LIGHT BULBS AS RF POWER INDICATORS

John A. Houser WB2GQY
23 Washington St.
Rensselaer NY 12144

The major appeal to the amateur – as well as some commercial applications – of light bulbs as rf power indicators is low cost. To this must be added the universal availability of bulbs and screwbase sockets for pennies.

As low cost is of primary interest to well over 50% of those interested in any project, and as I have always had an insatiable desire to find out the why's and wherefore's of standard light bulbs as rf power indicators, I decided it might be the opportune time to do a resarch project and determine once and for all just which bulbs might be suitable and which might not be, and also to determine whether light bulbs would make *good* rf power indicators, or poor, and to find out what precautions might have to be taken if one decided he was going to take this low-cost path of determining his transmitter output power rather than go for a more expensive power output meter.

Also, power output meters in the higher wattage ranges become quite expensive compared to the $2 to $5 which might be expended in a light bulb indicator. In general, porcelain screw bases are available for from 12¢ to 25¢ each, and bulbs from 15¢ to 65¢ each, and not more than four of each are necessary for up to 3 KW power indication.

Table 1 lists most of the common types of electric light bulbs readily available. One look at this table immediately reveals why such light bulbs might not be such good rf power indicators as some folks may have thought they were in the past. It also reveals that some very special precautions have to be taken in using them, or the user may find he has overloaded his transmitter and burned up a few components which might be expensive to replace.

The extremely high ratio of cold to hot filament resistance in all types of these bulbs immediately struck me as being the most undesirable factor in using them.

It is very easy to see, for instance, that if one wished to use a 250W bulb for indication on a 250W transmitter, and he computed the resistance at 250W to be 53Ω, (which it is, but only when *hot*), he would assume he had just about a perfectly matched indicator to plug in in place of his 52.5Ω feed line.

However, from this table, it is apparent that this 53Ω resistance is attained *only* at full brilliance and wattage, and the actual cold resistance is only 3.5Ω. In other words, if the bulb were connected to the antenna terminals of the transmitter, and the trans-

Table 1
Variation in Resistance, Cold to Hot State, Common Variety of Electric Light Bulbs.

Bulb Rating Watts At 115V	Cold Filament Resistance	Hot Filament Resistance	Ratio Cold to Hot Filament Res. (Approx.)
7.5	166	1750	1 to 10
25	40	529	1 to 13
40	27	331	1 to 12
60	20	219	1 to 11
100	9	132	1 to 15
150	6	83	1 to 14
200	4.5	65	1 to 14
250	3.5	53	1 to 15
500	2	26	1 to 13
750	1+	17.7	1 to 15

mitter keyed full power, the transmitter would be looking into *not* 53Ω, but 3.5Ω, which is a lot of difference, and an extremely low value for any pi network to match.

For a few seconds, until the filament attained full brilliance, the transmitter would be subjected to a terrific overload, due to this impedance mismatch.

Therefore the first precaution which might be emphasized in using light bulbs would be *not* to key the transmitter at full power with a cold bulb, but to gradually bring the power from some lower value to full power as the bulb attains full brightness (and hot, matching resistance).

Not until I got into this project did I realize the very high ratio of resistance of these filaments from the cold to hot state; I don't suppose very many people do. It also brings to mind how the house electric meter must jump every time a bulb is snapped on in the house. This is not an ad for those light dimmers being sold at all the electrical stores, but it sure brings to mind that power bills could be cut appreciably through their use, i.e., bringing the bulb gradually to full brilliance instead of just snapping on a switch.

Getting back to the bulbs, Table 2 gives in various configurations series, and/or parallel combinations which would be most likely to give the amateur a load for a particular transmitter power output, in nominal impedances near 52 and 72Ω. If the configuration mentions 200W, this does not mean that it would be suitable for indicating the output of a 100W output transmitter, because at half brightness, the resistance offered by the bulb is not identical to that at full brightness.

While a differance of an ohm or two would not be serious, nor would a difference of as much as five, or even ten watts, at high power levels, at low power levels less than 100W, for instance, such differences would be seen to become increasingly serious from the matched impedance standpoint. The configurations given match quite a variety of standard line impedances and a wide range of power outputs. Matches can be obtained for RG-8, 11, 17, 13, 58 and 59 type cable.[1]

One may not realize without measurement that the lead length of the filament support wires alone inside the 25–150W bulbs is very close to 18 cm. Even though they are coiled on a 2 to 1 ratio, the filament is inductive in every sense of the word. At higher frequencies, the filament support wires would appear inductive, and to these factors must be added the parallel capacity of the screwbase shell and the central base contact wafer. Even though such capacity is small, it would become significant at most amateur frequencies above the 30 MHz range. Though the 22 cm total wire path would perhaps indicate a bulb could be used up to 300 MHz, such is not at all the case.

