LightSquared and GPS: Experiences and Lessons Learned

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LightSquared and GPS – How Did We Get Here?

US National Broadband Plan (Oct 2010) calls for finding 500 MHz for additional wireless broadband

- 40 MHz in Mobile Satellite Service (MSS) band targeted initially (i.e., LightSquared)
- Also commits to no loss of critical Federal, State, Local capability

To permit LightSquared to use MSS for a standalone terrestrial 4G LTE broadband network, FCC permission was required

- Only limited ATC previously allowed in this low power space-to-earth band; standalone network not allowed
- Conditional Waiver granted by FCC on Jan. 26, 2011
  - Primary condition: harmful interference with GPS must be resolved
  - GPS is one of the most successful RF innovations in history - widely adopted and fundamental to government, commercial and consumer sectors, and innovation continues

<u>A year of testing ensued</u>

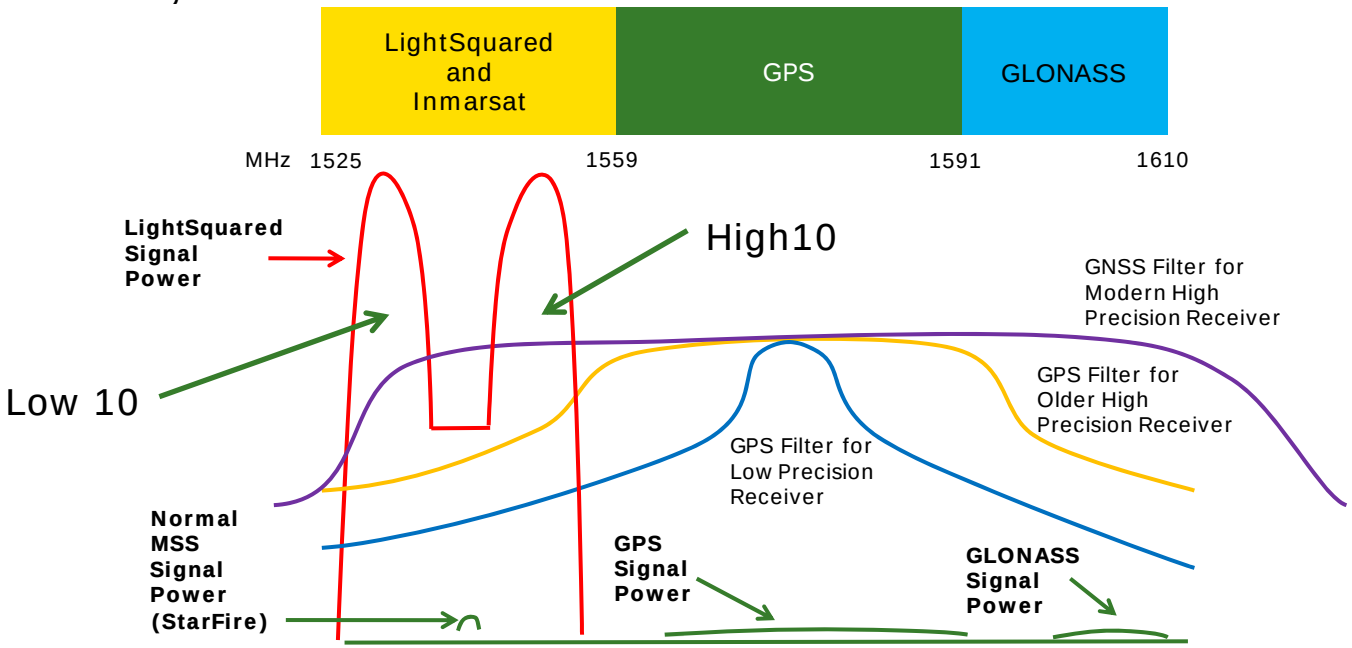
- Conclusion by GNSS industry, FAA, DOD, FCC, NTIA, others: interference with GPS exists, no simple solution possible
- FCC now proposing to vacate Conditional Waiver, suspend ATC indefinitely

The Basic Problem

LightSquared signals are a billion times stronger than GNSS(1) and MSS L-band augmentation signals(2)

Filters in GNSS receivers cannot suppress such nearby, extremely high power signals

High Precision wideband receivers cover GNSS bands, and if augmented, MSS band also



(1) Global Navigation Satellite System – includes GPS, Galileo, GLONASS, Compass

(2) Deere's StarFire and Trimble's OmniSTAR differential GPS augmentation systems

The Details

There were six types of potential problems:

- Overload – base stations overload RF front end of GNSS receivers
- Augmentation – MSS augmentation signals can't be received
- Handsets – handsets interfere with GNSS receivers
- Third Order Intermodulation – if both Low 10 and High 10 are used, 3rd order IM products fall directly into the GNSS band
- Handset OOBE – handsets are permitted under present FCC rules to emit out-of-band-interference into the GNSS band that is high enough to seriously interfere with GNSS
- Base station OOBE – not a problem, sufficient LightSquared filtering

