Counteracting Point-to-Point Microwave Propagation Issues with Adaptive Modulation

Scott D. Nelson
Wireless Transmission Product Group – North America
Scott.D.Nelson@Alcatel-Lucent.com

Primary Microwave Propagation Issues

Flat fading (thermal fading)

- Most commonly observed phenomena
- Minor fluctuations in receive signal level are common throughout the day
- Deeper fades (>10 dB) are often accompanied by refractive multipath fading

Multipath fading (dispersive fading, clear air fading, frequency selective fading)

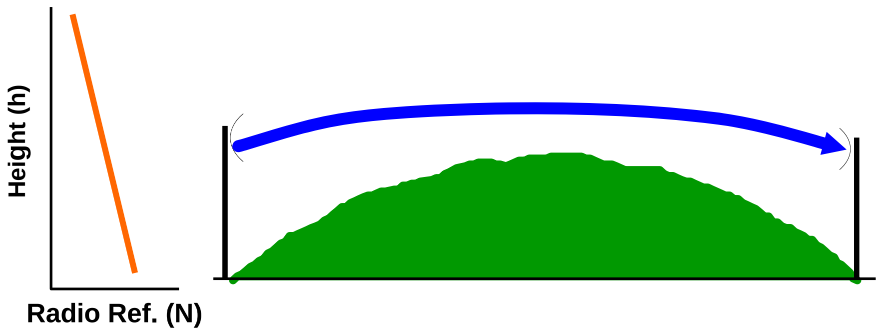
- May occur on both refractive or reflective paths
  - Reflective fading often most severe
- Typically uni-directional fading events
  - But often affecting both directions over the macro-event period
- Can occur even though RSL indications are above radio threshold
- Typical countermeasure is space diversity antennas

Rain fading

- Regional variations categorized by Robert Crain
- Bi-directional fading event
  - Equal in severity and duration for both directions

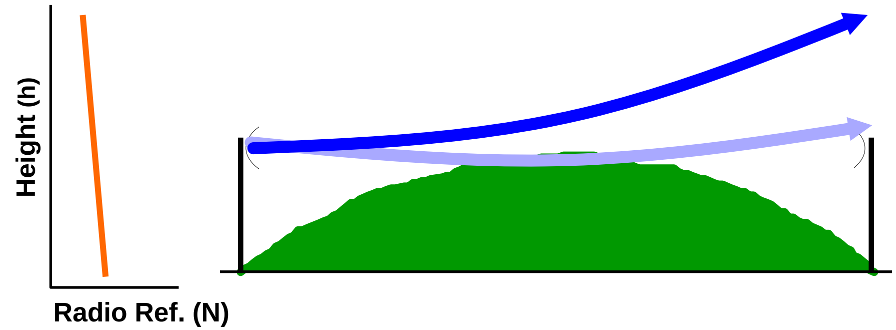
Refractive and Reflective Fading Phenomena

Normal Atmosphere



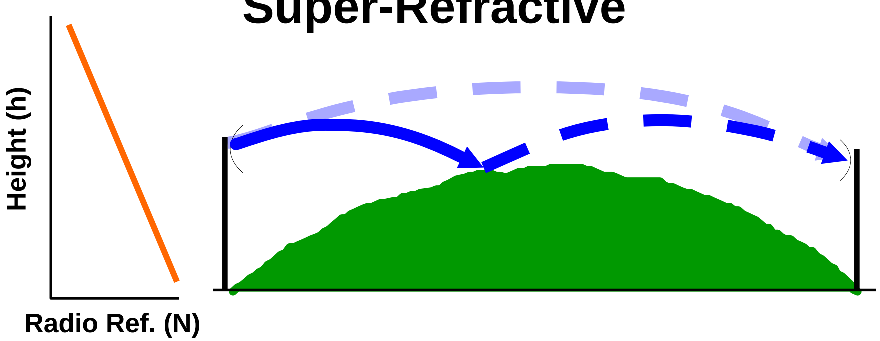
Normal Atmosphere (-100 < dN/dh < 0 N-units/km)

