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PCB阻抗及测试案例分享

一博经典案例2023

一博科技-SI研究部

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通道&性能描述

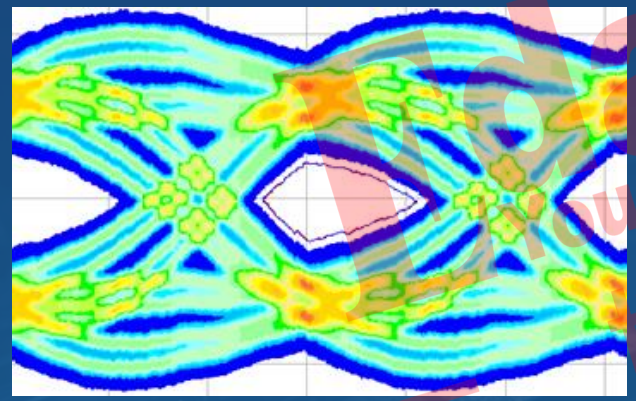
有源&无源

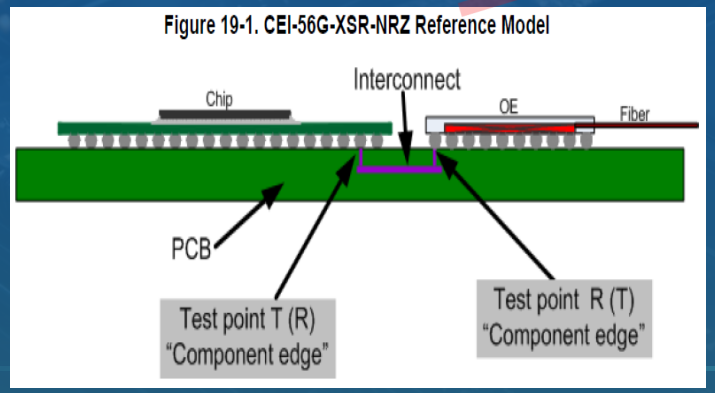
TX芯片+ PCB+RX芯片

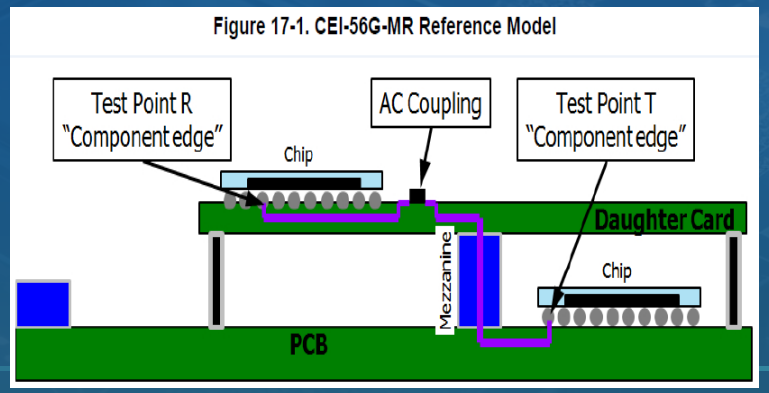
TX芯片+ PCB+ 连接器+PCB+RX芯片

TX芯片+ PCB+ 连接器+背板/铜缆/光纤+连接器+PCB+RX芯片

TX芯片+ PCB+FPC（软板）+ PCB+RX芯片

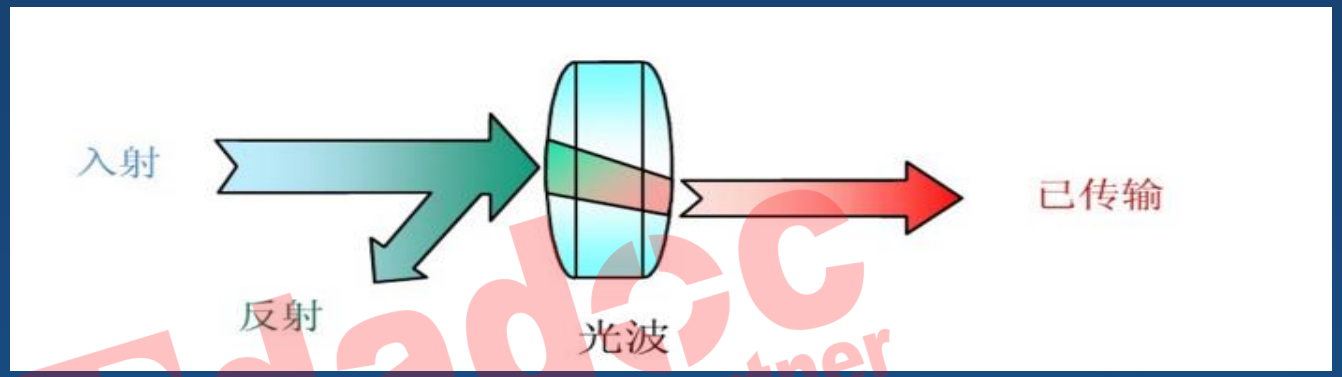






信号在通道中的传输

光：



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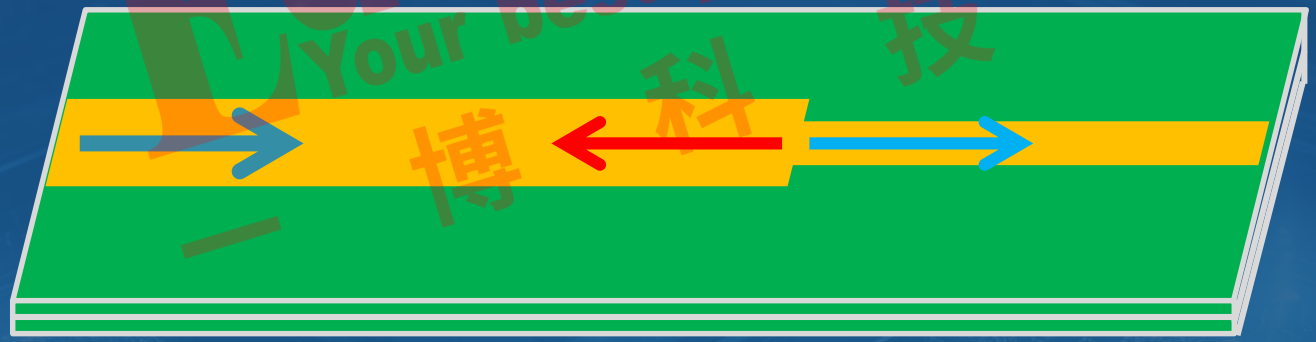


如何描述通道的好坏?

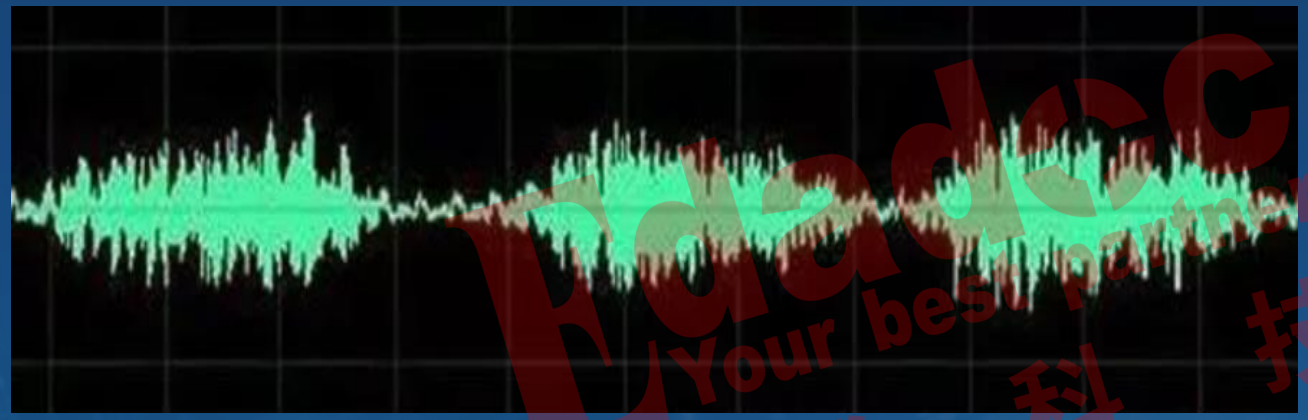
量化：Interconnect/Channel与一个标准的入射波相互作用，产生一个响应信号

