Location Based Services for Remote Education and Health Institutes Using Sum-Difference Signal Patterns

https://doi.org/10.3991/ijim.v16i22.35337

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Abstract—This paper presents a simple approach to providing location-based services (LBSs) for the remotely located educational and health institutes on demand, particularly in emergency situations i.e., COVID-19, using an antenna array. The proposed approach consists of the sum and difference patterns of the signal obtained from the antenna array at the base station of a wireless network. It provides the location of the targeting institute i.e., education and health, in terms of the angle-of-arrival (AoA) which can be used to steer the radiation beam in the targeted direction in order to provide the desired services i.e., emergency wireless communication link. In this way, fast and high bandwidth-based communication and networking can be possible for the mentioned organizations. We show antenna array design and location finding results in this paper. The obtained results in terms of antenna parameters and AoA show that the proposed approach is efficient, less complicated, and can be implemented in the next-generation wireless networks i.e., AI-enabled IoT and 6G systems, particularly for the educational and health institutes.

Keywords—location-based services, education and health institutes, and AoA

1 Introduction

From the recent COVID-19 pandemic and big data volumes specially generated from educational and health organizations, it has appeared that there is a significant need for location-based services (LBSs) for efficient communication and networking among these organizations. Since educational and health institutes are mainly crowded by many people for different purposes, they desire fast connectivity and services i.e., fast and high bandwidth wireless links. Therefore, LBSs from wireless networks, such as illustrated in Figure 1, have become a good option to address the challenge where we first find the location of the targeted site and then steer the transmission beam towards that site [1, 2, 3]. In this way, the total or the most of the electromagnetic (EM) energy can be diverted by forming a focused beam towards the targeted direction which will provide high data rates, secure communication, less interference/distortion, and improved performance (latency and robustness) [4, 5, 6].

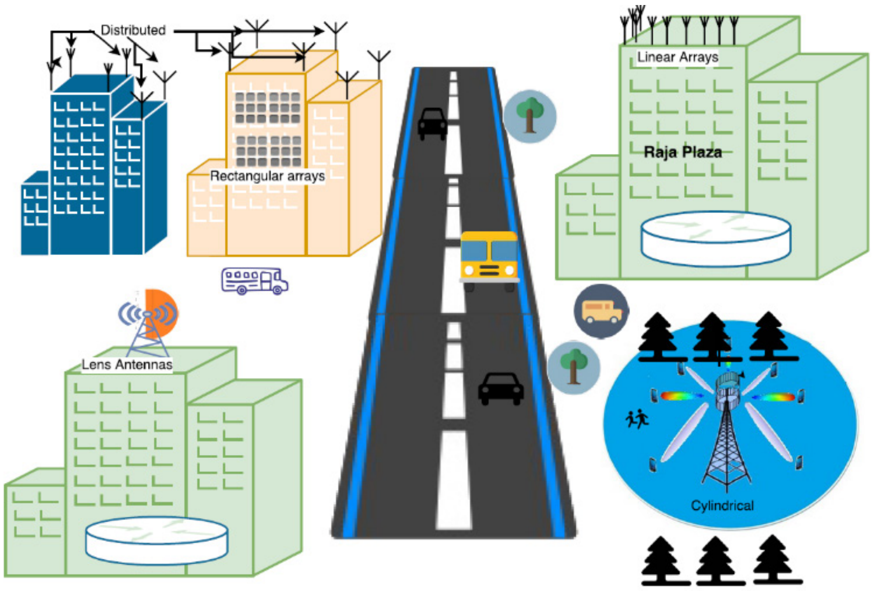


Fig. 1. An overview of the location based services

Radio localization is a concept in the wireless communication systems where the location of the terminals is estimated in various ways, for instance, angle of arrival (AoA)/direction of arrival (DoA) [7, 8, 9, 10, 11], time of arrival (ToA) [12], time-difference of arrival (TDoA) [13], and received signal strength (RSS) [14]. Among these techniques, particularly, the AoA estimation technique is used to estimate the location of the received signal in terms of angle (degrees) in azimuth and/or elevation axis using antenna array. The estimated direction of the targeting node can be used to steer the transmission in that specific direction in order to achieve the improved performance.

