Microwave In-band Full-duplex doubles microwave capacity

Microwave In-band Full-duplex technology improves microwave link capacity, optimizes spectrum resources, and boosts network capacity. It is expected to greatly reduce network OPEX, improve network service capabilities, and become a mainstream solution for microwave network deployment.

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At present, mobile broadband networks are rapidly developing, LTE technology has been commercially applied on a large scale, and the industry is widely researching 5G technology. Specifically, mobile networks are expected to experience massive growth in capacity over the next five years. The already-commercialized LTE-A Cat 6 enables a peak rate of 300Mbps, while LTE-A Cat 10 will provide a peak rate of 1Gbps according to the 3GPP standard, and 5G technology is expected to provide a rate of 10Gbps.

The huge rise in mobile data traffic heaps great pressure on backhaul networks. Microwave backhaul, a major backhaul solution for macro
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base stations, will remain a key measure for connecting macro base stations and small cells. Therefore, microwave transmission capacity must be improved to satisfy the rapid growth in mobile traffic.

**100% capacity improvement**

Microwave In-band Full-duplex (M-IFD) enables microwave transmission in full-duplex mode over a single frequency. It can be applied to the common frequency bands (6–42GHz), V-band (60GHz), and E-band (80GHz). Compared with existing duplex technologies under the same conditions, M-IFD doubles the air interface rate.

If the transmitter and receiver at the same end transmit and receive signals concurrently at the same frequency in microwave communication, the transmitter causes severe co-channel interference. This is much greater than the received signal strength on the receiver, which fails to receive signals properly as a result. In time division duplex (TDD) mode, signals are transmitted and received at the same frequency; however, the transmitter and receiver work alternately to avoid co-channel interference. In frequency division duplex (FDD) mode, signals are transmitted and received concurrently, but at different frequencies. To prevent co-channel interference, traditional TDD or FDD technology must either transmit and receive signals alternately or use different frequencies.

M-IFD cancels co-channel interference, and enables the transmitter and receiver to work concurrently at the same frequency. Compared with TDD and FDD technologies, M-IFD doubles the air interface rate under the same spectrum bandwidth, or saves 50% in spectrum resources while achieving the same rate as TDD and FDD. To double microwave capacity, M-IFD can work with existing microwave capacity improvement technologies such as higher order modulation, multiple-input multiple-output (MIMO), frame header compression, cross-polarization interference cancellation (XPIC), and link aggregation.

**Key technologies of M-IFD**

Microwave equipment features high transmit power, high-order modulation, and long-distance transmission. These features pose great challenges to M-IFD; for example, signals with high transmit power cause great near-end self-interference on the receiver. In the case of long-distance transmission, far-end self-interference may be caused by obstacles in the transmission path, surface scattering, and reflection at the peer site. Moreover, the increase in frequency bands and bandwidth may cause performance indicators to deteriorate, such as phase noise, which adds to the difficulties of implementing M-IFD. M-IFD adopts the following technologies to overcome these challenges and improve system performance: isolation enhancement, near-end self-interference cancellation (near-SIC), far-end self-interference cancellation (far-SIC), phase noise suppression, and synchronization precision improvement.

**Isolation enhancement:** On the same equipment where the transmitter and receiver work at the same frequency, co-channel self-interference occurs between the transmitter and receiver as well as between antennas. In the RF front-end circuit design, isolation between the transmitter and receiver can be improved by adding ground holes around signal wires,
increasing the distance between the transmit and receive channels, or optimizing the shielding cavity structure. The transmitter and receiver circuits can also be separated from each other if necessary. In the antenna design, isolation between antennas can be improved by adding near-field interference suppression structures or absorbing materials, optimizing the layout of transmit and receive antennas, or improving circulator isolation.

