Multi-Core Technology: The Next Generation in Microwave Communications

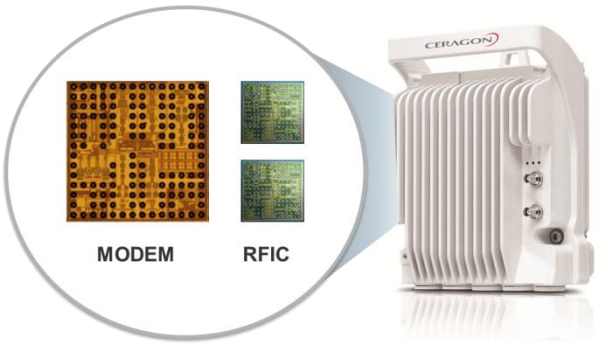
Background and Introduction

At the end of 2012, Ceragon Networks set a new benchmark for microwave communications by introducing the industry's first multi-core microwave radio, FibeAir IP-20C. A part of Ceragon's *Holistic HetNet Hauling* (3H)[1] vision, multi-core radio architecture marks the beginning of a new era in wireless communications, boosting microwave to new levels of capacity heretofore reserved to fiber optic cable. This paper describes the essence of multi-core radio technology and points out the many benefits associated with it: capacity, link distance, power consumption, form-factor, and expense.

Multi-Core Explained

Ceragon's unique multi-core radio architecture is based on an advanced parallel radio processing engine built around Ceragon's in-house baseband modem and RFIC chipsets. Optimized for processing of multiple radio signal flows, the architecture multiplies the capacity and increases the system gain over current technology. Utilizing common processing resources at the kernel of the radio terminal, the multi-core system reduces power consumption and maintains a small form-factor. This makes it advantageous to deploy in numerous heterogeneous network scenarios like small cells and fronthaul.

[1] More on Ceragon's 3H vision in a white paper, available on Ceragon's website



A parallel radio processing engine differentiates multi-core radios from other compact multiple-carrier solutions which are nothing more than multiple radio systems compacted into a single box. These do not offer the many benefits of centralized resources per multi-core technology.

Multi-Core Radio's Flexible Operating Modes

Ceragon's multi-core radio technology is inherently versatile and suitable for many different deployment scenarios. Multiple cores can be activated remotely for optimized performance in myriad applications to fit virtually any backhaul, fronthaul or other deployment scenario at far higher capacities than ever before. Its versatility makes it highly useful and cost-efficient in the dynamic HetNet.

The Basis

To illustrate the many advantages of multi-core technology, consider a generic, 1+0 single-core radio with high performance in terms of capacity, link distance and antenna size:

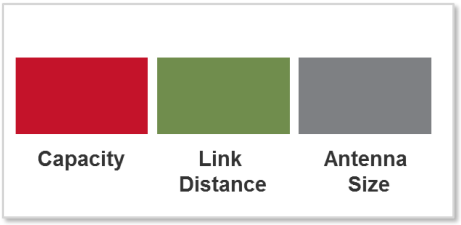


Figure 1 - Performance of the generic, 1+0 single-core radio

Multi-core technology can operate with just one active core where it will have similar parameters to the standard, but will provide additional capacity due to the high modulation in which it operates (2048QAM) and header compression techniques, and additional system gain due to the advanced in-house RF chipset. Turning on a second core opens up a world of possibilities enabling it to perfectly match the requirements of a variety of deployment scenarios, as explained below.

Doubling the capacity

Remotely turning on the second core automatically provides twice the bandwidth (and with it, capacity) of the single-core radio (whether we use an adjacent frequency channel or the same one with orthogonal polarization, i.e., XPIC). This significant capacity boost is achieved without compromising system gain or availability since it comes about from the use of an additional carrier at the same modulation and same Tx power and Rx sensitivity. No additional hardware is required, and the increased capacity is delivered using the same small form-factor system. Effectively, it is a pure doubling of capacity without any trade-offs.

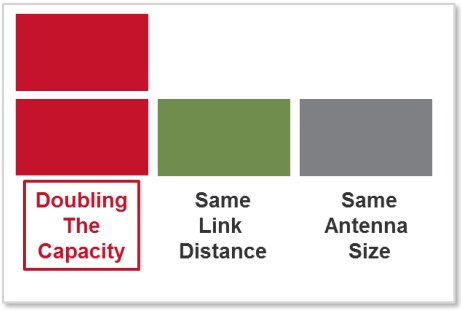


Figure 2 - Multi-core radio doubles the capacity

Doubling the link distance

Ceragon's multi-core radio can also be leveraged to increase link distance. FibeAir IP-20C splits the bitstream between its two cores using Multi-carrier Adaptive Bandwidth Control, which, in turn, makes possible a lower modulation scheme that significantly increases system gain (both higher Tx power and lower Rx sensitivity). Higher system gain contributes to longer signal distance, thus, the multi-core radio can achieve longer link spans, and can even double the link distance using the same hardwave (radio and antenna).

