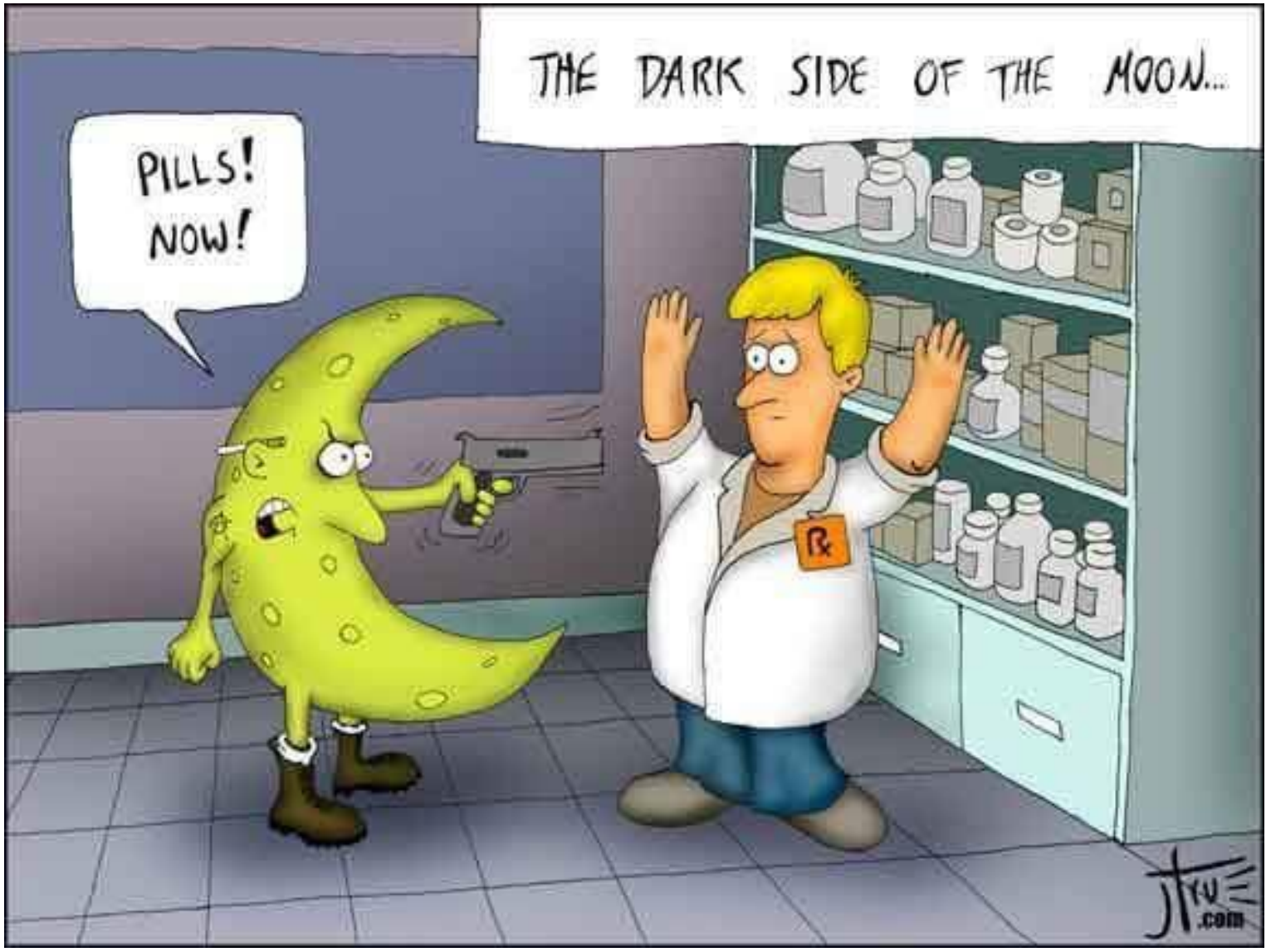
# Scattering on SHF and EHF

The Department of Redundancy Department

Update from Microwave Update 1999

Tom, WA1MBA, Tom

# This talk is NOT about EME



# One Score and Zero Years ago, MUD 1999

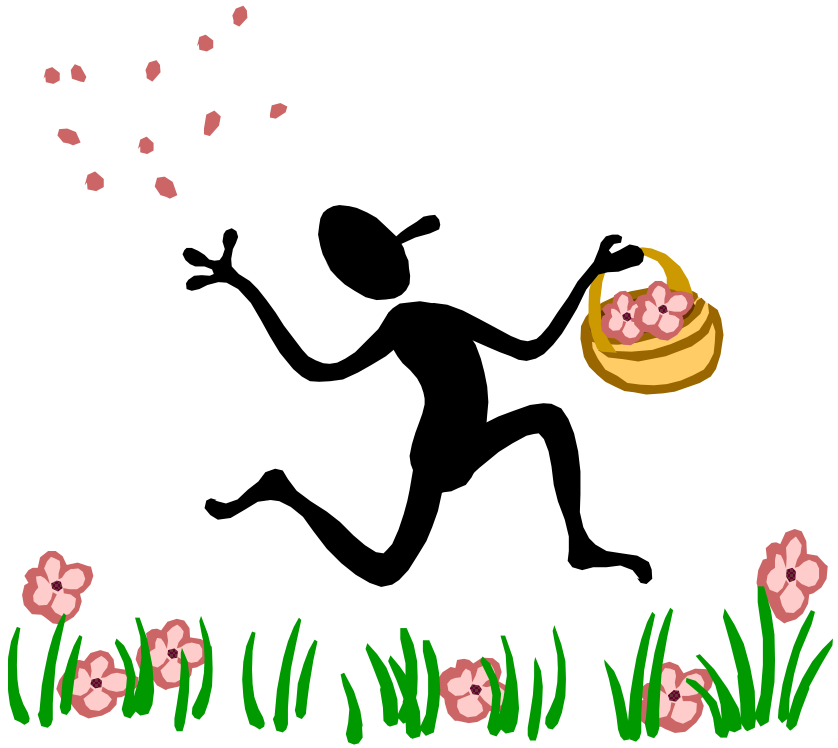
- If you were not there, snooze to next slide.
- 1999 ‘mba presentation was mostly correct
- Relied upon data from a program given constants based on incorrect assumptions
  - Specifically the dielectric properties of water at RF is different than visual light wavelengths
  - These resulted in incorrect graphs
  - General information was correct
  - Bands have changed
  - News about Nature Itself

# Natural Square Waves

# Scattering, SHF and EHF Outline

- What is Scattering?
- What is Rain?
- Scattering Dependencies
  - How does Scattering Work?
  - Particle Size, Wavelength and Dielectric values
  - Angles
  - Polarization
- SHF and EHF

# Scattering means . . .



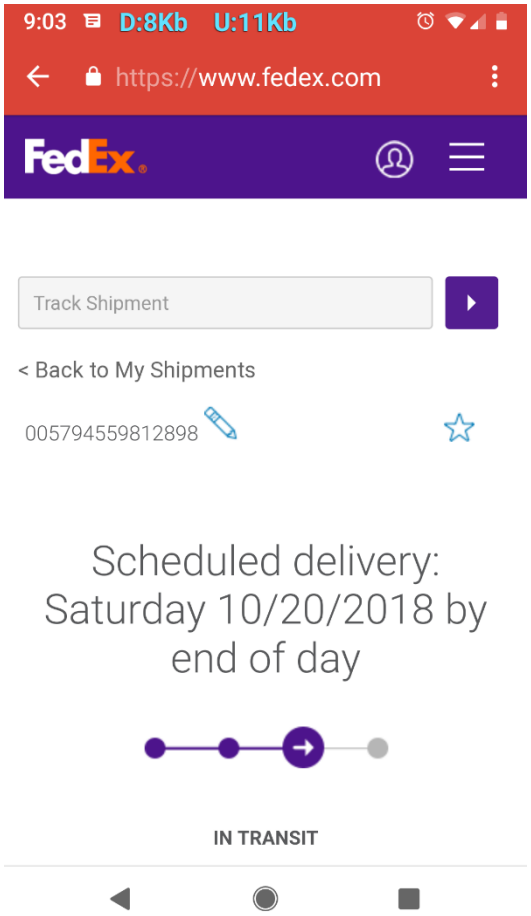
# Scattering is:

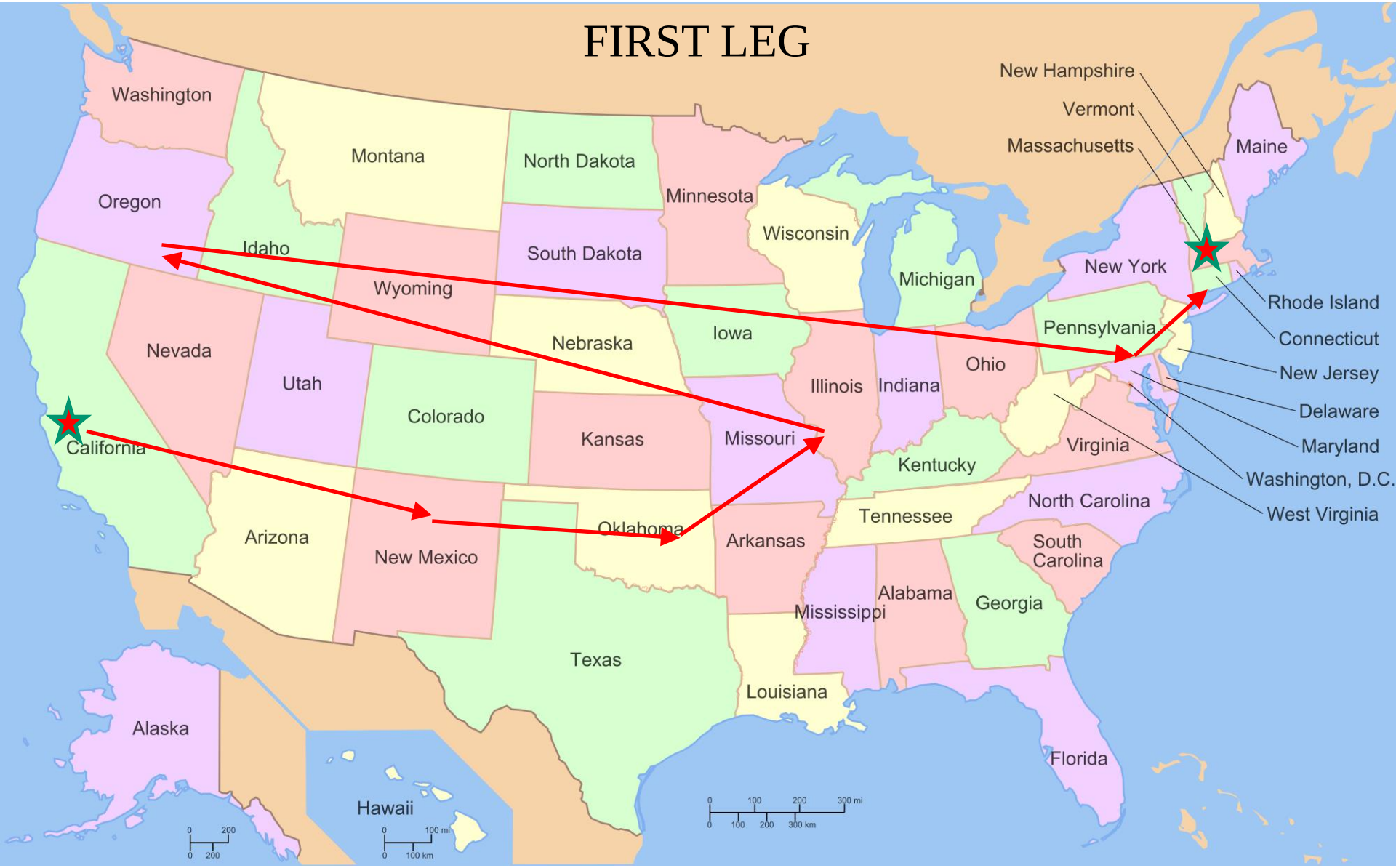
- Things going in many directions, often not the direction in which they are sent. We say:
  - Scattered to the four winds
  - Tom's scattered new phone delivery*
  - The Irish are scattered around the globe
  - The S11 scattering parameter value is -7 dB
- Hams are interested in the interaction between TEM waves and matter
  - Knife edge scattering
  - Tropo-scattering
  - Rain Scatter

