Volume 6, Issue 6, June 2016 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

A Wide Beam-width Microstrip Cross Antenna Design for broad Scan Angle Phased Array

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Abstract— A wide bandwidth, broad beam-width microstrip antenna element is reported for active phased array application. The antenna element offers a return loss better than -10dB over a bandwidth of 24.82% in Ku-band with beam-widths of 134° in H-plane and 126° in E-plane, respectively. The antenna is capable of realizing two orthogonal linear polarizations and a circular polarization respectively when different feeding approaches are utilized. Moreover, the wide-angle scanning characteristic of the 8×8 array composed of proposed element is evaluated. Besides, the microstrip steerable antenna array can be easily embedded into wearable medical or commercial devices.

Keywords— Broad beam-width, microstrip antenna, phased array, medical devices.

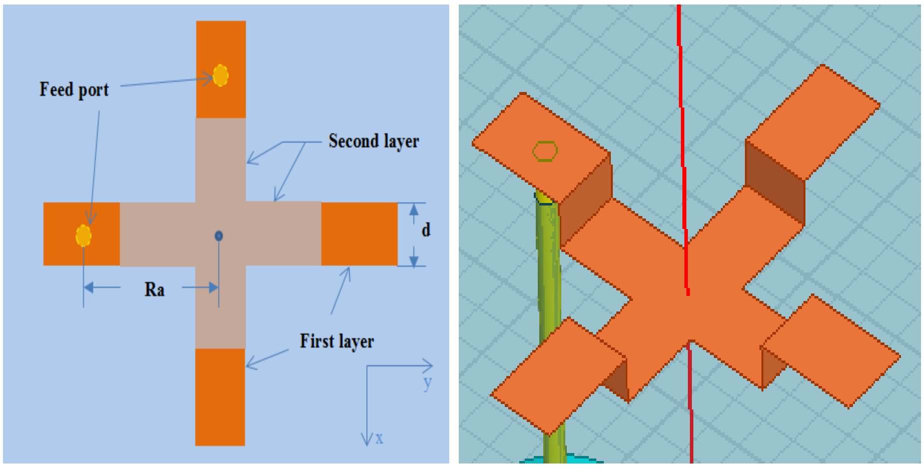
I. INTRODUCTION

Phased array antenna has enormous applications in various fields, such as radar communication, body-centric wireless communication [1] and commercial devices, due to its agile beam scanning characteristic, high efficient power control, easily integrated into microwave circuits, etc. Microstrip antenna (MA) occupies huge advantages in phased arrays due to its small volume and low-profile planar configuration. Active phased arrays require wide band, wide beam antenna elements with low cross polarizations for obtaining a wide array scan zone over a broad bandwidth. Unfortunately, the bandwidth of a typical MA is smaller than 3%, the 3-dB beam-widths of E-plane and H-plane of a MA are typically 100° and 110°, respectively [2]. Recently, several relevant designs have been reported in the excellent literatures [3-5]. A rectangular microstrip patch on a composite substrate has been used to achieve the broad 3 dB beam-width with 90° in E-plane and 70° in H-plane with high gain, respectively [3]. In [4] a novel wideband and broad-beam MA loaded with gaps and stubs is proposed. Based on two-layer stacked electromagnetic coupling technique, the 3 dB beam-width of the microstrip patch antenna in E-plane and H-plane are about ±60°. As reported in [5], by optimization, a compact, wide bandwidth, wide beam-width resonant microstrip meander line antenna element could obtain 3dB beam-width of 130° only in E-plane.

In this paper, a novel MA, which possesses wide bandwidth and broad beam-width in Ku-band, is proposed. In the design, a patch is design in a special feature, i.e., cross pattern with two-layer configuration, thus achieve broad beam-width. Furthermore, it is of our interest that, the proposed antenna design is agile in different applications: The orthogonal linear polarization could be realized by exciting either port; the circular polarization could be realized by exciting both ports.

II. ANTENNA DESIGN

The proposed microstrip antenna design, as is shown in Fig.1. The patch is in cross-shape of two layers, operating at 13.5GHz.



(a) (b)

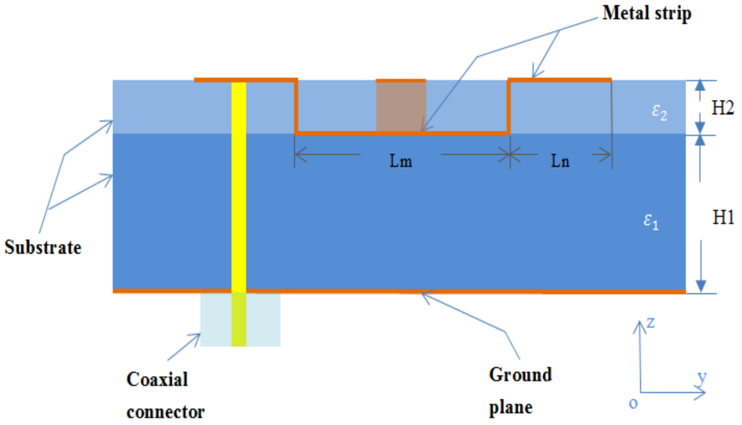


Fig.1.The proposed broad beam-width antenna with a cross and metal connection; (a) top view, (b)perspective view, (c)side view: Ra=2.4mm, d=1mm, Lm=3.45mm, Ln=1.5mm, H1=3.9mm, H2=0.5mm, ε1=3.5, ε2=2.2.

