Application Note

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Resolving Interference Issues at Satellite Ground Stations

Introduction

RF interference represents the single largest impact to robust satellite operation performance. Interference issues result in significant costs for the satellite operator due to loss of income when the signal is interrupted. Additional costs are also encountered to debug and fix communications problems. These issues also exert a price in terms of reputation for the satellite operator.

According to an earlier survey by the Satellite Interference Reduction Group (SIRG), 93% of satellite operator respondents suffer from satellite interference at least once a year. More than half experience interference at least once per month, while 17% see interference continuously in their day-to-day operations. Over 500 satellite operators responded to this survey.

Satellite Communications Overview

Satellite earth stations form the ground segment of satellite communications. They contain one or more satellite antennas tuned to various frequency bands. Satellites are used for telephony, data, backhaul, broadcast, community antenna television (CATV), internet, and other services. Depending on the application, each satellite system may be receive only or constructed for both transmit and receive operations. A typical earth station is shown in figure 1.

Figure 1. Satellite Earth Station

Each satellite antenna system is composed of the antenna itself (parabola dish) along with various RF components for signal processing. The RF components comprise the satellite feed system. The feed system receives/transmits the signal from the dish to a horn antenna located on the feed network. The location of the receiver feed system can be seen in figure 2. The satellite signal is reflected from the parabolic surface and concentrated at the focus position. Figure 3 shows the dimensions for the parabola dish and receiver position (focus). The dimensions show design parameters used to create antennas for specific frequency ranges and applications.

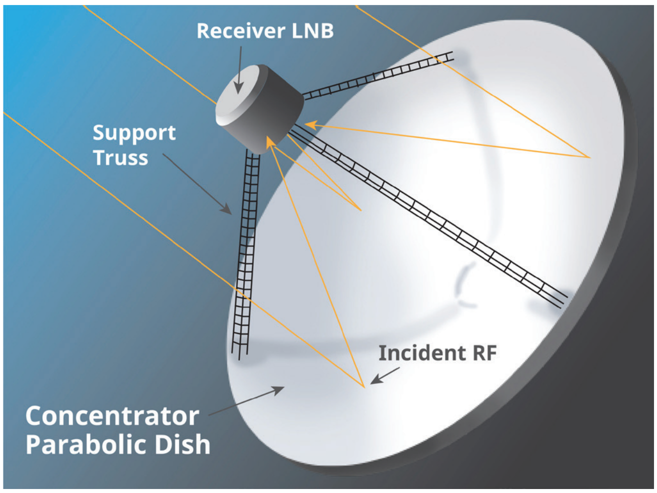

Figure 2. Parabolic Dish Concentrator with Receiver

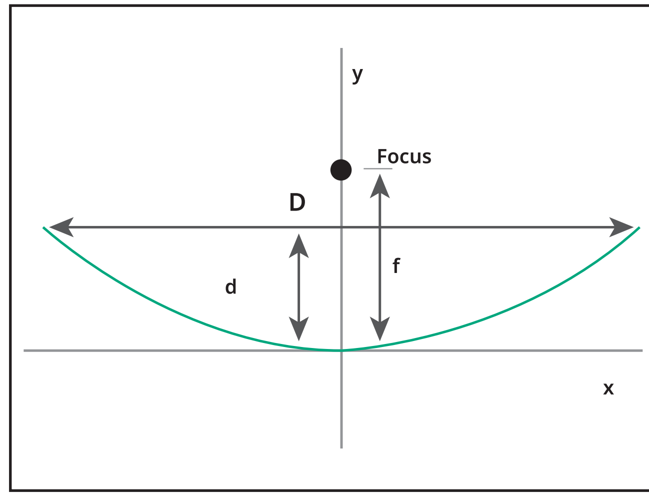

Figure 3. Distance Parameters for Antenna/Receiver System

Listed here are typical components used for the feed system. (See Figure 4)

- Block upconverter (BUC) is used for satellite communications uplink. The BUC:
  - Converts frequencies from a lower to higher frequency band for transmission
  - Amplifies the amplitude level of the RF signal that has been converted
  - Costs less if used in place of two separate modules (upconverter and amp)
  - Is located between the modulator output (satellite modem) and antenna
  - Is used for many satellite systems, L-band is upconverted to C, Ku, or Ka bands

- Low noise block downconverter (LNB) is used for satellite communications downlink. The LNB:
  - Converts the frequencies from the satellite to a lower frequency for reception
  - Minimizes signal distortion. A low noise amplifier (LNA) is often used to amplify the signal
  - Replaces two separate modules (LNA and downconverter), reducing cost
  - Is located between the antenna input and satellite modem

- Feed horn is a small horn antenna that conveys the RF signal between the transmitter/receiver from the parabolic reflector dish
- Orthomode transducer (OMT) is a waveguide component that serves as a polarized duplexer. The OMT is used with the feed horn to isolate orthogonal polarizations of a signal or to separate transmit and receive signals so they propagate through different ports.

