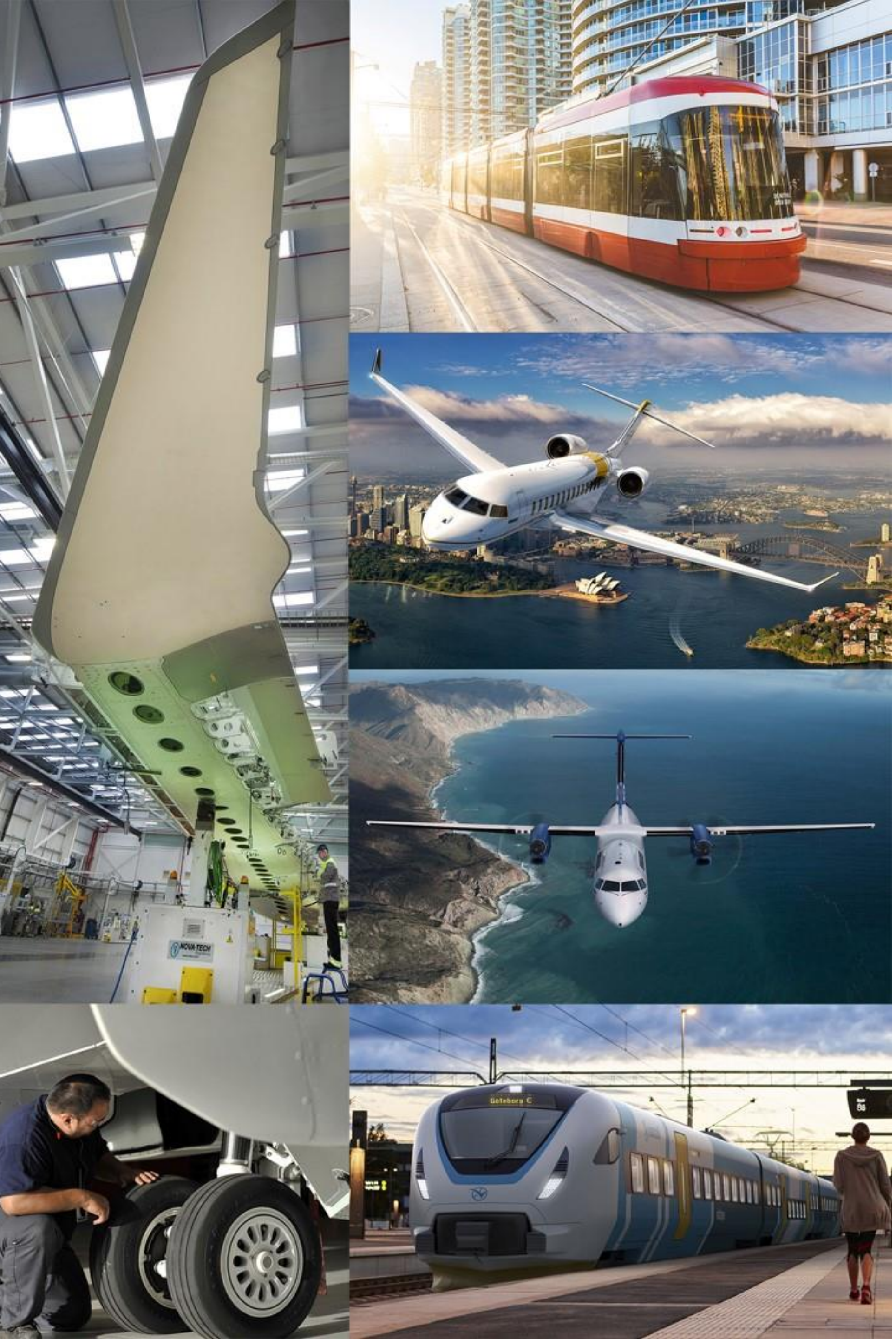

TRANSPORT CANADA
Delegates Conference
Ottawa, November 14-15, 2018

EPICEA R&D project

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(PHD in Engineering &

Doctor of Sciences in Physics)

Principal Engineer Specialist

Electromagnetic domain Knowledge Owner

Bombardier Aerospace

Strategic Technologies & Innovation

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AGENDA

- **ELECTROMAGNETIC COUPLING MECHANISM IN COMPOSITE # METALLIC AIRCRAFT**
  - Aircraft Structure Skin Effect
  - Lightning Indirect Effects on Systems
  - Signal Return Network Contribution
  - Systems` Susceptibility
  - Emissions

- **EPICEA**
  - EPICEA COLLABORATIVE TEAM
  - Rational and Trend → why we need EPICEA?
  - Description of the EPICEA test barrel structure;
  - EM Testing – Sample results for LIE;
  - EM Modeling – Barrel model generation;
  - Harness test data analysis
  - Conclusion

AIRCRAFT STRUCTURE SKIN EFFECT

- In an Electromagnetic Environment , the aircraft structure is governed by its electrical parameters : Conductivity σ and Permeability μ

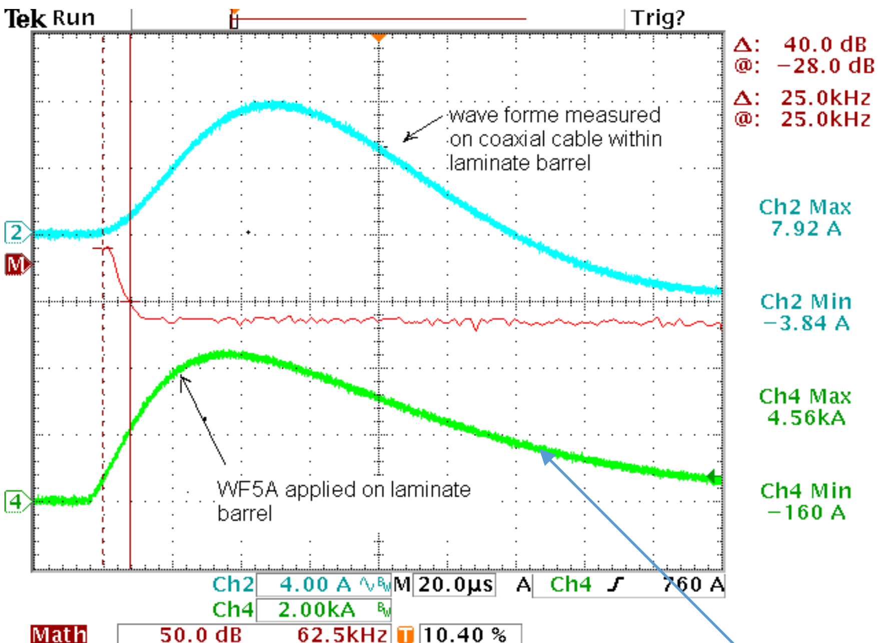
- Skin Effect : $\delta = \frac{1}{\sqrt{\mu \sigma f}}$

