The Johns Hopkins University

Whiting School of Engineering

Department of Electrical and Computer Engineering

Design and Analysis of Broadband Self-Biasing Structures for Microwave Applications

Dissertation Defense by

Walter Wall

Graduate Research Assistant

Electrical and Computer Engineering

Abstract

For many high power microwave applications, it is desirable to modify the properties of radiating elements on a time-scale which is must faster than traditional active control circuits to improve isolation between antennas and protect sensitive electronics. For these rapidly reconfigurable high power applications, self-biasing structures can be utilized to alter the propagation of an electromagnetic wave at microwave time-scales by dividing incident power among many high-speed nonlinear elements. These self-biasing structures have been previously implemented using nonlinear metamaterials, which consist of resonant subwavelength elements loaded with diodes. Due to the resonant nature of these structures, the bandwidth and consequently the activation time of these devices is inherently limited.

In this work, a nonlinear metamaterial is demonstrated which switches from a broadband reflective state at low power to a broadband transparent state at high power. Below the activation voltage, broadband reflectivity is created by inhibiting propagation through the metamaterial as a result of the effective permittivity and permeability having different signs. Above the activation voltage, reflection is suppressed by matching the relative permittivity and permeability. Both computational electromagnetic simulations and experimental results are presented at S-band frequencies in a WR-284 waveguide. To analyze the transient switching behavior of this structure a novel nonlinear multiconductor transmission line circuit is developed. Transient measurements of this structure conducted in WR-284 waveguide show excellent agreement with this model. This analysis is also used to develop a varactor-loaded metamaterial which is capable of transitioning from a broadband transparent state at low power to a broadband reflective state at high power.

Finally, a self-biasing switch is proposed to reduce the artifacts associated with time reversal based beamforming. This device consists of multiple diodes placed in series on a 50-Ω microstrip transmission line. At low incident voltages this device behaves like a high pass filter, rejecting low power transients over a broad bandwidth. Once the threshold voltage of these diodes is exceeded, the capacitive elements of this filter are shorted allowing energy to pass with significantly less attenuation. By preferentially attenuating low power transients this device can suppress the temporal artifacts associated with the time reversal process. An experimental demonstration of this device is performed using a reverberant cavity as a passive delay line network. Measured outputs from this cavity are used as inputs to a simulated array of Vivaldi antennas to demonstrate the proposed improvement in beamforming.

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Krieger 304

FOR DISABILITY INFORMATION CONTACT: Janel Johnson (410) 516-7031 janel.johnson@jhu.edu