The Lenkurt® Demodulator

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MEASURING POWER AND FREQUENCY
At 6000 Mc

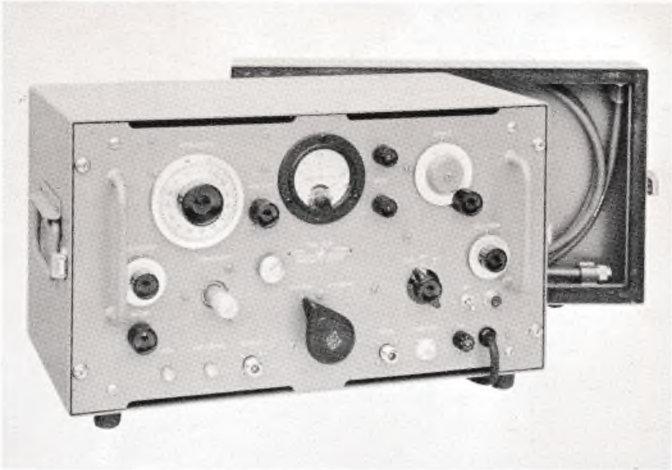
Because the wavelength is only about 2 inches, and because waveguide is used extensively in place of more conventional equipment components, the methods used for making measurements in the vicinity of 6000 Mc are considerably different from those used at lower frequencies. In carrier equipment, or in radio equipment operating at lower microwave frequencies, many measurements are made by connecting meter leads directly across points on the transmission path. This technique cannot be used with waveguide; instead, special apparatus must be employed to sample the energy passing through the waveguide.

Some of the special test instruments and measuring techniques used to measure power and frequency in waveguide circuits are discussed in this article.

Proper lineup and adjustment of microwave radio equipment requires that measurements of power and frequency be made at various points in the r-f circuits. When these measurements are made where waveguide is the transmission medium, some means must be provided to gain access to the energy passing through the circuit. Because the circumstances are not the same as at lower frequencies, microwave measurements require different types of test equipment. The individual items of test equipment utilize components which are considerably different in appearance from those used with carrier equipment. In this article, emphasis is placed on components of microwave test equipment. Among the individual components described are resonant cavities, crystal diodes, directional couplers, and bolometers.

Commercially available microwave test sets include the various components needed to make power and frequency measurements on waveguide circuits. The frequency meter portion of these test sets is normally based on the use of a built-in resonant cavity; the power meter portion is based on the use of a temperature sensitive device called a "bolometer." Test sets also normally supply a source of microwave test signal. A typical microwave test set is shown in Figure 1. Where test sets are not available, measurements can be

Fig. 1. A typical test set for measuring power and frequency on waveguide circuits.



made by setting up various arrangements of test equipment components.

Resonant Cavities

A typical resonant cavity of the type commonly used as a cavity wavemeter (to measure frequency) is shown in Figure 2. Is it essentially a cylindrical metal enclosure, one end of which can be moved by means of a micrometer screw adjustment. The micrometer scale normally reads in units of length. The reading is converted to frequency by reference to a calibration curve. Theoretically, a cavity wavemeter can be calibrated from its dimensions. In practice, however, the calibration is done by comparison with a standard meter. Although cavity dimensions can vary slightly with temperature, most wavemeters, once calibrated, will maintain sufficient accuracy under normal conditions to meet most field requirements. For critical applications, where extreme temperature variations are likely to be encountered, resonant cavities are made of materials (such as invar) with extremely low temperature coefficients. A crystal detector, an indicating meter, and a cavity wavemeter provide a means of measuring frequency equivalent to that provided in a standard microwave test set.

How a Resonant Cavity Works

A shorted quarter-wave transmission line is actually a resonant circuit. If two such resonant lines are connected in parallel, the resonant frequency is unchanged. In fact, connecting any number of shorted quarter-wave lines in parallel from the same two points

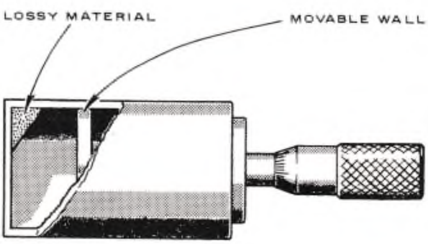


Fig. 2. A typical resonant cavity.

will not affect the resonant frequency. As more and more lines are connected in parallel, eventually a closed metal container will be formed—and this container is the simplest example of a resonant cavity. An example of this is shown in Figure 3.

