ATSC (NEXTGEN TV) SFN APPLICATION

ATSC 3.0 (NEXTGEN TV) SFN GENERAL INFORMATION, TIMING & SYNCHRONIZATION, COVERAGE PLANNING AND SELF-INTERFERENCE, GAP FILLERS APPLICATIONS AND CONSIDERATIONS.

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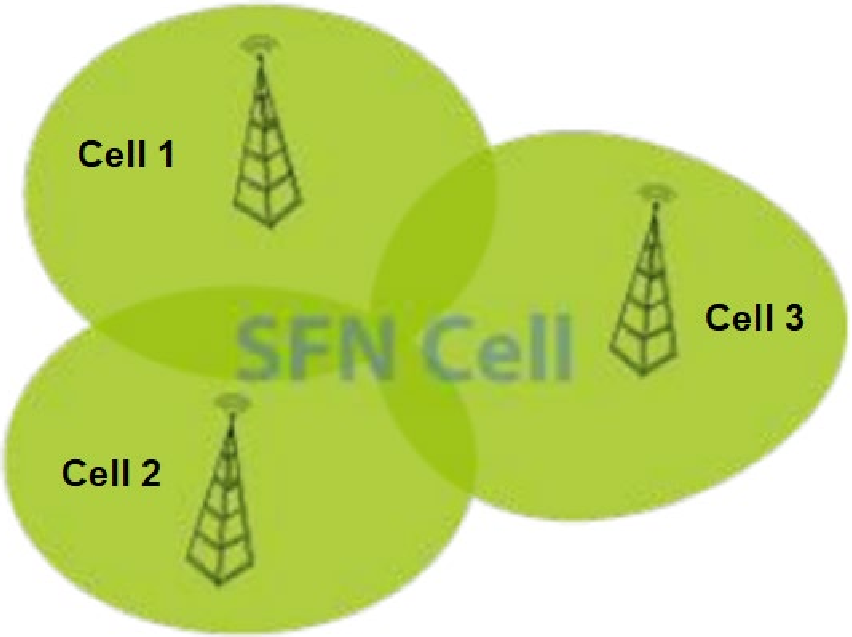
TV Systems Applications Engineer

PRESENTATION AGENDA



- Single Frequency Network (SFN)

ATSC 3.0 (NextGen TV)

- SFN Timing / Synchronization
- SFN Coverage (Self Interference)
- On channel (SFN) Gap Filler Application
- ATSC 3.0 SFN FLOW

