Joint Power Allocation for OFDM-Based Non-Concurrent Two-Way AF Relaying

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***Abstract*— We consider an amplify-and-forward non-concurrent two-way relaying for an orthogonal frequency division multiplexing (OFDM) system, where the base station (BS) serves a transmit-only user (TU) and a receive-only (RU) user, whose receive signal is interfered by the TU transmit signal. We design an overhearing-based interference cancellation scheme wherein the RU collects side-information by overhearing the TU transmit signal, and uses that to cancel its interference. We then jointly allocate power at the TU, BS, and the relay nodes across OFDM subbands to optimize the sum-rate, which is a non-convex problem. We solve it using successive convex approximation (SCA), which approximates the non-convex sum-rate optimization as a sequence of convex programs. The SCA approach is shown to converge within few iterations. Numerical results demonstrate the improved performance of the proposed algorithm over other state-of-the-art algorithms.**

***Index Terms*— Non-concurrent, sum-rate, power allocation.**

I. Introduction

TWO WAY RELAYING (TWR) improves the spectral efficiency of conventional half-duplex relaying by reducing the number of channel uses [1]. TWR enables two source nodes to exchange data via a half-duplex relay in two channel uses, when compared with the four channel uses in one-way relaying [2]. In the first channel use of TWR, both nodes simultaneously transmit their signals to the relay, which receives their sum. The relay amplifies and retransmits this sum-signal in the second channel use. Since both nodes know their respective transmit signal from the first channel use, they use it to cancel the self-interference/back-propagating interference (BI) from their receive sum-signal and detect BI-free data. Two data units are thus exchanged in two channel uses.

TWR assumes that a node wants to exchange data with its partner node. If TWR is used in cellular systems, it will assume that a user also wants to exchange data with the base station (BS). In cellular systems, a user, however, does not usually exchange data with the BS. Consider a transmit-only user TU who is uploading a video on to a cloud, or a receive-only user RU, who is downloading a Youtube video. We see that neither TU nor RU exchanges data with the BS, and consequently the BS cannot serve them using TWR. The BS, however, can serve them using one-way relaying, but will require four channel uses – two each for TU and RU. In the non-concurrent TWR (ncTWR) protocol [3], [4], the BS can serve both TU and RU in two channel uses as explained next.

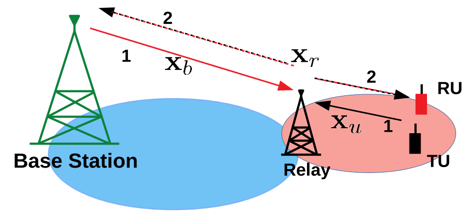

Fig. 1. *Illustration of ncTWR*: In the first channel use (labeled '1'), both BS and TU transmit to the relay. In the second channel use (labeled '2'), the relay amplifies the sum-signal received in the first channel use, and transmits it to both BS and RU.

In the first channel user of ncTWR, as shown in Fig. 1, both BS and TU transmit to the relay. The relay receives the sum of these two signal, amplifies it and in the second channel use, and broadcasts it to both BS and RU. The BS now serves both TU and RU in two channel uses. We note that the BI for the BS is its own data from the first channel use, which it can cancel. But the BI for RU, in contrast, is transmit data of the TU, which it cannot cancel. This is unlike the TWR wherein both receive nodes can cancel BI.

References [4] and [5] designed a precoder at the relay to cancel the BI, whereas references [3] and [6] assumed that the RU can overhear the first channel use signal of the TU, and then use it to cancel the BI. All these references [3]–[6] have considered single-carrier systems, and have ignored the use of OFDM in their system design, which is an important technology component of the existing 4G and the emerging 5G systems. The OFDM ncTWR system design has two challenging design aspects: i) a suitable BI cancelling scheme for the RU; and ii) a joint power allocation scheme to maximize the system sum-rate by jointly allocating power at the BS, TUE and the relay nodes, and crucially also across OFDM subbands (group of subcarriers is termed as a subband). We solve these two problems in the current work, whose main contributions are listed below.