We choose the top substrate with a small dielectric constant (Taconic TLY) and the bottom substrate with a high dielectric constant (Taconic RF-35) for the purpose of high radiation efficiency. The resonant frequency varies with the length of Lm+2*Ln+2*H2. We note that, H1 and H2 both have significant influence on the radiation pattern.

III. RESULTS AND DISCUSSION

As is shown in Fig. 1(b), the antenna patch consists of three parts, i.e., first layer, second layer, connection part between first and second layer. The connection plays a significant role in enhancing the radiation pattern width. Meanwhile the height H1 is also the key factor.

A. Return loss and polarization

The ANSYS/ANSOFT High Frequency Structure Simulator (HFSS) 15 has been used to simulate above structure. With a λ-refinement based on a target frequency of 12-15GHz, fast sweep were run between 11-16GHz. The simulated reflection coefficient (S11) is shown in Fig. 2. The -10dB bandwidth is 3.5GHz (~24.82% fractional bandwidth). The two ports with coaxial feeding have strong resonance, compared with one port. It can be inferred that two feeding ports are close to have positive influence on the refection coefficient. The case of only one of the two ports excited can realize different linear polarizations and the case of two ports excited simultaneously can obtain a circular polarization. The axial ratio of H plane is given in Fig.2. (b), with its value slightly above the 3dB line in some angles.

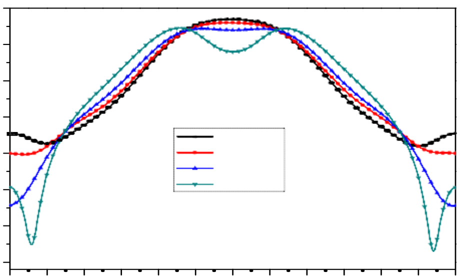


Fig.2. Simulated H-plane radiation pattern plot of antenna with different heights of the bottom substrate.

B. Effect of the height H1

The resulting radiation patterns for these increasingly higher positions of the radiating patch is showed in the Fig.3. As will be appreciated from Fig. 3, the radiated energy at H plane increases at relatively low radiation angels along the ground plane surface as the height of the radiated apertures is increasingly raised above the ground plane surface. However, when the height of H1 reaches approximately one-half effective wavelength (Measured in the surrounding substrate) the radiation patterns in a direction transverse to the ground plane surface will be totally depressed and further increase in height of the radiation patch above the ground plane will cause the radiating pattern to break up into multiple lobes.Obviously, we choose H3 between 3mm and 4mm.

C. Effect of the connection

To better understand the antenna behavior, electric current distribution on the cross antenna with two ports excited simultaneously is presented in Fig.4. The current distribution with only one port excited is easy to associate, just mainly districting in line patch parallel to E-plane. By investigating the current distribution on the cross patch, it can be easily known that, if the cross patches were in the same layer and without connection, it would have similar radiation pattern with two dipole overlapping. There is off-phase current on the opposite connection of either dipole, equivalent to off-phase polarization. They play a significant role in enhancing the beam-width, especially in E-plane, ensuring the radiation pattern decrease more tardy compared with conventional microstrip antenna.

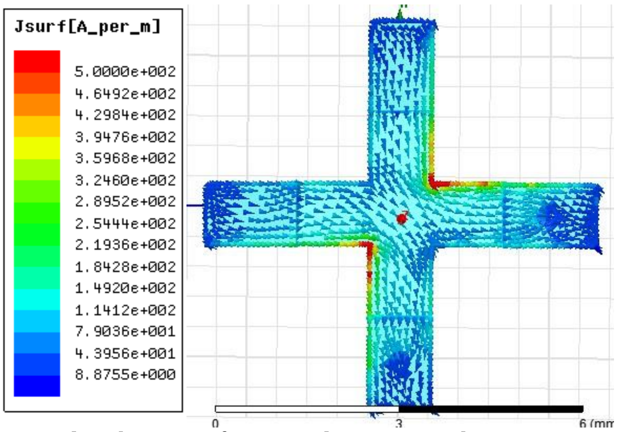


Fig.3.Surface current distributions of proposed antenna with two ports excited at 13.5GHz

