FROM RESEARCH TO INDUSTRY

cea tech

CEA LIST activity on *Cable Monitoring and Diagnosis*

Contact :

Mr Josy COHEN – Responsable de projet & ingénieur chercheur

Josy.cohen@cea.fr

+33 1 69 08 78 07

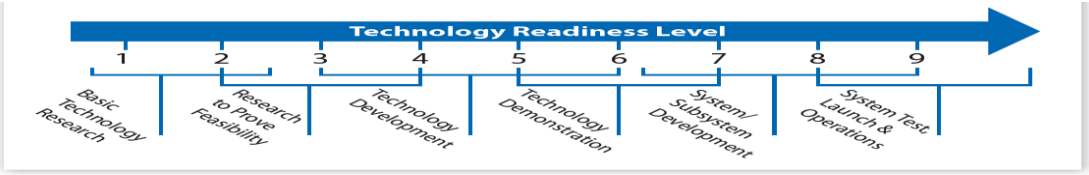
CEA experience in cable diagnosis

- Our Laboratory :

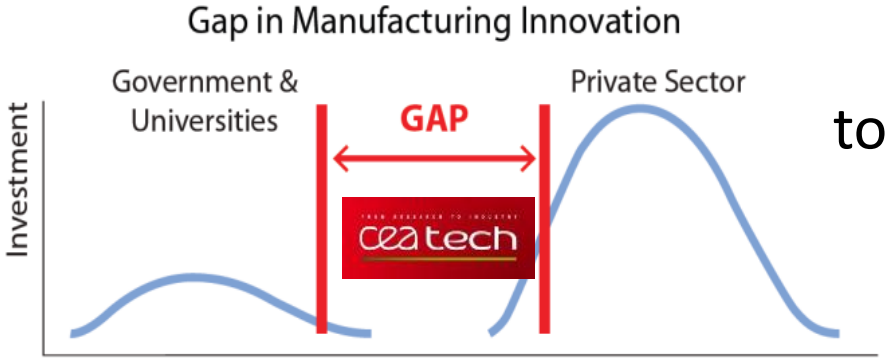
LFIC : Laboratoire Fiabilité et Capteurs Intégrés

More than 10 years experience and knowledge in network cable diagnosis

- CEA policy :

