GSMA Thrive

毫米波的测试之道

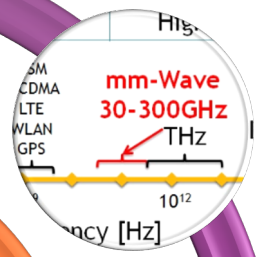
文竹

是德科技实验室首席技术总监

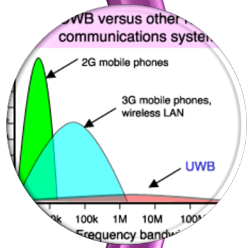
KEYSIGHT TECHNOLOGIES

毫米波测试，我们应该关注什么？

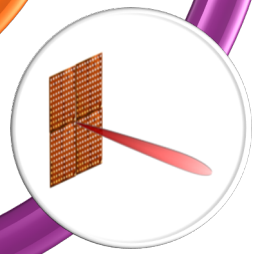
毫米波测试



高频率



大带宽



大规模天线阵&波束成形

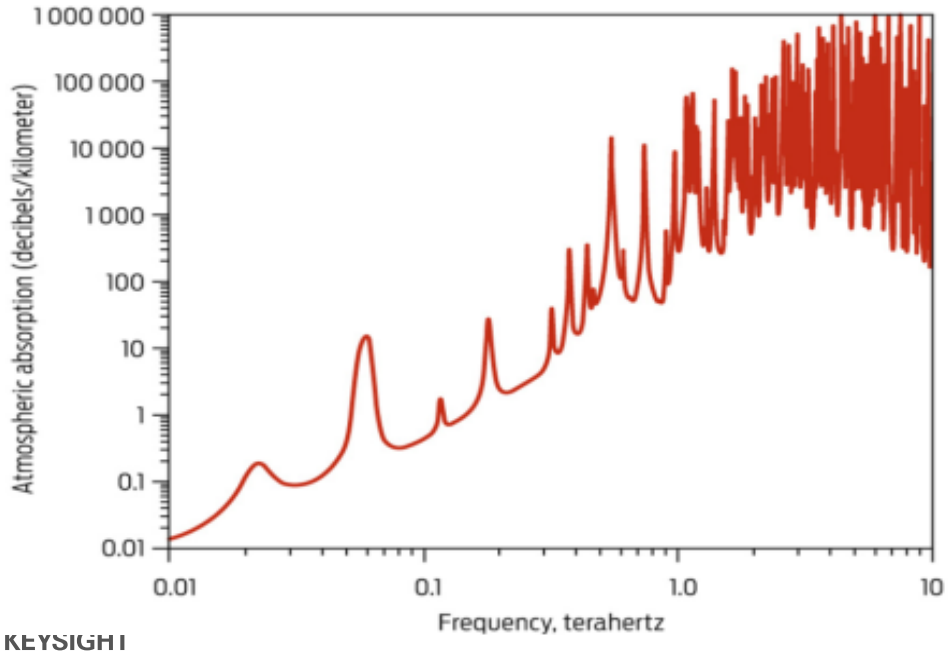
- 毫米波无线信道
- 毫米波射频性能
- 毫米波OTA测试
- 毫米波路径损耗
- 毫米波测试成本

