Efficiency, to the amateur, means what you will get out of a circuit in relation to what you put in. Little if nothing, is ever mentioned about the efficiency of an antenna.

We hear a lot about gain, expressed in dB's. However, gain is a long way from the final criteria of how good an antenna really is. By efficiency we mean exactly how much of the power fed to the antenna is used to achieve that dB gain.

The efficiency of an antenna is best shown as a ratio, a ratio of the power radiated to the power lost.

For example 100 watts fed to a 50% efficient antenna with 3dB gain. This means our ERP (in the most favored direction) is 100 watts.

When an antenna is resonant there are two properties present, these are radiation resistance (Rr) and ohmic resistance (plus skin effect). The ohmic resistance is the actual, real true resistance that heats up just like a carbon or wire resistor would. And similarly converts the RFE to heat. As far as we are concerned the unradiated power is lost or wasted. It is not received in Lower Slabovia so we can receive an RST of 599.

The RF power from our rig that is fed into our antenna is spent or dissipated in two ways. The power used up in the ohmic resistance is spent in heating up the wire in the antenna or the traps, bad connections or ground losses etc., etc.

Keep in mind that some of this ohmic loss is in the ground of the antenna. The remaining power is radiated/coupled into space to get that nice 599+ report.

The most efficient antenna is a simple 1/2 wave dipole. The impedance of such an antenna which is resonant, is on the order of 70 ohms when the antenna is at least 1/2 wave length above ground. On 80 metres, in a dipole made from #12 or 14 wire the ohmic losses will be on the order of 2-3 ohms (there are some ohmic losses introduced by surrounding objects and earth). The radiation resistance of 70 ohms minus the 2 ohms ohmic losses introduced by surrounding objects and earth leaves us with 68 ohms of Rr. This means for 100 watts fed to the antenna 95 will be radiated into space (95% efficient). That's efficiency, the 1/2 wave dipole is the most efficient antenna ever devised. **

What does this mean to the average ham who uses a beam antenna (or those of us who would like to). You will hear all kinds of discussion/arguments about the various merits, gain, which is better , traps , no traps, quads, losses and on and on.

Mobile antennas for the 160 - 80 - 40 metre bands are constantly discussed as to their merits. The latest being the screwdriver antenna! These are constantly discussed as to their merits, however no one even mentions or discusses their efficiency.

One important point to keep in mind: usually the higher the Rr in comparison to the R the more efficient the antenna is going to be. This is simply because the ratio of good power to lost power is so high.

Now, lets look at beams from an efficiency standpoint. First, consider the impedance. Most experienced hams, as well as newcomers, get hung up when they assume that all beam antennas have an impedance on the order of 50 ohms. This happens because the antenna is fed with 50 0hm cable and produces a very good match or a VSWR of 1:1 or very close to that figure.

Keep this fact in mind, nearly all beam or Yagi antennas have some sort of matching in order to transform the actual or real impedance of the Yagi "UP" to 50 ohms! A monoband three element beam using close-spaced elements, one tenth wavelength spacing, will have an impedance that is quite low. How low? How about 4 or 5 ohms. This is very possible with close element spacing. With our modern transceivers we would never be able to feed such antennas directly with coax with any success. The resulting mismatch and VSWR would be unacceptable. It would likely be right off the scale.

A beam antenna with such a low impedance feed point is certainly going to have problems with ohmic losses. This is where the efficiency factor rears its ugly head. We will have telescoping element connections, possible boom losses, the matching network itself and so on and so on. If our antenna impedance is 10 ohms and has a Rr of 5 ohms with ohmic losses of 5 ohms , we now have an efficiency of 50% in the beam. In a beam antenna with lots of traps, such as a tri-bander, there is no doubt that ohmic losses are going to increase so that the majority of the power is lost as heat. The trap beam, if well designed and tuned properly, will probably end up with about 6 dB of forward gain, compared to a dipole. Keep in mind that this 6 dB gain is for the remaining useful power compared to the dipole. There is no certain way of knowing the actual losses but be assured they are definitely present.

Also, even though aluminum can be a very good conductor (depending on your atmosphere), it can corrode and get quite scummy. If this happens, the ohmic losses will increase dramatically and thus performance and efficiency drops.

Second, lets look at another antenna factor that never changes: the shorter we make an antenna physically (for a particular frequency) the lower the antenna's impedance becomes, including, of course, Rr. For a startling example, we can take a normal 80 metre 1/4 wave length antenna of 60 feet and reduce it to a very short size. This is done by adding a loading coil. The idea is to shorten the antenna to a practical and usable length for mounting on an automobile. Instead of 60 feet we take all but 8 feet of wire and wind into a coil. The antenna is now about 8-9 feet long and will still resonate on 80 metres (3700 Khz). Mounted on the rear bumper of an automobile, truck, RV, etc., this antenna will present a Rr of 0.1 ohm and about an ohmic resistance of 4-5 ohms. This is a pretty bad situation. Most of the RFE is going to dissipate as heat in the ohmic portion of the antenna impedance so our antenna efficiency ratio becomes 0.1/5 or about 2.5%. So radiating 2.5 watts out of the 100 watts from a mobile transceiver (and 97.5% watts heating the antenna assembly) shows what can be accomplished with QRP (low power).

Now for some personal observations as to why a two or three element quad seems to outperform a multi-element yagi. *

In the construction of a quad or loop antenna, fairly large wire would be used (#12 or 14) and all joints would be soldered, leading to very low ohmic (real world) losses. Also the antenna will deteriorate very little electrically over time. An aluminum beam, on the other hand, will definitely deteriorate over time. The surface would get scummy (skin effect), joints will corrode, trap losses increase, etc. Over time, the beam's efficiency could drop to the 50% or less category. The quad or loop would maintain its 90-95 % efficiency over time. We start with the multi-element yagi being a superior antenna, but its inherent construction flaws allow a gradual degradation in it's efficiency that are usually not noticed.

Also, the quad would respond better as the incoming wave is changing from vertical to horizontal polarization or somewhere in between. If you do not agree with the above, try placing a section of aluminum tubing, such as would be used in the construction of a beam antenna, (hf), out on your patio for four or five months and have a look at it periodically. Some Yagi antennas have been up for years! Just imagine what has taken place up there exposed to all the elements and atmosphere borne material that would surely be deposited on such a large surface area (in relation to a quad).

Further to the above information and in regard to ground: a vertical 1/4 wave antenna is dependent upon a good ground system for a: resonance, b: efficiency of radiation, c: angle of radiation, and d: for radiation resistance (Rr).

The horizontal 1/2 wave antenna is dependent upon a good ground system, but to a lesser degree (it is already resonant). However, the ground is still required whether natural or enhanced for a: Rr (height above ground), b: efficiency of radiation, and c: angle of radiation. A good ground system is an absolute must for any vertical to have good radiation efficiency. This is even more true if it is a trap vertical that has been reduced in size.

* Vertical Antenna Hand Book by Capt. P.H. Lee, 1st Ed., Pg. 15, CQ publishing.

** HF Antennas For All Locations, RSGB, G6XN, L. Moxon, Pg. 26, Fig 3-11.