zero

WCA
WIRELESS COMMUNICATIONS ALLIANCE

UWB - The Coming Wave

Rajeev Krishnamoorthy
February 17, 2004

Agenda

- Overview
- Market
- UWB characterization
- Technical Aspects
- Guiding Principles and Challenges
- The Opportunity

Goal

Reliable Wireless Gigabit links to enable complete connectivity in homes and enterprises

The Vision


Broadband services:
Cable, xDSL,Satellite,
Terestrial
Home Gateway
Monitor
Camcorder
DVD
Desktop
computer
Printer
PDA
Audio
TV
Laptop
computer
Digital
Camera

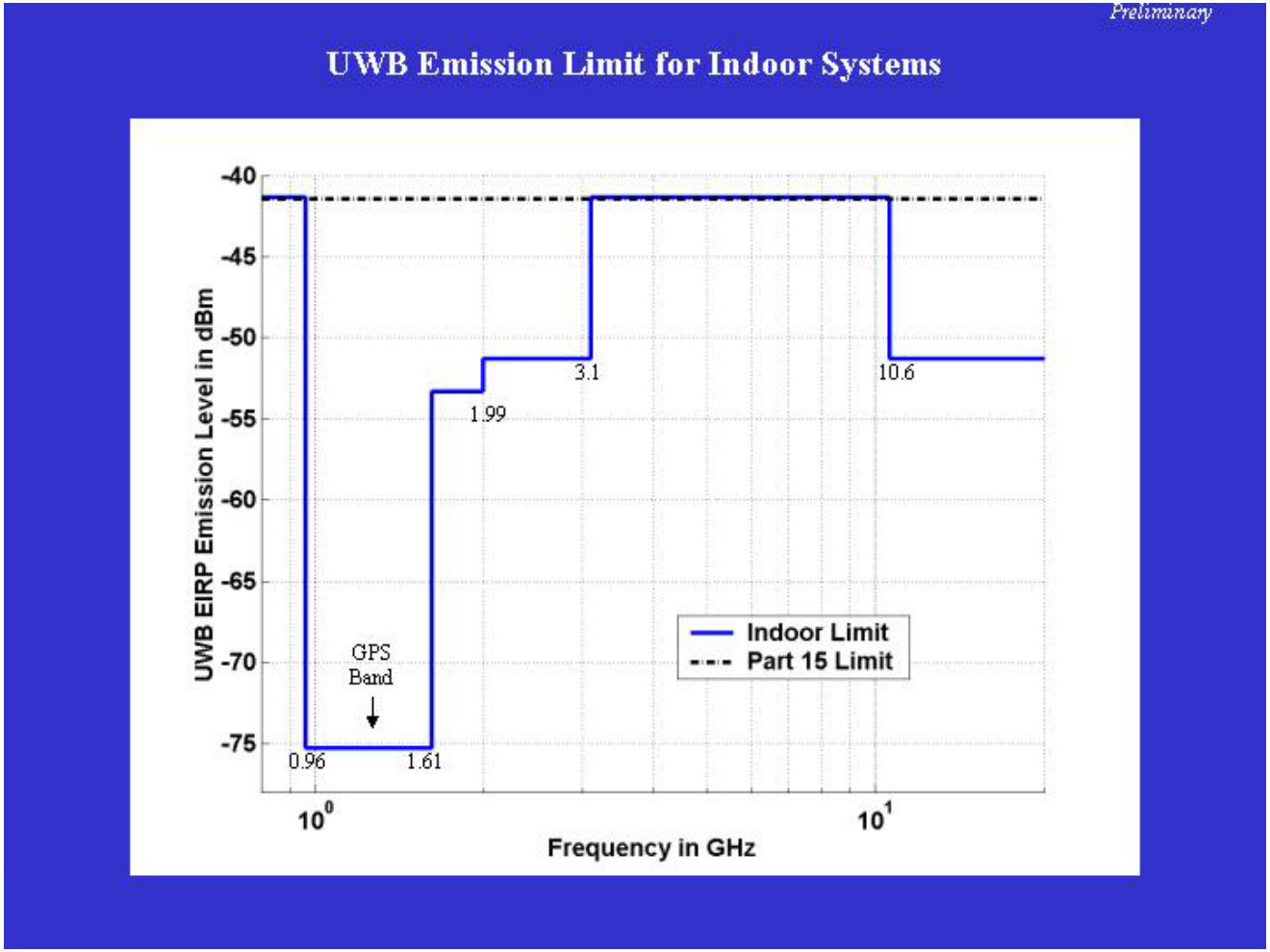
What is UWB?

