White Paper

Addressing the 4G and 5G backhaul capacity challenge with Air Division Duplexing

Achieving sufficient capacity to meet the forecast backhaul needs over the next few years will be a major challenge. This white paper describes the technique of Air Division Duplexing (ADD), which makes use of MIMO and spatial multiplexing techniques to achieve simultaneous transmission and reception of data on each carrier frequency, and has been shown to achieve full duplex data rates[1] in excess of 1 Gb/s in a 28 MHz channel allocation[2] in the microwave bands.

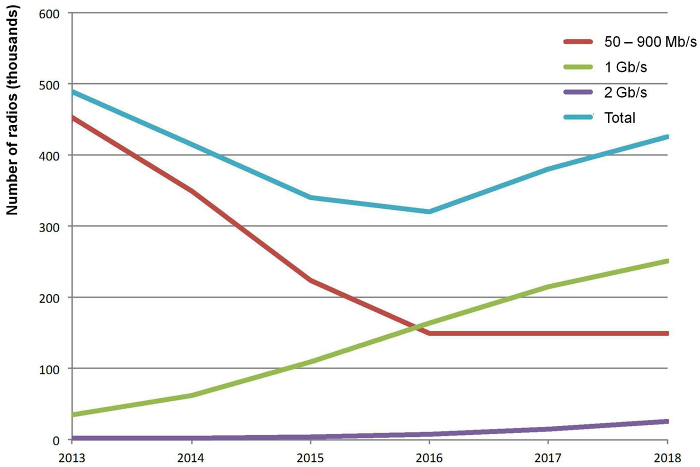


Figure 1: Forecast IP radio sales by capacity 2014 - 2018 (Source EJL Wireless Research)

Capacity scalability has been identified as one of the most important technical challenges in microwave backhaul. Data traffic continues to double in size each year, driven by the increasing adoption of smartphones and the growth in data-hungry applications such as HD video streaming. In addition, the deployment of heterogeneous networks (HetNets) and small cells in LTE-A networks means that the data rates handled by each macrocell will continue to increase. Consequently the wireless industry is facing a crisis in its ability to keep up with the demand for backhaul capacity, which will only become worse when 5G is introduced.

Connecting high-bandwidth data networking points by means of optical fibre is very expensive, and impractical in many cases. Microwave links have been used for many years, and already account for more than 50% of backhaul capacity with the proportion growing year-on-year. Figure 1 shows the 2013 market for Ethernet radio links of different capacities and the forecast for 2014 - 2018, extracted from a report by EJL Wireless Research[3].

> Simultaneous full-duplex communication can double spectral efficiency

The radio capacity challenge

A particular problem with the forecast is that it is currently very difficult to produce a 1 Gb/s radio with current spectrum allocations and radio technology. Channelization in the microwave

