Clash

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Underlying cause of the Clash:

How much received power does a communications system need?

For reasons

Energy per Received Bit

$$\frac{E_b}{N_0} \approx 10$$

Ambien

Receiver Antenna

A little Handwaving

By the Prof

Greatly Simplified Communication Theory

So for a data Rate of D (say 10 megabits/sec):

$$D \cdot E_b = Received\ Power(PR) \approx D \cdot 10 \cdot N_0$$

Or:

$P_R \geqq$ (Data Rate * 10 N_0)

Not Startling: To send larger amounts of Data, need to spray the user with proportionally more power

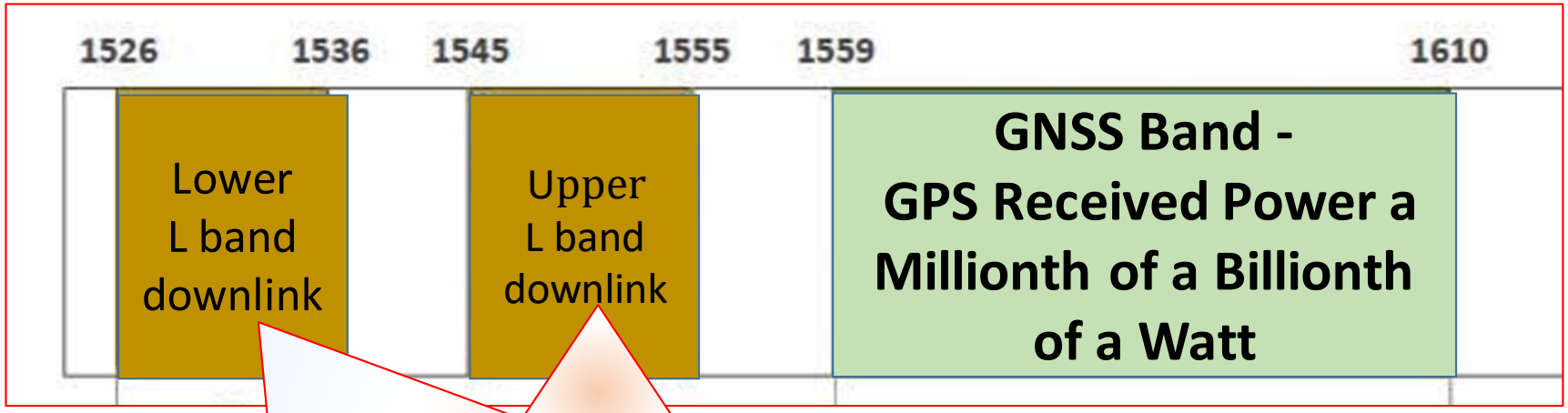
- A certain company (Lxxx) had License for transmitting Satellite to Ground for Communications

But the received power was very low and did not support a large D (Data Rate)

But Lxxx saw a great opportunity

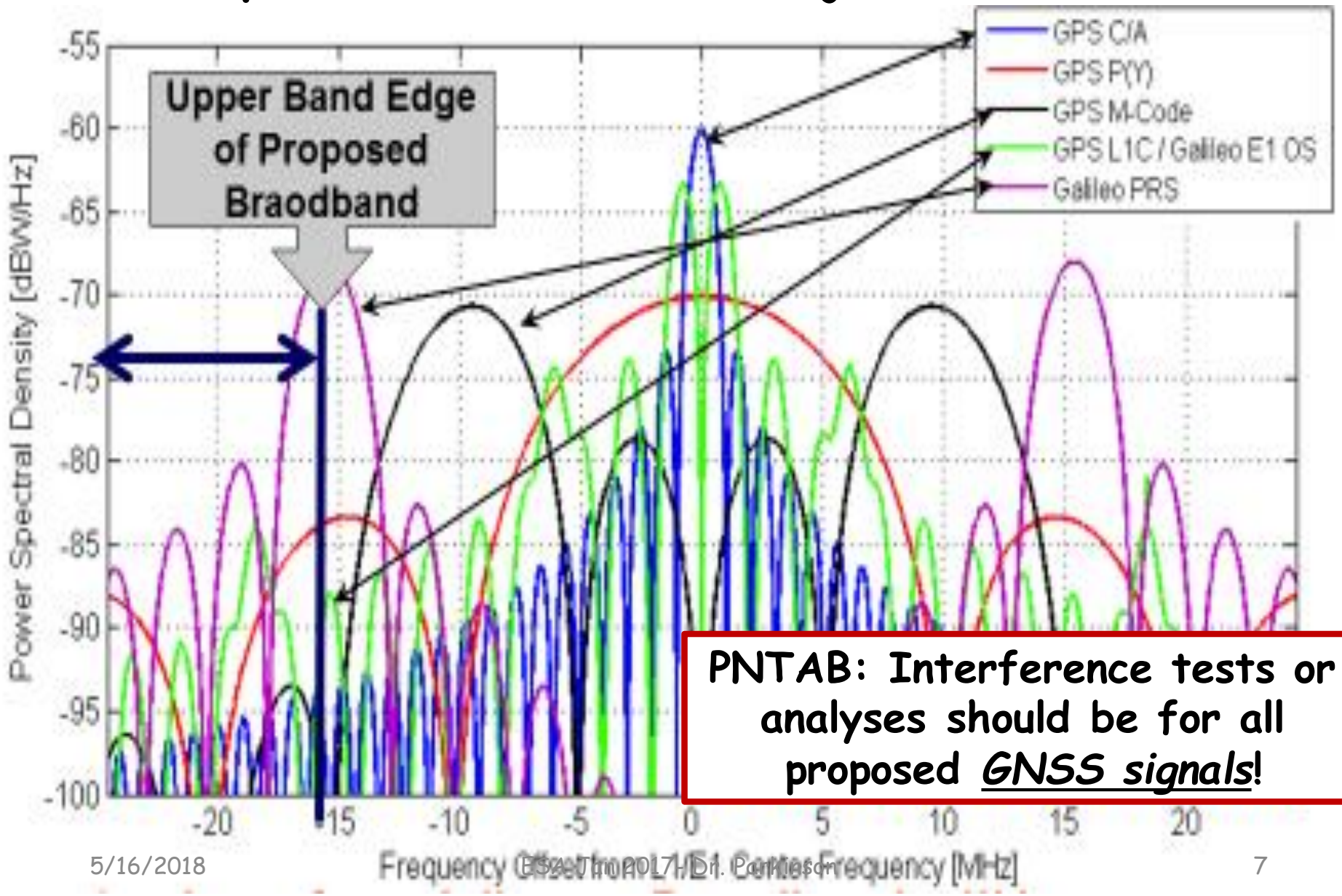
- Convert the License to high power ***terrestrial transmissions*** (Asked for 15.8 Kw)
  - Tower Spacing at about **¼ mile**
  - Would support broadband – sending movies etc.
  - **Spectrum Value would jump: $2B → $10B+**
- Tried to get the FCC to slip this through just before Thanksgiving 2010 – while everyone was digesting turkey
- PNT community found out and slowed the process down
- **But*But** apparently a predecessor Lxxx company had already found a significant ***Clash*** with GPS…
  - According to Harbinger lawsuit

