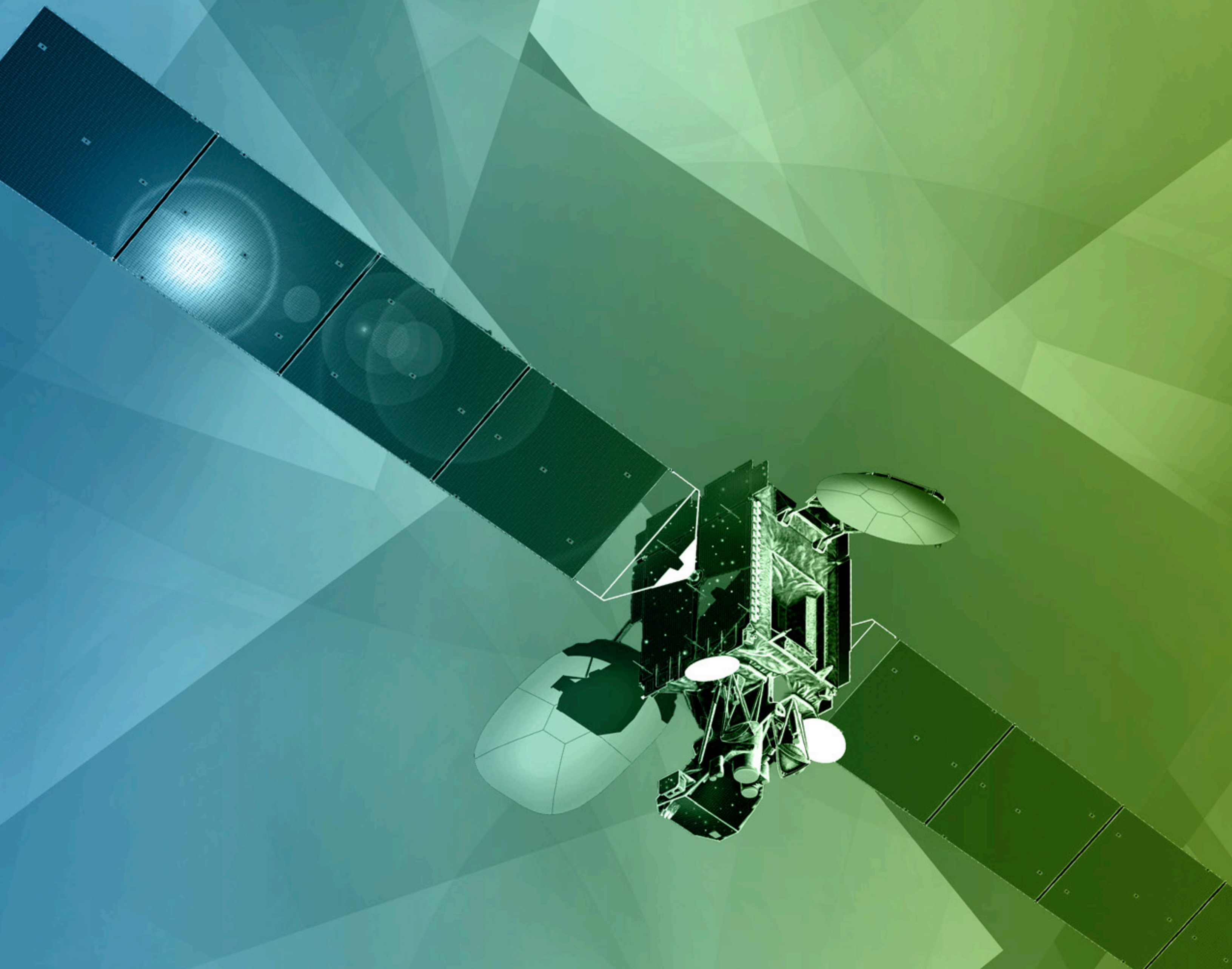


Intelsat-29e
Interference Mitigation Testing

Interference Scenarios and Mitigation Techniques Enabled by the Intelsat Epic^{NG} Class Satellites

INTELSAT
General Corporation

Introduction

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

Engineered to support demanding government communications and applications, Intelsat Epic^{NG} delivers reliability, security, performance and the flexibility to keep pace with changing geographic and mission requirements. Intelsat Epic^{NG}'s advanced digital payload creates an enhanced environment for battling interference and for mitigating jamming thereby helping to assure government organizations of coverage and connectivity for any operation, in any 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 infrastructures.

