MATLAB EXPO 2021

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

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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

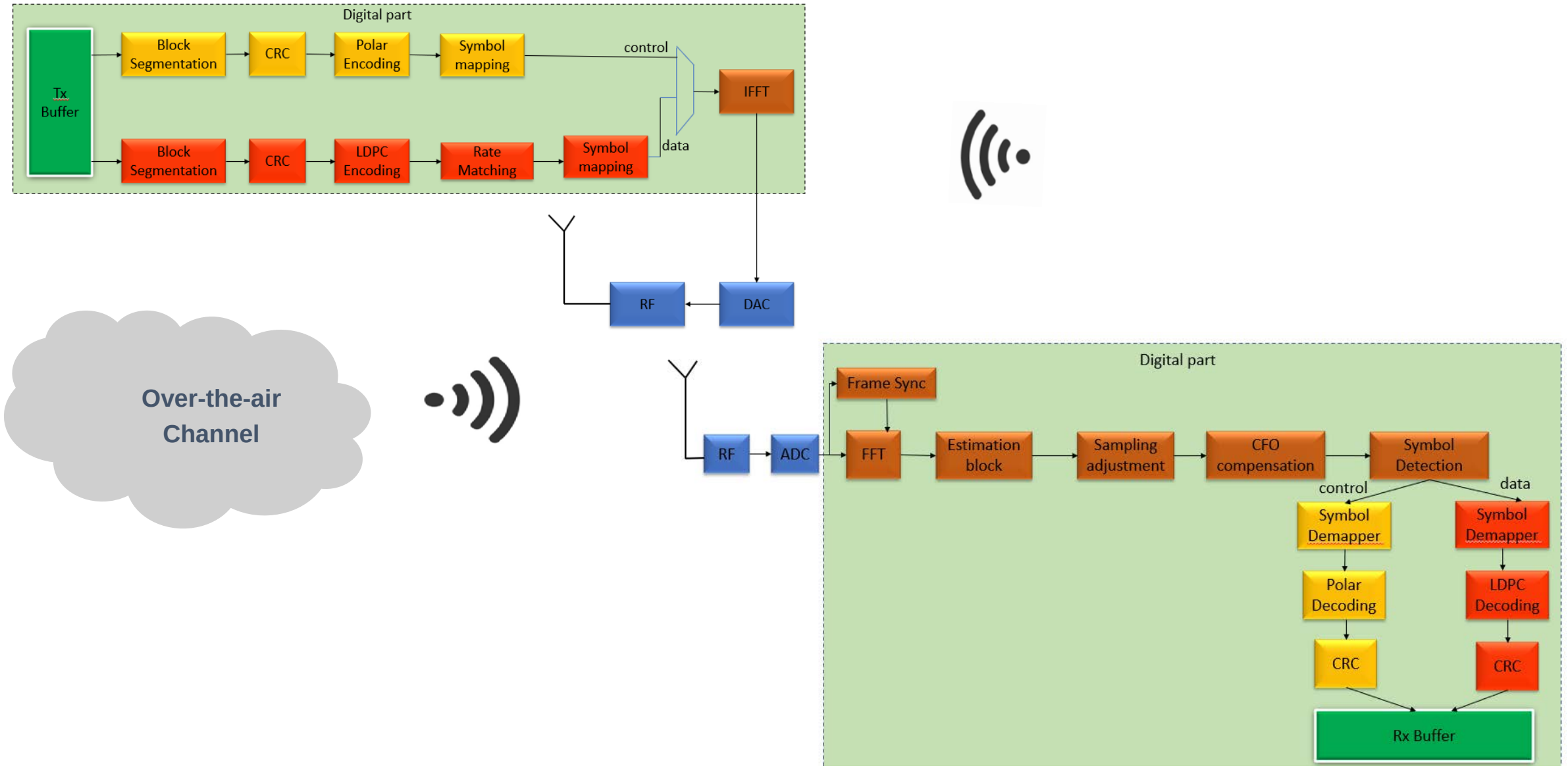
IIT Kharagpur

- Indian Institute of Technology, Kharagpur is the first IIT established in India in May 1950 by an act of Indian Parliament.
- This is the 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



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

Change in technology requires change on methodology	• Use 5G toolbox for standard compliant waveform generation & PHY Layer signal chains
Programming and Verification Expertise	• Autogenerate synthesizable VHDL code and testbench for verification using HDL Coder and HDL Verifier
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

