A Future Proof Spectrum Policy

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Peter K. Pitsch
Communications Policy Director
Intel Corporation

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A New Age Opportunity v. Age-Old Obstacles

- Going digital = revolutionary change in RF
  - Most significant technical change in RF history
  - Any computing device will also communicate

But . . .

- Command and Control Still Predominates in Regulation
  - Cumbersome, Litigation-prone, Politicized
  - Allows incumbents to block innovators to stymie competition
  - Rigidities lock in less valuable uses and technologies

So. . .

- Spectrum reform is next big thing
  - Technical flexibility must predominate

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Radio Free Intel-
How “Moore’s law meeting Marconi’s transmitter” will unleash innovation in radio.
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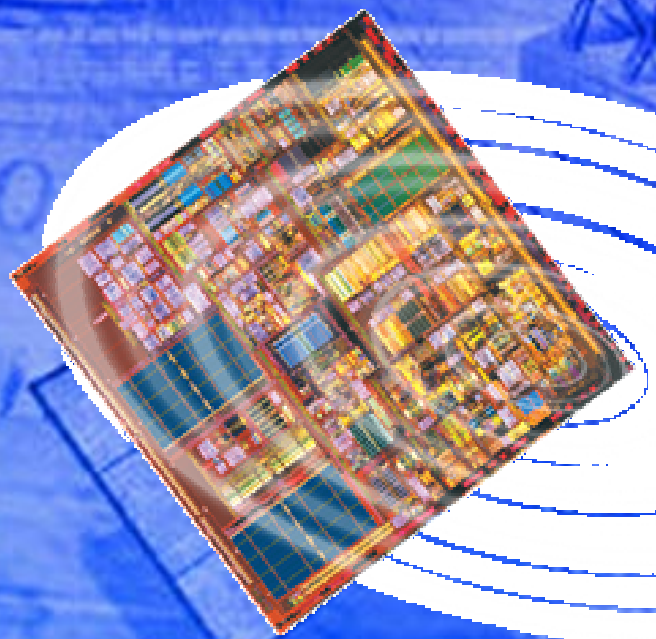
Moore’s law impact #1- More MIPS

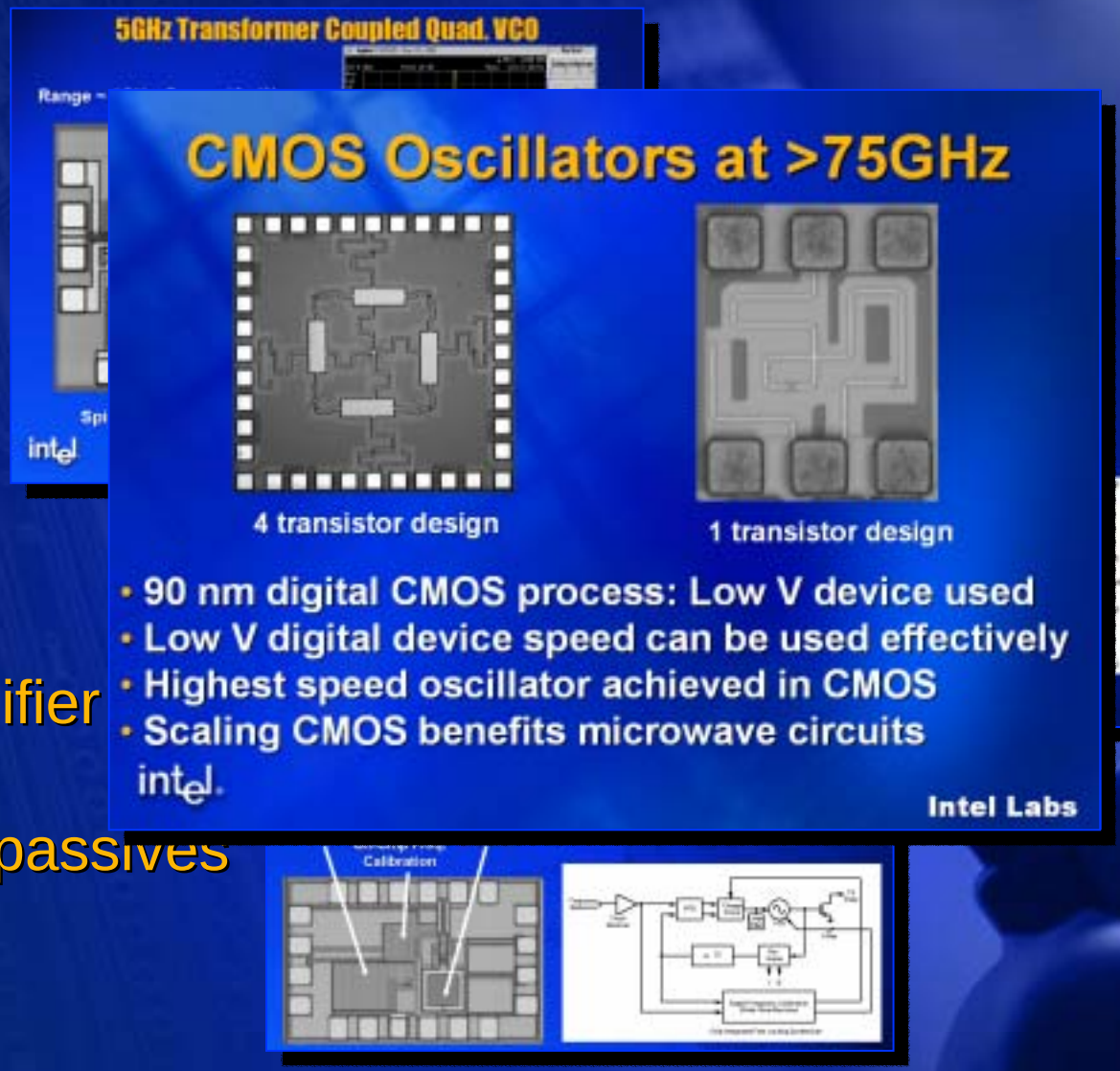
By 2010 based on Moore's Law, a single microprocessor will contain several billion transistors and process more than a trillion instructions per second.



