Singapore Ultrawideband Programme

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Ultrawideband (UWB) Wireless

- Brief UWB Overview
- Evolution of UWB Modulation Methods
- Spectral Sculpting and OFDM
- UWB as Precursor to Cognitive Radio

Ultrawideband (UWB) Technology

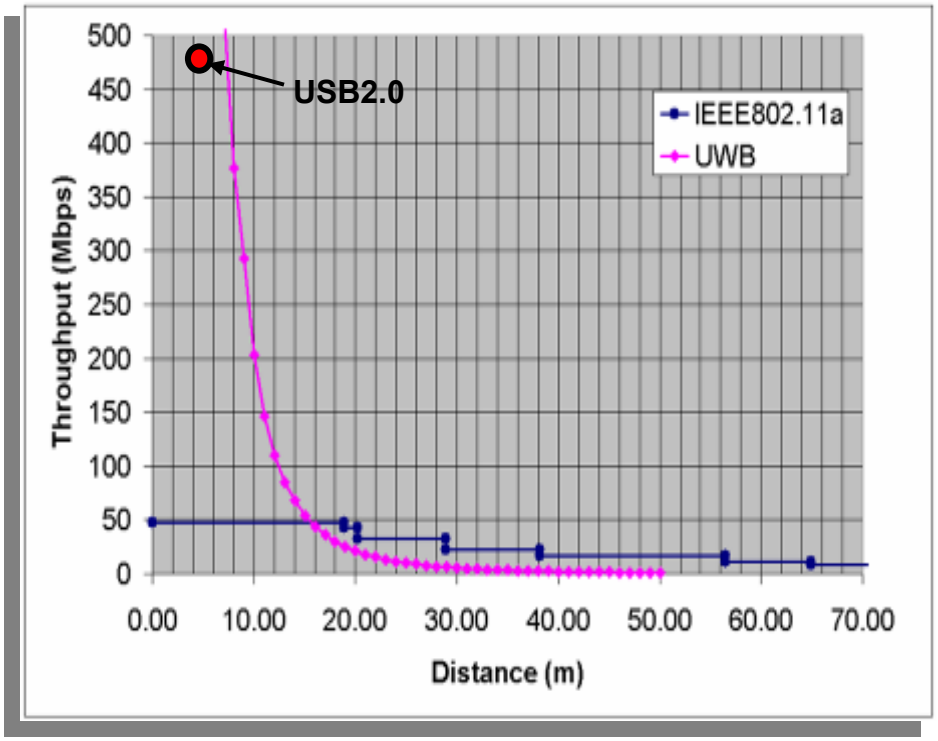
What is UWB?

- Unique RF technology formerly classified for military applications
- Declassified in mid 90s with Feb, 2002 FCC commercial use approval
- Uses wide spectrum (3.1-10.6 GHz)
- Initially narrow-pulse-based; now many favor OFDM-based modulation

What is compelling about UWB?

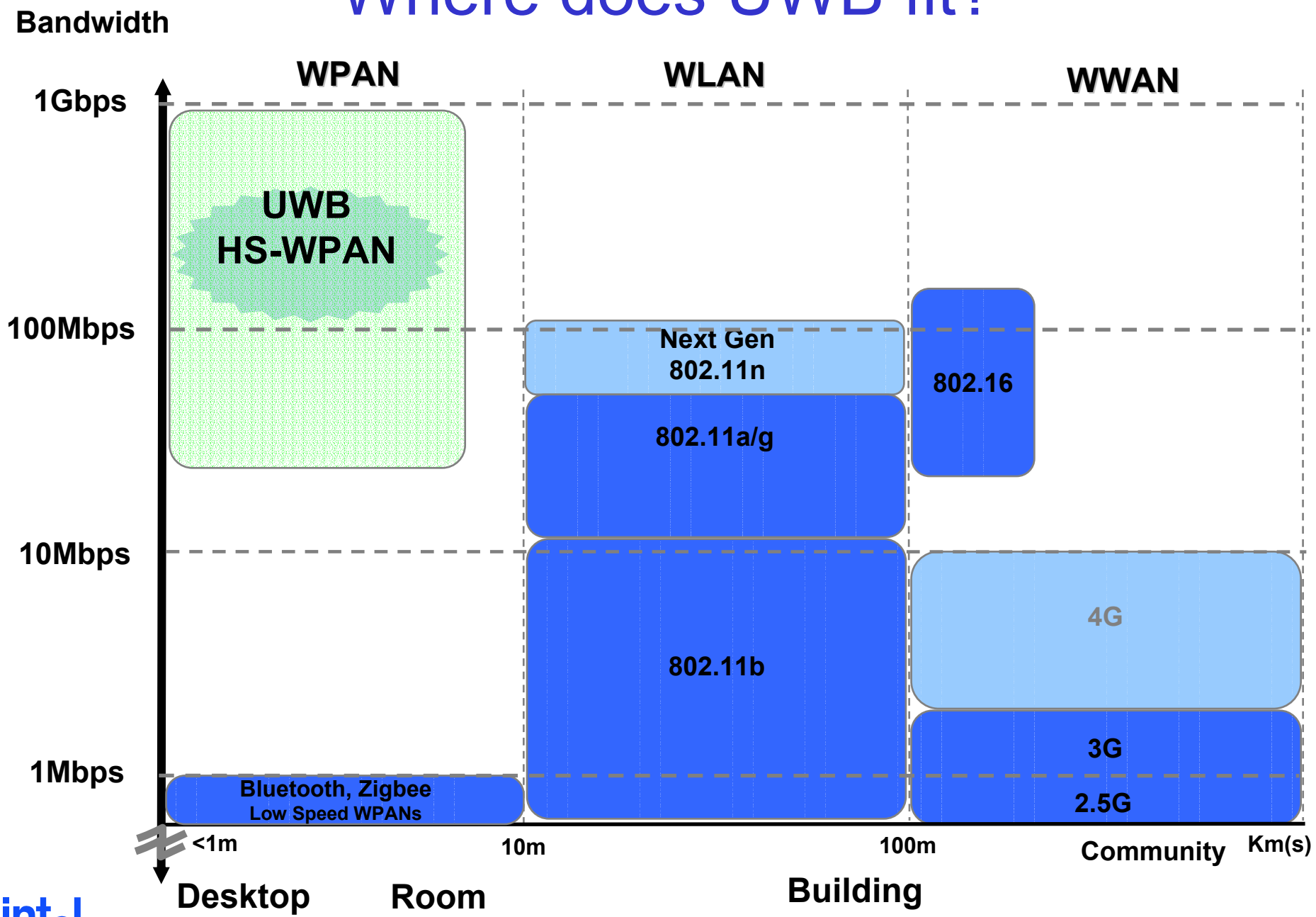
- Supports datacom speeds greater than 100 Mbps within 10m radius
  - OFDM supports 480 Mbps at 2 meters; multi-Gbps speeds for the future
- Can determine range between devices to within a few inches
- CMOS, low power, low cost designs plausible

Theoretical Data Rates Over Range



UWB is uniquely qualified to help meet the needs of high-speed WPAN

Where does UWB fit?



