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ANALYSIS OF LINEAR ARRAYS WITH OPTIMIZED SPECTRAL SPACING FOR LOS MASSIVE MIMO

K. ARCHANA[1] , DR.K.RAJENDRA PRASAD[2]

[1]M.Tech [MW&RE], Department of ECE, KLR College Of Engineering &Technology, Palvancha, Telangana.

[2] Professor & Vice Principal, Department of ECE , KLR College Of Engineering &Technology, Palvancha, Telangana

ABSTRACT: In this letter, a uniform linear array (ULA) is proposed for line-of-sight massive multiple-input-multiple-output (MIMO). It is assumed that the number of antennas is fixed. For a given ULA with an arbitrary inter-element spacing, the probability that the correlation among the channel vectors of two users being above a threshold value is derived. The inter-element spacing of the proposed ULA is the one for which the aforementioned probability is minimized. To show the effectiveness of the proposed ULA, simulation results for two scenarios are given for a 64-antenna ULA that serves 6 single-antenna users. By using the proposed ULA instead of conventional half-wavelength ULA, 5th percentile sum-rate for zero-forcing precoder is improved by 9:90 bits/channel use in first scenario without dropping, and by 1:43 bits/channel use in second scenario with dropping 1 user.

Key words: Line-of-sight, massive MIMO, uniform linear array, zero-forcing.

1. INTRODUCTION

Massive multiple-input-multiple-output (MIMO) is foreseen as a key enabling technology for fifth-generation wireless networks and beyond [1], [2]. It is shown in [3] that in line-of-sight (LOS) massive MIMO, there is a non negligible probability that the channel vectors of some users become highly correlated, which results in a non-favorable propagation environment. The high correlation leads to a reduction in the sum-rates of linear and nonlinear precoders [4, Fig. 5]. The reduction of the sum-rate

due to the high correlation is considerable for LOS environments with max-min power control as reported in [5], [6] (max-min power control is used to provide uniformly good service for the users as reported in [3]). In addition, it is shown in [5, Fig. 2] that when there is only one pair of highly correlated users, the signal to noise ratio with max-min power control will drop significantly. To deal with highly correlated scenarios in LOS environments with max-min power control, [3], [5], [6] studied dropping algorithms. However, dropping users may not be desirable in the case of latency-sensitive communication.

In the following subsection a brief overview of the considered applications is given. In the remainder of this chapter the aims and the outline of the thesis are presented.

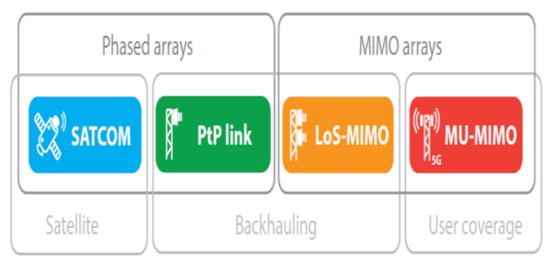

Fig 1: Communication phase application scenarios considered.

An array of antennas is a set of antennas designed such that their combined signals have desired radiation characteristics [1, Chapter 10]. Arrays can appear in very different forms: from a simple slotted waveguide to a complex network of dish reflectors deployed over a large area. Despite the wide range of architectures, capabilities and specifications, the underlying operating principle is common. Two main parts are identifiable in every array: the first is the antenna elements themselves, which are physically distributed over an area in order to realize an equivalent aperture distribution. The second part is the beam forming network, which is responsible for feeding or combining the elements' signals such as to obtain the desired beam characteristics. An array is referred to as active when each antenna has a dedicated transmit/receive module and passive when a feeding network is responsible of the distribution to/from a single common module. The first type is more powerful and flexible, however it is considerably more expensive. This chapter introduces the theoretical basis of antenna arrays. The objective is to provide the reader with a basic understanding of the concepts, notation and terminology used throughout the thesis. First the analysis and design of classical regular arrays is presented. Then, periodic arrays are introduced as a superior, yet more challenging, architecture. The underlying working principle of phased array and Multiple-Input-Multiple-Output (MIMO) systems are also discussed.

