March 29, 2018

***FILED VIA ECFS***
Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W., Room TW-B204
Washington, D.C. 20554

**Re: GN Docket No. 17-183**
**RM-11791**
**Notice of Oral *Ex Parte* Presentation**

Dear Ms. Dortch:

On March 27, 2018, representatives of the Broadband Access Coalition ("BAC") and Google LLC ("Google") met with representatives of the Commission's Wireless Telecommunications Bureau, International Bureau and Office of Engineering and Technology to discuss co-channel and non-co-channel interference protection to Fixed Satellite Service ("FSS") registrants and opportunities for sharing with fixed point-to-multipoint ("P2MP") users as proposed in the BAC's petition for rulemaking in the above-referenced proceedings.[1]

The BAC and Google representatives discussed the two attached presentations. The first presentation highlights the significant public interest benefits stemming from the BAC proposal, namely access for mobile 5G services in a portion of the band, access for P2MP on a frequency- and geography-coordinated basis and protection of incumbent FSS operations. The second presentation provides a detailed discussion of a technical analysis that demonstrates the ability of P2MP networks to protect FSS operations in large, rural parts of the country on both a co-channel and non-co-channel basis.

The BAC and Google representatives also reiterated the need for the Commission to require FSS registrants to update and supplement IBFS to ensure the accuracy and sufficiency of FSS data to inform Commission decision-making in the above-referenced proceedings.

Respectfully submitted,

Stephen E. Coran

Attachments

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[1] The meeting attendees are listed on the Appendix hereto.

**Appendix**
**List of Attendees**

**Broadband Access Coalition**

Jaime Fink – Mimosa Networks, Inc.
Bob Koppel – Counsel to Mimosa Networks, Inc.
Michael Calabrese – Open Technology Institute at New America
Steve Coran – Counsel to the Wireless Internet Service Providers Association

**Google LLC**

Andrew Clegg

**Federal Communications Commission**

Jose Albuquerque
Bahman Badipour
Christopher Bair
Paul Blais
Peter Daronco
Thomas Derenge (by telephone)
Ariel Diamond
Diane Garfield
Jennifer Gilsenan
Michael Ha
Walter Johnston
Julius Knapp
Evan Kwerel
Jonathan Levy
Robert Nelson
Nicholas Oros
Robert Pavlak
Barbara Pavon
Matthew Pearl
Paul Powell
Jamison Prime
Ronald Repasi
Jim Schlichting
Becky Schwartz (by telephone)
Dana Shaffer (by telephone)
Don Stockdale

# Point-to-Multipoint Broadband Opportunities in the 3700-4200 MHz Band

March 27, 2018

Broadband
Access Coalition

# Proposed **Win-Win-Win** for C-band
## Combining the BAC Proposal with the Intelsat/SES/Intel Proposal

**Mobile**

- Opens 100 MHz of spectrum at 3700 – 3800 MHz for mobile 5G in densely-populated urban areas
- May enable some level of global harmonization

**Satellite**

- Compensation to clear portion of band
- Protects incumbent FSS providers

**Wireless Broadband (Fixed Wireless)**

- Leverages unused FSS geography and frequencies
- Enables delivery of 25 Mbps -> 1 Gbps service to rural & residential unserved and underserved communities

BAC

# Key Points of the BAC Sharing Proposal

- Provide access for mobile 5G in the 3700 – 3800 MHz band in densely populated urban areas
- Provide access for P2MP broadband in frequency- and geography-coordinated spectrum across:
  - 3800 – 4200 MHz band and
  - 3700 – 3800 MHz band outside densely populated urban areas
- Protect incumbent FSS providers from harmful interference

BAC

# BAC & Intel/SES/Intelsat Proposals can be Combined and are Complementary

- The proposals are not inconsistent with one another
- As a stand-alone proposal, the Intelsat/SES/Intel proposal will do nothing to close the digital divide
  - It will not facilitate broadband service to unserved and underserved rural communities

BAC

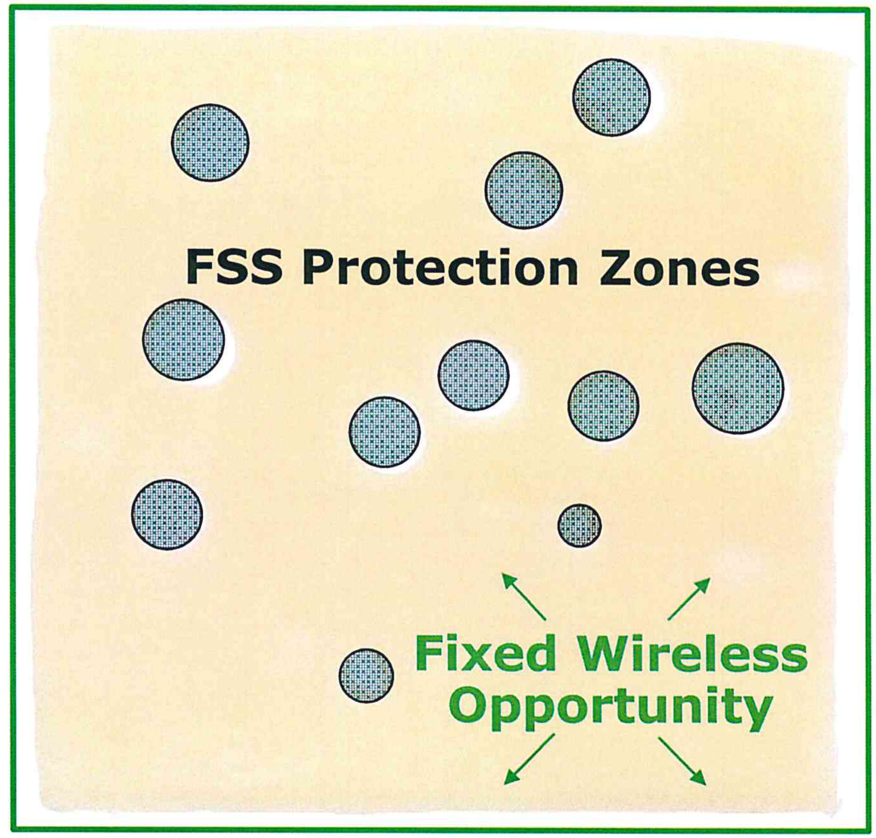
# A Technical Analysis of Band Sharing Must be Performed with Proper Assumptions

- Technical characteristics of P2MP are quite different than mobile service
- SES technical analysis not directly applicable to P2MP coexistence
  - Fixed wireless base stations typically operate on a directional, sectorized basis.
  - Mobile base stations use multiple antenna sectors to create omnidirectional coverage
  - Not all earth stations use all 500 megahertz of the C-band
  - Exclusion zones vary widely for co-channel versus adjacent channel sharing
    - Co-channel: 60 – 75 km
    - Adjacent channel: "a few to several km," worst case
  - SES assumes power levels that are higher than BAC proposed
  - SES assumes antenna heights that are higher than required for many P2MP operations

BAC

# Protecting the Holes in the Swiss Cheese

- Coordinating P2MP to avoid FSS interference
  - Geographic & LOS
  - Unused Frequencies
- With improved IBFS data and a proper technical study to protect FSS earth stations, there's a lot of potential "cheese" left for rural broadband

