Design of a broadband patch antenna using an L-shaped probe for direction finding applications

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***Abstract* - This paper proposes the design of a broadband rectangular shorted patch antenna for direction finding (DF) of unauthorized signals. The proposed antenna consists of rectangular shorted patch and L-shaped probe to achieve the broadband matching property and miniaturization of the patch size. To confirm the DF performance of the proposed antenna, the root-mean-square (RMS) error with the side lobe level are examined using the 4×4 patch array.**

***Index Terms* — Signal detection, Array antenna, Broadband patch antenna.**

1. Introduction

In recent years, with the development of wireless communications, the usage of various wireless applications, such as mobile communications, global positioning systems (GPSs), Wi-Fi, and Bluetooth, has drastically increased in an urban area [1]. In some applications, system performance degradation is often observed by unauthorized radio signals, and more recently, by intentional jamming signals. Thus, it is important to detect and estimate an accurate direction of arrival (DoA) of unauthorized signals in order to maintain the reliable performance of wireless communications in the urban area. In broadband DoA estimations, various types of antennas, such as a Vivaldi, spiral antenna, log-periodic dipole, and microstrip patch have been proposed for an array element. The microstrip patch antenna has been a suitable candidate for an array element due to its low profile, simple structure, and low cost. However, the conventional patch antenna is limited to use in broadband applications due to its narrow band characteristics [2].

In this paper, we propose the design of a broadband rectangular shorted patch antenna using the L-shaped probe for direction finding (DF) of unauthorized signals. The proposed antenna consists of a rectangular shorted patch and a L-shaped probe, and the radiating patch is electromagnetically coupled with the feeder to obtain broadband matching characteristics [3]. To verify the DF performance of the proposed antenna, we observe the root-mean-square (RMS) error of DoA with the side lobe level using the 4x4 patch array.

2. Geometry and performance of each antenna element

Fig. 1 shows the geometry of the proposed antenna. The antenna consists of a rectangular shorted patch and a L-shaped probe. The radiating patch is connected to the ground to miniaturize the length of the patch (L). The length (L_f) and width (W_f) of the L-shaped probe are 32.4 mm and 5 mm, and the height of the probe (H_f) is 13.5 mm. The rectangular shorted patch is electromagnetically coupled with the L-shaped probe to obtain broadband matching characteristic. The detail parameters of the proposed antenna are specified in Table I.

Fig. 2 presents the reflection coefficient of the proposed antenna. The average value is −15.8 dB in broad bandwidth (1.15 ~ 1.71 GHz), which includes GPS L1 and L2, GLONASS, L-band radar, DMB, and Mobile communications. −10 dB fractional bandwidth is greater than 39% to detect the various unauthorized signals in broad bandwidth.

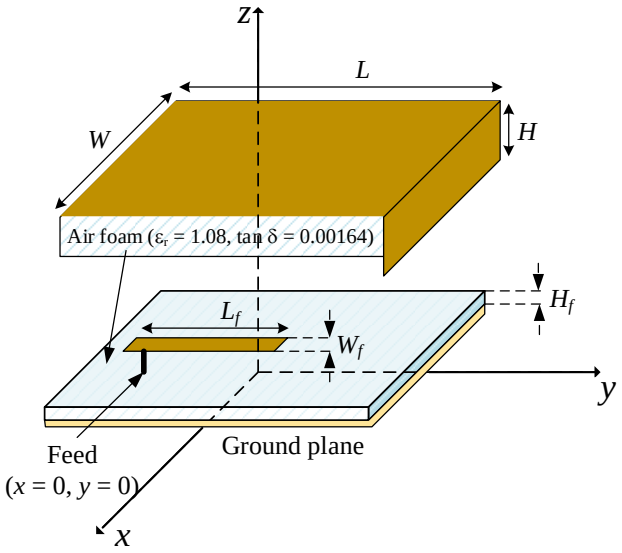

Fig. 1. Geometry of the proposed patch antenna.

TABLE I
Detail paraments of the proposed antenna

Parameters	Values
W	81 mm
L	34 mm
H	20.3 mm
W_f	5 mm
L_f	32.4 mm
H_f	13.5mm

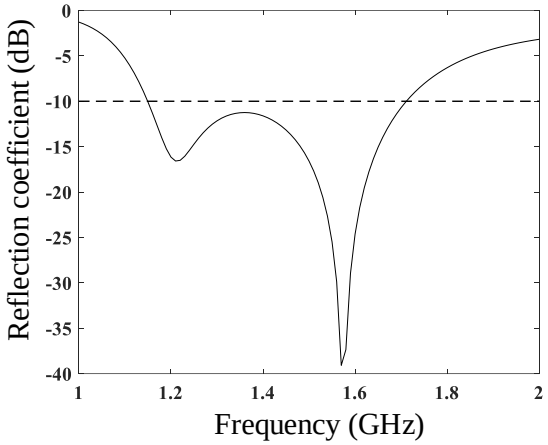

Fig. 2. Reflection coefficient of the antenna.

