

Introduction to Microwave Antennas

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Overview

- Frequency Spectrum
- Antenna Definition
- Antenna Fundamentals
- Academic Resources
- Antenna Types
- Small vs. Giant Antennas
- Future Trend

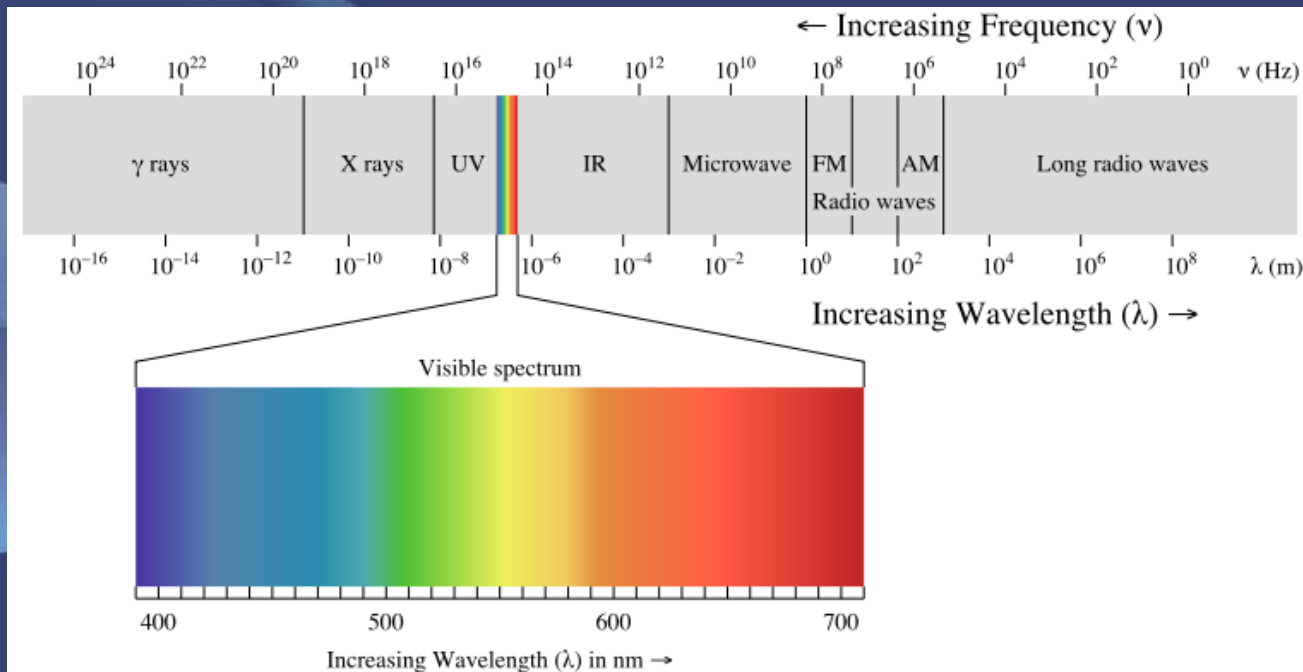
Electromagnetic Spectrum

EM Waves

- Frequency (f)
- Wavelength (λ)
- Photon Energy (E)

$$f = \frac{c}{\lambda} = \frac{E}{h}$$

c : speed of light in free space
 h : Planck's constant



Radio Waves Band

μWave & RF

- Frequency Management
- Frequency Assignment Authority



中华人民共和国工业和信息化部
Ministry of Industry and Information Technology of the People's Republic of China
无线电管理局



