EARTH STATION INTERFERENCE
IDENTIFICATION - MITIGATION - ELIMINATION

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This paper is designed to assist the earth station operator with the methods available for identifying and eliminating interference at earth stations. It will address the procedures that operators can utilize before, during and after construction in order to keep disruptions from interference at a minimum. The various types of interference that can disrupt service at the earth station will be addressed with emphasis on identifying specific interference types and the methods available for reducing or eliminating the their disruptive effects.

Prior to Construction

The steps that can be taken prior to earth station construction fall into two categories. The first category addresses potential interference directly. The second deals with the physical aspects of the proposed site.

It is very important that the potential earth station site, especially if it is to use C-Band or International Ku-Band services, have a **Preliminary Interference Analysis** performed in order to assess the potential for shared-band interference from terrestrial microwave systems. In order to perform this analysis the geographic coordinates, the earth station type and size, the proposed centerline height and the ground elevation are needed. This analysis will provide the distance, direction and relative signal strength of potential interfering microwave stations with respect to the proposed earth station's gain and pattern. This analysis will not take into account the possible advantage to be gained from local blockage or the adverse effects of possible reflection points in the area. In order to assess these parameters an On-Site RFI Measurement is recommended. It should be noted that several of Comsearch's major clients perform On-Site RFI Measurements regardless of the results of the Preliminary Interference Analysis.

On Site RFI Measurements provide the earth station operator with essential preliminary data that is needed to assess the viability of a potential site. Geographic coordinates are verified and are essential for licensing the earth station. The arc clearance is documented and possible obstructions noted. If needed the use of on-site or close-in existing blockage can be examined. Most importantly, if Terrestrial Microwave Interference is present, accurate on-site levels can be documented, including reflected signal levels, in order to determine the actual levels of interference into the proposed earth station. During this measurement other important physical aspects of the proposed site can be examined.

There are several important **physical aspects** of the potential earth station location that should be addressed by the operator prior to construction. All of these can have a bearing on the possible effects of interference into the earth station. The operator can examine these during the initial site visit. It should be noted that these following considerations are a part of a properly conducted On-Site RFI Measurement. In most cases they can best be assessed only with the on-site measurement.

Of the many physical aspects of the proposed site the need for **full arc clearance** cannot be over emphasized. Many operators fall into the trap of accepting partial arc clearance that includes the particular satellite that they need for the moment. In the world of rapidly changing services the feeds the operator needs today may change to different satellites tomorrow. Accepting less than full arc can be a risky and expensive gamble. From an interference reference any (shadowing) from arc obstructions that reduces the signal strength from the satellite into the earth station will increase the potential for or the effects of interference.

If the potential for interference exists at a location the question of the earth station being located on the **ground** or on a **rooftop** becomes important. In most situations a rooftop location carries with it a greater potential for interference than a ground location. Each situation, however, tends to be unique.

The proximity of **major traffic routes** including elevated freeways can play a role in adverse effects of certain types of known interference that can impact earth stations.

Airports and Military Bases can play a major role concerning interference into earth stations.

The location of **electrical transmission lines, substations, transformer poles**, **lighting poles and communications towers** can also be a factor.

During Construction

The steps that can be taken during construction to identify and eliminate interference are limited in that usually any identification would have been made prior to construction or the interference would not be discovered until the earth station was put into service. If it is known that terrestrial microwave interference exists there are steps that can be taken as a part of the construction process to eliminate or reduce its effects, especially if the earth station being installed is a smaller antenna. For example, local building blockage could be utilized when installing the antenna or screening/shielding could be erected during antenna installation to counter the known interference. It should be noted that screening/shielding is usually installed after the antenna is put into service.

One additional topic should be noted at this point even though it is not directly related to identifying and eliminating earth station interference. There have been numerous cases over the years where supposed (interference) was instead determined to be the results of poor or inadequate grounding of the earth station when installed. The earth station should be properly grounded as per the manufacturer’s specifications. If multiple antennas are involved there grounds should be tied together. When metal shielding or screening is used these should be well grounded and if possible tied to the earth station ground.

After Construction

Once the earth station has been operational and the operator encounters what is believed to be radio frequency interference (RFI) there are four steps involved with identifying and eliminating this interference.

