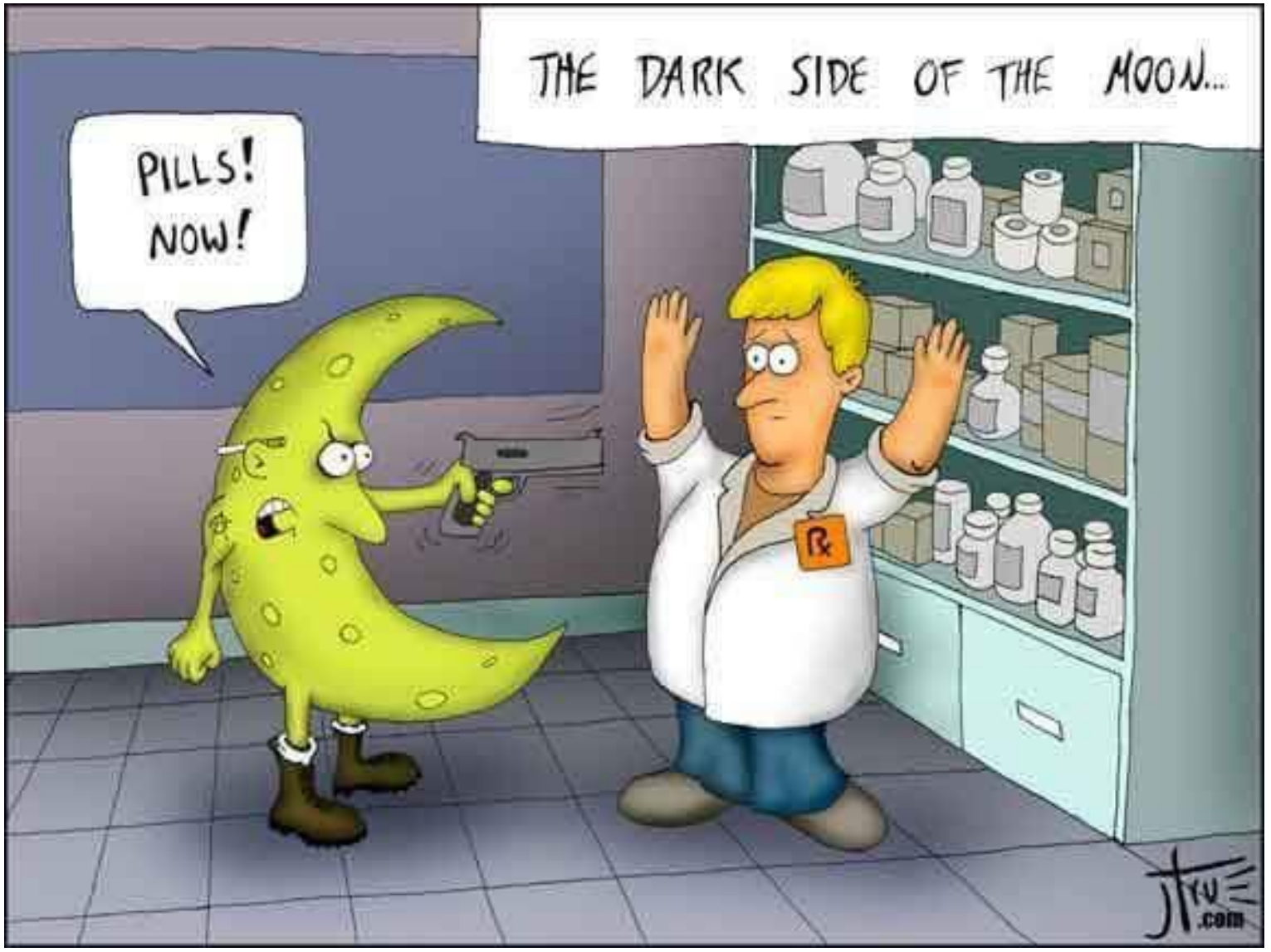
Scattering on SHF and EHF

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

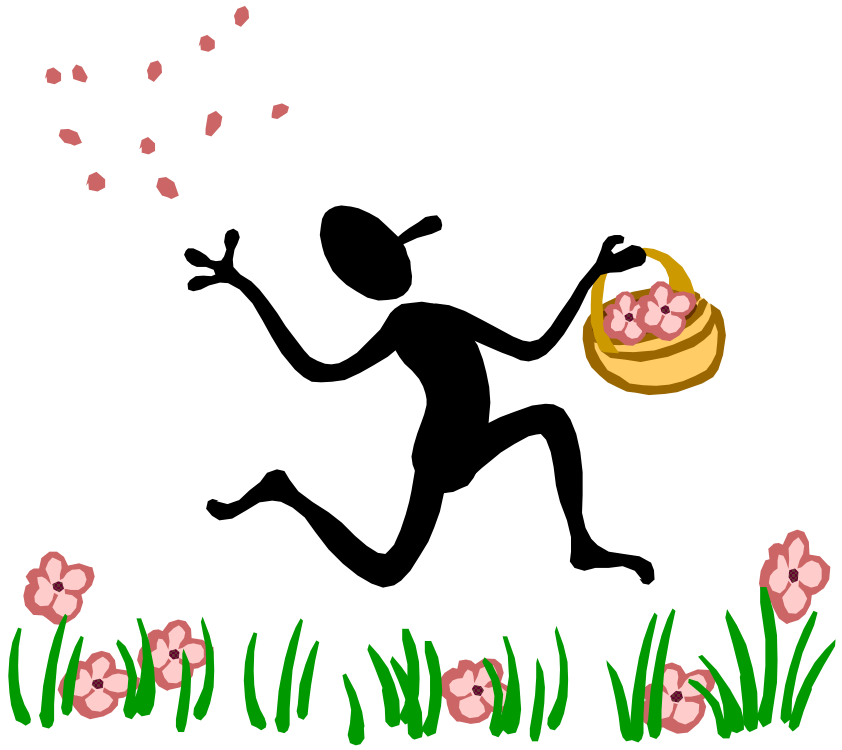
- If you were not there, snooze to next slide.
- 1999 ‘mba presentation was mostly correct
- Relied upon data from a program given constants based on incorrect assumptions
  - Specifically the dielectric properties of water at RF is different than visual light wavelengths
  - These resulted in incorrect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



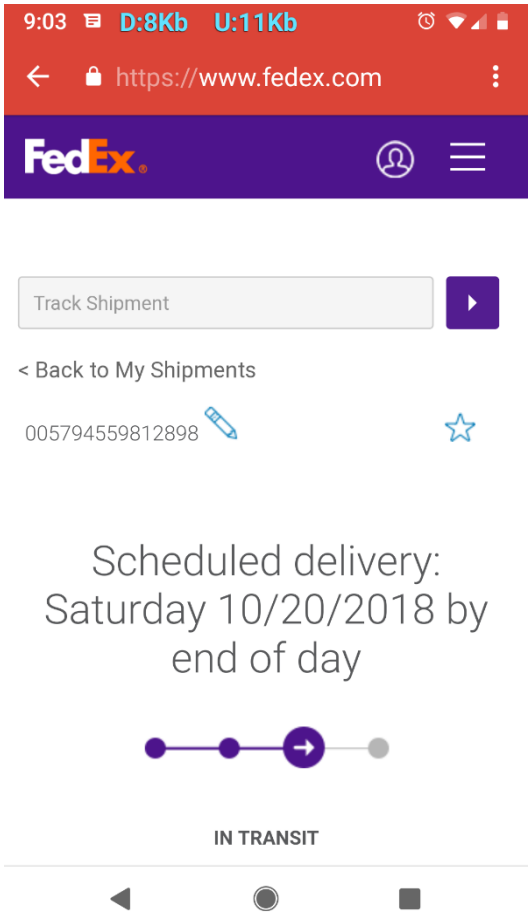
Scattering is:

- 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*

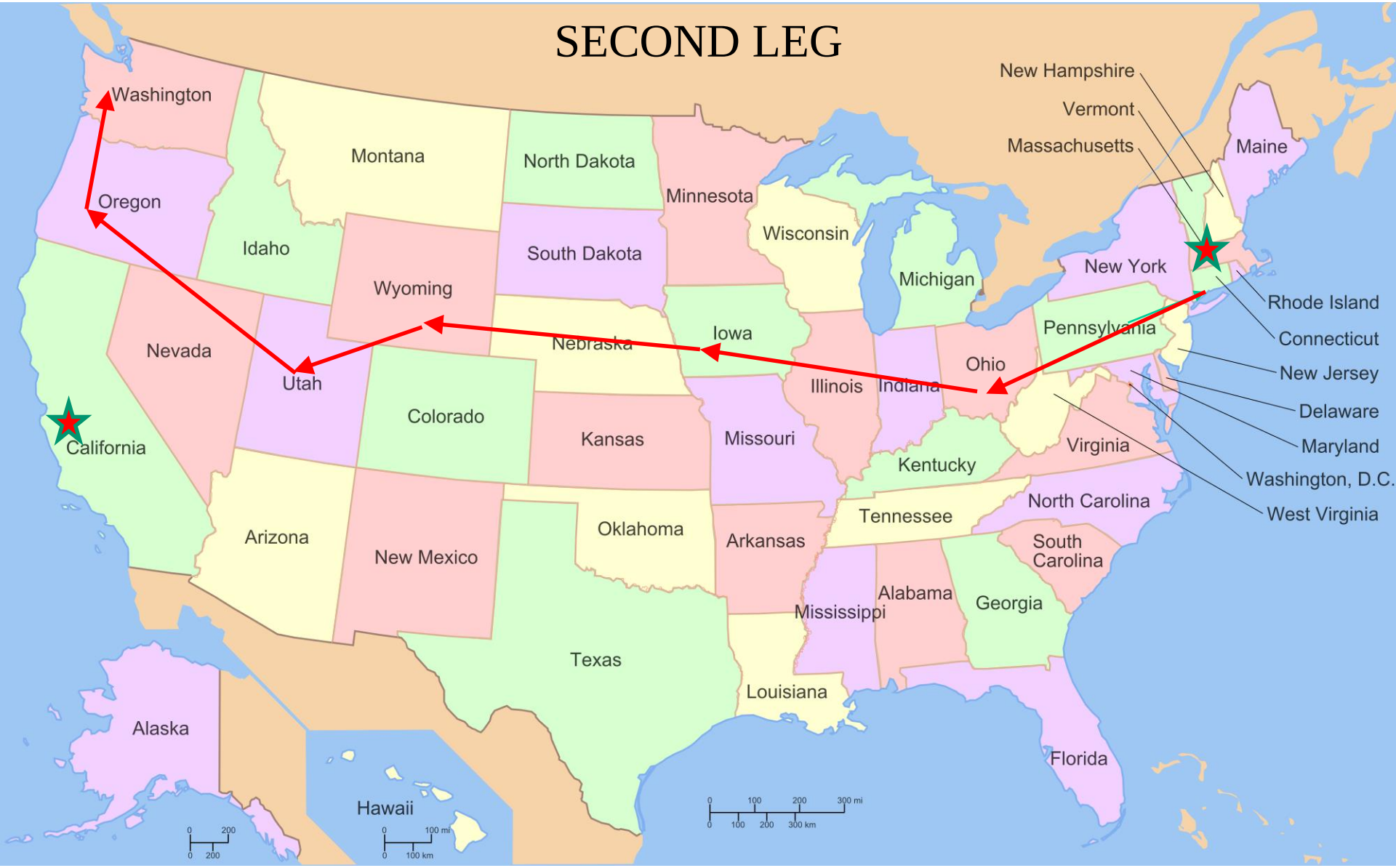
- Ordered Google Oct 5 – (G is in California)
- Deliver to me in Massachusetts
- Went via FedEx Ground
- Tracking info
- FED EX GROUND