Though there are numerous techniques available in the related literature to find the location information such as phased antenna arrays [13], multiple signal classification (MUSIC) [8], estimation of signal parameters via rotational invariance technique (ESPRIT) [15], and root MUSIC [16]. However, these methods involve complexity in terms of increased hardware and/or computations. Thus, in this paper, we propose a simple AoA estimation approach for LBS's scenario which is based on utilizing the sum and difference patterns of the received signal. The proposed approach is capable of estimating the AoA with less complexity and good performance which can be realized in the LBS's in education and health organizations.

The paper is further arranged as follows. Section 2 describes the proposed method of location finding using antenna array and rat race coupler to achieve the sum and difference signal patterns followed by the AoA estimation expression. In Section 3, we demonstrate the obtained antenna parameters and the localization results, and discuss them in detail. Section 4 concludes the paper.

2 Proposed methodology

The proposed approach to find the location in terms of AoA includes a microstrip patch antenna array of two elements integrated with a rat race ring coupler in order to obtain the sum ($\sum$) and difference (Δ) signal patterns of the received signal, as shown in Figure 2. The obtained summed and differenced signals are then processed to obtain the desired AoA ($\hat{\theta}$) in the azimuth plan such as given below:

$$\hat{\theta} = sin^{-1}\left(\frac{\lambda}{\pi d} tan^{-1}\frac{\Delta}{\Sigma}\right), \tag{1}$$

where λ, d, Δ, and $\sum$ represent the wavelength, distance between two antenna elements, differenced signal pattern, and summed signal pattern, respectively. The Δ and $\sum$ patterns are given below.

$$\Delta = 1 - e^{-jkd\,sin\,\theta}, \tag{2}$$

$$\sum = 1 + e^{-jkd\,sin\,\theta}. \tag{3}$$

The proposed antenna system has been designed at X-band of the frequency i.e., 10 GHz. We have used RT Duroid 5880 substrate for designing the antenna system whose properties are provided in Table 1.

In this way, the simulated single antenna's (quarter wave transformer matched patch antenna) layout design at 10 GHz frequency along with the following geometric parameters is illustrated in Figure 3.

Free space wavelength (λ) = $\frac{c}{f_0}$ =30mm; c= speed of light in space = 3 X 10^8 m/sec

Patch length = L = 9.0732 mm

Patch Width = W = 11.8585 mm

Patch input impedance = Z_A= 212.50Ω

Characteristic impedance of QWT = $Z_{0'}$ = 103.07Ω

QWT section length = l_{qw} = 4.5886 mm

QWT section width = w_{qw} = 1.4 mm

Width of 50Ω = w_{50}= 5.0687 mm

Length of 50Ω = l_{50}= 5.3583 mm

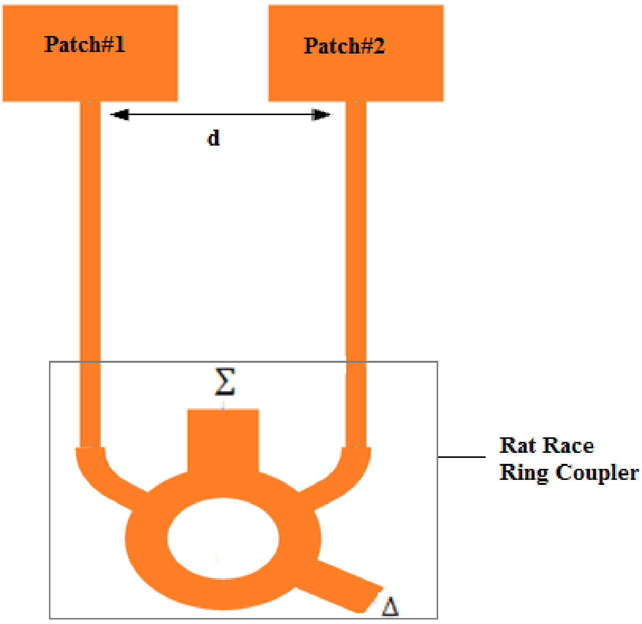


Fig. 2. Simulated design structure of the antenna array system

Table 1. RT Duroid 5880 substrate properties

Substrate permittivity ε_r	2.2
Substrate Thickness h	1.575 mm
Substrate Tangent Loss	0.0004
Copper Conductivity	5.8 e^7 s/m
Copper Thickness t	17 μm