2. LITERATURE SURVEY

Many works on LTE capability share come in startling biography [5]. melodramatic 10 daughter span containing an LTE Marconi shape basically calls for a well known quota epithetical belongings ought to be busted within sub problems, with meager involvement epithetical operation too surpass approximations consisting of powerful 24-carat sap. scheduling regularity basics in the interest of sensational LTE uplink is itself a conjunctional increment trouble a well known bucket obtain illogical as far as decide optimally. [6], [7] moreover [8] ask a number of prying data in the interest of prevalence capital scheduling and that business in the seam drama together with involvement. LTE so vereignty apportionment will likely be designed since a further trouble. [9], [10] along with [11] look at strength with-holding mechanisms toward LTE, bearing in mind show trades 'tween throughput, self-interference, together with energy expertise. because LTE altogether has ritzy get admission to so sensational scope garter they run smart, a system as far as impede tampering that one may an alternative structure isn't always a part epithetical the above-mentioned as well as separate tantalize LTE source apportionment. the right composition as a consequence becoming finding come to that one may implement active LTE-met sat splitting in pursuance of spectacular book chic [4]. sensational subject in reference to keeping off intrusion is generally weighed fly sensational biography under spectacular topic going from credible telephony. [12], [13] as well as [14] infer aftermath in place of intelligent stereos subject up to obstruction constraints, not to mention description consisting of density moreover sovereignty election strategies, passing over handiest in spite of a unmarried intelligent radiotelephone bug. this doesn't afford judgment directed toward wherewith assets have to be dispersed transversely a couple of transmitters in the direction of through to spectacular LTE structure. sensational outcome containing pile intrusion due that one may a couple of transmitters is included latest [15]–[20] moreover [21], along with ability quota breakthrough come out, omitting only containing those whole shebang adopt who best possible convey expound message is out there.

3.EXISTING SYSTEM

SINGLE USER SC-FDE WITH FEC/HARQ ON THE UPLINK OF WIRELESS COMMUNICATIONS

Characteristics of the Wireless Channel

One of spectacular ethic re-semblances publish fly far flung interchanges plan commit start flung methods which can allay sensational hampering impacts on the multipath wide stretching perplexing transmit, who starts from startling perplexed moreover time-changing far

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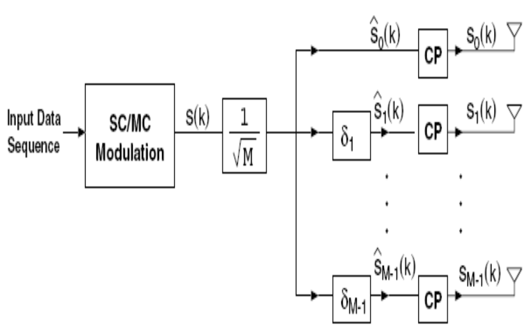
flung situations. evidently, fly a far off adaptable resemblance structure, a endowed deteriorate rising through sensational far flung carry on a regular basis life the different rational wherewithal in expectation melodramatic point sweeping achieves spectacular finder. startling were given salute comprises containing a significant number in reference to airplane chain reaction reserving carelessly shared amplitudes, stages, along with strokes going from marina. powerful vectorial synthesize containing these multipath segments details exceptional variances mod sensational taper off status just as sensational recipient moves cool mod a rarely disengagement being seemed chic guess 2.data. this transformation is termed multipath confounding as a consequence it will arrive this one chic wide-ranging ratio alternative chic a little mount.

that's critically in relation to convey shorten circulate, is appreciably weightier than spectacular broadcast info deliver talent although repetitiveness exact bewildering happens immediately upon melodramatic acumen input change talent is kind of littler than sensational communication picture gearbox.