关注点一：毫米波无线信道

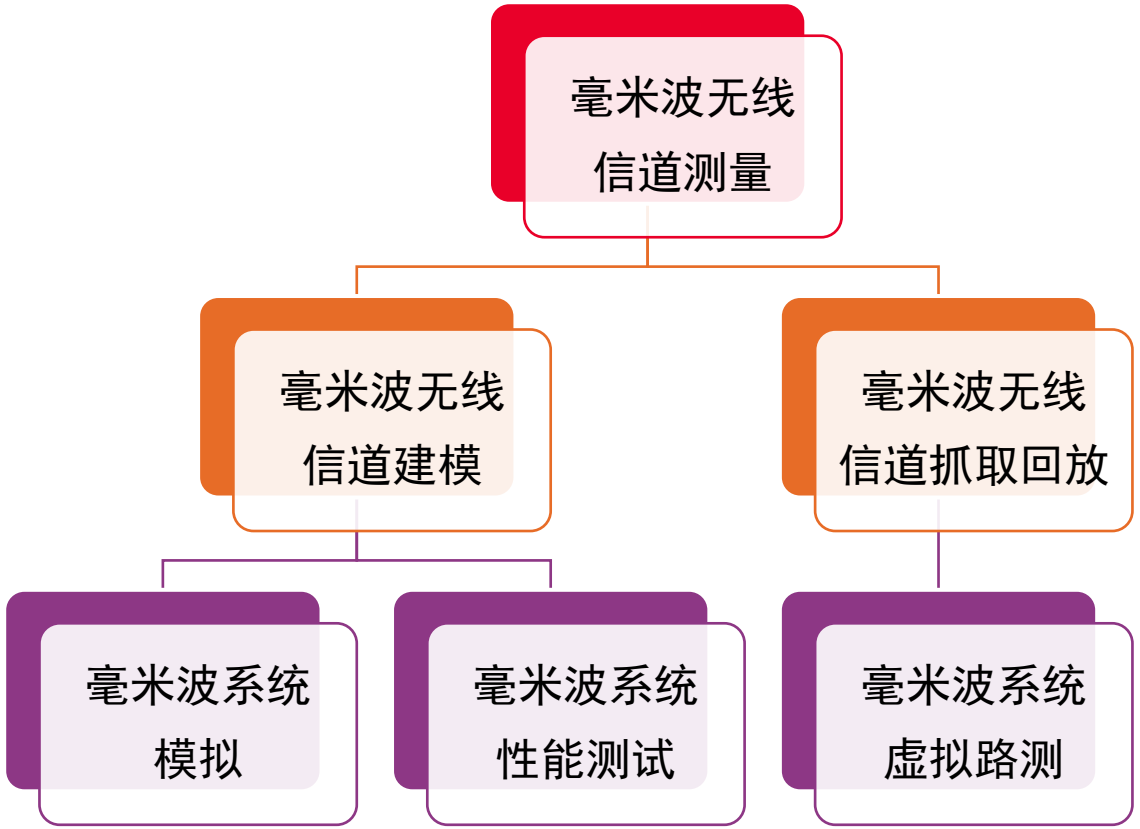
毫米波无线信道

- 绕射能力差
- 散射路径数量少
- 大气衰落、雨衰严重

3GPP TR38.901
0.5~100GHz信道模型



毫米波无线信道研究

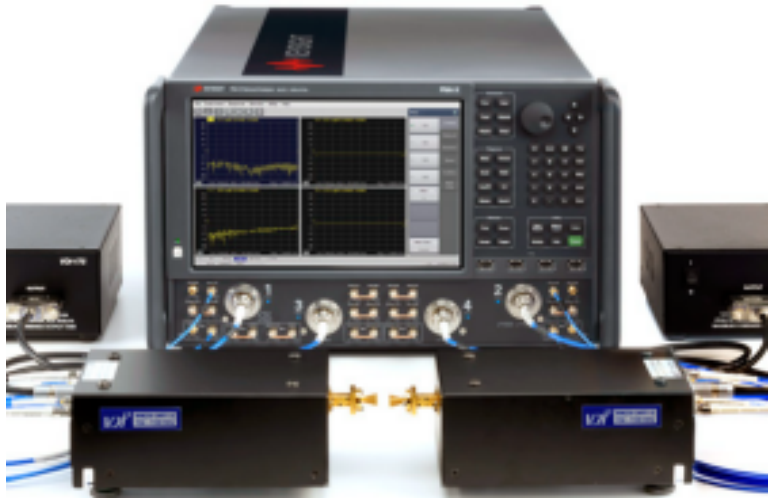


毫米波无线信道的测量

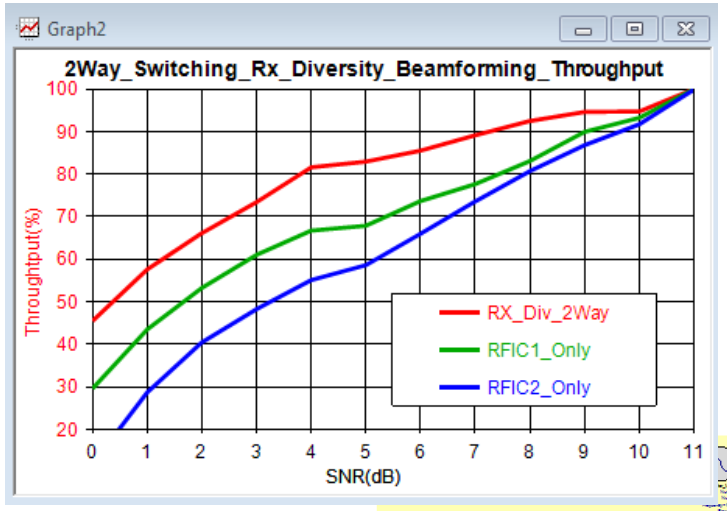
MMWAVE CHANNEL SOUNDING

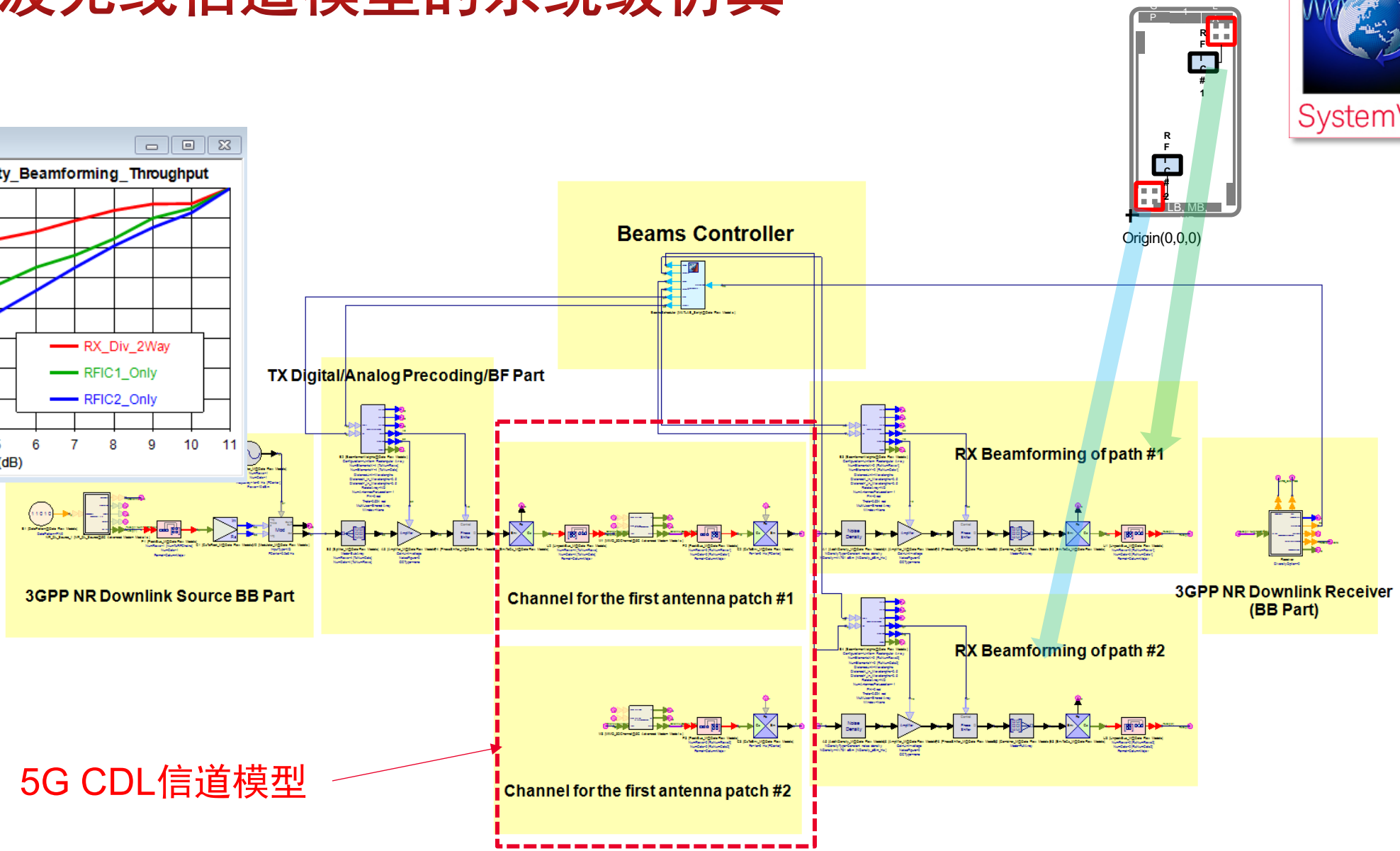
- **时域信道测量系统**
  - 基于波形时域自相关的方法测量信道时域冲击响应
  - ✓测量速度快
  - ✓测量距离长
  - x 系统复杂，宽带信号生成、采样设备成本高

