

Letizia Lo Presti Politecnico di Torino Italy









ICG 4 Saint Petersburg 15 September 2009



NavSAS research group



NavSAS is a joint research group of *ISMB* and *Politecnico di Torino* University operating in the satellite navigation and localization sectors.

- NavSAS staff consists of 28 researchers.
- Research is focused specifically on advanced technologies for GPS / EGNOS / Galileo receivers and applications.
- NavSAS cooperates with major industrial and institutional players operating in the field.
- See <u>http://www.navsas.eu</u> & <u>http://www.galileoblog.eu</u>



1 – Master on Navigation

2 – NAVKIT

3 – Signal Generator / Analysis

4 – Software receiver

5 – SAT SURF / SAT SURFER



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Master on Navigation and related applications



The one-year Master is a joint initiative of

and





with the cooperation of

INRIM Galileo Ferraris





UN OOSA

United Nations

Office for Outer Space Affairs



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Structure of Education in Italy





Specializing Master





The first five editions

UN/ISMB Project

| Country | - Students |
|-------------|----------------|
| Algeria - 1 | Madagascar - 1 |
| Egypt - 1 | Mexico - 1 |
| Georgia - 1 | Mongolia - 1 |
| Ghana - 1 | Nigeria - 2 |
| Haiti - 1 | Pakistan - 3 |
| Iran - 1 | Sri Lanka - 1 |
| Jordan - 1 | Vietnam - 2 |

| SIAN-Zhong | Guò |
|------------|-----|
| Projects | |

| Country |
|---------------|
| China - 3 |
| Indonesia - 1 |
| Vietnam - 1 |

| ALPIP-Meftia | Projects |
|---------------|-------------|
| Cou | ntry |
| Argentina - 4 | Ecuador – 2 |
| Brazil - 2 | Mexico – 1 |
| Colombia - 1 | Peru - 1 |

| J | E | A(| G | A | |
|---|---|----|---|---|--|
| | | | | | |

| Country |
|-------------|
| China - 6 |
| Vietnam - 4 |

National funds

| Cou | ntry |
|----------------|--------------|
| Bangladesh - 1 | France - 2 |
| China - 1 | Italy - 16 |
| Colombia - 2 | Lebanon – 1 |
| Ecuador – 2 | Pakistan – 3 |



1 – Master on Navigation
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What is NavKIT

- NAVKIT is a tool for autonomous training on satellite navigation subjects
- NAVKIT has been developed by professors and researchers of the NavSAS Group
- NAVKIT has been developed as a task of the ERIG project "Education Research and Innovation in GNSS" funded by the GNSS Supervisory Authority within the VI FP

European GNSS Supervisory Authority



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What is NavKIT

- The tool can be accessed via Web (<u>www.navsas.eu</u>) or can be installed as an application on your own PC
- It allows to learn the basic concepts of satellite navigation by means of a multimedia approach
 ✓ Videos (lectures)
 - \checkmark Exercises fully solved step by step
 - \checkmark Self evaluation tests
 - ✓ Frequently asked questions



The Target Audience

- The content of the lesson is organized in order to provide technical concepts also to non specialists
- The tool is designed for students but also for technicians and professionals in need of a starting training in the field





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N-FUELS: GNSS signal generator

N-FUELS (FUII Educational Library of Signals for Navigation) is a MATLAB®-based GNSS

signal generator;

It allows the simulation of

physical layer signal structu



for GPS, Galileo and EGNOS systems in all the current and future bands.

N-FUELS has been created both for **research** and **educational** use.

First of all, the study of signals and systems innovation generates the need of manipulating all the different GNSS signals.

This helps in comparatively analyzing <u>signals performance</u> and <u>testing</u> <u>novel processing algorithms</u>.



