Gigabit MM Wave Comm

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Presentation Overview

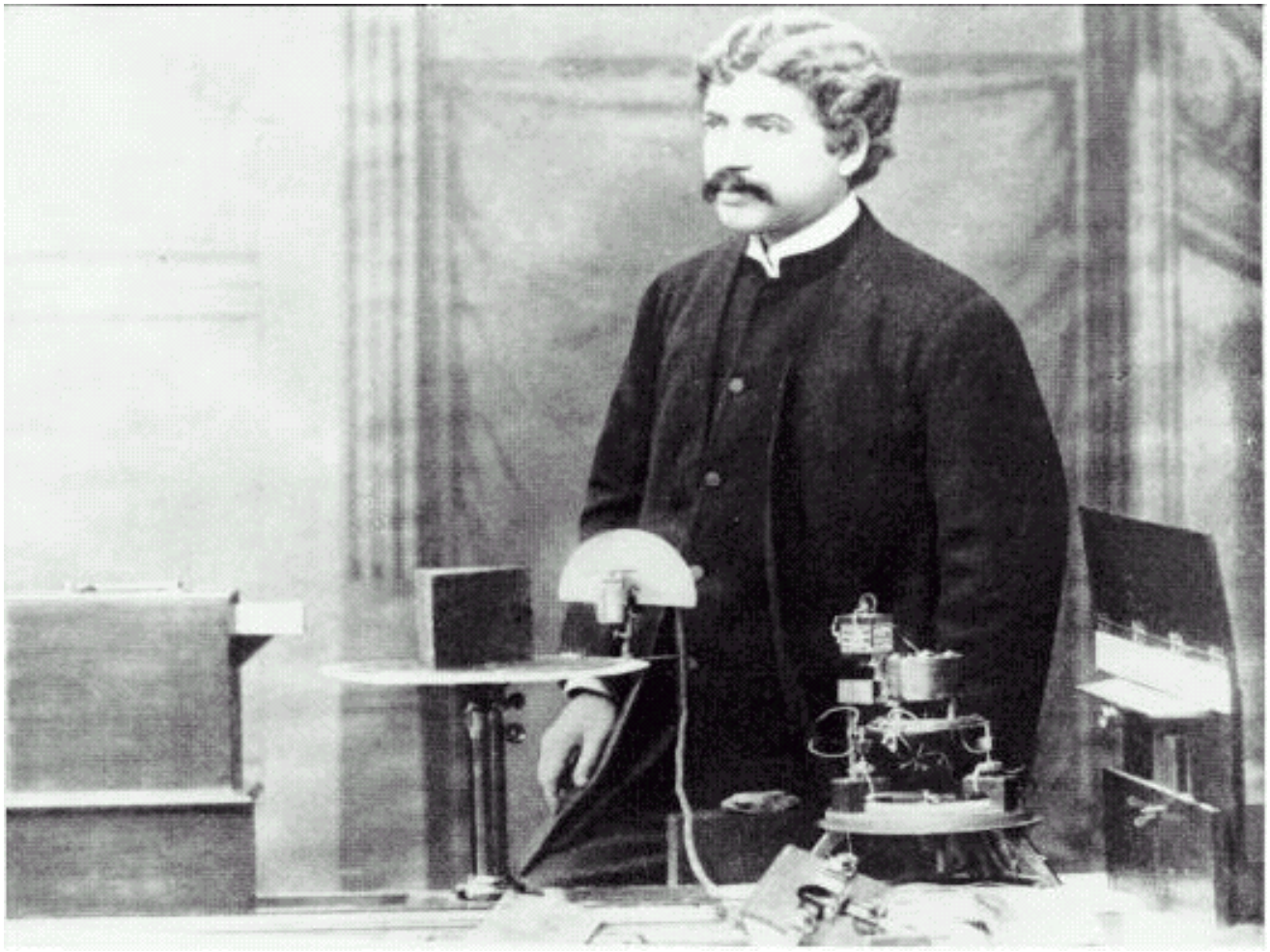
- History of MM Wave technology
- Current status and programs
- Technology and performance
- Regulatory environment
- Standards

History
MM Wave (10-1mm) 30-300 GHz

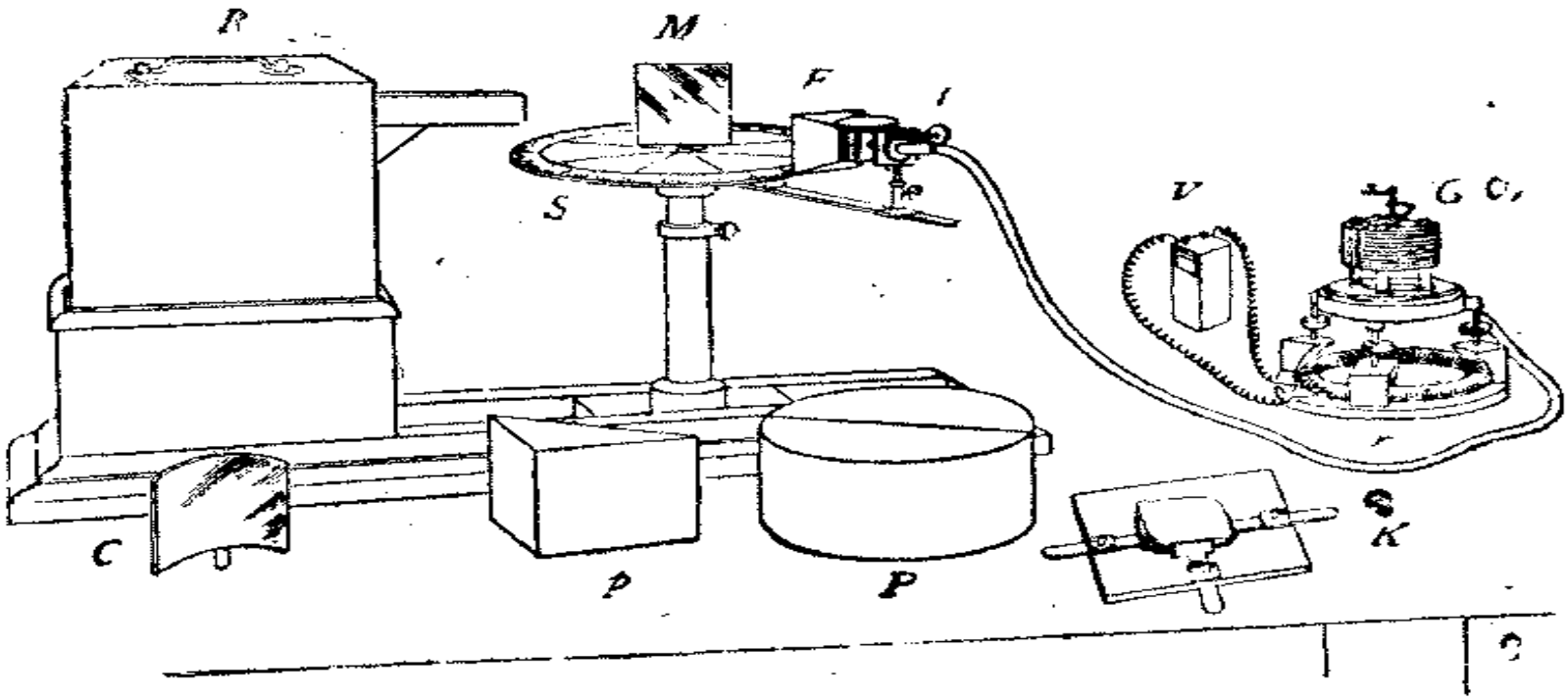
"The inventor has transmitted signals to a distance of nearly a mile and herein lies the first and obvious and exceedingly valuable application of this new theoretical marvel."

