



# The NOTEBOOK

BOONTON RADIO COMPANY · ROCKAWAY, NEW JERSEY  
 A Division of Hewlett-Packard Company

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## Precision Peak Power Measurements With The Peak Power Calibrator

G. RAYMOND POLEN, *Development Engineer*

### INTRODUCTION

The need for accurate measurements of peak RF power of pulsed sources, while having existed for over a score of years, has prompted surprisingly little in the way of simple reliable commercial equipment for performing the task. Today with the increasing number of electronic systems such as radar, air navigation, telemetry, communications, command and control, television, radio-sonde, and many others depending on pulsed RF signals, the need is greater than ever. Yet, in many instances, the systems engineer must devise his own method of peak power measurement. While some of these systems are fairly accurate, they are generally time consuming and expensive and often completely unsuitable for high volume or production line measurements. The time factor is an important one, not only from the viewpoint of time efficiency, but from the viewpoint of accuracy, for it is axiomatic in this type of measurement that time and error are quite directly related. Other criticisms of current methods have been that they exhibit a high degree of temperature sensitivity and a rather unwieldy procedure for recalibration.



Figure 1. Type 8900A Peak Power Calibrator

The techniques of CW power measurement have been quite steadily advanced over the years and to take advantage of this, peak power measurements are often a correlation process in which the performance of a device under the application of pulsed RF power is calibrated to a characteristic it exhibits upon application of a known CW power level.

### DEFINITION OF PEAK POWER

Occasionally there is some confusion in formulation of a concept of what peak power actually is. A relationship accepted by groups working in the field is:

$$P_{ave} = P_{peak} \times \text{Duty Cycle.}$$

Duty cycle is the fractional time a pulsed source is turned on. If the source were turned on 100% of the time, the duty cycle would be 1 and peak power and average power would be equal. Peak power, then, could be explained as the average power that would exist if the pulsed source were left on all the time. It is not the instantaneous peak power or envelope peak power that exists at the peak of the RF voltage waveform. Assuming a sinusoidal CW source with an average power of 1 watt, the peak power rating of the source is 1 watt also. If the source is turned off 50% of the time, the average power will be 1/2 watt, whereas the peak power rating remains 1 watt.

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**METHODS FOR MEASURING PEAK POWER**

Rearranging factors in the original equation:

$$P_{\text{peak}} = \frac{P_{\text{ave}}}{\text{Duty Cycle}}$$

From this equation, it is apparent that one method of pursuing the problem of peak power measurement is to measure average power and duty cycle and correlate the two. While average power can be measured with a fair degree of confidence, duty cycle can become an elusive parameter. Measurement of duty cycle requires that a decision be made as to when a source is "on" and when it is "off". In some systems employing complex waveshapes, this can be an arbitrary decision if left up to electronic circuitry. In our air navigation distance measuring systems (DME), for example, employing a gaussian shaped pulse, when should it be decided that the pulse is "off"? In a television system, where intelligence is being transmitted by both time and amplitude modulation of the pulsed source, there is a similar or even more demanding problem. A versatile peak power measuring system must not leave the determination of duty cycle up to the unimaginative mind of electronic circuitry, because the possible errors due to variations in pulse width, rate, or shape are too great.

Consider, then, another means of determining the peak power of a pulsed RF source. For a sinusoidal CW source it is generally agreed that:

$$P_{\text{ave}} = \frac{E_{\text{rms}}^2}{R_o} = \frac{(.707E_{\text{peak}})^2}{R_o} = \frac{(E_{\text{peak}})^2}{2 R_o}$$

As mentioned before, the average power and peak power of a source are equal if the duty cycle is 1. The voltage waveforms, then, must be identical for the duration of time the source is turned on, assuming a system of constant characteristic impedance or  $R_o$ . The peak voltage of the CW mode will be the same as the peak voltage when the source is pulsed, even though this is not the parameter to be measured. It is, however, a means of correlation between the two. Employing a device known as the peak detector, we have an element which will respond identically for a duration of time to both a CW and a pulsed source of the same power rating. While elements such as a bolometer may respond quite differently to the two, depending on the heating effect, the peak detector does not. This is the principle of the Boonton Radio Company Type 8900A Peak Power Calibrator.