The first is to try and answer a series of questions concerning the interference.

The second step involves in-system testing.

The third step is RFI testing external from the earth station in order to locate the source of the interference.

The fourth step is to eliminate the interference or reduce its level of disruption to an acceptable level.

The suggested list of questions will be examined, the in-system testing process explained, and then the external RFI testing procedures described. The various types of earth station interference will be examined with references made to the list of questions asked initially, the in-system testing and the RFI testing. The various methods of eliminating the different types of interference will then be addressed.

Preliminary Questions

The following is a series of initial questions that should be answered. This group of questions may differ slightly depending upon the type of service (C-Band, Ku-Band, etc.), the physical environment, the number and size of earth stations at the facility and the types of feeds involved (analog, digital or compressed digital video):

* Is the disruption/degradation constant or is it intermittent? If it is intermittent how often does it occur. Is there a cycle (every 10 sec., 30 sec., etc.)? When it occurs how long does it last? Does it occur only during normal working hours or can it happen at any time during the twenty-four hour period? Does it happen on weekends or holidays? Does it occur in association with sunrise and/or sunset? Does it occur mainly during the morning and evening (drive times) or could it be associated with morning, afternoon and evening meal times?

* Describe the disruption. For **analog video** is it a degradation of the audio and/or the video. What does it sound like? How does it appear at video? For **digital** is it an increase in BER or more severe with frame loss. **Compressed Digital Video** requires some unique questions: Is the degradation a momentary video freeze with audio loss, or does the screen break up into a (checkerboard) configuration. Does the video go completely (black)?

* When the interference occurs is the degree of degradation the same each time?

* How many transponders does it affect. Does it affect different satellites? If there are multiple earth stations at your facility does it affect more than one? Does it degrade all the feeds or only those with LNA's, or perhaps only those with LNB's, or maybe only those with the new or old LNA/LNB's? Have the LNB's on other feeds at the facility been deactivated during the disruption period? Many times if a LNB is defective it can under certain circumstances emit RF that can cause interference into other feeds.

* Has the earth station been realigned, the waveguides checked, the LNA/LNB's checked and the receivers checked? Many an (interference) case has been solved by replacing the receiver or the LNB, or by realigning the antenna.

* Does the earth station meet the newer spacing requirements? Could the problem be adjacent satellite interference?

* Has the polarity discrimination been checked for the possibility of adjacent transponder Interference?

In-System Testing

The second step in the RFI identification procedure is to perform In System-Testing**.** Once the earth station system's components have been eliminated as the cause of the disruption the remainder of the In-system Testing requires the operator to have access to an adequate Spectrum Analyzer preferably with digital storage capabilities. Although some information can be gained by viewing the IF ouput of the receiver, ideally the best analysis will be obtained by monitoring the output of the LNA/LNB on the degraded feed. The following procedures are recommended:

*If possible, view the output of the LNB/LNA during a time when there is no disruption. Is the satellite signal strength adequate? Is the crosspole discrimination within acceptable limits? With LNB systems it is helpful to take a look above and below the satellite band. If a (mirror image) of the satellite feeds is seen either above or below the band the LNB is defective. An LNB exhibiting this symptom can be deceptive in that it will test as having adequate gain but will go into compression and/or saturation when it detects an out of band signal that would not normally degrade its operation. In some cases it will radiate spurious emissions that will degrade other feeds.
Examine the spectrum above and below the satellite band for signals that are within the passband of the LNA/LNB. Strong signals in this area can send a properly operating amplifier into compression or saturation and cause degradation.

*When the disruption occurs try and repeat as much of the previous step as is possible. The storage capabilities of the analyzer may be needed at this point. Once the interference has been viewed real time or captured in storage it should be possible to then categorize what type of RFI is causing the disruption.

*It may be helpful at this point to attempt to view the RFI without the satellite feed present. This is most easily accomplished by increasing or decreasing the earth station elevation angle several degrees. This is especially helpful if the satellite feed is digital. Note: if the interference signal also disappears with the satellite signal then the problem is probably adjacent satellite or adjacent transponder interference.