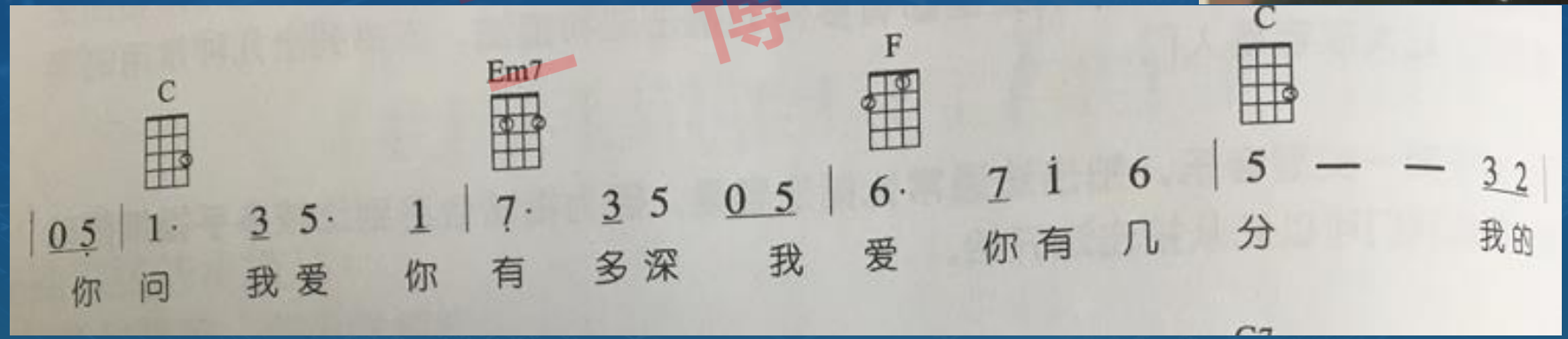
- 在时域描述：阶跃信号
- 在频域描述：正弦波

时域vs频域

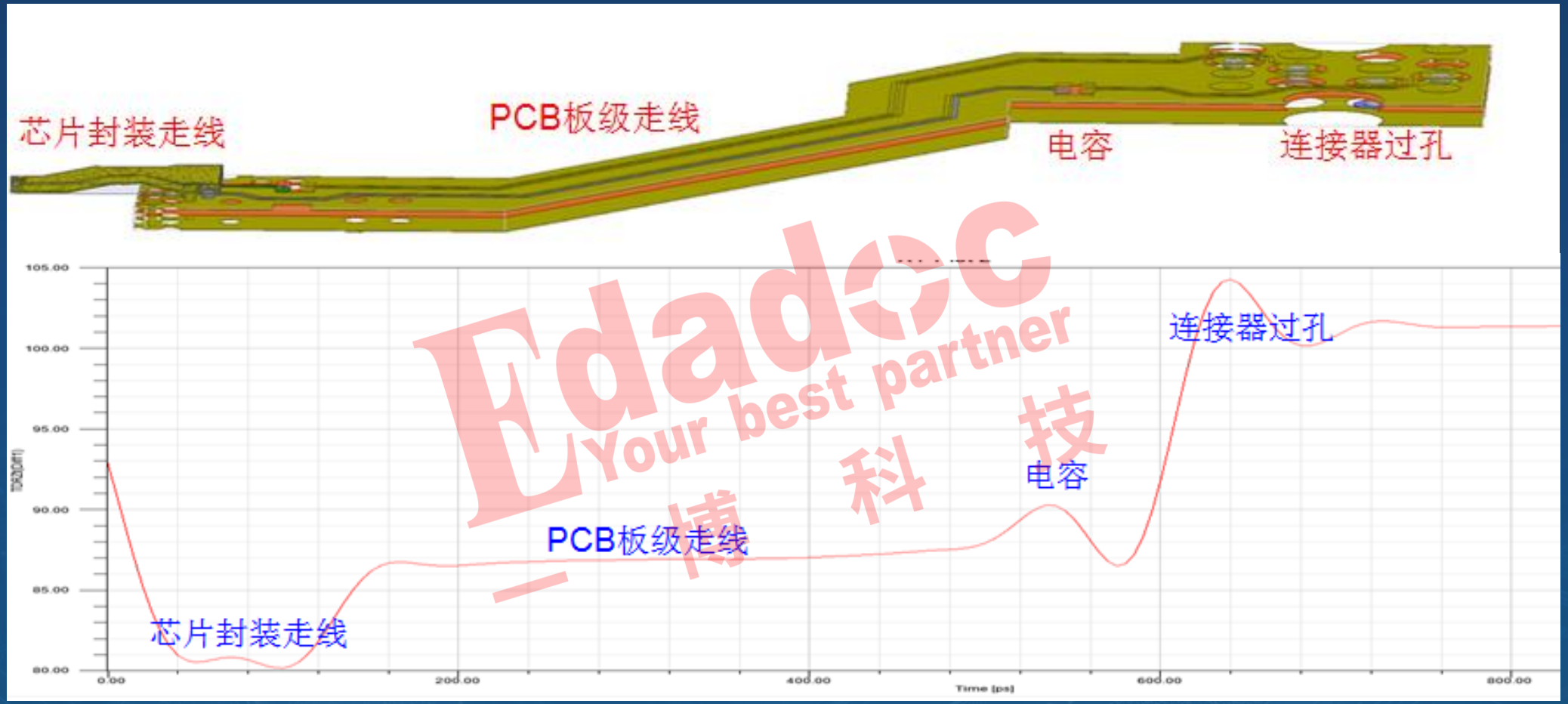
时域：随着时间变化

频域：静止、更直观、更好分析





通道在时域的量化：阻抗



0ps → 200ps → 400ps → 600ps →

时域与频域变换

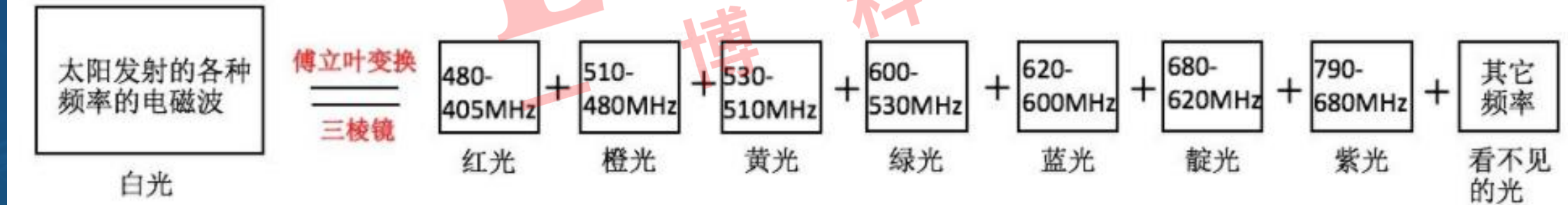
时域：是真实世界，是唯一实际存在的域

频域：不是真实的，只是一个遵循特定规则的数学构造

傅立叶变换

时域 ⇄ 频域

傅立叶逆变换



通道在频域的量化：S参数

在激励-响应波形中，每一种通道都可以用S参数来描述，比如R/C/L、trace、PKG、Connector、cable

在S参数中包含了通道的特性：阻抗、串扰、衰减

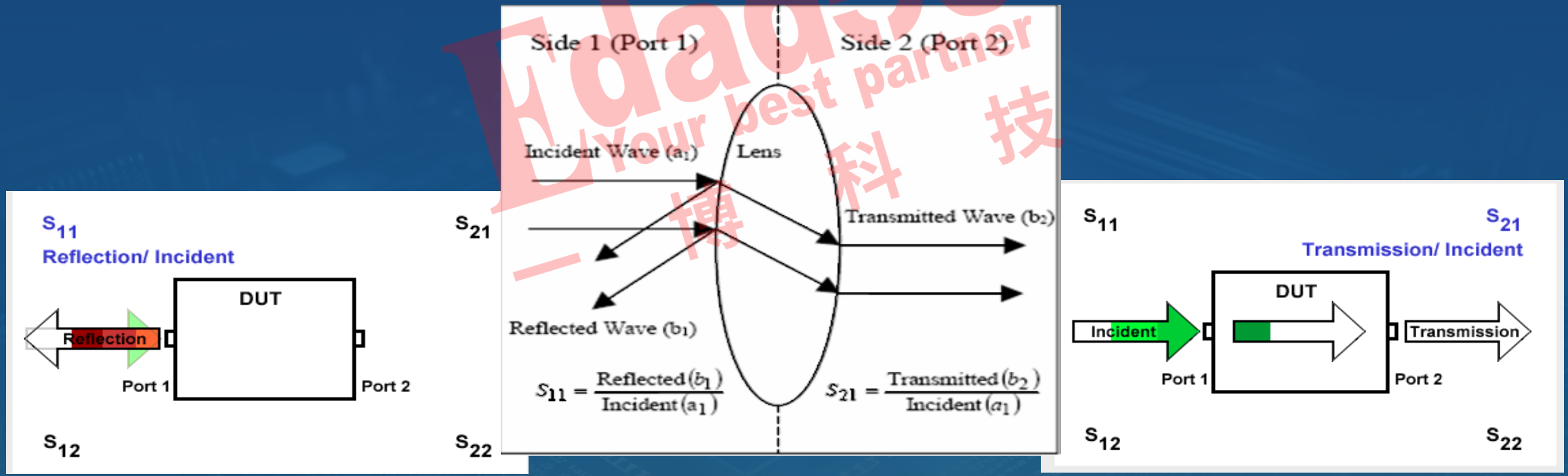
- 端口

S参数的定义

- Sij=输出端口i的正弦波/输入端口j的正弦波

➢ 幅度S(dB)=20log(输出端口的正弦波幅值/输入端口的正弦波幅值)

