ANTENNA EFFICIENCY

Mythology to Reality

In order to discuss “antenna efficiency” in a pedagogical manner, the term first must be defined.

What do we mean by “antenna efficiency” ? A quick reference search has narrowed to the following possibilities:

- Antenna radiation efficiency
- Antenna aperture efficiency
- Total antenna efficiency
- Antenna System efficiency

The term emerged in early days of radio when large, linear wire arrays - antennas for low frequency (LF) - suffered from many losses and morphed to define reflectors of parabolic or horn shapes. Little of the subject is found in the amateur radio literature until the emergence of YouTube “Geniuses”.

ANTENNA RADIATION EFFICIENCY

Power delivered to the antenna for radiation is

$$P_r = \frac{1}{2}|I_g|^2 R_L = \frac{V_g}{2}\left[\frac{R_r}{(R_r + R_L = R_g)^2 + (X_A + X_g)^2}\right] \qquad [1]$$

where:

P_r *is the radiated Power*
I_g *is the generator current*
R_L *is the antenna loss resistance*
R_r *is the radiation resitance*
X_A *is the antenna reactance*
X_A *is the generator reactance*

The conduction-dielectric efficiency $\boldsymbol{e_{cd}}$ is then defined as *the ratio of the power delivered to the radiation resistance* $\boldsymbol{R_r}$ *to the power delivered to* $\boldsymbol{R_r}$ *and* $\boldsymbol{R_L}$*.*

$$e_{cd} = \frac{R_r}{R_L + R_r} \quad \text{(dimensionless)} \qquad [2]$$

where:

e_{cd} *is the radiation effciency*
R_r *is the radiation resitance*
R_L *is the antenna loss resistance*

APERTURE EFFICIENCY

Aperture efficiency is the relationship between the effective and the geometric areas.

$$q = \frac{A_w}{A_g} \times 100\% \qquad [3]$$

where:

A_w *is the effective aperture*
A_g *is geometric aperture*

and,

$$A_w = \frac{\lambda^2 G}{4\pi} \qquad [4]$$

TOTAL ANTENNA EFFICIENCY

Total antenna efficiency considers many factors such as radiation resistance, aperture efficiency, conduction and dielectric losses, input terminal mismatch, and ground (earth conductivity) losses.

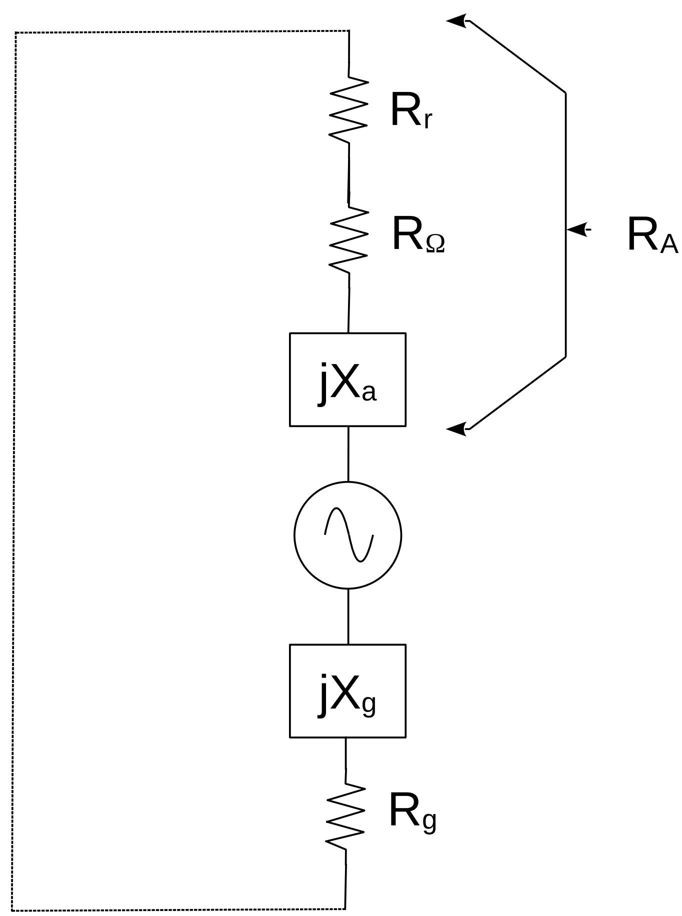

Figure 1. Antenna Model

Total Antenna Radiation Resistance

$$R_T = R_A \pm jX_a \pm jX_g + R_g \qquad [5]$$

From the total Antenna Radiation Resistance the antenna efficiency factor may be found by:

$$e_a = \frac{R_A}{R_T} \qquad [6]$$

R_T = Total Antenna System Radiation Resistance
R_A = Total Antenna Radiation Resistance
R_r = Antenna Radiation Resistance
R_Ω = Antenna Ohmic Losses
jX_a = Antenna Input Reactance
jX_g = Antenna Ground (Earth conductivity) Loss Reactance
R_g = Ground Radiation Resistance

Any calculation of Total Antenna System efficiency must include feedline losses, antenna tuners or matching device losses, VSWR losses. Note: BALUNs may have ~12~15% loss if the load is highly reactive. Antenna tuners can experience higher losses in some instances.

SUMMARY

- Definition the term - what's included?
- Define the Antenna, e.g.,
  - Short horizontal dipole
  - λ/2 horizontal dipole
  - Ground-mounted vertical
  - Aperture type (thin-wire, beams, parabolic, corner reflector, etc.)
- Accurate antenna system measurements are required before calculating efficiency
- A simple VSWR measurement at the input to a tuner, or feedline, is not definitive
- The antenna system should be non-reactive for best efficiency

Any discussion of antenna efficiency is futile unless the following factors are known

- Total radiation resistance
- Antenna radiation resistance
- Antenna loss resistance (dielectric and ohmic)
- Antenna input reactance
- Antenna ground losses (Earth conductivity)
- Aperture efficiency [7]
  - Typically 90% to 95% for horizontal, thin wire, elements
  - Typically 92% to 98% for linear element antennas
  - Can be as low as 55% for parabolas

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