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^{NG} 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 lower half 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 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 (top) with the spot coverage of Beam K01 on IS-29e (bottom). This difference in coverage areas leads to the first interference mitigation tool provided by Intelsat Epic^{NG} satellites, namely out-of-beam rejection.

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 it 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 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.

Figure 2 shows the uplink and downlink spectrum of this testing. IS-29e has an onboard spectrum monitoring system (SMS). Intelsat Epic^{NG} 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 2 shows the IS-29e Beam K01 downlink spectrum as received at the hub. Figure 2 was taken during nominal operations; the carrier was being properly received and the video quality from remote to hub was excellent.

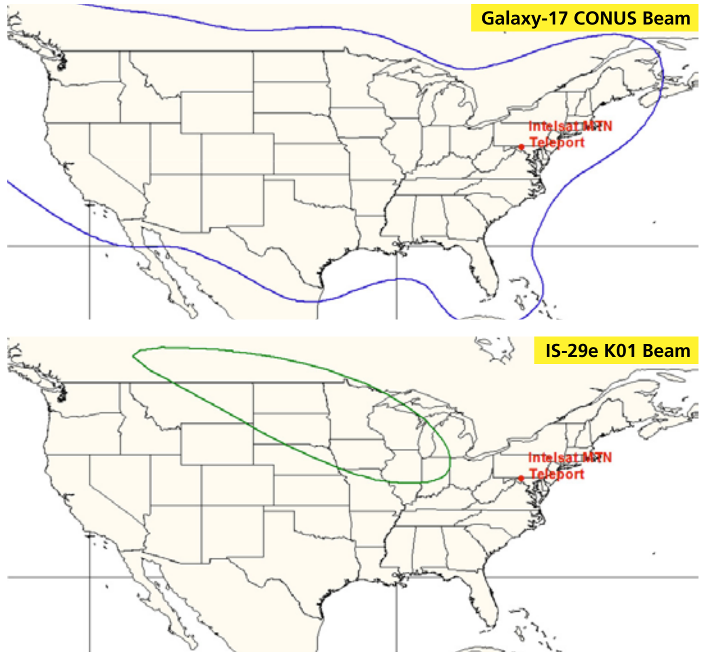


Fig. 1: Wide Beam versus Spot Beam Coverage Areas

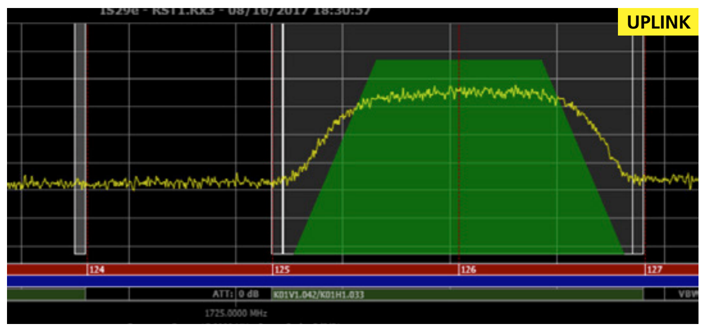
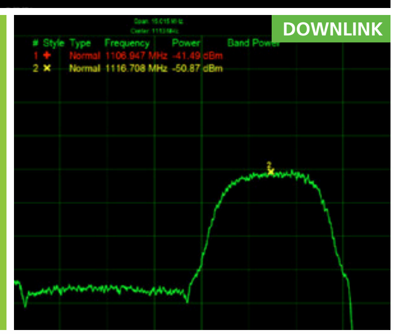