FCC Report & Order issued in early 2002

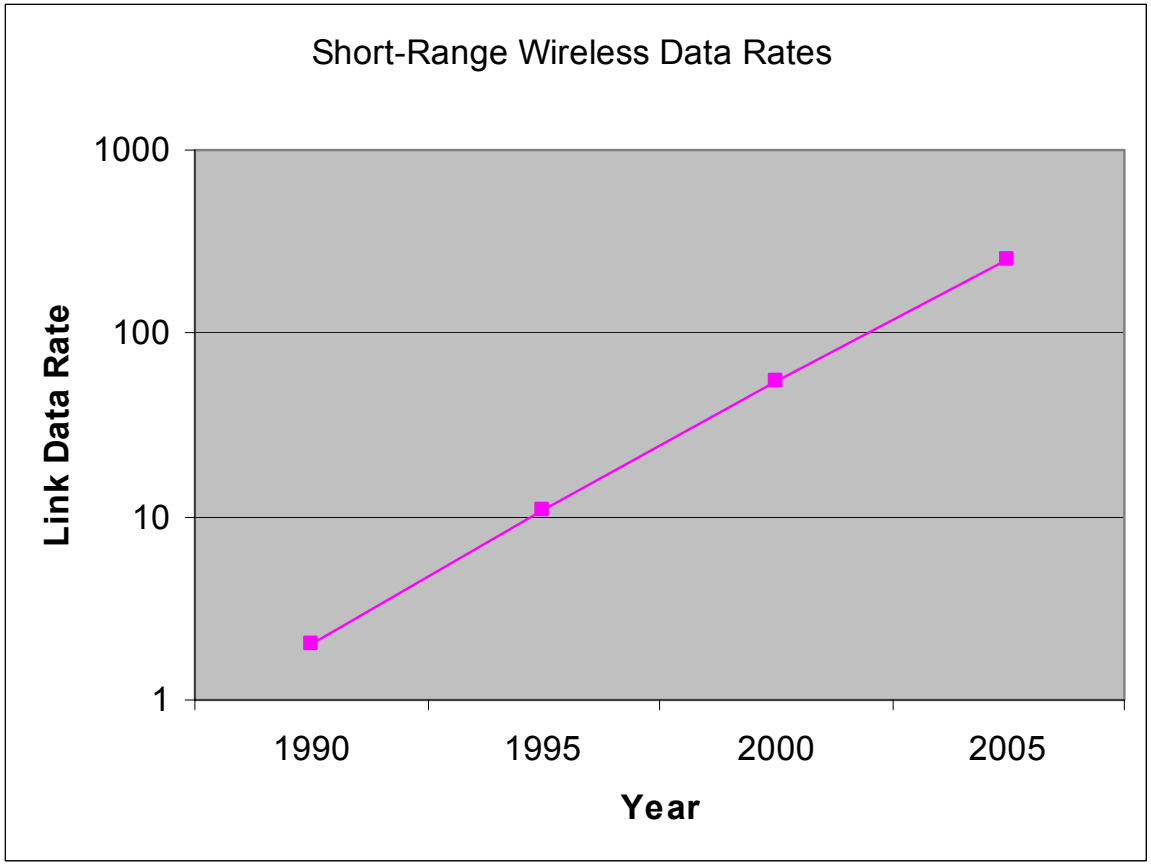
Allocates 7.5 GHz for Ultra Wideband Systems

