



# RF (Radio Frequency): Antenna design & simulation

*By*

*Pham Viet Dung*

**SAGI Summer School 2025  
Astronomical Techniques**

**July 13 - 25, 2025, 2025 at ICISE, Quy Nhon, Binh Dinh, Vietnam**

# About me

Ph.D. in Physics 2021 – 2024

Université Paris Cité – Doctoral School STEP'UP (ED560) Laboratoire AstroParticule et Cosmologie (APC) | Paris, France

- Major: Physics of the Universe  
Master of Science 2017 – 2019

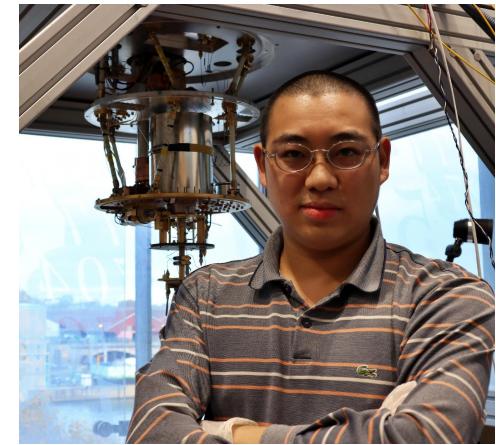
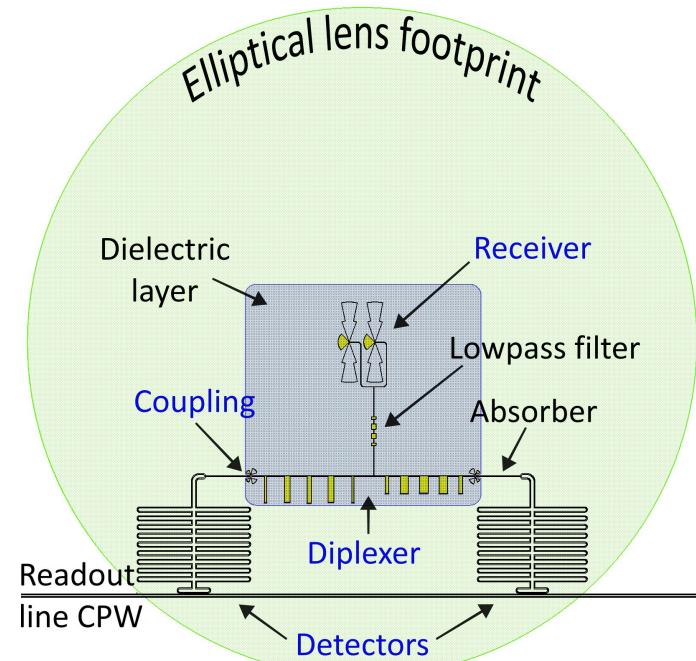
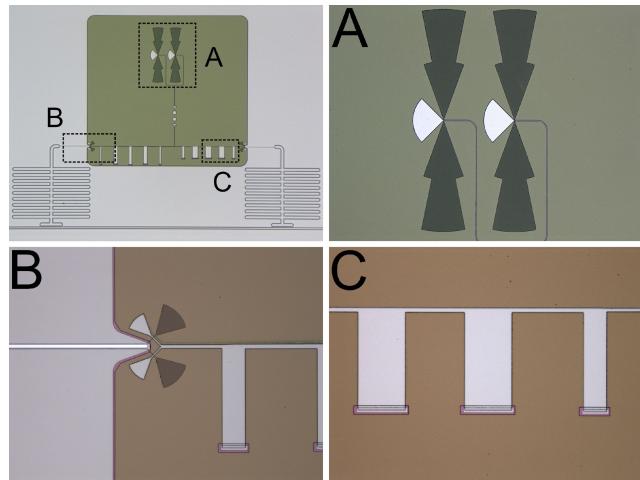
Université Paris Cité (UPC) & University of Science and Technology of Hanoi (USTH) | Hanoi, Vietnam

