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=-SpPvIauMBo (Part 2)

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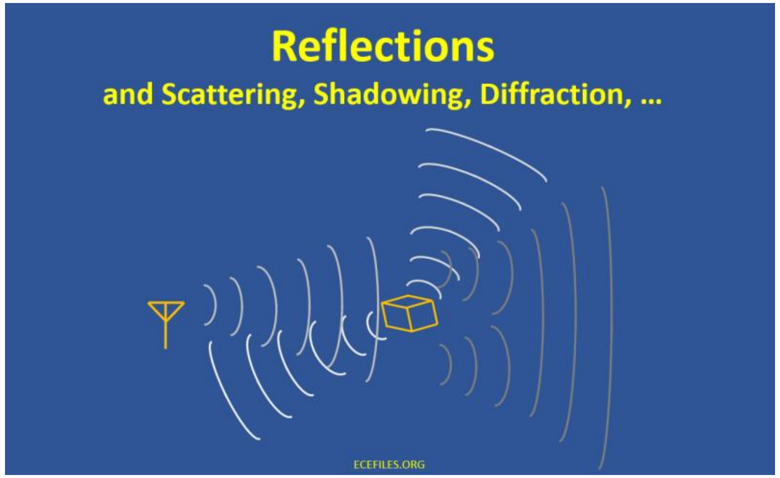
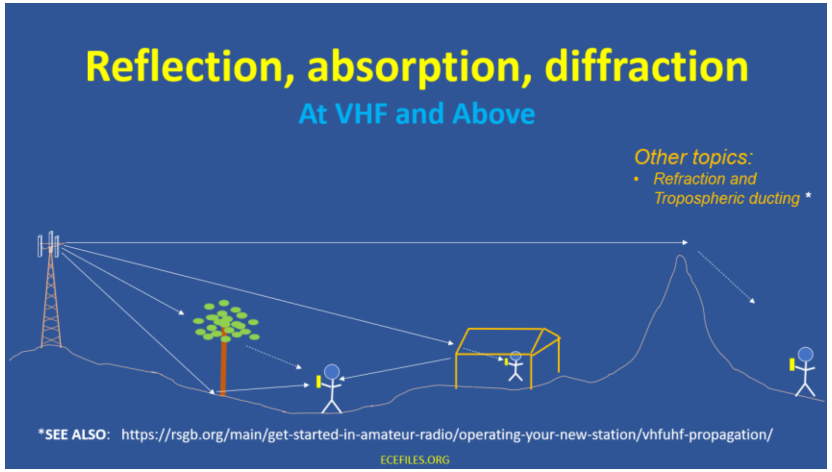
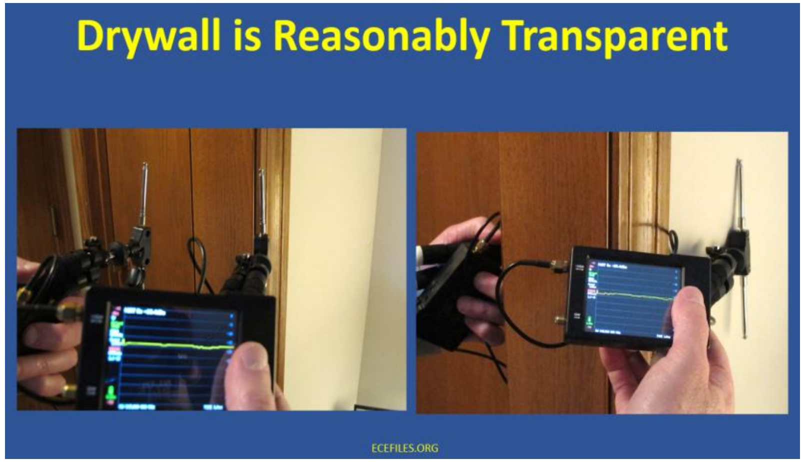
This episode covers reflection of radio waves and how this phenomenon is important in propagation and in the design and construction of directional antennas. Part 1 overviews both, as well as introducing related effects including refraction, diffraction, absorption, and scattering. The main focus is 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.



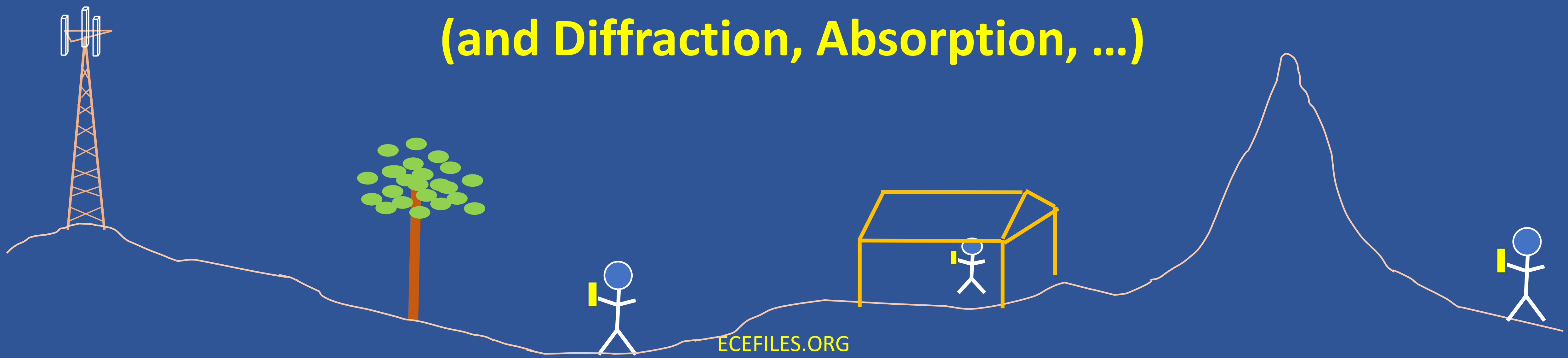




Antenna Briefs #7 – Part 1

Radio Wave Reflections

(and Diffraction, Absorption, …)



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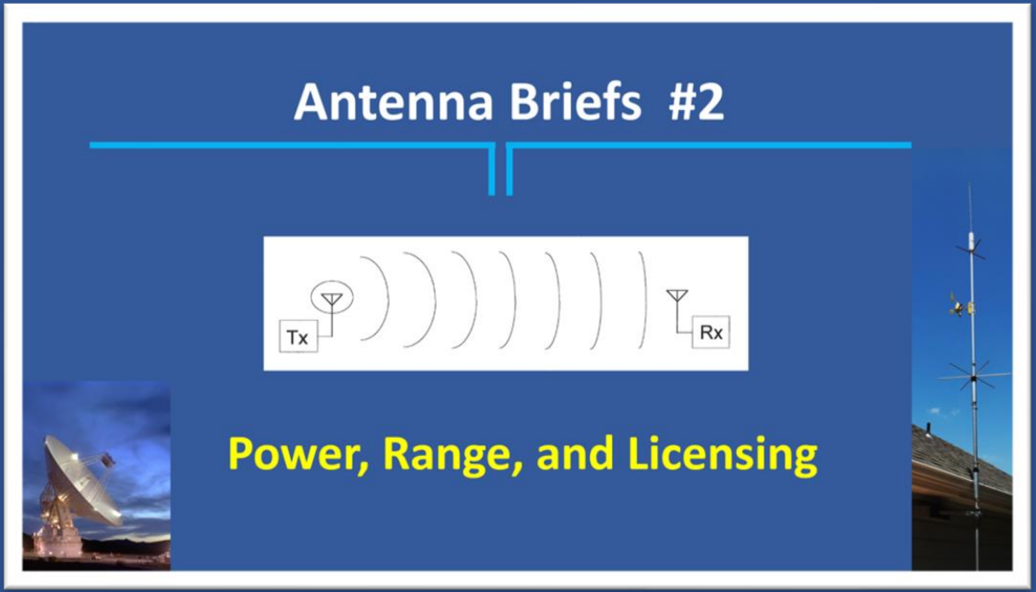
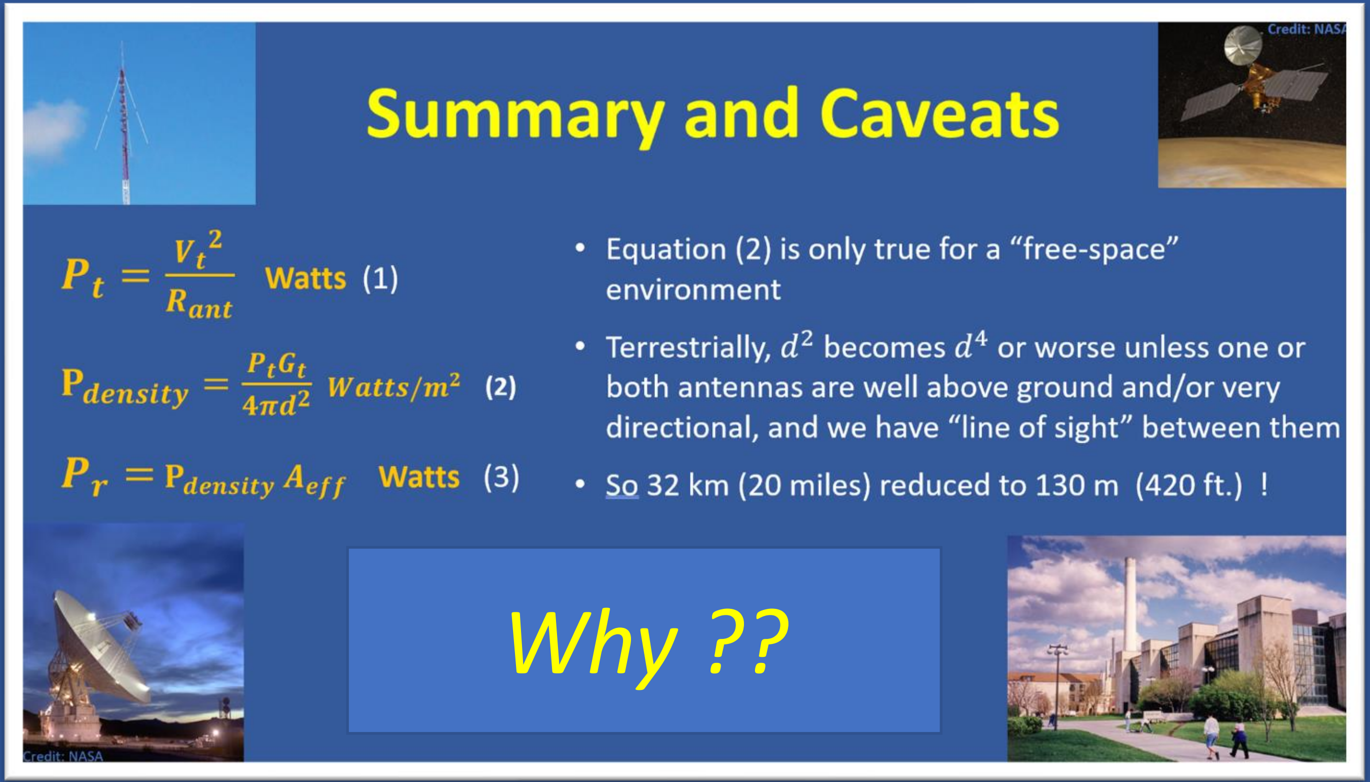
Recall Previous Episodes

