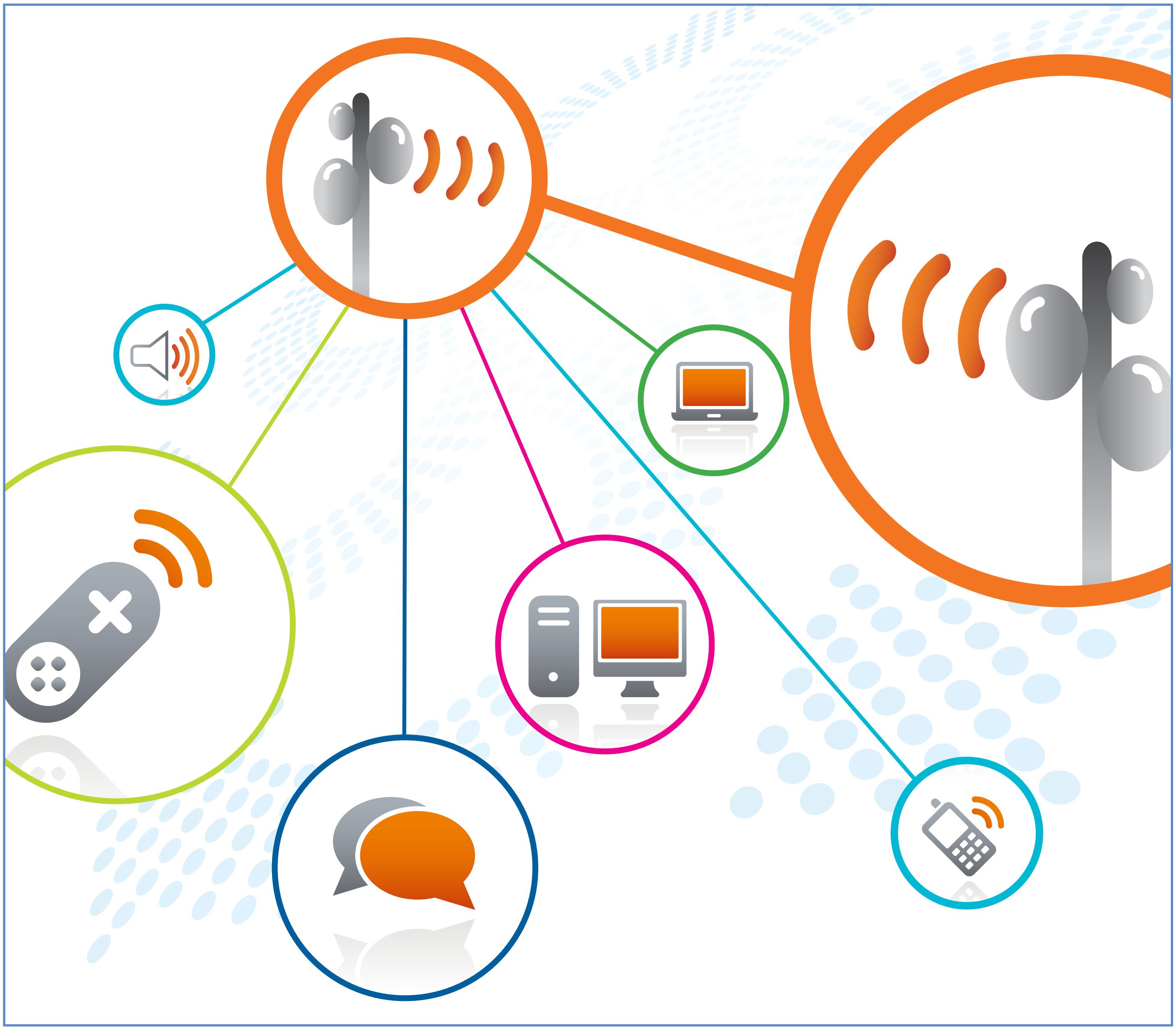
COMMSCOPE®

White Paper

Advanced Microwave Antenna Designs Address Growing Capacity and Cost Challenges



This paper focuses on a Microwave point-to-point backhaul antenna solution that addresses the multiple and simultaneous challenges of capacity, coverage, and costs faced by today's wireless operators. It also explores the cost and scarcity of available spectrum and how it can be more effectively and profitably utilized with Sentinel™ antennas, a new CommScope backhaul solution with extremely low sidelobe levels.

