ATSC 3.0 SFN Network Planning and Antenna Design

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Abstract - *The new ATSC 3.0 broadcast standard provides new transmission capabilities. Higher, more uniform signal strengths, required to reliably deliver higher data rates, will be achieved via a connected single frequency network platform while continuing to utilize the existing "main stick" in the form of high power and tall towers. The addition of an SFN to the existing infrastructure provides extended, robust service to consumers not reliably served by the main antenna. The use of modern network planning tools provides the service predictions essential to ensure required reception probabilities within the entire licensed area. Emphasis will be placed on analyzing reception probability as a marker of success, rather than the current methodology of assuming that field strength above 41dBu provides service. Further, reception probability takes into account network self-interference and permits analysis of the different use cases available within the NextGenTV standard. Current regulatory restrictions, based on predicted field strength, present challenges in SFN network design as well as antenna design. (The recent DTS NPRM will create less restriction on practical antenna designs in an SFN and this will help, but results will vary based on market complexities, since the interference criteria have not been relaxed.) This paper will use an actual proposed SFN network, based on current DTS rules, in the San Francisco Bay area as its model. The techniques used to optimize the network will be discussed followed by antenna designs developed to realize the theoretical calculations. Finally, by identifying populations served by an example use case, an overall analysis of expected performance is presented.*

ATSC 3.0 AND SINGLE FREQUENCY NETWORKS

The basic goal of single frequency networks (SFN's) is to boost the reception probability of a wider variety of services, to more people.

This is accomplished by adding additional transmission sites around the existing main antenna. In anticipation of ATSC 3.0 services, future proofing the main antenna with Future Fill was introduced in 2014 and implemented at the beginning of repack [1]. The use of predetermined illuminations that are simply modifiable in the field provides the flexibility to customize the null structure at a future date [2]. The combination of SFN's using real antenna designs, switching to Future Fill mode on the main antenna and the use of elliptical polarization used to provide a defined service will be discussed.

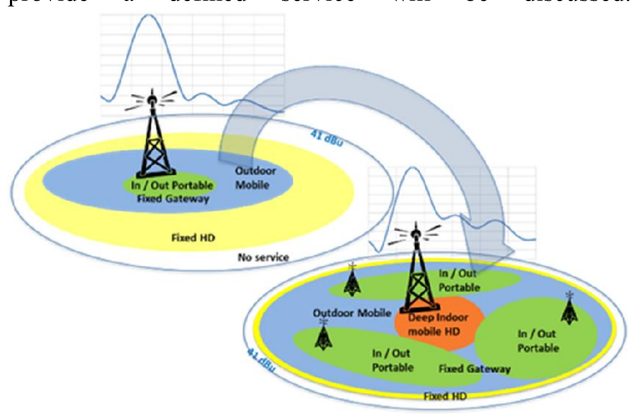

Figure 1: Saturate with main antenna and add SFN sites to boost the service and provide targeted data intensive services.

PUBLIC MEDIA GROUP (PMG)

PMG is a public benefit corporation focused on expanding access to content and data through market neutral technology infrastructure. They plan to manage every aspect of the ATSC 3.0 transition including the full buildout of a nationwide SFN. The first flagship SFN will most likely be in the San Francisco Bay area and will be the model used for examples in this paper.

PLANNING PROCESS AND SFN PERFORMANCE BASELINE

For decades, planning factors have been based solely on the required signal strengths at a fixed 30' height above ground to define the FCC (50/90) contours. Field strength is a necessary first step in any planning, but it is inadequate to plan for NextGen TV. ATSC 3.0 offers a whole tool box of services to the planner. As shown in Figure 4 later, planning relies on an iterative process using the FCC (50/90) contours to determine antenna locations and patterns, and confirm interference compliance, before analyzing reception probability for the required use cases. For the purpose of this paper, we have chosen a use case that falls in between a 10m fixed roof top and a fully mobile service. It basically defines a high data rate service to a portable handheld receiver, limited to approximately 20 mph of travel speed by Doppler restrictions. For this analysis, the following basic parameters will be used:

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%

Figure 2: ATSC 3.0 Parameters used for performance analysis.

Note that the Progira Plan planning software used for the analysis takes into account reception mode, MODCOD (modulation and coding), FFT, polarization, Guard Interval to analyze reception probability for a given use case and location. Even though the original field strengths are determined based on FCC (50/90) contours, the software applies correction factors for the higher location probabilities required for the given use case, in this particular application a location variability of 95% is required. As will be demonstrated later, the benchmark of the analysis is the population that will be served if the station converts to ATSC 3.0 with their current main antenna and does nothing else.

SAN FRANCISCO BAY AREA

Designing a NextGen SFN in the San Francisco Bay Area is challenging on many levels. Challenges include protecting the first adjacent and co-channels in market and neighboring DMA's [5].

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

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

Figure 3: Post repack full power stations in the San Francisco market [5].

Figure 3 shows that, after repack, there will be 16 full power stations in the San Francisco TV market of which 6 have first adjacent channels on both sides of their operating channel. A full network plan requires an iterative analysis of all stations involved. A very basic process is shown in figure 4. It is likely that variations on this process will be developed by SFN designers.

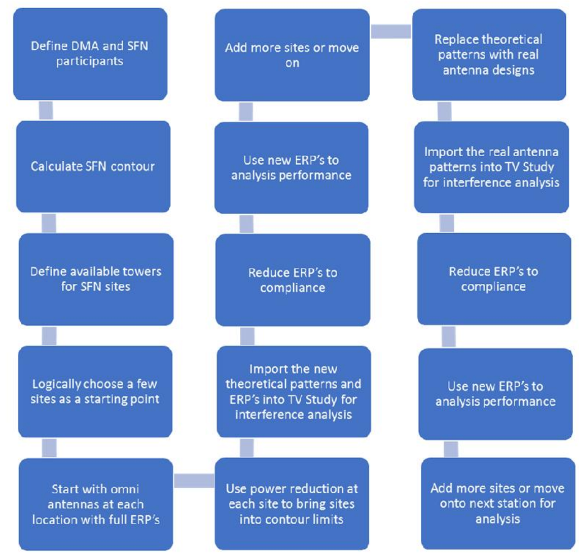

Figure 4: Fundamental flow chart of the SFN design process.