- Large Bandwidth
- Very low power
- Unlicensed

Power Limits



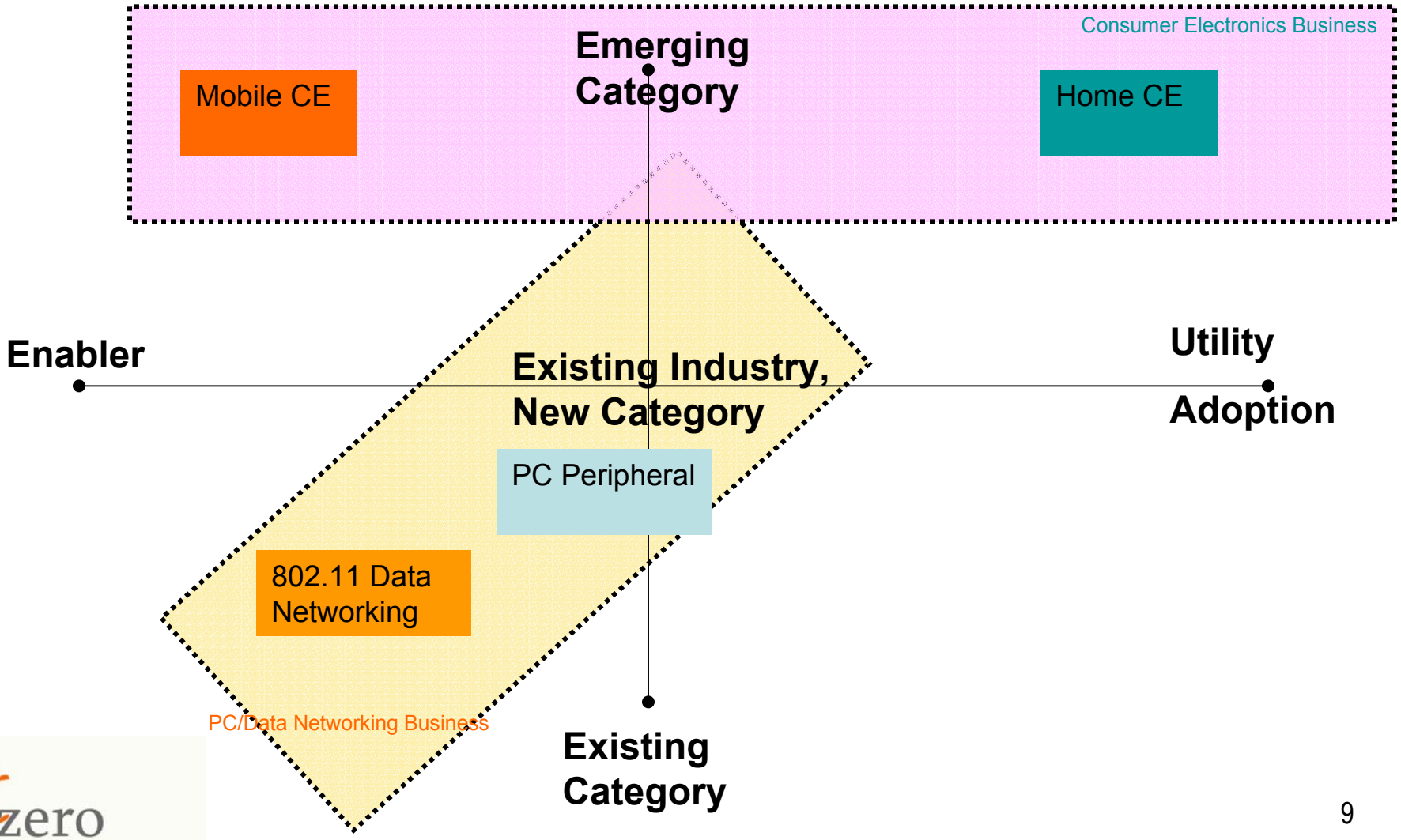
Why is this inevitable?



