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ATSC 3.0 SFN Network Planning and Antenna Design

John L. Schadler – Dielectric
Ryan Wilhour- Kesler and Gehman

Acknowledgement

- Public Media Group (PMG) and Ryan Wilhour – Kessler and Gehman
 - Focus on a nation wide NG SFN
 - Flagship DMA – San Francisco Bay
 - Kessler and Gehman – Network planning
 - All of the studies performed by Ryan Wilhour using Progira Plan
 - San Francisco Bay area was the model for all examples



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Today's Presentation

- SFN network design challenges
- SFN design process
- Real antenna designs applied to a real network

San Francisco Bay Area

- Designing a NG SFN challenging on many levels
 - Major Challenge
 - Interference Protection
 - In market first adjacent channels
 - Neighboring DMA's co-channels
 - 16 full power stations
 - 6 first adjacent channels on both sides

Post Repack

UHF	
Call Letters	Channel
KSTS	19
KDTV	20
KPJK	27
KBCW	28
KPIX	29
KQED	30
KTVU	31
KCNS	32
KKPX	33
KFSF	34
KICU	36

VHF	
Call Letters	Channel
KRCB	5
KRON	7
KQSL	8
KGO	12
KNTV	13

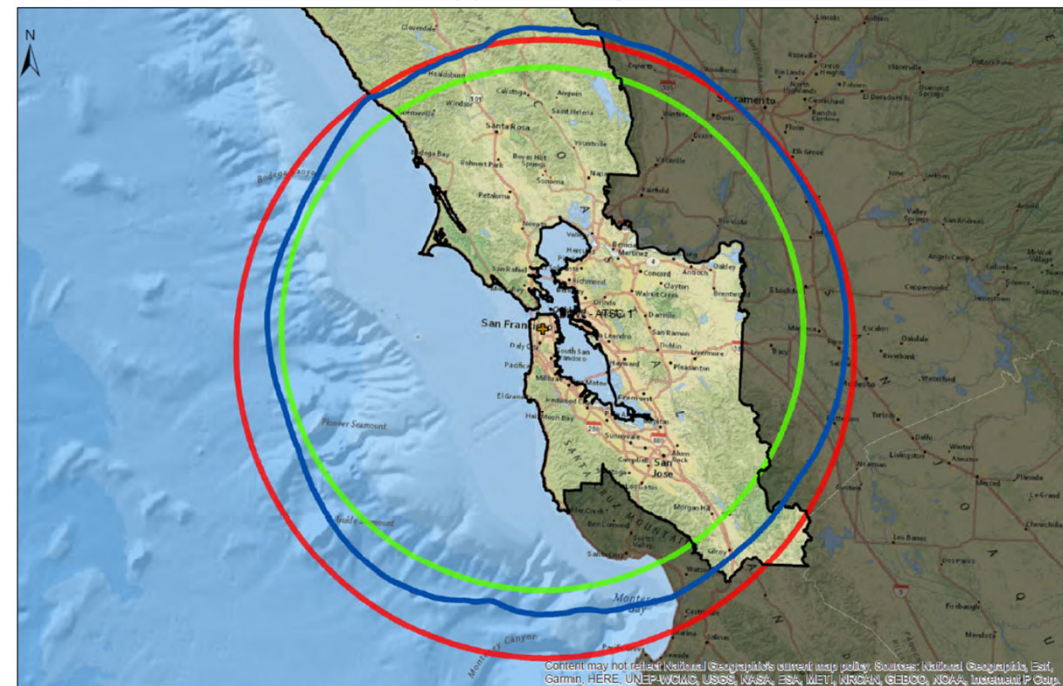
Demonstrating the Process

- Iterative process for all stations involved
- Focus on two stations
 - KBCW channel 28
 - Upper and lower adjacent
 - KPJK and KPIX
 - KICU channel 36
 - No adjacent
 - Neighboring co-channels
 - KHSL and KFRE
- Analysis based on current DTS rules
- The recent DTS NPRM attempts to relax some of the restrictions could have a potential impact but more work needs to be done

SFN Contour

- Defining the noise limited contour
- Union of 3 contours
 - FCC 41 dBu contour
 - 103 km radius
 - Largest station in market provision
- Use KBCW for example
 - TV study identifies KNTV as the largest station in the market
 - Coverage area of 46,756.6 km² or 122km radius
- KBCW's contour will basically be defined by the largest station alternative

KBCW - Noise Limited Contour, Section 73.626(C) Contour, "Largest Station" Alternative Contour.



