Past and On-going Galileo Research Projects at EPFL-IMT-ESPLAB

Navigare’09

Dr. Cyril Botteron

June 17, 2009
Agenda

- Intro to GNSS
  - GNSS modulations, main receiver blocks, ...

- Selected past projects
  - GPS Watch, GRDB, GPS L1/L2 rx, ...

- Some current projects
  - GAMMA-A, Signature, SARBACAN, SNSF GNSS, SoftRx, ...

- From GNSS to UWB
BPSK versus BOC Modulation

- Example of BPSK(m)
  - PRN code rate: $m \times 1.023$ MHz

- Binary Offset Carrier: BOC(n,m)
  - The code is modulated by a square wave
  - subcarrier frequency: $n \times 1.023$ MHz
  - PRN code rate: $m \times 1.023$ MHz

- Example of a BOC(1,1)
MBOC Modulation

- MBOC Modulation: 
  
  \[ G_{MBOC}(f) = \frac{10}{11} G_{\text{SinBoc}(1,1)}(f) + \frac{1}{11} G_{\text{SinBoc}(6,1)}(f) \]

- Galileo E1 CBOC
  - CBOC(6,1,1/11) for both pilot and data
  - 50%/50% power split pilot/data

- GPS L1 TMBOC
  - TMBOC(6,1,4/33) for pilot
  - BOC(1,1) for data
  - 75%/25% power split pilot/data

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Power Spectral Density (dBW/Hz)

Offset with respect to the carrier [MHz]
Main GNSS Receiver Blocks

\[ s(t) = A d(t) c(t) \cos(2\pi f_0 t + \phi) \]
GNSS - Current and intended signals

Green and blue signals: Open or commercial signals
Red signals: Military signals, Public Regulated Services
Grey signals: Usage of filed signal not yet defined officially

Source: "GNSS Signals and Spectra,” ICG ICG-4-02, Sept.4-7, 2007
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GPS Watch

- The beginning of the GNSS adventure at IMT! (from ~ 1995 to 1998)
  - GPS watch’s goals:
    - Dimensions: $57 \times 47 \times 20$ mm$^3$
    - Autonomy > 1 year (watch)
    - Low power GPS rx

- IMT’s contributions:
  - Low power receiver architectures and algorithms
  - Realization of a low power 12 channels GPS L1 C/A baseband ASIC (<40mA using TSMC CMOS 0.5um)

[Far00] “GPS Watch - An Analogue Watch Including a Very Low Power GPS Receiver,” ION GPS 2000
GRDB – Galileo Receiver for Distress beacon (1/3)

- Cospas-Sarsat status (05.2009):
  - 5 low-altitude earth orbit satellites (LEOSAR)
  - 4 geostationary earth orbit satellites (GEOSAR)
  - 29 mission control center (MCC)
  - 406MHz beacon population: > 600’000
  - 121.5/243 MHz processing ceased on Feb. 01, 2009
  - Persons rescued in 2007: 2386 (562 distress)
  - Since inception in 1982: 24798 persons

- Localization by LEOSAR (Doppler effect):
GRDB – Galileo Receiver for Distress beacon (2/3)

- Galileo Contribution to Cospas-Sarsat
  - Galileo SAR Service
    - Cospas-Sarsat space segment replacement
    - Global and drastic reduction of alert delay
    - New localization based on new principles
    - Reduction of false alert quantity (SAR RLM)

- GRDB’s goals (2005-2007)
  - Beacon prototype platform
    - Galileo BOC(1,1) receiver
    - Operations in presence of 20dBm/406MHz
    - SAR RLM decoding and new operating modes
GRDB – Galileo Receiver for Distress beacon (3/3)

- IMT’s contributions:
  - Novel front-end architecture
  - Novel correlator HW implementation

[Cha07] "Galileo E1b,c RF FE for SAR applications," ENC-GNSS 07
[Wae07] "Real-time Galileo E1 signal acquisition and tracking scheme", ENC-GNSS 07
[Cha06] "Galileo L1 RF FE Optimized for Narrowband Interferers Mitigation," ION GNSS 2006
A Low-Power L1/L2C RF FE Architecture

