

Introduction into Real-Time Network Adjustment with Geo++ GNSMART

Andreas Bagge
Gerhard Wübbena, Martin Schmitz

Geo++[®] GmbH
D-30827 Garbsen, Germany
www.geopp.de

Content



- Introduction
- GNSS Basic Principle
 - Error sources, Absolute Accuracy
- Differential GNSS
 - Spatial Variations, Distance dependent errors
- GNSMART Networks
 - Ambiguity Problem
 - State Monitoring, Modelling of error sources
 - Representation, FKP, VRS, ...
 - Communication Issues

GNSS-SMART =

Global Navigation Satellite System

State Monitoring And Representation Technique

= Technique

- to **determine** (State Monitoring) and
- to **represent** (Representation)

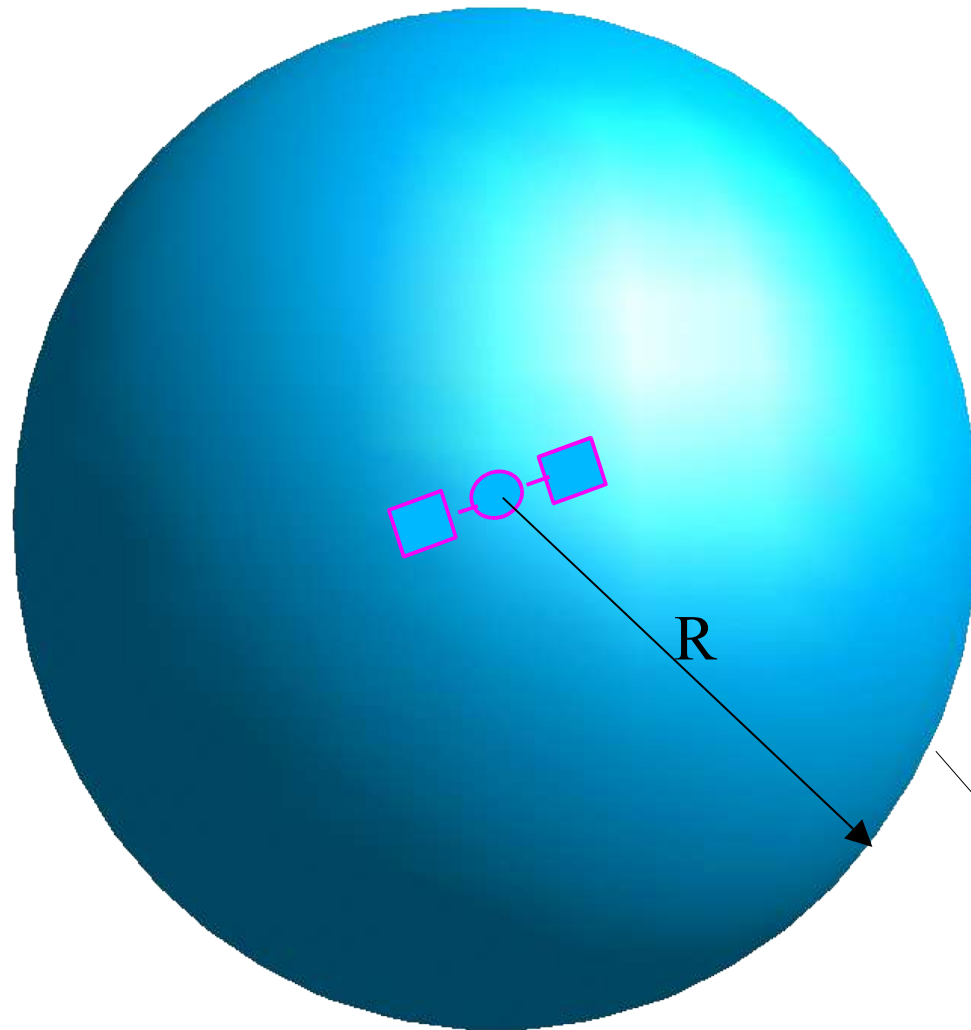
the **system status** of GNSS Systems

GNSMART

= Geo++ Software implementation of GNSS-SMART

GNSS Principle

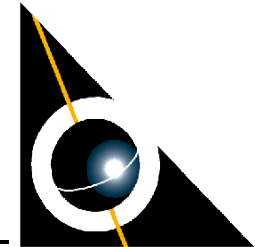
Range Observation



Range Measurement R
to 1 Satellite

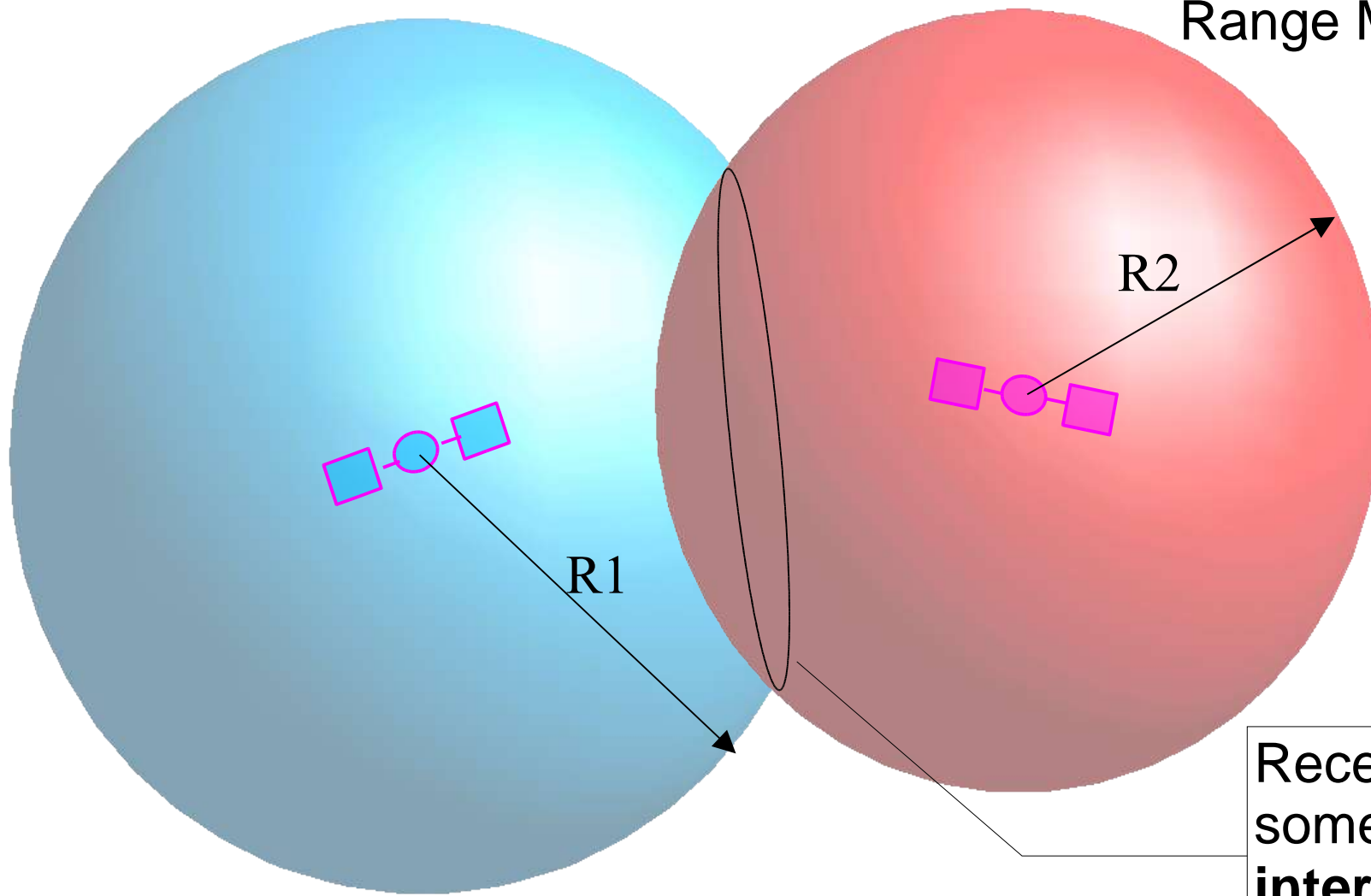
Receiver must be
somewhere on the
surface of sphere

Geometric Position from Range Observations



Geo++[®]