For example, let's consider a case where the multi-core radio, in 1+0 configuration (only one core is activated), transmits 260Mbps over a 28MHz channel with 2048QAM modulation. Activating the second core makes it possible to reduce the modulation to

64QAM and yet transmit more capacity: 280Mbps (2 X 140Mbps over the 28 MHz channel). Reducing the modulation from 2048QAM to 64QAM also delivers a 4dB improvement in Tx power and a 15dB improvement in Rx sensitivity - yielding an overall increase in system gain of 19dB. With this improved system gain, we can double the distance of the link and, at the same time, enjoy an additional 20Mbps in overall capacity.

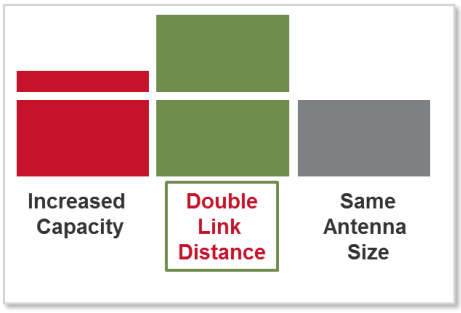


Figure 3 - Multi-core radio doubles the link distance and adds capacity

Halving the antenna size

The system-gain boost enabled by the multi-core radio can be leveraged to scale down the antenna size. A radio rule of thumb dictates that every doubling of antenna size on one side of the link translates into 6dB more link budget. The 19dB boost to system gain as described in the example above can be exploited to halve the antenna size (using 12dB of the 19dB gain), still leaving 7dB which can be used to further reduce antenna size on either side of the link. Smaller antennas cost less and are easier to install, thus the network operator enjoys CAPEX savings from the multi-core deployment and OPEX savings due to lower tower-leasing fees.

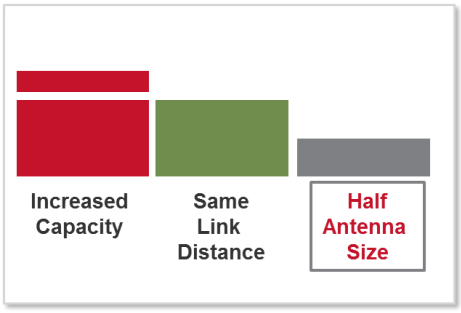


Figure 4 - Multi-core radio halves antenna size

Frequency decongestion and lower license fees

Another way in which this system-gain boost can be leveraged is in shifting from congested and expensive frequency bands to uncongested and less costly higher frequency bands. The system-gain boost described above can be used to compensate for the loss in link budget incurred by moving to higher frequencies. Relatively long-span links, which require operation in lower, more congested and expensive frequencies (6, 7 or 8 GHz), can be shifted to higher, less congested and less expensive bands (such as 11, 15, or 18GHz). Previously unusable for long links, the benefits of multi-core technology now make these frequencies available.

Quadrupling Capacity

Two separate multi-core radios can be deployed in LoS MIMO[2] configuration making it possible to operate a very efficient line-of-sight 4x4 MIMO link, leveraging MIMO and XPIC technologies together. With just two multi-core radio units, four independent bitstreams are transmitted over a single frequency channel resulting in a quadrupling of capacity. In LoS 4x4 MIMO configuration, microwave can, for the first time, achieve gigabits of capacity, more than enough for future network deployments.

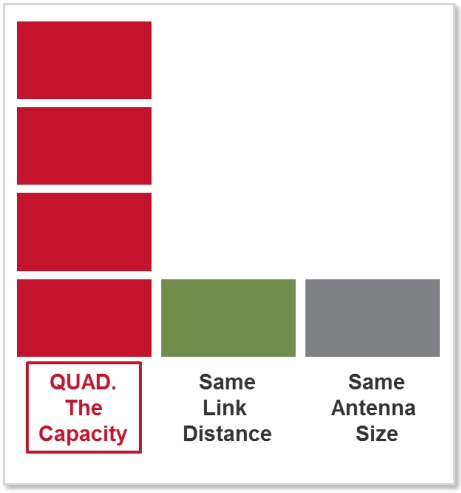


Figure 5 - Multi-core radio – quadrupling the capacity

[2] Line-of-Sight Multiple Input Multiple Output. More on LoS MIMO technology can be found in a technical brief available on Ceragon's website

TCO Savings: The upgrade of a single-core vs. multi-core system

In the above examples, we show how Ceragon's breakthrough multi-core technology can achieve doubling and quadrupling of capacity, longer link distances and smaller antenna sizes. Below, we show the cost ramifications to the network operator.

Let us consider a very practical scenario: an operative 1+0 link in the field that must be upgraded to 2+0 in order to accommodate growing demand for capacity. Here is a comparison between upgrades in the case of a single-core system vs. a multi-core system.

