Int. J. Electron. Commun. (AEÜ) 96 (2018) 228–237

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

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

Regular paper

# Dual band rectangular patch antenna array with defected ground structure for ITS application

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ARTICLE INFO

*Article history:*
Received 10 January 2018
Accepted 25 September 2018

*Keywords:*
Intelligent transportation system
Defected ground
Patch antenna array
Gain
Dual band

ABSTRACT

A dual band inset fed rectangular patch antenna array has been proposed for intelligent transportation system (ITS) application. This paper proposes 8–element patch array antenna with defected ground structure (DGS). The simulated results of 2, 4 and 8 element patch with and without DGS are also compared. Proposed antenna gets dual band of 5.02 GHz and 5.92 GHz centre frequency with DGS. The 8–element patch array antenna with DGS is fabricated and its result is compared with simulation result. 26.5 dBi and 24.9 dBi is measured gain of the proposed antenna structure for 5.02 GHz and 5.92 GHz centre frequency respectively.



## 1. Introduction

Safety of people, information of free parking area and automatic toll collection system are some of important ITS applications are focused in the proposed work. These applications of ITS are shown in Fig. 1. Many people were seriously injured and died due to vehicular accidents. So, there is a need to increase safety of people and to avoid vehicular accidents. V2X communications are main aspects to increase safety and avoid accidents. For V2X communication dedicated short range communication (DSRC) and WLAN are useful frequency bands. 5.9 GHz and 5 GHz is the resonant frequency for DSRC and WLAN respectively. For better connectivity between V2X the gain of 5.9 GHz and 5 GHz antenna should be high. The high gain can be obtained by array of antenna at these frequencies.

Lee et al. proposed meta-material transmission line based dual band patch antenna for Wi-Fi having centre frequencies of 2.4 GHz and 5 GHz [2]. Gupta et al. proposed a dual band meta-material antenna fed by coplanar waveguide having centre frequencies of 3.52 GHz and 5.17 GHz [3]. Liu et.al. proposed L shaped 4–element beam switchable array for 5.9 GHz having gain of 6 dBi [4]. Niikura et.al. proposed 3–element array for 1.89 GHz having gain of 4.5 dBi [5]. Mondal et.al. proposed microstrip phased array antenna for 5.88 GHz having mutual coupling 22 dB and gain 10.6 dBi [6]. Chang et.al. proposed probe fed $3 \times 3$ and $5 \times 5$ patch array for 5.85 GHz having gain 7.7 dBi and 9.3 dBi respectively [7]. Mondal et.al. proposed 4–element array for 5.88 GHz having gain of 10.9 dBi [8]. Varum et.al. proposed 5–element array for 5.75 GHz having 13.8 dBi gain [9]. Xiao-tao et.al. proposed a reconfigurable patch array for 5.2 GHz having 5.3 dBi gain [10]. Sugiura et.al. proposed a steared ring antenna array for 2.4 GHz having 6.7 dBi [11]. Liu et.al. proposed a reconfigurable $3 \times 3$ small directive array with Yagi–Uda configuration for 2.4 GHz resonant frequency having gain of 10 dBi [12]. Zhang et.al. proposed dual band dual circularly polarized with $4 \times 4$ element array antenna for 12.1 GHz and 17.4 GHz [13]. Varum et.al. proposed non-uniform and broadband circularly polarized with $4 \times 4$ element array antenna for 5.8 GHz [14]. Suzuki et.al. proposed a single layer slotted waveguide array for 3.6 GHz and 4.4 GHz [15]. Qiu et.al. proposed shaped-beam stacked patch array with stripline aperture–coupled feeding technique working on 10.8 GHz with 3.8% frequency band [16]. Peristerianos et.al. proposed fractal semi–printed antenna array for dual band at 2.45 GHz and 5.75 GHz [17]. Qi Luo et.al. proposed a circularly polarized equilateral patch array for 10.5 GHz [18]. Tomas et. al. proposed a 24 GHz radar antenna with substrate integrated waveguide (SIW) feeding network for ITS applications having gain of 11.1 dBi [19]. Yang et al. proposed a quasi-Yagi antenna for WLAN and DSRC having maximum gain of 7.8 dBi [20]. Wang et al. proposed $3 \times 2$ antenna array for WLAN and WiMAX having maximum gains of 15.1 dBi and 17.3 dBi respectively [21]. Chirag Arora et.al. proposed a patch antenna array using metamaterial

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https://doi.org/10.1016/j.aeue.2018.09.039
1434-8411/

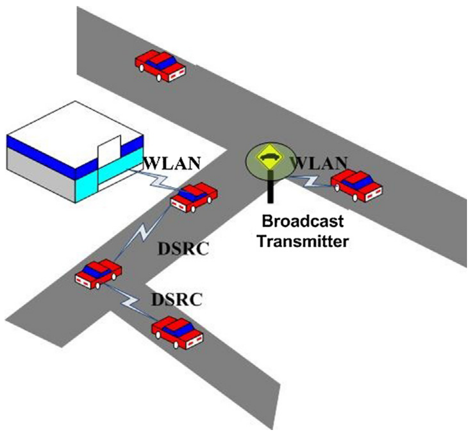


**Fig. 1.** Application of ITS [1].

technique for 5.8 GHz Wi-MAX applications having gain and bandwidth of 12.1 dBi and 780 MHz respectively [22]. He-Xiu Xu et al. proposed first time toward the miniaturization of three-dimensional (3-D) anistropic zero-refractive-index metamaterials (AZIM) in 2014 [23]. Further, in same year he proposed a three-dimensional (3D) highly-directive emission system produces extra high bandwidth from 3 to 7.5 GHz is proposed by him [24]. He also proposed an octave-bandwidth highly-directive half Maxwell fish-eye (HMFE) lens antenna in this same year [25]. In 2016, a 15 $\times$ 15 array of twisted complementary dual-split ring resonators with a peak gain of 13 dB is proposed by him [26]. In 2017, a general strategy to efficiently and flexibly control the emission beams with dual functionalities realized independently by orthogonal excitations [27]. In same, a triple-layer dual-mode meta-atom having H-shaped structure is combined with a pair of symmetric patches with 25 $\times$ 25 array elements having centre frequency of 9.6 GHz with gain of 18.8 dB [28] is proposed by him.

