Súradnicové systémy

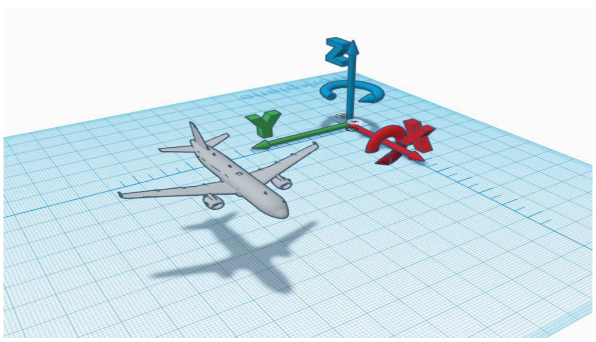
Kartézsky súradnicový sytém
René Descartes (Cartesius)
31. 3. 1596 – 11. 2. 1650
Francúzsky filozof, matematik a vedec.

Lat/Lon systém

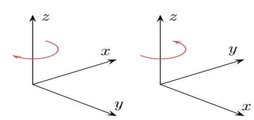
Valcové súradnice

Sférické súradnice

Súradnicové systémy: Kartézsky systém

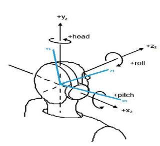


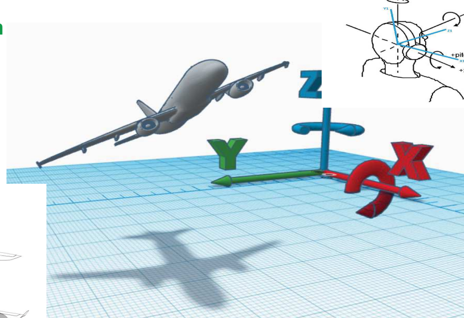
Right hand rule

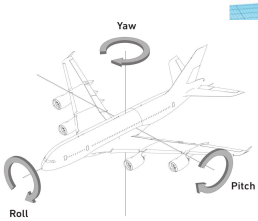


https://www.snb.ch/en/iabout/cash/series9/design_series9/id/cash_series9_design_200

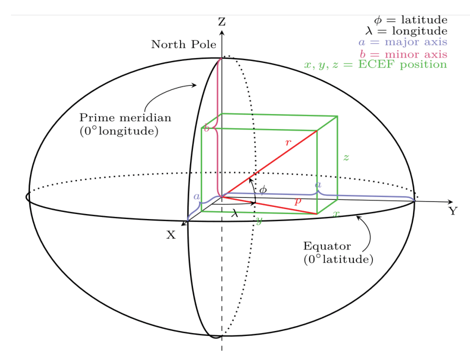
Priečny náklon roll
Pozdĺžny sklon pitch
Zatáčanie yaw



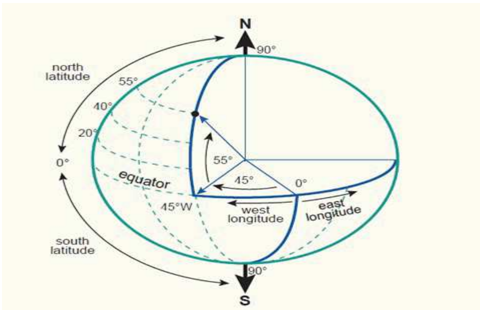




Súradnicové systémy



Súradnicové systémy



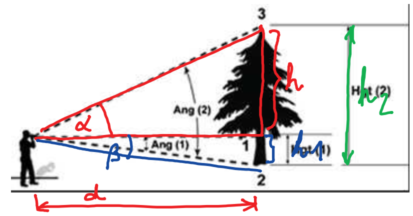
Triangulácia

$h = d \cdot tg\,\alpha$

$h_1 = d \cdot tg\,\beta$

(alebo odhad výšky postavy 1,8 m)