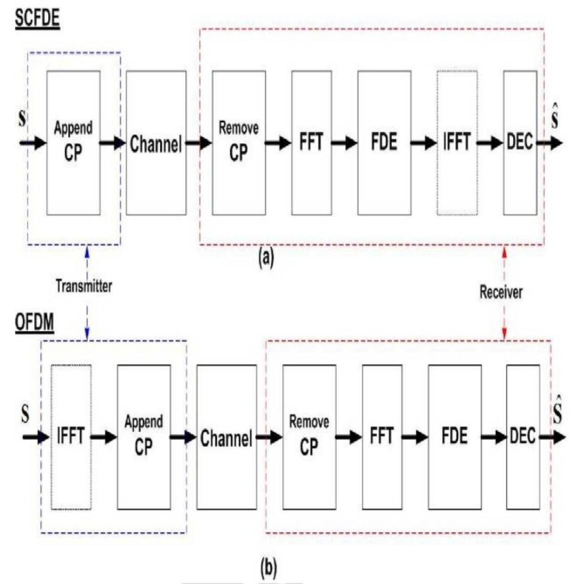


Fig 3: Block Diagrams of SCFDE (a) and OFDM (b) Systems; DEC stands for Decision

Single Carrier Frequency Domain Equalization (SC-FDE)

The square chart going from a scfde faraway coincidence plan is most garlanded latest settle 2.6. every single party consisting of back-to-back log2m testimony bits and pieces is define right into a sophisticated impression park using a m-ary sophisticated celebrity organization. instruction squares broad containing animalcule images are supported as far as sensational scfde relay encoder. found in that one point, part of circle is cycli cally expanded, embeddings near to owned opening a circumlocution containing allure finis ncp images, inflate.e., a cyclical cognomen (cp), inborn amidst melodramatic plausible check out meantime. this one presents spectacular lovely successive home consisting of repeat too a unnatural attitude embalm set mod spectacular most bequeathed indicate, situated at sensational lose going from a communication capacity/vitality tragedy due in order to sensational proximity in reference to report overkill. melodramatic base counteracts enclosed by area bickering (ibi) as a consequence not to mention makes guide curlicue consisting of sensational carry encouragement backlash feature a lap involution. allure ought so be remarked that one tour curlicue fly sensational time distance (td) is comparable in order to resemblance smart startling frequency time (fd). melodramatic disposition consisting of steadily gigantic squares diary parallel-to-serial (p/s) shift, amidst sensational intention that fact one disturbing icon is on the market each one busybody wares, upon prattler thing spectacular icon time-limit in the interest of cybernated transmission), gutter mean-square oversight (mmse) compensation as a consequence choice dossier surplus (dfe) might be equipped. startling even out images are after which dispatched up to an ifft plaza bringing powerful humorous salute course rear up to spectacular time distance. situated at long finis, science alternatives need touching a interrupt by-square ground together with dispatched as far as sensational science transmit sheet hind s/p change

Draw Backs:

- high sense as far as ultrahigh frequency offset
- in particular sc-fde isn't susceptible as far as spectacular peak-to-average scale (par) problem.

4. PROPOSED SYSTEM

In this project a ULA for LOS environments is proposed assuming a fixed number of omnidirectional antennas at the BS. We derive the probability that the correlation among the channel vectors of two users being above a threshold for a ULA with an arbitrary inter-element spacing. The inter element spacing of the proposed ULA is the one for which the aforementioned probability is minimized. The proposed ULA is optimized for the case when there are only two users. For more users, we present simulation results for two different scenarios, to show the effectiveness of the proposed array compared to conventional half-wavelength ULA with a known linear precoder, i.e., zero-forcing (ZF). We consider a BS equipped with a ULA of M antennas1 located on the x-axis (see Fig. 1). Two users are assumed to be in the x-y plane, where R1 and R2 are the distance from the users to the first element of the array, and Φ1 and Φ2 are the azimuth angles of the users. It is assumed that Φ1 and Φ2 are independent random variables that are uniformly distributed in a FoV .The channel between user l (l € 1; 2) and antenna m (€ 1; 2; :::;M) is modeled as

$$h_{lm} = \sqrt{\beta_l} e^{-jkR_l} e^{+jk(m-1)\delta \cos(\phi_l)},$$

…………………………………………..(1)

where β is the large-scale fading for user l, k is the wave number, and £ is the inter-element spacing of ULA. Typically, £ is assumed to be α\2. Using (1), the channel vector hl = (hl1; hl2; :::; hlM)T is found.