Adjacent band interference concern



Original proposal: Convert to terrestrial & transmit 15 kW+ ,
Example then Considered: With a minimum tower spacing of ~ ¼ mile (so impacted area must be much less than 1/8 mile or else impacted area could be, e.g., city-wide)

Woops! - GNSS is not just L1 C/A



PNTAB: Interference tests or analyses should be for all proposed *GNSS signals*!

Lxxx signal goal is *5 Billion times GPS* at ¼ mile (tower spacing suggests GPS never further than 1/8 mile)

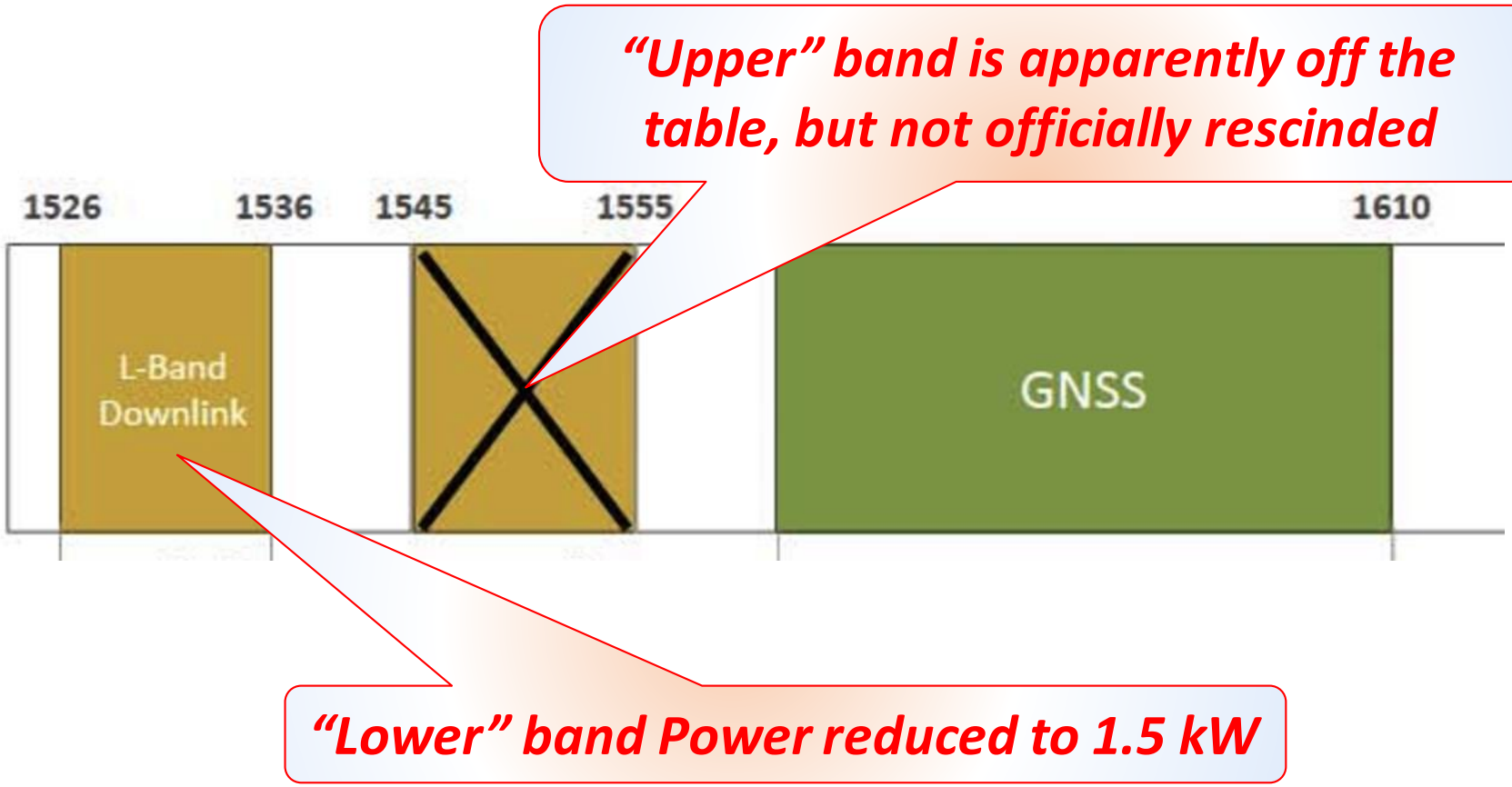
Lxxx Equivalent to - Niagara at ~ 1 Billion Watts
(167 feet with 64,750 cubic feet/ second)

5 Feet

GPS - 0.2 Watts (1 Tablespoon of water per second through 5 feet)

Illustrating Power Ratio of 5 Billion to One

Adjacent band interference concern



Interference tests were initiated by government and proposer. Results:

- Lxxx claimed minimal harm – stated: could be solved by retrofitting new filters or buying new GPS sets
- DOT showed substantial problems

Who to believe? The Tests:

- 1) FCC mandated Technical Working Group (TWG)
- 2) National Space-Based PNT Systems Engineering Forum (NPEF)
- 3) Department of Transportation (DOT) Adjacent Band Compatibility (ABC)
- 4) Roberson and Associates (RAA)
- 5) National Advanced Spectrum and Communications Test Network (NASCTN)

Evaluating the Quality of the GNSS interference tests

COMPLIANCE WITH PNTAB CRITERIA

PNTAB Evaluation Criteria	TWG	NPEF Rounds 1 & 2	RAA	NASCTN	DOT
1. Used 1 dB IPC as metric	●	●	○	○	●
2. Included all classes of receivers	●	○	○	○	●
3. Included all modes of operation	●	●	○	●	●
4. Focused on stressed conditions	●	●	○	●	●
5. Addressed impact on emerging GNSS	○	○	○	◑	●
6. Included GNSS experts and public	●	●	○	◑	●