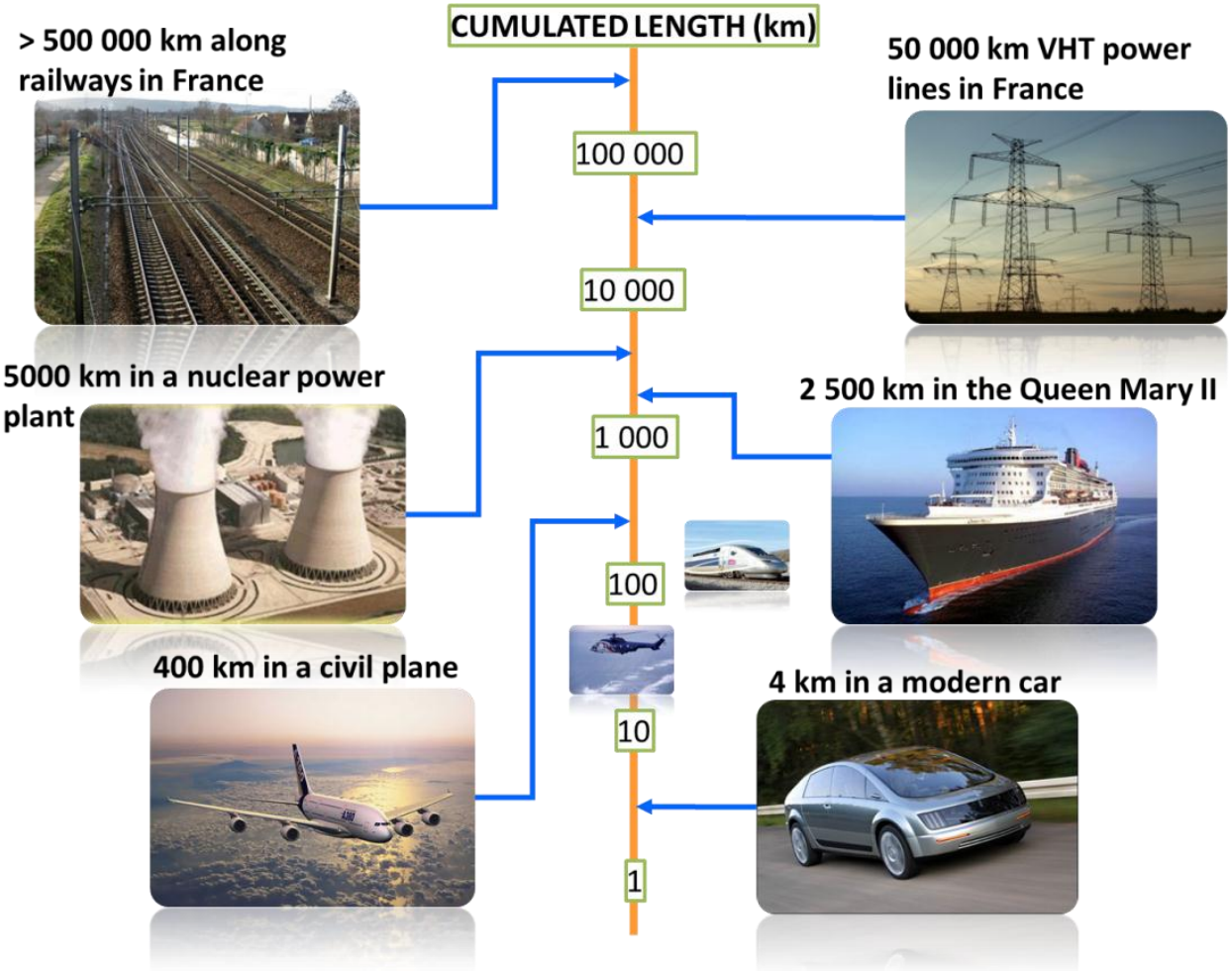


Source: AMP Steering Committee



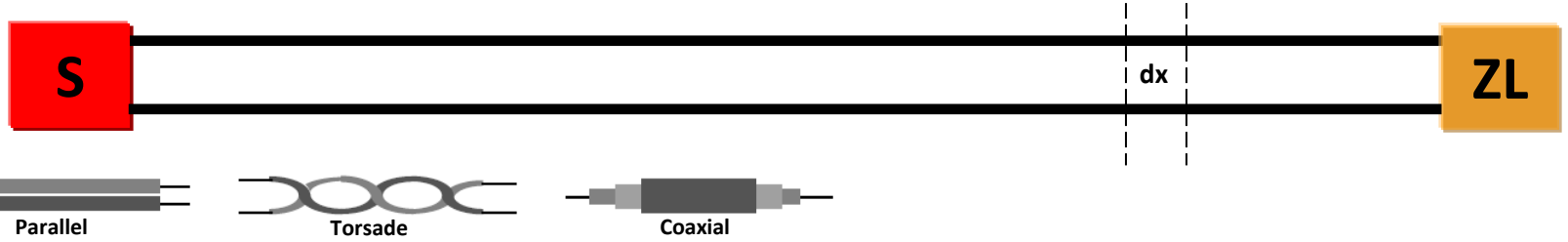
To create breakthrought
to take advantage and to create new jobs
by industrial transfer
for French companies

Ubiquitous cable

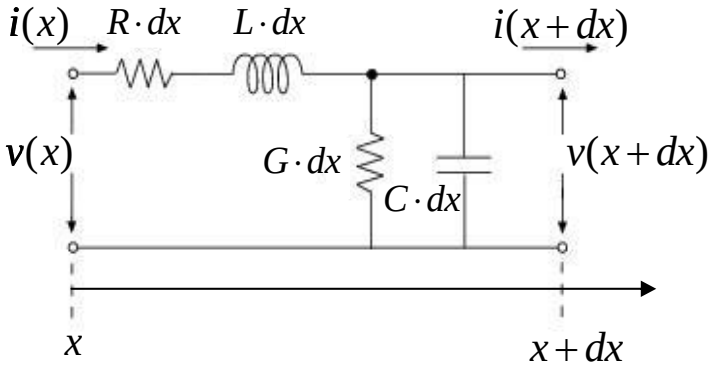


Reflectometry : Principle

- The reflectometry principle is related to the signal propagation mechanism into a transmission line (TL)



- **Modeling and characterization of a TL**
  - R, L, C, G Model
    - based on Telegrapher's equations
  - to figure out how a signal is propagated into a TL
  - we have to look signal distortion phenomenon
  - Attenuation and dispersion



Telegrapher's equations

$$\frac{\partial^2 v(x,t)}{\partial x^2} = LC \cdot \frac{\partial^2 v(x,t)}{\partial t^2} + (LG + RC) \cdot \frac{\partial v(x,t)}{\partial t} + RG \cdot v(x,t)$$

$$Z_c = \sqrt{\frac{R + jL\omega}{G + jC\omega}} \qquad V_g = \frac{1}{\sqrt{LC}}$$

Reflectometry : measurement of transmission line characteristic impedance variation

CEA Breakthrought

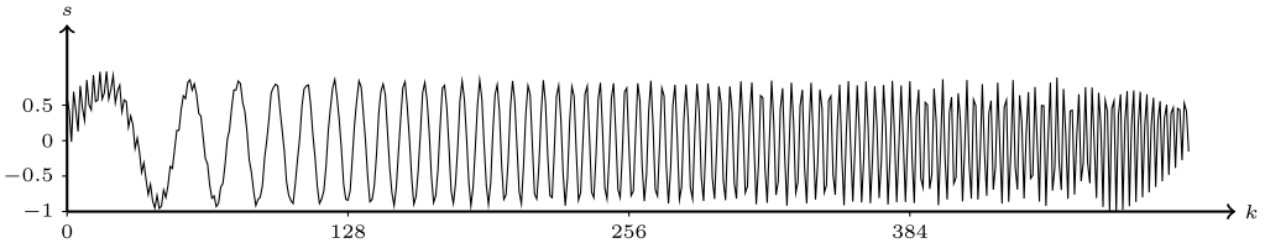
Some new technologies developed

On line Diagnosis

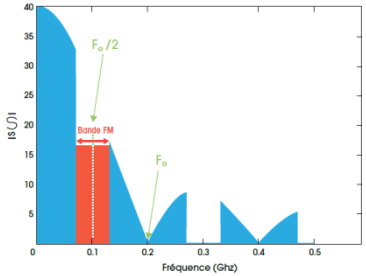
MCTDR (Multicarrier Time Domain Reflectometry)

- Probe signal corresponds to a sum of sine curves

$$s_n = \sum_{k=1}^{N/2} c_k \cos\left(\frac{2\pi k}{N} n + \theta_k\right)$$



- The probe signal spectrum is controllable by cancelling the desired carried signal