- Major: Satellite Technology

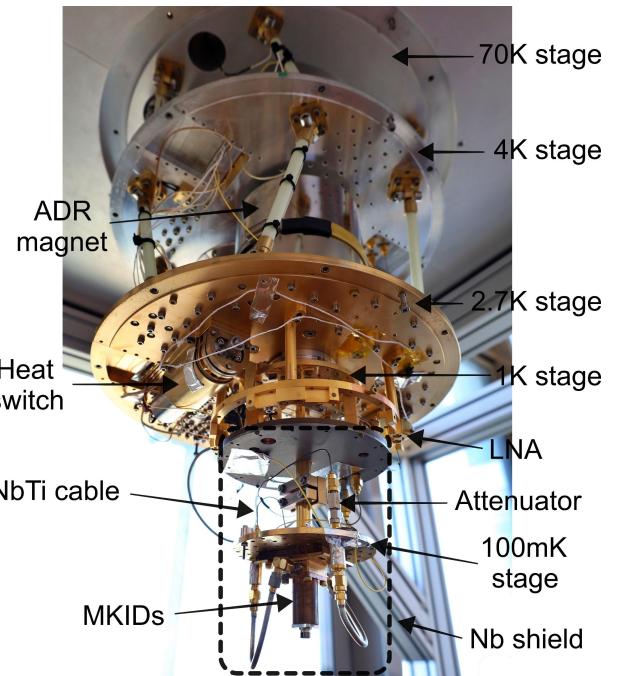
**Bachelor of Science 2014 – 2017**

University of Science and Technology of Hanoi (USTH) | Hanoi, Vietnam

- Major: Space and Applications

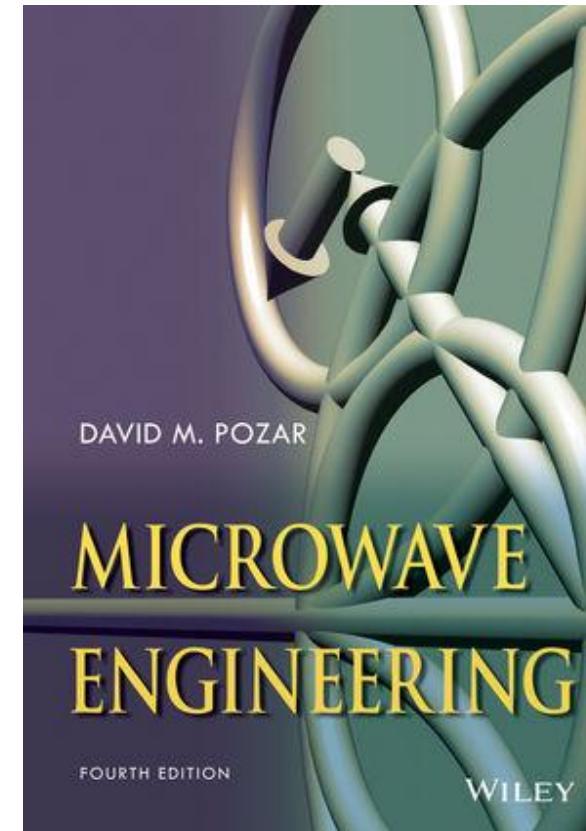
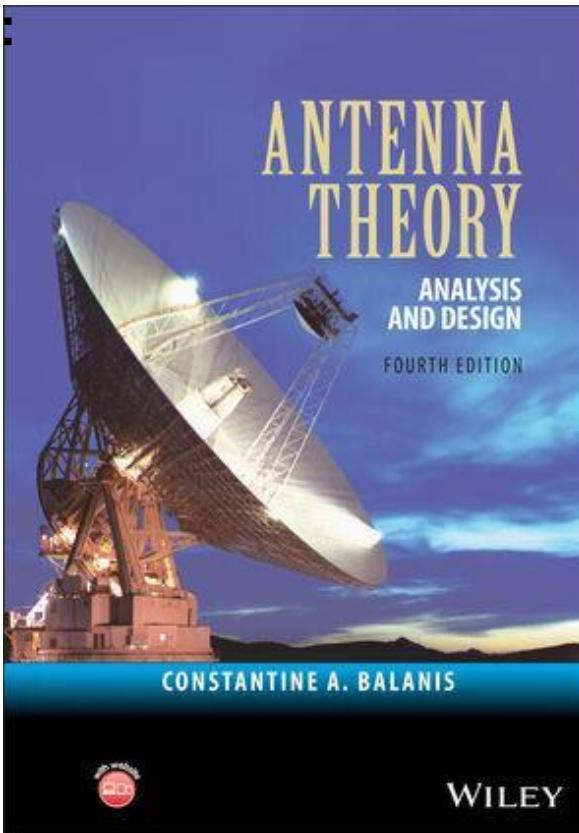


**Pham Viet Dung at APC**  
<sites.google.com/view/vdportfolio>



# Learning materials

## Textbooks



7/28/2025

**Learn computational electromagnetics (CEM):**  
<https://empossible.net/>  
<https://www.youtube.com/@empossible1577>



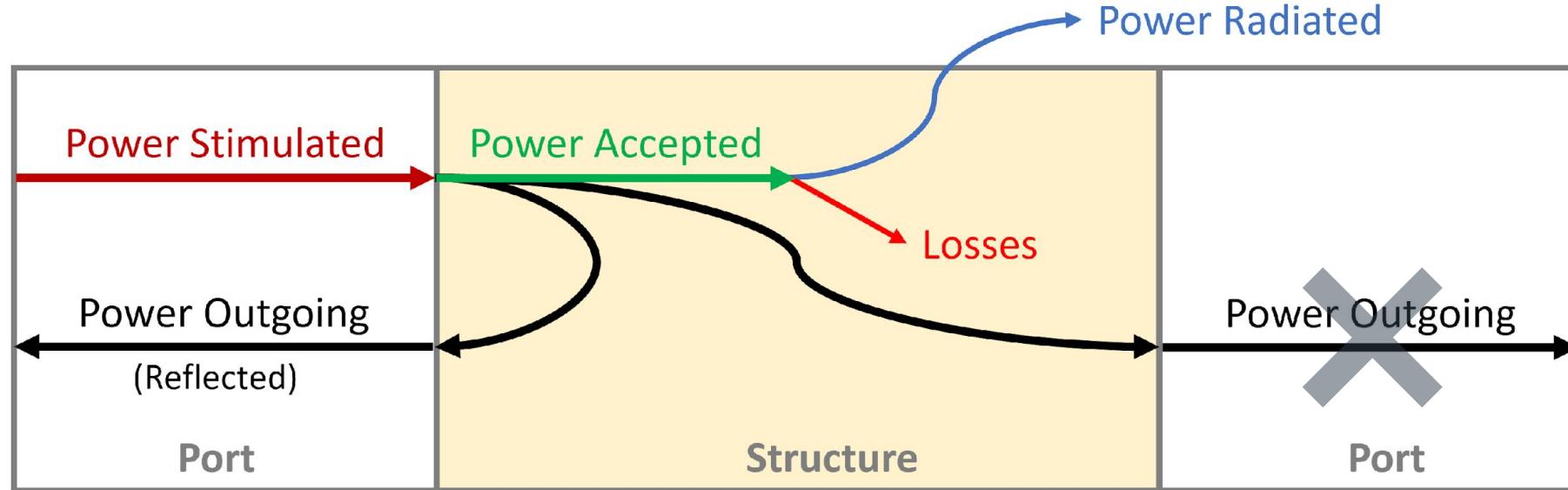
**The Antenna Theory Website:**  
<https://www.antenna-theory.com/>

