The Yaghjian/Best *Q* Formula and Fundamental Limits – Both Field and Circuit Viewpoints

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The use of fundamental limits in the expected performance realm of antennas has gained wide acceptance, though with varied forms. This paper relates the recent formula developed at VA Tech [IET Microw. Antennas Propag., 2011] to the formalism of Yaghjian and Best [IEEE Trans Ant & Prop, 2005]. Yaghjian provided a lengthy treatise, including loss and enhanced materials. The form is simplified to a simple free-space environment with no loss and their development of the "exact" Q form is reviewed. In the context of this exact form, both the field form based on the ideal dipole with an input bounding spherical surface a are considered. The circuit view is the equivalent wave impedance form developed by Chu in 1948. The field form is a simple application of the principles of Yaghjian's paper. All results are found to provide very similar results for the Q.

An alternate view is the return loss view that was developed by Yaghjian with a Taylor series approximation about the center frequency for an estimate of the Q. In practice, the Taylor expansion about the center frequency is not as easy as one would expect from experimental or simulated data. However, determining the 3-dB frequencies is relatively straight forward and provides a simple approach to estimating the Q from the fractional bandwidth of measured data. The comparison of the half-power data is made to the fundamental limit formula developed by this author and mentioned above. In addition, insight is provided into the high-pass filter nature of the antenna response as seen from this return loss evaluation.

The formulae provided by Yaghjian and Best provide useful approaches to estimating the Q of an antenna and presenting this in the context of the fundamental limit further validates the limit for use as a design tool in the development of new antennas. Of course, the basic limit does not address the needs for higher–order modes with directional antennas that further limit the bandwidth (though considered in Chu's original paper). Also not considered are the issues of improving the limit by modifying the assumptions built into the limit development, basically single-mode, lossless, and time-invariant properties.