BATHTUBS, SLINKIES, AND MIRRORS

Using common experiences to visualize wave physics in antenna feed line systems

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NEW IDEAS THAT YOU ALREADY KNOW

- It's easier to learn and understand something when the new idea fits into your vision of reality like a piece into a jigsaw puzzle.
- It's just an extension of what you already know.
- Once you know how it fits, it's easier to understand and remember.
- My goal is to make wave physics on antenna feed systems easier to understand.

A WAVE TRAVELS IN SOME MEDIUM

- A sound wave in the air
- A wave in water
- A wave down a string
- A wave of light
- A wave of electricity down a wire

AND THEN THE WAVE HITS SOMETHING

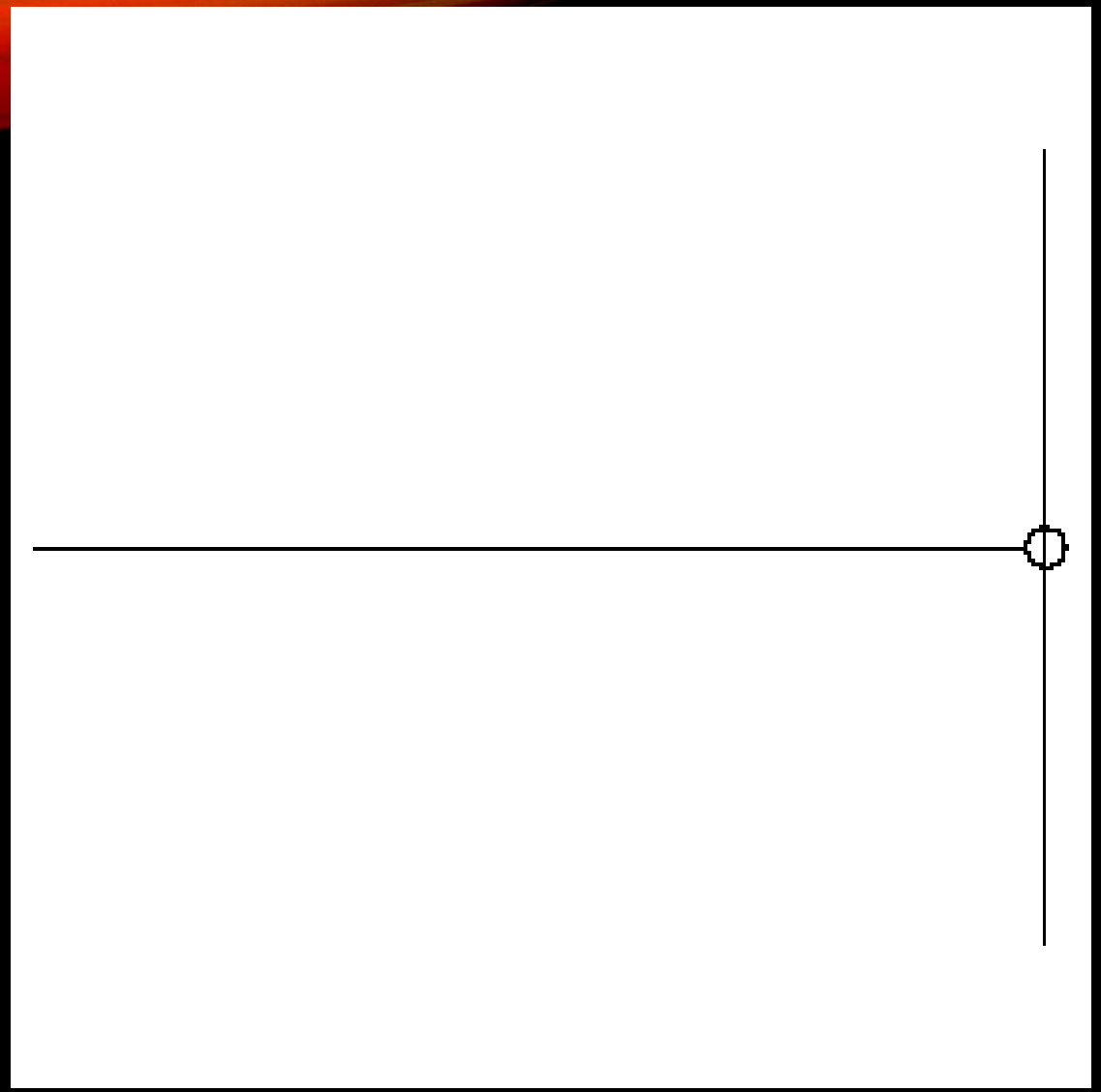
- A sound wave in the air
  - The end of the air (the canyon wall)
- A wave in water
  - The end of the bathtub
- A wave down a spring
  - The end of the spring
- A wave of light in the air
  - A window or mirror (The end of the air)
- A wave of electricity down a wire
  - The end of the wire

A SOUND WAVE

- Echo
  - Echo
    - Echo
      - Echo
        - Echo
          - Echo
            - Echo
              - Echo

SPRING DEMO

SPRING DEMO



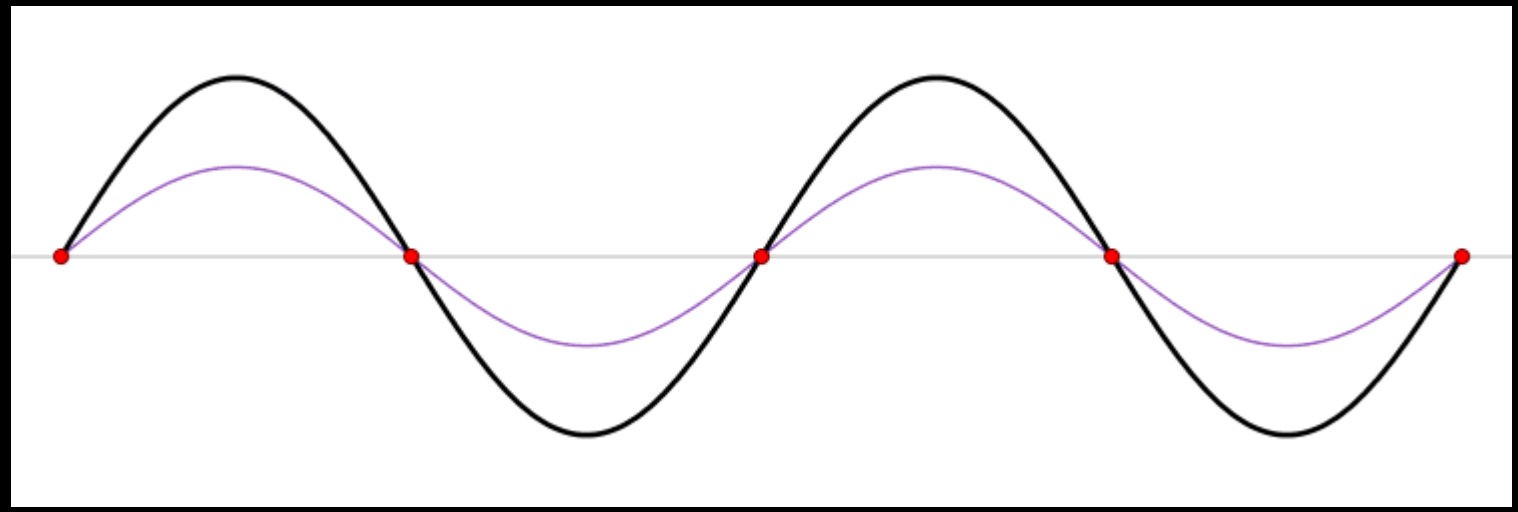
A RAY (WAVE) OF LIGHT HITTING A MIRROR

THE END OF THE WIRE

- We can't see anything
- But in all other cases, **the wave bounced back**
- Won't that also happen with electricity at the end of the wire?
  - Power spikes
    - Clicks you hear on the radio when you flip a light switch
    - Power spikes that cause sever overvoltage and destroy electronics
      - The inductive nature of power loads makes this problem far worse
      - Surge protectors

STANDING WAVES

- Waves move in one direction
- Waves reflect back



- The combined effect is standing waves

STANDING WAVES OFF THE SIDE A BRIDGE

STANDING WAVES AND RESONANCE

- When the reflected wave is reflected back
- And it matches and reinforces the original wave
- Then it builds up, finally limited by the resistance in the system.

