Real-Time Software Receiver for GPS Controlled Reception Pattern Antenna Array Processing

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Controlled Reception Pattern Antenna (CRPA)

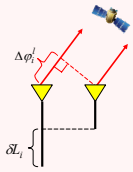
Objective: Enhance C/No & Reject Interference

•CRPA combines signals from antennas by

$$s(t)=\sum_{i=1}^{N} s_i(t)\cdot w_i = W^T S$$

•Build the steering vector, T, with phase coming from two sources
- Antenna's geometry and az./el. of satellite $\Delta\varphi_i^l$
- Cable difference delay δL_i

$$T=[t_1 \quad t_2 \quad \cdots \quad t_M]^T \qquad t_i=\exp\left(-j\left(\Delta\varphi_i^l+\delta L_i\right)\right)$$



•Deterministic Beamforming

$$W=T$$

•Adaptive Beamforming

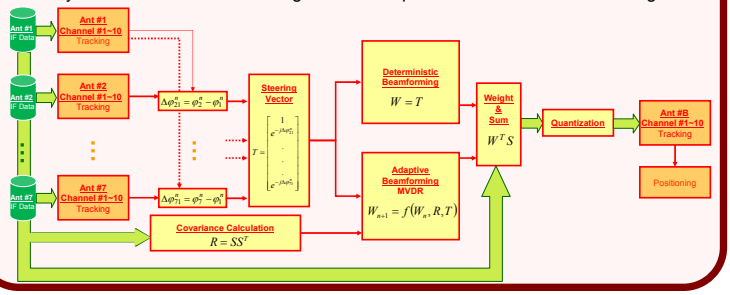
Minimum variance distortionless response (MVDR)

$$W_{n+1}=\gamma\left[I-\mu R\right]W_n+T \Rightarrow W_{n+1}=W_{n+1}\Big/\left|W_{r,n+1}\right|$$

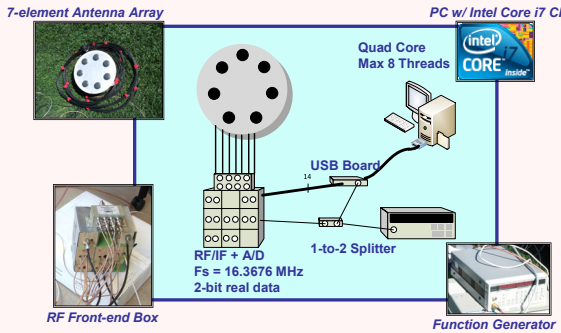
Implementation of CRPA in a Software Receiver

•Perform CRPA *without prior knowledge* of geometry of antenna array, az./el. of satellites and line bias.

•Only needs the difference of integrated carrier phase measurement for steering vector.



Hardware Architecture of Software Receiver

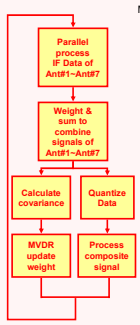


Software Architecture of Software Receiver

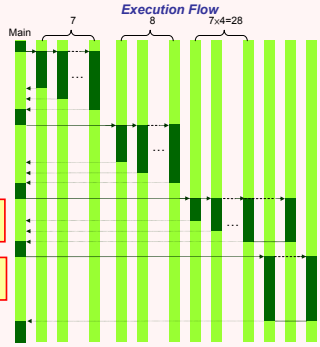
Component List

Component	Description
USB driver USB C++ library	Provided by chip manufacturer
Software correlator	Hand-coded inline assembly using SSE instruction set
Tracking Positioning	Use GPL-GPS open source code Modify interface to software correlator
MVDR adaptive beamforming -Covariance calculation -Weight update	Hand-coded inline assembly using SSE instruction set and C++ code
Weight-and-sum & Quantization	Hand-coded inline assembly using SSE instruction set
System program	Arrange threads to achieve real-time capability

