AE 242
Aerospace Measurements Laboratory

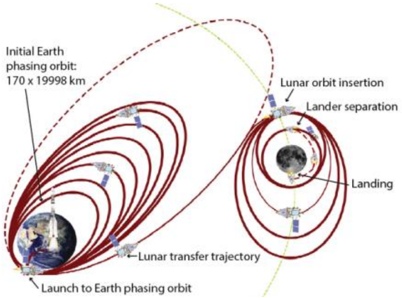
Position measurement

Robots operating in factory

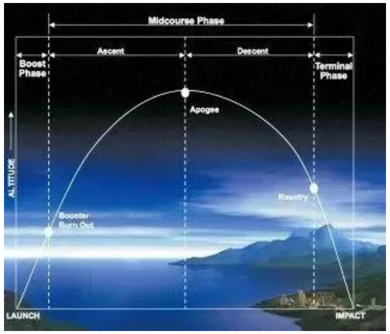
Driverless car

Maps for navigation

Maps for adventure



Inter planetary mission



Ballistic missiles

Presentation material from book "Understanding GPS principles and applications"
by
Elliot D. Kaplan and Christopher J. Hegarty (editors)

Use of GPS / GNSS

GNSS - Global Navigation Satellite System

GPS - Introduction

- GPS – Global Positioning system
- Owned and operate by DoD, USA
- Similar to radio service
- Free to use service
- Designed in such a way that can be used over the whole globe
- Consist of three segment: Space, Control & Monitor and user

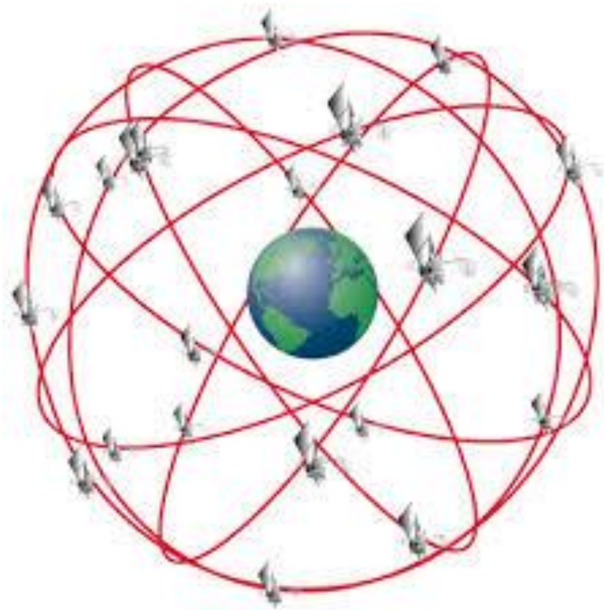
GPS - Introduction

- Space- Space vehicle (satellites)
- Control & Monitor – Few stations on the ground, which monitor satellite motion, clock etc. sends correction terms to satellite for rebroadcast
- **User – Radio receiver for processing information received from GPS satellites**

IRNSS - Introduction

- IRNSS – Indian Regional Navigation Satellite System. NavIc
- Owned and operate by ISRO, India
- Similar to radio service
- Free to use service
- Designed in such a way that it can be used over the Indian subcontinent. 1500 km from Indian Boundary
- Consist of three segment: Space, Control & Monitor and user

