A Novel Electromagnetic Bandgap Metal Plate for Parallel Plate Mode Suppression in Shielded Structures

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***Abstract*—A novel type of metal plate structure incorporated with electromagnetic bandgap holes for use as metal shields with the capability of suppressing the propagation of unwanted parallel plate mode has been proposed. The holes can be of any shape and the periods of those holes should be selected to half the guided wavelength of the parallel plate mode at a desired center frequency of suppression. To show the validity of the proposal, inert electromagnetic wave simulation, results of a shielded microstrip structure designed for application in the 76 GHz frequency band are demonstrated. Experiments are performed with a prototype designed in the 10 GHz frequency band and parallel plate mode suppression is verified successfully with the excellent agreement between experimental and simulation results.**

***Index Terms*—Electromagnetic bandgap holder, metal shields, parallel plate mode.**

I. Introduction

Electromagnetic bandgap (EBG) or photonic bandgap (PBG) structures have become very popular due to their enormous applications for suppression of unwanted mode transmission, radiation, etc. in the area of microwave and millimeter wave. The past several researches have been carried out on the guided wave properties of periodic structures which could produce stopband phenomena of electromagnetics extending from radio waves to optical wavelengths [1]–[3]. Recently, there are many publications showing the applications of two dimensional (2-D) photonic bandgap structures for microstrip lines and one of them is shown in [4], in which a pattern is etched directly on the microstrip ground plane to arrest unwanted radiation at discontinuities. Another example is shown in [5] where 2-D pattern is etched on the ground planes of a stripline to suppress parallel plate mode leakage. The disadvantages of those methods are, first, they do not provide a perfect conductor shielding to circuits, and, second, they may affect the main signal transmission, if proper care is not taken while designing, because patterns exist directly near the main signal fields.

In microwave or millimeter wave systems, metal shields are often utilized to protect the integrated circuits [6] from direct atmospheric contact or from interference of the surrounding circuits or devices. But, the presence of this metal shield often causes the problem of unwanted parallel plate mode transmission and, hence, the unavoidable crosstalk appears.

In this paper, a new type of metal plate structure with EBG holes inside for the use as a metal shield with the capability of suppressing the propagation of unwanted parallel plate mode has been proposed. The validity of the proposal has been demonstrated with simulation for a metal plate of a shielded microstrip structure designed for the application in the 76 GHz frequency band. Experiments are performed with a prototype designed in 10 GHz frequency band to verify the design accuracy.

II. Principle of Operation and Design

It is well known that any electromagnetic bandgap structure produces the phenomena of stopband in which propagation is prohibited if the period of EBG elements is chosen to be half the guided wavelength of the propagating mode at the center frequency of the stopband. Based on this principle, a novel metal plate structure has been proposed in which arbitrarily shaped holes with a period of half-guided wavelength are inserted into it to suppress the parallel plate mode propagation, which would appear in a shielded structure. To show the application of the proposed structure, an example of a shielded microstrip structure as shown in Fig. 1, is considered. It is very clear from Fig. 1 that a parallel plate waveguide is formed between the microstrip ground plane and the metal shield on top and any circuit discontinuity or unbalance may cause unwanted parallel plate mode propagation, besides the desired microstrip mode transmission. This will cause crosstalks among the surrounding circuits, and power loss due to leakage may also take place. To suppress such unwanted mode transmission, a metal plate embedded with circular holes of diameter D, period p, and depth d, can be used as shielding plate as shown in Fig. 1. Electromagnetic wave simulation is performed by using HFSS in the 76 GHz frequency band for a shielding plate with circular holes of diameter 1.2 mm, period of 1.62 mm, depth of 1.2 mm, the number of periods 9, and the gap with microstrip circuit g of 0.5 mm. The simulation results are shown in Fig. 2. It can be observed from Fig. 2 that an unwanted parallel plate (pp) mode is suppressed to nearly about -10 dB at 76 GHz, while the desired microstrip (ms) mode propagates without being affected. The level of suppression can be increased further, by increasing the diameter, depth of holes, and the number of periods. An example of how the level of parallel plate mode suppression changes against the size of hole is demonstrated in Fig. 3. It can be observed in Fig. 3 that both the bandwidth of stopband

