Aerospace EMC tests

Aircraft and Avionics EMC Testing for Aircraft Certification

Guido A. Rasek

Aerospace Testing Expo Europe 2006

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Two Main Categories for Aircraft EMC

- External aircraft EMC - aircraft manufacturer
- Internal aircraft EMC - avionics manufacturer

External EMC Phenomena

- High Intensity Radiated Fields (HIRF)
- Lightning Direct Effects

For military aircraft additionally:

- Electro Static Discharge (ESD) - Helicopter landing
- High Power Microwave (HPM) - RF warfare
- Nuclear Electromagnetic Pulse (NEMP)

Internal EMC Phenomena caused by External Phenomena

- Radio Frequency Susceptibility

  External HIRF threat becomes internal threat via aperture coupling

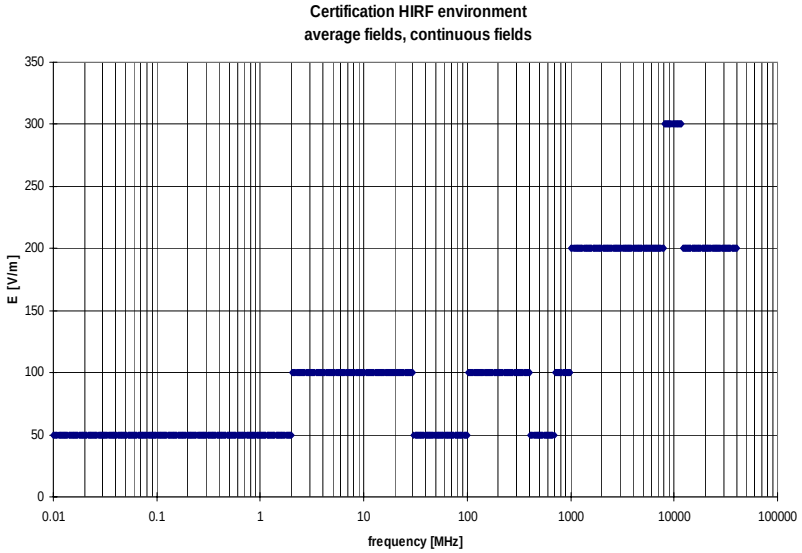
- Lightning Induced Transient Susceptibility

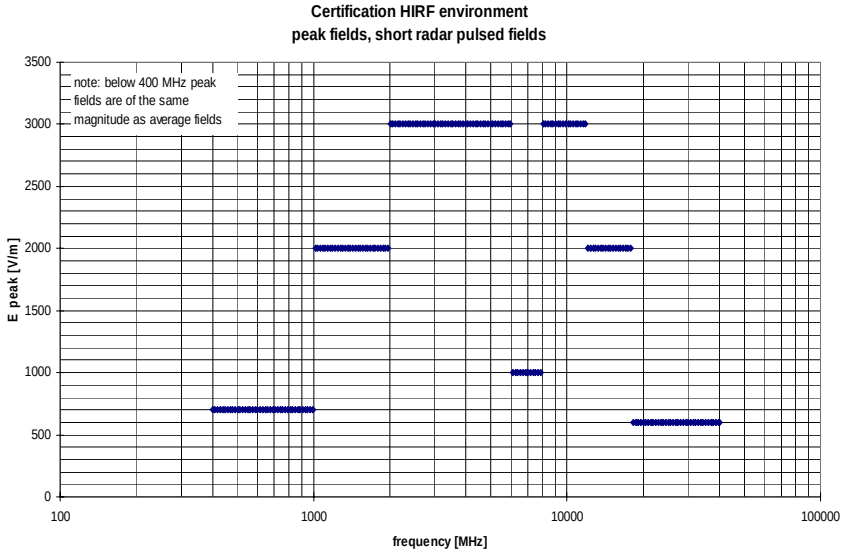
  External destructive threat becomes also an internal threat via RI coupling, aperture coupling, diffusion and excitation of resonances => Lightning Induced Transient Susceptibility

Purely Internal EMC Phenomena

- Power supply systems
  - variations in magnitude
  - oscillations, frequency variation
  - transients
  - interfering phenomena
  - AC ripples and harmonics
- Magnetic Effect on nearby equipment
- Radio Frequency Emissions
- Electrostatic Discharge (handling)

External HIRF-Threat





- Threat and testing techniques are described in Eurocae ED-107 for aircraft level and ED-14 for equipment level
- Average fields from 10 kHz to 40 GHz (above example)
- Peak fields from 400 MHz to 40 GHz (above example)

