

Welcome! Microwave 101

MILLING

Microwave 101 Webinar Series

PRESENTERS



Joe Marzin *Director, Technology Group*



Peter Xu Engineer, Product Support

REGISTER: www.comsearch.com/microwave-101/

- Microwave Components
- RF Propagation
- Field Survey
- 6 GHz Microwave Assurance

DAY 2: Microwave Fundamentals Part II (June 27)

- Path Reliability
- Path Design Considerations
- iQ·link Microwave Design Software (Live Demo)

DAY 3: Understanding the Frequency Coordination Process (July 25)

- Interference Analysis
 - \circ Microwave
 - o Earth Station
- Frequency Planning & Protection
- FCC Licensing & Management
- Comsearch Connect Customer Portal (Live Demo)
- FCC Regulatory Updates (6 GHz, 80 GHz, 13 GHz)



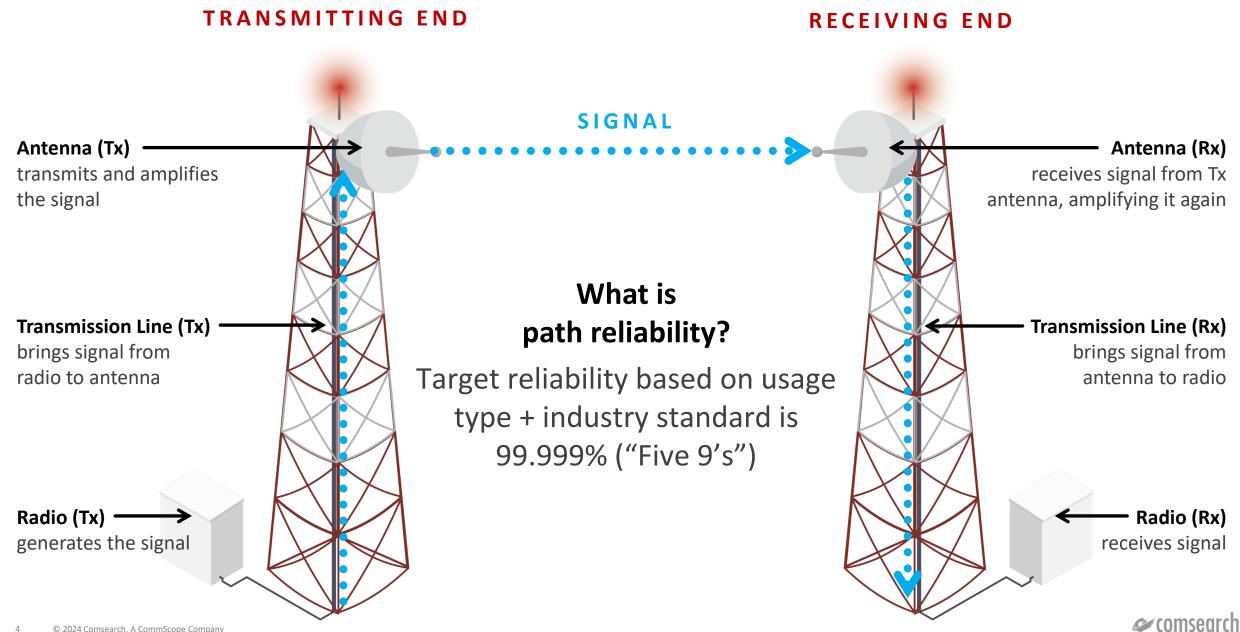
Microwave Fundamentals Part II 1. Path Reliability



Joe Marzin

Director, Technology Group

PATH RELIABILITY



PATH RELIABILITY | RELATIONSHIPS

Factors that Affect Reliability

| VARIABLE | RELATIONSHIP |
|----------------------|--|
| Transmit Power Level | Higher Power → More Reliable |
| Antenna Size | Larger Antenna → More Reliable |
| Diversity | Diversity Usage → More Reliable |
| Terrain | Rough → More Reliable |
| Path Length | Longer Path Length \rightarrow Less Reliable |
| Frequency Band | Higher Frequency Band → Less Reliable |
| Temperature | Higher Temperature → Less Reliable |
| Rain Rate | Higher Rain Rate → Less Reliable |
| Climate | Warm & Humid → Less Reliable |

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PATH RELIABILITY | OUTAGE

- The time that the Received Signal Level (RSL) is faded below the Receiver Threshold is known as **Outage**
- Outage is calculated as time below 10⁻⁶ BER for most microwave applications

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|--|---|---|---|--|---|--|---|--|---|
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Screenshot is from Comsearch's iQ·link[®] Microwave Design Software.