1896 Daily Chronicle of England

J.C. Bose and 60 GHz



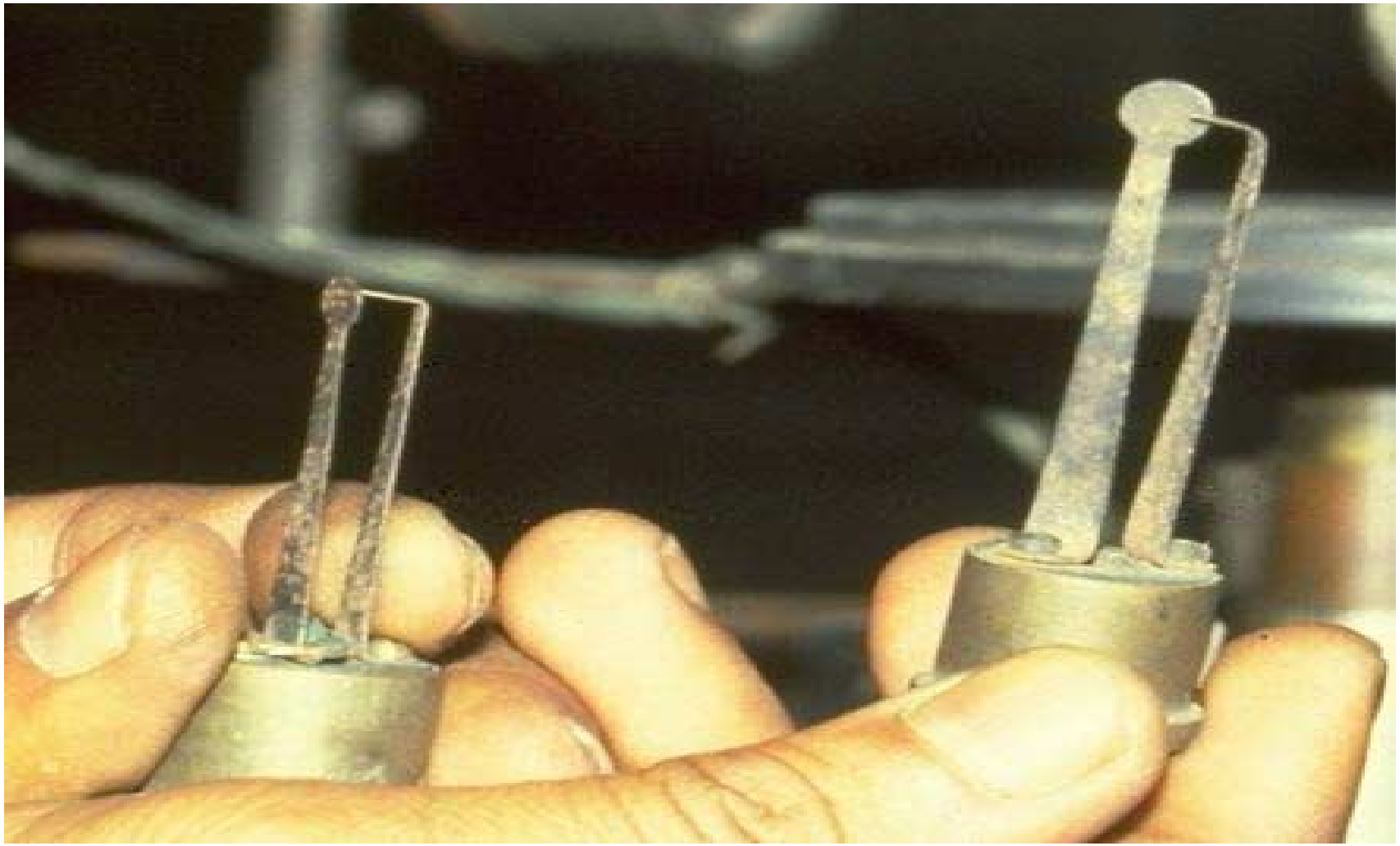
Bose Apparatus



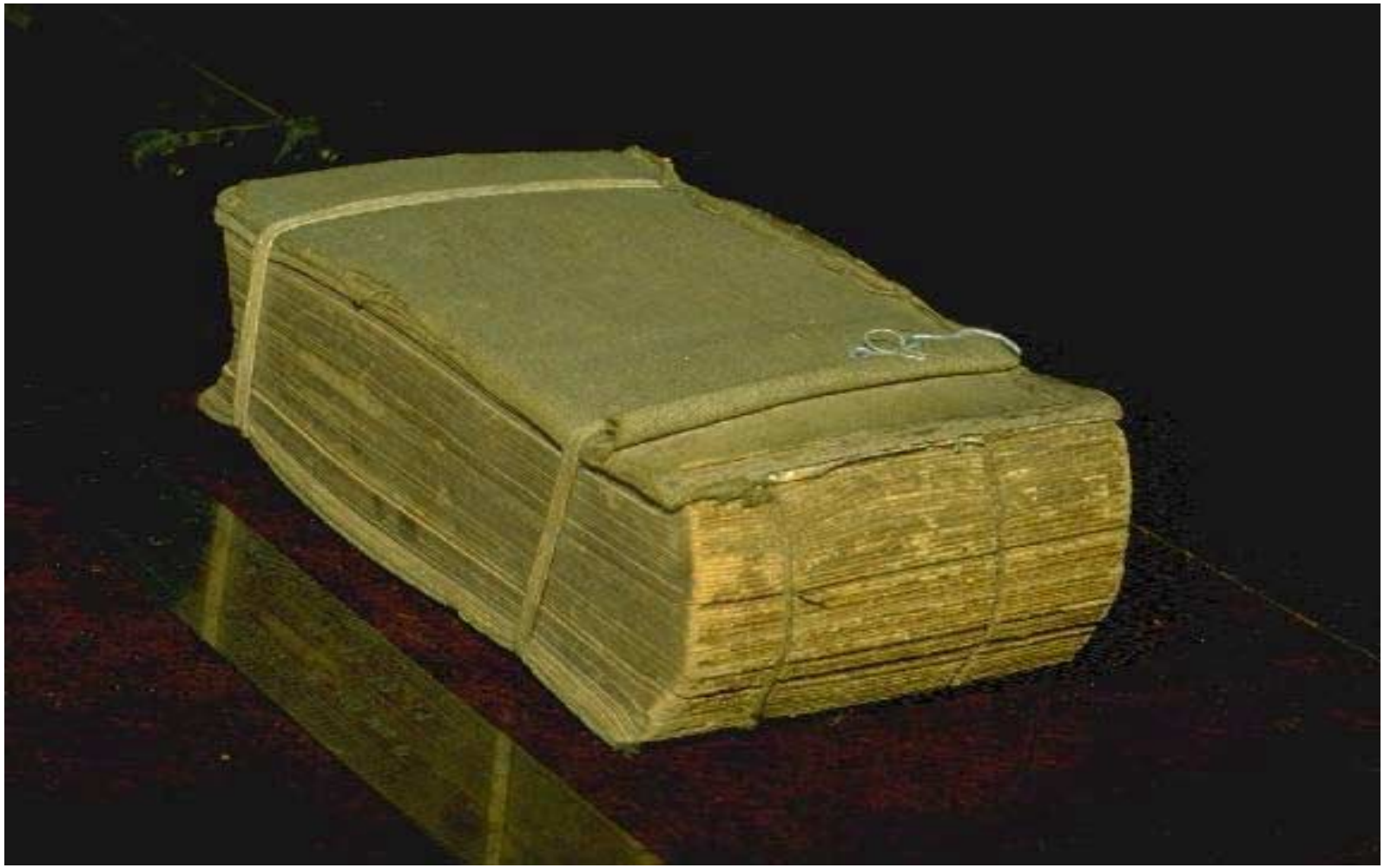
R, radiator ; S, spectrometer-circle ; M, plane mirror ; C, cylindrical mirror ; *p*, totally reflecting prism ; P, semi-cylinders ; K, crystal-holder ; F, collecting funnel attached to the spiral spring receiver ; *t*, tangent screw, by which the receiver is rotated ; V, voltaic cell ; *r*, circular rheostat ; G, galvanometer.

60 GHz Source, Antenna and Polarizer

Point Contact Detectors



60 GHz Polarizer:
Book with tin foil between the pages



Double Prism Attenuator

Bose’s Achievements

- 1895 demonstration of 60 GHz communications: 2 years before Marconi
- Semi conducting crystals and PN junctions
- MM wave components and assemblies
- Predicted existence of EM radiation from the sun and atmospheric absorption

Modern Times

- 1950s : Bell Labs demonstrated long haul communications using buried circular mm waveguide in advance of fiber optics
- 1960s : MM wave radio astronomy developed high performance components and assemblies
- 1970s : Military radar, radiometer, munitions, and communications programs enhanced the industrial base

Cont..

- 1980s: U.S. Government MMIC Phase I and II developed commercial industrial base for MM wave I.C.s
- 1990s: Broad emergence of government and commercial applications and programs
  - Auto radar at 77 GHz
  - Sat Comm at 20, 30, 44, & 60 GHz
  - Commercial products from 18 to 77 GHz

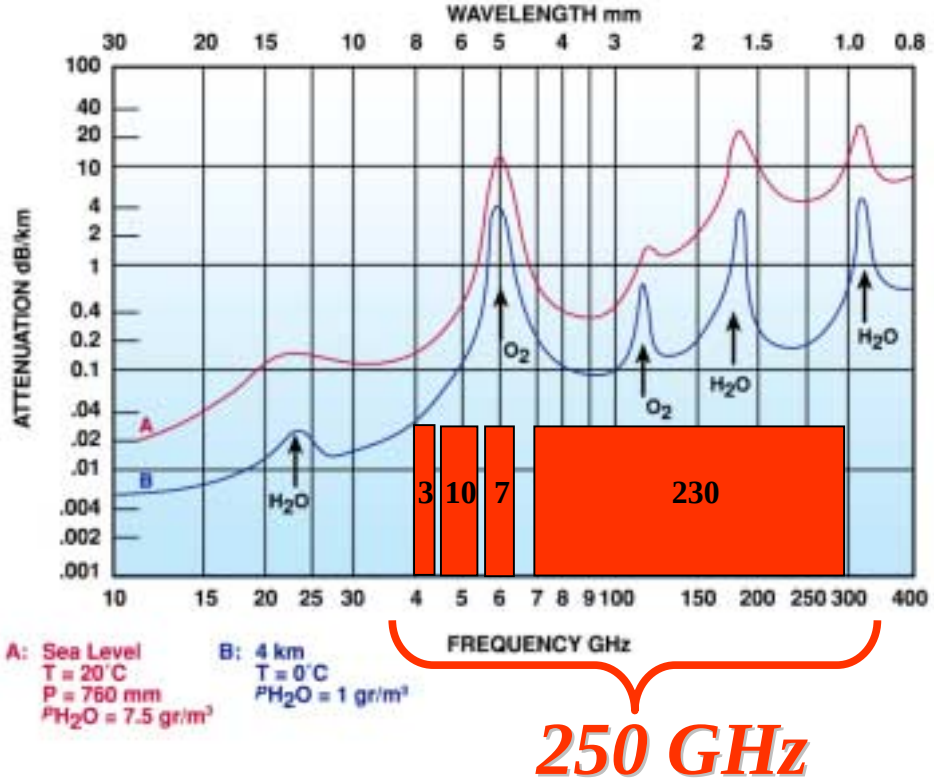
MM Wave systems 18-580 GHz

- Weather satellites: 18-400 GHz
- Radio astronomy: SWAS 550-580 GHz
- Imaging radar and radiometers: 94 GHz
- Level sensors and industrial sensors: 18-94 GHz
- Plasma reactor probes: 94 GHz
- Surveillance, Intelligence, and ESM: 18….