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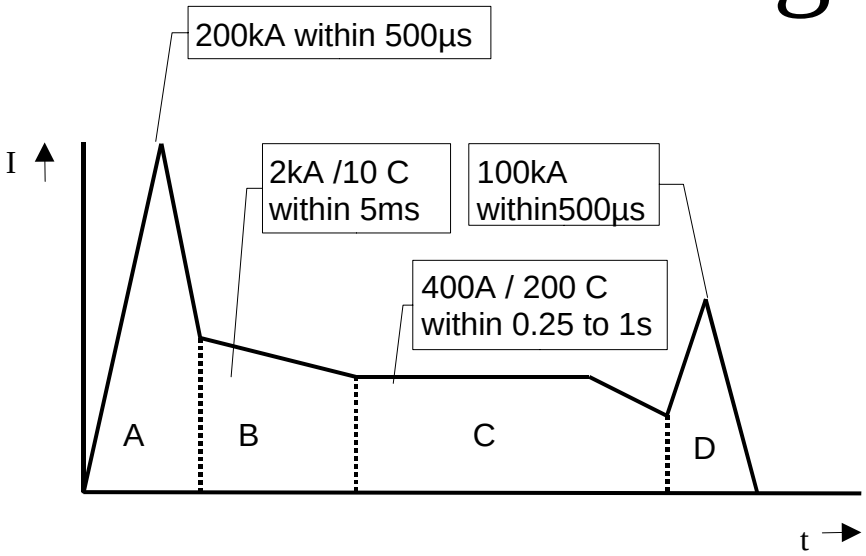
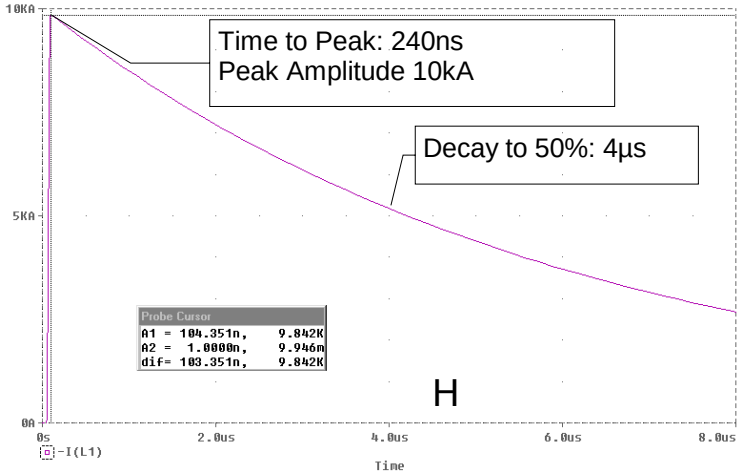
External Lightning Threat





- Threat (components A/B/C/D and H) is described in Eurocae ED-105 and ED-84
- Test techniques are given ED-14 for equipment level and ED-105 for systems and aircraft

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Necessary Steps for HIRF Compliance (simplified)

Function		Test Requirements
Catastrophic	Level A control	Aircraft Test
Catastrophic	Level A display	Aircraft Test (Generic Functions)
Hazardous	Level B	System Test
Major	Level C	Equipment Test

- Method details are quite complex and require extensive testing
- Aircraft Test can be done as
  - High Level Test
  - Transfer Function Test to determine levels for subsystems

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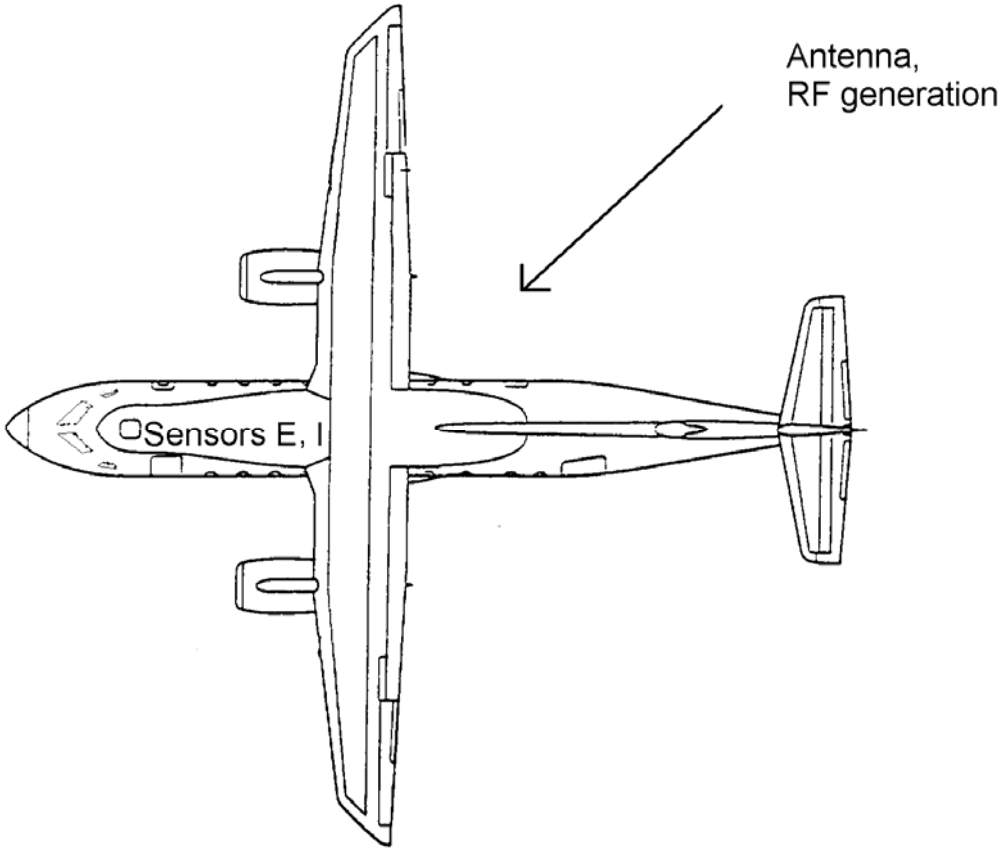
HIRF Aircraft Test and Transfer Functions



