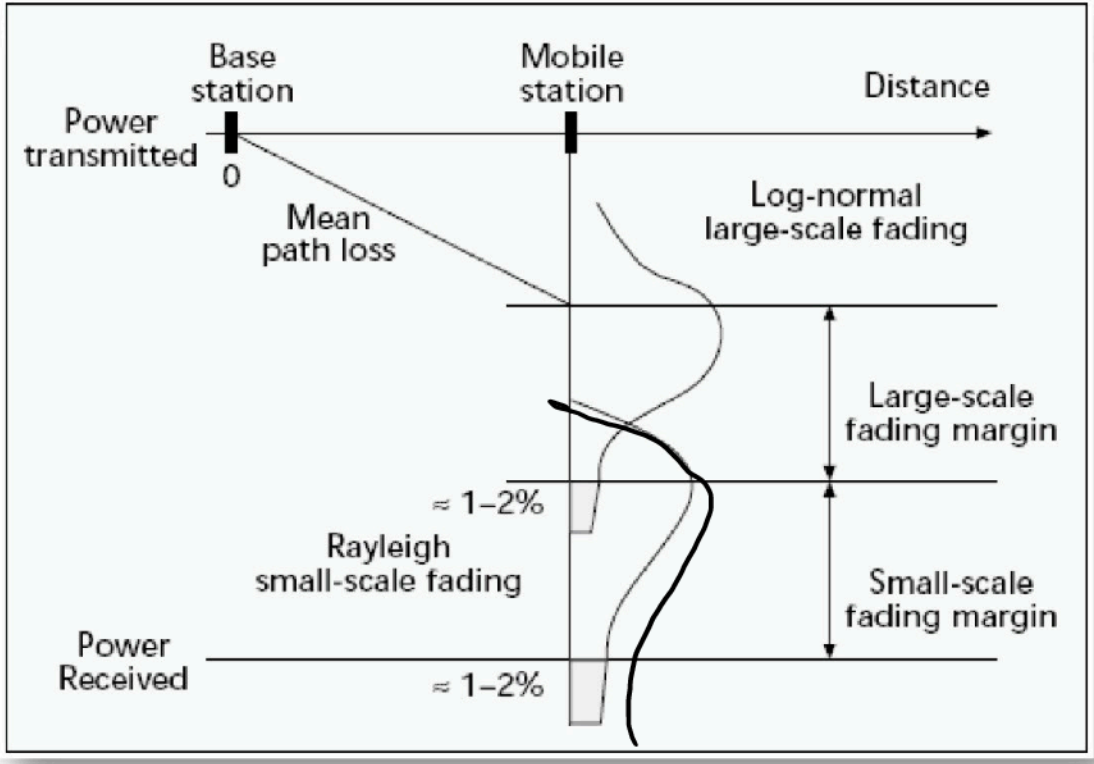
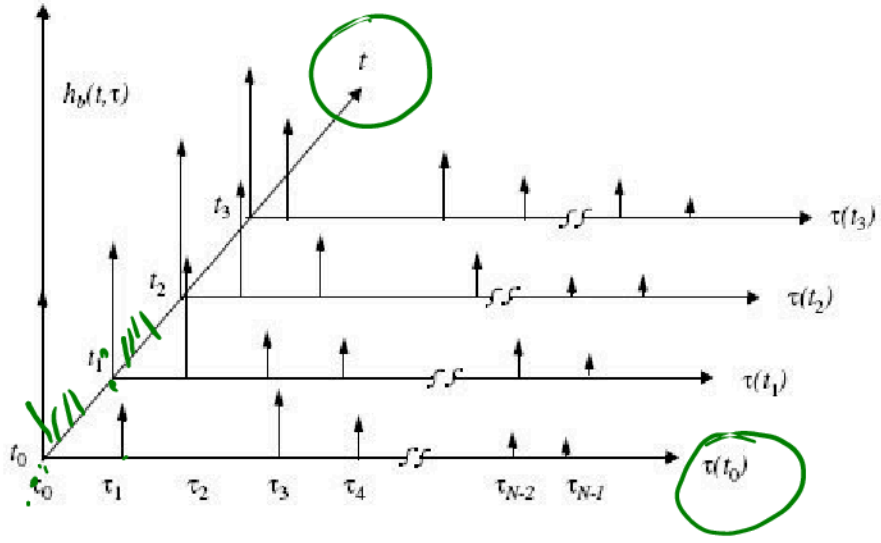
Enlace de RF

