Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Photonics and Nanostructures – Fundamentals and Applications xxx (2014) xxx–xxx
PHOTONICS AND NANOSTRUCTURES Fundamentals and Applications
www.elsevier.com/locate/photonics

Bandwidth and gain enhancement of optically transparent 60-GHz CPW-fed antenna by using BSIS-UC-EBG structure

Ning Wang, Huiping Tian *, Zheng Guo, Daquan Yang, Jian Zhou, Yuefeng Ji

The State Key Laboratory of Information Photonics and Optical Communications, School of Information and Communication Engineering, Beijing University of Posts and Telecommunications, Beijing 100876, China

Received 30 September 2014; received in revised form 18 November 2014; accepted 24 November 2014

Abstract

A method in terms of bandwidth and gain enhancement is presented for optically transparent coplanar waveguide fed (CPW-Fed) antenna, which supports unlicensed 60 GHz band (57–66 GHz) applications. The original antenna and mesh antenna in [8] were designed on a transparent material that is made of a 0.2-mm-thick fused silica 7980 Corning substrate (ε_r: 3.8 and tan δ: 0.0001). However, the peak gains of −5.3 and −5.4 dBi at 60 GHz of those antennas can be further improved. Thus, in this paper, a novel bidirectional symmetric I-shaped slot uniplanar compact electromagnetic band-gap (BSIS-UC-EBG) structure with a reflection phase band of 58.0–62.1 GHz is proposed to improve antenna performance. Based on this BSIS-UC-EBG structure, both transparent BSIS-UC-EBG antenna and transparent mesh BSIS-UC-EBG antenna with enhanced properties are presented and discussed. The analysis results show that the impedance bandwidth (the peak gain) of transparent BSIS-UC-EBG antenna and transparent mesh BSIS-UC-EBG antenna are enhanced to 36.6% (4.7 dBi) and 44.7% (5.8 dBi), respectively. In addition, we also discuss the comparison of radiation patterns at 60 GHz, and the results illustrate that the radiation patterns are basically identical.

Keywords: 60 GHz; BSIS-UC-EBG; Transparent mesh antenna; High gain; Wideband

1. Introduction

As wireless communications have been generally studied and dramatically promoted in the past few decades, applications involving Wireless Personal Area Network (WPAN), vehicular and navigation communications make new demands for conformal and optically transparent antennas. These antennas can be installed on building windows, light panels, monitors of mobile devices, windshields of vehicles or vessels, to realize enhanced performance, security and esthetics purposes. The first feasibility study of optically transparent antenna was conducted by National Aeronautics and Space Administration (NASA) Lewis Research Center Nyma Group [1]. They proposed two antennas with AgHT-8 optically transparent conductive coating deposited on sheets of clear polyester which operate at 2.3 and 19.5 GHz, respectively. Radiation patterns were studied and had good match with conventional opaque antennas. In Ref. [2], optically transparent antennas made from five different kinds of materials were fabricated and measured. Conventional copper-based antennas were also used as references. The author demonstrated that

---

* Corresponding author at: Beijing University of Posts and Telecommunications, P.O. Box 90, #10 Xitucheng Road, Haidian District, Beijing 100876, China. Tel.: +86 10 62282153.

E-mail address: hptian@bupt.edu.cn (H. Tian).

http://dx.doi.org/10.1016/j.photonics.2014.11.002
1569-4410/© 2014 Published by Elsevier B.V.

Please cite this article in press as: N. Wang, et al. Bandwidth and gain enhancement of optically transparent 60-GHz CPW-fed antenna by using BSIS-UC-EBG structure, Photon Nanostruct: Fundam Appl (2014), http://dx.doi.org/10.1016/j.photonics.2014.11.002

transparent coating like gold (Au) and silver (Ag) could be good candidates for transparent antennas. Beyond that, Colombel et al. [3] investigated multilayer technology for UHF band transparent antennas, drawing the conclusion that ITO/Cu/ITO could be the trade-off between transparency and radio-electrical properties. Most of previously proposed transparent monopole antennas could be built from conductive and transparent coating deposited on see-through substrates [4–8] by radio frequency sputtering (RF sputtering is the technology that uses positive ion in radio frequency discharge plasma to bombard the target, sputter target atoms, and deposit them on the grounding surface of the substrate). Radio-electrical performances and transparency of all mentioned antennas were discussed, validating the feasibility of the proposed designs.

