

Application Note

Products:

- R&S[®]ZNB (optional B54)
- R&S[®]ZV-Z195
- R&S[®]ZV-Z229
- R&S[®]RT-ZF7A

- Allion®AET20055
- Allion[®]AET21064

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Ronde & Schwarz Application Note 1 - 51





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1 關於 TC9

随著車用產業蓬勃的發展、車用影音娛樂與資料傳輸也隨之升級、車用網路也由較簡單的架構 演變為更複雜的脈絡、如今不同系統間的傳輸已成為人們關注的焦點、為了達到更快、更穩定的傳輸 以及降低成本、Open Alliance為物理層傳輸通道Cable/Connector制定了TC2-100Base以及TC9-1000Base之中的非屏蔽雙絞線(Unshielded Twisted Pair, UTP)線材的RF測試規範、此規範包含 獨立通信通道(Standalone Communication Channel, SCC)及全通訊通道(Whole Communication Channel, WCC)兩種特性與環境測試。本篇文章將針對TC9-1000Base UTP(頻 率範圍的要求在1~600MHz)測試方法以及**測試治具**提出一個詳細的量測**手**法。

Connector (SCC Context)表一

No.	Item	Requirement					
1	Characteristic Impedance Differential Mode	A. 100 ohms +/- 5% B. Rise time less than 500psec					
2	Propagation Delay	\leq 667ps 2 \leq f \leq 600 frequency f in MHz					
3	Insertion Loss	\leq (0.01 \sqrt{f}) dB 1 \leq f \leq 600, frequency f in MHz					
4	Return Loss	$\geq \{ \begin{array}{c} 38 & 1 \leq f < 75 \\ 20 - 20 \log(f/600) & 75 \leq f < 600 \\ 1 \leq f \leq 600, \text{frequency f in MHz} \end{array} \} dB$					
5	Longitudinal Conversion Loss	$\geq \left\{ \begin{array}{ccc} 55 & 10 \le f \le 80 \\ 77 - 11.51 \log(f) & 80 \le f < 600 \end{array} \right\} dB$ 1 $\le f \le 600$, frequency f in MHz					



Cable and Channel (SCC Context) 表二

No.	Item	Requirement						
1	Characteristic Impedance Differential Mode	A. 100 ohms +/- 5% B. Rise time less than 500psec						
2	Propagation Delay	For use in SCC with maximum length of $15m \le 6$ ns /m For use in SCC with maximum length of $10m \le 9$ ns /m						
3	Insertion Loss	For use in SCC with maximum length of 15m ≤ 1/15 (0.0023f+0.5907 \sqrt{f} -6*0.01 \sqrt{f} +0.0639/ \sqrt{f}) dB/m For use in SCC with maximum length of 10m ≤ 1/10 (0.0023f+0.5907 \sqrt{f} -6*0.01 \sqrt{f} +0.0639/ \sqrt{f}) dB/m 1≤ f ≤600, frequency f in MHz						
4	Return Loss	$\geq \left\{ \begin{array}{ccc} 22 & 1 \leq f < 10 \\ 27 - 5 \log f & 10 \leq f < 40 \\ 19 & 40 \leq f < 130 \\ 40 - 10 \log f & 130 \leq f < 400 \\ 14 & 400 \leq f \leq 600 \end{array} \right\} dB$ 1 $\leq f \leq 600$, frequency f in MHz						
5	Longitudinal Conversion Loss	\geq $\begin{cases} 55 & 10 \leq f \leq 80 \\ 77-11 & 51 \log (f) & 80 \leq f \leq 600 \end{cases}$ dB						
6	Longitudinal Conversion Transfer Loss	$1 \le f \le 600$, frequency f in MHz						



Whole Communication Channel (SCC Context) 表三

No.	Item	Requirement					
1	Characteristic Impedance Differential Mode	A. 100 ohms +/- 10% (Informative) B. Rise time less than 500psec					
2	Propagation Delay	\leq 94ns 2 \leq f \leq 600 frequency f in MHz					
3	Insertion Loss	≤(0.0023f+0.5907√f+0.0639/√f)dB 1≤ f ≤600, frequency f in MHz					
4	Return Loss	$\geq \left\{ \begin{array}{ccc} 19 & 1 \leq f < 10 \\ 24 - 5 \log f & 10 \leq f < 40 \\ 16 & 40 \leq f < 130 \\ 37 - 10 \log f & 130 \leq f < 400 \\ 11 & 400 \leq f \leq 600 \end{array} \right\} dB$ 1 $\leq f \leq 600$, frequency f in MHz					
5	Longitudinal Conversion Loss	$\geq \{ 50 \ 10 \leq f \leq 80 \} dB$					
6	Longitudinal Conversion Transfer Loss	$1 \le f \le 600$, frequency f in MHz					

上述獨立通訊通道(Standalone Communication Channel · SCC)的量測項目 LCL、LCTL 屬於 Common mode Conversion · 其他四項是在高頻測試中比較常見的項目:

差分特性阻抗 (Characteristic Impedance)

傳輸延遲 (Propagation Delay)

插入損耗 (Insertion Loss)

反射損耗 (Return Loss)

