# An Dual-Slant-Polarized Differentially-Fed In-band Full-duplex (IBFD) Antenna


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***Abstract*—In this paper, a dual-polarized antenna is developed with high isolation between its two polarizations for in-band full-duplex (IBFD) applications. A square patch antenna with horizontal and vertical polarizations is adopted as the antenna element. A new self-interference cancellation (SIC) feed network is proposed to differentially feed the antenna and combine the horizontal/vertical polarizations into ±45° polarizations. By making use of the symmetry of the antenna configuration and differential feeding, the proposed network can cancel out the coupled and reflected signals, leading to high isolation between the TX and RX ports. A high isolation of 46 dB is realized within the working band from 3.31 to 4 GHz (18.5%) and the gain is above 7.5 dBi. In addition, across the operation band, the radiation patterns show a good stability with the frequency variation.**



***Keywords*— *differentially feeding, dual-polarized, in-band full-duplex (IBFD), self-interference cancellation (SIC)***


## I. Introduction

In-band full duplex (IBFD), also known as simultaneously transmit and receive (STAR), can theoretically double the spectrum efficiency compared with traditional half duplex transmission techniques. The most difficult challenge for applying IBFD in wireless radios is to reduce the tremendous self-interference (SI) in both the digital-, analogue-, and antenna-domains. Particularly, the SI cancellation (SIC) in the antenna-domain is the first defense barrier against the SI and it can alleviate the complexity and pressure of the next active SIC circuits or algorithms [1-3].

Many proposed IBFD antennas have achieved SIC by exciting two orthogonal polarizations, i.e., one for transmitting (RX) and the other for receiving (TX). Due to the inherent orthogonality of the two polarizations, good isolation can be attained without introducing complex decoupling structures. Most of these dual-polarized antennas are fed with two physically separated networks to avoid the interference between them, which can realize tremendous isolation of up to 80 dB [4-6]. However, it is more preferable to design an integrated feed network to excite two polarizations simultaneously [7-8], despite the fact that the achieved isolation is usually lower than that obtained by physically separated feed networks. Besides, some of these integrated feed networks can transform linear polarizations into circular polarizations while maintaining the high isolation [9-10].

In this paper, a new integrated isolation feed network is proposed. It can not only differentially feed the antenna with two orthogonal polarizations, but also cancel the reflected and coupled signals to achieve SIC between the TX and RX ports. Moreover, it is the first isolation network for IBFD that can rotate the vertical and horizontal polarizations to ±45° polarizations for base station applications.

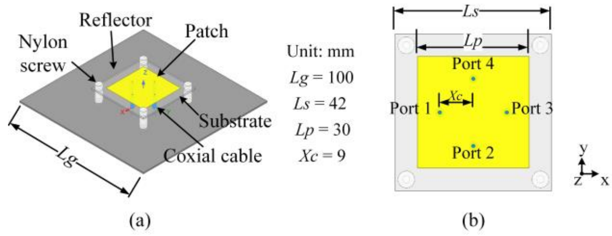


Fig. 1. Antenna configuration. (a) Perspective view. (b) Detailed view of the patch.

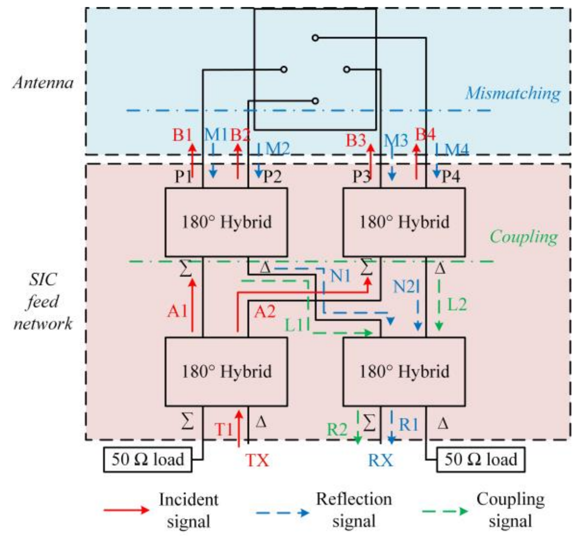


Fig. 2. Configuration of the SIC feed network and signal flow in the system.

## II. Antenna System

As shown in Fig. 1(a), the proposed antenna element is composed of a patch on a substrate, a metal ground as the reflector, coaxial cables for differential feeding, and nylon screws for supporting. The substrate has a dielectric constant of 4.4, a loss tangent of 0.005, and a thickness of 1 mm, which is above the ground with the height of 8 mm. Fig. 1(b) shows the detailed view of the patch. By differentially feeding two pairs of ports (Ports 1, 3 and Ports 2, 4) at the same time with the same or opposite phases, the antenna can realize +45° and -45° polarizations radiation, respectively.

