Extracting Position and Velocity Information in a Software GPS Receiver

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JUP Quarterly Review, October 2000

Atlantic City, NJ

GPS Software-Defined Receiver

General Principle:

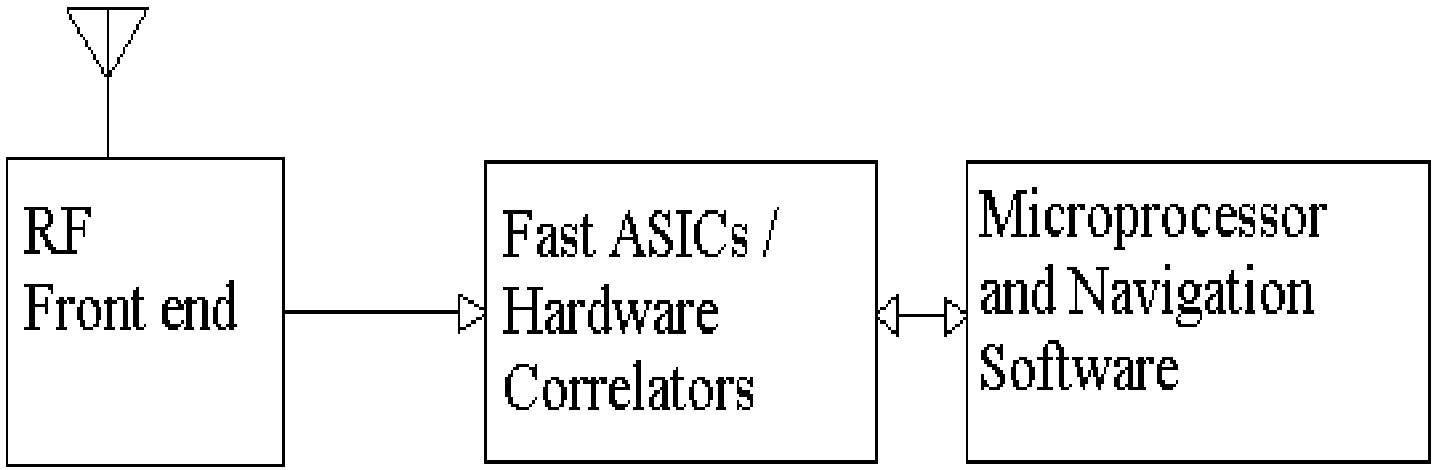
GPS signal is sampled as close to antenna as practical and remainder of signal processing takes place in a microprocessor

- More versatile than traditional architectures
- Allows parallel development at all stages
- Signal propagation is more readily analyzed