# But First . . .Tom's new Phone*

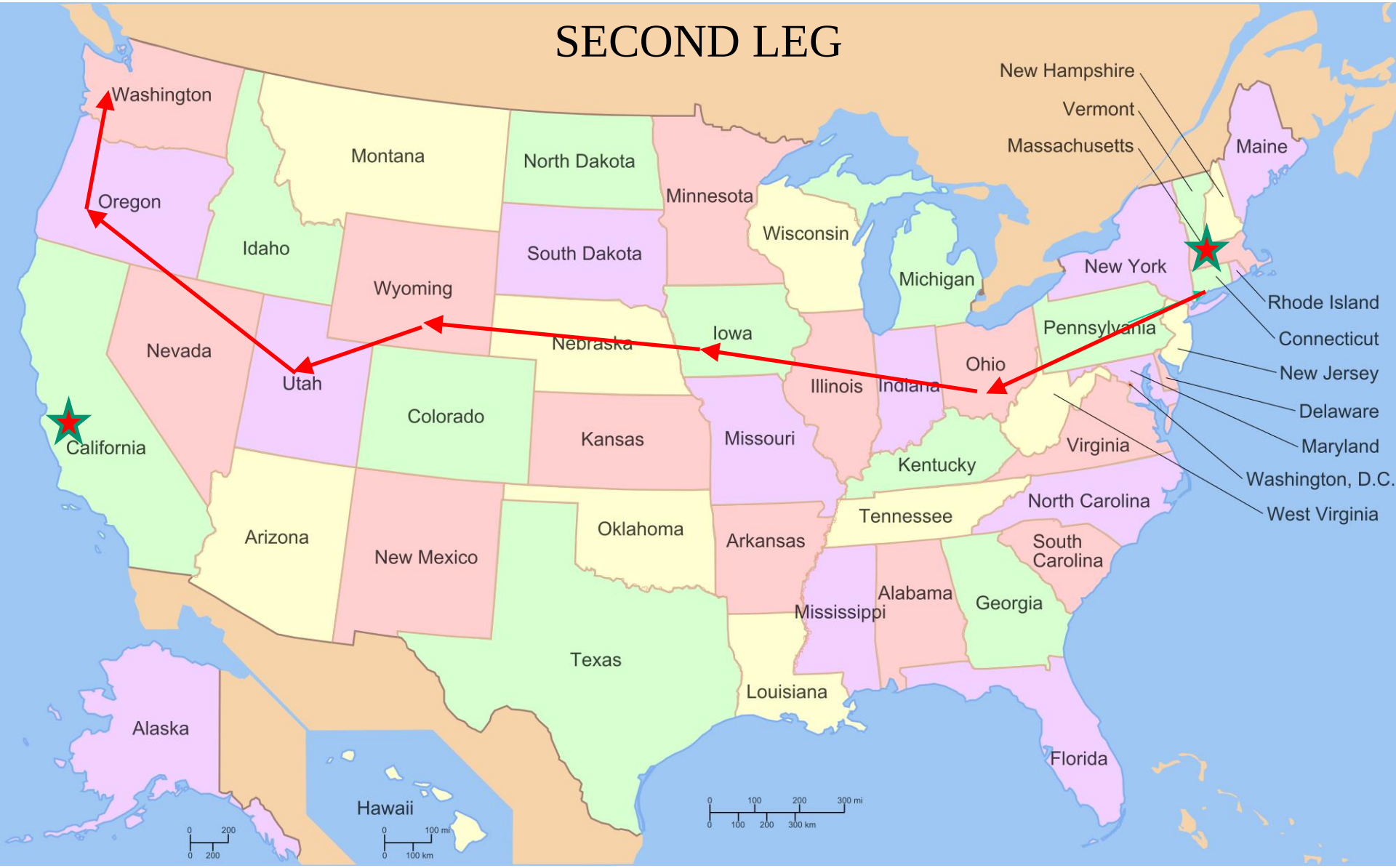
- Ordered Google Oct 5 – (G is in California)
- Deliver to me in Massachusetts
- Went via FedEx Ground
- Tracking info
- FED EX GROUND

# Scheduled delivery - October 20






WA1MBA Super VHF 2019



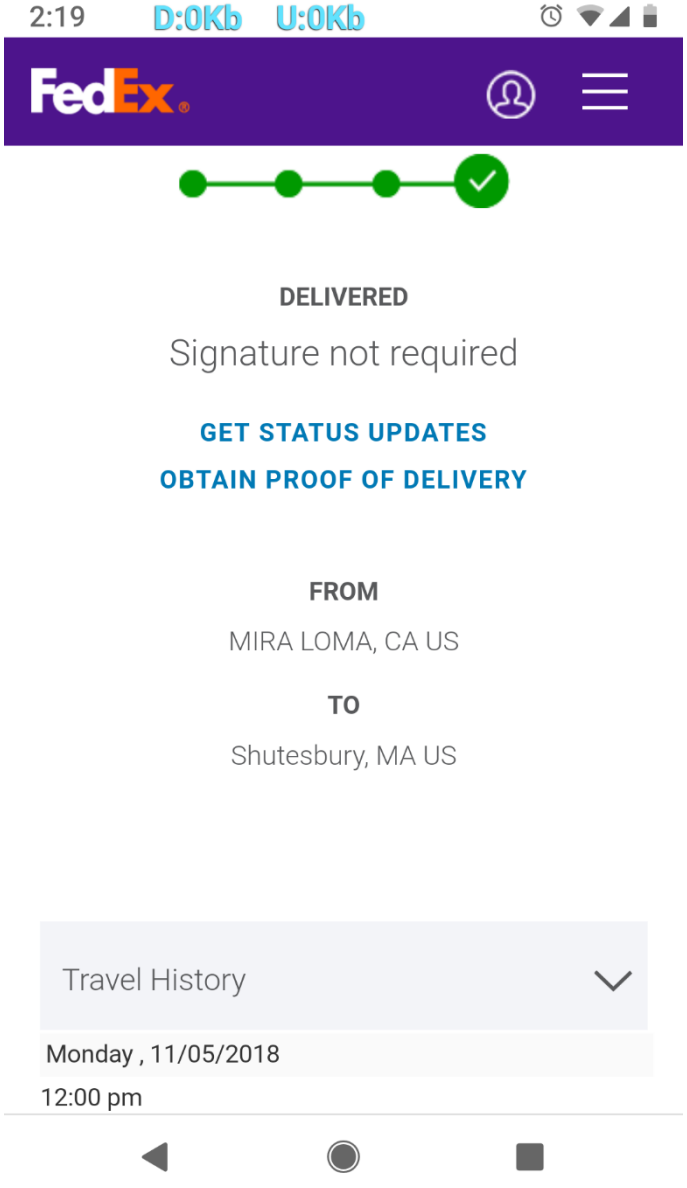

WA1MBA Super VHF 2019


WA1MBA Super VHF 2019

# STOPPED IN ONLY 17 STATES


WA1MBA Super VHF 2019

# Delivered November 5



# PONY EXPRESS

St. JOSEPH, MISSOURI to CALIFORNIA
*in 10 days or less.*

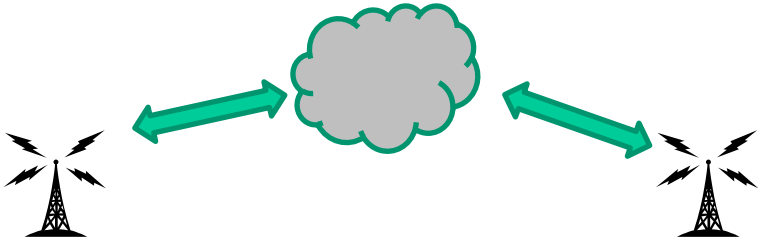
## WANTED

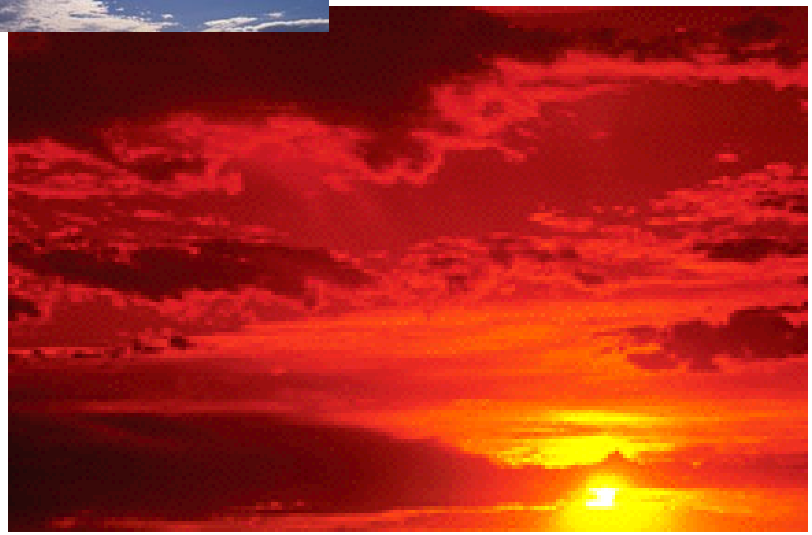
**YOUNG, SKINNY, WIRY FELLOWS**
**not over eighteen. Must be expert riders, willing to risk death daily.**

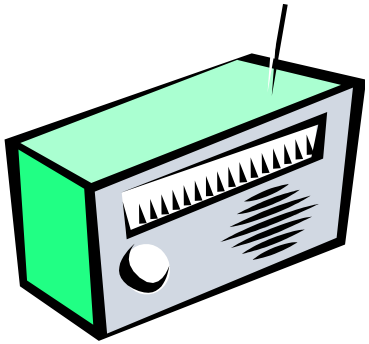
**Orphans preferred.**
**Wages $25 per week.**

APPLY, **PONY EXPRESS STABLES**
St. JOSEPH, MISSOURI

# Scattering - examples



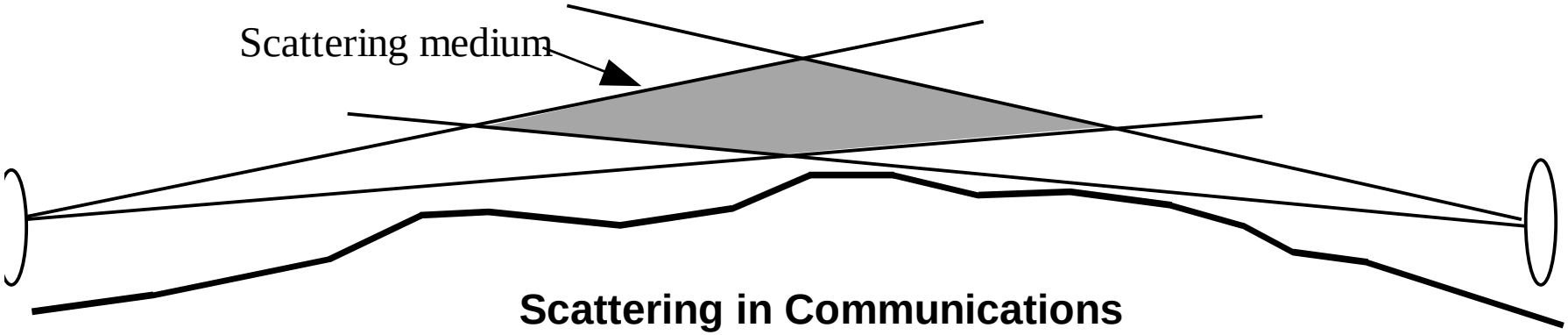




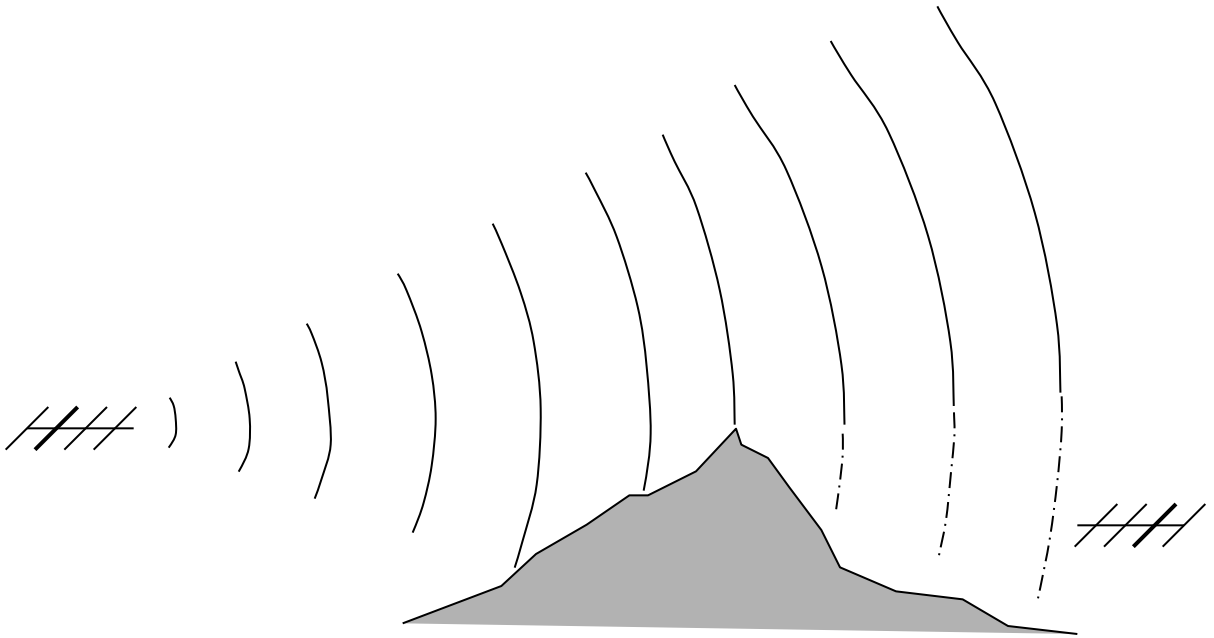
# Examples of Scattering

- Example: The atmosphere and visible light. Scattering increases with frequency (to a point), so the sky appears blue (violet is absorbed).
- Example: The atmosphere and VHF. Air turbulence is manifest in pressure differences, they have different refractivity, and act as particles (big ones) that can scatter VHF and UHF energy.
  - These ‘pressure difference zones” are too big to have strong scattering effects on frequencies above 1296 MHz
  - This talk is about 10 to 300 GHz scattering