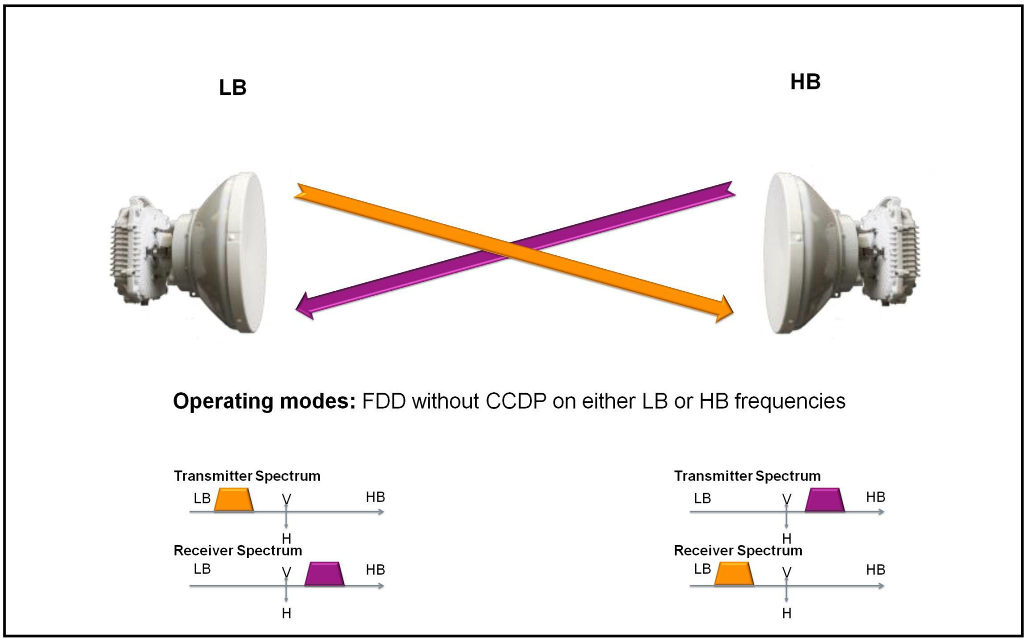


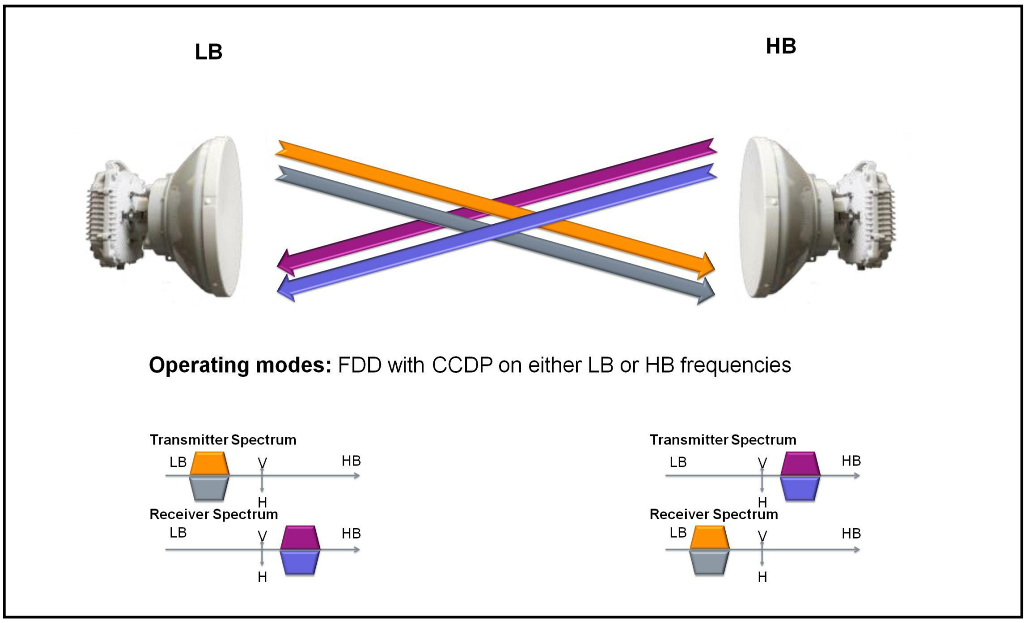
Figure 2: Standard FDD microwave backhaul radio with single polarization

bands (up to 42 GHz) is largely based on multiples either T1 or E1 fixed rates, with a base channelization of 3.5 MHz. Generally the largest channel allocation is 28 MHz, with some rare occurrences of a 56 MHz or possibly 112 MHz channel in some countries. The best data rates that can be achieved by currently available microwave systems are typically 400 - 500 Mb/s in a 28 MHz channel allocation using both vertical and horizontal polarization in an XPIC configuration. Spectrum licenses can account for up to 40% of a backhaul operator's OPEX over a 10-year period, and the leasing of tower space is also at a premium.

