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Calibration of SeaWinds on ADEOS-II via the QuikSCAT Calibration Ground Station

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Introduction

A scatterometer is essentially an orbiting radar aimed at the Earth's surface. It can be used to study weather patterns, track icebergs, observe polar sea ice, detect climatic changes, and estimate environmental factors such as vegetation and soil moisture. Correct calibration of the scatterometer is essential in order to yield accurate measurements of these data.

The QuikSCAT Calibration Ground Station (CGS) was developed by NASA Jet Propulsion Laboratory (JPL) to calibrate scatterometers which transmit a series of short, high-frequency electromagnetic pulses. The station (Figure 1) receives these transmitted pulses and digitally samples them for post processing. The BYU Microwave Earth Remote Sensing (MERS) Laboratory acquired the CGS in order to independently observe transmissions from the new SeaWinds scatterometer on the Advanced Earth Observation Satellite II (ADEOS-II), launched in December 2002. The satellite passes over Provo twice daily, allowing regular observation of the SeaWinds transmissions.

Figure 1: Receiver of the QuikSCAT Calibration Ground Station at BYU. Tubes pump cool air into the radome and protect sensitive cables connected to computers below.

Parameter Estimation Methods

The SeaWinds scatterometer transmits a 13.4-GHz linear FM downchirp in short 1.5-ms pulses. Basically, this means that if the signal could be heard by the human ear, each pulse would sound like a very short tone that decreases in pitch over time. Many signal parameters need to be measured in order to calibrate the SeaWinds instrument. These include frequency, chirp rate, pulse duration, pulse repetition interval, signal power, and the Doppler effect. Several methods exist to estimate these signal parameters.

Linear Regression on Unwrapped Phase

Linear regression on unwrapped signal phase is a well-known method to estimate signal parameters. First, the signal phase is unwrapped so that a second-order polynomial may be fit to it. This least-squares approximation to the unwrapped phase allows estimation [1] of the chirp rate, frequency, and phase of the signal. However, the drawback to this technique is the requirement of high signal-to-noise ratio (SNR). In other words, if the signal is weak or hard to detect, the phase unwrapping method becomes impossible to perform since noise destroys the ability to correctly unwrap the phase of the signal, just like noise in a radio transmission makes it harder for the listener to decipher a broadcast.

Phase Estimation by Zero-Crossings

The zero-crossings of a sinusoidal signal allow estimation of the unwrapped phase at discrete intervals of ð radians. Since the cosine function contains zero-crossings at odd multiples of ð/2, it is imperative to distinguish between the zero-crossing at ð/2 and that at 3ð/2 in order to avoid phase errors of ð radians. This distinction is easily made by noticing that the ð/2 zero-crossing has a negative slope while that at 3ð/2 has a positive slope. The zero-crossings of the waveform may be found between samples of opposite sign by linearly interpolating between them on the linear portion of the cosine function.

Wigner Distribution

The Wigner Distribution maps a signal to the time-frequency plane, creating a plot of the signal frequency over time [2]. In the case of SeaWinds, the Wigner Distribution displays a fairly straight sloped line, indicating an established chirp. This mapping is very useful for chirp detection and may be used to estimate the chirp rate by approximating the slope of the line in the time-frequency plane. This may be accomplished by integrating along all lines in the time-frequency plane and determining which integration yields the maximum value, revealing the chirp rate.

Results

Multipath effects from buildings and the Wasatch Mountains have not presented a significant factor in the received signal; Y Mountain has the highest elevation angle (19.5° with respect to the CGS) but does not block SeaWinds from illuminating the CGS receiver.

On January 27, 2003, the SeaWinds instrument passed over the Provo area for the first time as an operational instrument. Initial results were quite promising. The frequency rate, using zero-crossing analysis, was measured to be 250.743 kHz/ms for that particular pass. Since then, two flybys of the SeaWinds instrument have been archived daily for post processing and burned to CD-R for backup.

When enough data is collected, it will be analyzed and compared to the data of a previous SeaWinds scatterometer. Overall, this project has allowed me to gain valuable experience in maintaining a sophisticated receiving station and developing processing routines in MATLAB.

References

[1] Djuriæ, P. M. and Kay, S. M., “Parameter estimation of chirp signals,” *IEEE Transactions on Acoustics, Speech, and Signal Processing,* vol. 38, no. 12, pp. 2118-2126, Dec. 1990.

[2] Akay, O. and Boudreaux-Bartels, G. F., “Fractional convolution and correlation via operator methods and an application to detection of linear FM signals,” *IEEE Transactions on Signal Processing*, vol. 49, no. 5, pp. 979-993, May 2001.