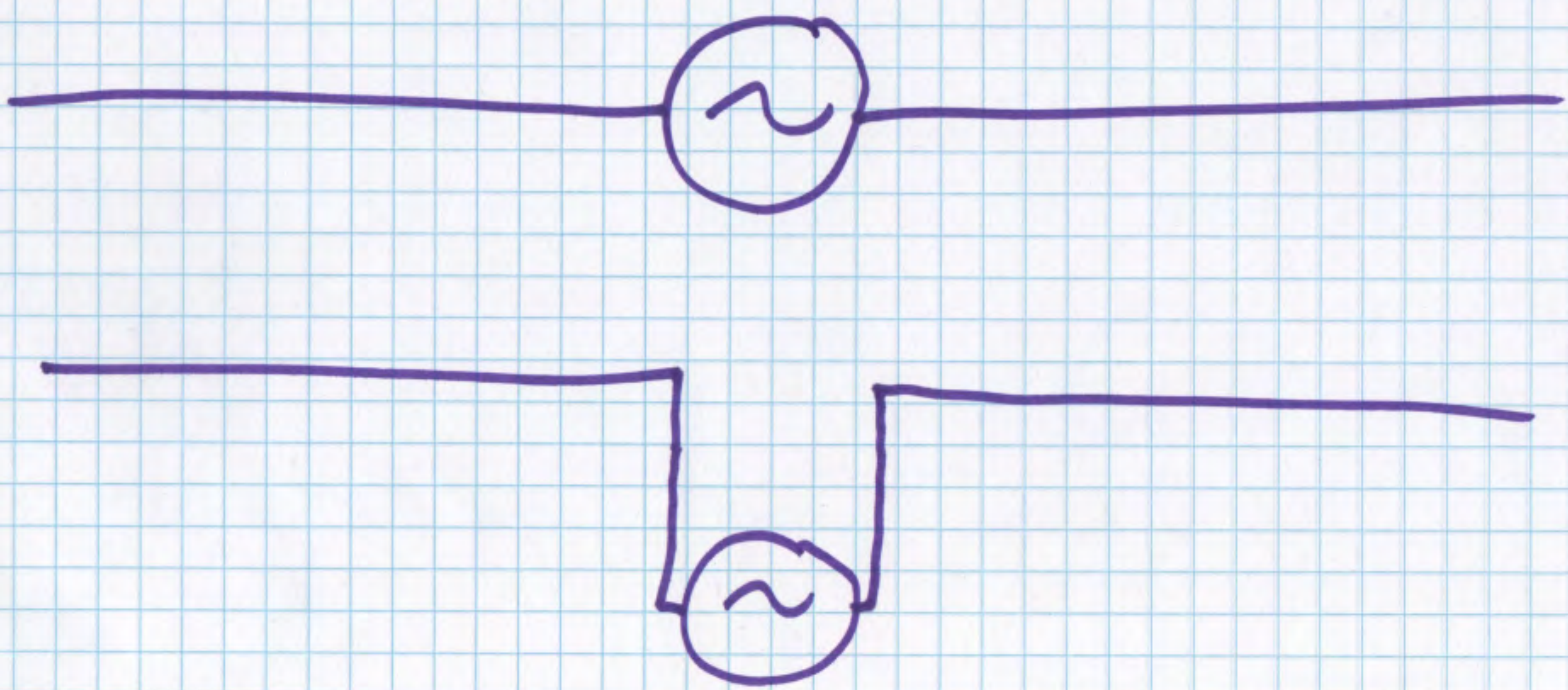
Transmission Lines

Chris Hamilton AE5IT

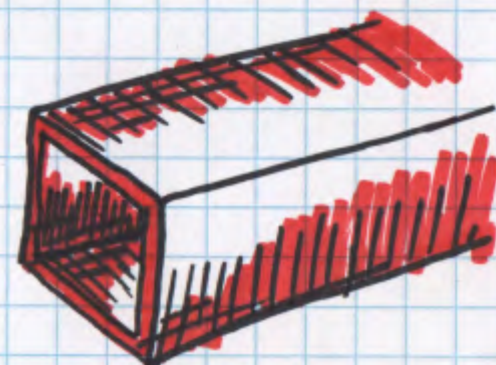
2020 Jan 25

What are transmission lines?



Co-axial

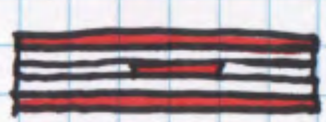
Twin-lead
window-line,
ladder-line,
homebrew

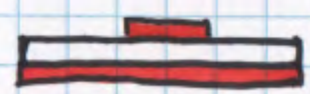


Wave guide

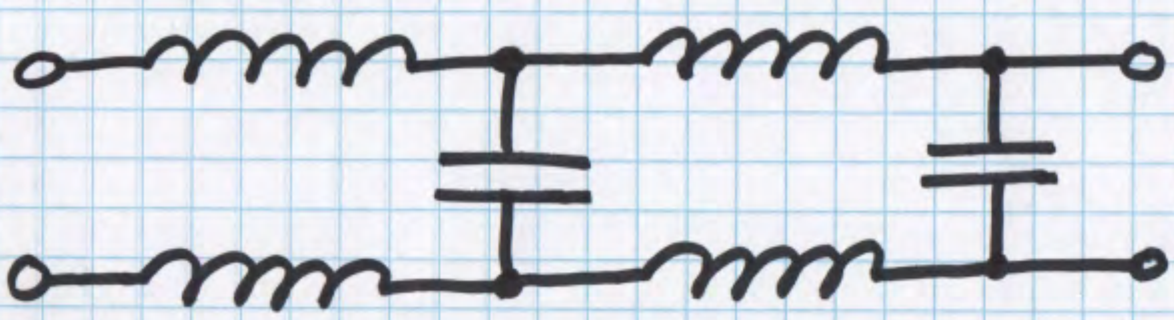
Strip line

Micro-stripline





Transmission lines behave <u>electrically</u> like series inductors & parallel capacitors



