SW Test Workshop

Semiconductor Wafer Test Workshop

Design and Analysis of Space Transformer with Hybrid Circuit Design on Probe Card

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Overview

- *Introduction of Probe Card Test*
- *Design Concept of Space Transformer*
- *Signal Integrity and Power Integrity*
- *Measurement and Analysis*
- *Summary*

Introduction of Probe Card Test

- Trend of Wafer Memory Test

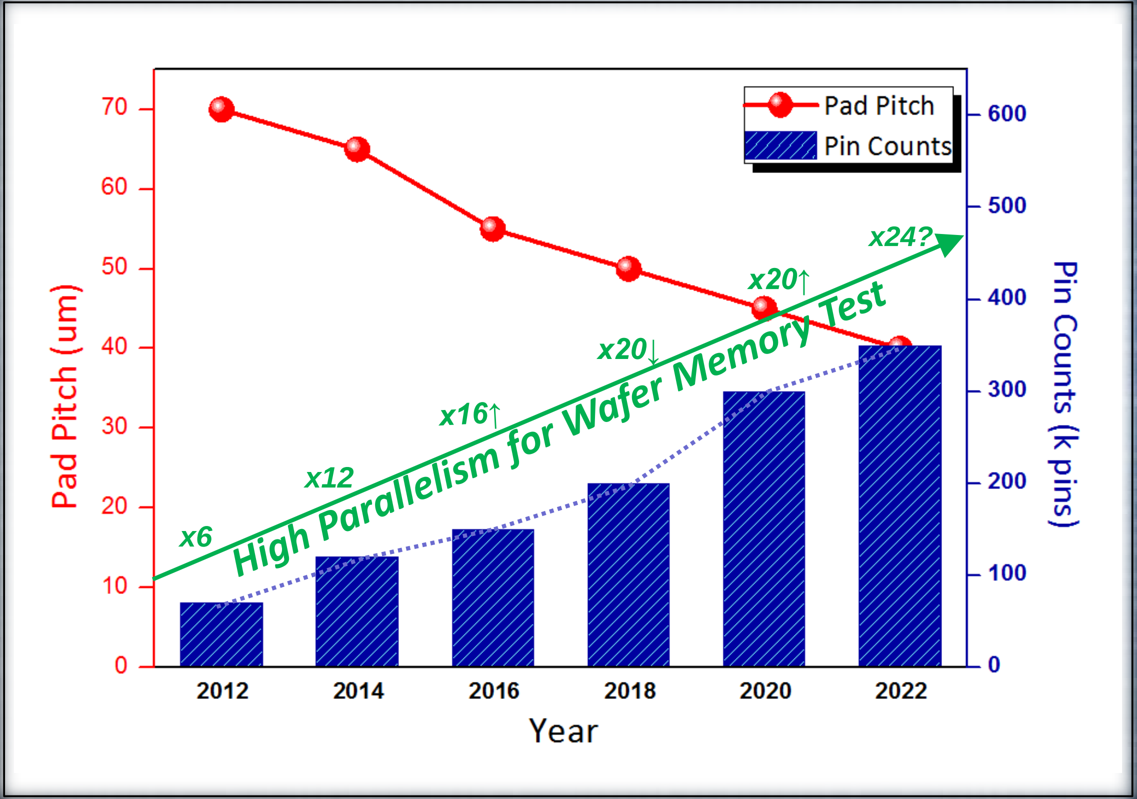


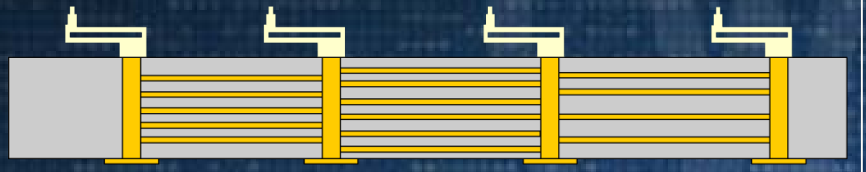
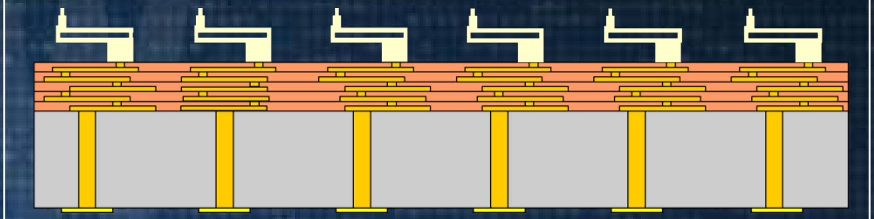
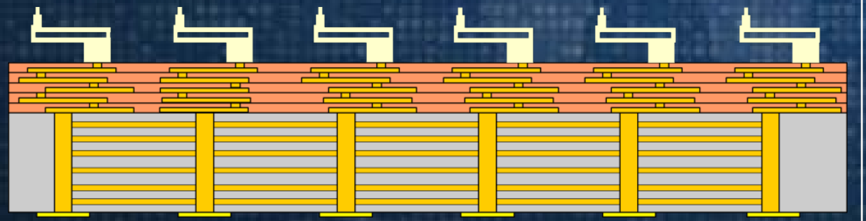
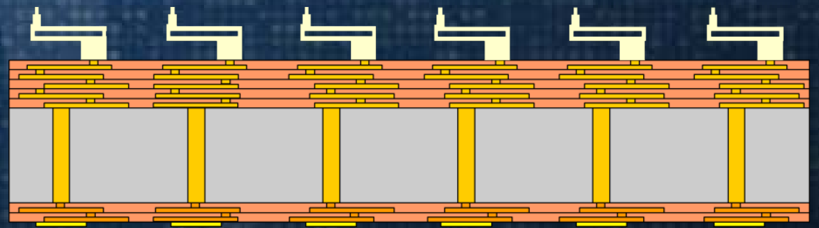
Fig. Trend of Pad Pitch and Pin Counts (High Parallelism) for Wafer Test

- ✓ *Shrinking Pad Size and Reducing Pad Pitch*
- ✓ *Increasing Pin Counts for High Parallelism Test*
- ✓ *Fasting Clock Speed and Small Timing Margin*
- ✓ *High Density Circuit Design for Fine Pitch*
- ✓ *Signal & Power Issues and Design Considerations*

- *Needs for High Performance and Technique of Space Transformer*

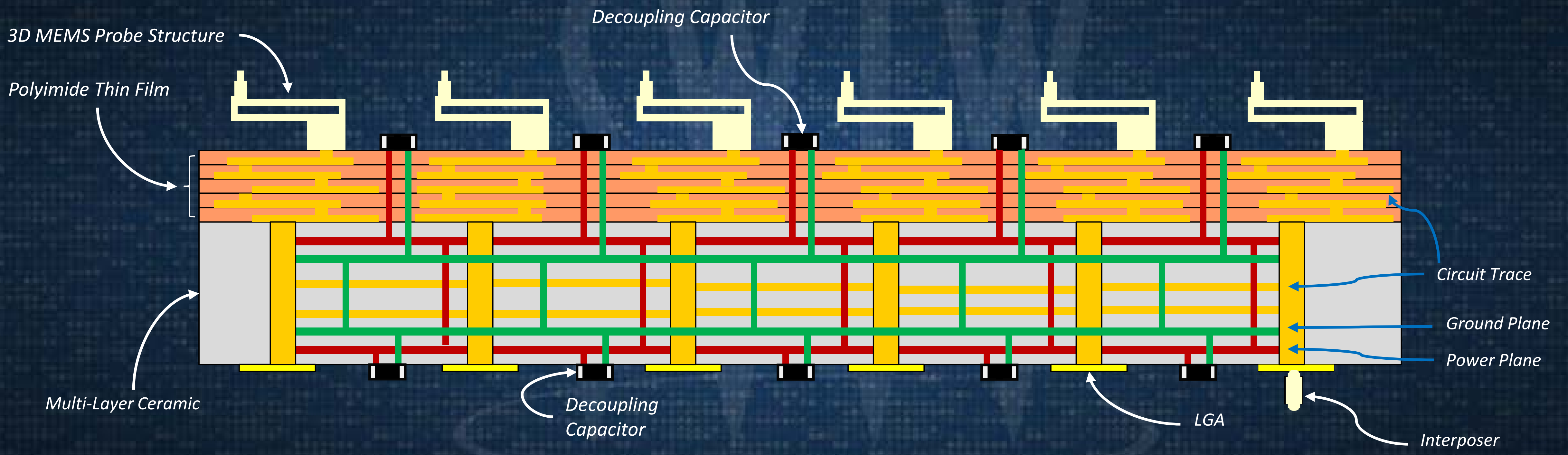
Design Concept of Space Transformer

• *Concept of Space Transformer for Circuit Design*

Normal Type	 ***Fine Pitch*** ★★★ ***Circuit Density*** ★★ ***Technology*** ★★★	*Polyimide Type (One Side)*	 ***Fine Pitch*** ★★★★★ ***Circuit Density*** ★★★★ ***Technology*** ★★★★
Hybrid Type	 ***Fine Pitch*** ★★★★★ ***Circuit Density*** ★★★ ***Technology*** ★★★★	*Polyimide Type (Two Side)*	 ***Fine Pitch*** ★★★★★ ***Circuit Density*** ★★★★★ ***Technology*** ★★★★★