The Perfect Storm

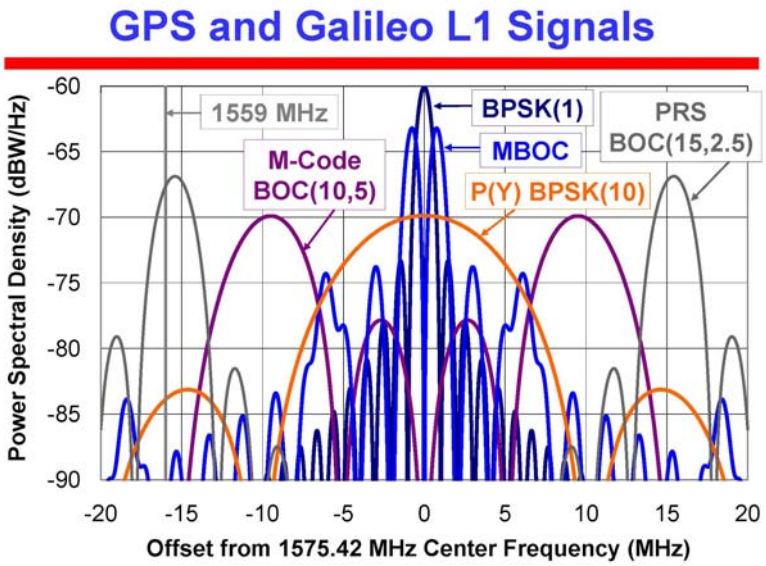
The Perfect Storm:

–FCC granted the Conditional Waiver and didn't anticipate the extent to which LightSquared would interfere with GPS

–LightSquared didn't understand that their signals would interfere with GPS, large investment made, needed to start rollout

–GNSS industry and US Government relied on the long-time primary MSS allocation for low power satellite signals (no change to FCC Table of Allocations), surprised by FCC's removal of MSS restrictions

About GPS (and GNSS)



GPS is not a digital communications system

–The issue is not correct reception of a 1 or a 0

–If it were, filtering in a narrow bandwidth would be appropriate

GPS is a digital navigation system

–The issue is timing the edge of a 1 or 0 transition to sub-ns accuracy

–High accuracy and multipath suppression require wideband signals and wideband filtering (many existing and future GNSS signals are also wideband)

–Receiver filtering needs to include all GNSS signals

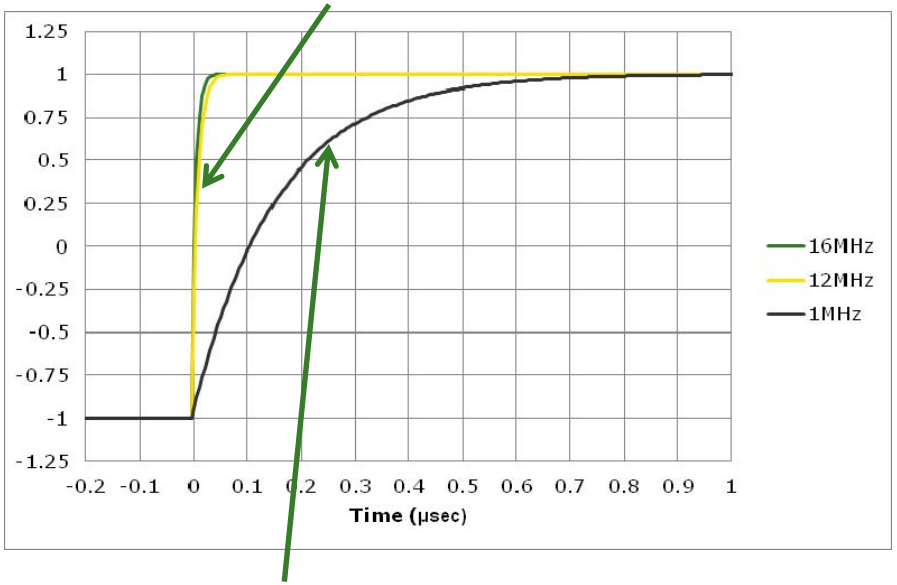
–Strong filtering of LightSquared signals may have adverse performance impacts