Fig. 2: Nominal Carrier Spectrums for Out-of-Beam Interferer Testing on IS-29e



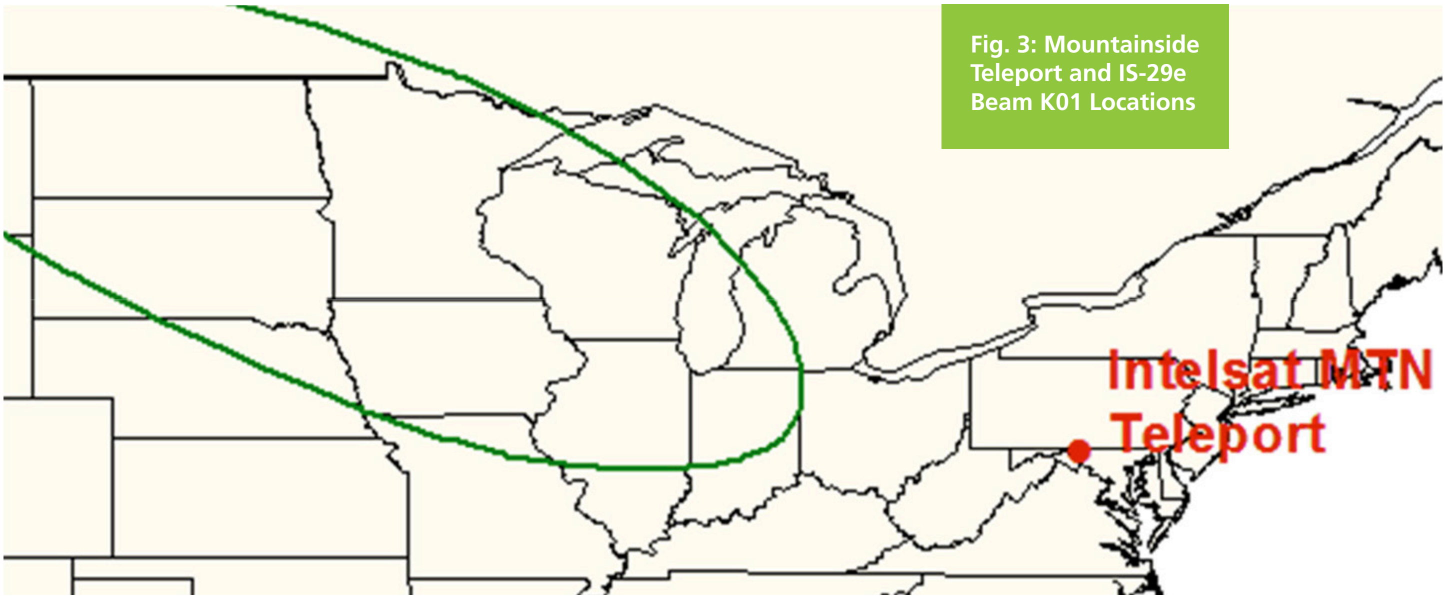
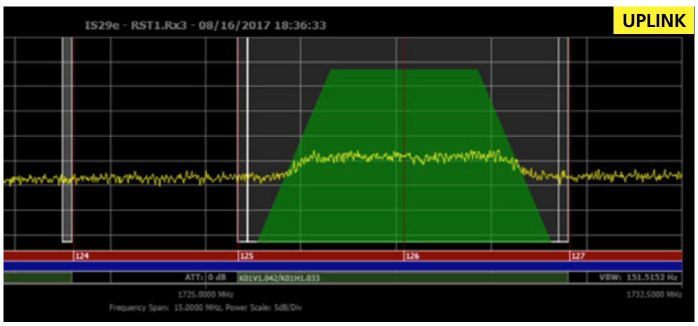