Design Concept of Space Transformer

- Hybrid Type (Circuit on Polyimide + Multi-Layer Ceramic) Space Transformer



- Hybrid Space Transformer composed of Polyimide Thin Film and Multi-Layer Ceramic
- Signal Integrity, Power Integrity Characteristics (Signal Trace, Power & Ground Plane, Impedance Matching)

Signal Integrity of Space Transformer

- *Design Considerations and Basic Study*

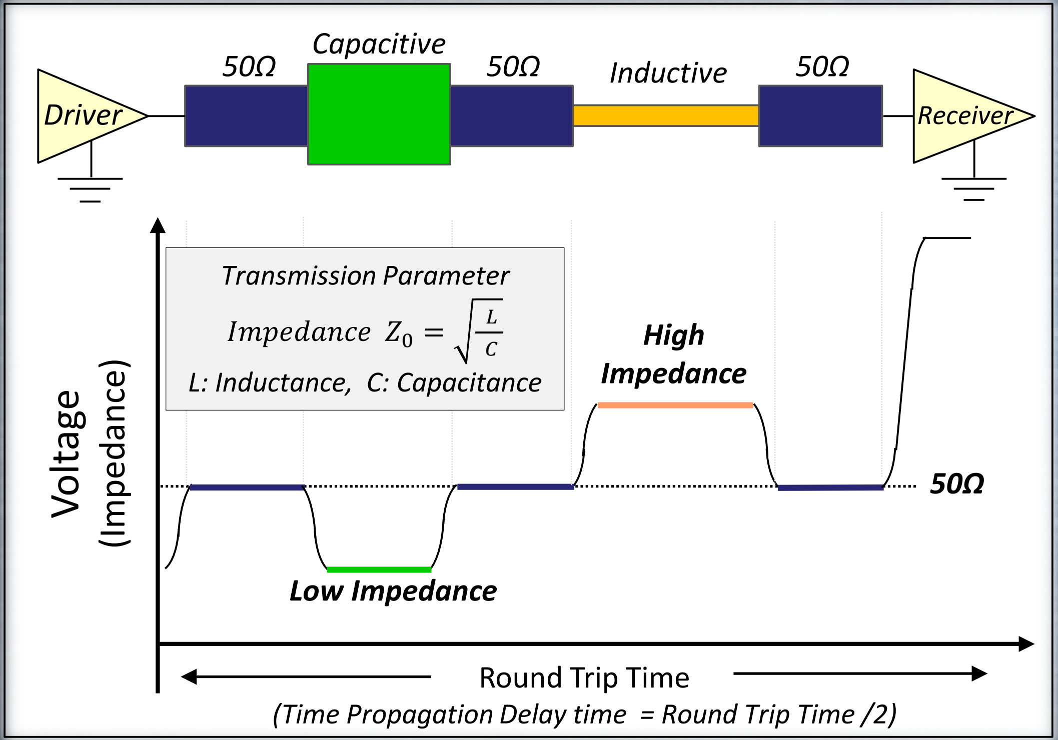


Fig. Time Domain Reflectometry (TDR) of Transmission Line

✓ *Impedance Mismatch*

- Transmission Line Signal Loss and Distortion

- Reflection and Bad Signal Quality

✓ *Unintentional Discontinuity*

- Stub, Test Pad, Neck of Via, Trace Corner, Trace Branch, Connectors, Crossover, etc.

Fig. Signal Stack Via

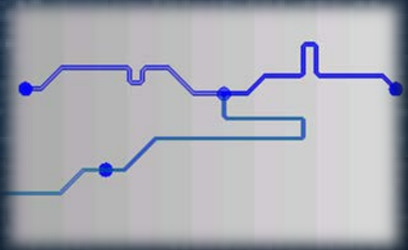


Fig. Signal Trace Branch

Signal Integrity of Space Transformer

- *Design Considerations and Basic Study*

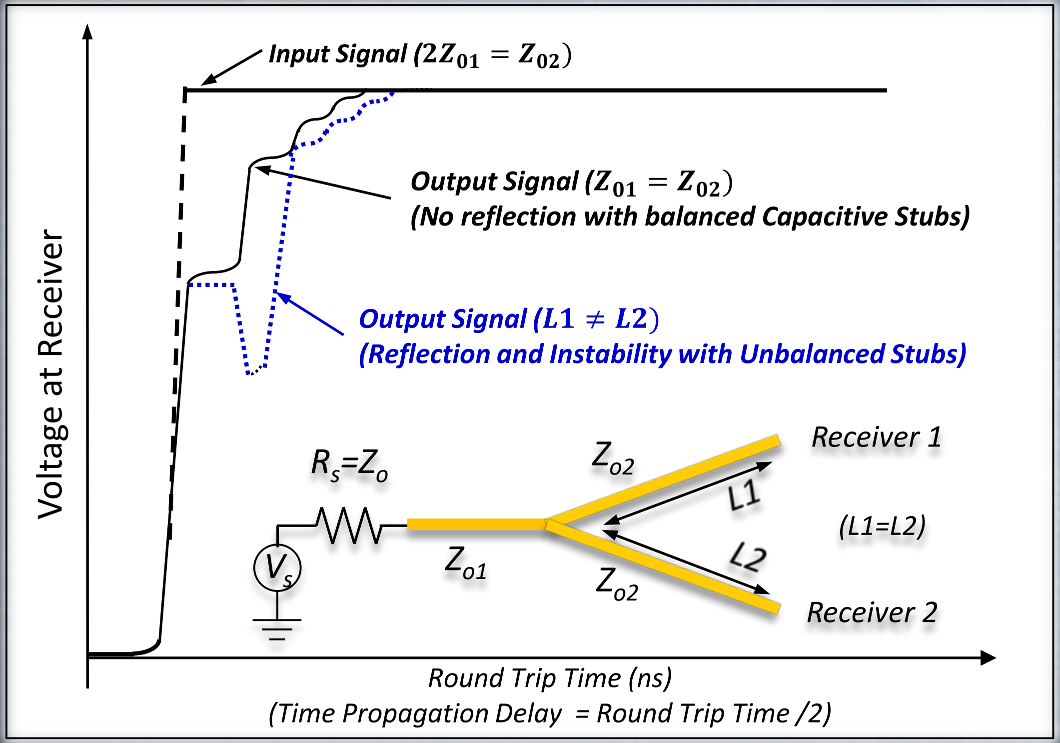


Fig. Signal Integrity produced by Stubs

✓ *One Driver is Connected to Multi-Receiver*
- *Impedance $2Z_{01} = Z_{02}$: No Reflection*
- *Impedance $Z_{01} = Z_{02}$: Step Reflection*
- *Unbalanced Structure (L1≠L2) : Instability*

✓ *Best Topology for Stub Design*
- *Symmetric Topology (Length)*
- *Minimize Impedance Discontinuity*

▪ *Challenge for Designing Multi-Stubs Trace on Space Transformer*

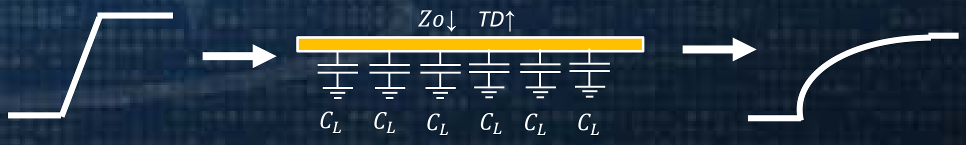


Fig. Effect of Distributed Short Capacitive Stubs

Signal Integrity of Space Transformer

- Design Considerations and Basic Study (Pre-Simulation and Case-Study)

