Waveguide Slot Filtering Antenna with Metamaterial Surface

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Abstract - Novel metamaterial waveguide slot antenna with filtering performance is presented. The antenna is composed of a rectangular waveguide, longitudinal slots cut in its upper broadwall and a metamaterial surface instead of the bottom broadwall. The antenna performs excellent filtering ability using the metamaterial surface, in the specified interfering band. And two kinds of the surface are described in this work. One is in the form of metal bed of nails while the other is made up by periodic mushroom-type cell.

Index Terms — Filtering antenna, Waveguide slot antenna Metamaterial surface.

1. Introduction

With the eruptible development of the wireless communication, electromagnetic compatibility (EMC) problems are increasingly serious, which promotes the development of anti-interference technology and has attracted abundant research efforts [1]. Filtering antennas [2]-[3], which have radiating and filtering functions simultaneously, can effectively improve the anti-interference performance of electronic systems so cater for the demand. And compared with the traditional design of cascading the filter right after the antenna, filtering antennas have more compact structure, lighter weight and lower cost.

Many kinds of design approaches of filtering antennas have been reported. In [2], a bandpass filtering performance was achieved by placing a parasitic loop at the top of a printed antenna. Based on multilayer low-temperature cofired ceramic (LTCC) technology, a quasi-elliptic filter was integrated into a microstrip line to feed a series-fed antenna array in V-band [3]. In our previous work, the waveguide divider for broadening the bandwidth of a waveguide slot antenna array [4]-[5] offers a proper structure to insert filters in the array, obtaining a filtering antenna array [6]. Recently, a synthesis process for filtering antenna design has been presented. In these designs, the antenna not only radiates, but also serves as the last resonator or the load impedance of the filter [7]-[8]. Nevertheless, in some designs, the filtering structure needs extra circuit area, leading to large size. While in the others, due to the lack of the exact extraction of the antenna’s equivalent circuit, the filtering performance is limited.

In this paper, a waveguide slot filtering antenna using metamaterial surface is proposed. The proposed filtering antenna consists of a waveguide slot antenna and a metamaterial surface embedded at the bottom of the waveguide cavity. Different from the previous design process, additional filter circuit is not necessary in our approach. The rejection function at the interference frequencies is achieved using the inherent bandgap of the metamaterial surface.

2. Geometry of the filtering antenna

The geometry of the proposed waveguide slot filtering antenna array is shown in Fig.1. The configuration is similar to the conventional waveguide slot antenna, except that the smooth metal plane in the bottom of the rectangular waveguide is replaced by a metamaterial surface.

(a) with bed of nails

(b) with mushroom-type substrate

Fig. 1. Structure of the proposed filtering antennas
The metamaterial surface can be achieved using many kinds of periodic structure, such as bed of nails, as shown in Fig. 1(a) and mushroom-type substrate, as shown in Fig.1 (b).

At the operating frequencies, the metamaterial surface performs as a perfect electric conductor (PEC), so the antenna radiates just like the traditional waveguide slot antenna. While in the interference band, the surface performs as a perfect magnetic conductor (PMC), with the height of the waveguide cavity less than \( \frac{\lambda_s}{4} \) (\( \lambda_s \) is the smallest wavelength of interference band), it can stop the propagation of electromagnetic wave in the waveguide cavity, so the interference signal is rejected and a filter function is achieved.

3. Simulation results

Due to the limit of the extent and the similarity between the antennas shown in Fig. 1(a) and Fig. 1(b), only the simulated results for Fig. 1(b) will be shown here.

Firstly, the simulated transmission coefficient of the metamaterial waveguide is plotted in Fig. 2. The metamaterial waveguide is composed of a rectangular waveguide and a mushroom-type surface replacing the smooth metal plane at the bottom of the waveguide cavity. As seen in Fig. 2, in the working band, it has a nearby-0dB performance. While in the interference band, its value is below -60dB, means the wave is strongly rejected. The rejection function arrives because there is a bandgap for the mushroom-type surface at the same frequency band.

![Fig. 2. Simulated S21 of the filtering waveguide](image)

Then, the filtering antenna is arrived cutting radiating slots in the upper broadwall. Four slots are adopted in this work. The offset and length of the slots are carefully adjusted to meet good impedance matching and radiation property. The received energy when illuminated by an ultra-wide band horn is plotted in Fig. 3. Compared with the value of -23dB in the working band, it is always below -65dB in the interference band (over 7.90~8.75GHz), this means a suppression level stronger than 40dB is achieved.

![Fig. 3. Simulated received energy illuminated by an ultra-wide band horn](image)

4. Conclusion

A novel design approach of waveguide slot filtering antenna is presented. The filtering function is obtained using the bandgap property of the metamaterial surface, which is embedded at the bottom wall of the waveguide cavity. A 4-slot antenna is designed and the excellent simulated results have verified the innovative method.

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References