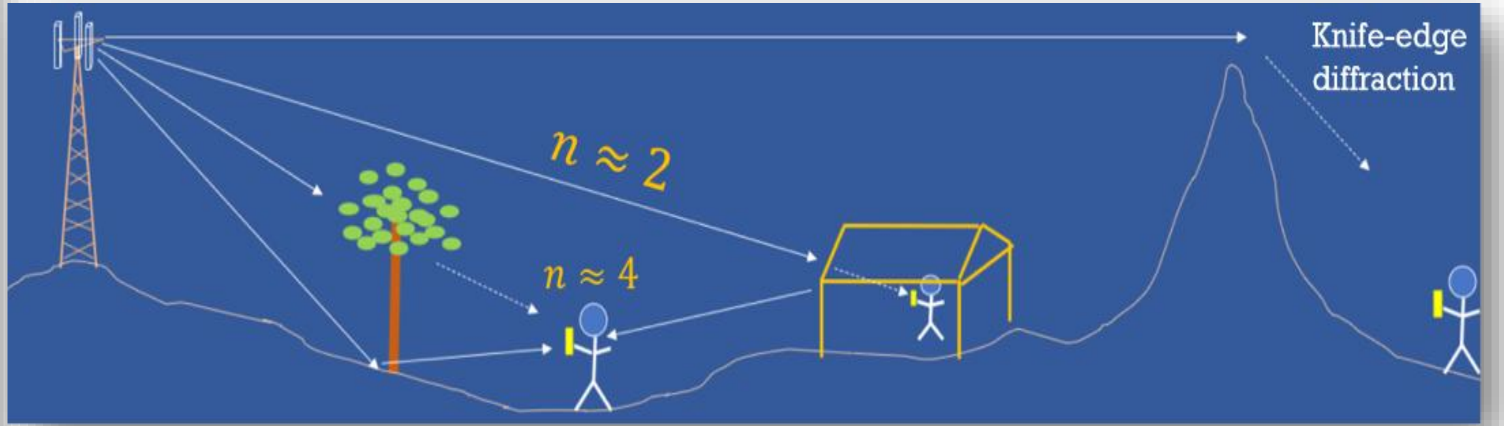
Radio Design 201 Microwave Circuits and Antennas

Episode 6, Part 1 – Antenna Height and Line-of-Sight

Slides downloaded from: https://ecefiles.org/

Companion videos at: https://www.youtube.com/playlist?list=PL9Ox3wpnB0kpOb7NdpHAK-jDpsZm3Xedx

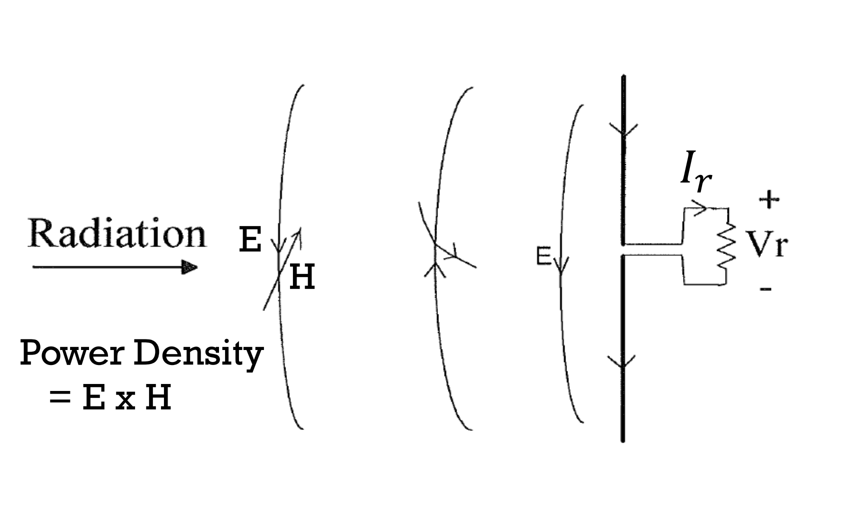
Microwave transmission is different from lower frequencies like HF. We show how microwave antennas are often elevated to satisfy line-of-sight requirements. Complexities considered include classic Fresnel issues, but also earth curvature and two-path cancellation (multi-path). This is part 1 of a two part episode. Part 2 will cover field strengths, field exposure limits, and an introduction to the mathematical treatment of radio waves presented in the university course that Radio Design 201 is abstracted from.



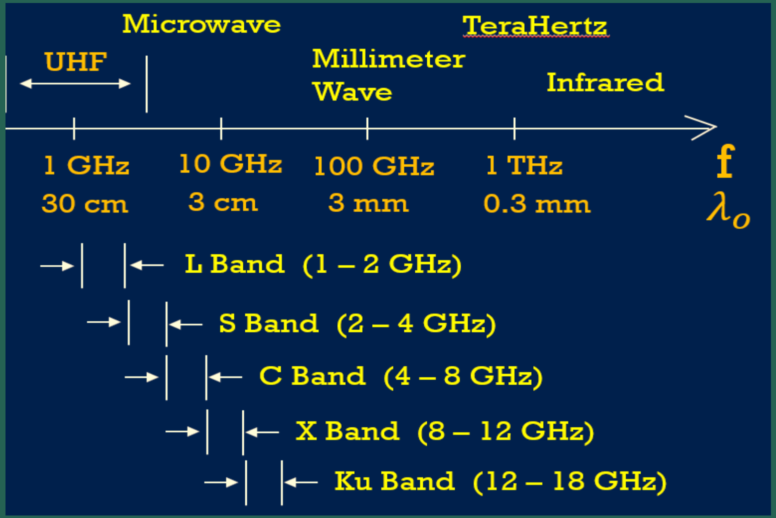
Radio Design 201 #6

Microwave Circuits and Antennas

Antenna Height and Line-of-Sight



MegawattKS - YouTube https://ecefiles.org



Why Use "Microwaves" ?

