A Nonlinear Metamaterial Reflector for Protection against High-Power Microwave Attack

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In this paper, we present a nonlinear metamaterial that exhibits high reflectivity for low power microwaves while appearing transparent when illuminated by high power signals. The metamaterial is used in the design of a parabolic reflector for a high gain receive antenna. Due to its nonlinear performance, the desired low-power communication or radar signals are reflected into the receiver, while high-power electronic attack signals pass through the medium, protecting the sensitive receiver components.

In the low-power state, the metamaterial is optimized to maximize the reflectivity by reducing material losses as well as transmission through the reflector. On the other hand, the high-power state of the metamaterial is optimized to minimize the reflectivity. This is achieved by controlling the effective material parameters of the reflector to ensure that the relative permittivity and permeability of the medium are well matched over the bandwidth of interest.

The nonlinear behavior of the metamaterial is achieved by incorporating passive (unbiased), low-power, high-speed diodes into each metamaterial resonator (A.R. Katko, A.M. Hawkes, J.P. Barrett and S.A. Cummer, IEEE Antennas Wireless Propag. Lett., 10, 1516-1519, 2011). When low-power signals are incident on the metamaterial, the voltages induced in the resonators are insufficient to turn on the diodes, so they behave primarily as capacitors. Under this condition, the medium appears highly reflective. If illuminated by a high-power signal, the resonators induce high voltages across the diodes, such that they present low impedances, and the metamaterial surface appears transparent.

The distribution of the diodes throughout the metamaterial reduces their individual power handling requirements in comparison to those used in traditional power limiters. By alleviating the high power constraint, faster diodes can be used, which reduces the recovery time. This allows for higher frequency operation and minimizes the spike leakage of the limiter.