A screenshot of the Antenna Theory website homepage. The header features the text 'Welcome to Antenna-Theory.com!' in purple. Below the header are several navigation links: 'Introduction to Antennas', 'Antenna Basics', 'Types of Antennas', 'Antenna Arrays', 'Antenna Measurements', 'Smith Charts and Impedance Matching', 'Antenna Design', 'Antenna Engineering Careers', 'Antenna Definitions', and 'Topics Related to Antenna Theory'. To the left of the text are two small images: one of a smartphone and one of a speaker. To the right are two small images: one of a large satellite dish and one of a smaller antenna tower. The footer contains a dark banner with the text 'ANTENNA TEST LAB Experience. Expertise. Insight.', 'Verify Specs', 'Boost Confidence', 'Optimize Designs', 'Antenna Gain Patterns', 'From \$525', 'Full 3D or 2D', 'In our anechoic chamber 300 MHz - 40 GHz', and 'AntennaTestLab.com 3'.

# Antenna basic: VSWR, |S11|, Return Loss



# Antenna basic: VSWR, |S11|, Return Loss



$$\text{Power Stimulated} = \text{Power Accepted} + \text{Power Outgoing (all Ports)}$$

In antenna case:

$$\text{Power accepted} = \text{Power stimulated (input power)} - \text{Power reflected (S11)}$$

**Return loss** = loss in the return path → More loss means more power accepted by the antenna

**Reflection Coefficient:** Return loss (dB) =  $-S_{11}(\text{dB})$

Design goal:  $S_{11} < -10 \text{ dB}$ : less than 10% power reflected → > 90% of power accepted (~radiated).

# Antenna design

- Antenna design fundamentally involves solving Maxwell's equations, which govern electromagnetic behavior at the macroscopic level.
- Fortunately, we have powerful simulation tools like HFSS, CST, and FEKO that help engineers model and analyze antenna performance efficiently.
- However, these tools often come at a high cost — for example, a single HFSS license can cost several thousand dollars, making them less accessible for individuals or small teams.

$$\nabla \cdot \mathbf{D} = \rho$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$



