A dummy load and power meter for HF

Jim Tregellas VK5JST
14 Sheringa Drive, Morphett Vale, SA 5162

Not everyone can (or wants to) afford that paragon of dummy loads, the Bird wattmeter, or for that matter the rather cheaper but still extremely good dummy load sold by Dick Smith. And getting your hands on the parts to build the dummy loads in the ARRL handbook isn't too easy either. But here is a dummy load and power meter, which you can build from standard parts, which covers the HF range and doesn't cost an arm or a leg.

Target specifications for the load/power meter were:

(a) VSWR <1.25 from 1 to 30MHz

(b) Power handling (50% duty cycle or 30 second max)
500 watt RMS or 1kW PEP (two tone SSB testing only)

(c) 50 ohm sampling output for a frequency counter or oscilloscope

(d) PEP power indication

After a lot of thought it was decided that these specifications could be best met by the forced air-cooling of a multi resistor array. Although the fan necessary is an additional expense, in the author's opinion it is a far better proposition than the alternative of immersing the resistors in an oil bath with the attendant problems of spillage and fire hazard.

Initial testing showed that an array of 134 x 6800 ohm 1 watt carbon composition resistors would be satisfactory. These were formed into a roughly square array of resistors standing on end, and sandwiched between two conductive planes (epoxy PCB), one of which was drilled with large holes so that air could be forced past the resistors. The near square shape was selected because a large number of resistors could be mounted around its perimeter, while the stray capacitance could be minimized and the air flow maximized by drilling a large number of ventilation holes in the lower PCB. The stray inductance of this shape is also very low because the conductive planes are short and fat, and the resistors have near zero lead lengths. Best of all, the planes are also effective heat dissipaters. The fan used for cooling was a 240 V 14 watt 80mm diameter unit. A 12 Vdc fan was not used because its semiconductor driven motor will almost certainly misbehave in the high RF fields within the dummy load case. This set-up was extensively tested at 80 metres and worked well.

The next design step was to establish how the design performed as the input frequency was varied. For this I am much indebted to Keith Gooley VK5OQ for his out of hours testing of the dummy load using a Hewlett Packard network analyser.

The results were interesting. As can be seen from figure 1, the VSWR linearly increases with frequency, reaching 1.5 at 30 MHz. Analysis shows this is due to the effect of a shunt capacitance of 48 pf (8 pf between the conductive planes and 40 pf due to the resistors).

Now if the dummy load is being used to test a conventional high power tube linear amplifier with its output tuning and loading capacitors, the 48 pf has no significance provided the leads between the amplifier and load are kept short. It simply becomes part of the loading capacitance at the amplifier output, which is never smaller than 150 pf at 30 MHz, even in amplifiers requiring quite high values of plate load resistance. The load therefore looks like a pure 50 ohm resistance and is useful to well beyond 30 MHz unmodified.

The situation is entirely different if the load is attached to the wide band FET or transistor output amplifier found in a typical modern transceiver. Here there is no mechanism to swallow up the effects of the stray capacitance, and steps must be taken within the dummy load to compensate for it.

Now a parallel circuit can be mathematically transformed to an equivalent series circuit at any single frequency. Doing this at 50 MHz generates a circuit of 31.87 ohm in series with 132 pf, which is equivalent in its effects to the parallel circuit of 50 ohm and 48 pf. If we use a series inductor to resonate with the 132 pf at 50 MHz, we are left with a pure resistance of 31.87 ohm at 50 MHz and a nearly pure but somewhat larger value of resistor at frequencies lower than this. (At very low frequencies the equivalent series circuit is 50 ohm in series with a near infinite capacitance). Some work with a Smith chart shows the VSWR up to 30 MHz should not exceed 1.2, and a little