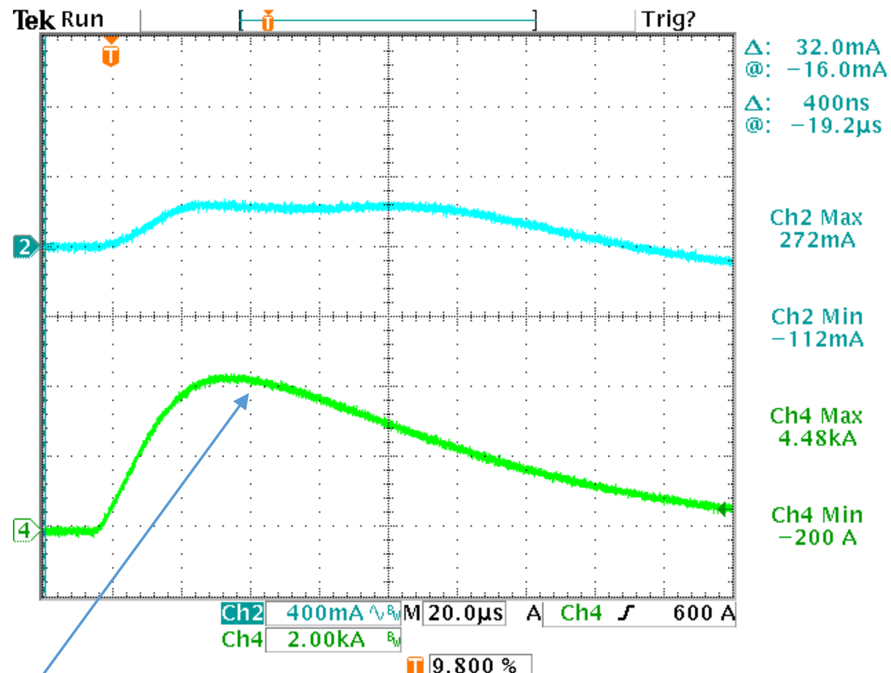
- Due to the structure skin effect δ, lightning current will propagate on the structure for some time τ_s, before penetrating the skin (governed by a thickness T) by induction and coupling to cables inside the aircraft

$$\tau_s = \frac{1}{\pi f} \times \left(\frac{T}{\delta} \right)^2 = \mu_o \sigma T^2$$

LIGHTNING-INDUCED CURRENT ON CABLE SHIELD

Common MODE SYSTEM BEHAVIOR
(WF5 lightning environment)





Coaxial cable current measured in composite barrel

Lightning Energy Applied to composite & Metallic barrel

σ

Coaxial cable current measured in aluminum barrel

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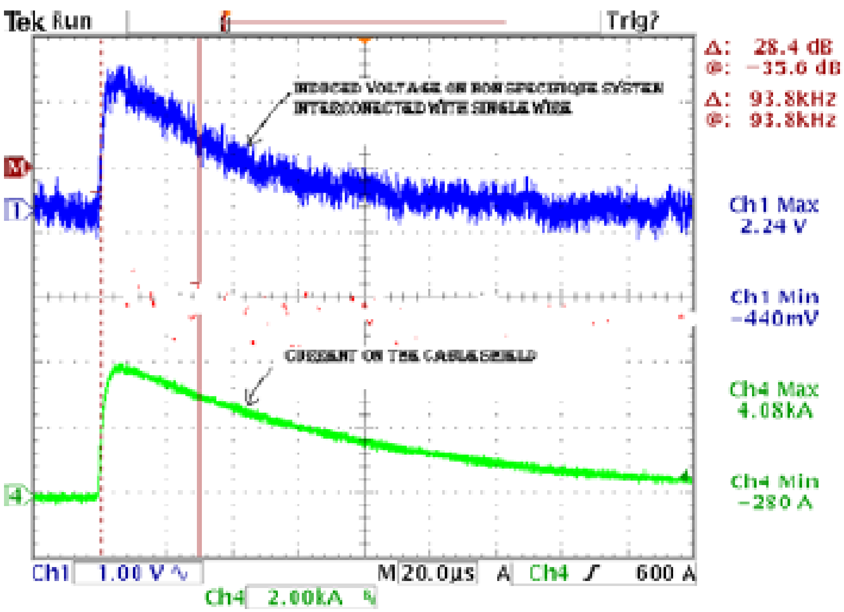
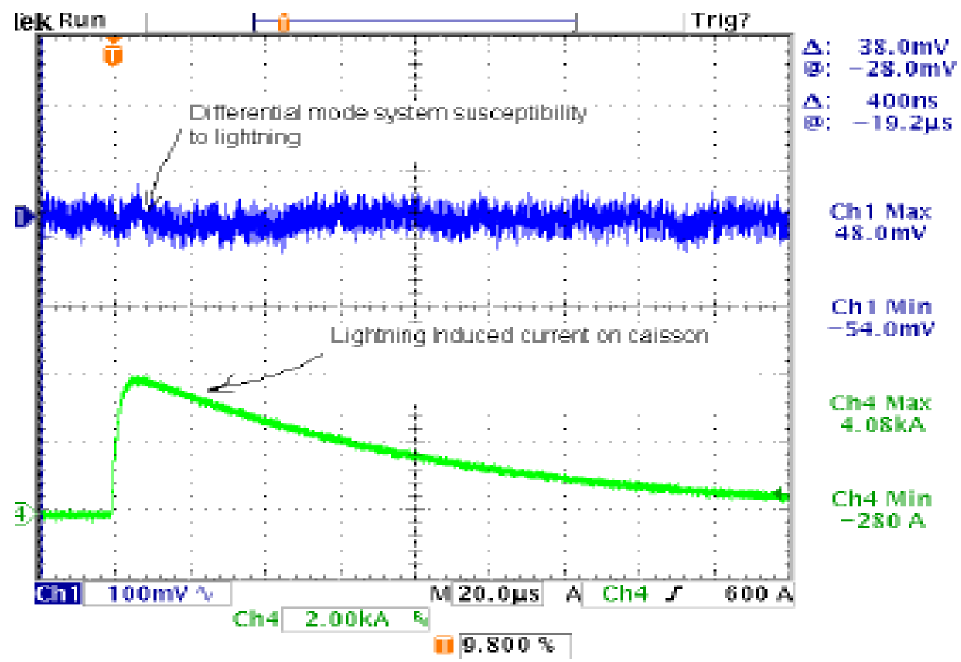
LIGHTNING-INDUCED CURRENT ON CABLE SHIELD

Differential MODE SYSTEM BEHAVIOR
(WF1 lightning environment)





Composite barrel

Metallic barrel

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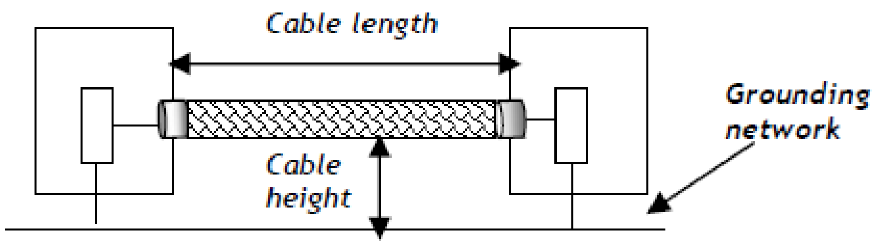
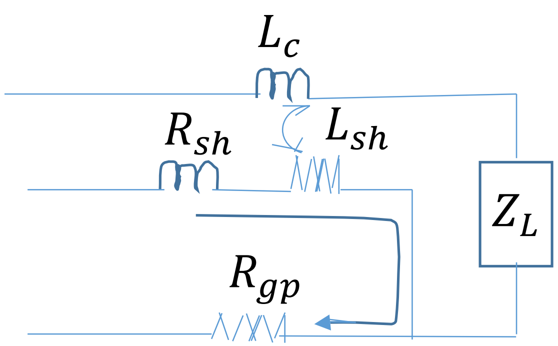
SIGNAL RETURN NETWORK CONTRIBUTION