# Scattering in Communications

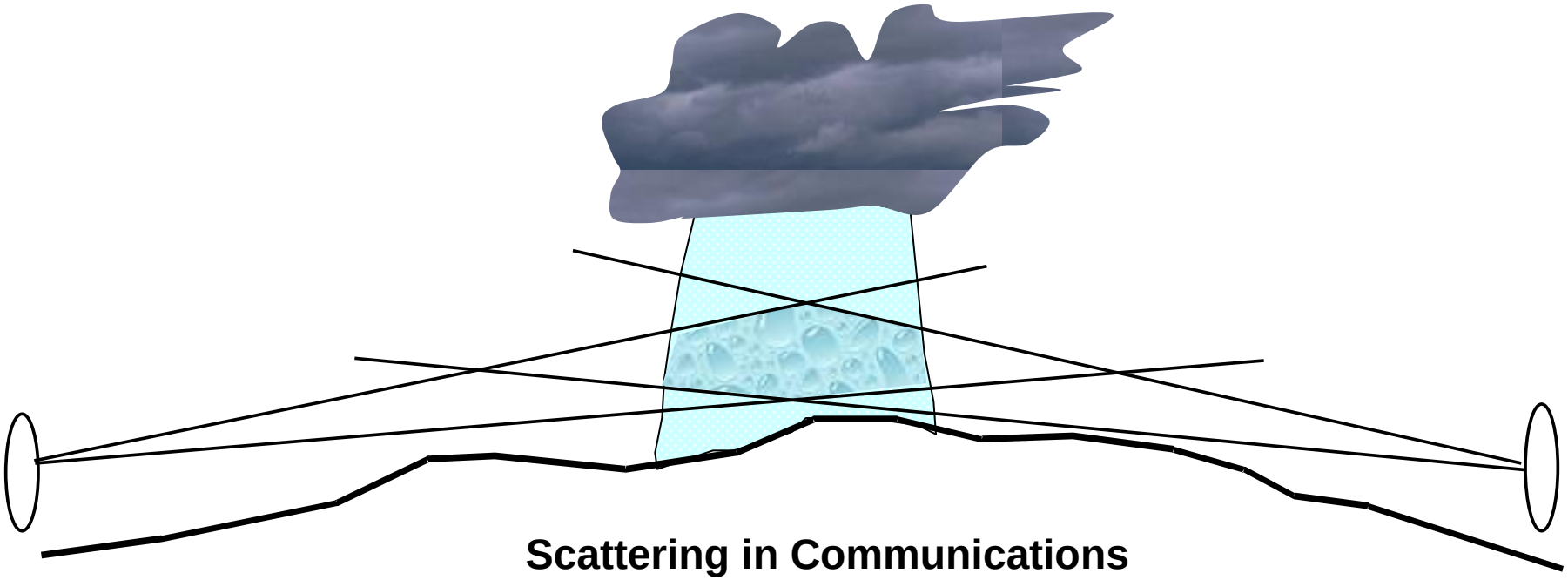


# Knife-edge Scattering



**Scattering in Communications**

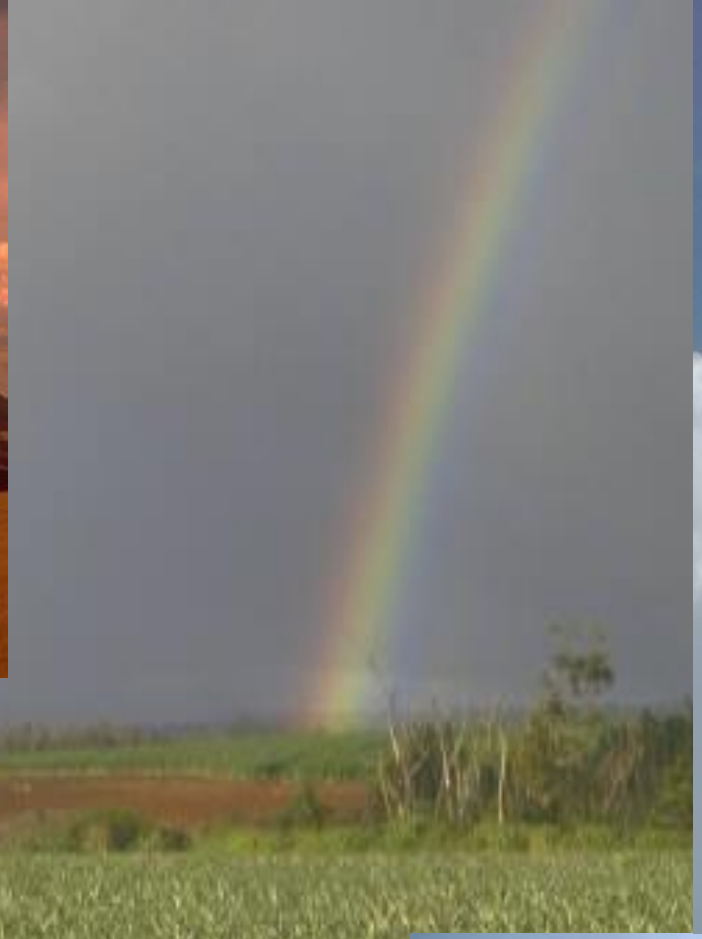
# Rain Scattering



**Scattering in Communications**

# Rain Scattering, SHF and EHF

- What is Scattering?
- What is Rain?
- Scattering Dependencies
  - How does Scattering Work?
  - Particle Size & Wavelength
  - Angle
  - Polarization
- SHF and EHF

