• Basic Amateur Radio

The (Not Quite) Ultimate Dummy Load

What has 66 resistors, dissipates 132 watts, is easy to construct and is educational? This dummy load may be the answer to what to do with the box of resistors Aunt Millie gave you for Christmas.

By Peter O'Dell,* AE8Q

That will never fly. I'd be surprised if that thing works above 20 meters. You're kidding!

Such was the chorus of support I received as I announced my intention to build a large dummy load from 2-watt, carbon-composition resistors. I must admit that I wasn't so sure that it would work myself, but I am a rather stubborn type who has to prove things for himself.

A dummy load is simply a resistive device that should be much better at generating heat than propagating rf energy (Fig. 1). The first dummy load I had was a 100-watt electric light bulb. Don't laugh; it worked. It was a good visual tuning indicator and the tube finals didn't seem to mind that it probably was not exactly a 50 Ω load. I've never tried one with a rig that has solid-state finals, but it should work with them, up to maybe 10 meters or so. If a light bulb presents such a good match, why do people use anything else? Ask some people who have been around for a few years. One staff member recalls working another station about 10 to 15 miles away with 30 watts into a light-bulb "dummy load." In fact, light bulbs are better signal radiators than the "antennas" that some hams use.

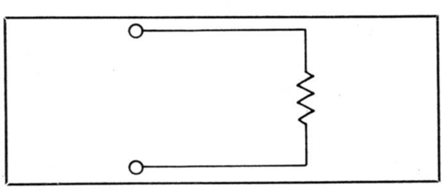
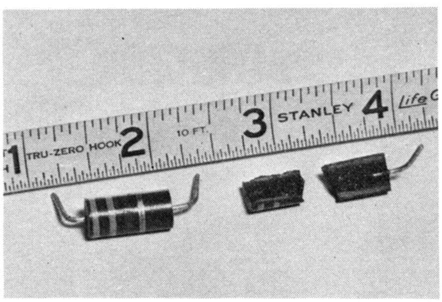
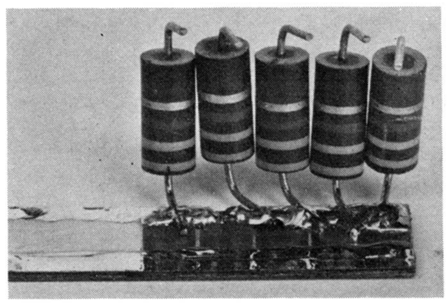


Fig. 1 — A dummy load consists of nothing more than a resistive device with two terminals. It converts the rf energy coming into it on the transmission line to heat.

*Basic Radio Editor



How do you spot a 2-watt carbon resistor? If it is a little over 1/2 inch (13 mm) long, then it is the right wattage. If you are not sure if it is carbon, take a blunt object and smash the resistor. A carbon composition resistor will look something like the pieces on the right when broken open; a wire-wound resistor will have wire inside (naturally).



Construction technique for assembling resistors. A bead of solder is run lengthwise along both edges of the pc board. In our case the leads of the resistors were precut and bent in the shape shown, resulting in a simple procedure for mounting. If your resistors have long, straight leads, it may be advantageous to adopt a different construction technique.

Besides radiation characteristics, the other important considerations for a dummy load are that it present something near a 50 Ω load and that it not be reactive. In other words, it should be a "pure" resistance. Obviously, there must be some kind of conductor that connects the transmission line to the resistor. For the lower frequencies, these conductors or leads are of relatively minor concern; but as we move toward the very-high frequencies the leads begin to act like inductors or capacitors, depending upon their size and location. Therefore, a dummy load that looks like a pure resistance to an 80-meter transmitter may look like a resistor in series with an inductor or capacitor to a transmitter operating at 10 meters. This effect will become more pronounced as the frequency is increased.

If we are talking about enough 2-watt resistors to handle the output of a typical hf transceiver of 100 watts or so, then we are also talking about several leads to several resistors. Without experimenting, it is quite reasonable to *assume* that the composite load will be quite reactive. Hence, the justifiable skepticism that greeted my idea.