Moore's law influence #2- CMOS RF

Siliconizing
Radios

VCO
power amplifier
low noise amplifier
synthesizer
high quality passives



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Digital Convergence

Transparent

A *physical device* designed for a specific purpose ...

A *core function* embedded in *every device*.

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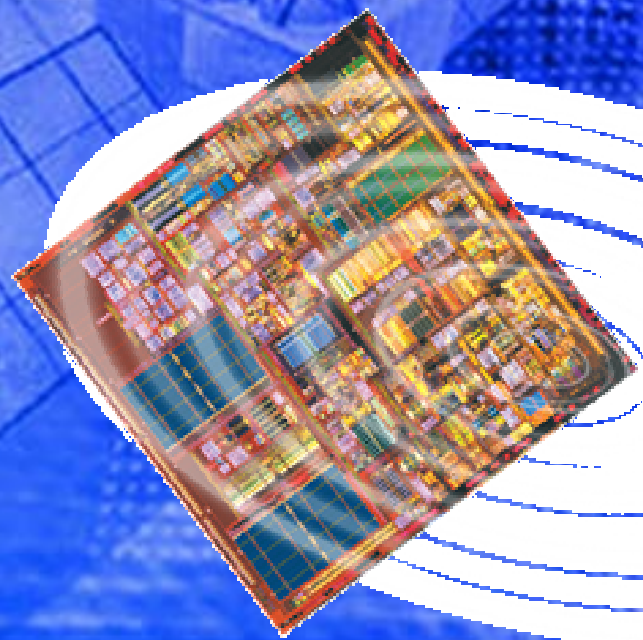
The Vision

Fully **integrated**
Always **connected**
Multiple **networks**



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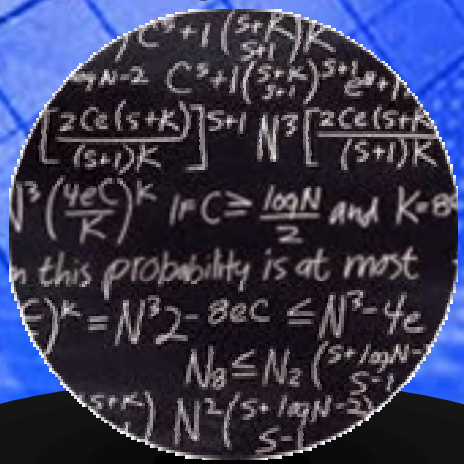
System-level Innovation