$h_2 = h + h_1$

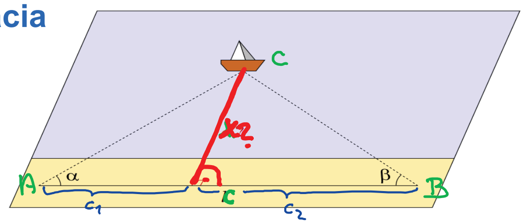


Triangulácia

$c = c_1 + c_2$

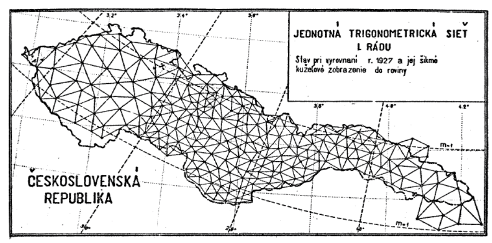
$tg\,\alpha = \frac{x}{c_1}$

$tg\,\beta = \frac{x}{c_2}$



$$x = c \cdot \frac{tg\,\alpha \cdot tg\,\beta}{tg\,\alpha + tg\,\beta}$$

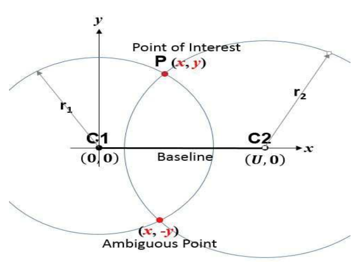
Triangulácia



Obr.1.1 Jednotná trigonometrická sieť I. rádu reprezentujúca pôvodnú realizáciu JTSK, prevzaté z (Abelovič, 1990).

Triangulácia

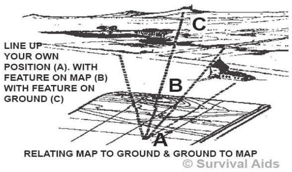
Trilaterácia

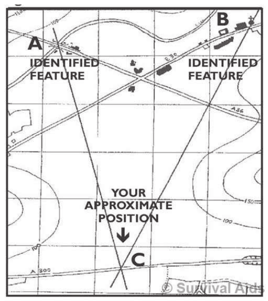


$$x = \frac{r_1^2 - r_2^2 + U^2}{2U}$$

$$y = \pm\sqrt{r_1^2 - x^2}$$

Navigácia: Kde som?

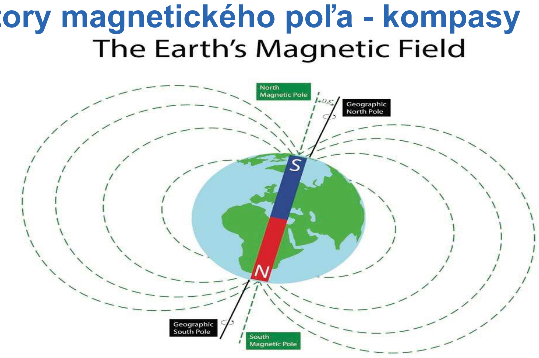


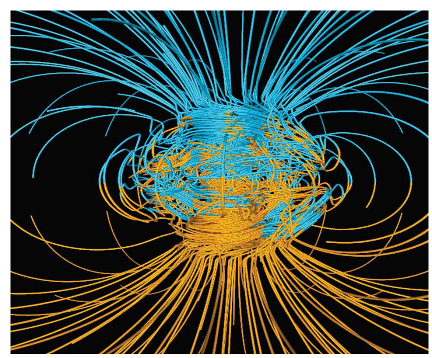


História: mapa + kompas

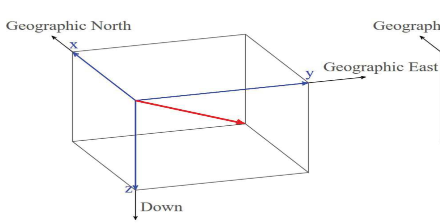
Model of a Han Dynasty (206 BC–220 AD) south-indicating ladle or sinan. It is theorized[by whom?] that the south-pointing spoons of the Han dynasty were magnetized lodestones.[28]

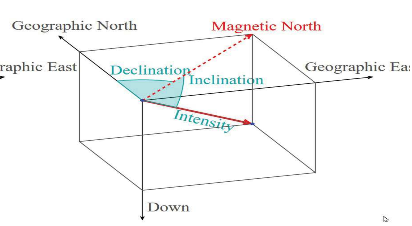
Senzory magnetického poľa - kompasy





https://en.wikipedia.org/wiki/Earth%27s_magnetic_field#/media/File:Geodynamo_Between_Reversals.gif



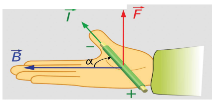


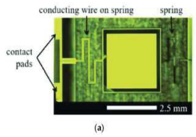
Magnetometer

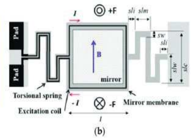
- AMR magnetometer
- GMR magnetometer
- Hall-Effect sensor
- Lorentz force-based MEMS sensor
- MEMS compass, and
- magnetic-field sensor

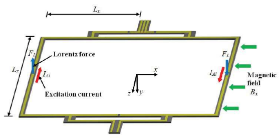
Lorentzova sila

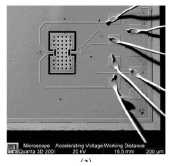
$$\mathbf{F} = I\boldsymbol{\ell} \times \mathbf{B}$$