High Speed WPAN Usage Models

Replacing Interconnect Cables

CE Segment

- Eliminate cable hassles for portable device content upload / display
- Ease install/config of next gen digital displays and home theater
- Ease AV load on WLAN

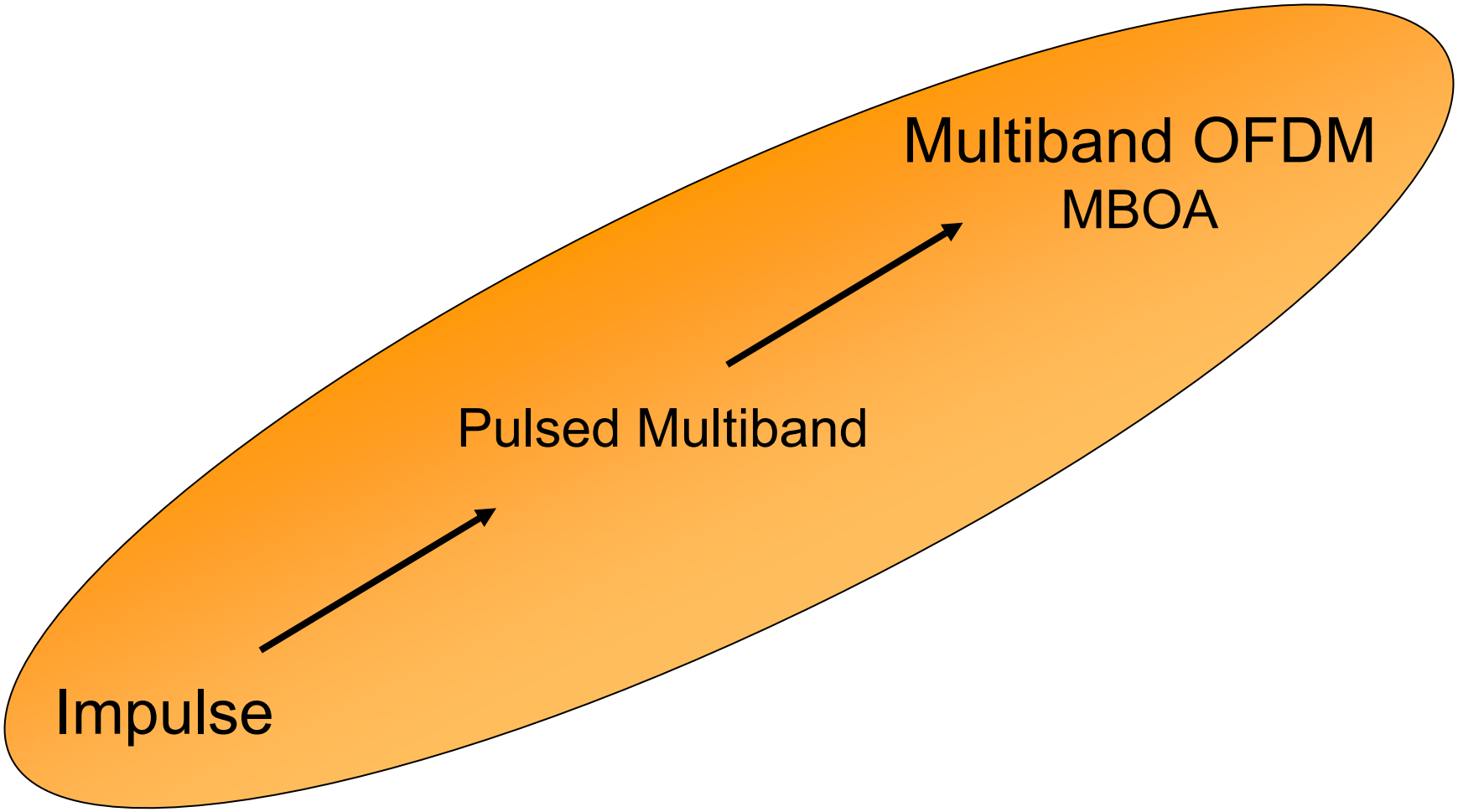
PC Segment

- Eliminate USB2 cables
- Highest value for portable devices
- Unwire high rate devices impractical w/ Bluetooth
- Applicable to digital home and digital office

