MIMO_0:INTRODUCTION

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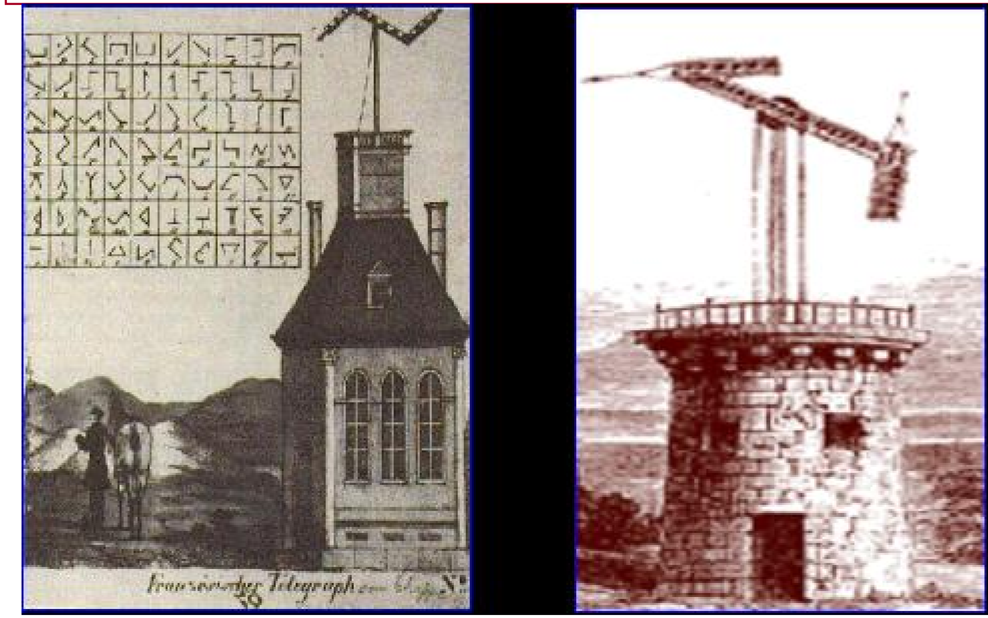
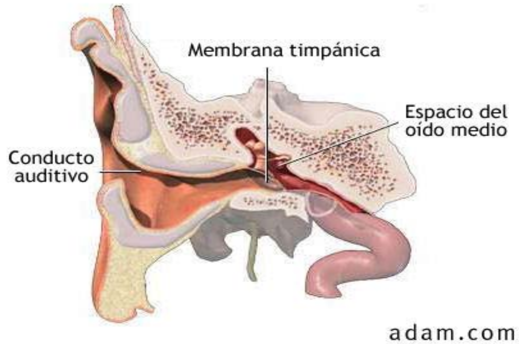
The roots of communications



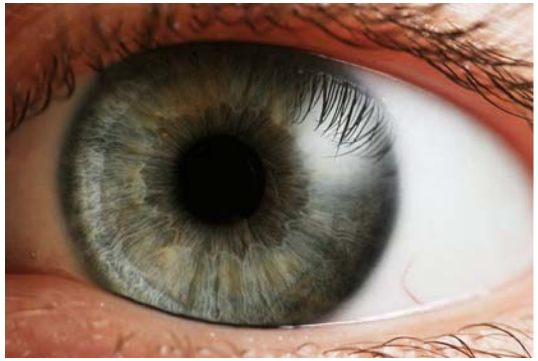
0.33 bits/sec

Chapé / Betancourt

100 Kbps.



15 Mbps..



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Comm. Layers

Session

⋮

Access Layer

Physical Layer (wired, wireless, optical)

SIGNAL PROCESSING

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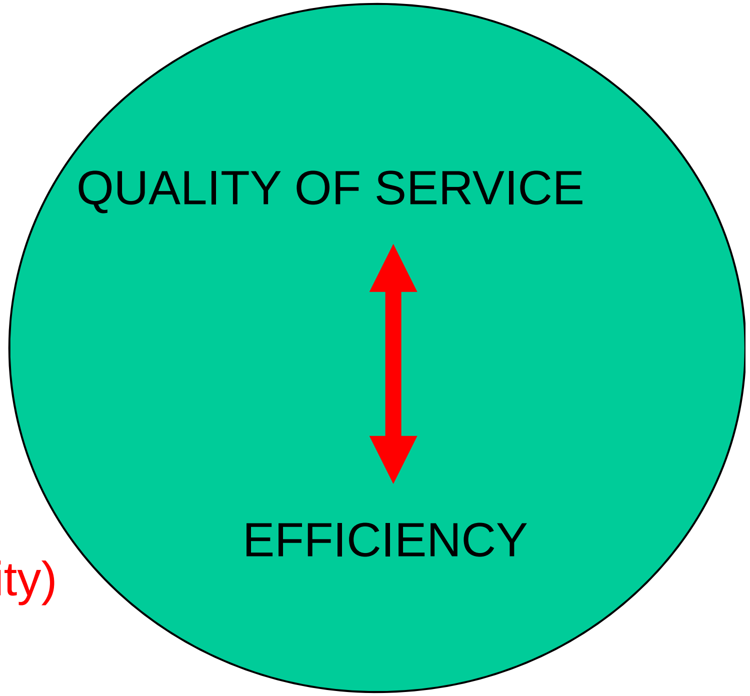
Wireless Systems

- Challenges
  - Higher data rate
  - Wider coverage
  - Energy efficient
  - Affordable
  - Reliable
- Possible solution
  - Multiple antenna systems:

ANTENNA ARRAYS (Spatial diversity)



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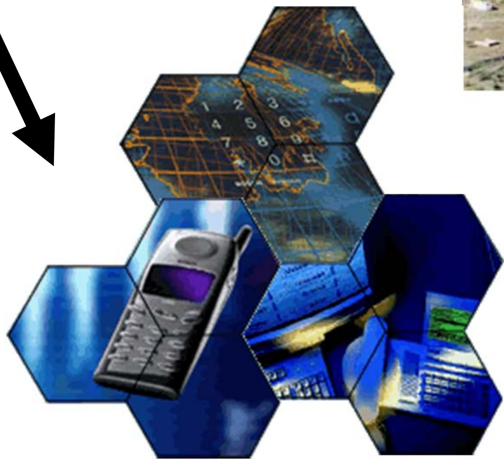
Combination of Wired Communications / Spatial Diversity contributions

