Applied EBG Structure for Microwave Snow Melting

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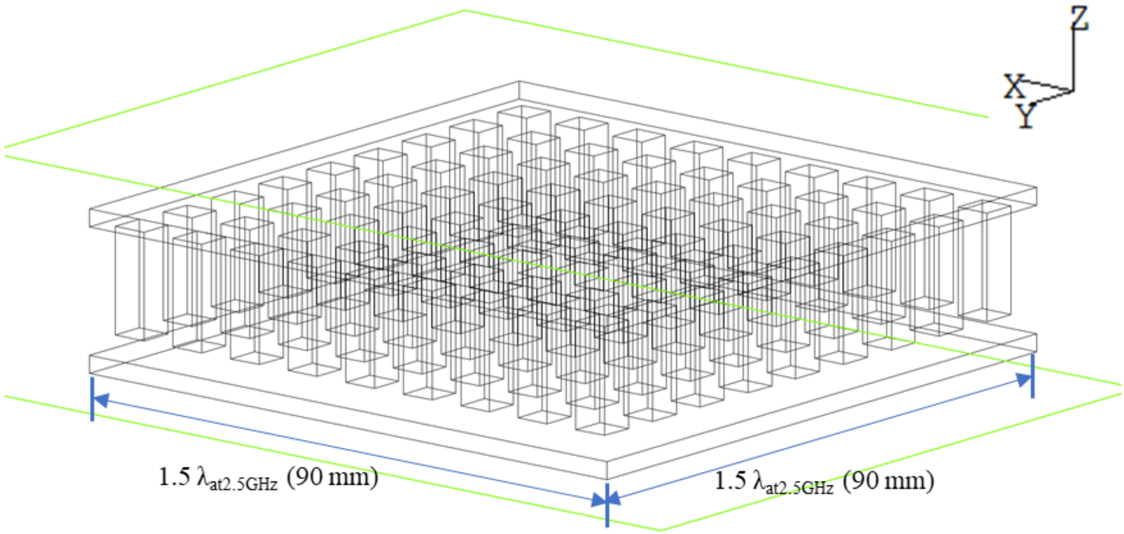
Abstract A novel snow melting method utilizing microwave radiation has been proposed to efficiently melt snow without requiring storage space. Initial attempt involved heating mortar blocks with microwaves, then used the generated heat to melt snow. However, direct microwave irradiation to snow would be more efficient due to the resonance between microwaves and water molecules. This study aims to develop a method for directly microwave emission onto snow without external radiation leakage. An Electromagnetic Band Gap (EBG) structure is employed to allow snow ingress but prevent microwave egress. While previous studies have utilized EBG in antenna designs, its integration with snow melting and drainage is novel. Electromagnetic field analysis shows that the EBG structure significantly attenuates electromagnetic waves at the specific frequencies, which indicates its potential for frequency-selective snow melting.
Key words: Electromagnetic Band Gap (EBG), waffle iron ridge waveguide, waveguide, Snow melting, Microwave heating, Microwave

1. INTRODUCTION

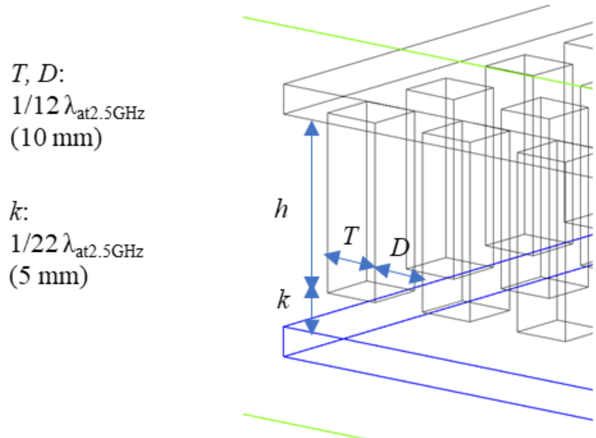
A snow melting method utilizing microwave radiation to quickly melt snow without occupying storage space for cleared snow has been reported [1] - [4]. To melt the snow located outside the snow melting device, it was not feasible to directly expose microwaves to the snow. Initially, microwave heating was applied to mortar blocks, and the snow was subsequently melted using the generated heat. However, direct irradiation of snow with microwaves would be efficient because microwaves heat substances through resonance with water molecules. Therefore, the purpose of this study is to establish a method for direct microwave emission onto snow without leaking radio waves externally. An EBG structure is employed to allow snow from shoveling to pass into the device while preventing microwaves used for snow melting from escapingEBG structures have the property of hindering the propagation of the electromagnetic waves at the specific frequencies. In this paper, a waffle iron ridge structure [4] is adopted as the EBG structure, which is compatible with waveguides used for snow melting.

