Int. J. Electron. Commun. (AEÜ) 70 (2016) 605–610

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

Dual-band reflectarray with crossed-dipole elements for GSM and LTE applications

Xi-Wang Dai*, Tao Zhou

College of Electronic and Information Engineering, Hangzhou Dianzi University, Hangzhou, Zhejiang 310018, People's Republic of China

ARTICLE INFO

Article history:
Received 12 April 2015
Accepted 24 January 2016

Keywords:
Dual band
Reflectarray
Crossed dipole
Square ring
FSS

ABSTRACT

A novel dual-band reflectarray for beam control of reflected waves at GSM and LTE bands is proposed in this paper. The reflectarray is constructed with two substrates separated at a distance form. Consisting of square ring and four stubs, the FSS cell element has the dual-band property for the changes of current distribution. A crossed-dipole element is printed on the surface of another substrate, and the progressive phase distribution is achieved for the reflected wave by adjusting the resonant length of the crossed-dipole element. The reflectarray can independently control the direction of both horizontally and vertically polarized reflect beams at two resonant frequencies. A reflectarray comprising 7 by 5 elements with operation at 1.7 GHz and 2.7 GHz is studied and measured, which can be applied in the GSM and LTE communication systems.

1. Introduction

Microstrip reflectarray, integrated with the advantages of reflectors and phased arrays, is proposed for replacing conventional parabolic reflector antenna [1–3]. A microstrip reflectarray consists of an array of microstrip patch elements, and reflects a beam in a specified direction when illuminated by a primary source. The concept of the reflectarray is based on phase compensation for each element dimension to achieve cophase reradiation and to concentrate the scattered wave toward a specific direction [4,5]. It has been widely applied to radar and space communication systems [6], and wireless communication systems [7,8]. Many methods to design the reflectarray with different element structures have been proposed by researchers. An MEMS-based phase-shifter cell based on an equivalent circuit model was presented in Ref. [9]. By controlling and regulating five key design parameters of the unit cell through the equivalent electrical circuit, the optimized design of the phase-shifter cell permits a 360° phase range along with the required number of linearly distributed phase states. The theoretical modeling and practical design of millimeter wave reflectarrays using microstrip patch elements with variable size were presented in Ref. [10]. Four reflectarray design examples operating at 28 and 77 GHz were presented and discussed. Multiple-polarization microstrip reflectarray antenna with high efficiency and low cross-polarization was demonstrated in Ref. [11]. Comparing with conventional parabolic reflectors, microstrip reflectarray has advantages such as low cost, low profile, low mass and volume, easy manufacturing, and scannable beam [12]. In the wireless communication system such as GSM1800 and LTE, microstrip reflectarray can be mounted on ceiling of tall buildings or embedded into walls to reflect beams covering different areas, especially those blind areas to the primary source.

In this work, a new reflectarray element for dual band application is proposed for GSM and LTE applications. The dual band reflectarray is composed of crossed-dipole elements and frequency selective surface using the structure of square ring with four stubs. The FSS configuration is on surface of one layer, and can be easily fabricated. A crossed-dipole is printed on another dielectric substrate with some distance away from FSS. With the crossed-dipole, it can control independently the direction of both horizontally and vertically polarized reflect beams. The dual-band reflectarray can be designed to scatter low frequency beam with horizontal polarization, and to scatter high frequency beam with vertical polarization. Using this method, a 7 by 5 reflectarray with variable size crossed-dipole and squaring ring with four stubs is presented. The properties of the new reflectarray are discussed and analyzed, which shows its effectiveness in the design of reflected beams properties for two different working frequencies with different polarizations, respectively.

2. FSS structure

An FSS consisted of a square ring with four stubs is a surface which exhibits different reflection and/or transmission properties

* Corresponding author. Tel.: +86 057186919150.
E-mail address: xwdai@hdu.edu.cn (X.-W. Dai).

http://dx.doi.org/10.1016/j.aeue.2016.01.016
1434-8411/

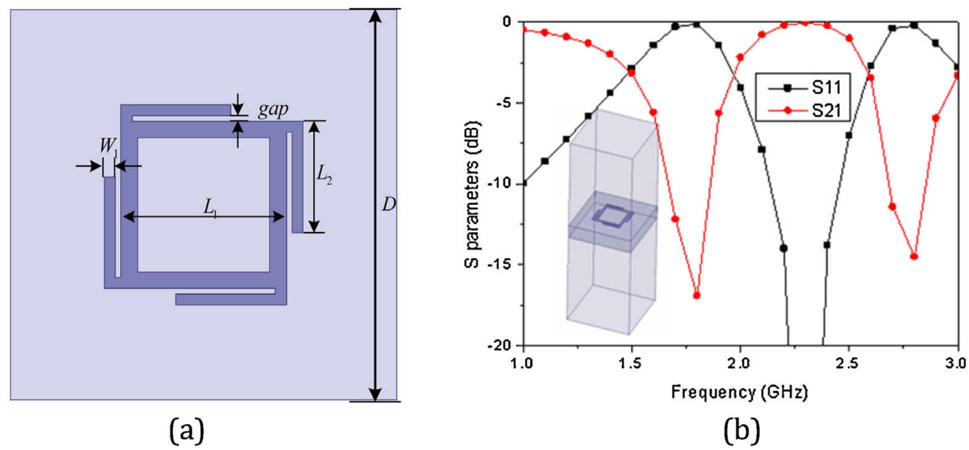

Fig. 1. Cell element of FSS (a) structure, (b) S parameters.

