CASE STUDY

Diagnosing Railway Carriage Communication Cables with AEM Networks TestPro CV100

How a handheld cable certifier helped a passenger rail operator verify physical-layer link integrity, locate hidden faults, and confirm compliance across inter-carriage repeater cabling — in just 6 seconds per link.

Challenge

A passenger rail operator needed to verify the physical-layer transmission performance of communication cables running between train carriages, and to accurately identify the condition and location of any faults — without disrupting service any longer than necessary.

Solution

AEM TestPro CV100 deployed on-board the train for in-situ autotest certification, TDR analysis, and connector mapping across inter-carriage repeater cabling.

Key Results

- Full TIA-568.2-E Cat5e / ISO 11801 Class D channel certification in ≈6 seconds per link
- Both tested channels passed all transmission parameters
- TDR precisely located two intermediate connectors per channel — matching physical installation
- Impedance within 100 Ω ±15% limit throughout both cables
- Subtle cable bends and routing transitions identified non-destructively

Industry

Rail / Transportation

Standard Applied

TIA-568.2-E Cat5e Channel

(equivalent: ISO/IEC 11801 Class D,

GB/T 50312 Class D)

Instrument

AEM TestPro CV100

Background

Modern passenger rail systems rely on digital communication networks running the length of the train to coordinate safety signalling, passenger information systems, CCTV, and inter-carriage control data. These networks are built on structured copper cabling — typically twisted-pair — routed through conduits along the undercarriage and through junction boxes at each carriage coupling.

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Unlike conventional building cabling, railway communication cables must withstand continuous mechanical stress: vibration, flexing at carriage joints, thermal cycling, and physical compression from cable clamps and routing bends. Over time, these stresses can introduce subtle faults — shield damage, partial conductor breaks, or impedance anomalies — that may not cause an immediate link failure but degrade transmission performance and reliability over time.

A passenger rail operator sought to validate the physical-layer performance of the communication cabling between carriages using a recognised structured cabling standard, and to establish a baseline record of cable condition that maintenance teams could use for ongoing monitoring and fault diagnosis.

The Problem with Visual Inspection

Traditional cable inspection relies on visual checks and simple continuity testers, which can confirm a cable is connected but cannot measure transmission performance, locate impedance anomalies, or identify partial damage to a conductor or shield. The operator needed measurements — not just continuity.

Why AEM TestPro CV100

The AEM TestPro CV100 is a professional cable certification and analysis instrument designed for in-situ testing of structured cabling. For this railway application, three capabilities were decisive:

1. Automated Channel Certification

TestPro performs a full autotest in approximately 6 seconds, measuring all parameters required by TIA-568.2-E, ISO/IEC 11801, and equivalent national standards (including China's GB/T 50312). Results are automatically compared against the selected standard's limit masks and reported as pass/fail with per-parameter margins.

2. Time-Domain Reflectometry (TDR)

TestPro's built-in TDR sends a test pulse down the cable and analyses the reflected signal to produce an impedance profile across the full cable length, enabling technicians to:

- Measure the precise physical length of the cable
- Locate connectors, splices, and junctions at their exact distance from the test point
- Identify impedance anomalies — even subtle ones caused by excessive bending, compression, or partial shield damage — without opening the cable
- Distinguish between open-circuit faults, short-circuit faults, and soft faults such as kinked or over-compressed conductors

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3. Wire Map / Pinout Detection

TestPro automatically reads and displays the wire map of the connected cable, identifying straight-through, crossover, or non-standard pinout configurations before testing begins. This prevents misinterpretation of results on cables with custom or legacy wiring — a common scenario in railway installations.

TestPro CV100 Specification	Detail
Standard Support	TIA-568.2-E (Cat5e–Cat8), ISO/IEC 11801, GB/T 50312, ANSI/TIA-568.5 (SPE)
Test Time (Autotest)	~6 seconds per channel
TDR Resolution	Sub-metre fault location across full cable length
Wire Map	Automatic detection: straight-through, crossover, custom pinouts
Parameters Measured	IL, NEXT, PSNEXT, RL, ELFEXT, PSELFEXT, Delay, Skew, DC Loop Resistance, Length
Form Factor	TESTPRO Handheld main unit + remote unit; suitable for confined spaces

Test Setup and Procedure

Testing was conducted on a stationary passenger train with the entire train de-energised in accordance with railway safety operating procedures. Two cable runs were selected for validation:

- Cable A (Short Run): The repeater communication cable connecting Carriages 7 and 8
- Cable B (Long Run): The repeater communication cable connecting Carriages 4 and 5

For each cable, connectors were removed from the repeater units at both ends and the TestPro main unit and remote unit were connected in their place. The instrument automatically detected the cable's wiring configuration, and the appropriate test standard was selected before the single-button autotest was initiated.

