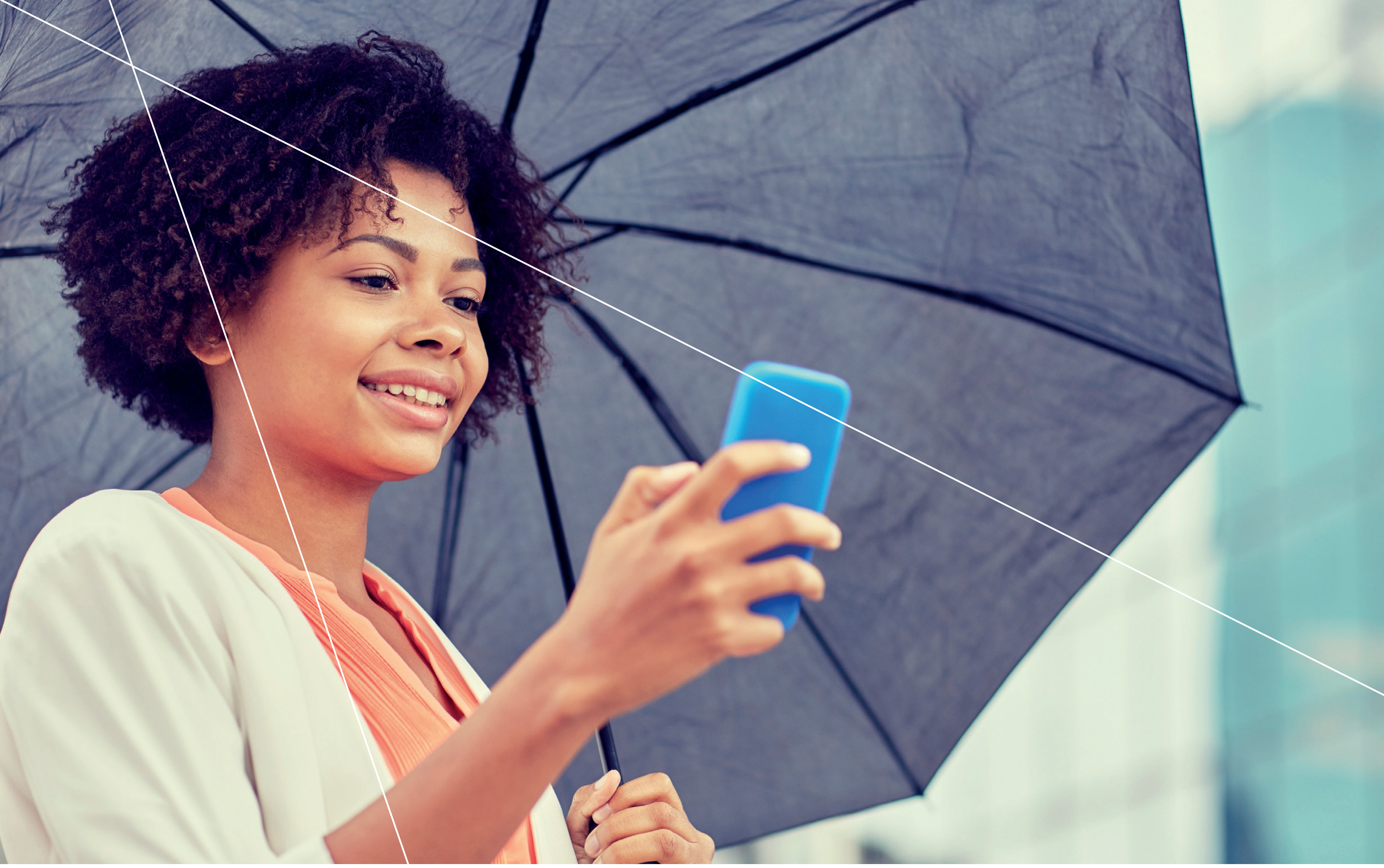

A CTO'S GUIDE TO RAIN FADE

SES Networks' O3b MEO solution delivers resilient, redundant broadband internet anywhere

Communications executives tasked with making network technology decisions are extremely busy, yet keeping up with the latest innovations in wireless technologies is imperative. Otherwise their network's performance will suffer and costs will be higher than they should be.