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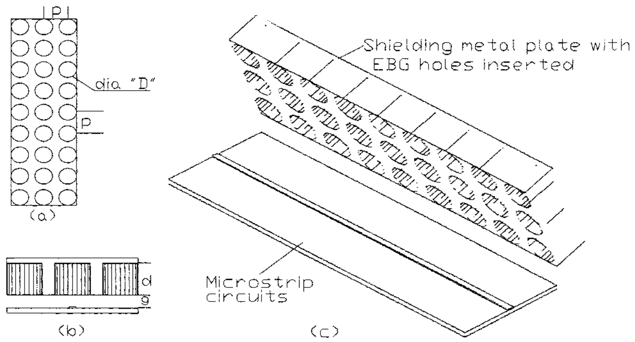


Fig. 1. Shielded microstrip structure by using the proposed EBG metal plate. (a) Top view; (b) cross-sectional view; and (c) schematic view.

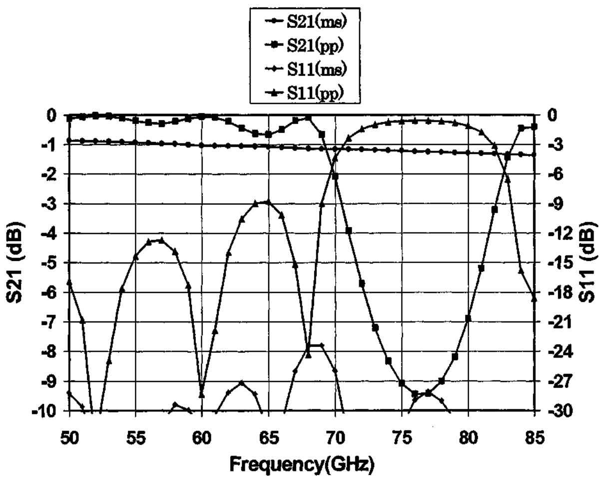


Fig. 2. Simulated s-parameters of microstrip (ms) mode and parallel plate (pp) mode.

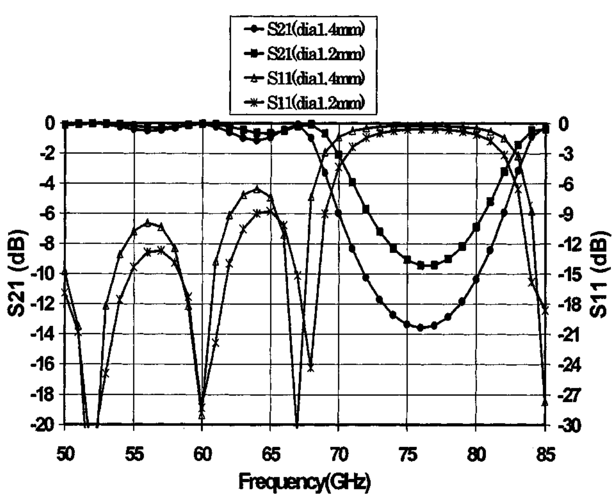
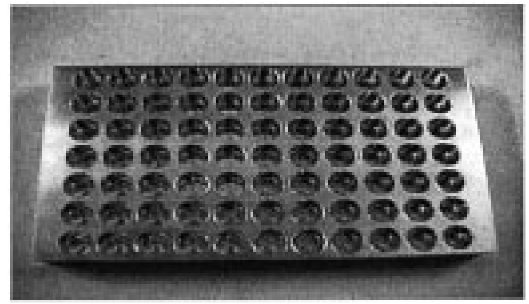


Fig. 3. Simulation results showing the variation of s-parameters of parallel plate mode against the diameter of hole.

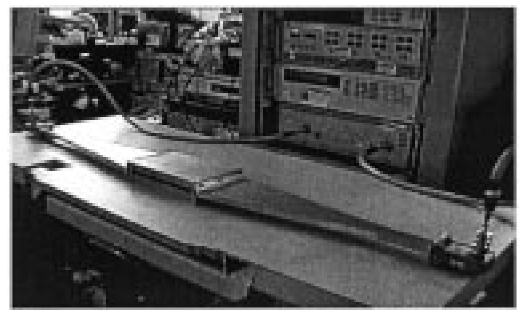
and the suppressed level of parallel plate mode increases largely with a small change of hole diameter from 1.2 mm to 1.4 mm, while the depth and period of holes are kept fixed.

