GNSS Introduction

Fabio Dovis

Electronics Department

Outline

- Introduction
- The radionavigation principles
- Position estimation
- Measurements errors
- The GPS system
- The GPS signal-in-space
- Galileo system description
- The Galileo signals

Bibliography

- Kaplan, E. D., *Understanding GPS: principles and applications*, Artech House, Norhood, MA, 1996

- Parkinson B., Spilker J. J. , *Global Positioning System: theory and applications*, *Vol.I e Vol. II*, American Institute of Aeronautics, 1996.

- Misra P., Enge P. *Global Positioning System: Signals, Measurements, and Performance*, Ganga-Jamuna press (http://www.navtechgps.com/)

- Tsui, J. B. Y., *Fundamentals of Global Positioning System*, John Wiley & Sons, New York, 2000.

Part I

Definitions

Definition: NAVIGATION

- "*To drive in a safe and secure mode a mobile from a starting point to its final destination*"
- Navigation is by definition a "real-time" process
- The movement is involved
- The position determination must be obtained and maintained on a temporal scale consistent with the mobile speed
- To be considered as a "navigation aid" a system must be:
  - Able to provide a navigation information in a suitable time;
  - Needed for the mobile safety;

(*From the definition within the radionavigation plans*)

Definitions: Localisation and Positioning

- In some cases the position of a mobile is needed for purposes different from navigation
  - Emergency
  - Security
  - Mapping
  - Location of points of interest
  -
- Such systems are not required to be strictly “real time”
- Their performance not necessarily are influencing maneuvers or driving systems

Radionavigation principles

- Determination of position and speed of a mobile by means of the estimation of parameters of an electromagnetic signal
  - Propagation time
  - Phase
  -
- In many cases such parameters are converted to estimated distances and the position is obtained by the intersection of geometrical loci (trilateration)

Position estimation: conical systems

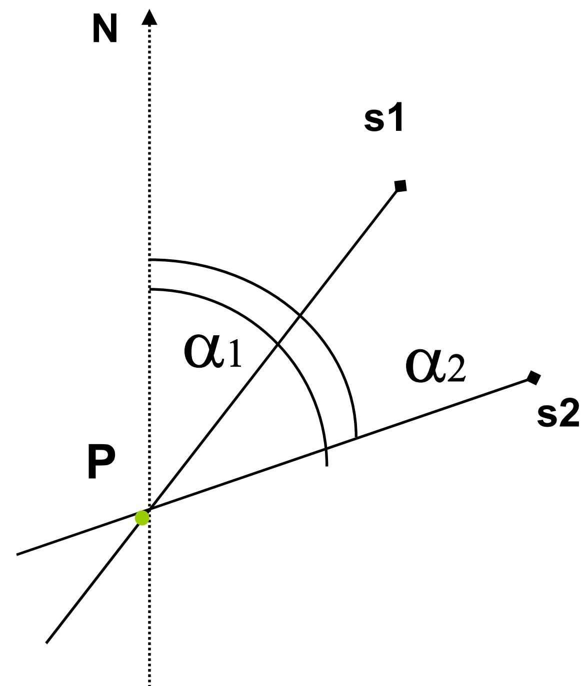
The position is obtained by the intersection of straight lines or cones

Transmitters must be at known locations

The receiver estimates the Angle of Arrival (AOA)