Until now, the only option available to operators demanding a higher throughput has been to use the millimetre-wave frequency bands above 42 GHz, particularly the bands at 60 and 70/80 GHz where channel allocations are in multiples of 50 MHz for the 60 GHz and 250 MHz up to 2 GHz for the 70/80 GHz. The EJL Wireless Research report shows that radio sales in the conventional microwave bands at 15 GHz, 18 GHz, 23 GHz and 38 GHz have actually declined slightly since 2010 because they have been unable to meet Gb/s capacity requirements. However, the millimetre-wave radios have disadvantages both in terms of distance because climatic and atmospheric attenuation is higher at these frequencies and sometimes also in cost, since in many countries the regulators charge more for licenses in relation to the amount of spectrum used (millimetre-wave bands are license free in some countries, but not in most developed or developing countries).

The challenge therefore is that there is an escalating need for Carrier Ethernet data throughput, but in most cases the telecom operators have limited radio frequency spectrum available to them in order to meet their future backhaul capacity requirements.

Figure 3: FDD microwave backhaul radio with Dual (or Cross) polarization



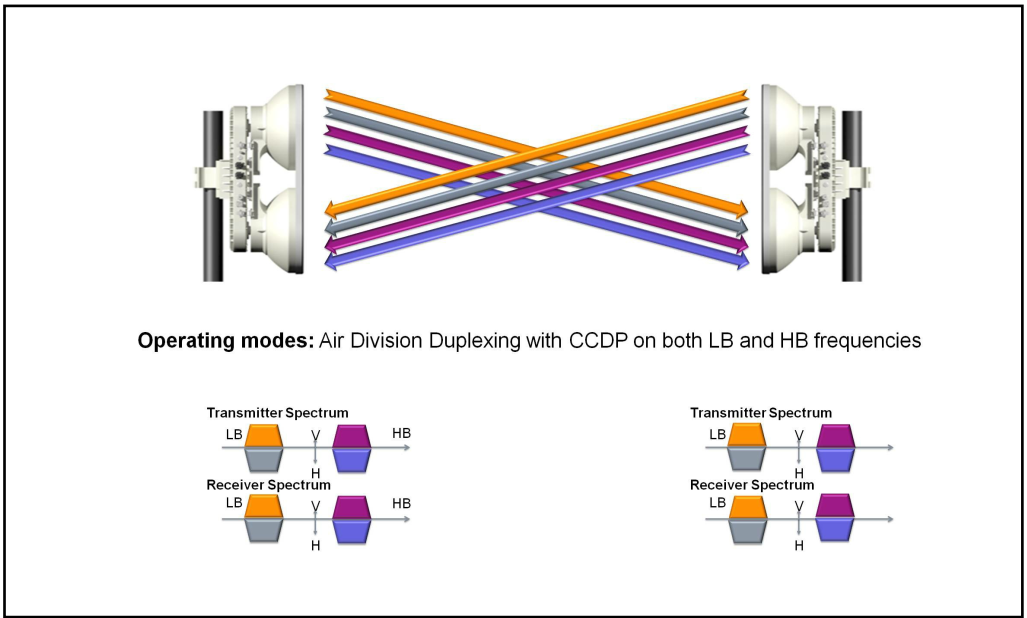


Figure 4: Air Division Duplex microwave backhaul radio

Spectrum allocation

Typically, traditional microwave frequency bands are specified as two separate but linked frequency allocations in the lower and upper halves of the band, known respectively as the 'Low Band' (LB) and 'High Band' (HB). A microwave link conventionally makes use of both these frequencies in order to achieve a link using FDD (frequency division duplexing), where each of the two frequencies is used for transmission in one of the directions, as shown in Figure 2. Increased capacity can be achieved by using more complex modulation schemes, but this places higher demands on the linearity of amplifiers, which adds to the cost, as well as requiring greater single to noise ratios on the receiver side for demodulation which reduces the overall system gain and range while increasing antenna size and cost. Increasing the order of modulation does not give a proportional benefit in capacity. 256 QAM is currently the most widely used modulation, which allows typically up to 200 Mb/s throughput to be achieved in 28 MHz channel bandwidth without data compression. When compression techniques are also applied, the claims are to double the throughput, however this technique depends on the traffic type and the sensitivity of the network to the additional latency added by the compression/decompression algorithms. Higher order modulations of 2048 QAM can achieve some 35% higher capacity than this but with performance trade-offs in system gain, transmitter power, antenna size or range.