在 Cable Insertion Loss 的規範中有定義最大長度 10m 及 15m 的規格,並依據實際測試樣品有浮動規格線。須注意的 是,製造商在開發的過程中,因為可能會有 inline connectors 的需求,在評估線損時也必須將 Connector Loss 考慮進去;另外,由於 TDR 的量測會隨著時間越長產生失真(波形上飄),因此規範對於電纜的 Impedance evaluation window 定義在 0.5 m 至 1.5 m 之間。

而在一個複合式的傳輸環境中·訊號的傳遞不能只單一考量自身的通道特性·不同的差動訊號對(differential pair)之間相互影響都可能會造成訊號的失真·因此當終端產品為 multi lane 時·除了 SCC 以外還必須考量到整個系統環境 (ES, Environment System)的相互串擾:



Environment System Context 表四

Types	Item
Connectors	PSANEXT Loss (Sdd31, Sddyx) PSAFEXT Loss (Sdd41, Sddyx) AFEXTDC Loss (Sdc41, Sdcyx) AFEXTDS Loss (Sds45, Sdsyx)
Cable and Channel- Informative	ANEXT Loss(Sdd31, Sddyx) AFEXT Loss(Sdd41, Sddyx) AFEXTDC Loss(Sdc41, Sdcyx) AFEXTDS Loss(Sds45, Sdsyx)
Whole Communication Channel	PSANEXT Loss(Sdd31, Sddyx) PSAACRF (Sdd41, Sddyx) AFEXTDC Loss(Sdc41, Sdcyx) AFEXTDS Loss(Sds45, Sdsyx)

在本文章的第三章介紹中·將詳細介紹規範中的規格設定、如何使用 <u>Rohde & Schwarz</u>的網路 分析儀 ZNB 進行校正及搭配<u>百佳泰(Allion Labs)</u>的測試治具及 Conductive Drum 完成 TC9-1000Base 的 Cable 量測



2 測試設置



Conductive Drum

Figure 2.1





 上圖(Figure 2.1)為測試 1000Base-T1 車用纜線裸線(UTP)測試的示意圖,必須搭配圖 (figure 2.2)的治具,待測物纒繞在 Conductive Drum (Allion[®]AET20055)來進行量測。



3 使用 ZNB 完成 TC9(UTP) 量測規範

3.1 使用向量網路分析儀 ZNB 單機完成規格驗證

3.1.1 向量網路分析儀 ZNB 參數設置與校正

請參考下圖 ZNB 網路分析儀 TC9(UTP)的環境設定。

Parameter	Value
Sweep f _{start}	300 kHz
Sweep f _{Stop}	1 GHz
Sweep type	Logarithmic
Sweep points	1600
Output power	minimum -10 dBm
Measurement bandwidth	≤ 500 Hz
Port reference impedance differential mode ¹	100 Ω
Port reference impedance common mode ¹	25 Ω for connector measurements and MDI Test Head 200 Ω for all other measurements
Data calibration kit (VNA)	used kit for calibration
Averaging function	May be applied, but not mandatory
Smoothing function	Deactivated

資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3.1.1.1 TC9 (UTP) 環境設定



ZNB 設置:	• [Preset]						
設定頻率、功率、點數與量測頻寬	 [Start : 300 kHz] [Stop : 1 GHz] [Power BW Avg : Power : {p* : 0 dBm}] [Power BW Avg : Bandwidth : {bw* : 500 Hz }] [Sweep : Number of Points : 1600] [Sweep : Sweep type : Log Swep] 						
StimulusTaceStart Frequency 300 kHzStimulusStardStart Frequency 300 KHzPowerLineMarkerGenter Frequency 599.7 MHzTime Domain XAxisStimulusSpan Frequency 599.7 MHzStardStorpPower 10 dBmCenterSpanPower 10 dBmCenterSpanPower 10 dBmCenterSpanPower 10 dBmCenterSpanPower 10 dBmCenterSpanPower 10 dBmCenterSpanPower 10 dBmTriggerCenterStimulus Axis Frequency Power Channel Base PbPower StimulusPower 10 dBmTriggerCalPower 10 dBmTriggerCalFigure 3.1.1.2 Bbc ztbda Bt U #g xDxStype 10 dBmTriggerFreq Step Size 1472 SSweepFreq Step Size 1472 SSweepSweep Time 1472 SStartStart 1500StartSweep Time 1472 SStartStart 1500StartStart 1500CenterSweep Time 1472 SSweepSweep Time 1472 SSweepSweep Time 1472 SStartStart 1500StartStart 1500CanSweep Time 1472 SStartStart 1500SweepSweep Time 1472 SStartStart 1500SweepSweep Time 1472 SStartStart 1500SweepSweep	Power Bw Avg *Tare MeasbindividitiPowerScaleConfig10 HzAverageStatulus100 HzStatulusStatulus100						
	Figure3.1.1.5 設定掃描格式						
p* → ज≣	問整最小-10dBm						
bw* → 可調整最大 500Hz							