Post-og teletilsynet
Norwegian Post and Telecommunications Authority

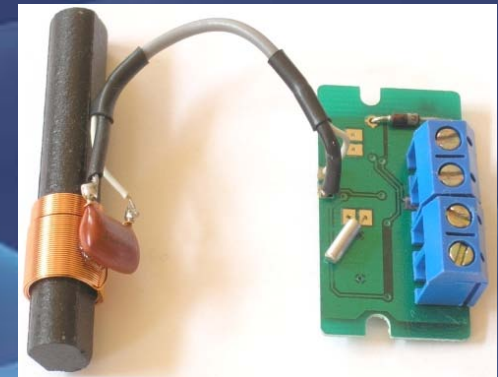
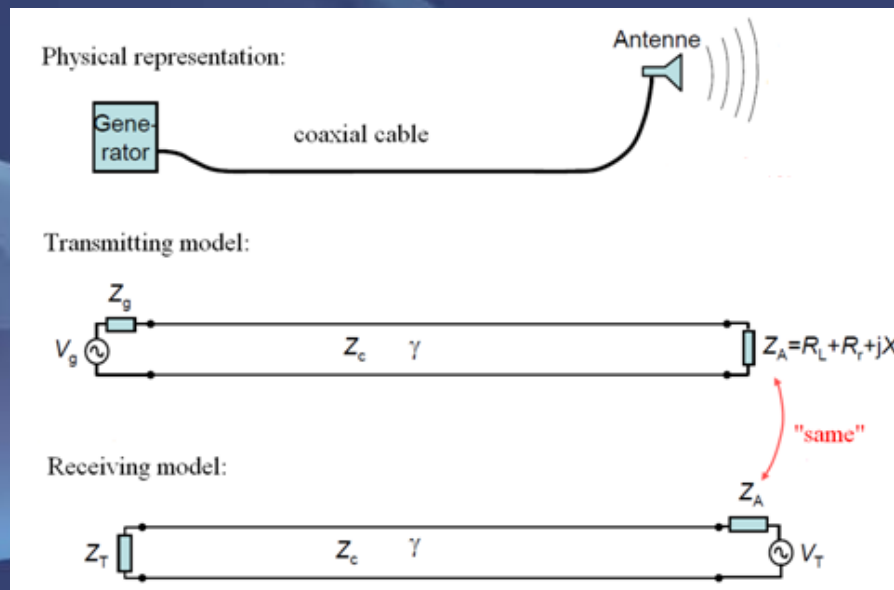


| | |
|---------------------|-----------------|
| HF band | 3 to 30 MHz |
| VHF band | 30 to 300 MHz |
| UHF band | 300 to 1000 MHz |
| L band | 1 to 2 GHz |
| S band | 2 to 4 GHz |
| C band | 4 to 8 GHz |
| X band | 8 to 12 GHz |
| K _u band | 12 to 18 GHz |
| K band | 18 to 27 GHz |
| K _a band | 27 to 40 GHz |
| V band | 40 to 75 GHz |
| W band | 75 to 110 GHz |
| mm band | 110 to 300 GHz |

| Band name | Abbr | ITU band | Frequency and Wavelength in air |
|--------------------------|-------|----------|-----------------------------------|
| subHertz | subHz | 0 | < 3 Hz > 100,000 km |
| Extremely low frequency | ELF | 1 | 3–30 Hz 100,000 km – 10,000 km |
| Super low frequency | SLF | 2 | 30–300 Hz 10,000 km – 1000 km |
| Ultra low frequency | ULF | 3 | 300–3000 Hz 1000 km – 100 km |
| Very low frequency | VLF | 4 | 3–30 kHz 100 km – 10 km |
| Low frequency | LF | 5 | 30–300 kHz 10 km – 1 km |
| Medium frequency | MF | 6 | 300–3000 kHz 1 km – 100 m |
| High frequency | HF | 7 | 3–30 MHz 100 m – 10 m |
| Very high frequency | VHF | 8 | 30–300 MHz 10 m – 1 m |
| Ultra high frequency | UHF | 9 | 300–3000 MHz 1 m – 100 mm |
| Super high frequency | SHF | 10 | 3–30 GHz 100 mm – 10 mm |
| Extremely high frequency | EHF | 11 | 30–300 GHz 10 mm – 1 mm |
| Terahertz | THz | | 300–30,000 GHz 1 mm – 90 μm |

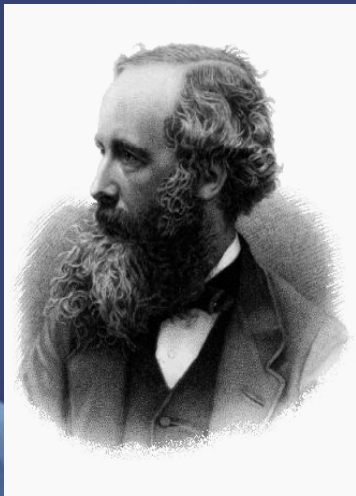
Definition of Antenna

- Analogy in Zoology
- IEEE definition
 - “A means for radiating or receiving radio waves.”
- A simple circuit model



Pioneers of Antenna

James Clerk Maxwell
(1831-1879)



1865/1873:

Maxwell Equations

... and that light is an electromagnetic disturbance propagated through the field according to electromagnetic laws ...