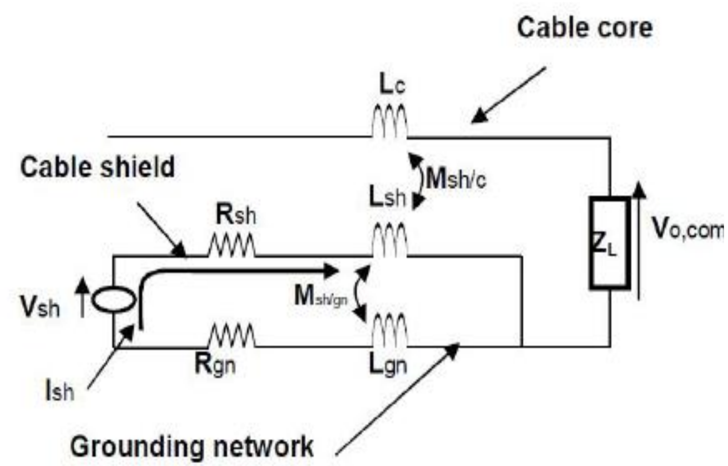
DISSIMILARITY OF ELECTROMAGNETIC COUPLING MECHANISM

Between Composite and Metallic Aircraft





Kirchoff circuitry on metallic aircraft



Kirchoff circuitry on composite aircraft

SYSTEMS SUSCEPTIBILITY ASSESSMENT

- ✓ EM. voltage at a system level on a metallic aircraft

$$V(f) = I_o \times \frac{length}{2}[Z_T(f) - Z_o\, Y_T(f\,)Z_{bd}] \times \exp(-j\pi\sqrt{\varepsilon_r}\,\frac{length}{\lambda}) \times \frac{\sin(\left(\sqrt{\varepsilon_r} - 1\right)\pi\frac{length}{\lambda}\,)}{\left(\left(\sqrt{\varepsilon_r} - 1\right)\pi\frac{length}{\lambda}\right)}$$

- ✓ EM. voltage at a system level on a composite aircraft

$$V(f) = I_o \frac{length}{2} \exp(-j\frac{\pi}{\lambda}\sqrt{\varepsilon_r}\;length)\left((Z_t(f) - j2\pi f\; M_{shg}) - Z_{bd}Z_oY_T(f)\right)$$

$$\times\frac{\sin\left[\frac{\pi\left(\sqrt{\varepsilon_r}\;-1\right)}{\lambda}length\right]}{\frac{\pi\left(\sqrt{\varepsilon_r}-1\right)}{\lambda}length}$$

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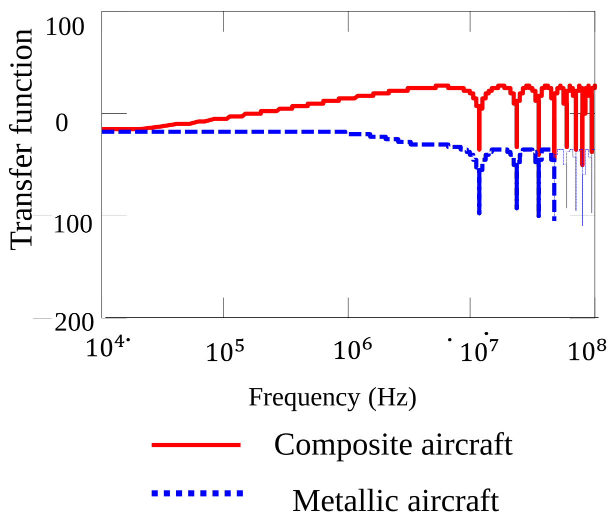
Comparison Composite # Metallic Aircraft



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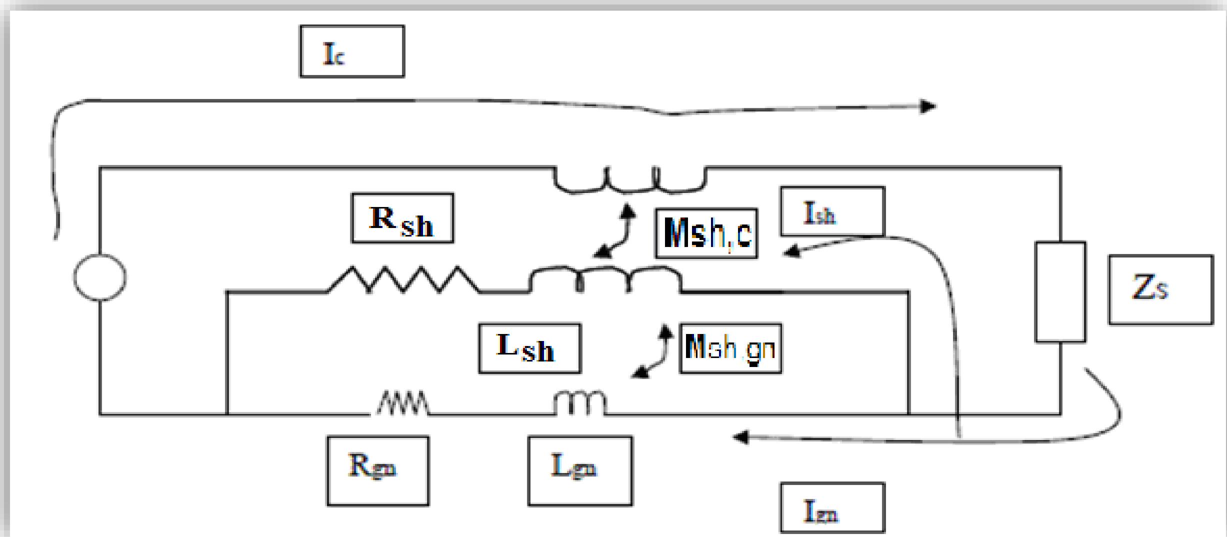
SPECTRAL COMPARISON OF EMISSIONS BY CONDUCTION DUE TO HARNESSES

Emissions at low frequencies are due to the magnetic field that is frequency dependent. Due to the SRN coupling with harnesses, those emission are higher on composite than on metallic aircraft



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SPECTRAL COMPARISON OF EMISSIONS BY CONDUCTION DUE TO CABLES

✓ **Composite Aircraft**

$$\frac{I_{sh}}{I_C} = \frac{(L_{gn} - M_{sh\,gn} + M_{sh\,c})}{(L_{sh} - M_{sh\;gn}) + (L_{gn} - M_{sh\;gn})} \left\{ \frac{\left[j\omega + \dfrac{R_{gn}}{(L_{gn} - M_{sh\,gn} + M_{sh\;c})} \right]}{\left[j\omega + \dfrac{(R_{gn} + R_{sh})}{(L_{sh} - M_{sh\,gn}) + (L_{gn} - M_{sh\,gn})} \right]} \right\} \qquad \text{(a)}$$

✓ **Metallic Aircraft**

$$\frac{I_{sh}}{I_c} = \frac{R_{st} + jM_{shc}}{(R_{st} + R_{sh}) + jL_{sh}} \qquad \text{(b)}$$

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SPECTRAL COMPARISON OF EMISSIONS BY CONDUCTION DUE TO HARNESSES

Composite # Metallic aircraft

✓ Composite

$$\omega_c = \frac{(R_{gn} + R_{sh})}{(L_{sh} - M_{sh\ gn}) + (L_{gn} - M_{sh\ gn})} \quad \text{(a)}$$

Then for $\omega \ll \omega_c$

$$\frac{I_{sh}}{I_c} \xrightarrow[\omega \to 0]{} \frac{R_{gn}}{R_{sh} + R_{gn}} \quad \text{(b)}$$

(d)

Then for $\omega_c \ll \omega$

$$\frac{I_{sh}}{I_c} = \xrightarrow[\omega \to +\infty]{} \frac{(L_{gn} - M_{sh\,gn} + M_{sh\,c})}{(L_{sh} - M_{sh\ gn}) + (L_{gn} - M_{sh\ gn})} \quad \text{(C)}$$

✓ Metal

$$\omega_c = \frac{R_{st} + R_{sh}}{L_{sh}}$$

Then for $\omega \ll \omega_c$

$$\frac{I_{sh}}{I_c} \xrightarrow[\omega \to 0]{} \frac{R_{st}}{R_{sh} + R_{st}} \quad \text{(e)}$$

Then for $\omega_c \ll \omega$

$$\frac{I_{sh}}{I_c} \xrightarrow[\omega \to +\infty]{} \frac{M}{L_{sh}} \quad \text{(f)}$$

