WHITE PAPER

Not all Ka-band satellites are the same

This white paper explores the factors that must be considered when choosing the right Ka-band satellite operator.

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Introduction

The telecommunications market is learning that there are many differences between competing Ka-band satellites and that there are key considerations that must be undertaken prior to making a decision. For example, quality of service must drive buying decisions and it is important to understand if the satellite operator and the technology are flexible enough to adapt to the changing requirements of the market.

Key considerations

In order to choose the right Ka-band satellite operator to best meet yours and your customers' requirements, it is essential to consider the following:

- Coverage – do the Ka spot beams provide full coverage with no gaps?
- Beam clustering – can national service be delivered through a single hub?
- Spectral density – does the bandwidth have sufficient power per MHz to deliver the communications services required whilst ensuring the smallest possible dishes can be employed?
- Diversity – what redundancy measures are employed to guarantee high levels of availability?
- Vendor platforms – does the operator employ a single vendor strategy or provide open architecture?
- Control – to what degree do customers have the ability to control and confi gure their service?

Executive summary

Whilst traditional Ku-band satellite technology has been used for two-way data applications, the spectrum has often carried a price premium due to its attractiveness for TV broadcast services, resulting in high costs to the end user. However, Ka-band satellites have been designed to deliver high throughput and high speed data services that deliver significant advantages over Ku-band capacity.

Advantages

- Lower cost – due to the efficiencies resulting from the use of smaller spot beams which concentrate power and reuse spectrum;
- Higher capacity – Ka-band satellites often have 10 to 20 times more capacity than Ku-satellites providing room for a customer to grow their network;
- Smaller dishes – efficiencies of operating at Ka-band mean that user terminals are cheaper and cost less to install and maintain;
- Sophisticated service offering – Ka-band operators are focused on data applications, which means a customer can purchase an entire end-to-end managed service from a single source.

Findings

- Ka-band satellites have a number of design factors which differentiate them from Ku satellites. Many complex engineering trade-offs are undertaken to achieve performance beyond that of Ku systems.
- Design trade-offs drive the architecture of a Ka-band satellite network and can result in dramatically different solutions from operator to operator.
- Decisions made early in the design lifecycle directly affect the ability of a Ka-band satellite to serve a particular communications application.
- The efficiency of data delivery to the end user is the result of satellite transponder design.
- Ka- satellites employ concentrated spot beams, rather than the continental or global beams employed at Ku or C-band. Quality coverage, therefore, has to be carefully designed to meet market demands.
- Networks need to ensure sufficient redundancy is available in the Gateway Earth Stations (GES) and the terrestrial communications links to guarantee quality of service.

Network flexibility is required to meet the varied requirements of the customers, who might range from Mobile Network Operators (MNOs) wishing to install high capacity, dedicated base station backhaul links, through to individual homes or business wanting simple, shared broadband internet access.

Ka-band has many inherent benefi ts over Ku, making it a compelling choice. However, caution should be applied when comparing Ka-operators on a like-for-like basis. This paper is not just about the benefi ts of Ka, but outlines the essentials that must be considered in choosing the right operator because not all Ka-band satellites are the same.

Not all Ka-band satellites are the same

Satellite technology has dramatically changed in the last decade with new satellites using frequencies in the Ka segment of the spectrum, specifically designed to enable high speed data transfer at lower cost than traditional Ku satellites.

A flexible spot beam architecture typically provides about eight times the transmission power of traditional Ku satellites, which results from focused antenna beams and efficient spectral reuse. This also offers significant cost savings.

Avanti Communications is the European pioneer of these game changing improvements, which are based on the deployment of new Ka–band satellite technology and corresponding developments in the ground segment. Avanti has learnt that the design of a good Ka service is particularly challenging as there exists a plethora of complex engineering trade-offs which must be performed, most of which are rarely undertaken for more traditional spacecraft.