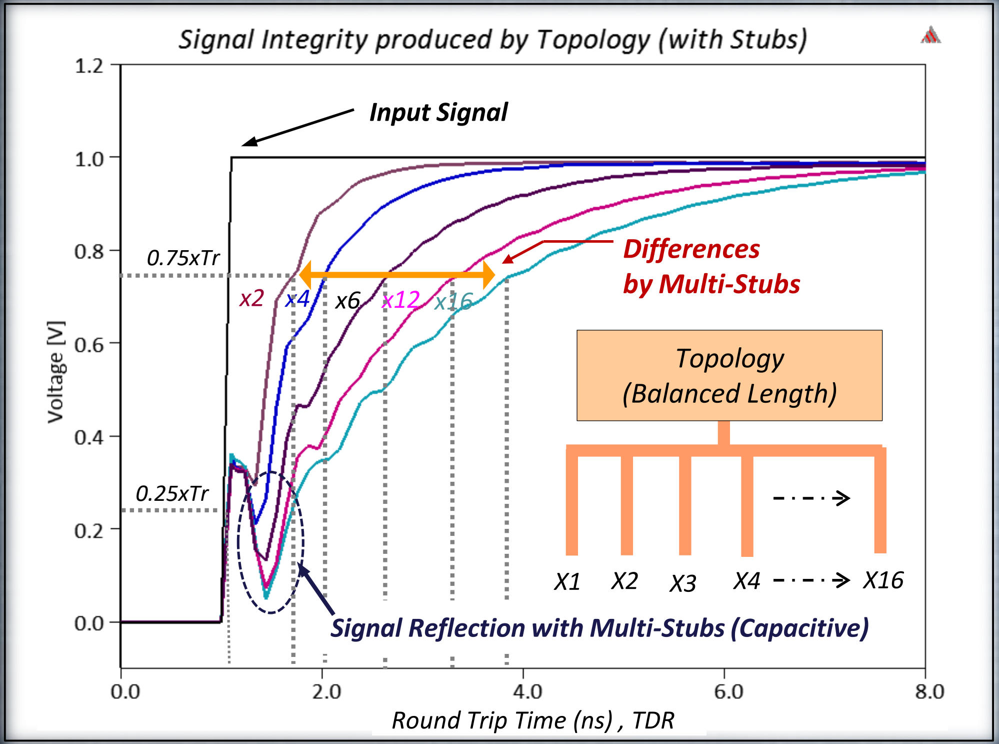


Fig. Propagation Delay Time (TPD) with Multi-Stubs Topology

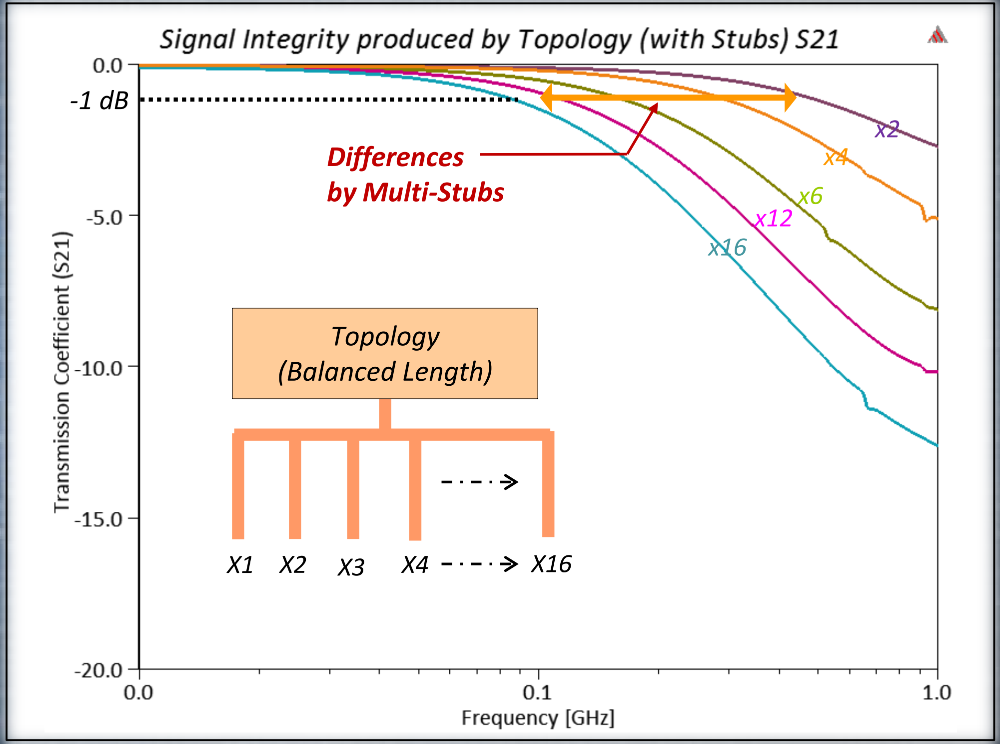


Fig. Transmission Coefficient (Insertion Loss)

✓ Signal Integrity produced by Multi-Stubs Topology (Increasing Capacitive and Impedance Mismatching)

Power Integrity of Space Transformer

- *Design Considerations and Basic Study*

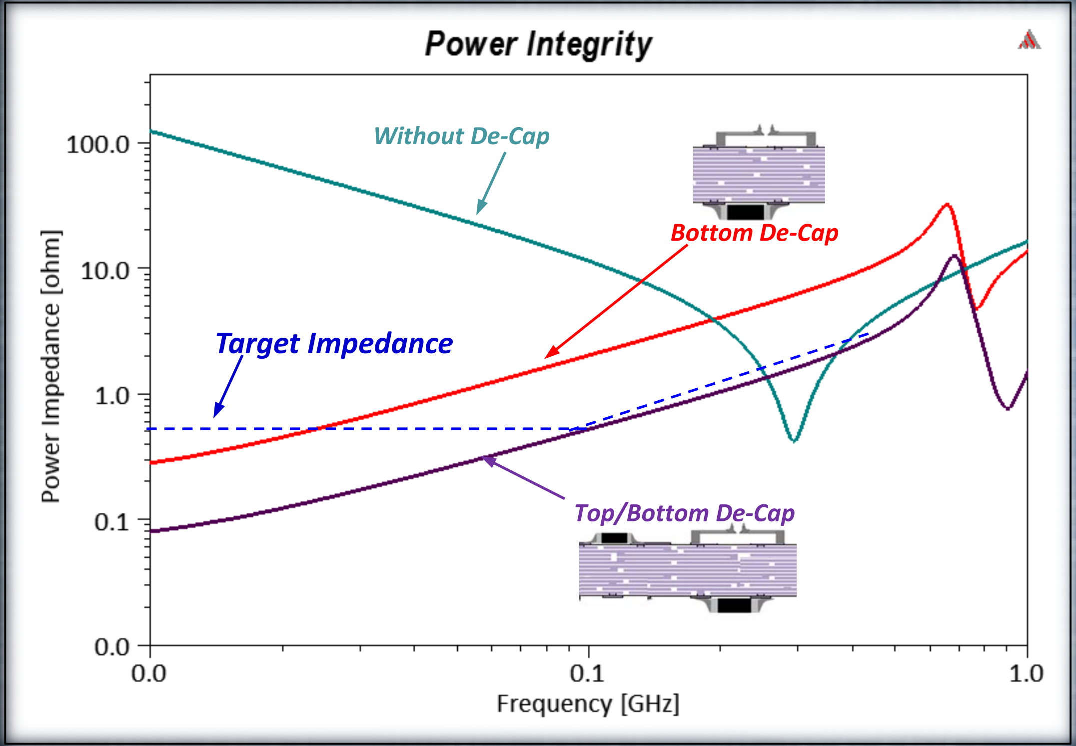


Fig. Power Integrity with Decoupling Capacitor

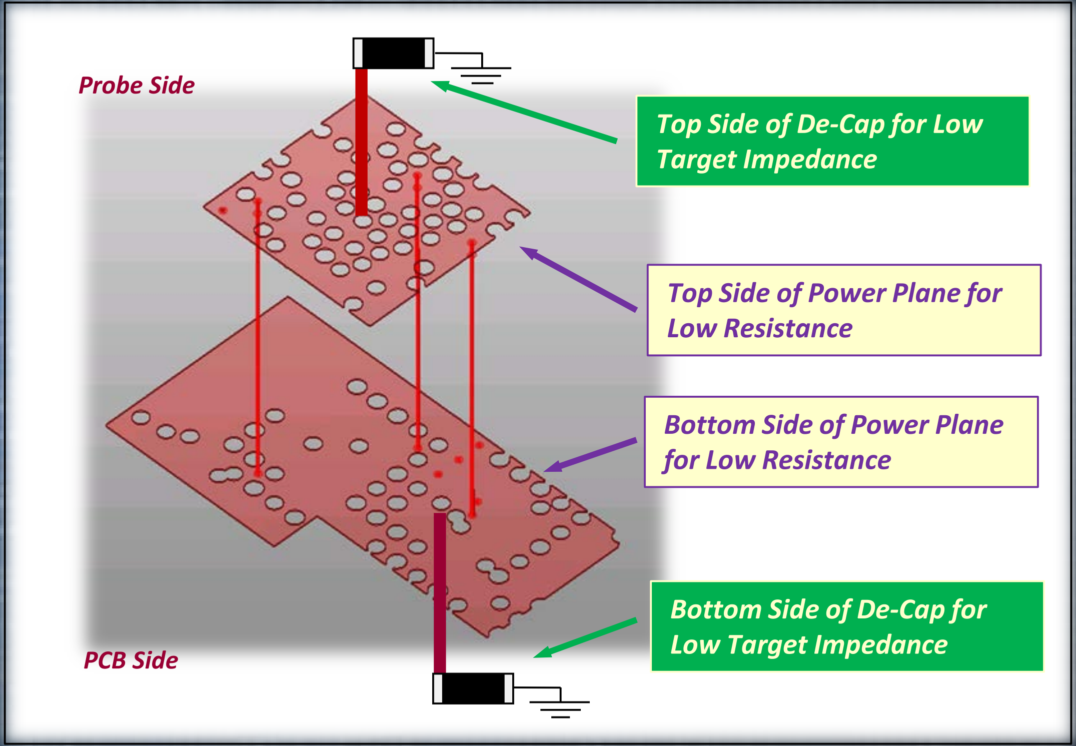


Fig. Power Plane Design for Low Resistance

✓ *Power (Target) Impedance can be Controlled by using Decoupling Capacitor and Position*