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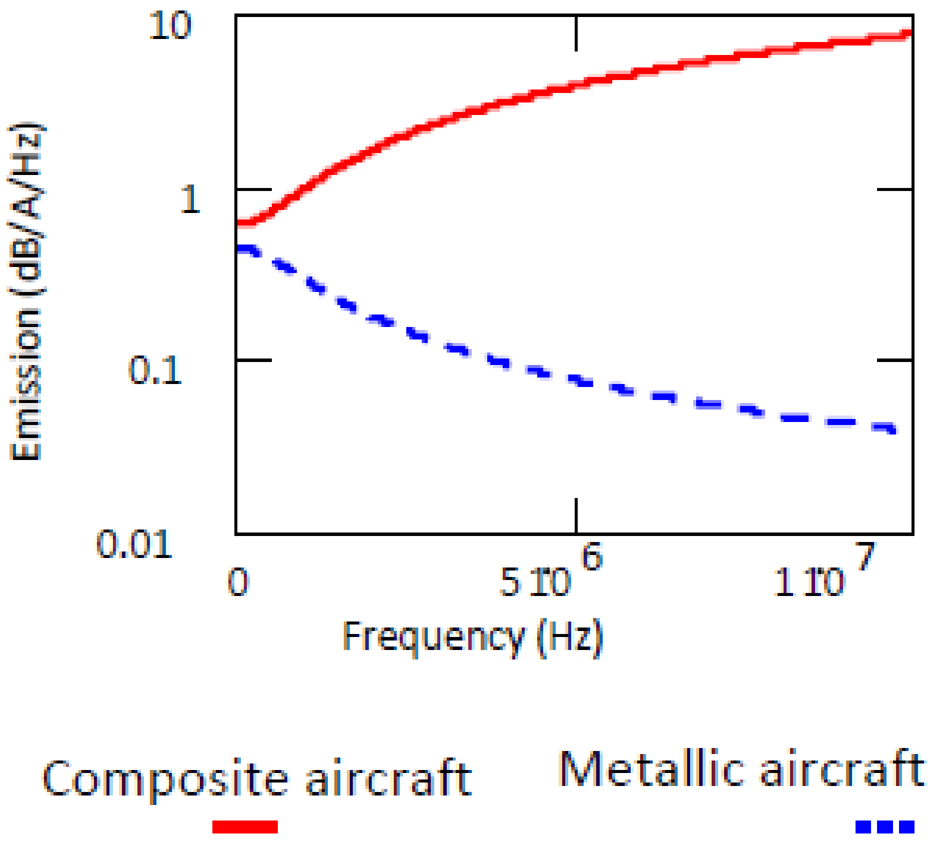
COMPARISON OF CONDUCTED EMISSIONS ON COMPOSITE METALLIC # METALLIC AIRCRAFT



EPICEA COLLABORATIVE PROJECT

ONERA
THE FRENCH AEROSPACE LAB

POLYTECHNIQUE MONTRÉAL
LE GÉNIE EN PREMIÈRE CLASSE

ARTTIC
INTERNATIONAL MANAGEMENT SERVICES

AxesSim

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the evolution of mobility

ÉTS
Le génie pour l'industrie

Fokker

GKN AEROSPACE

IDS
INGEGNERIA DEI SISTEMI

isoneo
solutions

NSERC
CRSNG

CARIC

EPICEA
ENV-714

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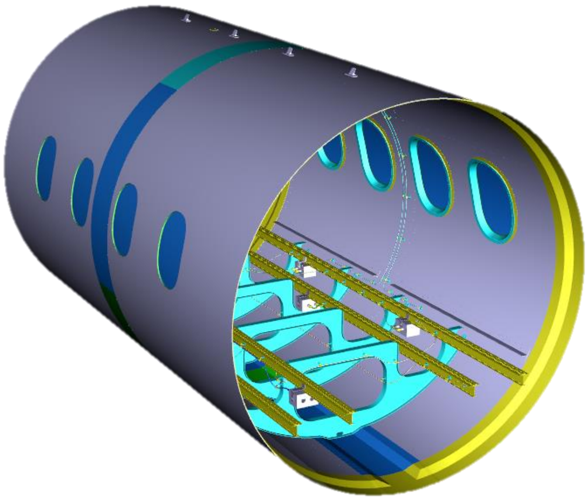
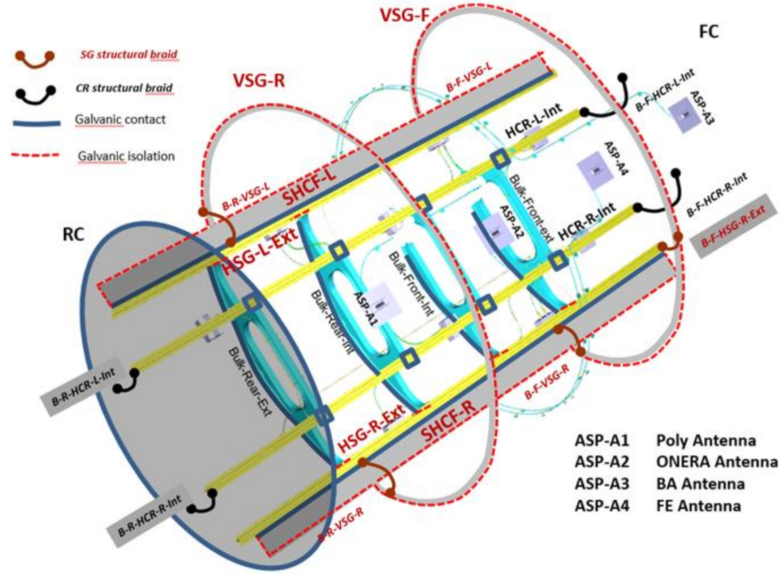
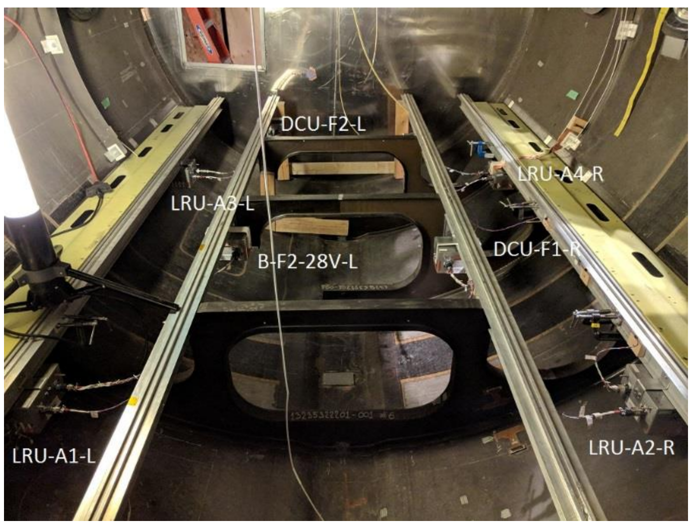
EPICEA PROJECT – Test Case
Description of the EPICEA Barrel – Structure View