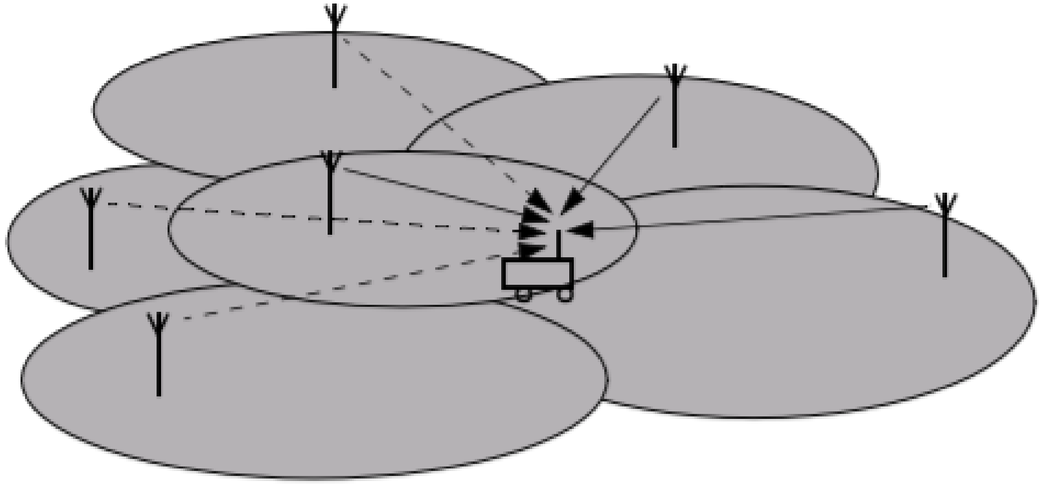
SINGLE FREQUENCY NETWORKS

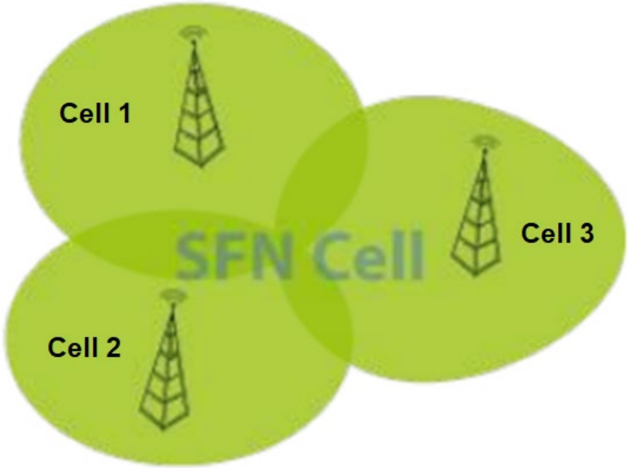
SINGLE FREQUENCY NETWORKS

Key Factors of an SFN:

- All the transmitters are broadcasting the same information, same signal / bits.
- All the transmitters are broadcasting at the same time
- All the transmitters are broadcasting on the same frequency or channel

Note: An SFN can be used for targeted sales commercials or information services, but during that time there could be increased interference areas.

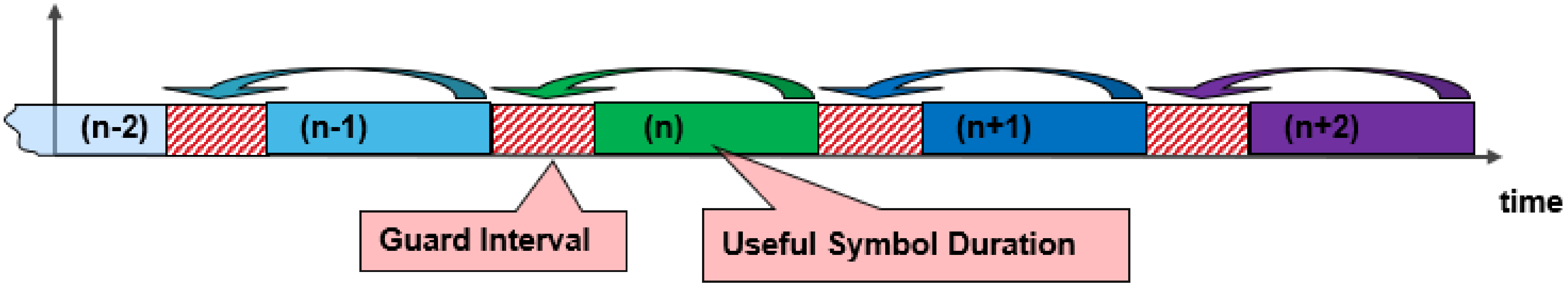




ATSC 3.0 (NEXTGEN TV) / COFDM SINGLE FREQUENCY NETWORKS

Single frequency networks (SFN) provide coverage over a specific geographical area. The size of the area can vary significantly – could be as large as an entire country or as small as a single town, typically there are three categories of SFN coverage areas: national, regional and local areas.

Single frequency networks utilizing COFDM (Coded orthogonal frequency division multiplex) modulations like; DVB-T, DVB-T2, ISDB-T, DTMB and ATSC 3.0 avoid harmful interference caused by multipath reception, using a guard interval.



GATESAIR SINGLE FREQUENCY NETWORKS

BENEFITS OF ATSC NEXTGEN SFN

The Benefits of using an ATSC 3.0 SFN:

Frequency Efficiency – One channel for large coverage area.