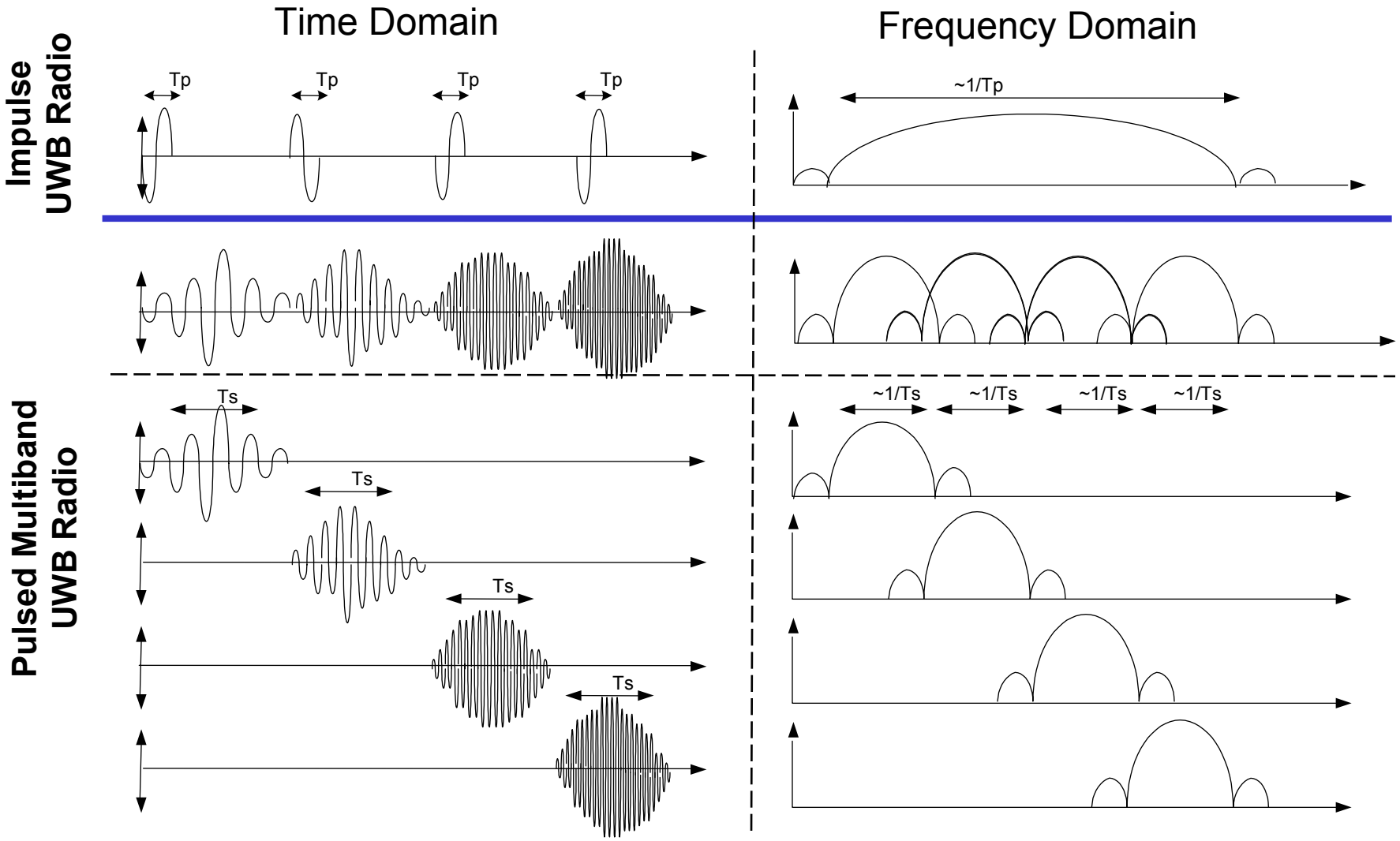
Mobile Segment

- Enable high rate apps beyond Bluetooth reach
- Wireless NB docking station
- HH+NB wireless linkage w/ resource sharing
- Wireless AV display from NB and HH

UWB Technology Evolution At Intel Corp.



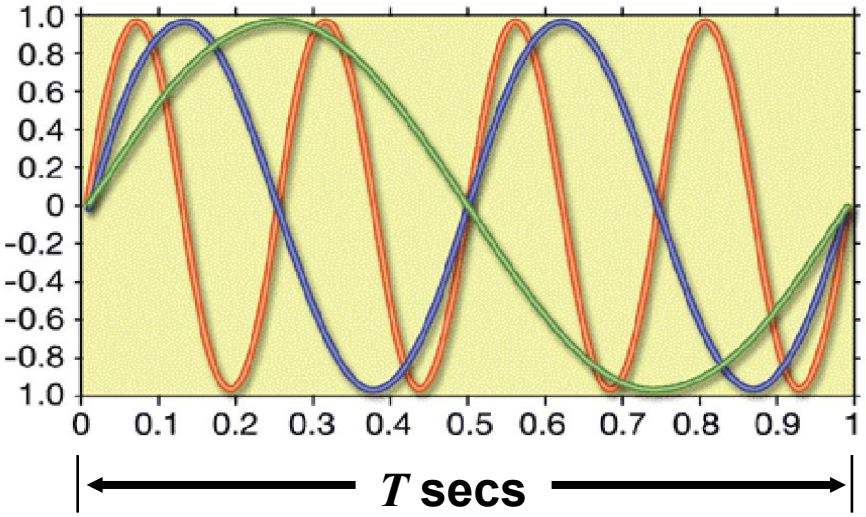
UWB Evolution
"Impulse" and "Pulsed Multiband" UWB



OFDM Fast Facts

- Invented more than 40 years ago
- Adopted & proven many times
  - Asymmetric DSL (ADSL)
  - IEEE 802.11a/g, 802.16a
  - Power Line Networking (HomePlug)
  - Digital Audio (DAB) & Video (DVB Europe, ISDB Japan)
- Proposed by Texas Instruments for IEEE 802.15.3a
- A “natural” for the future
  - FCC’s *Cognitive Radios*
  - Multimode radios

UWB via MB-OFDM



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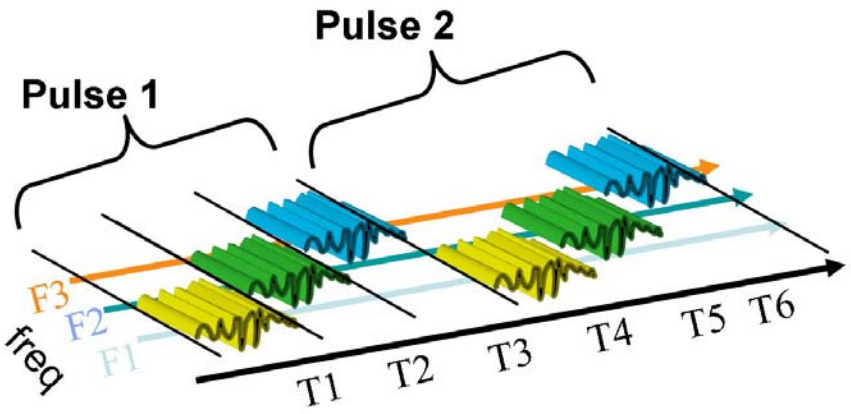


$$Z(t) = \sum_{k=0}^{N-1} C_k e^{j2\pi(k-\frac{N}{2})t/T}$$

Proposed Baseband Stats

- ***T = 312.5 ns; N = 128 tones***
- ***Tone spacing = 4.125 MHz***
- ***Total bandwidth = 528 MHz***

