Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Dual-Mode Broadband and Wireless Network (DMBWN)]
Date Submitted: [07 May, 2007]
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Re: []

Abstract: [Description of the concept of Dual-Mode Broadband and Wireless Network]
Purpose: [Contribution to TG3c at May 2007 meeting.]

Dual-Mode Broadband and Wireless Network (DMBWN)

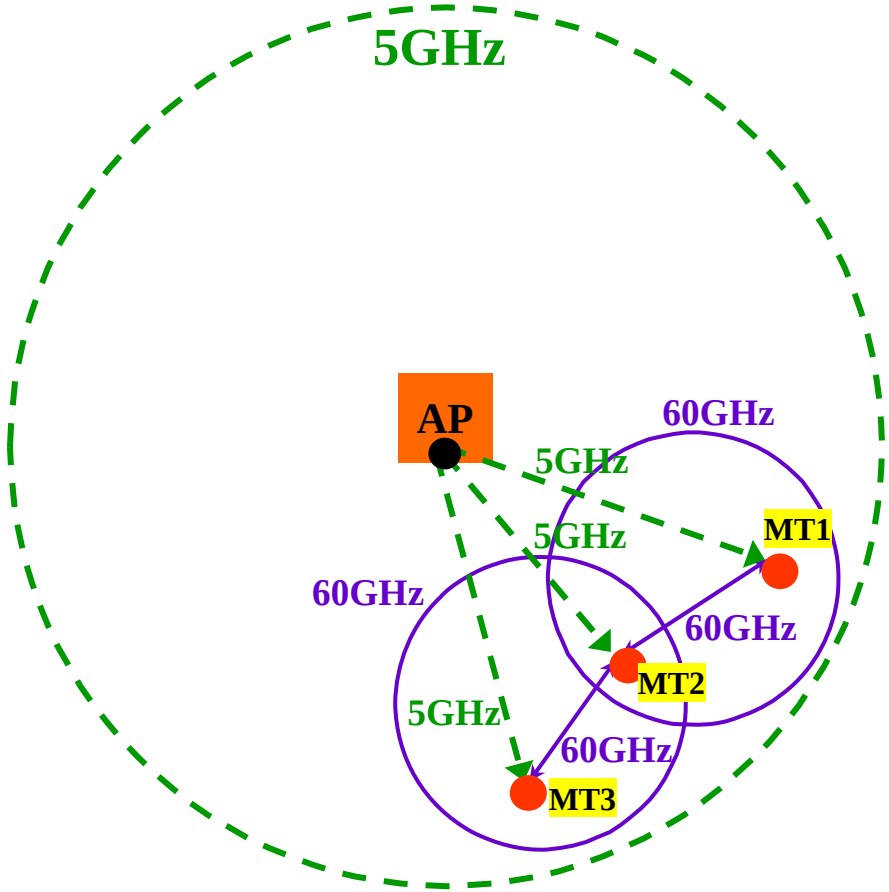
Ching-Kuang Tzung, Ta-Sung Lee*, Jenn-Hwan Tarng*, Yu-De Lin*, Fu-Chiang Chen*, Chi-Hsueh Wang, Tian-Wei Huang, Huei Wang, Shih-Yuan Chen, Powen Hsu, Tah-Hsiung Chu, Ruey-Beei Wu, and Chun-Hsiung Chen

National Taiwan University

***National Chiao Tung University**

May 07, 2007

Dual-Mode Broadband and Wireless Network (DMBWN): a backward compatible system concept



RF front-end architecture for 5GHz / 60GHz RF signal transmission/reception

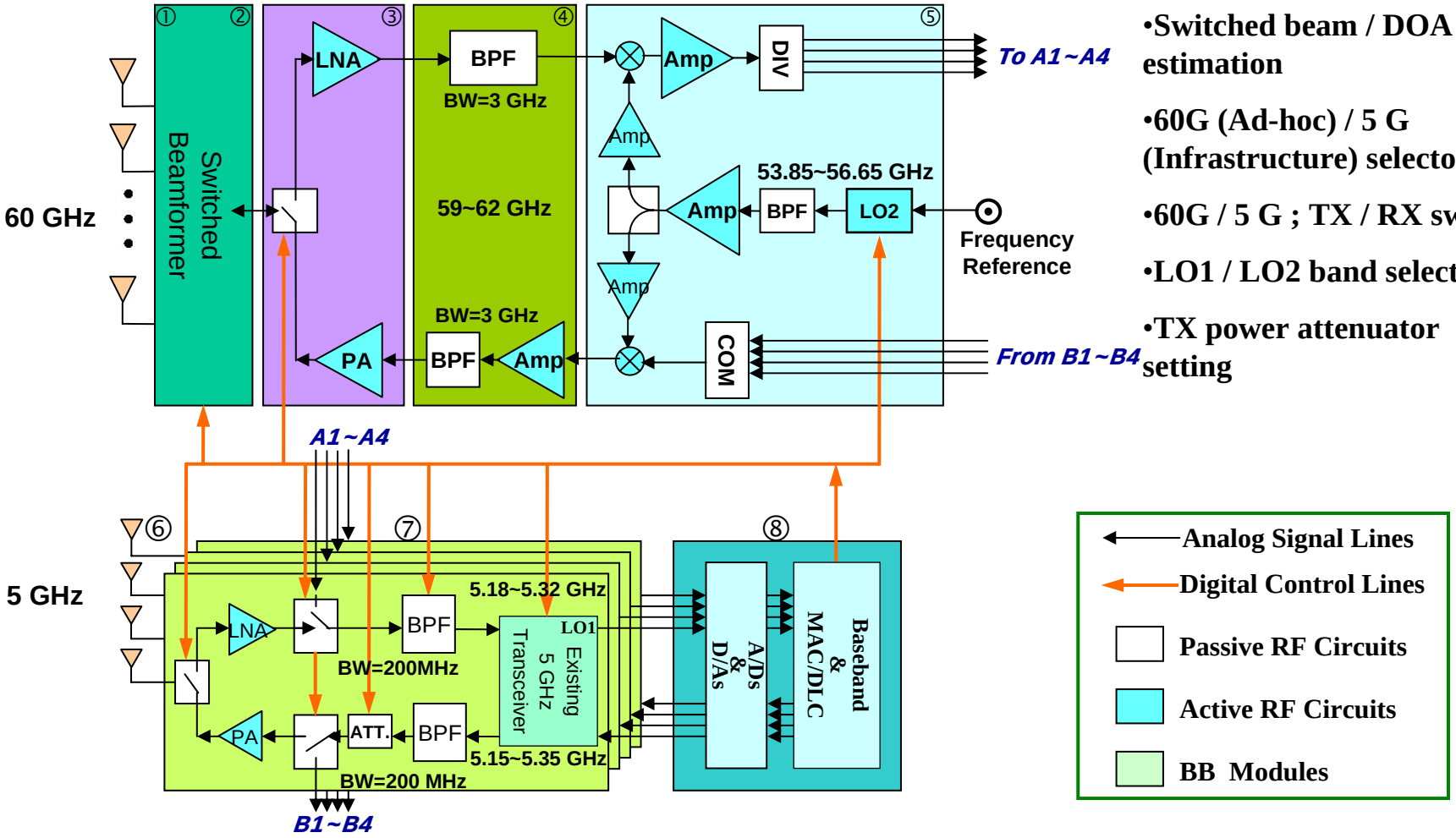
Smart antenna array based on switched beamforming

Motivation & Overview

- **Long Range**: lower operation frequency for communicating long-distance terminals**.**
- **Backward Compatible System**: the baseband realization is highly compatible with the OFDM based IEEE 802.11a/n standard.

- **5-GHz band**,
  - Infrastructure mode
  - MIMO-OFDM technique is adopted to improve the performance
- **60-GHz band**,
  - ad-hoc mode
  - Single -Carrier with Frequency-Domain Equalization (SC-FDE) strategy combined with switched beamforming for interference suppressing

60/5 GHz Dual-Mode Wireless Network Station



- Switched beam / DOA estimation
- 60G (Ad-hoc) / 5 G (Infrastructure) selector
- 60G / 5 G ; TX / RX switch
- LO1 / LO2 band selectors
- TX power attenuator setting

60-GHz Switched-Beam Antenna

- 60-GHz switched-beam antenna array has been developed in National Taiwan University
  - Linear polarization → circular polarization
  - 4 elements → 8 elements

