Performance of Joint Symbol Level Precoding and RIS Phase Shift Design in the Finite Block Length Regime with Constellation Rotation

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Abstract -- In this paper, we tackle the problem of joint symbol level precoding (SIgP)Sand) reconfigurable intelligent surface (BAS) pRaSe shifts designt with igons tellation stotation in the timite ablobk length/regime. Meany to incide as energy efficiency by mittimizing the total fransmit power while satisfying the iduality of iservice constraints.safthectotaln powert scoll sumption pawebecs ignificatitly minimized gthroughly the rexploitation cofglmultiuser pinterference bydkýmboli leveľ precoding sandbby the lintelligeint manipulatiba oft-the propagation letivirount entrusing reconfigurable intelligent surfaces a lab ladditibing the against ellation drotation, permuse hacons tributes to energy efficiency by aligning the Symboly phase lighthe tisersy thus lipiproving the utilization of constructive interference. The formulated power minimization problem is mon-convex and correspondingly difficultate solve directly. Hence I we diffiple an alternating top tirbization valgorithm to tackle the goint optimizatilom of hSLP cande RIS the asei shift plesign, til the of plittial aphase lif pach cushifs donistell aften optitation pisa obtained ly ias and exhaustive searchotalgorithmol/ThroughyiMonte-Carlotsimulation negults.hwe demonstrate that the proposed isolution wields substantial power thiniprizational asolgoin paved dto subaventional oSEP, nzeron forcing precoding with RIS vas wella's the benefinaring chemes without RIS as well as the benchmark schemes without RIS

Index Terms:—Symbol level precoding, reconfigurable intelligent surface, energy efficiency, finite block length, constellation rotation, short packets.

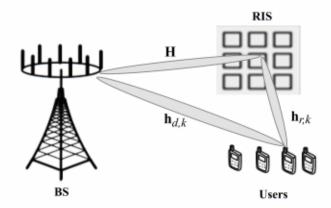
I. Introduction

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This work is funded by the Luxembourg National Research Fund (FNis) workpisr funded by the Euxembourg Nationale Research Fund (FNis) workpisr funded by the FEE wormbourg in Nationale Research FEE (FNIS) 6220/dS) InterCOVE programme under project RISOTTI C20/IS/14773976.

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- We formulate a novel joint optimization of SLP RIS rocused on the design in the infinite block length phase shift design with constellation rotation for power regime without constellation rotation for power regime. The result minimization in the finite block length regime. The resultinis case, we optimize the users constellation rotationing problem is non-convex making it quite challenging problem is non-convex making it quite challenging better alignment of the symbols. As a result to find a global optimal solution. In addition, there is a strong coupling between the SLP and RIS phase shift region leading to higher energy efficiency.
- we hables. Further, the discrete nature of the set of possible we formulate a novel joint optimization of SLP, constellation, rotations poses a significant challenge, in fils phase shift design with constellation rotation for finding an optimal solution to the problem. To tackle the power minimization in the unite block length regime. The less that he posed by the formulated problem, we leverage the length group optimization technique to decouple the challenging to find a global optimal solution. In SLP design and the design of RIS phase shifts into two additions there is a strong coupling between the SLP subproblems. Further, we obtain the optimal phase of and RIS phase shifts ariseles. Further, the discrete constellation rotation via an exhaustive search algorithm.
- constellation rotation via an exhaustive search algorithm nature of the set of possible constellation rotations. We provide a performance evaluation of the proposed poses a significant change in initiality an optimal design for a smart city street scenario under various solution to the problem. To tackle the complexity conditions. The simulation results validated the perforposed by the formulated problem, we leverage the mance improvement of the proposed design over the alternating optimization technique to decouple the conventional SLP, zero forcing precoding with RIS as SLP design and the design of RIS phase shifts into two well as the benchmark schemes without RIS.