High Precision Requires Wideband Receivers

GNSS is based on range measurements to the satellites

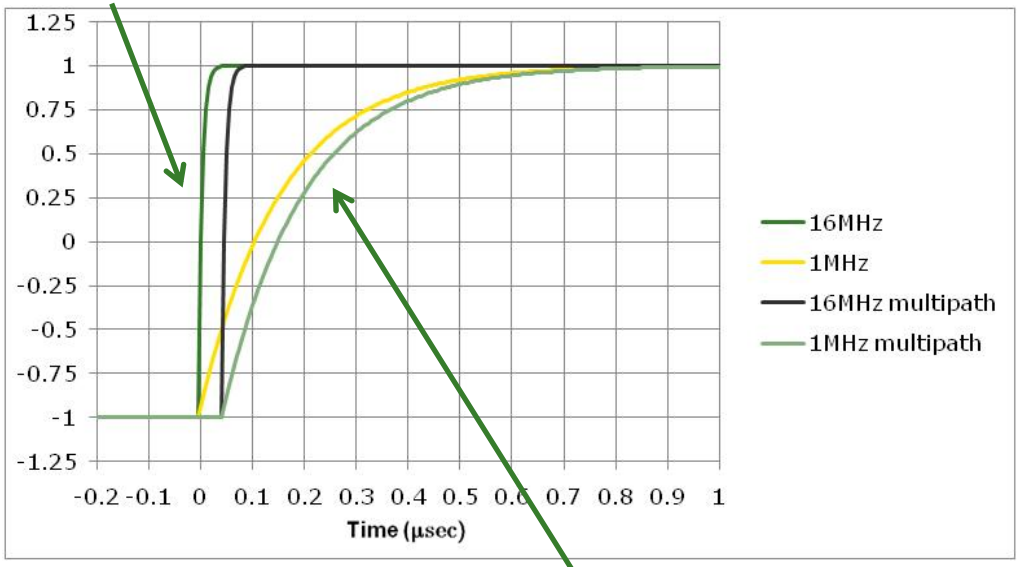
- Measure time of arrival (TOA) of spreading code transitions
- Accuracy of TOA measurement depends on sharp code edges
- Sharpness of code edges depends on bandwidth
- Also need sharp edges for multipath suppression

Code edge is here.



Where is the code edge?

Can distinguish code edge from multipath.



Difficult to distinguish code edge from multipath

Protect the GNSS Noise Floor

Multiple wireless and other systems could cumulatively add noise in GNSS bands until GNSS is degraded

GNSS Signals

- CDMA spread spectrum signals with very low power density

•C/A power density less than -190 dBm/Hz (~20 dB below thermal noise)

•Allows many GNSS signals to occupy the same spectrum without noise floor degradation

- De-spreading of the GNSS signals spreads any (even narrow band) interfering signal over the entire bandwidth

•The total power of all in-band interference is spread across the entire bandwidth, potentially increasing the noise floor

•If the total in-band interference power is greater than thermal noise, GNSS performance is degraded

•LightSquared handset could raise noise floor (handset 1 meter from a GNSS receiver (OOBE at specification limit) could degrade GNSS C/N_0 by 16 dB)

Existing and Future GNSS Receivers

Hundreds of millions of GPS receivers in the US would have been impacted by the original LightSquared design

Subsequent reduced-power designs impacted fewer existing receivers

- But many of those still affected are used in high value applications (military, aviation, construction, survey, agriculture, science, etc.)

Can new receivers be built that have the same performance as current receivers, do not foreclose future improvements, and can tolerate some form of terrestrial service ?

- Perhaps – it depends on the spectrum environment
- We need certainty in spectrum allocations

Lessons Learned – GNSS Industry

Demand for wireless broadband spectrum will continue

- More broadband is good, useful to GNSS

Spectrum issues can be critical

- Work with regulators (FCC, NTIA, ITU, etc.) on solutions that enable broadband but don't damage GNSS
- Study effects of other potential LightSquared-like systems
- Proposed changes to rules affecting GNSS must involve broader group of stakeholders

Design future GNSS receivers for a more challenging spectrum environment

- Understand the tradeoffs of performance vs. filtering
- Handsets can jam GNSS, just as base stations can
- Protect the noise floor

Receiver Standards and Interference Protection Criteria

If “Receiver Standards” means requirements on the design of the RF front end of GNSS receivers:

- Serious mistake that would stifle innovation
- FCC and industry in untenable position of having technical design developments mandated by government agency
- GNSS industry would oppose this

GNSS requires established international Interference Protection Criteria

- Must provide clear guidance, not constrain ultimate GNSS potential
- Implemented over a reasonable time frame
- Provide spectrum certainty
- More reasonable approach that could avoid significant adverse impact on GNSS industry

Suggestions for FCC

If spectrum reallocation is considered, use NPRM process

- Engages all concerned parties, allows time for proper analysis
- Consider all factors: economic, social, public safety, national security

Reallocation may not serve the public interest, but if done, allow time for fielded inventory to be replaced by normal economic processes

- Time required for many current receivers to be replaced is >10 years (aviation, military, survey, construction, agriculture, etc)

Reach out in advance to those affected

- Don't assume they are aware of FCC's concerns or intents
- Emulate Air Force, which has done a good job in this area for GPS

Protect the ultimate potential of GNSS

- Extraordinary global success story, deeply embedded in critical applications
- Need to consider global GNSS concerns, not just US GPS
- GNSS needs a quiet neighborhood (zoning rules should apply)
- Protection afforded GNSS should not limit its capabilities
  - Nobody could have predicted how important GPS would become
  - Nobody knows what future applications may be possible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