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Thermal Tuning of a Microwave Water-Based Metasurface

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I. INTRODUCTION

Fluidic metamaterials (MMs) have received increasing interest with their tunability and promising applications such as material sensing, bio-detection, imaging etc. [1]. With its relatively high permittivity [2, 3], water introduces many tuning-variables into MMs due to its temperature dependent parameters. It has been shown that water-based MMs can be tuned thermally, chemically and by reshaping/deforming of as well as partially filling their containers [4, 5]. Water-based metasurface (MS) absorbers are investigated heavily, where the latest MS had a 90% absorption from 20 – 40 GHz [6].

In [7], we studied a MS with a square lattice of ‘rod-like’ water inclusions in a foam material (the unit cell is shown in Fig. 1). The MS was capable of switching between reflecting and transmitting the incident power through 90° rotation of the MS. Furthermore, stacking several of these MSs effectively increased the switching efficiency.

Presently, we continue the study of the same MS as in [7] by investigating its thermal tunability in the temperature range from 0 °C to 100 °C. The thermal volumetric expansion of water has been neglected, since a temperature change from 20 °C to 100 °C only expand the volume with approximately 4% (density from 1 g/cm³ to 0.96 g/cm³). For a sphere, this corresponds to the radius increases with around 1% with similar red-shift of the spectrum.

II. CONFIGURATION AND RESULTS

A single unit cell of the MS is presented in Fig. 1 with its two cross sections. It consists of a water inclusion in a Rohacell 51 HF host. The water inclusion has the shape of a rounded rectangular cuboid and the geometrical parameters are shown in the figure. Their values are: \( a = d = 50 \) mm, \( r = 10.7 \) mm, and \( h = d_e = 45 \) mm. The angle \( \phi \) describes the rotation of the unit cell (or MS). The complex relative permittivity of water was taken from [2] and the relative permittivity of Rohacell 51 HF was measured in-house to be 1.075. The MS was implemented into Comsol Multiphysics used for the numerical calculations.

The electromagnetic response of the MS to a y-polarized plane wave at normal incidence travelling in the positive z-direction is investigated. The MS is characterized by the transmitted (transmittance) and reflected (reflectance) in-

![Fig. 1. Two cross sections of a single unit cell of MS.](image)

Fig. 2(a). Transmittance and (b) reflectance as a function of frequency and temperature for \( \phi = 0^\circ \). The colors show the magnitude of the transmittance and reflectance.

Fig. 2(b). Transmittance and (c) reflectance as a function of frequency and temperature for \( \phi = 90^\circ \). The colors show the magnitude of the transmittance and reflectance.

III. CONCLUSIONS

The thermal tunability of a water-based MS was investigated showing a frequency shift of around 200 MHz of the spectrum. The proposed water-based MS can be a cost-effective and bio-friendly alternative for microwave applications.

REFERENCES