1. Ansys Electronics Desktop (AEDT)

1.1 Overview

Ansys Electronics Desktop (AEDT) is a simulation platform designed for comprehensive electromagnetic and multiphysics analysis. It integrates solvers for high-frequency, low-frequency, electrothermal, and parasitic simulations into a single unified environment. This integration removes the need for switching between multiple software applications and ensures consistency in workflows.

AEDT includes tools such as:

- **HFSS** – High Frequency Structure Simulator for antennas and microwave structures.
- **Maxwell** – Magnetostatics and electromechanical analysis.
- **Icepak** – Thermal and cooling simulations for electronic systems.
- **Q3D Extractor** – Parasitic extraction in interconnects, IC packages, and PCB traces.

1.2 Workflow in AEDT

The general workflow in AEDT involves:

1. Creating the project and defining geometry.
2. Assigning materials from electromagnetic libraries.
3. Applying excitations, sources, and boundary conditions.
4. Generating mesh for finite element analysis.
5. Running solvers to obtain field solutions.
6. Visualizing results including field plots, radiation patterns, temperature profiles, and parasitic matrices.

1.3 Governing Principles

All AEDT tools are based on **Maxwell's equations** which govern electromagnetic behavior:

- div(D) = ρ (electric flux related to charge)
- div(B) = 0 (no magnetic monopoles exist)
- curl(E) = - ∂B/∂t (time-varying magnetic fields induce electric fields) curl(H) = J + ∂D/∂t (currents and time-varying electric fields produce magnetic fields)

These equations are solved numerically using the **Finite Element Method (FEM)** or other methods depending on the solver.

2. Ansys HFSS (High Frequency Structure Simulator)

2.1 Overview

HFSS is used for simulating electromagnetic behavior at microwave and radio frequencies. It is the industry standard for antenna, radar, satellite, and high-speed communication system design.

2.2 Antenna Analysis

HFSS was used to design and analyze antennas such as the half-wave dipole. The resonant length of a dipole is given by:

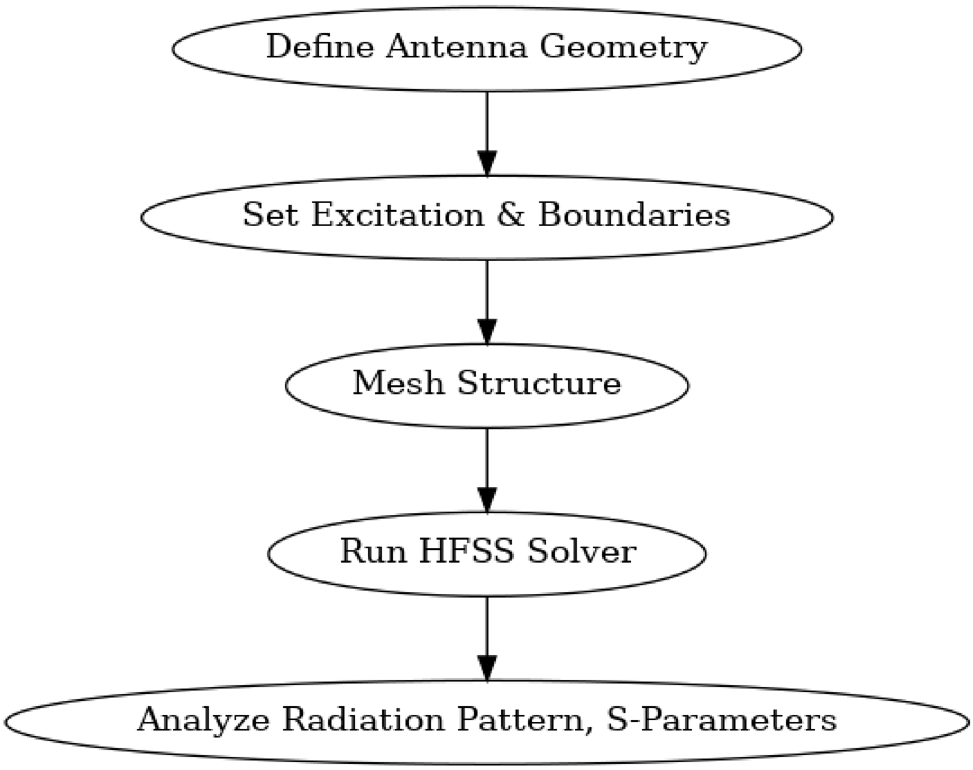
- $L = \lambda / 2 = c / (2 \times f \times \sqrt{\varepsilon_{eff}})$

where L is dipole length, f is frequency, c is speed of light, and ε_{eff} is the effective dielectric constant.