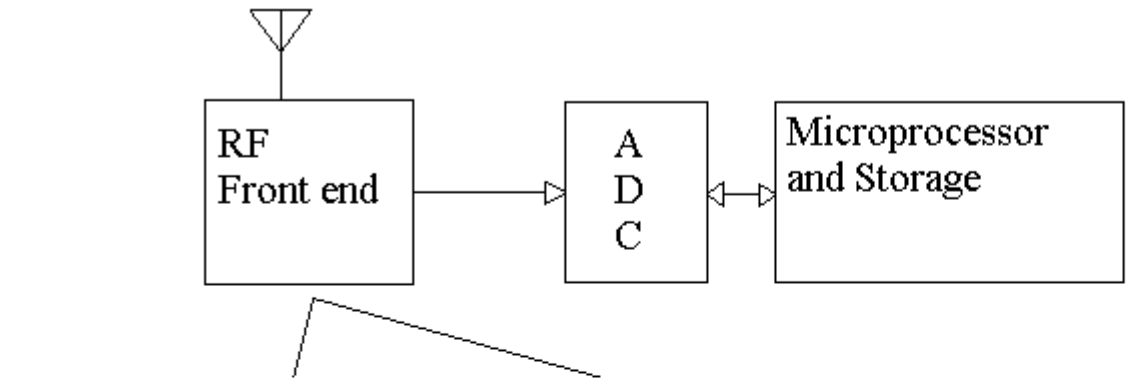
Research Motivation

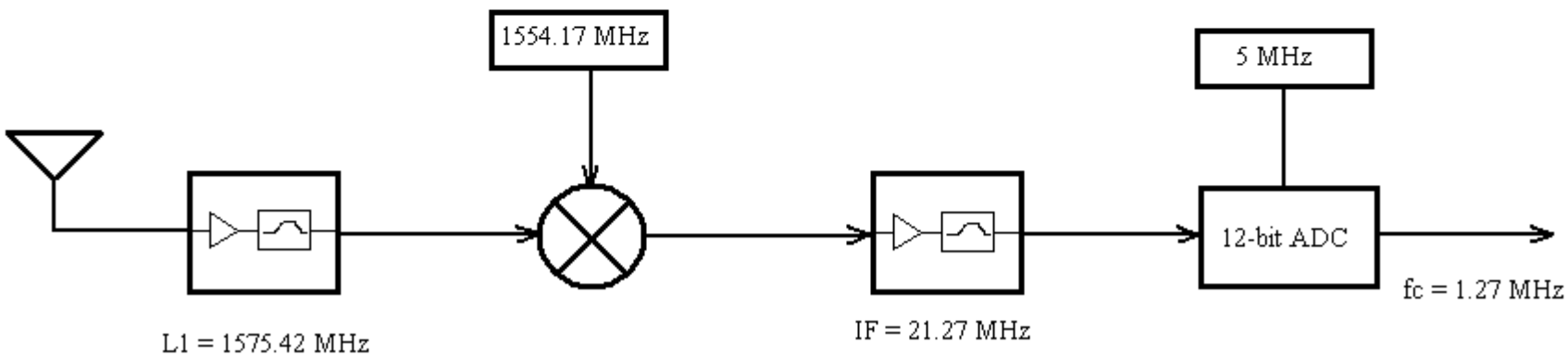
- **Previous studies of signal tracking revealed code-carrier divergence**
- **This problem would not raise concern in a communications software radio**
- **The uncertainty imposes an obstacle in high-accuracy carrier applications**

Tradition Receiver Architecture (High-Level)



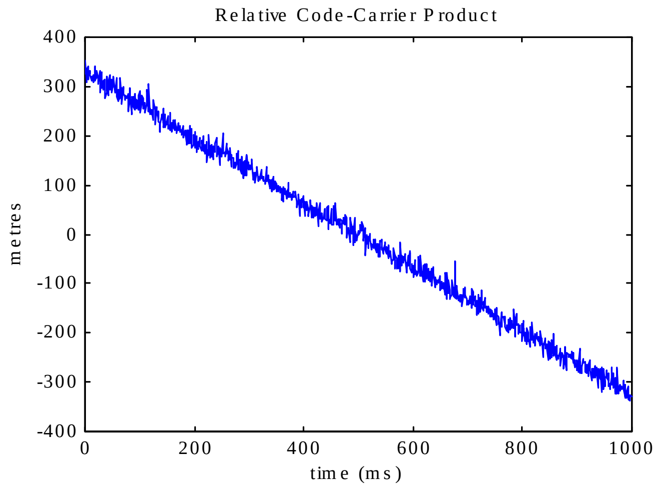
Software Receiver Architecture (High-Level)