Figure 1. Summary of PNTAB Criteria Evaluations

Lxxx Sponsored

"ABC"

JAMES R. HOREJSI, GG-15
DOD NPEF Co-Chair

KENNETH K. ALEXANDER
DOT NPEF Co-Chair

Example of ABC Test Results

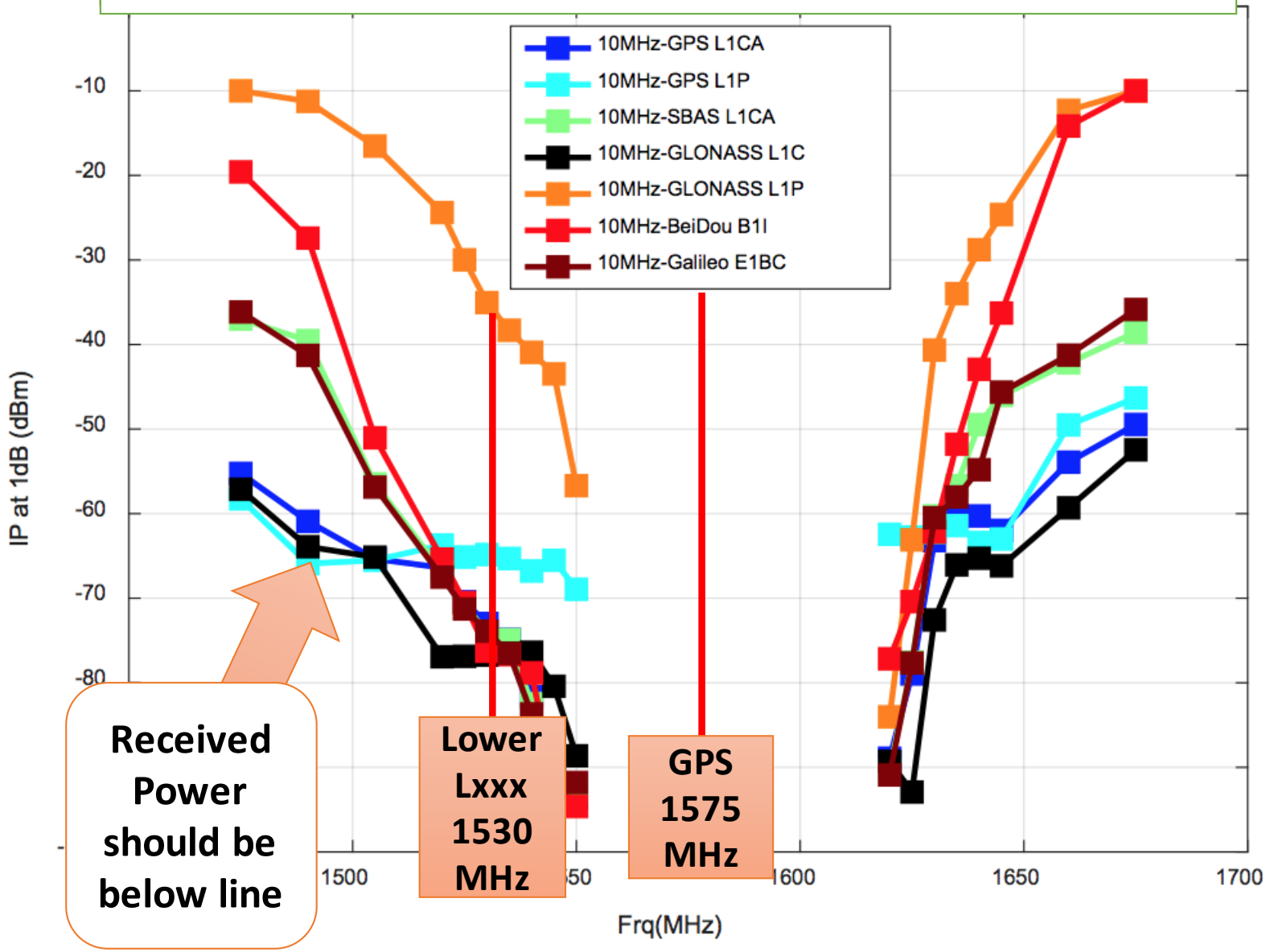
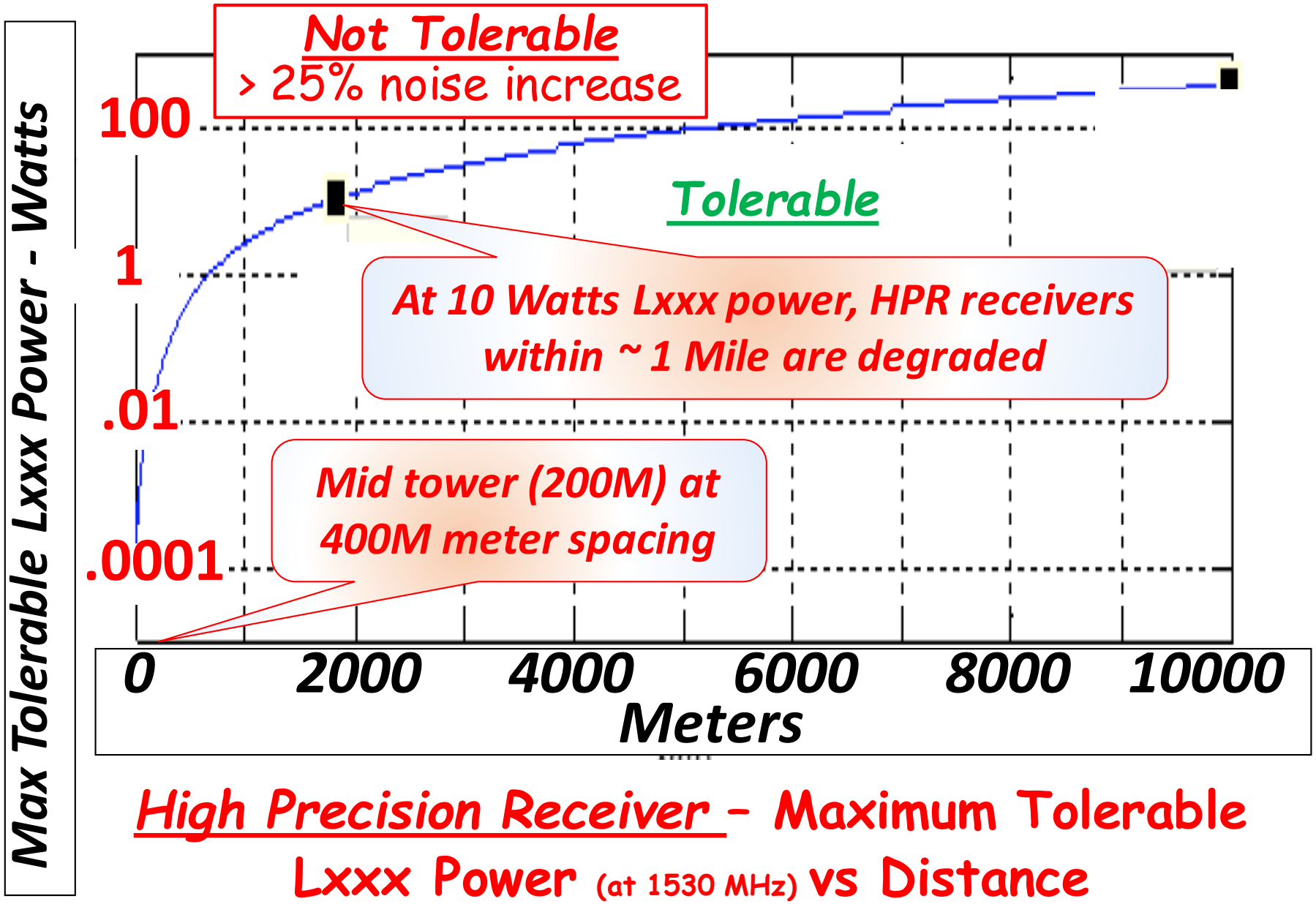
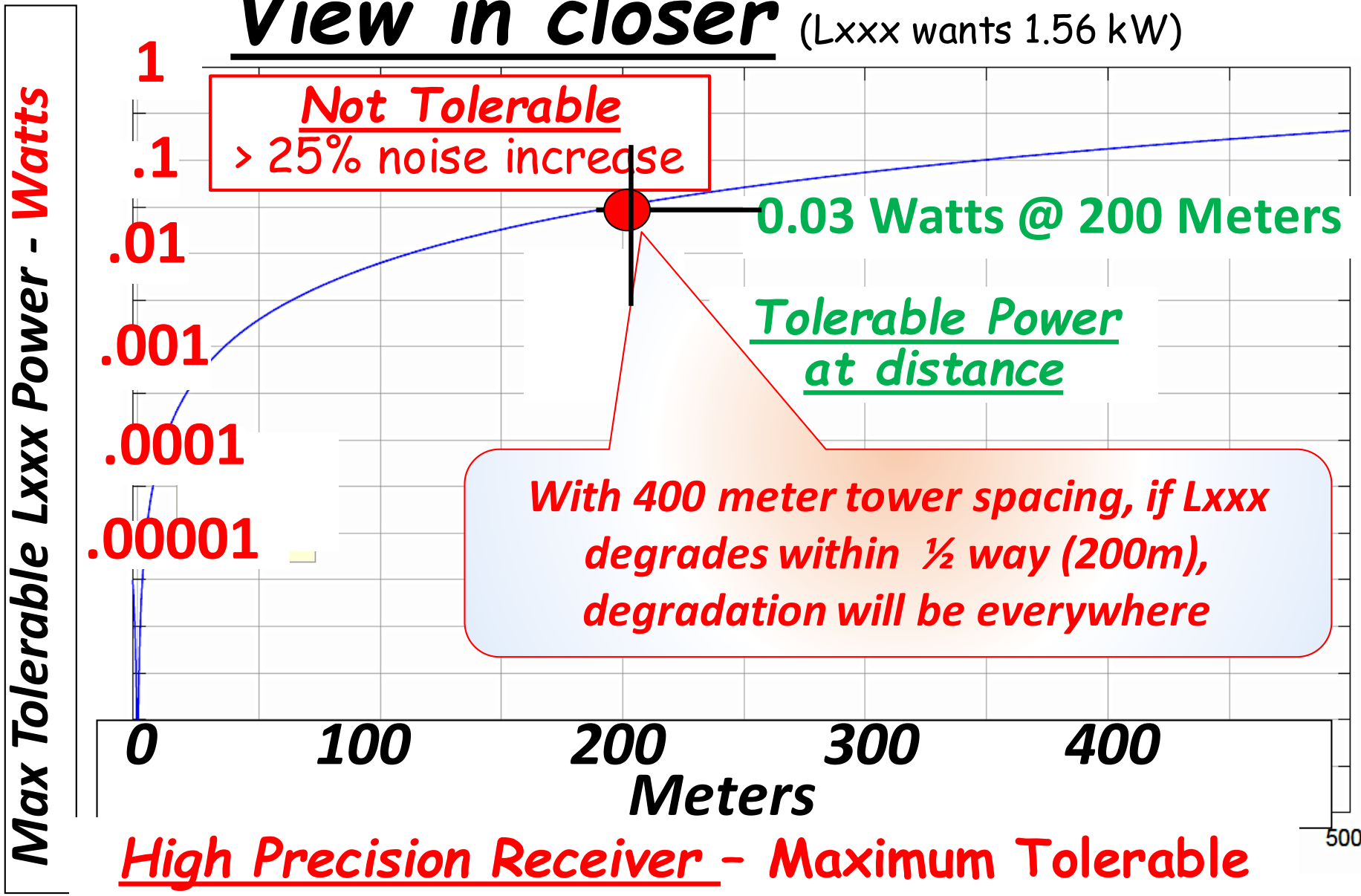


