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Emailed to: jams@trai.gov.in
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Re: Viasat Counter-Comments to the TRAI Consultation Paper on the "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed"

Dear Sir or Madam,

On behalf of Viasat, I am pleased to provide the following counter-comments in response to the TRAI Consultation Paper on the "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed".

Sincerely,

Ryan Johnson
Sr. Director, Regulatory Affairs
Viasat, Inc.

VIASAT COUNTER-COMMENTS

Viasat India Private Limited (Viasat) is part of a family of companies that are leading global providers of satellite and terrestrial broadband communications solutions and operators of a large fleet of Ka-band spacecraft. Viasat has been in operation for more than 30 years and has more than 5,200 employees across 30 offices around the world, including approximately 200 employees in two offices in Chennai, India. Today, Viasat services connect 150 million devices per year on airplanes and provide millions of connections to residential and enterprise customers, through a fleet of geostationary (GSO) satellites. Viasat has three additional Ka-band spacecraft, ViaSat-3 class satellites, under construction and slated for launch to serve the Americas, EMEA and Asia-Pacific, and has invested billions in broadband globally. Viasat also is developing a fleet of non-geostationary (NGSO) satellites that can augment the more affordable higher speeds and greater volumes of bandwidth offered by GSO with a lower latency component that is the main advantage of NGSO.

Viasat believes in fearless innovation and is finding better ways to deliver connections with the capacity to change the world. Viasat is developing the ultimate global communications network to power high-quality, secure, affordable, fast connections to improve people's lives anywhere they are—on the ground, in the air or at sea.

Viasat thanks the TRAI for the opportunity to submit these counter-comments to respond to specific comments filed by other participants in response to the TRAI's Consultation Paper on the "Roadmap to Promote Broadband Connectivity and Enhanced Broadband Speed" ("Consultation"). Viasat respectfully requests that the TRAI carefully consider these counter-comments given the serious adverse consequences that would result from acting on other comments submitted. Specifically, these counter-comments respond to comments submitted by Space Exploration Technologies Corp. (SpaceX), Ericsson and the Cellular Operators Association of India (COAI).

The issues Viasat addresses include (i) the preclusive effect of NGSO low earth orbit (LEO) "mega-constellations" on access to radio spectrum by other satellite systems, (ii) the many factors besides latency that are important for consumer broadband applications, and (iii) the critical need to maintain access to the 28 GHz band for satellite broadband services in India.

I. DEVELOPING APPROPRIATE RULES TO PROTECT GSO SATELLITES BEFORE PROVIDING NGSO MARKET ACCESS.

a. NGSO-GSO Spectrum Sharing Terms Need to Be Fully Examined and Further Developed Before Authorizing NGSO Systems in India.

Managing interference from NGSO systems and their associated earth stations into GSO networks is critical to achieve the significant benefits that can be provided by both types of systems. In its comments to the Consultation, SpaceX appropriately raises the need to address issues with regard to NGSO-GSO spectrum sharing criterion and the need for the ITU to update its equivalent power flux-density (EPFD) limits.[1] While raising the issue in the context of the V-band (which contrary to SpaceX's comments has been subject to emission limits since WRC-19[2]), SpaceX omits any discussion of the inadequacy of the ITU NGSO EPFD limits in the Ka band. Viasat provides the following counter-comments to provide the TRAI with a more complete explanation of this important spectrum management issue for India.

The ITU has long recognized the principle that NGSO systems must protect GSO networks.[3] This protection can be achieved by limiting the EPFD emitted by NGSO systems. In order to achieve this, for certain parts of the Ka band, the ITU has adopted EPFD limits in Article 22 of the *Radio Regulations* that NGSO systems must meet. As described below, there are well recognized shortcomings to the NGSO EPFD limits in the *Radio Regulations:*

- They were developed at a time when satellite technology and operating conditions were much different than today.

- They do not adequately address the issue of aggregate interference from multiple NGSO FSS systems.

- They do not apply to all portions of the Ka band where GSO networks operate, and specifically do not apply at 17.7-17.8 GHz, 18.6-19.7 GHz, 20.2-21.2 GHz, 28.6-29.5 GHz, and 30-31 GHz.

In order to address these shortcomings in the ITU NGSO EPFD limits, Viasat suggests that India consider adopting suitable limits across the entire GSO Ka band in order to provide adequate interference protection for GSO satellite networks from the operation of multiple NGSO systems. Viasat provides additional information on this critical spectrum management issue below to provide the TRAI with the full background.

The EPFD requirement is implemented internationally by the adoption of emission limits on NGSO systems in Article 22 of the ITU *Radio Regulations.* These limits were adopted in 2000. The limits attempt to constrain the EPFD emitted by (i) NGSO space stations towards GSO space stations; (ii) NGSO space stations towards GSO earth stations; and (iii) NGSO earth stations toward GSO space stations.

Although EPFD limits could be an effective means of facilitating the ability of NGSO systems to protect GSO networks from interference, the 20-year-old ITU limits are inadequate to protect the GSO networks being designed and deployed today, given that:

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1 *See* SpaceX comments at p. 6.

2 *See* ITU Radio Regulations, Art. 22.5L (WRC-19)

3 *See* ITU Radio Regulations, Art. 22.2 (WRC-07).

- Significant technological changes have occurred in GSO networks over the past two decades that make them far more spectrally efficient and enable new types of services.

- There is no rule limiting aggregate EPFD from multiple NGSO systems in the uplink direction—from NGSO earth stations into GSO satellite receivers. That is, no mechanism exists to manage the risk of aggregate interference from the potentially hundreds of thousands (or more) of earth stations communicating with multiple NGSO systems from multiple different operators.

- The aggregate EPFD limit in the downlink direction is based on a very small number of NGSO systems (3.5, to be exact).

- Any aggregate EPFD limits would have to be apportioned across all the different NGSO systems using the band.

- A suitable mechanism would have to be implemented to ensure that any aggregate limits are honored and that critical GSO operations are protected.

Managing NGSO interference into GSO systems is critical to protect existing longstanding and next generation GSO networks that are being deployed, particularly in the Ka band. To emphasize this principle, ITU *Radio Regulation* Article 22.2 makes clear that NGSO systems "shall not cause unacceptable interference to and, unless otherwise specified in these Regulations, shall not claim protection from geostationary satellite networks in the fixed-satellite service."[4]

As noted above, because the ITU's EPFD limits for the Ka band were developed two decades ago, they were based on satellite technologies, network architectures, and operating conditions that existed at the time. In general, today's very high throughput GSO satellites are far more spectrally efficient, employ lower total satellite receiver noise temperatures, have higher satellite receive antenna gains, and operate with smaller user terminals than GSO satellites whose characteristics were considered at the time in developing the Ka band ITU EPFD limits.