1) We consider an OFDM-based ncTWR system. Motivated by the overhearing-based BI-cancellation approach in [3] and [6], the RU herein also cancels the BI by overhearing the TU transmit signal. This approach is crucial for the OFDM ncTWR system as it yields signal-to-noise ratio (SNR) expressions which allows us to maximize the system sum-rate using geometric programming.

2) The sum-rate is maximized by allocating power across the OFDM subbands jointly at the TU, BS and the relay nodes.

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We use successive convex approximation (SCA) approach to approximate the non-convex sum-rate maximization as a convex geometric program (GP). The approximation is then successively improved by proposing an algorithm, which is numerically shown to converge within few iterations.

3) We show that the proposed algorithm has better sum-rate than the other state-of-the-art approaches.

II. System Model

Consider a non-concurrent amplify and forward (AF) TWR system wherein two users TU and RU communicate with the BS through a half-duplex relay. The BS sends downlink data to the RU, and the TU sends uplink data to the BS. We assume that, due to high path loss and shadowing, there are no direct links between the BS and the two users [4], [5]. We also assume that all the nodes are equipped with single antenna.[1] We consider an OFDM-based system with K subbands.

In the first channel use of ncTWR, both BS and TU transmit their respective downlink and uplink OFDM signals to the relay, which receives a sum of these two signals. The sum signal received by the relay on the kth subband is $y_r[k] = h_b[k]x_b[k] + h_u[k]x_u[k] + n_r[k]$, for $k = 1, \ldots, K$. Here $h_b[k]$, $h_u[k]$ are the kth subband channels for the BS$\rightarrow$Relay and the TU$\rightarrow$Relay links, respectively. We express $x_i[k] = \sqrt{p_i[k]}\tilde{x}_i[k]$ for $i = u, k$, where $\tilde{x}_i[k]$ has zero mean and unit variance such that $\mathbb{E}\left[\sum_{k=1}^{K} |x_i[k]|^2\right] = \sum_{k=1}^{K} p_i[k] \leq P_i$. Here $i = u, b$. We assume that the relay noise $n_r[k]$, which is independent and identically distributed (iid) across subbands, has complex normal distribution, denoted as $\mathcal{CN}(0, 1)$. We also assume that, similar to [3] and [6], the RU overhears the TU transmit signal, and uses it to cancel its BI in the second channel use. The signal overheard by the RU in the kth subband is

$$y_u^1[k] = h_o[k]x_u[k] + n_u^1[k]. \tag{1}$$

The superscript here and in the sequel denotes the channel use of the RU receive signal. The term $h_o[k]$ is the kth subband channel for the TU$\rightarrow$RU overhearing-link. The first-channel-use RU noise $n_u^1[k]$, iid across subbands, is distributed as $\mathcal{CN}(0, 1)$. We assume, similar to [4] and [5], a quasi-static channel model where channel coefficients are constant over multiple channel uses, and can be estimated perfectly, and are accessible to all the nodes.

In the second channel use of ncTWR, the relay amplifies its received signal and broadcasts it to both BS and RU. The relay transmit signal $x_r[k]$ for the kth subband is

$$x_r^k = \sqrt{p_r[k]}y_r[k] = \sqrt{p_r[k]}(h_b[k]x_b[k] + h_u[k]x_u[k] + n_r[k]),$$

where $p_r[k]$ is the amplification factor for the kth subband. Note that we assume that the relay receives and broadcasts the signal over the same kth subband. The relay signal satisfies the maximum transmit power constraint which is given as $\sum_{k=1}^{K} p_r[k]\,|h_b[k]|^2\, p_b[k] + p_r[k]\,|h_u[k]|^2\, p_u[k] + p_r[k] \leq P_r$.

[1] We consider single antenna nodes for the better exposition of the OFDM-based ncTWR. A natural future work is to consider multiple-input multiple-output (MIMO) nodes. This is, however, a highly non-trivial extension, with multiple possible novel OFDM-based MIMO ncTWR transceiver designs.

