MIMO-OFDM with ESPAR Antenna

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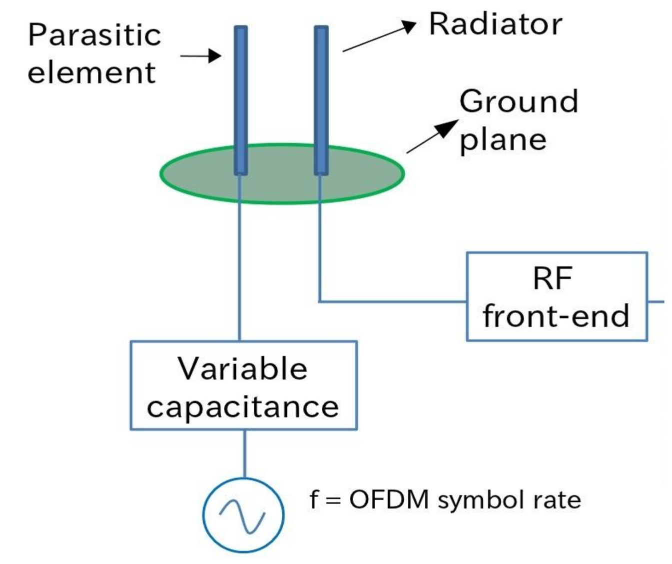
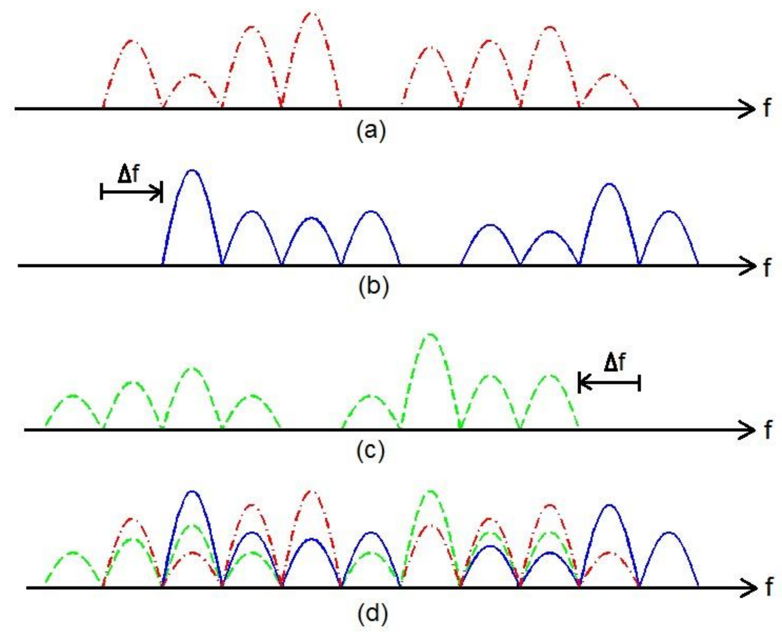
ESPAR antenna with periodically changing directivity



- ESPAR(Electronically Steerable Passive Array Radiator).
- It is a small size and low power consumption antenna.
- It is composed by a radiator element connected to the RF front-end and one or more parasitic(passive) elements terminated by variable capacitances.

