Radio Design 201 Microwave Circuits and Antennas

Episode 6 Part2 – Field Strength and EM Waves

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

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

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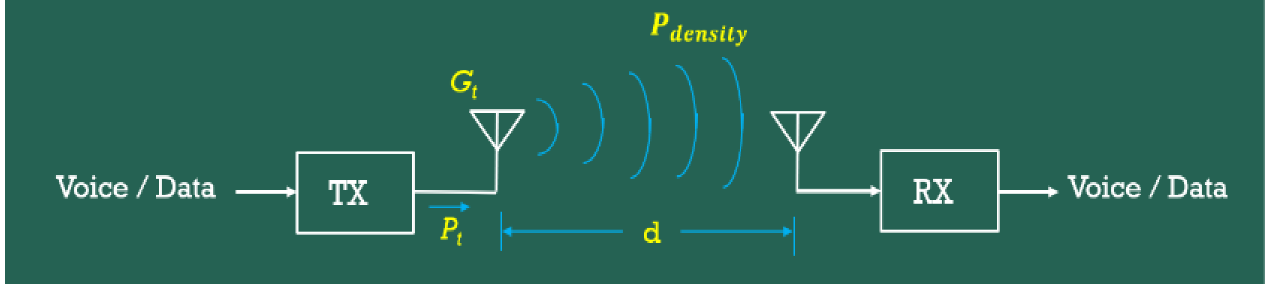
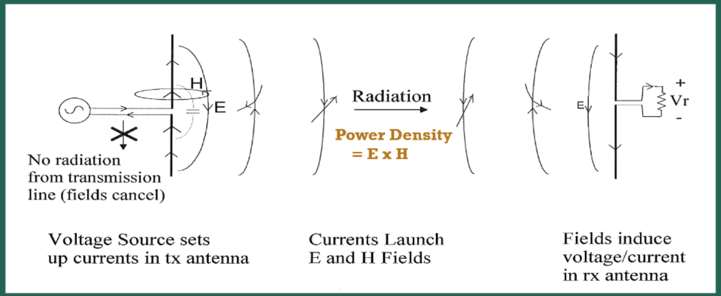
In this second part of Episode 6, we examine antennas and radio communication systems from the EM field point of view. Starting from the EM wave's power density in free space found using the methods of Part 1, we use Poynting's theorem to find the Electric field strength, and ultimately, with a receiving antenna's effective length (or effective height), the received voltage. This journey takes us many places along the way, including reviewing basic electric and magnetic field physics, some core math, university course curriculums, and university level laboratory work. We hope you enjoy the voyage :-)



$$P_{density} = \frac{P_t\, G_t}{4\,\pi\, d^n} \quad \left(\frac{W}{m^2}\right)$$



Power density in W/m²

E-field in V/m

$$P_{density} = E \times H = \frac{|E|^2}{Z_o}$$

Magnetic field in A/m

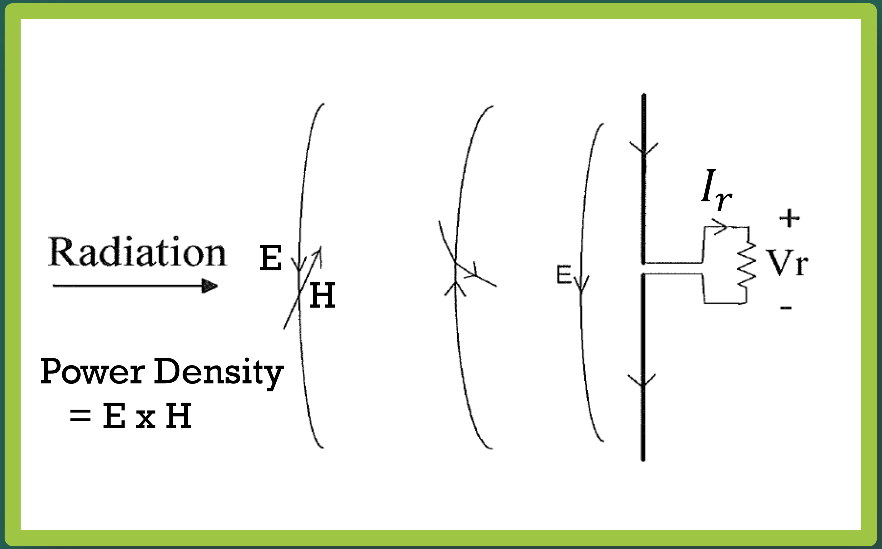
"Impedance" of free-space

(377 Ohms) $= \sqrt{\frac{\mu_o}{\epsilon_o}} = \sqrt{\frac{4\pi(1E-7)}{8.854E-12}}$

Radio Design 201 #6 Part 2

Microwave Circuits and Antennas

Antenna Height and Line-of-Sight and EM Fields



MegawattKS - YouTube https://ecefiles.org

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

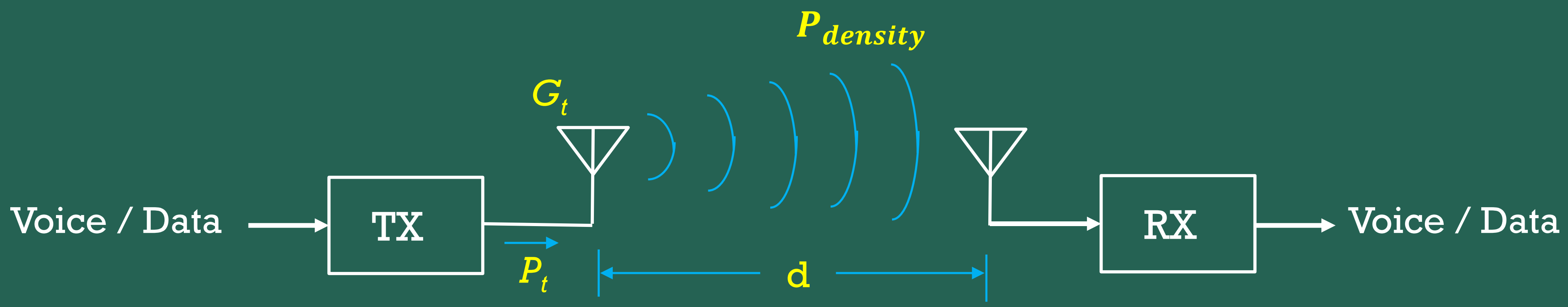
Line of Sight (Definitions and complexities)

