Optimizing receiver performance using Interference Limits

FCC Workshop on Spectrum Efficiency and Receiver Performance
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Lots of old, a little new, mostly borrowed…

- Dale Hatfield, Vanu Bose

- Bob Matheson's electrospace, William Webb's Ofcom SURs

- Kwerel & Williams; Ellen Goodman, Chuck Jackson, Julius Knapp, Paul Kolodzy, Rich Lee, Michael Marcus, Madelaine Maior, Preston Marshall, Matt Oetting, Doug Sicker, John Stine, Peter Tenhula & many others

- Silicon Flatirons meetings 2009, 2010, 2011

- Spectrum Policy Task Force Report 2002, NTIA Report on Receiver Standards 2003, Ofcom/TTP study of current and future receiver performance 2010

Receiver Management Strategies

- A description of the radio frequency environment(s) in which the receiver must be designed to operate

  - E.g. adjacent band signals; high level signals, either in-band or out-of-band; and signals from other serv... same band

Always necessary; usually sufficient

- A specification of minimal performance requirements for various receiver parameters

  - E.g. adjacent channel rejection, semi-adjacent... rejection, image frequency rejec... rejection, intermodulation respon... ...blocking immunity

It's Complicated; use only when unavoidable

Source: NTIA report TR-03-404

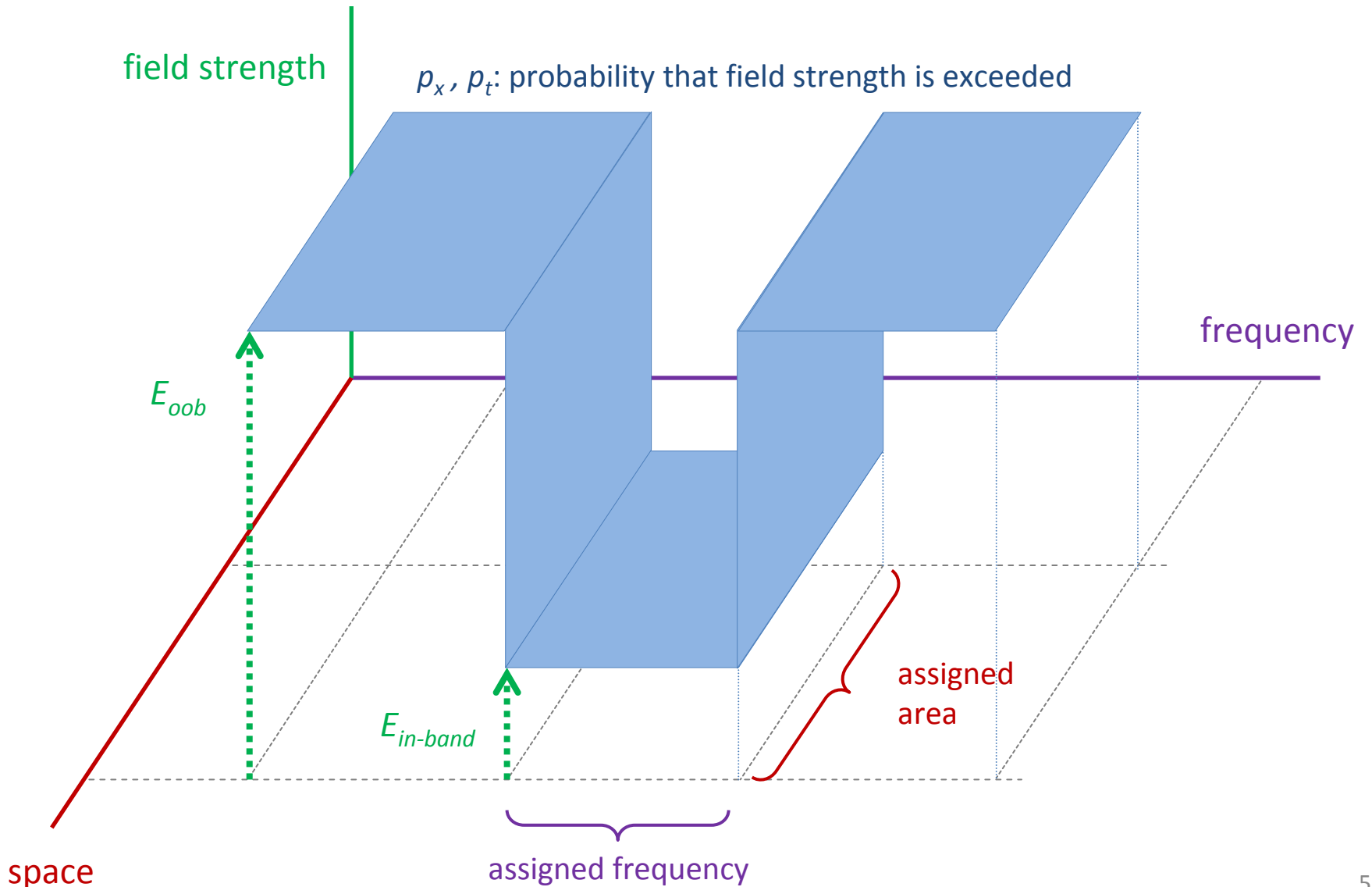# Receiver Interference Limits

A delineation by the regulator
of the radio interference environment
an assignee's system should expect to operate in
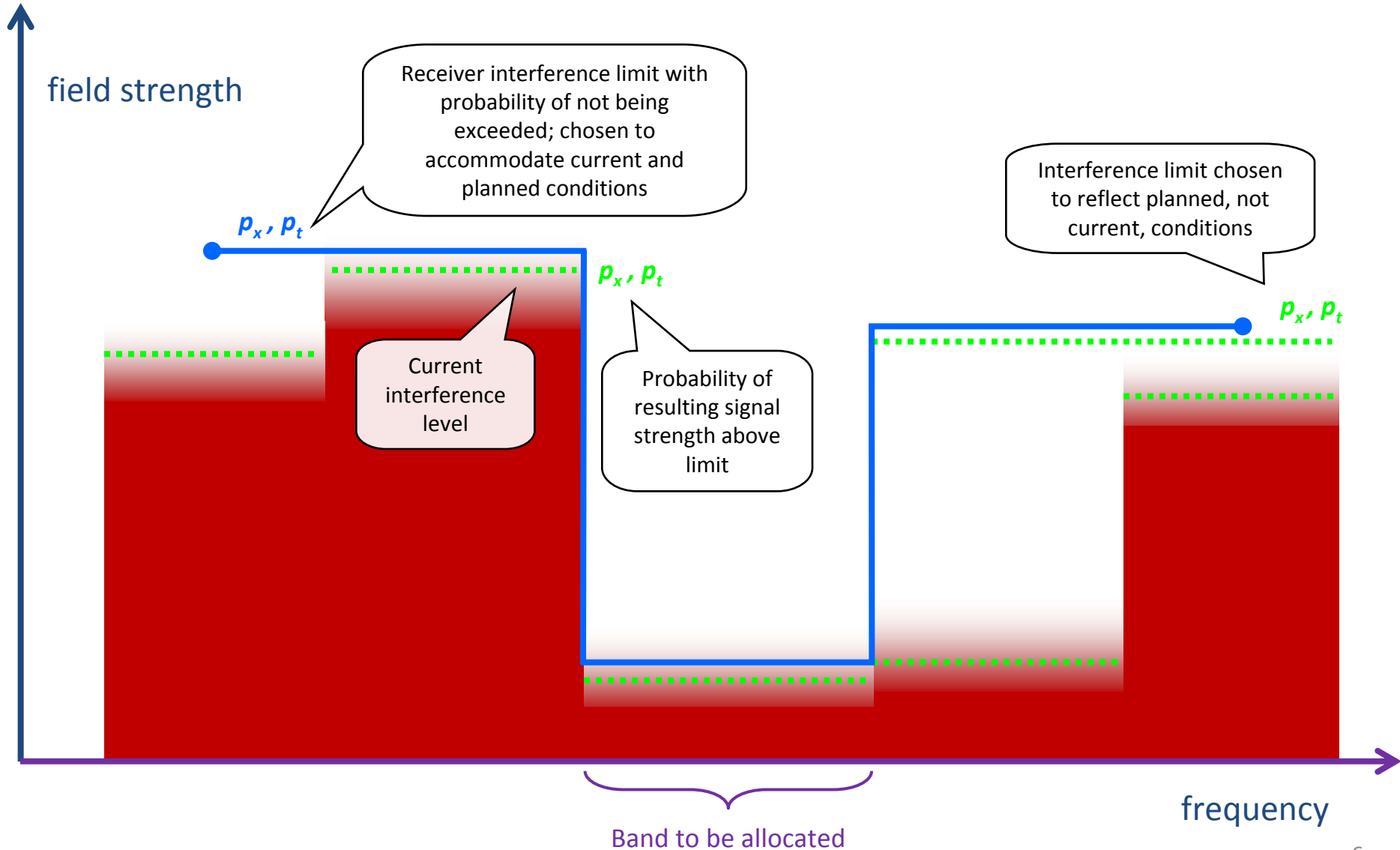without being able to make a claim of harmful interference

