

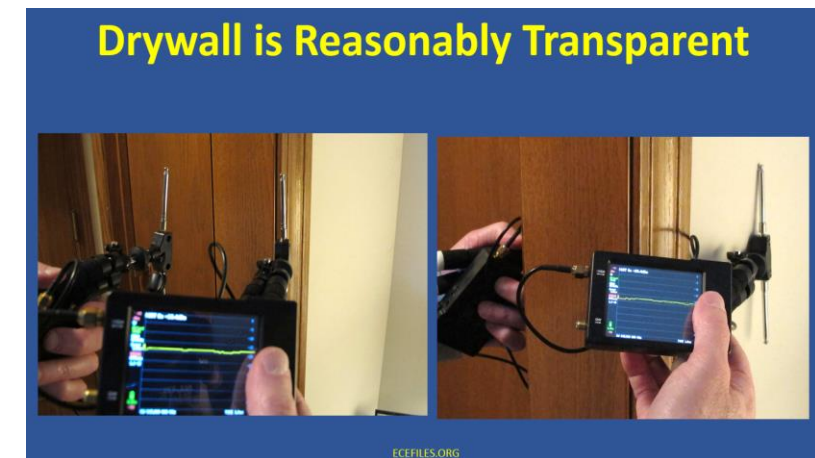
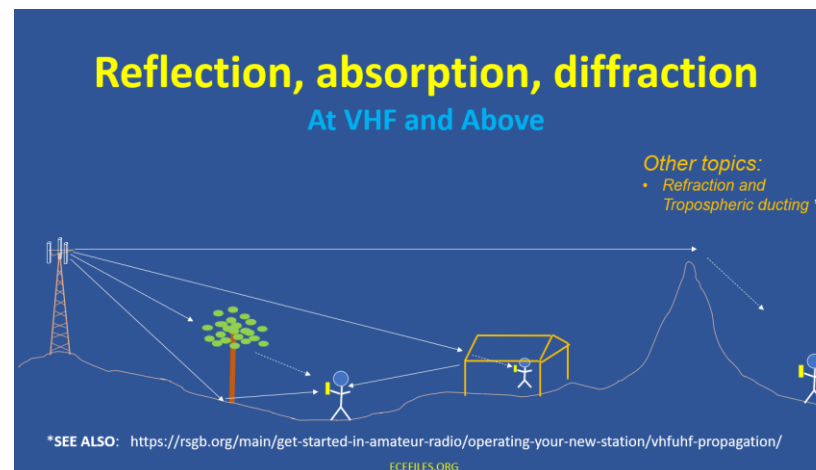
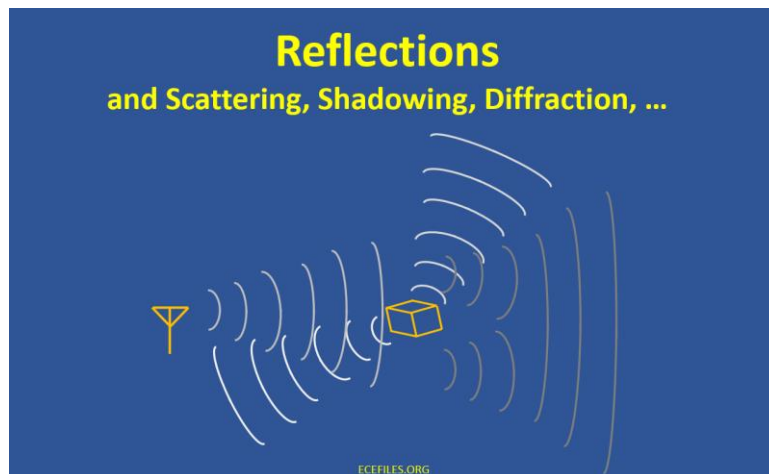
Antenna Briefs #7 -- Radio Wave Reflections (and Absorption, ...)

Slides downloaded from: <https://ecefiles.org/rf-design/>

Companion videos at: <https://www.youtube.com/watch?v=gKNsVSUiS9I> (Part 1)
and <https://www.youtube.com/watch?v=-SpPvlauMBo> (Part 2)

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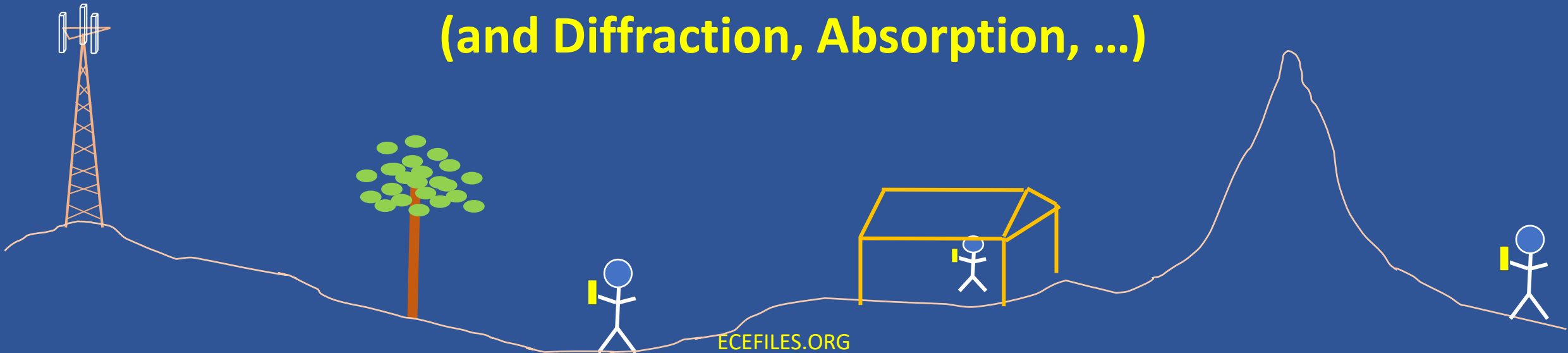
This episode covers reflection of radio waves and how this phenomenon is important in propagation and in the design and construction of directional antennas. Part 1 overviews both, as well as introducing related effects including refraction, diffraction, absorption, and scattering. The main focus is at frequencies of VHF and above, including cellular, but a brief mention of HF propagation is also made. The second part provides an overview of how EM fields are reflected (and/or absorbed) by materials including metal and wood, and shows real-world measurements of reflection and absorption (attenuation) for typical materials found in residential and commercial buildings.



Antenna Briefs #7 – Part 1

Radio Wave Reflections

(and Diffraction, Absorption, ...)



Recall Previous Episodes

Antenna Briefs #2



Power, Range, and Licensing



Summary and Caveats

$$P_t = \frac{V_t^2}{R_{ant}} \text{ Watts (1)}$$

$$P_{density} = \frac{P_t G_t}{4\pi d^2} \text{ Watts/m}^2 \text{ (2)}$$

$$P_r = P_{density} A_{eff} \text{ Watts (3)}$$

- Equation (2) is only true for a “free-space” environment
- Terrestrially, d^2 becomes d^4 or worse unless one or both antennas are well above ground and/or very directional, and we have “line of sight” between them
- So 32 km (20 miles) reduced to 130 m (420 ft.) !



