Design and Realization of DMR Based on GPS for Sea Surface Wind Measurement

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Outline

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Introduction

- Signals of Global Positioning System (GPS) can be used for purposes other than navigation and positioning.

- The utility of scattered GPS signals from rough surfaces brings a new technology for microwave remote sensing.

- The concept is to use GPS in a bistatic radar configuration with the GPS satellite transmitting an L-Band spread spectrum signal, and the receiver on an aircraft or spacecraft platform measuring the reflected signal.
Main Applications

- Ocean Altimetry
- Ocean Surface Wind Retrieval
- Sea Ice Remote Sensing
- Earth Moisture Remote Sensing
- Passive Target Detection
- Terrain Imaging
Geometry of GPS scattered signal

- GPS sat.
- RHCP
- LHCP
- Specular point
- Glistening zone
- Annulus
- Direct signal
- Scattered signal

\[ \tau = n \cdot \tau_c \]

\[ \tau = 0 \]

Correlation power

- Code delay
- Direct signal
- Calm sea
- Ideal wave
- Rough sea

Code Delay -> Path Difference -> **Altimetry**

Wave Characters -> **Wind Vector or Other Info**
Measure Technique

- Direct Transmitting GPS Signal is RHCP (Right-Hand Circularly-Polarization)
- Scattered signal is LHCP (Left-Hand Circularly-Polarization) due to phase shift at reflection
- Correlation is expressed as the integral:

\[ Y(\tau, \tau_0, t) = \int_{0}^{T_i} a(t + \tau_0 - \tau) \cdot u(t + \tau_0) dt \]

Here \( a(t) \) is the locally generated C/A code, \( u(t) \) is the received signal, \( \tau_0 \) is specular point delay, \( \tau \) is delay between \([\tau_0 - M, \tau_0 + 32-M]\) at half code chip, \( T_i \) is integration time,
Delay Mapping Receiver Design

GPS Navigation Solution

Specular point delay of 6 satellites

Local PRN Stepping Control

RHCP Antenna

RF Front

CHAN 1 SAT A

CHAN 2 SAT B

CHAN 6 SAT F

CHAN 7 SAT A

CHAN 8 SAT B

CHAN 12 SAT F

LHCP Antenna

I Q

mul

square add

smooth

Output

smooth

smooth

smooth

I Q

integral
Delay Mapping Receiver

- 12 parallel channels
- Channel 1-6 connected to RHCP antenna to receive direct signal from GPS satellite, working in close loop for code tracking, and positioning calculation.
- Use $2\sin(\theta)$ to calculate the path delay of the specular points relative to the direct signals for each satellite.
- Channel 7-12 connected to LHCP antenna to receive scattered signal, working in open loop mode.
- Channel 7-12 is configured to the code phase and carrier frequency calculated from direct channels.
- Local replica is then moved between $[\tau_0 - M, \tau_0 + 32 - M]$ to record the cross-correlation power stepped by half chip bins.
- At each step, the signal is integrated for one millisecond, measurements are filtered and output at 1Hz.
Data Collection

• 9 Test flights were done at TianJin, QingDao, DaLian with the DMR mounted on YUN-12 airplane.
• RHCP antenna is mounted on the top of the airplane to receive the direct signal from GPS satellite
• LHCP antenna at the bottom of the airplane, facing downward to sea surface to receive scattered signals.
Data Collection

YUN-12 Airplane For Test

LHCP Antenna

RHCP Antenna

Equipped DMR

Laptop & Software
Direct & Scattered Signal

direct and scattered cross-correlation power of satellite NO.22

During Taking Off & Landing, Test Window Closed, LHCP antenna was Shielded
Example of Output Data

Flight Date: Aug.3 2004
SV: NO.5
Cross-correlation of 32 half code Delay was Measured

Signal of LHCP Antenna

Flight Time: Aug.03.2004
Flight Height: About 1000m
SNR: >15dB

Cross-correlation of 32 half code Delay was Measured
Example of Sep.9.2004

Wind Speed Contour
(From scatterometer)

Flight Path

Ocean Reflected Wave Form
(Measured)

Flight Height: ~3000m
Flight Date: Sep.9.2004
Mean Wind Speed: ~7.2m/s
Reflection Waveform of 3 Flights

Wind From Scattermeter (Mean of 1 hour)

13:00 Sep.10.2004 >6m/s
13:00 Aug.03.2004 ~2m/s
11:00 Sep.18.2004 <1m/s

Wind Retrieval

Sea surface wind vector can be obtained by comparing the analyzed model and measured data
Conclusion

- Ocean Scattered GPS Signal was Successfully Detected
- Cross-Correlation Expansion Was Demonstrated
- Wind Information can be get from the wave characteristics
Thanks for your attention!