Analysis and Elimination of Common Interference in Satellite Communications

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Abstract. Because the satellite communication system is an open system, the satellite's frequency resources and transponder power are limited. Although there are international organizations and satellite companies in various countries for orbit, frequency, and power allocation and coordination, satellite communications cannot be completely prevented from being interfered. The well-known Falun Gong interference with Xinnuo satellite is an obvious example. Articles on satellite communication interference are scattered in various professional newspapers. This article will discuss the causes, judgment methods and solutions of common interference in satellite communication, focusing on the practical methods of solving interference.

1. Introduction
Satellite communication interference can be divided into natural phenomenon interference, equipment failure interference, ground electromagnetic environment interference, adjacent satellite interference and man-made interference. Of course some of the interruptions are interleaved and inseparable. For example, the interference of adjacent star may be caused by human factors, such as the inaccuracy of the antenna to the star. The uplinking of if interference on the satellite is not only a communication line problem, but also related to the local electromagnetic environment of the earth station.

2. Interference of Natural Phenomena
2.1. Solar Disturbance
2.1.1. Causes of formation
Every year around the vernal and autumnal equinoxes, when the satellite is between the sun and the earth, the earth station antenna will be pointed at the sun as well as at the satellite. At this time, the strong radiation noise of the sun will affect the normal satellite communication reception, that is, the solar eclipse interference. Severe disruptions can result, often referred to as a solar outage, as shown in figure 1.
2.1.2. Brief analysis
The duration of the interruption is related to the location of the earth station, the aperture of the antenna and the operating frequency. For the northern hemisphere, the higher the latitude of the earth station at the vernal equinox, the earlier the start and end of the eclipse; At the autumnal equinox, the higher the latitude, the later the start and end of the eclipse. The longitude of the earth station affects the beginning and ending time of the solar eclipse each day. In the case of the same latitude, the farther east you go, the later the beginning and ending time of the solar eclipse will be. The larger the aperture of the earth station antenna, the narrower the 3dB beam bandwidth will be, and the shorter the time affected by the sun. The higher the receiving frequency of the earth station antenna, the narrower the 3dB beam bandwidth and the shorter the duration of the eclipse. Monitoring departments will send the daily schedule of each place to users or put it on the website, so that users can make preparations in advance.

2.2. Ionospheric Scintillation Interference

2.2.1. Causes of formation
When the radio wave passes through the ionosphere, it is affected by the inhomogeneity of the ionosphere structure and the random time-varying, which causes the irregular change of the amplitude, phase, arrival Angle, polarization state of the signal in short period, and forms the ionospheric scintillation interference.

2.2.2. Brief analysis
The ionospheric scintillation is related to the working frequency, geographical position, geomagnetic activity and season of the earth station. The ionospheric scintillation is more serious near the
geomagnetic equator +200 and at high geomagnetic latitudes. The areas south of the Yangtze river and some areas north of the Yangtze river in China belong to the active ionospheric scintillation zone, as shown in FIG. 2. The discontinuity scintillation is greatest at the vernal and autumnal equinoxes and occurs at night. According to statistics, the maximum fading value at 4/6GHz in Hong Kong is 9dB.

2.2.3. Avoidance
Due to the slow change of the ionospheric scintillation amplitude, and the wide frequency range affected by the fading, and the drift of the ionospheric irregular region, the shorter the information length in the ionospheric scintillation environment, the less the possibility of interference. Therefore, the effective method to deal with ionospheric scintillation is to use time diversity or coding diversity as much as possible, or appropriately increase the reserve of ionospheric scintillation fading.

3. Electromagnetic Environmental Interference

3.1. Causes of Formation
Terrestrial microwave communication relay signals and radar signals (mainly c-band) are received together with satellite signals by the antenna of the earth station, which interfere with useful signals.

3.2. Judgment Method
When the satellite signal received by the user is interfered, the carrier can be turned off if possible. If there is still interference clutter, and the possibility of other interference is ruled out, it is reasonable to suspect the existence of electromagnetic environment interference.

Generally in the new earth station or the existence of interference around the suspected, you can conduct electromagnetic environment test. During the test, signals in band C on the ground can be transformed into signals in band L and observed with a spectrum analyzer. If interference signals appear in the corresponding frequency band and are larger than a certain interference tolerance, electromagnetic environmental interference can be identified in the frequency band. However, with the development of society and the expansion of urban construction, some earth stations with good electromagnetic environment in the suburbs will be more and more interferences.

For the receiving user station, the environment is more complex and diverse, electromagnetic interference can be seen everywhere. New station in the electromagnetic environment after the completion of the test, does not mean that there is no electromagnetic environment interference, to pay special attention to the surrounding microwave tower and other relay station construction, they will often cause changes in the electromagnetic environment.

3.3. Avoidance

3.3.1 Look for better shielding. Since the sum of the interference waves travels in a straight line, it will be reflected when encountering obstacles. You can use the method described above to find the radiant dead angle of interference radio waves and avoid the ground electromagnetic environment interference.