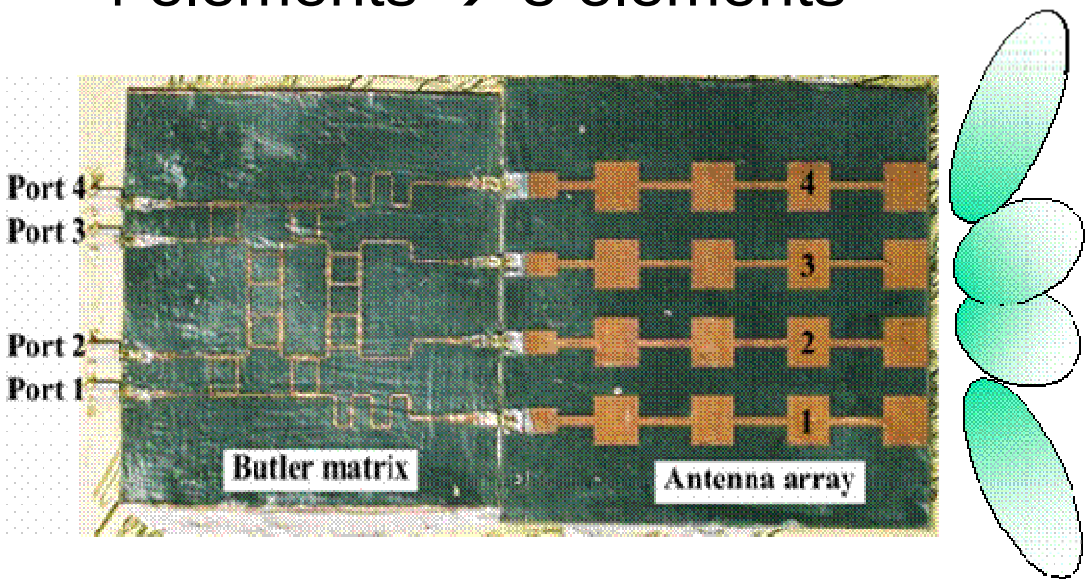
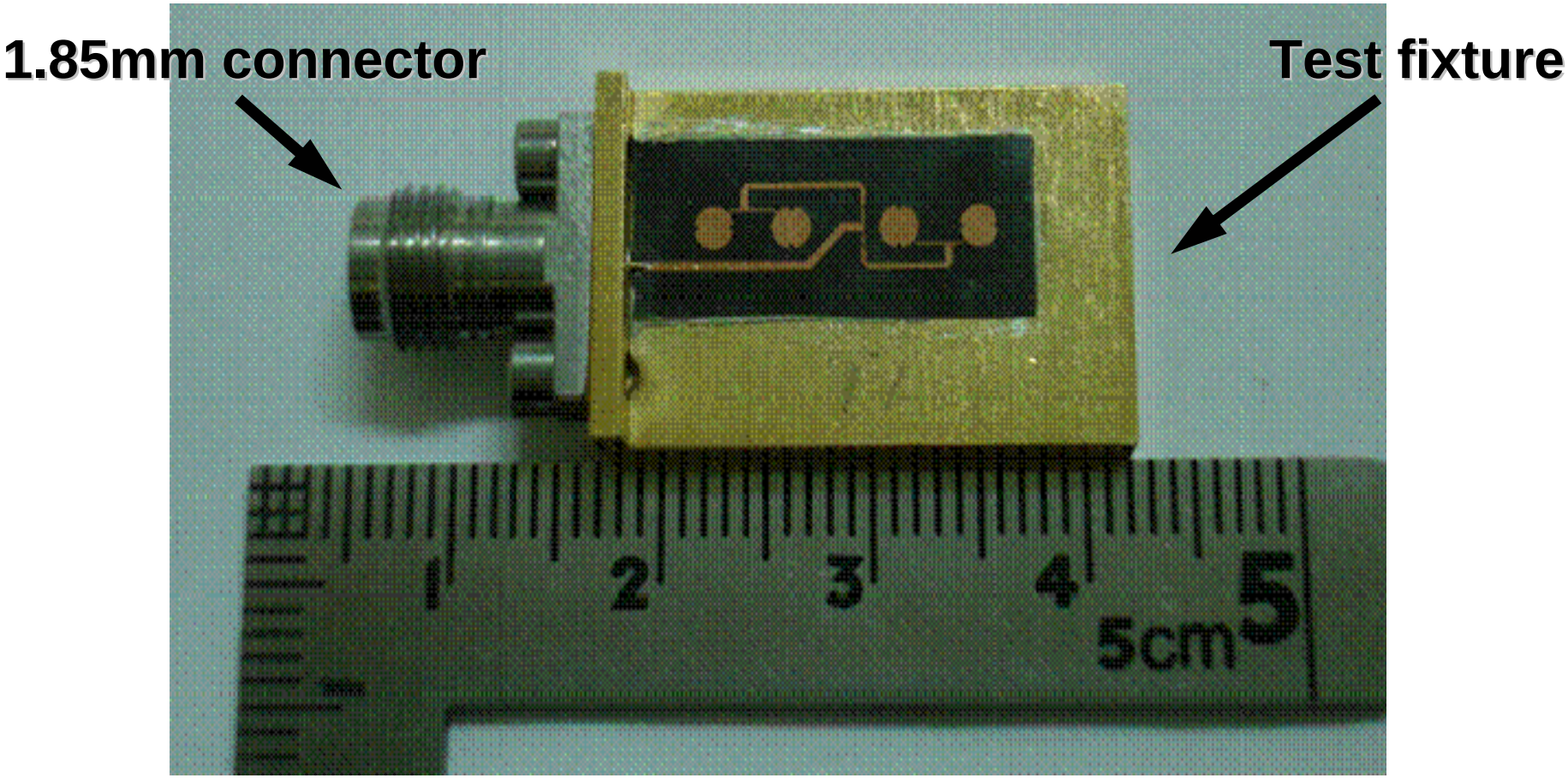
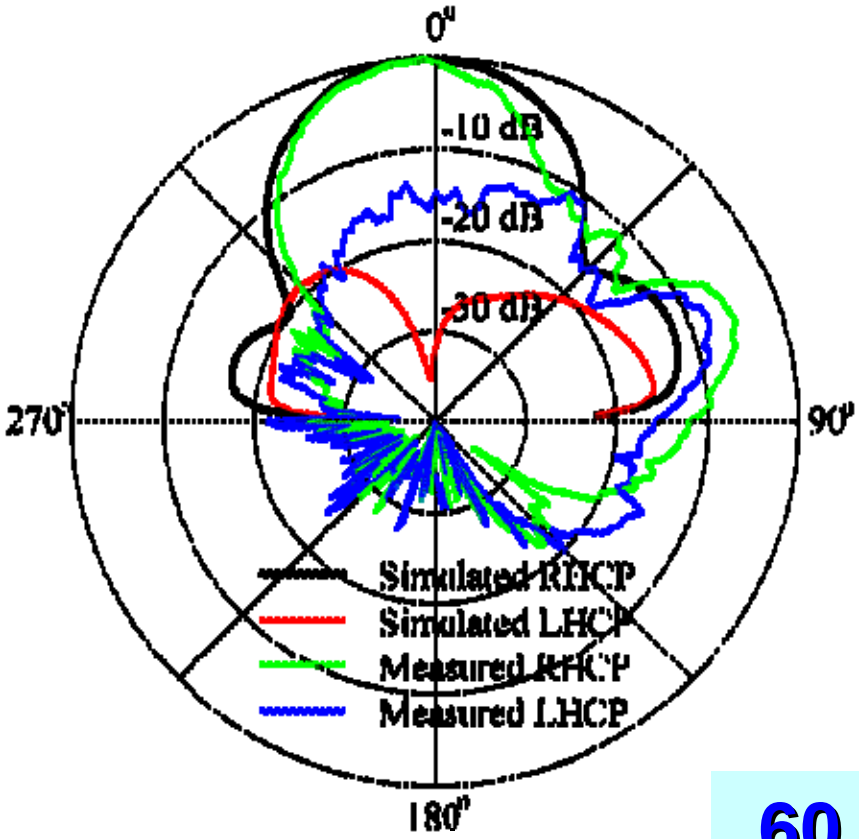
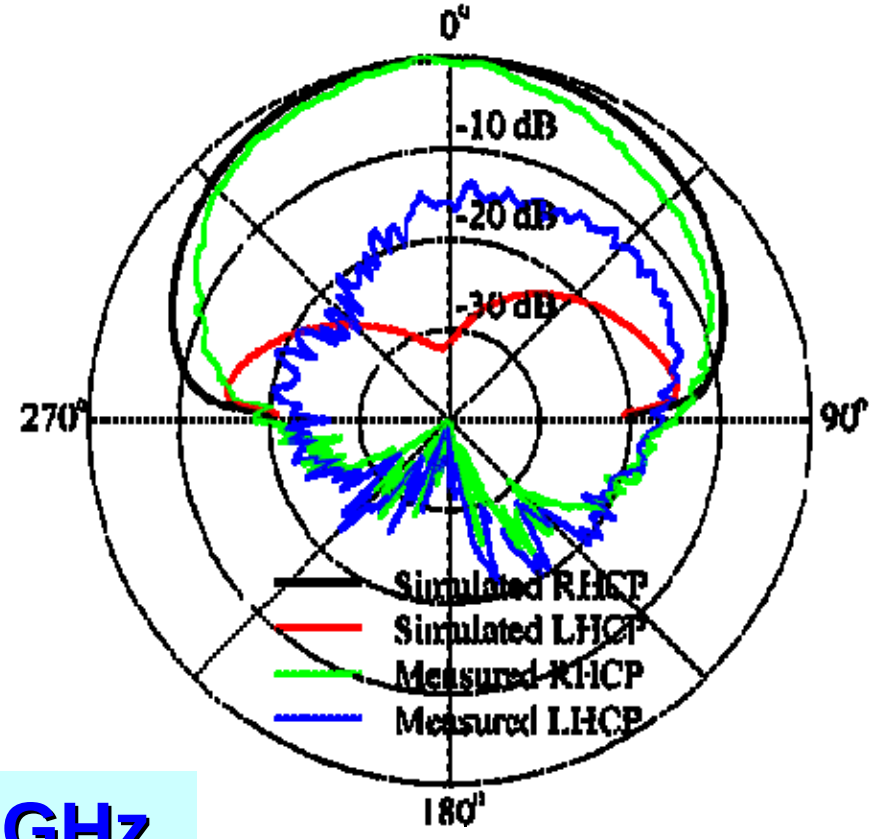


Photo of 1×4 Circular Patch Array



Radiation Patterns (1×2 array)



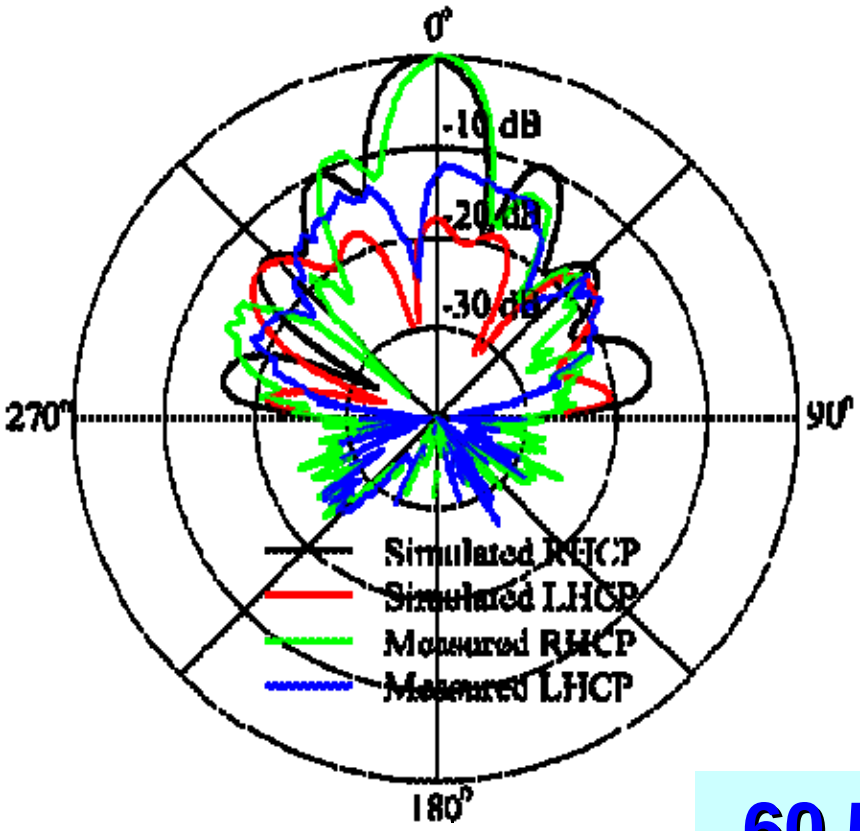


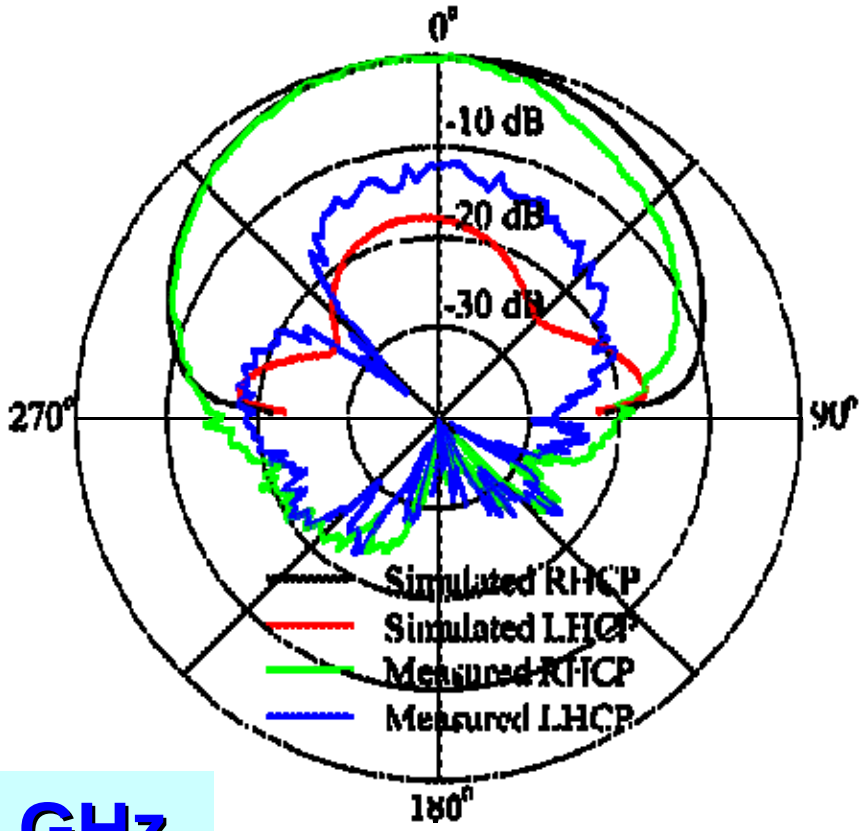
60.5 GHz

x-z plane

y-z plane

Radiation Patterns (1×4 array)

