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Direct Reading UHF Power Measurements

AT HIGH frequencies as at low the power flowing in a system is a frequently-sought factor. In fact, at high frequencies power assumes extreme significance, for neither voltage nor current as such can be readily measured.

Figure 1 shows a direct-reading high-frequency power meter that measures the output power from signal generators, oscillators, and similar equipment. In effect, this power meter is an automatic version of the common bolometer substitution bridge; but, because its operation is automatic, measurements can be made quickly—and no dc source, low frequency ac source, galvanometer, external hand-balancing potentiometer, etc., are required. The —hp— 430A Power Meter reads directly in power from 0.1 milliwatt full scale to 10 milliwatts full scale in five ranges. In use, the instrument operates as easily and quickly as a vacuum-tube voltmeter.

The high-frequency power to be measured is absorbed in a bolometer element. Since such elements customarily have an impedance of 200 ohms and are operated with 50-ohm transmission systems, an intermediate device is required to transform the bolometer impedance down to the line impedance so that maximum power transfer can occur. Such a device is the tunable bolometer mount shown in Figure 2.

The frequency at which high-frequency power can be measured is determined only by the bolometer mount. Two models are available and both are broad-band. The Model 475A operates over a band from 300 to 1000 mc, and the Model 475B from 1000 to 4000 mc.

Figure 1. *—hp— Model 430A Microwave Power Meter.*

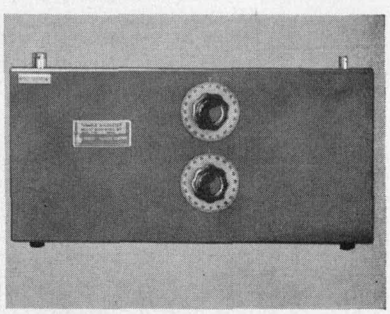

Figure 2. *—hp— Model 475B Tunable Bolometer Mount.*

MEASUREMENT SET-UP

High-frequency power can be measured with the simple set-up shown in Figure 3. The power to be measured is connected to the tunable mount, wherein the bolometer element is located. A second terminal on the mount connects the bolometer element to the power meter. The bias power necessary to raise the bolometer impedance to 200 ohms is

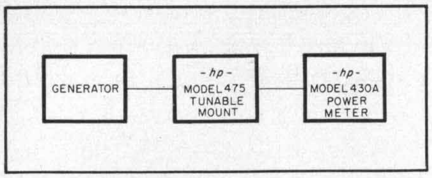

Figure 3. *Set-up For Measuring High Frequency Power.*

supplied automatically. When high-frequency power is applied, the two controls on the tunable mount are adjusted for a maximum reading on the power meter. The condition of maximum power transfer from the power source to the bolometer element is the condition of matched or conjugate impedances.

SELF-BALANCING CIRCUIT

The circuit of the –hp– 430A Power Meter includes a self-balancing bridge and an audio voltmeter to indicate the magnitude of the bridge amplifier output (Figure 4). The self-balancing bridge uses the external bolometer element, a non-linear resistor, as one of the bridge arms. A high-gain amplifier is connected across the bridge as a detector, and the output of the same amplifier is connected as the driving source for the bridge. Thus, there being sufficient gain, the circuit oscillates at an amplitude such that the bridge is balanced. Balance occurs when the bolometer element's resistance is 200 ohms. The oscillation frequency (10 kcs) is determined by the bridge constants.

When rf power is applied to the element, the amplitude of oscillation decreases the amount necessary to maintain the element's resistance constant at 200 ohms. This power decrease is equal to that power added by the rf source and can be read on the voltmeter which is calibrated in power units.

The sensitivity of the bridge is controlled by applying some dc power to the bolometer element independent of the audio power. Then, the power not supplied by the dc supply is automatically supplied in ac form by the self-balancing bridge. Changing the position of the range switch changes the amount of dc power applied. Vernier controls in the dc supply are provided to compensate for the effect of temperature variations on the bolometer element's resistance.