SIS Modulations N-FUELS: SISGEN & JAMGEN



| N-FUELS | |
|---|-------------------|
| Canaral Naisa & Impairment | |
| | |
| Signal Length [s]: 60 IF Carrier Freq [Hz]: 4130400 | |
| Sampling Freq [Hz]: 16367600 IF Carrier Phase [rad]: 0.31416 ND [dBW/Hz]: -201.3 | • • • • • • • • • |
| Satellite Signal Image: Multipath / Interference SET Image: Multipath / Interference ABOUT N-FUELS | |
| # Satellites: 1 SIS Doppler type: Fixed RX Front End | |
| more values separated by spaces Modulation : GPS_L1 ▼ Doppler Freq [HZ]: 260 Front End Filter Filter model: 1 ♥ Contend filter Butterworth, 4th order, BW = 4.092 MHz Butterworth, 4th order, BW = 20.46 MHz Butterworth, 12th order, BW = 51.15 MHz | |
| PRN codes: 13 4. Chebyshev, 2nd order, BW = 3.78 MHz | |
| more values separated by spaces Image: Code Delays [s]: 0.0008 | |
| Navigation Data IavMessage.txt | |
| Quantization | |
| ✓ Quantization # Bit: 2 Output Folder: cn045_60sec ✓ Signal out schar | |
| Plot double double | |
| ✓ Spectrum ✓ Time Domain | |
| Codes Doppler Frequency | |
| LOAD PARAM GENERATE SIGNAL | |
| Image: Save Param PLOTS | |
| | /32 _ |
| | /52 |

| Signal Length [s]: 60 IF Carrier Freq [Hz]: 159000 Sampling Freq [Hz]: 15867600 IF Carrier Phase [rad]: 0.51416 Satellite Signal |
|--|
| General Signal Length [s]: 60 IF Carrier Freq [Hz]: 1 Signal Length [s]: 1 Signal |
| Signal Length [s]: 60 IF Carrier Freq [Hz]: 4130400 Sampling Freq [Hz]: 16567600 IF Carrier Phase [rad]: 0.51416 Satellite Signal |
| Sampling Freq [Hz]: 16567600 IF Carrier Phase [rad]: 0.51416 Satellite Signal * Satellites: 1 SIS Doppler type: Fbed Modulation: GPS_L1 Doppler Freq [Hz]: 2003 more values exparated by spaces Code Delays [S]: 0.0006 Image values exparated by spaces Code Delays [S]: 0.0006 Image values exparated by spaces Code Delays [S]: 0.0006 Image values exparated by spaces Code Delays [S]: Image values exparated by spaces Image values exparate |
| Satellite Signal * Satellites: 1 SIS Doppler type: rower values exparated by spaces more values exparated by spaces rower values exparated by spaces 13 rower values exparated by spaces Code Delays [s]: 0.0008 13 14 15 15 16 17 18 19 10 19 10 < |
| * Satellites: 1 SIS Doppler type: Fixed |
| Modulation: GPS_L1 Doppler Freq [HZ]: 290 Front End Filter Filter model: 1 Butterworth, 4th order, BW = 4.092 MHz Butterworth, 3th order, BW = 4.092 MHz Butterworth, 12th order, BW = 51.15 MHz A Chebyshev, 2nd order, BW = 51.15 MHz Code Delays [s]: 0.0008 Code Delays [s]: Co |
| PRN codes: 13 more values separated by spaces Code Delays [s]: 0.0008 Navigation Data TaxMessage.bd |
| Image: separated by spaces Image: separated by spaces Code Delays [s]: 0.0008 Image: separated by spaces Image: separated by spaces |
| Navigation Data lavMessage.bt |
| |
| Quantization Output Folder: Cn02 Output Folder |
| |
| |
| Spectrum ☑ Time Domain |
| Codes Doppler Frequency |
| LOAD PARAM GENERATE 100 |
| -150 50 100 150 200 250 300 |
| Istituto Superiore Mario Boella SAVE PARAM PLOTS EXIT |
| |
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| |





N-FUELS – Student Version

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N-FULES – Student Version



3 – Signal Generator / Analysis

4 – Software receiver

5 – SAT SURF / SAT SURFER





Research on GPS/Galileo Receivers





N-GENE Software Receiver: Performance



- GPS L1 8 bits quantization at a sampling rate of 17.5103 MHz
- Galileo E1, GIOVE-A & GIOVE-B signals, upgradable to Multiplexed Binary Offset Code (MBOC) easily
 - EGNOS, WAAS & A-GPS

- Position Accuracy: r.m.s<10 m using code-based measurements and without applying carrier smoothing techniques
- Time to First Fix in Cold Start mode lower than 45 seconds
- Up to 20 channels





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SAT-SURF & SAT-SURFER













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SAT-SURFER Software Architecture