Adapting to the User

Adapting to the Network

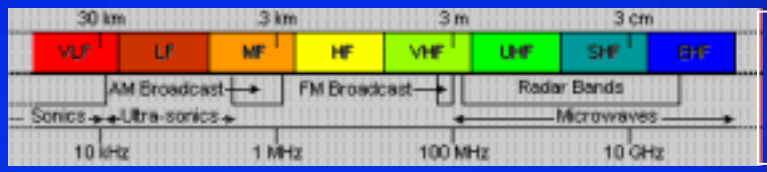
Adapting to Physics



Spectrum Scarcity

Radio Spectrum

Electromagnetic Spectrum

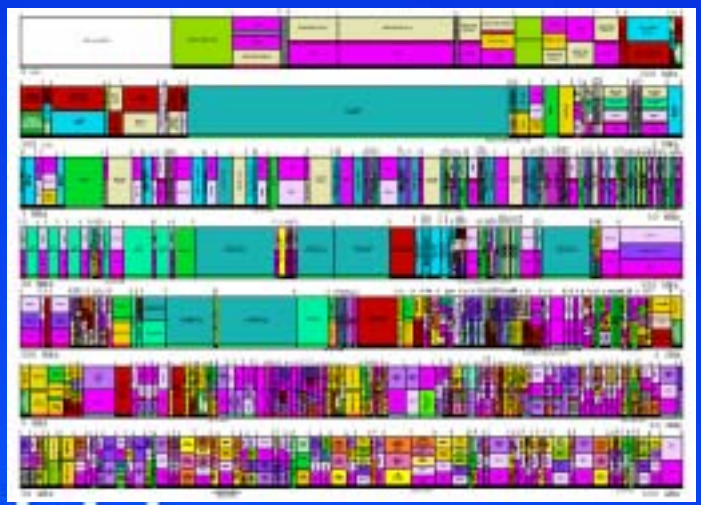


Infrared

Visible Spectrum

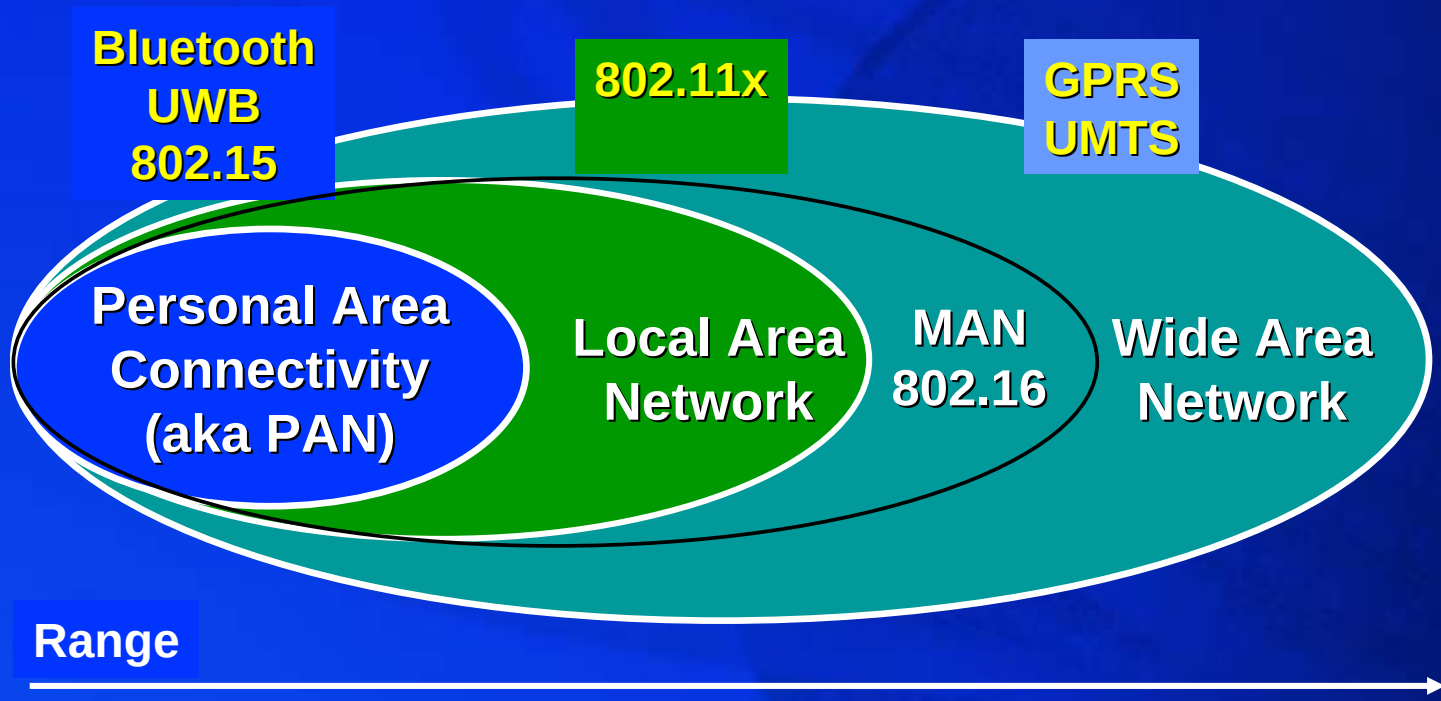
UV, Xray
Gamma Ray
Cosmic Ray

FCC Spectrum Allocations (3KHz – 300GHz)



...And it's all spoken for (spectrum is a scarce resource)!

And It's Getting Scarcer



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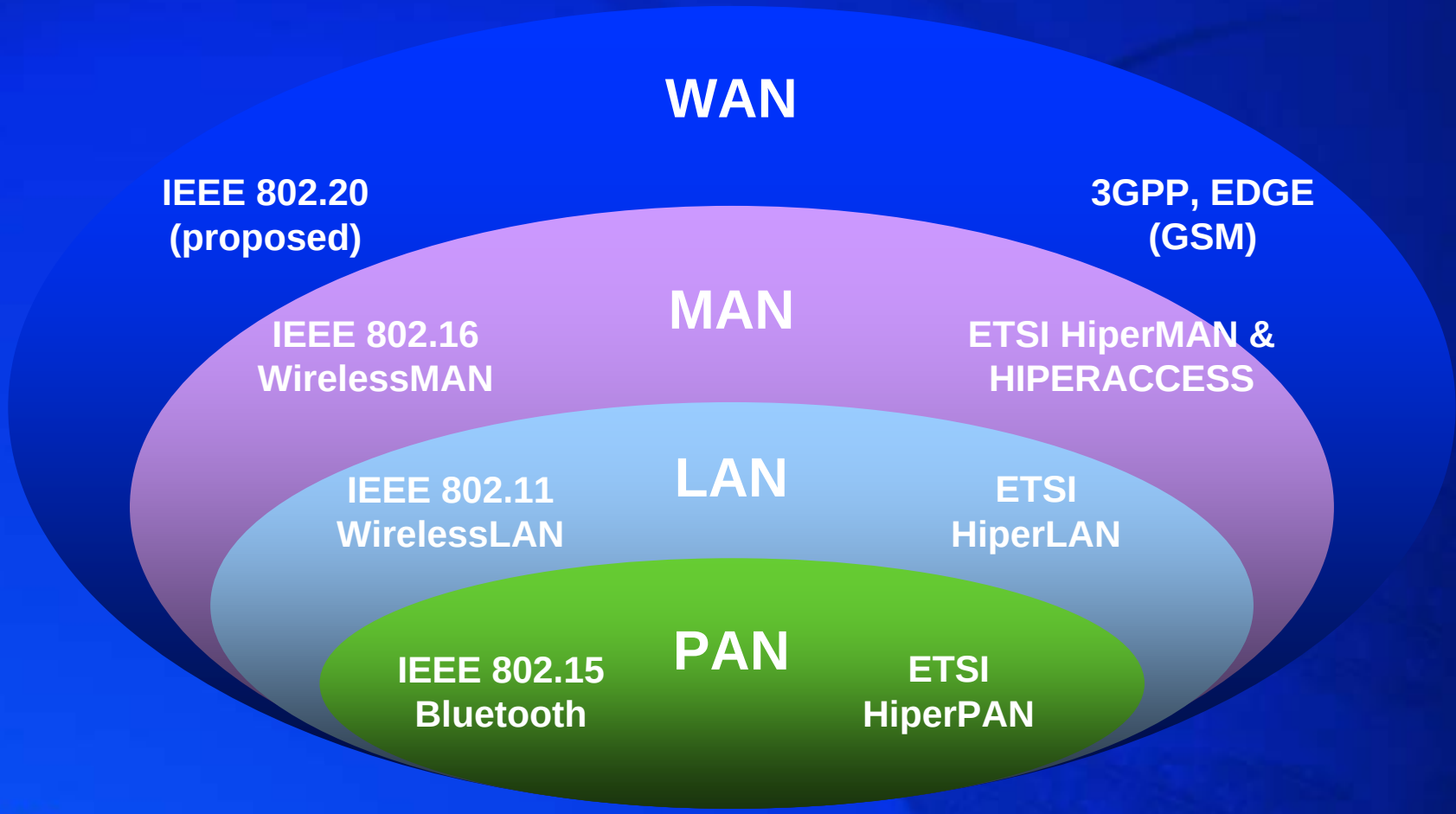
WAN
IEEE 802.20
(proposed)
3GPP, EDGE
(GSM)
MAN
IEEE 802.16
WirelessMAN
ETSI HiperMAN &
HIPERACCESS
LAN
IEEE 802.11
WirelessLAN
ETSI
HiperLAN
PAN
IEEE 802.15
Bluetooth
ETSI
HiperPAN

But Is This Scarcity Artificial?

