The Design of Band-pass Frequency Selective Surface with All Dielectric Metamaterial

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Abstract— The traditional metamaterial and frequency selective surfacesFSS basically is the mixed structure of the metal and dielectric. However, due to the inherent defects of metal materials, the dielectric metamaterial FSS is necessary. All dielectric metamaterial FSS can be designed, according to the constitutive parameters and dielectric resonator theory based on equivalent. This paper presents the design of dielectric materials FSS, and studies the principles and methods about using high dielectric constant to design dielectric FSS, and the design of the band-pass characteristics of dielectric metamaterial FSS has been proposed. In this paper, the design principle is much important practical significance and guiding significance for the all dielectric metamaterial FSS.

1. INTRODUCTION

The concept of metamaterials is late for thirty years than the frequency selective surfaces (FSS), but periodic structure of the FSS and metamaterials in the design is quite similar. In the traditional sense of the metamaterials and frequency selective surface, periodic structures are made of metal materials. But in the high frequency band (such as millimeter wave field), the metal material is much less practical due to the skin effect of metal surface. And the physical properties of metal material itself brings many limitations [1].

These problems can be well solved by dielectric materials. This article verifies the high dielectric constant of medium also have plasma liquid through the derivation of the Drude model, designs and simulates the one-dimensional grid structure all dielectric metamaterial FSS. At last the transmission characteristic curve is optimized and the simulation results are analyzed [2, 3].

2. THE METAL PROPERTIES OF HIGH DIELECTRIC CONSTANT OF MEDIUM

According to the Pendry's research [3, 6], Infinite array of metal wire can be equivalent to the plasma. Under the action of electromagnetic wave, the equivalent dielectric constant ε_{eff} meet Drude model:

$$\varepsilon_{eff} = 1 - \frac{w_p^2}{w \cdot (w + i \cdot \gamma)}, \quad w_p^2 = \frac{n \cdot e^2}{\varepsilon_0 \cdot m}$$

where, n for the electronic density, m and e for the respectively the electron mass and charge, i for the imaginary unit, ε_0 for the permittivity of free space, ω_p for the plasma frequency of metal. ω for the electromagnetic wave frequency, γ for the attenuation factor.

It can be seen from the formula that the equivalent dielectric constant to be negative, electromagnetic wave frequency must be smaller than the ω metal plasma frequency. Plasma frequency of the metal is generally high, however, the plasma frequency of the metal must be reduced to the scope of what we need to get a negative permittivity metamaterials needed.

The plasma frequency of the metal ω_p can be written as:

$$\omega_p^2 = \frac{ne^2}{\varepsilon_0 m_{eff}}$$

where, m_{eff} for electronic equivalent mass, n for electronic number per unit volume.

According to the formula, as a result of electronic number per unit volume is only related to the metal itself, so that one of the effective methods to reduce increase m_{eff}.

The Drude model of high dielectric constant of medium can be written as:

$$\varepsilon_{eff} = \varepsilon_0 \left(1 - \frac{\omega_p^2}{\omega^2}\right)$$

where, ω_p for the plasma frequency of medium model constructed, ω for the frequency of electromagnetic waves [4, 5].

3. THE DESIGN AND SIMULATION OF ONE-DIMENSIONAL GRATING ALL-DIELECTRIC FSS

According to the analysis in the previous section, the high dielectric constant of the medium is in the nature of metals. Palisade structure can be viewed as long column of high dielectric constant of the medium with air. Two kinds of composite material unit, through the medium, the dielectric constant of air cycle change on the influence of different frequency incident electromagnetic wave transmission coefficient of frequency selection [7–9].

Figure 1 is the simulation of the grating dielectric metamaterial FSS using CST MWS software. Dielectric periodic extension is adopted in the XY plane. Background conditions set in free space, the boundary conditions are set to: X and Y direction are periodic boundary (Unit Cell), Z direction for Open boundary (Open), the electromagnetic wave transmission along the Z direction. Using TE wave vertical incidence (electric field along the X direction), the curve of the S parameters can be calculated as shown in Figure 2.

As you can see from Figure 2, FSS frequency response is the single pass band, pass band is located in the x-band, pole 10.75 GHz band pass is the center frequency. The design of the pass band is in 10.53∼11.05 GHz for all dielectric FSS of 3 dB transmission pass band. The bandwidth is 497 MHz, has largely promoted the medium type of metamaterials pass band bandwidth. Analyzing the characteristics of the S parameters of graphics, pass band belt is more smooth, and the out-of-band grating lobe suppression is quite well.

To verify that the sensitivity of the incident plane wave angle, inspection transmission coefficient of different angles of incidence has been inspected. Figure 3 is for different incidence angles of TE wave feedback wave of S_{21} transmission parameter curves.

The different angle of incidence of S_{21} curve Can be seen in the Figure 3. With the increase of incident angle degree, center frequency does not change. It is proved that the one dimensional all dielectric FSS has good practical value.

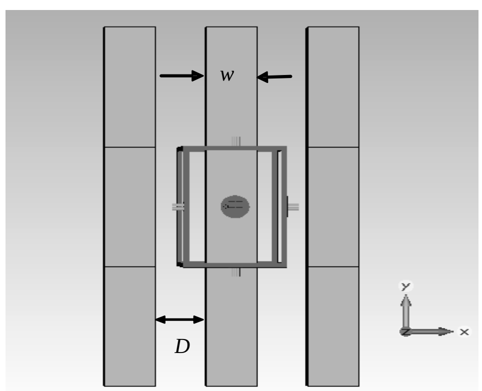

Figure 1: The structure diagram of the grating dielectric metamaterial FSS.

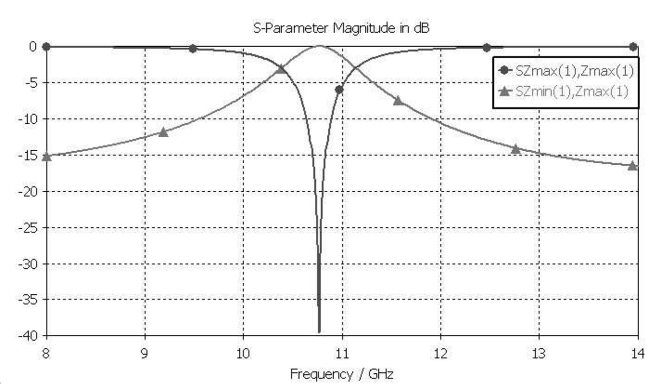

Figure 2: The S parameters of the grating dielectric metamaterial FSS.

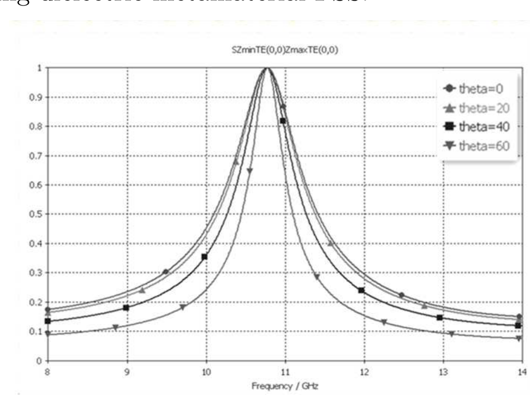

Figure 3: The S parameters of different incidence angles of TE wave feedback wave.

4. CONCLUSION

High dielectric constant of the dielectric materials have plasma liquid property as the metal. On the basis of the theoretical basis, design the one-dimensional grating all dielectric metamaterials FSS with good band pass characteristics.

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