Satellite Interference Geolocation Considerations May 2016

Paul Chan, MIEEE, MIET, MSc. Telecommunications
Spacecraft Engineer, Asia Satellite Telecommunications Co. Ltd. (AsiaSat)

Introduction

Interference is a problematic issue causing significant impact to satellite communications and sometimes making the satellite frequency spectrum unusable. When satellite operators experience interference, they may require to relocate their customers in a temporary frequency slot for service recovery until the interference issue is resolved. In some cases, commercial satellite operators have to pay outage compensation to their customers and it incurs unnecessary revenue loss. In addition, the non-saleable frequency spectrum due to interference occupation will limit the profit growth and business development. It is undoubtedly that the effectiveness of utilizing assigned spectrum resource in the outer space is a major goal to keep an operator successful. To achieve this goal, geolocation is a practical and proactive method to locate the source of interference and help tackle interference issues.

Figure 1 is an illustration of the orbital slots of AsiaSat Fleet in space. Considering the geostationary arc between the longitude 95degE to 125degE, there are 28 commercial communications satellites in service. We can see that the average satellite separation is only 1.1 deg which makes the work to minimize interference very challenging. Uplink Adjacent Satellite Interference (ASI) can be an issue for the satellite networks operating with communications satellites in such close proximity between their neighbouring satellites, if it is not properly coordinated and managed.

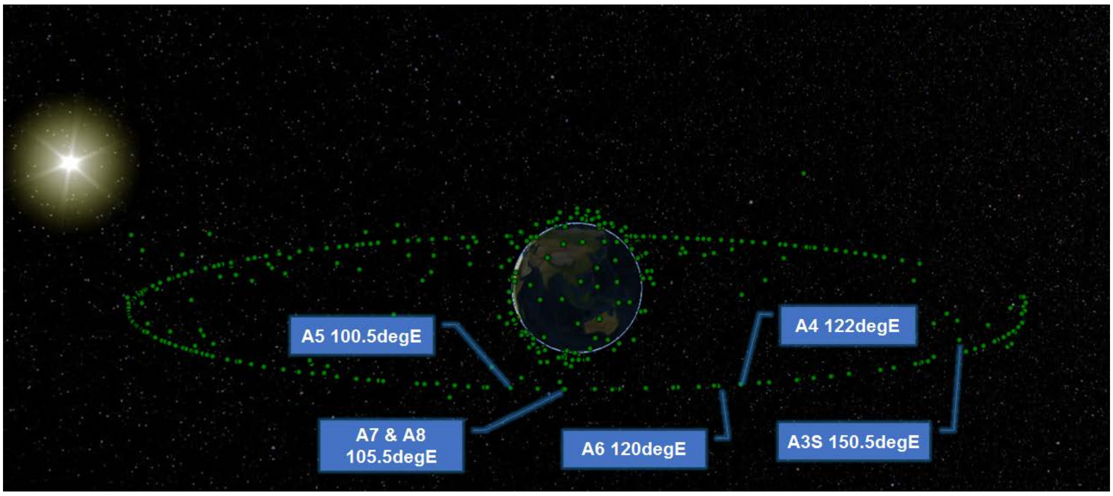

Figure 1 Graphic illustration of AsiaSat Fleet's Orbital Slots in Space[1]

Interference Types and Mitigation

With the growth in the amount of satellite networks, the probability of interference occurrence is increasing if coordination, network qualification and activation are not properly executed. Satellite operators are facing different types of interference threat every day and the interference can be classified into five main categories:

1. Uplink or Downlink ASI
2. Intentional jammer
3. Unauthorized transmission
4. Human error (Ground antenna mis-pointing, Wrong frequency, polarization, power, bandwidth or transmission time)
5. Equipment problem (Noise pickup, Oscillator drift or spurious)

Depending on the root cause of each type of interference, some suggested mitigation methods are summarized in the table below:

Interference	Possible Root Cause	Mitigation
1. Uplink or Downlink ASI	• Non-compliance antenna pattern • Non-compliance to coordination transmission limit • Antenna mis-pointing	• Network design and commissioning qualification • Coordination between satellite operator • Operation Training • Carrier ID • Geolocation
2. Intentional jammer	• Illegal attack to real time traffic	• Geolocation
3. Unauthorized transmission	• Illegal usage on satellite capacity	• Carrier ID • Geolocation
4. Human error	• Lack of operation training • Insufficient supervision • Improper communication	• Operation Training • Carrier ID • Geolocation
5. Equipment problem	• Insufficient equipment monitoring and maintenance	• Network design and commissioning qualification • Carrier ID • Geolocation

Geolocation is applicable in the mitigation method to all the main interference types.