Radiation patterns, return loss, and impedance bandwidth were studied. The reflection coefficient was calculated as:

- $\Gamma = (Z_{in} - Z_0) / (Z_{in} + Z_0)$

where Z_{in} is input impedance and Z_0 is characteristic impedance (commonly 50 Ω).



2.3 Antenna Arrays

HFSS simulated dipole arrays to study directivity and beamforming. The radiation of arrays is defined by the **Array Factor**:

- $AF(\theta) = \Sigma (In \times \exp(j \times (kd\cos\theta + \phi n)))$

where In is current amplitude, d is element spacing, and ϕn is phase shift.

2.4 Waveguides and Filters

The training also included waveguides and filters. HFSS calculated S-parameters such as S11 (reflection) and S21 (transmission). For a two-port device:

- S11 = b1 / a1
- S21 = b2 / a1

where a = incident wave, b = reflected wave.

2.5 Applications of HFSS

- 5G and IoT antennas.
- Radar and defense systems.
- Satellite communication

Applications of HFSS :

Application Area Example

Wireless Systems- 5G antennas, Wi-Fi devices

Defense- Radar arrays

Space- Satellite communication dishes

Electronics- Filters, couplers, and resonators

Application Area Example

3. Ansys Maxwell

3.1 Overview

Maxwell is used for low-frequency and magnetostatic problems, such as designing motors, transformers, and inductors. It solves field problems using finite element methods.

3.2 Magnetostatics

The governing law for magnetostatics is **Ampere's Law**:

- curl(H) = J

where H is magnetic field intensity and J is current density.

Material interactions such as ferromagnetism, paramagnetism, and diamagnetism were studied.

3.3 Electromechanical Devices

Maxwell is widely applied in designing motors and actuators. The torque generated in an electromagnetic system is derived from co-energy:

- Torque (T) = $\partial W_m / \partial \theta$

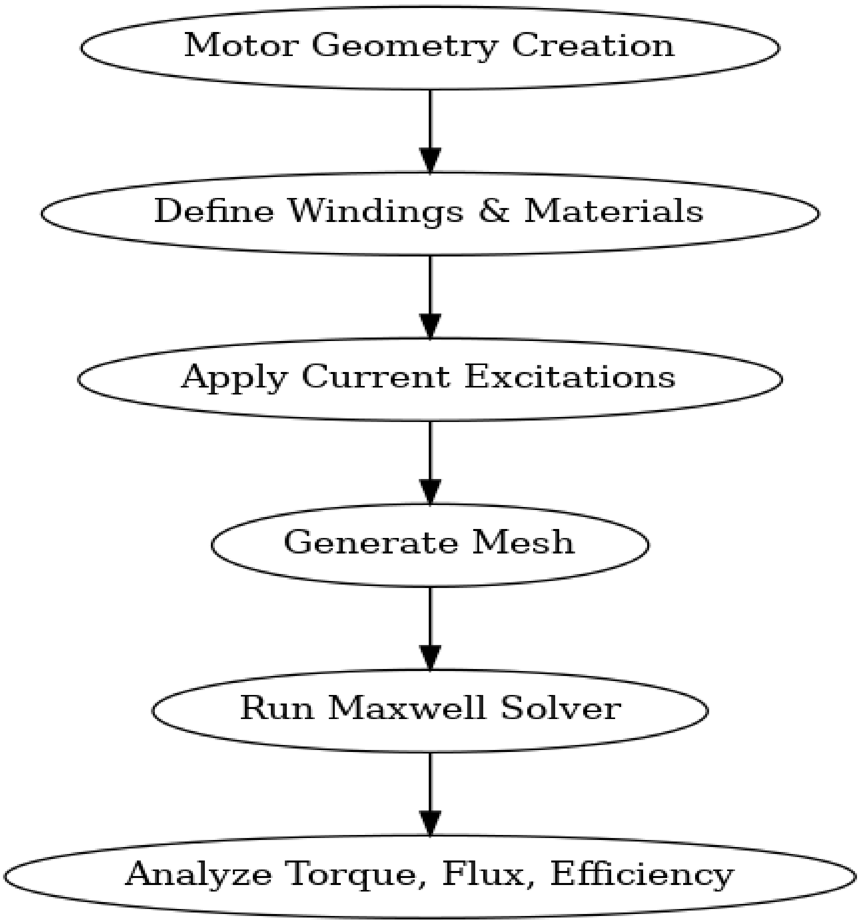
where Wm is magnetic co-energy and θ is angular displacement.