(from Episodes 1 and 5)

- Massive Amounts of Spectrum Available
- Highly Directional Antennas and High Gain
- Long Range Possible *(for line-of-sight paths)*

Today's "Lecture" Topics

Announcements

Welcome to Episode 6 !

Episodes 1 - 5 introduced this series

- *Frequencies and wavelengths*
- *Class projects*
- *Low-cost equipment and software*
- *Gain, pathloss, spectrums, and noise*

Episode 5 covered how to calculate received signal levels

Today's Topics

A Quick Review

Line of Sight (Definitions and complexities)

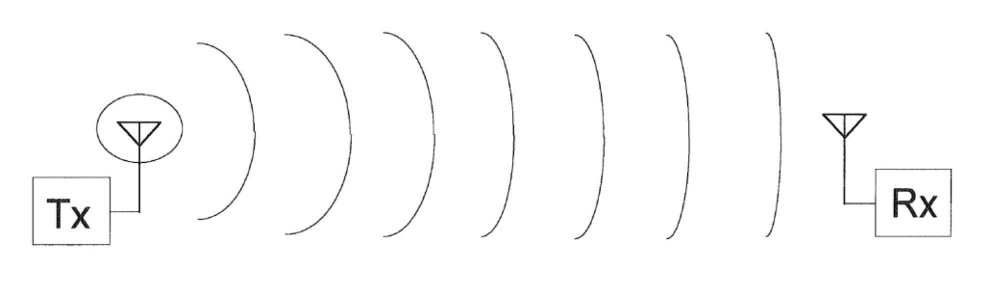
Power Density vs Field Strength