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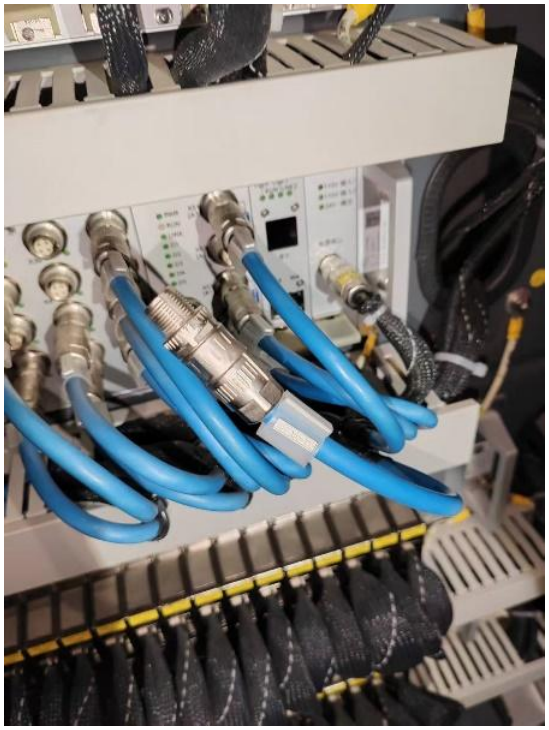

Fig. 1 — Inter-carriage repeater cables inside the carriage equipment cabinet. Blue cables connect to the communication repeater units.

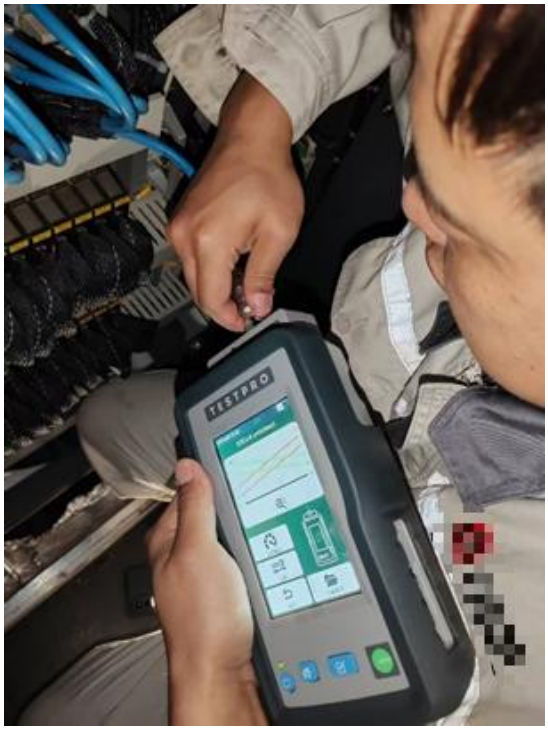

Fig. 2 — Technician connecting the TestPro CV100 main unit to the cable under test inside the confined carriage cabinet space.