_										
) 🇞	Calibration Setting								×
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Γ		Cal Type	Ports							
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	(Port Connector	Gender	Cal Kit	Kit Modified]				
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I	2	● P2 3.5 mm ▼	Male 🔻	ZV-Z33 ty ▼		_				
B	3	● P3 3.5 mm ▼	Male 🔻	ZV-Z33 ty ▼		_				
	4	● P4 3.5 mm ▼	Male 🔻	ZV-Z33 ty ▼						
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С	al k	kits* → 依照儀	器而不同	 此範例 	」為 ZV-Z	135				
如	儀	器內沒有上述的	り Cal kit	可透過ir	mport 的	方式新增至儀器				
此	範	例為單機校正·	如需執	行完整測	項可使用	合併校正的方式洞	成少校正時	問 (參考	ぎ3.4.3 章)	



3.1.2 使用 Through 驗證向量網路分析儀 ZNB 單機 TC9 規格

驗證向量網路分析儀 ZNB 單機規格請參考圖 3.1.2.1,輸入規格後接上兩個對稱的 Through 驗證

Test Paramete	r	Requirement				
RL	S _{dd11} , S _{dd22}	$\geq \begin{pmatrix} 44 & 1 \le f < 75 \\ 26 - 20 \log \left(\frac{f}{600} \right) & 75 \le f \le 600 \end{pmatrix} dB$ 1 \le f \le 600, frequency f in MHz Port reference impedances: 100 \Omega (DM), 200 \Omega (CM)				
	S _{dc11} , S _{dc22}	$\geq \begin{pmatrix} 61 & 10 \le f \le 80 \\ 83 - 11.51 \log(f) & 80 < f \le 600 \end{pmatrix} dB$				
	Jdc21, Jdc12	$10 \le f \le 600$, frequency f in MHz				
		Port reference impedances: 100 Ω (DM), 200 Ω (CM)				



Figure 4.2-2: Return loss requirement for VNA calibration accuracy



TC9(UTP) 規範·如沒有對稱的 Through 會影響差動電路的量測結果,可以參考下列步驟做不對 稱 Through 的特性移除





Figure3.1.2.1 單機驗證規格



	[Select : Trc1 (Sdd11)]
	• [Line : Limit test : Define limit line :
	Add : Type Upper : Start Stimulus 1
	MHz : Stop Stimulus 75 MHz : Start
	Response -44 dB : Stop Response -44
	dB: Show Limit Line : Limit Check]
	• [Line : Limit test : Define limit line :
	Add :
規格線設定(RL)	Type Upper : Start Stimulus 75 MHz :
	Stop
	Stimulus 600 MHz : Formula :
	-26+20· log (StimVal/1000000/600) :
	close : Show Limit Line : Limit Check :
	close]
	● [Select:Trc2(Sdd22) :依照 Trc1 的方
	式新增 Trc2 的規格線]
hde & Schwarz VNA	-
	Lines × Trace Meas Format
strznx* X + Ref 0 dB Cal 1 V Tre6 Sdc21 dB Mag Trc3 Sdc11 dB Mag 2 V Trc7 Sdc21 G Ca D Cal 1 V Tre6 Sdc21 dB Mag Trc3 Sdc11 dB Mag 2 V Trc7 Sdc21	□ Show Limit Limit Test Scale Config
Ket 0 dB Cal Irch Sdc12 dB Mag Irc4 Sdc22 dB Mag Irch Sdc12	dB Mag 1 dB/ Ref 0 dB Cal Check Repte Check Test Line Marker
(III) Type Start Stimulus Stop Stimulus Re	sponse Interpolation Clear X Display Start Stop
	Define Limit Line Circle Horiz. Line Center Span
	Global Check Channel Config
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+ Add X Delete Add I Get Trace C Show Limit Line	Shift Lines Cal Offset Embed Stimulus System
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						Formu	ula :						
						-83+1	1.51.	og	(Stir	mVal/	1000	000) :
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						close]							



•	[Select : Trc4 (Sdc22)	:依照	Trc3	的方
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	Single Ended							
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	P2 💽• L2							
	P3 💽• L3	✓	test_coupon.s2p ····					
	P4 💽 L4							
Embed								
Offset	Overview						🗙 Close	? Help
			Figure3.1.2.4 將不對	稱的 Through [;]	特性	移除		



3.2 使用向量網路分析儀 ZNB 搭配量測治具完成規格驗證

由於TC9(UTP)的同軸共纜線必須搭配特定的治具才可真實量測到特性·所以TC9(UTP)的規範 中明確制定了使用向量網路分析儀搭配治具的規格·此章節完整描述了如何完成向量網路分析儀搭配 治具的規格驗證。

3.2.1 向量網路分析儀 ZNB 參數設置與校正

Parameter	Value
Sweep f _{start}	300 kHz
Sweep f _{Stop}	1 GHz
Sweep type	Logarithmic
Sweep points	1600
Output power	minimum -10 dBm
Measurement bandwidth	≤ 500 Hz
Port reference impedance differential mode ¹	100 Ω
Port reference impedance common mode ¹	25 Ω for connector measurements and MDI Test Head 200 Ω for all other measurements
Data calibration kit (VNA)	used kit for calibration
Averaging function	May be applied, but not mandatory
Smoothing function	Deactivated