For the purpose of demonstrating the process, this paper will focus on two stations, KBCW and KICU. KBCW has an upper and lower adjacent channel that must be protected. KICU does not have an in market adjacent channel but needs to protect a neighboring co-channel station. As will be seen in both cases, power reductions are very significant in order to bring each station into interference compliance. Comparing the stations will help us to better understand the impact that adjacent channel and co-channel interference will have on ATSC 3.0 SFN designs. (Note that as the in-market adjacent channels change to ATSC 3.0 and join the SFN, the adjacent channel interference restrictions would have less impact, but the neighboring co-channel restrictions remain [5].)

SFN CONTOUR – SF BAY AREA

KBCW's transmit site is located on the Mt. Sutro tower. Currently, the network service area is defined by the FCC (50/90) noise limited contour or a circle of radius 103 km from the main antenna as described by the table of distances in 47 CFR 73.626 – DTV distributed transmission systems. An alternative to the table of distances approach that can also be used to determine the maximum service area is use of the largest station provision in section 73.622(f)(5) of the rules which seeks to equalize the coverage areas of all stations. This provides the same geographic coverage area as the largest station within their market [3]. TV Study identifies KNTV as having the largest service area in the market of 46756.6 km^2 which translates to 122 km radius. It is the union of the FCC noise limiting contour, 103 km radius and the largest station provision that will define the maximum noise-limited SFN service area, as shown in Figure 5. (The recent NPRM also follows these guidelines but permits potential extensions in order to achieve practical designs, as long as interference criteria are not exceeded.)

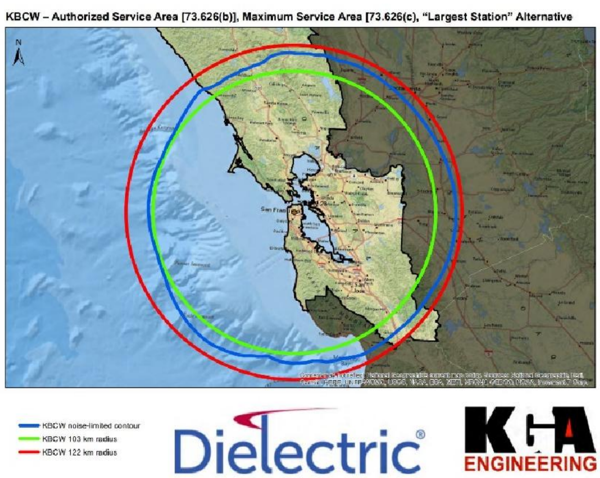

Figure 5: Defining the KBCW service area limits for an SFN in the San Francisco Bay Area based on largest station.

As can be seen in this example, KBCW's SFN limit will basically be defined by the 122km radius of the largest station alternative circle. In order to realize a successful network with optimum benefits for all participants, the network plan assumes that all stations involved in the SFN will co-locate to a relatively close common point. This will allow the contours of the stations to all be the same. In the case of KICU, it is assumed for analysis in this paper that their main antenna will re-locate to Mt. Sutro and their current location on Monument Peak becomes one of the SFN sites.

CHOOSING SFN SITES – SF BAY AREA

Due to very tough zoning issues, particularly in the Bay Area, erecting new towers is a daunting, if not impossible, task. It is therefore assumed that SFN sites will only be installed at existing tower locations. Per current DTS rules, these locations have to be about 10 miles within the maximum SFN service area in order to limit the signal strength at the area boundary. (The NPRM would permit locations closer to the boundary but, as will be shown later, interference will likely remain the dominant criteria in this particular market). Following the process outlined in Figure 4 through several iterations, the resulting SFN consists of a total of 10 sites, the Mt Sutro site plus 9 strategically selected SFN sites in the FCC service area, one of which is the KICU original site. The sites are Sutro, Monument Peak, Mt. St. Helena, Mt. Diablo, Black Mt., Grizzly Mt., Sanoma Mt., Half Moon, San Jose and Campbell.

PREDICTING THEORETICAL SFN AZIMUTH PATTERNS – SF BAY AREA

In this study, the main stick starts at its fully licensed 1MW ERP and each SFN site will begin as an omni directional azimuth pattern with an ERP of 200kW. Within Progira Plan software, power reductions are then performed in all directions to meet the FCC service area limitation.

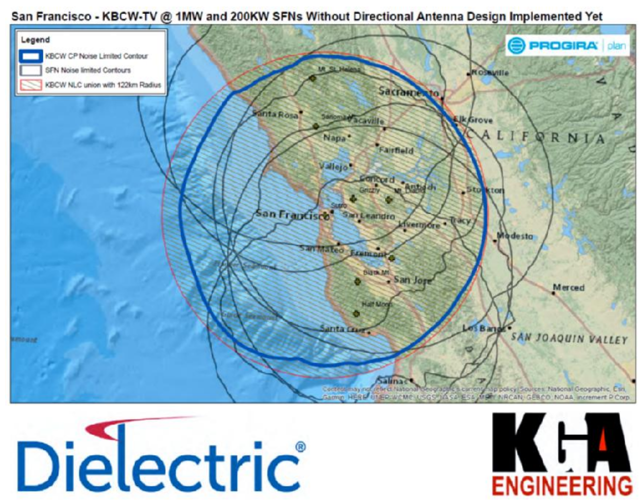

Figure 6: Chosen SFN sites start out omni directional before power reduction optimization.