A practical resonant cavity consists of a closed waveguide section with one dimension equal to an integral number of half-wavelengths of the resonant frequency. It can be excited in the same manner as any waveguide—i.e., by induction through a slot or from a probe inserted at the proper location.

Cavity Wavemeters

Resonant cavities used for frequency measurements are called *cavity wavemeters.* They are adjustable, and are calibrated to measure all frequencies within a certain band.

A special application of a cavity wavemeter, permanently adjusted to resonate at one frequency only, is called a *reference cavity.* In place of a micrometer dial, a reference cavity usually has only a simple screw adjustment which normally is set and locked once the cavity is tuned.

Three different types of cavity wavemeters are available—transmission, reaction, and absorption. They differ in the manner in which the resonant cavity is coupled to the waveguide. An example of each type is shown in Figure 4.

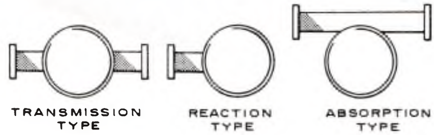


Fig. 4. Three types of cavity wavemeters.

Transmission- and absorption-type wavemeters are used with the signal source at one side of the cavity and a detector at the other. Resonance is determined by means of a microammeter connected to the detector. With the transmission type, the meter will peak at resonance, while with the absorption type, the meter will dip. Absorption-type wavemeters transmit maximum power at frequencies far from resonance. They can, therefore, be inserted directly into a transmission line and detuned when not in use. A transmission-type wavemeter, however, transmits maximum power only at resonance; it must be used with a directional coupler or some other arrangement that permits it to be removed from the transmission system when it is not in use. If left in the line, a transmission-type wavemeter would cause the r-f level to fluctuate with frequency changes.

Reaction-type wavemeters indicate resonance by a change in magnitude and phase of the reflection coefficient. The resonant frequency is best determined by instruments capable of detecting a

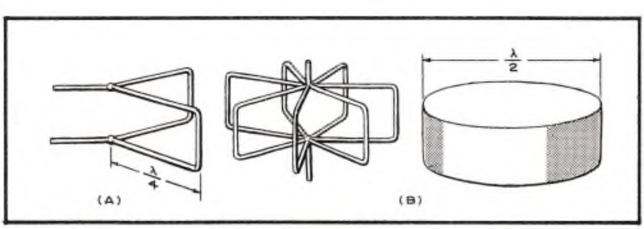


Fig. 3. Development of a Resonant Cavity.

change in phase. In addition to frequency measurements, the reaction-type cavity is often used as a reference cavity. The reference cavity in the transmitter afc circuit of the Type 74A Microtel system is essentially a reaction-type wavemeter. Because of its critical application, this cavity is made of invar.

Crystal Diodes

A crystal diode provides a convenient means of converting r-f energy in a waveguide into a measurable quantity. The crystal diode is connected to a probe (which may actually be a part of the crystal element) or loop which, in turn, is coupled to the electric or magnetic field in a waveguide. The sample of r-f energy intercepted by the probe is rectified by the crystal and can be measured with a microammeter.

Where the r-f energy in a waveguide is amplitude-modulated, a crystal diode can function as an AM detector. This characteristic is utilized in some types of measurements by deliberately inserting an AM signal into the transmission system. This signal can then be detected, amplified, and displayed on an oscilloscope to determine whether the desired characteristic has been obtained.

Bolometers

R-f power passing through a waveguide is normally measured by means of a *bolometer.* This device consists of a temperature-sensitive *bolometer element* in a *bolometer mount* which provides a means of connection to the waveguide. The bolometer element forms one leg of a bridge circuit. Since resistance of the bolometer will vary in accordance with the amount of power absorbed, power measurements can be made by determining the degree of balance of the bridge circuit.

There are two general classes of bolometer elements: (1) *barretters,* which have positive temperature coefficients and, (2) *thermistors,* which have negative coefficients. Any short piece of fine wire is a simple barretter. Instrument fuses are often used for the purpose, although the normal type of commercially available barretter consists of a piece of extremely fine platinum wire enclosed in a suitable capsule. Thermistors are made of metallic oxide materials selected because their resistance decreases as the temperature increases.