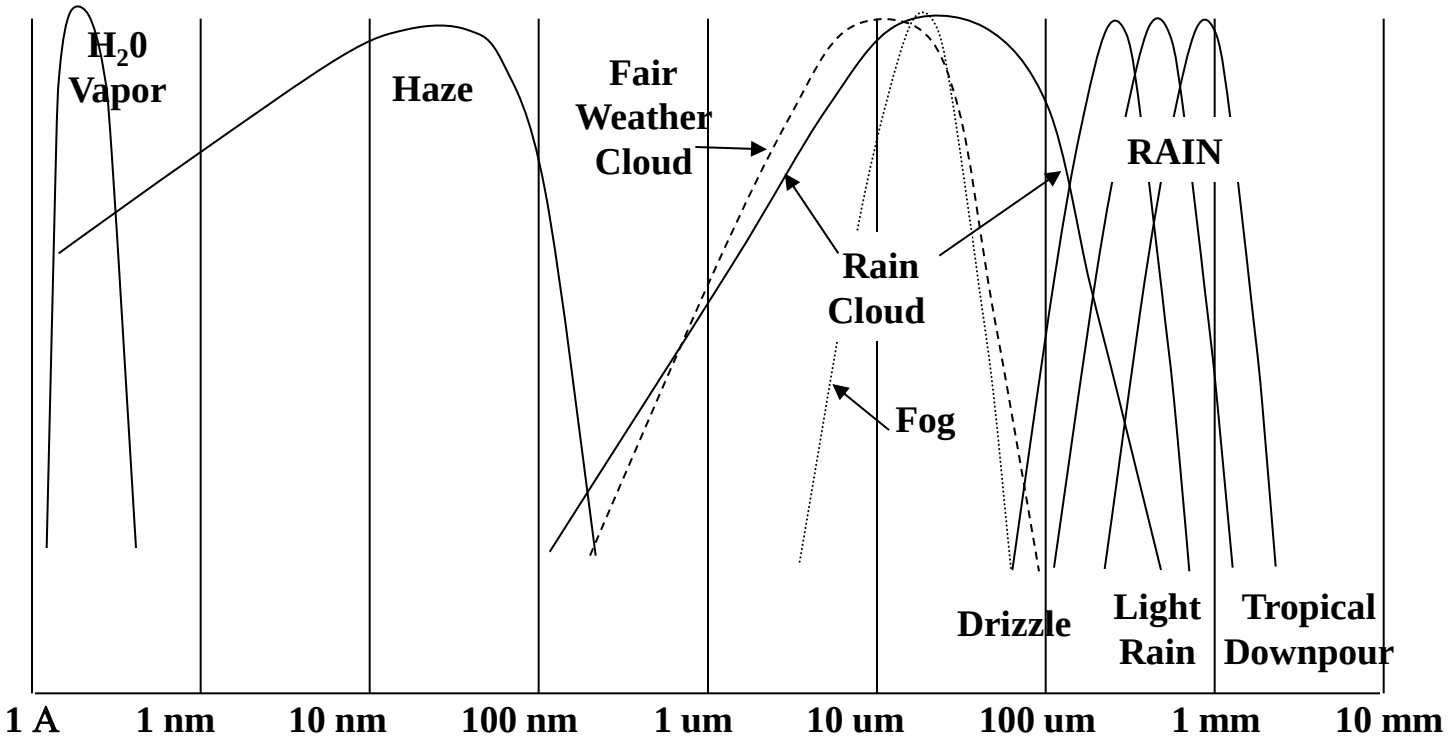





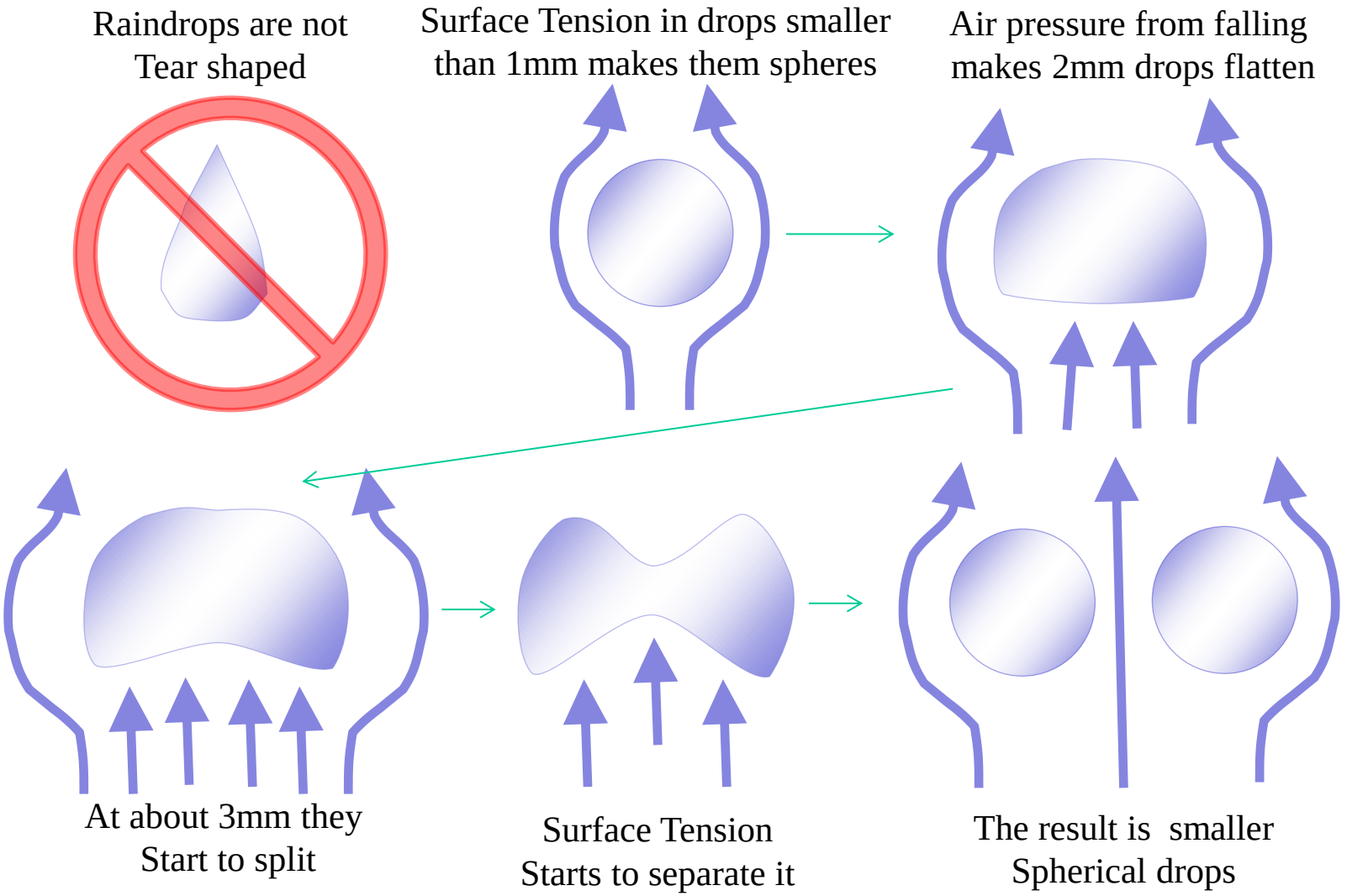
# Warm Day in Arizona


WA1MBA Microwave Update 1999

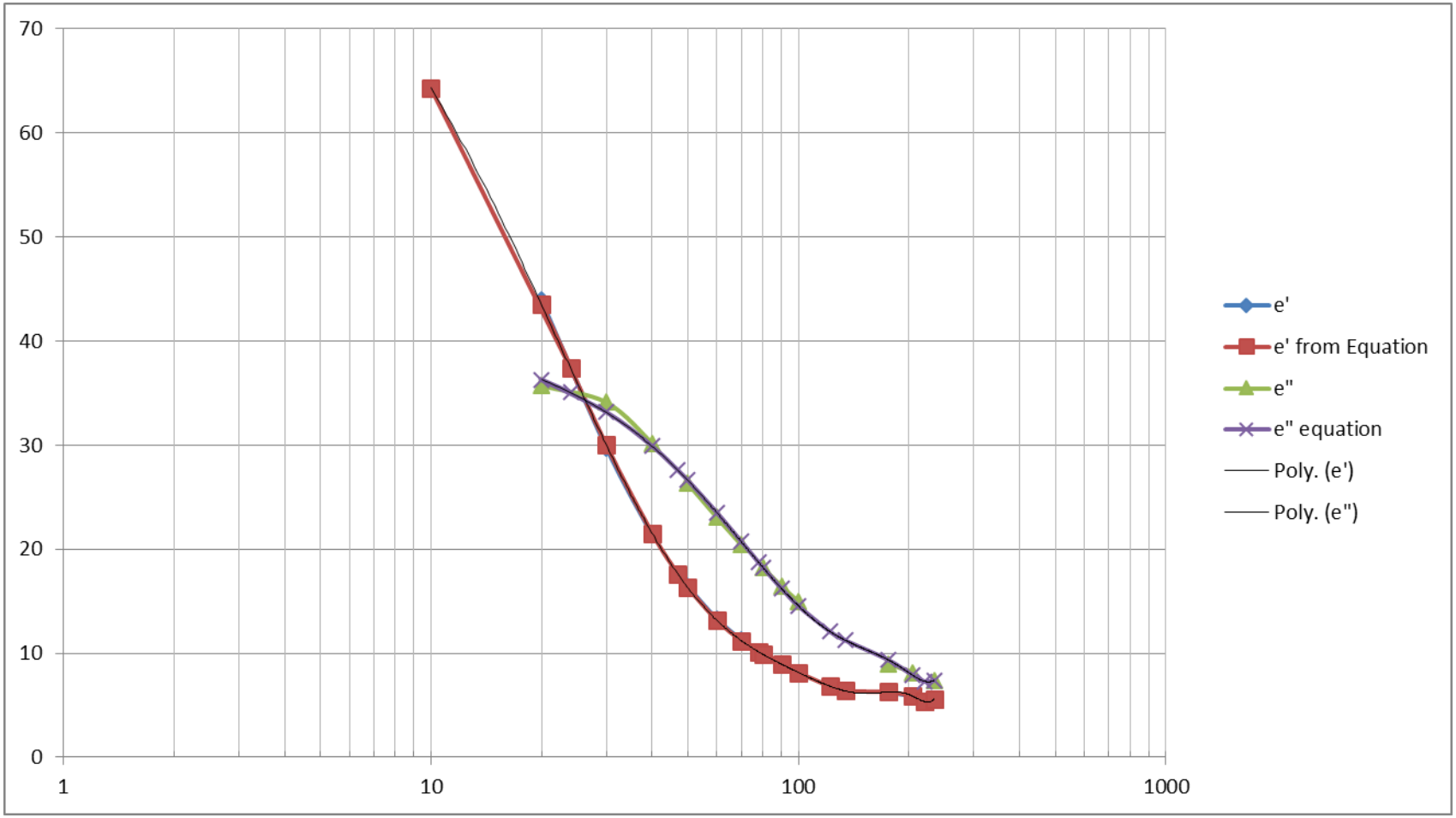
# Water Particle Sizes



# Raindrop Evolution



# Refraction (complex) changes over microwaves (dispersion)

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# Rain Scattering, SHF and EHF

- What is Scattering?
- What is Rain?
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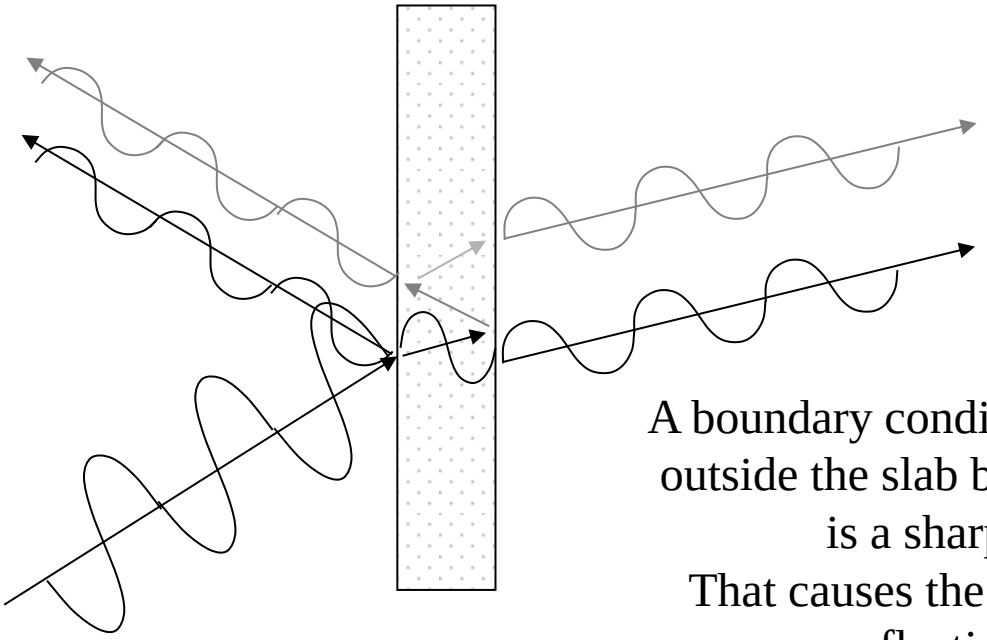
  - How does Scattering Work?
  - Particle Size & Wavelength
  - Angle
  - Polarization
- SHF and EHF

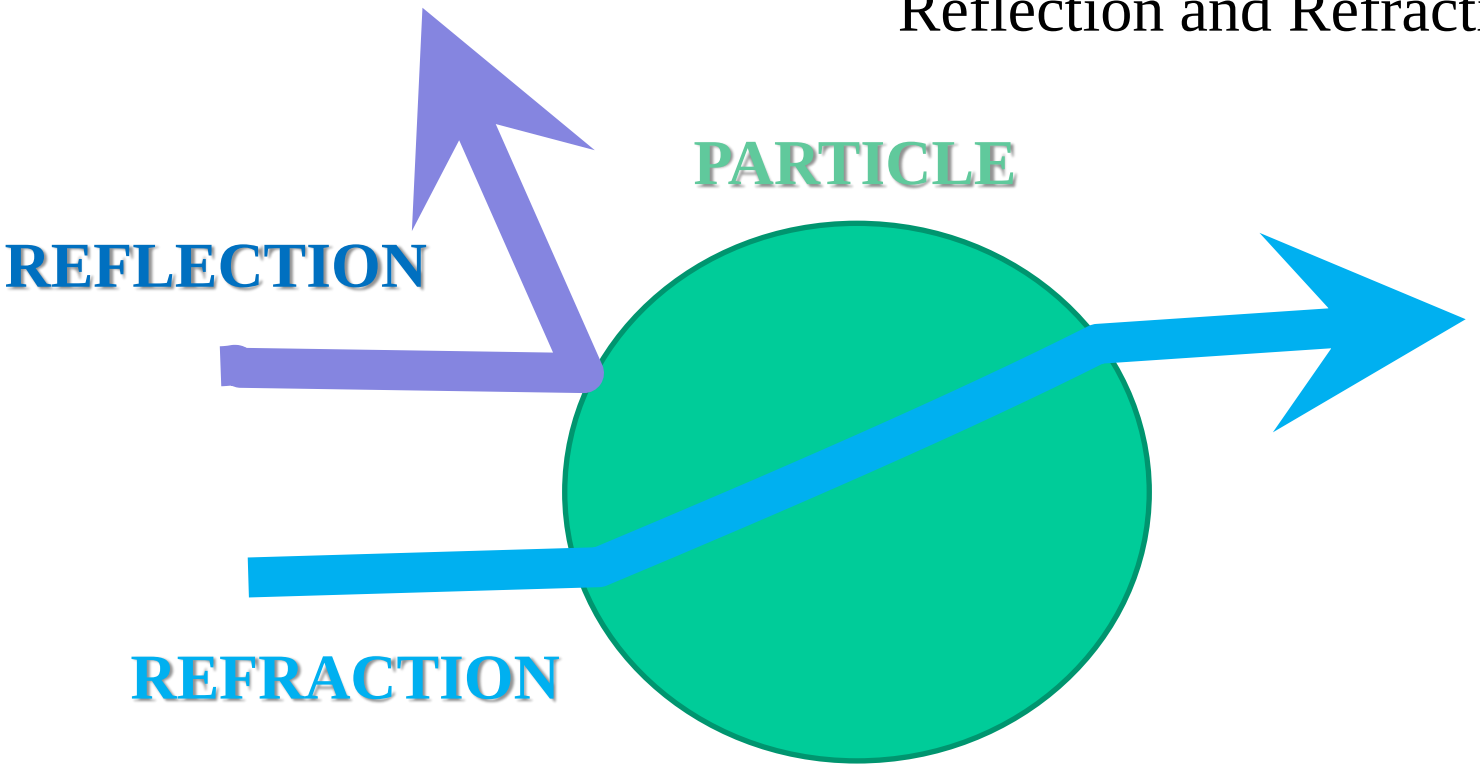
# Scattering – How does it work? TEM Waves in a Slab



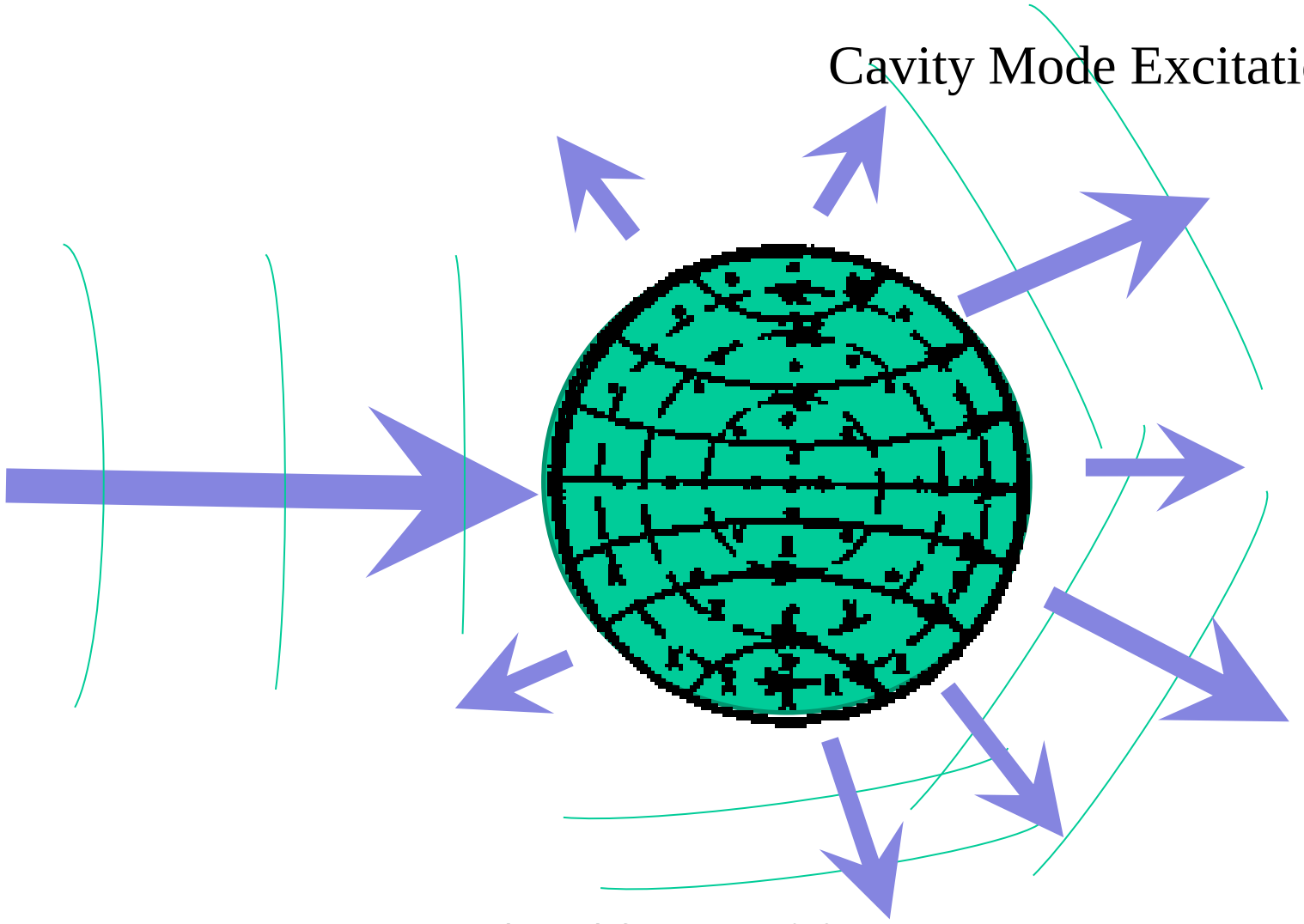
A boundary condition exists between inside and outside the slab because at that boundary there is a sharp impedance change.
That causes the TEM wave to split between reflection and transmission.
EM waves entering the slab will experience internal reflections and leak at the boundaries, all dependent on the dielectric difference across the boundary and the angle of approach

