Webinar series # 5
Wireless Network and IoT

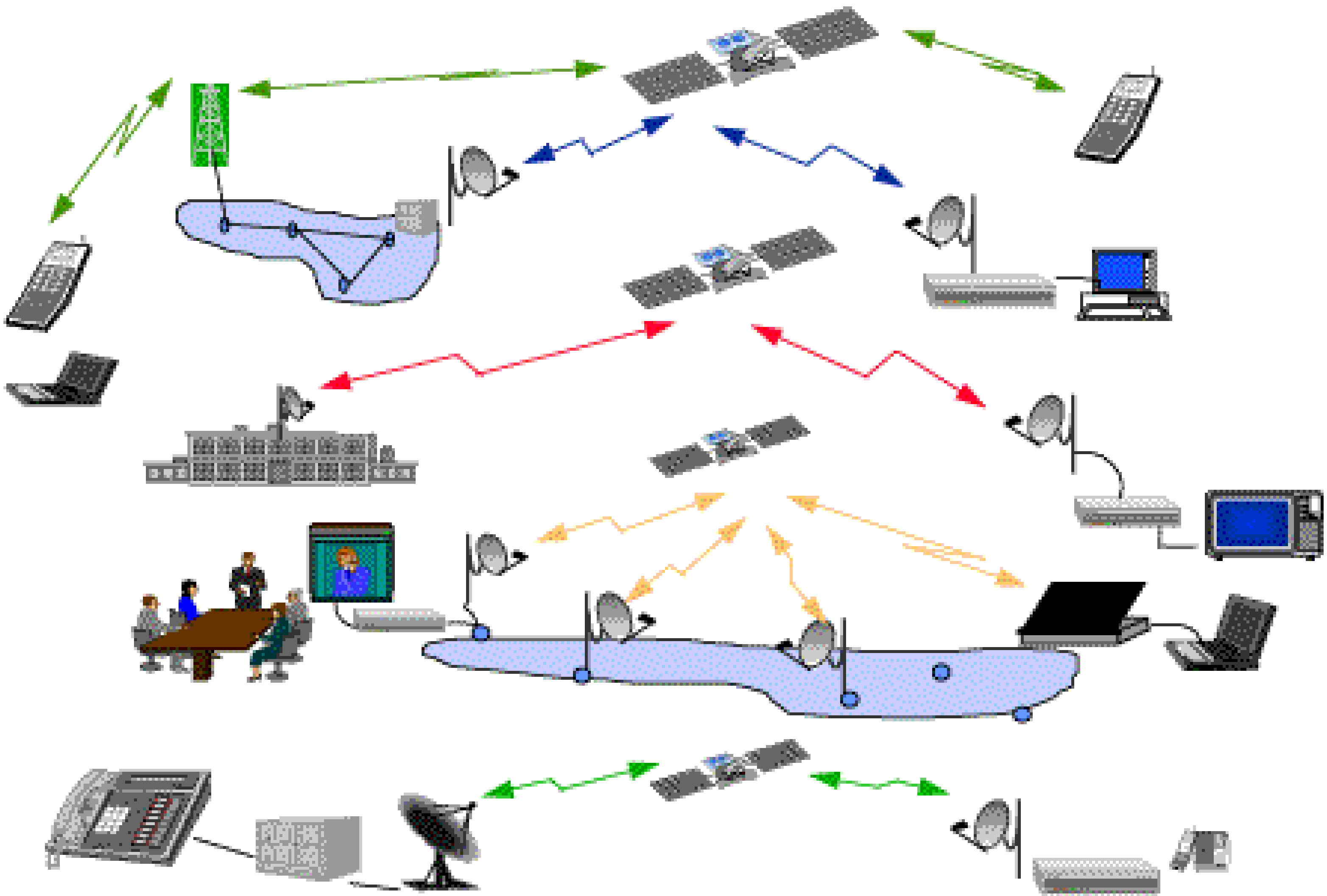
Curriculum Vitae

- Nama : I Gede Puja Astawa
- Pendidikan :
  - S1 Teknik Elektro – Sistem Pengaturan ITS (1993)
  - S2 Teknik Elektro - Teknik Multimedia Telekomunikasi ITS (2004)
  - S3 Information Science – NAIST Jepang (2012)
- Bidang Ilmu : Telekomunikasi
- Pekerjaan : Dosen PENS di
  - Prodi Teknik Telekomunikasi
  - Program Pascasarjana PENS
- Jabatan :
  - Kepala Departemen T Elektro
  - Ketua Group Riset Wireless Communication

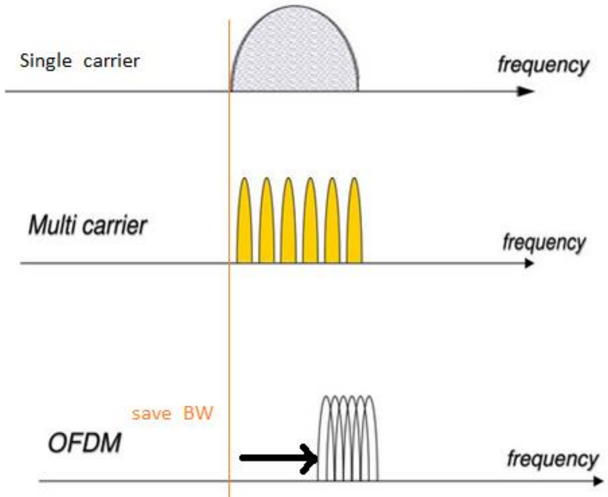
Outline

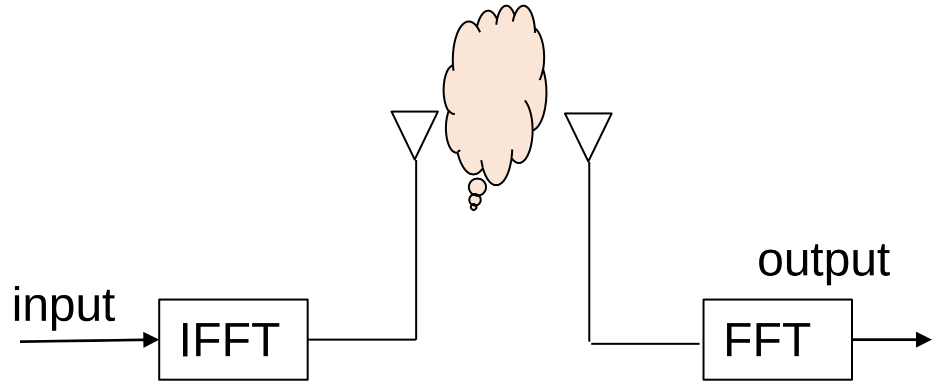
- Wireless communication
- Our research in wireless communication system
- Research Grant

Provide electronic exchange multimedia data, voice, data, video music, email;web page, etc

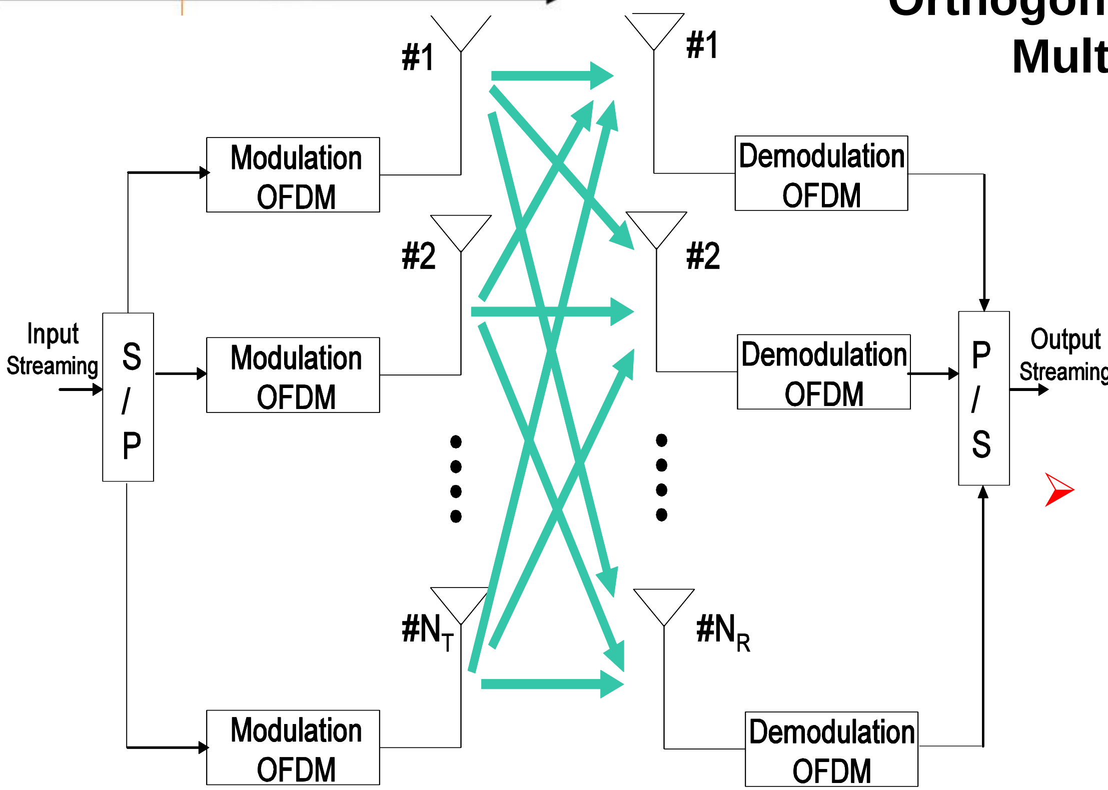


http://www.embsyslabs.com/communication-projects-in-embedded-domain.php





Orthogonal Frequency Divison Multiplexing (OFDM)