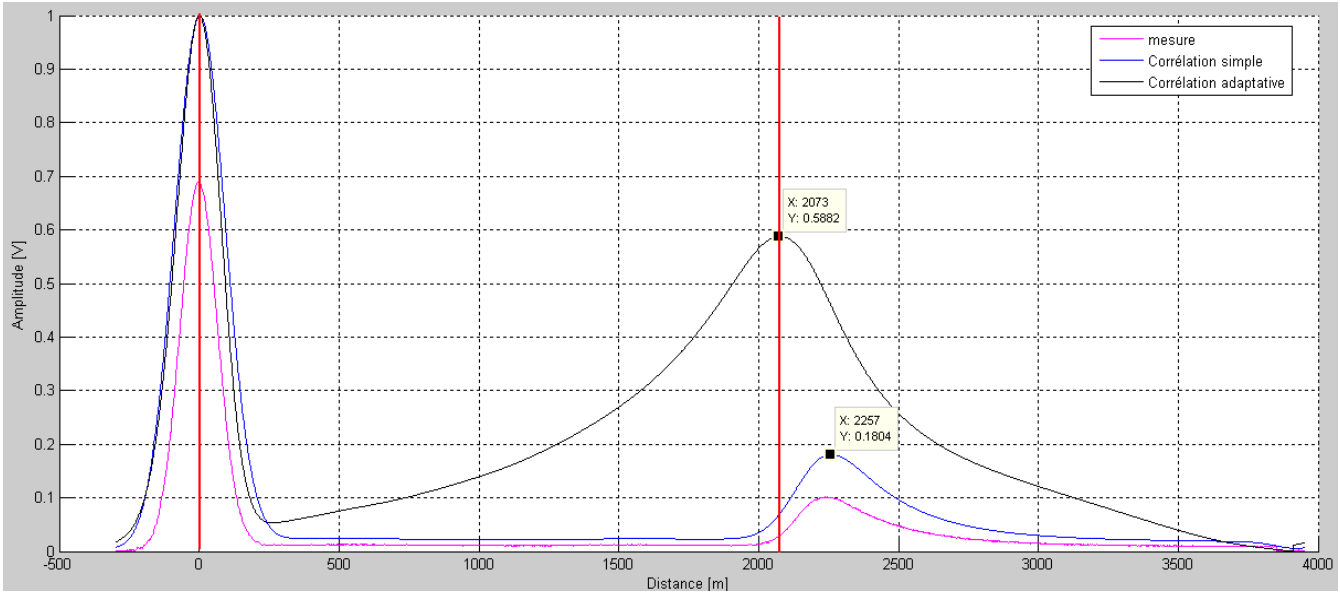
- Safe diagnosis : Harmless ness
- EMC Compliance
- Low sensitivity to SNR
- **MCTDR in TRL > 5**

AIRBUS GROUP AIRBUS HELICOPTERS DASSAULT AVIATION

Long distance

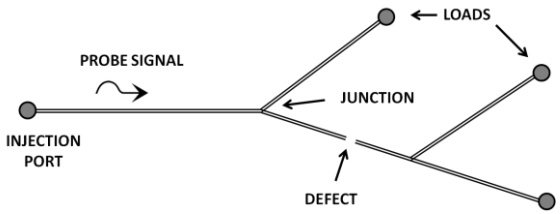
- Adaptive correlation for performance enhancement :
  - Sensitivity

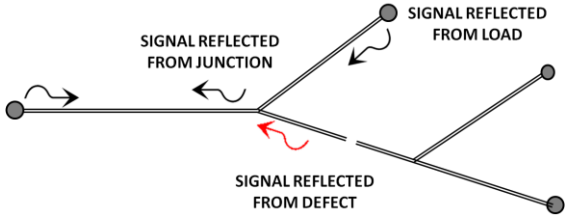
Railway signalization cable , reel length : 2km

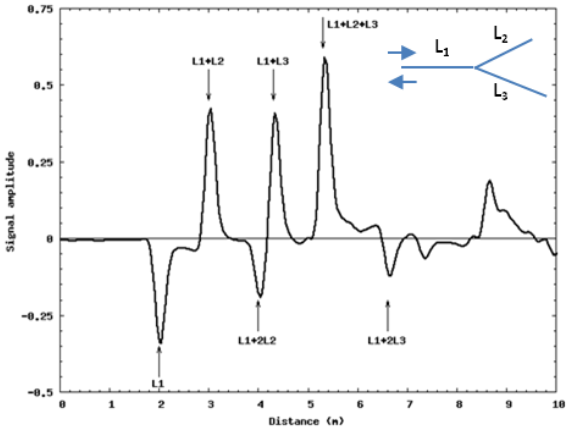


	Measure	Standard correlation	**Adaptive correlation**
Amplitude (V)	0.1	0.18	**0.59**
Localization (m)	2260	2257	2073
Relative error	13%	13 %	**3.7 %**