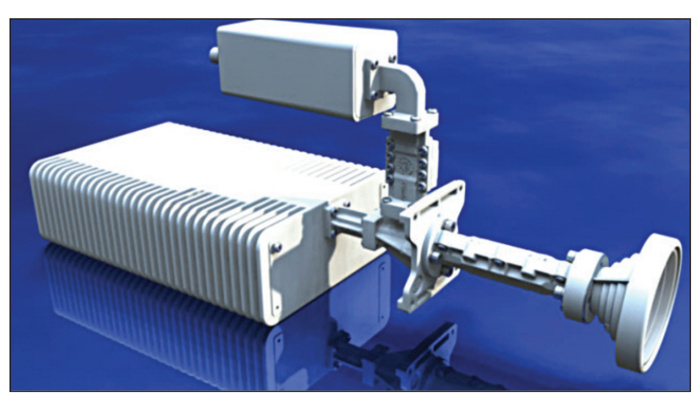

Figure 4. Shows the Complete Satellite Feed System Using all the Components Used for the Feed System

Two interfacility (IFL) cables for transmit and receive connect the feed network to indoor equipment used for demodulating and further processing of the signal (figure 5). Signals in the feed cables are often first converted to L-band to reduce loss and maintain signal integrity. For L-band, 75 Ω impedance cables with “F” connectors are common, although 50 Ω cables are sometimes used. IFL cables may also carry 48 VDC power for the BUCs and LNBs. Problems may occur over time, such as when ground loops are created due to corrosion in the cables and create high DC resistance.

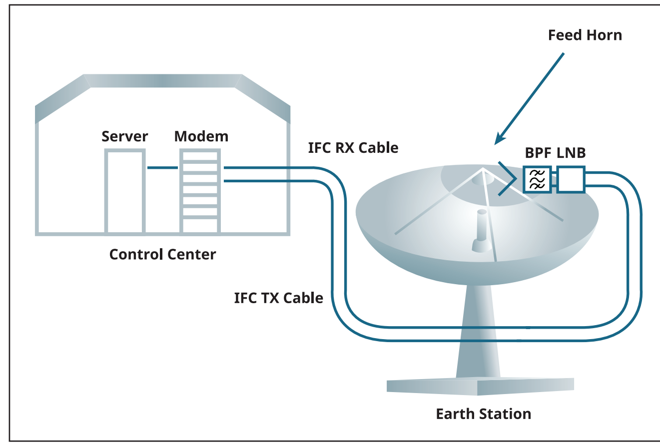

Figure 5. IFC Cable Pair Shown Between Outdoor Antenna and Network Office

In some cases, bandpass filters (BPFs) will be inserted into the feed network (figure 6). This limits the ability for nearby signals to distort the satellite signal. The main trade-off with BPFs is in-band insertion loss vs. out-of-band attenuation. Figure 6 is a commercial BPF inserted into a satellite feed system. A typical frequency response for a C-band BPF can be seen in figure 7. In this example, the in-band insertion loss is approximately 0.5 dB.

Figure 6. C-Band BPF Inserted into Feed Network

Common frequency bands used for satellite communications are shown in figure 8. The L-band is often used for backhaul between the satellite and indoor office network center. Only the range for both L-band uplink and downlink is shown as there are non-contiguous frequencies for each. Downlink refers to the signal sent from the satellite to ground station.

System bandwidths of satellite signals can range from 40 kHz to 72 MHz or even higher.

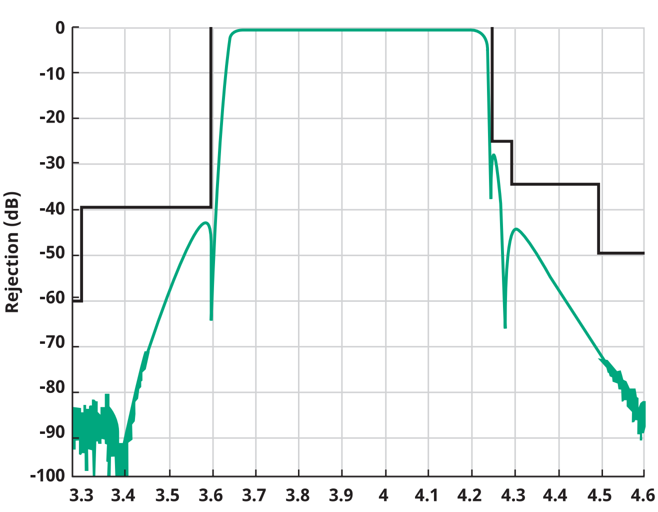

Figure 7. C-Band BPF Frequency Response

Band	Downlink GHz	Uplink GHz
L	1 - 2	1 - 2
C	3.7 - 4.2	5.925 - 6.425
X	7.25 - 7.75	7.9 - 8.4
Ku	10.9 - 12.75	14
Ka	18 - 20	26.5 - 40

Figure 8. Uplink and Downlink Frequencies

Interference Issues

Various types of interference have been identified in satellite communication systems.

- Adjacent frequency emissions from other signals (such as 5G cellular) with significantly higher power levels than the satellite signal. Due to the extreme distance between satellite and earth station, the incoming power flux density of the satellite signal at the earth station is very low and susceptible to interference.
- Aircraft interference
- Interference from high-power radar
- Interference from broadcast FM transmitters. Signals from nearby transmitters can overload the LNA at the ground station. Due to low power levels of the satellite signals, LNAs are optimized for gain. Satellite signals can be easily compressed by the LNA due to other signals present in the LNA bandwidth.
- Adjacent satellite interference (ASI)
- Other sources of interference at satellite ground stations:
  - Unwanted emissions from other satellite ground stations which may either be spurious or out of band
  - Unauthorized transmissions (piracy) and intentional jammers

The listing of interference sources is by no means comprehensive. Problems can occur due to equipment malfunction, operator frequency setting errors, and poor installation. Antenna misalignment can also cause interference problems between satellite stations.