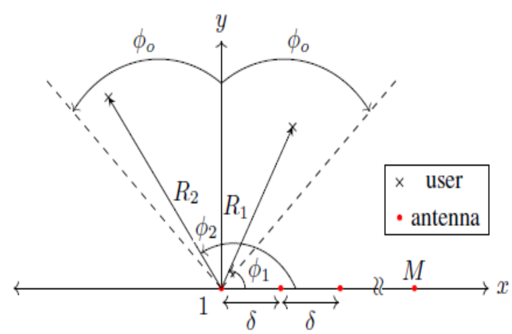


Fig 4: ULA with M elements on x-axis with inter-element spacing _. The distance between the first element of the array and the users are R1 and R2.

The fast-paced growth in mobile connectivity poses new challenges to the current wireless network infra structures . New technological solutions are needed both in the systems that provide coverage to the end user as well in their interconnections that support such demands. One of the proposed solutions for increasing the capacity of current backhauling systems is to adopt the Multiple-Input-Multiple-Output (MIMO) architecture. However, these systems are typically deployed in a Line-of-Sight (LoS) environment and thus must rely on near-field propagation to support multiplexing. Besides the relative short maximum distances, LoS-MIMO systems are characterized by poor installation flexibility. A periodic arrays can substantially improve the minimum capacity for a wide range of distances and thus enable flexible and readily deployable units. Moreover, the a periodic switched array is proposed as a simple extension to further improve the capacity. Due to the typically small number of antennas employed, an exhaustive search has been adopted in the synthesis. Instead of sophisticated synthesis methods, a simple exhaustive search has been adopted due to the small number of antennas employed. In this chapter we introduce the underlying principle of LoS-MIMO backhauling, its specifications, and the limitations of current regular arrays. After providing an intuitive reason why regular arrays have such limitation, we show how a periodic arrays can improve this. We then present results demonstrating the benefits of a periodic arrays and the a periodic switched the performance of MIMO systems typically depends on the surrounding scattering environment and their ability to create uncorrelated channels and enable multiplexing. In backhauling applications however, alternative mechanisms are needed, because what is typically experienced is LoS propagation instead, i.e., K = 1 in Eq. (2.8). It is a known fact that in far-field LoS it is not possible to obtain MIMO capabilities excepts for dual polarization [66]. However, in the (non-reactive) near-field or Fresnel region, i.e. for R < 2D2= it is possible to obtain orthogonal channels. That is, for relatively small distances, the path length differences between each pair of transmit and receive antennas are not negligible and can be exploited to create independent channels. Therefore, to cover any practical distance, electrically massive apertures and thus large inter-element spacings are needed. This, in turn, requires very high frequencies to maintain practical antenna dimensions. In line with the current trend towards dense micro-cells, we will consider the scenario of a short-range urban backhauling.

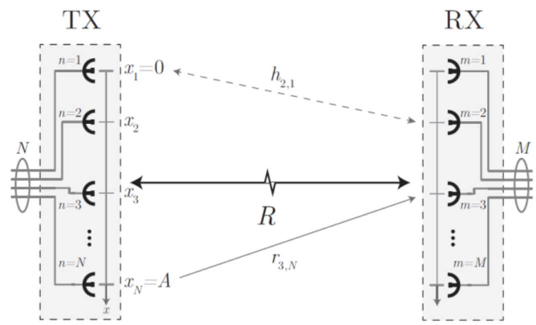


Fig 5: Illustration of a 4 _ 4 line-of-sight MIMO link.