Hypothetical example

The aggregate field strength due to third party operations
at 1.5 m above ground level
will not exceed
41 dB(μV/m) per MHz within the assigned band, and
65 dB(μV/m) per MHz in the 20 MHz beyond the band edge,
with no protection beyond that,
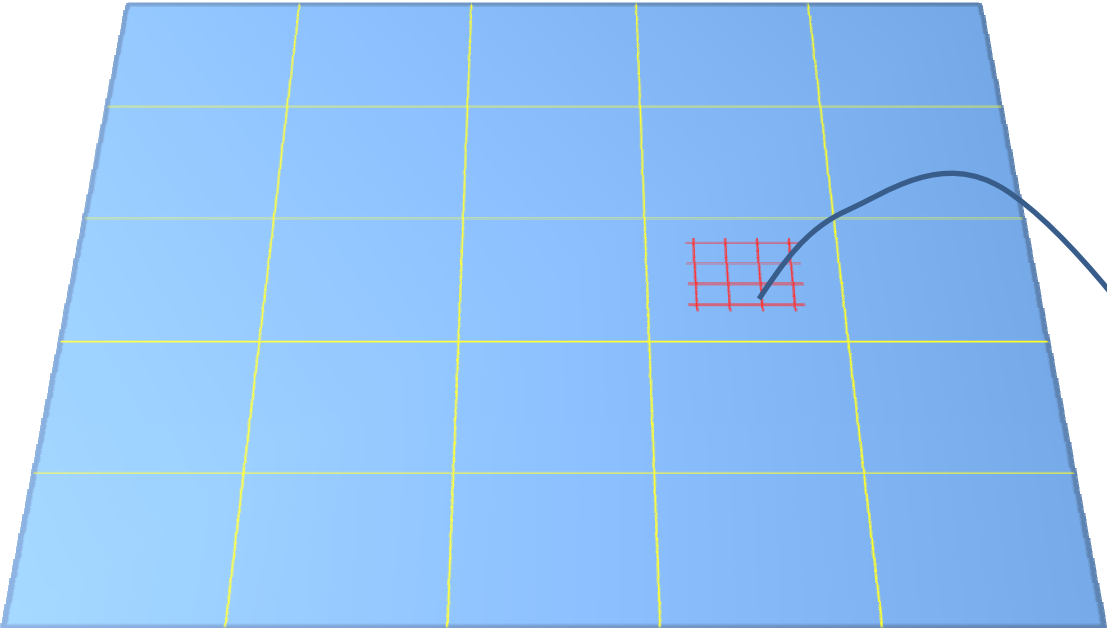at more than 5% of locations, more than 1% of the time