Comsedro

31,556,926

SECONDS IN A YEAR



An availability of **99.99% (four nines)** means an outage of 3155.7 seconds per year, or about **53 minutes**

An availability of **99.999% (five nines)** means an outage of 315.57 seconds per year, or about **5 minutes**



RF PROPAGATION | FADING TYPES

OBSTRUCTION

- Low K Factor -
- Path Blockage -



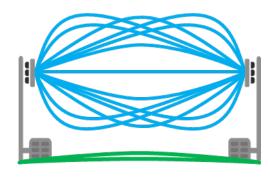
REMEDY

Increase antenna heights

MULTIPATH

- Phase Cancellation -

- Reflective or Atmospheric -



REMEDY

Space or frequency diversity

ABSORPTION

- Precipitation -
- Atmospheric Gases -



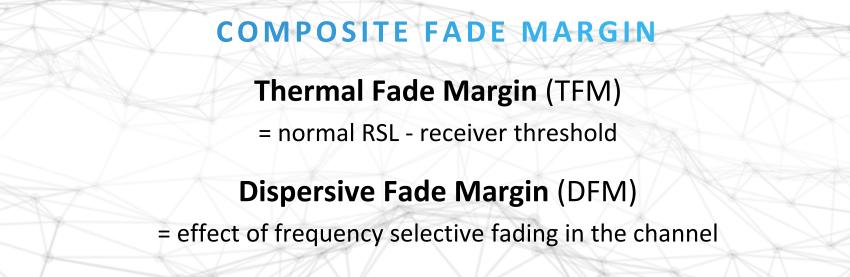
REMEDY

ACM or shorter paths



PATH RELIABILITY | FADE MARGIN

Amount signal may fade before a path outage results



External Interference Fade Margin (EIFM)

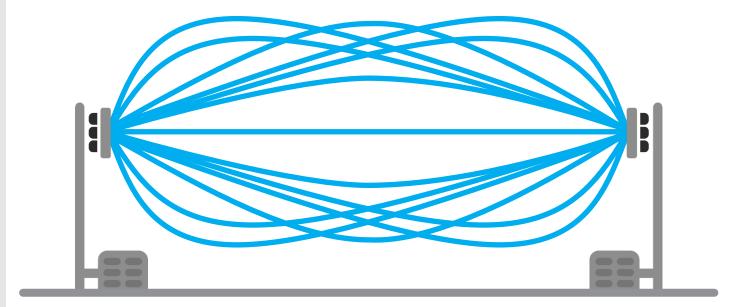
= effect of interference

 $\mathsf{CFM} = -10\log_{10}\left(10^{-\mathsf{TFM}/10} + 10^{-\mathsf{DFM}/10} + 10^{-\mathsf{EIFM}/10}\right)$



PATH RELIABILITY | MULTIPATH OUTAGE MODEL

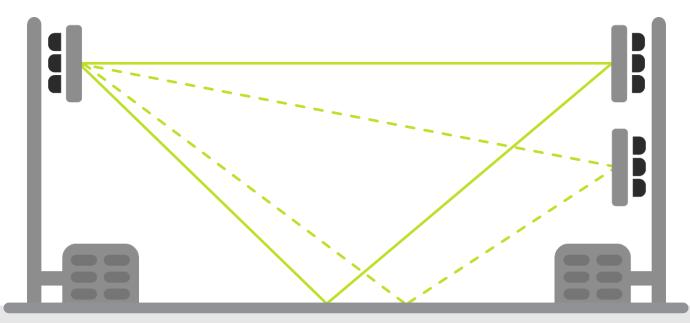
- Fade margin must be high enough for the path to meet the *reliability objective*
- Multipath outage models (e.g. Vigants, ITU) predict link outage based on:
 - **1**. Fade margin
 - 2. Climate
 - 3. Terrain
 - 4. Temperature
 - 5. Frequency
 - 6. Path length
- Outage time can be greatly reduced using frequency and/or space diversity





WHAT IS SPACE DIVERSITY?

Additional receive antenna to combat atmospheric or reflective multipath



WHAT IS THE OPTIMUM SPACING?

