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Power Measurements from 10 to 12,400 Megacycles

AT HIGH frequencies, instruments for measuring power have wide usefulness. This usefulness is based on the fact that measurements of h-f power can be made with good accuracy and have more significance than measurements of h-f voltage or current. To provide more complete coverage in the -hp- line of power-measuring equipment, a number of new devices have been added to the basic group of power-measuring instruments described in the May, 1950 issue[1]. The complete line now includes power-measuring equipment for use over the range from 10 to 12,400 mc.

Power measurements have many practical h-f applications. For example, in the laboratory it is often necessary to standardize the output power from signal generators. By use of the power meter and suitable bolometer mounts, such standardization becomes a simple and straightforward process. A typical set-up for signal generator standardization is shown in Figure 1. The signal generator is connected through a length of coaxial cable to a bolometer mount where the output power from the generator is absorbed. With present-day signal generators that have a source impedance reasonably well matched to the line impedance, this measurement can be made on the basis of maximum available power with an untuned bolometer mount. If the source impedance is unknown and a measurement of maximum available power is desired, a stub tuner can be used to transform the load impedance to the conjugate of the generator impedance. If the measurement is desired in terms of a "flat" load, a slotted section can be inserted into the transmission line and the load tuned so that no reflection occurs.

The basic range of power measurements with the -hp- Model 430 power meter is from less than 50 microwatts to 10 milliwatts, a very useful range for most signal generator applications. However, this range can be easily extended upward for higher power measurements. For example, lossy type coaxial cables can be used as attenuators at frequencies up to the UHF region, where the losses of standard cables may be high enough for a given application.

In waveguide systems, powers in the range from 1 to 2 watts can be attenuated to the range of the

Figure 1. *Set-up for standardizing signal generator output power using new -hp- Model 476A broad-band bolometer mount and new Model 430B power meter.*

[1]B. P. Hand, *Direct Reading UHF Power Measurements*, Hewlett-Packard Journal, Vol. 1, No. 9, May, 1950.

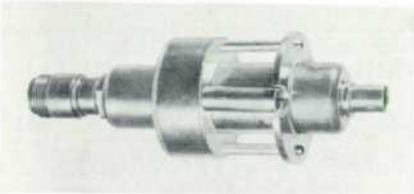

Figure 2. *New -hp- Model 476A 10-1000 mc untuned bolometer mount.*

power meter by the use of fixed precision attenuators. A group of such attenuators has been developed as part of the new equipments added to the -hp- power-measuring line. The frequency range and insertion loss of these attenuators, Model 370, is shown in the accompanying table.

Powers above the 1 to 2 watt range can be measured by the power meter in combination with directional couplers. In this case the waveguide is terminated with a high-power termination such as the -hp- Model 912A which is suitable for powers up to 250 watts in the larger size waveguide and 100 watts in the smaller size. At power levels higher than this, water loads can be used for terminations and a combination of directional couplers with attenuators used to sample and reduce the power to the range of the power meter.

For measurements of c-w power, the power meter can be used with a platinum-wire type bolometer element, but for pulsed power applications the thermal time constant of this device is such as to prevent direct-reading measurements. In pulse applications, therefore, it is customary to use the bead thermistor which has a time constant suitable for most pulse rates.

The use of bolometer elements in h-f power measurements is based on the assumed ability of such elements to absorb power equally well at both high and low frequencies. The power absorbed by the elements is converted to heat, which changes the resistance of the element.

The magnitude of the absorbed h-f power can be determined by measuring the change in the resistance caused by this heating effect. H-f power can also be measured with bridge substitution techniques, several methods being in use. In general, the bolometer element is connected into a bridge circuit and the h-f power to be measured is applied to the bolometer element. Enough d-c power is then applied to the element to bring its resistance to the value that balances the bridge. Next, the h-f power is removed and low-frequency power is substituted in its place and adjusted in magnitude until the bridge is again balanced. The low-frequency power is then equal to the h-f power that was applied in the beginning. Since the operating resistance of the bolometer element is known, the applied low-frequency power can be measured with a voltmeter or ammeter calibrated in power units.

All of these hand-balancing methods are tedious and somewhat difficult. As a result, there has come into wide use a somewhat different method, the self-balancing type of bridge. In this circuit the measurements are made automatically and the tedious hand-substitution of power is not necessary. The action of the circuit is such that the bridge is always automatically balanced, a feature that offers several advantages in practical measurements. For example, no reliance is placed on the characteristics of the bolometer element so that normal variations in its characteristics do not introduce errors into the measurements. Also, when using thermistors with long thermal time constants, the measurements are not slowed by the necessity for waiting for stabilization of the thermistor resistance when h-f power is applied or changed.

