torts or "squares off" a sine wave input. Harmonics are exact multiples of the basic or fundamental frequency. Thus, a nonlinear amplifier rich in second harmonic distortion produces an output which contains substantial energy at precisely twice the input or fundamental frequency. Type of harmonic generators include nonlinear amplifiers, diodes, saturable reactors, flip-flops, and almost any circuit in which the output is not a replica of the input. Filters must be employed following a harmonic generator in order to select the desired harmonic and to reject the undesired frequencies. Careful alignment of these filter-amplifier circuits is needed to make sure that the proper harmonic is selected and that all others are adequately suppressed.

There are classes of circuits that behave as frequency dividers. Each stage of a binary counter is a "divide by two" circuit; a "nixie" tube provides "divide by ten" capability; and other circuits such as single-shot multivibrators provide any desired countdown capability.

By mixing combinations of various frequency multipliers and dividers, practically any output frequency can be generated from one master crystal oscillator. The discussion of Principles of Single-Sideband Reception under Subsection 1-8, Receivers contains text and illustrations of a frequency synthesizer system capable of tuning to any of a wide range of frequencies in 1-kHz increments. By dividing the 1 kHz increments in a 10:1 divider and adding appropriate filters and mixers, frequency increments of 0.1 kHz are possible.

Another form of frequency generator having high stability and accuracy is one which resembles a free-running variable frequency oscillator but which in fact is stabilized by being phaselocked with a high-stability frequency standard. This type of oscillator is usually called a stabilized local oscillator (STALO) or stabilized master oscillator (SMO). In operation, a sample of the oscillator output is compared with marker frequencies developed from the output of a frequency standard. The comparison is made in a comparator or phase detector circuit which is a frequency deviation detector similar to an FM discriminator. The comparator develops, when phase lock is achieved, a DC error signal proportional to the amplitude and direction of frequency error of the STALO (SMO). This DC error signal is then applied to a feedback network to correct the STALO (SMO) error. A panel meter enables the operator to read the value of the error signal, and more important, to ascertain that the STALO (SMO) is phase-locked with the reference oscillator. This type of frequency control can produce the desired output frequency directly without generating a multitude of harmonic and mixer products which would have to be suppressed. This reduces the need for extensive and complicated filters.

Trouble points to look for in frequency synthesizers and stabilized oscillators include:

1. Trouble Point
   Small frequency errors (less than 1 kHz
   Cause
   Aging of reference crystal.
   Failure of temperature control in control in crystal overn.
   Failure of corrective feedback circuit.
2. Trouble Point
   Large frequency errors (increments of 1 kHz, 10 kHz, etc.)
   Cause
   Improper alignment of selective filter-amplifiers.
   Improper count-down in divider circuits.
3. Trouble Point
   Difficulty in achieving phase lock.
   Cause
   Insufficient harmonic amplitude into comparator.
4. Trouble Point
   Spurious emission at 1 kHz, 10 kHz, etc. increments from desired frequency.
   Cause
   Improper alignment of selective filter-amplifiers.

g. AN/URQ-9 AND AN/URQ-10 FREQUENCY STANDARDS

The Frequency Standard AN/URQ-9, and its transistorized counterpart-the AN/URQ-10, are reference standards intended to provide accurate frequency references against which the frequency of various frequency generating elements may be compared, or for which the reference signals may be substituted. Included in the category of frequency generating elements are; local oscillators of transmitters and receivers, input drive signals for frequency counters or synthesized signal generators, and reference inputs to electronic clocks and related equipment.

It has been determined by personal interview and written survey with fleet personnel that the use of the frequency standard is not well understood. It has also been ascertained that a high percentage of units now installed in ships' communications spaces are not being properly maintained.

As indicated by the name reference frequency standard, the AN/URQ-9 and AN/URQ-10 do not measure frequency. They are highly stable and accurate references against which other signal sources may be compared. The actual comparison may be performed by a technician using a frequency deviation meter and possibly an amplifier for one or both of the signals being compared. The comparison may also be performed automatically by a comparison circuit built into the equipment being serviced. This does not mean that the necessary adjustment is accomplished automatically. It merely means that the technician will not need to carry test equipment to the user (primary) equipment site to determine that an "off-frequency" condition exists. Further discussion of automatic, semi-automatic and manual frequency measurement techniques is beyond the scope of this article. The point to be remembered is that the frequency standard is a reference, not a meter or test instrument.