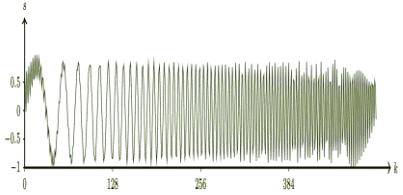
Complex network

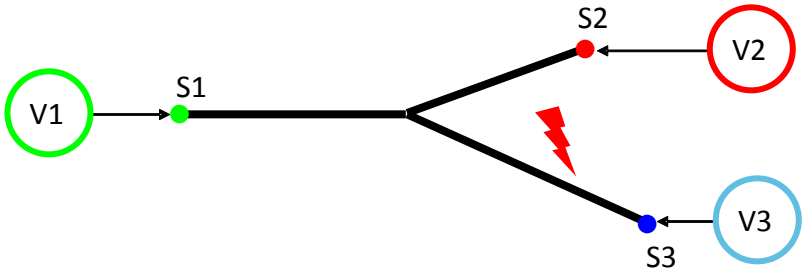


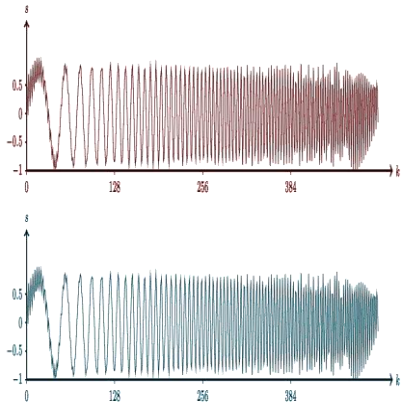




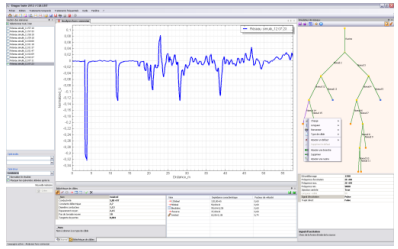
Distributed-MCTDR



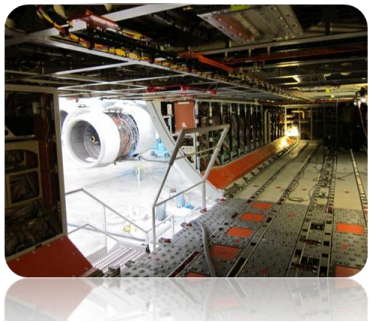


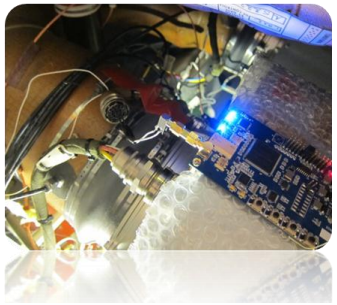


- The reflectometry distribution is obtained with a weighted mean process allowing a cross-correlation between reflectometers.
- Multi-sensing strategy allowing to avoid the ambiguity.
- A specific tool is proposed to facilitate the reflectometer deployment and to simulate the diagnosis strategy



Technology integration



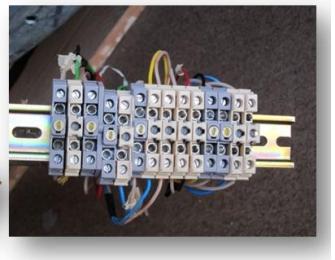


Avionic

DIAGNOCHIP, a 3 mm2 130nm integrated reflectometer

- A mixed Analog/Digital IP for real time processing
- 5cm resolution (4GHz guided wavelength)

Railway



Solar power

CEA breakthougth Valorisation

- Implemantation of CEA policy hard fault diagnosis:
  - Licence sales
  - Transfert project for academic laboratory
  - Bilateral industrial project :
    - For specific research
    - For technological or know how transfert
  - Spin off : Start up creation

⇒ Win MS

WiNMS
WIRE NETWORK MONITORING SOLUTIONS

But also

- Collaborative research project with different partners

WiN MS

WIRE NETWORK MONITORING SOLUTIONS

Large cable networks

Cable infrastructure monitoring solution to fight against cable theft

- Targets:
  - Railways infrastructure
  - Tunnels
  - Roads
  - Public lighting

Aeronautic maintenance

Troubleshooting tool

- Targets:
  - Airlines
  - Pure-player MRO
  - Aircraft maker
  - Defense

Automotive maintenance

Troubleshooting tool

- Targets:
  - Auto makers
  - Maintenance and repair network
  - Trucks, buses,...