Adjacent Frequency Emissions – 5G Example

The global rollout of 5G cellular networks at around 3.5 GHz has already proven to cause interference with legacy satellite downlinks. These 5G services exist at frequencies adjacent to or even overlapping historic broadcast video satellite services. For example, China Telecom operates their 5G signal at 3.4 – 3.5 GHz and China Unicom operates in the 3.5 – 3.6 GHz range. In the U.S., the current satellite range 3.7 – 4.0 GHz is being repurposed from satellite-based video broadcasts to 5G applications. A small 20 MHz guard band (3.98 – 4.0 GHz) is being allocated to separate the 5G frequency from the new broadcast video satellite frequencies used between 4.0 – 4.2 GHz. Figure 9 illustrates the band separation between one instance of a 5G deployment and the satellite frequencies. The top picture shows the range of many legacy LNBs. The lower image in figure 9 shows a BPF blocking the 5G carriers.

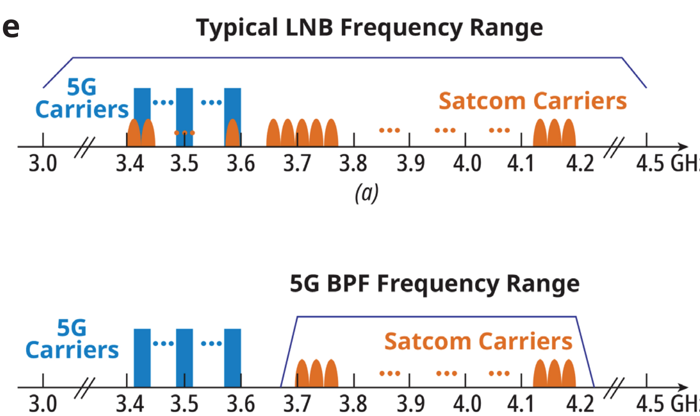

Figure 9. Existing Frequency Allocation for 5G and Legacy C-Band Satellite Downlinks

Interference problems have already been seen in many instances where the satellite downlink signals operate in frequency bands close to those used by 5G. At minimum, satellite earth station operators will need to install special bandpass filters in their network. 5G operators may need to reduce power depending on their proximity to earth stations. Inserting a BPF filter can cause interference issues if the connections are not properly mated. Problems also occur when the materials used by the BPF and LNB do not provide a good seal. This issue occurs mostly when retrofitting the receiver with a BPF. Legacy LNBs may not have a standard waveguide flange which is fully metallic thus causing radiation egress and ingress.

Aircraft Interference

Another source of interference (often temporary) may be generated by aircrafts. Airplane altimeters generate signals in the 4200 – 4400 MHz band, adjacent to the C-band downlink frequency 3400 – 4200 MHz for fixed satellite service stations (FSS). Even though there is no overlap in frequency, aircrafts are much closer to the earth station than the satellite. The altimeter signals can overdrive the LNA amplifier, distorting the satellite signal. Also, the LNA/LNB generally operate at frequencies wider than the authorized band so are susceptible to out of band signals. For example, the LNB may be rated from 3.4 – 4.2 GHz (or higher) while the C-band range is 3.7 – 4.2 GHz. Aircraft interference is intermittent and may be seasonal in nature. Problems are magnified if the fixed satellite station is close to an airport.

It is estimated that mitigating interference with a fleet of three satellites costs the operator $2M USD. This includes content downtime, fees and penalties the operator must pay, in addition to the technical support required to diagnose and fix the problem. Figure 10 illustrates interference for both aircraft and ground cellular station. Also shown is a nearby cellular base station which can also saturate the satellite receiver.

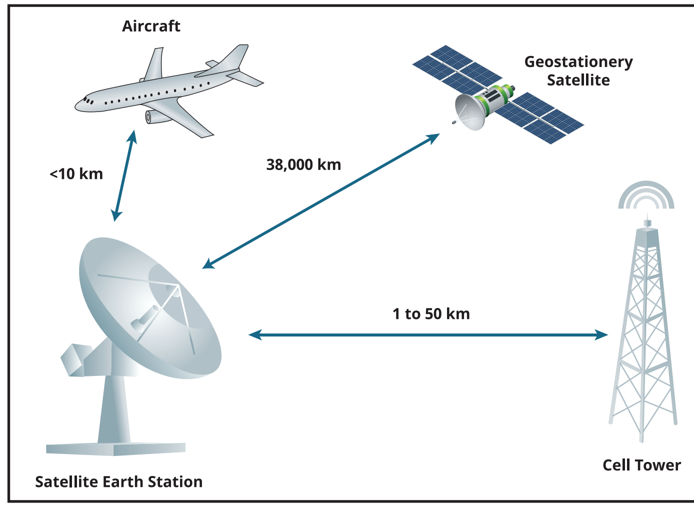

Figure 10. Satellite Interference Generated by Aircraft and Cellular Signals

High Power Radar Interference

The S-band (2 – 4 GHz) is used by a variety of services including high-power weather radar, air traffic control radar, and surface ship surveillance radar. Given the intermittent (pulsed) nature of radar signals, interference can appear irregular, and in the case of surface ships the interfering ship may disappear from view as it passes along the coast. Satellite ground stations near airports or coastal ports are especially prone to interference from these radar signals. The pulse analyzer option on the Field Master Pro™ MS2090A spectrum analyzer (option 421) is ideal for radar measurements (see figure 11). More information on the Field Master Pro MS2090A is discussed later in this application note.