and to bring it away from the square-law region to produce a somewhat more linear change in output voltage for a change in the applied RF level. As the diagram indicates, a variable dc supply is included also. The output of the supply is connected to a dc meter, which monitors its voltage, and to one leg of a mechanical chopper. If the chopper is set in operation and its selecting arm is connected to an oscilloscope, one can look, first at the dc level produced by the peak detector in response to an RF voltage, and then at the dc level from the variable supply. In operation, the supply is adjusted until the two voltages are exactly equal. The dc meter monitoring the output of the variable supply has been calibrated in terms of RF level required to produce a given dc from the peak detector and hence peak RF power can be read from it directly. CW power, of course, is correctly indicated also, since the calibration is in

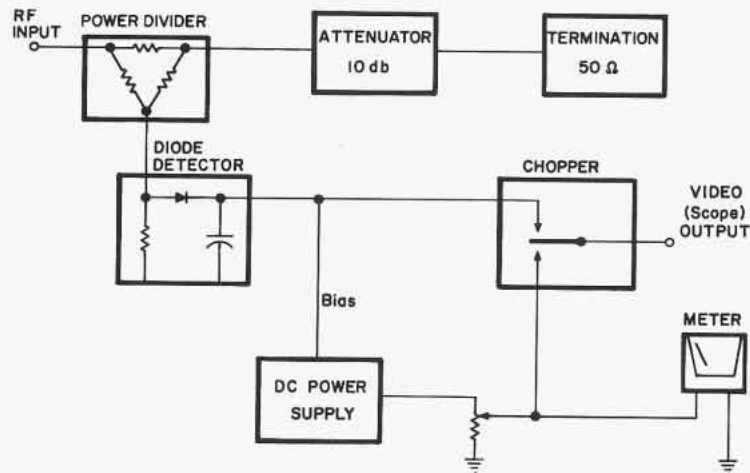


Figure 2. Block Diagram - Type 8900A

**TYPE 8900A PEAK POWER CALIBRATOR**

Figure 2 is a block diagram illustrating the basic operation of the 8900A. It can be seen that a signal applied to the front panel input connector is sent through two paths by virtue of the power divider. In one path, the signal passes through a 10 db attenuator and is absorbed in a 50-ohm termination. In the other path, the signal arrives at a diode peak detector which develops a dc level equal to the peak voltage of the RF waveform applied to it. The diode is forward biased to bring it to an operating point of maximum stability

terms of the peak voltage waveform.

The peak detector has a very important job, and if it does not do this job well, errors will be introduced. The output capacitor must be charged to the true peak of the waveform within the duration of the pulse, though not necessarily on the first cycle of the RF carrier. It may charge up in staircase fashion over a period of several cycles, but must reach the peak before a measurement is made. The 8900A specification states that 0.25  $\mu\text{s}$  should be allowed for this, although 0.10  $\mu\text{s}$  is typical with normal cable lengths and

oscilloscopes connected to the video output. Since no isolating amplifier is employed, extremely high external capacitance could increase the time required for the video output to rise to the true peak of the voltage waveform. The impedance of the output circuit is approximately 150 ohms. The peak detector also has a responsibility to remain faithful at low RF carrier frequencies. It must not start to discharge while it is waiting for the crest of the next cycle of the RF voltage waveform to appear. If it falls by even a few per cent, the dc output level, within the duration of the pulse, would be lower than the true RF voltage peak and an error would be introduced. The 8900A was designed to meet its accuracy specification at carrier frequencies down to 50 mc and has been found capable of doing this. The preliminary catalog lower limit of specification was placed at 150 mc as a gesture of conservatism. In a like manner, the preliminary specification of upper frequency limit is 1500 mc, although all units tested have been found to be within the accuracy limit up to 2.0 Gc.

Figure 1 is a photograph of the front panel of the 8900A. The 5½ inch meter actually occupies almost two-thirds of the front panel and was included to enable the user to take full advantage of the accuracy and stability of the instrument with readout easily to 0.1 db. Meter tracking accuracy and repeatability are of necessity a tightly controlled characteristic of the unit. A front panel "NULL" control is included to permit the user to "erase" the static dc bias on the diode from the video presentation. While this control need not be reset for a repetitive series of measurements, it gives the operator a range of adjustment to compensate for any possible long term aging effects on the diode. This adjustment is made with the function switch in the "CAL" position. In this position, also, a voltage divider from the reference power supply applies a preset voltage to the dc meter to deflect the needle to a calibration mark. This was included to give the operator confidence that the dc meter and power supply are operating properly should he question it at any time during a measurement. It should be noted, however, that unlike some measuring systems, the reference supply is not really a critical parameter in the measurement

because it is being used only for comparison rather than as an absolute reference for the measurement. The meter calibration is the absolute reference.