A bolometer can be mounted to absorb power directly from a waveguide, or from a probe which samples the r-f energy in the waveguide, coupling a definite portion of it to the bolometer.

Mounts

A crystal diode mount or bolometer mount provides means for coupling the element to the r-f energy, and for matching the impedance of the element to that of the transmission system. The mounts may be shorted sections of waveguide, connected to the transmission system by means of directional couplers, or they may be coaxial, and connected to the waveguide by means of a coaxial jack and probe.

A waveguide mount is essentially a short section of waveguide closed (shorted) at one end. Waveguide mounts can either be fixed to operate over a specific band of frequencies, or they may be tuned. Tunable mounts have tuning stubs which may be adjusted to exactly match the impedance of the element to that of the guide.

The bolometer element is held inside of the waveguide by the waveguide mount. Crystal diodes are mounted outside the guide, with the probe projecting into the waveguide.

Coaxial crystal diode and Bolometer mounts are also available, and are often used where a coaxial jack and probe are built into the main waveguide. Coaxial connectors are provided at each end of the mount so that, when connected to suitable instruments, the r-f power can be measured.

Directional Couplers

A directional coupler is a device used to sample the r-f energy traveling in one direction in a transmission system, with a minimum of interference from the r-f energy traveling in the other direction. There are two general classifications applied to waveguide directional couplers, the *multi-hole coupler* and the *cross-guide coupler*.

Multi-hole couplers are most often used for precision laboratory measurements and are sometimes called precision directional couplers. A typical multi-hole coupler is shown in Figure 5. It consists essentially of two parallel waveguide sections that have a common wall throughout most of their length. The main section is flanged at both ends and in use is a part of the r-f transmission system. The secondary section is used for measurement purposes. For example, a bolometer or crystal diode mount may be connected to the flanged end. The secondary section has a load termination at the blind end.

Wave energy traveling through the main section is induced into the secondary section through holes in the common waveguide wall. The holes are arranged in such a manner that wave energy in the main waveguide induces a wave traveling in the same direction in the secondary waveguide. An oppo-

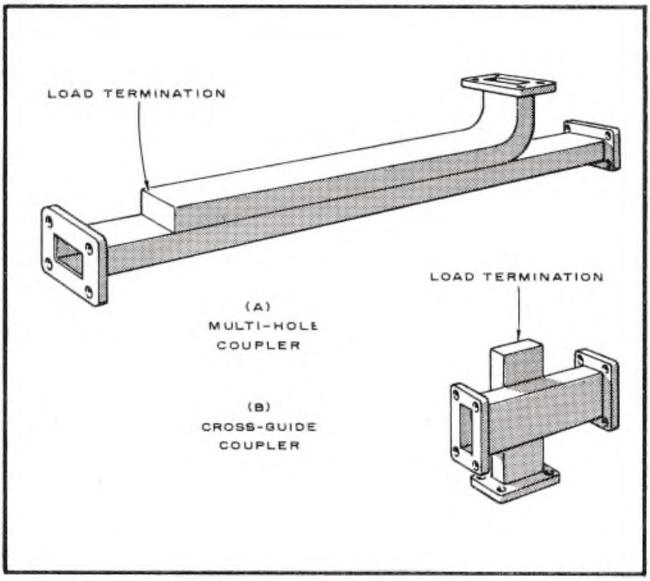


Fig. 5. Directional Couplers: At top, a typical example of a multi-hole coupler; at bottom, a typical example of a cross-guide coupler.

sitely directed wave is also induced in the secondary, but the energy of this wave is relatively small compared with the energy in the main waveguide.

There are two waves in the main guide. The wave carrying energy toward the load is called the preferred wave. Measurements in the secondary waveguide are normally related to the preferred wave. The preferred wave couples energy to the secondary flange, and the oppositely directed wave couples to the secondary load termination.

The power ratio between the preferred wave energy in the main guide and its component at the secondary flange is called the *coupling factor,* and is expressed in decibels.