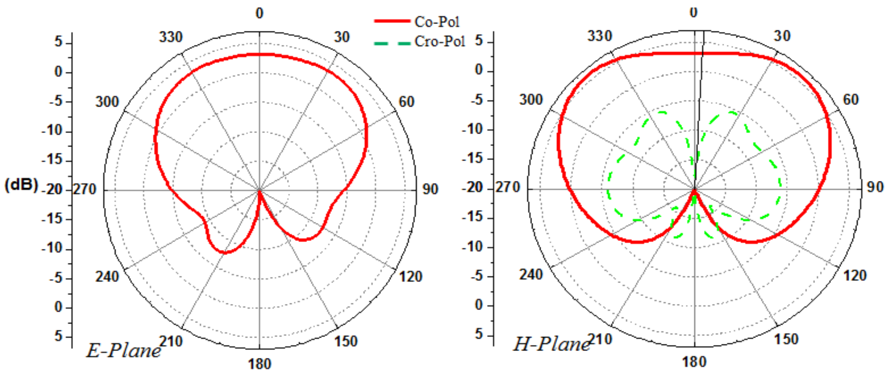


Fig.4. Simulated E- and H plane radiation patterns of the cross antenna at 13.5GHz.

D. Radiation of element

The simulated Co- and Cross-polar E- and H-plane radiation patterns of proposed cross antenna at 13.5GHz are shown in Fig.5. As it can be seen, the antenna has excellent polarization purity at 13.5GHz. The E-plane radiation pattern plot gives a beam-width better than 120°. H-plane plot exhibits symmetry with a beam-width exceeding 130°. The element also gives a gain better than 5dB over the bandwidth.

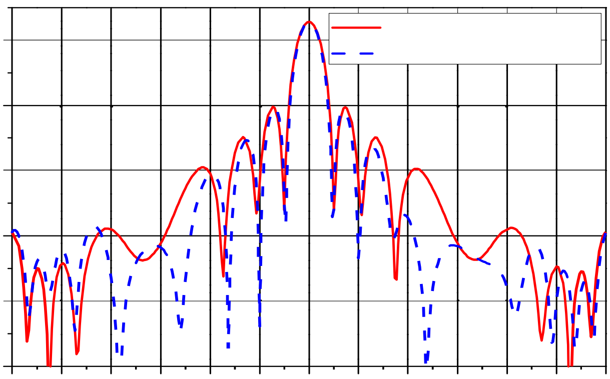


Fig.5. Simulated radiation pattern E- and H-plane without scanning at 13.5GHz

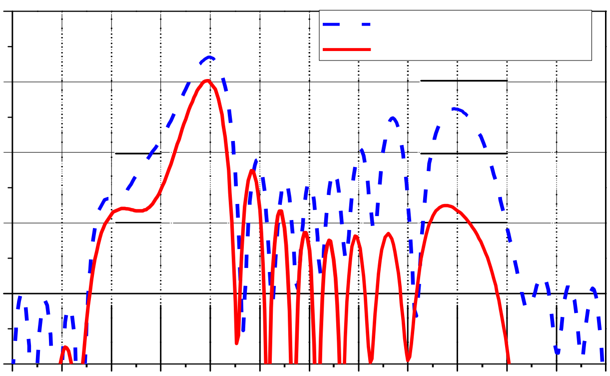


Fig.6. Simulated radiation pattern E- and H-plane with scanning to 60° at 13.5GHz

An 8×8 rectangular array of 64 elements has been simulated by employing the cross antenna as typical element with HFSS 15. The inter-element spacing is λ/2 to avoid grating side lobes during the scanning and reduce mutual coupling. Fig. 6 presents radiation simulation results of E-plane (gain-phi) and H-plane (gain-theta) without scanning (_scan=0°), the maximum gain achieves at 22.8dBi, which is in agreement with the theoretical value on the whole [7]. Meanwhile, Fig. 7 presents the radiation simulation results of E-plane (gain-phi) and H-plane (gain-theta) when scanning up to 60°, the peak gains fall down to 16.74dBi (H-plane) and 15.08dBi (E-plane) and side lobes are 3.9dBi (H-plane) and 6.2dBi (E-plane), respectively. Note that, the gain decrease is more than 3dB. This phenomenon is attributed by a certain mutual couplings between the adjacent elements [6]. The simulated radiationperformance indicates the array has ability in providing the scanning volume of ±60° in the E- and H-plane.

IV. CONCLUSION

A novel broad beam-width microstrip antenna based on cross configuration and two-layer layout is presented. It could realizes orthogonal linear polarization and a circular polarization by switching with beam-width of 134° in H-plane and 126° in E-plane, respectively. The wide-angle scanning characteristic of the array composed of proposed element is evaluated. Moreover, we anticipate that, the versatile beam steering abilities and high gain characteristics of proposed antenna are the power saving solutions for body area network node, so phased array antennas occupy a prospective foreground for use in body area network and medical .instruments.

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