Beamwidth Control of Base Station Antennas Employing Reflectors and Directors

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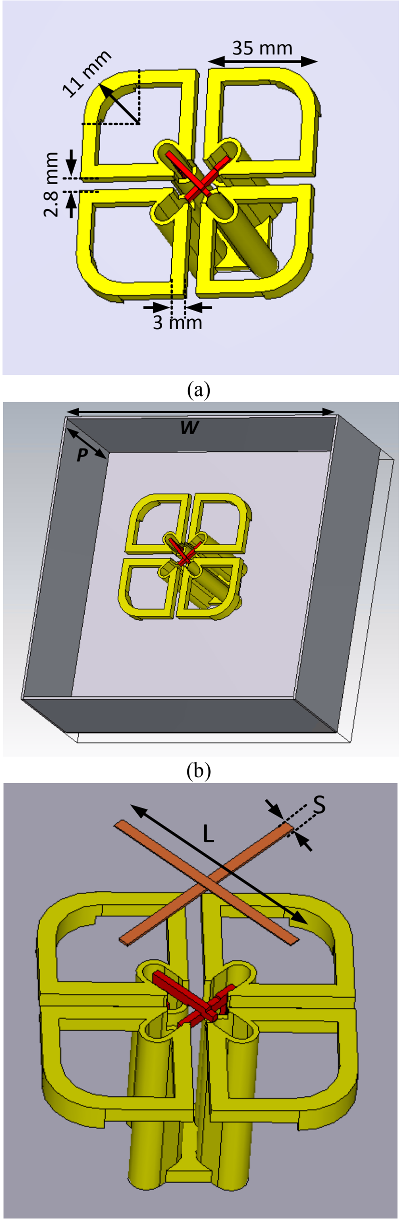
***Abstract*— The effects of reflectors and directors on the radiation pattern of a base station antenna are studied. A $\pm 45^0$ linear-polarized cross-dipole with an operating band from 1.7 GHz to 2.7 GHz is designed as an example. The antenna is then encircled by a conducting wall constructed using vertical reflectors to control its horizontal half-power beam-width (HPBW). Subsequently, cross-directors are placed above the antenna, which provides another solution to control the HPBW. A parametric study is conducted, and the findings can serve as design guidelines for the design of wide band base station antennas.**

***Keywords*— base station antenna; wide impedance bandwidth; half-power beam-width (HPBW); reflectors; directors**

I. INTRODUCTION

Base station antennas are important components in cellular communication networks. Recent communication services, such as 2G, 3G, 4G, and Wi-Fi, significantly increase the demand for wide band base station antennas. Generally speaking, there are two main considerations in designing base station antennas, namely, the impedance bandwidth and stable radiation performance across the operating band. Various antenna structures with different feeding method to achieve excellent impedance match have been reported [1-8] that can cover the frequently-used bandwidth from 1710MHz to 2690MHz. However, a more challenging job is to design an antenna element with stable radiation characteristics across the wide working band (more than 40%). To achieve stable radiation characteristics, magnetoelectric dipoles have been advocated [9]. This type of complementary antenna consists of an electric radiator (usually dipole) and a magnetic radiator (dipole or patch) placed orthogonally. The combined radiation pattern of the electric and magnetic radiators appears to be insensitive within the require bandwidth.

Driven by the demand to further increase the space utilization efficiency, dual-band base station antennas have been proposed [4, 5]. However, consistent radiation patterns for the dual-band elements are hard to be maintained. Practical solution in realizing dual-band operation is to employ two groups of antenna elements working in different bands in one array [10]. The antennas have to be placed close to each other to save the space and suppress the side lobe level. In this case, the antenna element working in the upper-band can have a disturbed radiation pattern. This is due to the presence of lower-band antennas as large scatterers. For both of these two scenarios, it is unlikely to achieve a stable radiation characteristic by adjusting the antenna structure itself. It is well known that placing a conducting wall between antenna elements can reduce the mutual coupling. We also remark that



(a)

(b)

Fig. 1. (a) A compact dual-band base station array. (b) The high band antenna element for the array.

the wall can have significant effects on the radiation pattern of the antenna element.

This paper studies the effect of conducting walls on the antenna radiation patterns. The optimized conducting walls are then used to achieve a stable radiation characteristic for base station antennas. Firstly, a $\pm 45^0$ dual-polarized cross-dipole is designed according to [8]. The reason to use this type of antenna is that the dual-polarization antennas become the mainstream solution since channel capacity can be enhanced, and the cross-dipole is one of the popular and promising structures [11]. The obtained antenna has a very wide bandwidth covering the frequently-used working band from 1.7 to 2.7 GHz. But the horizontal HPBW is unstable and increasing with frequency. Then, by employing vertical reflectors around the antenna, the consistency of the HPBW can be enhanced. In addition, another solution in controlling HPBW is proposed by employing director above the base station antenna element. Parameter sweeps on the dimension of the directors are given and design consideration is presented. Stable HPBW across the wideband is achieved with optimized directors. This can actually provides additional degree of freedom in controlling HPBW when employed together with conducting walls.

