

1961

The Institute of Radio Engineers

Subcommittee 15.5 Personnel

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1. INTRODUCTION

Single Sideband Transmitters as considered in this standard are intended for transmission of one or more single sideband voice channels to which may be multiplexed one or more radiotelegraph signals. A Single Sideband Transmitter may consist of an assemblage of several units such as a single sideband generator, frequency converter, and a linear power amplifier to perform the functions o. a complete transmitter. The Definitions of Terms and Methods of Measurement covered by this standard also apply to each unit or subunit of a Single Sideband Transmitter where applicable. The terms included herein are specifically defined in their relation to Single Sideband Transmitter techniques, taking into account historically established nomenclature in some cases.

2. DEFINITIONS OF TERMS

Amplitude - Frequency Response Characteristic: Of a device or a system, the variation with frequency of its transmission gain or loss.

Carrier (SSB): At any point in a system the frequency which, when combined in a demodulator with the signal frequencies at that point, will reproduce the original signal frequencies which were applied at the input of the transmitter.

Carrier Compression (SSB): The change in amplitude of the Carrier caused by the presence of the applied signal.

NOTE: The converse of Compression, namely expansion, can occur and is understood as being included in the term Carrier Compression.

Carrier Suppression (Carrier Amplitude SSB): The ratio of the Carrier power output to the Peak Power Output.

Compression (SSB): Compression is a process in which the effective gain applied to a signal is varied as a function of the signal magnitude, the effective gain being greater for small than for large signals.

Continuous Power Output (SSB): The power available at the output terminals of a transmitter producing a continuous single frequency wave under normal conditions of single sideband operation.

Conversion Frequency: The frequency supplied to a modulator for the purpose of converting or translating the signal input to a new frequency.

NOTE: The new frequency is the sum or difference of the input frequency and the Conversion Frequency.

Frequency Departure: The amount of variation of a carrier frequency or center frequency from its assigned value.

NOTE: The term "Frequency Deviation", which has been used in this meaning, is in conflict with this essential term as applied to Phase and Frequency Modulation and is, therefore, deprecated for future use in the above sense.

Frequency Drift Rate: The change of average frequency per increment of time.

Frequency Stability: The ability of a transmitter to maintain constant a specified frequency.

Frequency Tolerance of a Radio Transmitter: The extent to which the carrier frequency of a transmitter may be permitted to depart from the frequency assigned.

Independent Sideband Transmitter: See Single Sideband Transmitter.

Monitor: A device in which a sample of the output of any stage of a radio transmitter is processed in order to reproduce the original input frequencies plus whatever distortion and noise frequencies are present in the sample.

NOTE: A monitor should contribute negligible distortion and noise. Thus, the output of the monitor should give a true picture of the distortion and noise content of the radio signal at the point of measurement. A monitor, if used to check hum or jitter produced by the frequency generators, must use independent conversion frequency sources of suitable stability.

Nominal Transmitter Band: The frequency band between the lowest and highest output frequency for which the transmitter is designed when operating on a fixed carrier frequency.

Peak Envelope Power Output: See Peak Power Output.

Peak Power Output:[1] The output power averaged over the radio frequency cycle having the maximum peak value which can occur under any combination of signals transmitted.

SSB NOTE: The Peak Power Output capability of an SSB transmitter is related to allowable Signal-To-Distortion Ratio and this ratio should be specified when rating an SSB transmitter.

Pilot: A single frequency wave which is transmitted for purposes such as synchronizing the automatic frequency control or for gain control of the receiver.

NOTE: The pilot may be the Carrier.

Signal-To-Distortion Ratio: The ratio of the power of one frequency component of a Two-Frequency Test Signal, to the power of the distortion product which is measured.

NOTE: Of the pair of distortion products of whatever order, the one of higher power is measured unless otherwise specified.

Signal-To-Noise Ratio: The ratio of the output power of the specified signal at a stated power level to the output power, in a specified bandwidth, of the other energy exclusive of the signal and its intermodulation products.

NOTE: Components produced from hum, microphonics, and random variations such as thermal noise, are considered as noise energy. The measurement of noise power should be made to include both phase and amplitude components.