DEMO STANDING WAVES ON SPRING

EXAMPLES OF RESONANT WAVES

- Vibrating stings on a musical instrument such as a guitar, piano, violin
- Column of air in flute or trumpet
- Light in a laser
- Radio waves in a microwave oven

WILL STANDING WAVES HURT MY RADIO?

WILL STANDING WAVES HURT MY RADIO?

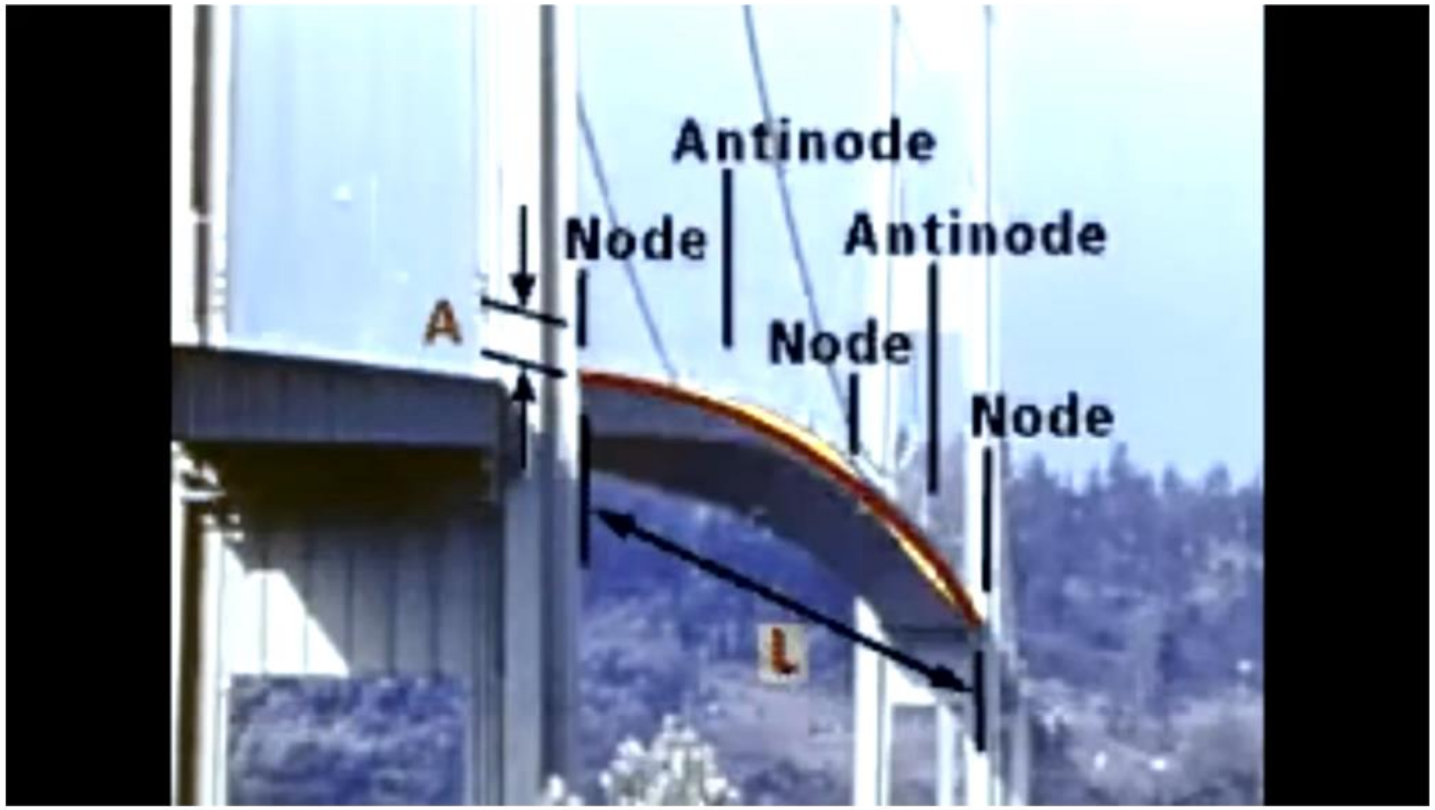
- Let's look at what standing waves will do to a bridge

(74) Standing wave Tacoma brid

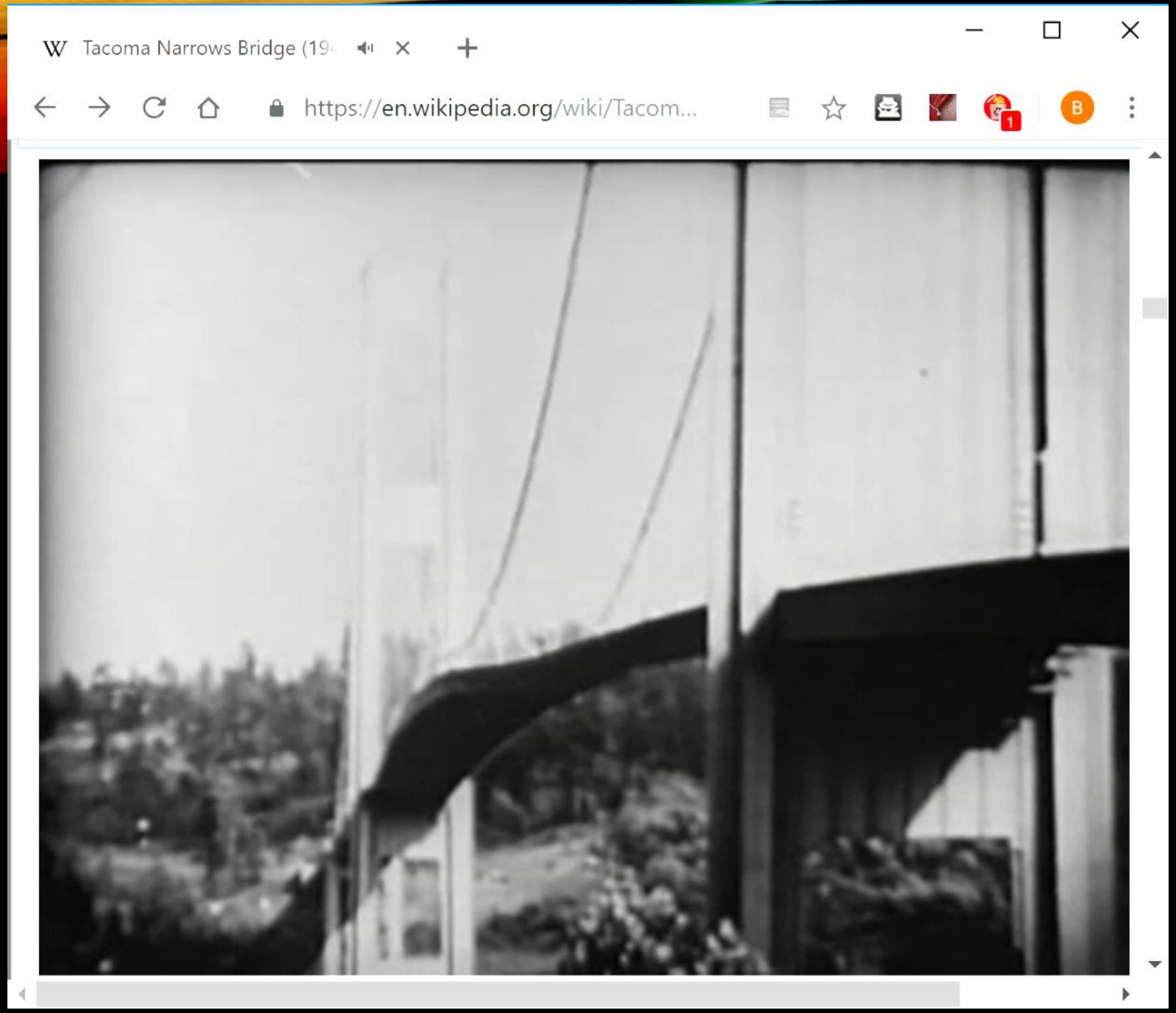
https://www.youtube.com...

YouTube

Search



Standing wave Tacoma bridge (looped)


Tacoma Narrows Bridge (19
https://en.wikipedia.org/wiki/Tacom...

STANDING WAVES IN A MICROWAVE

- Microwave and peeps.
  - 2.45 G
  - 300 / 2450 = .1225 meters
  - ½ wavelength = .061 meters
  - ½ wavelength = 2.4 inches

- The rotating plate moves the food so the standing don't heat just parts of the food.