---"A Dynamical Theory of the Electromagnetic Field"

Heinrich Hertz
(1857-1894)



1886-1888:

Systematic experimentation with electromagnetic waves; dipoles, ring, parabolic reflector; spark-discharge, spark gap

Guglielmo Marconi
(1874-1937)



1895: Demonstration of a wireless signal (1 mile in Italy)

1897: New demo (4 miles in England)

1901: Trans-Atlantic signal

1909: Nobel Prize in Physics

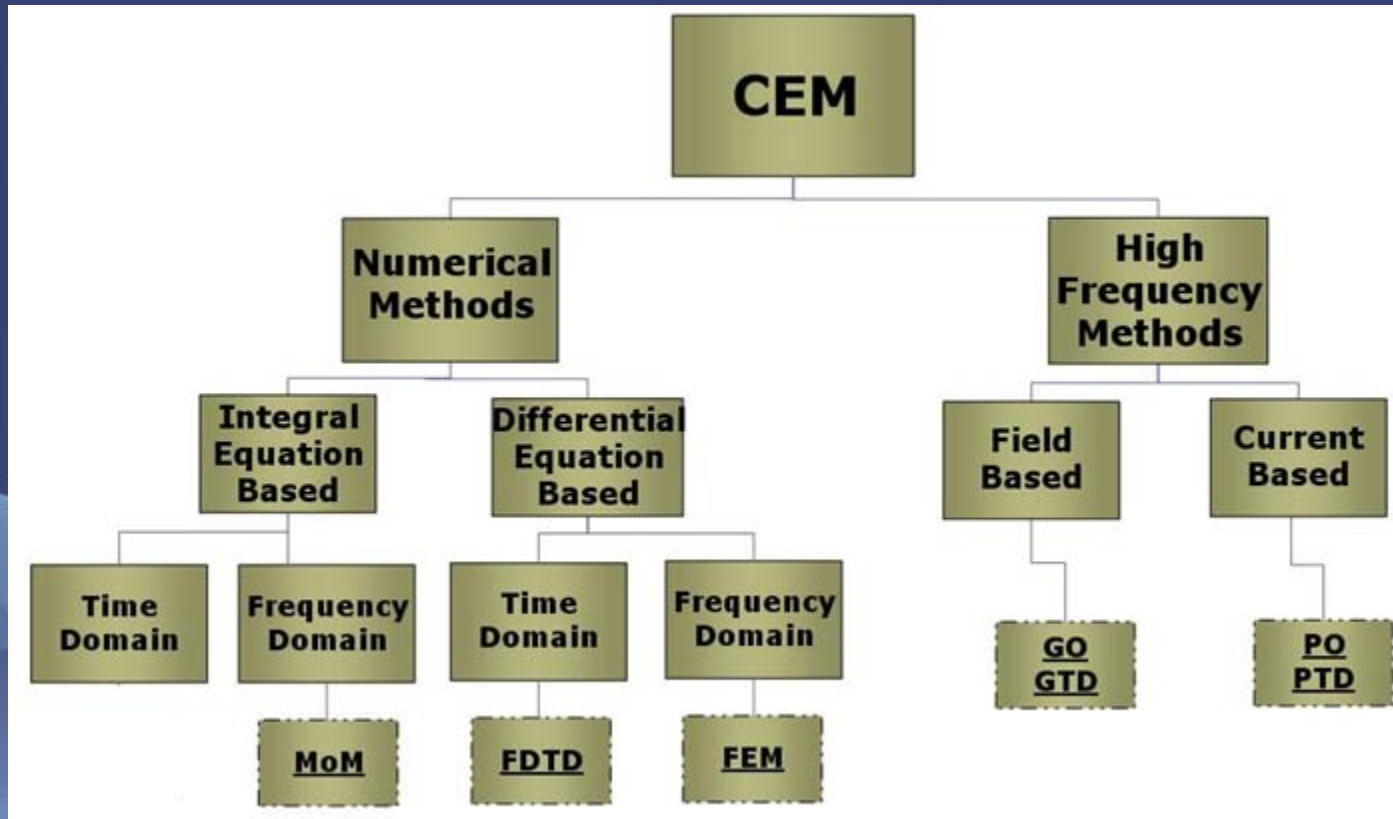
Theoretical Foundation

Maxwell Equations

- Current Continuity Law
- Wave Equation

| Formulation in terms of <i>total</i> charge and current | | |
|---|---|---|
| Name | Differential form | Integral form |
| Gauss's law: | $\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$ | $\oiint_{\partial V} \mathbf{E} \cdot d\mathbf{A} = \frac{Q(V)}{\epsilon_0}$ |
| Gauss's law for magnetism: | $\nabla \cdot \mathbf{B} = 0$ | $\oiint_{\partial V} \mathbf{B} \cdot d\mathbf{A} = 0$ |
| Maxwell-Faraday equation (Faraday's law of induction): | $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$ | $\oint_{\partial S} \mathbf{E} \cdot d\mathbf{l} = -\frac{\partial \Phi_{B,S}}{\partial t}$ |
| Ampère's circuital law (with Maxwell's correction): | $\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$ | $\oint_{\partial S} \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_S + \mu_0 \epsilon_0 \frac{\partial \Phi_{E,S}}{\partial t}$ |

Computational ElectroMagnetics



Glossary of A&P Terms

- Antenna Impedance
- Standing-Wave Ratio
- Field Zones
- Radiation Pattern
- Directivity / Gain
- Efficiency
- Polarization
- Operational Bandwidth
- Physical / Effective Aperture