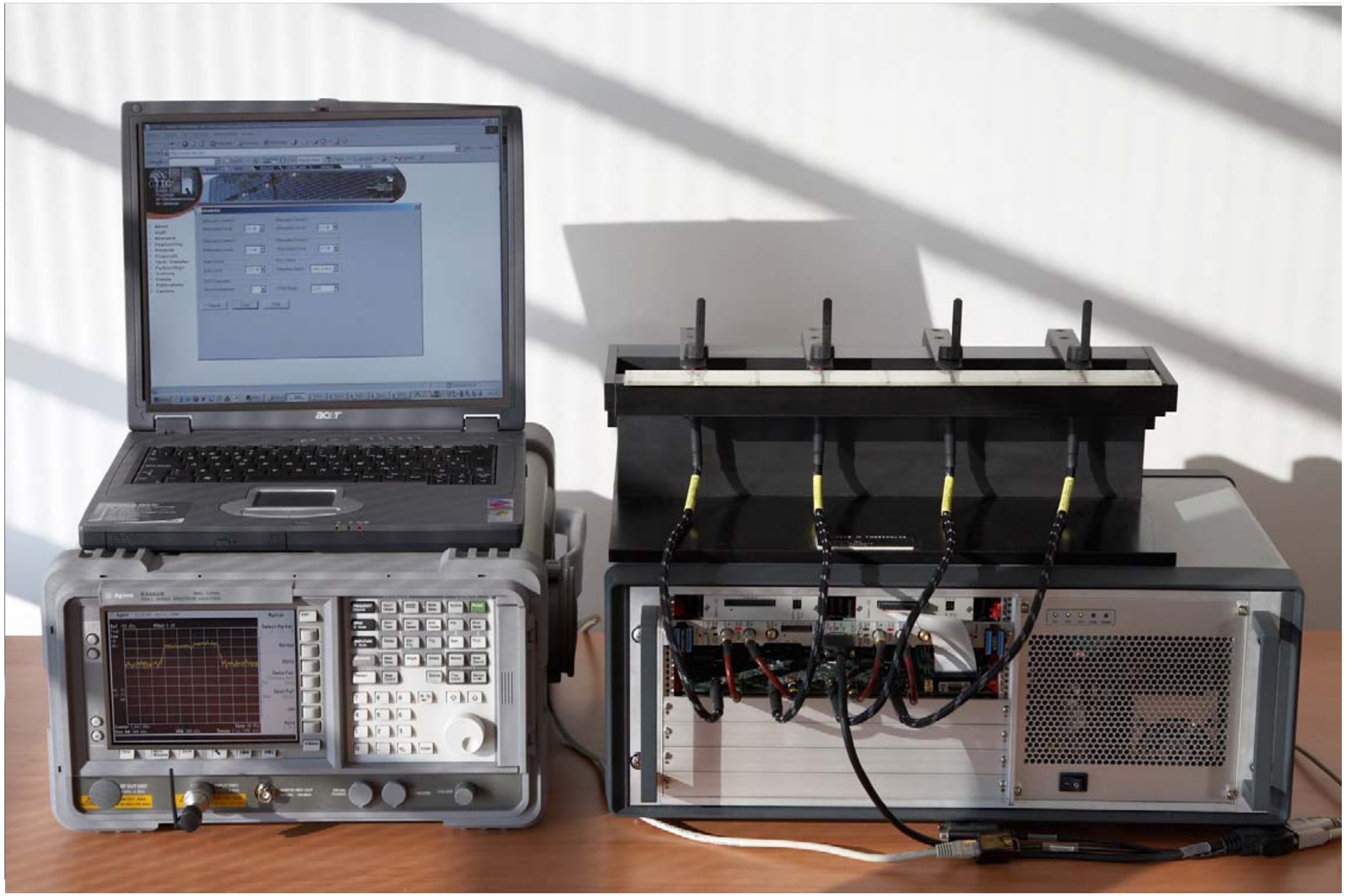
DSL Comm.

Radar/Sonar



Wireless Communications

Acoustics/Sonar/Radar/Civil Eng./Wireless



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PROYECTORES DE SONIDO. El Cine en Casa desde un sólo elemento

Los sistemas YSP de Yamaha incluyen en un sólo componente gran número de altavoces de reducidas dimensiones los cuales y mediante un avanzado método de aplicación de tiempo de retardo entre ellos permite proyectar "haces" sonoros que pueden ser orientados de manera precisa para conseguir un efecto sonoro envolvente óptimo.

Los haces direccionados producen ondas sonoras directas y otras reflejadas creando un verdadero sonido envolvente multicanal asi como sonido estereo de alta calidad o en 3 canales para el máximo realismo en conciertos musicales.

La ruptura tecnológica de los sistemas YSP abren una nueva era en el cine en casa facilitando su instalación y adaptándose a cualquier decoración. En cine en Casa sin cables.

¡ SOLICITE UNA DEMOSTRACION !

PARA 42" Y SUPERIORES

YSP-4000

- Dimensiones : 1030 (An) x 198 (al) x 144 (F) mm
- 42 altavoces con "TruBass"
- Potencia total: 120W
- Incorpora sintonizador FM con RDS
- Salida HDMI (repeater) compatible 1080p con conversión ascendente de video (a 1080i)
- Sistema de calibración automática "IntelliBeam" con comienzo directo
- Entrada de minijack frontal para lectores de MP3 externos con sistema de mejora de música comprimida
- Nuevos modos: 5ch stereo y My Surround
- Disponible plata y negro

Disponible en plata

PVP: 1.319€

PARA 32" Y SUPERIORES

YSP-3000

- Dimensiones: 800 (An) x 155 (al) x 152 (F) mm
- 23 altavoces con "TruBass"
- Potencia total: 82W
- Incorpora sintonizador FM con RDS
- Salida HDMI (swicher) compatible 1080p
- Sistema de calibración automática "IntelliBeam" con comienzo directo
- Nuevos modos: 5ch stereo y My Surround
- Disponible plata y negro