Scheduled delivery - October 20



FIRST LEG – within 60 miles of destination

SECOND LEG


Washington
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Montana
Wyoming
Utah
Arizona
Colorado
New Mexico
North Dakota
South Dakota
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Texas
Minnesota
Iowa
Missouri
Arkansas
Louisiana
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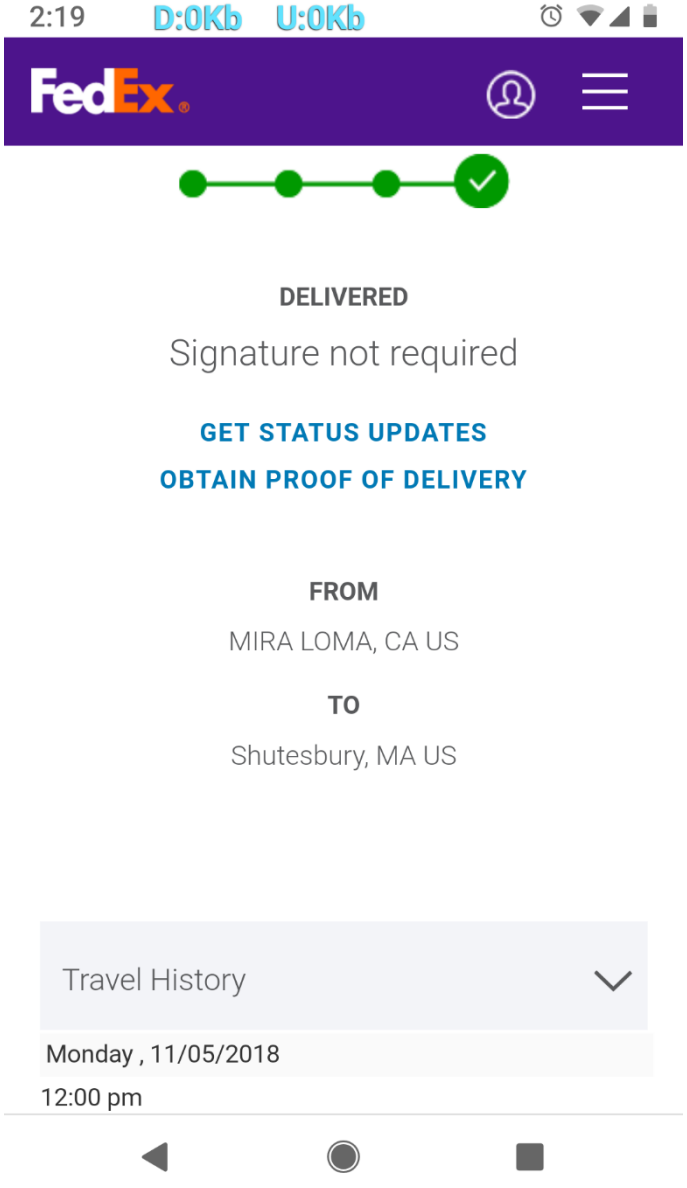
Alabama
Georgia
Florida
South Carolina
North Carolina
Virginia
West Virginia
Pennsylvania
New York
Maryland
Delaware
New Jersey
Connecticut
Rhode Island
Massachusetts
Vermont
New Hampshire
Maine
Washington, D.C.
Alaska
Hawaii

FINAL LEG

WA1MBA MUD 2019

STOPPED IN ONLY 17 STATES

Delivered November 5



PONY EXPRESS

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

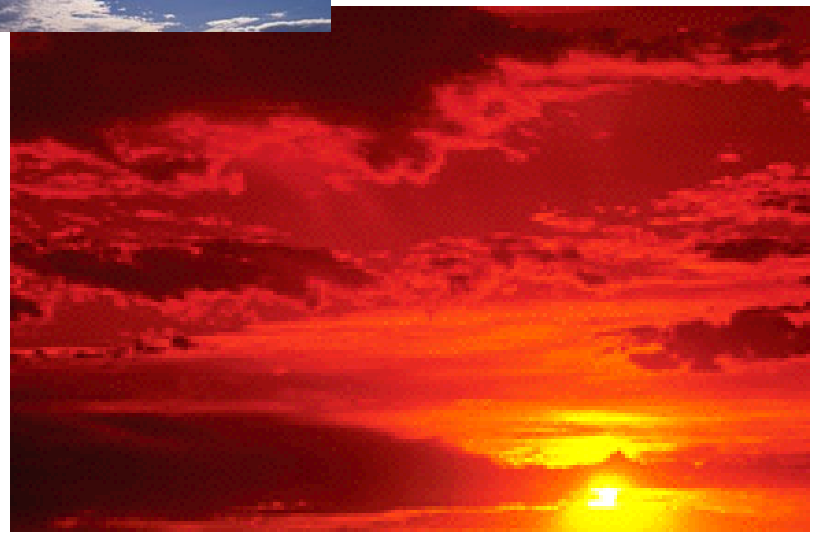
WANTED

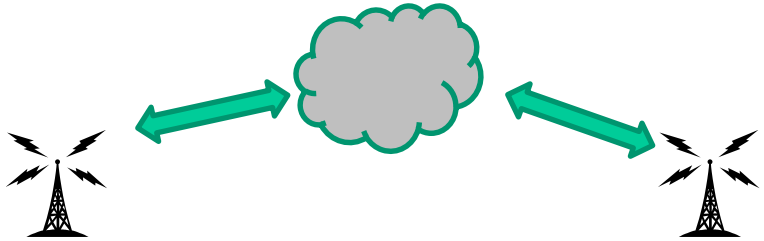
YOUNG, SKINNY, WIRY FELLOWS
not over eighteen. Must be expert riders, willing to risk death daily.

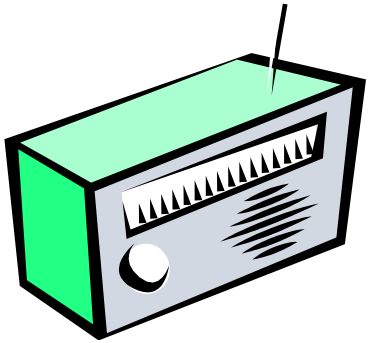
Orphans preferred.
Wages $25 per week.