When a CTO/CIO is tasked with building out or upgrading a communications infrastructure, it is important that he or she understands the capabilities and limitations of available options. An analysis of available choices should be undertaken in the most objective manner possible to determine which will best meet network performance, availability and scalability requirements. This can be challenging in very rainy areas since heavy rain can cause attenuation to signals. Communications innovations have been dramatic over just the last few years. It's difficult to keep up with the state-of-the-art in every single technology, but there have been some major paradigm shifts in satellite capabilities in just the last three years, the most significant of which is found in SES Networks' O3b constellation.

SES Networks' O3b Medium Earth Orbit (MEO) satellite solutions have a long list of advantages over other technologies: rapid deployment, high reliability, low capital outlay, low operating costs, low latency and very high throughput. A limitation specifically affecting customers in regions prone to extreme rain events is that the Ka-band frequency — which enables much higher data transfer rates than C or Ku-bands to the same antenna size — is more susceptible to signal attenuation, known as "rain fade".

Rain fade occurs mostly in the ITU-defined "Rain Zone P" which receives the heaviest rainfalls. SES Networks has several customers in ITU Zone P, and has analysed the data to learn how rain affects customer connectivity in worst-case, real-world environments.

SES Networks

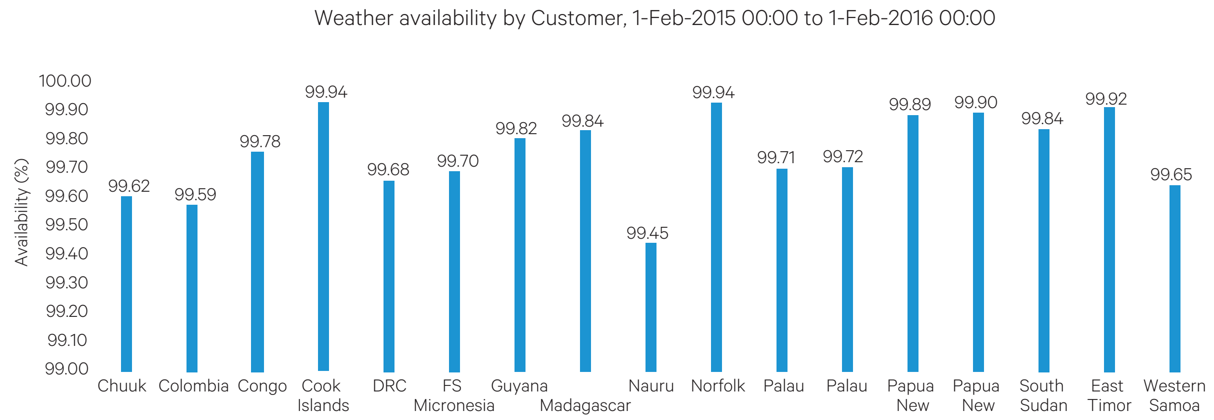

Table 1
Weather Availability, February 2015 - February 2016

COMPARISONS

To illustrate the differences in these technologies, imagine an operator on an island nation in Zone P:

Fiber: If the operator elects to run an undersea fiber cable from a nearby island, the first difficulties would be the permitting process within their own country, and working through the bureaucracy of the neighbouring country, taking over a year. Once the project is approved, installing the equipment and laying the fiber takes substantially more time, and the cost is substantial. However, once the fiber is installed, the operator is able to offer customers high speed broadband and 4G/LTE mobile services. In general, the connectivity would be unaffected by rain unless there is flooding or mudslides that impact the equipment.

Geosynchronous Satellites: If the operator instead decides to use a geostationary satellite (GEO) solution, the first benefit it would see is the speed at which the connectivity could be up and running. The cost of the antenna is far lower than for microwave or fiber, and the time needed to set up the customer's terminal is minimal. C-band is most commonly used by GEO satellites. The use of C-band, as well as the latency created by the altitude of the satellites, diminishes the performance of the connection. GEO C-band connectivity yields sub-broadband internet speeds, and at best 2G mobile service. However, the C-band frequency experiences little signal attenuation during heavy rain storms.

SES Networks O3b MEO: Finally, the operator that chooses to connect through the O3b satellite system gets the benefits of fiber performance, but without the expense of laying an undersea cable. As with any satellite service the infrastructure cost is relatively inexpensive, and the time to go live is extremely fast. Once the O3b connection is live, an operator is able to provide its customers with high-speed broadband access and 4G/LTE mobile service — just as if it had invested in a terrestrial fiber buildout. The trade-off the customer makes — especially if it is geographically located where there are intense rain events — is that from time to time the heavy rains could affect the connection.