- Correlation of RF fields outside the aircraft to the inside (Low Level Swept Field LLSF)
- Correlation of RF fields outside the aircraft to the inside cable currents (Low Level Swept Current LLSC directly or indirectly via direct RF injection Low Level Direct Drive)
- Low frequency range antennas have large dimensions
- High level tests require high RF power

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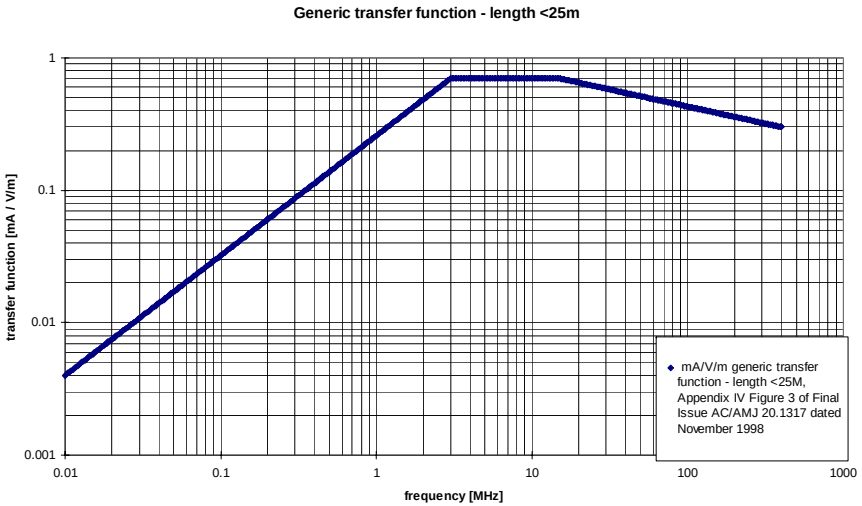
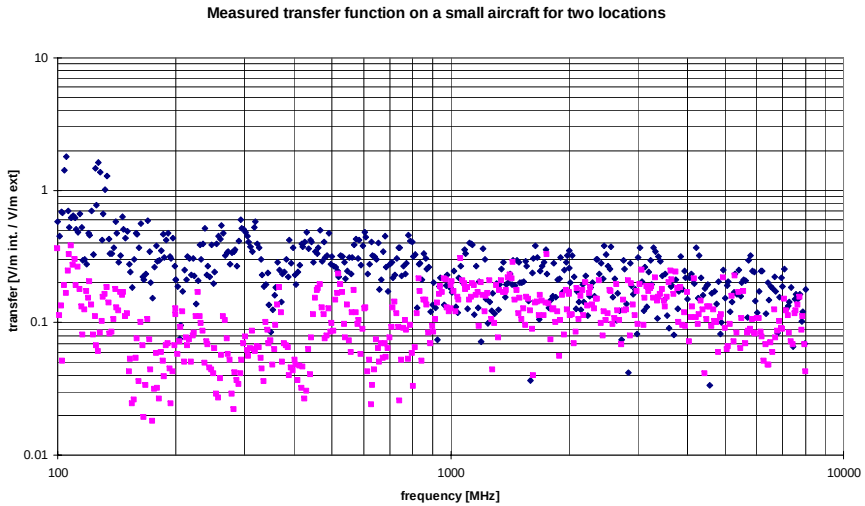
Transfer Functions

generic or measured





- External field vs. cable currents f ≤ 400 MHz
- External field vs. int. field f ≥ 100 MHz
- => conducted and radiated susceptibility data for system and equipment tests

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HIRF Test

example for a FADEC / engine test

- Engine running at full power for FADEC test (high level test, level: some kV/m)
- Air intake and exhaust areas need to be kept free
- Rotor burst zones and danger areas need to be avoided for staff during test with engine running

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HIRF Test

examples

- Climatic factors
- Location factors
- Test relevant functions in all types of modern aeroplanes and helicopters

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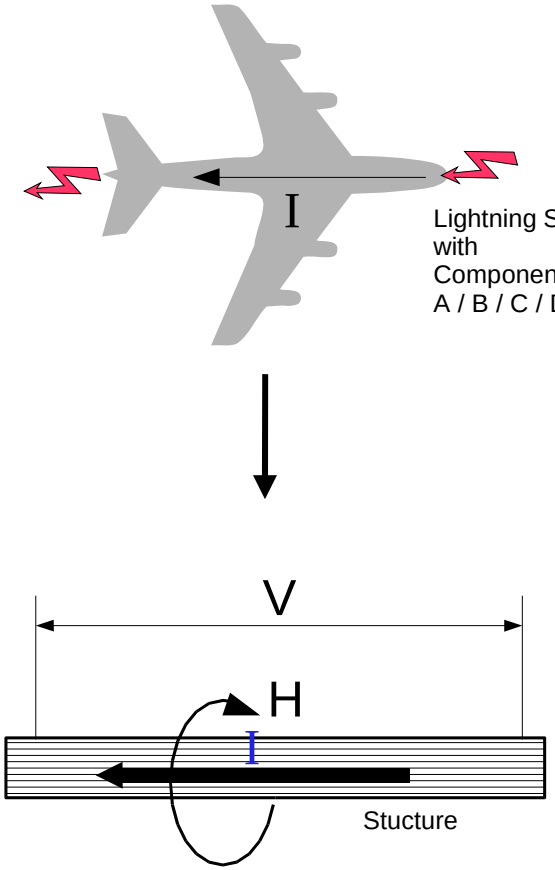
Lightning Aircraft Test and Transient Level Assessment