**Ansys**

HFSS

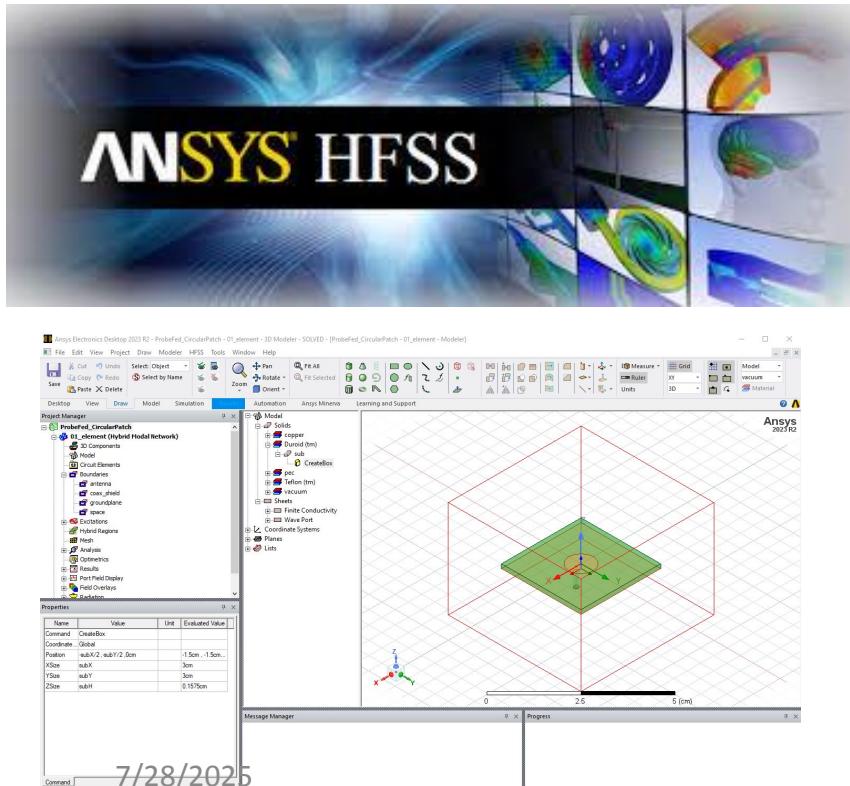
 **DS SIMULIA**  
CST STUDIO SUITE

 **XFDTD®**

 **Altair**  **FEKO**  
Comprehensive Electromagnetic Solutions 

# Software Tools

- **Ansys HFSS (High Frequency Structure Simulator):** Widely regarded as an industry standard, HFSS is a 3D EM simulation software that primarily uses the Finite Element Method (FEM). It's excellent for detailed analysis of complex antenna structures, including antenna arrays, RF/microwave components, and their interaction with surrounding environments. It also incorporates other solvers like SBR+ (Shooting and Bouncing Ray) for large-scale platforms and IE (Integral Equations).



The image shows a promotional banner for Ansys HFSS. The top part features the Ansys logo and the text "HFSS for RF and Microwave". Below this, a subtext reads "Design, simulate and validate high-frequency components and antennas". The banner includes several 3D models of microwave components and antennas, such as a probe-fed circular patch antenna, a multi-layered PCB, and a truck with a mounted antenna system. The bottom right corner has the number "7".

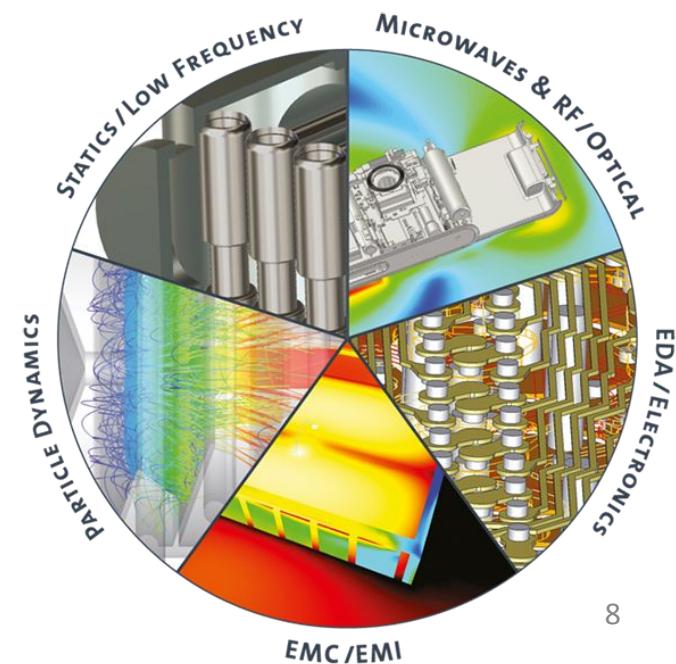
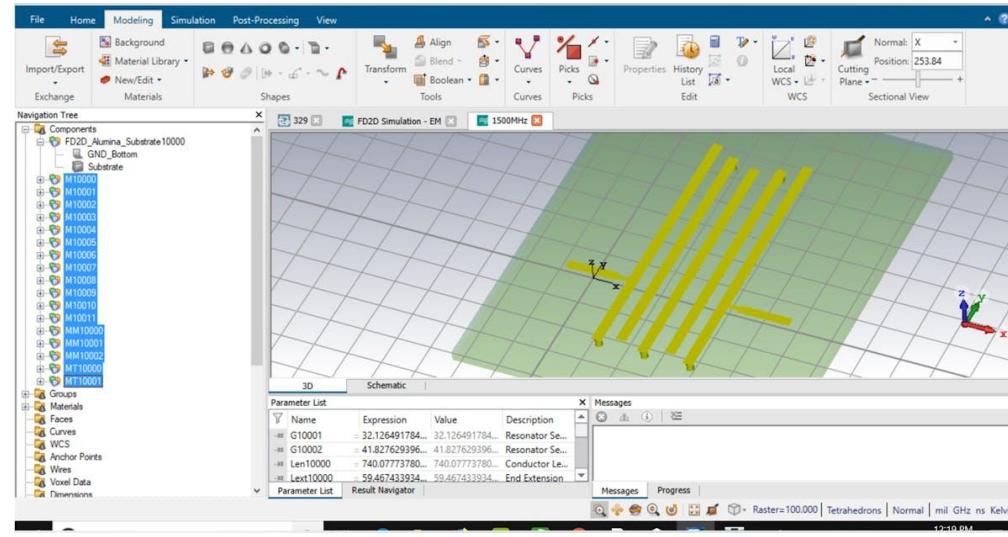
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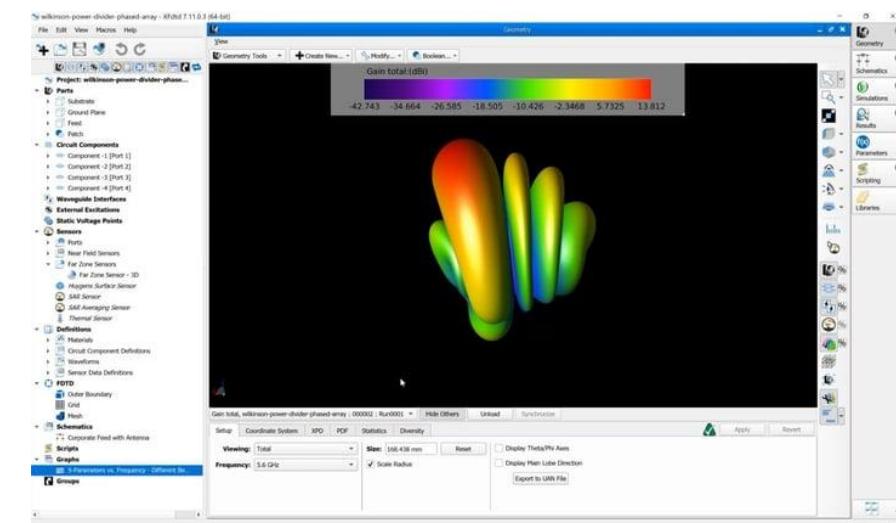
 **DASSAULT SYSTEMES**