Signal Integrity of Space Transformer

- *Design Signal Trace on Space Transformer (Hybrid Type and Normal Type)*

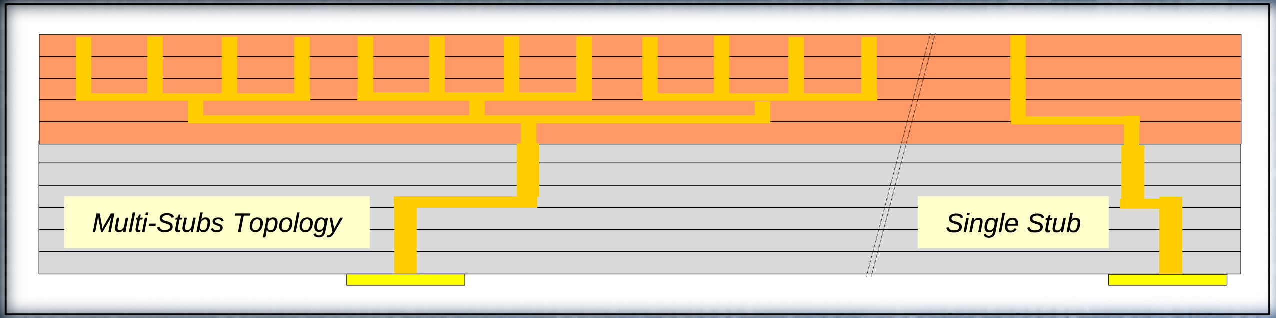


Fig. Simplified Signal Design of Hybrid Space Transformer

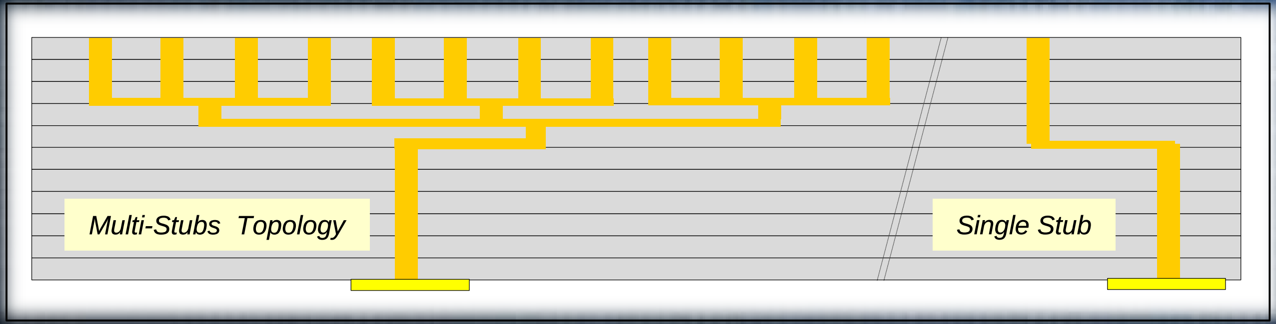


Fig. Simplified Signal Design of Normal Space Transformer

✓ *Signal Design Considerations*

- Single Stub Design (Simple Trace Line)
- Multi-Stubs Design Topology (≥ x12)
- Balanced Topology for Multi-Parallelism Test

✓ *Design Factors*

- Balanced Stub Topology, Length, Impedance

✓ *Signal Integrity*

- TPD, Skew, Transmission Coefficient, Eye Diagram

Power Integrity of Space Transformer

- Design Power Plane on Space Transformer (Hybrid Type and Normal Type)

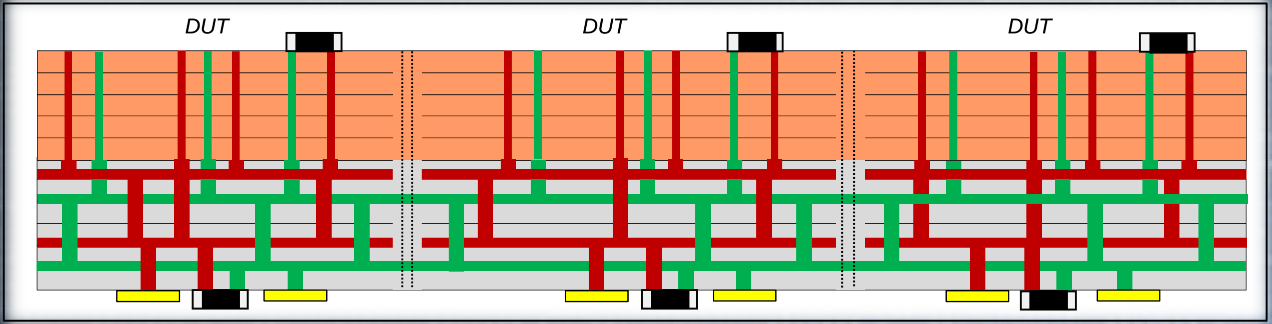


Fig. Simplified Power Design of Hybrid Space Transformer

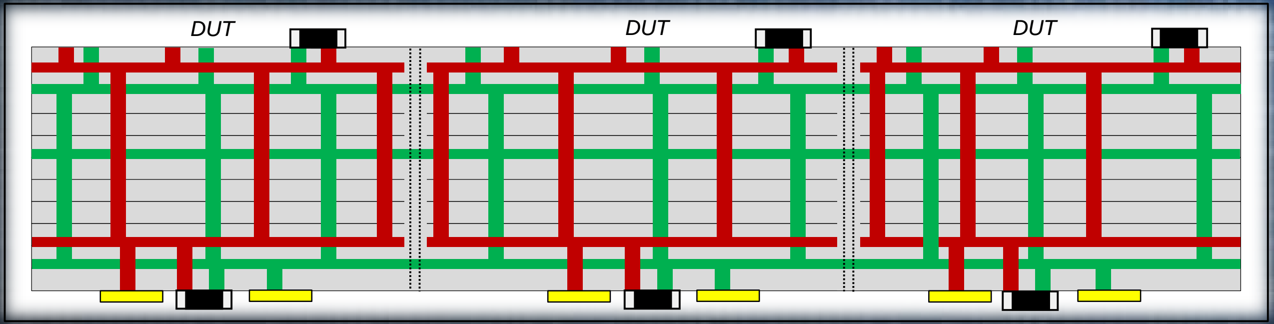


Fig. Simplified Power Design of Normal Space Transformer

✓ *Power Design Considerations*
- *Low Power Resistance*
- *Power Impedance (Target Impedance)*
- *Ground Plane (Return Current Path)*

✓ *Design Factors*
- *Power and Ground Plane, De-cap Capacity, Position of Decoupling Capacitor*

✓ *Power Integrity*
- *Power Impedance, Target impedance, SSN (Simultaneous Switching Noise)*

Measurement System for Signal and Power Integrity

• Measurement Setup to Analyze Signal and Power Integrity on Probe Card

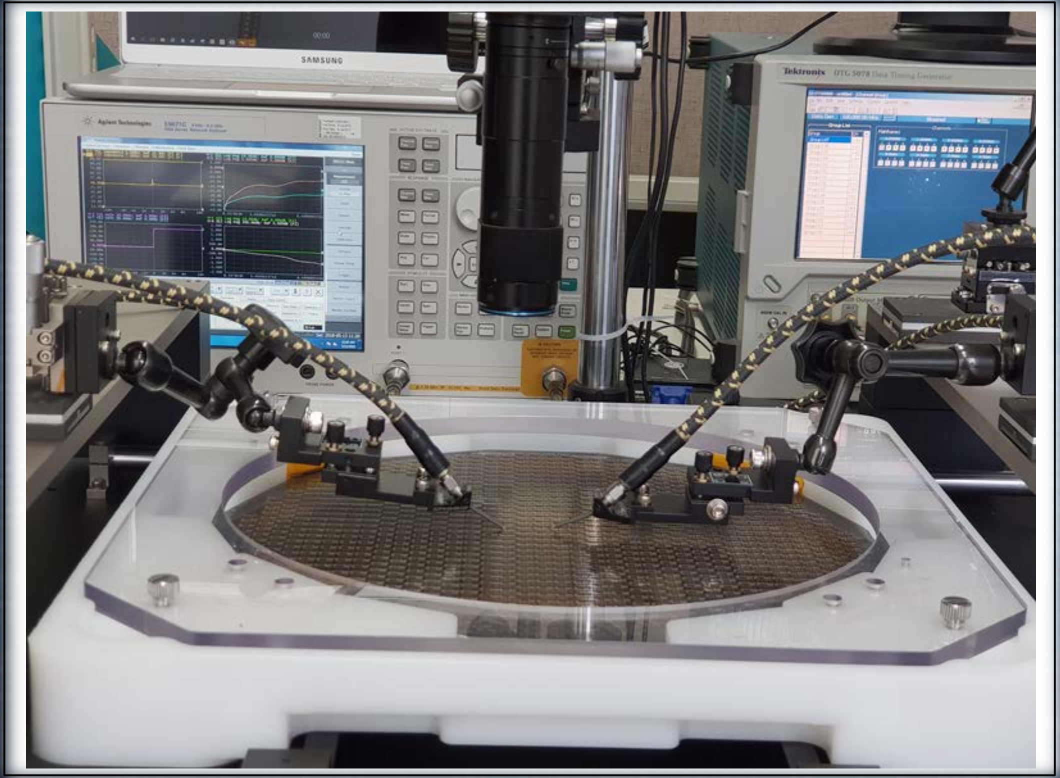


Fig. Measurement System for Probe Station

✓ Vector Network Analyzer (≤8GHz)