Fill in small areas that are signal holes (dead zones)

Network Flexibility – Hybrid networks SFN / MFN, allows for network planning flexibility, progressively adding or changing the network to meet new needs or coverage requirements. .

Signal - Higher Receive signal strength, receivers making use of signals from multiple transmitters, this helps improve indoor coverage.

LIMITATIONS OF ATSC NEXTGEN SFN

Limitations using an ATSC 3.0 SFN:

Signals received outside the Guard interval cause self interference within the network. Signals from distant SFN sites due to abnormal propagation (Multipaths) can cause interference.

Limitations on bit rate due to size of the SFN or the distance between SFN transmitting sites (large guard intervals), separation between transmitter sites limited by the guard interval.

SINGLE FREQUENCY NETWORKS

Calculating the Maximum Distance between Sites in an SFN for ATSC 3.0 using the 2 charts and the formulas below:

Sample Rate Post-Bootstrap (SRPB) = **(*N*+16)×0.384 MHz**
For 6MHz Bandwidth - bsr_Coefficient (N) = 2 (as listed below)
(2 + 16) * 0.384 = **6.912 MHz (SRPB)**

Guard interval sample rate (Gisr) * (1 / (SRPB)*10^6) = Guard interval in microseconds
1536 * (1 / 6.912MHz * 10^6) = 1536 * (1 / 6912000)= **222.2µs (Giµs)**

Guard Interval * Velocity of Light (Vo) = The distance in km
222.2µs * (300*10e3) = .0002222 * 300000 = **66.6 km (41.4 Miles)**

Example Parameters:
ATSC 3.0 (6MHz bandwidth)
64-QAM
16k Mode
Occupied Bandwidth: 5.83Mhz
Guard Interval : GI 6_1536

Charts are from: ATSC Standard: Physical Layer Protocol (A/322)

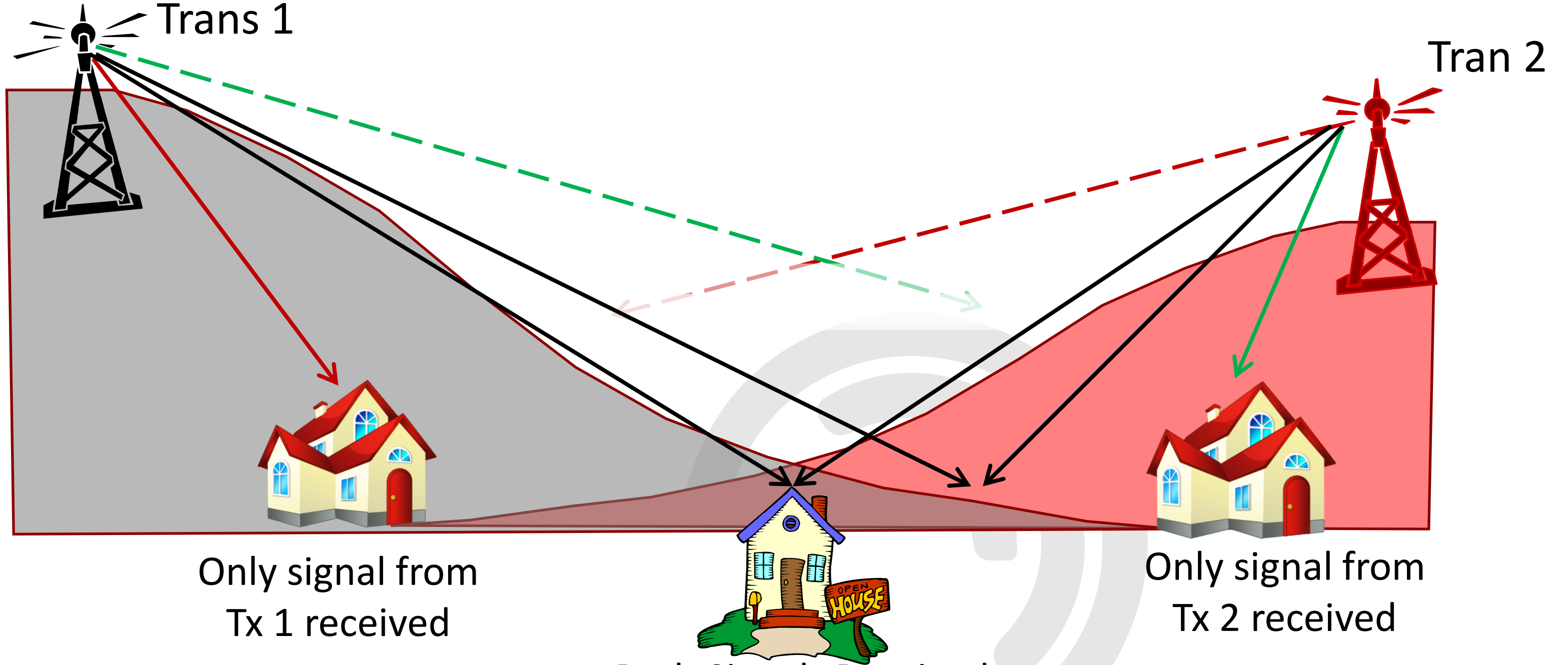
C_{red_coeff}	Number of Carriers (NoC)			Occupied Bandwidth		
	8K FFT	16K FFT	32K FFT	bsr_coefficient = 2	bsr_coefficient = 5	bsr_coefficient = 8
0	6913	13825	27649	5.832844	6.804984	7.777125
1	6817	13633	27265	5.751844	6.710484	7.669125
2	6721	13441	26881	5.670844	6.615984	7.561125
3	6625	13249	26497	5.589844	6.521484	7.453125
4	6529	13057	26113	5.508844	6.426984	7.345125

