Miles Per What?

For many years, Radio Amateurs interested in low-power communication have had a benchmark against which to judge the efficiency of their station. It's known as the 1,000 Miles Per watt award and is currently sponsored by the QRP Amateur Radio Club International. The award may be issued *….to any Radio Amateur transmitting from, or receiving the transmission of, a QRP station, such that the Great Circle Bearing distance between the two stations, divided by the QRP stations power output, equals or exceeds 1000 miles per watt*. Table 1 lists the current (as of June 2000) world records.

Band (MHz)	Power (µW)	Distance (miles)	Miles per watt.
1.8	20,000.00	536.00	26,800
3.5	613.00	522.00	851,550
7	221.00	452.00	2,045,249
10	480.00	774.00	1,612,500
14	80.00	1,294.00	16,175,000
18	5,000.00	908.00	181,600
21	39.90	3,217.00	80,626,566
24	12,000.00	1,531.00	127,583
28	6.00	1,310.00	218,333,333
50	0.05	6.71	134,200,000
144	0.16	14.00	87,500,000
1296	150.00	346.00	2,306,667
5760	155.00	37.00	238,710
10GHz	1,000.00	124.00	124,000

Table 1. World miles-per-watt distance records as of June 2000

Unfortunately, simply dividing the distance by the transmitter power to get a miles-per-watt figure, favours stations running very low powers communicating over short distances. Therefore, as a figure of merit, the simple miles-per-watt measurement is flawed.

While testing a 1mW, 3.5MHz QRP transmitter, I easily made contact with another station some 2.1 miles distant. The aerial I used for the tests was a 7MHz dipole and the path to the other station was hardly line-of-sight; the r.f. having to negotiate a low hill and many buildings. Hardly award-winning stuff. And yet according to the miles-per-watt formula, I had managed 2,100 miles per watt, and so was eligible for a certificate.

I felt this was nonsense and so decided to see how the formula could be modified in order to produce a more realistic figure of merit. The modification turned out to be quite simple and quite obvious - simply divide the distance in miles, by the ***square-root*** of the power in watts. Now my 1mW transmitter was only managing 66.4 **miles per root-watt**. A much more sensible figure, so I thought.

The following example should make it clear why the square-root of the power needs to be used as the divisor rather than just the power. Figure 1 shows a receiving station and two transmitting stations, one at 1,000 miles distant and one at 500 miles distant. Transmitter A and transmitter B differ only in the amount of power they can produce (same transmission mode, feeder, aerial system, etc.).

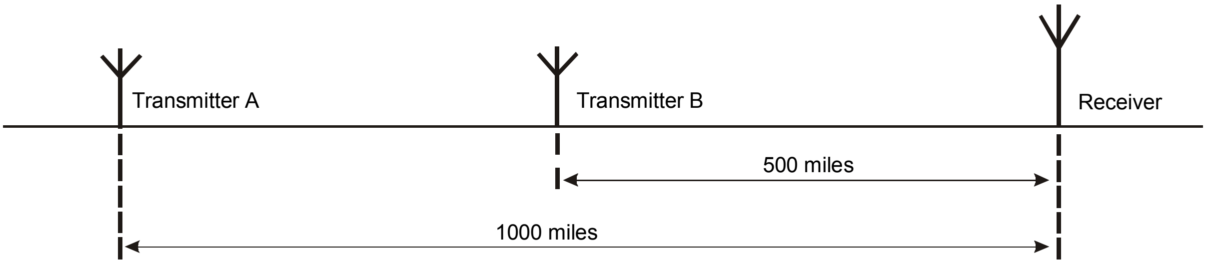

Figure 1.

Imagine transmitter A runs exactly 1W and produces a copyable signal of field strength ε, at the receiving station. Transmitter A can claim to have achieved both 1,000 miles per watt **and** 1,000 miles per root-watt. Next, transmitter B pops-up at a distance of 500 miles running 0.5W. Transmitter B claims his 1,000 miles-per-watt certificate because 500 miles running 0.5W is just as difficult as 1,000 miles with 1W, isn't it? Well, no, it isn't.

All other things being equal, and assuming free-space propagation, the field strength at the receiving aerial is proportional to the current flowing in the transmitting aerial and inversely proportional to the distance between the transmitting aerial and the receiving aerial. For example, doubling the distance halves the field strength (note: field strength, not power density), and doubling the current in the transmitting aerial doubles the field strength at the receiving aerial. If you want the detail, see chapter 2 of **HF Antennas For All Locations** by Les Moxon G6XN (ISBN 1 872309 15 1, published by The Radio Society of Great Britain).