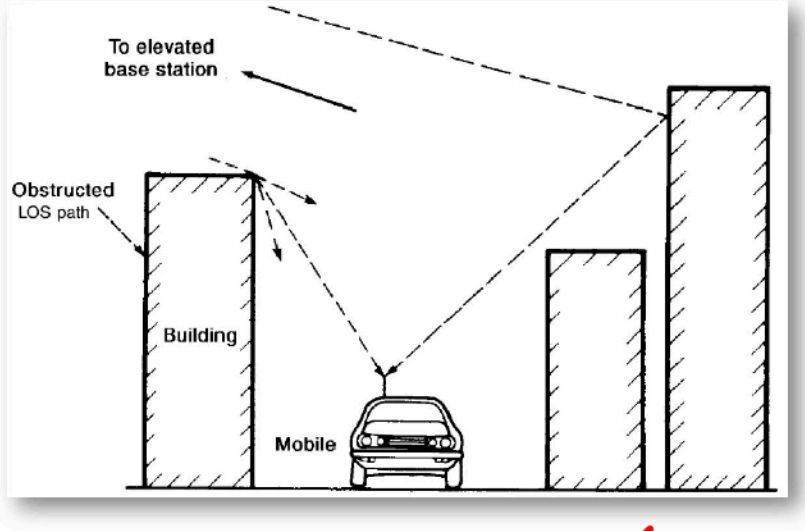


σ_τ

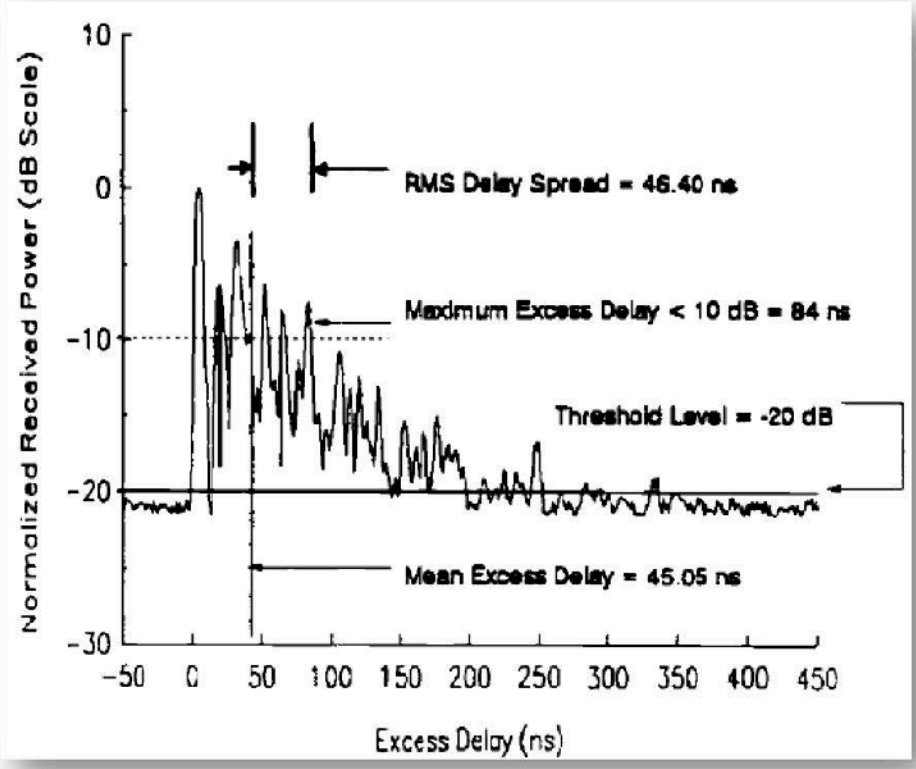
$T_c / f_{d_{max}}$

Modelo de pequeña escala





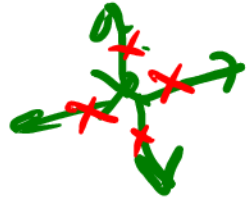
Modelo de pequeña escala SONDEO DE CANAL: CHANNEL SOUNDING.



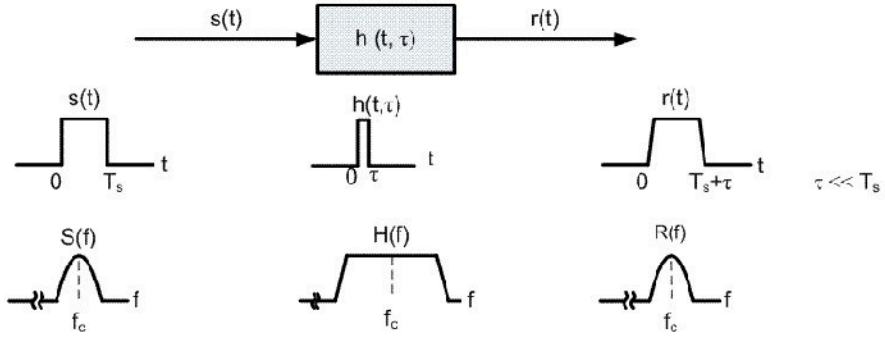
$$\bar{\tau} = \frac{\sum_k (p(\tau_k).\tau_k)}{\sum_k p(\tau_k)}$$

$$\overline{\tau^2} = \frac{\sum_k (p(\tau_k).\tau_k^2)}{\sum_k p(\tau_k)}$$

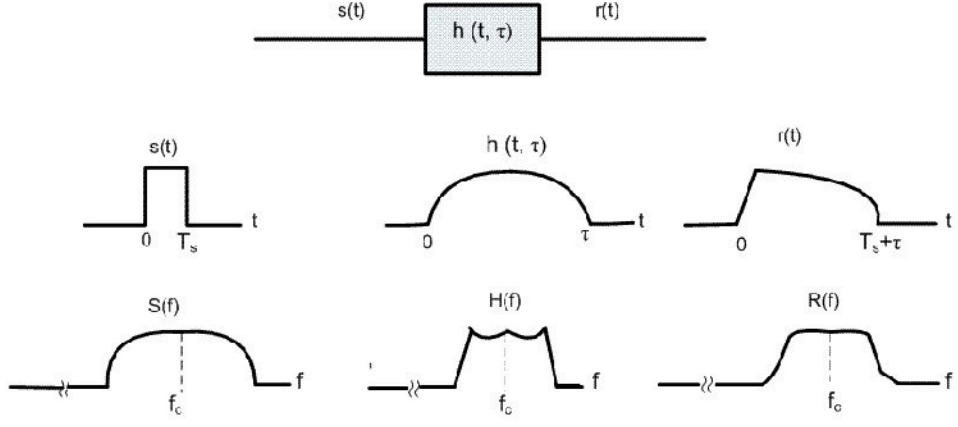
$$\sigma_\tau = \sqrt{\overline{\tau^2} - \bar{\tau}^2}$$



Modelo de pequeña escala



(a) Flat fading channel characteristics



(b) Frequency selective fading channel characteristics

Modelo de pequeña escala

Small-Scale Fading
(Based on multipath time delay spread)