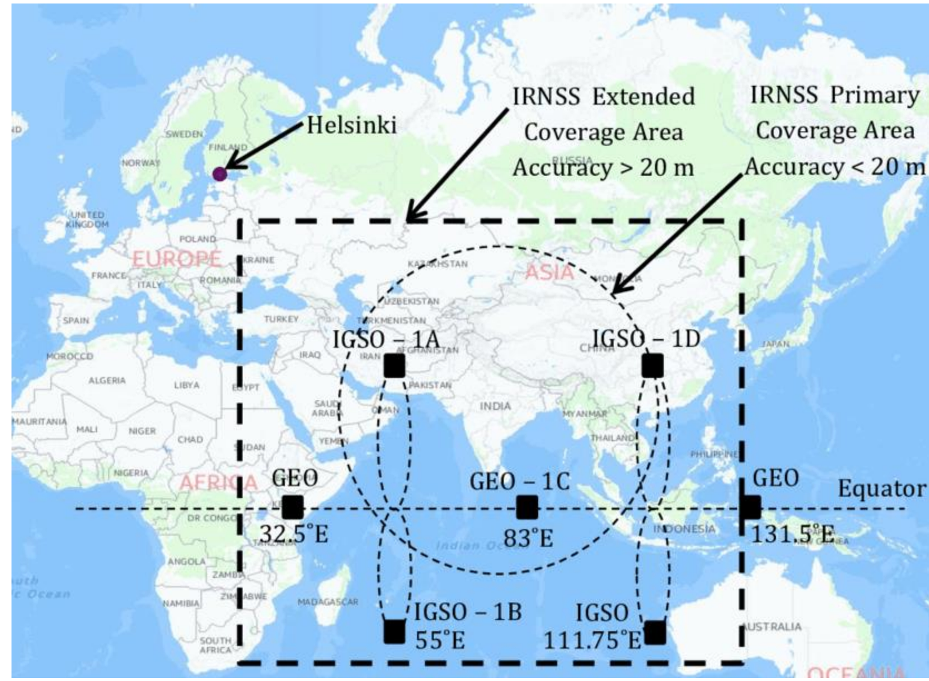
GPS and IRNSS



GPS constellation

- 24 satellites at 20200 km
- Mean orbital period is ~ 12 hours
- Four or more satellites visible over the globe

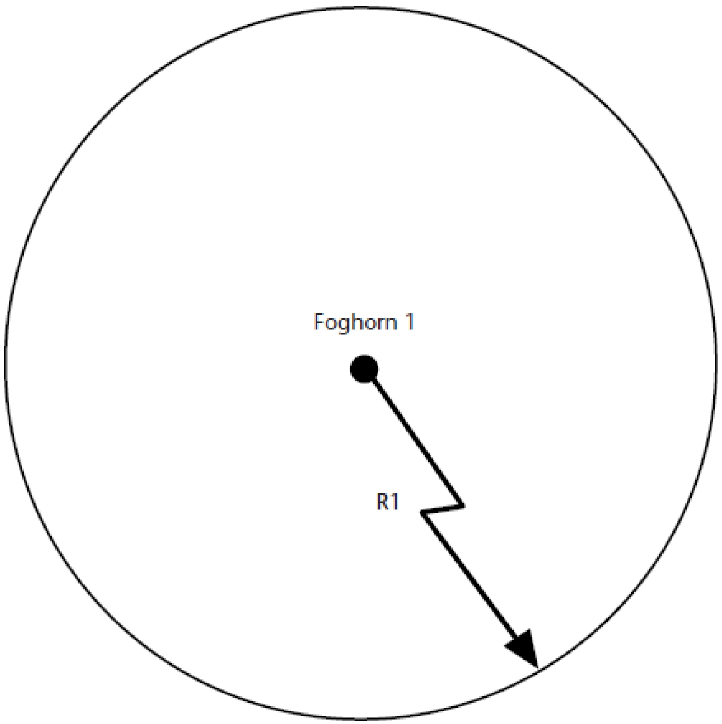
https://en.wikipedia.org/wiki/Global_Positioning_System



IRNSS constellation

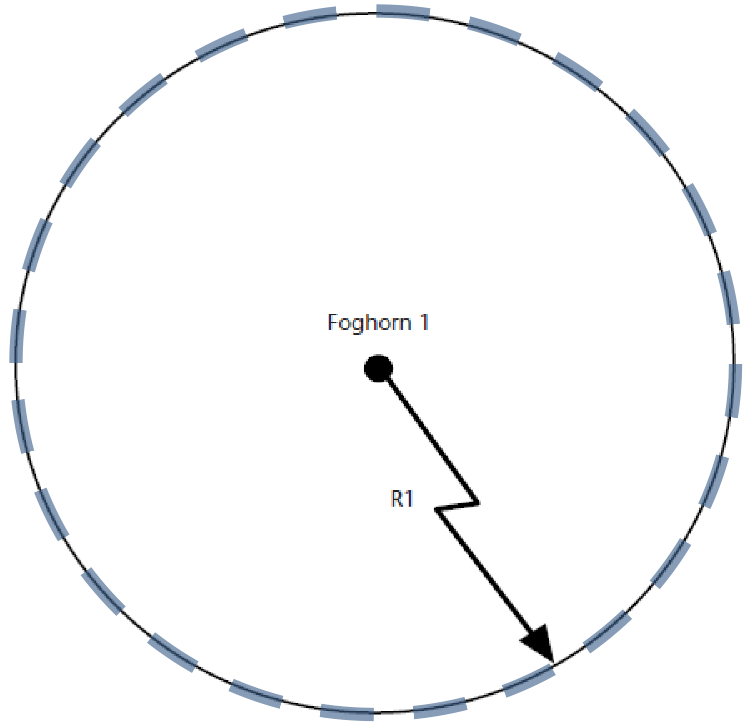
- Orbital height – 36000 km
- Three Geo stationary
- Four Geosynchronous
- Four or more satellites visible over IRNSS primary coverage area
- https://www.isro.gov.in/irnss-programme
- https://en.wikipedia.org/wiki/Indian_Regional_Navigation_Satellite_System

