Prototype Software-based Receiver for Remote Sensing using Reflected GPS Signals
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GPS Signal Characteristic
• GPS signal is RHCP (Right Hand Circular Polarization) type
• The polarization of GPS signal may change when reflected from RHCP to LHCP and vice versa
  – Based on reflecting material type and signal incidence angle
• The amplitude reduces for every reflection, because:
  – The reflection coefficient is less than one
  – Some of the signal is absorbed
  – Reflection may not be perfectly specular
  – The phase of the signal changes that might be neither RHCP nor LHCP (elliptical polarization)
• The chip delay increases for every reflection
  – Since it needs to travel extra distance
• Thus, the analysis of relative amplitude between the direct signal and reflected signal provides information about reflecting material type
• The chip delay corresponds to the path delay length or multipath amount

Remote Sensing Capability using GPS/GNSS Signal
• GPS / GNSS signals around 1.5Ghz is good for soil moisture analysis
  – The dielectric value difference is about 10 times between dry soil and wet soil
  – This value is about 30times more for water than dry soil
• Beside soil moisture, there are many other applications where GPS signals can be used for remote sensing applications
  – Wind velocity over ocean, ocean observation, ice monitoring etc
• An active radar can be tracked or detected while it’s observing, but not the passive one like GPS because it does not transmit any signal for observation
  – The signals are continuously transmitted only for navigation purpose
  – You can observe the things without being detected
  – Important aspect in military applications

Reflection Coefficient of materials for Horizontal and Vertical Polarization

Change in Phase Angle for Horizontal and Vertical Polarization
System Architecture

Data Observation, Rooftop of University Bldg
- Data observation height: about 20m
- Antenna Used: LPA Passive
- Data logged on different days

Data Observation, Tower
- Data Obs. Ht: 87m
- Antenna Used: LPA Passive
- Data logged for a single day only

Power Spectrum and Histogram of Raw Data

Algorithm, Signal Processing

Basic Concept
Results, Tower Data

- PRN ID: 30
- Antenna Orientation:
  - RHCP: Up
  - LHCP: Down
- Antenna Height: 87mtr.

Results, Tower Data

- PRN ID: 1
- Antenna Orientation:
  - RHCP: Up
  - LHCP: Down
- Antenna Height: 87mtr.

Results, Tower Data

- PRN ID: 25
- Antenna Orientation:
  - RHCP: Up
  - LHCP: Down
- Antenna Height: 87mtr.

Antenna Height Estimation

Extra Path Delay:
\[ \delta R = \frac{2h}{\sin(\theta)} \]
\[ h = \frac{\delta R}{2 \sin(\theta)} \]

- Multipath Model
  - Forward Scattering as shown above
- The extra path delay is about 0.5 chip delay which is about 150m
- The antenna elevation angle is about 55 degrees from the nadir
- Thus, height of the antenna, \( h = \frac{150}{2 \sin(55\pi/180)} \approx 92m \)
  - This is in very close proximity of actual antenna height from the ground

Results, Roof Data

- PRN ID: 14
- Antenna Orientation:
  - RHCP: Up
  - LHCP: Down
- Antenna Height: 20mtr.
Results, Roof Data

- PRN ID: 6
- Antenna Orientation
  - RHCP – UP
  - LHCP – Down
- Antenna Height – 20mtr.

Summary

- LHCP Antenna Orientation and Gain Pattern
  - The orientation of the antenna with respect to the satellite geometry (azimuth and elevation) has an effect on power level.
  - Hence, the total power computation shall be done by considering the satellite geometry and antenna orientation considering the gain pattern.
  - The power value shall be normalized for easy comparison.
  - A narrow beam antenna will provide good footprint resolution, but this also limits the satellite visibility duration.
  - Probably, an array of antennas is needed for wide coverage with better resolution.

- Difficult to automate the selection of a satellite that has good reflected signal.
  - Both amplitude and delay.
  - It seems that similar elevation angle of the satellite and LHCP antenna provides the best result.
    - For example, if the satellite is at 25 degrees above the horizon and the LHCP antenna is oriented at 60 degrees down, probably there will be no reflected signal.
  - It seems that an angle of 40-60 degrees provide good data provided there are visible satellites around that elevation as well.
  - This needs further experimentation and also depends on the antenna gain pattern.

Summary

- Correlator Output and spacing
  - Very small chip delays (less than two sampled chips) are not clearly identifiable.
    - But, we can see reflected signal with both the direct and reflected peak almost at the same correlator location.
    - Probably, we need wider bandwidth front-end in order to detect the peaks at very narrow correlator values, e.g. 0.0625 or less in our case.

- Integration of Samples
  - Long integration (averaging of I and Q power) period provides reduced noise.
    - However, we may lose the important observation point, especially in dynamic platforms.

- We have not modeled the amplitude value with respect to ground condition due to lack of enough samples at different time intervals.
  - This needs observation together with validation (reference) data.
  - Modeling for remote sensing applications need data from both static and dynamic platforms.

Future Plans

- Conduct Survey using UAV (remote controlled helicopter)
  - Test Flight Scheduled in Oct

- Conduct Survey at Experimental Ground of the University where a ground based Microwave Radar is stationed
  - This will provide good reference data, especially for soil moisture.

Questions?