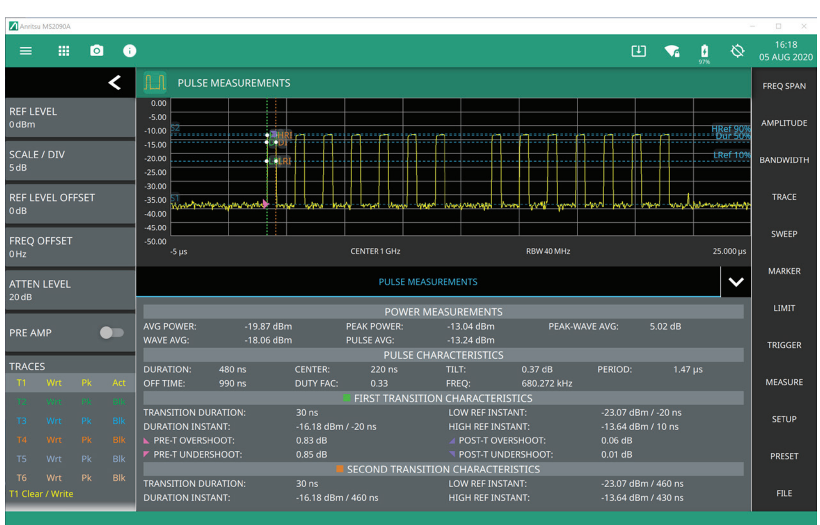

Figure 11. Field Master Pro MS2090A Pulse Analyzer Display

Out-of-Band Intermodulation Interference – FM

If more than one signal is transmitted by a power amplifier (or by multiple transmitters), a mixing or intermodulation (IM) process can result. These IM signals are present in the RF environment at multiples of one signal mixing with another signal at different frequencies. The power level of these intermodulation products are dependent on the relative power level of each signal. Terrestrial FM broadcast can be introduced at the IF level of the satellite earth station. In this instance, 90 MHz is mixed with 6 GHz RF frequency to produce interference at 6.09 GHz. Figures 12 and 13 illustrate the interference problem.

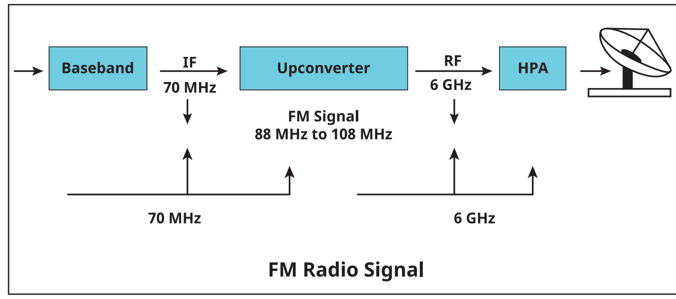

Figure 12. FM Signal Upconverter to Satellite Band

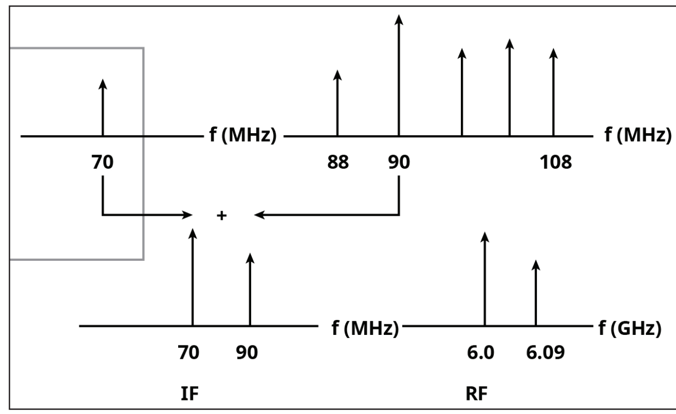

Figure 13. Intermodulation Signals (Interference) Shown

Adjacent Satellite Interference (ASI)

As more satellites are launched, the slot spacing becomes more crowded with only 2 degrees of separation for many geostationary satellites. At the same time, the number of portable and mobile terminals is growing rapidly. These two conditions lead to an increase in adjacent satellite interference. Downlink ASI is caused when the earth station dish is able to see the signal from multiple satellites at the same time. This occurs when the satellite beam is poorly aligned to its target earth station or from side lobe beams transmitted from the satellite (see figure 14).

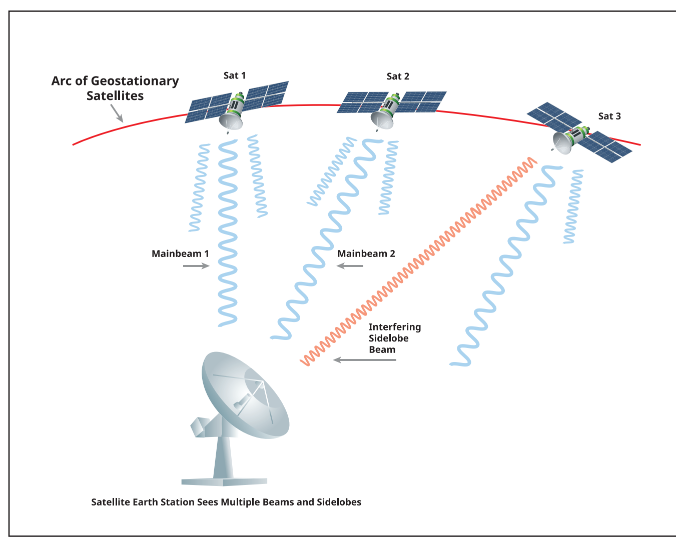

Figure 14. Adjacent Satellite Interferer

Interference Solutions

Anritsu offers a large portfolio of solutions for satellite operators to mitigate interference problems. These products are designed for both long-term spectrum monitoring as well as for addressing issues generated by equipment upgrades and interference from RF services operating in spectrum adjacent to satellite frequencies. Once interference is detected, remedies will need to be administered to address the problem.