# Matter – EM interaction

Reflection and Refraction

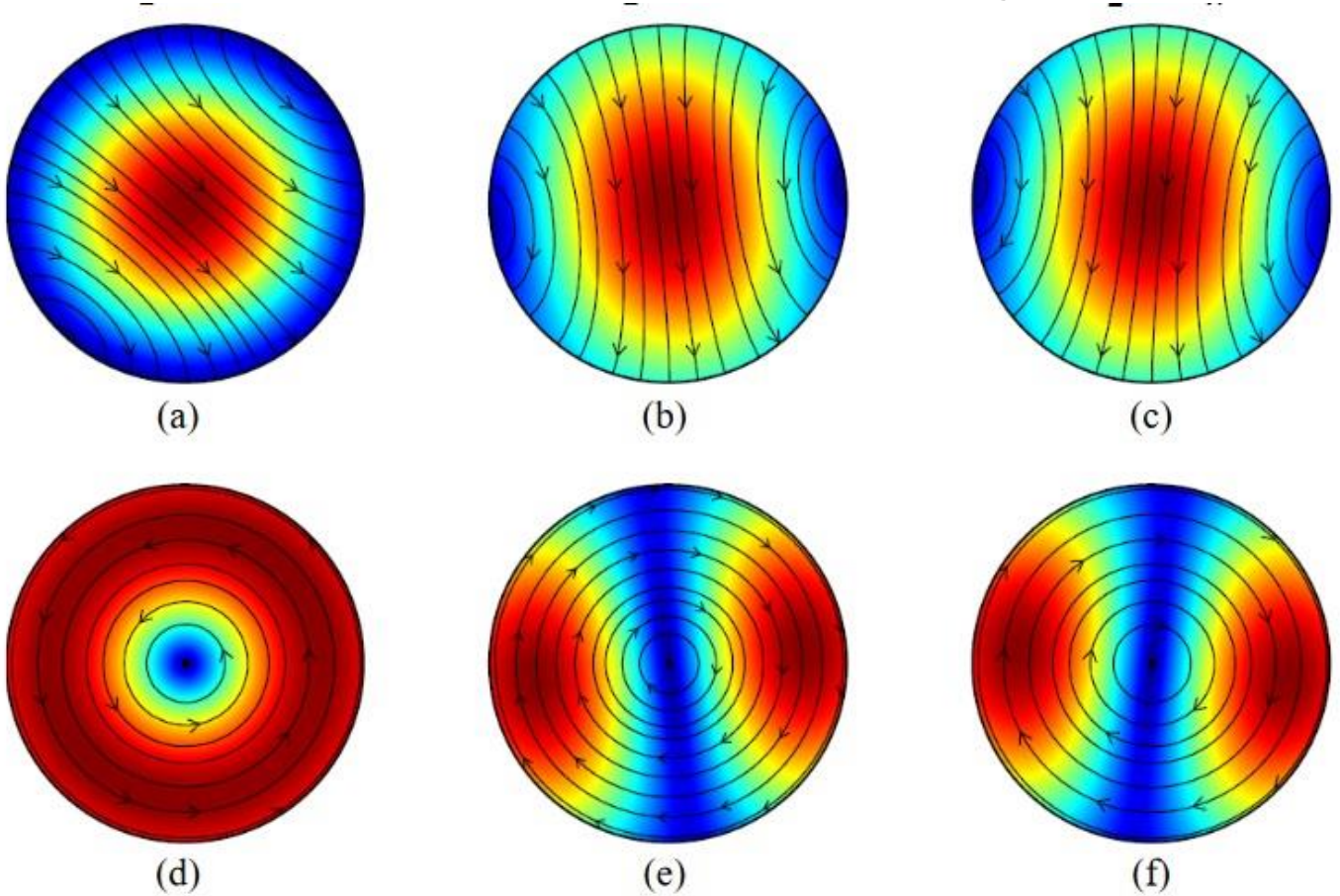


# Matter – EM interaction

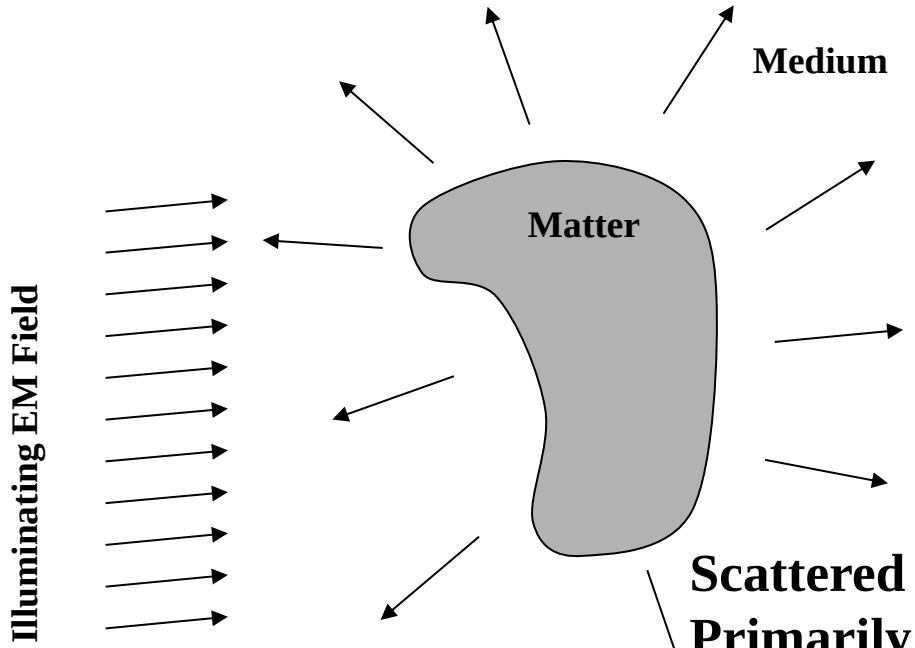


# Matter – EM interaction

Cavity Mode Excitation



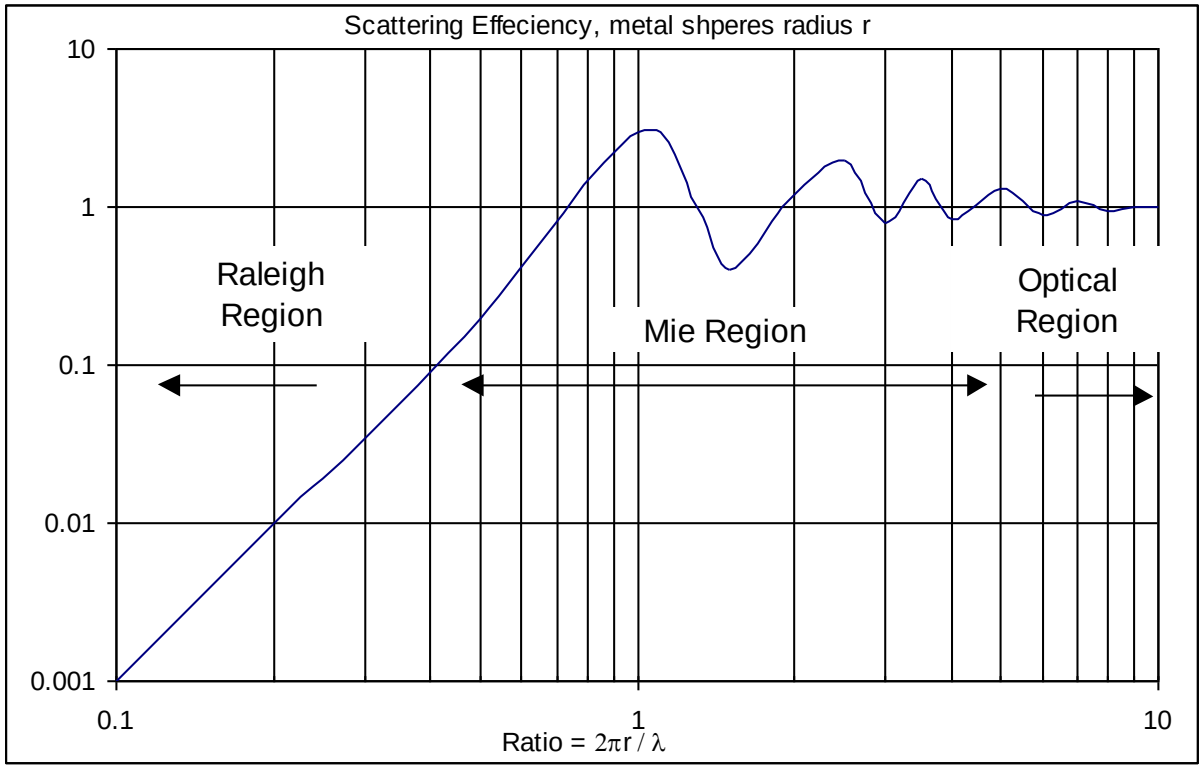
# Scattering




**Scattered secondary emission Primarily from excitation of and re-radiation from the particle**

# Size/Wavelength Dependency

Three “regions” based on $\chi = 2\pi r/\lambda$



# Effect of $\chi$ on Ham Radio Rain Scattering

- In Rayleigh Region scattering increases by $f^4$
- Assume $\chi$ is in Rayleigh Region in these examples
- Assume +20 dB s.n.r. at 10 GHz (excellent scattering conditions, good stations), and same system capabilities on other bands:
  - 5760 signals would be 10 dB s.n.r.
  - 3456 signals would be 1 dB s.n.r.
  - 2304 signals would be –6 dB s.n.r.
  - 1296 signals would be –16 dB s.n.r.
- I have heard scattering on 2304 up to 24 GHz

# Storms at 90° have Poorest Scattering when using horizontal polarization

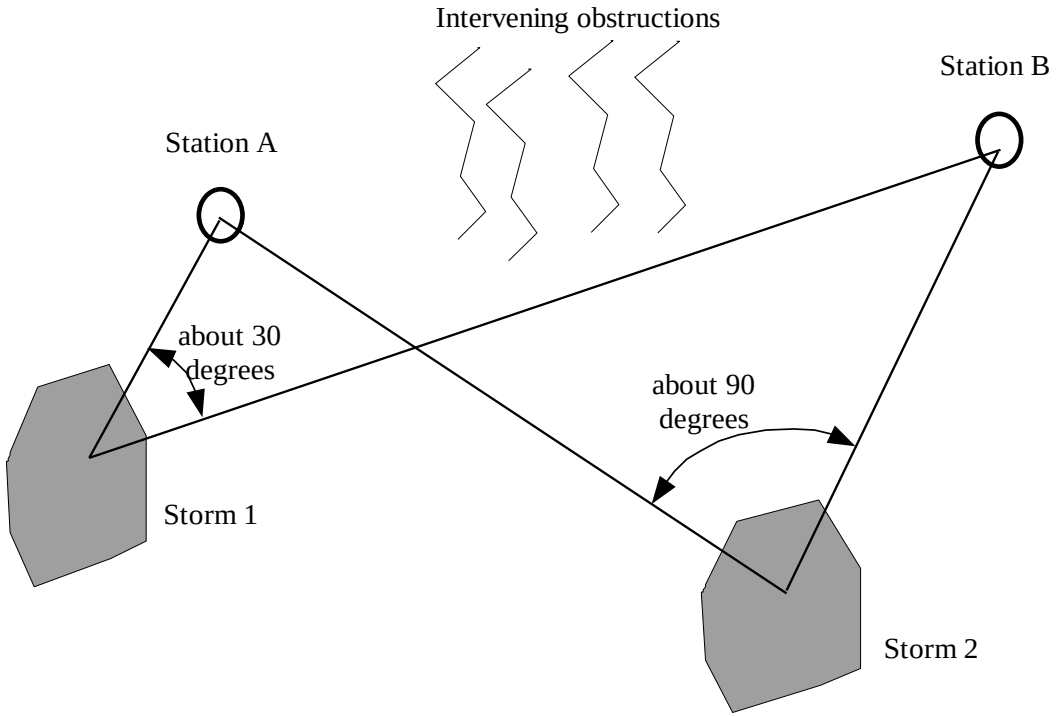



Figure 9. An example situation. The two stations are much more likely to communicate via storm 1 than storm 2 because storm 2 presents a 90 degree angle.

