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# A non-uniform collinear dipole array for sub-6 band

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**Abstract:** In the fifth-generation (5G) wireless communications, due to the advantages such as wide range and low cost, sub-6 frequency band is widely used. It is a challenge to develop the antennas for sub-6 base stations which are wide band, high gain and compact. In this paper, a center-fed collinear antenna array with a compact size is developed based on the turnstile antenna. Non-uniform dipole array has been used to achieve broadband so that the disadvantages of series can be improved. The gain bandwidth has been significantly increased as compared to uniform array antennas. Wider directivity gain bandwidth of 35% is provided by the non-uniform array. The proposed array antenna can be used to omnidirectional radiation applications. The directivity gain bandwidth reached to 20.7% better than traditional series-fed antennas.

**Keywords:** Turnstile antenna, collinear antenna array, broadband, omnidirectional, sub-6 band.

**Classification:** Antennas and Propagation

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## 1 Introduction

5G communication is a network designed to connect virtually everything and everyone together including machines, objects and devices. To satisfy this massive Internet of Things (IoT) ecosystem, a large number of compact base stations with small cells are required. There are two kinds of omnidirectional base station antennas which has been used normally in Japan [1,2]. One is they choose the omnidirectional antenna as the unit cell such as super turnstile antenna and side-fire helical antenna. The other one is setting the directional antenna in muti-sides to achieve omnidirectional radiation pattern. But this method always needs reflect ground which causes a large space. The super turnstile antenna [3] has the advantages of high gain in a range of wide bandwidth with omnidirectional radiation pattern, and it is widely used for VHF-TV broadcasting around the world[4]. Without the ground, this kind of antenna can be compact. The traditional turnstile antenna uses batwing radiator as the radiator which has broadband characteristics[5,6].

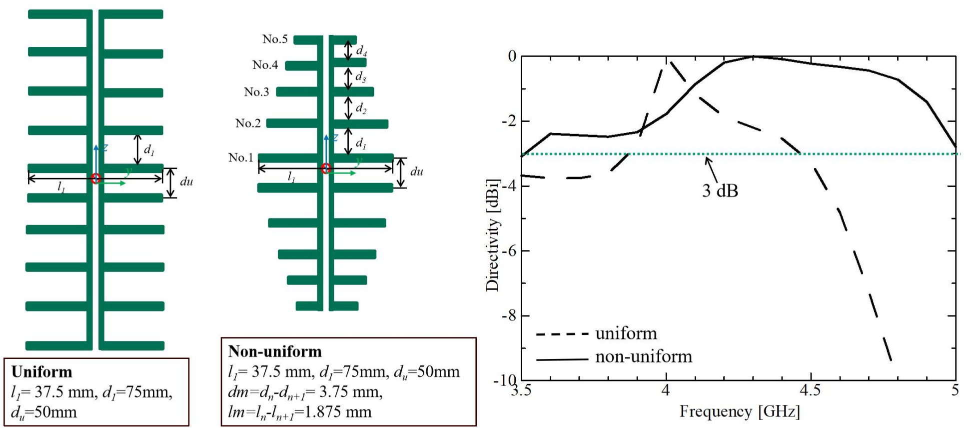
In communication engineering, the gain of the base station antenna must be required as high enough to cover a wide range, but there have been only limited research on this. A few specially constructed HP antennas were used by certain researchers to set up an antenna array and achieve higher gain. In [7], a broadband horizontally polarized (HP) omnidirectional planar antenna with arc dipoles is created with a peak gain of 8 dBi for mobile communications. However, the antenna is larger than $6\lambda$, and quite a few feeding wires are required, making the system bulkier and more complicated. The traveling wave antenna has also been employed for high gain omnidirectional HP radiation [8], however its beam varies with frequency. A slender Fabry-Perot antenna is proposed for high gain application in [9]. The realized gain of 8.52 dBi is reached from 2.41 to 2.5 GHz with a 10 dB impedance bandwidth. The proposed antenna is prototyped with the intended compact size of $2.95\lambda$, but its limited bandwidth (approximately 3.75%) reveals its most glaring flaw.