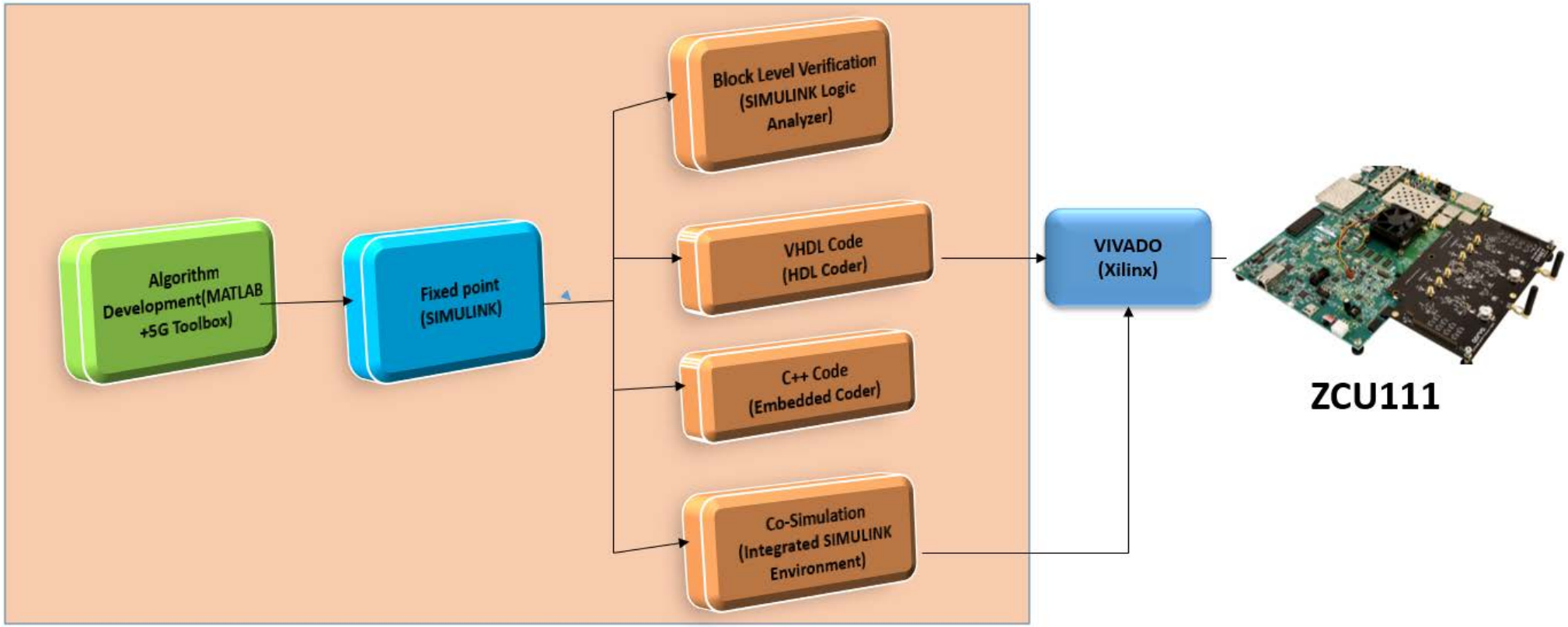
Design & Verification Approach

Algorithm Development
- MATLAB reference design
- Visualization

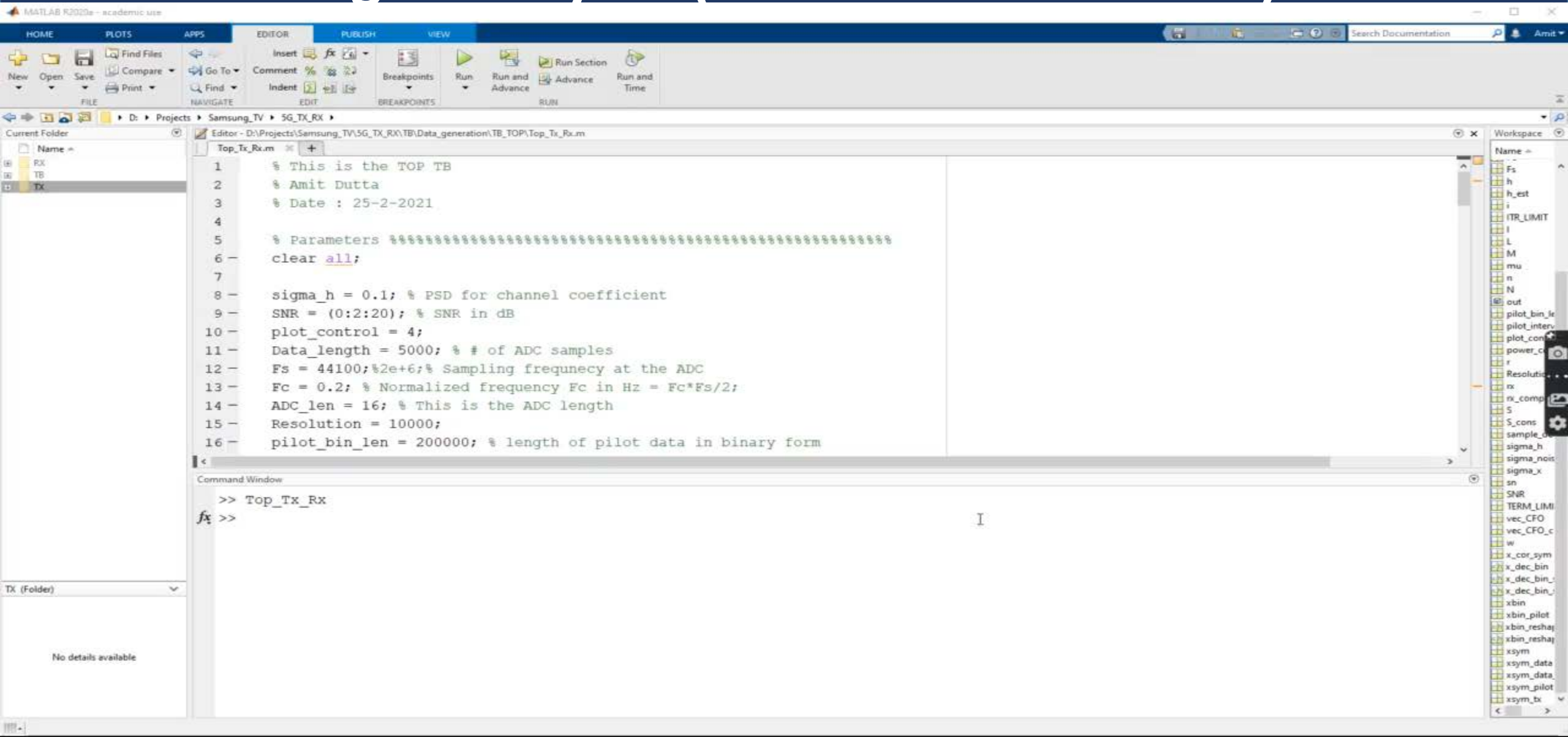
Design Elaboration
- Simulink modeling
- Hardware streaming
- Data type conversion