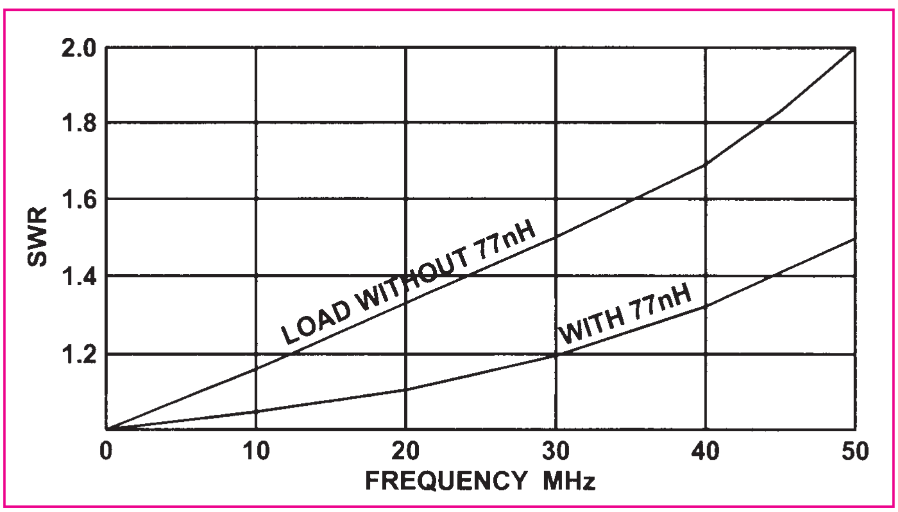

Figure 1

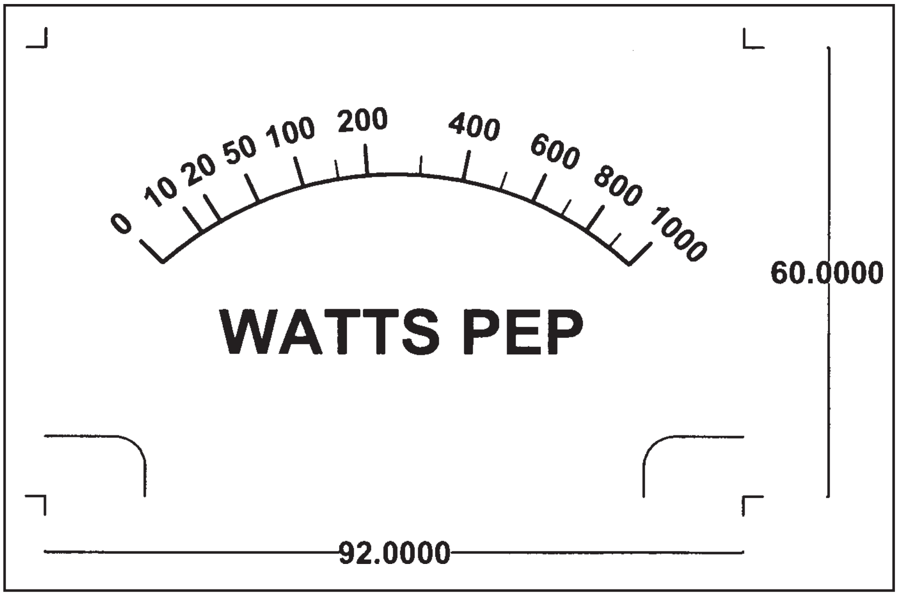

Figure 2

calculation shows the inductor value required is 77 nano-henries. Further testing on the network analyser by VK5OQ showed that all this theory works! (see figure1). The engineering of our dummy load thus simply becomes making up the resistor array, and then frequency compensating it with an inductor which will resonate with 132 pf at 50 MHz. A dip meter is used to make the inductor, and the NPO ceramic capacitors used to make up the 132 pf for inductor testing should have near zero lead lengths. The wire gauge selected for the inductor should reflect the 500 watt rating of the load (2.5mm). Also note that only the 1 watt resistors specified should be used, and the physical layout should be closely identical, as these two things determine the 48 pf of stray capacitance, which we are compensating with the inductor.