*Once the RFI has been acquired on the analyzer the answers to the following questions should aid in categorizing the type of interference causing the disruption. This information can be crucial in determining the source of the interference.

Note: It is important that the signal(s) thought to be the RFI have a direct relationship to the disruption to the system.

- Is the signal broadband noise?
    Does it cover the entire satellite band or possibly large portions of the band?
    How often does it occur?
    How long does it last?
    Is there a cyclic rate to the RFI noise (30 sec., 60 sec., etc.)?

-Is the interference a single frequency or multiple frequencies?
    Does it appear to be analog or digital?
    Is the amplitude stable or does it vary?
    Does the signal sweep or appear to drift?
    What is the signal's bandwidth?

-Does the RFI appear to be a radar type signal?
    Is it in band, out of band or both?
    After a few minutes of storage on the analyzer how much bandwidth does it occupy?
    Is there a cyclic rate to the interference?
    Does the amplitude increase with a cyclic rate?

The answers to these questions with reference to known types of earth station interference that have been encountered and documented over the years should supply the operator with an idea of what type of interference is causing the disruption. At this point it might be feasible that the source can be identified. The only other testing required would be to verify the source by its elimination or performing some sort of (shut down) test with the suspected source.

In many cases, especially if the source of the interference is not in the immediate vicinity of the earth station, additional field testing will be needed. This testing is the external RFI Testing.

External RFI Testing

External RFI Testing requires specialized test equipment that can run the gamut from very basic to extremely sophisticated. Some of these tests can be done by the earth station operator and can be successful especially when it is a small aperture earth station being affected and all that is required is a general direction for the RFI so that a shielding or screening can be utilized. The more sophisticated testing will usually require outsourcing to a company like **Comsearch** whose Field Services Group has at their disposal the experienced personnel and the proper equipment needed.

The following are a few of the various scenarios for external Field-Testing with a list of the equipment required. All of them assume that a spectrum analyzer is being utilized.

*In some cases the earth station itself can be used as the test antenna. With the spectrum analyzer monitoring the output of the LNA/LNB the antenna can be moved both in azimuth and elevation in order to determine the general direction of the RFI. The information gained is limited but may be enough to allow placement of a shield or screen or the relocation of the earth station to utilize existing local blockage.

*If the operator cannot use the earth station as a test antenna it is sometimes possible to utilize an LNB or LNA as a detector with the spectrum analyzer to determine the RFI direction.

*Usually the most sophisticated of the external RFI testing scenarios that the earth station operator can accomplish is to assemble a test system comprised of a vehicle equipped with a generator or DC inverter, a test antenna (small parabolic or standard gain horn), an LNA/LNB and the spectrum analyzer. With this system the operator may be able to track the RFI to its source. It should be noted that this procedure can be difficult, time consuming and even frustrating, especially if the RFI is intermittent and/or reflection points or structural knife-edges are involved. Once the source is identified a solution (if possible) can be determined.

*The most sophisticated of the external RFI tests is usually performed by a company such as Comsearch. The following is a typical equipment list utilized by the Field Services Group for testing of this nature:

-Vehicle with DC Inverter or AC Generator

- Spectrum Analyzer

- Test Antenna(s) Note: in most cases a broadband log periodic antenna will also be used in order to deal with RFI that is the result of spurious or harmonic emissions from lower bands.

- LNA(s) Units for the band in question and often additional units for lower bands.

- Portable antenna mount capable of heights up to 20' in order to overcome close in blockage. When needed lift equipment capable of heights to 90' have been used.

- GPS unit, compass, clineometer and area topographical maps for navigation and triangulation.

- Cellular Phone - for running shutdown tests, coordination with the earth station, and access to Comsearch database information.

Once the source of the interference has been verified and its true nature (primary frequency, harmonic emission or spurious output) determined then a solution (if possible) can be determined.

Note: One very important factor for all of these scenarios is that the RFI must occur during the testing periods often enough to allow the source to be identified.

Types of Earth Station Interference

Terrestrial Microwave - The C-Band and portions of the International Ku-Band share spectrum with Common Carrier microwave users. This type of RFI is usually easy to diagnose because there are FCC databases available for reference and the interference is usually constant. In a few exceptional cases the RFI from terrestrial transmitters will fade in and out or vary drastically in amplitude due to atmospheric conditions. These cases usually require Field Measurements for identification.