Applications for geolocating the signal-of-interest (SOI), identifying the signal, and clearing the spectrum are also available. Especially with the introduction of cellular 5G services in the C-band (currently used by satellite), a comprehensive set of tools is required to insure satisfactory satellite operations.

Spectrum Analysis – Field Master Pro MS2090A

The United Nations Office for Outer Space Affairs (UNOOSA) estimates there are close to >2,000 active satellites orbiting the earth. Each of these communicate with the ground through dedicated earth stations. In addition to sub-6 GHz bands, frequencies in the range up to 50 GHz are being utilized. Anritsu's Field Master Pro MS2090A is ideal for monitoring downlink signals to search for interference and noise. The Field Master Pro MS2090A is a real-time spectrum analyzer operating in the frequency range of 9 kHz to 54 GHz (see figure 15).

Figure 15. Anritsu Field Master Pro MS2090A Spectrum Analyzer

As already highlighted, many national regulatory authorities have auctioned and reallocated the C-band spectrum, reassigning the frequency bands for exclusive access. For example, in the United States the FCC reached a deal in 2020 worth billions of dollars with satellite operators to free spectrum to be used for 5G service. Companies such as Intelsat and SES use the C-band spectrum to serve TV broadcasters and CATV. Portions of the C-band have also been auctioned for 5G mobile usage in many other countries including Australia, Finland, Germany, Finland, South Korea, and the UK. In China, 5G service is in trial within the 3300 – 3600 MHz band.

Using the 5G NR Downlink Measurements option (option 888), the Field Master Pro MS2090A can be positioned at each earth station for measurements of the RSRP of surrounding 5G signals. The cell and sector ID associated with the cellular signal can also be obtained to identify the 5G operator. See figure 16 for illustration.

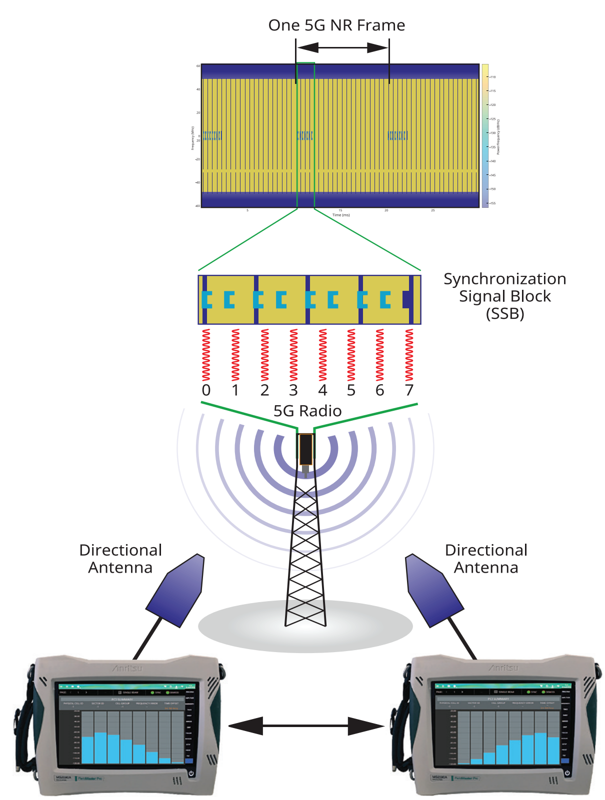

Figure 16. Field Master Pro MS2090A Displays RSRP vs. Beam Index Based on Over-the-Air Analysis of the 5G NR SSB

An example is shown here from a cellular operator in Asia operating in spectrum centered at 3.45 GHz. The 5G signal is displayed in figure 17. Figure 18 shows the same signal whose out of band emissions fall into the satellite band at 3.9 GHz.

Clearly, significant distortion occurs at the satellite receiver. Satellite LNA/LNBs are optimized for reception of very low-level satellite signals. Geostationary satellites orbit at a distance from earth of 36,000 km (22,400 miles). Typically, the LNA/LNB will be saturated with a total input power of approximately -50 dBm, depending on equipment used. The LNA/LNB would then begin to show non-linear behavior at about -60 dBm input into the receiver system. The international standards body publication,"Studies on Compatibility of Broadband Wireless Access Systems and Fixed-Satellite Service Networks in the 3 400-4 200 MHz band" (ITU-RS.2199-0), therefore recommends a maximum power into to the LNB of no higher than -60 dBm.

Once the 5G interference has been detected, it must be localized. In many cases more than one 5G base station is in the vicinity. The Field Master Pro MS2090A is used to identify the strongest power level from each of the base stations and provide identification. Figure 19 shows the RTSA display from the Field Master Pro MS2090A for a 5G signal centered at 3.45 GHz.

