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Angular Position Determination Of Satellites Using Vlbi And Δ-Dor Methodology

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Abstract:
The name, Differential One-way Ranging (Δ-DOR), comes from the fact that only a range difference, rather than an absolute range, is determined and that only the downlink is used. For a spacecraft, the one-way range is determined for a single station by extracting the phases of two or more signals emitted by the spacecraft. The DOR tones are generated by modulating a sine wave or square onto the downlink carrier at S-band, X-band, or Ka band. DOR observables are formed by subtracting the one-way range measurements generated at the two stations. The station differencing eliminates the effect of the spacecraft clock offset, but DOR measurements are biased by ground station clock offsets, instrumental delays and media effects.

Key words: *VLBI, Δ-DOR, DDC.*

1.Introduction

Very Long Baseline Interferometry (VLBI) is a technique that allows determination of angular position for distant radio sources by measuring the geometric time delay between received radio signals at two geographically separated stations. The observed time delay is a function of the known baseline vector joining the two radio antennas and the direction to the radio source.

An application of VLBI is spacecraft navigation in space missions where delay measurements of a spacecraft radio signal are compared against similar delay measurements of angularly nearby quasar radio signals. In the case where the spacecraft measurements are obtained from the phases of tones emitted from the spacecraft, first detected separately at each station, and then differenced, this application of VLBI is known as Delta Differential One-Way Ranging ('Delta-DOR' or 'ΔDOR')

2.Related Work

Gabor Lanyi et.al.,[1] gives an introduction to the concept of Angular position determination of spacecraft by radio interferometry. This paper describes a variety of interferometric techniques that are used to determine the angular position. This paper describes the techniques such as ΔDOR, VLBI, VLBA, Earth rotation synthesis. Our interest lies in usage of VLBI technique for ΔDOR measurements. This paper gives an overall principle of VLBI used for ΔDOR. Here it considers a quasar, whose position is well known and is close to the space craft, as reference source and determines the angular position of the spacecraft with respect to that of the quasar.

RobertoMadde et.al.,[2] the receiver architecture for ΔDOR support is well described in this research paper, the generation of intermediate frequency signals and modem system are described in this paper. We get the information about the algorithm used for signal processing of the received signal from the spacecraft and a nearby star. It also tabulates the experimental results obtained. This paper describes the modifications implemented in the ESA standard receiver, the Intermediate Frequency and Modem System (IFMS) for obtaining the required goals

Tsutomu Ichikawa [3] describes two way ranging to orbit determination. The accuracy of the spacecraft orbit solution obtained with X-band Doppler and precision ranging were found to be consistent with simple theoretical calculations, which predicted that angular accuracies of a few μrad were achievable.

CCSDS [4], gives the concepts for implementation of delta-differential one way ranging design techniques and overall processing of the received signal from the spacecraft. The techniques used for DELTA-DOR is well described in this document. The review chapters provide the information for implementation. It also discusses the application of Δ-DOR and gives the comparative results of Doppler and one way ranging methods with respect to ΔDOR.

Tjerkbijlsma et.al.,[5] gives the overview of the digital down conversion concept and the architecture used to implement i.e. how to lower the amount of samples per second by selecting a limited frequency band. Itdiscusses two simple algorithm of CIC filters and fir that is controlled by numeric controlled oscillator. The DDC processes the samples from the AD-converter in such a way that it selects a small band of the total frequency range. After selecting the desired frequency band the signal is processed by a concatenation of filters. By attenuating the unwanted frequencies the signal can be resampled at a lower rate. The reduced sample rate relaxes the processing after the DDC. Depending on the selected frequency range, sample rate, and desired quality, different filter combinations can be used to perform the DDC.

Song et.al.,[6] describes the methods for designing circuits for DDC using modern digital processing. Much of the signal processing performed in modern wireless communications systems takes place in the digital domain, which greatly increases processing demands of modern digital modulator/demodulator applications.

3.Block Diagram

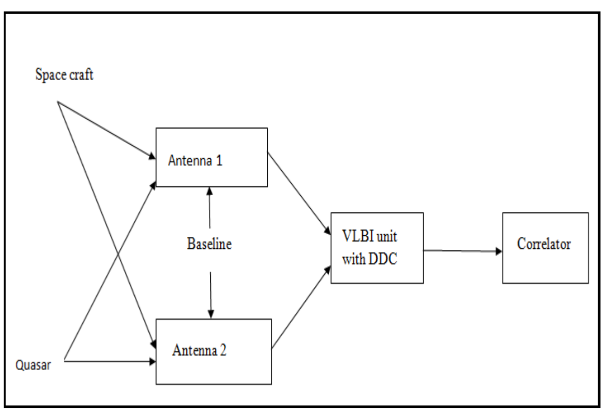

Figure 1: block diagram

The above schematic shows the block diagram this consists of spacecraft, quasar, and antenna 1&2, VLBI signal processing units and correlator.