By using orthogonal polarization, known as Co-Channel Dual Polarization (CCDP) or Cross Polar Interference Cancellation (XPIC), a second transmission path can be added to the link in each direction, as shown in Figure 3. This can effectively double the capacity, and is a standard technique that is currently used by network equipment vendors, operators and regulators.

MIMO techniques

Additional spectral efficiency can be achieved by the use of spatial multiplexing, known as MIMO (multiple input multiple output), which combines multiple antennas on each side of the link to increase the throughput. The increase in spectral efficiency is achieved because the transmitted signal from each aperture is at the same frequency.

However in order to resolve the MIMO transmissions, the radios need to be able to discriminate between the multiple signals, which requires there to be a minimum spacing between the antennas - this is proportional to link distance and inversely proportional to frequency. This means that the overall dimensions of radio system tend to be large (often up to 10m separation between radio units on the same tower), which is unpopular with operators as masts are already overcrowded. This implementation further doubles the operation costs as regulators may also charge a separate spectrum licence fee for each aperture as they are not strictly co-located and similarly the site owner may charge double the aperture rental fees for the separate antennas.

Air Division Duplexing

MIMOtech has taken the MIMO technique one step further, with the development of an entirely new technology that uses spatial multiplexing to achieve higher spectral efficiency. Air Division Duplexing is a patented technique that also uses two antennas, but in this case the separation between them is typically only 100mm, allowing it to be considered as a quasi single-aperture antenna from the point of view of licensing, site rental cost and implementation.

Unlike the techniques described earlier, Air Division Duplexing exploits the possibility of using both the go and return frequency bands of a microwave link simultaneously from both sites. Rather than having a transmitted signal in the High Band in one direction and in the Low Band in the opposite direction, both frequencies can be used for transmission in both directions simultaneously. A prerequisite for this is that the equipment must be optimized to cancel out self-interference.

Figure 4 illustrates the Air Division Duplexing technique. Because both frequencies and both polarizations are used simultaneously from both directions, this technology provides double the capacity of microwave radios currently on the market.

The MIMOtech Janus AirDuplex™ range of ultra-high capacity backhaul radios, shown in Figure 5, uses this technique to provide in excess of 1 Gb/s full duplex data rate[1] in a 28 MHz channel allocation[2] in the licensed and unlicensed bands up to 42 GHz, using 1024 QAM modulation. This makes the radios suitable for small cell, microcell and macrocell mobile deployments for a range of technologies including LTE/LTE-A, providing a cost-effective alternative to fibre and millimetre-wave links.

Conclusion

Using the Air Division Duplexing approach doubles the capacity and spectral efficiency when compared to current solutions without the penalty of additional OPEX costs going to alternative Line of Sight MIMO implementations. Both CAPEX and OPEX are reduced due to lower spectrum fees, lower site/tower rental fees and lower maintenance costs, while software definability offers downstream savings in upgrade costs.

In addition, the Air Division Duplexing technology brings reusability to frequency spectrum below 42 GHz that up to now has been limited to backhaul applications with a maximum of several hundred Megabits per second. These frequency bands can be re-applied for Gigabit backhaul applications.

The Janus AirDuplex™ product provides a high capacity cost-effective alternative to fibre or millimetre-wave links for 4G and potentially 5G backhaul and links for enterprise and government applications.

Figure 5: The MIMOtech Janus Air-Duplex™ radio

[1]Full duplex data rate is the available traffic data rate in each direction of the microwave link without payload compression being used. Intelligent Header compression is applied.

[2]The 28 MHz channel allocation is a Frequency Division Duplexing (FDD) channel allocation with go and return frequencies in both vertical and horizontal polarizations. This is also known as a co-channel dual polarized (CCDP) allocation.

[3]EJL Wireless Research, "Global Digital PTP Radio Market Analysis and Forecast, 2014-2018", 10th Edition April 2014

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