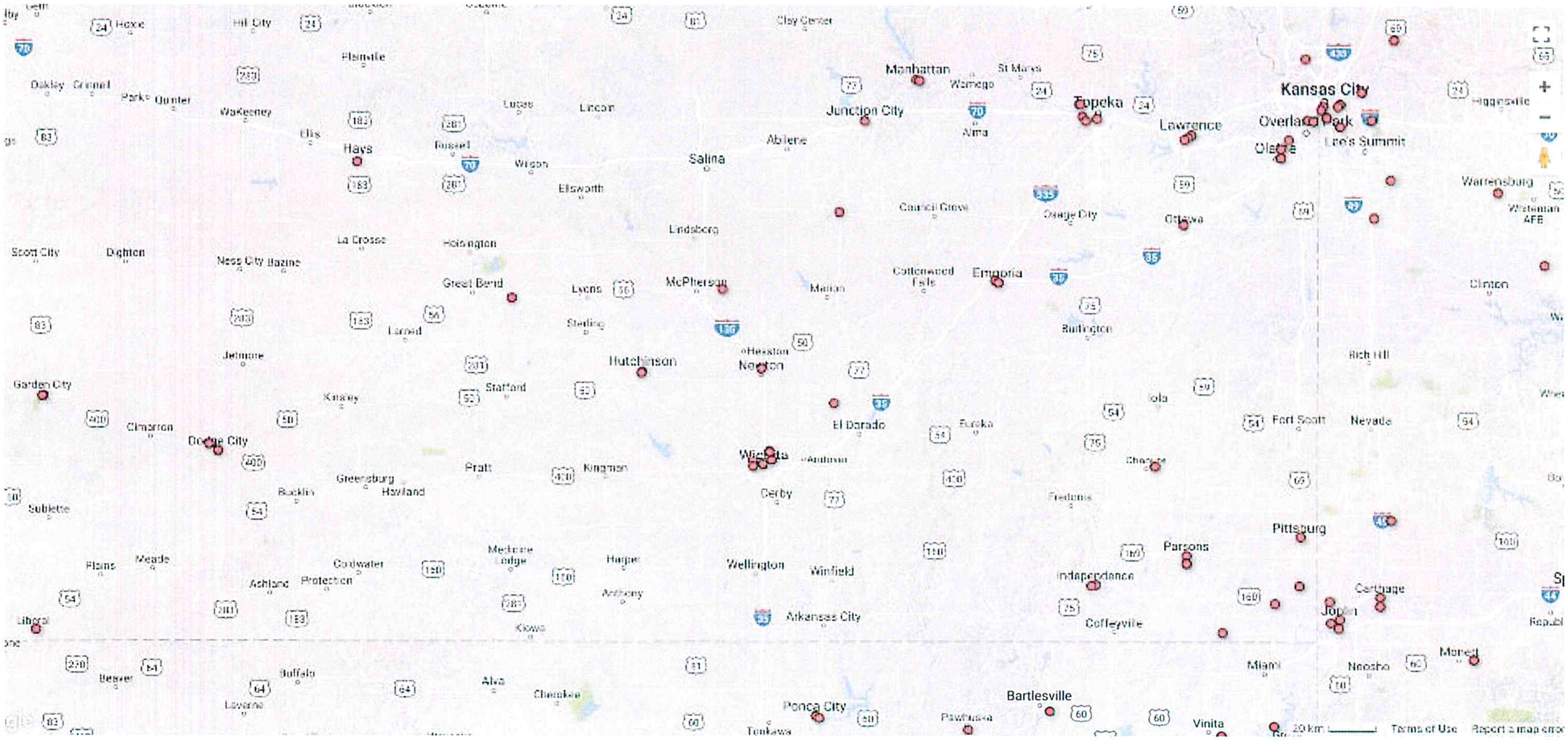



BAC

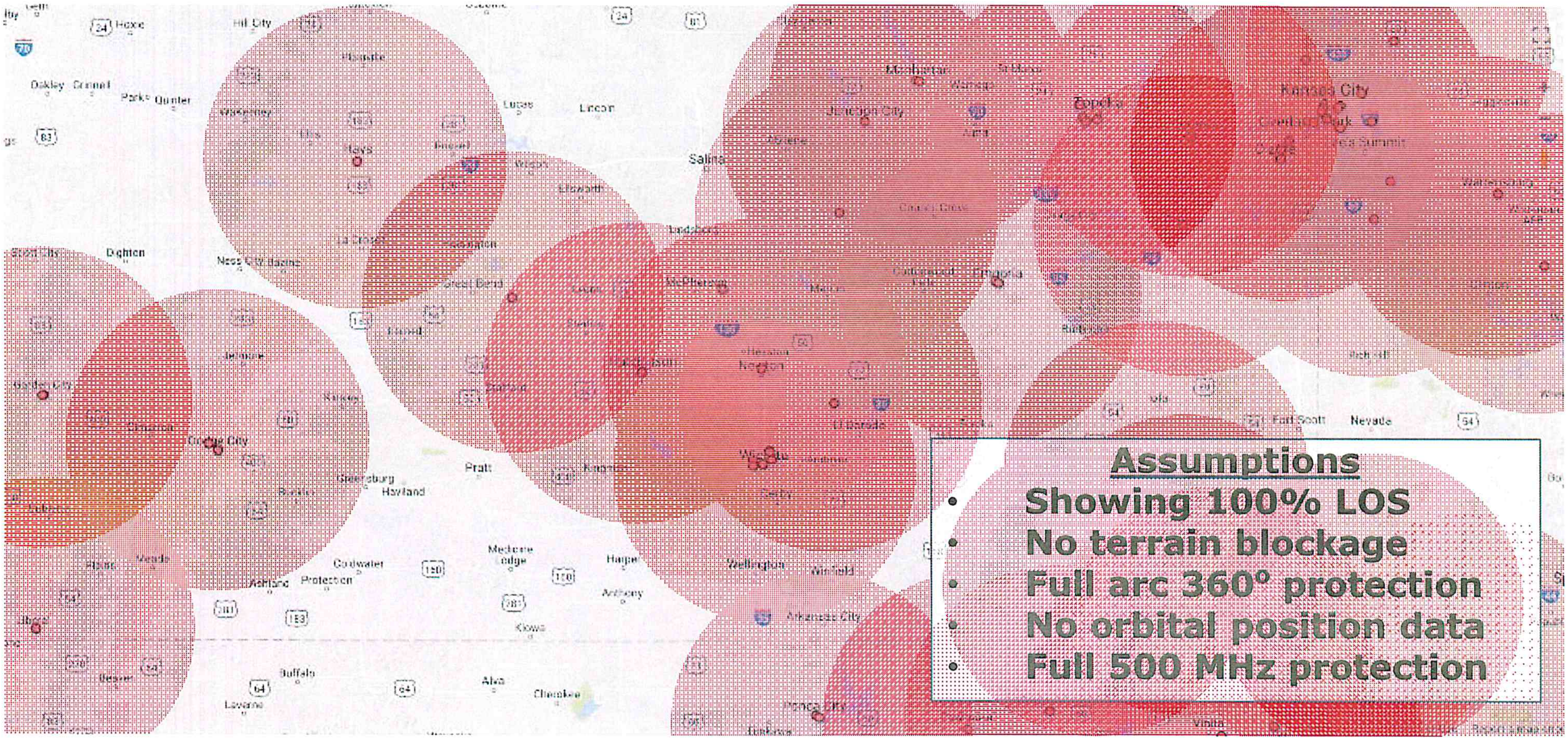
# Large Scale Rural Example

BAC

# Rural Kansas Registered FSS Sites



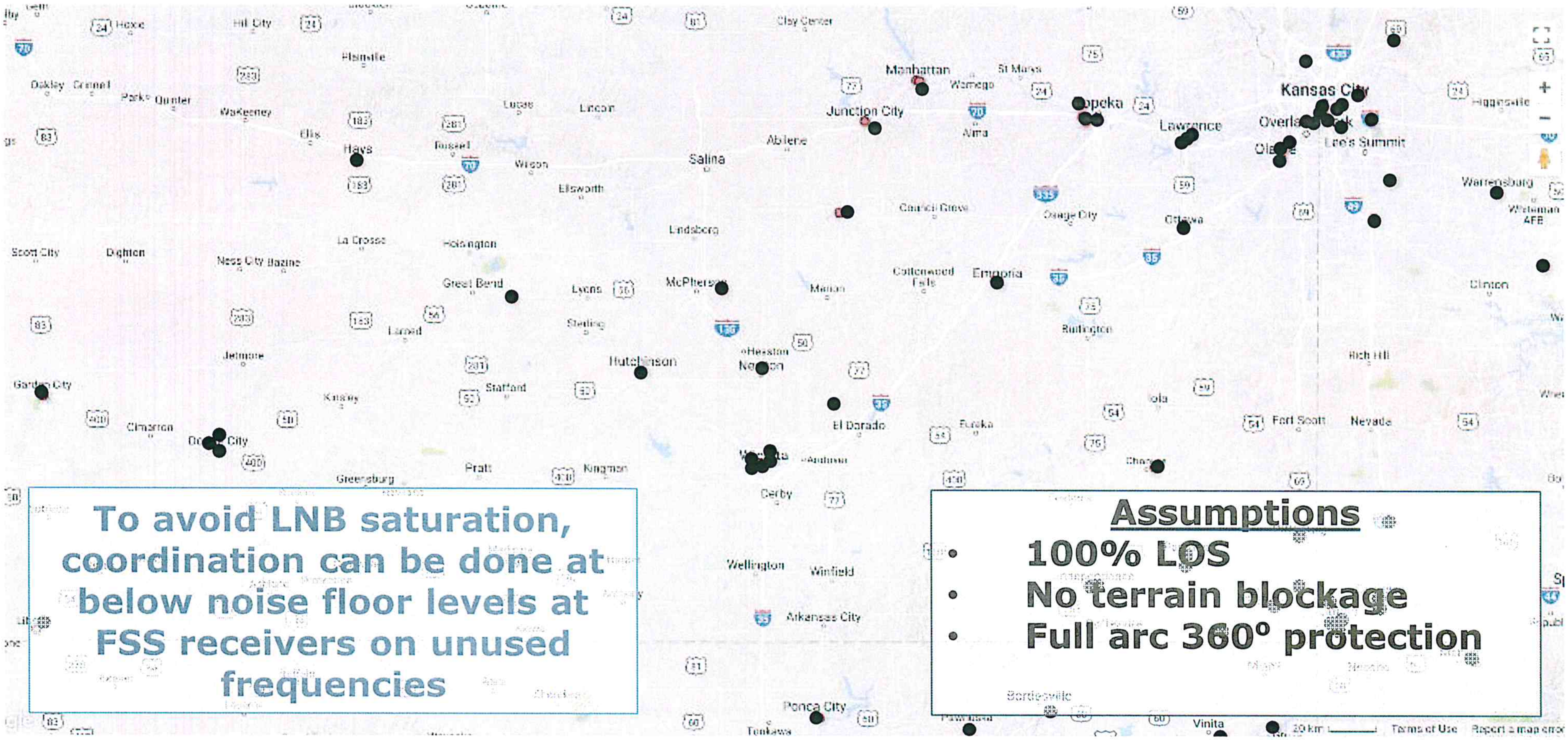
# Co-Channel 65km Zones – Geographic Cheese




**Assumptions**

- Showing 100% LOS
- No terrain blockage
- Full arc 360° protection
- No orbital position data
- Full 500 MHz protection

# **Adjacent Channel** 3km Zones – Frequency Cheese




To avoid LNB saturation, coordination can be done at below noise floor levels at FSS receivers on unused frequencies

**Assumptions**

- 100% LOS
- No terrain blockage
- Full arc 360° protection

# Conclusions: Co-Channel

- Co-channel sharing with large (worst-case) protection zones provides some rural opportunities
- With ITM (Irregular Terrain Model) and directional sector coordination, significant additional areas can be coordinated for P2MP fixed wireless

BAC

# Conclusions: Adjacent Unused Channels

- IBFS update needs to include frequencies in actual use by earth stations
  - Sub-3km protection zone and interference protection to prevent any LNB saturation
- Handling FSS transponder/frequency changes:
  - Near-term: fixed wireless coordination and channel changes can be accomplished with simple notification (e.g., similar to Part 96 process)
  - Potential future database option to automate channel changes

BAC

BAC

Google

# Point-to-Multipoint Coexistence with C-band FSS

March 27th, 2018

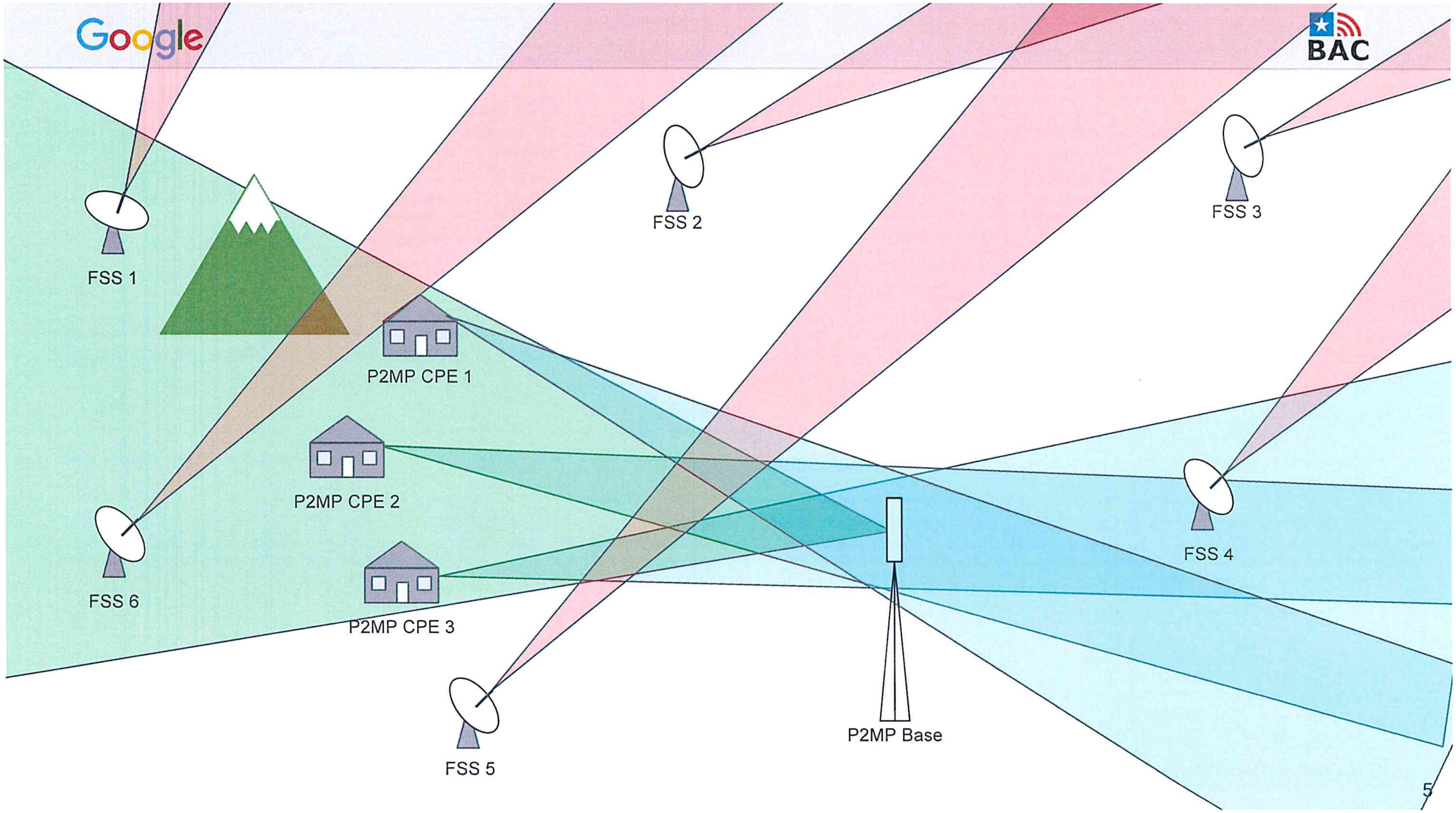
# Conclusions

- 3700-4200 MHz point-to-multipoint (P2MP) systems could immediately provide gigabit-class broadband service to *tens of millions of Americans*, without causing disruption to FSS
  - In many areas of the country, P2MP systems can operate in C-band (3700-4200 MHz) without causing interference to co-channel fixed-satellite service (FSS) systems
  - Co-channel sharing is possible by considering geographic and directional isolation between P2MP and FSS; that is, operating in areas with a relatively low number of earth stations, and using directional antennas that don't point toward earth stations in the area.
- If actual FSS frequency use were known, frequency separation could allow 25 Mbps - 1 Gbps P2MP broadband service to as many as *120 million Americans*

# Contents

- Considerations for coexistence between P2MP and FSS
- Areas in which P2MP and FSS may be able to co-exist
- Real-world example: Co-channel & non-co-channel

# Coexistence Considerations


Google
BAC
FSS 1
FSS 2
FSS 3
FSS 4
FSS 5
FSS 6
P2MP CPE 1
P2MP CPE 2
P2MP CPE 3
P2MP Base

# Calculation of Co-channel Interference from P2MP into FSS

Assume $n$ P2MP transmitters operating within C-band, with conducted power spectral densities of $PSD_i$ (in dBm/MHz). The aggregate interference power spectral density $IPSD_j$ (dBm/MHz) received by FSS station $j$ is:

$$IPSD_j = \sum_{i=1}^{n} \left( PSD_i + GT_{i,j} - PL_{i,j} + GR_{i,j} \right),$$

where:

$GT_{i,j}$ = Gain of P2MP antenna $i$ in the direction of FSS earth station $j$
$PL_{i,j}$ = Propagation loss from P2MP station $i$ to FSS earth station $j$
$GR_{i,j}$ = Gain of FSS earth station $j$'s antenna in the direction of P2MP station $i$

# Propagation Loss

- For analysis, PL is modeled by the NTIA Irregular Terrain Model (ITM) implementation of Longley-Rice
  - Same model adopted by WInnForum for protection of FSS due to Part 96 CBRS
- Very conservative model for interference prediction
  - Does not specifically take clutter (trees and buildings) into account
  - Extensive propagation testing in 3.6 GHz band shows clutter creates very high additional losses over ITM
  - Measured losses in urban and suburban environment are some 40-60 dB greater than ITM, due to buildings and foliage
  - Measured losses in rural environments have shown an additional ~17 dB/km of loss over ITM predictions, due to foliage
- Used WInnForum-compliant implementation of ITM for propagation analysis