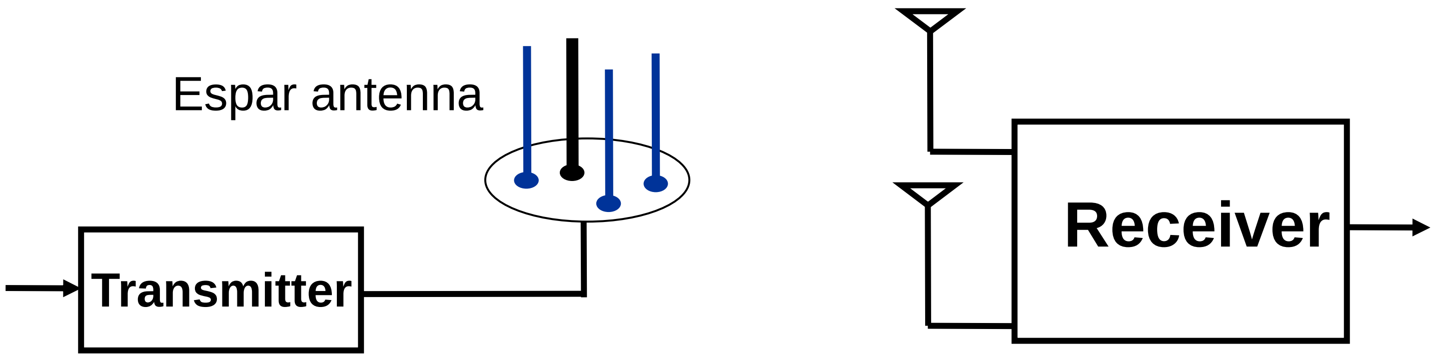
- ◆ Bit rate
- ◆ Capacity
- ◆ Bandwidth

- ➢ Complicated
- ➢ Problem for large size

Block Diagram of Conventional MIMO OFDM System

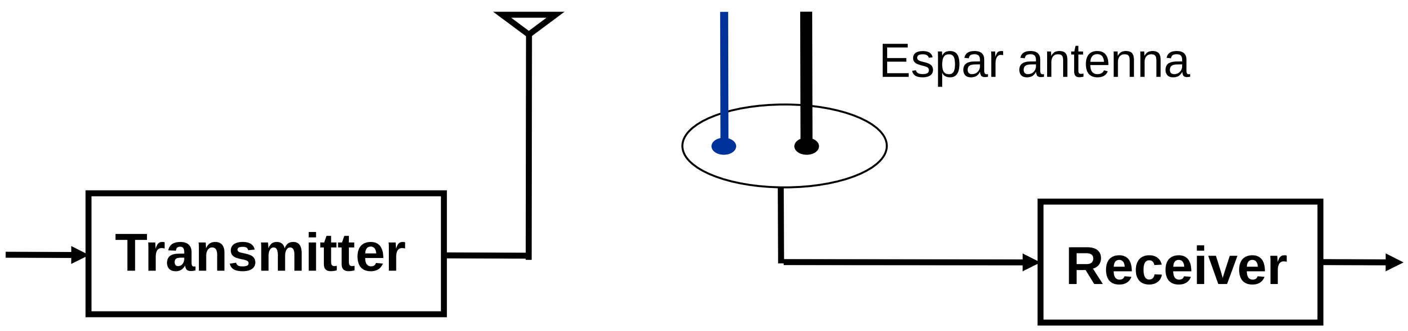
Previous Work

- **[1] → [A Novel Approach to MIMO Transmission using Single RF Front End]** by Antonis *Kalis,A G Kanatas, C Papadias*



- ☐ESPAR antenna contribute simplified number of RF chain
- ☐Number of parasitic element 3 and 5
- ☐Performance is still worse than conventional MIMO system

- **[2] → [Single RF maximal ratio combining diversity for OFDM system using an ESPAR antenna whose direction is oscillated in the symbol time]** by *Tsukamoto*



- ESPAR antenna contribute give diversity gain
- Number of parasitic element 1
- System is SISO not MIMO

Problem

- **[1]** **A Novel Approach to MIMO Transmission using Single RF Front End** by Antonis *Kalis,A G Kanatas, C Papadias* :
  - Performance is still below than the conventional MIMO system
- **[2] →** **Single RF maximal ratio combining diversity for OFDM system using an ESPAR antenna whose direction is oscillated in the symbol time** by *Tsukamoto*
  - The system is still SISO (Single Input Single Output)

Objectives

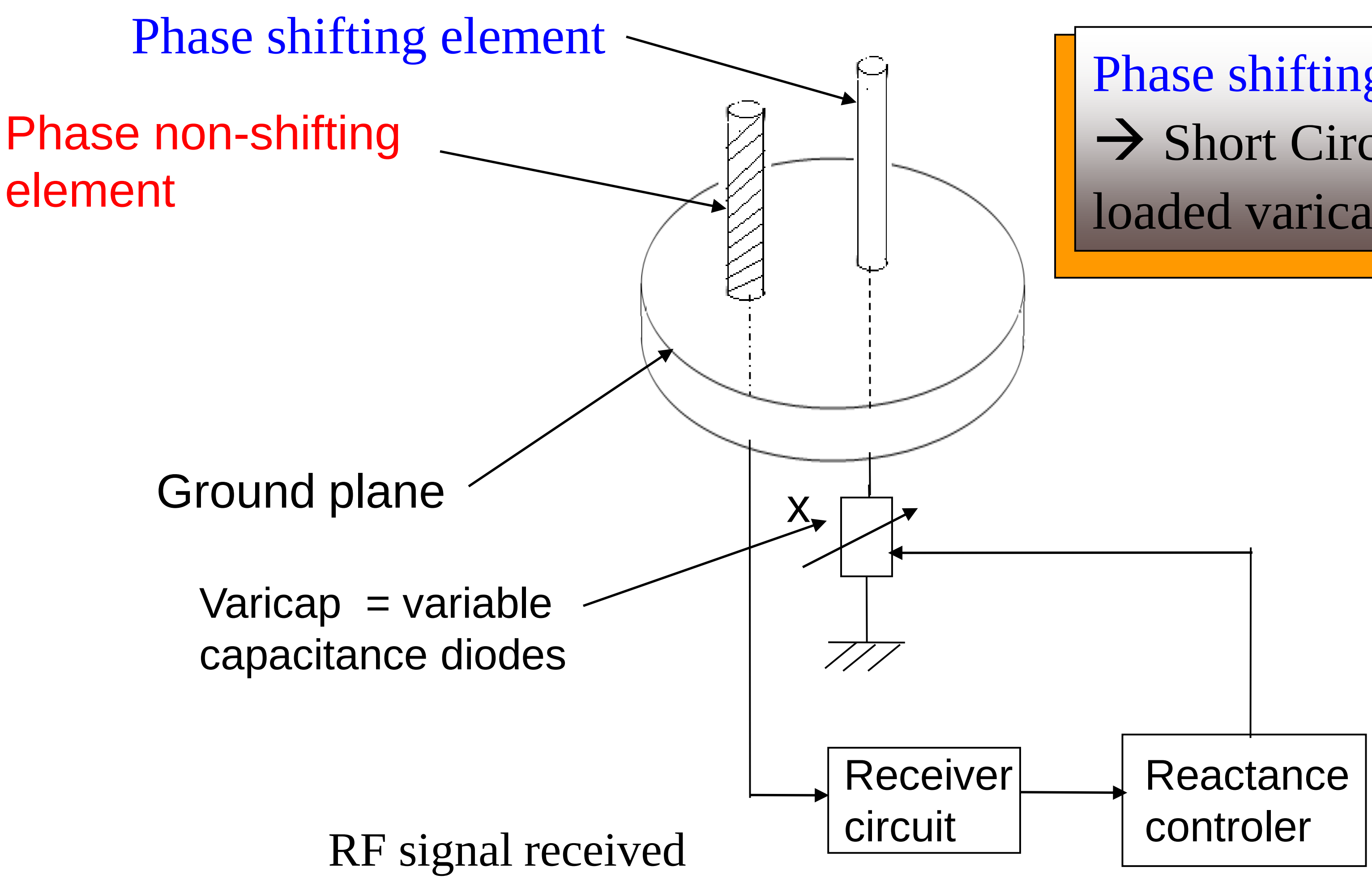
- Propose an RF signal processing based diversity scheme for MIMO-OFDM systems antenna in order to improve the bit error rate performance
- Shows and consider complexity of computational cost of MIMO decomposition

How do it ?

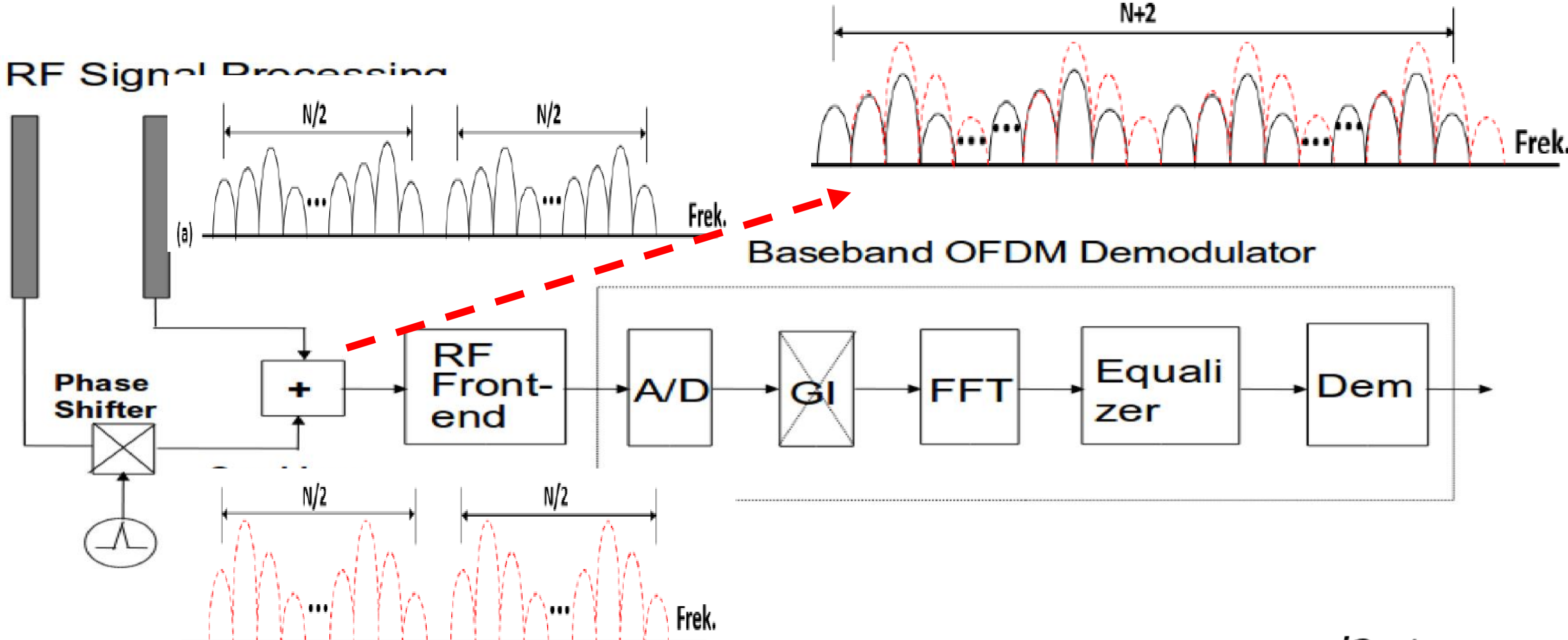
SISO-OFDM system scheme

An RF Signal Processing based Antenna

Phase shifting element
→ Short Circuit & loaded varicap



An RF Signal Processing Based Diversity Scheme for OFDM Systems



$$v(t) = \alpha . v_d(t) + \beta . e^{\frac{j2\pi t}{T_s}} . v_p(t)$$

α and β are weighting factors

V_d is the received signals ---> the phase non-shifting

V_p is the received signals ---> the phase shifting

T_s is FFT window period of the OFDM signal

A.Channel Estimation

pilot symbol (**p**) ⟶ Frequency domain

$$p = [p_0, p_1, \dots p_{N-1}]^T$$

$$u = \mathbf{Fr} = \square H_0 \square \mathbf{GH_1} \square p + z$$

$$u = \mathbf{Ph_0} \square \mathbf{GPh_1} + z$$

By Eq. of Covariance and Cross-Corelation

$$R = E[\mathbf{uu}^H] = I\,\mathbf{PR}_h P^H \square \mathbf{GPR}_h P^H G^H + \sigma_z^2 I$$

