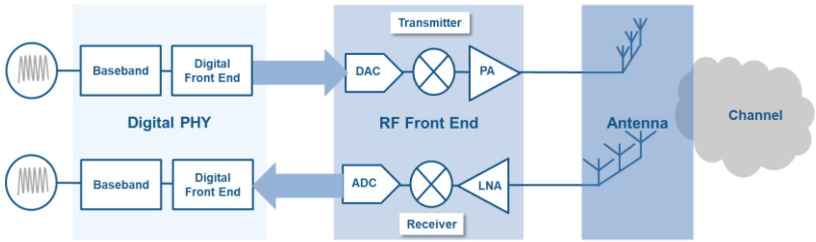
MATLAB EXPO
2021

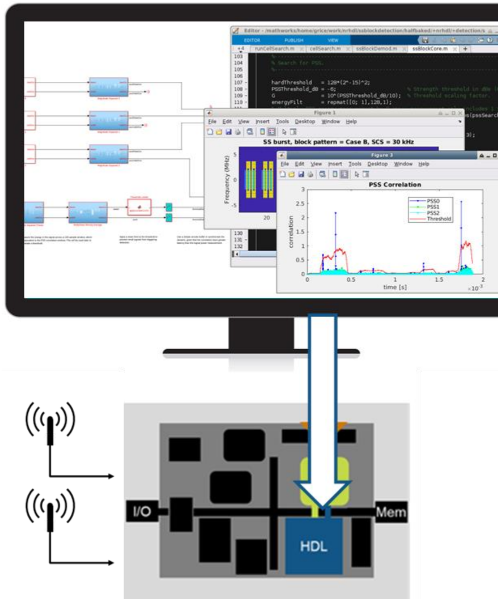
用MATLAB进行5G和无线设计

陈晓挺， MathWorks

MathWorks

今天的 3 个主题





泛链接

建模5G/无线连接系统和标准

复杂性

集成并仿真从天线到bit的多域设计

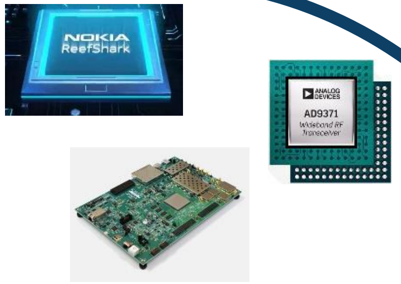
效率

迭代、优化和验证设计实现

无线通讯无处不在

移动终端

通信基础设施



半导体和组件:
基带、射频、天线

5G
Lte Advanced Pro
Wi Fi 6

连接设备
-汽车
-工业
-智能家居
-智能城市
-医疗

无线设计的共同挑战

物理层设计

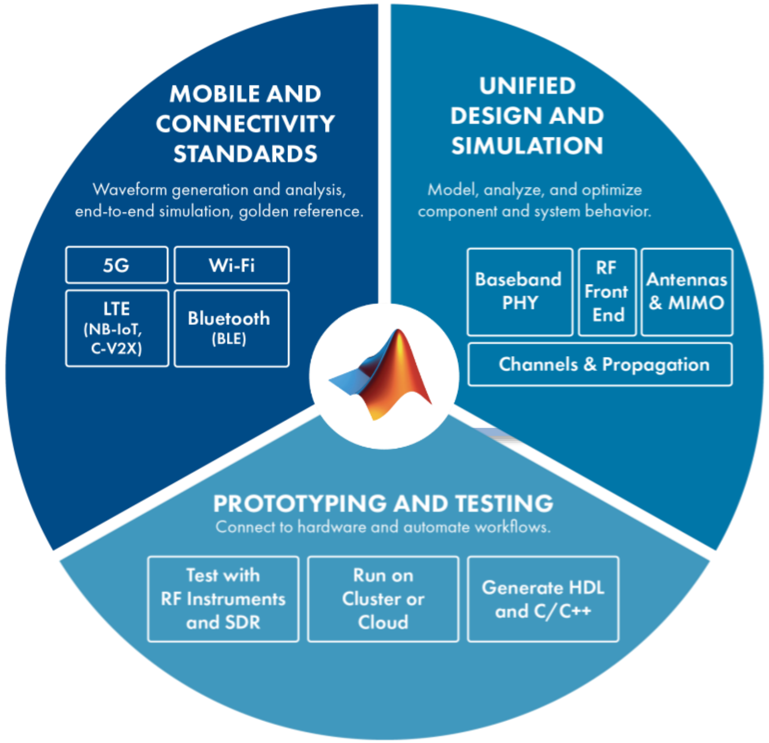
- OFDMA
- Mu-MIMO
- 信道估计和均衡
- 调制和编码
- 射频线性化 (PA 和 DPD)