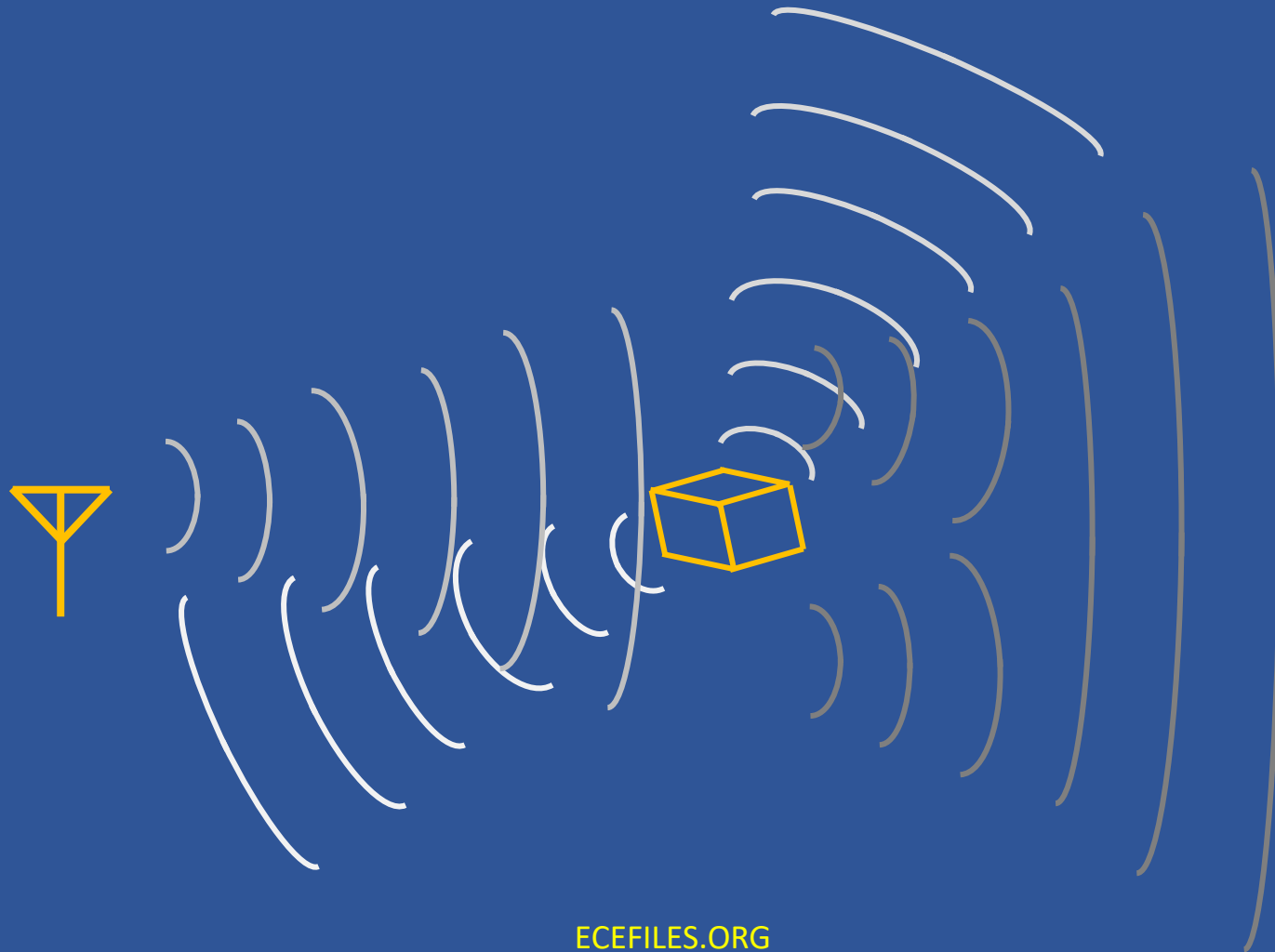
Why ??



Terrestrial Environments have “stuff” in them !



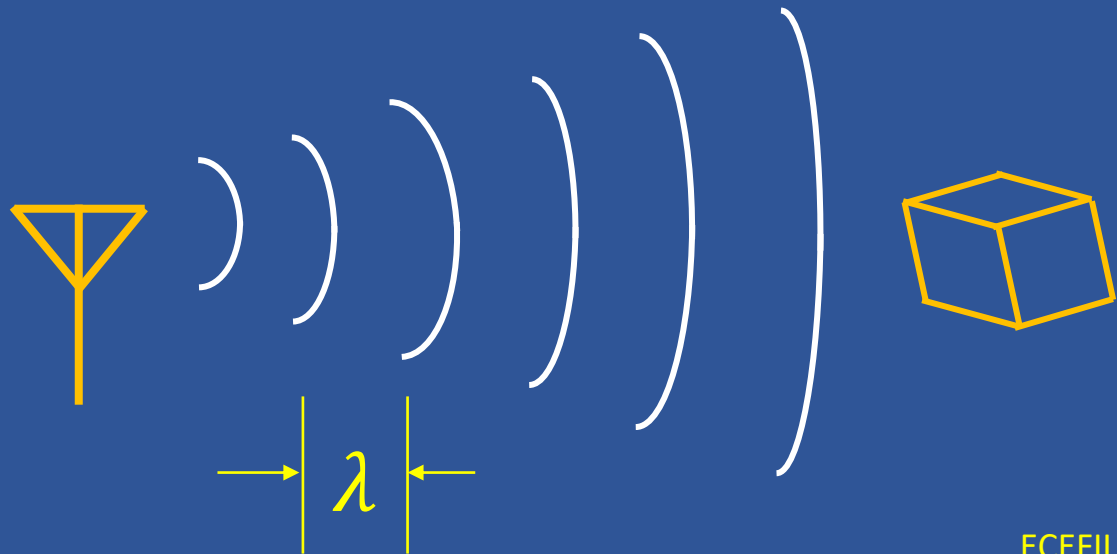
Which results in Reflections and Scattering, Shadowing, Diffraction, ...



Reflection Effects vary with Frequency

(and materials / geometry...)

f	λ
1 MHz	300 m (1000 ft)
100 MHz	3 m (10 ft)
1 GHz	0.3 m (12 in)



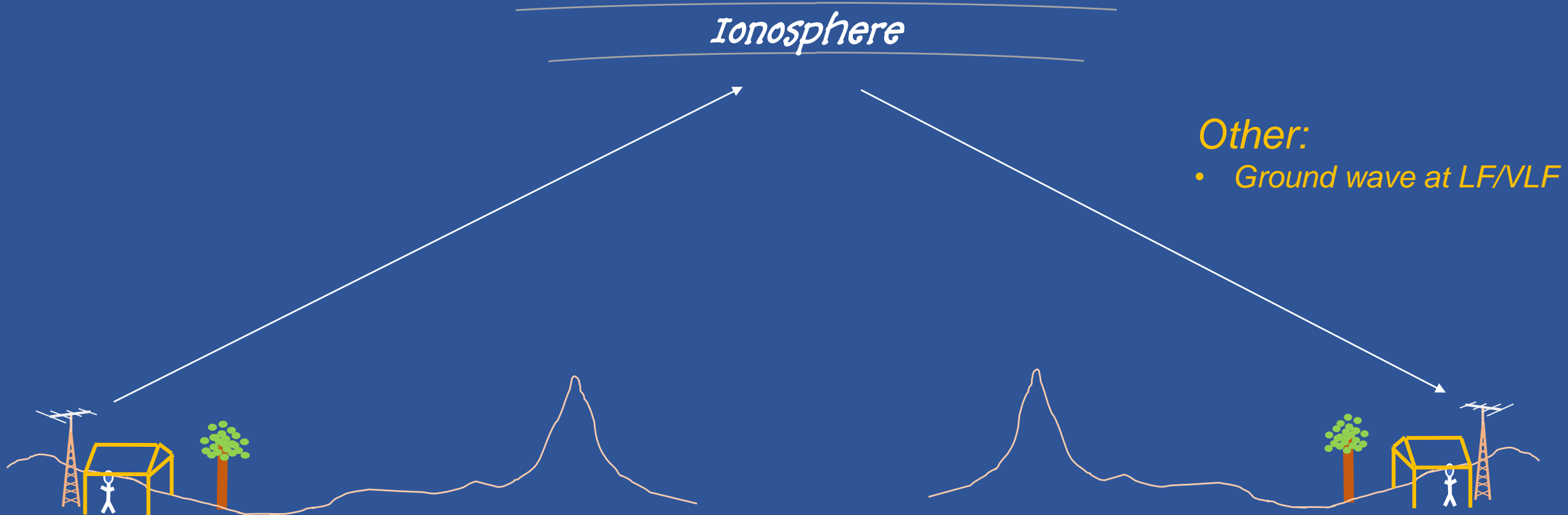
Episode 7 Topics

Topics

- • Applications to Propagation and Antenna Design
- *A little background / theory*
- Demonstrations 😊

Applications in Propagation

Refraction Below about 30 MHz

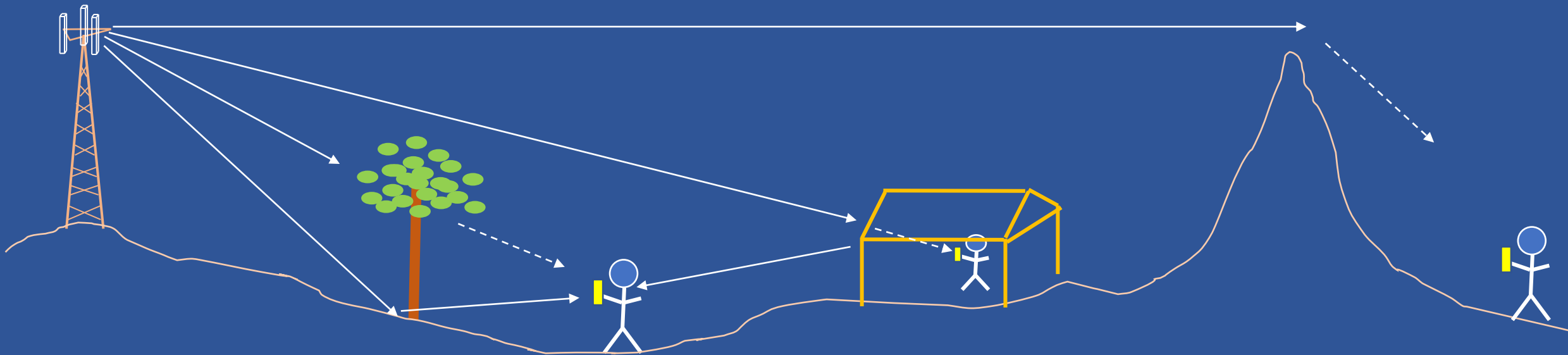


Reflection, absorption, diffraction

At VHF and Above

Other topics:

- *Refraction and Tropospheric ducting **



*SEE ALSO: <https://rsgb.org/main/get-started-in-amateur-radio/operating-your-new-station/vhfuhf-propagation/>

Indoor / Outdoor Propagation Studies at VHF/UHF



Antenna Briefs #3

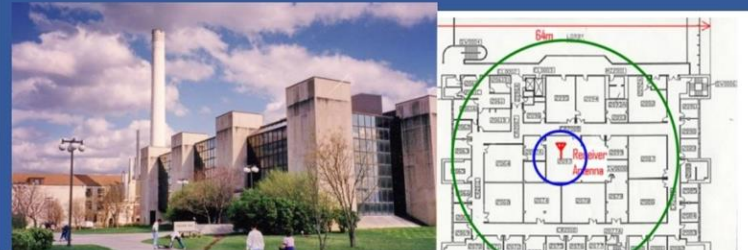
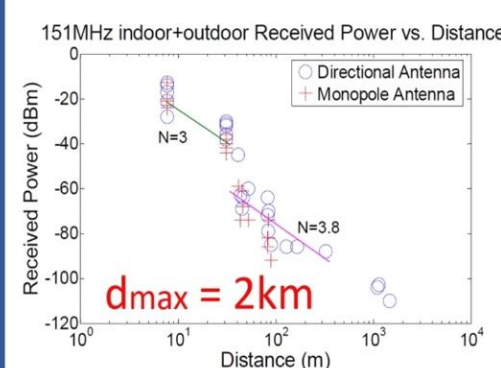
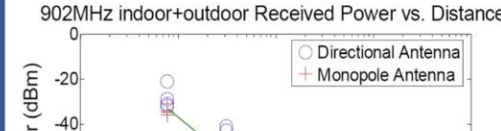
Maximizing Range

Example 2 -- Terrestrial Links (M)

$$P_r = P_t G_t \frac{1}{4 \pi d^n} A_{eff}$$

$n = 3 \text{ to } 5 !$

$P_t = 10 \text{ mW}, G_t = 1.6 \text{ to } 10, T = 290\text{K}, B = 10 \text{ kHz}$

151MHz indoor+outdoor Received Power vs. Distance

Received Power (dBm) vs. Distance (m)

Legend: Directional Antenna (○), Monopole Antenna (+)

$N=3$, $N=3.8$

$d_{max} = 2\text{km}$

902MHz indoor+outdoor Received Power vs. Distance

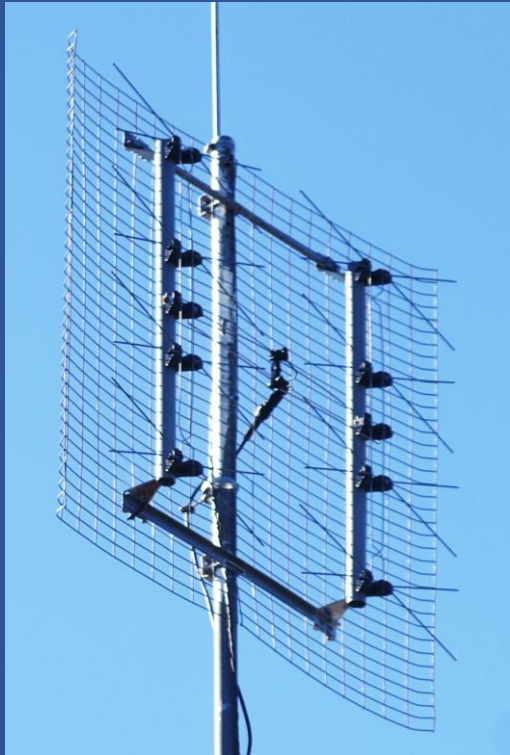
Received Power (dBm) vs. Distance (m)

Legend: Directional Antenna (○), Monopole Antenna (+)

Real World Antenna Siting



Applications of Reflection Theory in Antenna Design



https://en.wikipedia.org/wiki/Reflective_array_antenna



<https://www.harveynorman.com.au/one-for-all-vhf-uhf-outdoor-antenna.html>

ECEFILES.ORG

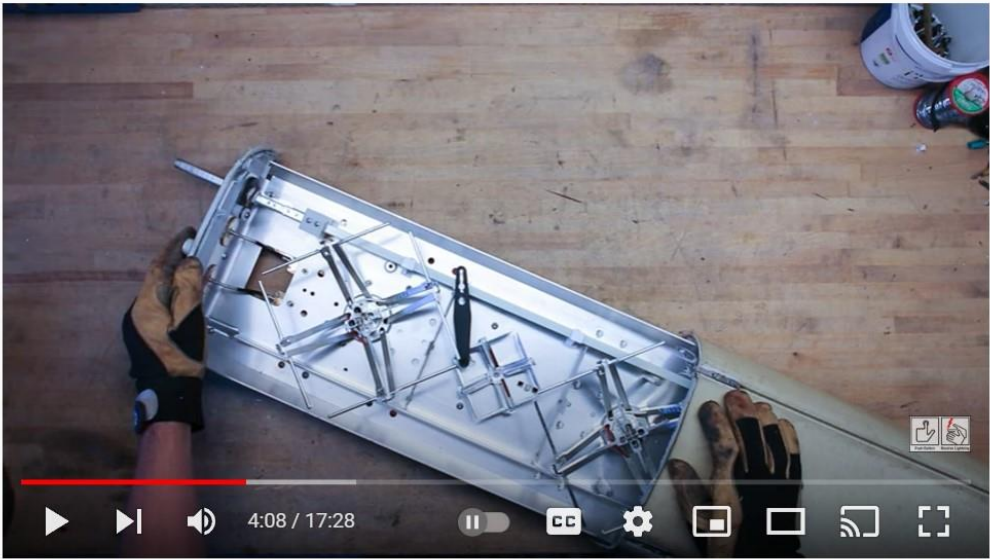


<https://blog.alliedmarketresearch.com/radar-systems-have-revolutionized-the-highly-sensitive-detection-technology-678>

More Applications in Antennas



YouTube Search



#basestation #teardown #radio
Teardown of Kathrein 1800/900 MHz Antenna For Mobile Phone Base Station

287 DISLIKE SHARE DOWNLOAD THANKS CLIP SAVE

A screenshot of a YouTube video player. The video shows a person wearing black gloves working on a large, silver metal antenna structure on a wooden floor. The video player interface includes a search bar, a play button, a progress bar showing 4:08 / 17:28, and various control icons like volume, closed captions, settings, and full screen. Below the video, there are social media sharing options and a list of actions: 287 likes, dislike, share, download, thanks, clip, and save.

More Applications in Antennas



https://commons.wikimedia.org/wiki/File:Parabolic_antennas_on_a_telecommunications_tower_on_Willans_Hill.jpg

Applications in Automotive Radar



Demo-day in Microwaves and Antennas course 😊

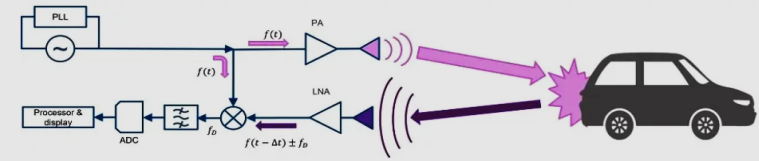


Fig. 1: FMCW automotive radar – Principle and building blocks.

An example of this radar signal is shown in figure 2 and figure 3. The returned signal is similar in shape to the transmitted one, but shifted in time as the two-way trip from the radar to the target takes an amount of time Δt that is proportional to the distance to the target R :

$$\Delta t = \frac{2R}{c}$$

With c being the light velocity.