In this paper, turnstile antenna feeding is used and a series-fed array is created to provide omnidirectional radiation. The series feed significantly decreases the number of ports and makes the antenna more compact when compared to the traditional super turnstile antennas. Non-uniform dipoles are employed as radiation elements for better broadband radiation, particularly for gain bandwidth extension. First, an array of planar, series-fed collinear dipoles is proposed. The directivity gain bandwidth of the non-uniform array is increased to 35% when compared to the traditional uniform series-fed array. Additionally, the radiation patterns in the horizontal plane at 3.5, 4, and 4.5 GHz are provided. Then non-uniform series-fed arrays are used to increase the gain bandwidth for omnidirectional patterns. In the simulation, the directional gain bandwidth of the omnidirectional antenna is extended from 14.7% to 20.7%, and the omnidirectional radiation patterns at 3.5, 4, and 4.5 GHz in the horizontal plane are also provided.

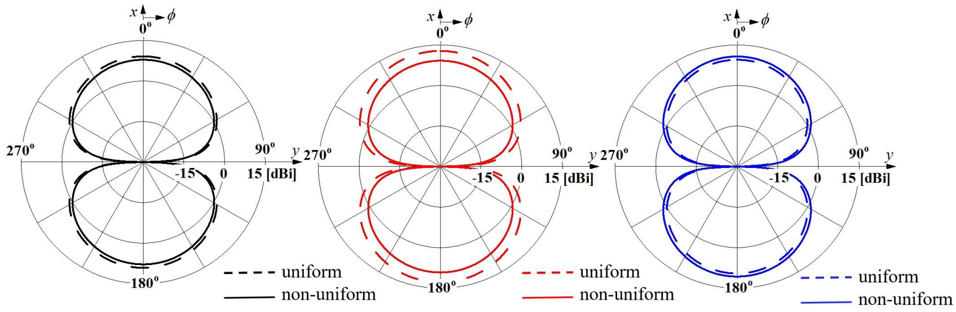
## 2 Non-uniform collinear dipole antenna array.

The geometry of the proposed antenna is shown in Fig. 1(a). The collinear antenna is vertically symmetrical from the center. Beginning in the middle and increasing in number, the number of the dipole elements in the upper half of the array is 1. $l_n$ presents the length of No.$n$ element. $d_n$ displays the separation between element No. $n$ and element No. $n$+1. Each dipole's length is decreased by $l_m$ from the first dipole element in the middle to the fifth dipole element at the end of the parallel stripline. The distance between the dipole elements reduces by $d_m$ from each preceding dipole spacing, similarly to the dipole length. For a uniform array, the length of each dipole element is the same for half a wavelength (4 GHz as the design frequency). The separation between the elements on the feeding line is one wavelength to maintain them radiating in phase. In non-uniform arrays, the No.1 dipole is located close to the center and is half a wavelength in size, while the following elements are 1.875 mm shorter. One wavelength separates the No.1 and No.2 dipole elements, and each further element's distance is then reduced by 3.75 mm.

Normalized directivity is shown in Fig1(b). It is obvious from the figure that the 3 dB directivity gain bandwidth of the non-uniform collinear dipole array covers from 3.5 to 5 GHz, which far exceeds that of the uniform array. Meanwhile, the radiation patterns of the proposed antenna in the horizontal plane at 3.5, 4, and 4.5 GHz are shown in Fig(c). The radiation patterns of the non-uniform array, like those of the uniform array, show an 8-shape pattern in the presented frequency band.



(a) Geometry of proposed collinear dipole array. (b) Normalized directivity.

