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Intro to Microwave Propagation for data

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North Texas Microwave Society

Categories of microwave paths

- Those who love propagation anomalies (Weak signal enthusiast)
- Those who don't
(data link operators)

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Power Levels

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For simplicity, links use dB and dBm to model performance

A relative change is measured in dB

dB=10 LOG (Relative intensity)

Specific levels measured in dBm

(dB referenced to a milliwatt)

With 802.11
-90 dBm weak
-50dBm strong

0dBm=1 mW
10dBm=10mW
20dBm=100mW
30dBm=1W
40dBm=10W
etc

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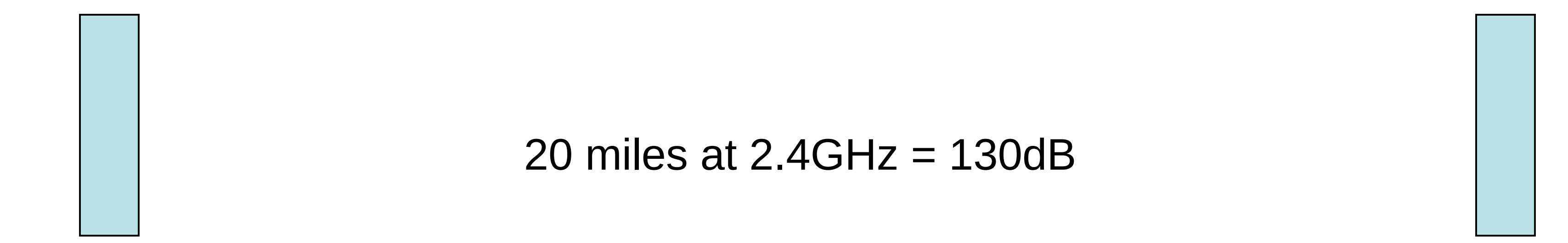
Free Space Path Loss

$$\text{Loss (dB)} = 36.6 + 20\text{LOG}(\text{Freq}_{\text{Mhz}}) + 20\text{LOG}(\text{Dist}_{\text{Miles}})$$

Great for calculating if there is nothing in the way (including air) but a worthwhile place to start.



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Propagation Anomalies

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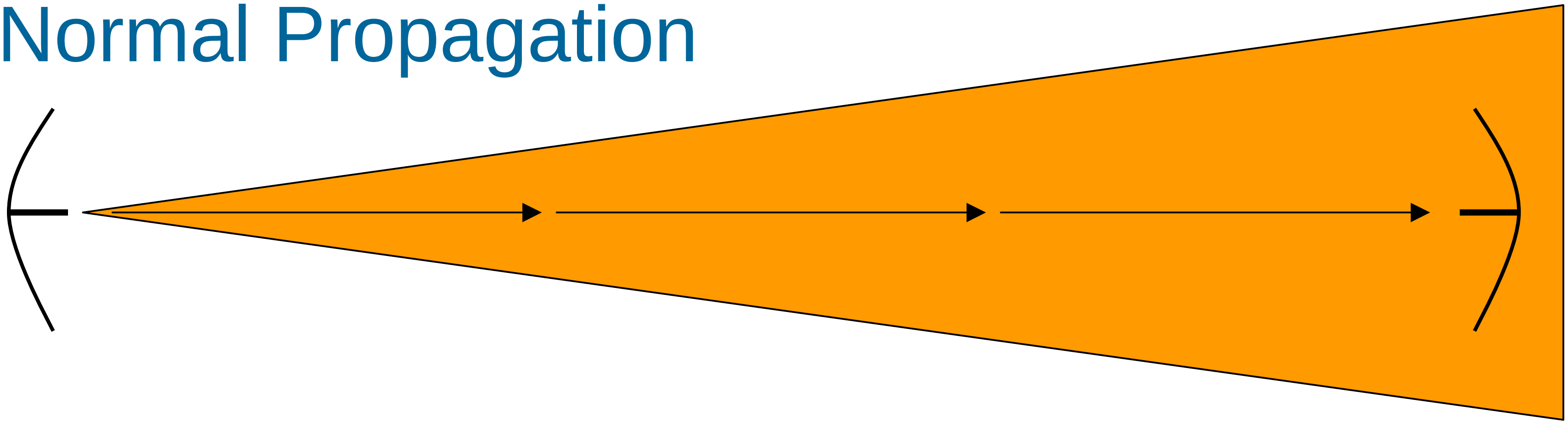
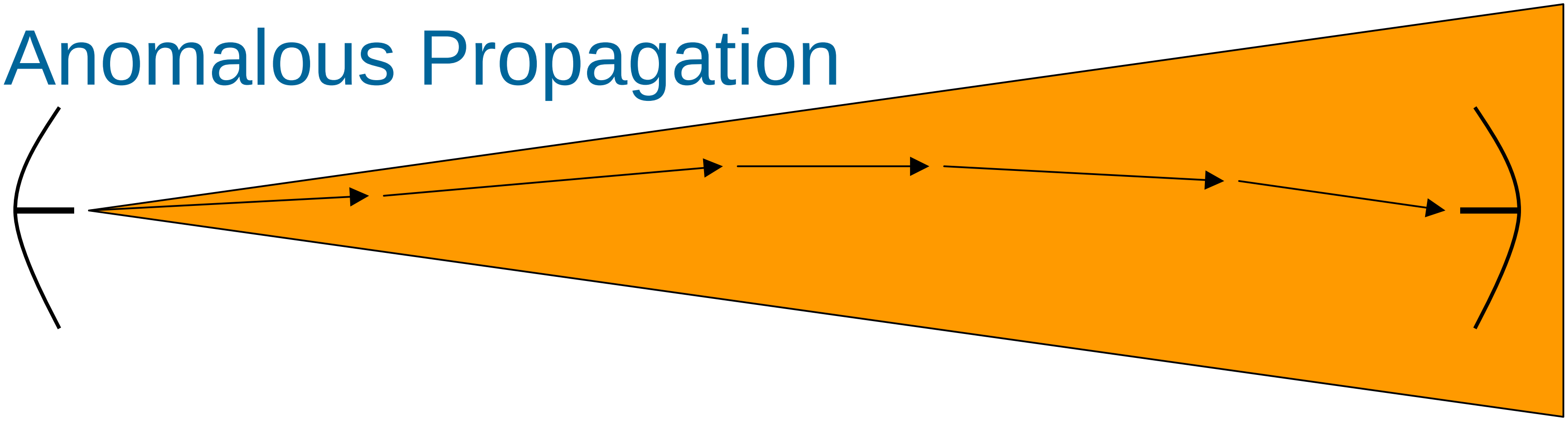
Normal Propagation