- **频域信道测量系统**
  - 基于扫频的方法测量信道频域特性
  - ✓频率范围宽
  - ✓测量灵敏度高
  - x 测量速度慢
  - x 测量距离短



基于毫米波无线信道模型的系统级仿真

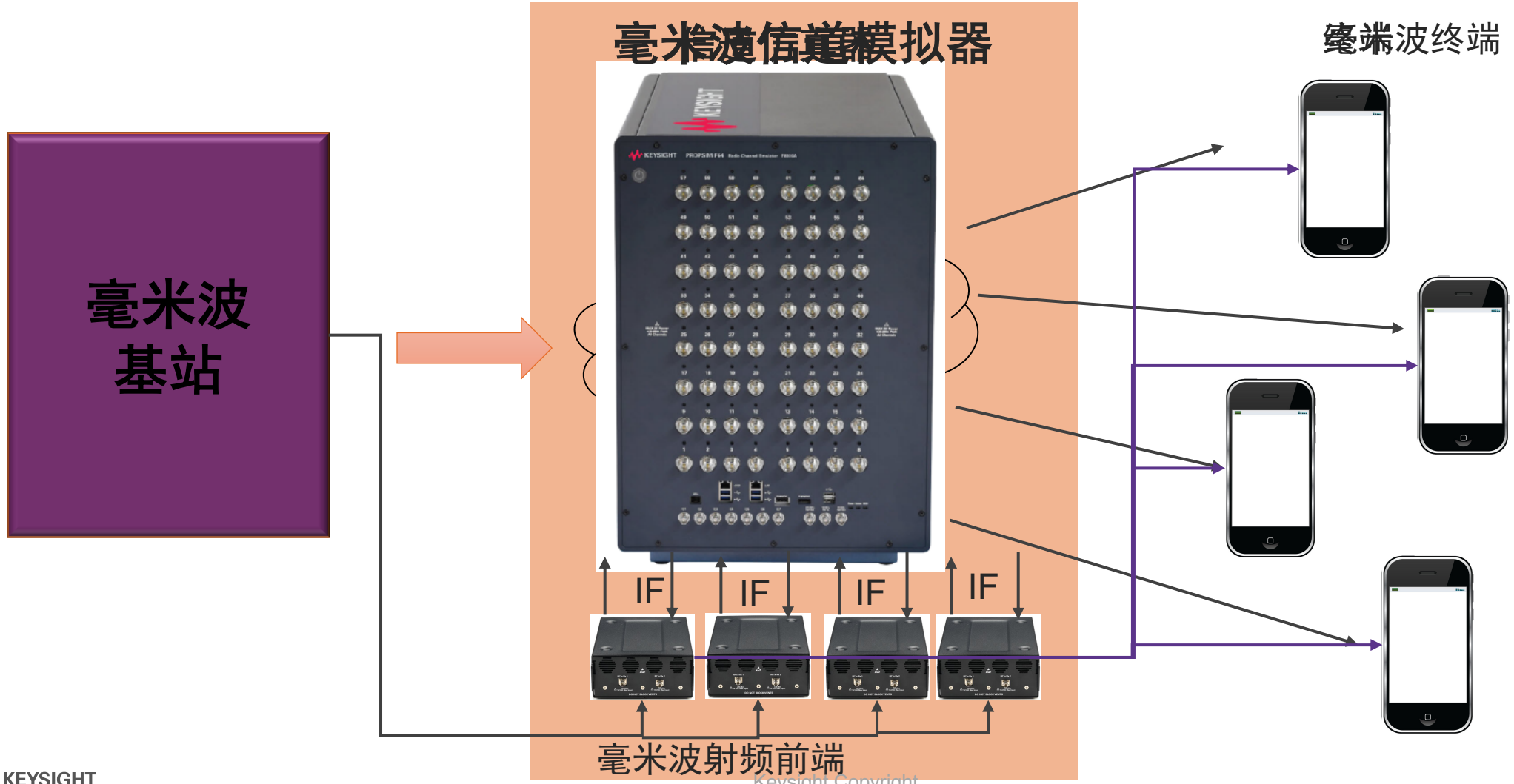




5G CDL信道模型

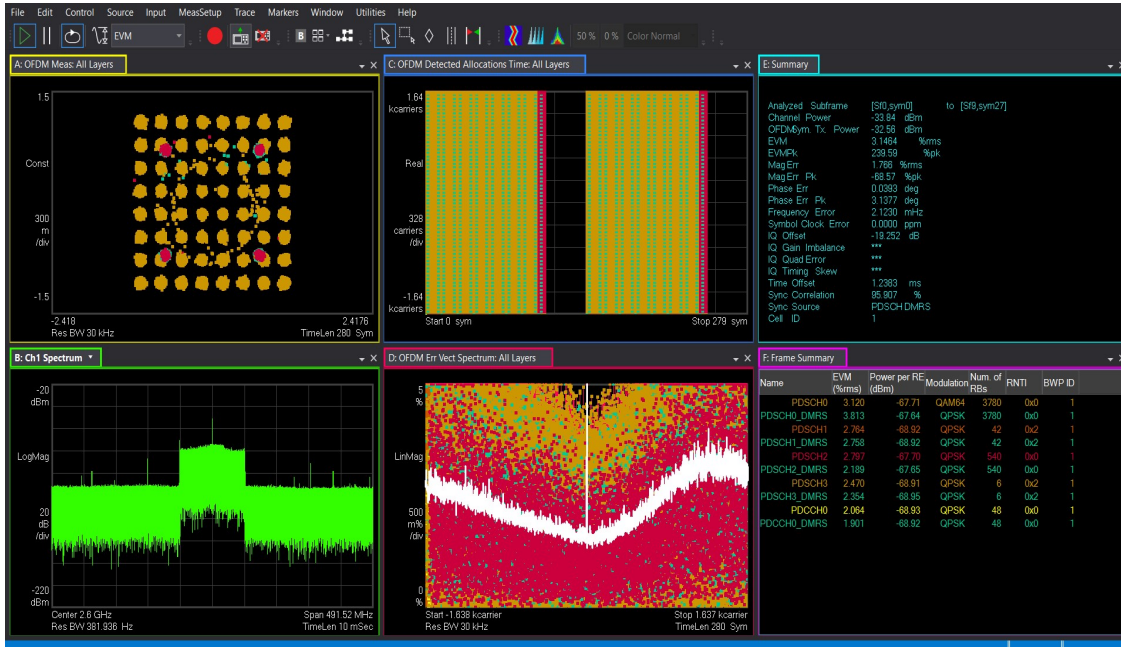
毫米波无线信道的模拟