Since many equipments contain their own "frequency standards," you may ask why we have the AN/URQ-9 and AN/URQ-10. The answer is simple. In order to calibrate the less accurate standards (approximately 1/10th as accurate) built into many equipments, the AN/URQ-9 and AN/URQ-10 frequency standards are calibrated in Navy calibration laboratories, then delivered "hot" to ships and shore installations where they must each be connected to a reliable power source to ensure that they retain the stability which has required 2 months or more to establish. Note that the "hot" condition is maintained by standby battery operation. This is limited to 2

hours for the AN/URQ-9, and 8 hours for the AN/URQ-10. Where the standard is used to drive precision timing devices, counters, synthesizers and such, it is obvious that an accurate and stable "house standard" or ship's standard is required. The ship's standard is the AN/URQ-9 or 10.

In order for the standard to continue to serve its intended function, it will be necessary to return it periodically to a laboratory for calibration. This should be done at least every 6 months. As is the case with all crystal oscillators, those employed in the frequency standards are subject to drift. Therefore, the accuracy of the unit will eventually degrade so that recalibration is necessary.

Drift is due to aging of the crystal which is the heart of the oscillator. As a rule, the older the crystal-the more stable it will be. This rule holds true only if the crystal is undisturbed. It can be disturbed by shock, vibration, inclination, temperature changes, effects of moisture, voltage variations and other changes in environment. It is within this framework that we speak of stability in terms of 1 part in 10^9 per day, or 1 part in 10^8 per 60 days. We mean that if the unit is kept operating so that the crystal is not disturbed, the output frequency will not vary from the assigned value by more than one ten-millionth of one percent of the assigned value within any 24 hour period, and not more than one millionth of one percent of the assigned value within any 60 day period. For a frequency of 5 MHz, this translates to a maximum deviation of 0.005 Hz within a 24 hour period and 0.05 Hz in 60 days.

It is necessary to maintain the battery pack in both the AN/URQ-9 and 10 to ensure that input power is maintained and that the output signal levels are matched to the user equipment input tolerances. To facilitate these tasks, Table 1-2 presents a brief summary of characteristics for both frequency standards.

TABLE 1-2. CHARACTERISTICS OF FREQUENCY STANDARDS AND ASSOCIATED DISTRIBUTION AMPLIFIER

Characteristics	AN/URQ-9	AN/URQ-10	AM-2123/U
Height (inches)	11	7-13/16	5-7/32
Width (inches)	21 (incl. case)	5-1/2	19
Depth (inches)	13	15-5/16	8-1/2
Volume (cubic feet)	1.78	0.38	0.33 (max.)
Weight (pounds)	70.8	22	16
Normal Mounting	19-inch rack	3 abreast in 19-inch rack	19-inch rack
Input Voltage	115V(±10% at 60 Hz (±3Hz)	115Vrms at 50 to 400 Hz	115Vrms at 50 to 400 Hz
Input power	56 Watts nominal; 240 max	15 Watts nominal	26 Watts nominal
Operating Temperature Range	0° to 50°C	0° to 50°C	0° to 50°C
Output Frequencies	0.1, 1.0 and 5.0 MHz	0.1, 1.0 and 5.0 MHz	0.1, 1.0 and 5.0 MHz
Output levels:			
50-ohm load	1 volt (min)	1 volt (min)	4 to 5 volts rms based on input of 0.5 to 5.0 volts rms
1-megohm load	2 volts (min)	2 volts (min)	
Continuous operation time on battery (after loss of primary power)	2 hours	8 hours	batteries not supplied with unit
Output spurious levels (50-ohm load)	0.1 mV (max)	0.1 mV (max)	at least 80 dB down
Output harmonic levels (50-ohm load)	10.0 mV (max)	10.0 mV (max)	at least 60 dB down
Frequency Stability (max drift)	1 part in 10^9 per day and not more than 1 part in 10^8 in 60 days	1 part in 10^9 per day and not more than 1 part in 10^8 in 60 days	N/A

When user equipments are located remotely from the frequency standard, it will be necessary to employ Radio Frequency Amplifier AM-2123(V)/U to sustain signal strength of the reference signal enroute to the user equipment. The amplifier will boost the output of the frequency standard from 1 volt to a maximum of 5 volts. In a low-loss, coax, 50-ohm distribution system, this will adequately serve distances of more than 1,000 feet. Input tolerances for some user equipments may dictate the need for attenuators to prevent overdriving the reference input circuits. Consult the technical manuals for user equipments prior to use.