The information presented in this document is based on analytical and network analysis of real mobile backhaul scenarios, using the iQ.link$_{XG}$® link planning software tool from Comsearch®. Sentinel™ microwave antennas clearly demonstrate significant cost savings, reliability improvements and capacity enhancement in the mobile backhaul domain. Operators, OEMs, link planners and regulators alike can all realize significant advantages with Sentinel microwave antennas.

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Today's Challenges

The fast-growing demand for fast, reliable communication, as well as for new mobile and cellular services drive ongoing challenges to industries, universities and R&D labs to search mobile backhaul technologies that can provide:

A) Effective, efficient ways to grow **coverage** at lower CAPEX and OPEX

B) Effective, efficient ways to grow **capacity** at lower CAPEX and OPEX

Both the development speed and breadth of adoption of new technologies are critical components to any solution to the increasing challenges of **coverage**, **capacity** and **cost** – the three legs of **C^3 solutions** (Fig. 1).

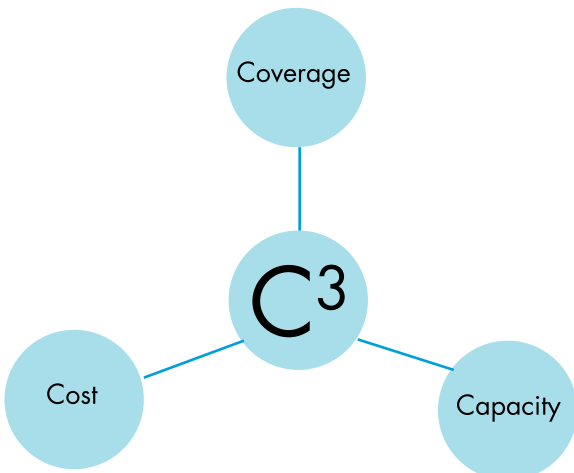


Figure 1: Today's stakeholder challenges

Today's Challenges to Antenna Manufacturers

Accepting these general objectives in principle is one thing, but achieving them in practice presents significant challenges for all. Operators, regulators, planners and system manufacturers have three main questions for antenna manufacturers about any new antenna solutions:

1. **Capacity:** How can we use our spectrum more efficiently, allowing more links within a spectrum or, conversely, minimizing spectrum requirement for a given number of links?

2. **Coverage:** Can we reduce outages due to multipath and selective fading to improve target annual reliability and future-proof links?

3. **Cost:** Can new technology translate to smaller antennas that combat harmful interference and reduce both CAPEX and OPEX of each link?

Capacity

The theoretical maximum capacity of a communication link is defined by Shannon's Law, which clearly indicates that it depends upon channel bandwidth **(B)** and carrier-to-noise ratio **(C/N)**, which is total received signal level to noise level ratio, as described mathematically below.

$$\text{Capacity} = B \times \text{Log}_2\left(1+\frac{C}{N}\right)$$

B - Channel BW   C - Carrier Power (RSL)   N - Noise in RX_R

Shannon's law indicates that the capacity of a channel—which is basically a measure of the channel's ability to convey data—can be increased by increasing the bandwidth, increasing the signal's power and reducing receiver noise. But spectrum crunch places limits on bandwidth expansion.

Today, in the era of digital communication, information flows as a group of bits, called symbols, so it is important to encapsulate the maximum number of bits in symbols. These symbols ride on higher frequency signals called carriers and, at the receiver, it is important to extract the information with minimum generation of noise. As a result, modulation and encoding schemes, reduced signal noise and accurate extraction of signal information all matter a great deal.

In a typical microwave point-to-point link, the carrier power or received signal level for a given link can be increased either by transmitting more power, by using higher-gain antenna or by increasing the sensitivity of receiver. The received signal level (RSL) fluctuation depends upon the condition of the radio link, including changing weather conditions in the area.

It is important to remember that in the microwave mobile backhaul domain, multiple links operate side by side, introducing the risk of interference (I) that must be included in any calculation of noise for link planning purposes as the carrier-to-interference ratio (C/I).

$$\text{Capacity} = B \times \text{Log}_2\left(1+\frac{C}{N+I}\right)$$

Conclusion 1:

For efficient communication, operators need an antenna with low risk of interference.