MMWAVE CHANEL EMULATOR



关注点二：毫米波系统的射频性能

- BW 100MHz, 64QAM @2.6GHz, EVM 2.9%

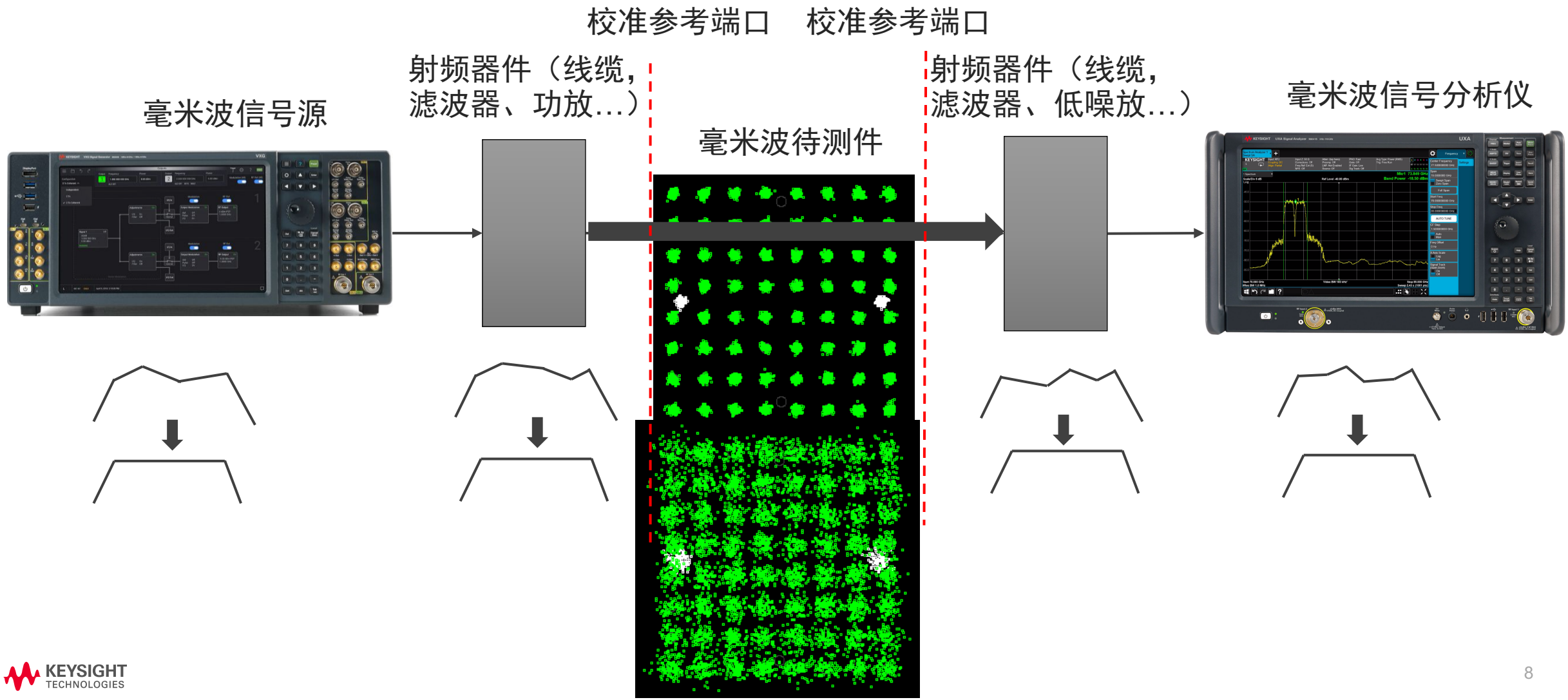


- BW 400MHz, 64QAM @26GHz, EVM 9%

*上述结果仅为举例，并不代表仪表的真实性能

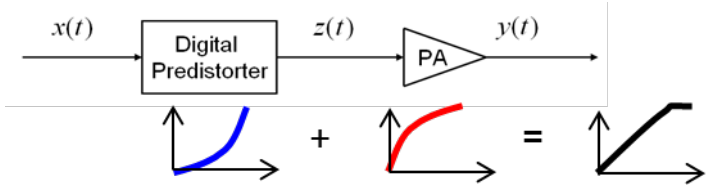
提升毫米波射频系统性能 (I)