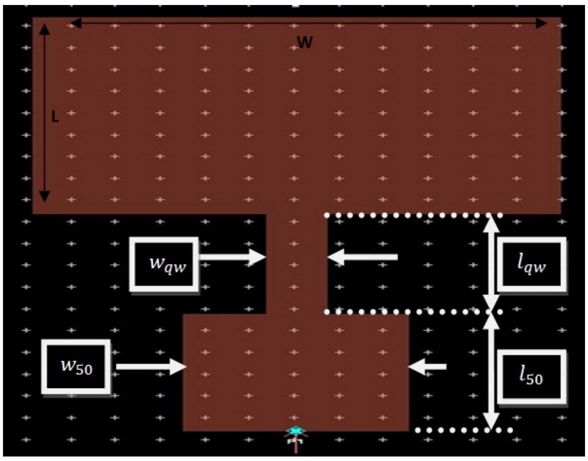


Fig. 3. The layout design of the simulated single patch antenna

Moreover, the rat race coupler has been simulated at 10 GHz frequency using RT Duroid substrate with the same substrate properties as mentioned above. The simulated layout design is shown in Figure 4, whereas the design parameters are also highlighted. The s-parameters of the simulated coupler i.e., reflection loss coefficient and port isolation are shown in Figure 5 (a) and Figure 5 (b), respectively. The obtained reflection loss coefficient curves (S11, S22, S33, and S44) of coupler ports exhibit good matching having reflection loss of each port around -44.85 dB. Furthermore, the port isolations (between Δ and ∑ ports and between two input ports), as shown in Figure 5 (b), are approximately -64 dB. The obtained phase differences between two input ports at Δ and ∑ ports are 180.07^0 and 0.07^0, respectively, showing good performance of the coupler.

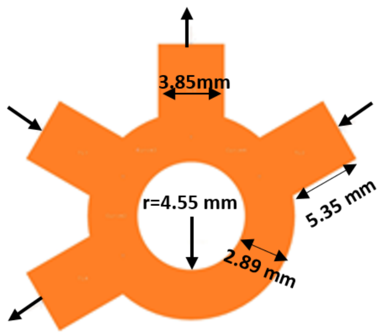
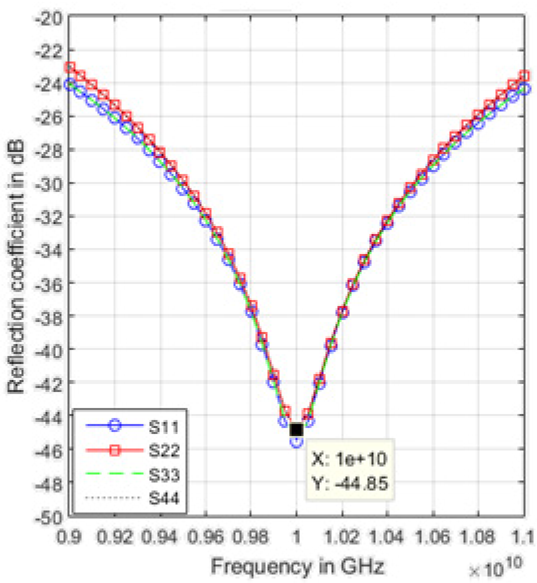
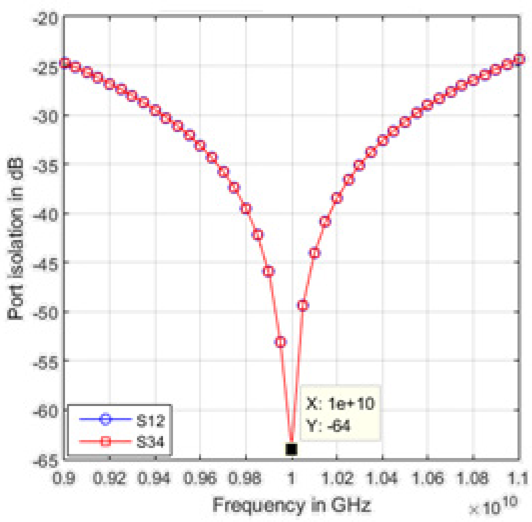