Disponible en negro

PVP: 849€

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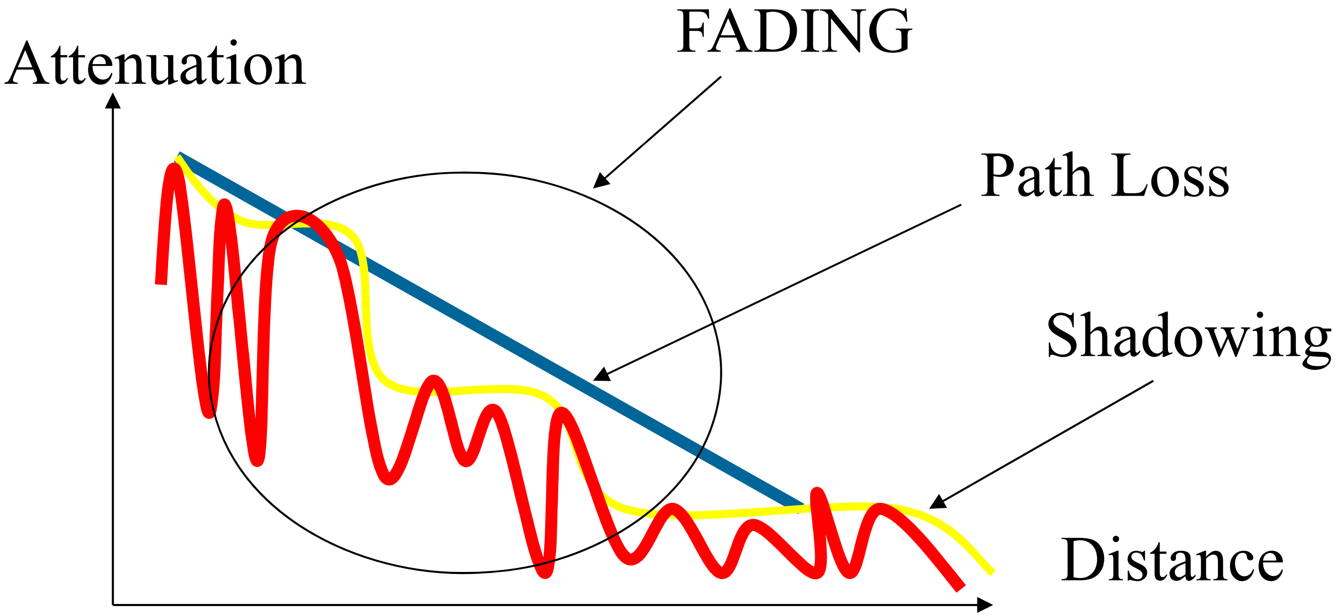
The Wireless Channel



Frequency Selective

$$h(t) = \alpha . g(t)$$

Flat Fading

$$h(t) = \alpha$$

Multicarrier Systems-> OFDM, Poly-Phase Filter Bank

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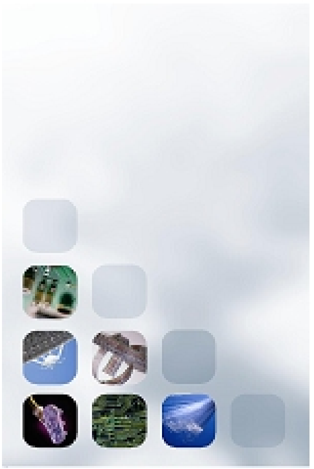
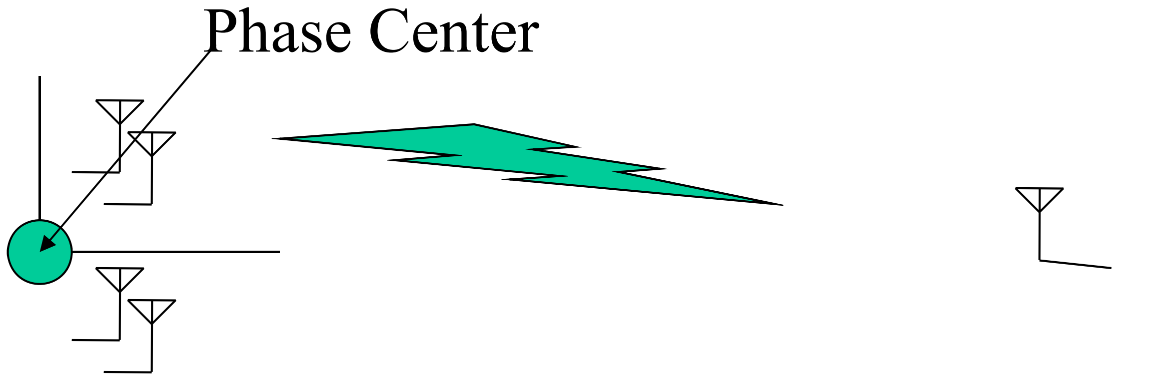
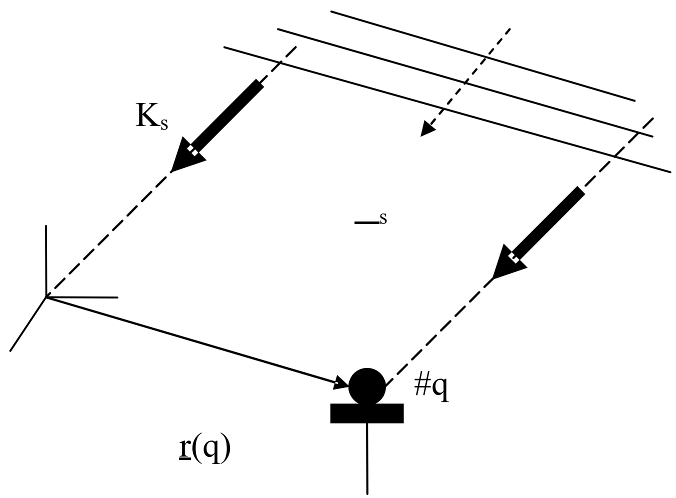


THE SPATIAL CHANNEL



LOS: Line of Sigth

$$e^{w_0.t} \longrightarrow e^{jw_o.t}.e^{j.K_s.r_q}$$



$$\underline{K}_s = \frac{2\pi}{\lambda}\left(\mathrm{sen}(\theta_s).\cos(\varphi_s), \mathrm{sen}(\theta_s).\mathrm{sen}(\varphi_s), \cos(\theta_s)\right)$$

$$\underline{r}_q = d_q\left(\cos(\varphi_q), \mathrm{sen}(\varphi_q), 0\right)$$

Wideband-Narrowband→Small group delay

$$x_q(t) = x_s(t-\tau_{qs}) \cong a_s(t).\exp(-j2\pi f_o t).\exp(j\varsigma_{qs});$$

$$\varsigma_{qs} = 2\pi f_o.\tau_{qs} = \frac{2\pi f_o}{c}.d_q.\mathrm{sen}(\theta_s).\cos(\varphi_s - \varphi_q)$$

$$\underline{h} = \alpha.\underline{S}_s$$ Flat-Fading, LOS STEERING VECTOR

Source Signal $$x_r(t) = s(t).\alpha.\underline{S}_s + \underline{w}(t)$$

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$$\underline{h} = \overline{\underline{h}} + \underline{h}$$

