Noise Figure of Electrically Small HF Antennas Impedance Matched using Active Non-Foster Matching

Steven R. Best
The MITRE Corporation, 202 Burlington RD, Bedford, MA 01730
www.mitre.org

When optimizing the performance properties of electrically small antennas, engineers most often focus on optimizing the antenna's matched impedance bandwidth and radiation efficiency. For most electrically small antennas, the radiation pattern is generally not a concern since small antennas often exhibit fundamental mode patterns. If the small antenna is to be used in a receive-only application, optimization of the antenna's performance properties should primarily focus on the antenna's noise figure.

At HF frequencies, where external noise often dominates, it is often assumed that antenna performance characteristics such as Voltage Standing Wave Ratio (*VSWR*) are not significant since the associated mismatch loss (τ) reduces both external noise and received signal. In general, this is not a valid design viewpoint because every receiving system is thermal noise limited. If the antenna mismatch loss and radiation efficiency loss are too high, the HF receiving system may not be external noise limited and it may become thermal noise limited.

We present an expression for antenna noise figure that includes the mismatch loss and radiation efficiency (η_r) terms and expresses the noise figure relative to the thermal noise limit. This allows one to determine if the antenna properties ultimately limit the performance of the receiving system. We evaluate the noise figure performance of small HF dipole and loop antennas as a function of the trade-space between the assumed levels of external noise, impedance matching and radiation efficiency. We show that the noise figure performance of the antenna relative to the thermal noise limit is given by

$$F_A = \frac{SNR_i}{SNR_0} = 1 + \frac{T_p}{T_A}\left(\frac{\tau(1-\eta_r)+1}{\tau\,\eta_r}\right) \qquad (1)$$

where F_A is referenced to the thermal noise limit, T_p is the ambient temperature of the antenna, and T_A is the integrated noise temperature of the external environment as seen by the antenna's radiation pattern.

In examining the trade space between impedance matching and radiation efficiency, we compare the nose figure performance of electrically small dipoles and loops impedance matched using conventional, passive impedance matching and active impedance matching using ideal active non-Foster circuits. Results demonstrate that non-Foster matching allows for very low antenna noise figure performance provided the non-Foster circuit itself has a low noise figure.