Comments
in Response to
TRAI
Consultation Paper
On

Allocation and Pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF carriers
Dated: 28th March 2014
Consultation paper No: 02/2014

Date: 17th April 2014

COMMENTS OF COMMSCOPE - ANDREW SOLUTIONS

CommScope - Andrew Solutions hereby submits comments in response to Telecom Regulatory Authority of India , *Consultation paper on Allocation and pricing of Microwave Access (MWA) and Microwave Backbone (MWB) RF carriers 28th March 2014 No. 02/2014.*[1]

I. INTRODUCTION

The submission herein, although submitted under the name CommScope, was prepared by the divisions of Andrew Corporation that were acquired by CommScope Corporation in 2007. Andrew Corporation's brand, core skills and know-how has developed over 75 years, and in that period the company has been and still remains a worldwide market leader in the design, development and manufacture of point to point microwave antennas.

We then have a network of manufacturing plants around the world for microwave antennas, including in Goa, India. Over the years, more than 2 million CommScope microwave antennas have been installed in microwave networks globally with many of our early antennas still in operation.

The following submission takes in to account technical advances in antenna design, and provides suggestions for the efficient utilization of Microwave spectrum in India.

II. ROLE OF MW ANTENNAS IN BACKHAUL NETWORKS

The quality and capacity capability of carrier's networks are more important than ever before. There is a growing shift towards wireless broadband wireless services. Worldwide,

[1] http://www.trai.gov.in/WriteReadData/ConsultationPaper/Document/Consultation%20Paper_Final%2028-3-14.pdf

regulators are dealing with increasing demands for access to radio spectrum. Spectrum is a finite resource and its management is contingent on effective policies and efficient practices to optimize its utilization and facilitate equitable sharing among users. That relies on more than just the radio technology; it relies on the infrastructure to support the radio. In the wireless backhaul infrastructure, including Microwave Access (MWA) and Microwave Backbone (MWB), microwave (MW) antenna plays the most important role for the efficient utilization of spectrum and to overcome the challenges of interference.

The importance of MW antennas has often been overlooked and thought of as a component where concessions can be made and costs can be shaved, which allow low cost low quality product to enter into the networks. These low quality antennas not only degrade the performance of the network but waste spectrum, which is a precious national resource.

It is important to note that Microwave (MW) antennas have various characteristics, but the radiation pattern of a MW antenna is the most important characteristic for the efficient utilization of spectrum. The radiation pattern of an antenna tells how much energy is transmitted to or received from any direction. The radiation patterns constitute a main lobe and many side lobes. For point-to-point communication, wanted energy is received or transmitted through the main lobe, in bore sight direction, called carrier signal “C”; whereas the energy which is received or transmitted through side lobes is unwanted energy, called interference signal “I”. The C/I ratio (the amount of power in an RF carrier to the power of the interference that exists within the channel) plays an important role in wireless communication.

MW antennas, with low sidelobe levels allow efficient utilization of spectrum, since these antennas permit more number of links with minimum number of channels in any region.

The role of MW antennas in today's wireless networks cannot be ignored, regardless whether the spectrum is assigned as bulk or on a link by link basis. In General, when the spectrum is assigned on bulk basis, the user faces the main challenge to use the spectrum more efficiently; whereas in link by link basis assignment, it is a big challenge for the regulators to mitigate interference issues and use spectrum more efficiently. However, in either case, the basic challenge is to use a finite resource most efficiently.

The MW antennas with low sidelobe levels offers better C/I ratio, which allows better utilization of higher modulation schemes, hence the availability of higher capacity can be increased significantly by deploying low sidelobes MW antennas. Moreover, if a larger channel size is used to increase capacity, the demand for the efficient utilization of spectrum becomes greater. This use of low sidelobe antenna not only results in better customer experience but also increases revenue potential for the carriers.

The size of the antenna is decided based on the required receive signal level (RSL). In dense environments where high capacity is in demand to satisfy user needs, the carrier to interference (C/I) ratio is another parameter that dictates the size of the antenna. In some cases, larger sized antennas are used not because of RSL but to improve C/I. The larger antennas solve the problem in this regard but also increase CapEx and OpEx costs. Using low side lobe antennas allows operators to use relatively smaller size antennas even in dense and high capacity demand areas**.** The potential to use smaller MW antennas does not only reduce TCO but allows site sharing strategy implementation more efficiently.

Above points clearly indicate that there is a huge potential for low side lobe antennas to mitigate today's and tomorrow's microwave link challenges. Commscope – Andrew Solutions has done various case studies and published white papers to demonstrate these points, which are available in the public domain and submitted with these comments.

III. MW ANTENNAS – NEW TECHNOLOGIES

For efficient spectrum management, it becomes extremely important to explore new MW Antenna technologies when demand is expected to exceed supply.

The antenna standards used in Europe and adopted in many areas worldwide are derived by the European Telecommunication Standards Institute – ETSI, for point-to-point antennas as recently as 2010.[2]

As per ETSI standards, MW antennas are graded in four classes (class 1, 2, 3 & 4) based on their radiation patterns. ETSI class 1 is the most relaxed antenna class, whereas ETSI class 4 has extremely low sidelobes for efficient spectrum management. With the passage of time there has been (and will be) more radio links and consequently a growth in the likelihood of interference in urban and suburban settings. As a result, the ETSI Class 1 standard (worldwide) is not used from 3 to 86 GHz, and in interference potential or currently congested environment the choice of antenna by Operators has changed from ETSI Class 2 to mainly but not exclusively to Class 3. This trend is evolving further and now the market is looking for ETSI Class 4 solutions.

The ETSI Class 4 standard referenced herein, however, represents a new opportunity in spectrum conservation and has become relevant because of urban electrical congestion and the demand for more radio links. Recently realized low-cost production techniques that are available to all companies have made the production of ETSI Class 4 antennas economically feasible,

[2] *See* ETSI EN 302 217-4-2 V1.5.1 (2010-01).

whereas in the past, their cost was prohibitive. Similar comments have been proposed by CommScope to FCC on October 5, 2012.[3] in response to Second *Notice of Inquiry* issued by the Commission on August 3, 2012, in the WT Docket No 10-153 proceeding.[4]

IV. CHANGE OF MW ANTENNA STANDARDS FOR FIXED LINE–OF-SIGHT RADIO SYSTEMS

Spectrum efficiency is enhanced when more stringent antenna pattern characteristics are utilized as long as appropriate low-cost antenna solutions are available and provided. With the growth of electrical congestion in urban environments, new economic antenna models compliant to Class 4 are useful and are already appearing on the market.