➡ *Power Density vs Field Strength*

EM Fields

Example University Labs

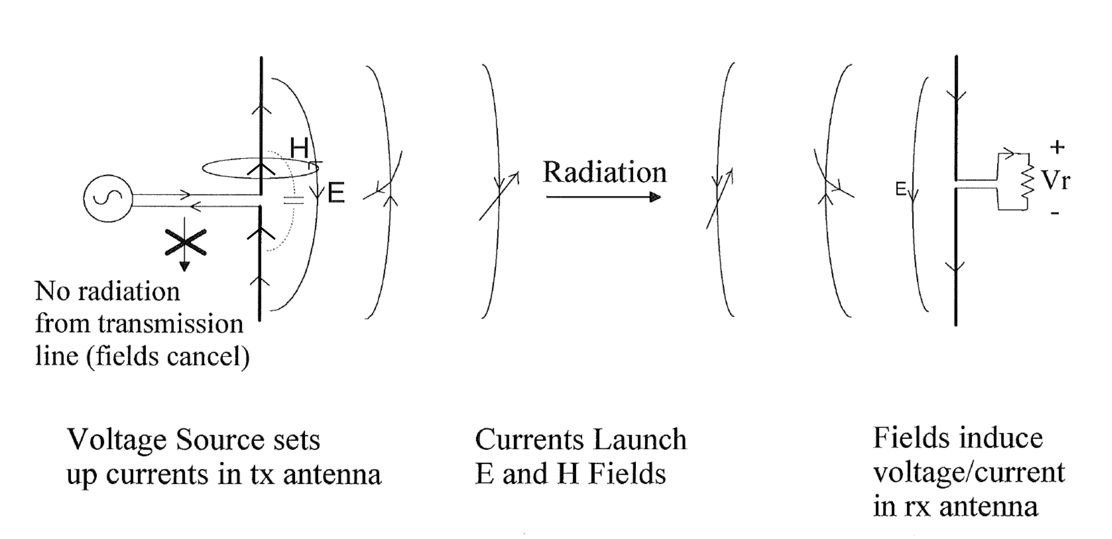
Power *Density* at Receiver

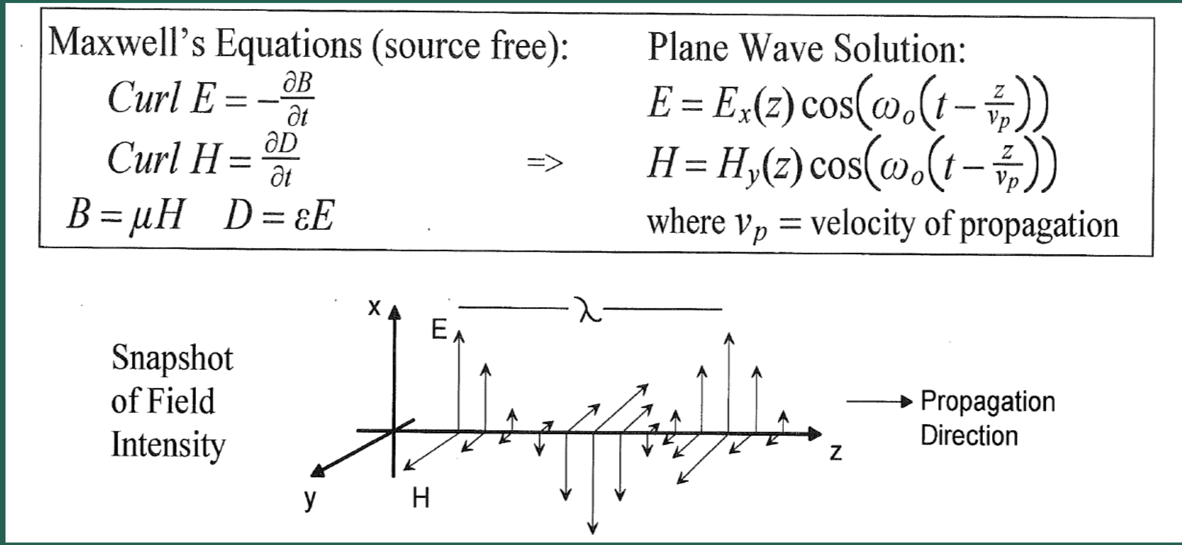


$$P_{density} = \frac{P_t\, G_t}{4\, \pi\, d^n} \quad \left(\frac{W}{m^2}\right)$$

- $P_{density}$ is independent of specific receiver used
- n=2 for line-of-sight propagation
- n= 3 to 5 with unclear path – but still in $\left(\frac{W}{m^2}\right)$

Power Density vs Field Strength





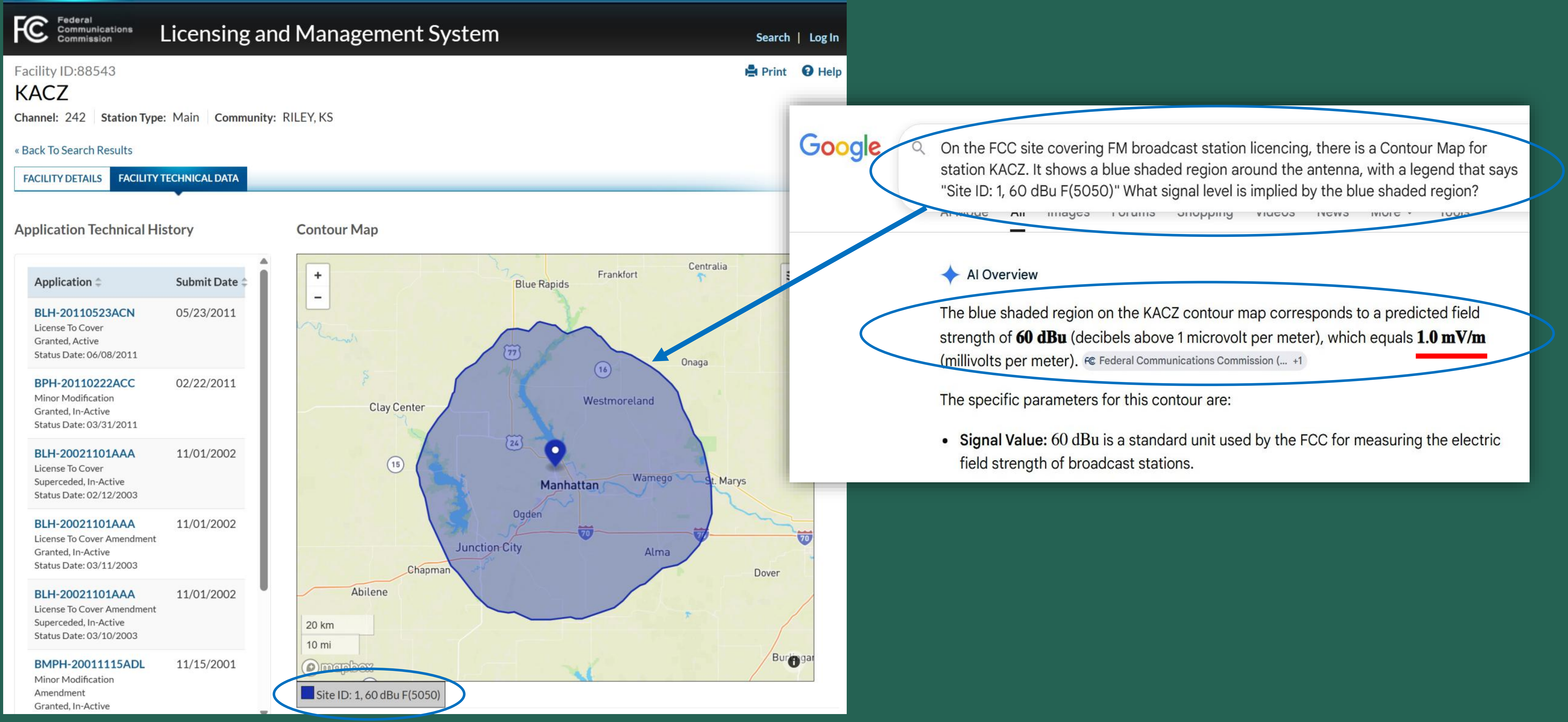
E is electric field-strength in *Volts/meter*

H is magnetic field-strength in *Amps/meter*

And… in the "far field", we have a "plane wave" where,

E x H is power density in *Watts/meter-squared*

KACZ FM's 1 mV/m Contour



Field Strength vs Power Density

Why specify as "field strength" (V/m) ?

perplexity.ai/search/cb414410-3b11-42f7-...

Answer Links Images ... Share Download Comet

why does the fcc give field strength values such as V/m instead of power density values like W/m^2 for radio transmitters?

Completed 2 steps >

The FCC uses both V/m and W/m² depending on context, but V/m predominates for several practical and historical reasons.

