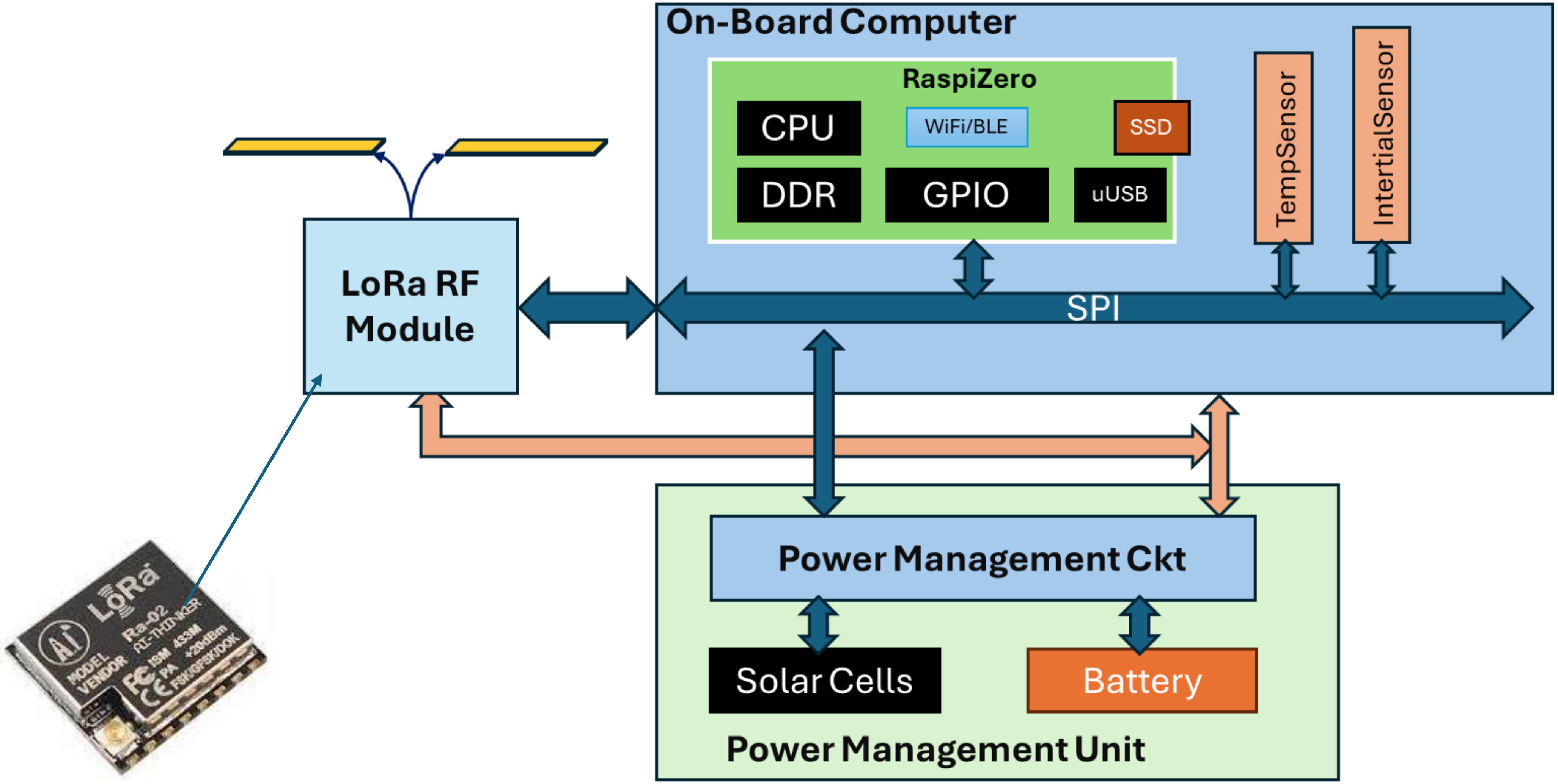
SI-2024: Introduction to CubeSat and Satellite Communication

Introduction to Antennas

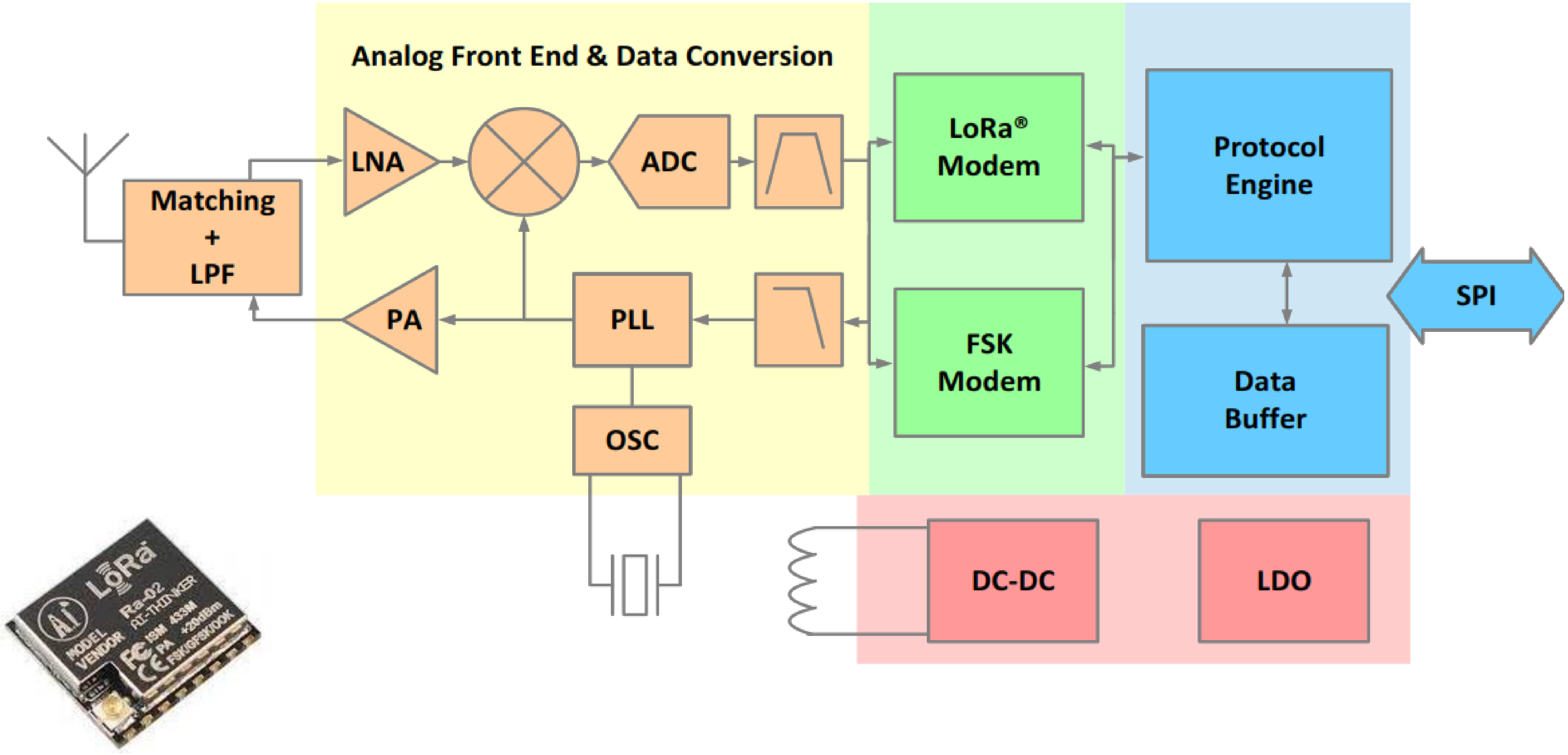
3rd July
2024

SiliconTech

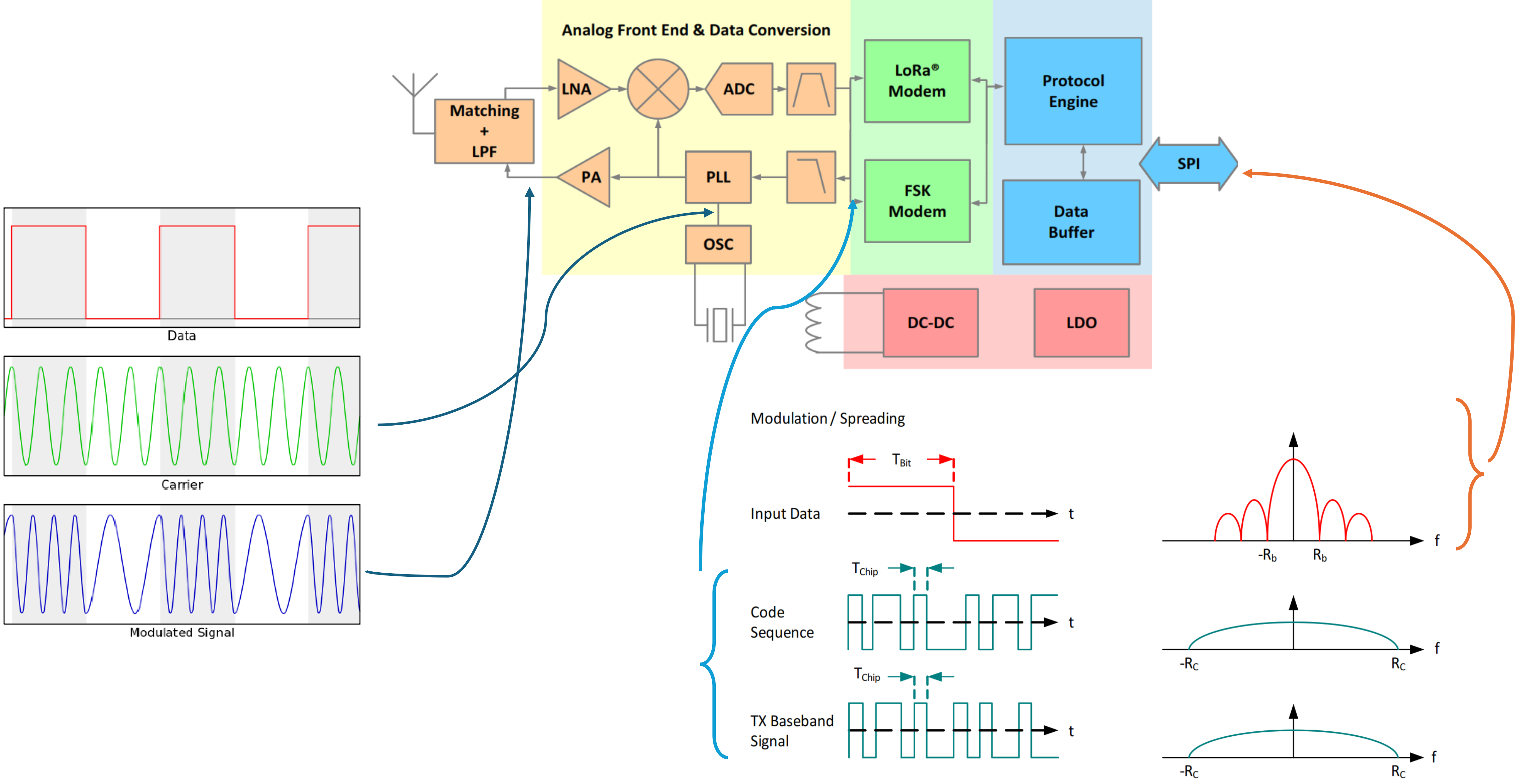
CubeSat Minimal Architecture



LoRa Transceiver (Radio) Architecture



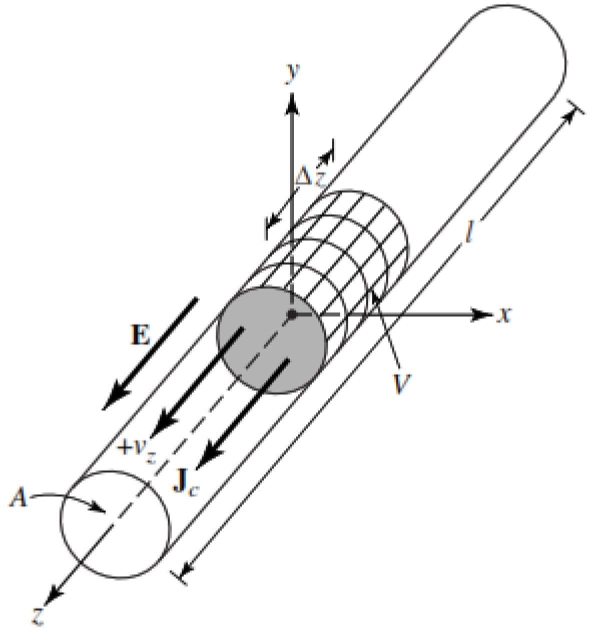
LoRa Transceiver (Radio) Architecture



Mechanism for Radiation

❖ The primary mechanism of radiation is due to ***accelerating (or deceleration) of*** charge