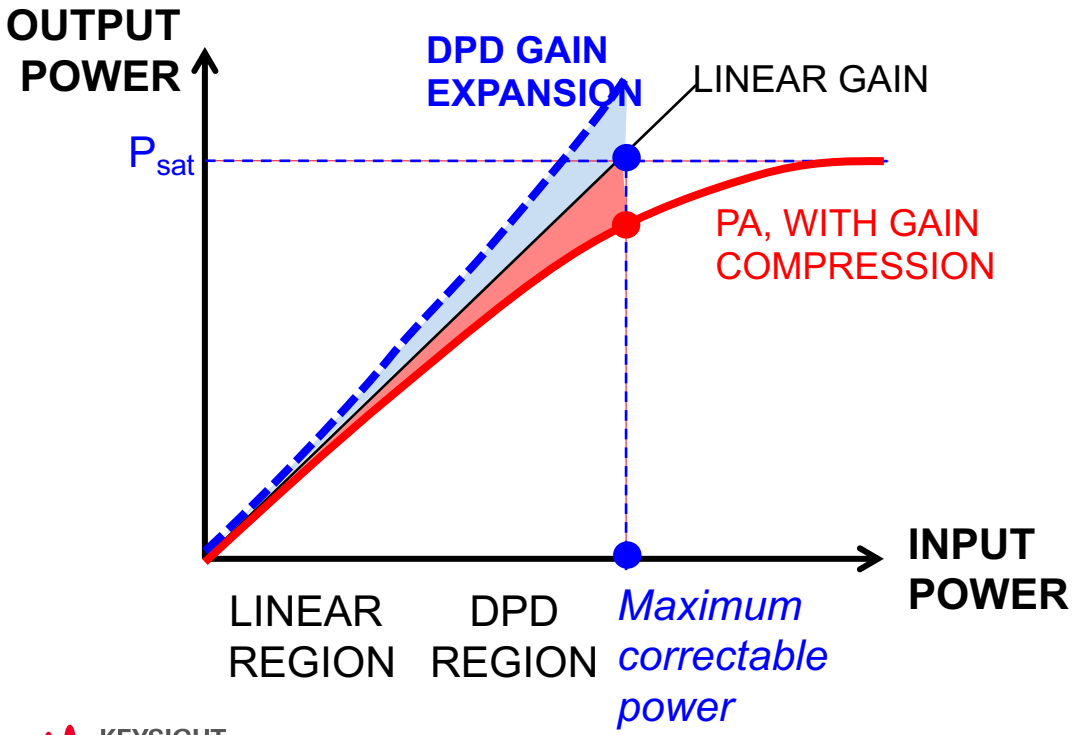
系统的线性校准



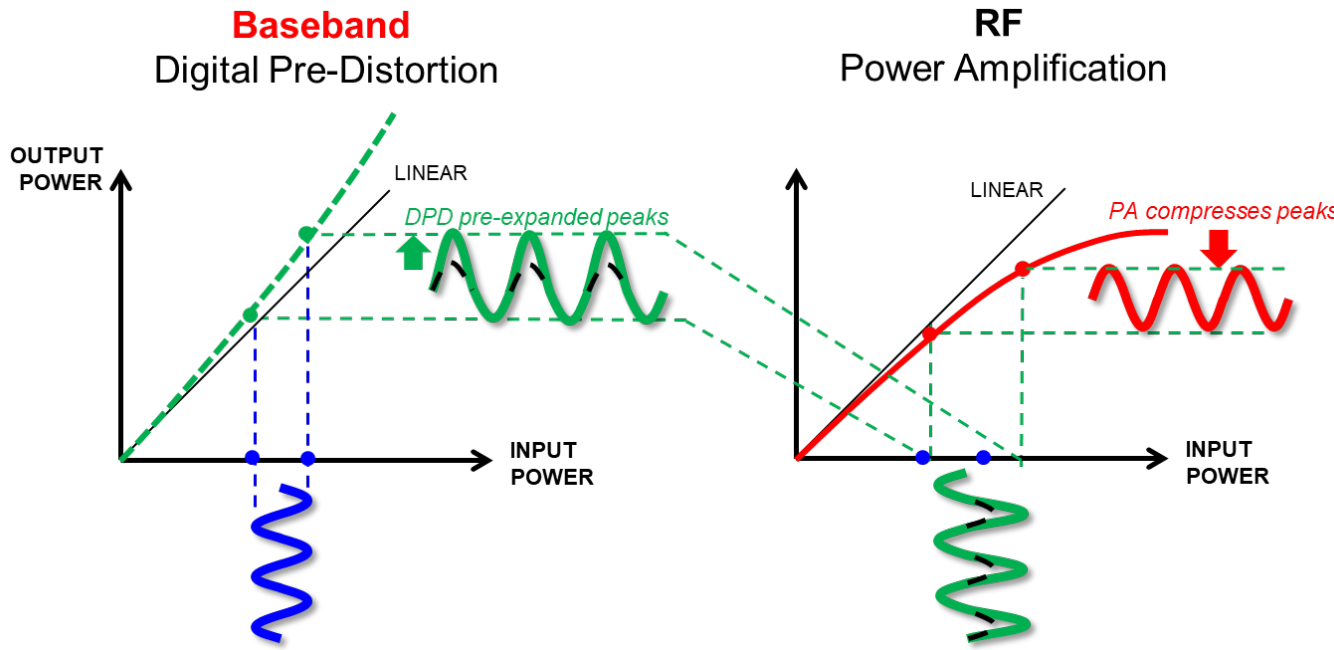
提升毫米波射频系统性能 (II)