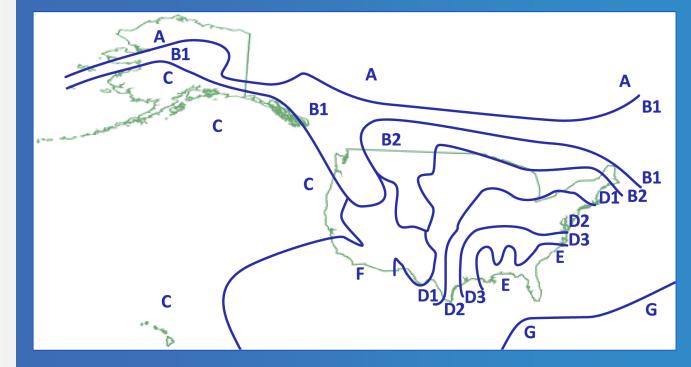
Reflection analysis determines the optimum spacing between the antennas

Typical spacing's range from 10 to 50 feet



PATH RELIABILITY | RAIN OUTAGE

- Rain fade is significant above 10 GHz
- Rain models (e.g. Crane, ITU) predict rate of rain that would cause attenuation to exceed fade margin
- Rain rate statistics are available down to city level
- Outage probability proportional to rain severity—not total annual rainfall
- Rain attenuation for horizontal polarity is greater than for vertical







PATH RELIABILITY | EXAMPLES

EFFECT OF ENVIRONMENTAL FACTORS ON RELIABILITY



| 6 GHz | | | | | | | |
|-----------|------------------------|-------------|---------|-------------------------|---|--------------------------|--|
| Climate | Temper | ature | | 1ax. Path ngth* (mi) | | | |
| Good | Сос | Cool | | Rough | | 28.1 | |
| Average | Avera | Average Av | | verage | | 17.6 | |
| Poor | War | Warm Sr | | nooth | | 11.5 | |
| 23 GHz | | | | | | | |
| Rain City | Multipath Climate | Tempe | erature | Terrain | L | Max. Path ength* (mi) | |
| Seattle | Average Average Smooth | | | 3.73 | | | |
| Chicago | Average | Average Ave | | Smooth | | 1.94 | |
| Miami | Poor | Wa | ırm | Smooth | | 1.38 | |

< 10 GHz

rain fading insignificant

10 - 18 GHz

multipath and rain fading

> 18 GHz

rain fading significant, multipath fading insignificant

* Maximum path length to expect for a single antenna system that still meets 99.995% reliability using Vigant's method







Microwave Fundamentals Part II 2. Path Design Considerations



Joe Marzin

Director, Technology Group

PATH DESIGN CONSIDERATIONS | FREQUENCY OPTIONS

COMMON BANDS

6.1 GHz (5.925 – 6.425)

6.7 GHz (6.525 – 6.875)

11 GHz (10.7 – 11.7)

18 GHz (17.7 – 19.7)

23 GHz (21.2 – 23.6)

OTHER OPTIONS

70/80 GHz "lightly licensed"

7 GHz (only in some areas)

5.8 & 60 GHz (unlicensed)



PATH DESIGN CONSIDERATIONS | FREQUENCY OPTIONS

LICENSED VS. UNLICENSED

| | Licensed | Unlicensed |
|-------------------------|---|---|
| Typical Applications | Backhaul, critical infrastructure | Spur links, temporary links, rural areas |
| Time to Begin Operation | Varies (2-16 weeks) | Immediately |
| Equipment Costs | Higher, more features | Lower, less features |
| Antenna Size | Somewhat flexible | Very flexible |
| Licensing Cost | Ranges—few hundred to a few thousand | Zero |
| Interference | Protection | No Protection |
| | | |



PATH DESIGN CONSIDERATIONS | LICENSING TIMELINE

How long does the process take?

Total time ... about 2-4 months

| WEEK(S) | PROCESS |
|---------|--------------------------|
| 2 | Path Design / Survey |
| 1 | Interference Analysis |
| 2 - 4 | Prior Coordination (PCN) |
| 1 | FCC Licensing |
| 4 - 8 | FCC License Grant |



PATH DESIGN CONSIDERATIONS | BANDWIDTH & ANTENNA SIZE

Licensed Microwave Maximum Bandwidths / Minimum Antenna Sizes

| | PART 101 MICROWAVE | | | | | |
|---|--------------------|-----------------------|-----------------------|--|--|--|
| | Band (GHz) | Largest Channel (MHz) | Smallest Antenna (ft) | | | |
| | 6.1 | 60 | 3 | | | |
| | 6.7 | 30 | 3 | | | |
| | 7 | 25 | 3 | | | |
| l | 11 | 80 | 2 | | | |
| | 18 | 80 | 1 | | | |
| | 23 | 50 | 0.75 | | | |
| | 70-90 | 5000 | 0.75 | | | |
| | | | | | | |