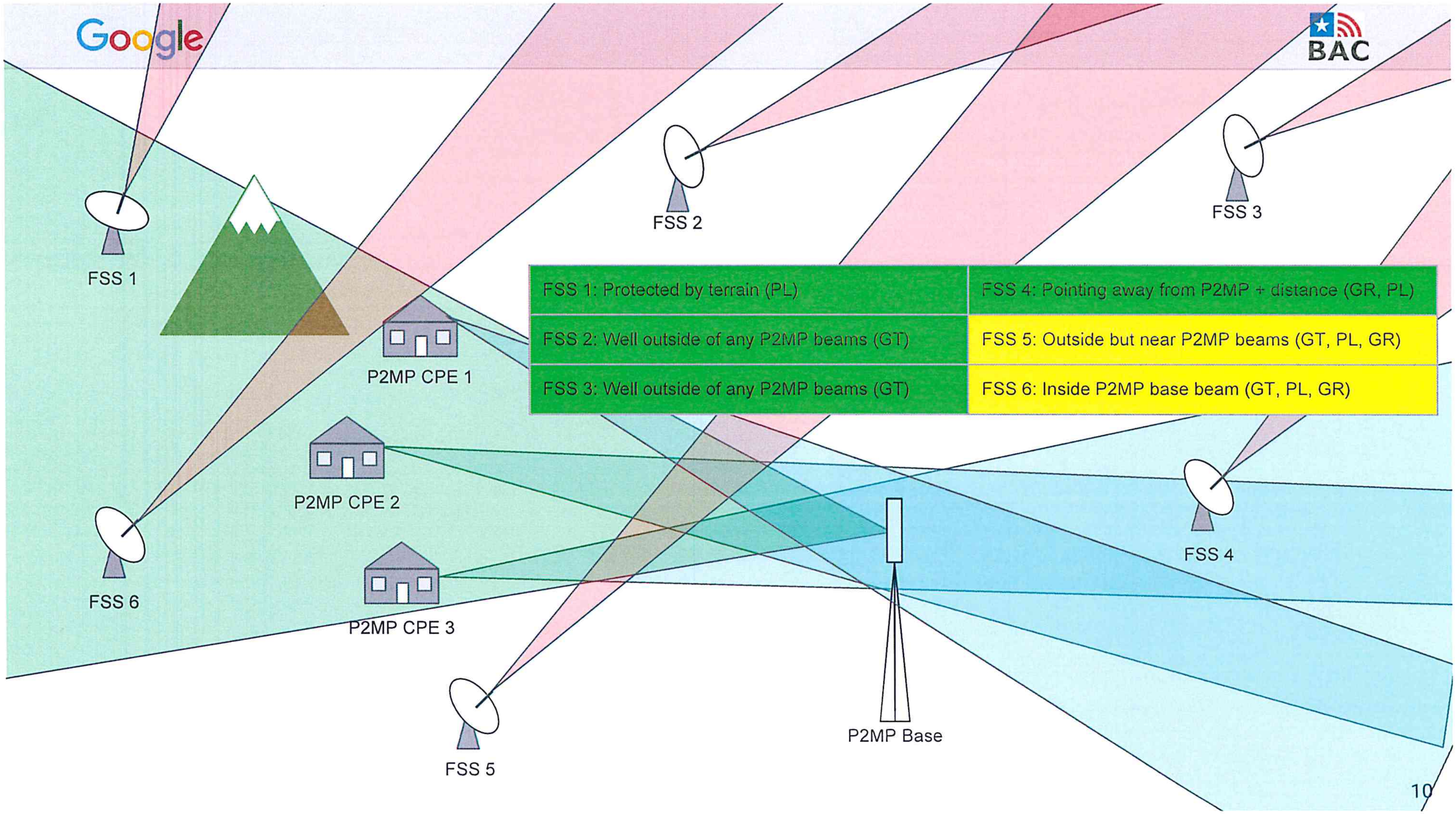
# P2MP/FSS Coexistence

- Coexistence is achieved when the aggregate interference from planned P2MP deployments does not exceed the interference limit of any FSS earth station in the area
  - The "area" can be defined by a distance beyond which interference into FSS reaches an inconsequential level
  - This analysis considered FSS earth stations out to a distance of approximately 100 km
- We use a co-channel FSS interference limit (expressed in power spectral density) of −129 dBm/MHz, which is the same limit used to protect co- and adjacent-band FSS in the CBRS band (e.g., 47 CFR 96.17(a)(2))
- Coexistence criterion:

$$\max_j(IPSD_j) \leq -129 \text{ dBm/MHz}$$

# Factors that Strongly Influence Coexistence ($GT_{ij}$, $PL_{ij}$, $GR_{ij}$)

- Terrain blockage between P2MP and FSS creates high propagation loss, reducing interference power received by FSS (affects $PL_{ij}$)
- Low height of P2MP antennas (affects $PL_{ij}$)
  - Most customer premise equipment is located at relatively low heights above ground level, increasing propagation loss and reducing their interference impact on FSS
- The use of directional P2MP antennas (affects $GT_{ij}$)
  - P2MP antenna discrimination reduces interference to FSS earth stations outside the P2MP beam.
- FSS beam discrimination (affects $GR_{ij}$)
  - FSS antennas are generally pointed upward, with low gain towards the horizon, where P2MP systems are located
- Low height of some FSS antennas (affects $PL_{ij}$)
  - While some FSS antennas are on rooftops, many are mounted on the ground, since they only need to see the sky. When mounted low to the ground, propagation losses to terrestrial systems are higher, reducing interference
- Frequency separation will provide additional isolation (discussed later)




| | |
|---|---|
| FSS 1: Protected by terrain (PL) | FSS 4: Pointing away from P2MP + distance (GR, PL) |
| FSS 2: Well outside of any P2MP beams (GT) | FSS 5: Outside but near P2MP beams (GT, PL, GR) |
| FSS 3: Well outside of any P2MP beams (GT) | FSS 6: Inside P2MP base beam (GT, PL, GR) |

# P2MP Data that Enter into Coexistence Calculation

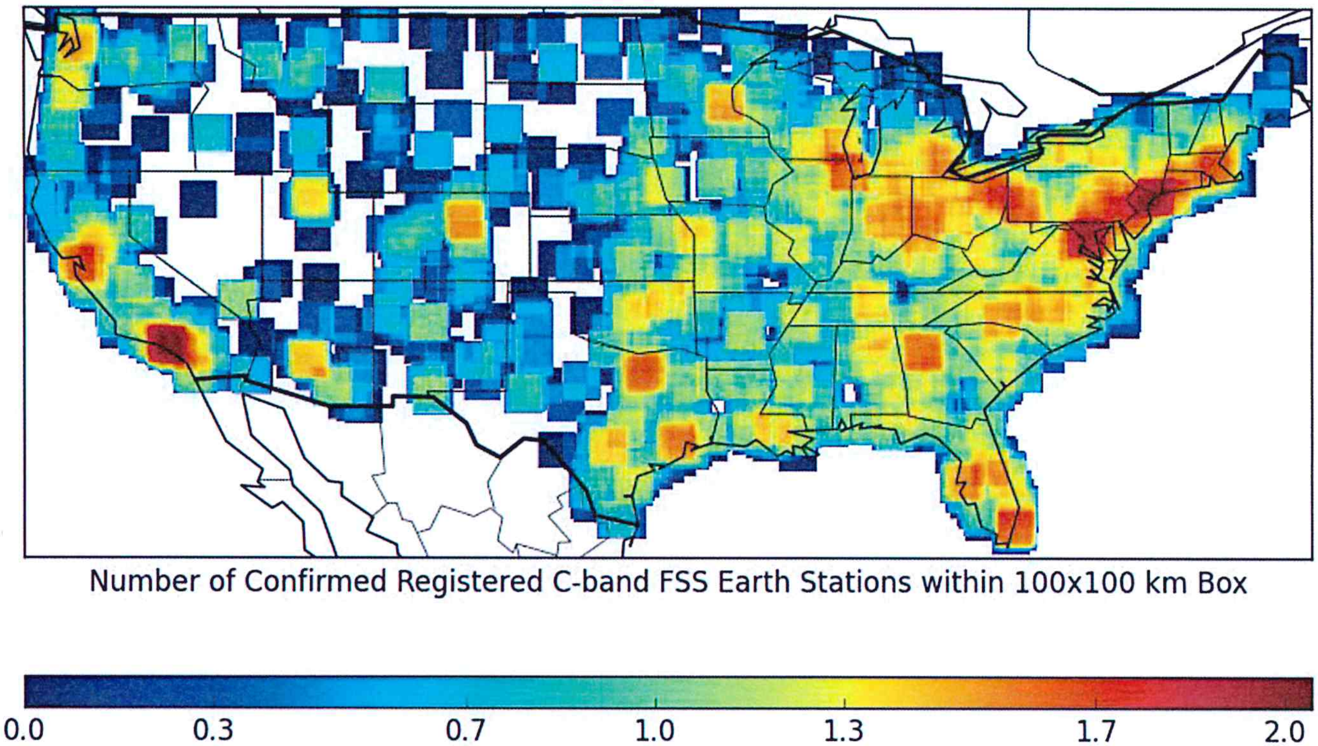
- Required minimum information for each P2MP node (base and CPE)
  - Location (lat/lon)
  - Conducted power spectral density, including any cable losses between transmitter and antenna
  - Antenna pointing azimuth and elevation
  - Antenna beam pattern (i.e., gain as a function of azimuth and elevation)
  - Height of ground above mean sea level
    - Determined by lat/lon combined with a terrain database
  - Antenna height above ground level
  - Frequency and bandwidth of P2MP signal (for non-co-channel analysis)
  - Out-of-band emission levels (for non-co-channel analysis)
- Additional considerations
  - Clutter impacting propagation

# FSS Data that Enter into Coexistence Calculation

- Required minimum information for each FSS earth station
  - Location (lat/lon)
  - Antenna pointing azimuth(s) and elevation(s)
    - Can be determined by orbital slot (or range of orbital slots) received by the earth station, combined with the earth station's lat/lon
  - Antenna beam pattern (i.e., gain as a function of off-axis angle)
  - Height of ground above mean sea level
    - Determined by lat/lon in combination with terrain database
  - Antenna feed point height above ground level (reference point for interference calculation)
  - Actual operating frequencies of the FSS receiver (for non-co-channel analysis)
- Additional considerations
  - Clutter impacting propagation

# Where could Co-channel FSS and P2MP Co-exist?

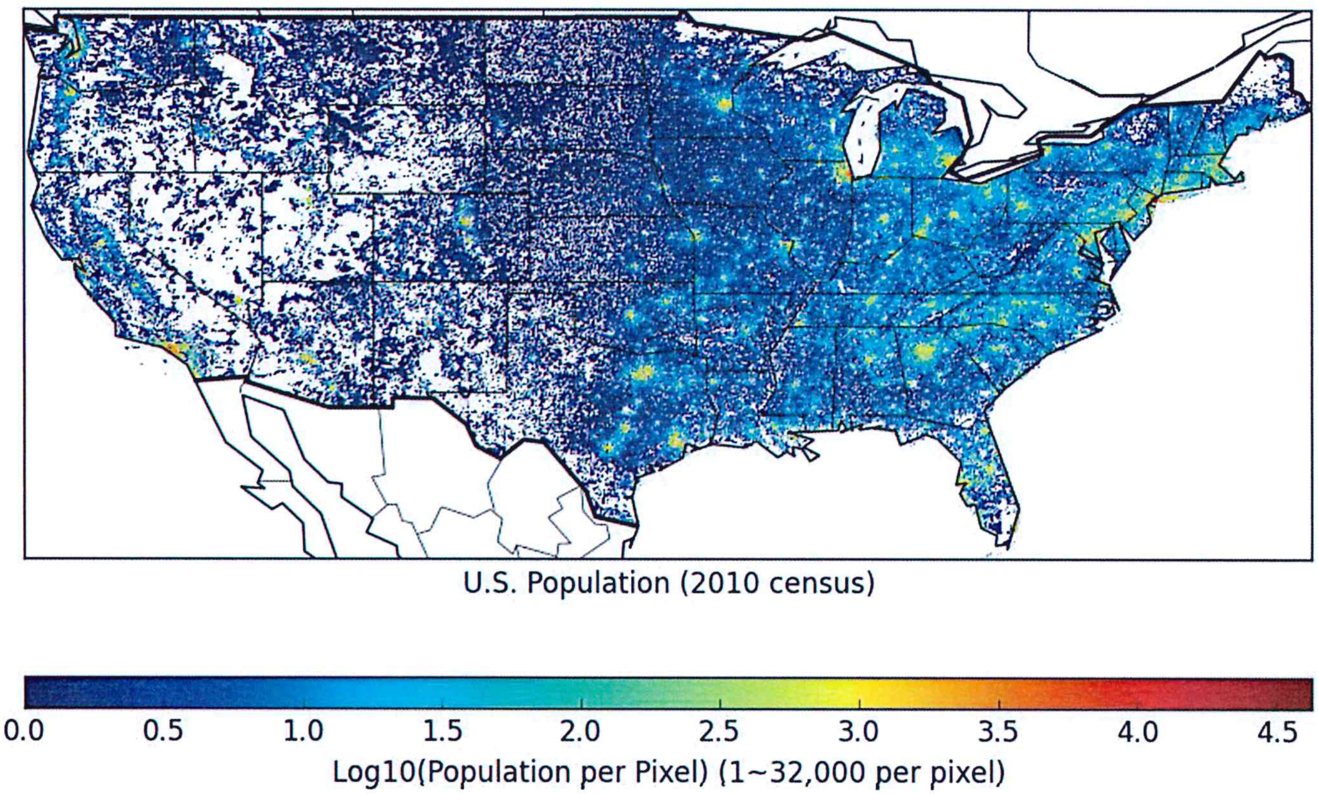
Google BAC




Number of Confirmed Registered C-band FSS Earth Stations within 100x100 km Box

Log10(Number of FSS Earth Stations) (1, 2, 5, 10, 20, 50, 100)