An antenna's radiation pattern envelope (RPE) is the characteristic that determines the effect of interference on the link. The RPE is a mask around the antenna's radiation pattern, indicating the envelope of the lobes from -180 to +180 degrees. RPEs are important in mapping links that don't create problematic interference with each other; hence, they are strictly regulated for compliance.

Sentinel™ is a new antenna solution from CommScope, featuring exceptional performance characteristics in a smaller form factor. For example, the RPE of a conventional, ETSI Class 3-compliant 2 ft. (0.6 m) antenna is contrasted below with the RPE of a similarly sized Class 4-compliant Sentinel™ antenna. Note Sentinel's extremely low sidelobe levels, indicating low risk of interference (Fig. 2).

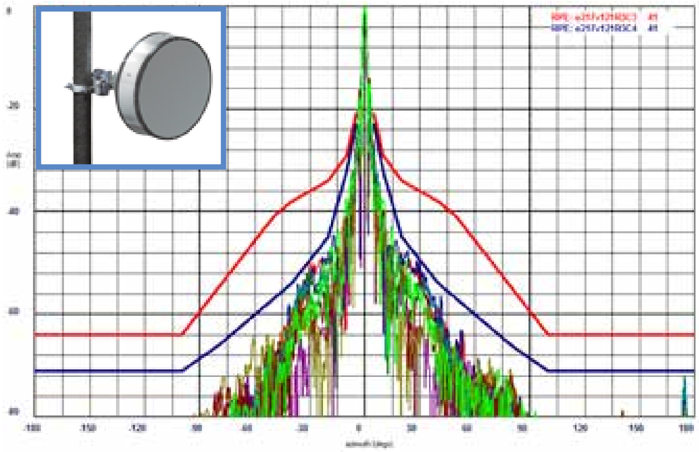


Figure 2: Sentinel™—an antenna solution with extremely low sidelobes

Sentinel™ microwave antennas not only meet ETSI Class 4 specifications—the most demanding ETSI RPE specifications for point-to-point antennas—they also exceed all regulatory requirements applied to current microwave antennas, such as specifications published by FCC, SRSP, ANATEL and others.

Conclusion 2:

CommScope's advanced Sentinel backhaul antennas offer lowered risk of interference.

This RPE advantage can be demonstrated on all other Sentinel™ antennas of different sizes and frequencies. This is because Sentinel™ technology is not based on earlier concepts that rely on complex offset geometries and large structures for tighter RPE sidelobes. Sentinel™ is an axis-symmetric design that provides superior interference resistance in a small footprint.

In order to maximise the capacity of the microwave link, adaptive coding and modulation (ACM) is also getting lot of attention. ACM is a feature of a radio link that allows it to change its modulation scheme in reaction to changing link conditions. Higher modulation schemes can support high-capacity, low-priority traffic; lower modulation schemes are suited to low-capacity, high-priority services such as voice transmission.

How much modulation is applied depends on several link characteristics and conditions:

- Radio capabilities
- Propagation scenario—weather and fading conditions
- Interference conditions
- Error performance and target availability percentage

Again, interference emerges as a key factor in determining the level of appropriate modulation. And while higher modulation supports more traffic, it also demands a higher C/I ratio. This means that reduced interference opens the opportunity to higher capacity within existing spectrum via higher modulation schemes. To achieve the requisite level of interference control, low sidelobe levels such as those offered by Sentinel™ antennas must be used.

Conclusion 3:

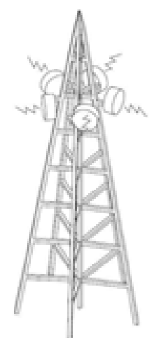
Sentinel's high C/I ratio enhances capacity in both conventional and ACM networks.

The Effective Utilization of Spectrum

We all know that wireless data usage is growing. New, bandwidth-hungry applications appear daily, demanding ever-more spectrum to operate. The bands between 6 GHz and 42 GHz, as well as 60 GHz and 80 GHz, are used for the mobile backhaul domain and they're filling up fast. As with any scarce commodity, spectrum use comes down to finding newer, more efficient ways to handle a finite amount of resources to derive the largest benefit for operators and users alike.

In a typical mobile backhaul network infrastructure, a node is connected to different sites, as shown below in figure 3. Antennas with low sidelobe levels will allow reuse of the same frequency channel several times at the same site, in different directions.

