Power Allocation for Balancing the Effects of *Channel Estimation Error and Pilot Overhead* in *FD* Decode-and-Forward *Relaying*

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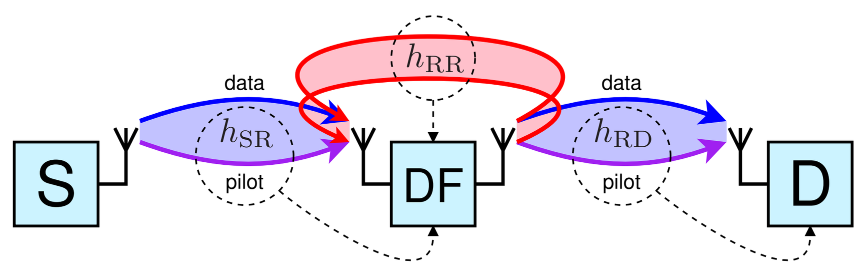
Research Questions

- How full-duplex transmission at the relay affects the optimal power allocation between the training and data transmissions?
- How much the system throughput can be improved by using optimal power allocation scheme compared to naive solutions?
- Is low-complexity near-optimal power allocation possible?

System Model

Optimal *power allocation between training and data* transmission is considered for point-to-point links in [10, 11]. Here similar optimization problem is considered for the *decode-and-forward full-duplex relay channel* when the relay suffers from self-interference due to hardware impairments.



The received *signal at the relay* reads (here x_R is known)

$$y_R = h_{SR}x_S + h_{RR}(x_R + m_R) + n_R$$

$$\xrightarrow{-\hat{h}_{RR}x_R} \quad y_R = \hat{h}_{SR}x_S + [\Delta h_{SR}x_S + \hat{h}_{RR}m_R + \Delta h_{RR}(x_R + m_R) + n_R], \qquad (1)$$

where $\hat{h} = h - \Delta h$ is the channel estimate and $\Delta h \sim \mathrm{CN}(0, \Delta g)$ is the estimation error. We also let $n_R \sim \mathrm{CN}(0,1)$ and $m_R \sim \mathrm{CN}(0, \sigma_m^2)$.

- **Problem:** "Noise" in (1) depends on x_S and is not Gaussian.
- **Solution:** Consider a *modified* S → R *channel model*

$$y_R = \hat{h}_{SR}x_S + w_R \qquad (2)$$

where $w_R \sim \mathrm{CN}(0, \sigma_{w_R}^2)$ is *independent of* x_S with

$$\sigma_{w_R}^2 = 1 + P_S^d \Delta g_{SR} + P_R^d \Delta g_{RR} + (|\hat{h}_{RR}|^2 + \Delta g_{RR})\sigma_m^2 \qquad (3)$$

and P_S^d (resp. P_R^d) is data symbol power at source (resp. relay).

The resulting *ergodic link-rate* for S → R (similarly for R → D) is

$$C_{SR} \propto \mathrm{E}\left\{\log\left(1 + \frac{P_S^d|\hat{h}_{SR}|^2}{\sigma_{w_R}^2}\right)\right\} \qquad (4)$$

where the expectation is w.r.t. $(\hat{h}_{SR}, \hat{h}_{RR})$. By (3), the rate of S → R link depends on the power allocations both at the source *and* relay.

- The achievable rate (4) is a lower bound to true capacity of (1).

Power Allocation Between Pilots and Data

If $\alpha_x \in (0,1)$ is the *fraction of energy devoted to data* transmission phase at node $x \in \{S, R\}$ then $C^* = \max_{\alpha_S, \alpha_R \in (0,1)} \min_{x \in \{SR, RD\}} C_x$ is the achievable rate given optimum power allocation.

- **Problem:** There is *no analytical solution* and *brute-force optimization is very complex*.

  ⟹ Optimize based on effective SINRs?
- **But:** The SINR of S → R channel depends on the estimate $\hat{h}_{RR}$ due to (3); cannot know it *before* allocating powers.

  ⟹ Replace (3) by a term that does not depend on $\hat{h}_{RR}$ explicitly?
- **But:** The algorithm may not converge to optimal power allocation anymore.