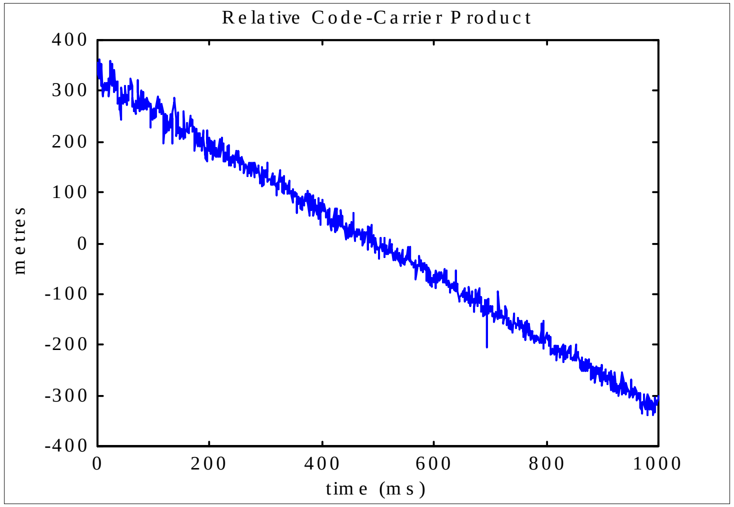


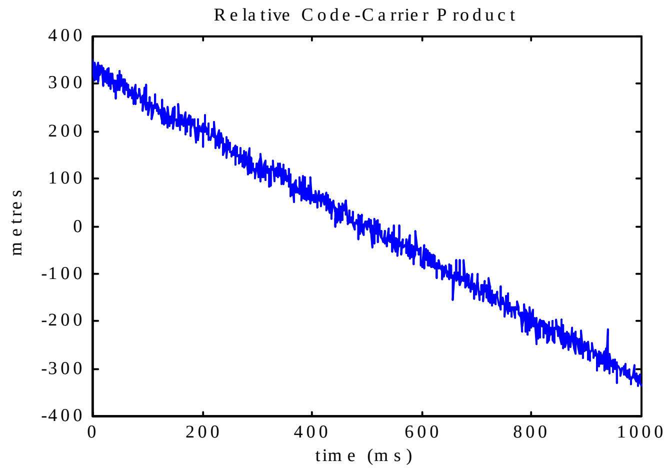


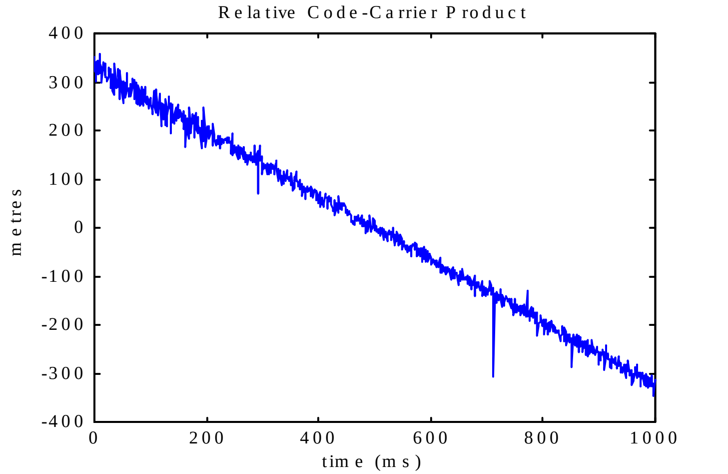
Initial Results

Code - carrier ranges on 4 satellites:

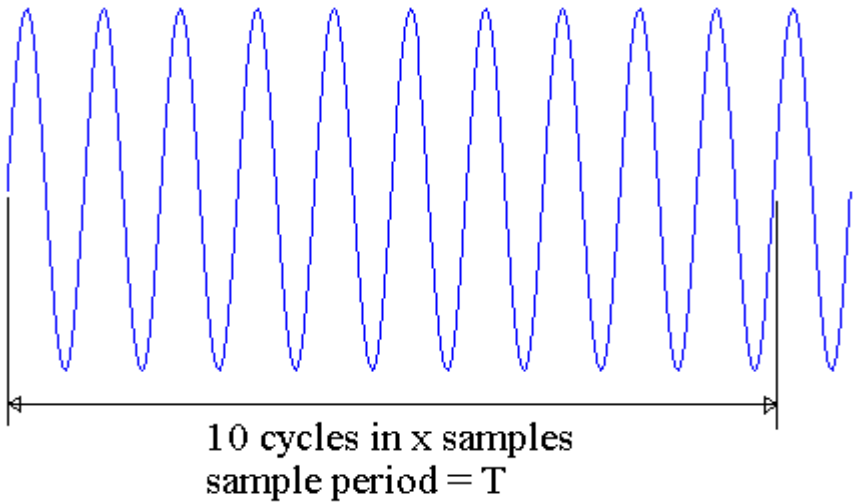


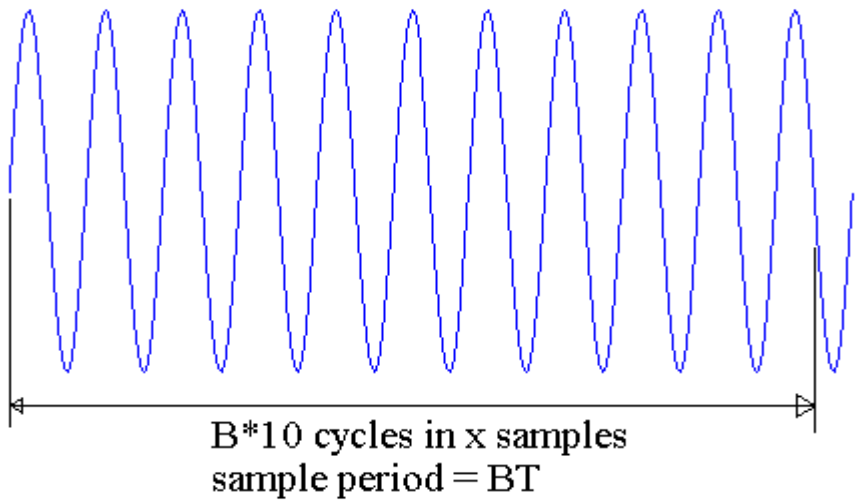






Sample Doppler





Apparent effect of a sample period error factor BT is a Doppler frequency error factor Bf