Near-SIC: Because the isolation achieved by the antenna and circuit design is limited, near-SIC is required to further reduce the near-end self-interference. Near-SIC provides the following functions:

RF interference cancellation: A few transmit signals are coupled from the transmitter to the receiver front end. Based on the amplitude, phase, and delay of the coupled signals, cancellation signals are generated. Their amplitude and delay are the same as those of the interference signals, but the phase differs by 180 degrees. In this way, the near-end self-interference can be canceled. Generally, multi-level interference cancellation circuits can be used to improve the cancellation capability. In addition, the integer nonlinear optimization algorithm that controls the adjustment of the amplitude, phase, and delay enables fast, automatic near-end self-interference cancellation.

IF interference cancellation: ensures that the quantification accuracy is not affected by strong interference when an analog-to-digital converter (ADC) converts received signals into digital signals. IF interference cancellation is similar to RF interference cancellation, except that cancellation signals and adjustment of their amplitude, phase, and delay are completed on the baseband. Interference cancellation signals are converted into analog signals by a digital-to-analog converter (DAC), and interference signals in received signals are canceled at the front end of the ADC.

Baseband interference cancellation: cancels residual near-end self-interference in digital baseband signals. The digital baseband algorithm estimates the interference signals and reconstructs interference cancellation signals to cancel residual interference.

Far-SIC: Far-end self-interference can be generated in any place over the signal transmission path. Therefore, far-end self-interference generally contains multiple multi-path signals with different delays. Far-end self-interference signals can be processed only in the digital baseband. Multiple parallel interference cancellation algorithms can be used to process multiple multi-path signals, improving the processing speed and saving logical resources. In addition, the cancellation algorithms must support a wide range of delays.

Phase noise suppression: Microwave phase noise increases as the frequency increases, and affects the performance of the baseband interference cancellation algorithms and demodulation algorithms. Phase noise in received signals can be reduced using the phase noise suppression algorithm. System noise can be reduced by optimizing hardware circuit design, using high-performance frequency source components, and also by optimizing the loop filter design and transmitter/receiver design. In
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addition, phase noise in self-interference signals can be effectively reduced by configuring the same local oscillator for the transmitter and receiver.

Synchronization precision improvement: When microwave equipment demodulates received signals, it restores the symbol synchronization clocks from the signals to ensure the sampling performance of the signals. However, in M-IFD, the power of the interference signals and useful signals is similar, making it hard for microwave equipment to identify the useful signals. Adaptive equalization is performed at the beginning of processing digital signals to cancel interference before synchronization, which improves synchronization precision and reduces noise.

Future evolution of microwave backhaul

The rapid growth of wireless network bandwidth requires improved microwave transmission capacity and more spectrum resources. Some operators and equipment vendors propose wireless network solutions that use microwave frequency bands, such as 11GHz, 28GHz, or even millimetric wave bands. These further cut the frequency resources available for microwave backhaul. M-IFD increases microwave link transmission capacity, simplifies O&M, improves frequency utilization, enables flexible network configuration, and enhances other aspects of network performance.

Flexible microwave networking: Densely deployed microwave backhaul sites no longer need spectrum resources in pairs. Uplink and downlink transmission channels can be established in a single frequency band. In this way, more subsidiary bandwidth can be divided from a microwave frequency band division for networking.

Co-site dense deployment: When multiple microwave devices are deployed in the same site, crosstalk between devices working in adjacent frequency bands can be canceled using interference cancellation technology. In this way, the deployment density of microwave devices in the same site can be improved.

Intra-frequency relay: Microwave relays can use M-IFD to cancel crosstalk generated by the transmit antenna on the receive antenna. In this way, the number of frequencies used on a network can be reduced.

Microwave equipment normalization: The integrated transceiver with self-interference cancellation technology features high transmit-receive isolation, and achieves the same effect as the broadband duplexer used in FDD communication. With the transceiver, no duplexer is required for equipment working in each sub-band, simplifying product supply and maintenance.

In conclusion, M-IFD improves microwave link capacity, optimizes spectrum resources, and boosts network capacity. It is expected to greatly reduce network OPEX, improve network service capabilities, and become a mainstream solution for microwave network deployment.