Geolocation Approach

Dual Satellite Geolocation (DSG)

A conventional geolocation approach is the so-called Dual Satellite Geolocation (DSG). It uses the technique of time difference of arrival (TDOA) and frequency difference of arrival (FDOA) multilateration described in [2]. When an uplink antenna (Interference Source) transmits a signal to a satellite (Primary Satellite), this uplink antenna is also transmitting a copy of the signal in a lower power level to a nearby satellite (Secondary Satellite). The power level of the signal copy towards the Secondary Satellite depends on the uplink antenna size. The larger antenna size has smaller antenna beamwidth, and hence its off axis gain towards the nearby satellite will be smaller. The smaller antenna size will be vice versa.

Due to the difference in the signal propagation path of the two satellite links, the downlink antenna systems of the primary and secondary satellite observe a different time delay for the signals received. The resulting differential time offset (DTO) gives partial location information of the interference source. (Green line in Figure 2)

In real situation, the two satellites are moving with respect to the ground station and each other. Therefore, the downlink antenna systems see a different Doppler shift in the frequency of the signals received. The resulting differential frequency offset (DFO) provides additional location information. (Red line in Figure 2)

Based on the position data of the two satellites, i.e. the ephemeris data, together with the DTO and DFO information, a line of position (LOP) can be computed and defined. By taking measurements of DTO or DFO at different times, additional LOPs can be retrieved. Finally, the intersect point of the two LOPs indicates the estimated location of the uplink interfering station.

AsiaSat published a paper in year 2012 to present the application of DSG system, satID, to detect sweeping interference with the support from SAT Corporation [4]. The geolocation principle of satID is shown in Figure 2.

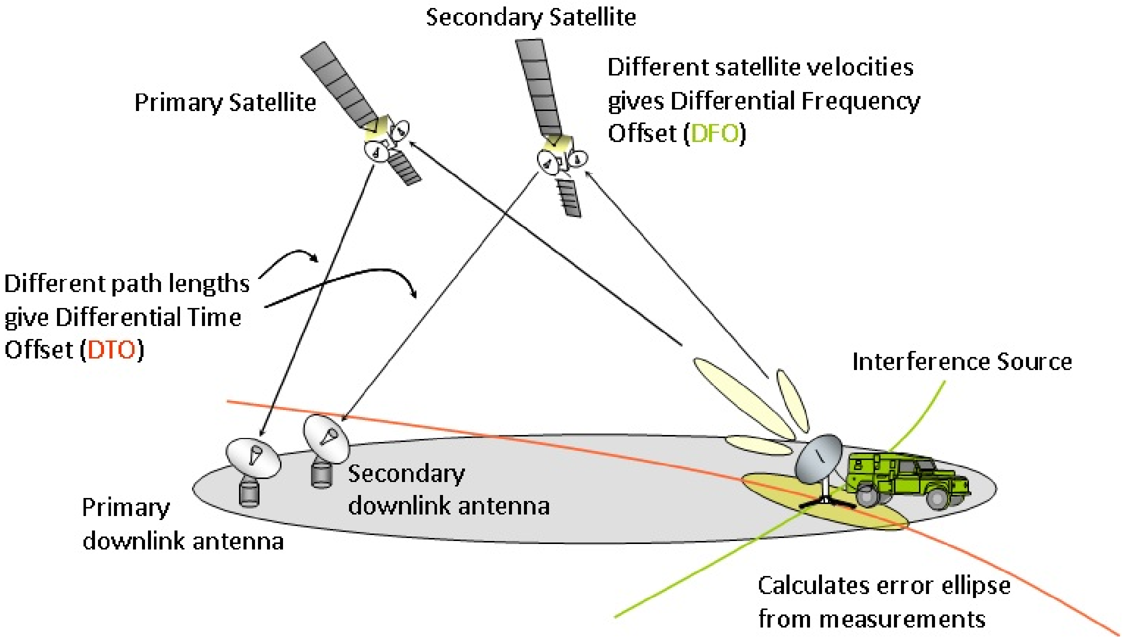

Figure 2 Geolocation Principle of satID

Single Satellite Geolocation (SSG)

Another approach is the Single Satellite Geolocation (SSG) method. The main advantage of this method is that only one satellite is required for the geolocation. Hence, it has less limitation on the geolocation application because it does not require two satellites to provide parameters for interference source calculation. One existing implementation available in the market is applying the concepts from quantum information theory for the algorithm process to find the best matching carrier to detect the interference source location. Another possible way is to track the interference for longer periods, e.g. over 24-hour cycle, for collecting more measurement samples in the correlation calculation assuming accurate ephemeris information is available. In Q1 2016, Siemens Convergence Creators announced that they would start the implementation of their single satellite geolocation solution (SIECAMS ILS ONE) to Eutelsat [3].

Geolocation Considerations

Geolocation is widely used in the industry for interference mitigation. In order to effectively facilitate the capability of this solution, the considerations below have to be studied thoroughly.