✓ Signal Integrity

- Measurement of Signal Transmission Line
- S-parameter, Insertion Loss, TDR, Eye-Diagram

✓ Power Integrity

- Measurement of Power Impedance (Z11)
- Decoupling Capacitor Effect, SSN

▪ Measurement and Analysis for Space Transformer

Signal Integrity of Space Transformer

- *Measured Insertion Loss and Comparison of Two Types of Space Transformer*

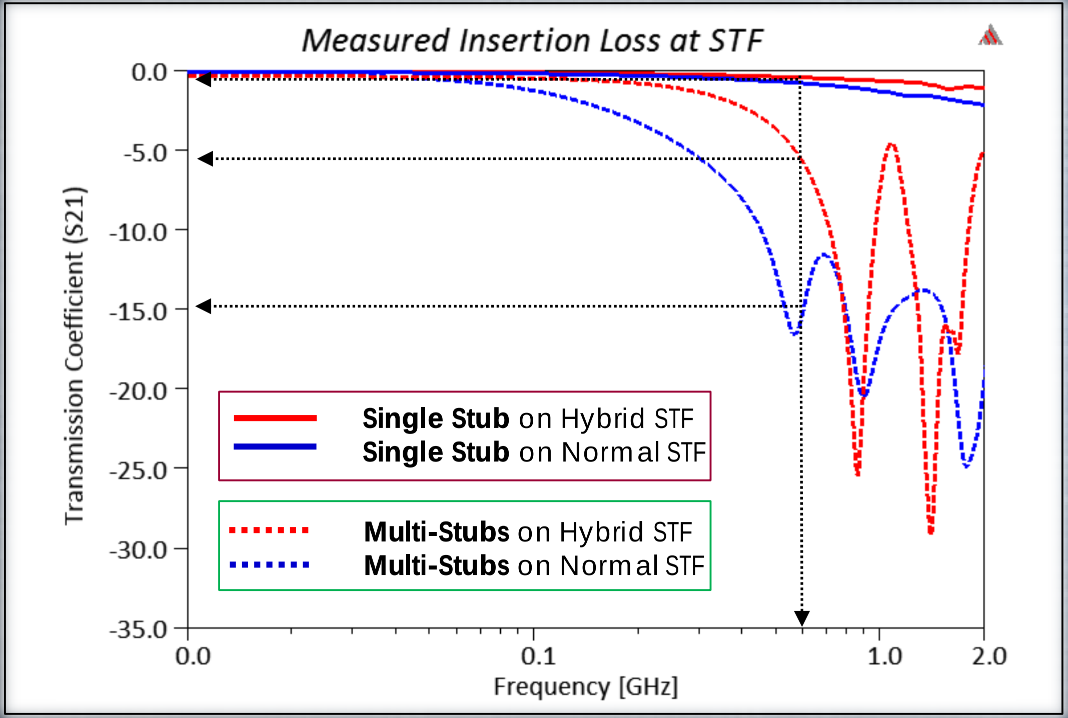


Fig. Insertion Loss of Two Different Types of STF

✓ *Single Stub Topology*
- *Measured Single Stub Trace*
- *Compared of Hybrid and Normal Type*
- *Slightly Differences of Insertion Loss*

✓ *Multi-Stubs Topology*
- *Measured Multi-Stubs Trace (x12)*
- *Compared of Hybrid and Normal Type*
- *Multi-Stubs Trace (x12) Balanced Length Design*
- *Large Differences of Insertion Loss*

▪ *For Multi-Stubs Topology, Hybrid Space Transformer Design is much more Effective*

Signal Integrity of Space Transformer

- Measured TDR and Comparison of Two Types of Space Transformer

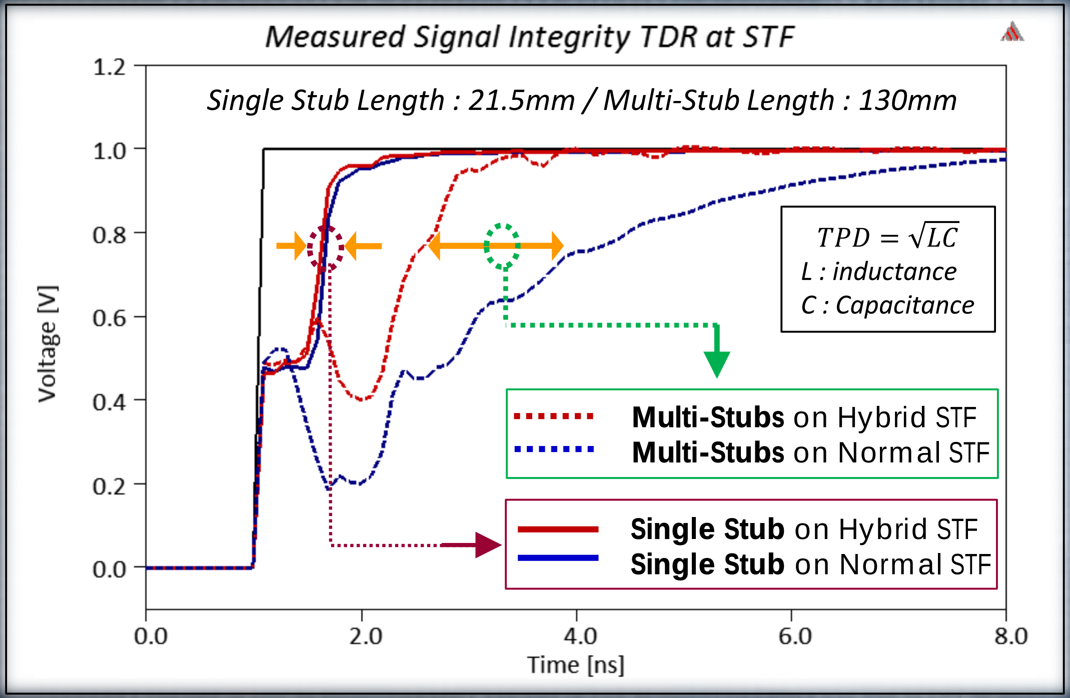


Fig. Propagation Delay Time (TPD) of Two Types of STF

✓ Measured TDR (Time Domain Reflectometry)
- Analyze for Impedance Mismatching Point
- Propagation Velocity, TPD (Propagation Delay Time)

✓ $TPD = \frac{\lambda \times \sqrt{\varepsilon_r}}{c}$ | λ : Length, ε_r: Dielectric Constant
c : Speed of light ($3 \times 10^8\ m/s$)

✓ Polyimide ε_r 3.4, Multilayer Ceramic ε_r 8 ~ 10
ex) Propagation Velocity of Polyimide, 1 mm = 6.15 ps/mm
Propagation Velocity of Ceramic, 1 mm = 10.5 ps/mm

✓ The Propagation Velocity of Transmission Line on Polyimide **1.7 times** faster than Ceramic
- If Multi-Stubs Length is much longer, the TPD of Polyimide Circuit is much faster than Ceramic Design