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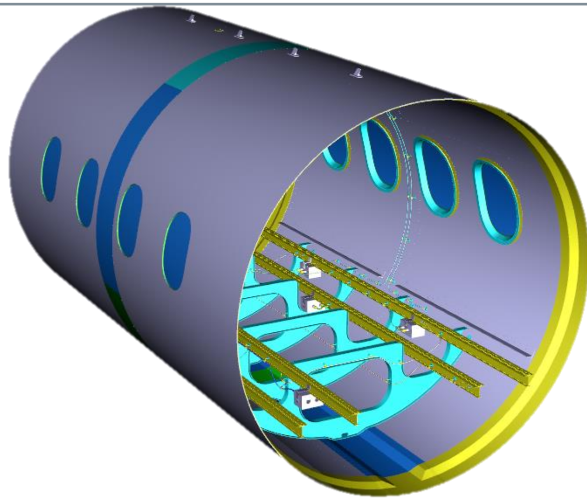
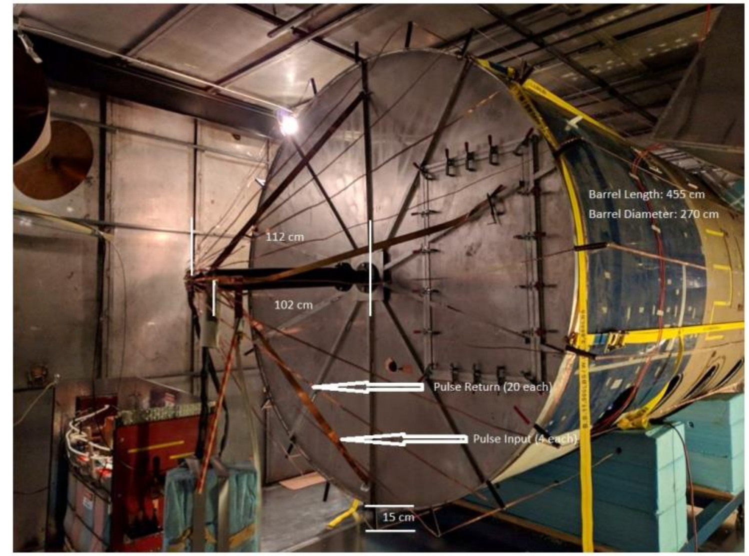
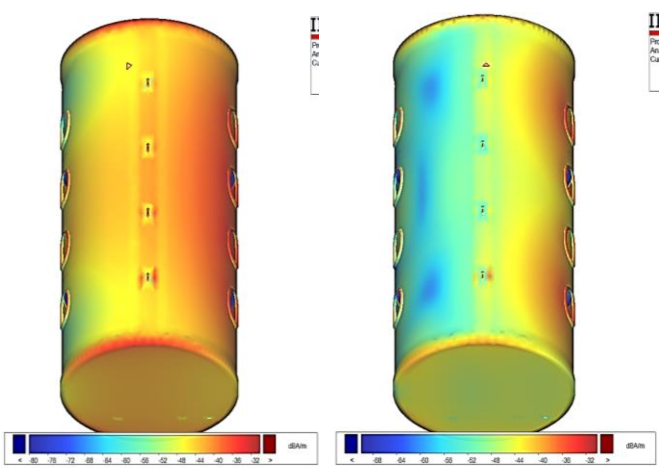
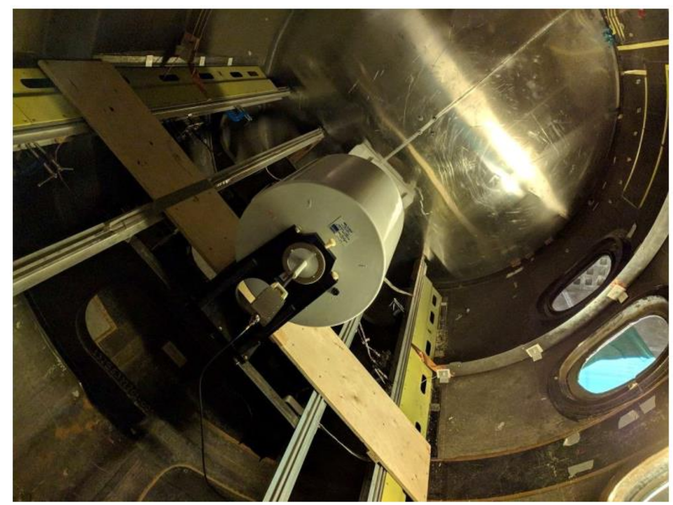
EPICEA PROJECT
LIGHTNING INDIRECT EFFECTS & HIRF TESTS





Surface current distribution @ 40 MHz and 120MHz





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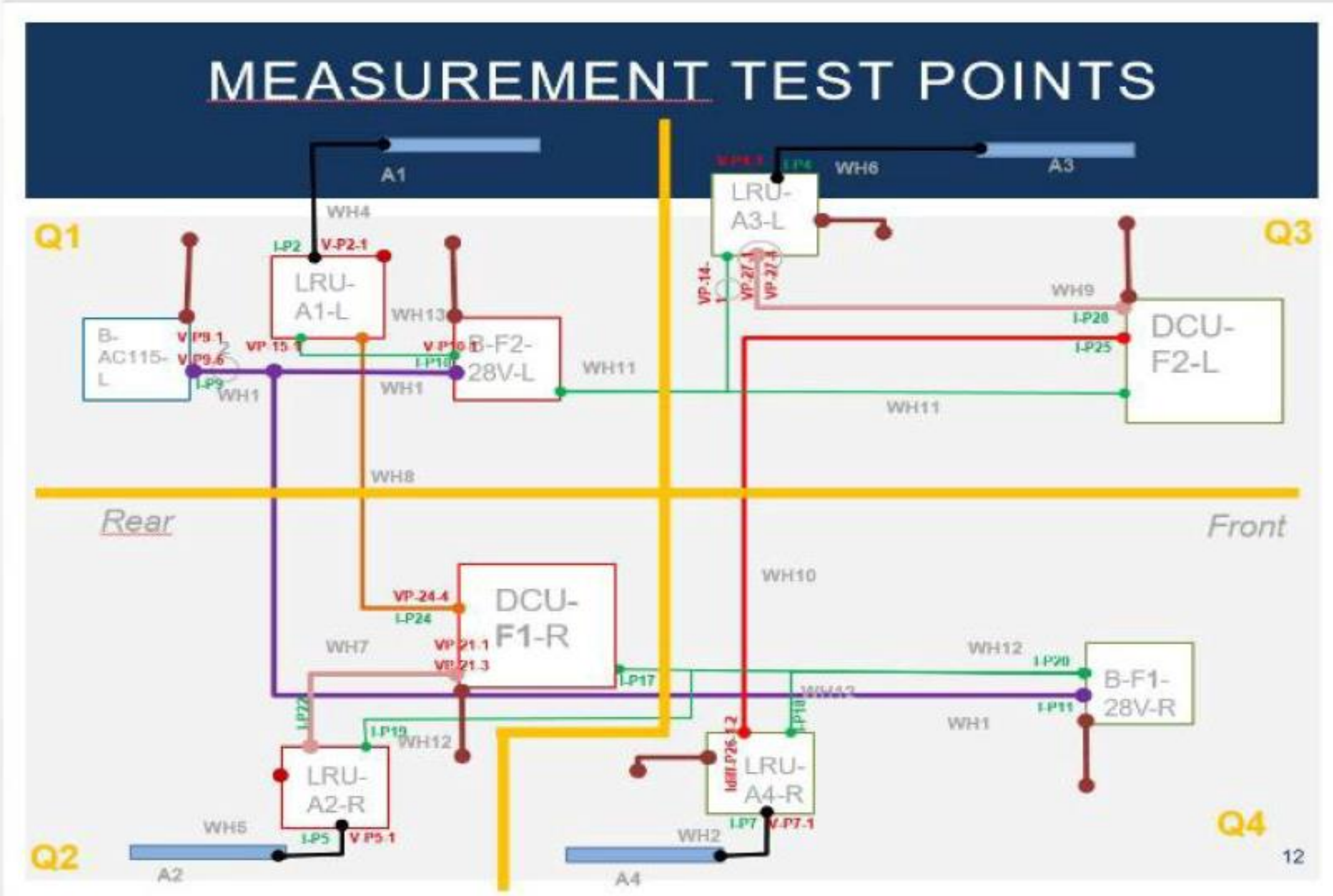
HARNESSES TEST FOR LIE & HIRF