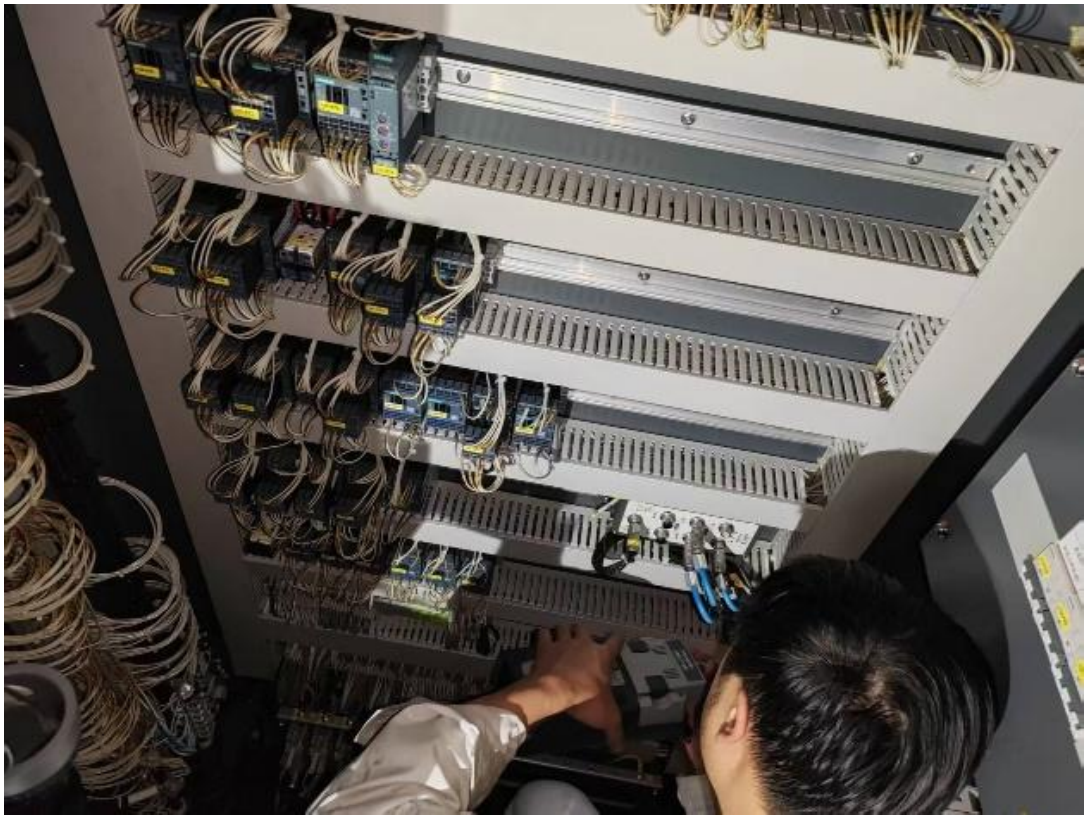

Fig. 3 — Technician accessing the inter-carriage cable connectors inside the carriage electrical cabinet prior to testing.

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Results

Cable A: Carriages 7–8, Short Inter-Carriage Run (~12m)

Upon connecting TestPro, the instrument immediately identified a 2-pair crossover wiring configuration — confirming that the cable uses a non-standard pinout. The wire map was displayed automatically and the correct configuration was selected in the instrument before testing to ensure accurate evaluation.

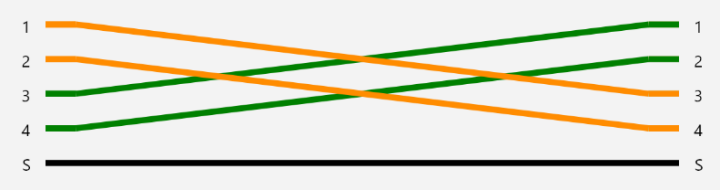

Fig. 4 — TestPro wire map display showing the 2-pair crossover configuration detected on Cable A.

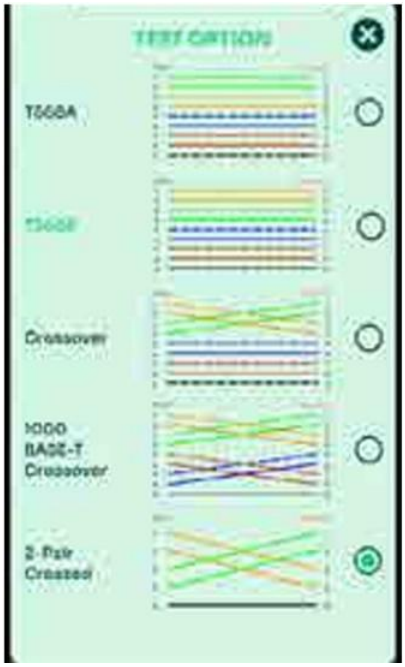

Fig. 5 — TestPro 'Test Option' screen with '2-Pair Crossed' selected to match the detected wiring configuration.

The autotest completed in approximately 6 seconds. All measured parameters — Insertion Loss, NEXT, PSNEXT, Return Loss, ACR-F, PS ACR-F, Delay, and Skew — passed the TIA-568.2-E Cat5e channel standard limits.

Autotest Result: PASS

All transmission parameters on Cable A (08X52-2) passed TIA-568.2-E Cat5e channel limits. The cable is certified for Gigabit Ethernet and equivalent applications.

