# GNSS Errors

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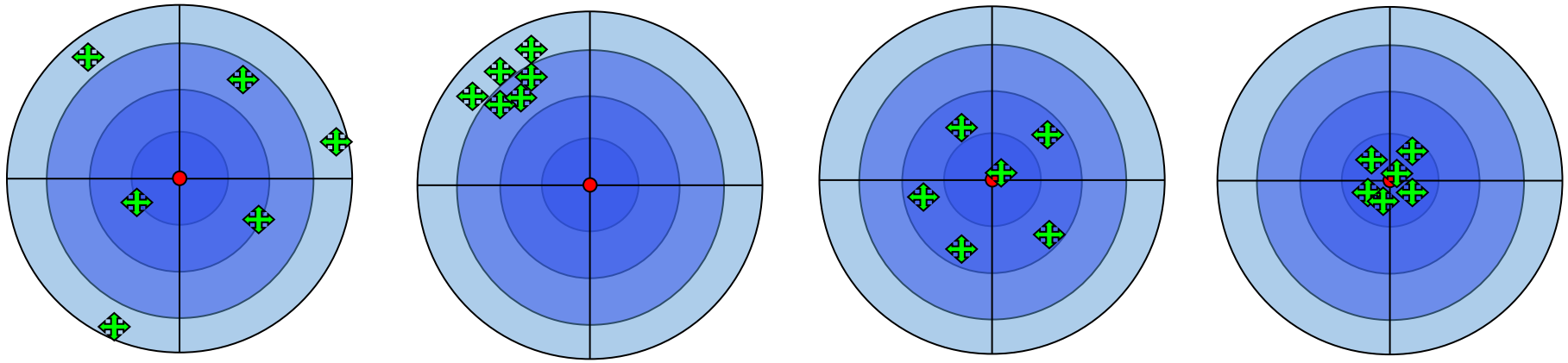
# Background Information: Accuracy vs. Precision

- Accuracy
  - Capable of providing a correct measurement
  - Measurement is compared with true value
  - Affected by systematic error
- Precision
  - Capable of providing repeatable and reliable measurement
  - Statistical analysis of measurement provides the precision
  - Measure of random error
  - Systematic error has no effect



Neither Precise nor Accurate | Precise but Not Accurate | Accurate but Not Precise | Precise and Accurate

# GNSS Measurement Errors

| Measure | Abbreviation | Definition |
|---|---|---|
| Root Mean Square | RMS | The square root of the average of the squared errors |
| Twice Distance RMS | 2D RMS | Twice the RMS of the horizontal errors |
| Circular Error Probable | CEP | A circle's radius, centered at the true antenna position, containing 50% of the points in the horizontal scatter plot |
| Horizontal 95% Accuracy | R95 | A circle's radius, centered at the true antenna position, containing 95% of the points in the horizontal scatter plot |
| Spherical Error Probable | SEP | A sphere's radius centered at the true antenna position, containing 50% of the points in the three dimensional scatter plot |

Source: GPS Accuracy: Lies, Damn Lies, and Statistics, GPS World, JAN 1998
https://www.gpsworld.com/gps-accuracy-lies-damn-lies-and-statistics/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# Commonly Used GNSS Performance Measurements

- TTFF
  - True Time to First Fix
  - Parameter: Cold Start, Warm Start, Hot Start
- Standard Accuracy
  - Accuracy attainable without any correction techniques
- DGPS Accuracy
  - Accuracy attainable by differential correction data
  - Code-phase correction
- RTK Accuracy
  - Accuracy attainable by differential correction data
  - Use both Code-Phase and Carrier Phase correction


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# TTFF and Typical Example Values

- TTFF
  - Cold Start : < 36 seconds
    - Time required to output first position data since the receiver power is on
    - No reference data like time or almanac are available
  - Warm Start : < 6 seconds
    - Time required to output first position data since the receiver power is on with the latest satellite almanac data in the receiver's memory
    - Time and almanac related reference data are already known
  - Hot Start : < 1 second
    - Receiver has already output position data
    - Time to reacquire an already tracked satellite due to temporary blockage by buildings or trees


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# Performance Measurement of RTK Accuracy

- A fix error and a variable error with respect to base-length is given
  - Such as : x cm + y ppm
  - Example: 2cm + 1ppm
    - There is a fix error of 2cm plus 1ppm error due to base-length between the Base and Rover
    - 1ppm ➔ 1 parts per million
    - ➔ 1cm of error in 1 million centimeter distance between the Base and the Rover
    - ➔ 1cm of error in 1000000 centimeter distance between the Base and the Rover
    - ➔ 1cm of error in 10000 meter distance between the Base and the Rover
    - ➔ 1cm of error in 10 kilometer distance between the Base and the Rover
    - ➔ **1cm of error for every 10Km of distance between the Base and the Rover**
    - ➔ 4cm of error for 40Km of distance between the Base and the Rover
    - **Thus the total error is : 2cm + 4cm due to 40Km of base length**
  - The longer the base-length, the larger the error
    - Do not assume that this error is linear
    - And it may not be valid for longer base-lines
    - Normally the recommended base-length for RTK for a Geodetic Receiver is 40Km


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