➢ 相位S=输出正弦波相位-输入正弦波相位



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阻抗&反射的影响

有源测试 vs.无源测试

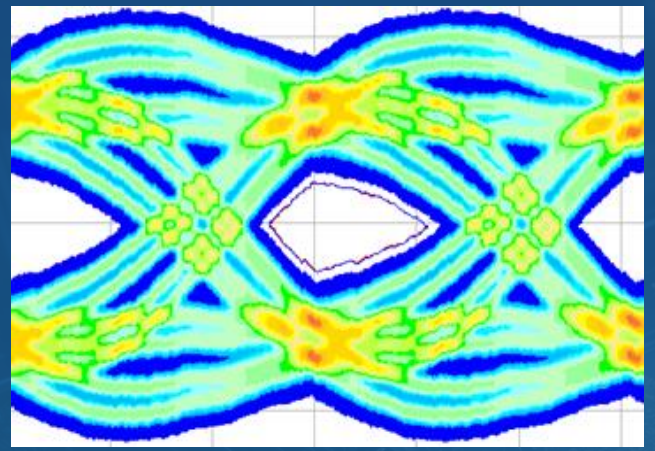
有源测试：芯片+通道（PCB、连接器、cable）

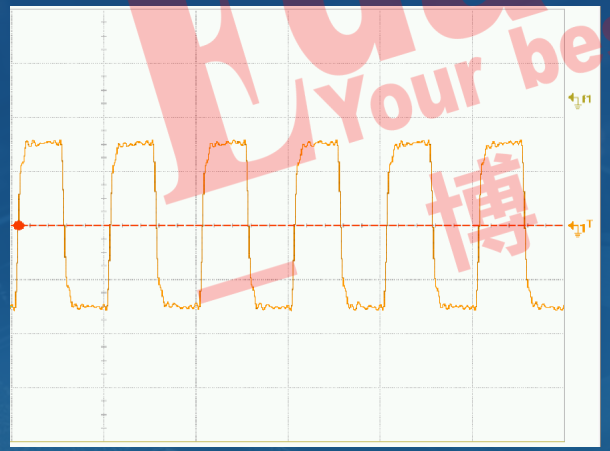
——单板上电带芯片，眼图、波形、时序、误码率、抖动容限……

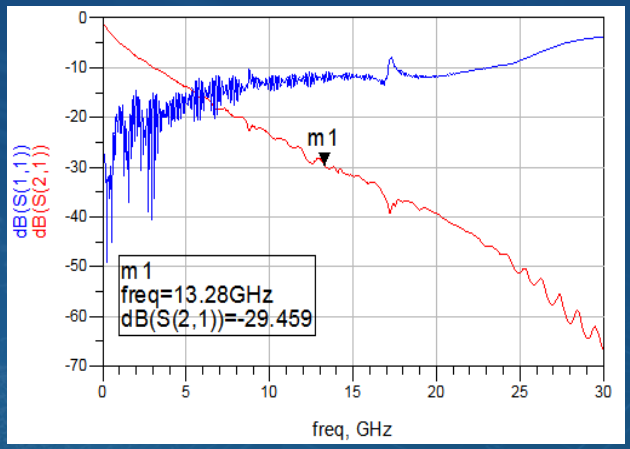
无源测试：通道

——单板不上电，阻抗、S参数（插入损耗、回波损耗/驻波比、串扰）、skew……