*** http://www.iec.org/online/tutorials/ofdm/**

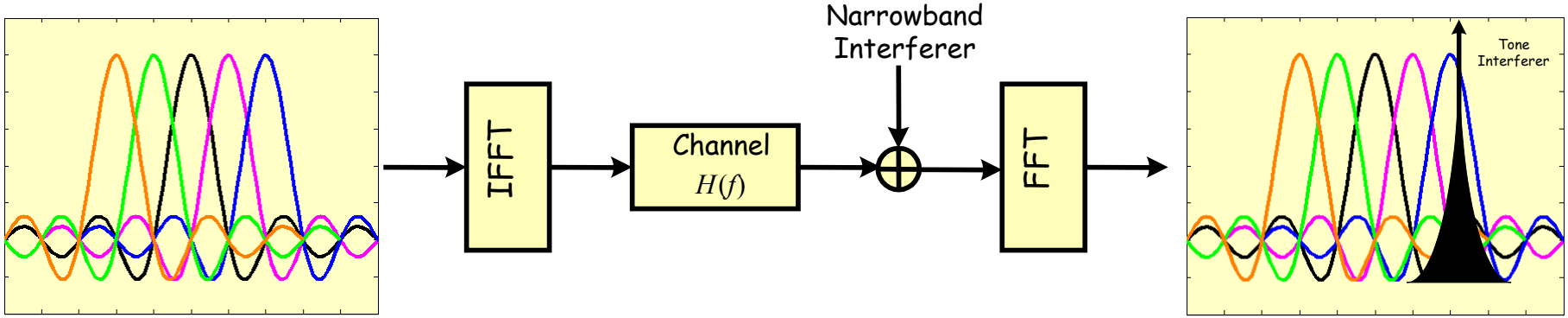
**** IEEE P802.15-03/268r1**

Strengths of OFDM (1)

- OFDM is spectrally efficient:
  - IFFT/FFT operation creates non-interfering sub-carriers
  - Sub-carriers can be brought close together ⇒ High spectral efficiency.

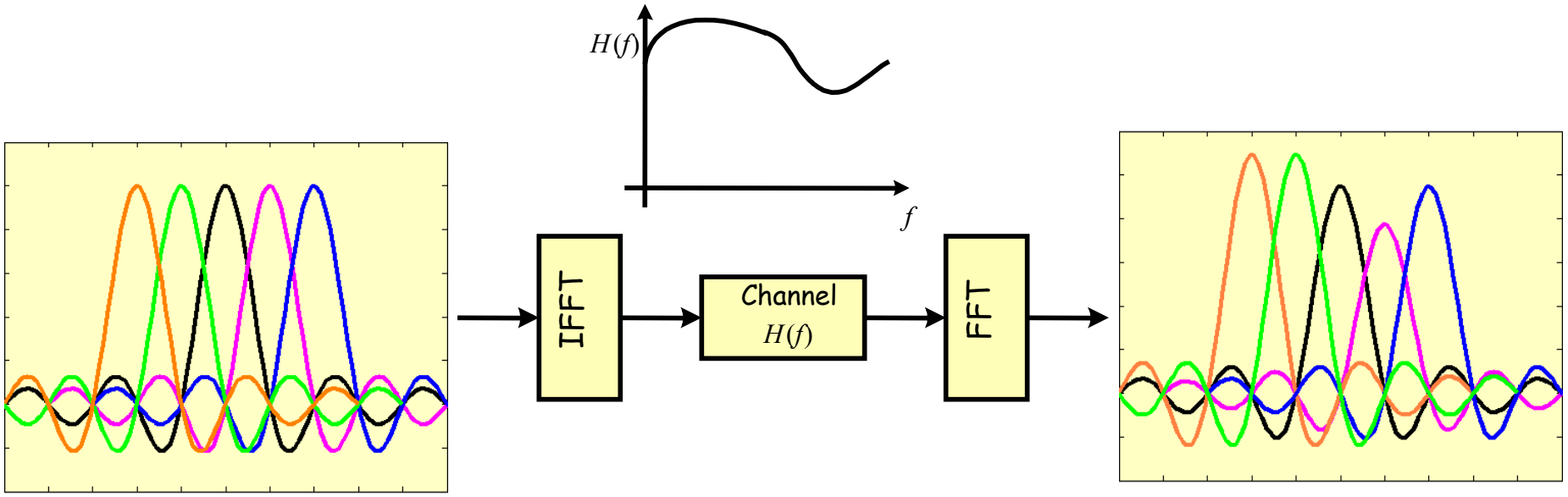
- OFDM is resistant to narrowband interference:
  - Narrowband interference will affect at most a couple of tones.

  ⇒Erase information from the affected tones, since they are now unreliable. Use FECs to recover the lost information.



Strengths of OFDM (2)

- OFDM with FEC is resistant to multi-path impairments.
- Cyclic prefix helps preserve orthogonality between sub-carriers.



Cognitive Radio Concept

FCC NPRM adopted Dec 17, 2003, ET-03-108*
FCC NPRM adopted May 14, 2004 (*to be published*)