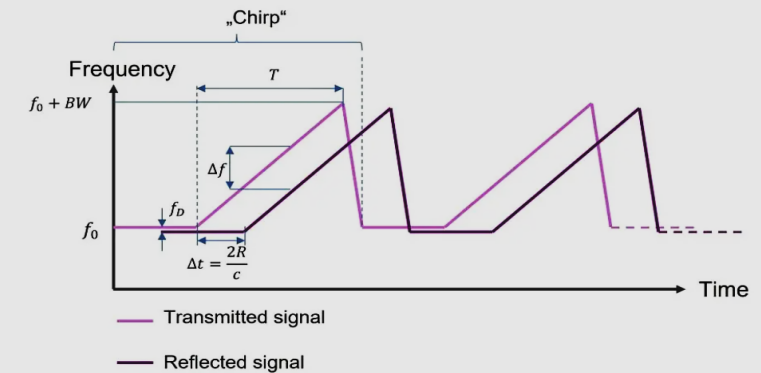
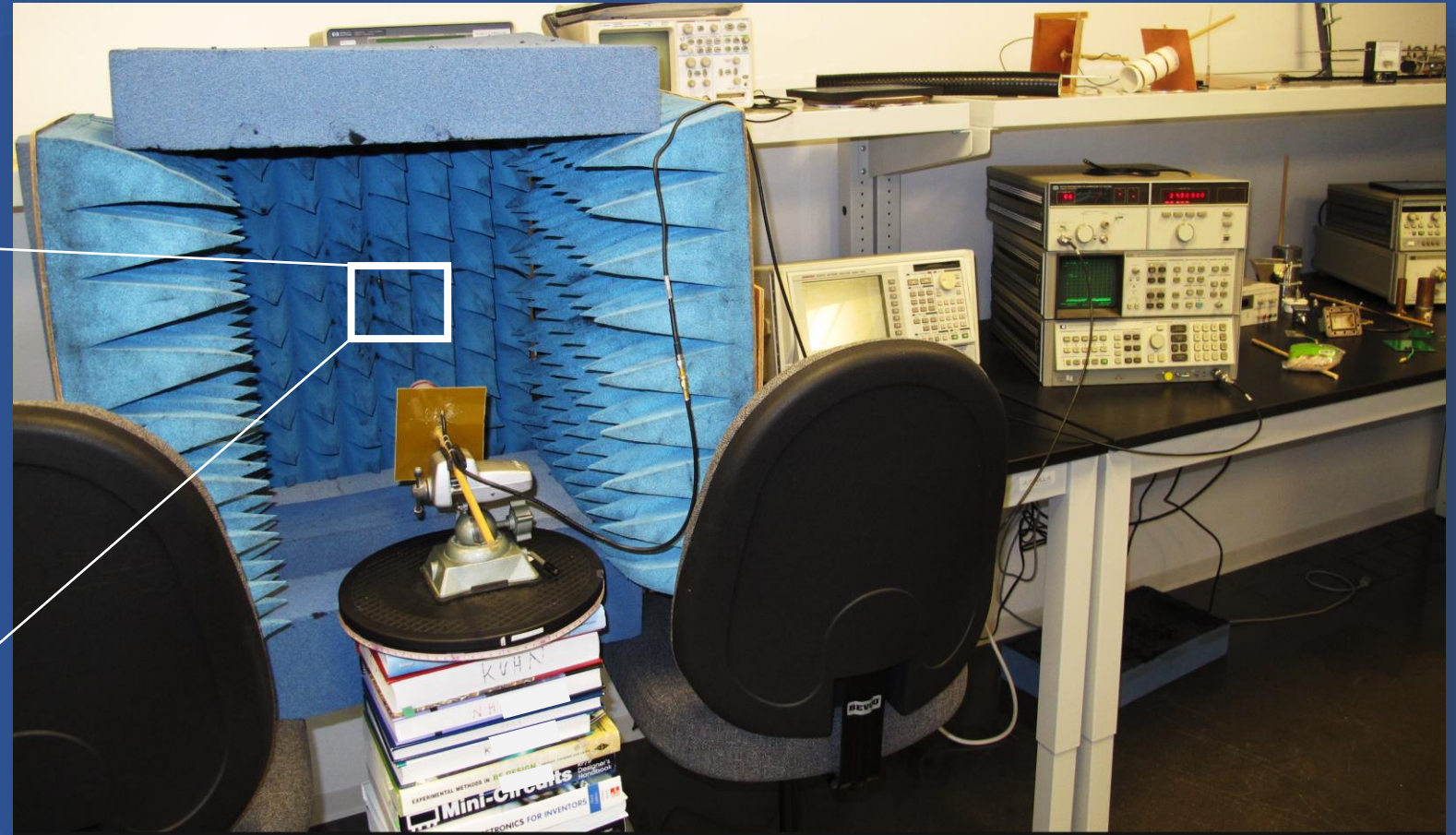


Fig. 2: Sawtooth FMCW radar signal: frequency vs. time.

Controlling Reflections in the Lab

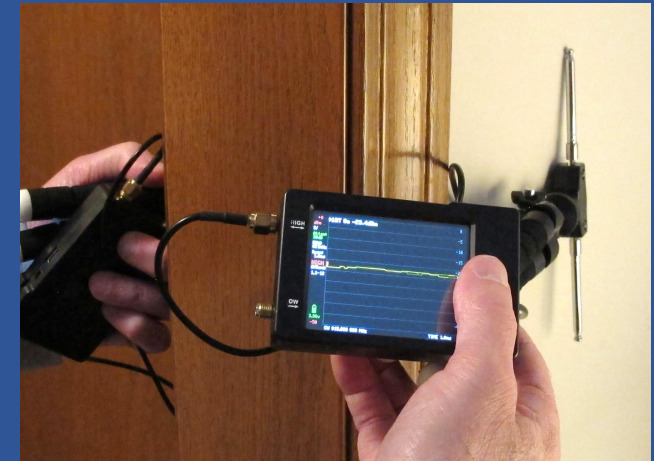
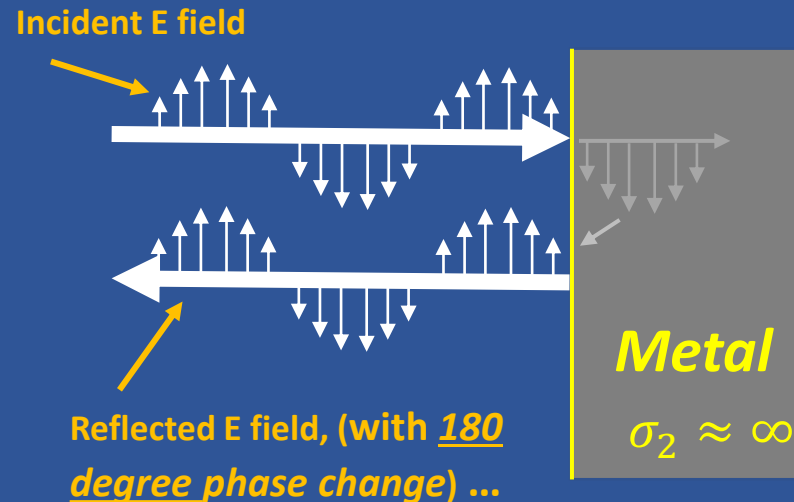
with Anechoic Materials



Antenna Briefs #7 – Part 2

Reflection of Radio Waves

(and Diffraction, Absorption, ...)



Episode 7, Part 2 Topics

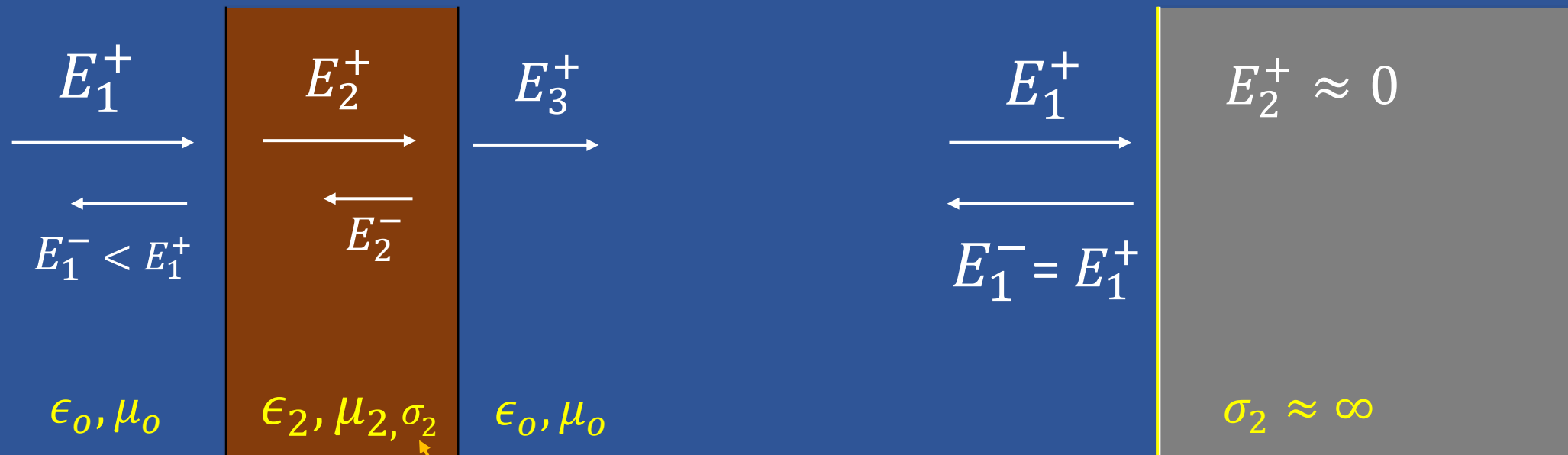
Topics

- Applications to Propagation and Antenna Design
- • A little background / theory
- Demonstrations 😊