通道是影响信号性能最重要的因素，所以各种高速接口协议对无源通道有明确的要求

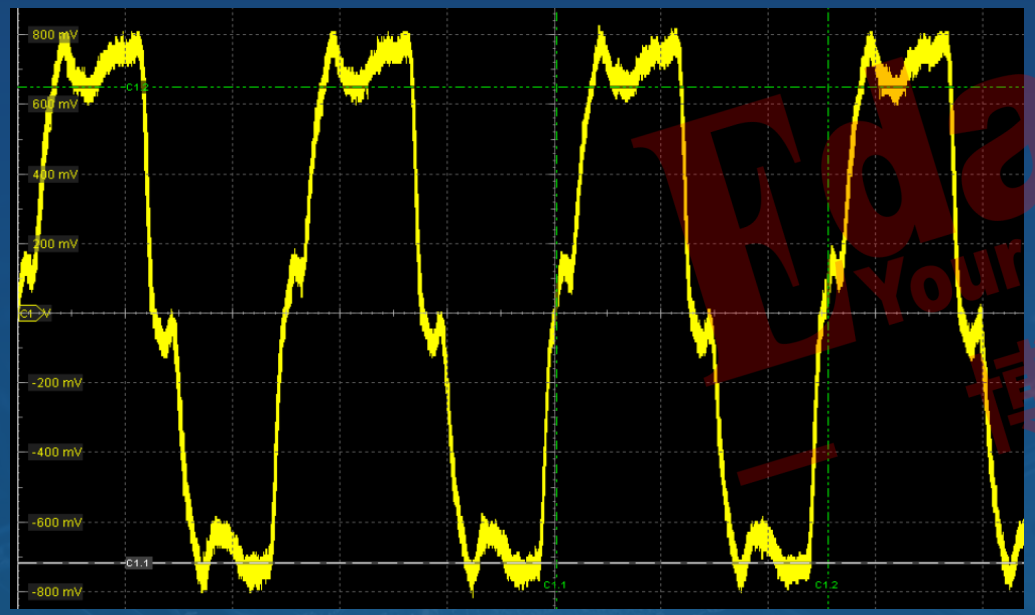


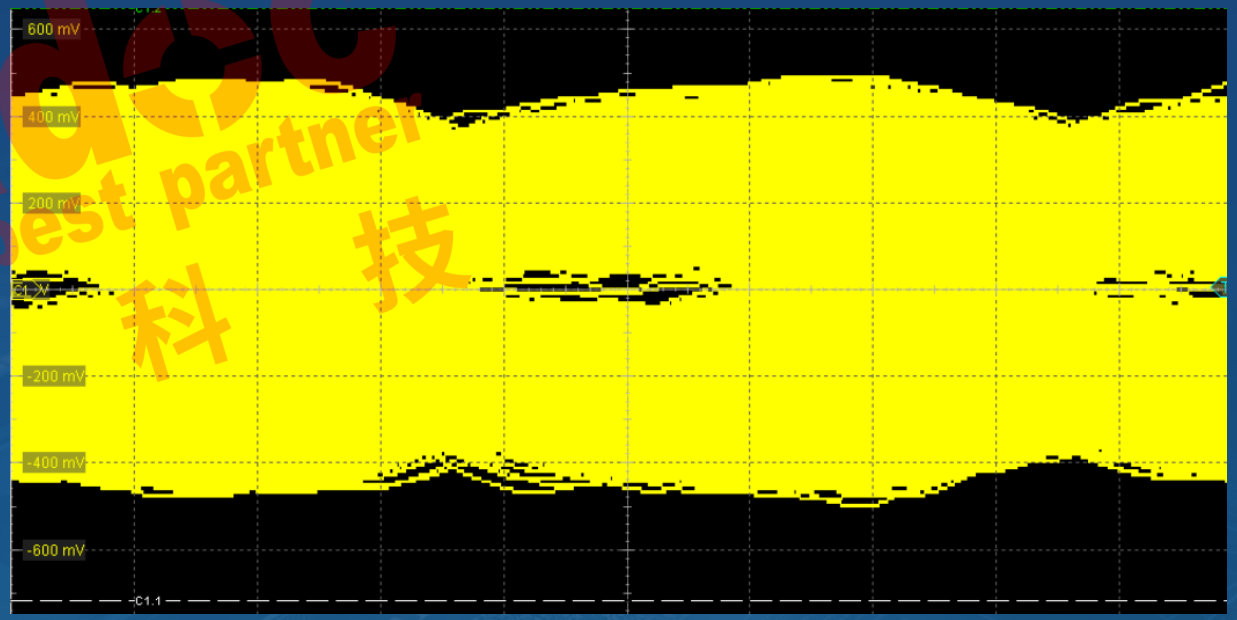




反射的影响

- 波形上过冲、非单调（台阶、回沟）、噪声、纹波、眼图闭合、误码率过高……





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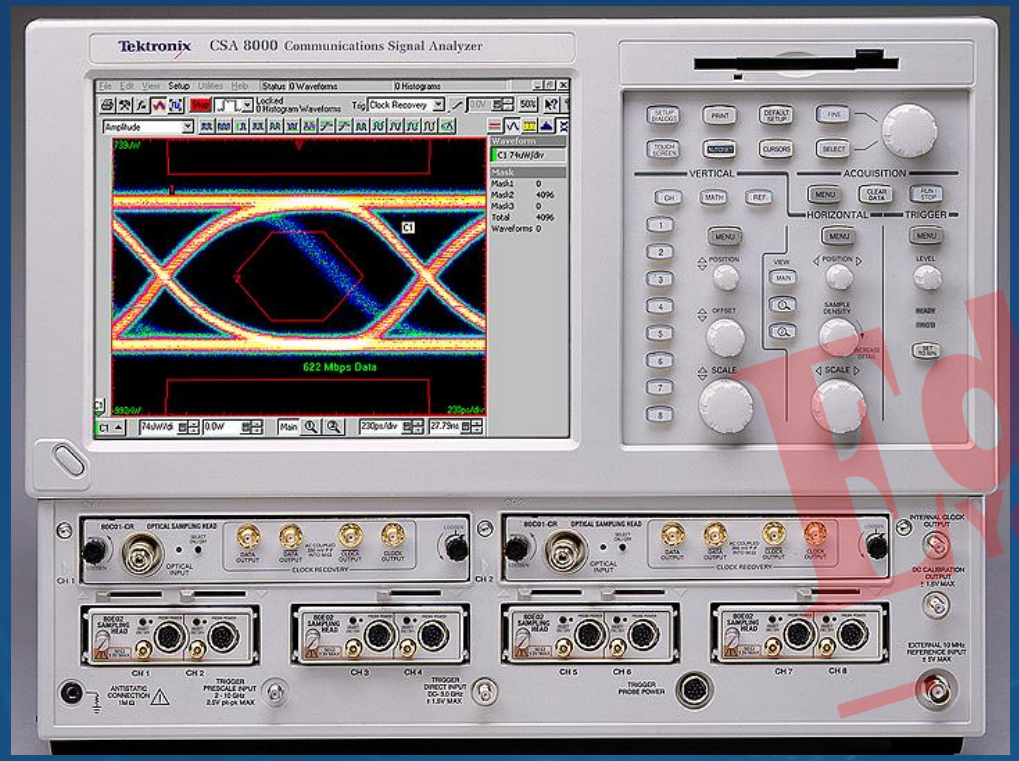
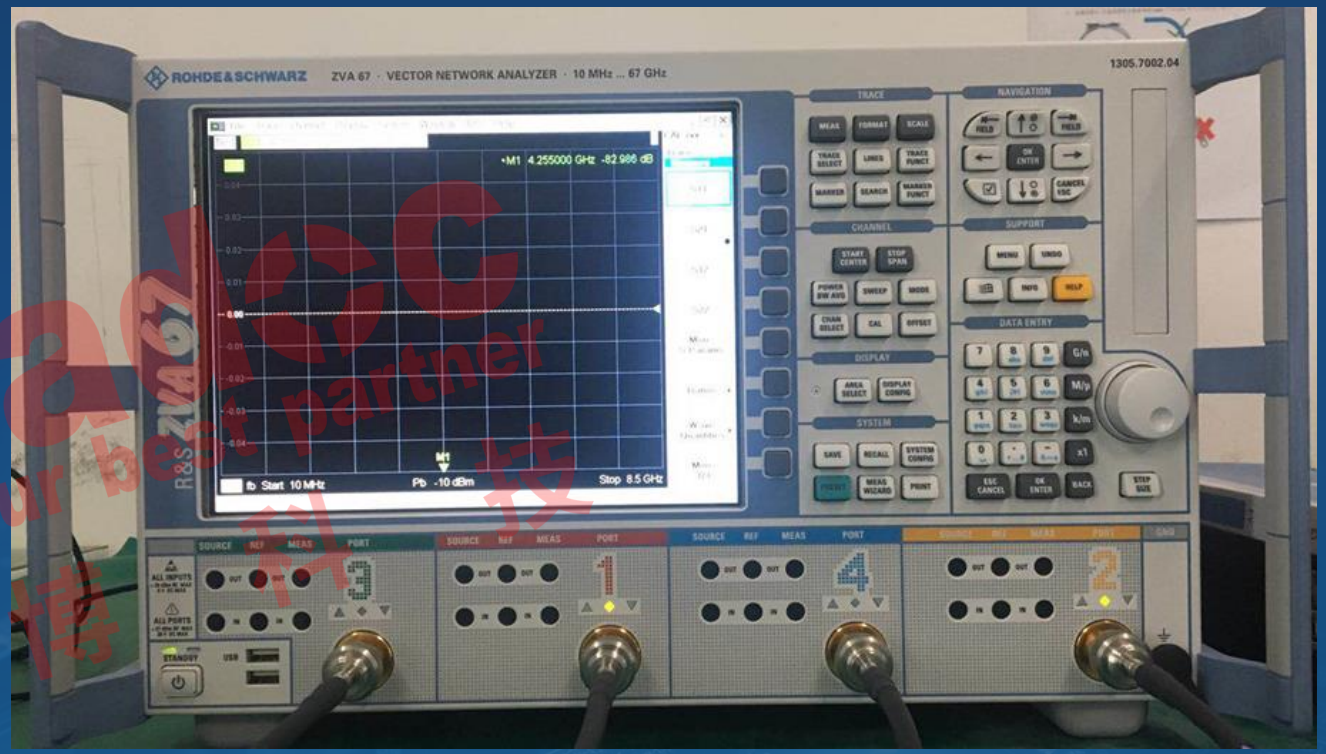
用矢网测阻抗