- KBCW 41 dBu
- KBCW 103 km radius
- KNTV 122 km radius
- San Francisco DMA

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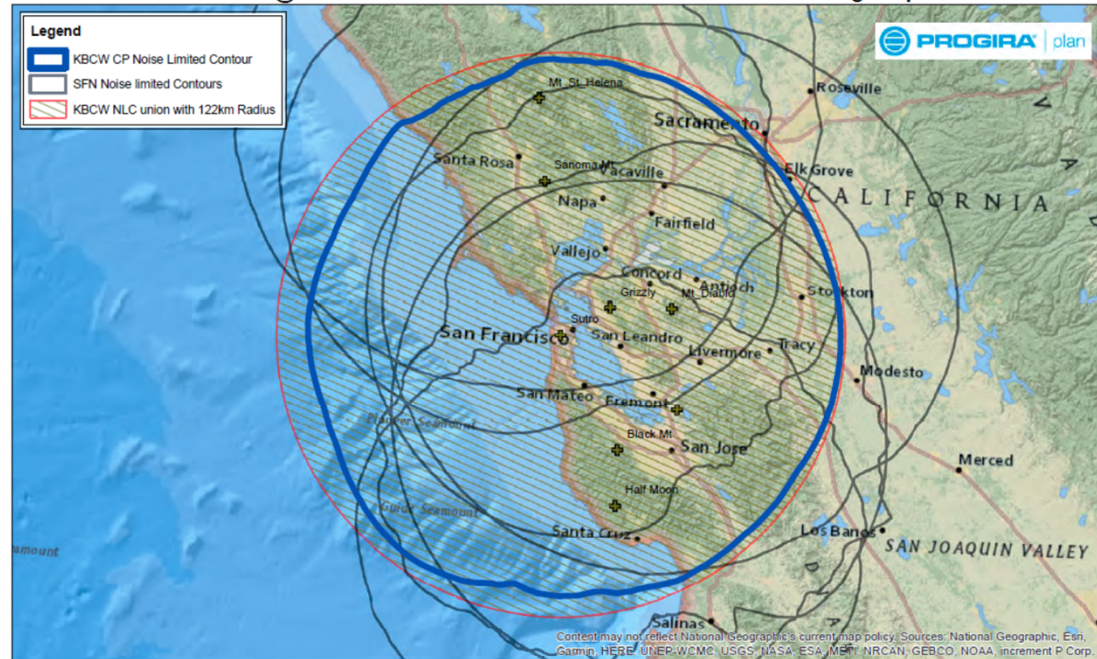
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Choosing SFN Sites – SF Bay Area – Starting Design Criteria

- Site selection
 - Zoning issues
 - Erecting new tower probably impossible
 - Limited to existing tower
 - > 10 miles inside NLC – limit signal strength toward contour
 - 9 SFN sites chosen + the main stick
 - Mt. St. Helena, Monument Peak, Mt. Diablo, Black Mt., Grizzly Mt., Sanoma Mt., Half Moon, San Jose, Campbell
- Starting ERP's and site radiation patterns
 - Main stick as licensed
 - Each SFN site 200kW - Omni

San Francisco - KBCW-TV @ 1MW and 200KW SFNs Without Directional Antenna Design Implemented Yet



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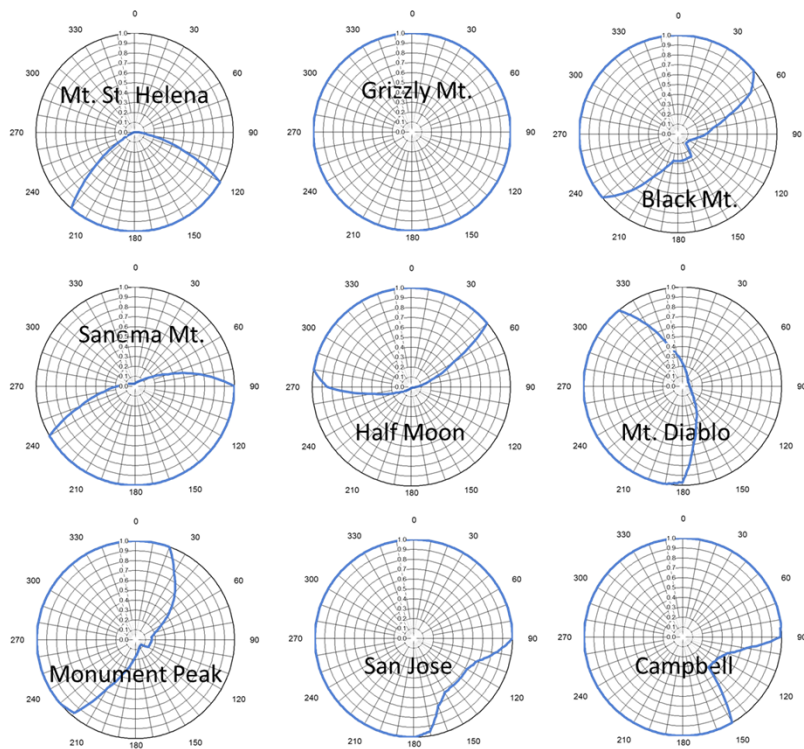
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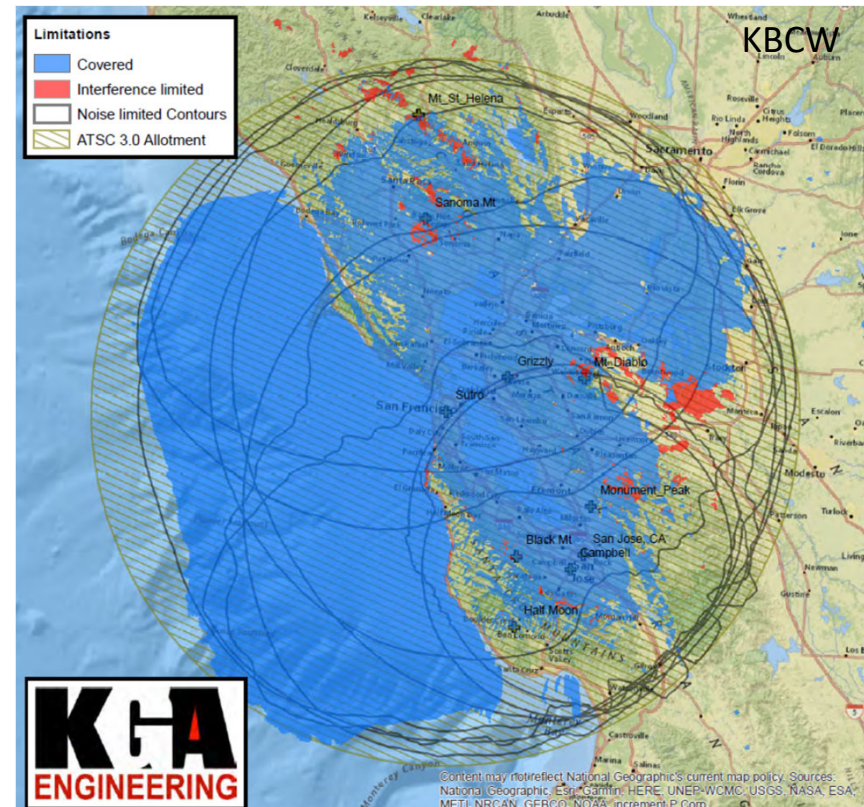
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Power Reductions to Meet Contour Limit