Channel
Mean

Rayleigh component

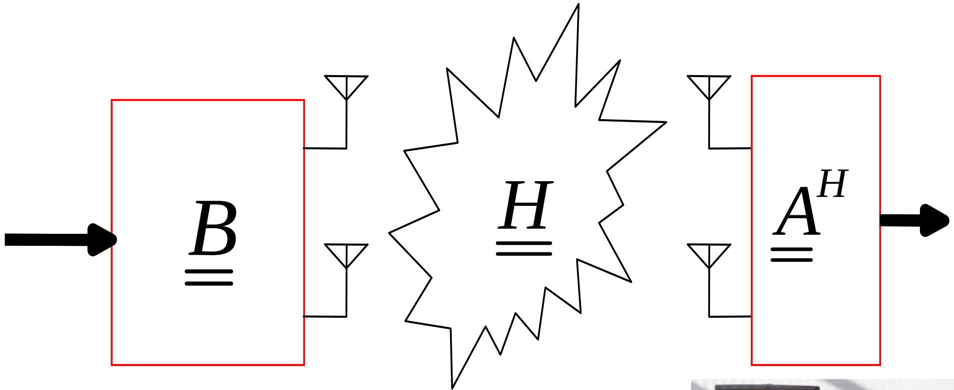
$$\underline{h} = G\left(\overline{\underline{h}}, \underline{\underline{\Sigma}}\right)$$

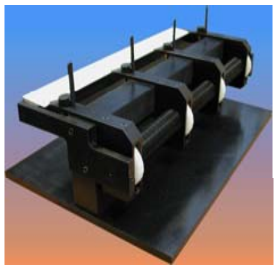
- Steering and/or Scattering cluster

Multi-Antenna Tx/Rx (MIMO)

- INCREASE SPECTRAL EFFICICIENCY -> RATE
- 4x4 -> 16 Channels (???) RELIABILITY

QUALITY/RATE trade-off





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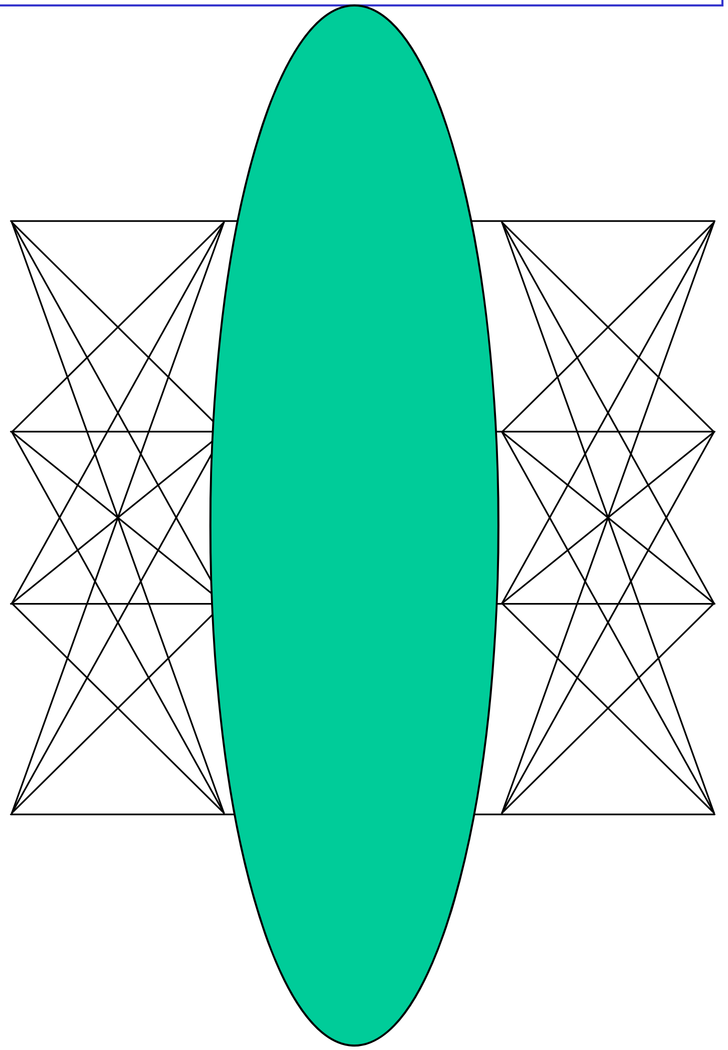
The MIMO Channel Model

- $\mathbf{H}$ is modeled statistically with a general Gaussian distribution

- Also known as the Kronecker

$$\mathbf{H} = \bar{\mathbf{H}} + \mathbf{R}_R^{1/2}\mathbf{G}\mathbf{R}_T^{T/2}$$

$$\mathbf{H} \sim \mathcal{CN}\left(\bar{\mathbf{H}}, \mathbf{R}_T \otimes \mathbf{R}_R\right)$$



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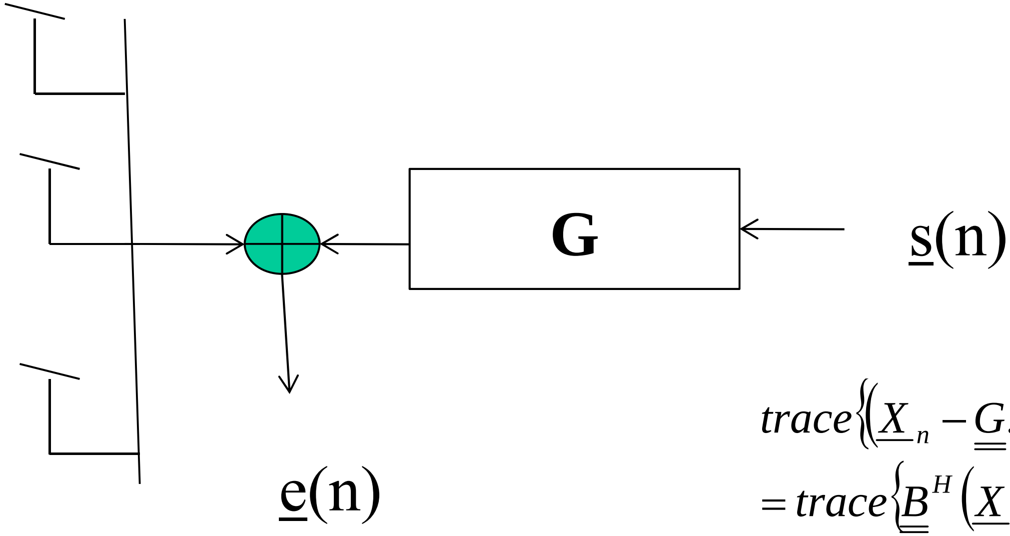
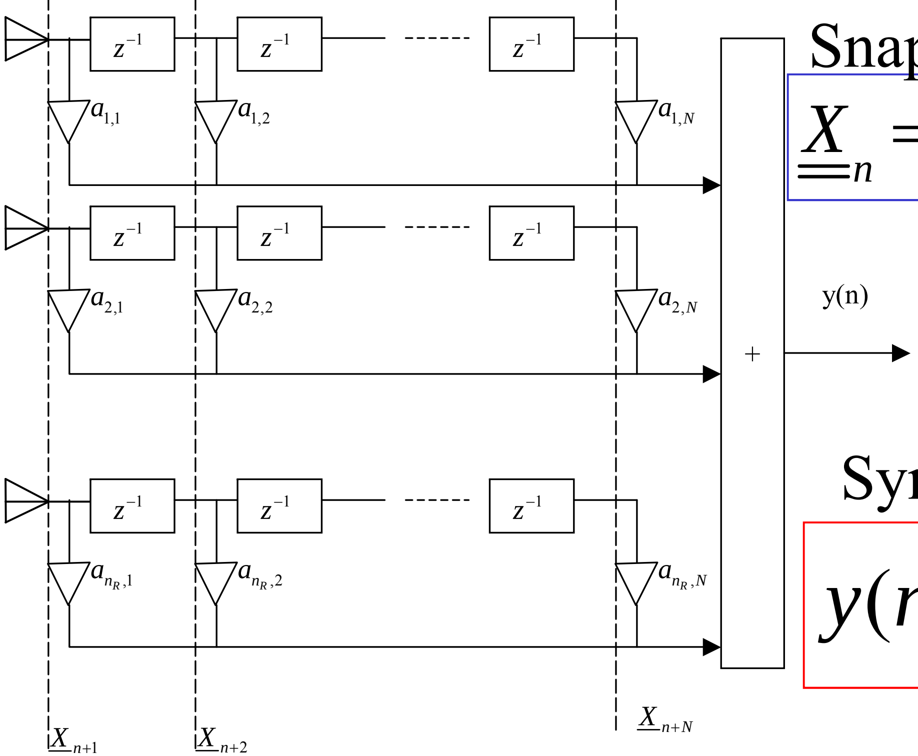
The Optimum Receiver