[1] Definition is from IRE Standards on Radio Transmitters: Definitions of Terms, 1948. The note has been added to cover the special circumstances of Single Sideband.

Sideband Suppression: The ratio of the amplitude of a single frequency test signal in the desired sideband, to the amplitude of its counterpart in the undesired sideband.

Single-Sideband Modulation (SSB): Modulation whereby the spectrum of the modulating wave is translated in frequency by a specified amount either with or without inversion.

Single-Sideband Transmitter: A transmitter in which one sideband is transmitted and the other is effectively suppressed.

NOTE: When the output on each side of the Carrier (SSB) includes sidebands containing separate information, a Single-Sideband Transmitter is often referred to as an Independent Sideband Transmitter.

Two-Frequency Test Signal: A combination of two sinusoidal waves of equal amplitude and different frequency used as an input signal for testing a Single-Sideband Transmitter.

NOTE: A Two-Frequency Test Signal is formed by combining the outputs of two sinusoidal oscillators or generators, with isolation to prevent intermodulation in the sources themselves. A calibrated attenuator in the path of the combined signal, and a level indicator are useful. The frequencies used for the Two-Frequency Test Signal may be selected in accordance with the requirements of the transmission system of which the Radio Transmitter is a part.

3. METHODS OF MEASUREMENT

3.1 Power Output

Measurement of Continuous Power Output and Peak Power Output must be based on the same operating conditions. In a given transmitter the Continuous Power Output efficiency might be improved by changing the bias or load resistance from the values normally used for speech transmission, but these changed conditions are not to be used in determining the Continuous Power Output.

3.1.1 Continuous Power Output

The transmitter is operated under nominal operating conditions including line voltage, load impedance, and environmental conditions such as temperature, humidity, and altitude unless otherwise specified. The Carrier is reduced to a negligible value and a single sinewave signal, at any frequency which produces a single sideband output within the flat portion of the Nominal Transmitter Band, is applied to the transmitter input. The power output is measured by any one of the methods described in section 3.1.3.

3.1.2 Peak Power Output

Modulation with a Two-Frequency Test Signal gives two RF output signals, plus harmonics, intermodulation products, and other spurious output. The undesired products are small compared to the fundamental frequencies, therefore, the peak signal power is essentially twice the measured average power. A small error is recognized, since the peak signal power measured in this way is not Peak Power as defined by IRE 15 in 1948 Standards, but is the Peak Power of the useful signal components only.

The transmitter is operated under nominal operating conditions including line voltage, load impedance, and environmental conditions such as temperature, humidity, and altitude unless otherwise specified. The Carrier is reduced to a negligible value and a Two-Frequency Test Signal, which produces a two-frequency single sideband output within the flat portion of the Nominal Transmitter Band, is applied to the input. The amplitude of the Two-Frequency Test Signal is increased until the specified Peak Power or the specified Signal-To-Distortion Ratio is reached. The Peak Power output shall be considered to be twice the average power.

3.1.3 Methods of Power Measurement

3.1.3.1 General

A load which permits power measurement is connected to the transmitter output terminals. The impedance of the load (including any instrument) should be within the range of impedances into which the transmitter is designed to operate. There are several methods of measuring the power delivered by a transmitter, of which typical methods are given below. The Calorimetric Method[2] is a basic method and will be considered standard. All others are alternate methods.

3.1.3.2 Calorimetric Method

The Calorimetric Method employs the observation of the temperature rise of a coolant of known specific gravity, specific heat and rate of flow in which coolant the power output of the transmitter is being dissipated. The heat developed in the load shall be transferred to the liquid coolant of known specific heat. The construction of the load shall be such that the loss of heat due to conduction and radiation from the apparatus is negligible.