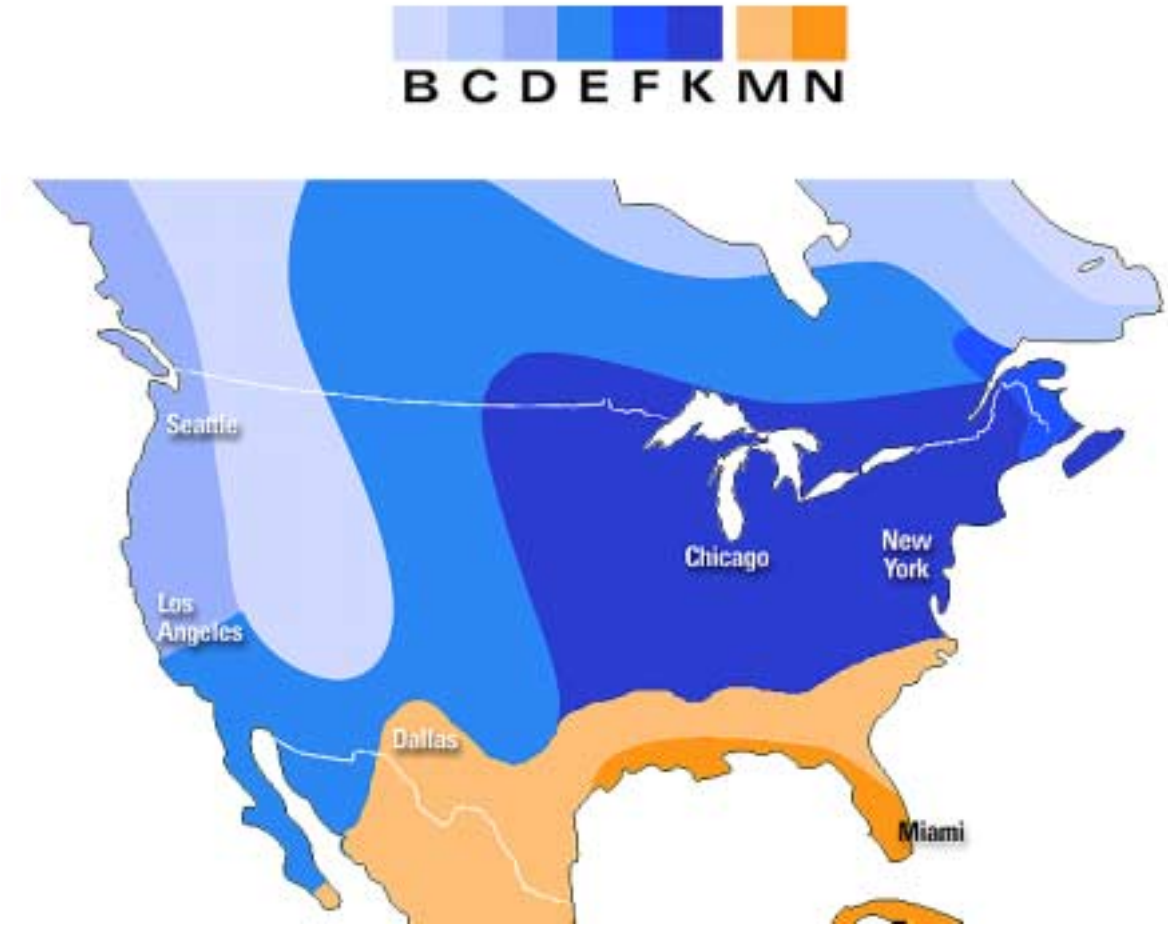
Technology and Performance

- MM wave propagation is well understood and proven
- Rain data is well quantified worldwide
- Long term propagation studies have validated the models
- There are very few surprises and the theory is very conservative

vvindows &
An Abundance of

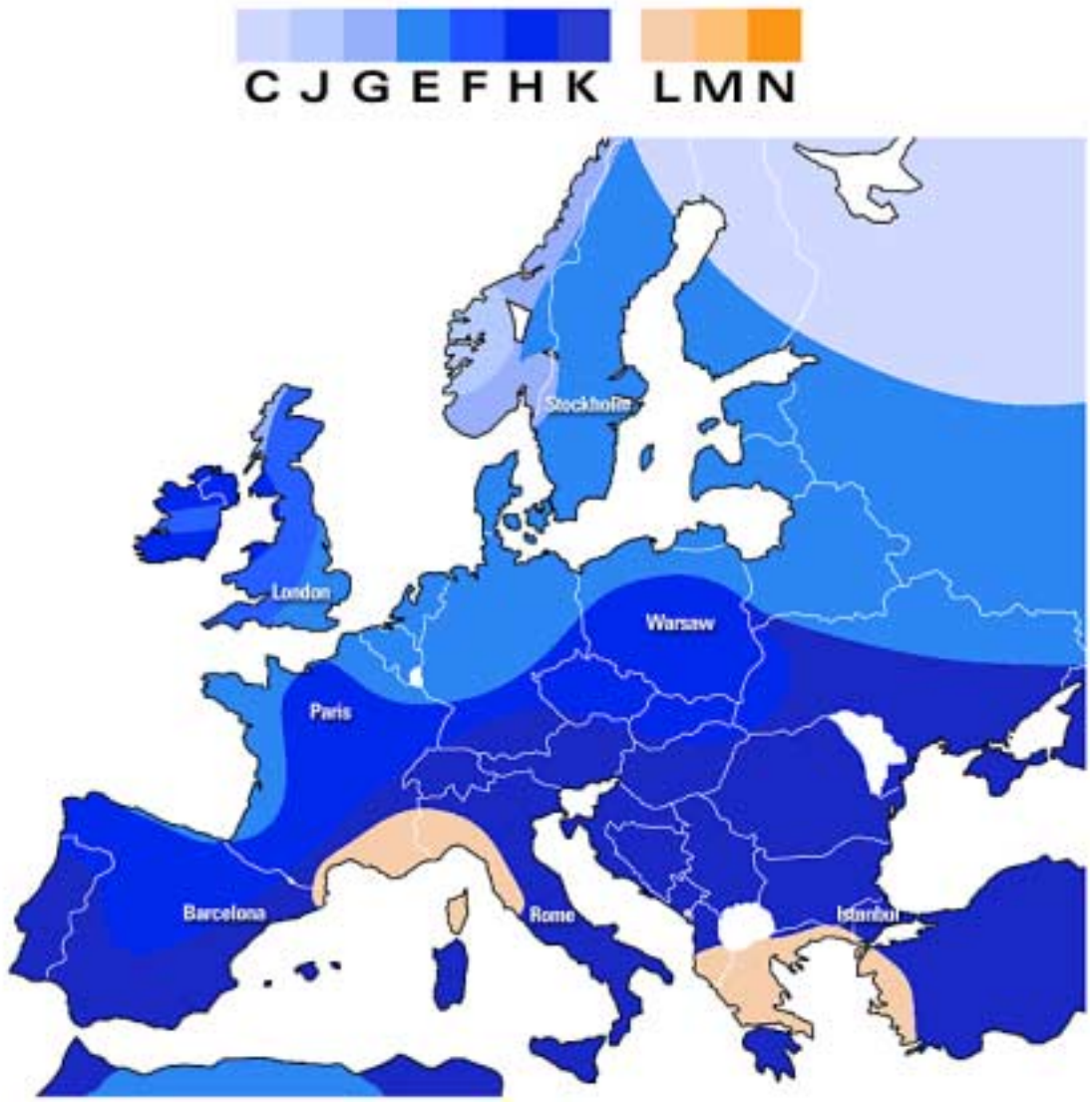


North American Rain Zones



- Almost all is Rain Zone K or better
- Rain Zone N is the worst case and is only the Gulf Coast

