

The GPS Software-Defined Receiver (a.k.a., the software radio)

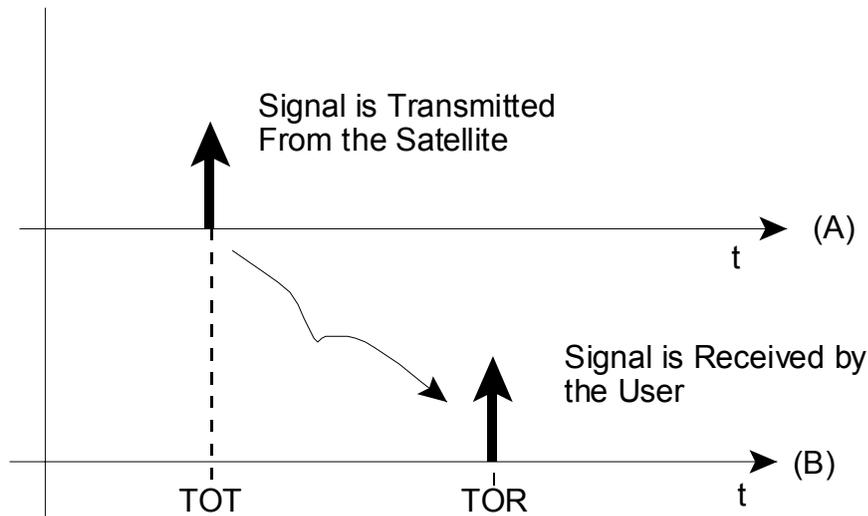
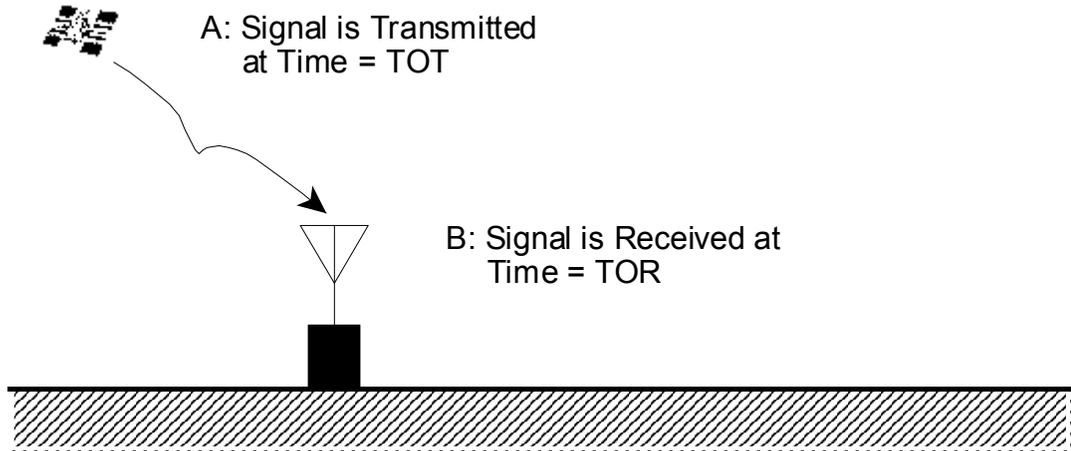
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Overview

- **GPS Ranging (time-of-transmission, etc)**
- **Spread-Spectrum Review**
- **Traditional GPS Receiver Operation**
- **Limitations of the Traditional Design**
- **Software Radio Fundamentals**
- **GPS Software Radio Advantages**
- **The Road Ahead...**