3.4 Coupled Analysis with Icepak

Electromagnetic losses produce heat in devices. Maxwell couples with Icepak to simulate this using the Joule heating equation:

- $Q = I^2 \times R$

where Q is heat generated, I is current, and R is resistance.



3.5 Applications of Maxwell

- Electric vehicle traction motors.
- Transformers in power systems.
- Electromagnetic actuators and relays.
- Magnetic sensors.

Table 2: Comparison of HFSS and Maxwell

Feature	**HFSS**	**Maxwell**
Frequency Range	High-frequency (RF/microwave)	Low-frequency (static, quasi-static)
Focus	Antennas, RF circuits	Motors, inductors, transformers
Method	Full-wave FEM	Magnetostatics, electrostatics FEM
Applications	Communication systems	Power electronics, EVs

4. Ansys Icepak

4.1 Overview

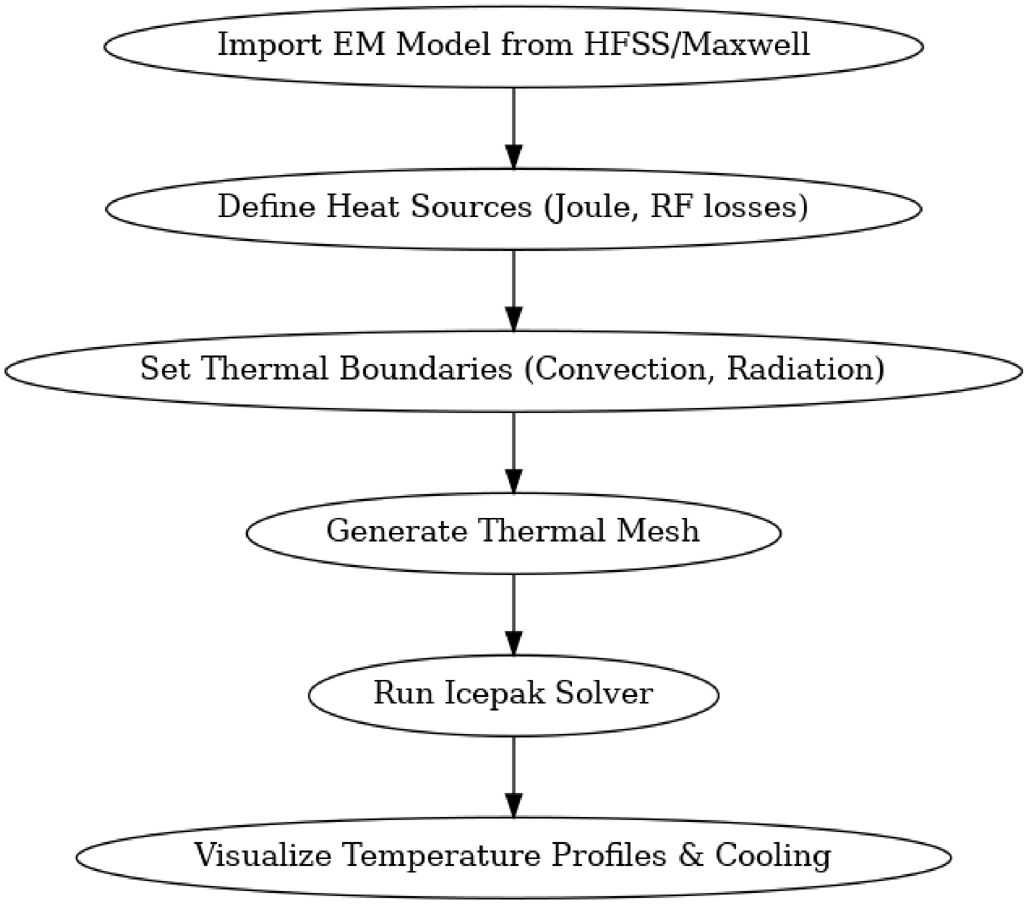
Icepak specializes in **thermal and cooling analysis**. It applies Computational Fluid Dynamics (CFD) methods within AEDT to simulate heat flow and dissipation in electronics.

4.2 Governing Heat Transfer Principles

- Fourier's Law: $q = -k \times \nabla T$ (heat conduction)
- Newton's Law of Cooling: $Q = h \times A \times (T_s - T_\infty)$ (heat convection)

4.3 Integration with Other Solvers

Icepak integrates with HFSS and Maxwell for **electrothermal analysis**. This allows designs such as antennas or motors to be validated for both electromagnetic performance and cooling requirements.