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

Scattering - examples



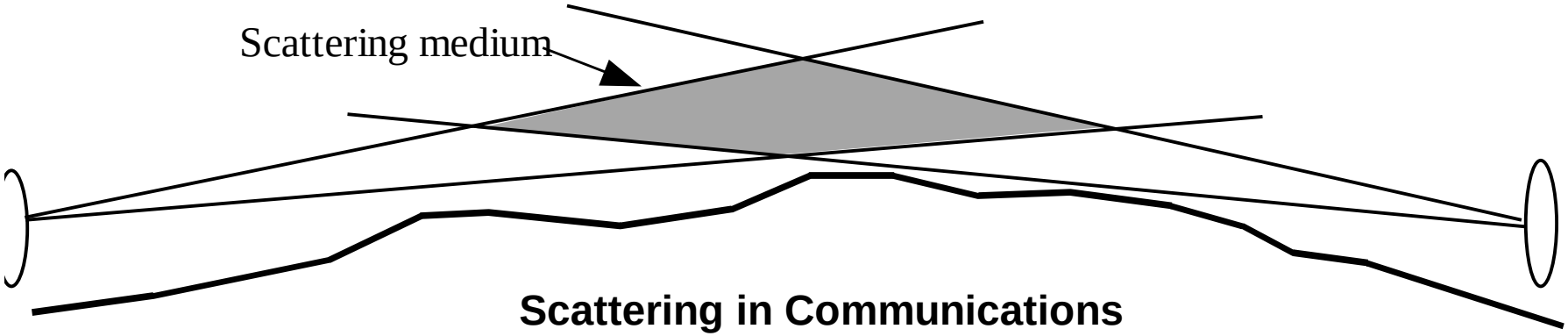




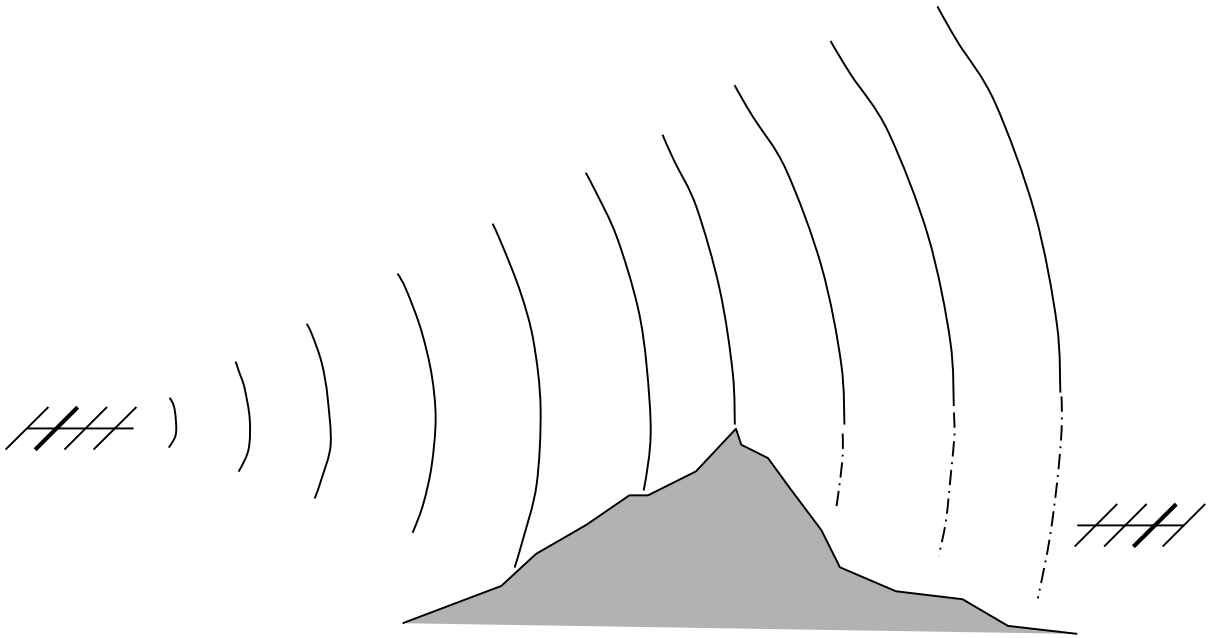
Examples of Scattering

- 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

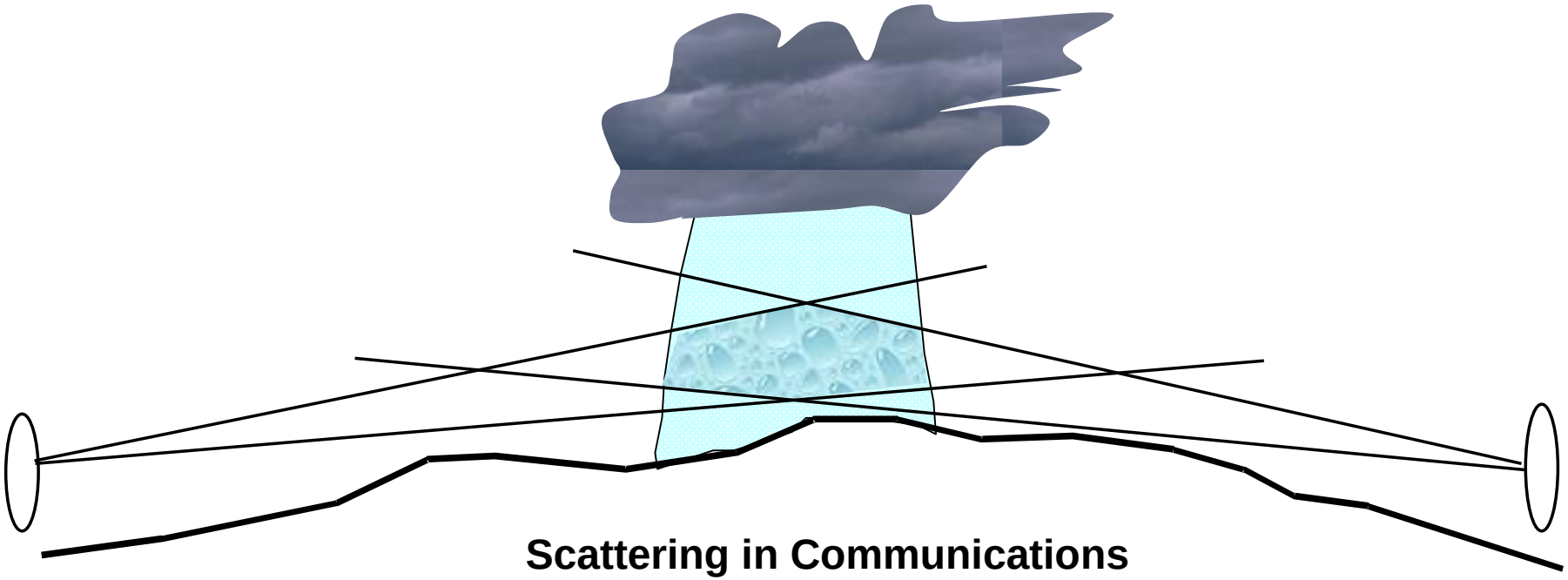


Knife-edge Scattering



Scattering in Communications

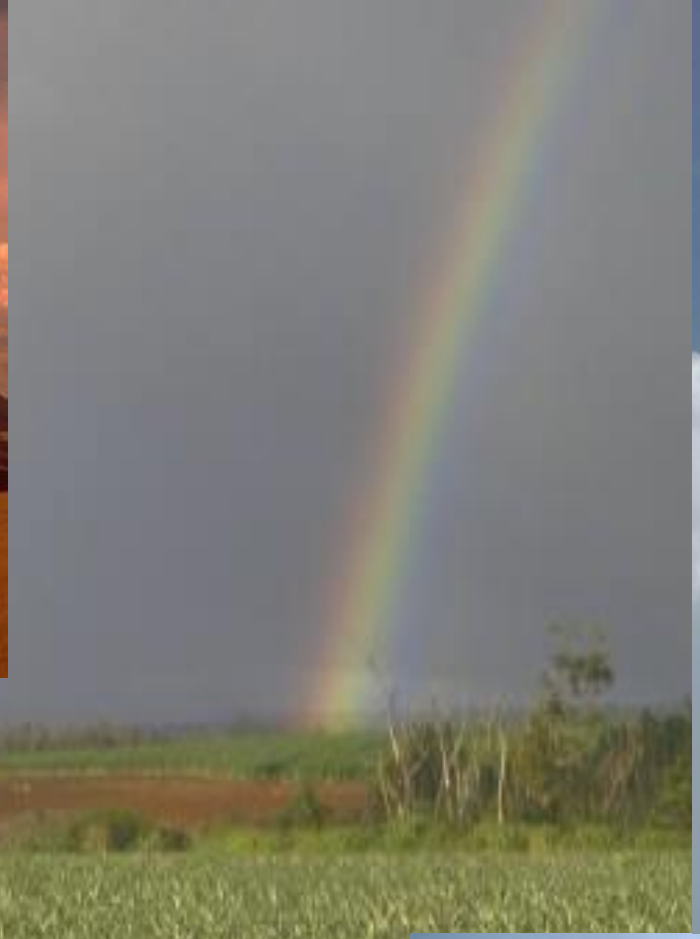
Rain Scattering



Scattering in Communications

Rain Scattering, SHF and EHF

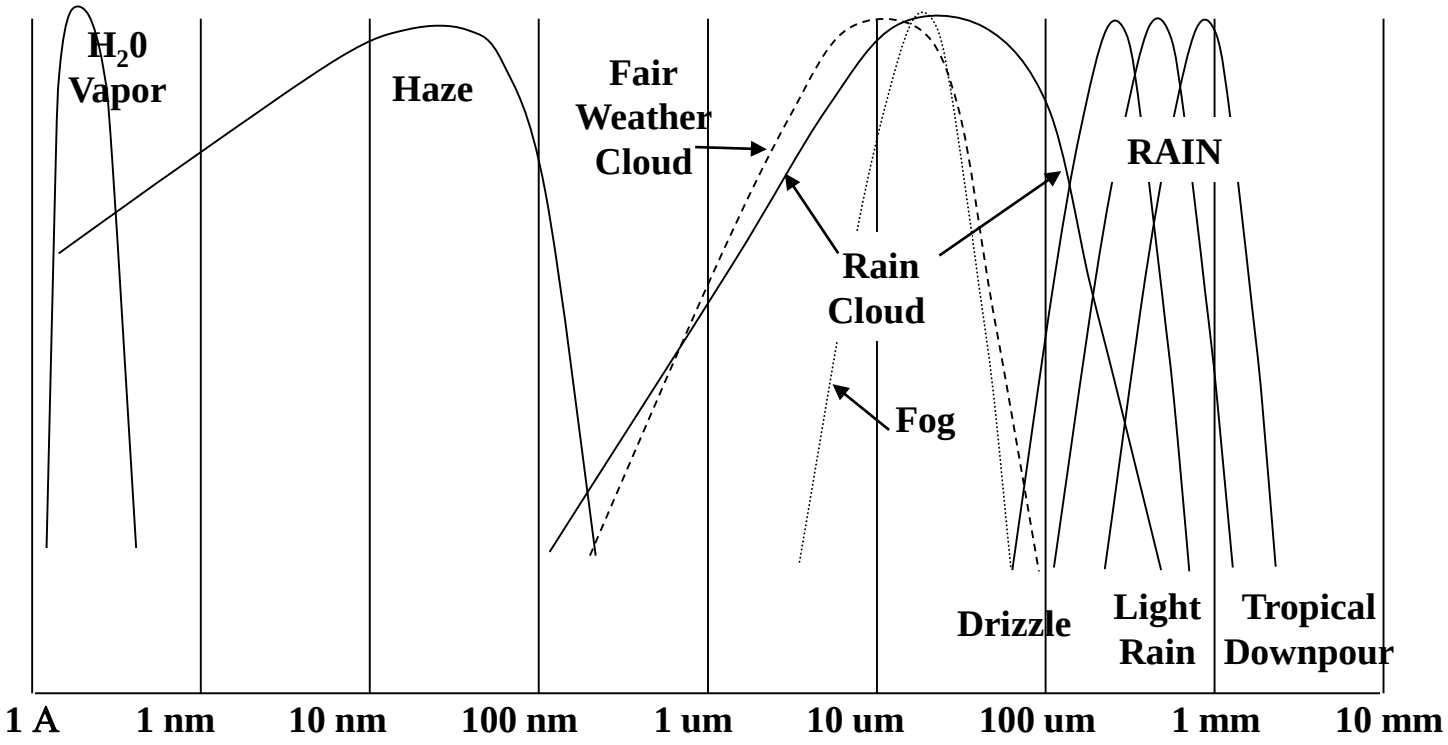
- What is Scattering?
- What is Rain?
- Scattering Dependencies
  - How does Scattering Work?
  - Particle Size & Wavelength
  - Angle
  - Polarization
- SHF and EHF