Figure 3: A node of typical mobile backhaul network



The channel's reuse factor will depend on two main variables: the antenna's radiation pattern envelope (RPE), and the required interference attenuation between adjacent links.

Consider for example a node in a star network and the maximum number of links it can support by reusing the same frequency channels in the 23 GHz band. If we're using 2 ft. antennas with required attenuation in co-channel hops of 40 dB, we can see in the graph below the possible angular separation between links with antennas of varying ETSI classifications, which define their sidelobe levels (Fig. 4).

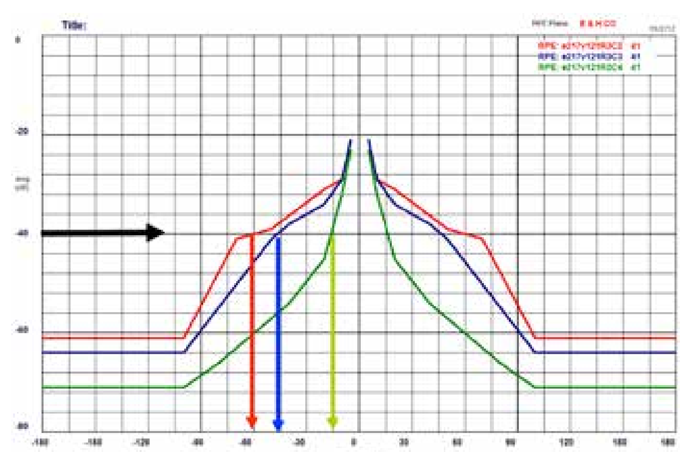


Figure 4: Example of antenna RPEs with different ETSI classifications

The frequency reuse factor, or the maximum number of links that can be used in the same frequency channel, on a node with antennas having different sidelobe levels are shown in Figure 5. It is important to remember that the improvement factor will depend upon the scenario of each independent network.

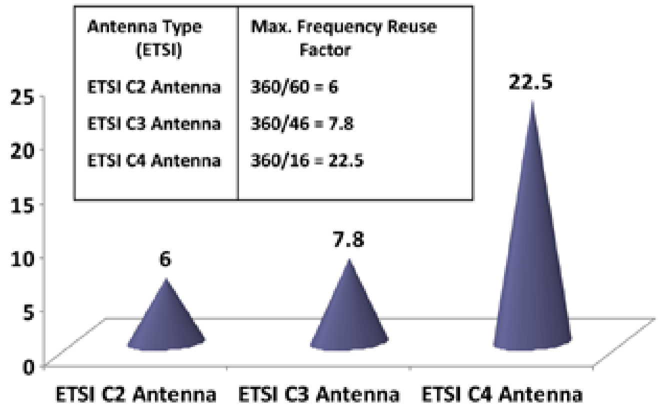


Figure 5: Example of maximum frequency reuse factor, demonstrating large potential cost savings

When the initial spectrum crunch and the growing threat posed by interference was felt several years ago, industry demand changed from ESTI Class 2 antennas to ETSI Class 3 for mobile backhaul network, with the improvements described in the table below.

By a similar token, Sentinel™ Class 4 antennas represents a quantum leap in efficiency over conventional Class 3 antennas. In fact, about three times as many links may be deployed in the same channel without interference problems. Sentinel™ therefore represents a remarkable dual opportunity:

1. **Increases performance** by boosting maximum frequency reuse by **a factor of 3**, and
2. **Reduces costs** by lowering spectrum requirements over a given number of links **by two thirds**.

These figures have been validated with IQ.Link$_{XG}$®, Comsearch's network planning software, on a 23 GHz network using 753 links with similar radios but with varying capacities of 2E1, 4E1, 8E1 and 17E1. Interference analysis was performed over a 100 km radius with one subdivided 28 MHz channel. Both vertical and horizontal polarizations were used. Terrain data of 5 m and 20 m was included in the study. The results:

- Run 1: Using only conventional Class 3 2 ft. (0.6 m) antennas, 70 of 753 links worked.
- Run 2: Sentinel™ 2 ft. (0.6 m) antennas were substituted in all links that failed run 1, yielding an additional 97 working links.
- Run 3: Re-running all links that failed Run 2 after assigning Sentinel™ to the entire network, yielding another 39 working links, raising effectiveness from 70 to 206—**a three-fold improvement in working links.**

These results are consistent with analytical model results. With Sentinel™ antennas, a larger number of links can operate within a given spectrum.