請參考下圖 ZNB 網路分析儀 TC9(UTP)的環境設定。

資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3. 2.1.1 TC9(UTP)環境設定

	由於環境與單機設定	相同,請參考 3.1.1.中
ZNB 設置	向量網路分析儀ZNB	參數設置與校正·如接
	續 3.1.1 章執行則不需	零執行[Preset]



3.2.2 使用量測治具驗證 TC9 測試系統規格

此章節提出了三種可以符合 TC9(UTP) 同軸共纜線量測的治具 · 請參考下圖 3.2.2.1 範例 · 如 有治具上需求請洽<u>百佳泰(Allion Labs)</u>或<u>台灣羅德史瓦茲(R&S)</u> · 再搭配向量網路分析儀 ZNB 完成圖 3.2.2.2 的 TC9(UTP) 規範 。



R&S 治具 R&S[®]RT-ZF7A



Allion Labs 治具 Allion[®]AET21064

Figure 3.2.2.1 符合 TC9(UTP) 規範的測試治具範例圖

ALLEN

Allion Labs 成品線治具(客製化)

Test Parameter	r	Requirement
LCL	S _{dc11} , S _{dc22}	$\geq \begin{pmatrix} 61 & 10 \leq f \leq 80 \\ c & c \end{pmatrix} dB$
LCTL	S _{dc21} , S _{dc12}	$(83 - 11.51\log(f) 80 < f \le 600)$
		$10 \le f \le 600$, frequency f in MHz
		Port reference impedances: 100 Ω (DM), 200 Ω (CM)

資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3.2.2.2 TC9 (UTP) 網路分析儀搭配測試治具規格







3.3 使用反嵌入軟體建立治具特徵模型

為了量測 TC9(UTP) 同軸共纜線的特性,必須將治具特性反嵌入,此章節將詳細介紹如何使用向量 網路分析儀 ZNB 搭配反嵌入軟體將治具特徵模型建立,再做反嵌入的應用。

3.3.1 向量網路分析儀 ZNB 參數設置與校正

TC9(UTP)的規範中·針對同軸共纜線 TDR 的測項也有明確的環境設定·所以在建立治具模型時·需同時將兩種環境的模型建立·請參考下圖 ZNB 網路分析儀 TC9(UTP)的環境設定。

Parameter	Value
Sweep f _{Start}	300 kHz
Sweep f _{Stop}	1 GHz
Sweep type	Logarithmic
Sweep points	1600
Output power	minimum -10 dBm
Measurement bandwidth	≤ 500 Hz
Port reference impedance differential mode ¹	100 Ω
Port reference impedance common mode ¹	25 Ω for connector measurements and MDI Test Head 200 Ω for all other measurements

資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3. 3.1.1 TC9 (UTP) 環境設定



Parameter	Value
Sweep f _{start}	1 MHz, (10 MHz) ²
Sweep f _{Stop}	2 GHz, (20 GHz) ²
Sweep type	Linear
Sweep points	2000
Filtering	Hann window
TDR Type	Step
Output power	minimum -10 dBm
Measurement bandwidth	≤ 500 Hz
Port reference impedances	50Ω single ended port impedances (This results in 100Ω differential mode reference impedance after conversion to mixed mode parameters.)
Data calibration kit (VNA)	used kit for calibration
Averaging function	May be applied, but not mandatory
Smoothing function	deactivated

資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3. 3.1.2 TC9(UTP)TDR 環境設定

ZNB 設置	 由於環境與單機設定相同,請參考 3.1.1.中向量 網路分析儀 ZNB 參數設置如接續 3.1.1 章執行則 不需執行[Preset]
ZNB設置(TDR)	 [Channel Config : Channels : New channel+ Diagram] [Start : 1 MHz] [Stop : 2 GHz] [Power BW Avg : Power : {p* : 0 dBm}] [Power BW Avg : Bandwidth : {bw* : 500 Hz }] [Sweep : Number of Points : 2000] [Sweep : Sweep type : Lin Swep]
設定平衡式 p* → 可調整最小-10dBm bw* → 可調整最大 500Hz	• [Meas : Balanced Port : (D) 2 x Balanced]



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3.3.2 使用向量網路分析儀 ZNB 搭配反嵌入軟體建立治具模型

在反嵌入軟體程式中,共分為三個步驟,首先量測相關治具(2x Thru or 1x Open or 1x Short or 1x Open & 1x Short)的S參數,接著量測治具含待測物的參數,最後讓程式計算治具的特性,程式會自動提供兩側治具的特性,請參考下圖 3.3.2.1,此章節將完整介紹執行步驟。





Analyzer - Rohde & Schwarz VNA	
反嵌入軟體操作步驟(TDR)	 ■ 點選至 Channel 2 ■ 因步驟闼前者相同請參考上述步驟
反嵌入軟體操作步驟	 No res (or r) hylog and an equal to the second second
	 [Offset Embed : Balanced : Network D1 : Fixture tool ISD : Run tool] Coupon type : 1x Open : Port1 & Port3 Active : Measure 將 TC9 (UTP) 的同軸共續線接到對應治員上:







Analyzer - Rohde & Schwarz VNA				Offcot Emb	- 🗇 X
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🏇 ISD - Balanced Ports		•	■ 🗖 🗙	Overview	Offset Scale Trace Config
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Coupon Type 1x Open			_	Logical Port 🚽	Single Stimulus Ended
	Measure			Network	Port Start Stop Sets
# △ Active	#	# 🛆 Apply	Display		Balanced Center Span
Port 1	Port 1	► logical 1	~		Ground Channel Sweep
Port 2	Port 2	(P1,P3)			Diff. Power Trigger
Port 3	Port 3	Logical 2	✓	D1 🖆	Config Cal Offset
Port 4	Port 4	(12,14)		Fixture Tool 🚽 👻	System
Select Ports & Connect Coupon to VNA	Select Ports & Connect DUT to VNA	Run Fixture Modeling Tool		Run Tool	File Print
Advanced Settings Timestamp	Suppress Remeasure Reset t Warnings	o Default 🗸 Apply 🗙	Cancel <mark>?</mark> Help	Tool Info	Display Setup
	Figure 3. 3.2.5	反嵌入軟體第三步	驟示意圖		
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P3					
P2 •	semi.s4p_right_DUT.s4p	🗖			
P4 :					
•					
- Overview					X Close ?
	Figure 3.	3.2.6 反嵌入成功示	意圖		



3.4 使用向量網路分析儀 ZNB 搭配 Conductive Drum 完成規範量測

本章節的量測實驗為百佳泰(Allion Labs)與台灣羅德史瓦茲(R&S)共同執行·TC9(UTP)的規 範中·明確規定量測同軸共纜線時需搭配對應治具及 Conductive Drum·本章節將完整介紹如何執 行整體量測·下圖 3.4 為使用<u>台灣羅德史瓦茲(R&S)</u>向量網路分析儀 ZNB 配合百佳泰(Allion Labs) Conductive Drum 量測示意圖



Figure 3.4 向量網路分析儀 ZNB 配合百佳泰 (Allion Labs) Conductive Drum 量測示意圖

如有 Conductive Drum 的需求請洽百佳泰 (Allion Labs) 諮詢相關應用



3.4.1 向量網路分析儀 ZNB 完成 S 參數環境設置

TC9(UTP) 規範中的測項分為了 Log Freq 的 S 參數測試及 Lin Freq 的 TDR 與 TDT 測試,針對同 軸共纜線配合治具及搭配 Conductive Drum 的量測也有明確的規格規範,所以此章節將詳細介紹如 何使用向量網路分析儀 ZNB 完成 TC9(UTP)搭配治具及 Conductive Drum 在 Log Freq 的 S 參 數設定,請參考以下環境設定及規格說明。

Parameter	Value		
Sweep f _{Start}	300 kHz		
Sweep f _{Stop}	1 GHz		
Sweep type	Logarithmic		
Sweep points	1600		
Output power	minimum -10 dBm		
Measurement bandwidth	≤ 500 Hz		
Port reference impedance differential mode ¹	100 Ω		
Port reference impedance common mode ¹	25 Ω for connector measurements and MDI Test Head 200 Ω for all other measurements		

資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3. 4.1.1 TC9 (UTP) 環境設定



IL	S _{dd21}	For use in SCC with maximum length of 15 m $\leq \frac{1}{15} \left(0.0023f + 0.5907\sqrt{f} - 6*0.01\sqrt{f} + 0.0639/\sqrt{f} \right) dB/m$ For use in SCC with maximum length of 10 m $\leq \frac{1}{15} \left(0.0023f + 0.5907\sqrt{f} - 6*0.01\sqrt{f} + 0.0639/\sqrt{f} \right) dB/m$			
		$1 \le f \le 600$, frequency <i>f</i> in MHz Port reference impedances: 100 Ω (DM), 200 Ω (CM)			
RL	S _{dd11} , S _{dd22}	$\geq \begin{pmatrix} 22 & 1 \le f < 10 \\ 27 - 5 \log f & 10 \le f < 40 \\ 19 & 40 \le f < 130 \\ 40 - 10 \log f & 130 \le f < 400 \\ 14 & 400 \le f \le 600 \end{pmatrix} dB$ $1 \le f \le 600, \text{ frequency } f \text{ in MHz}$ Port reference impedances: 100 Q (DM), 200 Q (CM)			
LCL LCTL	S _{dc11} , S _{dc22} S _{dc21} , S _{dc12}	$\geq \begin{pmatrix} 55 & 10 \le f \le 80 \\ 77 - 11.51 \log(f) & 80 < f \le 600 \end{pmatrix} dB$ $10 \le f \le 600, \text{ frequency } f \text{ in MHz}$ Port reference impedances: 100 Ω (DM), 200 Ω (CM)			