$$trace\{(\underline{X}_n - \underline{\underline{G}}.\underline{s}_n)(\underline{X}_n - \underline{\underline{G}}.\underline{s}_n)^H\} =$$
$$= trace\{\underline{\underline{B}}^H (\underline{X}_n - \underline{\underline{G}}.\underline{s}_n)(\underline{X}_n - \underline{\underline{G}}.\underline{s}_n)^H \underline{\underline{B}}\}$$
with
$$\underline{\underline{B}}\underline{\underline{B}}^H = \underline{\underline{I}}$$

-**G**=E($\underline{X}$n.$\underline{s}$(n)^H)
- /$\underline{e}$(n)/^{2} minimum over $\underline{s}$(n) ЄTx Alphabet
- Scenario free of interference
- Beamforming for quality limited by interference
- Instantenous/Indpendent decission on every stream

Tx/Rx Multichannel Processing



Snapshot

$$\underline{\underline{X}}_n = \left[\underline{X}_{n+1} \quad \underline{X}_{n+2} \quad \cdots \quad \underline{X}_{n+N}\right]$$

Symbol output

$$y(n) = traza\left(\underline{\underline{A}}^H . \underline{\underline{X}}_n\right)$$

$$\underline{\underline{A}} = \left[\underline{a}_1 \quad \underline{a}_2 \quad \cdots \quad \underline{a}_N\right] = \begin{bmatrix} a_{1,1} & a_{1,2} & .. & a_{1,N} \\ a_{2,1} & a_{2,2} & .. & a_{2,N} \\ .. & .. & .. & .. \\ a_{n_R,1} & a_{n_R,2} & .. & a_{n_R,N} \end{bmatrix}$$

Receiver Matrix

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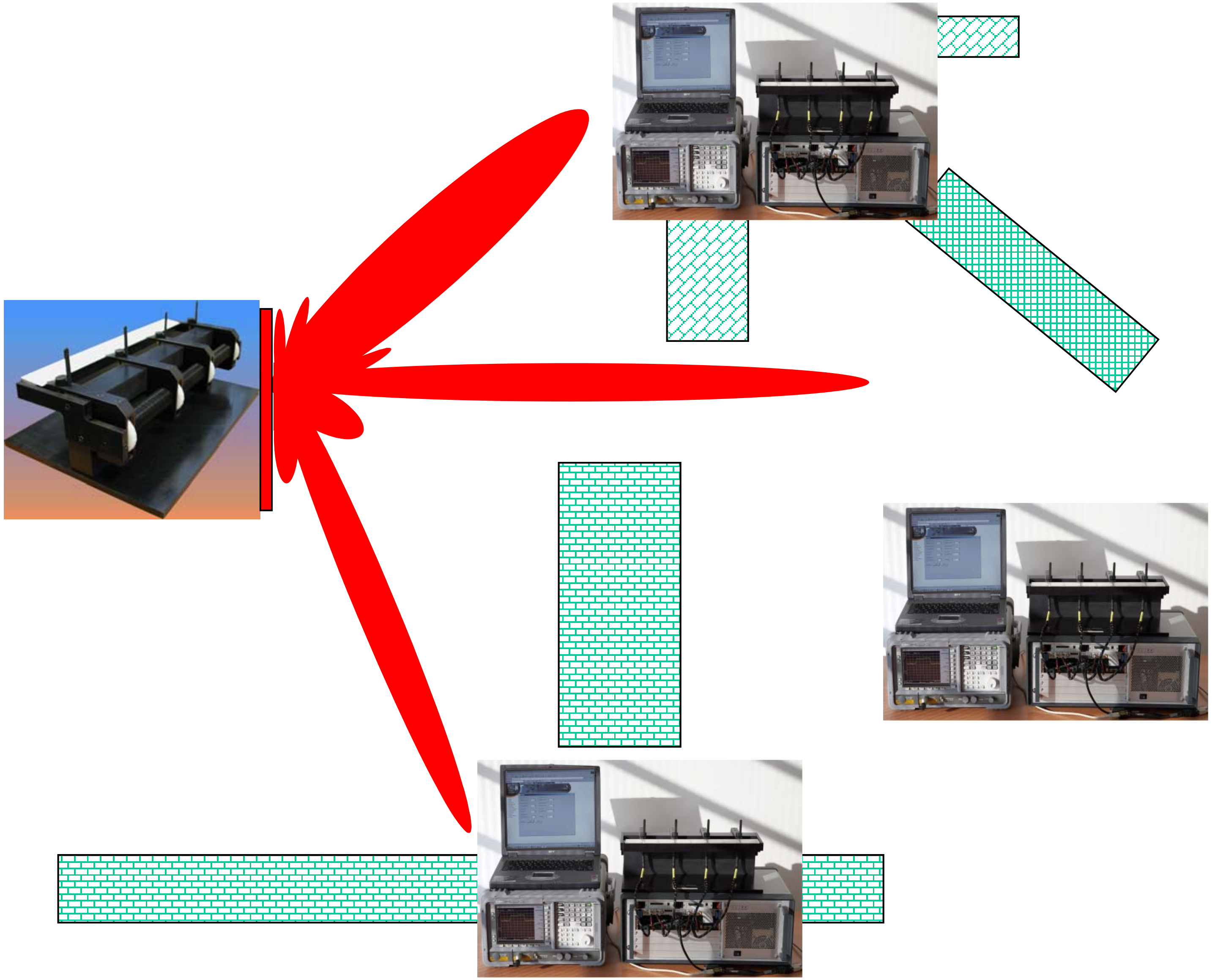
Spatial Diversity



