Microstrip Pseudo High-Pass Filters Using Multilayer Defective Ground Electromagnetic Bandgap Structures

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Abstract

Since most electromagnetic bandgap (EBG) structures are utilized for their low-pass characteristics, a structure with a pseudo high-pass transmission response was developed for use with microstrip traces in a practical PCB application. The multilayered EBG structure consists of individual island and dumbbell layers within a substrate containing a microstrip. This structure produced a defined low-frequency notch with minimal high-frequency transmission losses. Simulated and experimental results highlighting structural variation and coupling characteristics are demonstrated to characterize the multilayer island EBG structure.

1. Summary

Over the past 20 years, much effort has been spent researching and characterizing the properties of electromagnetic bandgap (EBG) materials. Three of the most widely published structures include the unit cell structure, the circular ground etching structure, and the dumbbell structure [1-3]. These EBG structures typically have been implemented in low-pass filtering applications. However, this created the desire to develop an EBG structure that could be utilized to give microstrip traces a bandpass transmission response for practical printed circuit board (PCB) applications.

The goal of this investigation was to develop an "ideal" EBG structure for use in a practical application. The EBG structure would be implemented on a PCB for operation over the frequency range of 1 to 10 GHz. It would not reside on the surface layer since PCBs are becoming increasingly dense, causing board area to become valuable. Additionally, the structure would be two dimensional to prohibit both the coupling of unwanted signals and the propagation of these signals on transmission lines. Even though the ideal EBG structure would have a bandpass type response, the developed structure exhibited a pseudo high-pass response to isolate low-frequency signals from high-frequency signals. The developed multilayer island EBG structure consisted of a microstrip, islands, and a dumbbell ground etching, all residing on different planes in the substrate.

The basis of this EBG structure is the dumbbell. The dumbbell EBG is a one-dimensional structure that resembles large squares on either side of the transmission line connected by a sliver of etched ground, thus giving the overall shape of a dumbbell. This structure creates an LC resonance in the response of the microstrip trace [3]. In [4], islands were added to the dumbbell structure to increase the capacitance. This investigation developed an EBG structure where the microstrip is on the top layer, the dumbbell structure in the bottom layer, and the islands in the middle layer. The computer model and the fabricated EBG structure are seen in Figure 1. Placing the islands within the structure is thought to have a greater impact on the overall field compared to island placement on the substrate-to-air transition. After considering fabrication issues, the stack-up was chosen, a nominal multilayer island structure was created, and its features were varied to determine their impact on the overall performance. This included the island length, the island spacing, the dumbbell structure, and a single island structure.

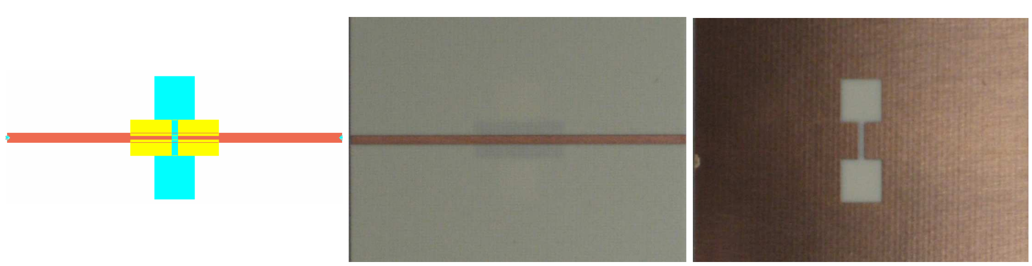

Figure 1 - Optimized Multilayer Island EBG

The nominal structure was optimized to meet certain performance requirements. In addition, three structures were cascaded and optimized to create a pseudo high-pass response. Figure 2 shows the results for the cascade of three multilayer island EBG structures. Each of these structures was fabricated and measured in a laboratory environment. The measured results were seen to be in good agreement with the simulated results. Additionally two scenarios were simulated, fabricated, and measured that examined coupling between the EBG structure and adjacent traces. One scenario was shown to increase the isolation between the adjacent traces while the second actually decreased the isolation.

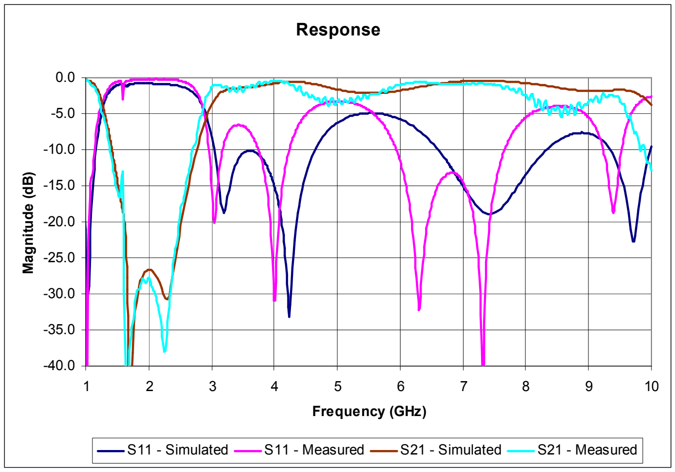

Figure 2 - Simulated and Measured Results of Three Island EBG Structure

This investigation produced an EBG structure with characteristics that had never been discussed. Whereas most EBG structures are utilized for their low-pass characteristics, the multilayer island EBG structure has the ability to act as a pseudo high-pass filter. This is important when trying to keep low frequency signals separate from high frequency signals. Even though this multilayer island EBG structure does not have all the “ideal” characteristics, it fulfills the need that caused the entire investigation. This multi-layer EBG structure is capable of producing a bandstop response and is meant to be used in conjunction with circuitry operating at frequencies above the stopband. It is the last characteristic that makes the structure unique and feasible for use in a realistic application.

2. References

1. F. R. Yang, K. P. Ma, Y. Qian, and T. Itoh, “A Uniplanar Compact Photonic-Bandgap (UC-PBG) Structure and Its Applications for Microwave Circuits”, *IEEE Transactions on Microwave Theory and Techniques*, Volume 47, Issue 8, August 1999, pp 1509-1514.

2. V. Radisic, Y. Qian, R. Coccioli, and T. Itoh, “A Novel 2-D Photonic Bandgap Structure for Microstrip Lines,” *IEEE Microwave and Guided Wave Letters*, Volume 8, Issue 2, February 1998, pp. 69-71.

3. D. Ahn, J. S. Park, C. S. Kim, J. Kim, Y. Qian, and T. Itoh, “A Design of the Low-Pass Filter Using the Novel Microstrip Defected Ground Structure,” *IEEE Transactions on Microwave Theory and Techniques*, Volume 49, Issue 1, January 2001, pp. 86-93.

4. J. U. Kim, K. S. Kim, S. J. Lee, J. S. Lim, D. Ahn, K. H. Park, and K. Kim, “A New Defected Ground Structure with Islands and Equivalent Circuit Model,” *Microwave Conference Proceedings, 2005. APMC 2005. Asia-Pacific Conference Proceedings,* Volume 1, 4-7 December 2005, pp. 4.