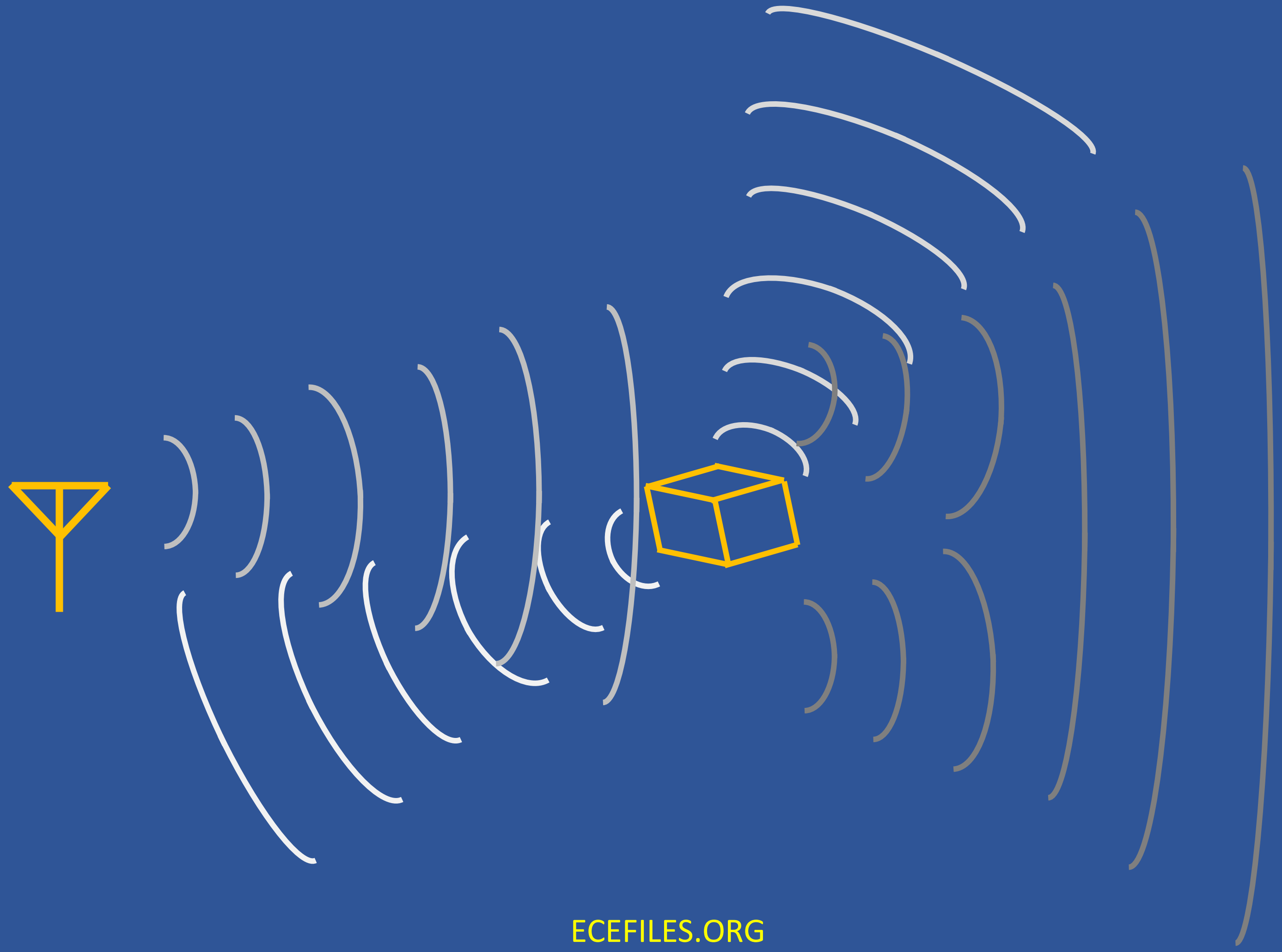




Terrestrial Environments have "stuff" in them !

Which results in Reflections

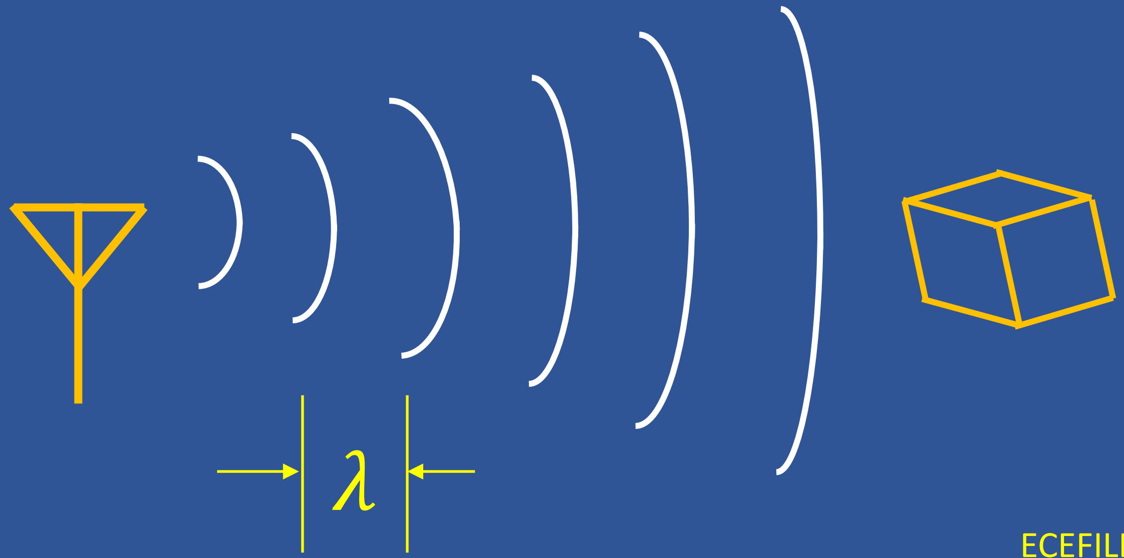
and Scattering, Shadowing, Diffraction, …



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)



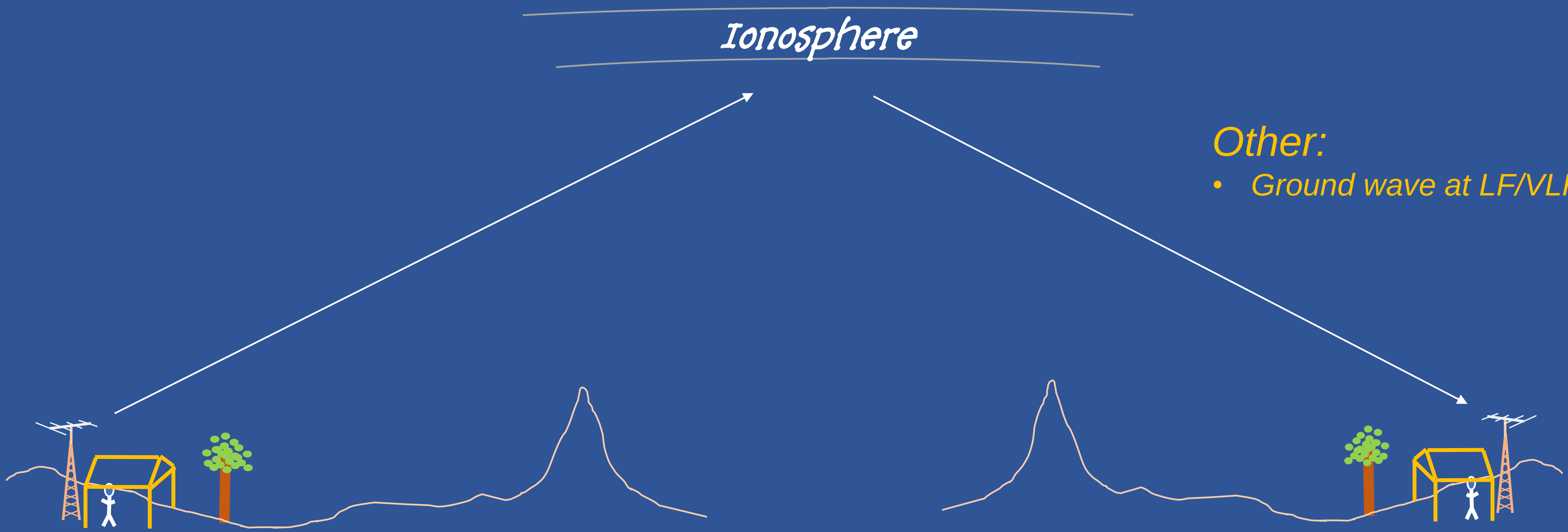
Episode 7 Topics

Topics

➞
- Applications to Propagation and Antenna Design
- A little background / theory
- Demonstrations ☺

