Planar Dual-Antenna System For Blind Spots Elimination in Mobile Communication System

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***Abstract*—A planar dual-antenna system (DAS), composed of series-fed microstrip antenna and planar Yagi-Uda antenna, is proposed for blind spots elimination in mobile communication system. The planar DAS is developed as a reflector in a non-line-of-sight (NLOS) environment. Broad-angle scattering and polarization transition can be realized. Equivalent bi-static radar cross section (BRCS) is used to demonstrate the effectiveness of the DAS in eliminating blindness and improving the propagation channel under the NLOS environment.**

I. Introduction

In the wireless communications system, there is a serious problem that the radio signal form the base stations which are usually mounted on the roof of buildings may be blocked by other high and dense buildings and other obstacles, especially in narrow streets. This kind of areas are typically called blind spots. Generally, RF boosters are capable of eliminating these blind spots but the cost is very high, because receivers, transmitters, power supplies are required. Planar reflectarray antennas with non-specular reflection performance can also be used [1]. However, the aperture efficiency of the reflectarray degraded greatly when a very large scattering angle was attempted for, because it is known that the maximum aperture is a cosine function of the scattering angle [2]. In [3], although a dual-antenna system (DAS), composed of patch array and open-ended waveguide, was proposed to realize a large scattering angle, there were still some disadvantages such as bulky size, high cost, non-planar structure, additional feed network and so on.

In our research, a new planar DAS composed of series-fed microstrip antenna (SFMA) and planar Yagi-Uda antenna is proposed to realize broad scattering angle and polarization transition. A four-element series-fed microstrip antenna is used to receive the wave signal form the base station. Usually, in wireless communication system the polarization of incident wave from the base station was vertical to the ground plane, whereas that of the mobile terminal was mainly horizontal. Therefore, it became necessary to design the DAS to have a polarization transition property. Thus, a planar Yagi-Uda antenna is used to reradiation with a different polarization.

II. Propagation Channel in Urban Areas

The schematic of propagation channel in urban areas is demonstrated in Fig. 1. The propagation channel between the

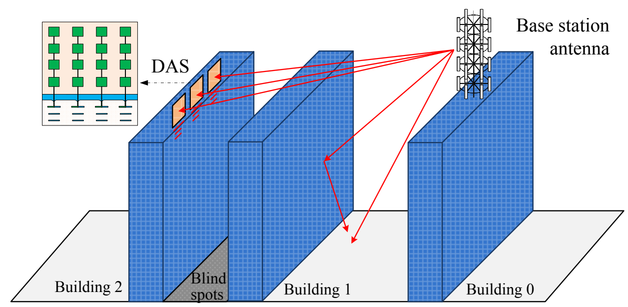

Fig. 1. Schematic of propagation channel in urban areas

base station antenna and the mobile user in such area is a non-line of sight (NLOS) path as shown in Fig. 1. DAS can be used to tackle this problem by rebuilding a path. The distance form DAS to the base station antenna and mobile user in the narrow street are d_1 and d_2 , respectively. The channel gain can be calculated by Friis transmission equation and radar range equation in equation :

$$\frac{P_r}{P_t} = \left(\frac{\lambda}{4\pi}\right)^4 \left(\frac{1}{d_1 d_2}\right)^2 G_t G_{dr} G_{dt} G_r \tag{1}$$

$$\frac{P_r}{P_t} = \left(\frac{G_t}{4\pi {d_1}^2}\right) \left(\frac{\sigma_{eq}}{4\pi {d_2}^2}\right) \left(\frac{G_r \lambda^2}{4\pi}\right) \tag{2}$$

where G_t and G_r, are gains of base antenna and mobile user, respectively. G_{dr} and G_{dt} are gains of two antennas in the proposed DAS. And λ is the free-space wavelength at the operating frequency. Term σ_{eq} is the equivalent bi-static radar cross section (BRCS) of the proposed dual-antenna system and can be calculated using:

$$\sigma_{eq} = \frac{\lambda^2}{4\pi} G_{dr} G_{dt} \tag{3}$$

It is obvious that σ_{eq} is proportional to the gains of two antennas in the DAS.