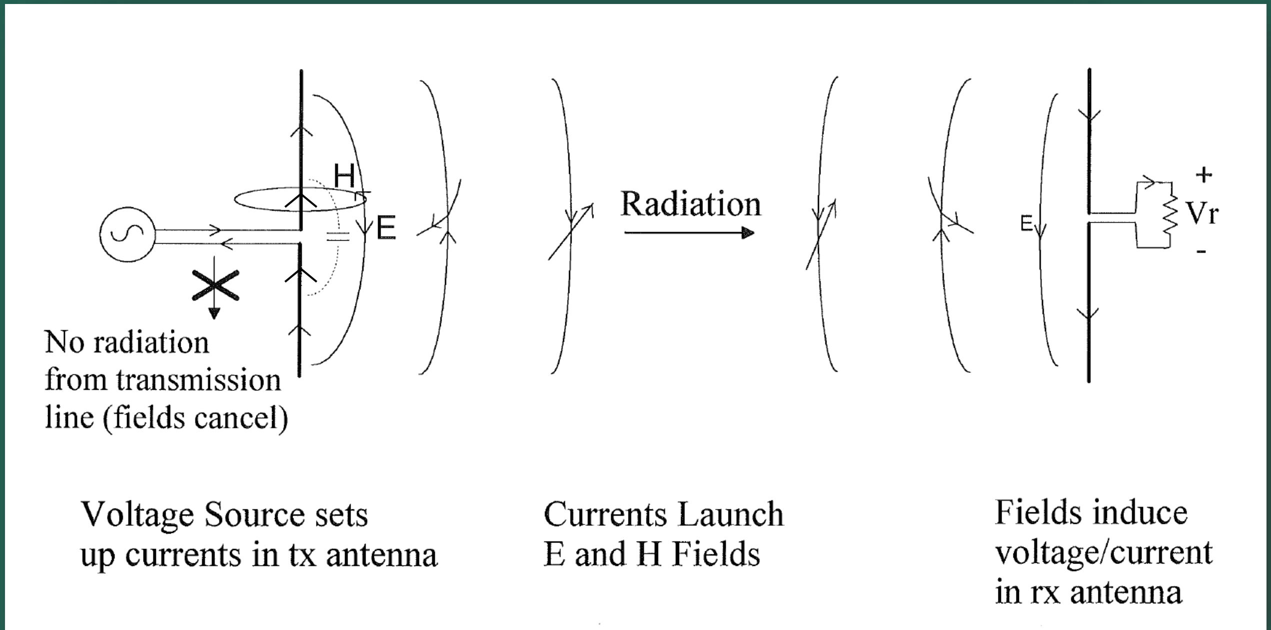
EM Fields

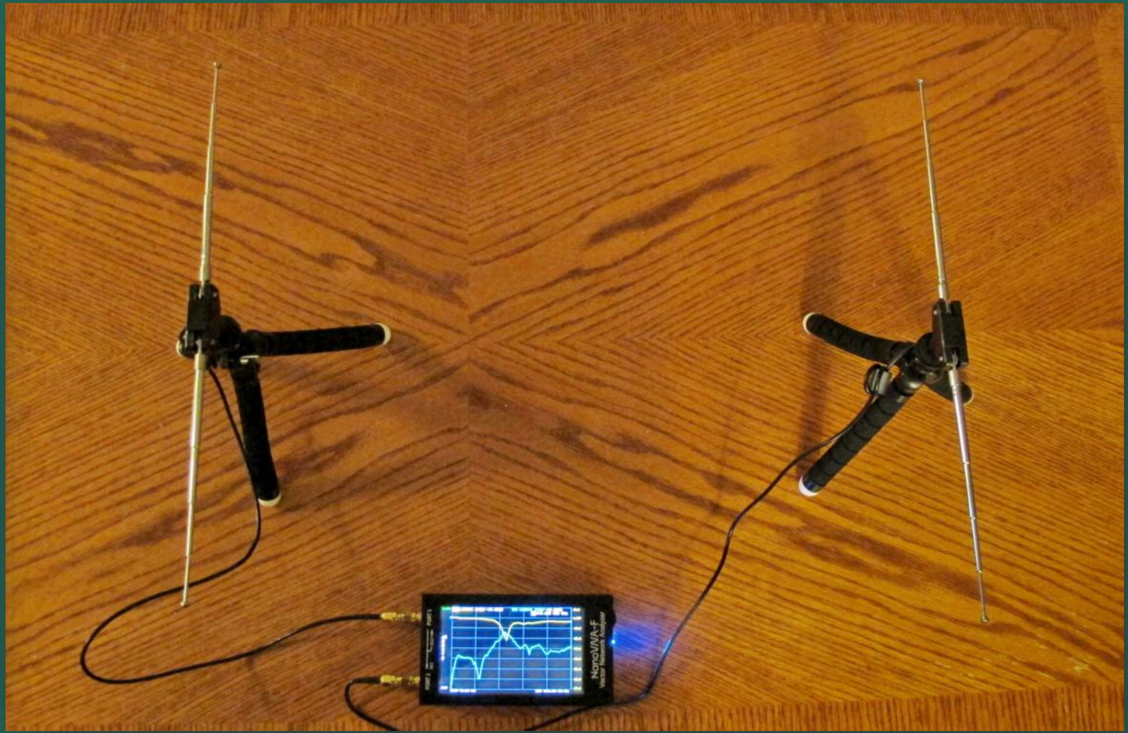
Example University Labs

Antenna and EM Field Basics

(from Episodes 3 and 4)

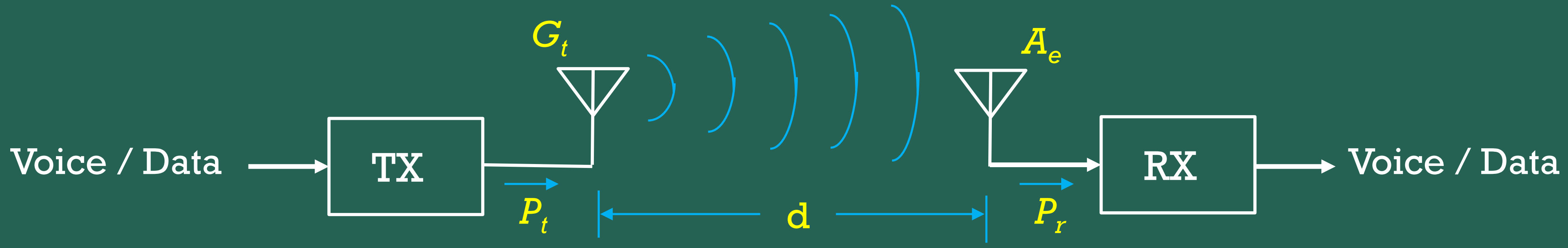


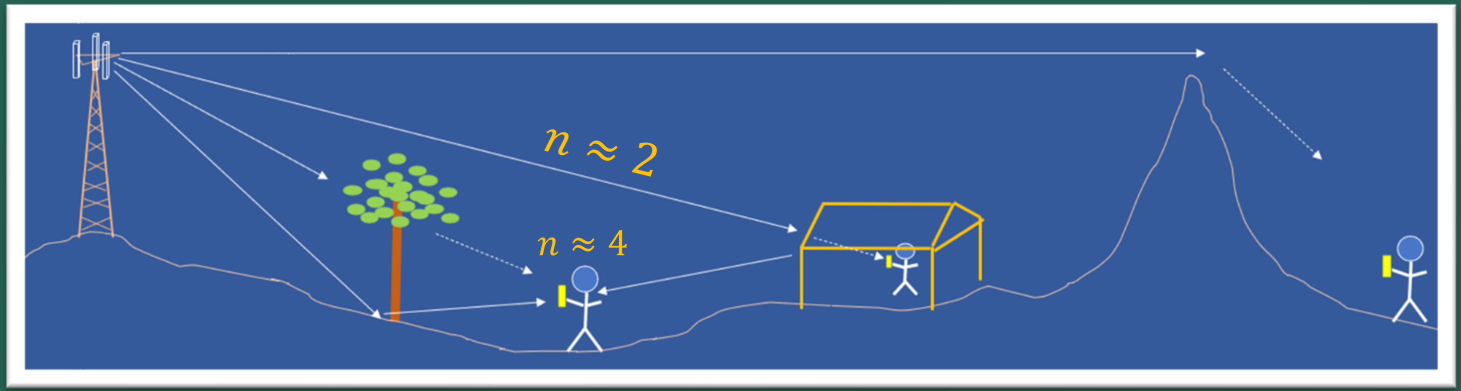




Received Signal Power

(from Episode 5)





$$P_r = \frac{P_t G_t}{4\pi d^n} A_e$$

See also: Antenna Briefs, Episode 7

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Example University Labs

Distance to Horizon vs Height

en.wikipedia.org/wiki/Horizon

Distance to the horizon [edit]

Very tall
Antenna tower

Earth radius

Formula [edit]