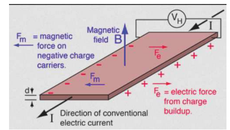








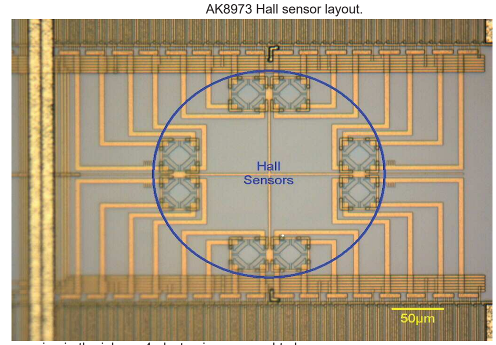
Hallov jav



$$V_H = \frac{I_x B_z}{nte}$$

Vychýlenie elektrónov spôsobuje Lorentzova sila

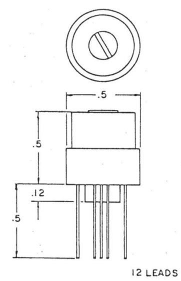
AK8973 Hall sensor layout.



https://www.memsjournal.com/2011/02/motion-sensing-in-the-iphone-4-electronic-compass.html

Dinsmore 1490

- miniature permanent magnet rotor
- jewel suspension + 4x Hall sensor
- response time 3.5 second (intentionally)
- weight 2.25 g
- temperature -20 – +85 deg C
- Vcc = 5 to 20 V

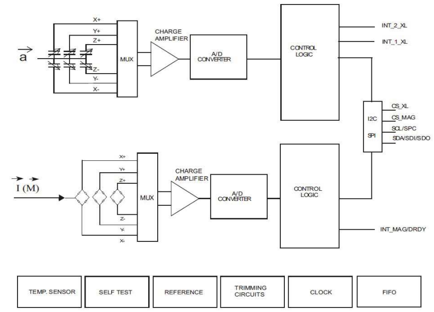


LSM303AGR

3 magnetic field channels
3 acceleration channels

- ±50 gauss magnetic dynamic range
- ±2/±4/±8/±16 *g* selectable acceleration full scales
- 16-bit data output
- SPI / I2C serial interfaces
- Analog supply 1.71 V to 3.6 V

Internal temperature sensor
Self test procedures



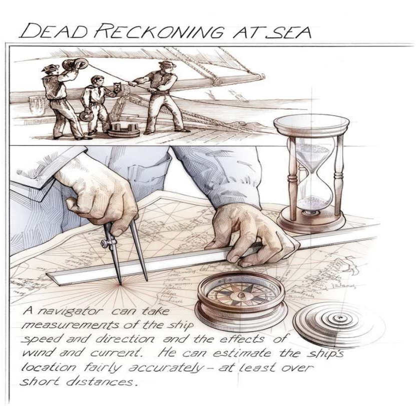
Dead reckoning

~~počítanie mŕtvych~~
– **navigácia výpočtom**

Polohu odvodíme od predošlých polôh na základe známeho smeru a rýchlosti

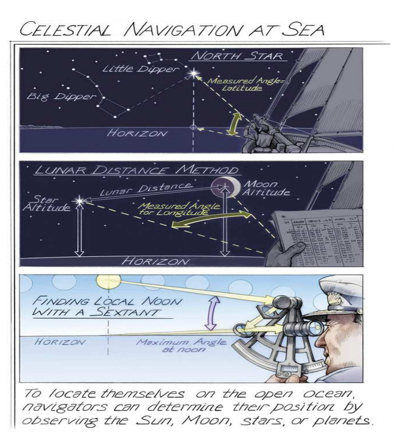
Odometria
– jedna z metód, používa sa odvaľovanie kolesa, alebo IRC snímač