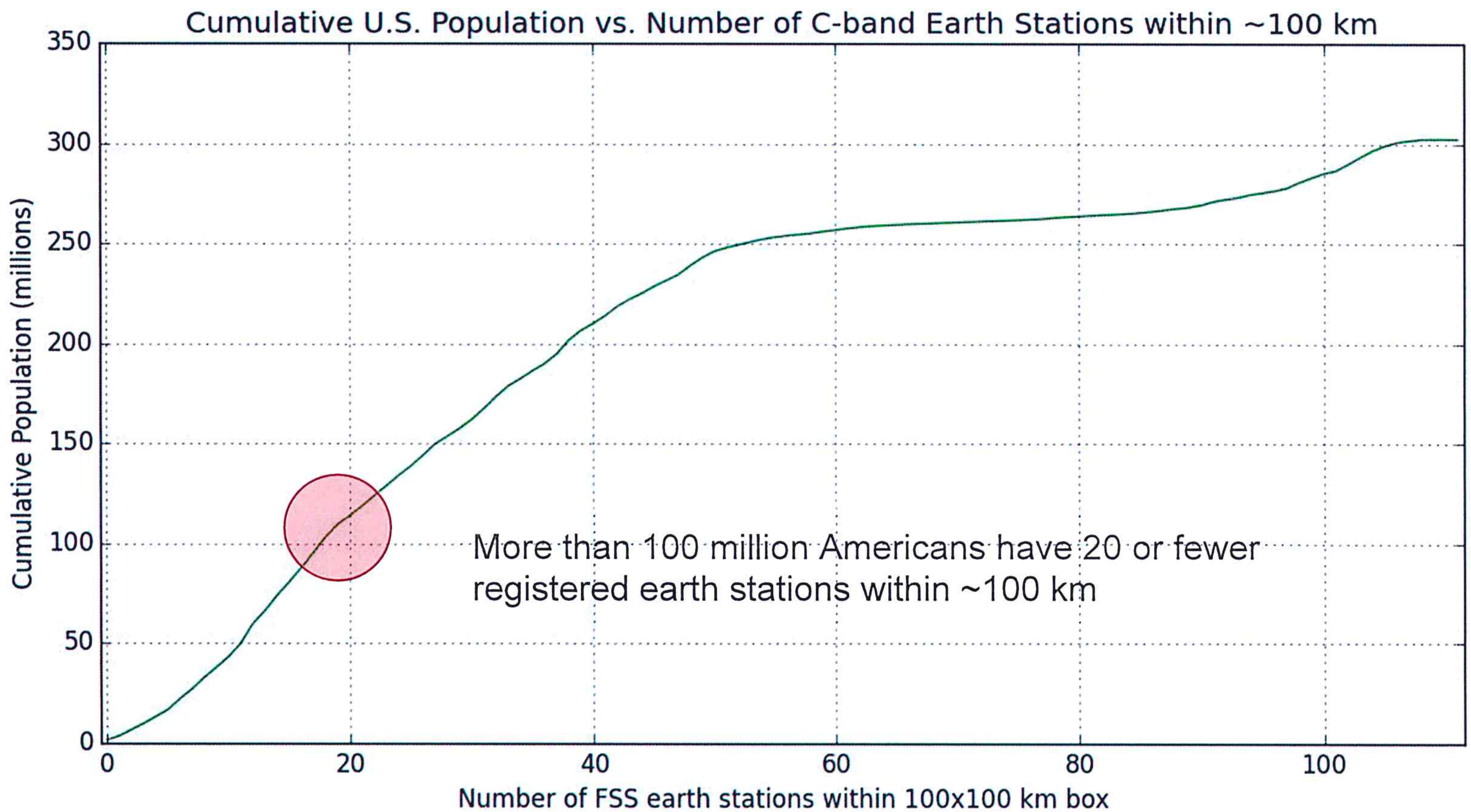
For each point in a 30 arc sec grid, this map displays the number of confirmed registered FSS earth stations within a 100x100 km box centered on the grid point. Source: FCC IBFS plus confirmation based on a 2014 Google Earth study.

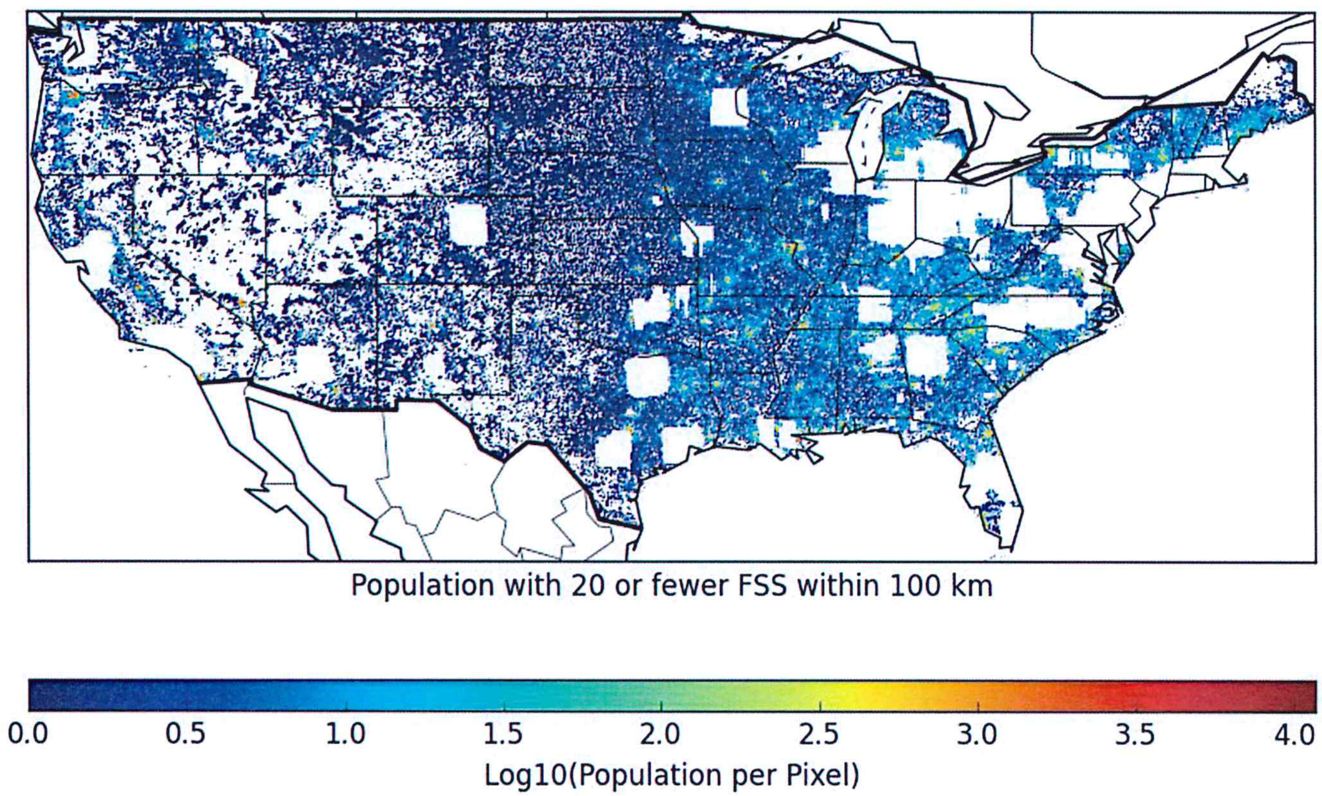



U.S. Population (2010 census)

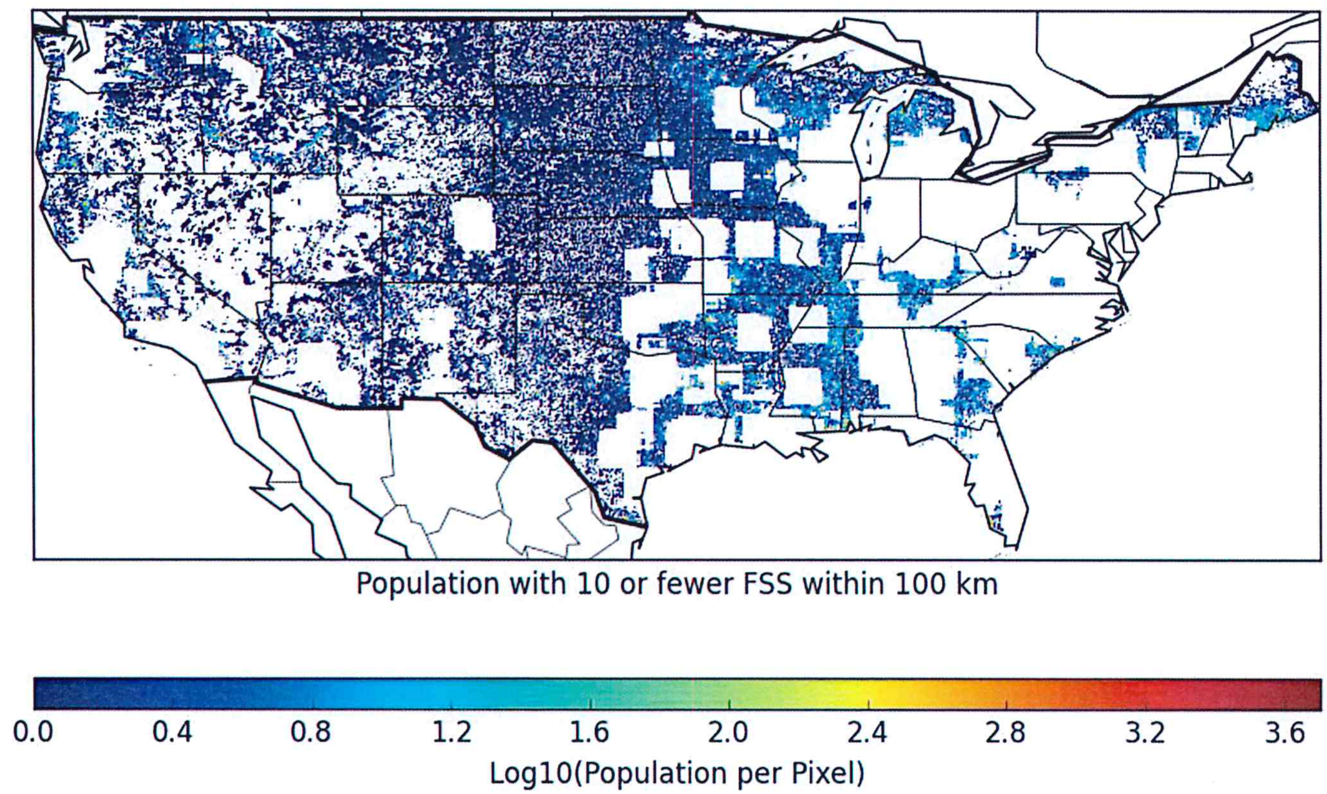
Each pixel is 30x30 arc seconds = ~0.75 $km^2$ depending on latitude. White = 0 population in the pixel. Population density >0 and ≤1 per pixel clipped at 1 for display. Data derived from U.S. Census Bureau statistics.