Prototype
- Deployment to development board
- Design optimization

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

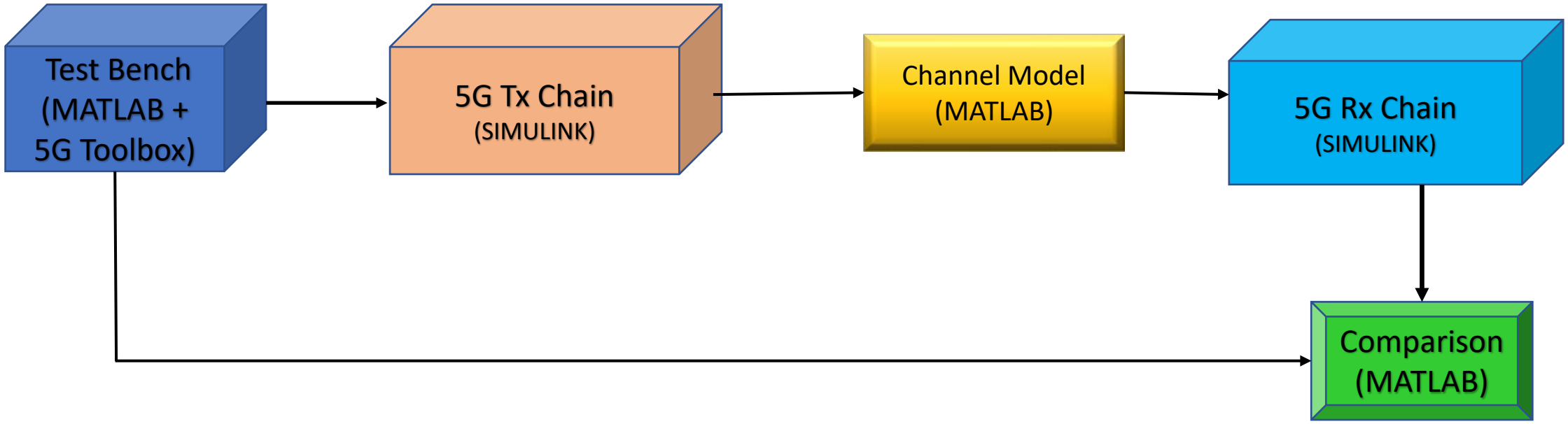


MATLAB Demo: Block Level Simulation with Simulink Logic Analyzer (IFFT with Test bench)