PATH DESIGN CONSIDERATIONS | EFFECTIVE ISOTROPIC RADIATED POWER

Licensed Microwave EIRP Restrictions

| Band (GHz) | Minimum Path Length w/o Reducing Power (km) | |
|----------------------|--|--|
| < 10 GHz | | |
| 10 – 18 GHz | | |
| > 18 GHz | N/A | |

The maximum allowable EIRP is 85 dBm for most Part 101 microwave bands



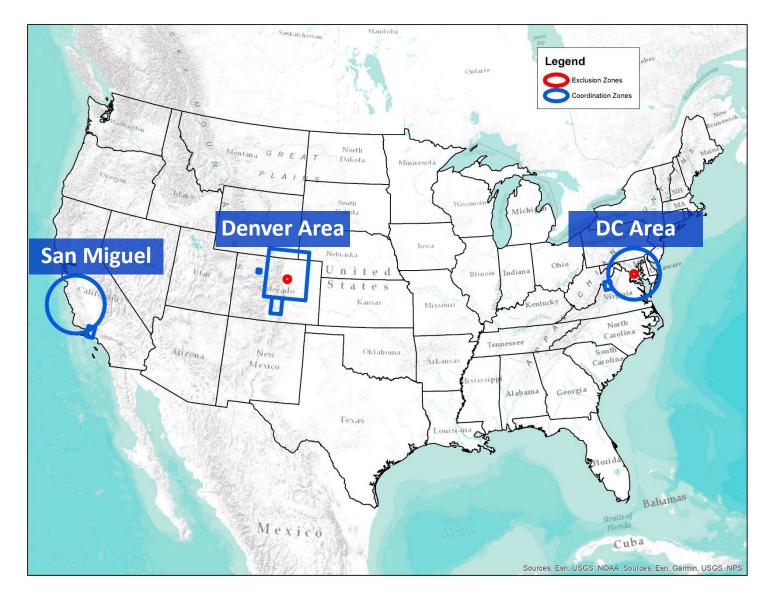
PATH DESIGN CONSIDERATIONS | QUIET ZONES

18 GHz DOD Quiet Zones (Parts 74, 78, and 101)











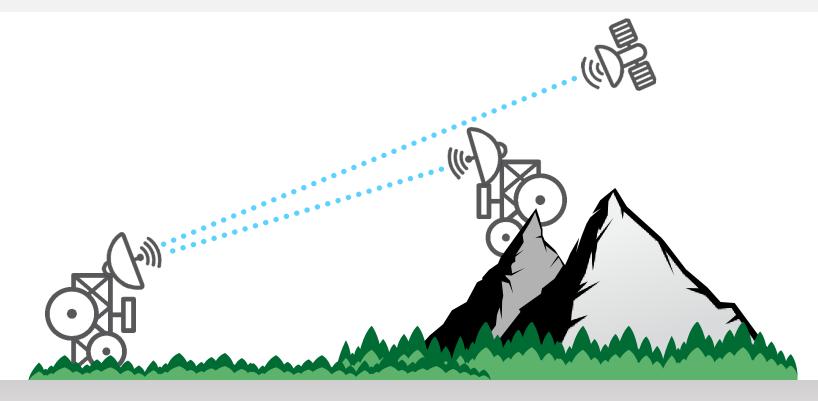






PATH DESIGN CONSIDERATIONS | GEO SATELLITE ORBIT

Microwave into Satellite Interference



6 GHz

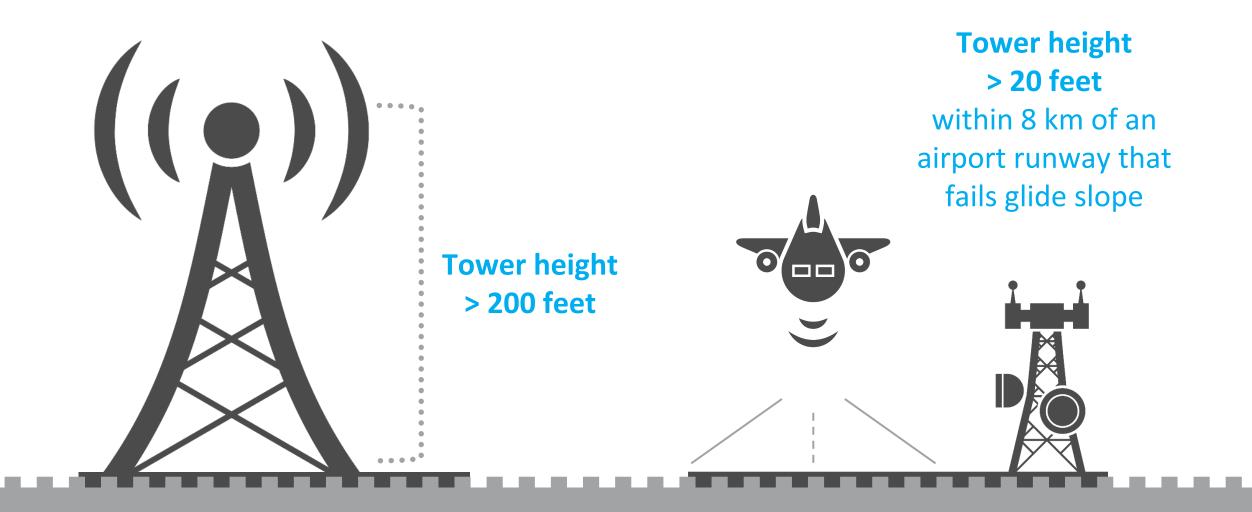
EIRP ≤ 65 dBm = Conditional Authorization EIRP > 65 dBm = Waiver Required and No Conditional Authorization





