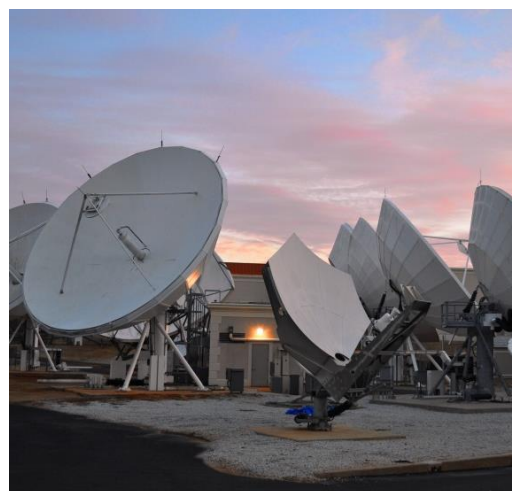
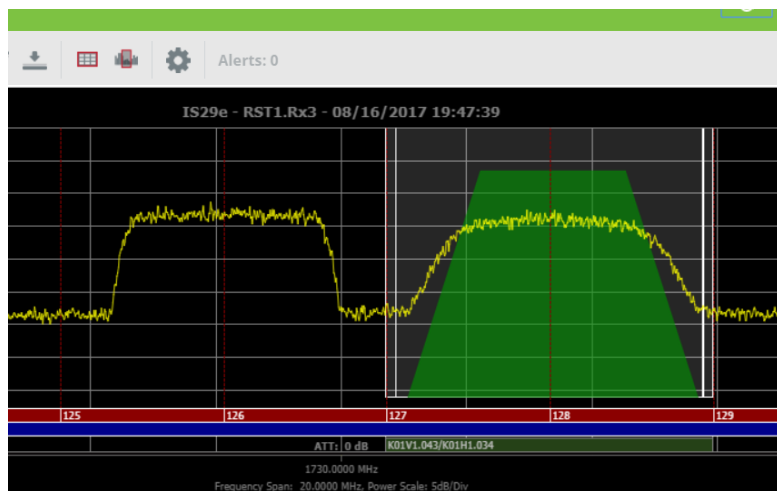


# Intelsat-29e Interference Mitigation Testing

## Interference Scenarios and Mitigation Techniques Enabled by the Intelsat Epic<sup>NG</sup> Class Satellites



## Introduction

Networks are constantly under attack from entities in search of critical data to steal. As cyber threats grow more advanced, so must your satellite communications infrastructure.

Engineered to support the most demanding government communications and applications, Intelsat Epic<sup>NG</sup> delivers reliability, security, performance and the flexibility to keep pace with changing geographic and mission requirements. It's advanced digital payload creates an enhanced environment for battling interference and mitigating jamming so government organizations are assured of secure coverage and connectivity for any operation conducted in an environment anywhere in the world – without interruption.

Intelsat maintains the highest standards of Information Assurance by assessing and building the Intelsat infrastructure, networks, and third party infrastructures against the most stringent DoDI 8500.01 and NIST Risk Management Framework (RMF) cyber security recommendations. Intelsat's Information Assurance program focuses on prevention and restoration by taking a systematic defense-in-depth approach that detects, prevents, and mitigates attacks enhancing resilience and mission assurance in its satellite, ground, and network infrastructure. Further, Intelsat maintains a comprehensive Information Assurance assessment and remediation program which includes annual penetration assessments, organization wide control assessments, and third-party SOC3 audits against Intelsat's satellite and terrestrial service environments including Intelsat's satellite commanding, teleport, terrestrial, and service management infrastructure and relevant service procedures.

## Background

This paper describes interference scenarios and counter mitigation techniques enabled by the Intelsat Epic<sup>NG</sup> class of satellites. The information in this paper is from over-the-air testing conducted on the Intelsat IS-29e satellite, a multi-spot, high frequency re-use, high throughput satellite (HTS). In particular, this paper describes how nominal operations can be maintained even in the presence of in-beam and out-of-beam interferers.

One way to interfere with an existing (aka friendly) signal is to transmit a second (aka interferer) signal towards the same satellite with the interferer occupying the same frequency band and polarization and radiating at an equal or higher power density than the friendly signal. Under this scenario, a receiving earth station cannot properly demodulate and/or decode the friendly signal due to the degraded receive signal-to-noise ratio (SNR).

This exact scenario was created on the Intelsat IS-29e satellite and mitigation techniques to counter it were tested. The scenario was created twice, once with the interference source located out-of-beam and once with it located in-beam. For each location, different mitigation techniques were employed and validated.