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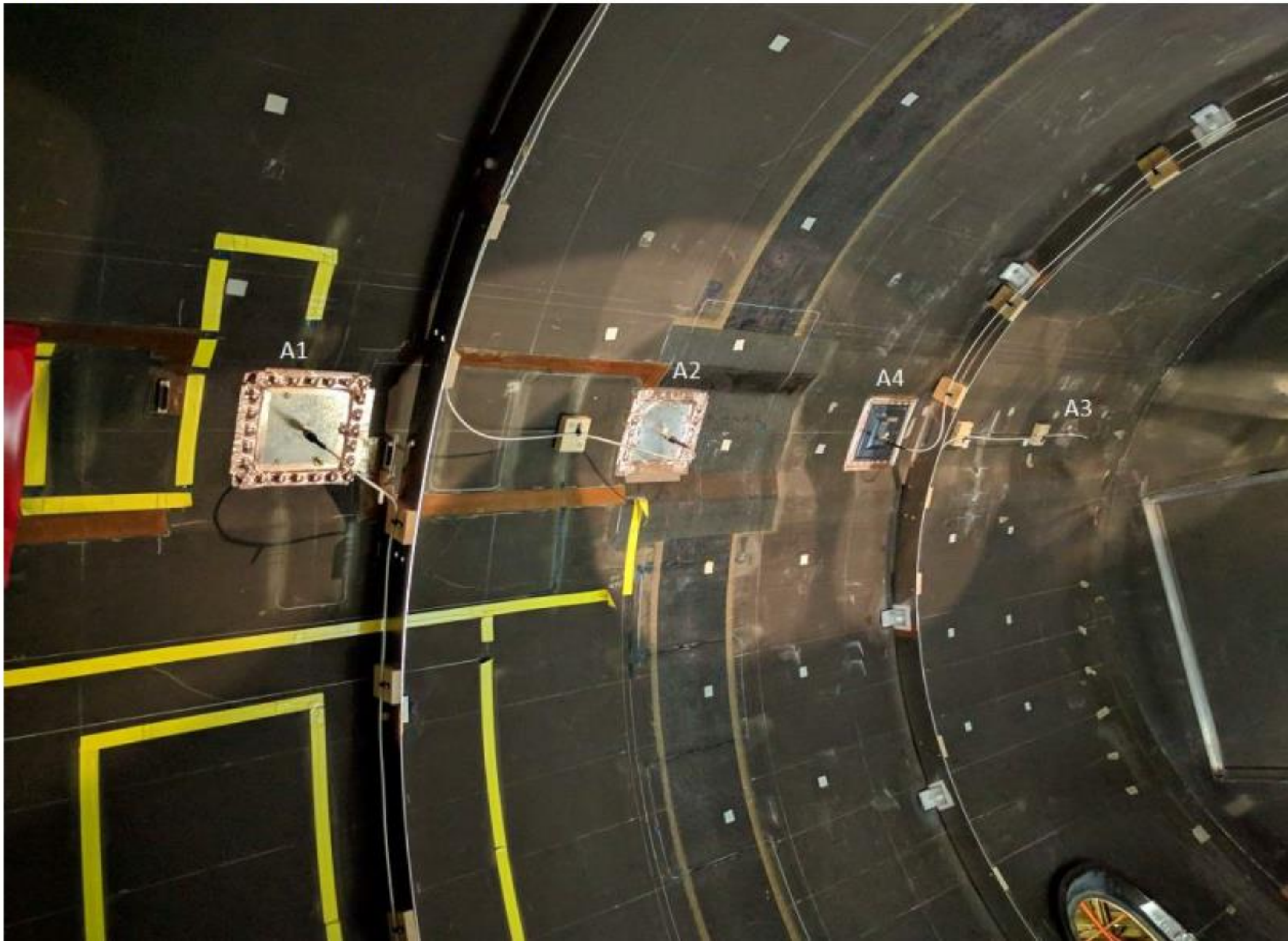
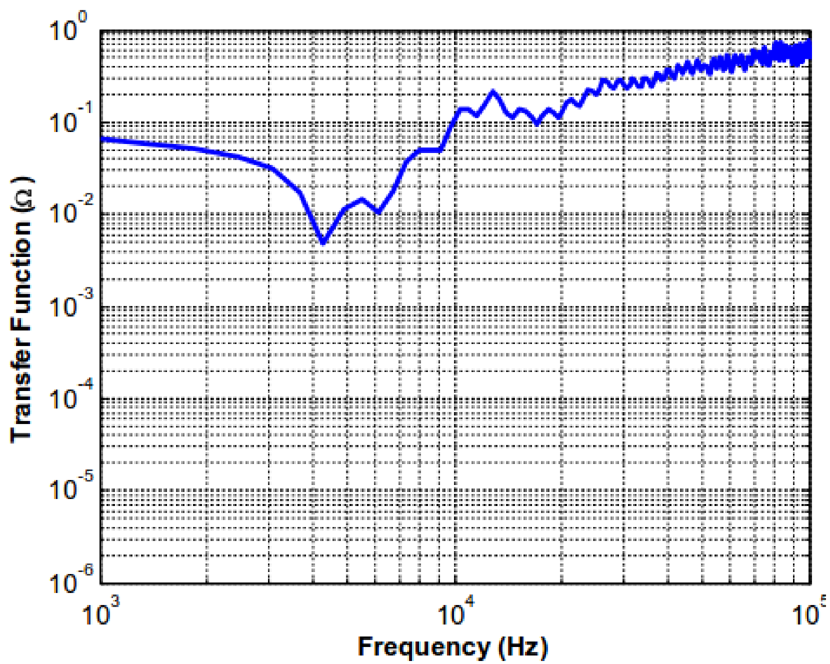
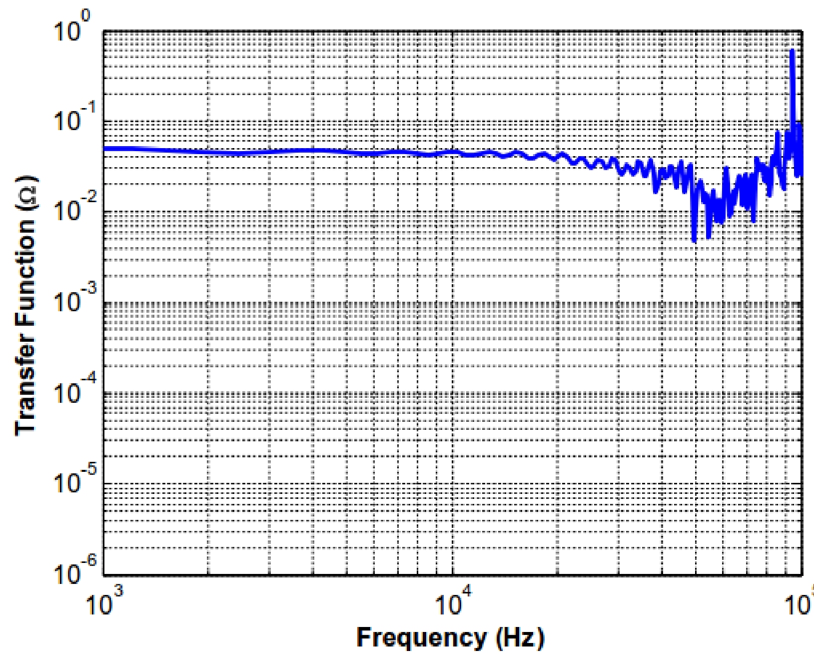
ANTENNAS INTEGRATION

Antennas without the ground straps



Cables Transfer Function





Computed Transfer Function at Test Point V P2-1 Computed Transfer Function at Test V P 4-1
(with all bundles in WH8 Short circuited)