泛连接

无处不在的连接

部署和验证

- 定点设计
- 并行化
- 面积-速度权衡
- OTA测试
- 快速原型和IP设计



系统工程

- 毫米波
- 链路预算分析
- 容量和吞吐量
- 系统级仿真
- 共存和干扰

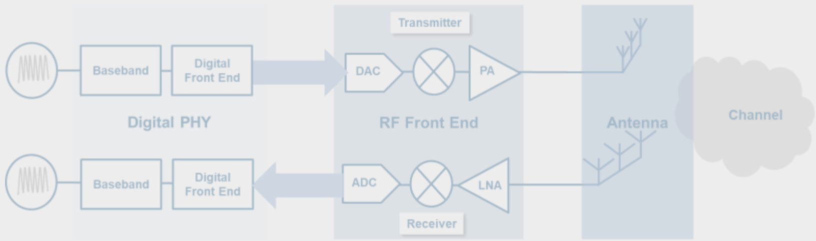
复杂性

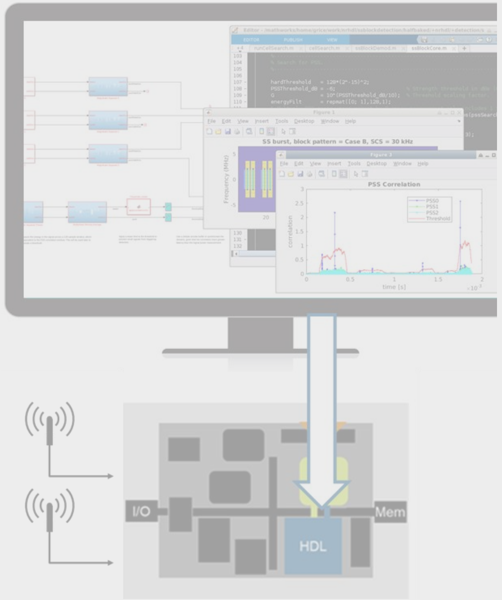
设计复杂性

效率

高效的部署和测试

今天的 3 个主题





泛链接

建模5G/无线连接系统和标准

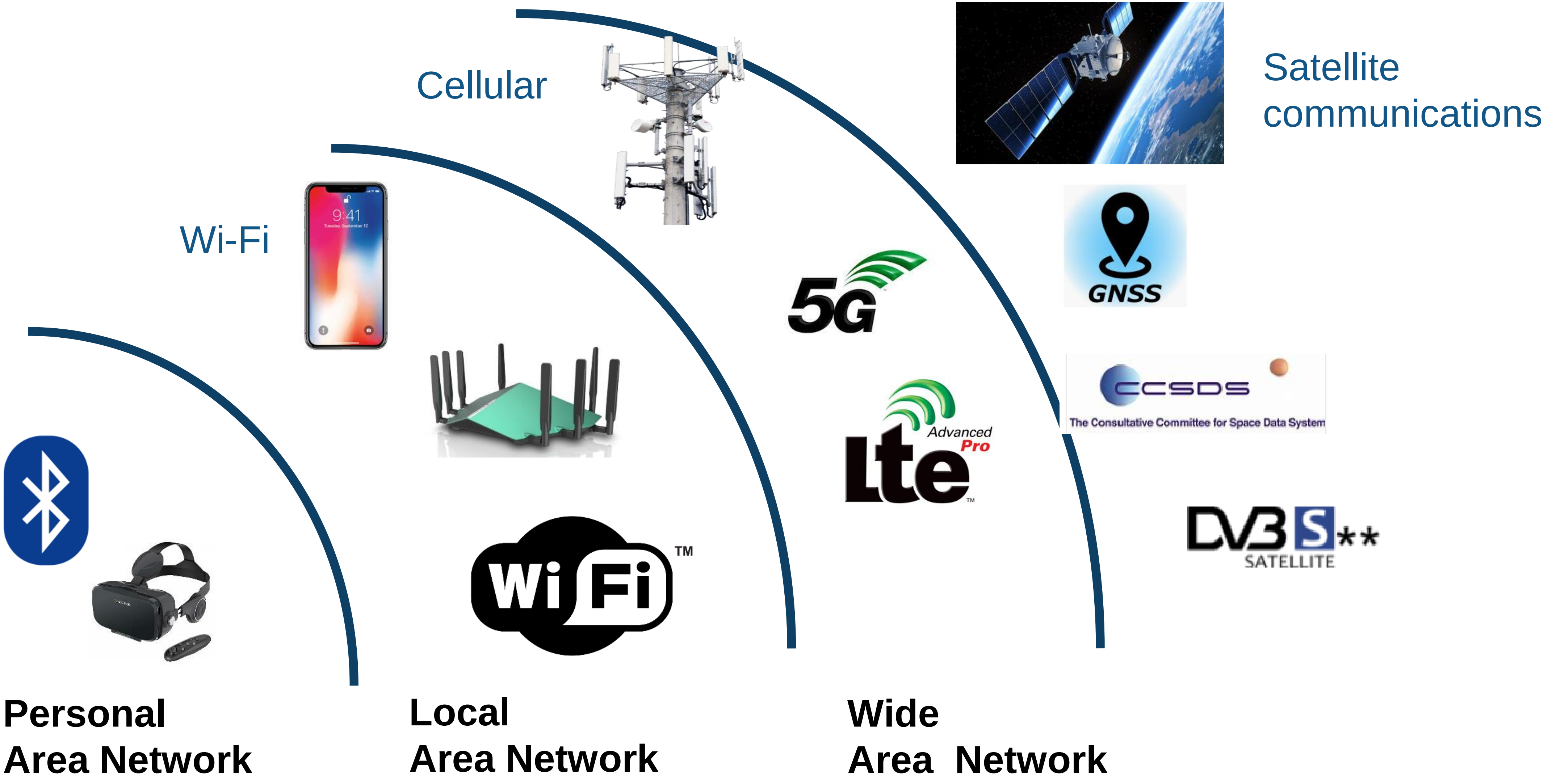
复杂性

集成并仿真从天线到bit的多域设计

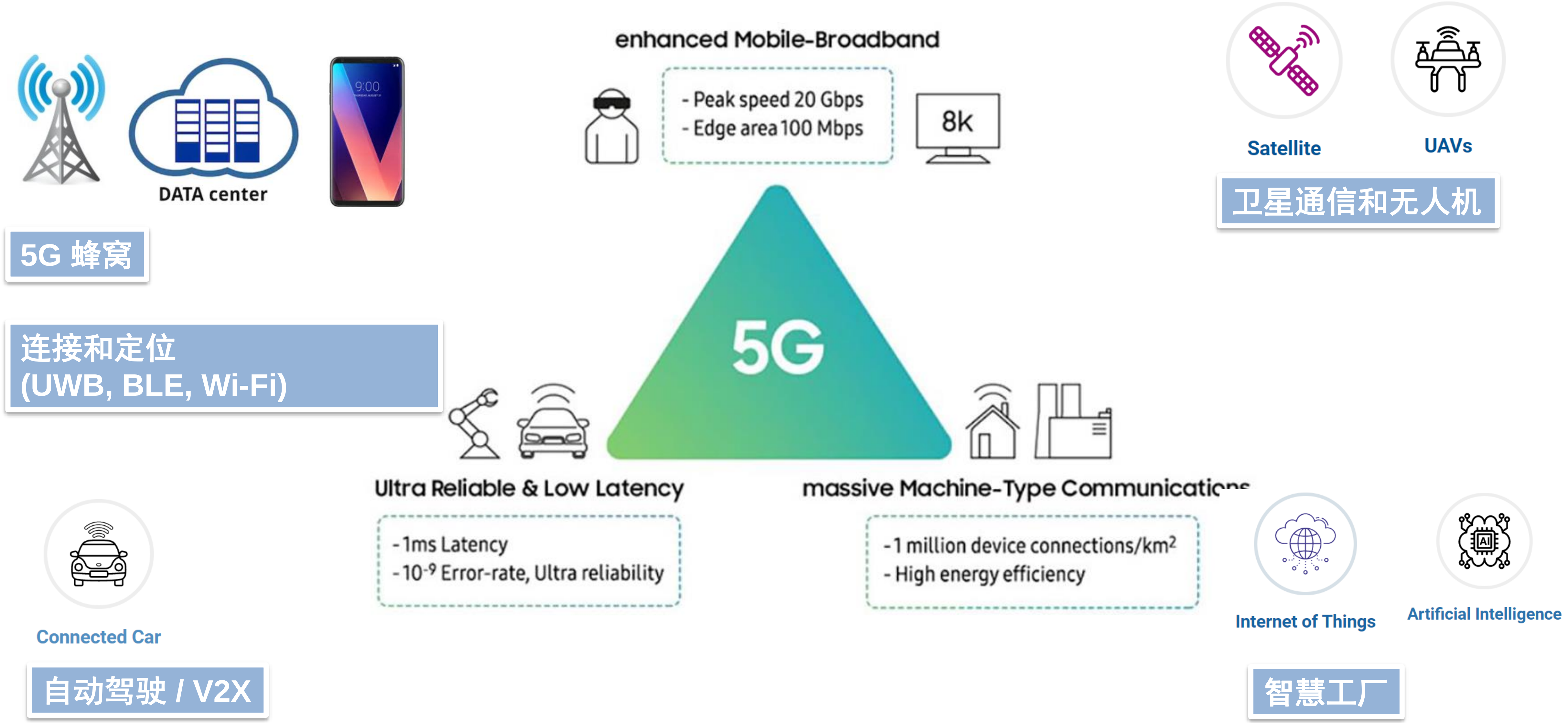
效率

迭代、优化和验证设计实现

泛链接 – 技术和标准


Cellular
Satellite communications
Wi-Fi
5G
GNSS
CCSDS
The Consultative Committee for Space Data System
Advanced Pro
Lte
DVB S2
SATELLITE
Wi Fi
Personal Area Network
Local Area Network
Wide Area Network

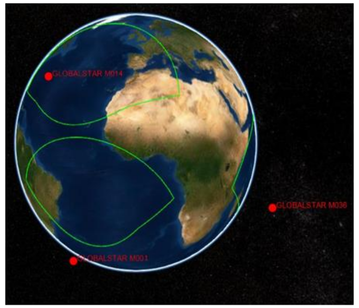
5G: 大趋势和驱动力


DATA center
5G 蜂窝
连接和定位
(UWB, BLE, Wi-Fi)
Connected Car
自动驾驶 / V2X
enhanced Mobile-Broadband
- Peak speed 20 Gbps
- Edge area 100 Mbps
8k
5G
Ultra Reliable & Low Latency
- 1ms Latency
- 10-9 Error-rate, Ultra reliability
massive Machine-Type Communications
- 1 million device connections/km2
- High energy efficiency
Satellite
UAVs
卫星通信和无人机
Internet of Things
Artificial Intelligence
智慧工厂

趋势: 新兴的卫星通信

以高速互联网连接发展为动力

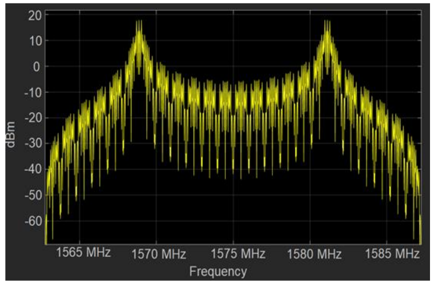
Orbit Propagation and Visualization; Access and Link Analysis

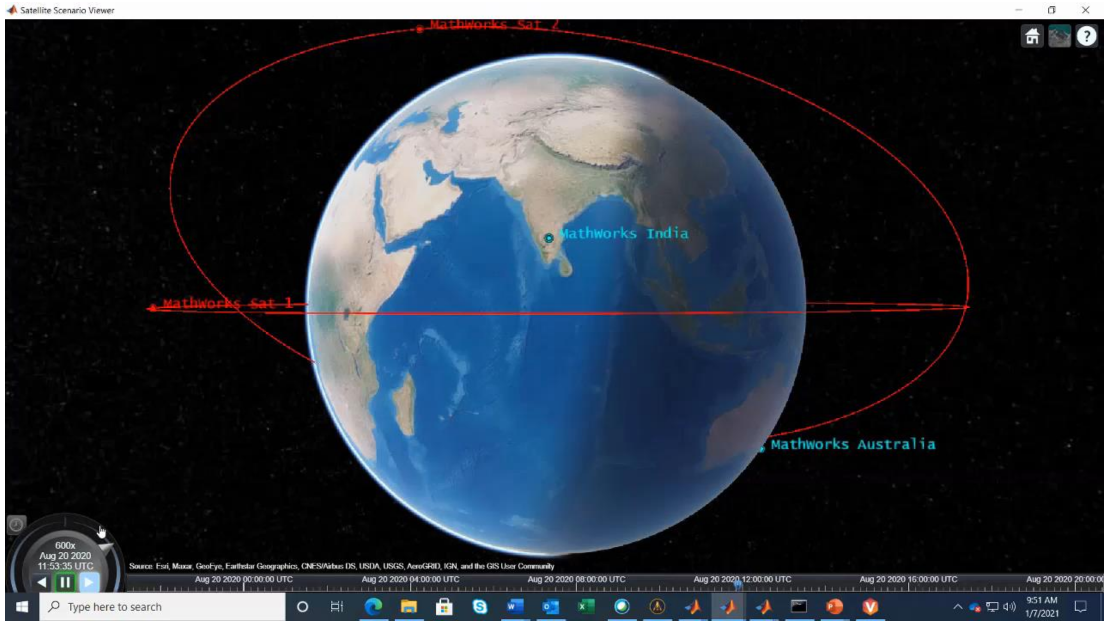


Link Budget Analysis

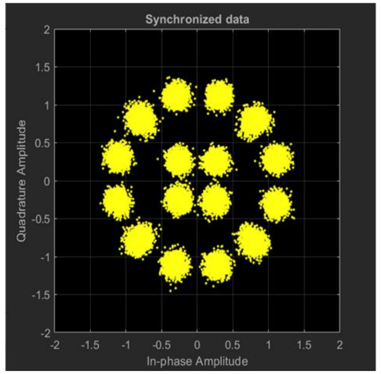
Name	L1
Distance (km)	3.6595e+03
Elevation (deg)	20.2176
Tx EIRP (dB)	51
Polarization loss (dB)	3.0103
FSPL (dB)	186.6387
Received isotropic power (dBW)	-141.6490
C/No (dB-Hz)	87.9502
C/N (dB)	20.1687
Received Eb/No (dB)	17.9502
Margin (dB)	5.9502