Sub-Refractive



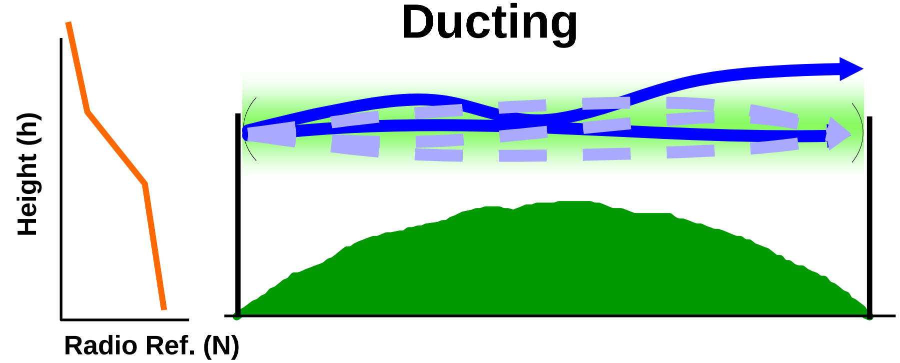
Subrefractive, Obstruction (0 < dN/dh < +o o N-units/km)

Super-Refractive



Superrefractive (-157 < dN/dh < -100 N-Units/km)

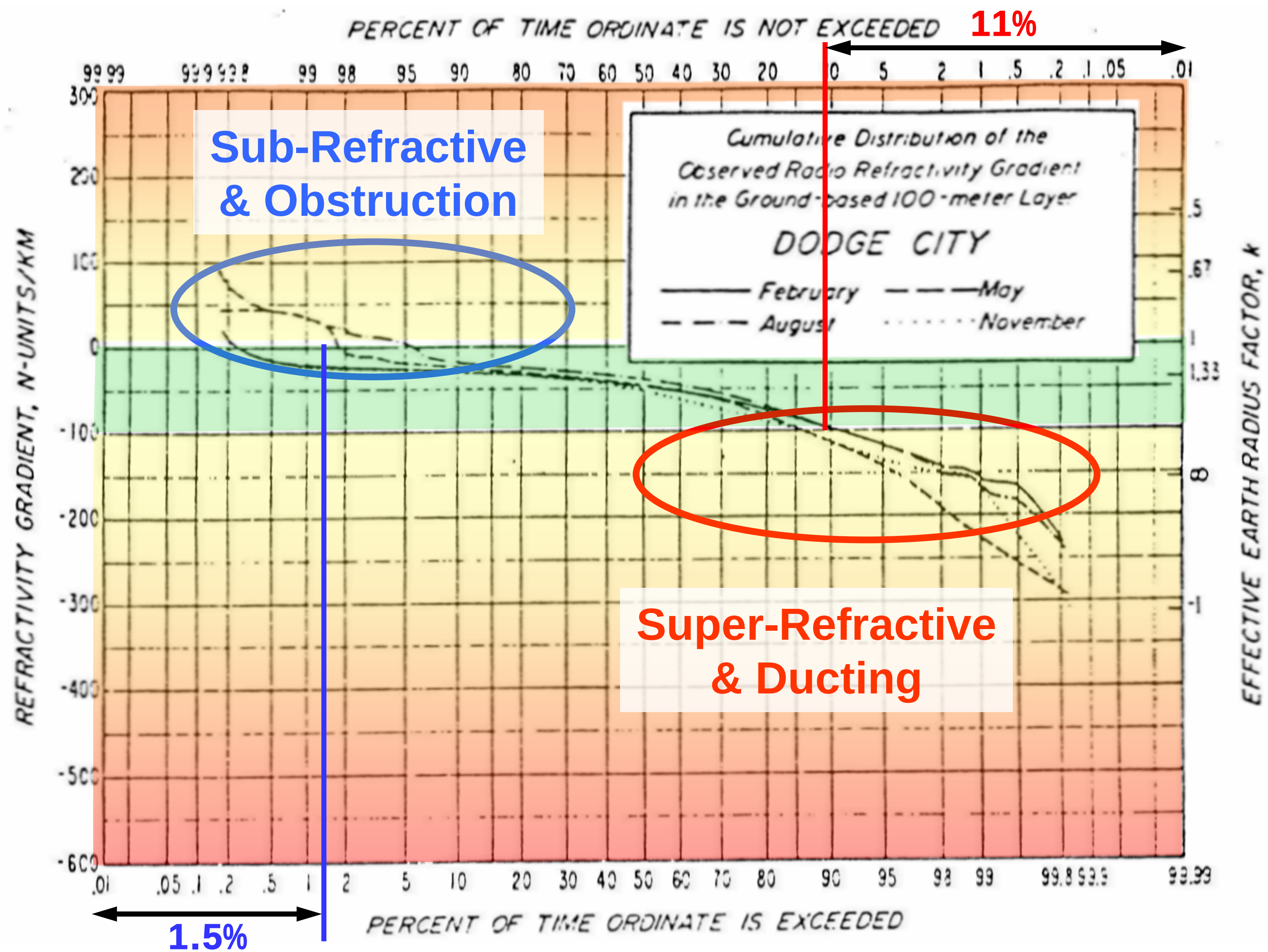
Ducting



Possible Ducting (-∞ < dN/dh < -157 N-units/km)