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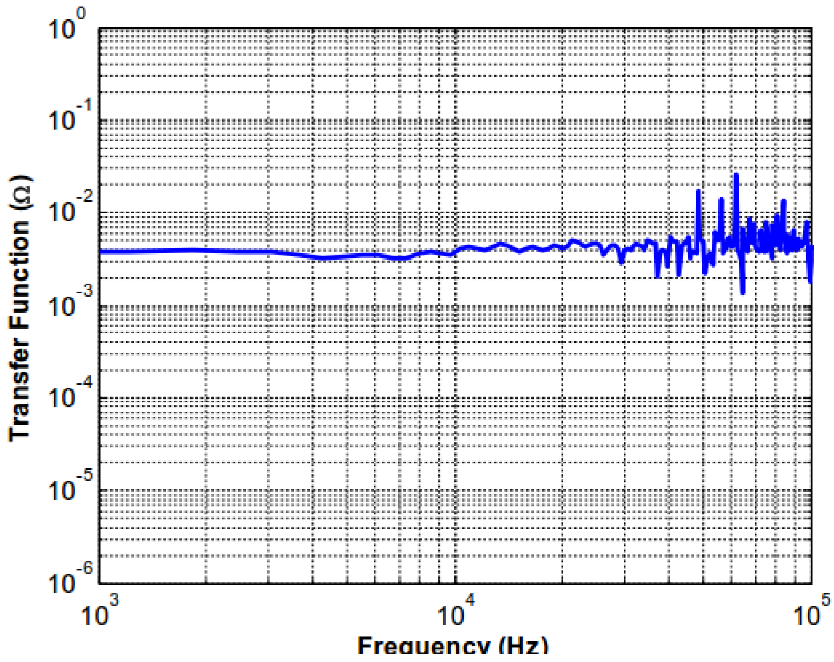
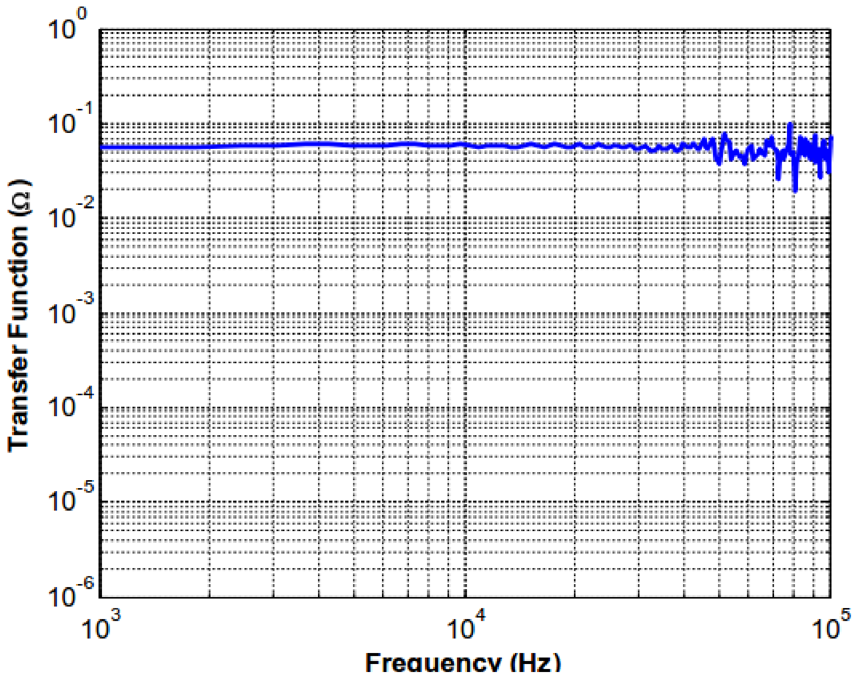
LIGHTNING INDIRET EFFECTS

Cables Transfer Function





Computed Transfer Function at Test Point V P5-1 Computed Transfer Function at Test V P 7-1 (with all bundles in WH8 Short circuited)

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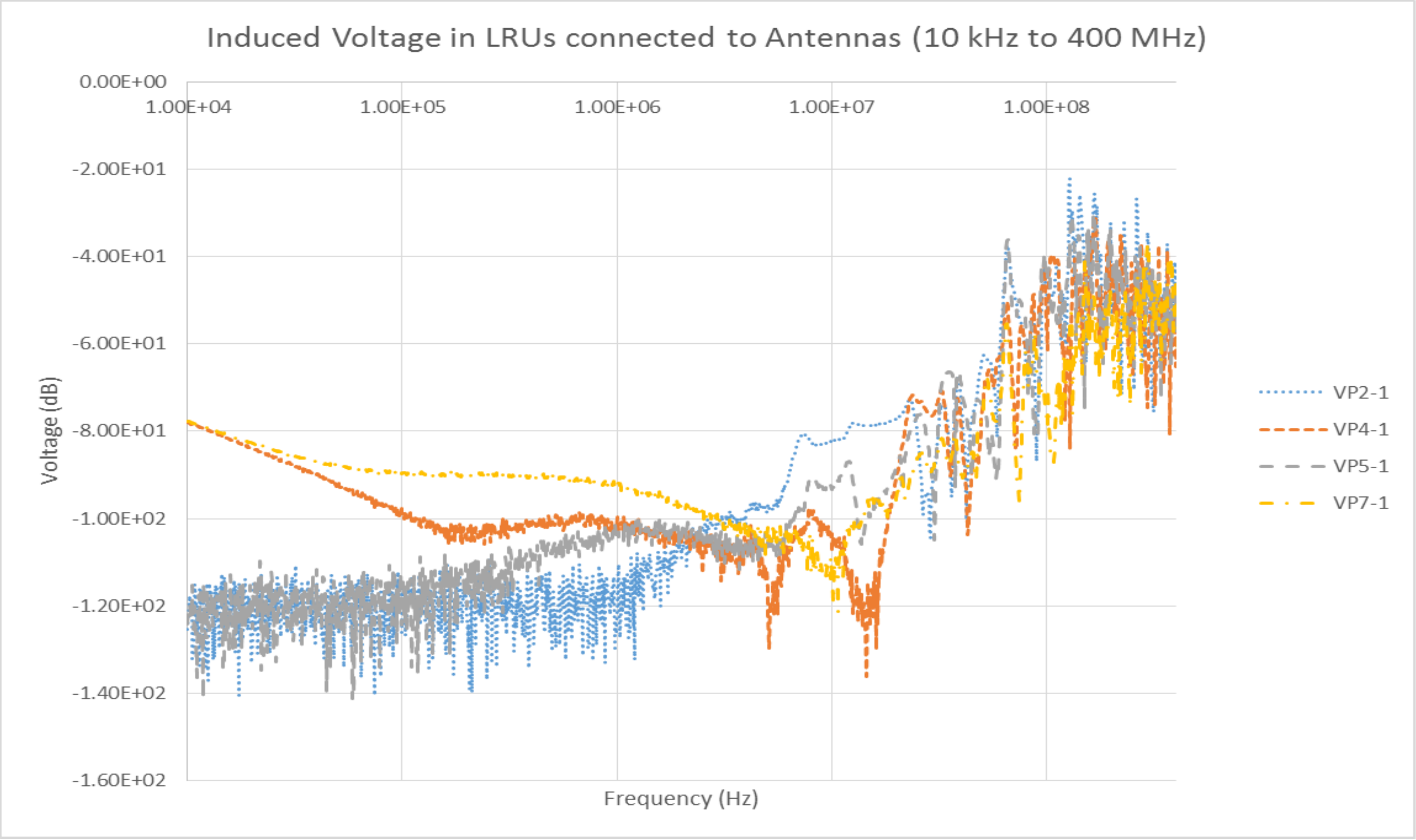
HIGH INTENSITY RADIATED FIELD EFFECTS