The load shall be equipped with means for accurately measuring the volume rate of flow of the coolant and with precision thermometers for measuring the temperature of the liquid entering and leaving the device. After the RF power has been applied, the rate of flow of the coolant shall be adjusted until an adequate difference between the input and output thermometer readings is obtained. Sufficient time shall be allowed to elapse to insure no further changes in the thermometer readings. When steady conditions have been obtained, both thermometer readings and the rate of flow of the coolant shall be noted. The average power dissipated in the load is calculated from the rise in temperature, rate of flow, specific gravity, and specific heat of the coolant. It is given by:

$$W_P = 264\,QGS\,(T_2 - T_1) \text{ where}$$

W_P = Average power dissipated in watts

Q = Coolant flow in U. S. Gallons per minute

G = Specific gravity of coolant (equal to 1 for water)

S = Specific heat of coolant (equal to 1 for water)

T_2 = Outlet temperature of coolant in degrees centigrade

T_1 = Inlet temperature of coolant in degrees centigrade

[2] Theoretical background and extensive bibliography on this subject will be found in "Radio Frequency Power Measurements," NBS Circular 536, published March 16, 1953 obtainable from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

3.1.3.3 Alternate Calorimetric Method

In the alternate calorimetric method, the power is measured by dissipating DC or low frequency AC power in the same load and noting the amount of power, measured in a conventional manner, that is necessary to produce the same temperature rise in the coolant at the same flow rate.

3.1.3.4 Current-Resistance Method

This method consists of measuring the rms RF current through the load and calculating the average power. Any phase angle in the load must be recognized and accounted for in the computation. The load may be a dissipative line.

3.1.3.5 Voltage-Resistance Method

The peak voltage across the load is measured and used to calculate either the Continuous Power of a single frequency test signal or the Peak Power of a Two-Frequency Test Signal. As in the Current-Resistance Method, any phase angle in the load must be recognized and accounted for in the computation. Likewise, the load may be a dissipative line.

3.1.3.6 Directional Wattmeter Method

This method uses a device which is usually designed for specified impedance and frequency ranges, and is calibrated to measure the incident and reflected power in the transmission line. The difference is the power absorbed by the load.

NOTE: The indicating meters used with directional wattmeters are generally of the average voltage or average current type instead of rms type. For this reason, with a Two-Frequency Test Signal, they read $(2/\pi)^2$ or 40.5% of peak power instead of 50% of peak power.

3. 2 Signal-To-Distortion Ratio

3. 2. 1 General

The Signal-To-Distortion Ratio of a transmitter is a measure of the degree of nonlinearity of its transmission characteristics. The Signal-To-Distortion Ratio also bears a direct relation to the disturbance which a transmitter may cause in the spectrum outside of its assigned channel.

A Two-Frequency Test Signal, when applied to the transmitter input terminals, produces a two-frequency single sideband output. However, the effect of nonlinearity of the transmitter characteristic is to produce additional frequencies, including harmonics, intermodulation products, and other spurious output. The intermodulation products which appear in the spectrum of the output in the frequency positions indicated in Figure 1, constitute one form of Spurious Transmitter Output, Inband. A Signal-To-Distortion Ratio measurement is made by comparing the amplitude of one of the desired output frequencies (either P or Q) with the amplitude of one of the undesired frequencies. This comparison is best made by an analysis of the output spectrum by means of a radio frequency spectrum analyzer. This method is designated as the Standard Method. Another method in which the spectrum analysis is performed after demodulation to audio frequency by a high quality receiving device, or monitor, is designated as an Alternate Method.

3. 2. 2. Measuring Set Requirements

For either method, the measuring set must perform the following functions with negligible distortion: (a) conversion of the sample of the transmitter output to a frequency convenient for filtering; (b) selection of any desired component of the spectrum by means of a narrow-band filter; (c) comparison of component amplitudes, by a meter or oscilloscope. A simplified block diagram of such a measuring set is shown in Figure 2.

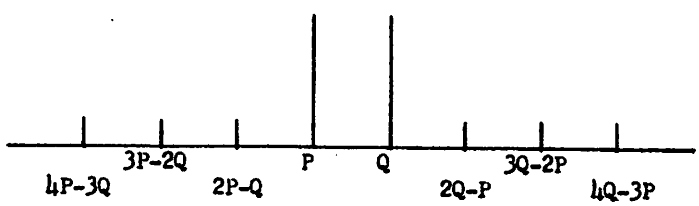
3. 2. 3 Methods of Measurement

3. 2. 3. 1 Standard Method

A Two-Frequency Test Signal is applied to the transmitter input, and a sample of the RF output to be measured is conveyed by a shielded conductor at a suitable level to the input of the measuring set. Care should be taken to avoid undesired entry of RF energy into the measuring equipment. The measuring set linearity should be tested by insertion of a known attenuation at the input, and its discrimination against the signal should be adequate to measure the Signal-To-Distortion Ratio. When the output of the measuring set is presented in panoramic fashion on an oscilloscope screen, a display similar to the spectrum shown by Figure 1 is obtained. The distortion component of interest may be identified easily and observed in its true relation to the other significant products. Calibration of the indicator scale should be checked by means of the calibrated attenuator.