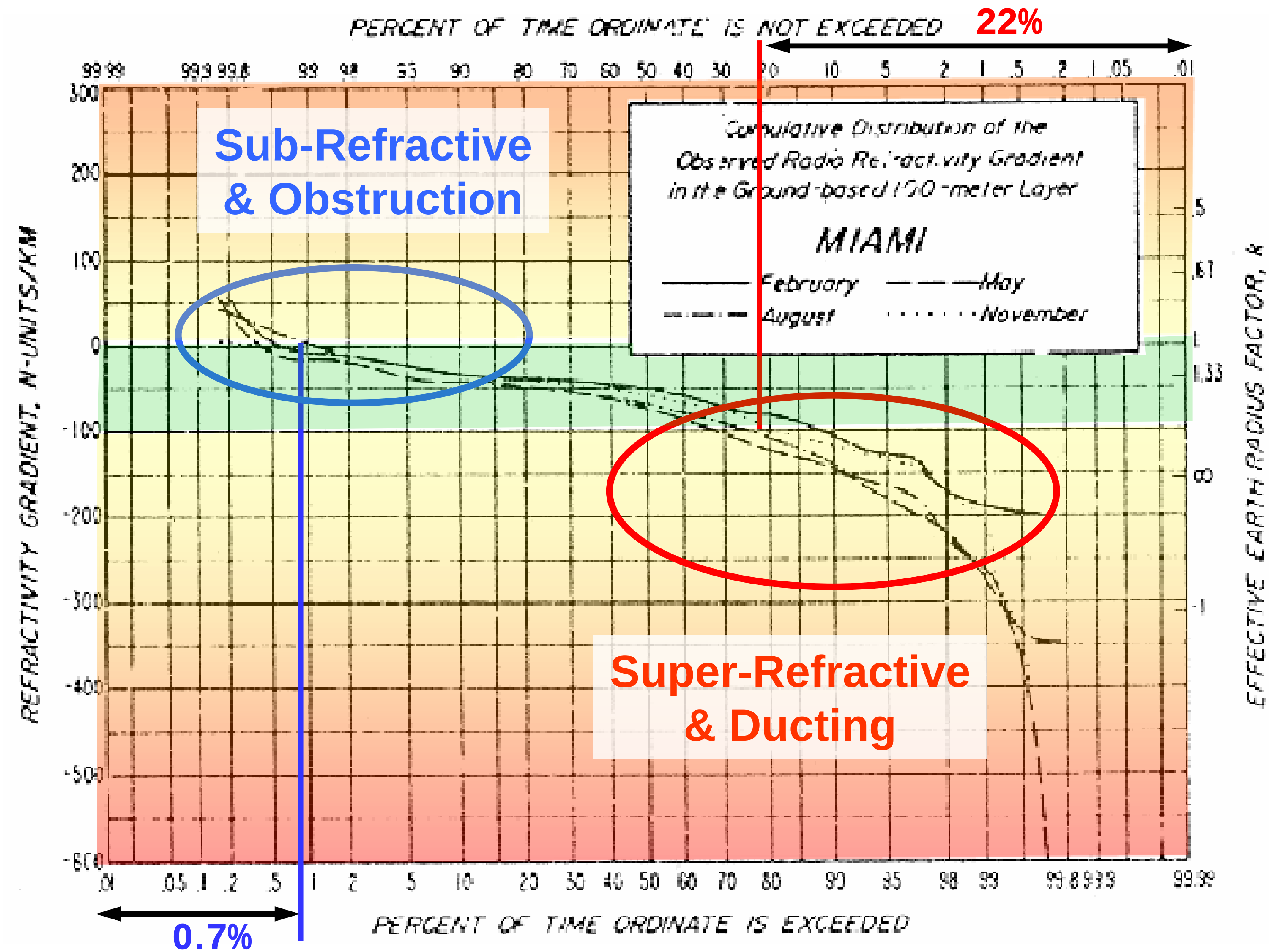
Alcatel·Lucent

Seasonal Microwave Path Variations – Average Climate

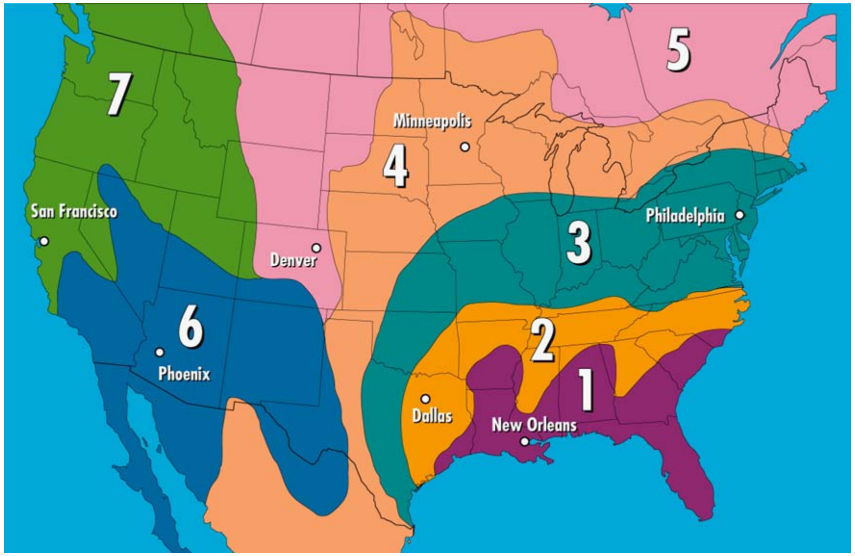


Alcatel·Lucent

Seasonal Microwave Path Variations – Poor Climate



Rain Fading

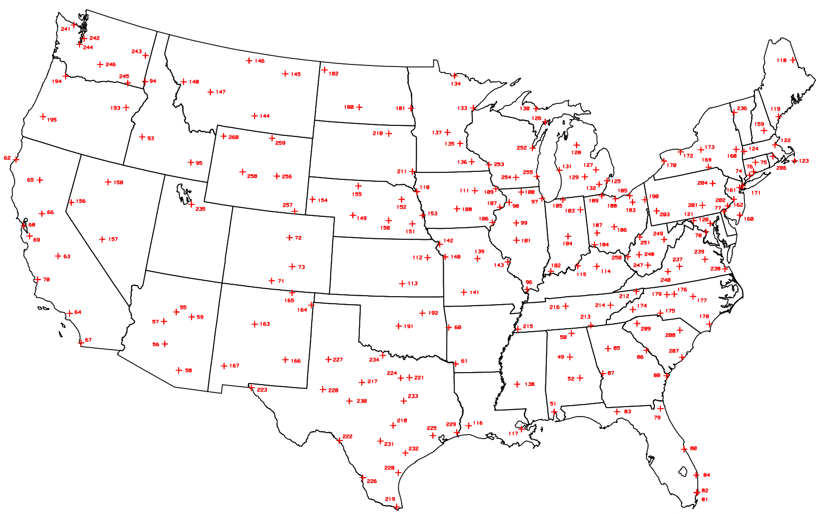


Crane rain regions

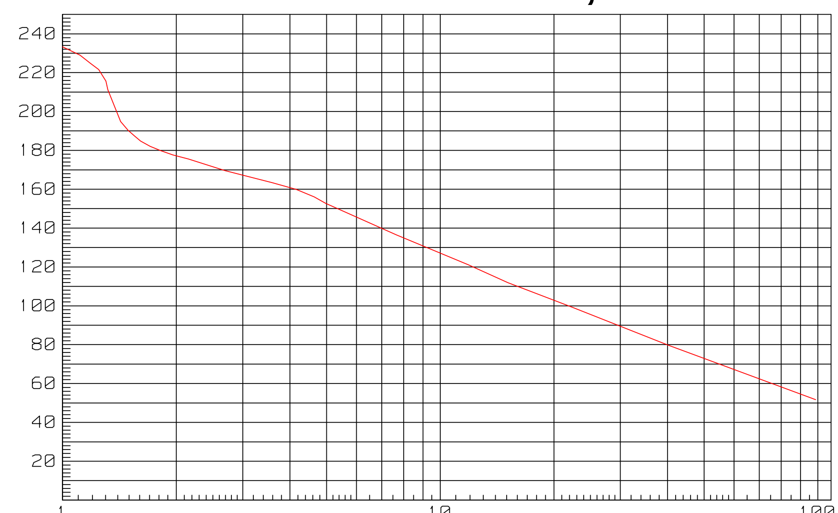
- Region #1 – most severe, shortest paths
- Region #7 – least severe, longer paths

US Weather Service rain recording stations

- Accounts for local anomalies
- Doesn’t account for rain cell size



Rain Curve 221 - Dallas, Texas



Average Number of Minutes per Year

Alcatel·Lucent

