Int. J. Electron. Commun. (AEÜ) 69 (2015) 622–628

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

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

Centre-fed dual band omnidirectional array antenna with electrical down tilt

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ARTICLE INFO

Article history:
Received 19 February 2014
Accepted 29 November 2014

Keywords:
Centre-fed
Electrically tilt
Linear array
Microstrip
Omnidirectional

ABSTRACT

A centre-fed dual band (3.5 GHz/5.8 GHz) omnidirectional microstrip array antenna for using in wimax applications is presented. Two distinct series fed back-to-back subarrays separated by a power divider are designated for these two bands. The proposed centre-fed structure reduces interference of two subarrays and provides a flexible progressive phase and so independent tilt angle control in dual bands. In addition, it is shown that compared to edge-fed dual band structure, the centre-fed structure makes the use of low permittivity substrates possible which are more appropriate for antenna radiation. The fabricated antenna can cover 3–3.7 GHz and 5.4–6.4 GHz frequency bands with $S_{11} < -10$ dB. It also shows about 10° down tilt in both frequency bands.

1. Introduction

The demand for high-speed telecommunication services like wimax is increasing rapidly. Two of the most common frequency bands of Wimax are 3.5 GHz and 5.8 GHz. Using dual band antennas in these systems usually reduces the hardware cost and complexity.

Omni-directional radiation pattern with moderate gain is the main requirement of such wireless applications. Dipole arrays [1,2], series-fed arrays [3,4] and coaxial collinear array antenna (coco) [5] are proposed to provide omnidirectional radiation pattern with moderate gain. In addition, down tilt in base station antennas efficiently delivers the power to users and also provides frequency reuse opportunity in adjacent cells [6].

The antennas designed for dual band wimax applications must cover 3.4–3.6 GHz frequency band for the first and 5.725–5.85 GHz frequency for the second band.

In this paper, a centre-fed down tilt dual band omnidirectional microstrip array is proposed. The antenna consists of two series fed linear array (two subarrays) and one power divider to feed them. Each linear array is responsible for one frequency band. The power divider also acts as a filter and prevents entering of each signal to the subarray assigned for the other frequency band. The designed antenna shows $S_{11} < -10$ dB over 3–3.7 GHz and 5.4–6.4 GHz and about 10° downtilit in both frequency bands.

Compared to edge-fed dual band omnidirectional array proposed in [7], this centre-fed structure does not require high permittivity substrate which is not efficient for antenna applications. Furthermore, centre-fed configuration provides independent progressive phase and tilt angle control in dual bands.

The remainder of this paper is structured as follow: Section 2 describes the antenna design procedure. The simulation and measurement results are reported in Section 3 and finally Section 4 concludes the paper.

2. Antenna design

The proposed antenna is a linear array consisting of a substrate and microstrip lines fabricated on two opposite faces of the substrate. As shown in Fig. 1, the structure involves three main sections: a subarray responsible for 3.5 GHz frequency band, a power divider, which is located at the middle of the structure, and finally a subarray responsible for radiation at 5.8 GHz frequency band. In this section, first, the design procedure for each single band array is described in part 2.1. In part 2.2, two possible dual band configuration is explained: edge-fed structure and centre-fed structure. It is shown that for dual bands with $f_{up}/f_{low} < 2$ (as in our case: $f_{up}/f_{low} = 5.8/3.5$), the edge-fed structure requires high permittivity substrates which are not desired in microstrip antennas. Therefore, a centre-fed structure is proposed which overcomes this limitation. Part 2.3 explains final proposed centre-fed structure including single band arrays (3.5 GHz/5.8 GHz), power divider and matching sections in detail.

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http://dx.doi.org/10.1016/j.aeue.2014.11.013
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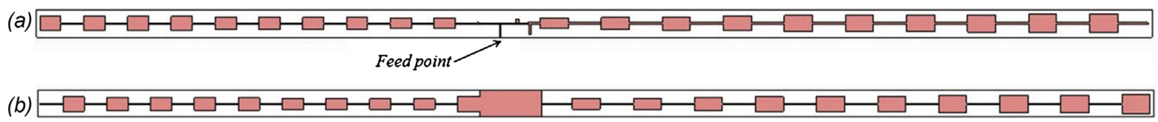

Fig. 1. dualband antenna structure. (a) Top layer and (b) bottom layer.

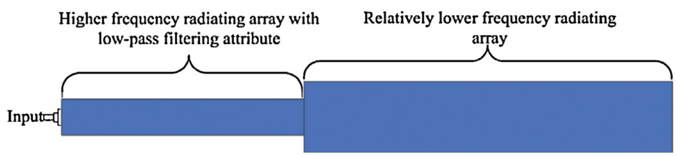

Fig. 2. Schematic of edge-fed dual band structure [7].

2.1. Single band array design

The microstrip lines on either sides of the substrate comprise wide elements substantially aligned over narrow elements. Each wide element which is the radiating element of the antenna acts as the ground plane for the narrow line [8]. The resulting structure is supposed to feed next elements in the subarray.