Undergrad EM Textbook View

Dielectric
(e.g. wood, drywall)

Conductor
(e.g. metal)

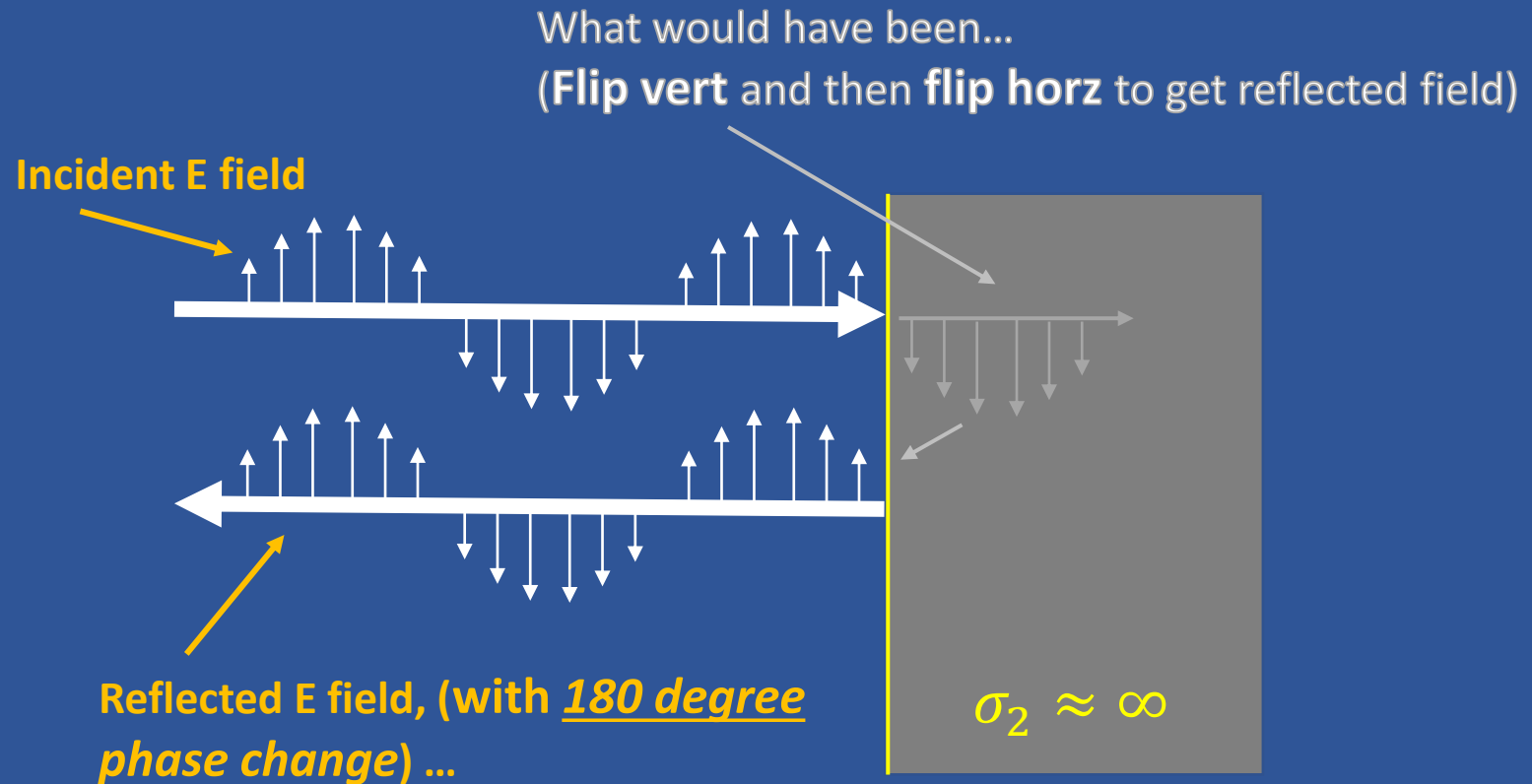
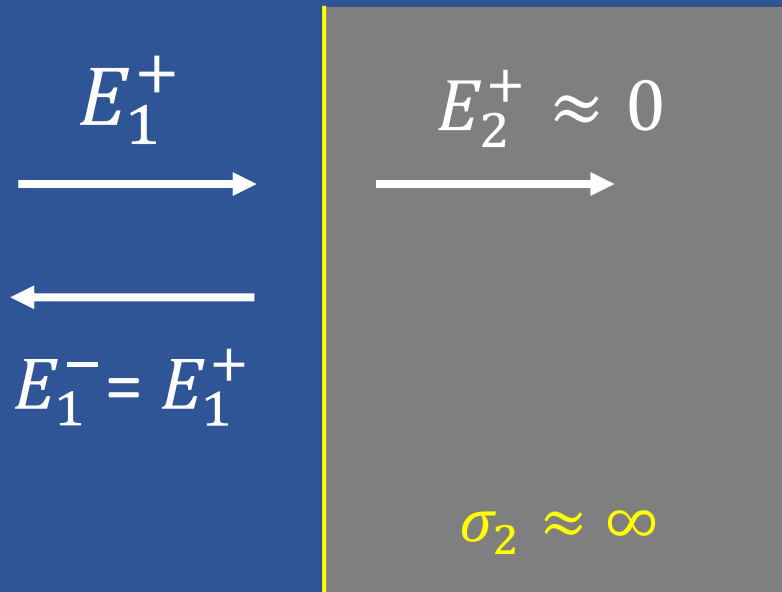


NOTE: Conductivity may be non-zero (or epsilon may be complex) for lossy dielectrics, resulting in absorption too... ECEFILES.ORG

How is Wave Reflected from Metal ?

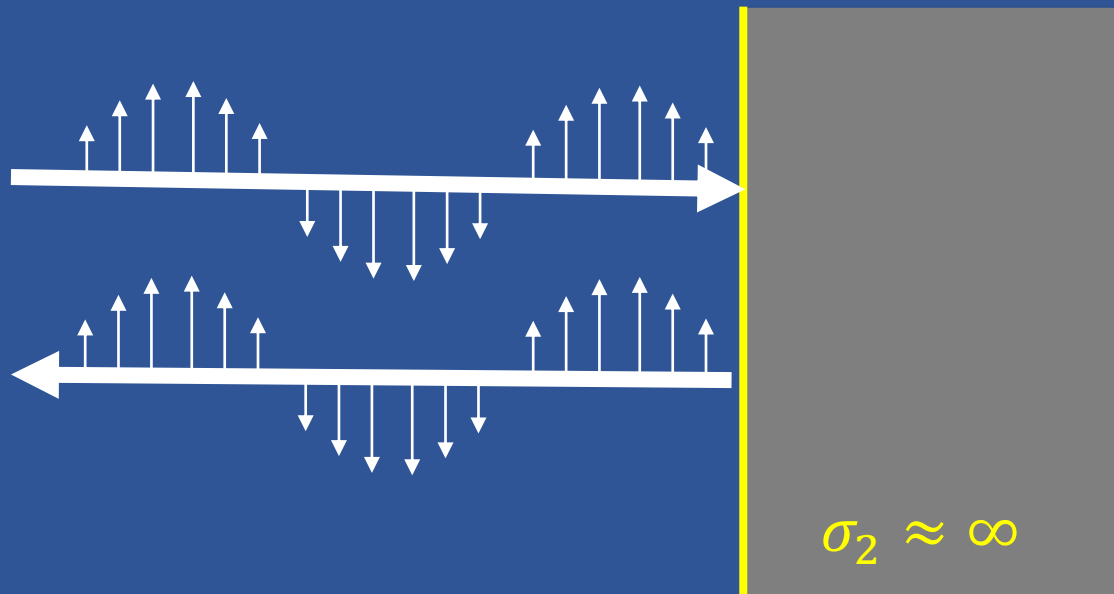
$E_{Tangential} \rightarrow 0$ at surface of metal (else surface currents would be infinity)

RF currents induced in "skin" (surface) of metal, create reflected wave and stop transmission into the metal