They're Mathematically Equivalent in the Far Field

In the far field, electric field strength E (V/m) and power density S (W/m²) are directly related through the impedance of free space $Z_0 \approx 377\ \Omega$:

$$S = \frac{E^2}{Z_0}$$

So specifying one uniquely determines the other. The FCC actually publishes **both** in its RF exposure tables — for example, its human exposure limits list E (V/m), H (A/m), and S (W/m²) side by side. But for transmitter emission compliance (especially Part 15), V/m is the dominant unit. giangrandi +1

Why V/m Is Preferred for Compliance Testing

The key practical reason comes down to **how measurements are actually made**: highfrequencyelectronics

- A calibrated field-strength meter or measurement antenna outputs an **RF voltage**. Converting that voltage reading to V/m via the antenna's calibration factor is direct and intuitive — no extra step needed.

Historical and Regulatory Consistency

The V/m convention predates power density measurements as a regulatory metric. Early radio regulation focused on interference between services, and engineers naturally measured what their antenna/receiver systems produced: a **voltage**. As a result, decades of FCC rules, test procedures (like ANSI C63.4), and enforcement actions are all written in V/m terms, making it impractical to switch. ultralightdx.groups

Where W/m² Does Appear

Power density becomes the preferred unit at **higher frequencies and for human RF exposure limits:** fcc +1

- Above ~300 MHz, the FCC's MPE (Maximum Permissible Exposure) tables transition emphasis to W/m² or mW/cm² because biological tissue interaction is better modeled with power absorbed per unit area.
- In the near field, E and H don't have a fixed Z_0 relationship, so both must be specified independently — and power density loses its simple meaning entirely. giangrandi

In short: V/m maps directly to what instruments measure (voltage), requires no antenna impedance assumption, and is embedded in decades of regulatory infrastructure — while W/m² is reserved for contexts like biological exposure where absorbed power is the physically meaningful quantity.

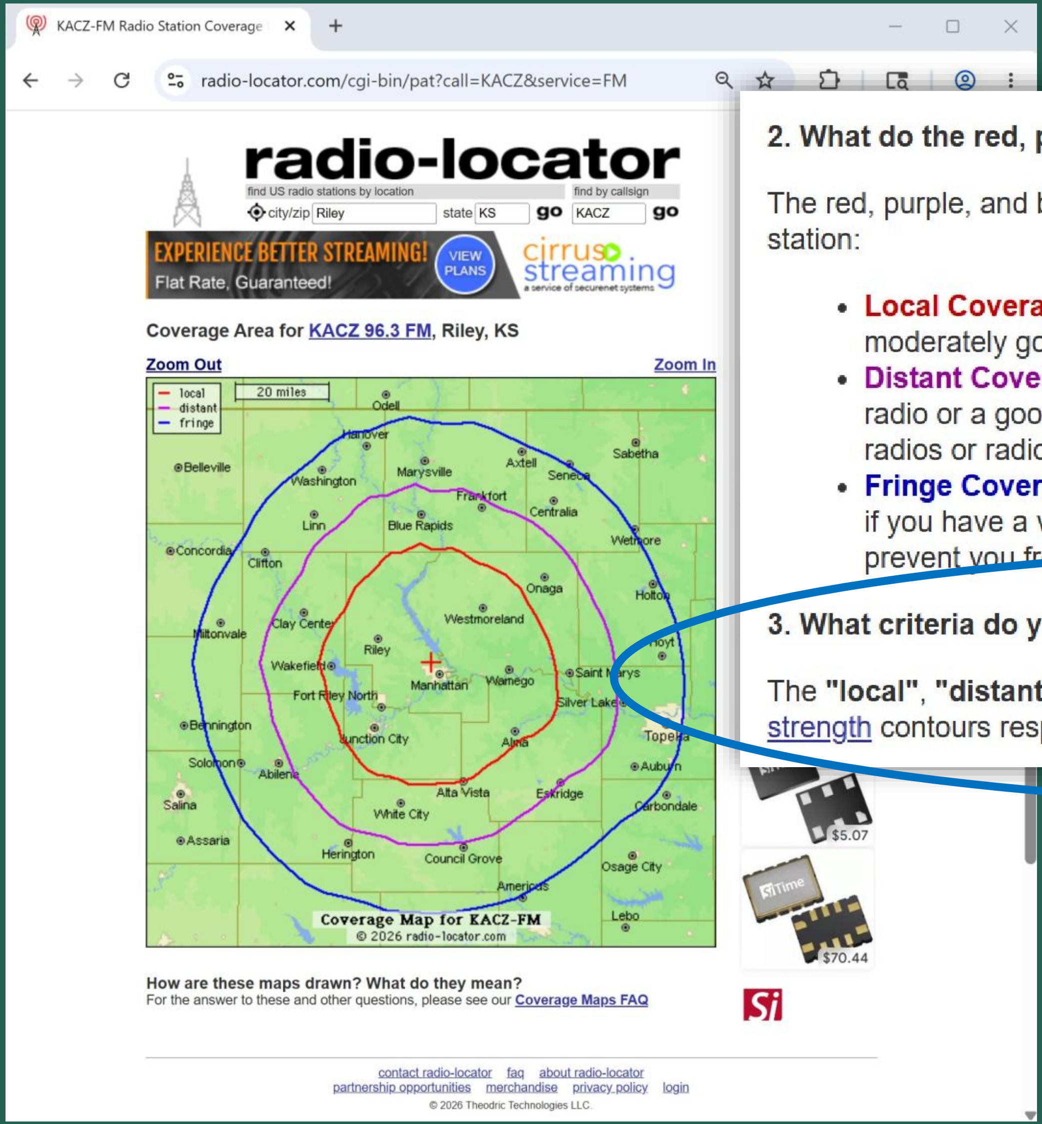
Prepared using Claude Sonnet 4.6

15 sources

Follow-ups

- Build an interactive EMF converter to toggle between V/m, W/m², and dBµV/m across different frequency bands — Computer
- Compare FCC Part 15 emissions limits: why V/m at 3 meters is the industry standard for test labs vs W/m² for safety compliance — Computer

Additional Receiver Contours



2. What do the red, purple, and blue lines mean?

The red, purple, and blue lines correspond to the "local", "distant", and "fringe" predicted coverage areas of each radio station:

- **Local Coverage:** Within this area, you should be able to receive the radio station on almost any radio with moderately good to very good reception.
- **Distant Coverage:** Within this area, the signal of the radio station may be weak unless you have a good car radio or a good stereo with a good antenna. You may not be able to receive the station at all on inexpensive radios or radios with poor antennas.
- **Fringe Coverage:** Within this area, the station's signal will be very weak. You may be able to receive this station if you have a very good radio with a good antenna, but it's possible that interference from other stations may prevent you from picking up these stations at all.