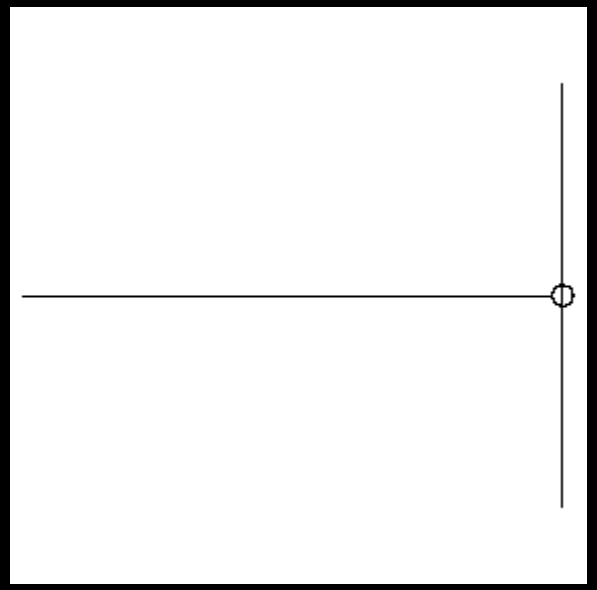
PARTIALLY MELT PEEPS IN MICROWAVE WITHOUT THE ROTATING PLATE.

OPEN/SHORT

- Spring Demo

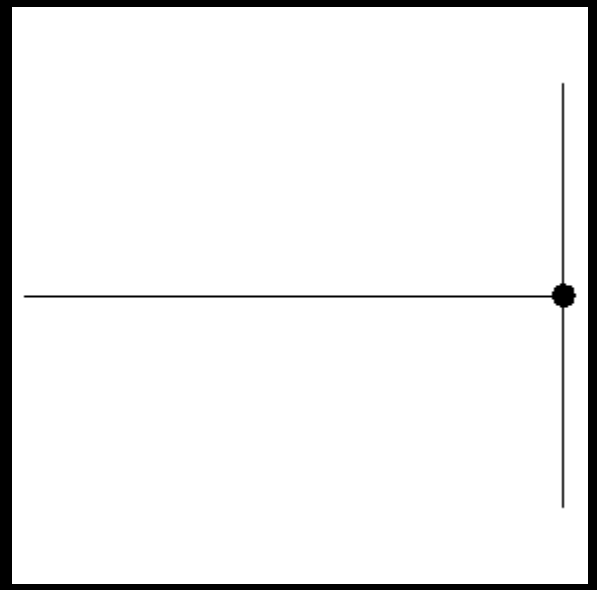
BACK TO THE SPRING

- Reflections with free end



- Momentum

- Reflections with secured end



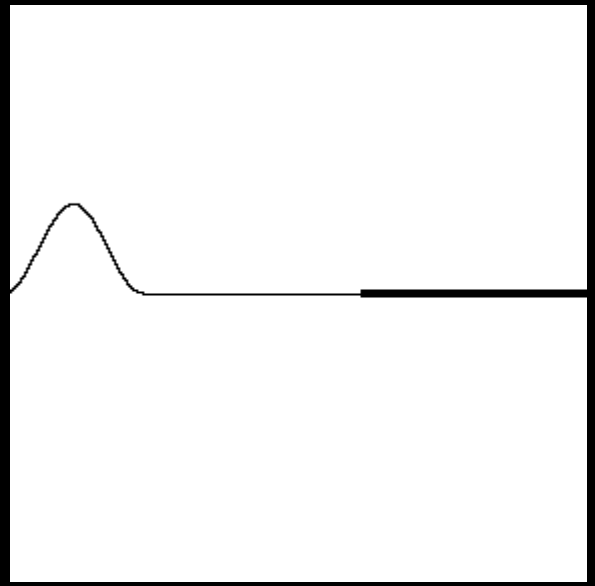
- Energy

MISMATCHES CAUSE REFLECTION

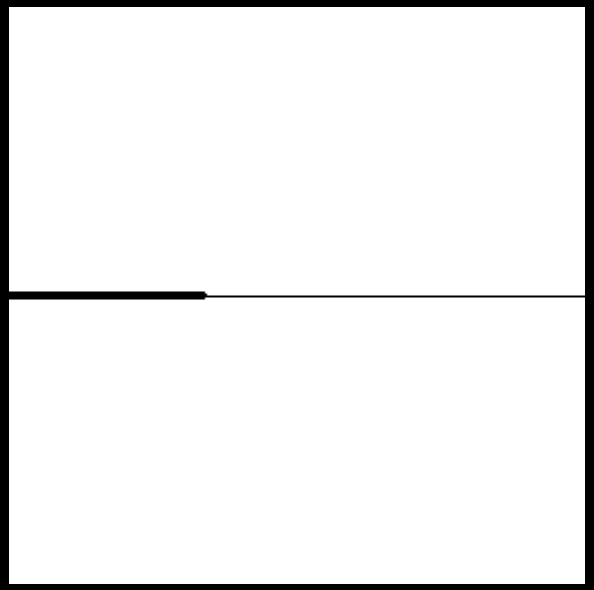
- Shorts cause reflection in one direction
- Opens cause reflections in the other direction
- As you move between a short and an open
  - The reflection will get smaller, minimize, and get larger in the opposite direction
  - At the minimized point, you have the best match.

- Discontinuities in the feed line
  - Kinks
  - Wrong connectors
  - Bad connection

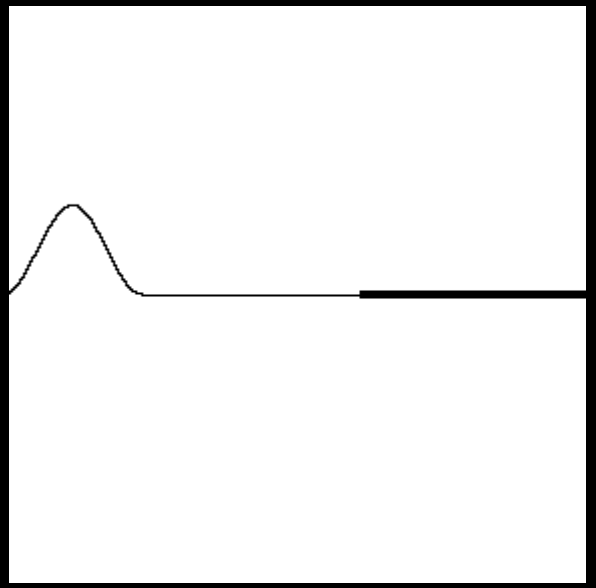
MISMATCH HIGH IMPEDANCE TO LOW IMPEDANCE

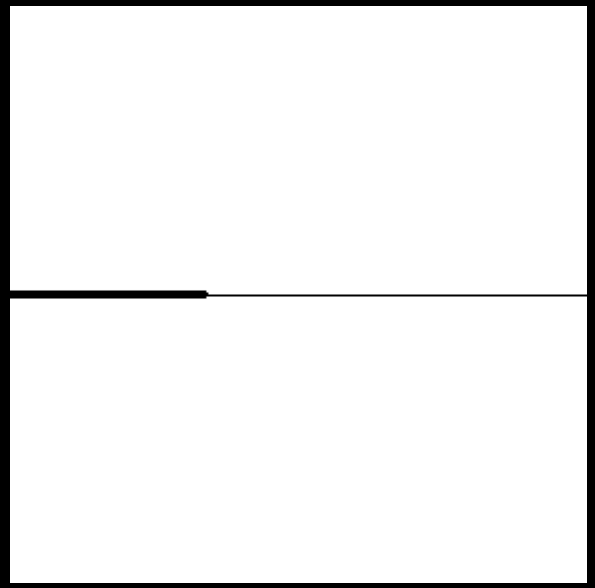


MISMATCH LOW IMPEDANCE TO HIGH IMPEDANCE



PARTIAL REFLECTIONS





PARTIAL REFLECTION OF WAVES OF LIGHT

SOMEWHERE IN THE MIDDLE

- Between the wave that is reflected positively
- And the wave that is reflected negatively
- Is a point where no wave is reflected at all. This is a matched junction.