Interference Limit for an Assignment

field strength

p_x , p_t : probability that field strength is exceeded

frequency

E_{oob}

$E_{in\text{-}band}$

assigned area

space

assigned frequency

Choosing Receiver Interference Limits

field strength

Receiver interference limit with probability of not being exceeded; chosen to accommodate current and planned conditions

p_x , p_t

p_x , p_t

Interference limit chosen to reflect planned, not current, conditions

p_x , p_t

Current interference level

Probability of resulting signal strength above limit

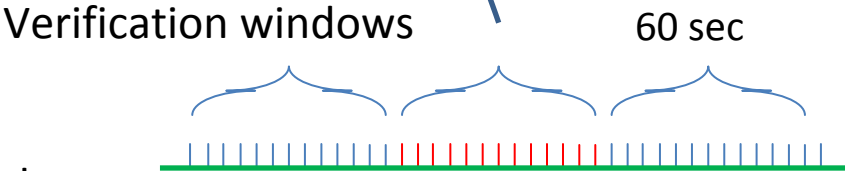Band to be allocated

frequency

Determining the signal environment

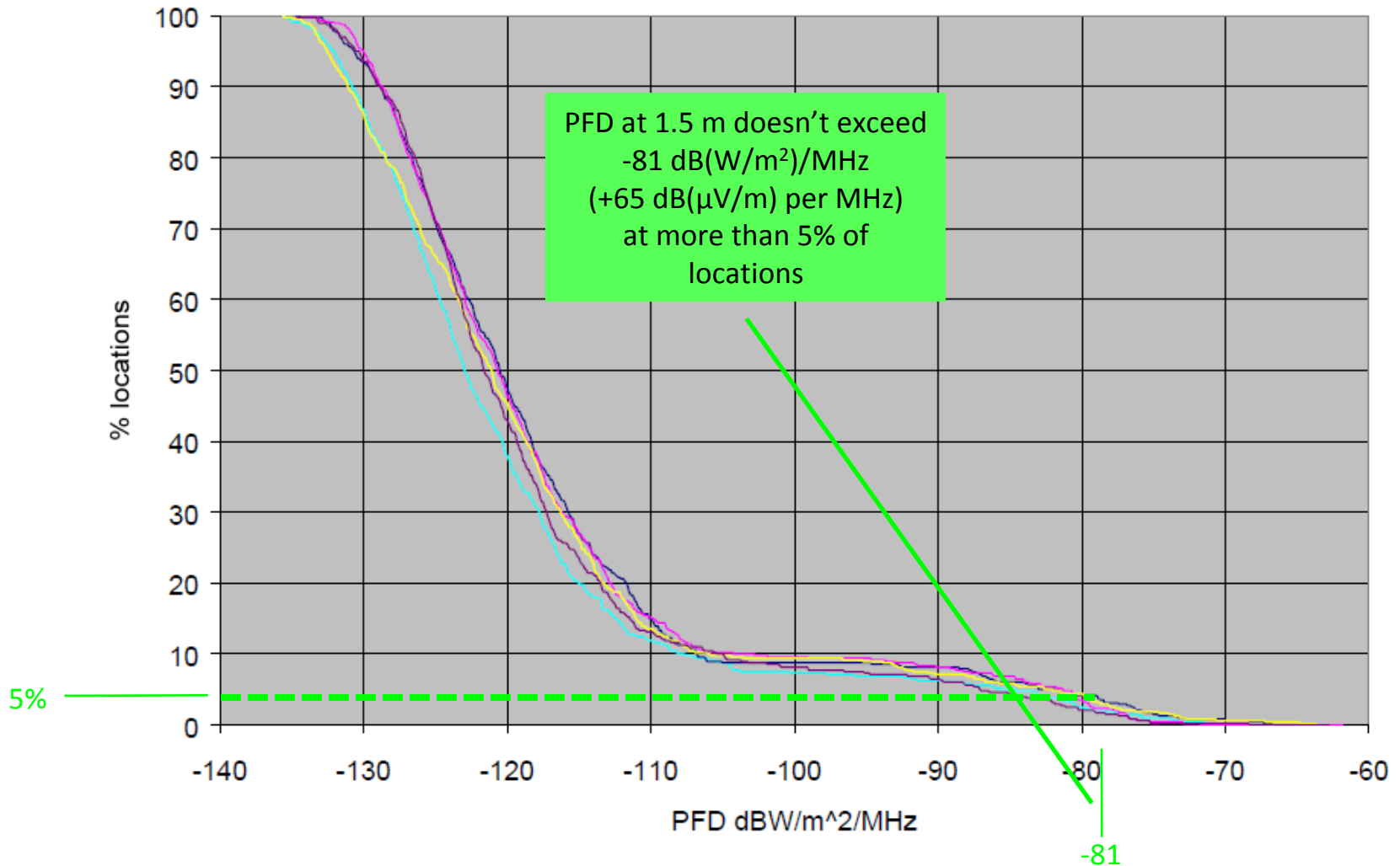For each measurement point in a verification area, observe over time; fraction that exceed E must be $< p_x$