- Inefficient distribution of a sufficient supply
  - Too much in low valued uses
  - Too little in high valued uses
- Markets can't improve the distribution because of improperly structured spectrum rights
  - Limited to specific uses
  - Limited to specific users
  - Some not available to any users

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What is the Solution?

- Markets
  - Increase the use of competitive markets in determining who has the spectrum and how it is used
- Technology
  - Increase supply by improving technical efficiency in response to market incentives
  - Increase competition by making spectrum more fungible

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Recommendations

Support non-interfering easements

- Underlays, e.g., UWB
- Overlays, e.g., agile radios

Support license spectrum reforms

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Our Regulatory Responsibility

Regulatory *Enablers*, Not *Barriers*

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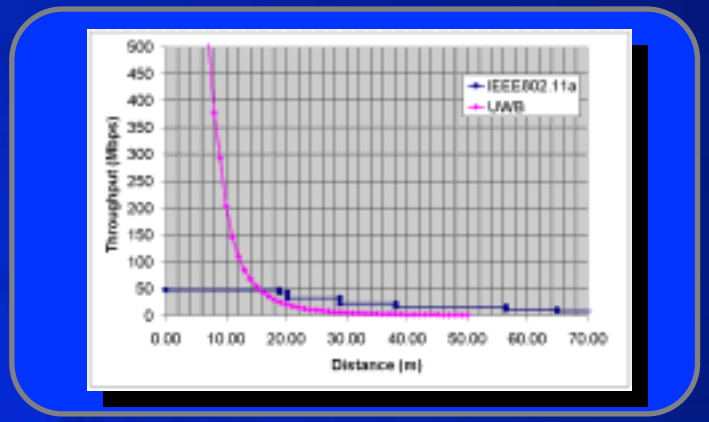
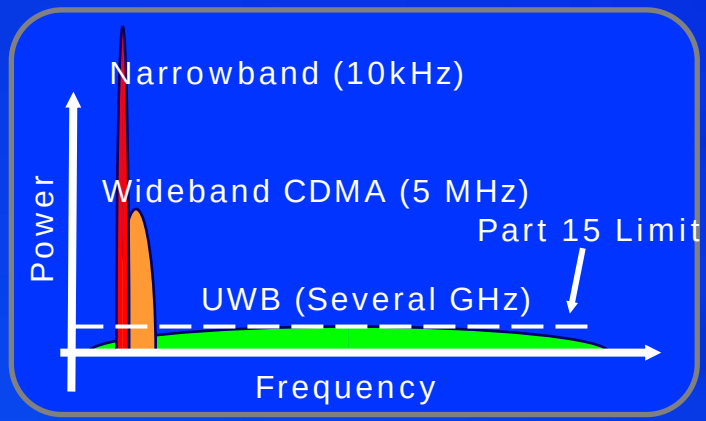
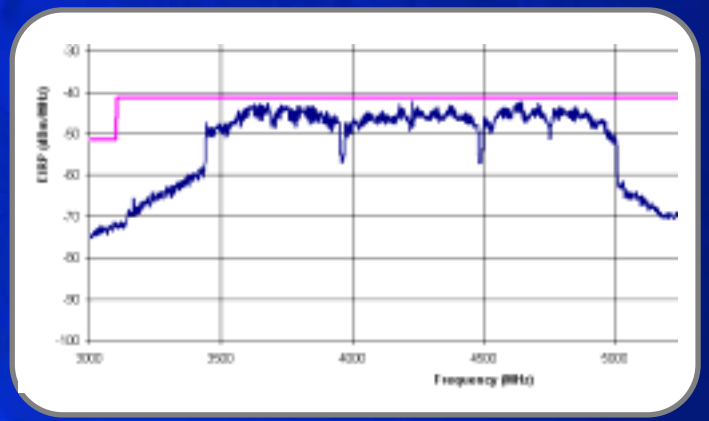
Ultra Wideband (UWB)

- Very high data rates
- “Underlay” technology
- Peaceful coexistence
- All-CMOS, low power & cost







UWB is next generation high-speed WPAN

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Underlay (UWB) Policy

- Fundamental Problems
  - Asymmetrical competition (one service against many); by operating over a wide swath of spectrum, UWB collects a wide swath of opponents.
  - UWB has no status in ITU (no allocation, operates on “non-conforming exception)
  - ALL CURRENT ACTIVITY UNDERTAKEN FROM A HOSTILE, PROTECTIONIST CONTEXT
- Doctrinal Issues
  - What is “Acceptable Interference”?
    - “Why should I (incumbent) accept any?”
      - 1 db rise in noise floor
        - US- NO, cites Public Safety
        - EC- Maybe
  - Un-intentional vs. Intentional
    - Analogous to non-profit entities being exempt from taxes.
    - Big distinction for ITU
    - Used by opponents.
  - Exclusivity
    - What rights of exclusion do licensed operators have?

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Agile Radios

- Able to find and use opportunistically vacant “white-space” in spectrum.
- Utilizes new techniques to decide how/where to operate based on current environment.
  - Spectrum sampling to learn your current environment “Cognitive”
  - Use various control mechanisms (TPC, DFS, Location, etc.) to adjust radio operating parameters to mitigate interference.