In an another case study of a different complex 23 GHz network topology first running with 2 ft. ETSI Class 3 antennas and then with Sentinel™ Class 4 antennas, IQ.Link$_{XG}$® demonstrated that 30% to 40% more links can be assigned and use about 42% less spectrum with Sentinel™ antennas regardless of the number of 28 MHz available channels, as shown below in Table 1.

Channels	Class 3	Class 4	% Improvement
1	136	190	39.7
2	241	323	34.0
3	321	449	39.9
4	382	493	29.1

Table 1: The incremental improvement from Class 3 to Class 4 relative to number of channels

With less spectrum needed for any particular link, The inescapable conclusion is that Sentinel™ delivers significant operational advantages on both sides of the performance/cost equation.

Conclusion 4:

Sentinel represents the potential for huge spectrum cost saving for operators.

Conclusion 5:

Sentinel ensures effective utilization of spectrum for operators, planners and regulators.

Coverage

A wireless link's path reliability is calculated by determining the fade margins required to counteract multipath and selective fading. The minimum C/I ratio required by the modem is determined by the performance objects set for it and the fade margin assumed in planning. In a typical wireless network such as the one shown below, if the main channel is faded but interference is constant, then its C/I ratio will vary (Fig. 6).

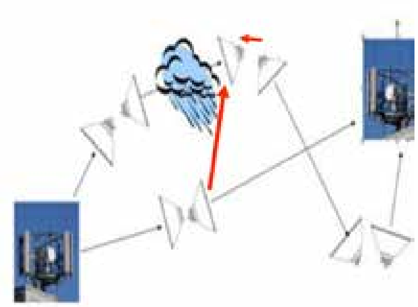


Figure 6: Link outages due to fading

In this case, the received signal level (RSL) may reach the receiver's threshold, causing the bit error rate (BER) of a digital link to increase significantly and result in a link outage. These outages can be avoided by using antennas such Sentinel™ which have a minimal risk of interference.

Conclusion 6

Sentinel is a coverage reliability guarantor.

Cost

The reduced OPEX that comes with more efficient use of spectrum has already been demonstrated in Figure 4. However, there are other savings opportunities to be had with Sentinel™ technology. For example, operators and planners often solve the problem of interference in networks by using larger and heavier antennas than originally planned, raising both CAPEX and OPEX. Consider this realistic scenario, validated by network planning software.