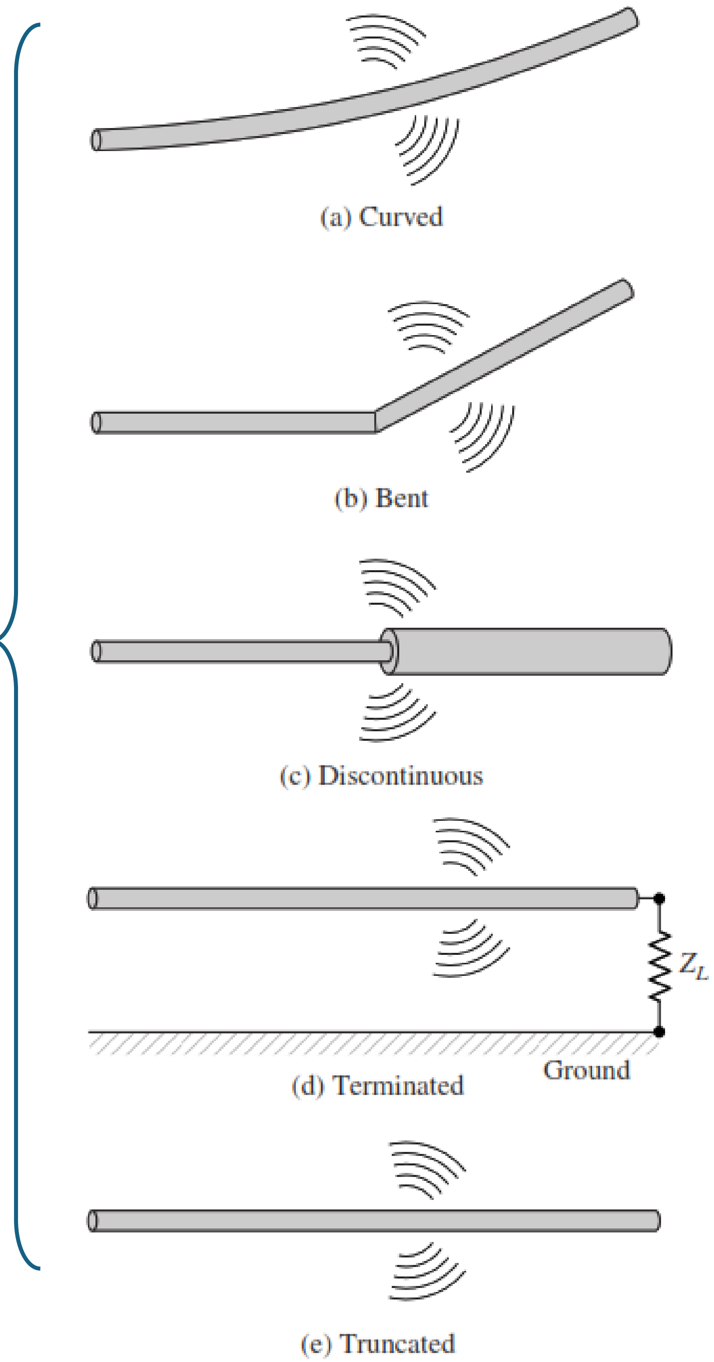
- Current in a conductor:
  - $J_z = q_v v_z$
- Current in an ideal conductor:
  - $J_s = q_s v_z$
- Current in an thin conductor:
  - $I_z = q_l v_z$
- For a time-varying current:
  - $\frac{dI_z}{dt} = q_l \frac{dv_z}{dt} = q_l a_z$



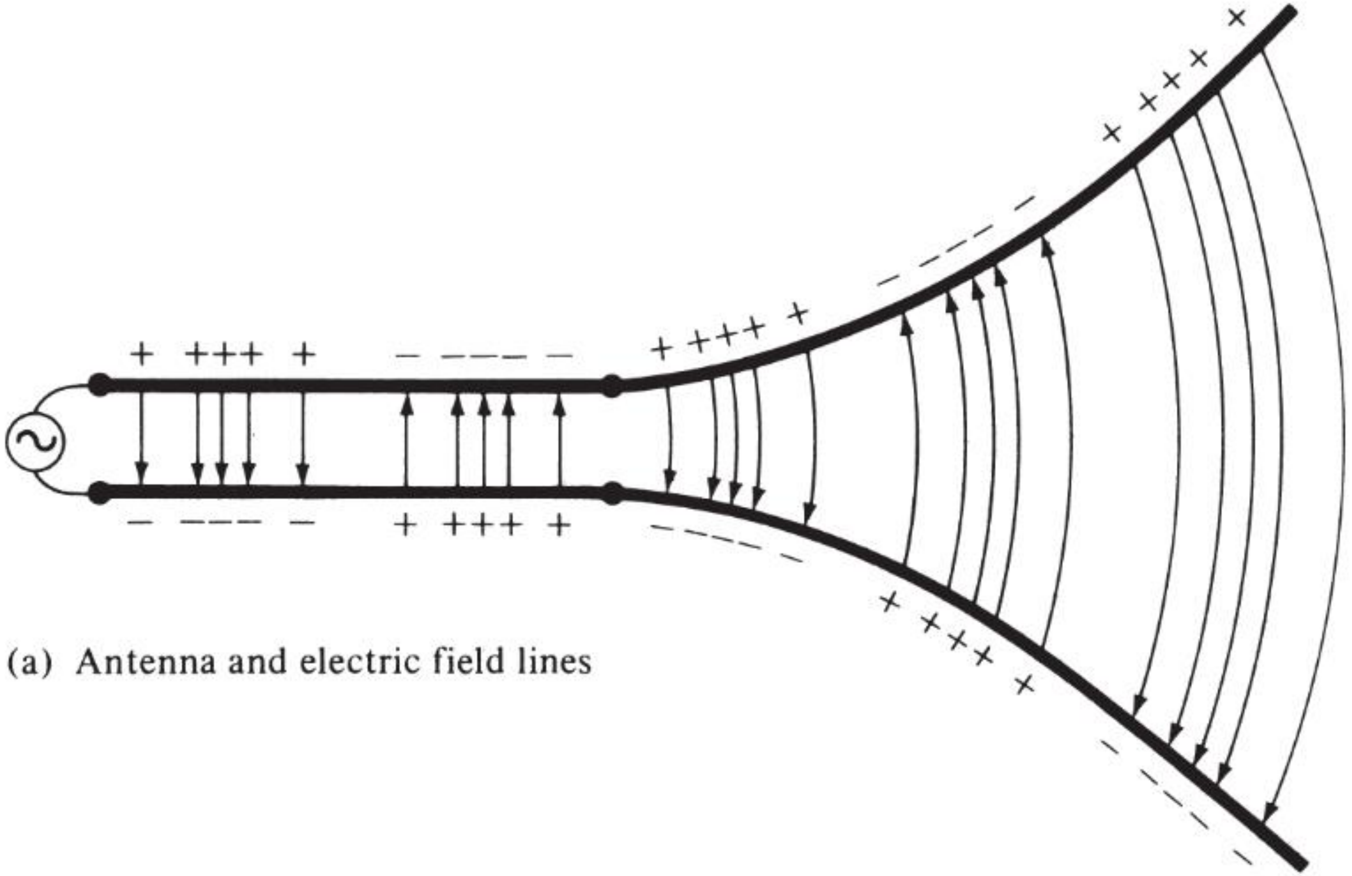
❖ To create radiation, there must be ***time-varying current OR accelerating (or deceleration) of*** charge

Mechanism for Radiation (Derived Facts)

- ☑ If a charge is not moving, current is not created and there is no radiation.
- ☑ If charge is moving with a uniform velocity:
  - ☑ There is no radiation if the wire is straight, and infinite in extent.
  - ☑ There is radiation if the wire is curved, bent, discontinuous, terminated, or truncated.
- ☑ If charge is oscillating in a time-motion, it radiates even if the wire is straight.