European Rain Zones

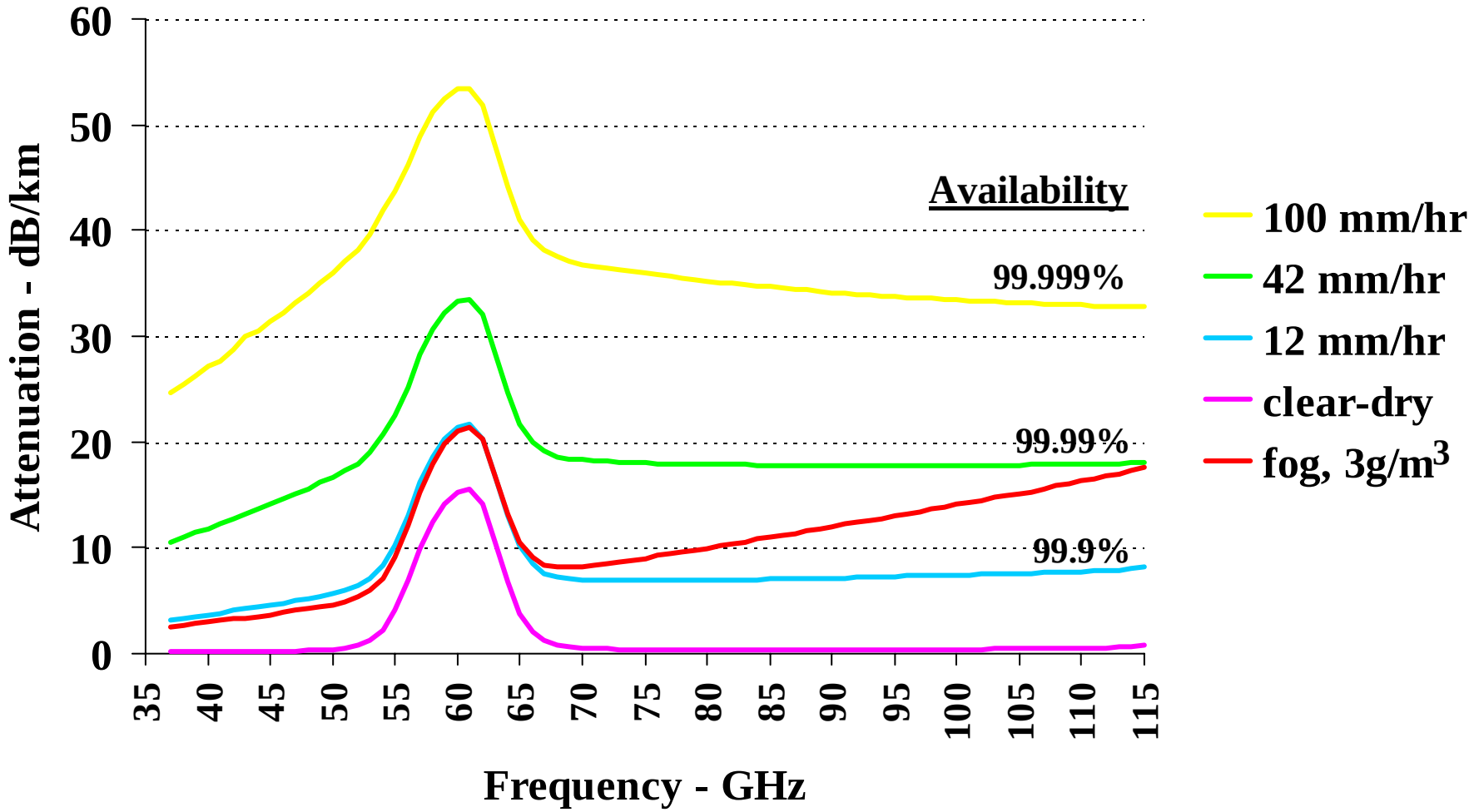


- Almost all is Rain Zone K or better
- Rain Zone N does not appear

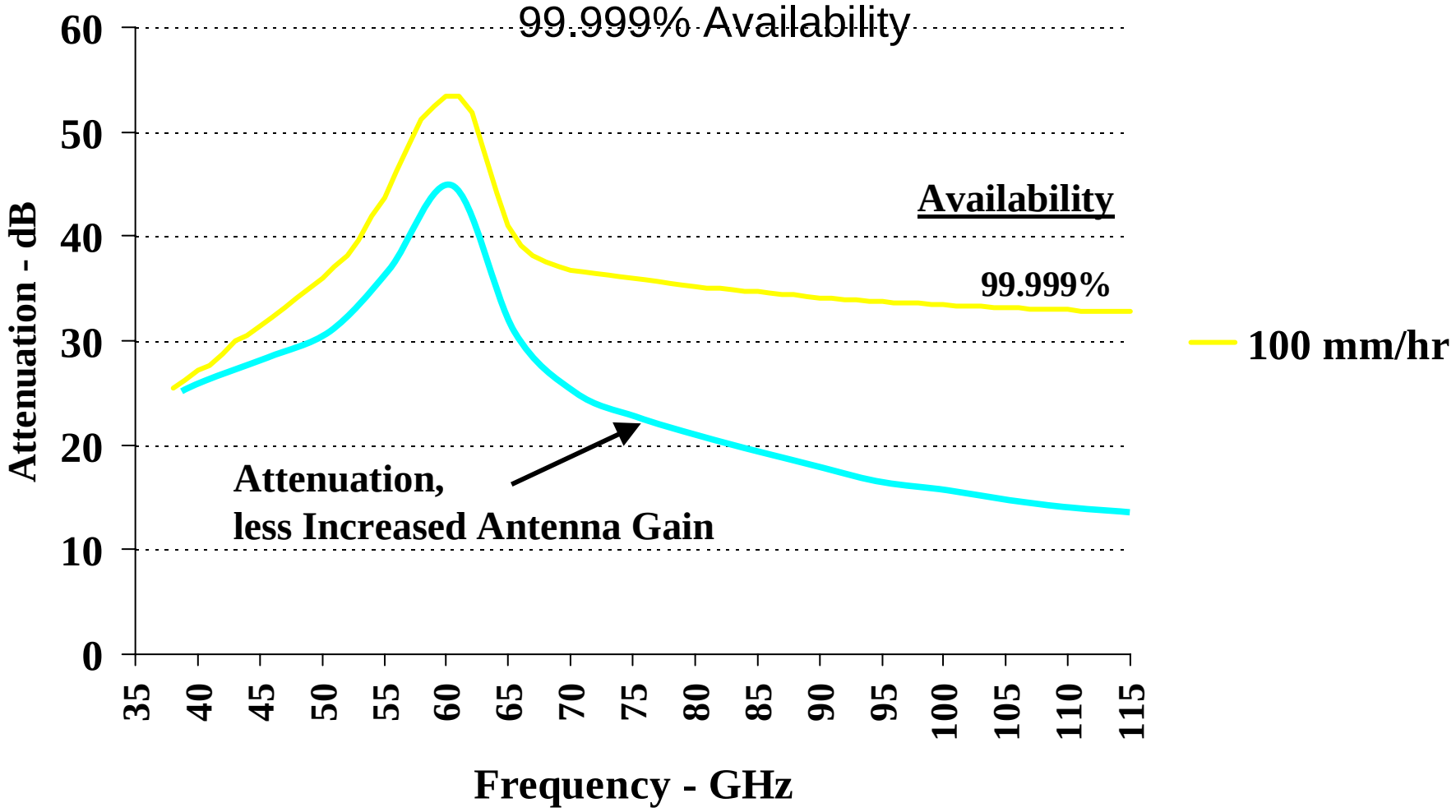
Telaxis COMMUNICATIONS

Rainfall Effects for Link Margin Analysis

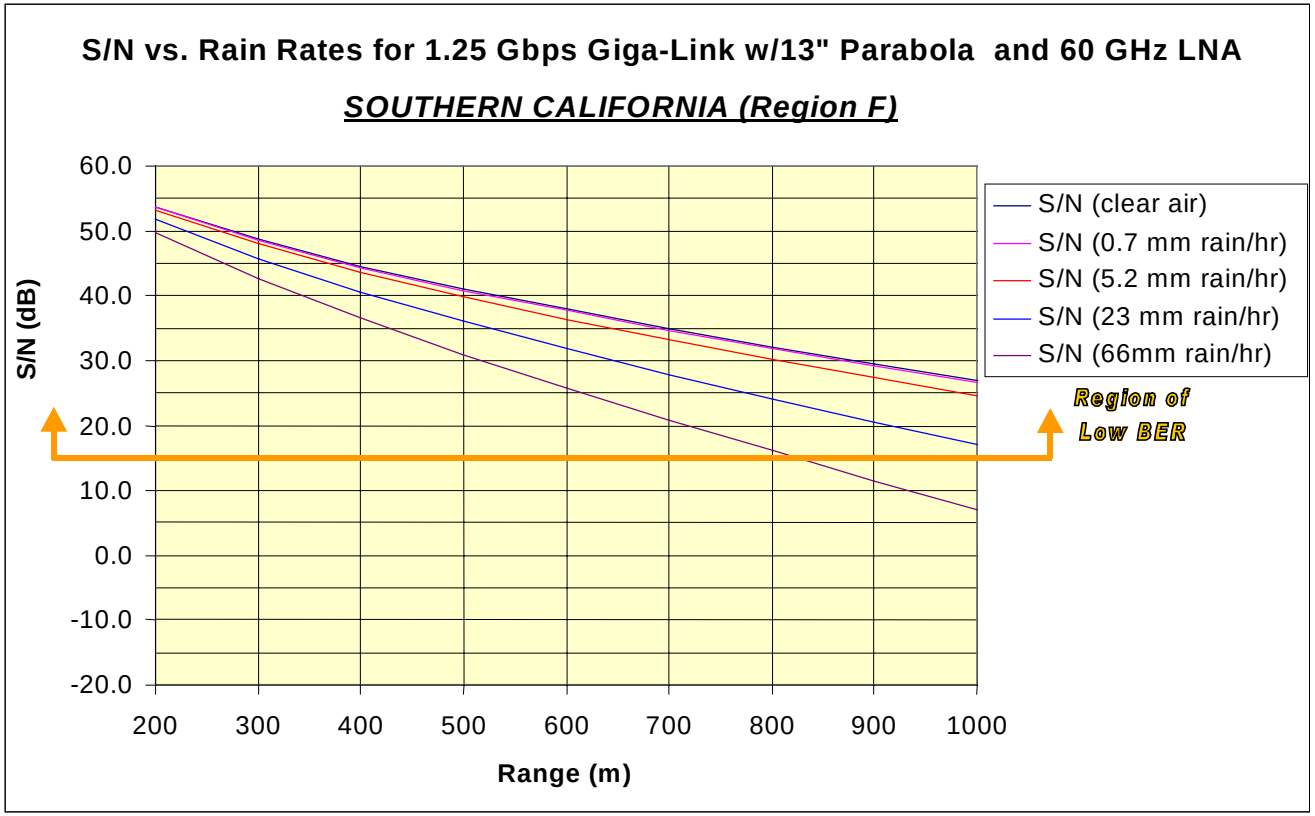
38 GHz to 115 GHz for Rain Zone K



Largely Offset by Increased Antenna Gain



GigaLink™ Family of Radios