# Scattering Distortion

- Because of multiple Doppler paths, rain scattering is noisy in frequency

$$\delta\phi = 2\pi \bullet f_{sig} \bullet \delta_t$$

- So, modulation that depends on coherence of frequency will loose intelligibility -
  - SSB and CW sounds like aurora

# Best Modes for Scatter

- Frequency Distorted by noise process so:
  - SSB and CW sounds like Aurora
  - FM will experience only amplitude noise!!
    - Conclusion: FM is best for intelligibility
  - Normally CW – use dashes to peak the noise
- Horizontal Polarization will experience serious nulls at 90 degrees (Raleigh)
    - Conclusion: If available try Vertical Polarization

# Rain Scattering, SHF and EHF

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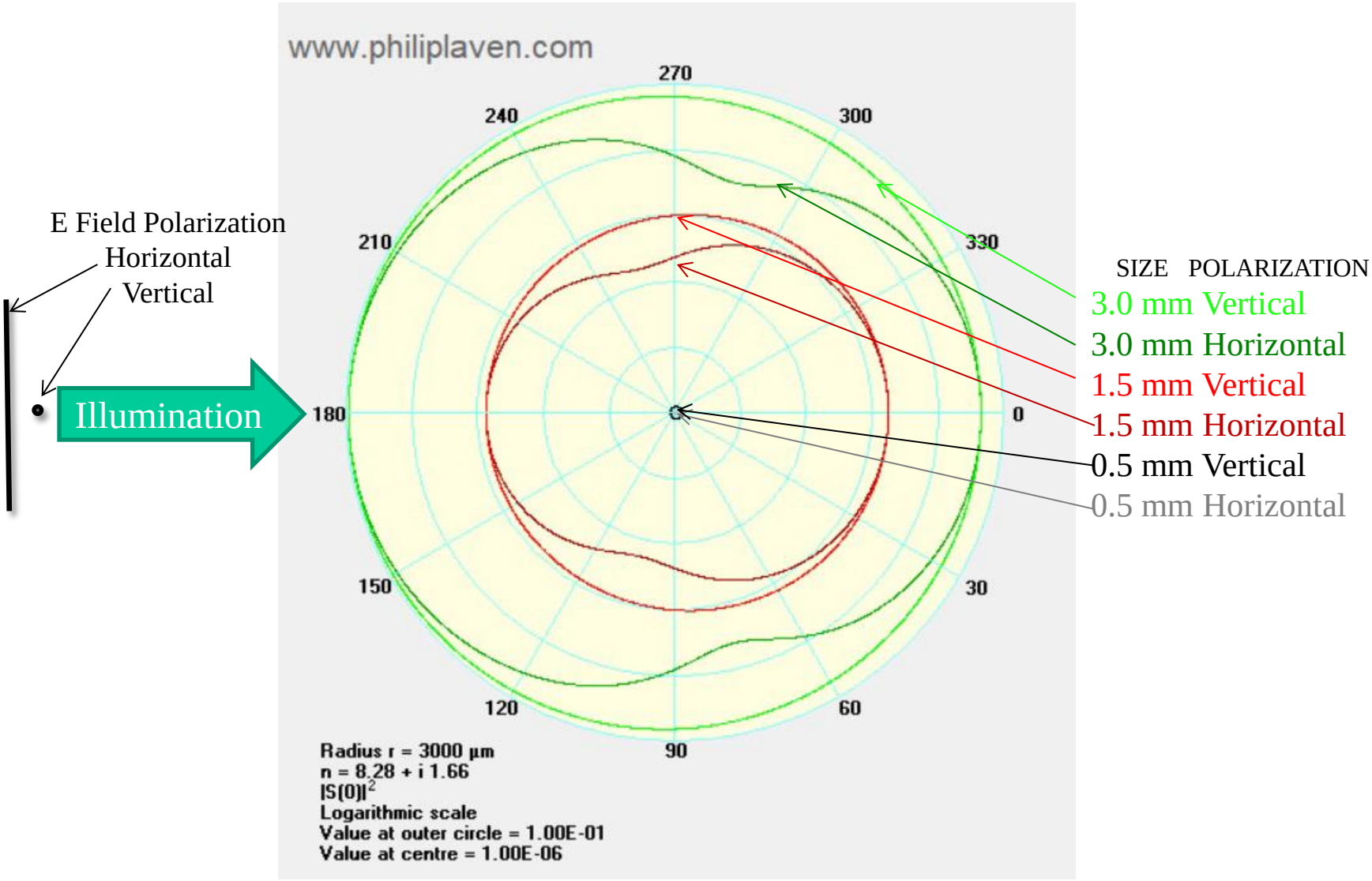
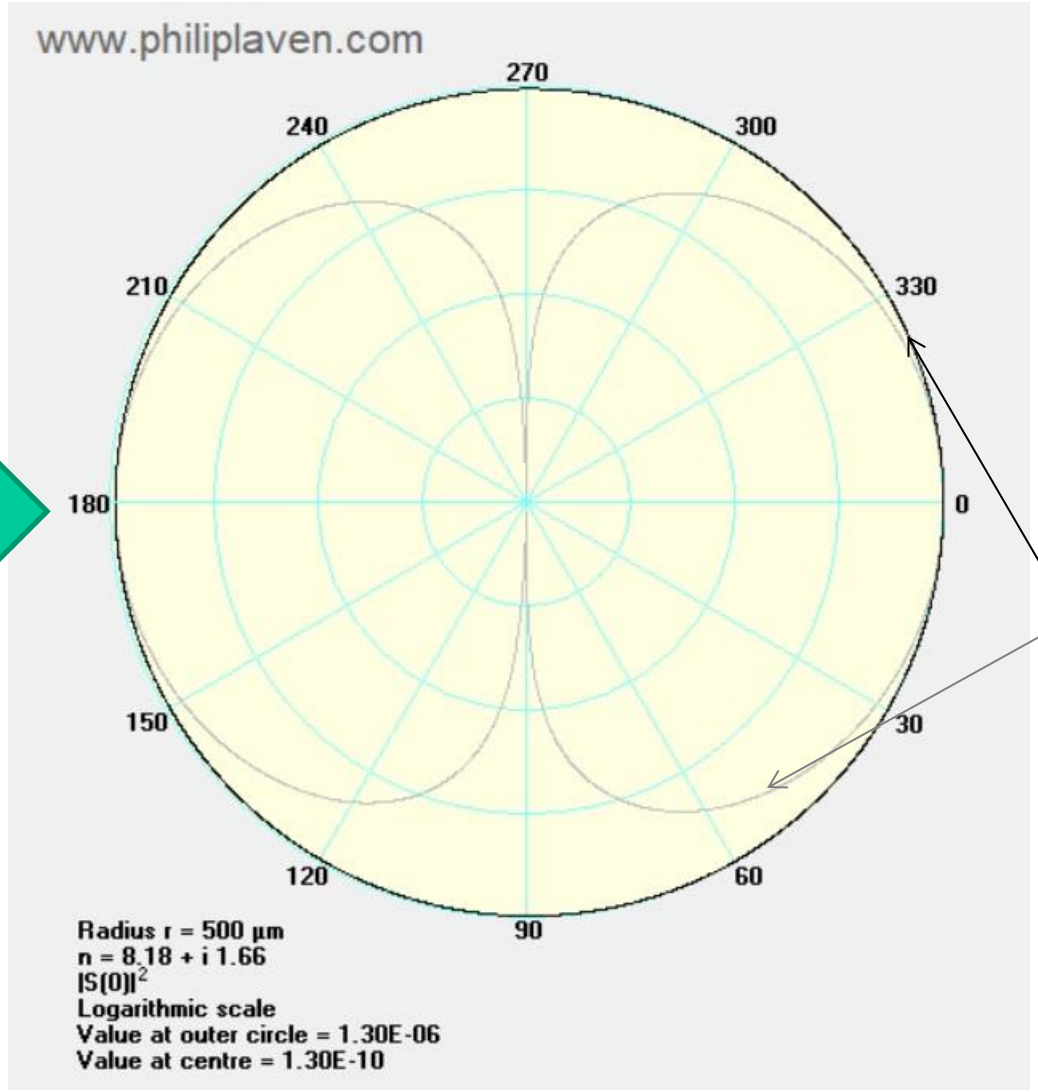
# 10 GHz Rain Scatter by Drop Size