Ranging using TOA Measurements



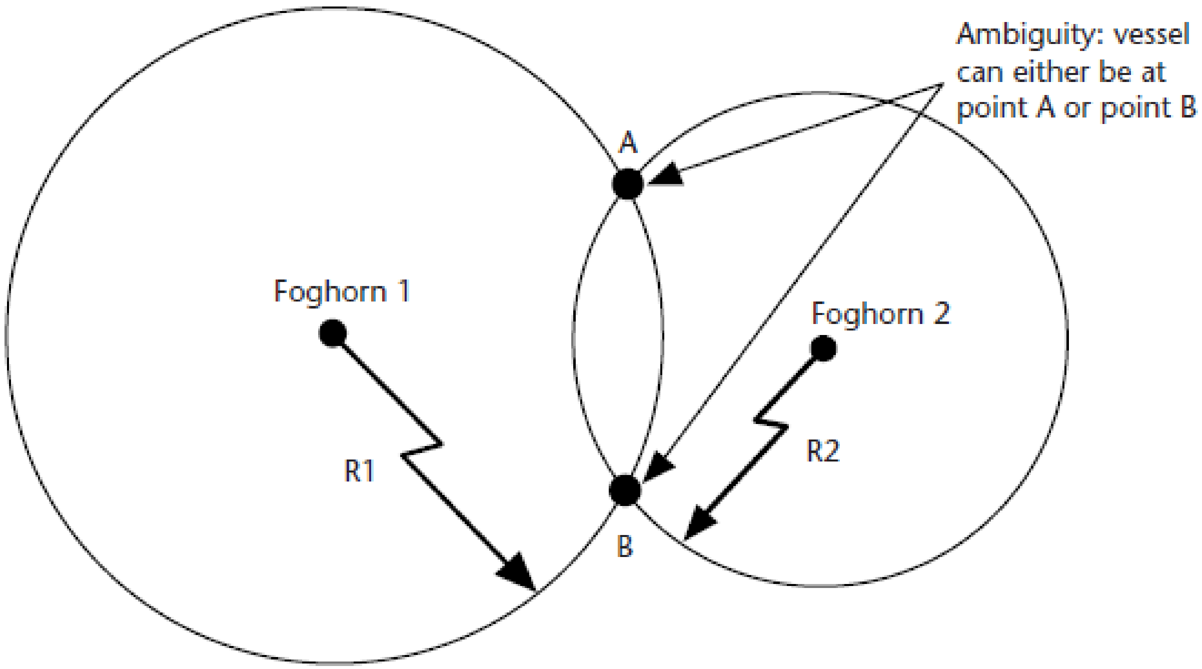
- Transmitter (Foghorn) – Transmitting signal at regular interval
- *How to find distance from foghorn?*