SAT-SURF & SURFER Features



- 1 Allows to log all the raw GPS and GSM data (both binary and NMEA Protocols)
- 2 Embeds different GPS modules depending on the user needs:
 - uBlox Modules
 - SiRF Modules
- 3 Equipped with a quad-band GSM/GPRS modem (worldwide coverage) for NAV/COM integration
- 4 Raw data storage in the various file formats for an easy post-processing:
 - ASCII, Excel® & MATLAB® files
 - RINEX 2/3 Log

| Disconnect Restart | ver kequests • Start Nil | ie stop imp to | | | | | |
|--|--|--|--|--|--|---|---|
| Messages | Navigation Data | | | | | | |
| Messages | Position Data | × | Y | 7 | DUPL | lata | |
| | Position (m) | 4472416.69 | 601433,6 | 4492690.93 | GDOF | 1,97 | PDOP 1.73 |
| | Velocity (m/s) | 0 | 0 | 0 | HDOF | 1,08 | VDOP 1,35 |
| | Error 3D (m) | 4492691753620 | Pos T | voe Stand Alone | GNSS | Time Data | |
| | Lathuda | 45:254.072 | Altère | 305,499 | WN | 1504 | TOW 486085.00 |
| ~ | Lanuoe | 40 304,372 | | 0 | | | 14 |
| | Longitude | 1.3532,251 | sheer | 0 | Leaps | Seconds | 19 |
| | SateliteData | | | | | | |
| | Satelites in Vie | w 12 | List of Satellite | es in View 367 | 15 16 18 19 21 22 | 25 26 27 | |
| SAT-Jun | Satelites in Fix | 11 | List of Satellite | es in Fix 367 | 15 16 18 19 21 22 | 25 27 | |
| | | GPS Tin UTC Tin | ne: 15:01: ne: 15:01: | 25 11 | GPS Da UTC Da | ate: C ate: C |)7/11/2008)7/11/2008 |
| Receiver Messages 1-30-200-5628 | Receiver Row D | GPS Tin UTC Tin Into Pseudorange | ne: 15:01: ne: 15:01: | 25 11 Carrier Phase | GPS Da UTC Da | ate: C ate: C |)7/11/2008)7/11/2008 |
| Receiver Messages 1 - 30 - 300 - 5528 1 - 22 - 231 - 456 - 27 - 152 - 252 - 27 - 152 - 252 - 27 - 152 - 252 - 27 - 27 - 27 - 27 - 27 - 27 - 2 | Receiver Raw D SallD (PRN) | GPS Tin UTC Tin Pseudorange [m] | ne: 15:01: ne: 15:01: Doppler (Hz) | 25 11 Carrier Phase [Cycles] | GPS Da UTC Da CN0 (dBHz) | ate: C ate: C |)7/11/2008)7/11/2008 |
| Receiver Messages 1.30: 200, 5828 1.20: 200, 5828 1.20: 10: 7673 1.20: 56: 7673 1.20: 56: 7673 | Receiver Raw D SallD (PRN) 25 | GPS Tin UTC Tin Pseudorange [m] 23849701,28 | Doppler (Hz) 822.8 | 25 11 Carrier Phase [Cycles] 106425924,324 | GPS Da UTC Da CN0 (dBHz) 41.0 | ate: C ate: C TOW [s] | 07/11/2008 07/11/2008 wn 1504 |
| Recher Messager 1-22: 20: 448 1-22: 20: 448 1-12: 3: 3262 1-12: 4: 3: 4: 356 1-12: 4: 3: 4: 356 1-12: 4: 3: 4: 356 1-12: 4: 4: 4: 3: 4: 356 1-12: 4: 4: 4: 3: 4: 4: 4: 4: 4: 4: 4: 4: 4: 4: 4: 4: 4: | Receiver Raw D | GPS Tin UTC Tin Pseudorange [m] 23849701,28 2351208,42 | Doppler (Hz) 822.8 1966.6 | 25 11 Carrier Phase [Cycles] 106425324,324 123657247,989 | GPS D: UTC D: CN0 (dBHz) 41,0 40,0 | ate: C ate: C TOW [s] 496084,998 496084,998 | 07/11/2008 07/11/2008 wn 1504 1504 |
| Receiver Messages 1.30: 200 - 5528 1.20: 200 - 5528 1.20: 201 - 5628 1.40: 867 - 5628 1.41: 87 - 8710 1.4: 87 - 8710 1.4: 87 - 8710 1.6: 22: 22: 100F 2: 22: 23: 24: 201 - 8752 | Receiver Row D Satil (PRN) 25 7 27 27 | GPS Tin UTC Tin Pseudorange [m] 23849701,28 23531208.42 24405480.49 | Doppler (Hz) 822.8 1966.6 2439.7 | 25 11 Carrier Phase [Cycles] 106425924,324 123657247,989 128251693,466 | GPS D: UTC D: CN0 (dBHz) 41.0 40.0 33.0 | ate: C ate: C TOW (s) 496084.998 496084.998 496084.998 | 07/11/2008 07/11/2008 07/11/2008 1504 1504 1504 1504 |