For additional information on AN/URQ-9, AN/URQ-10, and AM-2123(V)/U, refer to the technical manuals indicated below. If further information is then required, consult your nearest calibration facility or NAVSEC 6181D. (EIB 712)

Equipment Model	Publication Number
AN/URQ-9	NAVSHIPS 0967-007-8011 (Change 2) (formerly NAVSHIPS 93805(A)) dated 3 April 1967
AN/URQ-10	NAVSHIPS 0967-053-7010 (Change 1) dated 21 Oct 1966
AN/URQ-10A	NAVSHIPS 0967-170-3010 dated 15 Sept 1966
AM-2123(V)/U	NAVSHIPS 0967-136-1010
AM-2123A(V)/U	NAVSHIPS 0967-225-9010 dated 23 Jan 1967

h. FREQUENCY STANDARD SYSTEMS

Frequency Standards AN/URQ-9, 10 provided to ships are intended for installed system use and not as a "test equipment." The AN/URQ-9 and 10 provide a much higher order of frequency accuracy than that provided by frequency standards included within most new equipments. The frequency standards do not measure frequency, they provide highly stable and accurate reference signals against which other signal sources such as the Translator-Synthesizer unit of Radio Receiver R-1051/URR may be compared. When an AN/URQ-9 or 10 is provided to a ship, it should be permanently installed as a central system. (See Figure 1-8)

Equipments such as the AN/WRC-1, AN/URC-35, AN/WRR-2, AN/URT-23, AN/URT-24, and R-1051/URR are examples of communication equipments having the capability of using either an internal or external frequency standard. The internal frequency standard unit of these equipments is intended for use in installations not having an AN/URQ-9 or 10 installed or for backup use in the event of any failure of the installed external frequency standard system. Where there is no installed central reference system, the equipment's internal frequency standard must be calibrated periodically against an external frequency source, such as a portable AN/URQ-10, to maintain their rated accuracy. Frequency standard "age" with time, causing drift and a reduction in frequency accuracy.

It is essential that equipments such as the R-1051/URR, AN/WRR-2, and AN/URT-23, when used with multiplex equipment AN/UCC-1, use an installed ships frequency standard system in preference to the equipment's internal standard for maximum circuit reliability.

The basic frequency standard system, as shown in Figure 1-8, utilizes RF Amplifier AM-2123/U for isolation and distribution of 0.1, 1, and 5 MHz frequencies generated by the AN/URQ-9, 10. This RF amplifier must be used when more than one transmitter or receiver is to be connected to the frequency standard. The AM-2123/U accepts the three input frequencies from the frequency standard and provides 12 isolated outputs in any combination of the three input frequencies.

When installing the AM-2123/U, an appropriate amplifier plug-in module must be installed for each individual equipment for which it is to be used; i.e. 5 MHz modules for the AN/WRC-1, AN/URC-35, AN/URT-23, AN/URT-24, and R-1051/URR; 1 MHz module for the AN/WRR-2. If additional modules are required to change the frequency complement of the amplifier, they may be ordered on an exchange basis from ESO. The FSN for the amplifier modules are as follows:

AM-2123/U (0.1 MHz amplifier)	IN5820-940-3259
AM-2123/U (1 MHz amplifier)	IN5820-940-3260
*AM-2123/U (5 MHz amplifier)	IN5820-940-3262

*The AN/WRC-1 equipment requires two inputs, one for the transmitter.

Most communication equipments are designed to accept a reference input at a maximum level of 3 volts rms. The output of the AM-2123/U may be as high as 5 volts rms; however, the level of the signal at the user end of the reference feeder cable may be considerably lower than the 5-volt level at the source end. Attenuation over the cable run depends on the length of the run and the frequency. The voltage should be measured at the time of installation. If it is greater than 3 volts, an attenuator should be inserted at the user end connector. A suitable attenuator for this purpose is NARDA Model 755-3 (FSN 9N-5905-862-3291), which provides 3dB attenuation.

NAVSEC drawing RE-F2687915 provides ship Frequency Standard System installation information. The appropriate communication equipment technical manual should be consulted regarding use of the external standard as a comparison reference in the calibration of the equipment's internal frequency standard.

NOTE

When calibrating an equipment's internal frequency standard, it is essential that the standard be energized for a continuous period (not less than two weeks preferred).

It is essential that the communication equipments be run continuously (operate or in "standby" condition) since the on-off cycling of the equipments' prime power will cause a degradation of the equipments' internal frequency standard unit. (EIB720)

1-4 UHF COMMUNICATION SYSTEMS

It has been demonstrated repeatedly that UHF can provide satisfactory communication over line-of-sight distances. However, all parts of the system