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***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

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I. Introduction

This document is a model and instructions for LaTeX. Please observe the conference page limits.

II. Summary of the key findings

A. GXY

The article first introduces the design model of HMIMO. The article uses two classifications, namely power-based and hardware-based, with two subclasses under each classification.

Under the classification of power consumption, active HMIMO, also known as LIS, refers to the integration of a very large number of available software-programmable antenna software on an area-constrained surface, thus enabling signal transmission on this plane. Passive HMIMO, also known as RIS or IRS, does not require a dedicated power supply but is powered by its collection module and is, therefore, less costly. The highlight of this technology is the high efficiency of the transmitted signal and the simplicity of the signal processing.

Another way to classify HMIMO is based on the hardware construction, which divides HMIMO into continuous HMIMO and discrete HMIMO. before the article introduces the continuous HMIMO model, it first briefly explains the principle of holography in optics. By extension from the holographic concept, the so-called continuous HMIMO is the integration of numerous elements to form a continuous transceiver aperture in a finite plane.

The holographic MIMO completes the training by receiving a mixture of waves formed from the object reflected wave and the reference wave. In the subsequent communication process, the replica of reference wave is received, and the recovered wave beam is output. Discrete MIMO, on the other hand, has a fundamentally different structure, consisting of discrete elements that can be modulated, not an array of antennas.

After presenting the design model, the article summarizes the fabrication method for making HMIMO. There are many fabrication techniques, which can be classified into two categories, continuous aperture based and discrete aperture based. With the continuous aperture, the holographic principle is used to form a beam wave. The discrete aperture-based fabrication method is based on the software-defined super surface antenna. The subsection concludes with a brief introduction of two companies that have started to experiment with the manufacturing of HMIMO.

The last subsection of this chapter describes the four modes of operation of HMIMO, while two modes are described in detail. As mentioned above, continuous HMIMOS as active transceivers is a beam technology formed by antennas based on holographic theory. Whereas discrete HMIMOS as passive reflectors is composed of reconfigurable elements. Because it is simpler, much of the work is now done by the latter.

B. XQW

This part lists four common functions, six properties, and six communication applications, most of which are related to the 6G wireless system expectations. The author uses concise statements and diagrams to help readers understand what he mentions.

HMIMOS can support a wide range of electromagnetic interactions and they are EM Field Polarization, EM Field Redirection, Pencile-like Beamforming, and EM Field Absorption. And Fig. 2 gives us an intuitive form of these four functions.

Then the author summarizes core differences in properties among HMIMOS systems, massive MIMO, and conventional multi-antenna relaying systems.

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Thirdly, he uses Figure. 3 to give us a good illustration of six wireless communication applications for outdoor and indoor environments.

Lastly, the author uses a table to list some recent work on different combinations between the functions, features, and communication applications of HMIMOS.

C. ZY

HMIMOS-based wireless communication systems differ from multi-antenna transceiver-based classical communications in its properties. Wireless communication systems employing HMIMOS anticipate being able to alter electromagnetic wave propagation since traditional communication systems are unable to control the wireless environment in which they operate. HMIMOS is a nearly continuous aperture that uses metamaterials and/or reconfigurable, subwavelength-spaced antennas. In addition to providing for the most flexibility and accuracy in impact field recording and manipulation, these surfaces with dense electromagnetic (EM) excitation components also use less power and cost, making it possible to efficiently shape arbitrary EM waves. Holographic imaging-grade wireless communication is now possible because of HMIMOS's strong EM processing capabilities. However, to accomplish HMIMOS-assisted communication, this necessitates novel signal processing algorithms and network schemes, as well as new mathematical techniques for characterizing the physical channel and analyzing the ultimate capacity gain.

HMIMOS-based communication systems are faced with the potentially very big MIMO channel estimate difficulty as a result of the limitations of the current HMIMOS hardware architectures. Two solutions are outlined in the article. An strategy that is frequently used is to train all of the HMIMOS unit elements for a considerable amount of time using pilots that are mostly provided by the base station and received at the user equipment via common reflections. One is to use an all-digital or hybrid analog and digital transceiver architecture, taught with a lot of data through compressed sensing and deep learning, to estimate the channel and create the phase matrix. Hardware complexity, higher power consumption, and training costs are drawbacks.