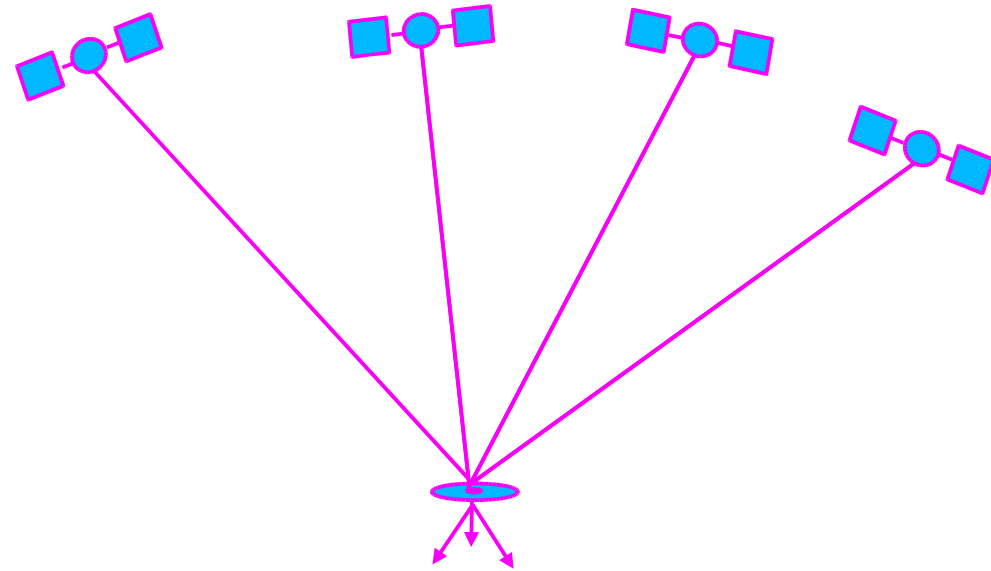
Range Measurements
to 2 Satellites



Receiver must be
somewhere on the
intersection circle
of both spheres

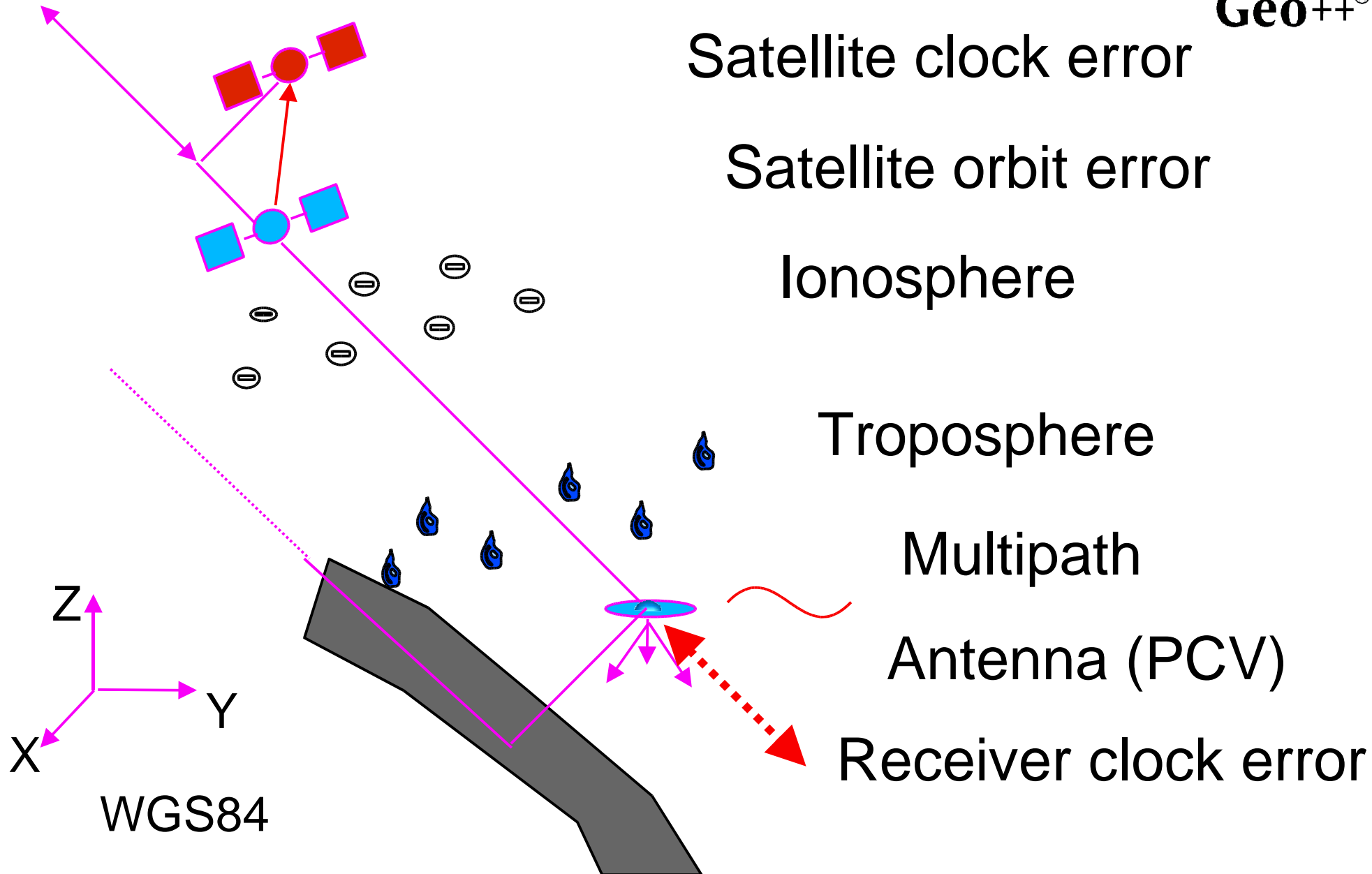
Absolute Positioning

- Position determination of a single (“Stand-Alone”) GNSS receiver in system of GNSS
- Accuracy with GPS/GLONASS
 - 5 – 20 m
 - for many applications not sufficient!
- full influence of all error sources



Error Sources

GNSS Error Sources



Magnitude of Error Sources



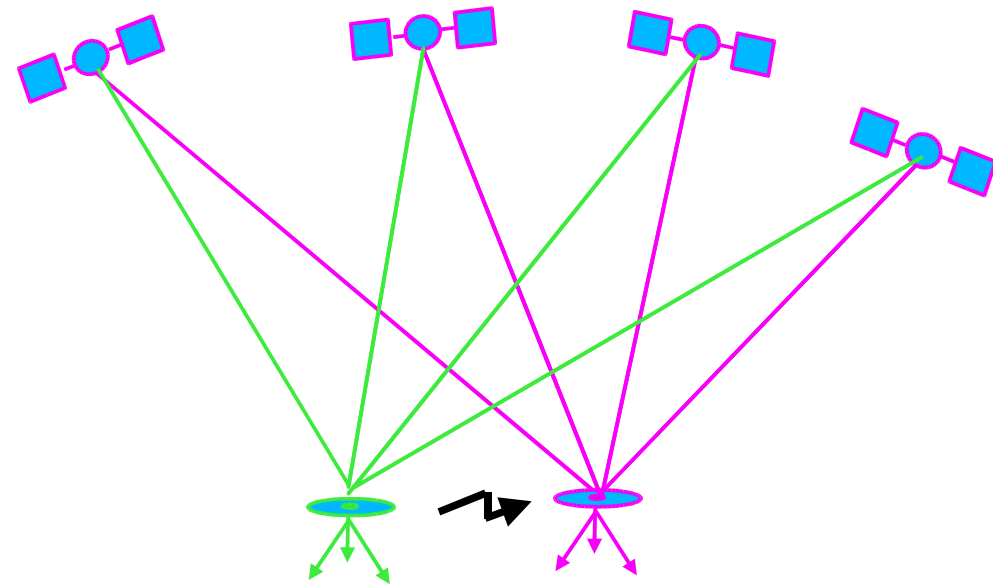
Error Source	Absolute Influence
Satellite Orbit	2 ... 50m
Satellite Clock	2 ... 100m
Ionosphere	0.5 ... >100 m
Troposphere	0.01 ... 0.5 m
Multipath Code	m
Multipath Phase	mm ... cm
Antenna	mm ... cm