Applications in Propagation

Refraction Below about 30 MHz



Other:

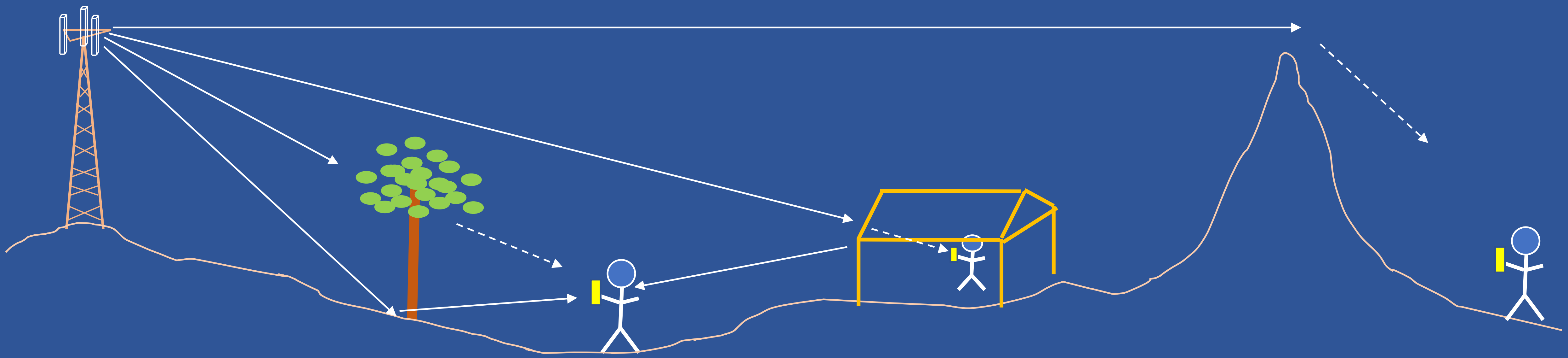
- *Ground wave at LF/VLF*

Reflection, absorption, diffraction

At VHF and Above

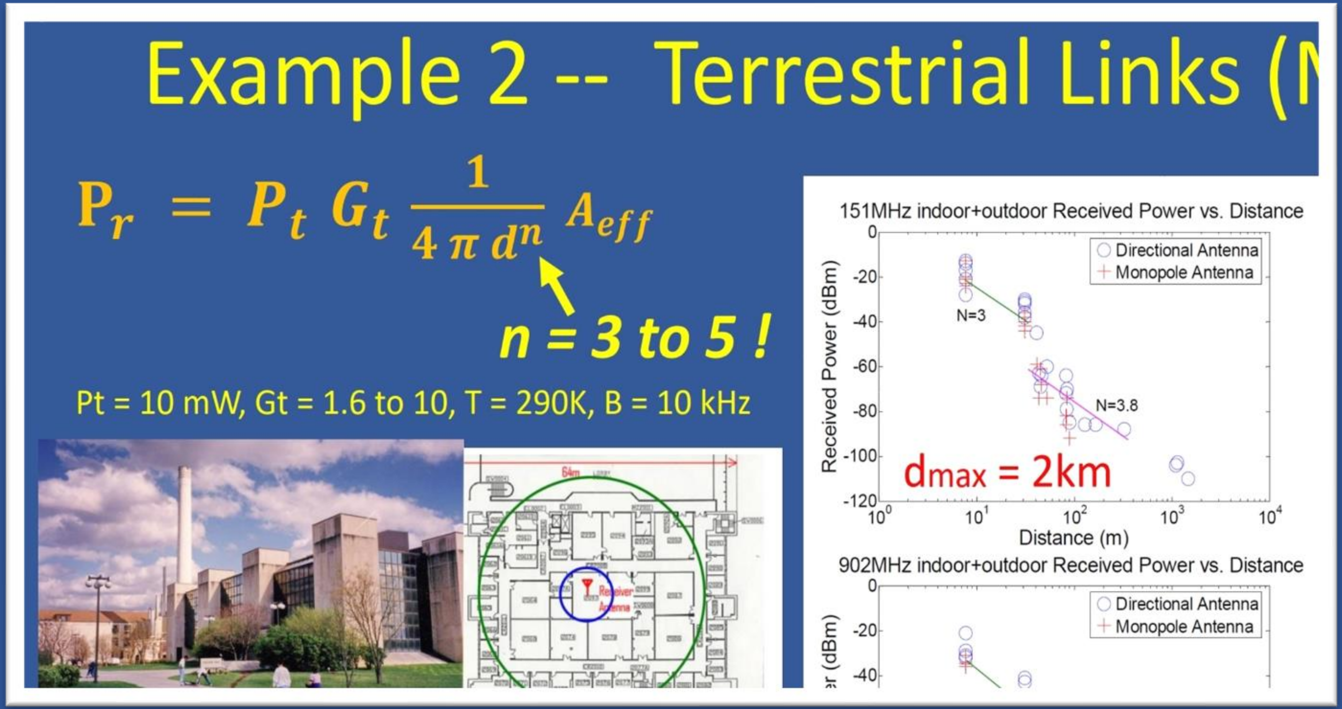
Other topics:

- *Refraction and Tropospheric ducting* *



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

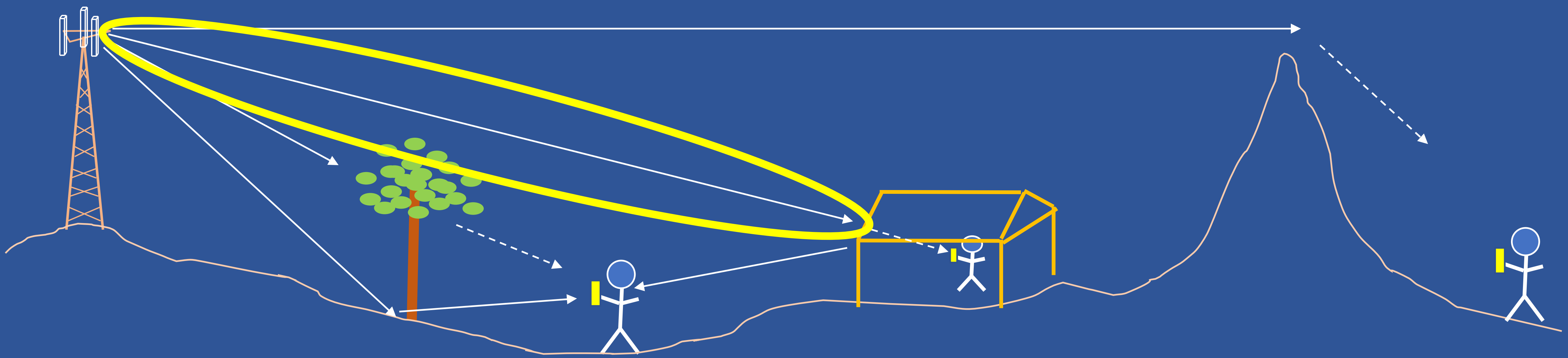
Indoor / Outdoor Propagation Studies at VHF/UHF



Fresnel Zones

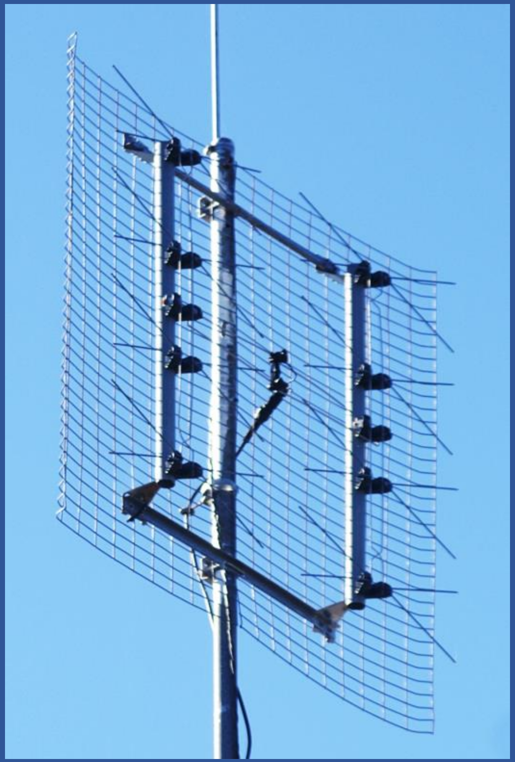
Other topics:

- *Knife-edge diffraction*



Real World Antenna Siting

Applications of Reflection Theory in Antenna Design

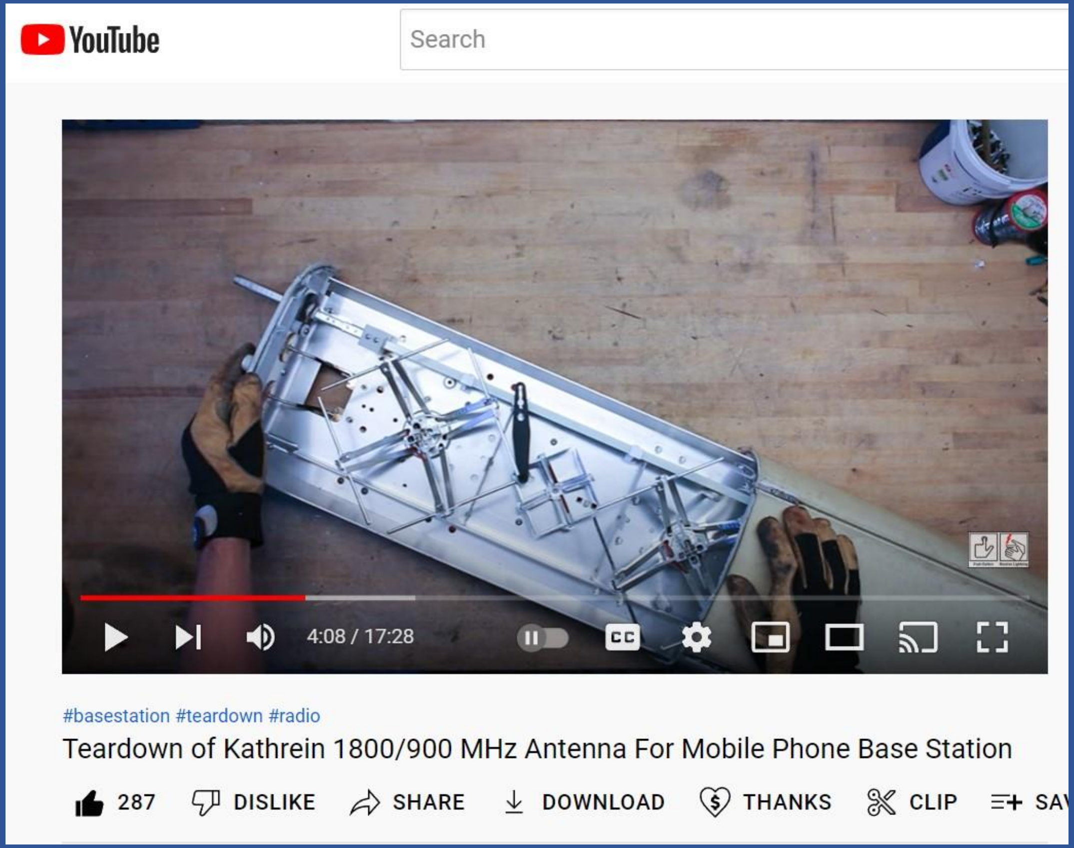


https://en.wikipedia.org/wiki/Reflective_array_antenna

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

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

More Applications in Antennas



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 ☺

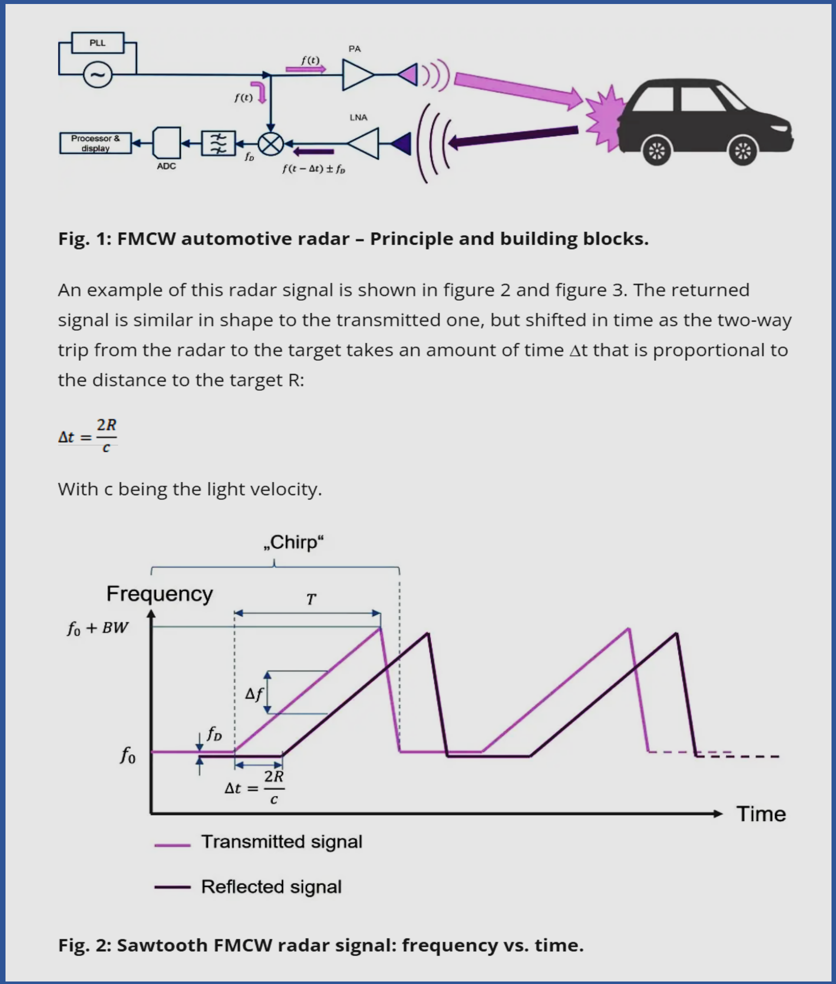


Fig. 1: FMCW automotive radar – Principle and building blocks.

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:

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

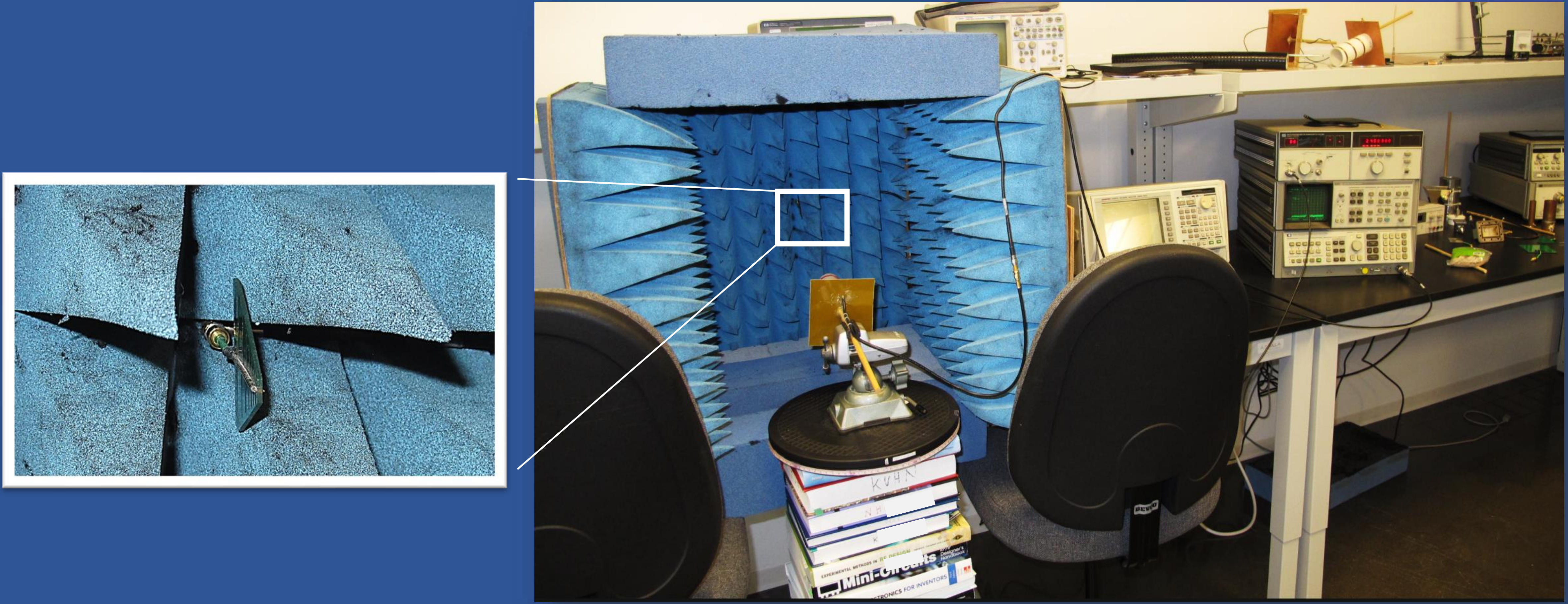
With c being the light velocity.