The approach taken with these trade-offs by different Ka satellite operators is reflected in the types and quality of service they offer. Avanti has always taken the requirements of its customers into account when designing its satellites and has taken its engineering decisions with these requirements clearly in mind.

Telecoms operators or Internet Service Providers do not tolerate poor service or network outage. So when considering the key design factors identifi ed above, Avanti has focused on providing the optimum solution for its customers. The following sections elaborate on this philosophy.

What is power spectral density

Satellites are widely different in form and function. Not only do they operate at different frequency bands (L, C, Ku and Ka) but they have different footprints and connectivity (and most importantly) power spectral densities.

Capacity is usually sold by the "MHz" and most conventionally for shared lease capacity, "power balanced" (though this is not always explicitly stated). This means that for a 36MHz transponder, each MHz is allocated 1/36th of the available power. It is this non-explicit expression of the power per MHz (or Power Spectral Density (PSD)) that leads to inaccurate comparisons.

The investment and consultancy communities further exacerbate the confusion by always quoting "Transponder Equivalents" i.e. "36MHz" units of capacity with no relation at all to the power available in that bandwidth or even the coverage/orbital location. One cannot value bandwidth without an understanding of the power provided within it.

Avanti's Ka spot beam satellites have class leading performance because they:

- Employ small spot beams with high gain;
- Use a dedicated transponder for each spot beam which, coupled with high gain, gives a high PSD;
- Have large, diverse gateway antennas which enable 100% gateway availability to be achieved.

In order to understand the importance of PSD it is necessary to have rudimentary appreciation for a link budget; estimating if you have enough power and bandwidth to deliver the bitrate you want with the margin required to overcome rain fade, to meet the required service availability criteria. In the case of broadband access and VSAT data services, the link budgets are usually constrained by the small size of the terminal antenna (74 to 120cm). Because of this, the most important parameter for the forward link is the downlink power available from the satellite known as the Effective Isotropic Radiated Power (EIRP), and crucially, over what bandwidth this is distributed. For wideband channels (>54MHz) a further factor relates to how many individual carriers are in use. In the return path, because of the low power from the terminal, the most important characteristic of the satellite is the receive sensitivity, known as "G/T" (Gain divided by noise Temperature), and to a lesser extent, the size of the gateway antenna (the bigger the better).

All satellite operators quote the "Saturated EIRP" for a transponder, this however, is already the first point of confusion. A transponder may be shared across several channels, or the channel bandwidth may vary considerably. Many conventional satellite designs (e.g. at Ku-band) have transponders with different bandwidths (36MHz, 54MHz and 72MHz) simply to fill up the available spectrum. Often the transponders have identical repeater designs and therefore the same power per channel. So a

36MHz transponder with 50 dBW has twice the PSD of a 72MHz transponder with same saturated EIRP of 50 dBW. The total power transmitted is the same in each case, but that power is spread across half as much bandwidth.

That is why the extra bandwidth (100%) is only sold at perhaps a 10% premium - in the world of small dishes, power is king.

In the return channel, the only way to improve the sensitivity is to increase the gain of the satellite, which is why Ka spot beams have another advantage (the noise Temperature is more difficult to reduce and is usually similar for most satellites operating in the same frequency band). How to increase gain? Increase the "directivity" of the spacecraft antenna, which means a smaller footprint and thus a more focused beam.