-> total: 5 ... 20 m

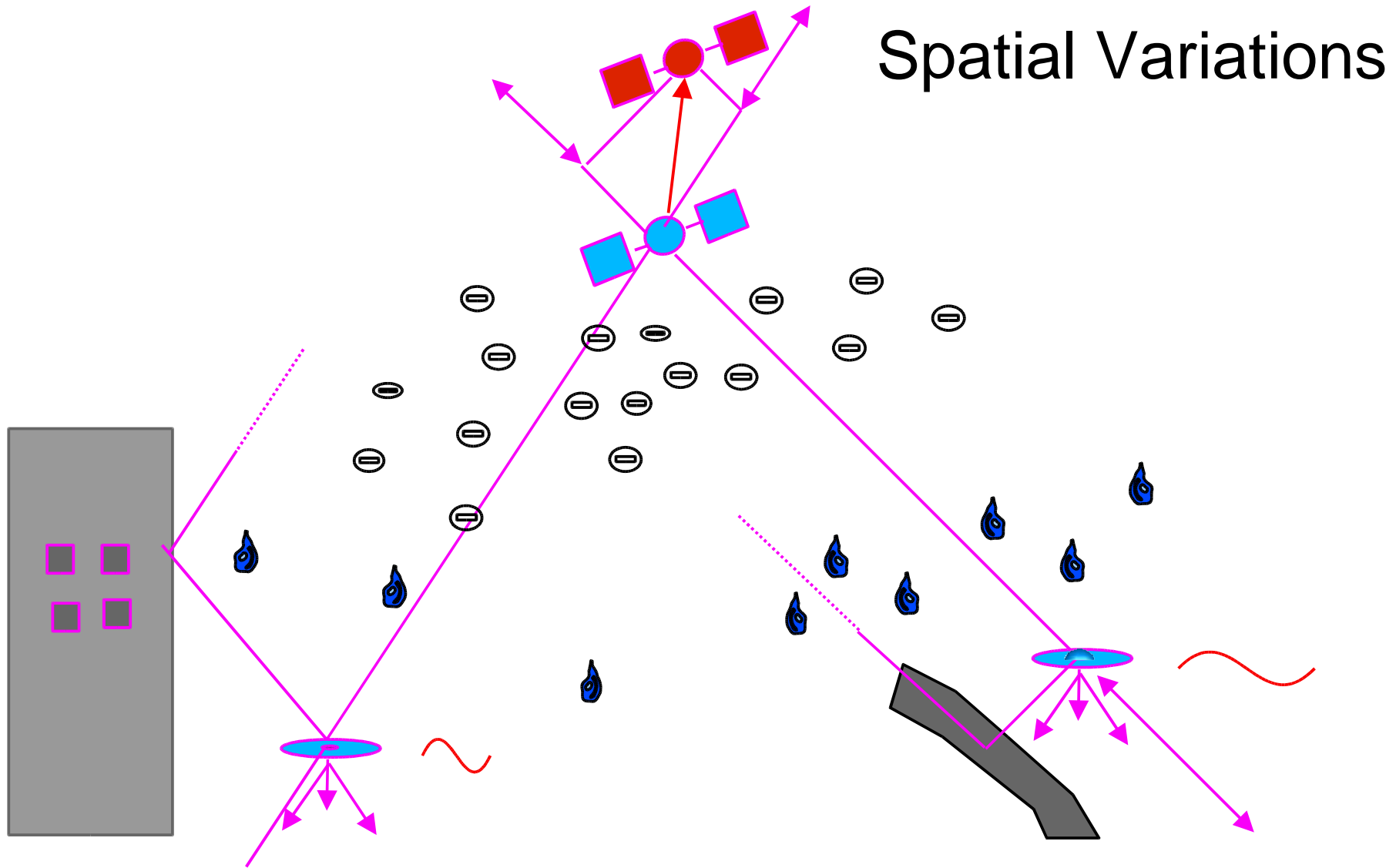
Differential GNSS

Differential („DGNSS“) Positioning

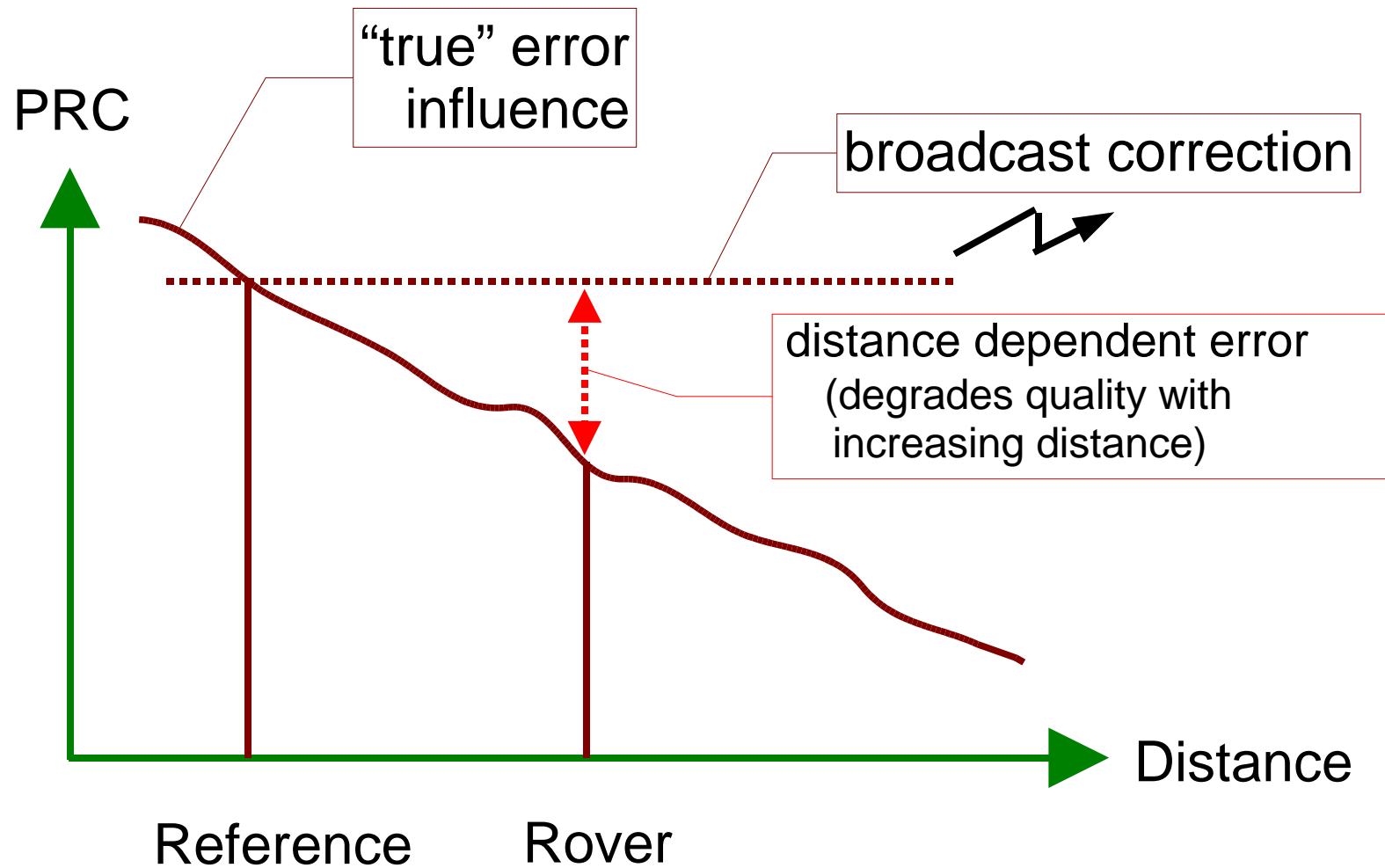
- Determine all error influences on a known station
→ „Corrections“
- Transmit corrections to the rover
- Apply corrections
→ reduce error influence
- Compute position
 - with code („DGNSS“) or
 - with carrier phase („RTK“)



DGNSS Error Sources



DGNSS/RTK Distance Dependency



Magnitude of Error Sources

Error source	Absolute influence	Relative influence
Satellite Orbit	2 ... 50m	0.1 ... 2 ppm
Satellite Clock	2 ... 100m	0.0 ppm
Ionosphere	0.5 ... >100 m	1 ... 50 ppm
Troposphere	0.01 ... 0.5 m	0 ... 3 ppm
Multipath Code	m	m
Multipath Phase	mm ... cm	mm ... cm
Antenna	mm ... cm	mm ... cm

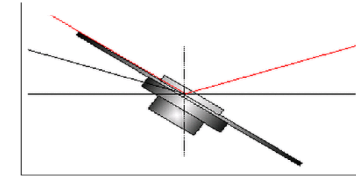
-> total: 1...2 cm + 1...20 ppm

 High spatial correlation

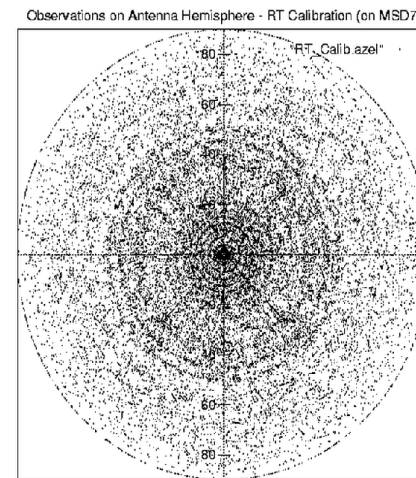
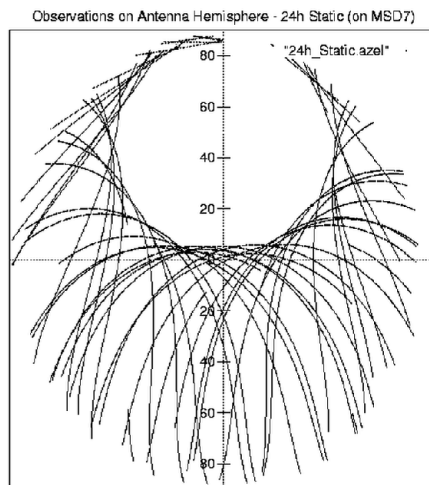
 Local (Calibration)

Geo++ Absolute Antenna Calibration

- orientation changes of antenna required
- robot to rotate and tilt the antenna
 - dynamic robot guidance
 - automatic operational procedure
 - real-time