Figure 3-23: HPR bounding ITMs for each of the emulated GNSS signals



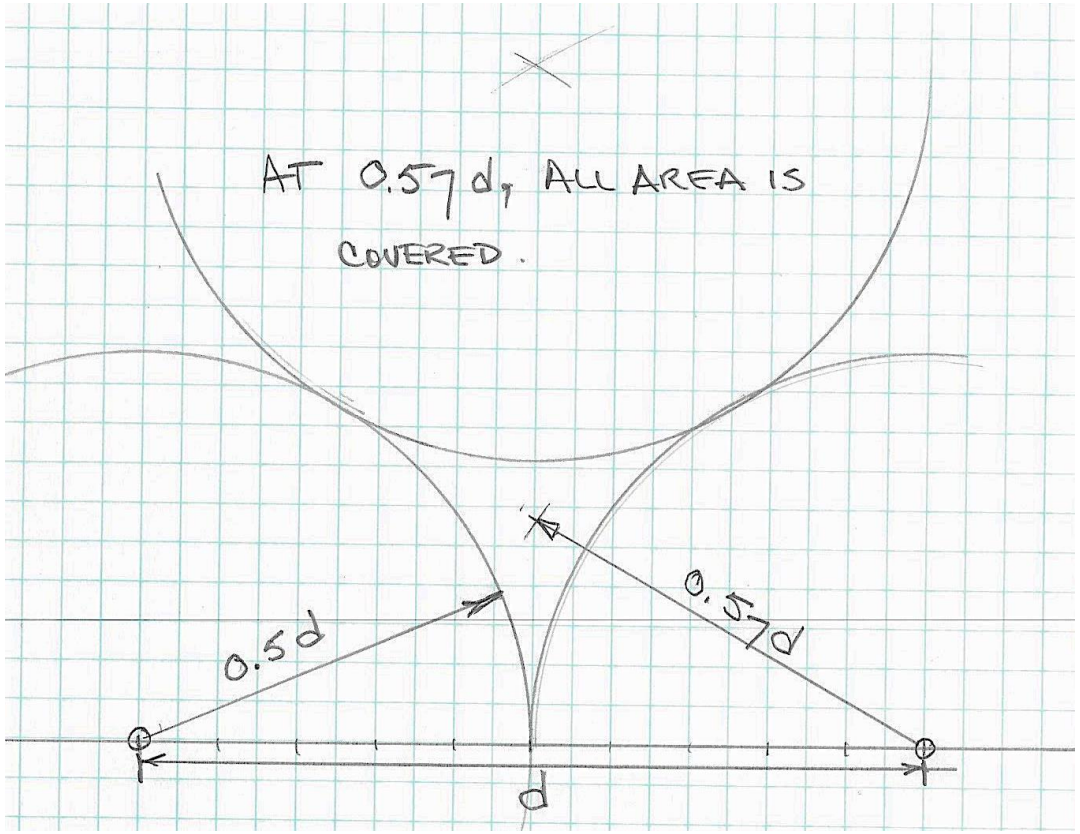
High Precision Receiver – Maximum Tolerable Lxxx Power (at 1530 MHz) vs Distance

View in closer (Lxxx wants 1.56 kW)



High Precision Receiver – Maximum Tolerable Lxxx Power vs Distance (Lxxx at 1530 MHz)

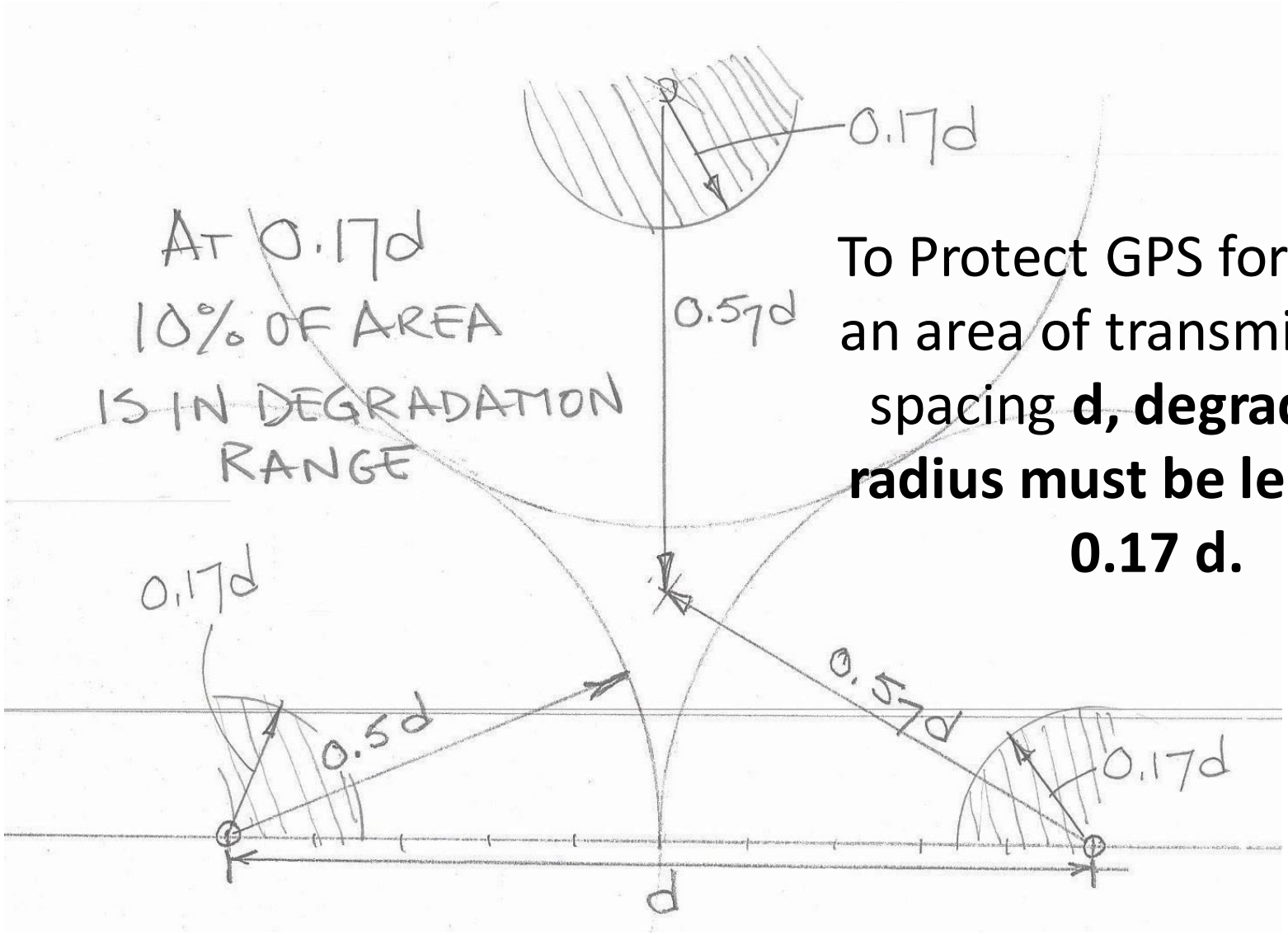
Max Lxxx Transmitter Power should be constrained by the % area that is degraded