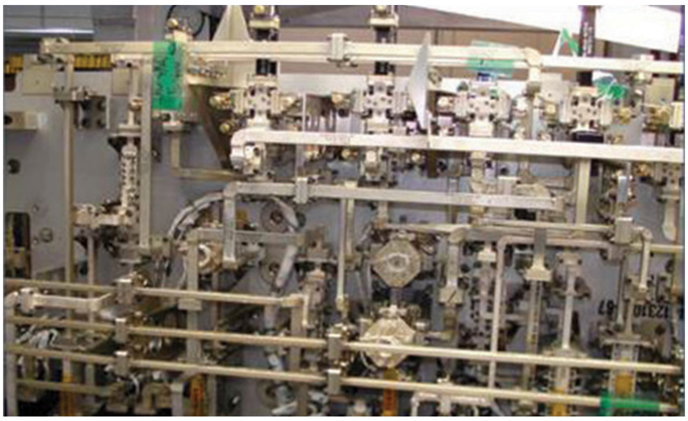
In summary, the most valuable satellite capacity is the one that provides a high power spectral density on the forward link and high gain in the return link. Avanti's Ka satellites achieve this by focusing transmitted power into small spot beams and operating at a high frequency which maximises gain. A satellite that delivers a large number of MHz notionally through a very wide beam - which distributes a modest amount of power into that beam - will deliver a very low PSD and therefore low powered, weak throughput inefficient Mbps. It is pointless to compare such services on a like-for-like basis.

Network topology

One of the key issues associated with the use of Ka satellites is the number of GES required to support the satellite. Driven by the ability to utilise much larger amounts of spectrum than Ku satellites, Ka spacecraft typically require several GES located within the satellite footprint.

A second design constraint relates to the number of spot beams. Unlike many Ku satellites, where all the transponders are linked to the same beam and employ a single antenna and associated feed horn - Ka satellites require a separate feed horn for each beam – which is a considerable number when forty or more spot beams are employed. This, combined with other design factors, often results in four or more antennas being required to support the large number of feed horns. When forty or more transponders are connected to as many feed horns spread across multiple antennas, the routing of wave guide (which carries the RF signals from the amplifi ers to the antennas) across the body of the satellite becomes a huge problem. Ka satellites often have three layers of wave guide routed across their surface.

In order to reduce the complexity of the wave guide on the spacecraft, many Ka systems route the traffic from neighbouring spot beams on the ground to different physical GES (i.e. all user beams generated by one antenna are routed to the GES beam associated with that antenna, even though the user beams are geographically separated). This simplifi es the wave guide layout on the spacecraft minimising cost and complexity for the manufacturer and operator, but it means that if a country such as Italy is covered by four spot beams, it is likely that each beam will be connected to a different GES, located in France, Greece, Germany and Spain, for example. This means that aggregation of traffic back into the customer's core network becomes a complex and costly activity. This is compounded if the customer wishes to use specific hardware at the GES – that hardware needs to be replicated and maintained in four different locations.



Optimising network topology may complicate waveguide design on the spacecraft, but it leads to simpler solutions for the (photo courtesy Orbital Sciences Corp)

Coverage

Avanti's customer focused approach is also refl ected in design of its spot beam coverage. Network Operators often have demanding coverage requirements driven by commercial or even regulatory factors, which mandate that services are available across an entire nation. It seems odd, but some Ka satellites only have limited coverage of many countries in their footprint, with a few spot beams focussed on major cities but leaving rural regions un-served. This is entirely the opposite of what most customers require. Satellite's key advantage over terrestrial technology is its ubiquity, and Avanti believes it is foolish to surrender that.

The HYLAS fleet have been specifically designed with the needs of national communications service providers in mind, ensuring comprehensive coverage from border to border.

One extremely interesting issue (to engineers, that is) relating to optimising coverage is the phenomena of inter-beam interference. Ka satellites reuse spectrum, so that frequencies used for communications in one beam are also used in another. However, if these beams are geographically next to each other, they will interfere, making communications difficult and reducing data capacity. To avoid this, Ka satellites employ what is known as "4 colour" reuse. This means that the typical 500MHz of user beam spectrum is split into two lots of 250MHz, and each of these 250MHz blocks of spectrum are employed in two different polarisations – giving a total of four possible combinations, or "4 colours" which won't interfere with each other.