# 10 GHz Rain Scatter 0.5 mm Close-up




Illumination

SIZE POLARIZATION

3.0 mm Vertical

3.0 mm Horizontal

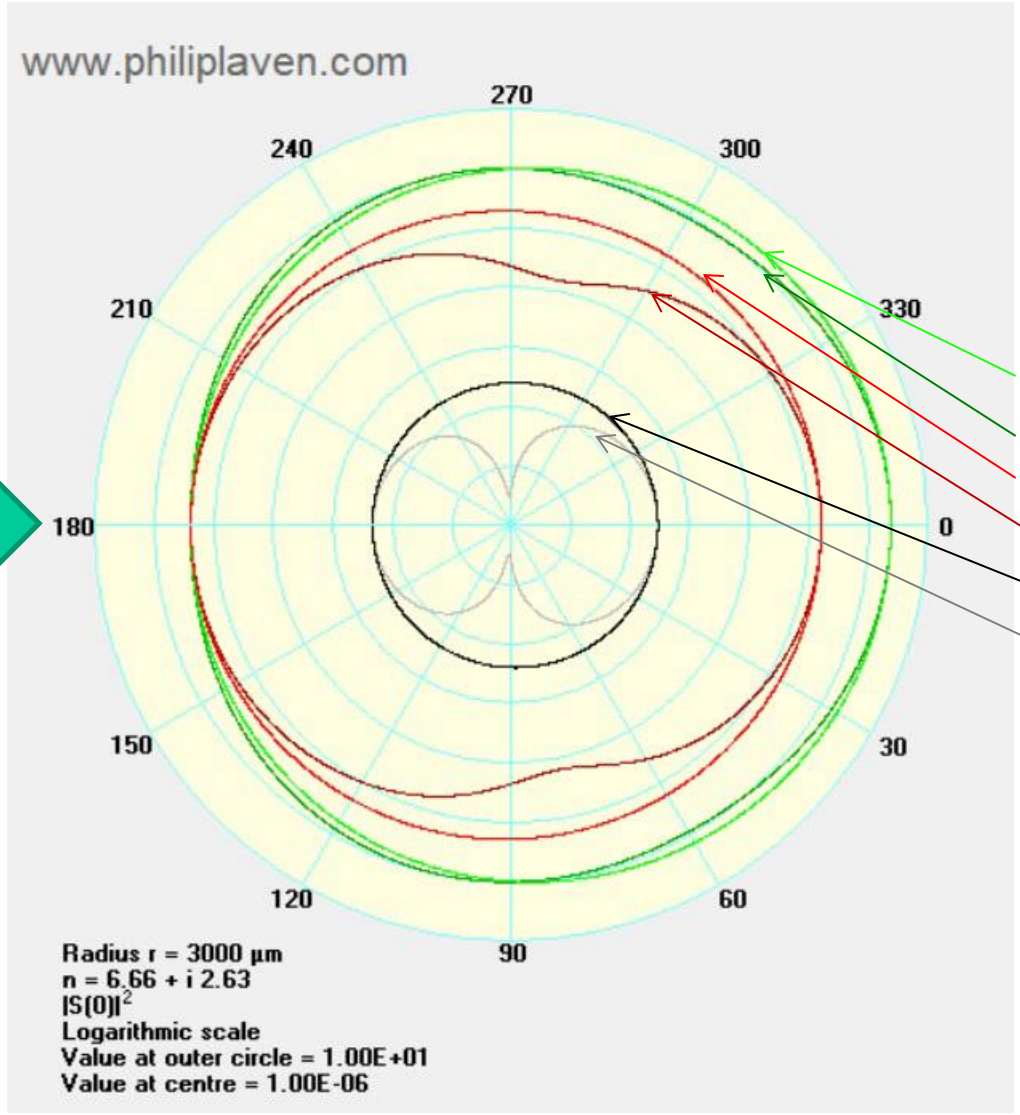
1.5 mm Vertical

1.5 mm Horizontal

0.5 mm Vertical

0.5 mm Horizontal

# 24 GHz Rain Scatter by Drop Size




Illumination

SIZE POLARIZATION

3.0 mm Vertical

3.0 mm Horizontal

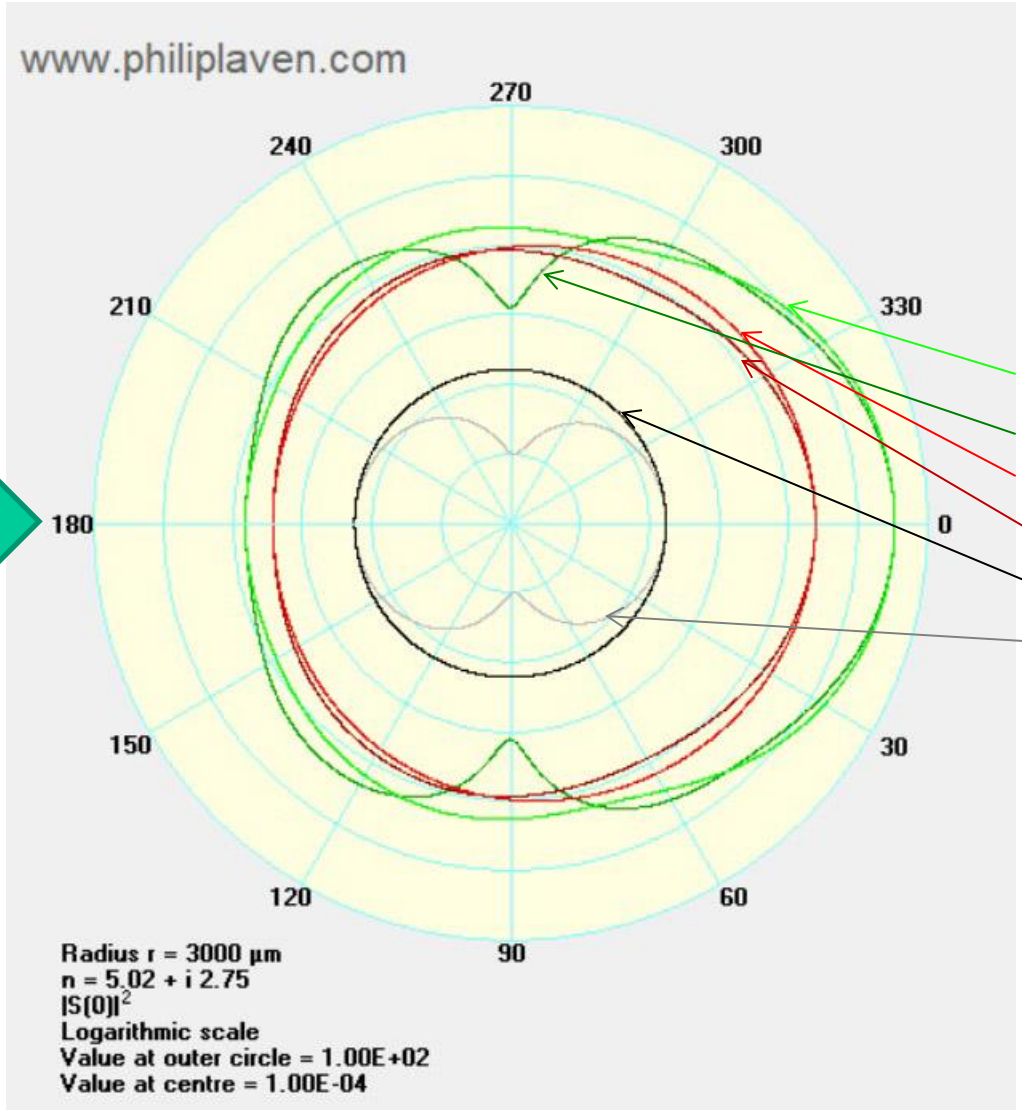
1.5 mm Vertical

1.5 mm Horizontal

0.5 mm Vertical

0.5 mm Horizontal

# 47 GHz Rain Scatter by Drop Size




Illumination

SIZE POLARIZATION

3.0 mm Vertical

3.0 mm Horizontal

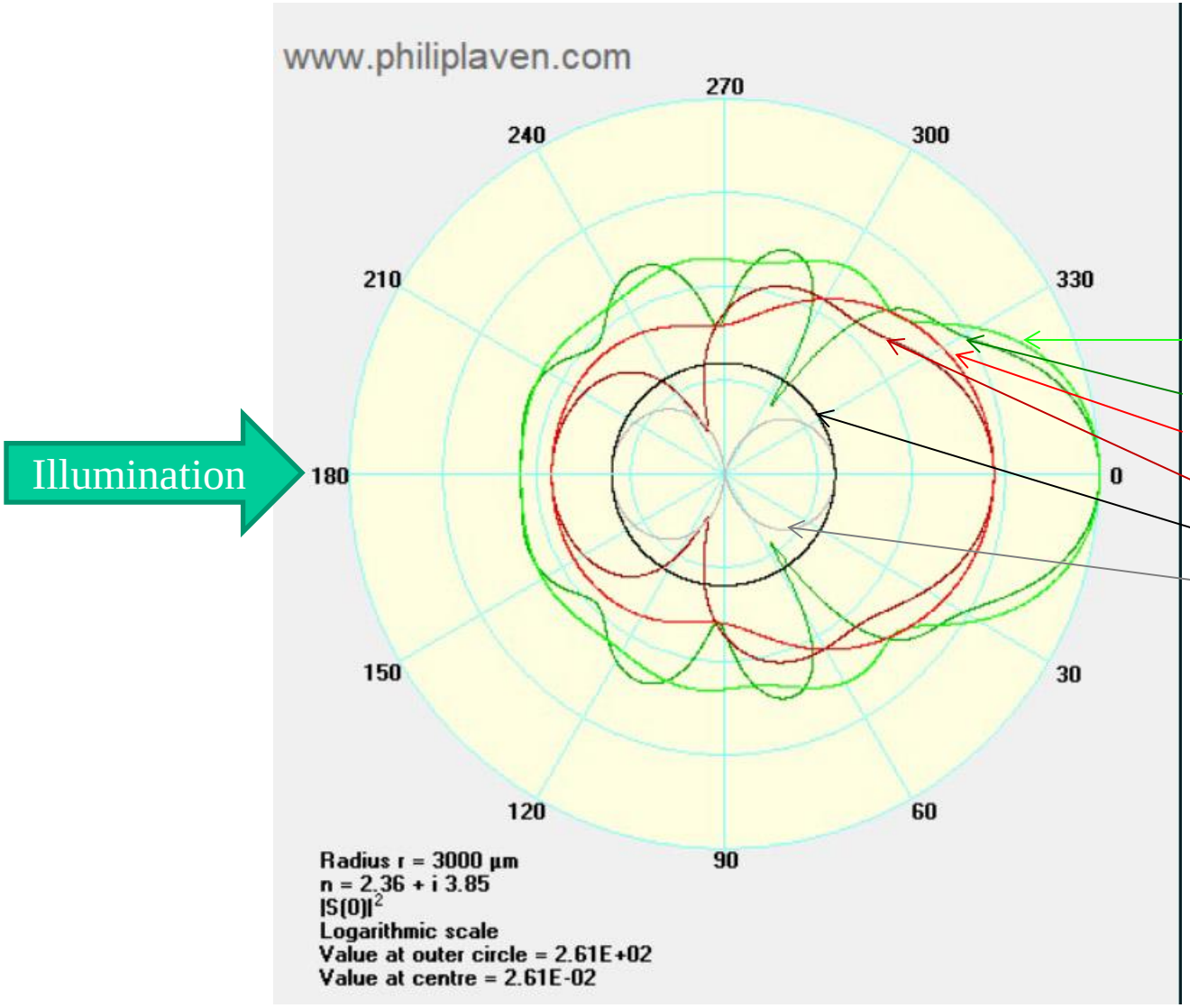
1.5 mm Vertical

1.5 mm Horizontal

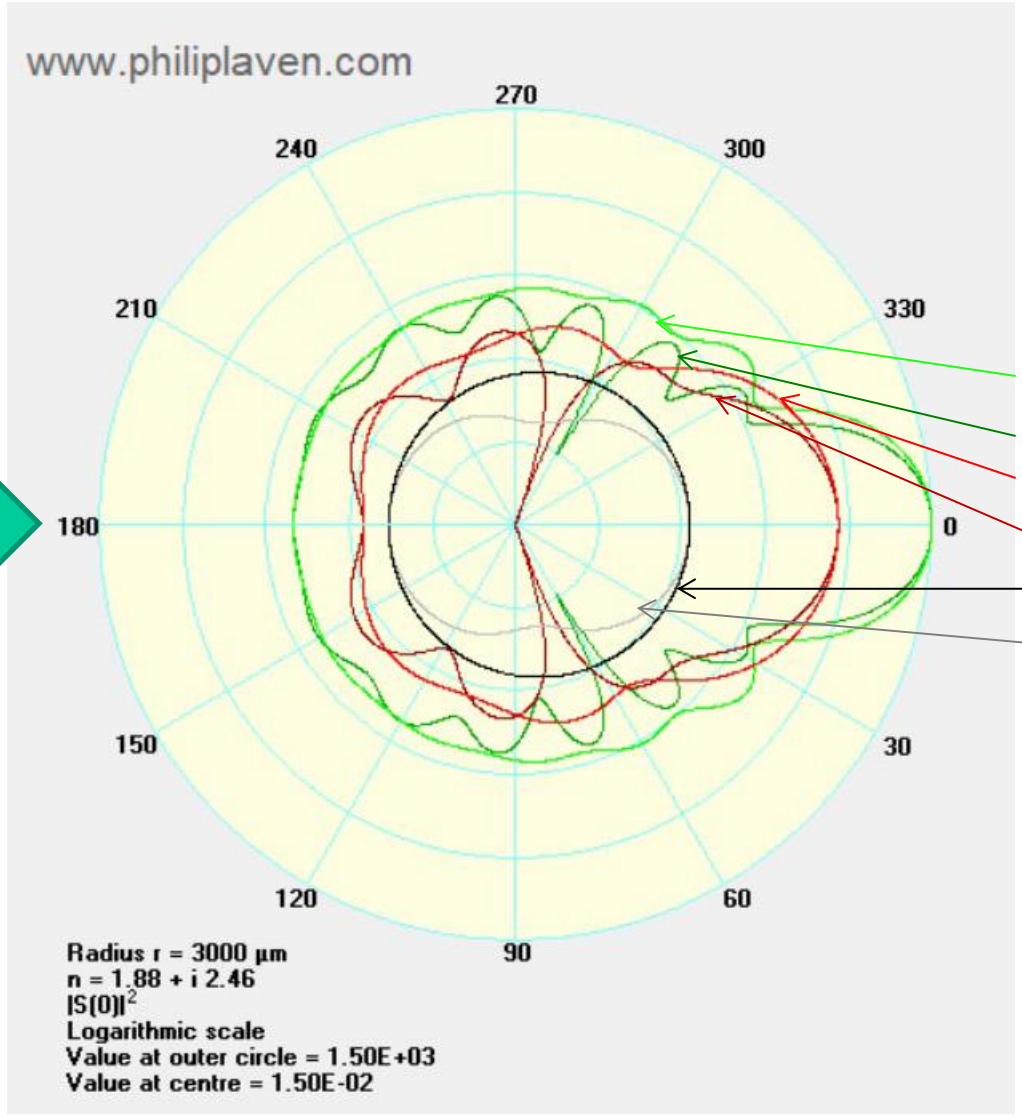
0.5 mm Vertical

0.5 mm Horizontal

# 78 GHz Rain Scatter by Drop Size



# 122 GHz Rain Scatter by Drop Size




Illumination

SIZE POLARIZATION

3.0 mm Vertical

3.0 mm Horizontal

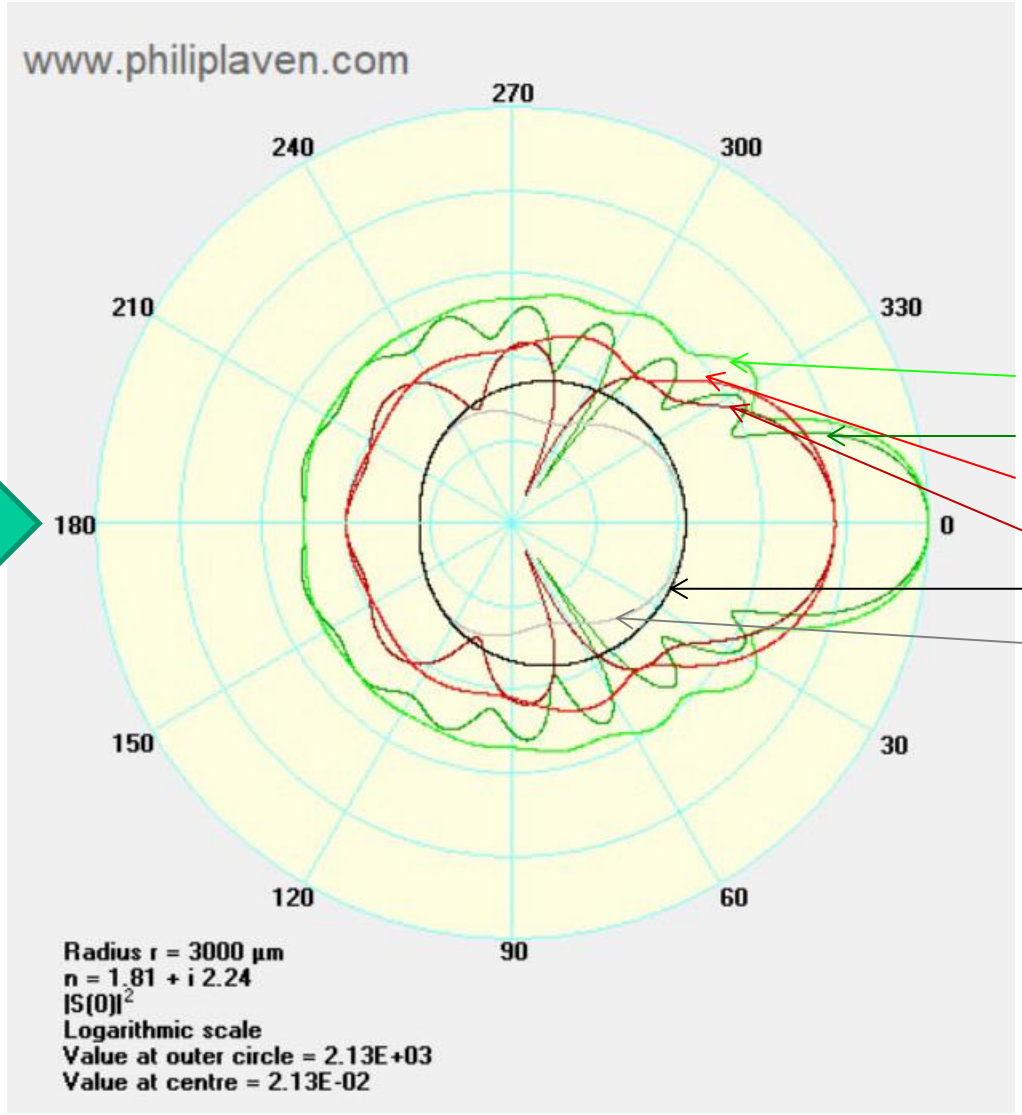
1.5 mm Vertical

1.5 mm Horizontal

0.5 mm Vertical

0.5 mm Horizontal

# 134 GHz Rain Scatter by Drop Size




Illumination

SIZE POLARIZATION

3.0 mm Vertical

3.0 mm Horizontal

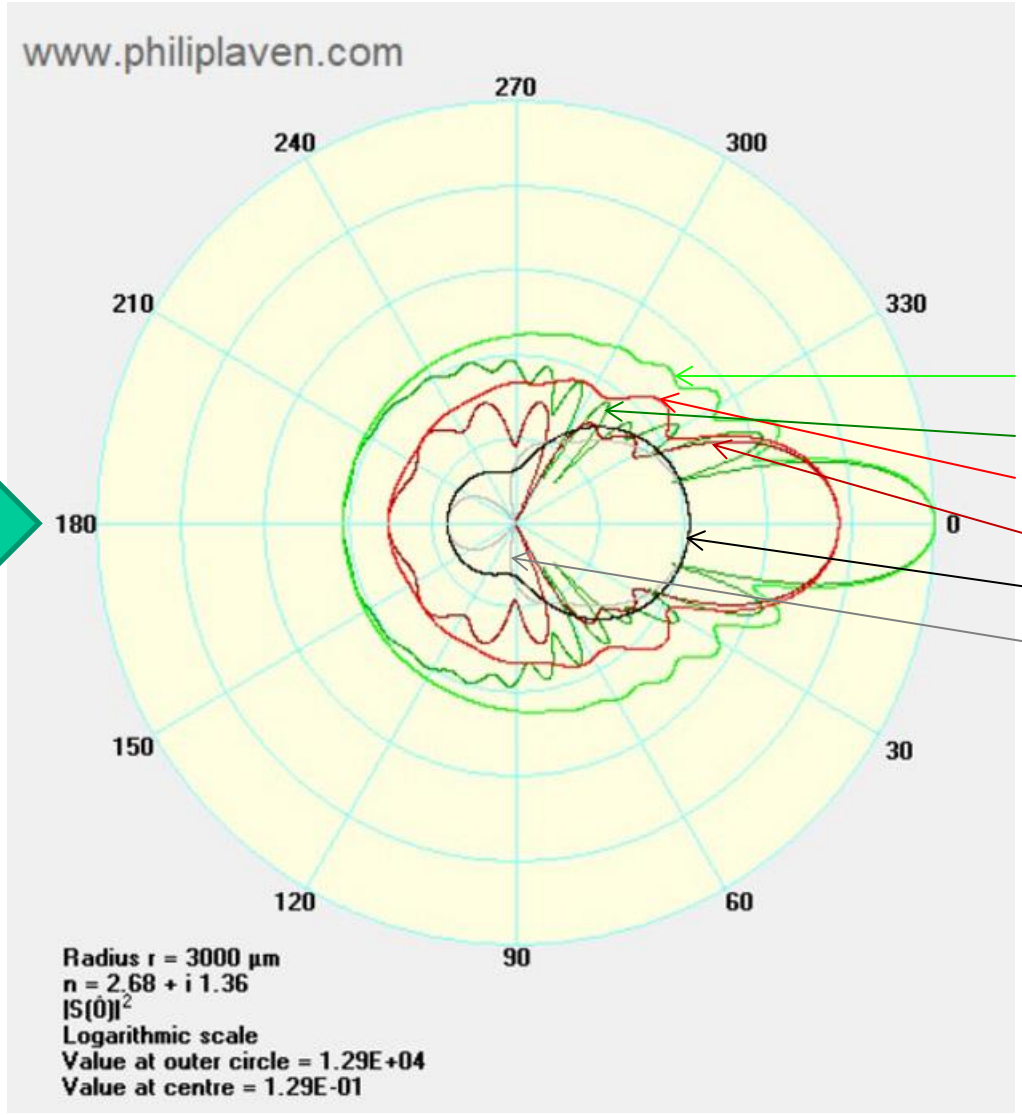
1.5 mm Vertical

1.5 mm Horizontal

0.5 mm Vertical

0.5 mm Horizontal

# 241 GHz Rain Scatter by Drop Size




Illumination

SIZE POLARIZATION

3.0 mm Vertical

3.0 mm Horizontal

1.5 mm Vertical

1.5 mm Horizontal

0.5 mm Vertical

0.5 mm Horizontal

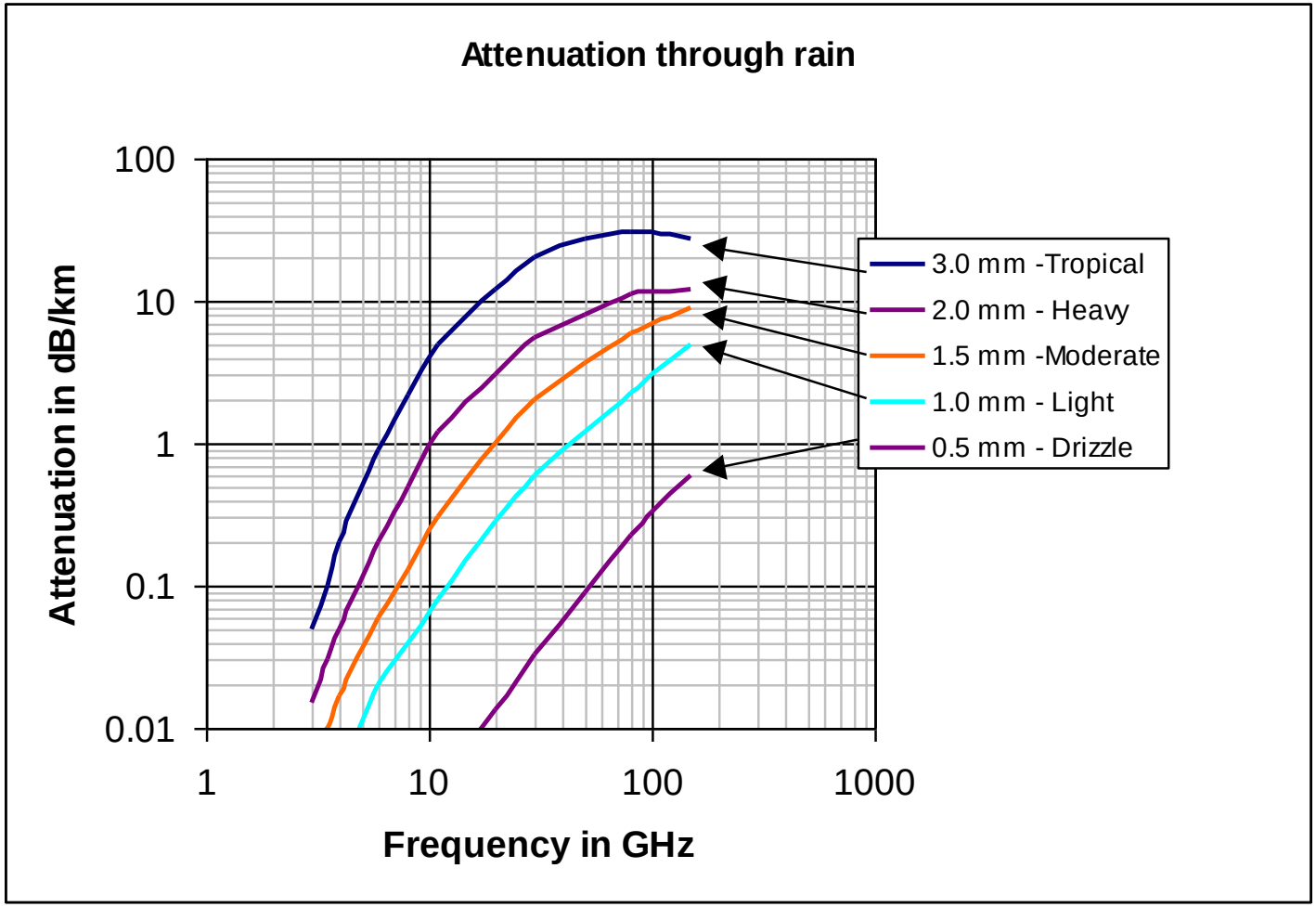
# Extinction (attenuation)

- Fairly complex equations including angular scattering, density of scatterers, distance through volume

$$F(\tau) = 2\pi \left[ \int_{\tau}^{\infty} S(t) E_2(t-\tau) dt - \int_{0}^{\tau} S(t) E_2(\tau - t) dt \right]$$

- Can be simplified to approximately $k=f^{1.9}$

# Attenuation Through Rain



# Scattering Attenuation

Here we see a chart of calculated extinction which includes atmospheric loss and scattering extinction at different rainfall rates

The atmosphere is set to 15 Celsius (59 Farenheit) and 50% relative humidity. Some Summer storms might be colder and with higher humidity.