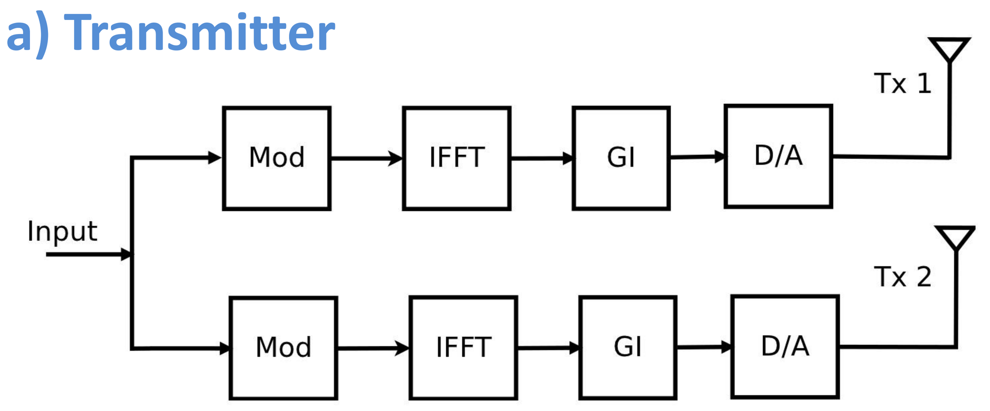


- In this scheme the directivity of the ESPAR antenna is changed by an oscillator which frequency is the OFDM symbol rate.
- The periodic variation of the directivity causes Inter ICI in the received signal.
- In the figure, (a) is the frequency non-shifted component, the positive and negative frequency shifted components are shown in (b), (c), and the total received signal in (d)

System model of MIMO-OFDM with ESPAR antenna

- Compared to the conventional MIMO-OFDM 2x2 systems, MIMO-OFDM with ESPAR antenna gives additional diversity gain and improves the bit error rate performance without increasing the number of RF front-end circuits.