Verification areas $\leftarrow$5 km$\rightarrow$

Verification windows   60 sec

For every verification window,
fraction of observations that exceed E should be $< p_t$

Example: Determining p_x for handset population
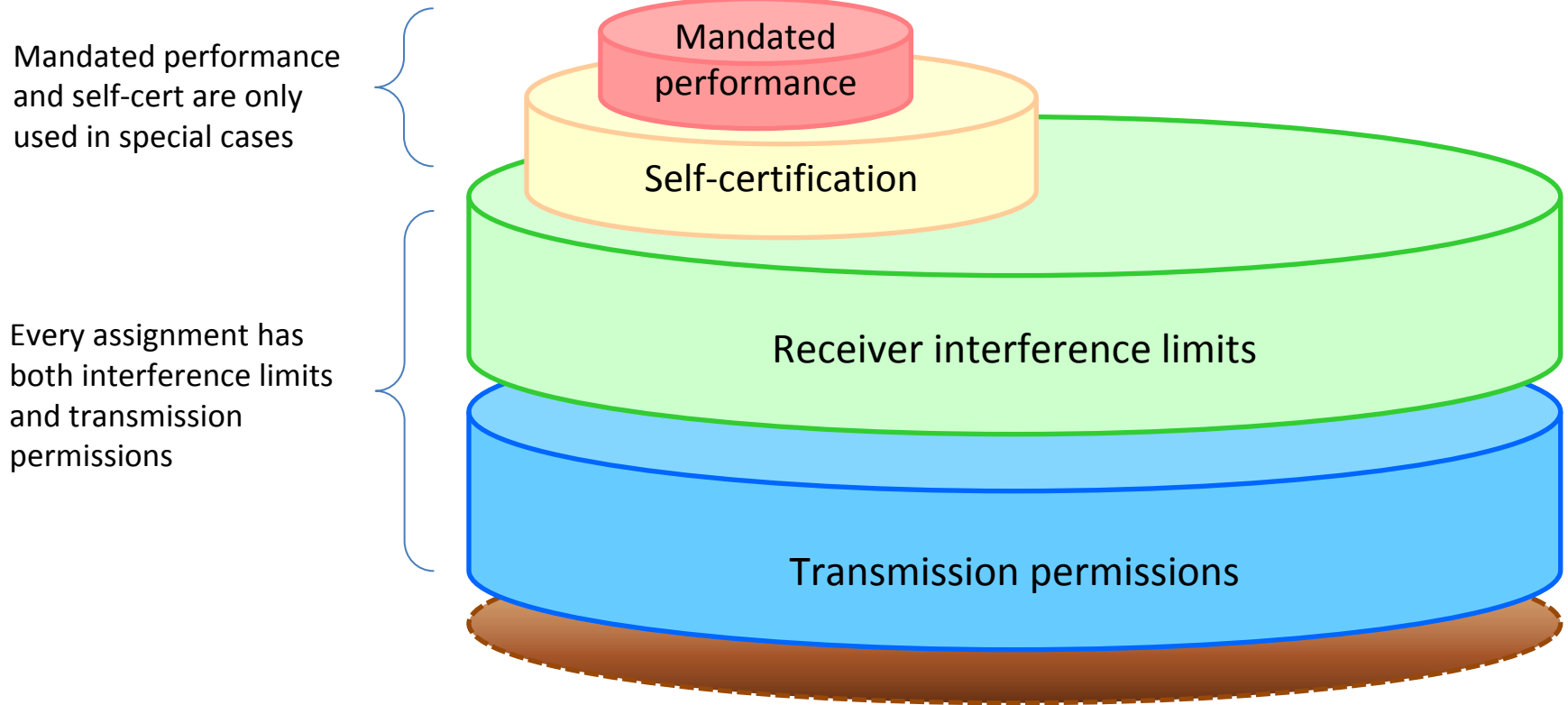