Inerciálna jednotka



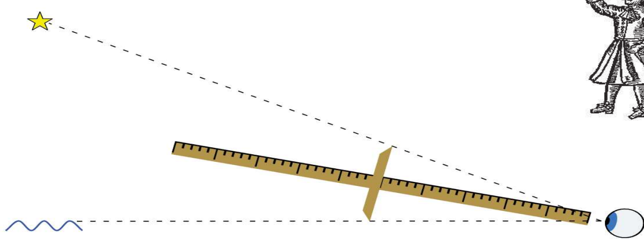
Navigácia na mori

– na mori ani vo vzduchu nemáme vhodné referenčné objekty



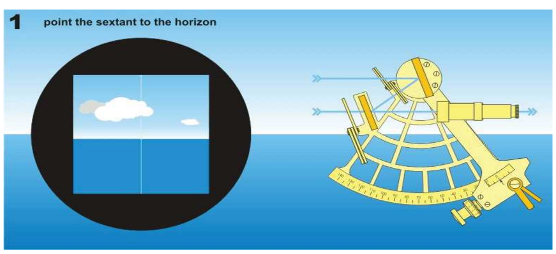
Hviezdna navigácia – Jakubova tyč

– na mori nemáme vhodné objekty

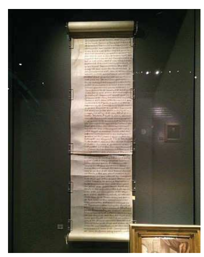


Hviezdna navigácia – sextant

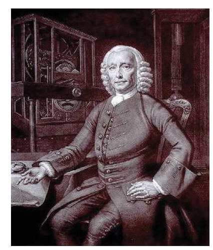
Hviezdna navigácia – sextant



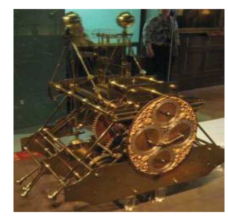
Zemepisná dĺžka – hodiny



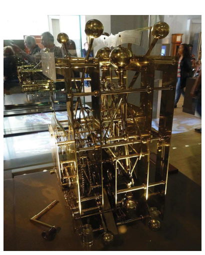
The Longitude Act 1714



John Harrison

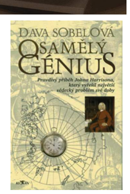


Chronometer H1



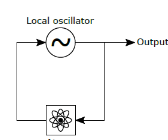
Chronometer H2

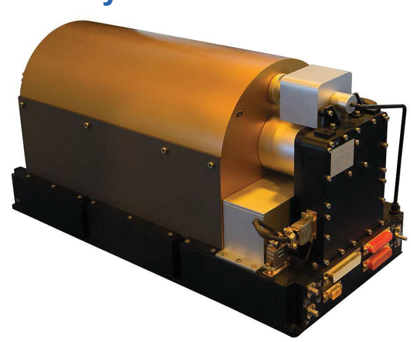
Chronometer H4



https://dennikn.sk/blog/1190155/pribeh-hodinara-ktory-vyriesil-jeden-z-najpalcivejsich-vedeckych-problemov-osemnasteho-storocia/

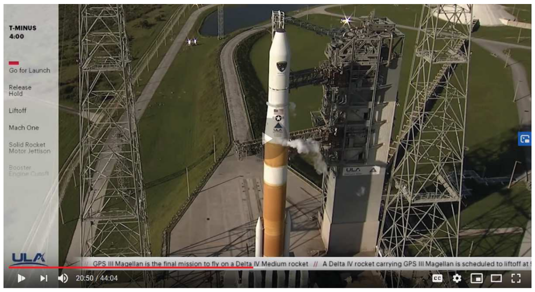
Atómové hodiny





Space Passive Hydrogen Maser used in ESA Galileo satellites as a master clock for an onboard timing system

Introduction video

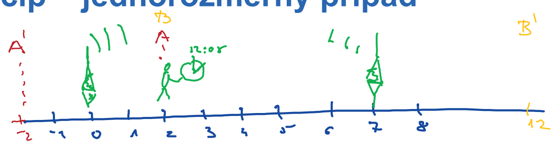


https://youtu.be/0AgiyxDoXtE?t=1539

Global Navigation Satellite System

GNSS

Princíp – jednorozmerný prípad



a) jeden vysielač: Na svojich hodinkách vidím 12:05
a počujem: „Som vysielač Ø a je 12:03"
=> som 2 min od bodu 'Ø' => A, resp. A'

b) dva vysielače: Na hodinkách vidím 12:05
a počujem: „Som vysielač Ø a je 12:03"
„Som vysielač 7 a je 12:00"
=> prienik bodov B a B' => poloha je A∩B

Čo ak nemáme presné hodinky na ruke?

Počujem: Som 'Ø' a je 12:03
Som '7' a je 12:00

Je čas 12:0t } neznáme,
ale viem, že: 'Ø' a '7' sú vzdialené 7 − 0 = 7

Takže $(t-3) + (t-0) = 7$ (od 'Ø', od '7')