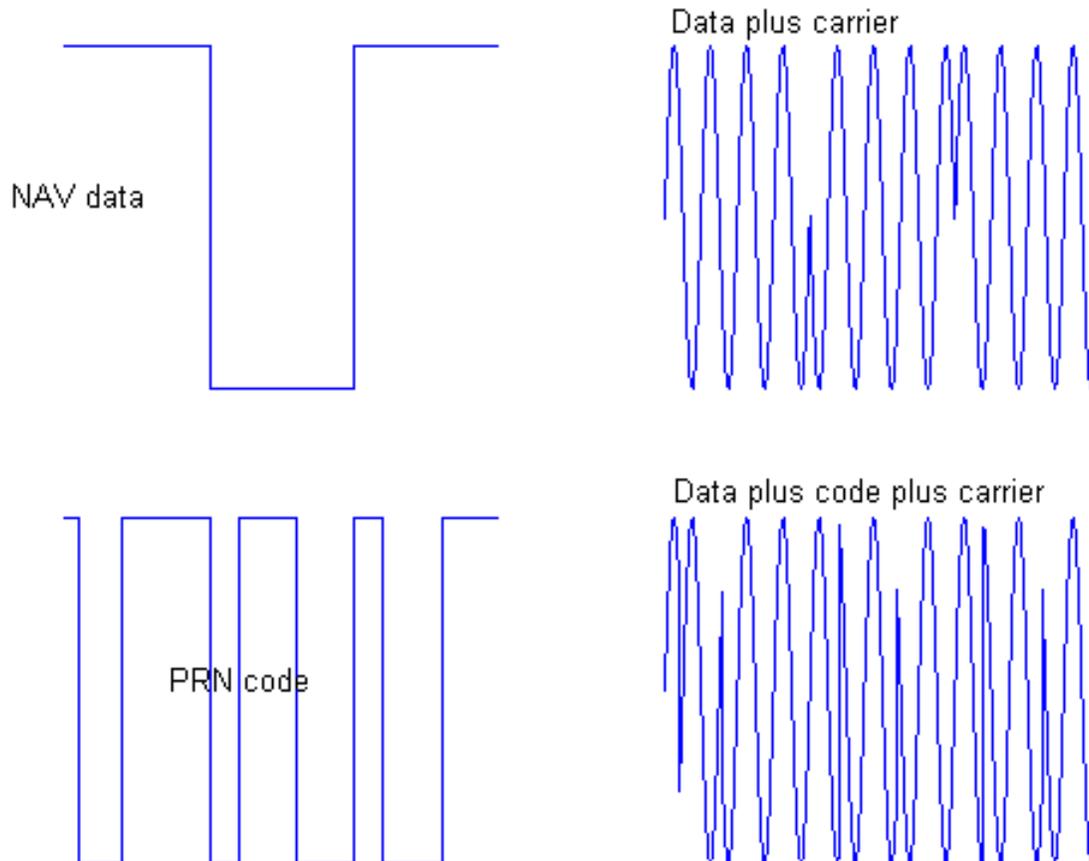




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Not to Scale



Spread-Spectrum Signal



Spread-Spectrum Ranging

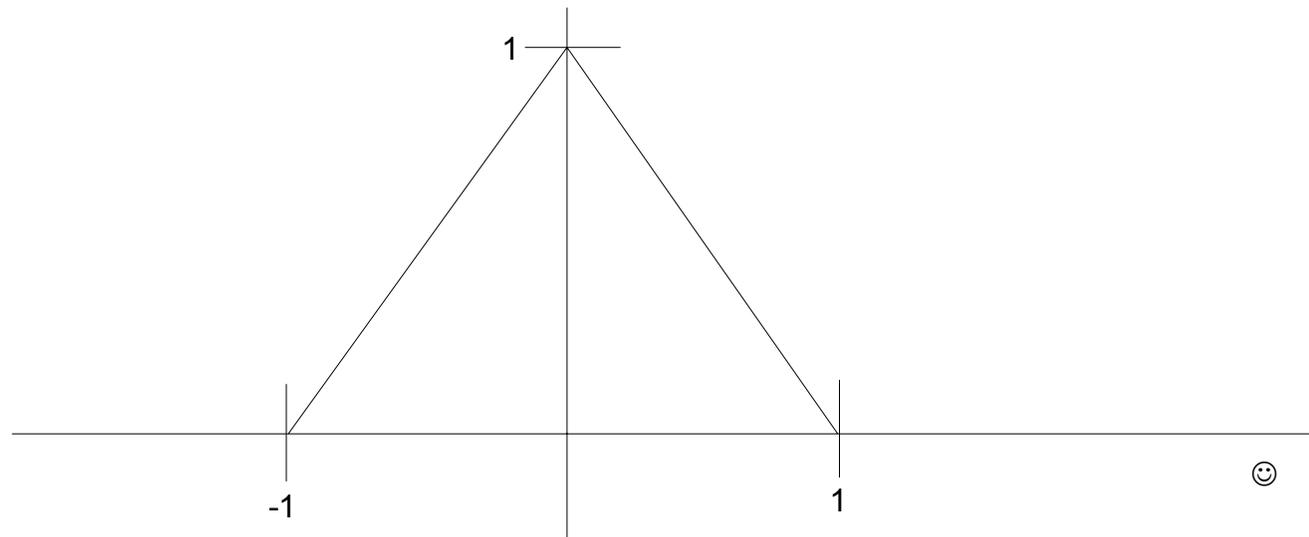
- The pseudorange is given by the speed-of-light times the difference of time-of-reception and time-of-transmission: $PR = (TOR - TOT) * c$
- When the signal is received, the receiver looks at its own clock to mark the TOR
- TOT is encoded by the satellite onto the signal through the navigation (NAV) data and the pseudorandom noise (prn) code



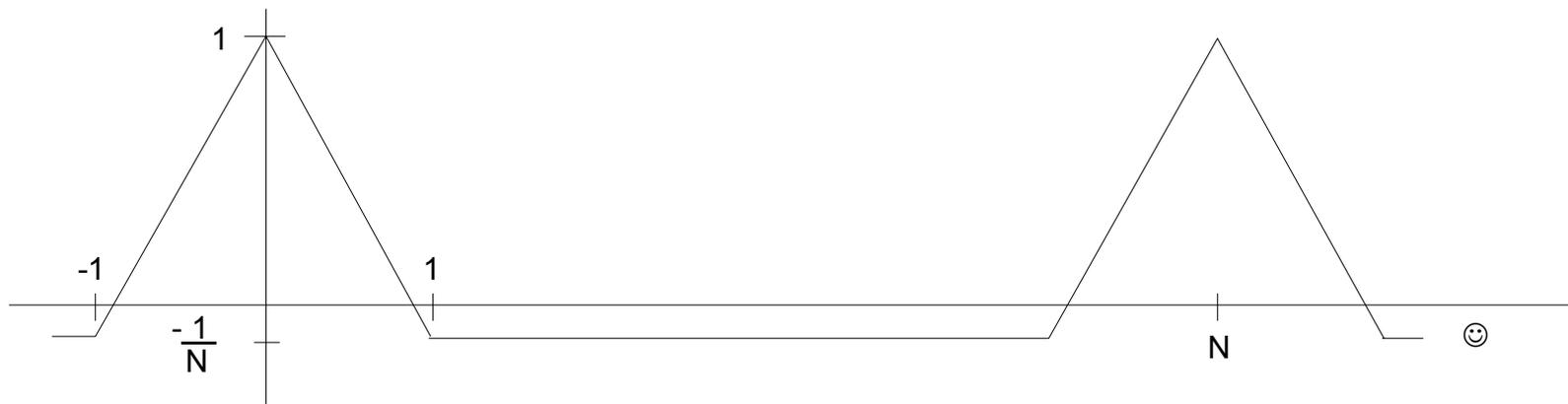
Spread-Spectrum Ranging (cont'd)

- **Time-of-transmission (TOT) is decoded from the signal by synchronizing a copy of the prn code (generated within the receiver) with the code which is in the received signal**
- **This synchronization is achieved by exploiting the properties of the correlation function of the prn code**
- **$R(\tau) = \int c(t)c(t+\tau)dt$**





(a)