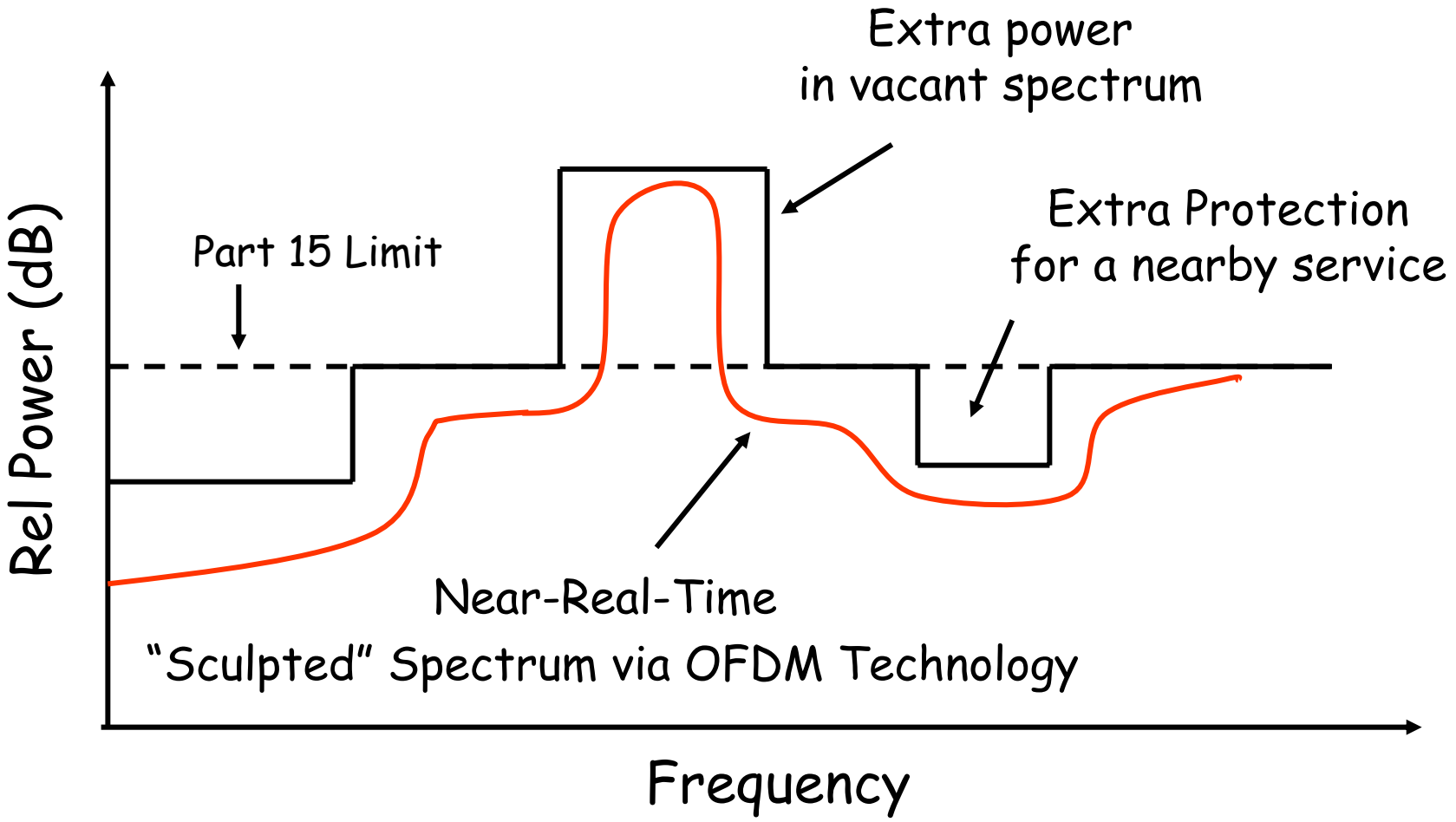
[Cognitive radio technologies] include, among other things, the ability of devices to determine their location, sense spectrum use by neighboring devices, change frequency, adjust output power, and even alter transmission parameters and characteristics.

(*Paragraph 1)

A cognitive radio (CR) is a radio that can change its transmitter parameters based on interaction with the environment in which it operates. This interaction may involve active negotiation or communications with other spectrum users and/or passive sensing and decision making within the radio.

(*Paragraph 10)

Cognitive Radio
Plausible Application to UWB Regulation

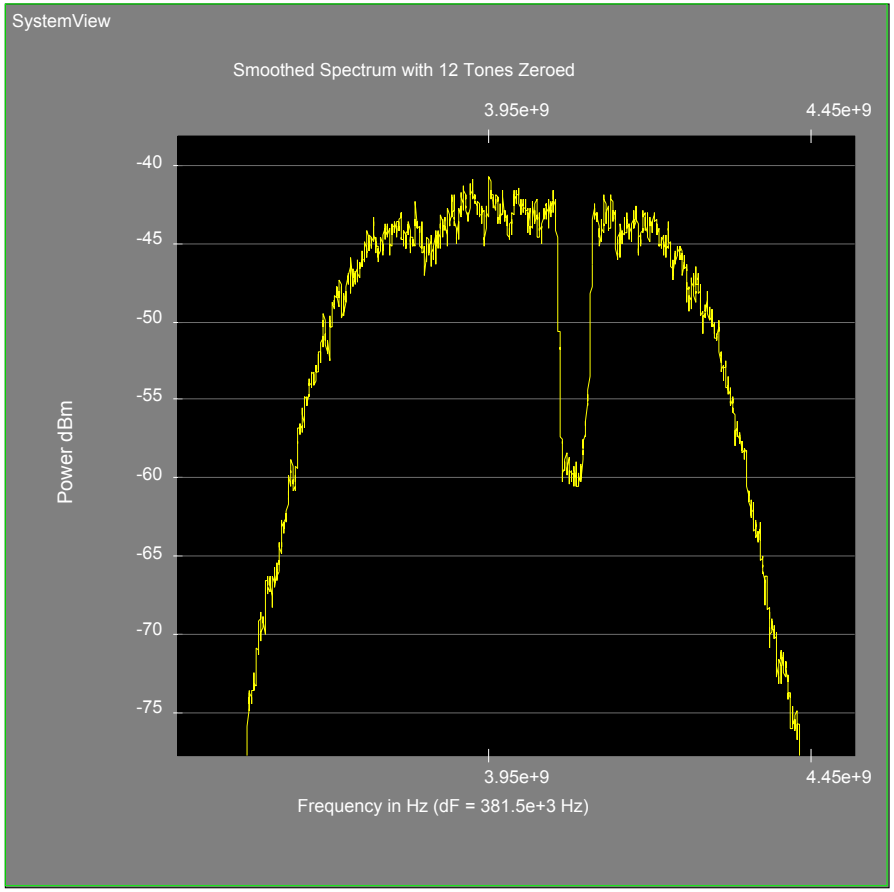


Basic Spectral-Sculpting Capability

An enabler for Future "Cognitive Radios"

