Massive MIMO Antenna Array Deployment for Airport in Air-to-Ground Communications

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***Abstract*—In this paper, a deployment of massive multiple-input multiple-output (MIMO) antenna array is proposed for the airport ground station in the air-to-ground communications, which is an integration of the centered massive MIMO and distributed MIMO. The proposed antenna deployment is discussed briefly and an example of forming multiple beams in different directions in horizontal plane and vertical plane is presented.**

Keywords—Massive multiple-input multiple-output (MIMO); air-to-ground communications (ATGC); uniform circular array (UCA); uniform linear array (ULA).

I. Introduction

In Air-to-ground communication (ATGC) systems, different from the mobile wireless communication systems, the signal coverage usually occurs in the upper half-space. And in the ATGC scenario, the channels have a much higher line-of-sight (LOS) probability [1]. For a low altitude, multipath propagation exists in ATGC channel, and the probability for appearance of multipath components is getting higher with decreasing of aircraft's altitude [2], [3]. Obviously, for a large and busy airport environment in ATGC, the multipath components and LOS component usually occur at the same time. To exploit the multipath and LOS components efficiently and provide a good service experience, it is a good choice to employ the massive multiple-input multiple-output (MIMO) technology which emerged recently and is regarded as one of key technologies in the fifth-generation wireless communications due to its high spectrum efficiency and energy efficiency.

Until now, there are still no Chinese airlines employing the ATGC in their flights. Moreover, several Chinese airlines announced allowing the passengers using mobile phones in the plane, and the homegrown passenger jet has been successfully tested. These will prompt the applications and developments of ATGC in China.

According to these facts, a massive MIMO antenna array configuration of ground station (GS) is discussed based on the airport environment in ATGC in this paper.

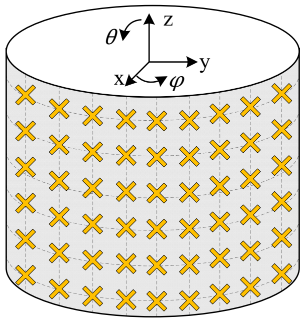
II. Proposed Antenna Configuration

Consider a large and busy airport in the ATGC scenario where many planes around the airport waiting for landing and in the airport waiting for taking off, which means that high system capacity is required. When the airplanes are approaching to the airport, the probability for appearance of multipath components goes up due to the decrease of airplane' altitude. To exploit the multipath components and LOS components as much as possible when GS communicates with airplanes, an antenna configuration combined centered massive MIMO and distributed MIMO is proposed and discussed.

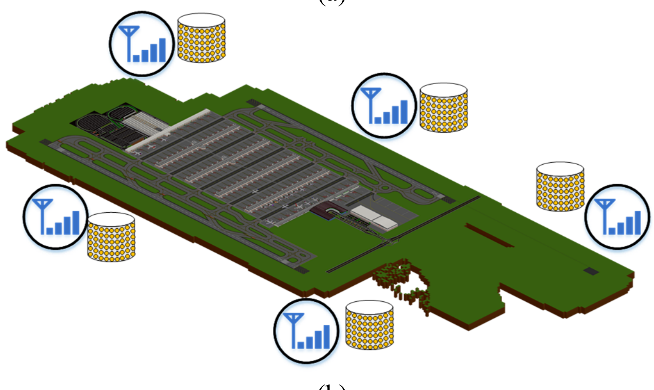
According to the antenna theory [4], the array factor of uniform circular arrays (UCA) can be expressed as

$$AF(\varphi,\theta)=\sum_{n=1}^{N} I_n e^{j(ka\sin\theta\cos(\varphi-\varphi_n)+\alpha_n)} \tag{1}$$
$$\alpha_n=-ka\sin\theta_0\cos(\varphi_0-\varphi_n)$$

where k, φ, θ, a and N are the wavenumber, azimuth angle, elevation angle, array radius and the number of elements, respectively, I_n and α_n are the amplitude excitation and phase



(a)



(b)

Fig.1 Illustration of (a) distributed MIMO deployment and (b) centered massive MIMO antenna array configuration for airport in ATGC scenario.

excitation of the nth element, (θ_0, φ_0) is the direction of the main beam, $\varphi_n = 2\pi(n-1)/N$ is the angular location.