Radio "UP" Time % of Year	Rain Rate (Region F) mm/Hr	Max. Range for BER = $1x10^{-7}$
99	0.7	1,496 m
99.9	5.2	1,373 m
99.99	23	1,057 m
99.999	66	825 m

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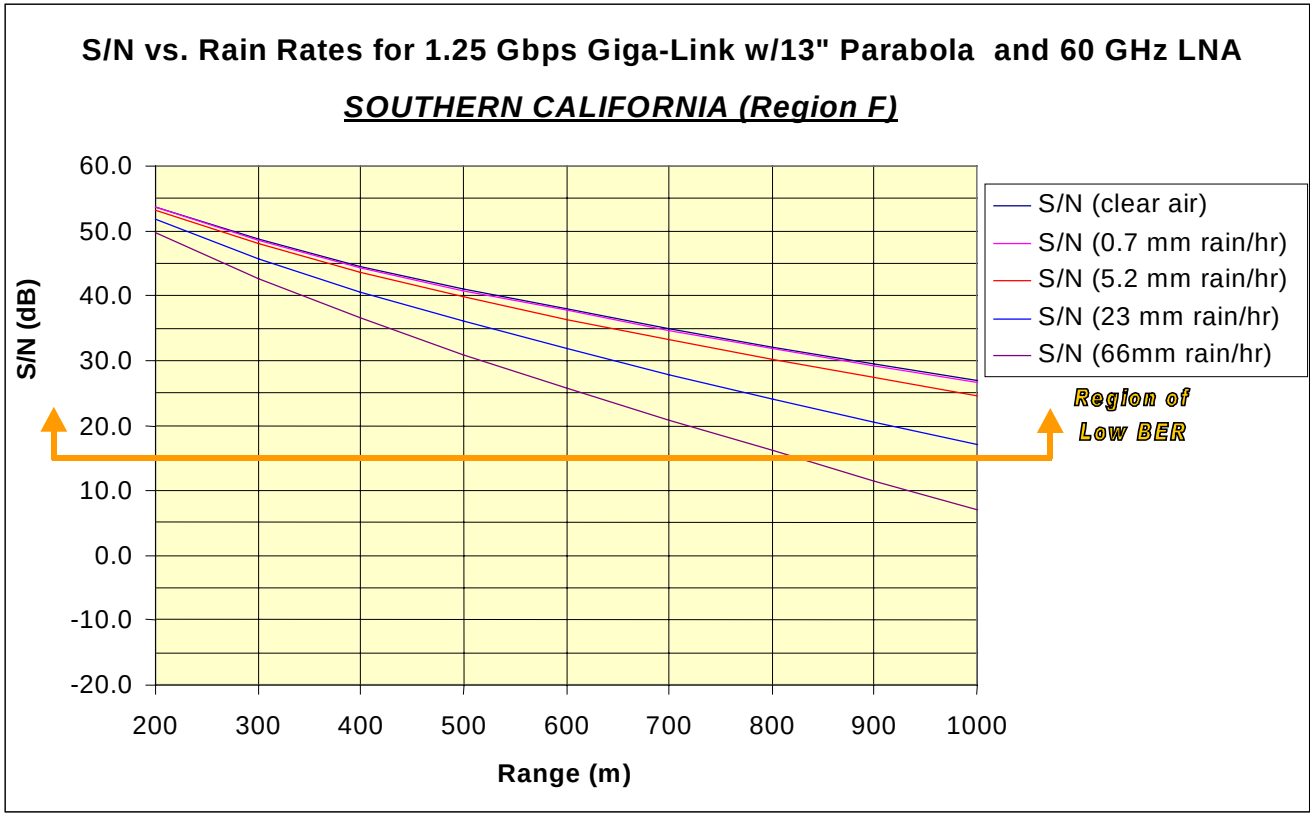

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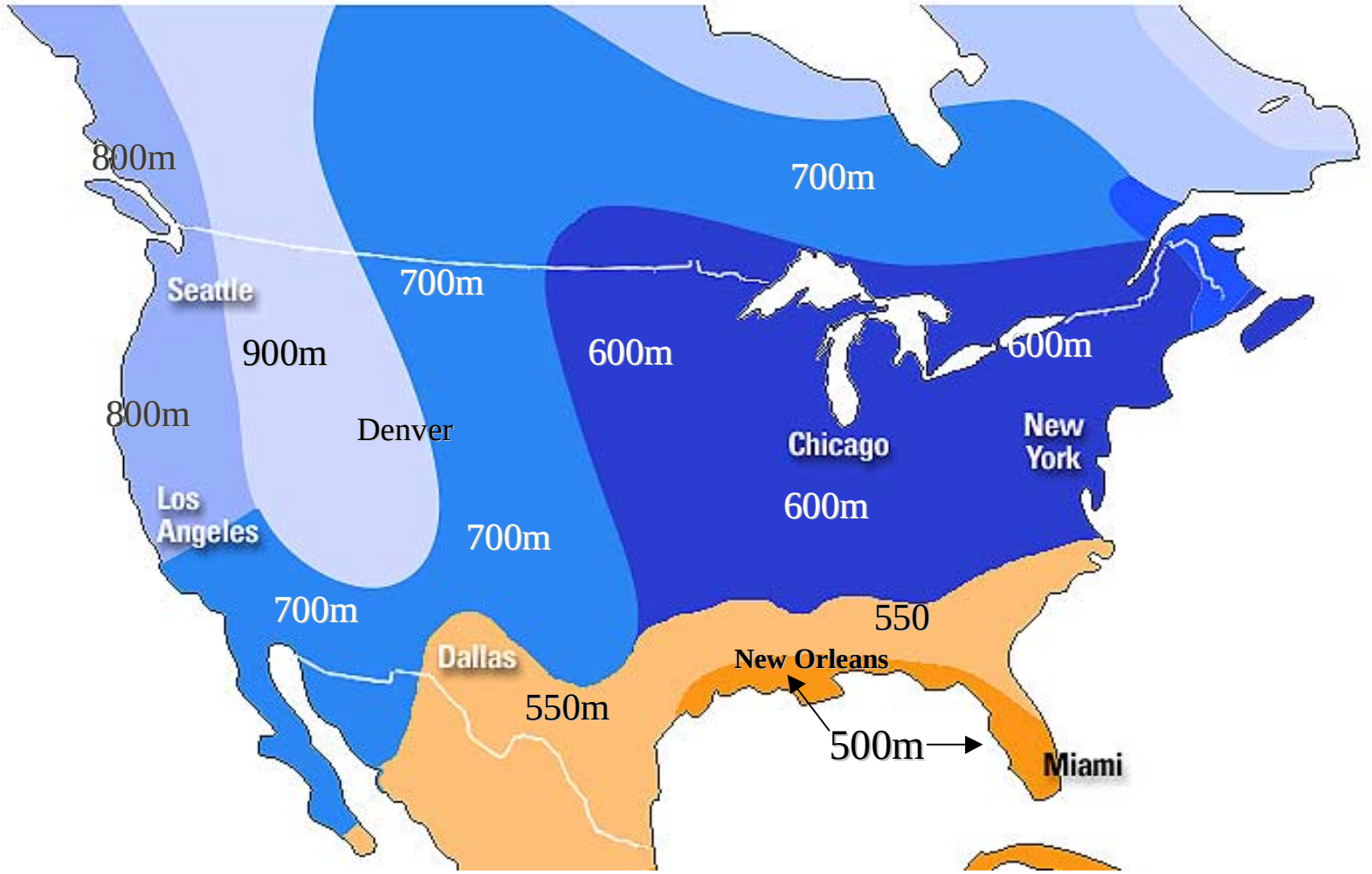
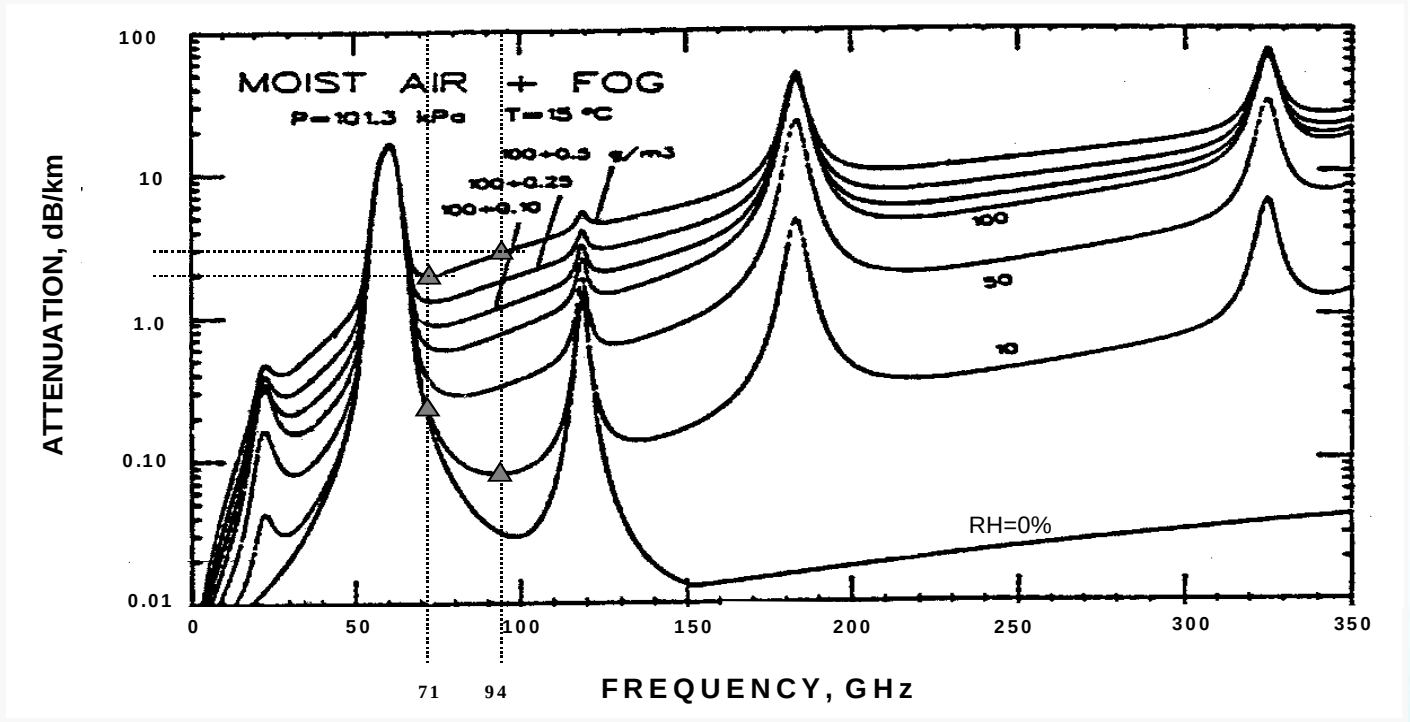
ITU Computed Distance at 99.999%*