3.3.2 Set up shielding nets. A barbed wire is set up around the antenna to prevent interference waves from entering. When the barbed wire is erected, the height must exceed the LNA and should not block the direction of travel of the satellite signal.

3.3.3 Install a filter before the signal enters the LNA to remove the interference carrier. The above method can only aim at the electromagnetic interference which is not too strong, and the best method for strong interference is to avoid this frequency band. That is, when the satellite frequency band is allocated, the user's local transmitting and receiving frequency bands avoid the interference frequency bands measured in the electromagnetic environment test.
4. Equipment Failure Interference
The interference caused by equipment failure is one of the most common interference in satellite communication, which is mainly divided into satellite failure and ground equipment failure.

4.1. Satellite Fault Interference
Satellite failure refers to the failure or failure of the entire satellite of a communication satellite or a certain transponder. As the satellite is in a harsh space environment and is "bombed" by high-energy particles such as solar storms, the satellite's control devices may be misoperated or damaged, and the attitude of the satellite may be affected. Although most of the key components of modern communication satellites are backed up and can be switched in time, there may still be many unexpected situations. This situation occurs, if the entire star fails and cannot be recovered, it can only be turned to a star. If only a certain transponder is involved, the method of replacing the transponder can be adopted.

4.2. Ground Equipment Failure Interference

4.2.1. IF forwarding interference
- Causes of Formation
  Due to the loose, virtual connection and cable rupture of the if cable connector of the earth station, it is difficult for the transceiver isolation of the if cable to transmit the received if signal back to the satellite through the uv-if cable, thus causing interference to other users.
  When the earth station receives the signal in the frequency band is very weak, coupled with the earth station's transceiver has certain isolation, it usually does not show up in the satellite spectrum, also does not constitute interference to other users. However, if there is a user on the satellite with high power, the earth station with poor if transceiver isolation will transmit the carrier wave for a second time.

- Judgment Method
  A single carrier can be transmitted on the transponder where forwarding interference is suspected. If a certain or several earth stations receive the carrier and forward it, the frequency sent to the satellite due to doppler shift will have a little deviation from the original frequency, and the power of secondary forwarding will be much smaller. In general, if the resolution bandwidth of the frequency spectrometer is set to less than 10Hz, these forwarding interferences can be seen.

- Avoidance
  To avoid interference of if forwarding, it is necessary to find it. Assuming that the forwarding bandwidth is the common 36MHz, after ODU or down converter of earth station, only the carrier set by ODU or down converter +20~30MHz can enter the if cable. Even if the uplink frequency of if is not set at 70MHz, it can only affect adjacent transponders. So the target of the search should consider the repeater first and the adjacent repeater second. The way to find is to ask the user to turn off the uplink amplifier power and see whether the forwarding interference next to the single carrier on the transponder disappears. If it disappears, you can turn it off a few more times to verify it. If it still exists, you can continue to find other users. Note that sometimes there are several forwarding interruptions in a single repeater, especially if there are VAST users. After finding the user causing the interference, the user should be asked to inspect the transceiver if cable and replace it if necessary until the problem is completely resolved.

4.2.2. Terrestrial FM radio interference
Terrestrial FM radio interference is similar to IF forwarding interference, both caused by poor shielding of the IF transmission cable.
- Causes of Formation
  Due to the poor shielding of the uplink IF cable of the earth station (including cracking, broken connectors, etc.), the ground FM broadcast (band 87 ~ 108MHz) is transmitted to the satellite through the IF cable, which will interfere with normal signals.

- Judgment Method
When FM broadcasting is found on the satellite, the interference location can be determined by HP8563E. Some stations can judge the location directly from the broadcast content. Some minority language radio stations and foreign language radio stations, through monitoring can also be roughly narrowed down the scope of interference search.

- **Avoidance**

When the intermediate frequency goes up, there is a certain band pass range when passing through the up-conversion equipment. We take an upconverter with input and output bandwidth of 40MHz as an example, assuming that the central frequency of the input signal is the 70MHz intermediate frequency that many users are used to, and the corresponding receiving center frequency is 4GHz, then FM broadcasting should fall at 4017~4138MHz. Therefore, when looking for the source of FM interference, generally in the repeater or adjacent repeater to find. To confirm whether it is the interference emitted by the user, the uplink power supply of the user can only be turned off to see whether the FM broadcasting on the satellite disappears at the same time. During the test, pay attention to turn off the power supply of the amplifier. Sometimes, if the uplinking if signal source is only turned off, the local broadcast can still pass the satellite on the amplifier, thus missing the opportunity to detect interference.

**Ways to completely avoid FM radio interference:**
- Redo or Replace the Cable.
- In some unqualified areas, you can try to exchange the receiving and sending cables (under the condition that the original receiving cable is well shielded), temporarily remove the on-board interference, and replace the cables when necessary.
- Install an IF attenuator on the input of the up-converter or ODU to reduce the strength of the ground FM signal and increase the strength of the user's IF signal. The increased power should be able to offset the attenuation of the IF attenuator. Of course, this can be achieved only when there is a margin in the user's IF transmit power. In practice, this method has a strong suppression effect on many unexplained intermediate frequency ground interference.