The operational environment for this testing was User Beam K01 on IS-29e configured in loopback. I.e. a signal uplinked in the K01 coverage area was received by IS-29e, routed onboard via the digital payload, and transmitted back to earth in the Beam K01 downlink. Beam K01 is shown in the right hand side of Figure 1. The up and downlink frequencies were Ku-band.

## Out-of-Beam Interference Mitigation

In a multi-spot satellite, the coverage area of each spot beam is typically significantly smaller than the area of a traditional, landmass-shaped, wide beam. Figure 1 contrasts the CONUS (contiguous U.S.) wide beam coverage of Galaxy-17, on the left, with the spot coverage of Beam K01 on IS-29e on the right. This difference in coverage areas leads to the first interference mitigation tool provided by Intelsat Epic<sup>NG</sup> satellites, namely out-of-beam rejection.

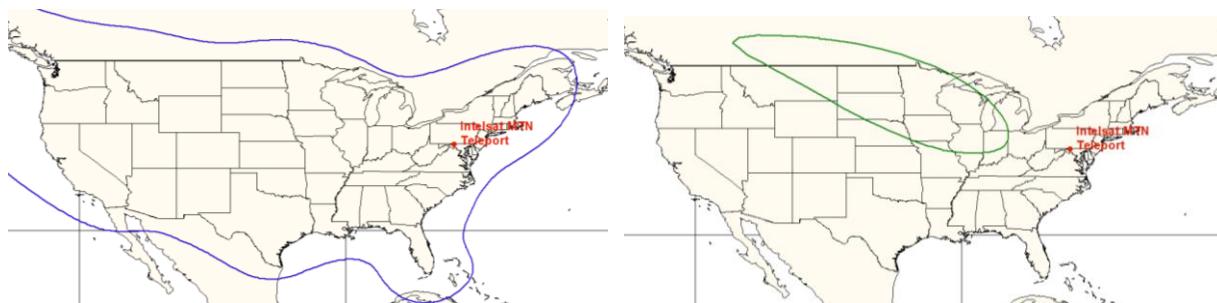


Figure 1 – Wide Beam versus Spot Beam Coverage Areas

The difference in coverage areas between a wide and a spot beam drastically restricts the locations from where an interferer can impact services. For the interference scenario described above and on the Galaxy-17 CONUS wide beam, an interferer could disrupt the friendly transmission from anywhere within CONUS.

When the same scenario is attempted on User Beam K01 on IS-29e, the interferer can be effective only if within the much smaller K01 coverage area. If the interferer is located outside of Beam K01, its signal will not be detected by the IS-29e satellite or will be received at a diminished level. When the interference source is located in Beam K01, other mitigation techniques are possible and are described later in this paper.

To validate out-of-beam mitigation, we operated a collocated hub and a remote terminal in the upper mid-west U.S., on loopback capacity in Beam K01. The remote terminal transmitted a 5 MHz wide carrier of digital video to the hub. At the hub, the carrier was received, the video decoded and viewed on a high-resolution monitor.

Figures 2 and 3 show, respectively, the uplink and downlink spectrum of this testing. IS-29e has an onboard spectrum monitoring system (SMS). Intelsat Epic<sup>NG</sup> satellites continually transmit their SMS data to Intelsat Operations for real time and archival uses. In Figure 2, the yellow line is the spectral power received at IS-29e from Beam K01. The green trapezoid in Figure 2 is an overlay from Intelsat's asset planning system and represents an approved and allocated carrier. The carrier shown is the remote-to-hub video carrier.

Figure 3 shows the IS-29e Beam K01 downlink spectrum as received at the hub. Figures 2 and 3 were taken during nominal operations; the carrier was being properly received and the video quality from remote to hub was excellent.

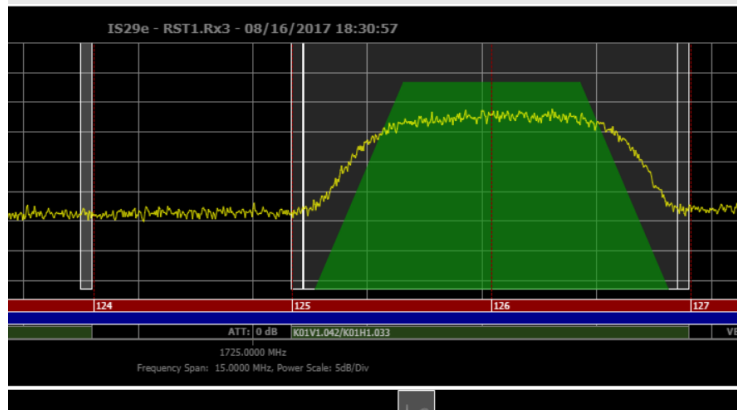


Figure 2 – Nominal Uplink Carrier Spectrum for Out-of-Beam Interferer Testing on IS-29e