* ITU Standard Rain Zones

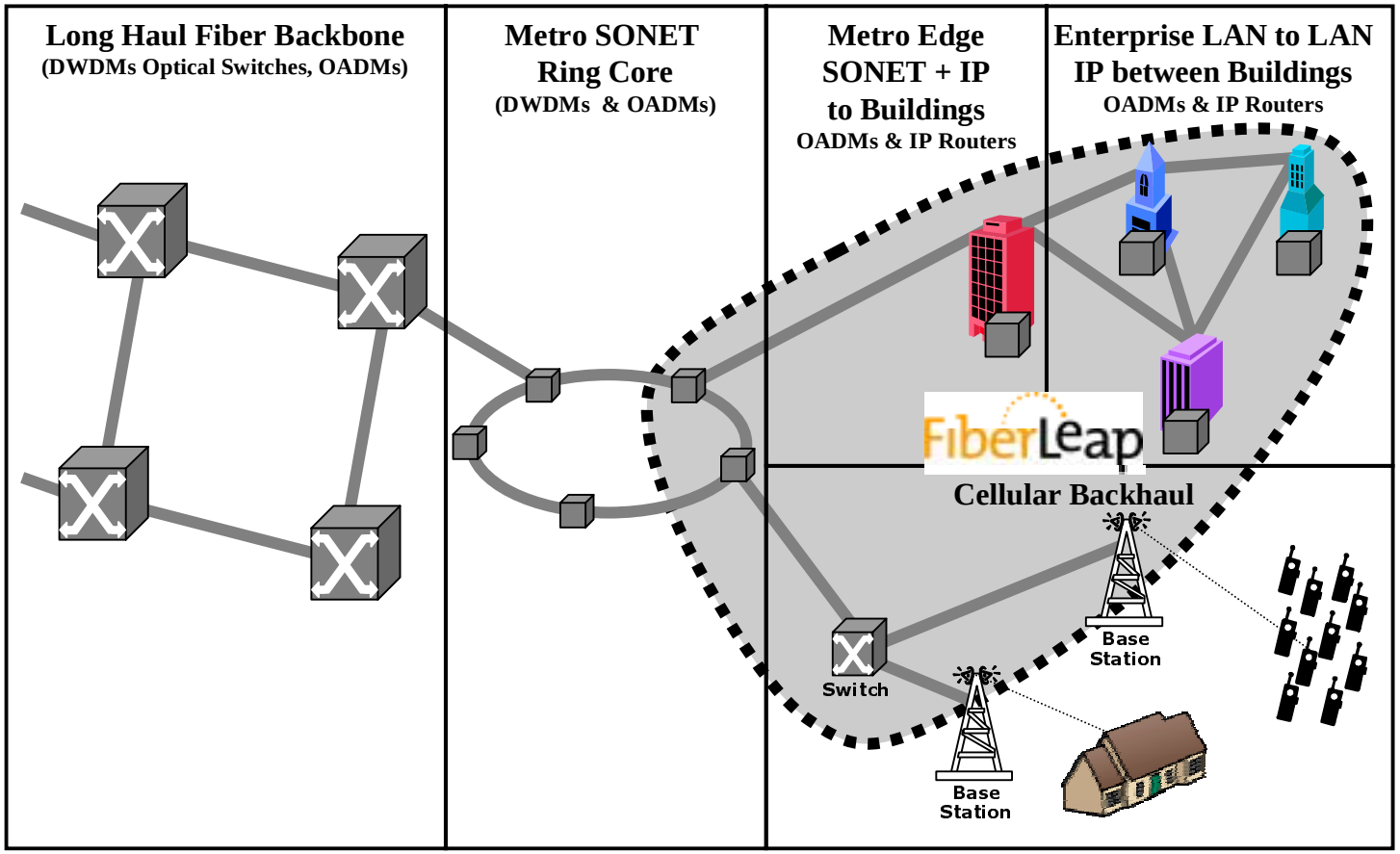
Atmospheric Attenuation at E-Band



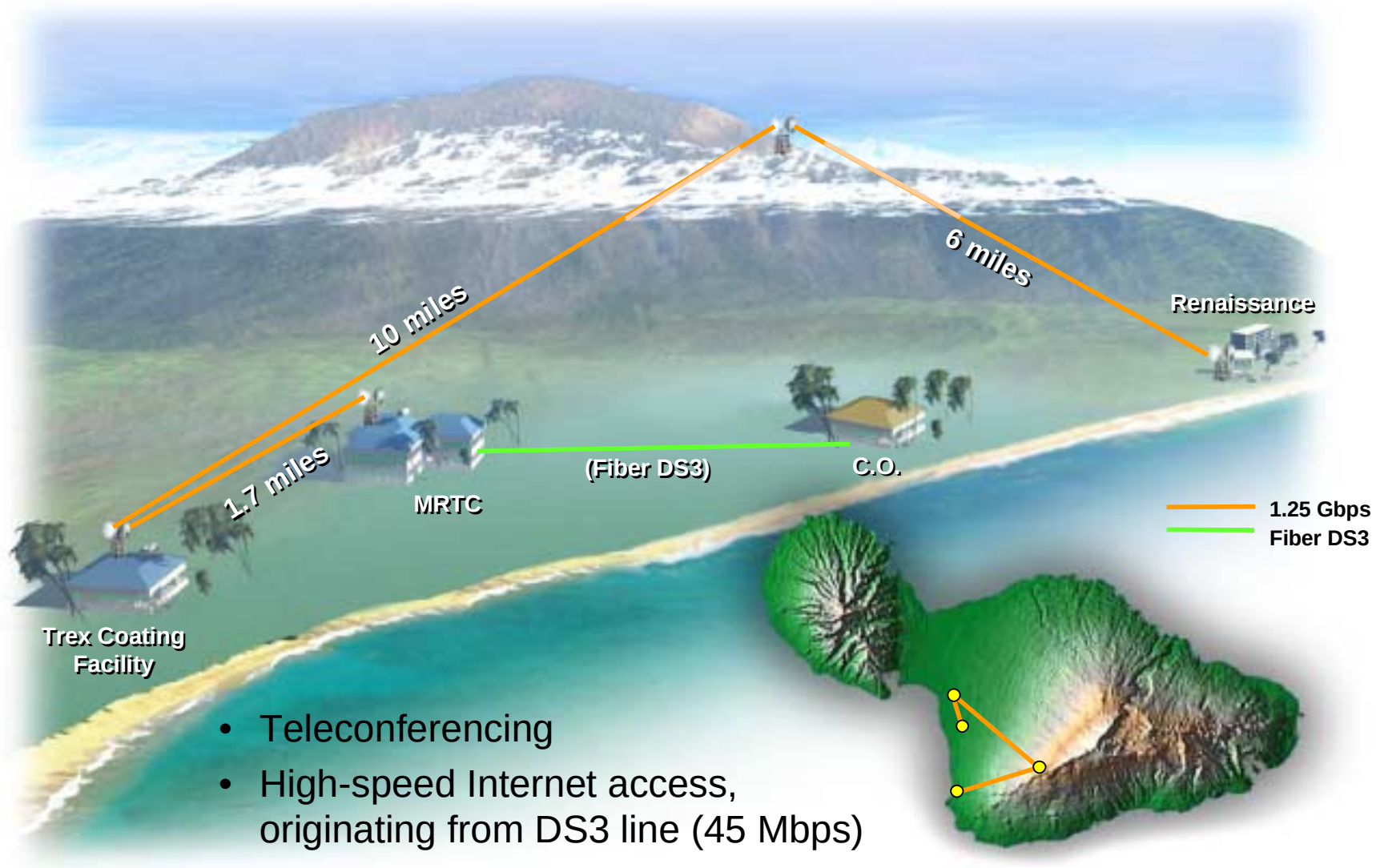
- Amospheric attenuation in dry air (10% RH at 15°C) has local minimum at 94 GHz (0.1 dB/km, versus 0.2 dB/km at 71 GHz)