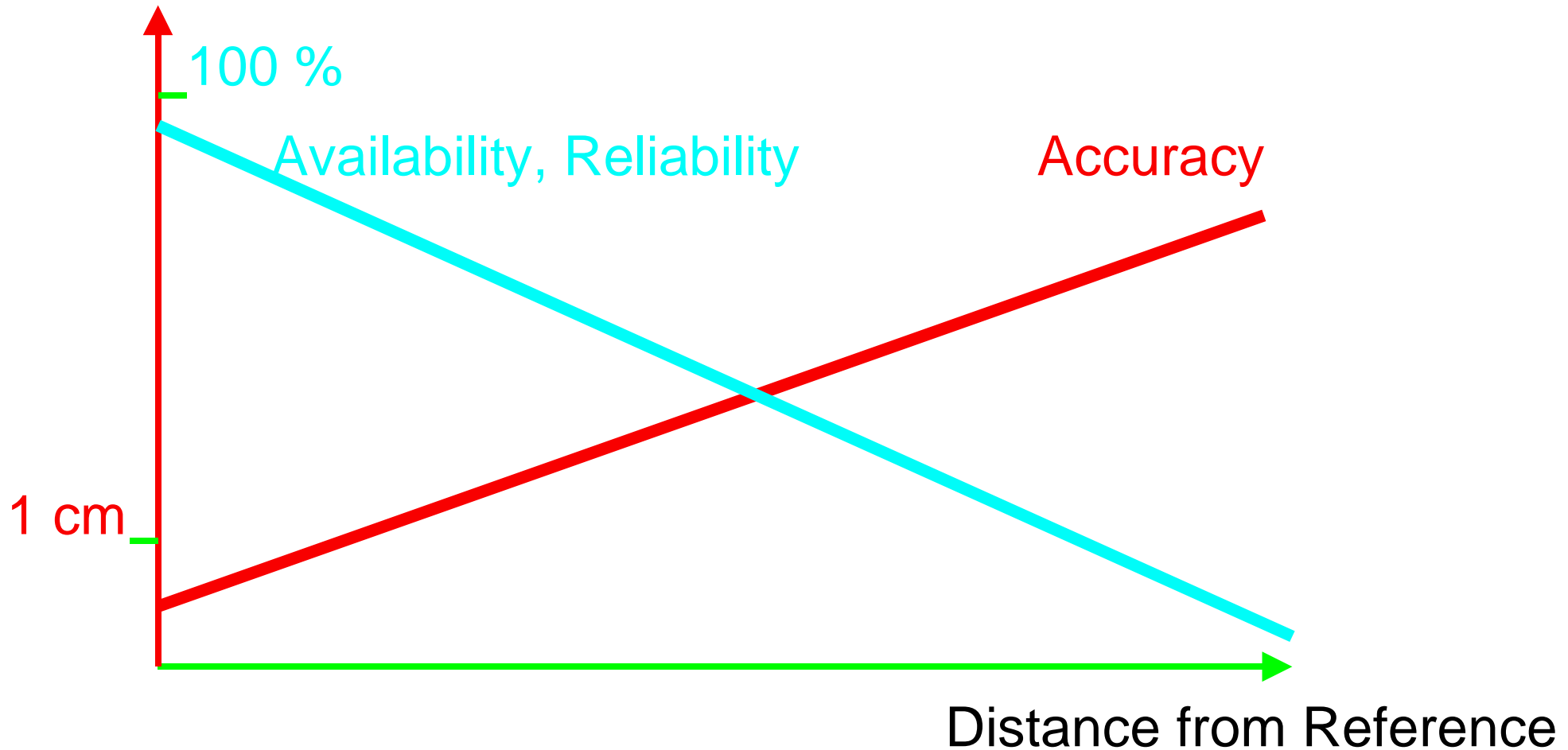
Old Relative Calibration



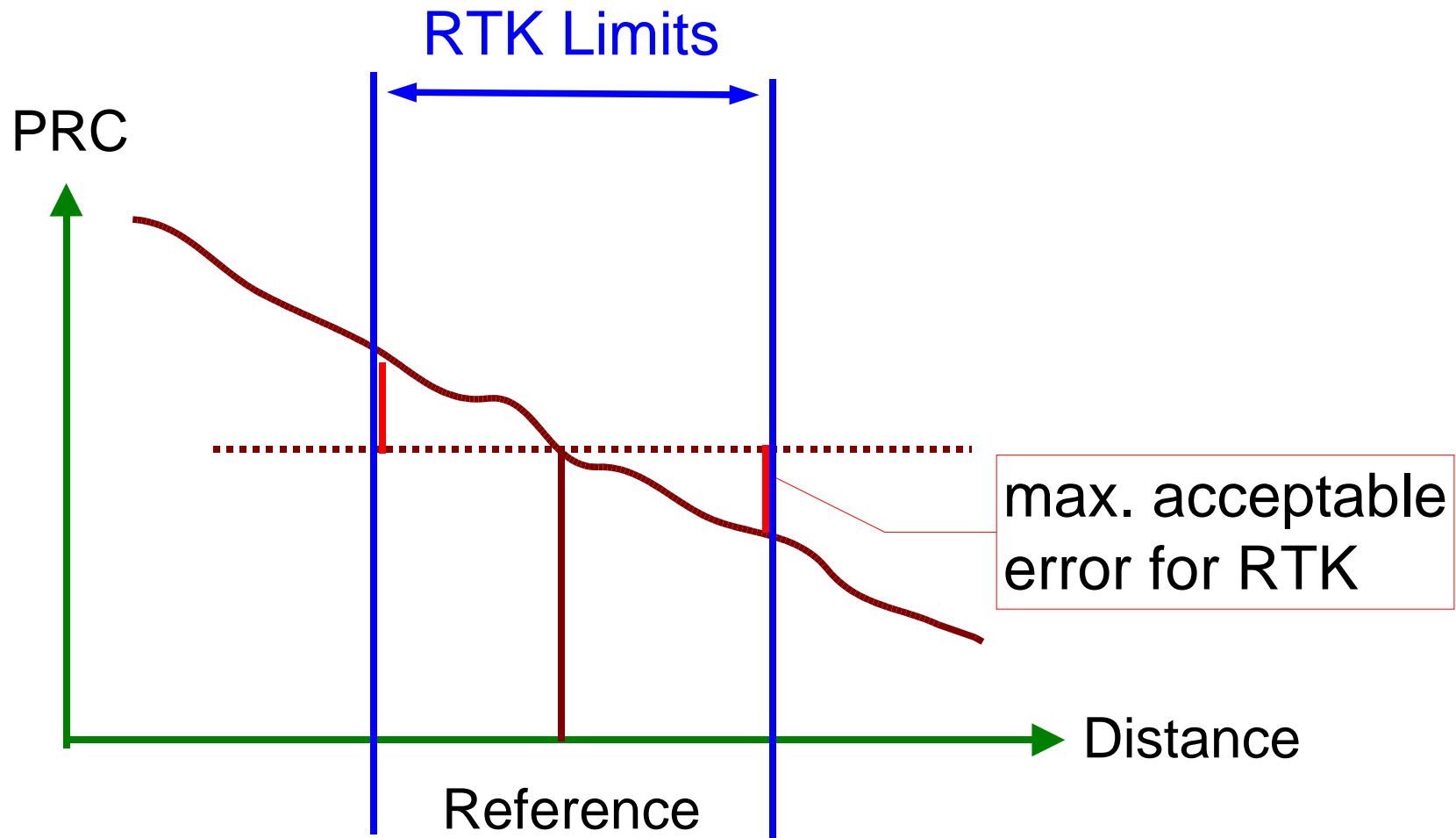
Geo++ Absolute Calibration



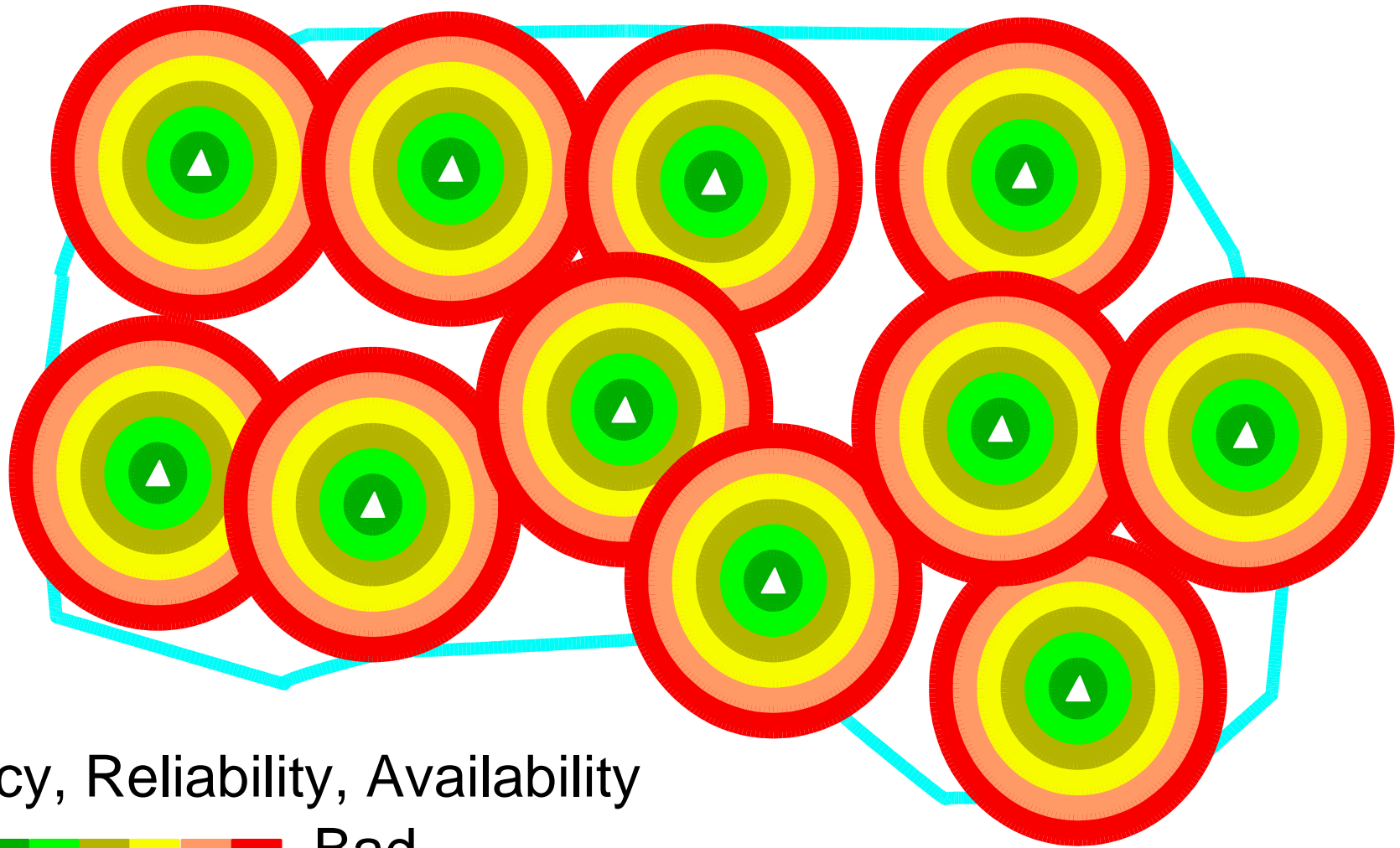
RTK: Accuracy, Reliability, Availability