| Exercise Manager 1.22: 20: 468 1 1.23: 20: 468 1 1.24: 10: 16: 757 1 1.41: 16: F8110 1 1.45: 20: 100F 2 2.22: 20: 40: 80 1 | Receiver Rave D | GPS Tin UTC Tin Pseudorange [m] 23849701,28 23531208,42 24405480,49 24473978,82 24405480,49 | Doppler (Hz) 822,8 1966,6 2433,7 2418,7 | 25 11 Carrier Phase [Cycles] 106425324,324 123657247,399 128251593,466 128611594,106 | GPS D: UTC D: CN0 (dBHz) 41,0 40,0 33,0 40,0 50,0 | ate: C ate: C TOW [s] 486084.998 486084.998 486084.998 486084.998 | 07/11/2008 07/1000 07/1000000000000000000000000000 |
| Receiver Messages 1.30:200 5228 1.20:200 5228 1.20:201 5278 1.20:201 5278 1.20:201 5278 1.20:201 5278 2.201 5279 2.21:58 525 Accidation Messages | Receiver Raw D Saild (PRN) 25 7 7 27 15 6 6 21 | GPS Tin UTC Tin Pseudorange [n] 23631208.42 24405480.49 24473978.82 19582112.84 | Doppler (Hz) R0228 1966.6 2439.7 2418.7 2782.7 2792.7 | 25 11 Cartiel Phase [Cycles] 106425324,324 123657247,389 128251633,466 128611594,106 71396284,265 | GPS D: UTC D: CN0 (dBHz) 41.0 40.0 33.0 40.0 50.0 50.0 | ate: C ate: C TOW [1] 486084.998 486084.998 486084.998 486084.998 486084.998 | WN 1504 1504 1504 1504 1504 1504 |
| Bit Control Messages 1 - 20 - 300 - 5528 - 1 - 20 - 300 - 5528 - 1 - 20 - 100 - 5578 - 1 - 20 - 100 - 5578 - 1 - 4 - 18 - FB1C - 1 - 6 - 52 - 1057 - 2 - 7 - 54 - 5539 - Application Messages - Coordination Messages - | Receiver Raw D Recover Raw D Recov | GPS Tin UTC Tin Pseudorange [m] 23849701,28 23849701,28 23849701,28 24405460,49 24473978,82 19562112,84 21358097,42 2473978,82 | Doppler [Hz] 822,8 1966,6 2439,7 2418,7 2782,7 | 25 11 Carriet Phase [Cycles] 106425324,324 123657247,399 128251833,466 128611594,106 71396284,255 8033422,310 90365111,227 | GPS D: UTC D: 41.0 40.0 50.0 46.0 | ate: C ate: C TOW [1] 496084.998 496084.998 496084.998 496084.998 496084.998 496084.998 | 07/11/2008 07/11/2008 07/11/2008 1504 1504 1504 1504 1504 1504 |
| Paccher Metagge 1 - 25 - 25 - 258 1 - 25 - 25 - 258 1 - 25 - 25 - 258 1 - 25 - 25 - 258 1 - 25 - 25 - 258 2 - 25 - 258 2 - 25 - 258 2 - 25 - 258 2 - 25 - 258 CocePrimary INFO: Request Stat Receive | Receiver Raw D SailD (PRN) 25 7 27 15 6 21 22 16 | GPS Tin UTC Tin Pseudorange 23849701,28 23531208,42 24473978,82 15652112,84 21338097,42 20774555,45 20747555,45 | Doppler [H2] 622.8 1966.6 2433.7 2418.7 2782.7 -333.8 4188.0 -260.8 | 25 11 Corrier Phase (Cycles) 106425924,324 123657247,389 128251693,466 128611934,106 128611934,106 90266111,272 90266111,272 | GPS D: UTC D: 41.0 40.0 38.0 40.0 50.0 46.0 45.0 51.0 | TOW [s] TOW [s] 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 | 7/11/2008 7/11/2008 1504 1504 1504 1504 1504 1504 1504 1504 |