Broadband Noise - This type of RFI will often the entire satellite band. It is most common at C-Band. Some of the more common sources are ignition noise (especially from small engines on lawn equipment, snow mobiles, motor scooters, fork lifts, etc.), faulty AC transformers or power lines, electromechanical relays in elevator controls or AC/Heating equipment, and certain types of outdoor lighting equipment. The source of this type RFI is usually found in close proximity to the earth station and is not difficult to verify once the source is determined.

Radar - There are no known radar types that share spectrum with any of the satellite bands. When radar systems cause interference into satellite receive bands it is the result of harmonic or spurious emissions. This type of RFI can be difficult to verify and locate. Because of the strong emissions from some of the units the source can be up to 50 miles or more from the earth station. It usually requires extensive Field Measurements with sophisticated equipment.

Aircraft Radio Altimeters - This equipment is allocated the 4200 - 4400 MHz band. Generally these units utilize 4250 - 4350 MHz. There have been a few rare instances where the altimeters were actually emitting below 4200 MHz and would cause disruption to the upper transponders of the C-Band. The most common disruptions are caused because the altimeters operate within the passband of the majority of the C-Band LNA/LNBs. These units cause interference into the earth station by compressing or saturating the LNA/LNB. This will cause an increase in the system's noise floor, usually a reduction in gain and often cause the LNA/LNB to emit spurious signals in the C-Band. Disruptions occur when the aircraft passes near or through the main beam of the earth station. The aircraft can be at virtually any distance and elevation when this occurs. This type of RFI is relatively easy to diagnose if a spectrum analyzer is available to the operator.

Microwave Ovens - These devices are authorized to operate at 2450 MHz (+/- 50 MHz). They normally do not cause interference into earth stations. There are certain models from certain manufacturers that can cause disruptions in the C-Band. The most common is a commercial model that causes interference to the upper portion of the C-Band **only when the unit is started** and not for the duration of its run time. This is the result of a faulty magnetron in units manufactured prior to 1993. There has recently been discovered a different model from the same manufacturer that causes interference over a greater portion of the C-Band when started. During the last 17 years there has been one reported case of a consumer grade model that covered the entire C-Band with spurious emissions while running. This type of RFI can be difficult to trace in that it is of very short duration and very intermittent.

Radar Detectors - There are certain brands and models of automotive radar detectors that utilize 11.5 GHz for a local oscillator frequency. These units will emit this often sweeping (+/- 50 MHz or more) signal at levels strong enough to cause RFI into International Ku-Band users and in some cases the extreme lower end of the Domestic Ku-Band. The majority of these disruptions are very short in duration due to the source being mobile. There have been cases of extreme outages when units where left powered up in vehicles parked near to the earth station. Note: This oscillator output allows for detection of units in passing traffic in those areas where they are illegal.

Cellular Telephones - It is believed that all cellular telephones emit 5th order harmonics at C-Band. (All of the various types, brands, models that have been encountered over the years have shown to emit these harmonics at varying levels.) These units were (type accepted) and approved by the FCC. There were no documented cases of these emissions causing interference to the old analog video on the upper transponders. However the recent use of compressed digital video on the upper C-Band transponders has brought this problem to (light).

Over the past three years there have been three documented cases of the older high power phones causing interference into compressed digital video feeds on the upper four transponders when activated within several hundred feet of the earth station. This type of RFI is difficult to verify and document without sophisticated equipment.

NOTE: There have been no documented cases of interference into C-Band earth stations from PCS (digital wireless) phones. There has been one documented case of interference from a PCS cell transmitter into C-Band earth stations.

Some Additional Thoughts and Comments

*Finding a single source of interference into an earth station can range from simple (sometimes determined with just a phone conversation) to very challenging requiring a lot of time, equipment and trained personnel. There have been a few cases over the years where the RFI was the result of two similar but separate sources. There were even some cases where the interference was from **three** separate and **dissimilar** sources. These situations tend to be quite frustrating even for trained personnel with adequate equipment.