RTK-Limits from Distance Dependency

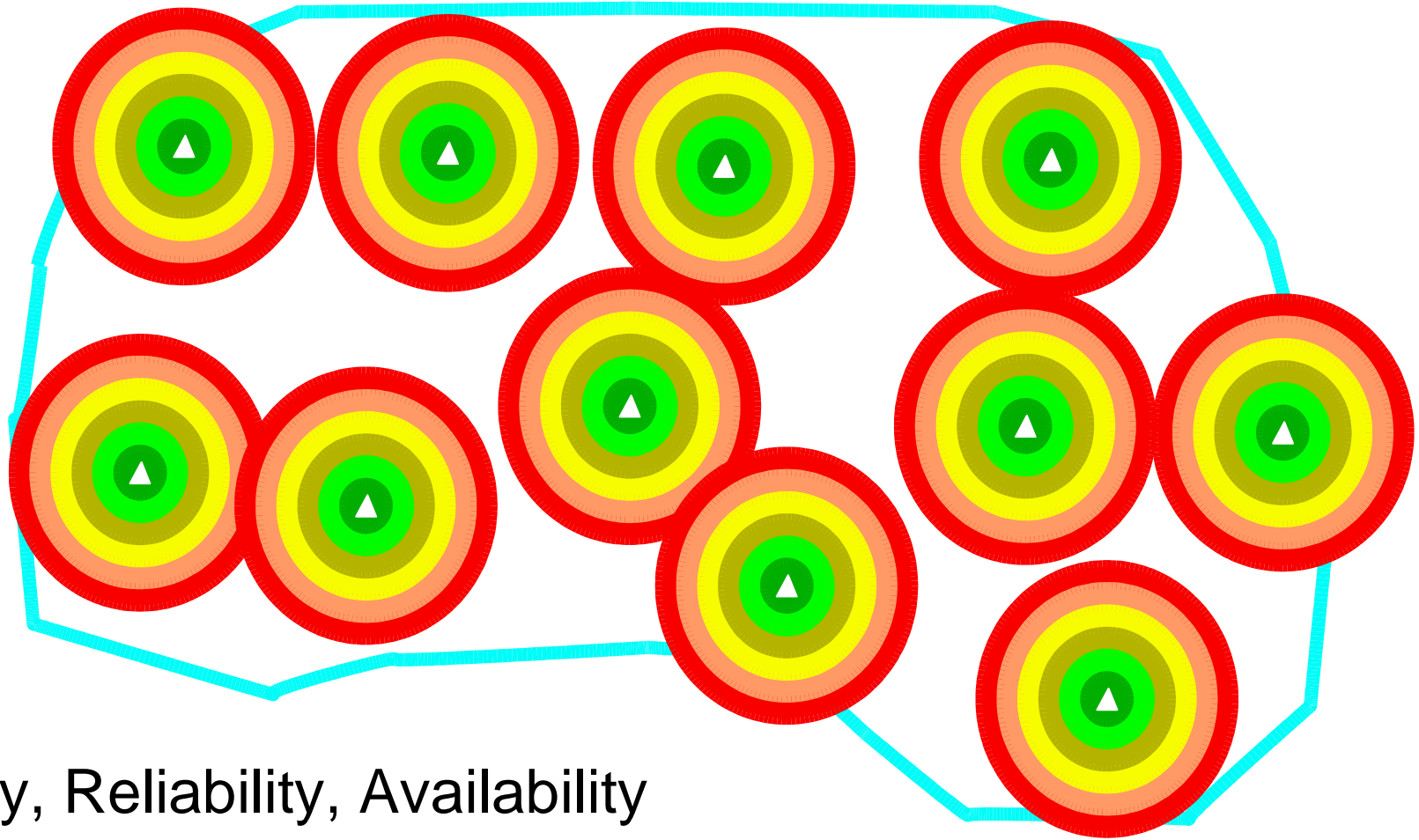



Stand Alone Reference Stations



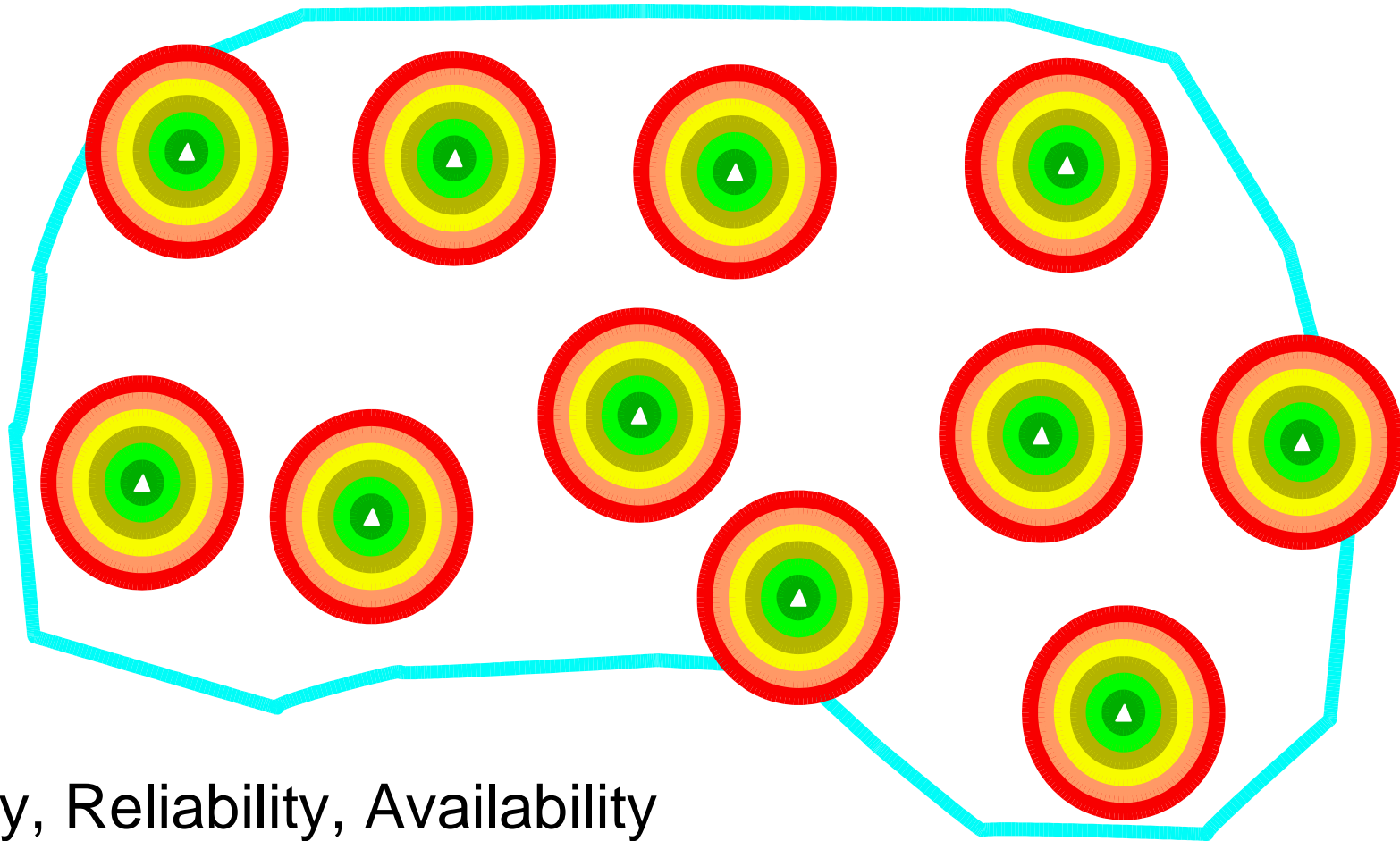
Accuracy, Reliability, Availability
Good  Bad

Stand Alone Reference Stations



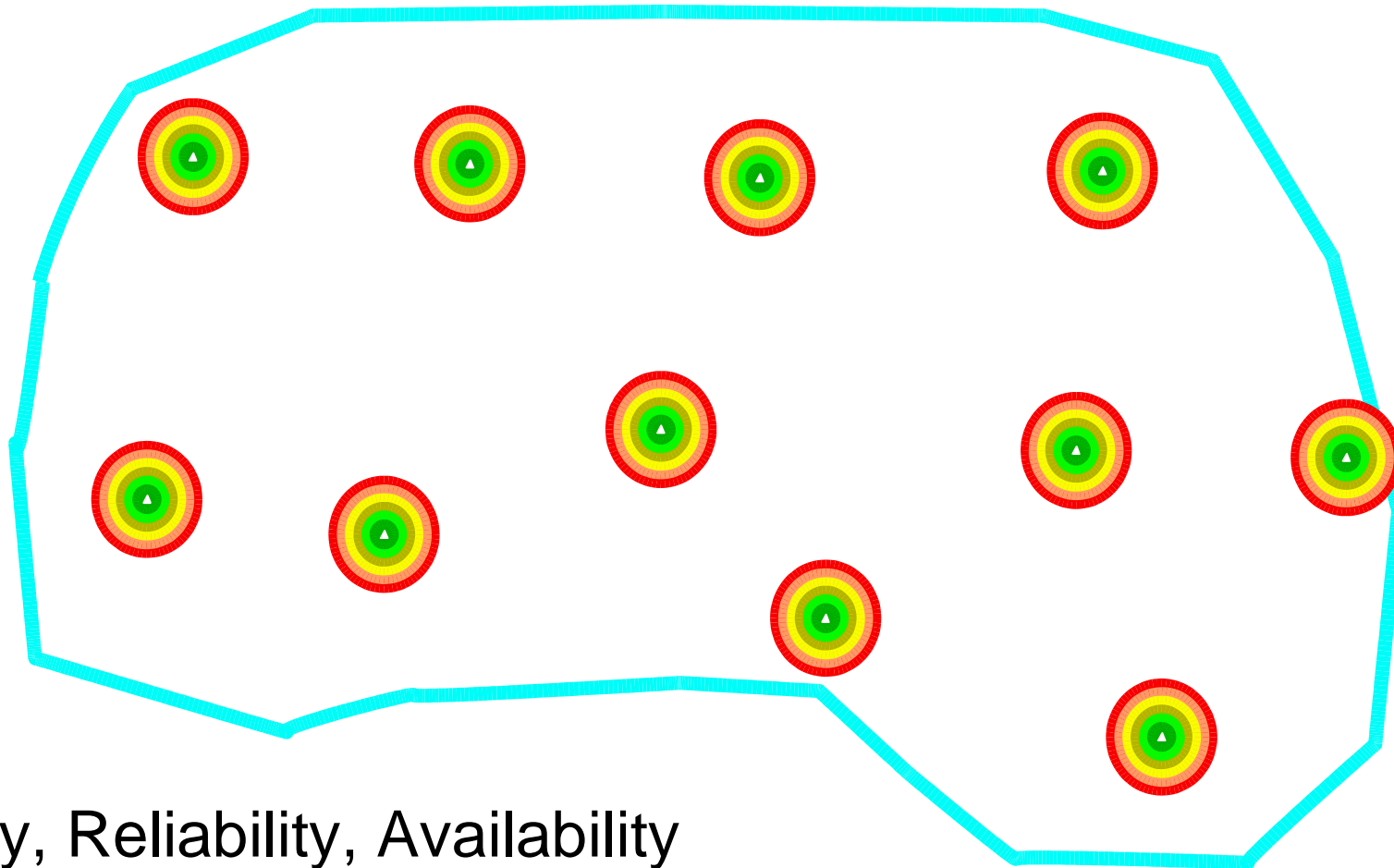
Accuracy, Reliability, Availability
Good  Bad