The refnainder-lift the paperais organized as follows: Section?? describes briefly the system model. In Section ??, we present the optimization approachate colvecthet formulated reprincipation problem Section ?? presents the numerical results to exaluate the performance in other proposed design of finally. We significant the paper in Section ?? SLP, zero forcing precoding with Norman Marketing and sections with the paper in Section of the paper in Section of

Bold appeared down case letters grespectively ollows. Send Stor ?? respectively be presente the steah part daild Ith Somagin ary part of esent | the notest the zerolidear oldern formulation. In Section ??, we propose an approach to solve the formulated optimization problem. System Modesents the numerical results to evaluate the performance of the proposed design As illustrated in Fig. ??, we consider a RIS-assisted Finally, we conclude the paper in Section of multiuser multiple-input single-output (MISO) system in the do Wortakio windle triogase nelacioli mes yestoro ete winne you ted by bold upper and lower case letters, respectively Rfrl RIS is thurspeactively represente the creater and a the itteagingrouparthophrise bufftings there unlidean of therent channels in RIS-assisted networks, which include the direct link from BS to user k, the indirect link from BS to RIS, and the reflection channels from RESletb user k denoted by $\mathbf{h}_{d,k} \in \mathbb{C}^{1 \times M}$, $\mathbf{H} \in \mathbb{C}^{N \times M}$, and $\mathbf{h}_{r,k} \in \mathbb{C}^{1 \times N}$, respectively. The transmitted symbols $\mathbf{d}[t] = [d_1[t], \dots, d_K[t]]$ are drawn from a Ψ -phase shift keying (PSK) constitution, where t is the index of the symbol interval. Note that we assume a quadrature the downlink, where a base station (BS) equipped with MPSK modulation, i.e., $\Psi = 4$, in this work. However, the The transmitted symbols $\mathbf{d}[t] = [d_1[t], ..., d_K[t]]$ are drawn from a Ψ -phase shift keying $(PSK)^n$ constellation, where where nuttais the additive white Gaussian noise (AWGN) with distribution $CN(91\sigma_n^2)$. Further, h_k denotes the equivalent link comprised the the direct BS link and the case and RIS dinks being expressed and does not impact the proposed system design. The BS bhanger it Olfansmitted precoder where $\Theta C \stackrel{M}{=} \stackrel{\wedge}{\otimes} diwith e^{i\theta} espection different is different passive that$ Nection beam forming married at the RISO trionist cases & consider is a nervestection verificiency; twitich is deptading 1 characteristicibe. Next $y \theta d$ sight $a 2\pi k$ is the phase of a the interior the right entire element of the RIS. $r_k[t] = \mathbf{h}_k \mathbf{x}[t] + n_k[t],$ whTo docilitate transmission with a dinite-block-length with a transmitted preceder matrix can be written as fellows $X_{
m three}$ [x[l]valex[L] where X consists of all the data vegtors in the blockd In additions, it is important to note that the precoder while the phases of the RIS remain fixed within a specific where $\Theta = \beta$ diag ($\beta = \beta$) is the passing matrix at the RIS. In this case, $\beta \in [0,1]$ is the reflection efficiency, which is equal to 1 for simplicity. Next $f(x) \in [0.2\pi]$ is the phase of the nth reflective element of the RIS.

The main abjective of shish works is to minimize the ligial transmit (powers by edointly optimizing in the clinite though the ligit attion, and RIS [Rhase, shift] designer in the clinite though alength data vectors in the block. In addition, it is important to note the appet of point SIP. RIS phase shift design with constellation to the impact of point SIP. RIS phase shift design with constellation to the impact of point SIP. RIS phase shift design with constellation for the intransmitted of even by the particle phase shift design with constellation for the intransmitted of even by the phase shift design with constellation for the phase shift design with the phase shift d

reginsen Accordingly; dhelipower stationization aproble 6382in be formulated as follows: III. Optimization Problem Formulation