Two By Two

What happens to the resistance and power-handling capabilities of resistors in parallel? Let's take a look at the case where we are dealing with only two resistors (Fig. 2). As depicted in Fig. 2A, the total resistance of two resistors in parallel is equal to the reciprocal of the sum of the reciprocals of the individual resistors. Let us suppose that we have the situation that is depicted in Fig. 2B. R1 is 100 Ω and R2 is 150 Ω; both resistors are

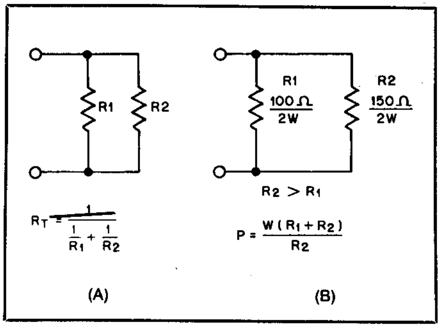


Fig. 2 — A shows two resistors in parallel and the formula for calculating the resistance of the circuit. The diagram and formula at B show what happens when resistors of unequal value are wired in parallel.

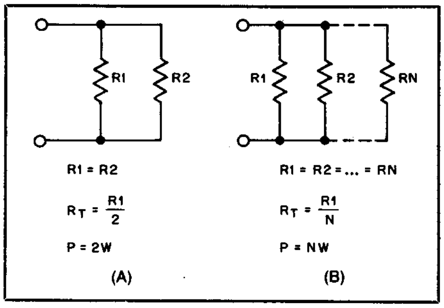


Fig. 3 — Using resistors of the same value, we can maximize the ability to safely dissipate heat. B shows the simple formulas that can be used to calculate the total circuit resistance and the effective wattage when equal-value resistors are used.

2-watt carbon composition. The reciprocal of 100 is 0.01; the reciprocal of 150 is 0.0067. The sum of these two numbers is 0.0167, which produces a reciprocal of 60 (ohms) for the effective resistance of the circuit. How much power can safely be dissipated by these two resistors in parallel? If you said 4 watts because both resistors are of the 2-watt size and, therefore, the power-handling ability should be the sum of the two, think again.

Each resistor by itself can handle 2 watts. But how is this power level determined? Power is equal to the voltage times the current. Since the two resistors are in parallel the voltage across one will always be the same as the voltage across the other. However, the current through each individual resistor is equal to the voltage divided by the resistance of that resistor. Thus, more current will flow through the lower value resistor for any given voltage across the resistors. Because that resistor has more current flowing through it, it will reach its level of maximum safe dissipation (2 watts in this case) before the other resistor reaches its maximum safe level. The formula for calculating the total safe power dissipation level (P) of two resistors in parallel is given in Fig. 2B. R2 is assumed to be larger than R1 and both resistors have the same wattage rating (W). This formula can be derived from Ohm's Law by simple algebraic manipulation. (I bet there are three or four of you who would enjoy deriving it.)

If we insert the values given in the example in Fig. 2B, we find that the total safe power dissipation is only 3.33 watts. If we are interested in maximizing the power dissipation for the fewest number of resistors, then intuitively we will want to use resistors of equal wattage and resistance.

The More the Merrier

Fig. 3 depicts what happens when we parallel 2 or more resistors of equal resistance and equal wattage. In this special case, the resistance of the circuit R_t is equal to one-half the resistance of one of the resistors. The formula for this relationship can be derived from the more general formula for resistors in parallel by simple algebraic manipulation. (Is anyone interested in staying after class and working out the math involved?) The safe power dissipation is equal to twice the wattage rating of the individual resistors.

This relationship can be extended to three or more resistors, as depicted in Fig. 3B. The resistors are numbered sequentially with N being the number of the last resistor in the chain. Again, all resistors are equal in resistance and wattage. Can you derive the formulas for the total resistance (R_t) and the total wattage (P)?

If we use three equal resistors, we find that the resistance of the three in parallel will be equal to one-third the resistance of the individual resistors and that the power rating will be tripled. If we go to four resistors, the total resistance will be one-fourth and the power rating will be four times that of the individual resistors. We can extend this relationship as far as we need to.

Suppose that we want to build a 50 Ω load from 2-watt resistors. The load will be required to handle the output power of our typical transmitter (120 watts maximum). We will be using equal-value resistors to minimize the number of resistors needed to safely dissipate the required amount of power. Therefore, we will need at least 60 of them (120 watts divided by 2-watt resistors equals 60 resistors). Plugging values into the formula in Fig. 3B and solving for R1, we find that the resistors must be 3000 Ω each to give us a total resistance of 50 Ω. On the other hand (and more likely in reality), if we had a stock of 3000-Ω resistors, we could calculate the number needed to make a 50 Ω load by dividing 3000 Ω by 50 Ω.