Flat Fading
1. BW of signal < BW of channel
2. Delay spread < Symbol period

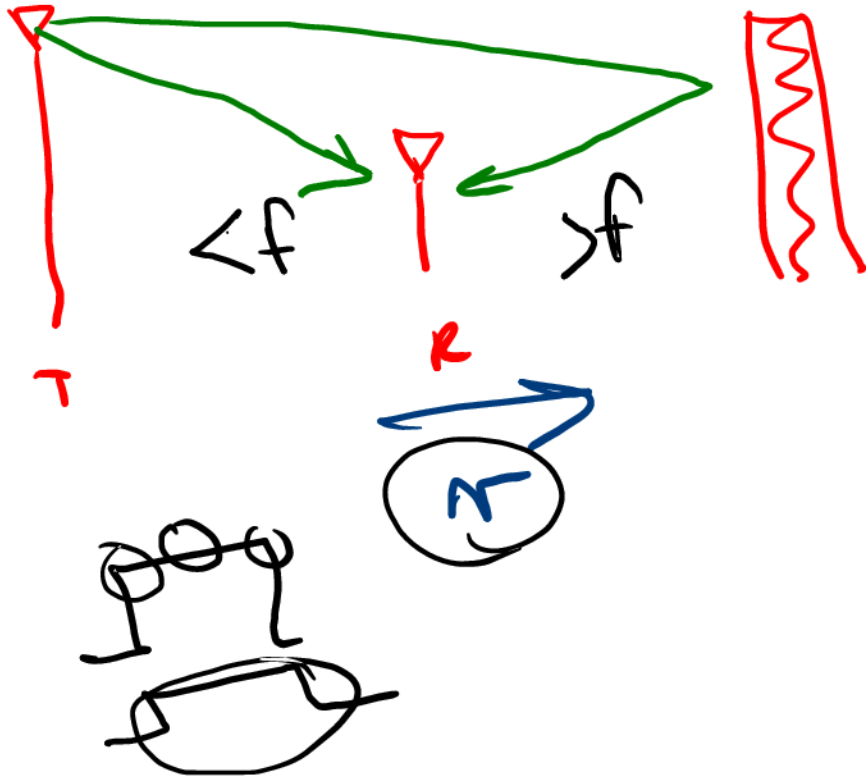
Frequency Selective Fading
1. BW of signal > BW of channel
2. Delay spread > Symbol period

Small-Scale Fading
(Based on Doppler spread)

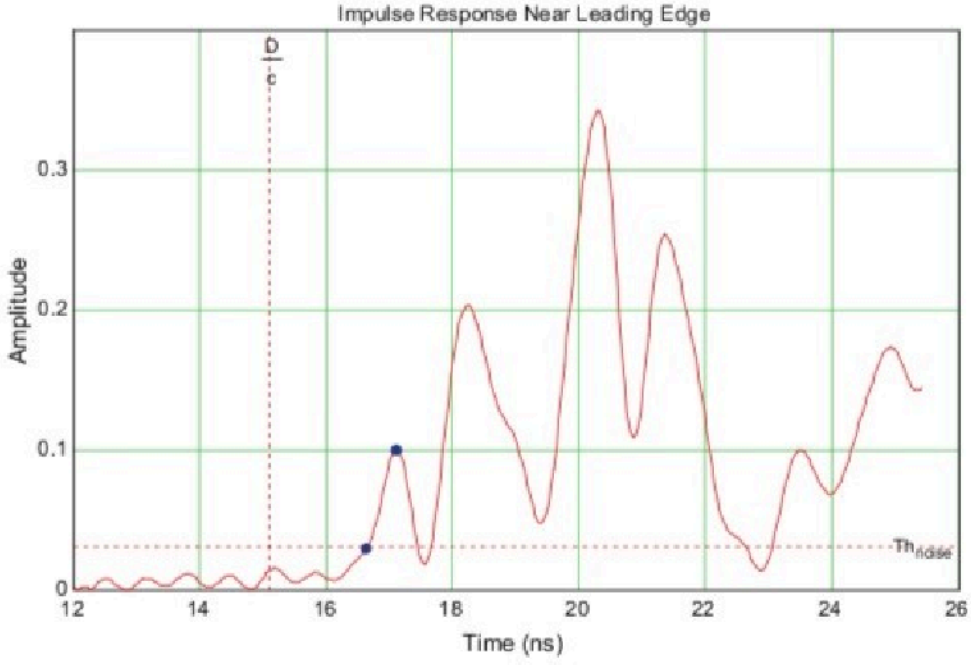
Fast Fading
1. High Doppler spread
2. Coherence time < Symbol period
3. Channel variations faster than base-band signal variations

Slow Fading
1. Low Doppler spread
2. Coherence time > Symbol period
3. Channel variations slower than baseband signal variations