The main objective of this work is to minimize the total transmits powerpon jointly optimizing SIP, depostellation rotation and RIS phase shift design in the finite block length regime. Accordingly, the power minimization prob lem can be formulated as follows? k 3 (e

$$\mathcal{P}: \underset{\mathbf{X}, \theta, \phi}{\operatorname{minimize}} \|\mathbf{X}\|^{2} \tag{3c}$$
s. t.
$$\Re(\hat{\mathbf{h}}_{k} \mathbf{X}[\ell]) \frac{2\pi}{\Psi_{k}} \sigma_{k} \sqrt{\frac{\Psi}{\gamma_{k}}} \Re(e^{-1}) \frac{2\pi}{\Psi_{k}} \right) k[\ell] \sim 0, (3d)$$

where, ≤ is an element wise operator, that guarantees receiving each symbol in the correct detection region. Further details on the extended regions are well presented in [?]. In addition, it is important to note that the received symbol constellation is scaled by $\sigma_k \sqrt{\gamma_k}$ where σ_k denotes the noise standard-deviation and γ_k is the desired user's signal-to-interference pthernoise ration(SINRED Theiseonmannter constant deserge the вревіні дивання развительня при на на при н Further details on the extended regions are well presented
• Constraints? and?! These are bi-linear constraints that
in [7]. In addition, it is important to note that the
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received symbol constellation is scaled by σ_k, γ_k, where σ_k
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• Constraint?? This constraint describes the discrete set
constraints considered in this problem are explained in
of possible phases of the users' constellation rotation.

detail as follows:
• Constraint?? This constraint describes the RIS phase
• Constraints?? and ??? These are bi-linear constraints
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that ensure the received signals fall in the correct It is important to grote that problem 12s in 636 is non-convext Further othere is a listrong coupling between discrete and continuous variables. In this case, the problem cannot be solved using standard convex optimization techniques, making it computationally intractable. To tackle the complexity of the formulated optimization problem, we split the joint optimization of SItPa and RIS phase shift design into two tractable sub-problems if the two sub-problems can be solved in an alternating manner by leveraging the alternating optimization It is important to note that problem ** in (3) is nonframework. Further, the optimal phase of the constellation rotation for each user is obtained via an exhaustive search algorithm. This is motivated by the fact that a slight change in the constellation rotation of one of the users leads to large completely different operation point in the parameter space the complexity of the formulated optimization problem, since this rotation affects the shape of the region is a nonlinear way and the phase offset of each rotation is drawn from a rather small set of yalues as suggested in 171. Accordingly, such changes make the optimization procedure unstable i.e. no stationary solution can be guaranteed while the performance Further the optimal phase of the constellation rotation for is typically, poor and the complexity of optimization is very high. In order to avoid this pitfall, we perform the optimization of the precoder and the phase shifts for each combination and then select the best combination via exhaustive search [4] a completely different operation point in the parameter

space silve Rropostati Optatienzation saagerif file region in in non-linear way and the phase offset of each initiation is drawn from a rather small set of values as suggested in Specifically, for each combination of rotation. Pive optimization projecture afinetable increasing the stationary of all for the block guarant eed while the performance is typically poor, and the cásuplezitybaloutionineniánou with high hilmonderconsumied total power. We princomath to note that the 18st changes the and the phase shifts for each combination and their select the best combinations via fixhais tive Ris phase shifts are optimized considering eall the idifferent symbol combinations in a block of length L. In this section, we detail the steps of the optimization

Arosonbot teveliprecoding optimization

Specifically, for each combination of rotation, we in this subsection we tackle the design of transmit precoder optimize the SLP and the RIS phase shift design for vectors x 11...x L. Specifically, for a given RIS phase shift all of the block symbols via an alternating optimization yector \(\theta\) and given combination of constellation rotations, we framework. In this case, we obtain a combination with solve the SLP problem to obtain the transmitted signal \(x \)! It is important, to the minimum consumed total power. It is important, to all symbol combinations in a block. The resultant subproblem note that the ES changes the precoder \(x \)[\(\ell\)] it is in portant. Solve the symbols while the RIS phase shifts remain fixed. Specifically, and RIS phase shifts are optimized considering all the different symbol combinations in a block of length