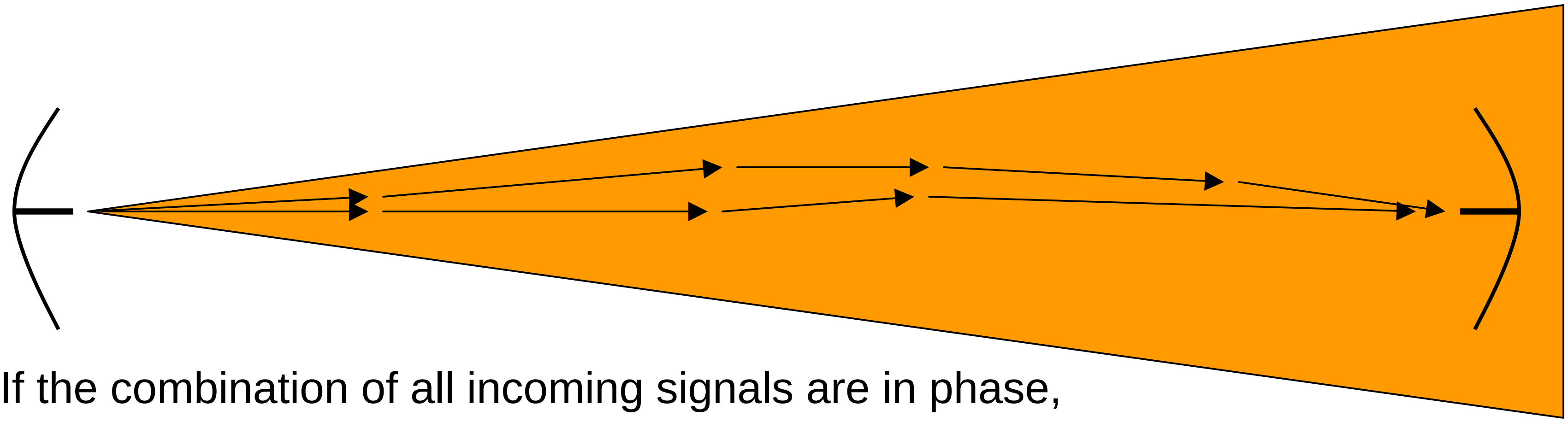


Anomalous Propagation



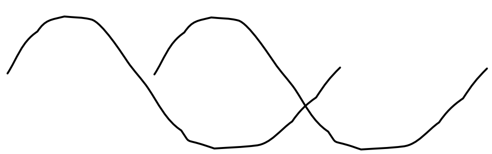
Atmospheric Multipath

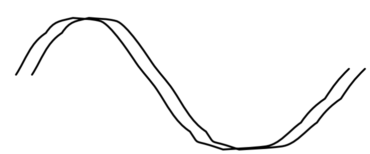
- Multipath causes fading



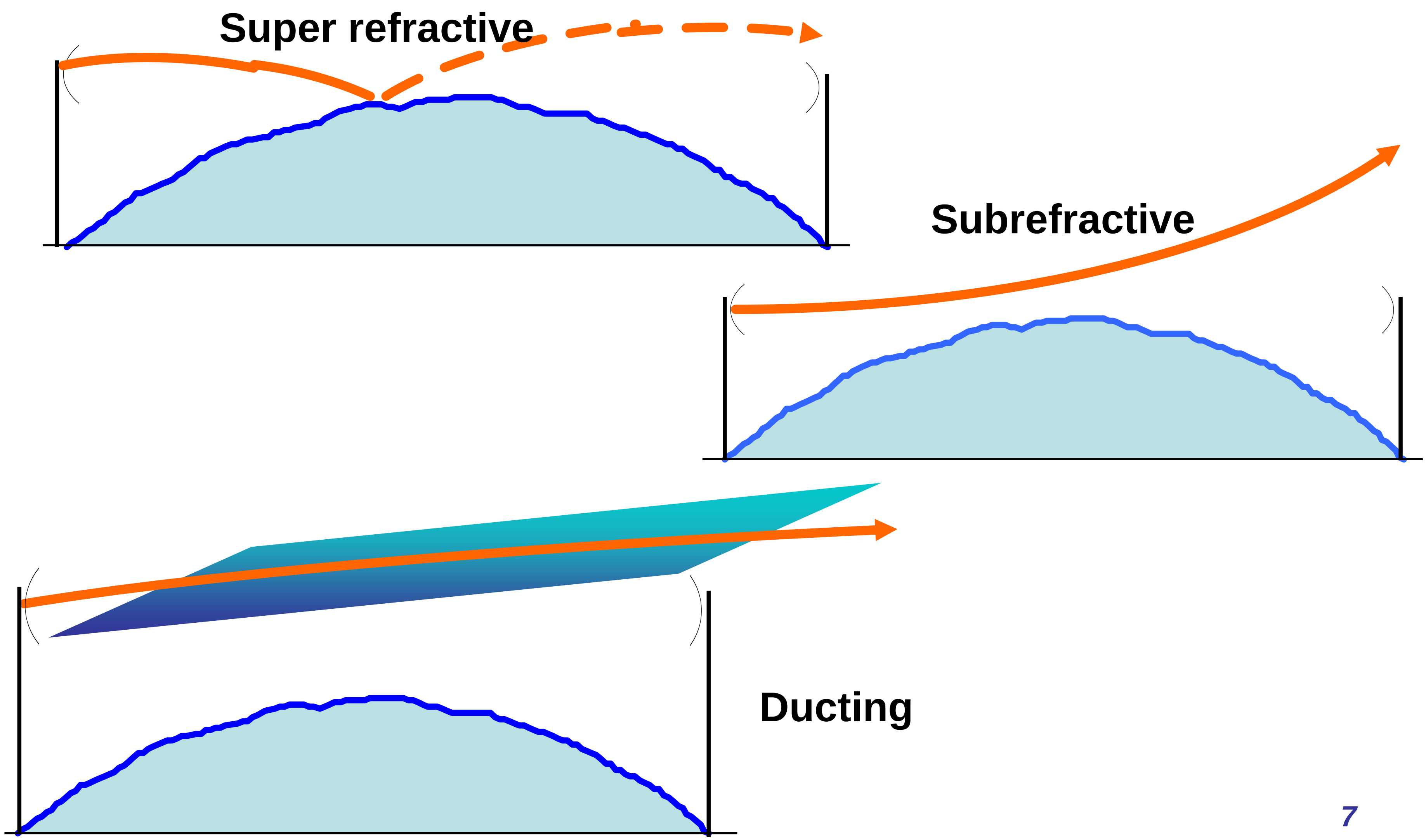
If the combination of all incoming signals are in phase, enhancement occurs..if out of phase (e.g. near –180 degrees), attenuation occurs.