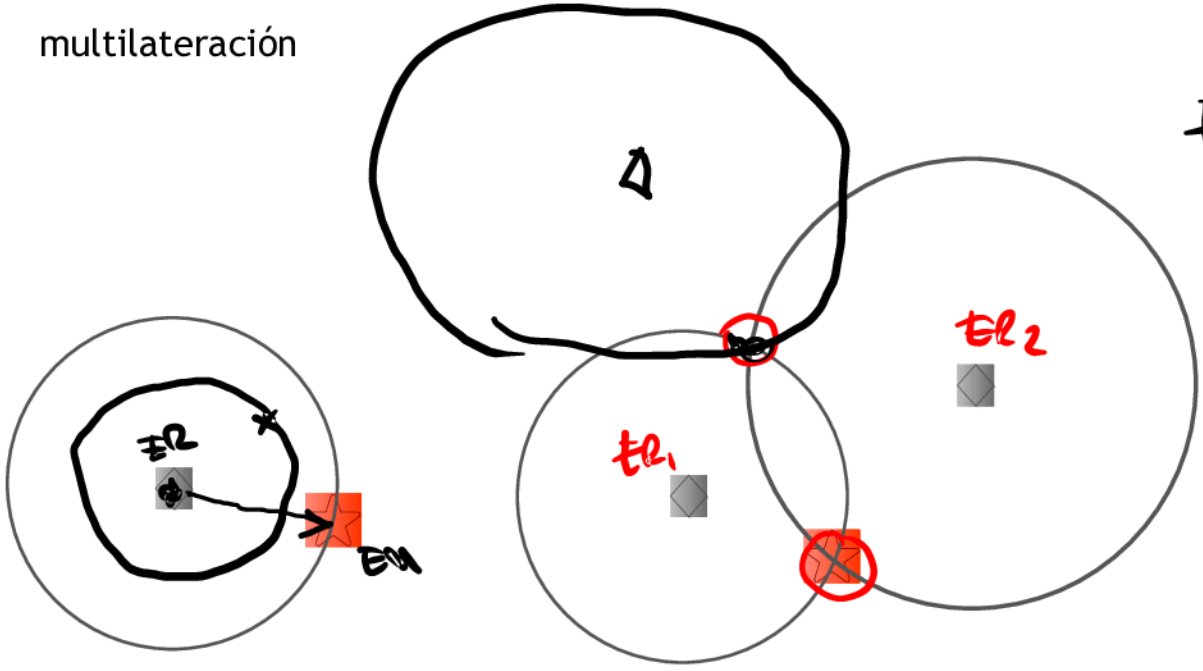
$T_C \times \frac{1}{f_{d\,max}}$



Efectos en el Posicionamiento



Triangulación: multilateración



EB: EST. BASE
ER: EST. DE REF
EM: EST. MÓVIL
¿DONDE?