 $\Im(\mathbf{h}_k \mathbf{x}[\ell]) - \sigma_k \sqrt{\gamma_k} \Im(d_k[\ell]) \leq 0, \forall k$ The Sproblem one (4) recommend that tease, standard convex

togls, edg., sGVXccsplyerwl? hacane behexploited to solventhe problem effectively, [n addition] the problem cap, be, solved RSing Da mon-negative deas 0 squares (NNLS) halgorithm (which uses the geometrynef \$LPs constructive pegions (2). (For more details and the tNN is raiger that refer to held combinations in a block. The resultant subproblem is formulated as follows, B. RIS Phase Shift Design

In this subsection, we tackle the design of RIS phase shifts for given transmit precoder vectors. It is important to note that afters solving (the xSLP -problem, \mathbb{n}(d(4))) the Ooptimization of RIS phase shifts will not result in further reduction of total transmit power. Accordingly, with the phase shift optimization. The problem in (4) is convex. In this case, standard we aim at increasing the parameter subspace by making the QoS constraints, i.e. reseived signal constraints, inactive such that the transmit power can be subsequently reduced via can be solved using a non-negative least squares (NNL) precoder design, in the next iteration. For that reason, to further agorithm, which uses the geometry of SLP constructive minimize the transmit power in the next iterations, we model a regions 1/1. For more details of the NNLS algorithm, refer new objective function to maximize the QoS. In this case, the phases of the RIS are optimized to improve the QoS which can therRifferPasasthSpaffarDetegspace around the previously found solution; The resultant optimization problem is formulated as shifts for given transmit precoder vectors. It is important to note that after $\sum_{k=0}^{\infty} \sum_{k=0}^{\infty} \sum_{k=0}^{\infty} \mathbb{SLP}$ problem in (4). θ Z

²The proposed design can be enhanced by applying low-complexity methods proposed R(R) x dead of grandstive search Movever (5b) integration of this method in our proposed joint optimization of SLP. RIS phase shifts and constillation found in its beyond the scope of this work.

²Thet bio posed designs sambe tenhance daby littoph in enfowt of fiblic xity due the ods proposed im [Phinistend of okljaintiv/IsParell/Holwever, lthe integration tif this shelladd in outa piop osedljoift tit pthoizaltion of ISLR iRIS. Phase rshifts died will stall disease that ion is disvenight the respect CSI this thought the performance.

³The number off symbol combinations Q is equal to Ψ^K... Assuming quadraturer PSRSHodulation; the notab number of combinations of constellation rotatitelsaisi also @atsiosuggestddoirQ 2)s suggested in [?].

the optimization of the RS 2 phase, shifts will not result of whither (tell) which must of 2 lister a such in the each ase, which is the result of the resul

The joint SLP and phase shift design is carried out for different combination of constellation rotations and we obtain the combination with the fininimum total transmit power. We summarize the joint SLP RIS phase shift and constellation rotation optimization by Algorithm $\Re d_k[\ell] \ge 0, \forall k, \ell$ (5c)

Algorithm 1. Joint SLP and RIS phase shift design in the where (ℓ,k) -th entry of Z is $z_{\ell,k}$, which is the QoS limit block length with constellation rotation metric. In this case, $z_{\ell,k} = \sigma_k \sqrt{r}$, A similar procedure inputs the horotograph of the problem of the pro

11 The produce of Pand phase; shift design is carried out for different convergences of constellation rotations and we obtain the combination with the minimum total transmit powered we summarize the joint SLP, RIS phase shift and constellation of the convergence of the point SLP, RIS phase shift and constellation of the convergence of the point SLP.

C. Complexity Analysis

We briefly provide a complexity analysis of the proposed optimization algorithm. According to [?], the complexity of Weobtiefly iprovide a complexity satisfy is the groups of the proposed optimization algorithm and sending problem the groups of optimization algorithm and sending problem in [AL] by the INNLY halsorithm congistery by the Module of the complexity of the proposed estign is selected by included by implementing low-complexity algorithm proposed design can be reduced by implementing low-complexity algorithm proposed in [?].

