Performance Evaluation of Transceiver Beamforming in Integrated Multifunctional Wireless Systems

Hayato MINAMINO[†a)], ***Student Member and*** **Teruyuki MIYAJIMA**[††], ***Member***

1. Introduction

To deliver a variety of services in next-generation mobile communication systems, various wireless functionalities, including wireless information transfer (WIT), are required. An integrated wireless system that combines WIT, wireless energy transfer (WET), and sensing has been considered [1], where bandwidth and hardware are shared among multiple functionalities to achieve efficient resource utilization. In [1], transmit beamforming (BF) at the base station (BS) was used for efficient transmission in the integrated multifunctional system. However, the impact of clutter-induced degradation was not taken into account. In [2], we proposed a transmit and receive BF design for the integrated multifunctional wireless system. In this paper, we demonstrate the effectiveness of the proposed BF in the integrated multifunctional wireless system under the influence of clutter.

2. System Model and BF Design

We consider an integrated multifunctional wireless system that combines WET, WIT, and sensing. The system consists of a BS with N_a antennas, an energy receiver (ER), an information receiver (IR) with a single antenna, a sensing target, and a clutter. The BS uses transmit BF $\mathbf{w} \in \mathbb{C}^{N_a \times 1}$ to send a signal embedded with information data, enabling energy harvesting at the ER and information decoding at the IR. In addition, the BS performs target sensing using receive BF $\mathbf{t} \in \mathbb{C}^{N_a \times 1}$ to suppress echoes reflected from the clutter.

The transmitted signal of BS at time l is denoted as $\mathbf{x}[l] = \mathbf{w}s[l]$. The received signal at IR and ER are expressed as $r_{\mathrm{I}}[l] = \mathbf{h}^T\mathbf{x}[l] + n_{\mathrm{I}}[l]$ and $r_{\mathrm{E}}[l] = \mathbf{g}^T\mathbf{x}[l] + n_{\mathrm{E}}[l]$, where $\mathbf{h}$ is the channel between BS and IR and $\mathbf{g}$ is the channel between BS and ER. The received signal at BS is expressed as $y[l] = \mathbf{t}^H(\alpha\mathbf{A}(\theta_0)\mathbf{x}[l] + \alpha\mathbf{A}(\theta_1)\mathbf{x}[l] + \mathbf{n}[l])$, where α denotes a complex amplitude related to the radar cross section and the range to the target, $\mathbf{A}(\theta) = \mathbf{a}(\theta)\mathbf{a}^T(\theta)$, $\mathbf{a}(\theta)$ is the steering vector, θ_0 and θ_1 are the angles of the target and the clutter.

We aim to maximize the sensing SINR γ_s subject to constraints on the harvested power P_e, the communication SNR γ_c, and the transmit power at BS. Specifically, the optimization problem is expressed as

$$\max_{\mathbf{w},\mathbf{t}} \ \gamma_s \quad \text{s.t.} \ P_e \geq \Gamma_e, \ \gamma_c \geq \Gamma_c, \ \|\mathbf{w}\|^2 \leq P_0, \tag{1}$$

where Γ_e is the required harvested power, Γ_c is the required communication SNR, and P_0 is the available transmit power at BS. This problem is difficult to solve because the variables $\mathbf{w}$ and $\mathbf{t}$ are coupled. To address this issue, we first fix $\mathbf{w}$ and solve for $\mathbf{t}$ by a generalized eigenvalue problem. Then, using the obtained $\mathbf{t}$, we solve for $\mathbf{w}$ by semidefinite relaxation and Dinkelbach's transform. By iterating these processes, we obtain the solutions for both $\mathbf{w}$ and $\mathbf{t}$.

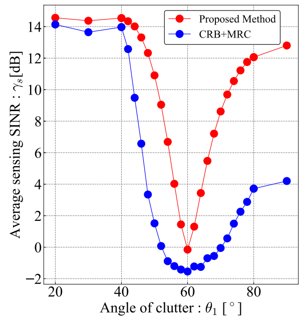

Fig. 1 Sensing SINR.

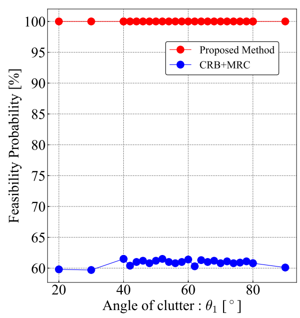

Fig. 2 Feasibility probability.

3. Simulation Result

We set $N_a = 8$, $P_0 = 30$ dBm, $\eta = 0.6$, $\sigma_s^2 = -90$ dBm, $\sigma_c^2 = -90$ dBm, $\theta_0 = 60°$, $\Gamma_e = -15$ dBm, $\Gamma_c = 20$ dB, carrier frequency was 920 MHz and the results were averaged over 1,000 trials. Figs.1 and 2 show the sensing SINR γ_s and the feasibility probability as a function of the angle of clutter θ_1. We compared the performance with the case using the transmit BF based on the Cramér-Rao bound (CRB) [1] and the receive BF based on maximal ratio combining (MRC). We can observe that the proposed method outperforms the compared method when the clutter is close to the target, achieving a higher feasibility probability.

4. Conclusion

We evaluate a transceiver BF in an integrated multifunctional wireless system in the presence of clutter.

References

[1] Y. Chen, et al., "Transmit Optimization for Multi-functional...," Proc. ICC, Oct. 2023.

[2] H. Minamino, et al., "A Study on Near-field Beamforming for Integrated...," IEICE Gen. Conf., B-17-06, Mar. 2025.

[†]The author is with Graduate School of Science and Engineering, Ibaraki University, Hitachi-shi, Ibaraki, 316-8511, Japan.
[††]The author is with Faculty of Applied Science and Engineering, Ibaraki University, Hitachi-shi, Ibaraki, 316-8511, Japan.
a) E-mail: 24mn650s@vc.ibaraki.ac.jp