dist. ER → M

3ER

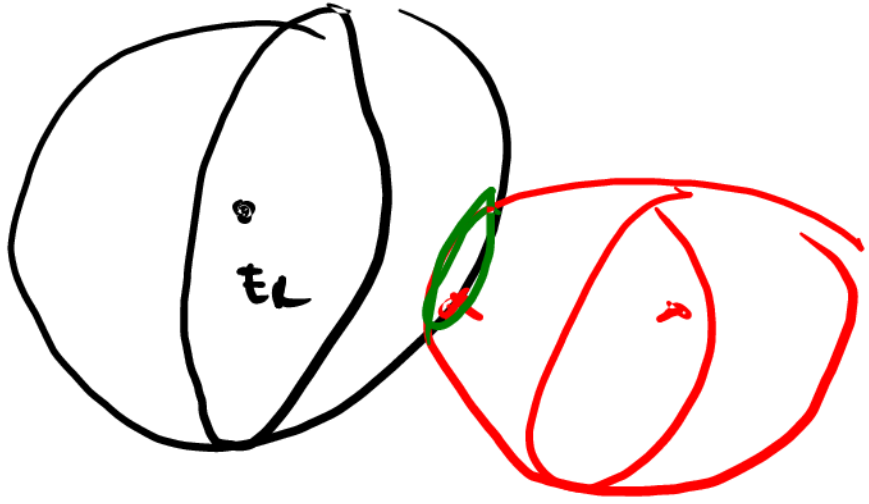
Pos. UNICA

2 PUNTOS

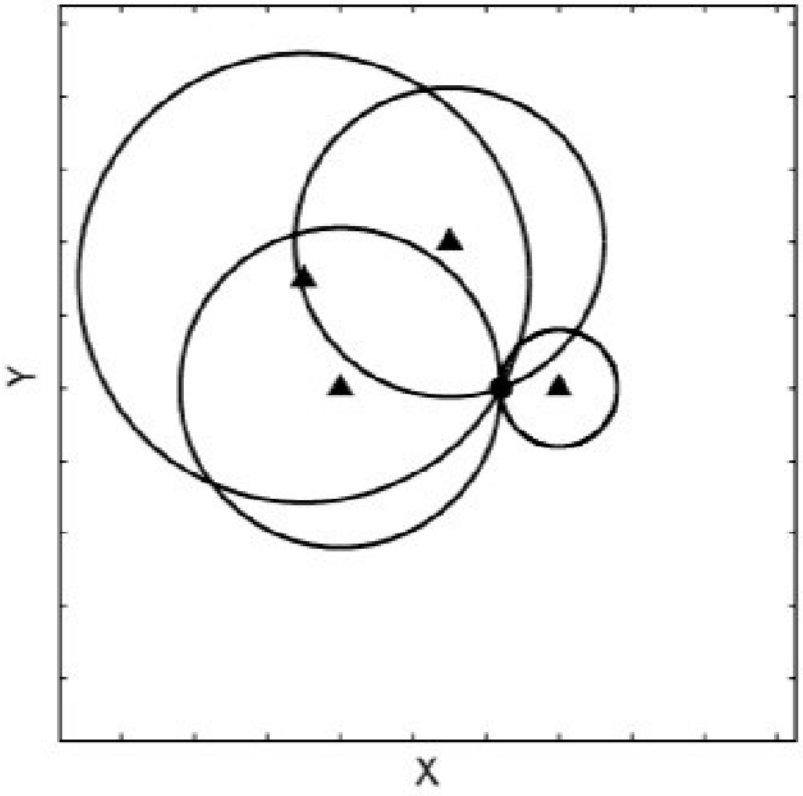
LOP: LINE OF POSIC.
CIRCULOS

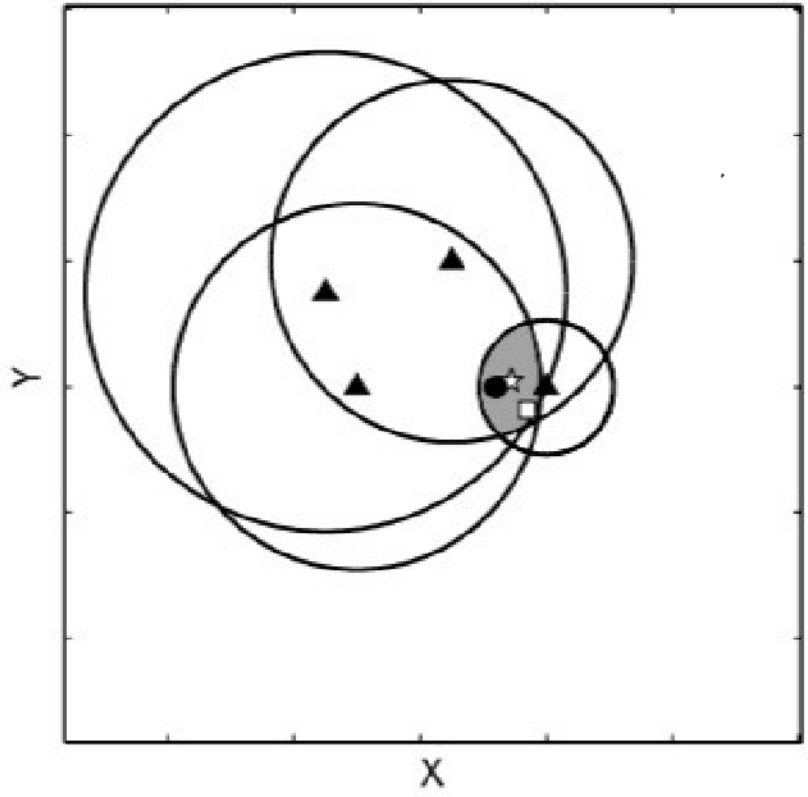
X, M, Z

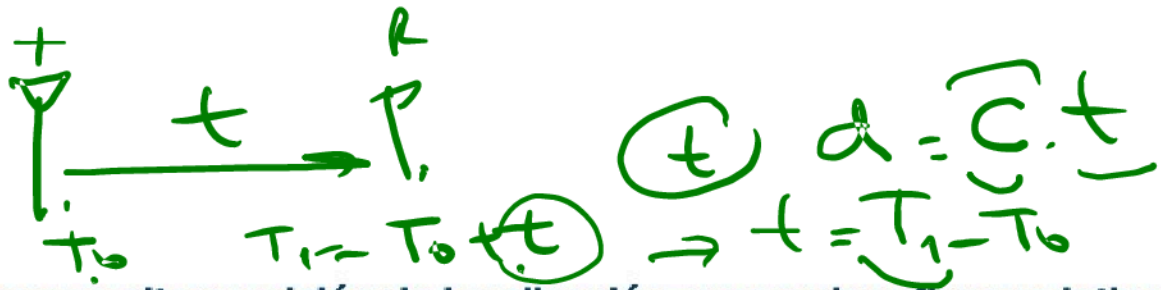
$E^2 \to NRO$ DIM +1



Triangulación: multilateración





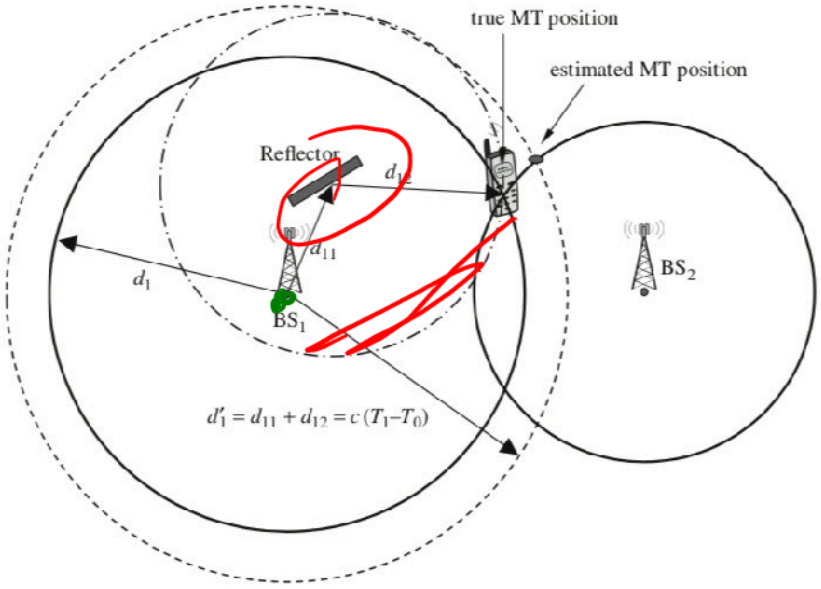


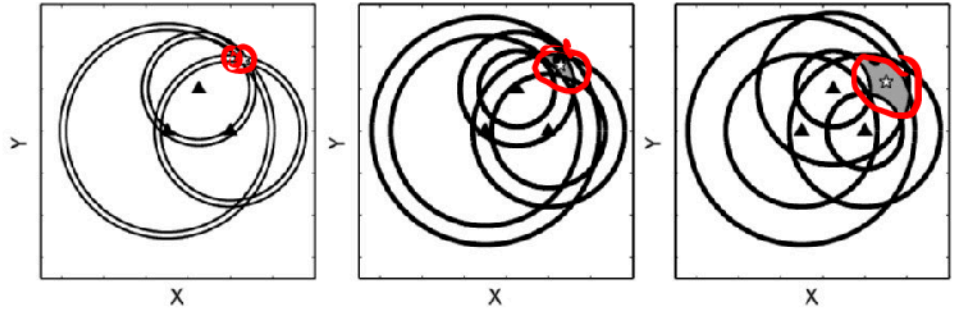
Proporciona una alta precisión de localización, no requiere fingerprinting

TOF

Requiere sincronización temporal entre los transmisores y receptores, puede requerir marcas de tiempo y múltiples antenas en el transmisor y receptor. La línea de visión es necesaria para tener buena precisión.