Source: Ofcom/Transfinite 2008

Additional Measures

- Receiver interference limits
  - Necessary but not always sufficient
- What if users aren't trusted to deploy receivers that function "satisfactorily" given the limits?
  - Decoupled receivers: sold and operated independently of licensee
  - Unlicensed devices: no license required
  - In bands shared with Feds, perhaps even licensees…
- So: add device performance requirements
  - Self-certification
    - warranty-of-fitness, self-certification to individual or industry standard
  - Mandated performance
    - front-end selectivity, mandated industry standard

Cumulative Requirements

Mandated performance and self-cert are only used in special cases

Every assignment has both interference limits and transmission permissions

Mandated performance

Self-certification

Receiver interference limits

Transmission permissions

Benefits of Interference Limits

- Business value
  - Regulator delegates system design decisions, e.g. Tx vs. Rx performance
  - Reduces business risk
    - Receivers: guarantee of no interference from future allocations
    - Transmitters: no harmful interference claims from poor receivers
    - Both: better estimate of deployment costs from knowing interference risks
  - Increases economic efficiency: adjust Tx and Rx rights by negotiation to reach social welfare optimum
- Regulatory value
  - Allows future repurposing of quiet bands
  - Establishes technology-neutral rules
  - Facilitates dynamic sharing by automatic calculation of permissions

Resources

Silicon Flatirons roundtable: http://bit.ly/A1z4SU

Two-pager: http://sdrv.ms/ReceiverLimits

White paper on its way

Backup

Cumulative Requirements

- Licensees
  - **interference limits only**: next to busy band that matches their interference limits
  - interference limits **+ self-cert**: next to quiet band that's planned to be filled later
  - interference limits + self-cert **+ mandated performance**: where performance is critical, e.g. aviation
- Unlicensed or decoupled receivers
  - **interference limits only**: never
  - interference limits **+ self-cert**: next to busy band that matches their interference limits
  - interference limits + self-cert **+ mandated performance**:
    - next to quiet band that's planned to be filled later
   - in shared band with Feds

Cumulative Receiver Management Options

increasing regulatory intervention →

		Interference environment	Device Performance	
		Receiver Interference Limits	Self-certification Includes warranty-of-fitness, self-certification, conformance to industry standard	Mandated performance Includes front-end selectivity, mandated industry standards*
Federal assignments		all assignments	**If necessary**, e.g. to facilitate efficient coexistence among diverse systems	**If essential**, e.g. for safety of life in aviation
FCC assignments	Licensed	all assignments	**Not necessary if** next to busy band that matches their interference limits **Required if** next to quiet band that's planned to be filled later	**If essential**, e.g. for safety of life in aviation
	Decoupled receivers Part 15 devices	all assignments	**Required if** next to a busy band that matches their interference limits	**Required if** next to quiet band that's planned to be filled later
FCC assignments in bands shared with Federal users	Licensed	all assignments	**Not necessary if** in a busy band that matches their interference limits **Required if** in a quiet band that's planned to be filled later	**If essential**, e.g. for safety of life in aviation
	Decoupled receivers Part 15 devices	all assignments	all assignments	**Required if** next to quiet band that's planned to be filled later

Comparison with Interference Temperature

Interference Temperature	Receiver Interference Limits
Focus on in-band, co-channel operation	Focus on solving out-of-band, cross-allocation interference
Designed to facilitate and encourage second party, co-channel operation	Does not grant second party rights in a primary licensee's frequency block
Aims to create additional operating rights	Adjunct to existing definition of operating rights
Needs to be measured at all locations at all times	Only needs to be measured when concern that limit is being exceeded
Deterministic values	Probabilistic