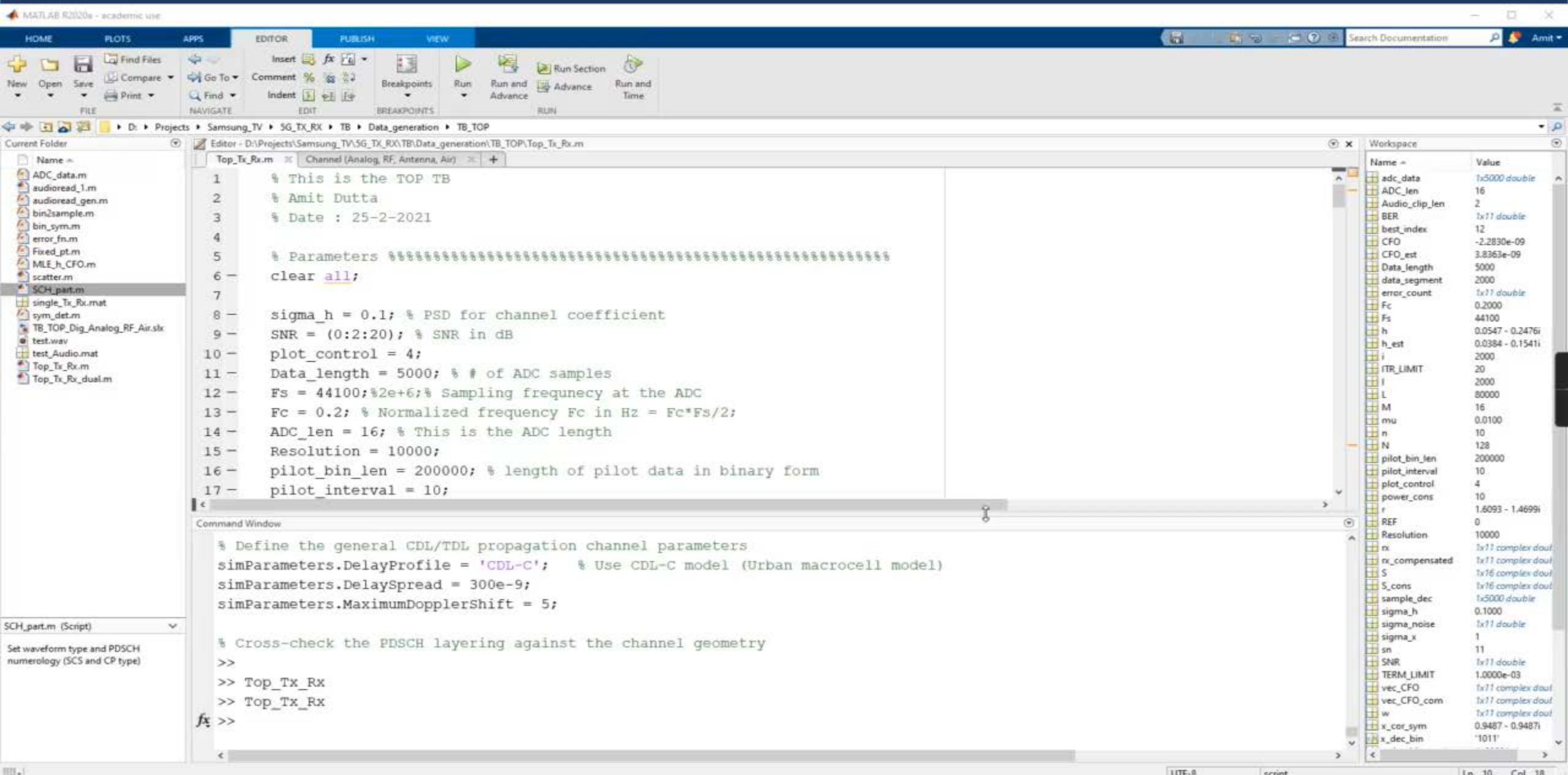


End-to-End System validation

- ✓ **The overall system validation diagram**

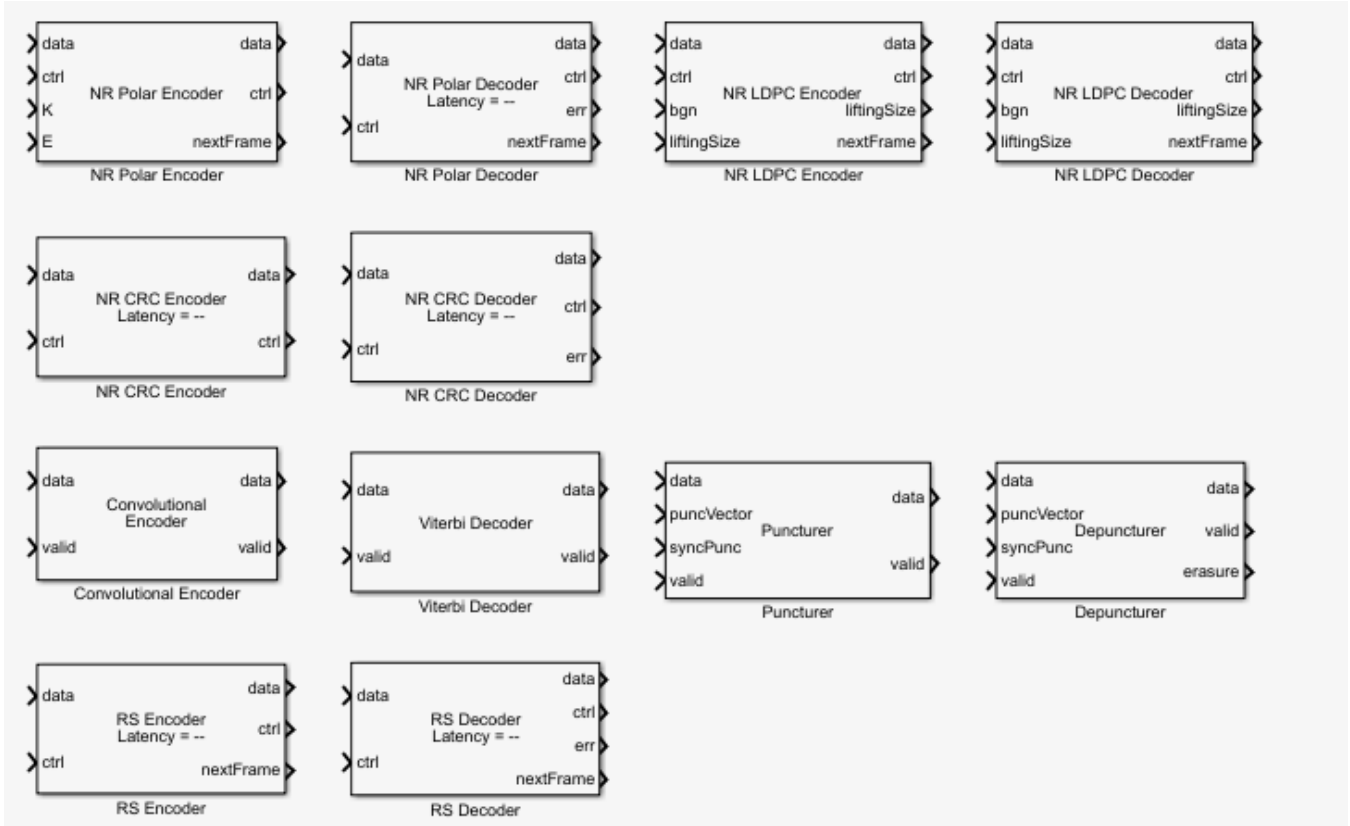


MATLAB Demo


% This is the TOP TB
% Amit Dutta
% Date : 25-2-2021
% Parameters
clear all;
sigma_h = 0.1; % PSD for channel coefficient
SNR = (0:2:20); % SNR in dB
plot_control = 4;
Data_length = 5000; % # of ADC samples