The kth-subband signals received by the BS and the RU in the second channel use are given respectively as

$$y_b[k] = \sqrt{p_r[k]}g_b[k]\Big(\underbrace{h_b[k]x_b[k]}_{\text{BI}} + h_u[k]x_u[k]\Big) + \bar{n_b}[k]$$

$$y_u^2[k] = \sqrt{p_r[k]}g_u[k]\Big(h_b[k]x_b[k] + \underbrace{h_u[k]x_u[k]}_{\text{BI}}\Big) + \bar{n_u^2}[k]. \tag{2}$$

Here $g_b[k]$ and $g_u[k]$ are the kth subband channel for the Relay$\rightarrow$BS and Relay$\rightarrow$RU links, respectively. Also $\bar{n_b}[k] = \sqrt{p_r[k]}g_b[k]n_r[k] + n_b[k]$ and $\bar{n_u^2}[k] = \sqrt{p_r[k]}g_u[k]n_r[k] + n_u^2[k]$ are the effective noise at the BS and the RU in the second channel use, where $n_b[k] \sim \mathcal{CN}(0, 1)$ and $n_u^2[k] \sim \mathcal{CN}(0, 1)$. The BS uses its self-data to cancel the BI in $y_b[k]$ in (2) as

$$\tilde{y}_b[k] = \sqrt{p_r[k]}g_b[k]h_u[k]x_u[k] + \bar{n_b}[k]. \tag{3}$$

The RU, by using the signal overheard in the first channel use in (1), cancels its BI as

$$\begin{aligned}\tilde{y}_u[k] &= y_u^2[k] - \frac{\sqrt{p_r[k]}g_u[k]h_u[k]}{h_0[k]}y_u^1[k] \\ &= \sqrt{p_r[k]}g_u[k]h_b[k]x_b[k] + \bar{n_u^2}[k] \\ &\quad - \frac{\sqrt{p_r[k]}g_u[k]h_u[k]}{h_0[k]}n_u^1[k].\end{aligned} \tag{4}$$

III. Joint Power Allocation to Maximize Sum-Rate

We now maximize the system sum-rate by jointly allocating power across the K subbands, and the transmit nodes. We first show that this problem is non-convex and then propose to use the SCA approach to solve it. We begin by deriving the rate expressions for the kth subband for the end-to-end TU$\rightarrow$Relay$\rightarrow$BS and BS$\rightarrow$Relay$\rightarrow$RU links. These expressions, derived using (3) and (4), are given respectively as

$$R_b[k] = \frac{1}{2}\log_2\Big(1 + \text{SNR}_b[k]\Big) \tag{5}$$

$$R_u[k] = \frac{1}{2}\log_2\Big(1 + \text{SNR}_u[k]\Big), \text{ where} \tag{6}$$

$$\text{SNR}_b[k] = \frac{|h_u[k]g_b[k]|^2\, p_r[k]p_u[k]}{1 + |g_b[k]|^2\, p_r[k]}$$

$$\text{SNR}_u[k] = \frac{|g_u[k]h_b[k]|^2\, p_r[k]p_b[k]}{1 + |g_u[k]|^2\, p_r[k] + \left|\frac{g_u[k]h_u[k]}{h_o[k]}\right|^2 p_r[k]}. \tag{7}$$

The factor of 1/2 is due to the half-duplex relay constraint. The system sum-rate for the K subbands is

$$R_{\text{sum}} = \sum_{k=1}^{K} R_b[k] + R_u[k]. \tag{8}$$

We will now allocate the power jointly at the relay, BS, and TU over K subbands to maximize R_{sum} by imposing power constraints at each transmit node. Before doing that, we define power vectors $\mathbf{p}_j = (p_j[1], \ldots, p_j[K])^T$ for $j = r, b, u$ which we will later optimize. We now write R_{sum} as $R_{\text{sum}}(\mathbf{p}_u, \mathbf{p}_b, \mathbf{p}_r)$ to indicate that it is a function of the optimization variables