4.4 Applications of Icepak

- Cooling of motors and transformers.
- PCB thermal reliability studies.
- Cooling of high-frequency RF amplifiers.

Table 3: Applications of Icepak

Application	Example
Motors	EV traction motor cooling
PCBs	High-speed board thermal analysis
RF Devices	Cooling of amplifiers
Power Modules	IGBT and MOSFET thermal design

5. Ansys Q3D Extractor

5.1 Overview

Q3D Extractor analyzes parasitic effects in interconnects such as PCB traces, connectors, and IC packaging.

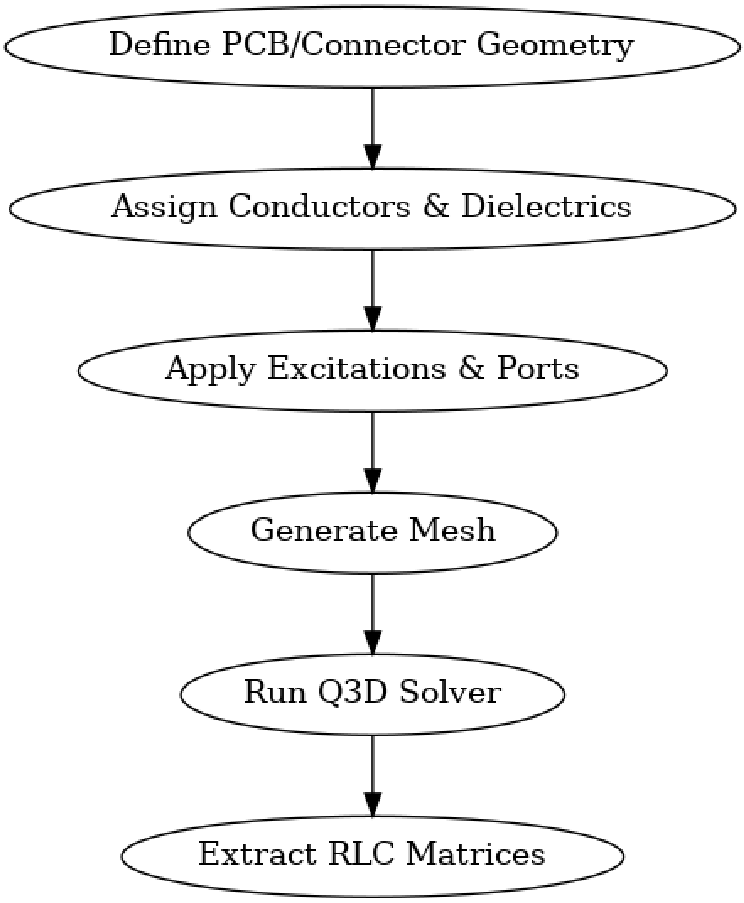
5.2 RLC Parasitic Extraction

It computes distributed resistance (R), inductance (L), and capacitance (C). Signal delay in interconnects is given by:

- $\tau = \sqrt{(L \times C)}$

where L and C are inductance and capacitance per unit length.

One of the key strengths of Q3D Extractor is its ability to compute full RLC matrices. These matrices represent the distributed electrical properties of conductors and dielectrics within a system. For example, the series resistance of traces contributes to power losses, the capacitance between adjacent traces results in coupling and potential crosstalk, and inductance affects signal delay and resonance. These parameters are extracted using field solvers based on finite element methods, providing high accuracy across a wide frequency range.



5.3 Applications of Q3D

- Signal integrity in high-speed boards.
- Power integrity in IC packaging.
- Crosstalk analysis in multilayer PCBs.
- Connector optimization.

Applications of Q3D

PCB High - speed DDR memory lines
IC Packaging- Flip-chip parasitic analysis
Connectors -USB and HDMI design
Power Systems -Delivery network optimization

6. Supporting Electromagnetic Theory Modules

6.1 Vector Algebra

Revisited vector operations including dot product, cross product, divergence, and curl.

6.2 Transmission Line Theory

Telegrapher's equations describe voltage and current in transmission lines:

- $dV/dx = -(R + j\omega L) \times I$
- $dI/dx = -(G + j\omega C) \times I$

6.3 Wave Propagation

Electromagnetic waves satisfy the wave equation:

- $\nabla^2 E - \mu\varepsilon \partial^2 E/\partial t^2 = 0$

6.4 S-Parameters

Return loss is defined as:

- $RL = -20 \log |\Gamma|$

where Γ is reflection coefficient.

6.5 Applications of Theory Modules

- Antenna design validation.
- Transmission line matching.
- RF circuit design.
- EM propagation studies.