Waveform Generation





End-to-End Simulations



趋势:Wi-Fi发展-由物联网驱动

更多设备 和
密集环境

802.11ac → 802.11ax Wi-Fi 6

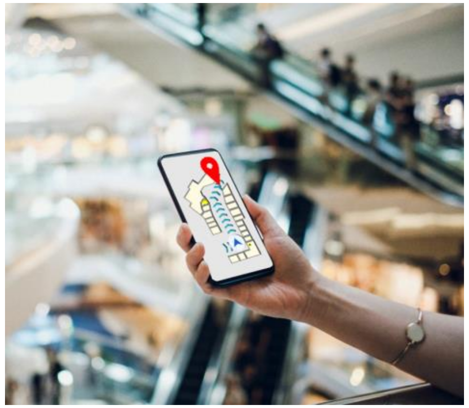
100s of Mbps, 大量连接下的高效率

工业 4.0

802.11ax → 802.11be Wi-Fi 7

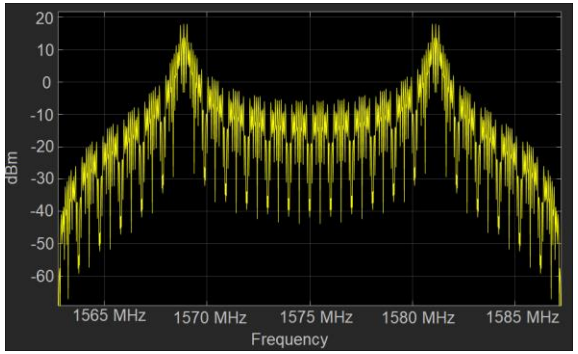
Gbps, 减少延迟和抖动

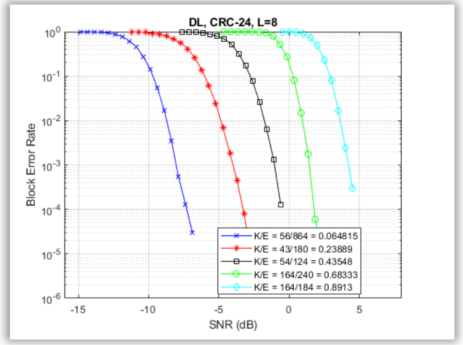
802.11az - Positioning

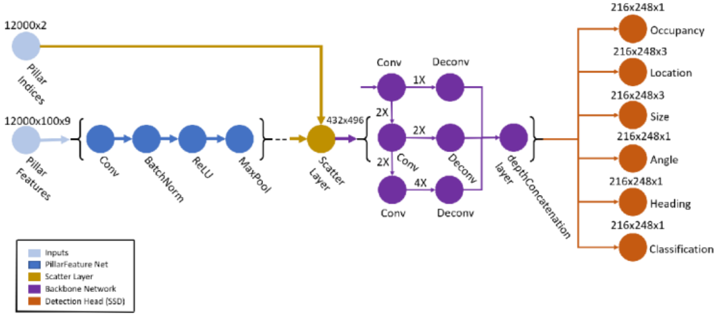


测向与定位

基于标准的互联设计的常用用例



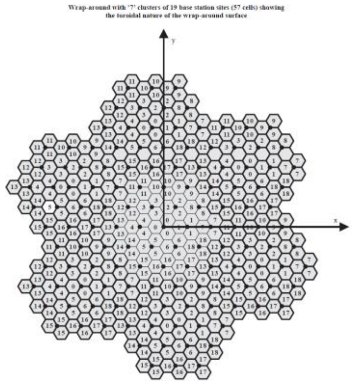




波形生成

链路级仿真

AI 工作量
预训练模型，训练，
评估，验证

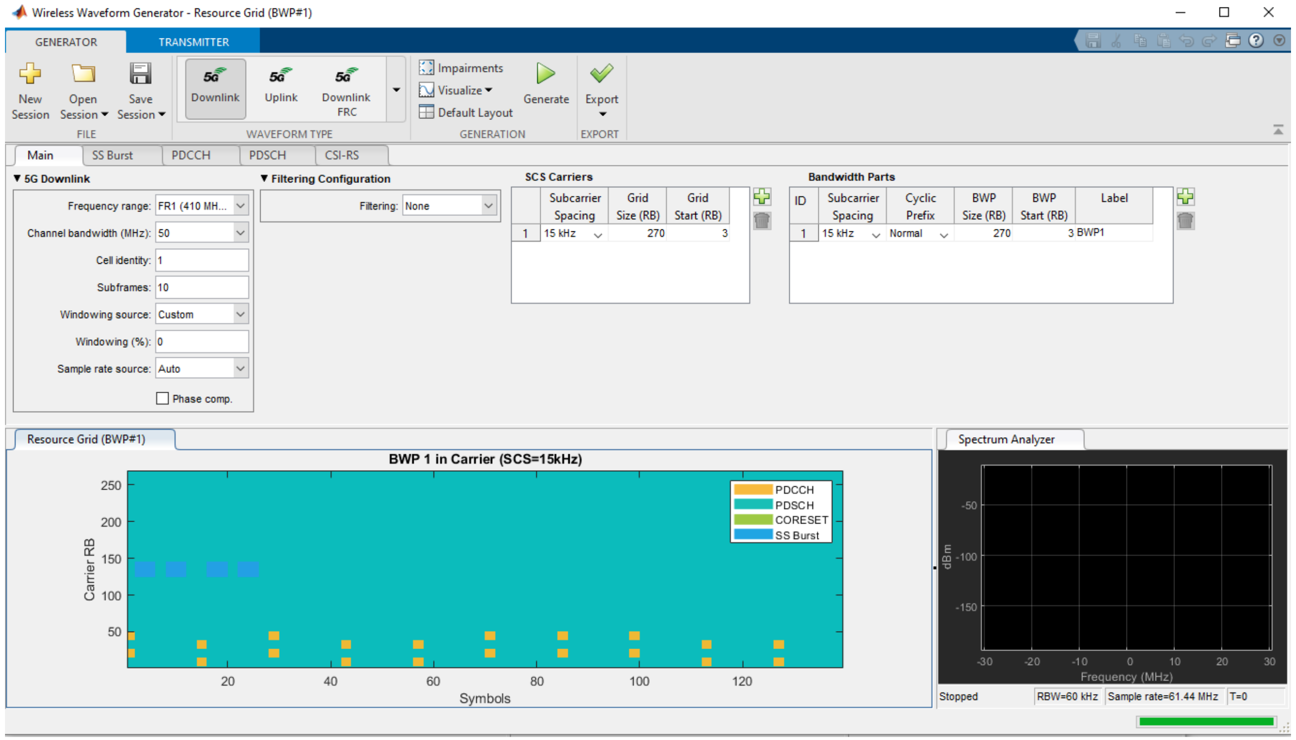


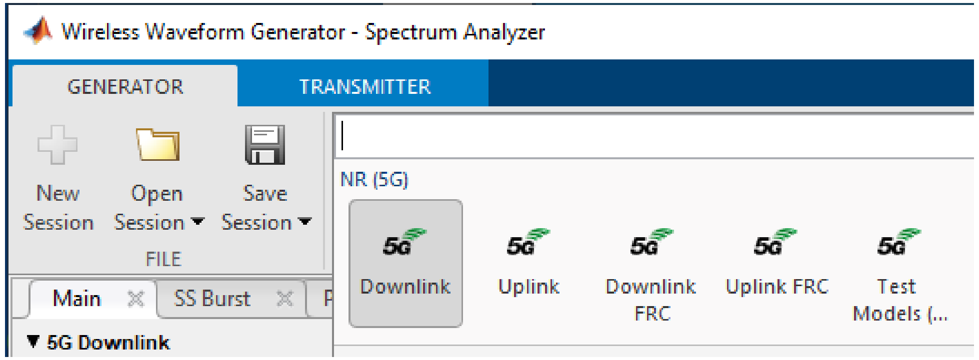
干扰与共存

网络仿真

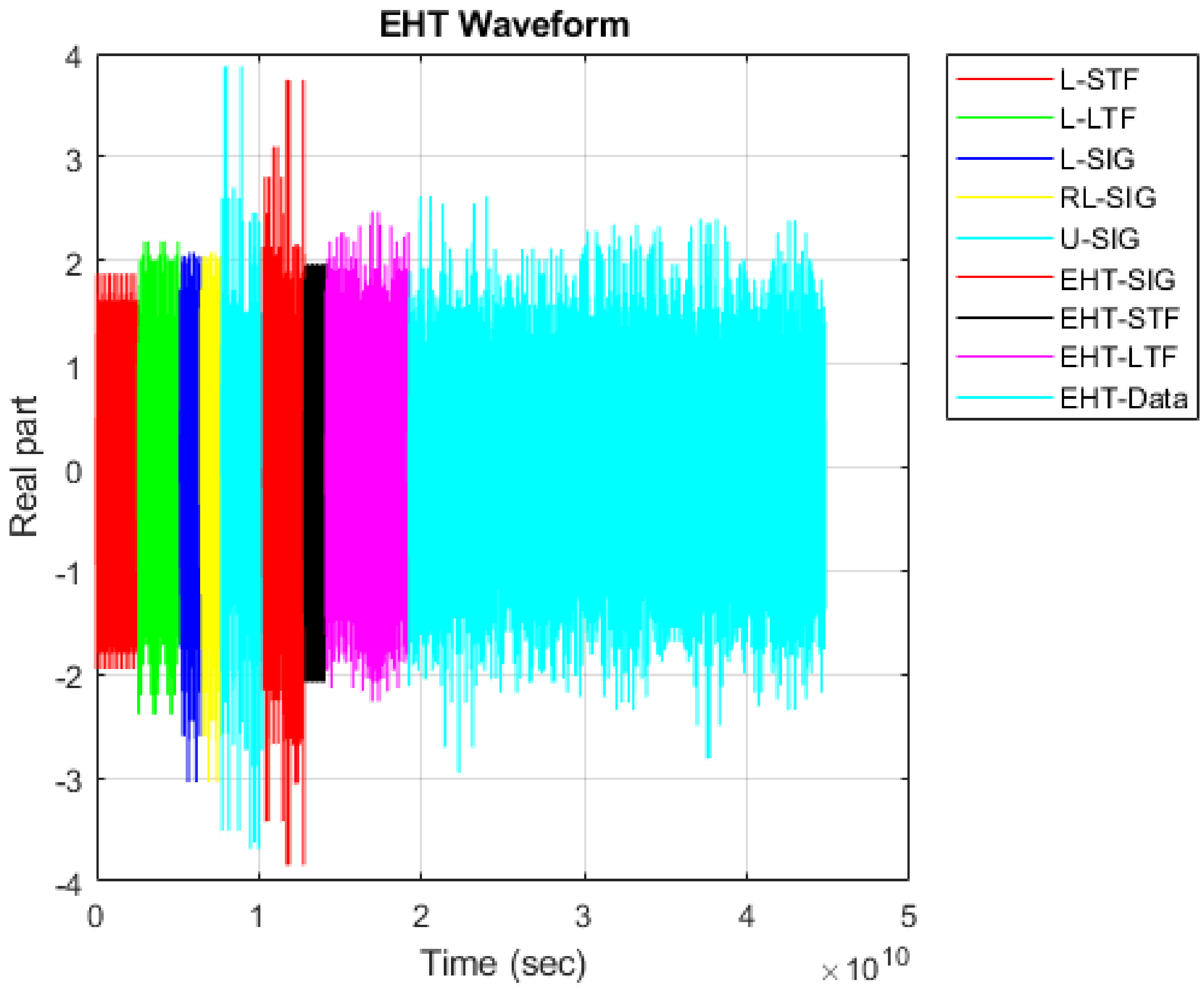
无线波形发生器App

- 交互式波形生成
- 5G NR 现成波形:
  - NR-TMs / FRCs
- 自定义下行和上行波形
  - 新功能 R2021a