CommScope - Andrew Solutions believes improved and consistent antenna standards to address problems such as these are appropriate and necessary and thus suggest TRAI for an initiative to encourage the use of low side lobe MW antennas, such as ETSI class 4 antennas, where technology already exists. This will ensure increased utilization and efficiencies of the radio spectrum for wireless backhaul systems. This proposal does not present an additional cost burden to the industry.

CommScope - Andrew Solutions and the vast majority of competing point-to-point antenna manufacturers design and specify antennas to meet ETSI standards for the worldwide market. Therefore we expect that other major antenna vendors should be well prepared to conform to the recommendations in this submission.

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[3] http://apps.fcc.gov/ecfs/document/view?id=7022029281

[4] Amendment of Part 101 of the Commission's Rules to Facilitate the Use of Microwave for Wireless Backhaul and Other Uses and to Provide Additional Flexibility to Broadcast Auxiliary Service and Operational Fixed Microwave Licenses, et al., *Second Report and Order, Second Further Notice of Proposed Rulemaking, Second Notice of Inquiry, Order on Reconsideration, and Memorandum Opinion and Order*, FCC 12-87, 27 FCC Rcd 9735 (2012).

V. SUMMARY AND CONCLUSION

CommScope - Andrew Solutions hopes that the TRAI consultation paper will prompt stakeholders to engage in a meaningful review of the antenna standards and the importance of MW antenna quality for fixed Line-of-sight radio systems, and that the information submitted in this filing will facilitate the discussion. CommScope - Andrew Solutions believes that TRAI policies should encourage the use of higher performance antennas when they are available.

In summary we are advocating the use of low side lobe MW antennas for MWA and MWB in different frequency bands, to help the industry cope with the arrival of congestion and to allow the implementation of more radio links per unit area and meet the objectives of efficient utilization of spectrum.

CommScope - Andrew Solutions intends to continue to work with the industry to assist TRAI to develop effective rules based on the record that is generated in this paper.

Respectfully submitted,

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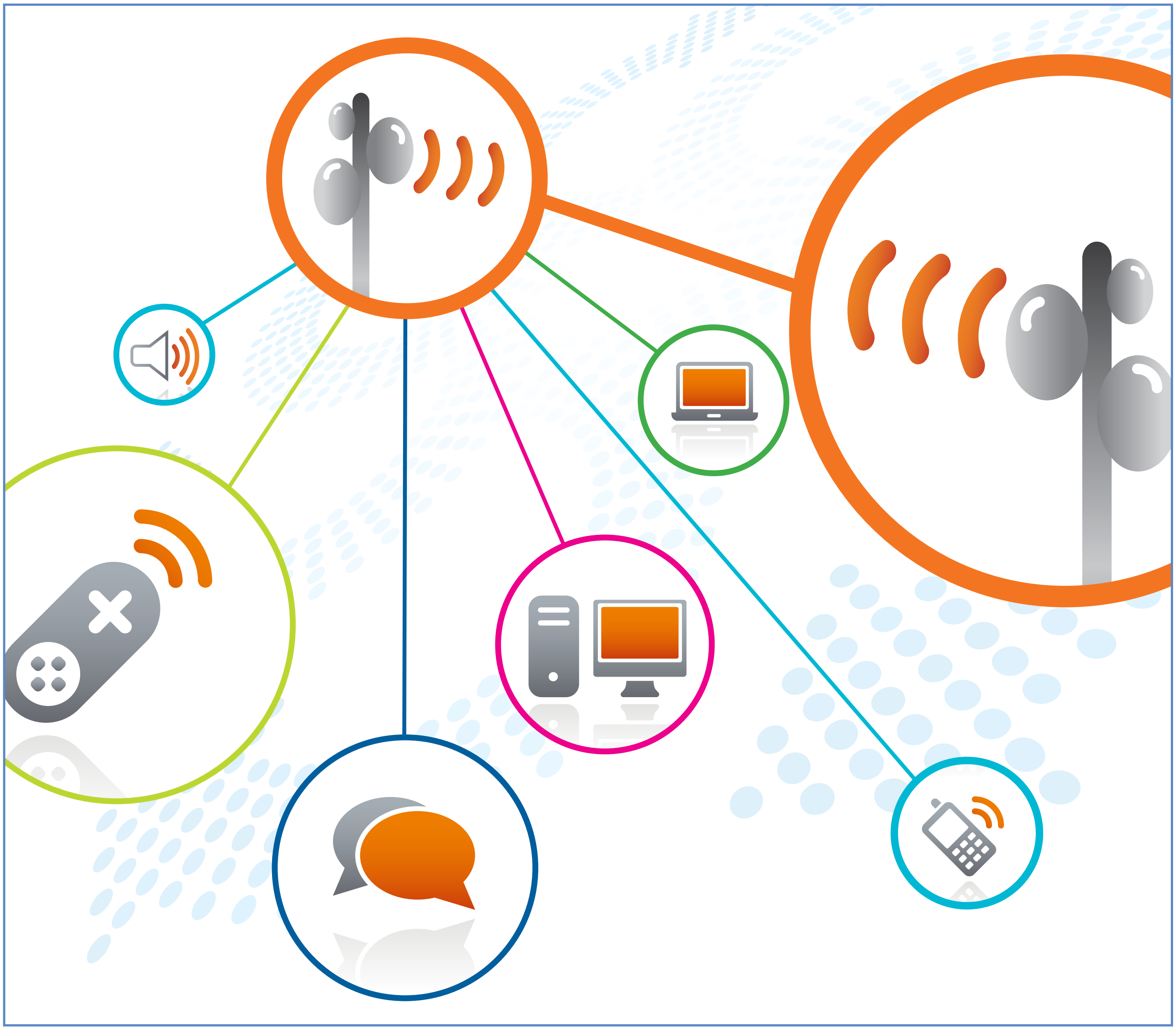
Appendix

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 **C³ solutions** (Fig. 1).

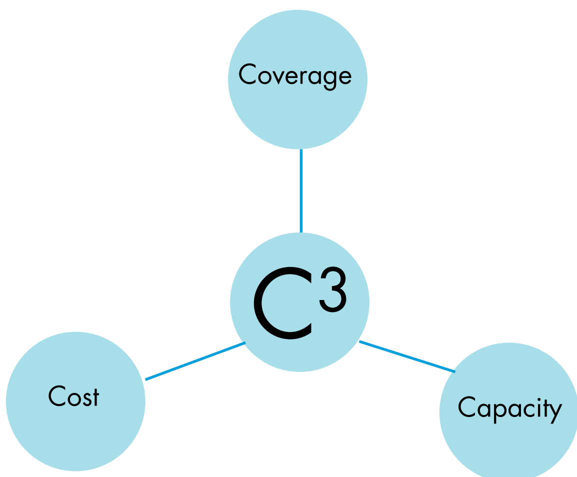


Figure 1: Today's stakeholder challenges

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).