The -hp- Model 430A Power Meter, introduced in 1948, was developed on the self-balancing principle and was designed for the measurement of c-w power with the use of a fuse or barretter. Since the introduction of the 430A, many customers have requested a similar instrument that could be used to measure pulsed power. Such an instrument has now been designed and assigned the model number 430B. The new Model 430B can measure either continuous or pulsed power and operates with fuses, barretters or thermistors of 100- or 200-ohm value. The power-measuring range of the new 430B is the same as that of the 430A, 0.1 milliwatt full scale to 10 milliwatts full scale in five ranges. First production units of the 430B are expected to be available some time after mid-summer.

The d-c biasing power range available from the Model 430B provides for operating barretters that have a 200-ohm value at a nominal level of 15.3 mw and for operating thermistors that have a 100-ohm value at

-hp- EQUIPMENT FOR USE WITH MODEL 430A[1] OR 430B[2] POWER METER

Frequency Range (mc)	Type of System	Detector Mount	6, 10, 20 DB Fixed Attenuator	High Power Termination
10-1000	coaxial	476A[3]		
1000-4000	coaxial	475B[1]		
2600-3950	waveguide	S485A[6]	S370A, B, C[5]	S912A
3950-5850	waveguide	G485B[4]	G370A, B, C[5]	
5850-8200	waveguide	J485B[4]	J370A, B, C[5]	
7050-10,000	waveguide	H485B[4]	H370A, B, C[5]	
8200-12,400	waveguide	X485B[4]	X370A, B, C[5]	X912A

[1]For use with 200-ohm fuse or barretter.
[2]For use with 100- or 200-ohm fuse, barretter or thermistor.
[3]50-ohm mount; uses 200-ohm fuses.
[4]For use with 200-ohm barretter or crystal.
[5]Suffixes A, B, C signify 6, 10, 20 DB, respectively.
[6]For use with 200-ohm barretter.

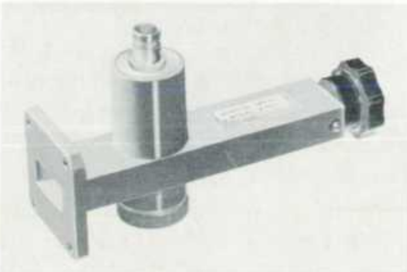

Figure 3. *New -hp- Model 485B waveguide detector mount.*

14.4 mw and a 200-ohm value at 9 mw. However, thermistors that have a 200-ohm value at 9 mw are incapable of operation at 200 ohms on the 10 mw range.

BOLOMETER MOUNTS

When using a bolometer element to make h-f power measurements, the element is connected as a termination for the h-f transmission system in order to absorb the power flowing in the system. However, h-f bolometer elements are commonly operated at resistance values such as 100 or 200 ohms to make best use of their characteristics. The elements generally do not provide a proper load either for the usual coaxial system or for waveguide systems, so that some impedance-matching device is required.

In coaxial systems several types of such devices are used. One such device is the fixed-tuned mount. This type of mount is easy to use but has had the disadvantage of being quite narrow in bandwidth so that a relatively large number of such mounts were required for general work. However, a broad-band fixed-tuned mount has been designed for the 10-1000 mc range, as described later.

A satisfactory device for broadband work is the tunable mount. Such mounts can be in the form of a stub-and-line-stretcher, a double-stub tuner, or a triple-stub tuner. These devices all operate so as to introduce transmission-line tranformation and shunt susceptances in a combination such that the transmission line is terminated with a load that absorbs maximum power.

The most practical of these devices is the double-stub tuner. By special design, the range of transformation of the double-stub tuner can be made to approximate that of the triple-stub tuner. In addition, the double-stub tuner is less susceptible than the triple-stub tuner to losses caused by heavy currents flowing in high-susceptance stubs. On the other hand the double-stub tuner is easier to build than the stub-and-line-stretcher.

The -hp- Model 475B Tunable Bolometer mount is basically a double-stub tuner with provision for mounting a bolometer and for connecting into the power meter and coaxial transmission circuits. The mount was designed to match a 200-ohm barretter to nominal 50-ohm coaxial systems over a wide frequency range from 1000 to 4000 megacycles. Because of the impedance-transforming properties of the tuner,. inexpensive instrument fuses can be operated satisfactorily as bolometers up to 4000 mc.

The frequency range of the power meter is determined by the bolometer mount used. Thus, with the Model 475B, the power meter can be operated over a range from 1000 to 4000 megacycles. The Model 475B is also useful in applications requiring a double-stub tuner.