3. What criteria do you use to define the "local", "distant" and "fringe" coverage areas?

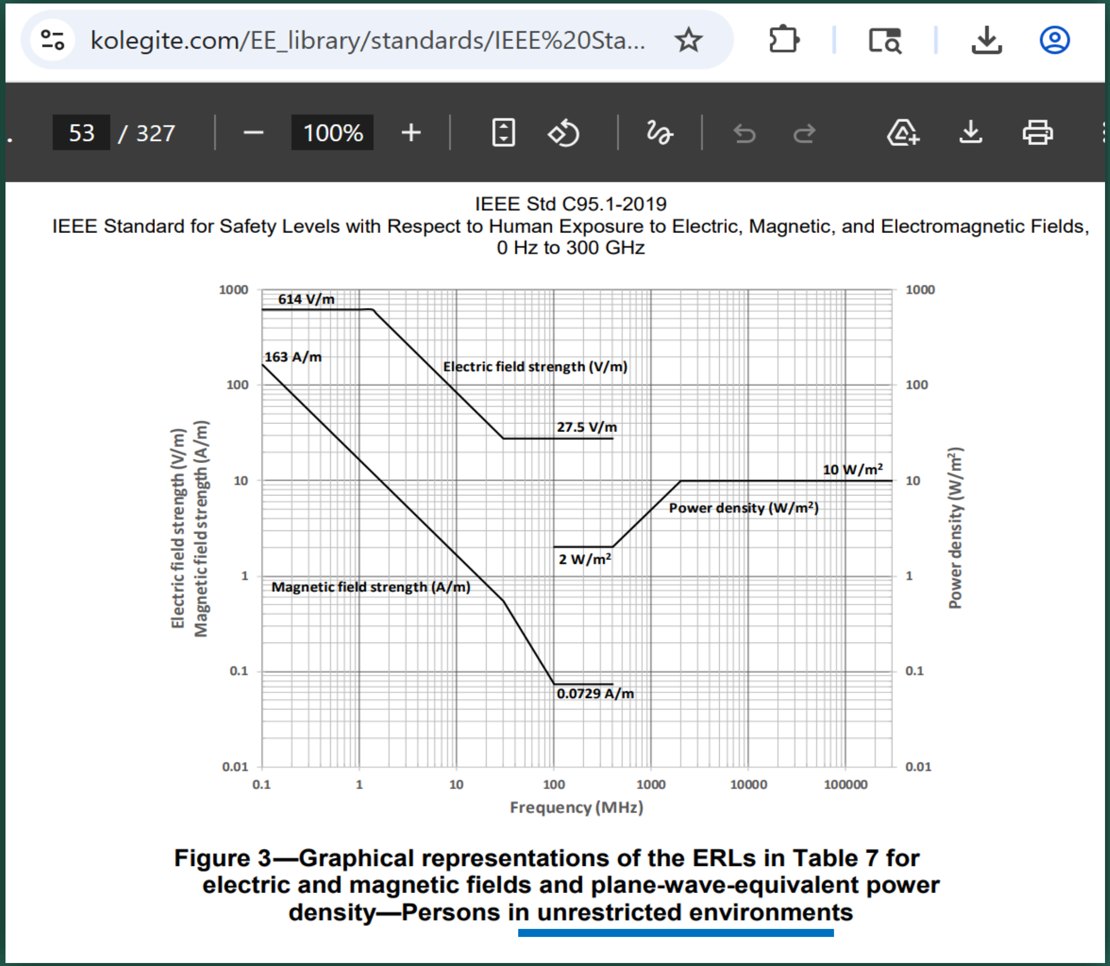
The **"local"**, **"distant"** and **"fringe"** lines on the FM maps correspond to the predicted 60, 50, and 40 dBμ signal strength contours respectively.

Theoretically a good FM receiver/dipole could work down to *20* dB uV/m or lower !

(P_r = -95 or -100 dBm or less)

See Radio Design 401 series

RF Exposure Limits for Transmitters



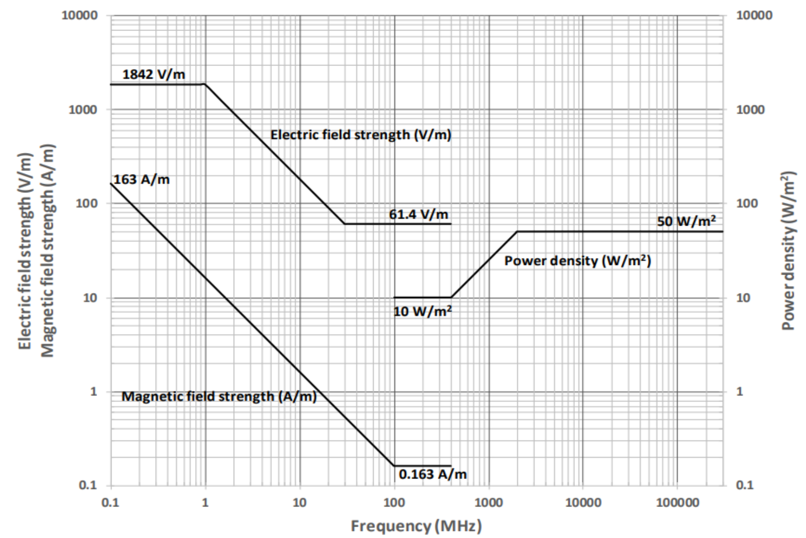


Figure 4—Graphical representations of the ERLs in Table 8 for electric and magnetic fields and plane-wave-equivalent power density—Persons permitted in restricted environments

CAUTION: Rules are complicated and change with time

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University "Lecture" Notes

1

Basic EM Theory
Review

Electric Field (E)

Force between charges (Coulomb's Law (1785))

$Q_1 \oplus \xleftrightarrow{F} \oplus\, q_t$

$$F = \left(\frac{1}{4\pi\epsilon_0}\right)\left(\frac{Q_1 q_t}{R^2}\right) \text{ Newtons}$$

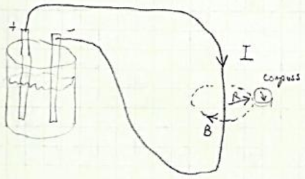
ϵ_0: 8.854E-12 in MKS units

E Field is Force per unit charge

$$\bar{E} = \frac{\bar{F}}{q_t} = \frac{Q}{4\pi\epsilon_0 R^2}\hat{r} \quad \frac{\text{Volts}}{\text{meter}}$$

Magnetic Field (B)

Produced by moving charge (currents)



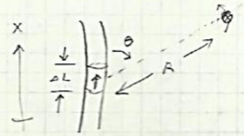
μ_0: 4π E-7 in MKS units

$$B = \frac{\mu_0 I}{2\pi R} = \mu_o H$$

(Oersted's Experiment (1820))

2

For non-infinite wires:



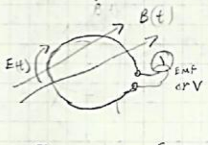
$$\Delta B = \frac{\mu_0 I \, \Delta L}{4\pi R^2}\sin\theta$$

(Biot-Savart Law)

$$\bar{B} = \int_{x_1}^{x_2} d\bar{B}$$

Field Linkage / Interaction

Faradays Law: (Time varying B(t) Creates E field) (1831)



$$\underbrace{EMF}_{\oint E \cdot dl} = -\frac{d\varnothing}{dt} \qquad \text{Flux } \varnothing = \iint B \cdot dA$$

In point form

$$\boxed{\underbrace{\text{Curl } \vec{E}}_{\nabla \times \vec{E}} = -\frac{\partial \vec{B}}{\partial t}}$$

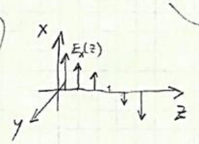
$$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x & E_y & E_z \end{vmatrix}$$

$\nabla \times \vec{E}$: 3D Vector operator w/ 6 spacial derivatives!

If $\bar{B}(t) \equiv B_y(t,z)\hat{y}$

NOTE
"Curl" of E reduces to when E is only x-directed

SKIP



$$\text{Curl } E \equiv \frac{\partial E_x}{\partial z}$$

So $\frac{\partial E_x}{\partial z} = -\frac{\partial B_y}{\partial t}$ here

3

No curl:
Curl: or

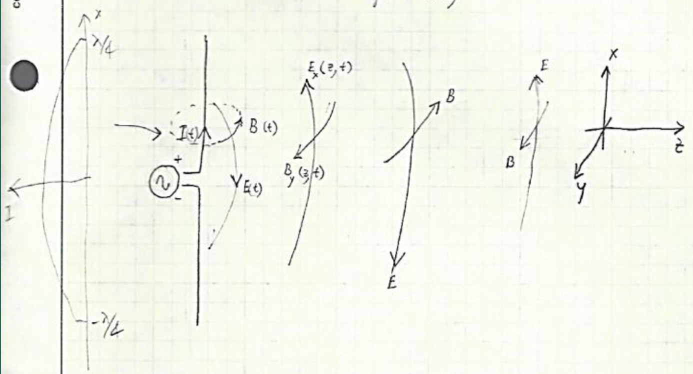
Maxwell (1861-1864)

"Discovered" mathematically a dual relationship

$$\boxed{\text{Curl } B = \underbrace{\mu_0 \epsilon_0 \frac{\partial E}{\partial t}}_{\text{maxwell's term}} + \underbrace{\mu_0 J}_{\substack{\text{Oersted's term} \\ \text{(Previously known)}}}}$$

J: current density

Implies possibility of producing EM waves!