Figure 3.4.1.2 TC9(UTP) 同軸共纜線搭配治具及 Conductive Drum 規格設定



ZNB 設置	 由於環境與單機設定相同,請參考 3.1.1.中向量 網路分析儀 ZNB 參數設置如接續 3.1.1 章執行則 不需執行[Preset] [Trace Config: Add Trace + Diagram] 		
新增 IL 的曲線	• [Meas : S-Params : Sdd21]		
Trc1 Sdd11 dB Mag 10 dB/Ref 0 dB Trc2 Sdd22 dB Mag 10 dB/Ref 0 dB Trc5 Sdc12 dB Mag 1 Trc5 Sdc12 dB Mag 1 D dB PASS Trc2 0 dB 1 PASS Trc2 0 dB 1 PASS Trc2 0 dB 1 D dB 1 PASS Trc2 1 D dB 1 D dB	Trc3 Sdc11 dB Mag 2 ~ Trc7 Sdd21 dB Mag 1 dB/ Ref 0 dB 3 ~ Trc4 Sdc22 dB Mag Trc1 Sdd12 dB Mag 1 dB/ Ref 0 dB 3 ~ SS Trc5 PASS Trc7 Sdc10 0 dB 0 dB		
	• [Select : Trc1 (Sdd11)]		
	• [Line : Limit test : Define limit line : Add :		
	Type Upper : Start Stimulus 1 MHz : Stop		
	Stimulus 10 MHz : Start Response -22 dB :		
	Stop Response -22 dB : Show Limit Line :		
	Limit Check]		
規格線設定(RL)	• [Line : Limit test : Define limit line : Add :		
	Type Upper: Start Stimulus 10 MHz : Stop		
	Stimulus 40 MHz:Formula:		
	-27+5·log (StimVal/1000000) : close :		
	Show Limit Line : Limit Check]		
	• [Line : Limit test : Define limit line : Add :		
	Type Upper: Start Stimulus 40 MHz: Stop		



	Stimulus 130 MHz : Start Response -19 dB :
	Stop Response -19 dB : Show Limit Line :
	Limit Check]
•	[Line : Limit test : Define limit line : Add :
	Type Upper : Start Stimulus 130 MHz : Stop
	Stimulus 400 MHz : Formula :
	-40+10·log (StimVal/1000000) : close :
	Show Limit Line : Limit Check]
•	[Line : Limit test : Define limit line : Add :
	Type Upper : Start Stimulus 400 MHz : Stop
	Stimulus 600 MHz : Start Response -14 dB :
	Stop Response -14 dB : Show Limit Line :
	Limit Check : close]
•	[Select:Trc2(Sdd22) :依照 Trc1 的方式新 增 Trc2 的規格線]

🚸 Defi	ne Limit Lines						
¢	Туре	Start Stimulus	Stop Stimulus	Response	Interpo		
1	Upper 🗖	1 MHz	10 MHz	-22 dB22 dB	Lin		
2	Upper 🗖	10 MHz	40 MHz	- 27 + 5log (StimVal / 1000000) ····	Lin		
3	Upper 🗖	40 MHz	130 MHz	-19 dB19 dB	Lin		
4	Upper 🗖	130 MHz	400 MHz	- 40 + 10log (StimVal / 1000000) ···	Lin		
5	Upper 🗖	400 MHz	600 MHz	-14 dB14 dB	Lin		
•			l				
+ Ad	dd X Del	ete All Cet File	recall ☑ Shov Line Save ☑ Limit	v Limit t Check X Close	? Help		
Figure 3. 4.1.4 新增 RL 規格							



	• [Select : Trc3 (Sdc11)]
	 [Line : Limit test : Define limit line : Add : Type Upper : Start Stimulus 10 MHz : Stop Stimulus 80 MHz : Start Response -55 dB : Stop Response -55 dB : Show Limit Line : Limit Check] [Line : Limit test : Define limit line : Add :
規格線設定(LCL & LCTL)	Type Upper : Start Stimulus 80 MHz : Stop Stimulus 600 MHz : Formula : -77+11.51·log (StimVal/1000000) : close : Show Limit Line : Limit Check : close]
	● [Select : Trc4(Sdc22) :依照 Trc3 的方式新 增 Trc4 的規格線]
	● [Select:Trc5(Sdc12) :依照 Trc3 的方式新 增 Trc5 的規格線]
	● [Select:Trc6(Sdc21) :依照 Trc3 的方式新 增 Trc6 的規格線]

🊸 Defi	ine Limit Li	ines						Ō		×
	Т	ype	Start Stimulus	Stop Stir	mulus	Respo	onse		Ir	nterpo
1	Upper	•	10 MHz	80 MHz		-55 dB55 dB			Lin	
2	Upper	•	80 MHz	600 MHz		- 77 + 11.5log (Stin	nVal / 10000)C ····	Lin	
+ A	dd	🗙 Dele	te Get Trace	🚰 Recall	✓ Show Line	Limit				
+ , In	isert	Dele	te All 🖆 İmport File	💾 Save	🖌 Limit	Check	×	Close	?	Help
			Figu	re 3. 4.1.5 新增 L	.CL & LCTL	規格				