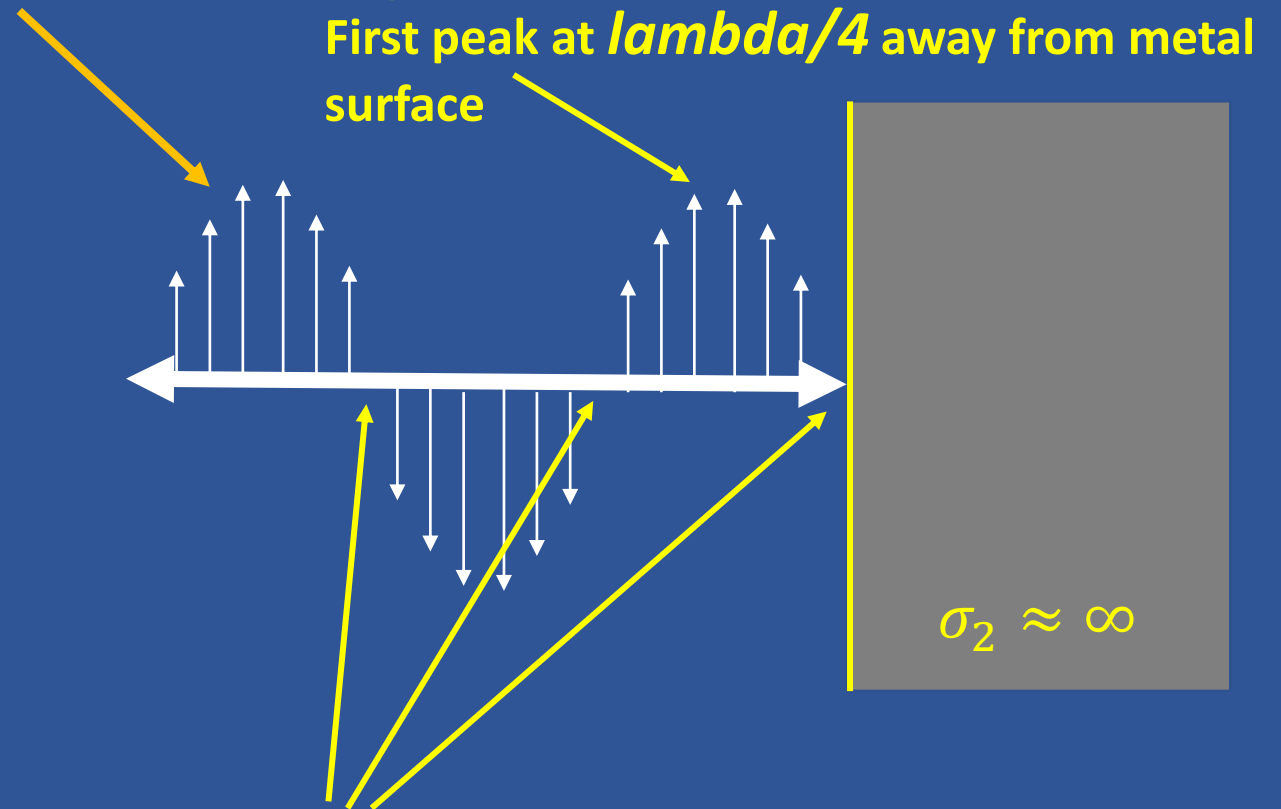


Skin-Depth and Standing Waves

Incident and reflected fields add, total field amplitude doubles, and resulting wave is “standing”



“Skin-depth” δ of current flow $\rightarrow || \leftarrow \delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$
 is a couple microns at 1 GHz.



Field is zero (or small) at N times $\lambda/2$, for all t

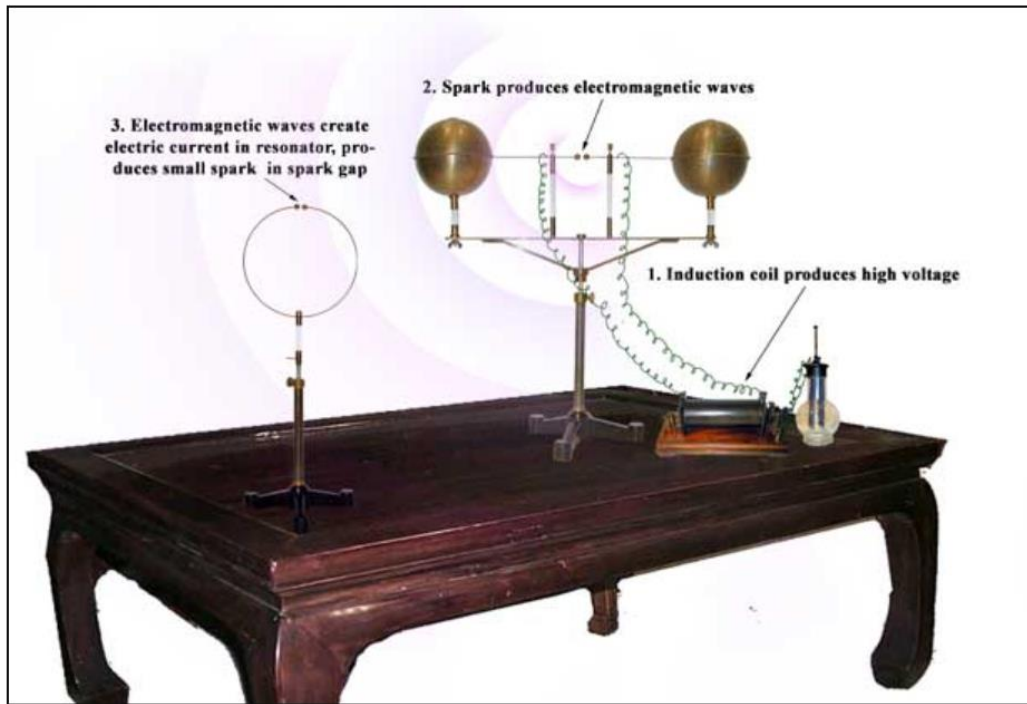
Episode 7 Topics

Topics

- Applications to Propagation and Antenna Design
- A little background / theory
- • Demonstrations 😊

Hertz Demonstrations 😊

Hertz's Experiment:



http://www.sparkmuseum.com/BOOK_HERTZ.HTM

Node "Null"

Antinode "Peak"

Hertz moved his receiver between the antenna

INDUCTION COIL

BATTERY

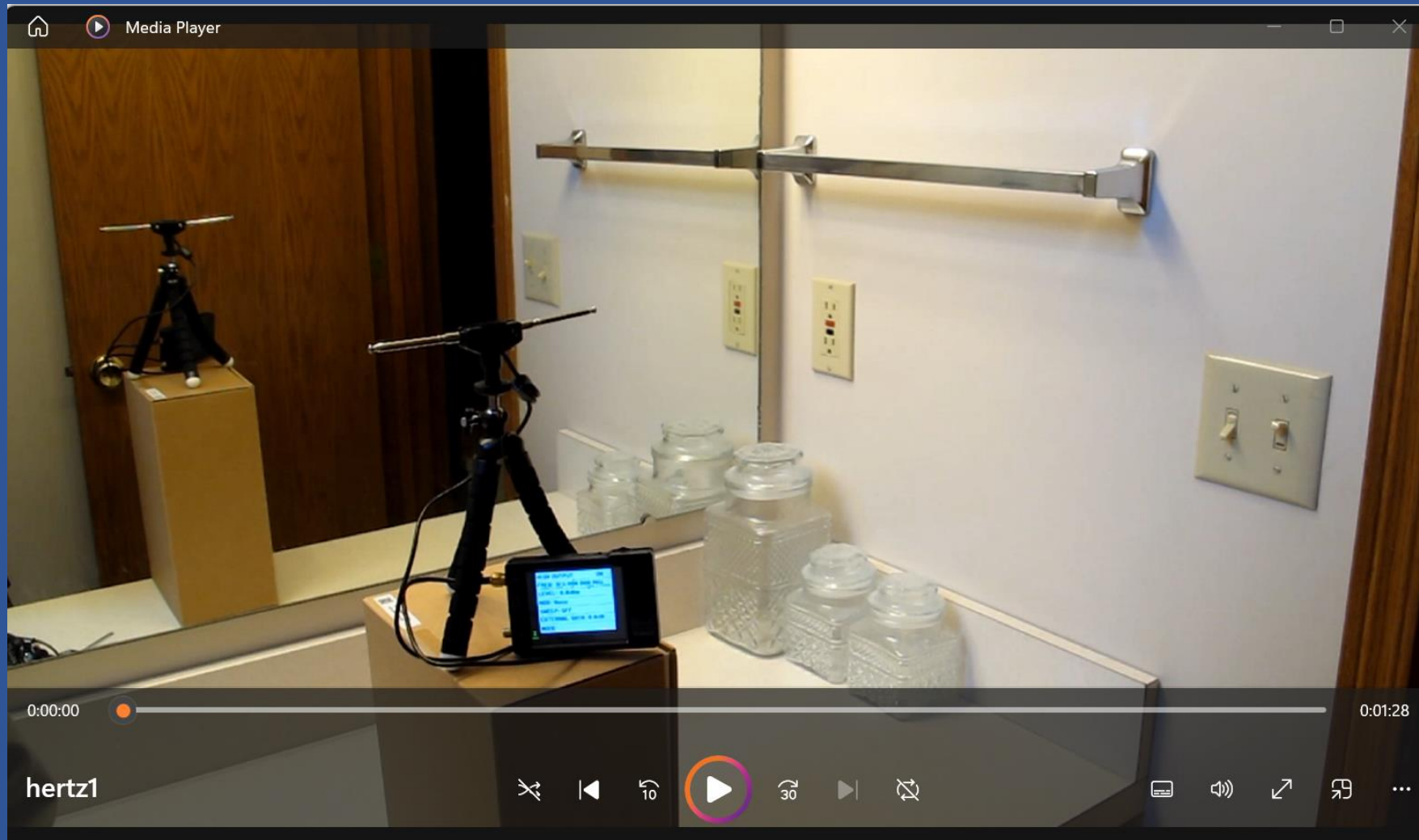
How Heinrich Hertz Discovered Radio to Validate Maxwell's Equations