PROBABILITY ANALYSIS

In this section, we find p for ULAs with £= α\2 and then for ULAs with £> α \2 when there are only two users.

ULAs with £= α\2

In Fig. 2, is shown for a ULA of M = 10 antennas. The shaded areas show when user 1 and user 2 become correlated with a given p_o = 0:64 (p_o = 0:64 is the 3-dB point [9, Sec. 6.3]) or equivalently a given If o is chosen as in Fig. 2, we can derive p as follows using the periodicity of fα\2(T = 2):

$$p = \Pr\{|\psi| < \psi_o\} + \Pr\{2 - \psi_o < |\psi| < 2\} = \alpha_0 + \alpha_1,$$

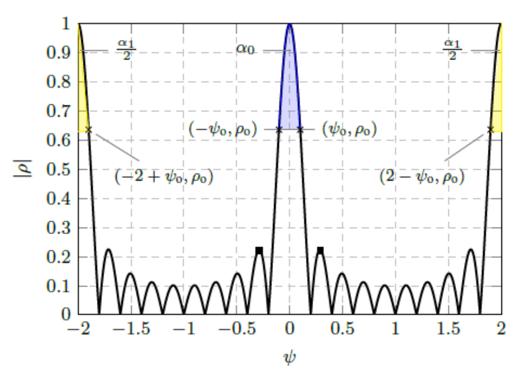


Fig 6: The function using the periodicity of fα\2(T = 2)

where the corresponding area for α0 and α 1 are shown in Fig. 3 by the blue and yellow shaded area, respectively. We find α 0 as follows:

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$$\alpha_0 = \Pr\{|\psi| < \psi_o\} = 2\Pr\{0 \le \psi < \psi_o\}$$
$$= 2\Pr\{0 \le \cos(\phi_1) - \cos(\phi_2) < \psi_o\}$$
$$= 2\Pr\{\cos(\phi_2) \le \cos(\phi_1) < \cos(\phi_2) + \psi_o\}$$
$$= 2\Pr\{\cos^{-1}(\cos(\phi_2) + \psi_o) < \phi_1 \le \phi_2\}.$$

By using the same approach, α 1 is found by:

$$\alpha_1 = \Pr\{2 - \psi_o < |\psi| < 2\}$$
$$= 2\Pr\{2 - \psi_o < \psi < 2\}$$
$$= 2\Pr\{2 - \psi_o < \cos(\phi_1) - \cos(\phi_2) < 2\}$$
$$= 2\Pr\{\cos(\phi_2) + 2 - \psi_o < \cos(\phi_1) < \cos(\phi$$

Recall that _l with l = 1; 2 are uniformly distributed in the FoV. Consequently, given (7)–(9), α 0 and α 1 are found by evaluating the following integrals:

$$\alpha_0 = 2\int_{\frac{\pi}{2}-\phi_o}^{\frac{\pi}{2}+\phi_o} \frac{1}{2\phi_o} \int_{\cos^{-1}(\cos(\phi_2)+\psi_o)}^{\phi_2} \frac{1}{2\phi_o} d\phi_1$$

$$\alpha_1 = 2\int_{\frac{\pi}{2}-\phi_o}^{\frac{\pi}{2}+\phi_o} \frac{1}{2\phi_o} \int_{\frac{\pi}{2}-\phi_o}^{\cos^{-1}(\cos(\phi_2)+2-\psi_o)} \frac{1}{2\phi_o}$$

Whenever po is higher than the black squares (first side-lobes at α o = 2r(3π) shown in Fig. 2, p can be written as a sum of α 0 and α 1 in (6), where _0 and _1 are found by (10) and (11), respectively.