 \succ



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規格線設定(Ⅱ) * Ⅱ 規格公式中有兩種格式 · 差別在第一項分 母分子的部分 · 分母取決於同軸共纜線最長的 長度 · 分子取決於目前待測的同軸共纜線長度			項 長 長度	 [Line : L Type Up Stimulus ((0.00 * (Stim 0.01 * 2))) ^ (1/2) 	imit test : Defi oper : Start Sti 600MHz : Fo 23 * StimVal / 1 Val / 1000000) ((StimVal / + (0.0639 / (2)))))	ne limit lir mulus 80N rmula : {- .000000) ^ (1/2 1000000) (StimVal/	ne : Add : 1Hz : Stop 10 / 15 * + (0.5907)) - (6* ^ (1 / 1000000)	
🚸 Defi	ine Limit l	ines					() ()	×
< . >	-	Гуре	Start Stimulus	S	top Stimulus	Respons	e	Interpo
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+ A	dd	🗙 Dele	te Get Trace	r Red	call DShow	/ Limit		
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			Fig	gure 3.	4.1.6 新增 IL 規格	ζ 1		



3.4.2 向量網路分析儀 ZNB 完成 TDR 環境設置

TC9(UTP) 規範中的測項分為了 Log Freq 的 S 參數測試及 Lin Freq 的 TDR 與 TDT 測試,針對同 軸共纜線配合治具及搭配 Conductive Drum 的量測也有明確的規格規範,所以此章節將詳細介紹如 何使用向量網路分析儀 ZNB 完成 TC9(UTP)搭配治具及 Conductive Drum 在 Lin Freq 的 TDR 與 TDT 參數設定,請參考以下環境設定及規格說明。

Parameter	Value
Sweep f _{Start}	1 MHz, (10 MHz) ²
Sweep f _{Stop}	2 GHz, (20 GHz) ²
Sweep type	Linear
Sweep points	2000
Filtering	Hann window
TDR Type	Step
Output power	minimum -10 dBm
Measurement bandwidth	≤ 500 Hz
Port reference impedances	50Ω single ended port impedances (This results in 100Ω differential mode reference impedance after conversion to mixed mode parameters.)
Data calibration kit (VNA)	used kit for calibration
Averaging function	May be applied, but not mandatory
Smoothing function	deactivated

資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3. 4.2.1 TC9 (UTP) TDR & TDT 環境設定





資料來源: Channel Components Requirements for 1000Base-T1 Link Segment Type A

Figure 3. 4.2.2 TC9 (UTP) TDR 規格數據



ZNB 設置(TDR)	 [Channel Config : Channels : New channel+ Diagram] [Start : 1 MHz] [Stop : 2 GHz]
	$[\mathbf{Bower} \mathbf{BW} \mathbf{Ave} : \mathbf{Bower} : \{\mathbf{p}^* : 0 \ \mathbf{d} \mathbf{Bm}\}]$
p* → 可調整最小-10dBm	
bw* → 可調整最大 500Hz	Power BW Avg : Bandwidth : {bw* : 500
	Hz }]
	• [Sweep : Number of Points : 2000]
	• [Sweep : Sweep type : Lin Freq]
StimulusTraceStart Frequency 1 MHzStimulusMeasFormatStop Frequency 2 GHzPowerLineMarkerCenter Frequency 1.0005 GHzTimomain XAxisStartStopSpan Frequency 0 dBmCenterSpanPower 0 dBmChannelSweepFrequency 1.0005 GHzFrequencyTimomain XAxisPower 0 dBmCenterSpanCtw Frequency 1.0005 GHzCenterSpanPower 0 dBmChannelSweepFrequency FrequencyFilePintePower Channel Base PbFilePinteDisplaySetupApplicPreset	TraceBandwidthPowerScaleFormat500 HzPowerScaleConfig10 HzBand-widthLineMarker100 HzAverageStimuts1 kHzStantStop10 kHzCenterSpan100 kHzCenterSpan100 kHzPowergTrigger100 kHzSelectivityCale1 MHzDUTSystemSelectivityStatuStatuSelectivityStatuStatuSelectivityStatuStatuSormalSystemStatuStatuStatuStatuSubStatuStatuSpanStatuStatuSpanSpanStatuSelectivityStatuStatuSormalStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuStatuStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuStatuSpanStatuSta
Figure3.4.2.3 設定起始截止頻率、功率	Figure3.4.2.4 設定掃描頻寬
Sweep Number of Points 2000Sweep ParamsTrace Meas2000ParamsSweep ParamsFindH2Sweep TriggerLineSweep Time 217 msTriggerStartValueSweep ControlStartMeas Delay 0Sweep ControlCenterMeas'ments Freg Sweep Mode SteppedFriggerFired Sweep Mode SteppedFridFired SteppedFridFired SteppedFiredFired SteppedFiredFired SteppedFiredFired SteppedFiredFired SteppedFiredFired SteppedFiredFired SteppedFired </th <th>Sweep ParamsTrace MeasInin FreqSweep ParamsIog FreqSweep TriggerSegmentedTriggerPowerSweep ControlCW ModeStartTimeChannel ConfigDefine Segments Srg XAxisSweep TriggerSig XAxis Freq basedStartSig XAxis Freq basedStartSig XAxis Freq basedStartSig XAxis Freq basedSig XAxis PowerSig XAxis Freq basedSig XAxis PresetSig XAxis Freq basedSig XAxis PresetSig XAxis Freq basedSig XAxis PresetSig XAxis Freq basedSig XAxis PresetFigure 3.4.2.6Str Ha Ha TiFigure 3.4.2.6Str Ha Ha Ti</th>	Sweep ParamsTrace MeasInin FreqSweep ParamsIog FreqSweep TriggerSegmentedTriggerPowerSweep ControlCW ModeStartTimeChannel ConfigDefine Segments Srg XAxisSweep TriggerSig XAxis Freq basedStartSig XAxis Freq basedStartSig XAxis Freq basedStartSig XAxis Freq basedSig XAxis PowerSig XAxis Freq basedSig XAxis PresetSig XAxis Freq basedSig XAxis PresetSig XAxis Freq basedSig XAxis PresetSig XAxis Freq basedSig XAxis PresetFigure 3.4.2.6Str Ha Ha TiFigure 3.4.2.6Str Ha Ha Ti