$t - 3 + t - 0 = 7$

$2t = 10$

$t = 5$ => je čas 12:05 a viem koľko je hodín

Princíp v rovine – priamka, rovina

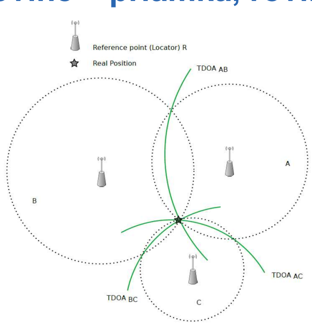
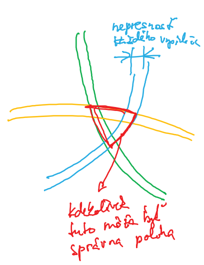
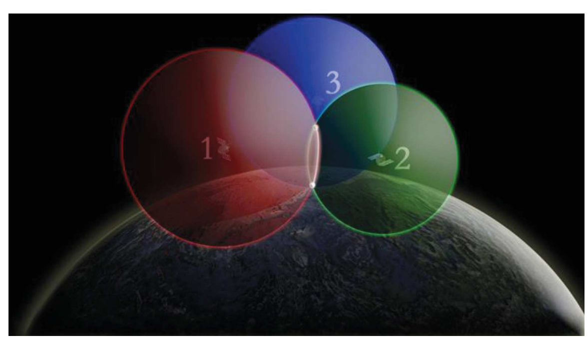


Figure 6. Time difference of arrival (TDoA)-based algorithms.

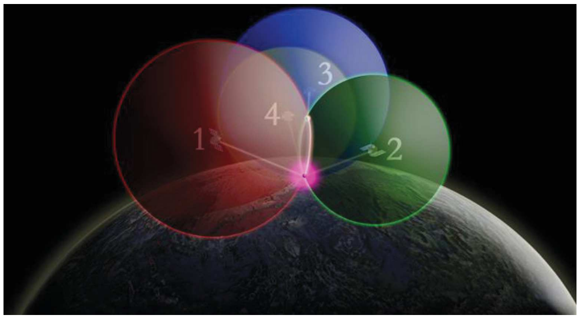
Každé meranie je zaťažené nepresnosťou:

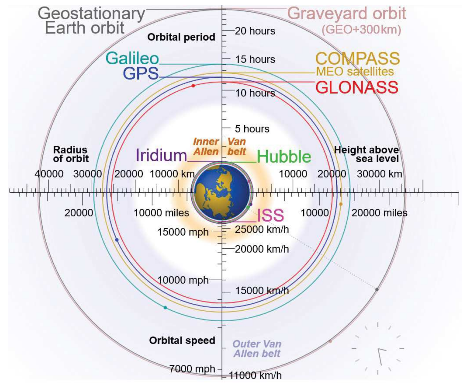


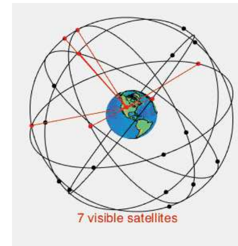
V priestore



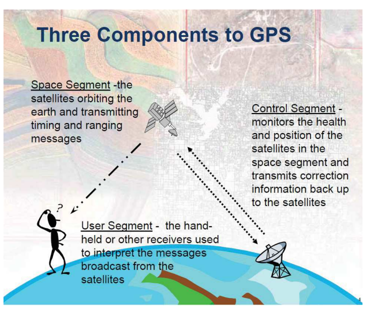
V priestore





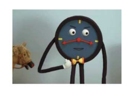


Tri segmenty GPS



GPS = hodiny

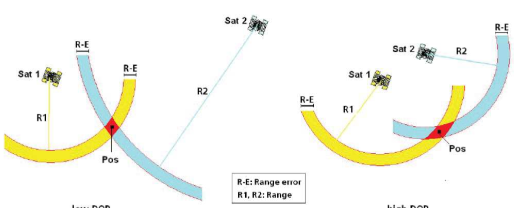
The Clock Problem



- To measure distance from speed of light we need a VERY accurate clock
  (clock error of 1/100 sec = distance error of 3000 km!).
- GPS Satellites have very accurate atomic clocks.
- Our receivers do not have atomic clocks, so how can we measure time with necessary accuracy?

Satellite Geometry

Presnost'

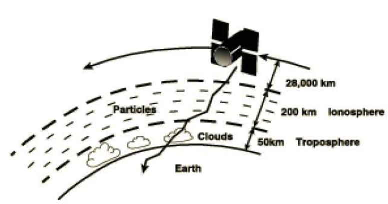


Atmospheric Effect

Presnost'

- GPS signal slowed down through the charged particles of the ionosphere and then through the water vapor in the troposphere

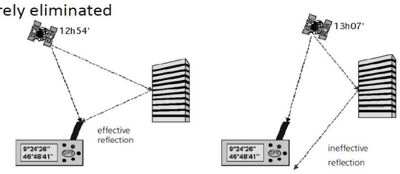
- Must correct for atmospheric effects with modeling