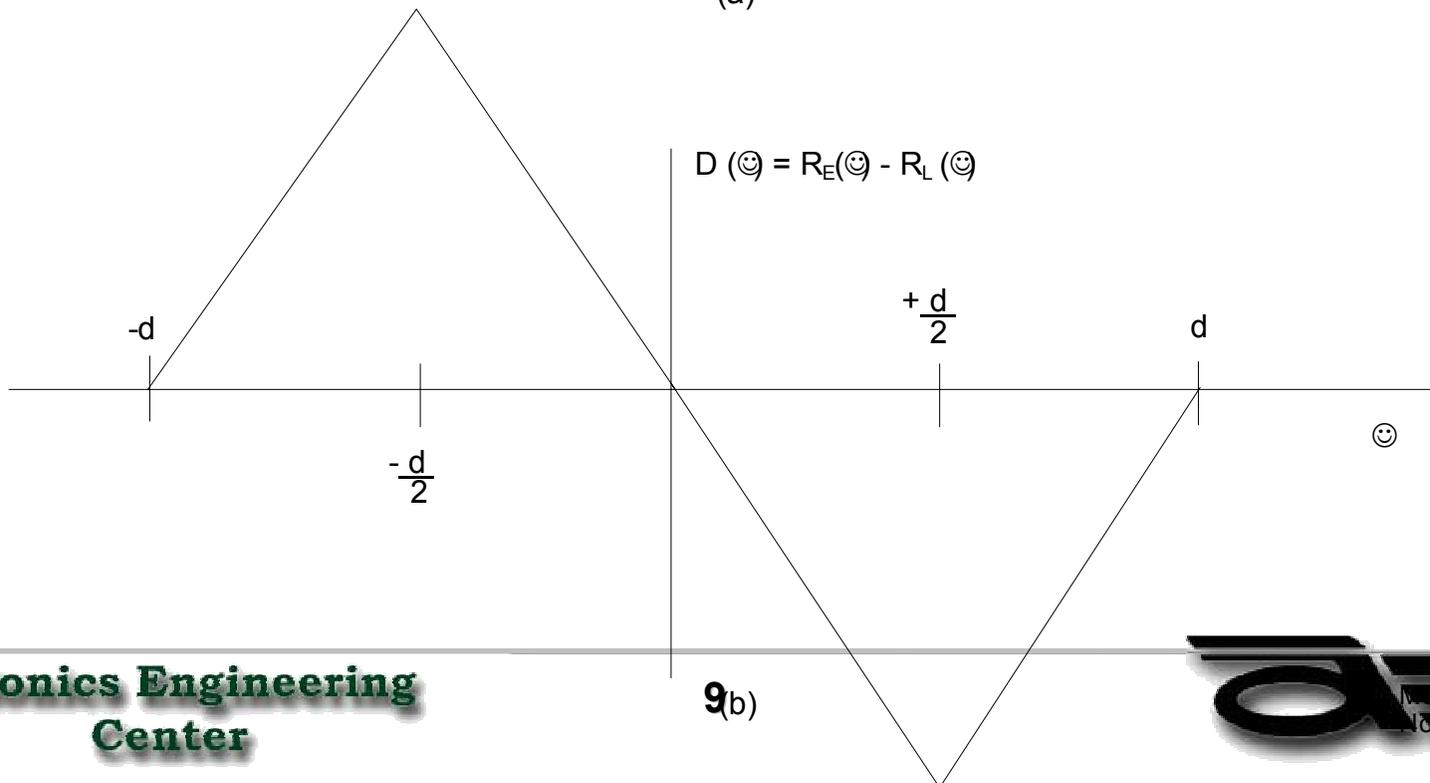
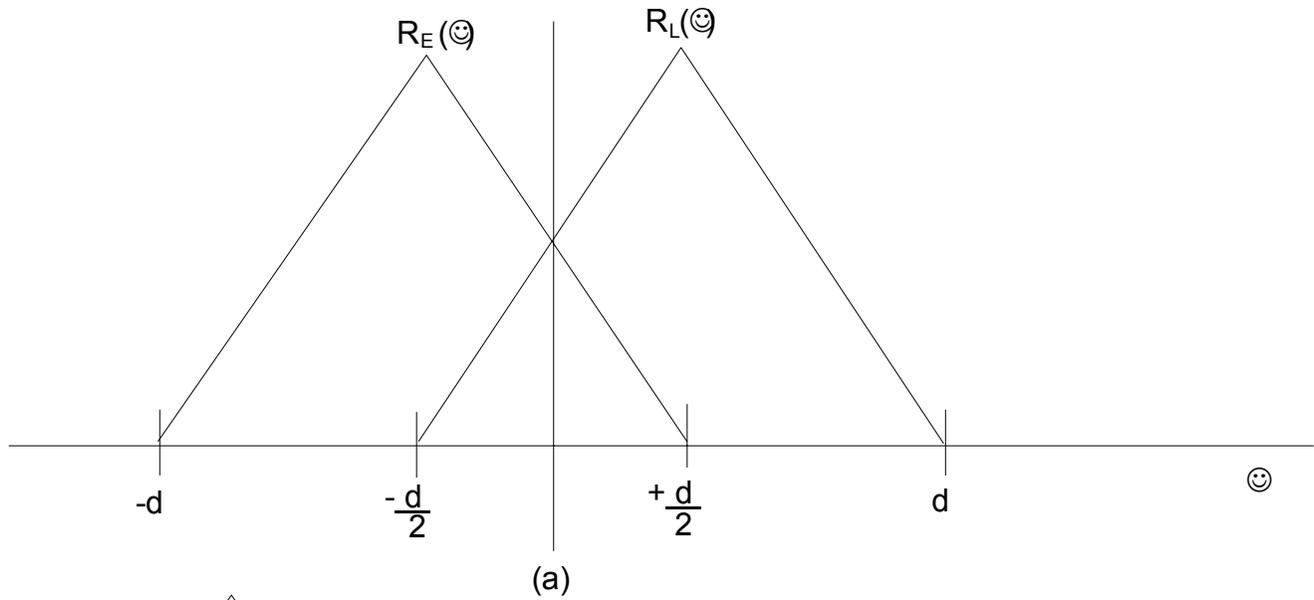


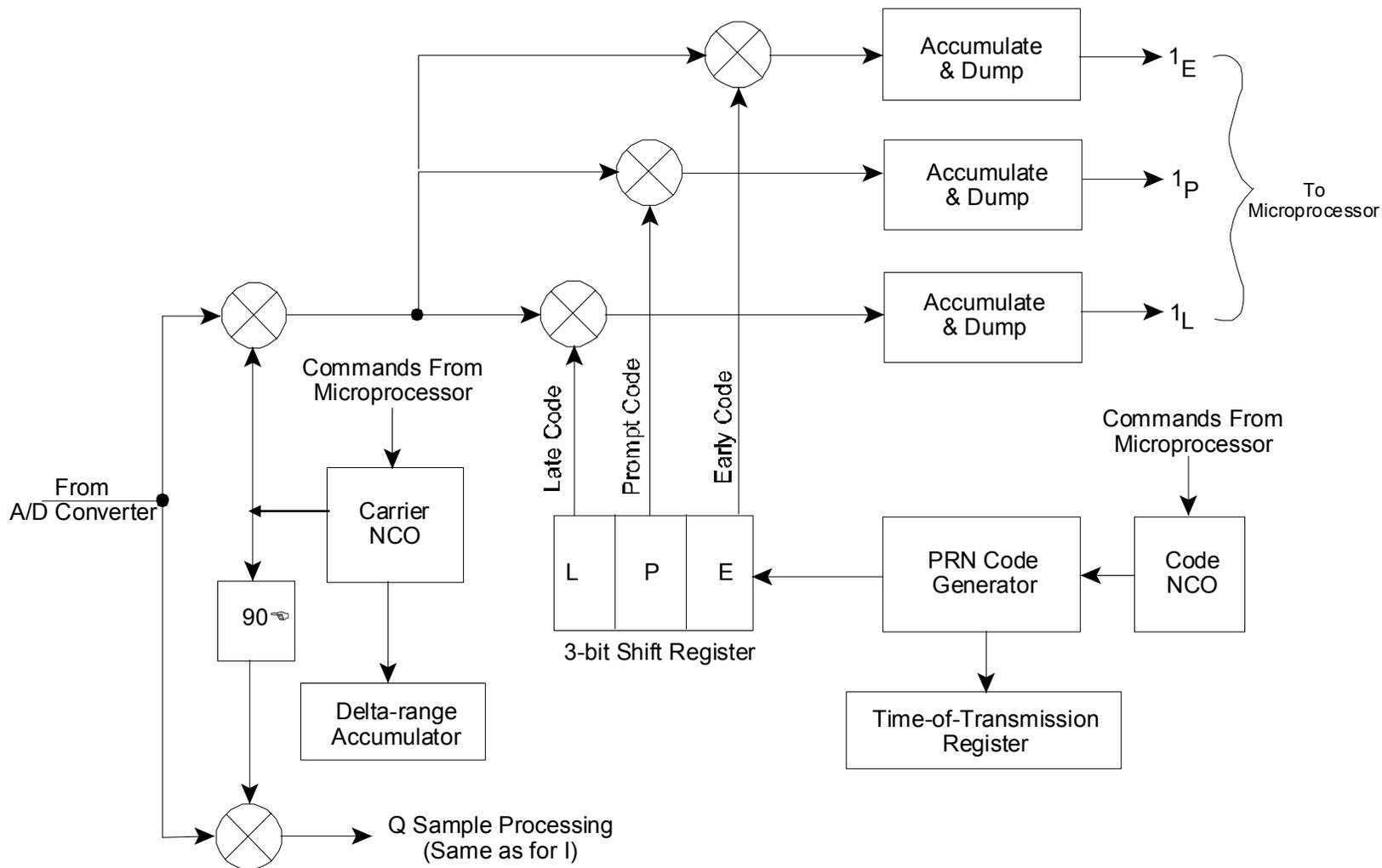
(b)
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Traditional Spread-Spectrum Tracking