-
- Friis Transmission / Radar Range Equation
- Radar Cross Section
-

Literatures of Antenna

1. W.L.Stutzman, G.A.Thiele "Antenna Theory and Design" (John Wiley & Sons, 1981)
2. R.S.Elliott, "Antenna Theory and Design" (Prince Hall, 1981)
3. C.A.Balanis "Antenna Theory: Analysis and Design" (John Wiley & Sons, 1982)
4. J.D.Kraus, R.J.Marhefka "Antennas: for all applications" (McGraw-Hill)
5. R.E.Collin "Antennas and Radiowave Propagation" (McGraw-Hill, 1984)
6. K.F.Lee "Principles of Antenna Theory" (John Wiley & Sons, 1984)
7. 陆钟祚, "实用无线电天线" (中国科学技术仪器公司, 1951)
8. 谢处方, "电波与天线" (人民邮电出版社, 1958)
9. 任朗, "天线理论基础" (人民邮电出版社, 1980)
10. 谢处方, 丘文杰, "天线原理与设计" (西北电讯工程学院出版社, 1985)

Conferences/Journals of A&P

1. *IEEE* International *AP-S* Symposium
2. European Conference on Antennas and Propagation (*EuCAP*)
3. International Symposium on Antennas and Propagation (*ISAP*)
4. *IASTED* Conference on Antennas, Radar and Wave Propagation
5. Nordic Antenna Symposium

6. *IEEE* Transactions on Antennas and Propagation
7. *IEEE* Antenna and Propagation Magazine
8. *IEEE* Antenna and Wireless Propagation Letters
9. *IET* Microwaves, Antennas & Propagation

Types of Antenna

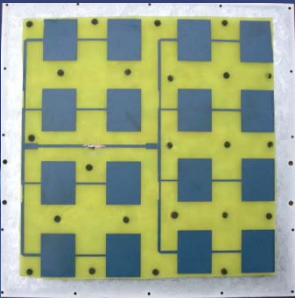
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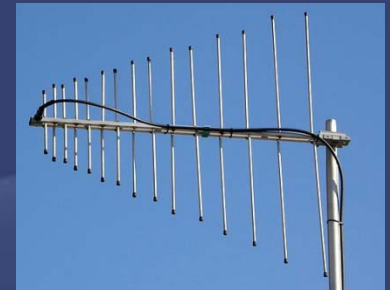
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4



5



6



1. Wire antennas
2. Aperture antennas
3. Microstrip antennas
4. Array antennas
5. Reflector antennas
6. Lens antennas

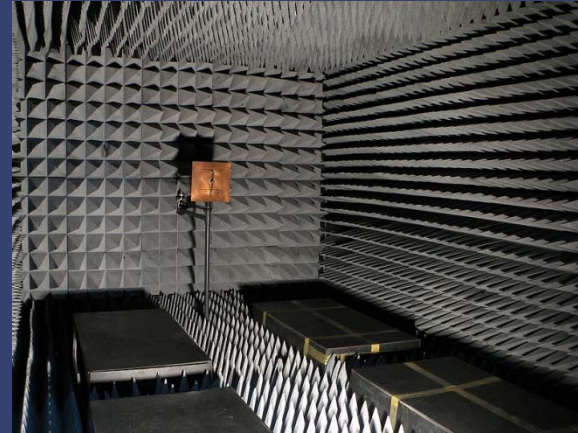
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Antenna Measurement