- Power reductions performed in all directions to meet FCC limitations



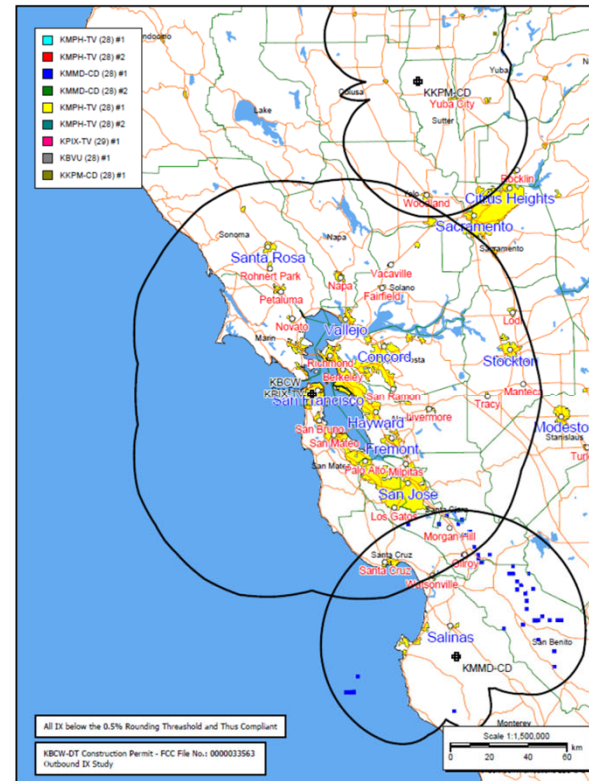
Main antenna – 1 MW ERP Each SFN site – 200 kW ERP



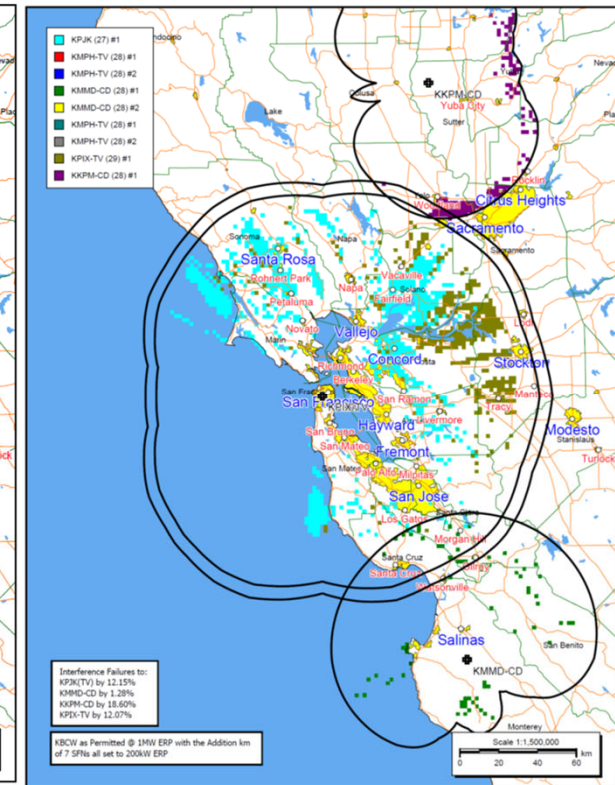
Interference Compliance

- Import the SFN design into TV Study to test for interference compliance
- Interference protection
 - Equivalent level as currently provided to DTV signals
 - Combined interference effect of multiple DTS transmitters must comply with the Root Sum Squared method of calculation
 - At a given location the combined field strength level

$$F_c = \sqrt{\sum_{s=1}^S f_s^2}$$



Interference map as permitted



Interference map with addition of the 9 sites

Forces the ERP's of the main stick and the SFN sites be reduced

Impact of in Market Adjacent Channel Interference Compliance

- KBCW channel 28 case study
 - Limitations placed on SFN sites
 - Protect KPIX (27) and KPJX (29)
 - Result of the RSS aggregate field strength summation