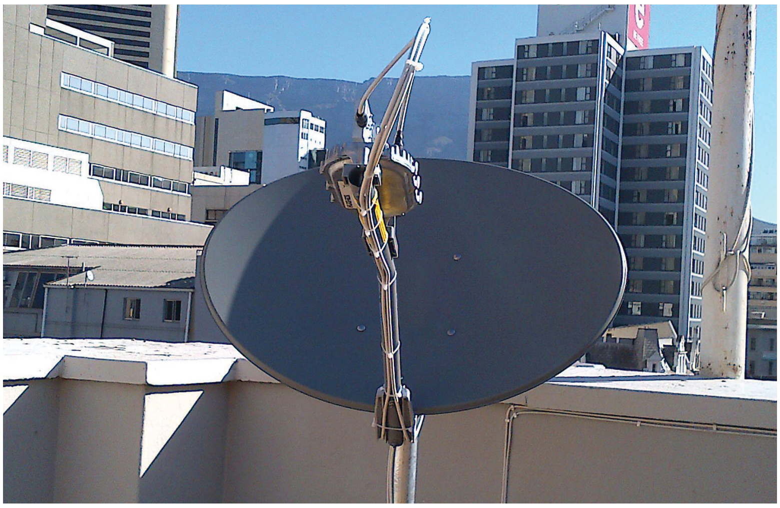
When designing a coverage pattern, it is mathematically possible to place spot beams to cover any region using these four combinations, or "colours", without any spot beam having the same "colour" as any of its immediate neighbours. However, depending on spot beam size and location, it is still possible to experience interference from other, nearby spot beams with the same frequency and polarisation combination. To avoid this, the spot beams must be moved apart. However, this can cause "canyons" in coverage between neighbouring spot beams where the rapid roll-off in spot beam performance means that high quality services cannot be achieved. This leads to non-uniform service performance within the coverage area and complicates service provision. Avanti has avoided this problem by performing extremely detailed simulations of spot beam performance and optimising the geographic locations of its beams. Avanti's customers require high quality, uniform services driving the optimisation process.

The HYLAS fleet provides full national coverage of all key countries in EMEA

Simplicity

In many cases, satellite solutions are deployed to end users residing in remote regions or challenging terrain. Either way, it is clear that the satellite equipment installed at each customer premises must be easy to install and maintain. In particular, moving parts, such as tracking antenna, should be avoided at all costs. Avanti's satellites operate in the geostationary orbit and so appear fixed in the sky from any location on the Earth. Thus, they are always visible and require only a single, fixed antenna to facilitate services. In particular, when compared to satellites in other orbits, they do not require three tracking antennas (two to maintain communications with two moving satellites and a third for back-up) or have to perform complicated handover procedures when one satellite moves out of view and the next appears.

In contrast, Avanti's user terminals are small and easy to install – we think it's just common sense to minimise the costs of user terminals and their installation, while maximising reliability.