$\mathbf{p}_u, \mathbf{p}_b$, and $\mathbf{p}_r$. The sum-rate maximization problem can now be stated as

$$\mathbf{P1}: \underset{\mathbf{p}_r,\mathbf{p}_b,\mathbf{p}_u}{\text{Max}} \; R_{\text{sum}}(\mathbf{p}_r, \mathbf{p}_b, \mathbf{p}_u) \tag{9a}$$

$$\text{s.t.} \sum_{k=1}^{K} p_r[k] \left|h_b[k]\right|^2 p_b[k] + p_r[k] \left|h_u[k]\right|^2 p_u[k] + p_r[k] \le P_r \tag{9b}$$

$$\sum_{k=1}^{K} p_b[k] \le P_b \quad \sum_{k=1}^{K} p_u[k] \le P_u. \tag{9c}$$

The three constraints are on the maximum transmit power of the relay, TU and BS, respectively. We will next show that this problem can be solved using SCA, wherein each approximated problem is cast as a GP. We know from [7] that a GP has a posynomial objective and upper-bounded posynomials inequality constraints. We notice that the first inequality constraint $\sum_{k=1}^{K} p_r[k] \left|h_b[k]\right|^2 p_b[k] + p_r[k] \left|h_u[k]\right|^2 p_u[k] + p_r[k] \le P_r$ is a posynomial in the variables $\mathbf{p}_r, \mathbf{p}_b$ and $\mathbf{p}_u$. This is because the coefficients of the variables $p_r[k], p_b[k]$ and $p_u[k]$ are non-negative. Also the posynomial is upper-bounded by $P_r \; \forall \; k = 1, \cdots, K$. Similarly, the constraints $\sum_{k=1}^{K} p_b[k] \le P_b$ and $\sum_{k=1}^{K} p_u^k \le P_u$ are posynomials in $\mathbf{p}_b$ and $\mathbf{p}_u$, and are upper-bounded by P_b and P_u, respectively. To simplify **P1**, we now cast it in the epigraph form [7].

$$\mathbf{P2}: \underset{\mathbf{p}_r,\mathbf{p}_b,\mathbf{p}_u,\boldsymbol{\gamma}_b,\boldsymbol{\gamma}_u}{\text{Max}} \sum_{k=1}^{K} \frac{1}{2}\log_2\left(1+\gamma_b[k]\right) + \frac{1}{2}\log_2\left(1+\gamma_u[k]\right) \tag{10a}$$

$$\text{s.t.} \; \gamma_b[k] \le \frac{\left|h_u[k]g_b[k]\right|^2 p_r[k]p_u[k]}{1+\left|g_b[k]\right|^2 p_r[k]} \tag{10b}$$

$$\gamma_u[k] \le \frac{\left|g_u[k]h_b[k]\right|^2 p_r[k]p_b[k]}{1+\left|g_u[k]\right|^2 p_r[k] + \left|\frac{g_u[k]h_u[k]}{h_o[k]}\right|^2 p_r[k]}$$

$$\text{(9b), (9c).} \tag{10c}$$

It is easy to see that the constraint will be active at the optimum otherwise the objective can be increase without violating the constraints. The problem **P2** can equivalently be expressed as

$$\mathbf{P3}: \underset{\mathbf{p}_r,\mathbf{p}_b,\mathbf{p}_u,\boldsymbol{\gamma}_b,\boldsymbol{\gamma}_u}{\text{Min}} \prod_{k=1}^{K} \Big[\left(1+\gamma_b[k]\right)\left(1+\gamma_u[k]\right) \Big]^{-1}$$

$$\text{s.t. (10b), (10c), (9b), (9c).} \tag{11a}$$

We have dropped the constant 1/2 and the monotonically increasing log term from the objective. We now re-cast the constraints (10b) and (10c) in problem **P3** as

$$\mathbf{P4}: \underset{\mathbf{p}_r,\mathbf{p}_b,\mathbf{p}_u,\boldsymbol{\gamma}_b,\boldsymbol{\gamma}_u}{\text{Min}} \prod_{k=1}^{K} \Big[\left(1+\gamma_b[k]\right)\left(1+\gamma_u[k]\right) \Big]^{-1} \tag{12a}$$