10-1000 MC 50-OHM MOUNT

In the frequency range lying between radio frequencies and the lower UHF region, it is frequently desirable to measure low voltages on transmission circuits. In this range the engineer usually thinks in terms of voltage and oftentimes overlooks the usability of the power meter in determining voltages that lie below the most sensitive voltage range of the high-frequency voltmeter. The Model 430 power meter can be used in such applications to determine voltages as low as 0.05 volt, corresponding to 50 microwatts in a 50-ohm circuit.

To aid in making power measure-

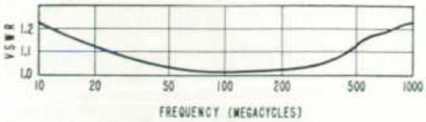

Figure 4. *Typical VSWR characteristic of Model 476A when compared with 50 ohms.*

ments in this range, the new Model 476A bolometer mount has been developed for use from 10 to 1000 megacycles. This mount was developed for use with nominal 50-ohm coaxial systems and has an input impedance of approximately 50 ohms so that no tuning is required.

The Model 476A uses four selected 200-ohm instrument fuses in a series-parallel circuit arranged to appear as 200 ohms to the power meter and as 50 ohms to the coaxial transmission circuit. The match of the mount to a 50-ohm source over the 10-1000 mc range is indicated in the typical VSWR curve shown in Figure 4.

The Model 476A can be used in many applications where it is desired to standardize the output calibration of various generators in the 10-1000 mc range. The VSWR curve shows that the mount is a reasonably good standard load for 50-ohm circuits. Thus, the device can be used as a standard load for 50-ohm generators and at the same time the power absorbed can be measured with the Model 430 power meter.

The error introduced in power measurements due to variation of the Model 476A from a "flat" load is small but is influenced somewhat by the source impedance of the line feeding the device. With the types of sources found in practical work, the error will seldom exceed 0.5 db in the worst case where the VSWR approaches 1.25. Over the range from 20 mc to 500 mc where the VSWR is less than 1.15, the error due to mismatch by the Model 476A will seldom exceed 0.2 db. If the source impedance is closely matched to 50 ohms, the error introduced by the Model 476A will be even less.

WAVEGUIDE MOUNTS

Waveguide mounts are usually designed so that the bolometer element extends between the wider surfaces of the guide. One terminal of the element is brought out through the wall of the guide in such a manner that d-c or low-frequency biasing power can be applied to the element. A quarter-wave shorting section is located in back of the bolometer element to aid in achieving maximum absorption of the power flowing down the guide.

As part of the -hp- waveguide program announced earlier this year, a series of waveguide bolometer mounts has been designed for the frequency range from 2600 to 12,400 megacycles. The first of the series, the Model S485A, is designed for use with 3″ x 1½″ waveguide over the frequency range from 2600 to 3950 megacycles. In this mount, a fixed quarter-wave matching section is located behind the bolometer element. By compensation of this section, it has been possible to achieve a low VSWR for the mount and dispose of the need for hand-tuning to achieve best match. The mount is designed for use only with 200-ohm barretters and has a VSWR of less than 1.3 over its rated frequency range.

The remaining four mounts in the series are the Models G485B, J485B, H485B, and X485B, corresponding to the -hp- *G, J, H* and *X* sizes of waveguide. These mounts can be used with either barretters or silicon crystals such as the 1N21B or 1N23. The mounts are tunable and considerable care has been taken in their design and construction to prevent "holes" or other undesirable operating conditions due to tuning plunger losses. When barretters are used, the mounts provide a good match for waveguide systems and in general their VSWR is less than 1.5 over their rated frequency range. If a completely "flat" line is desired in these applications, the mount can be preceded by a slide-screw or E-H tuner.

These waveguide mounts, as well as the coaxial mounts, can all be used with either the Model 430A or the new Model 430B power meter to make power measurements over the range from less than 50 microwatts to 10 milliwatts, or to higher powers with attenuators and directional couplers. In addition to the above-described waveguide bolometer mounts, a series of thermistor mounts will be available about midsummer.

—B. P. Hand and
N. B. Schrock

SPECIFICATIONS

MODEL 370A, B, C
6, 10, 20 DB
FIXED ATTENUATORS

Models are provided in fixed values of 6, 10, or 20 db; suffixes A, B, C after model number signify units for 6, 10, or 20 db respectively.