	Fiber	GEO	O3b
Deployment	Slow	Fast	Fast
Reliable	Mod	High	High
CAPEX	Very High	Low/Mod	Low
OPEX	Low	Mod/High	Low
Latency	Low	High	Low
Throughput	High	Low	High
Adaptability	Low	High	High
Rain Fade (ITU zone P)	N/A	Low	Mod
3G/4G Capable	Yes	No	Yes

Table 2
Strength and Weaknesses of Primary Options

TIME TO MARKET & CAPEX

Satellite solutions are faster to deploy than terrestrial fiber in time to market. While the process of zoning, trenching, and laying fiber — either on land or across the ocean floor — takes substantial time, the process for getting high speed connectivity up over an in-orbit satellite is extremely fast. Once a terminal has been set up, connectivity can be flowing the same day.

Additionally, the only capital expense (CAPEX) required is for the terminal hardware itself. In every case, whether laying long-haul or short-haul fiber, the buildout cost for satellite communications is many magnitudes lower. To further reduce upfront costs, operators can also opt for a fully managed service that includes the terminal hardware.

SATELLITE RELIABILITY

An entirely terrestrial infrastructure

is more vulnerable to both natural and man-made incidents which can affect performance. Multi-orbit, multi-band satellite systems are extremely reliable and resilient in comparison to connections that are exclusively terrestrial.

A water main break, fire, ice storm, bridge collapse or war does not disrupt a satellite's function. Any of these occurrences, however, can affect a terrestrial-based network. For terrestrial services, network outages can occur at any point along the infrastructure.

As a satellite network consists of a satellite, teleport, Network Operations Center (NOC) and customer terminals, the opportunities for prolonged network outages are generally limited to those components on the ground, and thus are significantly reduced. The O3b satellite constellation itself is designed with multiple backup systems and layers of redundancy, resulting in high reliability and performance.

THE EFFECT OF RAIN ON WIRELESS COMMUNICATIONS

Rain fade is attenuation of wireless communication signals as a result of rain or ice droplets whose separation approximates the signal wavelengths. The phenomenon can affect satellite data connection quality as well as satellite television and other systems. Most satellite communication takes place in the microwave portion of the electromagnetic radiation spectrum (Figure 1). Signals at these wavelengths are affected by heavy concentrations of water droplets or ice crystals in the atmosphere. When the mean distance between water droplets or crystals is comparable to the wavelength of the electromagnetic signals, attenuation can occur. The observed effect is a degradation or loss of communications during heavy downpours, snow squalls, and blizzards.