- Correlation of lightning current through the aircraft to transients in internal cable bundles
- Correlation of lightning current through the aircraft to voltages and currents on pins of connectors
- Test needs individual rig construction for every aircraft
- Test is performed for A, D and H components

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Aircraft Lightning Test

- Aircraft with return conductor rig
- Aircraft insulated from ground
- Measurements made inside during injection

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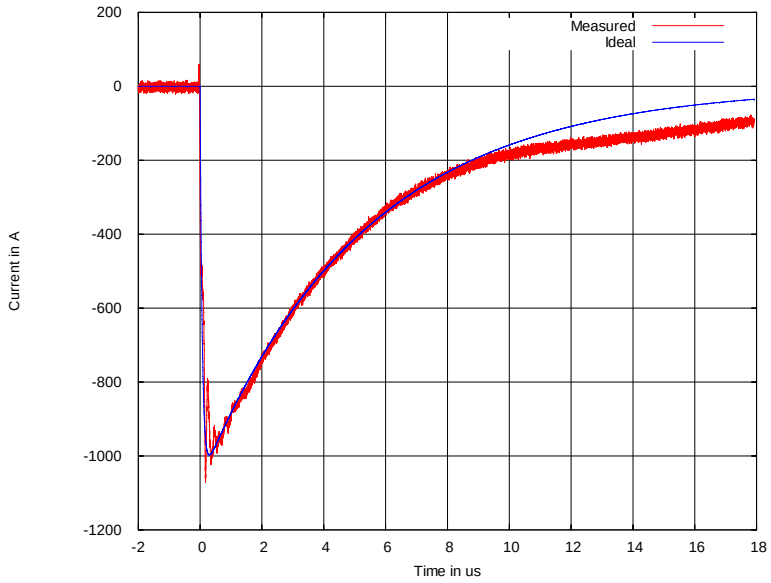
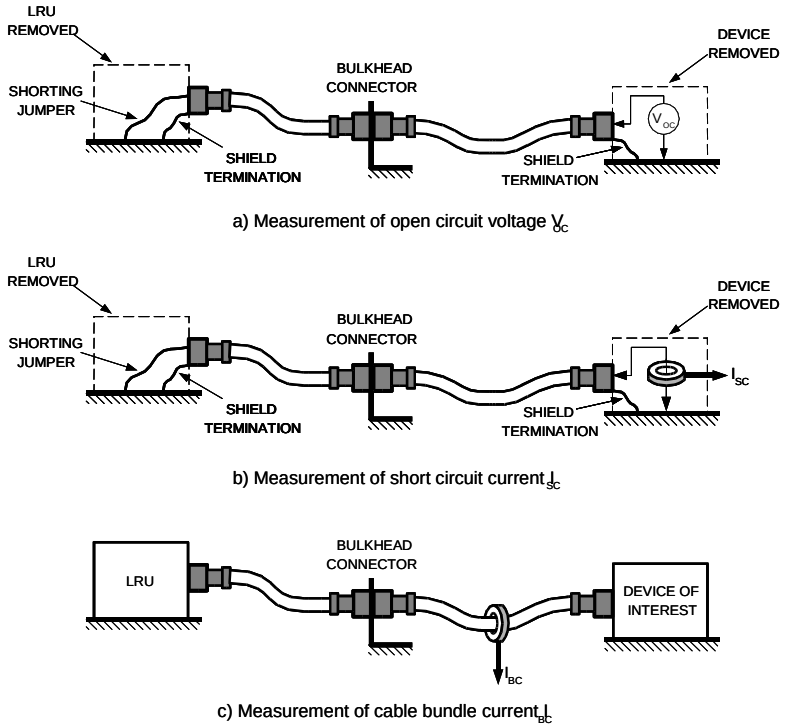
Actual Transient Level (ATL) Assessment



Component H current excitation



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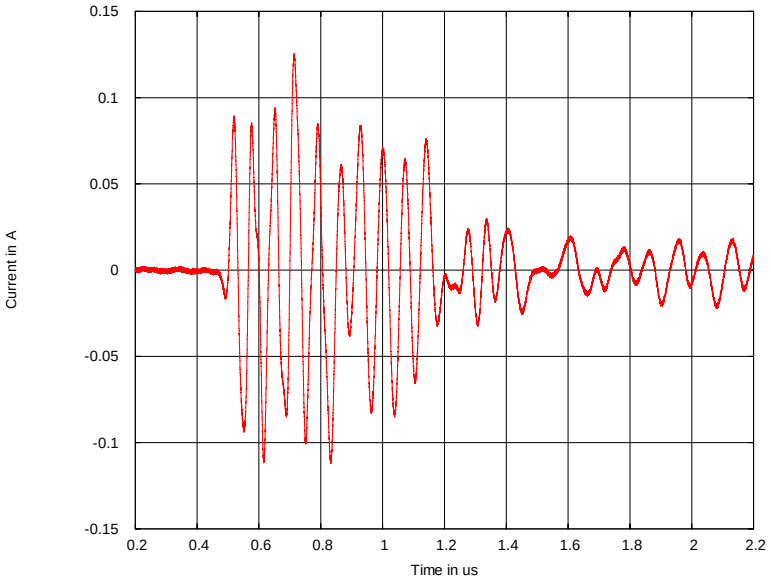
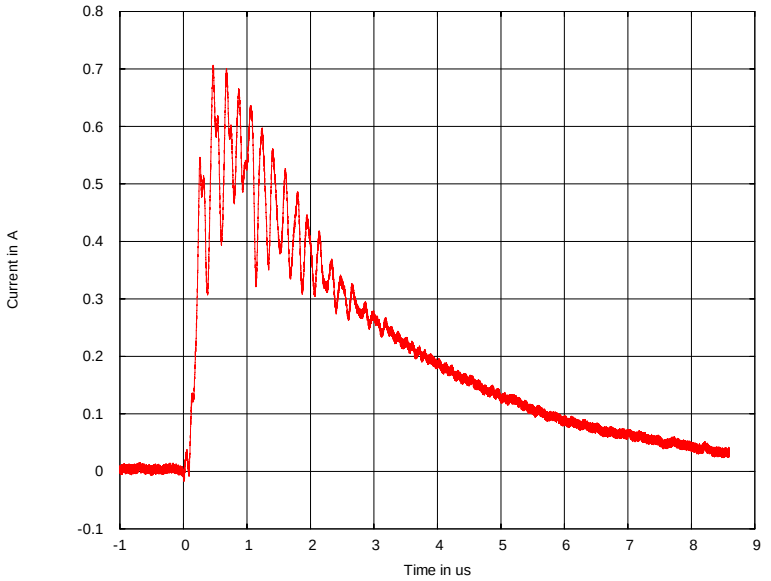
Component H Measured Transients