Ranging using TOA Measurements



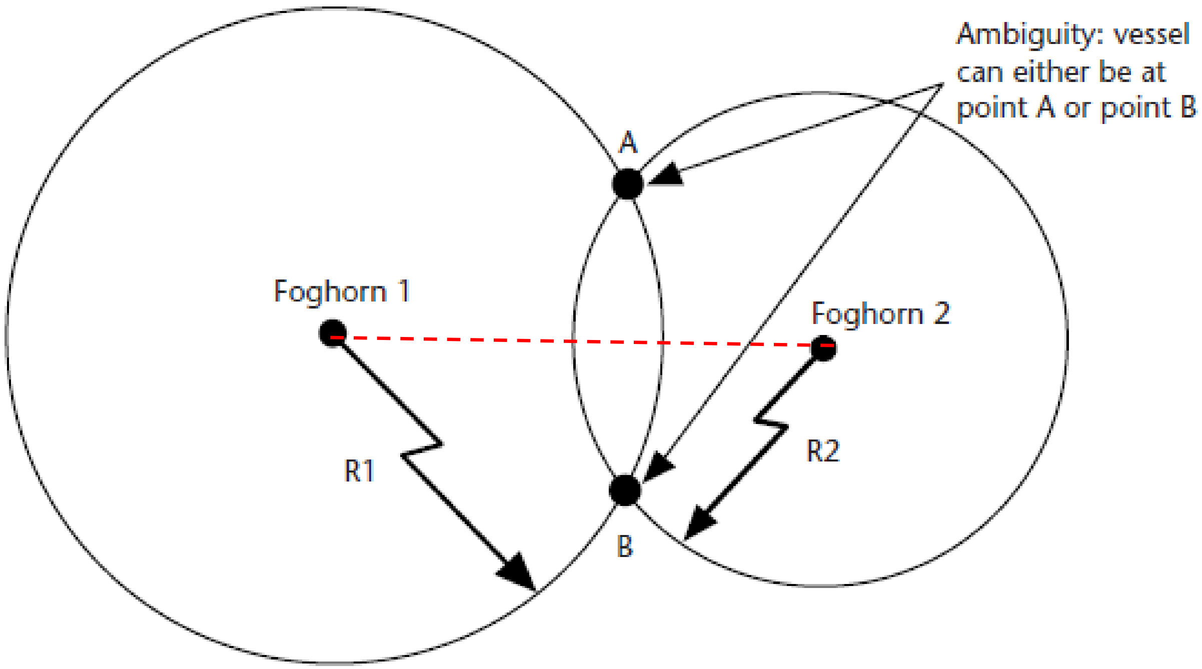
- A receiver having precise synchronized clock with transmitter clock
- By measuring time of signal travel, distance from transmitter can be estimated
- Receiver can be somewhere on the circle

Ranging using TOA Measurements



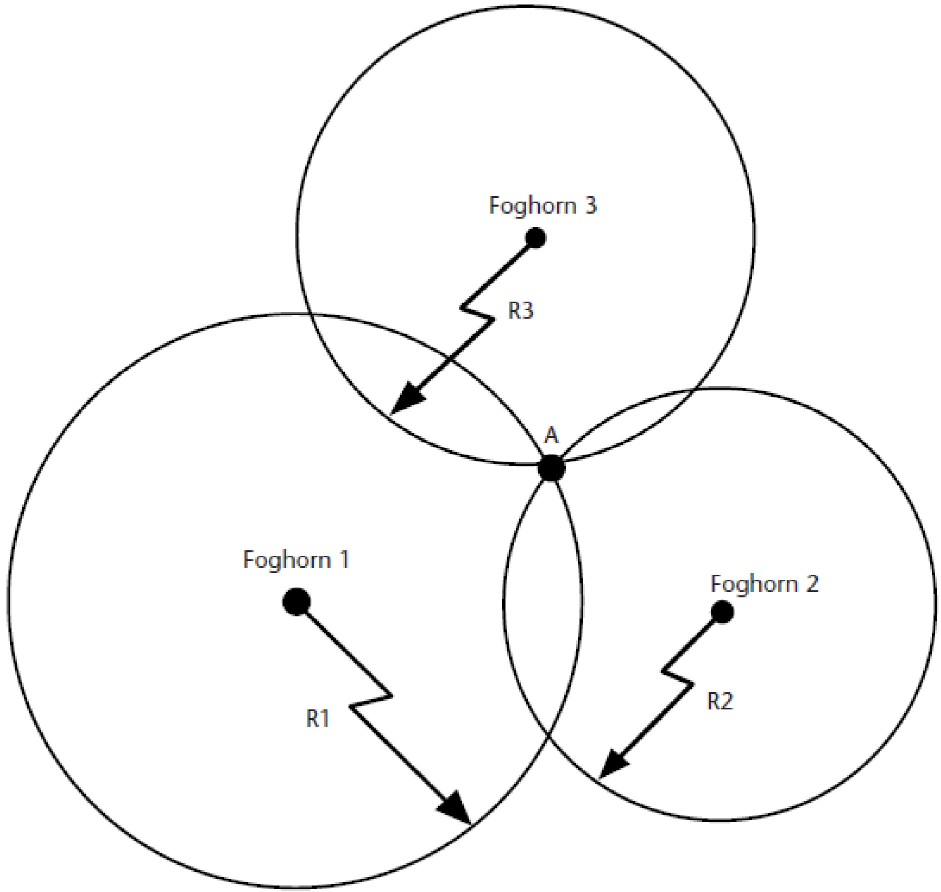
- By measuring time of signal travel from two transmitter
- Receiver can be at the intersection of two circles