Variable Effect of Rain Cells on Microwave Paths

Orientation of path azimuths to frontal systems, rain cell size, and rainfall rate can all have an effect on how well adaptive modulation counteracts precipitation

Alcatel·Lucent

How Does Adaptive Modulation Counteract These Phenomena?

Flat fading (thermal fading)

- Sub-refractive fading resulting in reduced receive signal level (RSL)
- Fast response to RSL changes > 100 dB / second are critical

Multipath fading (dispersive fading, clear air fading, frequency selective fading)

- Super-refractive fading and ducting resulting in multiple signal reflections
- Quick response to forward error correction may not be sufficient
- Monitoring gain coefficients in time domain equalizer (TDE) may work

Rain fading

- Rapid variations in RSL related to rain cell size & speed and rainfall rate
- Moderate response to RSL changes from 10-100 dB / second are sufficient

What Does Adaptive Modulation Do for Microwave Links?

Improves link availability

- For critical portion of traffic versus all-or-nothing transmission

Potential realizations

- Existing paths with < 50% critical traffic
- New paths with lower priority growth traffic

Increases link capacity

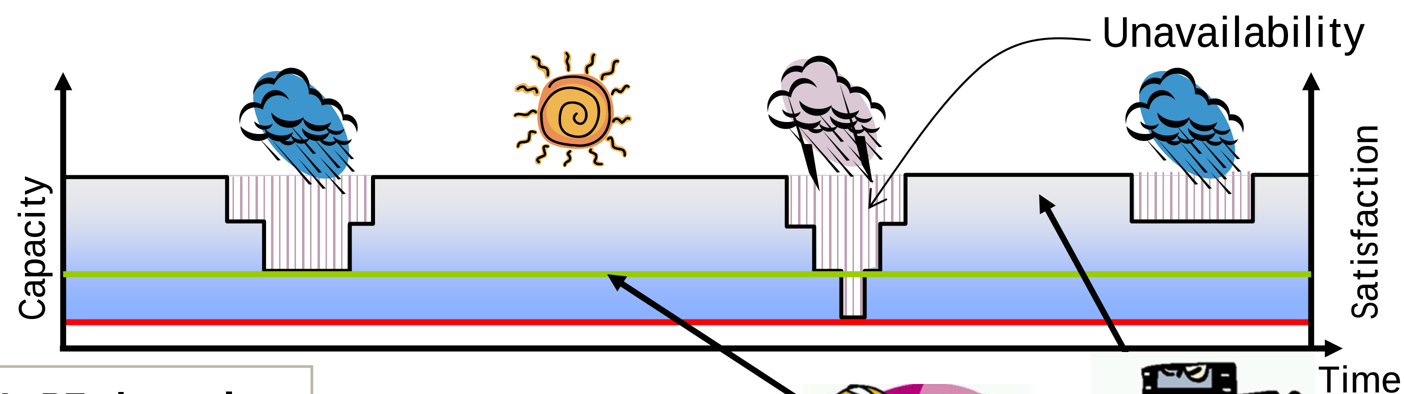
- Take advantage of higher-but-less-robust modulation levels