2. FDTD ANALYSIS

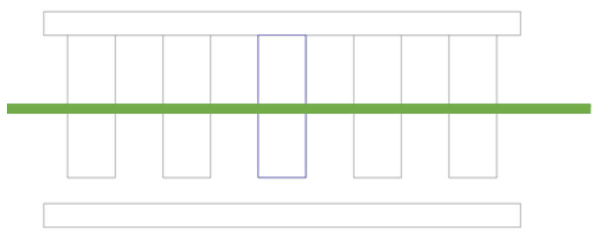
The analytical model and dimensions of the EBG structure with waffle iron ridge are shown in Fig. 1. The design frequency was set to 2.5 GHz. In Fig. 1, the structure is periodic in the xy direction. In this case, the angle of incidence on the EBG is generally assumed to be from the z-axis direction. In this paper, it is assumed that this EBG is installed in a waveguide in practical use. For this reason, plane waves are injected and applied from the positive direction of the x-axis. Therefore, the periodic boundary condition is not used. The electric field distribution in this case is shown in Fig. 2. Figures 2(a)-2(d) show the electric field distribution at each frequency between 1 GHz and 4 GHz, respectively. They show the electric field intensity in dBV/m. At 1 GHz and 4 GHz, the electric field intensity within the EBG structure is significantly higher, while at 2 GHz and 3 GHz, the electric field intensity decreases. This observation indicates that the structure hinders the passage of electromagnetic waves at certain frequencies.



(a) Total view



(b) Rod structure



(c) The cut surface to reveal electric field distribution

Figure 1 Analysis model of EBG structure

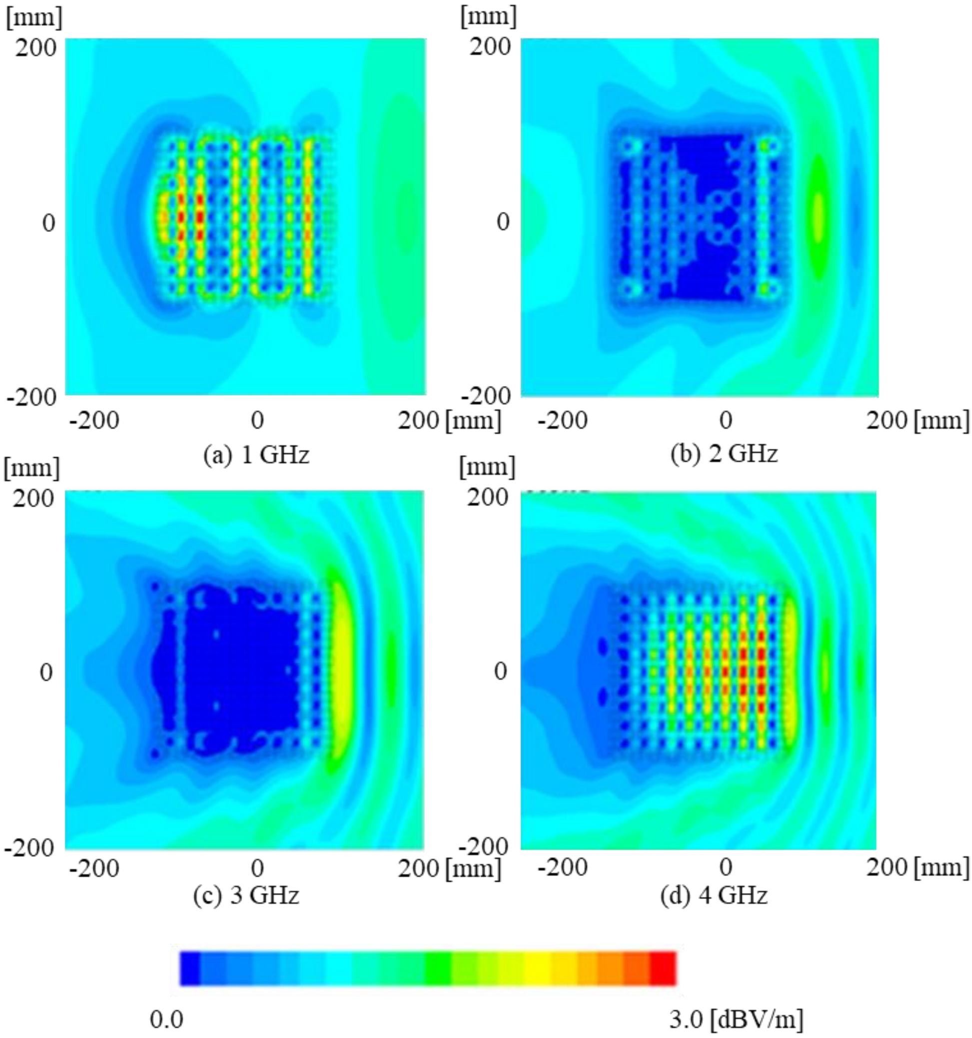


Figure 2 The electric field strength of the airborne EBG structure in units of dBV/m

3. CONCLUSION

This paper proposed the adoption of a waffle-iron-ridge EBG structure as a novel method for snow melting through direct microwave irradiation onto the snow, while ensuring minimal external radiation leakage. Unlike traditional applications where EBG structures employ periodic boundary conditions and radio waves enter from the vertical direction, this study adopts a practical approach wherein plane waves enter from the horizontal direction, specifically from the positive direction of the x-axis, without necessitating periodic boundaries. The results demonstrated that the waffle-type structure, designed to allow passage of snow and water, exhibited a band gap phenomenon with significant attenuation of electromagnetic waves at frequencies between 2 GHz and 3 GHz, while maintaining high field strength at 1 GHz and 4 GHz. This characteristic highlights its potential as an effective band gap structure for snow melting applications.

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