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

https://semiengineering.com/radar-for-automotive-basics-of-fmcw-radar/

Controlling Reflections in the Lab

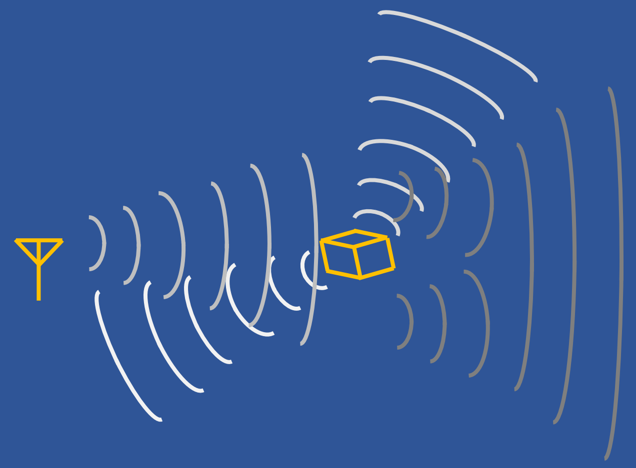
with Anechoic Materials

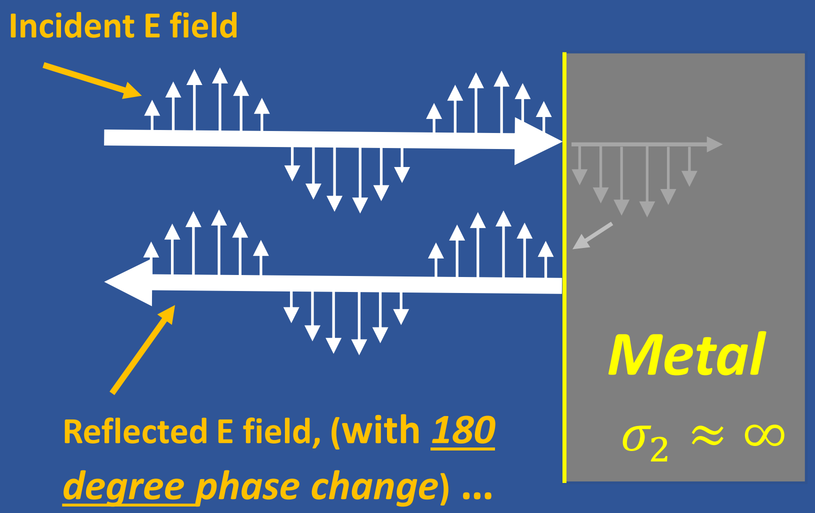


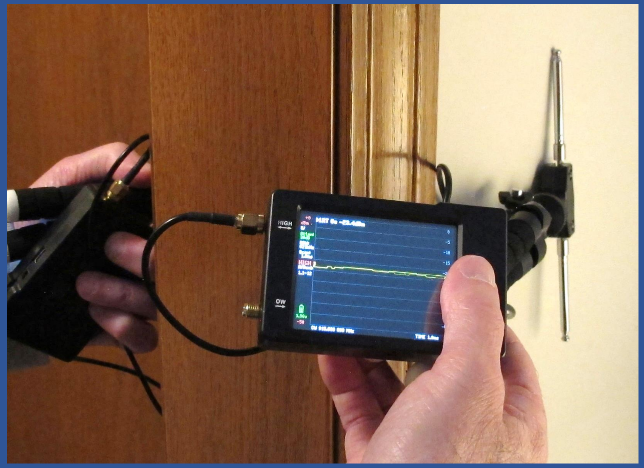
Antenna Briefs #7 – Part 2

Reflection of Radio Waves

(and Diffraction, Absorption, …)







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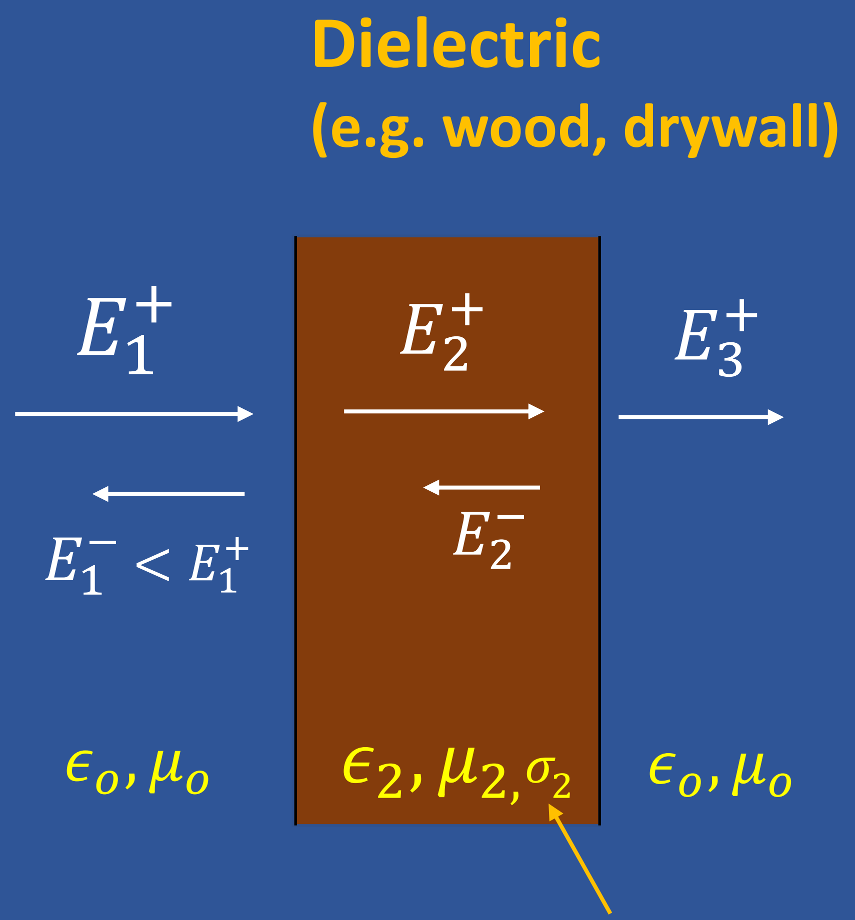
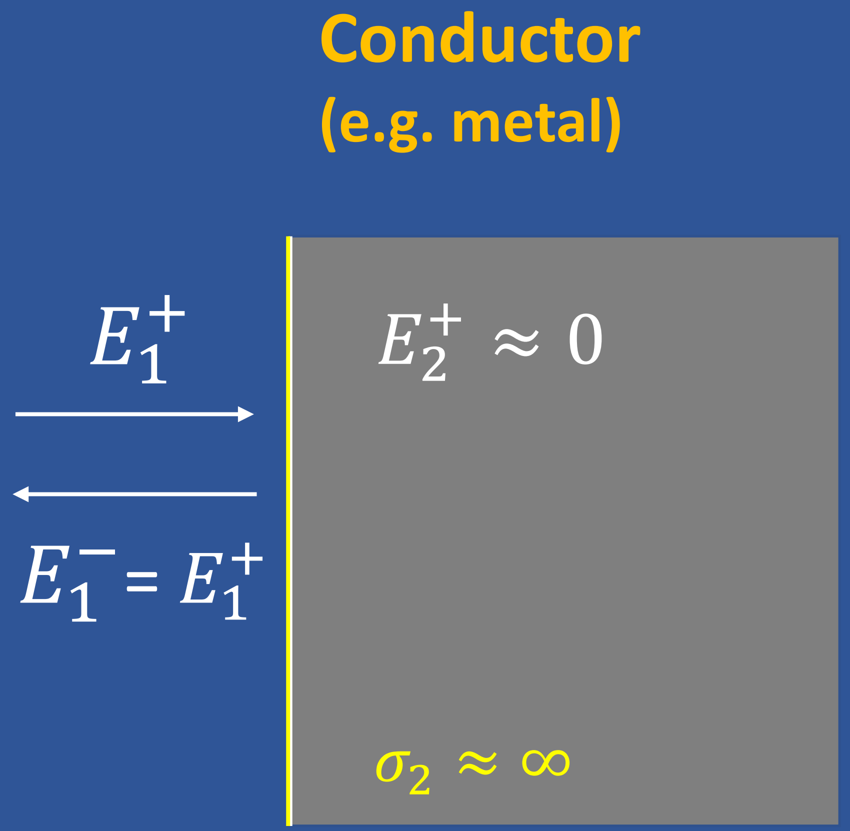
Episode 7, Part 2 Topics

Topics

- Applications to Propagation and Antenna Design
- → A little background / theory
- Demonstrations ☺