Applications and Products

FiberLeap Applications in Fiber Networks



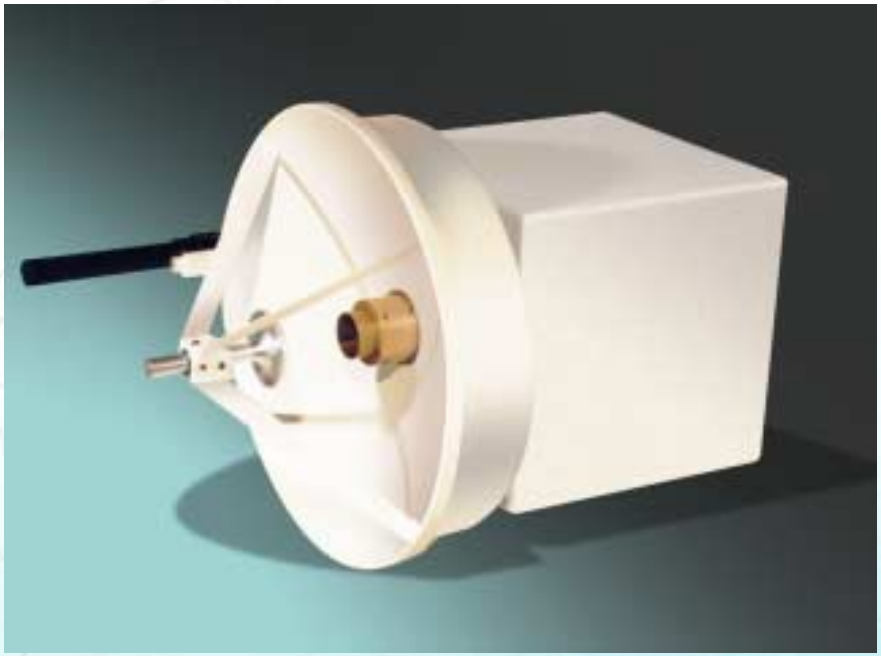
Prototype Technology Demo
January 2002, Kihei, Maui



- Teleconferencing
- High-speed Internet access, originating from DS3 line (45 Mbps)

Loea Prototype Transceiver Specifications

- Low-noise MMW transceiver
  - Separate Tx/Rx channels at 71.00-72.75 and 73.00-74.75 GHz
  - Simple on-off keying
- MMW Cassegrain dish antenna
  - 12, 24, 48-inch diameters (0.7, 0.4, 0.2-degree beamwidths)
  - 240 Watts ERP from 3-milliwatt transmitter (with 48-inch dish)



GigaLink™ Family of Radios

Half Mile Solution with Parabolic Antenna

GigaLink™ Family of Radios

Quarter Mile Solution with Patch Array Antenna

Latest Product

- Variable data rate: OC-3 to OC-12
- 1 Km “Typical” with 99.99% availability
- SONET/SDH, Gigabit Ethernet and Fiber Channel
- Direct fiber connection to Access Unit
- Integral high-gain antenna
- Roof, wall or window mount

Patents granted and pending

Regulatory Environment

Outline

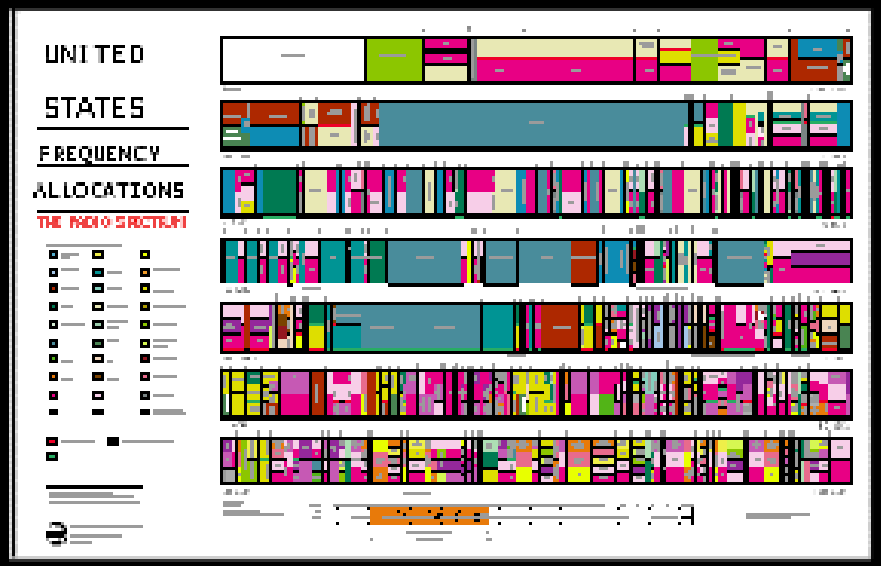
- US Spectrum Management Basics
- RF Safety Issues
- 30 GHz Band
- 55-80 GHz Band
- 90 GHz Band (W Band)
- Conclusions

US Spectrum Management Basics

- National Telecommunications and Information Administration (NTIA) controls all use by Federal Government
- FCC controls all use by private users and local government
- State Department has key role in ITU issues

US Spectrum Management Basics

- US national spectrum allocation table is created and managed jointly by FCC and NTIA



US Spectrum Management Basics

- In order to a band to be available for normal use, both allocations and FCC service rules are needed
- All new and modified rules need public comment - all comments are addressed in decision
- FCC presently has service rules as high as 77 GHz

mmW RF Safety Issues

- At mmW frequencies RF is generally absorbed at skin
- Eye damage is dominant concern
- FCC limit
  - Adopted in consultation with 4 other health-related agencies
  - For 1.5-100 GHz: 1 mW/cm^2 averaged over 30 minutes

55-80 GHz Band

- UK first suggested unlicensed use of 60 GHz area in 1989 noting effects of O_2 absorption
- EC selected 76-77 GHz for automobile radars around same time
- FCC adopted unlicensed 59-64 GHz and 76-77 GHz rules in 1995

55-80 GHz Band

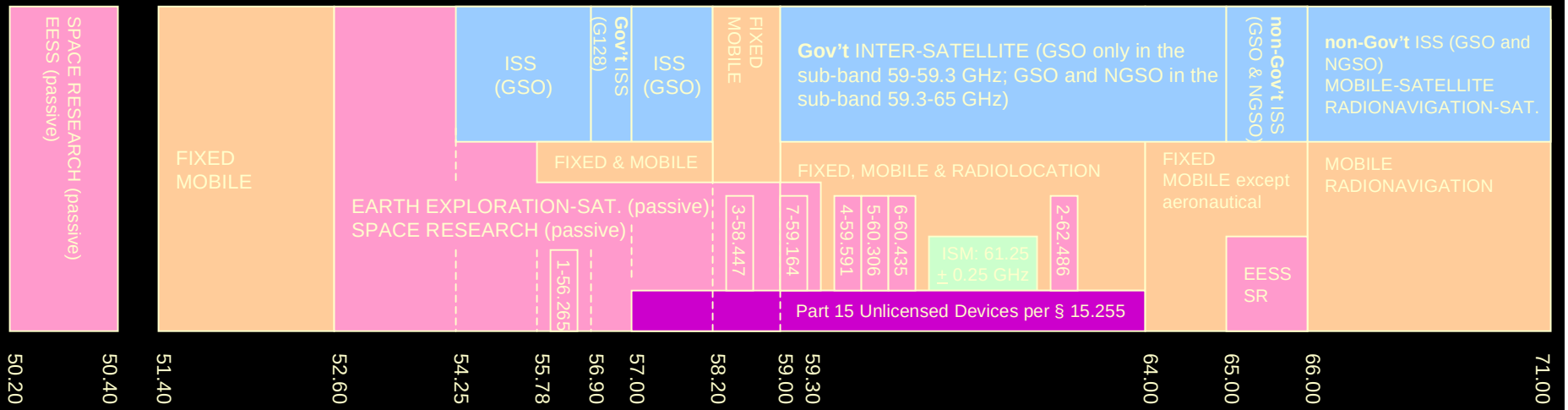
- In December 2000 overall bandplan revised slightly
- Unlicensed area now 57-64 GHz
  - All uses permitted *except* radar
  - First commercial product approved 11/2000

Harmonix Corp.