- Sinewave voltage source creates
  - I(t) in wire (why?), Due to displacement current thru Capacitance
  - Associated B(t) near source
  - Associated E(t) " "
- Fields regenerate each other according to
  - curl $E(t) = -\partial B/\partial t$ (Faraday)
  - Curl $B(t) = \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$ (maxwell)
- Fields propagate away at speed of light. $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

Example University Curriculum (2026)

engg.k-state.edu/academics/undergraduate/degree-maps/ee-electronics-communications.pdf

ics-communications 1 / 2 100%

CURRICULUM EFFECTIVE FALL 2024 | REVISED FALL 2026

Electrical Engineering (Electronics and Communications)

123 credit hours total

YEAR 1 FALL	YEAR 1 SPRING	YEAR 2 FALL	YEAR 2 SPRING	YEAR 3 FALL	YEAR 3 SPRING	YEAR 4 FALL	YEAR 4 SPRING
*MATH 220 (4) Analytic Geometry and Calculus I KSC-3	MATH 221 (4) Analytic Geometry and Calculus II PR: MATH 220 ≥C	MATH 340 (4) Elementary Differential Equations PR: MATH 221 ≥ C	MATH 222 (4) Analytic Geometry and Calculus III PR: MATH 221 ≥ C	ECE 431 (3) Microcontrollers PR: ECE 241, CIS 208 ≥ C	ECE 512 (3) Linear Systems PR: ECE 410 or 519, ECE 540, MATH 340 ≥ C	ECE 590 (3) Senior Design Experience I PR: ECE 525, 540 ≥ C	ECE 591 (2) Senior Design Experience II PR: ECE 590 ≥ C
CHM 210 (4) Chemistry I	ECE 241 (3) Introduction to Electrical and Computer Engineering	*PHYS 213 (5) Engineering Physics I KSC-4 PR/CO: MATH 220	PHYS 214 (5) Engineering Physics II PR: PHYS 213 PR/CO: MATH 221	ECE 525 (3) Electronics I PR: ECE 410 or ECE 519 ≥ C	ECE 526 (3) Electronics II PR: ECE 511, 525 ≥ C	ECE 530 (3) Control Systems Design PR: MATH 340, ECE 512 ≥ C	●ECE 660 (3) Communication Systems I PR: ECE 512 ≥ C
DEN 160 (1) College of Engineering Orientation	CIS 208 (3) C Programming for Engineers PR: MATH 100 ≥C	STAT 510 (3) Introductory Probability and Statistics I PR: MATH 221	ECE 441 (3) Design of Digital Systems PR: ECE 241 ≥ C	ECE 540 (3) Applied Scientific Computing for Engineers PR: MATH 221 and CIS 208 or CIS 200 ≥ C	ECE 502 (2) Electronics Laboratory PR: ECE 511 ≥ C PR/CO: ECE 526 ≥ C	ECE 647 (3) Digital Signal Processing PR: ECE 512 ≥ C	▲Elective (3) Technical ECE 764 Etc…
DEN 161 (1) Engineering Problem Solving	*Elective (3) Social and Behavioral Sciences KSC-5	ECE 410 (4) Circuit Theory I PR: MATH 221 ≥ C	ECE 511 (4) Circuit Theory II PR: MATH 340, ECE 410 ≥ C	ECE 557 (4) Electromagnetic Theory I PR: ECE 410, MATH 222, PHYS 214 ≥ C	ECE 581 (3) Energy Conversion I PR: ECE 410 or ECE 519 ≥ C	▲Elective (3) Electronics and Communications	*Elective (3) Social and Behavioral Sciences KSC-5
*ENGL 100 (3) Expository Writing I KSC-1	*ENGL 200 (3) Expository Writing II KSC-1 PR: ENGL 100			*Elective (3) Arts and Humanities KSC-6	*Elective (3) Institutional KSC-7	*Elective (3) Arts and Humanities KSC-6	*Elective (3) Institutional KSC-7
*COMM 106 (3) Public Speaking KSC-2							
(16 credit hours)	(16 credit hours)	(16 credit hours)	(16 credit hours)	(16 credit hours)	(14 credit hours)	(15 credit hours)	(14 credit hours)

KEY
- = Prerequisite for another course
- PR = Prerequisite requirement
- PR/CO = Prerequisite or concurrent requirement
- = Class applies as specialization
- * = K-State Core (KSC) course
- ▲ = See department approved electives
- ● = Only offered in the semester shown

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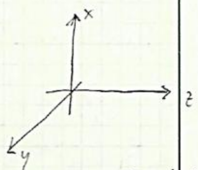
Degree map is for advising purposes only. Students are responsible for complying with University Catalog requirements.

University "Lecture" Notes (Continued)

4

Plane wave Solution (The math)



In free space, far from source

Assume

E is x-directed & varies only w/ z, t
B is y-directed " "

Valid in local space at long z, in broadside direct

Then

$$\left(\nabla \times E = \frac{\partial E_x}{\partial z}\hat{y}\right) = -\frac{\partial B_y}{\partial t}\hat{y} \quad (1)$$

$$\left(\nabla \times B = -\frac{\partial B_y}{\partial z}\hat{x}\right) = \mu_0 \epsilon_0 \frac{\partial E_x}{\partial t}\hat{x} \quad (2)$$

Take $\frac{\partial}{\partial z}$ of (1) and $\frac{\partial}{\partial t}$ of (2) to get

$$\frac{\partial^2 E_x}{\partial z^2} = -\frac{\partial^2 B_y}{\partial z\,\partial t} \quad (3)$$

and

$$-\frac{\partial^2 B_y}{\partial z\,\partial t} = \mu_0 \epsilon_0 \frac{\partial^2 E_x}{\partial t^2} \quad (4)$$

Combining (3) & (4)

$$\frac{\partial^2 E_x}{\partial z^2} = \mu_0 \epsilon_0 \frac{\partial^2 E_x}{\partial t^2}$$

The well known "wave equation" ☺

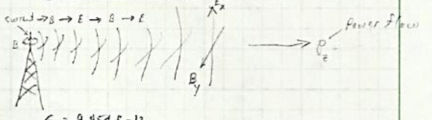
1

Radio wave Transmission & Reception

Recall Maxwell's Eqns & radio wave production

Curl $B = \mu_0 J + \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$

Curl $E = -\frac{\partial B}{\partial t}$ $\Rightarrow$



$\rightarrow \frac{\partial^2 E_x}{\partial z^2} = \mu_0 \epsilon_0 \frac{\partial^2 E_x}{\partial t^2}$

$\epsilon_0 = 8.854\,E{-}12$
$\mu_0 = (4\pi)1E{-}7$

Solution in free space is

time delay ∝ z

$$\boxed{\begin{aligned} E_x(t,z) &= E_0 \cos[\omega(t - t_{0z})] \text{ w/ } t_z = z/c \\ B_y(t,z) &= B_0 \cos[\omega(t - t_{0z})] = \tfrac{1}{c} E_x(t,z) \\ c &= \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.998\,E8 \text{ m/s} \end{aligned}}$$

Can also be shown (Poynting's Theorem)

$$\boxed{P = E \times H \Rightarrow |P| = \frac{|E|^2}{Z_0}\hat{z} \ \frac{\text{watts}}{m^2} \quad \text{where } Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} = 377\,\Omega}$$