KBCW	Starting Contour Limited	Reduced Interference Limited	Impact
Site	ERP kW	ERP kW	dB
Mt. Sutro	1000	200	-7.0
Mt. St. Helena	200	0.4	-27.0
Monument Peak	200	5	-16.0
Mt. Diablo	200	0.5	-26.0
Black Mt.	200	50	-6.0
Grizzly Mt.	200	0.5	-26.0
Sanoma Mt.	200	3	-18.2
Half Moon	200	200	0.0
San Jose	200	3	-18.2
Campbell	200	3	-18.2

Impact of Neighboring Market Co-channel Interference Compliance

- KCIU channel 36 case study
 - Limitations placed on all of the sites
 - Protect KHSL (36) and KFRE (36)
 - Result of the RSS aggregate field strength summation

KICU	Starting Contour Limited	Reduced Interference Limited	Impact
Site	ERP kW	ERP kW	dB
Mt. Sutro	860	3	-24.6
Mt. St. Helena	200	0.11	-32.6
Monument Peak	200	200	0.0
Mt. Diablo	200	0.06	-35.2
Black Mt.	200	54	-5.7
Grizzly Mt.	200	644	5.1
Sanoma Mt.	200	56	-5.5
Half Moon	200	100	-3.0
San Jose	200	163	-0.9
Campbell	200	100	-3.0

SFN Performance Baseline

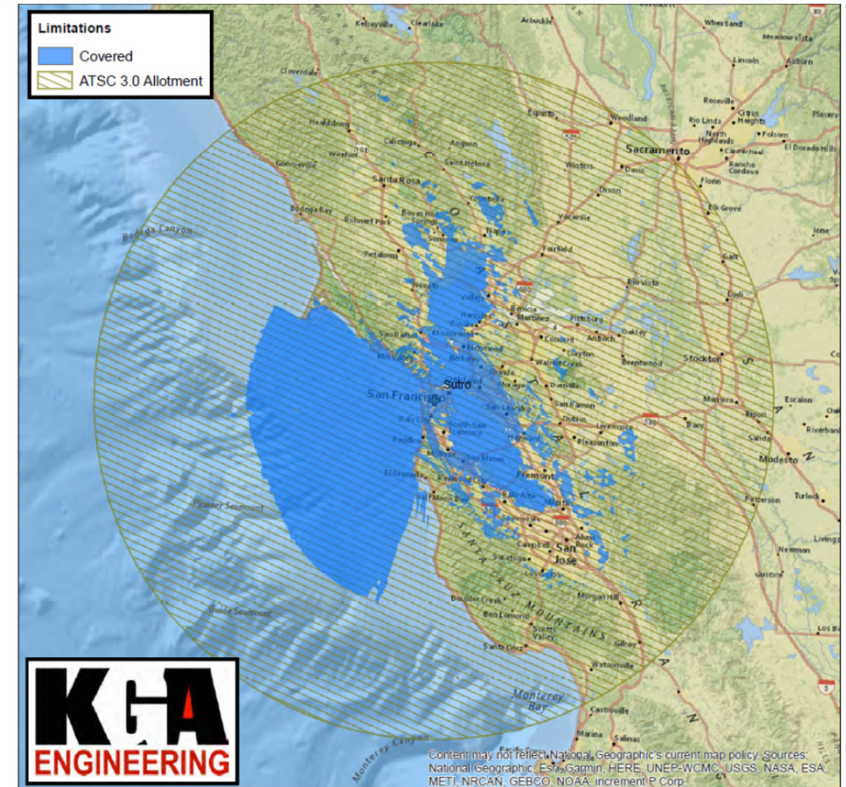
- ATSC 3.0 tool box
- For analysis
 - Service that falls in between 10m roof top and fully mobile
 - “Outdoor portable”



Receive Ht	1.5m
Receive mode	Outdoor Portable
Polarization	EPOL
Mod-Cod	256 QAM
Bit Rate	25 Mbps
S/N	19.2 dB
FFT	32K
FEC	10/15
Location variability	95%
Time variability	90%