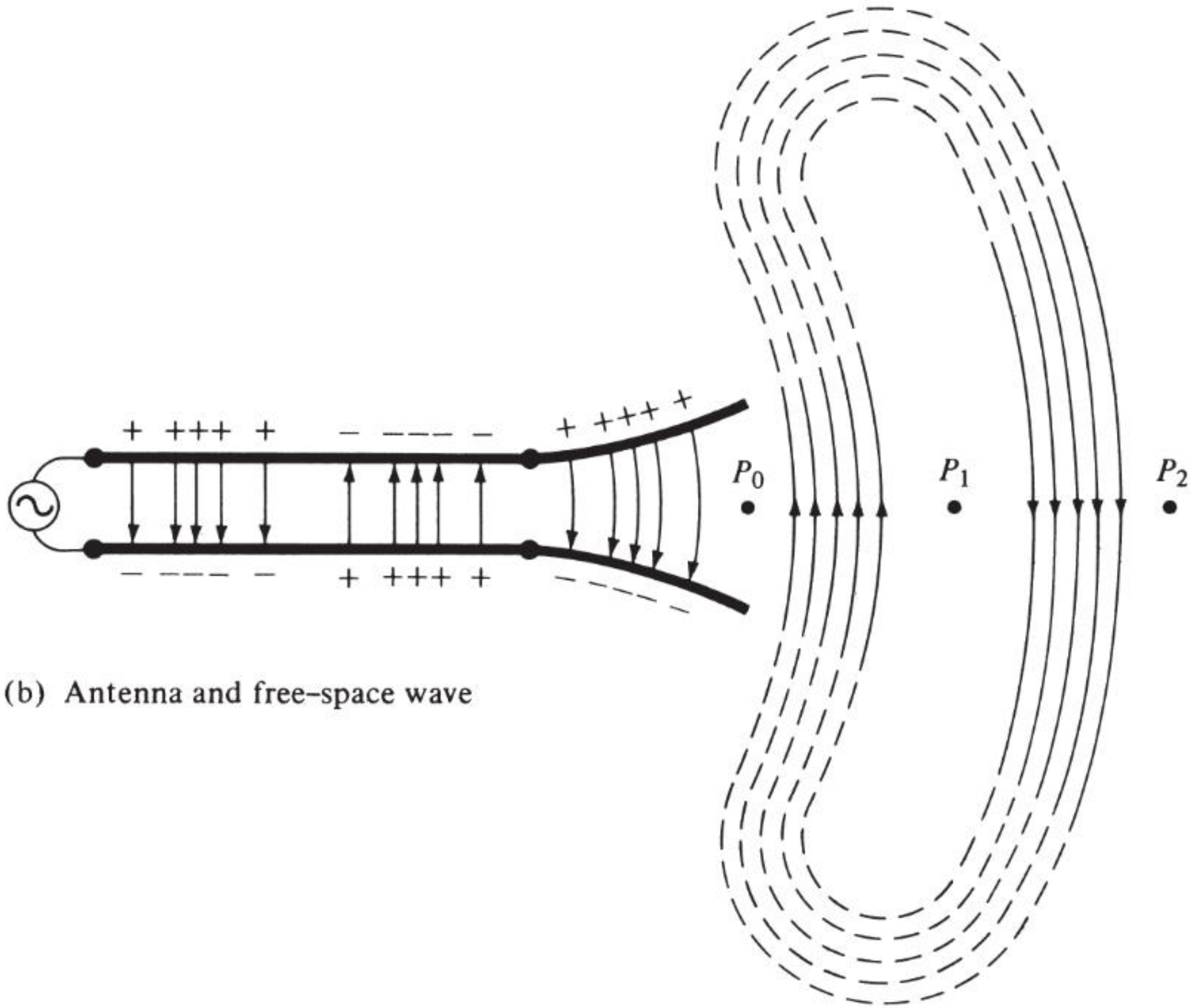


Two-Wire Antenna and Electric-Field Lines



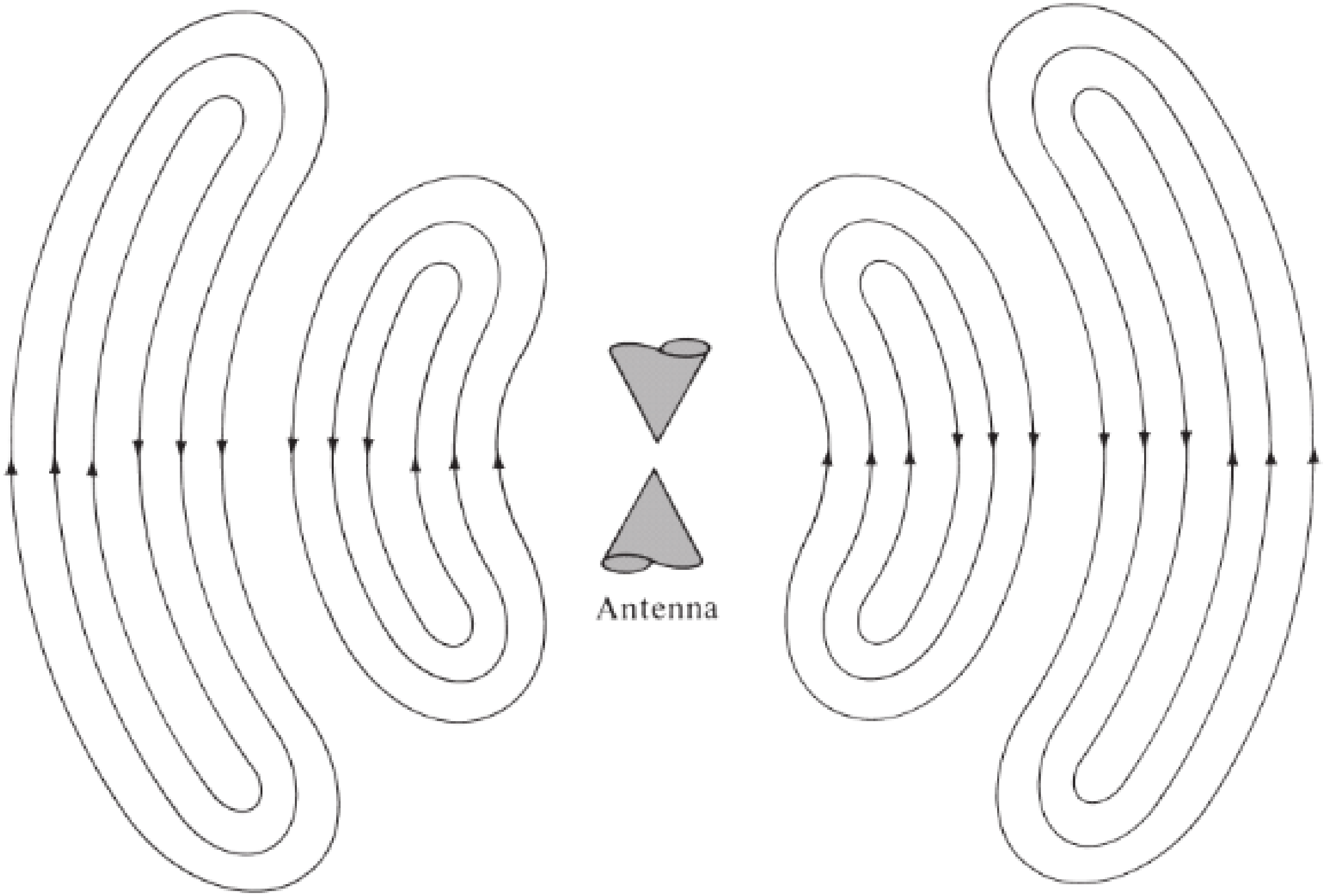
(a) Antenna and electric field lines

Two-Wire Antenna and Free-Space Wave

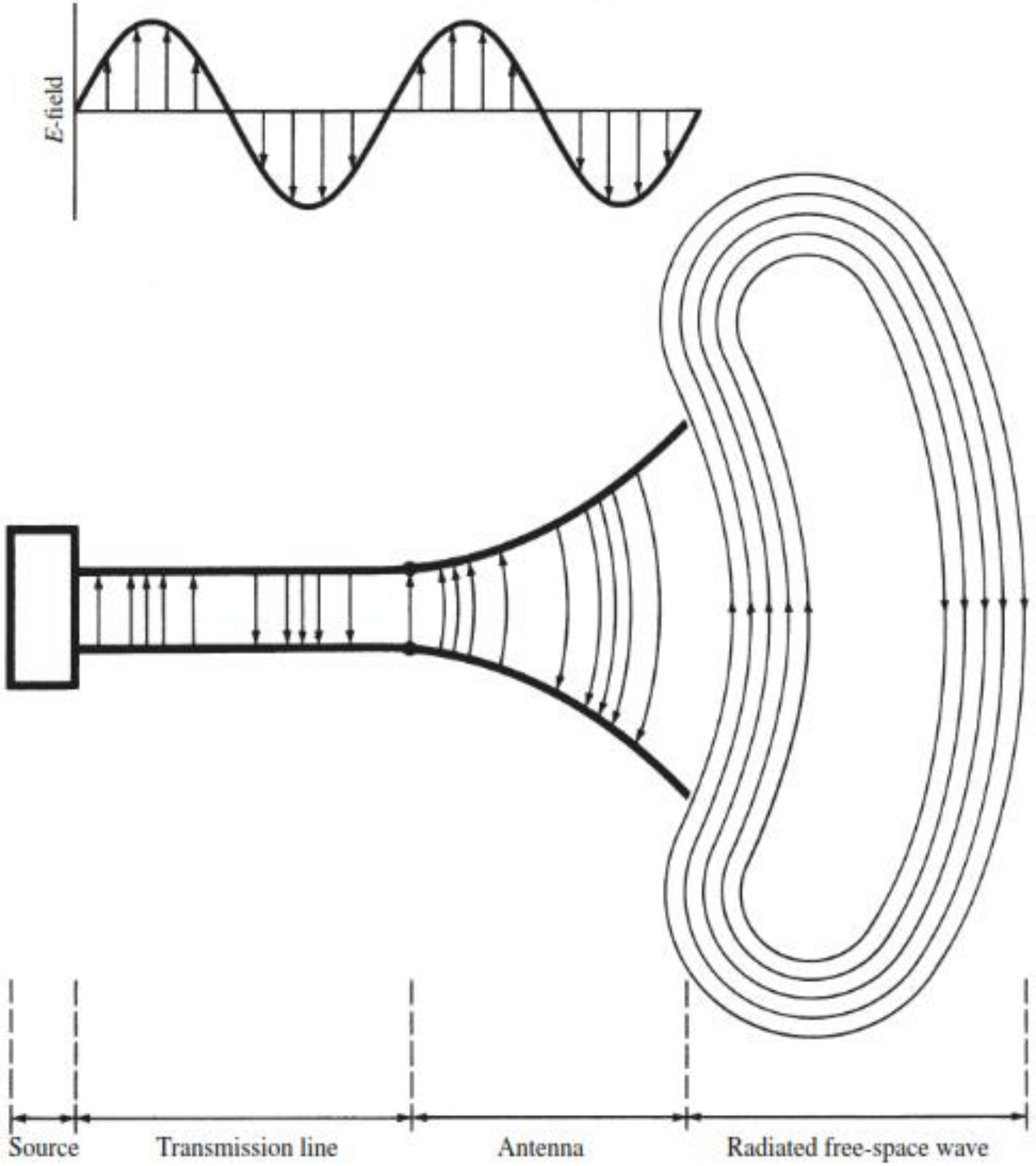


(b) Antenna and free–space wave

Detached Wave Visualization



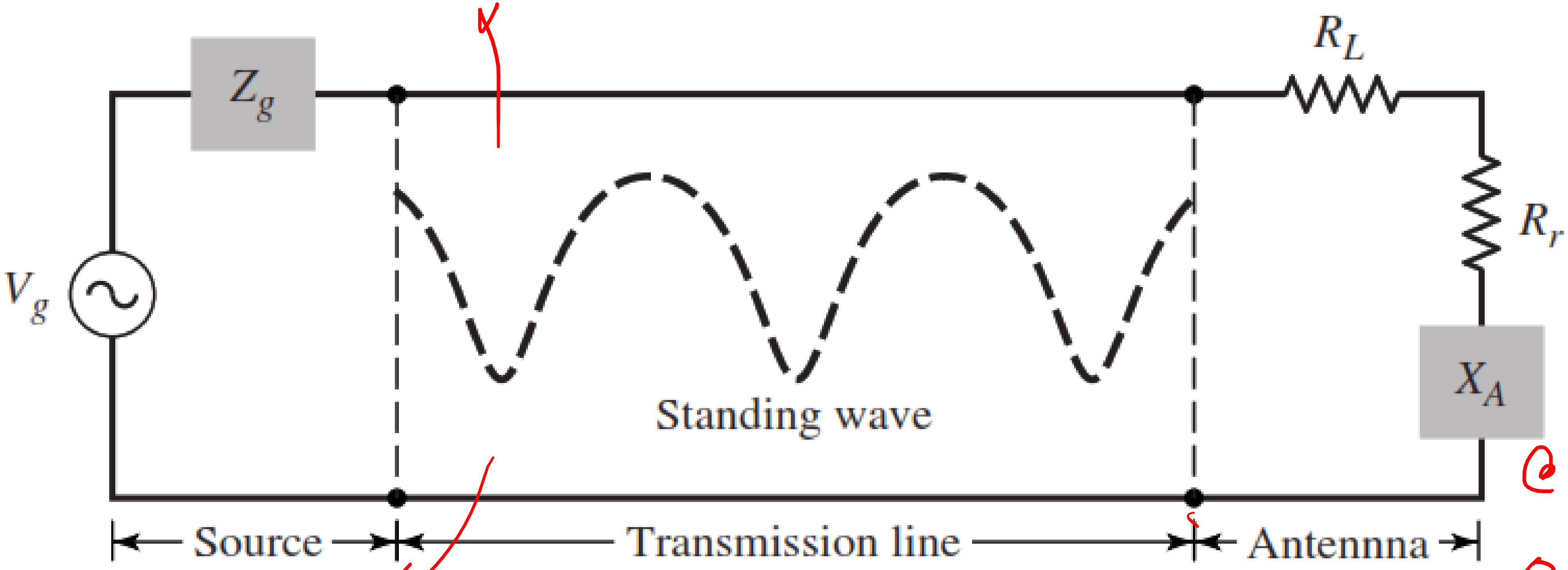
Two-Wire Antenna and Free-Space Wave



Thevenin Equivalent of Source-TransmissionLine-Antenna

$j\omega L = 2\pi\, 433\text{e}6 \times L = 3.64$

$L = \dfrac{3.64}{2.4\text{e}9} = \sim 1.3\,\text{nH}$



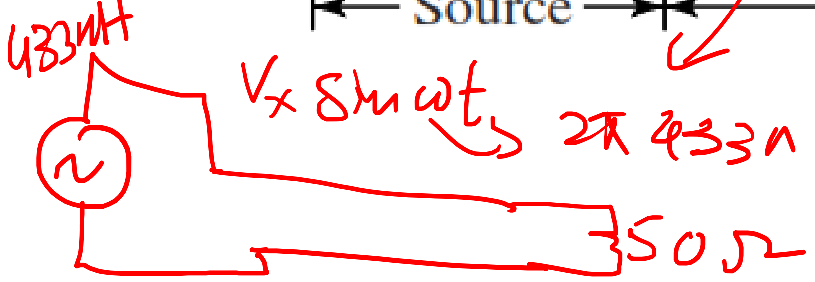
R_r 74Ω