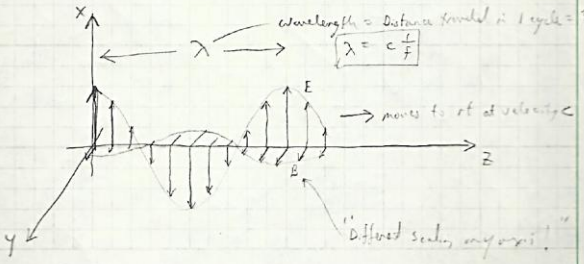
→ Proof:

$P = E \times H$
$= E \times \frac{1}{\mu_0} B$
$= E \times \frac{\sqrt{\mu_0 \epsilon_0}}{\mu_0} E$
$= E \times \sqrt{\frac{\epsilon_0}{\mu_0}} E$
$= \frac{E \times E}{Z_0}$ w/ $Z_0 = \sqrt{\mu_0/\epsilon_0}$

Graphing E, B fields: (@ t=0)

wavelength = Distance traveled in 1 cycle

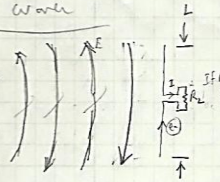
$\boxed{\lambda = c\,\frac{1}{f}}$



2

Reception of waves

Short Dipoles



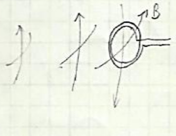
Incident E field

If $R_L = \infty$, $V_{oc} = E\,L_{eff}$

Effective Length ($\approx L$ for $L \ll \lambda/2$)

($L_{eff} = 2/\pi \times L$ for $L = \lambda/2$)

Small loops



$V_{oc} = N \frac{d\phi(t)}{dt}$

$A\,B(t) = A\,B_0 \cos(\omega t)$

90° Phase Shift

Incident B Field

$V_{oc} = N\,j\omega\,B\,A$ ← Area of loop

turns

Radian Freq

Field Strength at Receiver

Consider "isotropic" radiator w/ TX power P_t watts in free space (no reflection)

Pwr density at distance R is: $P = \frac{P_t}{4\pi R^2}$

For non isotropic case,

$$P = \frac{P_t\,G_t}{4\pi R^2} = \frac{EIRP}{4\pi R^2}$$

"Directivity Gain"

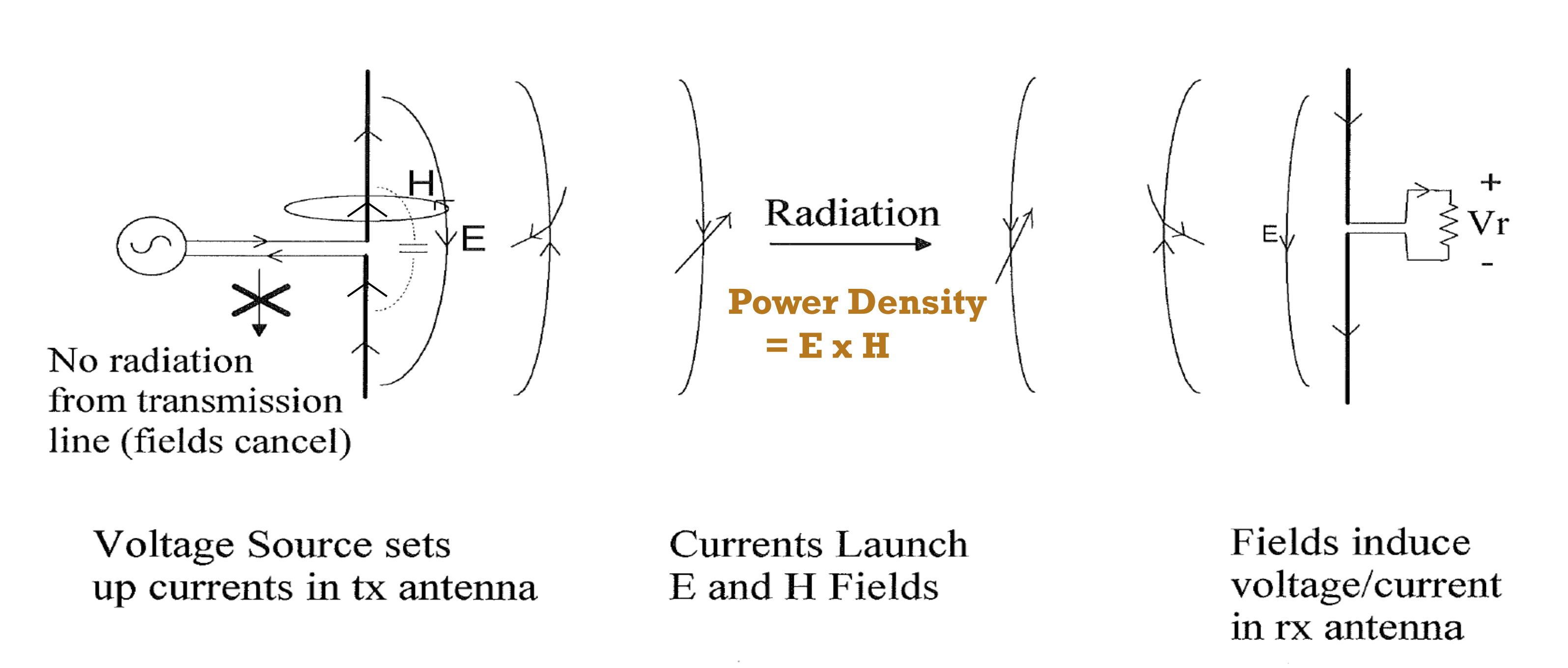
Effective Isotropic Radiated Power

Example: Dipole in broadside direction $G_t = 1.6$ (i.e. 2dB)

Then, From Poynting's Theorem ($P = |E|^2/Z_0$) $\Rightarrow |E| = \sqrt{P\,Z_0}$

$$E = \sqrt{Z_0 \frac{EIRP}{4\pi R^2}}$$

Poynting's Theorem



Power density in W/m²

E-field in V/m

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Magnetic field in A/m

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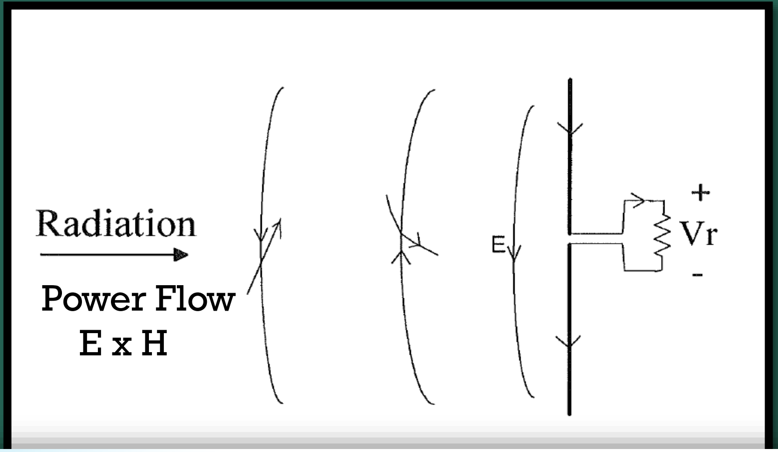
Antenna "Effective Length" and V_{oc} V_r P_r



Google

effective length of a half-wave dipole antenna used for receiving

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AI Overview

Alternatively called "Effective Height"

The effective length (h_{eff}) of a half-wave receiving dipole is calculated as $\frac{\lambda}{\pi}$ (or roughly 0.64 times the physical length L). It represents the theoretical length of a conductor that would produce the same open-circuit terminal voltage when interacting with an incident electromagnetic wave. University of Toronto +2