From the array factor of UCA, it can be known that the beam scanning in horizontal plane (x-y plane illustrated in Fig.1 (a)) is almost without distortion in radiation pattern. This characteristic of UCA is very useful to the communications between GS and airplanes in a busy airport under ATGC scenario. Because it can form beams in any direction in x-y plane to serve the airplanes.

As to the beam forming in vertical plane, the uniform linear arrays (ULA) is employed, and its array factor can be expressed as [4]

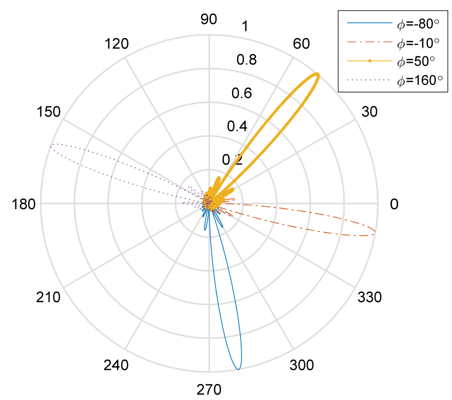
$$AF_n = \sum_{l=1}^{L} I_l e^{j(l-1)(kd_z \cos\theta + \beta_z)} \quad (2)$$

where L, d_z, k are the number of array elements, element spacing, wavenumber, respectively, and

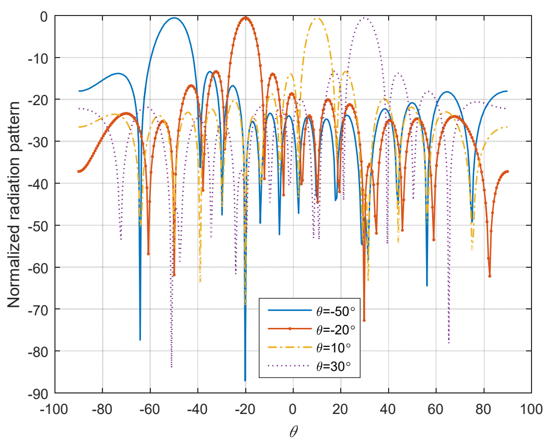
$$\beta_z = -k\, d_z \cos\theta_m$$

where θ_m is the direction of the main beam.

According to the above analysis, an antenna configuration of GS can be proposed for airport environment in ATGC, which is a combination of centered massive MIMO antenna arrays and distributed MIMO antennas. For each centered massive MIMO antenna array (e.g. 128 elements), whose elements are mounted



(a)



(b)

Fig.2 Forming multiple beams in different directions in (a) horizontal plane and (b) vertical plane.

as a cylindrical array, as illustrated in Fig.1 (a), the elements can be formed not only UCA in horizontal plane, but also ULA in vertical plane. The element spacings in both horizontal and vertical planes are half-wavelength. This antenna configuration allows the massive MIMO system forming beams in both horizontal plane and vertical plane freely. Specially, the massive MIMO system can form beams to point airplanes in any direction without pattern distortion in horizontal plane. This is very important for the airport situation in ATGC. An example of forming multiple beams in horizontal plane and vertical plane is presented in Fig.2. It can be seen that there is no distortion in radiation pattern for the beams in different φ directions.

The massive MIMO system employs the massive MIMO antenna selection algorithm, such as the algorithms in [5] and [6], on each centered massive MIMO array to select an antenna subset. Then the antennas form beams to point the directions the selected antennas covered. Last, combine the centered massive MIMO antenna arrays to form a distributed MIMO system, as illustrated in Fig.1 (b).

Apparently, the proposed antenna configuration can capture the multipath components and LOS components sufficiently, in which the beamforming in centered massive MIMO can be used to capture the LOS components, and the multipath components can be handled by the centered massive MIMO and distributed MIMO. Therefore, the proposed antenna deployment can achieve the good capacity performance, as well as the quality of service. And it has the capability to obtain high capacity which is a requirement for the airport GS in ATGC scenario.

III. Summary

In this paper, a massive MIMO antenna array configuration is proposed for the airport GS under ATGC scenario with a brief discussion, which is a combination of centered massive MIMO and distributed MIMO. For each centered massive MIMO antenna array, the provided example shows it can form multiple beams freely in vertical plane and horizontal plane, due to the combination of ULA and UCA. Hence, the study in this paper provides a reference for antenna design of airport GS in ATGC.

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