Stand Alone Reference Stations



Accuracy, Reliability, Availability
Good  Bad

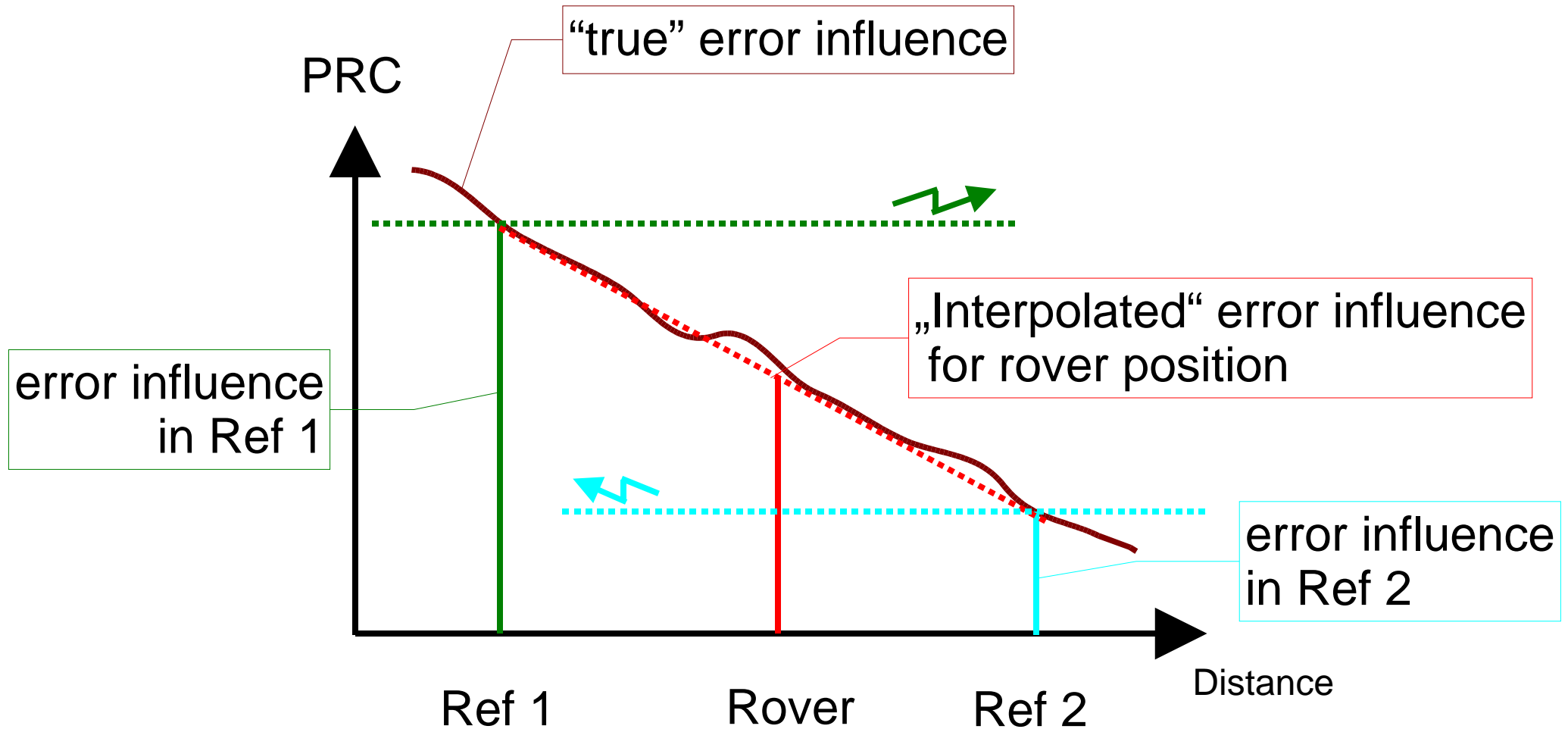
Stand Alone Reference Stations



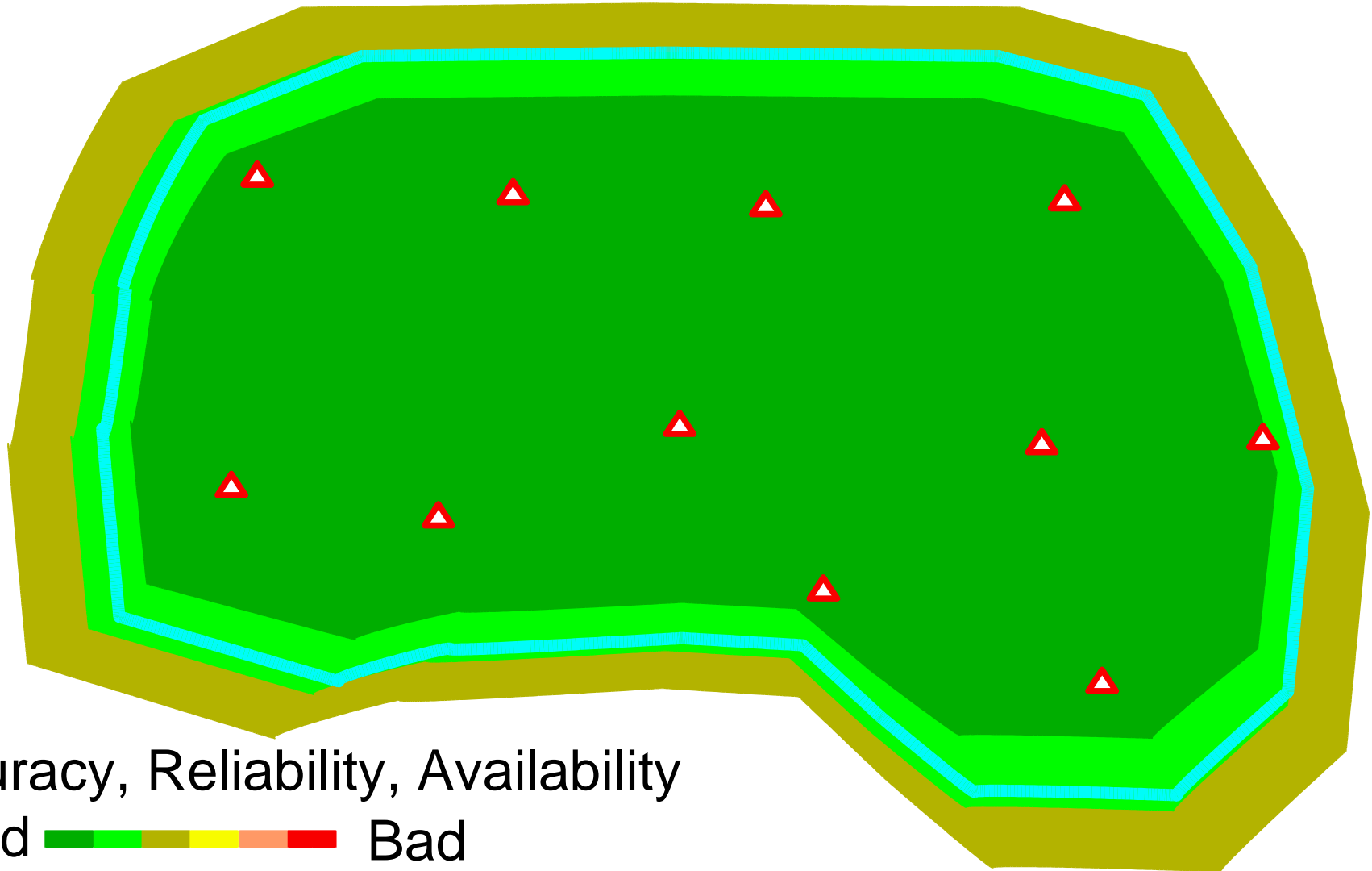
Accuracy, Reliability, Availability
Good  Bad

RTK Networks

Distance dependent Errors in RTK Networks



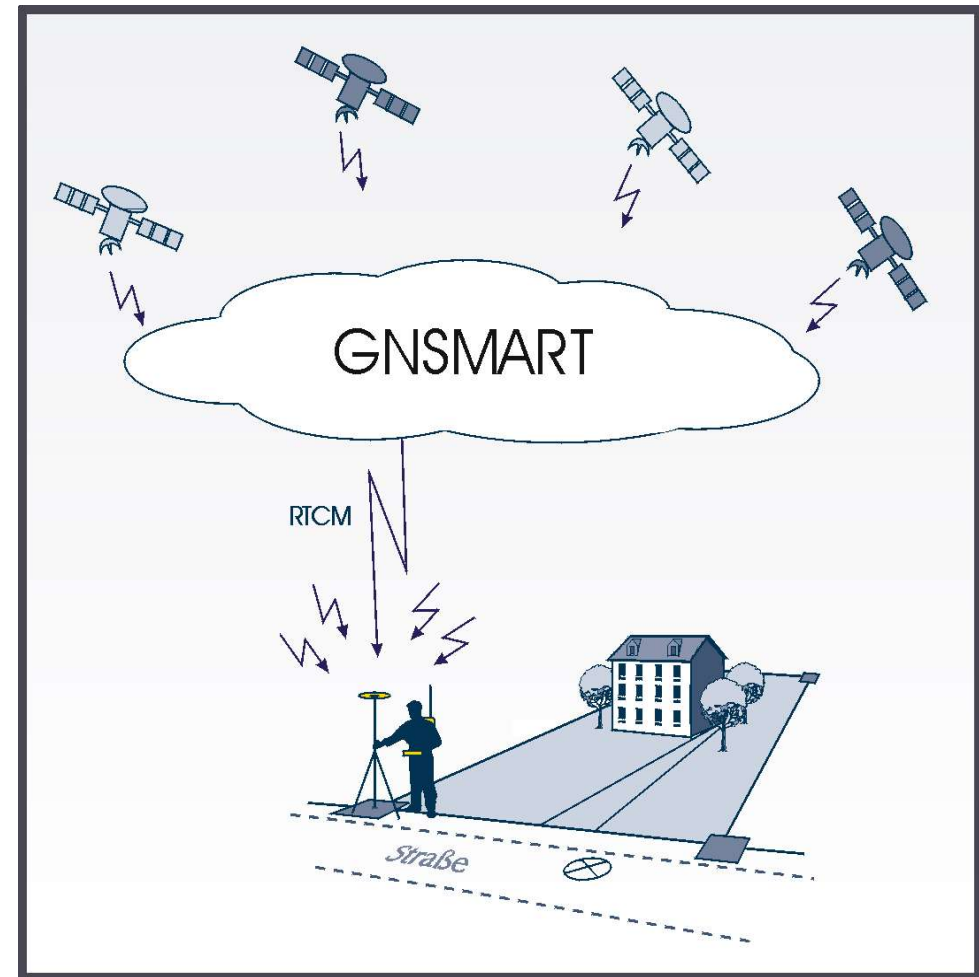
GNSS-SMART Network



Accuracy, Reliability, Availability
Good  Bad

GNSMART: User View

- user in the field
 - one way communication link
 - receive all necessary correction/reference data
 - determine absolute RTK position
 - anytime/anywhere
- 1 cm accuracy



1 cm accuracy - everywhere!

