Absolute RF Power Measurement using Simple Techniques

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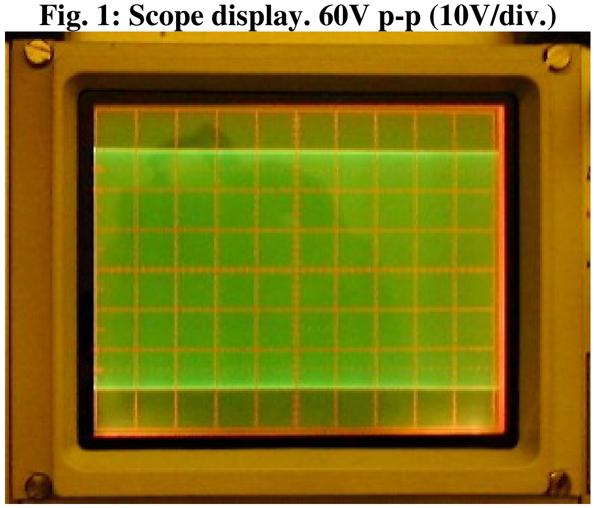
Most HF amateur stations are equipped with some sort of RF power meter. The "SWR/power" meter is a popular instrument, and is also relatively inexpensive. It is basically a reflectometer in a metal case, with a meter (switchable or crossed-needle) which reads the DC output voltage of the reflectometer's forward and reflected power pickups.

These meters are usually designed for $Z_o = 50\Omega$. They will read power accurately only if terminated in 50Ω resistive.

The HF operator may wish to calibrate his SWR/power meter against an absolute power-measurement standard from time to time. Laboratory standards are very costly, and even an accurate commercial meter such as the Bird 43 represents a significant outlay.

If an accurate 50Ω dummy load is available in the shack, we can measure RF power by measuring the RF voltage developed across the load. If a calibrated oscilloscope is available, we can connect our 10X scope probe across the dummy load, apply a CW signal from the transmitter, and measure the peak-to-peak voltage V_{p-p}. A typical oscilloscope display is shown in**Fig. 1**.

Fig. 1: Scope display. 60V p-p (10V/div.)



The peak-to-peak voltage is 2.828 times the root-mean-square (rms) voltage. $V_{p-p} = 2.828 * V_{rms}$, so $V_{rms} = 0.3535 * V_{p-p}$.

Average power $P_{av} = (V_{rms})^2 \div R$

P_{av} is expressed in watts. (Note: We are measuring the average power of a CW signal. ***"RMS power" is a misnomer!***)

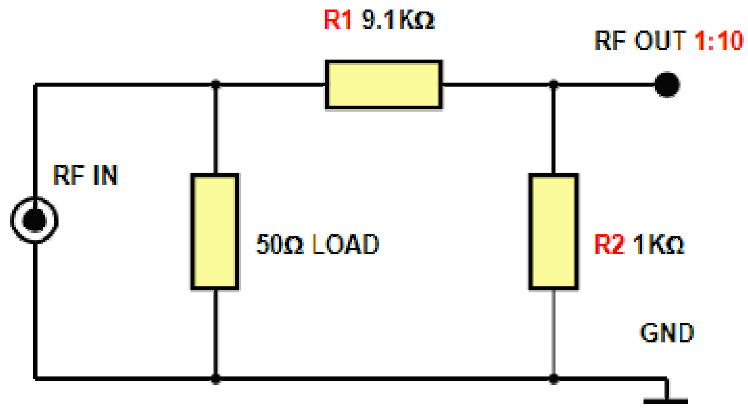
For example, if the oscilloscope reads 20V p-p with a 10X probe, $V_{p-p} = 20 * 10 = 200V$.

Thus, $V_{rms} = 0.3535 * 200 = 70.7V$

$P_{av} = (70.7)^2 \div 50 = 100W$.

A 10:1 resistive voltage divider may be connected between the dummy load and the oscilloscope probe to reduce the RF voltage applied to the probe, as shown in **Fig. 2**. The resistors should be non-inductive, and of adequate power rating.