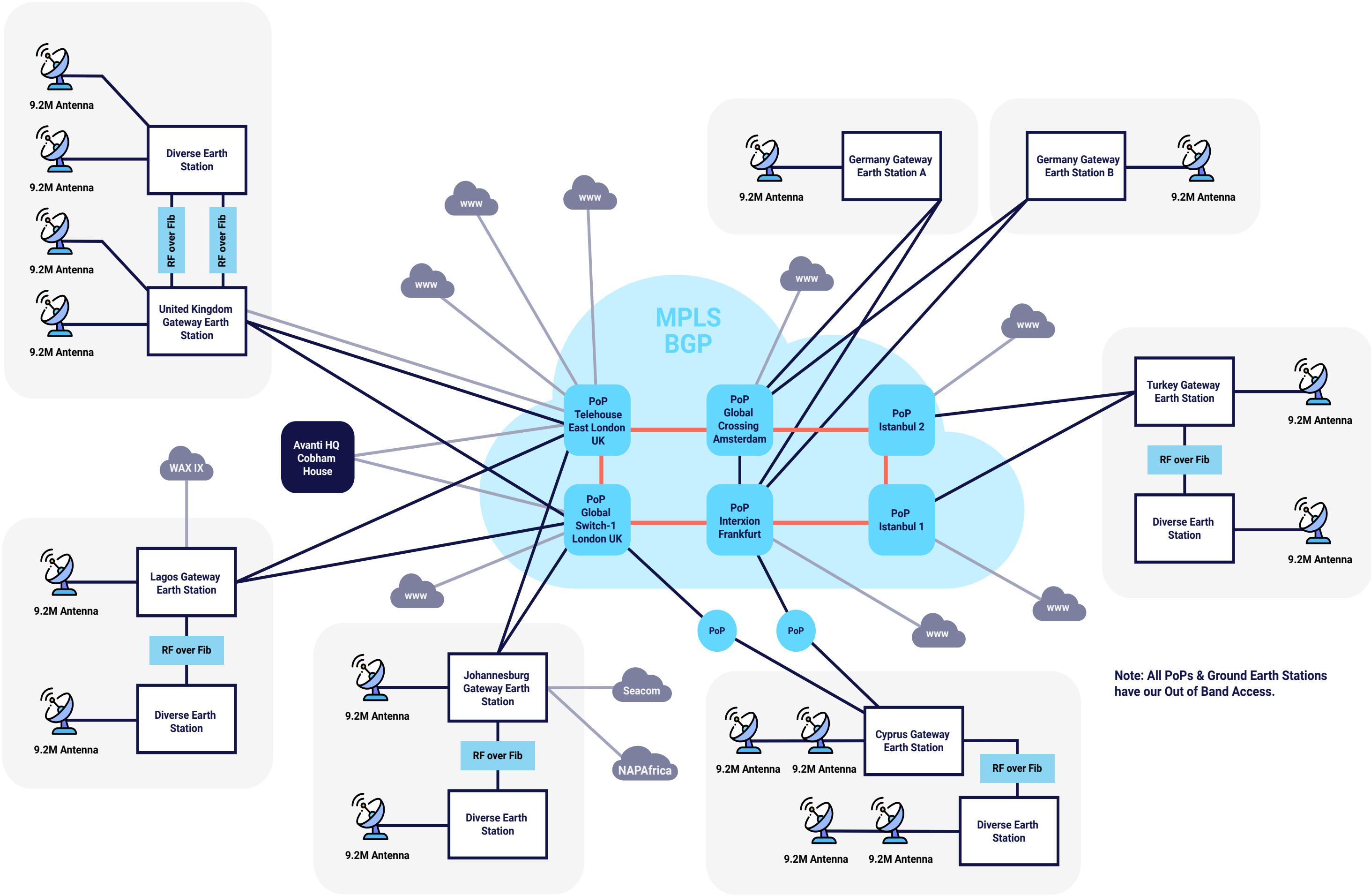
Avanti 's high performance satellite terminals are small and easily installed

Reliability

Although he may not realise it, even the man in the street has probably experienced rain fade. In the case of Ku-band satellites used for TV broadcasts, the television picture will appear blocky and will break up as data transmitted from the satellite is corrupted as it passes through "storm cells" in the atmosphere. If the responsible storm cell lies over the viewer's house, only TV reception in the immediate vicinity will be affected. However, if the storm cell covers the up-link station which transmits to the satellite, all viewers are affected no matter where they reside. TV consumers accept this level of service, but Avanti believes that professional telecoms users will not.

By design, Avanti's communications services operate in two-way mode, which allows a number of rain fade mitigation techniques to be employed that can't be employed by Ku-band broadcast satellites. If the storm cell lies over a base station location, the fade in the return signal can be detected at the GES, which responds by adding more error correction to the signals destined for that base station – a process known as Adaptive Coding and Modulation or ACM. Although this reduces the overall throughput slightly while the storm cell passes, it ensures that the data gets through and that the link is maintained.