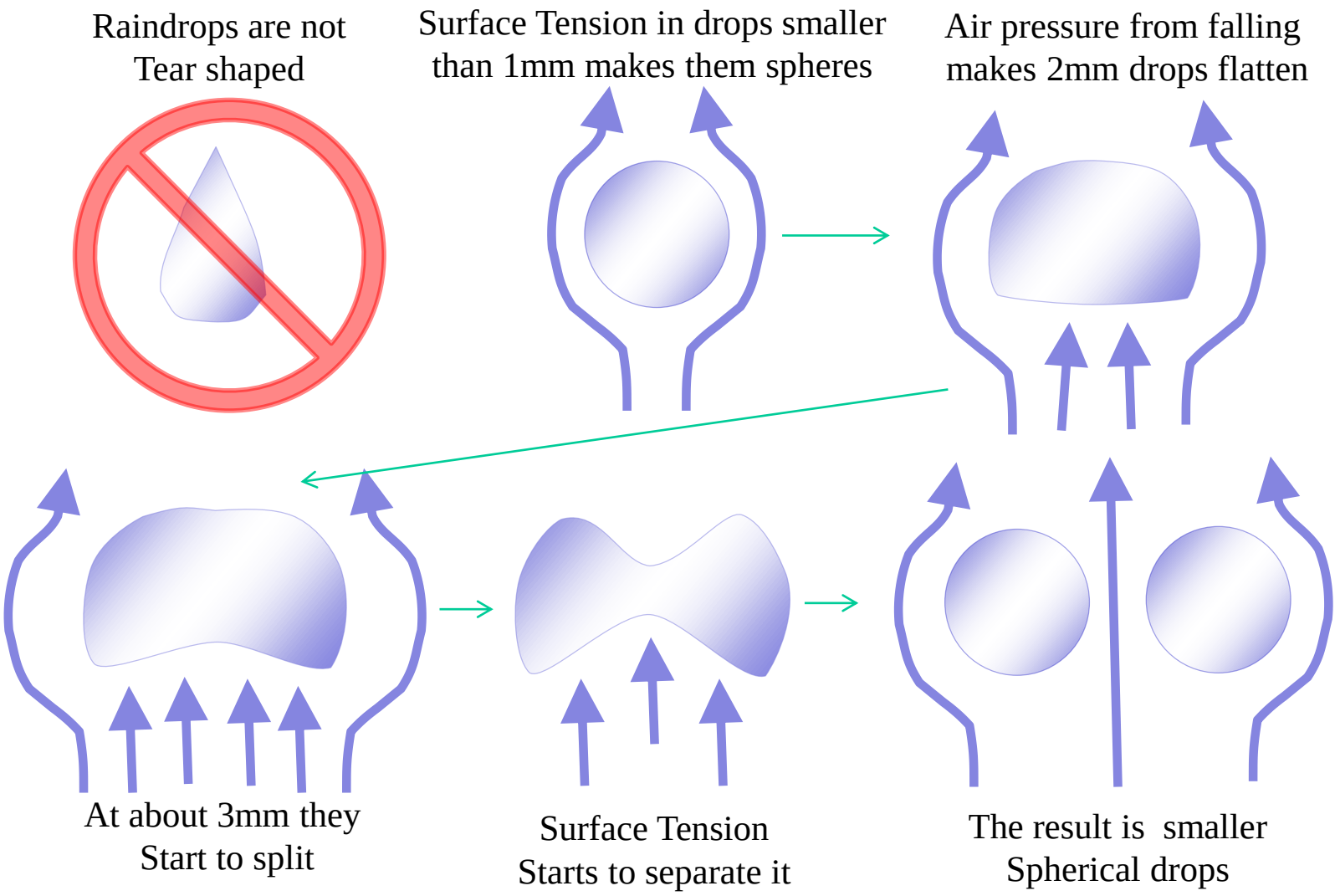


Warm Day in Arizona

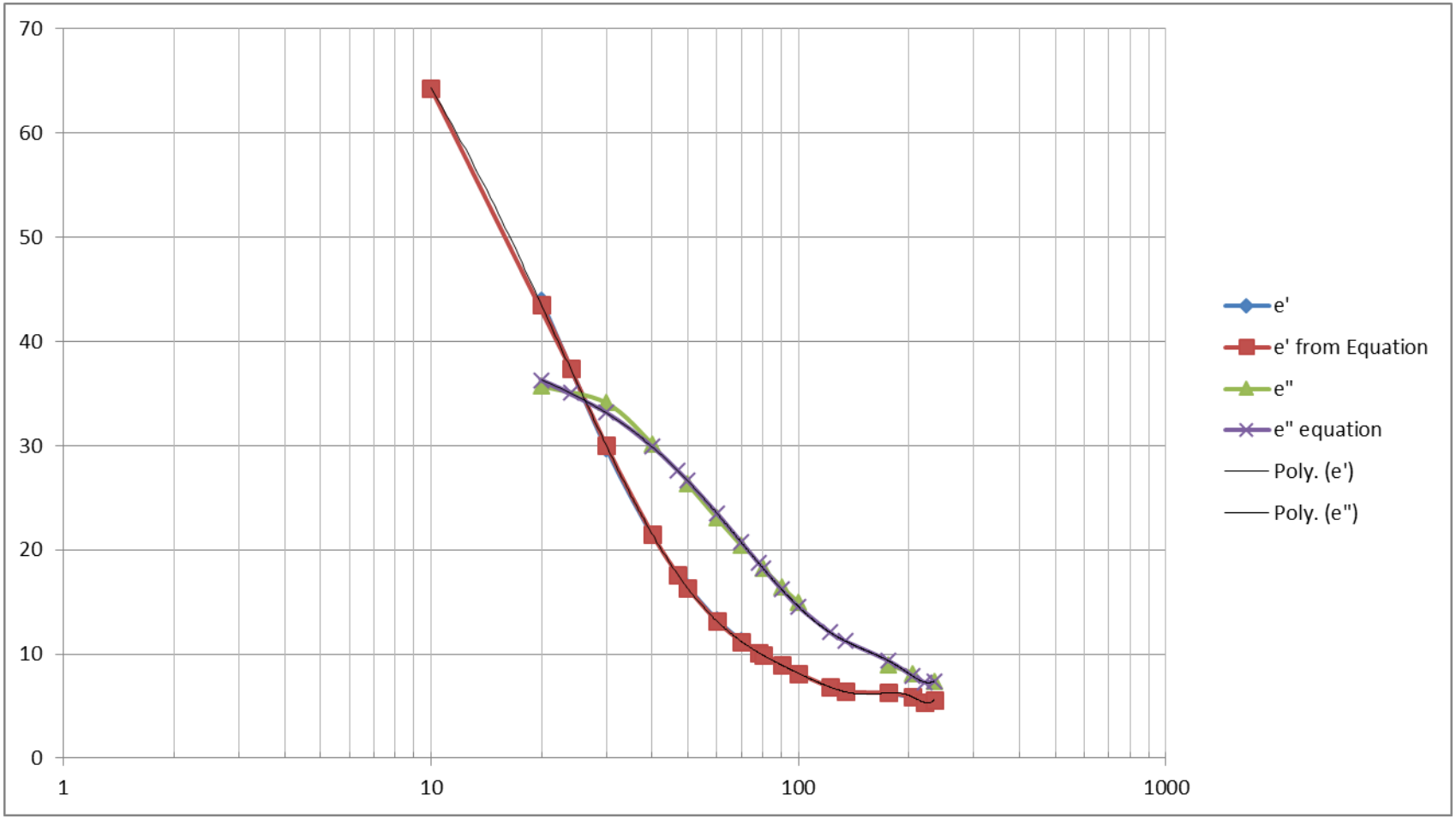
Water Particle Sizes



Raindrop Evolution



Refraction (complex) changes over microwaves (dispersion)



Rain Scattering, SHF and EHF

- What is Scattering?
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  - How does Scattering Work?
  - Particle Size & Wavelength
  - Angle
  - Polarization
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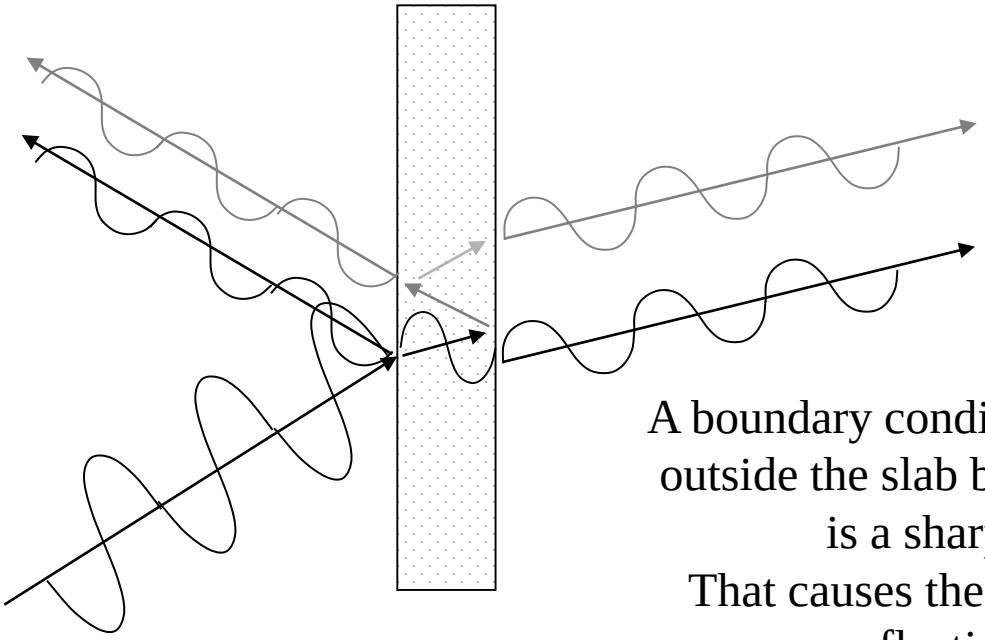
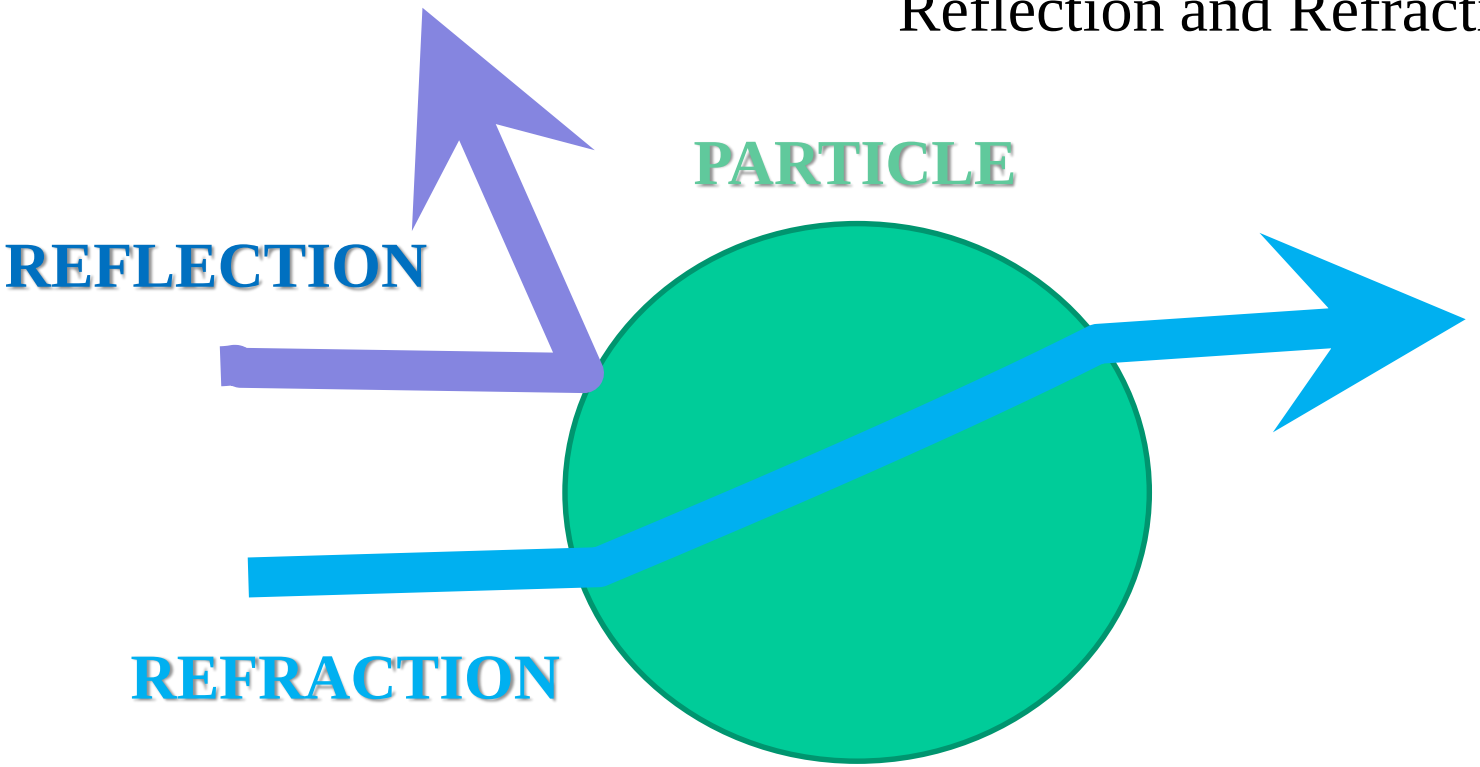
Scattering – How does it work? TEM Waves in a Slab



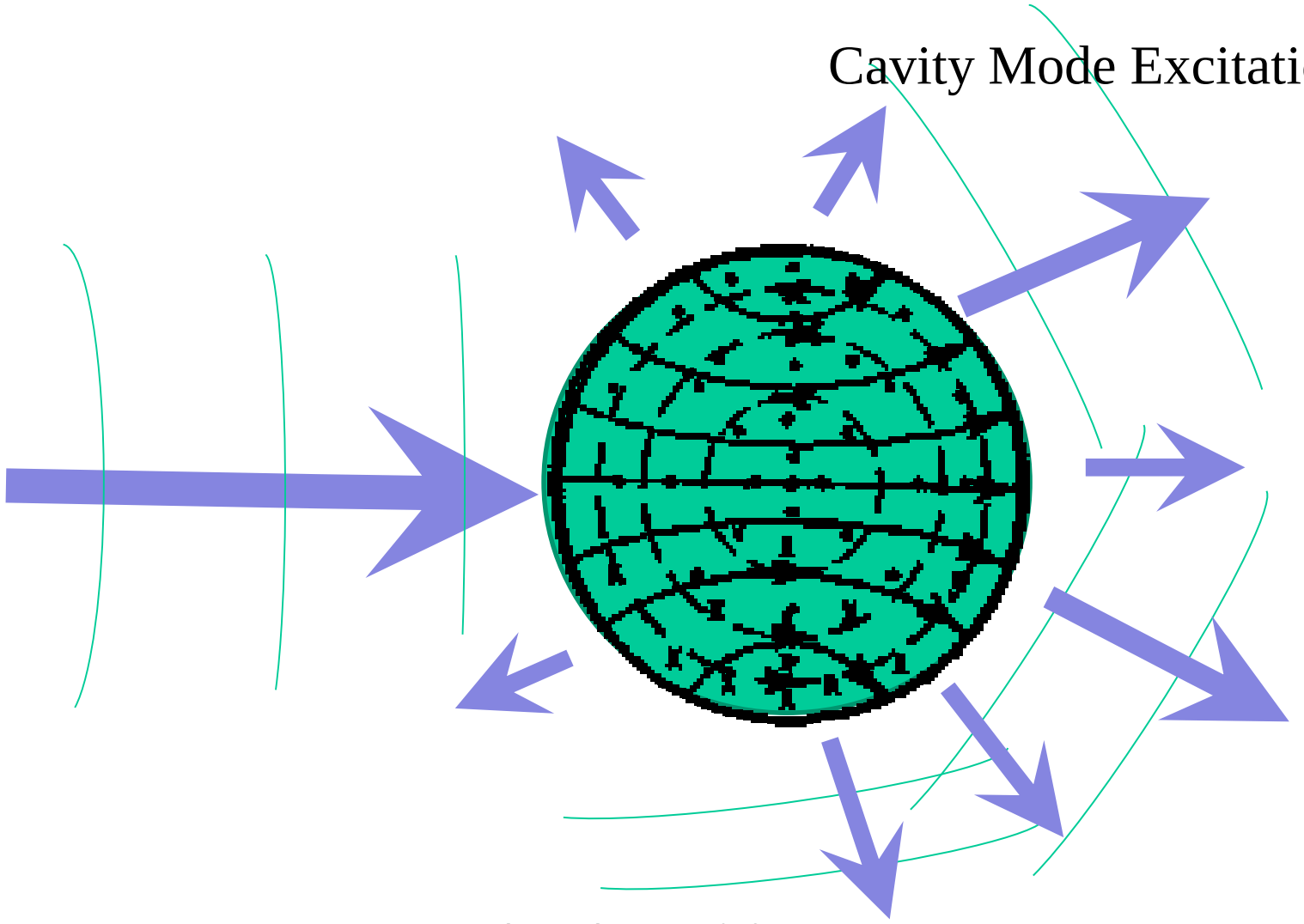
A boundary condition exists between inside and outside the slab because at that boundary there is a sharp impedance change.
That causes the TEM wave to split between reflection and transmission.
EM waves entering the slab will experience internal reflections and leak at the boundaries, all dependent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