Fig. 3: Mountainside Teleport and IS-29e Beam K01 Locations



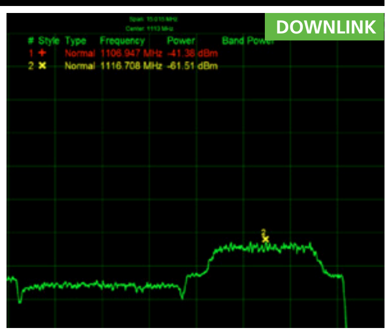
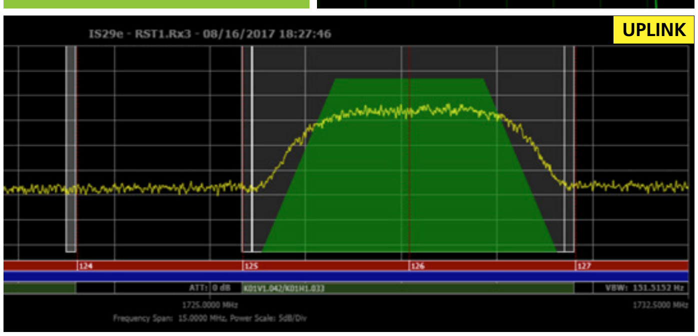


Fig. 4: Out-of-Beam Interferer Spectrums on IS-29e



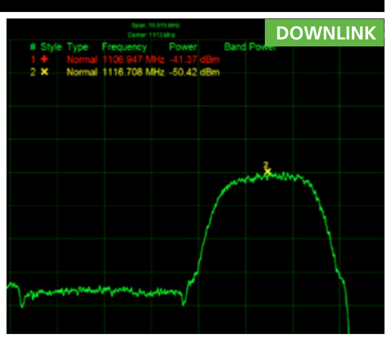


Fig. 5: Simultaneous Friendly and Out-of-Beam Interferer Transmissions

To demonstrate out-of-beam interference 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 3.

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 by the satellite at a much lower level than the friendly carrier. Figure 4 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 at the satellite is approximately 12 dB below that of the friendly carrier.

With both the friendly and interferer carriers transmitting, the uplink and downlink spectrums were as shown in Figure 5. Even with the transmission of an equal power interference signal, out-of-beam rejection by IS-29e K01 was sufficient to enable excellent video reception at the hub. Received video quality was the same as with no interferer present.

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^{NG} 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 6. This is identical to the start of the out-of-beam interferer testing, i.e. Figure 2. As before, in this mode, the video signal was properly received at the hub and video quality was excellent.

An 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 7 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.

Simultaneous transmissions of friendly and interferer carriers are shown in Figure 8. In this scenario, video reception at the hub was not possible. i.e. the friendly carrier was successfully jammed.

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 segment of uplink bandwidth.

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 on the ground 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 all reconfigurations and resumption of successful video transmission was less than 20 minutes.

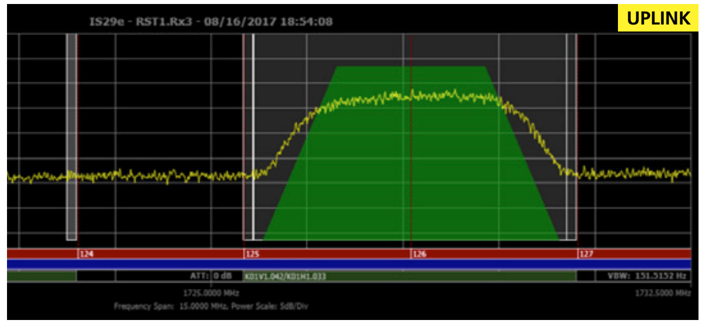
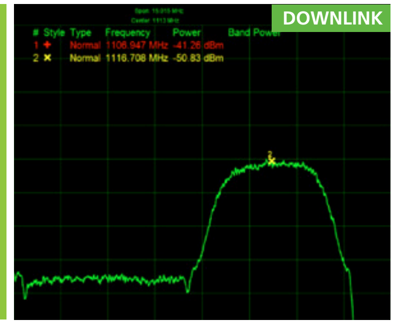