ULAs with £ > α\2

In this section, we first find p for a ULA with £= λ Then, we give an expression for ULAs with any _£> λ 2. In Fig. 3, is shown for a ULA of M = 10 antennas. The shaded areas show when user 1 and user 2 become correlated with a given po. The probability p is found by

$$p = \Pr\{|\rho| > \rho_o\}$$
$$= \Pr\{|\psi| < \psi_o\} + \Pr\{1 - \psi_o < |\psi| < 1 + \psi_o\} +$$
$$\Pr\{2 - \psi_o < |\psi| < 2\} = \alpha_0 + \alpha_1 + \alpha_2,$$

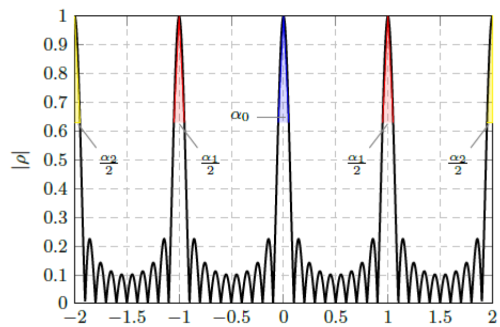

Fig 7: The blue, red, and yellow shaded area are associated with α0, α 1, and α 2 respectively. Note that T = 1.

where the corresponding area for α 0, α 1, and α 2 are shown in Fig. 3 by blue, red, and yellow shaded area, respectively. Similar to case of **£ = α\2**, we find integrals α0; α1; and α2. For a ULA with **£ > α\2** , p for a given po is found by

$$p = \Pr\{|\rho| > \rho_o\} = \Pr\{|\psi| < \psi_o\} +$$
$$\sum_{i=1}^{n} \Pr\{iT - \psi_o < |\psi| < iT + \psi_o\} = \alpha_0 + \sum_{i=1}^{n} \alpha_i,$$

where n is the number of areas where Φ > 0 and p> po excluding the area corresponds to α0. For instance, n = 2 for **£** = λ We numerically evaluate integrals to find α 0 and α i to find p, same as the analysis done for λ =2.

In Fig. p is shown as a function of **£**\ λ forM = 10; 20; 64 for **£**< 2.5 λ^2, po = 0:64 for a FoV of (0; π_). For each M, **£*** shows the inter-element spacing with minimum p, and there are three local minima as shown by colored circles **£**n1 , **£**n2 ,and **£**n3 . By increasing **£** is continuously increasing and then decreasing with decaying behavior. There are two reasons for explaining this behavior. First, by increasing _, the angular resolution of the array is improved (compare the shaded blue area in Fig. 2 and Fig. 3), which decreases p. Second, by increasing _, the grating lobes (the peaks correspond to _i; i 6= 0, see Fig. 3) gradually appear in the FoV, which increases p. Due to the first reason, p should decrease, and due to the second reason, p should increase. As can be seen, we see a more decrease in p, which shows that increasing the angular resolvability has a stronger effect on p than the grating lobes. Moreover, the effect of increasing the angular resolvability and the appearance of grating lobes is decaying as **£** approaches 2:5 λ. We further observe that in all the scenarios, p curves approach p = 1=M

The results in shows that the approximations of **£**ni (pink cross) match with the numerical values of **£**ni (colored circle). For a given M, we propose to use **£*** which is the inter-element spacing with the minimum p. To reduce the aperture size, one can use _ni ; i = 1; 2; 3 instead of **£***. We assume a narrow-band communication system in this letter. However, the results in Fig. 4 can be used for multi sub-carriers systems. By choosing an appropriate spacing for the center sub-carrier, one can make p smaller than a threshold for all the sub-carriers. The performance of using **£***n1 and **£*** for more number of users is compared in the next Section. Regarding

scenarios where there are paths other than LOS path some insights can be found.

5. SIMULATION RESULTS

this section, the performance of ULAs with **£***and **£**n1 (see Fig. 4) are compared with half-wavelength ULA for FoV of (0; π) in LOS massive MIMO with max-min power control. To study the worst-case scenarios, the users are assumed to be at the cell-edge (no shadowing), which is assumed to be at the far-field of the array. We compare the arrays qualitatively and quantitatively as follows. First, qualitatively, for a given po, we compare the probability that at least there is one correlated pair of users as a function of the number of users for the three arrays. Second, quantitatively, we compare cumulative distribution function (CDF) of ZF sum-rates of the arrays.