Assembly and calibration

First drill both PCBs as per the drawings, and then drill the back panel of your metal box to match the hole pattern in the bottom PCB. Now solder the four brass nuts to the lower PCB using steel screws to temporarily hold the nuts in position while soldering occurs.

Next, bend the bottom lead of each 6k8 resistor at right angles to the resistor axis and as close to the body as possible. Form the inner rectangle of resistors by inserting the straight resistor lead of each 6k8 through the hole in the upper PCB. When this lead is soldered to the upper PCB surface, the resistor body should be hard up against the PCB. The bent lead should face outwards and all resistors should be equally spaced and at right angles to the PCB surface. This assembly is then soldered to the lower PCB, and the excess resistor leads trimmed off. Now add the outer row of resistors one at a time, soldering these into final position. Do not be tempted to assemble both resistor rows at once – it doesn't work. You should end up with a neat assembly where the resistors have virtually zero lead lengths and the PCBs are spaced 13 mm apart. The detector assembly and sampling resistor network for the CRO are added in space, at the edge of the resistor array. The only comment necessary on the remaining

Photo 1

Photo 2

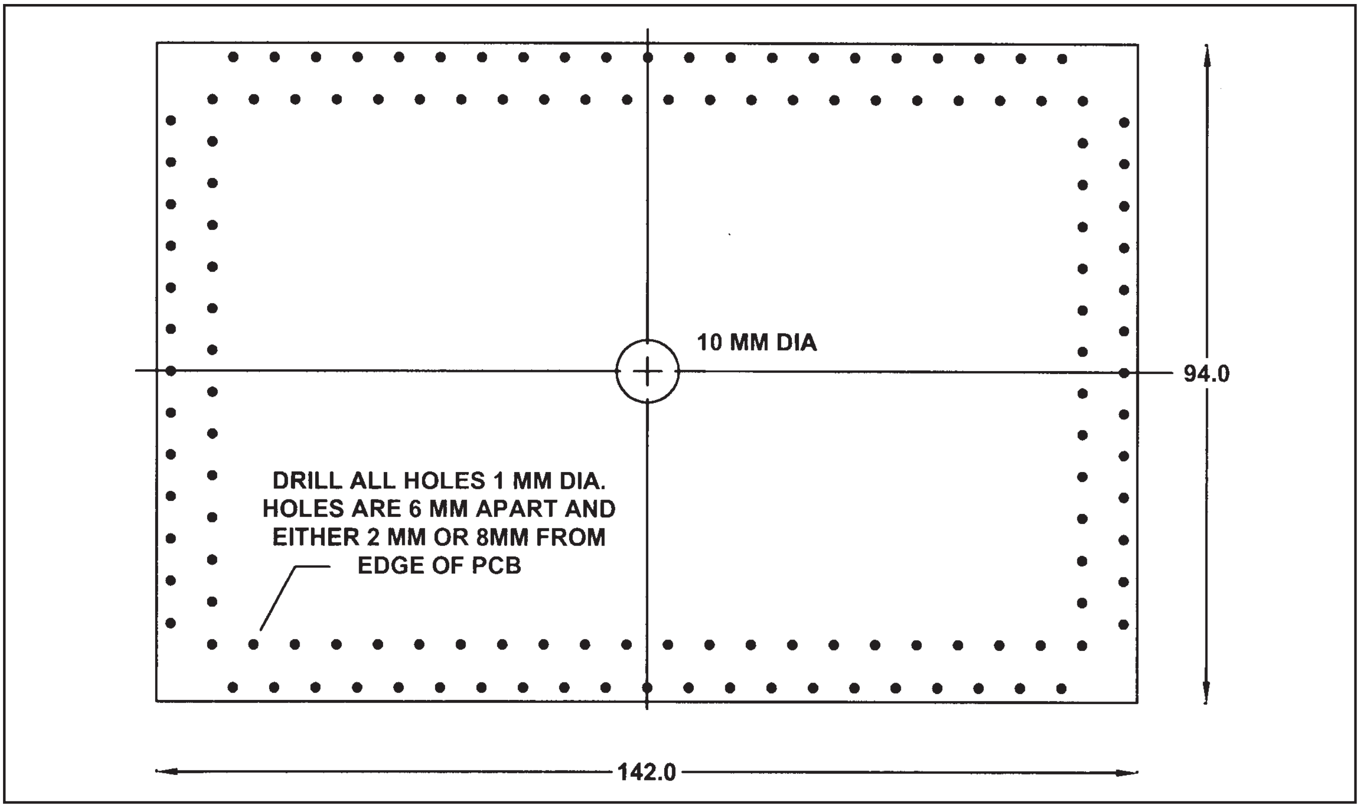

Figure 3. Upper PCB drilling details

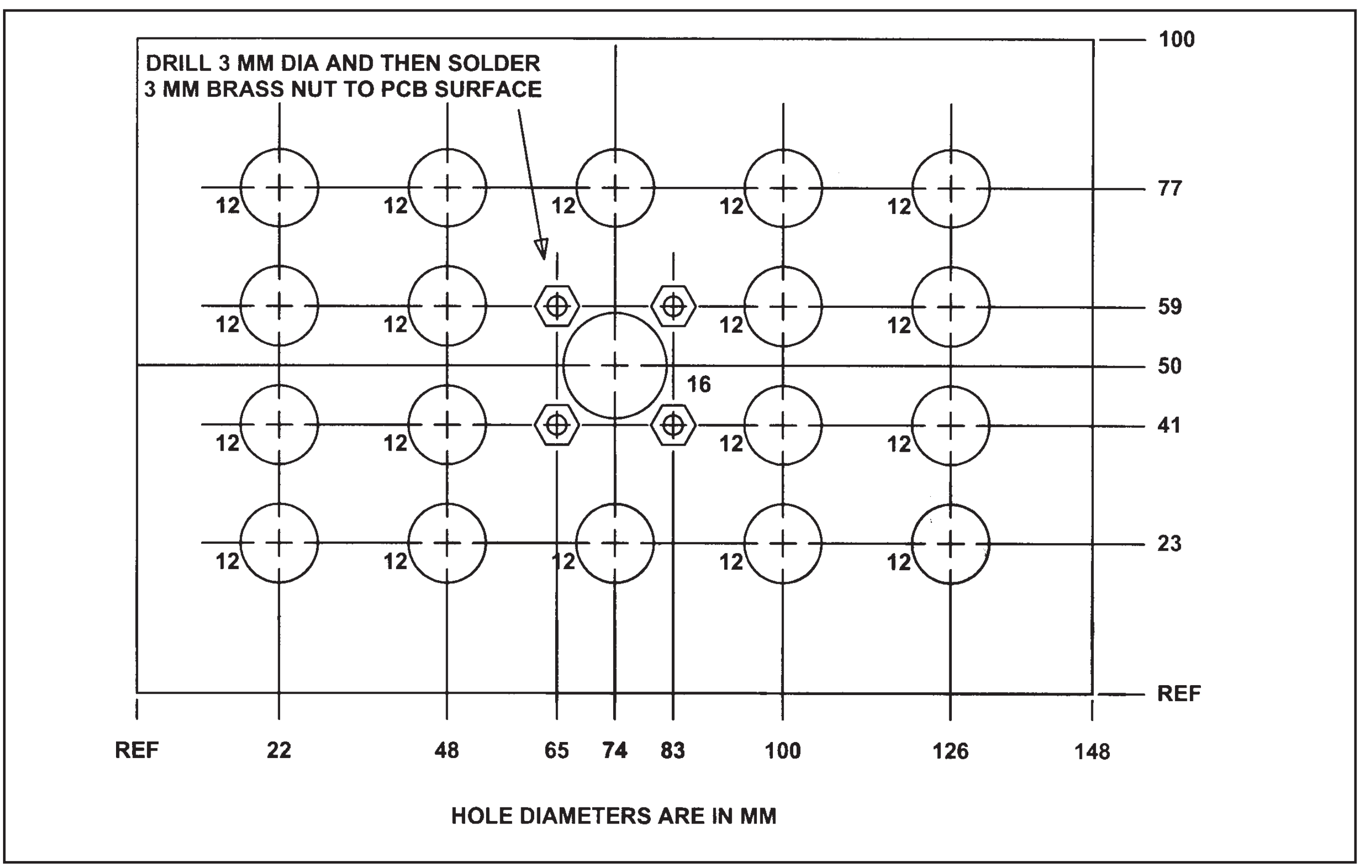

Figure 4. Lower PCB drilling details

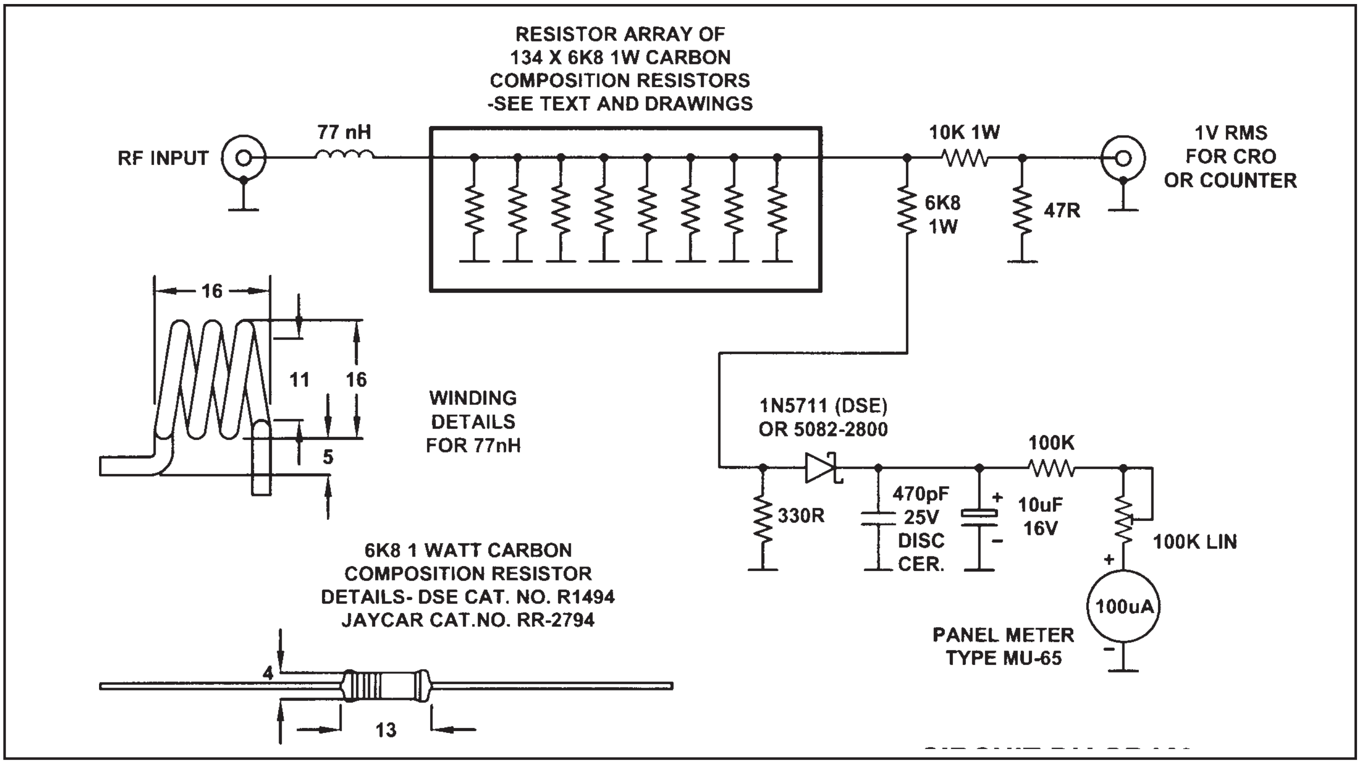

Figure 5. Circuit diagram 1kW PEP power meter and dummy load

assembly is to make sure that the mains supply to the 240 V fan is both safely wired and securely earthed to the metal case.

If the assembled array has a resistance lower than 50 ohm due to tolerances, adjust it to exactly 50 ohm by removing 6k8 resistors until the value is right. Replace the removed resistors with physically identical 1 M ohm resistors, so that the air flow through the array is not upset. Alternatively, if the resistance is high, add a few resistors around the perimeter keeping their lead lengths short.