Example

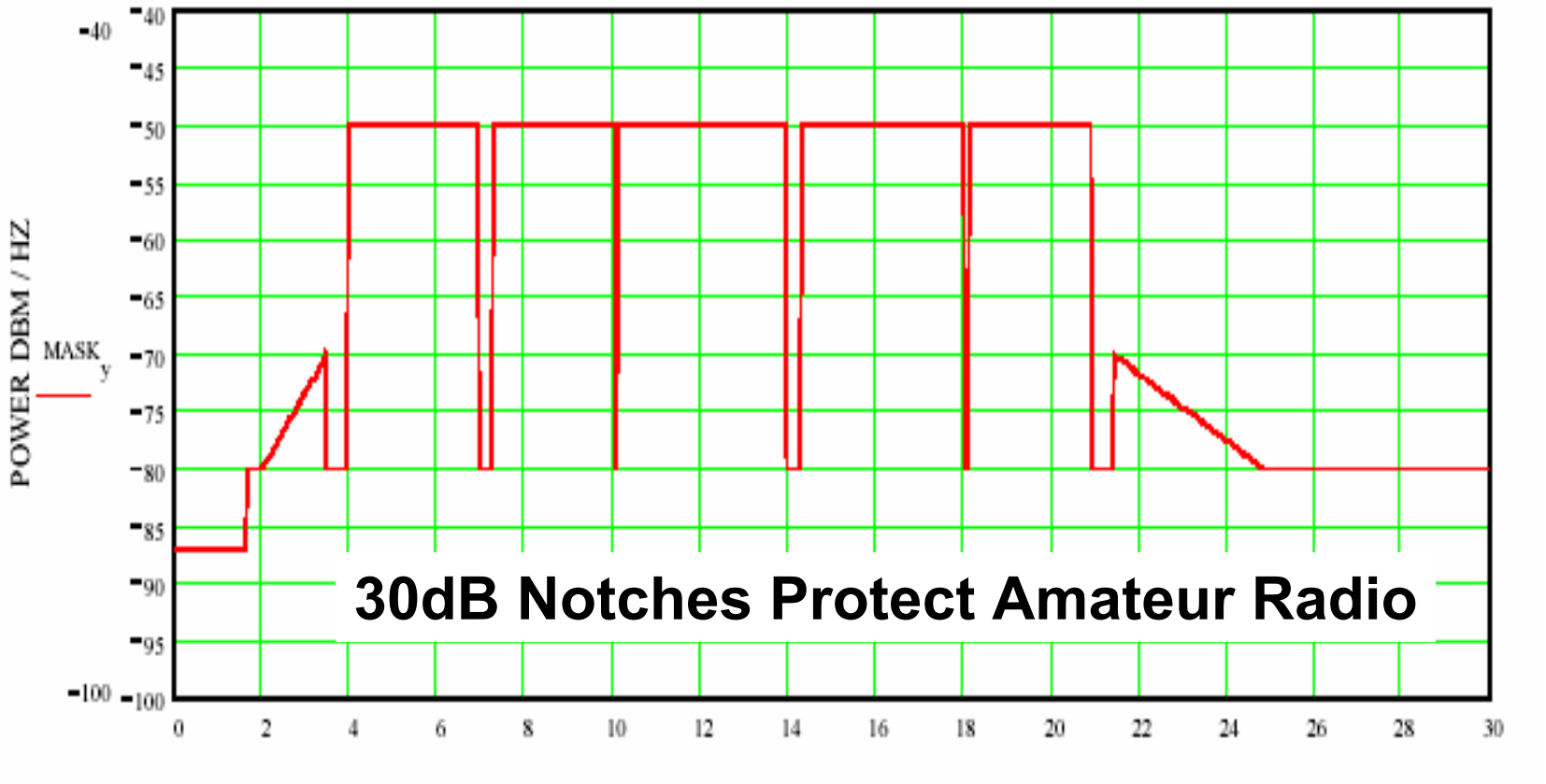
Detected narrow-band service near 4 GHz needs protection.



- 128-tone OFDM transmitter "zeros out" 12 adjacent tones near detected service
- Notch depth > 15 dB
- 116 out of 128 tones remain active
- All-digital operation -- no analog filtering required
- Advanced techniques allow deeper notches

HomePlug Power Line Spectral Mask

A Precedent for Low-Cost, High-Performance "Sculpting" via OFDM Technology



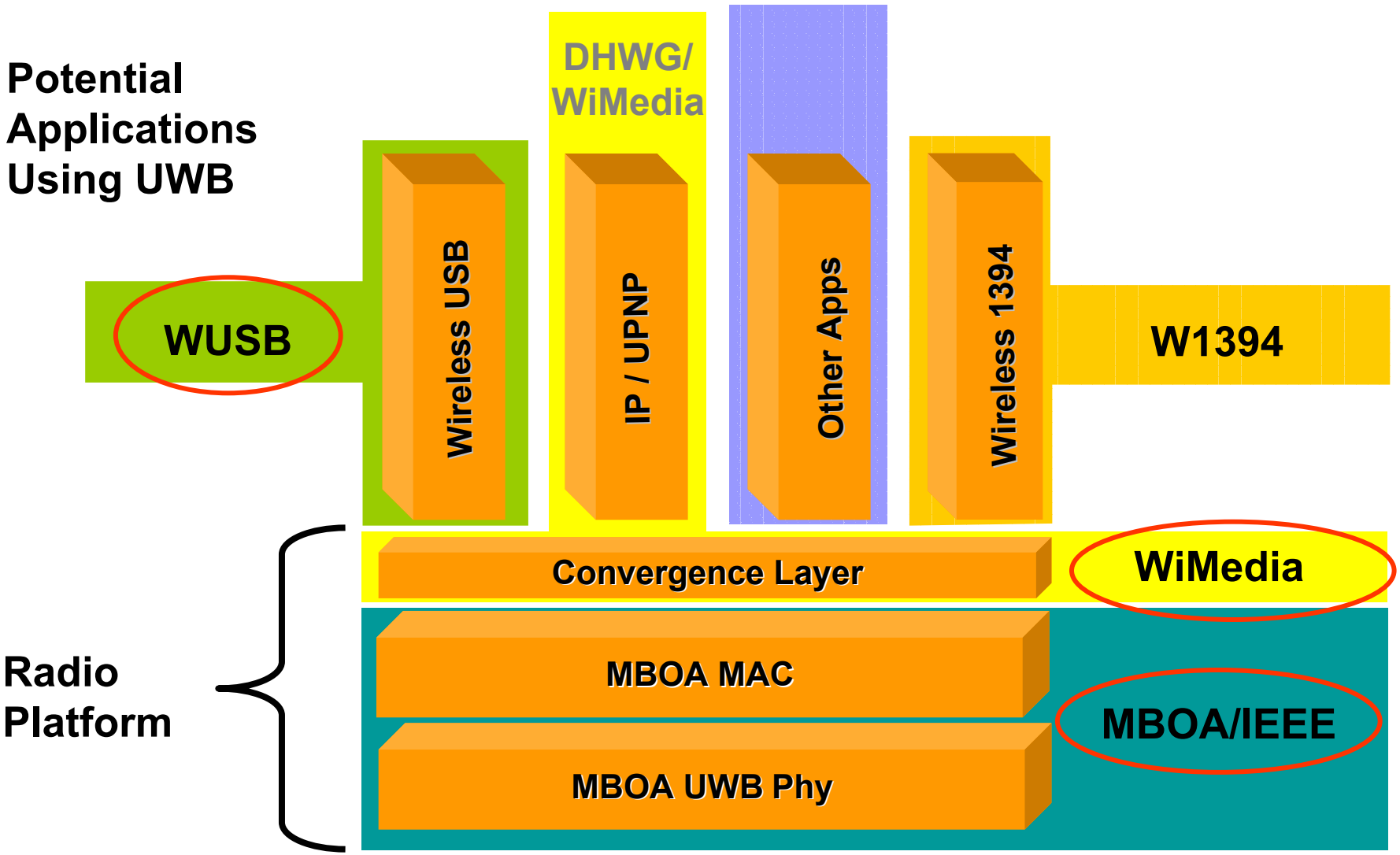
Frequency, MHz

Source: HomePlug Alliance, HomePlug & ARRL Joint Test Report, January 24, 2001

MBOA Membership

Member Companies

UWB Common Wireless PAN Vision



Market Segment Expectations

- 2004: Standards, industry enabling
- 2005: Market segment enabling
  - Early adopters, external modules
    - Dongles, PC cards
- 2006: Volume ramp, internal solutions
  - Broader app support (WUSB, W1394, …)
  - Internal modules
    - PCI, Mini-PCI, PCI-E

Dates are estimates only, subject to change

Looking Forward
A Plausible Research Area for Singapore's UWB-Friendly Zone?