Fig. 6: Nominal Uplink & Downlink Spectrums for In-Beam Interferer Testing



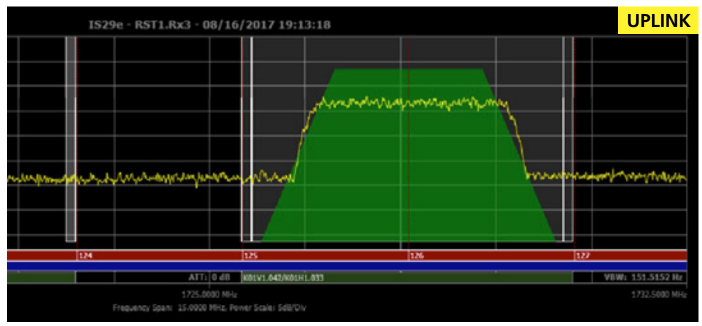
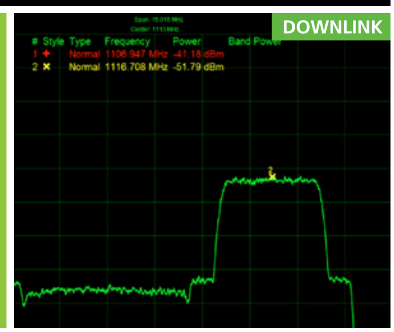


Fig. 7: In-Beam Interferer Only Spectrums



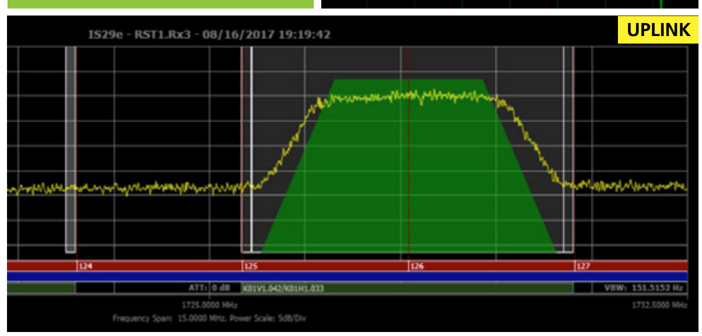
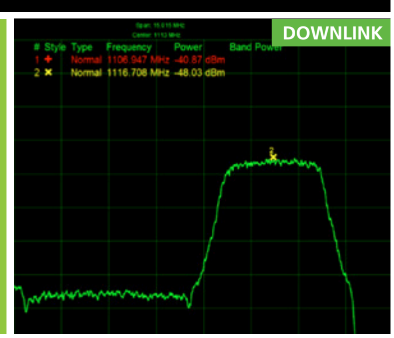


Fig. 8: Simultaneous Friendly and In-Beam Interferer Transmissions



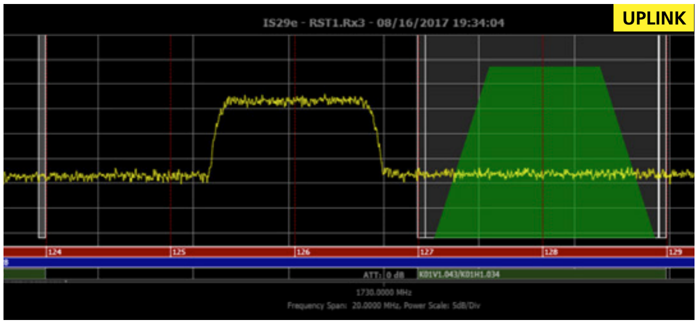
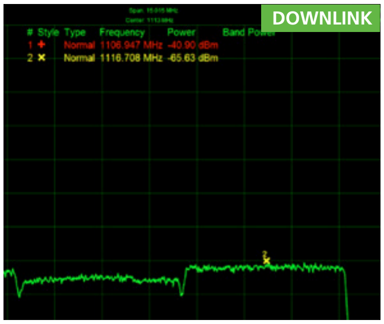