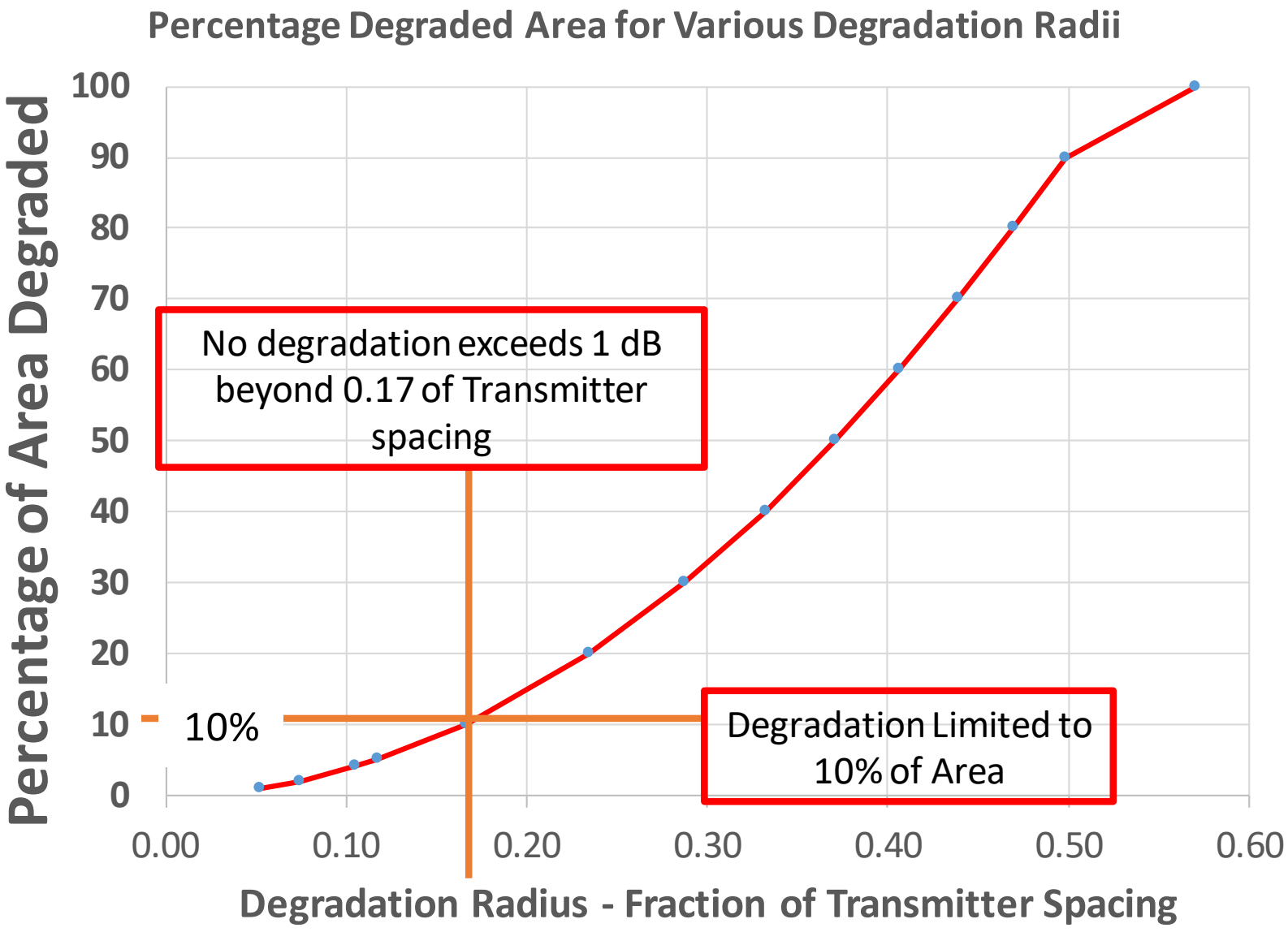
Geometric problem directly scales with spacing of transmitters (d)

For Example:
At 0.57 **$(1/3^{0.5})$ d,** 100% of the area would be covered

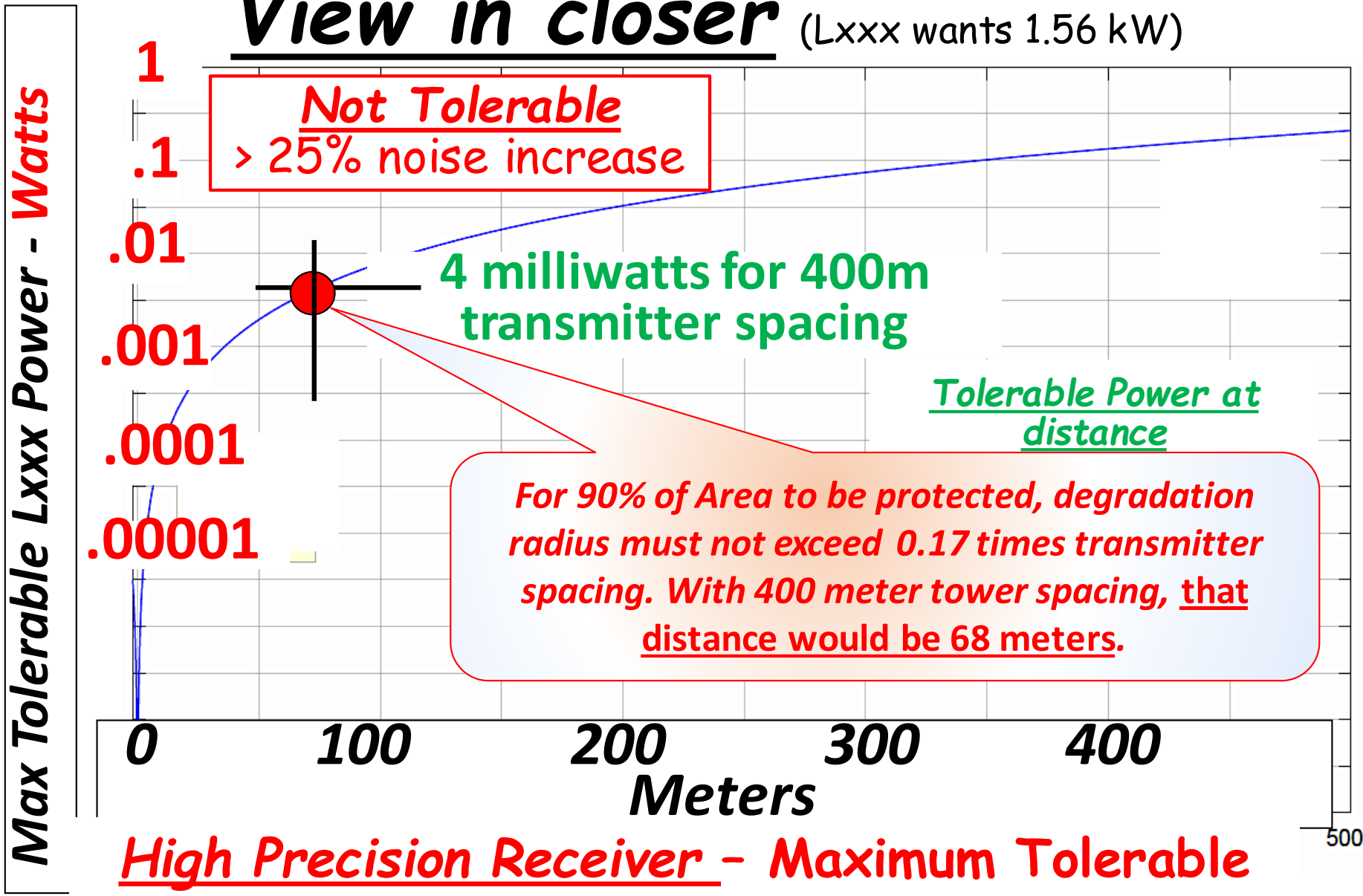
What degradation radius would result, if degradation were limited to 10% of the area?