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Agile radio policy

International Proceedings- Intel Positions

- **EC TCAM Sub Working Group on SDR & R&TTE Directive**
  - Examining impact of SDR on R&TTE Directive for conformity.
  - Main issue is who is responsible for software changes
    - Intel believes the R&TTE directive does not pose a barrier to SDR deployment; and
    - Questions arising from responsibility for software software changes can be addressed by industry standards initiatives.
    -
- **ITU-R Report/Recommendation on SDR**
  - Intel Drafted US Submission
    - Promote innovative spectrum management
      - Access to new spectrum
      - “Impedance” matching spectrum to service.
    - Global circulation
      - Allow frequency agile devices to migrate
      - Coordinate certification regimes
    - Encourage standards activity
      - Justifies forbearance by regulators

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Agile radio policy

- **FCC U-NII Devices in 5Ghz (FCC 03-110)**
  - Intel strongly supportive
  - Only the central controller is required to have DFS capability
  - No mandated TPC triggers or DFS implementations
  - Compliance date for rules tied to test procedure availability

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Use of Vacant "white-space" Spectrum

- Unlicensed Devices in TV bands (FCC 02-380)
  - Radical reform
  - Great propagation characteristics
  - 75 Companies filed comments
- Intel Recommendation
  - Spectrum sampling to learn your current environment
  - Use various control mechanisms (TPC, DFS, Location, etc.) to adjust radio operating parameters to mitigate interference
  - Demonstrate cognitive system < 1st H '04