The Core Details

- **Formula:** $h_{eff} = \frac{\lambda}{\pi} = \frac{2L}{\pi}$
- **Open-Circuit Voltage Calculation:** $V_{oc} = h_{eff} \cdot E_0$ where E_0 is the strength of the incident electric field.

$$P_{density} = \frac{|E|^2}{Z_o} = \frac{P_t G_t}{4\pi d^n}$$

$$|E| = \sqrt{Z_o P_{density}}$$

$$V_{oc} = |E| L_{eff}$$

$$V_r = V_{oc} \frac{R_{in}}{R_{in} + Z_{ant}}$$

$$P_r = V_{oc} \frac{|V_r|^2}{R_{in}}$$

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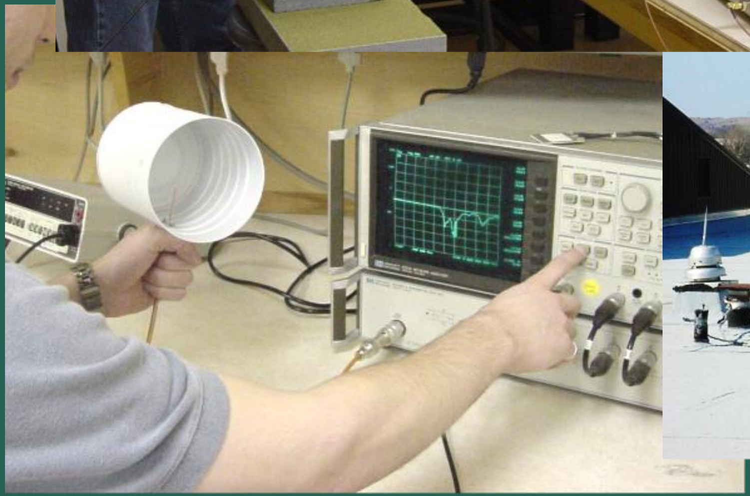
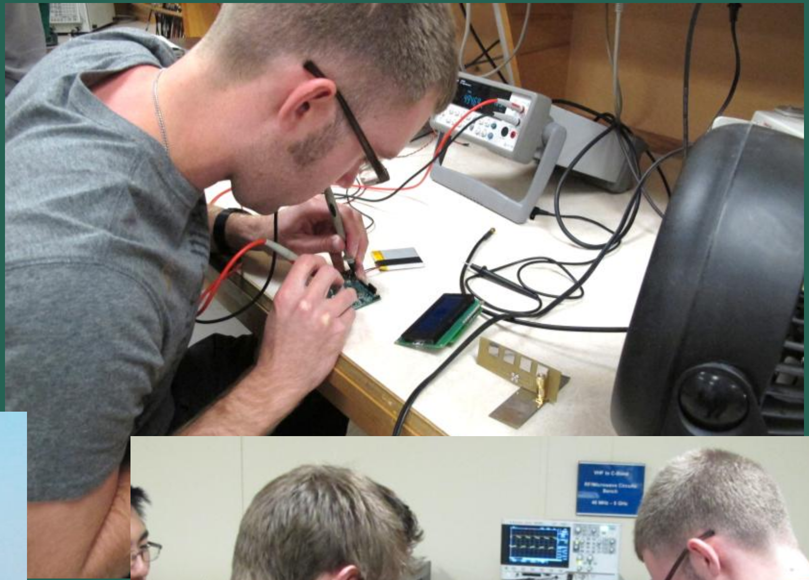
Example University Lab Work





Example Lab 1 Assignment

See: https://ecefiles.org/microwave-circuits-and-antennas-course-notes/

ECE 764 Lab 1
Familiarization with Radios and Spectrum Analyzers
Due in-class, Wednesday

Overview

In this lab, you will work with a partner to learn about radio transmission and associated signal strength measurements. Radio transmissions will be made using unlicensed handheld units and signal strength will be measured using one of the lab's spectrum analyzers. The main parts of the lab include:

a. *Find a partner and exchange contact information so you can schedule time to do the lab.*
b. *Select two of the four options for radio sets: CB (27 MHz), MURS (150 MHz), FRS (465 MHz), or ISM band (900 MHz). Each person in a team selects one band so that peformance versus band comparisons can be made by the team.*
c. *Research information on the service band(s) selected, including allowable frequencies and maximum transmission power*
d. *Measure the frequency of operation of the selected radios.*
e. *Compute the wavelength, and the ideal length of a lambda/4 monopole antenna from the radio frequency.*
f. *Measure/observe the bandwidth of the signals transmitted using the spectrum analyzer.*
g. *Measure the received power level versus distance.*
h. *Observe how received power is affected by obstructions such as building materials and people*
i. *Test the radio transmission range capabilities between the lab and various locations within the new Engineering Hall building*
j. *Test the transmission range from inside the building to outside*
k. *Test the transmission range when operating outdoors only*
l. *Document your results in a team report (with two independent sections, one written by each teammate).*
m. *Document general conclusions on transmission performance versus the two frequency bands tested at the end of the report.*

Lab Partners and Writeups

At the end of this lab you must writeup your results in the form of a report. Each student must do one "Section" that covers their radios. Do NOT intermix the results as you go.

Before the first section, provide a brief introduction summarizing the goals above, and introducing the radios/frequencies involved. This can be written by either teammate.

Each section should include ***subsections*** with ***a narrative and pictures*** explaining the procedures, the results you got for that part, any problems you encountered (plus the resolution if any), and conclusions/observations relative to theory. As described in the course syllabus, grades will be based on the Completeness, Correctness, and overall Quality (CCQ) of your writeups, so please strive to provide a good engineering report.

Partner Selection

Record the name and contact information of your teammate below

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Radio Service Band Selection

Each person in a two-person team should select a radio band to be responsible for (CB, MURS, FRS, or ISM band). In the lab, try-out the radios provided and make your selection, recording it below. Then "sign-up" for your band on the table posted in the lab. If your selected band is already taken, you will have to chose another. *(Sorry. This is to make sure we cover all bands. Don't be afraid of the "old" CB radios. You may find they outperform the newer fancy ones -- there's got to be some tradeoff against the absurdly long antennas !)*

Responsible Person	***Service Band***
________________	________________
________________	________________

Researching Information on Selected Service Band

Using the web and information provided on our class webpage, each teammate should try to determine and document the following for their selected radio band:

- *The full text name of the service band from the acronym (e.g. CB=citizens band) and who/what it is for*
- *The number of channels and associated frequency range for that service (listing every channel is not needed)*
- *The modulation used (e.g. AM, FM, FHSS, etc.)*
- *The part and subpart of FCC CFR rules that govern that service*
- *The maximum legally allowed transmitter power or radiated field strength*

Measuring Frequency of Operation

You can measure the frequency of operation of your radios using either the frequency counter in the lab, or one of the spectrum analyzers. The frequency counter is the simplest to use. Be sure to configure the counter to provide the required resolution of at least 1 ppm (6 significant digits). Also be sure to record the channel you are on, if there is an option (***For the CB radios, use channel 15 which is setting A on the larger one. For the ISM band, leave the radios on the "public band" channel***)

Channel	***Frequency***
________________	________________MHz

NOTE: The frequency-counter may not work for the ISM band radios (since they use "frequency hopping" and don't stay on a frequency long enough). For the ISM band radios, an alternative is to use the spectrum analyzer and record the maximum and minimum frequencies you see, and quote the average value. You could try the "peak-hold" function in the Display menu for this...

CAUTION: DO NOT let the antenna of your radio touch the frequency counter's or spectrum analyzer's antenna, since the radios could be too powerful. Keep the antennas separated by a minimum of lambda/4 at all times.