Contact: contact.dacle@cea.fr

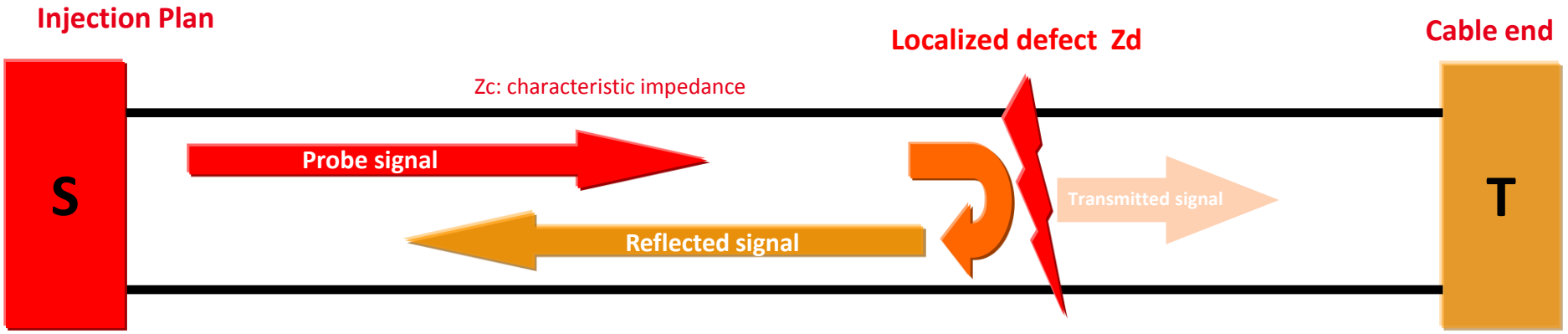
http://www.win-ms.com

leti & list

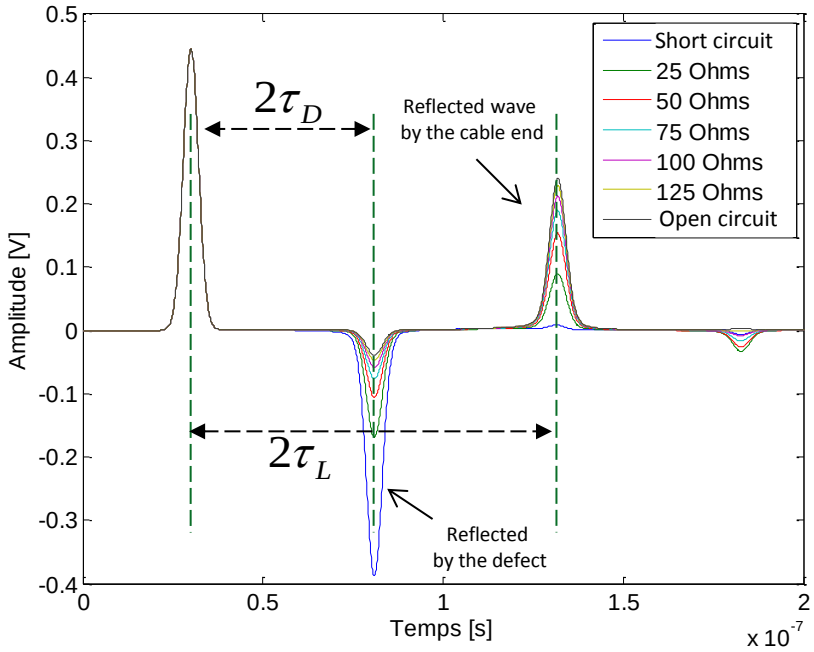
CEA Breakthrought

Some new technologies in progress

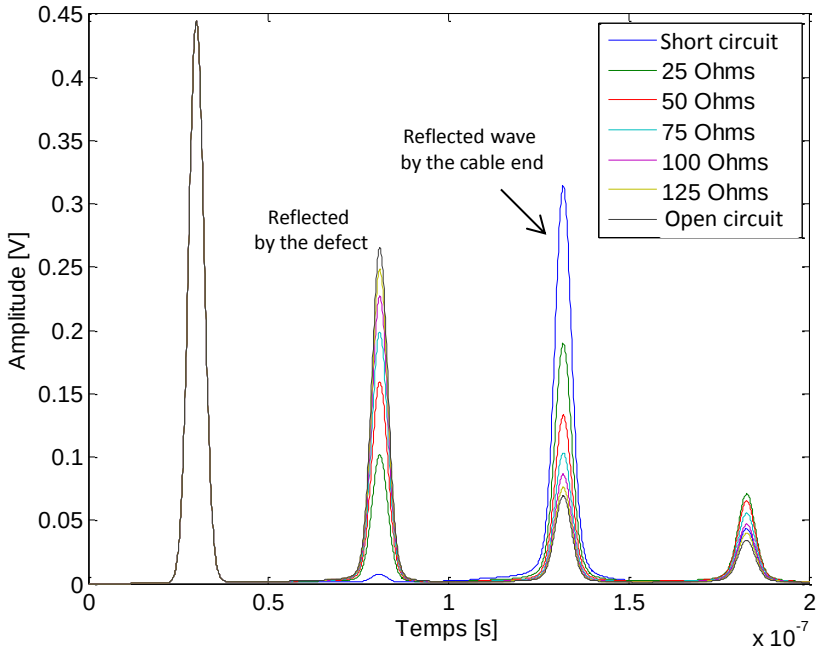
Reflectometry for soft defect



Parallel defect



Serial defect



Reflectometry for soft defect

- **External source of failure**
  - Mechanical stress
  - Assembly errors
  - Corrosion, oxidation
  - Effect of environment s
- **Internal source of failure**
  - Manufacturing errors
  - Wear-out defect
  - Local hot-spot

Wear type	Primary signs	Detection method
Overheating of the wire	Wear zone	Visual inspection **Reflectometry**
Bad contact	Change in impedance Local hot spot	Thermal, Point by point test **Reflectometry**
Intermittent short circuit faults	Electromagnetic Magnetic Interference Electric arc	Visual inspection **Reflectometry**
Short circuit faults	Circuit-breaker system	**Reflectometry**
Broken insulation	Crack, damaged area	Visual inspection **Reflectometry**
Exposed conductor	Loss of the function Fire	Visual inspection **Reflectometry**
Corrosion	Loss of signal or data	Visual inspection **Reflectrometry**
Humidity	Loss of signal or data	**Reflectometry**

Wear out and/or Loss of the function

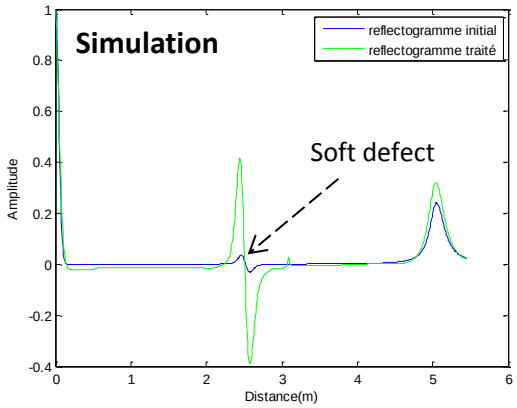
Local alteration of R, L, C, G parameters
Local alteration of the characteristic impedance Zc
Local alteration of the propagation speed