61,039 views... 3K DISLIKE SHARE DOWNLOAD CLIP SAVE ...

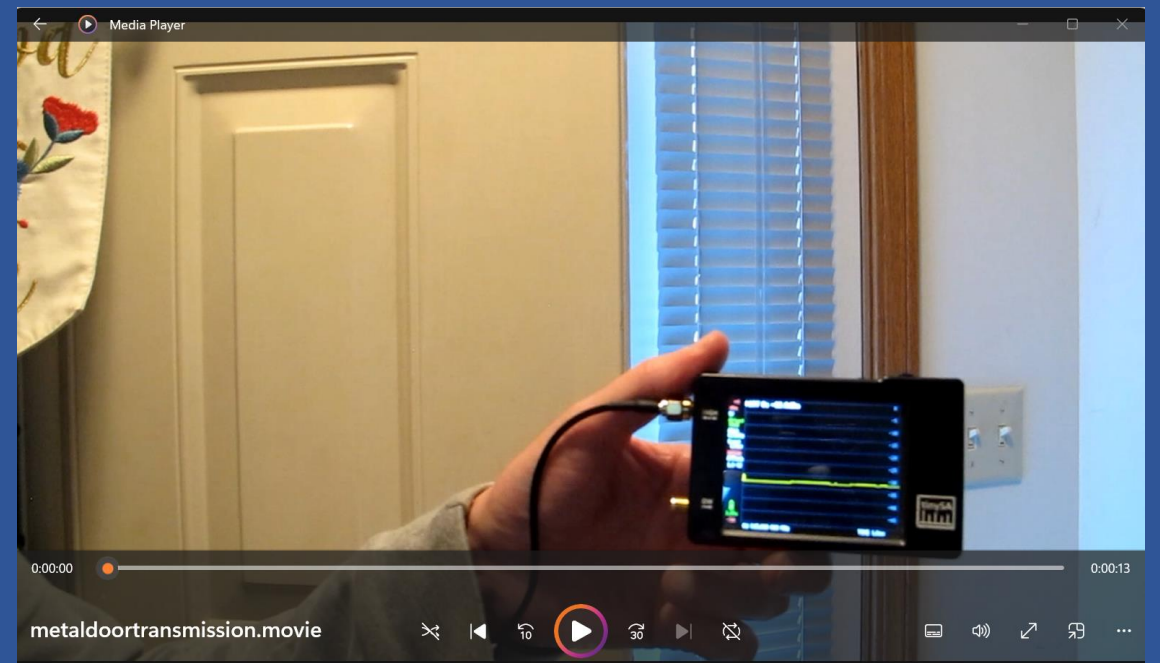
Kathy Loves Physics & History
105K subscribers

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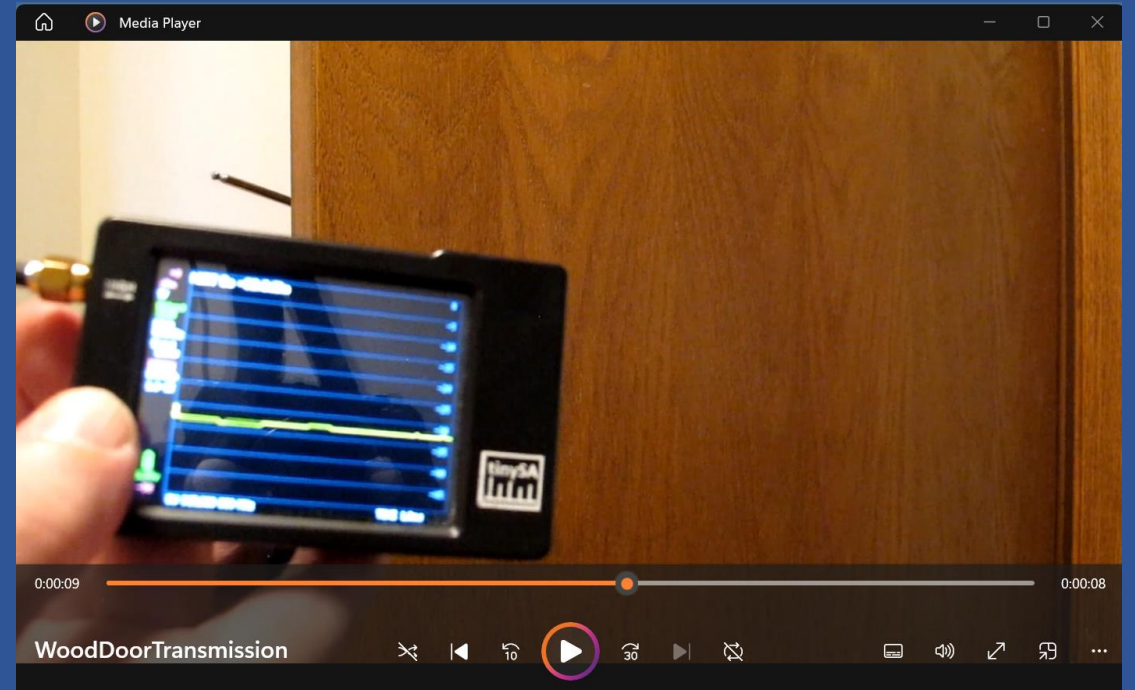
Demo with 915 MHz Dipoles