A technical demonstration of the inadequacy of existing Ka band NGSO EPFD uplink limits with respect to today's GSO networks is provided in Appendix 1. As shown in Appendix 1, even a single NGSO FSS system operating at the EPFD uplink levels has the potential to cause harmful interference into multiple GSO FSS networks, resulting in significant signal degradation and capacity losses for GSO networks, while multiple NGSO FSS systems operating simultaneously pose an even greater risk to GSO FSS networks. Similarly, demonstrations can be provided for the inadequacy of EPFD downlink limits.

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[4] *See* ITU Radio Regulations Art. 22.2 (WRC-07).

As previously noted, the ITU NGSO EPFD limits do not apply in the 17.7-17.8 GHz, 18.6-19.7 GHz, 20.2-21.2 GHz, 28.6-29.5 GHz, and 30-31 GHz bands, meaning that NGSO systems are only subject to the unspecified obligation in Article 22.2 not to cause unacceptable interference to GSO network operations in these bands.

Therefore, it is critical that administrations look at adopting their own protection criteria domestically for GSO FSS systems serving their countries and not rely on the ITU EPFD limits. In addition, administrations would need to develop a suitable rule governing the aggregate EPFD limits in the Earth-to-space (uplink) direction from all co-frequency earth stations of all authorized NGSO FSS systems. And they would need to consider the adequacy of the existing aggregate ITU Ka band EPFD limit in the downlink direction, because that limit is based on a simple calculation of "3.5 NGSO systems"— markedly fewer than are being contemplated today.

India may be faced with the possibility of either licensing or granting market access to multiple NGSO systems, potentially including existing and future Indian owned or operated networks, each of which would contribute to the aggregate EPFD received by any given GSO network from co-channel NGSO operations. The impact of multiple NGSO systems thus must be taken into account.

Viasat recommends India ensure the aggregate EPFD levels generated by all of the NGSO operations that are authorized to and from India actually comply with suitable limits across all GSO Ka bands in order to protect GSO networks. A suitable methodology may be developed to apportion any aggregate EPFD "allowances" across various authorized NGSO systems. This action would be consistent with ITU Resolution 76 (REV. WRC-15) which calls on administrations to "take all possible steps" to ensure that NGSO systems protect GSO networks through EPFD limits. But suitable enforcement mechanisms still would need to be developed.

Viasat strongly recommends that India evaluate the ITU's NGSO EPFD limits for the Ka band anew and adopt suitable NGSO EPFD limits for systems seeking to operate in India in light of the GSO satellite networks planned for critical broadband services in India. More restrictive EPFD limits are required to ensure that NGSO systems can share spectrum with GSO FSS networks. The EPFD limits are critical to protect operations of GSO networks and conversely actually have very little impact on NGSO systems. NGSO systems protect GSO networks by implementing GSO arc avoidance (*e.g.*, not transmitting to/from a subscriber terminal unless the projection of the transmission path avoids the GSO arc by a suitable angle) in order to comply with EPFD limits. Even large avoidance angles, greater than 20 degrees, have negligible impact on NGSO systems coverage and capacity. This is particularly true of "mega-constellations" which have many satellites available to serve each location on the Earth and can easily choose those that avoid GSO interference at each and every location.

b. SpaceX's NGSO Band-Splitting Proposal Would Lead to Monopolization of Shared Spectrum and Shared Orbit Resources.

SpaceX's comments also raise a number of concerns that India may consider when weighing how those seeking access to the Indian communications market are proposing to share common resources such as spectrum and satellite orbits. SpaceX's proposed approach for dividing spectrum among various NGSO systems[5] does not protect India's ability to launch and effectively operate its own NGSO systems or allow for additional or competing NGSO systems to serve the very communities that this Consultation is intended to benefit by providing more efficient and effective broadband service options. In fact, the reality behind SpaceX's "band splitting" proposal is that it would enable SpaceX to occupy and control most of the spectrum and orbit resources in the bands where it proposes to operate – and preclude future competitors from innovating and competing in the market.

Spectrum is a scarce resource that can be beneficially shared among many different satellite systems. Viasat urges the Authority to ensure that any spectrum sharing plans that it considers allow for sharing by multiple NGSO systems, in addition to multiple GSO networks. Satellite operators have identified techniques to allow multiple NGSO systems to share spectrum with each other through mutual coordination.

Where spectrum is shared by NGSO systems, the efficacy of these sharing techniques is highly dependent on the architecture of the relevant systems. Certain sharing techniques are ineffective in the case of in-line events during which a satellite from one system blocks the communications path being used by another system (*e.g.,* is located between and/or in-line with an earth station and a zone surrounding a satellite of another system). SpaceX's proposed sharing rules would preclude not only future LEO systems from sharing spectrum, but also satellites in other orbits, such as Medium Earth Orbit (MEO).

As the TRAI is aware, several operators plan, or have started, to deploy "mega-constellations" consisting of thousands of satellites that would operate in LEO. These LEO "mega-constellations" will be able to "blanket the sky," causing many in-line interference events with other satellite systems that would preclude other systems from using spectrum that otherwise could be shared. Notably, these "mega-constellations" would only rarely experience in-line events themselves because their far greater number of satellites that perform a spectrum blocking function for other NGSO systems also provide them with alternative communications path to avoid the satellites in the far smaller NGSO constellation (an option unavailable to NGSO constellations with far fewer satellites).

This effect can be seen in the following table, which shows the probability of satellites in NGSO System B blocking all of the satellites in NGSO System A. Three constellation sizes are considered for each system: 300, 3,000, and 30,000 satellites. Typical orbital parameters were

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5 *See* SpaceX comments at p. 6-7.

used, and the user terminal was modeled at 20.6° N, 79° E (*i.e.*, geographic center of India), as a representative location in India. Several observations can be made:

- A 30,000 satellite NGSO system will blanket the sky, blocking all other constellations, including other similarly-sized constellations.

- 300 and 3,000 satellite NGSO systems never block 30,000-satellite systems.