The distance to the true (geometric) horizon (not accounting for atmospheric refraction) from an observer at height h above the surface of a celestial body assumed to be perfectly spherical can be calculated using the formula:

$$d = \sqrt{2Rh + h^2} \approx \sqrt{2Rh}$$

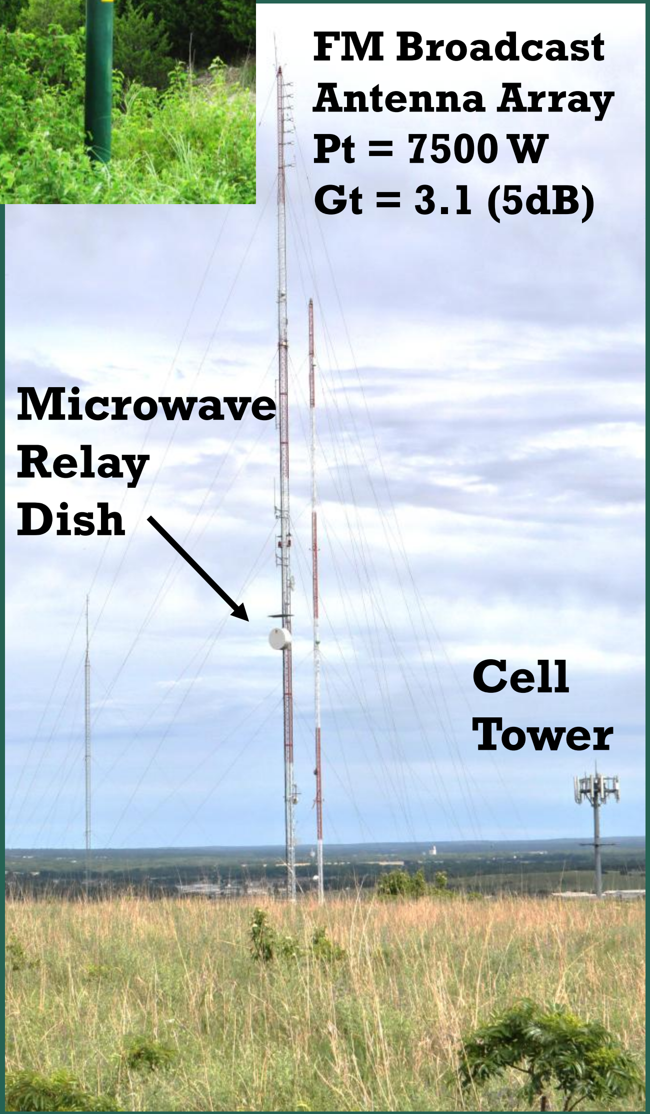
Calculator

Radius	6371009	m
Height	50	m
Distance	**25241**	**m**

About 15 miles

Mount tower/antenna on high-land if possible !

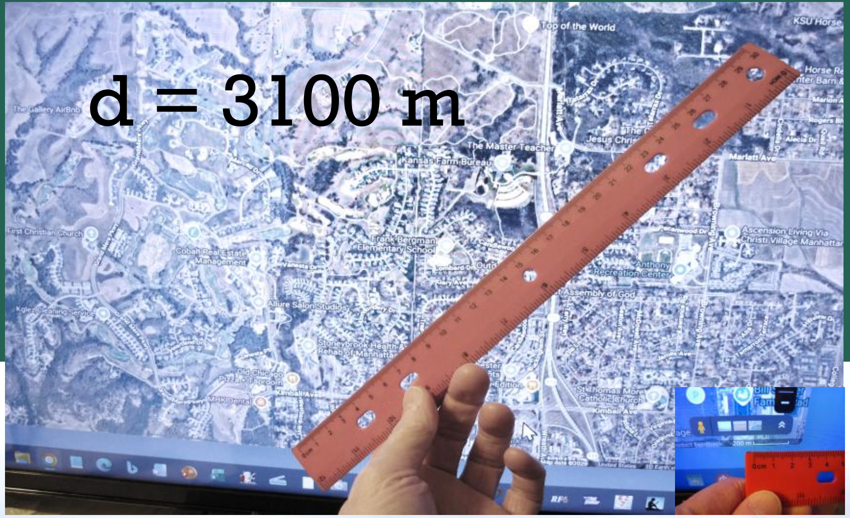
A Real-World Example



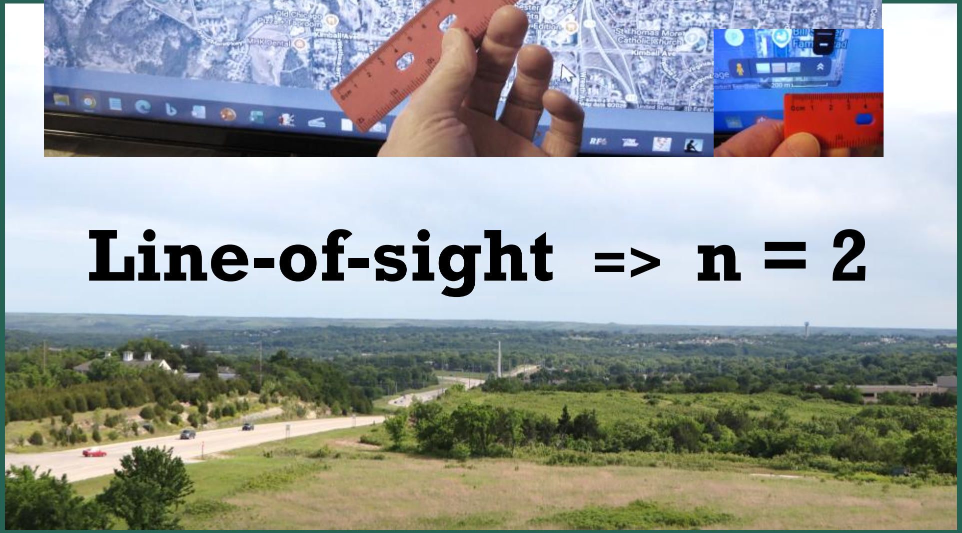
FM Broadcast
Antenna Array
$P_t = 7500$ W
$G_t = 3.1$ (5dB)