Matter – EM interaction

Reflection and Refraction

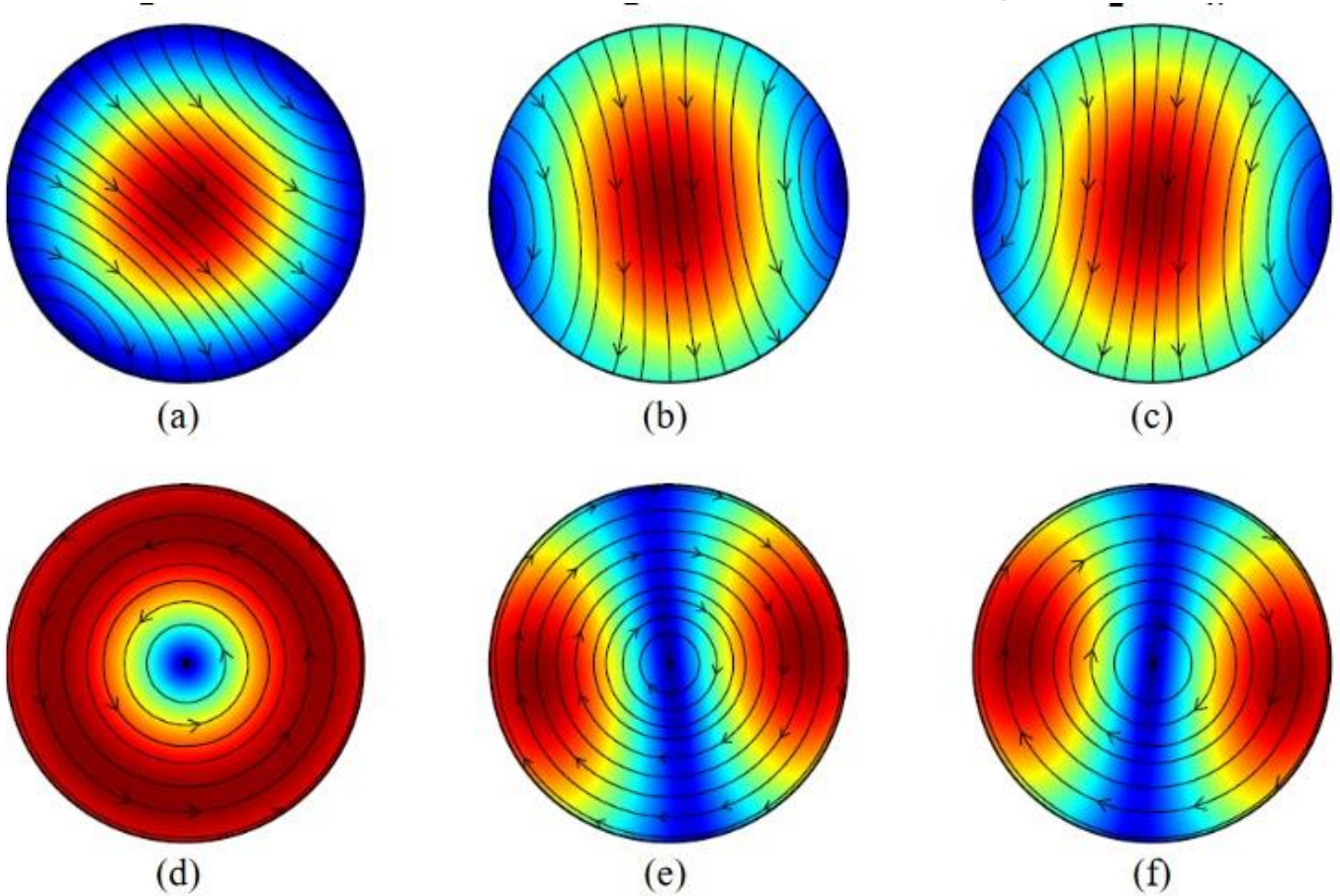


Matter – EM interaction

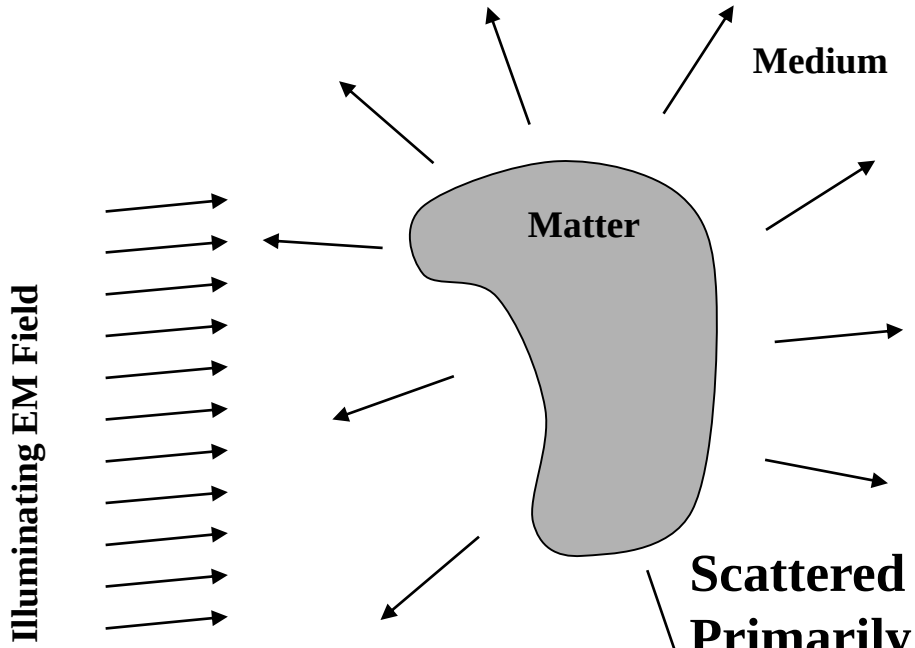


Matter – EM interaction

Cavity Mode Excitation



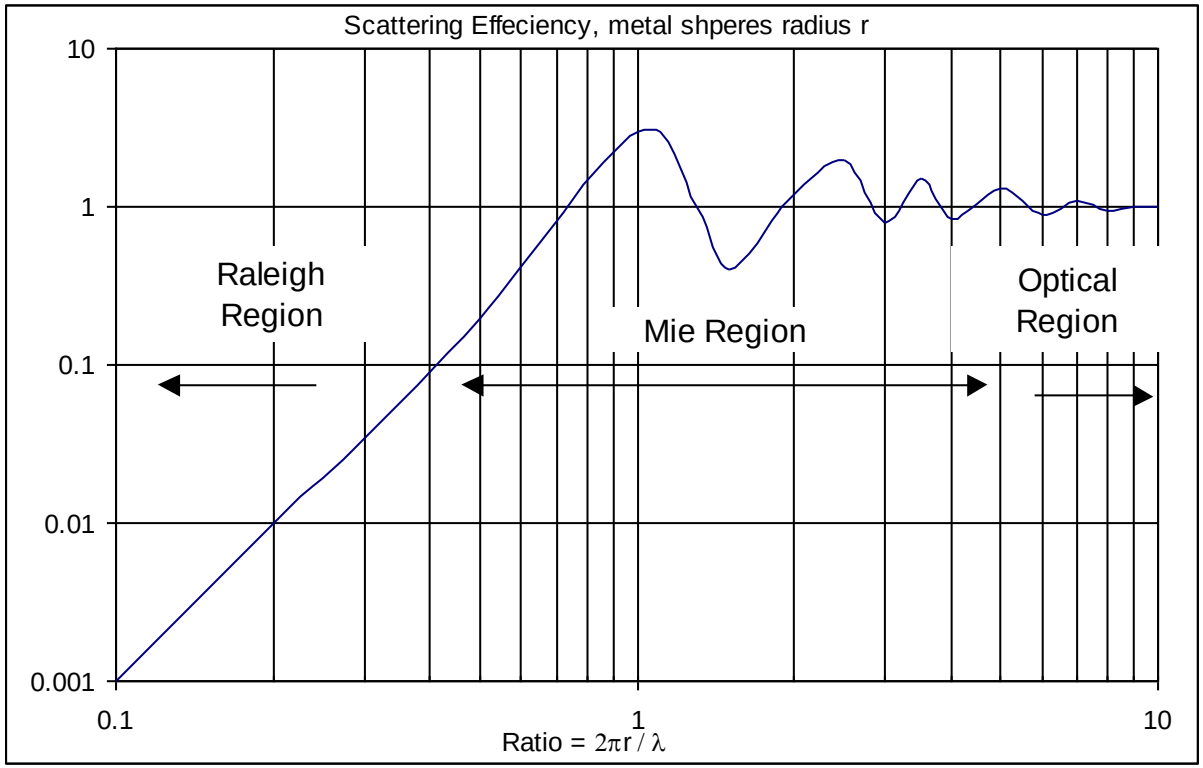
Scattering



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

Size/Wavelength Dependency

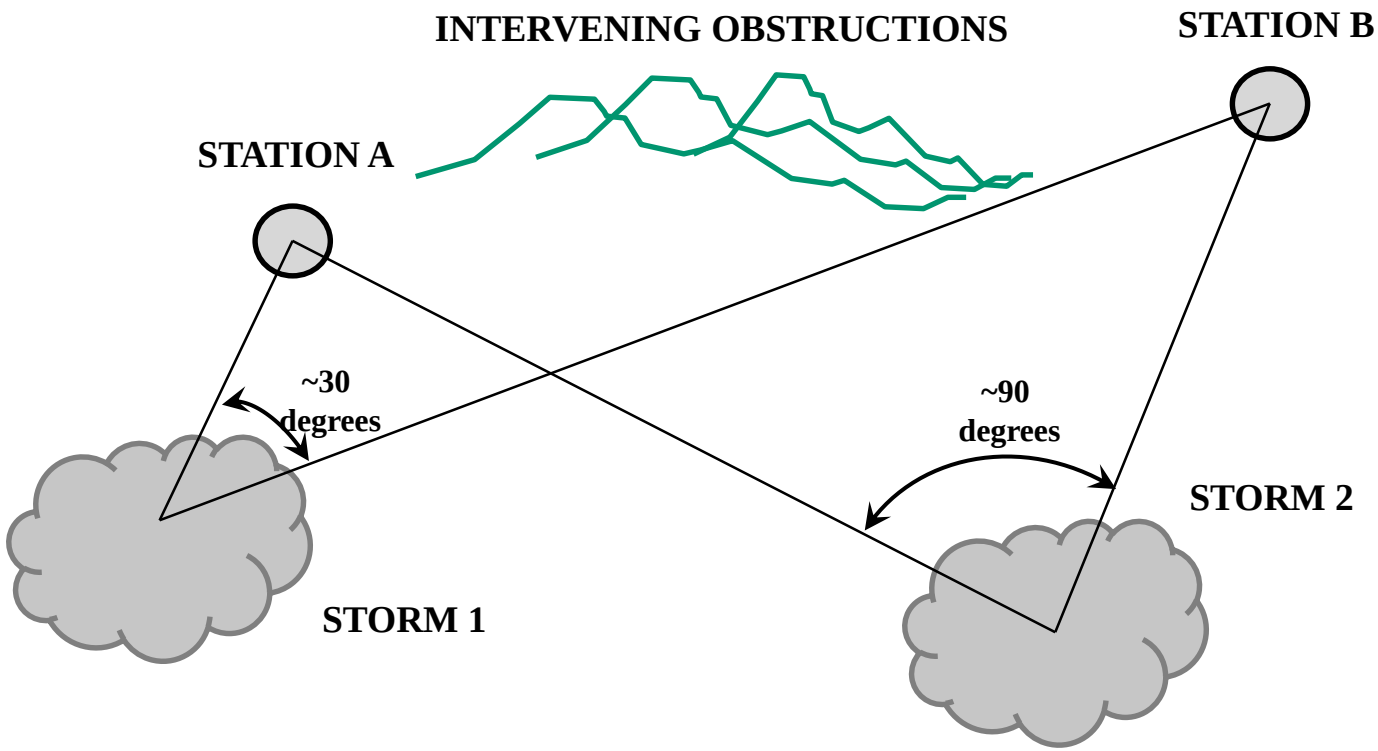
Three “regions” based on $\chi = 2\pi r/\lambda$