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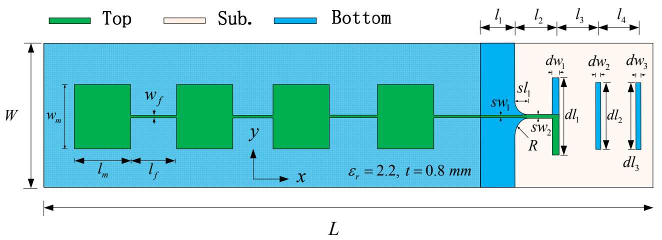

Fig. 2. Geometry of one unit DAS. (Total size of $L \times W \times t$ = 589 $mm \times$ 110 $mm \times$ 0.8 mm. Other parameters: w_m = 58.95 *mm*, l_m = 49.5 *mm*, size of strip line: w_f = 1.3 *mm*, l_f = 50.2 *mm*, l_1 = 30.0 *mm*, l_2 = 33.0 *mm*, l_3 = 34.25 *mm*, l_4 = 33.0 *mm*, dl_1 = 64.0 *mm*, dl_2 = dl_3 = 55.0 *mm*, dw_1 = 5.5 *mm*, dw_2 = dw_3 = 4.0 *mm*, sw_1 = 1.3 *mm*, sw_2 = 2.86 *mm*, sl_1 = 17.2 *mm*, *R* = 12.0 *mm*.)

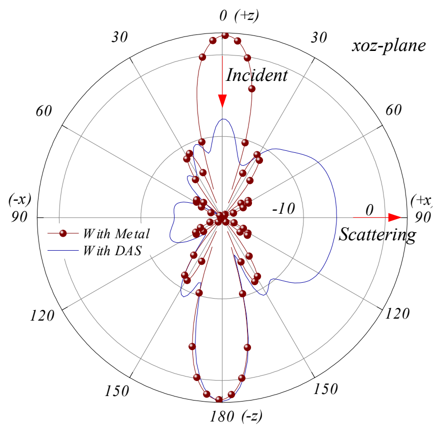

Fig. 3. Scattering pattern of 1-unit DAS.

III. Design of Planar Dual-antenna System

The high performance SFMA and planar Yagi-Uda antenna are selected as the receiving and reradiating part, respectively. The geometry of one unit DAS is shown in Fig. 2. The coordinate with other parameters are also shown in this figure. As can be see clearly, the low profile (only 0.8 mm) and planar structure permits ease of massive fabrication and mounting.

A series-fed microstrip antenna (SFMA) [4] consists of a linear array of microstrip elements connected in series by a microstrip transmission line. This array tends to minimize the feedline lengths and therefore minimize the radiation from the feedline as well. The patches of approximate length 1/2 wavelength and the spacing is adjusted to enhance the antenna bandwidth and reduce sidelobes in the radiation pattern whilst allowing enough separation between the patch elements to minimize mutual coupling effects. The substrate height and permittivity determine the characteristic impedance of the stripe line. The strip line width is selected to meet impedance matching condition. The main beam of the SFMA is at 0 degree and the maximum gain is more than 12 dBi with respect to 50 Ω at 2.0 GHz .

The employed planar Yagi-Uda antenna has a driven element, two directors and a large ground plane as a reflector. The two arms of the driven part are printed on top and bottom layer, respectively, and fed by a parallel stripline through a transition from a microstrip line. More than 8.2 dBi gain can be realized in *xoz*-plane at 2 GHz

The simulated equivalent BRCS of one unit of the proposed DAS in *xoz* plane are illustrated in Fig. 3, compared with the BRCS of a metal plate with the same size, when plane waves are incident from +*z* direction. The metal plate presents a symmetrical BRCS pattern and the value in $\theta = 90^\circ$ is tending to zero, determined by how thin the metal plate is. For the proposed DAS, the forward scattering is over 10 dB smaller than the metal plate, indicating that the aperture efficiency of the DAS is quite good. Moreover, the scattering along +*x* direction has a maximum value of -5.8 dBsm at 60°, and stable value form 60° to 120° (BRCS: -6.3 to -5.8 dBsm). Thus, the DAS can realizes large orthogonal scattering with a normal incidence that cannot be achieved naturally by traditional reflectarray or other planar structures. Practically, this kind of DAS unit can be placed as many as required along *y* direction or increase the number of patch elements on one unit in order to improve the performance.

IV. Conclusions

A novel planar dual-antenna system (DAS) is proposed for blind spots in wireless communication system. Planar series-fed microstrip antenna and planar Yagi-Uda antenna are combined together to receive and reradiate the wave signal form the base station. The EM waves can be reradiated to the normal direction to the incidence, which is theoretically difficult to be realized by conventional reflectarray antennas. Furthermore, the DAS can also be used to increase the multipatch richness for MIMO (Multiple Input Multiple Output) communication.

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