Active Broadband Matching for High-Power Transmitting Electrically Small Antennas

Nathan Strachen*, John Booske, and Nader Behdad
University of Wisconsin-Madison, Madison, WI 53706

The high frequency (HF) band (3-30 MHz) is used in many military communications due to its unique long distance propagation characteristics. However, the wavelength of electromagnetic waves at this band is very long and ranges from 10-100 m. With such large wavelengths, practical HF antennas are inevitably electrically small. Electrically small antennas (ESAs) are known for having very large reactance and low radiation resistance values. If passive matching techniques are used to match to a 50 Ω system, the bandwidth will be very small. According to the Bode-Fano limit, there is a fundamental limit on the bandwidth of the antenna given a passive matching network. The small bandwidth of an ESA is especially problematic for electronic attack applications, where simultaneous jamming of a large bandwidth is desired.

In order to overcome the fundamental limits of passively matched ESAs, our work focuses on developing high power broadband active matching circuits. Previous work in this area has focused on developing low power non-Foster impedance matching circuits that can surpass the Bode-Fano limit (S. E. Sussman-fort, S. Member, and R. M. Rudish, Non-Foster Impedance Matching of Electrically-Small Antennas, vol. 57, no. 8, pp. 2230-2241, 2009.). However, little attention has been given to developing high power broadband transmitting ESAs for applications such as jamming. Conventional low-power non-Foster circuits can suffer from high loss and instability when scaled to higher power levels. In contrast, our approach uses multi-stage amplifier circuits to synthesize a two port network with high gain, high isolation, good input matching, unconditional stability, and high efficiency.

Designing broadband active matching networks that are stable is very challenging due to the highly reactive impedance of the ESA. In order to achieve high gain and stability, we used both transistor and vacuum triode stage amplifiers. The triode stage was designed to provide unconditional stability to the circuit, and to withstand the large voltage and current swing at the ESA terminals. The transistor stage was designed to have high gain, and to drive the triode stage. Working prototypes were realized with a class-A design. A more efficient class-B design may be realizable. We will present our most recent progress on realizing broadband, stable, and efficient active matching networks. Specifically, we will emphasize progress in stability, high voltage, and high current capability. Theoretical and practical upper bounds on the maximum power that can be radiated given an antenna with a maximum linear dimension of 1 m will be emphasized.