What for Watts

Throughout this article we have been talking about 2-watt resistors. The reason is that the largest stock-value wattage for carbon-composition resistors is usually 2 watts. Larger wattage resistors are often available, but they almost invariably are wire-wound. These resistors are pretty much what the name implies — a precise length of high-resistance wire wound into a coil and encased in some heat-conducting package. Because of the construction, wire-wound resistors are totally unsuitable for dummy loads; they're highly reactive.

Where do you get 2-watt carbon composition resistors these days? You probably won't find them at your local CB-supply house or discount store. You will find them at large industrial electronic supply houses, but the cost may be prohibitive. I checked the catalog of a national distributor (with a $25 minimum purchase) and found that they sell 2-watt resistors for about $12 per hundred. Such pricing is reasonable if several individuals go together and buy enough to exceed the minimum order. If it turns out that this is the only way that you can obtain enough resistors to build one dummy load and you have no one to share the costs with, it will cost you less to buy a commercial dummy load or kit. Probably the best source for the resistors is a hamfest flea market. I have often seen bags of resistors of the same value go for $2 or less at these gatherings.

Here is where knowing the formulas that we developed earlier will help you. Surplus dealers will not likely have a wide range of values to choose from. It will be incumbent upon you to do a little mental arithmetic and decide which value resistors are suitable for use and which are not, in addition to the number needed.

Table 1
Resistor-Capacitor Color Code

Color	*Significant Figure*	*Decimal Multiplier*	*Tolerance (%)*	*Voltage Rating**
Black	0	1		
Brown	1	10	1*	100
Red	2	100	2*	200
Orange	3	1,000	3*	300
Yellow	4	10,000	4*	400
Green	5	100,000	5*	500
Blue	6	1,000,000	6*	600
Violet	7	10,000,000	7*	700
Gray	8	100,000,000	8*	800
White	9	1,000,000,000	9*	900
Gold	-	0.1	5	1000
Silver	-	0.01	10	2000
No Color	-		20	500

*Applies to capacitors only

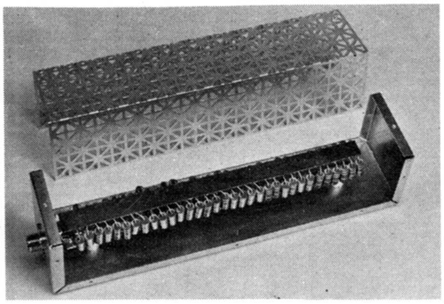
Since carbon-composition resistors are marked with the standard color code (Table 1), you may want to memorize it or carry a copy with you (a full explanation of the color code can be found in chapter 17 of *The 1981 Radio Amateur's Handbook*, available from ARRL for $10). Carbon-composition resistors are usually tubular in construction, with the value of the resistor specified by the color code; wire-wound resistors are customarily encased in oblong, box-like structures, with the value of the resistor printed on the top. If there is any doubt about what kind of resistors you have, it would be advisable to break one apart and see what is inside.

Wet vs. Dry

As can be seen from the accompanying photographs, we have constructed the dummy load in two different formats. The enlongated version is meant to be used as an air-cooled (dry) dummy load. The heat dissipated in the resistors of the dummy load is transferred to the air around the load by convection. If the duty cycle is less than 100%, the power rating of the dummy load can be exceeded. A rule of thumb is that if the resistors become too hot to touch (don't key the transmitter while touching them!) then you should reduce the power level, the duty cycle or both. A perforated cabinet may be constructed to further reduce any incidental radiation.

The second version of the dummy load is shown attached to a paint-can lid. A significant improvement in the transfer of heat can be accomplished by immersing the dummy load into an oil bath. Thus, a dummy load that would be rated for 100 watts dry may be able to withstand several hundred watts for a minute or two if submerged in oil. The best oil to use is transformer oil, which you may be able to obtain from your local utility company. If local hams are employed by the utility, check with them. Be wary of transformer oil that individuals may have had for several years because it may be contaminated with PCB, a highly toxic substance. If you have no luck with transformer oil, you may want to use mineral oil. Purchased in a drug store, mineral oil can cost up to $3 per pint. The reason for the high cost is that the product has been certified as fit for human consumption and it may carry the label of a major pharmaceutical house. Veterinarians have used quantities of mineral oil to treat horses, cattle and other large animals for years. A check with local veterinarians specializing in large animals indicated that mineral oil should be available from this source for about $5 to $10 per gallon. (It may be less embarrassing as well as less expensive to buy a gallon of mineral oil from the veterinarian.)