Keep this in mind!
It helps us understand things later

Properties of transmission lines

Resistance & ohmic loss
conductors + dialectric

Characteristic Impedance

Both measured in Ohms
Ω

Propagation velocity

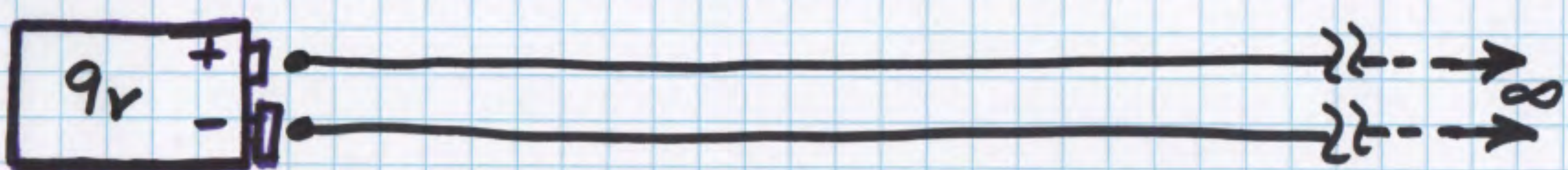
Non - radiating

Frequency dependency

Characteristic Impedance

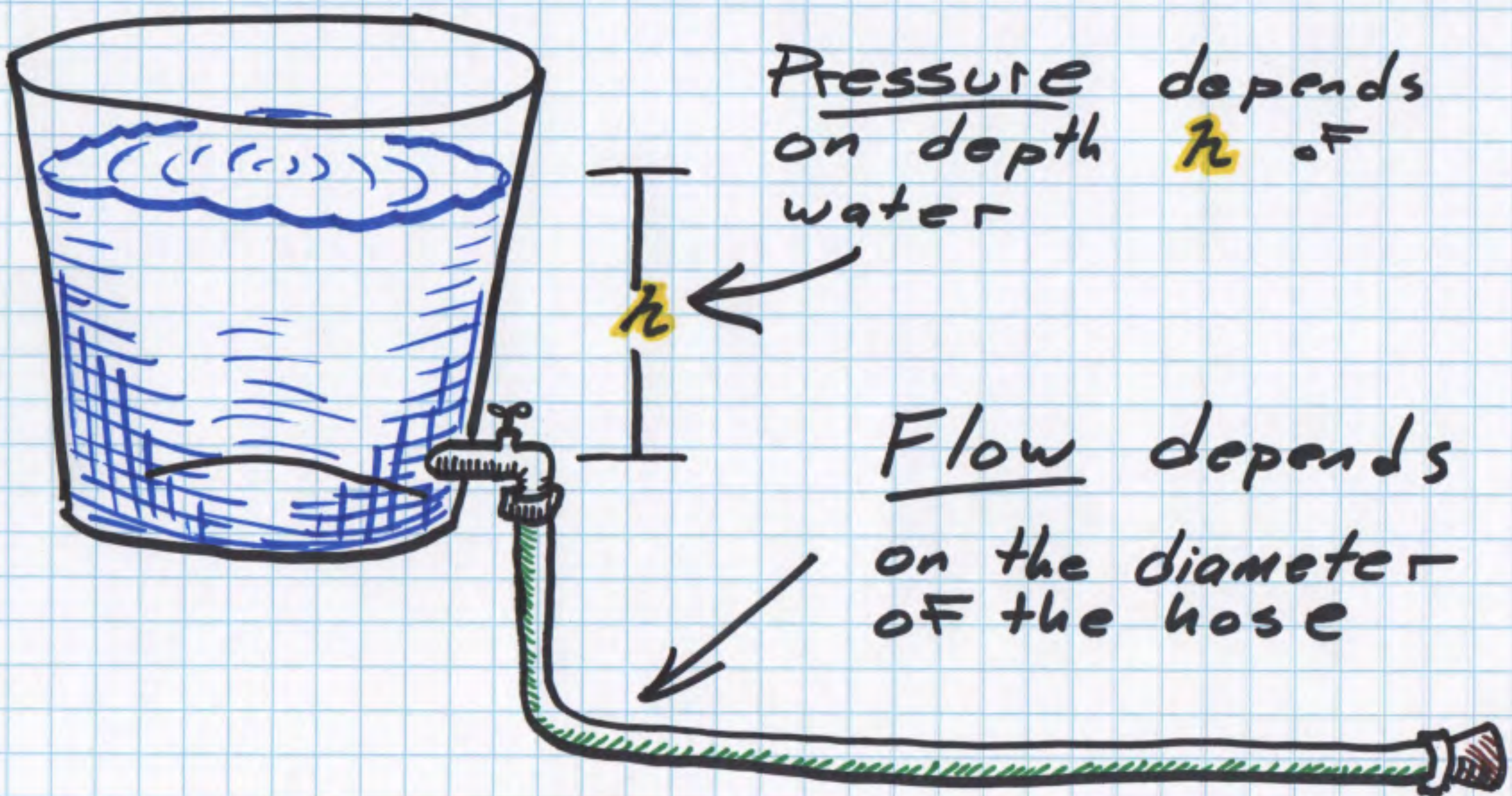
Regardless of load

what current flows through the line when a voltage is applied?



Water Analogy

(There's *always* a water analogy)



Voltage is like Pressure

Current is like Flow

$$\left(\frac{\text{Voltage}}{\text{Current}}\right) \qquad \left(\frac{\text{Pressure}}{\text{Flow}}\right)$$

These ratios are a property of the line - which depend on its <u>physical</u> construction

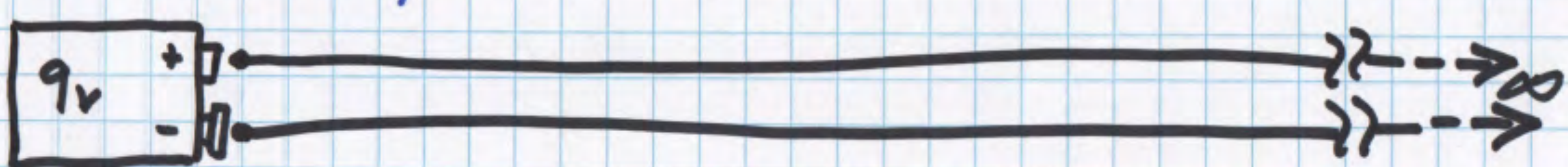
$$\frac{\text{Voltage}}{\text{Current}} = \frac{E}{I}$$

$$E = I \cdot R \qquad \frac{E}{I} = R \qquad R = \frac{E}{I}$$

300 Ω
line

9 V
battery

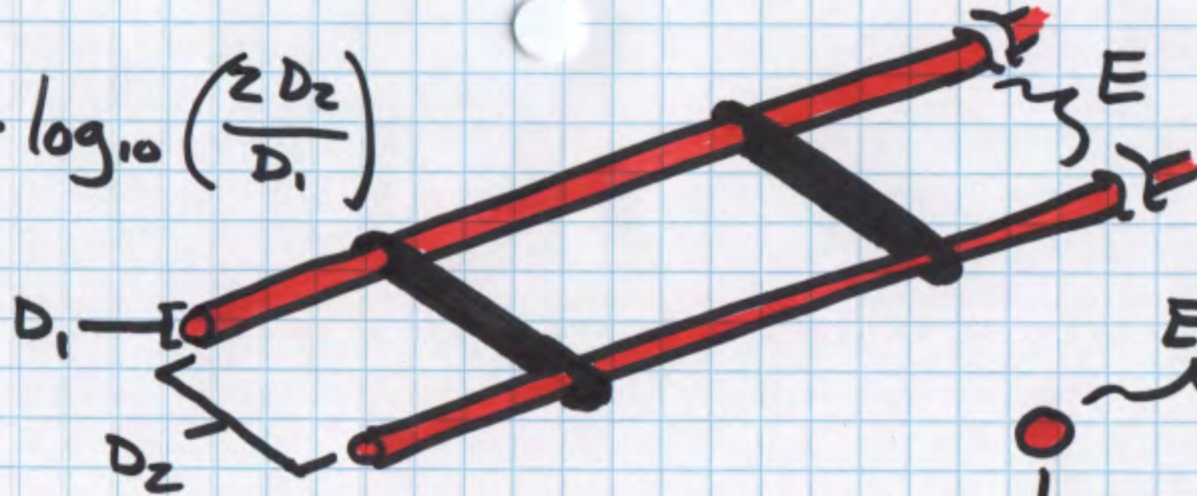
$$300 = \frac{9}{I} \qquad I = \frac{9}{300} = 0.03\,A$$

