Lessons Learned from Studies of Metamaterial Slow Wave Structures for HPM Generation

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Abstract**—**The University of New Mexico (UNM) together with its consortium partners has been investigating the use of metamaterial slow wave structures (MTMSWSs) for high power microwave (HPM) generation (http://ece-research.unm.edu/FY12MURI/). During the course of this over 5-year project we have learned many new things and this presentation will summarize the highlights of lessons learned.

Keywords-HPM, high power microwaves, metamaterial slow wave structures, dispersion engineering

I. INTRODUCTION

UNM has been studying dispersion engineering using double negative (DNG) MTMSWSs to develop novel sources of HPM generation. Whereas the overall goal of this project has been to develop a new class of HPM amplifiers, the work to-date has focused exclusively on oscillators. As part of this effort the UNM group has made key advances in understanding DNG MTMSWSs. This presentation reviews the highlights of these advances.

II. OVERVIEW OF KEY ADVANCES

A. HPM Generation

The UNM Group has demonstrated the generation of 100 MW in L-band (1.43 GHz) using a MTMSWS. This is the highest power generated to-date from a DNG SWS recorded [1]. The SWS is a biperiodic array of split ring resonators (SRRs) that provides negative permeability μ. Insertion of this structure into a below-cutoff cylindrical waveguide provides negative permittivity ε. The DNG behavior was verified in HFSS simulations and experimental cold tests.

B. Similarity between DNG MTMSWS and Conventional Periodic Structure with Deep Corrugations

During the course of this research program it was realized that conventional periodic structures with corrugation depths beyond a critical value display properties originally thought to only be attributed to metamaterial structures, such as negative dispersion in the first passband [2]. It was also observed that negative dispersion went hand-in-hand with the appearance of a hybrid mode as the lowest order mode. This was later investigated in detail [3] and confirmed through a rigorous electromagnetic analysis.

This work was supported by AFOSR MURI Grant FA9550-12-1-0489.

C. Group Theory for the Optimized Design of MTMSWSs

Another innovative advance has been to use group theory to optimize MTMSWS design. The C_{2v} point group was identified as having the properties most relevant to MTMSWS design based on SRRs. A multibeam DNG Cherenkov device was designed using the C_{2v} group [4].

D. Evolution of Microwave Fields in Below Cutoff Waveguide with Metamaterial Inserts

Another important finding was the experimental observation that the evolution of microwave fields in a below cutoff waveguide with metamaterial inserts takes place over many cycles of the RF fields. Three distinct time scales were identified over which the metamaterial structure becomes fully responsive. These observations have also been partially explained through both full wave and circuit modeling of the structures [5].

E. Diagnostics for Breakdown Studies

Finally, a comprehensive diagnostic suite was designed and implemented in order to look for evidence of breakdown and the evolution of plasma in a MTMSWS during HPM generation. No breakdown was observed during the 100 MW generation of 1.43 GHz radiation.

III. CONCLUSIONS

A comprehensive 5+ year program studied the use of MTMSWSs for HPM generation. During the course of this program several key advances were made. This presentation summarized the highlights of these advances.

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