Fs = 44100;%2e+6;% Sampling frequnecy 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
>>
Set waveform type and PDSCH numerology (SCS and CP type)

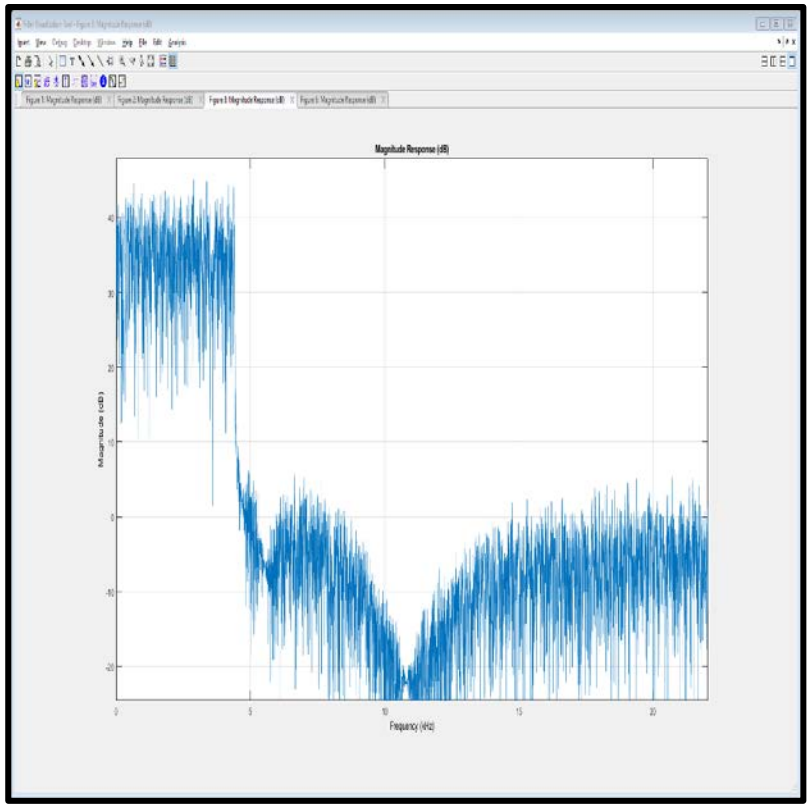
Wireless HDL Toolbox- Hardware Optimized HDL IPs

- FFT
- IFFT
- Memory
- Symbol Mapper/Demapper
- Polar Encoder/Decoder
- LDPC Encoder/Decoder
- CRC blocks