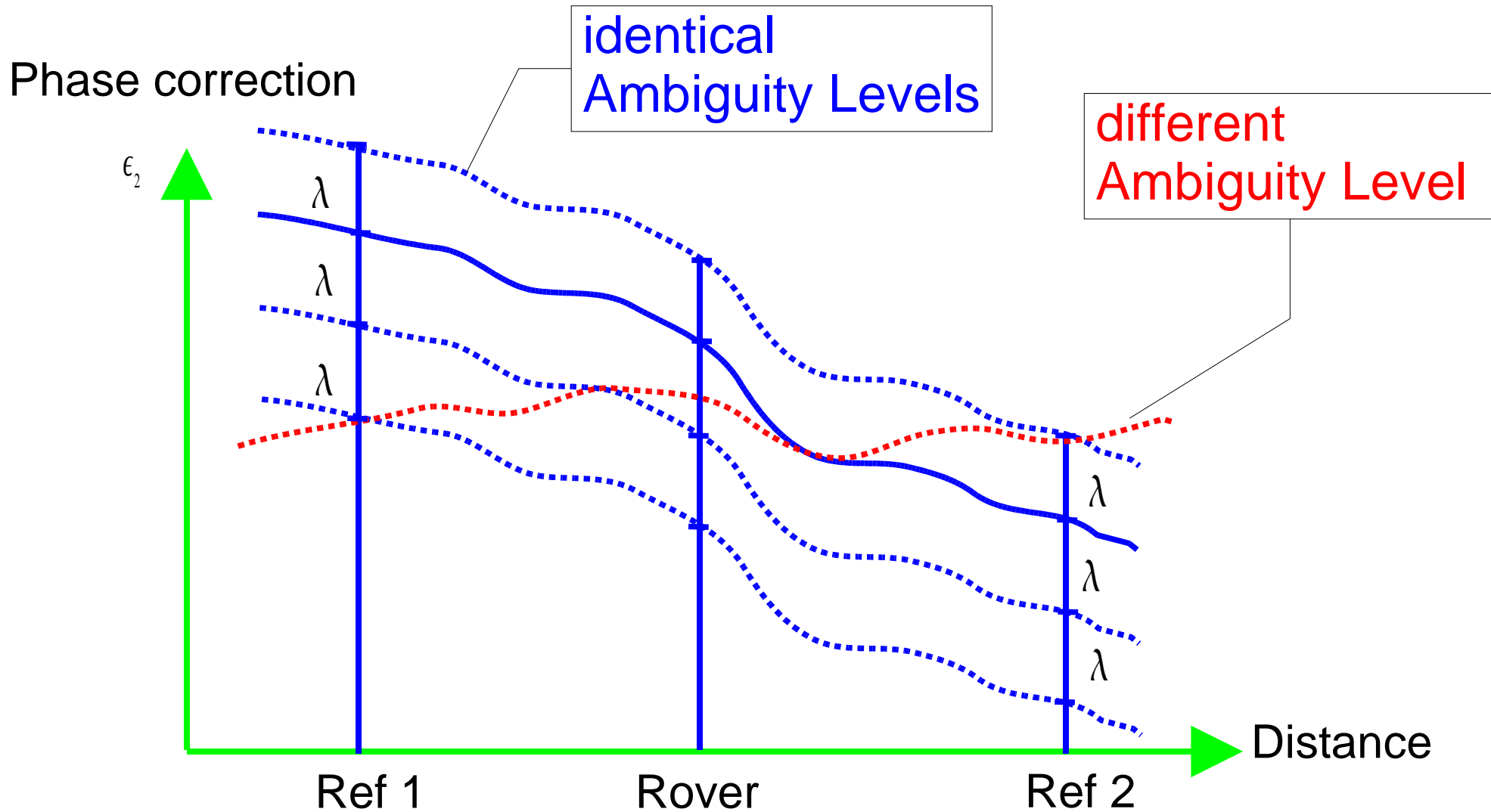
Network RTK: Network Tasks



- **primary** task (pre-requisite): **State Monitoring**
 - determine **distance (and site) dependent** errors
 - **carrier phase ambiguity resolution**
- **secondary** task: **Representation**
 - **represent** network information for user
 - distance dependent errors
 - orbit, ionosphere, troposphere
 - reference station dependent errors
 - multipath, antenna, clock
 - using adequate formats (RTCM, FKP, VRS, SSR)

Carrier Phase Ambiguity

Ambiguity Level



GNSMART State Monitoring

GNSMART State Monitoring



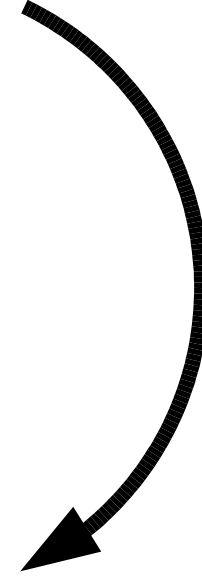
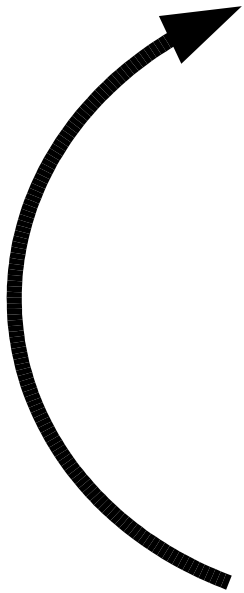
- **Complete** State Space Model (**SSM**) for all error sources with **carrier phase accuracy**
- **Multi-station** RT network solution
 - Increased **redundancy** compared to triangle processing!
 - Increased inter-station distances (**sparse networks**)
 - **Robust** against single station/communication failures
- **undifferenced** observables
 - **Multiple Stations**
 - **Multiple Signals** (L1,L2,P1,P2,C/A)
- **undifferenced ambiguity** resolution
 - Low Elevation Ambiguity Fixing

GNSMART: State Modeling



- **functional models**
 - **dynamic processes** with temporal and/or spatial stochastic characteristics
 - static parameters
- **stochastical models**
 - **stochastic processes** with temporal and/or spatial characteristics

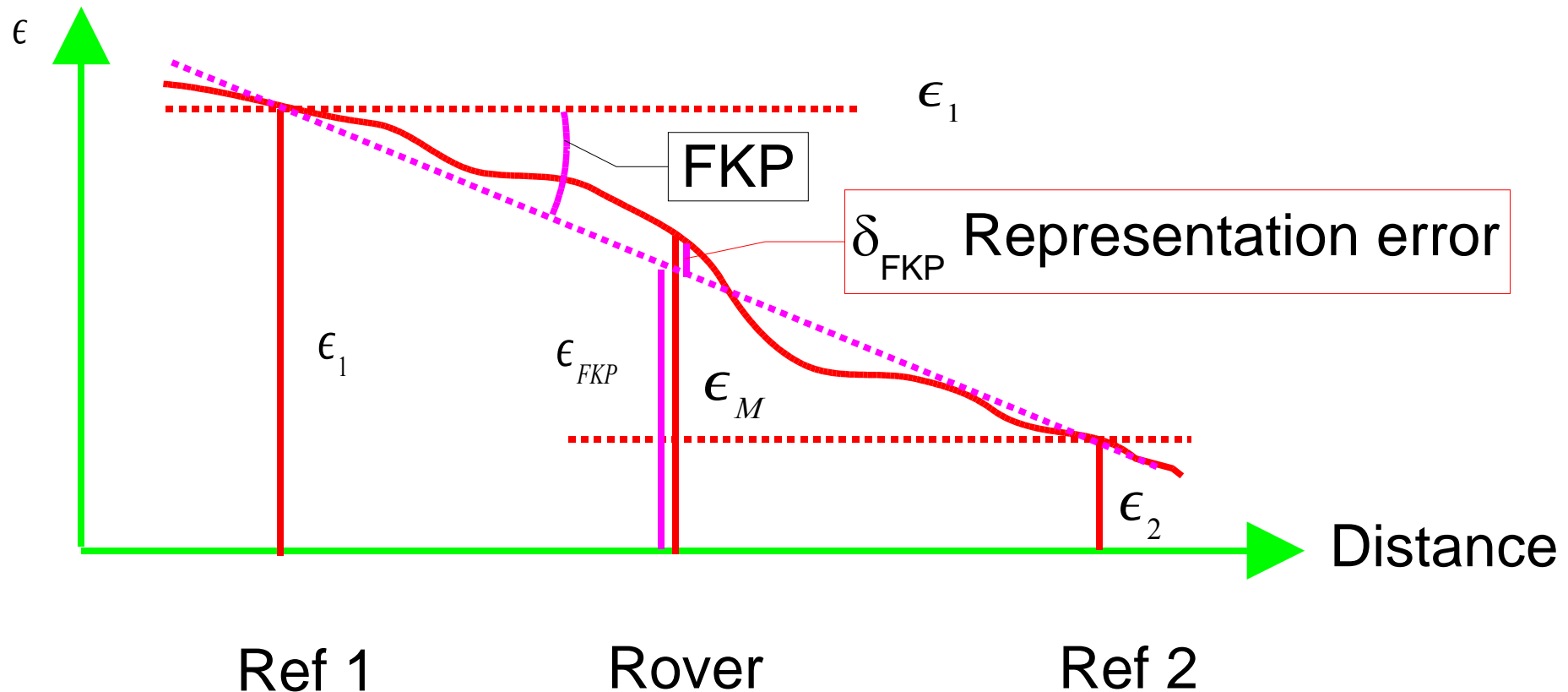
- **GNSS error modelling** needs
 - correct **ambiguity level**
 - -> **Ambiguities must be solved**
-
- **Ambiguity search** needs
 - **accurate** observations
 - **bias-free** observations
 - -> **GNSS errors must be modelled**



GNSMART Representation

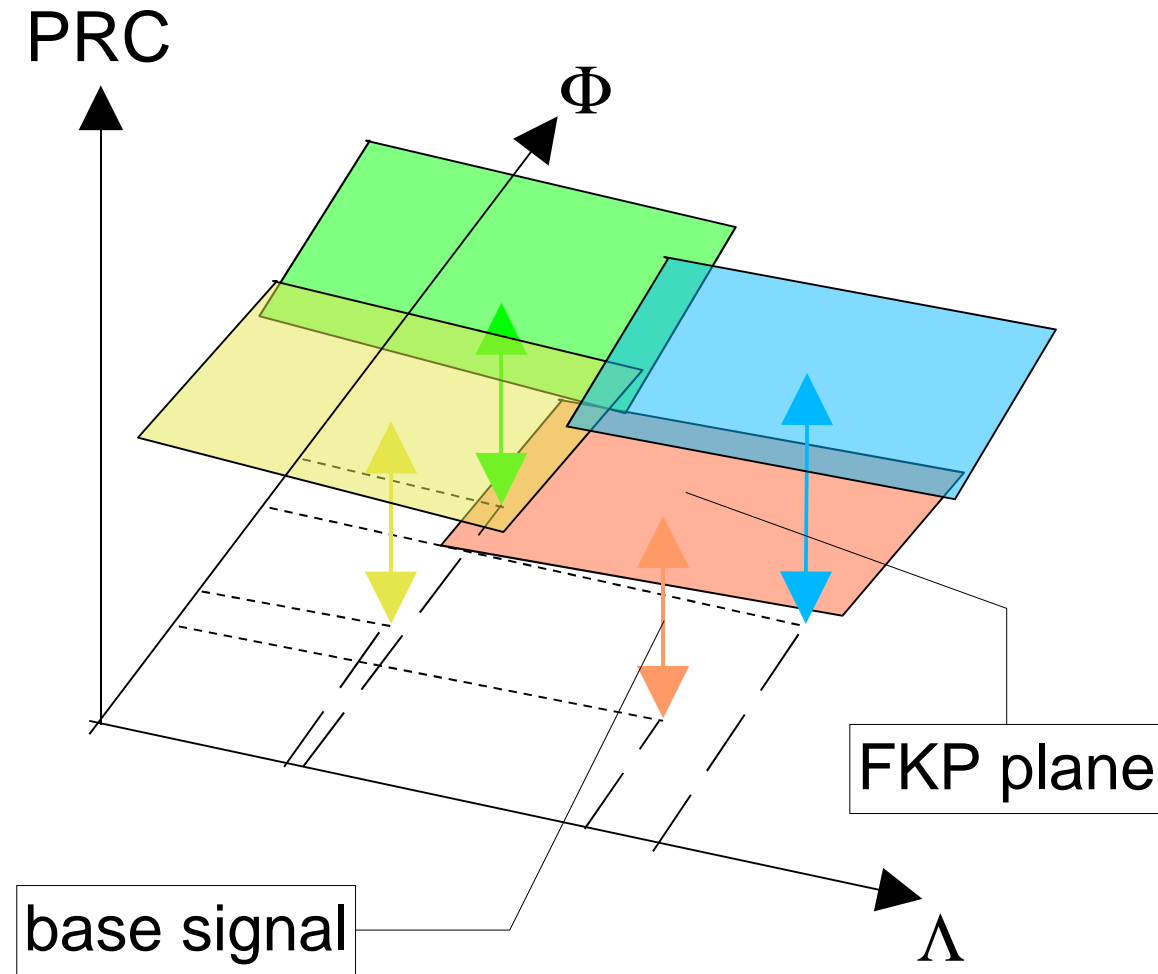
FKP Representation

Phase correction



FKP Representation in GNSMART

- **base signal** of reference station (corrections)
- one linear **FKP plane** for each
 - reference station
 - signal (L_i, L_0)
 - Satellite
- optional: higher order polynomials