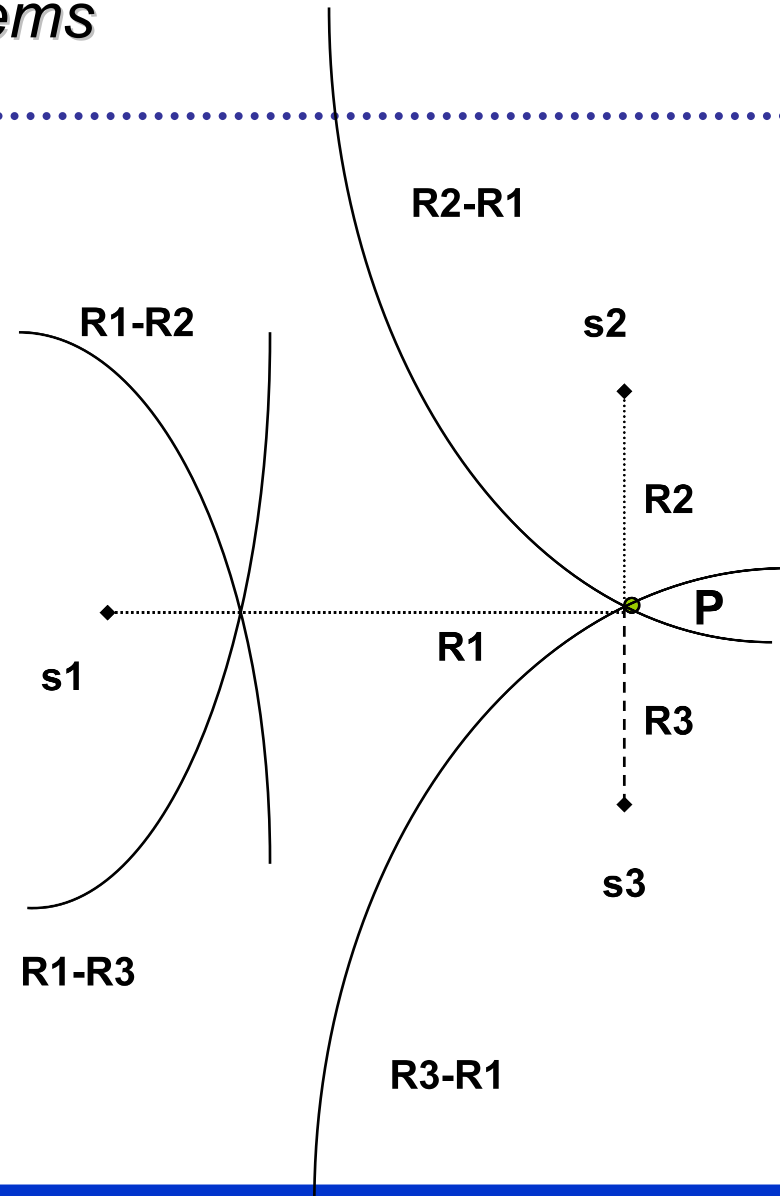
The estimation can be based on

- Antenna arrays
- Radiation patterns (e.g. VOR system)
- Doppler measurements



Position estimation: hyperbolic systems

- Sources placed at known locations (foci)
- The receiver measures the time difference between the propagation times (TDOA) of the signals coming from two sources
- The position is obtained by the intersection of at least two hyperbola (in a 2-dimension domain)
- Examples: OMEGA, DECCA, LORAN-C, TRANSIT

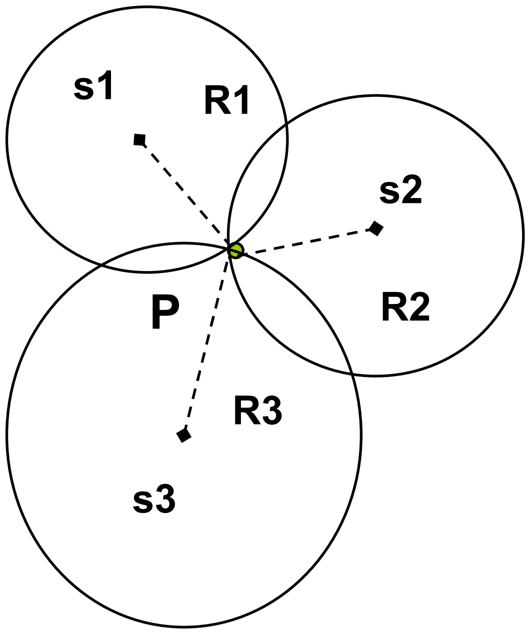


Position estimation: hyperbolic systems

- In general, it is easier (and cost-effective) to measure the distance difference with respect to the distance absolute values

Position estimation: spheric systems

- Sources placed at known locations
- The receiver evaluates a parameter of the signal incoming from the sources whose value is proportional to the distance
  - time of arrival (TOA): the signals must be timestamped with the transmission time
  - received signal strength
- estimates the spheres centered in the sources
- The position must be inferred by the intersection of at least three spheres.
- E.g.: GPS, GLONASS, Galileo



Position estimation: spheric systems

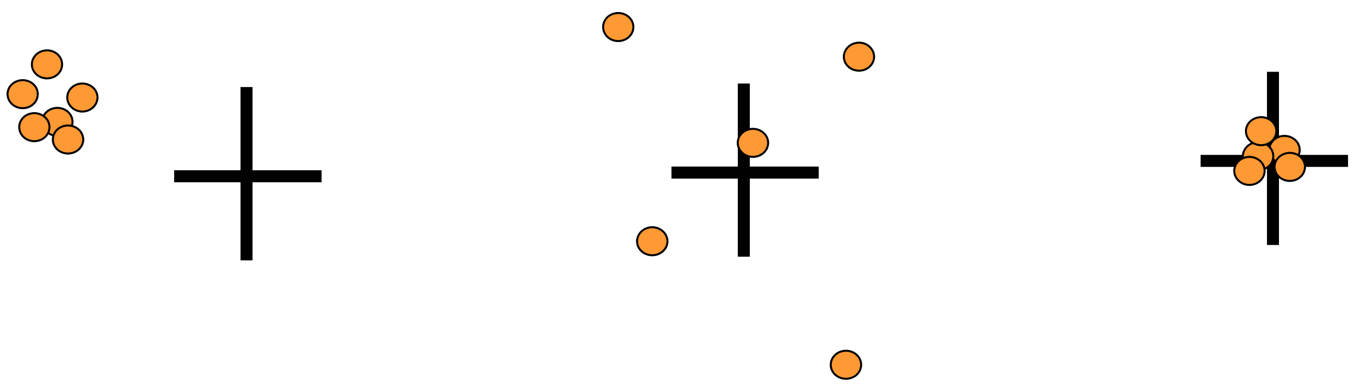
- A sphere is defined by:
  - center (TX location)
  - radius (defined estimating the TOA or RSS)
- The time estimation can be performed as
- Two ways: the time needed to reach and come back is measured (*round-trip time*)
  - transmitters can be not synchronized
  - a precise time reference is not required
  - “privacy” problems, the user is seen by the system
- One way:
  - the users only receive the signal
  - transmitters must be synchronous with high precision (within 10 ns)