Microwave
Relay
Dish

Cell
Tower

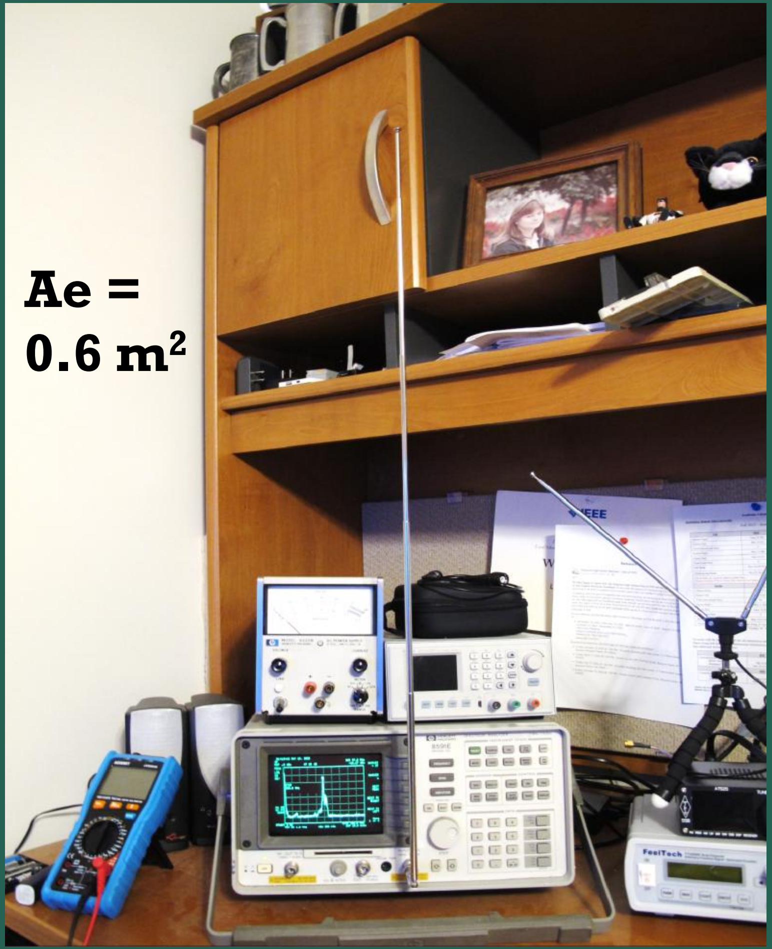


$d = 3100$ m



Line-of-sight => n = 2

FM Broadcast Reception in my home-office lab



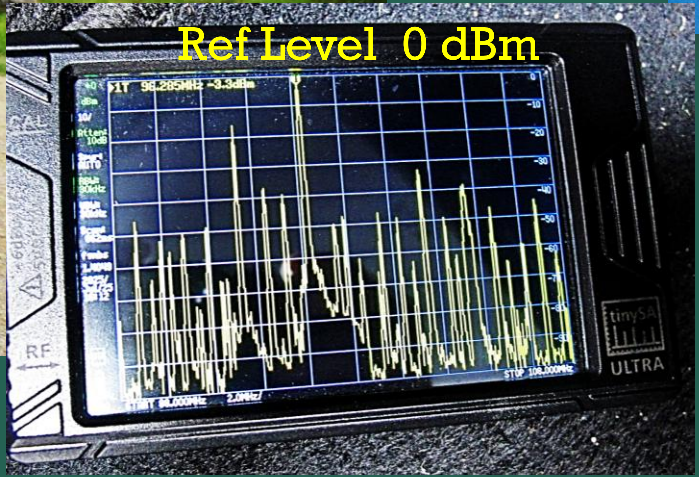
$A_e =$
$0.6\ m^2$

P_r Measured at the Antenna Site

From Radio Design 401, Episode 8

6-element
Vertical Array
10° Beamwidth

Pt = 7.5 kW
EIRP=21 kW



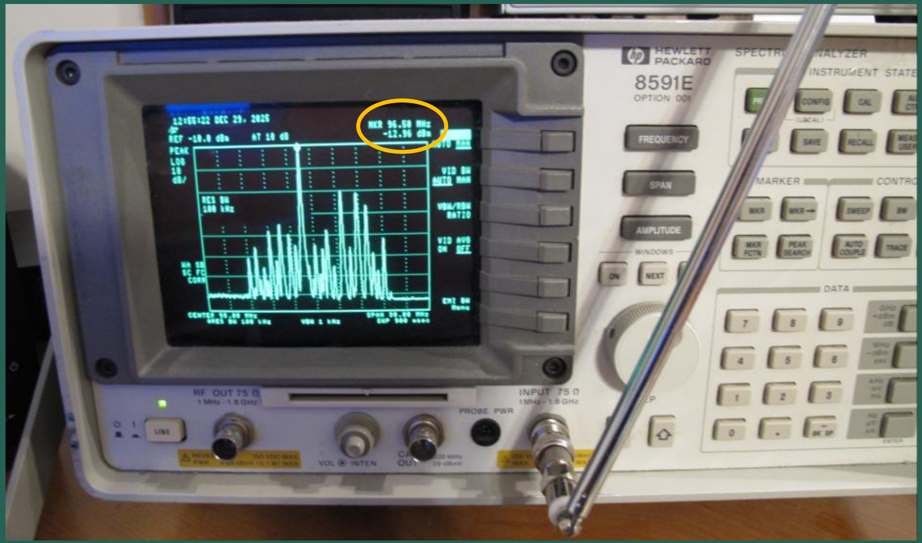
Why "only" one milliwatt received ?