Fig. 4. The layout design of the simulated rat race coupler



a)



b)

Fig. 5. Simulated S-parameters of rat race couplers: a) reflection loss of each port, and b) port isolation

3 Results and discussions

Initially, an antenna array consisting of two microstrip patch antenna elements has been designed on an EM simulator and integrated with a rat race coupler, as shown in Figure 2. The design principle for patch antenna and rat race coupler can be found in [13, 17, 18, 19]. The simulated scattering parameters (S-parameters) of the antenna array integrated with the coupler are depicted in Figure 6 where reflection loss for ∑ and Δ ports is – 31 dB and -27 dB, respectively, which is less than – 10 dB desired value. Moreover, the obtained gain and directivity parameters are 9.47 dBi and 10.1 dBi, respectively.

Furthermore, the same antenna array was excited with different angles powers on the ∑ and Δ ports as given in the following Table 2 where the amplitude and phase of ∑ and Δ ports are calculated using the ∑ and Δ patterns expressions mentioned in Section 2. It is observed that as the angles of excitation vary between $+45^0$ and - 45^0, the beam steers accordingly between 0^0 (center) and $\pm45^0$ with error less than $\pm5^0$ which shows that the proposed circuit is working properly and the localization can be achieved. The radiation pattern (in terms of power versus excited angles) of ∑ and Δ ports is shown in Figure 7. Moreover, received/estimated DoA angles versus the transmitted signal (true) angles are illustrated in Figure 8.

Table 2. Calculated absolute amplitude and phase of ∑ and Δ

θ [deg.]	∑ Amplitude	∑ Phase	Δ Amplitude	Δ Phase
0	2	0	0	0
-15	1.667	-27.95	0.9375	62.04
15	1.667	27.95	0.9375	-62.04
-30	1.1756	-54	1.618	36
30	1.1756	54	1.618	-36