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08X52-2

Pass

Project	: Default	**Test Time**	: 4/16/2026 7:33 PM
Operator	: Default		

Equipment

Model	: TestPro CV100	**Serial Number**	: Main: 5600-1371, Remote: 5600-1372
Device Software	: Main: 5.5.302, Remote: 5.5.302	**Calibration Date**	: Main: 6/23/2025, Remote: 12/17/2025
Main Adapter	: M12D CHANNEL	**Main Adapter S/N**	: 24053
Remote Adapter	: M12D CHANNEL	**Remote Adapter S/N**	: 24054

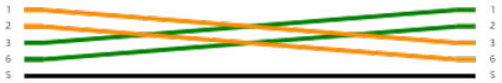
Test

Profile	: Copper 2 Pairs	**Limit**	: TIA-568.2-E Cat 5e Channel
Cable Type / Grade / NVP	: UTP / CAT5E / 68%	**Cable Manufacturer / Name**	: Generic Unshielded / 2-Pair (Pin12-36)
Connector Type / Grade	: Shielded / CAT5E	**Connector Manufacturer**	: Generic Shielded
Connector Name	: CAT5E		

Hierarchy

Project : Default

Parameter	Result	Pair	Value	Limit
Length(m)	Pass	3,6	12,1	100,0
Prop Delay(ns)	Pass	1,2	59,0	555,0
Delay Skew(ns)	Pass	1,2	0,0	50,0
DC Loop Resistance(Ω)	Pass	1,2	0,000	25,000
Res. Unbal, pair-pair(Ω)	Info	1,2-3,6	0,000	0,200
Res. Unbal, wire-wire(Ω)	Info	1,2	0,000	0,200



RF Parameters

Parameter	Result	Main								Remote							
		Worst Margin				Worst Value				Worst Margin				Worst Value			
		Pair	Margin (dB)	Limit (dB)	Freq (MHz)	Pair	Value (dB)	Limit (dB)	Freq (MHz)	Pair	Margin (dB)	Limit (dB)	Freq (MHz)	Pair	Value (dB)	Limit (dB)	Freq (MHz)
RL	Info	3,6	8,5	17,0	12,70	1,2	24,8	16,0	25,00	3,6	8,1	17,0	20,20	3,6	24,5	10,0	99,50
Insertion Loss	Pass	3,6	20,9	23,7	97,75	3,6	2,8	23,7	98,00		-	-	-		-	-	-
NEXT	Pass	1,2-3,6	18,6	37,4	37,50	1,2-3,6	51,6	30,2	98,50	1,2-3,6	19,3	37,3	38,00	1,2-3,6	55,1	32,5	72,00
PS NEXT	Pass	1,2	21,6	34,4	37,50	1,2	51,7	27,2	98,75	1,2	22,3	34,3	38,00	1,2	55,2	29,6	71,25
ACR-F	Pass	1,2-3,6	23,8	42,6	5,50	3,6-7,8	-8,5	51,2	2,05	3,6-1,2	24,2	44,4	4,45	4,5-7,8	-16,2	30,4	22,45
PS ACR-F	Pass	3,6	25,8	53,2	1,15	1,2	42,2	14,4	99,75	1,2	25,2	54,4	1,00	1,2	41,8	14,4	100,00
TCL	Info																
ELTCTL	Info																
ACR-N	Info	1,2-3,6	25,1	57,0	1,15	1,2-3,6	48,9	6,4	98,50	1,2-3,6	23,5	57,0	1,15	1,2-3,6	52,8	12,5	72,00
PS ACR-N	Info	3,6	28,1	54,0	1,15	3,6	48,9	3,4	98,50	3,6	26,5	54,0	1,15	3,6	52,8	9,3	72,50

Fig. 6 — TestPro CV100 full test report for Cable A (08X52-2), showing PASS status against TIA-568.2-E Cat5e channel limits. Length: 12.1m. All RF parameters within specification.

The TDR waveform provided additional diagnostic detail beyond the pass/fail result:

- Total cable length: approximately 12 metres (start connector to end connector), consistent with the physical installation distance between the two repeater units
- Two intermediate connectors identified: clearly visible as impedance events in the TDR trace, spaced approximately 2 metres apart — matching the physical junction locations at the carriage coupling
- Maximum impedance: approximately 103 Ω, within the standard's 100 Ω ±15% limit (85–115 Ω acceptable range)
- Minor impedance fluctuations approximately 1 metre from each connector: assessed as cable routing transition points where the cable changes from horizontal to vertical routing and is secured with cable ties — benign, but documented as a baseline reference