Signal Integrity of Space Transformer

- *Measurement of Propagation Delay Time on Probe Card (Including Hybrid STF)*

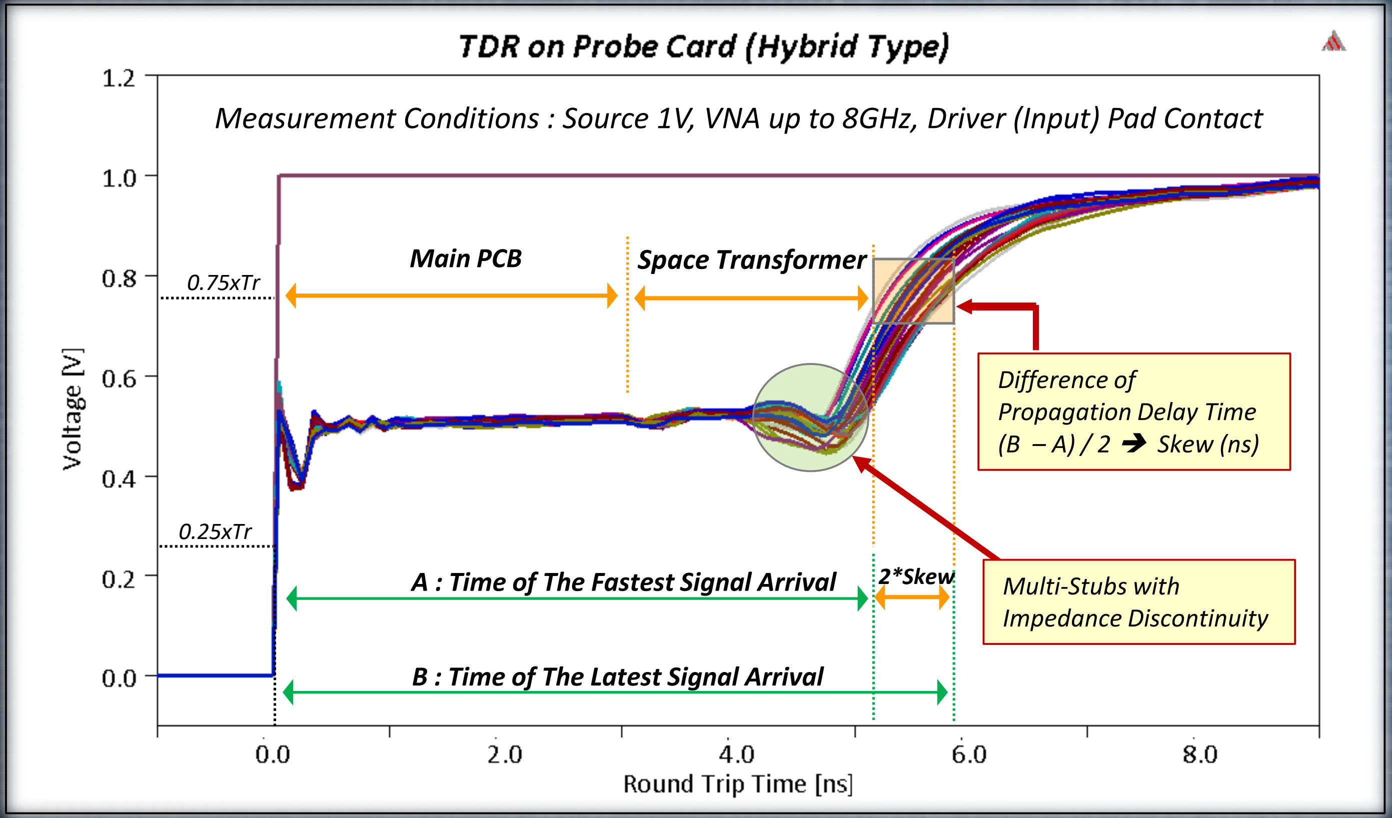
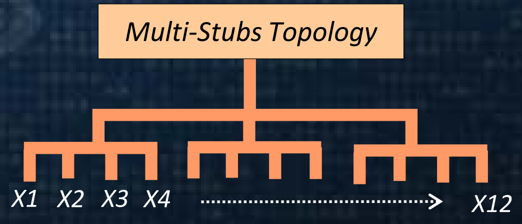


Fig. Measured TDR on Probe Card (Hybrid Space Transformer Type)

✓ *Measured of TDR on Probe Card*
- *TPD= Round Trip time /2*
- *Skew (Time Differences by Topology)*
- *(The Latest Signal - The Fastest Signal) / 2*

✓ *Analyzed TDR of Probe Card*
- *Multi-Stubs Topology makes Signal Reflection and Impedance Discontinuities at the Stubs Junctions*



Power Integrity of Space Transformer

- *Measured Power Impedance (Comparison of Two Types of Space Transformer)*

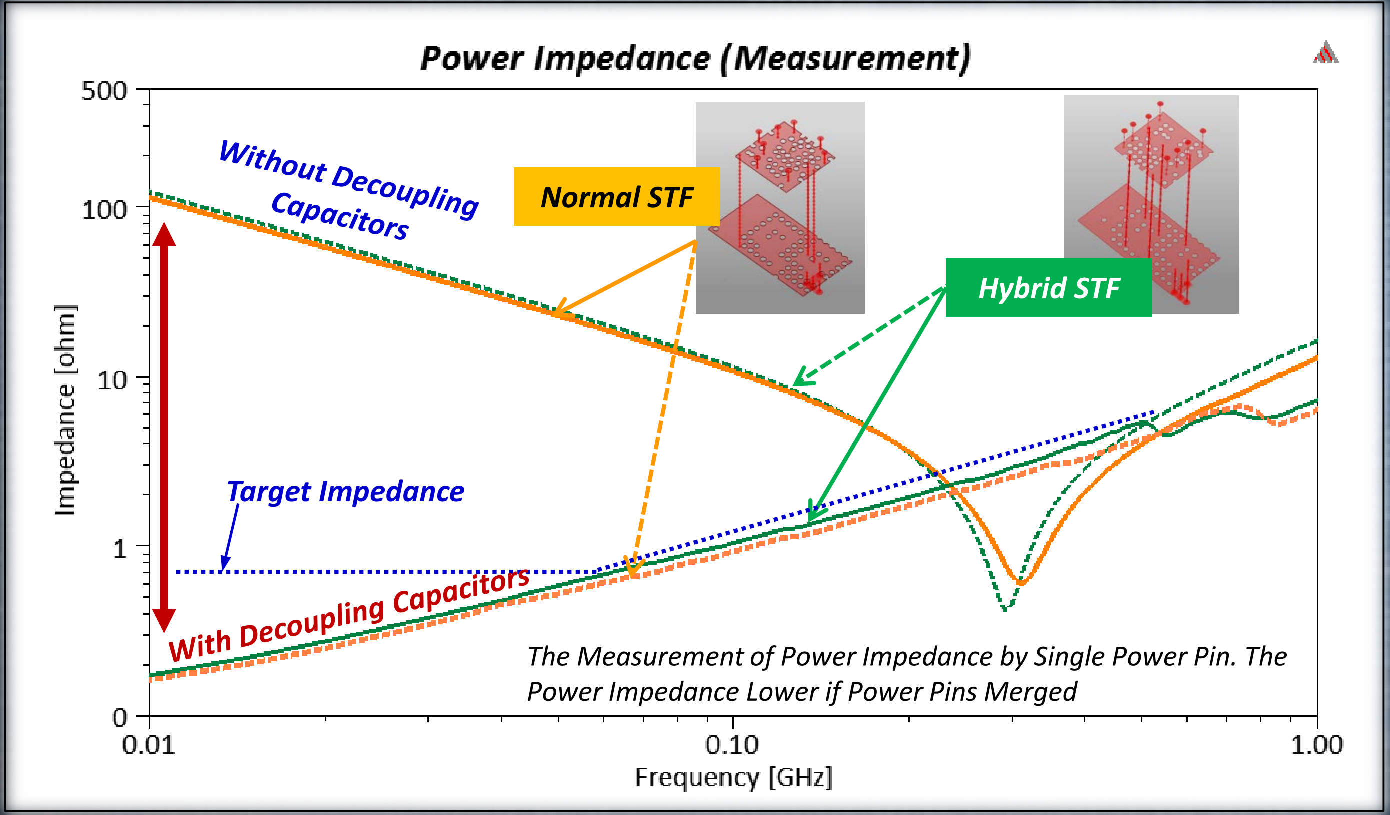


Fig. Measurement of Power Integrity

✓ *Power Integrity Comparison*
- *Normal Type and Hybrid Type*
- *Measurement for Single Power Pin*
- *Target impedance,*

✓ *Without Decoupling Capacitors*
- *Capacitance and Inductance of Plane*
- *Characteristics (Impedance, Resonance)*

✓ *With Decoupling Capacitors*
- *Decoupling Capacitors affect Power Impedance and lower Noise Level*

Power Integrity of Space Transformer

- *SSN (Power Noise with Decoupling Capacitor Effect) at Normal Space Transformer*

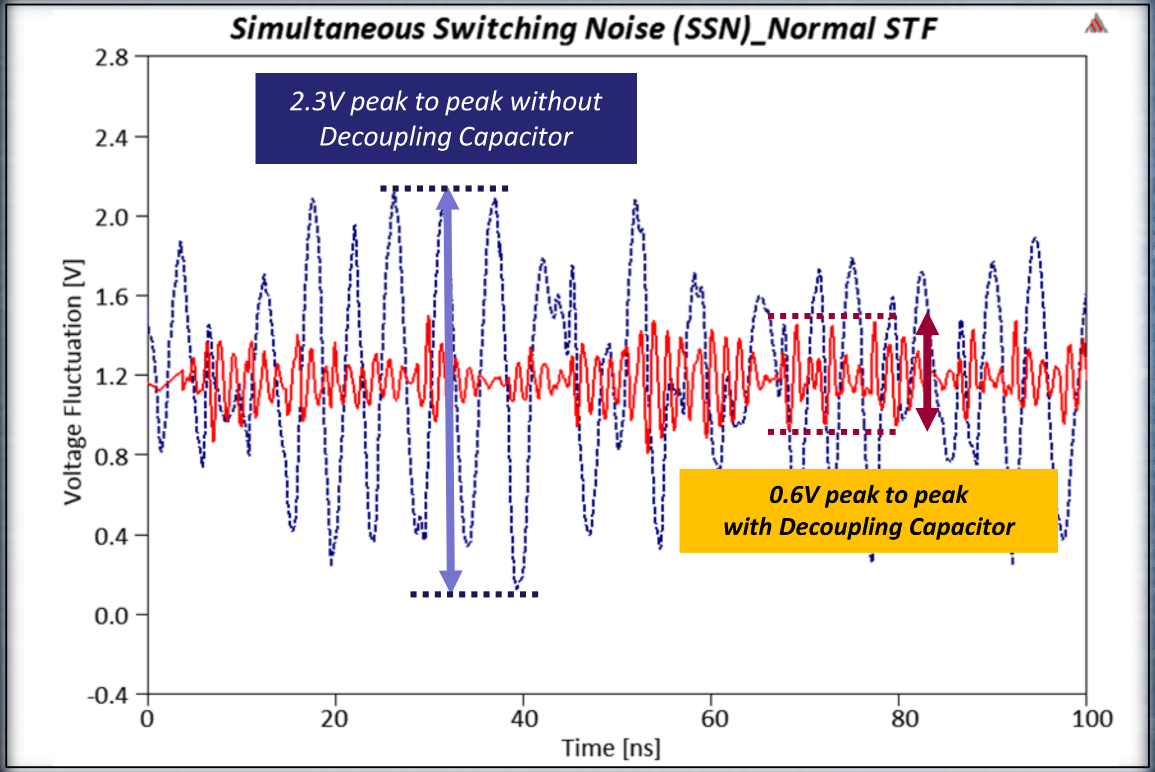


Fig. SSN at Normal Space Transformer

✓ *SSN Analysis for Normal STF*
- *De-Capacitor reducing Power Noise*
- *Effect for Both Side of Decoupling Local*