Calculated/Measured Signal in House 3.1 km Away

Pt = 7500 W
Gt = 3
d = 3.1 km (3100m)
Ae = 0.6 m^2

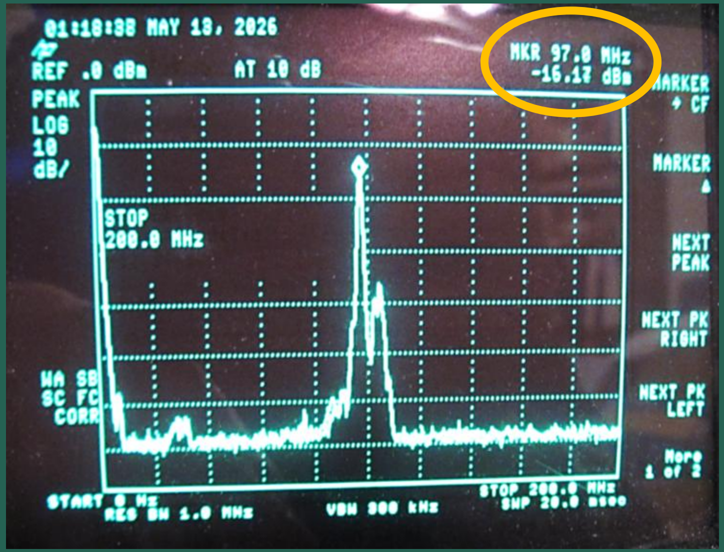
=> $$P_r = \frac{P_t G_t}{4\pi d^2} A_e = 0.11\, mW = -9.6\, dBm$$