Undergrad EM Textbook View



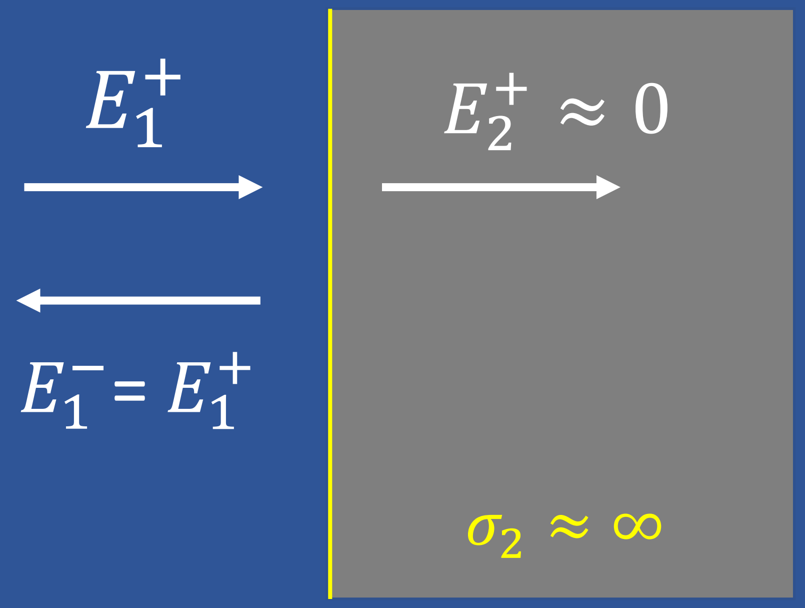


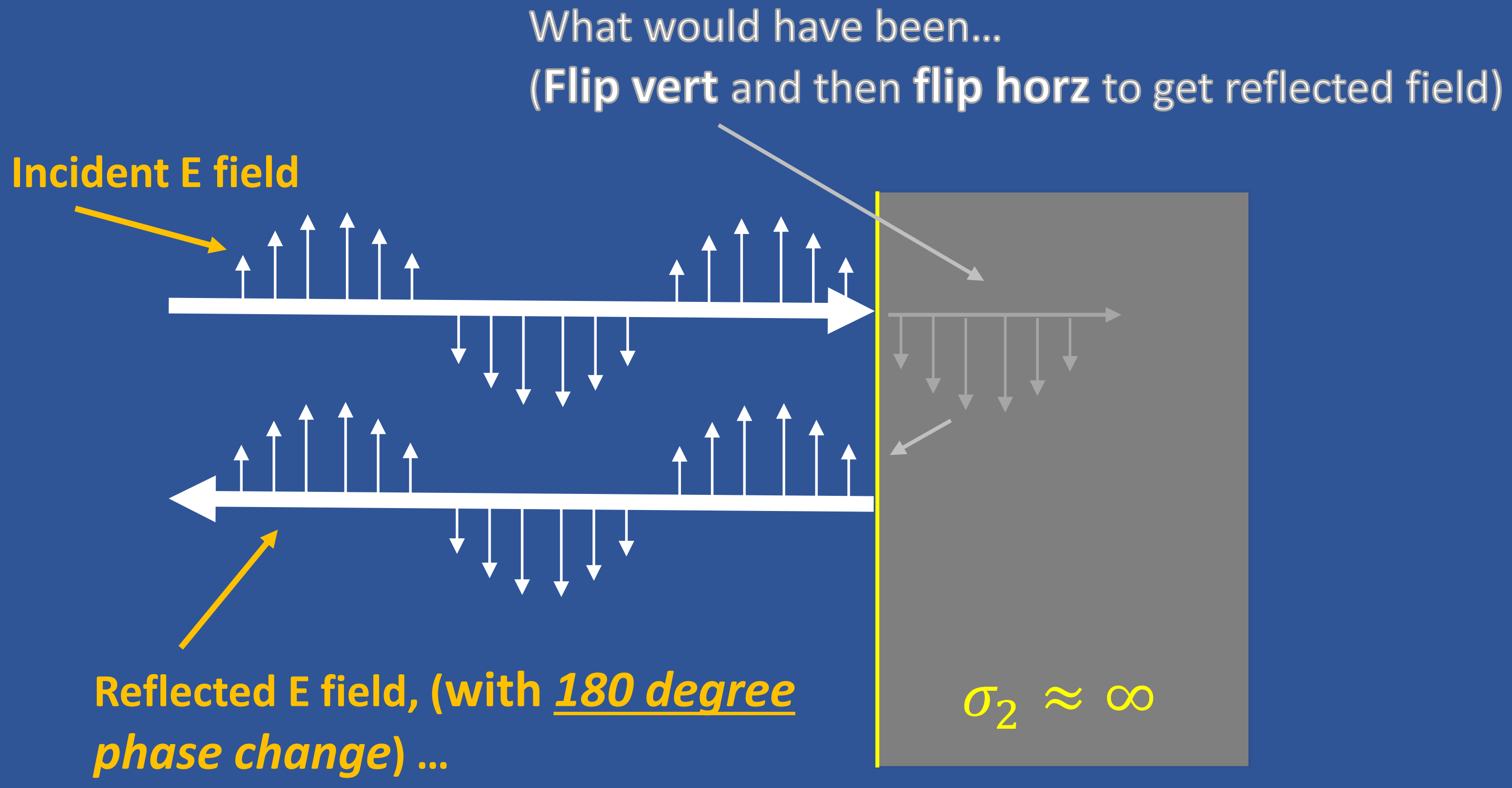
NOTE: Conductivity may be non-zero (or epison may be complex) for lossy dielectrics, resulting in absorption too…

How is Wave Reflected from Metal ?

$E_{Tangential}$ -> 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





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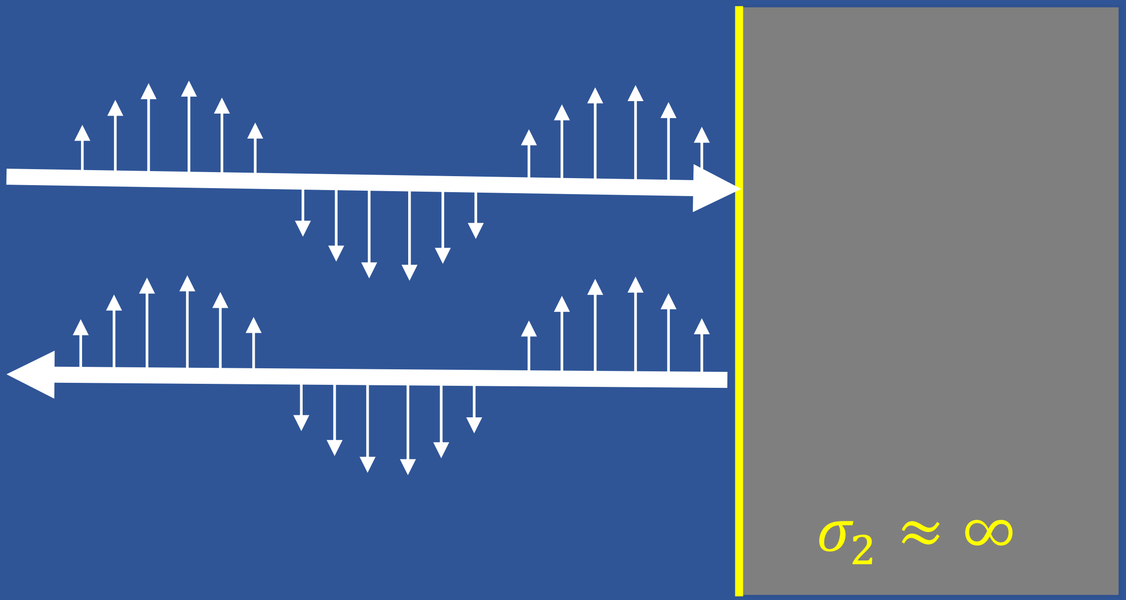
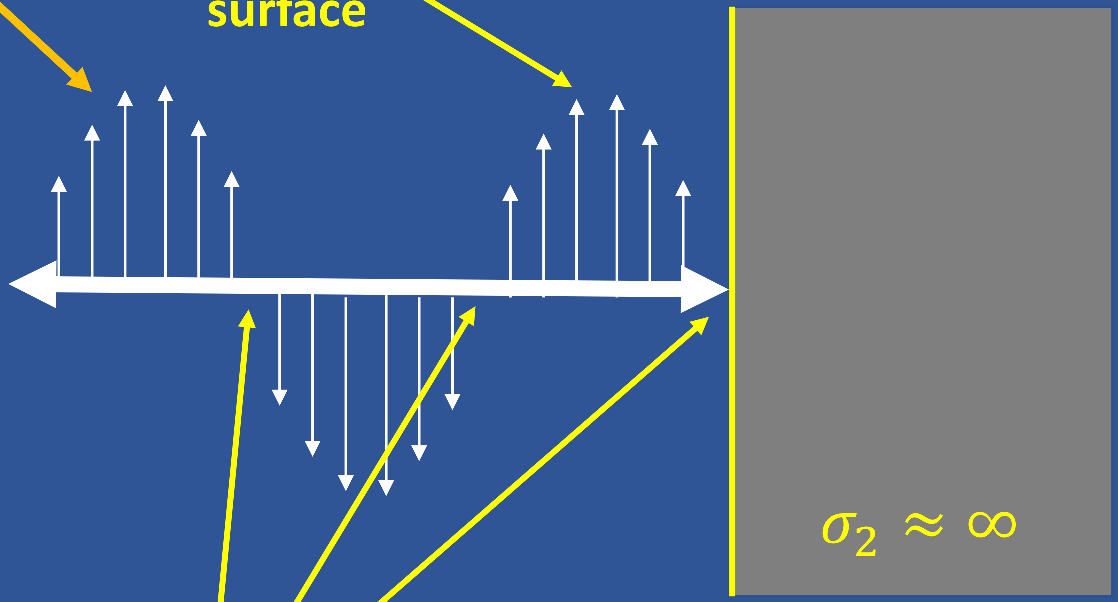
Skin-Depth and Standing Waves

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

First peak at *lambda/4* away from metal surface





“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** , ***<u>for all t</u>***