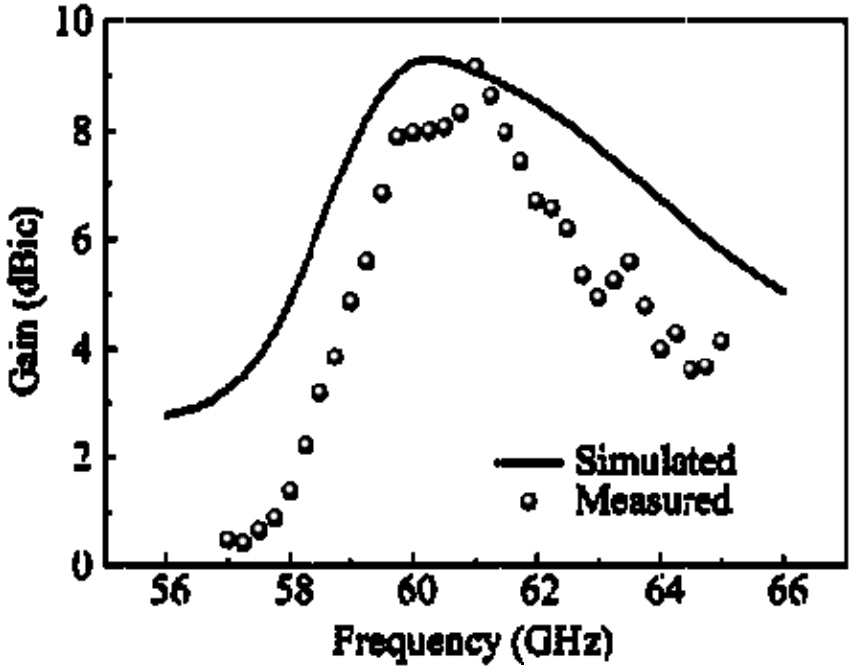


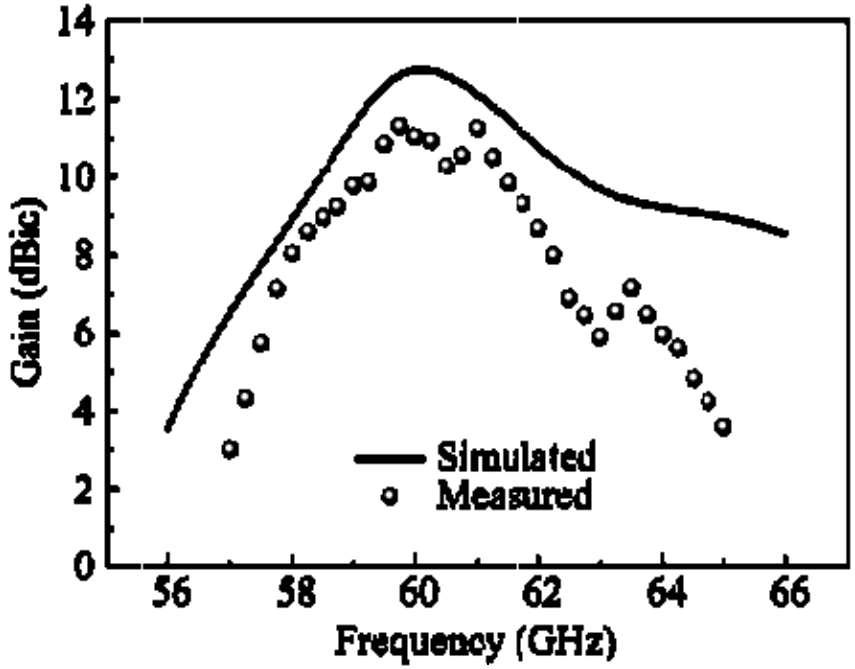


60.5 GHz

x-z plane **y-z plane**

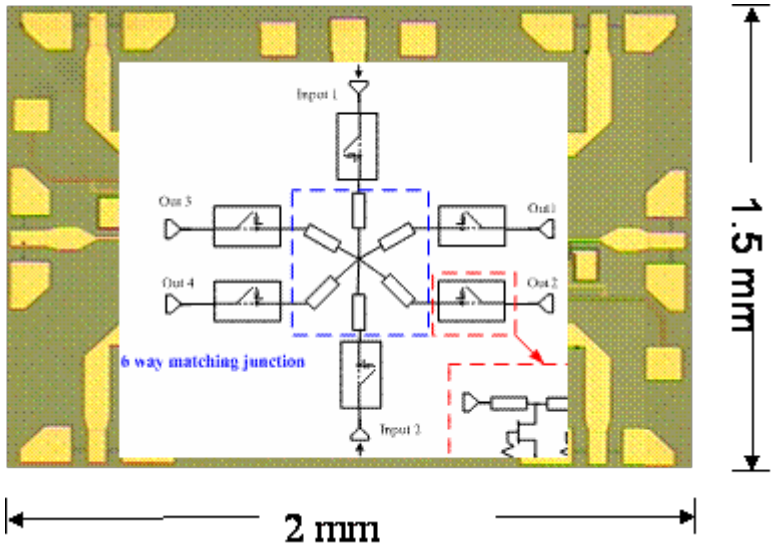
In-Band Peak Gains

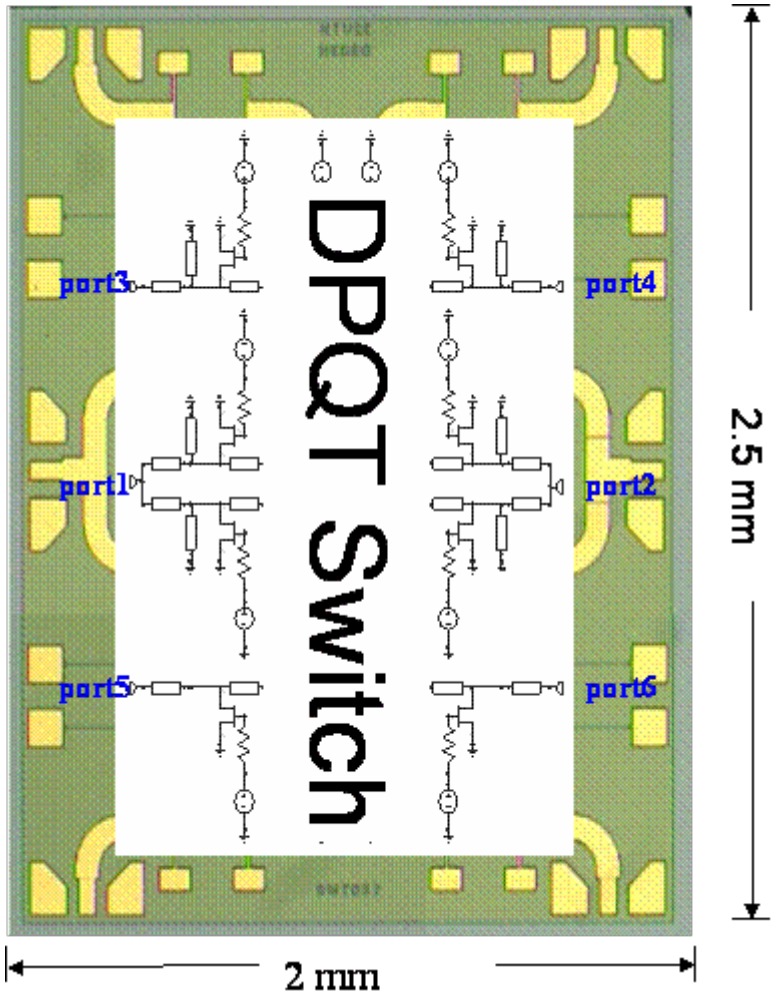




1×2 array **RHCP** **1×4 array**

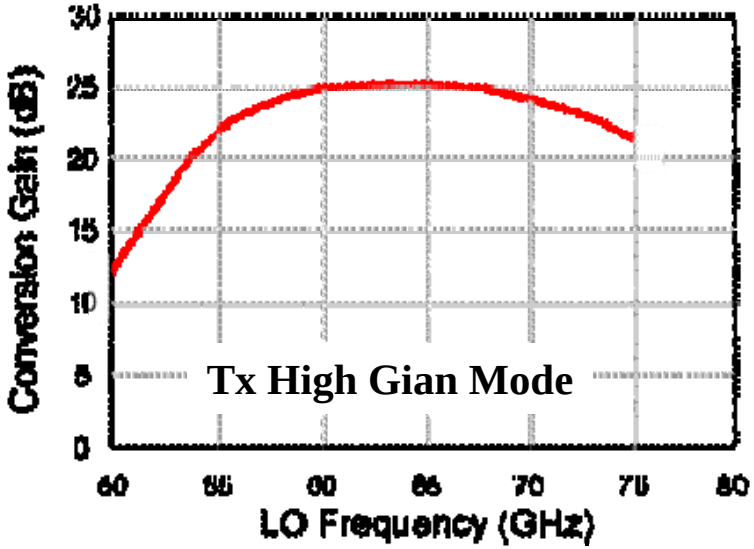
60GHz DPQT Switch



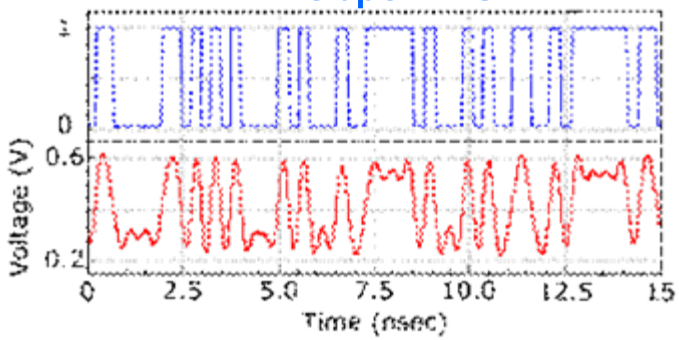


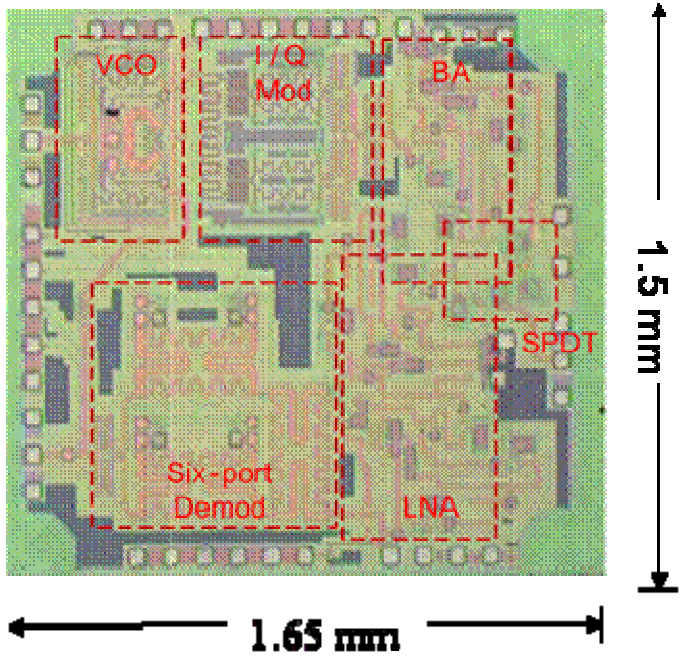
- 0.15 mm PHEMT , DPQT Switch
- Low insertion loss at 60GHz
- High isolation