Winter: December 2025



P_r = -13 dBm = 0.05 mW

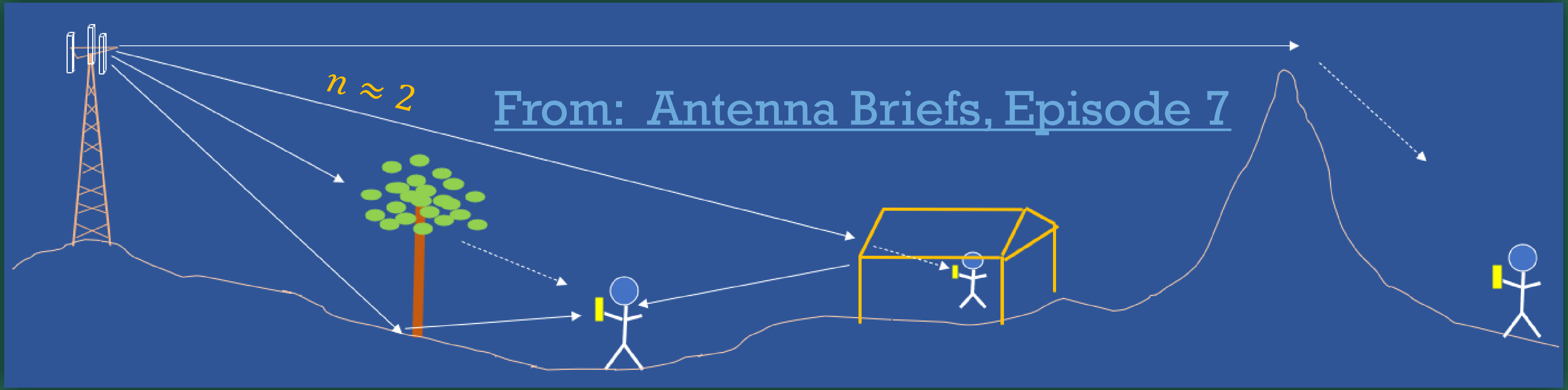
Spring: May 2026



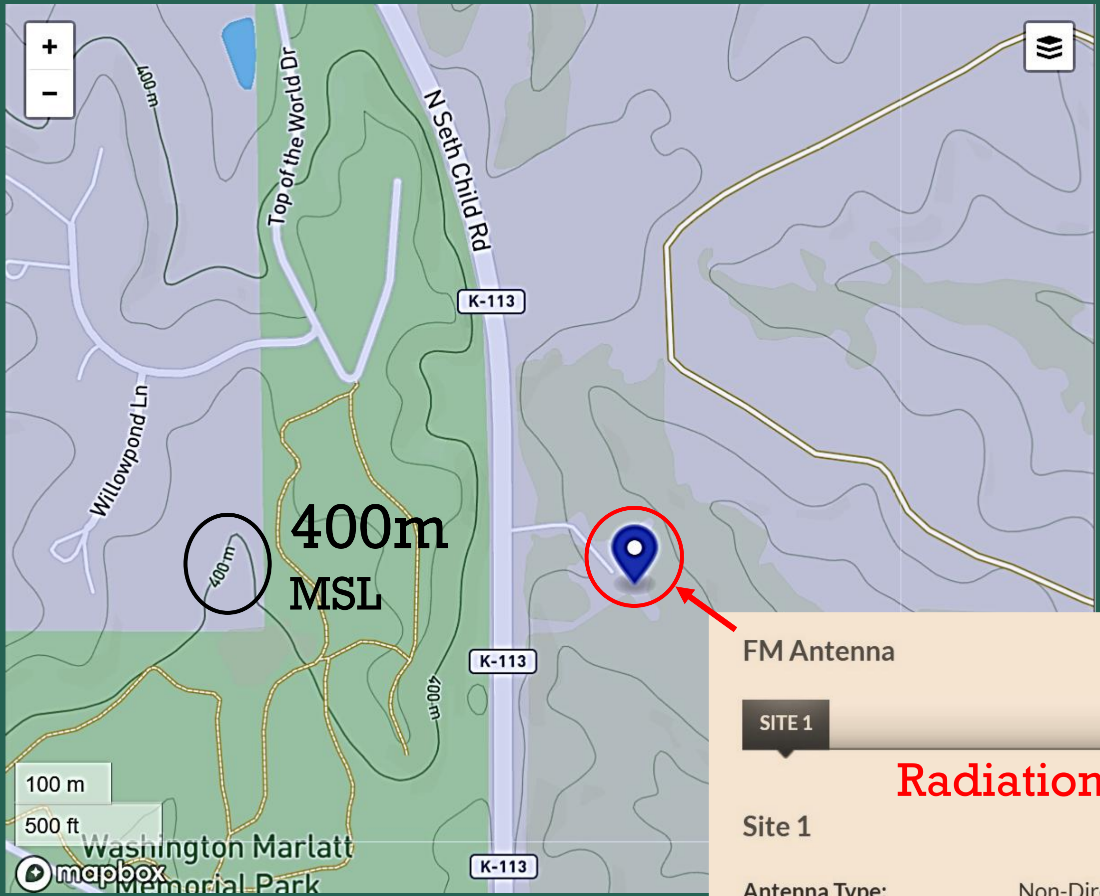
P_r = -16 dBm = 0.025 mW

Why Less than Calculated ?

- A_e estimate
- Walls
- Trees !
- Multi-path
- Polarization



Antenna Height and Topography



FM Antenna

SITE 1

Radiation-Center Above Mean Sea Level

Site 1

Antenna Type:	Non-Directional	RCAMSL:	505 meters
Number of Sections:	6	HAAT:	145 meters
Wavelength Spacing:	0.5	Overall antenna height above ground:	121.9 meters

Fresnel Zone Clearance

Fresnel zone

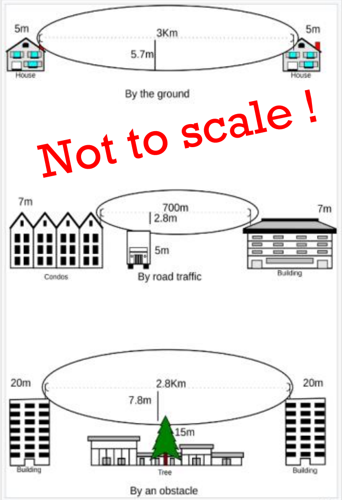
17 languages

Article Talk Read Edit View history Tools

From Wikipedia, the free encyclopedia

This article includes a list of general references, but it lacks **sufficient corresponding inline citations**. Please help to improve this article by introducing more precise citations. *(January 2017) (Learn how and when to remove this message)*

A **Fresnel zone** (English: /freɪˈnɛl/ *fray-NEL*), named after physicist Augustin-Jean Fresnel, is one of a series of confocal prolate ellipsoidal regions of space between and around a transmitter and a receiver. The size of the calculated Fresnel zone at any particular distance from the transmitter and receiver predicts whether obstructions or discontinuities along the path will cause significant interference.



Several examples of how Fresnel zones can be disrupted

Not to scale !

Background [edit]

The primary wave will travel in a relative straight line from the transmitter to the receiver. Aberrant transmitted radio, sound, or light waves which are transmitted at the same time can follow slightly different paths before reaching a receiver, especially if there are obstructions or deflecting objects between the two. The two waves can arrive at the receiver at slightly different times and the aberrant wave may arrive out of phase with the primary wave due to the different path lengths. Depending on the magnitude of the phase difference between the two waves, the waves can interfere constructively or destructively.

Maximum clearance [edit]

For practical applications, it is often useful to know the maximum radius of the first Fresnel zone. Using $n = 1$, $d_1 = d_2 = D/2$, and $\lambda = c/f$ in the above formula gives

$$F_1 = \frac{1}{2}\sqrt{\lambda D} = \frac{1}{2}\sqrt{\frac{cD}{f}},$$

where

D is the distance between the two antennas,
f is the frequency of the transmitted signal,
$c \approx 2.997 \times 10^8$ m/s is the speed of light in the air.

Substitution of the numeric value for c followed by a unit conversion results in an easy way to calculate the radius of the first Fresnel zone F_1, knowing the distance between the two antennas D and the frequency of the transmitted signal f:

- $F_1[\mathrm{m}] = 8.656\sqrt{\frac{D[\mathrm{km}]}{f[\mathrm{GHz}]}}$
- $F_1[\mathrm{ft}] = 36.03\sqrt{\frac{D[\mathrm{mi}]}{f[\mathrm{GHz}]}}$

Not in fundamental Units !