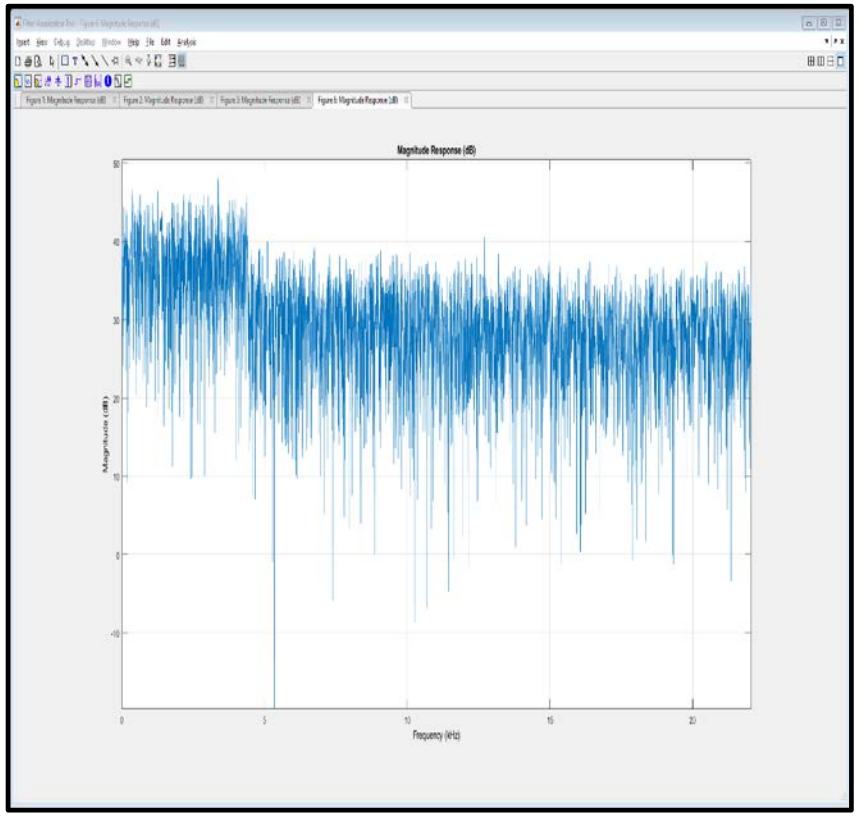


Achieved Results with 5G Tx-Rx Chain

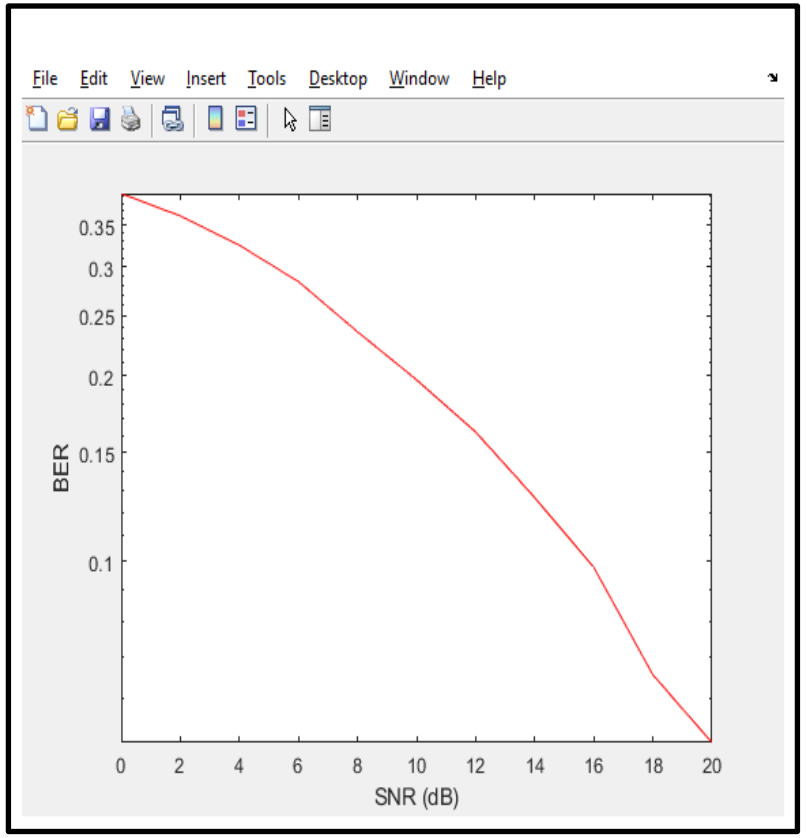
Tx Spectrum