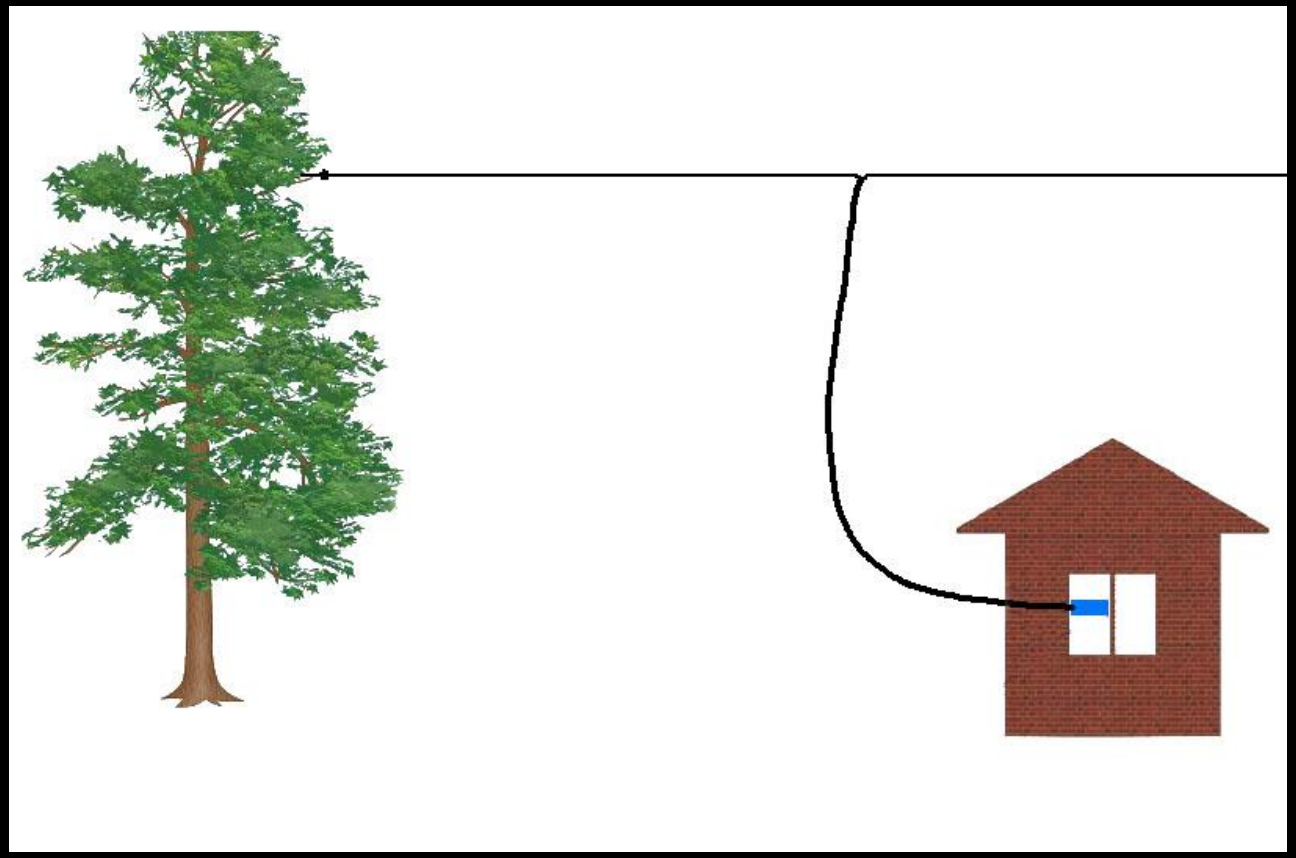
- Reflected waves travel more than once on the feed line.

MATCH / MISMATCH DEMO

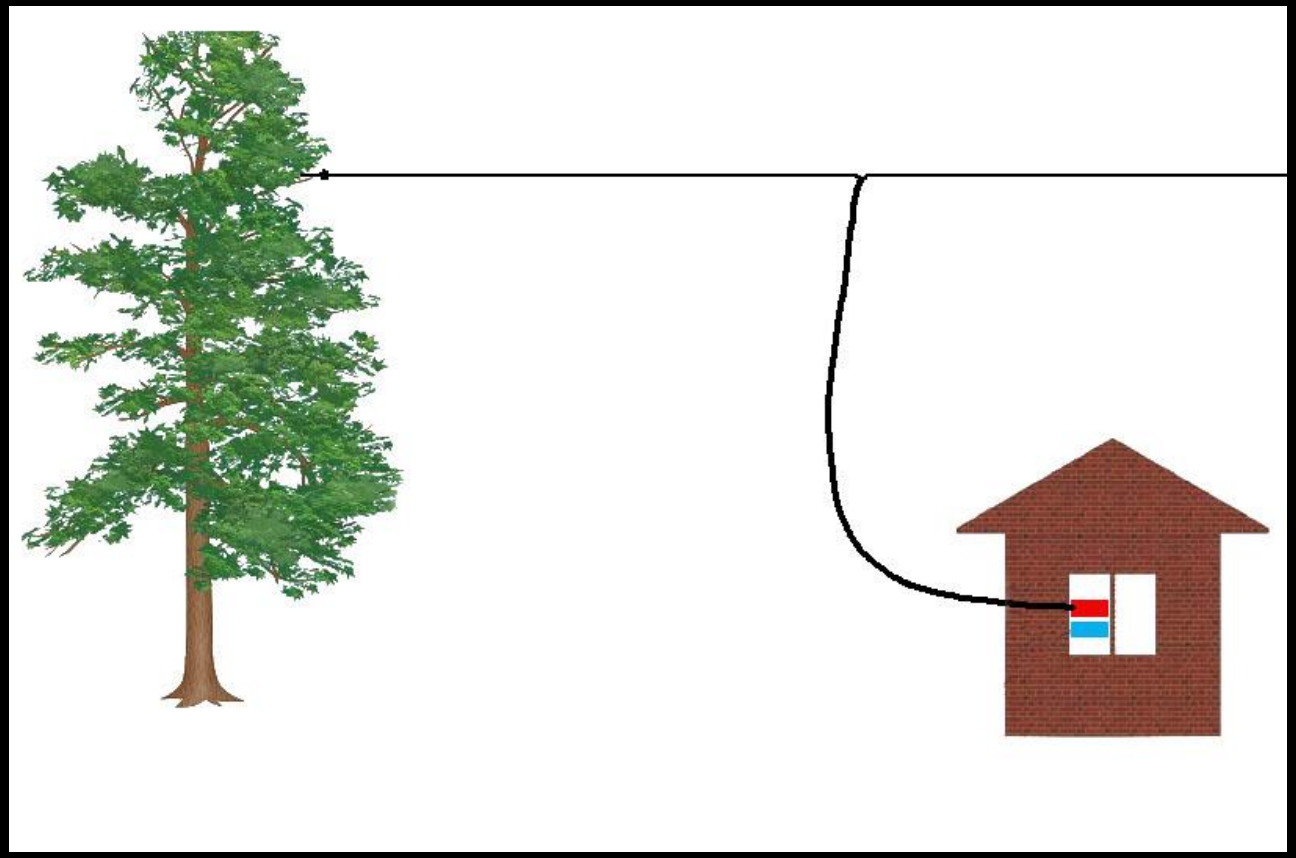
TRANSMISSION LINE LOSSES

- Refection Points
  - Mismatched Feedline / Antenna
  - Mismatched sections of Feedline
  - Kinks and feed-line damage
  - Mismatches because connector is not rated for higher Frequency
    - Ex. 239 connectors on UHF