Performance Analysis Benchmark

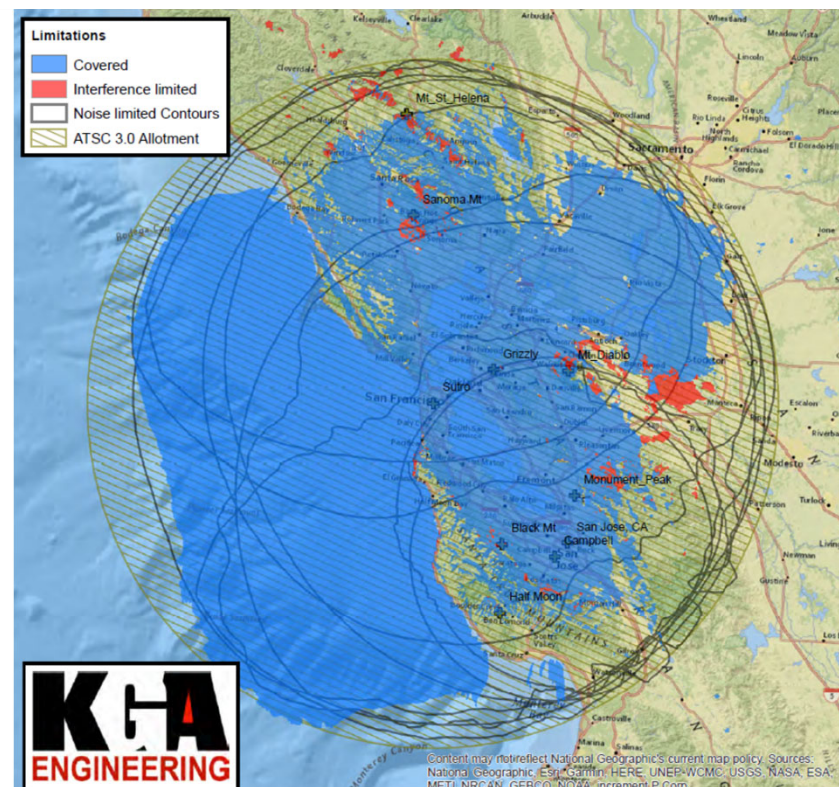
- Based upon the population that would be served if the station converts to ATSC 3.0 with their main antenna only at fully licensed ERP



KBCW Current Infrastructure Converted to ATSC 3.0	3,510,937
KICU Current Infrastructure Converted to ATSC 3.0	3,847,082

Performance Theoretical Patterns Contour Limited Only

- Turn on the 9 SFNs at full 200kW ERP
- Main stick at fully licensed ERP
- Ignoring interference limitations
- Note that this contour limited only scenario is not practical since it is not IX compliant

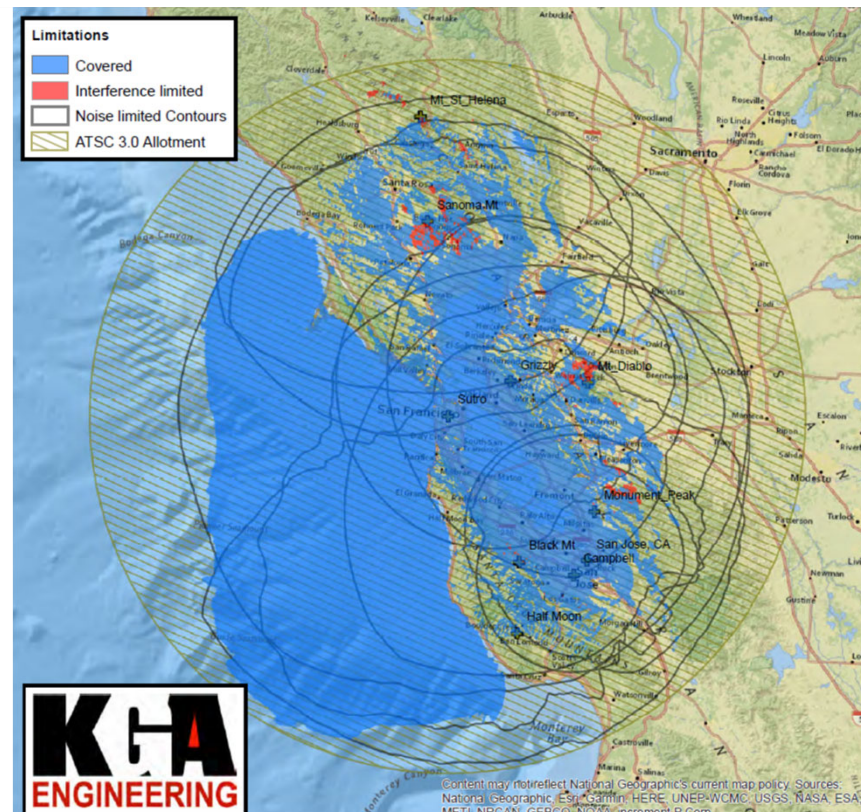


KBCW w/ SFN Theoretical Patterns Contour Limited	6,745,414
KICU w/ SFN Theoretical Patterns Contour Limited	6,518,875