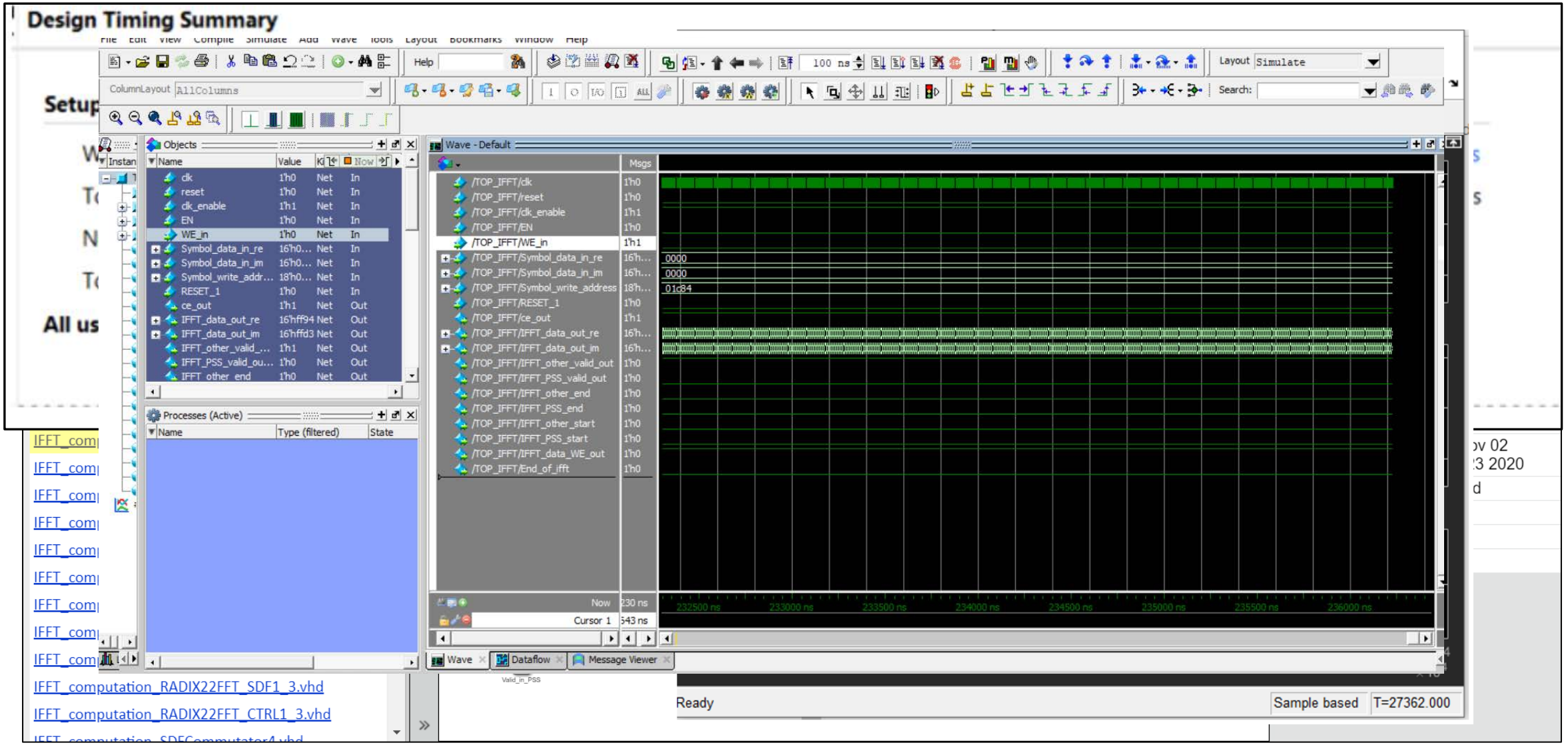
Rx Spectrum



BER generated curve



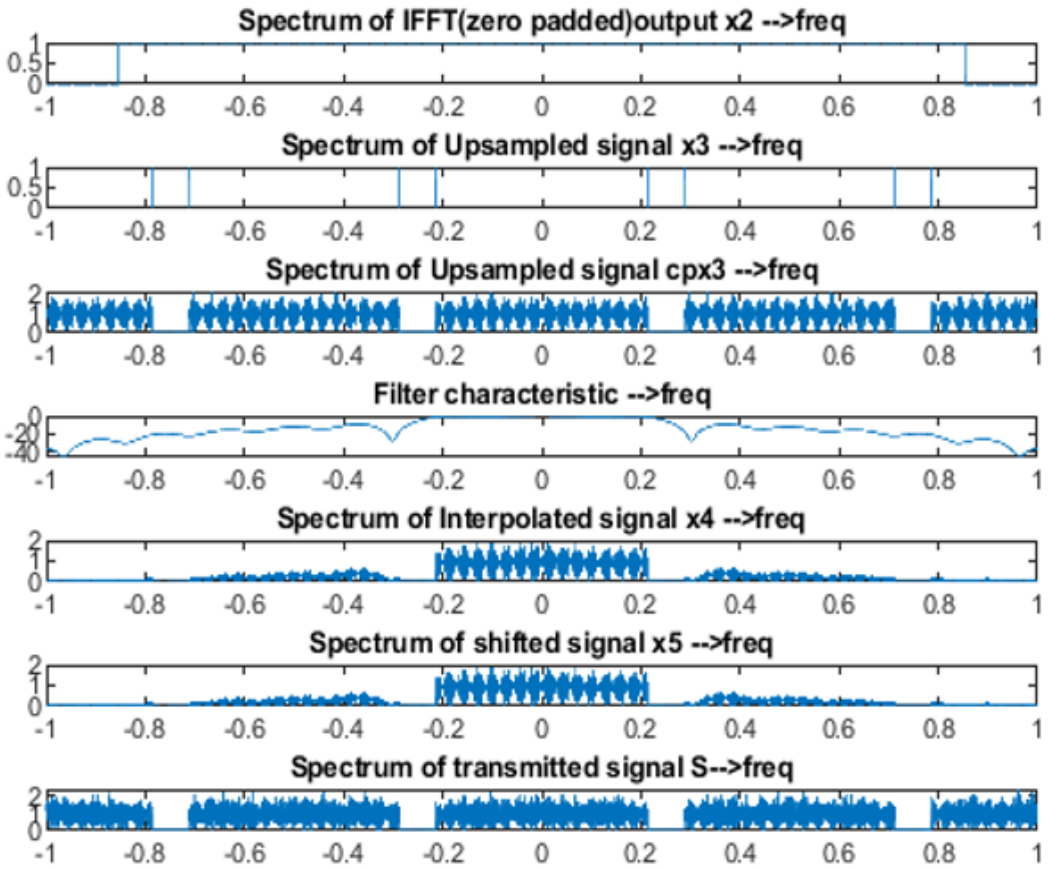
RTL and Synthesis Results- Component Level