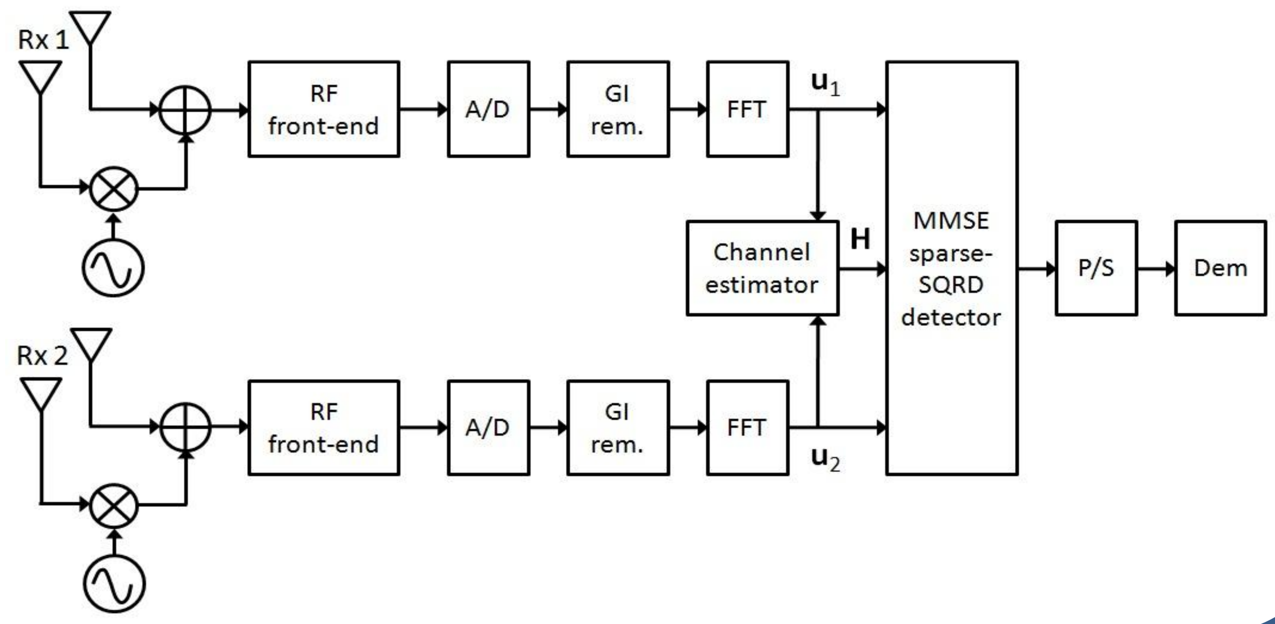
a) Transmitter



- Based in the WLAN IEEE 802.11n standard

b) Receiver

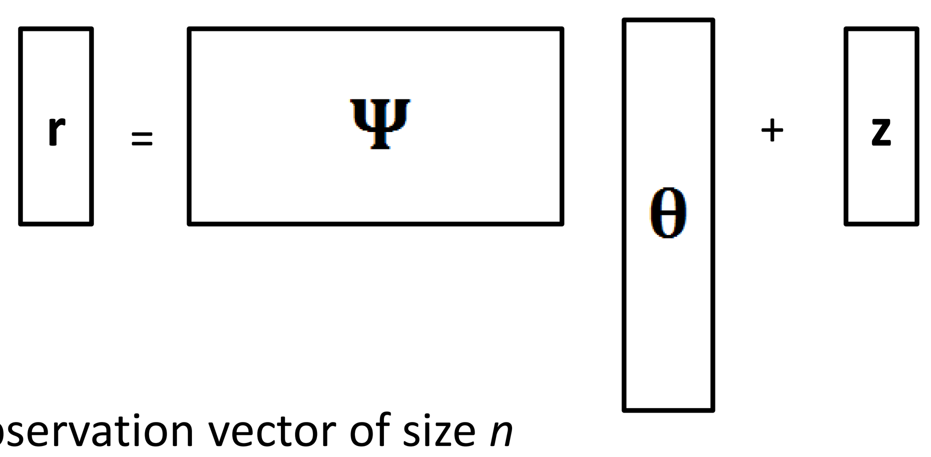
- For every receiver it uses a 2-elements ESPAR antenna with periodically changing directivity
- It uses the low complexity MMSE sparse-SQRD algorithm for the detection process.



Compressed Sensing based channel estimation

- Compressed Sensing (CS) is a set of new algorithms that allows the reconstruction of sparse signals from much fewer measurements.

$$\mathbf{r} = \mathbf{\Psi}\boldsymbol{\theta} + \mathbf{z}$$



r: observation vector of size *n*
$\mathbf{\Psi}$: *n* x *p* measurement matrix. (*n*<<*p*)
$\boldsymbol{\theta}$: sparse unknown vector of size *p*
z: noise vector

- For MIMO-OFDM with ESPAR antenna, when the pilot symbol is transmitted, the vector of received symbols at the *i*-th receiver and after the FFT block is given by

$$\mathbf{u_i} = \mathbf{G}_{-1}\mathbf{P}_1\mathbf{h}_{i,1}^{-1} + \mathbf{G}_0\mathbf{P}_1\mathbf{h}_{i,1}^{0} + \mathbf{G}_1\mathbf{P}_1\mathbf{h}_{i,1}^{1} + \mathbf{G}_{-1}\mathbf{P}_2\mathbf{h}_{i,2}^{-1} + \mathbf{G}_0\mathbf{P}_2\mathbf{h}_{i,2}^{0} + \mathbf{G}_1\mathbf{P}_2\mathbf{h}_{i,2}^{1} + \mathbf{z}$$

- To exploit the sparsity of the channel impulse response, the previous equation can be expressed as

$$\mathbf{u_i} = [\mathbf{G}_{-1}\mathbf{P}_1, \mathbf{G}_0\mathbf{P}_1, \mathbf{G}_1\mathbf{P}_1, \mathbf{G}_{-1}\mathbf{P}_2, \mathbf{G}_0\mathbf{P}_2, \mathbf{G}_1\mathbf{P}_2] \begin{bmatrix} \mathbf{F} & 0 & 0 & 0 & 0 & 0 \\ 0 & \mathbf{F} & 0 & 0 & 0 & 0 \\ 0 & 0 & \mathbf{F} & 0 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{F} & 0 & 0 \\ 0 & 0 & 0 & 0 & \mathbf{F} & 0 \\ 0 & 0 & 0 & 0 & 0 & \mathbf{F} \end{bmatrix} \begin{bmatrix} \mathbf{c}_{i,1}^{-1} \\ \mathbf{c}_{i,1}^{0} \\ \mathbf{c}_{i,1}^{1} \\ \mathbf{c}_{i,2}^{-1} \\ \mathbf{c}_{i,2}^{0} \\ \mathbf{c}_{i,2}^{1} \end{bmatrix}$$