Now consider the signal path which attenuates the incident power and dissipates the remainder in a 50-ohm load. This is provided as a convenient means of calibrating or standardizing the instrument. If the 50-ohm load is replaced by an accurate CW power measuring device such as a bolometer or calorimeter, and a CW source is connected to the input connector, the effect of the applied power level can be monitored on the average reading CW standard and the peak reading diode detector simultaneously. Therefore, one need only to know accurately the attenuation between the front panel input connector and the CW standard to determine what effect a known power level at the input has upon the peak RF detector. The 10 db pad was introduced merely to reduce the CW level to one within the range of several commercially available standards. The -hp- 431 Power Meter, with the 478A Bolometer or the -hp- 434 Calorimeter, are quite satisfactory for this application. The CW source requirements also are met by readily available units.

A basic objective of the 8900A is to provide a peak power measurement instrument of sufficient accuracy to serve as a working standard, without the usual rigorous limitations of standards labora-

tory equipment. The high quality forward-biased diode is an order of magnitude more stable environmentally than the uncompensated bolometer or calorimeter. Operator skill level, also, has been reduced to absolute minimum. The objective then is to "capture" the established accuracy of known standards and to faithfully repeat this knowledge under a much more demanding set of conditions.

While the specified accuracy of the BRC 8900A Peak Power Calibrator is  $\pm 0.6$  db, when frequency correction is applied, it should be explained that utilization to a higher degree of accuracy, by virtue of its inherent stability, is both practical and recommended. The  $\pm 0.6$  db figure is based on absolute worst case error without benefit of some error theories which propose a probable error as the RMS value of the worst case. The worst case error is also based on a minimum of standards equipment to perform a calibration. With high quality standards laboratory type equipment for calibration, operation to about a  $\pm 0.3$  db worst case error is considered practical. Major potential sources of error are in the measurement of the attenuation path from the input connector to the CW standard output connector and error of the CW standard itself. Other worst case errors included in the 8900A analysis are:

1. Input VSWR reflection error.
2. Meter tracking and repeatability error.

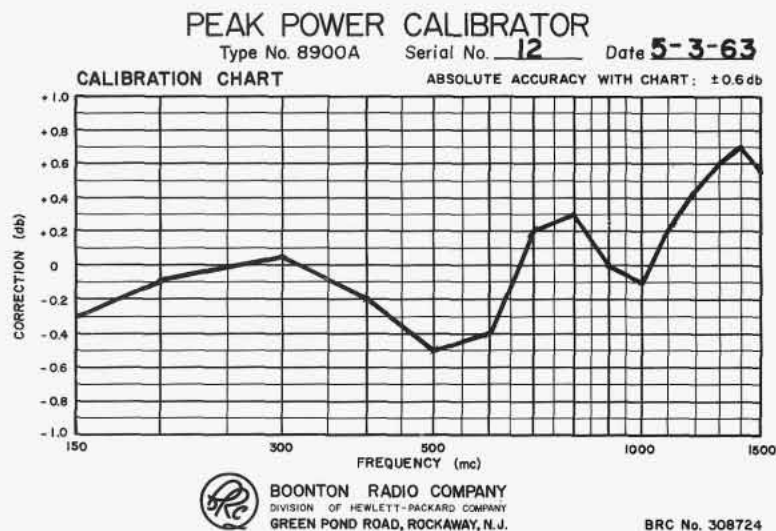


Figure 3. Typical Frequency Correction Curve - Type 8900A



3. Operator readout error.
4. Possible errors due to aging of the detector diode.

The aging error is included as a safety factor. Calibration checks of two prototype units, which had been in constant use for 6 months, exhibited less than .05 db discrepancy when rechecked at the end of that period. This amount of discrepancy could be attributed to any of the other errors first mentioned, but in a conservative evaluation, possible effects of aging must be considered. Provisions for recalibration permit the user to connect the standardizing equipment quite easily to external connectors on the instrument. Should field replacement of the detector diode become necessary, internal adjustments have been incorporated to permit adjustment of the front panel meter to accommodate its particular idiosyncrasies without necessity for an additional correction curve. A frequency correction curve is necessary when working to the highest degree of accuracy to remove errors due to the frequency sensitivity of the power divider diode detector, 10 db attenuator, and type N connectors. Without frequency correction, overall accuracy is conservatively rated at  $\pm 1.5$  db over the specified frequency range. Figure 3 illustrates a typical individual frequency correction curve which can be supplied with the 8900A.