- **The correlation function is an even function of code offset**
- **As a result, one does not know if the locally-generated code is too early by a certain amount or too late by the same amount**
- **In a traditional receiver, tracking is achieved through the use of a so-called delay-lock loop (DLL)**

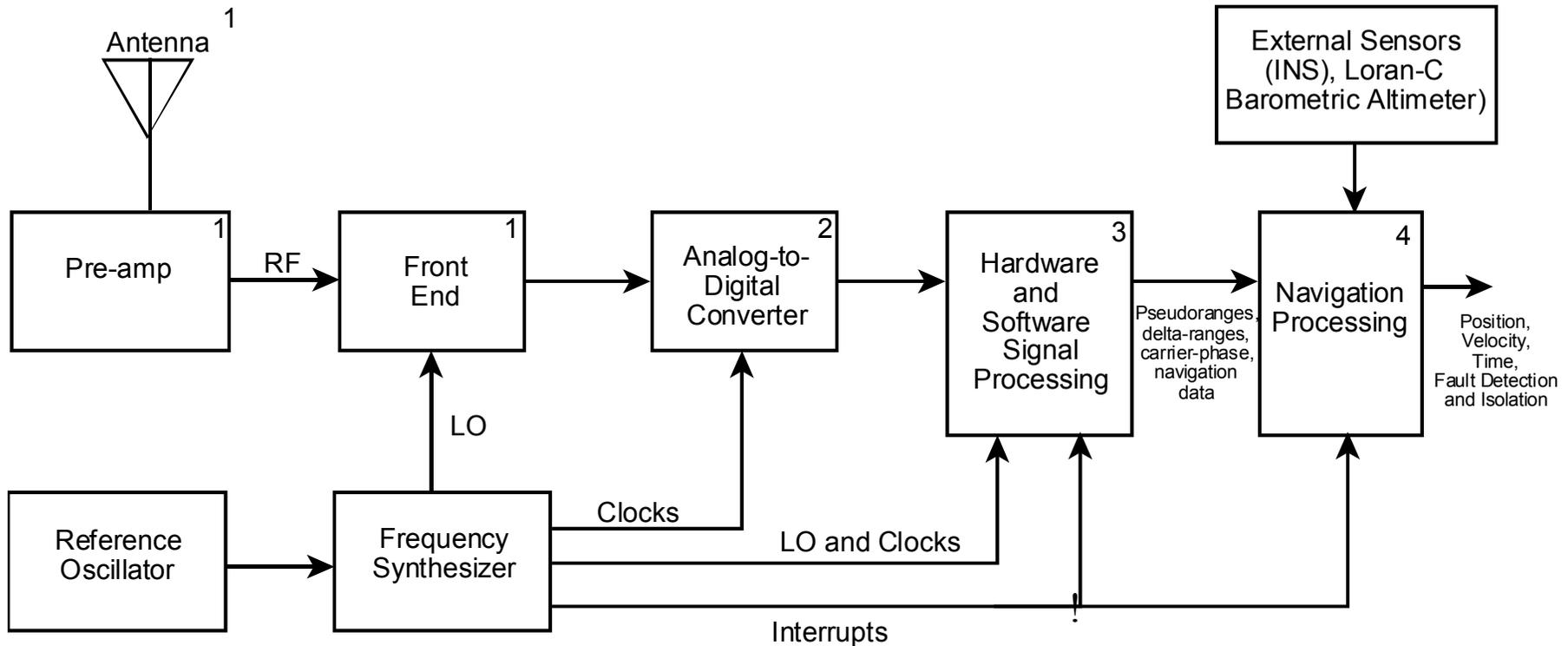






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1: Single-frequency designs process L1 (1575.42 MHz) signal only;
Dual-frequency designs process L1 and L2 (1227.6 MHz) signals

2: Several types available: Single-bit (hard-limiting), Multi-bit, Adaptive thresholds

3: Single-channel designs sequentially process each satellite tracked;
Multi-channel designs multiplex the A/D output into parallel channels with each tracking separate satellites

4: Integration of GPS and external sensor data may occur outside of the GPS receiver

Limitations of Traditional Receiver Design

- **Signal processing is performed exclusively in the time-domain**
- **Frequency and other transform-domain processing techniques are not possible**
- **Phase and delay-lock loop tracking techniques are cursed with the noise vs. dynamic tracking error trade-off**
- **In general, any kind of block-data processing techniques are not possible**



Software Radio Fundamentals

- **NO DEDICATED DIGITAL HARDWARE PROCESSING ! ! ! ! !**
- **Flexible baseband processing through the exclusive use of software**
- **Computational Speed versus Flexibility trade-off:**
 - » **ASIC: great speed; zero flexibility**
 - » **Desktop PC: low speed; great flexibility**
 - » **FPGA's, DSP's: in-between**

