CGMS-XXVIII
USA-WP-18
Agenda Item: I.2

STATUS OF INTERFERENCE LOCATION SYSTEM

Summary and Purpose of Document

To provide an update on the installation and operation of an interference monitoring system capable locating and identifying transmitter within the GOES footprint.

Action Requested: None

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Prepared by USA
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INTRODUCTION

NOAA/NESDIS is pleased to provide an update on its efforts to develop and install a Transmitter Location System, (TLS) for use with the GOES Data Collection Service (DCS). The TLS is designed to geographically localize sources of interference to commercial geosynchronous communications satellites. It is commonly used at C-band and Ku-band to locate signals with modulation bandwidths ranging from CW to over 1 MHz, but can be applied to other communications bands, including the UHF/S-band system used with the DCS.

The proposed installation and operations activities consist of three Phases. The objectives of the three phases are to:

- Explore the potential to adapt the TLS system to the GOES/DCS communications network and define the system hardware and software modifications needed to accomplish this adaptation;
- Implement the necessary hardware and software modifications and perform a proof of concept demonstration on the GOES DCS system; and
- Construct and deliver to NOAA/NESDIS a TLS system modified for use with the GOES DCS.

As defined, each phase would be initiated separately, with the decision to proceed with subsequent phases contingent upon satisfactory results from the preceding phase(s). This approach would provide the most cost effective means to evaluate the ability of the TLS to successfully resolve interference within the DCS network prior to committing to a major system investment.

Background

In the late-1990's NOAA/NESDIS anticipated the needs of the GOES Data Collections community to resolve incidents of interference to satellite transmissions. There have been several improvements by NESDIS to effectively monitor sources of interference but none have lead to the identification and removal of those sources. By investigating new principles of interference monitoring, NOAA found a method to passively and very accurately locate sources of interference affecting the geostationary satellites. Two methods emerged that assist NOAA in this area: the Transmitter Location System, a method locating an unknown transmitter and Phase Calibration, a method for locating unknown transmitters using calibrated oscillator phases. Together, these technologies provide system users with a capability to locate interference sources that is unmatched by any other method.

The TLS uses interferometric techniques to determine the location of a signal that is being carried over a satellite transponder. This method is totally passive and requires only that the TLS downlink site be in the transponder "footprint" of both the interfered satellite and an adjacent satellite that has a transponder closely matching the characteristics of the interfered transponder. For the DCS, GOES East will serve as the adjacent satellite for Goes West, and *vice versa*. Alternative candidates for adjacent satellites include older GOES satellites whose DCS transponders are still active.

The TLS determines the transmitter's location by observing the difference in arrival times and the difference in frequency caused by transmission of the interfering signal through these two satellites. By combining the measured time difference of arrival (TDOA) and frequency difference of arrival (FDOA) with accurate satellite orbit information, the TLS is able to report position accuracy as good as a few kilometers.

Typically, the limiting factor to the accuracy of the geolocation solution is the uncertainty in the satellite ephemeris for both the primary and adjacent satellites. The TLS system minimizes the effects of inadequate knowledge of the satellite ephemerides by utilizing existing signals on either satellite as position calibrators to largely remove satellite ephemeris errors from the resulting geolocation.

Once the TLS has acquired and processed the needed data, the results of the geolocation measurement are provided as a position ellipse depicting the calculated location of the interference source. This information is presented in graphical form as a map overlay of the position ellipse showing the nominal coordinates of the measured location.

Phase I: Site Performance and System Definition

Adapting the TLS to the GOES DCS application presents a number of technical challenges that will impact both the ability of the system to acquire the needed measurements and resulting accuracy of the derived geolocation. For this reason, NOAA proposes that the effort begin with a detailed study of these issues to develop the optimum system configuration and operating strategy.

The GOES DCS differs from the typical TLS application in that the signals are much narrower bandwidth and the frequency bands used (particularly the UHF uplink) are much lower. In addition to the obvious impact on the system RF processing hardware, this difference also potentially impacts the accuracy with which the TLS can determine the geolocation of the interference. The very narrow bandwidth of the DCS signals (1-3 kHz) degrades the precision of the TDOA measurement as compared to the signals normally measured with the TLS. Further, the comparatively low uplink/downlink frequencies (UHF/S-band *vs.* C-band or Ku-band) results in a much smaller Doppler shift for a given differential velocity of the satellites, thus degrading the precision of the FDOA component of the geolocation solution.

Offsetting these two factors is the fact that the characteristics of the uplink antennas employed allows the use of two widely spaced satellites, GOES East and GOES West, as the primary and adjacent satellites for the TDOA/FDOA measurements. This large satellite spacing yields a much greater change in TDOA as a function of uplink transmitter location. Thus it is likely that the geolocation uncertainty due to TDOA measurement uncertainty will be on the same order as with the current C-band and Ku-band operations.

With respect to the FDOA measurements, the potentially greater differential velocities between these satellites may partially, or even fully, compensate for the loss of resolution due to the lower uplink frequency. Another useful technique would be to use other existing satellites whose DCS transponders are still active as the adjacent satellite. Because the station keeping for those satellites is likely to be less precise, they would have larger differential velocities (and produce larger Doppler shifts), thereby further improving the precision of the geolocation.

In the Phase 1 effort we plan to perform system simulations and analyses to establish the expected performance of the TLS with the DCS signals, and to determine the optimum measurement and data analysis strategies to use with the DCS. Phase 1 will consist of the following tasks.