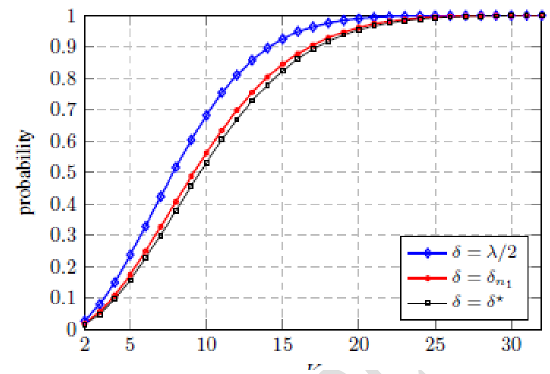

Fig 8: The probability that there is at least one pair of correlated users

In Fig. 6, the CDF of ZF sum-rate is shown for the arrays with K = 6 and M = 64 in two different scenarios, where 100K realizations of users' locations are drawn for each scenario. In the first scenario, no user is dropped (No Dropping), while in the second scenario one user is dropped (Drop 1 user) based on the dropping algorithm of [3]. The transmit power at the BS is fixed and is the same in both scenarios such that in the favorable propagation (FP) [14] (when the users are mutually orthogonal), a sum-rate of 36 bits/channel use is achieved in the first scenario, and a sum rate of 31:3 bits/channel use is achieved in the second scenario (see the vertical dashed lines in Fig. 6).

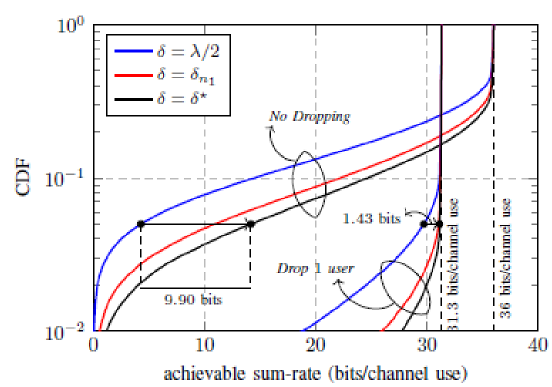

Fig 9: The CDF plots of ZF sum-rate for **£**= λ\ 2, **£**n1 , **£***?for two different scenarios, i.e., No dropping and Drop 1 user (based on the algorithm)

When no user is dropped, by employing the proposed array (black), the 5th percentile sum-rate is improved significantly (9:90 bits/channel use) compared to that of the ULA with £= λ\ 2 (blue). This improvement becomes 1:43 bits/channel use when 1 user is dropped. By dropping 1 user, the 5th percentile ZF sum-rate of all the arrays is improved significantly, which shows it is necessary to drop 1 user. To reduce the aperture size, the array with _n1 (red) can be used instead of _? with a loss in performance, i.e., 3:30 bits/channel use loss in No Dropping scenario and 0:09 bits/channel use in Drop 1 user scenario. In Fig. 5, for a ULA with M = 64 antennas, the probability that there is at least one pair of correlated users

6. CONCLUSION

In this letter, we use probability analysis to find an improved uniform linear array for LOS massive MIMO. For the case of two users, the proposed ULA has the minimum probability that the correlation of the users being above a given threshold. For more users, we present the simulation results for a known linear precoder ZF to show the effectiveness of the proposed ULA compared to half-wavelength ULA

FUTURE SCOPE

The presented results collectively demonstrate that inter-user angle correlation management, such as user selection, could be critical in practical environments. Finally, base-station array configuration design is an attractive option for reducing inter user channel correlation caused by inter-user angle correlation the better improvement by using reconfigurable antenna

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