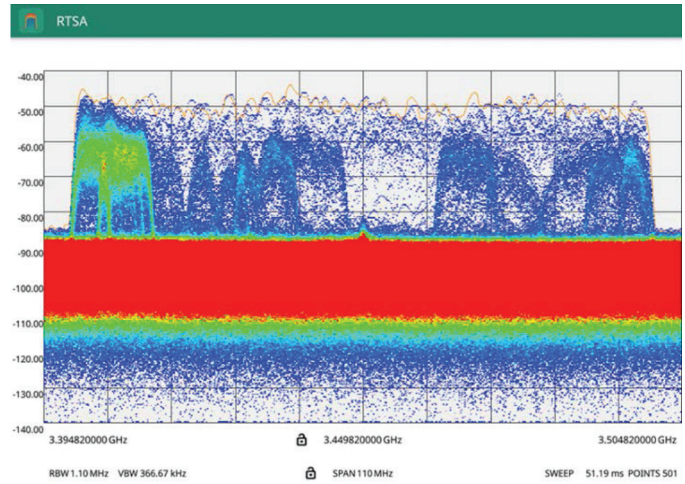

Figure 17. Cellular 5G Signal Centered at 3.45 GHz

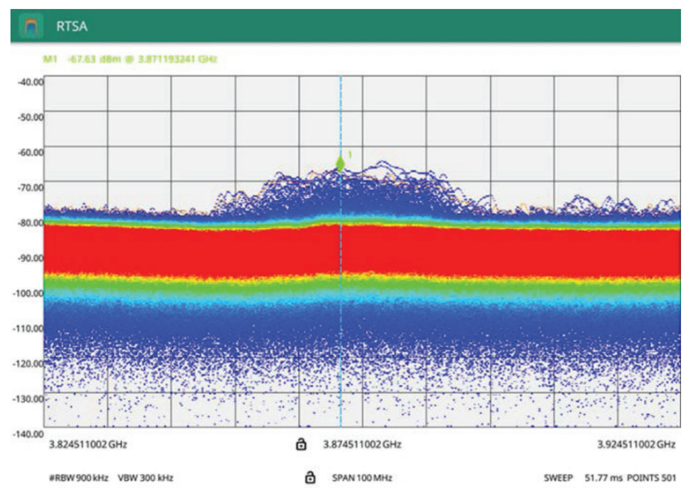

Figure 18. 5G Interference in Satellite Band

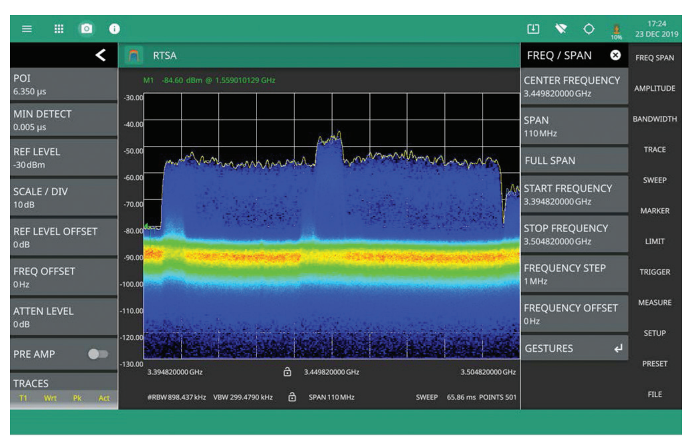

Figure 19. Field Master Pro MS2090A RTSA Display of 5G Signal

Using the Field Master Pro MS2090A Physical Cell ID (PCI) scanner (option 888, 5GNR downlink measurements), a list of 5G signals in the area is compiled. Along with the power levels, the PCI is presented (see figure 20).

Various measurement parameters obtained in the PCI scan are shown in figure 21.

Figure 20. Field Master Pro MS2090A RTSA 5G Signal Scan Signal Causing Interference Outlined in Green Rectangle