examples



Measured cable bundle current for long cable (WF 3H reaction)



Measured cable bundle current for short shielded cable (WF 3H and WF 6H reactions)

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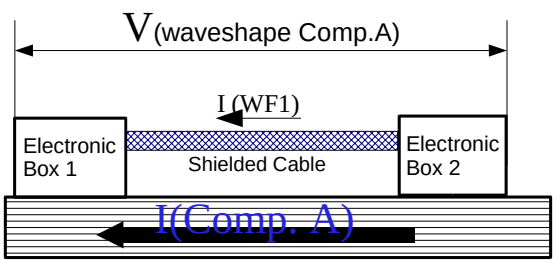
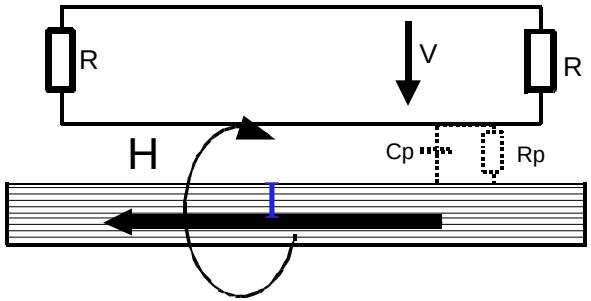
Origin of the Waveforms for Lightning Induced Transients

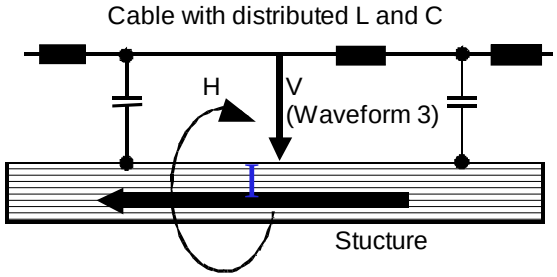


Waveform 1(6.4/69µs) is induced in low impedance cable loops through the magnetic field of current of component A.
The induced current waveshape is the one of the current component A.

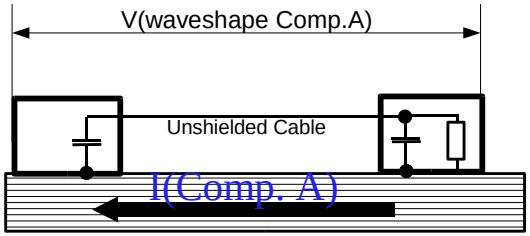
$$V = L \frac{dI}{dt}$$



Waveform 2(0.1/6.4µs) is induced in high impedance cable loops through the magnetic field of current of component A.
The induced voltage waveshape is the derivative of the current component A.



Waveform 3 is a damped sinusoidal wave (DSW) with 1 and 10MHz.
Waveform 3 is one of the responses of component A and of component H due to reflections and internal resonances.



Waveform 4 represents the voltage drop caused by current of component A. This voltage drop appears between ports which are connected via unshielded cables. This voltage can also occur in shielded leads due to the current in shield and capacitance between the leads and shield.

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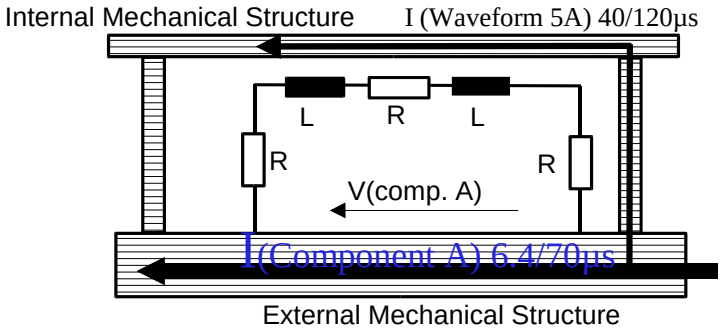
Origin of the Waveforms for Lightning Induced Transients



Waveform 5A (40/120µs) is caused by redistribution and diffusion of external current A (6.4/70µs) to internal structures. The inductances and resistances decrease risetime and increase duration.
Waveform 5B (50/500µs) occurs in CFC-structures due to higher resistance and inductance of fuselage.