- Even 3,000 satellite NGSO systems have significant blocking effect on many other constellations.

	NGSO System B		
NGSO System A	**300 Satellites**	**3,000 Satellites**	**30,000 Satellites**
300 Satellites	2.9%	31.3%	100%
3,000 Satellites	0%	21.8%	100%
30,000 Satellites	0%	0%	100%

Probability that NGSO System B blocks a location from service by NGSO System A.

These dynamics create powerful incentives that undermine spectral efficiency and threaten to harm competition and consumers. Among other things, NGSO mega-constellation operators would have an incentive to:

- Deploy more satellites than they need, as doing so effectively precludes others from accessing the same spectrum, and consequently give those LEO operators an effective monopoly and unfair competitive advantage;

- Utilize large numbers of spectrally inefficient and unreliable satellites instead of deploying much smaller constellations comprised of efficient and reliable satellites; and

- Reject much more reasonable approaches to spectrum sharing and coordination with smaller NGSO constellations, even at altitudes other than LEO.

In Viasat's view, no individual NGSO satellite system should be able to preclude all other operators from using the shared spectrum resource—a result which Viasat believes would run contrary to the intent of TRAI's efforts to expand, rather than limit, the amount of capacity available for broadband service to the Indian market.

Before India considers SpaceX's or any other spectrum sharing proposals, or authorizes NGSO systems to serve India, it would be prudent to consider and address the following core policies: (i) the need to ensure equitable access to limited radio frequency spectrum and orbital resources by multiple innovative NGSO systems, (ii) the need to facilitate robust competition in the provision of a wide variety of satellite-based broadband services including current and prospective networks that may be based in India, and (iii) the importance of regulatory certainty to enable investment and innovation in the Indian market.

Viasat specifically requests that India examine the following issues:

- How some NGSO constellations seek to deploy many more satellites than are necessary, creating very large numbers of band-splitting events.

- How band-splitting events, as suggested by SpaceX, unduly constrain the coverage and capacity of, and drive-up costs for, *other* NGSO systems that use far more spectrally efficient and reliable satellite designs.

- How the preclusive effects on spectrum access and effective competition are exacerbated when these NGSO FSS constellation operators advocate for rules that facilitate (i) their wasteful approach to spectrum usage and (ii) their risky approach to satellite design and manufacturing that undermines safe space operations.

The "band-splitting" approach proposed by SpaceX ignores the substantial public benefits that exist when a given mission can be accomplished with fewer satellites in an NGSO constellation:

- More NGSO systems can co-exist within the same and/or distinct orbits (*i.e.*, altitudes), providing consumers with more service options and resulting in more competition.

- Fewer band-splitting events that have a preclusive effect on spectrum access by other NGSO systems.

- Lower risk of collisions and resulting generation of less orbital debris.

In fact, SpaceX's band splitting approach would not give appropriate priority to system designs that are both (i) more spectrally efficient when measured on a per-spacecraft basis and (ii) less dangerous from an aggregate constellation collision risk perspective. Stated another way, incentivizing the deployment of more satellites than are necessary results in the consumption of substantially more orbital resources than would be utilized when constellations employ satellites that individually are more capable—when fewer satellites are needed to do the same job.

What SpaceX advocates also creates risks to competitive markets. By way of example, the deployment of many thousands of NGSO satellites would provide effectively ZERO remaining "look angles" or communications paths to and from earth for any other NGSO system, blocking access to critical spectrum by those other systems, but barely affecting that "mega-constellation." In contrast, dis-incentivizing such preclusive behavior would enhance space safety for others, and also would facilitate innovation and competition, allowing more operators to effectively share the limited physical orbital resource and the limited spectrum resource.

Viasat recommends that India license NGSO systems in a manner that (i) facilitates the ability of NGSO systems to share limited spectrum resources with GSO networks by maintaining adequate angular separation and otherwise complying with suitable EPFD limits and (ii) ensures that the rules adopted to ensure spectrum sharing between NGSO systems do not require smaller NGSO systems to bear capacity, coverage, and service level reductions that the much larger NGSO systems would not need to bear.

As the Organization for Economic Cooperation and Development (OECD) aptly recognized in its recent study, "Space Sustainability: The Economics of Space Debris in Perspective" with these mega-constellations, "[w]ith this level of orbital density, according to multiple modelling efforts, it is not a question of *if* a defunct satellite will collide with debris, but *when*."[6] Given SpaceX's failure rates for the satellites already launched and that their many defunct satellites remain in the low earth orbit even today, Viasat is concerned that if left to SpaceX's own devices and approach to satellite design and manufacturing with regard to collision risk, space safety could be undermined and the threat to other NGSO operators' access to the LEO orbits could be catastrophic. Although beyond the scope of this Consultation, Viasat has filed comments in the recent Department of Space Draft Spacecom Policy consultation on this pressing issue. Viasat strongly suggests that these issues be addressed prior to NGSO systems being authorized to access the Indian market.

II. MULTIPLE DIMENSIONS TO A USERS' BROADBAND EXPERIENCE DRIVE ADOPTION: It is recommended that TRAI take into count all other factors, including cost-effectiveness and quality of service (QoS) when evaluating the needs of Indian consumers.

Today's satellite broadband technologies provide high-quality service to end-user consumers that compares favorably to those of terrestrial providers. This development reflects the significant efforts that satellite broadband providers have made to improve their technologies and service offerings.

Any attempt to define broadband in terms of specific fixed performance indicators would fail to account for the fact that consumers' broadband needs vary and evolve, and that "good quality" broadband means different things for different applications and in different contexts. More specifically, adopting a fixed definition of broadband would fail to account for the fact that: (i) different users place different values on the various dimensions or capabilities of "broadband" services; (ii) different applications have varying performance objectives and optimization goals in designing and implementing their networks and service offerings, and pricing their services.

As a result, users and network operators make trade-offs between and among the different characteristics of broadband in order to achieve a balance that is optimal for their

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6 OECD report available at: https://www.oecd-ilibrary.org/docserver/a339de43-en.pdf?expires=1606009526&id=id&accname=guest&checksum=99C6DC3D5BFCF30877B62412FA2BEE1E.

needs, or the needs of their customers. For example, some users and applications require high volume data throughput but are largely indifferent to latency (*e.g.,* streaming video). Other users and applications may place a premium on mobility over minimum speed, yet others demand high service availability (*e.g.,* public safety). Another key factor is the high cost and greater power requirements of LEO end user terminals. A system that requires a much more expensive end user terminal, or a terminal that requires much more electrical power, would preclude many locations from ever being equipped for service, even if other attributes of the service itself are attractive. Even within a given set of broadband applications, variations exist in user performance requirements that caution against a "one-size-fits-all" definition.

