Orbits

- **LEO**: Low earth orbit
- **MEO**: Medium earth orbit
- **GEO**: Geostationary earth orbit

**USA** → **GEO** → **Japan**
**EU** → **MEO** → **India**
**Russia** → **USA**
**India** → **China**
**China** → **Russia**

- **GPS** → **satellites around earth**
  → mostly in **MEO**
  \[\rightarrow \text{LEO too close} \ldots\]
  \[\rightarrow \text{... needs satellites for earth coverage}\]
  \[\rightarrow \text{GEO too far} \ldots\]
Navigation Message

being sent continuously from satellite

Why so low? Because

Note: WiFi bitrate

Satellite constantly sending:

< , , >

An GPS satellite clocks are synchronized. How?

Centers ingesting GPS signals, computing satellite locations and clocks, and these corrected estimates to satellites to adjust each clock and ephemeris

Infrequent needed like more satellite location in case of
GPS Localization: Basic idea.

(a) Receiver from itself to each satellite, $r_i$.
(b) Formulates as $x, y, z$, where $x = \begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix}$.
(c) $b$ does not need to solve.
(d) GPS receiver's clock also gets...
Basic GPS Localization

$tx\ time\ (t^s)$

$rx\ time\ (t_r)$

GPS Signal
Basic GPS Localization

\[ Range(R) = (t_r - t_s) \times c \]

However, 3D location needs 3 equations; hence, use 3 satellites.
Basic GPS Localization

\[ \text{Range}(R) = (t_r - t^s) \times c \]

However, 3D location needs 3 equations ... hence, use 3 satellites

\[
\begin{align*}
\sqrt{(x_1^s - x_0)^2 + (y_1^s - y_0)^2 + (z_1^s - z_0)^2} &= (t_r - t_{1^s}) \\
\sqrt{(x_2^s - x_0)^2 + (y_2^s - y_0)^2 + (z_2^s - z_0)^2} &= (t_r - t_{2^s}) \\
\sqrt{(x_3^s - x_0)^2 + (y_3^s - y_0)^2 + (z_3^s - z_0)^2} &= (t_r - t_{3^s})
\end{align*}
\]
Basic GPS Localization

Range\((R) = (t_r - t_s) \times c\)

However, 3D location needs 3 equations ... hence, use 3 satellites
Basic GPS Localization

Range\( (R) = (t_r - t_s) * c + \delta_{clk} * c \)

New unknown \( \delta \) ... use 4th satellite and estimate both location and \( \delta \)
Basic GPS Localization

\[ \text{Range}(R) = (t_r - t_s) \times c + \delta_{\text{clk}} \times c \]

New unknown \( \delta \) ... use 4th satellite and estimate both location and \( \delta \)

\[
\begin{bmatrix}
  c & c & c & c \\
  X & Y & Z & \delta_{\text{clk}}
\end{bmatrix}
\begin{bmatrix}
  R_1 \\
  R_2 \\
  R_3 \\
  R_4
\end{bmatrix}
\] → 1-3m error
Estimating receive time $t_r$ at GPS hardware

How to detect presence of a signal $S$ in received signal $Y$.

Given $y_5, y_6, y_7, y_8, y_9, \ldots$ Find $s_1, s_2, s_3, s_4, s_5$

Correlation:

$$C = \frac{1}{K}$$

But $y_i = s_i$ because of

Then $C = \frac{1}{K} \begin{bmatrix} S \end{bmatrix} = \frac{1}{K}$

If $S$, then decoding possible.

Thus, $S$ and $N$ need to be

i.e.,

In practice, how will $K$ impact $E[S.N]$?

better is decoding.
Not enough

What if the signal changes slowly ... then $S$ will also match well with

Thus, $S$ should match well with signal $S[n]$

caused

Ideally,

Moreover:

signal $Z$, expected from $S$ should exhibit property.

Otherwise $Z$ will

and GPS receiver will detect the

Summary:

necessary for satellite signals:

1. Uncorrelated to noise
2. Good auto-correlation
3. Weak cross-correlation

GPS uses that satisfy these properties.