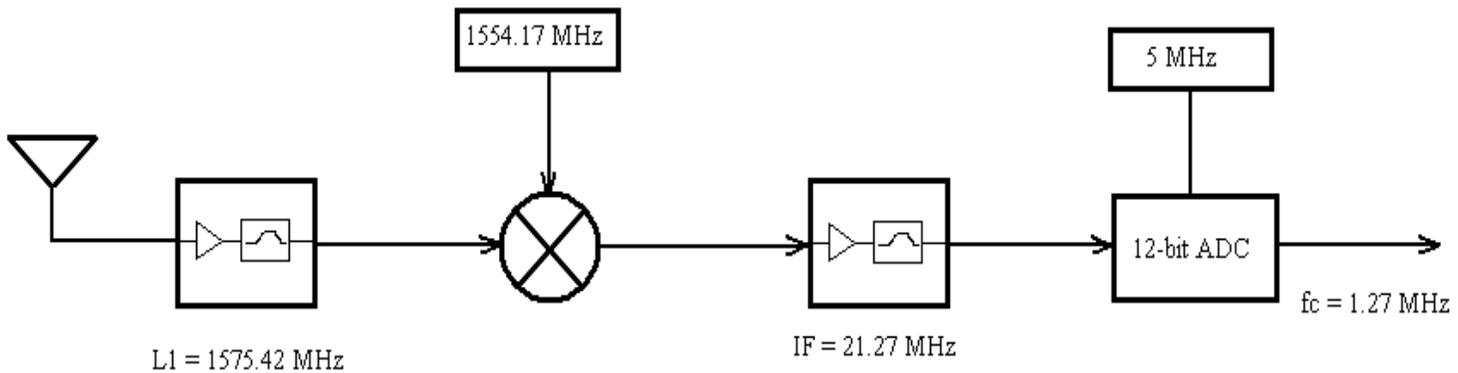


GPS Software Radio Advantages

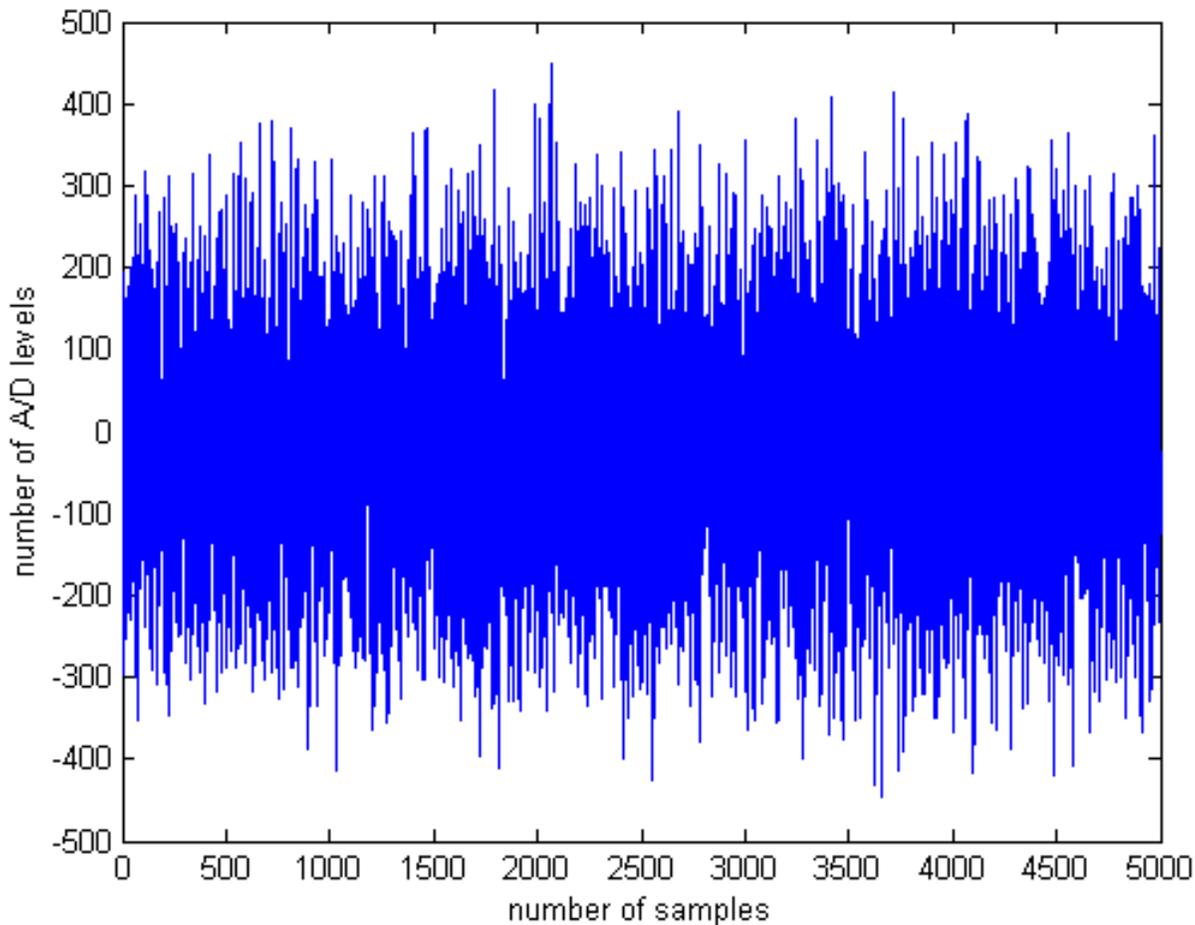
- **FFT-based signal acquisition**
- **Signal Quality Monitoring (correlation function analysis, etc)**
- **Interference detection and mitigation via spectrum estimation/time-frequency estimation**
- **Frequency domain tracking (looking towards total elimination of the feedback loops)**
- **Deep GPS/INS integration**
- **Yet-to-be-discovered block-processing applications**



