

Satellite Video Transmission and the Analog to Digital Conversion Process

By Gary Edwards

The changing frontier for television broadcasters and cable television providers includes the conversion from analog to digital transmissions for their satellite links. While the benefits are obvious—superior picture quality, more efficient use of the spectrum, and the opportunity to bundle additional services—the systemic requirements are complex and some of the unintended consequences potentially dangerous. One of the major unintended consequences involves interference, which is frequently encountered during the upgrade of C and Ku-band receive/only earth station antennas to digital satellite receive standards. The reception of digital signals from satellites requires a cleaner interference environment than analog signals with little tolerance from undesired in-band noise. Broadcasters and other downlink operators have learned that sites previously suitable for analog reception may not be suitable for digital reception. The interference criterion for analog modulation at C-band is approximately -144 dBW/MHz, while the interference criterion for digital modulation is typically -156 dBW/MHz (see below for discussion of why this is).

Broadcasters attempting to determine potential interference sources into C-band downlinks, typically looked at 4 GHz terrestrial microwave as the interference suspect on their operator's checklist. These days, more often than not, terrestrial microwave is not the source of interference for these satellite downlinks. Experienced field engineers have documented in-band sources of interference from cellular, PCS, pagers, and UHF transmitters, military and FAA radars, and aircraft Radar altimeters. The affects of interference on digital downlinks is much more than the occasional sparkles experienced on analog downlinks, a full freeze frame or a blank screen is the result for the digitally delivered video carrier.

What's New in the Real World?

A recent interference issue into domestic Ku-band VSATs and Hubs has been interference from automobile radar detectors. Several times over the past year Ku-band satellite users have stated that earth stations located near a highway or a parking lot have experienced in-band noise on the lower transponders in the 11.7–12.2 GHz range. It has been determined that the source of interference is a local oscillator built into many common radar detectors. Earth station owners have discovered that if the interference



Figure 1 Domestic Ku-band Earth Station Located on Urban Rooftop

originates from parked vehicles nearby, a simple resolution to the interference problem can be found by disconnecting the detector at the source. See Figures 1 through 4 for such an example. Figures 1 and 2 show the relative position of a domestic Ku-band rooftop earth station and a parking area on an adjacent rooftop. Figure 3 shows the spectrum analyzer plot of the 11.7–12.2 GHz spectrum as seen at the earth station location.



Figure 2 Parking Area on Adjacent Rooftop

Reference Level
DBW, -112

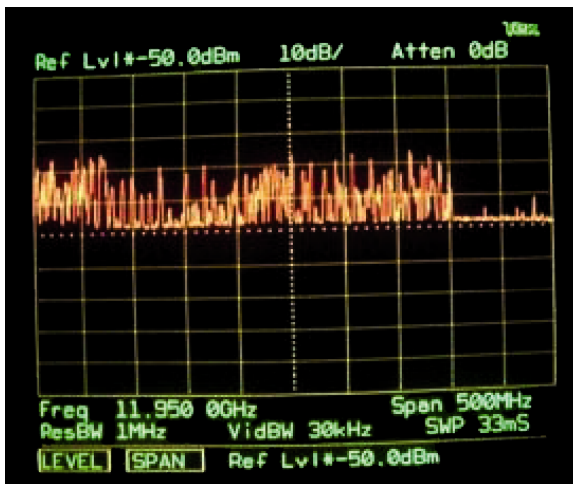


Figure 3 Spectrum Analyzer Photo of Radar Detector Interference in the 11.7–12.2 GHz Band

In this instance, it was determined that the mini-van shown in Figure 4 was the source and once the radar detector was unplugged, the interference at the earth station stopped. Unfortunately, if these types of emissions originate from a nearby roadway, the only real mitigation technique that will solve the interference problem is to erect shielding or move the earth station to a suitably protected location.

New York, NY

Azimuth 180° to 360°

Date: December 13, 2000

Time of Day: 11:47

Ant. Polarization: V

Ant. Centerline: 6 ft

Sweeping RFI from radar detector operating in automobiles located on rooftop of the middle parking garage to the west of the earth station.

Frequency Range of RFI: 11,700 to 12,000 MHz

Maximum Signal Level Measured: -138 dBW



Figure 4 Radar Detector Found in Mini-van at Center of Photograph

What's New in the Regulatory World?

Recent actions by the Federal Communications Commission (FCC) have shown that currently authorized spectrums can be subject to reallocation at any time. The reclassification of the 3650–3700 MHz spectrum for a proposed wireless service (1) left many earth station operators scrambling to get their antennas licensed prior to the December 1, 2000, deadline. Those that did not make the filing deadline were subject to having their earth stations granted under a secondary status, not eligible for protection unless they were within ten miles of a “grandfathered” or previously licensed antenna authorized for reception of the same band.