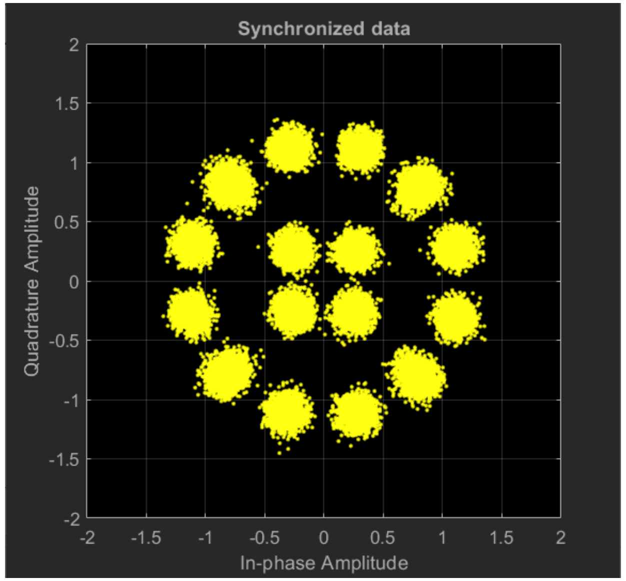


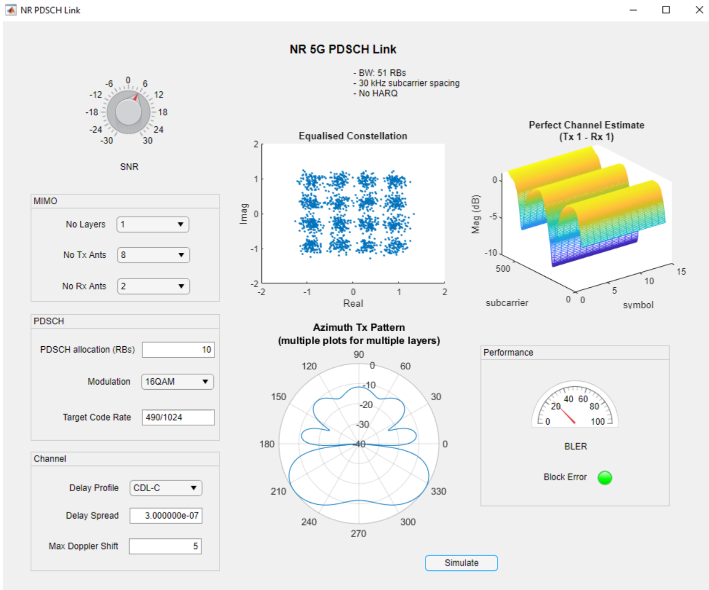


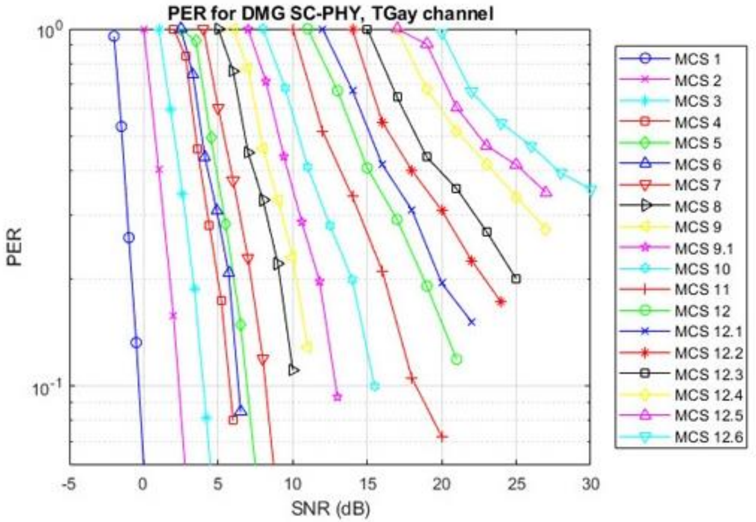
IEEE 802.11be 波形生成



端到端链路级仿真







带射频损伤和校正的
端到端
DVB-S2仿真

5G NR PDSCH Throughput

802.11ax下行OFDMA
和多用户MIMO
吞吐量仿真

干扰与共存

- 2.4 GHz

BLE ZigBee Wi Fi™

- 5/6 GHz

Wi Fi™

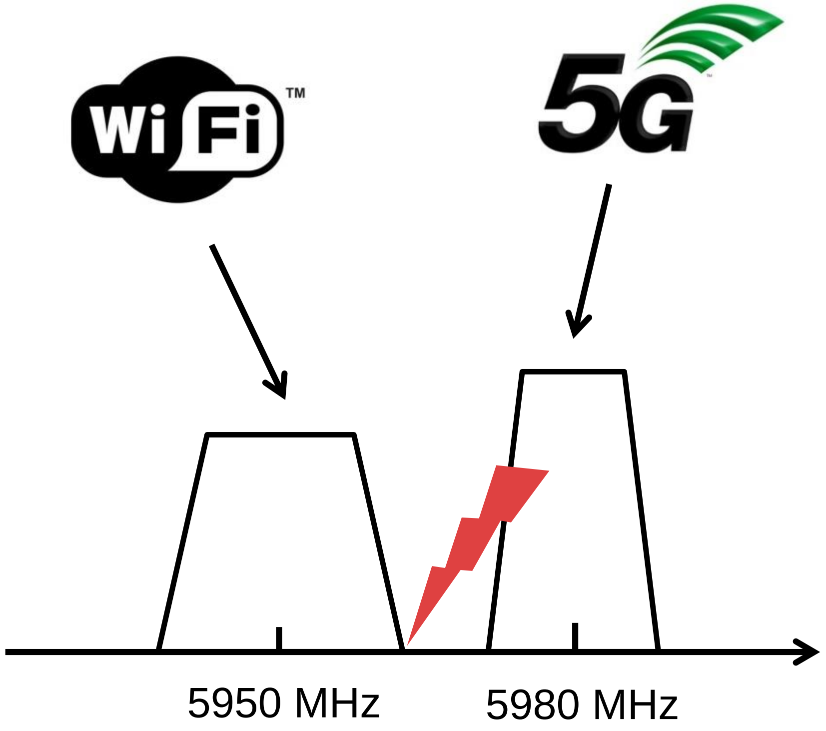
Lte Advanced Pro™ 5G

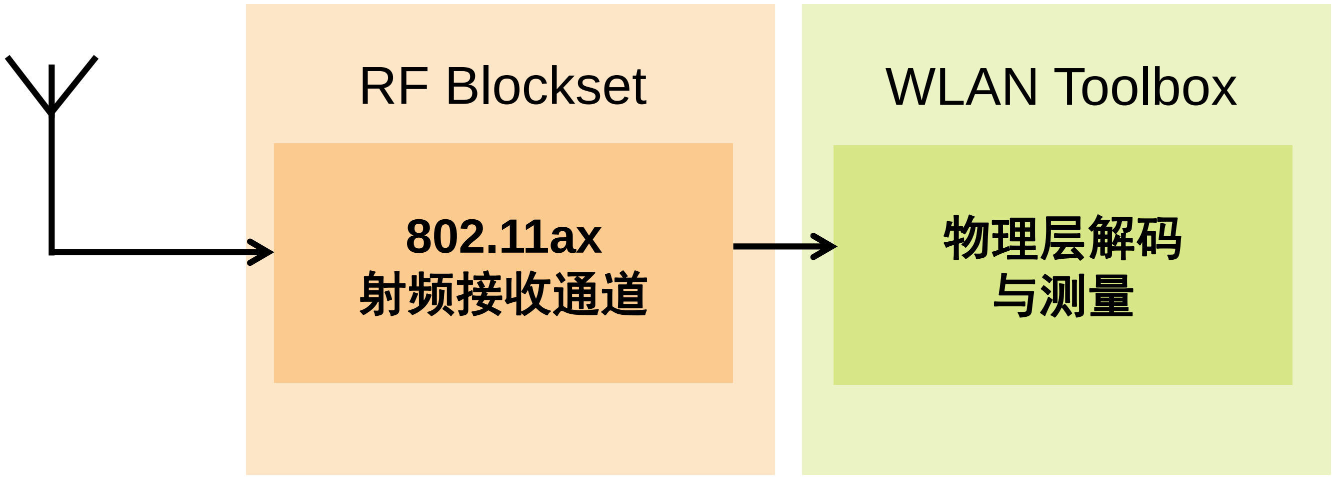
- 60 GHz

Wi Fi™ 5G

示例 - 5G干扰下的802.11ax射频接收机

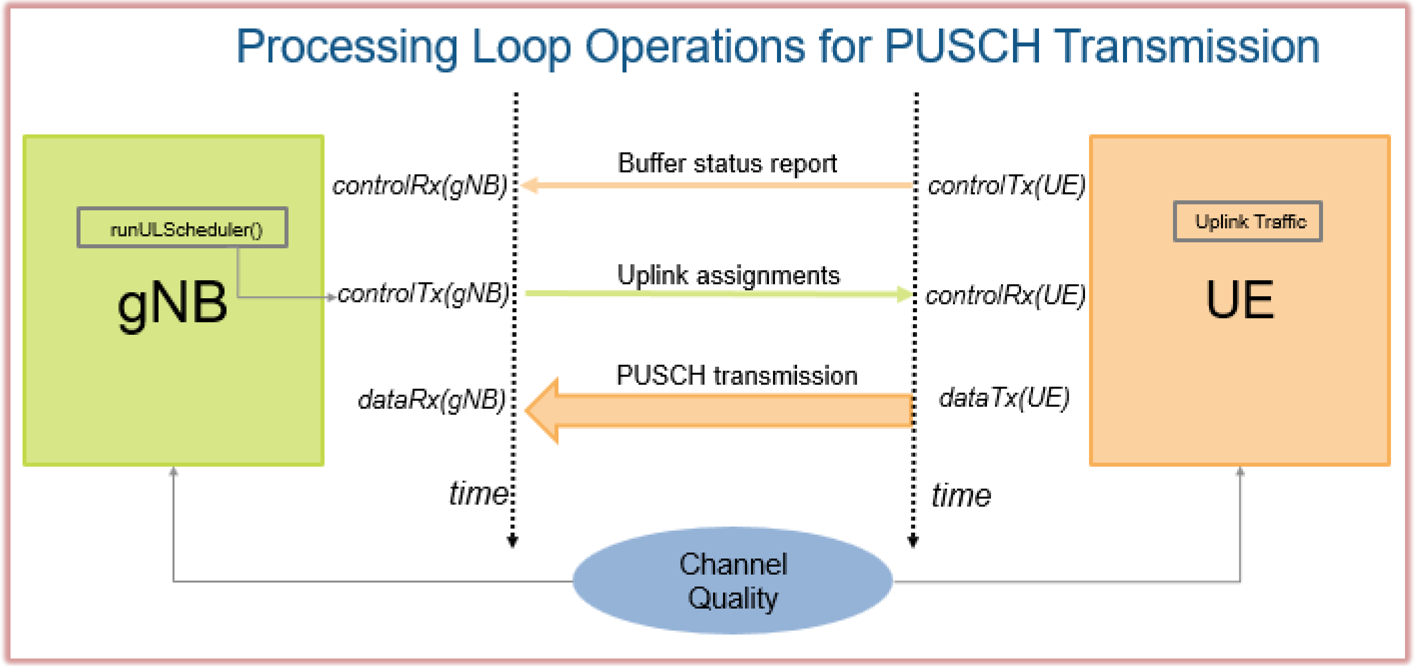
发射波形	802.11ax at 5950MHz
干扰	NR-TM at 5980MHz
测验	- 信道 - EVM per subcarrier - EVM per OFDM symbol



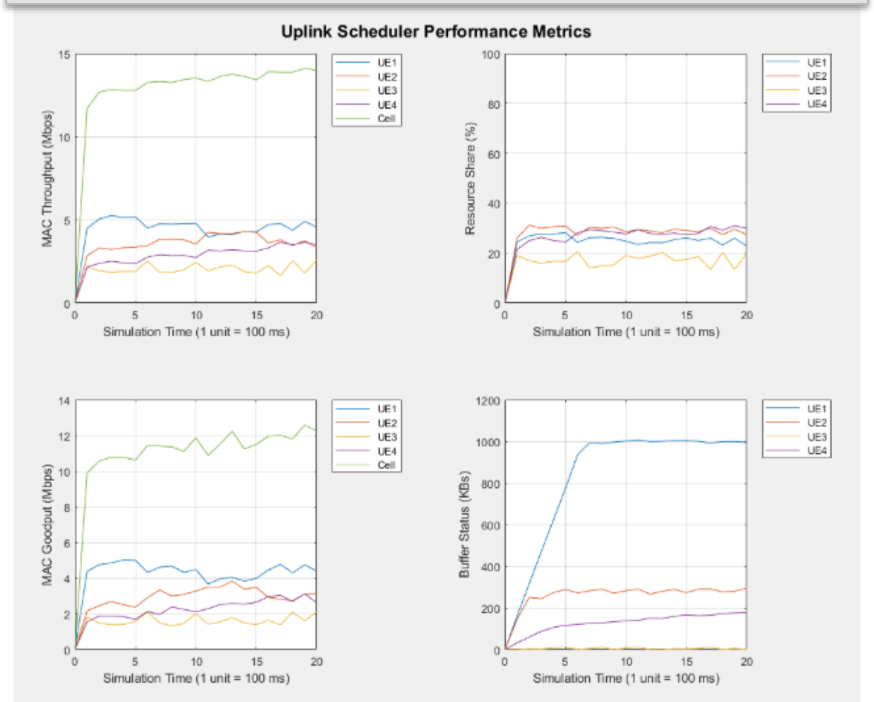


5G NR 系统级仿真

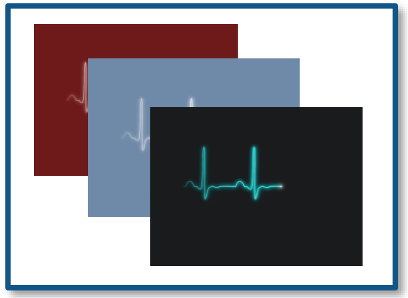
- 评估不同调度器的性能
  – Round-robin, proportionally fair, best CQI