| dB/km | Rain Rate mm/hr | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GHz** | **0.5** | **1** | **2** | **4** | **5** | **10** | **15** | **20** | **25** | **30** | **40** | **50** | **75** | **100** |
| **10** | 0.019 | 0.027 | 0.045 | 0.088 | 0.112 | 0.248 | 0.403 | 0.571 | 0.749 | 0.937 | 1.336 | 1.760 | 2.908 | 4.157 |
| **24** | 0.214 | 0.287 | 0.435 | 0.732 | 0.881 | 1.629 | 2.379 | 3.131 | 3.884 | 4.639 | 6.150 | 7.665 | 11.459 | 15.263 |
| **47** | 0.556 | 0.816 | 1.276 | 2.090 | 2.468 | 4.199 | 5.777 | 7.263 | 8.685 | 10.056 | 12.687 | 15.202 | 21.142 | 26.736 |
| **78** | 0.996 | 1.444 | 2.181 | 3.391 | 3.926 | 6.255 | 8.258 | 10.077 | 11.769 | 13.366 | 16.351 | 19.128 | 25.462 | 31.209 |
| **122** | 1.757 | 2.308 | 3.180 | 4.560 | 5.157 | 7.690 | 9.810 | 11.700 | 13.435 | 15.056 | 18.047 | 20.793 | 26.950 | 32.439 |
| **134** | 1.654 | 2.217 | 3.104 | 4.501 | 5.104 | 7.653 | 9.778 | 11.668 | 13.401 | 15.018 | 17.996 | 20.726 | 26.835 | 32.267 |
| **241** | 3.308 | 3.892 | 4.798 | 6.204 | 6.805 | 9.317 | 11.388 | 13.215 | 14.880 | 16.427 | 19.262 | 21.846 | 27.586 | 32.652 |

FOR MORE INFORMATION

Set your internet browser URL to:
**http://www.wa1mba.org/**
At this site you can find sounds of rain scattering contacts (even snow scatter), and a lot of links to other sites that have info about microwaves, and in particular, 10Ghz and above.

References: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Rayleigh, Lord (J.W. Strutt)(1871), On the light from the sky, its polarization and colour, *Philos. Mag.*, 41(107),274.

Ulaby, Fawwaz T., Richard K. Moore, and Adrian K. Fung, Microwave Remote Sensing Active and Passive, Volume 1 (See chapters 4, 5, and 6), Artech House, Norwood, MA, 1981. All three volumes of this fine work are highly recommended for serious millimeter wave interests.

Williams, T., WA1MBA, "10 GHz, a Nice Band for a Rainy Day," CQ VHF February 1997, CQ Publications.

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