$$\text{s.t.} \; \gamma_b[k]\Big(p_r[k]^{-1}p_u[k]^{-1} + \left|g_b[k]\right|^2 p_u[k]^{-1}\Big) \le \left|h_u[k]g_b[k]\right|^2 \tag{12b}$$

$$\gamma_u[k]\Big(p_r[k]^{-1}p_b[k]^{-1} + \left|g_u[k]\right|^2 p_b[k]^{-1} + \left|\frac{g_u[k]h_u[k]}{h_o[k]}\right|^2 p_b[k]^{-1}\Big) \le \left|g_u[k]h_b[k]\right|^2$$

$$\text{(9b), (9c).} \tag{12c}$$

We observe that the upper-bounded constraints (12b), (12c) are posynomials in $\boldsymbol{\gamma}_b, \boldsymbol{\gamma}_u, \mathbf{p}_r, \mathbf{p}_b$ and $\mathbf{p}_u$ as the coefficients of $\gamma_b[k], \gamma_u[k], p_r[k], p_b[k]$ and $p_u[k]$ are non-negative. The objective function in **P4** is non-convex as is the inverse of product of two posynomials, and consequently not a posynomial [7]. We handle this non-convexity by approximating these two posynomials as monomials – product of two monomials is a monomial, and its inverse is a monomial [7]. The approximated problem, thus can be solved as a GP. To achieve this objective, we use the following lemma from [8].

Lemma 1: The monomial approximation of $1+\gamma_b[k]$ is $c_1[k]\gamma_b[k]^{a_1[k]}$ where $a_1[k] = \left(\frac{\widehat{\gamma}_b[k]}{1+\widehat{\gamma}_b[k]}\right)$ and $c_1[k] = \widehat{\gamma}_b[k]^{-a_1[k]}(1+\widehat{\gamma}_b[k])$. Similarly the posynomial $1+\gamma_u[k]$ is approximated as $c_2[k]\gamma_u[k]^{a_2[k]}$ where $a_2[k] = \left(\frac{\widehat{\gamma}_u[k]}{1+\widehat{\gamma}_u[k]}\right)$ and $c_2[k] = \widehat{\gamma}_u[k]^{-a_2[k]}(1+\widehat{\gamma}_u[k])$. Here $\widehat{\gamma}_b[k] > 0$ and $\widehat{\gamma}_u[k] > 0$ are arbitrary points near $(1+\widehat{\gamma}_b[k])$ and $(1+\widehat{\gamma}_u[k])$, respectively.

By using Lemma 1, the objective can be re-formulated as

$$\underset{\mathbf{p}_r,\mathbf{p}_b,\mathbf{p}_u,\boldsymbol{\gamma}_b,\boldsymbol{\gamma}_u}{\text{Min}} C \prod_{k=1}^{K} \Big[\gamma_b[k]^{\left(\frac{\widehat{\gamma}_b[k]}{1+\widehat{\gamma}_b[k]}\right)} \gamma_u[k]^{\left(\frac{\widehat{\gamma}_u[k]}{1+\widehat{\gamma}_u[k]}\right)}\Big]^{-1}, \tag{13}$$

where $C = \prod_{k=1}^{K} \widehat{\gamma}_b[k]^{-a_1[k]}\widehat{\gamma}_u[k]^{-a_2[k]}$ is the net multiplicative constant. We see that the objective, after this approximation, is a monomial. We next iteratively improve the above approximation by proposing the following algorithm.

Algorithm 1 Joint Power Allocation Using GP

Input: Given a tolerance $\epsilon > 0$, and the maximum number of iterations L.

Output: Optimization variables $\mathbf{p}_r, \mathbf{p}_b$ and $\mathbf{p}_u$.

1 *Initialization*: Calculate initial values of $\widehat{\boldsymbol{\gamma}}_b^1$ and $\widehat{\boldsymbol{\gamma}}_u^1$ by allocating equal power across all K subbands.