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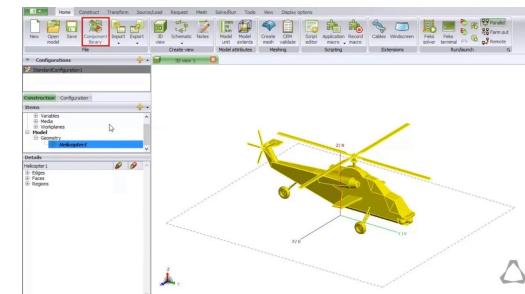
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- **Remcom XFDTD:** This software is based on the Finite-Difference Time-Domain (FDTD) method and is well-suited for analyzing designs ranging from simple dipoles to complex mobile devices with multiple antennas. It's known for its capabilities in 5G antenna arrays, IoT devices, and bio-EM effects.



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- Altair FEKO: FEKO is a comprehensive EM simulation software that utilizes a wide range of numerical methods, including Method of Moments (MoM), Finite Element Method (FEM), Finite Difference Time Domain (FDTD), and asymptotic methods like Physical Optics (PO) and Geometrical Theory of Diffraction (GTD). This makes it suitable for various antenna types and electrical sizes, from wire antennas to large reflector antennas.

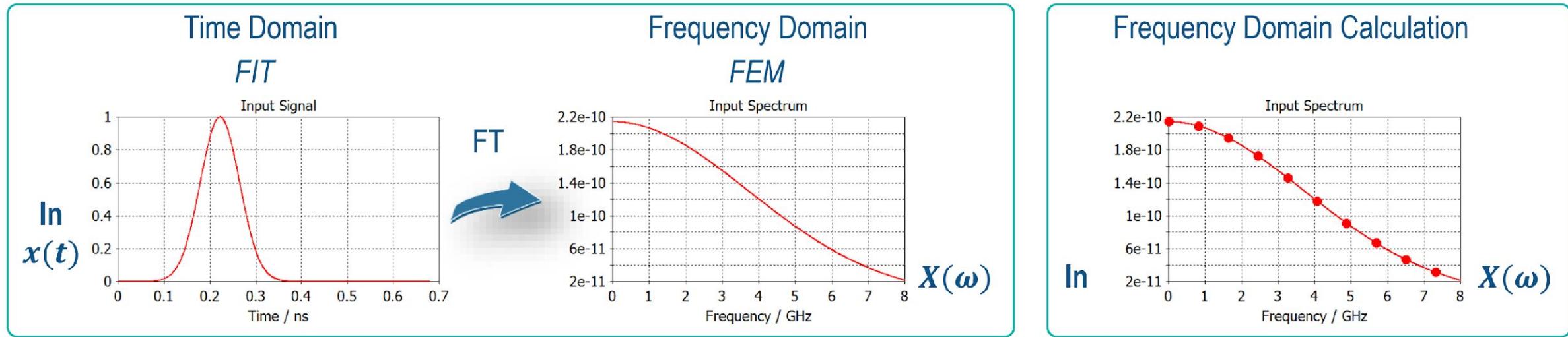


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- **COMSOL Multiphysics:** While not exclusively an antenna simulation tool, COMSOL provides a powerful platform for multiphysics simulations, including electromagnetics. Its FEM-based solver can be used for antenna design and analysis, often in conjunction with other physics (e.g., thermal, structural).

# Cross-Domain verification (*Solver Independence*)

How can you tell that your simulation is correct?



→ To insure that simulated results and settings of a selected solver are correct a cross domain verification between different solvers can be performed.