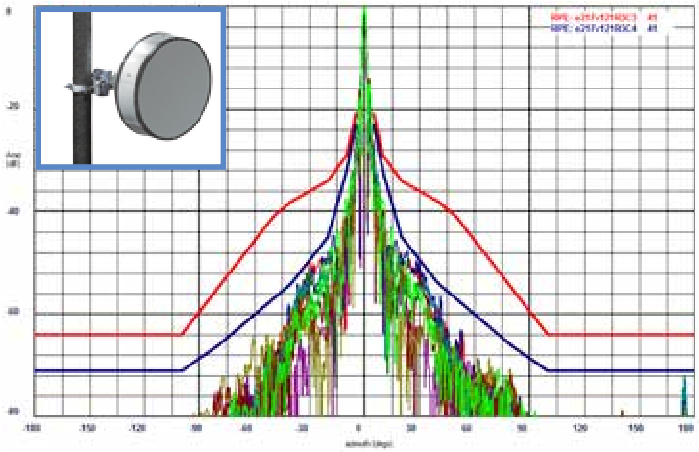


Figure 2: Sentinel™—an antenna solution with extremely low sidelobes

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:

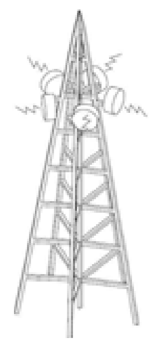
Sentinel's high C/I ratio enhances capacity in both conventional and ACM networks.

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).

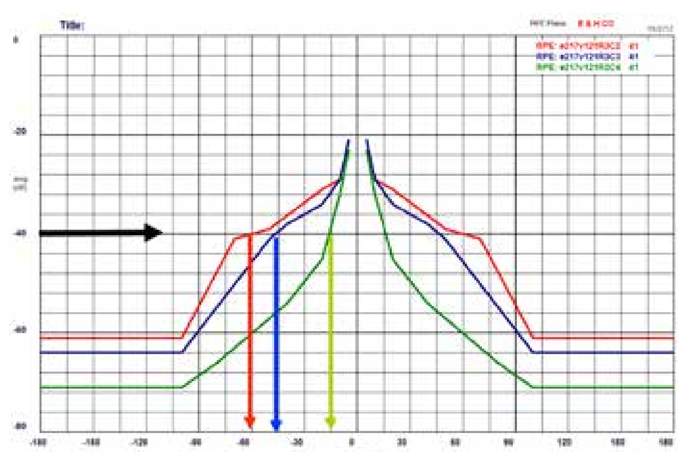


Figure 4: Example of antenna RPEs with different ETSI classifications

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.

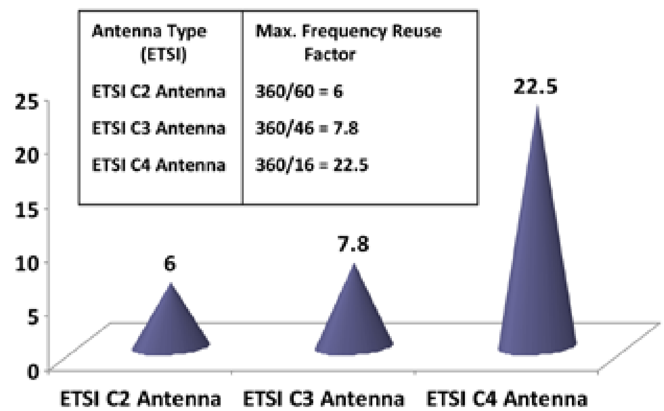


Figure 5: Example of maximum frequency reuse factor, demonstrating large potential cost savings

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).

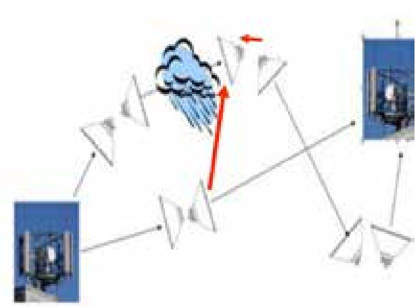


Figure 6: Link outages due to fading

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.