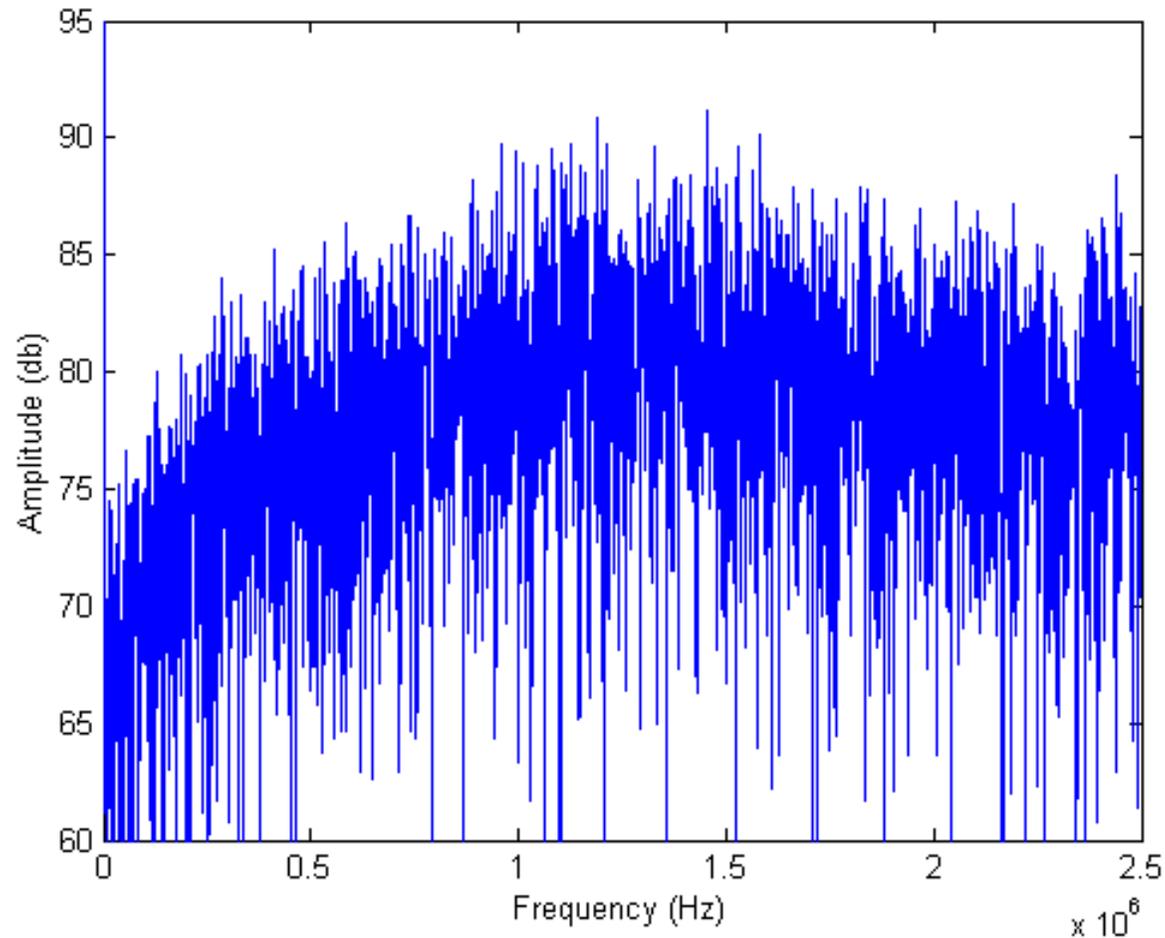
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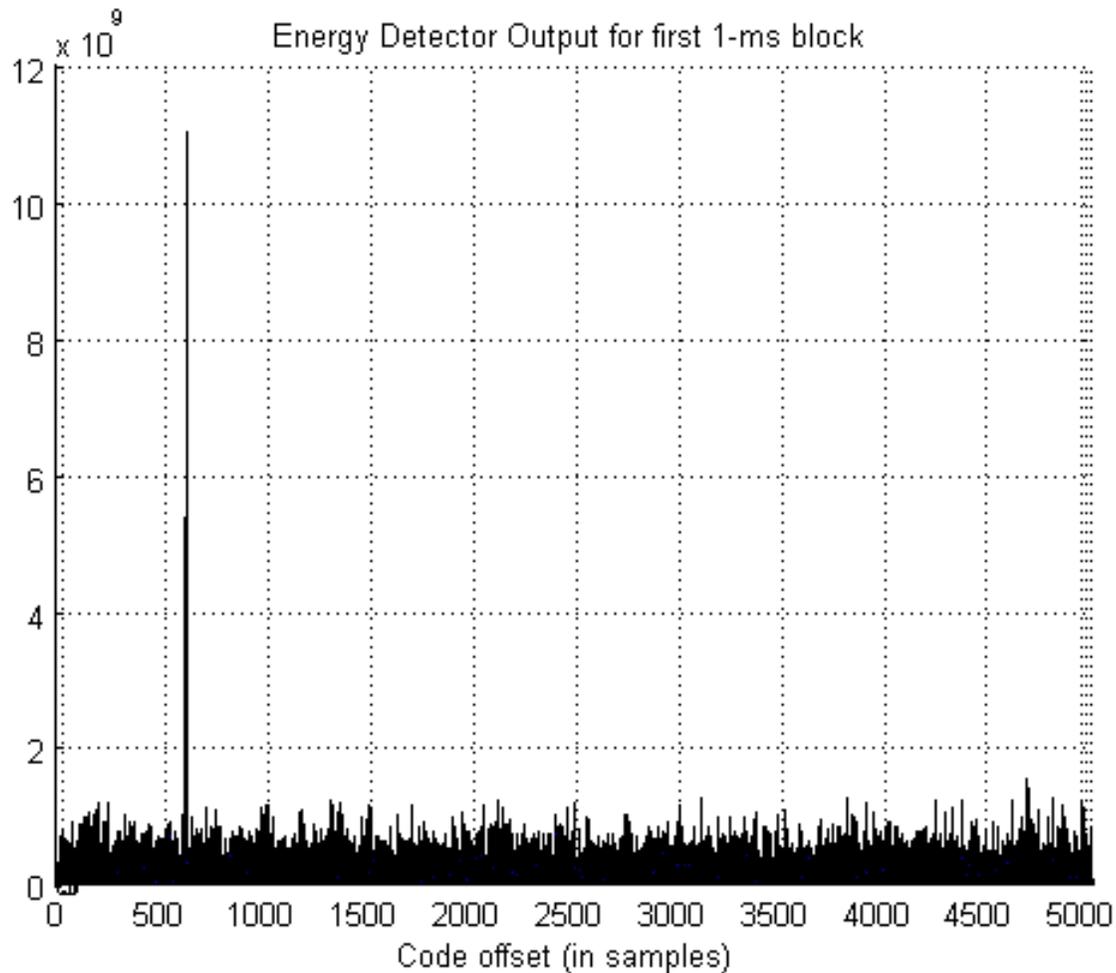
Raw Data from the A/D Converter