The voltmeter that follows the bridge amplifier consists of a two-stage amplifier driving a bridge rectifier. Overall negative feedback in the voltmeter minimizes tube replacement and line voltage effects. Sensitivity controls for the voltmeter are ganged with the sensitivity controls for the bridge. It will be noted that the voltage out of the bridge amplifier decreases when high-frequency power is applied to the bolometer element. This effect would ordinarily cause the meter reading to decrease instead of increase. Therefore, the metering circuit is arranged so that a constant dc current of full-scale magnitude is applied to the meter in the forward direction, while the rectifier output is applied in reverse direction. The meter action is thus made straightforward, reading zero when no high-frequency power is applied and increasing when it is applied.

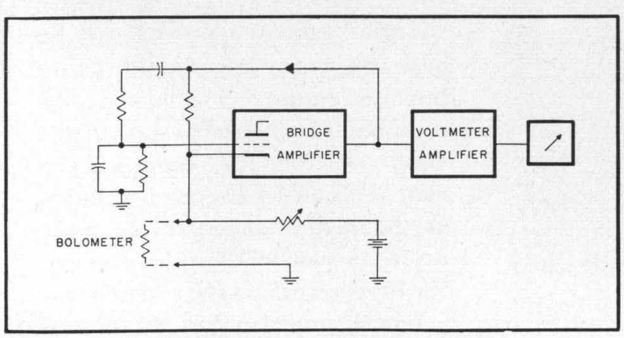

Figure 4. *Basic Circuit of Power Meter.*

The bridge itself is not sensitive to the frequency of the h-f power and will operate down to relatively low rf frequencies. However, the mounting arrangement for the bolometer element is very important, for it must be designed to couple h-f power into the element without reflection —preferably over a wide frequency range for maximum usefulness and simplicity of operation.

BROAD-BAND BOLOMETER MOUNT

A cross-sectional drawing (Figure 5) of the tunable mount shows it to be a double-stub tuner. This tuner matches a 200-ohm element to a nominal 50-ohm line, but can also be used as a transformer between lines having the same nominal impedance. Two broad-band mounts have been developed. The –hp– 475A is useable from 300 to 1000 mc and the –hp– 475B from 1000 to 4000 mc. However, the magnitude and phase of the source impedance have some effect on the useable frequency range as described later.

To permit the mounts to be used

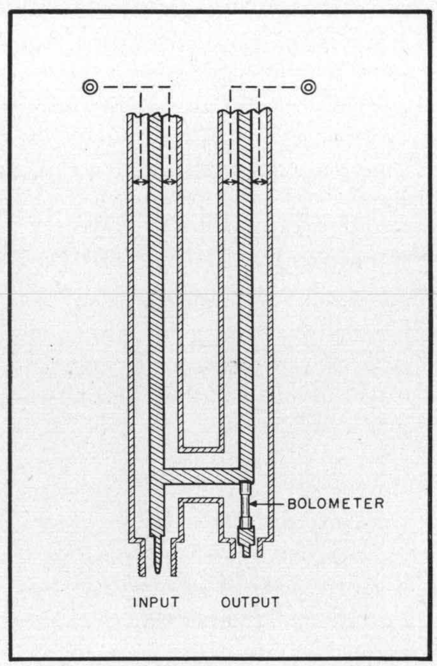

Figure 5. *Cross-sectional Drawing of Tunable Bolometer Mount.*

as double-stub transformers between two lines, a male type N connector is supplied with each mount. When using a mount as a transformer, the bolometer element is removed and the male type N connector attached to the output end of the mount.

Special attention in the design of the mounts has been given to the shorting contacts in the stubs to minimize losses at high susceptance settings. Accordingly, the contacts consist of a 1/16″ thick block of solid silver mounted on heat-treated beryllium copper fingers. The contact as a whole is finished in a lapping machine to obtain a fine, non-eccentric finish. The contacts are driven by a special wire cable and pulley arrangement that prevents backlash or binding.

PRINCIPLE OF OPERATION

A double-stub tuner is approximately equivalent to a single-stub tuner properly located on a transmission line. However, the double-stub tuner obviates the necessity for searching out the proper location for the stub. Triple-stub tuners can be used, but are often more difficult to tune, more expensive to construct, and do not offer any special advantages for this work.