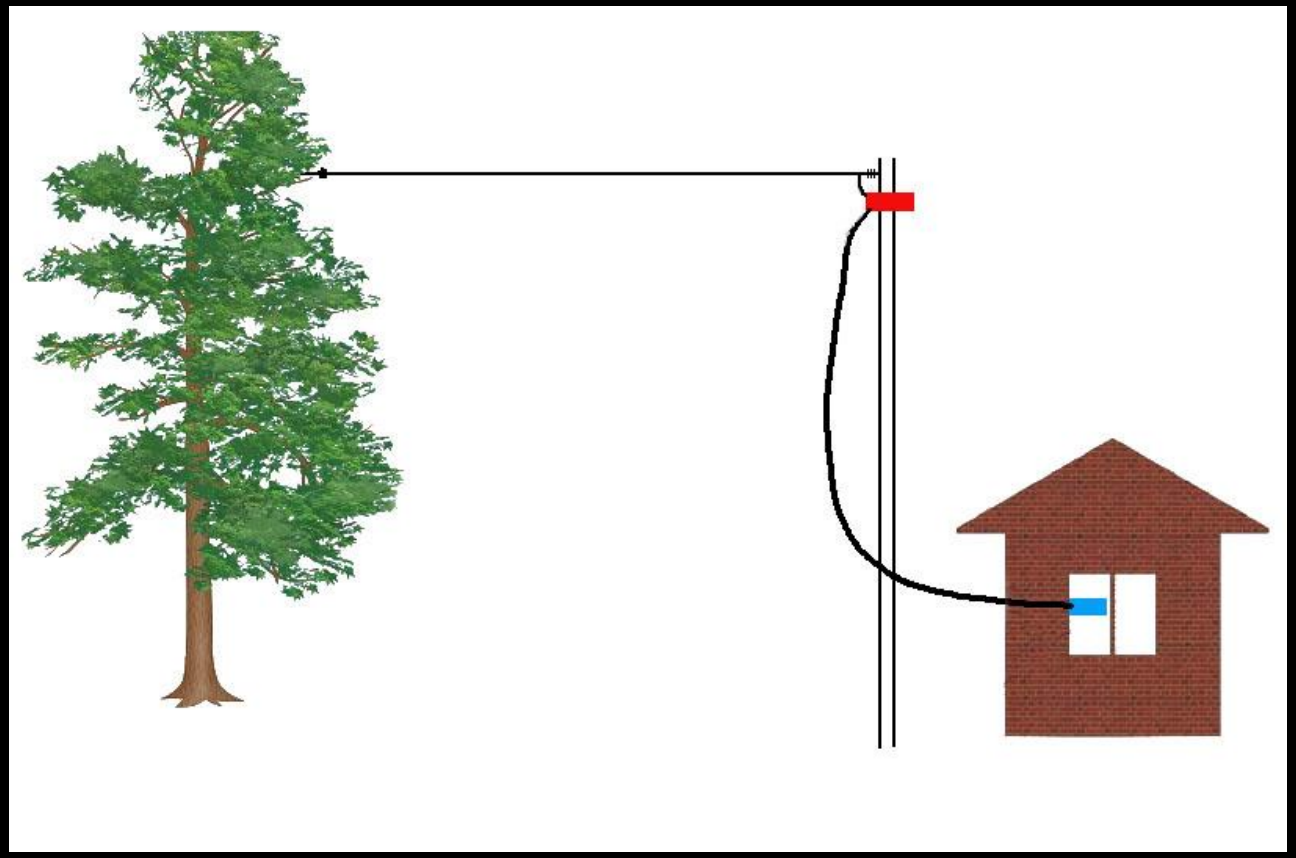
FINALLY WE TALK ABOUT ANTENNAS



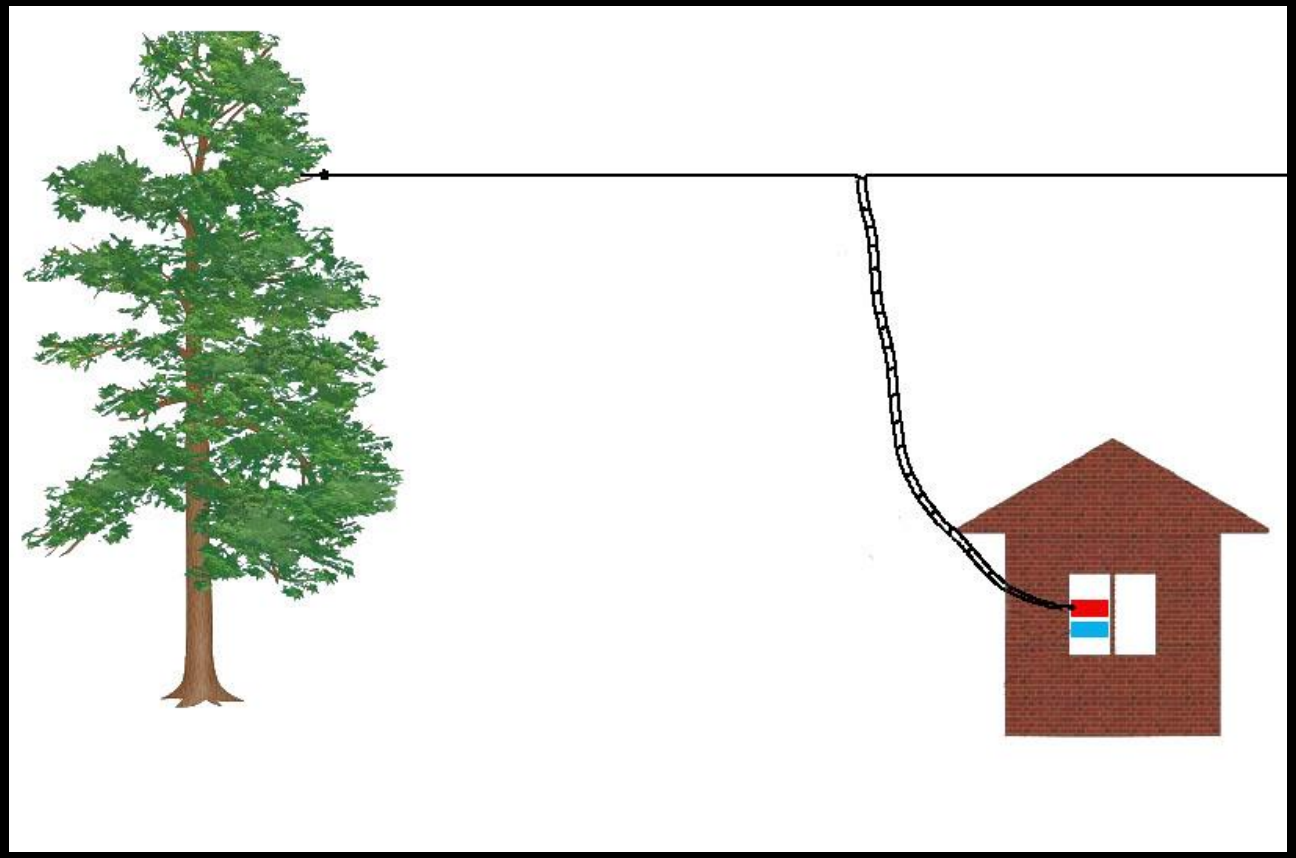
ANTENNA TUNER IN SHACK



ANTENNA TUNER AT ANTENNA FEED POINT



LADDER LINE IS GREAT



LINE LOSSES ON 100 FEET OF FEED LINE

Feed Line	Freq	SWR 1:1	Loss	SWR 3:1	Loss	SWR 10:1	Loss
RG-58 Coax	10 MHz	1.12 dB	23 %	1.66 dB	32 %	3.71 dB	67%
RG-213 Coax	10 MHz	0.62 dB	13%	0.97 dB	20%	2.40 db	42%
450 ohm Ladder	10 MHz	0.21 dB	5 %	0.33 dB	7.4%	0.93 dB	19%

OPEN / SHORT REVISITED

- Short reflect in opposite direction
- Opens reflect in same direction

Short (Fixed end) spring stretches out, and is then pulled back, but because the end is fixed, the pull back is against the wave. The reflection is reversed.