In this section, we conduct Monte-Carlo simulations to evaluate the performance of the proposed softilion against then this section, and beautiful and the proposed softilion against the state of the performance in the proposed softilion and the state of the performance in the state of the softilion and the state of the consideron the state of the consideron the state of the softilion and th

A teepityett is distance. From the Isase aration for the binding freite block city site or The onsers late uniformly distributed at random between 20 to 40 meters in the y-direction, see Fig. ??. Due por the logation of the RIS which is high above the users, the pathlosa exponent of the BS-RIS link is set lower than that for the other links. The symbol constellation scaling is set at a feet the phase. This can be adjusted according to different QoS staguirements.

5 We provide led the distance-dependent path loss as $\alpha = -30 - 10 \rho \log_{10}^{10} (d) \, dB$ [?], where d is the link distance, and ρ is the path-loss exponent. To account for small scale fading, we considered for Rician channel model for all channels involved. For instance, the BS-usere k charled k, can be written k solve k by k charled k charled k, can be written k solve k by k charled k charled k can be written k solve k by k charled k charled k can be written k by k solve k by k charled k component, respectively. The Rician factor k is 10 dB. To validate the performance of the proposed point SLP and RIS phase shift design with the proposed point SLP and RIS phase shift design with constant k by k by k by k by k by k compared k in the finite block length regime (Proposed), we compared k the finite block length regime (Proposed), we compared k the finite block length regime (Proposed).

17: $\theta^{\star} = \theta$ $X^{\star} = X$ Zero forcing precoding without RIS (ZF, no RIS): In this scheme ZF precoding is performed without the help of the RIS.

distrZerbefording.pdecoding with RISt(ZH) with eRIS): the this directionese ZF ignecoding to performation whether RiSmission is higherwhere the uses and the pBS his side of by othe RIS of the BS-RIS with tissue'ts yound there there of in general the pBS his side of by othe RIS (She symbol intestell RIS) is brething clear the open formation as a SER directed in growithing the differential QoRIS equirements.

WConsentional symbolic velipsending with RISs(SIP infi-30 nite()) with RIS). In this scheme we perform conventional and SIPs preceding with the pholorer the RISs out for small scale proposed we obtain the pholorer the RISs out for small scale proposed we obtain the pholorer the RISs of the RISs out for small channels his velocities device on the RISs of the RISS o

- Zero forcinaspecodinguiation Paralise(ZF, no RIS): In this scheme ZF precoding is performed without the Parameter Value
- Zero Carrier frequency (1/12) with RIS 2/2F, With RIS):
 In the imperor users (R) with RIS 2/2F, With RIS):
 In the imperor users (R) performed where transmission obtained in the users and 4 he BS is aided by the strength of the imperor and 4 he BS is a like and 4 he BS is a like
- Conventional symbol level preceding without RIS (SLP RIS height no RIS): In this scheme we perform conventional symbol representation of the RIS. pathloss exponent RIS-user (ρ_{vu})
 2.6
- Conventional specific Bever precoding 6with RIS (SLP infinite, with a RIS) with this scheme we perform conventional SLP precoding with the help of the RIS.

A. Althypissoff archaigent mits mitty DMS r (SLP finition of BLS)k length this scheme we carry out SLP precoding in the finite block length with constellation rotation. However, communication is carried out via the BS direct link.