The results predict the best theoretical azimuth pattern to be applied at each site. Figure 7 is a map of the SFN sites with the new azimuth patterns pulled inside the permitted service area. Note that the ERP's at each site remain at 200 kW's and the main antenna remains at 1 MW. Figure 8 depicts the optimized theoretical patterns generated for each site.

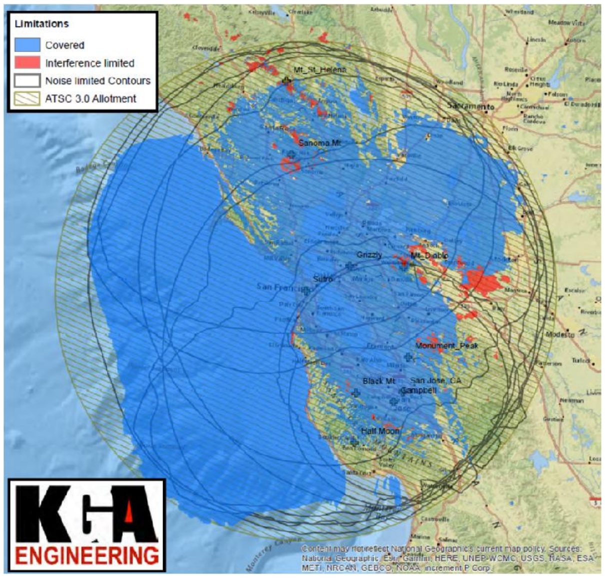

Figure 7: SFN sites after power reductions defining the best fit theoretical patterns.

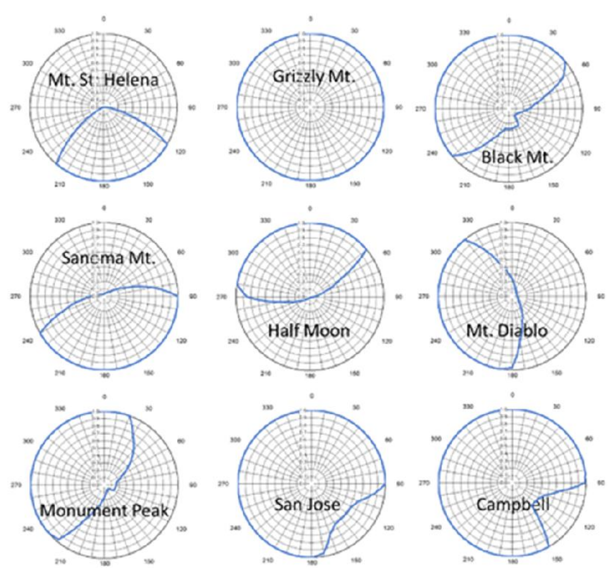

Figure 8: Best fit theoretical azimuth patterns for each site.

TESTING FOR INTERFERENCE COMPLIANCE

The next step is critical – the network design must now by tested for interference compliance, by exporting the design into TV Study. The limitations include interference protection as defined in FCC 17-158 report and order, which states a protection threshold for NextGen TV signals will provide an equivalent level of protection as provided to DTV signals from both co-channel and adjacent channel interference [4]. In accordance with the interference rules and calculations as stated in the FCC 08-256 report and order [3], the combined interference effect of multiple DTS transmitters must comply with the root-sum-squared (RSS) method of calculation. This means that the combined field strength level at a given location is equal to the square root of the sum of the squared field strengths from each transmitter in the DTS network at that location. This forces the ERP of the main stick and some of the SFN sites to be reduced in order that the aggregate signal strengths do not exceed the co-channel or adjacent channel interference level when the SFN sites are turned on. This analysis is performed in TV Study. In the case of KBCW, in market adjacent channel interference required a reduction on the main antenna from 1MW to 200kW ERP. The interference limits also force all but one of the 9 SFN sites to a reduced ERP from the starting point of 200kW.

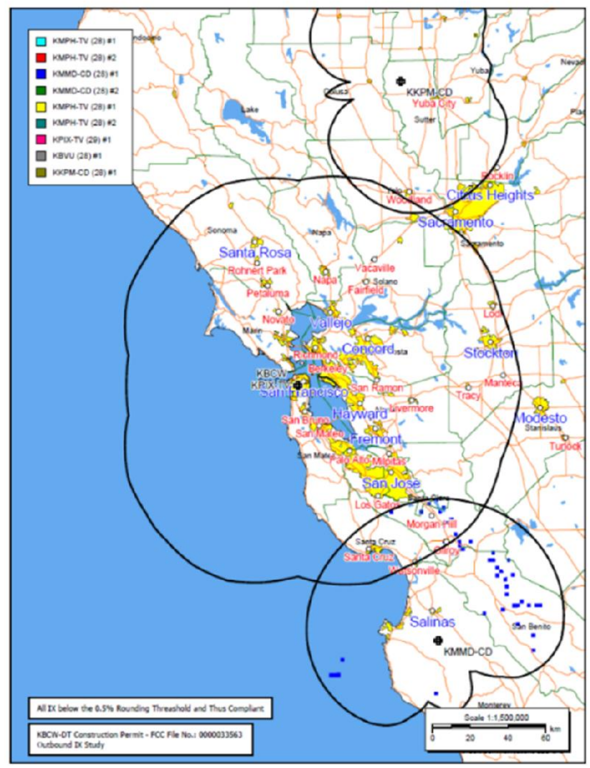

Figure 9: Interference map of KBCW as permitted.

Looking at an interference map of KBCW as permitted (Figure 9), versus KBCW as permitted with the addition of the originally planned 200kW SFN sites (Figure 10), it is apparent that the impact and limitations placed on the ERP's is a result of the first adjacent channel KPJK (channel 29) and co-located adjacent channel KPIX (channel 27). This is due to the RSS aggregation methodology described earlier. Usually, co-located adjacent channels are not a problem, but not when throwing an SFN into the mix on one of the channels as is the case in the San Francisco Bay Area!

