THESIS TOPIC PROPOSAL

Title : Numerical modeling of the transition from multipactor effect to RF discharge inception

Reference : **PHY-DPHY-2026-09**
(to be mentioned in all correspondence)

Start date : 01/01/2027	**Application deadline : 15/03/2026**

Key words

Numerical simulation, Space, High-Frequency, Electron interactions, Plasma, Discharges

Profile and desired skills

Master's degree in physics, electrical engineering, or plasma science, with strong background in: Electromagnetism and plasma physics; Numerical modeling and scientific programming (Python, Java, C++); Interest in high-frequency components and space applications.

Presentation of the doctoral project, context and objectives

Context and motivation

High-frequency (HF) and radio-frequency (RF) payloads in telecommunication satellites operate under increasingly demanding power levels and compact architectures. This evolution enhances data throughput but also brings components closer to critical electrical breakdown regimes. Among the key limiting phenomena are the multipactor effect and RF discharge inception, both driven by electron avalanche processes in vacuum.

The multipactor effect originates from a resonant interaction between an RF electromagnetic (EM) field and electron emission from material surfaces. When sustained, this avalanche can lead to signal distortion, power reflection, material erosion, and eventually trigger a transition toward a gaseous or surface RF discharge. Understanding and predicting this transition is essential to improve RF component power-handling capabilities, reduce conservative design margins, and avoid costly failures in orbit or during ground testing.

While the multipactor threshold and discharge inception can be estimated experimentally, such tests require complex vacuum setups and high-power RF chains. Therefore, advanced numerical modeling has become a key strategy to predict and mitigate these phenomena under realistic geometrical, electromagnetic, and material conditions.

Scientific objectives

The objective of this PhD is to develop a physical model capable of describing the transition from the multipactor regime to the inception of an RF discharge, including the key coupling mechanisms between electromagnetic wave propagation, electron emission and transport, and gas ionization dynamics.

The work will:

- Extend existing simulation capabilities of multipactor under electrostatic or electromagnetic assumption to include the electron collisions with the background neutrals or the desorbed molecules;
- Investigate the conditions leading from a purely electronic avalanche (multipactor) to partial plasma formation and RF discharge inception, depending on the nature of the residual gas effects or the process stimulating the desorption from the surface;
- Investigate the perturbations (of the EM wave, temperature increase, etc.) created by the presence of the plasma;
- Compare the simulation results with experimental multipactor and RF breakdown data available from CNES and ONERA test campaigns, and propose criteria for predicting discharge onset under flight-representative conditions;
- Assess the effect of the geometry starting from 1D simple geometry to 3D geometry such as complex RF components.

Methodology

1 - Benchmark and model selection: evaluate existing numerical approaches and identify gaps in the description of material and plasma processes.

2 - Code development: there are 3 tools existing at ONERA:

- A 1D electrostatic Pacticle-In-Cell (PIC) electrostatic tool dedicated to the test of the physical processes that can be used in the first intention to validate the physics.
- A 2D PIC Maxwell tool that is under development to test the Maxwell coupling of the process.
- The Multipactor plugin of SPIS (Spacecraft Plasma Interaction Software) for the simulation of 3D structured coupled to EM field obtained by an external solver.

- Implement new numerical modules for collisions in the 1D tool to test the physical responses of the new collisions.
- For the collisional processes selected, to test the collisional processes with Maxwell solver using the 2D tool.
- When validated, integrate into the SPIS simulation workflow the new processes to extend to 3D complex geometries.

3 - Validation and analysis:

- Conduct reference simulations on simplified geometries (parallel plates, coaxial lines) to validate against analytical and experimental thresholds.
- Apply the model to representative RF components (waveguides, circulators, connectors) to study power thresholds and discharge transition regimes.

Expected outcomes

- Improved understanding of the physical parameters controlling breakdown thresholds (geometry, field amplitude, material charging, residual gas pressure).
- Validated predictive models supporting CNES and ONERA efforts to qualify high-power RF systems.
- Publications in international journals on plasma–RF interactions and space environment effects.
- To be involved in the evolution at the European scale to new ground test specifications and reduced power margins for space-qualified RF hardware.
- Participation to the development of a numerical framework to self-consistently simulate the full transition from multipactor to RF discharge inception.

Planned collaborations

The PhD will be conducted at ONERA – The French Aerospace Lab (DPHY Department), in collaboration with CNES, within ongoing research efforts on RF breakdown prediction and plasma–surface interaction modeling.

ONERA Laboratory

Department : Physic, instrumentation, environment, space

Place (ONERA centre) : TOULOUSE

Contact : Pierre SARRAILH / Ludivine LECLERCQ
Tel. : +33 5 62 25 26 06 - Email : pierre.sarrailh@onera.fr

Thesis director

Names :
Pierre SARRAILH / Ludivine LECLERCQ

Laboratory : ONERA
Tel. : +33 5 62 25 26 06
Email : pierre.sarrailh@onera.fr

More information : https://www.onera.fr/rejoindre-onera/la-formation-par-la-recherche