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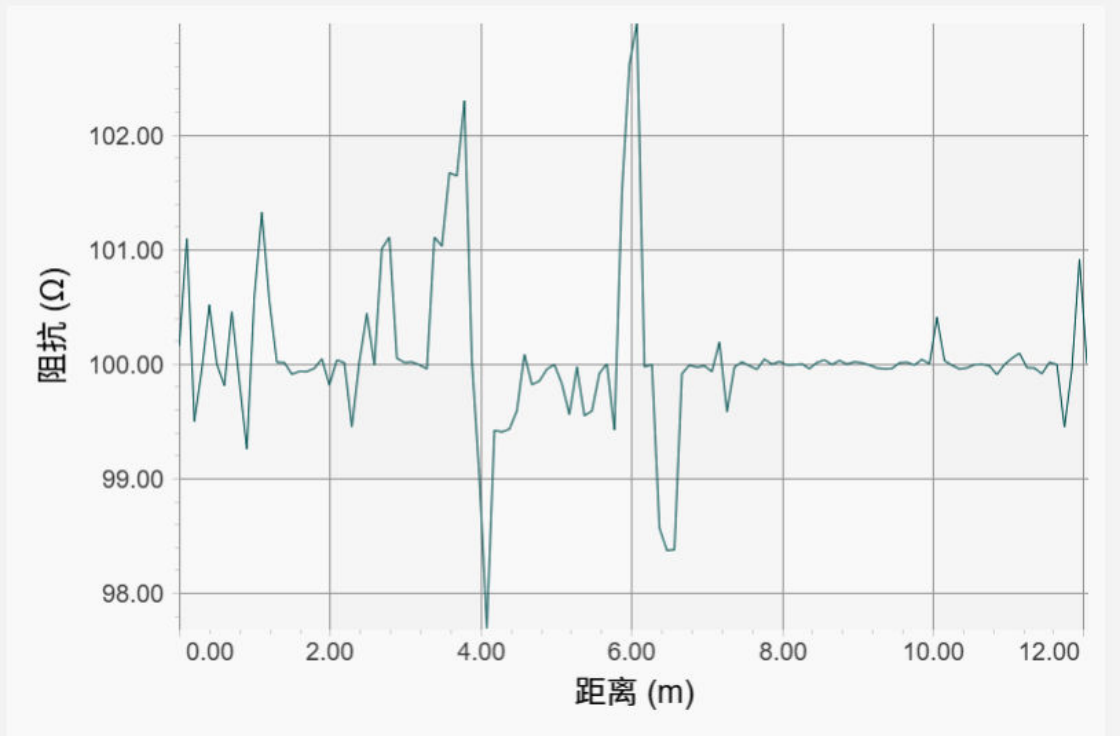

Fig. 7 — TestPro TDR impedance trace for Cable A (~12m). The two large events at ~4m and ~6m correspond to the intermediate connectors at the carriage coupling junction. Minor fluctuations near 0m, 4m, 6m and 12.5m indicate cable routing bends. Maximum impedance ~103 Ω, within the 100 Ω ±15% limit.

Cable B: Carriages 4–5, Long Inter-Carriage Run (~33m)

The Carriage 4–5 cable is substantially longer, running the full length of a carriage plus the inter-carriage coupling section. The cable connectors were disconnected from the repeater units at both ends and the TestPro main and remote units connected in their place.

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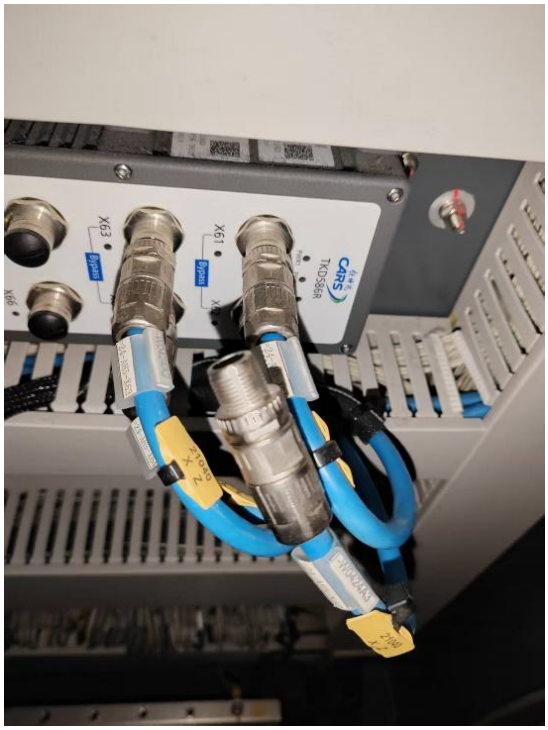

Fig. 8 — Inter-carriage repeater connectors for the Carriage 4–5 cable, showing the yellow-labelled blue cables prior to disconnection for testing.