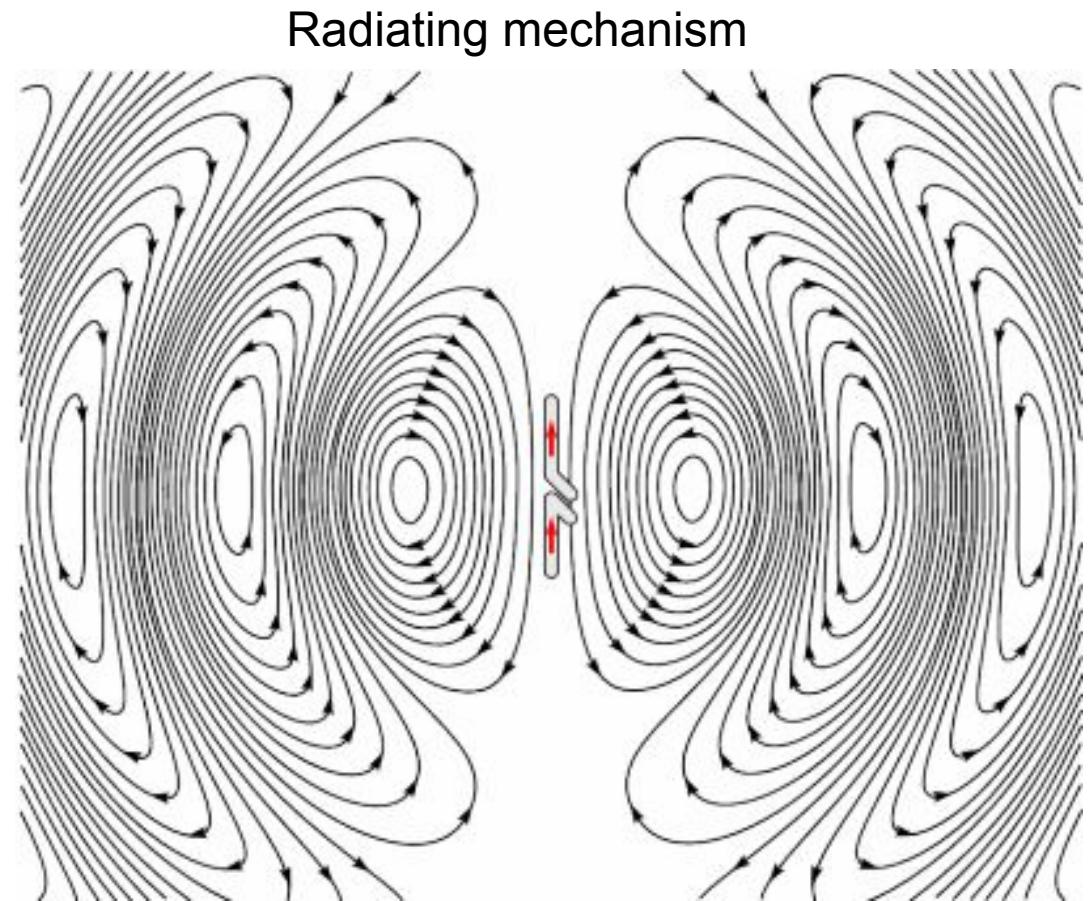
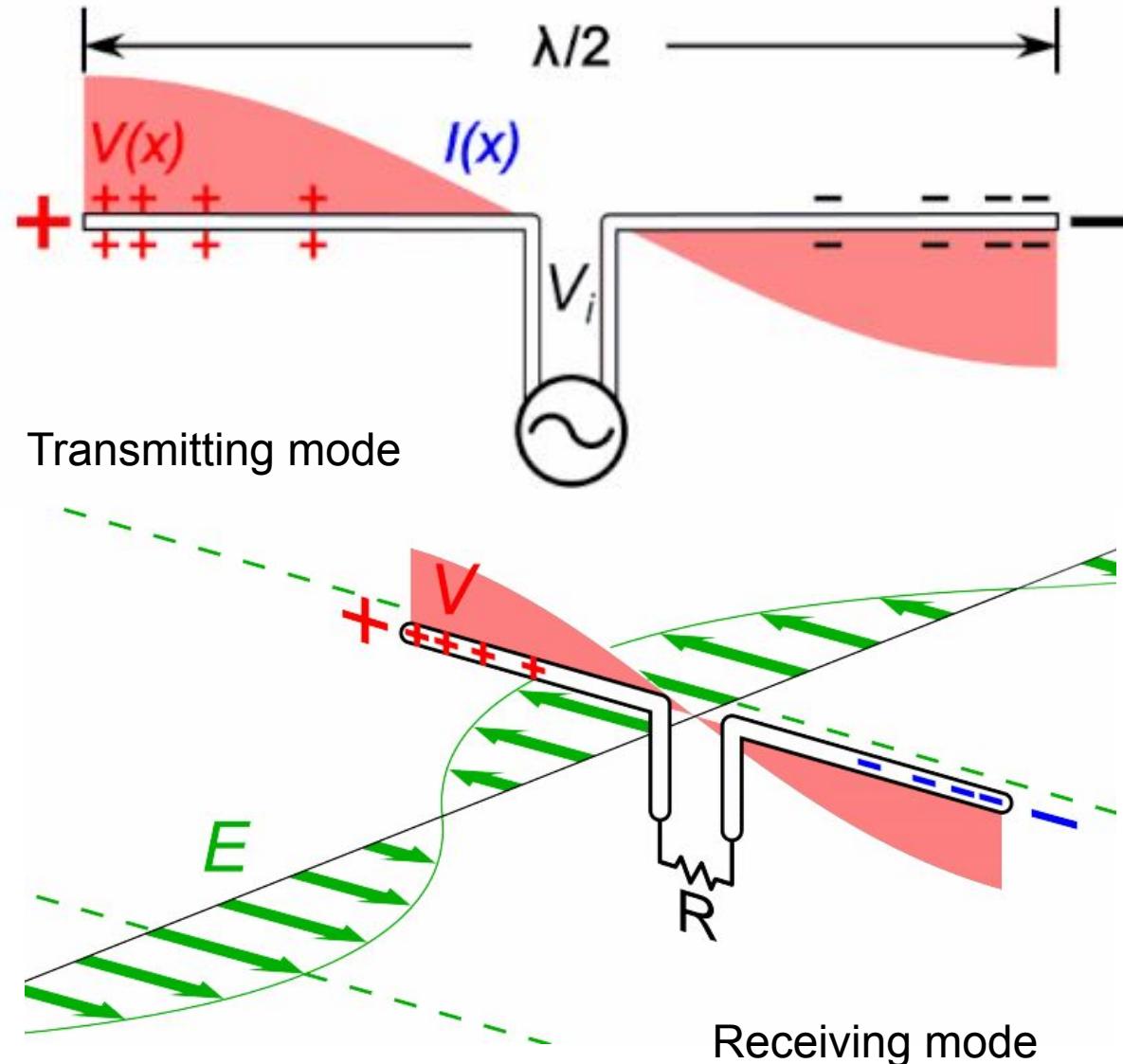