GI Pattern	Duration in Samples	8K FFT	16K FFT	32K FFT
GI1_192	192	✔	✔	✔
GI2_384	384	✔	✔	✔
GI3_512	512	✔	✔	✔
GI4_768	768	✔	✔	✔
GI5_1024	1024	✔	✔	✔
GI6_1536	1536	✔	✔	✔
GI7_2048	2048	✔	✔	✔
GI8_2432	2432	*N/A*	✔	✔
GI9_3072	3072	*N/A*	✔	✔
GI10_3648	3648	*N/A*	✔	✔
GI11_4096	4096	*N/A*	✔	✔
GI12_4864	4864	*N/A*	*N/A*	✔

SINGLE FREQUENCY NETWORK TIMING / SYNCHRONIZATION

TIMING / SYNCHRONIZATION

Transmitters in an SFN all work together.
The data transmitted should be Identical, and transmitted at the same time, so synchronization of them must be precisely controlled.
Time synchronization increases in complexity with the number of transmitters with an SFN.



TIMING / SYNCHRONIZATION

Transmitters in an SFN must be time synchronized.
The most common way of synchronizing all the transmitters is by GPS (Global Positioning System) anther method is PTP (Precision Time Protocol).

The use of a timing reference (GPS, PTP) to compensate for the network distribution and to synchronize each transmitter output time in a network is called **Delay Compensation**. A timing reference is also used to frequency lock each transmitter in an SFN for frequency stabilization.

Additional delay compensation can be added or removed in the transmitters systems where the modulators have different processing times or different manufactures are used , this is due to differences in modulator (exciter) processing times, or other data delivery latencies in equipment, additional delay is typically called **Static Delay Compensation**.