- Wavefroms 1 through 5B are typical but may not cover all aspects of lightning induced interaction, e.g. previous WF 6H example
- Levels up to level 5 may not be sufficient, higher levels occur during transients measurement

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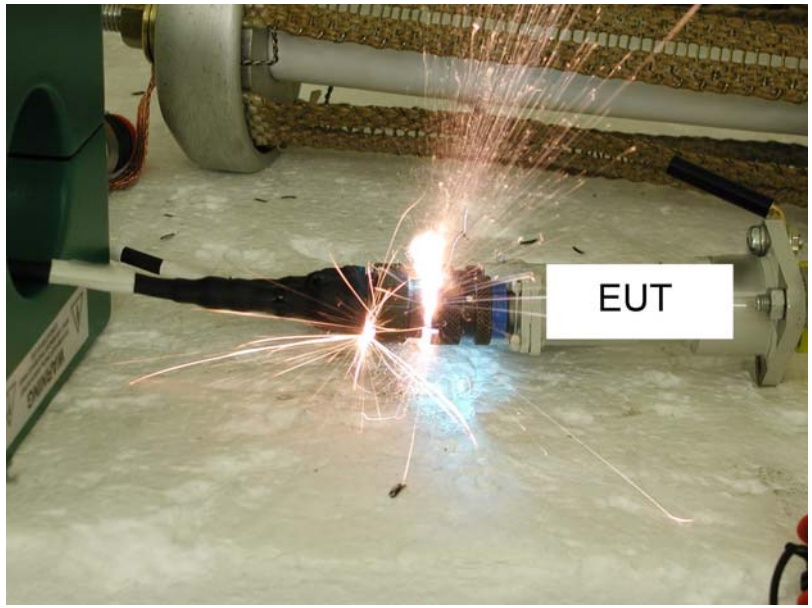
Lightning Induced Transients Effects



- Lightning Induced Transients cause system interferences and failures
- Lightning Induced Transients can be very destructive as well (photo)

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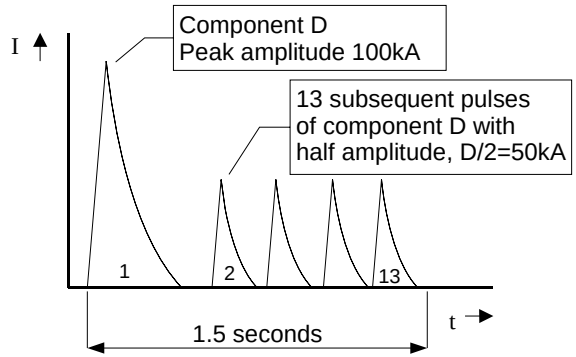
Origin of the Multiple Patterns

Multiple Stroke

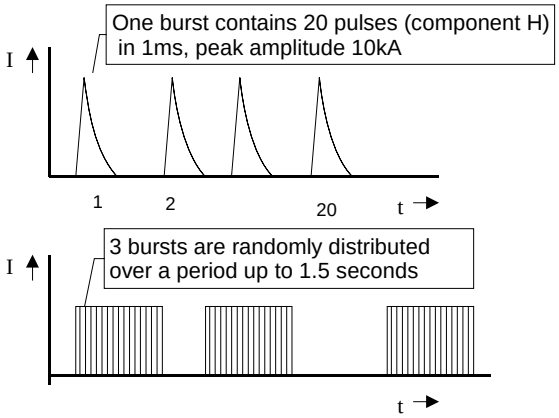
Real Lightning:



Test pulses:
Typical cloud-to-ground lightning contains more than one stroke current. Investigations showed up to 14 strokes, randomly spaced.
For evaluating test pulses all waveshapes are the same, only the amplitude of subsequent pulses differ.
Specifications require waveform 1, 2, 3, 4, 5A for multiple stroke.

Multiple Burst

Real Lightning:



Test pulses:
Component H represents high rate of rise pulses with a lower amplitude and duration than the return stroke.
These pulses occur throughout a lightning flash and they are less destructive than component A. The high repitition rate may disturb electronics.
These pulses cause resonant effects with damped sine waves.
The latest specifications assume 3x20 pulses for the multiple burst with waveforms H3 and H6. H6 is a current waveform.

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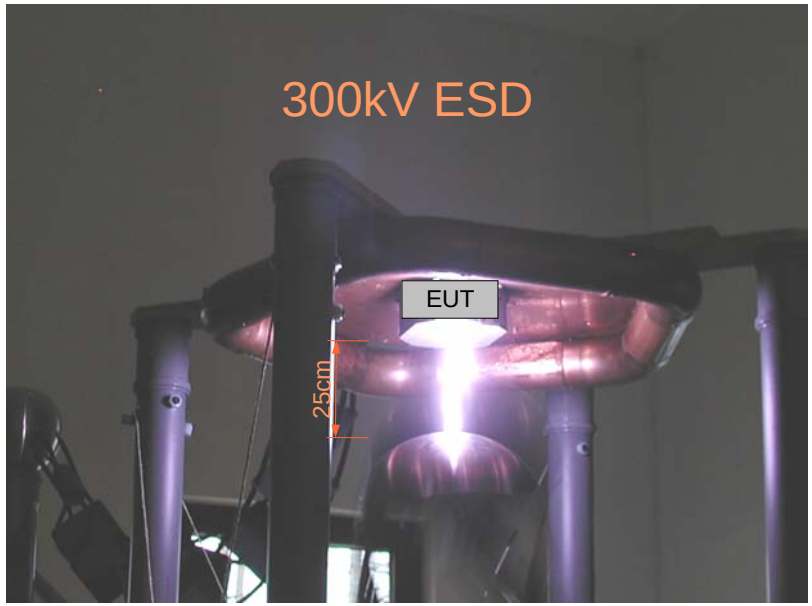
External Electrostatic Discharge (ESD) Threat