Channel impulse response

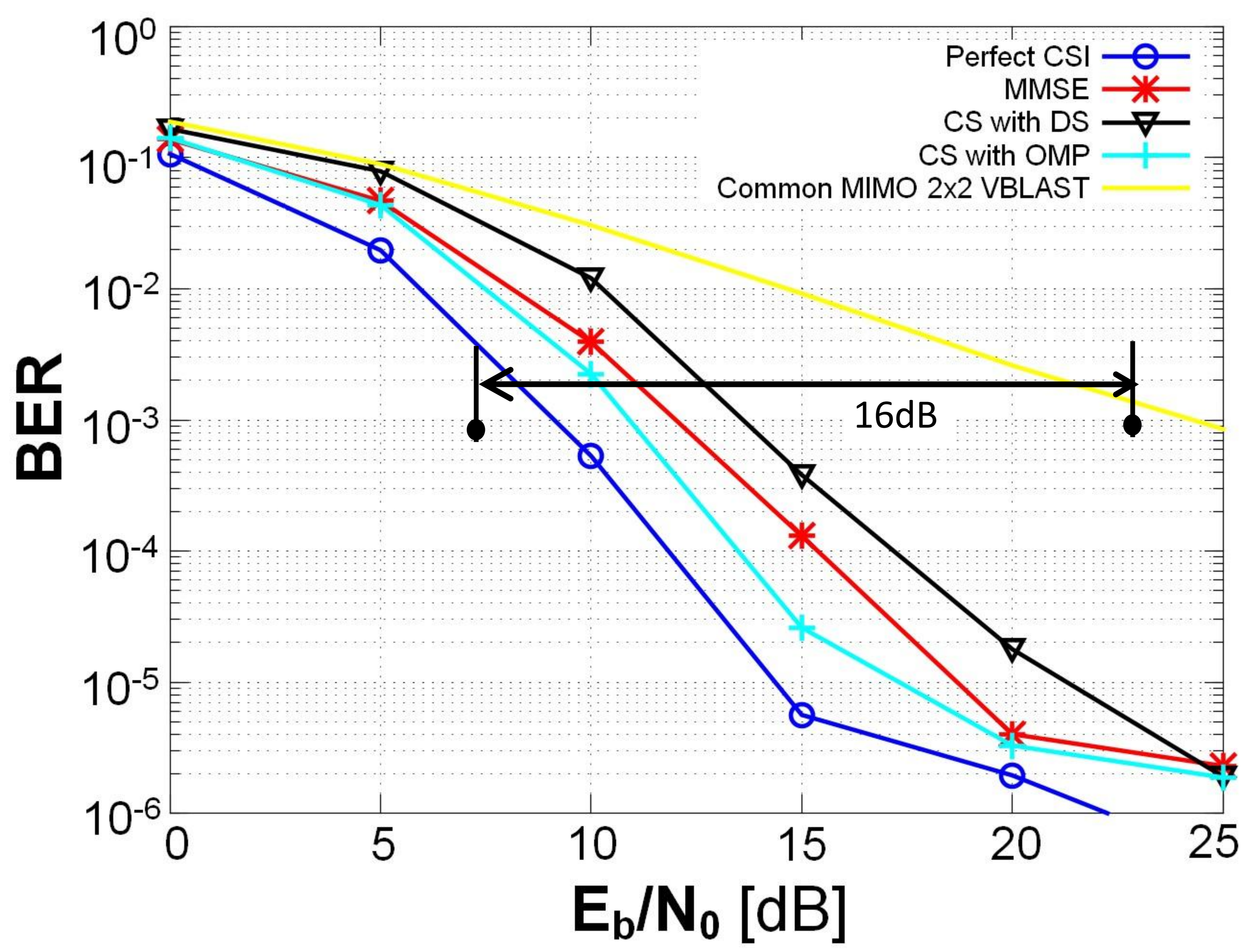
F : *N x L* matrix part of the Fourier matrix.
N : number of sub-carriers
L : number of channel taps.

- To solve the previous equation, Dantzig Selector (DS) or Orthogonal Matching Pursuit (OMP) algorithms can be used.

Simulation Results

Simulation Settings

Parameter	Value
Modulation	16-QAM
Channel bandwidth	20MHz
Pilot Sequence	HTLTF, P2 Cyclic Shift 850nS
Number of sub-carriers	56
FFT size	64
GI	1/4
Path model	2 rays Rayleigh frequency selective Fading
Noise type	AWGN
Channel Estimation	MMSE, perfect CSI, CS with L = 16
Detection	MMSE sparse-SQRD



- For a BER of 10^{-3} and using perfect CSI, MIMO-OFDM with ESPAR antenna achieves an additional diversity gain of 16dB compared to a common MIMO 2x2 VBLAST system.
- Using CS-based channel estimation with OMP we obtain better estimation accuracy and it improves the BER compared to the MMSE channel estimator.

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