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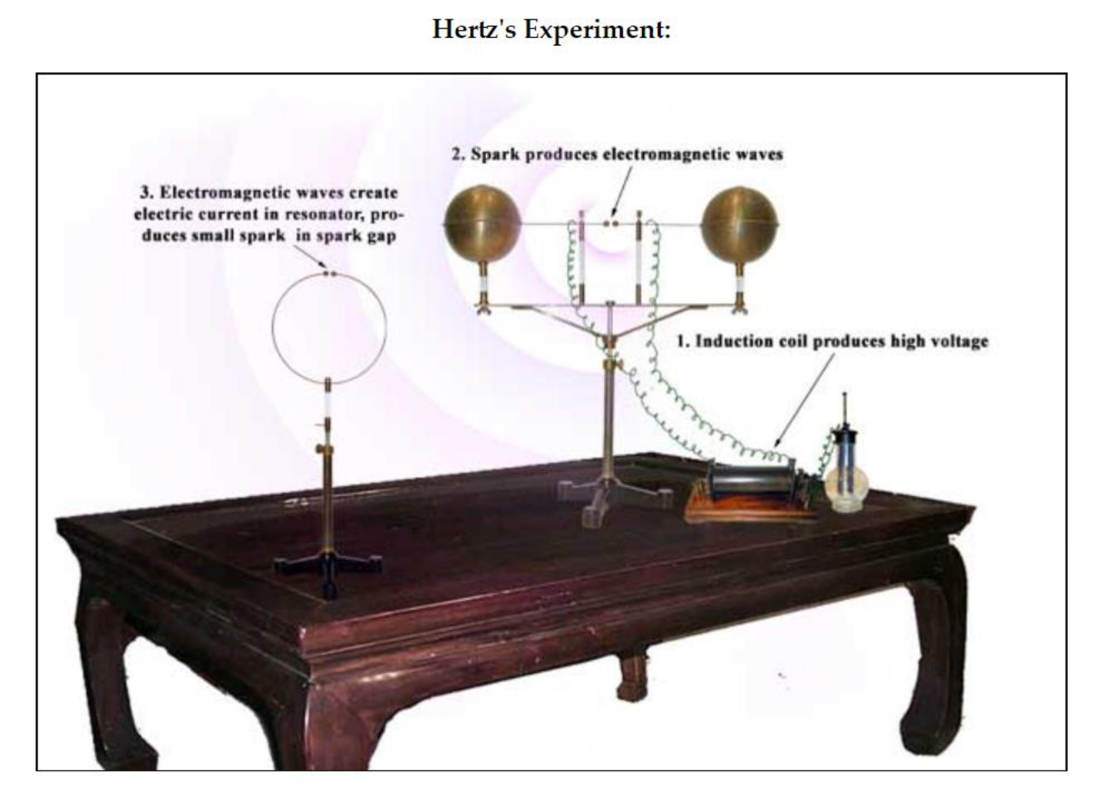
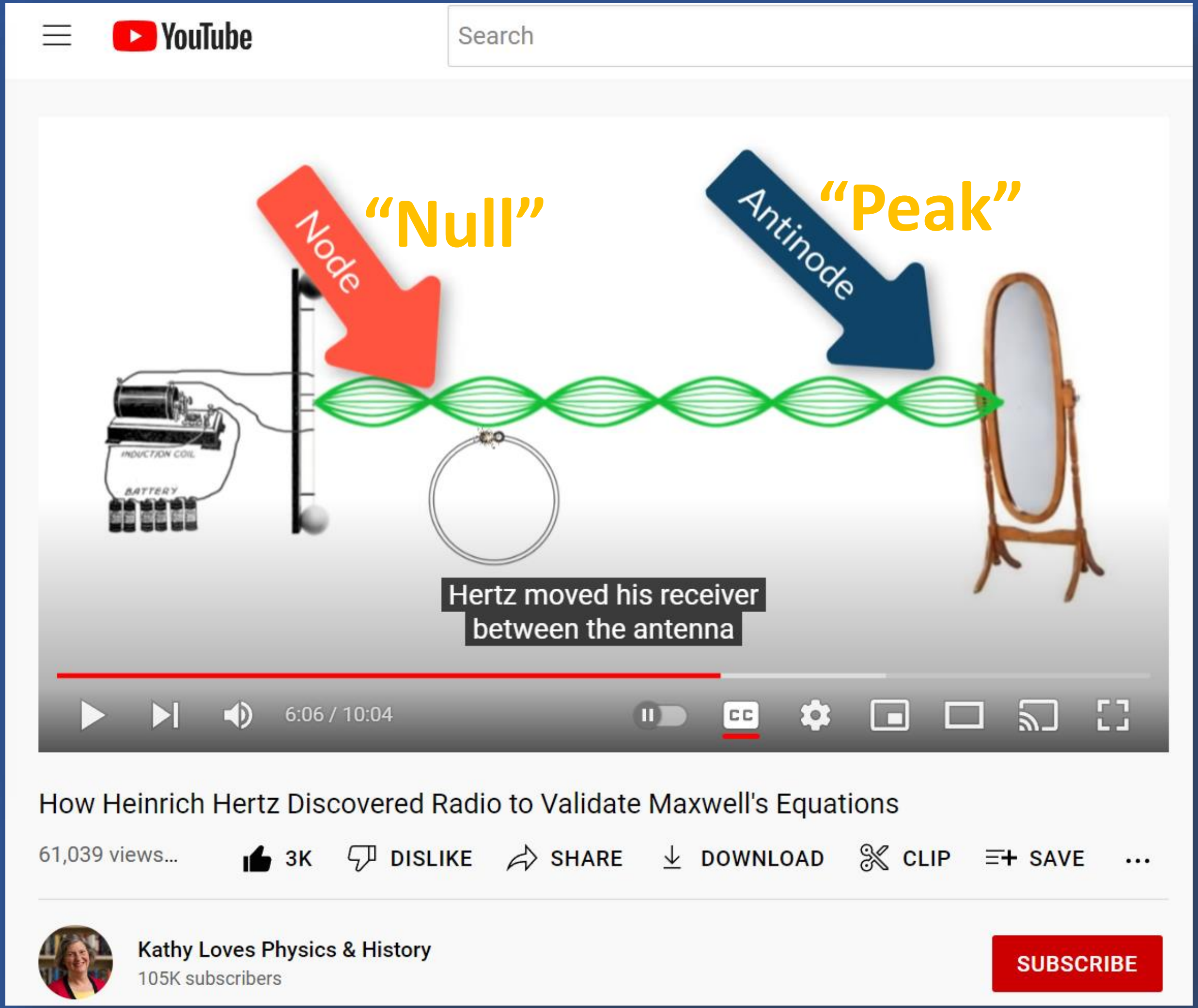
Hertz Demonstrations ☺