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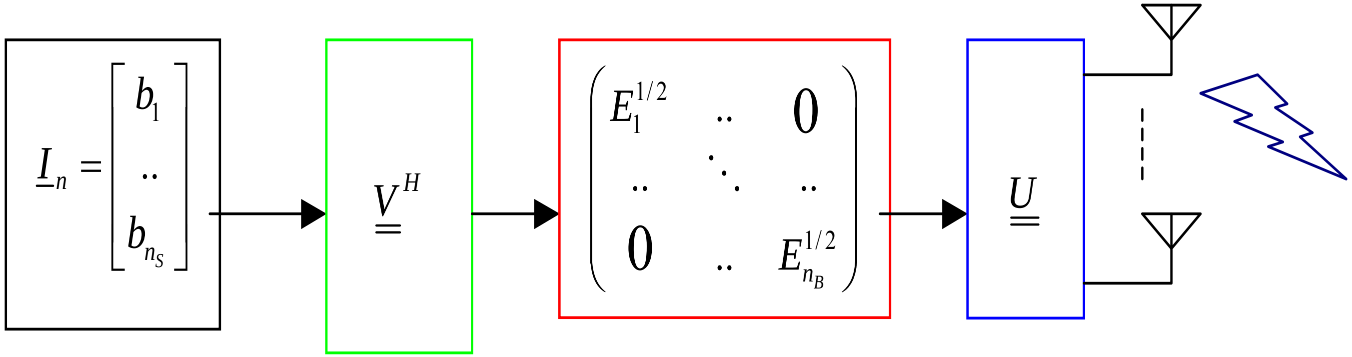
Tx Architecture



$$\underline{I}_n = [b(1) \quad b(2) \quad .. \quad b(n_S)] \quad con \quad b(i) = \{+1, -1\} \; \forall i = 1, n_S$$

$$\underline{S}_n = \underline{\underline{V}}^H . \underline{I}_n$$

Linear/Non-Linear

Code - Constellation

$$\underline{\underline{V}}^H = \begin{bmatrix} 1 & j & 0 & 0 \\ 0 & 0 & 1 & j \end{bmatrix}$$

$$\underline{\underline{V}}^H = [1 \quad 3 \quad j \quad 3j]$$

Tx Architecture

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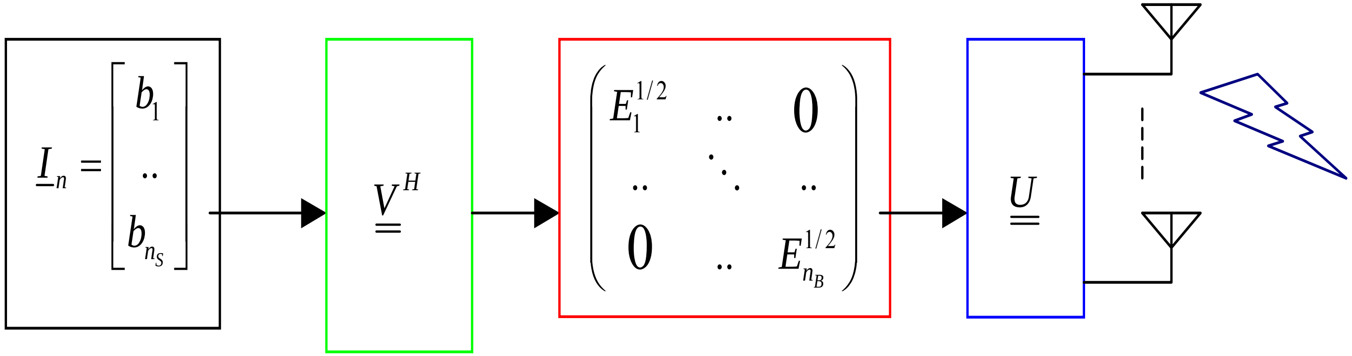

$$\underline{I}_n = \left[b(1) \quad b(2) \quad .. \quad b(n_S) \right] \quad con \quad b(i) = \{+1, -1\} \ \forall i = 1, n_S$$

Power allocation to each symbol (n_B symbols)

$$\underline{\theta}_n = diag\left[E_1^{1/2}, .., E_{n_B}^{1/2} \right] . \underline{\underline{V}}^H . \underline{I}_n = \underline{\underline{P}} . \underline{\underline{V}}^H . \underline{I}_n$$

Beamforming

$$\underline{X}_{T,n} = \underline{\underline{U}} . \underline{\underline{P}} . \underline{\theta}_n = \underline{\underline{U}} . \underline{\underline{P}} . \underline{\underline{V}}^H . \underline{I}_n$$

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Tx Architecture

$$\underline{\underline{Q}} = E\left(\underline{X}_{T,n}.\underline{X}_{T,n}^{H}\right) = \underline{\underline{U}}.\underline{\underline{P}}.\underline{\underline{V}}^{H} E\left(\underline{I}_{n}.\underline{I}_{n}^{T}\right).\underline{\underline{V}}.\underline{\underline{P}}.\underline{\underline{U}}^{H} = \underline{\underline{U}}.\underline{\underline{P}}.\underline{\underline{V}}^{H}.\underline{\underline{V}}.\underline{\underline{P}}.\underline{\underline{U}}^{H}$$

Without loss of generality

$$\underline{\underline{V}}^{H}.\underline{\underline{V}} = \underline{\underline{I}}_{n_B} \qquad \underline{\underline{U}}^{H}.\underline{\underline{U}} = \underline{\underline{I}}_{n_T}$$

$$\underline{\underline{Q}} = \underline{\underline{U}}_{B}.\underline{\underline{P}}^{2}.\underline{\underline{U}}_{B}^{H} = \underline{\underline{U}}_{B}.\underline{\underline{Z}}.\underline{\underline{U}}_{B}^{H} \qquad E_{T} = Trace\left(\underline{\underline{Q}}\right) = Trace\left(\underline{\underline{Z}}\right)$$