III. Practical Demonstration With a Prototype

Experiments are performed, by using a prototype designed at X-band, to demonstrate the parallel plate mode suppression based on the proposed technique of using the novel EBG metal plate and also to verify the design accuracy. The experimental setup is illustrated in Fig. 4. The fabricated EBG metal plate with circular holes inserted is shown in Fig. 4(a). Fig. 4(b) shows the arrangement for measurements where, parallel plate waveguide formed between top and bottom metal plates are excited with parallel plate mode by using H-plane horn at both input and output ports, respectively. A metal plate with an arrangement of 7×11 EBG holes, each 13 mm in diameter, 13 mm in depth, and with a period of 15 mm, is designed for parallel plate mode suppression around 10 GHz frequency band. S-parameters are measured by using top metal plate with and with out EBG holes inside and results are shown in Fig. 5. The figure shows that when the top metal plate is without EBG holes, parallel plate



(a)



(b)

Fig. 4. Experimental setup with (a) EBG metal plate with circular holes and (b) parallel plate guide excited with H-plane horn.

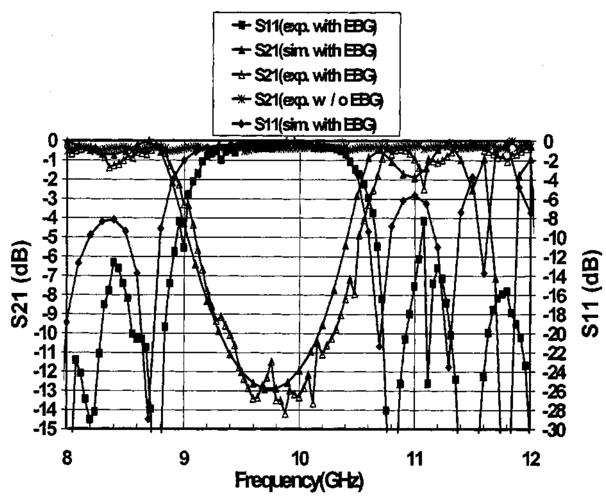


Fig. 5. Simulated and measured transmission and reflection characteristics of the proposed EBG metal plate designed at X band.

mode travels with a minimum loss in the entire frequency band, whereas by using the EBG metal plate, parallel plate mode is suppressed below 10 dB around 10 GHz frequency band. It is also obvious from the figure that the agreement between the simulation and experimental results are excellent. Therefore, the same technique and design method can also be applied in the higher millimeter wave frequency such as 76 GHz band.

IV. CONCLUSION

A novel metal plate structure incorporated with EBG holes to suppress unwanted parallel plate mode in shielded structures has been proposed. Validity of the proposal is demonstrated by simulation results of a shielded microstrip structure designed for application in 76 GHz frequency band. Experiments are also performed with a prototype designed at X band to observe the parallel mode suppression practically and to verify the design accuracy. Excellent agreement between the experimental and simulation results have been achieved and hence, this technique can also be applied in the higher millimeter wave frequency such as 76 GHz band.

REFERENCES

[1] L. Brillouin, "Wave guides for slow waves," *J. Appl. Phys.*, vol. 19, pp. 1023–1041, Nov. 1948.

[2] S. Lee and W. Jones, "Surface waves on two-dimensional corrugated surfaces," *Radio Sci.*, vol. 6, pp. 811–818, 1971.

[3] A. Hessel, M. H. Chen, R. C. M. Li, and A. A. Oliner, "Propagation in periodically loaded waveguides with higher symmetries," *Proc. IEEE*, vol. 61, February 1973.

[4] V. Radisic, Y. Qian, and T. Itoh, "Novel 2-D photonic bandgap structure for microstrip lines," *IEEE Microwave Guided Wave Lett.*, vol. 8, pp. 69–71, Feb. 1998.

[5] K. P. Ma, J. Kim, F. R. Yang, Y. Qian, and T. Itoh, "Leakage suppression in stripline circuits using a 2-D photonic bandgap lattice," in *IEEE MTT-S Int. Microwave Symp.*, vol. 1, Anaheim, CA, June 1999, pp. 73–76.

[6] Y. Ohashi *et al.*, "76 GHz flip-chip MMIC's in through-hole packages," in *28th Eur. Microwave Conf.*, vol. 2, Oct. 1998, pp. 433–438.

[7] "Agilent HFSS Version 5.2," Agilent Technologies Inc., Palo Alto, CA.