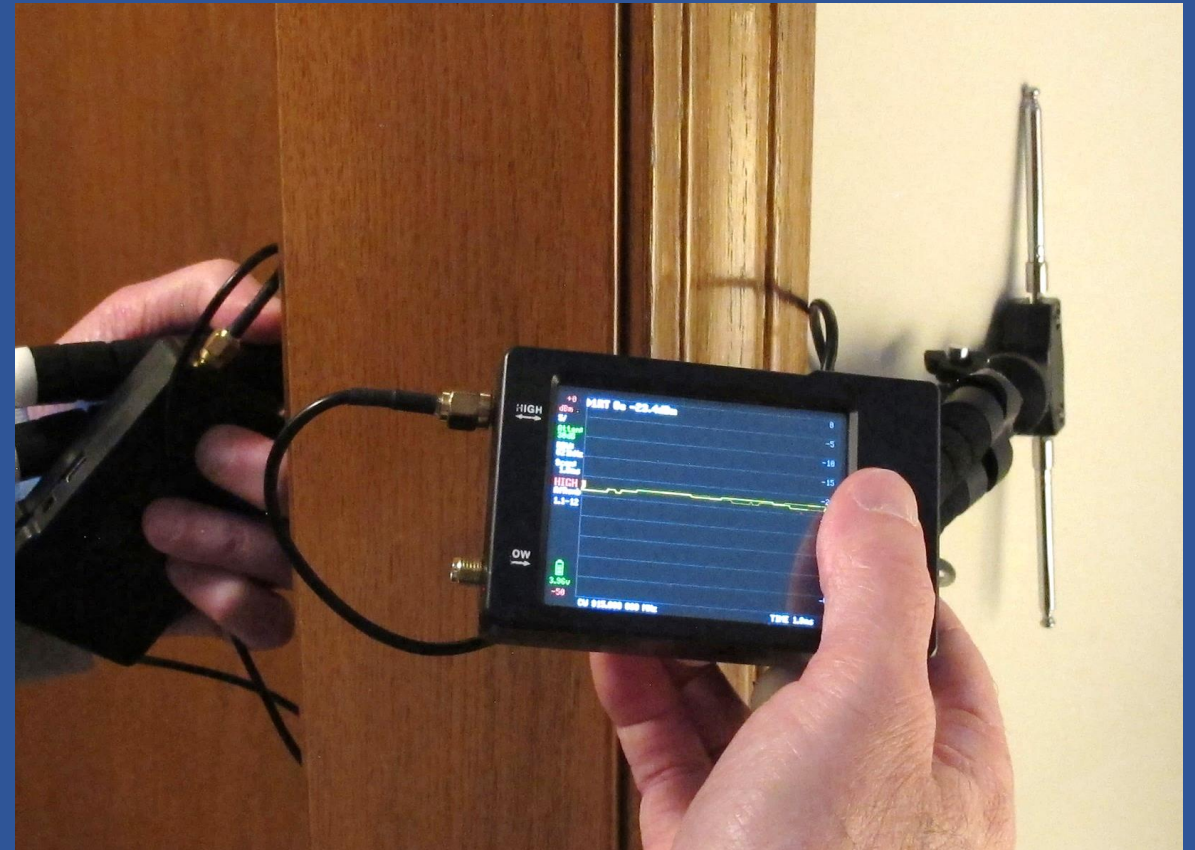
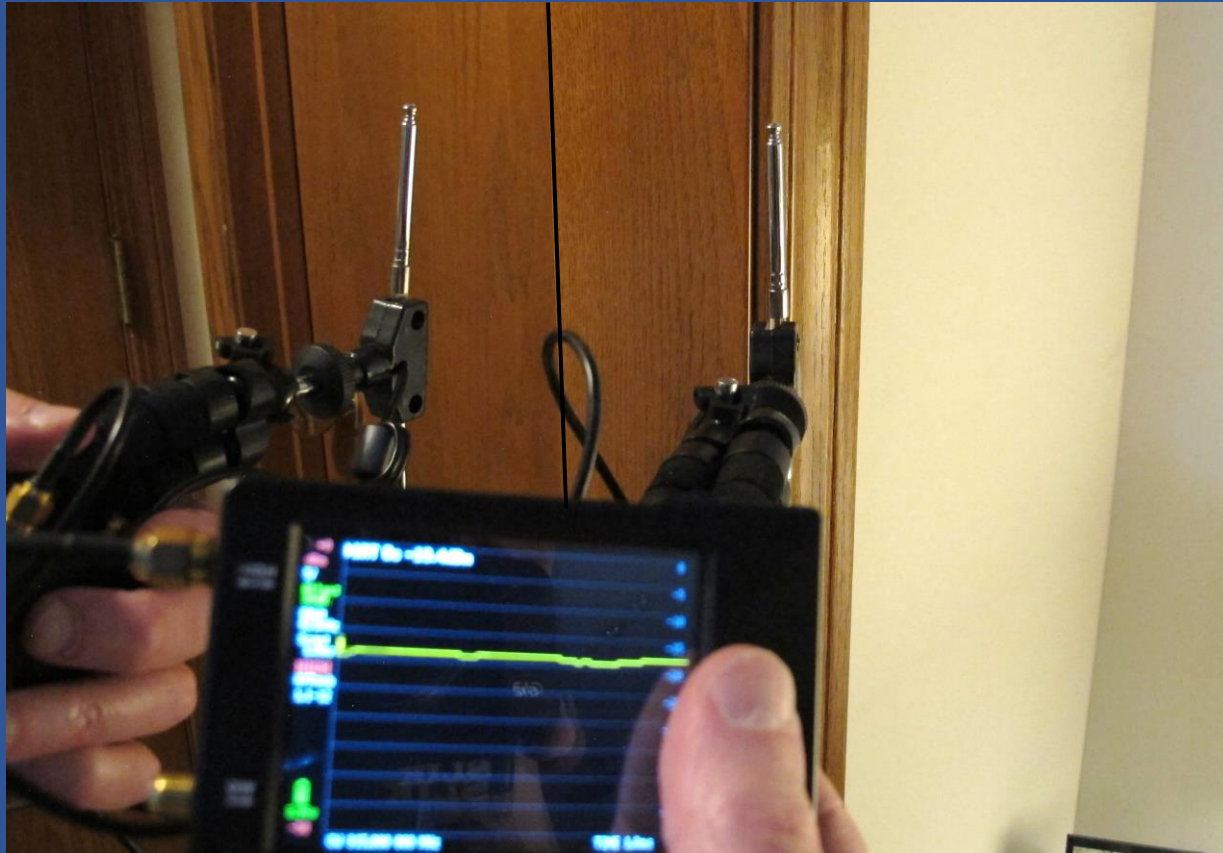
Metal Exterior Doors Reflect and Block Transmission



Wood Interior Doors have Little Effect



Drywall is Reasonably Transparent



BUT Windows may Not be !



Measuring Transmission through Energy Efficient Windows



Figure 1. Exterior view of building.

From: "Wireless communication problems in energy-efficient building construction"

2016 IEEE International Symposium on Electromagnetic Compatibility

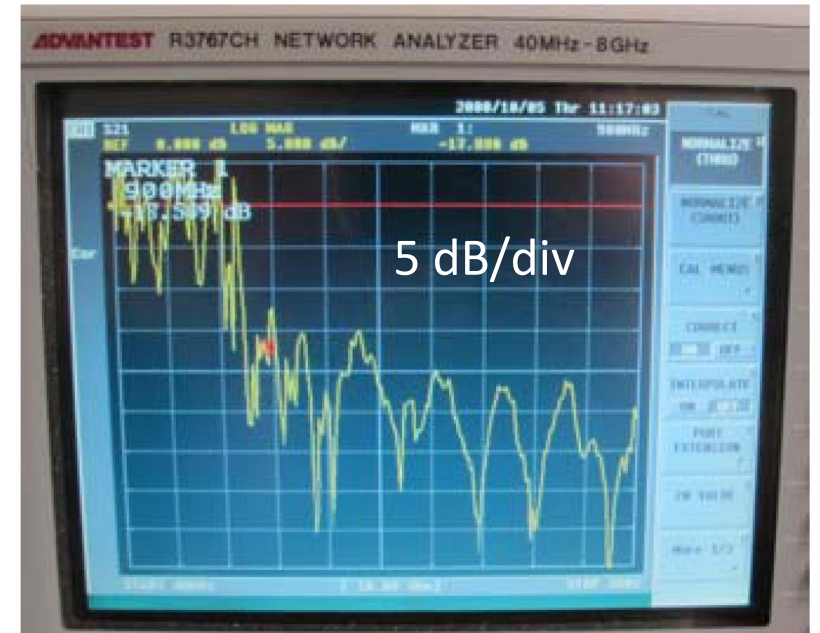


Figure 4. Radiowave transmittance measurement: 40 MHz through 3 GHz horizontal, 5dB/division vertical. Data below about 800 MHz is not valid (see text).

How Can We Use What We've Learned ?



II. ATTENUATION FROM ENERGY EFFICIENT GLASS

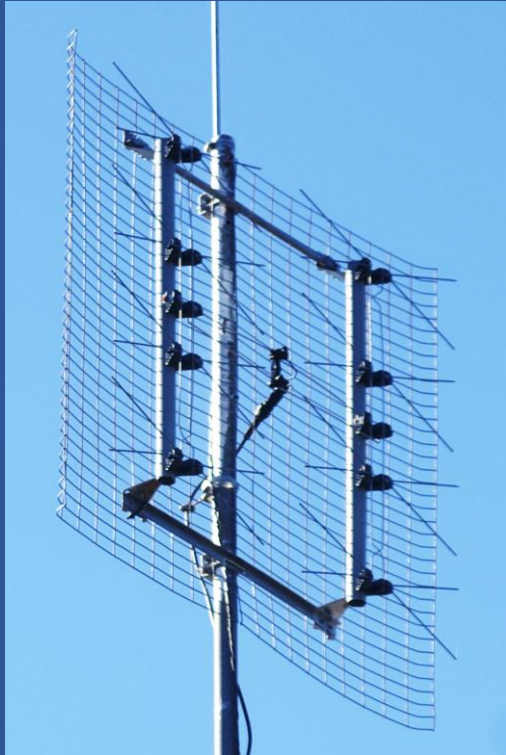
An exterior view of the newly completed building is shown in Figure 1.



Figure 1. Exterior view of building.

From: "Wireless communication problems in energy-efficient building construction" 2016 IEEE International Symposium on Electromagnetic Compatibility

How Can We Use What We've Learned ?



https://en.wikipedia.org/wiki/Reflective_array_antenna



<https://blog.alliedmarketresearch.com/radar-systems-have-revolutionized-the-highly-sensitive-detection-technology-678>

Thanks for Watching

How Can We Use What We've Learned ?