Other factors that may be relevant include some of the following: peak up/downstream speed, symmetry between up/down speeds, jitter, packet loss, service availability, mobility, price and allowance caps. These along with other dimensions can be combined in broadband solutions to respond to different consumer demands and desired price points. Moreover, because broadband solutions can vary across large numbers of technical performance, environmental, and economic dimensions – and incorporate different combinations of features, performance, and price – at any given point in time a variety of broadband solutions are both technically and economically preferable.

As Viasat explained in its comments to the Consultation,[7] most global Internet traffic is not latency-sensitive. As discussed above, a focus on latency as the single most important attribute above all other network management, environmental, affordability or quality of service factors is misplaced. The goal for providing broadband services universally should focus on cost-effectiveness and overall quality of service for the applications that are most in demand from the intended users.

Cost effectiveness and quality of service are two of the goals that have shaped the way Viasat has designed and built its GSO networks and associated ground terminals, especially for the next generation of very high throughout GSOs, such as ViaSat-3. As is the case with every other technology, the quality of satellite technology turns on precisely how the technology is deployed, the economic viability and attractiveness of the underlying business models, and how the provider manages the provision of service to customers. Today's satellite broadband technologies provide affordable high-quality service to end-user consumers that compares favorably to that of many terrestrial providers – with a clear trend of substantial improvements in speed, volume, service quality and price relative to many other alternatives in many locations. This development reflects the significant efforts that satellite broadband providers have made to improve their technologies and service offerings. Indeed, Viasat alone has invested billions of dollars of private capital to develop a state-of-the-art broadband network designed to overcome the historical limitations of legacy satellite networks and provide a high-quality end user experience.

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7 *See* Viasat comments at p. 5.

Viasat notes that the comments submitted by one party, SpaceX, focus on latency as a major, if not singular, benefit to consumers.[8] Viasat believes that GSO networks offer the most affordable and cost-effective technology today with the best prospects for continued speed and bandwidth gains in the foreseeable future. That is why Viasat has invested and is deploying GSO networks to provide global coverage. The cost of development and sustainment of LEO space and ground systems raise substantial concerns in terms of affordability in comparison to the next generation GSO networks, like ViaSat-3. Even worse, the chance of improvements in price and quality reaching end users is likely zero in a regulatory environment that grants monopoly-like spectrum control to a LEO operator that emphasizes using satellites to preclude competition, as opposed to improving efficiency.

The nature of LEO constellations means that, at any given time, many of their satellites are located over water or non-populated land masses. For very large "mega-constellations" with very low orbits, and limited view of the earth for each satellite, less than 5 percent of a constellation's bandwidth may see demand for service to customers at any time. This is in contrast with 100 percent availability for GSO networks. In addition, LEO networks have a much shorter productive life, typically around 5 years, in comparison to 15 years for a typical GSO satellite. This means that LEO networks have to constantly be replenished at significant expense. Thus, LEO systems will likely struggle to compete economically with the latest next generation GSO networks that can offer high quality service over a much longer period of time resulting in substantial cost-efficiencies for the benefit of consumers. While lower latency can add value to some applications, most users will prefer higher speeds, and more Gigabytes of data at a more affordable price.

In addition to cost effectiveness, speed is another crucial element of high-quality broadband service. Notably, the amount of speed (and total bandwidth) actually provided to an end user is by far the most important factor in ensuring a quality experience with video streaming or downloading applications. In fact, a recent report by the well-recognized Sandvine Internet traffic monitoring firm finds that all but a fraction of global broadband traffic (*e.g.,* gaming) is non-latency sensitive. That means that consumers in most cases will value affordability and speed over latency in terms of quality of service for the applications that they value the most.

The table below presents data extracted from the *2020 Global Internet Phenomena* report, the most recent Sandvine report analyzing global Internet traffic.[9] The vast majority of applications in the table below are non-latency sensitive. In fact, only the *first-person* gaming applications sub-set of the gaming category are latency sensitive in that category.

8 *See* SpaceX comments at p. 4.

9 *See* Sandvine, *Global Internet Phenomena Report: Global Application Category Traffic Share*, slide 6 (May 2020).

Application Category	Total Traffic Percentage (2020)
Video Streaming	57.64%
Social Networking	10.73%
Web	8.05%
Marketplace (purchase and download apps, music, movies, books and software updates)	4.97%
Messaging	4.94%
File Sharing	4.64%
Gaming	4.24%
VPN	2.56%
Cloud	1.83%
Audio	0.39%

Other factors that can also be important in providing a quality consumer experience, for example, include low packet loss and jitter rates, but these may not be as important as other factors discussed above, depending on how they are managed and the applications consumers value most. Low rates of packet loss are essential to ensure the integrity of data that is sent and received over a broadband service. Low jitter helps to compensate for packet delay, but, like latency, is far less significant than speed of the connection for the vast majority of applications like video streaming, as jitter can be addressed by other network management tools like buffering and caching. Therefore, there is no significant correlation between low jitter and a high-quality end-user experience. Speed is by far a more important factor in ensuring a quality experience with video streaming applications, which are by far the highest global Internet traffic category.

Taking all the network performance dimensions into account, Viasat has optimized its GSO networks to provide the largest possible throughput for users to ensure that consumers receive high-quality services capable of supporting important broadband applications at the most affordable prices. Viasat suggests that TRAI look closely at the multitude of dimensions involved in the consumer broadband experience for particular applications and not focus on a single criterion, such as latency.

III. CONTINUED ACCESS TO THE 28 GHZ BAND IS CRITICAL FOR SATELLITE BROADBAND SERVICES IN INDIA: 5G/IMT Has Access to Vast Amounts of mmWave and Low- and Mid-Band Spectrum Outside of the 28 GHz Band.

As Viasat explains below, suggestions from COAI[10] and Ericsson[11] to identify the 27.5-29.5 GHz (28 GHz) band for 5G/IMT in India, instead of satellite broadband, would have a

[10] *See* COAI comments at p. 15.