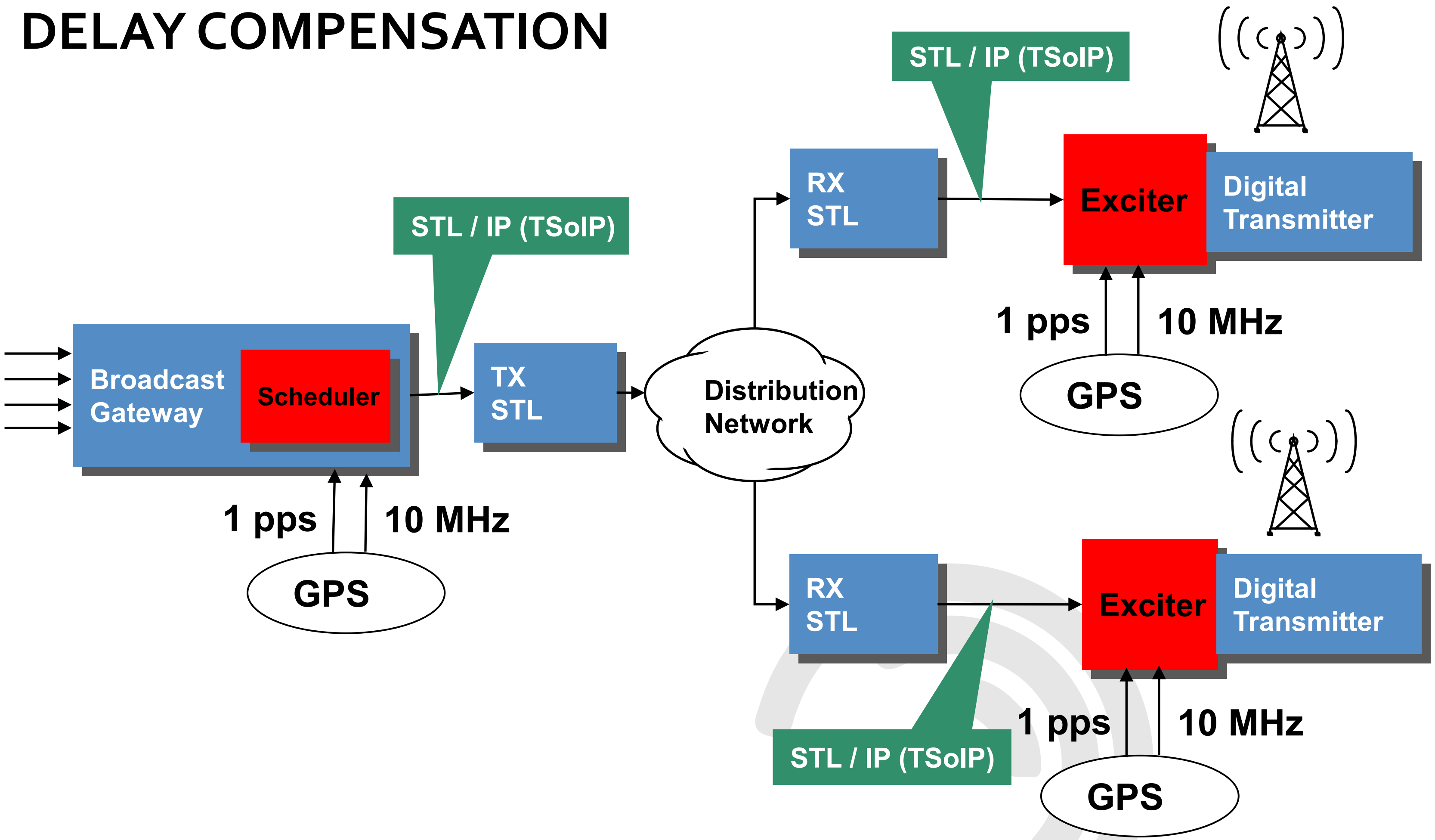
Static Delay Compensation can also be used to increase or delay the time of propagation of a specific site to reduce or move SFN self interference to locations that have no population (example; over water), normally done at the Broadcast Gateway.