Fig. 9: IS-29e Reconfiguration to Terminate Interferer & Reallocate Friendly Carrier

Fig. 10: Beam K01 Downlink at Hub with Interferer Terminated by Satellite



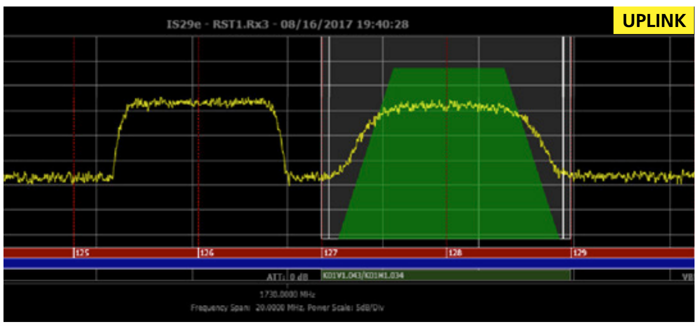
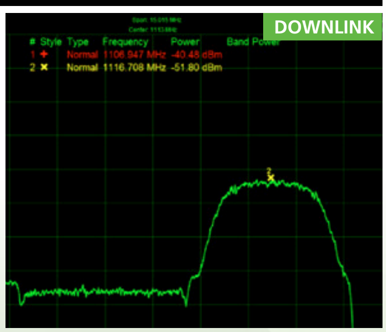


Fig. 11: IS-29e Reconfigured to Terminate Interferer & Reallocate Friendly Carrier



Figures 9 through 11 visualize the sequence of steps taken to counter the in-beam interferer. In Figure 9, satellite reconfiguration is underway.

The video carrier's uplink bandwidth has been reallocated to avoid the interferer. The new allocation is the green trapezoid. Transmission of video carrier at the new allocation has not yet started.

The interfering carrier is still transmitting 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 10 shows the IS-29e K01 downlink (received at the hub) where the interferer has been blocked; aka has been "notched out." The friendly video transmission has not yet restarted.

With the video transmission re-started, Figure 11 shows both the friendly and interfering uplinked signals (top) and IS-29e's clean downlinked signal (bottom). At this point, successful video transmission has been re-established.

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

1. The interferer was removed from the Epic^{NG} satellite downlink with no interaction with the interferer's transmitter.
2. Post mitigation, the video signal's downlink was in the same bandwidth segment as before.
3. All 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 the interference mitigation process. 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^{NG} 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^{NG} satellites. Active identification of the interferer and payload reconfiguration are required to provide mitigation and these can be accomplished in a timely manner.