Multi-Path

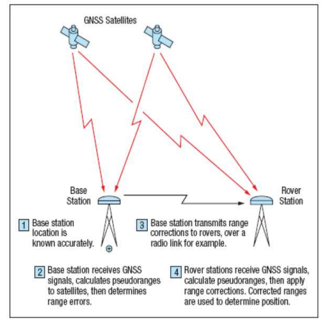
Presnosť

- Signals can be reflected on the way to the receiver. This is called “multipath propagation”
- These reflected signals are delayed from the direct signal, and if strong enough, can interfere with the direct signal
- Techniques have been developed whereby the receiver only considers the earliest-arriving signals and ignore multipath signals, which arrives later
- It cannot be entirely eliminated



Differential GPS (DGPS)

- Differential GNSS uses a fixed GNSS receiver, referred to as “base station” to transmit corrections to the rover station for improved positioning
- Error due to signal transmission through the atmosphere can be corrected using DGPS
- Atmospheric errors are the same over short distances.
- Error in base station, can be removed from remote (roving) receiver position, and code phase signal.



NMEA 0183

National Marine Electronics Association standard

combined **electrical** and **data** specification for communication between *marine electronics*
echo sounder, sonars, anemometer, gyrocompass, autopilot, GPS receivers,...

electrical EIA-422 (most hardware also EIA-232),
typ. Baud rate 4800, 8 data, none parity, 1 stop, no handshake

data – simple ASCII, serial protocol, data are transmitted in a "sentence"

`$XXYYY,a1,a2,a3,....,an*cc<CR><LF>`

XX: **GP** – GPS, **GL** – GLONASS, **GA** - Galileo
YYY: **RMC** - recommended minimum data - základné údaje, ktoré poskytujú všetky prijímače
GGA - sada údajov o odchýlkach pre presnejšiu lokalizáciu
GSA - zoznam čísiel max. 12 satelitov, použitých pre navigáciu
GSV – podrobnejšie údaje o sateliteoch - sila signálu a poloha na oblohe
GLL - Lat/Lon - len geografická poloha a čas (podmnožina údajov RMC)

NMEA 0183

RMC veta

$GPRMC, 161229.487,A,3723.2475,N,12158.3416,W,0.13,309.62,120598, ,*10

Table 1-11 RMC Data Format

Name	Example	Units	Description
Message ID	$GPRMC		RMC protocol header
UTC Time	161229.487		hhmmss.sss
Status[1]	A		A=data valid or V=data not valid
Latitude	3723.2475		ddmm.mmmm
N/S Indicator	N		N=north or S=south
Longitude	12158.3416		dddmm.mmmm
E/W Indicator	W		E=east or W=west
Speed Over Ground	0.13	knots	
Course Over Ground	309.62	degrees	True
Date	120598		ddmmyy
Magnetic Variation[2]		degrees	E=east or W=west
Mode	*A*		*A=Autonomous, D=DGPS, E=DR*
Checksum	*10		
<CR> <LF>			End of message termination

1. A valid status is derived from the SiRF Binary M.I.D 2 position mode 1. See the *SiRF Binary Protocol Reference Manual.*
2. SiRF Technology Inc. does not support magnetic declination. All “course over ground” data are geodetic WGS84 directions.

NMEA 0183

GLL veta

$GPGLL, 3723.2475,N,12158.3416,W,161229.487,A,A*41

Table 1-5 GLL Data Format

Name	Example	Units	Description
Message ID	$GPGLL		GLL protocol header
Latitude	3723.2475		ddmm.mmmm
N/S Indicator	N		N=north or S=south
Longitude	12158.3416		dddmm.mmmm
E/W Indicator	W		E=east or W=west
UTC Time	161229.487		hhmmss.sss
Status	A		A=data valid or V=data not valid
Mode	*A*		*A=Autonomous, D=DGPS, E=DR* *(Only present in NMEA version 3.00)*
Checksum	*41		
<CR> <LF>			End of message termination

Copernicus II (12 Channel)

Trimble

Size : 19x19x2.54mm
Sensitivity : -160dBm
Time to First Lock (cold start) : 38 sec
Dual serial ports with reconfigurable UART rates
NMEA, TSIP, and TAIP protocols

Update rate	
TSIP	1 Hz
NMEA	1 Hz
TAIP	1 Hz
Accuracy (24 hour static)	
Horizontal (without SBAS)	<2.5 m 50%, <5 m 90%
Horizontal (with SBAS)	<2.0 m 50%, <4 m 90%
Altitude (without SBAS)	<5 m 50%, <8 m 90%
Altitude (with SBAS)	<3 m 50%, <5 m 90%
Velocity	0.06 m/sec
PPS (static)	±60 ns RMS
PPS (stationary mode indoors at –145 dBm)	±350 ns RMS