[11] *See* Ericsson comments at p. 6-7.

deleterious effect on the telecommunications market in India. As noted by TRAI in the Consultation and supported by Viasat in its comments,[12] Ka band spectrum access, particularly the 27.5-29.5 GHz (28 GHz) band, is essential for satellite broadband services in India. In addition, the Member States of the ITU have repeatedly rejected attempts by the 5G/IMT proponents to identify the 28 GHz band for 5G/IMT and have instead reaffirmed the importance of the 28 GHz band for satellite broadband services. The ITU World Radiocommunication Conference in 2019 (WRC-19) made vast amounts of separate spectrum, including mmWave bands, available for 5G/IMT. Viasat provides greater detail on each of these points below for the benefit of TRAI.

The latest commercial satellite broadband networks, including Viasat's networks and various Indian satellites, currently use the 28 GHz spectrum to provide broadband Internet service to millions of end users, and hundreds of millions of personal electronic devices each year, around the world, whether at home, at work, or traveling in vehicles, on ships, or on aircraft. As with all other successful services, satellite broadband spectrum requirements expand as user demand continues to grow.

Full Use of the Ka Band. Over 120 GSO fixed satellite service (FSS) Ka band satellites, including those being built and deployed by ISRO for use in India (*i.e.,* GSAT 11, 19, 20, and 29), are now in orbit around the world, providing a wide range of services to individuals, businesses, and governments. Many more Ka band GSO satellites are under construction to meet the growing demand for service and need to use the 28 GHz band to meet this demand.

Provision of Competitive Services. Ka band satellite systems provide services that are competitive with, and in some cases superior to, terrestrial service. Ka band spectrum "powers" satellite broadband services that:

- Can be offered at speeds of 100 Mbit/s and higher.
- Can be deployed to a given location almost immediately through a small antenna that can be mobile, transportable, or fixed in place, depending on end-user requirements, and that does not need to be individually licensed or coordinated.
- Are extendable to anyone near that satellite antenna by using a Wi-Fi hot spot to distribute the satellite connection—whether to entire communities or everyone on an airplane, ship, train or bus.
- Meet needs that no other technology now addresses, or will address, including:
    - Connecting otherwise unserved and underserved families, communities, and small businesses around the world, many of whom are located in pockets of heavily populated areas;
    - Connecting widely-dispersed government facilities;

[12] *See* Viasat comments at 4-5.

  - Connecting passengers and crew on trains, buses, ferries, ships and aircraft;
  - Supporting emergency responders, national defense and security;
  - Enabling disaster recovery and relief operations; and
  - Providing always-available global communications capabilities.

- Further important policy goals, such as enabling telemedicine and connecting healthcare facilities, facilitating precision farming, monitoring critical infrastructure, extending access to education and libraries, supporting the development of e-commerce, access to banking, and the creation of new jobs.

Mobile Satellite Broadband Services. Viasat has also pioneered Ka-band satellite-powered mobile broadband services to aircraft, ships and other land-based users, using innovative antenna designs called Earth Stations in Motion (ESIM). For example, passengers and crew on aircraft use ESIM to obtain the gate-to-gate, high-speed broadband for entertainment, cabin support and fleet digitization and maintenance that they demand.

The size of the market for satellite-powered connectivity on aircraft is described in a report by the London School of Economics (LSE), which forecasts ubiquitous global connectivity on aircraft through ESIM by 2035, reaching 7.2 billion passengers and creating a total market of $130 billion, for the benefit of airlines, content providers, retail goods suppliers, hotel and car suppliers, and advertisers.[13] LSE also explains that the digital transformation of the airline industry is giving rise to the "connected aircraft" facilitated by satellite communications to create an Internet of Things (IOT) environment delivering significant commercial efficiencies for airline operations.[14] Viasat recommends that India plan for these needs by ensuring the availability of adequate Ka band spectrum, including the 28 GHz band, for satellite broadband services in India.

Global shipping and passenger vessels also rely on ESIM for navigation and broadband communications, benefiting cargo, passengers and crew. Trains, buses and other land-based vehicles also rely on satellite broadband services for passenger connectivity, operations and maintenance support and fleet tracking.

Urban Quality Broadband for the Increasingly Unserved. The digital divide is a reality, and Viasat and other satellite broadband providers aim to bridge the digital divide, allowing more people to benefit from broadband services by connecting the unconnected in underserved and

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13 *See* London School of Economics, *Sky High Economics – Chapter One: Quantifying the commercial opportunities of passenger connectivity for the global airline industry* (September 2017) available at: https://www.lse.ac.uk/business-and-consultancy/consulting/consulting-reports/sky-high-economics.

14 *See* London School of Economics, *Sky High Economics – Chapter Two: Evaluating the Economic Benefits of Connected Airline Operations* (June 2018) available at: https://www.lse.ac.uk/business-and-consultancy/consulting/consulting-reports/sky-high-economics-chapter-two.

unserved areas across India. Viasat's Community Internet broadband service empowers communities, students, and micro-enterprises, driving growth and connectivity and supporting many new services in the areas of telemedicine, remote education, disaster recovery and relief, and agriculture.

Maximizing Spectrum Efficiency. The advanced satellite broadband services and capabilities described above are made possible by the increased spectrum efficiency of Ka band satellite networks. Satellite technology has advanced to the point that today's satellite broadband systems are approaching "Shannon's Limit" in terms of spectral efficiency.[15] Today's satellite systems provide actual transmissions at near the maximum capacity that theoretically can be achieved over a given amount of spectrum and power flux density. This means that making more spectrum available is the only way to increase satellite capacity and serve more end users. Therefore, access to adequate spectrum is now the primary limiting factor in extending cost-effective and reliable satellite broadband networks to address all the unserved and underserved around the world.

The needs of the satellite industry have long been recognized by the International Telecommunication Union (ITU) and its Member States, including India. Consistent with the affirmation of the primary ITU allocation of the 28 GHz band to the Fixed Satellite Service (FSS) globally by the ITU at WRC-15 and WRC-19, Viasat and other members of the satellite industry have made significant investments in satellite infrastructure that has already been deployed, and even more that is being constructed for deployment in the next few years.