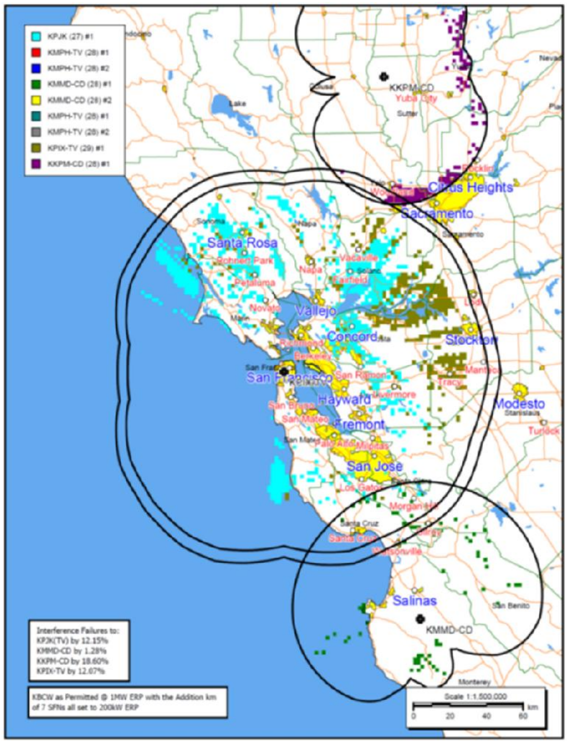

Figure 10: Interference map of KBCW with the addition of the 9 SFN sites.

The new ERP's at each site to meet the compliance criteria for KBCW are given in Figure 11.

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

Figure 11: KBCW's ERP's defined at each of the SFN sites.

Using the same process, SFN sites, and theoretical azimuth patterns, KICU is now analyzed. As mentioned earlier, KICU does not have an in-market adjacent channel but needs to protect neighboring co-channel stations KHSL and KFRE. The maps for KICU showing the as permitted and with the addition of the 9 SFN sites turned on are given in Figures 12 and 13.

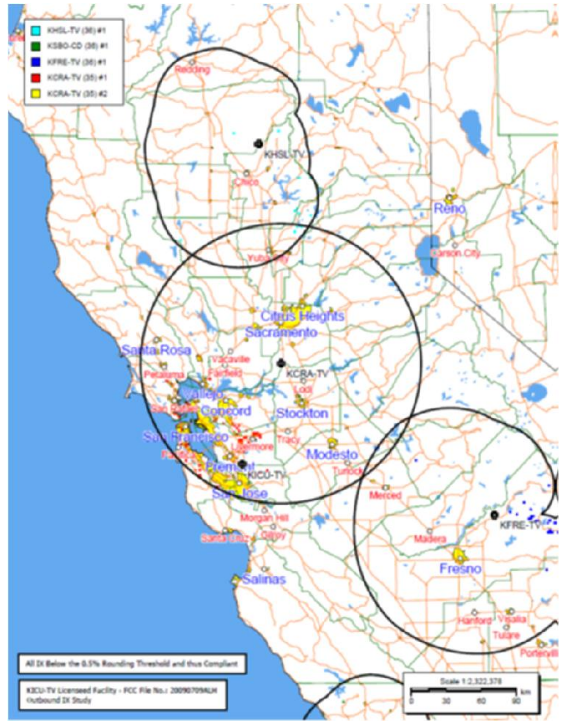

Figure 12: Interference map of KICU as permitted.

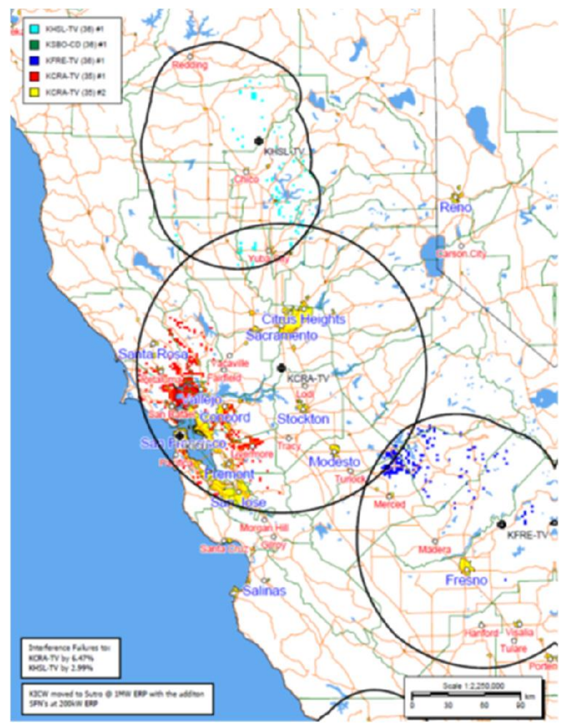

Figure 13: Interference map of KICU with the addition of the 9 SFN sites.

Using the same best fit theoretical patterns as shown in Figure 8, the new interference compliant ERP's for KICU's main antenna and each SFN are given in Figure 14.

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

Figure 14: KICU's ERP's defined at each of the SFN sites.

We again see the impact that interference compliance has on the SFN network design. In the case of the San Francisco market, interference is the dominant criterion in SFN design – under current and proposed DTS rules.

SFN PERFORMANCE ANALYSIS

As a baseline, Progira Plan calculates the service areas, and the populations contained within, that can receive the chosen signal with user selectable probability, using each station's current infrastructure and full licensed ERP. In this study the location probability selected was 95%, i.e. 95% of locations within the service area able to receive the signal above threshold for the chosen ATSC 3.0 use case parameters and reception mode described in Figure 2.