A 0.13μm CMOS 60-GHz Transceiver



Rx: 4Gbps BPSK





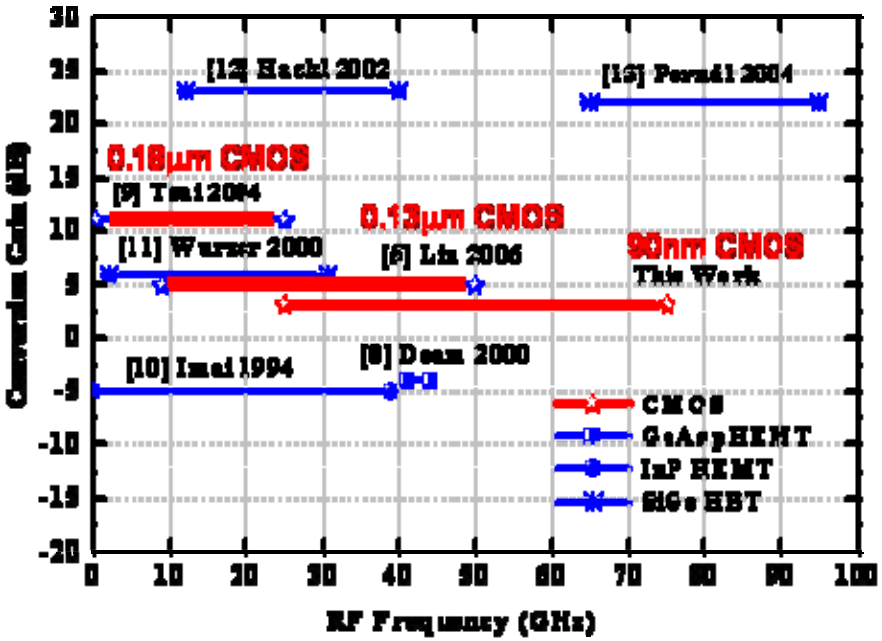
- Low power consumption (97mW)
- Tx Pout = -2dBm, IQ Modulation
- Miniature chip size, and **Low Cost**

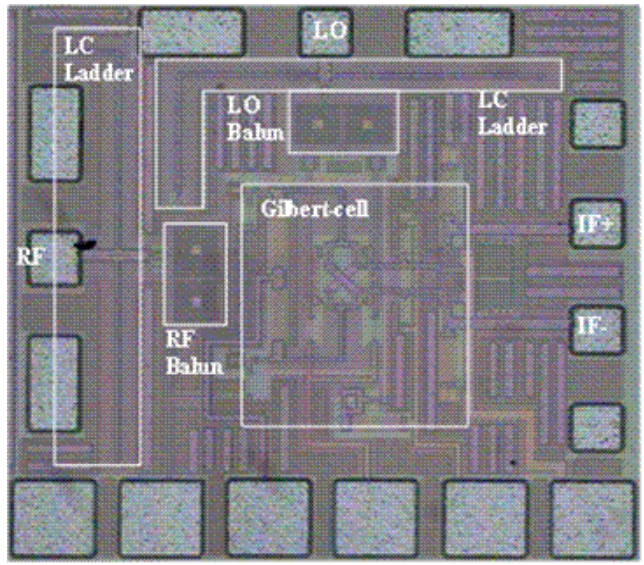
C-H. Wang, H-Y. Chang, P-S. Wu, K-Y. Lin, T-W. Huang, H. Wang, C-H. Chen, "A 60GHz Low-Power Six-Port Transceiver for Gigabit Software-Defined Transceiver Applications," 2007 *International Solid-State Circuit Conference (ISSCC),* San Francisco, CA, Feb. 2007.

25-75 GHz 90nm CMOS Gilbert-cell Mixer

Process : 90nm CMOS
Topology : Gilbert-cell
Chip size: 0.55 mm × 0.55 mm
RF Frequency : 25-75 GHz

Conversion Gain : 3 ± 2 dB
LO Driver Power : 6 dBm
Power Consumption : 93 mW
Isolation : 30 dB

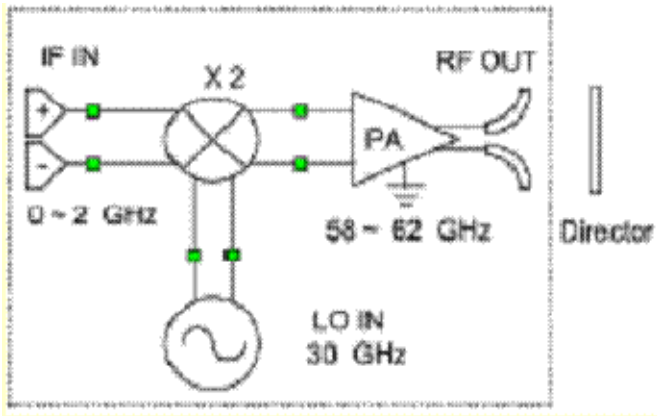


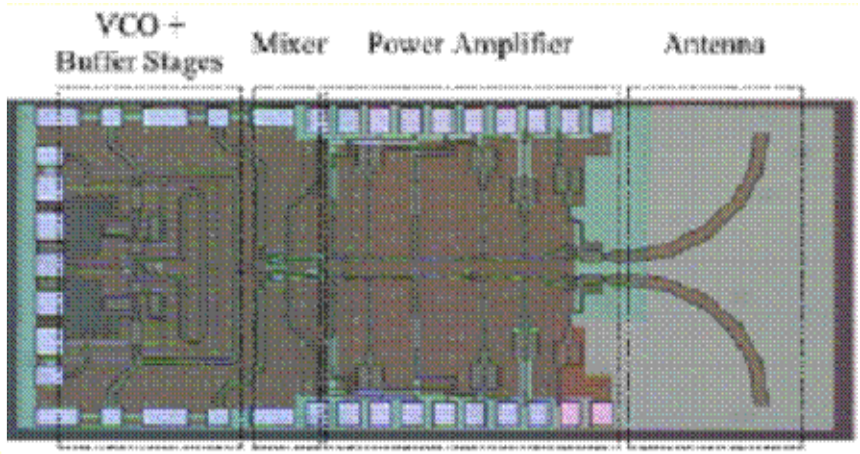


Jeng-Han Tsai, Pei-Si Wu, Chin-Shen Lin, Tian-Wei Huang, John G.J. Chern, and Wen-Chu Huang, " A 25-75-GHz Broadband Gilbert-cell Mixer Using 90-nm CMOS Technology," *IEEE Microwave and Guided Wave Letters*, April 2007.

60-GHz Transmitter with Integrated Antenna

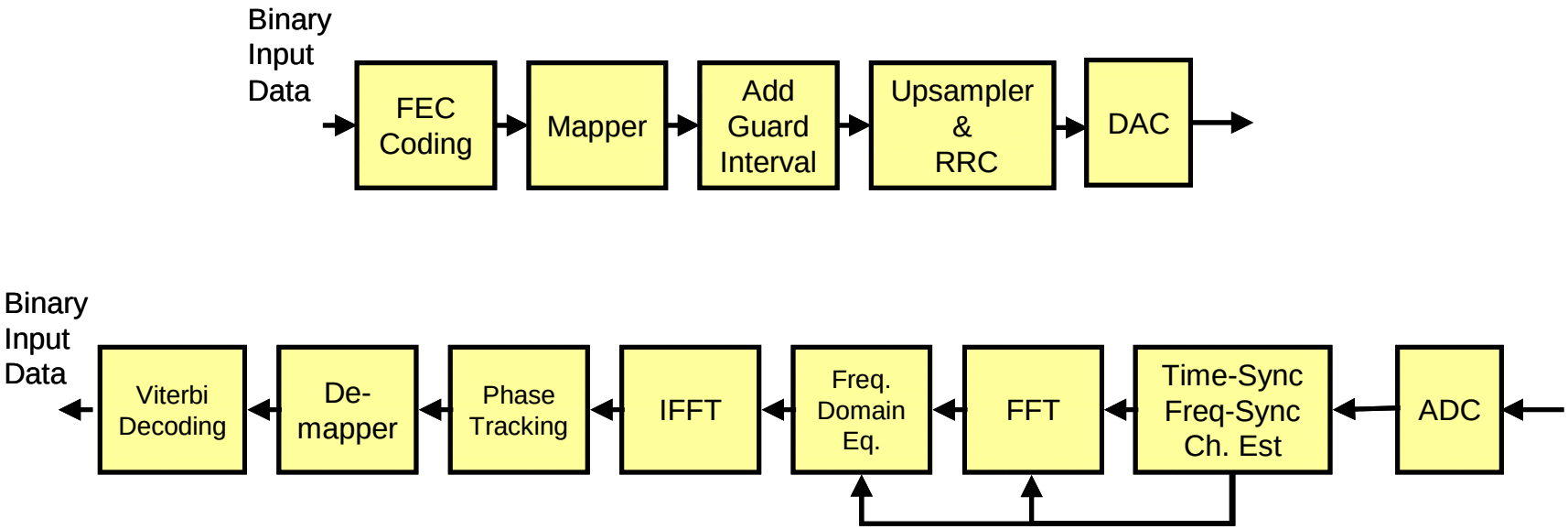
- Technology: 0.18- μ m SiGe BiCMOS process
- Chip size: 1.3 x 0.8 mm^2
- Conversion gain: 20.2 dB
- Output power: 15.8 dBm
- DC power consumption: 281 mW





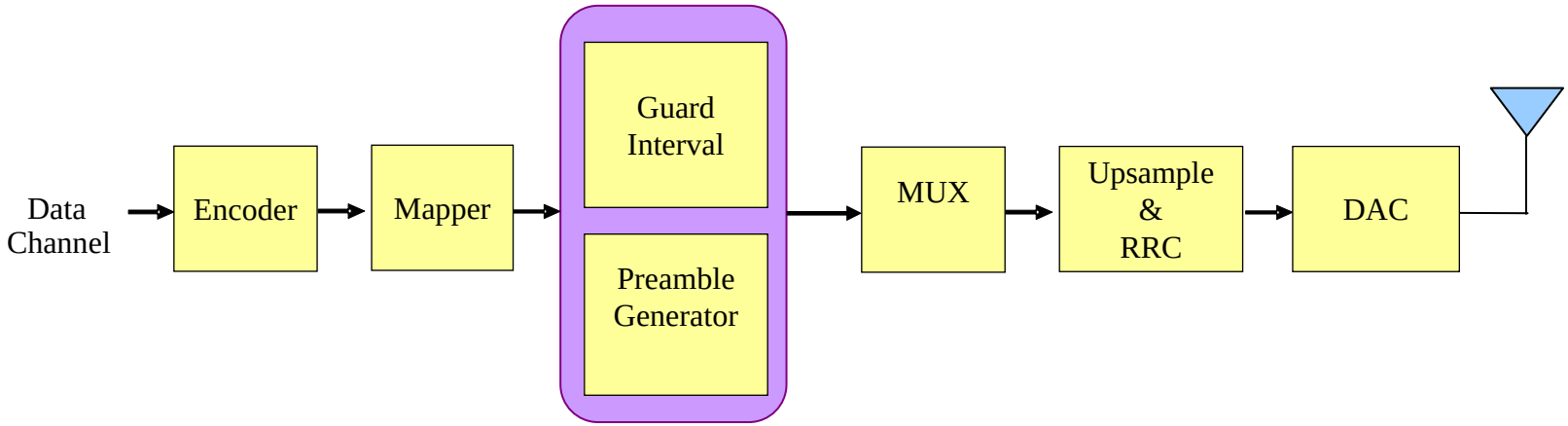
Chi-Hsueh Wang, Yi-Hsien Cho, Chin-Shen Lin, Huei Wang, Chun-Hsiung Chen, Dow-Chih Niu, John Yeh, Chwan-Ying Lee, and John Chern,"A 60-GHz transmitter with integrated antenna in 0.18-mm SiGe BiCMOS technology," 2006 *International Solid-State Circuit Conference (ISSCC),* San Francisco, CA, Feb. 2006.