That global consensus continues to be affirmed. Over 120 countries (a growing number), including India, have expressed their intention to follow the international consensus and the WRC decisions to (i) preserve the 28 GHz band for satellite broadband services, and (ii) accommodate 5G/IMT technology in other bands globally harmonized for 5G/IMT bands, including over 17 gigahertz of separate mmWave spectrum made available by WRC-19 for 5G/IMT, particularly the full 24.25-27.5 GHz (26 GHz) band.[16]

In identifying possible spectrum for 5G/IMT, WRC-15 expressly rejected consideration of

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[15] *See* M. Viswanathan, Channel Capacity & Shannon's theorem - demystified, GAUSSIANWAVES, Apr. 23, 2008, https://www.gaussianwaves.com/2008/04/channel-capacity/.

[16] ITU Press Release, *WRC-19 identifies additional frequency bands for 5G*, Nov. 22, 2019 ("While identifying the frequency bands 24.25-27.5 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48.2 and 66-71 GHz for the deployment of 5G networks, WRC-19 also took measures to ensure an appropriate protection of the Earth Exploration Satellite Services, including meteorological and other passive services in adjacent bands. In total, 17.25 GHz of spectrum has been identified for IMT by the Conference, in comparison with 1.9 GHz of bandwidth available before WRC-19. Out of this number, 14.75 GHz of spectrum has been harmonized worldwide, reaching 85% of global harmonization.") https://news.itu.int/wrc-19-agrees-to-identify-new-frequency-bands-for-5g/.

the 28 GHz band because of the existing use of that spectrum for satellite broadband services.[17] Instead, WRC-15 directed that the 28 GHz band be considered for use by ESIM, in order to extend global mobile connectivity by satellite.[18]

WRC-15 also adopted ITU Resolution 238 to identify candidate bands for designation for 5G/IMT, and to guide the process for any decision to actually designate a candidate band for 5G/IMT. In doing so, Resolution 238 reinforces the basis for ensuring continued access to the 28 GHz band for existing and evolving satellite broadband services. Resolution 238 acknowledges that:

- The identification of frequency bands allocated to mobile service for 5G/IMT may change the sharing situation regarding applications of services to which those frequency bands are already allocated (such as the Fixed Satellite Service);

- The need for existing services to be protected and allowed to continue to develop must be taken into account when considering frequency bands for possible additional allocations to any service, including 5G/IMT;

- Any identification of frequency bands for 5G/IMT should take into account the use of bands by other services and the evolving needs of these services; and

- Any identification of a band for 5G/IMT service should not impose any additional regulatory or technical constraints on services to which the band is currently allocated on a primary basis.

The 5G/IMT systems that have been proposed for mmWave bands are incompatible with satellite broadband. In fact, this incompatibility with satellite services is why both WRC-15 and WRC-19 declined to initiate any studies associated with the possible introduction of 5G/IMT in the 28 GHz band. Viasat therefore respectfully requests India to satisfy the spectrum requirements for 5G/IMT in the 24.25-27.5 GHz (26 GHz) band and other bands identified by the ITU for 5G/IMT.

Significantly, WRC-19 not only decided that the 28 GHz band should be considered for use by ESIM in order to extend global mobile connectivity by geostationary satellites, WRC-19 further requested studies on the use of parts of the 28 GHz band for both ESIM operating with NGSO systems under Agenda Item 1.16 and satellite-to-satellite links under Agenda Item 1.17.

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[17] *See* http://interactive.satellitetoday.com/how-wrc-15-led-to-the-big-c-band-decision.

[18] *See* ITU Resolution 158 (WRC-15) "Use of the frequency bands 17.7-19.7 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space) by earth stations in motion communicating with geostationary space stations in the fixed satellite service," considering "d" and considering further "a."

Viasat urges TRAI to disregard any attempts by the 5G/IMT proponents to seek identification of the 28 GHz band for 5G/IMT and to instead preserve access to the 28 GHz band for satellite broadband services and identify the 26 GHz and other mmWave and low- and mid-bands for 5G/IMT.

Appendix 1 – Twenty-Year-Old ITU Single Entry EPFD↑ Limits Do Not Protect Modern Very High Throughput GSO FSS Networks

This Appendix provides additional technical detail on the important EPFD issues discussed in Viasat's counter-comments above. It is important to note that the ITU Article 22 *Radio Regulations* only apply to NGSO systems operating in the 17.8-18.6 GHz and 19.7-20.2 GHz bands. As such, they do not cover all the bands in which GSO FSS Ka band satellites operate. In addition, the ITU NGSO EPFD limits were developed using user antenna or earth stations that were significantly larger (*e.g.,* 70 cm – 5 m) than the typical diameters of antennas in use with GSO networks today (*e.g.,* 45-60 cm) that are much more affordable. Similarly, the reference antenna patterns used in Article 22 for Ka-band EPFD↑ from 20 years ago when the EPFD limits were created are based on much lower satellite antenna gain (*e.g.,* 10 to 20 dB lower) than today's GSO satellite antennas. Today's satellite antenna high gain makes them far more spectrally efficient but also more susceptible to interference from NGSO systems and, therefore, more restrictive NGSO EPFD↑ limits are required. Moreover, the NGSO EPFD↑ limits are "single entry" values that apply only to individual NGSO systems; there is no ITU limit governing aggregate NGSO EPFD↑ emissions from multiple NGSO systems.

It should also be noted that this Appendix only addresses EPFD↑ limits. It does not address EPFD↓ limits which would be a more complex analysis but are also required in any examination of these issues to determine appropriate limits to protect GSO networks.

The impact of Ka-band NGSO FSS systems operating at the ITU's EPFD↑ limit on co-frequency GSO FSS networks is characterized by data rate reduction, the appropriate metric for modern Ka-band GSO networks. Today's two-way satellite connections mainly carry Internet traffic, so maintaining connections is more important than providing a constant bit rate. Adaptive coding and modulation (ACM) is used to combat link degradation resulting from aggregate EPFD↑ by maintaining the connection, but with reduced throughput. This decrease in throughput results in decreased satellite beam capacity, EPFD↑ impact is on a beam-by-beam basis.