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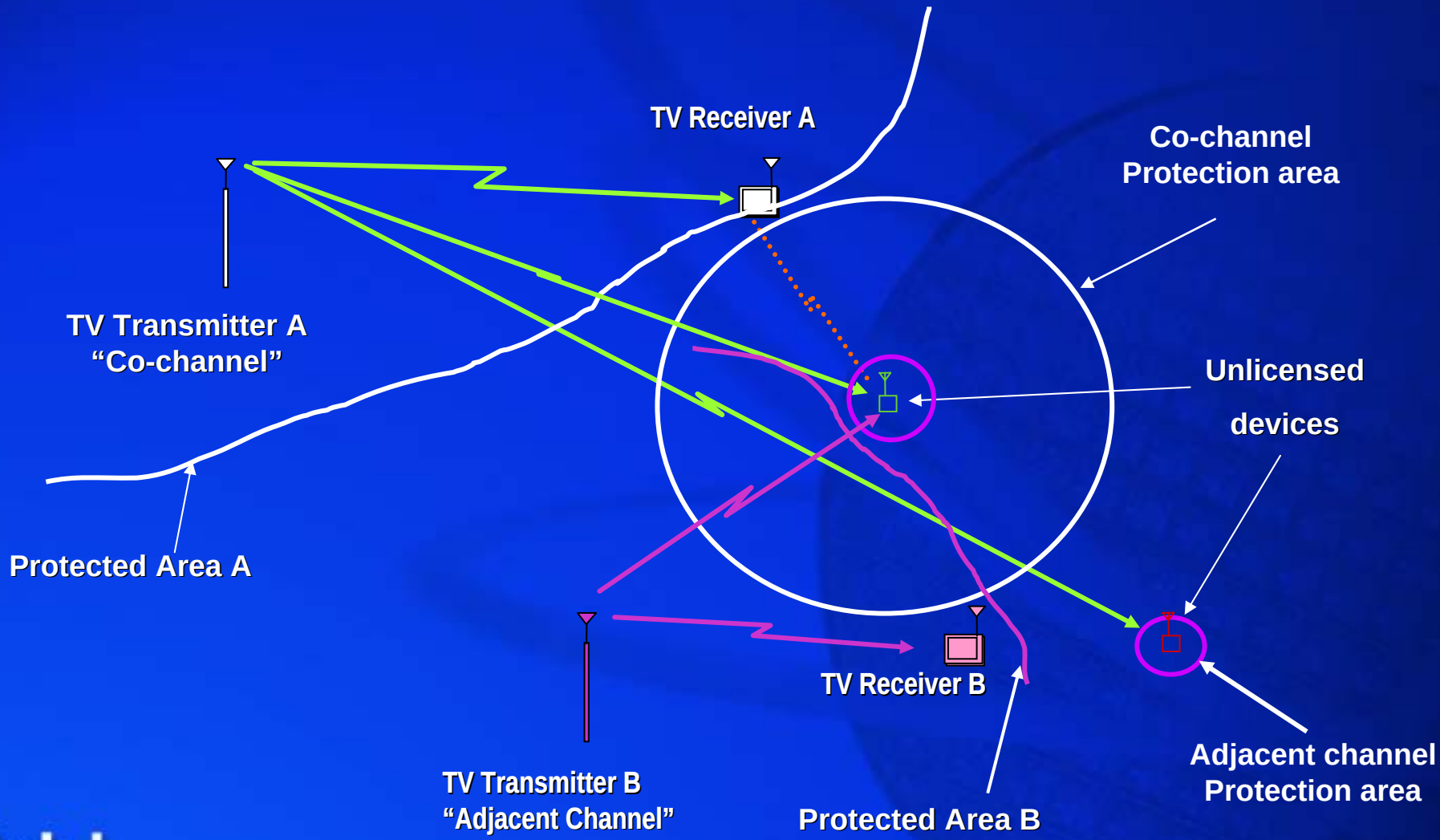
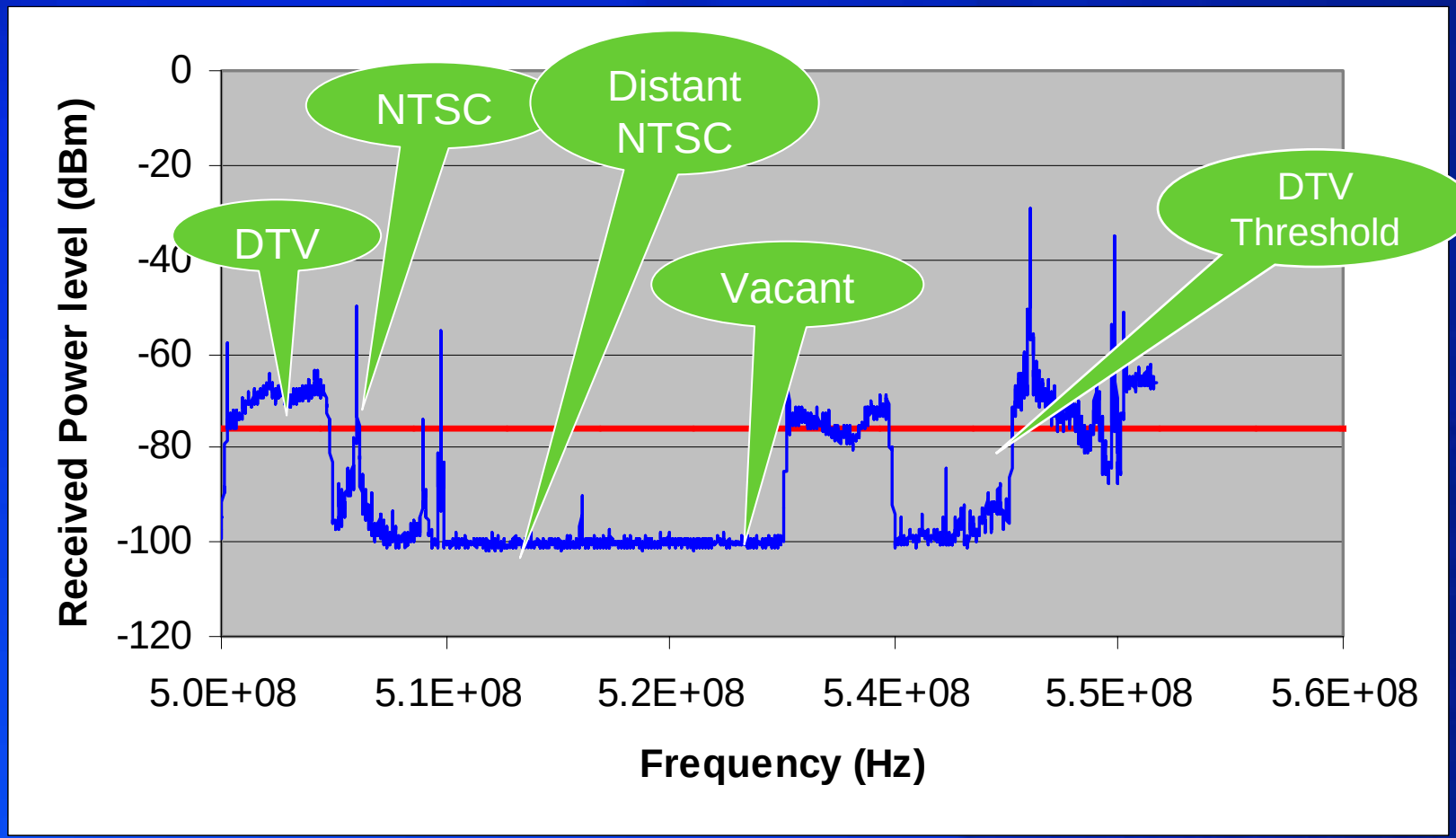
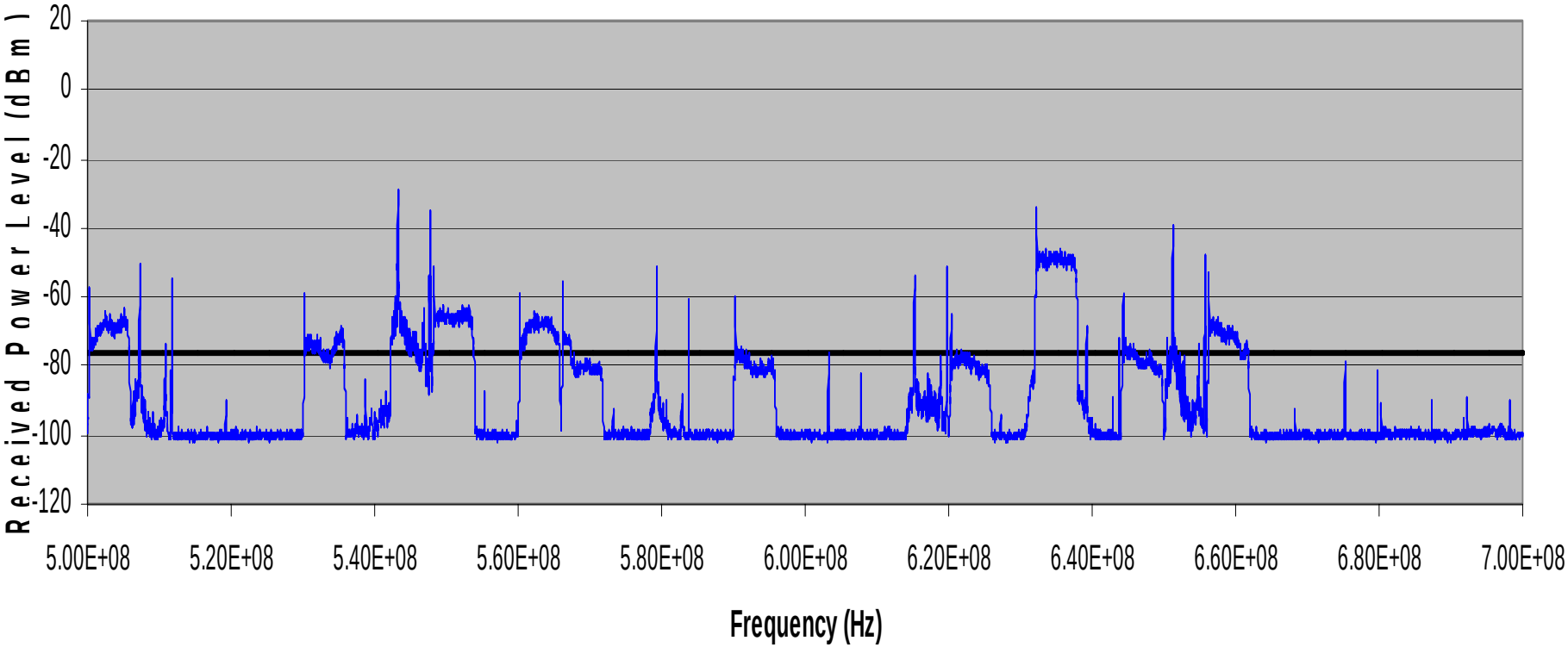
Topology of Concern