Ranging using TOA Measurements



- By measuring time of signal travel from two transmitter
- Receiver can be at the intersection of two circles
- Correct location can be obtained if we know receiver is on which side of line joining transmitters

Ranging using TOA Measurements



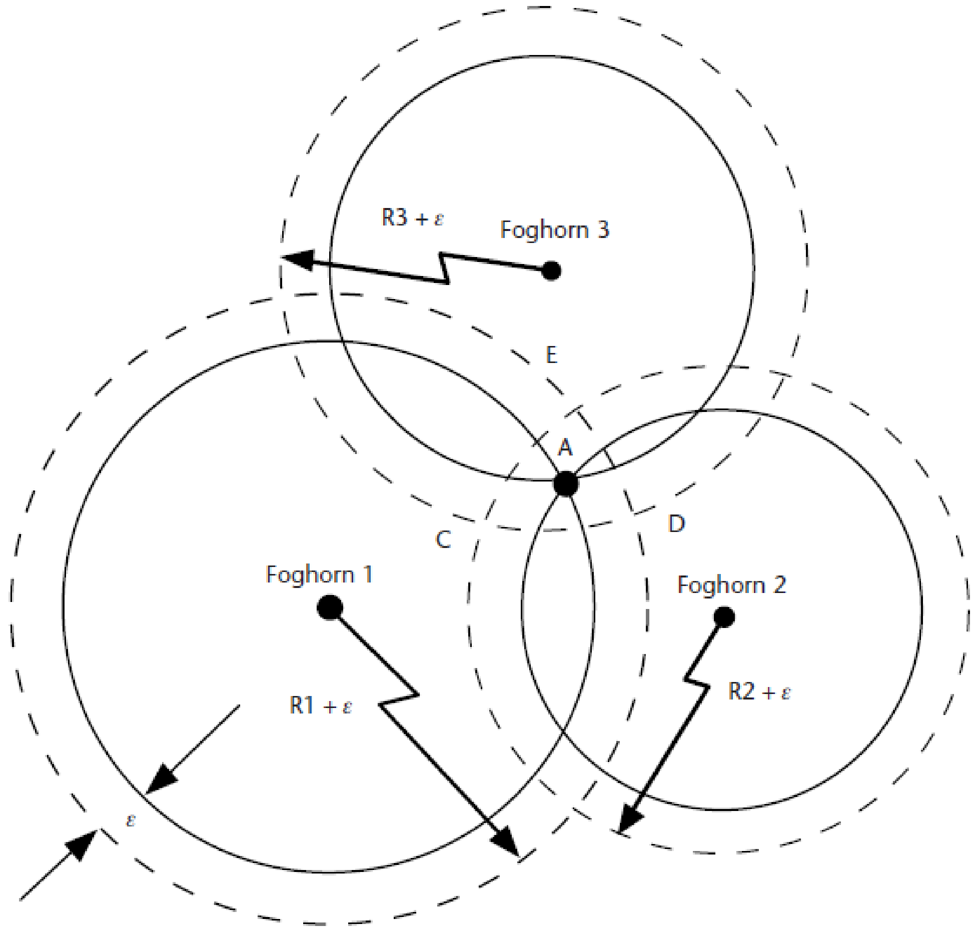
- By measuring time of signal travel from three transmitters
- Receiver will be at the intersection of three circles, ambiguity in position is resolved