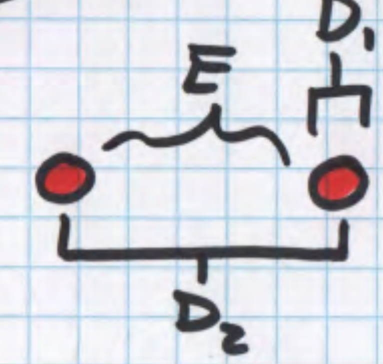


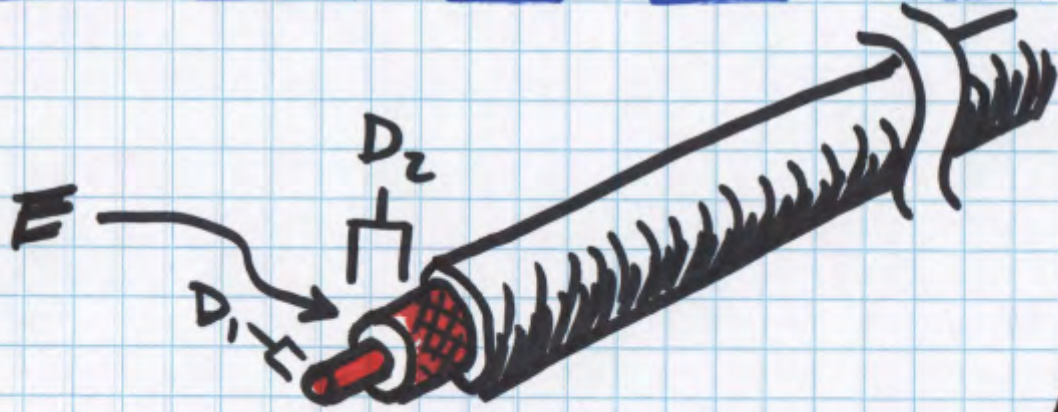
What determines char. Imp.?

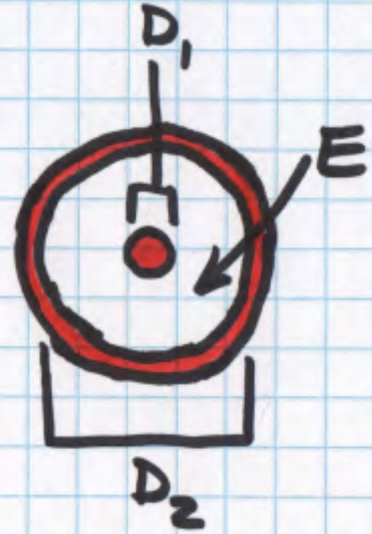
- Distance between conductors
- Permitivity of insulation between conductors
  (Dialectric constant)
- Size of conductors

$$Z_0 = \frac{276}{\sqrt{E}} \cdot \log_{10}\left(\frac{2D_2}{D_1}\right)$$







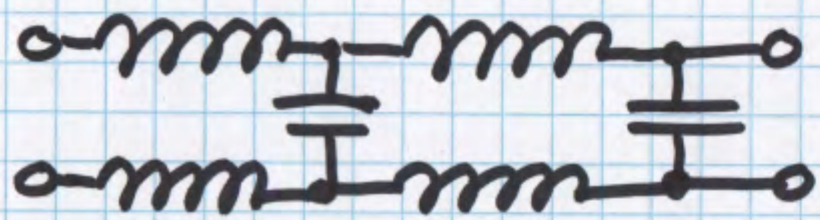


$$Z_0 = \frac{138}{\sqrt{E}} \cdot \log_{10}\left(\frac{D_2}{D_1}\right)$$

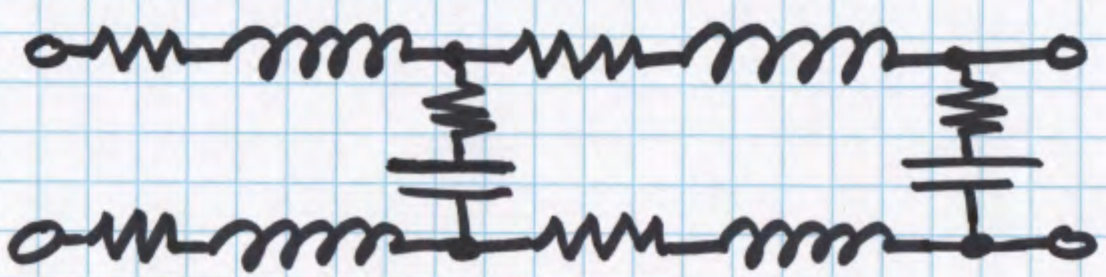
Line Loss

Transmission lines are made from real-world materials

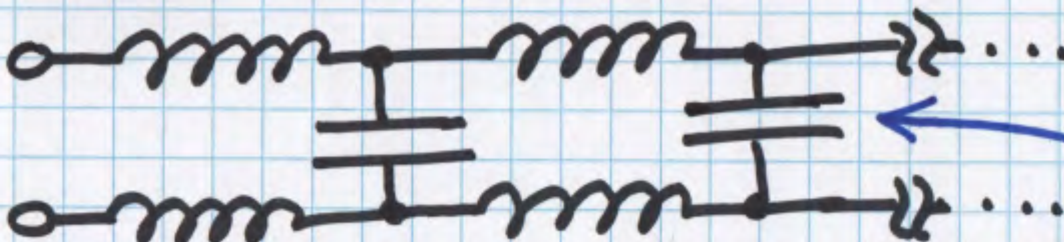
idealized model

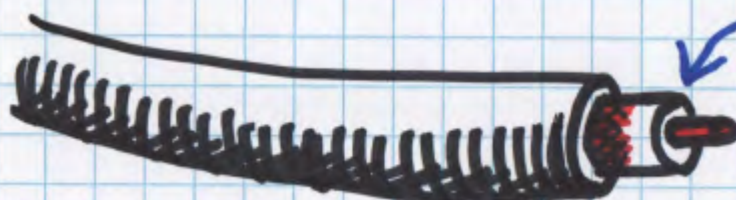


more realistic



Propagation Velocity / Velocity Factor





some insulator

E: dialectric constant of insulation

$$VF = \frac{1}{\sqrt{E}}$$

VACUUM $E=1$ $\quad VF = \frac{1}{\sqrt{1}} = 1$

AIR $E=1.00054$ $\quad VF = \frac{1}{\sqrt{1.00054}} \approx \frac{1}{1} \approx 1$

POLYETHELENE $E=2.26$ $\quad VF = \frac{1}{\sqrt{2.26}} \approx \frac{1}{1.5} \approx \frac{2}{3}$