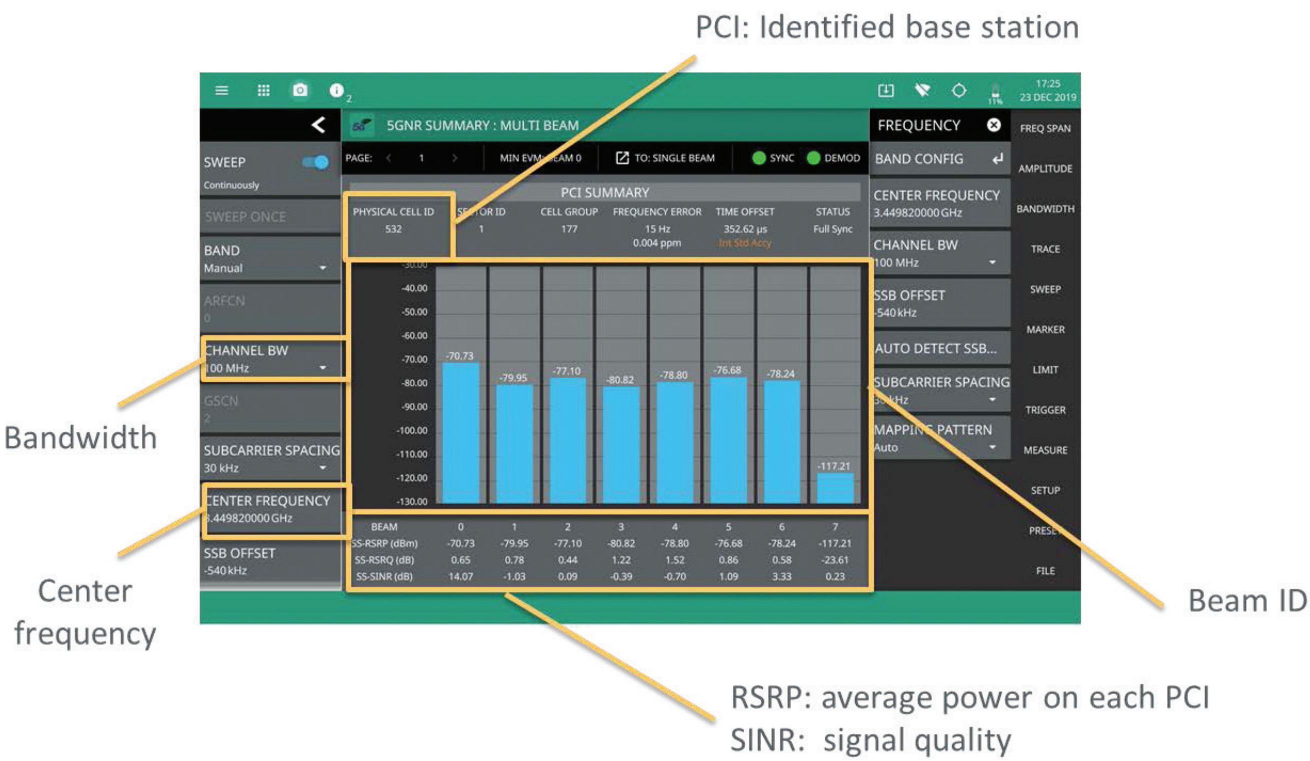

Figure 21. Field Master Pro MS2090A RTSA 5G Signal Scan

Mobile InterferenceHunter™ (MX280007A)

Anritsu's Mobile InterferenceHunter (MIH) MX280007A is a quick and reliable way to find single or multiple sources of interference. The ability to work with multiple signal sources, reflections, RF shadows, drifting signals, radar signals, and multi-path distinguish the Mobile InterferenceHunter MX280007A from more expensive solutions targeted at single fixed-frequency interference sources. Equipment needed is an Anritsu spectrum analyzer, mag-mount antenna, and the MIH software (see figure 22). It is recommended that the Field Master Pro MS2090A be used as the spectrum analyzer, given its real-time capability and high probability of signal intercept. This is particularly important for measurements of "bursty" signals such as S-band radar that operates in the 2 – 4 GHz range.

Figure 22. Anritsu Mobile InterferenceHunter

Spectrum Clearing

The MIH contains a spectrum clearing feature. As new allocations are made for 5G in the C-band, it is imperative that the repurposed spectrum be cleared of legacy signals while also ensuring that remaining satellite frequency bands are free of 5G interference. In Spectrum Clearing mode (Figure 23), the Mobile InterferenceHunter MX280007A allows users to set a go/no-go threshold, which can be calculated based on the width of the spectrum analyzer's channel power measurement. This number, in combination with the Min-Hold capability, allows for efficient localization of both good areas (shown in green) and areas that need assistance (shown in red) within a sector or town. It's also possible to change this threshold after collecting data, if necessary.

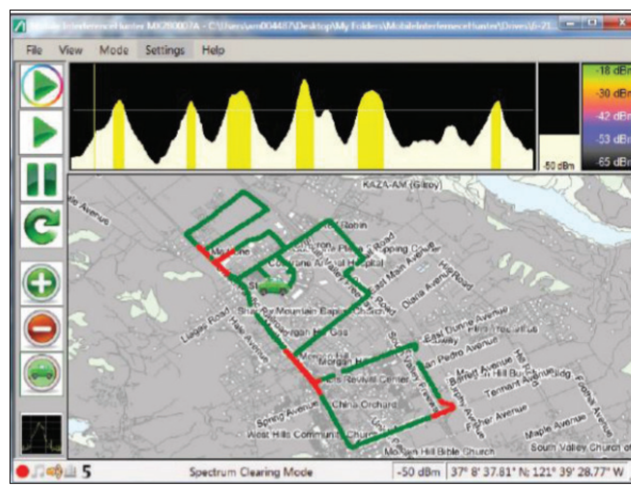

Figure 23. MIH Spectrum Clearing Plot

In the United States, the Federal Communication Commission (FCC) has launched an accelerated spectrum clearing program for the C-band. Satellite operator Intelsat has projected spending more than $1 billion in clearing costs. The clearing will take place over the lower 300 MHz range (3.7 – 4.0 GHz) with the top 20 MHz of that range to be used as a guard band. Similar efforts for C-band clearance are taking place at many other international locations.

For earth station operators, efforts are underway to adopt advanced signal compression technology to pack content from a 500 MHz band into just 200 MHz. Ground infrastructure, such as antennas and filters, will need to be deployed to protect the remaining bandwidth from interference.

Interference Hunting

MIH is also used for pin-pointing the location of interference signals. A common inference source are signals generated by unauthorized satellite operators. The satellite signal may be generated without proper authorization (piracy) or by experiments being conducted by nearby research labs and private enterprise. Jamming may also be due to hostile transmissions designed to interfere with communications. One method traditionally used by satellite operators for localization of interference signals is Time Difference of Arrival (TDOA). Operators use the satellites themselves to triangulate an interference signal (see figure 24). However, there are many sources of error in this approach. Positioning accuracy is in many instances limited to a 20 km radius. Primary sources of inaccuracy include imprecise information about the satellite positions and errors in obtaining their instantaneous velocity.

In order to pinpoint the interferer position, MIH is used. Using both audio signals and mapping for the driver, the MIH software makes hundreds of measurements per second to guide the user to the signal (see figure 25).