✓ *Power Plane Design reducing Inductance*
- *Maximum the Number of Power Pins*
- *Placing De-cap as close as possible to Device Side*

▪ *Simultaneous Switching Noise (SSN)*

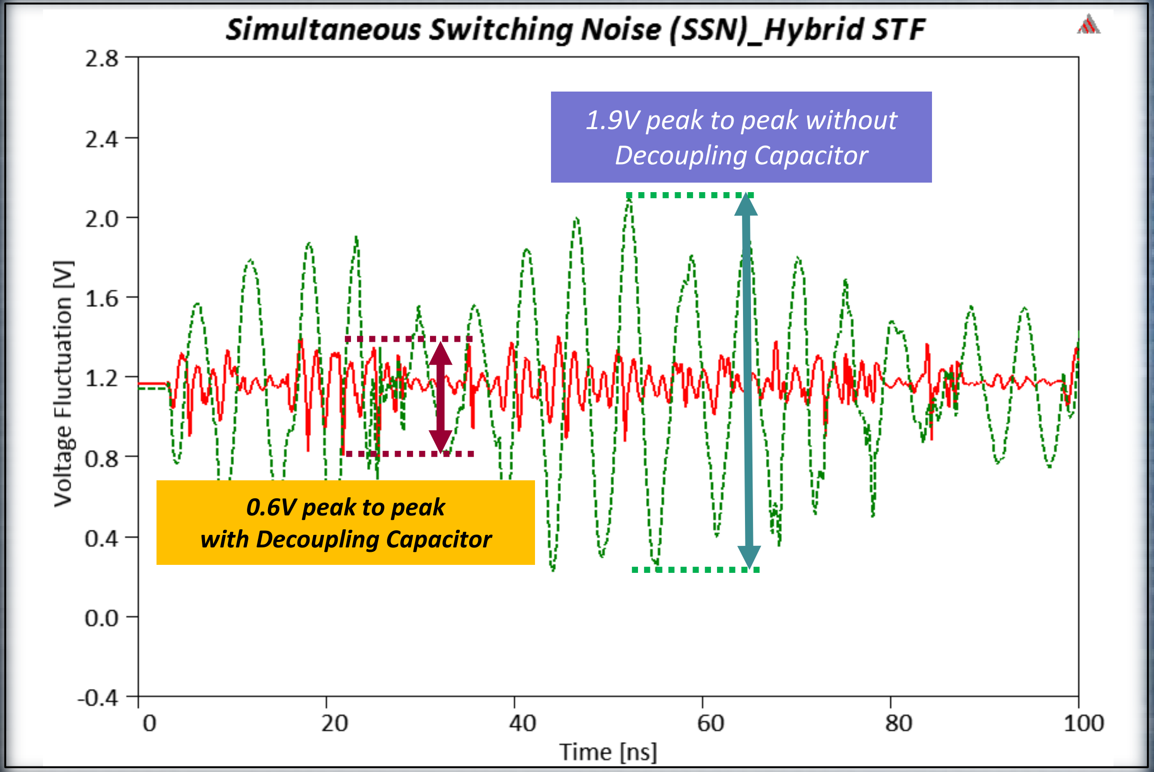
$$\Delta V = NL\frac{\Delta I}{\Delta t}$$

N : **Number of Switching Driver**
ΔI : *Increase of Maximum Power (Current)*
Δt : *Increase of Clock Frequency*

▪ *SSN caused by Simultaneous Switching Output Buffers*

Power Integrity of Space Transformer

- *SSN (Power Noise with Decoupling Capacitor Effect) at Hybrid Space Transformer*



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Signal Integrity of Space Transformer

- *Measurement of Eye Diagram (Comparison of Two Types of Space Transformer)*

Normal Type Space Transformer

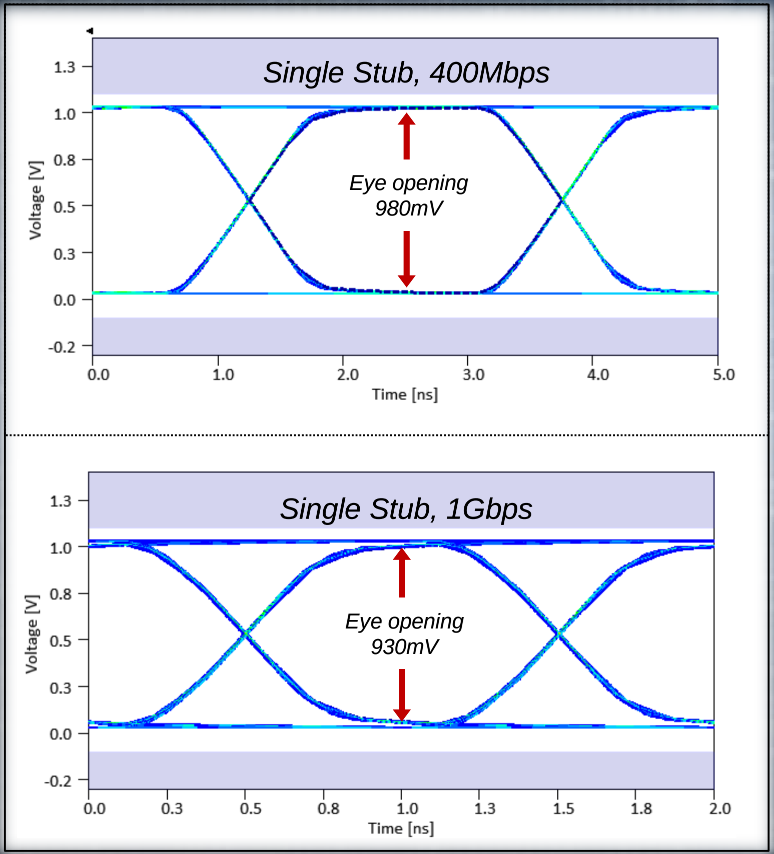

Fig. Eye-Diagram of Normal STF

Comparison

VS

Comparison

Hybrid Type Space Transformer

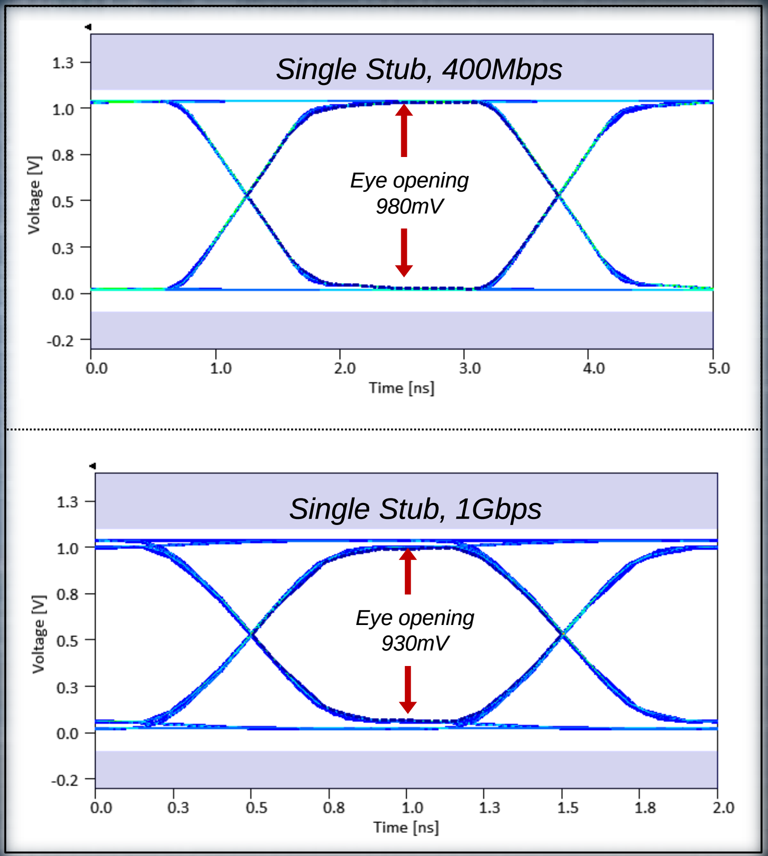

Fig. Eye-Diagram of Hybrid STF

Signal Integrity of Space Transformer

- Measurement of Eye Diagram (Comparison of Two Types of Space Transformer)