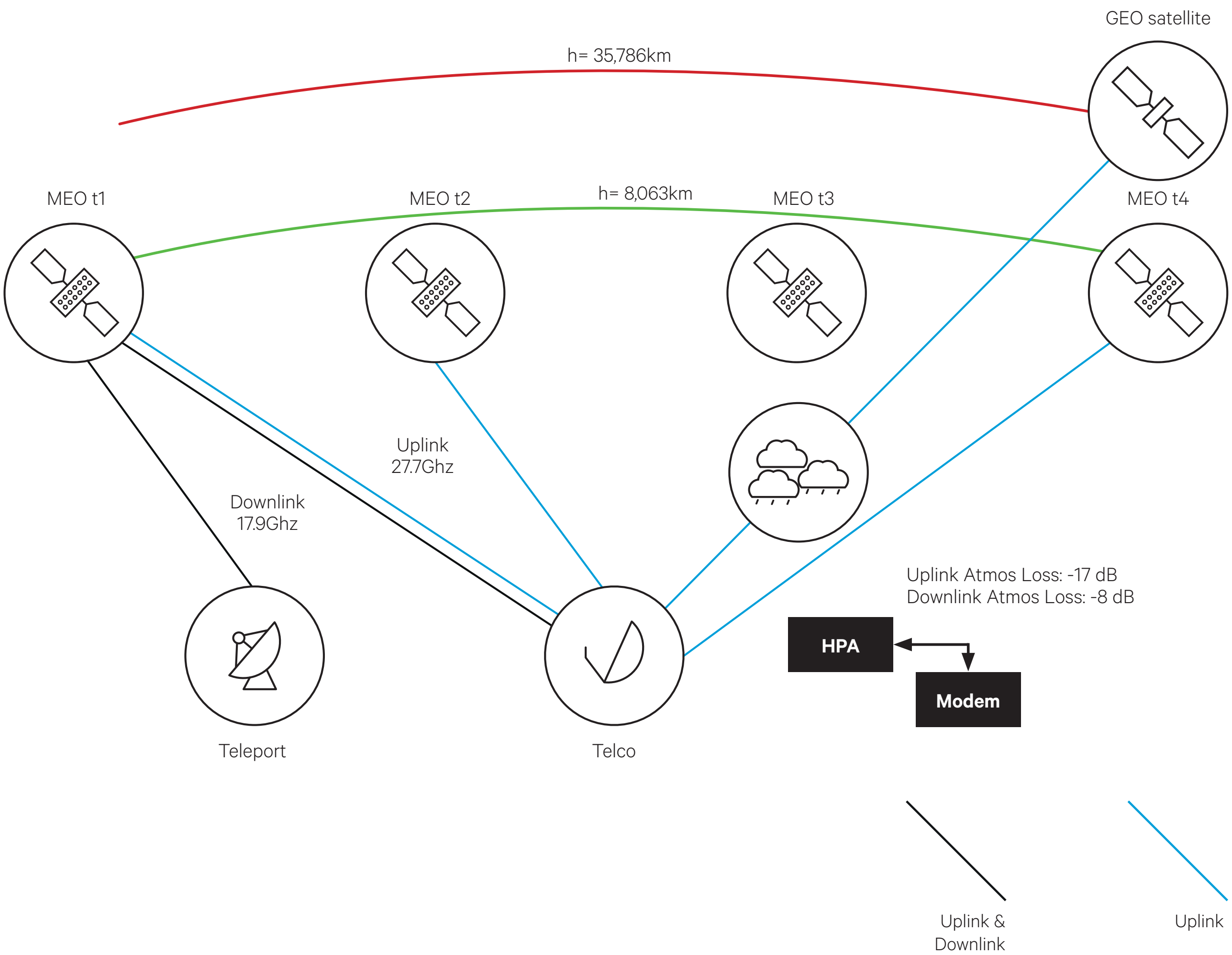

Figure 1
MEO orbit means less time a rain event will affect a customer signal

KA-BAND VS C-BAND

In cases where low latency is important, SES Networks prefers to use the O3b MEO Ka-band frequency over the more heavily used C-band frequency for two simple reasons:

1. Ka-band provides significantly more usable spectrum than any other feasible frequency band. The utilisation of Ka-band offers 1.3 GHz of bandwidth, and with dual polarization each O3b satellite uses 2x reuse of this spectrum for a total per spacecraft allowance of 2.6 GHz. Ka enables the goal of providing effective low-latency, high bandwidth data.

2. The Ka-band, which is a shorter wavelength, is capable of much higher data throughput than C-band on the same or similar customer terminal sizes.

Although the wavelength of C-band signals makes it less susceptible to rain fade, the overall performance expected from a C-band system will never be able to compete with a Ka-band system on similar-sized terminals. Even accounting for rain fade in locations with extreme occurrences of high rain intensity events, the throughput performance of Ka-band systems such as O3b is vastly superior, as evidenced by the data in Table 3.

O3b (Ka-band) Daily Avg Performance	Application	GEO (C-band) Daily Avg Performance
2.7 Million pages	Web Page Views (2MB)	242,758 pages
1,076,763 Files	Files Uploaded (3MB)	129,471 Million Files
3,230,288 Photos	Photos Emailed (1MB)	38,413 Photos
1,436 minutes 4G/LTE	Mobile Service	1,439 minutes 2G
1,436 minutes HD	Netflix Streaming Video	1,439 minutes SD
1,345,953 Songs	iTunes Music Downloads (4MB)	121,379 Songs
5,383,813 eBooks	Amazon eBook Downloads (1MB)	485,516 eBooks

Table 3
Comparing Ka-band (216Mhz) and C-band (36Mhz) throughput capabilities over a 24-hour period, based on 2.4 meter receiving antenna

HOW SIGNALS ARE IMPACTED BY RAIN LOCATION

Rain fade is caused by rain affecting the signal between the the customer's ground receiving terminal and the satellite. Rain events are typically of shorter duration in the O3b network as the satellite is not in a stationary orbit, but is constantly in motion. Generally, when there is rain fade, it is because of rain between the customer's receiving terminal and the satellite. The rain fade incident is typically not of long duration because of the tracking of the O3b Medium Earth Orbit (MEO) satellites, causing the look angle to change constantly (see more on this below). However, if the rain event is directly over the customer ground terminal, the duration will be longest.