The shorter the wavelength, the more pronounced this may become





Propagation Anomalies



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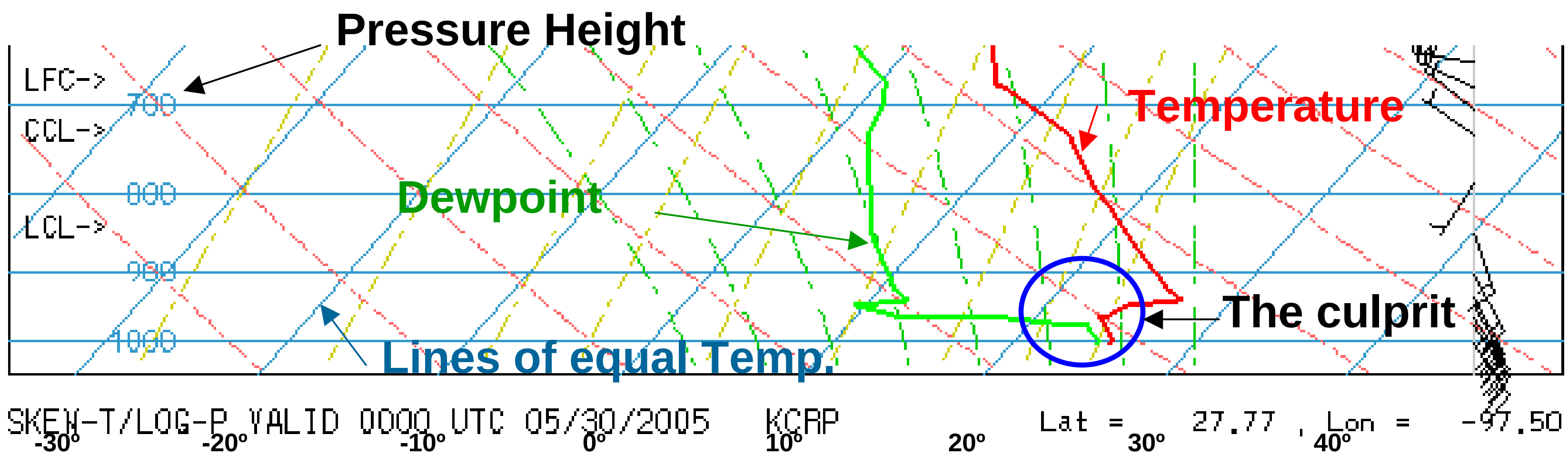
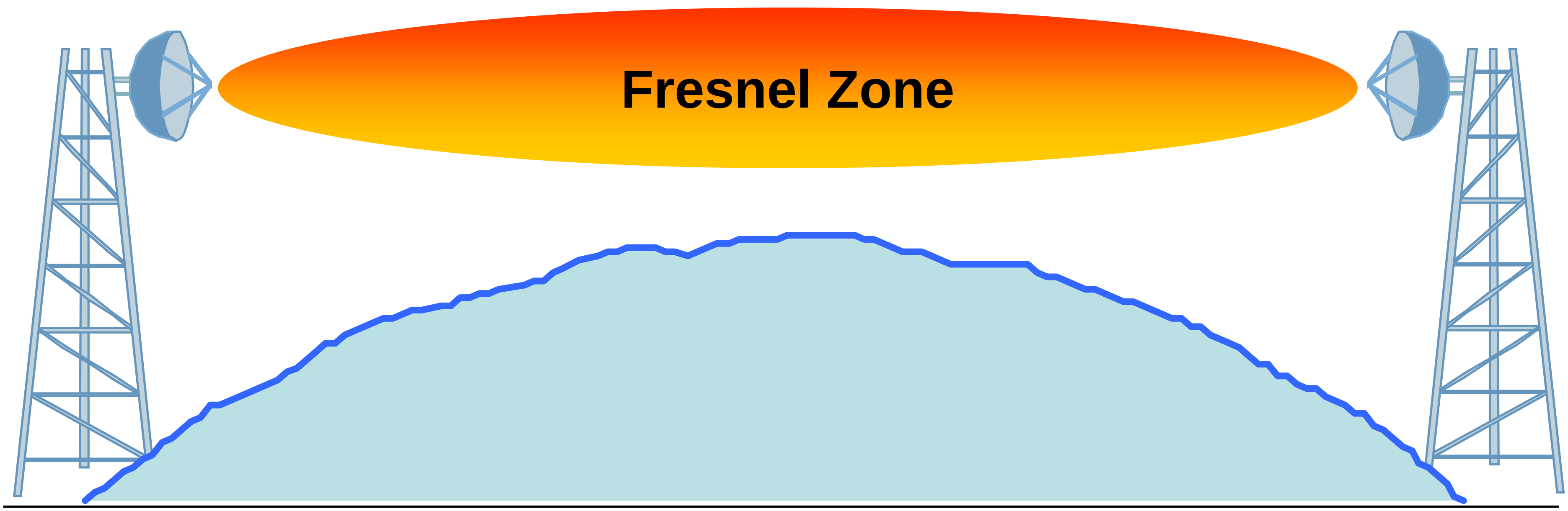