## **Free Version (Learning Edition):**

CST Studio Suite is a commercial software, but Dassault Systèmes (the company behind CST) offers a **CST Studio Suite Learning Edition** which is free for students, educators, and researchers for personal and educational use.

**Available at:** <https://www.3ds.com/edu/education/students/solutions/cst-le>

# The Dipole antenna



# Antenna design: Half-wave Dipole antenna

Geometry:

Half Wave  
Dipole Antenna

### Wavelength to Frequency

$v = \lambda f$

$v$  = wave speed ( $c$  for light in a vacuum)  
 $\lambda$  = wavelength  
 $f$  = frequency

sciencenotes.org

$$\begin{aligned} \text{Total length: } L &= \frac{\lambda}{2} \\ &= \frac{11.1}{2} = 5.55 \text{ (mm)} \end{aligned}$$

UnitConverters.net

[Home](#) / [Frequency Wavelength Conversion](#) / Convert Gigahertz to Wavelength In Millimetres

Convert Gigahertz to Wavelength In Millimetres

Please provide values below to convert gigahertz [GHz] to wavelength in millimetres [mm], or [vice versa](#).

From:	<input type="text" value="27"/>	gigahertz
To:	<input type="text" value="11.10342437"/>	wavelength in millimetres

**Result:** 27 gigahertz = 11.10342437 wavelength in millimetres

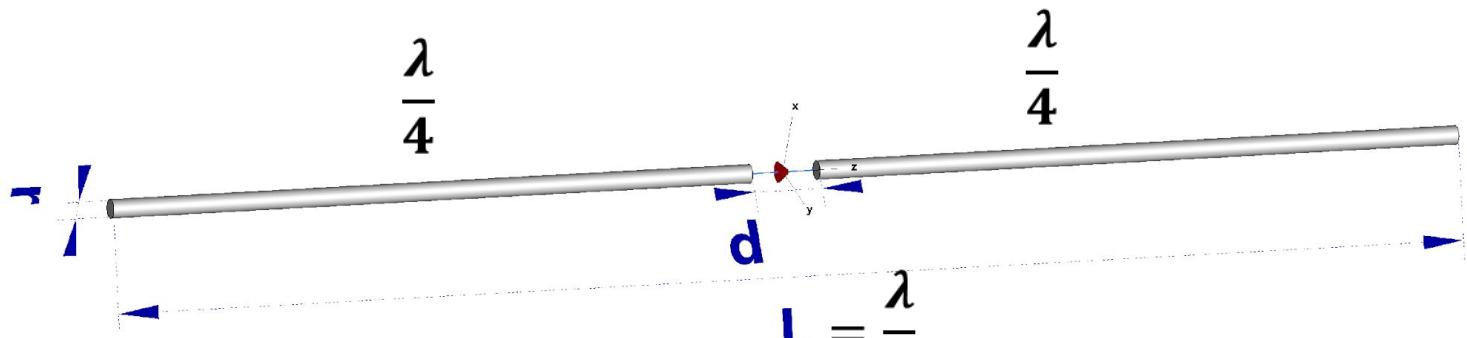
- Target frequency: **27 GHz**

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15

# Antenna design: Workflow

1. 3D modeling: Parametric design
2. Setup: Port, boundary, mesh...
3. Simulation: Solver
4. Post processing: Optimization...



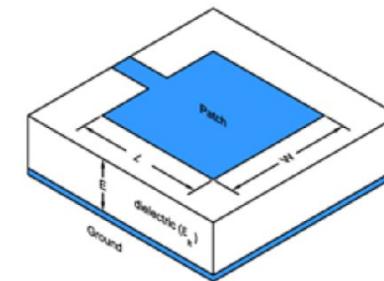
- Total length – **L**  
As calculated  $L = 5.55$  mm
- Wire Radius (or Diameter) – **r**  
 $r/\lambda < 0.01$  (electrically thin)  $\approx \lambda/300$
- Feed Gap between arms – **g**  
Typical feedpoint gap:  $\approx \lambda/50$  (0.1–2 mm)
- Input impedance target – **Z**  
 $Z$  for half-wave dipole is around 65–75  $\Omega$