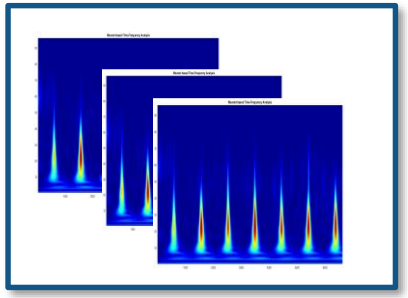


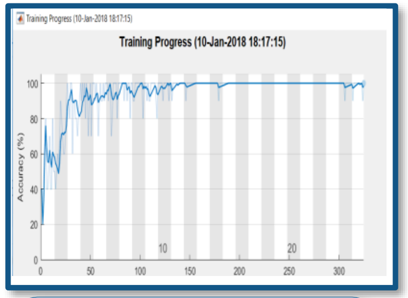
Throughput, goodput, buffer status

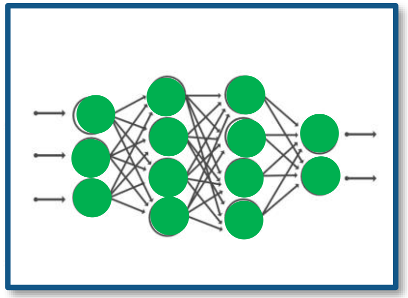


Deep Learning for Wireless Workflow









含标记的
合成数据

变换

训练网络

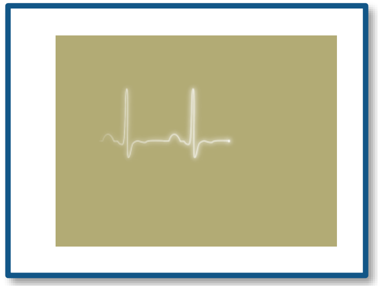
训练模型

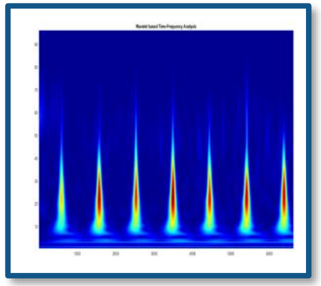
新的信号

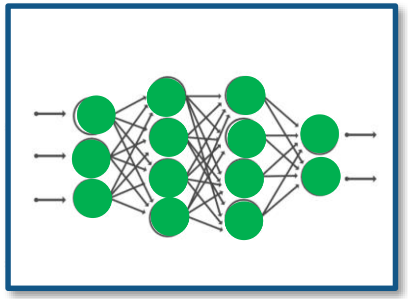
变换

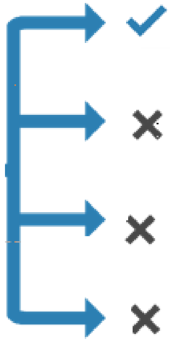
预训练模型

分类

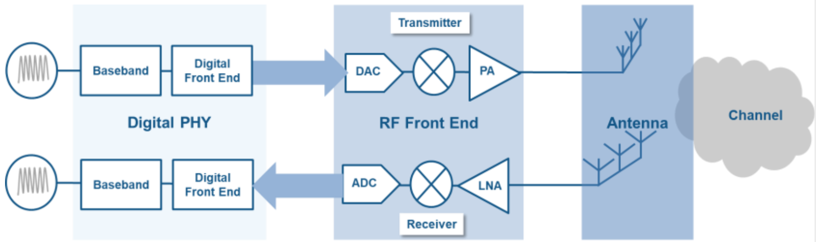


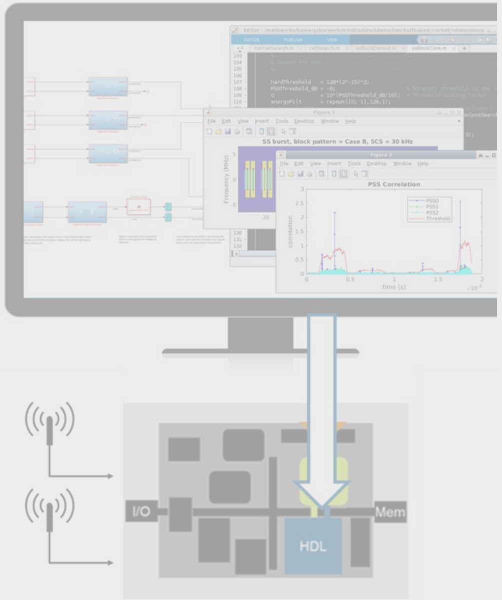






今天的 3 个主题





泛链接

建模5G/无线连接系统和标准

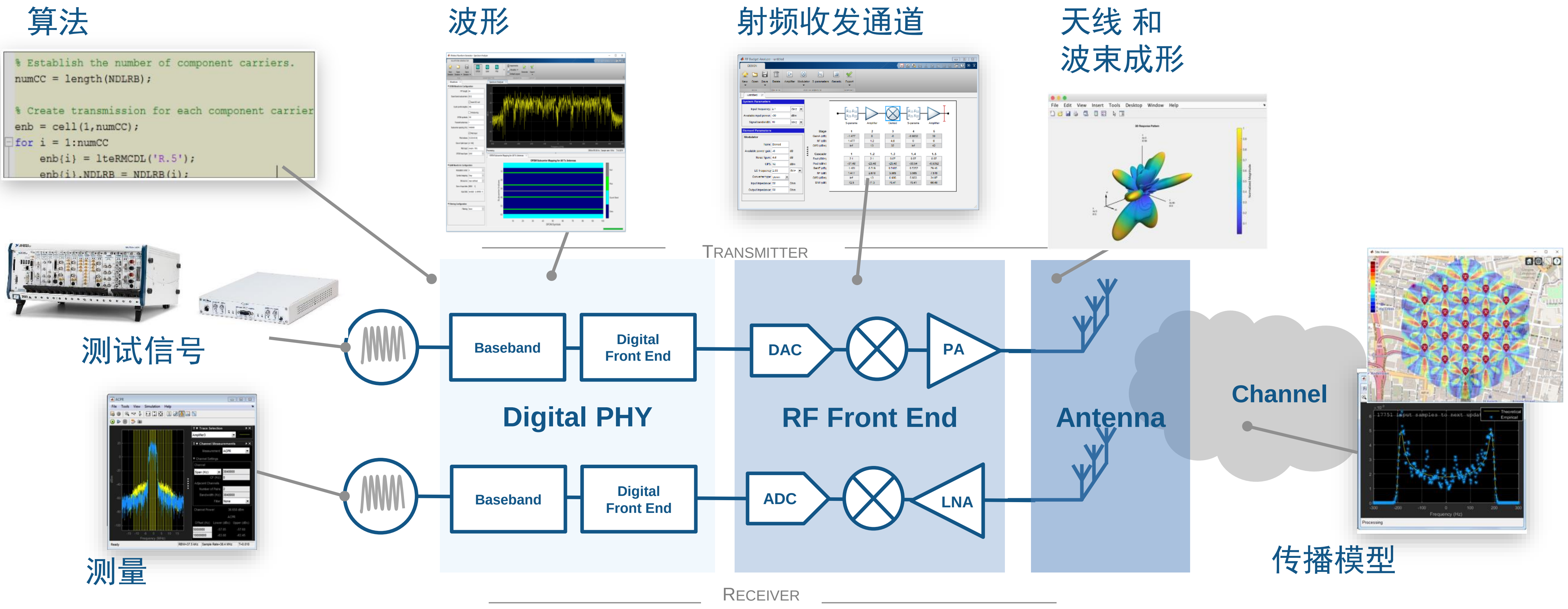
复杂性

集成并仿真从天线到bit的多域设计

效率

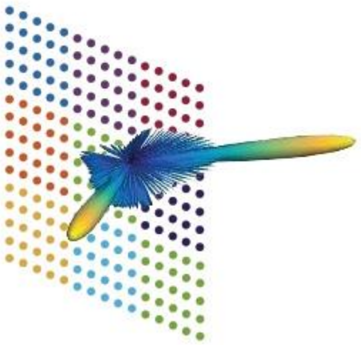
迭代、优化和验证设计实现

集成多领域建模的复杂性

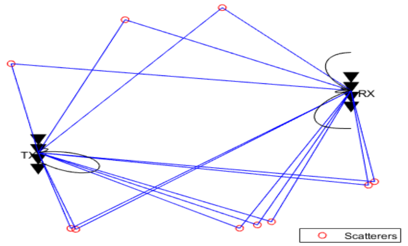


天线到比特的多域设计工作流程

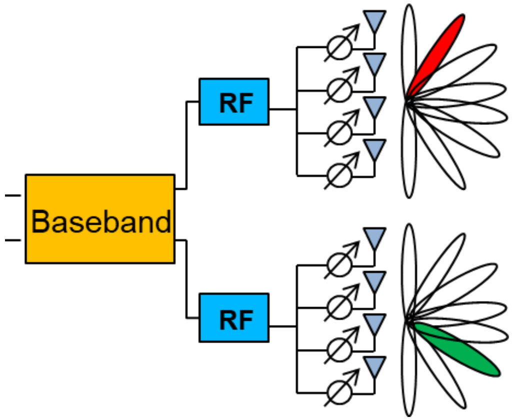
设计天线阵列



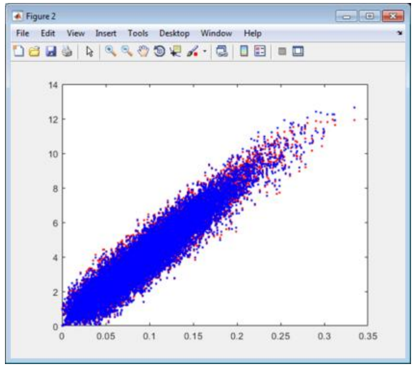
加载信道模型



混合波束成形

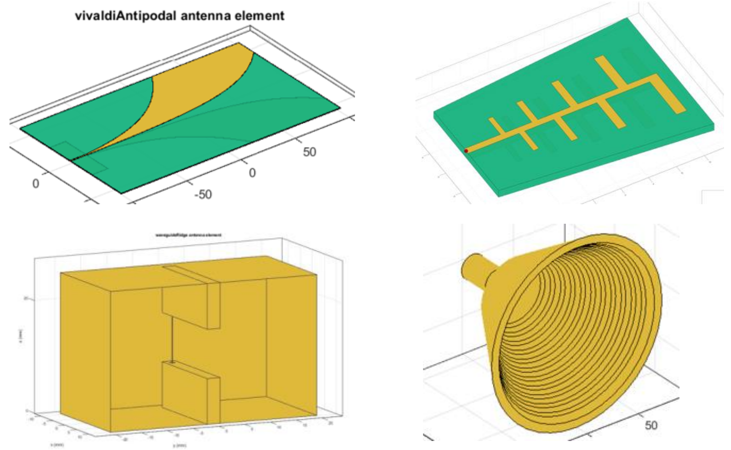


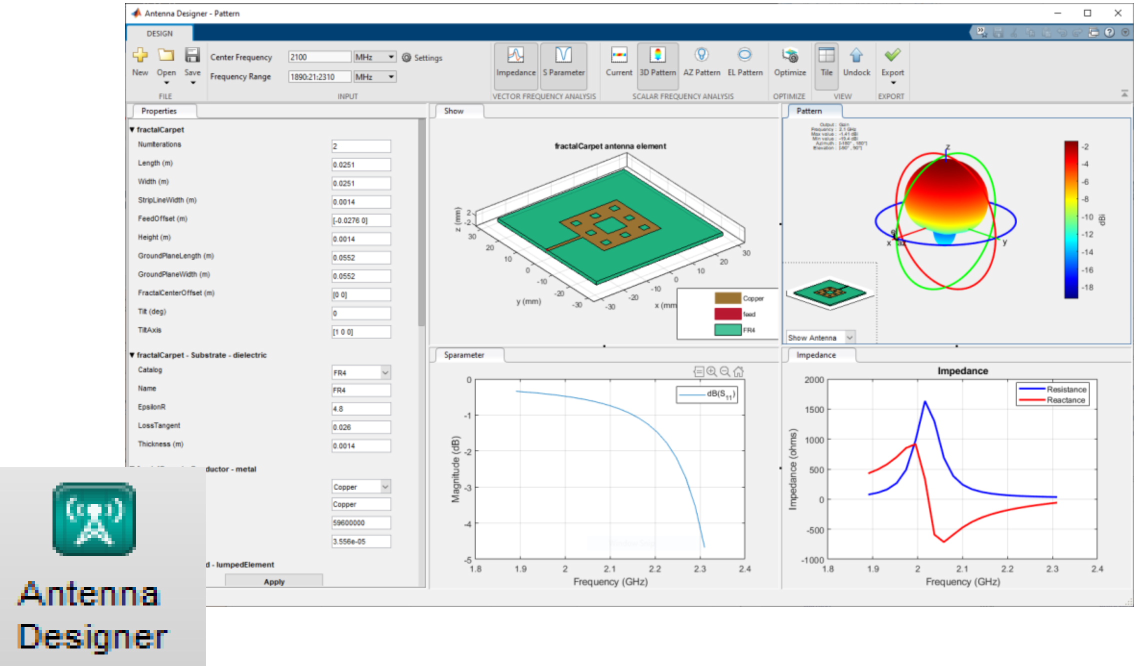
细化射频前端

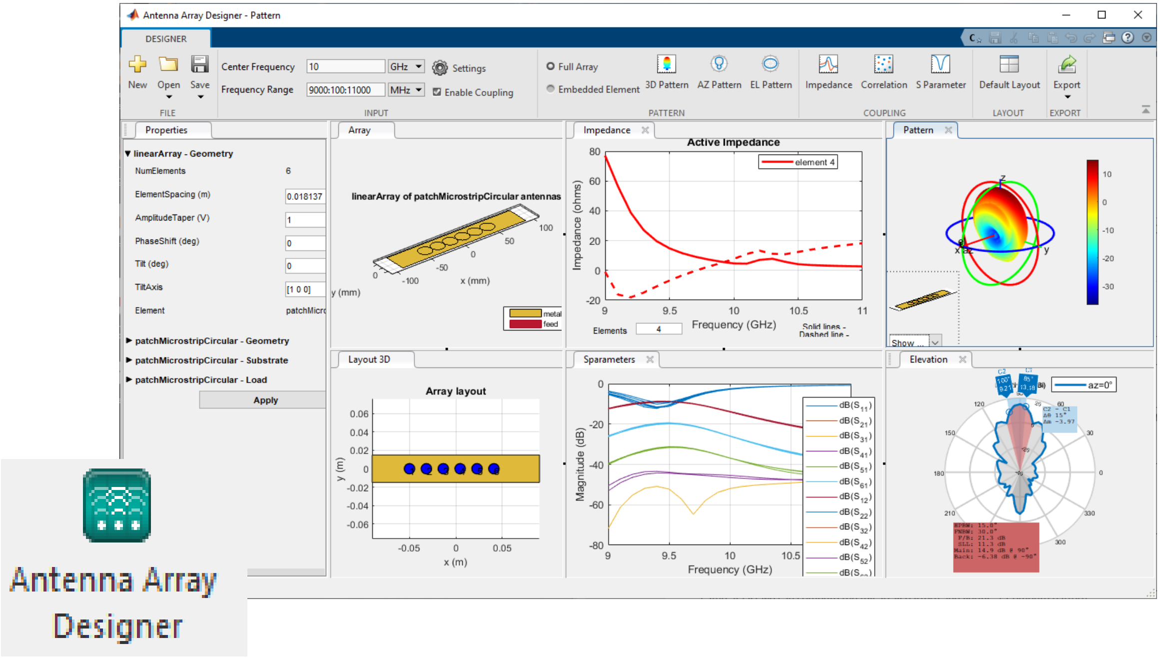


设计，分析和可视化天线单元和阵列

- 开始使用天线和阵列目录，以及应用程序
- 执行full-wave电磁仿真 使用代理优化改进性能
- 设计和制造PCBs(Gerber文件生成)
- 分析安装在大型平台上的影响