To Protect GPS for 90% of an area of transmitters at spacing **d, degradation radius must be less than 0.17 d.**


Percentage Degraded Area for Various Degradation Radii
Percentage of Area Degraded
100
90
80
70
60
50
40
30
20
10
0
No degradation exceeds 1 dB beyond 0.17 of Transmitter spacing
10%
Degradation Limited to 10% of Area
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Degradation Radius - Fraction of Transmitter Spacing

View in closer (Lxxx wants 1.56 kW)



High Precision Receiver – Maximum Tolerable Lxxx Power vs Distance (Lxxx at 1530 MHz)

Maximum Lxxx Transmitter power to protect GPS High Performance Receivers - HPR

Transmitter Spacing (d)	Radius to protect 90% of the Area from HPR GPS degradation	Tolerable Lxxx Transmitter Power for 90% High Performance GPS Protection
1000m	170m	25 milliwatts
400m	68m	4 milliwatts
100m	17m	0. 2 milliwatts

Clash – *Fundamental Incompatibility*

Lxxx Proposals			
~ Date	Power	Spacing	Comments
2010	15.6 kW	400 Meters	Original "Thanksgiving" Proposal to FCC
2012	1.56 kW	400 Meters	Quickly dropped power when PNT community protested
2015	1.56 kW	400 Meters	Last Official, Same as 2012
2017	19.8 W	Would not say	Verbal only: Presumably less than 400 Meters spacing