Triangulación: TOA/TOF





Triangulación: TOA

$d = ct$ · n_i: todos los errores.

(x, y) posición del móvil

(x_i, y_i) posición de la ER$_i$

$$\hat{d}_i = c(t_i + n_i)$$

$$\hat{d}_i^2 = (x - x_i)^2 + (y - y_i)^2$$

MÉTODO DE LAS SECANTES

(RECTAS DE LA INTERS. DE 2 CIRC.)

N ER

$$d_1^2 = (x - x_1)^2 + (y - y_1)^2$$

$$d_2^2 = (x - x_2)^2 + (y - y_2)^2$$

$$\vdots$$

RESTO $\quad d_N^2 = (x - x_N)^2 + (y - y_N)^2$

$$d_2^2 - d_1^2 = (x - x_2)^2 + (y - y_2)^2 - (x - x_1)^2 - (y - y_1)^2$$

$$\vdots$$

$$d_N^2 - d_1^2 = (x - x_N)^2 + (y - y_N)^2 - (x - x_1)^2 - (y - y_1)^2$$

$$d_2^2 - d_1^2 = x^2 - 2xx_2 + x_2^2 + y^2 - 2yy_2 + y_2^2 - x^2 + 2xx_1 - x_1^2 - y^2 + 2yy_1 - y_1^2$$

$$d_2^2 - d_1^2 = x_2^2 + y_2^2 - x_1^2 - y_1^2 + x(-2x_2 + 2x_1) + y(-2y_2 + 2y_1)$$

$$d_2^2 - d_1^2 - x_2^2 - y_2^2 + x_1^2 + y_1^2 = x(2x_1 - 2x_2) + y(2y_1 - 2y_2)$$

$$d_2^2 - d_1^2 - x_2^2 - y_2^2 + x_1^2 + y_1^2 = x(2x_1 - 2x_2) + y(2y_1 - 2y_2)$$

$$D_2$$

$$\begin{bmatrix} D_2 \\ D_3 \\ \vdots \\ D_N \end{bmatrix} = \begin{bmatrix} 2x_1 - 2x_2 & 2y_1 - 2y_2 \\ 2x_1 - 2x_3 & 2y_1 - 2y_3 \\ \vdots & \vdots \\ 2x_1 - 2x_N & 2y_1 - 2y_N \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

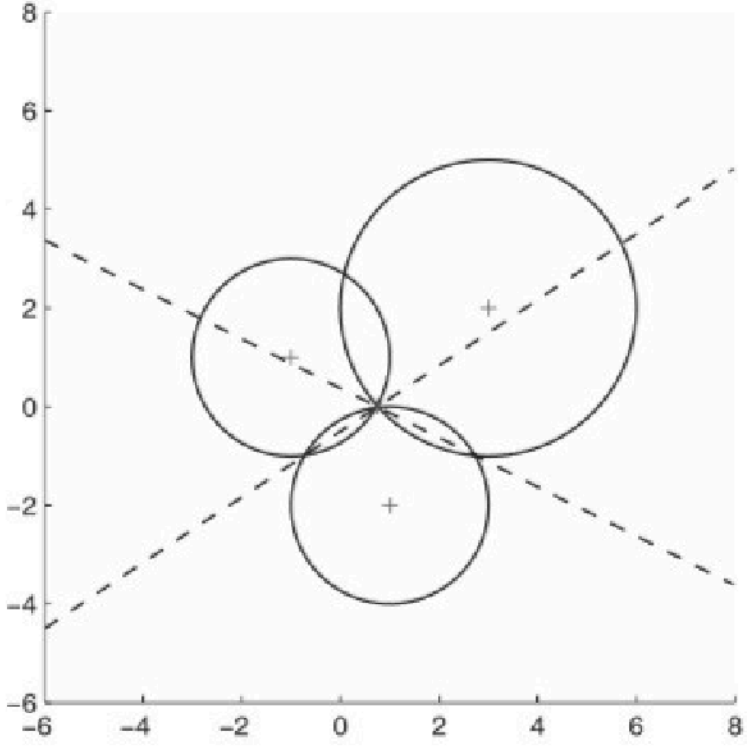
N-1

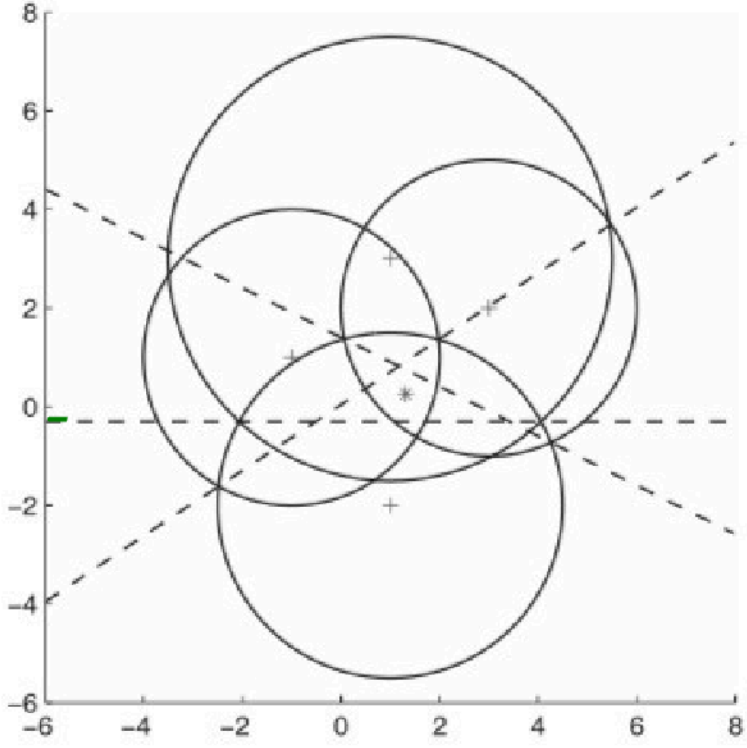
D $\quad$ A

MÍNIMOS CUADRADOS

$$\hat{X} = (A^T A)^{-1} A^T D$$

Triangulación: TOA TIME OF ARRIVAL / TIME OF FLIGHT.