Test required for externally mounted equipment

- Especially helicopters carry a significant charge after flight operation
- During landing a discharge takes place
- Test parameters are 300 kV, 1 nF and R, L limitations

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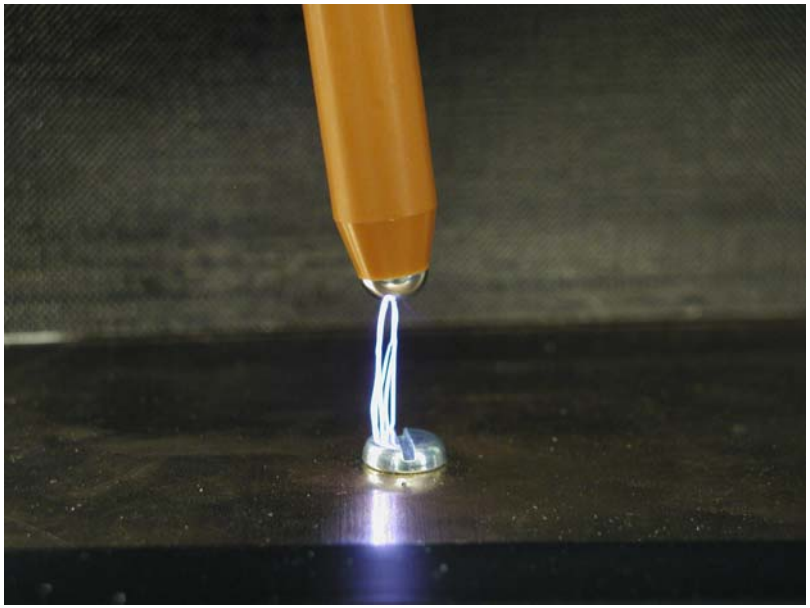
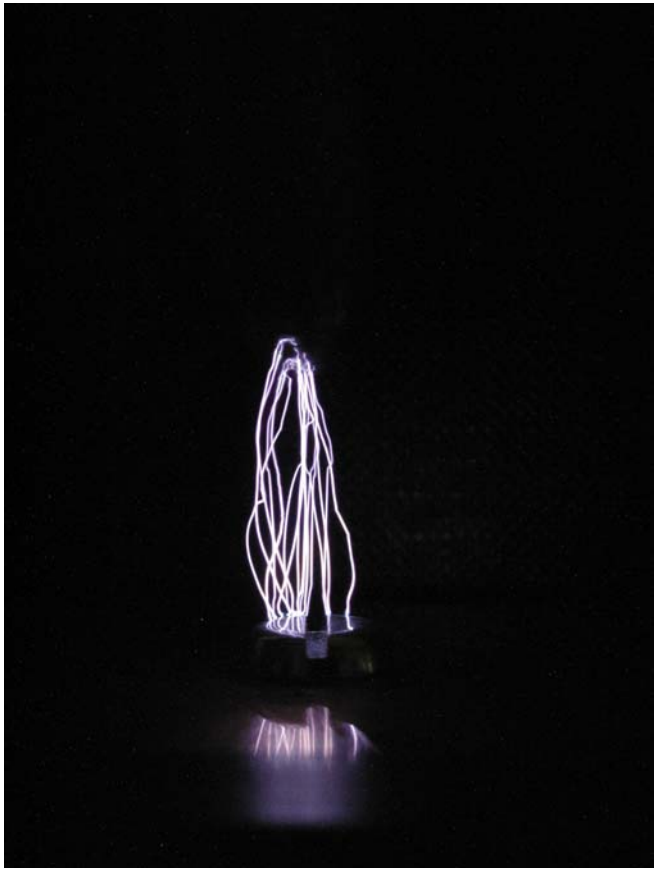
Internal Electrostatic Discharge (ESD) Threat





Immunity to electrostatic discharges caused by human contact during equipment handling, test for all equipment