# Antenna design: Patch antenna at 2.4 GHz

- Microstrip calculator:  
[https://www.pasternack.com/t-calculator-microstrip.aspx?srsltid=AfmBOopS\\_NagaPW5Qc-5jeR8eRh0JwCsbjzaZQtCnCQ3GA48YnhA7tPn](https://www.pasternack.com/t-calculator-microstrip.aspx?srsltid=AfmBOopS_NagaPW5Qc-5jeR8eRh0JwCsbjzaZQtCnCQ3GA48YnhA7tPn)
- Patch antenna calculator:  
<https://www.pasternack.com/t-calculator-microstrip-ant.aspx?srsltid=AfmBOorEfNmMO0lbxCrev5uHhvc4oFuOBcZJGx3aVUIJ-EhwnFoJaRzU>

$$\text{Width} = \frac{c}{2f_o \sqrt{\frac{\epsilon_{eff}}{2}}}; \quad \epsilon_{eff} = \frac{\epsilon_R + 1}{2} + \frac{\epsilon_R - 1}{2} \left[ \frac{1}{\sqrt{1 + 12(\frac{h}{W})}} \right]$$

$$\text{Length} = \frac{c}{2f_o \sqrt{\epsilon_{eff}}} - 0.824h \left( \frac{(\epsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\epsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} \right)$$

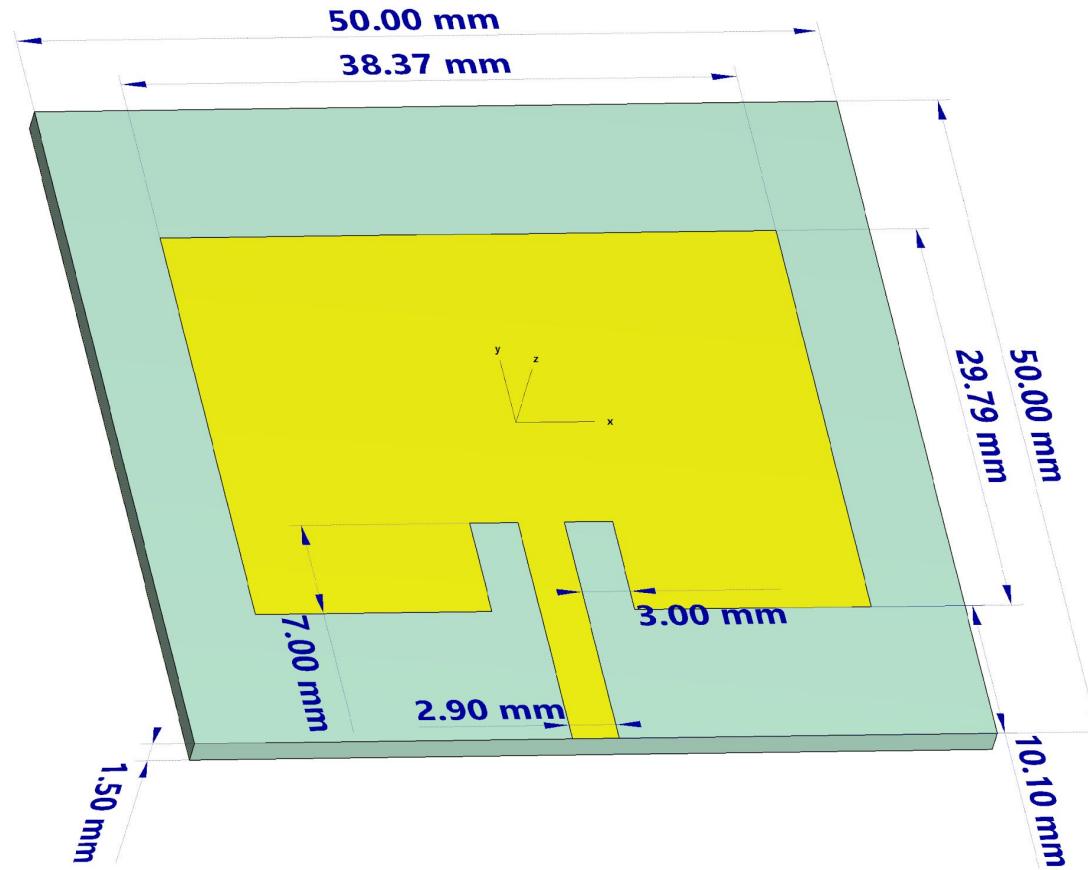


Microstrip Patch Antennas (or simply patch antenna) are increasingly useful because the antenna is printed directly onto a circuit board. Additional benefits of patch antennas is that they are easily fabricated making them cost effective. Their low profile design, often square or rectangular, allows them to be mounted to flat surfaces.

Pasternack carries a variety of panel and patch antennas which can be seen [here](#).

\*\*Note: All of our calculators allow SI prefix input. For example, if you wish to input "25000000", just type "25M" instead. See the quick-reference table below for all compatible SI prefixes.

# Antenna design: Patch antenna at 2.4 GHz



- Substrate: FR-4 (loss free),  $\epsilon_r = 4.3$
- Substrate thickness: 1.5 mm
- Microstrip impedance:  $50 \Omega$