Google BAC

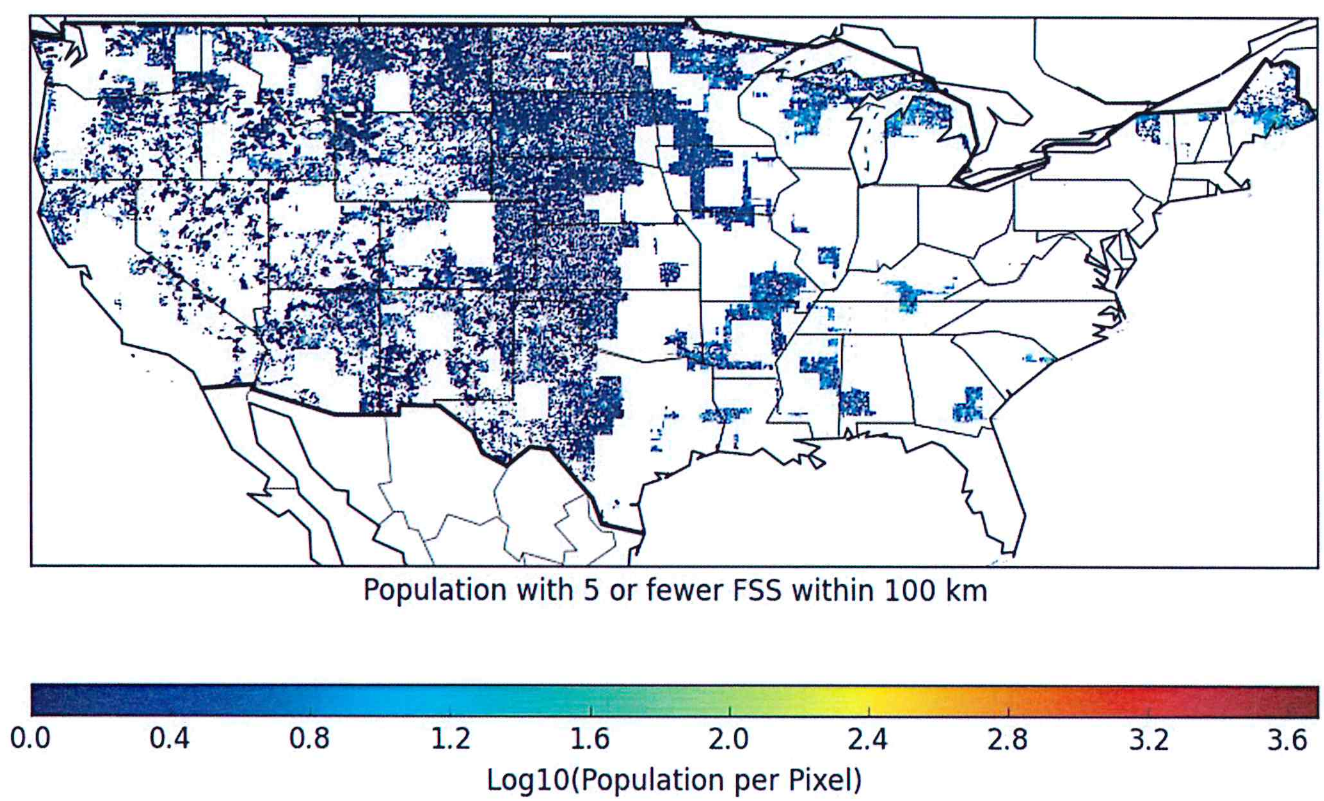

Cumulative U.S. Population vs. Number of C-band Earth Stations within ~100 km
Cumulative Population (millions)
350
300
250
200
150
100
50
0
0
20
40
60
80
100
Number of FSS earth stations within 100x100 km box
More than 100 million Americans have 20 or fewer registered earth stations within ~100 km



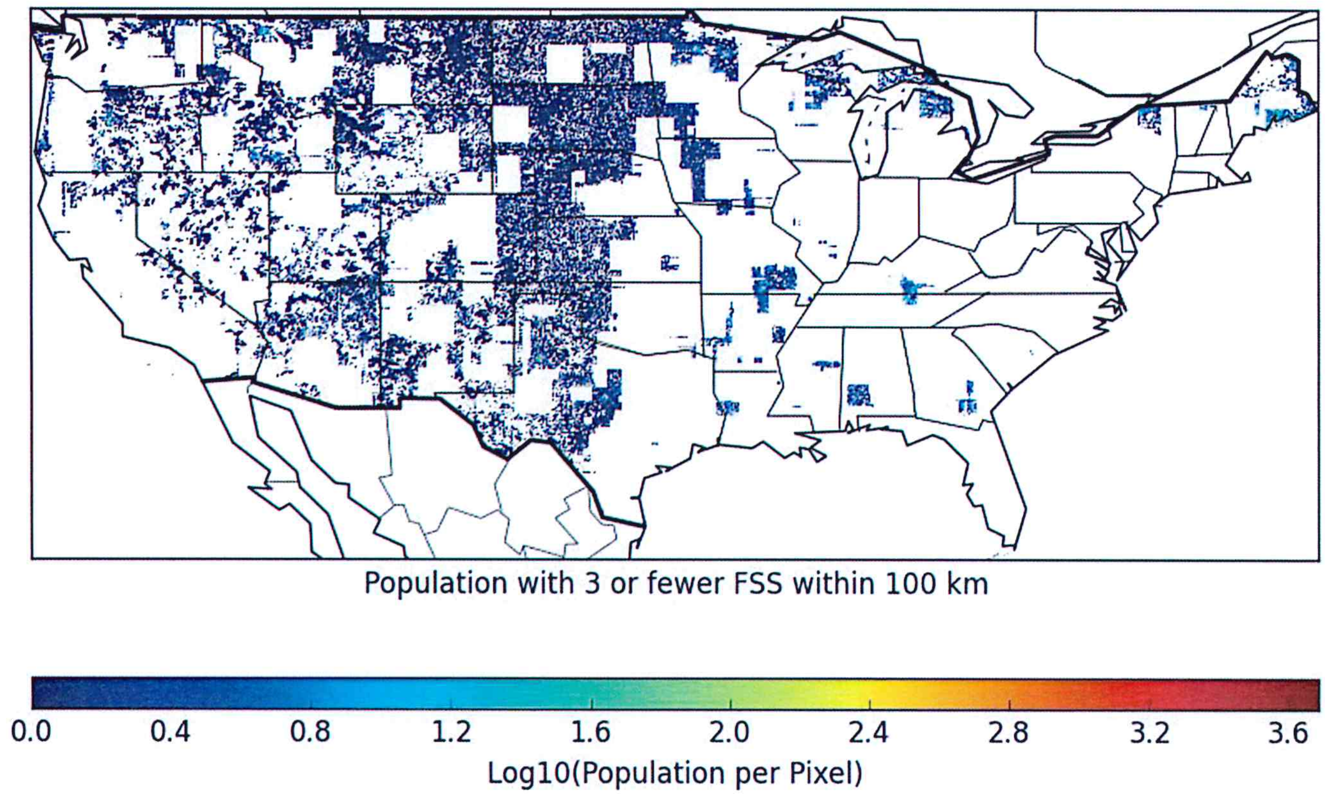

114 million Americans




43 million Americans

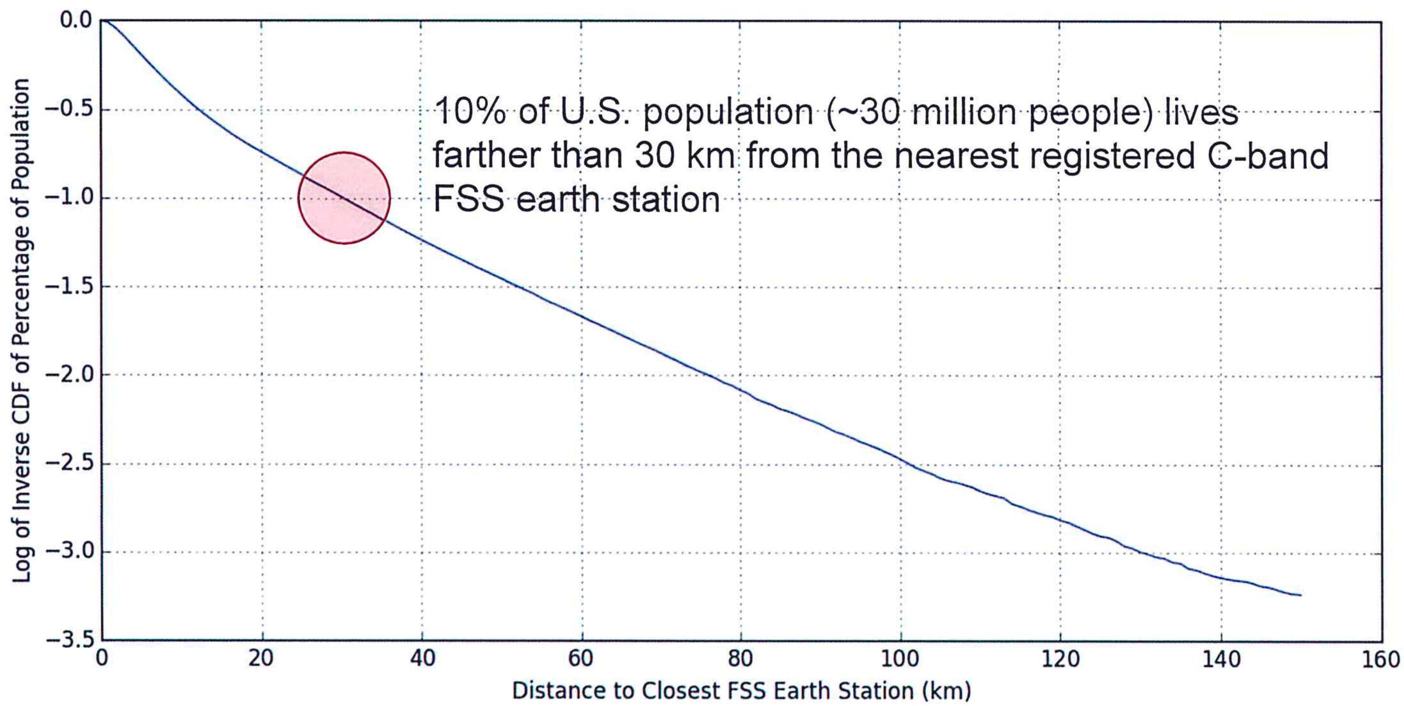



17 million Americans




10 million Americans

# Distance to Closest FSS C-Band Earth Station



# Actual Co-channel Coexistence Example

# Real-world Deployment

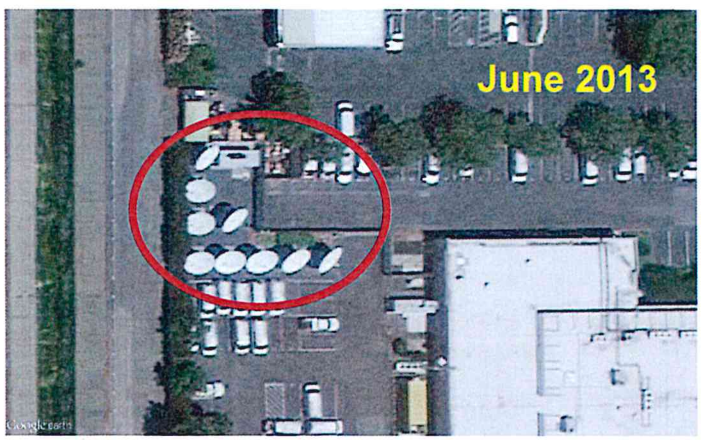
- Based on overlay/replacement of current 5 GHz (unlicensed) deployment now providing point-to-multipoint broadband service in California just outside of the Bay area
- The current deployment, without modification, was analyzed to determine if it could be replaced with, or complemented by, a system utilizing C-band (co-channel with FSS) to provide improved broadband service
- This example is not "cherry-picked"
  - Existing system deployed prior to, and without regard for, and considerations related to C-band FSS

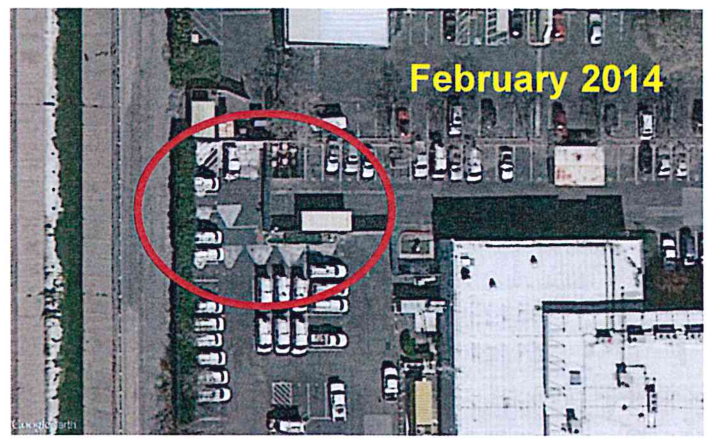
# Analysis Procedures

1. Pull IBFS list of registered 3700-4200 MHz FSS earth stations within 150 km of P2MP area of operation
2. Validate the existence and operation of the registered sites
    a. Perform historical Google Earth imagery search for FSS antennas. Determine if antennas currently exist, or were removed in the past, or never existed, at or within ~1 km of registered coordinates
    b. Drive by sites for further information gathering. Confirm no dishes are in place, or, if so, determine if dishes are actually in use. In some cases, talk to the dish owner or the owners of the building on which the dish is mounted to determine status.
    c. If antenna(s) exist, correct antenna coordinates based on (a) and (b)
3. Gather all required operational data for P2MP and FSS (i.e., slides 11 & 12)
4. Compute best- and worst-case aggregate interference at each FSS earth station as a function of pointing, across its registered GSO arc range, in 1 deg increments
5. Based on actual P2MP and FSS operations, determine if coexistence criterion is met
    a. If not, determine if simple solutions or mitigating factors can achieve the coexistence criterion