Other Ka-band satellite operators do not adopt this approach due to the expense of investing in the redundant GES sites. In addition, the problem varies from operator to operator depending on the GES location and the nature of the satellite's orbit. Non-geostationary satellites, for example have a particular problem, in that they move across the sky sweeping out an arc and moving in to and out of storm cells as they go, increasing the chances of encountering a storm cell if they are present.
In the same way that Avanti has dealt with the problems associated with the availability of the space to ground communications link, we have applied a similar, high quality of service philosophy to our terrestrial communications as well. All of Avanti's ground stations have a highly resilient architecture with diverse fi bre links and points of presence at several major interconnection sites, ensuring that the terrestrial links we use are as reliable as those to and from our spacecraft.



Avanti's resilient and redundant terrestrial network

Integration

Most customers require a satellite communications service that can be integrated into their existing telecoms network without compromising service quality. Some satellite operators point to the effects of latency on geostationary satellite signals as resulting in a low quality service. They claim that slow download speeds experienced by some users in Africa, for example, result from the effects of latency on IP protocols.

However, satellite operators have been mitigating against the effects of latency for many years by using IP enhancement protocols. This speeds up the delivery of internet content so that latency effects are inconsequential to all but the most demanding real-time protocols.

In fact, slow download speeds are due simply to insufficient satellite bandwidth and high contention ratios rather than latency. This is where Ka satellites again have an advantage over their Ku counterparts as a typical Ka satellite transponder will deliver up to 250MHz of capacity, compared with the 36MHz offered by most Ku transponders. When coupled with the increased power (and greater spectral efficiency) of Ka services, the actual data throughput that can be achieved is an even higher multiple. The extra capacity enables limited bandwidth and high contention ratios to be easily overcome and a high quality of service to be offered to all.

Other issues associated with integration of a satellite service relate to the choice of equipment to be deployed. By focusing on data services, Avanti has been able to develop a unique capacity to tailor solutions to meet a customer's specific requirements and integrate them seamlessly into their networks.

For example, rather than have an exclusive agreement with a single satellite equipment provider, Avanti operates an open platform which welcomes all manufacturers. In particular, Avanti's satellite services use the latest generation platforms from proven vendors to provide a reliable connectivity solution. A range of managed services are based on products from several of the most respected satellite equipment vendors, including Hughes, iDirect, Newtec, Comtech, Novelsat, and others.

Conclusion

Ka systems have opened up a new era in satellite communications, enabling high speed, high quality services to be delivered to a new generation of end users.

Utilisation of Ka frequencies has enabled costs to be reduced and performance increased. For the fi rst time, satellites can be used to deliver economical high speed, two-way services to individual end users. However, it is important to select the right Ka-band Service Provider, as not all Ka satellites are the same. In particular, a prospective purchase of Ka-band services should consider:

- **Bandwidth quality** – Avanti uses small spot beams and dedicated transponders for each beam, ensuring high PSD and G/T for efficient communications.
- **Network topology** – in Avanti's network, all spot beams from a single country are linked to a single GES, minimising network complexity for customers.
- **Coverage** – all of the key countries served by the HYLAS fleet are 100% covered with no performance "canyons", ensuring a uniformly high level of performance.
- **Simplicity** – the HYLAS fleet operates in geostationary orbit and are very high powered ensuring that end user terminals are low cost, free from moving parts, simple to install and easy to maintain.
- **Reliability** – Avanti's terrestrial network employs redundant ground stations to enable traffic switching during periods of heavy rain or maintenance at the primary GES, to guarantee high levels of availability.
- **Integration** – Avanti operates an "open" system which invites all manufacturers to operate their hubs and user terminals across our network. This means we can tailor a solution for easy integration with our customer's existing networks.
- **Available now** – Avanti has a satellite fleet with a proven track record and plans under execution to bring new capacity on stream when it is needed.

Ka services, in particular, offer compelling benefi ts, provided that is, that the right Ka network is employed. Avanti has focused on designing a network architecture optimised for high speed data applications that can be trusted and relied upon by the most demanding of professional users and can accommodate the widest variation in user specification.

Be More.

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