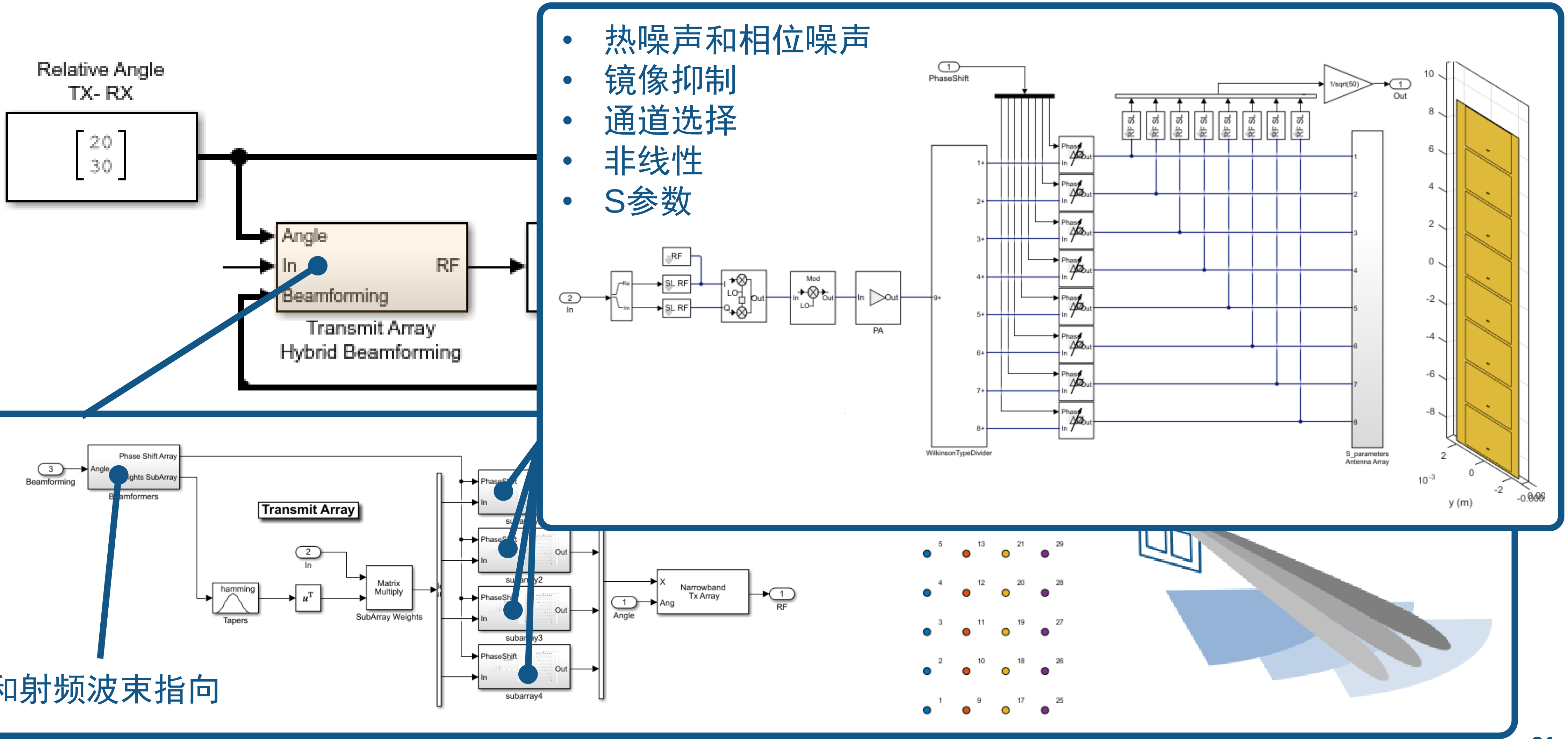






混合波束形成的体系结构探索

- 热噪声和相位噪声
- 镜像抑制
- 通道选择
- 非线性
- S参数



基带和射频波束指向

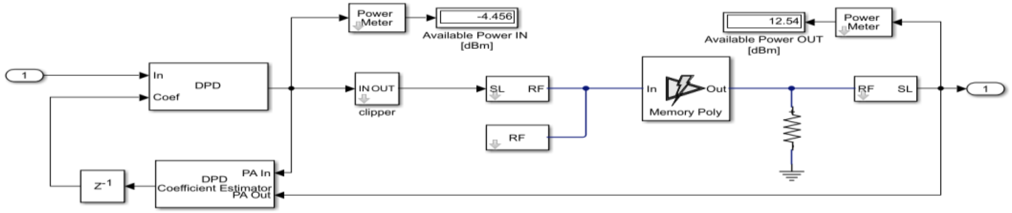
功率放大器线性化:5G仿真结果

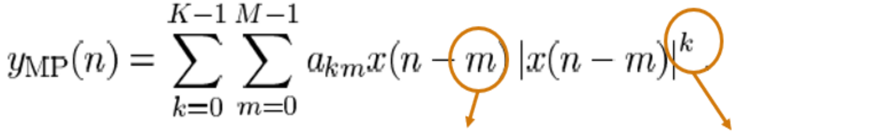
1. 生成 5G 波形

```
rc = "NR-FR1-TM3.1"; % Reference channel(NR-TM or FRC)
% Select the NR waveform parameters
bw = "100MHz"; % Channel bandwidth
scs = "30kHz"; % Subcarrier spacing
dm = "FDD"; % Duplexing mode
```

2. 建模 PA 记忆和非线性

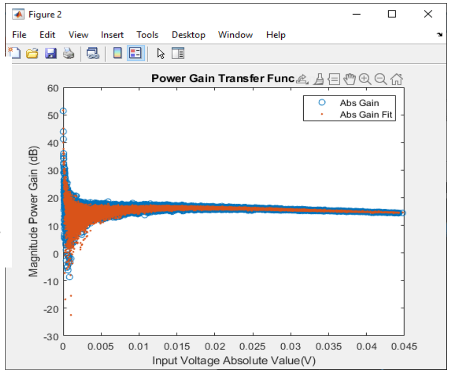
```
rxWaveform_dpd = rf_dpd(txWaveform);
```





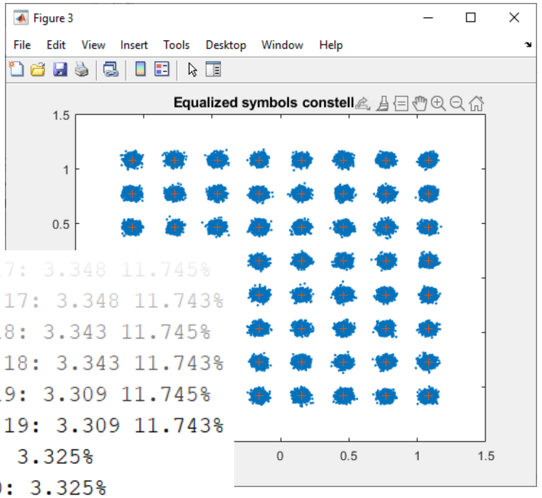
$$y_{MP}(n) = \sum_{k=0}^{K-1} \sum_{m=0}^{M-1} a_{km} x(n-m) |x(n-m)|^k$$

Memory depth   Degree of non-linearity



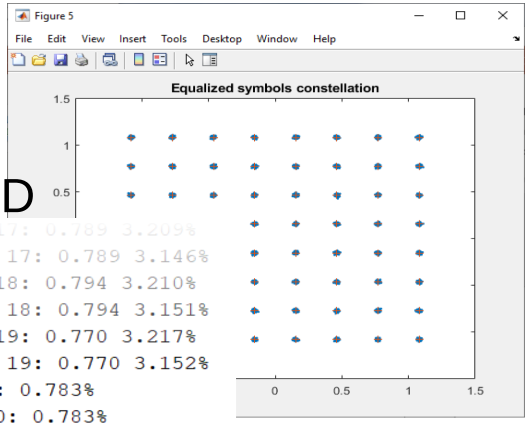
4. 创建包含DPD的射频系统

3. 测量 EVM




```
Low edge RMS EVM, Peak EVM, slot 17: 3.348 11.745%
High edge RMS EVM, Peak EVM, slot 17: 3.348 11.743%
Low edge RMS EVM, Peak EVM, slot 18: 3.343 11.745%
High edge RMS EVM, Peak EVM, slot 18: 3.343 11.743%
Low edge RMS EVM, Peak EVM, slot 19: 3.309 11.745%
High edge RMS EVM, Peak EVM, slot 19: 3.309 11.743%
Averaged low edge RMS EVM,frame 0: 3.325%
Averaged high edge RMS EVM,frame 0: 3.325%
Averaged RMS 3GPP EVM frame 0: 3.325%
Averaged overall RMS EVM: 3.325%
Peak EVM = 12.1753%
```

4. 测量 EVM + DPD

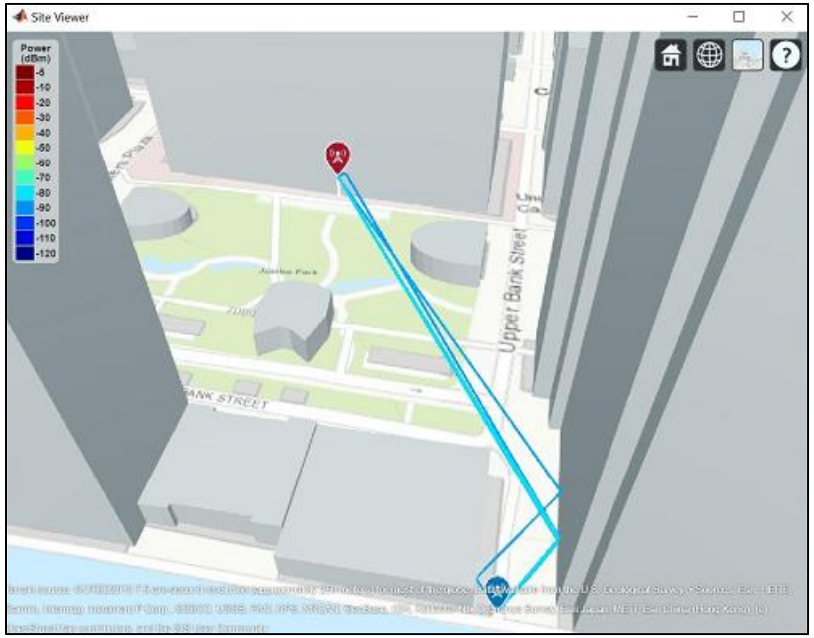



```
Low edge RMS EVM, Peak EVM, slot 17: 0.789 3.209%
High edge RMS EVM, Peak EVM, slot 17: 0.789 3.146%
Low edge RMS EVM, Peak EVM, slot 18: 0.794 3.210%
High edge RMS EVM, Peak EVM, slot 18: 0.794 3.151%
Low edge RMS EVM, Peak EVM, slot 19: 0.770 3.217%
High edge RMS EVM, Peak EVM, slot 19: 0.770 3.152%
Averaged low edge RMS EVM,frame 0: 0.783%
Averaged high edge RMS EVM,frame 0: 0.783%
Averaged RMS 3GPP EVM frame 0: 0.783%
Averaged overall RMS EVM: 0.783%
Peak EVM = 3.7347%
```