For a stationary, geosynchronous orbit (GEO) satellite, a rain event between the satellite and ground terminal will inevitably last longer than with the O3b system. O3b teleports have been installed in the driest geographic locations possible, but it is still possible for a rain event to cause rain fade at those locations, even while the customer site is completely dry.

MONSOON EFFECT – HOW SIGNALS ARE IMPACTED BY RAIN INTENSITY

Rain temperature and distance between raindrops have an impact on signal strength, but the most important factor is raindrop size distribution. When a rain is particularly intense (both in quantity of rain and size of the raindrops) it will have the most significant impact on a satellite signal.

OVERCOMING RAIN FADE

ANTENNA SIZES

Rain fade mitigation is accomplished by deploying larger antenna sizes in areas with higher rainfall. In the rainiest regions, use of larger terminals (7.3 – 9.2m antennas) will ensure maximum uptime and minimal signal degradation.

Antennas at O3b system gateways are at least 7.3 meters to ensure the strongest signal possible at all times, using 20db — like using a spotlight instead of a candle for high concentration in a specific area. This provides 20x more power than is necessary to maintain the link, and this 20db is used as margin to maintain the link during rain, providing maximum performance in rainy or clear sky conditions.

MEO ORBIT & TWO ANTENNA TRACKING

Because of the nature of the O3b MEO satellite system design, the ground terminals generally consist of two antennas to track the orbiting satellites. When a satellite passes overhead, one of the antennas tracks it while the other antenna waits to lock onto the next satellite in the constellation as it comes over the horizon. Once the second antenna locks onto the next satellite, the first terminal breaks with the first satellite, and resets back to the horizon, again waiting for the next satellite to appear.

Because of this dual antenna configuration, the system is inherently better equipped to deal with rain fade issues than a geostationary satellite because the look angle is in constant transition.

The MEO orbit provides for movement relative to rain cells, so that the spacecraft link channel will transit the rain cell at a fast rate as illustrated in Figure 2.

Modems are designed to acquire signals so that in the event of a signal drop, the link can recover quickly.

Figure 2
Comparing Ka-band (216Mhz) and C-band (36Mhz) throughput capabilities over a 24-hour period, based on 2.4 meter receiving antenna

Forward				
Received Signal/Noise	Maximum	↓	↓	Minimum
MODCOD	> 16APSK 8/9	8PSK 8/9	QPSK 4/5	QPSK 1/4
Bit Rate (Mbps)	614 or better	461	276	86

Return				
UPC Back-off	12 dB	↓	↓	2 dB
Uplink Power	Low Power	↑	↑	Peak Power
Received Signal/Noise	Maximum	Maximum	↓	Minimum
MODCOD	> 16APSK 3/4	> 16APSK 3/4	8PSK 8/9	QPSK 1/4
Bit Rate (Mbps)	518 or better	518 or better	288	86

Figure 3
UPC adjusts terminal amplifier, increasing power based on the actual "beacon" signal strength compensating for return uplink fade events at the terminal

ADAPTIVE CODING AND MODULATION

Adaptive Coding and Modulation (ACM) automatically changes the modulation and coding (MODCOD) to compensate for changes in link conditions such as rain fade. ACM optimizes the channel throughput during all conditions, and specifically during rain events the MODCOD is reduced to provide more margin to maintain the link (Figure 3).

Once the rain event passes, the link returns to its normal data rate. Satellite transmission protocols (DVB-S2) ACM allows for the data rate to be adjusted automatically as channel conditions warrant.

UPLINK POWER CONTROL (UPC)

High transmit power (EIRP) of 48 dBW is equivalent to a GEO transmit power (EIRP) of 60 dBW. This high EIRP provides for a robust channel that can mitigate fade to prevent any data rate impact.

Power for uplinks can be increased during fade periods without violating maximum uplink flux requirements.

TELEPORT LOCATION

Teleports are located in dry areas in order to maximise the power to the user and avoid rain fade at that end of the link. When possible, SES Networks selects teleport locations that are both dry and near Tier 1 telecommunications and cross-connect facilities to achieve optimal access to the internet backbone.

REAL WORLD PERFORMANCE

TELECOM COOK ISLANDS RAIN EVENT – JANUARY 2014

A rain fade with a peak depth of 12 dB on downlink was seen at Cook Islands T1 terminal in January 2014.
The graph below illustrates how the O3b satellite system responded (Figure 4) to the heavy rain event.