1. Measurement uncertainty

Result accuracy of geolocation is the most important parameter to be evaluated for reliability justification. It is well known that the accuracy of geolocation depends mainly on the Ephemeris error and achievable processing gain of the carrier signal to noise ratio. The ephemeris will be heavily depending on the ranging data collected from the operator. In general, operator requires 2 to 3 days of ranging data to determine the satellite drift and position information. Also, when the satellite itself is equipped with electric propulsion system for maneuver control, the actual ephemeris will be continuously changing during the thruster firing period. Depending on the type of electric propulsion, the firing duration for each maneuver can last from one to six hours for twice a day. At this specific occasion, the actual ephemeris would not be available for geolocation. Conventional chemical propulsion duration is comparatively much shorter than that of the electrical propulsion. However, it does not mean that the satellite with electric propulsion is not suitable for geolocation. The only consequence is the measurement accuracy on the geolocation during the electric thruster firing period. The processing gain of the correlation Signal-to-Noise Ratio (SNR) depends on the interference SNR on the primary and secondary satellite. The SNR on the secondary satellite depends on the receive G/T of the interference location at the secondary satellite coverage and also its uplink antenna size.

2. Compatible adjacent satellite

For having the signal copy from a secondary satellite to perform correlation calculation, an adjacent satellite that receives and retransmits interference uplink in the same polarization and geographic area as the interference is required. However, this condition may not be always met in the real situation. For example, a satellite with multi-spot beams coverage in Ka-band may not be able to find an adjacent satellite with overlapping geographic beam coverage in the same frequency band. Without a compatible adjacent satellite, DSG detection is not possible.

3. Reference sites

To correct the ephemeris error and the geolocation system measurement uncertainty, the typical method is applying reference sites information to calibrate the results. It should be noted that this information may not be available at the time of geolocation. It is because the other customer uplink locations (i.e. potential reference sites) on the same polarization as the interference may not be within the secondary satellite coverage. Also, the reference site carrier towards the secondary satellite may not have enough SNR for a good correlation calculation.

When good reference sites information is not available, operator would need to set up on their own. All they need to do is to setup a carrier uplink at a location which can provide transmission towards the primary satellite as well as radiating to the secondary satellite by its side lobe at the same time in order to provide useful information to the geolocation calibration. The more information available will be more favorable to the calculation. Since time is required to set up ground reference, the interference may have gone at the time for geolocation measurement. A systematic database for searching customer uplink information is essential to help the reference sites information support.

4. Latest and accurate ephemeris data

Usually, the secondary satellite available for DSG is not owned by the primary satellite (i.e. the one suffering from interference) operator. Hence, getting the latest detailed ephemeris data of the secondary satellite may be difficult. In most cases, we can only rely on the public two line element (TLE) data as the geolocation result input. This information is limited and sometimes being out-of-date. If accurate ephemeris data is available, it will be beneficial to the correlation calculation.

Considering on AsiaSat fleet, AsiaSat 5 (100.5degE) and AsiaSat 7 (105.5degE) have an orbital separation of 5 deg. These two satellites are acting as a good secondary satellite to each other for geolocation in both C and Ku-band. Similarly, AsiaSat 4 (122degE) and AsiaSat 6 (120degE) have an orbital separation of 2 deg which is also an optimum adjacent satellite pair for geolocation in C-band. Taking this advantage in the orbital slots, AsiaSat can manage its own internal resources for more accurate and quicker geolocation application and does not require other operators' satellite information.

5. SSG application

With the new and innovative technology available, geolocation may not be solely depending on the conventional DSG method. Some products by using single satellite geolocation have been available in the market for operator to implement. To provide better understanding to the satellite community, it is the best for those solution providers for more demonstration on the product's capability. Therefore, when DSG is not possible, the satellite operator can have an alternative solution to tackle interference. If the achievable accuracy of SSG can be enhanced as the level of DSG, satellite operator can have an alternative and a more cost effective solution.

Conclusion

As interference mitigation is critical to maintain high service quality and protect our customers' networks, AsiaSat is willing to be **partnering** and contributing to the advanced technology of geolocation in the industry. We are also **committed** to providing interference free environment and **ever better** service to all customers and affiliates. Although satellite interference cannot be predicted, we believe its occurrence can be reduced by the joint efforts of the satellite industry community. Let's continue to work together!

Reference

1. AGI online application for viewing real-time satellites. Analytic Graphics Inc. Retrieved from http://apps.agi.com/SatelliteViewer/

2. P. C. Chestnut, "Emitter Location Accuracy Using TDOA and Differential Doppler," IEEE Trans. Aerosp. Electron Syst., vol. AES18, no. 2, pp. 214-218, Mar. 1982.

3. Press release, "Eutelsat to Implement SIECAMS® ILS ONE for Advanced and Simple Geolocation". Siemens Convergence Creators GmbH. Retrieved from http://www.convergence-creators.siemens.com/eutelsat-siecams-ils-one-satellite-geolocation.html/

4. Application of a Dual Satellite Geolocation System on Locating Sweeping Interference, http://www.asiasat.com/sites/default/files/Application-of-a-Dual-Satellite-Geolocation-System-on-Locating-Sweeping-Interference.pdf