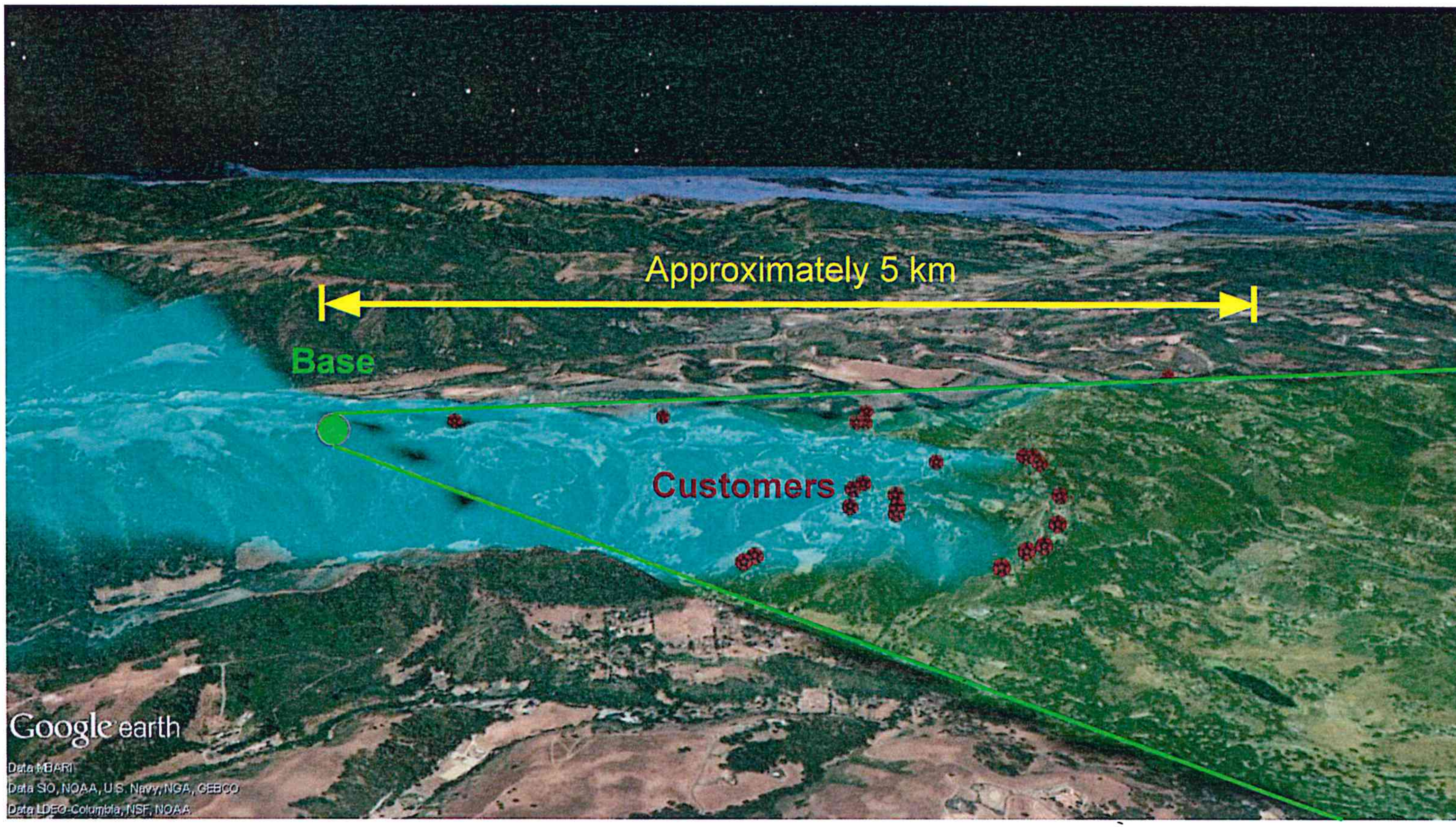
# FSS Earth Station Registration Validation

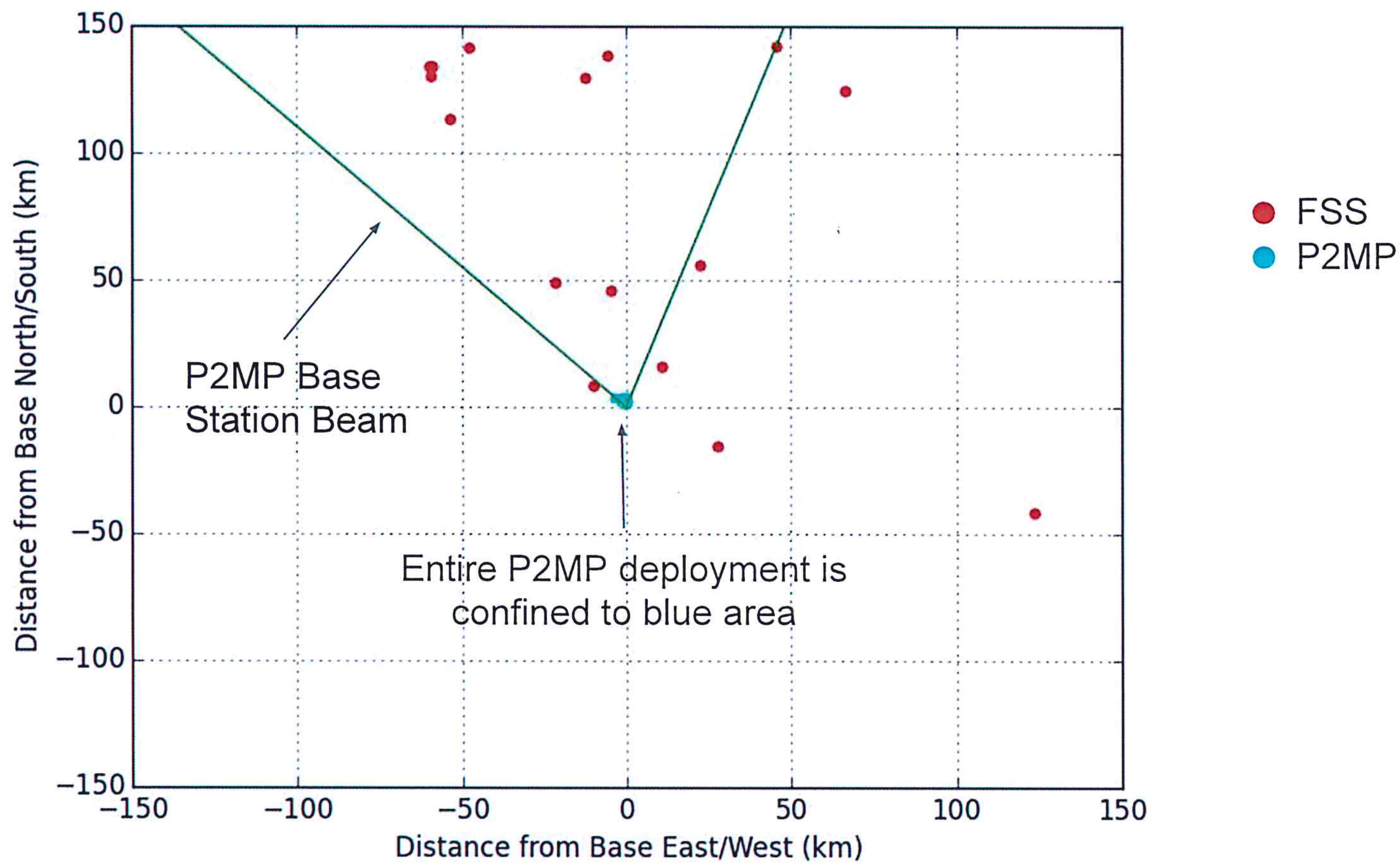
- 37 registered FSS earth station sites were found in IBFS
  - All are full-band registrations (3700-4200 MHz)
- Of the 37 sites, Google Earth analysis and in-person visits determined that 21 of the registrations (**57%**) are not valid
  - 12 could not be found in any historical imagery back to the 1990s
    - 11 of the 12 belong to one licensee
  - 8 were previously removed (see one example below)
  - 1 exists but is no longer in operation (confirmed by in-person visit)



# P2MP Deployment



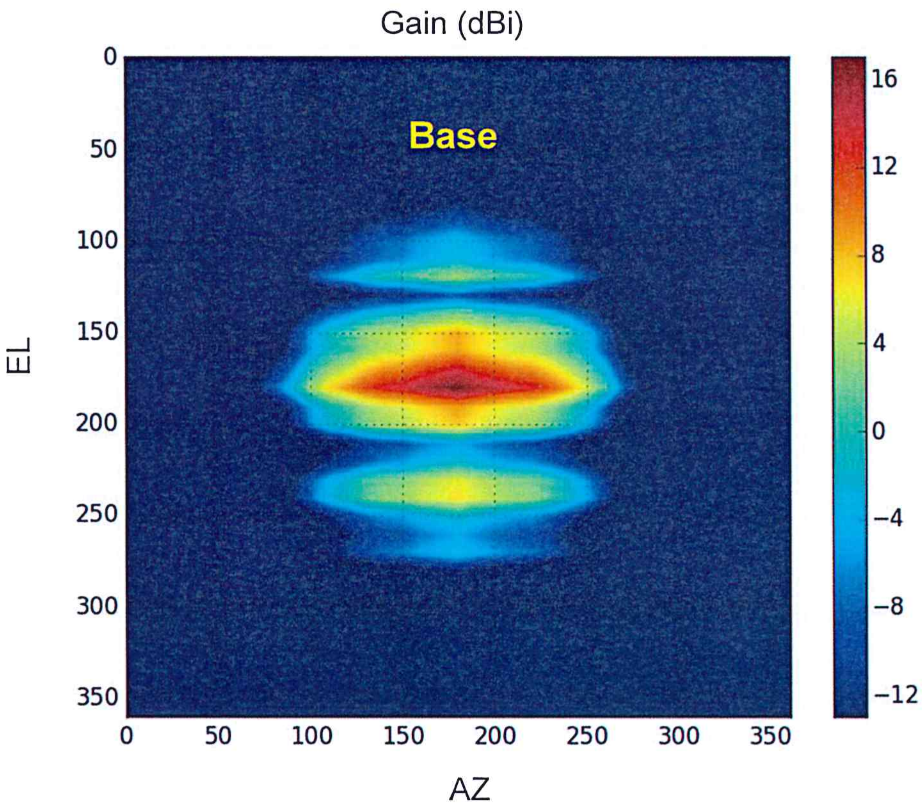


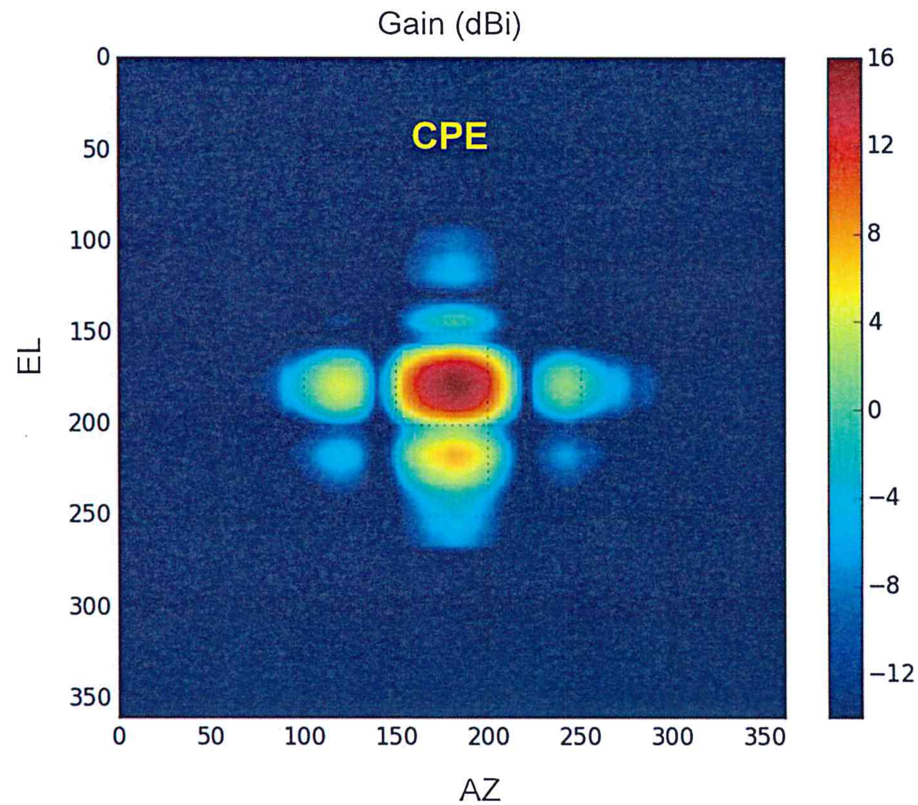
150
100
50
0
−50
−100
−150
−150
−100
−50
0
50
100
150
Distance from Base North/South (km)
Distance from Base East/West (km)
P2MP Base
Station Beam
Entire P2MP deployment is
confined to blue area
FSS
P2MP

# P2MP Characteristics

- Base height: 9.1 m AGL
- CPE height: 4.6 m AGL
- Bandwidth: 10 MHz
- Conducted Power (base and CPE): 30 dBm
- Antenna Gain (base): 17 dBi
- Antenna Gain (CPE): 16 dBi
- Base horizontal beamwidth: 60 deg
- CPE horizontal beamwidth: 40 deg