为什么可以用矢网测阻抗



采样示波器+ TDR模块

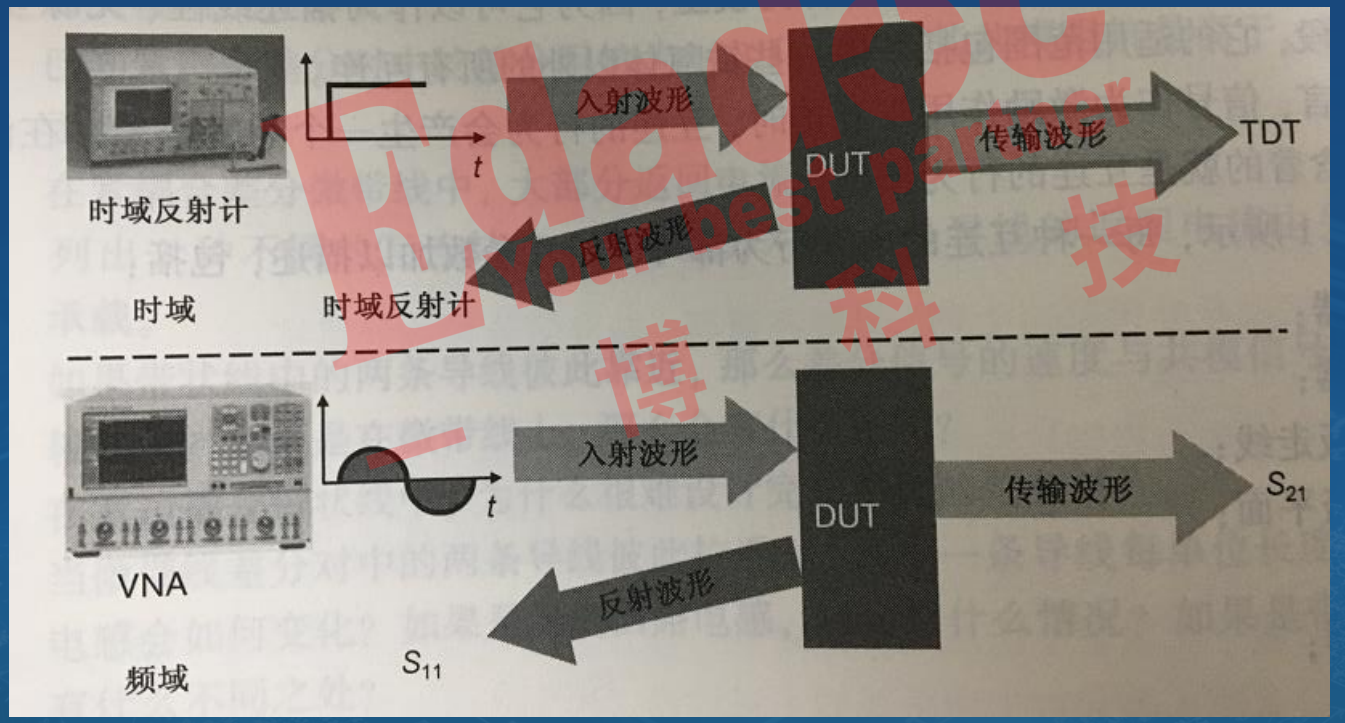


矢量网络分析仪

时域测量vs.频域测量

- TDR: Time Domain Reflect,一个阶跃波
- VNA：Vector Network Analyzer，各种频率的正弦波

矢量：正弦波的幅度和相位都要被测量

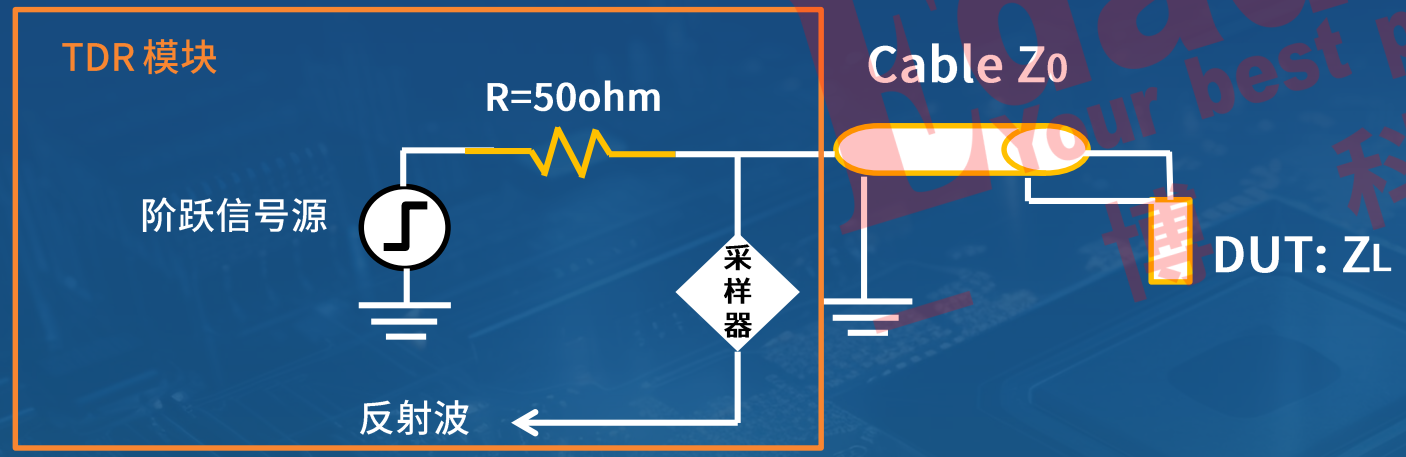


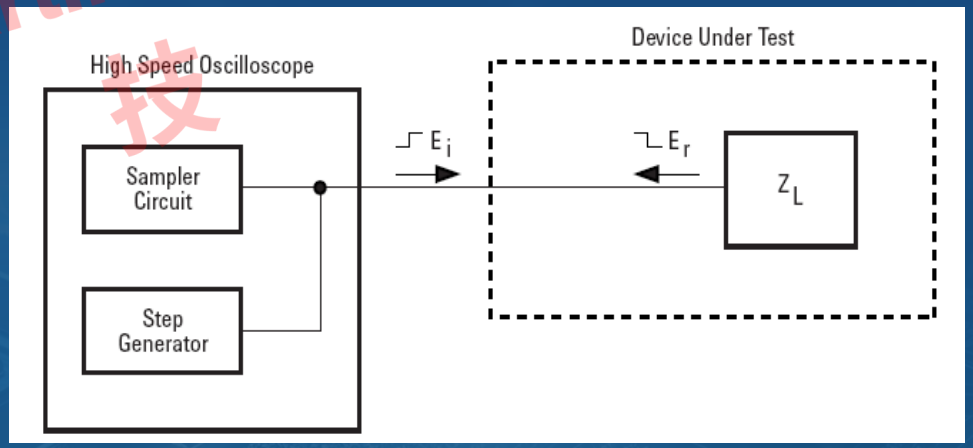
时域反射仪测试的原理

- TDR: Time Domain Reflection 时域反射仪

$$\rho = \frac{V_{反射波}}{V_{入射波}} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$Z_L = Z_0 * \frac{1+\rho}{1-\rho}$$





矢网测阻抗的原理

- Vector Network Analyzer

$$TDR: \quad \rho = \frac{V_{reflected}}{V_{incident}} = \frac{Z_{load} - Z_0}{Z_{load} + Z_0} \qquad Z_{DUT} = Z_0 \cdot \frac{1+\rho}{1-\rho}$$

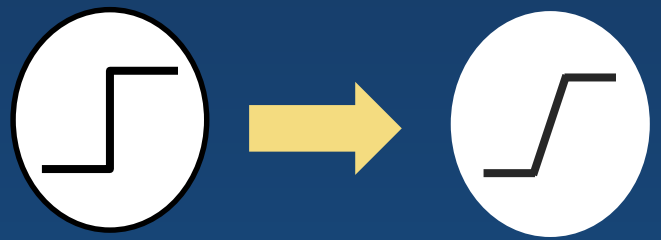
$$VNA: \quad S_{11} = \frac{V_{reflected1}}{V_{incident1}} = \frac{Z_{input(DUT)} - Z_0}{Z_{input(DUT)} + Z_0} \qquad Z_{input(DUT)} = Z_0 \cdot \frac{1+S_{11}}{1-S_{11}}$$