Wavelength and Antenna Size

As discussed in class, you can compute the wavelength for any given frequency if you know the speed of propagation. Using the speed of light (since we're in "open-air" which is close to the permittivity of vaccuum), find the wavelength. Record this computed value below to 3 significant digits. Using more than 3 significant digits is unnecessary for our purposes - since we are mainly interested in how long to make our receiving antenna. Such antennas work fine as long as you're within about 2 to 5 % of the correct length (which implies 2 significant digits).

From the wavelength, find the length of a lambda/4 antenna in cm. You should use this for configuring your receiving monopole antenna for the remainder of this lab. (Except for the CB case, which is too big - so just set the antenna to its full extent)

Frequency	***Wavelength in meters***	***Antenna length in cm***
____________	____________	____________

Modulated Signal Bandwidth

Adjust the antenna on the spectrum analyzer to the proper length computed earlier and set it up to monitor your transmitted signal (set frequency, span, amplitude reference level, etc.)

Transmit using one of your radios while monitoring your audio on the other radio and the spectrum on the spectrum analyzer. While speaking a continuous vowel sound (e.g. "eeeeeee"), observe the spectrum bandwidth. Try talking close to the mic to get the widest bandwidth and record it. Does it agree with the information you researched previously?

NOTE: For the ISM band radio, this is at best a challenge. You could try setting the analyzer on one of the frequencies it hops to and using the Display>Peak-hold function...

Record your result in kHz below, and take a photo of your setup and the spectrum observed for use in your writeup...

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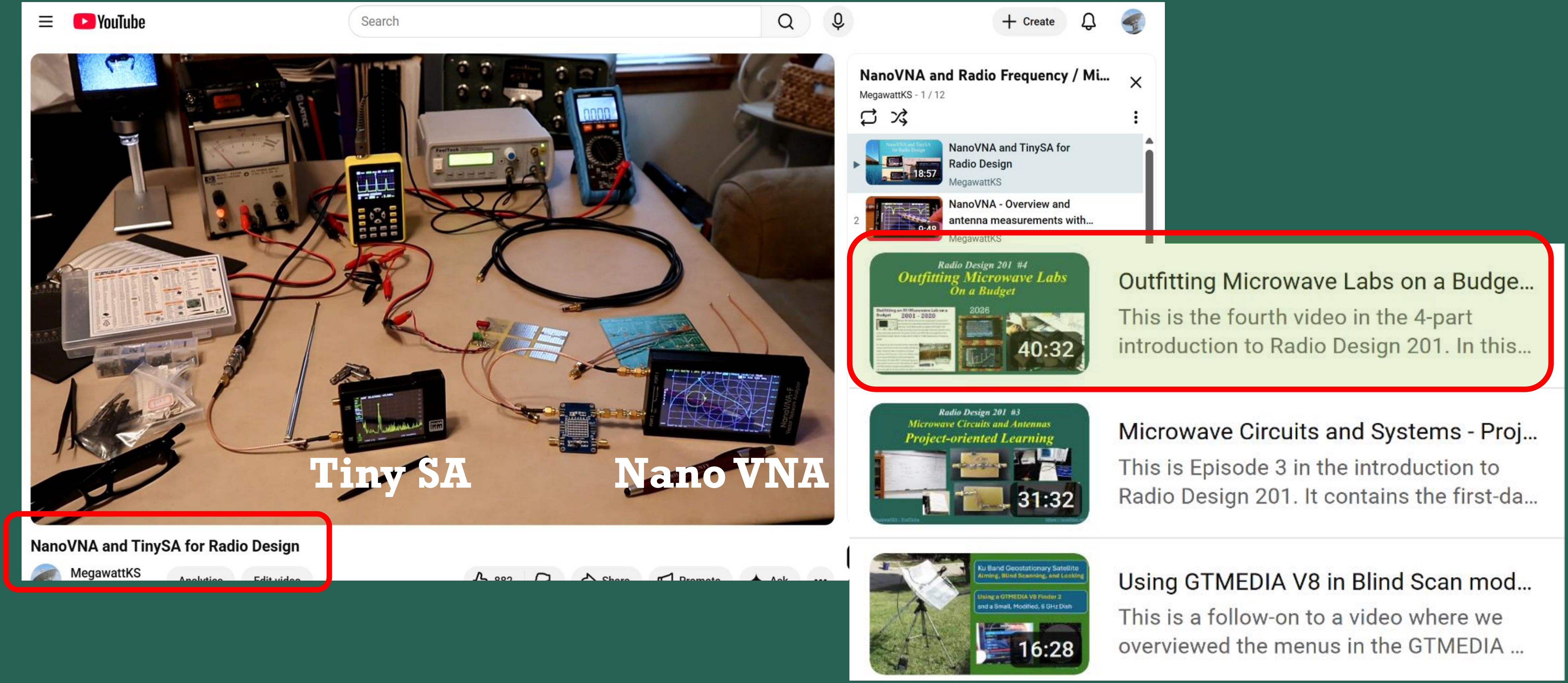
Received Power versus Distance

As above, tune the center frequency of the analyzer to the frequency you are using.   Set the span to about 100 kHz or 1 MHz. Then, using one of the radios, transmit a signal from various distances from the analyzer's antenna, *recording the distance and the power of the signal displayed.* Do this for at least the following distances. 1 foot, 2 feet, 4 feet, and 8 feet.

Keep the antennas in a "co-pole orientation" during your work (e.g. both vertical) ! Note that powers are formatted in dB relative to the "reference level" at the top of the screen (typically the top line is 0 dBm and the major divisions are 10dB, making the next line down -10 dBm, and so forth). You may need to change the Amplitude>RefLevel to a higher value, especially for the case of the CB or MURS radio due to their higher power and longer antennas. If the signal level is at/over the top of the screen, it will not be read correctly and you will need to adjust Amplitude>RefLevel. Similarly if the signal is "in the noise"

Radios (CB, FRS, ISM bands)

Home Lab Equipment
(Spectrum Analyzer, Antennas, etc.)



Upcoming Topics

Episode 3
(p/o 4-part intro)

Episode 5

This Episode

Next Episode

ECE 764 Spring 2017 Schedule

(Tentative)

Week	*Material*	*Assignments*
1	Introduction to comm systems, frequencies, and wavelengths Calculating and measuring received signal strengths	Verify you have lab access Lab 1 assigned
2	EM theory review and demos Basic antenna theory	Purchase lab kit
3	Basic antenna types: dipoles, monopoles, loops Antenna characterisitics: polarization, patterns, and impedance	Lab 1 due
4	Measurement of antenna patterns and signal reflection/transmission Transmission lines and reflection coefficient	Lab 2 assigned
5	Introduction to Smith Charts, plotting of impedance/admittance Simulation with Agilent ADS	
6	Lambda/4 lines and impedance transformation with microstrip Microstrip components and coupled-line microwave filters	Lab 2 due
7	PC board design, layout, and parasitics Two-port circuits and S-parameters	Lab 3 assigned
8	Circuit analysis and simulation with S-parameters Amplifier insertion gain, matching, stability, noise figure, and compression specs	Lab 3 due
9	Project discussion (including needed baseband, ADC and DSP functions) Basic mixer concepts and hybrid-ring microstrip implementations	Project assigned
10	Voltage controlled oscillators Frequency multipliers	Prototype design/layouts due
11	Project discussions (pads, RF connector test points, test planning)	Probotype boards back
12	Frequency synthsizers and phase-locked loops	
13	Project testing/debugging discussions	Test, debug, respin boards Submit final board layouts
14	Analysis and design of directional antennas: Array theory Dish antennas and antenna feeds: e.g. helix, horn, and patch antennas Antenna simulations with ADS, EZNEC and other tools	
15	Additional radar and wireless performance issues	

Thanks For Watching !

For more info …

MegawattKS - YouTube https://ecefiles.org

Obstructions, Reflections, and Diffraction