For all simulation results in this paper we average the transmit power in 100 channel realizations and 10 blocks per realization which results in 1000 blocks 1 the analyses in this paper were carried out focusing on the QPSK modulation. Parameters utilized in the simulations are specified in Table ??. TABLE I: Simulation Parameters 2.4 GHz Carrier frequency (f_c) 8 Number of users (K) 4 Number of BS antennas (M)4 Number of RIS elements (N)64 BS height20 58 155 30 35 1.5 m User height Block Length (L) RIS height

Fig. 2: Average its ansmit power as a function $30f_{\rm r}$ block length. pathloss exponent BS-RIS ($\rho_{\rm br}$) | 2.3

In this wild section, we stild some effect of block length on the average hloss exponent. We way the block length L from 8 to 64 and the results are depicted in Fig. ??. The proposed solution with RIS and constellation rotation results in a sub-Aanfalabduction in power teansumption vas compared to all the bonsidered thenchmark schemes. We observe higher gains of the proposed design against conventional SLP precoding (SLP infinite, with RIS) when the block length is short. Specifically, at L = 8, the gain between the proposed solution and the conventional SLP is about 4 dB. In this case, the design of RIS-assisted SLP with constellation rotation is important for reduced power consumption in the finite block-length regime. Further, the proposed design results in power savings of about 5.5 dB with respect to the design-without RIS (SLP finite, no RIS). This validates the impact of our proposed scheme in reducing the total consumed power as compared to the design without RIS. This also shows the symbiotic benefits of MUI exploitation by SLP and the manipulation of the propagation environment by RIS. It is important to note that with increasing block length, the transmit power for the SLP in finite block length regime increases. However we still note a performance gain of about 1.5 dB with respect to the conventional SLP at L = 64. Pürther, we obtain a performance gain of 6 dB at L=64 with the proposed solution compared to the finite block2engthrSigP with snoiRISower as a function of block length.

B. Analysis of average transmit power as a function of the number of RIS elements, we study the effect of block length on Inhibitive subsection, swe tapalyze, three fact distillation being the RIS redensents on the average subtal analysis power of the object of the average subtal analysis power of the object of the object of the state of the

conventional SLP precoding (SLP infinite, with RIS) when the block length is short. Specifically, at $L_0 = 8$, the gain between the proposed solution and the sconwentional SLP is about 4 dB. In this case, the design of R B assisted SLP with constellation rotation is important for reduced power consumption in the finite block length regime. Further, the proposed design results in power savings of about 5.5 dB with respect to the design without RIS (SLP finite, no RIS . This validates the impact of our proposed scheme in reducing the total consumed power as compared to the designs without RIS. This also shows the symbiotic benefits of MUI exploitation by SLP and the manipulation of the propagation environment by RIS. It is important to note that with increasing block length, the transmit power for the SIA in finite block length regime increases. However we still note a performance gain of about 1.5 dB with respect to the conventional SLP at L = 64. Further, we Fig. 3: Average transmit power as a function of the number of RIS elements, proposed solution compared to the finite block length SLP with no RIS.

addition, we observe that with increasing number of RIS. B. Analysis of average transmit power as a function of elements, the average transmit power is reduced for all the the number of RIS elements are considered schemes utilizing RIS. Furthermore, we can observe a performance gain of the proposed solution of around 4 dB and 6 dB at N=64 compared to conventional SLP (SLP infinite, with RIS) and the SLP finite, not RIS scheme, respectively. This validates the benefits of RIS deployment in the proposed design.

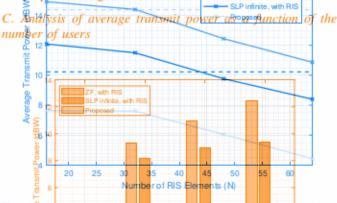


Fig. 32 Average transmit power as a function of the number of RI\$ elements.