The relevant excerpt from the ITU-R Radio Regulations for Ka-band uplinks follows:

> *22.5D 3) The equivalent power flux-density, epfd↑, produced at any point in the geostationary-satellite orbit by emissions from all the earth stations in a non-geostationary-satellite system in the fixed-satellite service in the frequency bands listed in Table 22-2, for all conditions and for all methods of modulation, shall not exceed the limits given in Table 22-2 for the specified percentages of time. These limits relate to the equivalent power flux-density which would be obtained under free-space propagation conditions, into a reference antenna and in the reference bandwidth specified in Table 22-2, for all pointing directions towards the Earth's surface visible from any given location in the geostationary-satellite orbit. (WRC-2000)*

TABLE 22-2 (WRC-03)

Limits to the epfd↑ radiated by non-geostationary-satellite systems in the fixed-satellite service in certain frequency bands

Frequency band	*epfd↑ (dB(W/m²))*	*Percentage of time epfd↑ level may not be exceeded*	*Reference bandwidth (kHz)*	*Reference antenna beamwidth and reference radiation pattern*
27.5-28.6 GHz	*−162*	*100*	*40*	*1.55°* *Recommendation ITU-R S.672-4, L_s = −10*
29.5-30 GHz	*−162*	*100*	*40*	*1.55°* *Recommendation ITU-R S.672-4, L_s = −10*

Unlike the EPFD↓ limits, the EPFD↑ limit is a single maximum value that an NGSO FSS system can operate at, but not exceed. Hence, the aggregate EPFD↑ at all times and at all locations on the GSO arc could be N times the single-entry limit, where N is the number of NGSO FSS systems operating in the band. Because EPFD↑ at the GSO arc results from sidelobe, not mainbeam, emissions, band sharing techniques employed among NGSO systems would not significantly reduce this impact. NGSO FSS systems implement GSO arc avoidance to meet EPFD↑ limits.

Several GSO FSS networks currently operational, or to be operational shortly, could be significantly harmed by even a single NGSO FSS system operating in compliance with ITU-R EPFD limits. These include Viasat's 1st, 2nd, and 3rd generation GSO FSS networks. Competitive pressures will almost certainly result in future two-way broadband Ka-band systems having similar, or even higher, G/T beams, as reflected in the sampling of GSO networks at the ITU in Table 2 below.

Table 1 shows the uplink degradation and associated uplink data rate reduction that these high G/T satellite beams could experience from a single NGSO FSS entrant operating at the EPFD↑ limit,[19] and also shows the evolution in GSO network design over just the past

[19] The Appendix provides technical analysis relating uplink degradation and uplink data rate reduction to EPFD↑.

decade. Figure 1 shows the uplink data rate reduction that these beams could experience as a function of the number of NGSO FSS systems operating in the band.

Table 1 – Impact of Single Entry EPFD↑ on Viasat's Ka-Band GSO FSS Satellites.

Viasat Generation	Service Entry	Capacity	Ka-band G/T	Degradation[20]	Data Rate Reduction[21]
1st	2012	140 Gbps	21.7 dB/K	0.6 dB	5%
2nd	2018	300 Gbps	30.8 dB/K	3.4 dB	26%
3rd	2021	1,000+ Gbps	32.9 dB/K	4.7 dB	35%

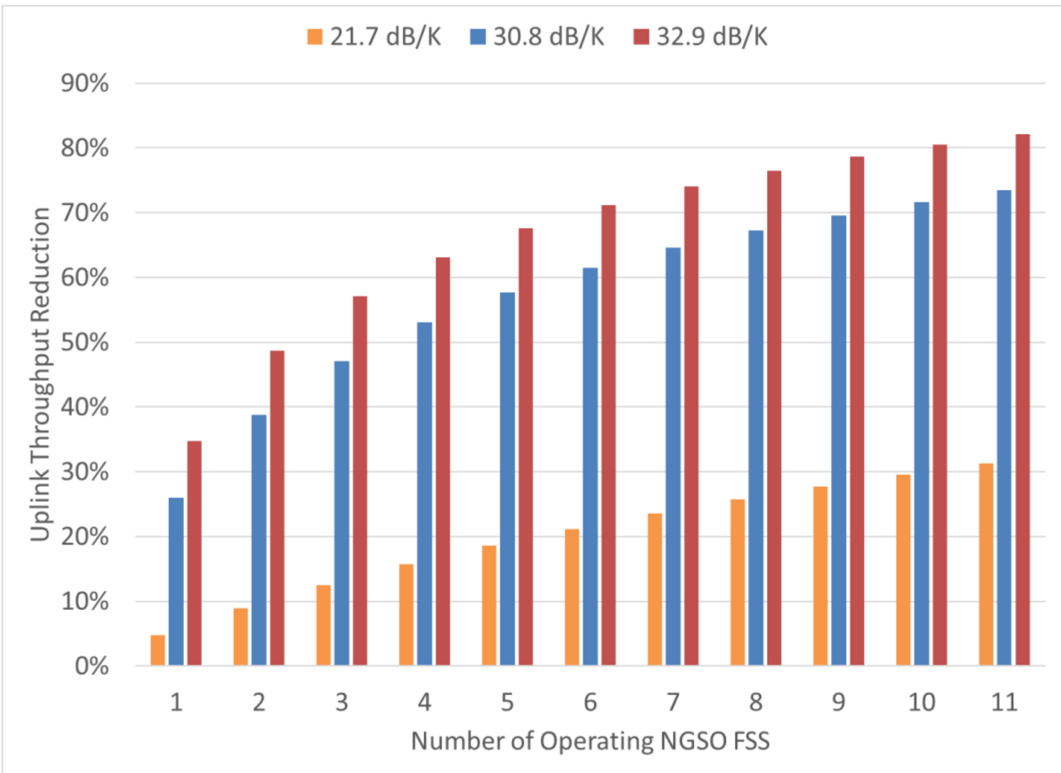

Figure 1 – Impact of Aggregate EPFD↑ From Multiple Co-Frequency NGSO FSS Systems[22].

20 Computed using Equations *(3)* and *(4)* from the Annex.

21 Computed using Equation *(9)* from the Annex.

22 Computed using Equations *(3)* and *(6)* from the Annex.

In addition to the Viasat networks used as an illustration, other very high throughput GSO FSS systems would be similarly impacted. Relevant ITU Ka-band coordination filings include those shown in *Table 2*.

Table 2 – Selected Ka-Band Networks.