Calibration is simple. So the power meter will indicate watt PEP, a very long detector time constant is necessary. This is selected so that the carrier peak voltage in between modulation peaks is stored without much ripple, and the lowest frequency at which these peaks are likely to occur is 150 Hz for speech or 700 Hz or so for two tone testing. If we instead assume that peaks occur at a 50 Hz rate and lengthen the time constant accordingly, we can calibrate the load using conventional 50 Hz ac mains power and a DVM. To calibrate the load proceed as follows:

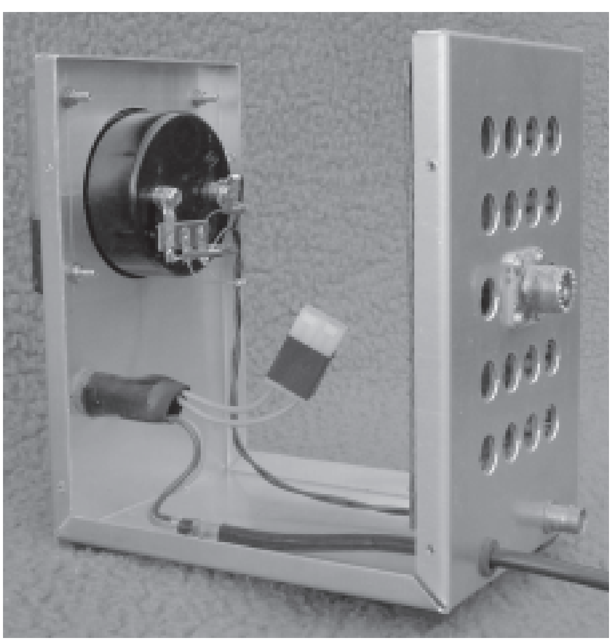

Photo 3

Find a reasonably heavy 50 Hz power transformer capable of supplying an ISOLATED output voltage of between 50 VRMS (50 watt) and 120 VRMS (288 watt) to the 50 ohm load. Measure the AC voltage across the load terminals with your DVM, calculate the power in the load from $V^2/50$ ohm, and adjust the trim pot until the meter reads correctly - DONE!

Finally, a few words on power measurements. This form of metering measures the RMS power existing at the peak of a modulation envelope (watt PEP) and consequently is useful for two tone SSB measurements, peak audio SSB measurements, modulated DSB envelopes, modulated AM, or any other measurement where the RF carrier envelope varies cyclically between a maximum and minimum e.g. Morse code. For transmission modes where the height of the envelope does not vary eg FM, un-modulated AM, single tone SSB, the metering simply indicates RMS power.

Note that the load has a maximum rating of 500 watt and can only be used to its 1 kW limit for two tones SSB testing where the average carrier power is one half of the peak envelope power. Single tone testing to 1kW has not been tried (PEP = average power) although the load will probably survive quite happily for brief periods.

ar