Low Cost 5G Test Bed for the Futuristic 6G Research

Dr. Amit Kumar Dutta, Assistant Professor
G. S. Sanyal School of Telecommunications,
Indian Institute of Technology, Kharagpur
Agenda

- Introduction
- Overview of 5G Testbed System
- Challenges and Approach to implement 5G Testbed System
- MATLAB Simulation Results and Analysis
- Future scope of Work
- Summary and Conclusion
IIT Kharagpur

- Indian Institute of Technology, Kharagpur is the first IIT established in India in May 1950 by an act of Indian Parliament.
- This is one of the most premier educational institute of science and technology in India and the world.
- Currently, it houses more than 40 Departments, Schools, Centers and offers B.Tech, M.Tech, M.S, PhD degrees.
- With more than 750 faculties and 15,000 students at present in a sprawling green campus on ~2200 acres of land, this is also one of most prestigious institute of research in the world.
Overview of 5G Testbed System

- This is an end-to-end 5G cellular standard testbed development project on FPGA platforms compliant to 3GPP Rel-16.
- Contains one base station (gNB) and one user equipment (UE) with complete RF support in sub-6Ghz range.
- It contains PHY with 6G research.
- A low-cost testbed with single antenna at Phase I and MIMO in Phase-II
- Funded through IIT Kharagpur by Govt. of India under ISIRD scheme and SERB.
- The modem is being co-developed as part of an IIT KGP incubated Start-up “VORAI SEMICONDUCTOR Pvt. Ltd.”
Details of Transceiver Requirement

Over-the-air Channel
### Challenges

| Change in technology requires change on methodology | • Requires a flexible development environment  
• Change in architecture involves reprogramming |
| Programming and Verification Expertise | • Proficiency in HDL programming  
• Dedicated team to write verification Test benches  
• Late detection of errors |
| Reuse the IP | • Can I create reusable IPs for other projects? |
| Verification of the Design | • How to do functional verification with Hardware? |
| Fast Prototype | • Can I create a working prototype with small team? |
## Proposed Approach

<table>
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<tr>
<th>Change in technology requires change on methodology</th>
<th>• Use 5G toolbox for standard compliant waveform generation &amp; PHY Layer signal chains</th>
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<tr>
<td>Programming and Verification Expertise</td>
<td>• Autogenerate synthesizable VHDL code and testbench for verification using HDL Coder and HDL Verifier</td>
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| Reuse the IP                                        | • Leverage existing HDL IP in Wireless HDL Toolbox  
|                                                     | • Customize IPs for further reuse                                                     |
| Verification of the Design                          | • Validating the subsystems at system level  
|                                                     | • Over the air testing with Qorvo RF frontend.  
|                                                     | • RTL Co-simulation and FPGA in the loop verification                                 |
| Fast Prototype                                      | • Rapid prototyping & hardware deployment                                             |
Algorithm Development
- MATLAB reference design
- Visualization

Design Elaboration
- Simulink modeling
- Hardware streaming
- Data type conversion

Prototype
- Deployment to development board
- Design optimization

Production
- Deployment to custom hardware
- Validation with complete hardware solution

Design & Verification Approach
MATLAB Demo: Block Level Simulation with Simulink
Logic Analyzer (IFFT with Test bench)
End-to-End System validation

The overall system validation diagram

- Test Bench (MATLAB + 5G Toolbox)
- 5G Tx Chain (SIMULINK)
- Channel Model (MATLAB)
- 5G Rx Chain (SIMULINK)
- Comparison (MATLAB)
MATLAB Demo

```matlab
% This is the TOP TB
% Amit Dutta
% Date : 25-2-2021

% Parameters #################################################################################
clear all;

sigma_n = 0.1; % PSD for channel coefficient
SNR = (0:2:20); % SNR in dB

plot_control = 4;

Data_length = 5000; % # of ADC samples
Fs = 44100;%e+6; % Sampling frequency at the ADC
Fc = 0.2; % Normalized frequency Fc in Hz = Fc*Fs/2;

ADC_len = 16; % This is the ADC length
Resolution = 10000;

pilot_bin_len = 200000; % length of pilot data in binary form
pilot_interval = 10;

% Define the general CDL/TDL propagation channel parameters
simParameters.DelayProfile = 'CDL-C'; % Use CDL-C model (Urban macrocell model)
simParameters.DelaySpread = 300e-9;
simParameters.MaximumDopplerShift = 5;

% Cross-check the PDSCH layering against the channel geometry

>> Top_TX_RX
>> Top_Tx_Rx
>>
```
Wireless HDL Toolbox - Hardware Optimized HDL IPs

- FFT
- IFFT
- Memory
- Symbol Mapper/Demapper
- Polar Encoder/Decoder
- LDPC Encoder/Decoder
- CRC blocks
Achieved Results with 5G Tx-Rx Chain

Tx Spectrum

Rx Spectrum

BER generated curve
RTL and Synthesis Results - Component Level
Future Scope of Work (6G components)

✓ Apart from the standard 3GPP Rel-16 components, we also plan to add few futuristic modules planned for 6G.

✓ **THz beamforming:** There will be a special module for pencil beamforming targeted for THz signal.

✓ **New waveform:** There will a waveform module based on the Filter bank to counter the THz large bandwidth effect.
THz Channel Modeling and Results

Source: THz related current work from Dr. Amit Kumar Dutta, Ankam Madhusree, IIT KGP
Summary and Conclusion

- 5G Toolbox standard compliant built-in functions and Wireless HDL Toolbox hardware optimized IPs helped us in quick validation of 3GPP 5G NR physical layer signal chains.
- Using complete Model-Based Design approach with MATLAB and Simulink helped us to bridge the gap between system engineers and hardware designers.
- The indigenous developed 5G testbed system is scalable and 6G algorithms can be easily plugged into it for testing.
- The Tx-Rx system can be used as any commercial Modem.
- The developed test bed can be used for validating various subsystems by different institutions and startups.
MATLAB EXPO 2021

Thank you