| Receiver Messages 1 - 22 - 20 - 646 1 - 22 - 20 - 646 1 - 22 - 20 - 646 1 - 22 - 20 - 646 1 - 22 - 20 - 646 1 - 24 - 20 - 646 1 - 4 - 18 - 5610 1 - 4 - 18 - 5610 2 - 21 - 64 - 2358 Application Messages Core/Imany/INFO: Request Stat Receives | Receiver Raw D SailD (PRN) 7 | GPS Tin UTC Tin Pseudorange [m] 2343701,28 23531208,42 24405480,49 24473978,82 19562112,84 21358097,42 20774559,45 20774559,45 20774559,45 | Depter [Hz] 8228 1966.6 2439.7 2418.7 2782.7 333.8 4180.0 -280.8 1995.0 | 25 11 Carriel Phase [0xcles] 106425924,324 123657247,389 128251893,466 128611934,106 12965111,272 75715365,309 90266111,272 75715365,309 90266111,272 | GPS D: UTC D: 41.0 40.0 50.0 46.0 45.0 45.0 45.0 45.0 45.0 45.0 45.0 | TOW [s] TOW [s] 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 486084.998 | 7/11/2008 7/11/2008 1504 1504 1504 1504 1504 1504 1504 1504 |
| Society Society 1 25 20 48 1 25 20 48 1 25 82 14 1 25 82 14 1 25 828 14 1 25 828 14 2 25 826 14 2 25 826 14 2 22 16 526 2 21 54 526 Application Messages 100 10 10 (CoePhinany) INFO. Request Stat Receiver 10 10 10 | Recover Ray D SulD (PRN) 27 15 6 21 12 18 18 19 3 | GPS Tin UTC Tin Preudorange [n] 23849701.28 23531200.42 24473978.82 24473978.82 24473978.82 24473978.82 24473978.82 24473978.82 24473978.82 24473978.82 24473978.82 24473978.82 1958276.76 20403393.40 20904544.85 | Depter [Hz] B228 1966.6 2418.7 2782.7 333.8 4188.0 -260.8 1995.0 3444.5 5 | 25 11 106425324,224 12825193,466 12825193,466 12825193,466 12825193,466 12825193,466 12825193,466 12825193,466 128254,255 9035411,272 75715336,309 9036111,272 75715336,309 9036111,272 | GPS D: UTC D: 41.0 40.0 50.0 46.0 51.0 51.0 43.0 51.0 40.0 | TOW [s] 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 486084.938 | 07/11/2008 07/10/1000 07/1000 07/10000000000000000 |
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SAT-SURF & SURFER Features



SAT-SURF is made of components of the shelf. The HW + SW tool is an innovative and complete GPS+GSM evaluation kit. It can be effectively used to test all the receiver features, Assisted-GPS strategies (OMA-SULP compliant) and/or Differential GPS techniques.

SAT-SURF & SAT-SURFER is a complete educational tool. It includes several exercises with solutions for students. This is then a perfect tool for a lab dedicated to ICT technologies.



SAT-SURF & SAT-SURFER is a ready-to-use tool. The tool has already been delivered to many education institutions such as Hanoi University of Technology (Vietnam), Asia Institute of Technology (Thailand) and Politecnico di Torino (Italy).



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Partnership

- SAT-SURF and SAT-SURFER have been designed and developed by the NavSAS Group and represents a technology transfer example;
- SAT-SURF is manufactured and distributed by SAET s.r.l., a high-tech Italian SME;
- SAT-SURFER has been written by the NavSAS Group.





www.navsas.eu

www.saetsrl.com



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Contact Information

NavSAS Group navigation@ismb.it Tel.: +39 011 2276200

Our web site: *http://www.navsas.eu*



Thank you for attention