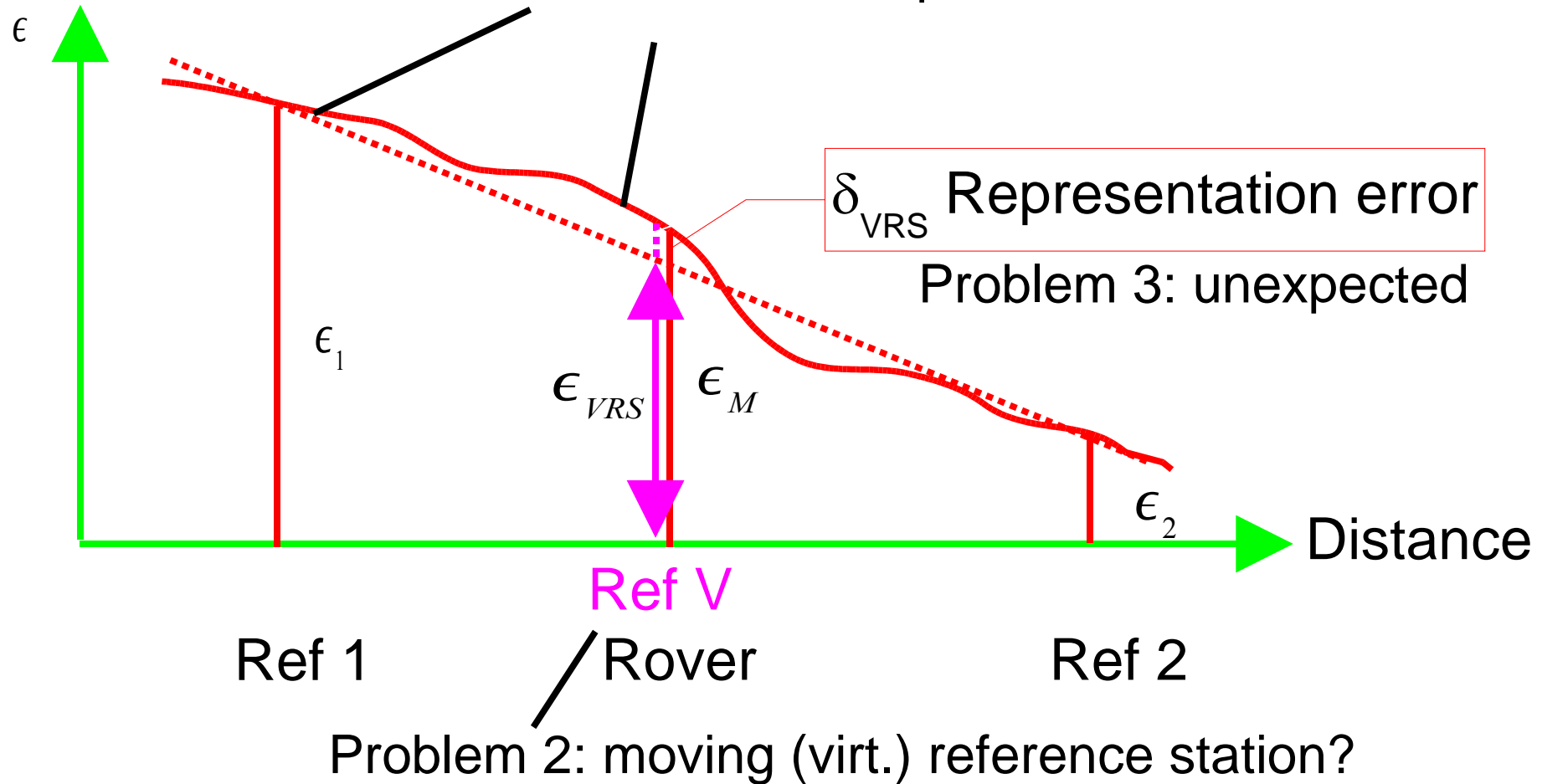


Individualized Corrections Virtual Reference Station (VRS)



Phase correction

Problem 1: transferred tropo model consistent?

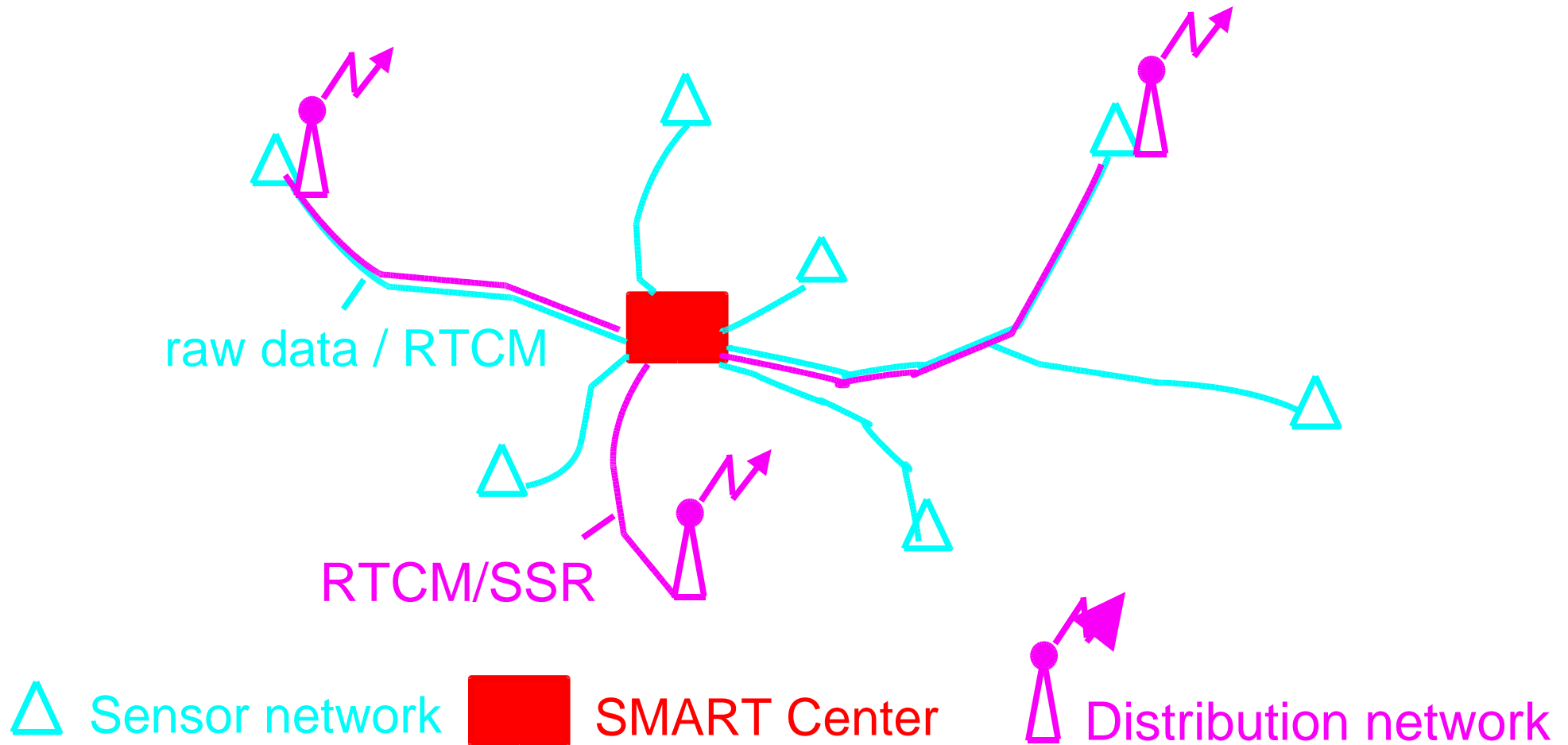


Problem 2: moving (virt.) reference station?

Communication

GNSS-SMART System structure

Central Concept



Communication within Network



- Reference Station to Network Center
 - Telecommunication lines
 - Modem, ISDN
 - Leased Lines
 - Internet
 - local provider (static IP, data integrity?)
 - Intranet
 - Radio Links
 - directed antenna beacons
 - Mobile Phone data (GSM, GPRS, UMTS)
 - Satellite Communication
- Data formats
 - receiver specific raw data
 - 19200bps, bi-directional
 - pre-processed data (RTCM, RTCM++)
 - 2400bps, uni-directional

Reference/Center to Rover

- **Mobile phone (GSM)**
 - bidirectional communication (SSR,OSR (FKP,PRS,VRS))
- **mobile Internet (GPRS, UMTS)**
 - bidirectional or uni-directional
 - NTRIP
 - encryption for
 - access control
 - charging
- **„Broadcast“ media**
 - VHF, TV, Radio, Satellite communication
 - SSR, FKP
 - no VRS,PRS
 - encryption for
 - access control
 - charging

Conclusions



- GPS positioning is affected by **absolute** and **distance dependent errors**
- DGPS and local RTK systems can only avoid absolute errors
 - lead to **limited RTK** (and DGPS) **distance**
- GNSMART network **monitors** all errors
 - allowing RTK (and DGPS) applications with
 - **homogenous accuracy, reliability and availability**
- GNSMART supports all currently used representation modes
 - **FKP, VRS, PRS**
- GNSMART is well prepared for **future developments**

Further Information



For **general information** on GNSMART please refer to the Geo++ home page

<http://www.geopp.com/gnsmart>

For **background publications** refer directly to the Geo++ Publications page

http://www.geopp.com/publications/english/lit_e.htm