As the HMIMOS unit cell is built of metamaterials and is subject to strict tuning limits, it is challenging to integrate environmental awareness into HMIMOS-based communication systems. Solving non-convex design optimization issues is necessary for HMIMOS design. With high-fidelity beams and efficient radio management, smart holographic beamforming for continuous HMIMOS enables the intelligent location and tracking of solitary or small groups of devices. However, there are currently no self-optimizing holographic beamforming methods that make use of intricate aperture combining and low-level modulation.

The centralized configuration of HMIMOS necessitates the transmission of control information from various multi-antenna base stations, HMIMOS, and users (with one or more antennas per user) to the central controller, which presents issues with huge calculation and high energy consumption. To improve user scheduling, HMIMOS configuration, resource allocation, and beamforming, distributed algorithms must be created.

III. A DETAILED DESCRIPTION OF THE RESULTS AND THEIR SIGNIFICANCE

The article introduces the application of HMIMO systems in different scenarios, and shows that HMIMO has obvious gains for existing wireless communication systems in indoor and outdoor environments. In order to further elaborate, the paper selects two use cases from HMIMO applications in indoor and outdoor environments to analyze and introduce.

A. High Accurate Indoor Positioning

The paper analyzes the performance of the active continuous HMIMOS application for indoor positioning, mainly based on the study by S. Hu et al [1]. In [1], the potential of LIS for positional has been scientifically demonstrated. Specifically, S. Hu first showed the CRLB expression when the target, with coordinates $(0, 0, z_0)$, was located on the LIS's central perpendicular line (CPL). In the derivation, the parameter τ:

$$\tau = (R/z_0)^2 \tag{1}$$

which is the surface-area normalization parameter mentioned in this paper, has been introduced and will also be the transverse coordinate of the final distribution function in Fig.1. The CRLB approximation for non-CPL targets is further derived according to the conclusion for CPL targets. The Cartesian distribution of the CRLB of the location information has been soon derived. However, in the practical application scenario, the measurement of the system will not be as ideal as the theory, so S. Hu introduced an unknown vector φ to represent the amount of distortion based on the ideal one. As derived in [1], this paper quoted the modeling results of CRLB for z-dimension with unknown φ.

In addition, the CRLB is the minimum lower bound used in statistics to represent the variance of an unbiased estimator. Under a deterministic model, the variance of the estimate about the location will never be smaller than its CRLB, whatever estimation method is used, which means that the variance of the location estimate can only be close to the CRLB. The closer it is to the CRLB, the better the possible localization of the system. In Fig.1, it concludes that the larger the τ, the greater the localization potential of the system. When the distance between two adjacent antenna elements is $\lambda/2$, the total number of antennas elements$N$ in the surface-area πR^2 can be donated as:

$$N = \frac{4\pi R^2}{\lambda^2} = \frac{4\pi\tau z_0^2}{\lambda^2} \tag{2}$$

The N of a typical traditional massive-MIMO array is 200, so the $\tau \approx 0.01$. However, LIS typically has a larger N, which means larger τ. Therefore, corresponding to the CRLB results in Fig.1, HMIMO used for positional has better performance.

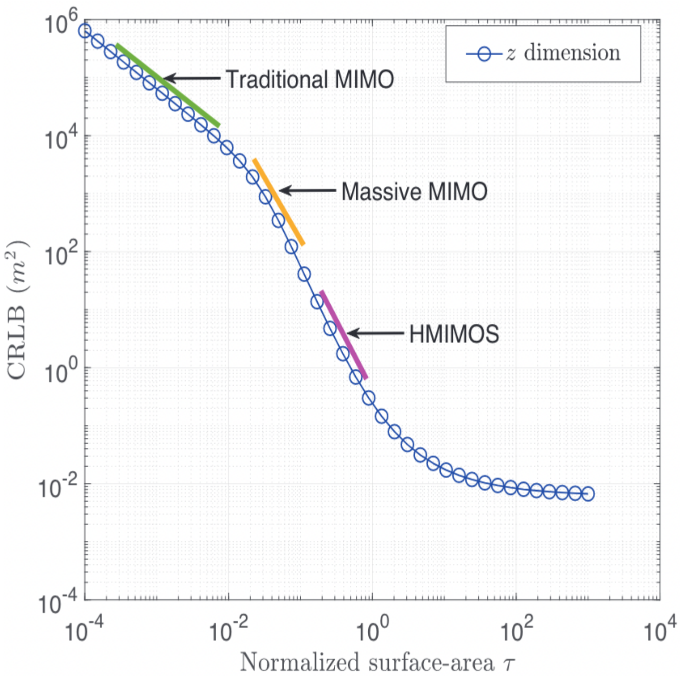

Fig. 1. CRLBs of positioning with an active HMIMOS of a radius R for the case where a single user is located $z = 4m$ away from the center of surface. The wavelength λ is 0.1m, and t represents the normalized surface area