Mutual coupling is one of the important parameters of the antenna. As number of element increases in array the mutual coupling between the elements is also increased that distort the desired signal. So reduction in mutual coupling is necessary. Zhao et al. proposed an antenna interference cancellation chip (AICC) to mitigate the mutual coupling between two elements. The tuning capacitors and shunt inductors are used to minimize mutual coupling [29]. Jiao et al. proposed periodic crossing EBG structure to reduce the mutual coupling [30]. Yu et al. proposed reduction of mutual coupling between two element patch antenna array by 3-D meta-material structure (3DMMS) [31].

In this paper, an 8-element dual band antenna array is proposed having centre frequencies of 5 GHz and 5.9 GHz. The proposed array antenna produces high gain. This array structure is suitable for ITS applications. In this paper 2-element, 4-element, and 8-element array with and without defected ground structure (DGS) are designed, simulated and results are compared. From this comparison it shows that 8-element patch array with DGS produces better result for ITS applications. The 8-element patch array with DGS produces very high gain of 26.5 dBi and 24.9 dBi at 5 GHz and 5.9 GHz centre frequency respectively. Slots on the ground plane (DGS) will disturb the flow of the current. Due to this disturbance the characteristics of transmission line such as capacitance and inductance is changed. The change in capacitance and inductance values helps in impedance matching of the antenna [32]. The slots in ground plane (DGS) also improve the bandwidth and gain of the antenna [1]. DGS also reduces mutual coupling and enhance the isolation [33,34]. Some of authors proposed defected microstrip structure (DMS) in [35,36]. Xiao et al. proposed a multi-band band-stop filter with T-shape DMS [37]. Ding et al. proposed a beamforming antenna based on DMS [38]. Zakaria et al. proposed DMS based band-pass filter for wide-band application [39].DMS enhances the bandwidth of the antenna and helps in producing multiple resonant frequencies. But the gain of the antenna is decreased by this DMS structure. Further DMS structure is not helpful in array design, it disturbs the current variation on the patch elements and the gain is decreased.

In this paper Section 2 describes design specification. Result and discussion is described in Section 3 and in Section 4 conclusion of paper is described.

## 2. Design specification

In the proposed work, first of all two inset–fed rectangular patch antennas for 5 GHz and 5.9 GHz are designed. The design of inset–fed rectangular patch and its parameters are shown in Fig. 2. In the proposed antenna structure, the dielectric material used is FR-4 with height ($h$) of 1.524 mm having dielectric constant 4.4. The length and width of the substrate material are $l_1$ and $w_1$ respectively. The length and width of the patch are $l_2$ and $w_2$ respectively. $w_3$ is the inset gap and $l_3$ is the inset distance. Feed line length and width are $l_4$ and $w_4$ respectively.

The values of the parameters for each frequency are given in Table 1. These are calculated from formulas given in [40,41]. Then,the proposed antenna structure is designed and simulated for each frequencies.

Fig. 3 shows the 2–element patch array with defected ground structure. These two different patches are separated by distance approximate $2\lambda_g$ ($\lambda_g$ = guided wavelength) and combined by 50 Ω microstrip line to form 2–element array for dual band. The length and width of the substrate material for 2–element patch array are $w_5$ and $l_5$ respectively. The two patches are separated by distance $w_6$. The length and width of the 50 Ω strip line is $l_6$ and $w_7$ respectively. The horizontal and vertical lengths of slot in ground plane are $w_{11}$ and $l_{11}$ as shown in Fig. 3.

From Fig. 4, the length and width of the substrate material are $w_8$ and $l_8$ respectively. The group of 2–element array is separated

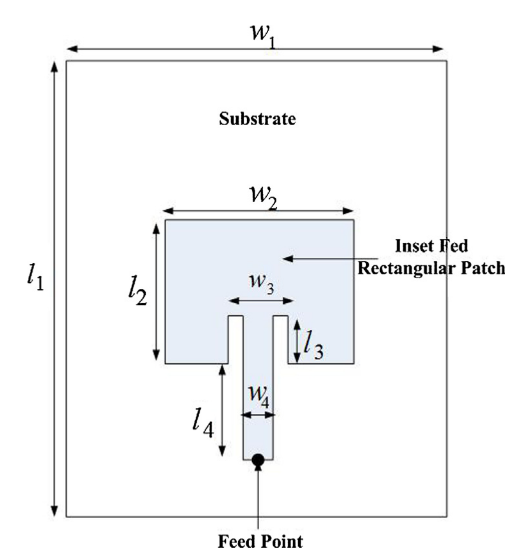


**Fig. 2.** Structure of inset fed rectangular patch antenna for 5 GHz and 5.9 GHz.