Flow Chart

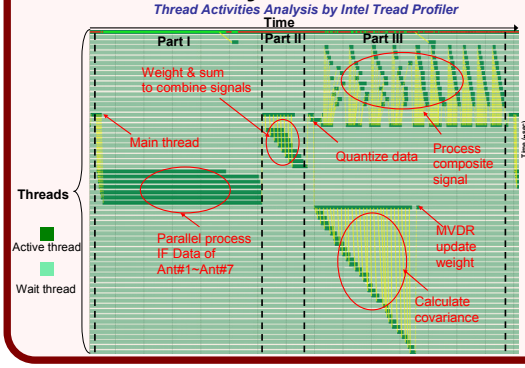


Execution Flow

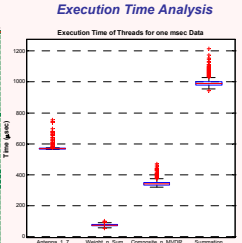


Software Analyses for CRPA Software Receiver

Thread Activities Analysis by Intel Tread Profiler



Execution Time Analysis

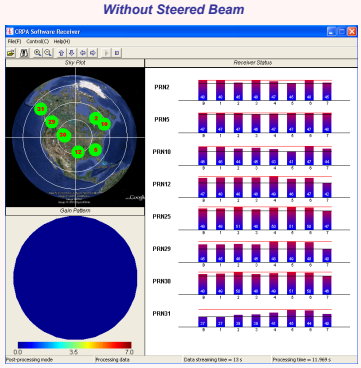


Part #	I	II	III	Sum
Time (usec)	572.93	75.23	345.81	993.98

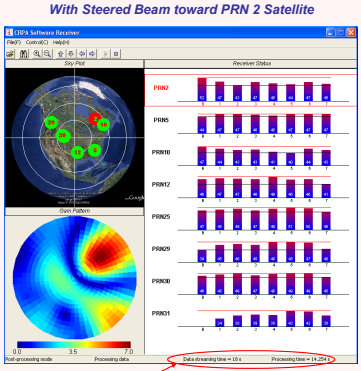
The total execution time for 1 msec data length is less than 1 msec.

Executing Program of CRPA Software Receiver

Without Steered Beam



With Steered Beam toward PRN 2 Satellite

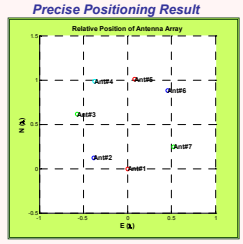


The processing time is less than data streaming time

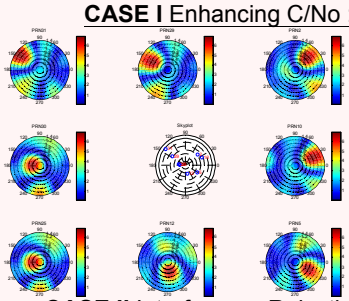
Experiments for CRPA Software Receiver

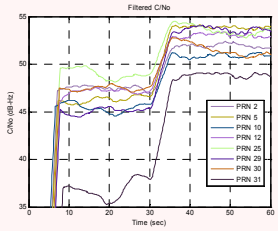
Photo of Hardware

Precise Positioning Result

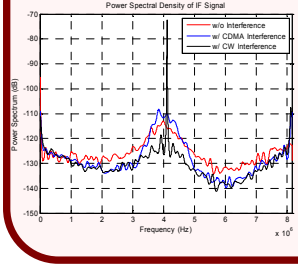


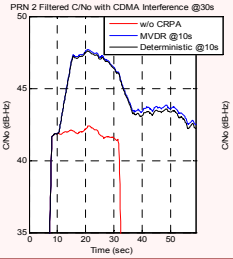
CASE I Enhancing C/No : Without Interference

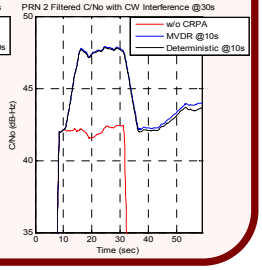




CASE II Interference Rejection : With Injected Interference







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