Frequency Dependency

Loss : Capacitor ESR varies

Dialectric losses

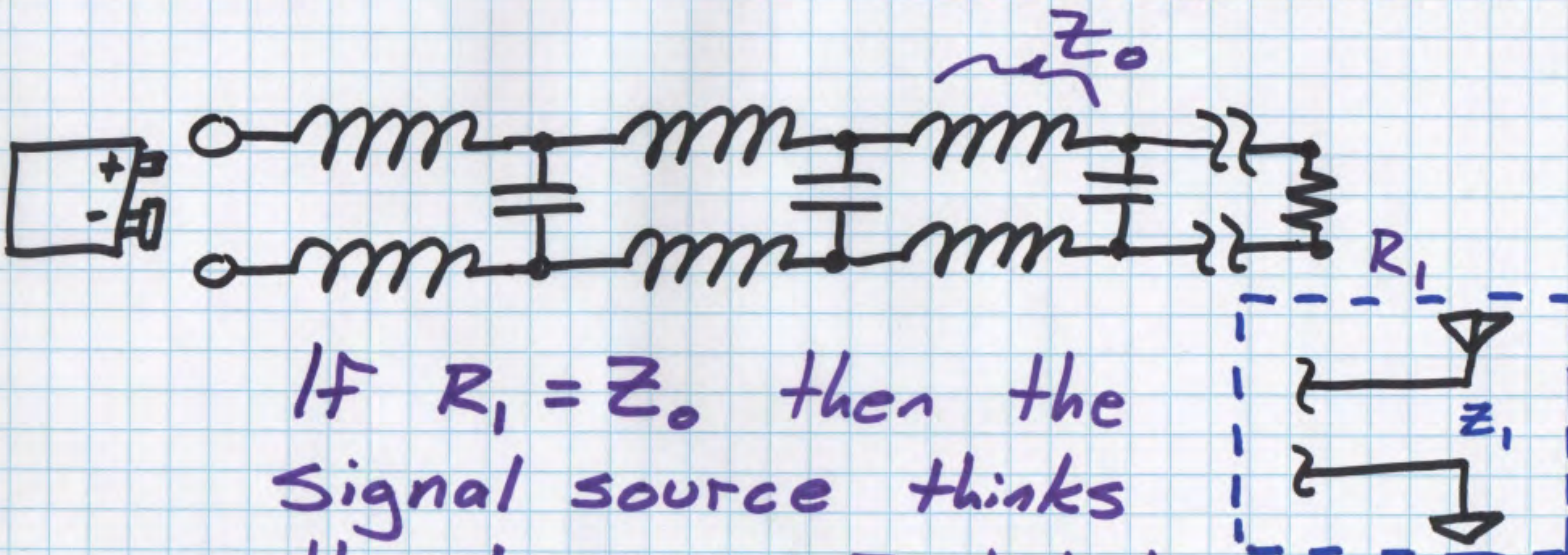
Leaky shielding

Construction imperfections

Skin depth

Distance b/w conductors

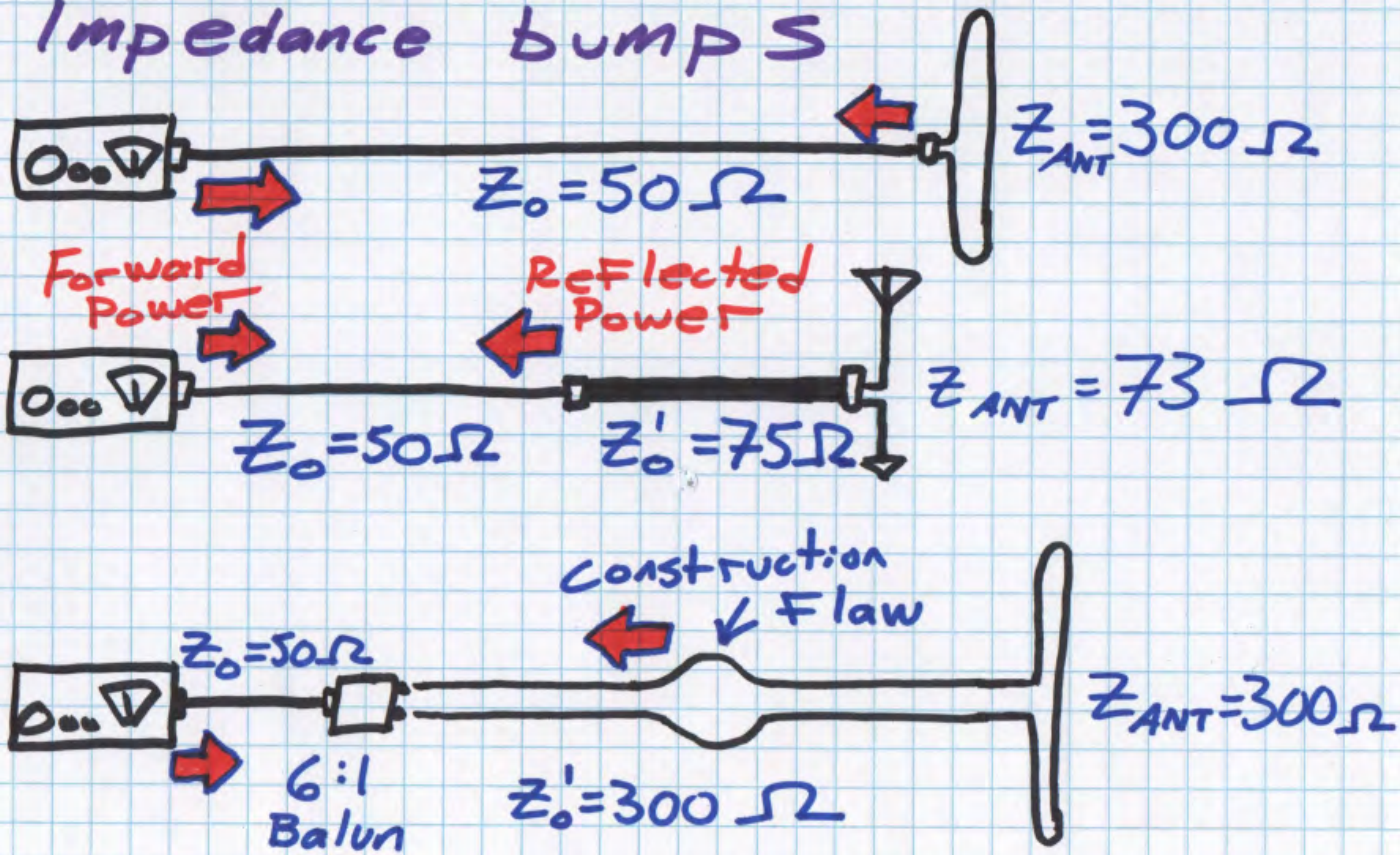
Loads & Matching



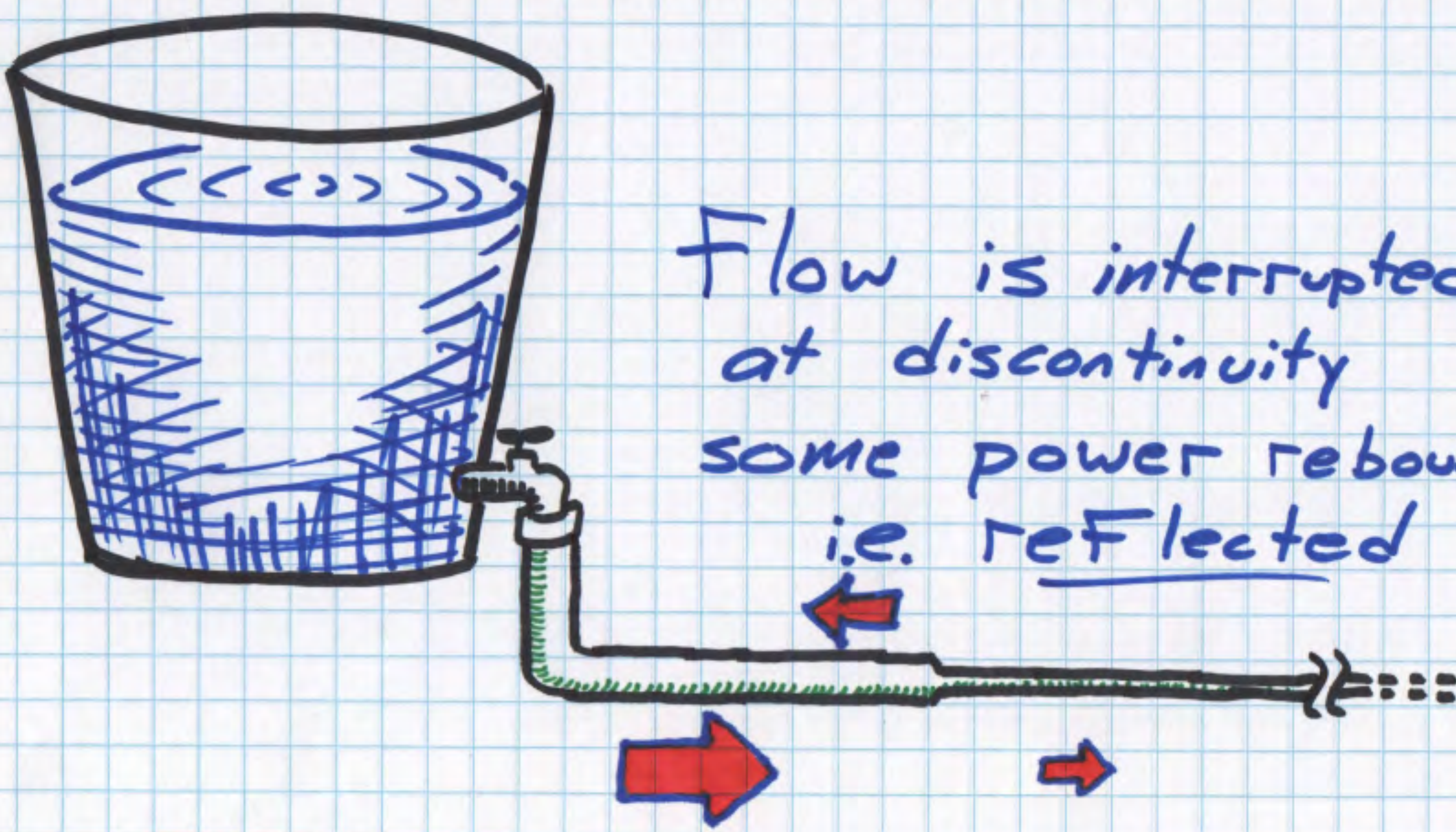
If $R_1 = Z_0$ then the signal source thinks the line is infinitely long