Voltage is zero

Current flows

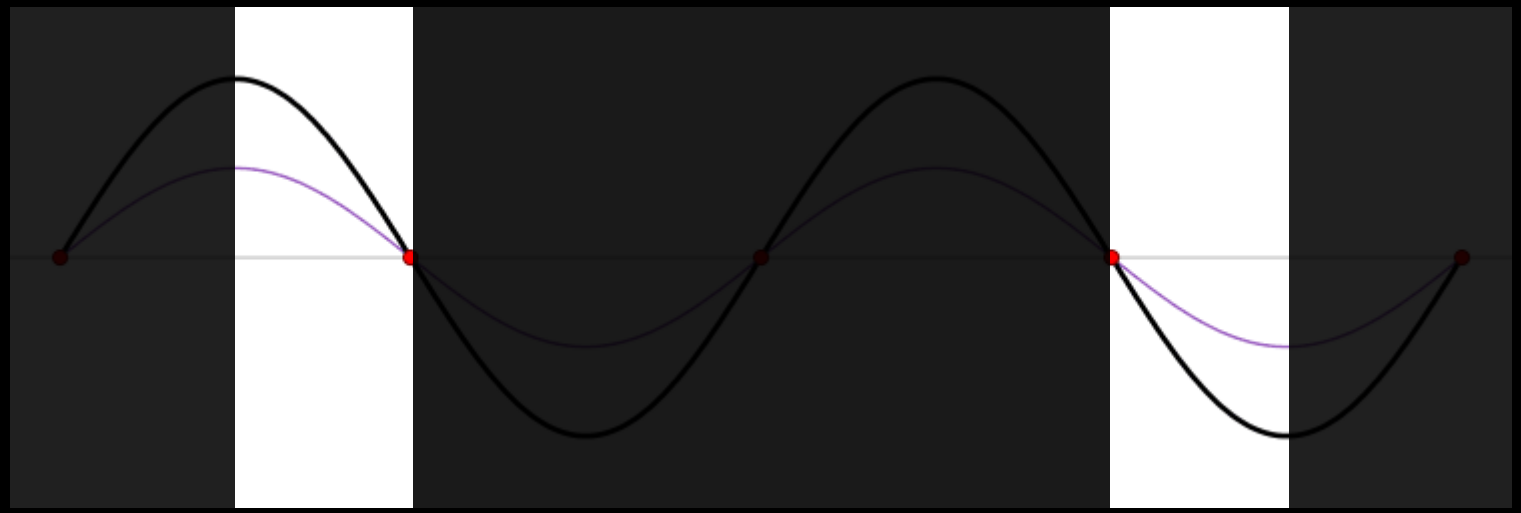
Open spring swings, then swings back. Reflection is same.