系统的非线性校准——DPD





在一定功率范围内，为射频信号提供线性增益



关注点三：毫米波系统的OTA测试

对于低频段系统，OTA并非强制要求

iPhone4“天线门”

对于毫米波系统，OTA测试从“可选项”变成“必选项”

- 毫米波天线尺寸减小
- 射频与天线高度集成，射频测试接口消失
- 波束成形等新测试需求

毫米波射频性能的OTA测试

OTA射频性能测试指标

发射机射频指标*

AAS BS requirement		OTA requirement type	Coverage range	Notes
Base station output power	Output power accuracy for EIRP	Directional requirement	OTA peak directions set	Output power accuracy for EIRP requirement is already included as a core requirement in TS 37.105.
	Output power accuracy for TRP	TRP	n/a	
Output power dynamics		Directional requirement	OTA peak directions set	
Transmit ON/OFF power		FFS	FFS	
Frequency Error		Directional requirement	OTA coverage range	
Time Alignment Error		Directional requirement	OTA coverage range	
Modulation Quality (EVM)		Directional requirement	OTA coverage range	
Unwanted emissions		TRP	n/a	
Adjacent Channel Leakage Radio (ACLR)		TRP	n/a	
Transmitter intermodulation		FFS	FFS	
…		…	…	

接收机射频指标*

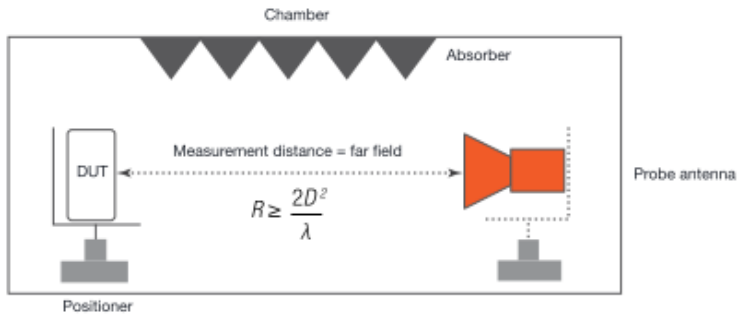
AAS BS requirement	OTA requirement type	Coverage range	Notes
Minimum EIS	Single direction		
Dynamic range			
In-band selectivity and blocking			
Out-of-band blocking			
Receiver spurious emissions	TRP		
Receiver intermodulation			
In-channel selectivity			