3. 2. 3. 2 Alternate Method

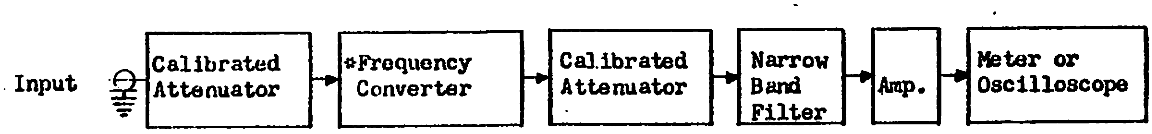
In this method, by proper choice of the two test frequencies, a single narrow-band filter may be used to measure the various distortion components. For example, 1000 cycles combined with 1575 cycles produces a third order component which may be selected by a 425 cycle narrow-band filter. This same filter will accept the fifth order product if the second oscillator frequency is changed from 1575 cycles to 1287. 5 cycles. Higher order products may be similarly selected.



P and Q are two transmitted sine waves.

Distortion products are spaced apart by the difference frequency (Q-P)

Figure 1. Spectrum of Non-Linear Distortion



* The converter may be swept in frequency and coupled to the oscilloscope sweep for panoramic spectrum display.

Figure 2. Analyzer For Signal-To-Distortion Measurement

3.3 Carrier Suppression (Carrier Amplitude SSB)

This test is used to determine the ability of a transmitter to adequately suppress the Carrier, and to determine the accuracy of the Carrier insertion controls. It is also sometimes used as an operating procedure for setting Carrier Suppression.

The Carrier output is first reduced to a negligible value by setting the Carrier insertion controls to minimum, and performing any necessary balancing adjustments on the balanced modulator. A Two-Frequency Test Signal is applied to the transmitter input at a level sufficient to obtain the specified Peak Power Output. One test frequency is then removed, and the other is maintained at a constant input level, to establish a reference output power 6 decibels below specified Peak Power. Next, the remaining test signal is removed and the carrier insertion controls are adjusted to set the Carrier at the desired level, and the transmitter voltage or power output is again measured. The ratio, in decibels, of the voltage or power of the one test frequency to the voltage or power of the Carrier, plus 6 decibels, represents the Carrier Suppression below Peak Power Output.

NOTE: The device for measuring the RF output voltage of the transmitter may be an RF Voltmeter, or a radio receiver with a calibrated attenuator. The voltages of the Carrier and of the one test frequency may be measured with the spectrum analyzer used for the Signal-To-Distortion Ratio measurements. A directional wattmeter in the transmitter output provides a convenient means of measuring power output. (See Section 3.1.3.6).

3.4 Carrier Compression

The Carrier insertion controls are adjusted to produce the desired Carrier level at the transmitter output, as measured by a selective RF voltmeter or spectrum analyzer. A single frequency or other specified signal is then applied to the transmitter input at a level which in combination with the Carrier produces the specified transmitter Peak Power Output. The Carrier level is again measured, but now in the presence of the signal. The ratio, usually expressed in decibels, of the Carrier voltage without and with the signal being present is the Carrier Compression.

NOTE: The selective RF Voltmeter must be capable of separating the relatively weak Carrier component from the transmitter output in the presence of the signal, and should introduce no compression of its own. A spectrum analyzer, such as used for measuring Signal-To-Distortion Ratio, is also a satisfactory instrument for this measurement.

3.5 Frequency Response

For these measurements the transmitter Carrier is essentially suppressed. The frequency response of the transmitter may be measured by feeding a sine wave signal at a constant level to the input of the transmitter. The input signal is applied at the proper level to drive the transmitter to the desired power output at the reference frequency. (The output level should be out of the Compression range; about one-quarter Peak Power Output is suggested.) The power output of the transmitter is recorded for various input signal frequencies. The ratio of the power output with constant input signal level at the various specified signal frequencies to the power output at the reference frequency expressed in decibels, represents the transmitter frequency response.