WAVEGUIDE SIZES:
Model S370: 3″x1½″ (2.6-3.95 kmc)
Model G370: 2″x1″ (3.95-5.85 kmc)
Model J370: 1½″x¾″ (5.85-8.2 kmc)
Model H370: 1¼″x⅝″ (7.05-10.0 kmc)
Model X370: 1″x2″ (8.2-12.4 kmc)
Model P370: .702″x.391″ (12.4-18 kmc)

ACCURACY: Attenuation set within 0.2 db at calibration frequency. Calibration frequencies are 3, 4.5, 7, 8.6, 10 and 15 kmc (each model calibrated at appropriate frequency).

VSWR: Approx. 1.15 maximum over frequency range shown following above waveguide sizes.

MAXIMUM DISSIPATION: Approx. 1 watt average, 1 kw peak.

PRICE: Model S370: $75.00
Model G370: $65.00
Model J370: $65.00
Model H370: $60.00
Model X370: $55.00
Model P370: $60.00

Prices f.o.b. Palo Alto, California.

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MODEL 476A
UNTUNED BOLOMETER MOUNT

NOMINAL FREQUENCY RANGE: 10 - 1000 mc.

POWER RANGE: 10 mw max. with -hp- Model 430. 80 mw maximum power input.

VSWR: 1.15 maximum from 20 to 500 mc; 1.25 maximum from 10 to 1000 mc.

CONNECTORS: RF input, type N jack (UG-23/U); power meter input, type BNC jack (UG-625/U).

BOLOMETER ELEMENTS: Four selected 1/100 ampere instrument fuses. (included)

DIMENSIONS: 5″ lg, 1¾″ diam.

SHIPPING WEIGHT: 2 lbs.

PRICE: $125.00 f.o.b. Palo Alto, California

MODEL 430B
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 (O dbm = 1 mw). Power range can be extended with attenuators or directional couplers.

EXTERNAL BOLOMETER: Either barretters or thermistors can be used. Suitable barretters are certain 1/100-ampere instrument fuses or Sperry 821 barretter; suitable thermistor is W.E. D166382 type. Barretter should have resistance of 200 ohms at approx. 15 mw. Thermistors can be operated at either 100 or 200 ohms. Thermistor resistance should be 100 ohms at approx. 14 mw or 200 ohms at approx. 9 mw. Thermistors can not be operated at 200-ohm level on 10 mw range.

FREQUENCY RANGE: Determined by bolometer mount. (Not supplied.)

ACCURACY: Within 5% of full scale value.

DIMENSIONS: 12″ wide, 9″ deep, 9″ high.

WEIGHT: 19 lbs.; shipping weight, 32 lbs.

POWER: Operates from nominal 115-volt, 50/60 cycle source. Requires 75 watts.

CABLES SUPPLIED: 7′ 6″ power cable permanently attached; 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 430 panel.

Price upon request

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MODEL 912A
HIGH POWER TERMINATIONS

WAVEGUIDE SIZES:
Model S912A: 3″x1½″ (2.6-3.95 kmc)
Model X912A: 1″x½″ (8.2-12.4 kmc)

DISSIPATION: S912A, 250 watts average, 100 kw peak; X912A, 100 watts average, 50 kw peak. Forced air cooling must be used when units are being operated above 50% of rated power.

VSWR: 1.1 Maximum.

PRICE: Model S912A: $125.00
Model X912A: $75.00

Data subject to change without notice

MODEL S485A
UNTUNED DETECTOR MOUNT

WAVEGUIDE SIZE: For use with 3″ x 1½″ waveguide.

RECOMMENDED FREQUENCY RANGE: 2600 to 3950 mc.

DETECTOR ELEMENT: Designed for use with 200-ohm barretter. (Barretter not included.)

VSWR: Less than 1.3 over recommended frequency range.

INPUT FLANGE: Plain cover flange of UG-53/U type.

OUTPUT CONNECTOR: Type BNC jack.

PRICE: $125.00 f.o.b. Palo Alto, California

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MODEL G, J, H, X485B
TUNED DETECTOR MOUNTS

WAVEGUIDE SIZES:
Model G4853, 2″x1″; 3.95-5.85 kmc.
Model J485B, 1½″x¾″; 5.85-8.20 kmc.
Model H485B, 1¼″x⅝″; 7.05-10.0 kmc.
Model X485B, 1″x½″; 8.20-12.4 kmc.

DETECTOR ELEMENT: 200-ohm Barretter or silicon crystal of 1N21 type. (Element not provided.)

VSWR: Can be tuned to give less than 1.5 VSWR with barretter over recommended frequency range.

INPUT FLANGE: Plain cover flanges are provided.

OUTPUT CONNECTOR: Type BNC jack.

PRICE: Model G485B: $95.00
Model J485B: $90.00
Model H485B: $85.00
Model X485B: $75.00

All prices f.o.b. Palo Alto, California.