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

The next step is to turn on the SFN as designed using the best fit theoretical patterns as shown in figure 8 and the reduced ERP's as listed in figures 11 and 14 in order to bring the SFN into interference compliance. The populations served with the theoretical SFN design are as follows:

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

This clearly illustrates the positive impact the SFN has on overall service for this use case. For KBCW, the SFN provides a 34% increase in population served over the baseline. Similarly, it provides a 27.5% increase for KICU.

Note that these numbers represent reliable reception of a high data rate signal by a moving handheld device at 1.5m. This cannot be achieved with ATSC 1.0 or simply converting current infrastructure to ATSC 3.0.

It is widely expected that ATSC 3.0 deployments will take advantage of the many options available within the standard, and transmit multiple modulation and coding (MODCOD), FFT selections to reach a variety of receive antennas. These other use cases can readily be analyzed to predict service with high reception probability using the Progira Plan software.

DESIGNING REAL ANTENNAS FOR AN SFN NETWORK

Referring to Figure 8 and the understanding of the current, and proposed, DTS rules which impose hard limits on the signal strengths, it is apparent that many antenna patterns will need to be highly directional with high front to back ratios. The most common practices to produce high front to back ratios in broadcast antennas are implementing directional panels or using large fins, directors or back planes on slotted coaxial pylon antennas.

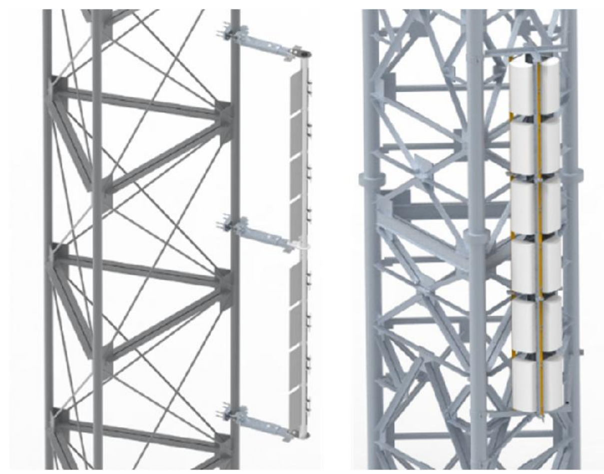

Figure 15: Typical directional broadcast antennas.

The disadvantage of slotted coaxial pylon antennas with large fins or directors is bandwidth. A slot radiator is inherently narrow band and thus has limited channel range. Panel antennas on the other hand are broadband and would be a better choice for co-located shared SFN sites. One disadvantage of panel antennas is they exhibit a much higher wind-load than a pylon antenna. Another choice, which has been the basis of the SFN antenna designs in the San Francisco Bay area, is a special slot cavity wide-band (WB) antenna. The WB antenna was introduced in 2015 and has been widely used as an auxiliary and transitional antenna during repack. Slot cavity WB's are basically a cross between a panel and a slotted coaxial design, providing panel bandwidth in a pylon package. The basic building block of the WB is a waveguide slot cavity radiator that provides true wideband performance. The slot cavity radiator can be viewed as a broadband coax to waveguide transition. The outer conductor of the coaxial line is terminated at the waveguide wall while the inner conductor simply extends into the cavity parallel to the guide's electric field lines and forms a probe antenna which radiates from the waveguide. Groups of 4 or 8 cavities are fed in a simplified corporate feed structure which maintains pattern stability over the operating bandwidth. A parasitic dipole above each slot is used to add vertical component for elliptical polarization. The design is simple and rugged and exceed the requirements necessary for the high voltages associated with the peak to average power ratios of ATSC 3.0, even in multi-channel configurations. To increase the elevation gain, the 4 and 8 bay sections can also be stacked in a vertical array with each bay fed by an external power divider.

Figure 16: Slot cavity WB antenna.

SLOT CAVITY WB ANTENNA WITH HIGH FRONT TO BACK RATIO

The method used to produce the high front to back ratios without the need of large directors or fins is to axially offset WB antenna bay sections. From basic array factor theory, a simple equation can be derived for calculating the azimuth pattern for the special case of two offset antenna bays. Equation (1) can be used to calculate the total array pattern when using antenna bay offset and a phase differential between the bays.

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

Where:

P(θ) = Bay element pattern $\quad k = \frac{2\pi}{\lambda}$

θ = Azimuth angle $\quad$ d = Antenna bay offset

α = Phase differential between antenna bays

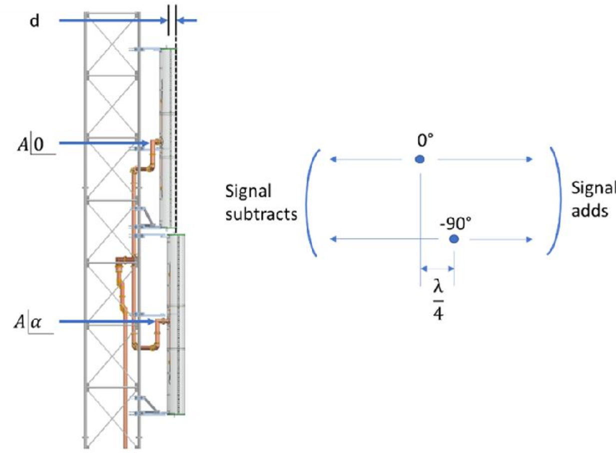

Figure 17: The use of offset WB sections to create a high front to back ratio azimuth pattern.

The offset technique allows for full optimization of the antennas back lobe level. By simply changing the offset distance (d) between 0 and λ/4 and the phase relationship between sections (α) between 0° and -90°, the front to back ratio is fully controlled as shown in figure 18.