Triangulación: seudo-rango (pseudorange)

$$t_{Ri} + \eta = \frac{\sqrt{(x_i - x)^2 + (y_i - y)^2}}{c} + t_{M_i} + \epsilon_i$$

$t_{Ri} = t_i + \eta$ sinc.

$t_{Ri} = t_{Mi} + \varepsilon_i$

$t_i = t_{UM} + t_{Mi} - \eta$

$t_{UR} = t_{UM} - \eta$

$t_{UR} = \frac{\sqrt{\quad}}{c} - \eta$

$(t_i - t_{Mi})$

$d^2 = (x - x_i)^2 + (y - y_i)^2 + c^2 b$

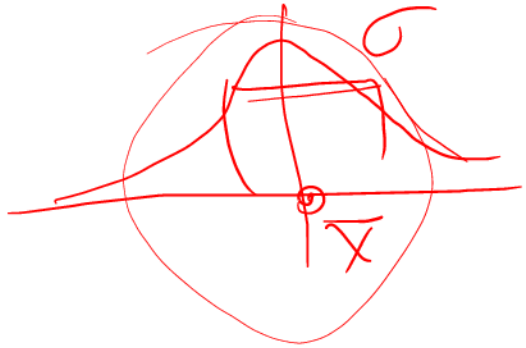
$ct_{UR} + c\eta = \sqrt{(x_i - x)^2 + (y_i$

$c(t_{UR} + \eta) = \sqrt{\quad}$

Triangulación: seudo-rango resolución por Kalman

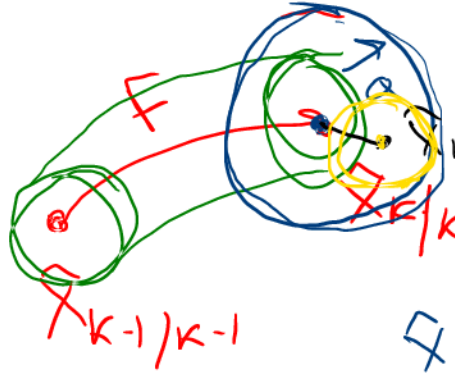
$$\hat{\mathbf{x}}_{k|k-1} = \mathbf{F}_k \hat{\mathbf{x}}_{k-1|k-1}$$

$$\mathbf{P}_{k|k-1} = \mathbf{F}_k \mathbf{P}_{k-1|k-1} \mathbf{F}_k^T + \mathbf{G}_k \mathbf{Q}_k \mathbf{G}_k^T$$



$$\hat{\mathbf{x}}_{k|k} = \hat{\mathbf{x}}_{k|k-1} + \mathbf{W}_k \left[\mathbf{z}_k - \hat{\mathbf{h}}(\hat{\mathbf{x}}_{k|k-1})\right]$$

$$\mathbf{P}_{k|k} = \mathbf{P}_{k|k-1} - \mathbf{W}_k \mathbf{S}_k \mathbf{W}_k^T$$



$$\mathbf{W}_k = \mathbf{P}_{k|k-1} (\nabla^T \mathbf{h}_k^x)\, \mathbf{S}_k^{-1}$$

$$\mathbf{S}_k = (\nabla \mathbf{h}_k^x)\, \mathbf{P}_{k|k-1}\, (\nabla^T \mathbf{h}_k^x) + \mathbf{R}_k$$

$$\hat{\mathbf{x}}_{k/k-1} = \begin{bmatrix} x_{k/k-1} \\ y_{k/k-1} \\ b_{k/k-1} \end{bmatrix}$$

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2} + b$$

$$F = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \qquad R = \begin{bmatrix} \sigma_x & 0 \\ 0 & \sigma_y \end{bmatrix} \qquad \hat{X} = \begin{bmatrix} x \\ y \\ \dot{x} \\ \dot{y} \\ b \end{bmatrix}$$

$$GRBT = \begin{bmatrix} \sigma_x & 0 & 0 & 0 & 0 \\ 0 & \sigma_y & 0 & 0 & 0 \\ 0 & 0 & \sigma_{\dot{x}} & 0 & 0 \\ 0 & 0 & 0 & \sigma_{\dot{y}} & 0 \\ 0 & 0 & 0 & 0 & \sigma_b \end{bmatrix} \qquad X_{k+1} = F X_k \qquad \begin{bmatrix} x_{k+1} \\ y_{k+1} \\ \dot{x}_{k+1} \\ \dot{y}_{k+1} \\ b_{k+1} \end{bmatrix} = F \begin{bmatrix} x_k \\ y_k \\ \dot{x}_k \\ \dot{y}_k \\ b_k \end{bmatrix}$$

$$F_{x_k} = \begin{bmatrix} 1 & 0 & \Delta T & 0 & 0 \\ 0 & 1 & 0 & \Delta T & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_{k-1} \\ y_{k-1} \\ \dot{x}_{k-1} \\ \dot{y}_{k-1} \\ b_k \end{pmatrix}$$