- UWB via OFDM may evolve to "Cognitive UWB"
  - Today's UWB broadband antennas, analog front-ends, digital baseband designs lead the way
- Higher power across the UWB band
  - Singapore: 10 dB higher power than US FCC mask
- Spectral sculpting protects existing services
  - Via on-the-fly detection
  - Via policy engines with updatable software

Backup

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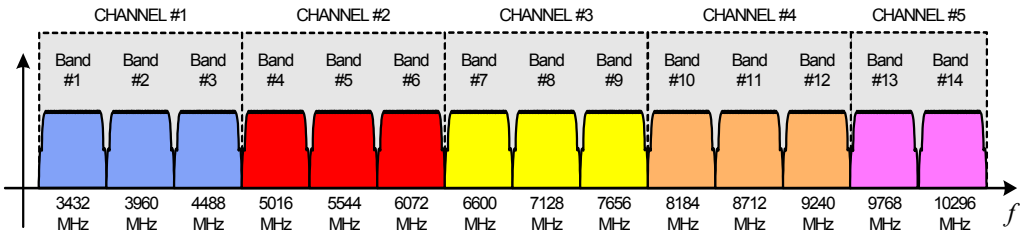
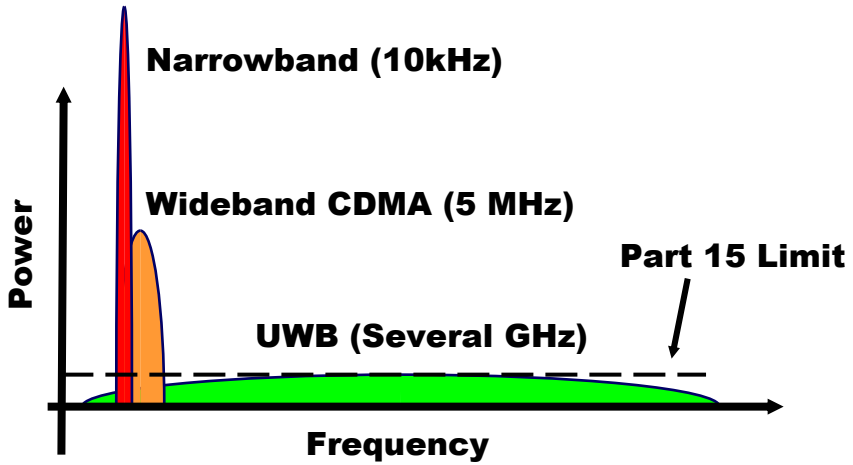
MultiBand OFDM Band Plan





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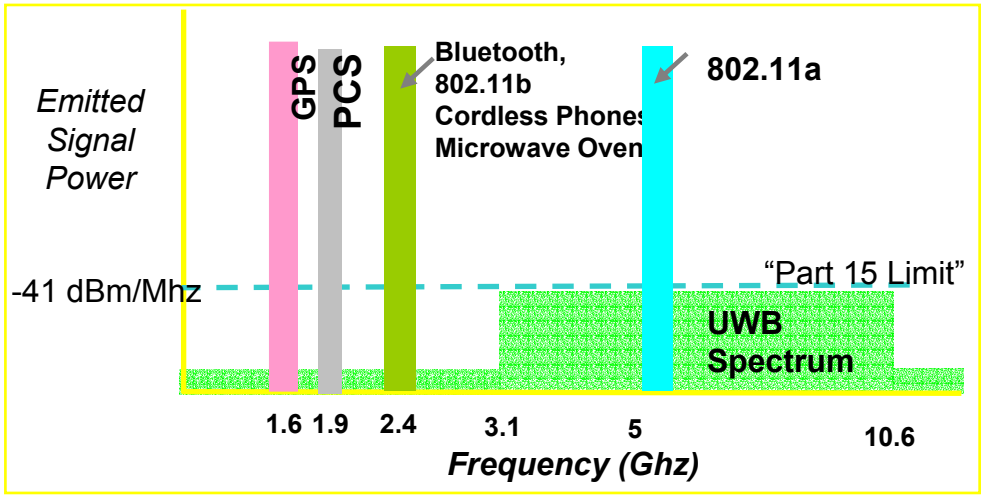
UWB for High Speed WPAN

- Wireless PAN
  - NOT Wireless LAN
- Order of magnitude Vs WLAN
  - Higher data rate (~500Mbps)
  - Lower power (< 250 mW)
  - Shorter range (< 10m)
- USB2.0 speeds w/o the cable
  - Peripheral connectivity in PC, CE and mobile segments
  - Enables new usage models
- "Underlay" wideband (7.5 GHz) spectrum
  - Interference mitigated by very low power
- Future: higher power possible with “spectral sculpting”