A double-stub tuner can be thought of as a pi section (having adjustable-value legs) that is used for impedance-matching. From the standpoint of high-frequency techniques, the principle of the double-stub tuner can be readily visualized with the aid of an admittance diagram such as the Smith chart. A possible set of conditions in the tuner is shown in Figure 6, while the accompanying admittance diagram operations are shown in Figure 7.

At the point A in Figure 6, the admittance of the bolometer element, normalized to the line admittance, is $Y_{bol}/Y_{line} = \frac{1}{200} / \frac{1}{50}$ or 0.25.

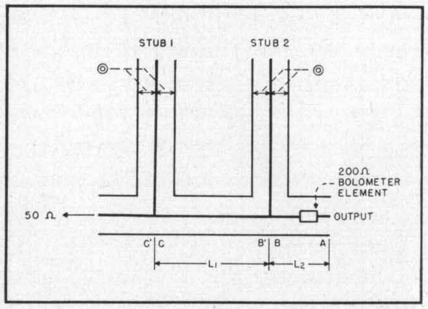

Figure 6. *Diagram of Tunable Bolometer Mount.*

This value is shown at point A in the diagram of Figure 7 and is the starting-point for analyzing the tuner's operation.

The normalized admittance value of 0.25 at point A, when viewed from point B in Figure 6, is transformed by the length of line L2. L2 is designed to be less than one-quarter wavelength at all operating frequencies. The transforming action of L2 is shown in Figure 7 as transforming the normalized admittance of 0.25 at A to that at point B.

The shorted stubs introduce into the line shunt susceptances that are adjustable in magnitude. When operating a tuner, it is necessary to adjust these stubs so that the combined effects of the susceptance of stub 2, the transforming action of line L1, and the susceptance of stub 1 will bring the normalized admittance from point B in Figure 7 to the center of the diagram. In practice this is easily and quickly accomplished experimentally. Electrically, the susceptance of stub 2 changes the admittance at point B in Figure 6 from B to B′ on the diagram. Line L1, which by design is less than a half wavelength at all frequencies, transforms the admittance from B′ on the diagram to C.

It can be seen that the action of the tuner thus far has been to introduce susceptance and line transformation in a combination such that the conductive component at C is equal to the transmission line conductance but that a susceptive component exists. Stub 1 then tunes out the susceptive component by introducing an equal susceptance of opposite sign. The combination of tuner and bolometer element now appear to the transmission line as a matched conductive load. Had the transmission line had a susceptive component, the combination of tuner and element would appear as the conjugate of the transmission line admittance.

The operation of the tuner can be analyzed for other conditions in a similar manner.

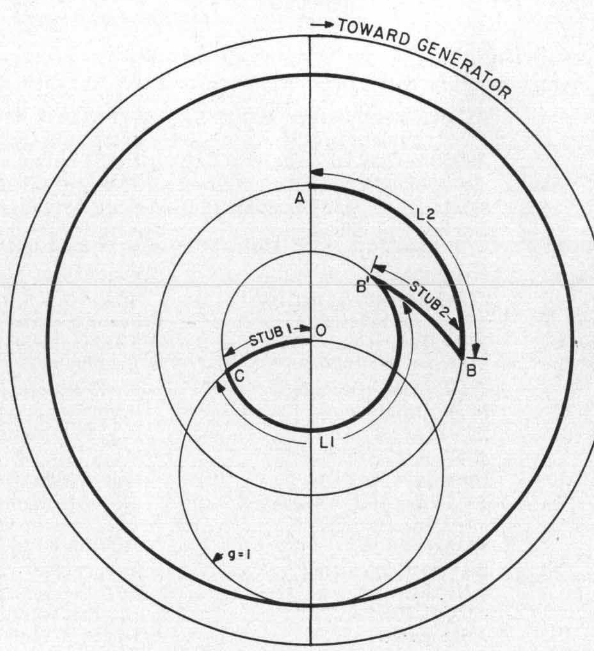

Figure 7. *Admittance Diagram Operations for Conditions Shown in Fig. 6.*

FREQUENCY CONSIDERATIONS

The high frequency limit for the double-stub tuner occurs as the spacing between the stubs approaches a half-wavelength. This condition causes the line between the stubs to fail to act as a line transformer and results in a condition where no combination of stub settings will transform the bolometer element's admittance to the line admittance. At a half wavelength, the stubs are effectively in parallel.