Matched condition

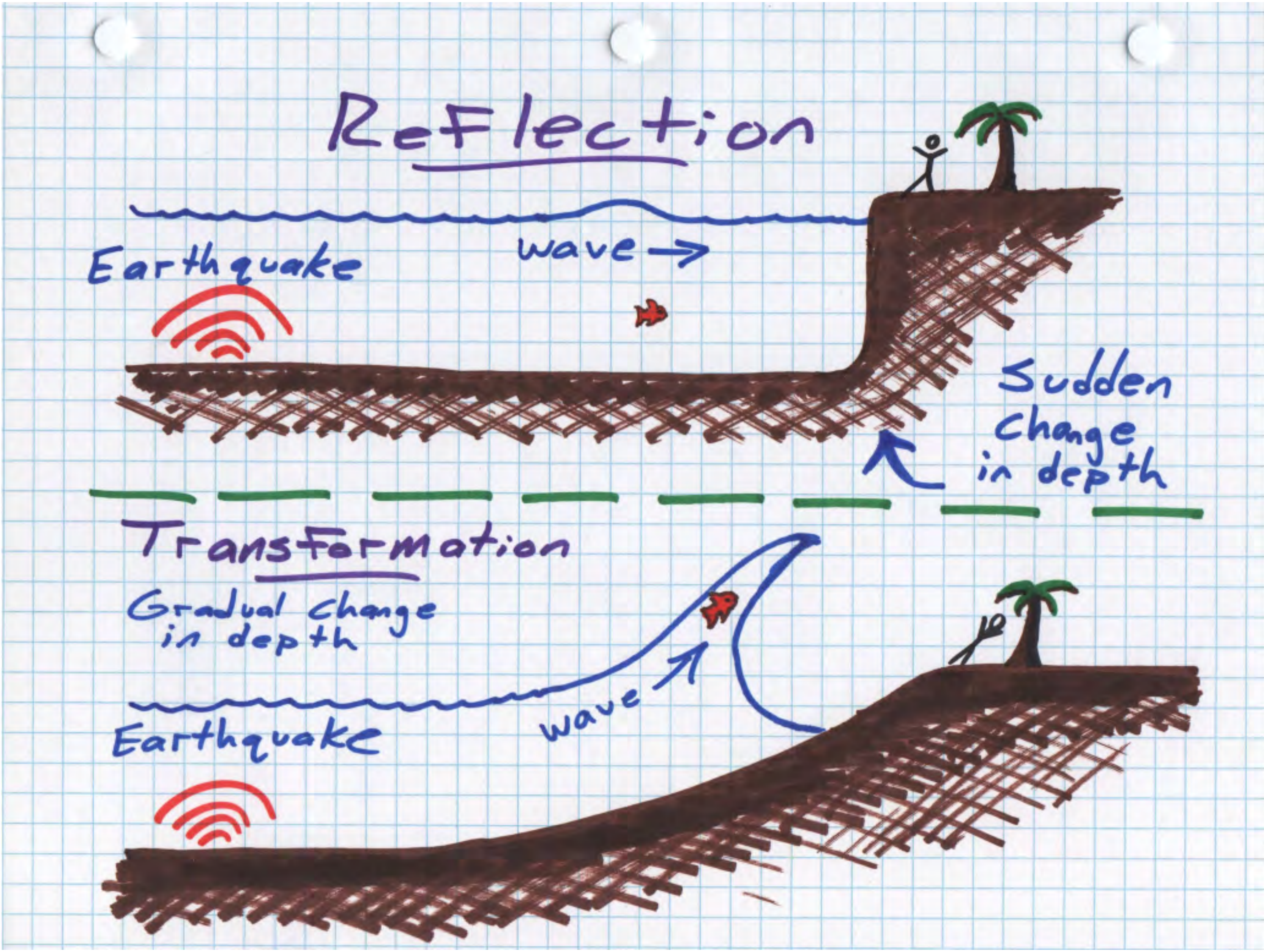
Un-matched Loads, Discontinuity, and Impedance bumps