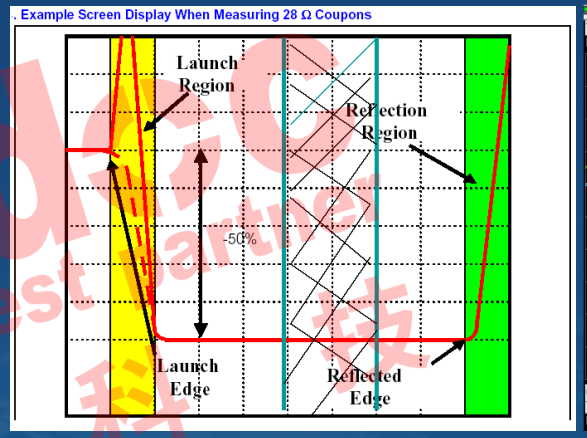
矢网的阻抗测试结果

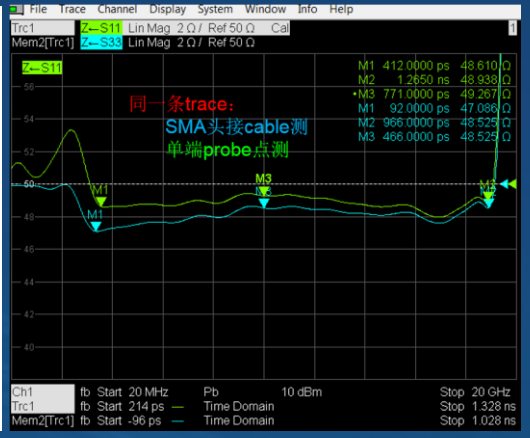

File Trace Channel Display System Window Info Help
Trc1 Z←Sdd11 Lin Mag 5 Ω / Ref 85 Ω Cal
1
Z←Sdd11
M1 1.6930 ns 92.228 Ω
M2 2.1270 ns 83.063 Ω
•M3 3.6120 ns 93.275 Ω
120
115
110
105
100
95
90
85
80
M1
M2
M3
Ch1 fb Start 20 MHz
Trc1 fb Start 1.22 ns
Pb
Time Domain
-10 dBm
Stop 20 GHz
Stop 4.48 ns
Trc1 Z←Sdd11 Lin Mag 5 Ω / Ref 85 Ω Ch1 Cal
Ch1:

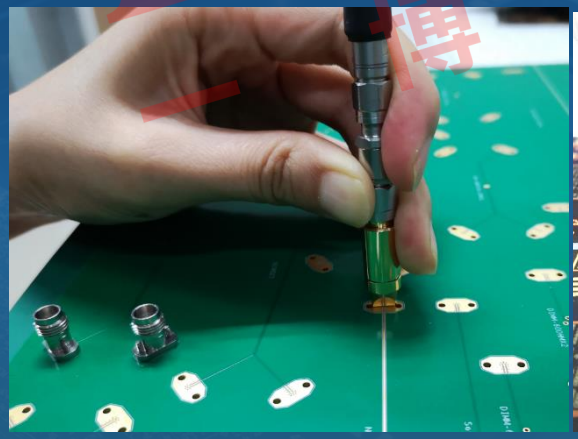
影响阻抗测试结果的因素

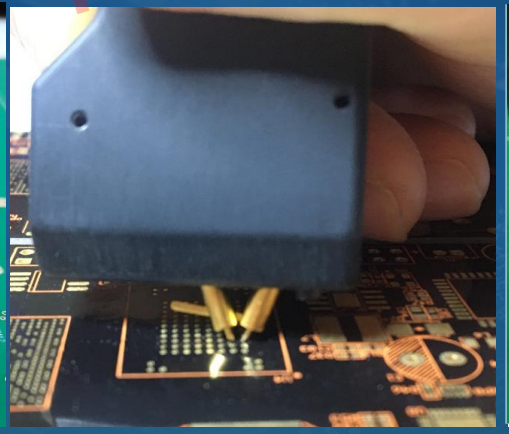
- 合适的上升时间
- 合理的测试位置
- 合适的DUT长度
- 合适的测量区间
- 合适的测试手段











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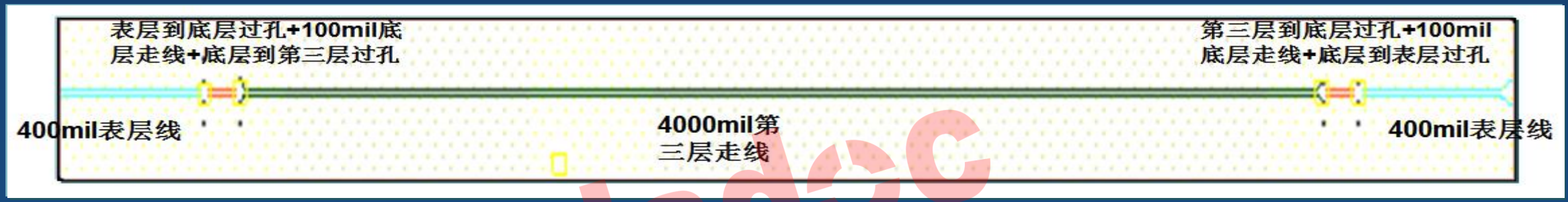
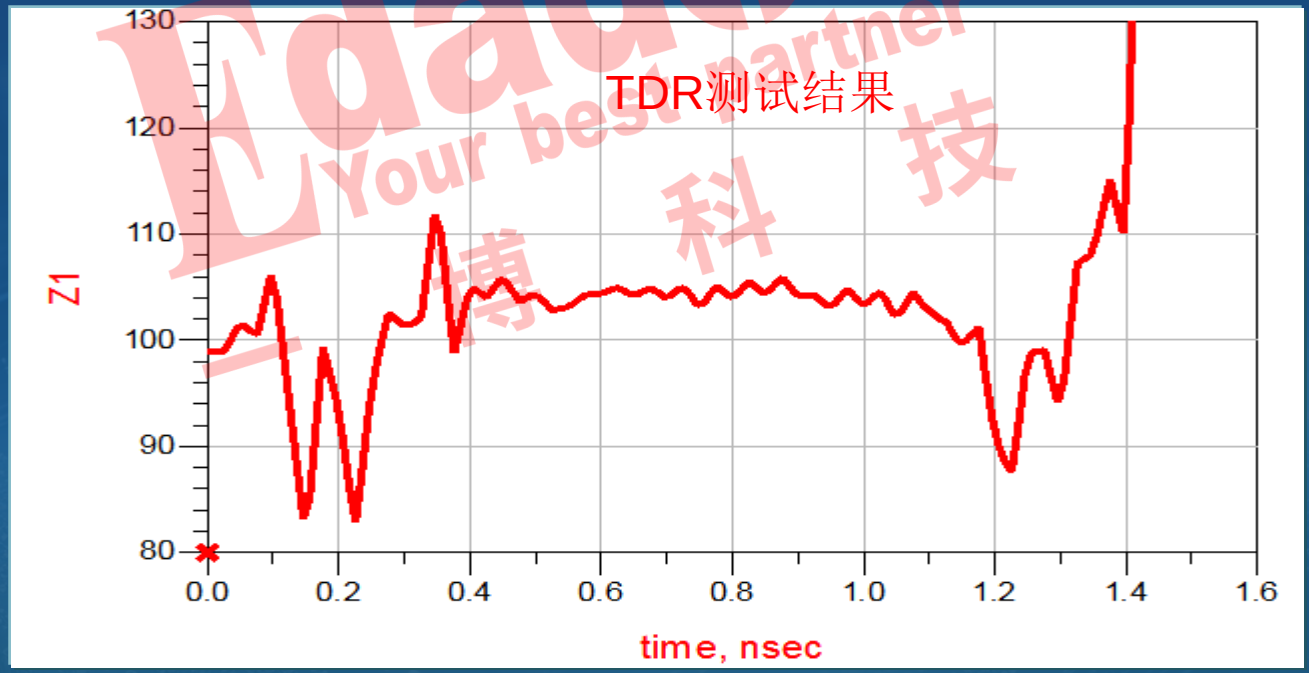
由阻抗反推S参数

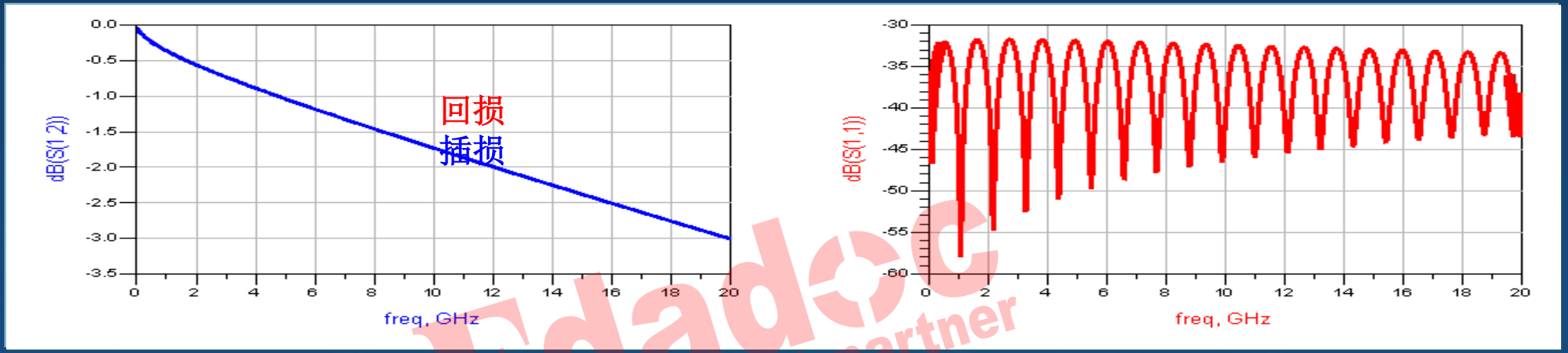
能不能通过阻抗反推出S参数?