### 4.2.3. Intermodulation interference

There are two types of intermodulation interference that we observe on the spectrum analyzer: the intermodulation interference generated by the repeater and the intermodulation interference generated by the ground equipment. The intermodulation interference caused by the transponder and the earth station are caused by the earth station, so these two types of interference are introduced together here.

- **Causes of Formation**

The cause of intermodulation interference in the repeater is the multi-carrier operation, which makes the repeater work in the non-linear region. Earth station of the interference is caused by the ground equipment, such as a modem, frequency converter, power amplifier, etc., if the uplink mismatch, or the link design problem, didn't set aside enough slack, in some cases, in order to achieve sufficient carrier to noise ratio for receiving, to increase the some equipment output level to nonlinear area, can produce the interference.

- **Judgment Method**

The judgment method for transponder to produce transponder interference is to let the user who produces transponder reduce the transmitting power. If the transponder reduces the transmitting power at the same time until it disappears, it can be basically determined that the transponder enters the nonlinear region due to the excessive transmitting power of the user. The judgment method of the cross-modulation interference generated by the earth station is to let the user who produces the cross-modulation reduce the power of the uplink device step by step from medium frequency to radio frequency. If the power of a certain device is reduced, resulting in the reduction or disappearance of the cross-modulation, it indicates that the device is the cause of the cross-modulation.

- **Avoidance**
The way to avoid the transponder to produce cross-modulation interference is to control the power when the service is open to test as far as possible, in strict accordance with the link calculated power uplink, can not let a certain carrier power is too high.
The solution to the cross-modulation interference in the earth station is to test the uplink equipment in the station strictly to make the third-order intermodulation meet the specified indexes. Make sure that the modem, up-converter, power amplifier, etc. Have enough back off, do not work in the nonlinear area; Ensure all levels of uplink equipment have good power matching.

4.2.4. Spurious interference
Spurious interference is also one of the satellite communications interference often seen. We often see some unknown clutter in the satellite spectrum, and some are spurious interference due to ground equipment failure. It is especially common for users who no longer use satellite communications, but their uplink equipment has not been turned off. Over time, the equipment has problems and is unmanaged, causing interference to other users.

- Causes of Formation
  Uplink equipment spurious indicators are unqualified, and there are clutter or harmonics in the operating frequency band
  The uplink device output level is set unreasonably, and it works in the non-linear region, causing carrier noise or spectrum spread.

- Judgment Method
  If irregular clutter or noise is found on the satellite repeater, after eliminating the possibility of interference such as FM broadcasting and intermodulation, it may be the spurs generated by ground equipment.

- Avoidance
  Carefully test the equipment inside the new earth station to make it comply with the standard.
  Reasonably set the working point of the uplink equipment, and strictly implement the calibrated power when entering the network. The increased power should be reported to the satellite company.
  Any changes to the equipment should be notified to the satellite company in a timely manner.
  Satellite companies should promptly urge users who have already cancelled their leases or changed their frequency to switch off or change the settings of their equipment, so as not to leave an idle device unattended for a long time.
  The frequency range involved by spurious interference may be relatively wide, and it is difficult to determine the source of the interference. You should first find the users who have recently changed, and ask the suspected user to check whether the spurs have disappeared after shutting down. It is more feasible.

5. Other Interference

5.1. Sweep Interference
In satellite communication, some frequency band or even the whole frequency band are suddenly encountered. Since such interference often involves a wide range of frequencies and can be very damaging to normal users, it should be eliminated as soon as possible.

5.1.1. Causes of formation
- Failure or loss of control of a user's equipment is the most common cause. This problem is most likely to occur at earth stations where satellites have been deactivated but the uplink equipment has not been shut down and has been unattended for a long time.
- Malicious interference by individual users.

5.1.2. Avoidance
- Users who have withdrawn their lease or have had their satellite disabled for a long time should be urged to turn off all uplink equipment.
To implement positioning, grasp sufficient evidence, investigate its legal responsibility.

5.2. Single carrier interference

5.2.1. Causes of formation

- A legitimate user launched for polarizability without notifying the satellite company.
- Legitimate users in the carrier parameter conversion, temporarily changed the carrier into a single carrier.
- Illegal user malicious interference.

5.2.2. Avoidance

In single carrier interference, the error of legitimate users is common. It's not hard to figure out which users are using the frequencies that have been assigned to them and the people who have used that frequency in the past.

6. Conclusion

The above is just the experience summarized by the author in combination with years of working in the field of satellite communication. With the progress of satellite technology and communication technology, there will be more and more complex interference, and the technology of eliminating and resolving interference will continue to improve, so that satellite communication can better serve us.

7. References

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