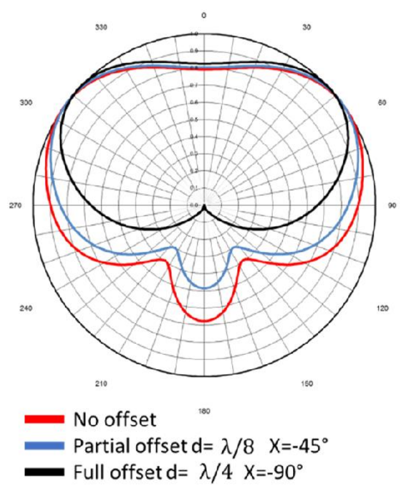

Figure 18: Azimuth patterns of offset WB sections. Varying the offset and feed phase controls the level of front to back ratio.

Since the technique is used on directional antennas and the direction of interest is the same direction as the offset, the elevation pattern is optimized in that same direction. Even though the elevation pattern is not as important in other directions, to fully understand the pattern characteristics using offset, a complete 3-dimensional radiation pattern must be analyzed.

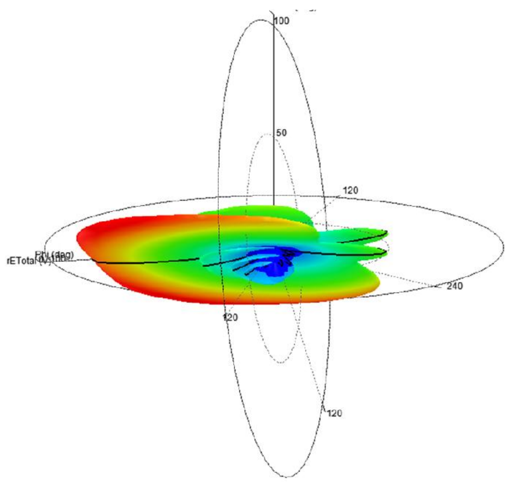

Figure 19: Full 3-dimensional radiation pattern of two 8-layer WB sections using full λ/4 offset and 90-degree phasing.

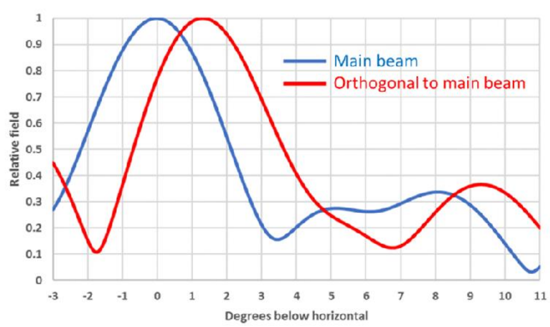

Figure 20: The elevation pattern difference between the direction of offset and orthogonal to the direction of offset.

As is seen the total beam tilt variation in this case is 1.3 degrees around the azimuths of interest. Along with the simplicity and low windload, another advantage of using this technique is future proofing. If future FCC rulings do allow for contour expansion outside of the current DTS rules, the offsets and phasing can be field adjusted to accommodate new coverage areas.

RE-ANALYZING THE SFN NETWORK USING REAL ANTENNA DESIGNS

The final step in the full SFN analysis is to replace the theoretical azimuth patterns with real antenna designs. All the designs are WB antennas with some taking advantage of the bay offset technique described earlier. Figure 21 details the overlaid real antenna patterns relative to the best fit theoretical patterns used for analysis to this point.

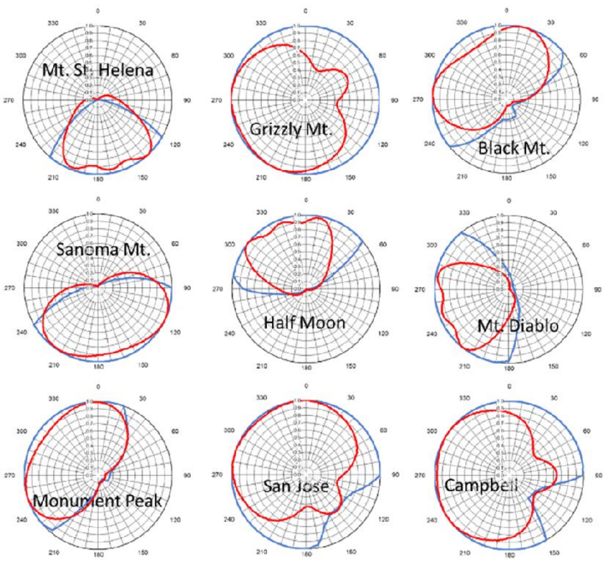

Figure 21: Real WB antenna patterns overlaid on the theoretically generated patterns. Blue – theoretical. Red – real.

Note that in some cases, the ERP had to be reduced again to remain within the theoretical pattern footprint. The populations served using real antenna designs in the SFN are as follows:

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

As can be seen from the data comparison between the software produced theoretical azimuth patterns and the real antenna patterns, that with careful antenna design, a minimal loss of only 4.5% of the population served was observed for KBCW and 2.9% for KICU.

POLARIZATION

The channel characteristics are not the same for transmitted horizontal polarization (HPOL) and transmitted elliptically polarized signals (EPOL). This can be explained by understanding that elliptical polarization helps mitigate the effects of small scale, fast fading which is present both indoors and outdoors at handheld receiver heights. Testing has confirmed that transmitting elliptical polarization to a linearly polarized receiver in motion in a heavy scatter environment provides 5 to 7 dB of margin improvement (MI) over transmitting a linearly polarized signal to the same receiver [6]. This improvement is directly proportional to an increase in the carrier to noise ratio.

$$MI = SNR_{cp} - SNR_{linear} \quad (2)$$

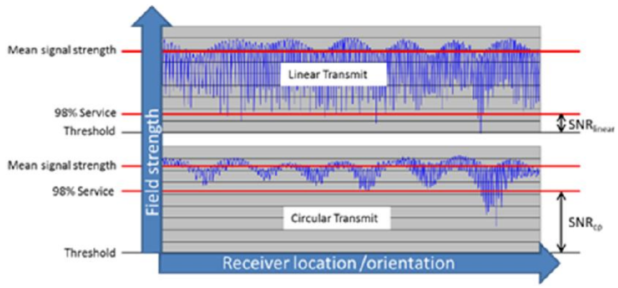

Figure 22: Defining margin improvement (MI).