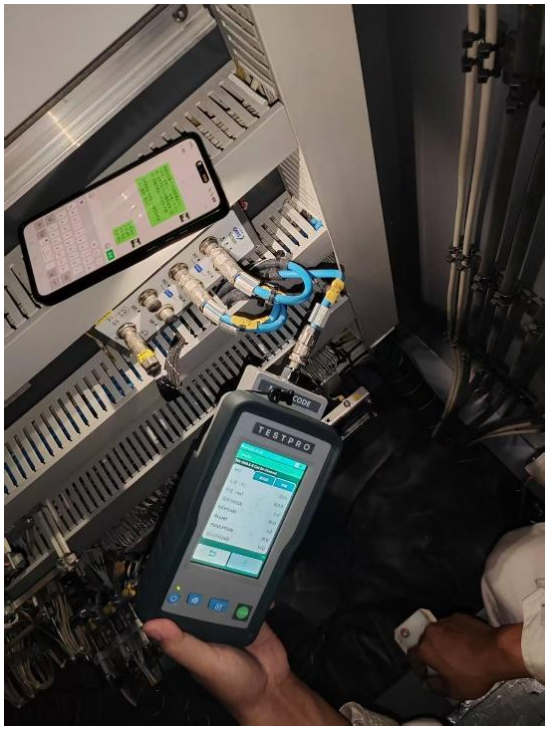

Fig. 9 — Technician holding the TestPro CV100 displaying test results inside the carriage cabinet. The remote unit is connected at the far end of the cable.

As with Cable A, the autotest completed in approximately 6 seconds and all parameters passed the TIA-568.2-E Cat5e channel standard.

Autotest Result: PASS

All transmission parameters on Cable B (04X62) passed TIA-568.2-E Cat5e channel limits. The cable is certified for Gigabit Ethernet and equivalent applications.

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04X62

Pass

Project	: Default	**Test Time**	: 4/16/2026 7:42 PM
Operator	: Default		

Equipment

Model	: TestPro CV100	**Serial Number**	: Main: 5600-1371, Remote: 5600-1372
Device Software	: Main: 5.5.302, Remote: 5.5.302	**Calibration Date**	: Main: 6/23/2025, Remote: 12/17/2025
Main Adapter	: M12D CHANNEL	**Main Adapter S/N**	: 24053
Remote Adapter	: M12D CHANNEL	**Remote Adapter S/N**	: 24054

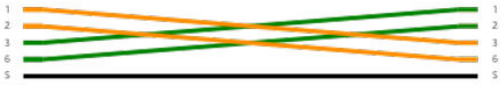
Test

Profile	: Copper 2 Pairs	**Limit**	: TIA-568.2-E Cat 5e Channel
Cable Type / Grade / NVP	: UTP / CAT5E / 68%	**Cable Manufacturer / Name**	: Generic Unshielded / 2-Pair (Pin12-36)
Connector Type / Grade	: Shielded / CAT5E	**Connector Manufacturer**	: Generic Shielded
Connector Name	: CAT5E		

Hierarchy

Project : Default

Parameter	Result	Pair	Value	Limit
Length(m)	Pass	1,2	33,5	100,0
Prop Delay(ns)	Pass	3,6	165,0	555,0
Delay Skew(ns)	Pass	3,6	1,0	50,0
DC Loop Resistance(Ω)	Pass	1,2	0,823	25,000
Res. Unbal, pair-pair(Ω)	Info	1,2-3,6	0,178	0,200
Res. Unbal, wire-wire(Ω)	Info	1,2	0,305	0,200