Ranging using TOA Measurements

Assumptions

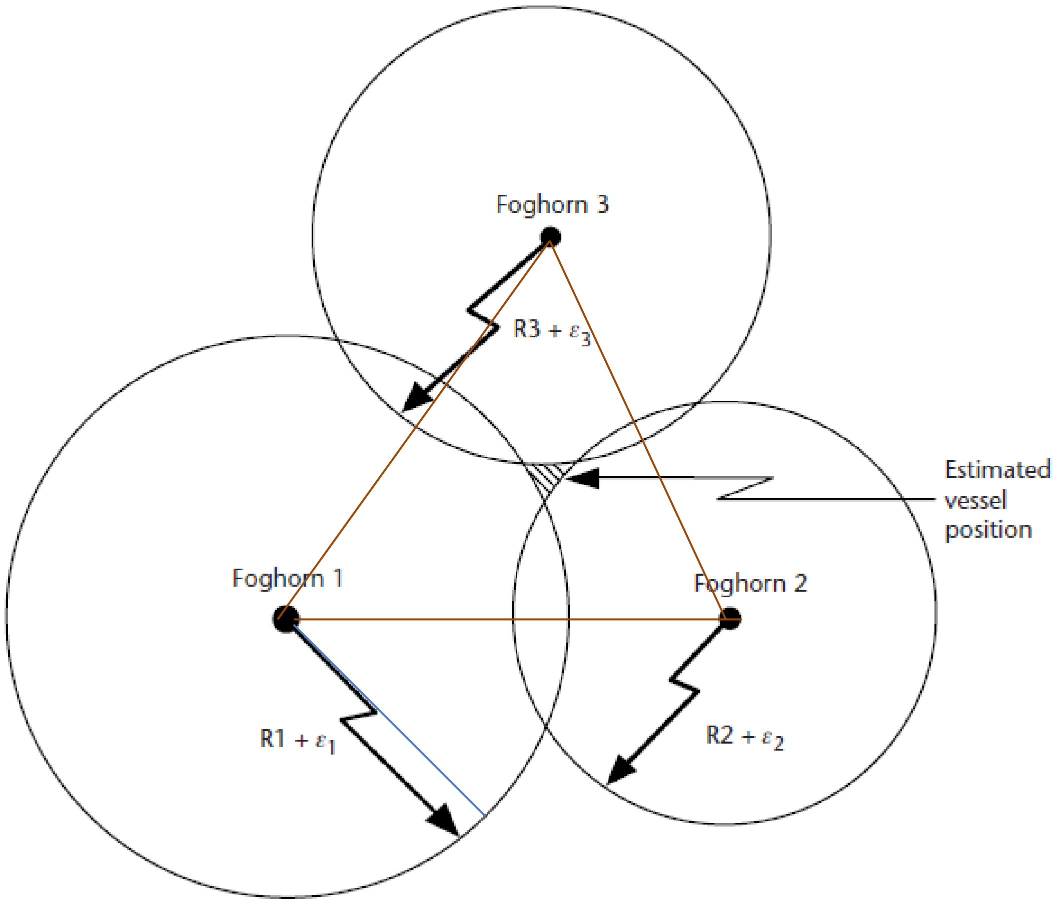
- Transmitter and receiver clocks are synchronized
- No errors in measurement of time

Ranging using TOA Measurements



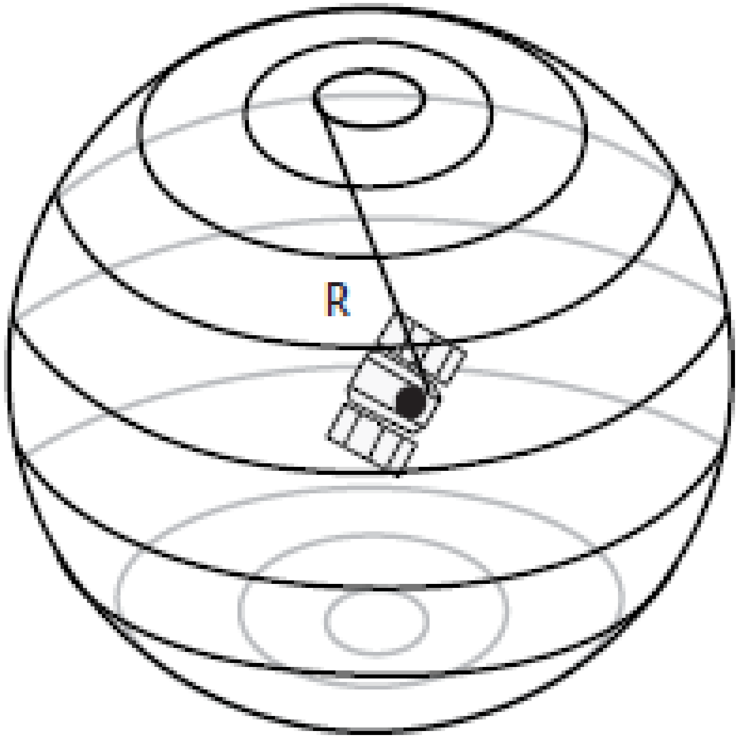
- Position estimate will have error
- Bounds on error will depend on error band of individual receiver