For a land receiving mobile antenna location, the field strength E, which will be exceeded for q% of the locations is given by equation (3) [7]:

$$E(q) = E(median) + Q_i\left(\frac{q}{100}\right)\sigma_L(f)\ dB\left(\frac{uV}{m}\right) \quad (3)$$

Where $Q_i(x)$ is the inverse complementary cumulative normal distribution as a function of probability and σ_L is the standard deviation of the Gaussian distribution of the local means in the study area.

$$\sigma_L = K + 1.3\log(f)\ (dB) \quad (4)$$

K=1.2 for receivers with antennas below clutter height in urban environments for mobile systems. The frequency (f) is in MHz and the estimated values for $Q_i(x)$ can be found in reference [7]. An estimate relating the E-field correction factor in dB to the q% of locations is given by equation (5) and graphed in figure 23.

$$L_{cf}(q\%) = 170.4 - 1047.8q\% + 2351.7q\%^2 - 2288.6q\%^3 + 826.2q\%^4\ (dB) \quad (5)$$

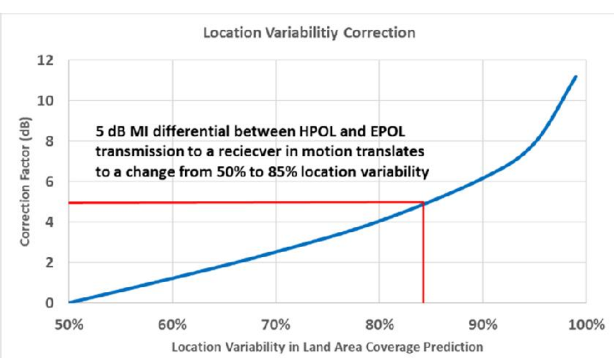

Figure 23: Location variability in land area coverage prediction vs. E field correction factor.

To help quantify the benefits of transmitting elliptical polarization over linear polarization to a linearly polarized receiver in motion in a high scatter environment, a service population case study can be performed. As can be seen in figure 23, a 5 dB differential between using HPOL and EPOL transmission can be analyzed by studying a comparison between reception probabilities of F(50,90) and F(85,90). In doing so, population predictions show a typical difference of approximately 30% to 40% between EPOL and HPOL transmission in an ATSC 3.0 SFN network for the described mobile usage case. This can be interpreted as saying approximately 35% more people will have access to reliable mobile service in harsh conditions with the use of elliptical polarization transmission.

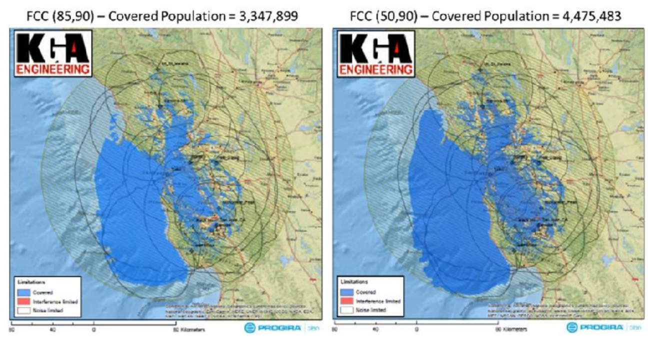

Figure 24: Example of populations covered by HPOL and EPOL transmission in a harsh mobile environment condition.

THE USE OF FUTURE FILL

When switching to the Future Fill mode, the peak gain is lowered due to the increased null fill. The reduction is typically on the order of 1.5dB. It must be noted that the required ERP reductions of the main antennas in order to meet adjacent channel and co-channel interference compliance will typically be more than the Future Fill gain reduction. Since we can assume the station will have plenty of transmitter power left over at the main antenna site after joining the ATSC 3.0 SFN, the station can easily come back up to full compliance ERP after switching to the Future Fill mode. For example, if KBCW's main antenna were to switch to Future Fill mode, they would experience a 1.4dB reduction in peak gain. Since their ERP had to be reduced 7dB in order to meet interference compliance, the transmitter power can easily be brought back up 1.4dB in order to remain at 200kW ERP. At the same time, the null structure in the Future Fill mode provides a 6 dB increase in signal strength close in to the antenna. Effectively, the close in areas are now back to their full compliant ERP from the main stick as shown in Figure 26. This in effect tends to recover some high signal strength areas which may have been lost to the forced ERP reduction.

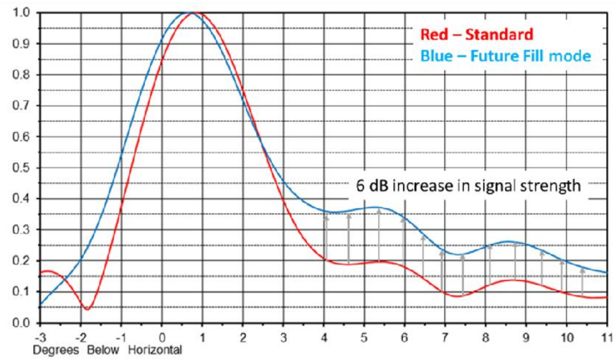

Figure 25: KBCW's standard elevation pattern and Future Fill mode.