What causes the LOS multipath?

- Temperature, moisture and pressure



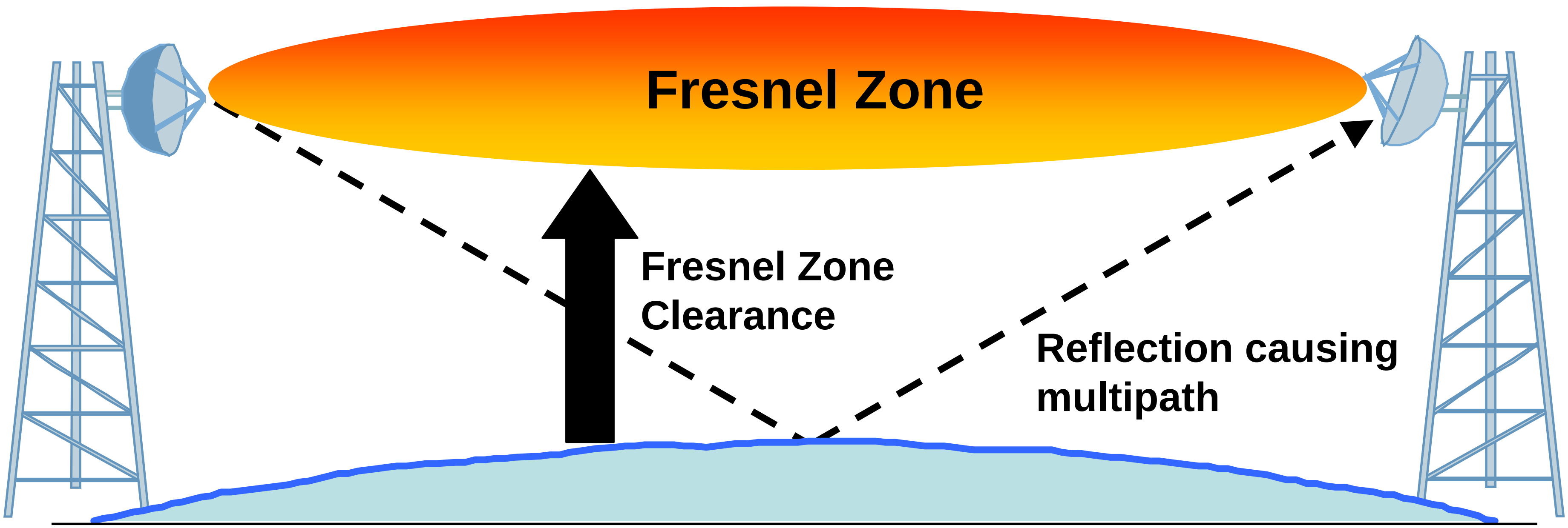
Weather service soundings indicate the "current" state of what's going on above