Effect of χ on Ham Radio Rain Scattering

- In Rayleigh Region scattering increases by f^4
- Assume χ 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



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

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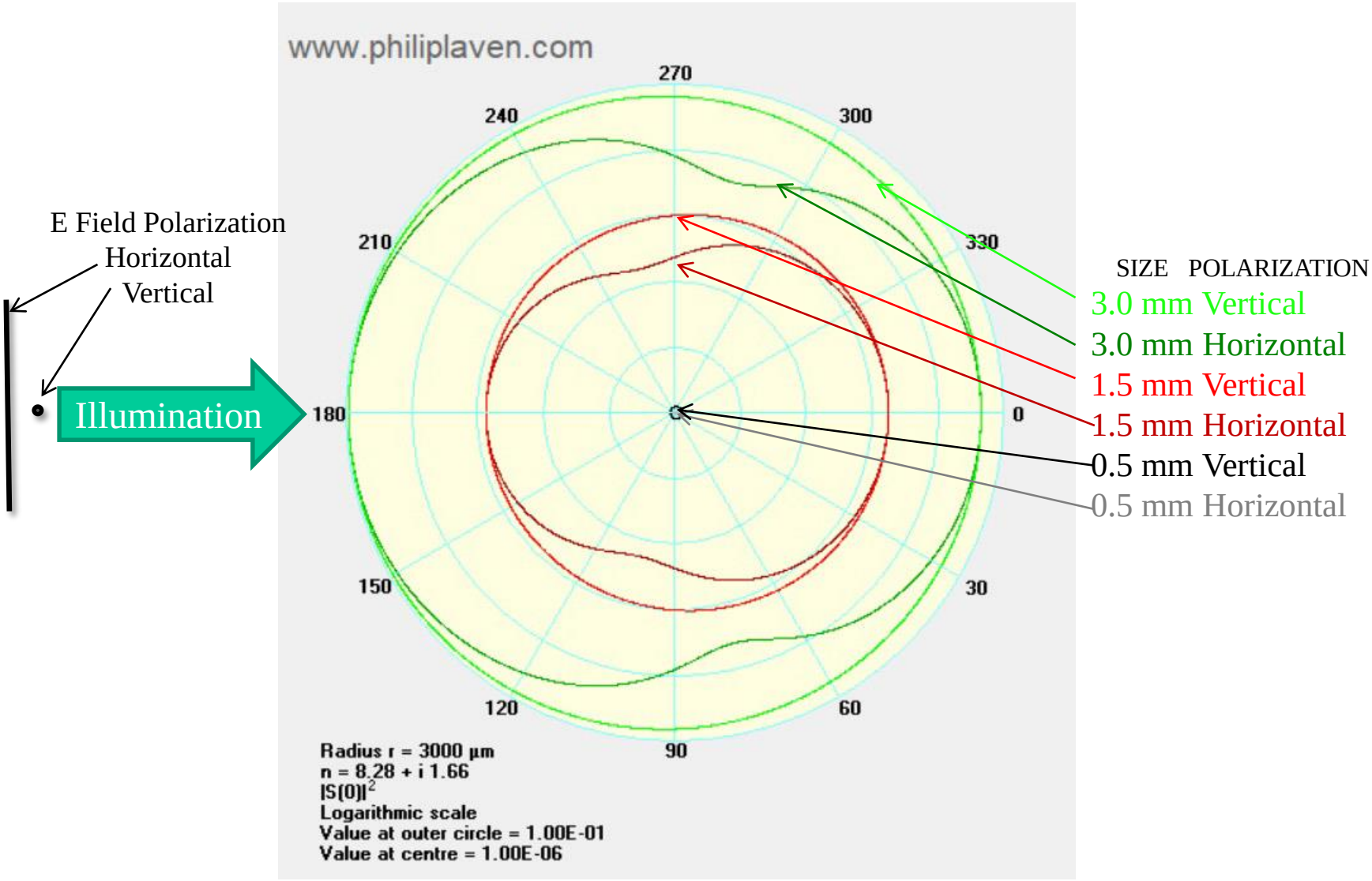
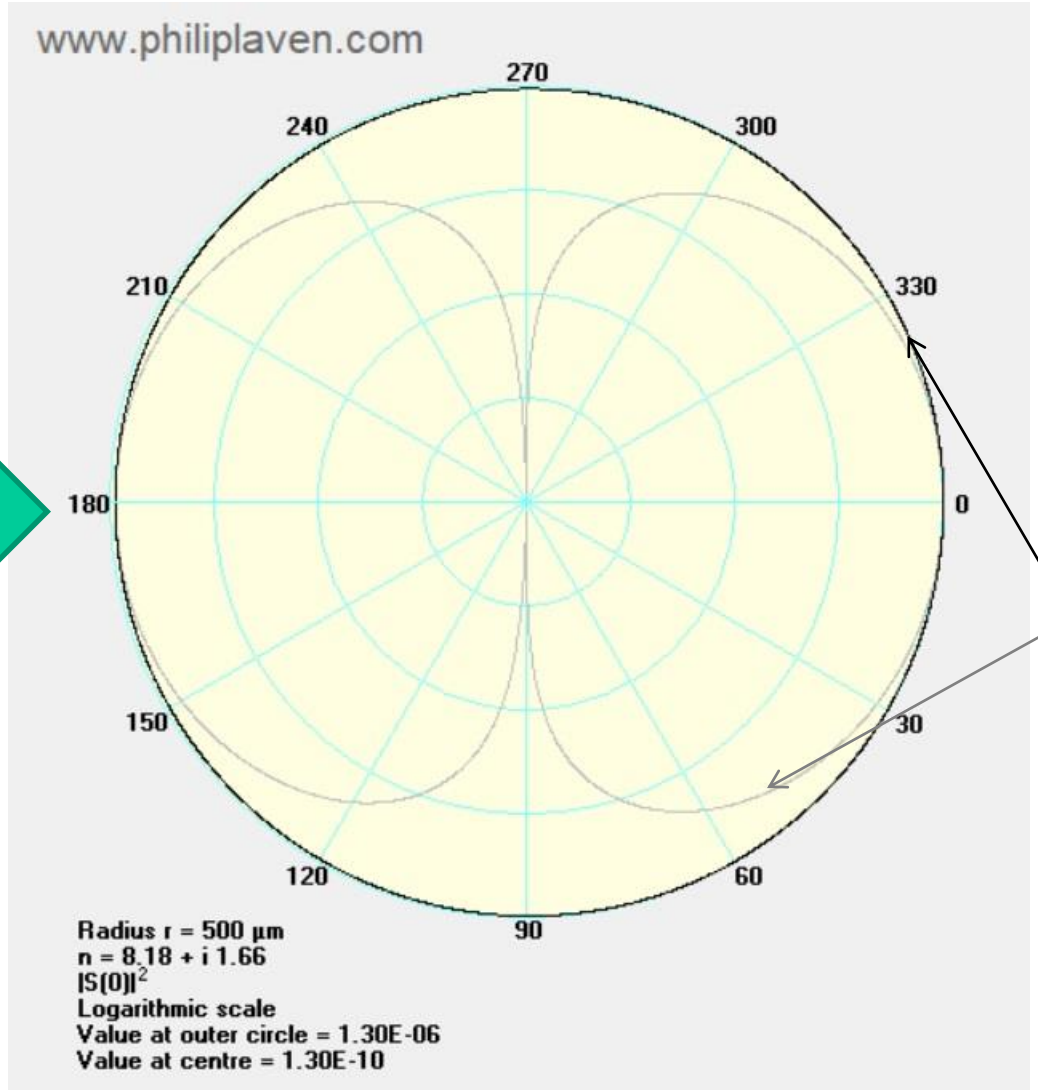
10 GHz Rain Scatter by Drop Size