$$B_i = E[\mathbf{uh}_i^H] \Rightarrow B_o = I\,\mathbf{PR}_h \text{ and } B_1 = \mathbf{GPR}_h$$

where $R_h = E[h_i h_i^H]$

CIR for radiatic and parasitic element $h_i = W_i^H u$

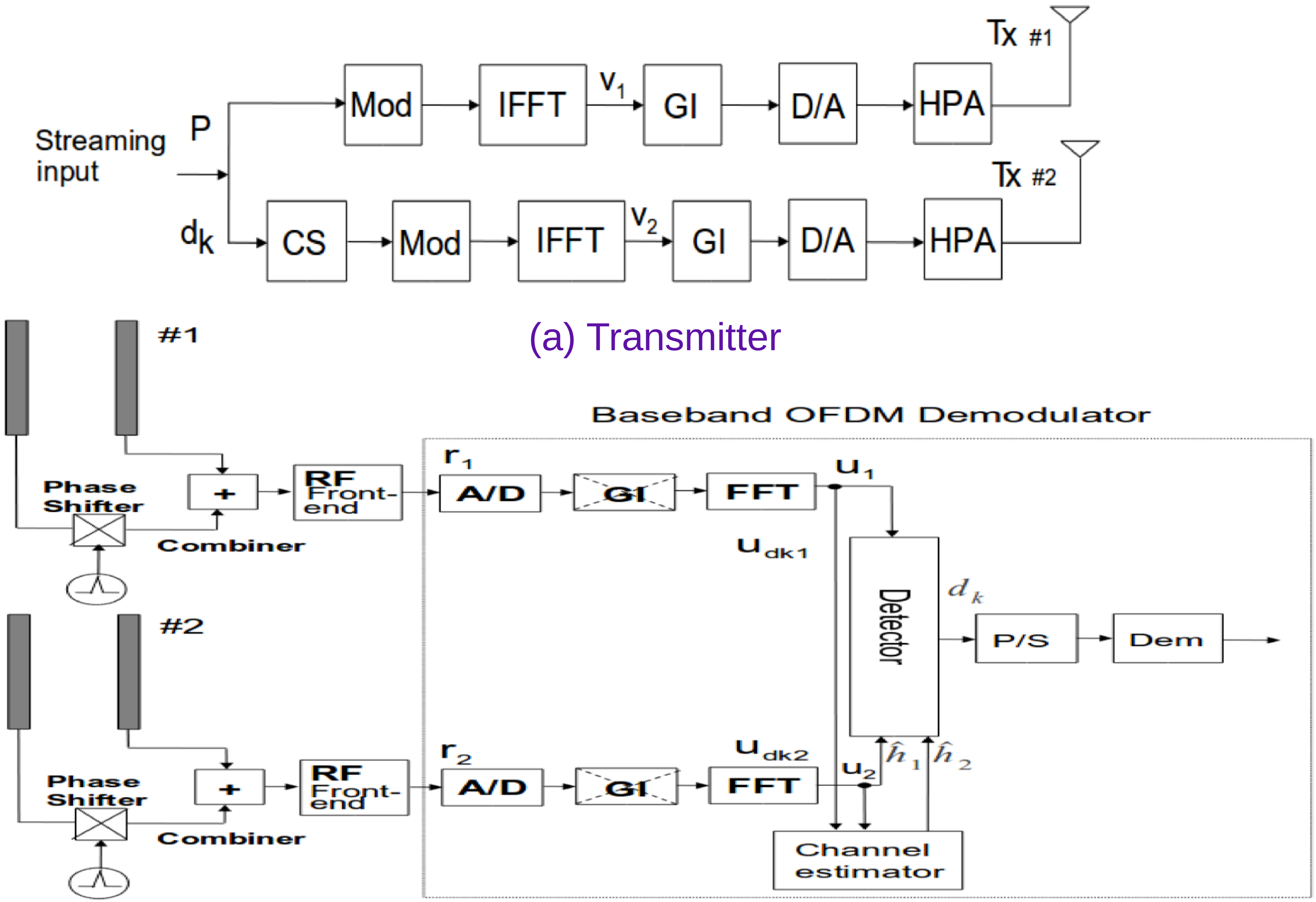
$$W_i = R^{-1} B_i$$

B.Frequency Domain Equalizer

In the following using ZF equalizer by equation

is the estimated channel response

RF Signal Processing Based Diversity Scheme for MIMO-OFDM Systems



(a) Transmitter

(b) Receiver

A.Channel Estimation

Received signal

$$u_i = \boldsymbol{P}_1 h_{i,1}^{ns} + \boldsymbol{GP}_1 h_{i,1}^{s} + P_2 h_{i,2}^{ns} + \boldsymbol{GP}_2 h_{i,2}^{s} + z$$

Auto-correlation

$$R = E[u\boldsymbol{u}^H]$$

$$= \boldsymbol{P}_1 R_h P_1^H + G\boldsymbol{P}_1 R_h P_1^H G^H +$$

$$P_2 R_h P_2^H + G\boldsymbol{P}_2 R_h P_2^H G^H + \sigma_z^2 I$$

Cross-correlation

$$B_i = E[\mathbf{u}\mathbf{h}_i^H]$$

$$B_i^{ns} = P_i R_h$$

$$B_i^{s} = \mathbf{GP}_i R_h$$

Rectangular shaping multi-path

$$R_h(k) = e^{-j\pi\Delta_f\tau_{rms}} \frac{sin\left(\pi\Delta_f\tau_{rms}k\right)}{\pi\Delta_f\tau_{rms}k}$$

Exponentially decaying multi-path

$$R_h(k) = \frac{1}{1 + j2\pi\Delta_f\tau_{rms}k}$$

Channel impulse response estimated

$$h_{i,l}^{ns} = (W_i^{ns})^H u_i$$

$$h_{i,l}^{s} = (W_i^{s})^H u_i$$

$$W_i^{ns} = R^{-1} B_i^{ns}$$

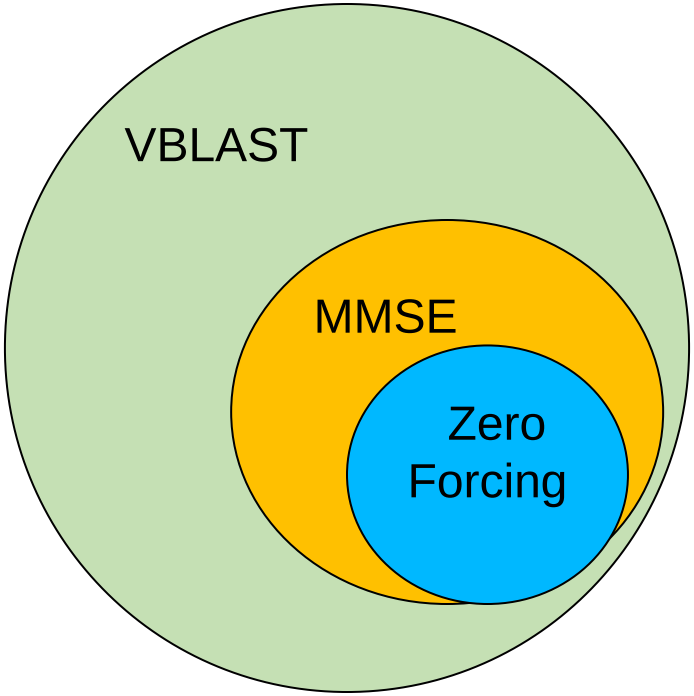
$$W_i^{s} = R^{-1} B_i^{s}$$

MIMO Detector/ Equalizer

a. ZERO FORCING $\hat{x}_{ZF} = H^{+}r$

b. MMSE $\hat{x}_{MMSE} = (\alpha I_{Nt} + H^{H}H)^{-1}Hr$

c. V-BLAST



B. Frequency Domain Equalizer

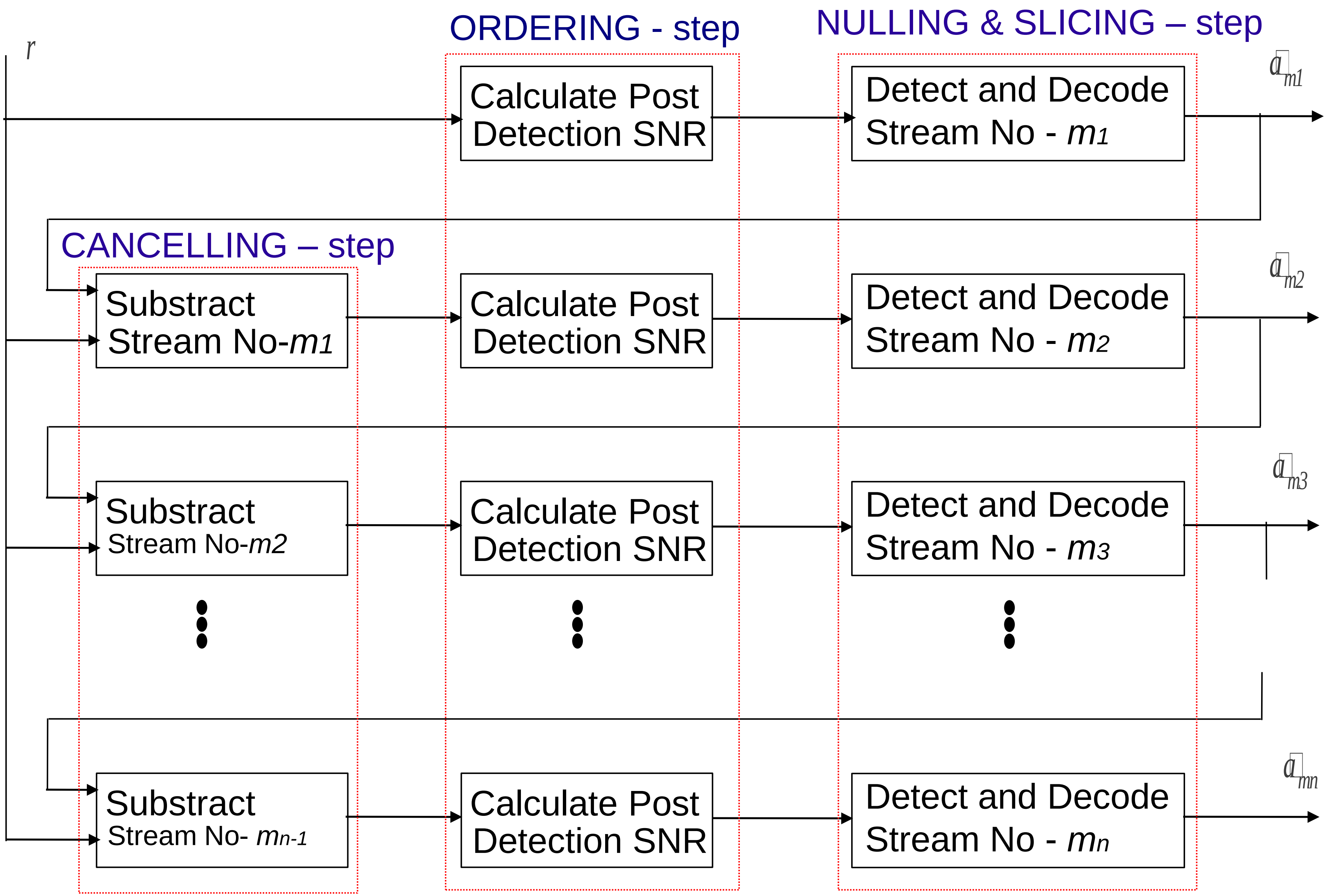
In this work, the mimo equalizer use a V-BLAST (Vertical Bell Layer Space Time) based algorithm.