Anechoic Chamber

- Absorber
- Shield
- Size



Network Analyzer

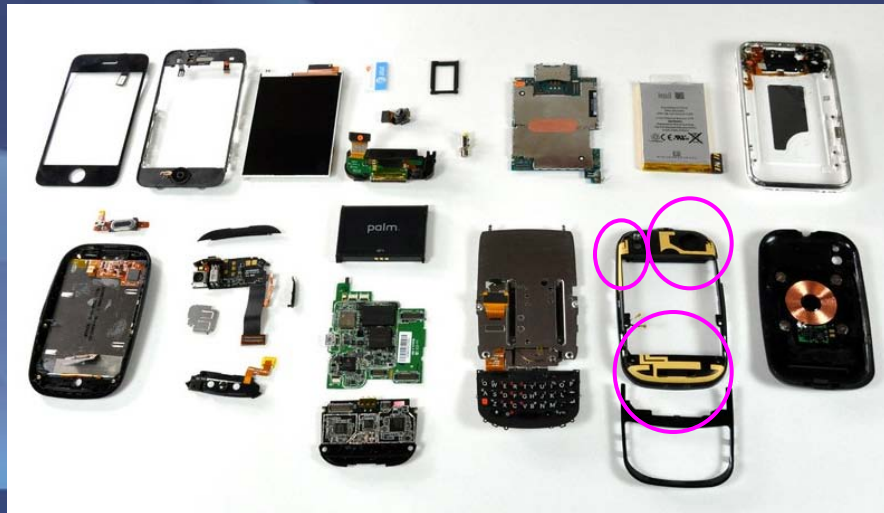
- HP/Agilent (USA)
- Rohde & Schwarz (GER)
- Anritsu (JAP)



Small Antennas

Wireless Terminals

- Ericsson T28 (1999)
- Palm Pre (Jun. 2009)



Preliminary 'Virtual Teardown' for Palm Pre Major Cost Drivers
Major Cost Drivers (US Dollars)

| Subsystem Description | Cost | Percent of Total |
|-------------------------------------|-----------------|------------------|
| Baseband | \$15.41 | 9.1% |
| RF/PA | \$4.54 | 2.7% |
| Standalone Applications Processor | \$10.97 | 6.5% |
| Bluetooth | \$1.83 | 1.1% |
| WiFi | \$4.80 | 2.8% |
| GPS | \$1.09 | 0.6% |
| Sensors | \$1.69 | 1.0% |
| Misc (Including Speakers, USB, MP3) | \$2.24 | 1.3% |
| Primary Memory | \$15.96 | 9.4% |
| Secondary Memory | \$3.85 | 2.3% |
| Display | \$39.51 | 23.2% |
| Camera | \$12.39 | 7.3% |
| Form Factor | \$19.38 | 11.4% |
| Battery | \$4.16 | 2.4% |
| Software / Licensing | \$22.61 | 13.3% |
| Conversion Costs | \$9.58 | 5.6% |
| Grand Total | \$170.02 | 100.0% |

Radio Telescopes (Giant Antennas)

1. Shanghai Astronomical Observatory (25m)
2. [GMRT](#) (45m), India
3. Parkes Observatory (64m), Australia
4. Green Bank Telescope (100m), USA
5. [Arecibo](#) (305m), Puerto Rico
6. EISCAT (Tromsø, Svalbard, Kiruna(Swe))

1



2



3



4



5



6



Glimpse of Future

- Radio Telescope Array
 - [ALMA](#), SKA, EVLA
- Active Antennas
 - Subsystem (amplifiers)
- Smart Antennas
 - MIMO array
- Meta-materials for A&P Applications
 - Cloaking
- Measurement Advances
 - Reverberation vs. Anechoic Chamber
- CEM

References

- W.L.Stutzman, G.A.Thiele "Antenna Theory and Design"
- C.A.Balanis "Antenna Theory: Analysis and Design"
- J.D.Kraus, R.J.Marhefka "Antennas: for all applications"
- <http://wikipedia.org/>
- <http://forum.eet-cn.com/>

Thanks for your attention!

Q & A