Ease of Channel Characterization using 3kHz Filter



Vacant Channels Exist in SF Bay Area Sweep between Channels 21-51 (Intel Data)



List of Channels Available
SF Bay Area (Intel Data)

642 30th Street @280ft		2080 Gough Street @394ft	
Vacant	Unusable for TV Receiver	Vacant	Unusable for TV Receiver
21	22	21	22
23	25	23	25
33	28	33	31
35	31	35	40
46	36	46	42
	40		50
	42		
	47		
	48		
	49		
	50		
	51		

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Support license spectrum reforms

- Remove use restrictions
- Define outputs (emissions at boundaries)
- Assign spectrum (“Swiss cheese”) exhaustively
- Facilitate simultaneous exchange
  - Voluntary
  - Reveals “opportunity cost”
  - Simultaneity
    - Reduces transaction costs and holdout problems
    - Facilitates aggregation and relocation

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Broadband innovation

802.16; Designed from ground up for outdoor MAN

- Higher throughput at longer ranges (up to 50 km)
  - Better bits/second/Hz at longer ranges
- Scalable system capacity
  - Easy addition of channels maximizes cell capacity
  - Flexible channel bandwidths accommodate allocations for *both* licensed and license exempt spectrum
- Coverage
  - Standards-based mesh and smart antenna support
  - Adaptive modulation enables tradeoff of bandwidth for range
- Quality of Service
  - Grant/Request MAC supports voice and video
  - Differentiated service levels: E1/T1 for business; best effort for residential
- Cost & Investment Risk
  - Interoperable equipment lets operators purchase equipment from more than one vendor – WiMAX-Certified*
  - Standards-based platform improves OpEx by sparking innovation across the ecosystem: radio, NW mgmt, antennas, services

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* "WiMAX," "WiMAX Forum" and "WiMAX CERTIFIED" are marks of the WiMAX Forum."

Broadband innovation

Evolution of Broadband Wireless

Point to Multi-Point, Last Mile Wireless Equipment Timeline

‘90’s ’01	’02 ’03	’04 ’05
Off-the-Shelf 802.11 for License Exempt; Proprietary for Licensed	**Proprietary 70+ OEMs**	**Standard-based 802.16 Solutions & Proprietary**
Spectrum: • **License exempt 2.4 GHz** • **Licensed MMDS 2.5 GHz (AT&T Project Angel, Sprint BB Direct)** • **Licensed LMDS (26, 28, 39 GHz; Winstar, Teligent, ART)** • **Data rate:** 2-11 Mbps peak • **Chip sets:** use 802.11 or DOCSIS PHY or proprietary	• **Spectrum:** • **License exempt 2.4 & 5.x GHz** • **Licensed 2.5, 3.5 GHz, etc.** • **Data rate:** 6-54 Mbps peak • **Chip sets:** OEMs develop their own Silicon - some use 802.11x PHY with custom MAC • **Air interface:** • **OFDM & CDMA approaches** • **Proprietary mesh network and antenna techniques (beamforming, MIMO)**	• **Spectrum:** < 11 GHz • **Data rate:** Up to 75 Mbps peak • **Chip sets:** Volume silicon supplier • **Air interface:** 256 OFDM • **Standards:** Interoperable, carrier-class, economies of scale, rapid innovation, lower costs

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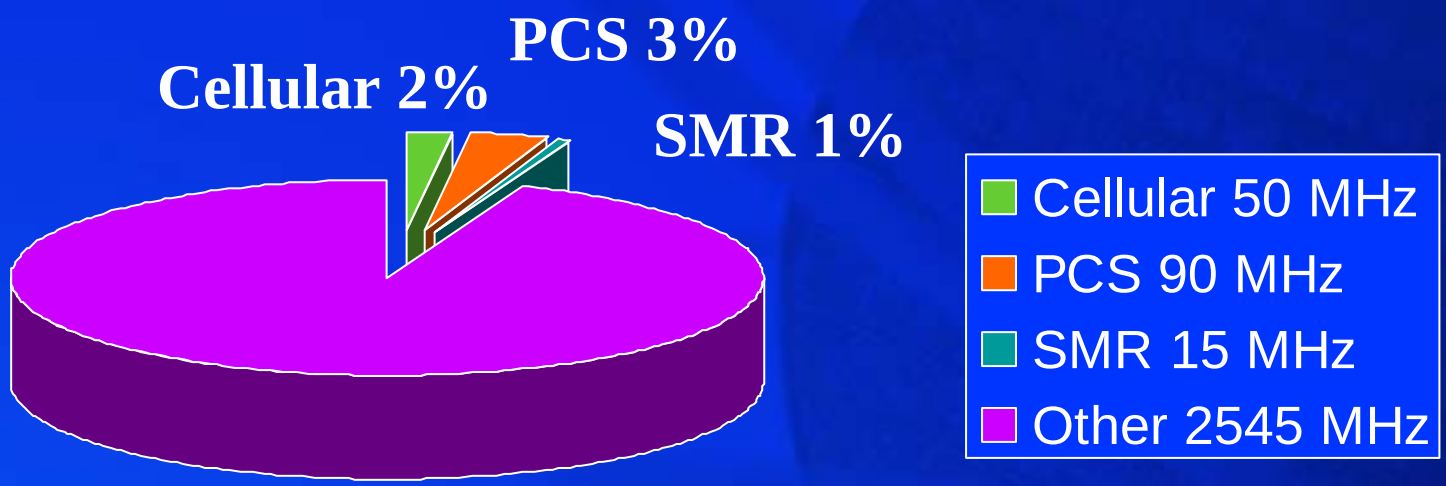
Spectrum in 300-3000 MHz Range Fully Available to Market