A FCC NPRM initiated by the Fixed Wireless Communication Coalition (FWCC) calls for restrictions on the amount of spectrum satellite earth stations may license and protect, leaving little, if any, room for expansion should satellite delivered programming get moved from existing transponders to one outside of the restricted range (2). One benefit of this NPRM includes the proposal to allow blanket licensing of networks of small aperture C-band terminals, the so-called CSATs. In this proposal, limiting the operational parameters of the remote stations will allow for a quick coordination of many terminals and streamline the licensing and approval process, which will result in a faster network deployment at C-band. Additionally, this may relieve some of the burdens commonly associated with using C-band for large network deployments while at the same time providing users the many benefits of highly reliable C-band links.

In addition to the FCC activities discussed above, it is important to note that there is another NPRM that can affect both broadcasters and cable TV entities. This NPRM involves the digital migration on the terrestrial, not the satellite side. The OET NPRM (3) proposes to formally allow digital modulation in the 944–952 MHz, 2, 7, and 13 GHz BAS bands. While digital links are currently being installed in this band, a waiver request is required, and this action would remove the need for a waiver. An important aspect of this NPRM is the requirement by BAS and CARS applicants to coordinate these links under part 101 rules. This NPRM would fundamentally change the manner in which fixed links channels are assigned in the 2, 7, and 13 GHz bands. Typically, the channels in these bands are assigned by coordinators of the local Society of Broadcast Engineers (SBE) on a somewhat ad hoc and informal basis. If this rule making were to be put into effect, before the licensing of BAS and CARS band channels, prior coordination notifications would be required, as specified in Part 101 of the FCC rules.

Comparison of Interference Criteria for FM-TV and Digital TV

The traditional method for analyzing the effects of interference into FM-TV has involved determining the maximum permissible level of interference power at co-channel operation and further considering the offset of the terrestrial carriers versus the satellite carriers. The maximum permissible interference power level is calculated as a function of carrier-to-interference ratio. Through experimentation and analytical methods the carrier-to-interference (C/I) required for broadcast quality FM video is 25 dB. The interference objective for most satellite television broadcast and CATV earth stations receiving

FM television at 4 GHz was based upon this required C/I and the received signal level as calculated below:

Maximum Permissible Levels of Interference Analog FM-TV at C-Band

Satellite Downlink EIRP	34	DBW
Gain of 4.5 m Receive Antenna	44	DBW
Free Space Loss	-196.4	dBW
Received Satellite Signal Power	-118	dBW
Required Carrier-to-Interference Ratio	25	dB
Max. Permissible Level of Interference	-143.4	DBW/MHz

For digital video, or digital systems in general, the long term interference objective is set to provide a C/I ratio necessary to degrade the carrier-to-noise (C/N) ratio by not more than 0.5 dB, or 10 dB below the thermal noise floor. A sample calculation is shown below:

Maximum Permissible Levels of Interference Digital Video TVRO at C-band

Satellite Downlink EIRP	25	DBW
Gain of 4.5 m Receive Antenna	44	DBW
Free Space Loss	-196.4	DBW
Digital TVRO System Noise Temperature	150	K
Digital Signal Noise Bandwidth	8	MHz
Received Satellite Signal Power	-127.4	dBW
Received Noise Level (kTB)	-137.5	dBW
Downlink Carrier-to-Noise Ratio	-10.1	dB
Max. Permissible Level of Interference	-156.4	DBW/MHz
Resulting Carrier-to-Noise Plus Interference Ratio	9.6	dB

Typically an interference objective will be derived using link analyses. In those instances where link analyses are not available, FCC rules and ITU Radio Regulations can be used (see Radio Regs Appendix S7 and ITU.R SF.1006).

The Proactive Approach to Interference Free Operation

Earth station owners need to realize that with the introduction of more stringent interference criteria, along with new FCC rulings, they must now coordinate and protect their earth station antenna sites to ensure interference issues are addressed. This is especially true for earth station owners that have

never licensed or protected their site to the new digital downlink standards. Owners that have previously licensed and protected their site must now also re-coordinate their site to the new digital downlink standards to ensure an interference free operation.

A proactive approach in evaluating the environment prior to the switch from analog to digital is not only sensible in avoiding signal loss of the digital carrier, but the downlink operator can use this opportunity to audit their system for compliance with current FCC and Industry standards. Accuracy of the earth station antenna's site coordinates, which may seem minor to some, will go along way in protecting the site from future growth of services operating in the shared band of their antenna. Securing the correct site coordinates not only increases the precision of the interference study, but reinforces the accuracy of the frequency coordination and FCC registration and protection of the C and Ku-band antenna against existing and future services authorized in the shared band.