5x every 5 years == Storage CAGR
Content Transmission

Markets

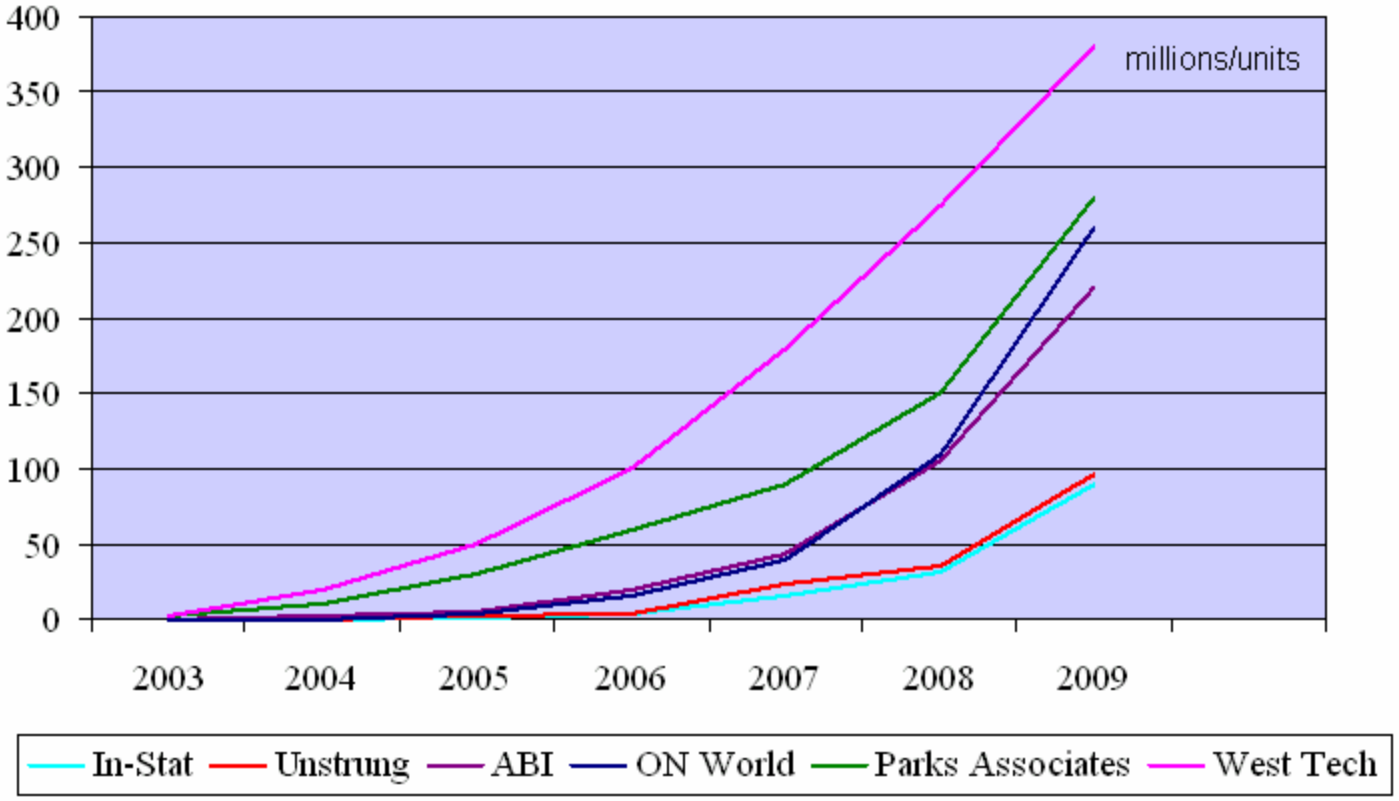
Market Segments



Device and Application Requirements

Characteristic	VGA	SVGA	XVGA	SXVGA
Horizontal pixel count	640	800	1024	1280
Vertical pixel count	480	600	768	1024
Total pixel	307200	480000	786432	1310720
Total bits @ 16bit color	4915200	7680000	12582912	20971520
Total bits @ 24bit color	7372800	11520000	18874368	31457280
Mbit/s at a minimum animation of 30 frame per second- 16 bit col	147	230	377	629
Mbit/s at a minimum animation of 30 frame per second- 24 bit col	221	345	566	943
Mbit/s after compression	6 - 32	15 - 50	20 - 70	30 - 100
	(DVD)	(projector)	(laptop) (projector)	(PC to monitor)