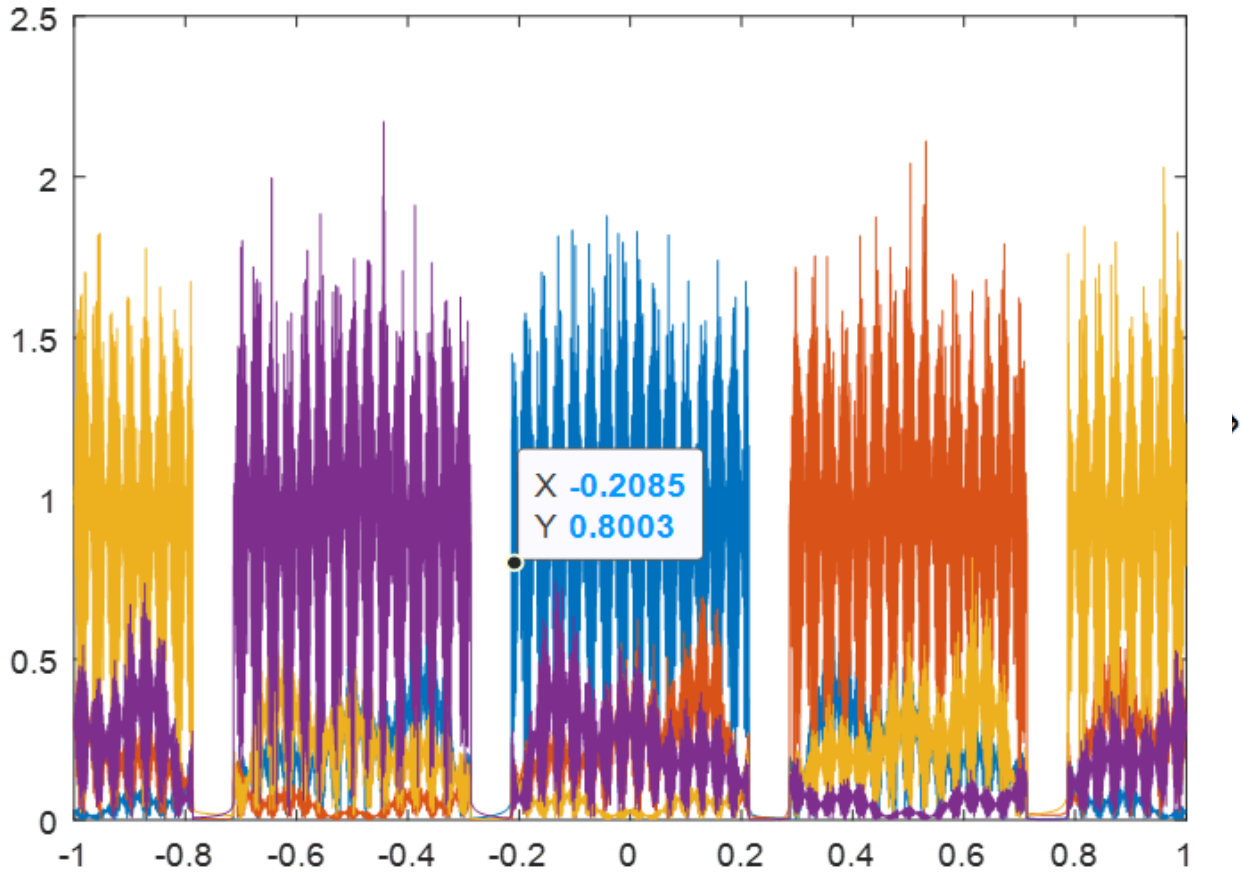
Future Scope of Work (6G components)

- ✓ 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



Tx spectrum



Rx spectrum

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.

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Thank you