Update rate	
TSIP	1 Hz
NMEA	1 Hz
TAIP	1 Hz
Accuracy (24 hour static)	
Horizontal (without SBAS)	<2.5 m 50%, <5 m 90%
Horizontal (with SBAS)	<2.0 m 50%, <4 m 90%
Altitude (without SBAS)	<5 m 50%, <8 m 90%
Altitude (with SBAS)	<3 m 50%, <5 m 90%
Velocity	0.06 m/sec
PPS (static)	±60 ns RMS
PPS (stationary mode indoors at –145 dBm)	±350 ns RMS

NEO-6

50 Channels	
GPS L1 frequency, C/A Code	
SBAS: WAAS, EGNOS, MSAS	
	NEO-6G/Q/T
Cold Start[2]	26 s
Warm Start[2]	26 s
Hot Start[2]	1 s
Aided Starts[3]	1 s
	NEO-6G/Q/T
Tracking & Navigation	-162 dBm
Reacquisition[5]	-160 dBm
Cold Start (without aiding)	-148 dBm
Hot Start	-157 dBm
	NEO-6G/Q/M/T
	5Hz
GPS	2.5 m
SBAS	2.0 m
SBAS + PPP[7]	< 1 m (2D, R50)[8]
SBAS + PPP[7]	< 2 m (3D, R50)[8]

Accuracy: 1.8m
Search channels: 66
Tracking channels: 22
Sensitivity: -165dBm
Update rate: 10Hz

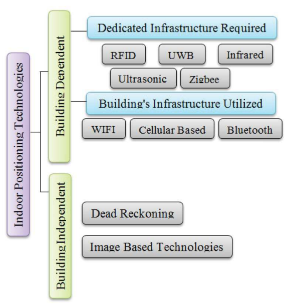
BCM47755

1. ARM-based 32-bit Cortex-M4F
2. ARM-based Cortex-M0

Simultaneously receive the following signals:

GPS L1 C/A
GLONASS L1
BeiDou (BDS) B1
QZSS L1
Galileo (GAL) E1
GPS L5
Galileo E5a
QZSS L5

Indoor navigation



Real Time Location Systems

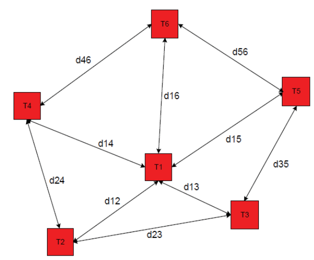


Figure 3: Relative location among a group of nodes

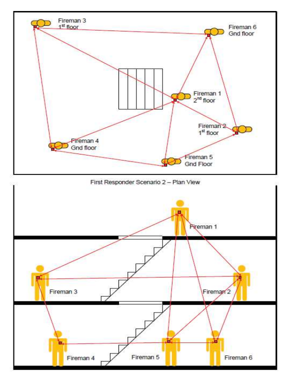


Figure 4: First responder scenario

Real Time Location Systems

A – anchor (kotva)

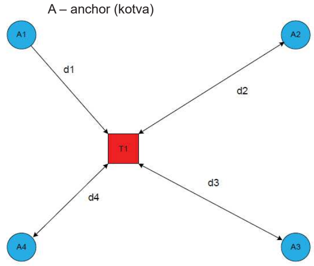


Figure 2: RTLS with fixed infrastructure

Sledovanie a lokalizácia pacientov a materiálu v zdravotníctve

Sledovanie a lokalizácia tovaru a balíkov, paliet v skladoch a logistike.

Sledovanie a monitoring zvierat v živočíšnej výrobe

Sledovanie stavu a pohybu materiálu, zásob, polotovarov v priemyselnej výrobe.

Real Time Location Systems

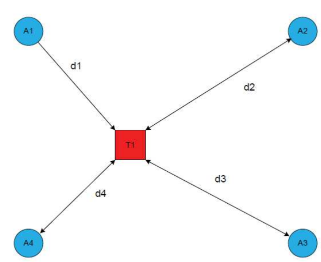


Figure 2: RTLS with fixed infrastructure

Evaluation:

Received Signal Strength (RSS)

Time Of Arrival (TOA)

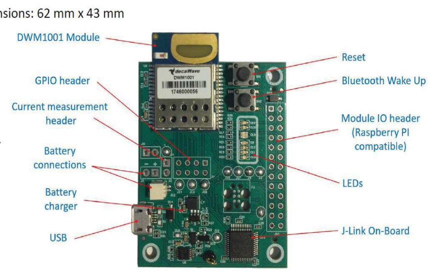
Time Difference Of Arrival (TDOA)

Angle of arrival (AOA)

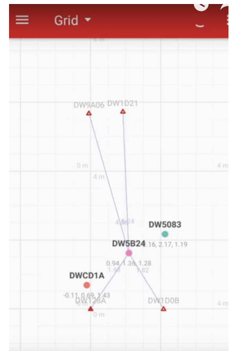
Ultra Wideband (UWB) transceiver
Decawave DW1000

