Fundamental Limit on Antenna Size and Performance:
A Static Energy Viewpoint

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The fundamental-limit theory on antenna size and performance indicates that not all energy outside an antenna can contribute to far-field radiation. Some non-radiating energy remains in the vicinity of an antenna interacting with the antenna and limits the antenna bandwidth or radiation efficiency. The question is where the non-radiating energy originates. An intuitive answer would be that the static fields of the antenna contribute to the non-radiating energy. Then, the next question is how much of the static energy is included in the amount of the identified minimum non-radiating energy.

In order to answer to these questions, we investigate a static electric dipole problem, compared to the ideal antenna with a spherical TM_{01} mode excitation. We found that the minimum non-radiating energy of the ideal antenna with a spherical TM_{01} mode excitation is actually due to the static electric energy that exists between the charges. This result implies that the amount of the static electric energy needs to be charged when the ideal antenna starts radiating. The corresponding time required to charge the static energy is related to the excess delay that Davis, *et al*, (URSI NSRM 2007) observed in the time-domain approach of radiation-Q derivation.

Because all magnetic energy is used for radiation in a single TM mode excitation, we can take a low-frequency approximation ($kr \rightarrow 0$) on the electric fields and obtain the non-radiating energy from the fields. For the antenna with the spherical TM_{01} mode excitation, the $1/r^3$ terms can be conveniently chosen in order to evaluate a minimum radiation-Q. Again, the energy of the $1/r^3$ terms is the same as the static electric energy. Thus, it appears that the static energy of antennas is the fundamental cause of the limits on antenna size and performance.

These observations will provide a better understanding of antenna limit theories to antenna and system engineers. The same concept can also be applied to antennas with a single TE mode excitation.