Receiver of V-BLAST Architecture

V-BLAST Receiver extracts data streams by ZF or MMSE filter with successive interference cancellation.

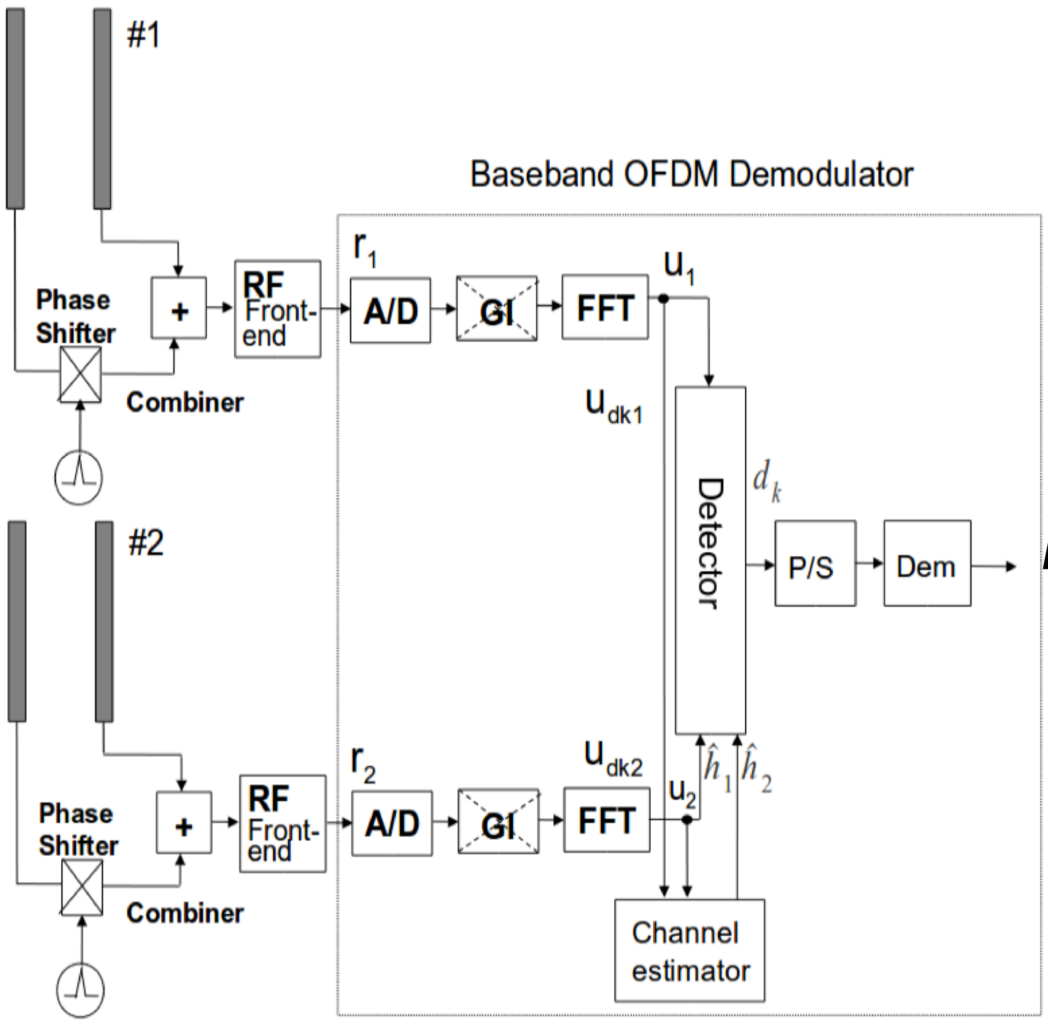
Steps for V-BLAST detection

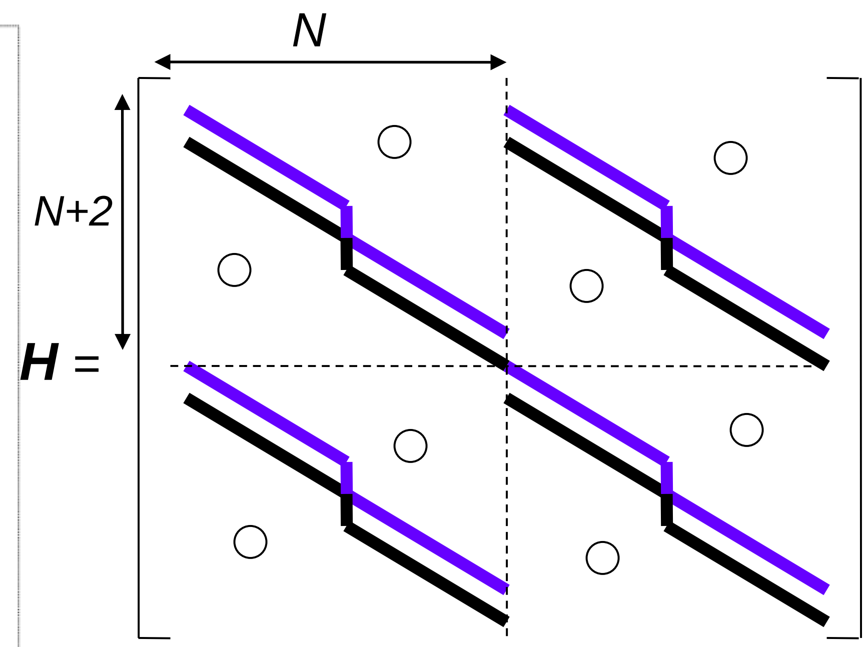
1. Ordering : choose the best channel.
2. Nulling : using ZF or MMSE
3. Slicing : making a symbol decision
4. Canceling : subtracting the detected symbol


ORDERING - step
NULLING & SLICING – step
CANCELLING – step
r
Calculate Post Detection SNR
Detect and Decode Stream No - m1
Substract Stream No-m1
Detect and Decode Stream No - m2
Substract Stream No-m2
Detect and Decode Stream No - m3
Substract Stream No- mn-1
Detect and Decode Stream No - mn
a m1
a m2
a m3
a mn

MIMO decoder using 1 V-BLAST Processors

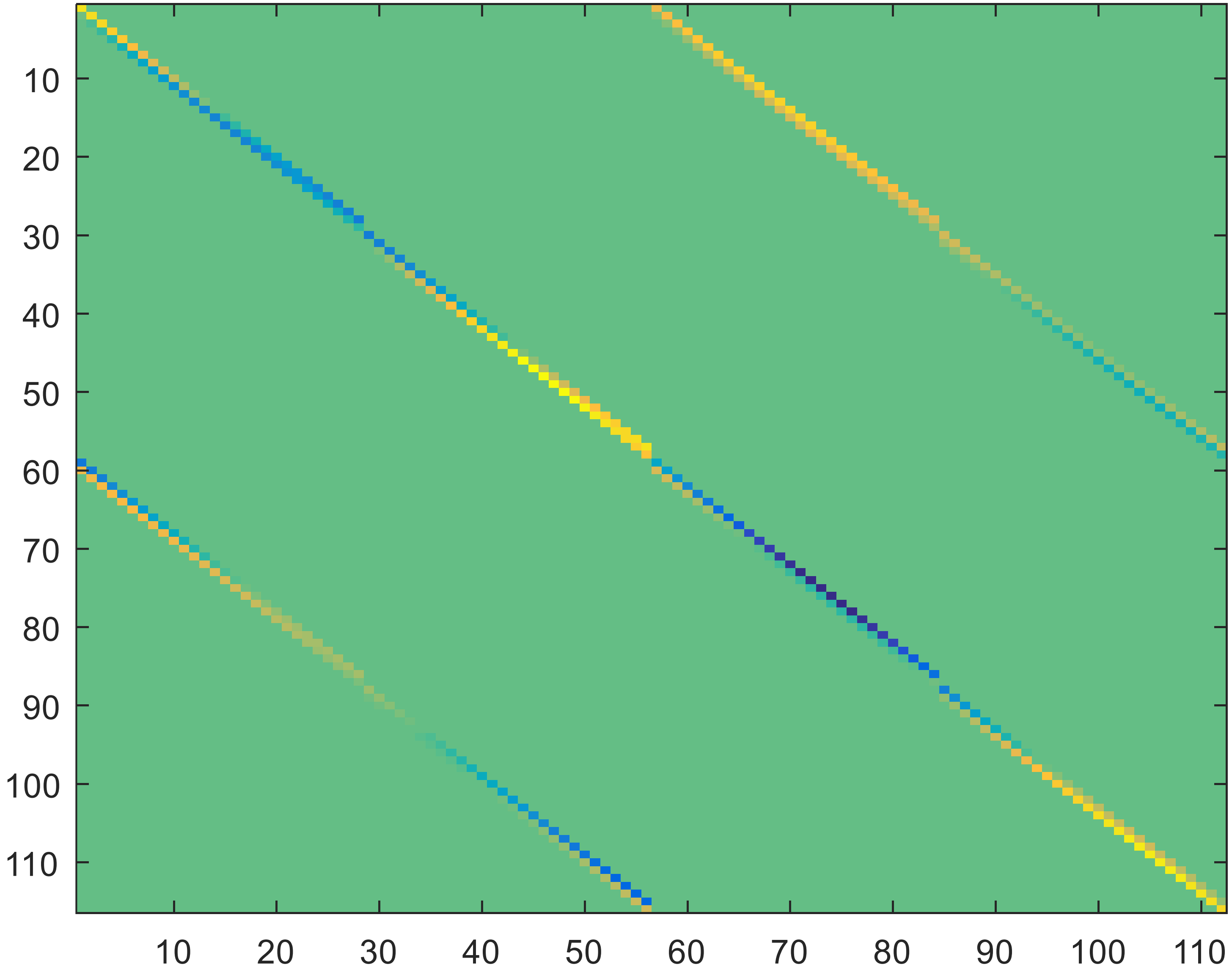
$$
\begin{matrix}
H_{1,-\frac{N}{2}} & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 \\
H_{2,-\frac{N}{2}} & H_{1,-(\frac{N}{2}-1)} & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
0 & H_{2,-(\frac{N}{2}-1)} & H_{1,-(\frac{N}{2}-2)} & 0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & 0 & H_{2,-(\frac{N}{2}-2)} & \ddots & 0 & \cdots & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & 0 & \ddots & H_{1,-1} & 0 & \vdots & \vdots & \vdots & \vdots \\
\cdots & \cdots & \cdots & 0 & H_{2,-1} & 0 & \cdots & \cdots & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & 0 & H_{1,+1} & 0 & \cdots & \cdots & \cdots \\
\vdots & \vdots & \vdots & \vdots & 0 & H_{2,+1} & \ddots & 0 & \cdots & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots & 0 & \ddots & H_{1,+(\frac{N}{2}-2)} & 0 & \cdots \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 & H_{2,+(\frac{N}{2}-2)} & H_{1,+(\frac{N}{2}-1)} & 0 \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 & H_{2,+(\frac{N}{2}-1)} & H_{1,+\frac{N}{2}} \\
0 & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & 0 & H_{2,+\frac{N}{2}}
\end{matrix}
$$