Therefore, a sampling oscillator error of 1/B leads to a SAMPLE DOPPLER B

Signal Downconversion and Sampling

γ True Doppler Scale Factor

ε Local Oscillator Error Scale Factor

$f_C = \gamma f_{L1} - \varepsilon f_{LO}$ Downconversion, No Sampling

$f_C = \beta(\gamma f_{L1} - \varepsilon f_{LO})$ Conventional Sampling

$f_C = \beta(\gamma f_{L1} - \varepsilon f_{LO}) - \beta M f_S$ Bandpass Sampling

$M = floor(f_{IF} / f_S)$ Number of "Folds" in Scheme

Velocity Measurements

Carrier velocity measurements are based on calculated Doppler:

$$f_{nom} = f_{L1} - f_{LO} - Mf_S$$

$$f_{Dop} = f_C - f_{nom}$$

$$= (\beta\gamma - 1) f_{L1} - (1 - \beta\varepsilon) f_{LO} - (\beta - 1) M f_S$$

$$V_{CAR} = f_{Dop}\lambda_{L1} = c(\beta\gamma - 1) - (1 - \beta\varepsilon) f_{LO}\lambda_{L1} - (\beta - 1) M f_S \lambda_{L1}$$

Velocity Measurements

Code velocity measurements can be based on chip rate:

$$R_{CODE} = \gamma\beta R_{nom}$$

$$R_{Dop} = R_{CODE} - R_{nom} = (\gamma\beta - 1)R_{nom}$$

$$V_{CODE} = R_{Dop}\,\lambda_{chip} = c(\gamma\beta - 1)$$

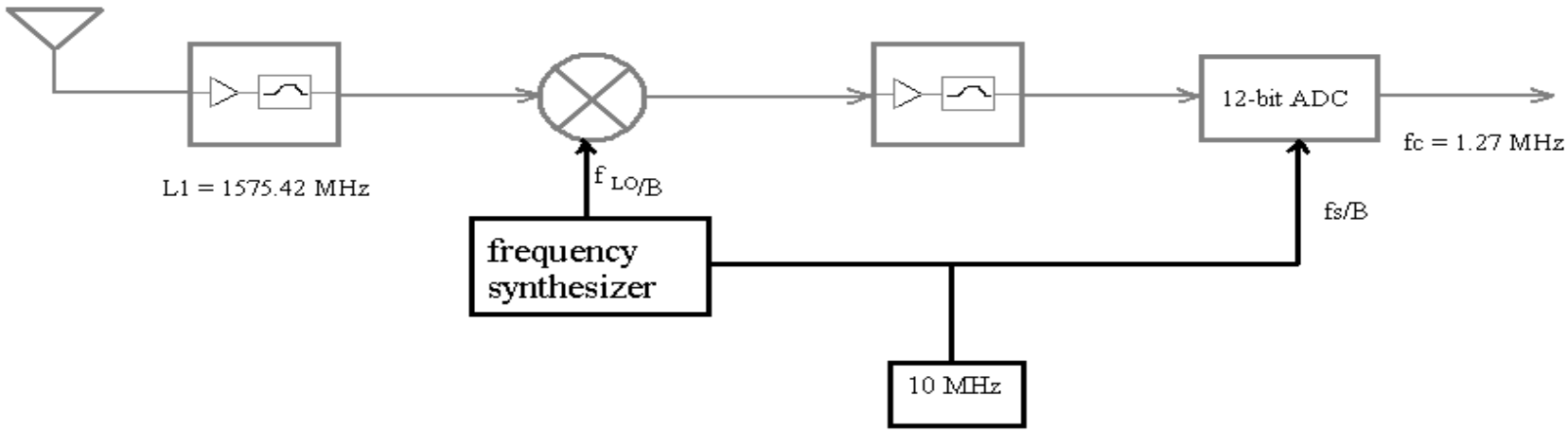
The velocities may be subtracted to yield a residual:

$$V_{C-C} = (1 - \beta\varepsilon)\, f_{LO}\lambda_{L1} + (\beta - 1)Mf_S\lambda_{L1}$$

Residual Code-Carrier Velocity

- Remaining velocity term is not dependent on γ, and is thus the same for all SVs
- Contains terms of LO error and sample Doppler, which cannot be decoupled with one measurement
- This effect is not observed in a traditional receiver