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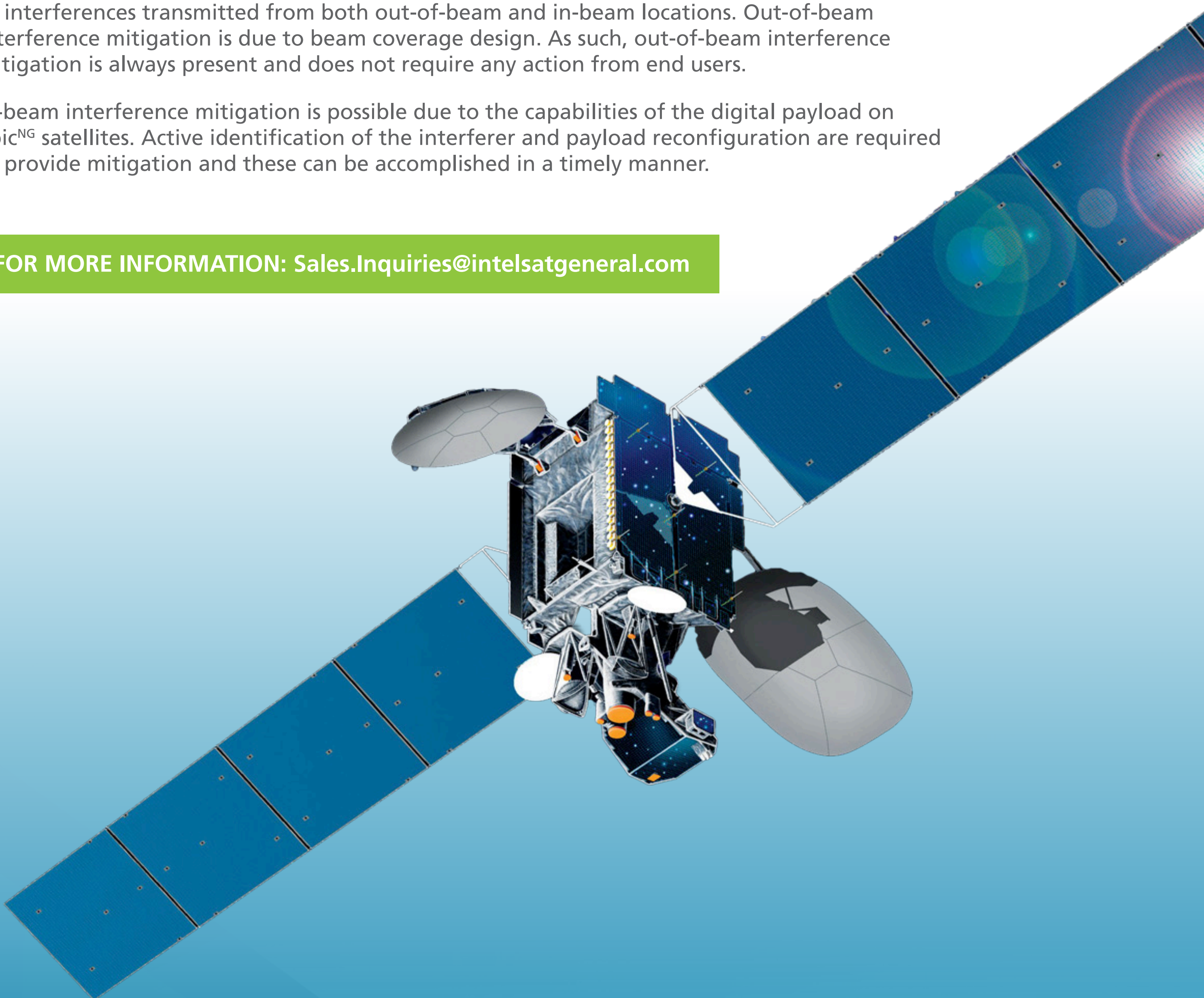

About Intelsat General Corporation

Based in McLean, Viginia, Intelsat General Corporation (IGC) is a wholly owned subsidiary of Intelsat, operator of the world's first Globalized Network. IGC provides its government and commercial customers with high-quality, cost-effective, communications solutions via Intelsat's leading satellite backbone and terrestrial infrastructure. Our customers rely on IGC to provide secure and seamless broadband connectivity, video communications, and mobility services for mission-critical operations anywhere on the globe through our open, interoperable architecture.

We support the full range of en route communications at broadband speeds, including Intelligence, Surveillance and Reconnaissance applications. Whether you're maneuvering on land, sea or air, our C-, Ku- and X-band mobility solutions provide capacity, coverage and connectivity for converged voice, data and video applications.

From remote military outposts, disaster recovery sites and embassies to health and homeland security agencies, Intelsat General's solutions support even the most complex operations, from routine to mission critical, anywhere on the globe.

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