It is possible, then, to standardize the 8900A with a CW source, a CW power standard, and an oscilloscope. The procedure permits calibration at any frequency desired, and the user need not, as in some instruments, standardize at dc and wonder what the instrument is actually doing at a proposed measurement frequency.

A basic factor in the philosophy of the 8900A is that of actual observation of the pulse waveform during the measurement. While this requires the use of a suitable auxiliary oscilloscope, it was considered important in the reduction of subtle errors; some of which are variations in pulse width, rate, or shape, as previously mentioned. It has an inherent advantage, however, in permitting measurement of intermediate levels of power in a complex waveshape. The operator may ignore characteristics, such as overshoot, if they contribute

nothing to the effectiveness of his system or he may measure them as he chooses. In some applications, the user may be monitoring the effectiveness of a system at the time the measurement is made in an effort to correlate system performance to peak RF power. It then becomes important that he verify the output power has not changed by even a few tenths of a db at the time of the reading. Some frequently useful methods of peak power measurement have the disadvantage that the operator stops looking at the waveform at the precise moment of measurement, which is the most important time of all. A typical oscilloscope display from the 8900A during a measurement is shown in Figure 4.

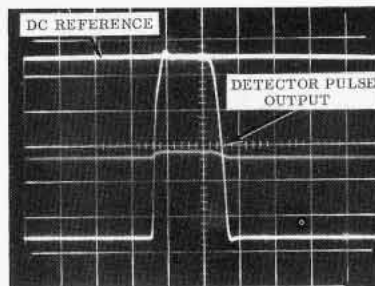


Figure 4. Typical Oscilloscope Display -  
Type 8900A

While the 8900A has a basic range of 200 mw full scale, it was designed with the intention that higher power measurements would be desired. Use of a high quality attenuator or directional coupler at the input will provide higher scale ranges. The directional coupler can provide an "in line" measurement with the source delivering useful power to an external load, thus providing a continuous monitoring capability. The accuracy of the external attenuating device is necessarily a factor in the overall accuracy of the measurement. If, for example, the 8900A were calibrated to an accuracy of  $\pm 0.4$  db, and a range extending 40 db attenuator known to an accuracy of  $\pm 0.2$  db were added to its input, accuracy of the overall measurement would be  $\pm 0.6$  db. The accuracy of the measurement, reduced to its basic meaning, is really the degree of confidence that the operator has in the measurement and this confidence

can come only from a thorough understanding of the theory and practical limitations of the measuring system.

## CONCLUSION

In conclusion, the 8900A is BRC's approach to the general problem of accurate peak power measurement. Its basic features are high stability, ease of standardization, and elimination of some of the subtle errors of many present-day systems. Its characteristics have been conservatively rated and it is recommended that the user fully understand the theory of operation and knowledgeably apply it to measurement applications, especially where his requirements demand greater than specified accuracy. The complete specifications for the 8900A are given below.

## SPECIFICATIONS

### Radio Frequency Measurement Characteristics

RF RANGE: 150 to 1500 MC

RF POWER RANGE:

200 mw\* peak full scale

\*may be readily increased through use of external attenuators or directional couplers

RF POWER ACCURACY:  $\pm 1.5$  db\*

\* $\pm 0.6$  db with custom calibration curve

RF POWER PRECISION:  $\pm 0.1$  db

RF PULSE WIDTH:  $> 0.25$   $\mu$ sec

RF REPETITION RATE: 1.5 MC maximum

RF IMPEDANCE: 50 ohms

RF VSWR:  $< 1.25$

### Physical Characteristics

#### MOUNTING:

Cabinet for bench use; readily adaptable for 19" rack mounting

#### FINISH:

Gray engraved panel; green cabinet (Other finishes available on special order)

#### DIMENSIONS:

Height 6-1/8" Width 7-3/4"

Depth 11"

WEIGHT: Net: 10 lbs.