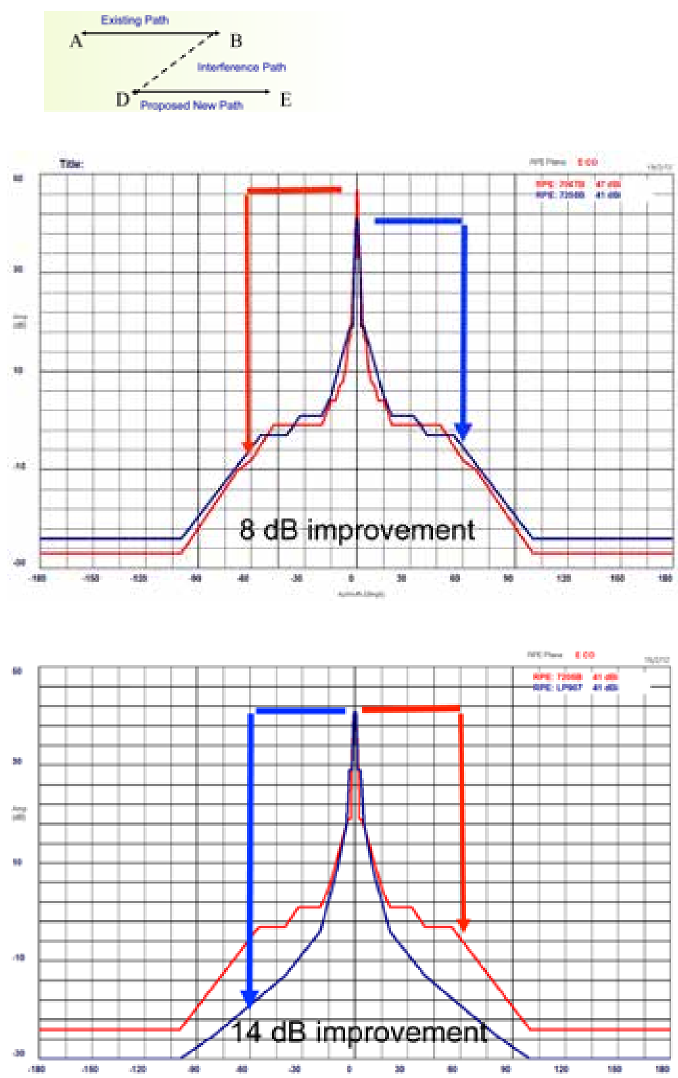
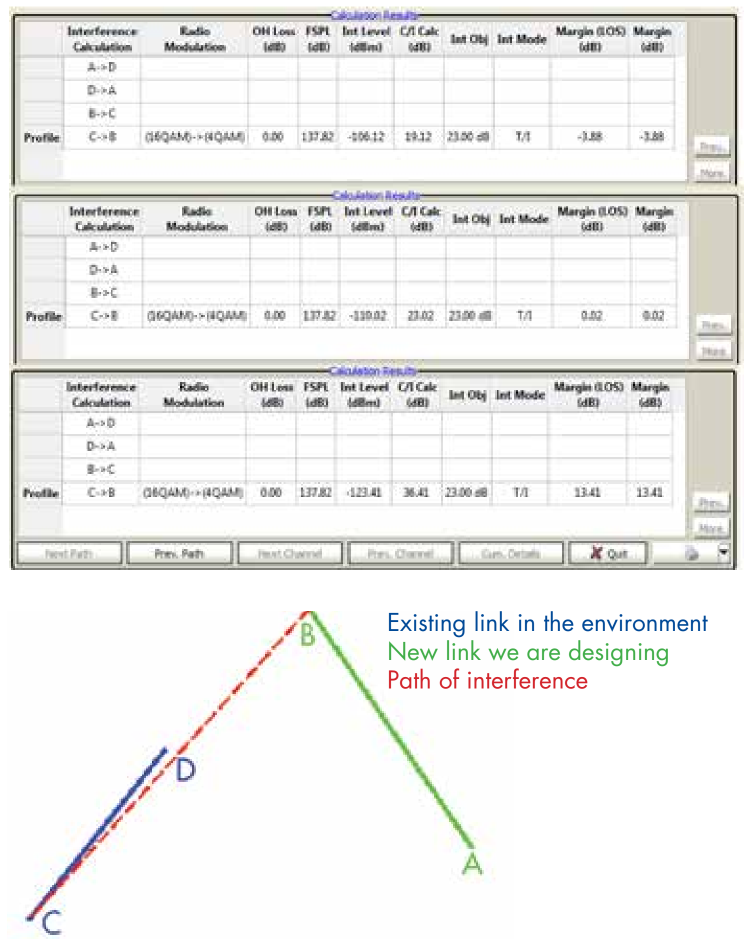


Figure 7: Example of the greater C/I ratio improvement with smaller Sentinel™ antenna instead of larger Class 3 option

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$_{XG}$®.



	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

	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

	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

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.

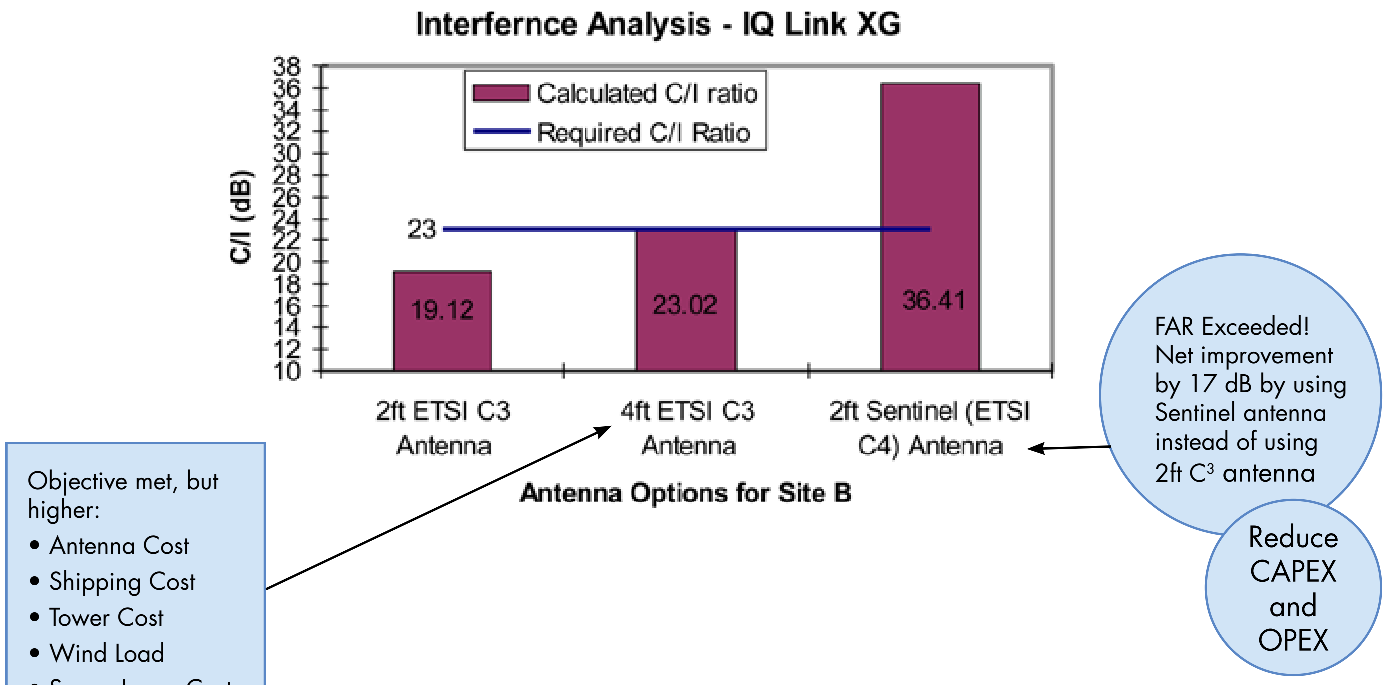


Figure 9: Sentinel's reduced size saves money while reducing interference concerns