Normal Propagation



K Factor = Curvature of the Earth

Ground Reflections / Refractions / Multi-Path



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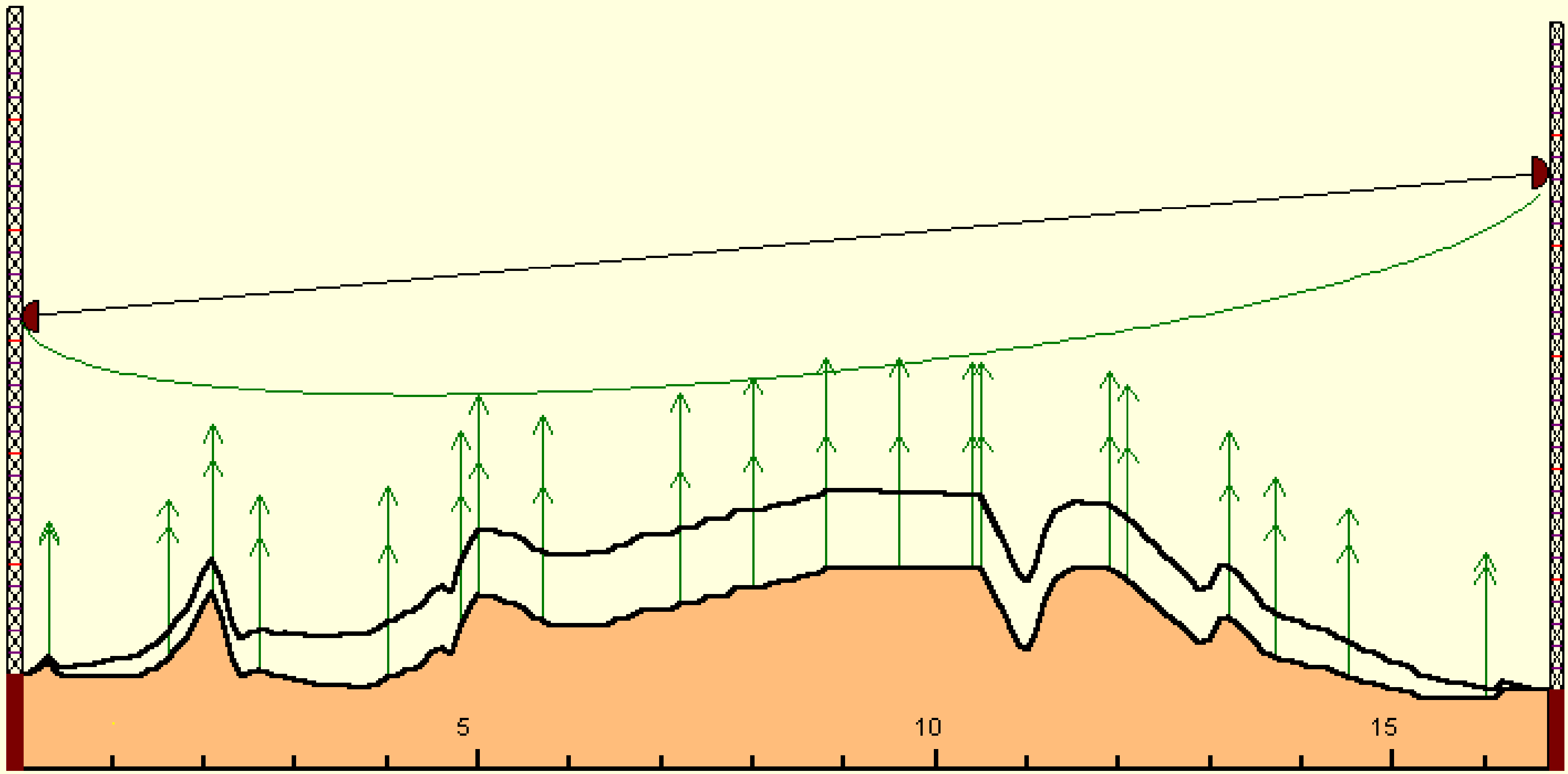
Path Clearance



Site: Dallas
Lat: 33 33 33 N
Lon: 88 33 33 W
Grnd Elev: 201 ft AMSL
Tower Hght: 300 ft AGL
Azimuth: 320.14 deg
Main Ant Hght: 161 ft

Frequency: 6.175 GHz
Distance: 16.7 miles
Propagation Region: Average
Path Roughness: 20 ft
K Values: Inf 1.33 1.33

Site: Plano
Lat: 33 44 44 N
Lon: 88 44 44 W
Grnd Elev: 194 ft AMSL
Tower Hght: 300 ft AGL
Azimuth: 140.04 deg
Main Ant Hght: 233 ft

Fresnel Zones

- Caused by diffraction by objects in path
- Even zones attenuate, odd enhance
- Fresnel zone radius calculation

$$R_{(feet)} = 72.1\sqrt{\frac{d_1 d_2}{F_{GHz}(d_1 + d_2)}}$$

d1=distance to transmitter in miles
d2=distance to receiver in miles
F_{GHz}=Frequency in Gigahertz

- Conventional practice is to ensure about a 0.6 Fresnel zone clearance along path which provides best compromise to avoid deep nulls. Don't put antenna up too high!