Spectrum of Raw Input Signal

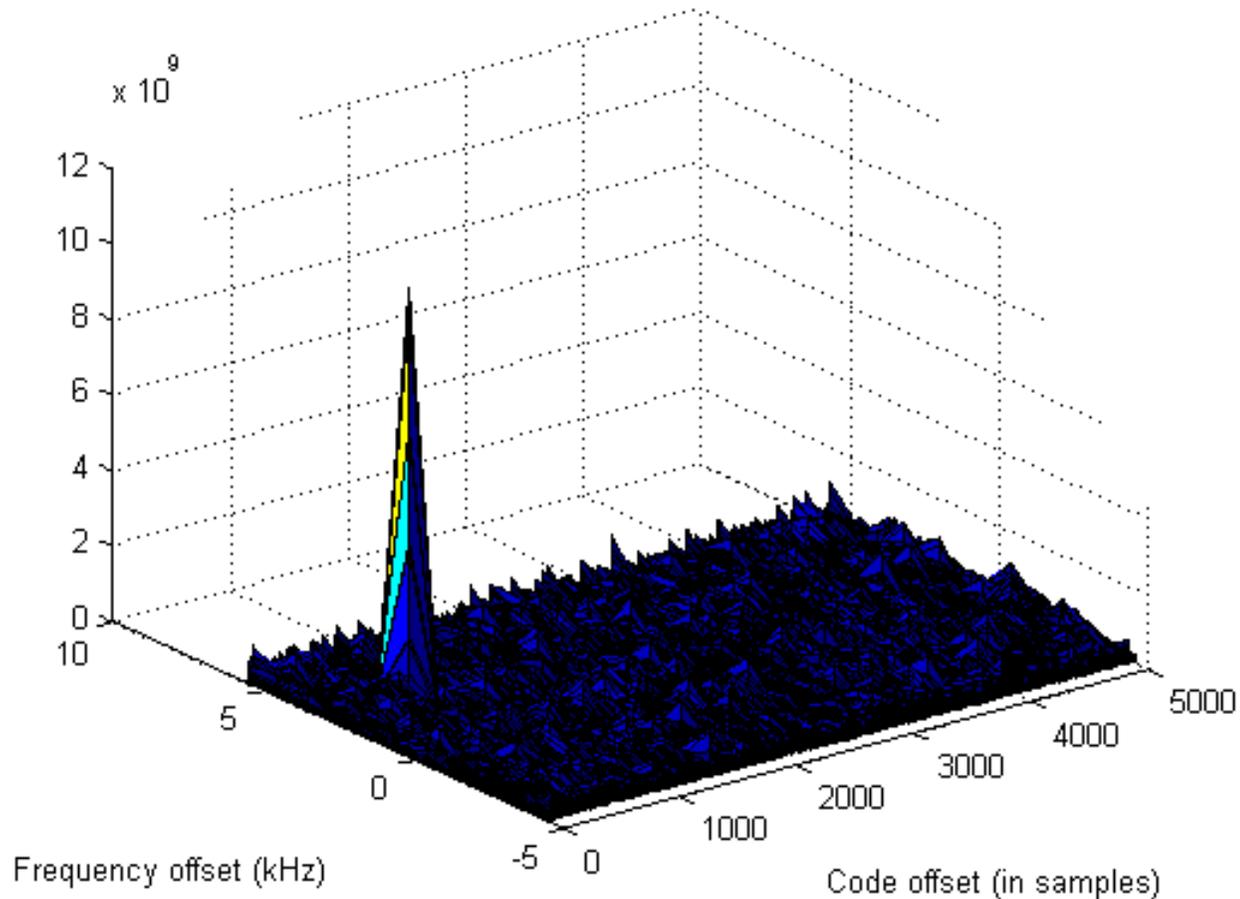


Energy Detector vs. Code Offset

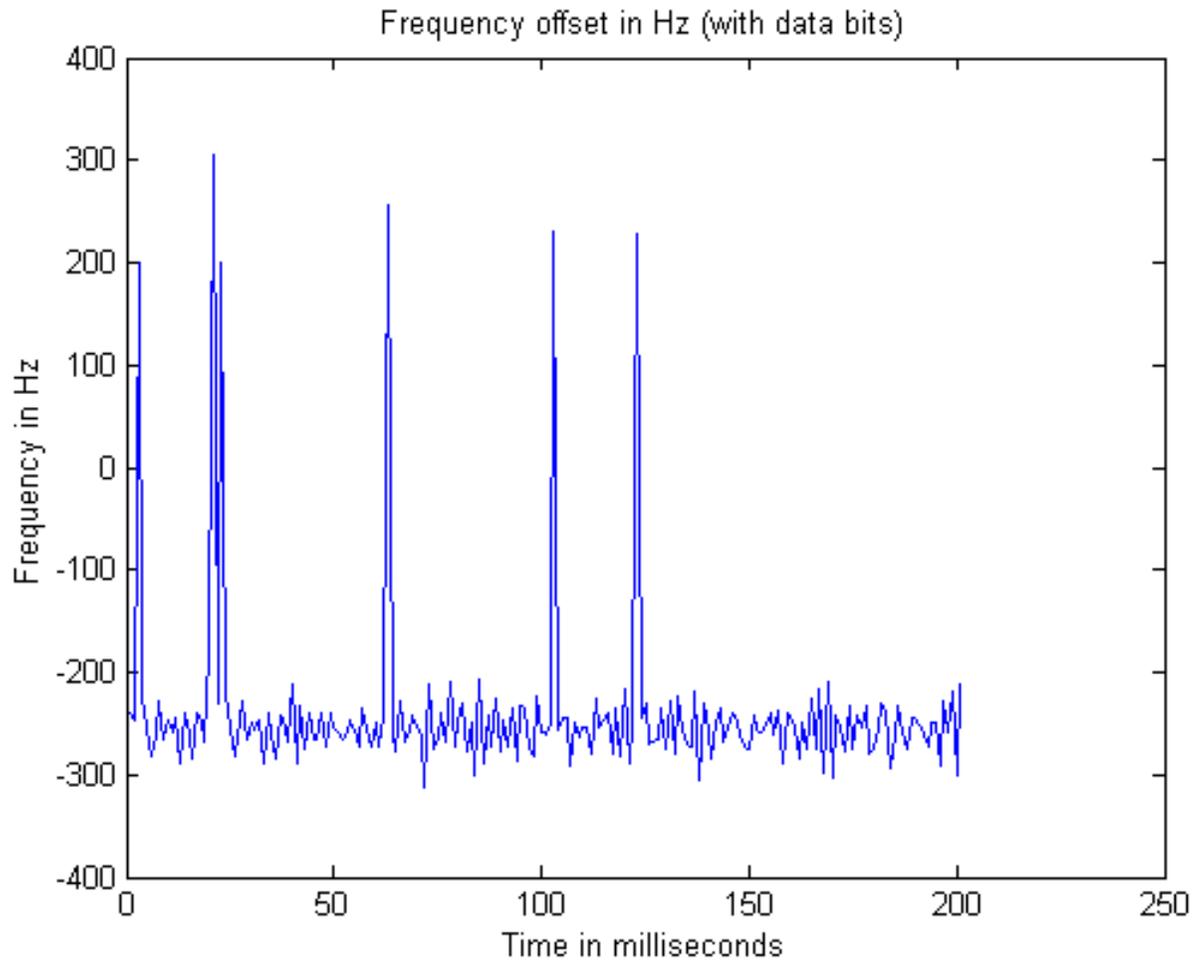


Energy Detector vs. Code/Freq

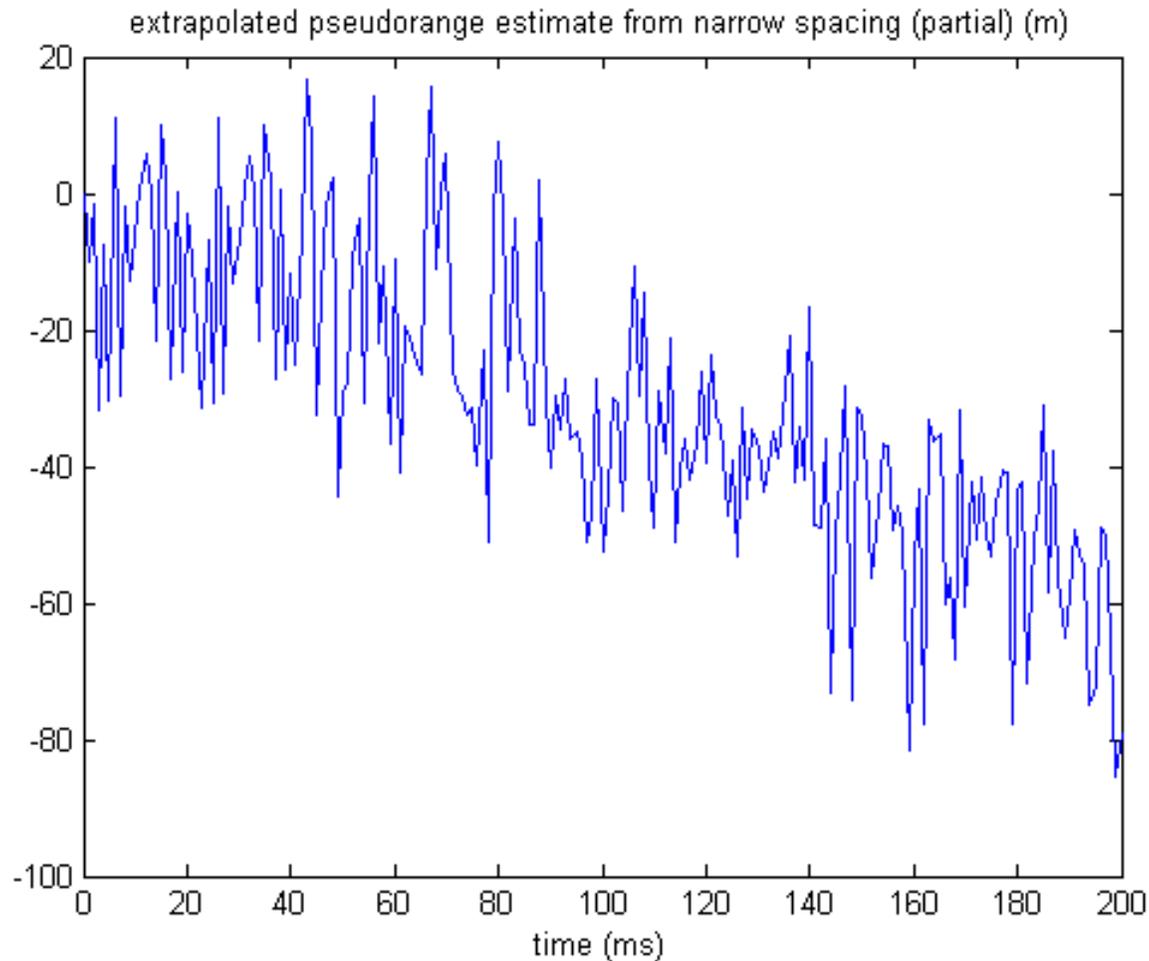
Energy Detector Output for first 1-ms block



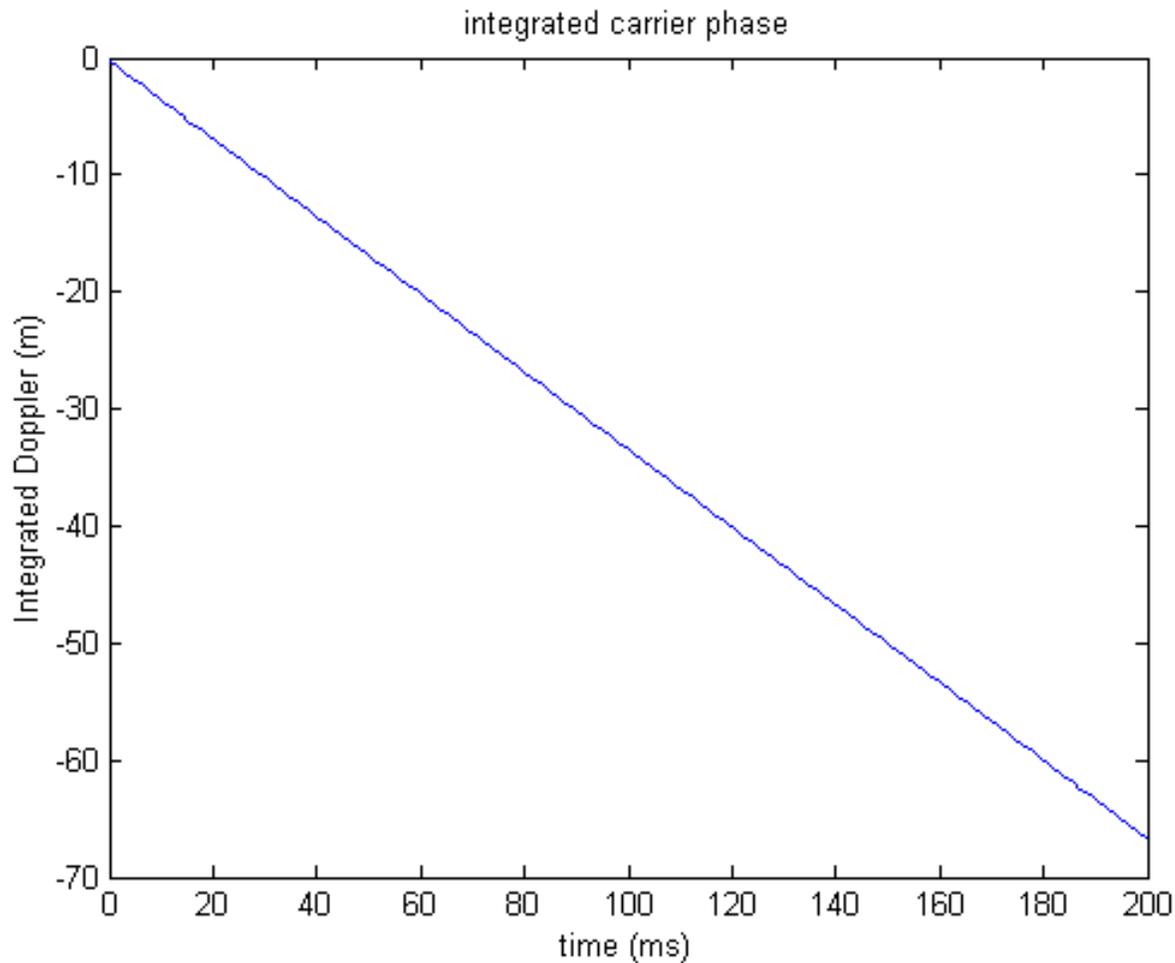
Frequency Offset vs. Time



Pseudorange (partial) vs. Time



Carrier-phase vs. Time



The Road Ahead...

- **To date, most of the advantages of the GPS software radio concept have been applied to signal acquisition**
- **Novel tracking algorithms (such as frequency-domain approaches) are just now being explored**
- **Interference detection and mitigation**
- **Joint time-frequency estimation**
- **Deep GPS/INS integration**
- **Other block processing techniques**



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