A paper study against terrestrial microwave in shared C and Ku-band services would be the first step in identifying whether a terrestrial transmitter that previously operated without conflict to analog satellite reception, is lurking not far away at levels that would disrupt digital satellite downlink reception. The office analysis identifies whether any local 4 or 11 GHz terrestrial microwave transmitters could cause potential interference into the existing C or Ku-band antenna operating under the more stringent digital standards.

In order to detect the other forms of potential interference, such as cellular, PCS, engine noise, military and aircraft radar altimeters, that can present signal disruption in the C and Ku-band spectrum, on-site RFI measurements are the next logical step in completing a pre-conversion site audit. The measurements can confirm whether terrestrial microwave is a threat to digital downlink reception, as well as confirm the presence of the previously mentioned emitters. At this point, the identification of in-band interference sources, whether it be terrestrial microwave or broadband noise, gives the antenna operator time to investigate preventive measures to preclude downlink signal interference. In those cases where significant interference levels were documented that could prohibit digital downlink reception, recommendations on filtering, in instances of aircraft altimeters, and shielding, in instances of broadband noise, can be made. RF shielding in many instances can be constructed to clear those cases with interference margins of approximately 20 dB or less above the desired downlink interference objective.

After establishing a clear picture of the interference environment, the next logical step is to update the protection and licensing status of the individual C or Ku-band earth station to digital standards. Frequency coordination with those users in the shared band, along with filing the updated information with the FCC, will protect the earth station operator from existing and future authorized users of their shared band.

Although the domestic Ku-band downlink frequency range of 11700–12200 MHz is not currently shared with any co-primary authorized users, this band can be just as susceptible to in-band sources of interference. On-site RFI measurements have documented many of the same sources of interference that affected the C-band downlinks, with the addition of automobile radar detectors and some vintage case cellular phone systems creating havoc with digital Ku-band downlink reception. Even though frequency coordination and FCC licensing and protection of domestic Ku-band downlinks is

not available, the identification of the interference source in advance provides the opportunity for the operator to address and diminish the possibility of service interruption prior to going online with the new digital system.

About the Author

Gary K. Edwards is a Senior Manager for Satellite Engineering Services at Comsearch and is responsible for the management of the Satellite Earth Station group. He has over 19 years of experience in spectrum management and satellite earth station frequency coordination, interference analysis and licensing with the Federal Communications Commission. Gary attended Virginia Polytechnic Institute in Blacksburg, Va., and holds an Associate in Applied Science degree in science technology from Northern Virginia Community College. He can be reached at gedwards@comsearch.com.

A Case Study:

A Broadcasting Network's C-band Satellite Earth Stations

Analog to Digital Transmission Conversion

A majority of the television broadcasters with C-band satellite earth stations have begun the conversion from analog to digital transmission. Potential interference is a critical, but often overlooked facet of this conversion. Comsearch has directly assisted several companies with this process. Many broadcasters have taken a proactive approach to interference mitigation due to the fact that analog C-band downlink operators are discovering that previously clean satellite reception is no longer available after converting from analog to digital mode. Degradation occurs because of lower interference tolerances of digital satellite signals. These signals may be compromised by terrestrial microwave traffic at 4 GHz, in-band harmonics from PCS or cellular transmitters, or out-of-band emissions from radars, microwave ovens, and other electronic equipment.



Office Interference Analysis

Comsearch's first step in assisting an earth station operator with this project was to complete an office interference analysis to determine the impact of existing or proposed terrestrial microwave signals on their existing network of earth station sites. By utilizing the more stringent digital receive criteria, the interference analysis identified any existing or proposed terrestrial interference conflicts and considered all 4 GHz terrestrial microwave transmitters within the coordination contours of the C-band earth station. The analysis identified the predicted interference receive levels of these transmitters and calculated the terrain path loss between the earth station and these facilities to determine if a potential interference conflict existed. We used our extensive knowledgebase containing all licensed, proposed, or prior coordinated microwave paths in the country for all analyses. Many of these studies identified potential conflicts with local terrestrial microwave facilities that would not have been a problem with the existing analog receive, but could interfere with a digital receive signal.

On-Site RFI Measurements

One such particular receive site was for a broadcaster located in Philadelphia, Pennsylvania (see Figures 1a and 1b). Our office analysis identified several potential interference conflicts with local 4 GHz terrestrial microwave that did not meet the more stringent digital receive criteria. The broadcaster decided to have our Field Group conduct on-site RFI measurements to not only document the

actual receive levels of these 4 GHz terrestrial transmitters, but search for unpredictable problems such as reflections, high-powered out-of-band radiators, or in-band harmonic signals. The RFI measurements quantify the interfering signal levels arriving at the earth station and the measurements allow for direct evaluation of expected interfering signal levels versus the digital reception criteria. Comsearch's experienced field engineers collect test data in accordance with acceptable industry practices.