Potential realizations

- Reduce need for wide RF channels on new hops
- Extend use of existing licenses

Modulation schemes

256 QAM	99.99%
128 QAM	99.995%
64 QAM	99.999%



Example with 10 MHz RF channel:

- 45 Mb/s @ 64-QAM with 99.999%
- 52 Mb/s @ 128-QAM with 99.995%
- 60 Mb/s @ 256-QAM with 99.99%
- 52.17 Mb/s average throughput

Capacity

Customer satisfaction

Outage

Voice traffic

Best-effort traffic

Alcatel·Lucent

Can I Use Adaptive Modulation Today?

Yes!

High frequency microwave and millimeterwave bands

- 18, 23, 28, 38, 60 & 80 GHz bands
- Spectral efficiency requirement is 1 bit / second / Hertz
  - CFR 47, Part 101.141 (a) (1)
- BPSK and FSK can meet this requirement
  - Commercial products typically offer minimum of 4 QAM / QPSK modulation

Lower frequency bands

- 4 and 6 GHz
  - 64 QAM meets requirements for 4.47 bits / second / Hertz @ 10, 20 & 30 MHz
- 10/11 GHz
  - 16 QAM meets requirements for 2.98 bits / second / Hertz @ 30 MHz
  - 32 QAM meets requirements for 3.3525 bits / second / Hertz @ 40 MHz
- Radios that change between these levels and higher can be used today

47 CFR, Part 101.141 (a) (3)

(3) The following capacity and loading requirements must be met for equipment applied for, authorized, and placed in service after June 1, 1997 in the 3700–4200 MHz (4 GHz), 5925–6425 and 6525–6875 MHz (6 GHz), 10,550–10,680 MHz (10 GHz), and 10,700–11,700 MHz (11 GHz) bands:

Nominal channel bandwidth (MHz)	Minimum payload capacity (Mbits/s) [1]	Minimum traffic loading payload (as percent of payload capacity)	Typical utilization [2]
0.400	1.54	N/A	1 DS–1
0.800	3.08	N/A	2 DS–1
1.25	3.08	N/A	2 DS–1
1.60	6.17	N/A	4 DS–1
2.50	6.17	N/A	4 DS–1
3.75	12.3	N/A	8 DS–1
5.0	18.5	N/A	12 DS–1
10.0	44.7	[3] 50	1 DS–3/STS–1
20.0	89.4	[3] 50	2 DS–3/STS–1
30.0 (11 GHz)	89.4	[3] 50	2 DS–3/STS–1
30.0 (6 GHz)	134.1	[3] 50	3 DS–3/STS–1
40.0	134.1	[3] 50	3 DS–3/STS–1

[1] Per polarization

[2] DS and STS refer to the number of voice circuits a channel can accommodate. 1 DS–1 = 24 voice circuits; 2 DS–1 = 48; 4 DS–1 = 96; 8 DS–1 = 192; 12 DS–1 = 288; 1 DS–3/STS–1 = 672; 2 DS–3/STS–1 = 1344; 3 DS–3/STS–1 = 2016.

[3] This loading requirement must be met within 30 months of licensing. If two transmitters simultaneously operate on the same frequency over the same path, the requirement is reduced to 25 percent.

2.46 – 3.7 b/s/Hz
Minimum = 16 – 32 QAM

4.47 bits / second / Hertz
Minimum = 64 QAM

4.47 bits / second / Hertz
Minimum = 64 QAM

2.98 bits / second / Hertz
Minimum = 16 QAM

4.47 bits / second / Hertz
Minimum = 64 QAM

3.35 bits / second / Hertz
Minimum = 32 QAM

Key Benefit of Adaptive Modulation = Lower Total Cost of Ownership

Reduce tower construction costs and tower/rooftop lease rates

- Via reduced tower loading from antenna systems and better aesthetics
  - Smaller antennas
  - Less need for space diversity

Savings on frequency planning and license costs

- Utilize less spectrum to meet growing capacity requirements
- Improve frequency coordination with higher interference tolerance

Radio equipment cost improvements

- Ability to use less linear devices and subsystem that are less expensive
- Higher factory throughput and yield

www.alcatel-lucent.com/microwave