传播信道

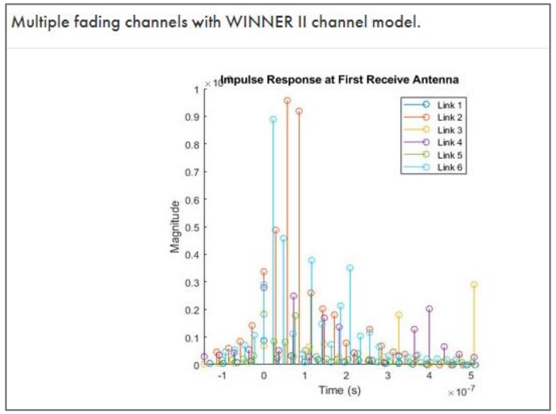
- 散射MIMO信道
- 自由空间路径损耗

- 射线追踪通道

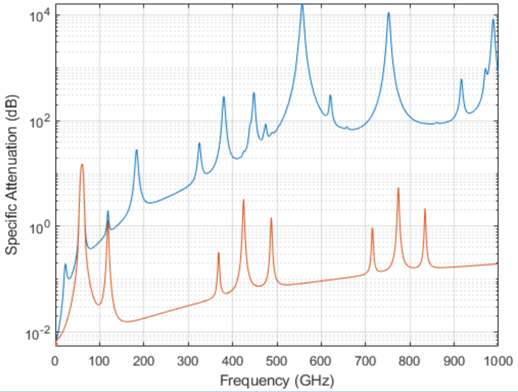


R2021a : Up to 10 reflections

- Winner II 衰落信道



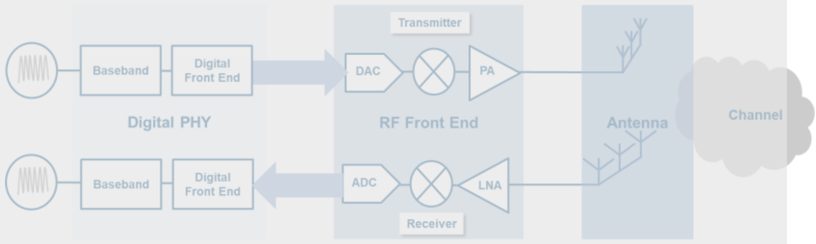
- 气体、雾、云造成的衰减

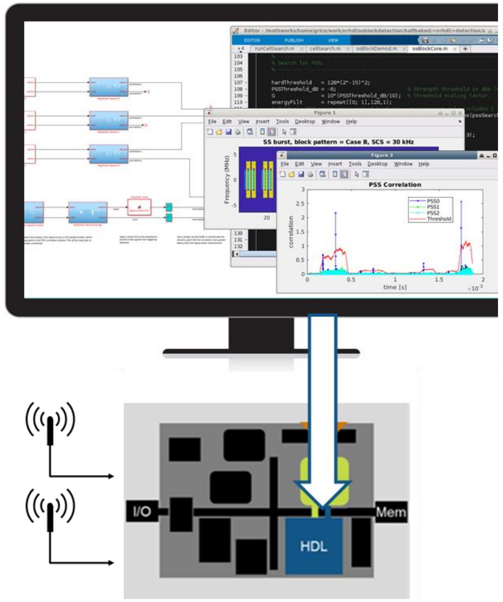


阵列波束控制和射频传播

- 偶极子反射天线RDBA矩形阵列，工作在期望的频率
- (电子)控制阵列波束并评估覆盖范围和链路

今天的 3 个主题





泛链接

建模5G/无线连接系统和标准

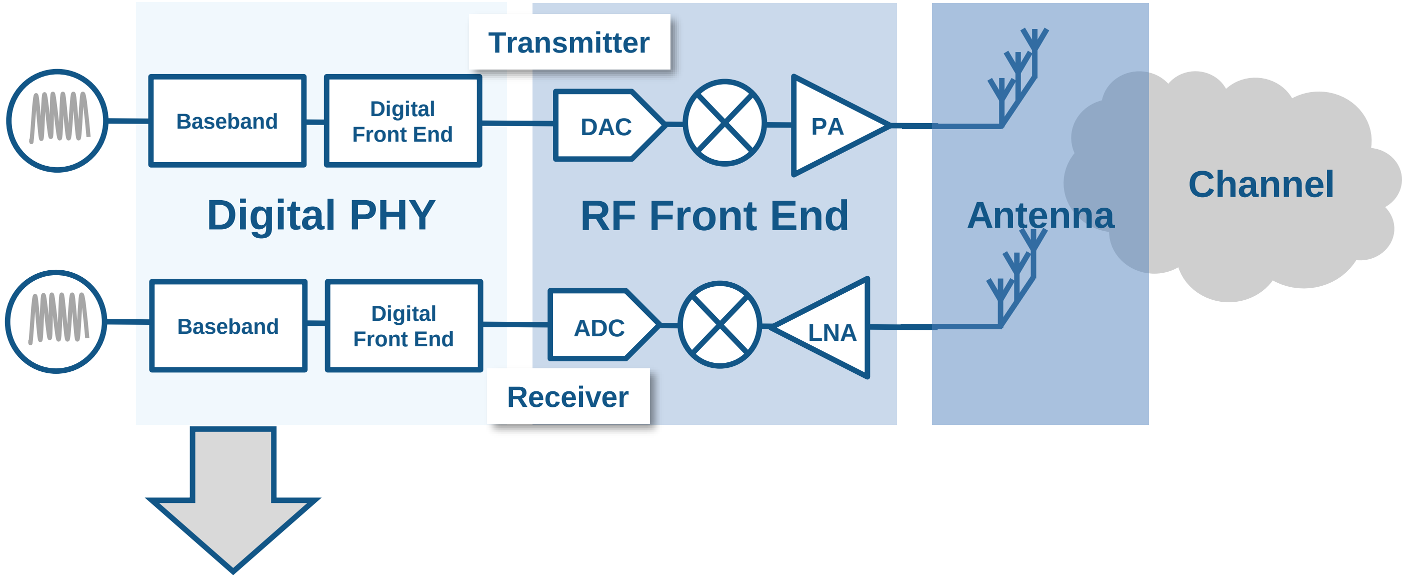
复杂性

集成并仿真从天线到bit的多域设计

效率

迭代、优化和验证设计实现

硬件部署、验证和测试



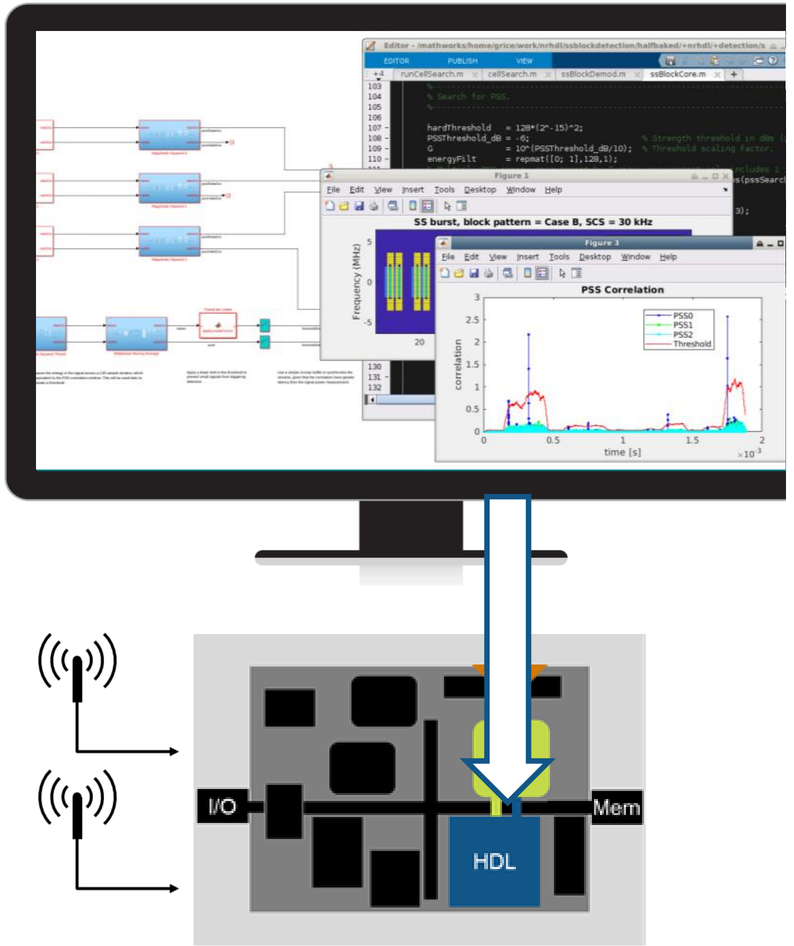
- Simulink
- HDL Coder
- Wireless HDL Toolbox
- HDL Verifier

原型
SDR, FPGA, SoC

Wireless HDL Toolbox

产品宗旨:

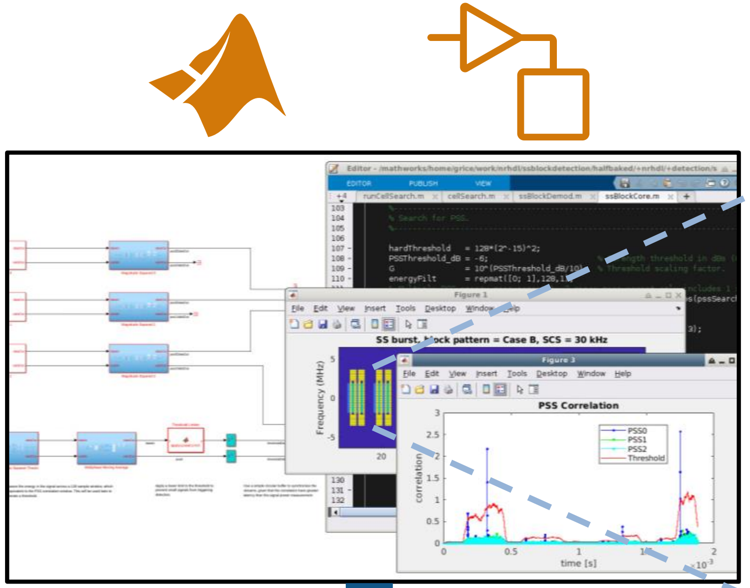
提供高价值的参考应用程序和HDL IP块，
以加快通信系统的
设计、实现和验证的步伐

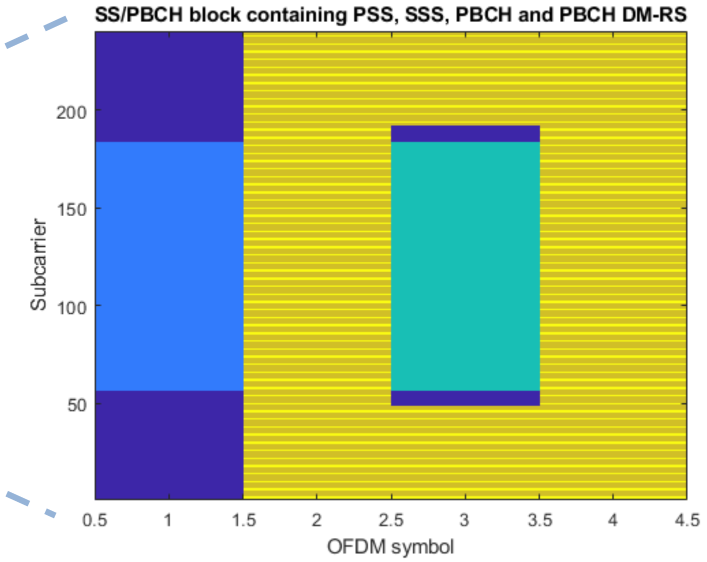


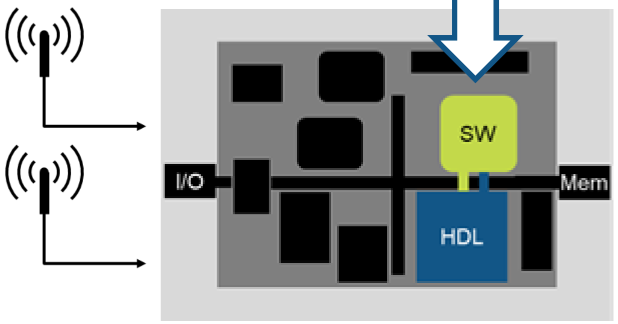
应用:

1. 5G接收机参考应用
2. 自定义OFDM参考应用

5G MIB 恢复参考应用

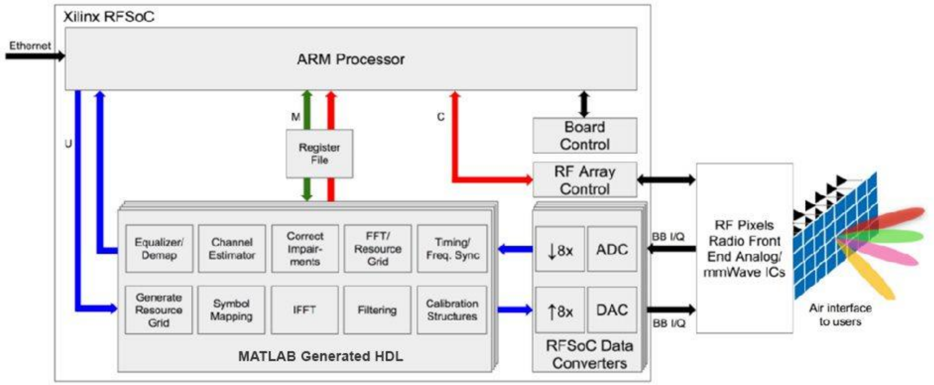






- 广播信道(BCH)解码，BCH包含主信息块(MIB)
- Hardware-proven. Demo shipping in Comms Zynq HSP in R2020b