RF Parameters

Parameter	Result	Main								Remote							
		Worst Margin				Worst Value				Worst Margin				Worst Value			
		Pair	Margin (dB)	Limit (dB)	Freq (MHz)	Pair	Value (dB)	Limit (dB)	Freq (MHz)	Pair	Margin (dB)	Limit (dB)	Freq (MHz)	Pair	Value (dB)	Limit (dB)	Freq (MHz)
RL	Pass	3,6	8,2	16,4	23,05	3,6	24,3	15,8	26,65	1,2	6,2	16,4	23,05	1,2	22,5	16,4	23,20
Insertion Loss	Pass	3,6	17,0	23,9	99,50	3,6	6,9	24,0	99,75		-	-	-		-	-	-
NEXT	Pass	1,2-3,6	12,1	56,1	2,80	1,2-3,6	52,0	31,6	82,00	1,2-3,6	12,0	37,6	36,25	1,2-3,6	45,3	31,5	82,75
PS NEXT	Pass	1,2	15,1	53,1	2,80	1,2	52,0	28,6	82,00	1,2	15,0	34,6	36,25	1,2	45,4	28,5	82,50
ACR-F	Pass	1,2-3,6	29,8	17,7	96,50	3,6-4,5	-9,4	57,4	1,00	1,2-3,6	29,0	17,5	99,25	1,2-4,5	-19,4	57,4	1,00
PS ACR-F	Pass	3,6	32,8	14,7	96,50	3,6	47,3	14,4	99,50	3,6	30,2	54,4	1,00	3,6	46,4	14,4	99,50
TCL	Info																
ELTCTL	Info																
ACR-N	Info	1,2-3,6	14,7	52,3	2,80	1,2-3,6	45,8	10,0	82,00	1,2-3,6	18,2	56,4	1,75	1,2-3,6	39,1	9,9	82,50
PS ACR-N	Info	3,6	17,7	49,3	2,80	3,6	45,7	7,0	82,25	3,6	21,2	53,4	1,75	3,6	39,1	6,9	82,50

RL **Insertion Loss** **NEXT**

Fig. 10 — TestPro CV100 full test report for Cable B (04X62), showing PASS status against TIA-568.2-E Cat5e channel limits. Length: 33.5m. All RF parameters within specification.

TDR analysis of the longer cable provided a more detailed topology map:

- Total cable length: approximately 33 metres — the distance between the start and end connectors at the two repeater units
- Intra-carriage span: approximately 24 metres between the connectors at each end of the carriage body, consistent with the physical carriage length
- Two intermediate connectors identified: located approximately 2 metres apart, matching the physical junction box positions at the inter-carriage coupling — identical topology to Cable A
- Maximum impedance: approximately 101.6 Ω, well within the 100 Ω ±15% limit
- Minor impedance fluctuations near connectors: same characteristic as Cable A — cable routing transitions from horizontal to vertical at cable tie and bend points

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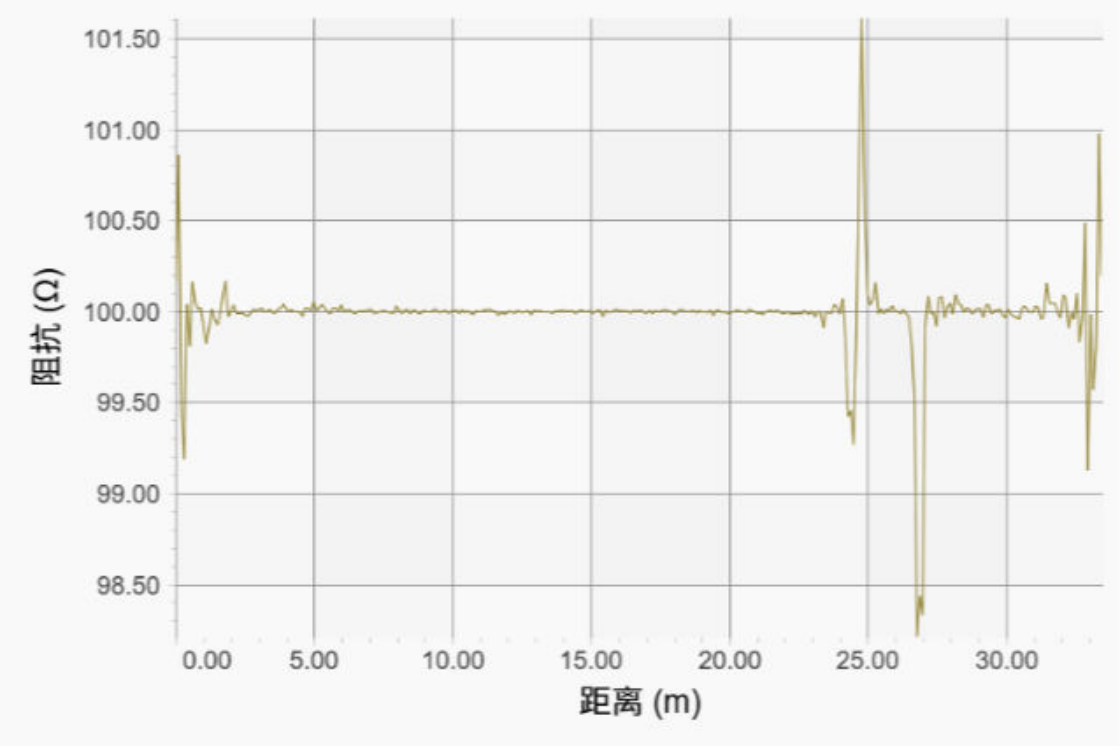

Fig. 11 — TestPro TDR impedance trace for Cable B (~33m). The two events at ~25m and ~27m correspond to the intermediate connectors at the inter-carriage junction. The flat trace across 0–25m reflects a clean, undisturbed cable run along the carriage body. Maximum impedance ~101.6 Ω, within the 100 Ω ±15% limit.