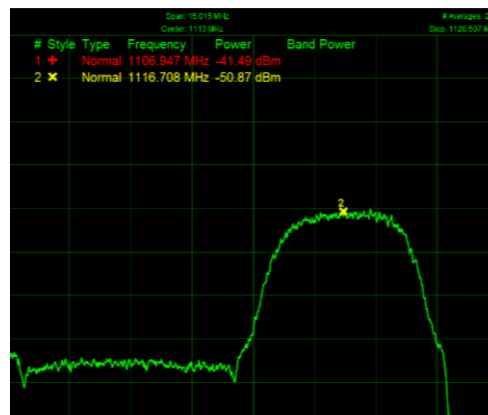


Figure 3 – Nominal Downlink Carrier Spectrum for Out-of-Beam Interferer Testing on IS-29e

To demonstrate out-of-beam interference and mitigation, Intelsat’s Mountainside Teleport (MTN), located in Hagerstown, MD, transmitted an interferer that matched the friendly carrier. The locations of the MTN Teleport and the IS-29e Beam K01 (nominal beam edge) are shown in Figure 4.



Figure 4 – Mountainside Teleport and IS-29e Beam K01 Locations

The MTN interferer matched the friendly carrier in size (symbol rate), modulation, and transmitted power level (EIRP). Since MTN is outside, but still close to, K01 coverage area, its transmitted signal was received at a much lower level than the friendly carrier. Figure 5 shows the uplink and downlink spectrums of the interfering carrier (the friendly carrier has been turned off). Due to the out-of-beam location of the interferer’s transmission, its received power spectral density level in the satellite is approximately 12 dB below that of the friendly carrier.

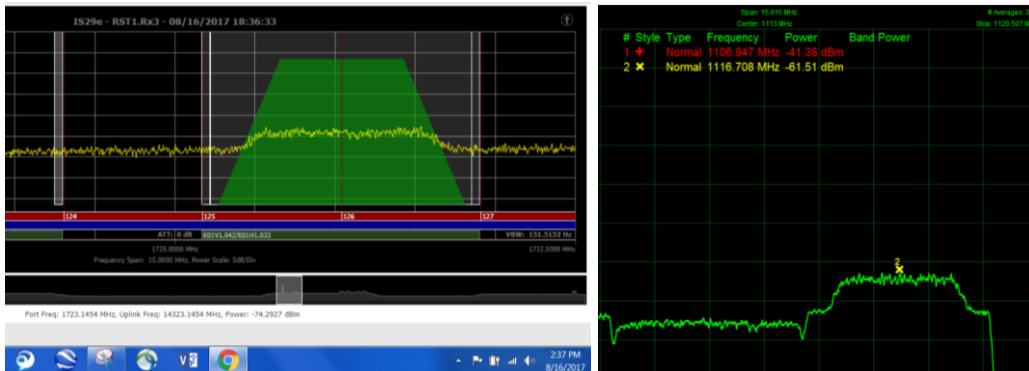


Figure 5 – Out-of-Beam Interferer Uplink & Downlink Spectrums on IS-29e

With both the friendly and interferer carriers transmitting, the uplink and downlink spectrums were as shown in Figure 6. Even with the transmission of an equal power interference signal, out-of-beam rejection by IS-29e was sufficient to enable excellent video reception at the hub. Received video quality was the same as with no interferer present.



Figure 6 – Simultaneous Friendly and Out-of-Beam Interferer Transmissions

The out-of-beam interference protection provided by IS-29e is passive and always present; i.e. this protection does not require any action by the end user nor by Intelsat, the satellite operator. This interference protection is inherent in the design of IS-29e and in all of the Intelsat Epic<sup>NG</sup> satellites.

## In-Beam Interference Mitigation

After validating that IS-29e provides out-of-beam carrier rejection and thereby interference mitigation, we moved the interference source to inside Beam K01 and validated a second interference mitigation technique.

To create an in-beam interferer, we transmitted a matched carrier from the hub location. This carrier was separate from, and in addition to, the remote-to-hub video carrier. At the start of this test, the video carrier was as shown in Figure 7. This is identical to the start of the out-of-beam interferer testing, i.e. Figures 2 and 3. As before, in this mode, the video signal was properly received at the hub and video quality was excellent.



