Toward a High Power, High Speed Plasma-Switch Impedance Tuner Under Software-Defined Radio Control

Caleb Calabrese[(1)], Austin Egbert[(1)], Justin Roessler[(1)], Alden Fisher[(2)],
Charles Baylis[(1)], Mohammad Abu Khater[(2)], Dimitrios Peroulis[(2)], Robert J. Marks[(1)]

[(1)]Baylor University, Waco, TX 76706
[(2)]Purdue University, West Lafayette, IN 47907

In a radar transmitter, the maximum detectable radar range increases with the transmitted power. A matching circuit can be designed to maximize the output power for a relatively narrow frequency band. However, in a spectrum-sharing radar, the operating frequency must often change quickly to facilitate sharing with potentially interfering wireless devices. When the operating frequency of the circuit changes, the power amplifier's optimal load impedance changes. Furthermore, if the amplifier is part of a phased-array element, and the phased-array beam angle is steered in a different direction, the impedance presented by the antenna changes due to mutual coupling effects, degrading the match. Changing operating frequency or antenna impedance can lower output power unless the circuit is re-matched in real time. We describe the design of quickly reconfigurable matching circuits that can handle power levels needed for radar transmitters. The design objective of the matching networks is to be tunable from 2 to 4 GHz, providing an octave of tunable bandwidth, with reconfiguration search times less than or equal to 100 microseconds.

Previously presented initial work has demonstrated fast optimization of a low-power prototype of this tuner design. The low-power prototype used six off-the-shelf, low power (less than 34 dBm) field-effect transistor (FET) switches to expose six matching stubs. This prototype was used to design and demonstrate fast reconfiguration algorithms for this tuning circuit topology, and a full reconfiguration search in a software-defined radio setup could be completed in under 20 µs for some cases, while obtaining good Smith Chart coverage with the 64 available tuning states.

After demonstrating fast, real-time optimization with the low-power prototype, the design is being transitioned toward a circuit with a power-handling goal of 50 W. While the RF matching topology and means of interfacing with the new tuner are largely equivalent, switches (along with power and control circuitry) must be used that meet both the power and timing specifications while maintaining reasonable size and cost. The new switching mechanism consists of laser diodes which stimulate electron flow in "semiconductor plasma" silicon chiplets. While a significant challenge is focusing the laser diode power onto the chiplet to ensure low-loss switching performance, different approaches for focusing this power are being tested. Additionally, turn-on effects must be considered in assessing the time needed for the switches to fully actuate, evaluating tradeoffs between switching speed and RF performance. At this point, varying Smith Chart coverage has been achieved depending on the technology being used, and initial reconfiguration searches have completed in under 100µs in a low power software-defined-radio-controlled setup. At this point in the development of the circuit, the initial experimental results are guiding the development toward the use of micro-lenses to focus the laser power. Experimental measurements of Smith Chart coverage and search performance of the semiconductor plasma tuner will be presented and discussed.