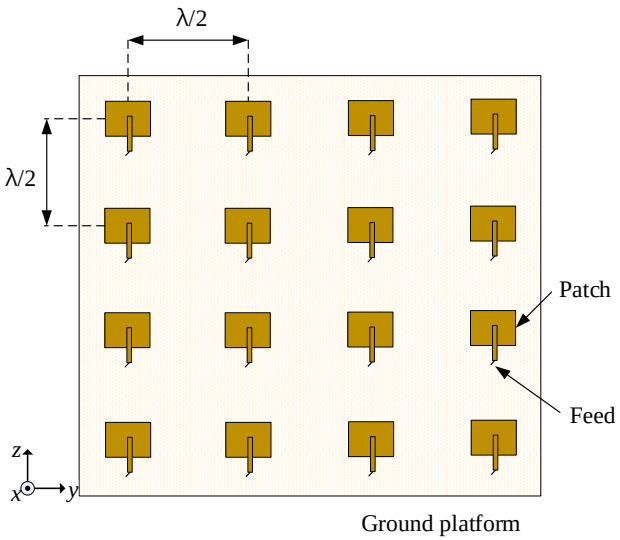

Fig. 3. Array configuration with the proposed antennas.

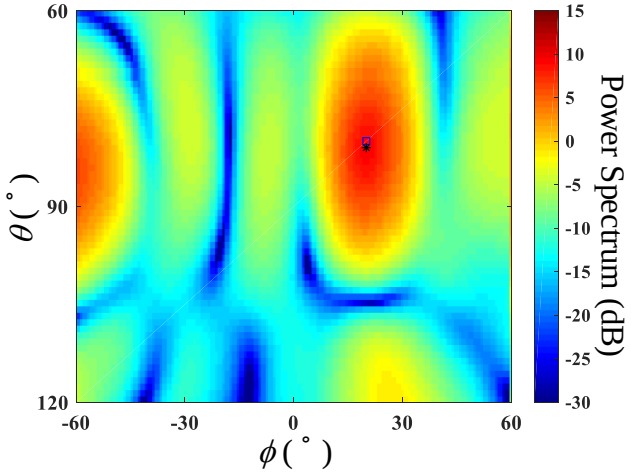

Fig. 4. DoA estimation performance with the 4 x 4 array.

3. DoA estimation using the array

Fig. 3 represents the 16-element array using the proposed rectangular shorted patch antenna as an individual element to verify DF performance. The spacing between individual elements is about a half wavelength at 1.5 GHz, and the dimensions of the ground platform are 800 mm × 600 mm.

Fig. 4 shows the simulation results of DoA performance using the proposed 4 × 4 array. The pattern of the power spectrum is calculated using the MUSIC algorithm when the direction of the incoming signal is $\theta = 80°$ and $\phi = 20°$. To verify the DF performance of the proposed antenna, we observe the RMS error and the side lobe level of the power spectrum. The RMS error and side lobe level are 0.71° and 3.3 dB, respectively.

4. Conclusion

We have investigated the design of the broadband rectangular shorted patch antenna using the L-shaped probe for DF of unauthorized signals. The proposed antenna consists of the rectangular shorted patch and the L-shaped probe to obtain broadband matching characteristics and to miniaturize the patch size. The average value of the reflection coefficient was −15.8 dB in broad bandwidth (1.15 GHz ~ 1.17 GHz). To verify the DF performance of the proposed antenna, we have observed the RMS error using the 4×4 patch array at 1.5 GHz. The RMS error and side lobe level were 0.71° and 3.3 dB, when the direction of the incoming signal is $\theta = 80°$, $\phi = 20°$.

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References

[1] Y. X. Sun, K. W. Leung, and K. Lu, “Broadbeam cross-dipole antenna for GPS applications,” *IEEE Access*, vol. 6, no. 10, pp. 5605-5610, Oct. 2017.

[2] G. Giunta, C. Novi, and S. Maddio, “Efficient tolerance analysis on a low cost, compact size, wideband multilayer patch antenna,” *IEEE Antennas and Propagation & USNC/URSI National Radio Science Meeting*, 2017, San Diego, USA, pp. 2113-2114.

[3] A. A. Kishk, K. F. Lee, and W. C. Mok, “A wide-band small size microstrip antenna proximately coupled to a hook shape probe,” *IEEE Trans. Antennas and Propag.*, vol. 52, no. 1, pp. 59-65, Jan. 2004.