Proposed low power solution:
- Shifted LO solution (without quadrature mixer)
- Selection using a Weaver architecture
- Power consumption $\sim$ L1 heterodyne FE

[Cha05] “A Low Power RF Front-End Architecture for an L1/L2CS GPS Receiver,” ION GNSS 2005
GPS L1/L2 – CTI Project (1/2)

- GPS L1C/A L2C receiver platform for time transfer applications (2004-2007)
  - GPS Disciplined oscillator (GPSDO)
  - Ionospheric delay
  - Accuracy & stability goals:
    - Max PPS error <25ns (over 24 hours w.r.t. UTC)
    - Mean MTIE < 40ns (for interval over 1 week)
    - Holdover error < 7us (after 24 hours, -20°C-70°C)
- Challenges:
  - Small profile double oven OCXO (OSA)
  - RF signal transport (IMT)
  - GPS L1C/A & L2C receiver design (IMT)
  - Ionospheric error corections (IMT)

Loss(RG213) = 17dB/60m or = 85dB/300m

Challenges:
- Small profile double oven OCXO (OSA)
- RF signal transport (IMT)
- GPS L1C/A & L2C receiver design (IMT)
- Ionospheric error corections (IMT)
GPS L1/L2 – CTI Project (2/2)

- Dual frequency front-end development
- GPS L1C/A L2C receiver development

[Cha05] “Dual-frequ. RF FE for Long Antenna-GPS Receiver Links,” ION GNSS 2005
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Gamma-A: Galileo Receiver for Mass Market Applications in the Automotive Area

- GAMMA-A’s goals:
  - 3-frequency receiver concept for automotive applications
  - L1 GPS/EGNOS/ GALILEO
  - E5a/L5 GPS/GALILEO
  - E5b GALILEO signals
  - Innovation
  - 12 core technologies studied

- EPFL’s contribution:
  - Analyze possible tracking algorithms for processing
    - CBOC on Galileo E1 OS
    - TMBOC on GPS L1C OS

Signature’s goals:
- Prototype a GNSS based solution for flexible road user charging providing high integrity in a cost-effective and scalable manner.

EPFL’s contribution:
- Development of high-sensitivity assisted receiver prototype
Sarbacan: SAR BeAcon development with CANada

- Sarbacan’s goals
  - Development and validation of 3 types of 406MHz SAR beacons prototypes
  - Including SAR RLM processing and new MQPSK generation

- EPFL’s Contribution
  - GNSS receiver optimizations
  - Leading GNSS preliminary designs
  - Specific software GNSS rx solution

Aviation beacon
Maritime beacon
Personal beacon
Focus on algorithms for:

- High sensitivity
- Multipath mitigation

=> Taking profit of new GNSS signals’ structures and properties

E5 AltBOC(15,10) spectrum and correlation peak

Soft RX - Development of a GPS L1 software receiver

- 12 channel receiver with $F_s = 4$ MHz requires $3 \cdot 10^8$ additions and $4 \cdot 10^8$ multiplications per second
  => Solution: distributed arithmetic architecture

Single Instruction Multiple Data (SIMD)
+ data bit-depth independent
- platform dependent

Bitwise Processing (or vector processing)
+ high // and speed
- conversion into int

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From GNSS rx developments to UWB developments

- UWB for high data rates short range communications
  - Shannon capacity theorem: $C \sim B \cdot \log_2[1+P / (B \cdot N_0)]$
  - E.g., for wireless USB, or for other high data rates cables replacement

- UWB for low data rates low power communications
  - E.g., for sensors networks, for Wireless Personal Area Networks (WPAN)

- UWB for locating devices (tags, nodes, etc)
  - E.g., for manufacturing, geo-fencing, etc.
PX PosLoc: UWB-based *Local Positioning System for Locating Tag Transmitters*

Measured precision:

67% (1 measure)

=> 0 ± 30.5 cm (phys)

=> 17.6 ± 20.7 cm (median)

67% (16 measures)

=> 0 ± 19.7 cm (phys)

=> 17.6 ± 5.5 cm (median)


[Mer08] “Experimental Platform for an Indoor Location and Tracking System,” *ENC-GNSS 08*
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