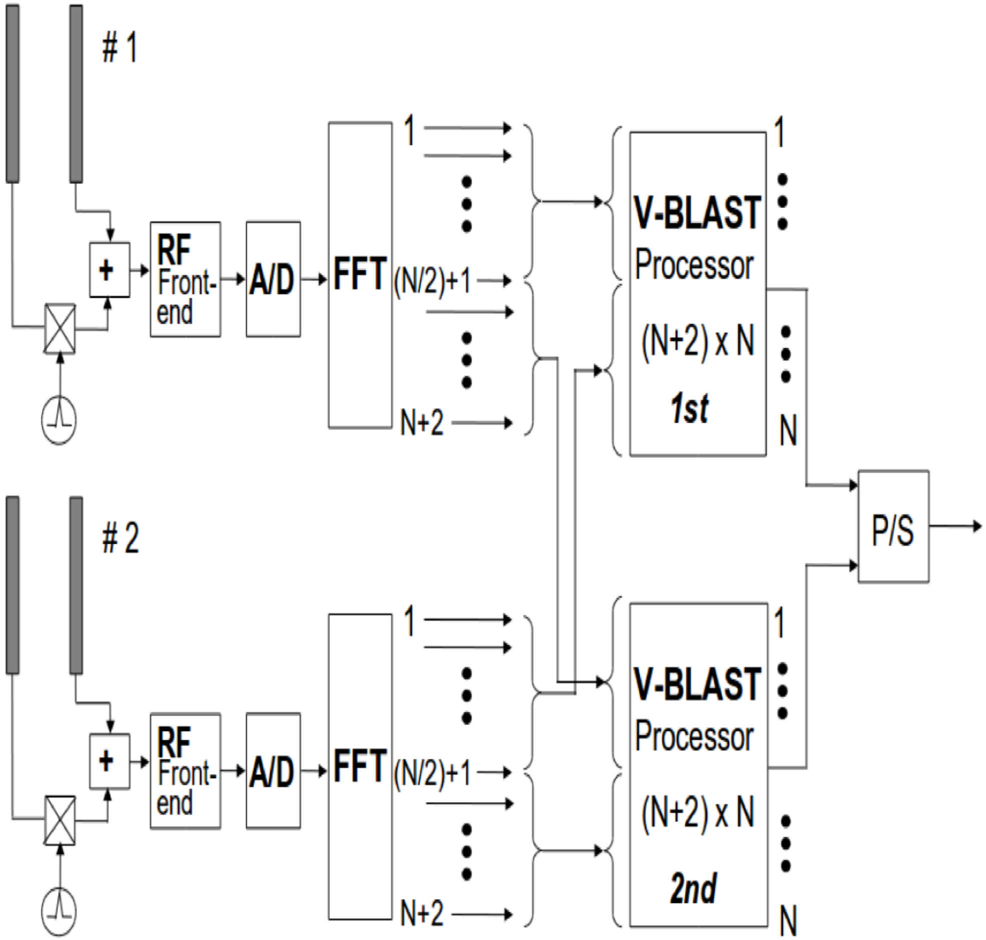


Original channel matrix

Channel Matrix Size for 1 V-BLAST Processors



MIMO decoder using 2 V-BLAST Processors



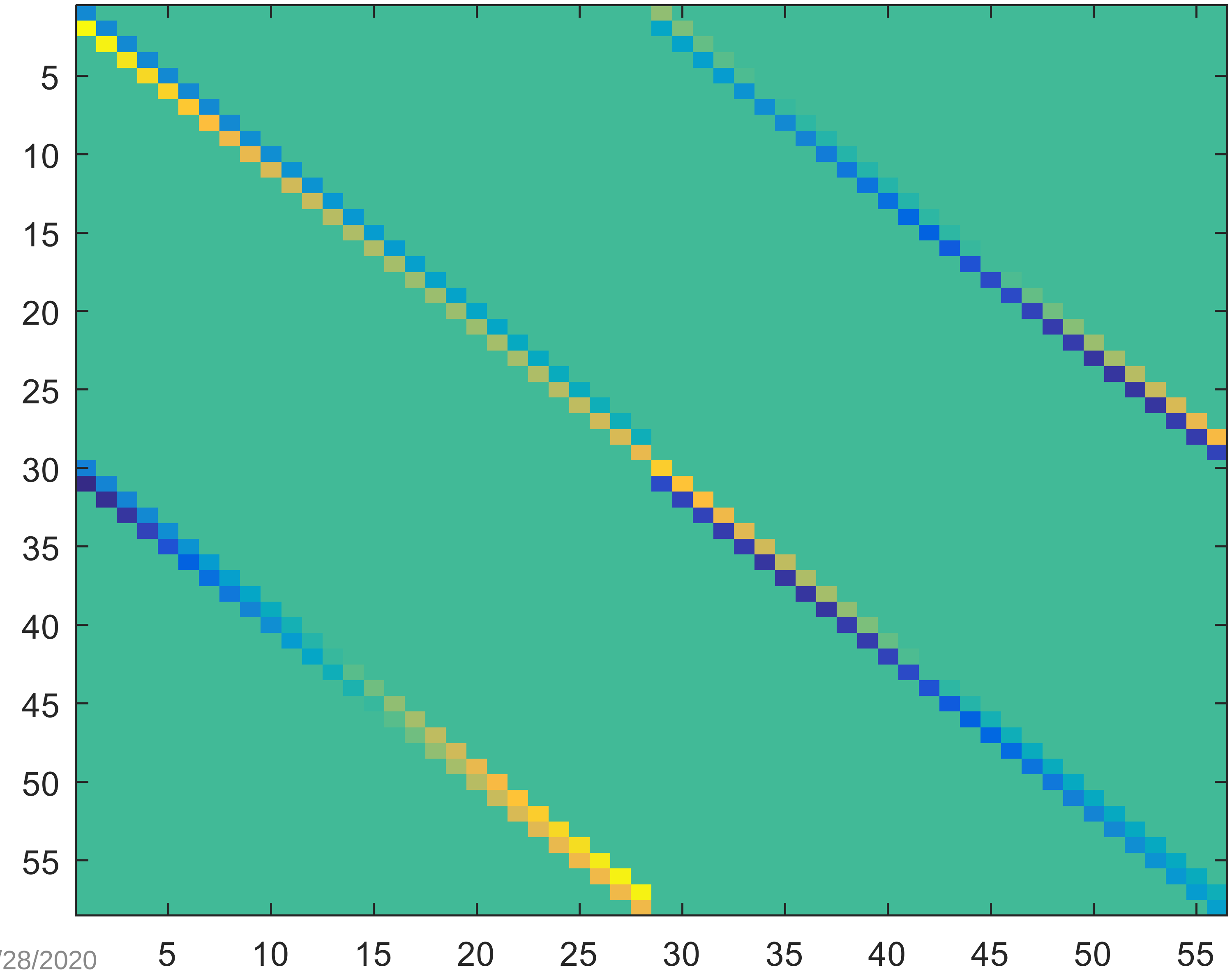
$$
\mathbf{H}_{up} = \begin{pmatrix}
H_{1,-N/2} & 0 & \dots & 0 & H_{1,-N/2} & 0 & \dots & 0 \\
H_{2,-N/2} & \ddots & \ddots & \vdots & H_{2,-N/2} & \ddots & \ddots & \vdots \\
0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\
\vdots & \ddots & \ddots & H_{1,-1} & \vdots & \ddots & \ddots & H_{1,-1} \\
0 & \dots & 0 & H_{2,-1} & 0 & \dots & 0 & H_{2,-1} \\
H_{1,-N/2} & 0 & \dots & 0 & H_{1,-N/2} & 0 & \dots & 0 \\
H_{2,-N/2} & \ddots & \ddots & \vdots & H_{2,-N/2} & \ddots & \ddots & \vdots \\
0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\
\vdots & \ddots & \ddots & H_{1,-1} & \vdots & \ddots & \ddots & H_{1,-1} \\
0 & \dots & 0 & H_{2,-1} & 0 & \dots & 0 & H_{2,-1}
\end{pmatrix}
$$