- Spacecraft: it is a deep space mission which will be located 250 to 400 million kilometers from earth and whose angular position must be estimated.
- Quasar: it is a star or any naturally radiating object that is closely located to the spacecraft; its angular separation with respect to the spacecraft should be less than 10˚.
- Antenna 1&2: these are the receiver stations located on earth for reception of signals from the spacecraft. The two antennas must be located at a distance of greater than or equal to 10,000 kilometers apart, this is known as baseline.
- VLBI signal processing units and correlator: this is a major part where the signal processing operations are performed, it consists of DDC, filters etc. the correlator is one which correlates the signals received from both the stations and determines the differential delays.

2.Algorithm

- Phase modulation at space craft.
- Sending phase modulated tones.
- Receiving the DOR tones.
- Performing DDC.
- Filtering.
- Phase correlation of received tones.

$\tau = B * \cos\theta / C$

Using the above formula we can determine the angular position of a space craft, where τ is the phase difference between the two received DOR tones.

B is the length of the base line vector separating the two ground stations.

θ is the angular position of the spacecraft.

C is velocity of light.

3.Results

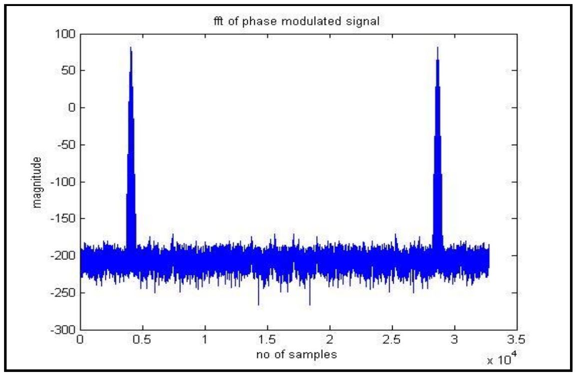

Figure 2: phase modulated wave

The above shown figure.2 is the phase modulated DOR tones generated at satellite and it is sent in the down link.

These tones are down converted by passing through the filter with frequency response shown below in fig.3

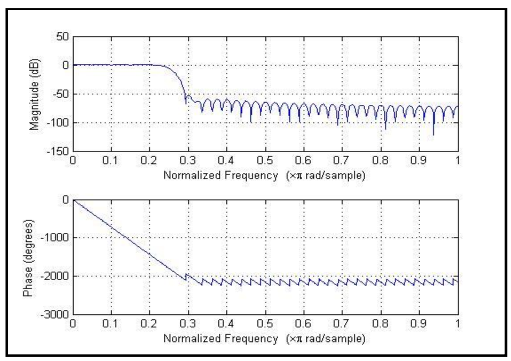

Figure 3: filter response

The below shown figure 4 is the final down converted and decimated signal i.e output of DDC.

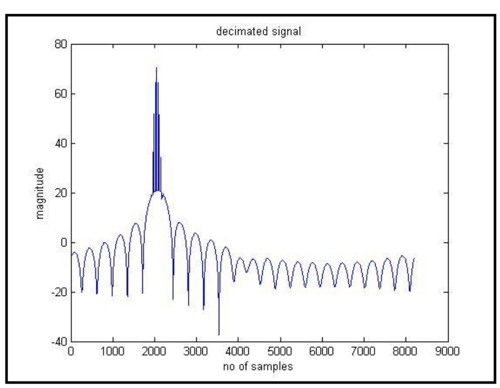

Figure 4: decimated signal

This decimated signal is given to a demodulator to obtain the original signal which is shown below this signal is passed to a correlator which gives differential delay which in turn gives the angular position of the satellite.

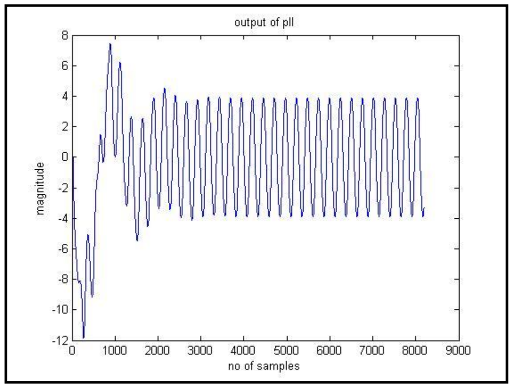

Figure 5: demodulated signal

4.Reference

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