PATH DESIGN CONSIDERATIONS | TOWER REGISTRATIONS

FCC / FAA Tower Registration Requirements





PATH DESIGN CONSIDERATIONS | OPERATION

When Can I Operate My Path?

- A. **Conditional Authorization**—Can operate once FCC application is *filed*
 - No waivers
 - No environmental impact
 - Must be more than 56.3 km away from international borders
 - Cannot lie within 10 GHz restricted zones
 - - Cannot lie within 18 GHz restricted zones (DC, Denver, San Miguel, and Guam)
 - Must be >15 GHz if in Puerto Rico
 - If 23 GHz, only operating on non-restricted channels
- B. No Conditional Authorization—Can operate once FCC license is granted







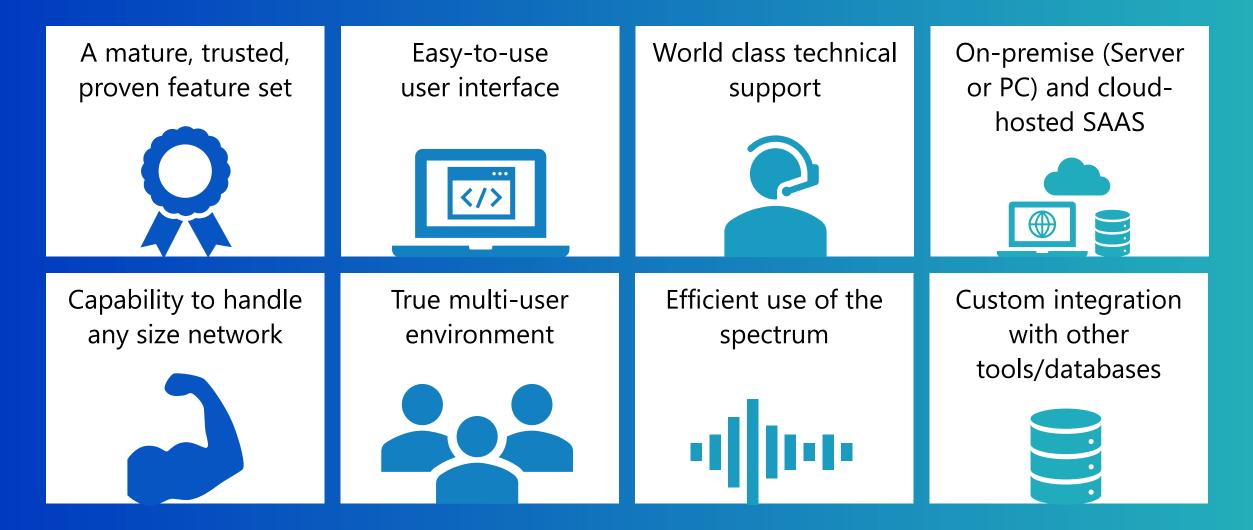
Comsearch iolink[®] All the right tools to design and manage your microwave backhaul network for 5G and beyond

Microwave Fundamentals Part II 3. iQ·link Demo



Peter Xu **Engineer, Product Support**

iQ·link[®]: A wireless microwave Point-to-Point and Point-to-Multipoint, fixed network design software tool





iQ[.]link[®] Software Offered in Two Editions

- 1. iQ·link **Enterprise**: Multi-user installations on Windows or RedHat / CentOS Linux Servers with a database supporting an unlimited number of links
- 2. iQ·link **Solo**: Single-user installations on Windows PCs

https://www.comsearch.com/products/planning-tools/iqlink/



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Thank You!