- U-TURN的测试例子

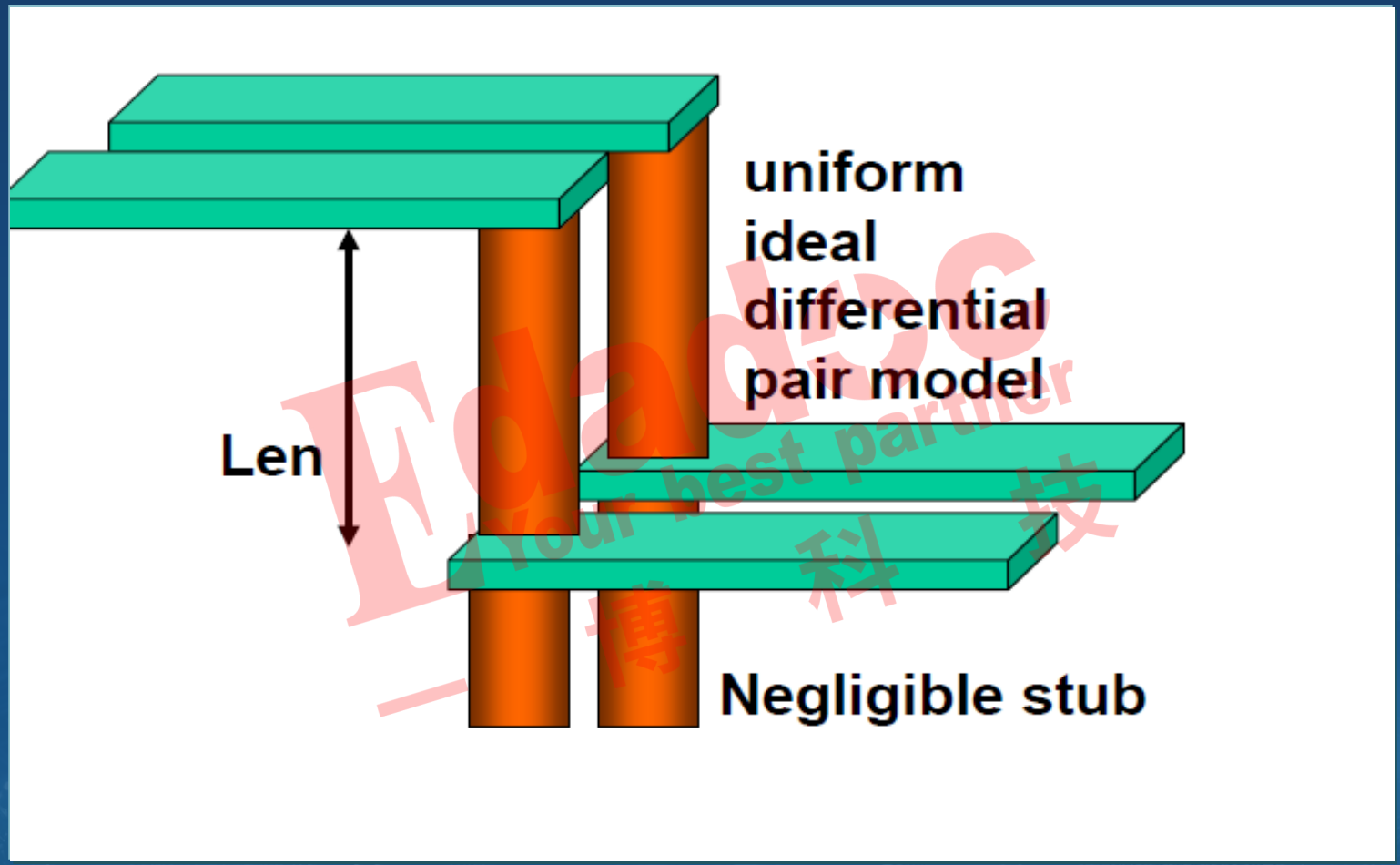




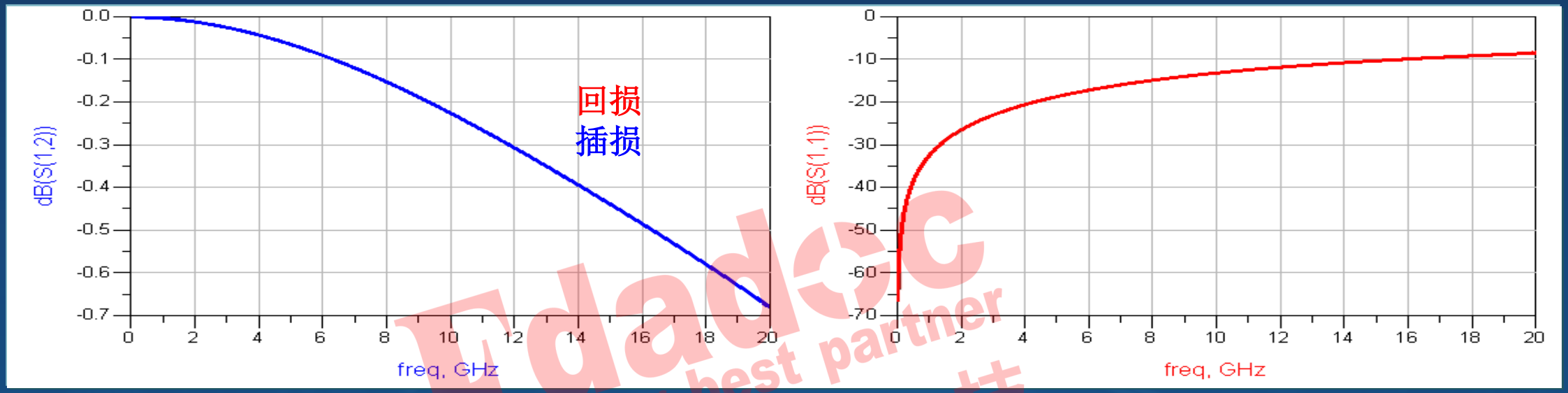
走线仿真拟合



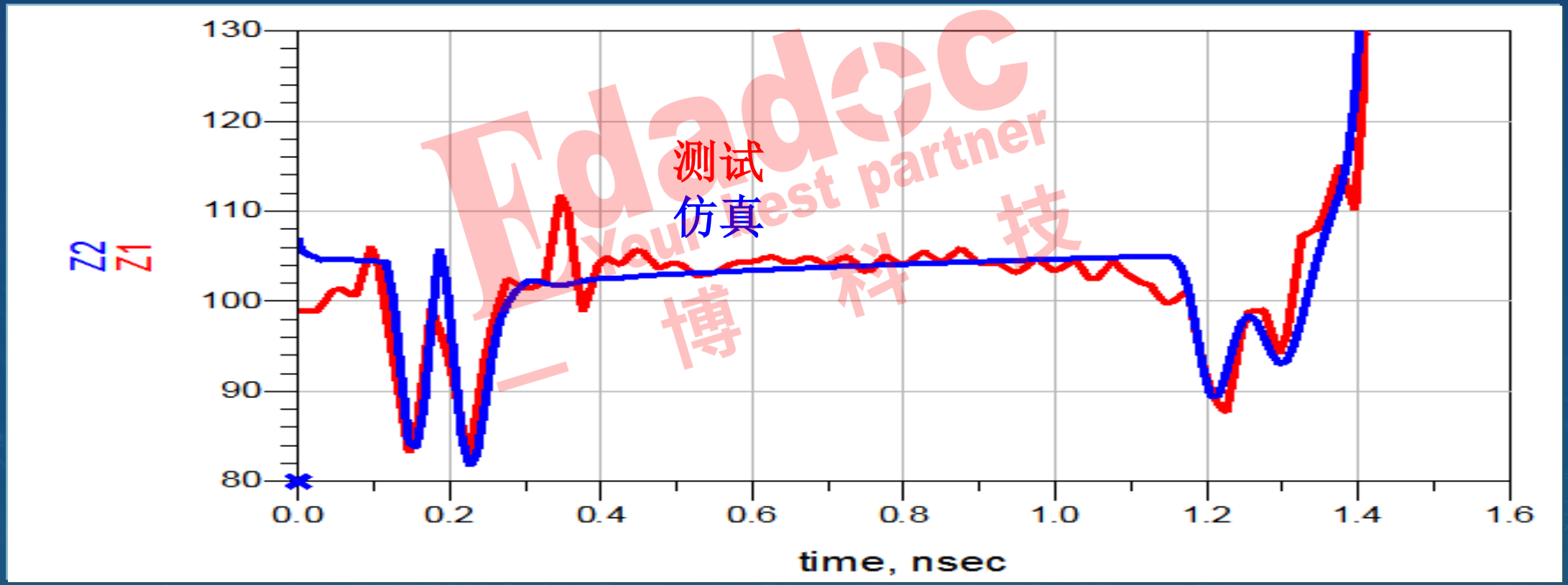
过孔仿真拟合


uniform
ideal
differential
pair model
Len
Negligible stub