#### Power Requirements

8900A: 105-125/210-250 volts,  
50-60 cps

## Low Level Measurements Using the Signal Generator Power Amplifier

CHARLES W. QUINN, *Sales Engineer*

The normal applications of the 230A Power Amplifier (Fig. 1) have been discussed in Notebook Number 32.

Because of the choice of amplifier tubes, the noise figure of this new versatile amplifier is in the order of 6 to 8 db. Further, for most of the range, the noise figure is closer to 6 db. This feature opens another field of application—Low Level Measurements. It is the purpose of this article to discuss the many ways this power amplifier can be utilized in low level work.

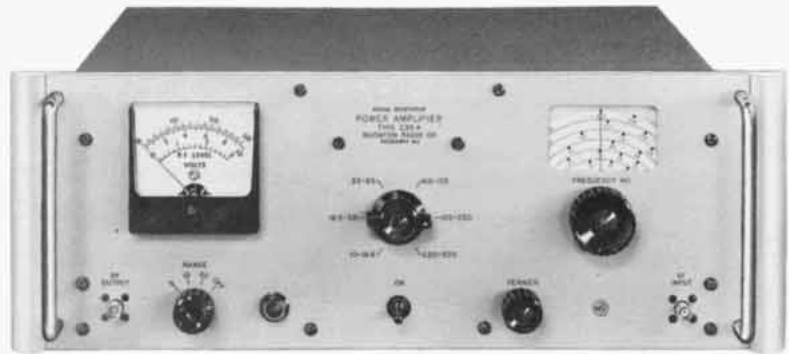


Figure 1. Type 230A Signal Generator Power Amplifier

### TUNED MICROVOLT METER

One of the most useful applications is the wedding of the 230A with an HP 411-A RF Millivoltmeter. The 411-A is connected as shown in Fig. 2, without a termination, but driving into the high impedance probe. Stub tuning at the output may improve the gain and VSWR at some frequencies. Under these conditions, the 230A will provide approximately 40 db of gain. The result is that full scale maximum sensitivity (which is normally 10 mv) is now approximately 100  $\mu$ v, and 10  $\mu$ v can be observed with ease. This configuration can be used to detect leakage and for harmonic analysis, using substitution to determine the gain at the frequency of operation. In this application it is possible to measure approximately 80 db of insertion loss with 1 volt as a source voltage.

### PREAMPLIFIER FOR FREQUENCY COUNTERS

When used in combination with the HP 524 and the 5243L and 5245L series counters with appropriate converters, the 230A Power Amplifier can make direct counter measurements possible with signal levels approximately 30 to 40 db below normal counter requirements.

### "OFF THE AIR" MEASUREMENTS

This application is especially useful when it is desirable to make transmitter measurements without interrupting transmission, when direct connection to transmission line is not desirable, or when the output of the transmitter is too low for normal measurements. In

cases where direct connections are not made, an antenna may be substituted and remote measurements made up to several miles, depending upon the radiated power. (See Fig. 3.)

There are some precautions which should be taken in this application.