Voltage swings freely

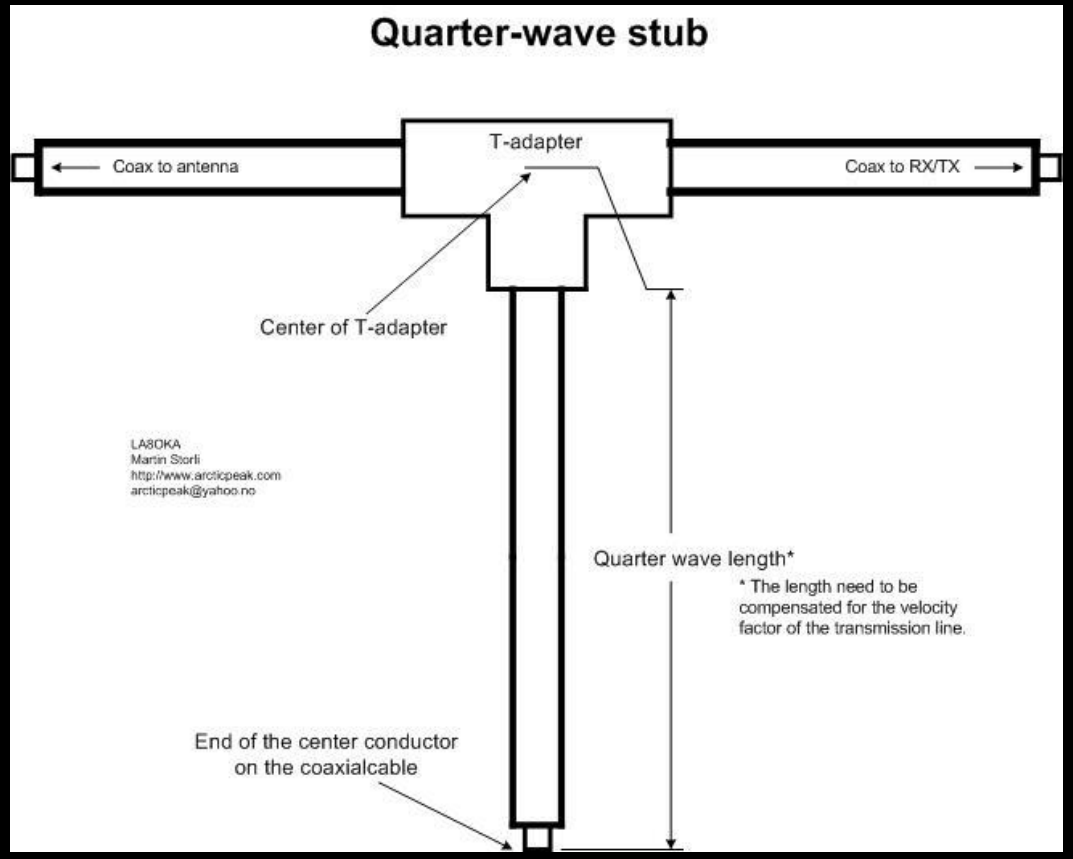
Current is zero

QUARTER WAVES

- Open on one end appears Closed (Shorted) on the other



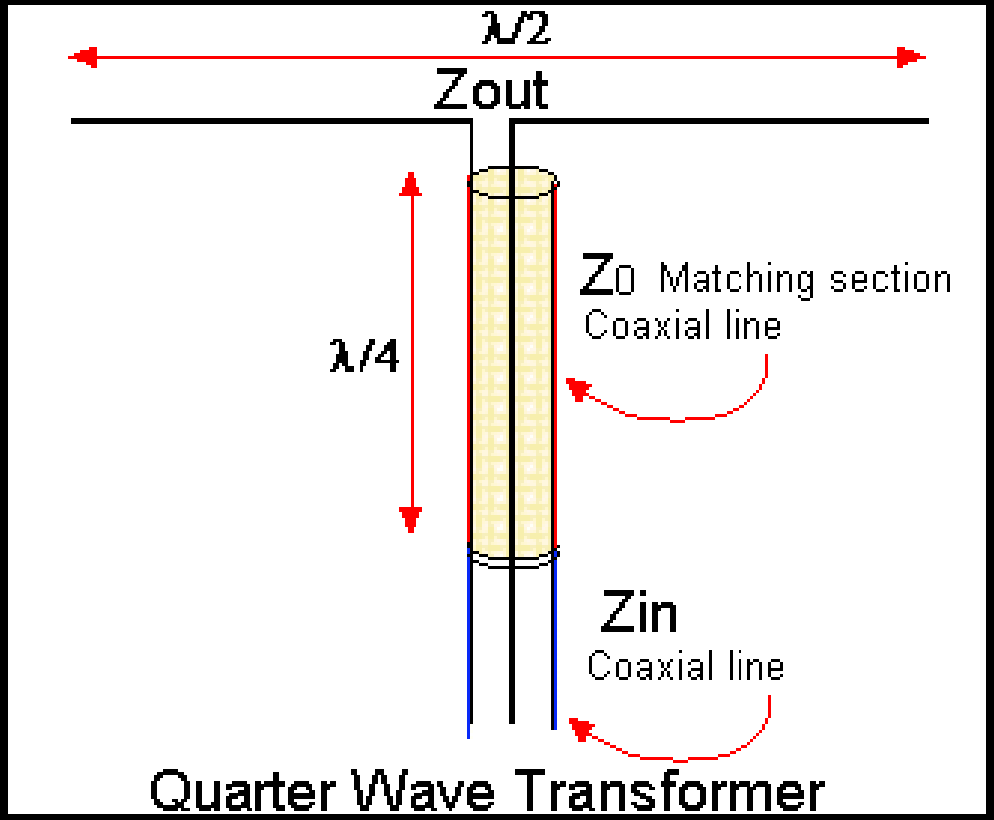
QUARTER WAVE STUB



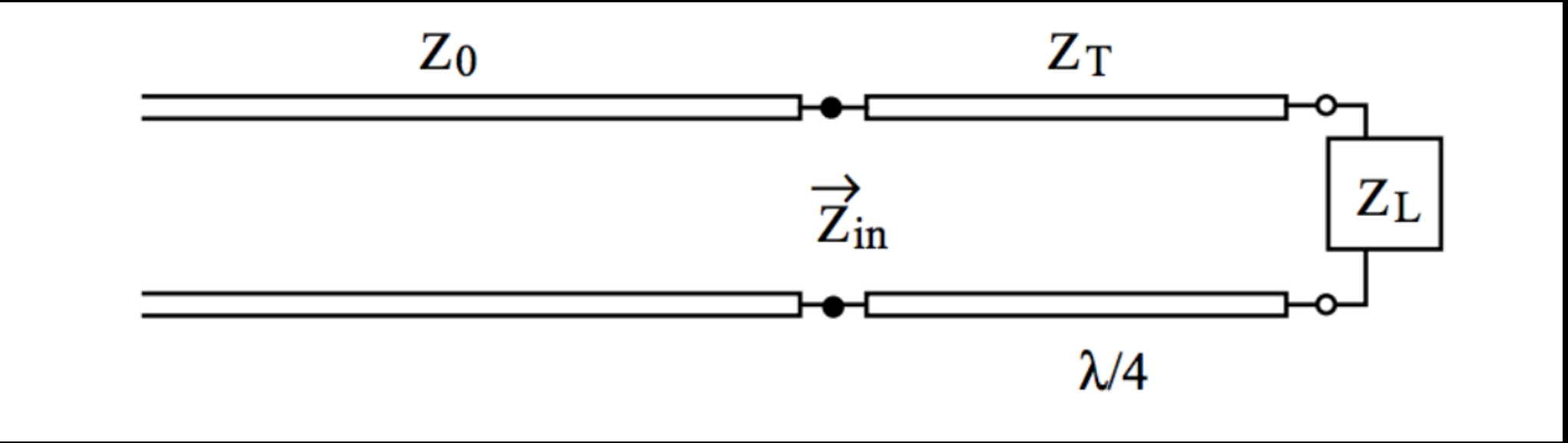
QUARTER WAVE STUB FILTER

- At a specific frequency:
- Open quarter wave stub will appear as a short.
- Can be used to short out harmonics. Use open quarter wave stub at harmonic frequency.
- My transmitter at 40 meters with second harmonics (20 meters)
  - Open quarter 20 meter stub will short out my 2^{nd} harmonics.

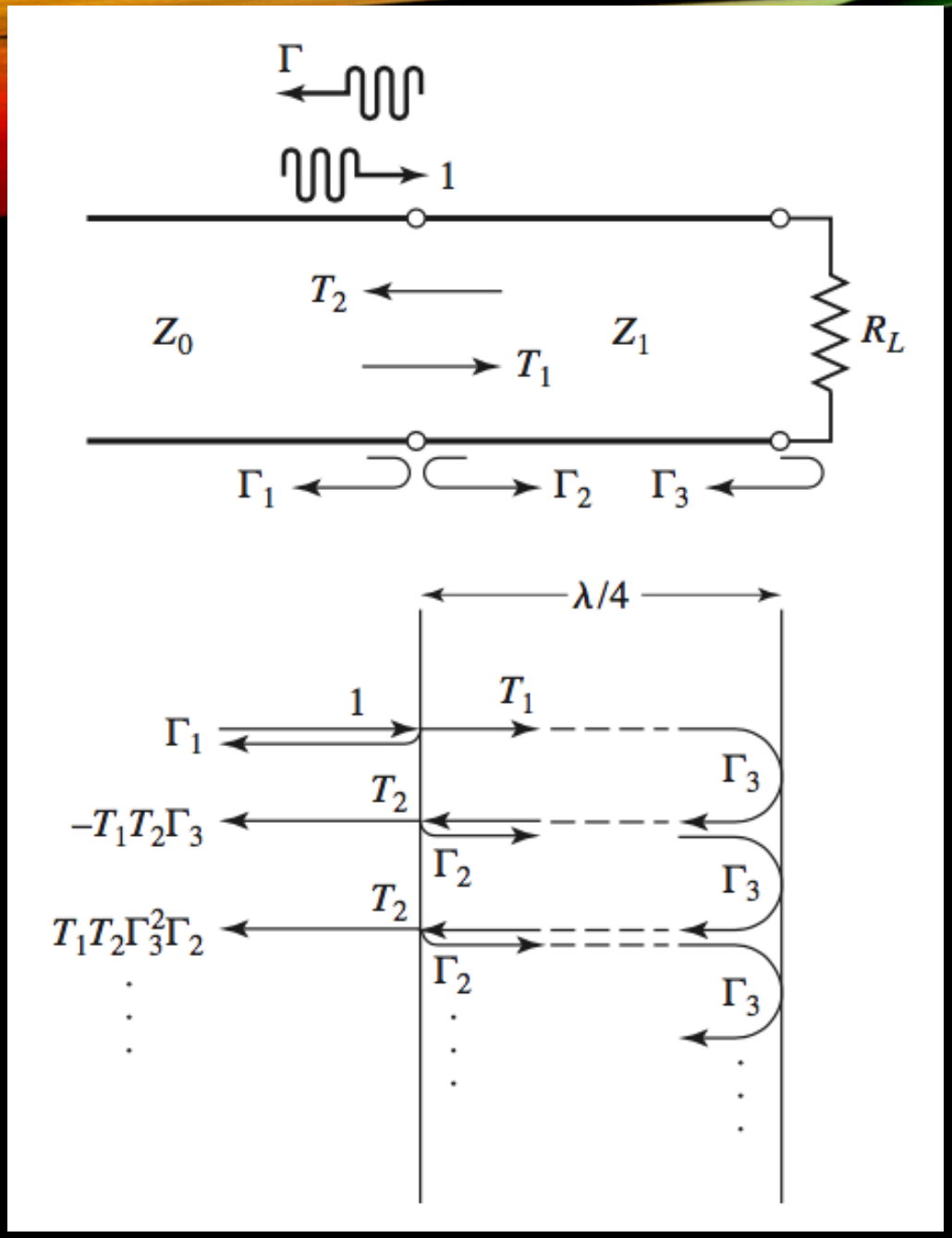
QUARTER WAVE TRANSFORMERS



QUARTER WAVE TRANSFORMERS



$$Z_T = \sqrt{Z_0 Z_L}$$

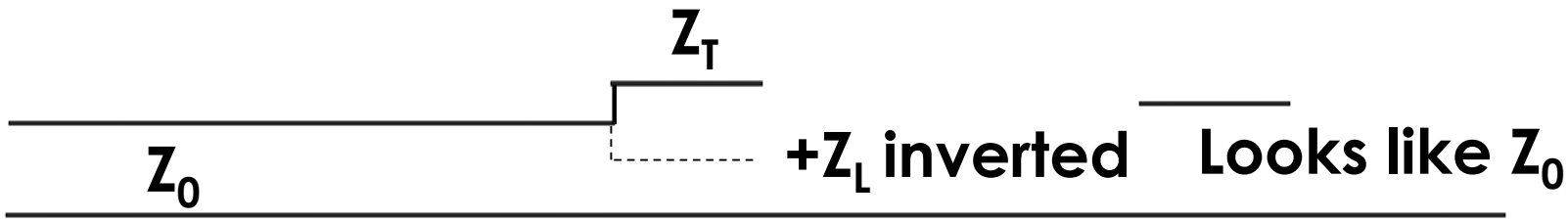


An infinite number of reflections and re-reflections sum up

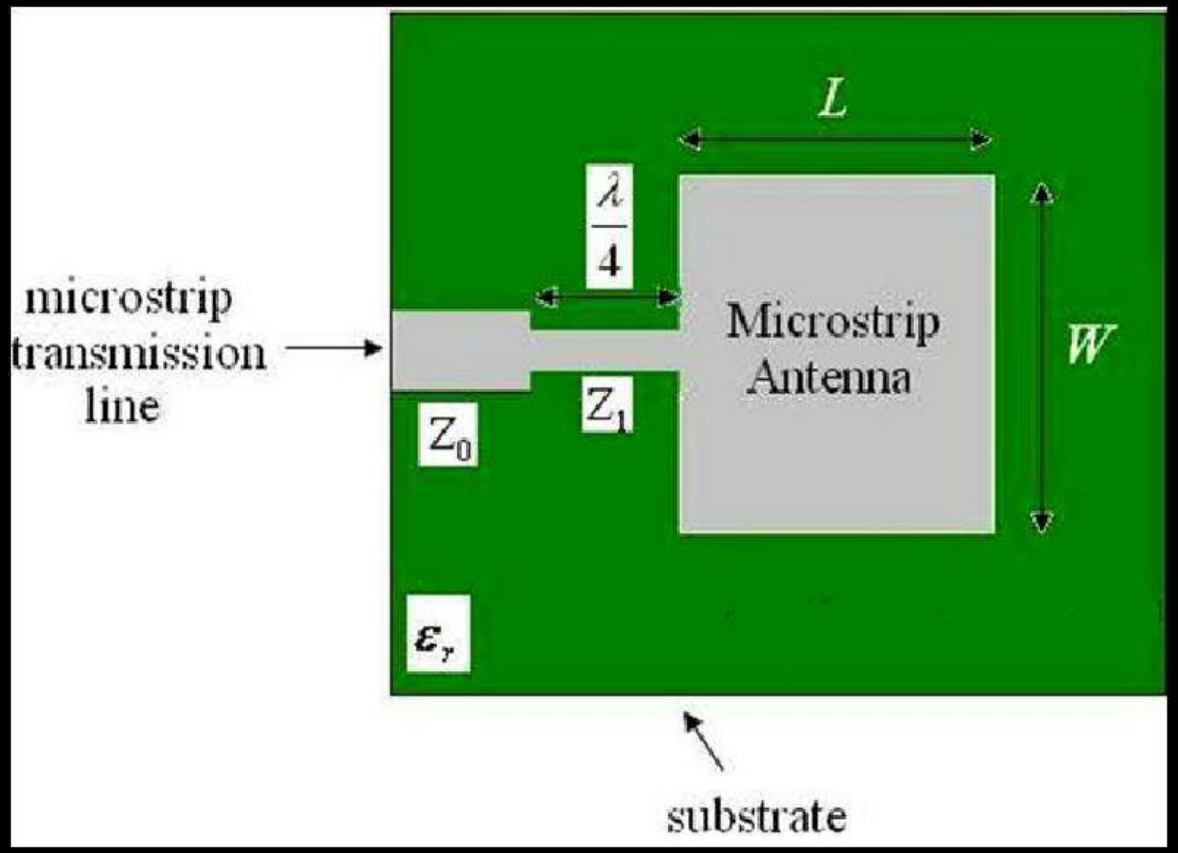
- No reflections
- No power loss
- Load appears as Z_0