RF Pixels 基于Zynq RFSoC的数字基带验证毫米波射频电子



数字基带在HDL中实现，用于验证RF Pixels射频前端。

挑战

测试并演示包含专业射频电子硬件和毫米波频谱技术的无线电前端设计

解决方案

使用MATLAB和Simulink实现数字基带，并将其部署到Zynq RFSoC板上进行无线测试

成果

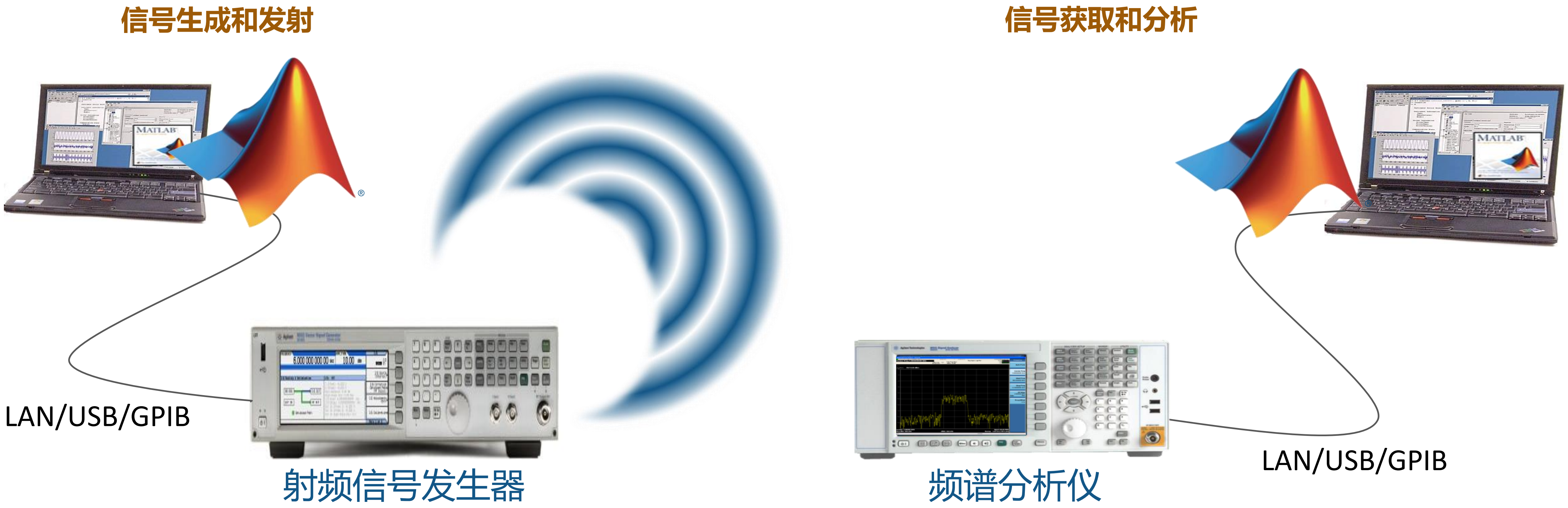
- 工程工作减少了一年或一年以上
- 数字基带实现由单个工程师完成
- 设计迭代从几周减少到几天

“通过修改 Wireless HDL Toolbox 中的 LTE 黄金参考模型，并使用 HDL Coder将其部署到 Zynq UltraScale + RFSoC 硬件板上，我们节省了至少一年的工程师人力——这种方法使我一个人能够完成实现，而不需要雇佣额外的数字工程师。”

- Matthew Weiner, RF Pixels

[Link to technical article]

无线测试: 将设计转移到实验室

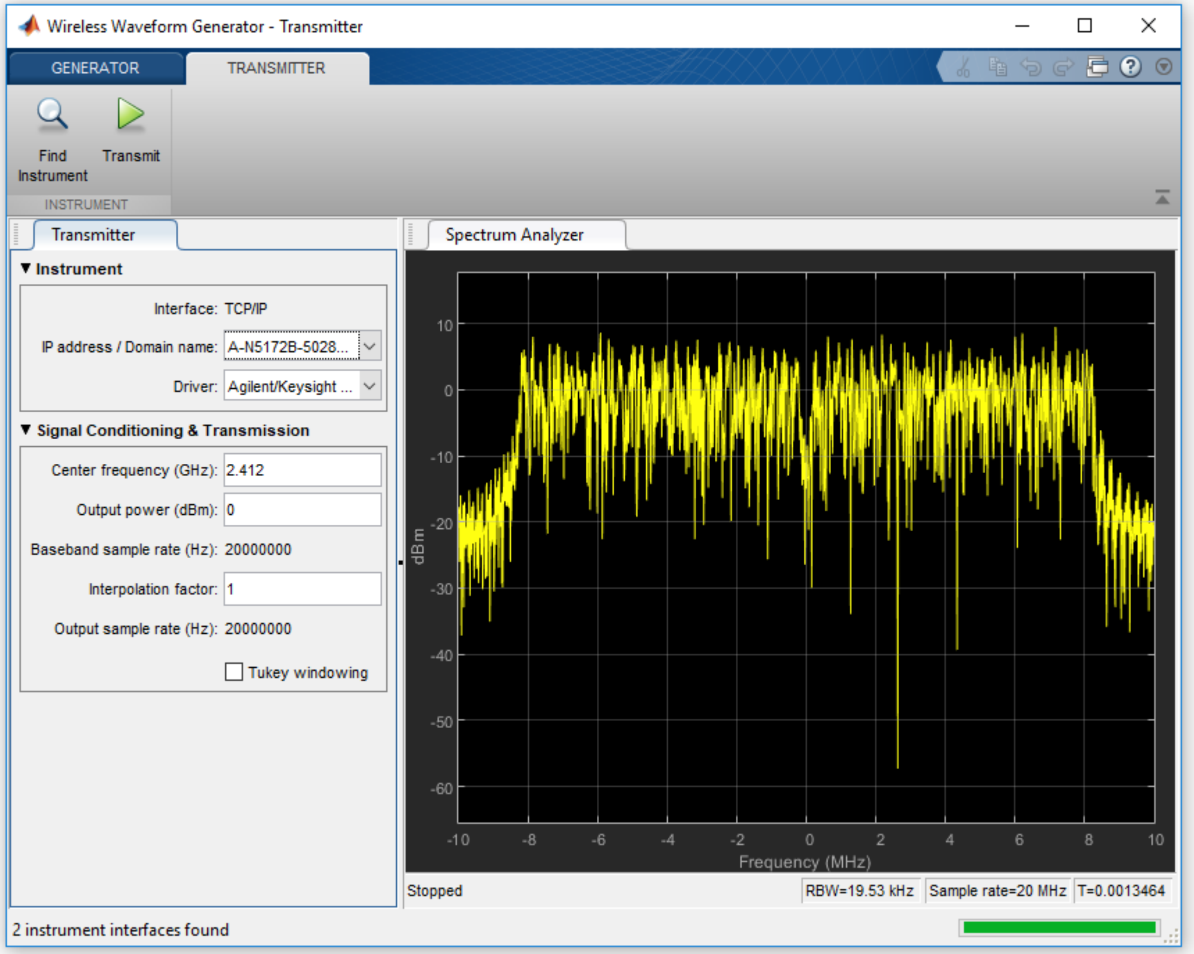


无线测试: 将设计转移到实验室

在无线波形发生器APP中连接射频仪器

使用射频仪器(如Keysight/ Agilent, Rohde & Schwarz)发送无线波形

- 需要仪器控制工具箱
- 自动发现可用的仪器
- 发送/停止无限循环波形
- 可配置传输频率、输出功率和(整数)内插因子



MATLAB和Simulink工具用于无线设计

物理层设计

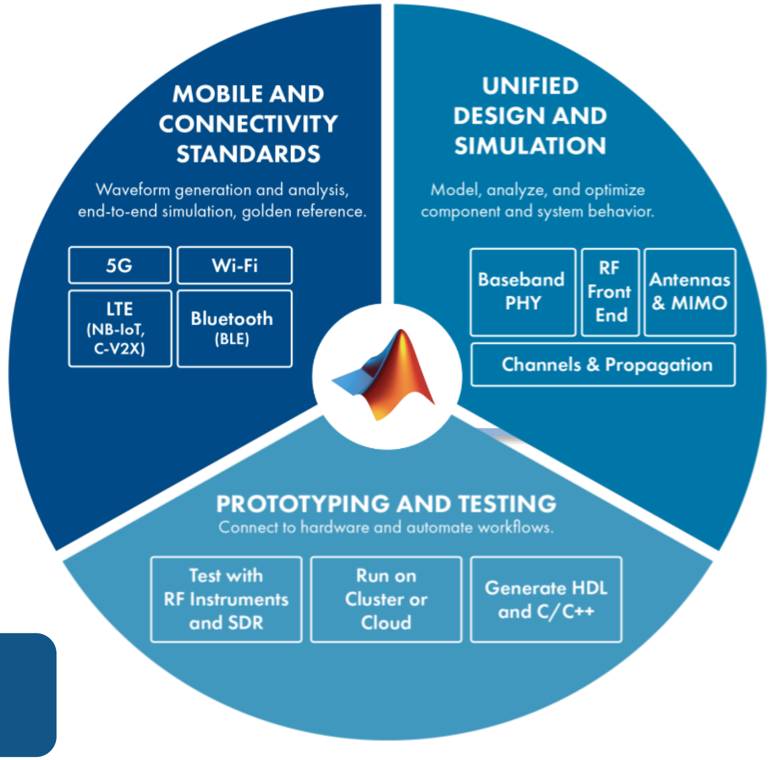
泛链接

Ubiquitous Connectivity

系统工程

复杂性

Design Complexity



部署和验证

效率

Efficient deployment & testing

如何了解更多

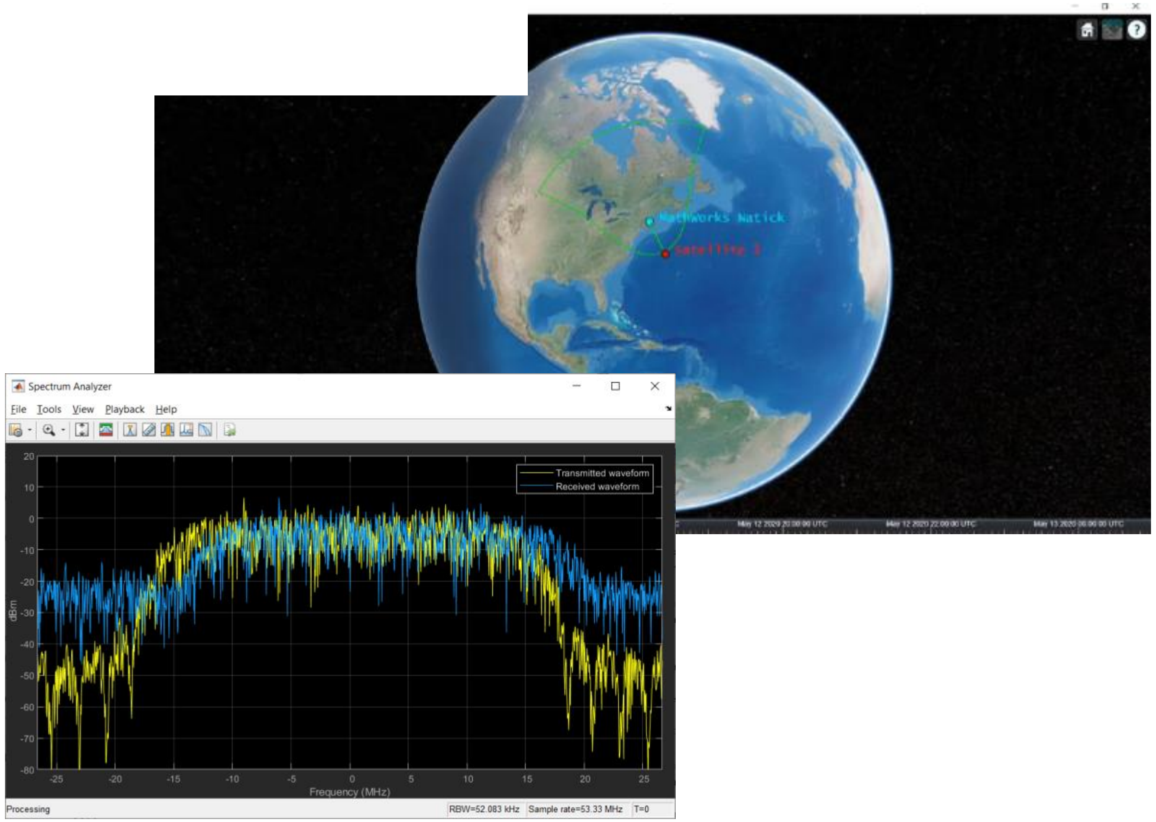
无线通信产品页面

mathworks.com/products/

- 5G
- LTE
- WLAN
- Satellite-communications

无线通信解决方案页面

mathworks.com/solutions/wireless-communications.html



MATLAB EXPO 2021

Thank you

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