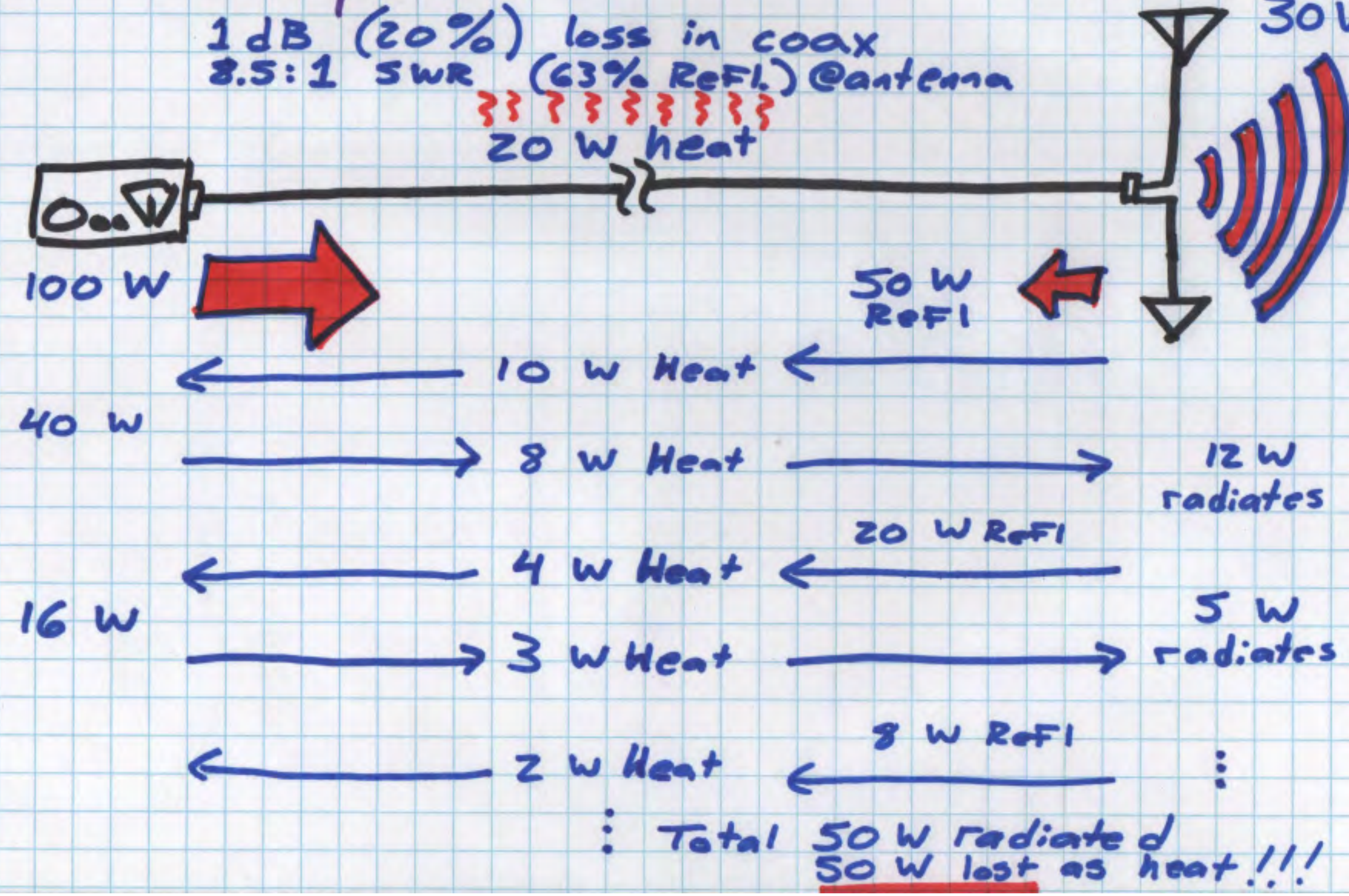
There's Always a Water Analogy



Flow is interrupted at discontinuity
some power rebounds
i.e. reflected


Reflection
wave
Earthquake
Sudden change in depth
Transformation
Gradual change in depth
wave
Earthquake

Reflections cause power loss



Reflections cause power loss

- Due to power traversing lossy transmission line <u>multiple</u> <u>times</u>
- Lower loss line = better performance

Hardline, Heliax, Ladder Line

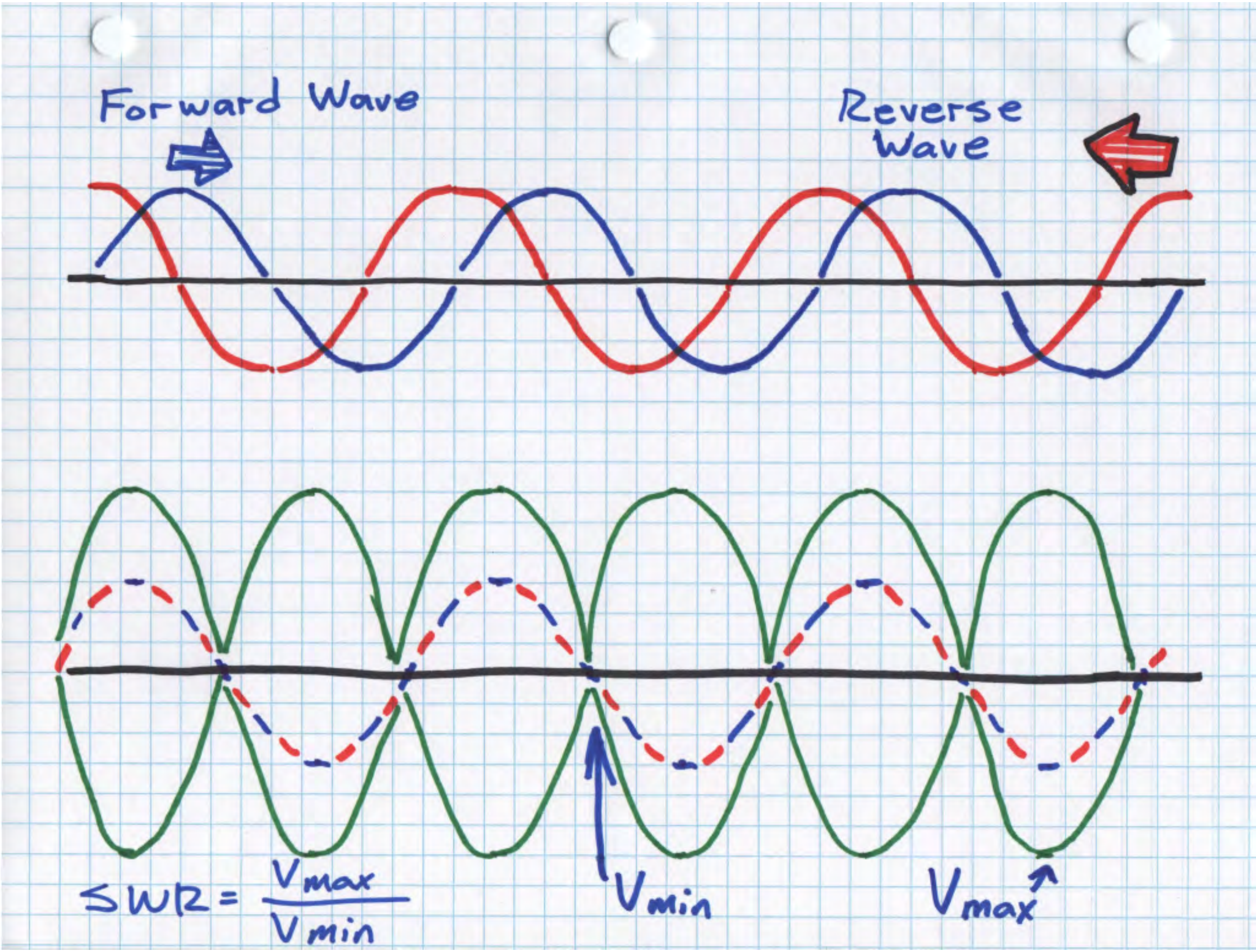
(((50 W)))

100 W · 1 dB line loss · 8.5:1 SWR = 50% loss

100 W · 0.054 dB line loss · 8.5:1 SWR = 6% loss

(((94 W)))

"Loss due to SWR"


Forward Wave
Reverse Wave
SWR = Vmax / Vmin
Vmin
Vmax

SWR Lessons

With short runs of low-loss line SWR is not a big deal

-UNLESS-

- Voltages get high enough to flash over
- Currents get high enough to start a fire