10 GHz Rain Scatter 0.5 mm Close-up



Illumination

SIZE POLARIZATION

3.0 mm Vertical

3.0 mm Horizontal

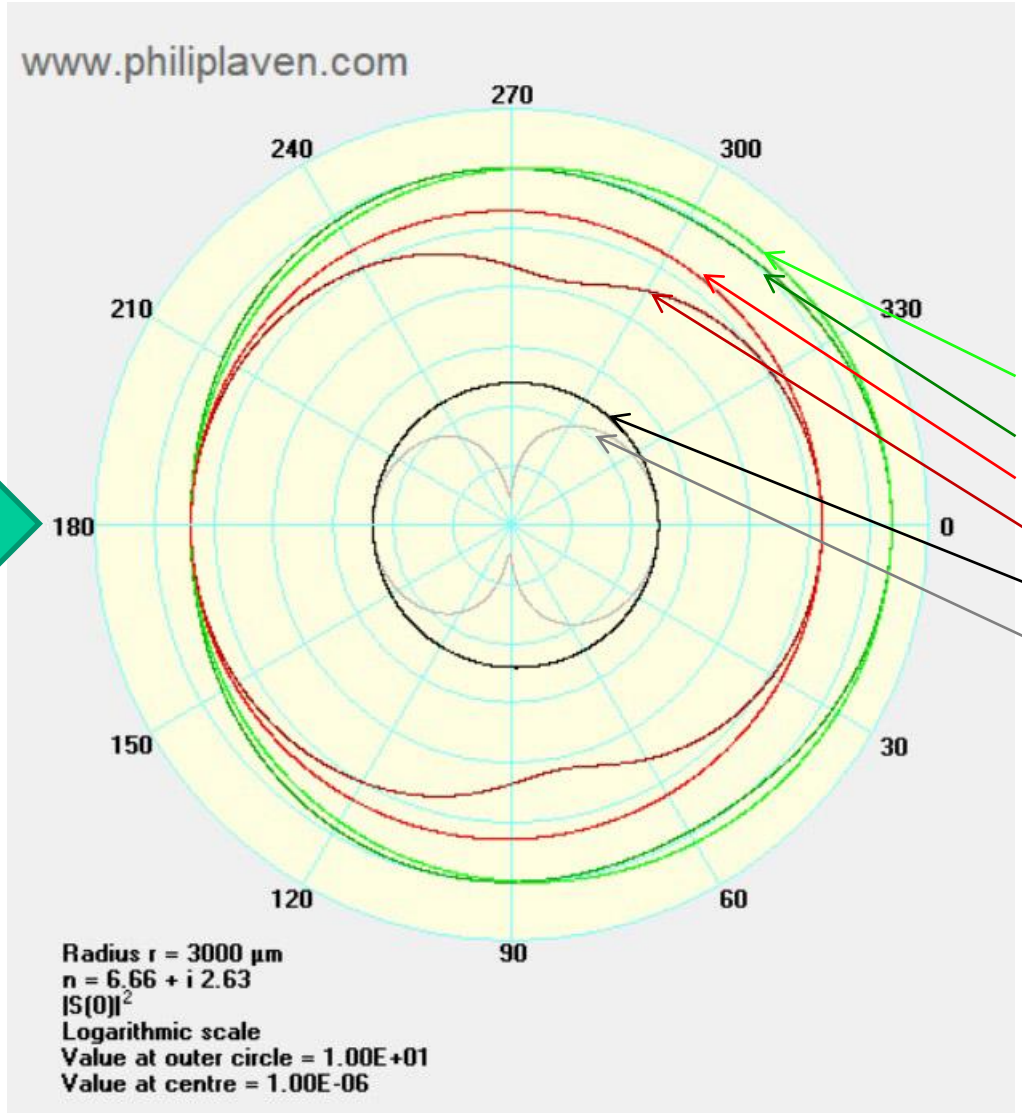
1.5 mm Vertical

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

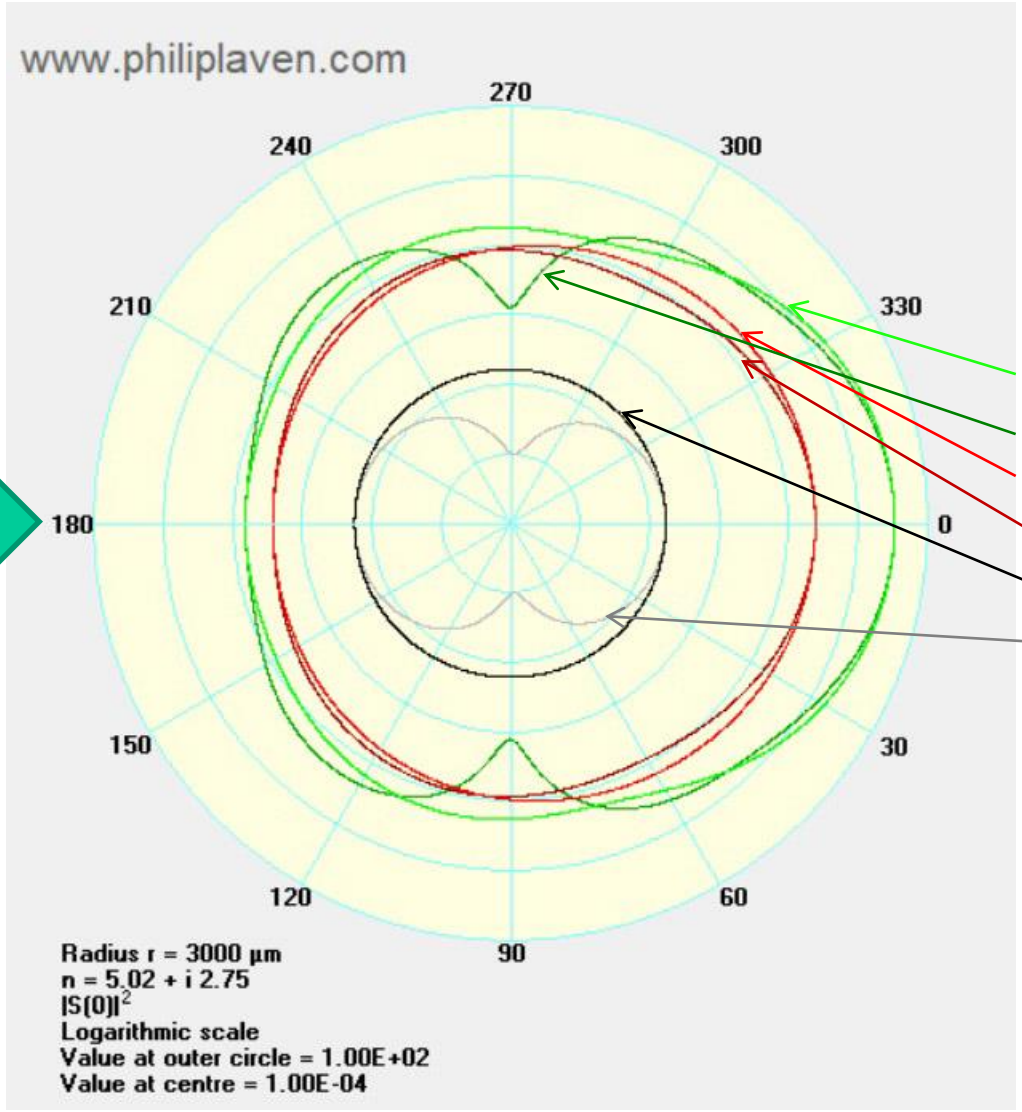
1.5 mm Vertical

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

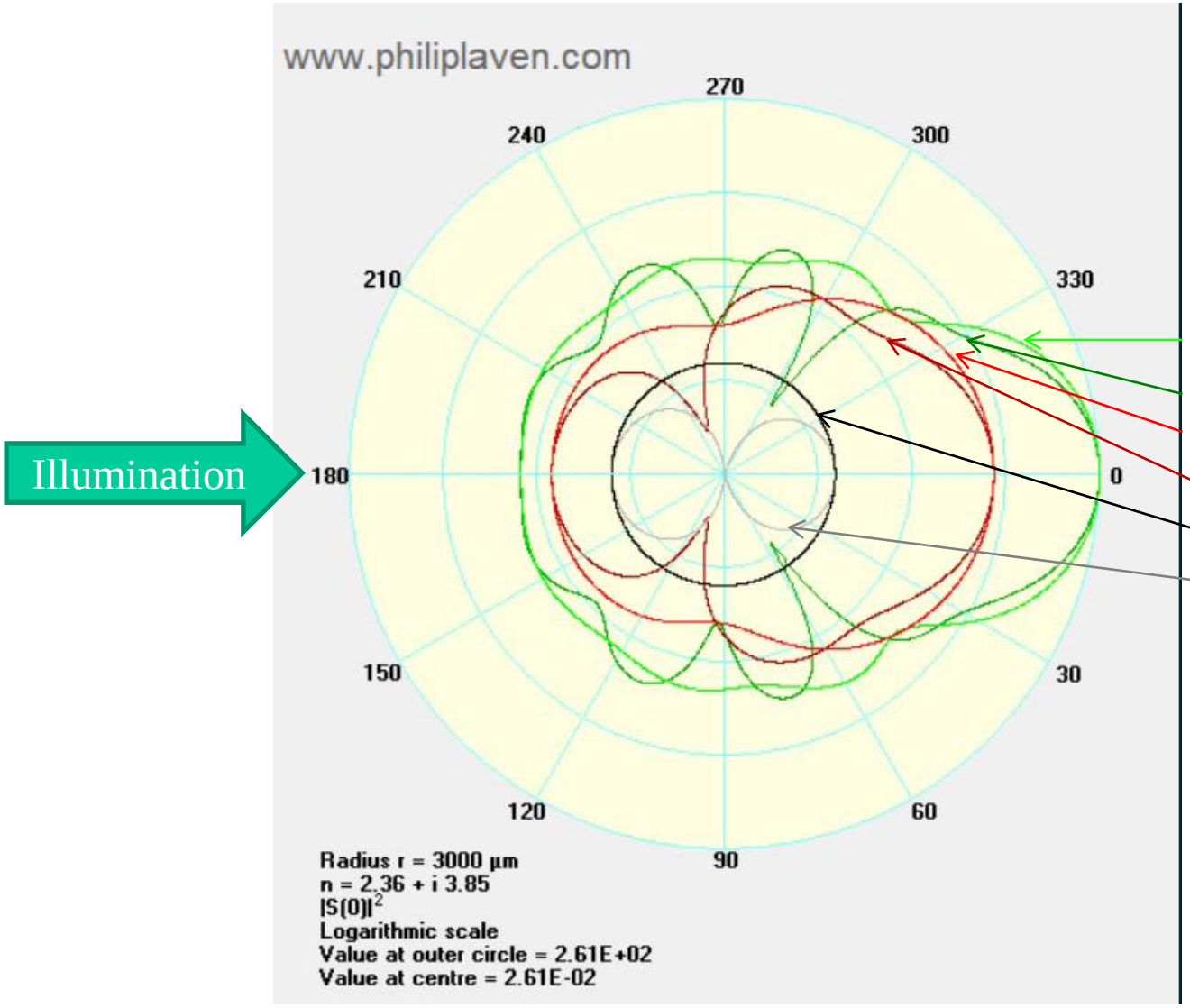
1.5 mm Vertical

1.5 mm Horizontal

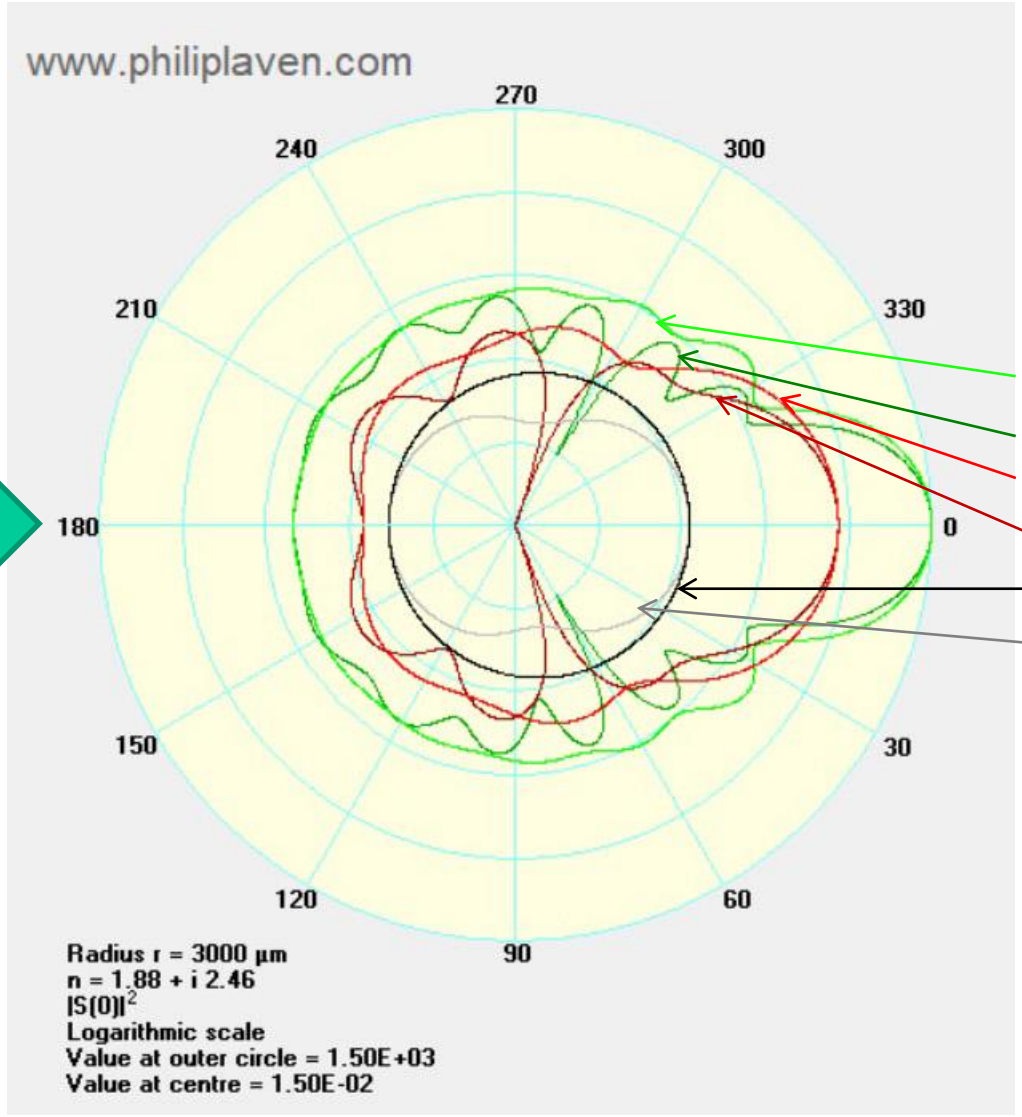
0.5 mm Vertical

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

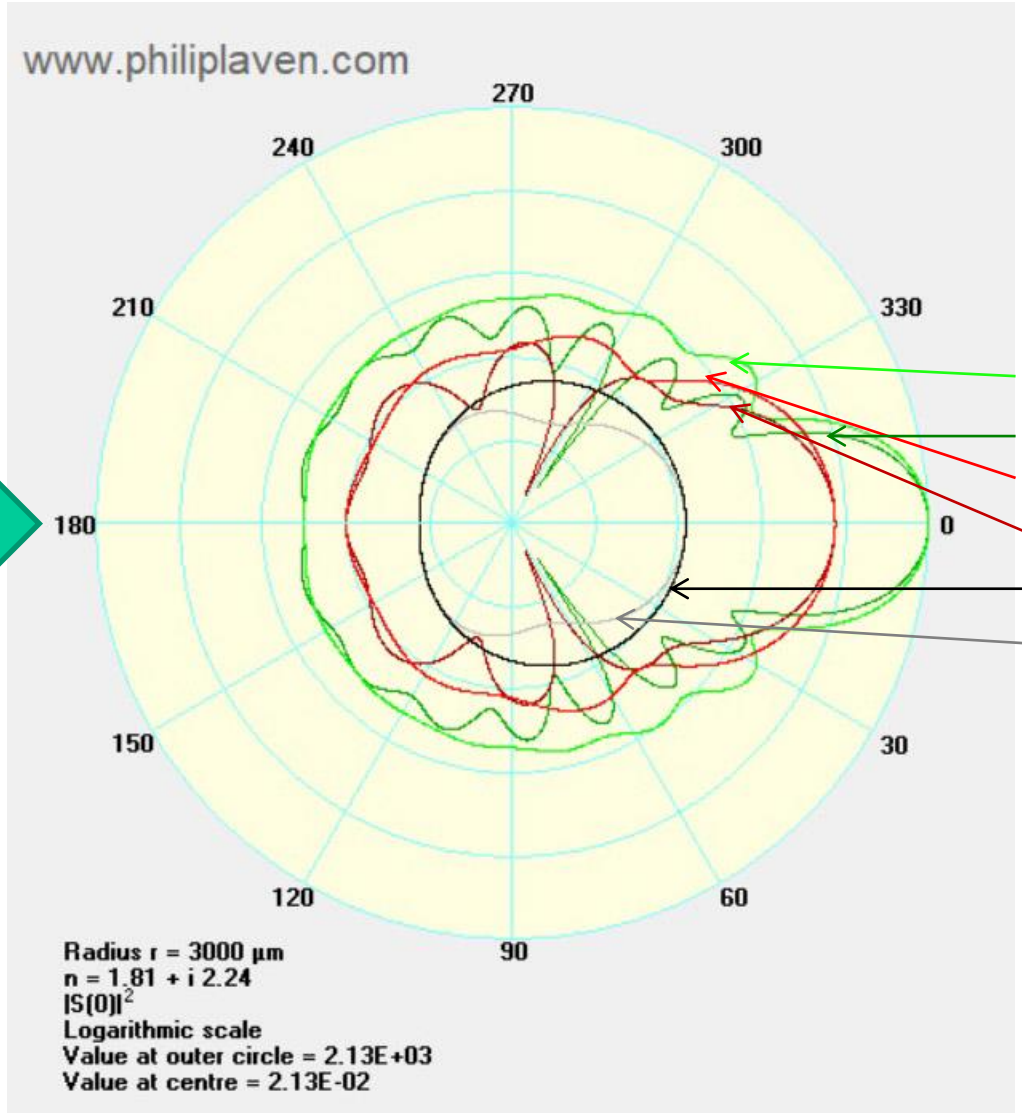
1.5 mm Vertical

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

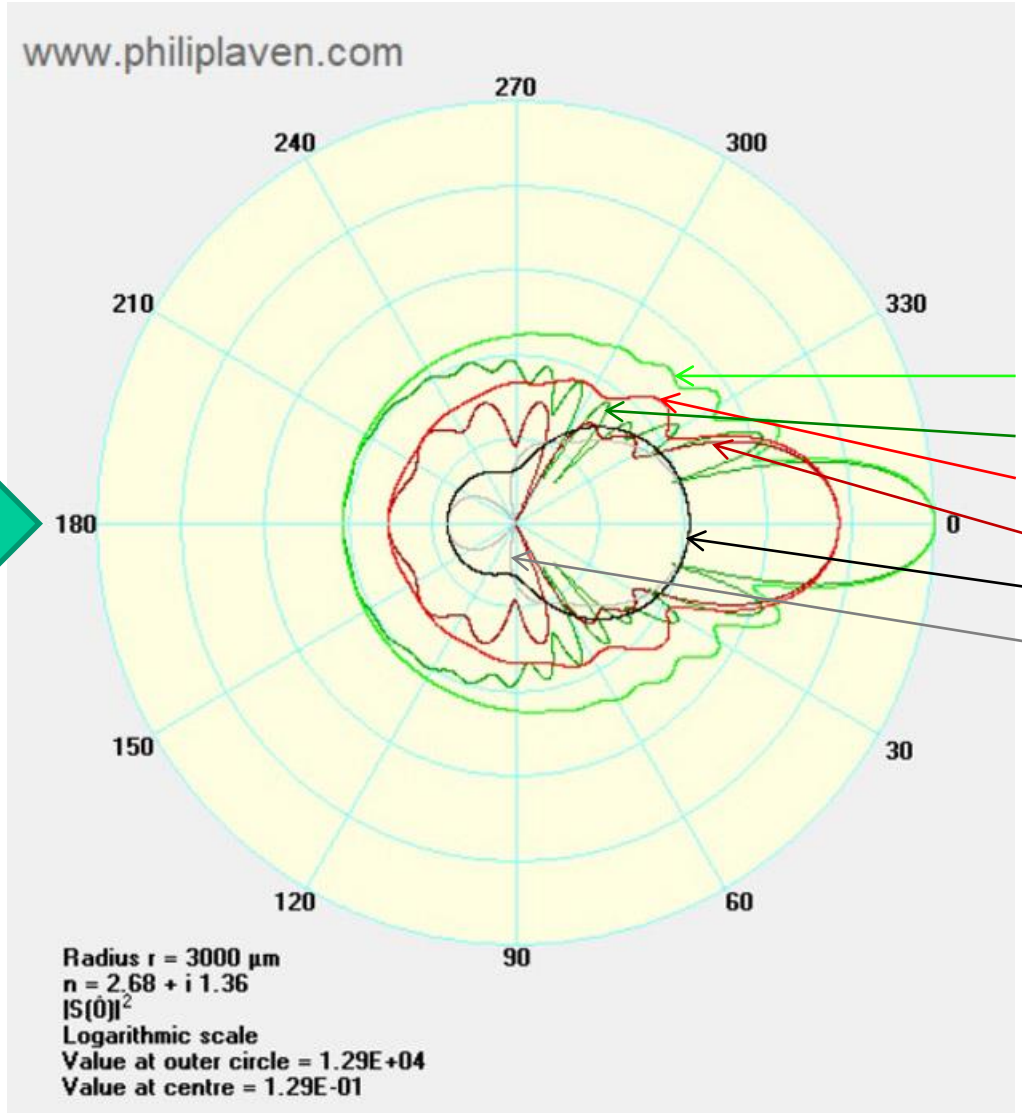
1.5 mm Vertical

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

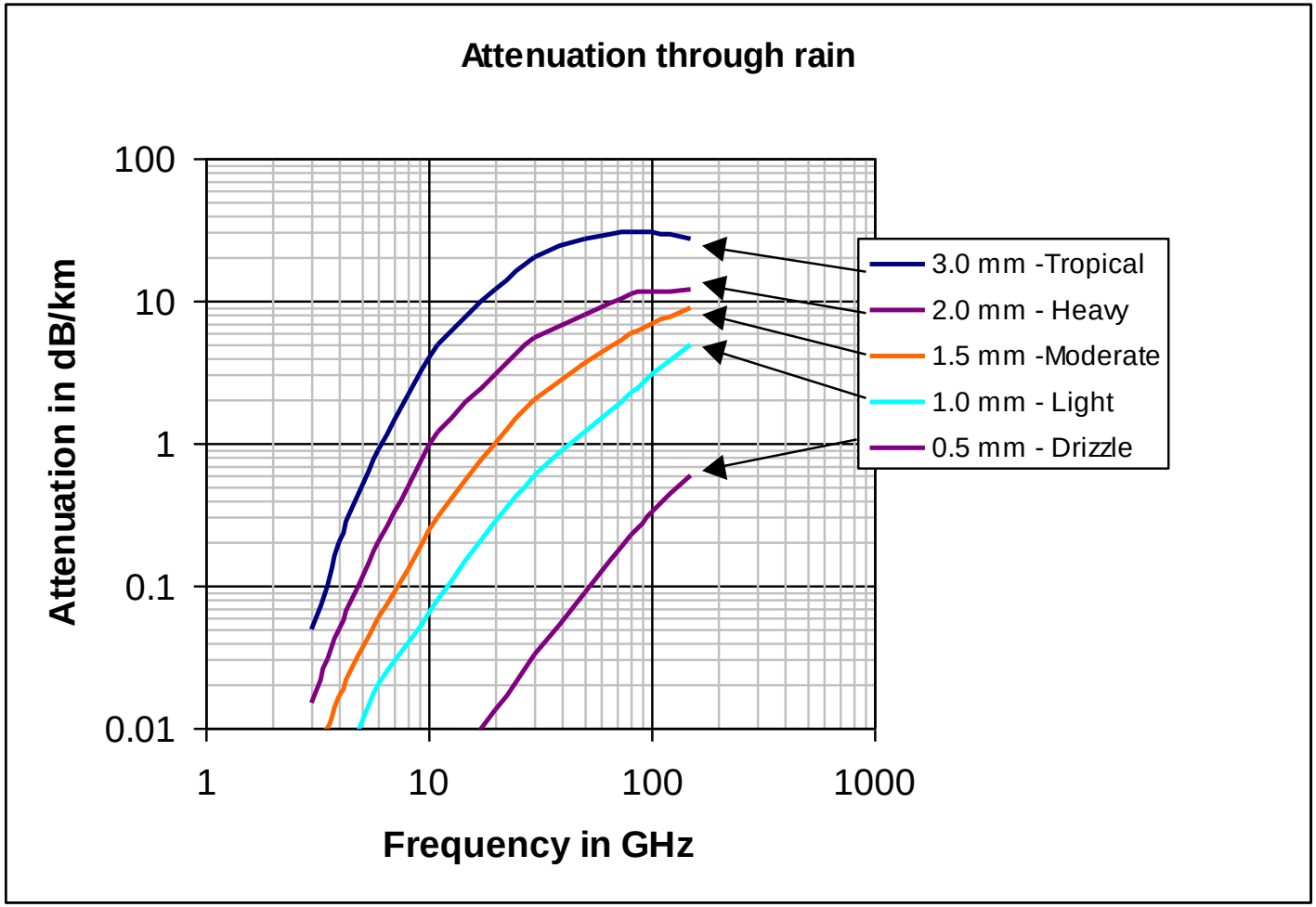
Extinction (attenuation)

- 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 Fahrenheit) 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:

Bohren, Craig F. and Donald R. Huffman, "Absorption and Scattering of Light by Small Particles", John Wiley & Sons, NY 1983

Mie, G., (1908). Beitrage zur Optik truber Median speziell kolloidaler Metallosungen, *Ann. Phys.,*25, 377-445

Liebe, H.J., (1983) "Atmospheric EHF Window Transparencies near 35, 90, 140, and 220 GHz," *IEEE Transactions on Antennas and Propagation,* AP-31, pp. 127-135..

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.

Williams, T., WA1MBA, "Narrow-Band 10 GHz and Some Observations From New England", New England VHF Conference, August 1995, ARRL Publications.


PRO TIP
If you stir coconut oil into your kale it makes it easier to scrape into the trash.