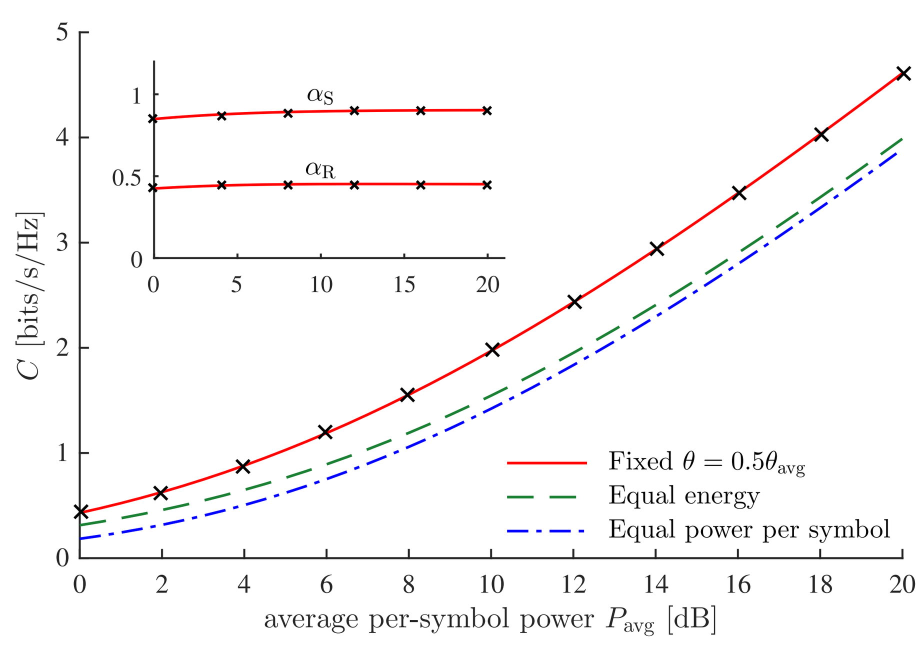
Proposed Algorithm

1. Set $|\hat{h}_{RR}|^2 \leftarrow \theta$, where θ is *fixed* parameter.
2. Calculate *analytically* optimal α_R^* given α_S.
3. Calculate *analytically* optimal α_S^*.
4. **If** $\mathrm{sinr}_{SR} \geq \mathrm{sinr}_{RD}$ for *assumed* SINRs, done!
5. **Else** solve $\mathrm{sinr}_{SR}(\alpha_R) - \mathrm{sinr}_{RD}(\alpha_R) = 0$ numerically, given *analytically optimized* α_S^*.

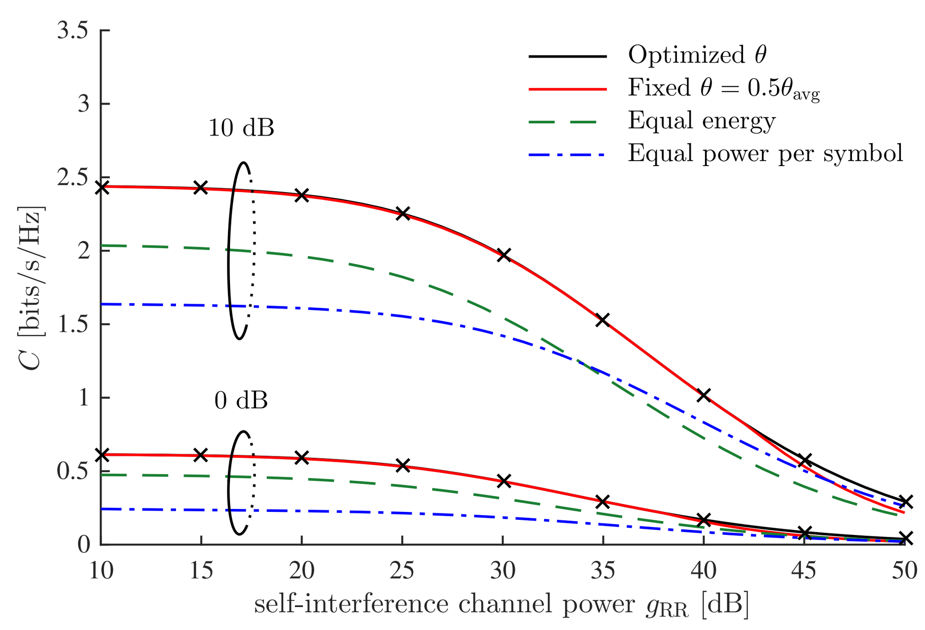
Proposed algorithm *always converges* to a solution and *does not need calculation of expectations*.

Numerical Examples

For the examples below, we set $\sigma_m^2 = 10^{-3}$ and let $h_{SR}, h_{RD} \sim \mathrm{CN}(0,1)$ along with $h_{RR} \sim \mathrm{CN}(0, g_{RR})$. Both of the examples below also use $\theta_{avg} = \mathrm{E}\{|\hat{h}_{RR}|^2\} = g_{RR} - \Delta g_{RR}$ scaled (ad-hoc) by 1/2 for the θ.



Achievable rate vs. the *average per-symbol power* P_{avg}. Self-interference channel strength is set to $g_{RR} = 30$ dB. Solid lines = proposed algorithm, markers = brute force.



Achievable rate vs. *self-interference channel power* g_{RR}. The two sets of curves correspond to average symbol powers $P_{avg} \in \{0, 10\}$ dB.

Conclusions

Power allocation between pilots and data in FD decode-and-forward relay channel was studied.

- A modified channel model that allowed achievable rate analysis was developed.
- Optimal power allocation was found to improve the achievable rates up to 1 bits/s/Hz.
- Proposed low-complexity power allocation scheme is near-optimal for all considered cases.
- Algorithm details and extension to Ricean fading self-interference channel are in the paper.

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