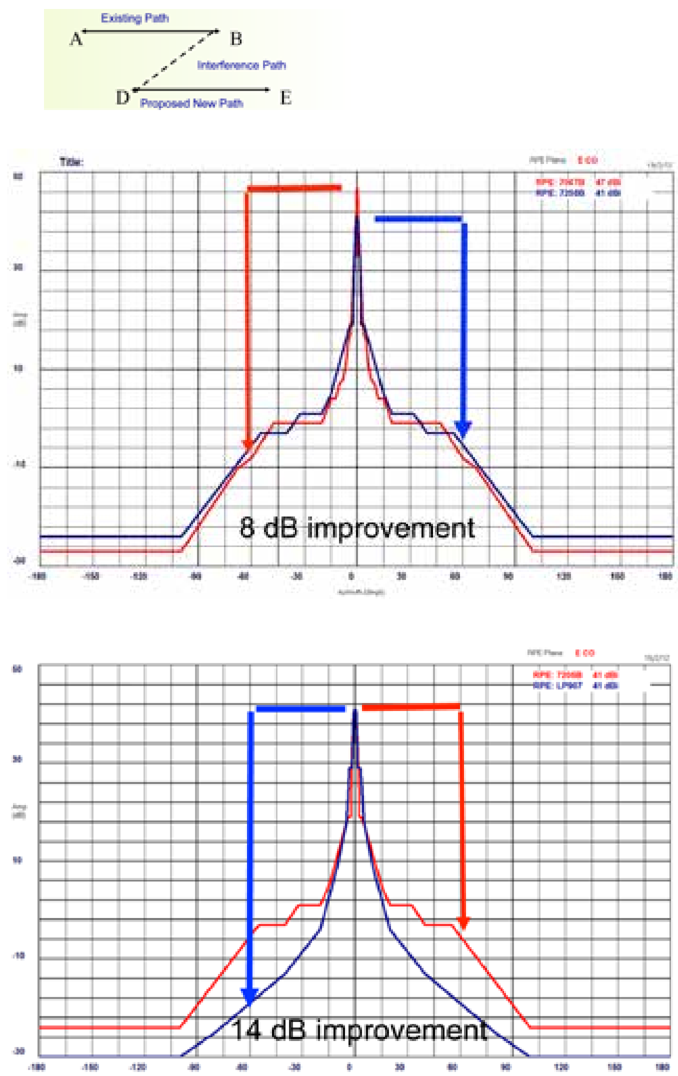
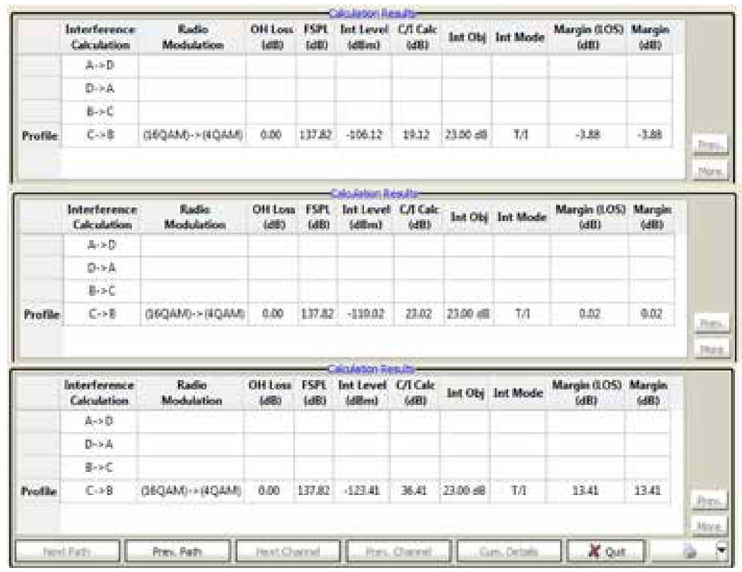


Figure 7: Example of the greater C/I ratio improvement with smaller Sentinel™ antenna instead of larger Class 3 option

Figure 7 shows the 2 ft. (0.6 m) 23 GHz Class 2 antenna as one proposed solution for site D. There exists a risk of interference from site B, already in operation, so the objective is to improve the C/I ratio over link D–E. The traditional Class 3 solution would be to use a 4 ft. (1.2 m) antenna instead, improving C/I by 6–8 dB. However, the second option is to replace with a 2 ft. (0.6 m) Sentinel™ Class 4 antenna, which actually delivers superior C/I ratio improvement of 14 dB.

This kind of interference scenario is a common challenge for network planners, particularly in areas with high densities of microwave links. In Figure 8, you can see this premise tested in a realistic 23 GHz network using iQ.link$_{XG}$®.



Calculation Results

	Interference Calculation	Radio Modulation	OH Loss (dB)	FSPL (dB)	Int Level (dBm)	C/I Calc (dB)	Int Obj	Int Mode	Margin (LOS) (dB)	Margin (dB)
	A->D									
	D->A									
	B->C									
Profile	C->B	(16QAM)->(4QAM)	0.00	137.82	-106.12	19.12	23.00 dB	T/I	-3.88	-3.88

Calculation Results

	Interference Calculation	Radio Modulation	OH Loss (dB)	FSPL (dB)	Int Level (dBm)	C/I Calc (dB)	Int Obj	Int Mode	Margin (LOS) (dB)	Margin (dB)
	A->D									
	D->A									
	B->C									
Profile	C->B	(16QAM)->(4QAM)	0.00	137.82	-110.02	23.02	23.00 dB	T/I	0.02	0.02

Calculation Results

	Interference Calculation	Radio Modulation	OH Loss (dB)	FSPL (dB)	Int Level (dBm)	C/I Calc (dB)	Int Obj	Int Mode	Margin (LOS) (dB)	Margin (dB)
	A->D									
	D->A									
	B->C									
Profile	C->B	(16QAM)->(4QAM)	0.00	137.82	-123.41	36.41	23.00 dB	T/I	13.41	13.41