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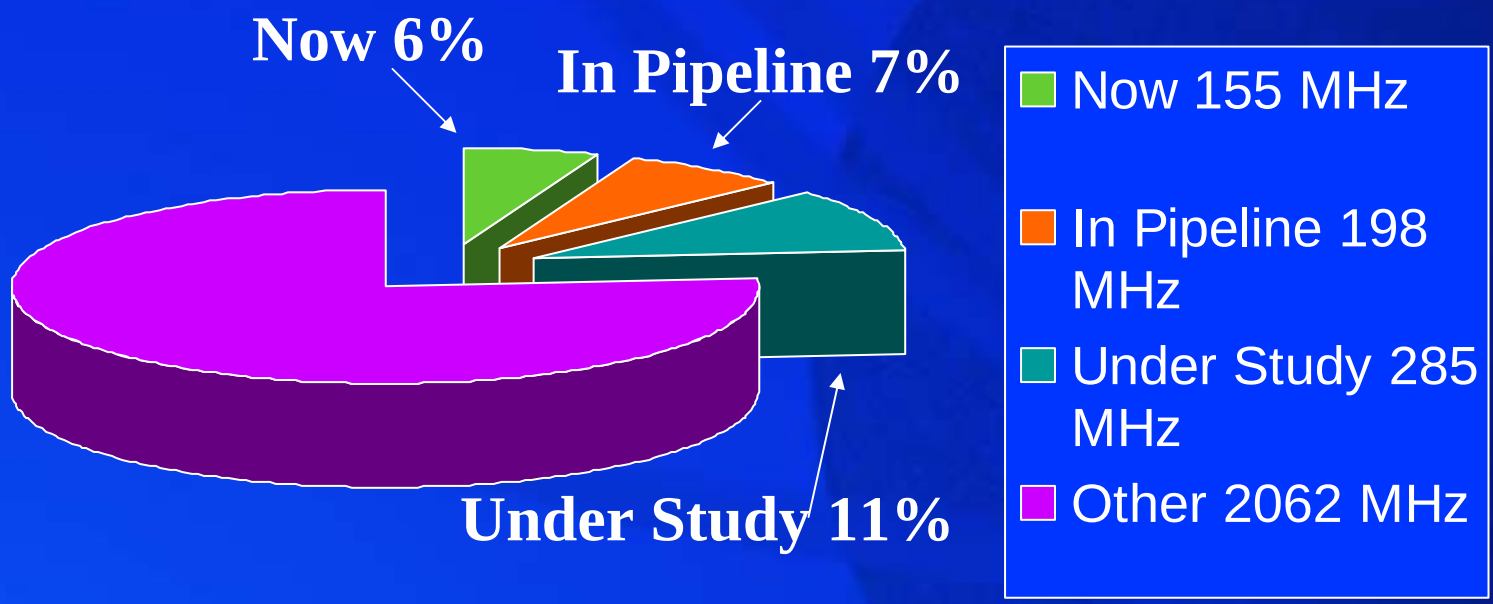
Spectrum Potentially Available for Market Allocation by 2007



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Broadband Policy

MMDS/ITFS NPRM

- 2.500-2.690 GHz
  - Underutilized
  - > Cellular & PCS
  - Interleaved band plan
    - 1-way video
    - 2-way data precluded
  - ITFS site licensing
- Reform
  - Coalition plan
    - Deinterleaving
    - Market by market transition
  - Improvements
    - Facilitate aggregation
    - Eligibility
    - Certainty

Prime Spectrum Candidate

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Ingredients for Efficient Markets

- Properly defined and assigned spectrum usage rights
  - Exclusive licenses, clear rights and obligations
  - Exhaustively assigned (all areas, all spectrum)
  - Rights easily transferable, divisible, aggregatable
  - Flexible choice of services and technology

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Making Occupied Spectrum Available to the Market

- Exhaustively assign area-wide blocks with interference protection for incumbent uses: “license the Swiss cheese, protect the holes”
- Licenses should be exclusive, flexible and transferable
- Establish efficient market-like rules for clearing incumbents: new licensees can move incumbents to comparable facilities

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Making Occupied Spectrum Available to the Market

- This “overlay” license approach successfully applied to PCS
- Should be applied more broadly- examples:
  - Applied to 60-69, but missing rules for efficient clearing of incumbents
  - MDS/ITFS
    - Reallocate ITFS for flexible use
    - Auction overlay licenses in ITFS spectrum

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Key Messages

- Intel innovating through key wireless research
- Intel working with industry
- Intel working to define future spectrum policies
  - Cooperate with regulators and stake holders
  - Worldwide effort
  - Recognize fundamental problem
  - Make incremental reforms
  - “And/both” not “either/or”

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Productivity Effects

- U.S. Labor productivity
  - ’73-’95 1.35%
  - ’95-’00 2.54%
- ICT Contribution
  - 2/3’s due to ICT
  - Production & Use
- Effect
  - Productivity = living standard
  - 2x living standard
    - 1.35% = 53 years
    - 2.54% = 28 years
    - One Generation Ahead!

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