Ranging using TOA Measurements



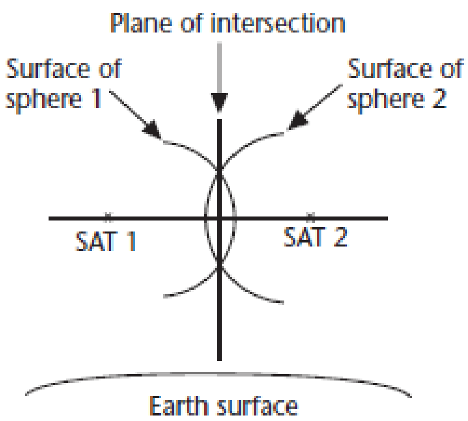
- Errors may not be constant in all the receivers
- Is the error dependent on the placement of transmitters?
- Can this concept extended to 3D positioning?

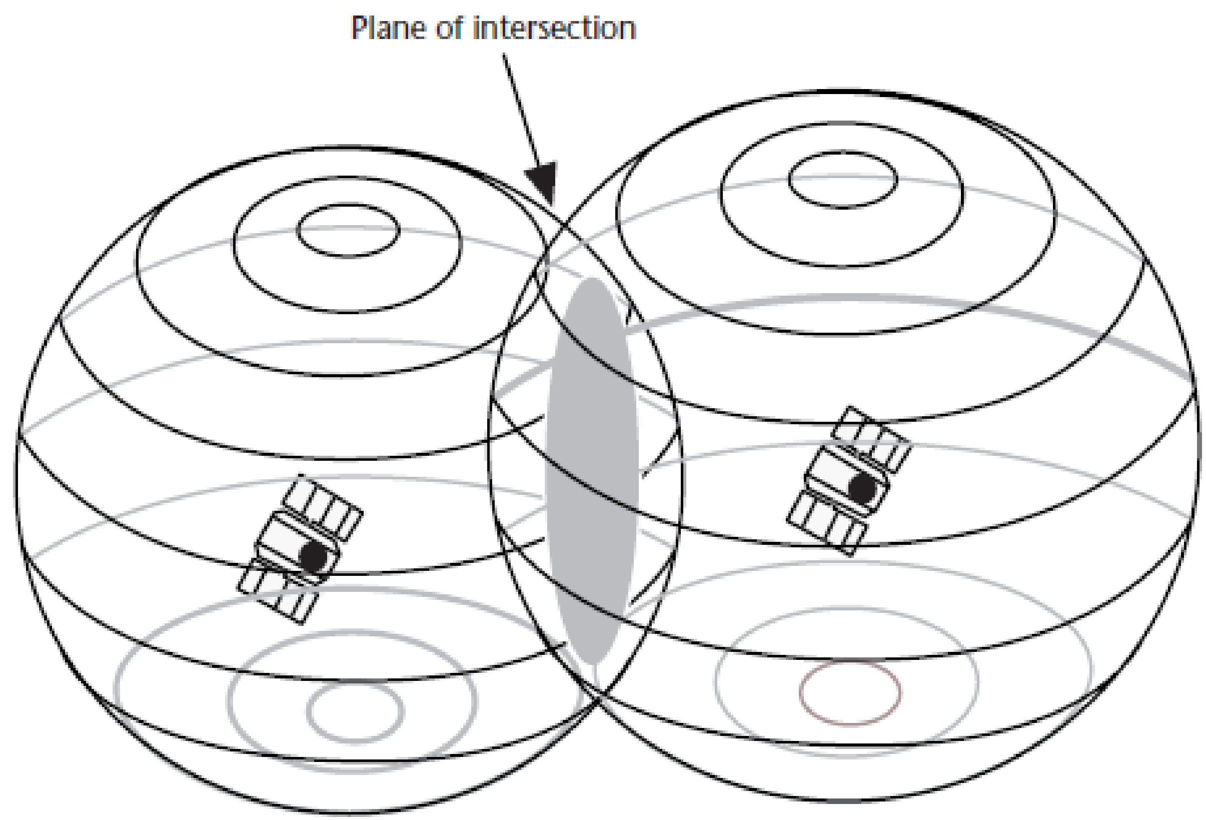
Three dimensional Position Location



- ➢ Assume ranging measurement possible using signal from single satellite
- ➢ User will be somewhere on the sphere