2 **for** $m \leftarrow 1$ ***to*** L **do**

3 Given a feasible $\mathbf{p}_i, \forall i = r, b, u$ compute $\frac{\hat{\gamma_b^m}[k]}{1+\hat{\gamma_b^m}[k]}$, $\frac{\hat{\gamma_u^m}[k]}{1+\hat{\gamma_u^m}[k]} \forall k = 1, \cdots, K$.

4 Solve the GP to calculate $\mathbf{p}_r, \mathbf{p}_b, \mathbf{p}_u, \boldsymbol{\gamma}_b, \boldsymbol{\gamma}_u$

$$\underset{\mathbf{p}_r,\mathbf{p}_b,\mathbf{p}_u,\boldsymbol{\gamma}_b,\boldsymbol{\gamma}_u}{\text{Min}} C \prod_{k=1}^{K} \Big[\gamma_b[k]^{\left(\frac{\widehat{\gamma}_b[k]}{1+\widehat{\gamma}_b[k]}\right)} \gamma_u[k]^{\left(\frac{\widehat{\gamma}_u[k]}{1+\widehat{\gamma}_u[k]}\right)}\Big]^{-1}$$

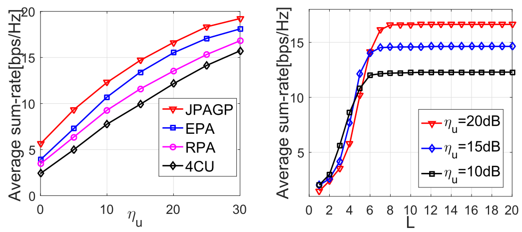
$$\text{s.t.} \; \alpha_l^{-1}\hat{\boldsymbol{\gamma}}_l \le \boldsymbol{\gamma}_l \le \alpha_l\hat{\boldsymbol{\gamma}}_l, \text{for } l \in \{b, u\}$$

$$\text{(9b), (9c), (12b), (12c).} \tag{14}$$

5 Do until convergence
if $\max|\boldsymbol{\gamma}_b - \widehat{\boldsymbol{\gamma}}_b^m| \le \epsilon$ *and* $\max|\boldsymbol{\gamma}_u - \widehat{\boldsymbol{\gamma}}_u^m| \le \epsilon$
then break
else $\widehat{\boldsymbol{\gamma}}_b^{m+1} = \boldsymbol{\gamma}_b$ and $\widehat{\boldsymbol{\gamma}}_u^{m+1} = \boldsymbol{\gamma}_u$

6 **return** $\mathbf{p}_r, \mathbf{p}_b$ *and* $\mathbf{p}_u$.

Remark 1: The initial values of $\widehat{\boldsymbol{\gamma}}_b$ and $\widehat{\boldsymbol{\gamma}}_u$ in step-3 of the algorithm are derived using equal power allocation, and the values of $\left(\frac{\widehat{\gamma}_b}{1+\widehat{\gamma}_b}\right)$, $\left(\frac{\widehat{\gamma}_u}{1+\widehat{\gamma}_u}\right)$ are calculated accordingly. The fourth step solves an approximated GP around the current guesses $\widehat{\boldsymbol{\gamma}}_b$, and $\widehat{\boldsymbol{\gamma}}_u$. The inequality constraints in (14), known as trust region constraints, are added to confine the domain



(a) **(b)**

Fig. 2. (a) Average sum-rate vs η_u for $\eta_b = 10$ dB,$\eta_u = 5$ dB and $K = 16$; and (b) Sum-rate vs L for $\eta_b = 10$ dB and $\eta_o = 5$ dB.

of variables γ_b and γ_u around the current guess $\widehat{\gamma}_b^m$ and $\widehat{\gamma}_u^m$, respectively. The parameters α_b and α_u control the desired approximation accuracy and the convergence speed.

Remark 2: This algorithm approximates the posynomial with a monomial and, therefore, not optimal. But this heuristic approach, as shown in [9] and [10], results in a global optimum solution 96% of the time, and only marginally degrades the sum-rate by 2%, when compared with the ϵ-optimal solution.