Approximately 47% increase over benchmark

Performance Theoretical Patterns Contour Compliant Interference Compliant

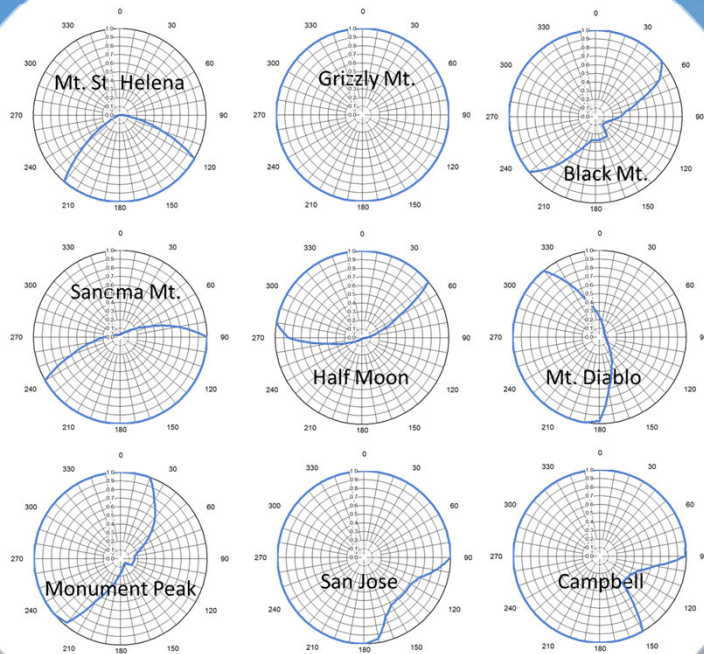
- 9 SFNs at reduced ERP for interference compliance
- Main stick at 200kW ERP
- Observe
 - Negative (20%) impact from IX compliance
 - Positive overall impact of the SFN (30%)



KBCW w/ SFN Theoretical Patterns	5,318,521
KICU w/ SFN Theoretical Patterns	5,306,799

Approximately 30% increase over benchmark

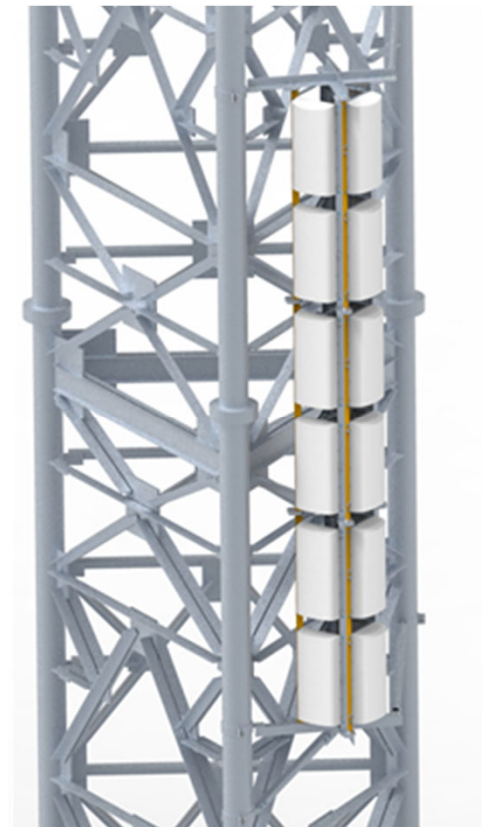
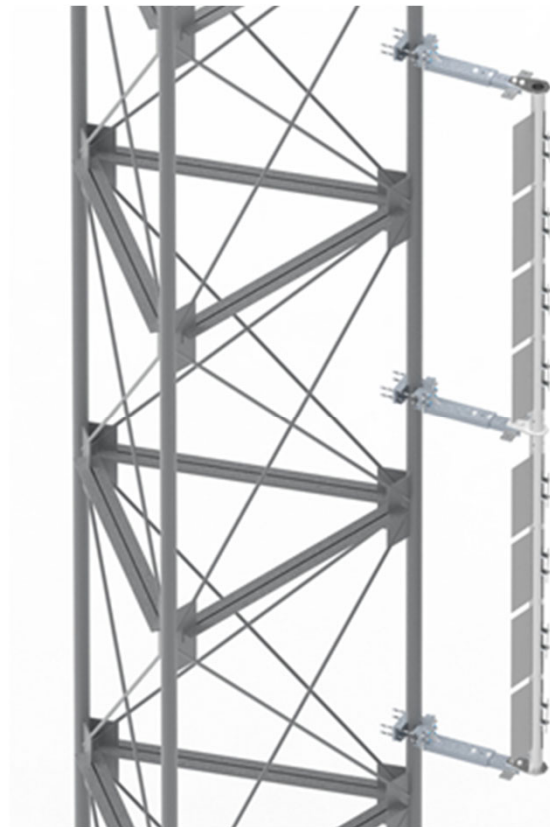
Designing Real Antennas for a SFN Network



- Current DTS rules impose hard limits on signal strengths
- Many antenna designs will be directional with high front to back ratios

Typical Methods to Produce Directional Broadcast Antennas with High Front to Back Ratio

- Slotted coaxial antenna
 - Large fins or directors
 - Narrow band – single channel
- Panel antenna
 - Broadband – Better suited for co-located SFN sites
 - High windload