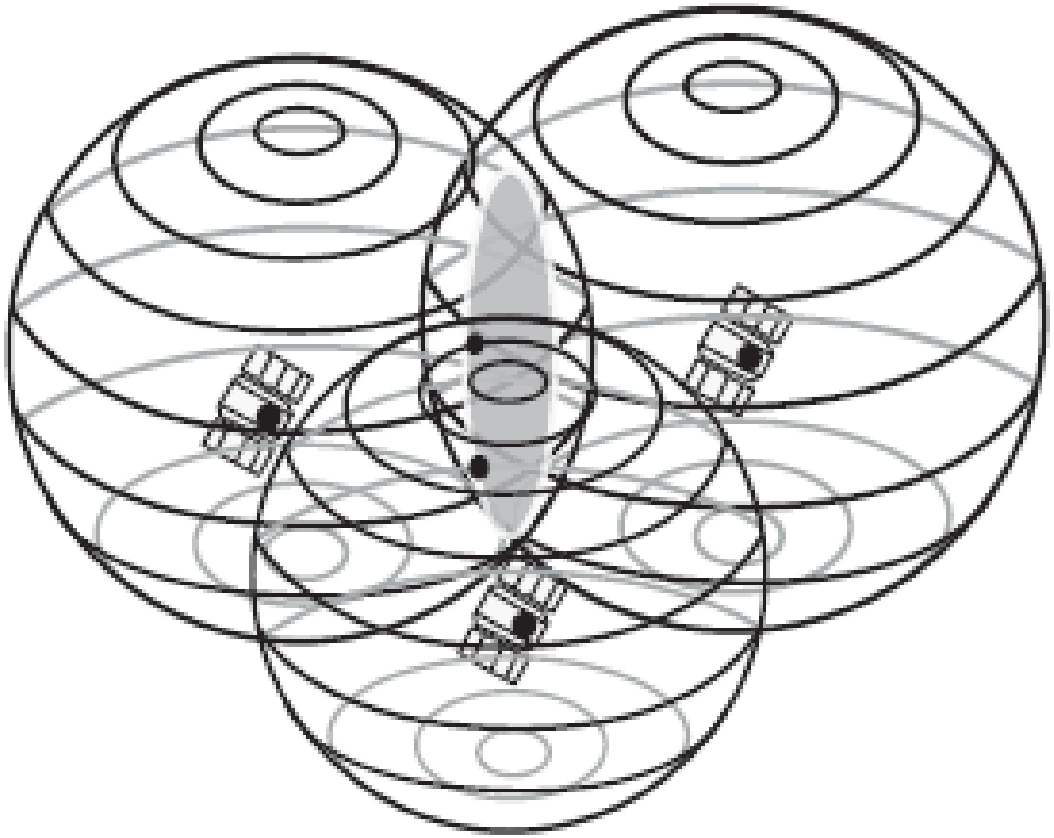
Three dimensional Position Location

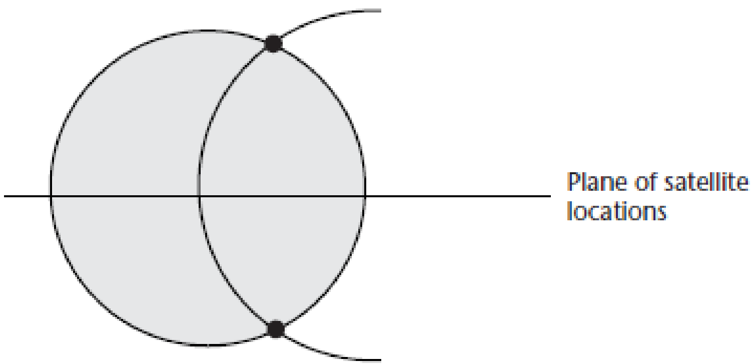




- Assume ranging measurement possible using signal from two satellites
- User will be somewhere on the intersection of two spheres (circle)

Three dimensional Position Location





- ➢ Assume ranging measurement possible using signal from three satellites
- ➢ User will be somewhere on the intersection of third sphere with the circle (two points)

Three dimensional Position Location

- Range measurement
  - Position of transmitter (satellite) is required
  - Clock synchronization (between satellite and user) is required

- **How many satellites for three dimensional position estimation?**