Upper channel matrix

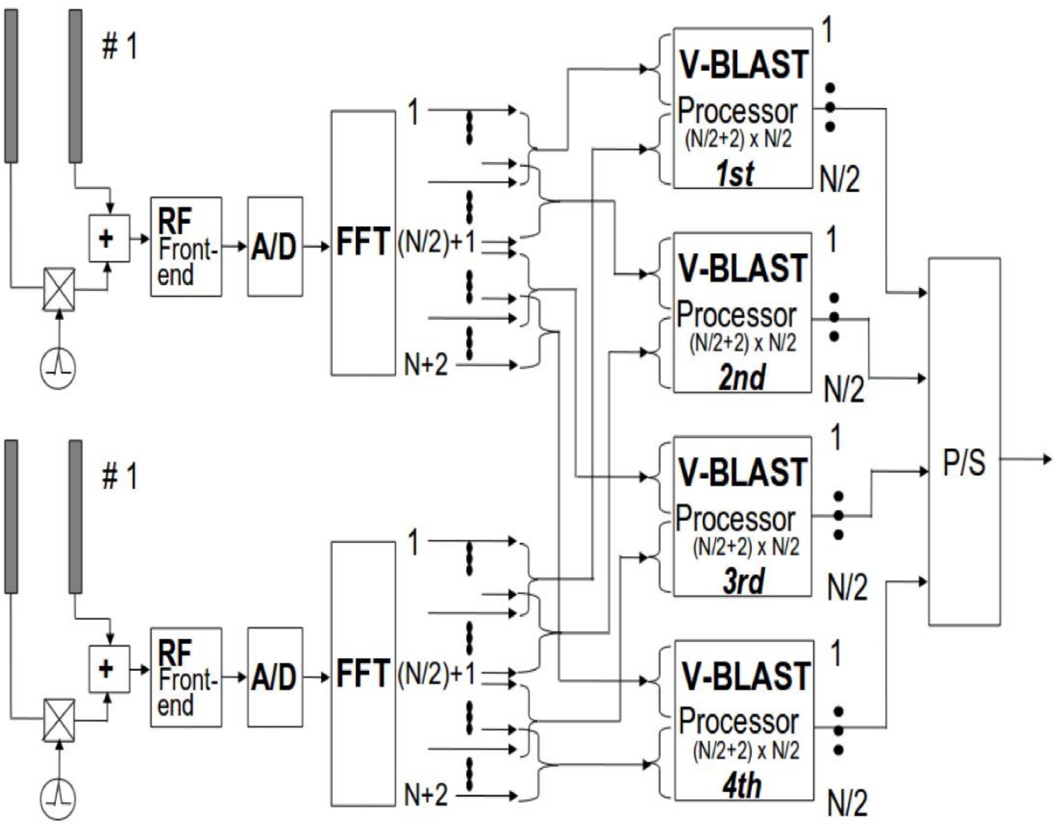
$$
\mathbf{H}_{lo} = \begin{pmatrix}
H_{1,+N/2} & 0 & \dots & 0 & H_{1,+N/2} & 0 & \dots & 0 \\
H_{2,+N/2} & \ddots & \ddots & \vdots & H_{2,+N/2} & \ddots & \ddots & \vdots \\
0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\
\vdots & \ddots & \ddots & H_{1,+1} & \vdots & \ddots & \ddots & H_{1,+1} \\
0 & \dots & 0 & H_{2,+1} & 0 & \dots & 0 & H_{2,+1} \\
H_{1,+N/2} & 0 & \dots & 0 & H_{1,+N/2} & 0 & \dots & 0 \\
H_{2,+N/2} & \ddots & \ddots & \vdots & H_{2,+N/2} & \ddots & \ddots & \vdots \\
0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\
\vdots & \ddots & \ddots & H_{1,+1} & \vdots & \ddots & \ddots & H_{1,+1} \\
0 & \dots & 0 & H_{2,+1} & 0 & \dots & 0 & H_{2,+1}
\end{pmatrix}
$$

Lower channel matrix

Channel Matrix Size for 2 V-BLAST Processors



MIMO decoder using 4 V-BLAST Processors



$$\mathbf{H}_{uA} = \begin{pmatrix} H_{1,-N/2} & 0 & \cdots & 0 & H_{1,-N/2} & 0 & \cdots & 0 \\ H_{2,-N/2} & \ddots & \ddots & \vdots & H_{2,-N/2} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,-N/4} & \vdots & \ddots & \ddots & H_{1,-N/4} \\ 0 & \cdots & 0 & H_{2,-N/4} & 0 & \cdots & 0 & H_{2,-N/4} \\ H_{1,-N/2} & 0 & \cdots & 0 & H_{1,-N/2} & 0 & \cdots & 0 \\ H_{2,-N/2} & \ddots & \ddots & \vdots & H_{2,-N/2} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,-N/4} & \vdots & \ddots & \ddots & H_{1,-N/4} \\ 0 & \cdots & 0 & H_{2,-N/4} & 0 & \cdots & 0 & H_{2,-N/4} \end{pmatrix}$$

$$\mathbf{H}_{uB} = \begin{pmatrix} H_{1,-N/4} & 0 & \cdots & 0 & H_{1,-N/4} & 0 & \cdots & 0 \\ H_{2,-N/4} & \ddots & \ddots & \vdots & H_{2,-N/4} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,-1} & \vdots & \ddots & \ddots & H_{1,-1} \\ 0 & \cdots & 0 & H_{2,-1} & 0 & \cdots & 0 & H_{2,-1} \\ H_{1,-N/4} & 0 & \cdots & 0 & H_{1,-N/4} & 0 & \cdots & 0 \\ H_{2,-N/4} & \ddots & \ddots & \vdots & H_{2,-N/4} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,-1} & \vdots & \ddots & \ddots & H_{1,-1} \\ 0 & \cdots & 0 & H_{2,-1} & 0 & \cdots & 0 & H_{2,-1} \end{pmatrix}$$

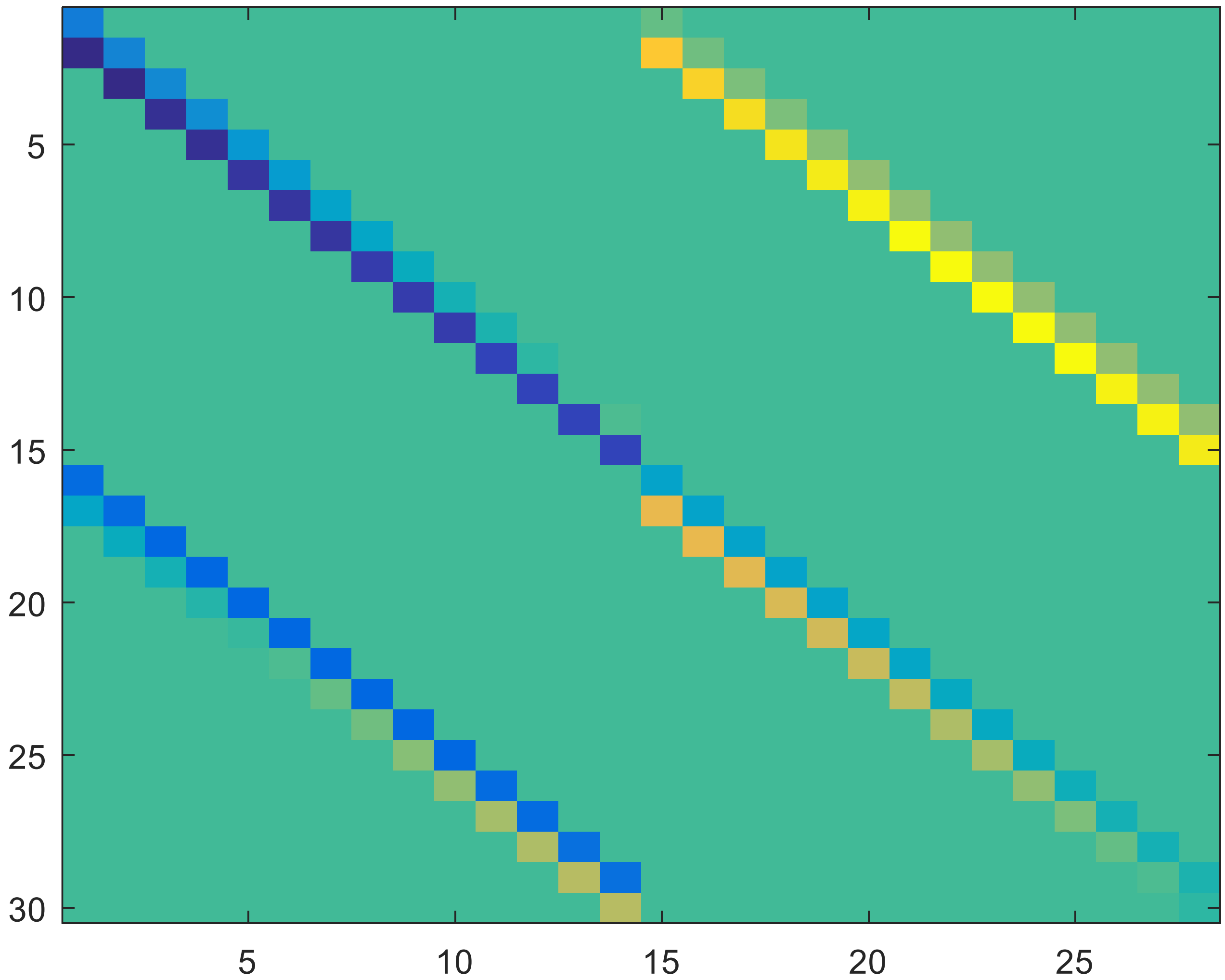
Upper channel matrix

$$\mathbf{H}_{lA} = \begin{pmatrix} H_{1,+N/2} & 0 & \cdots & 0 & H_{1,+N/2} & 0 & \cdots & 0 \\ H_{2,+N/2} & \ddots & \ddots & \vdots & H_{2,+N/2} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,+N/4} & \vdots & \ddots & \ddots & H_{1,N/4} \\ 0 & \cdots & 0 & H_{2,+N/4} & 0 & \cdots & 0 & H_{2,N/4} \\ H_{1,+N/2} & 0 & \cdots & 0 & H_{1,+N/2} & 0 & \cdots & 0 \\ H_{2,+N/2} & \ddots & \ddots & \vdots & H_{2,+N/2} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,+N/4} & \vdots & \ddots & \ddots & H_{1,+N/4} \\ 0 & \cdots & 0 & H_{2,+N/4} & 0 & \cdots & 0 & H_{2,+N/4} \end{pmatrix}$$

$$\mathbf{H}_{lB} = \begin{pmatrix} H_{1,+N/4} & 0 & \cdots & 0 & H_{1,+N/4} & 0 & \cdots & 0 \\ H_{2,+N/4} & \ddots & \ddots & \vdots & H_{2,+N/4} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,+1} & \vdots & \ddots & \ddots & H_{1,+1} \\ 0 & \cdots & 0 & H_{2,+1} & 0 & \cdots & 0 & H_{2,+1} \\ H_{1,+N/4} & 0 & \cdots & 0 & H_{1,+N/4} & 0 & \cdots & 0 \\ H_{2,+N/4} & \ddots & \ddots & \vdots & H_{2,+N/4} & \ddots & \ddots & \vdots \\ 0 & \ddots & \ddots & 0 & 0 & \ddots & \ddots & 0 \\ \vdots & \ddots & \ddots & H_{1,+1} & \vdots & \ddots & \ddots & H_{1,+1} \\ 0 & \cdots & 0 & H_{2,+1} & 0 & \cdots & 0 & H_{2,+1} \end{pmatrix}$$