Example: Determining p_x for base stations
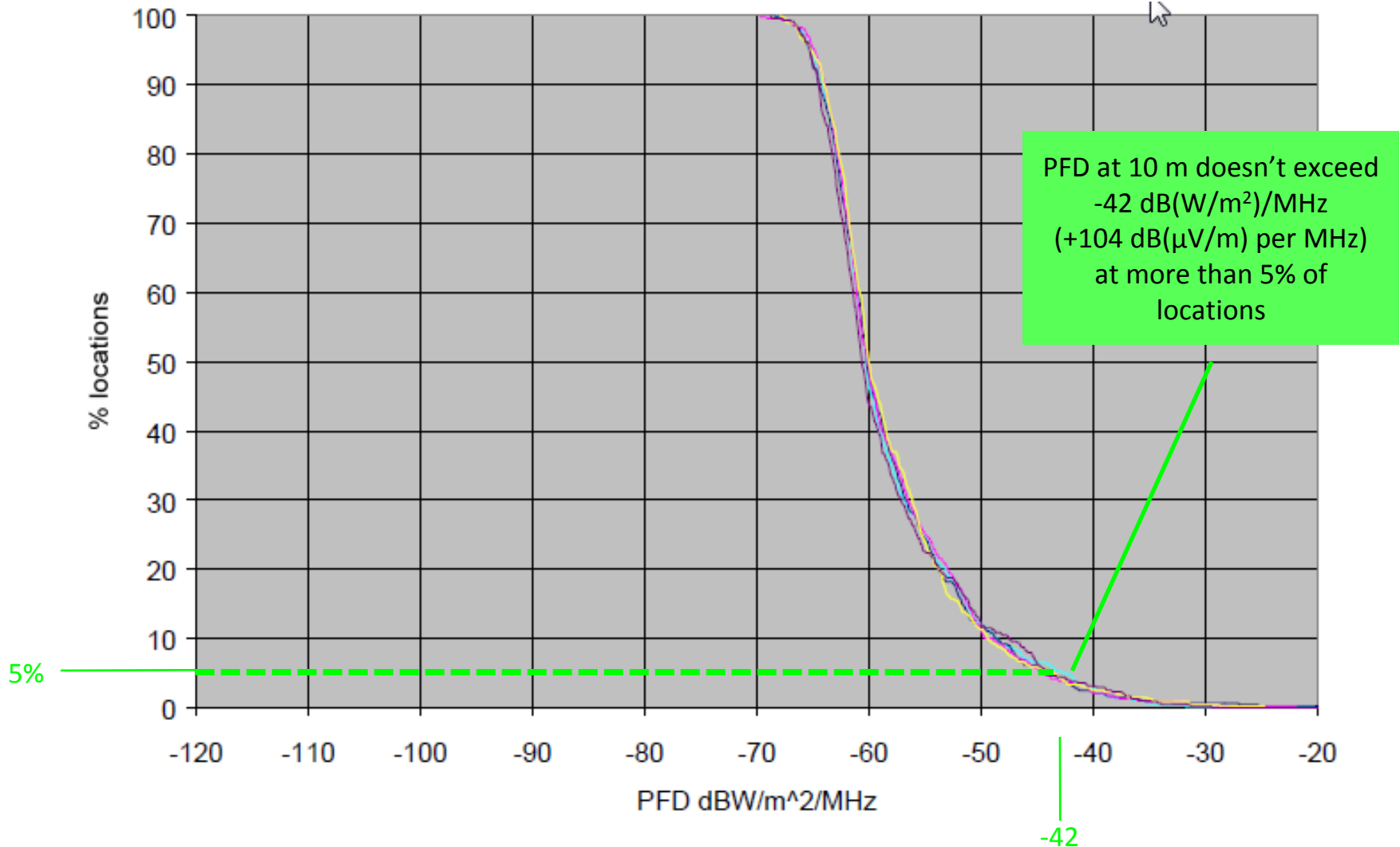
Source: Ofcom/Transfinite 2008. Modeled PFD of IMT-2000 base station population