Parameter	Cable A (7–8, ~12m)	Cable B (4–5, ~33m)
TIA-568.2-E Cat5e Autotest	PASS ☑	PASS ☑
Cable ID	08X52-2	04X62
Cable Length (TDR)	12.1m	33.5m
Max Impedance (TDR)	~103 Ω	~101.6 Ω
Impedance Limit (100Ω ±15%)	85–115 Ω ✓	85–115 Ω ✓
Intermediate Connectors Found	2 (spaced ~2m apart)	2 (spaced ~2m apart)
Wiring Configuration	2-pair crossover	Standard
Routing Anomalies Detected	Minor bends near connectors	Minor bends near connectors

Analysis: What the TDR Revealed

The pass/fail autotest confirmed that both cables meet the TIA-568.2-E Cat5e standard for data transmission. But the TDR analysis provided a level of diagnostic insight that a simple pass/fail result cannot:

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Connector Mapping

Both cables have an identical physical topology: a start connector (at the repeater), two intermediate connectors spaced approximately 2 metres apart at the carriage coupling junction box, and an end connector at the far repeater. The TestPro TDR trace located all four connectors on each cable without any prior knowledge of the installation — purely from the impedance reflections. This precisely matched the physical installation records.

Routing Transition Detection

In both cables, the TDR revealed small impedance fluctuations approximately 1 metre from each connector. These were not faults — the cables passed all transmission tests — but they are diagnostically significant. These fluctuations occur at the points where the cable changes routing direction, from horizontal (along the carriage underframe) to vertical (rising to the junction box), with cable ties applying localised mechanical stress. Having a baseline TDR record means maintenance teams can re-test in the future and detect any progression of these anomalies before they become service-affecting faults.

Fault Identification Capability

That neither cable showed open-circuit, short-circuit, or significant impedance fault events confirms a healthy baseline. The TestPro CV100 is capable of detecting and locating the following fault types — none present in these cables, but which would be immediately visible in the TDR trace:

- Open circuit (broken conductor or disconnected connector)
- Short circuit (conductors in contact)
- Shield damage (localised loss of shielding continuity)
- Partial conductor break (conductor damaged but not fully severed)
- Excessive compression (cable crushed or over-clamped)
- Excessive bend radius violation (sharp bend introducing impedance discontinuity)

Conclusions and Operator Takeaways

The on-train validation exercise demonstrated that the AEM TestPro CV100 is fully capable of characterising railway inter-carriage communication cabling to recognised international standards in a practical field environment. The key conclusions:

- Both tested cables are compliant with TIA-568.2-E Cat5e / ISO 11801 Class D channel requirements — suitable for Gigabit Ethernet and equivalent communication applications.
- The TestPro CV100’s 6-second autotest is fast enough to test cabling during a routine service window without extending downtime.
- TDR analysis provides a detailed physical map of each cable’s topology and condition — pinpointing connectors, routing transitions, and impedance anomalies with sub-metre resolution.

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- Baseline TDR traces recorded during this exercise give maintenance teams a reference for future comparison, enabling early detection of cable degradation before it causes service disruption.
- Non-standard wiring configurations (such as the 2-pair crossover on Cable A) are automatically identified — preventing misdiagnosis in installations that deviate from standard pinouts.
- The instrument's ability to detect partial damage, over-compression, and over-bending non-destructively makes it a powerful tool for proactive maintenance programmes.

Recommended Next Step

Extend the TestPro CV100 testing programme to all inter-carriage repeater cables in the fleet. The resulting database of baseline TDR traces and certification records will support a predictive maintenance strategy — identifying cables approaching failure before they cause service-affecting faults.

About AEM Networks

AEM Networks is a global leader in network testing, certification, and verification solutions. The AEM TestPro platform delivers professional-grade cable certification for structured cabling in enterprise, industrial, transportation, and smart-building environments, supporting TIA-568, ISO/IEC 11801, IEEE 802.3, GB/T 50312, and Single Pair Ethernet standards.

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