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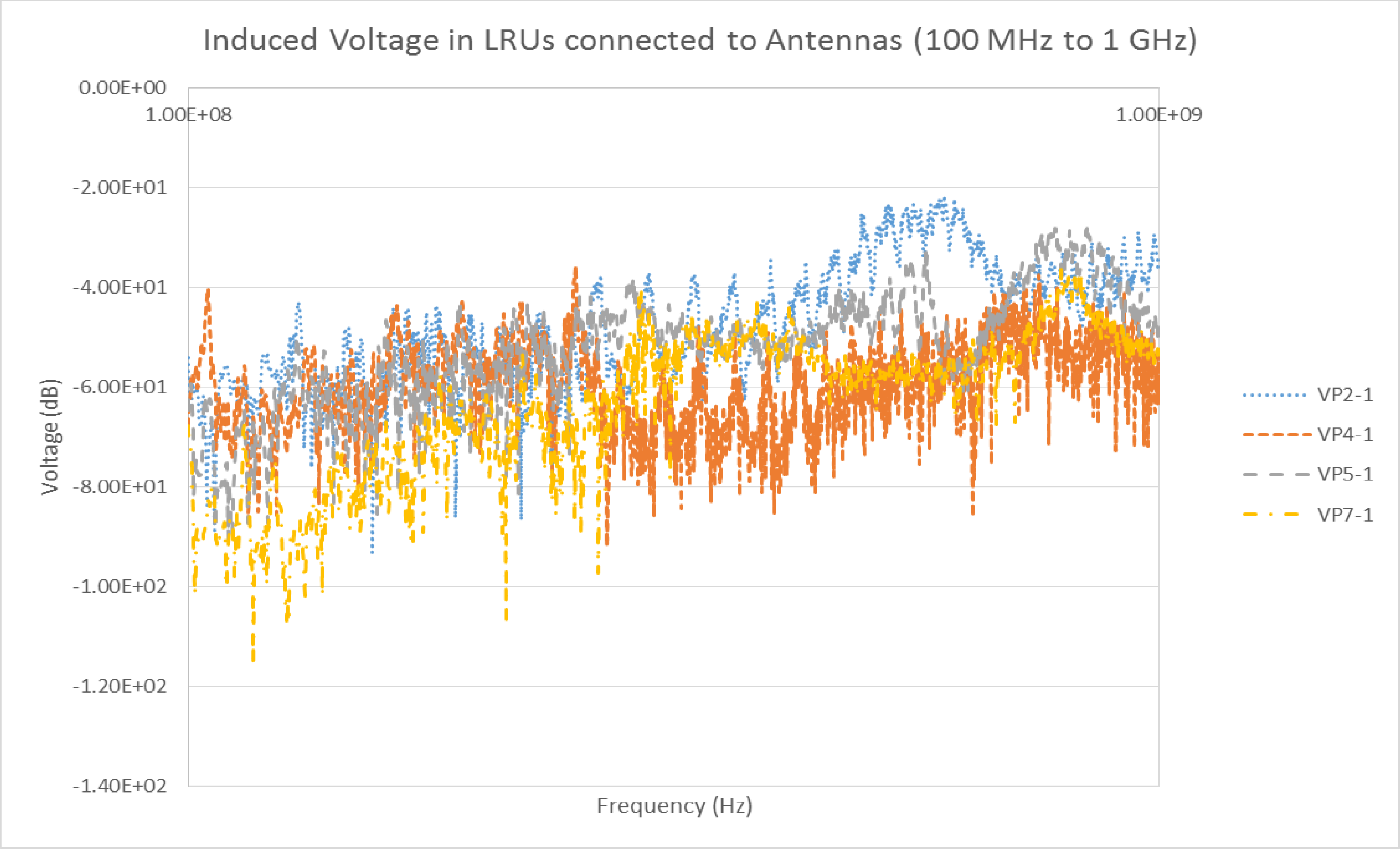
HIGH INTENSITY RADIATED FIELD EFFECTS



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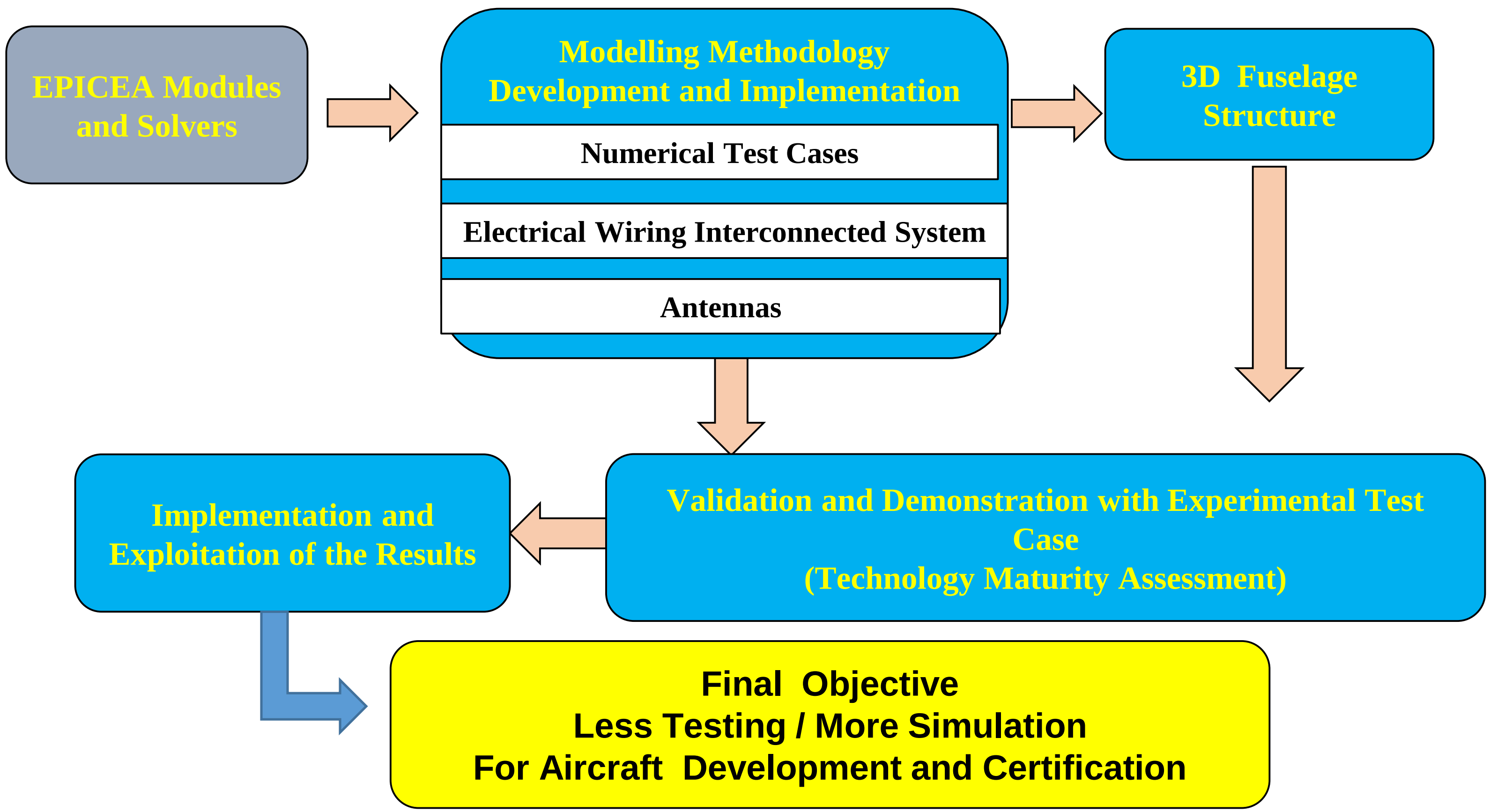
CONCLUSION

- EPICEA is An innovative set of tools to do efficient and simplified electromagnetic modelling for the systems and cabling in composite aircraft



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QUESTIONS

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