In some cases, Delay Compensation and Static Delay Compensation are utilized together especially in large SFN's to maximize service.

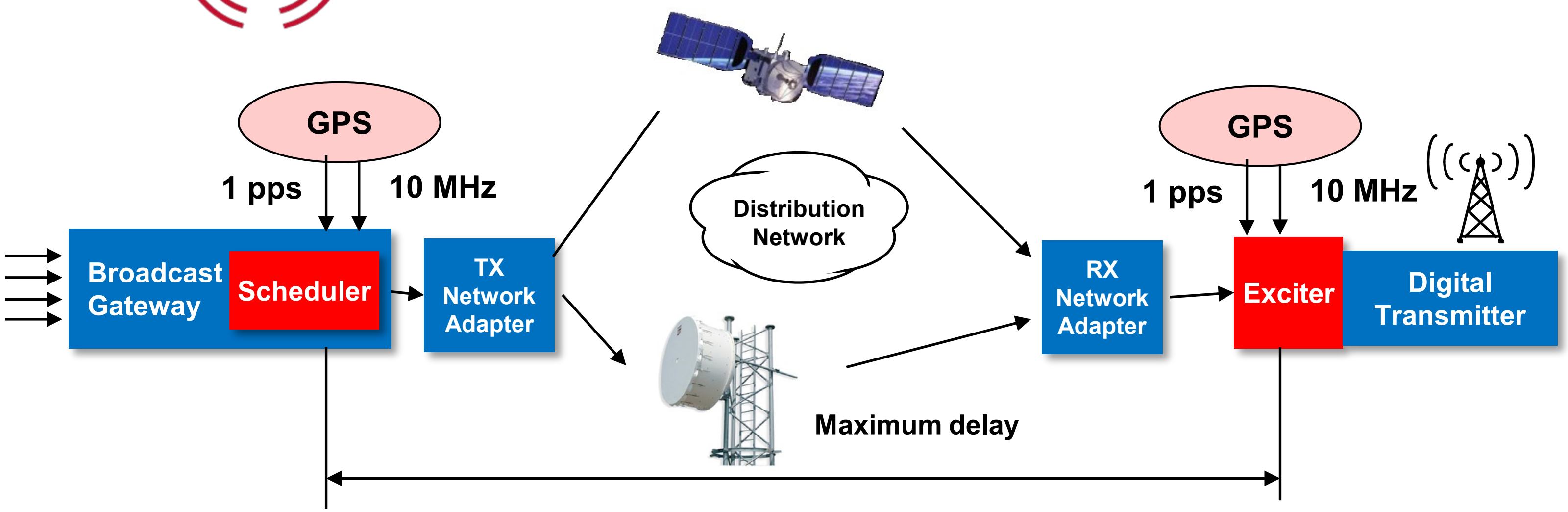
ATSC 3.0 Physical Layer, operates in the International Atomic Time (TAI) domain

TIMING / SYNCHRONIZATION

DELAY COMPENSATION



TIMING / SYNCHRONIZATION



Broadcast Gateway (Scheduler) information required to calculate Bootstrap Reference Emission Times for the Timing & Management Stream Packet (TMP) :

Timing refence: GPS (Global Positioning System) / PTP (Precision Time protocol)

Transmitter ID:

Transmitter Time Offset: (optional) indicates additional +/- delay add to the Transmitter/exciter relative to the Bootstrap Reference Emission Times. (Static Delay) This allows for propagation changes to a specific transmitter ID to enhance network SFN service.

Maximum delay: Maximum delay describes the difference in time between a specific Physical Layer frame leaving the Broadcast Gateway (Schedular) and the corresponding Physical Layer frame available at the Transmitter exciter output of each Transmitter / exciter within the SFN.

The maximum delay is a value adjustable in the Broadcast Gateway (Schedular). The set value must be higher than the longest actual network delay.