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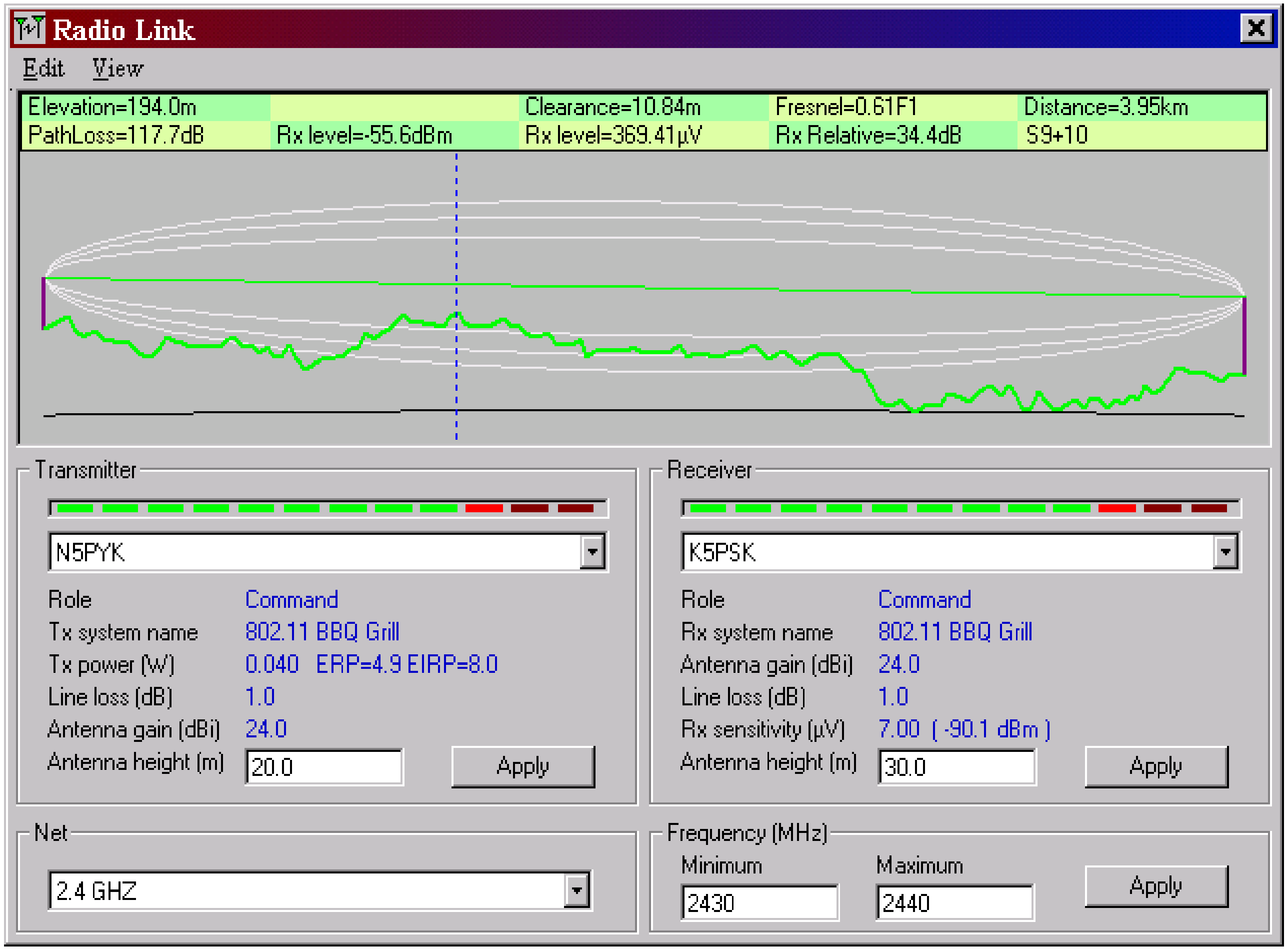
Fresnel Clearance



1.0, 1.5, and 1.75 Fresnel zones depicted on Radiomobile tool. No surface features are automatically assumed in Radiomobile, but they can be modeled. See the Yahoo Group entitled Radio_Mobile_Deluxe and check out file *profile.zip*