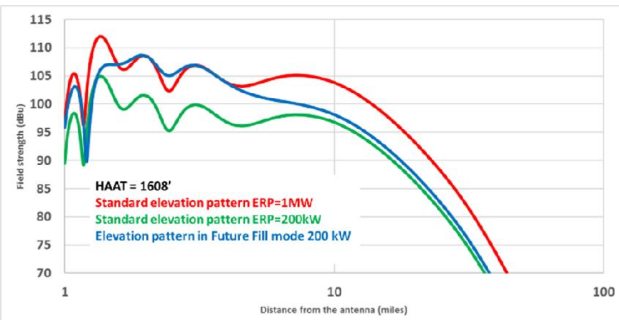

Figure 26: KBCW signal strength vs. distance from the antenna. Comparison of current operation, reduced ERP to meet the contour limit with the addition of an SFN and switching to Future Fill mode with SFN's.

Future Fill may not add much in terms of population gain at lower signal strength services but is very effective when considering any type of service that may require a high bit rate to a deep indoor mobile receiver. Using the San Francisco Bay SFN model, an analysis is performed based on populations served by different signal strength levels at 30' above ground. Figure 27 is an example of the effectiveness of Future Fill when high signal strengths are desired.

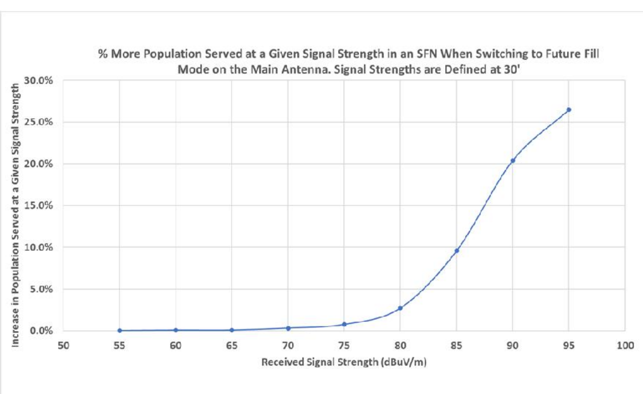

Figure 27: The percentage of population increase at a given signal strength if KBCW switched to their future fill mode.

For consistency, the population gains for the service conditions listed in Figure 2 are as follows:

KBCW w/SFN Real Patterns +FF	5,095,096
KICU w/SFN Real Patterns +FF	5,156,450

Note the gains are small for the Future Fill mode for this type of use case. The real benefit could be in the enhanced provision of more data intensive services in areas closer to the main antenna.

SUMMARY

A summary of results derived in this paper, using current DTS rules, based on the ATSC 3.0 parameters listed in Figure 2 is now given. Figure 28 is a summary of the population served with high probability, using a handheld device and high data rate, for both KBCW and KICU. Compared to the baseline, which is described as the stations doing nothing but switching over to ATSC 3.0 with their current infrastructure, are the scenarios of joining the designed SFN and switching to a Future Fill mode. Also, a comparison between the theoretically designed SFN vs. using real antenna designs is given.

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 w/SFN Real Patterns +FF	5,095,096	31.1%
KBCW overall pop gain	1,584,159	
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 w/SFN Real Patterns +FF	5,156,450	25.4%
KICU overall pop gain	1,309,368	

Figure 28: Population summary.

The effectiveness of the preliminary SFN design in the San Francisco Bay Area is now clear. For the basic usage case outlined and analyzed in this paper, a significant population increase can be expected for a station joining the SFN when compared to remaining only on their main stick.

DTS NPRM IMPACT

As noted throughout this paper, the current DTS rules have been used to design and analyze a Single Frequency Network for the San Francisco Bay Area. The results are very encouraging. However, the current DTS rules are considered to place unnecessary restraints on the SFN designer and a DTS Notice of Proposed Rule Making (NPRM) is currently under consideration. The key amendment of the NPRM is that the service area now permits extension of coverage beyond the station's authorized service area as long as the FCC (50/10) interference contour of any DTS station does not extend beyond that of its reference facility. As illustrated in Figure 29, in practical terms this provides the SFN designer greater flexibility in choosing SFN sites (also called nodes) closer to the boundary of the original service area. It is possible that the study described in this paper would yield even more favorable results under the constraints of the NPRM. Further studies will be required once the Rule Making is finalized to confirm this increased flexibility in a variety of different markets.

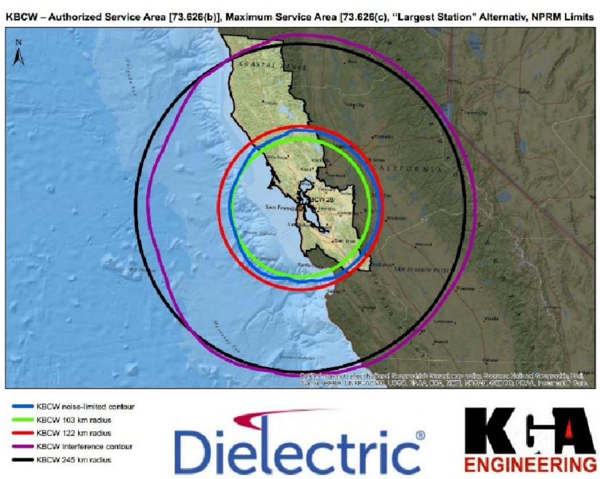

Figure 29: NPRM Service area and Interference area for KBCW compared to current DTS limits.

CONCLUSIONS

The plan that is in place to provide Next Generation coverage in the San Francisco Bay Area will bring new and creative services. It will be the beginning of a robust and flexible nationwide media delivery platform for terrestrial broadcasters. It is clear that ATSC 3.0 will re-define the SFN design process. By planning ahead and through the use of innovative antenna design as well as advanced SFN planning tools, requirements for new services can be achieved. The combination of elliptical polarization, activating the Future Fill mode on the stations main stick and the use of antenna bay offset optimizes the SFN network for best performance. The current DTS NPRM will definitely impact the SFN planning process favorably in many markets but, in the case of San Francisco, the availability of suitable tower sites and interference constraints will likely still dominate the design.

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[7] ITU-R P.1546-5 Method for point to area predictions for terrestrial services in the frequency range 30MHz to 3000 MHz