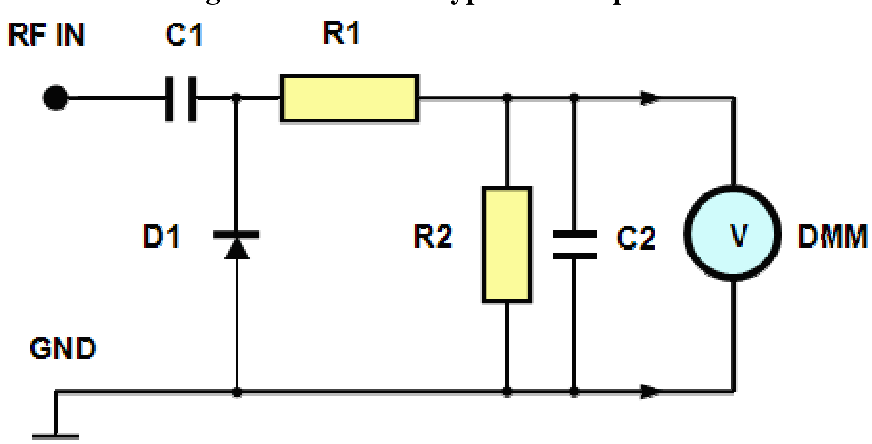
Fig. 2: Schematic of 10:1 voltage divider.



In the example shown in **Fig. 2**, R1 = 9.1kΩ and R2 = 1kΩ. At 100W in 50Ω, the power dissipated in R1 + R2 is $(70.7)^2 \div 10000 = 0.5W$. ($P = V^2 \div R$). Thus, R1 and R2 should be 1W and 0.25W metal-film, respectively. *Leads should be kept as short as possible.*

A simple diode probe connected to a digital multimeter (DMM) is a reasonably accurate alternative if an oscilloscope is not available. **Fig. 3** is a schematic of a typical probe.

Fig. 3: Schematic of typical diode probe.



C1: 1nF 1kV. **C2:** 10nF 100V. **R1:** 470KΩ ¼W. **R2:** 1.1MΩ ¼W. **D1:** See text.

The diode probe is a half-wave peak rectifier; its output voltage is equal to the peak value of the applied RF voltage, less the diode barrier voltage. To minimise the diode drop, D1 should be a germanium diode such as 1N34A, OA90 or OA91. These diodes have a barrier voltage of approx. 0.25V vs. 0.4V for a Schottky diode (e.g. 1N5711) or 0.7V for a silicon diode (e.g. 1N4148). The OA91 has 115V PIV, but may be difficult to locate. A 1N5711 Schottky diode (PIV = 70V) may also be used for D1.

A silicon diode such as the 1N4148 is not recommended, as its higher barrier voltage will introduce greater error at low power levels.

Assuming that D1 is a 1N34A, the applied peak RF voltage is equal to the DC output voltage + 0.25V.

Thus, $V_{pk} = (V_{dc} + 0.25)$ volts, or $V_{dc} = (V_{pk} - 0.25)$ volts.

As for the oscilloscope case:

Average power $P_{av} = (V_{rms})^2 \div R = (0.707\ V_{pk})^2 \div R = (V_{pk})^2 \div 2R$

Thus, $P_{av} = (V_{dc} + 0.25)^2 \div 2R$

Example: $V_{dc} = 20V$, $R = 50\Omega$. $P_{av} = [(20.25)^2 \div (50 * 2)] = 4.1W$

In **Fig. 3**, R1 = 470kΩ, and R2 = 1.1MΩ. These resistor values provide scaling from peak to RMS for a sine-wave input. A DMM with $Z_{in} > 10\ M\Omega$ will not significantly load down the probe. The DMM reads $0.7 * V_{dc}$ or $0.7 * (V_{pk} - 0.25)$, which is pretty close to V_{rms}.

For the above example, if $P_{av} = 4.1W$, $V_{pk} = 20.25V$, and the DMM will read 14V. ($V_{rms} = 0.707 * 20.25 = 14.3V$).

Because of the PIV limitations of the diodes, the 10:1 voltage divider **(Fig. 2)** must be placed between the 50Ω dummy load and the probe for higher power readings.

Example: For $P_{av} = 100W$, $V_{rms} = (PR)^{½} = (100 * 50)^{½} = 70.7V$

$V_{pk} = 1.414 * 70.7 = 100V$. The divider ratio is 10:1. Thus, $V_{pk} = 10V$ at the probe input. The DMM will read $0.7 * (10 - 0.25) = 6.8V$

The probe should be built into a metallic shielding enclosure. *Leads should be kept as short as possible.*

For those who would prefer to purchase and build a kit, Elecraft offers an RF probe kit for $10.00 under their order code RFPROBE.