Antennas can be too high for reliable microwave paths

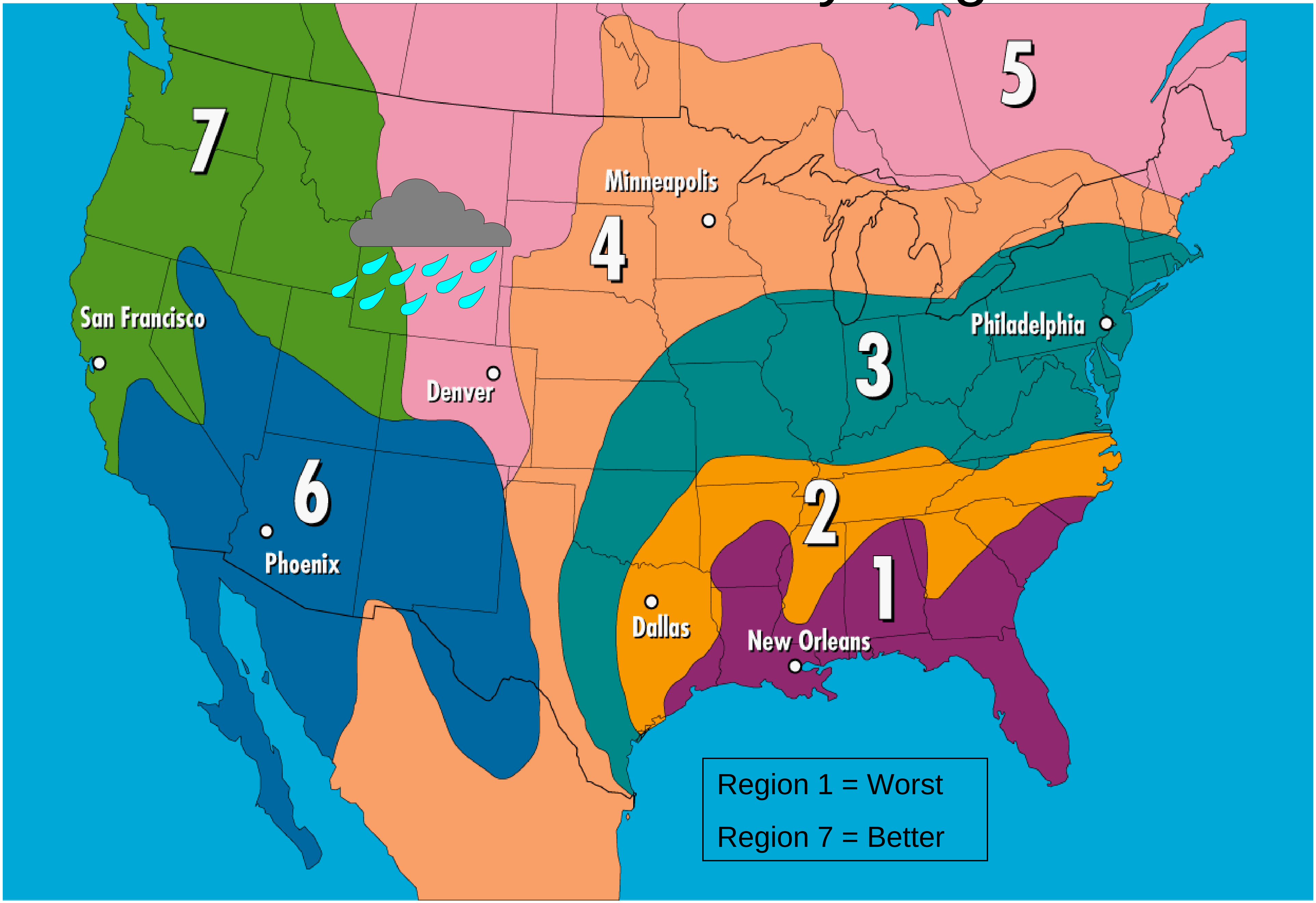
Fresnel clearance		
dist to xmit	2.50	miles
dist to rx	4.70	miles
Freq	2.43	GHz
Fresnel Radius	59.09	feet
0.6 Clearance	35.45	feet

Blue Vertical line indicates 0.6 Fresnel zone clearance at highest obstacle. Trees or buildings not modeled in this path, but must be included.

Other considerations

- On 3 mile paths or less, only FSL need be considered
- Recommended that minimum 5dB margin be applied for miscellaneous other losses
- Atmospheric and moisture attenuation becomes highly evident above 10 GHz
- Heavy rain can cause some signal distortion as low as 2 GHz

Rain Fade Risks By Region



Region 1 = Worst

Region 7 = Better

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Path availability

- Barnett's emprical fade estimate
- Intended to estimate % of time in a year where fade exceeds a specified depth below free space for a given path and frequency

$$Pmf(\%)=0.00006 \times abfd^{3} \times 10^{(-M/10)}$$

	4 for very smooth terrain including over-water
a=	1 for average terrain with some roughness
	1/4 for mountainouts, very rough, or very dry terrain.
	1/2 Gulf coast or similar hot, humid areas
b=	1/4 Normal interior temperate or northern climate
	1/8 mountainous or very dry climate
f=	frequency in gigahertz
d=	path length in kilometers
M=	fade depth exceed below free space level, in decibels

Example: North Texas
A=1
B=0.333
F=2.43 GHz
D=40km
Fade margin= 20 dB
0.031% unavailability per year
Or 270 hours

From Freeman pp 64-65

Rainfade causes

- Two types of fade mechanisms
  - Path attenuation
  - Phase distortion
- Various bands are limited in various ways
  - 2m Precipitation static (raises noise floor)
  - 2.4G Phase distortion typically limiting
  - 10G Path attenuations + phase distortion

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Link Budget

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- Link budgets are a tool to plan RF links. They are not guarantees of success.