The lower frequency limit occurs because the electrical length of the stubs grows shorter as frequency decreases. This means that the range of susceptance available in the stubs is limited. Thus, no setting of stubs can be found to match a source that differs appreciably from 50 ohms resistive. At certain low frequencies in the 300-1000 mc model (475A), source impedances that differ from 50 ohms by a factor exceeding 1.8 may not be useable with the tuner because of this effect. Figure 8 illustrates the frequencies and source impedances concerned.

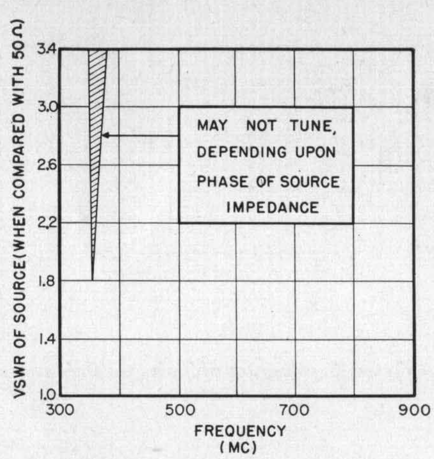

Figure 8. *Low Frequency Limits for —hp— 475A Tunable Bolometer Mount.*

—B. P. Hand

SPECIFICATIONS FOR MODEL 430A MICROWAVE POWER METER

POWER RANGE: Full scale readings of 0.1, 0.3, 1, 3, and 10 milliwatts. Also calibrated in db to give continuous reading from −20 dbm to +10 dbm (0 dbm = 1 milliwatt). Power range can be extended with attenuators or directional couplers.

EXTERNAL BOLOMETER: Bolometer mount determines frequency range. Bolometer element must be 200 ohms at power level of approximately 15.3 milliwatts and have positive temperature coefficient. Suitable bolometer elements are 1/100 ampere instrument fuse and Sperry 821 barretter. (Bolometer element and mount not supplied.)

ACCURACY: Within 5% of full scale reading.

SIZE: 12″ wide, 9″ deep, 9″ high.

WEIGHT: 17 lbs.; shipping weight, 32 lbs.

POWER: Operates from nominal 115-volt, 50/60 cycle supply. Requires 60 watts.

CABLES SUPPLIED: 7′6″ power cable permanently attached to instrument; 3′ input cable consisting of shielded cable with one end free; other end has type BNC plug (UG-88/U) to mate with UG-185/U input jack on 430A panel.

PRICE: $250 f.o.b. Palo Alto, Calif.

MODEL 475A TUNABLE BOLOMETER MOUNT

FREQUENCY: Approx. 300 to 1000 mc. Varies with VSWR, phase of source, and value of bolometer element.

POWER RANGE: 0.1 milliwatt to 10 milliwatts (with —hp— Model 430A Power meter).

BOLOMETER ELEMENT: Selected 1/100 ampere instrument fuse supplied; Sperry 821 barretter can be used; an adapter set is supplied to permit use of barretter.

CONNECTORS: Type N female (UG-23/U) for incoming power; BNC type UG-89/U for bolometer element connection. Spare male type N connector supplied so that mount can be used as a conventional double-stub transformer.

SIZE: 10¼″ deep, 36″ wide, 3¾″ high.

WEIGHT: 15 lbs.; shipping weight 50 lbs.

PRICE: $200 f.o.b. Palo Alto, Calif.

MODEL 475B TUNABLE BOLOMETER MOUNT

FREQUENCY: Approx. 1000 to 4000 mc. Varies with VSWR and phase of source and value of bolometer element.

SIZE: 7½″ deep, 18″ wide, 3¾″ high.

WEIGHT: 8 lbs.; shipping weight 22 lbs.

PRICE: $200 f.o.b. Palo Alto, Calif.

Other specifications same as Model 475A above.

Data subject to change without notice.

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