Recent researches adopt Ag/Ti bilayer with mesh structures printed on it by standard photolithographic wet etching process [6,7], and attain properties close to analogous non-transparent antennas. Nevertheless, most of the above transparent antennas operated at low frequencies. For instance, antennas working at 800 MHz [2,3,6], 2.4 GHz [4], 19.5 GHz [1], and 1–6 GHz [5] were reported, respectively. As a hotspot in modern communication technologies, the unlicensed 60 GHz band bears 9 GHz bandwidth and gigabits data rates. Consequently, millimeter-wave antenna featuring good bandwidth and gain performance is in demand for current wireless communication. Hautcoeur et al. [8] conducted a study on optically transparent monopole antenna operating at 60 GHz.

With current tendency for wideband and high gain antennas [9], periodic electromagnetic structures, which have the same characteristics with frequency selective surface (FSS) and high-impedance surface (HIS), have been a good candidate to optimize the antenna performance. They are usually viewed as artificial magnetic conductor (AMC) or electromagnetic band-gap (EBG) structure. Extensive researches on improving antenna performance by introducing periodic structures have been done in recent past [10]. In Ref. [11], the Spiral-arms-shaped metallo-electronic band-gap structure (MEBG) was embedded in a ultra-wide bandwidth (UWB) monopole antenna for achieving an impedance bandwidth of 33 GHz, with a 60% reduction in antenna size. Beyond that, the stop band property of mushroom-like EBG structures could also be used to design the trap UWB antenna [12], broaden bandwidth of microstrip antenna [13] and improve antenna's gain and directivity performance [14]. Using the presented aperture-coupled microstrip patch antenna (ACMPA) in [15] as a reference, a 16-element array of uniplanar-compact EBG structure was designed and loaded around the radiating patch, with a 4.5 dBi gain increase. It was also proved that UC-EBG surface could reduce the E-plane coupling in the 16 element patch array by 11 dB [16]. Mushroom-like EBG could reduce mutual coupling of surface waves in aperture coupled microstrip antenna [17] and waveguide-slot-array antennas [18]. In addition to that, the HIS which is organized by quasi-periodic structures had been proposed, with the ability to control the phase of radiated field or scattered field [19]. Design methodology of compact miniaturized EBG structures was studied and applied to achieve reduction in antenna electrical size [20].

The periodic electromagnetic structures can have different functions corresponding to different locations in antennas. The Sievenpiper EBG, which locates on the top three layers of LTCC tape, can realize a 6 dB enhancement in antenna's broadside directivity performance by preventing the main beam been degraded into two lobes [21]. Superstrate consisted of EBG could be reflective surface and form a resonant cavity with metallic ground plane, resulting in antenna gain enhancement [22]. In Ref. [23], a dual-layer FSS, which is placed under the antenna, achieved an ultra-wide in phase reflection band, and dramatically improved the antenna gain. The FSS could not only play the role of shield between antenna and conducting surfaces, but also prevent impedance mismatch in antenna [24]. Thus, the thought of presenting a 60 GHz transparent periodic electromagnetic structure to improve the performance of transparent antenna and transparent mesh antenna, which have not been studied before, naturally came to the authors' mind.

The aim of this paper is to deliver the feasibility for promoting properties of optically transparent antennas with BSIS-UC-EBG (Bidirectional symmetrical I-shaped slot uniplanar-compact Electromagnetic Band-gap), and to present potentially an ideal transparency components which can be used for wireless communications.

This paper is structured as follows. In Section 2, two structures of EBGs and optically transparent antennas loaded with EBG are thoroughly elaborated. And the design philosophy of transparent antennas is also introduced in this section. Then, in Section 3, we discuss the analysis results of former structures presented in Section 2. The detailed optimization process and reflection phase curves of EBG have been shown to justify the rationality of the BSIS-UC-EBG. Antennas' performances on impedance bandwidth, gain and radiation pattern have also been discussed. Finally, Section 4 draws the conclusion.

Please cite this article in press as: N. Wang, et al. Bandwidth and gain enhancement of optically transparent 60-GHz CPW-fed antenna by using BSIS-UC-EBG structure, Photon Nanostruct: Fundam Appl (2014), http://dx.doi.org/10.1016/j.photonics.2014.11.002