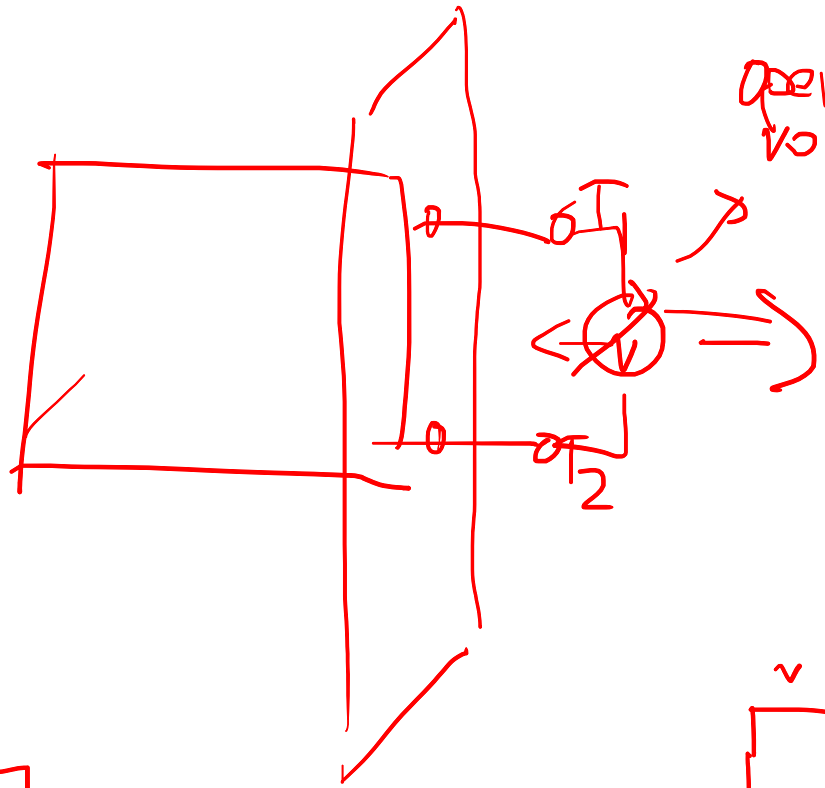
$j3.64$

@435 MHz

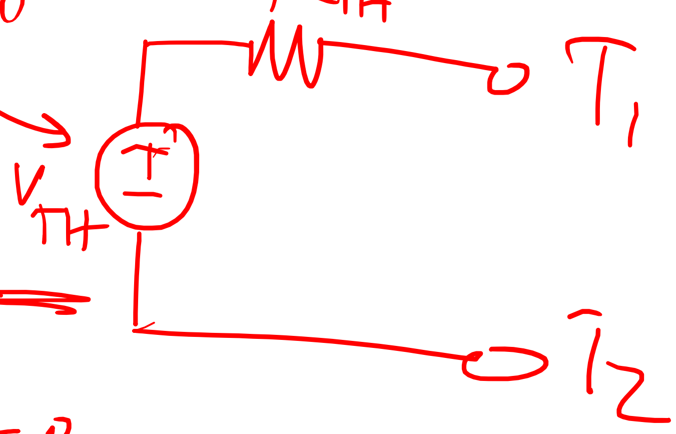
0.57 H

$$Z_A = (R_L + R_r) + jX_A$$





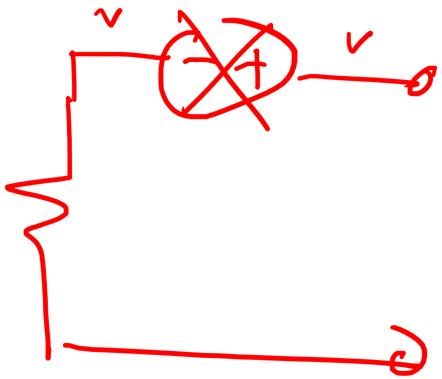
open-ckt voltage

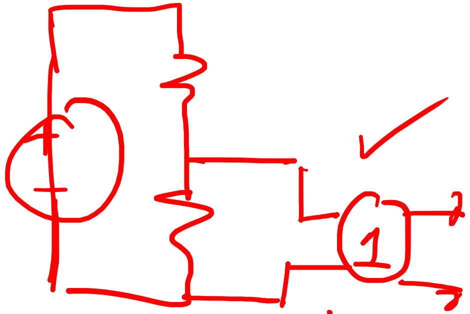


Make all independent src = 0

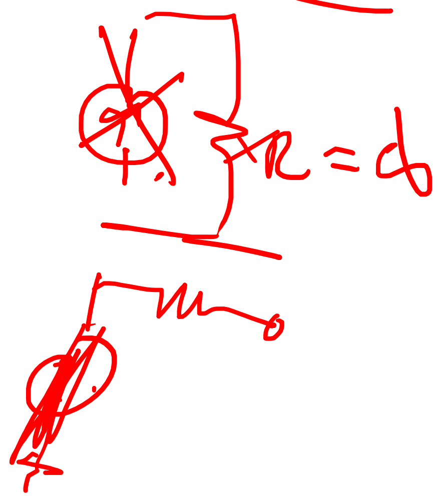
V → short
I → open

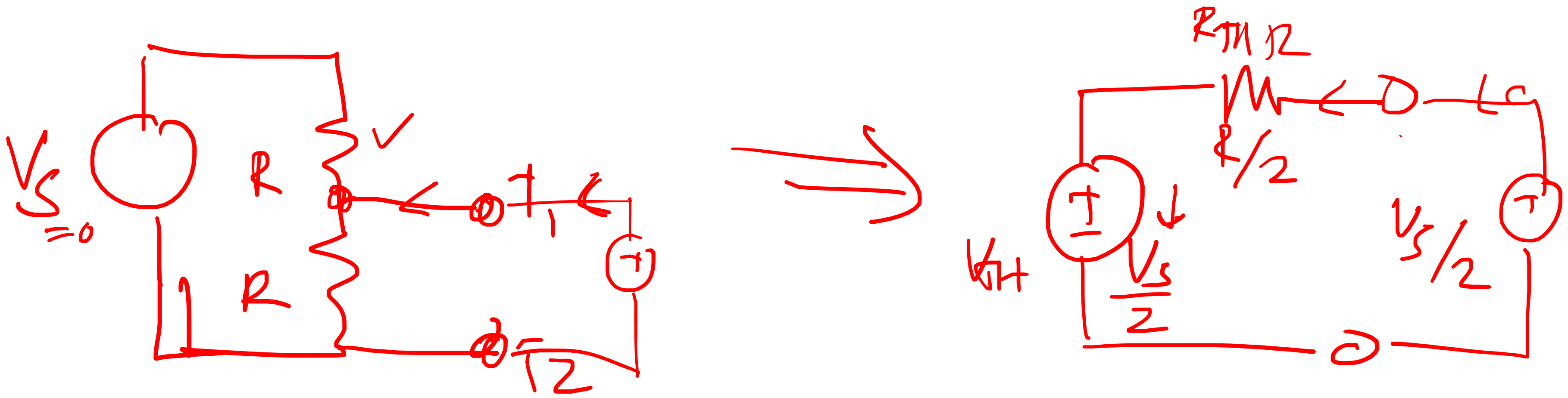
V=0



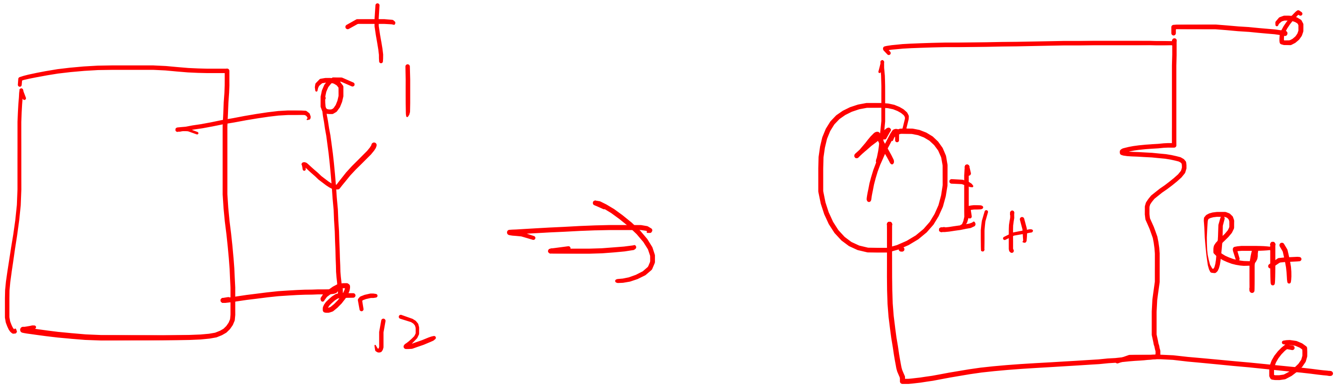


VCVS

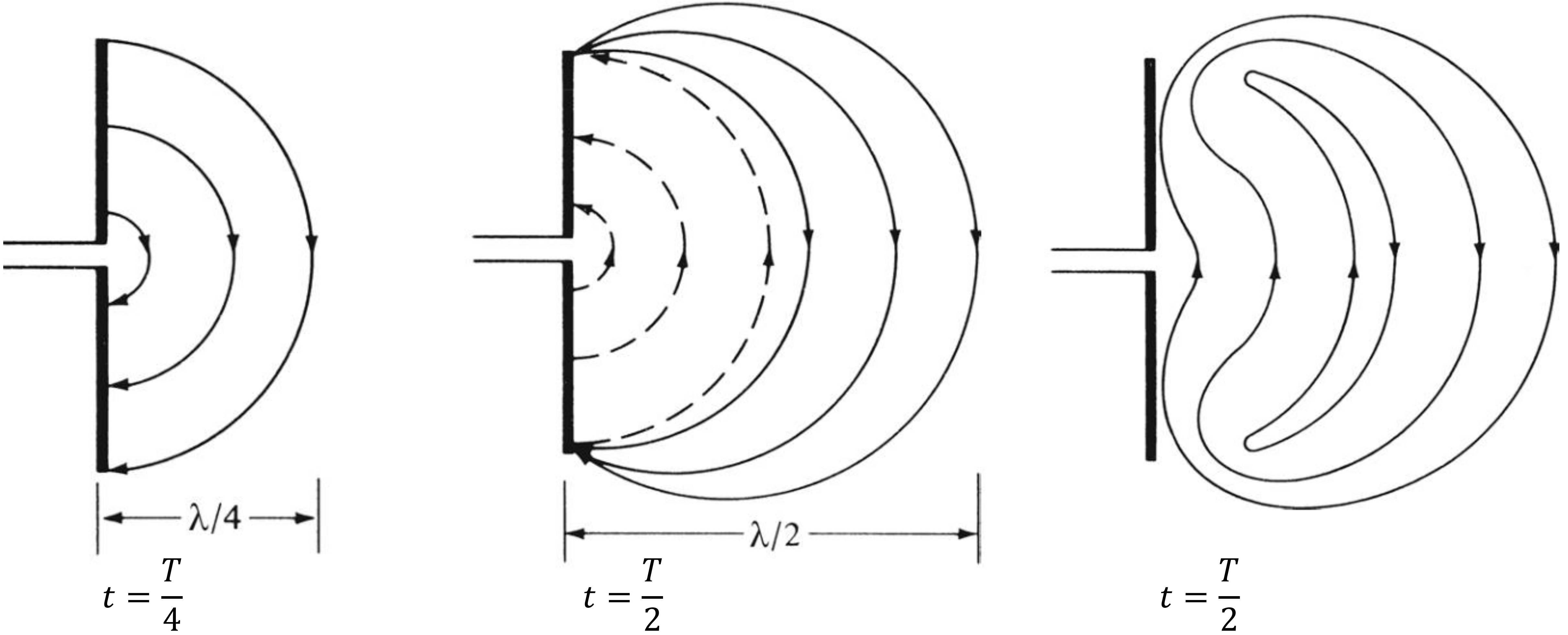




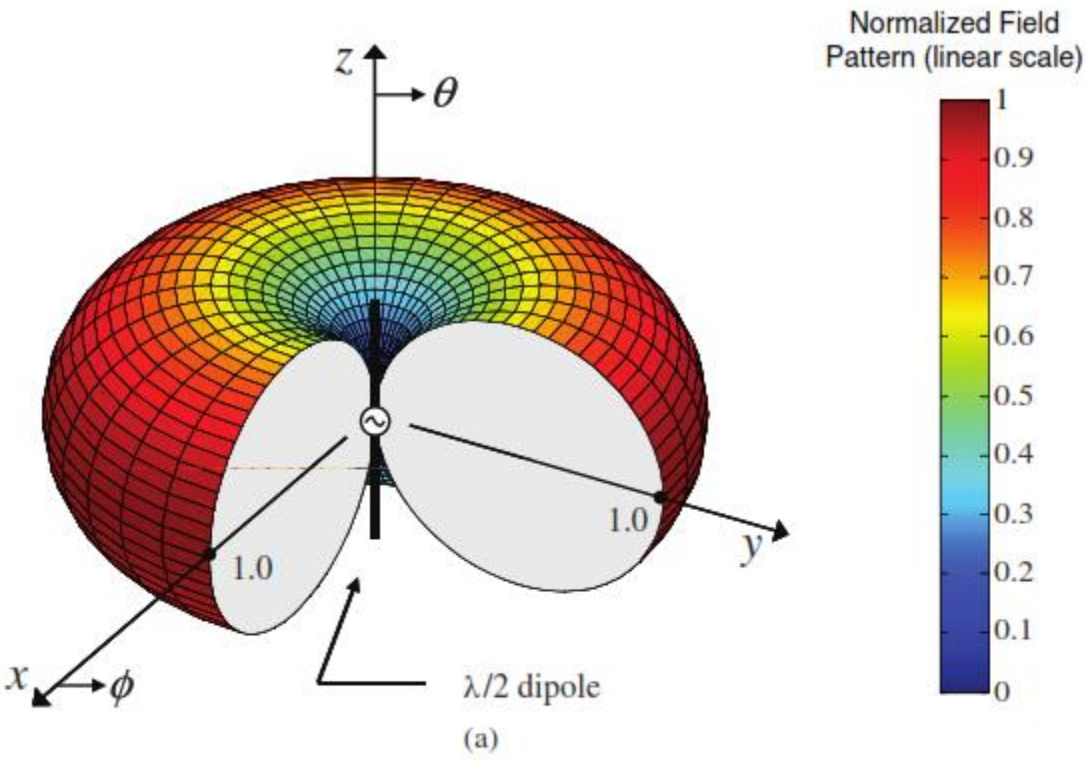
2



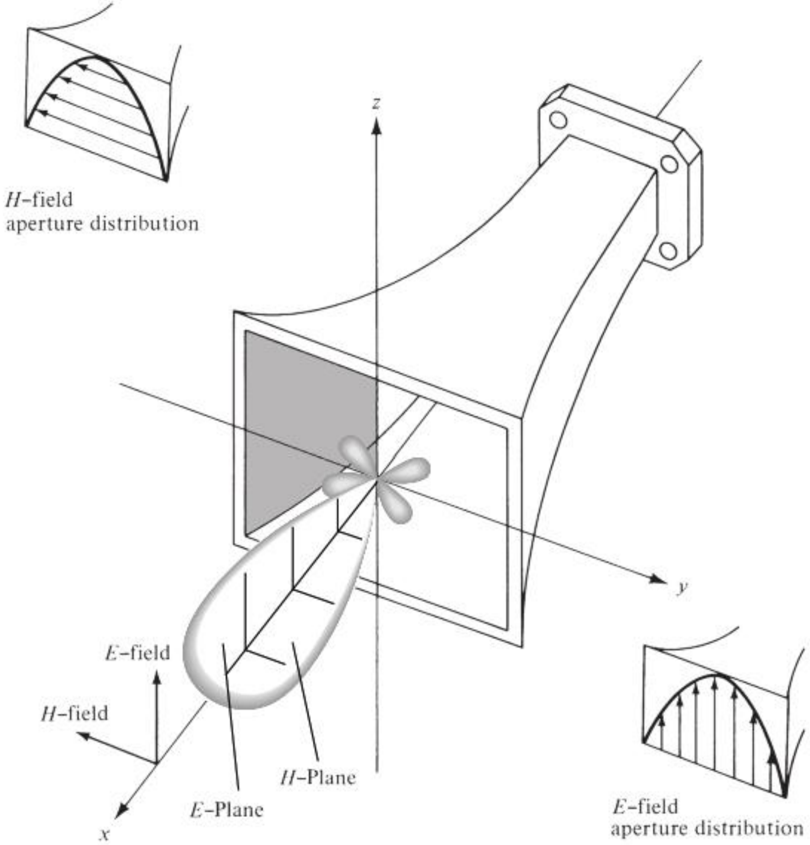
Formation and Detachment of Free-Waves from a Dipole Antenna