To feed all elements in phase, the distance between adjacent elements should be one wavelength (λ_g); hence, the length of wide elements, considered as radiating elements, and the related transmission lines should be typically 50% of the wavelength considering the permittivity of the substrate.

In other words, half wavelength elements with half wavelength spacing leads to a standing wave array with a broadside beam.

To get a scan angle different from broadside, the distances between elements should be changed which leads to a leaky wave periodic array [9]. This condition causes the antenna to go from open-stopband region to radiating region [10]. Design of a leaky wave antenna is performed by calculating α and β for the desired side lobe level (SLL) and scan angle, respectively. However, SLL is not a design criterion for us. In contrast, achieving desired scan angle while providing high efficiency has higher priority in our design. Therefore, calculating the β is more important and there is no need to calculate the parameter α in such a leaky wave antenna independently. According to the periodic or slow wave leaky wave antenna, the following equations can be used to determine β for a desired angle [9,11]:

$$\beta_n = \beta_0 + \frac{2n\pi}{P} \tag{1}$$

where P is the period of the structure or the distance between adjacent elements. Since the antenna is operating in the first space harmonic ($n = -1$):

$$\beta_{-1} = \beta_0 - \frac{2\pi}{P} \tag{2}$$

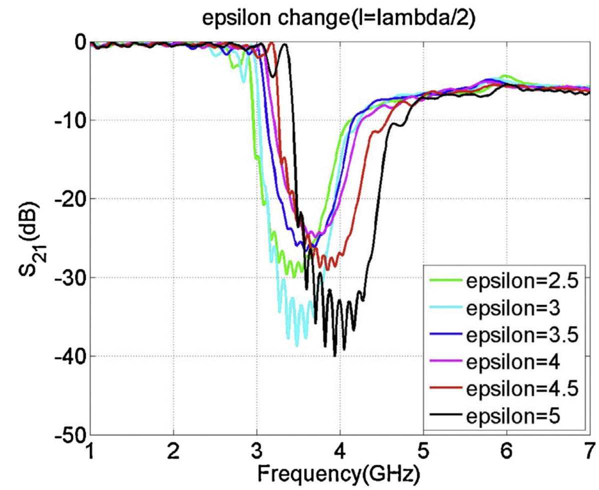

Fig. 4. Transmission response of filter-antenna structure vs different permittivities.

The angle of radiation of a leaky wave antenna is calculated as follows:

$$\sin\phi = \frac{\beta_{-1}}{k_0} \tag{3}$$

where ϕ is the angle measured from broadside and k_0 is the free space wavenumber.

In typical down-tilted base stations, the main beam is supposed to be down tilted about 10° from the broadside. In the proposed antenna that the arrays are located back to back, in one arm the beam is steered +10° for its frequency band and in the other arm, the beam is steered −10° for its frequency band resulting equal beam positions for both frequency bands.

2.2. Dual band array configurations

2.2.1. Edge-fed dual band array configuration

An edge-fed dual band (2.6 GHz/5.8 GHz) array has been introduced in [7]. As shown in Fig. 2, the first section of this structure which is responsible for radiation at high frequency is also a low pass filter (filter-antenna). Therefore, each section radiates at its specific frequency without interference.

The circuit model of this periodic structure that shows filtering characteristic [12] is shown in Fig. 3.

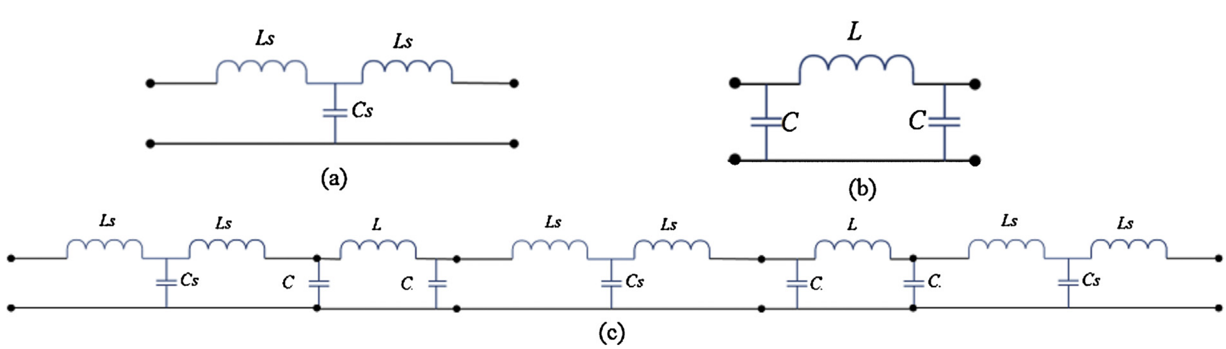

Fig. 3. (a) equivalent circuit of discontinuities, (b) equivalent circuit of high impedance line, and (c) equivalent circuit of one section of the antenna [7].