Useful

~~Stupid~~

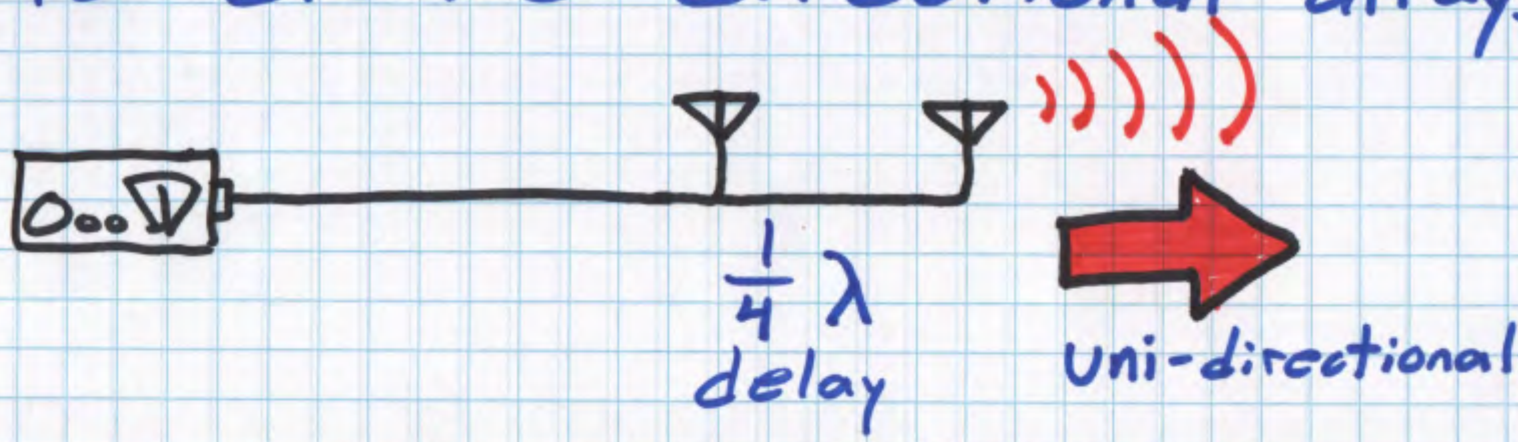
Transmission Line

Tricks

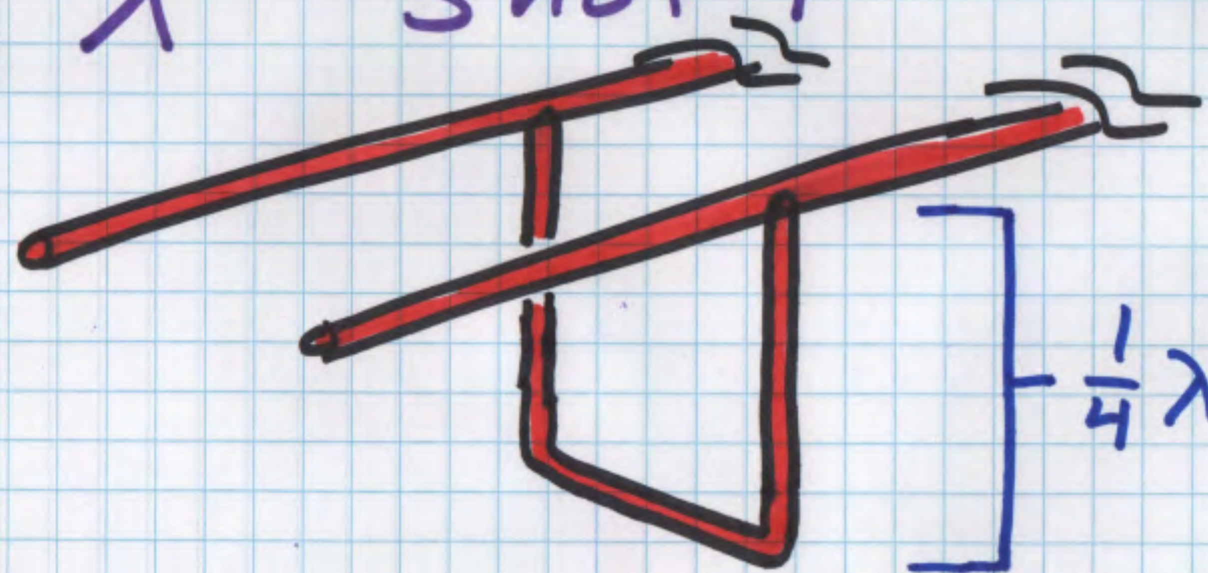
Phasing Lines

We are working with wavelengths from $\frac{3}{4}$ to a few dozen meters.

Use delay lines to deliver signals slightly out of phase to create directional arrays



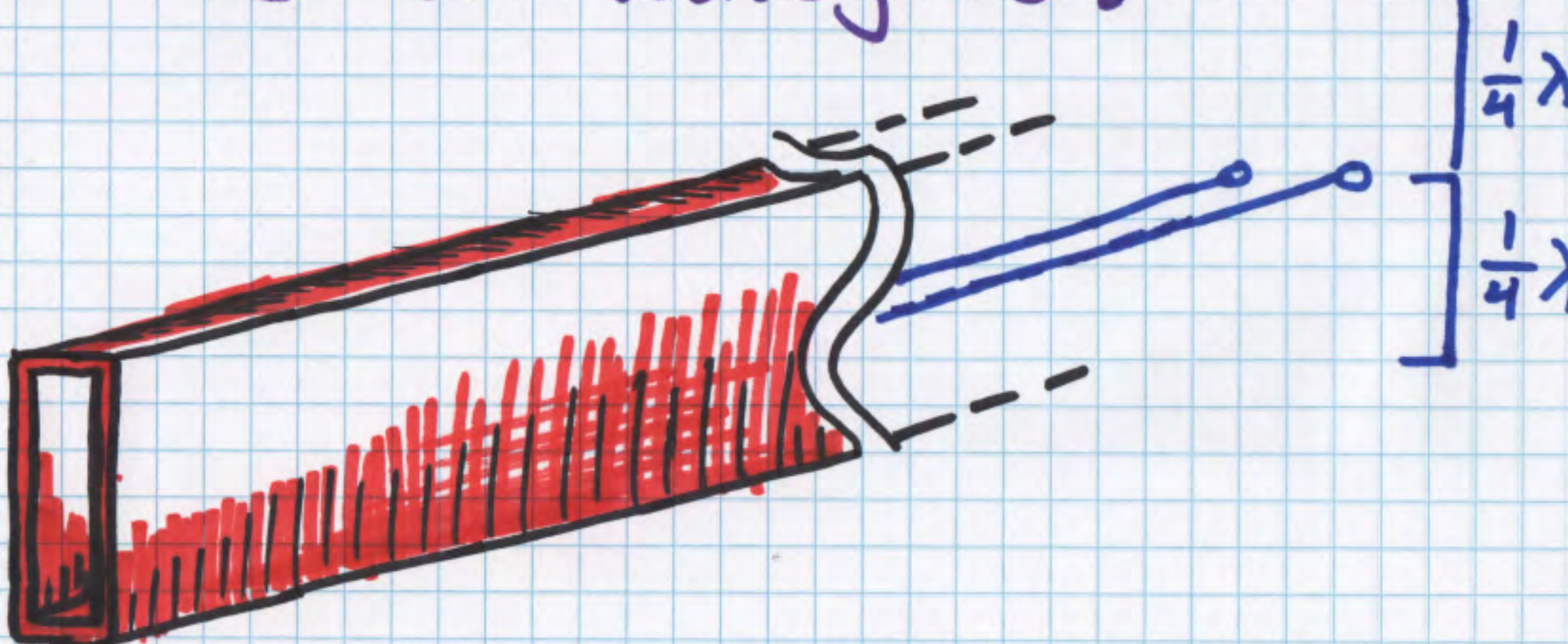
$\frac{1}{4}\lambda$ short



- Provides DC ground
- Invisible to RF
- Narrow-band (very)