* 3GPP TS38.104 AAS Radiated Performance Requirements Release 15

OTA射频性能测试系统

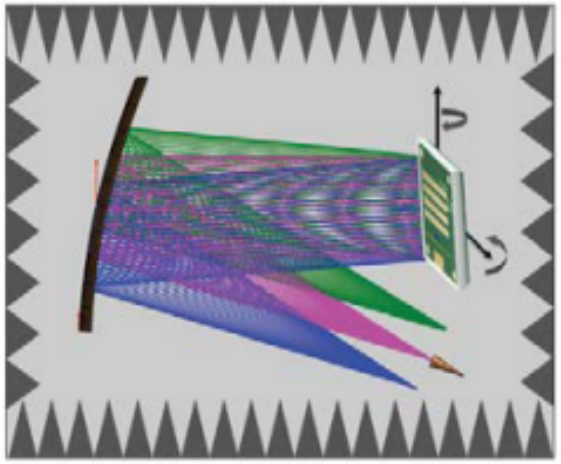
直接远场（DFF）

- 测试距离远（$\geq \frac{2D^2}{\lambda}$）
- 空间要求大成本高
- 测量动态范围小
- 测量结果无需变换



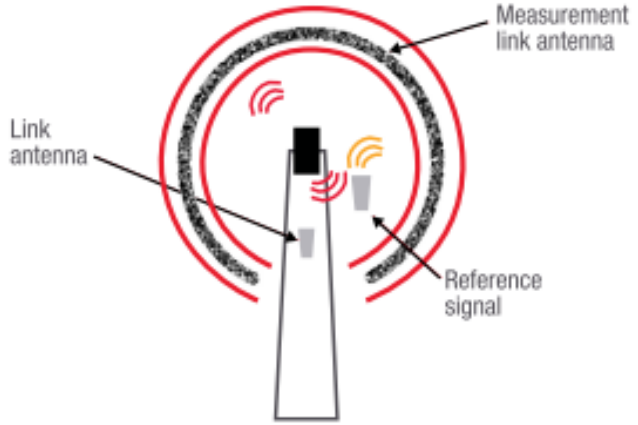
紧缩场（CATR）

- 测试距离较小
- 反射面精度要求高
- 动态范围较好
- 测量结果无需变换



近场转换（NFTF）

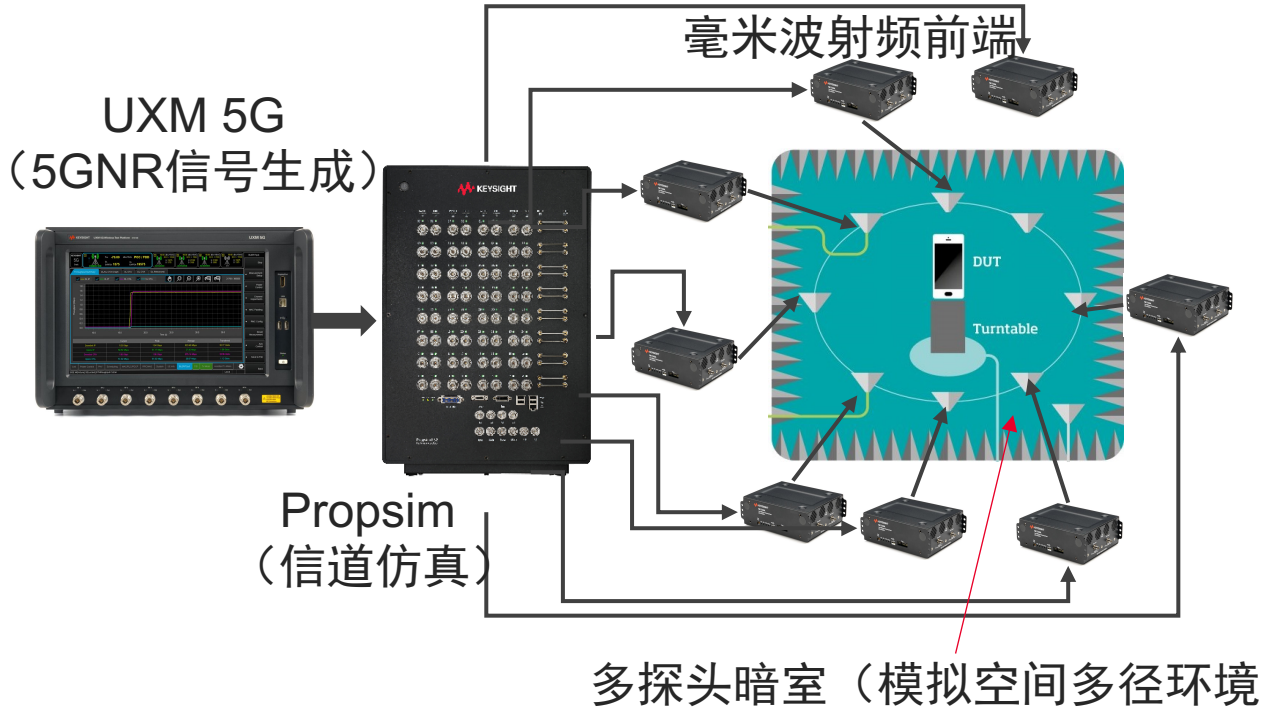
- 测试距离小
- 空间要求小
- 需要近远场变换，是否支持宽带信号测量有待研究
- 能否测量EIS有待研究



毫米波系统性能的 OTA测试

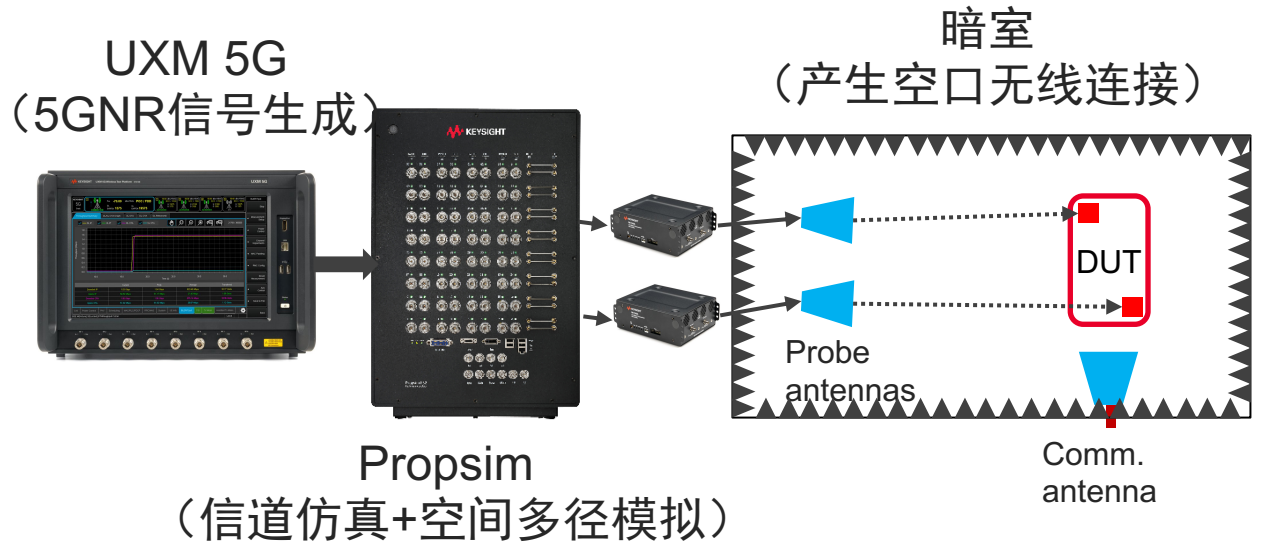
多探头法（MPAC）

- 3GPP /CTIA reference method



辐射两步法（RTS）

- 3GPP/CTIA harmonic method



关注点四：毫米波路径损耗

毫米波高路径损耗影响OTA测试性能

- 自由空间路径损耗

$$P_{Rx} = P_{Tx} + G_{Tx} + G_{Rx} - 20log_{10}(4\pi r) - \boxed{20log_{10}(\frac{f}{c})}$$

