SATELLITE COMMUNICATIONS NETWORK TECHNOLOGIES AND BEST PRACTICES FOR MINIMIZING EMI/RFI

Mr. Justin Luczyk
ViaSat Inc., justin.luczyk@viasat.com

ABSTRACT

With the growing applications and use of satellite communications systems and desire to use non-formally trained users versus fully trained satellite service operators, there has been an increase in the number of EMI incidents impacting remote users and satellite operators / service providers. On traditional general purpose satellite networks, identifying and resolving EMI issues is a complicated and lengthy process that may require weeks or months of time an effort. High Capacity Satellite networks, employing end-to-end performance and monitoring techniques illustrates how an optimized systems approach to satellite data services vastly reduces the number of EMI incidents and allows for much more rapid identification and resolution of these challenges.

EMI PROBLEM

Over the past decade we have seen substantial growth in the need for data communications and information sharing due to demand for better command and control; intelligence, surveillance and reconnaissance video; position location information; imagery products as well as situational awareness and reporting. With this growth has come a stronger reliance on satellite communications (SATCOM) by tactical units. As the prevalence of SATCOM has grown, so has the variety of different terminal types, from traditional 1.2m and 2.4m to sub 60-cm micro-sat systems to airborne and land mobile communications on the move. The combination of this expansive growth and lack of additional formally trained satellite operators has led to additional problems in creating and then identifying, managing and resolving Electro Magnetic Interference / Radio Frequency Interference (EMI/RFI).

The EMI problem impacts both users as well as service providers in a significant way. From the user perspective, EMI can lead to significantly decreased network speeds and performance resulting in poor user satisfaction and additional time spent to accomplish the mission. Even if a user's own terminal is accurately pointed and configured, EMI from other offending users can negatively impacted the properly pointed one, causing unnecessary testing and troubleshooting. For satellite operator and service providers, EMI costs them overall network capacity, meaning they are able to serve fewer users. Additional it consumes more power to overcome both at the ground station and at the spacecraft. In broadcast operations, EMI creates interference reducing the broadcast signal quality and the number of broadcast channels, while in broadband operations, EMI reduces the network capacity and can increase the power required to overcome the EMI. It is in the best interest of both satellite operators and users to work to actively minimize EMI interference in order to utilize the full capability of each spacecraft as well as to provide users the quality and service speeds they have purchased and require operationally.

Exhibit 1: Examples of new and emerging terminals: Airborne COTM and Microsat

UNDERLYING CAUSES OF EMI

There are two main causes of EMI as it relates to satellite communications. The first is poorly pointed user antennas. This is generally due to lack of accurate signal peak or polarization and can have a dramatic impact on user performance. A poorly pointed antenna, operating within a network, can cost 4-5 times the resources of an accurately pointed system and result in dramatically slower performance. The growth of small mirco-sat terminals (with larger beam width) and satellite Communications on the Move (COTM) systems operating with rapidly changing motion dynamics has only added to poor pointing accuracy in recent years.

The second significant cause of EMI has been the growth of rogue/unauthorized carriers in recent years. [1] While many think of rogue carriers as intentionally working to 'steal' bandwidth or cause disruption this is often not the case. Many times users unintentionally operate without proper authorization, particularly when the satellite or frequencies change and they lack the most recent Communications / Electronics Operating Instructions (CEOI) or frequency plan. Additionally with the growing use of satellite terminals by non-formally trained personnel, these users are more prone to make unintentional errors while configuring their terminal that lead to EMI and other problems.

Under the "traditional" satellite model, the varying abilities of the user managing their assigned frequencies and remote terminals, as well as the arms-length relationship of the satellite operator (they are just allowing access to MHz), identifying and troubleshooting EMI problems becomes a very onerous task. As networks grow, this problem is exacerbated as many users fail to perform proper network entry procedures to include calling the satellite operator to perform remote terminal peak and polarization optimization. In this architecture, when an EMI problem is suspected, it can take weeks to month to resolve, since it is challenging to tell if the problem stems from a terminal on the impacted network, a terminal on another network on the same satellite, or from a network operating on an adjacent satellite at the same frequency band. Delays also stem from the fact there are no set procedures for users and operators to validate and resolve this type of EMI issue including coordination with other satellite and network operators. When operations are ongoing, often it is not possible to shut down a carrier to troubleshoot and thus remote terminals must be checked one-by-one, a time consuming and labor intensive process.