Slot Cavity WB Antenna

- Introduced in 2015
- Widely used as a transitional and aux antenna during repack
- Panel bandwidth in a pylon package
- Basic building block
 - Radiator – w/g to coax transition
 - Simple – Rugged
 - ATSC 3.0 ready
 - Is not voltage limited

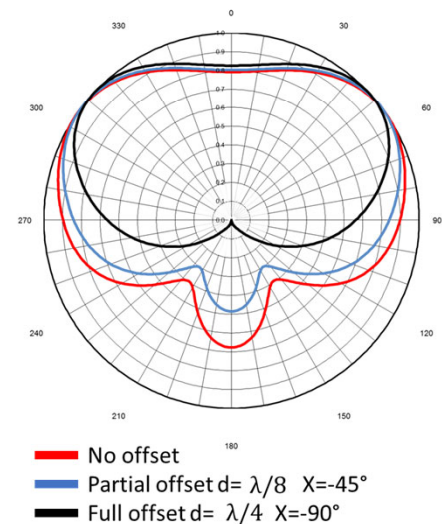
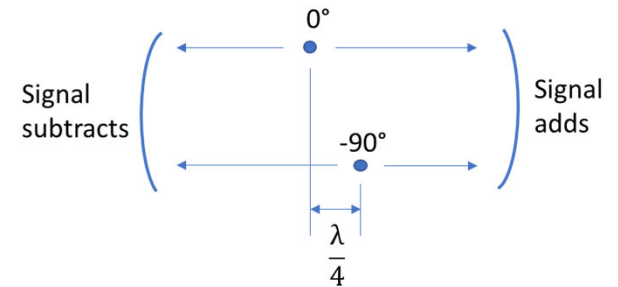
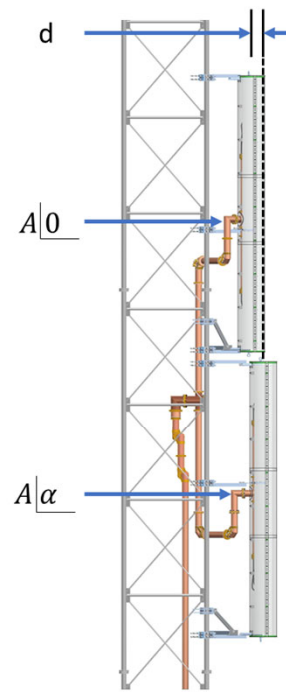


WB Antenna with High Front to Back Ratio

- Axial bay offset technique
 - Eliminates the need for large fins or directors
 - Calculate the total array pattern of offset bays
 - d =bay offset
 - α =phase differential between bays

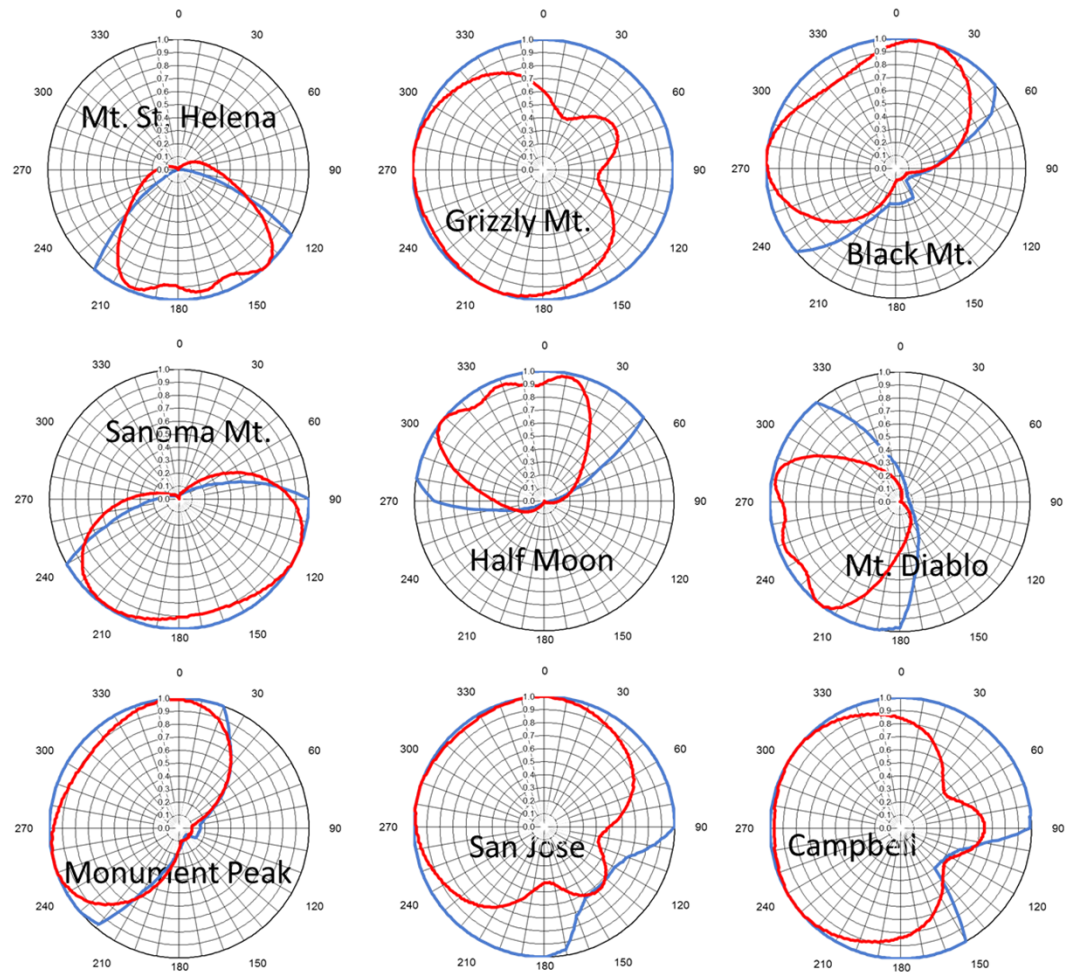
$$F(\theta) = P(\theta)[1 + e^{jkd\cos\theta + \alpha}]$$