Projected Volumes



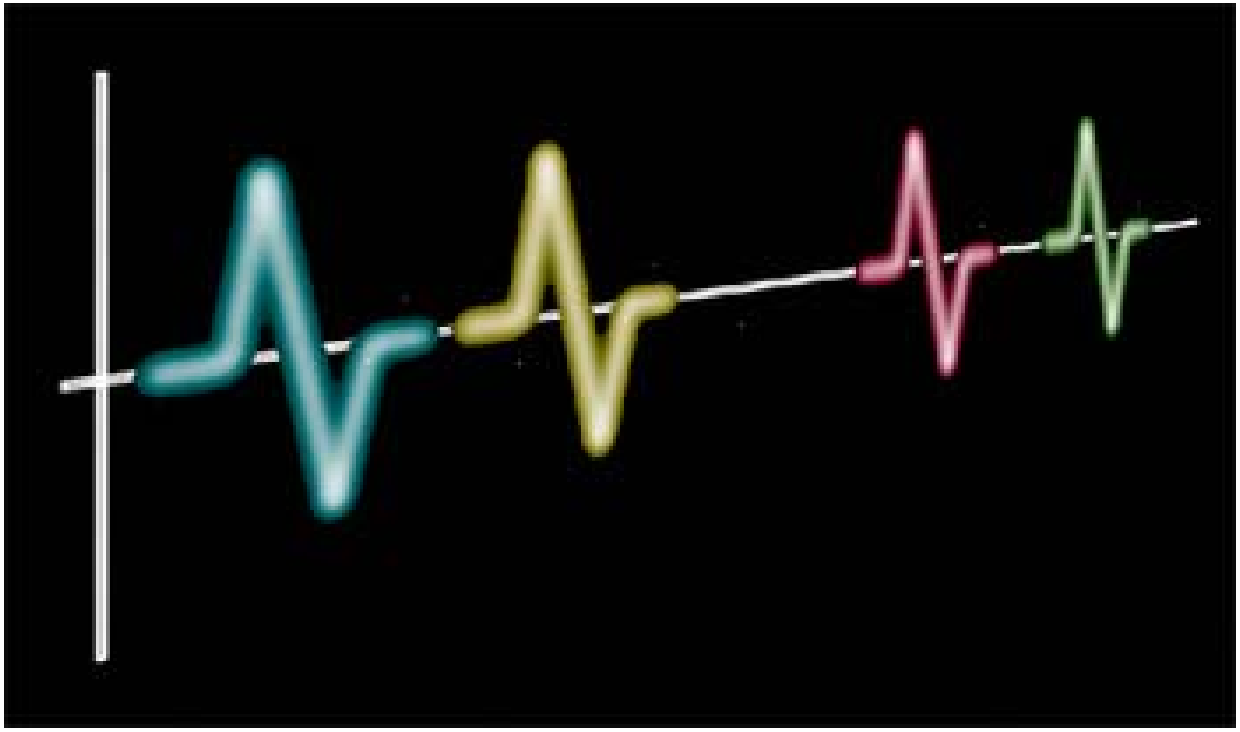
Source: OnWorld, Nov. 2003, “UWB: Poised to Transform the Wireless World”

History

A (very brief) history

- Military uses
  - Detection avoidance
  - Imaging, ranging
- The past decade
  - Regulatory approval
  - Development of carrierless systems
    - RF implications
  - Applications
    - Low-power, low bit rate
    - Position location, imaging
    - The beginnings of high data rate communication

Impulse Radio
One of the original ideas



Current Status

- Standardization effort underway
  - Considerable interest and participation from
    - Large semiconductor manufacturers
    - Consumer Electronics vendors
    - Startups
- Market understanding and segmentation
  - Experience from initial efforts with 802.11
- The merging of data networks and A/V in the home