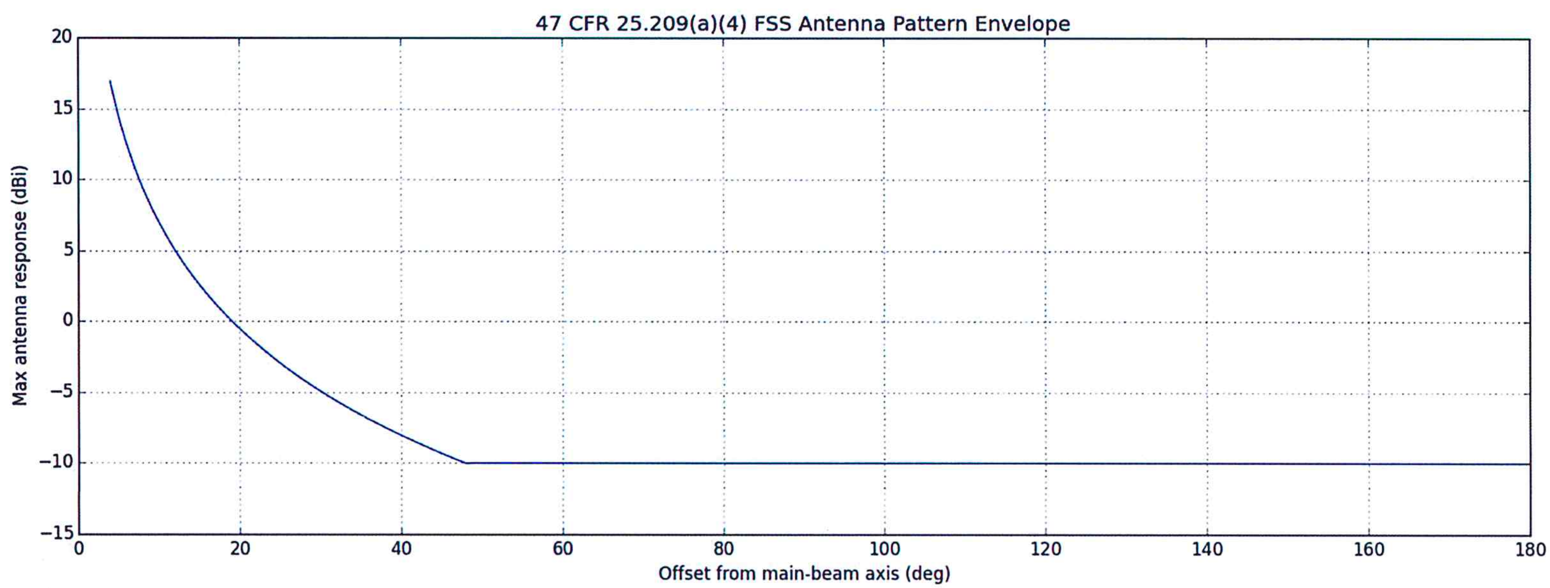
# P2MP Antenna Patterns



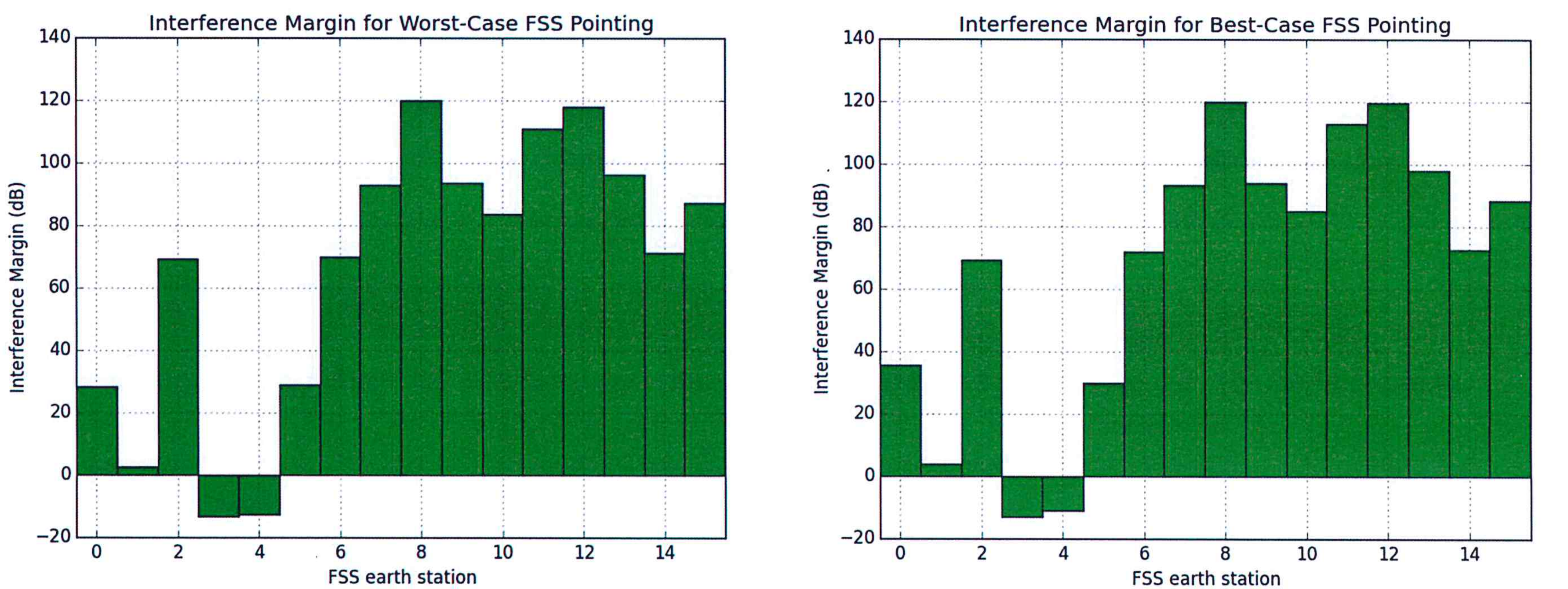



# FSS Characteristics

- Lat/lon as confirmed by imagery
- Feed point height as registered and confirmed by imagery
- Antenna gain pattern envelope: 47 CFR 25.209(a)(4)

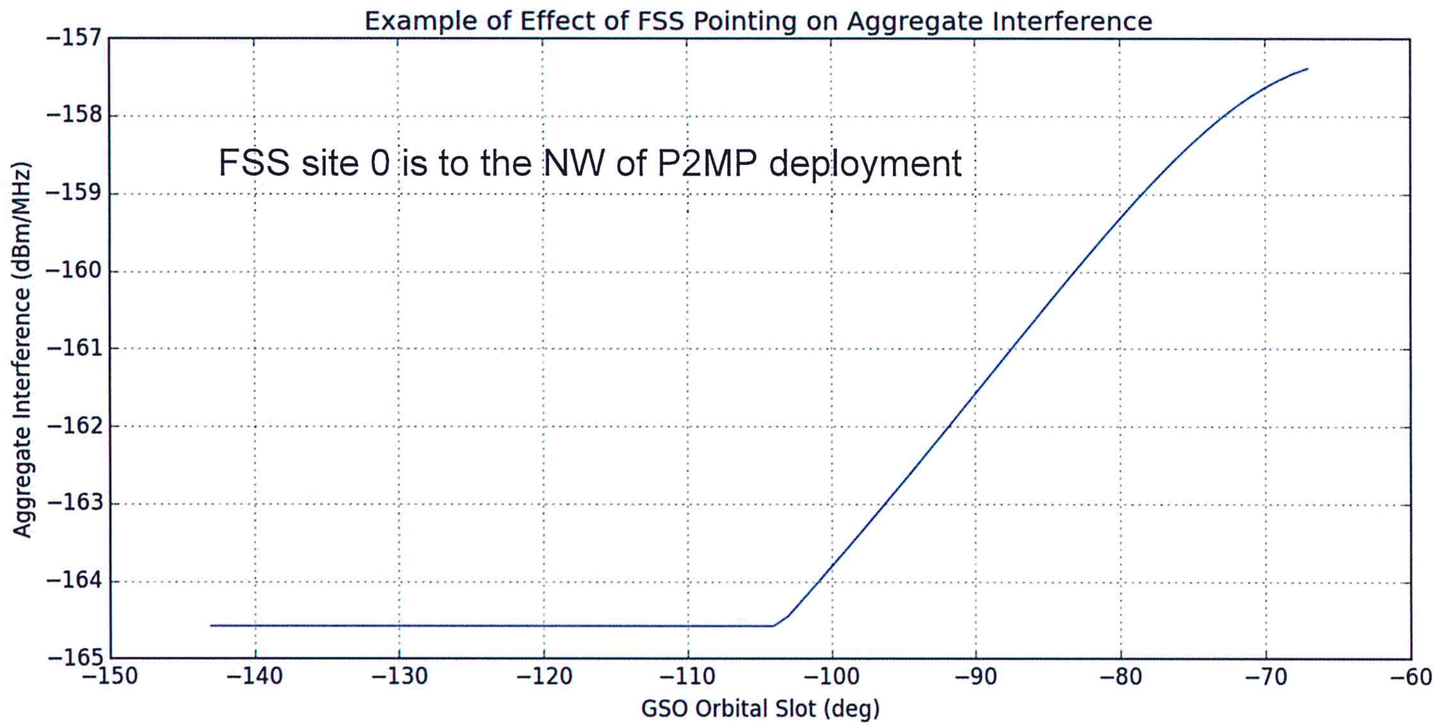


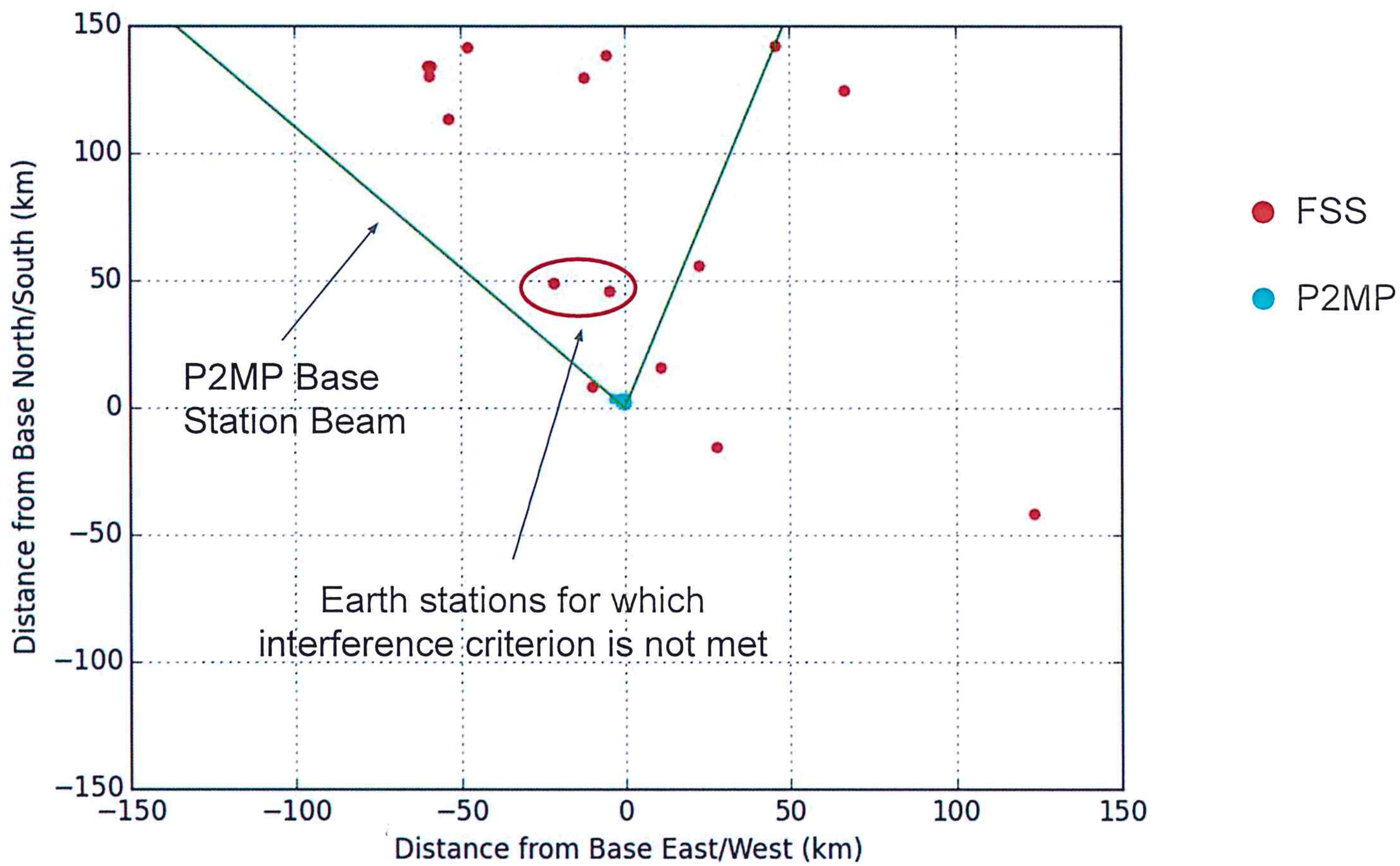
# Results: Co-Channel Interference Margin




In most cases, the FSS interference criterion is met by tens to well over 100 dB. In two cases, the interference objective is not met under the default assumptions.

