Vehicular Navigation with Cellular CDMA Signals

Joe Khalife, Kimia Shamaei, and Zaher M. Kassas

**Motivation**

The global navigation satellite system (GNSS) is at the heart of autonomous vehicles navigation systems. However, GNSS signals are unreliable due to:
- Severe attenuation in deep urban canyons
- Intentional and/or unintentional jamming
- Spoofing!

**Approach: Exploit SOPs**

Ambient signals of opportunity (SOPs) may enhance and assist conventional navigation techniques.

**Cellular CDMA as SOP**

- Uses code division multiple access (CDMA), which is good for ranging
- Abundant and free to use
- Higher received power and bandwidth than GNSS

**CDMA Receiver Stages**

A three-stage cellular CDMA software-defined radio (SDR) has been implemented in order to extract the “pseudorange”, $\rho$, and the base transceiver station (BTS) information.

1. **Acquisition Stage**
   - Signals from different BTSs are identified and a coarse estimate of their corresponding code delay and Doppler frequency is obtained.

2. **Tracking Stage**
   - The code delay and Doppler frequency estimates are maintained and refined using tracking loops.
   - The pseudorange is also calculated.

3. **Decoding Stage**
   - The message transmitted by the BTS is decoded and information that can be used for navigation is extracted.

**Navigation Solution**

To estimate the position of the receiver and its clock bias, $r$, and $\delta t$, respectively, a weighted least-squares (WLS) problem with pseudorange measurements from 4 or more BTSs is solved.

**Pseudorange Model**

Under measurement noise $v$, $\rho$ is given by:

$$\rho = ||r - r_{\text{BTS}}|| + c \cdot (\delta t - \delta t_{\text{BTS}}) + v.$$

The position of the BTS, $r_{\text{BTS}}$, and the pseudorange, $\rho$, are known. The clock bias of the BTS, $\delta t_{\text{BTS}}$, is also needed to solve for the receiver’s state. It can be estimated either in a mapping/navigating receiver framework or in a simultaneous mapping and localization (SLAM) framework.

**References**