Task 1.1: Satellite On-Board Systems Analysis. A critical component affecting the ability of the TLS to produce meaningful measurements is the performance of the turnaround oscillators on board the respective spacecraft. In this Task we plan to analyze data and other information to verify that the performance of the on-board transponders is adequate to produce useful TDOA/FDOA data.

Task 1.2: Evaluation of Alternative Adjacent Satellites. In this Task we plan to assess the availability of satellites other than GOES East and GOES West for use as additional/alternative adjacent satellites. We will perform system simulations to determine the extent to which such alternate adjacent satellites can improve the quality of the geolocation result.

Task 1.3: Satellite Orbital Parameters Analysis. In this Task we plan to perform orbital analyses based on historical data and satellite station keeping strategies to determine the typical geolocation precision that can be achieved with an operational TLS system.

Task 1.4: Assessment of Phase Calibrator and Position Calibrator Candidate Signals. The TLS utilizes existing signals within the satellite transponder to compensate for satellite on-board oscillator phase noise and imperfect satellite ephemeris data. In this Task we plan to evaluate the characteristics of existing DCS traffic to establish the optimum strategy for selecting and processing calibrator signals.

Task 1.5: Design Modifications Necessary for an Operational TLS System for GOES DCS**.** This Task involves the definition of the hardware and software modifications necessary to adapt the current TLS for use with the GOES DCS network. One particularly promising approach we plan to explore is to acquire and cross-correlate the full DCS transponder and to isolate the phase/position calibrator signals and the unknown signal by post-processing the correlated data using Fourier transform techniques.

This Task will lay the groundwork for the Phase 2 Proof of Concept Demonstration.

Task 1.6: Technical Report of Phase 1 Results. The deliverable product from the Phase 1 effort will be a detailed technical report that provides the results of the system studies and analysis together with a design document for the system modifications necessary to implement a transmitter location system for the GOES DCS network.

Phase 2: Proof of Concept Demonstration

The Phase 2 effort will consist of procuring the necessary hardware and implementing the software modifications needed to conduct a proof of concept demonstration of the TLS system using live signals from the GOES satellites. The proof of concept will be performed using existing TLS equipment adapted as required to perform the measurements on GOES DCS signals.

Phase 2 can proceed immediately upon completion of Phase1 after authorization to proceed is determined. The Phase 2 effort will consist of the following tasks.

Task 2.1: Hardware Modifications. This Task will involve the procurement and installation of the RF front-end hardware needed to adapt the TLS system for measurements at S-band.

Task 2.2: Software Development. The TLS data acquisition and data processing software will be modified as required to collect and process the satellite downlink signals from the GOES satellites.

Task 2.3: Proof of Concept Demonstration. Once the hardware and software changes have been implemented, we plan to utilize an existing TLS system to perform a series of proof of concept measurements using GOES DCS signals. Depending on the availability of appropriate signal feeds and other facilities, this demonstration may be performed either remotely or at the NESDIS CDA station at Wallops Island, VA. The demonstration will involve the geolocation of existing signals on the GOES DCS. The demonstration will focus on determining the geolocation of signals uplinked from known locations to allow geolocation accuracy to be unambiguously established.

Task 2.4: Detailed Design of a TLS System for the GOES DCS Network. Based on the results obtained from the proof of concept measurements, a detailed design for implementation of a TLS system adapted for use with the GOES DCS will be produced. This design will include specific enhancements and modifications needed to implement an operational system together with a timeline and detailed budget for constructing and delivering an operational system to NOAA/NESDIS.

Task 2.5: Technical Report of Phase 2 Results. A detailed technical report that provides the actual geolocation results for a series of signals accessing the GOES satellites will be generated. The report will also include the detailed design information developed in Task 2.4.

Phase 3: Construction and Delivery of a TLS for GOES DCS

Phase 3 will involve the actual construction and delivery of a TLS for use with the GOES DCS network. Because of the substantial differences between the GOES DCS network and the current applications of other TLS models, we anticipate that this Task will involve significant changes to the data processing and analysis software. The system construction will consist of two main tasks: hardware construction and software development.

Task 3.1: Hardware Construction. The construction of the TLS for use with the GOES DCS will draw upon the system studies and design developed in Phase 1 and validated in Phase 2. The hardware configuration will largely be identical to other TLS models, with some modification to adapt the current design to the GOES DCS. The areas in which the design will be modified are primarily the RF front end hardware, which will be configured for operation at S-band, as well as any special design considerations based on the specifics of the installation site, presumed to be the Wallops Island CDA site.

Task 3.2: Software Development. The existing TLS software will require some modifications for use with the GOES DCS. The narrowest processing bandwidth of the current TLS hardware is 62.5 kHz. This means that each measurement will include components contributed by each of the DCS channels containing active transmissions during the integration period. The most straightforward way to isolate the signal of interest from these extraneous signals is by software post-processing of the correlated data using Fourier transform methods. Some rudimentary aspects of this software will be developed as part of the Phase 2 effort. However, the development of a fully functional automated processing system to perform this signal isolation will be a major activity of the Phase 3 effort. The software development effort will proceed in parallel with the hardware procurement and system construction.

CONCLUSION

NESDIS continues to investigate the transmitter location system and evaluate the benefits tit has on the DCS service and possibly the GOES system. A preliminary visit to the Wallops CDA station were performed to make initial considerations for satellite parameters and operational procedures of the GOES RF system. NESDIS plans to proceed with the Phase1 activities as budget considerations permit.