Lower channel matrix

Channel Matrix Size for 4 V-BLAST Processors



Error rate performances for *n* V-BLAST processors

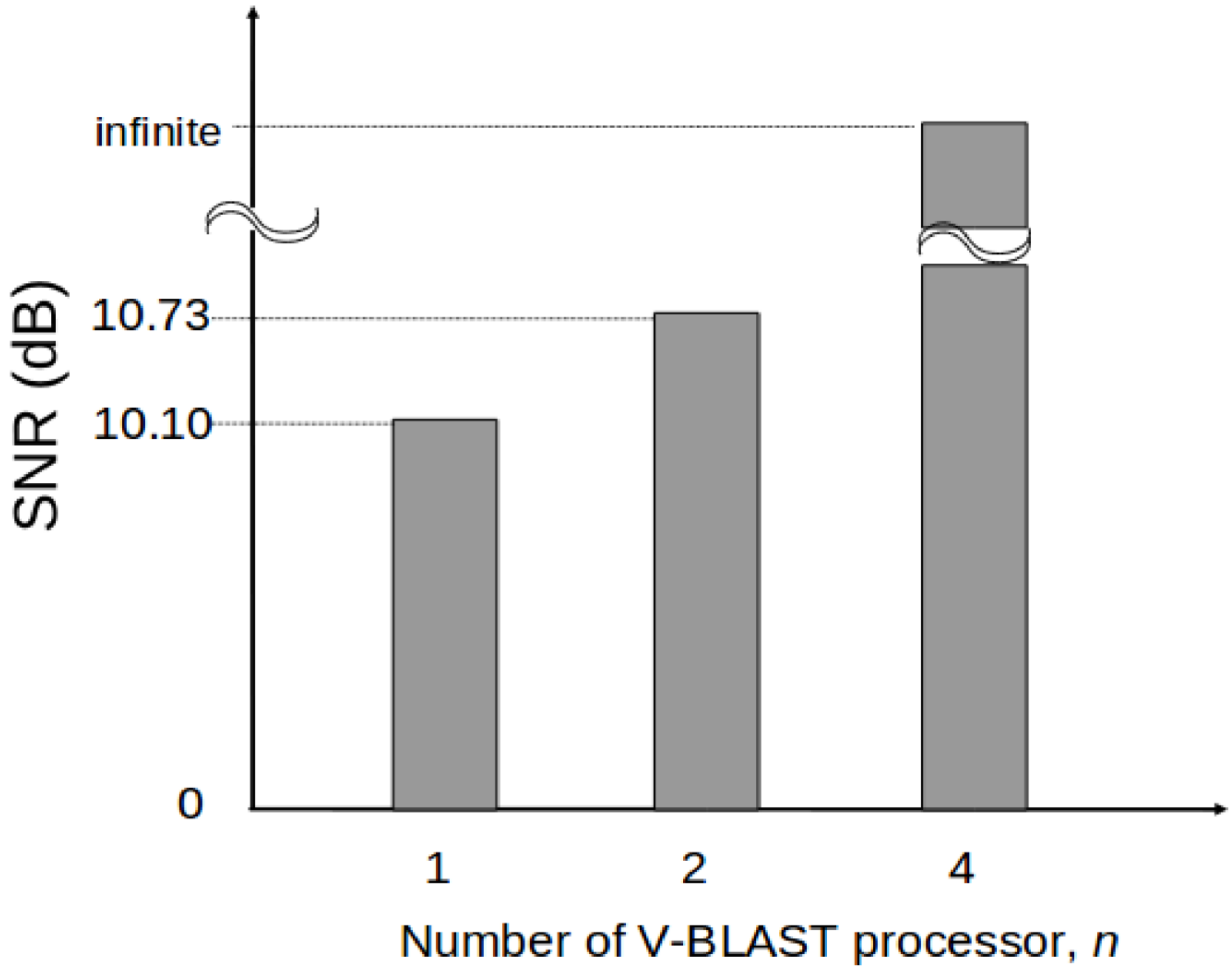


Table Of Simulation Parameters

	Parameters	Value
Transmitter	Pilot sequence Modulation Number of Sub carrier IFFT/FFT size Antenna Dimension Guard Interval ratio	HTLTF IEEE802.11n QPSK 56 64 2 x 2 1/4
Channel Model	Rayleigh Fading	2 – rays
Receiver	Channel estimation Equalization	MMSE MMSE and Kalman

MIMO decomposition Computational Cost

	MIMO Detection Type	4 - QAM ModDemod		64 - QAM ModDemod	
		Multiplication	Addition	Multiplication	Addition
CONVENTIONAL	ZF (2x2)	$43.1x10^{2}$	$35.3x10^{2}$	$43.1x10^{2}$	$35.3x10^{2}$
CONVENTIONAL	MMSE (2x2)	$45.4x10^{2}$	$37.5x10^{2}$	$45.4x10^{2}$	$37.5x10^{2}$
CONVENTIONAL	MLD (2x2)	**$23.8x10^{3}$**	**$20x10^{3}$**	**$57.3x10^{5}$**	**$48.2x10^{5}$**
CONVENTIONAL	V-BLAST (2x2)	$11x10^{3}$	$79x10^{2}$	$28.4x10^{3}$	$15x10^{3}$
CONVENTIONAL	ZF (2x4)	$79x10^{2}$	$68.9x10^{2}$	$79x10^{2}$	$68.9x10^{2}$
CONVENTIONAL	MMSE (2x4)	$81.2x10^{2}$	$70.6x10^{2}$	$81.2x10^{2}$	$70.6x10^{2}$
CONVENTIONAL	V-BLAST (2x4)	$21.1x10^{3}$	$16.3x10^{3}$	$38.6x10^{3}$	$23.5x10^{3}$
PROPOSAL	ZF (2x2)	$11.8x10^{6}$	$11.7x10^{6}$	$11.8x10^{6}$	$11.7x10^{6}$
PROPOSAL	MMSE(2x2)	$11.8x10^{6}$	$11.7x10^{6}$	$11.8x10^{6}$	$11.7x10^{6}$
PROPOSAL	V-BLAST(2x2)	**$59.7x10^{5}$**	**$59.1x10^{5}$**	**$59.7x10^{5}$**	**$59.1x10^{5}$**

Conclusions

- This work has shown that a MIMO-OFDM receiver using RF signal processing can achieve comparable spectral efficiency gains.

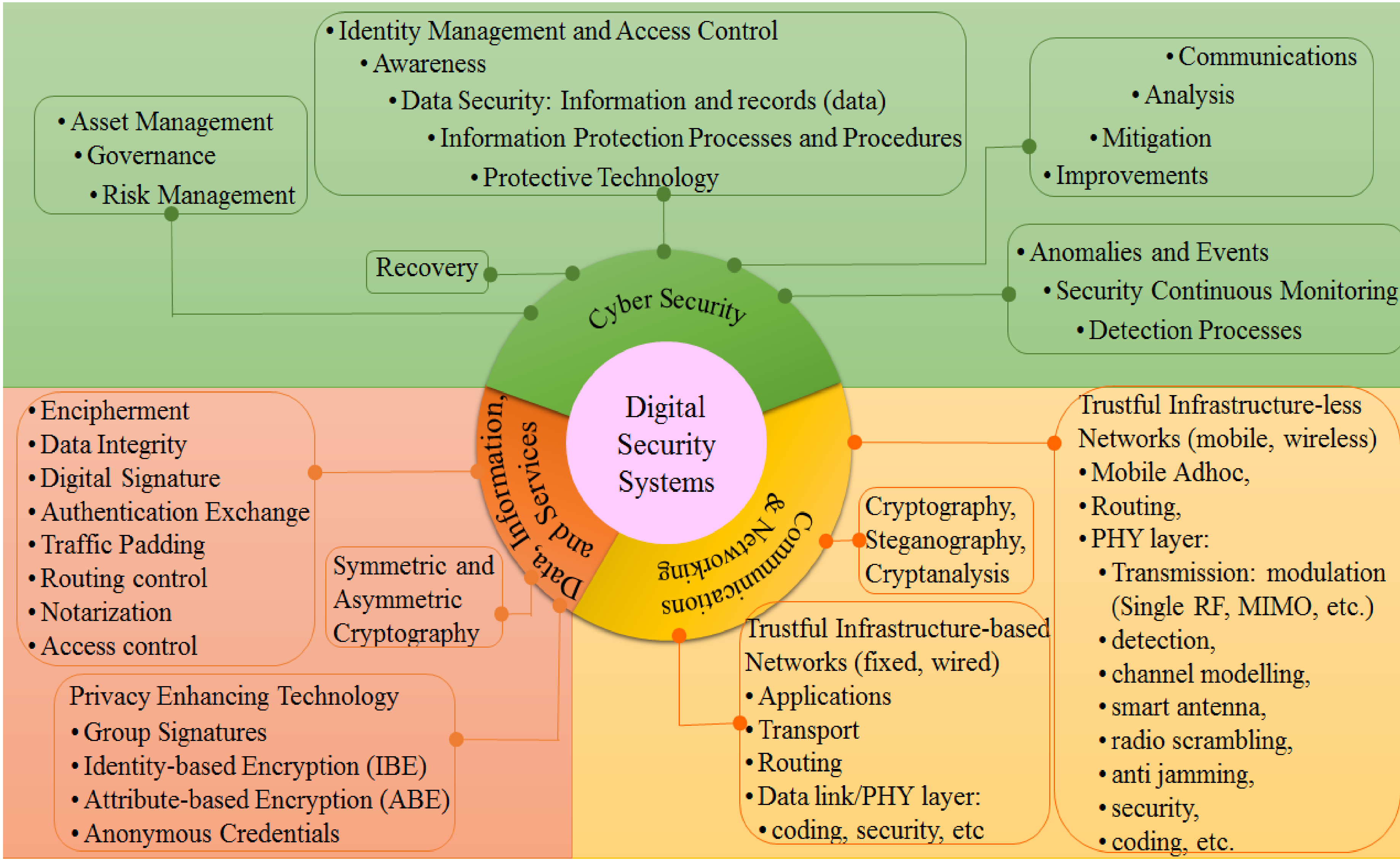
- Computer simulation results verify the performance of the proposed scheme. The proposed scheme gives a diversity gain in a frequency selective-fading channel.

- Although diversity gains have been obtained, the complexity of computation is still a constraint in this approach requiring reduction of the channel matrix size to one half of the original matrix.

- Further research is needed to appropriately and correctly simplify the channel matrix size to decrease the complexity time consumption of the computation.