New Front End



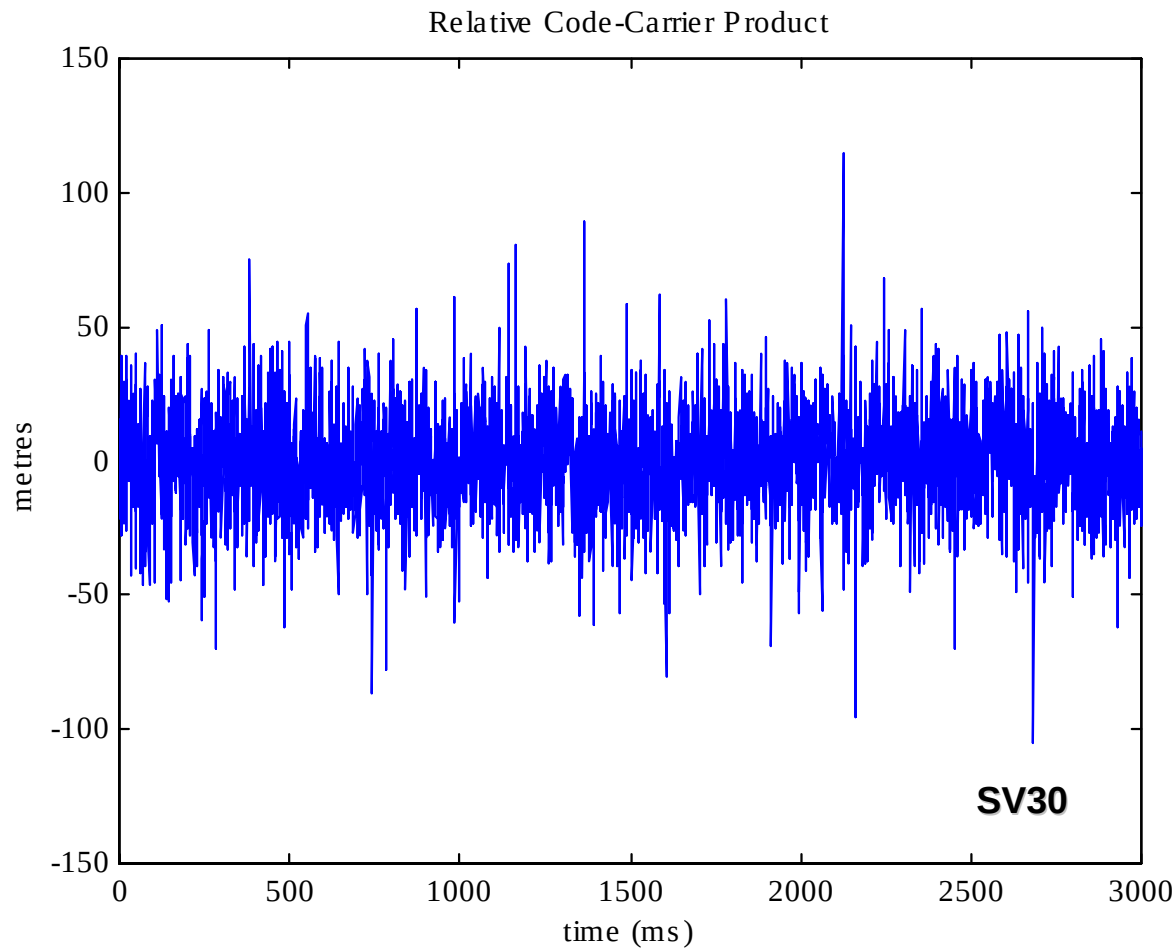
- LO and sample clock driven by same oscillator

$$V_{C-C} = (1 - \beta\varepsilon) f_{LO} \lambda_{L1} + (\beta - 1) M f_S \lambda_{L1}$$

$$V_{C-C} = (1 - \beta \frac{1}{\beta}) f_{LO} \lambda_{L1} + (\beta - 1) M f_S \lambda_{L1}$$

$$V_{C-C} = (\beta - 1) M f_S \lambda_{L1}$$

Code-Carrier (New Front End)



Conclusions

- Divergence in initial results was due to a local oscillator error that affected the carrier, but not the code
- Remaining divergence term due to sample Doppler may be present, but is likely to be very small
- Further improvements on front end will allow higher SNR and better determination of data trends

Continuing Work

- **Obtain cleaner data sets from hardware**
- **Collect longer records for navigation data extraction and decoding**
- **Seek and explore new tracking methods to boost performance expectations**