Network Name	**Admin.**	**G/T (dB/K)**
F-SAT-N8	F	33.0
NUSANTARA-BR1-E	INS	33.0
QATARSAT-G5	QAT	33.0
USASAT-31K	USA	32.2
ARSAT-F	ARG	29.0
INSAT-KA[23]	IND	28.0

23 Available to GSAT 11, 19, 20, and 29.

Annex – epfd↑ Technical Analysis

The epfd↑ resulting from operation of a co-frequency NGSO FSS system is potential interference into a GSO FSS network's uplink. The impact of this interference is characterized by the interference-spectral-density to thermal-noise-spectral-density ratio, I_0/N_0, which can be calculated as:

$$I_0/N_0\ (dB) = epfd_{\uparrow}\ (dBW/m^2) - 10\log_{10} B_R\ (Hz) + G/T\ (dBi/K) - G_1\ (dBi/m^2) - k\ (dBW/(K\cdot Hz))$$

(1)

Where epfd↑ is effective PFD in the uplink direction (dBW/m^2)

B_R is the reference bandwidth associated with the epfd↑ value (Hz)

G/T is the GSO satellite receive beam G/T (dB/K)

G_1 is the ideal gain of a 1-meter squared area at the uplink frequency (dBi)

$$G_1\ (dB) = 10\log_{10}\left[\frac{4\pi \times F\ (Hz)^2}{c\ (m/s)^2}\right]$$

(2)

Where F is the uplink frequency (Hz)

c is the speed of light, 299,792,458 m/s

k is Boltzmann's constant, -228.6 dBW/(K×Hz).

Plugging in the 40-kHz reference bandwidth and using 28.72 GHz as the uplink frequency (< 0.2 dB error across the two bands), gives

$$I_0/N_0\ (dB) = epfd_{\uparrow}\ (dBW/m^2) + G/T\ (dB/K) + 132\ dB$$

(3)

The degradation experienced by a GSO FSS uplink is a function of the I_0/N_0. It can be calculated as:

$$\gamma\ (dB) = 10\log_{10}\left[1 + 10^{I_0/N_0\,(dB)/10}\right]$$

(4)

When there are multiple NGSO FSS systems operating in the band, the degradation is given by:

$$\gamma\ (dB) = 10 \log_{10}\left[1 + 10^{\theta_1/10} + 10^{\theta_1/10} + \cdots + 10^{\theta_N/10}\right]$$

(5)

Where N is the number of co-frequency NGSO networks operating in the band

θ_k is the I_0/N_0 resulting from the k-th NGSO network's epfd (dB)

If the epfd↑ form each of the NGSO networks results in the same I_0/N_0, then Equation (5) reduces to:

$$\gamma\ (dB) = 10 \log_{10}\left[1 + N \times 10^{I_0/N_0\ (dB)/10}\right]$$

(6)

Today's two-way satellite connections mainly carry Internet traffic, so maintaining connections is more important than providing a constant bit rate. Thus, even small amounts of link degradation have significant impact on GSO network performance. Modern GSO networks utilize adaptive coding and modulation (ACM) to improve spectral efficiency and transmission performance.

ACM combats the link degradation resulting from aggregate epfd↑ by maintaining the connection, but with reduced throughput. This decrease in throughput results in decreased satellite capacity. The impact of aggregate epfd↑ degradation is related to decrease in satellite link capacity by the slope of the ACM modem operating curve. Modem performance has improved significantly over the last two decades and is expected to continue improving in the future. Today's state-of-the-art modems provide DVB-S2X class performance.

Future modem performance is bounded by the Shannon limit, which relates the maximum achievable spectral efficiency to the available carrier-to-noise ratio (C/N) (in this context, N is the total noise in the link, including thermal and interference). The Shannon limit is:

$$\varepsilon(bps/Hz) \ = \ \log_2\left(1 + 10^{C/N(dB)/10}\right)$$

(7)

Figure 2 shows the Shannon limit curve, the DVB-S2X modem MODCODs, and the least squares 2nd degree polynomial fit to the MODCOD's.

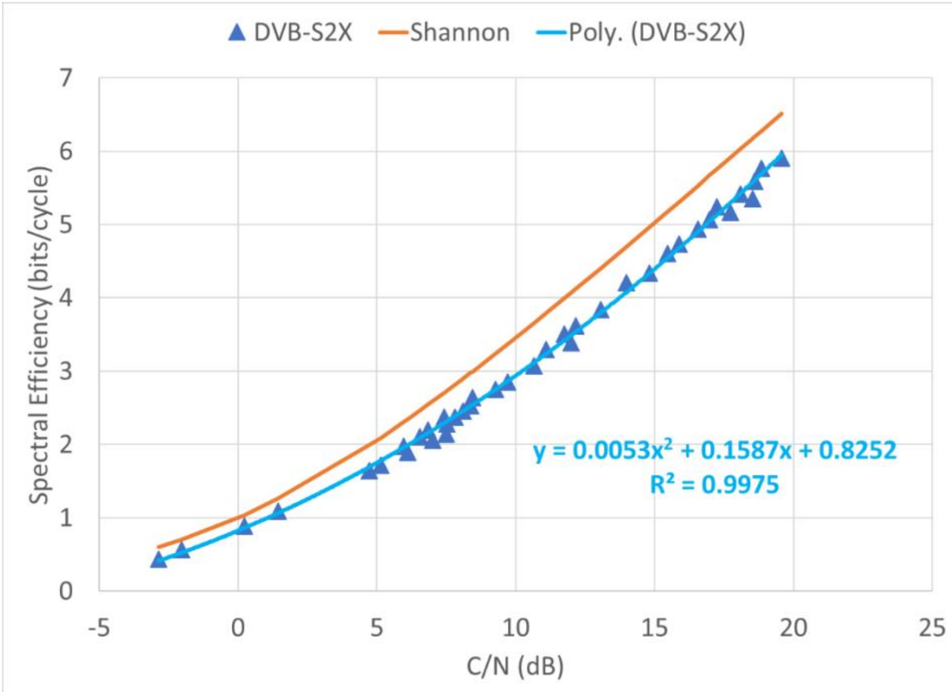

Figure 2 – Modem Operating Curve.

The fit equation,

$$\varepsilon\ (bps/Hz) = 0.0053 \times (C/N)^2 + 0.1587 \times (C/N) + 0.8252$$

(8)

Provides the DVB-S2X operating curve.

The ITU recently introduced the concept of "percent degraded throughput", %DTp, as the appropriate metric for ACM links. The percent degraded throughput, %DTp, is given by

$$\%\mathrm{DTp}(\rho, \gamma) = 100\left[1 - \frac{\varepsilon(\rho - \gamma)}{\varepsilon(\rho)}\right]$$

(9)

Where

ρ is the undegraded C/N

γ is the degradation

ε(x) is the spectral efficiency function.