Gigalink - 622 Mbps

www.hxi.com

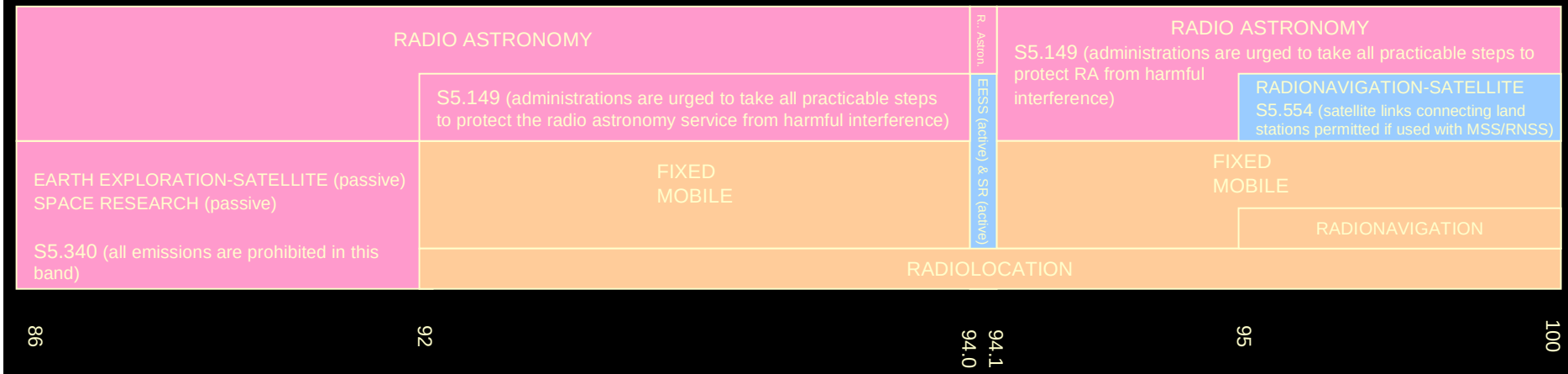
New 50-71 GHz Bandplan



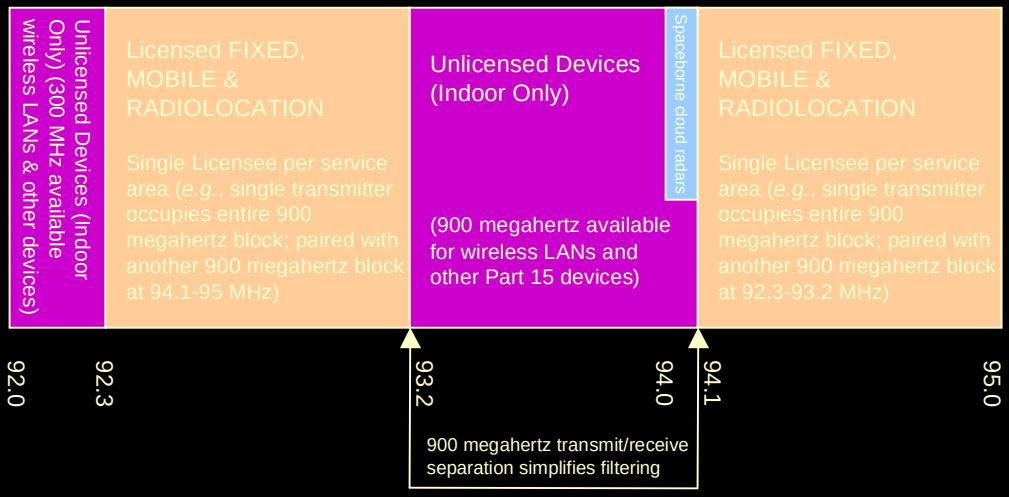
90 GHz Band (W Band)

- Technology in the US and Japan is now available for this band
- “Chicken and egg” problem may be discouraging development of products
- FCC plans to propose service rules this year
- 14 July 2000 FCC forum explored possible approaches with international industry

ITU 90 GHz Allocations



Example of 90 GHz Band Plan Being Considered by FCC



MMW Spectrum for Point-to-Point Communications

- 92-95 GHz – FCC Exploration, championed by Dr. Michael Marcus (OET) since mid-2000
  - OET forum July 14, 2000, first explored possible commercial uses for the 92-95 GHz band (follow-up at International Microwave Symposium last May)
  - Government co-primary in band, currently used widely for military radar and communications
  - Possibility of commercial spectrum auctions is concern for NTIA

MMW Bands Ideally Suited to High Bandwidth, Fixed Point-to-Point Communications

- Spectrum above 70 GHz uncluttered with existing services; modern needs can be addressed without concessions to historical constraints
- 71-76 GHz band alone contains more bandwidth than combined bandwidth of all MMDS, LMDS, and DEMS bands
  - Sufficient to accommodate Gigabit Ethernet (1.25 Gbps) and OC-48 (2.49 Gbps) full-duplex data transmission with simple modulation schemes

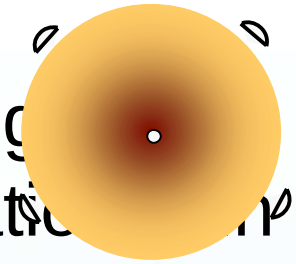
Higher Frequencies, Narrower Beams Alter Band Management Paradigms

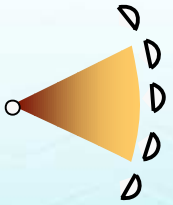
- Motivation for Band Management is to Allow Equitable Sharing of Airwaves as a Limited Resource

Below 5 GHz:

– As this resource becomes unlimited (e.g. case of free-space laser communication) motivation for band regulation disappears

– Omni-directional (Broadcast) transmission ⇒ high spectral scarcity; resolvable through spectrum parceling only; gives rise to band auctioning and geographical-area licensing





5 GHz – 40 GHz:

Petition Filed for Rulemaking in 71-76 and 81-86 GHz Bands

- Petition for Rulemaking filed with FCC 9/10/01 by Kelley, Drye & Warren on behalf of Loea Communications, recommending:
  - Fixed point-to-point licensing based upon existing Part 101 provisions
  - Third-party frequency/path coordination
  - Proscription of auctions and area-licenses
- Petition subsequently put out for comment

Proposed Service Rules for New Bands Use Existing Framework

- Based upon Existing Rules for Fixed Point-to-Point Microwave Services Listed under CFR Section 47, Part 101; Adding 71-76 and 81-86 GHz Bands with:
- Authorized Bandwidth - Part 101.109(c) – Max bandwidth: 5,000 MHz, each band
- Transmitter Power, Part 101.113(a) – Maximum EIRP: +55 dBW
  - Commensurate with other band limits above 19.7 GHz
- Antenna Gain/Beamwidth, Part 101.115(c) – Min. Gain: 50 dBi, Max. HPBW: 0.6°
  - Gain 12 dB higher than other bands above 19.7 GHz
  - Enables spatial-parceling paradigm
  - Precise proposal limits await consensus of WCA Above-60 GHz Committee
- Modulation Spectral Efficiency - Part 101.141 – No limits
  - Commensurate with other bands above 19.7 GHz

Proposed Coordination/Licensing Procedure for Fixed P2P Use of 71.0-76.0 GHz and 81.0-86.0 GHz

- Based upon existing coordination and licensing procedures for point-to-point microwave services listed under FCC Part 101
- Frequency/Path Coordination, through third-party entity, required prior to FCC application, provides temporary interference protection
- FCC application and point-to-point

Standards

Frequency Coordination

- MUST harmonize international allocations
- MUST harmonize international standards
- MUST harmonize service rules

Standards

- Organizations to date
  - IEEE 802…..
  - WCAI above 40 GHz working group
    - Doug Lockie and Wayne Pleasant Co-Chairs
      - 10-12 company participants
  - ETSI
    - BRAN
    - TM

High Altitude View

- Bandwidth must be allocated in large chunks without detailed channel assignments
  - Low order modulation
  - Saturated operation to achieve power
  - Minimal data formatting and FEC
  - Phase noise and stability issues
- Interface standards should be “radio friendly”
  - No DC/low frequency signaling
  - Near constant bit rate
  - PTP protocols

- 1, 10, 40, 100 Gigabit Ethernet will rule
- Sonet SDH and PDH will continue to need support for legacy applications
- Fiber optical interfaces and compatibility will be necessary
- Transparency to existing and proposed protocols
- Fixed wireless backhaul may require unique and dedicated data formats

And Finally…..

- Suggest starting a study group to look at the issues
- Be prepared for rapid frequency expansion above 100 GHz
- Fiber optical , laser, and MM wave technology is converging, finally.

Contributors

- Mike Marcus: FCC
- Dana Wheeler: Harmonix
- John Lovberg: Trex/Loea
- D. Emerson: NRAO
- Patrick Newton: Millitech LLC

Thank you