TIMING / SYNCHRONIZATION

Broadcast Gateway (Schedular) Timing and Management Generator

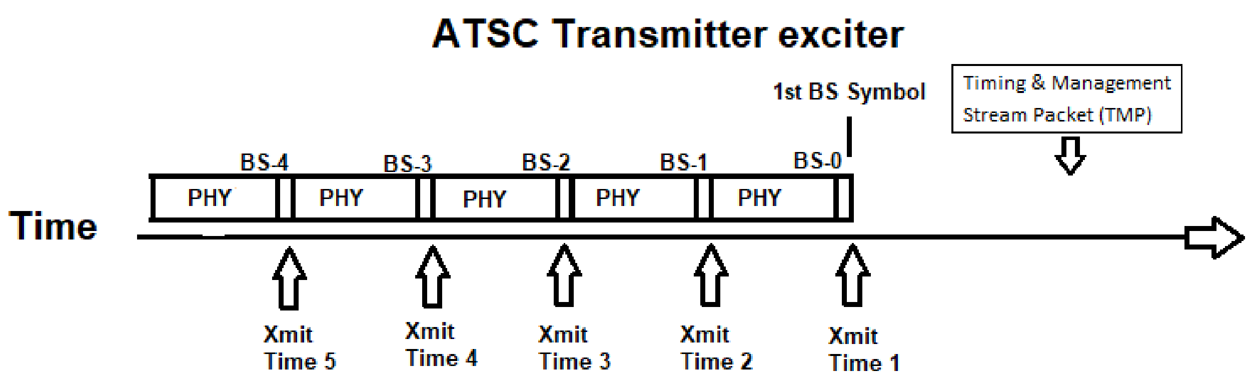
ATSC 3.0 Timing & Management Stream Packet (TMP) from the Schedular SFN synchronization data includes:

xmtr-id

num_emission_tim shall indicate the number of sequential Bootstrap Reference Emission Times that are contained within the Bootstrap_Timing_Data () 'for' loop. Up to 64 values may be indicated (0 thru 63)

Bootstrap_Timing_Data () shall contain a list of the Bootstrap Reference Emission Time – A time value indicating the instant at which the leading edge of the first symbol of a Bootstrap is to be emitted from the Transmitter Antenna.

tx_time_offset shall indicate the emission time offset of the Transmitter to which it is addressed relative to the Bootstrap Reference Emission Times of all frames



Timing and Management Data for each Physical Layer frame must be sent from the Broadcast Gateway - Scheduler and arrive at the transmitter exciter at least one Physical Layer frame in advance of the start of the exciter construction of the Physical Layer frame that it describes.

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SINGLE FREQUENCY NETWORK COVERAGE

COVERAGE/SERVICE PLANNING

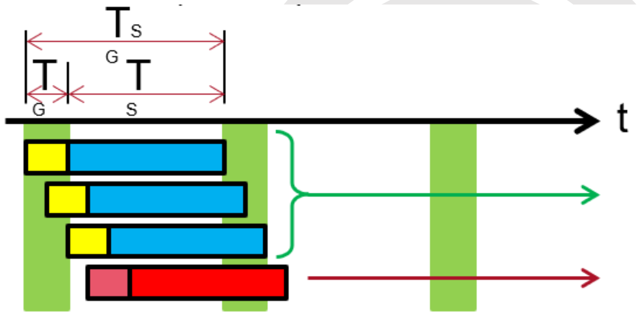
Broadcast Service is a balance of the following parameters:

Transmitter Power – TPO
Transmission Line – Line Losses
Antenna Gain – Lower gain antenna tend to have more Multipaths
Antenna Polarization – Multipaths
Tower Height – HAAT & AHAGL
Modulation Parameters – Data Rate & Guard interval

It is always best to look at TV service from the planning stage of any SFN network.

Self-interference or reflections (multipaths) outside the selected guard interval can be determined before the network is constructed.