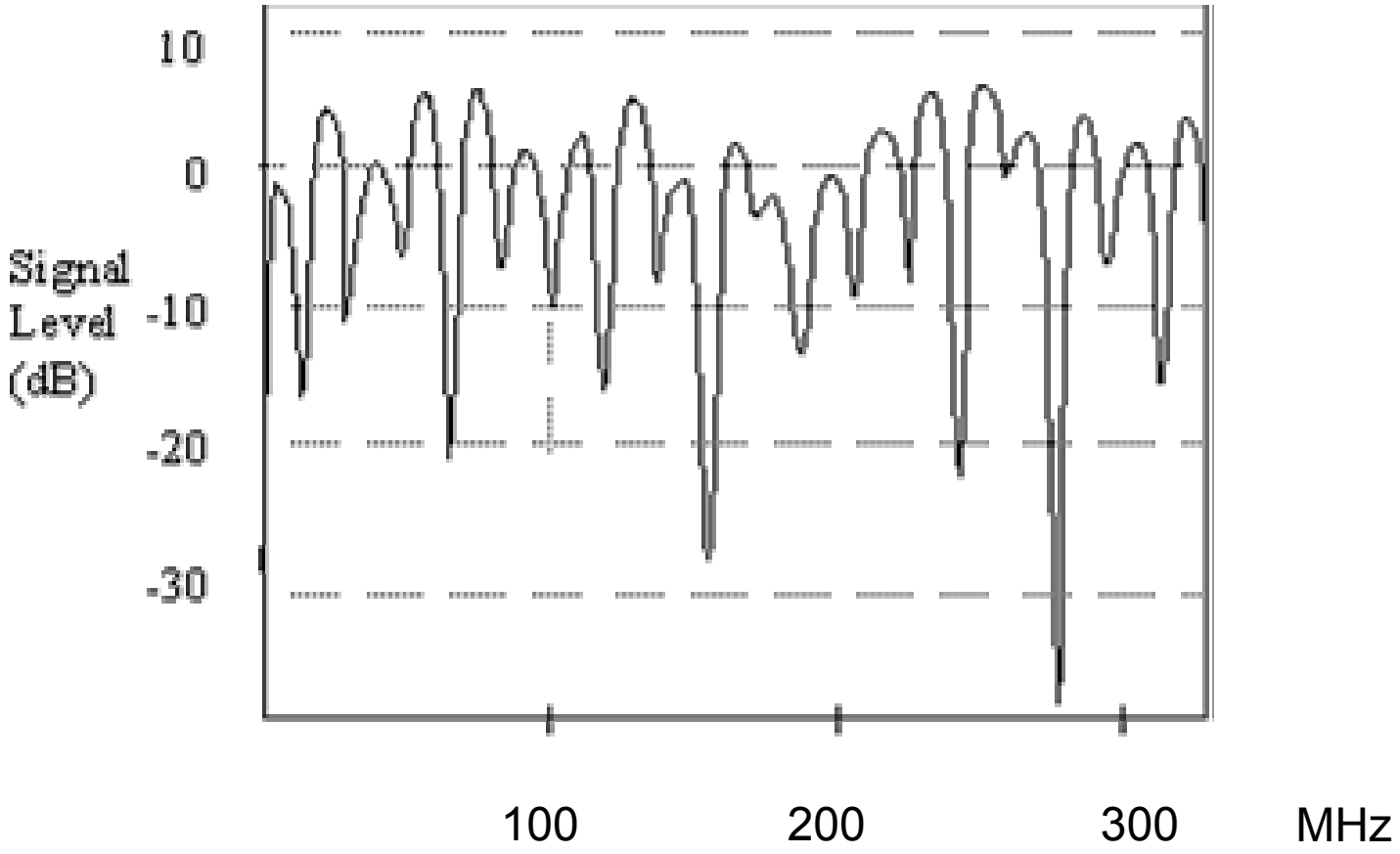
zero

UWB Technical Characterization

Key UWB Attributes

- **Bandwidth**
  - Huge!
    - 7.5 GHz is 10-100 times larger than any other allocation
- **Power**
  - Miniscule!
    - About a millionth of other wireless systems
- **Interference**
  - Huge!
    - Raw interference could be about a million times larger than desired signal

Frequency Diversity
One of the inherent advantages



What does this get us?

Capacity is

$$C = B\ \log_2\left(1+\frac{S}{N+I}\right)^{*} \qquad \left\{+B\ \log_2\left(1+\frac{S}{N+I}\right)+\ldots\right\}$$