Radiation Pattern

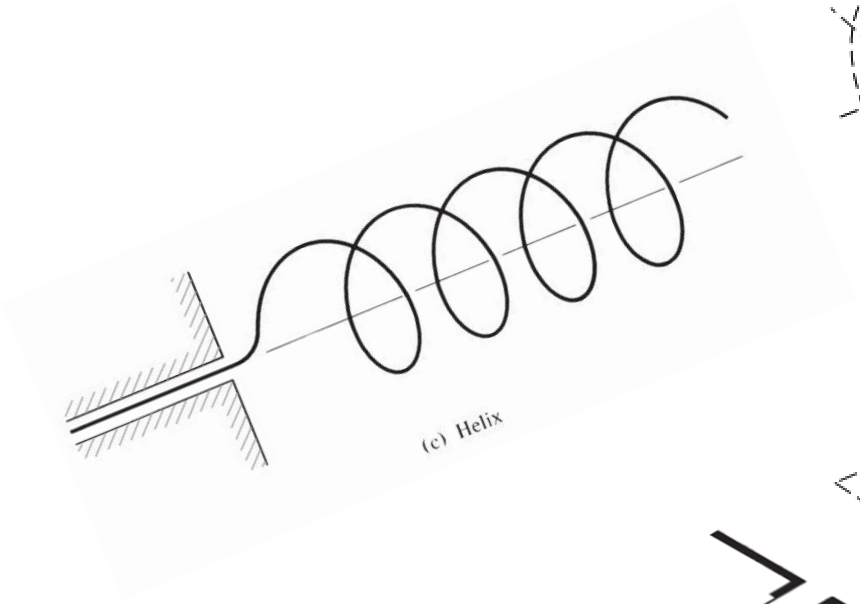


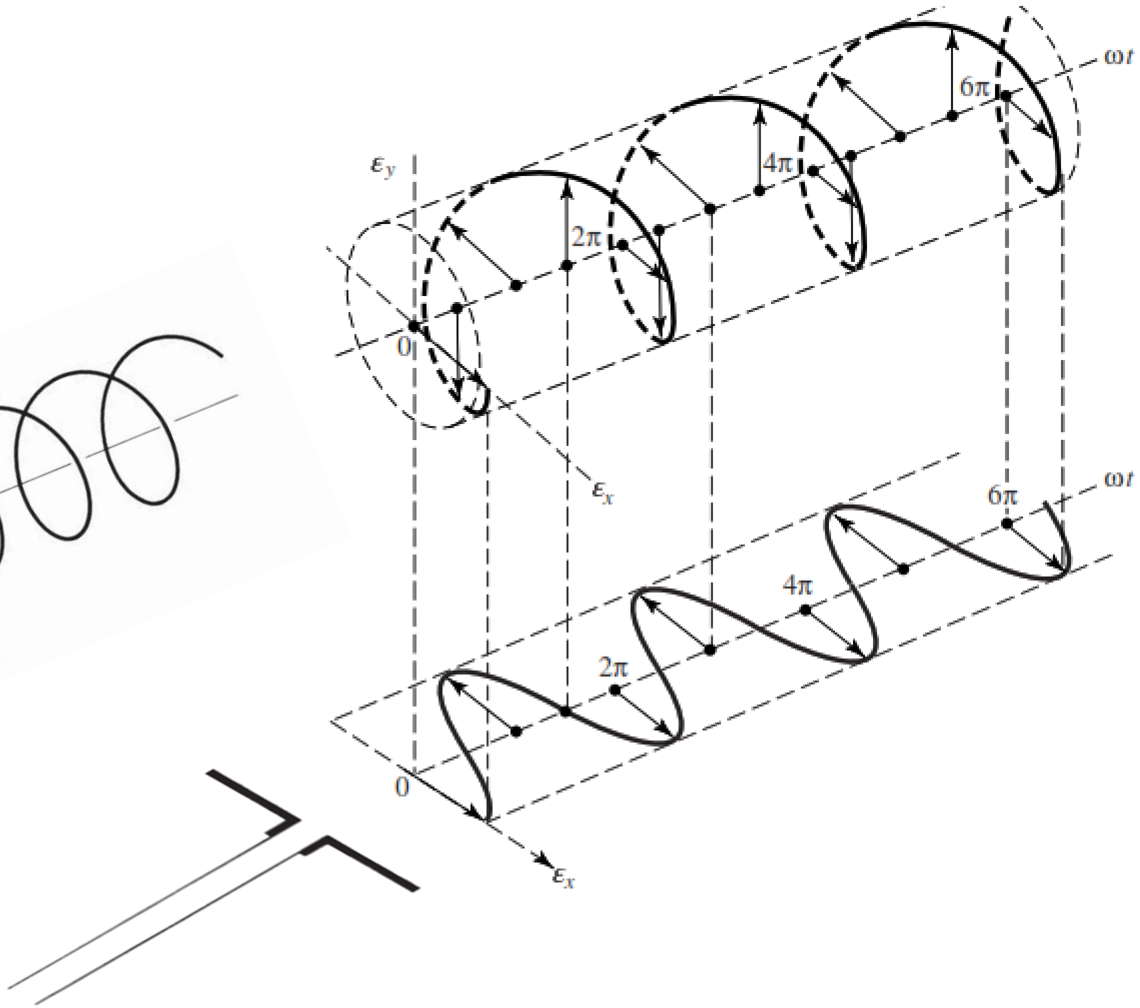
Dipole Antennas



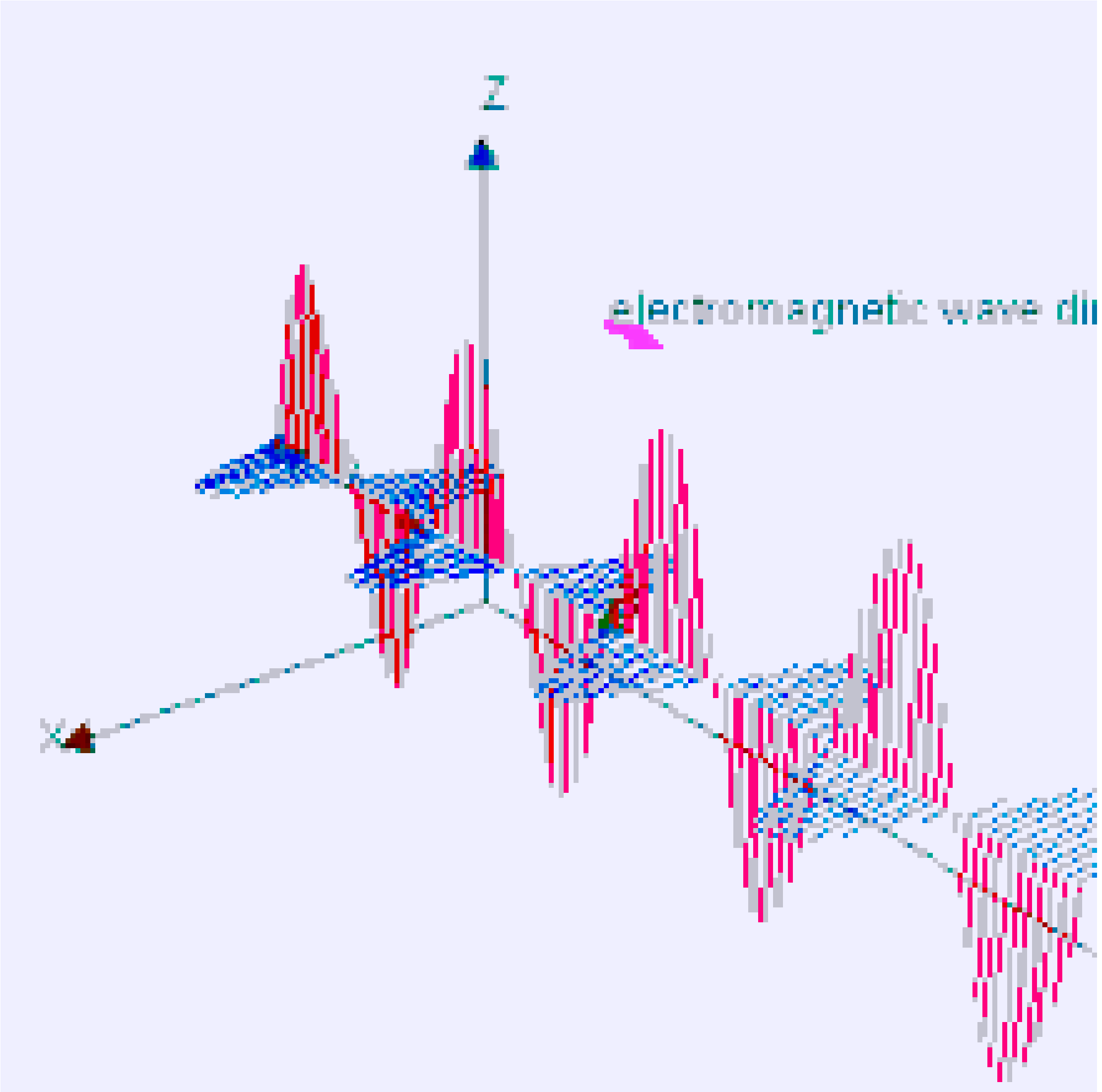
Horn Antennas

Polarization

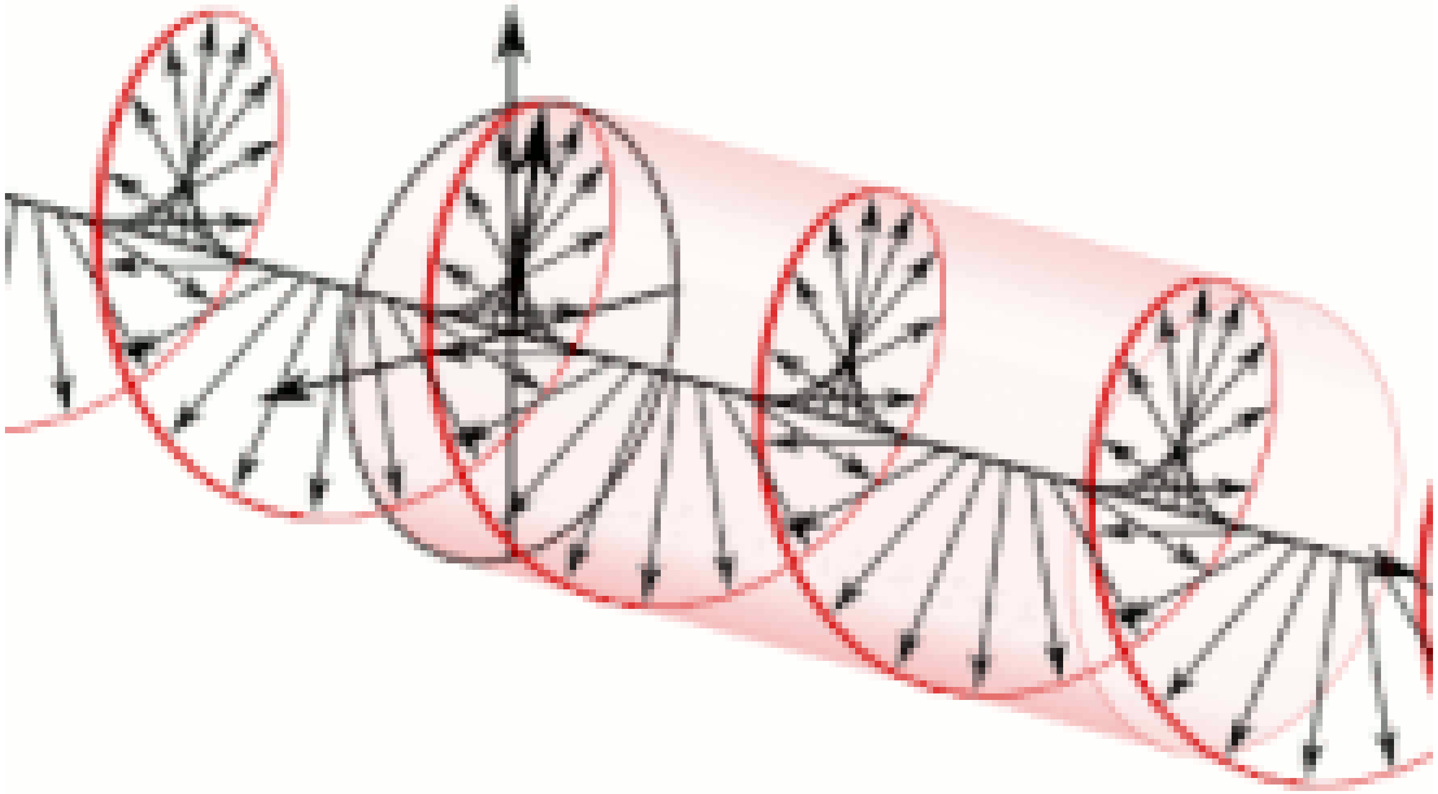




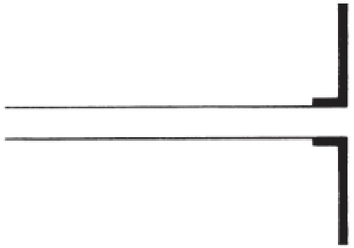
Linear-Polarized EM Wave



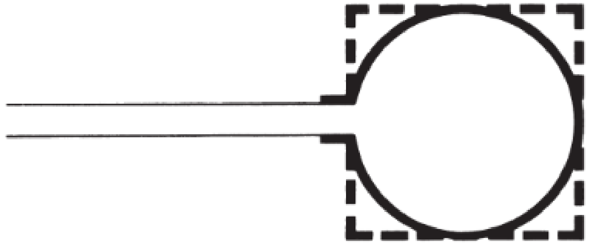
Circular-Polarized EM Wave



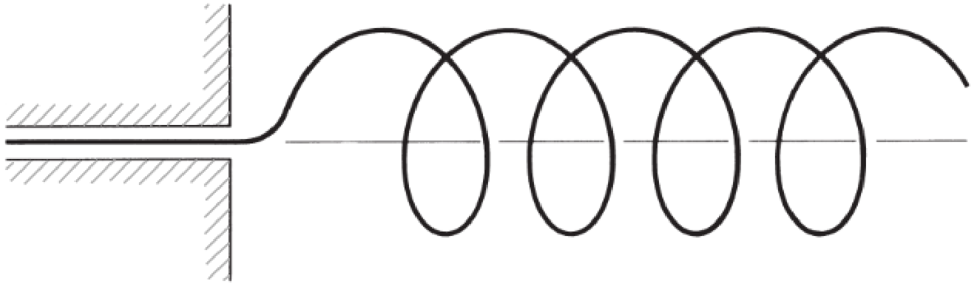
Types of Antennas



(a) Dipole

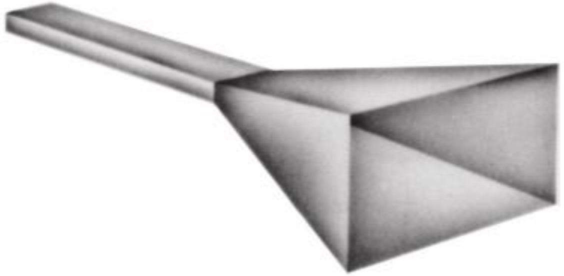


(b) Circular (square) loop



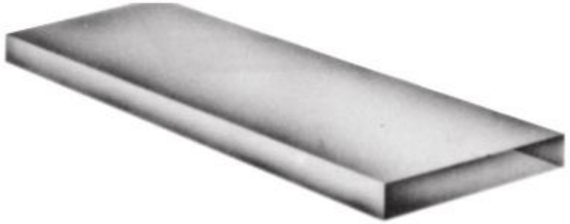
(c) Helix

Wire Antennas



(a) Pyramidal horn

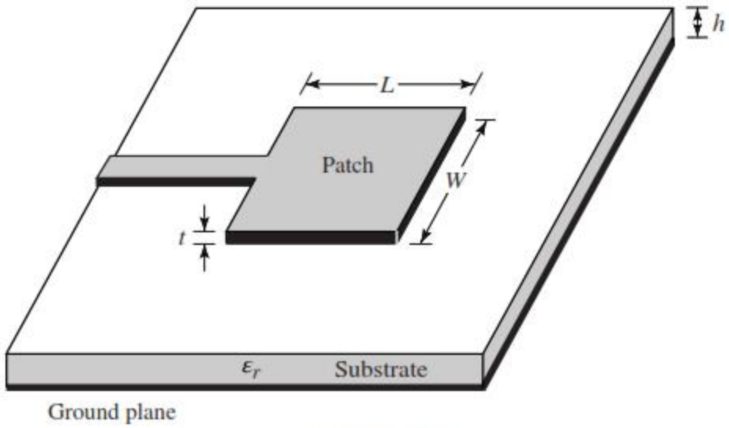
(b) Conical horn