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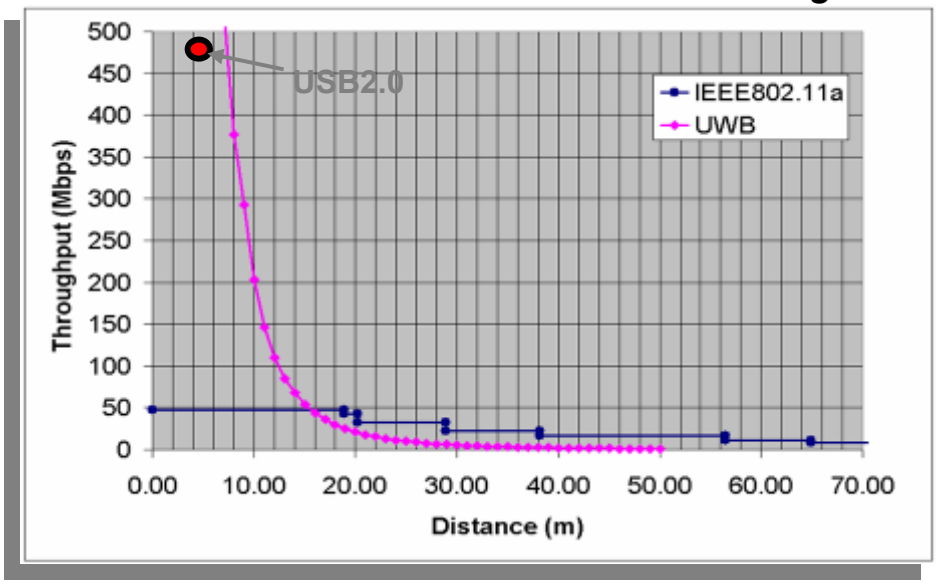
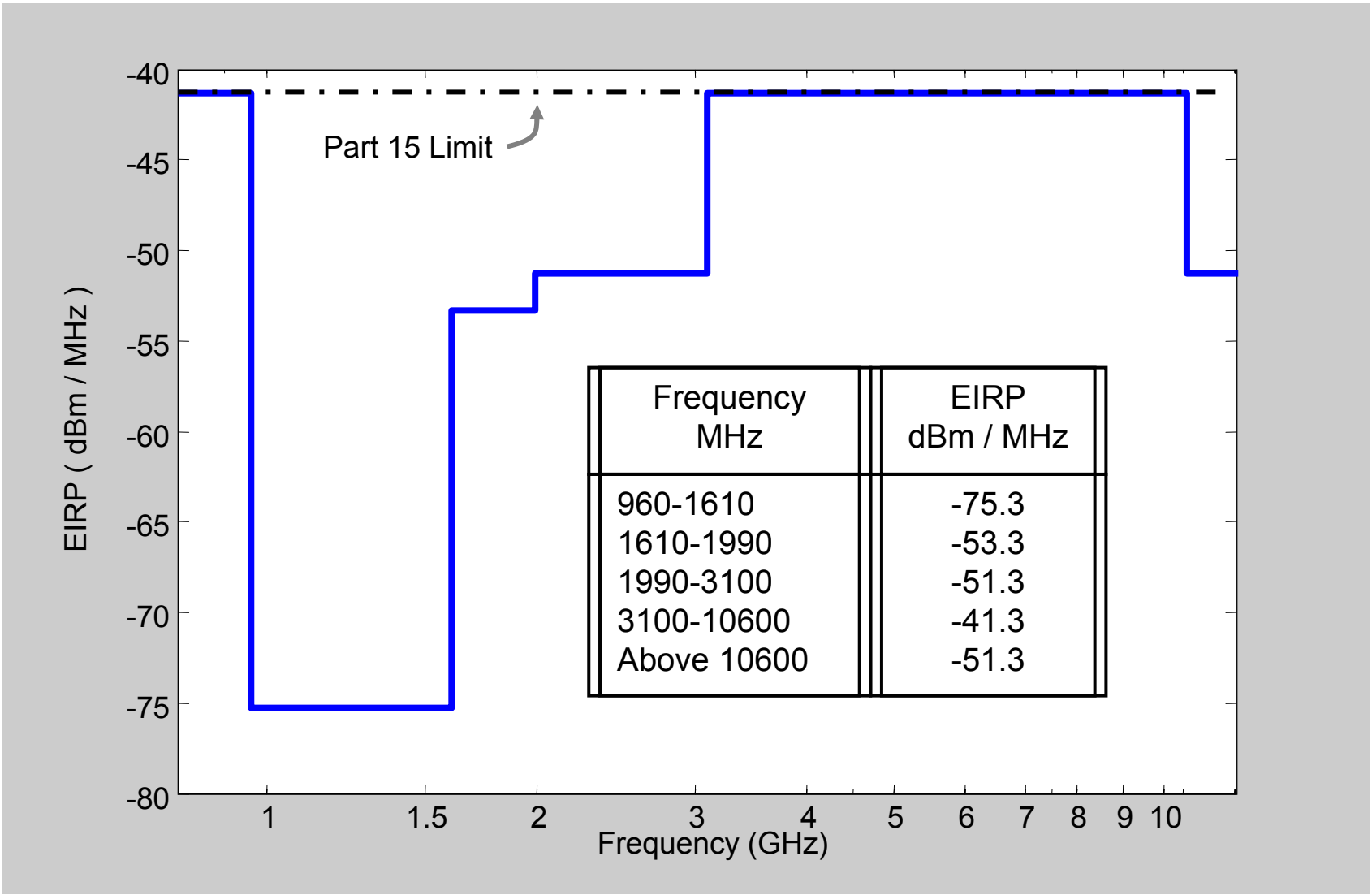


USB 2.0 Speeds within 5m range…

FCC Spectral Mask, Indoor UWB

April 22, 2002



Frequency MHz	EIRP dBm / MHz
960-1610	-75.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

Allied Groups
WiMedia & WUSB

WiMedia Alliance

- Provides Interoperability among multiple applications over a single radio
- Working groups formed to address Security and Bandwidth Sharing rules
- Relationship established with WUSB addressing interoperability
- Intel joined WiMedia Board Of Directors
- V1.0 WiMedia spec targeted Q404

WUSB Promoter Group

- Intel founded in Feb with other key companies to define 1st high speed wireless interconnect based on MBOA radio
- Same look and feel as wired USB
- Relationship established with WiMedia to write to their Software Convergence Layer
- V1.0 WUSB spec targeted Q404

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UWB Regulatory Update *(3/01/04)*

- Regulatory activity worldwide is focused on the ITU-R Task Group 1/8
  - Developing a compatibility study and a "Regulatory Guidance" Recommendation for protecting incumbent services from UWB
  - Individuals active in this activity are those who will also write the individual country regulations
  - Focus is below 6GHz – IMT-2000 (3G&4G), 5GHz, 3.4GHz (WiMAX)

- World Wide Regulatory Update
  - Singapore – UWB Friendly Zone (UFZ) launched in Feb 2003
  - Japan – approve UWB for indoor use initially and mimic the FCC guidelines
  - EU – working group to study interference, IMT-2000 is a key opponent
  - PRC – hasn't assigned 3G spectrum yet, unlikely anytime soon
  - Canada – "Consultation document" for regulations this month, then 1-2 yrs.
  - Australia – Expected to generally follow the ITU-R recommendation
  - Russia – Proposal to SCRF is expected in July - plans first hearing on UWB