Figure 7 – Nominal Uplink & Downlink Spectrums for In-Beam Interferer Testing

The interferer signal was then transmitted from the hub location. As in the previous test, the interfering carrier matched the friendly carrier in size (symbol rate), modulation, and transmitted power level (EIRP). Since the interferer transmitter was now located in the Beam K01 coverage area, its signal was received by the satellite at the same power level as the friendly carrier. Figure 8 shows Beam K01's uplink and downlink spectrums with just the interferer carrier present (the video, aka friendly, carrier has been turned off). Note that a different modulator type, one with a tighter carrier roll-off, generated the interfering carrier and thereby created a sharper carrier spectrum.

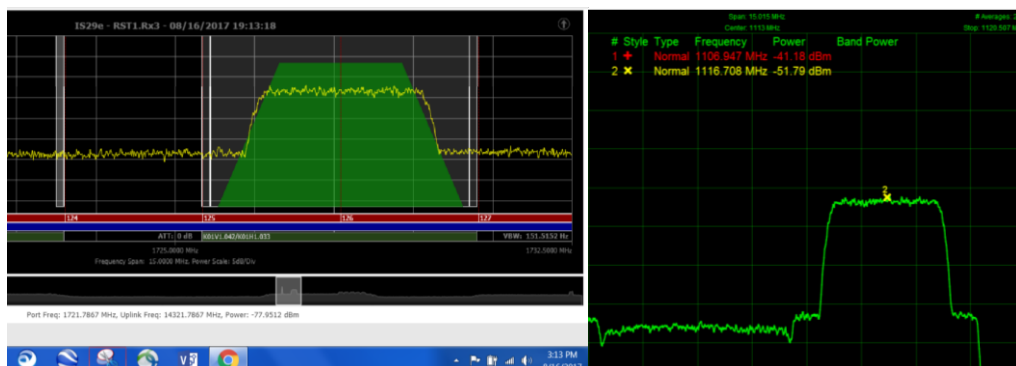
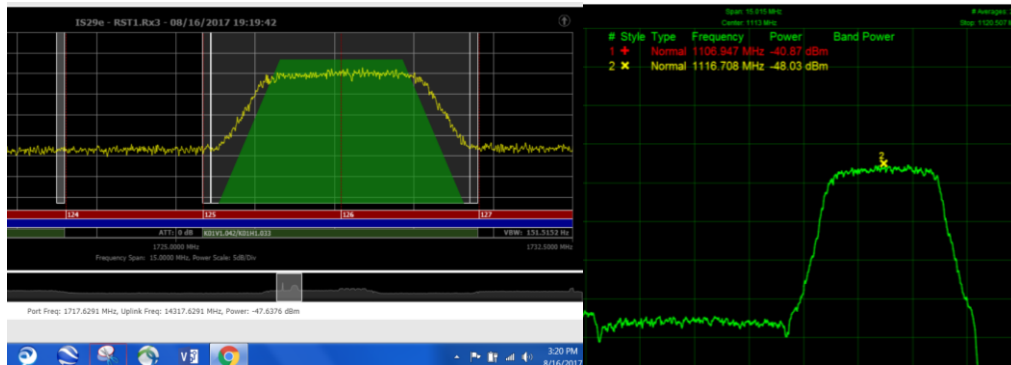


Figure 8 – In-Beam Interferer (only) Uplink & Downlink Spectrums

Transmission of friendly and interferer carriers simultaneously is shown in Figure 9. In this scenario, video reception at the hub was not possible. I.e. the friendly carrier was successfully jammed.



*Figure 9 – Simultaneous Friendly and In-Beam Interferer Transmissions*

To mitigate this interference scenario, two steps were taken, (1) IS-29e’s onboard digital payload was reconfigured and (2) the video carrier’s transmit frequency was changed to a clear uplink frequency.

Reconfiguration of the onboard digital payload accomplished the following:

1. Notched out the interferer – i.e. terminated it at the satellite; did not transmit it back to earth.
2. Assigned new, interference-free, uplink bandwidth to the video carrier.
3. Routed the new video carrier uplink bandwidth to the original downlink bandwidth allocation.

As the satellite was reconfigured, the video carrier transmitter changed its frequency to match the new uplink assignment.

With these two steps, the interference was completely mitigated and video reception returned to normal. Total time for these reconfigurations and restart of successful video transmission was less than 20 minutes.

Figures 10 through 12 visualize the sequence of mitigation steps taken to counter the in-beam interferer. In Figure 10, satellite reconfiguration is underway. The video carrier’s uplink bandwidth has been re-allocated to avoid the interferer. The new allocation is the green trapezoid. Actual transmission of video carrier has not yet restarted.