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

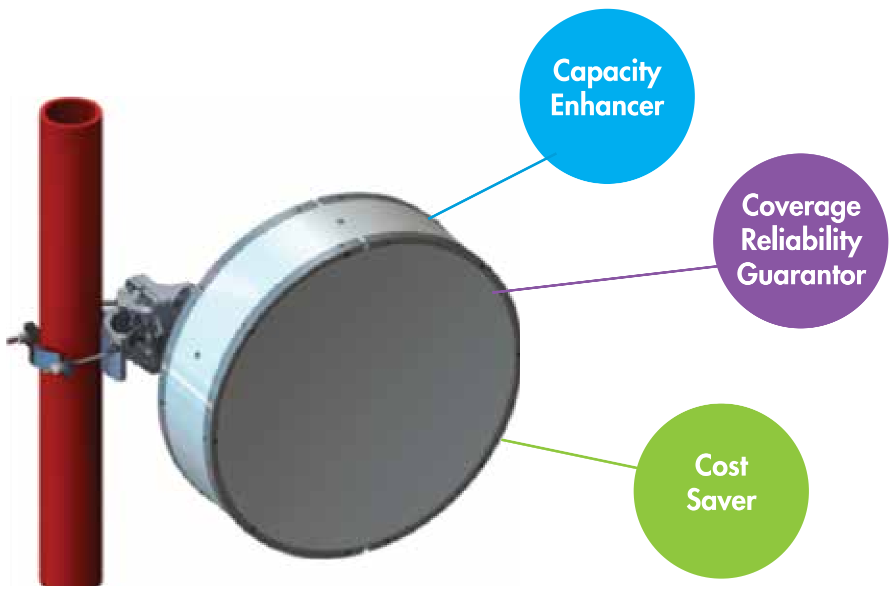
Smaller Sentinel antennas effectively combat interference while delivering massive CAPEX and OPEX savings.

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 C³ Antenna Solution to Today's Mobile Backhaul Crunch

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WP-105696.2-EN (4/13)

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White Paper

Innovation in Backhaul Antenna Technology to Deliver Higher Capacity Through Spectral Efficiency

Dipesh Rattan, Product Line Manager, CommScope
Joe Marzin, Technical Director, Comsearch
November, 2013

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Contents

Executive summary

Recent advances in microwave antenna engineering—together with enhancements in manufacturing processes—have allowed new high-performance (very low side lobe) point-to-point antennas to be offered at economic prices. The antennas reviewed in this paper are the European Telecommunications Standards Institute (ETSI) Class 4 compliant Andrew Solutions® Sentinel® antennas.

This paper describes options for network operators to achieve capacity, quality of service (QoS) and total cost of ownership (TCO) improvements. The improvements can be dramatic.

Described herein is a 1048-link (2096-antenna), 38GHz, well-designed network that can realize more than 14 percent improvement in traffic loss (outages) by simply swapping existing Class 3 antennas for Andrew Solutions Sentinel Class 4 antennas. The swap resulted in improvements in every radio link.

The financial payback described is due to availability (network outage) improvements and depends on the value of traffic, among other factors. The result, over five years, shows a potential €2,566,000 financial benefit to the operator. The incremental investment in Sentinel could be recovered in 28 weeks.

However, it is believed that if the network had been designed with Sentinel Class 4 antennas from the start, the capacity per geographic area, the backhaul pipe size, the tower lease savings and the QoS dividends would substantially eclipse the financial benefit resulting from improved network availability.

There are various ways to optimize a network to achieve payback from Sentinel antennas. This work has been done to provoke thought and discussion, encouraging network operators to realize the potential benefits available from a new breakthrough in antenna technology.

Preamble

Since 2012, several networks have been deployed using CommScope's Sentinel microwave antennas. These antennas are fully compliant with ETSI Class 4 standards—they have dramatically lower side lobes than ETSI Class 3 antennas.

The importance of antenna side lobes in a point-to-point radio link is increasing. As interference in a network grows, capacity per geographic area drops. Good antennas protect from interference because their low side lobes provide immunity to the interference. Therefore, they increase backhaul link and network design capacity.

Sentinel antennas can deliver a variety of benefits to the microwave backhaul network, as follows:

1. Sentinel antennas save backhaul spectrum, improving operator income because they:
   a. Increase network availability
   b. Enhance throughput per radio link
   c. Enhance design capacity
   d. Improve network performance
   e. Potentially reduce subscriber churn

2. Sentinel antennas offer the operator a chance to use smaller-diameter antennas, resulting in:
   a. Savings on antenna spend (overall price paid)
   b. Savings on logistics
   c. Savings on installation cost
   d. Savings on tower lease charges

3. Sentinel antennas help future-proof spectrum. As the operator needs more microwave links, the spectrum is clean and allows for expansion.
4. In areas where interference sources are unknown or unquantified, Sentinel antennas offer a new remedy to link and/or network problems.
5. Sentinel antennas allow the operator to increase the size of backhaul pipe by improving the carrier-to-interference (C/I) ratio.

Introduction—a real network case study

Together with Comsearch®, CommScope conducted a study comparing Sentinel ETSI Class 4 antennas with Class 3 antennas of equal size and frequency and assessed their respective impact on network throughput and backhaul design capacity.

This study looked at a portion of a well-designed mobile network in Hungary, analyzing 1,048 microwave backhaul links, the operating frequency bands, and the radio equipment deployed.

The analysis was focused on dense urban areas using the 38GHz frequency band with full IP radio equipment with adaptive coding and modulation (ACM).[1]

In basic terms, the network performance (throughput) was analyzed with the existing radio equipment and 38GHz Class 3 antennas. The antennas were then simply swapped for Andrew Solutions Sentinel antennas. Nothing else was changed.

Network analysis: objective and background

The objective of the study was to examine whether Andrew Solutions Sentinel antennas would reduce network interference levels and, consequently, improve availability and throughput for link traffic.

Decrease in the fade margin of microwave links—caused by threshold degradation due to internal and external interference sources—leads to an increase in network unavailability and lost traffic.

This lost traffic may result in two unwanted effects for the operator:

- The direct effect, where lost traffic simply translates to a loss of possible revenue for data transmission
- The indirect effect of a negative impact on customer satisfaction that could result in subscriber churn, again impacting the revenue of the operator—in other words, low QoS

Hence, the interference (low C/I ratio) reduces capacity of the network and lowers QoS.

Sentinel antennas exceed the requirements of ETSI Class 4 specifications, which are denoted by the blue line in the graph below.

[1] All data used in the course of the study is available upon request from the National Media and Infocommunications Authority.

The multicolored lines are the measured performance of the Andrew Solutions Sentinel antennas at 37GHz, 38.5GHz and 40.0GHz.

The low side lobes, as shown below, diminish the risk of interference to the microwave link.