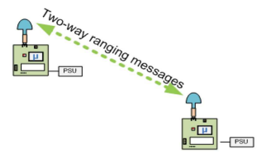
Key Features

- Ranging accuracy to within 10cm
- UWB Channel 5 PCB antenna (6.5 GHz)
- 6.8 Mbps data rate
- 60 m line-of-sight range typical
- IEEE802.15.4-2011 UWB compliant
- Nordic Semiconductor nRF52832
- Bluetooth®connectivity with antenna
- Motion sensor: 3-axis accelerometer
- Current consumption sleep mode: <15μA
- Supply voltage: 2.8 V to 3.6 V
- Size: 19.1 mm x 26.2 mm x 2.6 mm



Ultra Wideband (UWB) transceiver
Decawave DW1000





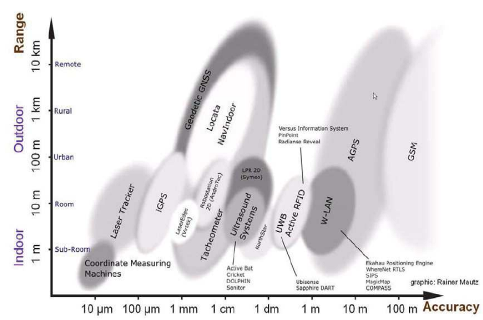
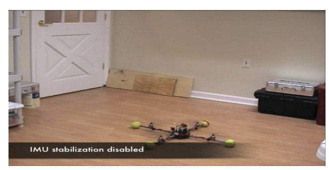
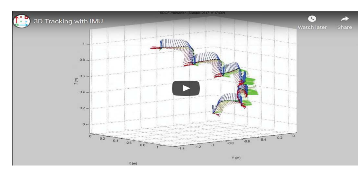


Figure 2.1: Overview of infrastructure-based indoor positioning methods and according accuracies as presented by Mautz (2009)

Lokalizácia a navigácia s mapou prostredia
Inertial Measurement Unit (IMU)

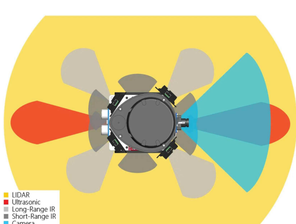
https://www.youtube.com/watch?v=TJIntyaSNqM

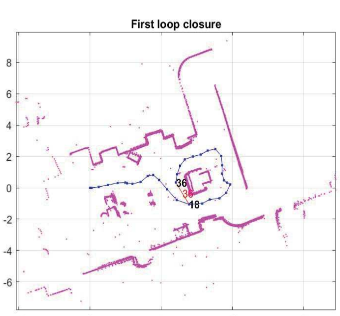




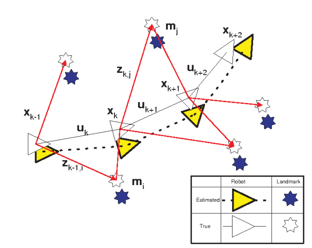
https://x-io.co.uk/gait-tracking-with-x-imu/

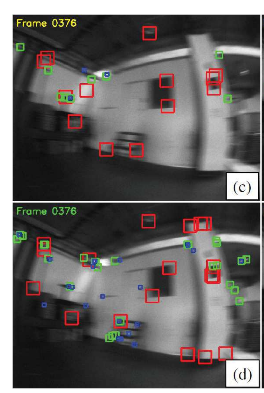
10. Lokalizácia a navigácia bez mapy
Simultaneous Localization and Mapping (SLAM)



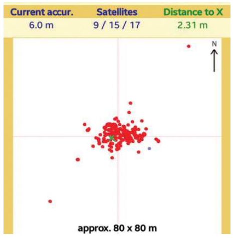


10. Lokalizácia a navigácia
Visual SLAM

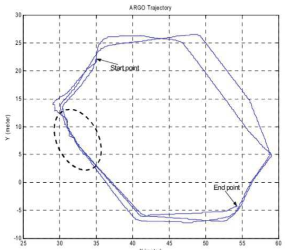




Cvičenia



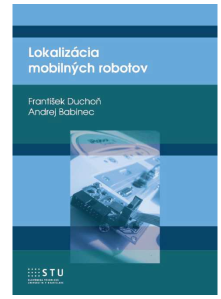
6 hodín merania



3x: polygón 1 km peši
4 km autom

http://senzor.robotika.sk/sensorwiki/index.php/Meranie_s_GPS

Chcem vedieť viac...



http://www-personal.umich.edu/~johannb/Papers/pos96rep.pdf