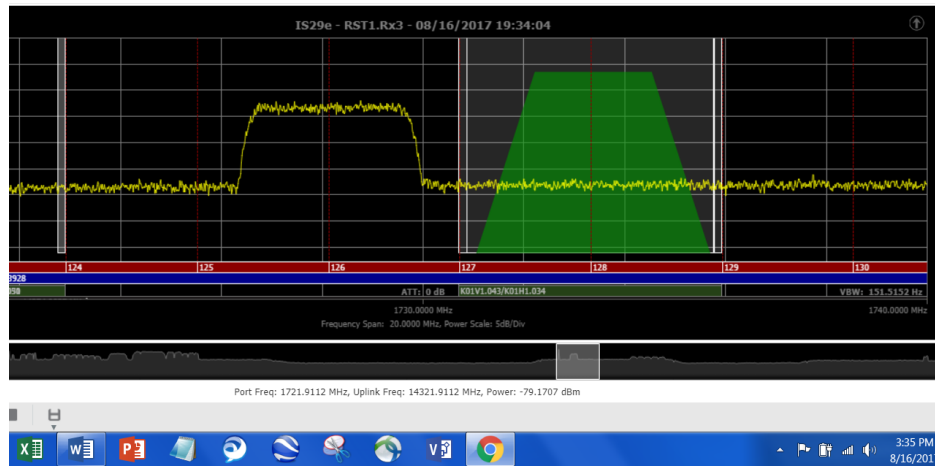


Figure 10 –IS-29e Re-configuration to Terminate Interferer & Re-allocate Friendly Carrier

Transmission of the interfering carrier has been left as is but the uplink bandwidth it occupies has been deallocated on the satellite. As such, this uplink bandwidth is no longer routed onboard to a downlink path and, thereby, is terminated at the satellite. I.e. the interferer is no longer corrupting IS-29e’s transmissions back towards earth.

Figure 11 shows the IS-29e K01 downlink as received at the hub where the interferer has been blocked (aka is “notched out”). The friendly video transmission has not yet restarted.

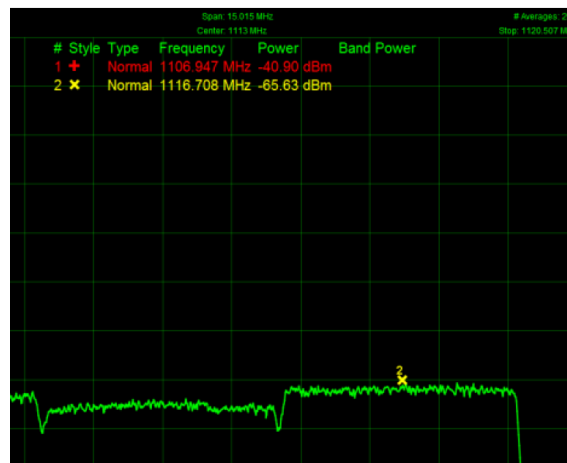


Figure 11 – Beam K01 Downlink at Hub with Interferer Terminated

With the video transmission re-started, Figure 12 shows the two uplinked signals (left) and IS-29e’s single downlinked signal (right). At this point, successful video transmission has been re-established.





Figure 12 –IS-29e Reconfiguration to Terminate Interferer & Reallocate Friendly Carrier

Key items to note about this mitigation of an in-beam interferer:

1. The interferer was removed from the Epic<sup>NG</sup> satellite downlink with no interaction with the interferer’s transmitter.
2. Post mitigation, the video signal’s downlink remains in the same bandwidth segment as before.
3. Mitigation actions, including satellite re-configuration, required less than 20 minutes.

The second item is important in that the earth station receiving the video signal typically does not have to take any actions during this interference mitigation. Over this test sequence, the video receive terminal saw, in the same bandwidth segment, (1) a clean video signal, (2) a corrupted video signal, (3) nothing, and (4) a restored, clean video signal.

## Summary

This testing validated that the Intelsat Epic<sup>NG</sup> satellites can successfully provide mitigation to interferences transmitted from both out-of-beam and in-beam locations. Out-of-beam interference mitigation is due to beam coverage design. As such, out-of-beam interference mitigation is always present and does not require any action from end users.

In-beam interference mitigation is possible due to the capabilities of the digital payload on Epic<sup>NG</sup> satellites. Active identification of the interferer and payload re-configuration are required to provide mitigation and these can be accomplished in a timely manner.

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