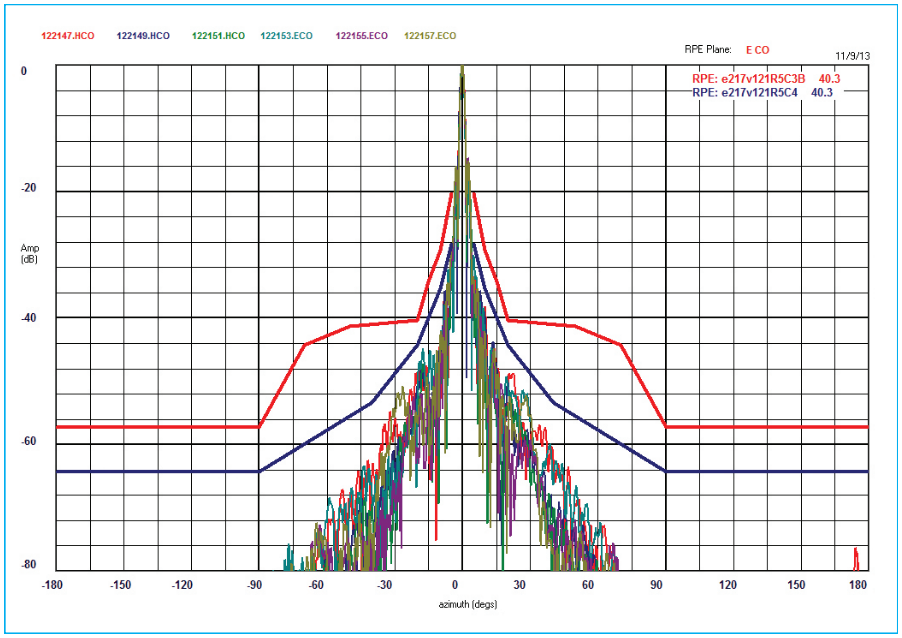


Figure 1: ETSI Class 4 radiation pattern envelope and measurements for a 38GHz Sentinel antenna

The approach

In the microwave backhaul network under examination, the following factors led to tight channel re-use and high interference:

- Limited spectrum available to the mobile operator
- Strict spectrum management requirements
- High density of links within the network

These factors are, by no means, unique to this particular network and reflect the typical environment in which networks around the world have to operate.

It is emphasized that the only change made to the network was to remove the Class 3 antennas and replace them with a Class 4 Sentinel antenna of the same size and frequency.

The modulation index of each link was noted:

- Ranging from 4 QAM to 256 QAM (in this network)
- The Class 3 links were analyzed in an unfaded state (the ETSI term is "nominal mode of links")
- Keep in mind: a radio will naturally rise up to the fastest data rate (modulation index) as a function of interference (an opportunity for more traffic potential—see "Future work" section below)

Comsearch's iQ.link® XG, an industry-leading microwave planning and optimization tool, was used to model and analyze the network.

Methodology

The below steps were carried out on iQ.link® XG for analysis of this network data:

1. The engineering reference on every microwave radio was set to the highest order modulation scheme allowed on the links.
2. An interference check was performed on the original network (using Class 3 antennas) to batch calculate the cumulative threshold degradation (TD). As stated earlier, this is caused by network interference (low C/I ratio).
3. The link unavailability/outage was then calculated, highlighting the effect of decreased fade margin on link availability.
4. The existing ETSI Class 3 antennas were then replaced with Andrew Solutions Sentinel ETSI Class 4 antennas as follows:

Original ETSI Class antennas			Sentinel ETSI Class 4 antennas			
Frequency band	Diameter	Polarization	Type	Frequency band	Diameter	Polarization
38 GHz	0.3 m / 1 ft.	Single	SHP1-38	38 GHz	0.3 m / 1 ft.	Single
38 GHz	0.3 m / 1 ft.	Dual	SHPX1-38	38 GHz	0.3 m / 1 ft.	Dual
38 GHz	0.6 m / 2 ft.	Single	SHP2-38	38 GHz	0.6 m / 2 ft.	Single
38 GHz	0.6 m / 2 ft.	Dual	SHPX2-38	38 GHz	0.6 m / 2 ft.	Dual

5. The interference check was then repeated on the revised network, calculating the cumulative TD due to the network interference.
6. The link unavailability/outage on the network with Sentinel antennas was then calculated, and the results were compared against those recorded with the ETSI Class 3 antennas.

Threshold degradation results

Threshold degradation measures a reduction of fade margin on a link and, thus, corresponds to a decline in the link data rate. The threshold of the ACM shift point was used to calculate the fade margin of the highest modulation.

Table 1 shows the number of links and the distribution of TD in the receivers before and after the Sentinel antenna implementation.

Threshold degradation (TD)	Before antenna swap # of radios (receivers)	After Sentinel antenna swap # of radios (receivers)
0 dB, no interference cases	1584	1776
0 < TD ≤ 0.4 dB	285	214
0.4 < TD ≤ 1 dB	105	42
1 < TD ≤ 2 dB	53	30
2 < TD ≤ 3 dB	21	10
3 < TD ≤ 5 dB	22	8
5 < TD ≤ 10 dB	20	13
TD > 10 dB	6	3

Table 1

- The total number of receivers with no interference increased from 1584 to 1776 when replaced by Sentinel antennas
- The number of receivers with TD between 0 dB and 0.4 dB decreased from 285 to 214
- The number of receivers with TD between 0.4 dB and 1.0 dB decreased from 105 to 42
- The number of receivers with TD between 1.0 dB and 2.0 dB decreased from 53 to 30

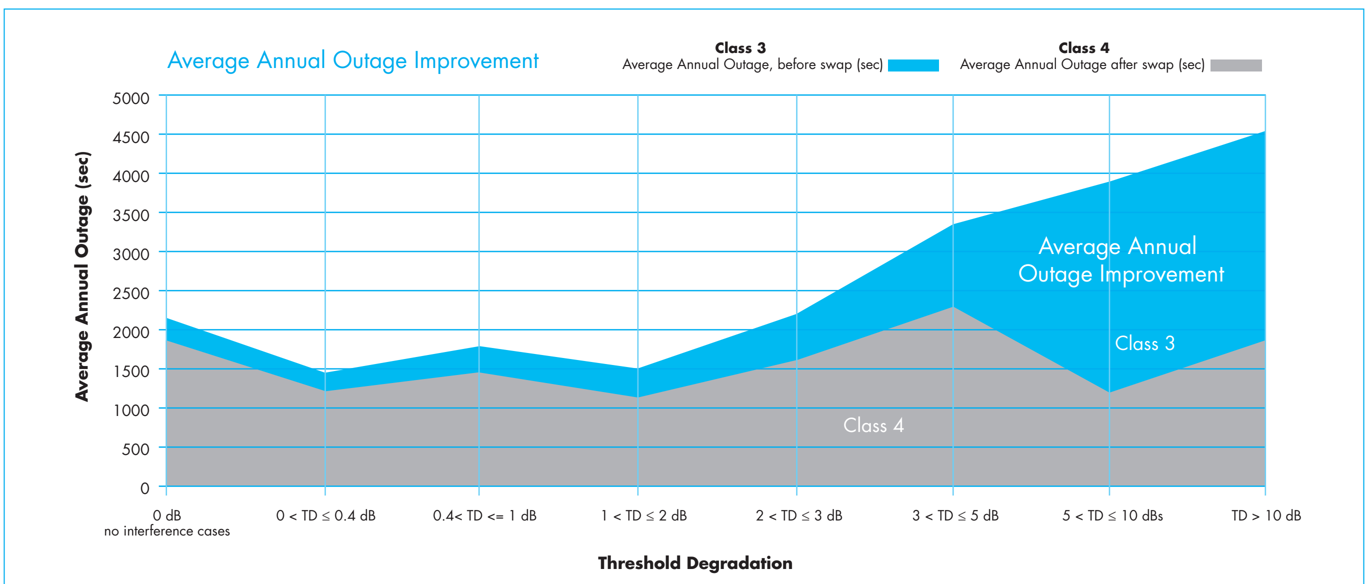
Table 2 summarizes the TD from both ends of the links and the average outage improvement per year after the Sentinel antenna implementation.