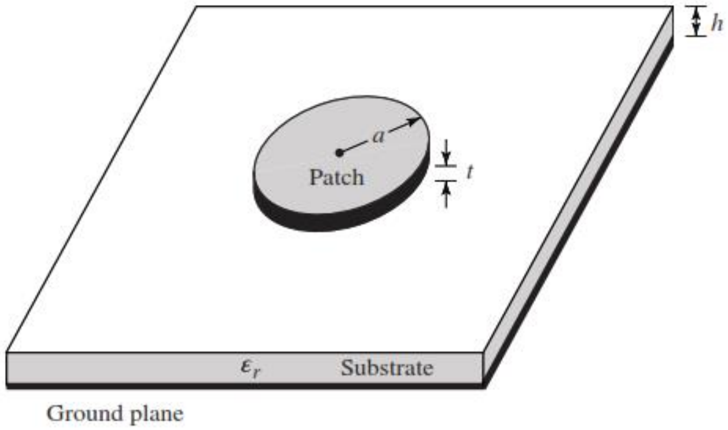
(c) Rectangular waveguide

Aperture Antennas

Types of Antennas

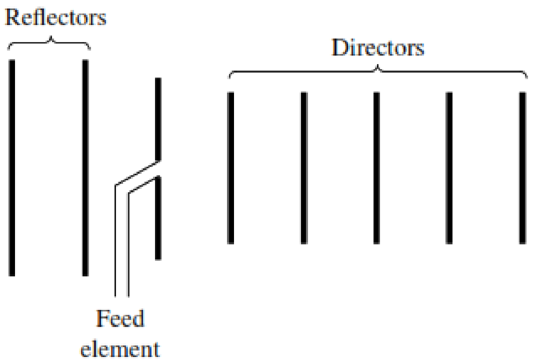


(a) Rectangular

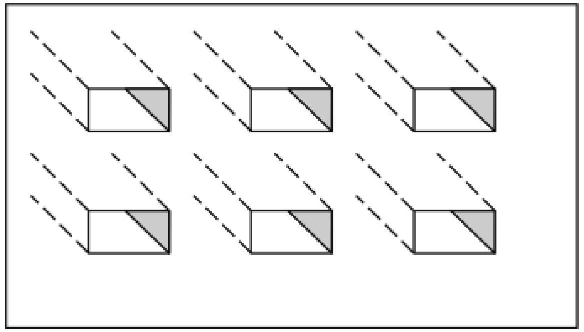


(b) Circular

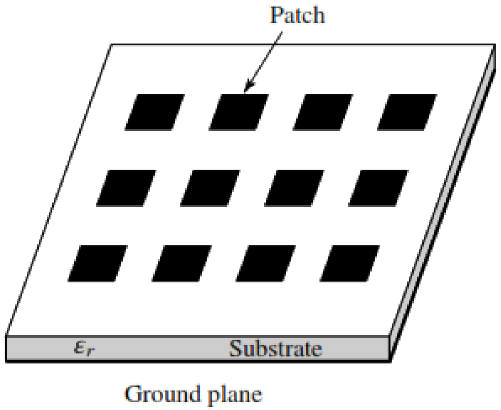
Patch (Microstrip) Antennas



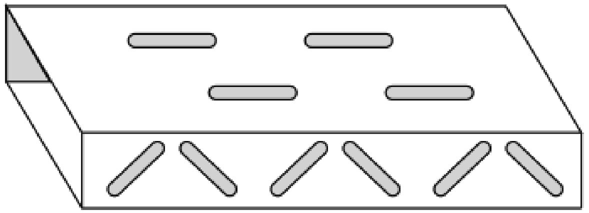
(a) Yagi-Uda array



(b) Aperture array



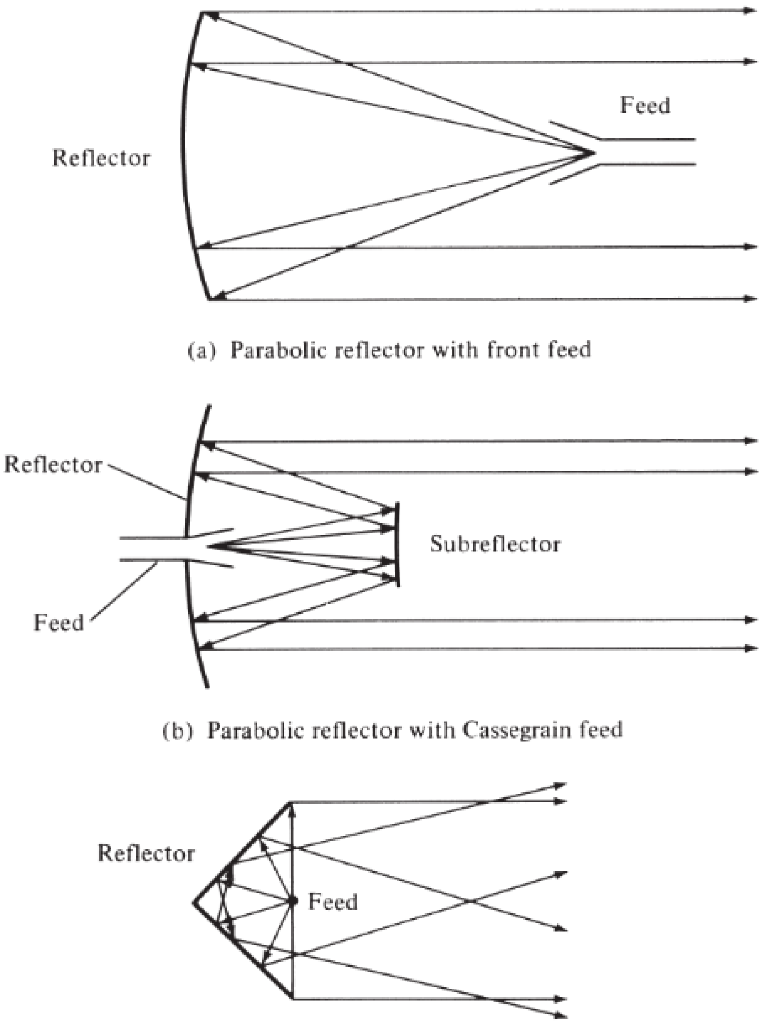
(c) Microstrip patch array



(d) Slotted-waveguide array

Array Antennas

Types of Antennas



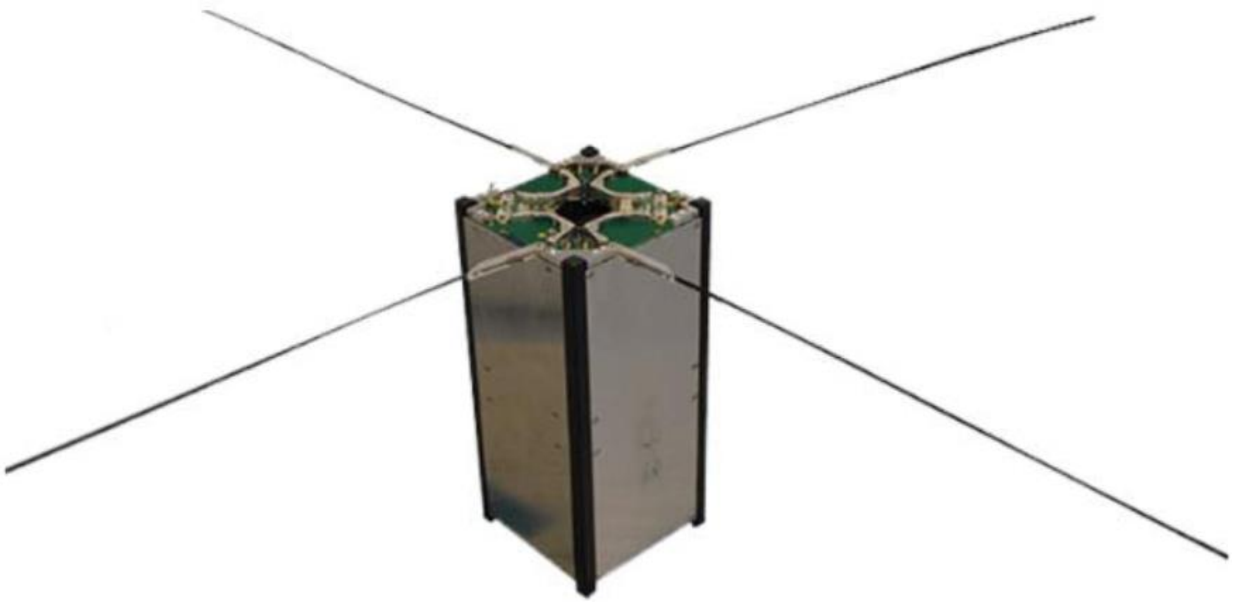
(a) Parabolic reflector with front feed

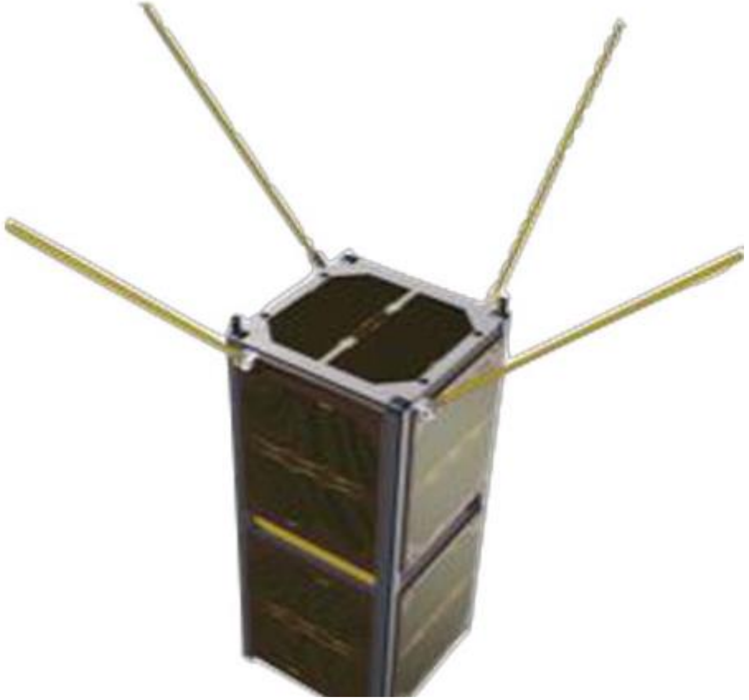
(b) Parabolic reflector with Cassegrain feed