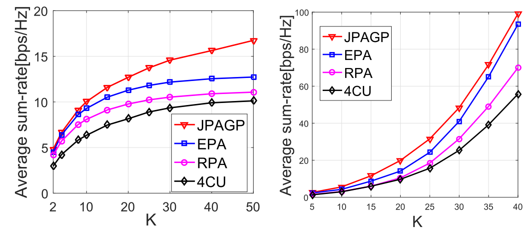
IV. Simulation Results

We now numerically compare the performance of the proposed joint power allocation algorithm using GP (denoted as JPAGP) for an OFDM asymmetric AF TWRN with K subbands. We compare the performance of the proposed algorithm with i) conventional equal-power allocation (EPA) [11]; ii) random power allocation (RPA) [11]; and iii) 4-channel-use (denoted as 4CU) one-way relaying protocol [3] where the BS serves TU and RU in two channel uses each. In the RPA scheme, random power is allocated across the subbands for the TU, Relay and BS nodes to satisfy their individual power constraint of P_u, P_r and P_b, respectively. We assume that, similar to [4] and [5], the channels between the different links are distributed as $\mathcal{CN}(0, \eta_i)$ where $i = b$ for BS$\leftrightarrow$Relay link, $i = u$ for Relay $\leftrightarrow$ RU link and $i = o$ for TU $\rightarrow$ RU overhearing link.

We plot in Fig. 2a the sum-rate by varying η_u. For this study, we fix the noise power as unity, and fix $\eta_b = 10$ dB and $\eta_o = 5$ dB with respect to the noise power. We also assume $P_u = 5$ dB, $P_r = 10$ dB, and $P_b = 10$ dB with respect to the noise power. We choose, similar to [8], $\alpha_b = \alpha_u = 3$. We also fix $\epsilon = 10^{-2}$ and $K = 16$ subbands. We see from the Fig. 2a that the proposed algorithm outperforms both sub-optimal EPA and RPA schemes. Further the 4-channel-use one-way relaying, due to four channel uses, has inferior sum-rate than both other schemes.

We investigate in Fig. 2b the convergence behavior of the proposed algorithm by plotting the sum-rate achieved by the algorithm in each iteration. For this study, we consider the same parameters as in Fig. 2a. We observe that the algorithm converges within 8 GP iterations for various η_u values.

We compare in Fig. 3a and Fig. 3b the proposed algorithm by varying the number of subbands K. In Fig. 3a, we fix $\eta_u = \eta_b = 10$ dB and $\eta_o = 5$ dB for all K values, whereas in Fig. 3b we fix $\eta_u = \eta_b = \eta_o \triangleq \eta = 2$ dB for $K = 5$ subbands, and then we double η with every $K = 5$ subband increment. We observe that the proposed algorithm outperforms both EPA and RPA algorithms for different values of subbands. In Fig. 3a, for $K = 40$ subbands, it yields 6 bps/Hz and 3.5 bps/Hz higher average sum-rate than the RPA and the EPA, respectively. For larger K values, the proposed algorithm has higher flexibility to optimize the power budget, which increases the sum-rate difference when compared with smaller K values. In Fig. 3b, for $K = 25$ subbands, the proposed algorithm yields 8.5 bps/Hz and 13.1 bps/Hz higher average sum-rate than the EPA and the RPA, respectively. For $K = 40$, the gap between the proposed and the EPA is reduced as the system now is operating in the high-SNR regime, where equal power itself is close to optimal.



(a) **(b)**

Fig. 3. Average sum-rate versus K for (a) fixed η_b, η_u and η_o; and (b) variable η_b, η_u and η_o.

V. Conclusion

We considered an OFDM-based non-concurrent TWR (ncTWR) where a receive-only user (RU) experiences back-propagating interference (BI). The RU cancels the BI by overhearing the transmit-only user signal. We developed a joint power allocation algorithm which solves the non-convex sum-rate optimization using successive convex approximation approach. We showed that the proposed algorithm yields better average sum-rate than the baseline equal and random power allocation schemes. The present work considered single-antenna nodes. A future line of work is to design sum-rate optimal transceivers for multi-antenna OFDM-based ncTWR systems.

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