$$X_k = X_{k-1} + \dot{X} \cdot \Delta t$$

$$X_k = X_{k-1} + \dot{X}_{k-1} \Delta t$$

$10 \qquad 10 + 3\frac{m}{s} \cdot 1s = 13$

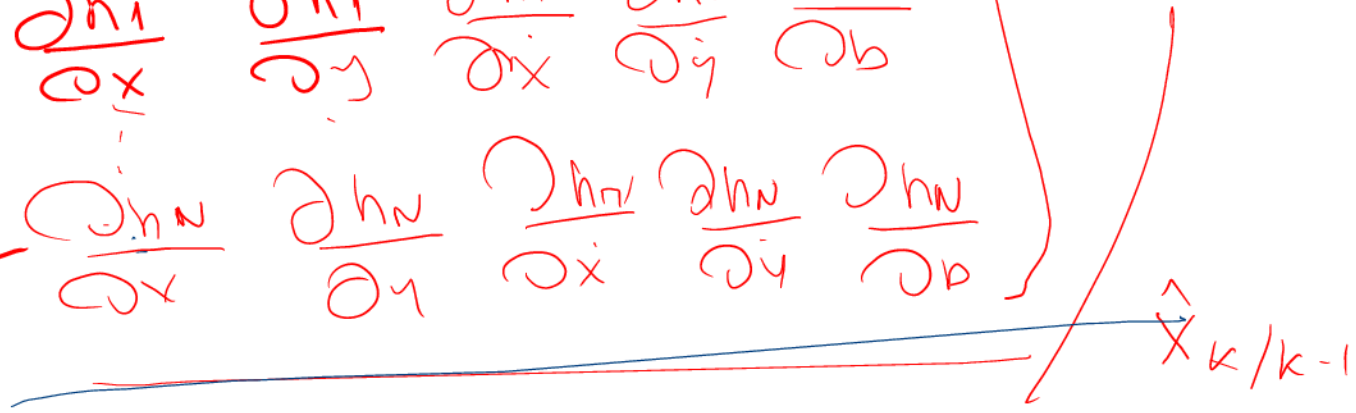
1s 2s

$3 m/s$

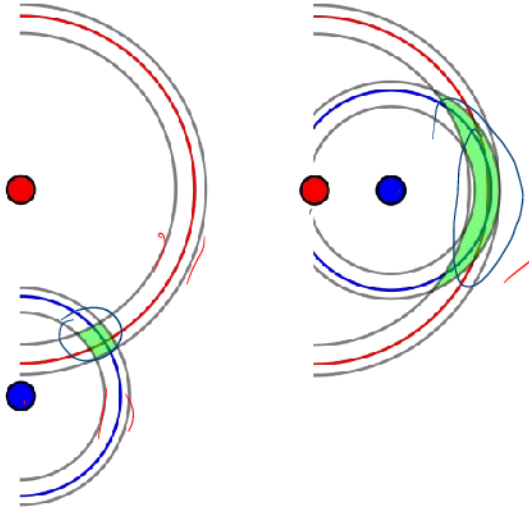
$13 + 3\frac{m}{s} \cdot 2$

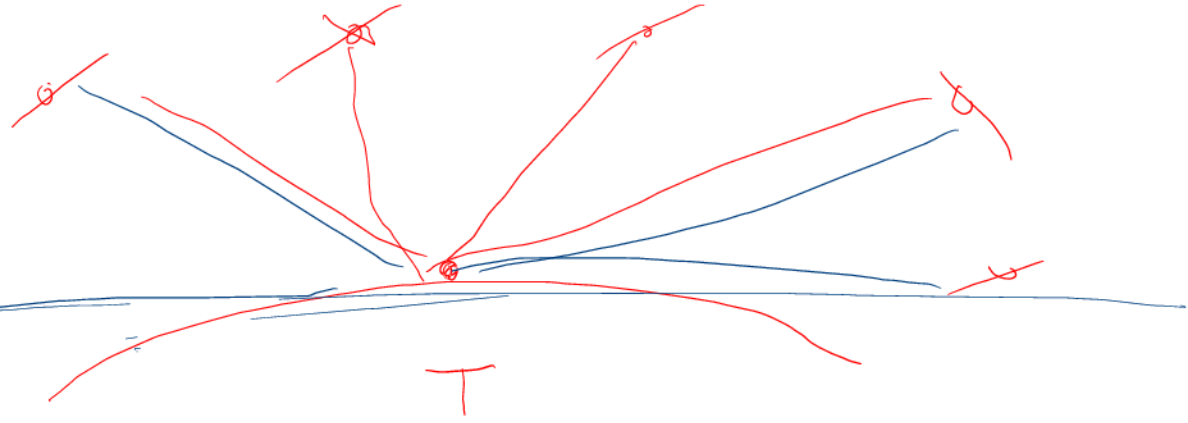
$19 m$

$$\nabla h = \begin{bmatrix} \frac{\partial h_1}{\partial x} & \frac{\partial h_1}{\partial y} & \frac{\partial h_1}{\partial \dot{x}} & \frac{\partial h_1}{\partial \dot{y}} & \frac{\partial h_1}{\partial \theta} \\ \vdots & & & & \\ \frac{\partial h_M}{\partial x} & \frac{\partial h_M}{\partial y} & \frac{\partial h_M}{\partial \dot{x}} & \frac{\partial h_M}{\partial \dot{y}} & \frac{\partial h_M}{\partial \theta} \end{bmatrix}$$



Precisión - Dilution of Precision





$$A = (H^T H)^{-1}$$

$$\sigma^2 = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{xx} & \sigma_{yx} & \sigma_{bx} \\ \sigma_{xy} & \sigma_y^2 & \sigma_{xy} & \sigma_{yy} & \\ & & & & \\ & & & & \sigma_{bb}^2 \end{bmatrix}$$

$\sqrt{\sigma_x^2}$ DOP X

$\sqrt{\sigma_{bb}^2} =$ DOP T