See also [edit]

- Beam diameter
- Diversity scheme
- Elliptical reflectors and acoustics
- Fresnel diffraction
- Fresnel integral
- Fresnel number
- Fresnel zone plate
- Fresnel zone antenna
- Microwave
- Near field
- Path loss
- Rain fade
- Weissberger's model

References [edit]

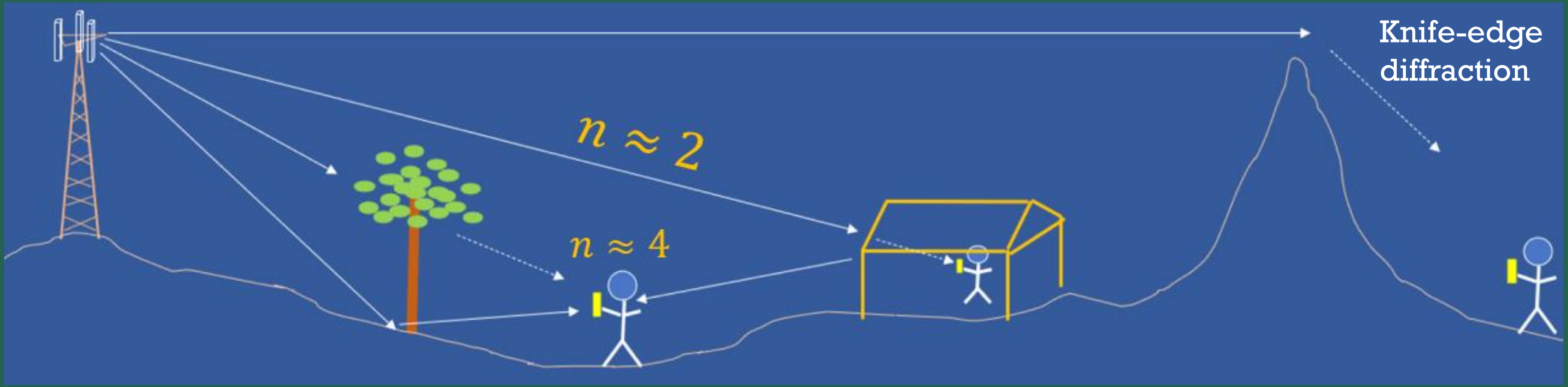
1. ^ Coleman, Westcott, David, David (2012). *Certified Wireless Network Administrator Official Study Guide*. 111 River St. Hoboken, NJ 07030: John Wiley & Sons, Inc. p. 126. ISBN 978-1-118-26295-5.
2. ^ "Fresnel Zone Clearance". softwright.com. Retrieved 2008-02-21.
3. ^ Tomasi, Wayne. *Electronic Communication Systems - Fundamentals Through Advanced*. Pearson. p. 1023.

Example "maximum clearance" values at D = 3 km distance

Frequency f	**Fresnel Zone Radius (F1)**	**Angle off direct path @ midpoint**
0.1 GHz	47 m	1.8°
3 GHz	8.7 m	0.33°

Consider antenna beamwidth and earth curvature / bulge /etc. for very long paths as well !

Fresnel zones, diffraction, and Two-ray Cancellation

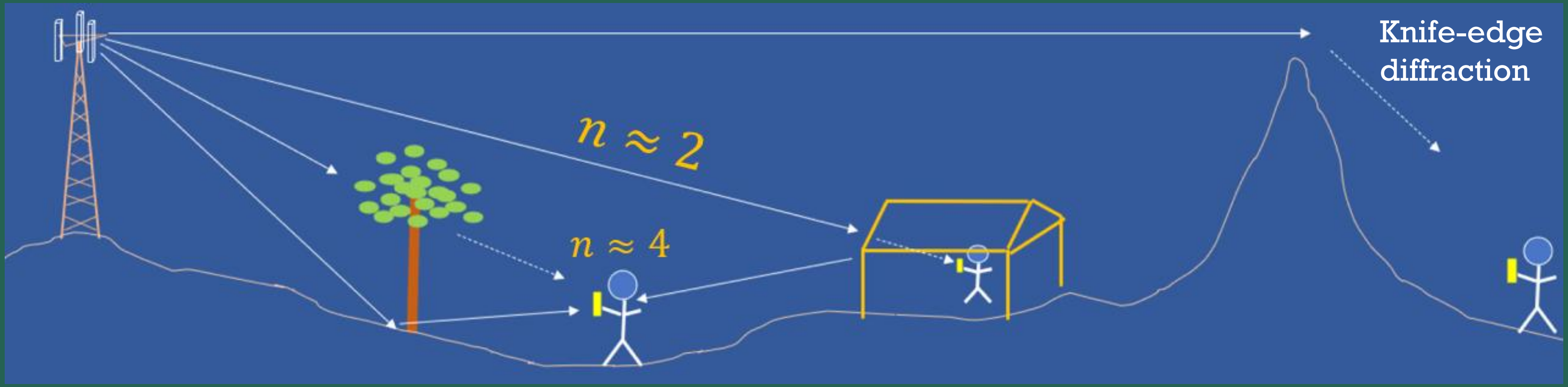


Scenario	Primary Concern and considerations
Over-land path, rolling terrain	Fresnel zone diffraction loss
Flat water or smooth plains, long path	Two-ray cancellation (n=4); antenna height tuning critical
Short path, high antennas	Free-space (n=2); neither dominates
Partial obstacle (building, ridge)	Fresnel zone obstruction and diffraction/reflections

Prepared using Claude Sonnet 4.6

15 sources

Knife-edge Diffraction vs Frequency



- You (and microwaves) can't see through a hill, but …
- Sufficiently *low frequency* radio waves can reach the other side ☺

Thanks For Watching !

For more info …

[MegawattKS - YouTube](#) https://ecefiles.org