The annual outage is defined as the time that the radio operates below the design capacity level in a time period of 12 months (e.g. 99.999%).

Sum of threshold degradations (TD)	Average annual outage before swap, seconds	Average annual outage after swap, seconds	Average annual outage improvement, seconds
0 dB, no interference cases	2124.69 s	1868.99 s	255.7 s
0 < TD ≤ 0.4 dB	1458.22 s	1215.01 s	243.2 s
0.4 < TD ≤ 1 dB	1790.85 s	1461.49 s	329.4 s
1 < TD ≤ 2 dB	1507.64 s	1125.34 s	382.3 s
2 < TD ≤ 3 dB	2194.83 s	1598.78 s	596.0 s
3 < TD ≤ 5 dB	3350.50 s	2293.90 s	1056.6 s
5 < TD ≤ 10 dB	3890.36 s	1179.91 s	2710.4 s
TD > 10 dB	4562.34 s	1880.54 s	2681.8 s

Table 2

In this network, the antenna change to Sentinel led to a significant improvement in link availability. Note that the outage seconds reduced more for higher TD values (shown in Figure 2 below).



Average Annual Outage Improvement (sec)							
0 dB, no interference cases	0 < TD ≤ 0.4 dB	0.4< TD <= 1 dB	1 < TD ≤ 2 dB	2 < TD ≤ 3 dB	3 < TD ≤ 5 dB	5 < TD ≤ 10 dB	TD > 10 dB
255.7 s	243.2 s	329.4 s	382.3 s	596.0 s	1056.6 s	2710.4 s	2681.8 s

Figure 2: average annual outage improvement with Sentinel

Result—qualitative

1. Deploying ETSI Class 4 antennas resulted in improved TD in the links (due to significant reduction in the interference) compared to the existing Class 3 antennas.
2. This led to increased fade margins, causing a direct improvement in the outage seconds (of a particular modulation).
3. This provides increased link availability and allows the operator to maximize the size of backhaul pipe available from the existing radios.

Result—backhaul capacity gain

With an increase in network availability, the backhaul design capacity increased.

Table 3 below shows the percentage gain in design traffic for the number of microwave links after the Sentinel antenna swap.

Design traffic gained (TG)	Number of links
0 ≤ TG ≤ 5 %	132
5 < TG ≤ 10 %	148
10 < TG ≤ 15 %	425
15 < TG ≤ 20 %	212
20 < TG ≤ 30 %	71
30 < TG ≤ 50 %	32
50 < TG ≤ 80 %	15
80 < TG ≤ 100 %	13

Table 3

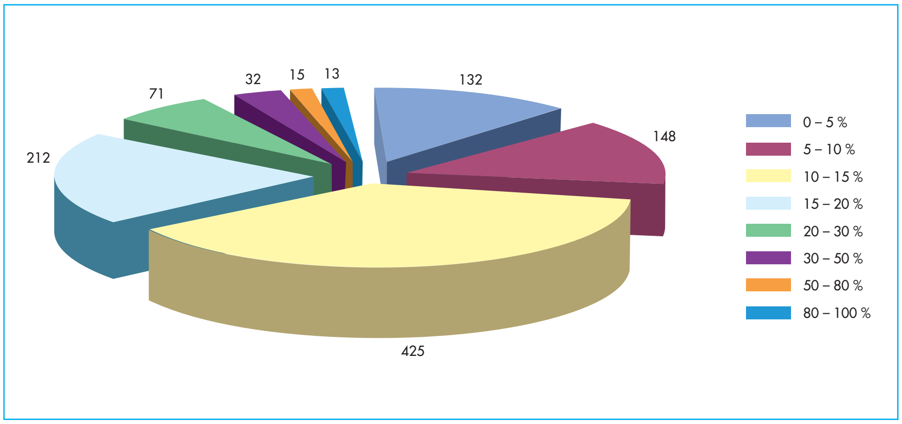
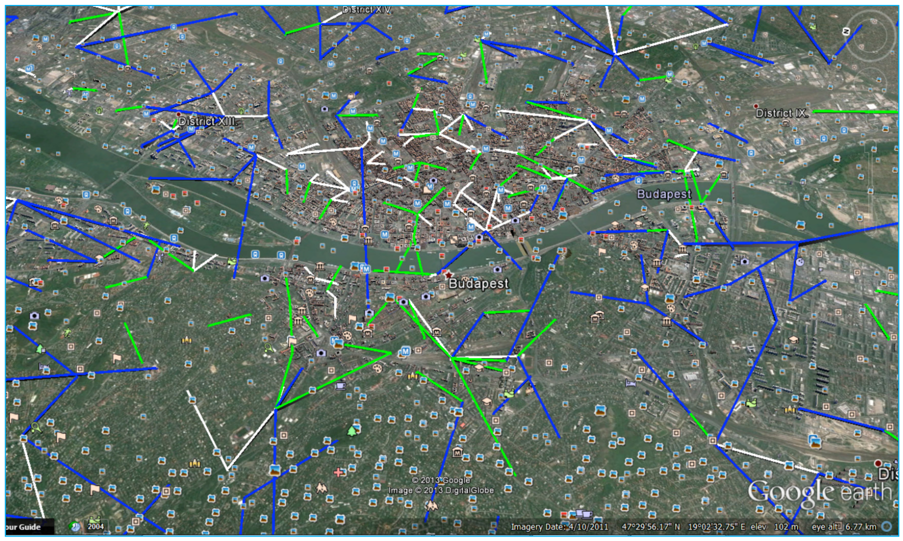