过孔仿真拟合

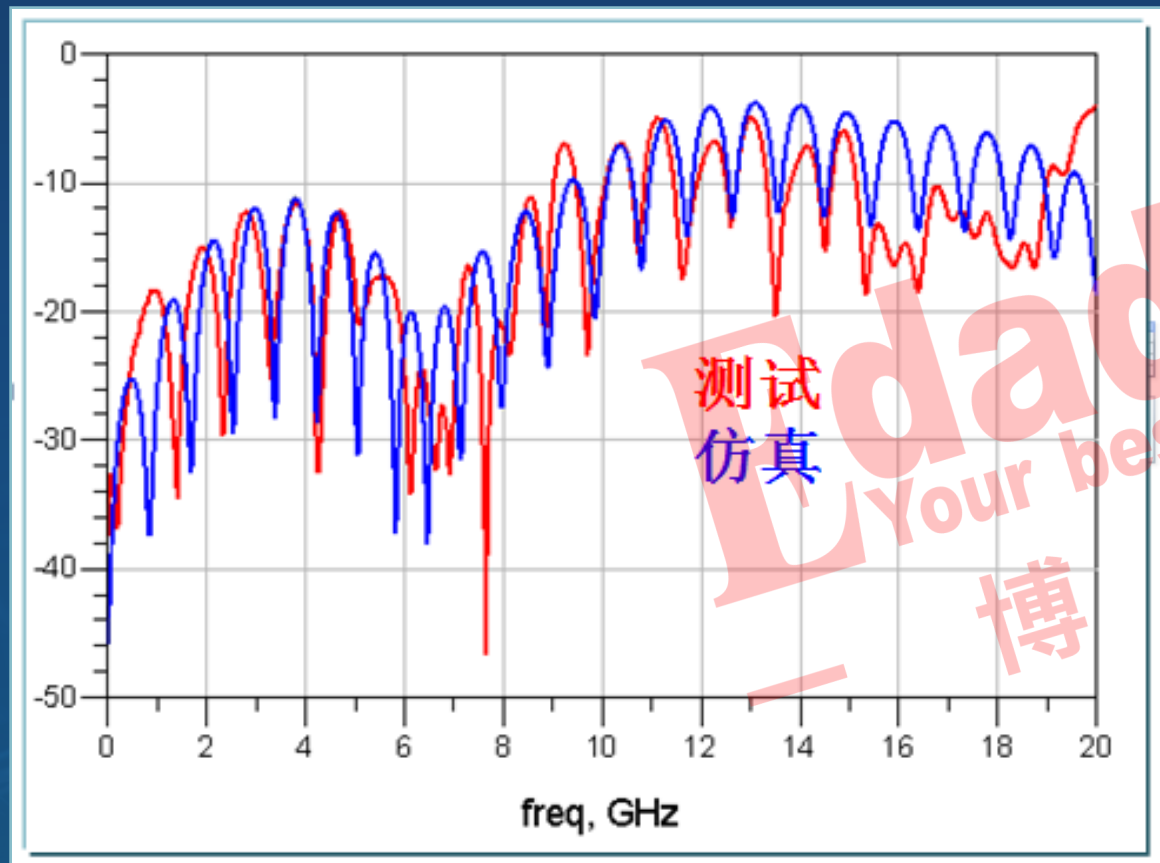


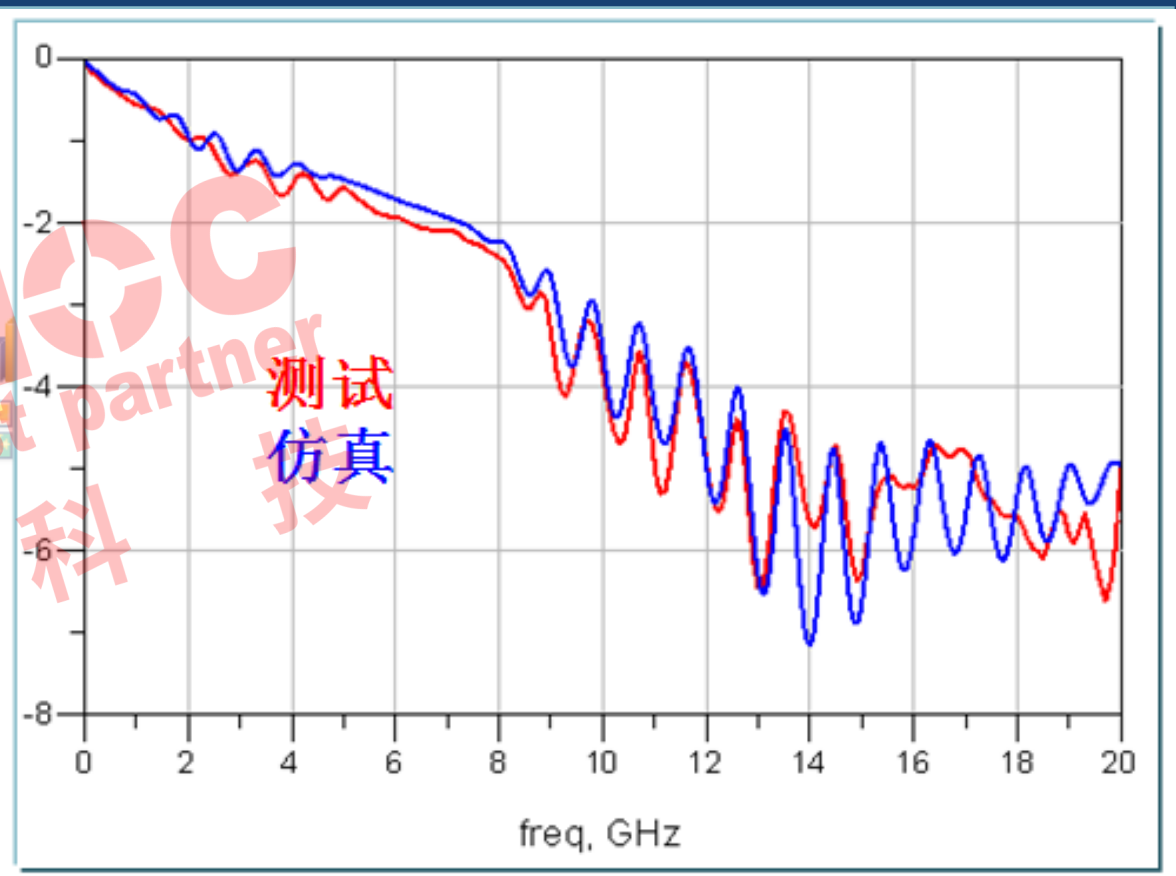
U-turn仿真拟合TDR结果



推导S参数

这时候我们阻抗基本能拟合上的话，S参数也能拟合的很好。





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