Next Path | Prev. Path | Next Channel | Prev. Channel | Calc. Details | Quit

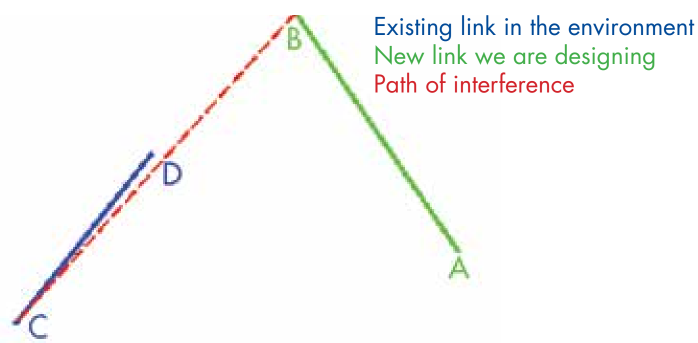


Figure 8: The iQ.link$_{XG}$® interference analysis of a sample 23 GHz Network

In this case, the new A–B link is 5.83 km long. The operator plans the link with 4 QAM radios and 2 ft. (0.6 m) 23 GHz Class 3 antennas currently available in the market. Using the latest ITU-recommended propagation models and checking the link unavailability due to rain as well as outage from multipath and selective fading, it is determined that this link barely meets the Operator's target annual reliability of 99.998%.

A detailed interference analysis between this new link and an existing link that is licensed and operating in the environment, reveals a case of potentially harmful interference. The iQ.link$_{XG}$® analysis shown below demonstrates that against the required C/I objective of 23 dB only 19.12 dB is achieved—which means site B will experience 2.1 dB of degradation to its threshold and therefore to its fade margin.

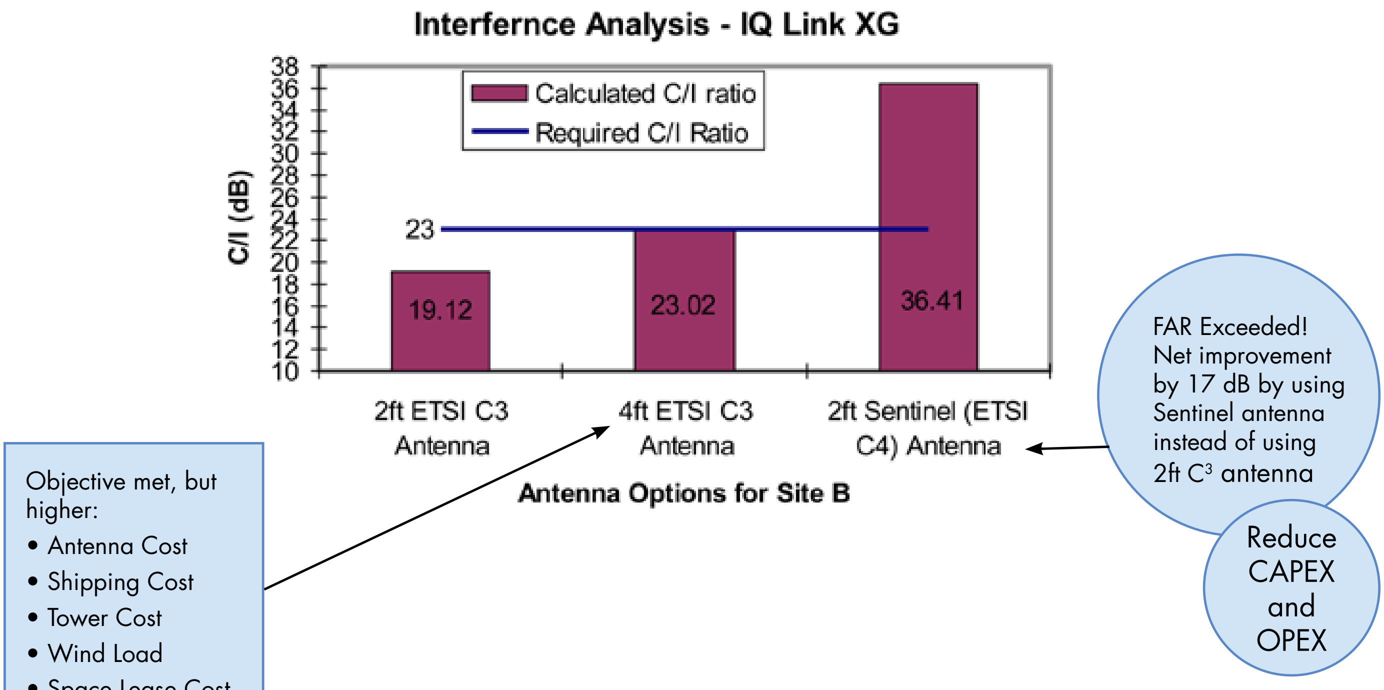


Figure 9: Sentinel's reduced size saves money while reducing interference concerns

Since this link was originally predicted to just barely meet the operator's reliability target, the interference loss is too costly and the operator decides on a traditional approach of upsizing to a 4 ft. (1.2 m) antenna at site B.