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	● [Meas : Z← Sij : Sdd11]					
	• [Trace Config : Time domain : Time					
設定 TDR	domain on : Type low pass step]					
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	Extrapolation on]					
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🍫 Low Pass Settings 💿 🖻 🗖	Traces					
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Frequency Gap and Open Short N Number of Points	Match Side Lobe Level Time . Center Span					
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	Infinite Averaging Display Setup					
	Trace Data Applic Preset					
Figure3.4.2.	2.9 設定 TDR					
Ŭ	• [Line : Limit test : Define limit line :					
	Add · Type Lower · Start Stimulus 5 ns ·					
	Stop Stimulus 15 ps : Start Despapes OF					
	Stop Stimulus 15 hs . Start Response 95					
	Ω : Stop Response 95 Ω : Show Limit					
	Line : Limit Check]					
規格線設定	• [Line : Limit test : Define limit line :					
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	Stop Stimulus 15 ps - Start Despass 105					
	Stop Stimulus 15 IIS . Start Response 105					
	Ω : Stop Response 105 Ω : Show Limit					
	Line : Limit Check : Close]					



Defi	ine Limit Li	nes								۲	ø (⊐ >
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											Data	
	MH ₂			Pwr -10 dBm	Bw 10 kHz				Stop 20 GHz			



3.4.3 向量網路分析儀 ZNB 校正

完成所有測項設定後,可透過向量網路分析儀 ZNB 內建合併校正的功能,同時完成所有測項的校

正,本章節將完整介紹如何完成校正。



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🍫 Define Calibrat	tion					۲		×
Ports	P1	✓ P3 (👩 🗹 р.	2	P4			
		P	I, P2, P3, P4					
Туре	2	2	2	\rightarrow	₽	5	52	
	Refl Norm	Refl Norm	Refl OSM	Trans Norm	Trans Norm	One Path	TOSM	
	Open	Short	77	77	Both		→	
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	Source	_						
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		Figure		校正 Devet 數	卫注答法			
		Figure	23.4.3.3 選擇	仪止 Port 數。	反) 皮			
¹ 🎨 Calibration Setting								
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2 • P2 3.5 mm •	Male ▼ ZV-Z3	3 ty 🔻						
3 ● P3 3.5 mm ▼	Male ▼ ZV-Z3	3 ty ▼						
4 P4 3.5 mm	Male V-Z3	3 ty ▼						
Same Connector all Ports	Same Gender all Ports						r Im Ca	port Kit
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		Fig	ure3.4.3.5 點	選 Apply 完度	式校正			

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3.4.4 使用量測治具與 Conductive Drum 進行 TC9 (UTP)量測

完成校正後·將先前完成的反嵌入模型套入(參考 3.3 章節)·即可使用向量網路分析儀 ZNB 配合 治具及 Conductive Drum 完成最精準的量測·下圖 3.4.4.1 為整體量測示意圖·圖 3.4.4.2 為 TC9 (UTP) 實測結果



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[1] Link Segment Type A (UTP) 1000BASE-T1 Ethernet Channel and Components Specification - TC9, Open Alliance, Weblink: TC9 (opensig.org)

[2] Automotive Ethernet 1000Base-T1 TC9 measurement using VNA, Weblink: Appl. Note, Tech. Info, White Paper, Edu. Note (PAD-T) (rohde-schwarz.com)

[3]汽車乙太網-TC9 測試的深度剖析, Weblink: 汽車乙太網-TC9 測試的深度剖析 | 百佳泰 Allion Labs

[2021/6/11 上午 10:43] Yang lan 5TWAEI:

[4]Channel and Components Requirements for 1000BASE-T1 Link Segment Type A

Provide By



Make ideas real



5 使用儀器及配件清單

機型	規格
向量網路分析儀 4 port 100kHz - 8.5GHz	R&S [®] ZNB8
延伸 ZNB8 4 port 的動態範圍	R&S [®] ZNB-B54
Cable	R&S [®] ZV-Z195
校正器	R&S [®] ZV-Z229
測試治具	R&S [®] RT-ZF7A
測試治具	Allion [®] AET20055
測試治具	Allion [®] AET21064
滾桶治具	Allion [®] Conductive Drum

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