(c) Corner reflector

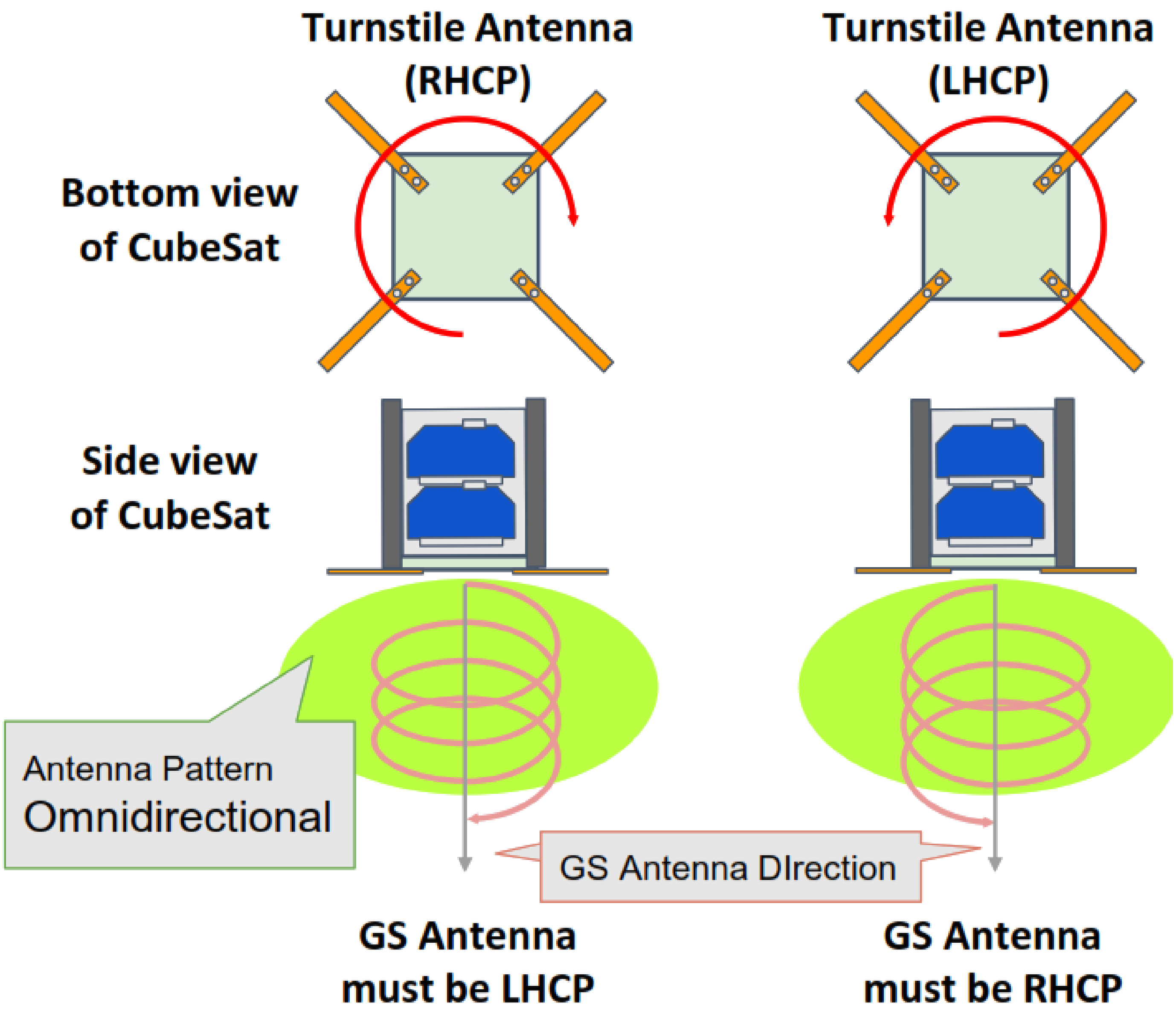
Reflector Antennas

Deployable CubeSat Antennas

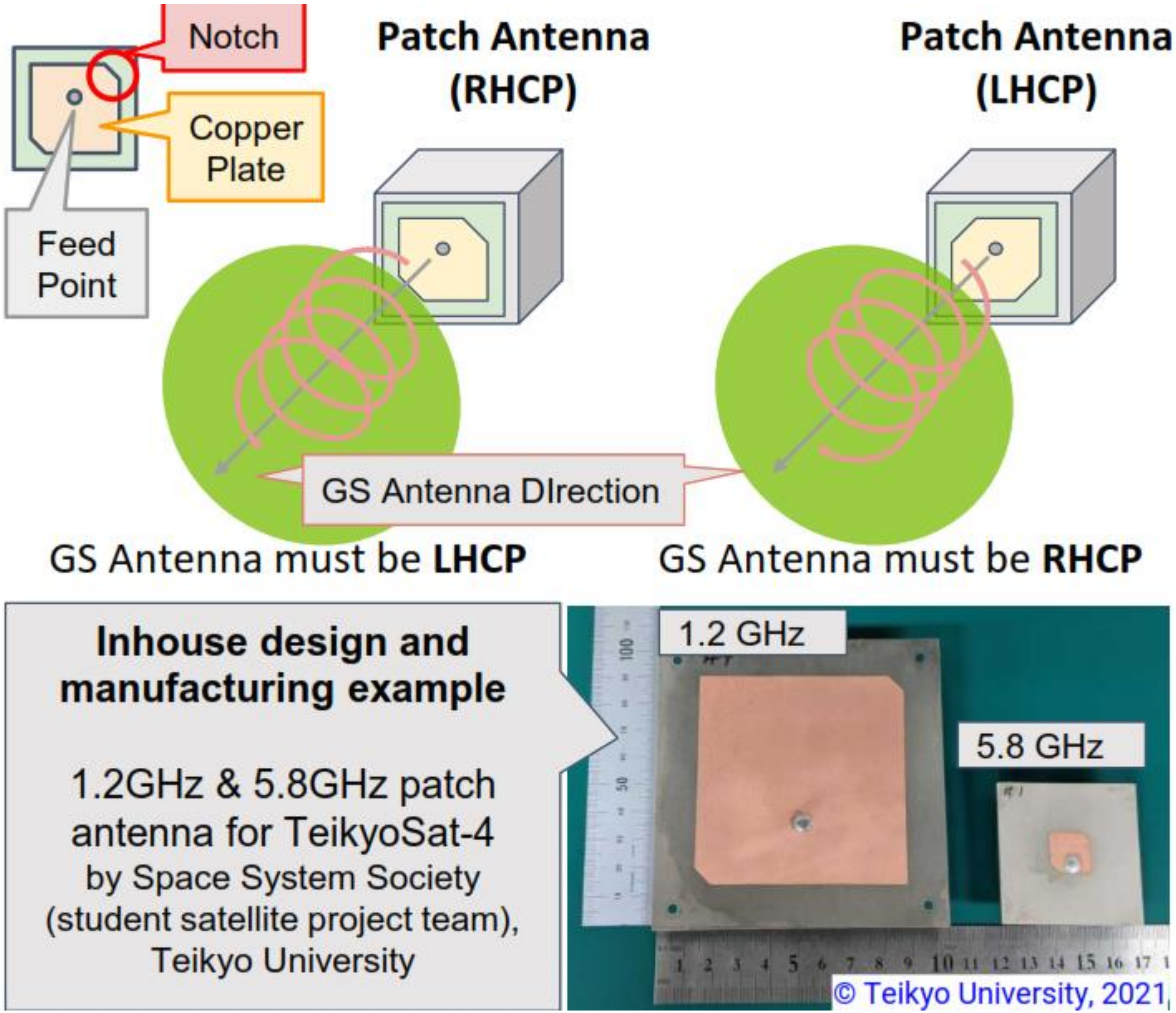




CubeSat Turnstile Antennas

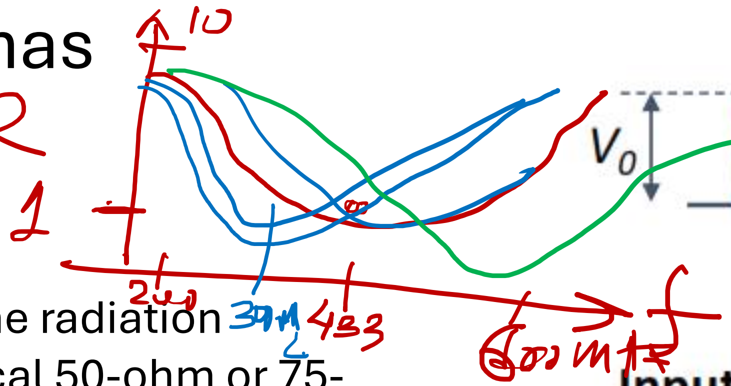


CubeSat Patch Antennas

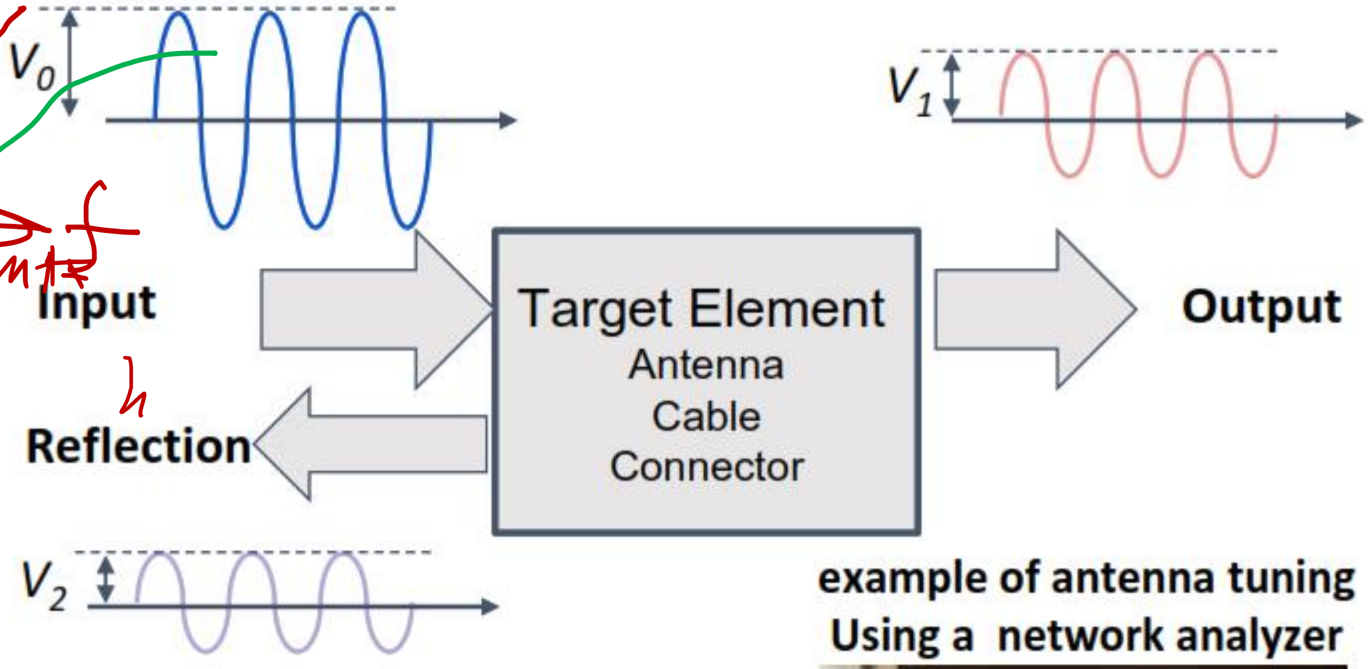


Tuning Antennas

VSWR



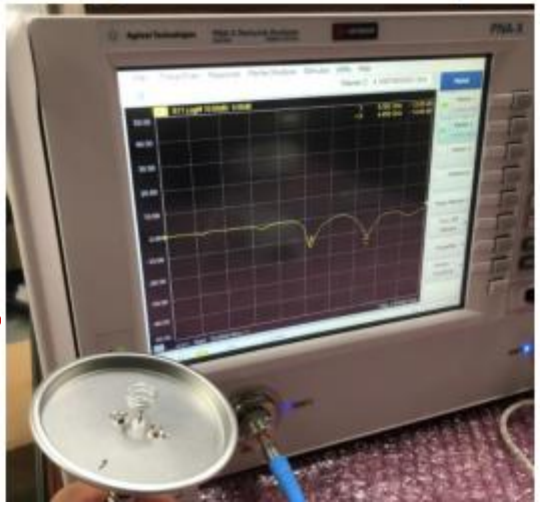
- **Impedance** is the radiation resistance. Typical 50-ohm or 75-ohm
- For effective signal transmission (or reception) this reflection should be minimum.
- The reflection is measured through **VSWR** (Voltage Standing Wave Ratio). Ideal VSWR = 1.0 but realistically < 2.0
- Antenna is tuned using Vector Network Analyzer (**VNA**) by measuring the VSWR while resizing the antenna elements or adjusting RLC circuit parameters.

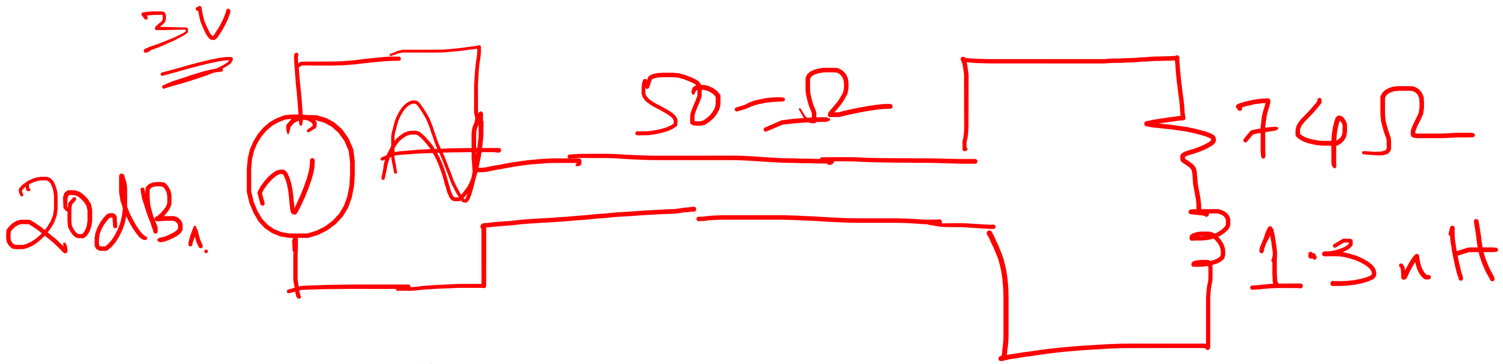


$$\text{VSWR} = \frac{1 + \frac{V_2}{V_1}}{1 - \frac{V_2}{V_1}}$$

example of antenna tuning
Using a network analyzer

VNA





$3 \times \sin(\omega t) = V_I \cdot \sin \omega t$

$2\pi \, 433e6$

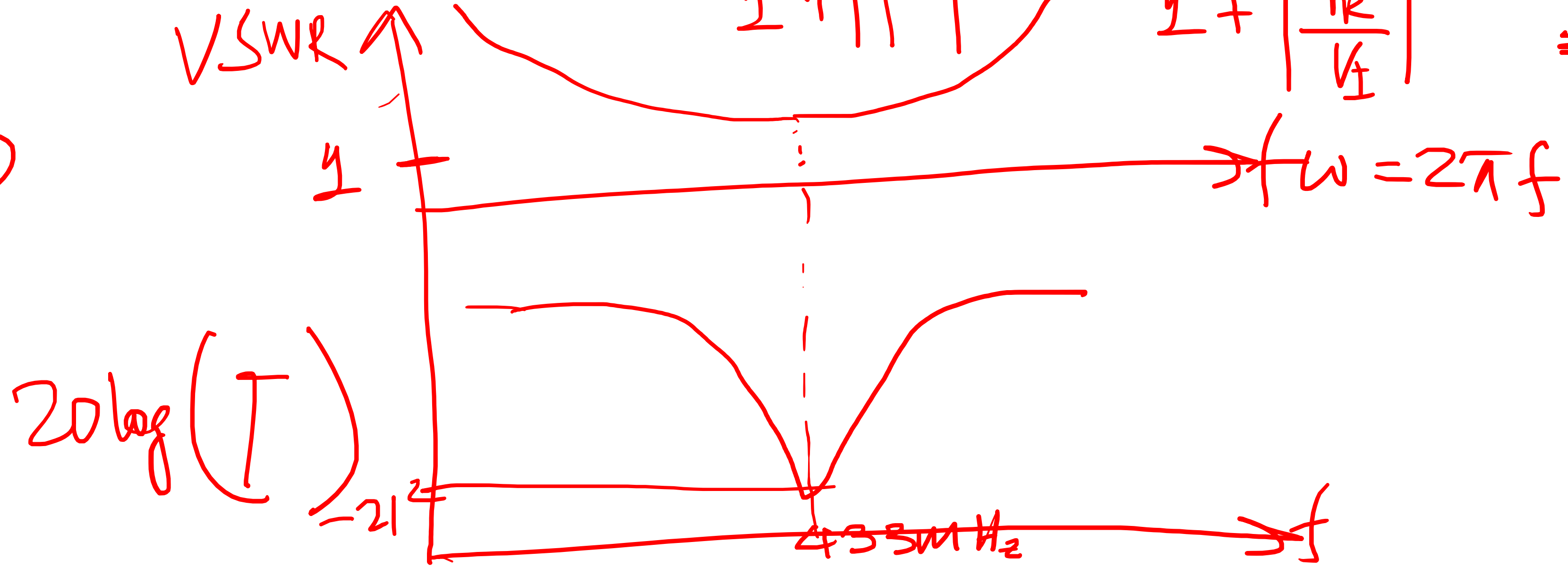
VSWR → Voltage standing wave ratio

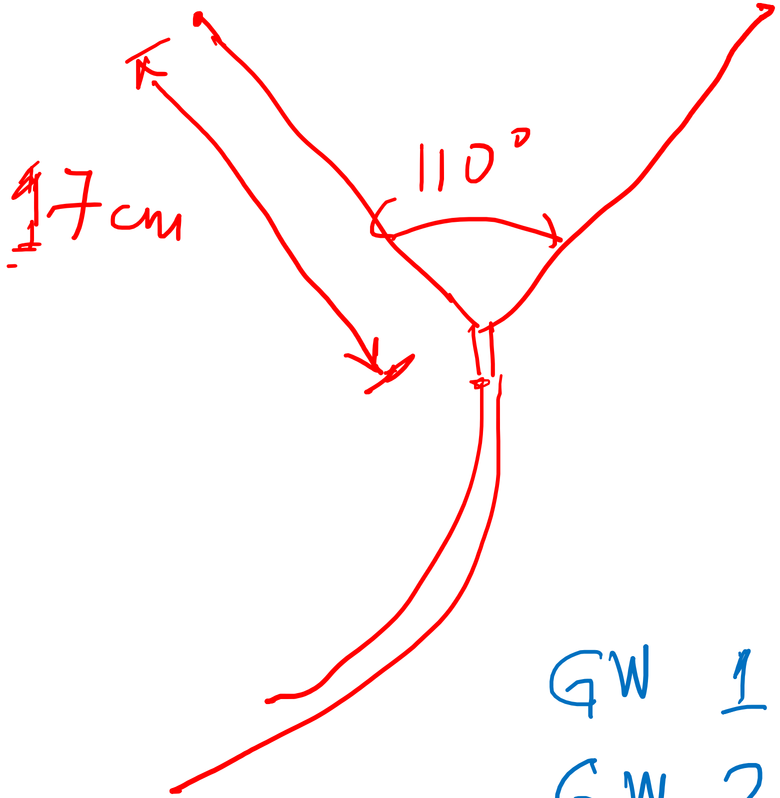
$$VSWR(\omega) = \frac{1-|\Gamma|}{1+|\Gamma|} = \frac{1-\left|\frac{V_R}{V_I}\right|}{1+\left|\frac{V_R}{V_I}\right|} = 1$$

