Design Considerations and Examples of Non-Foster Matched Electrically-Small Antennas for High Power Transmit Applications

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Many military and civilian communication applications utilize the high frequency (HF) band (3 MHz–30 MHz) and the very high frequency (VHF) band (30 MHz–300 MHz). In such applications, the antennas are usually electrically small due to the large wavelengths (1 m–100 m) of electromagnetic waves in these bands. Electrically small antennas (ESAs) are characterized by small radiation resistances and large reactances, indicating that ESAs have very high radiation quality factors (Qs). When matched with conventional passive circuits, such high Q ESAs suffer either from narrow bandwidth or from low gain due to the constraints imposed by the gain-bandwidth limitation theory (R. M. Fano, J. Franklin Inst., 249(1), 57-83, 1950). A new dimension in the impendence matching of ESAs is offered by non-Foster matching networks that produce negative reactances to bypass the gain-bandwidth limitations (T.-Y. Shih and N. Behdad, IEEE Trans. Antennas Propag., 66(11), 2018). When using non-Foster matching circuits for high power transmit applications, it is particularly difficult to achieve high radiated power due to the high Q of the ESA and the maximum voltage/current capability of the active devices.

In this work, we investigate the theoretical limits of the radiated power of an ESA, matched with a non-Foster circuit, with a passive LC circuit, and without a matching circuit. We also investigate the factors to be considered when designing non-Foster matched ESAs for high power transmit applications. The transmission efficiencies and power efficiencies of the non-Foster circuits implemented by different active devices are also examined and compared. In our design examples, we select and employ active power devices (e.g., vacuum tubes, power transistors) based on the radiation Qs of the ESAs and the maximum ratings of the voltages and currents of the active devices to achieve the desired radiated power. The architecture of the proposed non-Foster matching circuits is new. The first two stages of the circuits are used to generates the required high voltage (current) swing at an electrically dipole-like (loop-like) antenna terminal. In one of our examples, high power gallium nitride (GaN) high electron mobility transistors (HEMTs) are used to design a voltage amplifier (a.k.a. current buffer) that provides a maximum voltage of 125 V, a maximum current of 8.7 A, and a power handling capability of 46 dBm (40 W). The detailed design considerations and the design examples of non-Foster matched ESAs for high power transmit applications will be presented and discussed at the symposium.