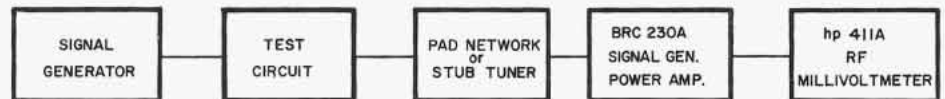


Figure 2. Tuned Microvoltmeter Setup with Stub Tuning

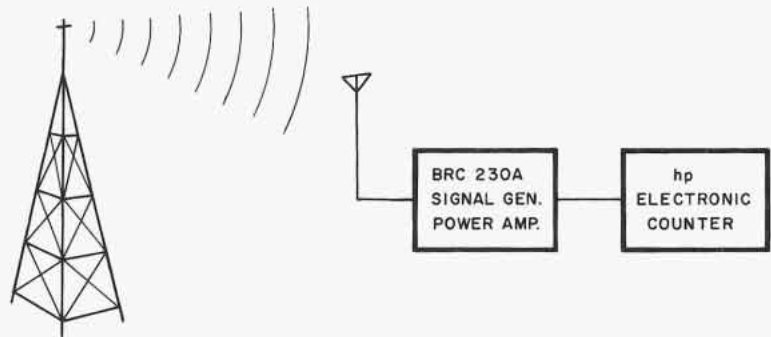


Figure 3. Setup for Remote Frequency Monitoring

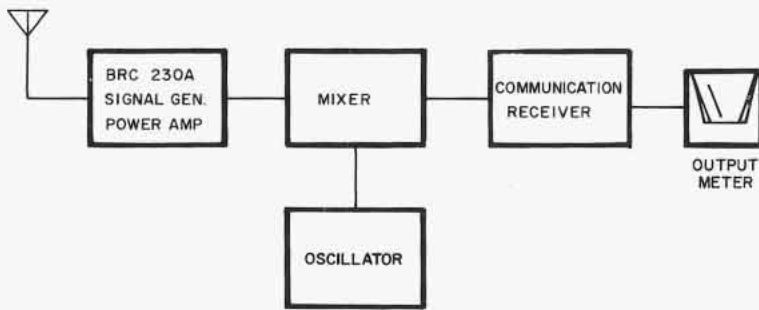


Figure 4. Setup for Leakage Detection

1. The effects of noise and modulation should be considered.
2. For AM signals, the negative modulation peak must not go below the triggering level.
3. For FM, the period must be sufficiently long for good averaging.
4. Even-order distortion, or carrier shift under modulation will be observed.
5. The absolute value of the peak noise voltage must be less than the triggering uncertainty, or hysteresis value.
6. The measurement must be made in the absence of interfering signals to the extent of the above noise limitation.

7. It is most desirable to check frequency at zero modulation.

#### RF LEAKAGE DETECTION

In the design of RF equipment, it is often necessary to detect very small signals, much less than  $1 \mu\text{v}$ , usually picked up on a standard loop. When the frequencies involved get above 30 mc, it is quite common to use a good communication receiver as an IF amplifier and precede it with a broadband mixer. Normally, the insertion loss of the mixer will degrade the 10 db signal-to-noise ratio to approximately 10 to 20  $\mu\text{v}$ . Adding the 230A Power Amplifier,

as shown in Figure 4, will improve this figure to .2 to .5  $\mu\text{v}$  for the same bandwidth of approximately 10 kc.

#### RECEIVER DESIGN

In the early stages of receiver design, the 230A Power Amplifier has numerous applications:

1. In the development of the IF amplifier stages, the 230A can serve as a temporary front end or RF pre-selector.
2. It can be used to provide high levels for limiters and detectors at IF frequencies above 10 mc.
3. It can be used to increase the output of a signal generator to determine proper mixing levels, thereby optimizing mixer gain and noise figure.

#### CONCLUSION

The 230A Power Amplifier is an extremely versatile instrument, capable of amplifying very small signals, as well as providing large signals, greater than 10 volts, for high level measurements with moderate input levels. With these features it becomes a valuable laboratory tool and also has many applications in the production line.

## BRC CUSTOMER SERVICE DEPARTMENT

In order to offer improved service on repairs, accessories, and replacement parts, BRC has established a Customer Service Department which will operate as part of our Sales organization. The new department is staffed with personnel highly skilled in the repair and servicing of the complete line of BRC equipment.

Under the direction of Ray Tatman, the department is responsible not only for the scheduling and processing at the factory of repair instruments, but for handling all communications with our engineering representatives and customers regarding field repair and servicing of BRC instruments. Much of this communication will be handled by means of special "Service Notes" which will be issued periodically by Ray to keep BRC Engineering Representatives and cus-

tomers posted with the latest servicing information.



Ray Tatman

Ray Tatman, head of the new operation, comes to BRC from the Hewlett-Packard Company in Palo Alto, California, where he spent two and one-half years in that Company's Customer Service Department. Ray, who hails from Oroville, California, attended Chico State College from 1949 to 1951 where he studied accounting and business administration. From 1951 to 1955 he served as an electronic technician in the U. S. Navy. In 1959 he received his degree in Electronics Engineering from California State Polytechnic College in San Luis Obispo, California.

The basic objective of the Customer Service Department is to provide the best possible service to our customers. If you have any questions regarding service, calibration, or repair, please do not hesitate to call or write us.

## DON'T MODIFY YOUR RX METER YET

In a Service Note on Page 7 of Notebook Number 31, a new method was described for modifying the Type 250-A RX Meter which would provide for both a reduced signal level and increased sensitivity. It has since come to our attention that a number of instruments, modified in accordance with the instructions given, would no longer meet factory specifications. The calibrated oscillator frequency in these instruments changed beyond the specified  $\pm 1\%$  limits and, in some cases, additional RF leakage occurred which prevented bridge balance above 150 kc.