It is easy to see that the sometimes suggested trick of using a capacitor in series with a light bulb as a load should be approached with caution, for it would be very easy indeed to run into a series resonant circuit which might result in damage to the

Table 2

Possible Configurations for Various Power Outputs at Various Impedance Terminations

A. – Nominal 70 to 73Ω Impedance Loads:		
175W Load:	3–60W bulbs in parallel	(73Ω)
	OR	
	7–25W bulbs in parallel	(70Ω)
3,000W Load:		
	4–750W bulbs in series	(71Ω)
B.) Nominal 50 to 55Ω Impedance Loads:		
250W Load:	4–60W bulbs in parallel	(54.9Ω)
500W Load:	2–150W bulbs in series, both paralleled by 1–150W bulb	(55Ω)
1,000W Load:	2–500W bulbs in series	(53.6Ω)
2,250W load:	3–750W bulbs in series	(53.1Ω)

transmitter to which such circuit were connected.

In the course of my preparation of this article, I discussed the ramifications with a number of interested hams. Some of them suggested I extend the research to include the use of the smaller types of indicator (pilot) bulbs as loads for testing out transmitters with power outputs in the 1W to 20W range, not only just for amateur applications, but also with a view to using them as loads in testing FM transmitters.

When one considers that there are well over 100 types of these small bulbs, rated from .001W to 2W, and if all of these were to be considered individually, it could take a vast amount of time – and eventually one would end up with perhaps only five or so of these bulbs that would be at all suitable, so such research was not included in this article. However it did open up a field in which there may be a demand for information and may be the subject of a subsequent article.

Frequency Ranges

The use of standard screw-base ceramic or steatite porcelain light bulb sockets is entirely feasible for all of the configurations shown and will handle all amateur bands, 160 through 10. Naturally the leads from socket to socket should be as short as possible in either the series and/or parallel configurations. I found these leads can be kept to approximately 2 cm for such interconnections. Likewise, the coax termination lead should be kept to 2 cm or less.

If extra precautions as to lead lengths are observed, and the bases of the bulbs removed to enable connections directly to the stem wires, it would appear reasonable to suspect that these bulbs might be used for 6, 5, and perhaps 2 meter bands, but it is also quite evident the 2 meter band would be the practical limit.

One should be able to conjecture that light bulbs as power rf indicators are not quite the equal of well-designed power output meters which maintain their rated impedances over a very wide power output range – bulbs do not – but then, they *are* cheap in comparison.

Visual comparison of brightness is completely satisfactory for comparison purposes. For instance, a 500W bulb connected to the 115V mains should show the same brilliance as one of the 500W bulbs as used in the 1 KW load.

Actually a transmitter supposedly putting out 2,000W PEP is putting out something less than 1,000W with average voice modulation; it would be more of the order of 500–750W average power. Remember that the light bulb is only going to show average power output, not peak, and as ham transmitters are limited to 1,000W dc input to the final amplifier, one cannot expect much more than 500–750W output (average) unless the efficiency of the final amplifier stage approaches 85% which is very unusual, although I am hearing lately that certain high-power transistors are in development which will deliver such high efficiency figures; a bit above that which heretofore has been obtainable with tubes. You should be hearing a lot more about these super-efficiency transistors in the near future; and I expect them to be appearing in certain ham transmitters within a year or so.

Naturally a CW transmitter with the final operated Class C may deliver as much as 850W with 1,000W dc input, while a DSB transmitter on phone could not be expected to deliver more than 650W with Class A or B modulation.

The research and conclusions I reached on this project brought to mind the old subject of using light bulbs in series with primaries of transformers to reduce the secondary output voltages, which is a trick which has been used for years by hams and others. The information contained herein indicates they are not only quite suitable for such usage, but in fact make quite ideal voltage regulators of a sort.

In fact, the question immediately arises as to why bulbs would not make rather ideal voltage regulators for high voltage supplies if used as a variable-resistance dc regulator in the dc leg. This again opens up a field which might bear intense investigation.

. . .WB2GQY

[1] Solid Dielectric RF Transmission Lines, W8LUQ, *Radio News* Oct. 1946.
Line Matching: Table of Power and Voltage Loss in DB, *Radio News* Feb. 1947.