Power budget or total energy available at Tx

(Average power per amplifier

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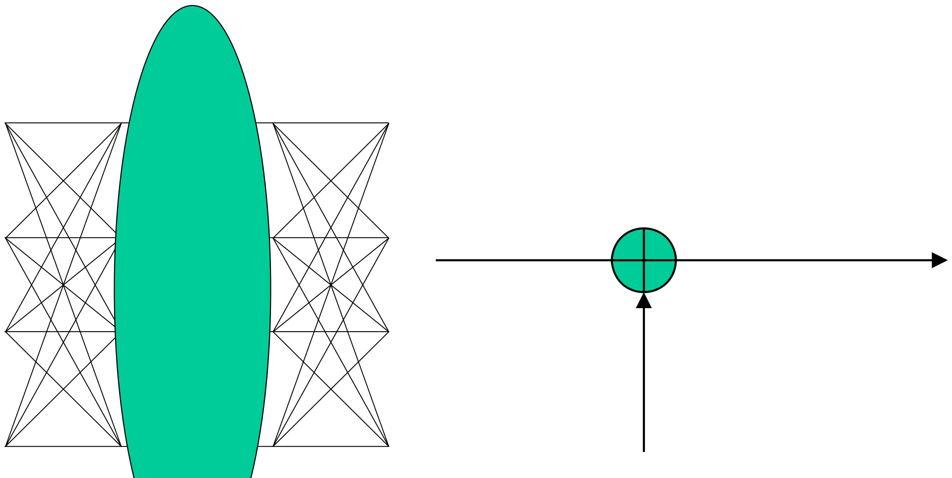
The channel architecture

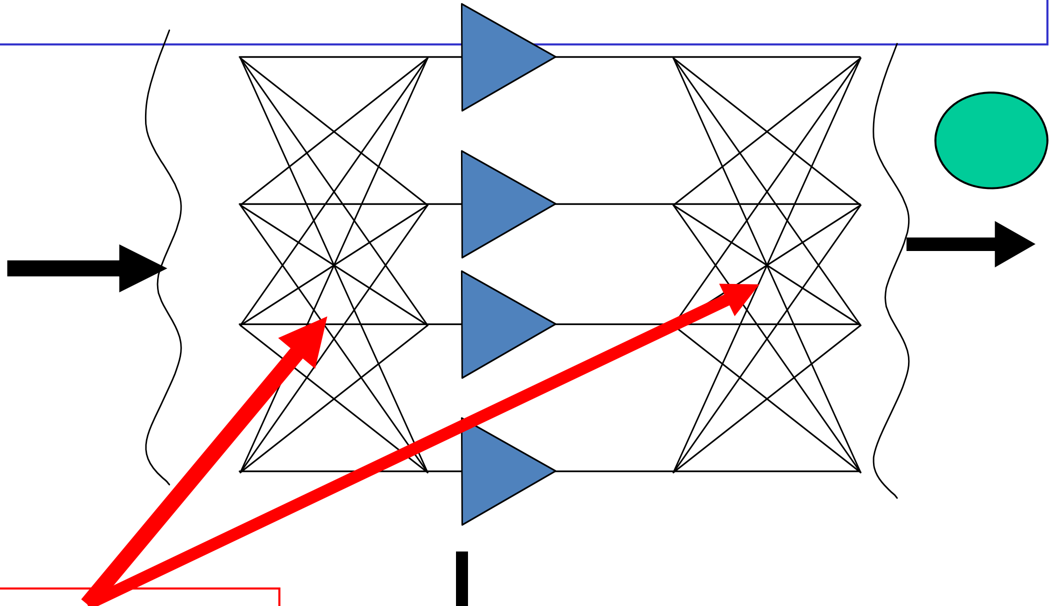
$$\underline{\underline{H}} = \underline{\underline{V}}_h . \underline{\underline{\Gamma}}_h . \underline{\underline{U}}_h^H \quad con \quad \underline{\underline{\Gamma}} = diag\left[\gamma_{H1} \quad .. \quad \gamma_{H\min(n_T, n_R)} \right]$$

$$\underline{\underline{H}}^H . \underline{\underline{H}} = \sum_{q=1}^{n_R} \underline{h}_q . \underline{h}_q^H = \underline{\underline{U}}_h . \underline{\underline{\Sigma}}_h . \underline{\underline{U}}_h^H \quad con \quad \underline{\underline{\Sigma}}_h = \left[\lambda_{H1} \quad \lambda_{H2} \quad .. \quad \lambda_{H\min(n_T, n_R)} \right]$$

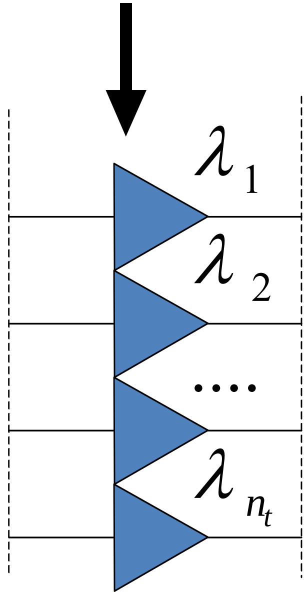


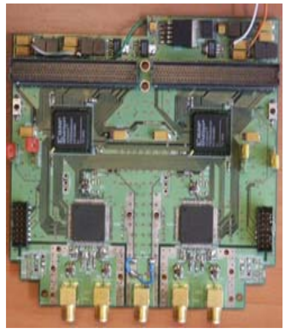
$$\underline{\underline{R}}_0 = N_0 . \underline{\underline{I}}_{n_R} + \underline{\underline{R}}_{oo}$$

CSI Channel State Information



CSI: Channel State Information





Hard to afford perfect CSI, especially CSIT

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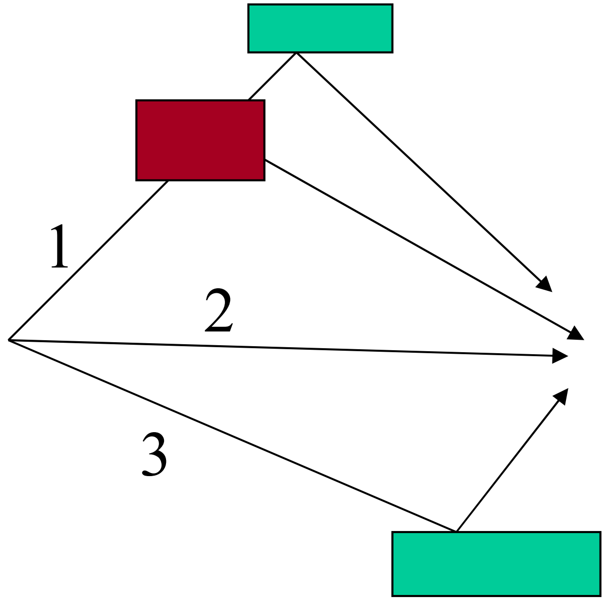
The LOS MIMO Channel

$$\underline{\underline{H}} = \left[\underline{S}_{T1}\ \underline{S}_{T2}\ \underline{S}_{T3}\right]$$