# Aggregate Interference vs FSS Pointing




150
100
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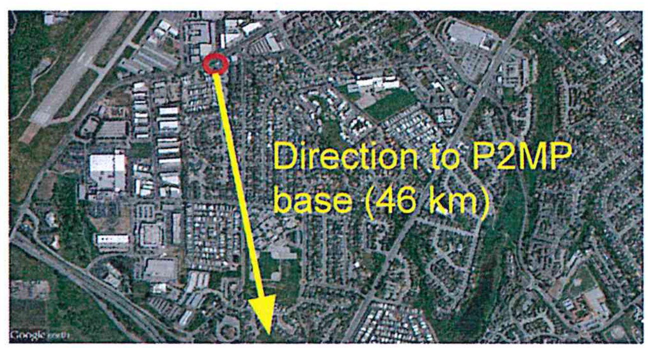
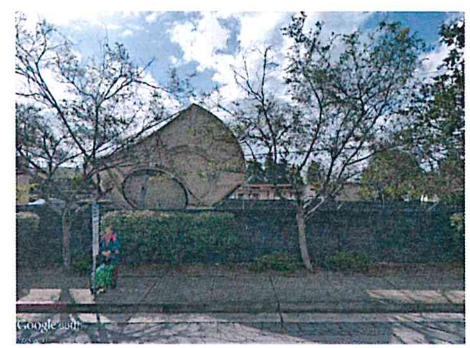
−150
−100
−50
0
50
100
150
Distance from Base North/South (km)
Distance from Base East/West (km)
P2MP Base
Station Beam
Earth stations for which
interference criterion is not met
FSS
P2MP

# First FSS site over interference criterion

- Over margin by 13.4 dB
- Have met with operator to discuss nature of their operations
  - Most of their needs are now met by fiber
  - Use of FSS is limited to “a small portion of the upper part of the band”
- Potentially significant clutter loss in real-world propagation
  - Elevation to base antenna: 0.6 deg
  - Surrounding clutter exceeds path elevation
  - Needed clutter loss (~14 dB) is very small compared to observed clutter losses in measurements



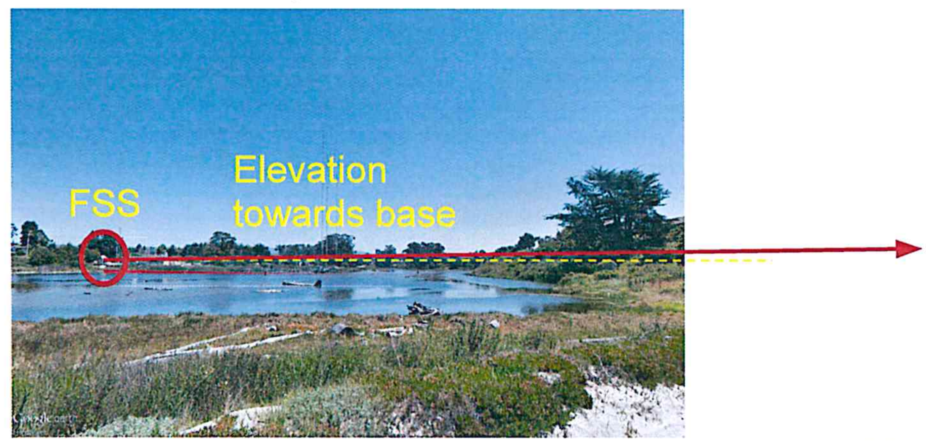



Google BAC

# Second FSS site over interference criterion

- Over margin by 12.7 dB
- 0.5 deg elevation to base; clutter likely a strong factor
- Site operated by licensee that uses only 23 MHz of spectrum at one carrier frequency, despite being registered for 500 MHz of spectrum


Side view showing elevation to P2MP base



# Impact of Frequency Separation

- Although propagation and clutter losses likely clears all 500 MHz of spectrum for co-channel P2MP use in this specific scenario, the two earth stations that require additional study both limit their frequency use (one uses 23 MHz of spectrum, the other uses a "limited range of frequencies near the top of the band.")
- If frequency separation is taken into account, interference objective is different since fundamental P2MP emissions would be placed outside of the frequency range being received by the earth station
- Relevant interference criteria become:
  - Blocking interference: keeping the overall signal strength low enough so as not to cause overload of the earth station's front end. The blocking criterion for C-band FSS established in Part 96 is -60 dBm
  - Out-of-band emissions: OOBE from P2MP appearing in-band for FSS. The objective is the same as for the co-channel case (-129 dBm/MHz), but the OOBE level for P2MP is much lower (by tens of dB) than the in-band power spectral density

# Blocking Criterion

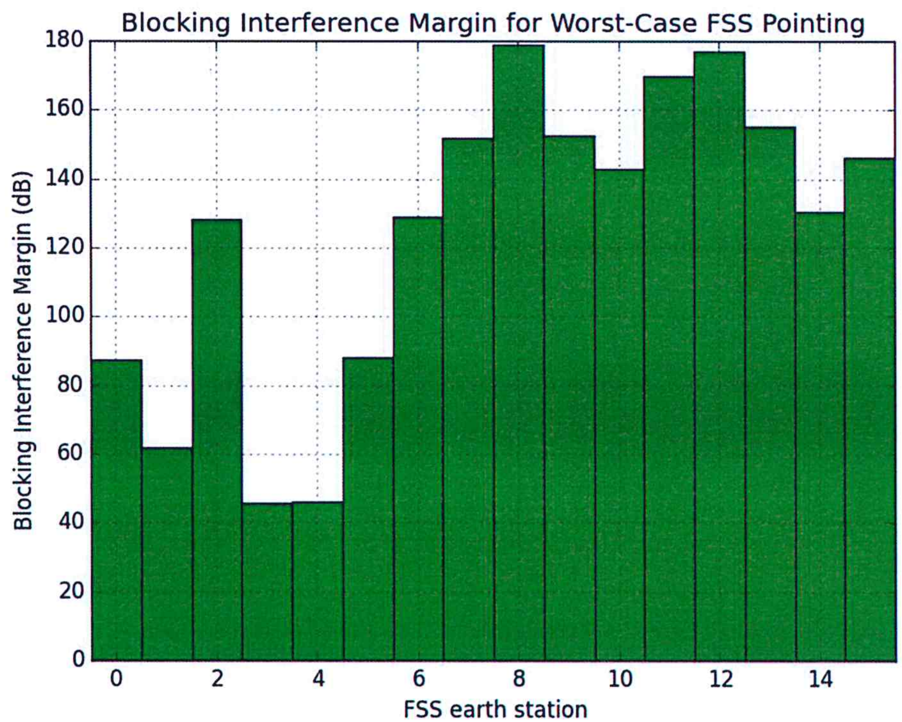
- Blocking criterion: Total aggregate power of P2MP signals as received by FSS is less than −60 dBm
- Assuming *n* P2MP transmitters each with transmit power $P_i$ (dBm), the aggregate interference power $I_j$ (dBm) is given by:

$$I_j = \sum_{i=1}^{n} (P_i + GT_{i,j} - PL_{i,j} + GR_{i,j}),$$

where (as before):
$GT_{i,j}$ = Gain of P2MP antenna *i* in the direction of FSS earth station *j*
$PL_{i,j}$ = Propagation loss from P2MP station *i* to FSS earth station *j*
$GR_{i,j}$ = Gain of FSS earth station *j*'s antenna in the direction of P2MP station *i*

- Relevant factor is total power, not power spectral density

# Results: Blocking Margin




- Blocking criterion is met by a minimum of 45 dB, up to nearly 180 dB
- Operating non-co-channel in this scenario is absolutely not a factor based on blocking criterion

# Out-of-Band Emissions Criterion

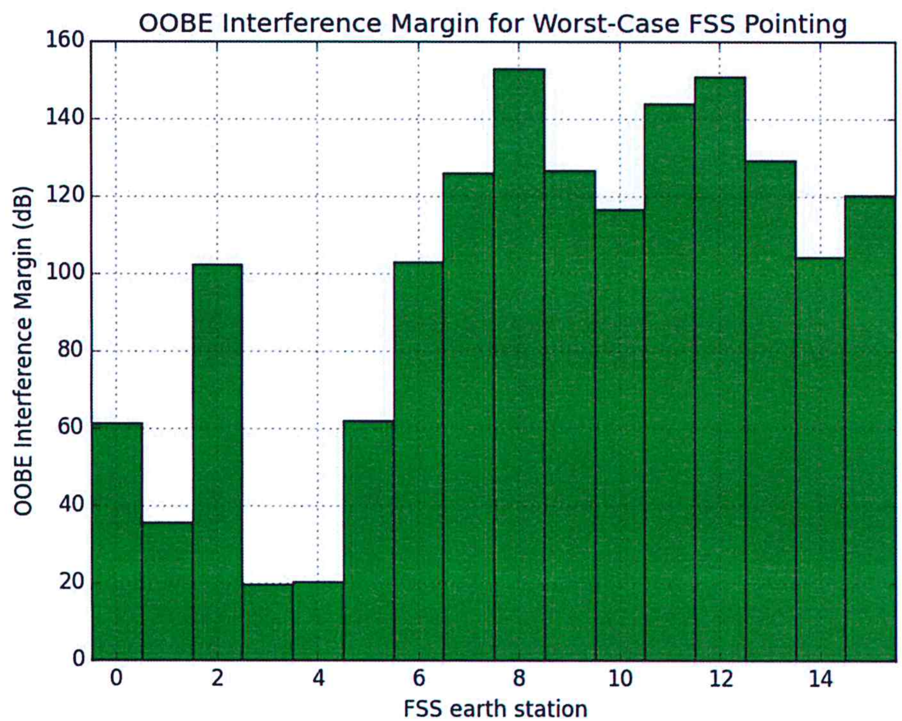
- OOBE criterion: Total aggregate OOBE power spectral density from P2MP signals as received by FSS is less than −129 dBm/MHz
- Assuming $n$ P2MP transmitters each with OOBE of $OOBE_i$ (dBm/MHz), the aggregate interference power spectral density $IPSD_j$ (dBm/MHz) is:

$$IPSD_j = \sum_{i=1}^{n} \left( OOBE_i + GT_{i,j} - PL_{i,j} + GR_{i,j} \right),$$

where (as before):
$GT_{i,j}$ = Gain of P2MP antenna $i$ in the direction of FSS earth station $j$
$PL_{i,j}$ = Propagation loss from P2MP station $i$ to FSS earth station $j$
$GR_{i,j}$ = Gain of FSS earth station $j$'s antenna in the direction of P2MP station $i$

For this analysis, a worst-case OOBE level of -13 dBm/MHz is assumed

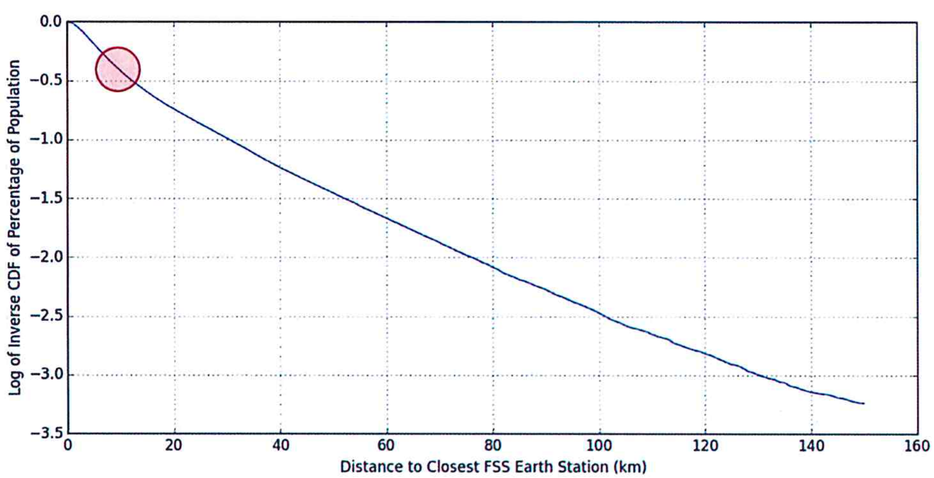
# OOBE Margin Results




- Assumed OOBE = -13 dBm/MHz
- OOBE criterion is met by a minimum of ~20 dB, up to nearly 150 dB
- Operating non-co-channel in this scenario is absolutely not a factor based on OOBE criterion

# Non Co-Channel Summary

- All interference margins are met by at least tens of dB when operating non-co-channel with FSS earth stations in the given scenario
- Result is consistent with very small non-co-channel exclusion zones as computed in ITU-R Recommendation S.2199: “a few to several km” to protect against blocking, “a few km” to protect against OOBE




Assuming “a few to several km” means 10 km, as much as 40% of the U.S. population (~120 million Americans) could potentially be served by non-co-channel P2MP broadband.

Without accurate information on actual FSS frequency use, the true number cannot be determined.

# Conclusions

- 3700-4200 MHz point-to-multipoint (P2MP) systems could immediately provide gigabit-class broadband service to *tens of millions of Americans*, without causing disruption to FSS
  - In many areas of the country, P2MP systems can operate in C-band (3700-4200 MHz) without causing interference to co-channel fixed-satellite service (FSS) systems
  - Co-channel sharing is possible by considering geographic and directional isolation between P2MP and FSS; that is, operating in areas with a relatively low number of earth stations, and using directional antennas that don't point toward earth stations in the area.
- If actual FSS frequency use were known, frequency separation could allow 25 Mbps - 1 Gbps P2MP broadband service to as many as *120 million Americans*