With large bandwidth, low power, and high interference

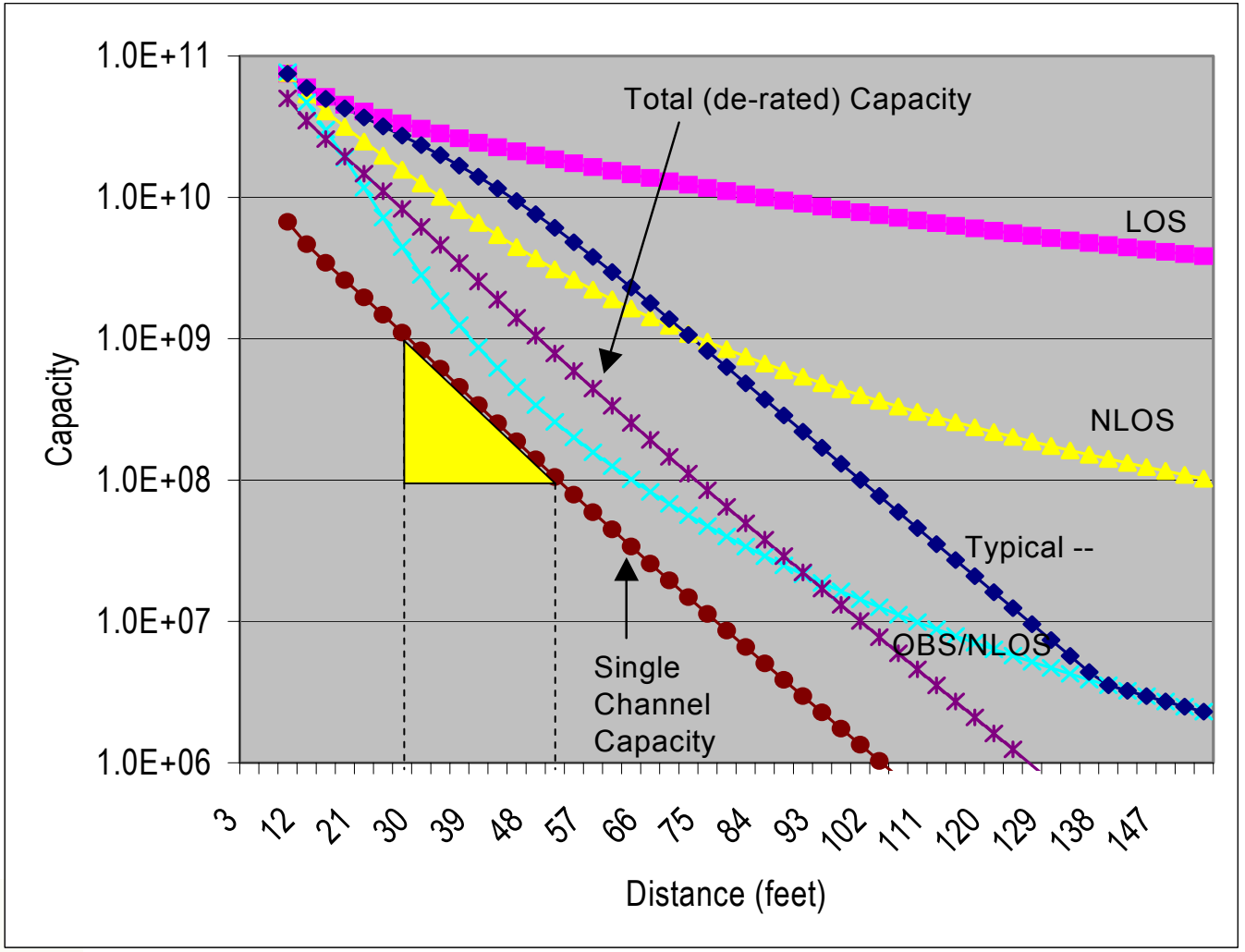
$$C \to \infty \times 0\,!$$

Calls for a fresh new approach
(Shannon's Law is not the relevant metric)

* *Assuming interference is noise-like*

zero

Capacity and Link Rates



Opportunities & Challenges

Attribute	*Opportunity*	*Challenge*
Bandwidth	•Potential for huge data rates (10-100x) and capacity •"Waste" spectrum to gain other benefits	•Synchronization •Very high speed processing •Broadband non-resonant circuits
Power	•Coexists with other wireless systems •Transmitter can be made power efficient	•Receiver design •Signal Extraction
Interference	•Hostile Interference: Robust operation in almost any environment •Self-Interference: Multiple Devices, Capacity	•Very powerful, narrowband interferers Omnipresent unintentional emissions •Robust performance critical for multiple device operation, networks

Final Thoughts

Some Guiding Principles

- Degrees of freedom
  - Bandwidth is good
  - power is secondary
  - space is icing on the cake
- Hardware complexity is preferred (in moderation) to control complexity
- Priorities
  - It works, it works well, many work well, low power and cheap

Summary – the Highlights

- Interference
  - Self, alien, bursty, continuous, in-band, out-of-band
- Link & System Range
  - Application specific, cable-replacement length insufficient
- Reliability
  - Substantially higher than for data, no retransmissions
- Multi-user capacity
  - Enable multiple colocated devices & users
- Power
  - Chipset/module: instantaneous and ongoing
  - 10% of battery life
- Cost
  - Volumes, die size, system cost, commodization

What's Exciting About This?

- **A Huge Opportunity**
  - The natural progression from WANs and LANs to wireless picocellular networks & cable replacement
- **A Tough Job**
  - Very high barrier to entry
- **A Broad Swathe**
  - Enables huge capacity in a given volume of space
  - Can be used in a number of vertical applications

What will make this happen?

- **Regulatory: The largest unlicensed spectrum allocation**
  - Enables very large capacity
  - Technology ownership will determine market success
- **Product: Process Technologies and CAD Tools**
  - Enable low-cost wideband RF and fast Digital ICs
- **Market Driver: The Digitization of Multimedia**
  - Growth in content