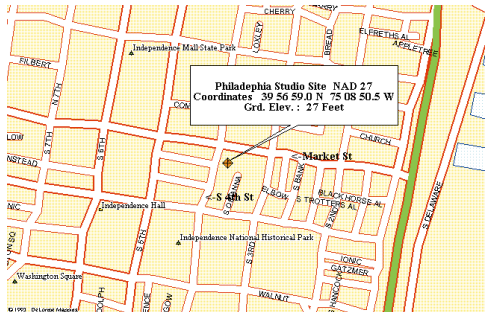


Figure 1a



Figure 1b

Philadelphia, Pennsylvania Studio Site

The measurements at the Philadelphia site documented that the receive levels of the predicted terrestrial transmitters would be within the acceptable levels of and meet the more stringent digital criteria. However, the measurements did document the presence of aircraft radar altimeters which were at levels that could degrade reception, particularly in the digital receive band (see Figure 2). Documentation of the presence of this potential interference source and the confirmation of sufficient site attenuation to clear the local 4 GHz terrestrial cases, enabled this broad-caster to prevent possible interruption of service at this site and confidence that the switch over from analog to digital service would be uneventful. In those cases where significant interference levels have been documented that could prohibit digital downlink reception, recommendations on filtering, in instances of aircraft altimeters, and shielding, in instances of broadband noise can be made.

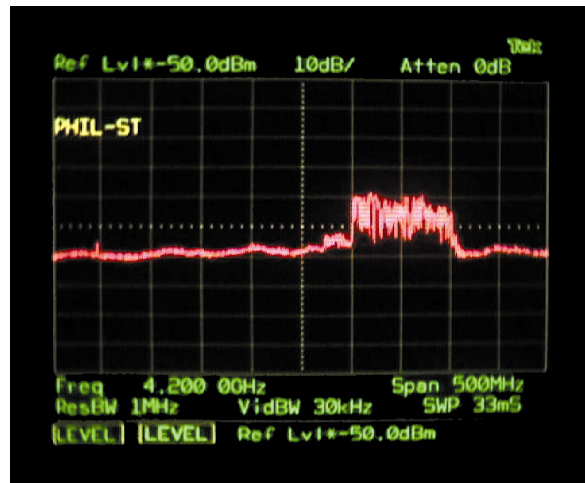


Figure 2 Philadelphia, PA Studio Site, Azimuth 211°
Test antenna pointed toward the azimuth that the existing 5 meter earth station is positioned towards. Spectrum analyzer was set to monitor airplane radio altimeter transmissions.

Federal Communications Commission Regulations

Earth station owners need to realize that with the introduction of more stringent interference criteria, along with new Federal Communication Commission rulings, they must now coordinate and protect their earth station antenna sites to ensure interference issues are addressed. Recent actions by the FCC have shown that currently authorized spectrums can be subject to real location at any time. The reclassification of the 3650–3700 MHz spectrum for a proposed wireless service(4) left many earth station operators scrambling to get their antennas licensed prior to the December 1, 2000 deadline. Those that did not make the deadline were subject to having their earth stations granted under a secondary status, not eligible for protection unless they were within ten miles of a “grandfathered” or previously licensed antenna authorized for reception of the same band. Another concern for earth station operators is an FCC NPRM initiated by the Fixed Wireless Coalition (FWCC) that calls for restrictions on the amount of spectrum satellite earth stations may license and protect, leaving little, if any, room for expansion should satellite delivered programming get moved from existing transponders to one outside of the restricted range (5).

Summary

The case study on the Philadelphia site project reinforced the obvious need to evaluate and protect your earth station site from potential interference sources, especially when dealing with a conversion from analog to digital reception, but also shows that protection of your earth station receive spectrum from regulatory changes can be a crucial part of your systems integrity. The protection services offered by Comsearch identify and correct your interference problem before it becomes a costly issue. We determine your interference problems on paper, not in the field. Our engineers utilize Comsearch’s proprietary database that is updated daily with information obtained directly from the FCC and our clients, providing the technical information required on all coordinated, applied, and licensed systems to ensure your system is well protected. Our historical database contains accurate data on the interference environment around your protected earth station. It is invaluable when you upgrade, expand, or negotiate issues with other shared users of C-band spectrum in your area. Comsearch ensures the correct interference objectives and clearance criteria are used to fully protect your facility and eliminate expensive problem resolutions.

Reference List

- (1) Federal Communications Commission, ET Docket No. 98-237, FCC 00-363.
- (2) Federal Communications Commission, IB Docket No. 00-203.
- (3) Federal Communications Commission, ET Docket 01-75.
- (4) Federal Communications Commission, ET Docket No. 98-237, FCC 00-363.
- (5) Federal Communications Commission, IB Docket No. 00-203