as a function of frequency. The square ring and the four stubs structure compose the multi-resonance structure, which shows the dual band characteristic. The cell element structure is shown in Fig. 1(a). The periods in both x and y directions are D = 70 mm and the circumference of the square ring is 160 mm. The branch has a width of 2 mm and a length of 25 mm, while the gap between the branch and the nearest edge of the square ring is 1 mm. The structure is attached on the surface of a dielectric substrate with a thickness of h = 1.0 mm and relative permittivity of ε_r = 2.55.

An infinite periodic model using HFSS software simulation was performed to analyze the reflection and transmission coefficients. The properties of the square ring with four stubs versus frequency at normal incidence of plane wave are shown in Fig. 1(b). It can be found that two complete reflections occur at f_{01} = 1.7 GHz for GSM1800 and f_{02} = 2.7 GHz for LTE communication system, which means that this structure can scatter only the desired frequency but is transparent to the electromagnetic wave at other frequencies. The 3 dB impedance bandwidth for the proposed design is 26% ranging from 1.5 to 1.95 GHz at low frequency band, and 15% ranging from 2.58 to 3.0 GHz at high frequency band, which is wide enough to cover the GSM1800 band and 2.7 GHz LTE band. At two resonance frequencies, the current distributions of the structure are shown in Fig. 2. At f_{01} = 1.7 GHz, the current of structure is mainly distributed on the ring, while at f_{02} = 2.7 GHz, the current is mainly distributed on the branch. The resonance frequencies of the square ring with four stubs can be adjusted by its parameters.

In order to find the influences on the resonant frequencies of corresponding structural parameters, a parametric study has been carried out. By altering parameter L_1 and fixing other parameters, the simulated S_{21} of the proposed reflectarray is shown in Fig. 3(a). It can be seen that when the value of L_1 increases, both the resonant frequencies decreases, which indicates that the influence of square ring on the resonant frequency is great. This situation is similar to L_2. In Fig. 3(b), the value of L_2 varies from 23 mm to 35 mm, while other parameters are fixed. Both the resonant frequencies decrease with increase of L_2. Fig. 3(c) shows the simulated S_{21} of the proposed reflectarray with different values of *gap*. It is observed that the value of *gap* has the impact on the interval between the two resonant frequencies. With *gap* increasing from 2.5 mm to 3.5 mm as well as other parameters are fixed, the first resonant frequency decreases and the second resonant frequency increases, which mean that the interval becomes large. Thus, by altering these parameters, the operating frequency can be adjusted to the requirement.

The crossed-dipole array is printed on the other dielectric substrate. The effect of crossed-dipole on the dual band FSS cell element is considered. When the plane wave incident on the FSS at normal incident angle, the variation of reflection losses at f_{01} = 1.7 GHzand f_{02} = 2.7 GHz are within 2 dB. The performance of cell structure is favorable for designing a dual band reflectarray with varying dipole length.

3. Design of dual-band reflectarray

In wireless communication systems, base station antennas usually are installed on the top of high buildings for wireless signal coverage. However, antennas of different communication systems are located at different buildings in order to reduce mutual interference. High building, or new infrastructure will affect the

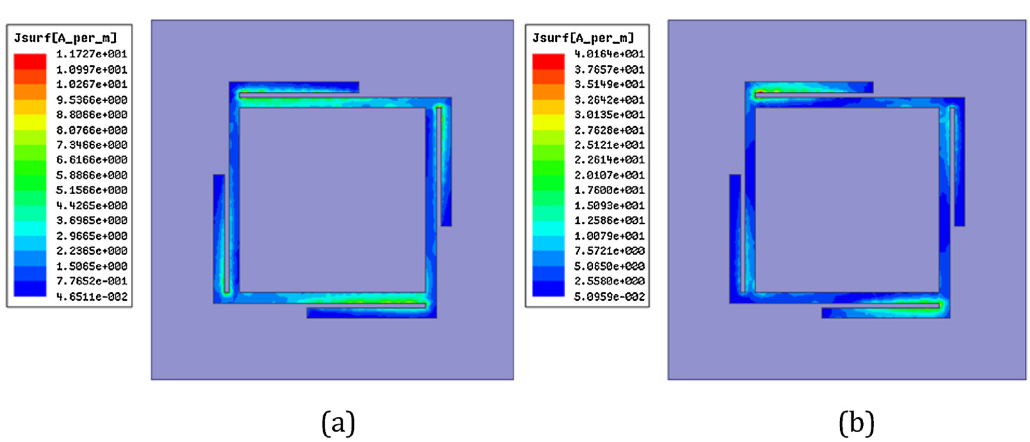

Fig. 2. Current distributions at different resonant frequencies. (a) 1.7 GHz and (b) 2.7 GHz.