- Allows for full optimization of back lobe level
- Future proof
 - If future FCC rulings allow for contour expansion, the pattern can be field adjusted to accommodate new coverage areas



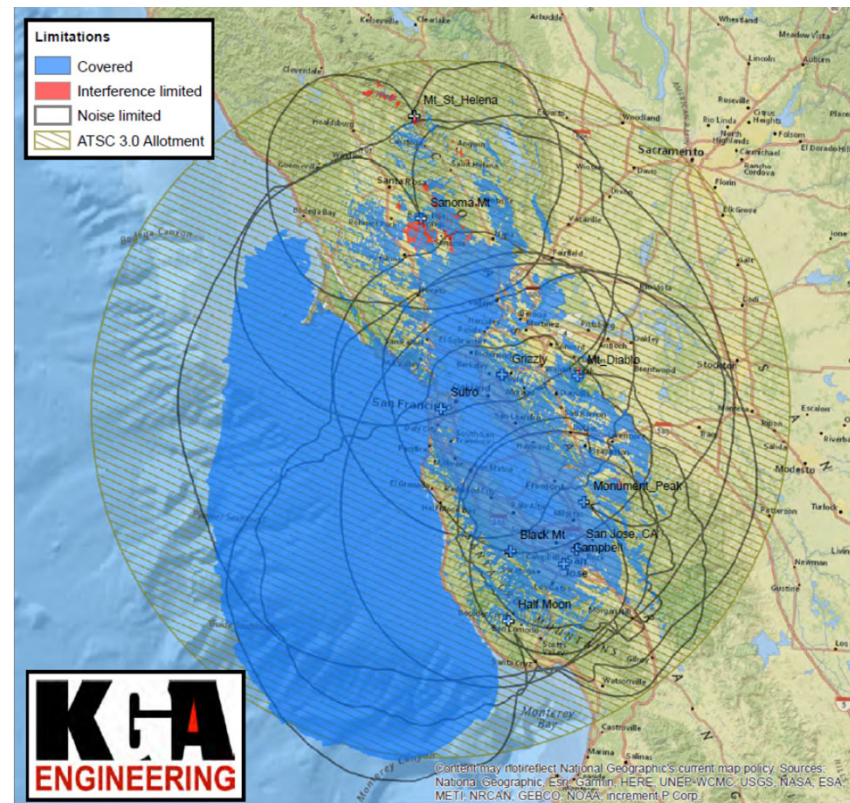
Re-Analyzing the SFN Using Real Antenna Designs

- Replacing the theoretically generated azimuth patterns with real antenna designs
- All the designs used in this network are WB style
 - Some take advantage of bay offset
- In some cases the ERP had to be reduced again



Performance Real Patterns Contour Compliant Interference Compliant

- 9 SFNs at reduced ERP for interference compliance
- Main stick at 200kW ERP
- Theoretical patterns replaced with real designs
- Observe
 - Minimal loss of approximately 3% population over theoretical



KBCW w/SFN Real Patterns	5,080,732
KICU w/SFN Real Patterns	5,151,172

Approximately 27% increase over benchmark

Summary

Scenario	Populations	% Gain Over Baseline
KBCW Current Infrastructure Converted to ATSC 3.0	3,510,937	
KBCW w/ SFN Theoretical Patterns	5,318,521	34%
KBCW w/SFN Real Patterns	5,080,732	30.9%
KBCW overall pop gain	1,569,795	
KICU Current Infrastructure Converted to ATSC 3.0	3,847,082	
KICU w/ SFN Theoretical Patterns	5,306,799	27.5%
KICU w/SFN Real Patterns	5,151,172	25.3%
KICU overall pop gain	1,304,090	

In the SF Bay Area, an overall population gain for a basic outdoor portable service of approximately 30% can be expected by joining the SFN

Conclusions

- Analyzed a real SFN design for the San Francisco Bay Area
 - Using current DTS rules
 - Most likely not be impacted by the DTS NPRM
- “Edge Case” – Many Challenges
- Impact of in market adjacent channels and neighboring co-channels
- Impact can be lessened through careful network design
- Innovative antenna design can reduce the impact of demanding patterns needed for protection

Thank you!

Questions?