Figure 3: improvement on every link

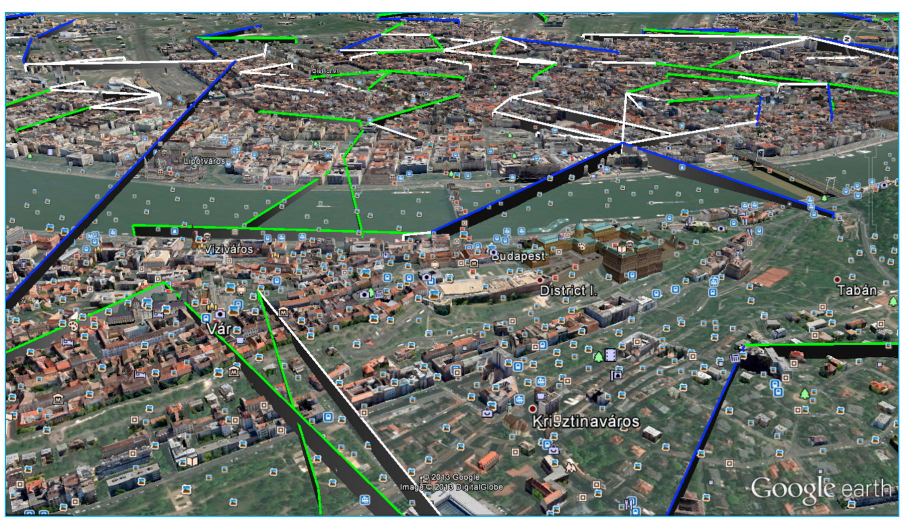
Result—Google Earth images

The images below show design traffic gain on microwave links using ETSI Class 4 antennas overlaid on a Google Earth map of Budapest, Hungary.

Category	% range of design traffic gain	Legend
1	0 ≤ TG ≤ 5 %	
2	5 < TG ≤ 20 %	
3	20 < TG ≤ 100 %	



In this network, 75 percent of the links showed a design traffic improvement from 5 to 20 percent. 11 percent of the total links showed traffic gain between 20 and 100 percent with Sentinel, and some links even doubled the traffic for which they had been designed.



Annual gain in backhaul traffic with Sentinel—improvement in QoS

The key benefit of any improvement in the network performance is in the actual throughput and design capacity. As the numbers below reveal (Table 4), the Sentinel antennas led to a demonstrable gain in the design capacity on a microwave backhaul network.

The increase in time spent at the design capacity would be the outage improvement percentage of each TD category, weighted by the fraction of receivers in each category, and summed across all categories.

14.36 percent is an increase in the time spent at "design capacity" from the Table 1 and Table 2 values (above).

Average link throughput:	75.36 Mbit/s
Total network throughput:	78.98 Gbit/s

Annual average link traffic lost before swap	191.290 Gbit/link
Annual average link traffic lost after swap	163.820 Gbit/link
Annual average link traffic gained after swap	**+27.47 Gbit/link**

Annual total network traffic lost before swap	200.472 Tbit
Annual total network traffic lost after swap	171.684 Tbit
Annual total network traffic gained after swap	**+28.79 Tbit**
Annual total network traffic percentage gain after swap	**+14.36% (relative to Class 3 lost traffic)**

Table 4

The gain in backhaul design traffic may be trivial; however, the backhaul network with Class 3 antennas is well designed and its outage performance (at a particular modulation) still improves with Sentinel antennas. Therefore, there is a benefit to QoS.

The gain in design traffic and an improvement in QoS are likely to be much higher for a troublesome network.

Return on investment estimates with Andrew Solutions Sentinel antennas—economies for the operator

The Class 3 antennas cost €300 each, on average. The Class 4 antennas cost €450 each, on average. So the difference in cost of a same-size antenna is €150. That's 2096 antennas x €150 = €314,000 of additional one-time spend for Sentinel investment.

Swapping out Class 3 for Class 4 antennas gave a small design traffic gain per year, which translates into a potential 27.47Gb/link/year average, as stated in Table 4 above.

Assuming each Gbit costs €20 for the operator, this equals €576,000 of income (27.47 x 1048 x 20) in Year 1 (assuming 100 percent network utilization). Hence, the payback period for the incremental Sentinel investment will be 28 weeks (314k/576k x 52) at €20/Gbit (assuming 100 percent network utilization).

The five-year return potential will be €2,566,000 ((€576,000 x 5) - €314,000) at 100 percent network utilization.

Clearly, assumptions were used in developing the financial aspects of this case study. The traffic gain is a very subjective way to justify changing a network from Class 3 to Class 4 antennas and will draw a lot of discussion. The densification of links (capacity) is a better route to illustrating Class 4 traffic advantages.

Future work

The microwave backhaul network could be designed with Sentinel Class 4 antennas from the start. This would allow the C/I benefit of Class 4 antennas to enable larger backhaul pipes, i.e. more traffic potential.

The potential traffic gain with Sentinel Class 4 antennas could be further examined by generating the entire data set of time predicted to be spent at each ACM level for each link, both for the original design and after swapping the antennas. Then, the predicted link and network traffic lost and gained could be determined explicitly from the data.

Alternatively, the microwave backhaul network could be redesigned with Sentinel, allowing the C/I benefit to enable the use of smaller antennas. To get the same or better link throughput as Class 3, the Class 4 antennas could be, on average, smaller in diameter. Therefore, installation time and cost would be less; warehousing and freight bills should decrease; and tower lease charges would drop due to smaller antennas. This would result in substantial cost savings for the operator.

For some operators, QoS improvements may be the area for focus where they could look at improving the link availability through the deployment of Sentinel antennas.

Conclusion

Recent advances in microwave antenna engineering and manufacturing have allowed new high-performance (very low side lobe) point-to-point antennas to become available at price points that permit their use in the mainstream of network design rather than consigning them to their historical niche roles. The antennas evaluated in this paper are the ETSI Class 4 compliant Andrew Solutions Sentinel antennas.

This paper has shown, through the use of a case study on an existing network, that network operators can achieve substantial capacity, QoS and TCO improvements.

A potential financial return over five years of €2,566,000 based on availability improvement has been shown with a potential recovery of the initial investment in Sentinel antennas of 28 weeks. It has also been demonstrated that, if a network was designed using Sentinel Class 4 antennas from the outset, even greater benefits could be realized in terms of network density, tower lease savings and QoS.

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