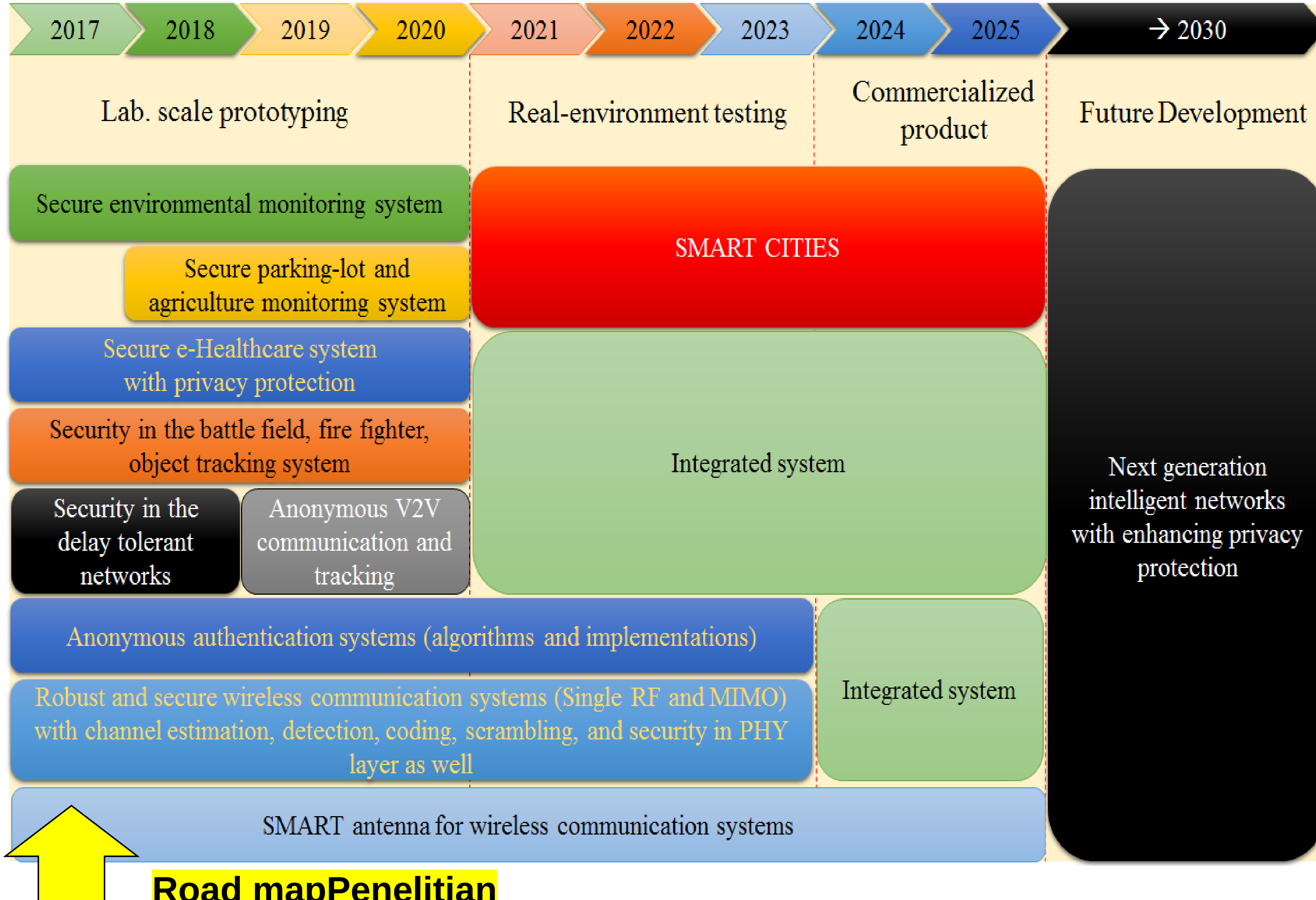
- Complexity of computational cost our proposal for 2x2 dimension for 4-QAM is about 250 times and for 64-QAM is comparable to conventional MIMO - OFDM system using MLD.

Research Area



Research Area

Roadmap

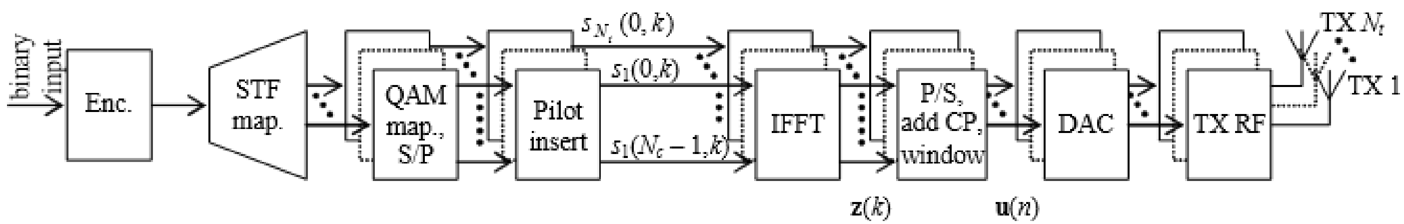


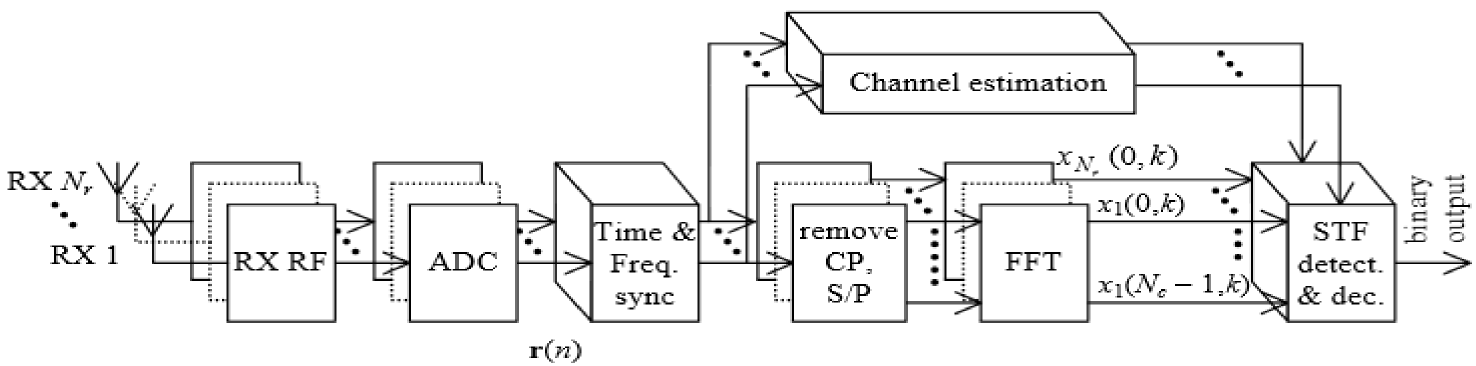
Road mapPenelitian

Penelitian Nasional yang didanai

1. Perencanaan Dan Implementasi Sistem Komunikasi Nirkabel Multi-Carrier Orthogonal Frequency Division Multiplexing (OFDM) Untuk Multi Antena Berbasis Universal Software Radio Peripheral (USRP) 2013 – 2015 (Penelitian PTUP)
2. Rancang Bangun Sistem Penerima Digital Video Broadcasting Second Generation Terrestrial (DVB-T2) Menggunakan Transmisi Sistem MIMO berbasis Single RF Antenna (PTUP)

Eksperimental – Set up

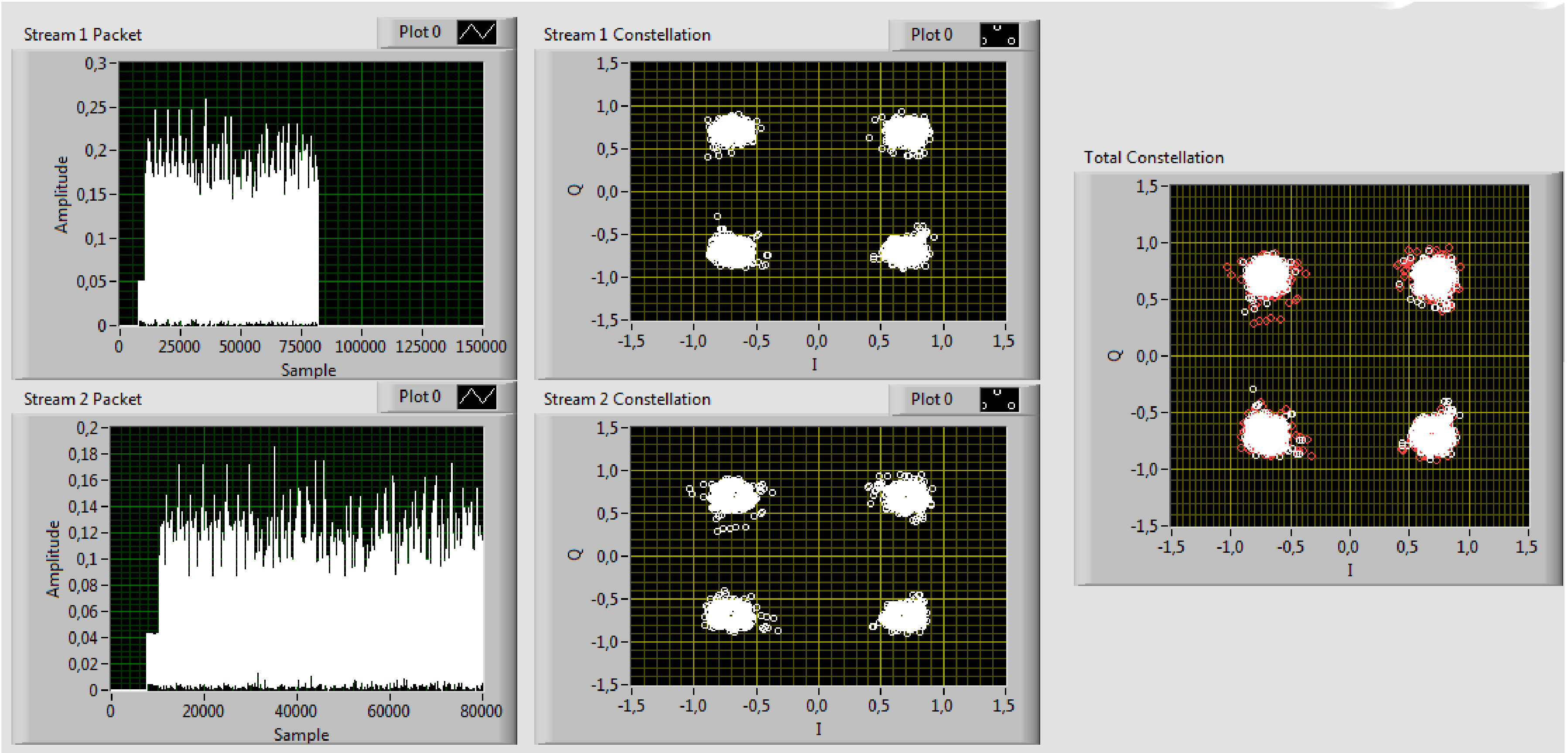




Tabel Parameter

	Parameter	Nilai
Pengirim	Pilot Sequence	32 symbol
	Modulasi	4QAM
	Jumlah subcarrier	128
	Ukuran FFT	128
	Guard Intervals	32 bits (16 zeroes at the edges and at 1 zero at DC)
	Data Rate	200 KBps
	Frekuensi Carrier	910 MHz
	1 Frame Data	320 bit
	Rasio Cyclic Prefix	1/4
	Data of symbol OFDM	192 bit
Penerima	Equalizer	Zero Forcing

Eksperimental Results: Constellation






Terimakasih