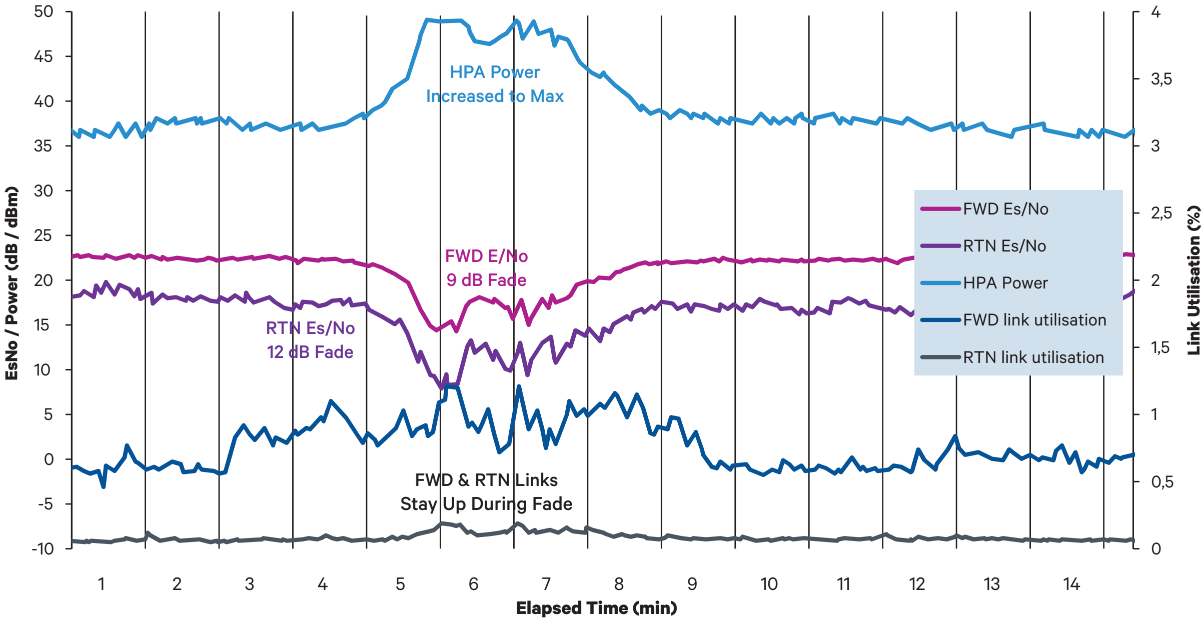

Figure 4 | Rain Fade Example - Cook Islands
Actual reporting data from Tier 1 terminal during heavy rain event on The Cook Islands in January 2014

The system responds in two ways:
1. Modem ACM changes to accommodate the lowered Es/No while maintaining a link
2. The terminal increases its HPA power to compensate for the increased uplink attenuation (estimated at 20 dB)

TIMOR TELECOM CASE STUDY

As the leading telecommunications operator in East Timor, Timor Telecom (Figure 5) has been in operation for 11 years, servicing more than 600,000 clients. The company is the undisputed market leader, with a more mature, better quality, highly capable and reliable network covering the entire country.

SES Networks' O3b MEO solution enables Timor Telecom to significantly increase its broadband coverage and improve the speed and quality of its services for corporate and private clients, even while competing against another operator with access to a fiber link.

"East Timor has been up on the O3b Network since July of 2014 — meaning we have already experienced our rainy season. Timor Telecom was prepared for rain impact on our link, and worked with O3b to mitigate any issues we and our customers might face. We did experience some signal degradation with rain, but actually less than expected — our overall availability is still at 99.9%. At the end of the day, rain fade is not impacting the much improved connectivity we are providing to our customers."

Gerardo Angelo,
Director - Engineering and Operations, Timor Telecom

Figure 5
Timor Telecom solution and Tier 1 terminal in East Timor

CONCLUSION

SES Networks' O3b satellite system averages more than ten times (10x) the data rate of a modern Ku-band system, providing an even greater advantage over C-band systems. This high throughput benefit is on top of the 75% reduction in latency inherently provided by the lower O3b orbit.

SES Networks' customers are guaranteed network performance quality and uptime that meets or exceeds service level agreements, even in the rainiest locations where rain fade issues can occur. Due to the resilient architecture of SES Networks' multi-orbit, multi-band satellite system, rain fade issues are fully mitigated. Customers in every weather zone have consistently available fiber speed connectivity offering customers the highest quality of experience possible and a quicker, more cost-effective solution.

A CTO'S GUIDE TO RAIN FADE

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