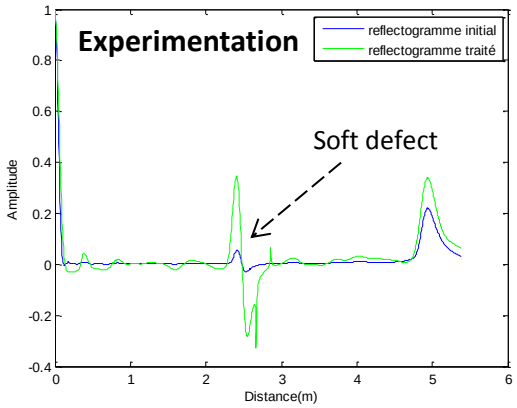
$\Gamma L \neq 0$

- Open defect
- Soft defect

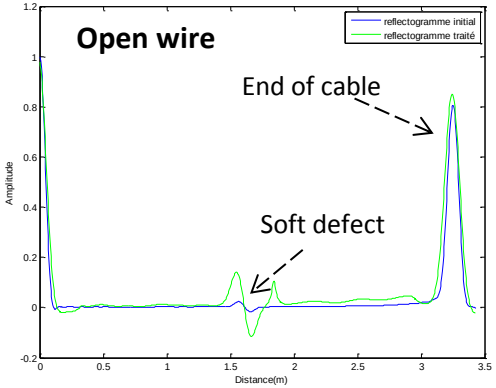
Soft defect detection (chafing)

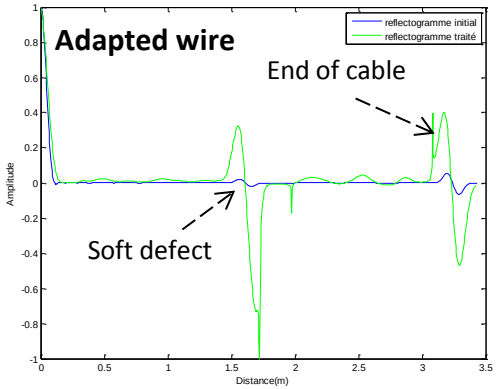
- One of our advance post processing for soft defect signature amplification





Cab_224b
Twisted pair (5 m) - Shielded - AWG24 0.25mm²
Soft defect = sheath + shield (pulled out) 2cm

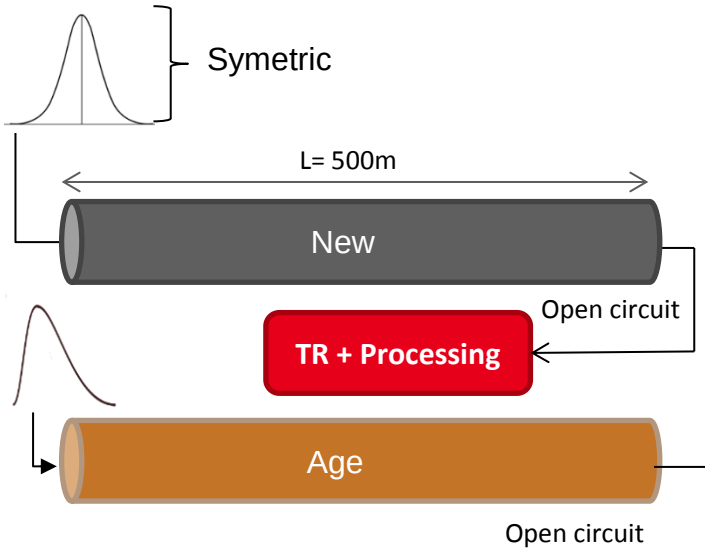


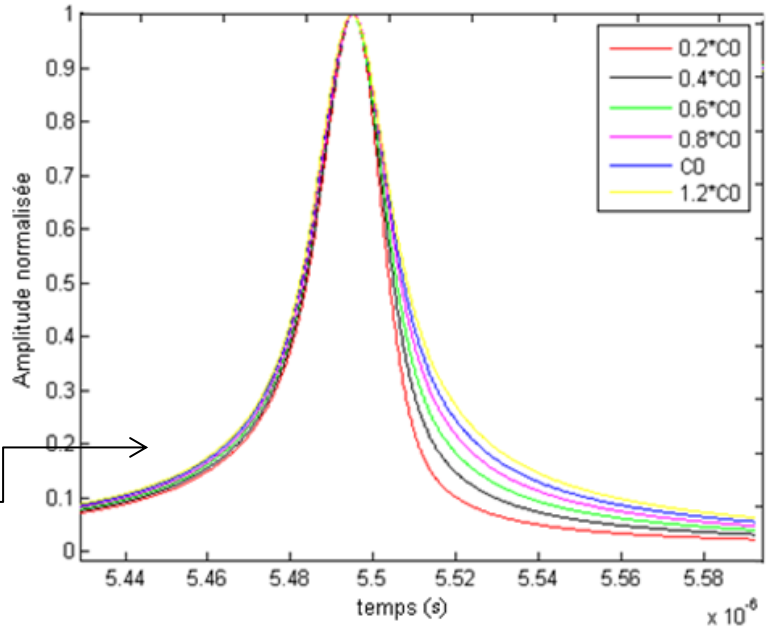


Coaxial cable RG58CU (3.20 mètres)
Soft defect = sheath + shield (pull out) 2cm

Prognostic diagnosis (aging)