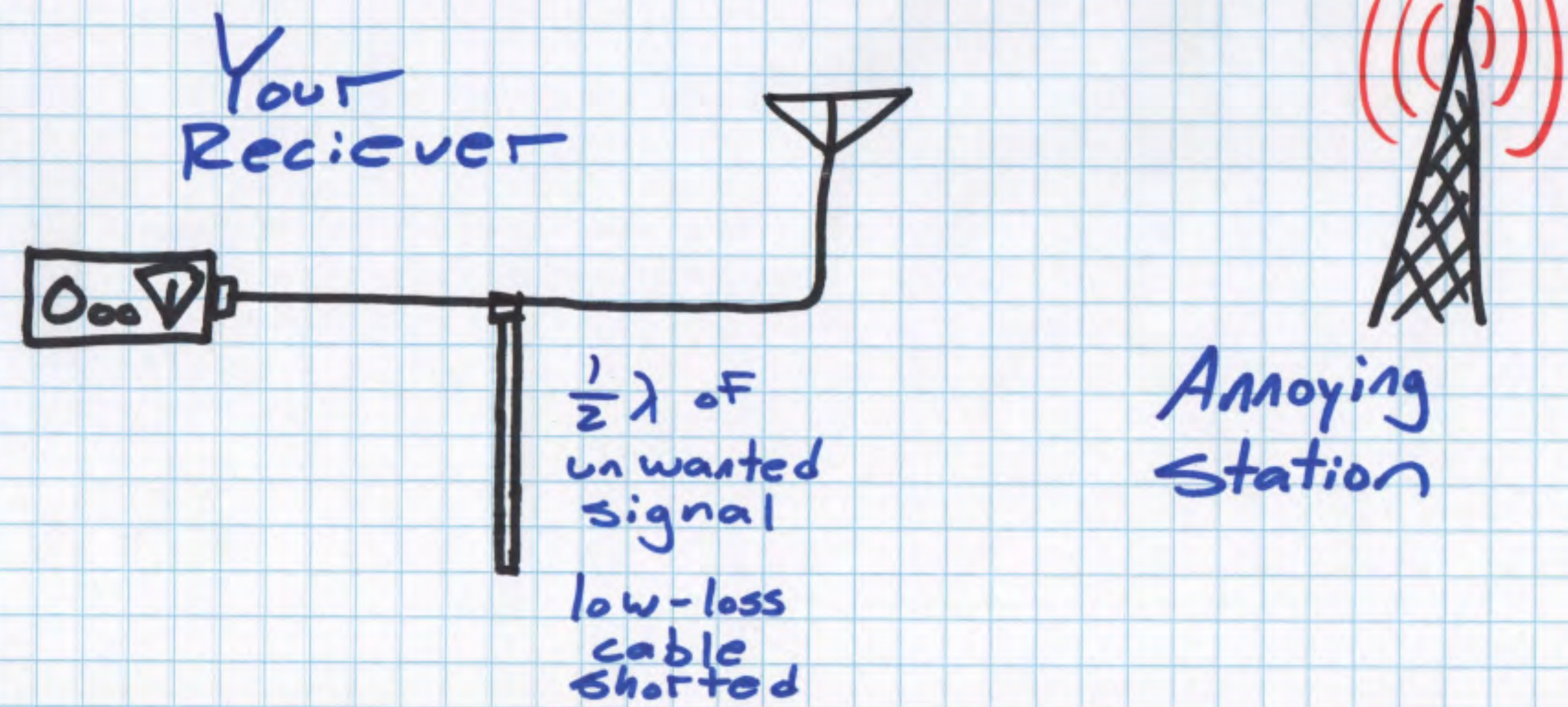
Continuous $\frac{1}{4}\lambda$ short

Is a Waveguide!

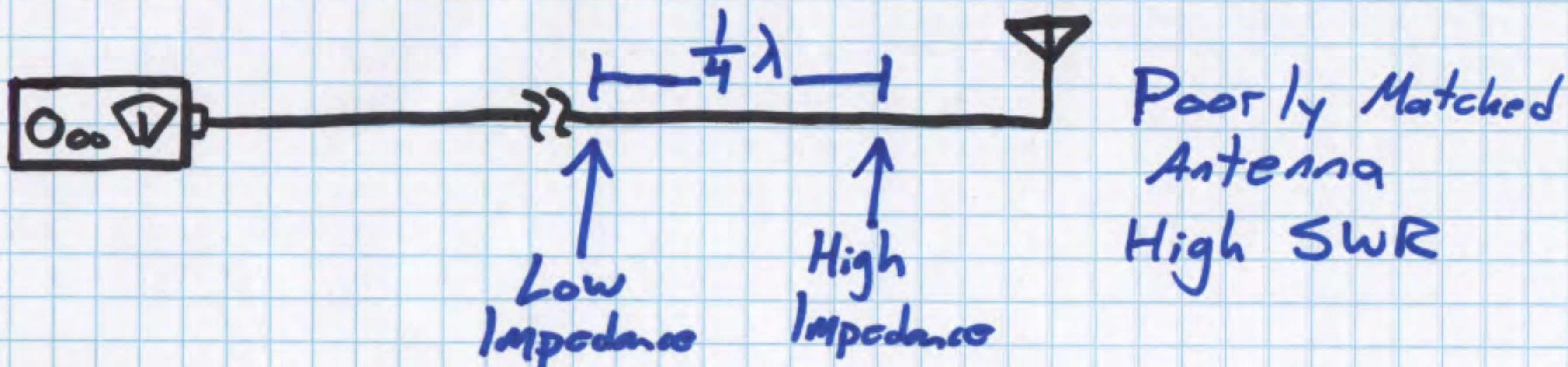


$\frac{1}{2}\lambda$ Short is

a narrow-band notch Filter



Impedance Transformer

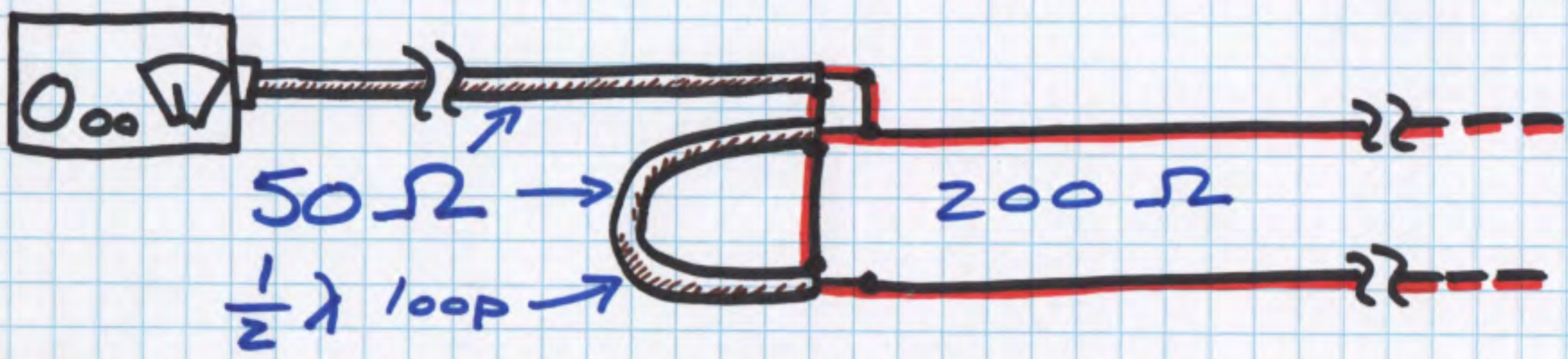


Maybe you can shorten or lengthen your transmission line to find a reasonable match to your transmitter.

Hint: G5RV does exactly this!

Impedance Transformer

Coax Loop 4:1 Balun



- Connect all shields
- Connect input center to one side of loop center
- Loop centers are 200 Ω output

Further resources

- Basic Antennas; Joel Hallas W1ZR
- Standing up for Standing Waves; Bill Hays
- Similarities in Wave Behavior; Dr JN Shive, AT&T Archives (YouTube)