A MEDIUM POWER SYSTEM FOR MEASURING THE EFFECTIVE EFFICIENCY OF SENSORS

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1. INTRODUCTION

Generally, measurements on power sensors traceable to national standards have been performed at power levels of the order of 10 mW or less. These levels of power are usually suitable for a majority of sensors on the market. However, recently with the development of commercial radio and the increasing use of cellular communication systems, there is a demand for measurements on sensors at higher powers. Such a system capable of measuring powers of the order of 1 to 10 W over the frequency range 50 MHz to 4 GHz is described here.

2. MEDIUM POWER SYSTEM

The medium power system is shown in Figure 1. Power from a synthesised source enters the solid state or travelling wave tube amplifier, passes through a low pass filter and enters the input of the coupler. About 20 dB of the power is coupled into the side arm of the coupler while most of the power is incident upon the mount (device) under test (DUT). The coupled power is further attenuated by the 40 dB attenuator so that the power reaching the Hewlett Packard 8481D high sensitivity diode sensor is approximately 60 dB down on the signal incident upon the mount under test. The operating range of this diode mount is from -20 to -70 dBm, with a maximum overload limit of 20 dBm. The power handling capacity of the HP 778D directional coupler is rated at 50 W average and the HP 779D coupler is capable of operating up to at least 15 W.

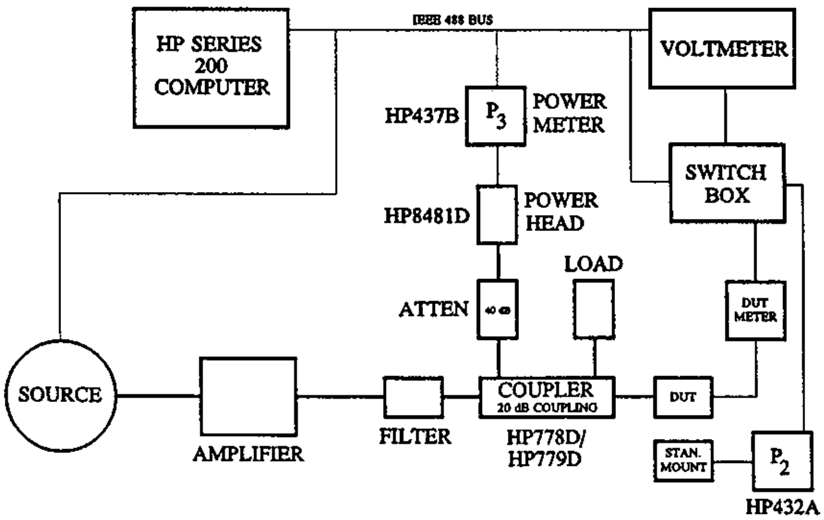

Figure 1. THE MEDIUM POWER SYSTEM.

The synthesised source, universal switch box, voltmeter and the HP 437B power meter are under IEEE 488 bus control from the HP 200 series computer. The switch box is used to separately switch the voltage outputs from the DUT power meter and the HP 432A power meter to the input of the voltmeter and also may be used to apply a short circuit across the input of the voltmeter so that the voltmeter internal offsets may be zeroed.

2.1 CALIBRATION OF SYSTEM

The medium power system is calibrated against a 10 mW HP 8478B thermistor mount that has been calibrated to national standards using the 14 mm twin load calorimeter. The voltage reflection coefficient (vrc) of the standard mount was measured on an HP 8510 automatic network analyser (ANA) as were the S-parameters: S_{21}, S_{22}, S_{31} and S_{32} of the HP 778D and HP 779D couplers.

To calibrate the medium power system, the source is connected directly to the input of the coupler, with the amplifier and filter removed, as the power required to calibrate the system (~10 mW) can be provided by the source alone. The modification of the system at the input of the coupler, between the calibration of the system and the measurement of the DUT, is permissible as the ratio P_2/P_3 is independent of source match. The standard thermistor mount is connected directly to the output (test) port of the coupler.

The calibration process is directly under the control of the program written for the HP 200 series computer. This program allows the system to be calibrated at multiple frequencies at levelled power from the synthesised source to give power levels at the standard thermistor mount at or near 10 mW.

The choice of coupler determines the frequencies over which the calibrations may be performed; below 2 GHz the HP 778D coupler is used while above this frequency the HP 779D has to be selected.

At present there are two solid state amplifiers and one travelling wave tube (TWT) amplifier for this system. The solid state amplifiers cover the frequencies from 0.05 to 1 GHz and 1 to 2 GHz respectively while the TWT amplifier covers the range 2 to 4 GHz.

Selecting "POWER CALIBRATION" from the menu on the computer monitor sets the program into calibration mode and a choice of couplers is displayed on the monitor. Depending on the choice of coupler, a list of the valid calibration frequencies is displayed on the computer monitor. The frequencies for calibration may be entered in any order into the computer. Once the selected frequencies have been entered, the calibration proceeds; measurement of the powers P_2 and P_3 (see Figure 1) being made at each frequency in the calibration. At the end of the calibration, the main menu of the program is displayed on the monitor and the standard thermistor mount may be removed from the test port of the coupler or alternatively, the calibration may be repeated, if desired.

