

De-embedding Process to Improve Isolation for In-Band Full Duplex Radios (IBFD)

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Abstract—To address the growing demands for spectral efficiency and higher throughput in modern wireless links, in-band full-duplex (IBFD) radios have emerged as a promising solution. These systems operate by transmitting and receiving signals across the same frequency band, necessitating the mitigation of high-power self-interference (SI). Without adequate interference suppression, desired signals can be masked, and receiver components may become saturated. This paper explores a de-embedding process in digital twin model to enhance wideband SI cancellation in IBFD radios, focusing on practical challenges and strategies for implementation.

Index Terms—De-embedding, digital-twin model, self interference cancellation, IBFD, high isolation

I. INTRODUCTION

In-band full-duplex (IBFD) radios enhance throughput by simultaneously using the same spectrum for both transmit and receive operations [1]–[3]. This approach allows these radios to utilize both time and frequency resources for wireless communication. Unlike traditional time-division duplexing (TDD) or frequency-division duplexing (FDD), IBFD radios optimize the available radio spectrum (see Fig. 1).

A key challenge in IBFD systems is the mitigation of high-power self-interference, as depicted in Fig. 2, to prevent receiver desensitization [4], [5]. To address this issue, IBFD radios may employ a multi-stage self-interference (SI) cancellation strategy, achieving isolation levels exceeding 100 dB. The initial stages of this strategy include a high-isolation antenna system and a specialized RF self-interference cancellation (SIC) filter [4] (see Fig. 2). Specifically, the system integrates a high-isolation antenna for stage 1 and a microstrip-based RF-SIC filter for stage 2. The antenna stage utilizes polarization diversity to provide up to 40 dB of isolation, while the filter stage adds an additional 25 to 30 dB of cancellation for a total of 65 dB to 70 dB of isolation.

In practical implementations, however, discrepancies between ideal and fabricated components significantly affect system performance, as illustrated in Fig. 3. Phase and amplitude mismatches introduced by cables, splitters, and connectors often degrade SI cancellation effectiveness. To counter these impairments, compensating mechanisms are crucial for maintaining high isolation levels across the desired frequency range. This paper introduces a de-embedding strategy to optimize self-interference cancellation (SIC) by effectively combining the first two stages.

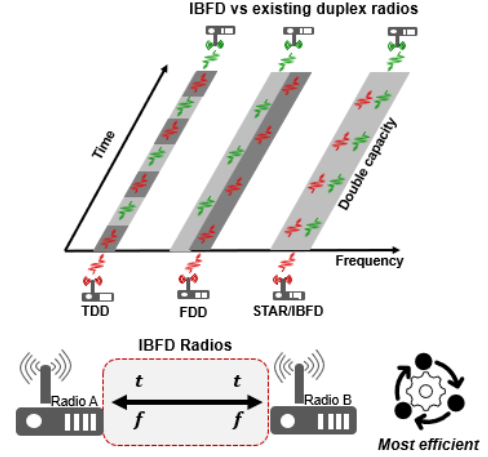


Fig. 1. IBFD over existing duplex radios

II. DE-EMBEDDING STRATEGY

The de-embedding process addresses component impairments by accurately characterizing and compensating for deviations between ideal and practical hardware. This process consists of the following steps:

A. Component Characterization and De-embedding

The first step involves measuring the scattering matrix (S-parameters) of each component. These S-parameters are then converted into transmission matrices (T-matrices) to accurately model the frequency-dependent behavior of the components. Doing so, a complete matrix is generated that includes all added component effects. This matrix can be subsequently

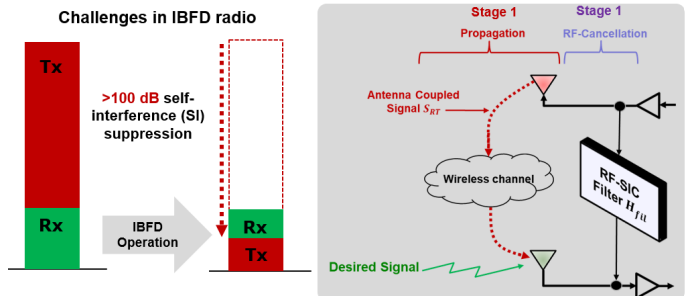


Fig. 2. Antenna and filter cancellation stages at the IBFD radio's front end

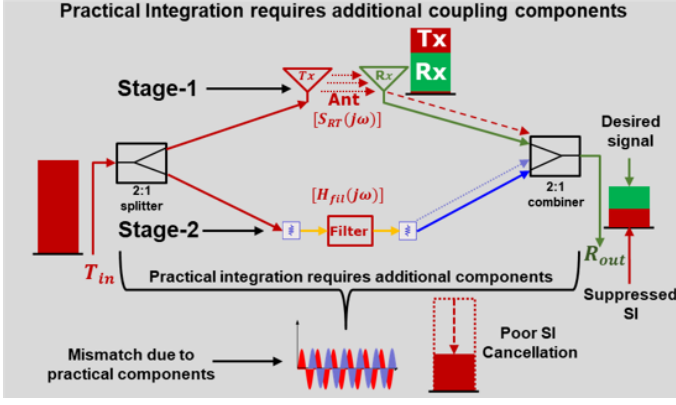


Fig. 3. Poor cancellation due to component impairments

used to de-embed the impairments and compensate for their effects in the final filter design.

B. Filter Design Optimization

The de-embedded parameters are used to refine the RF-SIC filter design. As shown in Fig. 4, the de-embedding process is leading to optimize filter parameters. The updated filter transfer function compensates for phase and amplitude mismatches introduced by practical components, resulting in enhanced isolation (see Fig. 5).

III. MEASUREMENT RESULTS

To validate the proposed de-embedding approach, the combined antenna and filter stages (Stage 1 and 2) were tested before and after applying the compensation strategy. As shown in Fig. 5, the initial design achieved an isolation level of approximately 50 dB across a 1 GHz bandwidth. After the de-embedding process and digital twin optimization, the isolation improved to 65 dB, representing an enhancement of 10–20 dB. These results demonstrate the effectiveness of mitigating practical hardware impairments to achieve robust IBFD performance.

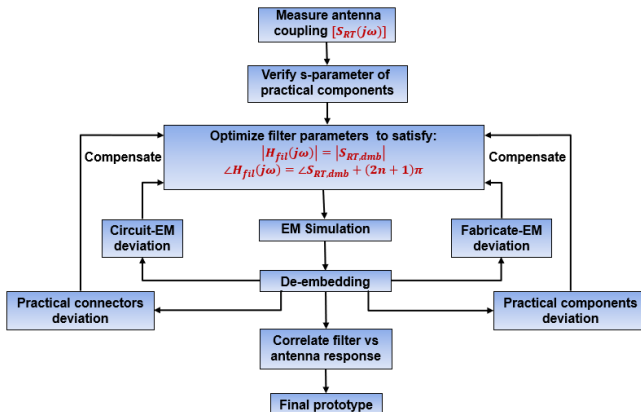


Fig. 4. Filter design algorithm and optimization.

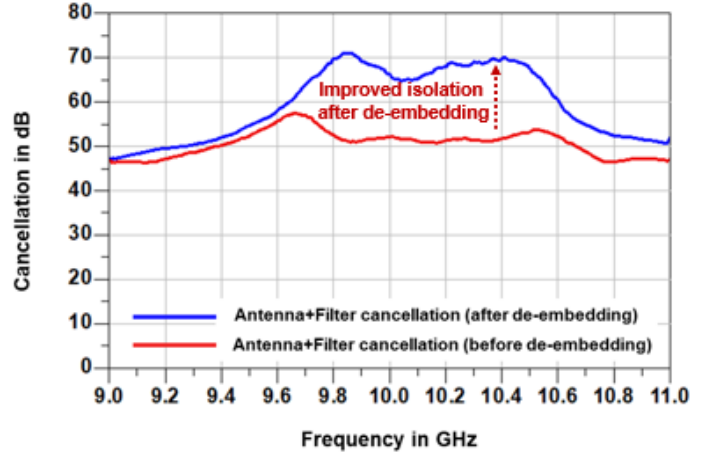


Fig. 5. Cancellation performance of the two stages (Stage 1 and 2) with and without de-embedding

IV. CONCLUSION

The proposed de-embedding strategy requires digital twin model optimization to achieve wideband SI cancellation for IBFD radios. This ensured high isolation across broadband frequencies, enhancing IBFD performance and enabling integration into next-generation wireless networks.

V. ACKNOWLEDGMENT

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