In-Band Full Duplexing

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Outline

1. Introduction
2. In-Band Full-Duplexing (IBFD)
3. Toward a High Level Taxonomy
Modes of Channel Operation

- Simplex
- Duplexing
  - Half-duplex (TDD)
  - Full-duplex
    - Out-band
    - In-band
Data in a simplex channel is always one way.

An example of simplex is Television, or Radio.
A half-duplex channel can send and receive, but not at the same time.

An example of half-duplex is talk-back radio, and CB Radio (Citizens Band).
Full-duplex

- Data can travel in both directions simultaneously. There is no need to switch from transmit to receive mode like in half duplex.
- An example can be a consumer which uses a cable connection to not only receive TV channels, but also the same cable to support their phone and Internet surfing.

![Full Duplex Operation Diagram]
Data can travel in both directions simultaneously, but in the separated frequency bands (frequency-division-duplexing (FDD)).
In-band full-duplex

- Data can travel in both directions simultaneously, and in the same frequency band.

![Diagram showing in-band full-duplex communication](image-url)
In-band full-duplex (IBFD) operation has emerged as an attractive solution for increasing the throughput of wireless communication systems and networks.

<table>
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<th>Mode of channel</th>
<th>Disadvantages</th>
<th>Non simultaneously</th>
<th>Spectrum efficiency loss</th>
<th>Self-interference</th>
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<td>Full-duplexing</td>
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<td>In-band</td>
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Antenna Design of IBFD

- Separated antenna

- Shared antenna

Source: [1]
Simultaneous transmission and reception in a single frequency band can cause the transmitted signals to loop back to their receive antennas.

Self-interference refers to the interference that a transmitting IBFD terminal causes to itself, which interferes with the desired signal being received by that terminal.
Introduction

In-Band Full-Duplexing (IBFD)

Toward a High Level Taxonomy

Topologies of IBFD terminals at the network level

- Bi-directional Full-duplex (BFD)
- Full-duplex Relay (FDR)
- Full-duplex Cellular (FDC)
Bi-directional Full-duplex (BFD)

Source: [2]
Full-duplex Relay (FDR)

Source: [2]
Full-duplex Cellular (FDC)

Source: [2]
Criteria for Classification of Research Works on IBFD

- Topologies of terminals at the network level
  - Bi-directional Full-duplex (BFD)
  - Full-duplex Relay (FDR)
  - Full-duplex Cellular (FDC)

- Effect in network layers
  - Physical layer (e.g. self interference management)
  - MAC layer (e.g. carrier assignment, scheduling)
  - Network layer (e.g. multi radio network)

- Wireless network types
  - Cellular Networks
  - Relay Networks
  - Cognitive Radio Networks
  - Heterogeneous Networks
  - Energy Harvesting Networks
Classification of Research Works on In-band full-duplex

- Interference Cancellation methods in IBFD (Providing in-band full-duplexing)
- Modelling of interference cancellation
  - Ideal Self-IC Scheme
  - Imperfect Self-IC
- Resource Allocation with in-band full-duplexing in different networks
  - Cellular Networks
  - Relay Networks
  - Cognitive Radio Networks
  - Heterogeneous Networks
  - D2D communications
  - Energy Harvesting Networks
References