- Aging monitoring based on time reversal reflectometry





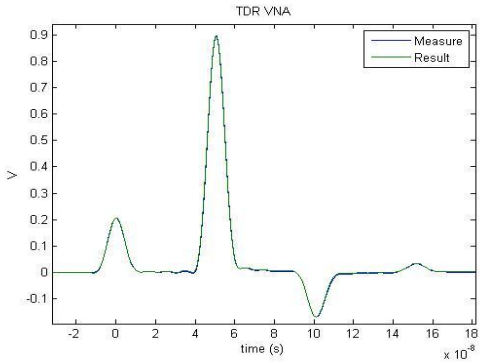
Aging effect

Simulations	C_0 x 1.2	C_0	C_0 x 0.8	C_0 x 0.6	C_0 x 0.4	C_0 x 0.2
Asymmetry Coefficient	1.09	1	0.9045	0.7934	0.6683	0.5127

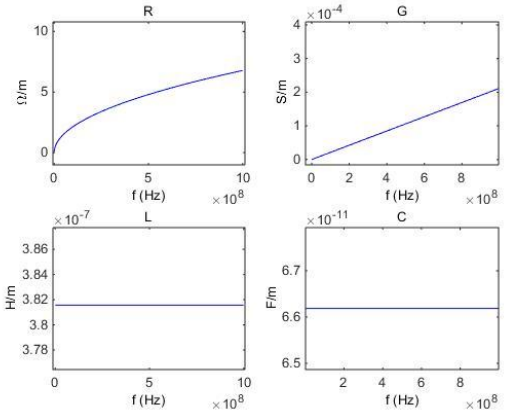
Cable and aging characterization

Cable characterization by RLCG parameters extraction

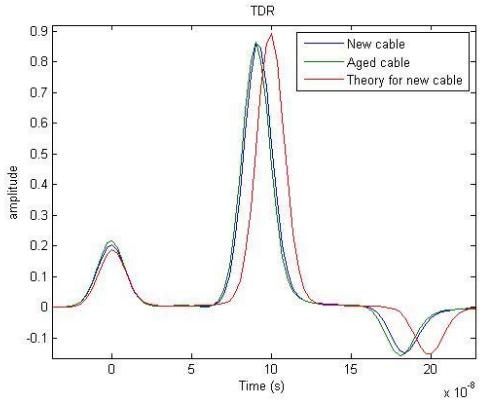
Coaxial (5 m) Zc = 75 Ω

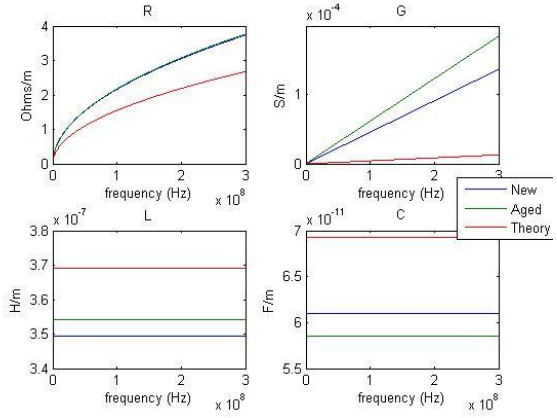


$V^2 = 3,7$
Likelihood ratio



Aging characterization



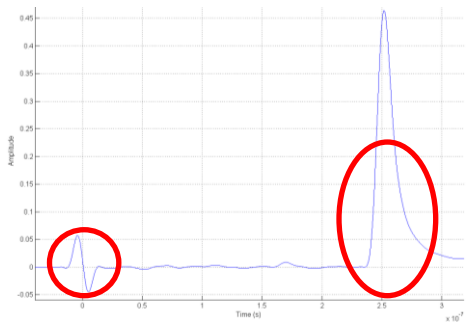


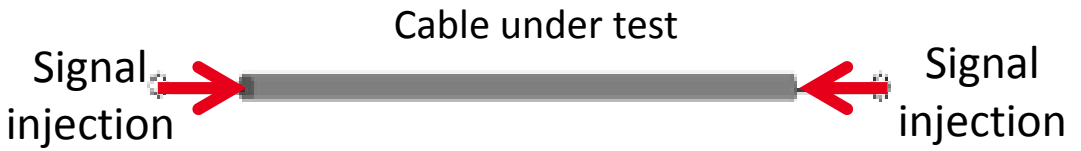
New

Aged

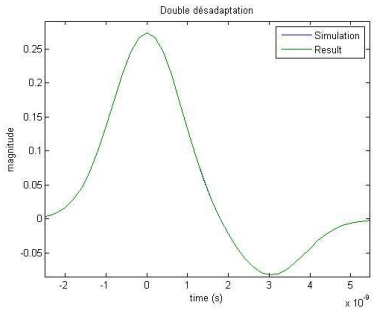
Coaxial (9,8 m) Zc = 75 Ω

Interconnection characterization

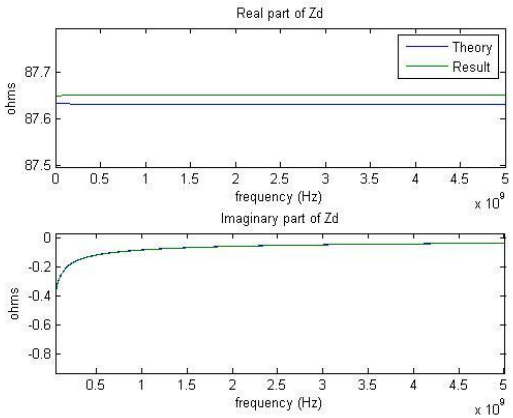




Cable connection and junction characterization



$V^2 = 4{,}65$
Likelihood ratio

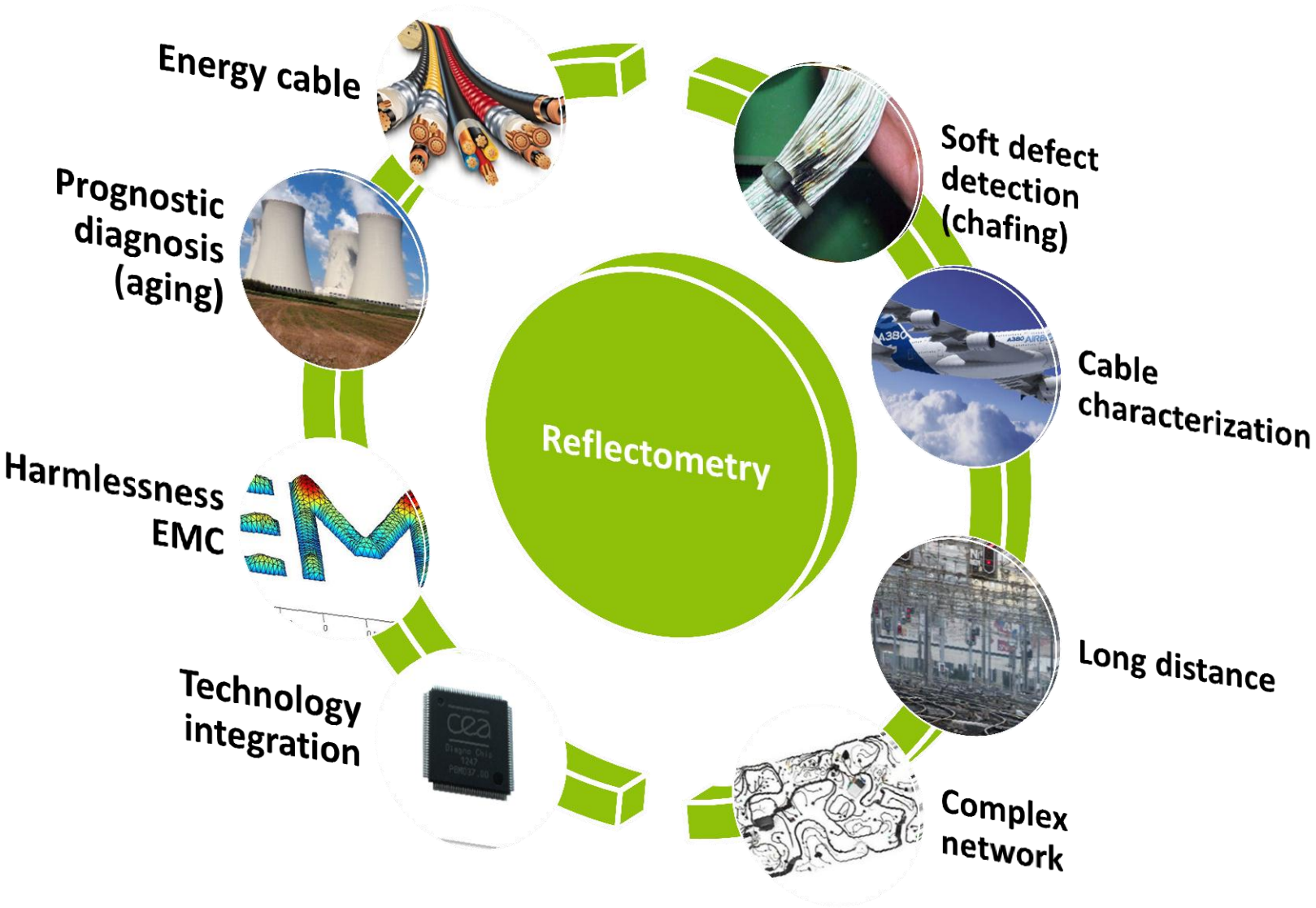


0,1% real part
1-2% imaginary part
ld = 30 cm

⇒ To characterize interconnection or connector (database)

⇒ To diagnosis soft defect in the interconnection

Beyond reflectometry



Aera of expertise

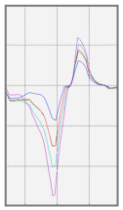
More than 25 patents
And 60 publications

Modeling and simulation
- Laboratory equipment for characterization
- Cable and connector modeling
- Complete numerical simulation

CST

MathWorks

Advance post processing algorithm
- Soft defect detection (e.g. chafing)
- Cable Parameter extraction



HW Signal processing
- Specific digital processing architecture
- Specific filtering (de-noise)
- Dynamic correlation for performance improvement

HW Electronic
- Multiplexing
- System protection
- Cable coupling

CEA Breakthrought

All these new technologies and know how in LFIC

What are the new technologies for the future ?

Which new application domain ?

⇒ Use a cable like environement sensor (temperature, humidity, …)

⇒ New application domain : SHM for Composite

CEA ready to collaborate with industrials

to work in partnership

Merci pour votre attention

leti
Centre de Grenoble
17 rue des Martyrs
38054 Grenoble Cedex

list
Centre de Saclay
Nano-Innov PC 172
91191 Gif sur Yvette Cedex