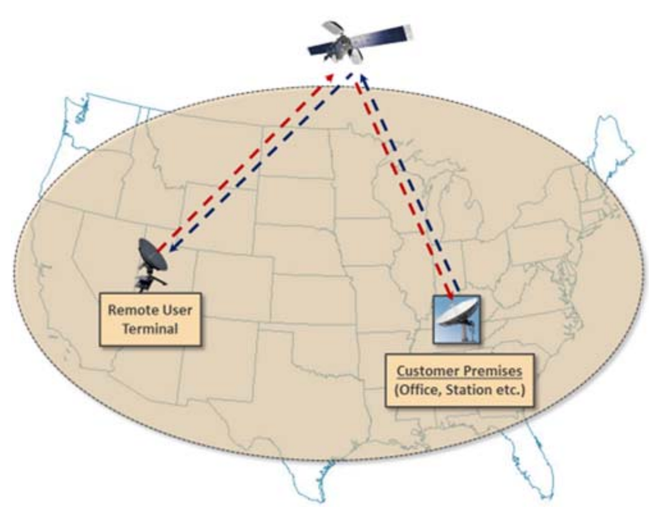

Exhibit 2: Traditional Satellite Beam Architecture

However, based on their design and network capabilities, new end-to-end performance and monitoring techniques that are being used on High Capacity Satellites (HCS) as well as the managed services model provide a more effective way to reduce EMI. These new end-to-end performance and monitoring techniques are applicable to traditional wide-beam satellite as well as HCS and are optimized at inception for 2-way IP data communications allowing for much more robust management of the network and identification of problems. While today they may not be viable for all users based on geography and leasing agreements, they should be used whenever possible and their architecture can be used as a guideline for best practices.

END-TO-END PERFORMANCE MONITORNING TECHNIQUES AND HIGH CAPACITY SATELLITE NETWORKS

Unlike traditional satellites, the spacecraft and network design for High Capacity satellites networks have been optimized from the ground up to provide 2-way IP data communication. The coverage area of an HCS is divided into many spot beams, unlike a conventional satellite which provides coverage though one large shaped beam. The use of spot beams enables large-scale frequency re-use, with adjacent cells using alternate frequencies and polarizations.

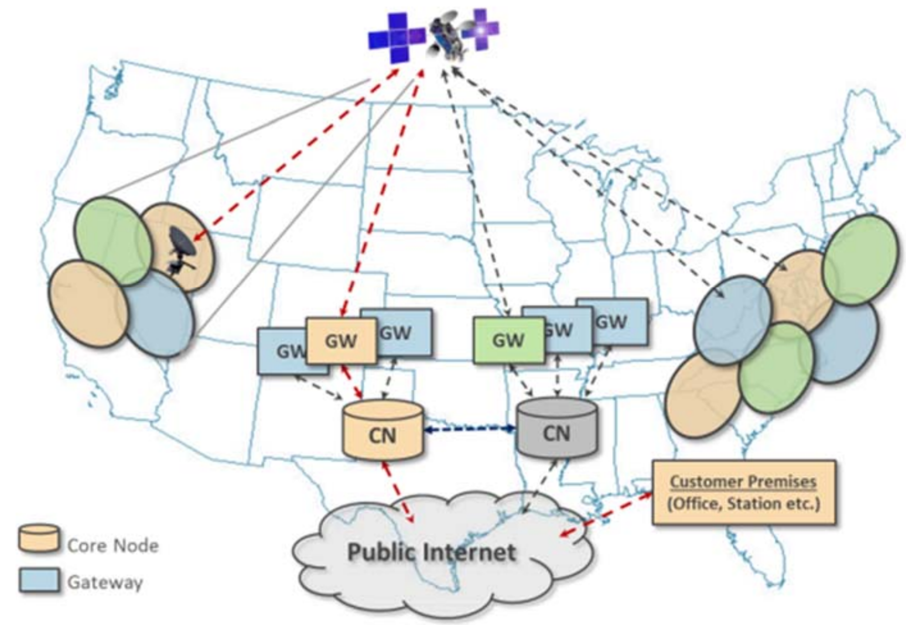

Exhibit 3: High Capacity Satellite Beam Architecture

The spot beams concentrate the electromagnetic energy into a smaller area than conventional satellites, making the spot beams "hotter" than a wider conventional satellite beam. With an HCS end-to-end network, there have been three primary techniques employed to minimize and resolve EMI challenges:

- System Approach to Network Design
- Network Tools
- User Training

Since the design of these High Capacity Satellites is focused on a specific use case and intended purpose, a systems approach to the network design can be implemented to simplify user hardware and allow for improved network awareness and monitoring and control. User hardware for a HCS network is typically purpose built to operate as a part of that network. This allows for the design of remote systems to be more simplistic (from a user perspective) and easier to install because there is no need to give remote users the wide variety of options in modem or RF configuration often needed when operating in the traditional satellite paradigm. While the user sees the remote hardware as more simplistic, in reality at the network level, advanced management of remote terminals can be performed to monitor and even control a myriad of different configuration options such as frequencies, polarization, modulation and coding, etc.