If Z of the load is high,

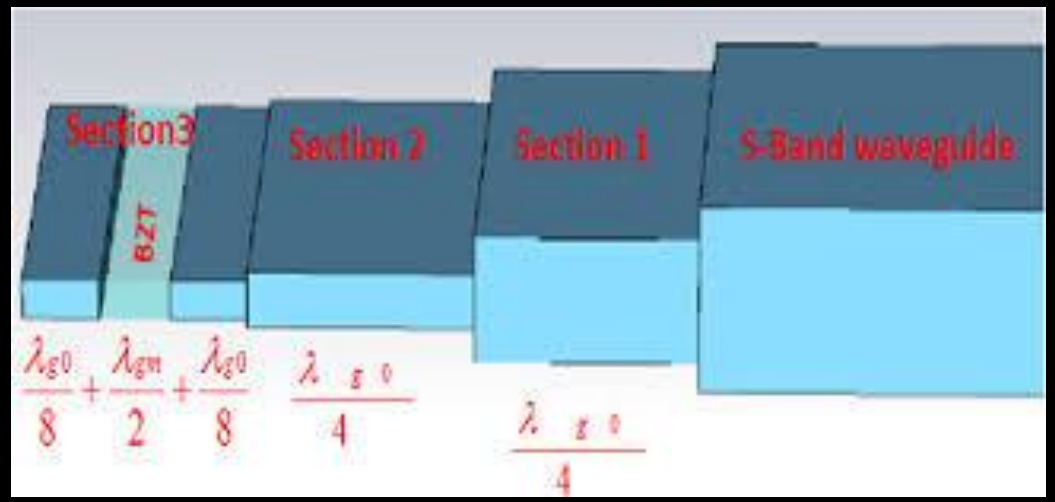
the other end of a quarter wave section makes it look low. Z_T combined with the inverted $Z_L = Z_0$



QUARTER WAVE TRANSFORMERS ON PC BOARDS



MICROWAVE
- STEPPED GUIDE
- VARIABLE GUIDE (MICROWAVE HORN)

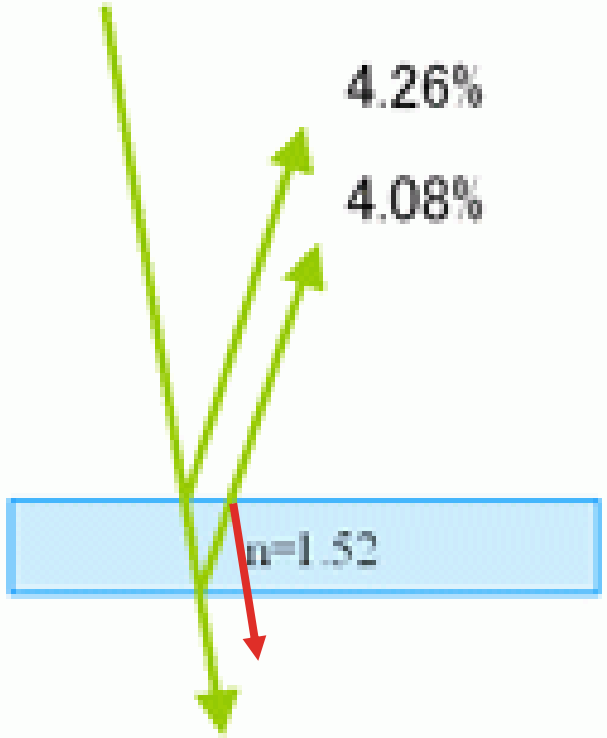


THESE ARE ALL FORMS OF MATCHING FROM SOUND GENERATOR TO THE OPEN AIR

QUARTER WAVE ANTI-REFLECTIVE COATING

example of Anti Reflection coating effect

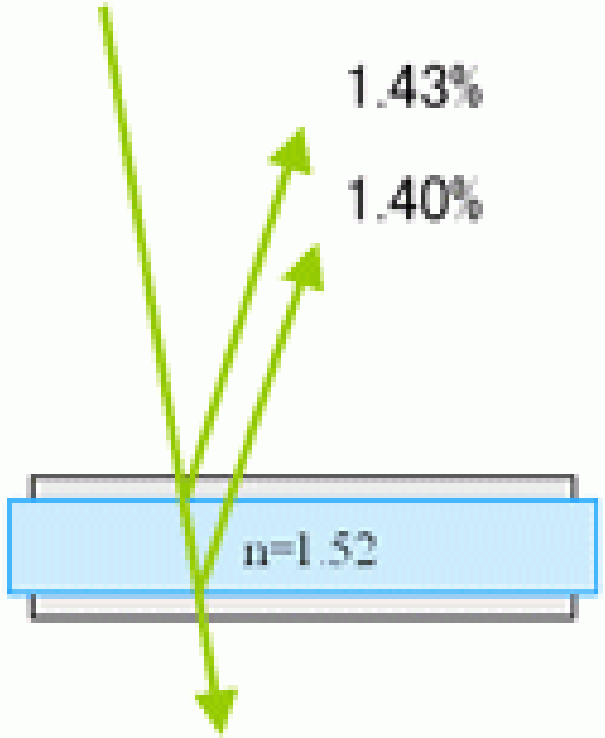
Without AR Coating



Transmittance = 91.83%

Reflectance = 8.17%

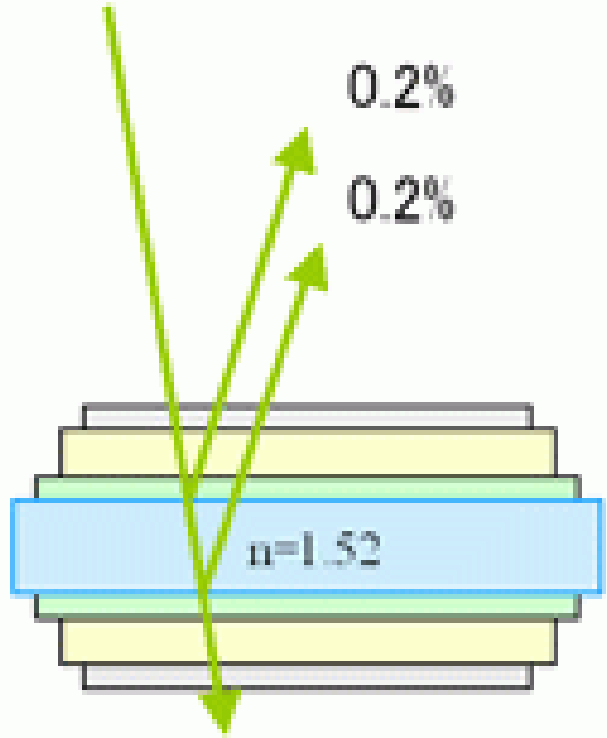
Single-layer coating of MgF2



Transmittance = 97.19%

Reflectance = 2.81%

Multi-layer coating by NIDEK



Transmittance = 99.6%

Reflectance = 0.4%

In Summary, waves are waves