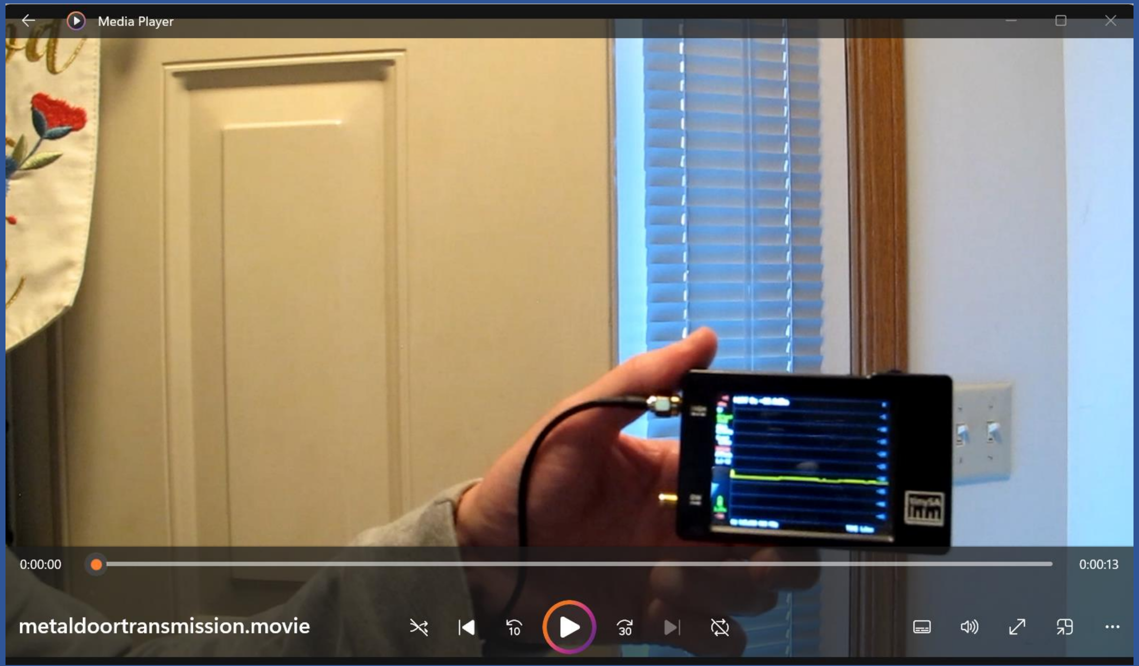


http://www.sparkmuseum.com/BOOK_HERTZ.HTM

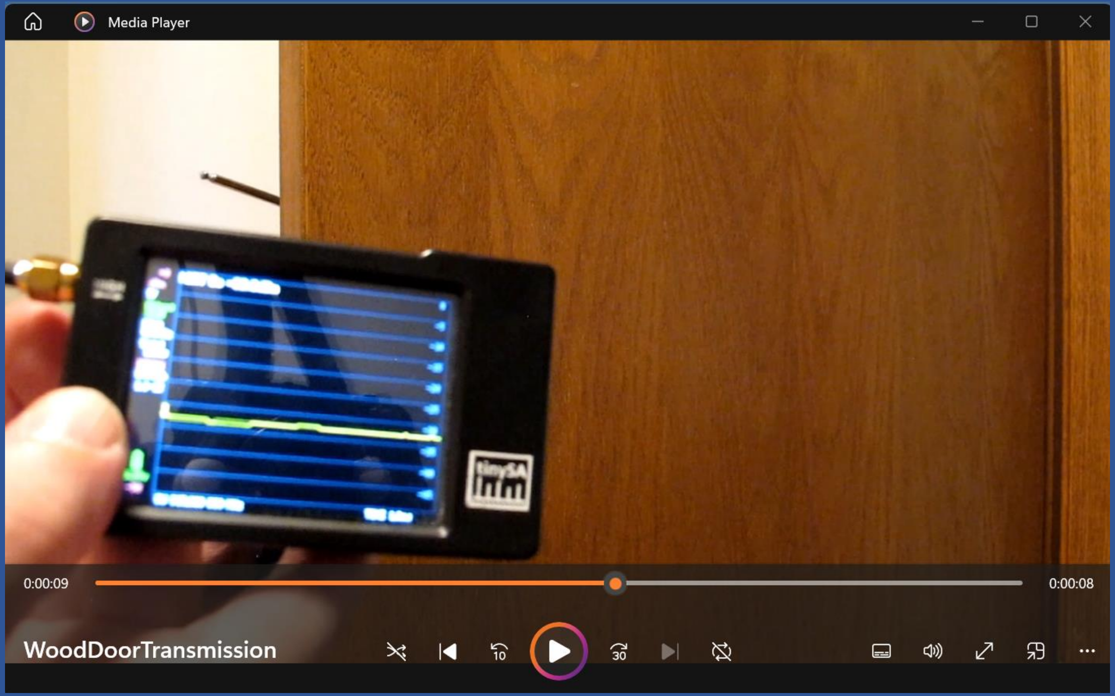


Demo with 915 MHz Dipoles

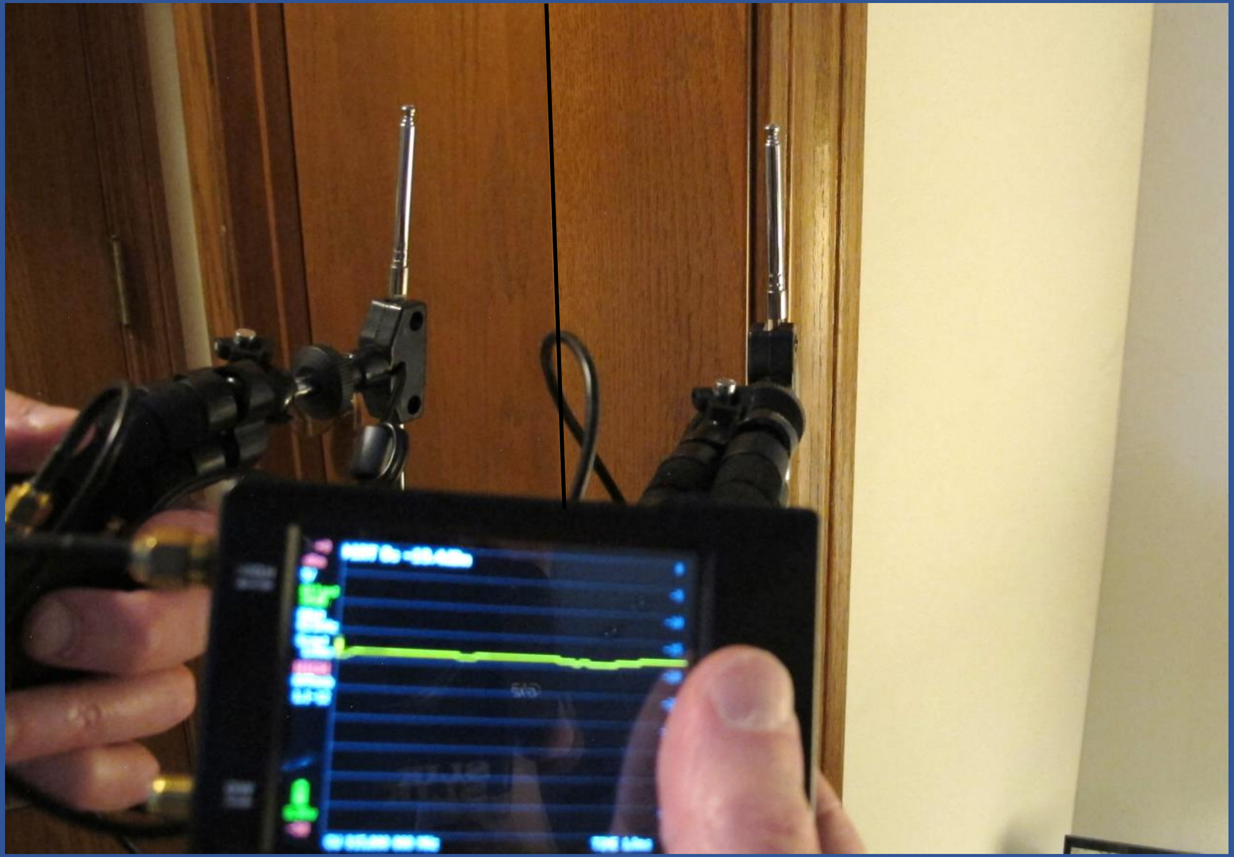
Metal Exterior Doors Reflect and Block Transmission



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.

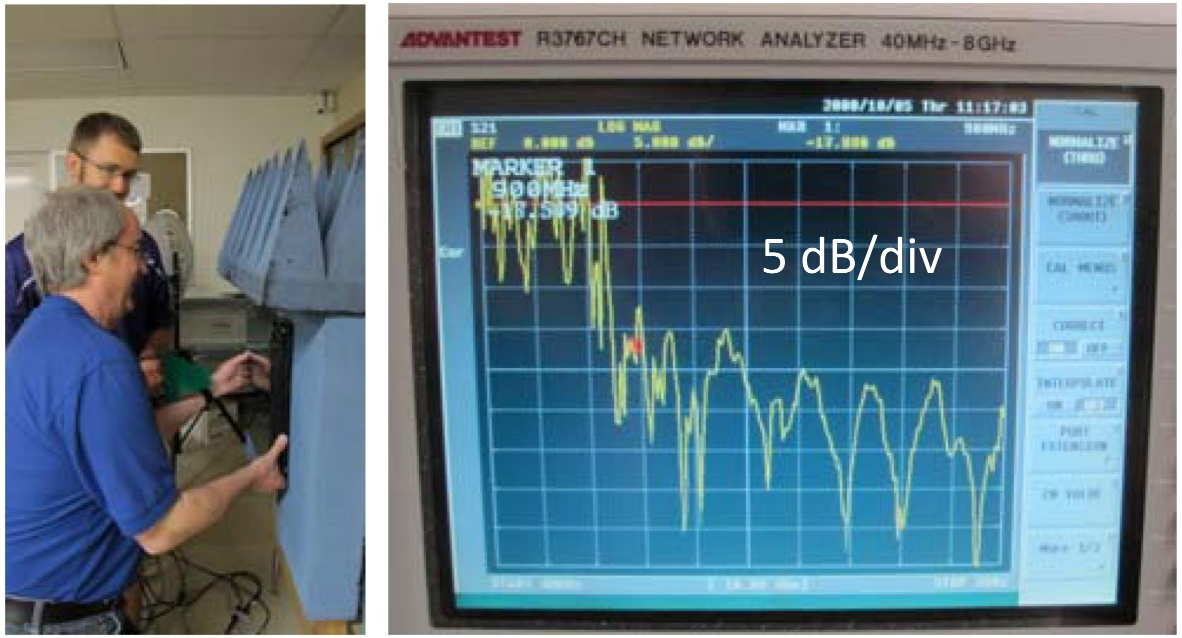


Figure 4. Radiowave transmittance measurement: 40 MHz through 3 GHz horizontal, 5dB/division vertical. Data below about 800 MHz is not valid (see text).

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

2016 IEEE International Symposium on Electromagnetic Compatibility

How Can We Use What We've Learned ?

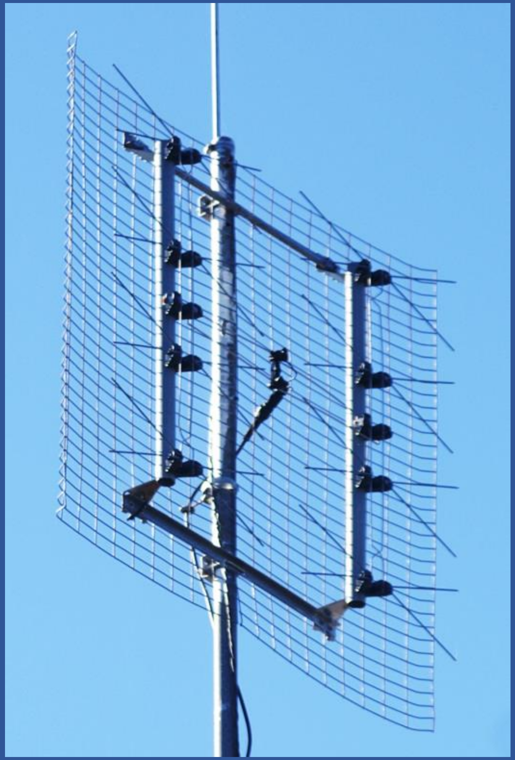
II. ATTENUATION FROM ENERGY EFFICIENT GLASS

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 ?