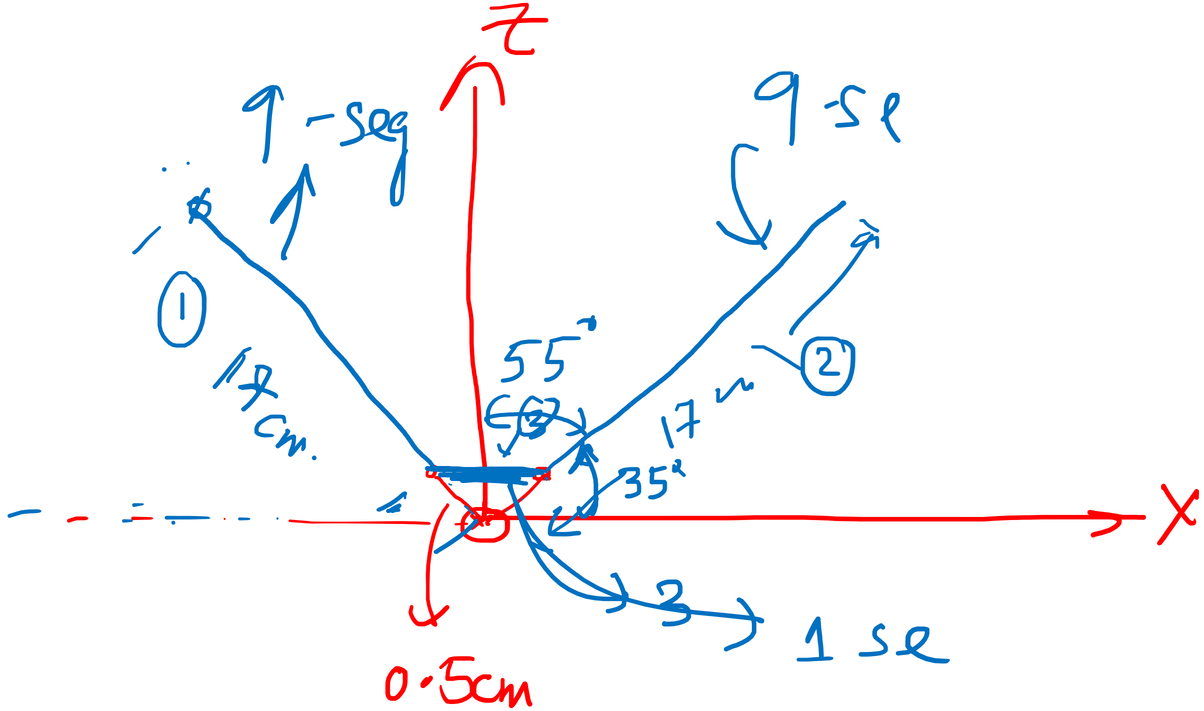
$V_R = V_R \cdot \sin(\omega t) \to 0$

$\Gamma = \frac{V_R}{V_I} = 0$

$20 \log(\Gamma)$



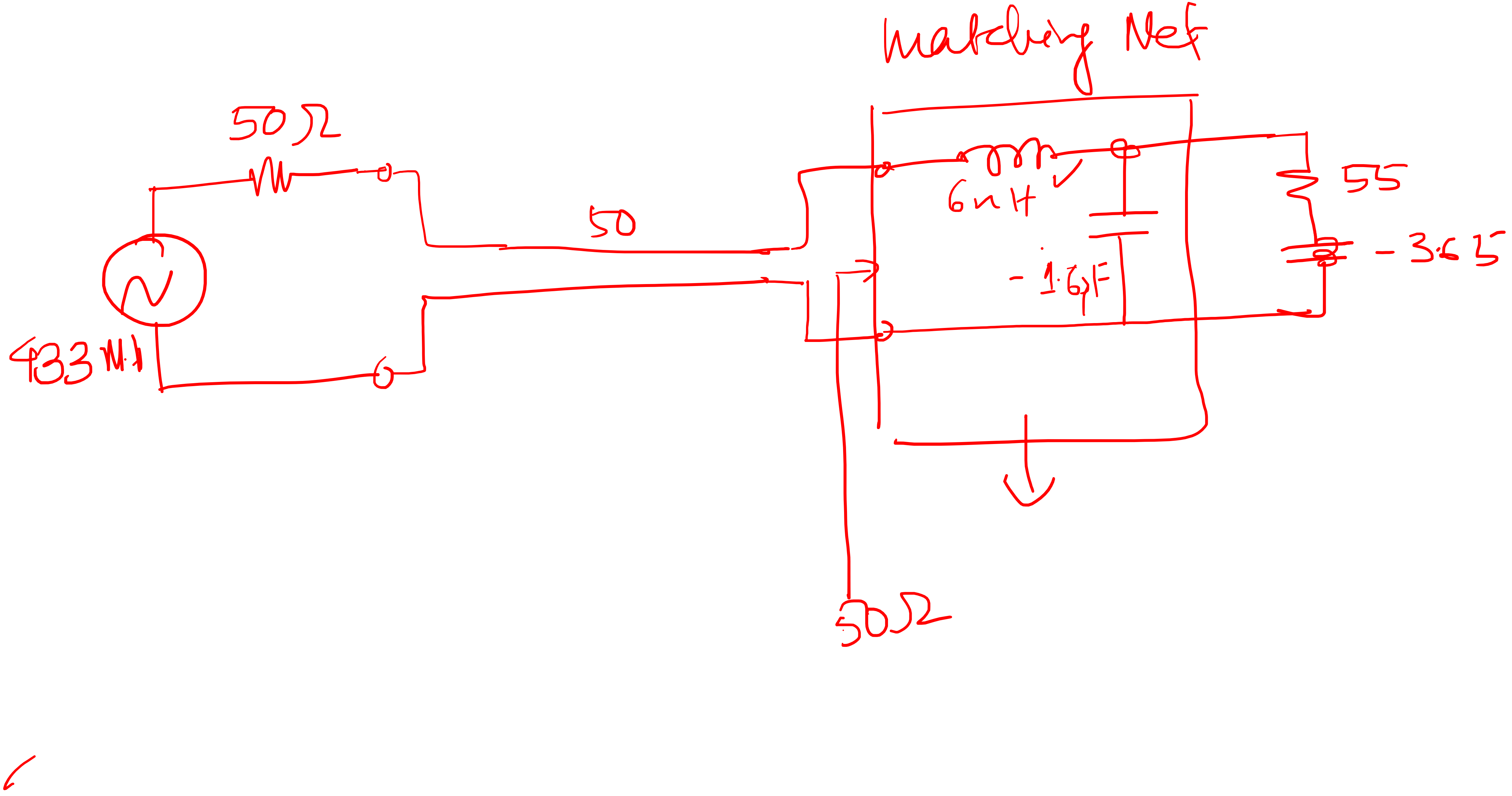




GW 1 $x_1\ y_1\ z_1$ $x_2\ y_2\ z_2$ 0.001

GW 2 , ,,

GW 3

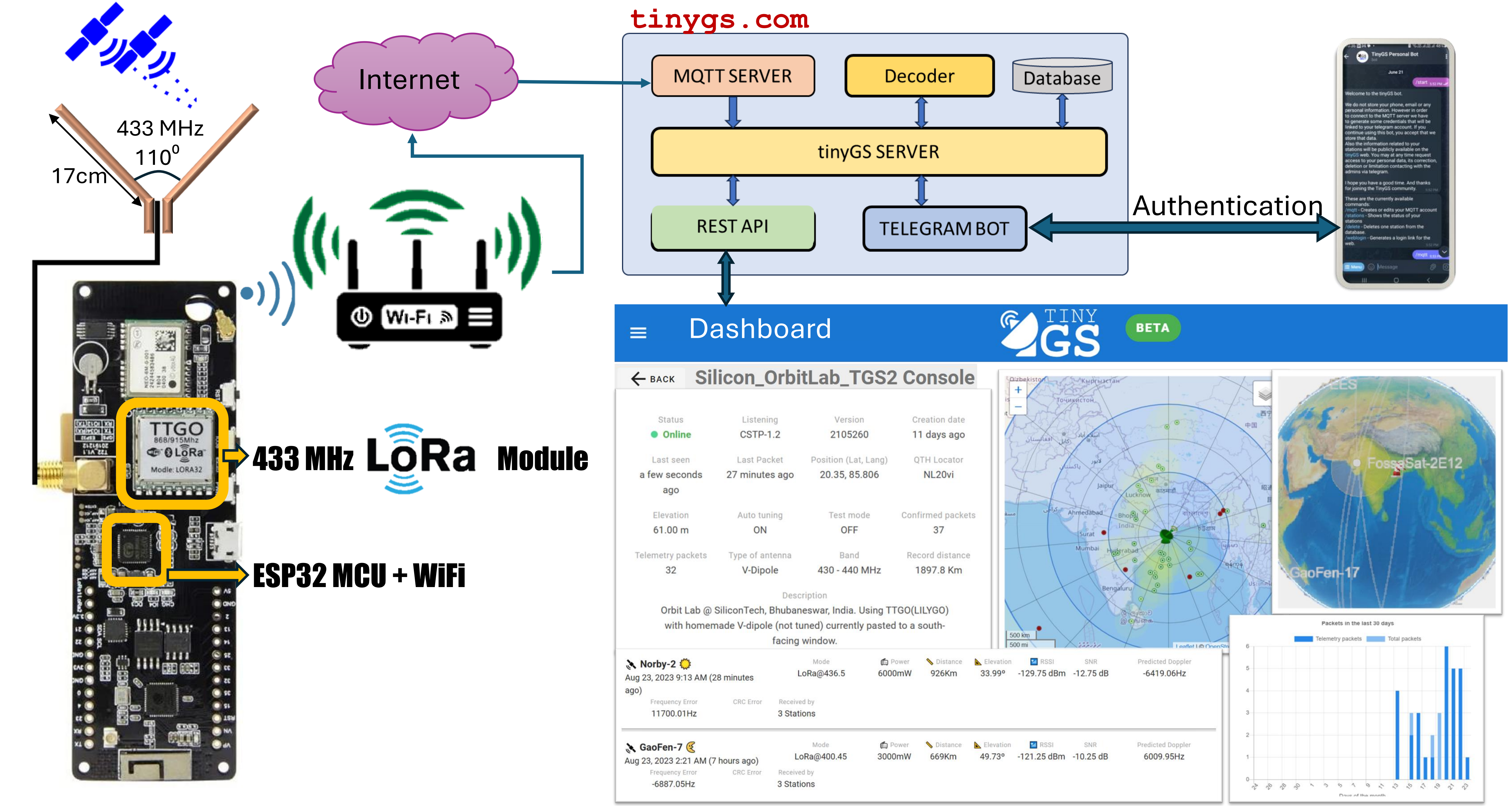


Matching Net
50Ω
50
6nH
55
-3.65
-1.6pF
433MHz
50Ω

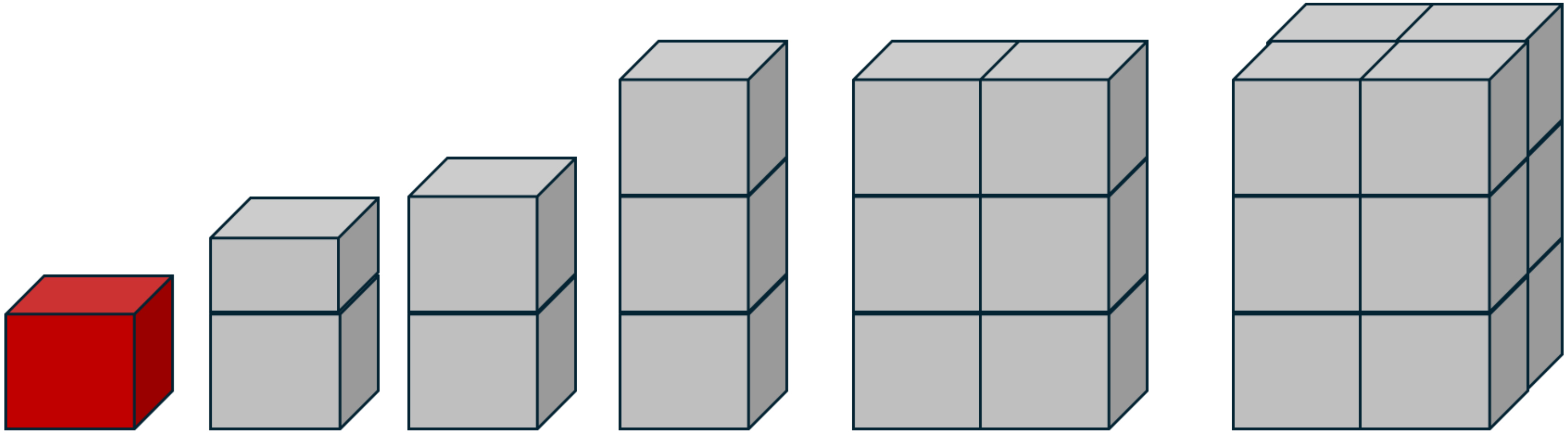
Appendix

Silicon Tech

Tiny Satellite Ground Station



CubeSat Standard Sizes



1U (4”x4”x4”) | 1.5U | 2U | 3U | 6U | 12U

Our target <1U

Minimal Payload