60-GHz Single Carrier Baseband (1)



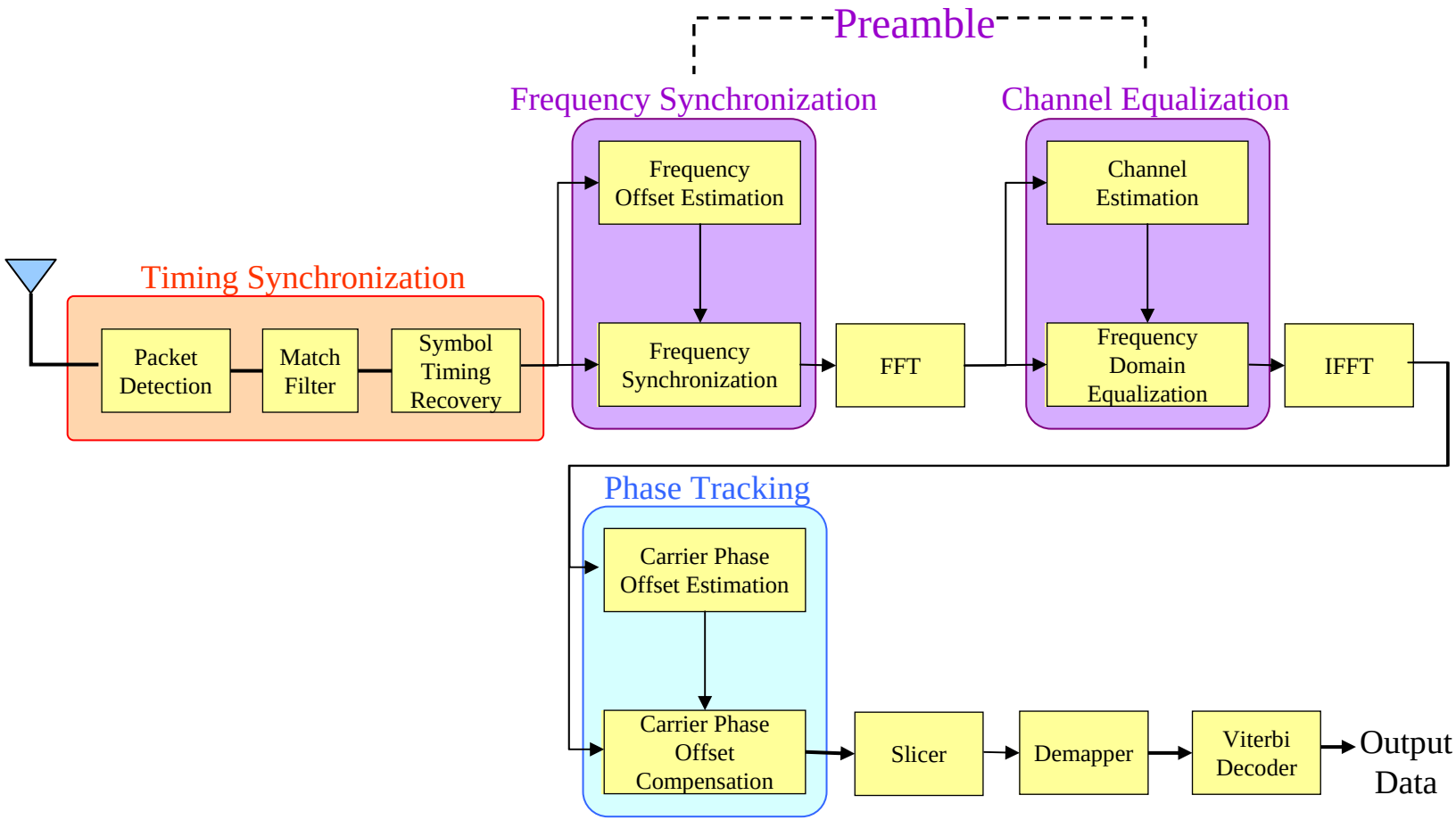
Diagrammatical description of the SC-FDE system.

60-GHz Single Carrier Baseband (1)



Diagrammatical description of the SC-FDE transmitter

60-GHz Single Carrier Baseband (2)



Diagrammatical description of the SC-FDE receiver

Functionality Description of Single Carrier Transceiver

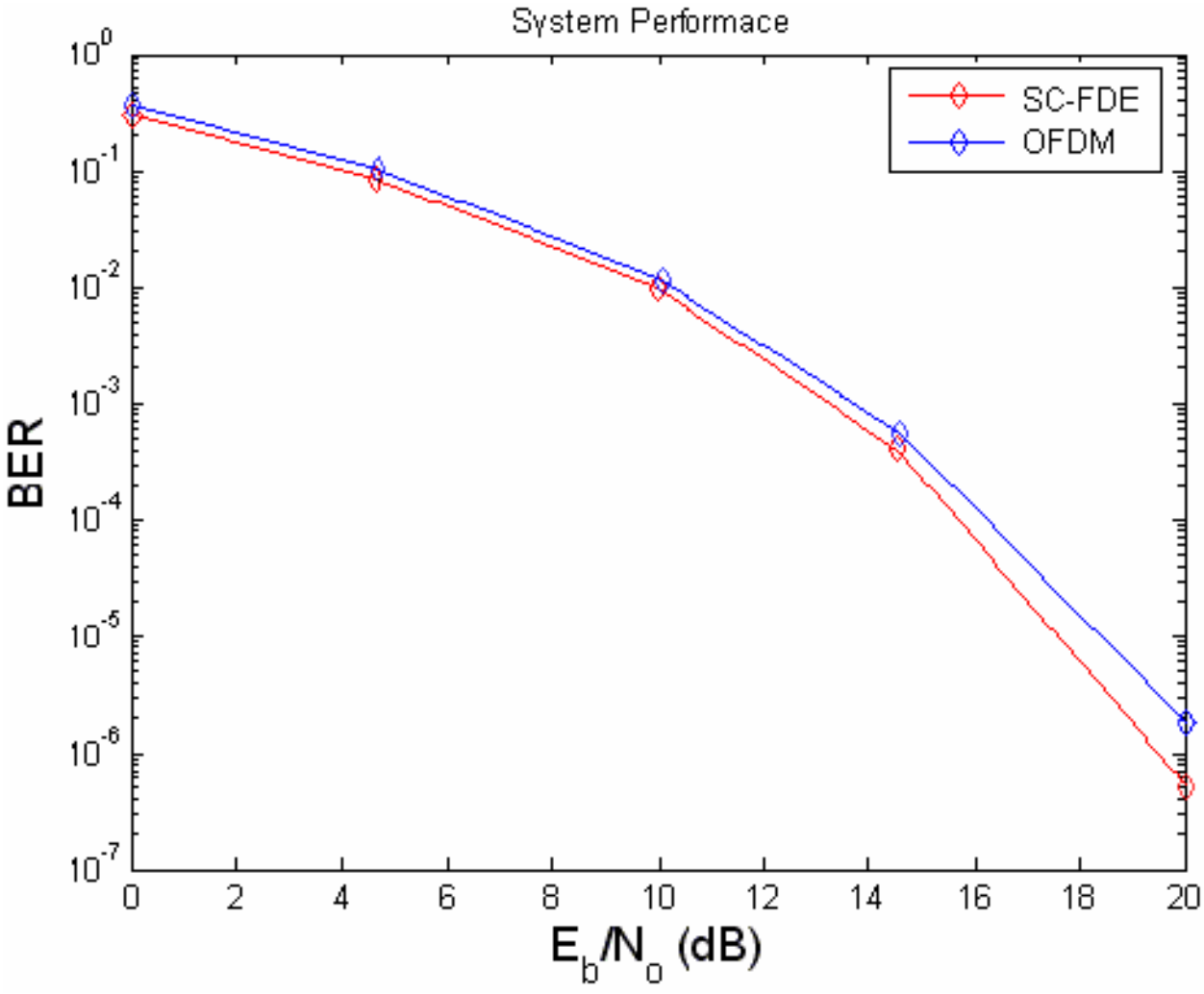
- **Transmitter**
  - **Preamble:** The preamble channels, following the structure used in IEEE 802.11a, is attached in front of the data
  - **Upsample & RRC (Polyphase Interpolator):** Most of the samples in the upsampled signal are zero and thus required no operations in root-raised cosine filter. With the polyphase structure, a factor of *L* (the upsample rate) is saved for computation

- **Receiver**
  - **Symbol Timing Recovery:** To sample message signals at the receiver, a delay-locked loop is used to find the peaks of the output waveforms
  - **Frequency Estimation:** Short preamble is used to correct the frequency offset
  - **Channel Estimation:** Long preamble is used to perform channel estimation in the frequency domain
  - **Phase Estimation:** To correct the frequency offset that varyies during the reception of the packet

Parameters of Single Carrier Transceiver

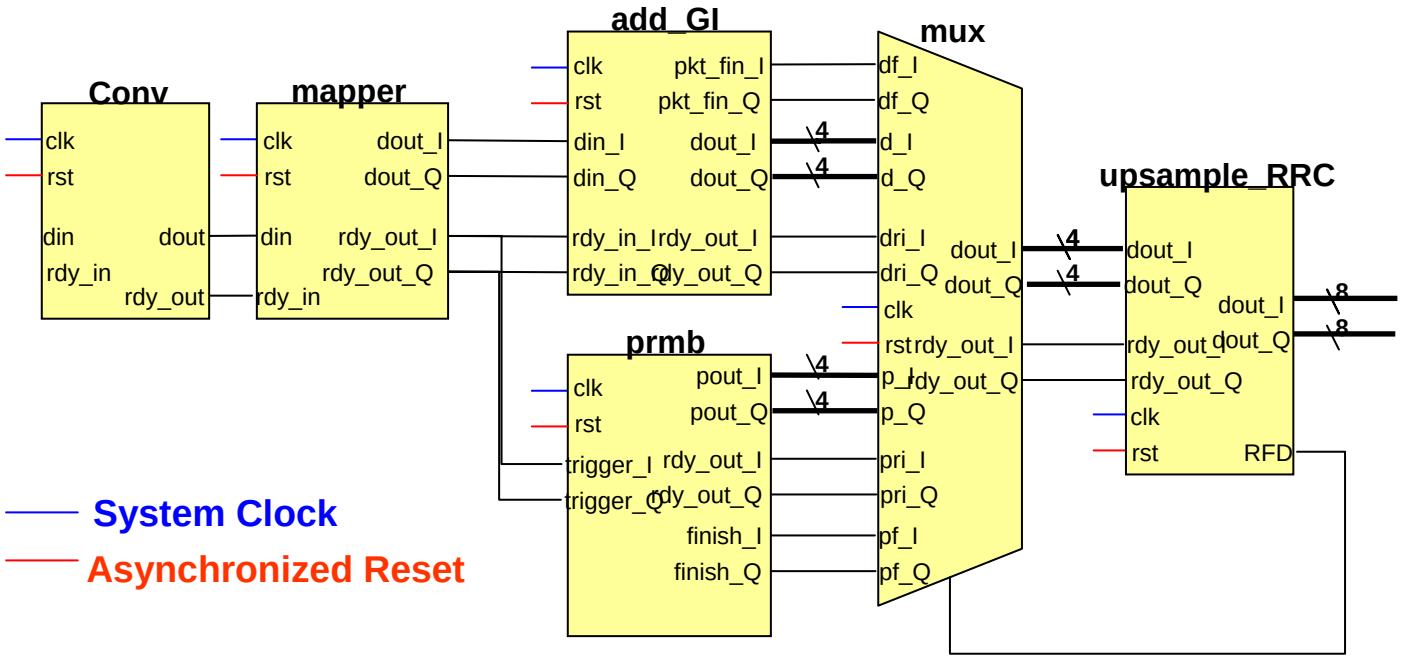
Number of frames/packet	6
Number of total symbols/frame	64
Number of data symbols/frame (N_S)	48
Number of Guard Interval symbols/frame (N_G)	16
FFT Size	64
Long Preamble Size (symbols)	64+16 (CP)
Short Preamble Size (symbols)	16
Modulation Schemes	QPSK
Coding Rates	1/3
Pulse Shaping	RRC (α=0.25)

Performance of Single Carrier Receiver



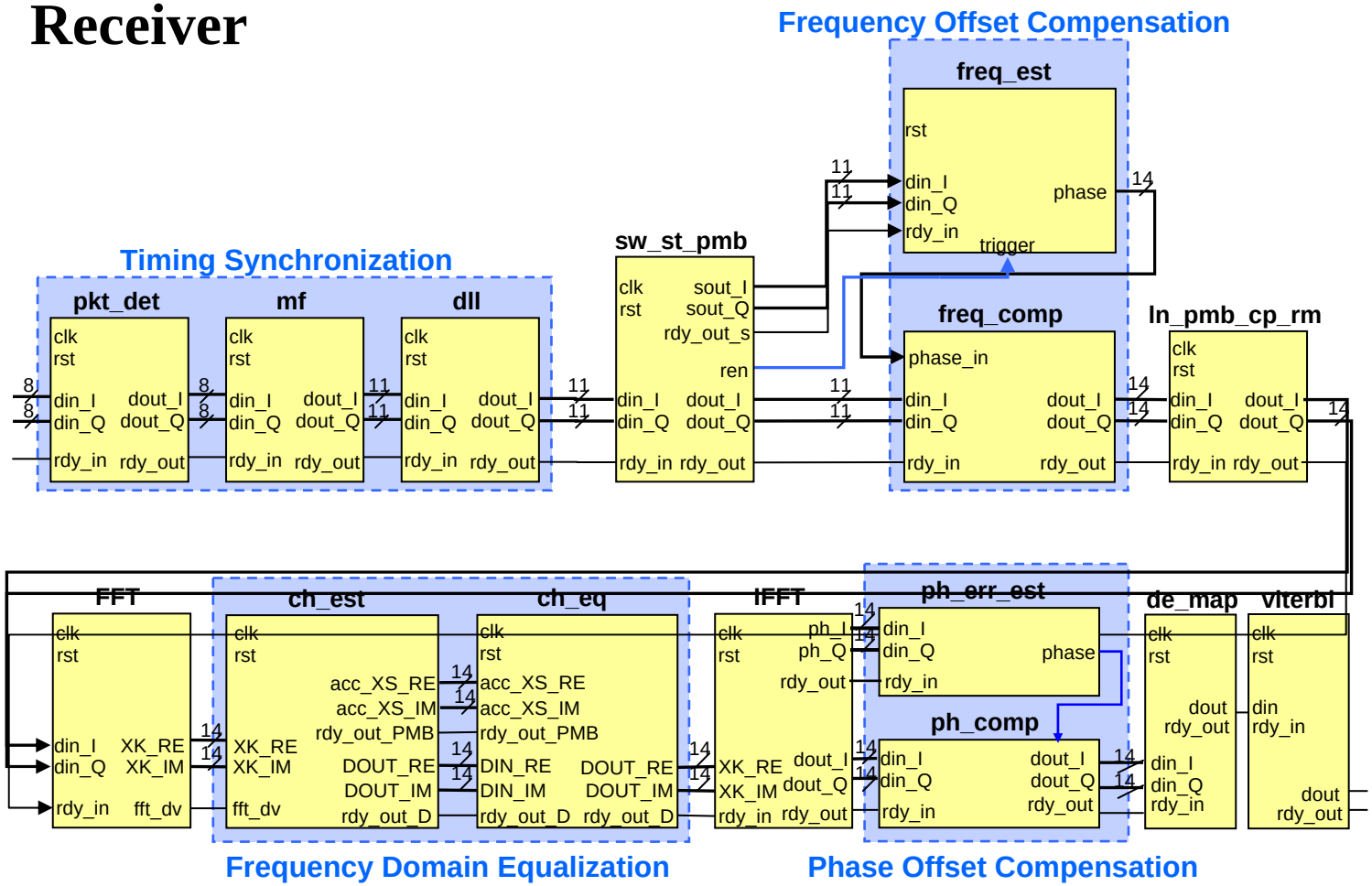
60-GHz Single Carrier Baseband HW Architecture (1)

- **Transmitter**



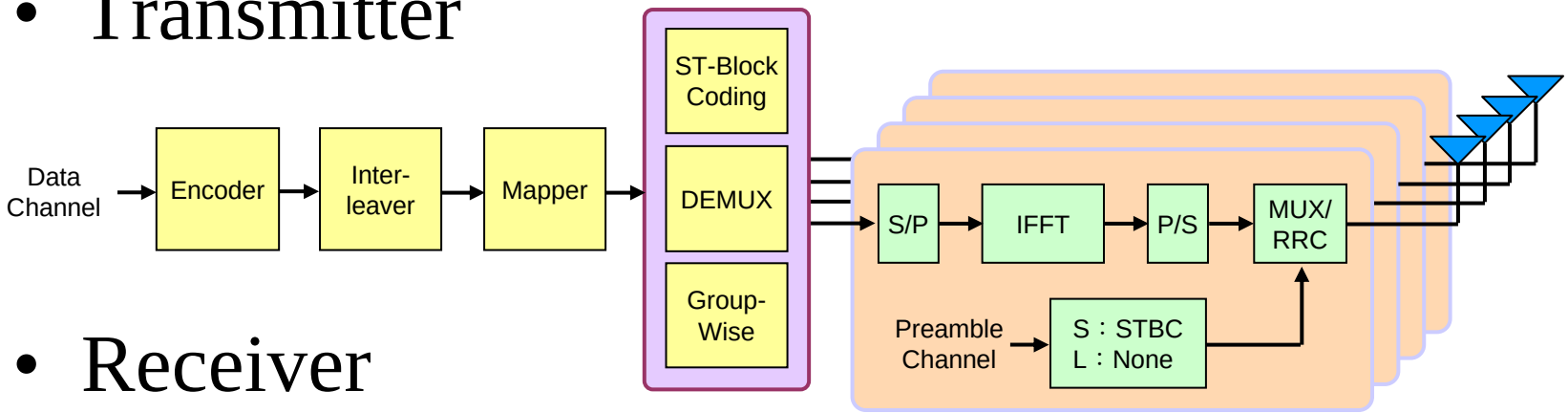
60-GHz Single Carrier Baseband HW Architecture (2)

- **Receiver**

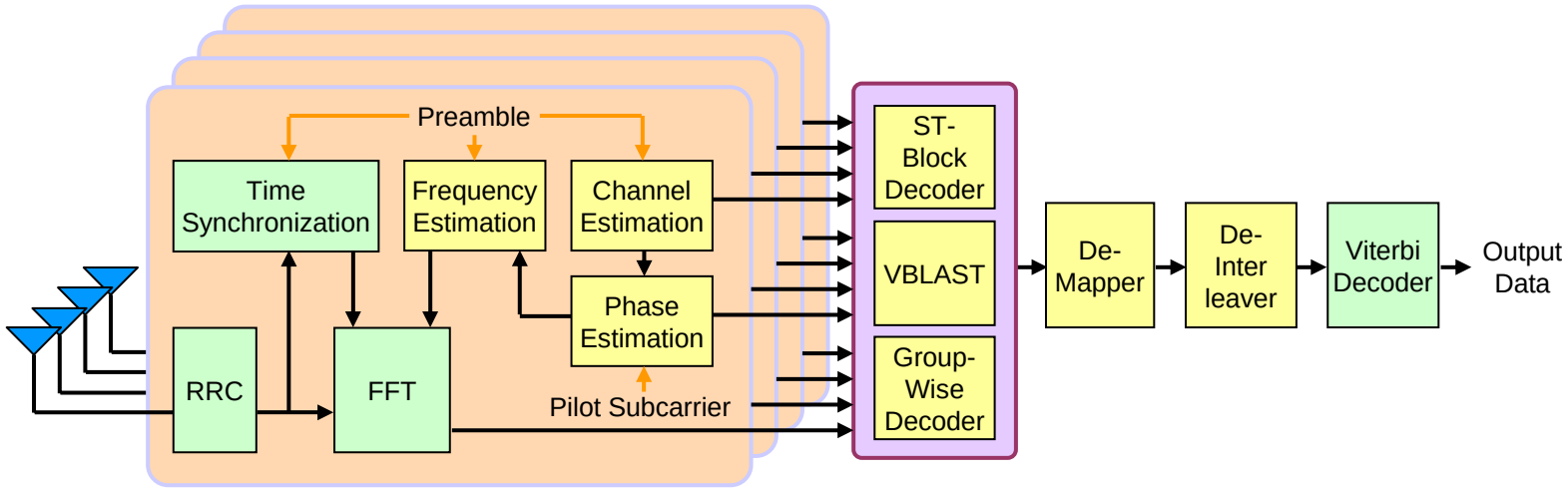


5 GHz MIMO-OFDM Transceiver Architecture

- Transmitter



- Receiver



Functionality Description of MIMO-OFDM Transceiver (1)

- **Transmitter**
  - **Channel Encoder** : Using the convolution code for error correction
  - **Interleaver** : The transmitted information is better resistant to the channel distortion by distributing the same coded bits into different positions in the packet
  - A MIMO system is typically designed to meet two different, yet opposite, targets:
    - High spectral efficiency (**Spatial Multiplexing)** : **VBLAST**
    - Reliable transmission (**Spatial Diversity)** : **Space-time block codes (STBC)**
  - **Preamble** : The preamble channels, coded by the rule of STBC, will be attached in front of the data channel modulated by IFFT

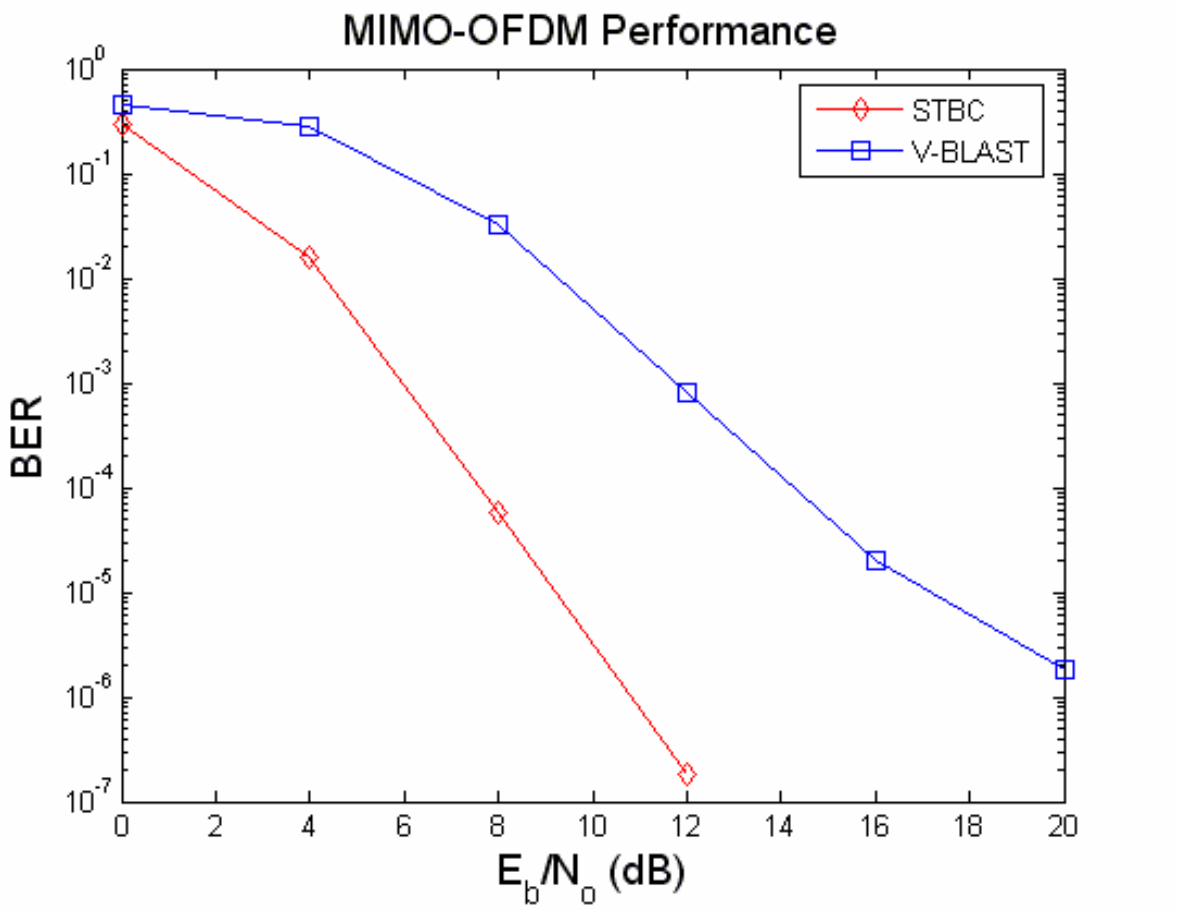
Functionality Description of MIMO-OFDM Transceiver (2)

- **Receiver**
  - **Time Synchronization** : To find out where the symbol boundaries are and what the optimal timing instants are to minimize the effects of inter-symbol-interference (ISI) and inter-carrier-interference (ICI)
  - **Frequency Estimation** : To correct the frequency offset, which is caused by the difference of oscillator frequencies at the transmitter and the receiver
  - **Channel Estimation** : Owing to the same symbol structure as data symbols, long preamble becomes the best candidate for performing this job
  - **Phase Estimation** : To correct the frequency offset that varyies during the reception of the packet
  - **Space-Time Block Decoder** : Decode the data with diversity gain
  - **VBLAST Decoder** : Decode the data with multiplexing gain

Parameters of MIMO-OFDM Transceiver

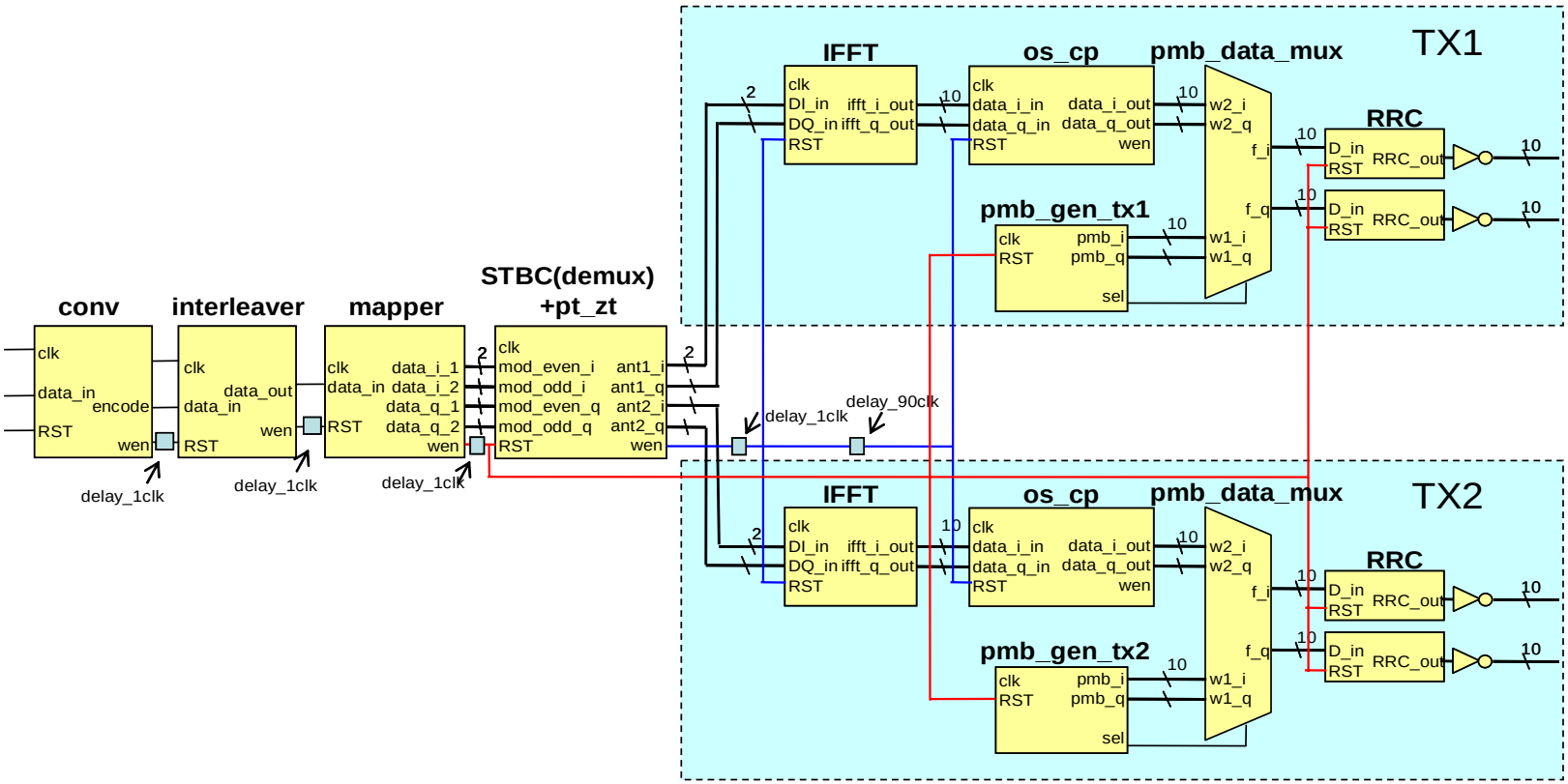
Number of Transmit Antennas	2
Number of Receive Antennas	2
Number of Long Preambles / Packet	2
Number of Short Preambles / Packet	10
Number of OFDM Symbols / Packet	6
Number of Data Tones / Symbol	48
Number of Zero Tones / Symbol	12
Number of Pilot Tones / Symbol	4
FFT Size	64 {-32:31}
Long Preamble Size	64+16 (CP)
Short Preamble Size	16
Locations of Data Tones	{-26:-22, -20:-8, -6:-1,1:6, 8:20, 22:26}
Locations of Zero Tones	{-32:-27, 0, 27:31}
Locations of Pilot Tones	{-21, -7, 7, 21}

Performance of MIMO-OFDM Receiver



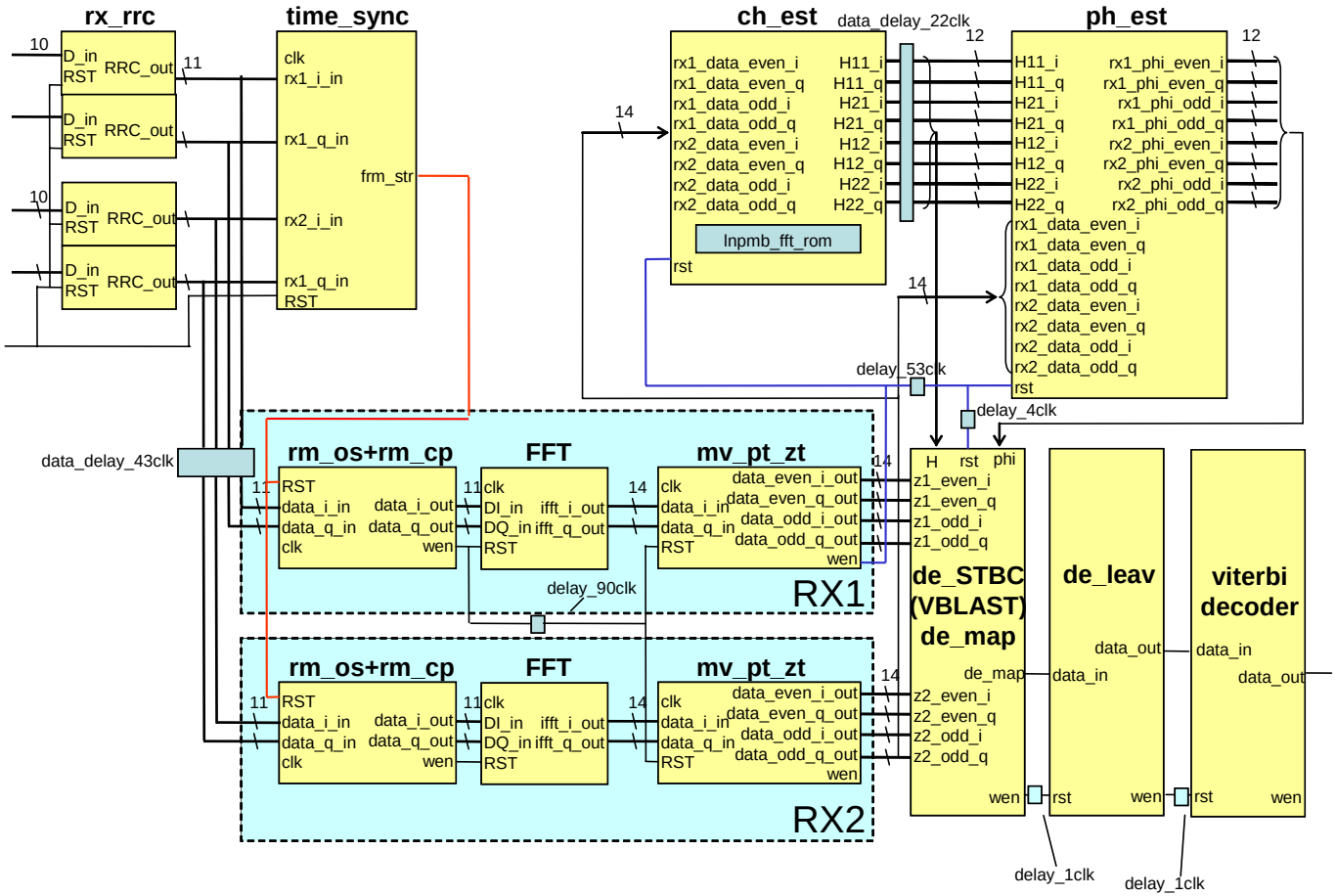
5-GHz MIMO-OFDM Baseband HW Architecture (1)

- **Transmitter**



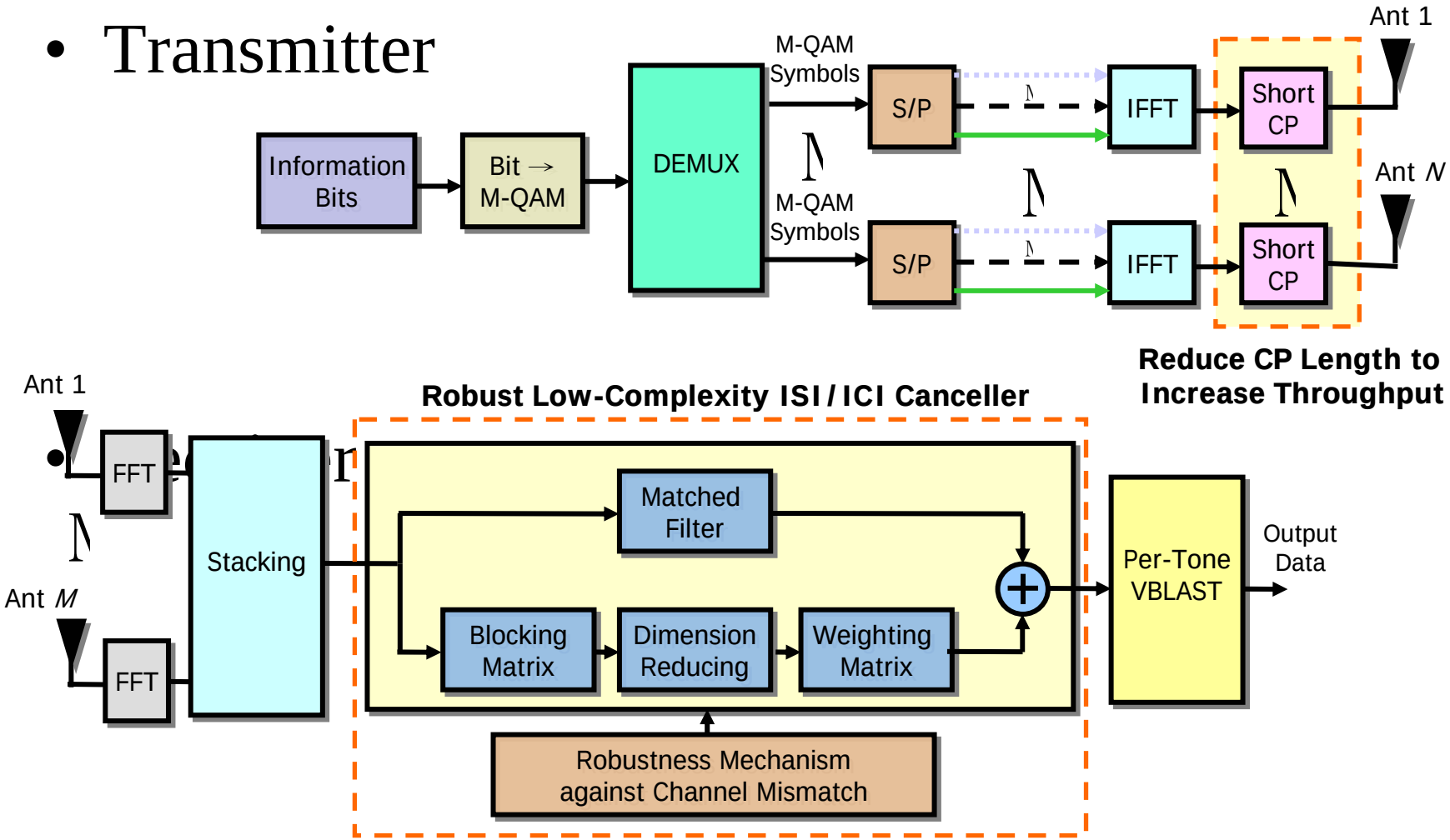
5-GHz MIMO-OFDM Baseband HW Architecture (2)

- **Receiver**



High Throughput MIMO-OFDM Technique

- Transmitter

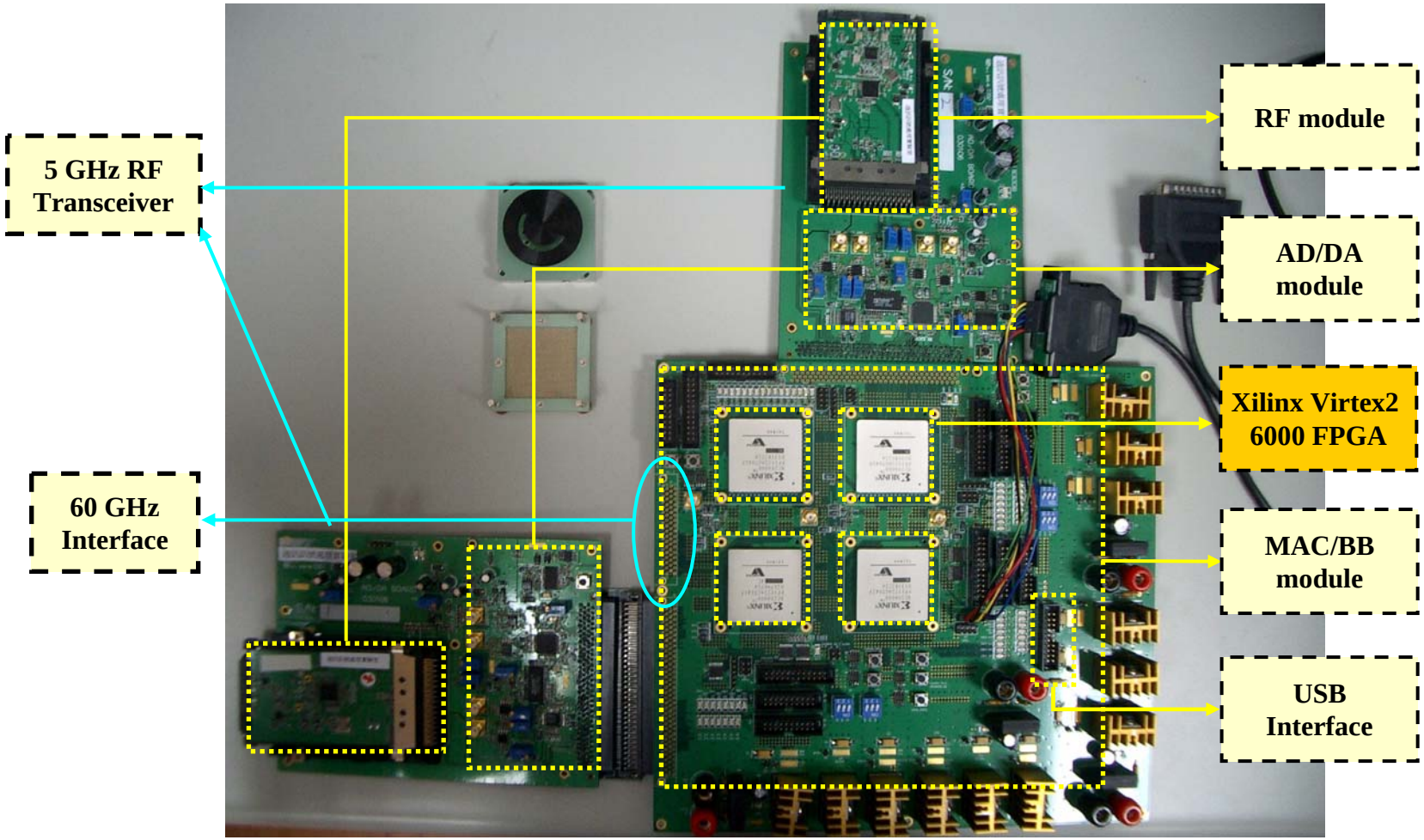


Functionality Description of High Throughput MIMO-OFDM

- The transmitter is performed in a similar way as it is in MIMO-OFDM system, except that the CP length is shortened to increase throughput
- Therefore, ISI and ICI are enhanced such that interference cancellation mechanism is required
- Robust Low-Complexity ISI/ICI Canceller
  - **Matched Filter**: To match the received signal
  - **Blocking Matrix**: To separate the interference part from the received signal
  - **Dimension Reducing & Weighting Matrix**: An adaptive estimation of the combination of ISI and ICI
  - **Robust Mechanism against Channel Mismatch**: A mechanism that guarantees the performance of interference cancellation when channel mismatch is present

Complete Hardware Platform

- Baseband transceiver consists of four FPGAs



Description of HW Platform (1)

- **Modules at the platform**
  - **RF Module (MAX 2828)**
    - Specifically designed for single-band IEEE 802.11a applications covering world-band frequencies of 4.9 GHz to 5.875 GHz
  - **AD/DA Module (ADS2807and DAC2900)**
    - ADS2807 is an analog to digital converter which provides a high bandwidth track-and-hold and gives excellent spurious performance up to and beyond the Nyquist rate.
    - DAC2900 is a digital to analog converter which offers exceptional dynamic performance, and enables to generate very-high output frequencies suitable for “Direct IF” applications

Description of HW Platform (2)

- **MAC/BB module (FPGA-based)**
  - Composed of four Xilinx Virtex-II 6000 modules, giving significant improvement in processing speed, size, weight, power, and costs compared to DSP solutions
  - Both 5 GHz MIMO-OFDM and 60 GHz SC baseband transceivers are implemented on this module
- **USB Interface module**
  - USB interface was designed into the platform to provide a convenient input for audio/video signals

Summary

- Presented the 60/5 Dual-Mode Broadband and Wireless Network (DMBWN) as a backward compatible system
- Future works will be devoted to realize the 60 GHz transceiver, and switched beamforming smart antenna, which can be integrated with the developed 5 GHz system.
- Academically, we will continuously make efforts to develop advanced signal processing algorithms, such as cross-layer signaling, channel estimation and interference cancellation methods, for the proposed dual-band WLAN system.

Next Step Towards Down Selection

- **A Formal Joint Submission would be made in July Meeting in San Francisco**
- **National Taiwan University/ TEEMA (Taiwan Electrical & Electronic Manufacturers' Association) has agreed to create a joint submission with COMPA**

Thank you!