*The list of devices (cell phones, GPS units, garage door openers, electronic test devices, remote controls, remote fire and security sensors, etc.) in our society that emit spurious or harmonic signals in the satellite bands (especially the C-Band) is virtually endless. The vast majority of these emissions are of such low levels and so rarely in close proximity to an earth station that it has not represented a major problem. With the three cell phone cases as reference, the trend towards digital may see an increase in **reported** RFI into systems from these devices. It may be later determined that the compressed digital video is not so much more susceptible than analog video was when related only to interference levels. However, what may be seen is that minor (hits) to analog video systems that went unnoticed by consumers and even the majority of operators by these and other RFI sources will be painfully noticeable by everyone with compressed digital video. Satellite technicians have even (coined) a new phrase, (digital freeze) to describe what is a minor disruption to digital video.

*It should also be noted that these devices are often harmless to a properly operating earth station system. However if there is a defective component (especially an LNB) in the system the result can be a disruption in service when these devices are activated near the earth station.

*It has been determined that with the increased use of **compressed digital video** there will be an increased possibility for interference into existing C-Band earth stations that previously had not had interference problems. Many of the earth stations were installed in locations that met the analog video interference criteria of approximately **-145 dBwi**. This represented the maximum interference level that would still allow a C/I (carrier to interference ratio) of 25 dB. This is -145 dBwi is representative of a 5 meter earth station and a satellite EIRP of 34 dB. The increased susceptibility of compressed digital video to interference has caused this criteria to be lowered to a more realistic level of **-156 dBwi**. In other words there are many earth stations in operation taking analog video feeds at this time that coexist with RFI lower than -145 dBwi but higher than -156 dBwi. These stations may experience interference degradation when they convert to compressed digital video.

*It should also be noted that the majority of the newer lower temperature LNB’s tend to be more sensitive to strong out of band interference sources.

There are four ways in which to mitigate or eliminate interference into earth stations:

1. Eliminate the source of the interference.
2. Relocate the earth station to an area that is either interference free or has better local blockage in the direction of the interference.
3. Shield or Screen the earth station from the source of the interference.
4. Reduce the effects of the RFI by filtering at RF or IF, or using an effective bandpass filter.

<u>Eliminate the Source</u>

- By far the most effective method in eliminating interference.

-Rarely used when dealing with an active terrestrial microwave system.

-Used quite often when dealing with broadband noise except in cases where the source is heavy vehicular traffic.

-This is the best solution for radar interference since it is the harmonic or spurious that is to be eliminated. Usually involves repairing faulty components or installing a lowpass filter.

-Not an option with aircraft radio altimeters.

-Although the microwave oven is not eliminated, the spurious emission can be removed with repair or unit replacement.

-Not a viable solution for radar detectors although their use in the immediate vicinity of the earth station might be restricted.

-Not an option concerning RFI from cellular telephones.

<u>Relocate the Earth Station</u>

-Theoretically possible for resolving all RFI interference scenarios except aircraft radio altimeters. However, except in the case of small aperture antennas, usually not economically feasible unless no other solution is possible.

<u>Shield or Screen the Earth Station</u>

-Not feasible for aircraft radio altimeters. Rarely, if ever, used for broadband noise interference. Most effective when 20 dB or less of interference attenuation is acceptable.

Filtering at the Earth Station

-Bandpass filters can be utilized to eliminate or reduce out of band interference. This is the only reliable method for eliminating/reducing interference from aircraft radio altimeters.

-For analog video feeds there has been success using multiple cavity RF filters, multiple cavity L-Band (for LNB s) filters, and IF notch filters. The most commonly used has been the IF Notch Filter. Can be effective when needed attenuation is 20 dB or less and **the interfering signal is analog.**

Several Notes on Filters: If the satellite receive signal is digital or if the interference is digital with a bandwidth in excess of 5 MHz IF filtering usually will not work. If the analog interference into the analog satellite receive is less than 10 MHz separated from the satellite center frequency IF, RF or L-Band filtering will not be effective. RF and L-Band multiple cavity filters are very difficult to tune properly. Filtering will not remedy in-band broadband noise interference, radar interference, and cellular phone or microwave oven interference. IF and RF filtering is usually used to eliminate or reduce terrestrial microwave RFI.