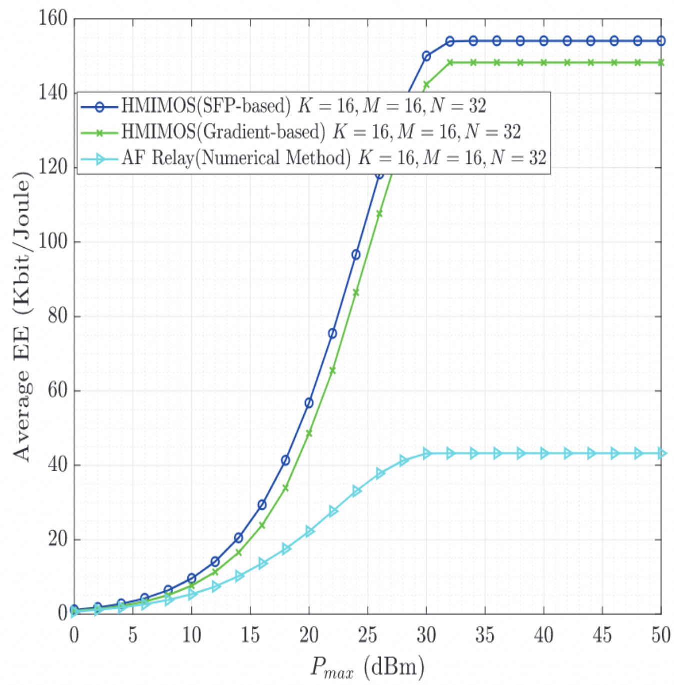

Fig. 2. Average EE with HMIMOS-assisted communication versus the maximum BS transmit power P_{max} in dBm

B. Maximize Energy Efficiency (EE)

Improving EE has been one of the great interest issues in the field of communication. The paper talks about the contribution of HMIMO to EE maximization in the application section, then the performance analysis of HMIMO for EE maximization could be very attractive. Its performance results listed in the paper are mainly from the study of C. Huang et al [2]. In [2], C. Huang proposed two RIS-based EE maximization algorithms:

- Based on the gradient descent method to obtain the RIS phase coefficients, and then used the fractional programming to optimize the distribution of transmit power.
- Based on sequential fraction programming to optimize the RIS phase shifts directly.

The performance analysis of this case in this paper reproduces algorithms proposed in [2]. The authors of this paper analyze and compare the results following the approach of [2]. Although this paper takes different values for the parameters K, M, N from [2], the conclusions are the same. K measures users in the RIS-based communication scenario, M measures the antenna base stations, and N measures the element intelligent surface. As shown in Fig.2, algorithms based on RIS significantly improve the EE with a gain of almost 200% compared to the conventional AF relay. At the same time, this paper also points out that EE increases after P_{max} reaches $32dBm$, which instead causes a decrease in EE. This has been explained in [2], EE is not infinitely increasing with P_{max}, EE is finite. EE will not increase again after reaching its maximum value. Therefore the excess $32dBm$ of P_{max} is not available to increase EE.

IV. COMMENTS

For this part, I was looking forward to seeing the combination of HMIMO and 6G wireless networks, but after reading it, I found that the author didn't cover a lot of 6G. For example, there are only attributes of HMIMO listed in this part. Readers couldn't see the contrast between HMIMO and massive MIMO and conventional multi-antenna relaying systems in a straightforward way. As a consequence, readers are supposed to consult relevant materials to understand the requirements of 6G and some basic knowledge of traditional MIMO, or readers themselves have a certain reserve of communication knowledge about the MIMO system.

This part is quite subtle since the author uses some serial numbers such as F1, C1, A1, A2, and so on to represent the functions, characteristics, and applications respectively. And at the end of this part, he combines the three parts together and summarizes some recent works using the serial numbers to make the table. And each concept in the table was interpreted in the previous article. So it's really much easier for readers to understand these works. And this gives scholars a good index of HMIMOS-based wireless communication systems.

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[1] S. Hu, F. Rusek and O. Edfors, "Beyond Massive MIMO: The Potential of Positioning With Large Intelligent Surfaces," in IEEE Transactions on Signal Processing, vol. 66, no. 7, pp. 1761-1774, 1 April1, 2018, doi: 10.1109/TSP.2018.2795547.

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