A small amount of the power appearing at the secondary flange may be due to the energy of the oppositely-directed primary wave. The power ratio between the desired wave at the secondary flange and this undesired wave is called the *directivity,* assuming primary waves of equal magnitude. The directivity is expressed in decibels.

The definitions of coupling and directivity apply also to the cross-guide coupler, which is commonly used where there are space restrictions and where laboratory accuracy is not required. An example of a cross-guide directional coupler is shown in Figure 5. Although the axis of the waveguide sections which comprise the cross-guide coupler are at right angles, the operation is similar to that of the multi-hole coupler. Wave energy from the main guide is coupled into the secondary, and the direction of wave energy depends upon the direction of energy flow in the main guide.

Cross-guide couplers are available with flanges at both ends as well as with a flange at one end and a load termination at the other end. An advantage of a cross-guide coupler with a secondary load termination is that reflections from the termination to the secondary flange are minimized.

The secondary flanges should be covered by shorting plates or by waveguide terminations when they are not being used. Normally, shorting plates will be sufficient to prevent radiation which would cause deterioration in service. However, in some applications, matched terminations are used to provide optimum operation.

Typical values of coupling are 3 to 20 decibels for multi-hole, and 20 to 30 decibels for cross-guide couplers. Typical directivity for multi-hole couplers is 40 decibels or better, and for cross-guide couplers, 20 decibels or better.

Test Set

The components necessary for frequency and power measurements are incorporated in commercial microwave test sets. In addition to a cavity wavemeter, crystal detector, bolometer and power meter, a microwave signal generator is included in the test set, which greatly increases its versatility. The signal generator is similar to signal generators used at lower frequencies in that the oscillator may be tuned over a specific range, and the output power is adjustable. The signal generator is used where test and adjustments in a microwave system require a test signal of known value. Among the measurements which can be made are transmitter deviation, path loss and receiver sensitivity.

When power or frequency measurements are to be made, the waveguide energy is sampled by means of a probe or directional coupler, and is connected to the test set through a coaxial lead. The power meter includes a self balancing bridge circuit with the bolometer in one leg of the bridge. R-f power is read directly on the indicating meter. Frequency is measured in terms of the reading on the micrometer dial. To simplify field measurements, probes and coaxial jacks are often built into key spots in the waveguide system of microwave terminals and repeaters.

Frequency Measurement

The basic equipment for frequency measurements in the field include a cavity wavemeter, a crystal detector and mount, a potentiometer and a microammeter. These may be part of a microwave test set, or they may be used separately.

The sample of waveguide energy is applied to the cavity wavemeter. The crystal diode rectifies the energy so that an indication may be obtained on the microammeter. Rather than applying the rectified energy to the microammeter directly, a potentiometer is used to divide the voltage. This helps to prevent damage to this sensitive instrument. The cavity wavemeter is then adjusted to obtain the desired meter indication, either a peak or dip depending upon the type of cavity wavemeter used.

An oscilloscope can be used to facilitate the measurement. When connected to the output of the detector, the pattern on the oscilloscope (a straight line at frequencies off resonance) will jump as the resonant frequency is passed. This permits a rough frequency measurement to be done quite easily and rapidly. Once the rough micrometer setting has been made, the oscilloscope is replaced by the microammeter for the final measurement.

Power Measurement

For power measurement, a bolometer element and mount, and a microwave power meter are required. The power meter will include three legs of the bridge circuit, bridge power supply and the indicating meter. The bolometer element is the fourth leg of the bridge. R-f energy reaching the bolometer element changes its resistance and this tends to change the bridge balance. Self-balancing bridges are normally used with a power meter. The energy required to maintain the bridge balance is equal to the energy absorbed by the bolometer. The indicating instrument is direct reading and is calibrated in milliwatts or dbm.

Conclusion

While the components and measurement technique used in microwave measurements are somewhat different from those used at carrier frequencies, the quantities to be measured are not changed. In general, more precautions and a little more care must be exercised in making tests at microwave frequencies. However, they are not difficult to make, and only require an understanding of the measurement technique to be used and of the operation of the test equipment. Detailed descriptions of microwave test equipment and measurement techniques are included in the catalogs and instruction manuals of test equipment manufacturers.

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Equipment Engineering Considerations and Ordering Information is included in new Lenkurt publication Form 53A1-EE.

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