NOTE: It is recognized that the above method does not include dynamic regulation effects when multiple input signals are applied which might alter the transmitter frequency response.

3.6 Sideband Suppression

This test is used for determining the adequacy of the sideband filters or phasing networks to suppress the undesired sideband. By the use of a single frequency signal and negligible Carrier, the generation of intermodulation products from these two signals is minimized. These intermodulation products are not considered as part of the suppressed sideband signal, but since they do occur at the same frequency (as the counterpart of the signal in the suppressed sideband), the only means of minimizing their effect on the measurement is to minimize their generation.

The Carrier is reduced to a negligible value, and a single frequency signal is applied to the input at a level which will drive the transmitter to about one-quarter Peak Power Output. By means of a frequency selective RF voltmeter or spectrum analyzer, the level of the signal is measured (at the transmitter output) in the desired sideband, and then its counterpart is measured in the suppressed sideband. The ratio of the signal in the desired sideband to its counterpart in the suppressed sideband is the Sideband Suppression for that particular signal frequency. The measurements should be repeated using signals spaced at frequency intervals within the Nominal Transmitter Band. The lowest ratio of the signal in the desired sideband to its counterpart in the suppressed sideband is considered the Sideband Suppression of the transmitter.

3.7 Signal-To-Noise Ratio

3.7.1 General

The Carrier is reduced to a negligible value, and a single frequency signal is applied to the input at a level which will drive the transmitter to the specified Continuous Power Output. The applied input signal frequency should be such that it falls within the Nominal Transmitter Band. However, it is suggested that the signal frequency be placed in the upper part of the Nominal Transmitter Band so that harmonics of the signal frequency will fall outside of this band.

3.7.1.1 Standard Method

When noise components in the transmitter output consist of discrete frequencies as well as white noise, it may be necessary to measure both types in order to obtain an accurate Signal-To-Noise-Ratio. The discrete noise components are measured with a selective spectrum analyzer. This analyzer must have sufficient stability, selectivity, and sensitivity to measure noise components which may be adjacent to the desired RF output signal. The white noise is measured by using a spectrum analyzer of known bandwidth to scan the required spectrum, but avoiding the discrete components. The output of this analyzer is fed to a RMS voltmeter to indicate the noise power level. These measurements of the noise components in the Nominal Transmitter Band are then reduced to a power basis (sum of all individual component powers). The ratio of the power in the desired signal to the power in the undesired noise components gives the Signal-To-Noise Ratio at the specified power output level. The ratio is usually expressed in decibels.

3.7.1.2 Alternate Method

An alternate method of measuring Signal-To-Noise Ratio may be employed as for example, one in which a single sideband receiver having the required stability and low noise characteristics is used. The output of the receiver is measured on a RMS voltmeter to indicate the signal power output. A selective filter circuit is then inserted to remove the signal frequency energy so that the residual energy only is indicated on the RMS voltmeter. The ratio of the two readings in power is the Signal-To-Noise Ratio. The bandwidth of the receiver should be greater than the Nominal Transmitter Band so that the noise components are not attenuated.

3.8 Frequency Stability and Frequency Drift Rate

3.8.1 Frequency Measuring Apparatus

Figure 3 shows a block diagram of suggested frequency measuring apparatus. The frequency standard is usually a 100 kc or a 1 mc crystal oscillator with sufficient stability for the required accuracy of measurement. The spectrum generator produces a band of spectrum points usually separated by 10 kc in the range of the frequency to be measured. The spectrum points are derived from the frequency standard by multiplying, dividing and mixing processes so each has a stability equal to that of the standard. The spectrum point nearest the frequency to be measured is used to obtain a mixer output frequency in the range of 0 to 5000 cps. A calibrated receiver may be used as the tunable mixer. Its calibration accuracy must be sufficient to determine the frequency spectrum point used and it should have sufficient selectivity to pass the desired spectrum point and the frequency to be measured but reject all other spectrum points.