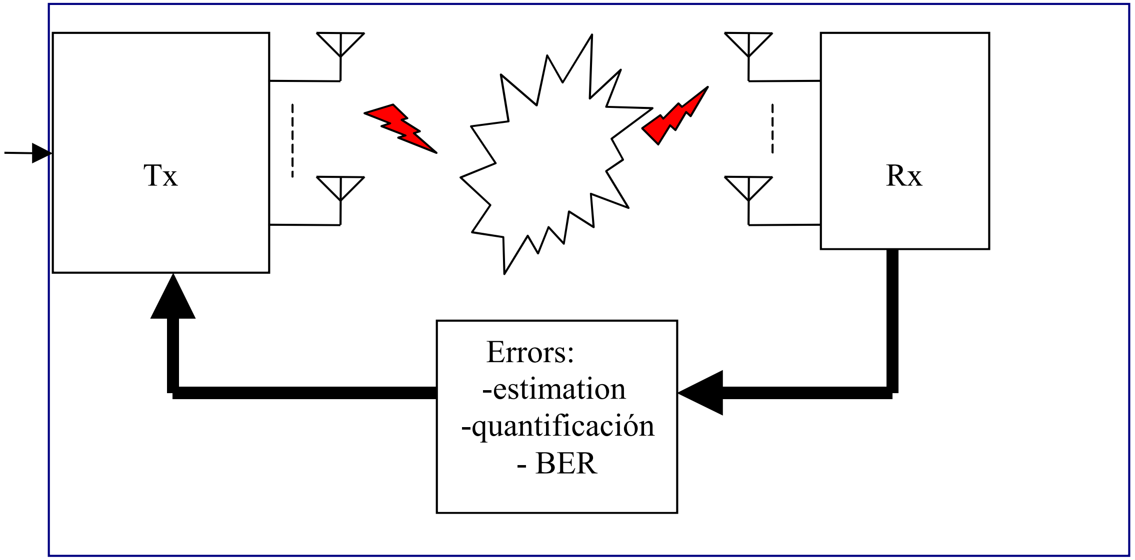
$$\underline{\underline{H}}^{H} = \left[\underline{S}_{R1}\ \underline{S}_{R2}\ \underline{S}_{R3}\right]$$



Use the best channel (#2) or all the available paths?

Eigenvectors interpretation of steering vectors

CSIT (Complexity)

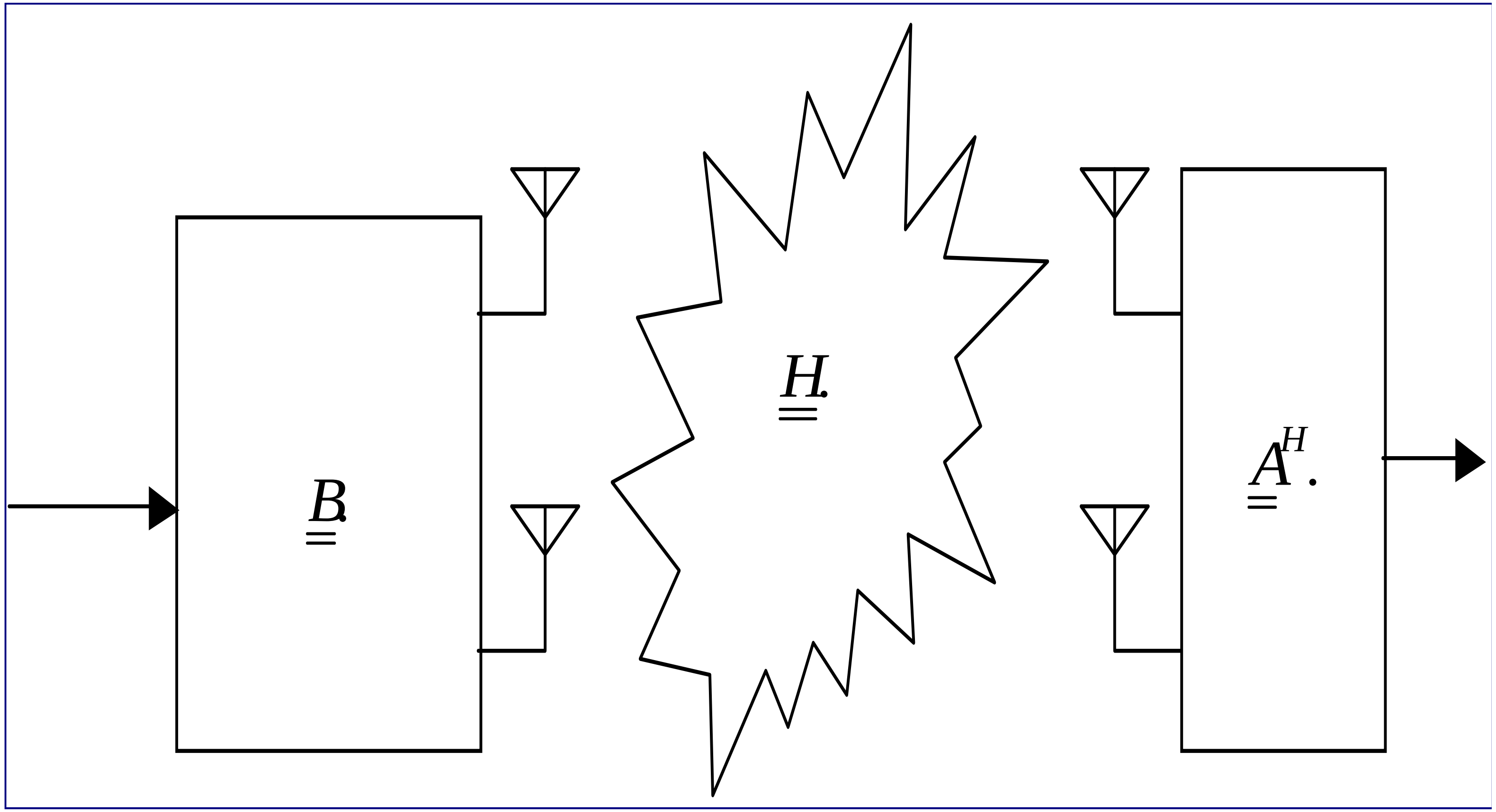


- Capacity of the feedback channel

- Not accurate

-User Mobility, FDMA, TDMA

SUMMARY



Flat Fading, CSIT and CSIR, Single Symbol

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