2.2 MEASUREMENTS

By selecting "POWER MEASUREMENT" from the menu on the display a measurement on the sensor under test may be performed. The appropriate amplifier and filter are connected between the synthesised source and the input of the directional coupler as shown in Figure 1. The sensor under test (DUT) is connected to the test port of the coupler and a BNC cable from the switch box, is attached to the *recorder output* of the meter connected to the DUT. The program asks for: the sensor type, serial number, full scale recorder voltage output of the sensor's meter and the power required to give full scale output of the meter (the power range of the meter) to be entered.

A selection of amplifiers is then displayed on the monitor. The amplifier that covers the frequencies used in the calibration is chosen. Messages are then displayed requesting the power meter of the sensor under test to be zeroed and then for the range hold to be set on the meter.

As the measurement proceeds, messages are displayed on the monitor, when necessary, requesting the filter to be changed. The number of times the filter has to be changed depends on the range of frequencies covered during the calibration.

At the end of the measurement, the program asks for a *filename* for which a suitable name of no more than eight characters is entered. The frequency, calibration data (P_2, P_3 for the calibration; see Figure 1), measurement data (P_2, P_3 for the measurement), the S-parameters for the coupler, the efficiency and the vrc for the standard mount, at each frequency, are then written to floppy disc. The frequency, P_2, P_3 for the calibration and P_2, P_3 for the measurement are also printed. The main menu is then displayed on the monitor. The measurement may be repeated any number of times, if desired.

2.3 MISMATCH CORRECTION

The power data stored on floppy disc after the measurements have not been corrected for coupler directivity and test port mismatch. To correct this data, the "POWER CORRECTION" option is selected from the main menu displayed on the monitor and the filename of the data to be corrected is entered. The data on the floppy disc contain all the information necessary, apart from the vrc of the DUT, to allow for a full correction to be performed. The program will prompt for the real and imaginary part of the vrc of the DUT, measured previously on a vector network analyser, to be entered. From this and the data stored on disc, the corrected efficiency and calibration factor, expressed as a percentage and in dB respectively, are calculated for each measurement frequency and the results printed.

3. RESULTS

To evaluate the performance of the medium power system, the system was calibrated at frequencies of: 0.05, 0.1, 0.3, 0.5, 0.7, 1, 1.3, 1.5, 1.7 and 2 GHz with the HP 778D coupler and at 2, 3 and 4 GHz with the HP 779D coupler respectively using the standard thermistor mount. A medium power 40 dB attenuator (comprising of Weinschel 10 and 30 dB attenuators), that had been previously calibrated on an HP 8510 ANA, was then connected to the standard mount and measured as the DUT at a power level of about 10 W using the 30 W solid state amplifiers for the frequencies between 0.05 and 2 GHz and the 20 W travelling wave tube amplifier for frequencies between 2 and 4 GHz. The results are shown in Table 1. During the measurements, a power level of 1 mW at the HP 432A meter was taken to correspond to a power level of 10 W (a factor of 10^4 up on the measured power) giving efficiencies of the order of 100%. From a knowledge of the S-parameters of the 40 dB attenuator, the vrc of the mount and its efficiency, the effective efficiency of the combination of the 40 dB attenuator and standard mount can be calculated; these values are also shown in Table 1 for comparison with the measured values. It can be seen that the agreement between the measured and calculated efficiencies are generally good and well within the overall uncertainties given below.

4. UNCERTAINTIES

The following contributions to the uncertainty of the measurement of the effective efficiency of the DUT were identified (values in brackets refer to 95% confidence limits):

a) Coupler directivity and mismatch uncertainty (1.5% to 4.1%).

b) Standard sensor effective efficiency uncertainty (1.8%).

c) Sensors' mismatch uncertainty (0.25%).

d) Detector diode non linearity uncertainty (0.17% & 0.5%).

e) Signal source and amplifier harmonic uncertainty (0.0003% & 0.11%).
f) HP 437B power meter resolution and offset uncertainty (0.03% & 0.011%).
g) Voltmeter resolution uncertainty (0.002%).
h) HP 432A power meter resolution uncertainty (0.004%).
i) Signal source and amplifier power stability uncertainty (0.012% & 0.23%).
j) DUT power meter recorder uncertainty (0.3%).

The total uncertainty contribution at a 95% confidence level was found from the root of the sum of the squares of the individual uncertainties. The resultant total uncertainty was estimated to be: 4.5% at 50 MHz, 3.0% at 100 MHz, 2.8% at 300 MHz and approximately 2.6% from 500 MHz to 4 GHz for a DUT vrc of 0.2; smaller values of DUT vrc give lower uncertainties.

TABLE 1. COMPARISON OF MEASURED AND CALCULATED EFFECTIVE EFFICIENCY OF STANDARD MOUNT WITH 40 dB ATTENUATOR

f/GHz	MEASURED EFFICIENCY/%	CALCULATED EFFICIENCY/%
0.05	111.6	111.1
0.10	110.6	110.5
0.30	109.0	108.9
0.50	108.8	108.3
0.70	108.4	107.8
1.00	107.1	106.2
1.30	106.7	105.8
1.50	104.9	104.5
1.70	105.4	104.8
2.00	104.8	104.2
2.00*	105.5	104.2
3.00	100.8	100.8
4.00	102.5	102.3

* value using HP 779D coupler.

5. CONCLUSION

A medium power system has been developed which enables the effective efficiency of medium power sensors to be measured over the frequency range 0.05 to 4 GHz. The system is potentially capable of operating up to 12.4 GHz but this requires the purchase of additional amplifiers.