The measurement of beat frequencies below approximately 50 cps may be difficult unless the apparatus is designed to operate and measure frequencies down to zero. A means of determining whether the frequency being measured is higher or lower than the standard frequency spectrum point is also necessary. It is desirable to provide a separation between the measured frequency and the spectrum point for the purpose of measuring Frequency Stability and Frequency Drift Rate. For more accurate readout the frequency to be measured should be multiplied to a higher frequency.

3.8.2 Method of Measurement

The Discriminator/Analog Recorder Method is standard. The frequency to be measured is mixed with a standard frequency to obtain an output frequency (usually in the audio range) which can be measured with suitable accuracy and added to (or subtracted from) the standard frequency to obtain the frequency measurement. The frequency is monitored by some means such as an analog recorder during the period of time of interest.

The maximum frequency change due to a specified change in environmental or operating conditions is the measure of Frequency Stability. The frequency change is usually expressed as cycles per second, percent of initial frequency, or parts in a stated power of 10 (e.g. x parts in 10^n parts). The change in average frequency during the specified time interval is the Frequency Drift Rate. The maximum Frequency Drift Rate is obtained by estimating the maximum slope which occurs on the frequency versus time record during the time interval of interest.

NOTE: It is recognized that the frequency to be measured will contain some variation in frequency either random or periodic which may be classed as noise. The time constant or period of integration of the frequency measuring apparatus determines a cutoff frequency above which these components are integrated and below which they are displayed or recorded by the measuring apparatus.

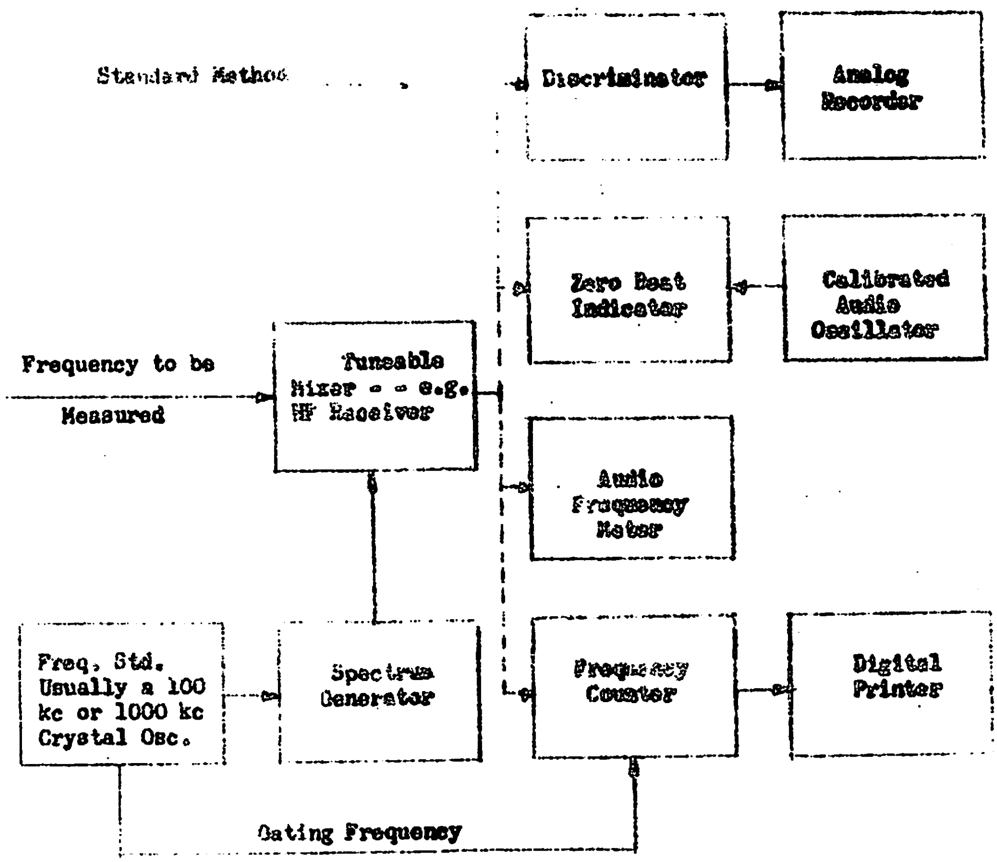


Figure 3. Block Diagram of Frequency Measuring Apparatus