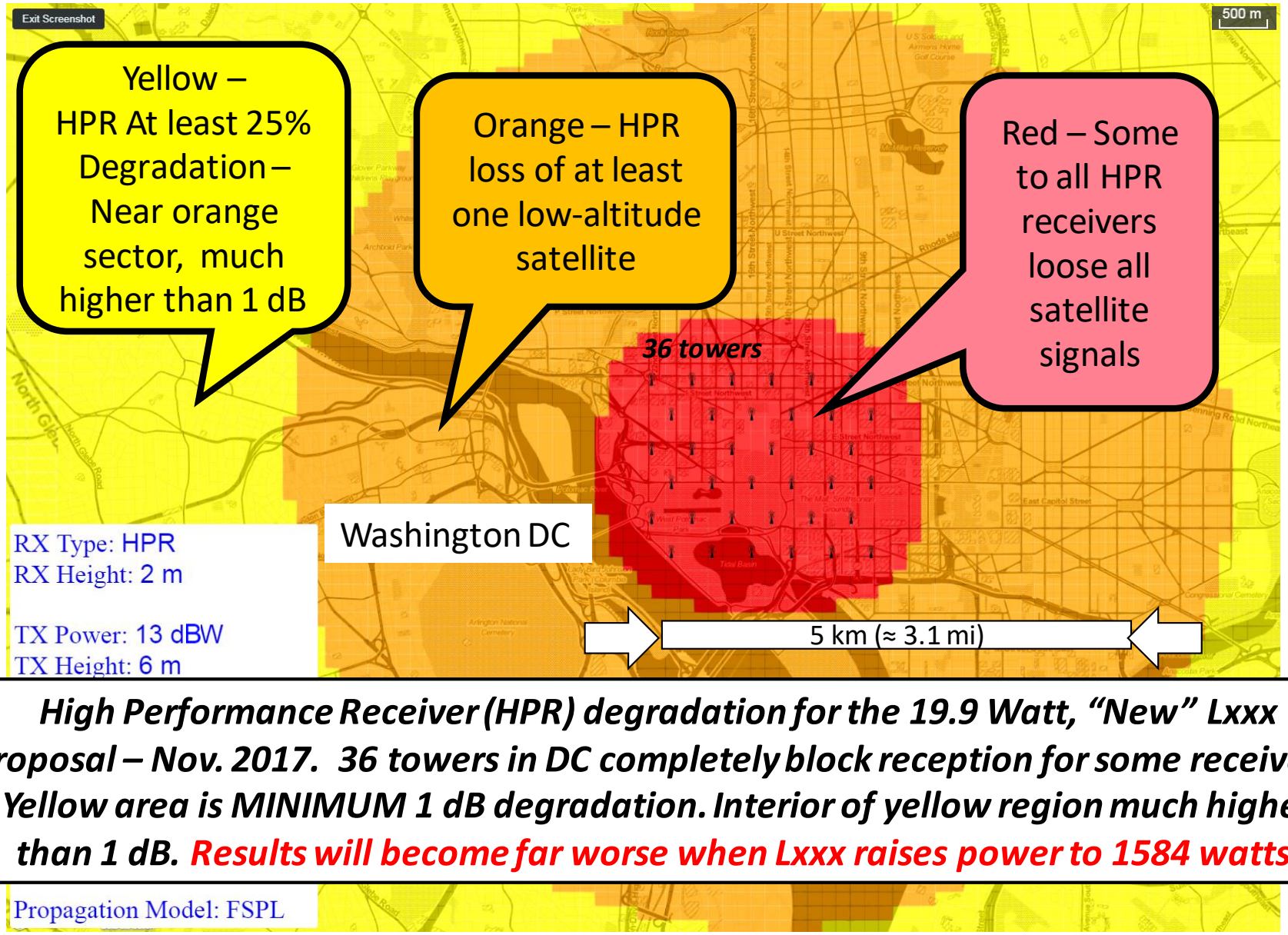
DOT Adjacent Band Compatibility Tests

Deployment	Stand off distance (m)	Max Tolerable EIRP			
		GLN	HPR	TIM	CEL
Macro Urban	10	0.8 mW	64 μW	8.7 mW	12.3 W
	100	79.4 mW	6.5 mW	0.9 W	1.26 kW

But Wait – it may be worse…

- Multiple towers contribute additive noise
- Reflections from ground and buildings can increase normal $1/R^2$ models by factors of over 10 (measured in Las Vegas)
- The newer GNSS signals have wider bandwidths for greater accuracy and A/J, but the receivers will also have greater BW
- The new military signal deliberately pushes energy away from the center frequency

Impacts in DC Area "new" verbal proposal 19.9 Watts



High Performance Receiver (HPR) degradation for the 19.9 Watt, "New" Lxxx Proposal – Nov. 2017. 36 towers in DC completely block reception for some receivers. Yellow area is MINIMUM 1 dB degradation. Interior of yellow region much higher than 1 dB. Results will become far worse when Lxxx raises power to 1584 watts.

The Clash – History Review

- To meet original model, Lxxx wanted 15kW at 400 meters tower spacing in two bands. (call this implied Data rate - D_0)
- Their upper band was a complete non-start and abandoned – ($D_0/2$)
- They then said 1.5 kW was a good first step, and this was tested by DOT – and found wanting in 2011. (***$D_0/20$***, **unless tower density increases – *call this the modified data rate*)**
- When the ABC testing in 2016 reconfirmed the problem Lxxx said they would consider an entry level of 19.8W, but would not specify the tower spacing (**$D_0/1500$ if density does not increase)***

*** Does not scale as separation distance squared – but about as cubed. If separation dropped to 100 meters, pick up factor of 4^3 or 64 – this is close to $D_0/20$**

So what?

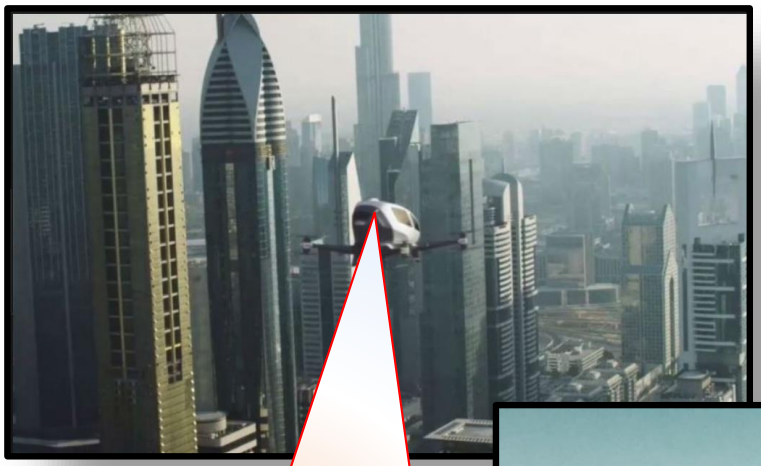
Summary of Preliminary 2013 US GPS Benefit Estimates

Application Category	Range of Benefits ($ billions)	Mid-range Benefits ($ billions)
Precision Agriculture – grain*	10.0-17.7	13.7
Earthmoving with machine guidance in construction*	2.2-7.7	5.0
Surveying	9.8-13.4	11.6
		0.145
		0.055
		0.185
	7.6-16.3	11.9
		0.038
		0.05
		5.5
	9.8-31.4	20.6
TOTAL (with alternative estimates for timing and consumer LBS averaged)	**37.1-74.5**	****68.7**

- Over $65B In Annual Benefits in identified ***Commercial Areas***

- Hi Productivity - Heavy Reliance on High Precision GPS receivers

In Harm's Way: Rapidly growing RPV/UAV applications



Both RPV Control and Air Traffic Monitoring depend on GPS – probable paths less than 400 Meters to Transmitter sites ***Apt to be Directly in Main Beam***

The Point

- To be viable, Lxxx must achieve a minimal data rate Perhaps $D_{0,}$ or $D_0/20$
- But this implies a certain Lxxx Received Power level $P_R \geqq (D_0 * 10\ N_0)$ *at the furthest distance*. (again see "scaling" note)
- If achieved by repurposing the 1525 -1535 MHz band at 400 m spacing:
  - as little as 30 milliwatts would degrade GPS High Performance Receivers everywhere
- Any game of trading tower power and spacing, still is approximately the same result
- Toughening GPS might help ***a little***,, but does not solve the problem for existing High Performance Receivers

A New Offer by Lxxx? **Allow Lxxx to proceed, and any receivers who experience problems would be able to swap for a new (presumably immune) set**

- The 1 dB is not to protect from loss of lock – ***it is to preclude errors in timing (ranging) precision and accuracy.***
- Most high precision users will not know this instantaneously – only found out after the fact
- In any area – the number of current users is totally unknown
- The using community would probably have no knowledge of such an arrangement
- Any such "swaps" would incur substantial time delays and loss of productivity
- This is an invitation for protracted litigation – who caused what, when, and where?
- The military has stated the interference for their receivers is similar – how could that be handled? Would Lxxx be a source of classified receivers?

This offer does not seem viable

Avoid the Clash – Just say no !!!

- For results approaching the Lxxx Data rate requires power on the ground ***everywhere***, at levels GPS cannot tolerate.
- The only apparent solutions –
  - leave the space to ground spectrum vicinity unchanged
  - Make a swap, or allow Lxxx to buy spectrum at least 100 MHz away from any GNSS signal