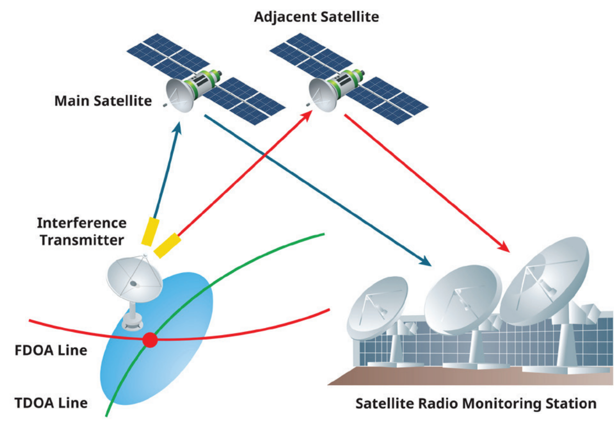

Figure 24. Satellites Using TDOA for Signal Geolocation. Inaccuracies of 10-20 km Often Result, Requiring Use of Mobile Interferencehunter to Pinpoint Interference Position

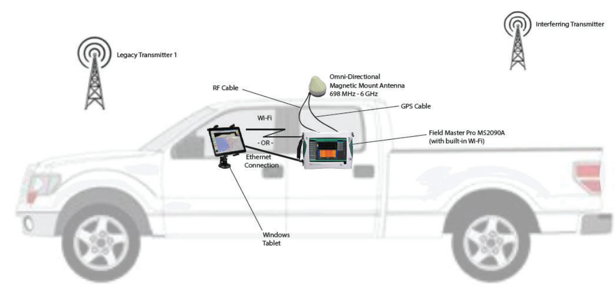

Figure 25. MIH Guides Driver to Signal Location

Spectrum Monitoring

Satellite operators often require round the clock monitoring for their signals. The ideal solution for a satellite monitor is Anritsu's Remote Spectrum Monitor (RSM) MS27103A. The RSM MS27103A receiver provides 12 (optionally 24) RF inputs to monitor multiple earth station dishes simultaneously. A high-speed multiplexer is integrated into the RSM MS27103A for switching between each dish RF signal. See figure 26 for illustration of the RSM MS27103A. The RSM MS27103A is typically located in the control room where all the feeds are routed. At the control room, any high frequency signals have already been frequency converted in the dish LNB down to a lower IF frequency, making the 6 GHz frequency range of the RSM MS27103A ideal for this application

Key features for the RSM MS27103A include:

- Frequency Range: 9 kHz – 6 GHz
- 12 RF inputs for multiple satellite antennas
- High-speed scanning between all RF inputs
- 20 MHz IF bandwidth
- Sweep rates up to 24 GHz/s
- Gigabit Ethernet
- Watchdog timer to insure long-term stability
- 30-40 dB antenna port-to-port isolation

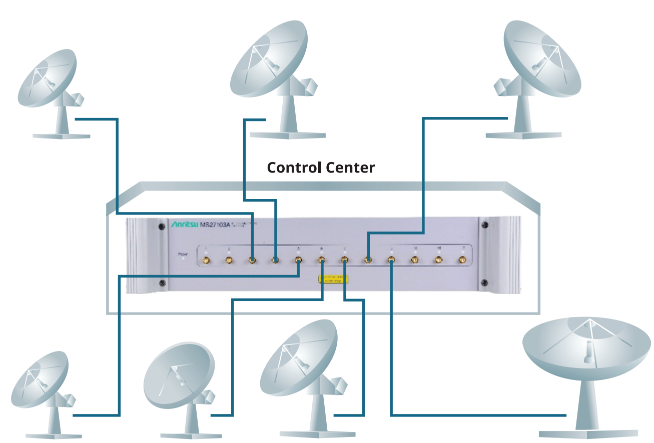

Figure 26. A Single Remote Spectrum Monitor MS27103A in a Rack in the Control Center Monitoring Many Earth Station Dishes

Using optional Vision PC software, all signals from each RF port are automatically recorded at user-settable time intervals. Various features can be enabled to provide alerts when interference is present or when the satellite signal is degraded. Reports on the health of the network can also be automatically sent on a daily or weekly basis.

Using Vision's high-speed port scanner, each spectrum trace from each RF port can be displayed on a monitor screen. See figure 27 for an example of a multiple spectrum display.

Summary

Anritsu provides a comprehensive solution for interference problems in a satellite network. This includes the ability to monitor spectrum, detect interference, set alarms, troubleshoot signal problems, spectrum clearing, and pinpointing the position of an interference source.

For more information visit our website at www.anritsu.com.

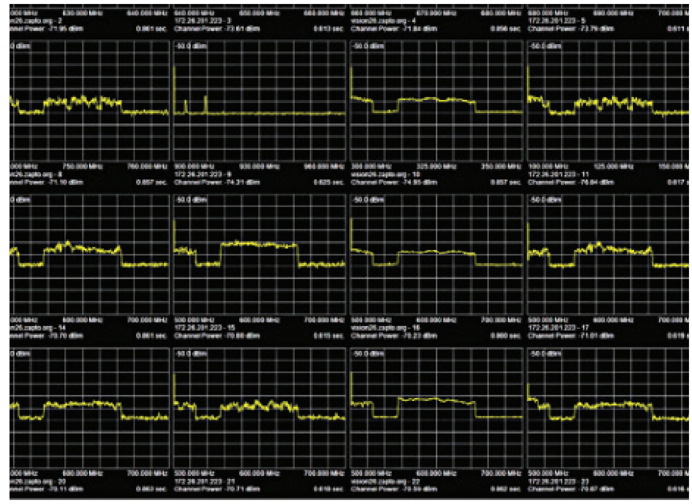

Figure 27. Multi-Spectrum Display

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Specifications are subject to change without notice.

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