In view of these problems, we are recommending the discontinuance of this modification until such time as the problem is resolved. Work is being continued toward a solution to the problem and additional information will be published as soon as it becomes available.

### ELECTRONICS, ELECTRONICS, EVERYWHERE

Over the years, BRC has received inquiries at the IRE show from a number of unusual organizations; sources which one might not readily associate with the electronic instrumentation field. This year, we did it again. A request for information about BRC equipment was received from the Dept. of Pediatrics, University of Washington, Seattle, Washington.

### 202H and 202J Instruction Manuals Now Available

The final instruction manuals for the Types 202H and 202J Signal Generators are now available. Included in the manuals are complete calibration and maintenance data, and parts lists. Copies of the manuals are being distributed through the BRC Engineering Representatives' offices. If you own a 202H or 202J and have not received your copy of the new instruction manual, contact our representative nearest you for your copy. Addresses and telephone numbers of our Representatives are given on Page 8 of this issue. Requests should include name of department and person to whom manual should be mailed.

## MEET OUR REPRESENTATIVES

### RMC Sales Division

One of the newest members of the BRC sales family is the RMC Sales Division of the Hewlett-Packard Company (formerly RMC Associates). RMC has two offices and handles BRC equipment sales in the Metropolitan New York City and Northern New Jersey areas. The Division's main office is located at 236 East 75th Street. A branch office is located at 391 Grand Avenue in Englewood, New Jersey.

RMC was founded in 1953 by Robert Asen, Milton Lichtenstein, and Charles Sargeant, all of whom were previously with Burlingame Associates as Field Engineers. Charles Sargeant has since retired. Robert Asen is Manager of the new Division and Milt Lichtenstein is Sales Manager. Rod Foley is Manager of the Englewood Branch.

to provide local service to customers.

We are proud to welcome RMC into the BRC family and invite all of our customers in the New York/Northern New Jersey area to contact them for complete information on BRC products.



Milton Lichtenstein, RMC Sales Manager



Robert Asen, RMC Manager



New York City Headquarters - RMC

The organization has an efficient and skilled technical staff consisting of eight Field Engineers, who are equipped to provide complete engineering service on our products; three Staff Engineers who are responsible for inside sales functions and provide "on-the-spot" technical assistance to customers; and a Customer Service Department which provides complete repair and recalibration services on all Hewlett-Packard instruments. An extensive stock of spare and replacement parts is also available

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## EDITOR'S NOTE Q Meter Award

Seymour Krevsky, winner of the increasingly popular Q estimating contest, held each year at the IEEE show, was presented with a Type 160-A Q Meter by Bill Myers, General Manager of BRC. With near winning estimates in both 1957 and 1959, Mr. Krevsky is proving to be a perennial threat in the competition.

Mr. Krevsky received his B.S.E.E. from Newark College of Engineering in 1942 and his M.S.E.E. from the same college in 1950. He is currently studying for his doctorate at Polytechnic Institute of Brooklyn.

In 1944 Mr. Krevsky entered the service as a member of the technical



Seymour Krevsky

staff of the Aircraft Radio Laboratory at Wright Field, Dayton, Ohio, where he performed studies on measurement techniques of parasitic FM in AM signal generators and in pulse modulated systems. Since that time he has done development and research work at the Coles Signal Laboratory and USARDL, and is presently engaged in advanced communications systems analysis and synthesis at the RCA Surface Communications Systems Laboratory.

Mr. Krevsky is a senior member of the IEEE, PGCS, PGAP, and PGMTT. He has had numerous articles published in IRE and SCEL publications, and was written up in "Who's Who in Engineering" in 1958 and 1962.

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Tel: (505) 526-2486  
TWX: 505-524-2671

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Tel: (503) 222-7337

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BIVINS & CALDWELL, INC.  
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Tel: (703) 282-5451  
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HEWLETT-PACKARD (CANADA) LTD.  
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TWX: 602-792-2759

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HORMAN ASSOCIATES, INC.  
941 Rollins Ave.  
Rockville, Maryland  
Tel: (301) 427-7560  
TWX: 301-427-4651

\*Indicates Instrument Repair Stations

†For instrument repair contact: Customer Service, Hewlett-Packard Company, 395 Page Mill Rd., Palo Alto, California, Tel: (415) 326-1755