In our example, halving the distance - by using transmitter B - would double the received field strength, provided we maintained the transmitter power at 1W. But transmitter B is actually running only half the power of transmitter A, namely 0.5W. And here's the twist, halving the power reduces the current in transmitter B's aerial to **0.707** of its 1 watt value (0.707 is the square root of 0.5). Remember, power is proportional to current **squared** so current is proportional to the **square-root** of power.

Although we've doubled the field strength by halving the distance, we've only reduced the field strength by about **one-third** by halving the power. More precisely, the field strength is now 0.707ε / 0.5, which is equal to 1.414ε. That's actually an **increase** in field strength of some 41%. Now it's quite clear why the simple miles-per-watt formula favours smaller powers used over short distances.

To make transmitter B's signal (field strength) equal to that of transmitter A, transmitter B should only run 0.25W. That halves the current in transmitter B's aerial (relative to 1W) and our new formula gives us the 'right' answer:

$$\frac{\text{Distance in miles}}{\sqrt{\text{Power in Watts}}} = \frac{500}{\sqrt{0.25}} = 1000$$

For comparison purposes, I've added a miles per root-watt column to the table of world records - see Table 2.

Band (MHz)	Power (μW)	Distance (miles)	Miles per watt	Miles per root-watt
1.8	20,000.00	536.00	26,800	3,790
3.5	613.00	522.00	851,550	21,083
7	221.00	452.00	2,045,249	30,405
10	480.00	774.00	1,612,500	35,328
14	80.00	1,294.00	16,175,000	144,674
18	5,000.00	908.00	181,600	12,841
21	39.90	3,217.00	80,626,566	509,289
24	12,000.00	1,531.00	127,583	13,976
28	6.00	1,310.00	218,333,333	534,805
50	0.05	6.71	134,200,000	30,008
144	0.16	14.00	87,500,000	35,000
1296	150.00	346.00	2,306,667	28,251
5760	155.00	37.00	238,710	2,972
10GHz	1,000.00	124.00	124,000	3,921

Table 2. World miles-per-watt records plus miles-per-root-watt figures (June 2000)

The immediate thing you'll notice is that no-one has reached the magic 1,000,000 miles per root-watt. By the way, from now on I'll use m.p.W. for miles per watt and m.p.r.W. for miles per root-watt.

At first I thought that was all there was to it. But then I noticed that the m.p.r.W. figures were quite interesting. Clearly, the figures for 1.8MHz , 5760MHz and 10GHz are very low. This may be due to increased noise level on 1.8MHz and lack of sufficient stations on all three bands. Similarly, the figures for 18MHz and 24MHz seem rather low as well, but note that they are now within a mere 10% of one another.

Looking at the 3.5MHz, 7MHz, 10MHz, 50MHz, 144MHz and 1296MHz bands, the consistency of the results is surprising. It seems 30,000 is the magic number here. True, the 3.5MHz figure is somewhat low but this could possibly be due to the higher noise level on that band and the relative inefficiency of 3.5MHz aerials compared to those used on 7MHz and above.

Three figures do stand out: those for 14MHz, 21MHz and 28MHz. The old figures for 21MHz and 28MHz were 80,626,566 and 218,333,333 m.p.W. respectively. That's almost a 3-to-1 ratio. But the new m.p.r.W. figures are within 5% of one another! Quite a surprise.

Why these three figures are so much greater than the rest is something of a mystery. The use of high-gain aerials is one possible reason, but even so, the discrepancy is so large that I doubt whether that's the complete answer.

It should be possible to arrive at a theoretical figure - based on free-space propagation - for the maximum miles per root-watt that might be achieved on any particular amateur band. Allowance could then be made for such things as: transmitting aerial gain, receiving aerial gain, receiver sensitivity, receiver bandwidth, external noise at the receiving aerial and any processing gain due to the use of complex modulation techniques and digital signal processing. The current world records could then be compared to the theoretical figures. A higher theoretical figure would provide an impetus for further attempts at the record, while a significantly lower theoretical figure might indicate the need for further investigation into anomalous propagation modes.

Despite the inertia behind the miles-per-watt award scheme, using miles per root-watt certainly gives a better figure of merit and more consistent results than the old miles-per-watt formula. I hope, in future, QRP'ers will try the miles-per-root-watt formula and report on whether it provides a better and more consistent measure of their station's performance.