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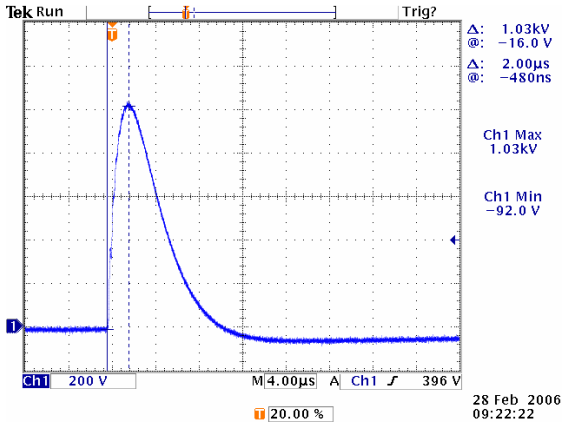
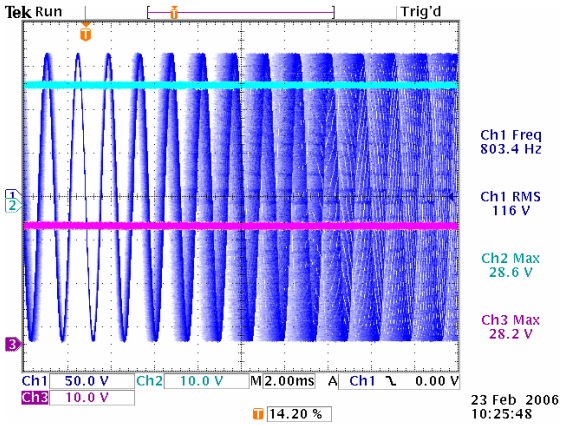
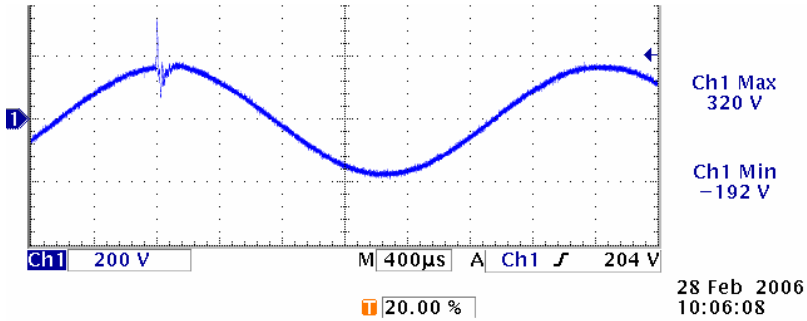
Internal EMC Phenomena Examples: Power Supply Systems



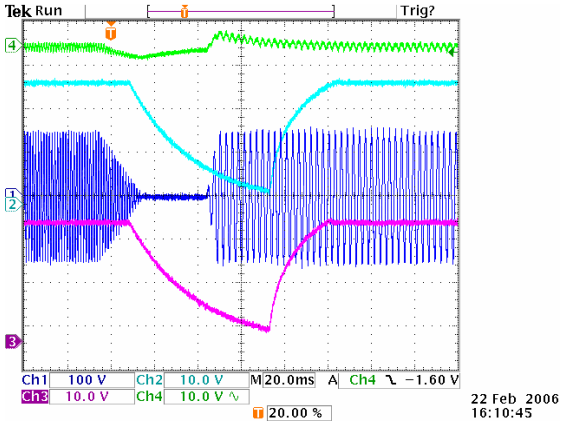
1 kV Voltage spike calibration



Frequency variation 100 Hz/s



Voltage spike test on AC system



800 Hz to 360 Hz transient

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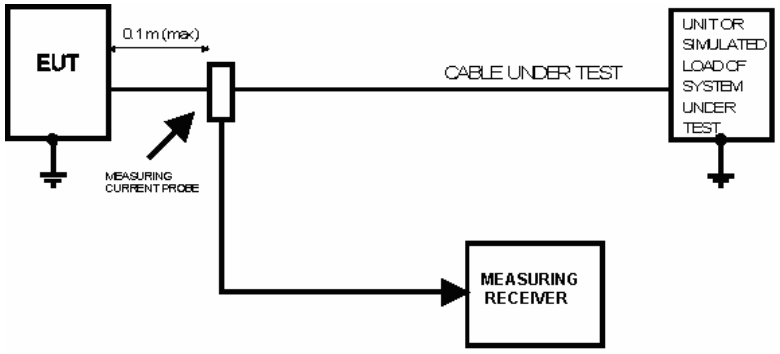
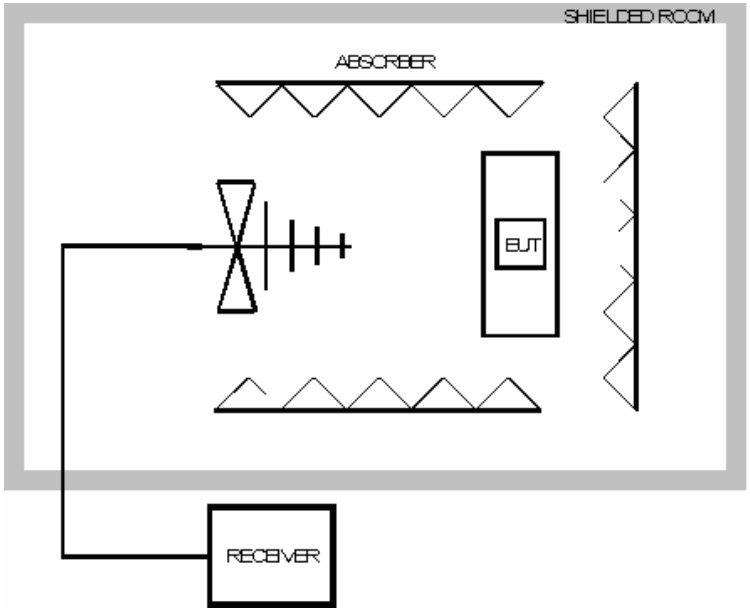
Radio Frequency Emissions

for equipment





Conducted RF emission
150 kHz – 30 MHz (typical)

Radiated RF emission
2 MHz – 6 GHz (typical)

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Closing Remarks

- Aircraft, system and equipment tests need a clear analysis of functions to be tested prior to the start of the tests
- As a consequence measurement and injection points as well as operation modes need to be defined
- Cabling and monitoring need to be defined prior to the start of the tests to obtain reliable results

For more information please visit our stand #738 in hall A1 or at www.emcc.de

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