Definitions: Accuracy and precision

- The position determination is always an estimate based on measurements
- The presence of disturbances, propagation errors, etc. can be modeled as random factors affecting the estimated position that is thus modeled as a random variable
- Performance of a positioning procedure can be evaluated in a stocastic way, using statistical parameters:
  - Mean
  - Variance (or standard deviation)

Definitions: Accuracy and Precision

- Accuracy: measure of how close a point is to its true position
- Precision: measure of how closely the estimated points are in relation to each other

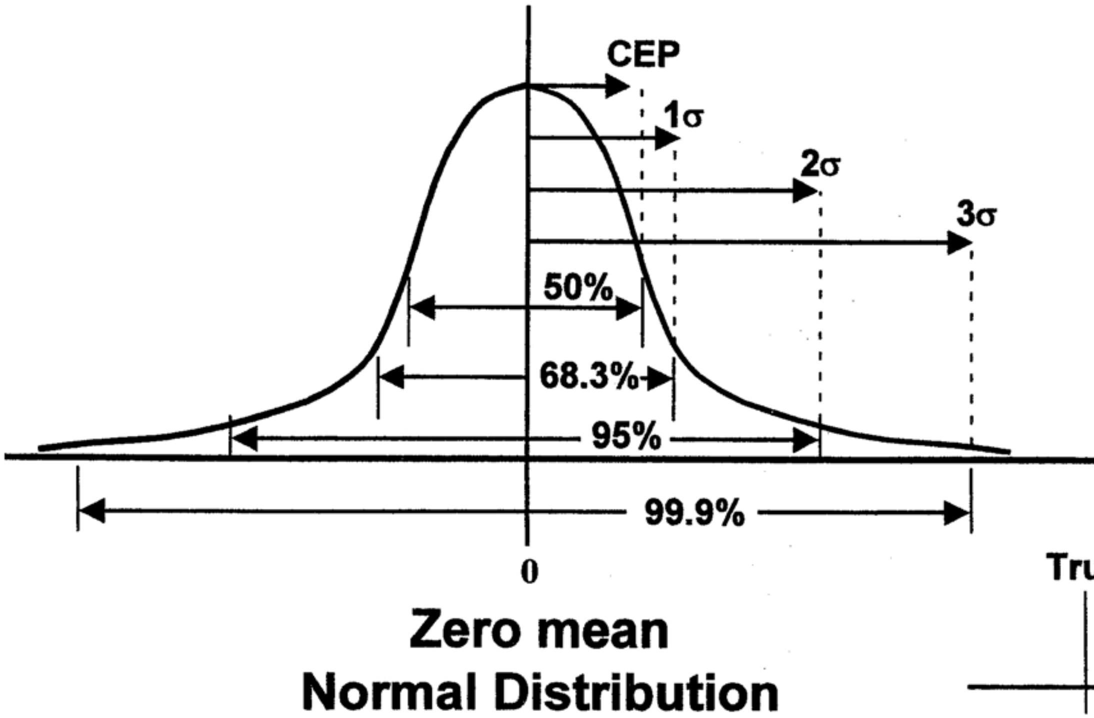


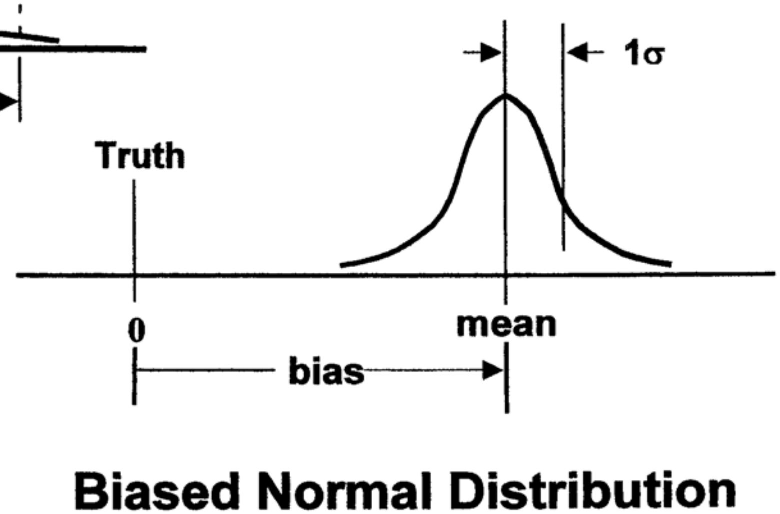
High precision
Low Accuracy

Low precision
Low Accuracy

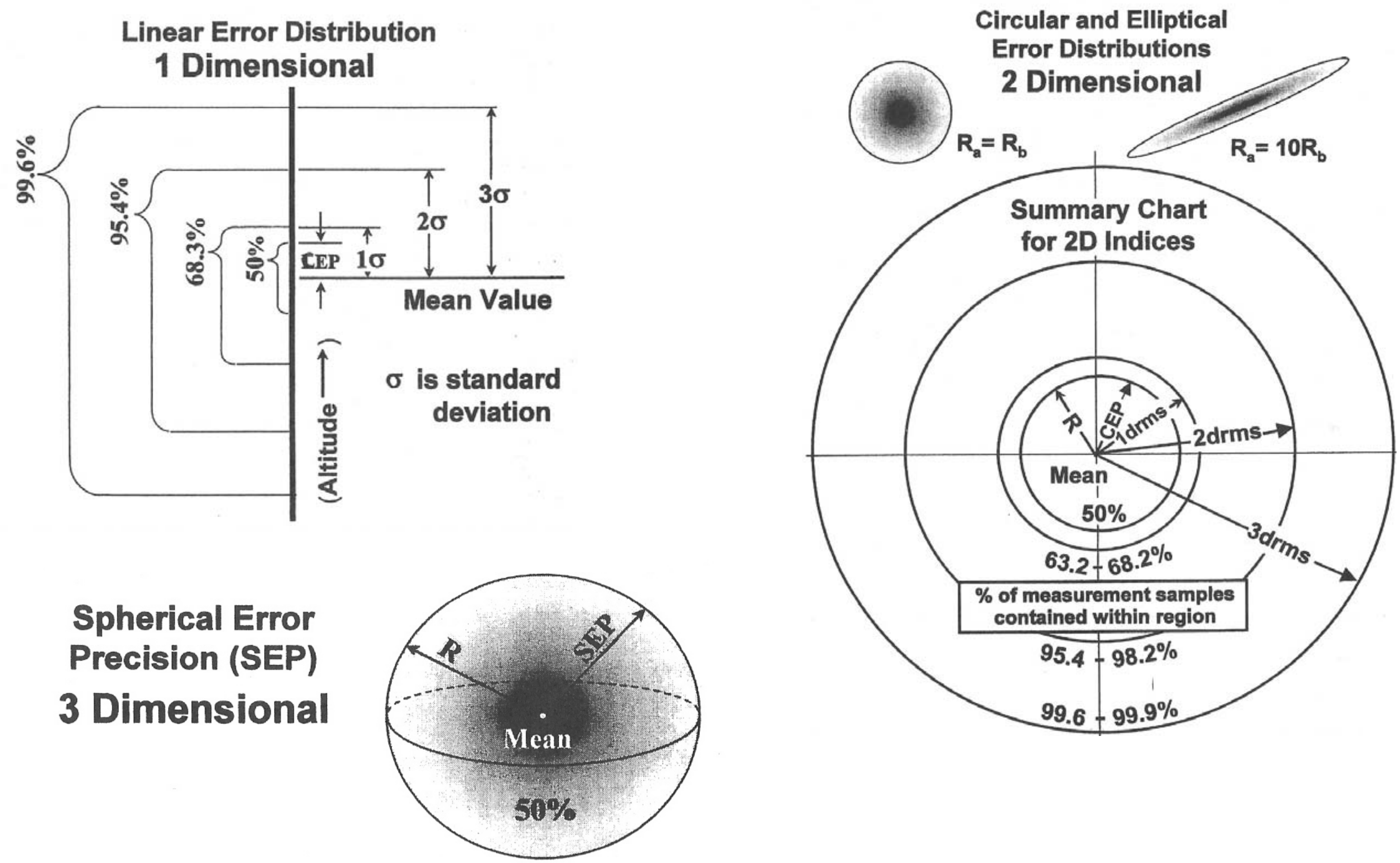
High precision
High Accuracy

Example: Gaussian distribution





Accuracy indexes



End of Part I