Single-core system

The upgrade process is complicated and involves:

- Purchasing a new radio
- Sending an installation team to the site
- Dismantling the existing radio
- Replacing the single-mount radio-antenna interface to accommodate two carriers (either a coupler in case of single polarization, or an OMT[3] if using XPIC)
- Re-installing the old radio together with the new one
- Connecting both radios to a switch to provide Layer 2 LAG in order to obtain a 2+0 multi-carrier link

The upgrade of the single-core system incurs a high initial cost for re-installing and re-configuring the link, as well as an inflated site-leasing fee due to extra equipment and footprint, and more operating expense due to increased power consumption. The upgrade process involves sending an installation team to both ends of the link and hours of link down-time, incurring loss of revenue and impaired customer quality-of-experience (QoE) throughout. During its lifetime, the upgraded 2+0 single-core system will consume 100% more power than the 1+0 system and is virtually twice as likely to require on-site maintenance.

Multi-Core system

Network operators can initially install a multi-core system with just one activated core, providing enough capacity for today and ensuring the ability to expand capacity on the

[3] Orthogonal Mode Transducer: A mediation device designed to combine two orthogonally polarized carriers in the same antenna port.

fly in the future. The multi-core system is initially installed as 1+0 but is always ready for 2+0. When the upgrade to 2+0 becomes necessary, the operator merely needs to:

- Purchase a license from Ceragon for the second core
- Remotely upload the license and activate the second core via Ceragon's network management system (NMS)

No site visits are required and there is virtually no downtime. Subscribers enjoy continuous, uninterrupted service. No additional switch is needed since the system can perform N+0 Multi-Carrier Adaptive Bandwidth Control (ABC)[4] internally between its multiple cores, Ceragon's method for utilizing the multi-channel capacity in a much more efficient manner than Layer 2 LAG. The network operator enjoys much lower power consumption than 2+0 systems which are constructed from single-core radios, and site leasing fees do not increase since no additional hardware is installed.

Behind the scenes, network operators deploying multi-core technology enjoy warehouse management simplification and savings as a single spare part is suitable for many different deployment scenarios that operators can implement remotely and on-the-fly as dynamic network situations warrant.

Below is a table that summarizes the benefits of multi-core systems over traditional single-core systems during field upgrade.

[4] More on Ceragon's Multi-carrier ABC technology can be found in a technical brief available on Ceragon's website

Table 1 - TCO comparison between single- and multi-core systems

	Single-Core system	Multi-Core system
Initial installation	1+0 link with 1+0 antenna mediation device (remote or direct mount)	2+0 installation (remote or direct mount), only one core is purchased and activated
Upgrade to 2+0	• Obtain new radio equipment • Send technical team to both ends of the link (two site visits, at least) • Dismantle existing radio and mediation device • Install new mediation device (OMT or splitter) • Re-install old radio with new radio • Obtain and install Ethernet Switch for 2+0 L2 LAG	• Obtain license for second core • Activate second core remotely (via NMS) • Remotely define the link as 2+0 with L1 Multi-Carrier Adaptive Bandwidth Control (more efficient than LAG)
Downtime	Hours of downtime for complete reconfiguration of the link Negative impact on end-user QoE	No downtime
Power consumption	100% than 1+0 link (even more with external switch)	Only 55% more power consumption than 1+0 configuration (single core)
Site leasing fees	More or less double, as equipment is doubled	No impact, multi-core system within same small form factor unit
Warehouse management	Complicated with different equipment for different deployment scenarios (standard/high power, low/high capacity)	Simple with single-spare, versatile radio for many deployment scenarios

Innovative multi-core microwave solutions reduce operational expenditure as they provide long-term insurance and peace of mind against future capacity demands.

Summary

Ceragon's Multi-Core radio technology sets a new standard in microwave transmission, delivering Multi-Gbps anywhere. Far less costly to deploy than fiber, Ceragon's multi-core microwave solutions solve today's HetNet hauling challenges in the most cost-efficient manner. Inherently versatile, a multi-core radio is suitable for a wide range of deployment scenarios and can be upgraded, by remote software definition, to deliver more capacity and/or longer link distance as dynamic deployment scenarios dictate. As usual, Ceragon is the innovator of this next-generation microwave technology with the first multi-core radio in the industry, FibeAir IP-20C, which transports up to 2Gbps radio throughput over a single frequency channel, enabling operators to enjoy significant capital and operational savings while future-proofing their networks for escalating capacity demands.

About Ceragon Networks Ltd.

Ceragon Networks Ltd. (NASDAQ: CRNT) is the #1 wireless backhaul specialist. We provide innovative, flexible and cost-effective wireless backhaul solutions that enable mobile operators and other wired/wireless service providers to deliver 2G/3G, 4G/LTE and other broadband services to their subscribers. Ceragon's high-capacity, solutions use microwave technology to transfer voice and data traffic while maximizing bandwidth efficiency, to deliver more capacity over longer distances under any deployment scenario. Based on our extensive global experience, Ceragon delivers turnkey solutions that support service provider profitability at every stage of the network lifecycle enabling faster time to revenue, cost-effective operation and simple migration to all-IP networks. As the demand for data pushes the need for ever-increasing capacity, Ceragon is committed to serve the market with unmatched technology and innovation, ensuring effective solutions for the evolving needs of the marketplace. Our solutions are deployed by more than 430 service providers in over 130 countries.

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