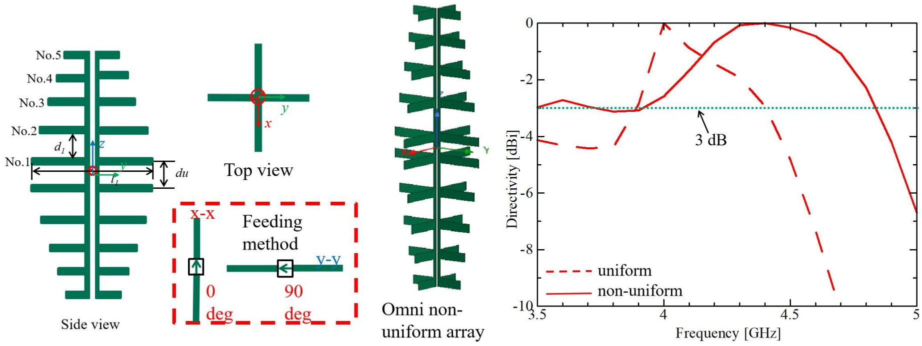



(c) Radiation patterns in the horizontal plane at 3.5, 4, 4.5 GHz.

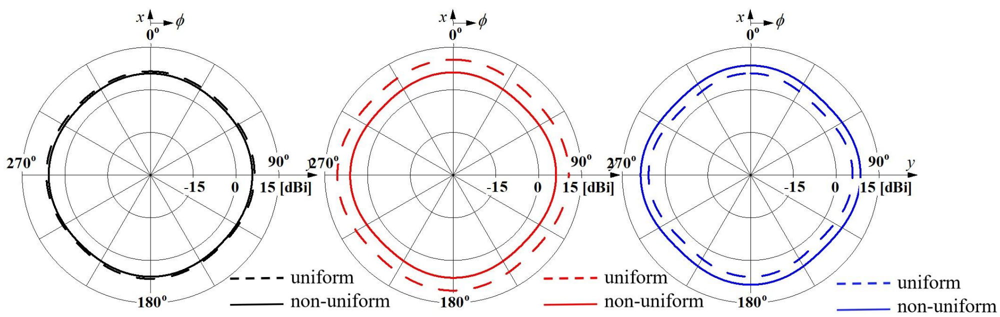
**Fig. 1.** Non-uniform collinear high directivity dipole array.

## 3 Omnidirectional non-uniform collinear dipole antenna array.

Two planar non-uniform collinear dipole arrays are placed orthogonally, as shown in Fig. 2 (a). The mutually orthogonal dipole arrays are fed, similarly to a turnstile antenna, with equal amplitude but 90 degree phase difference in order to produce an omnidirectional radiation pattern.




(a) Structure of omnidirectional array (b) Normalized directivity.




(c) Radiation patterns in the horizontal plane at 3.5, 4, 4.5 GHz.

**Fig. 2.** Omnidirectional non-uniform collinear dipole antenna array

The normalized directivity gain of the omnidirectional antenna is depicted in Fig. 2(b). The gain bandwidth of the non-uniform antenna array is still 20,7% superior to that of the uniform antenna array. The radiation patterns at 3.5, 4, and 4.5 GHz in the horizontal plane are shown in Fig. (c), and the non-uniformity of the array does not affect the radiation pattern of the four-leaf clover shape. It can be observed that the gain bandwidth of the omnidirectional antenna can also be increased by the non-uniform array.

## 4 Conclusion

A series-fed array was developed in this study to produce omnidirectional radiation with turnstile antenna feeding. For improved broadband radiation, especially for increasing gain bandwidth, non-uniform dipoles were used as radiation elements. First, a planar, series-fed collinear dipole array was presented. Compared to the conventional uniform series-fed array, the non-uniform array has a wider directivity gain bandwidth of 35%. Afterward, the gain bandwidth for omnidirectional patterns is expanded using non-uniform series-fed arrays. The simulation included the omnidirectional radiation patterns at 3.5, 4, and 4.5 GHz in the horizontal plane was investigated. Meanwhile, an extension of the directivity gain bandwidth of the proposed antenna was investigated. The bandwidth increases from 14.7% to 20.7%. It is proven that the gain bandwidth may be expanded by the non-uniform array.

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