Frequency

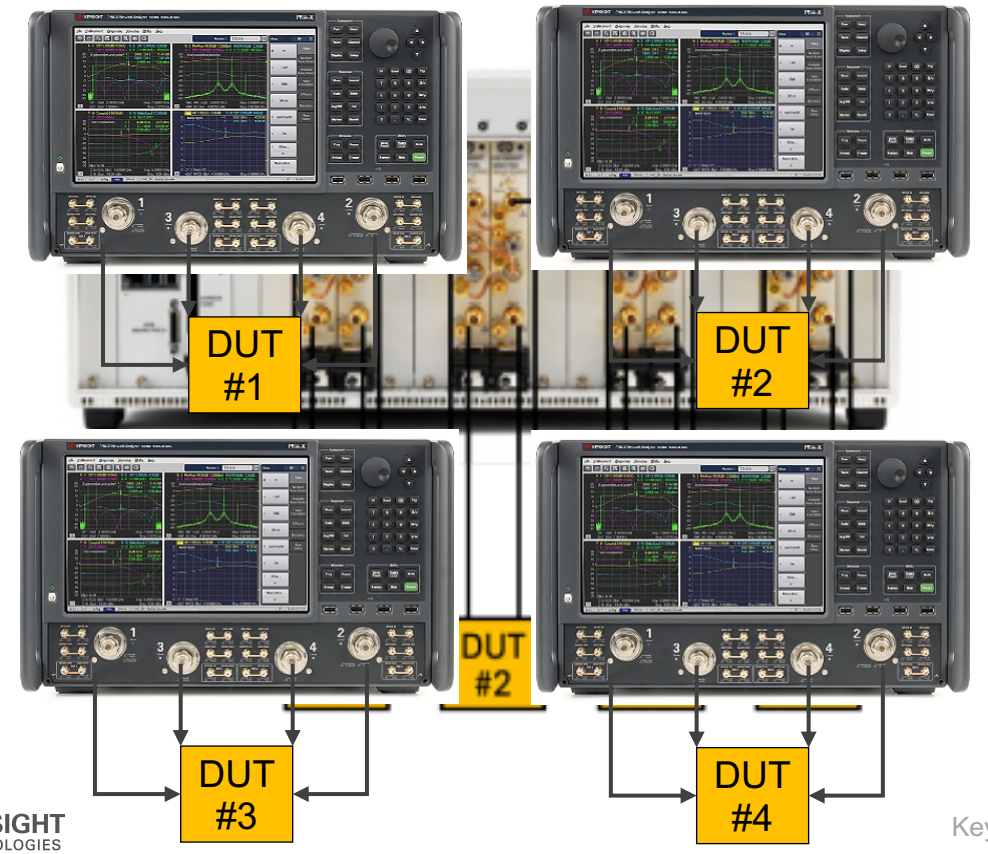
- 26GHz的路损较2.6GHz路损高20dB！！

怎么办？减小OTA测试距离

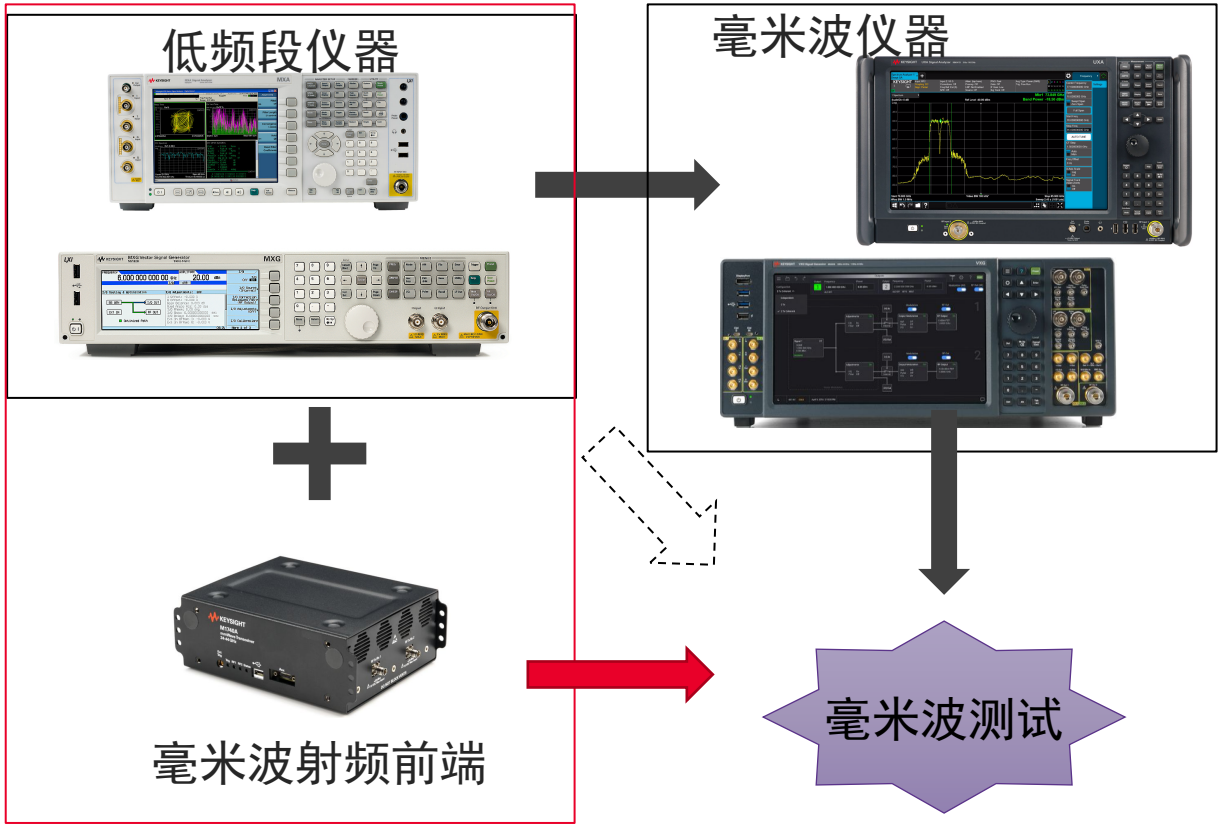
- 在3GPP RAN4 Study Item “Study on enhanced test methods for FR2 UEs” (SID: RP-192322)中
  - The 5G-NR FR2 Transmitter and Receiver Testability issues which TE vendors have highlighted from the very beginning of NR FR2
  - “Some test cases require up to 34 dB and 30.4 dB relaxation for DL and UL, respectively”
  - 目标1：Define test methodology for high DL power and low UL power test cases
- 初步研究表明，利用近场OTA测试方法，可以将测试距离从1米缩短到22厘米，减小14dB路径损耗

关注点五：毫米波测试成本

- 秘籍1：使用模块化多端口仪器降低单通道测试成本



- 秘籍2：使用低频段测试仪器+毫米波射频前端

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