The controlled ecosystem of a HCS network and terminals also allows for a more robust set of management tools by both users and service operators. As opposed to having just raw information about a particular user terminal, such as signal level (dB), the operator has network intelligence in terms of knowing not only signal level but also how that compares to user peers, as well as the carrier the user is on, packet loss, network congestion, connectivity to the internet etc. Even with the advances described above, EMI still can and does still exist in a HCS networks. In the Exede network, typically about 11% of terminals are operating below target performance, with 4% severely impaired. However the network tools are able to quickly generate reports that define and identify poor performing terminals and track terminal performance over time (is the degradation gradual or abrupt), and work to actively remediate EMI problems even before they are reported by users.

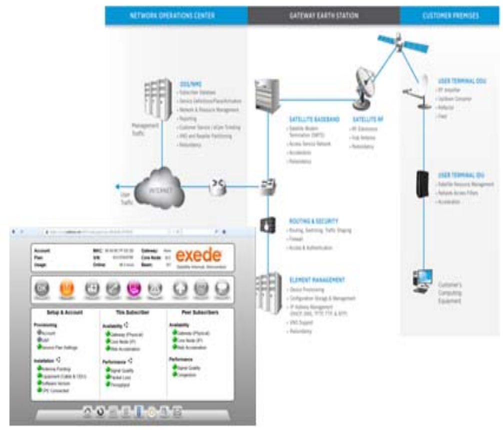

Exhibit 4: Example of HCS Network Visibility and Management Tools

While the HCS network was the catalyst for a more detailed systems approach to network design and advanced network tools, this methodology does have the ability and should be used on "traditional" wide-beam satellites as well. Fundamentally, the only hurdle to overcome is establishing an end-to-end network authority for the DoD or alternatively for each operational network. Historically, due to how DoD procurement took place, with different entities responsible for the various aspects of the satellite network such as bandwidth lease or satellite selection, gateway infrastructure, modem technology, and terminal options and design, there has been no single entity responsible for the entirety of the network. However, after seeing how this methodology and tools have allowed HCS to scale while reducing many of the challenges faced by traditional satellite networks, it is apparent that a similar approach of having a single end-to-end network authority would greatly benefit DoD operations.

Finally, user training continues to be critical in reducing the number and impact of EMI events. The roll-out of HCS networks, often with more than 1,000 installations a day, has made streamlined training and training tools even more critical. Because of the scale, there isn't a way to send a what we would typically think of as a satellite technician out to install each terminal in an HCS network, and instead the tools and training has been designed to be effective to train "cable TV installers", with a 70% annual turnover rate, into satellite installers with a target install time of 2-4 hours. In order to accomplish this, training has needed to be drastically simplified, and tools to support the installers have been required to be simplified and improved. As purpose built networks, the HCS architecture eliminates the need to train users on "corner cases" and unique configurations. Also, little to no RF knowledge is required by HCS terminal installers as that aspect of the network can be completely managed at the network operator level. Additionally, pointing aids and other tools implemented on the systems can be optimized for ease of use and provide real-time feedback at the network level. Although HCS networks do not completely remove the training burden, it drastically reduces the training time from several weeks to months of instructor led formal training to less than eight hours of self-paced web training.

Exhibit 5: Web Based User Training Portal

It is clear that the advances of HCS are able to drastically reduce the challenges associated with EMI. By designing the network specifically for 2-way IP data, remote terminals and training can be simplified, diagnostics of remote terminals are streamlined and control of many parameters of the service can be managed by the service provider. This allows for a dramatic reduction in EMI events and more rapid resolution when they are identified, as well as better overall control of the network and services. While many of these techniques and technology was developed specifically for HCS because of their massive scale, in many cases the same principals can also be applied to existing satellite networks operating on traditional satellites that are in use by the DoD today.

[1] Satellite Industry Association, 2014. Industry Experience and Best Practices for Minimizing EMI/RFI, Washington, DC: