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MATLAB LTE SYSTEM TOOLBOX For Development of LTE Physical Layer

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Outline

- Problem Statement: The Requirement
  - Challenges in LTE PHY Development
  - WHY MATLAB LTE System Toolbox?
- LTE Physical Layer Development in 3 stages
  - Stage 1
  - Stage 2
  - Stage 3
- Development Setup
- Results
- Conclusion

PROBLEM STATEMENT

Introduction

3GPP

LTE

- Higher Data Rate
- Lower Latency
- Higher Spectral Efficiency
- Higher Capacity



LTE DEVELOPMENT

- The requirement was to develop and prototype LTE Physical Layer for:
  - Concept proving
  - Capturing system requirement

CHALLENGES IN DEVELOPING PHY LAYER



- Challenge #1: Reading and understanding the specs

- Challenge #2: Creating an executable spec to investigate system performance and act as a golden test-bench

- Challenge #3: Evaluate algorithms which will meet performance requirements

- Challenge #4: Converting the Design for Dedicated Hardware

- Challenge #1: Reading and understanding the specs
- Challenge #2: Creating an executable spec to investigate system performance and act as a golden test-bench
- Challenge #3: Evaluate algorithms which will meet performance requirements
- Challenge #4: Converting the Design for Dedicated Hardware

- Two Approaches of Development:
  - Study, understand vast 3GPP standard and then carry out development
(MATLAB/other software)
  - Use LTE system Toolbox of MATLAB for hand in hand understanding and development of LTE physical layer

WHY ???
"MATLAB LTE SYSTEM TOOLBOX"

- **Standard-compliant functions** for the design, simulation, and verification
- **Accelerates** LTE algorithm and physical layer (PHY) development
- Supports **golden reference verification**
- **Conformance testing**
- Enables **test waveform generation**
- Analyze **end-to-end communication** links
- Implementation **comply** with the LTE standard

LTE PHYSICAL LAYER DEVELOPMENT

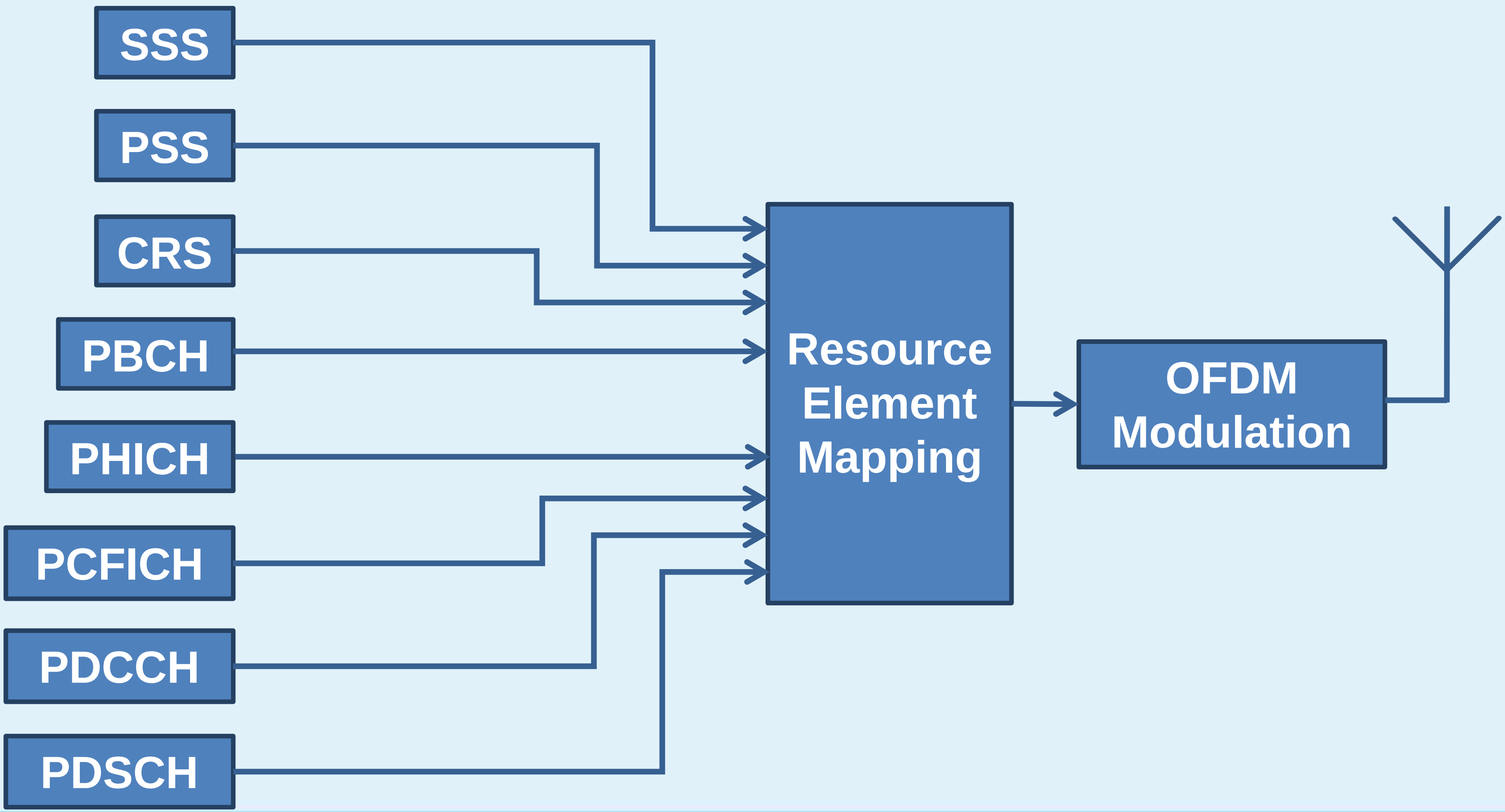
3 Stage Development of LTE Physical Layer using LTE System Toolbox

- Stage 1: Development of Physical layer using high level functions

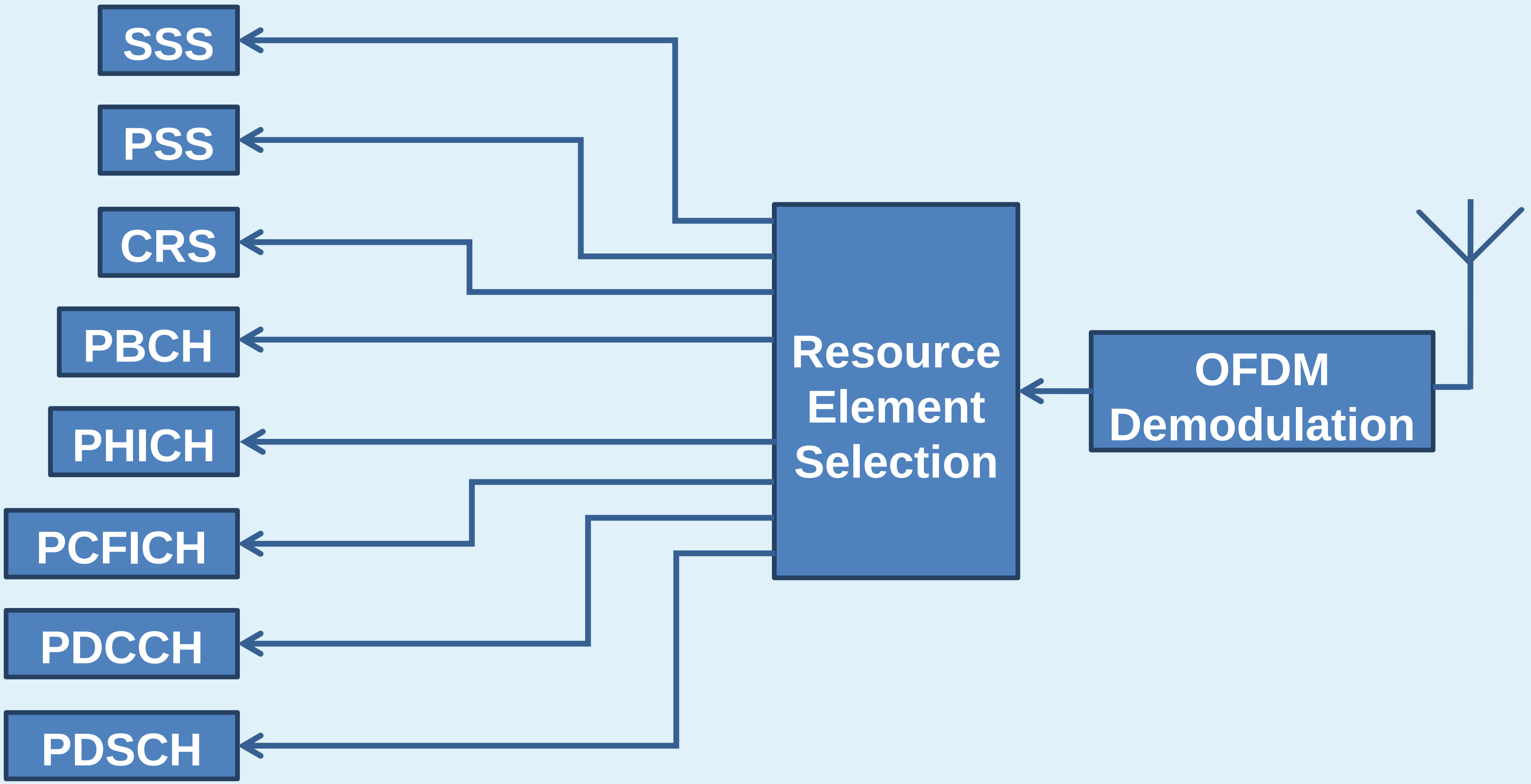
- Stage 2: Development of Physical layer using mid level functions

- Stage 3: Development of Physical layer using low level functions

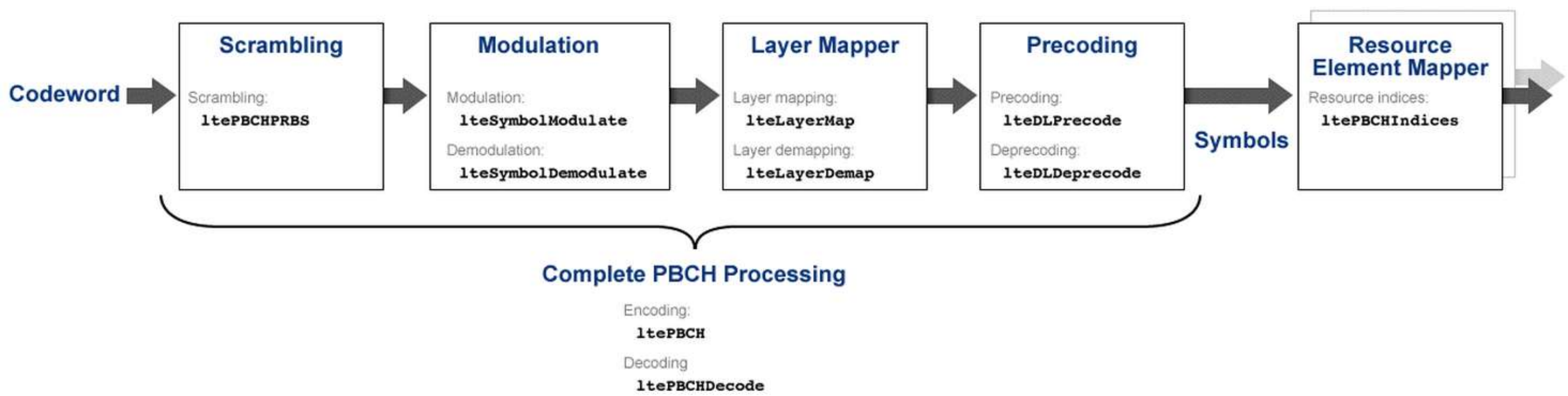
Stage 1: DL Transmitter Development



Stage 1: DL Receiver Development



Stage 2: Individual Channel and Signal Development (one example)



Stage 3: Low level function development (Scrambling)

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

$$c(n) = \left(x_1(n + N_C) + x_2(n + N_C)\right) \bmod 2$$
$$x_1(n + 31) = \left(x_1(n + 3) + x_1(n)\right) \bmod 2$$
$$x_2(n + 31) = \left(x_2(n + 3) + x_2(n + 2) + x_2(n + 1) + x_2(n)\right) \bmod 2$$

$$N_C = 1600$$

$$c_{\text{init}} = N_{\text{ID}}^{\text{cell}}$$

$$x_1(0) = 1,$$

$$x_1(n) = 0, n = 1, 2, \ldots, 30$$

$$c_{\text{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$$

Physical Layer Processing (DL)

UE Receive Chain

- PDSCH, DLSCH Decoding
- ↑ PBCH, PHICH, PCFICH & PDCCH Decoding
- ↑ ZF Equalization
- ↑ Channel Estimation
- ↑ OFDM Demodulation
- ↑ Frequency Offset Estimation & Correction
- ↑ IQ Offset Correction
- ↑ Cell Search & Synchronization
- ↑ Data Received From USRP Device

eNodeB Transmit Chain

- Data from MAC Layer
- ↓ Generation of PSS,SSS & CRS
- ↓ PBCH, PHICH, PCFICH & PDCCH Encoding
- ↓ DLSCH & PDSCH Encoding
- ↓ OFDM Modulation
- ↓ Data Transmission By USRP Device

Physical Layer Processing (UL)

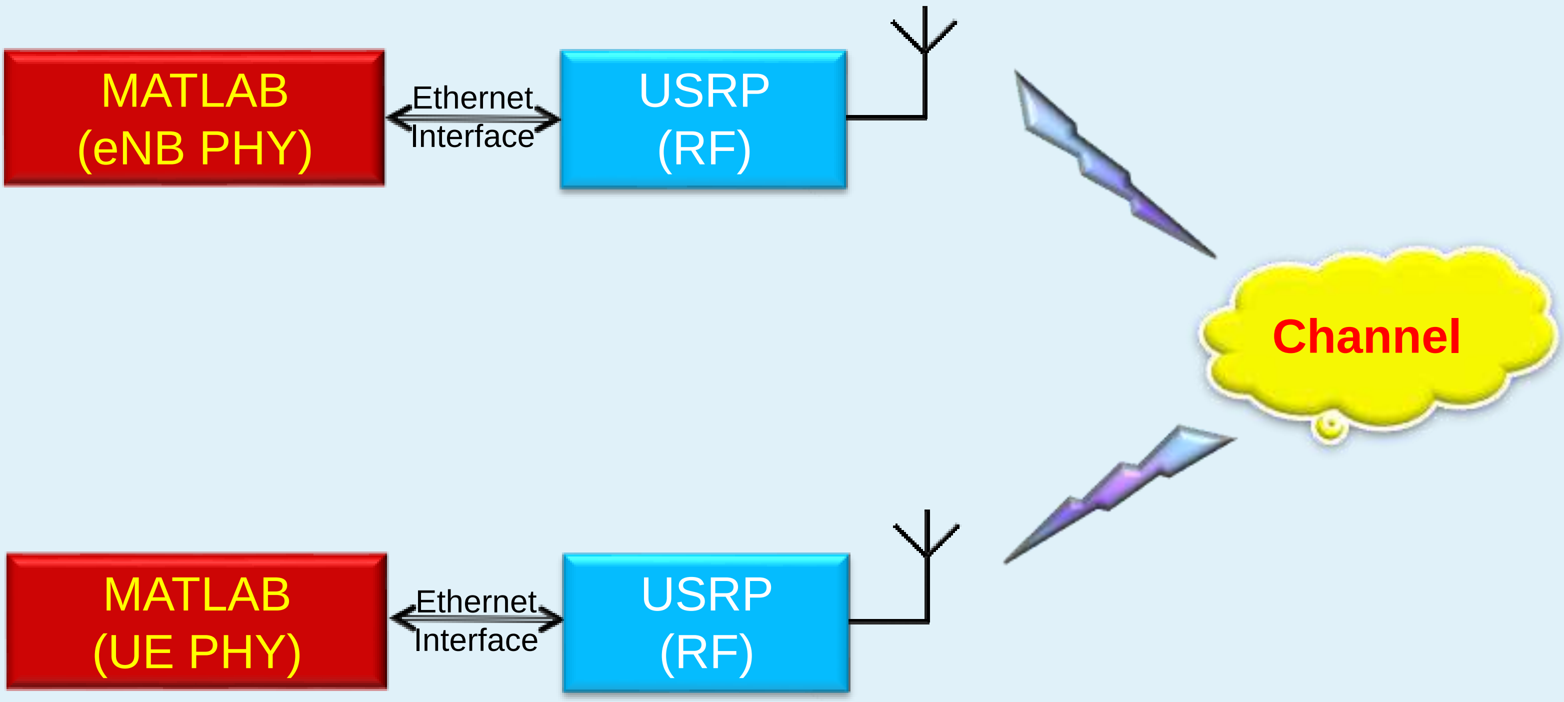
UE Transmit Chain

1. Data from MAC Layer
2. PUSCH DRS / PUCCH DRS Encoding
3. SRS Encoding
4. ULSCH, PDSCH / PUCCH Encoding
5. SC-FDMA Modulation
6. Data Transmission By USRP Device

eNodeB Receive Chain

1. Data Received From USRP Device
2. Frame Synchronization
3. IQ Offset Correction
4. Frequency Offset Estimation & Correction
5. SC-FDMA Demodulation
6. Channel Estimation
7. ZF Equalization
8. PUSCH, ULSCH / PUCCH Decoding

DEVELOPMENT SET UP



End-to-End Development Setup

RESULTS

Results from Setup

- **Cell search procedure completed successfully**
- **Broadcast message decoded in downlink**
- **Control information and data decoded**

```
>> DL_PBCH
>> DL_PBCH_decoding

Performing cell search...
Cell-wide settings after cell search:
      DuplexMode: 'FDD'
    CyclicPrefix: 'Normal'
           NDLRB: 6
         NCellID: 150
       NSubframe: 0


Cell-wide settings after MIB decoding:
      DuplexMode: 'FDD'
    CyclicPrefix: 'Normal'
           NDLRB: 50
         NCellID: 150
       NSubframe: 0
        CellRefP: 1
    PHICHDuration: 'Normal'
              Ng: 'One'
          NFrame: 24
```

```
Displaying DCI Information...
         DCIFormat: 'Format1'
               CIF: 0
    AllocationType: 0
        Allocation: [1x1 struct]
         ModCoding: 0
            HARQNo: 0
           NewData: 1
                RV: 0
          TPCPUCCH: 0
          TDDIndex: 0

PDSCH settings after DCI decoding:
            RNTI: 1
          PRBSet: [50x1 uint64]
         NLayers: 1
              RV: 0
      Modulation: {'QPSK'}
    NTurboDecIts: 5
        TxScheme: 'Port0'


ans2 =

     1

PDSCH decoded Sucessfully
>>
```

CONCLUSION



Conclusion

- **Top down approach** enabled the quick development of physical layer based eNodeB and UE reducing the time to prototype.

- The Communications System Toolbox Support Package for USRP Radio enabled to test the system over air without the need of converting the code for actual hardware


THANK
YOU