Over the years hams have used various other oils as a coolant in dummy loads.



Dry dummy load. The resistors are mounted in two long rows. The bottom pc board is mounted to two standoff insulators. The enclosure was specially constructed in the ARRL lab to fit the dummy load. Any metal cabinet that the dummy load will fit in will serve to reduce incidental radiation and to prevent possible accidental contact when the transmitter is being keyed.

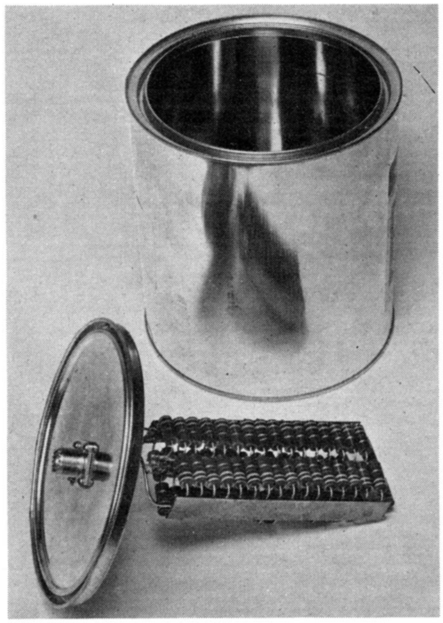
Most of these oils, including motor oil and cooking oils, have a considerably lower flash point than transformer oil or mineral oil. We advise you to err on the side of caution in this matter — one accidental fire could easily cost 20 times the saving of using a less costly oil.

Whether to build wet or dry is a choice each builder will have to decide. A dry dummy load is certainly less messy and easier to build. Also, there is no need to scrounge for an empty paint can and oil to fill it. On the other hand, a dry dummy load will not handle nearly as much power.

Putting It Together

The 3300-Ω resistors I used were a portion of a large donation of parts from a member. Each resistor came with the leads clipped short and bent as shown in the photograph. My first thought was to drill equally spaced holes through the circuit board and mount the resistors with the shortest possible leads. Common sense [read: laziness — Ed.] intervened and I decided to solder the resistors directly to the circuit board without straightening them or drilling the holes. Two strips of double-sided circuit board, 1-inch wide by whatever length necessary, are used if the dry dummy load is to be constructed. You will need three strips half as long if the wet format is chosen. The outer copper laminations are not connected. We are not sure what the effect will be to use single-sided pc board — we ran out of resistors before we thought of trying it that way. One side of the bank of resistors is connected to the center pin of a coax connector and the other side is attached to the ground side. Make the connecting leads as short as possible.

Once the dummy load has been built, attach an SWR indicator and transmitter and check the SWR of the dummy load. On both models constructed in the lab we showed an SWR no greater than 1.1 to 1, 80 through 10 meters. Incidentally, we used a reactance bridge to double check



The wet dummy load. In this format the length has been halved by constructing with two sets of two rows each. A small pinhole is punched in the top of the can to allow the can to "breathe." The can shown was obtained from a chemical supply house. If you have available a paint can that has been emptied it should work — be sure to clean out the paint before adding the oil. Some paint and hardware stores that buy paint in bulk may be willing to sell you a new, clean paint can.

the figures obtained from the SWR bridge and found no discrepancy. At 2 meters we found that the dry dummy load had an SWR of 1.8 to 1 and the wet one had an SWR of 2.6 to 1. While it may not be suitable for vhf work, this design is perfectly adequate for hf.

Lessons to Be Learned

I am not one who advocates building anything and everything just for the sake of building it — particularly if the end result is not better and less expensive than something that can be bought. (The SWR figures on this dummy load are not as good as those of most commercial dummy loads, especially at vhf.) You are justified in building this if you happen to have enough resistors around, you know where you can get them cheap or you want to do it as a group project and go for a quantity discount.

This project demonstrates the value of knowing the most basic fundamentals of electronics — and being able to recognize what is significant and what is not. If you know the fundamentals, you will be in a better position to make use of the bargains that you encounter at flea markets and surplus houses. If you know the fundamentals of electronics, you will be able to make do in an emergency whether you have the exact replacement part or not. If you don't know the fundamentals of electronics, now is the time to start learning them. QST