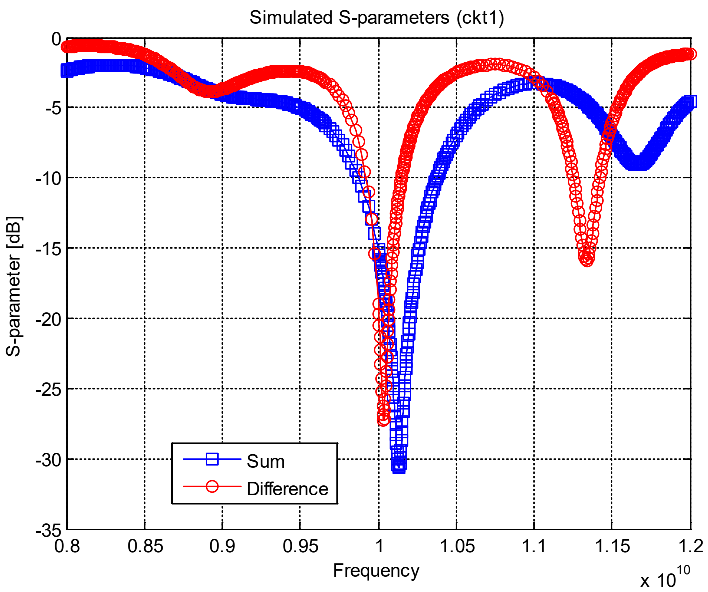


Fig. 6. Simulated S-parameters of Δ and ∑ ports

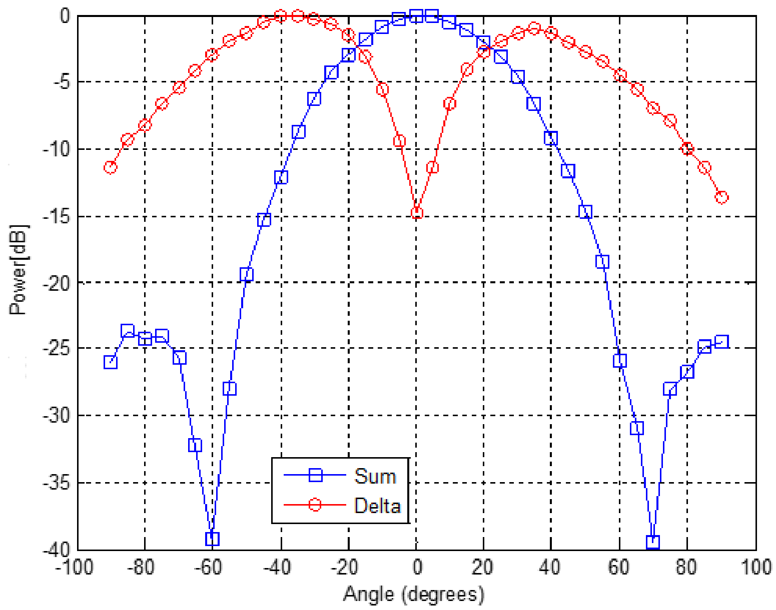


Fig. 7. Radiation patterns of Δ and ∑ ports

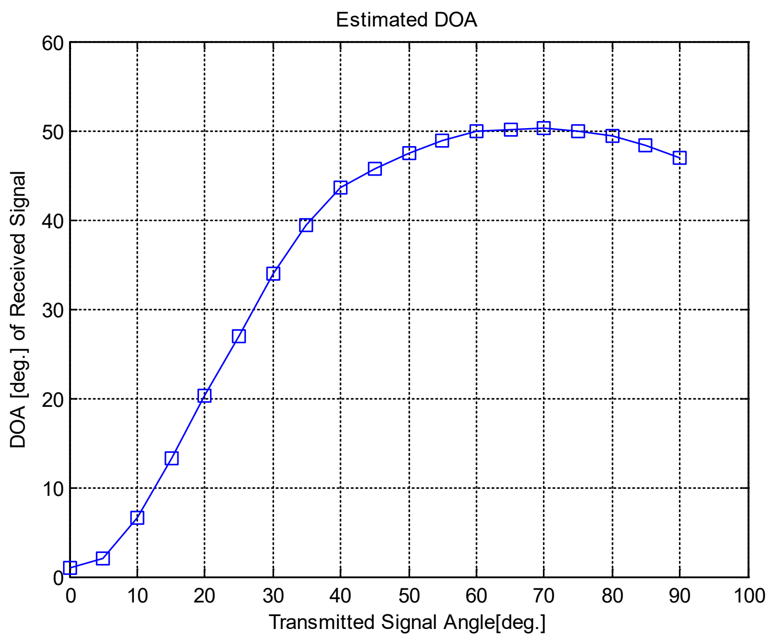


Fig. 8. The estimated AoA/DoA versus Transmitted signal (true) angle

4 Conclusion

In this paper, we have demonstrated a simple approach, i.e., sum and difference patterns, towards the location based services system for the educational and health organizations. The proposed approach is capable of finding the direction of the desired organizations in terms of AoA within $\pm 45^0$ range which is in good agreement to other related works. The method is simple in the way that we perform most of the calculation of the sum and difference signal patterns in the RF domain which contributes in reducing the computational cost. Therefore, the proposed approach can be applied for the remotely located institutes like education and health to provide them the location based fast and high bandwidth services.

5 Acknowledgement

The authors acknowledge the Higher Education Commission (HEC) of Pakistan for the research grant to this work under National Research Program for Universities (NRPU) scheme with project No: 20- 15948/NRPU/R&D/HEC/2021.

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Article submitted 2022-09-14. Resubmitted 2022-10-18. Final acceptance 2022-10-18. Final version published as submitted by the authors.