802.11 Link Budget							
Frequency	2430 MHZ	TX POWER	14.8	dBm			
TX Power	30 mW	Power at feed	13.8	dBm			
TX Antenna Gain (dB	24 dB	EIRP	37.8	dBm	or	1.1	Watts
TX System Losses	1 dB						
		Free Space Loss	132.3	dB			
RX Senstivity	-90 dBm						
RX Antenna Gain (dB	16 dB	Signal at RX Ant Aperture	-94.5	dBm			
RX System Losses	1 dB	Signal at RX Ant port	-78.5	dBm			
Path Length	25 miles	Signal at RX	**-79.5**	**dBm**			
		Link Margin	10.5	dB			

Power (dBm) = 10 * LOG (PWR in mW)

Power (mW) = $10^{\text{(PWR in dBm/10)}}$

Radio Mobile

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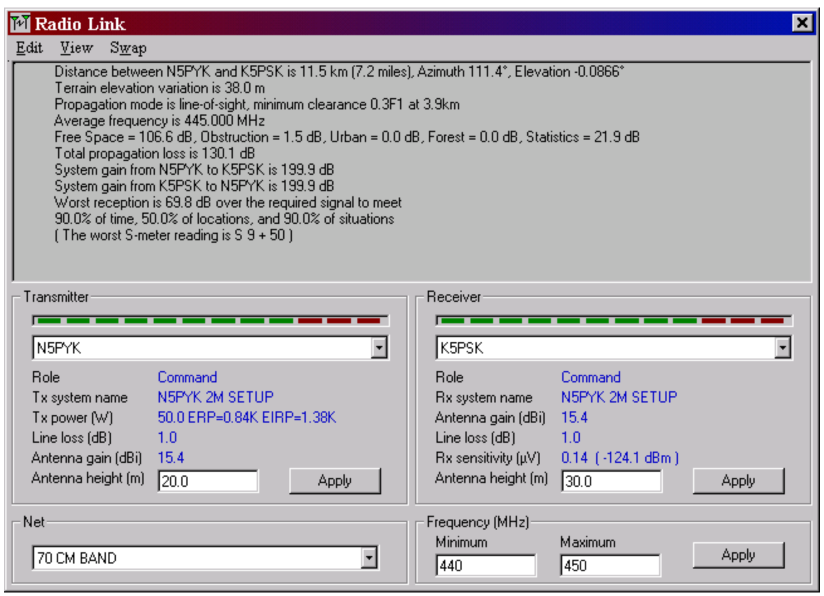
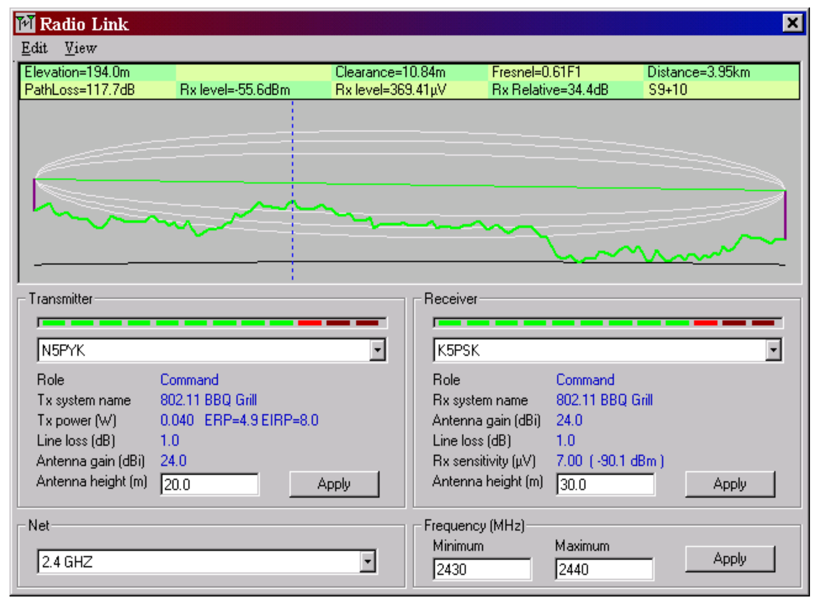
- Freeware by Roger Coude, VE2DBE
- Highly useful for tool RF coverage and path analysis
- Allows quick analysis of Fresnel clearance
- Uses elevation data from shuttle radar topography mission





http://www.cplus.org/rmw/english1.html

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Frequency Congestion

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- The number of channels available is finite
- On 2.4 and 5.7 GHz, we must compete with part 15 devices. Even though we have “rights” to the frequencies, it will be difficult to clear them
- As amateurs, we must consider using 802.11 on other bands (33cm, 23cm, 13cm, 6cm, 3cm, and up)
- We must also remember to respect band plans and not interfere with weak signal operations.
- There is plenty bandwidth for all…at least for now

Unlicensed Spectrum

FCC Part 15

"……. operators of spread spectrum transmitters are reminded that the operation of Part 15 devices is subject to the conditions that any received interference, including interference from ISM operations, must be accepted and that *harmful interference may not be caused to other radio services*.

Should the operation of these systems cause harmful interference, the operator of the Part 15 system is required to correct the interference problem, even if such correction requires the cessation of operation of the Part 15 transmitter.

Thus, the Commission strongly recommends that utilities, cellular stations, public safety services, government agencies and others that employ Part 15 transmission systems to provide critical communication services should exercise due caution to determine if there are any nearby radio services that could be affected by their communications."

However, there are more of them than us so we must play nice!

References

- Freeman, Roger L. Radio System Design for Telecommunications (1-100 GHz), John Wiley and Sons, Inc. 1987