II. HPBW CONTROL

A. *Antenna Element*

Fig. 1 shows a configuration of the antenna element consisting of two orthogonally placed dipole antennas. The height of the dipole antenna seating on a base reflector is *38 mm* (approximately quarter-wavelength at the centre frequency 2.2 GHz). Such an antenna structure is able to achieve an excellent impedance match (VSWR<1.5) from 1.7 to 2.7 GHz, due to the mutual coupling between the dipole arms. The detailed balun structure and matching method are not presented here, but can be found in [8]. Due to the ground effect introduced by the base reflector, the horizontal HPBW of the dipole increases with frequency dramatically, from 65° at 1.7 GHz to 94° at 2.7 GHz. The horizontal HPBW is a crucial performance indicator for base station antennas and is usually required to stabilize around 65°. The following subsections present two methods to manipulate the HPBW without changing the configuration of the antenna.

B. *Conducting Walls Composed by Reflectors*

As shown in Fig. 1(b), conducting walls (vertical reflectors) perpendicular to the base reflector are employed around the base station antenna. The walls can have significant effects on the radiation pattern, mainly depending on the width (W) and height (P) of the walls. Fig. 2 depicts the variations of the HPBW in the working band with different dimensions of conducting walls. By introducing the conducting walls, the HPBW is reduced for higher frequencies due to the fact that the formed cavity can centralize the radiation power.

Following conclusions have been summarized according to the parameter sweep. Firstly, a lower conducting wall can introduce a smooth variation of the HPBW. Secondly, conducting wall with different width can result in significantly changed HPBW. By optimizing *W* and *P*, a rather stable HPBW can be obtained. The HPBW can be stabilized between 60° to 70° with a *W*= 120 mm, and *P*= 20 mm. Another advantage of the conducting wall is that it reduces mutual coupling from other antennas when several antennas are formed into an array.

C. *Directors*

Another effective method to control HPBW is to employ directors above the antenna. As shown in Fig. 1(c), cross directors are introduced above the antenna element. Like the director for Yagi antennas, they are separated from the dipole arm of 26 mm, approximately 0.2 wavelengths at the centre frequency. By optimizing the length (*L*) and width (*S*) of the directors, the resonant frequency of the directors can be tilted, which reduces the HPBW of the antenna in certain frequency ranges.

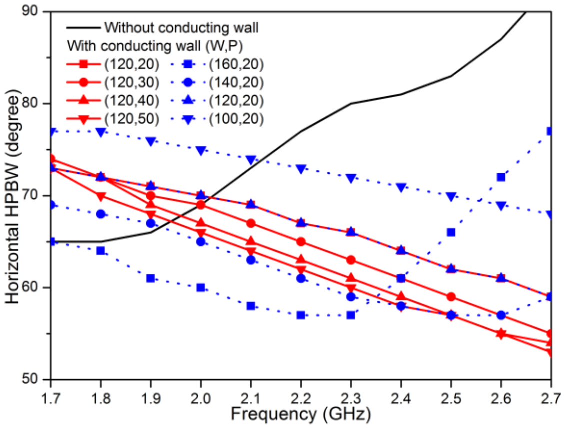


Fig. 2. Horizontal HPBW of the antenna element encircled by conducting wall.

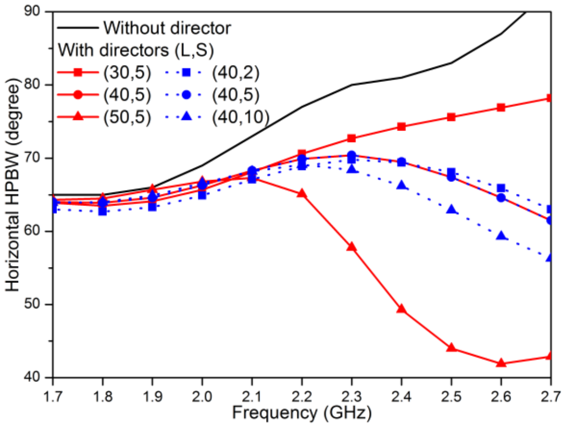


Fig. 3. Horizontal HPBW of the antenna employing directors.

Fig. 3 shows the HPBW of the antenna with different *L* and *S*. According to the figure, it is noticed that the director length *L* is the dominant parameter in controlling the HPBW. This is due to the fact that the resonant point of the director is manly determined by the length. In this design, we are not trying to obtain a director resonant at the working band of the antenna. For example, when *L*= 50 mm, the directors resonant around 2.7 GHz. In this case, the directors' ability of centralizing the power around 2.7 GHz is very powerful, thereby leading to a significantly reduced HPBW. However, if the director is too short (30 mm), their capacity of reducing the HPBW is too weak. In this case, the HPBW of the antenna still goes up at higher frequencies. To obtain a stable HPBW, the optimized solution is to have the directors with *L* = 40 mm, where the directors resonant at 3.5 GHz. In addition, the width of the cross-directors also affects the HPBW, which provides additional degree of freedom in optimization. A very steady HPBW of 67°±3° is obtained by employing cross-directors with *L*= 40, *S*= 2.

III. CONCLUSION

A study on the effects of reflectors and directors on the horizontal HPBW of a dual-polarized base station antenna element is conducted. It is found that the HPBW can be easily manipulated by constructing conducting walls around the antenna element or by placing director above the antenna element. With the optimized conducting walls and directors, the antenna element can have a much more stable horizontal HPBW than before without changing the configuration of the antenna itself. The results could be useful in designing compact dual-band base station antenna arrays. Our future work will focuses on combining the two methods together to not only control the HPBW but also provide shielding for antenna elements, which can reduce the distortion in radiation pattern in array environment.

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