Fig. 2 shows the diagram of the proposed IBFD antenna system with the isolation feed network, which is composed of a dual-polarized patch antenna and a novel isolation feed network. The proposed network consists of four identical 180° hybrid couplers, parallelly connecting in pairs. The sum input port (∑) can output two signals with equal amplitudes and

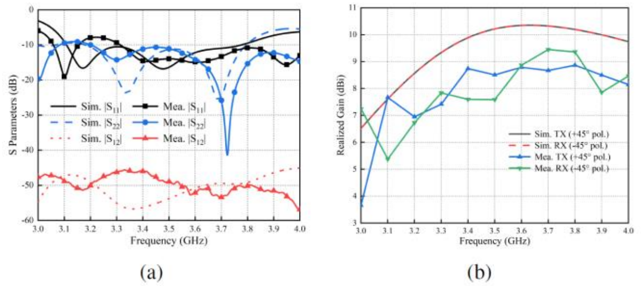


Fig. 3. Simulated and measured results of proposed IBFD single antenna system. (a) S parameters. (b) Realized gains.

phases, while the differential input port (Δ) is able to offer two signals with equal amplitudes but opposite phases. When the TX port is excited (the signal path is labelled by red solid arrows), the phases at Ports 1 to 4 are 0°, 0°, 180°, and 180°, respectively, leading to a +45° polarized radiation. Similarly, when the RX port is excited, the phases at Ports 1 to 4 are 0°, 180°, 180°, and 0°, respectively, exciting a -45° polarized radiation.

As shown in Fig. 2, ideally, the signal will all flow into the antenna and then radiate, making no signal go back to the RX port so that the isolation between the TX and RX ports will be infinite. However, there will be some imperfections including reflection caused by mismatching (as labelled by blue dash lines) and coupling signals (as labelled by green dash lines) in practical situations. The proposed SIC feed network has an ability to cancel these unwanted signals between the TX and RX ports. The reflected and coupling signals *R1* and *R2* can be calculated using

$$\begin{aligned} R1 = N1 - N2 &= (M1 - M2) - (M3 - M4) \\ &= \alpha(B1 - B2) - \alpha(B3 - B4) \\ &= \alpha(0.5A1 - 0.5A1) - \alpha(0.5A2 - 0.5A2) = 0 \end{aligned} \quad (1)$$

$$\begin{aligned} R2 = L1 + L2 &= \beta(A1 + A2) \\ &= \beta(0.5T1 - 0.5T1) = 0 \end{aligned} \quad (2)$$

where $\alpha$ is the reflection ratio between the antenna's input ports and the network's output ports and $\beta$ represents the coupling coefficient between the sum and differential ports of the couplers.

It thus can be concluded form (1) and (2) that both the interference R1 caused by the reflection and the interference R2 caused by the coupling can be neutralized at the RX port thanks to the skillfully designed feed network, leading to a high level of isolation between the TX and RX ports.

## III. Results

Fig. 3 shows the simulated and measured results of the antenna system. It can be observed from Fig. 3(a) that the measured bandwidth of the proposed system is 3.31-4 GHz. Within the bandwidth, the measured isolation between the two ports is > 46 dB and the realized gains are > 7.5 dBi.

The simulated and measured radiation patterns of the TX (+45°) and RX (-45°) polarizations in the *xoz* plane at 3.3 GHz, 3.6 GHz, and 3.9 GHz are given in Fig. 4. Good agreement between the simulated radiation patterns and the measured ones is achieved and the patterns of TX and RX modes are similar and stable within the operation bandwidth.

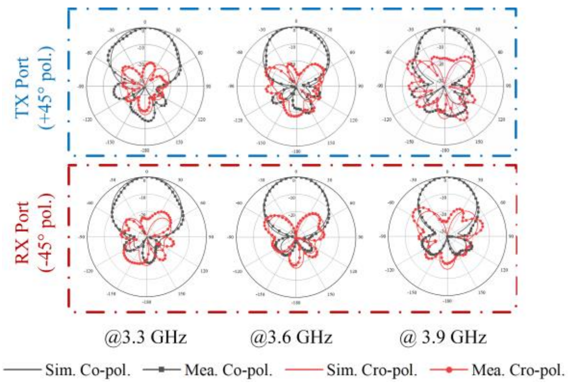


Fig. 4. Simulated and measued radiation pattern in the *xoz* plane of the proposed antenna system.

## IV. Conclusion

In this paper, a ±45°-polarized IBFD antenna is developed by feeding a square patch antenna with a new SIC feed network. The proposed SIC feed network achieves three goals at the same time, i.e., differentially feeding the patch antenna with two polarizations, combining the original horizontal and vertical polarizations into ±45° polarizations, and cancelling the unwanted coupling signals for SIC. The obtained antenna has a wide impedance bandwidth from 3.31 to 4 GHz (18.5%) within which the isolation is > 46 dB and the gain is > 7.5 dBi.

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