The operator licenses and builds the link with a larger 4 ft. (1.2 m) antenna at site B. The link performs adequately and meets the objective, as shown above in Figure 9, but only at the cost of significant OPEX penalties. Had the operator chosen a 2 ft. (0.6 m) Sentinel™ antenna instead, the same interference solution would have also resulted in significantly reduced, rather than increased, operational costs.

It would be very advantageous for an operator to avoid potentially harmful interference without resorting to older, larger antenna designs. Analysis clearly shows that Sentinel™ technology offers the operator some very significant advantages in both performance and total cost of ownership:

- Ability to use smaller antennas on existing links, where a bigger antenna was used to avoid harmful interference.
- Ability to use smaller antennas on new link designs, which would normally require a bigger antenna to avoid interference.
- Better protection of the link's fade margin, helping to future-proof the network.
- Save $2,400 on annual tower leasing costs per 0.6 m (2 ft.) Sentenel™ microwave antenna over a 1.2 m (4 ft) Class 3 option at $100 per ft, per month.

Conclusion 7

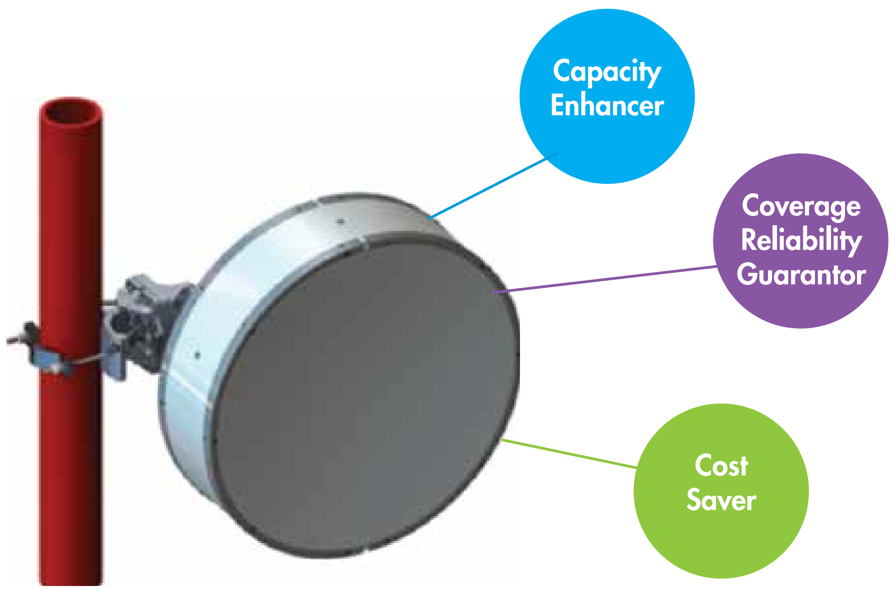
Smaller Sentinel antennas effectively combat interference while delivering massive CAPEX and OPEX savings.

Conclusion

Growing capacity demand means growing your network is a foregone conclusion. But expansion is more than an obligation of business—it's a chance to seize a real opportunity to boost performance while reducing costs. By future-proofing with Sentinel™ technology, a network is protected from demand surges that could otherwise cause major outages.

Spectrum availability is only getting tighter. Operators would be well advised to seek every opportunity to maximize the spectrum they currently have, because buying more is expensive—and soon, it may be impossible. Coverage is critical as well, since interference can bring a network to a grinding halt. And costs are a constant concern, both in deployment and in operation of networks across the globe.

For these three reasons—capacity, coverage and cost—Sentinel™ antennas from CommScope represent a key opportunity for operators to plan for the future of their networks while protecting both their capital and operating budgets.



Sentinel™ is a Global C^3 Antenna Solution to Today's Mobile Backhaul Crunch

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