Normal Type Space Transformer

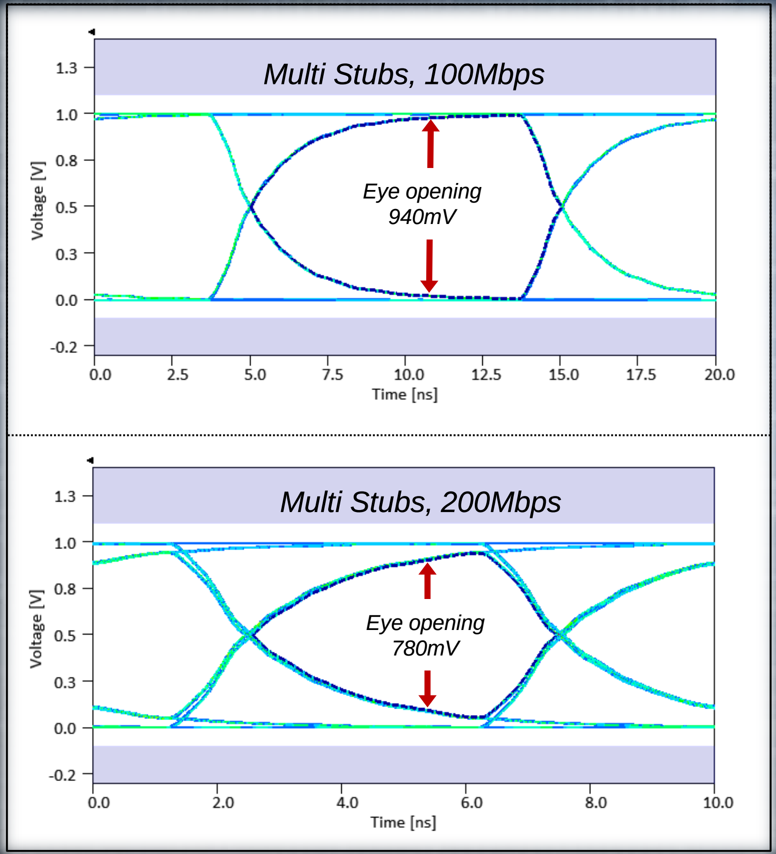

Fig. Eye-Diagram of Normal STF

Comparison

VS

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Hybrid Type Space Transformer

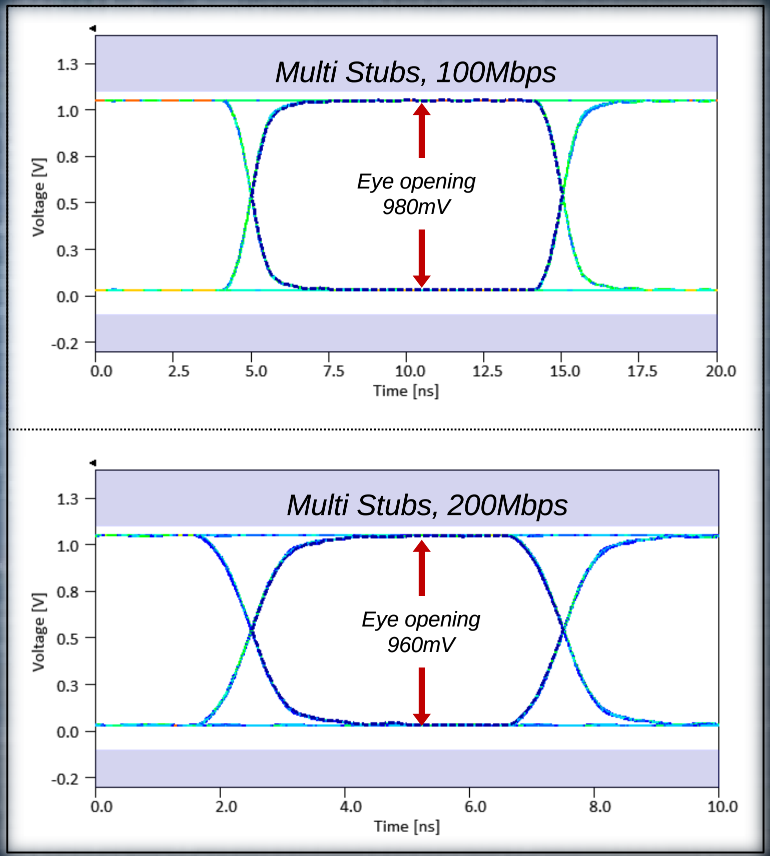

Fig. Eye-Diagram of Hybrid STF

Signal Integrity of Space Transformer

- *Measurement of Eye Diagram (Comparison of Two Types of Space Transformer)*

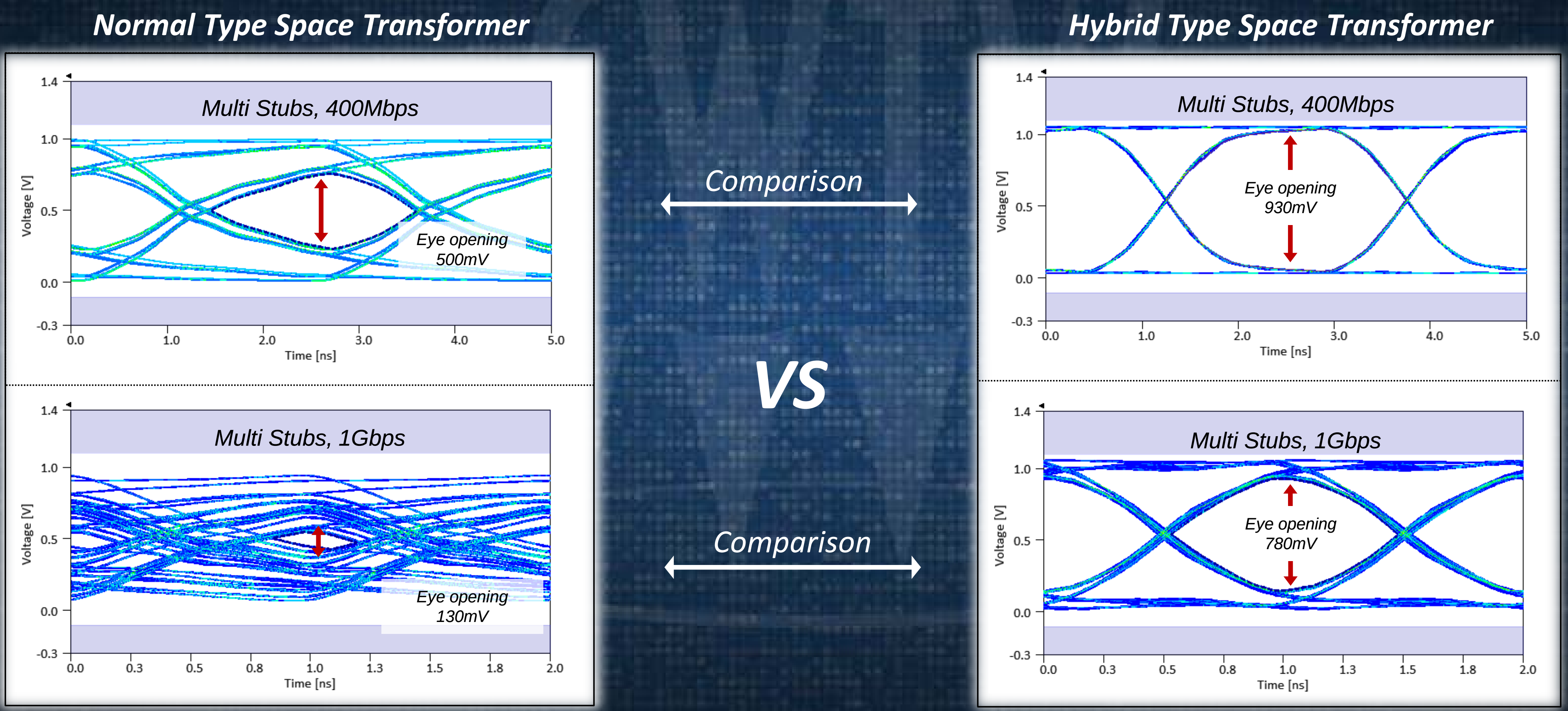

Fig. Eye-Diagram of Normal STF

Fig. Eye-Diagram of Hybrid STF

SUMMARY

- ✓ ***Designed** the Space Transformer and **Compared** of Two Types of Space Transformer*
- ✓ ***Performed** the Basic Study of Signal and Power Design on Probe Card*
- ✓ ***Measured** Electrical Characteristics of Signal and Power at Space Transformer*
- ✓ ***Analyzed** Signal Integrity and Power Integrity for Space Transformer Performance*
- ✓ ***Verified** the Hybrid Type of Space Transformer on Probe Card*

Acknowledgements

SAMSUNG ELECTRONICS

Microfriend Inc.

YONSEI UNIVERSITY

- *SANG-KYU YOO*
- *YONG-HO CHO*
- *JONG-MYEON LEE*
- *JONG-GWAN YOOK*