In this subsection, we analyze the effect of the number of RIS elements on the average total transmit power. For this analysis, we set the block length to L=8 and the number of RIS elements of the block length to L=8 and the number of RIS. Exercises transmitt powers a length to L=8 and the number of lustres provides significant power savings compared to all the considered benchmark schemes as shown in Fig. ??. In This list beserves to bus the tenth of the assumber not be sense of all the considered benchmark schemes as shown in Fig. ??. In This list beserves to bus the tenth of the assumber not be sense of all the considered benchmark schemes as shown in Fig. ??. In This list beserves to bus the tenth of the saving benchmark of the saving benchmarks the tenth of the saving benchmarks as the west of the propositive of the tenth of the saving benchmarks the saving

behehmarkss (ZFti with RISisand ISIaPeinfinite) with tRISI RISS therbases eas the humber of dishrsjancre ases. This is mainly because the increased MUI can be effectively exploited via the Cint optimization of SEP, this phase shifts and constitution the number $R^{t} \stackrel{\text{users}}{=} 2$, we observe power savings of 2 dB by the proposed solution compared to conventional SLP (SLP infinite, with RIS) and 2.75 dB with ZF precoding (ZF with RIS) scheme. This performance gap increases to 4.5 dB and 6.4 dB with conventional SLP and ZF precoding, respectively, at $K \ge 4$. Further, we observe a performance gain of 4.9 dB and 790 dB of the proposed against the conventional SLP and ZF precoding, respectively, at K = 5. The proposed solution becomes more and more effective as the number of users increases since there is a higher chance of exploiting constructive interference. Specifically, with increasing number of users the total number of symbol combinations that can occur in a packet increases exponentially. Accordingly, the choice of the constellation rotation becomes more and more important for the system performance. This is due to the broken symmetry of the symbol constellation as not all symbol constellations are equally probable as explained in [?]. Thus 4: the composeen seneme words a fuentian to falst materine development of future large multiuser networks, while also providing significant energy efficiency gains.

This subsection studies the effect of the number of users on the average total transmit power. We vary the nullabilitisopapers we ratualised the nareals most tetal transmit gower minimization in rRIS assisted SIP on the finite block length regime with constellation retationes Specifically, total transmit.nowernwas tminimizedeviar the noptimization of nSIPs BISp phase schift design than desensical attender of the phase schift design than design than the phase schift design that the phase schift design that the phase schift design that the phase schift design than the phase schift design that the phase the prone convexity, of the aformulated problem, we presented to calternating contimization it to valve other joint contimization of SLP and RIS phase shift. Next he optimal phase of the Segnstellation arotation sward obtained avian anotexhaustive swarch, Numerical eresults, demonstrated the beffectiveness of the proposed design in minimizing power consumption as compared to conventional SLP without constallation potation. thrs design without RLS and zero forcing we observed that with shorter block lengths ithe proposed design is bighly heneficial-in obtaining/significant power-savings-compared to the conventional RIS rassisted precoding designosed against th To durther enhancer the proposed designs, future ework, will resort to machine learning to address the complexity of the proposed solution. Further, the case of imperfect CSI motivates the use of subust optimization which would make the design applicable to segnarios with non-negligible uses mobility otal number of symbol combinations that can occur in a packet increases exponentially. Accordingly, the choice of the constellation rotation becomes more and more important for the system performance. This is due to the broken symmetry of the symbol constellation as not all symbol constellations are equally probable as explained in [?]. Thus, the proposed scheme holds potential to facilitate the development of future large multiuser networks, while also providing significant energy efficiency gains.

VI. Conclusion

In this paper, we studied the problem of total transmit power minimization in RIS-assisted SLP in the finite block length regime with constellation rotation. Specifically, total transmit power was minimized via the optimization of SLP, RIS phase shift design, and constellation rotation. Due to the non-convexity of the formulated problem, we resorted to alternating optimization to solve the joint optimization of SLP and RIS phase shift. Next, the optimal phase of the constellation rotation was obtained via an exhaustive search. Numerical results demonstrated the effectiveness of the proposed design in minimizing power consumption as compared to conventional SLP without constellation rotation, the design without RIS and zero forcing. We observed that with shorter block lengths, the proposed design is highly beneficial in obtaining significant power savings compared to the conventional RIS-assisted precoding design.

To further enhance the proposed design, future work will resort to machine learning to address the complexity of the proposed solution. Further, the case of imperfect CSI motivates the use of robust optimization, which would make the design applicable to scenarios with non-negligible user mobility.