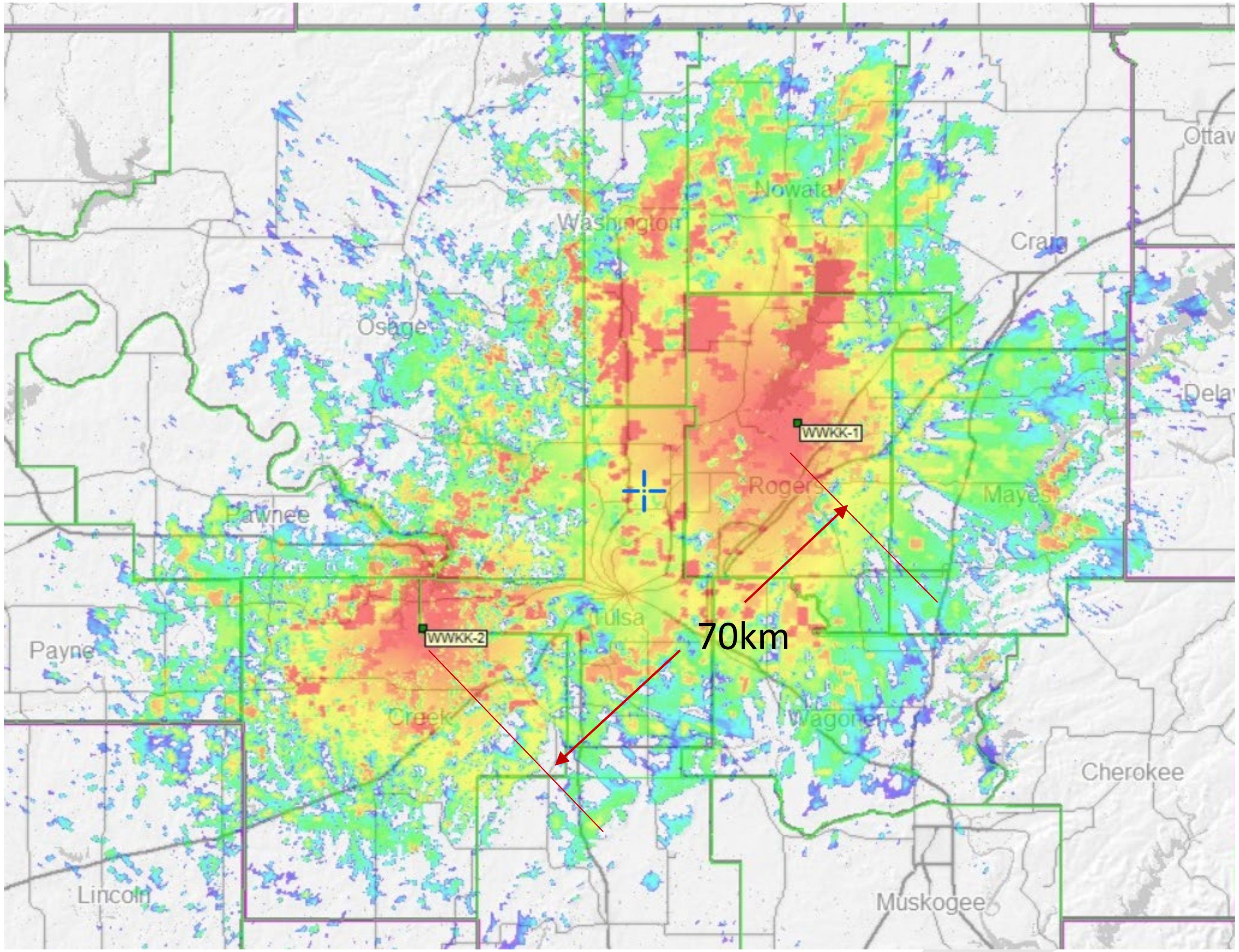
The diagram shows in time: multi path reception when received inside & outside the guard interval



Multi path signals received within the guard interval help the receiver by adding additional signal strength

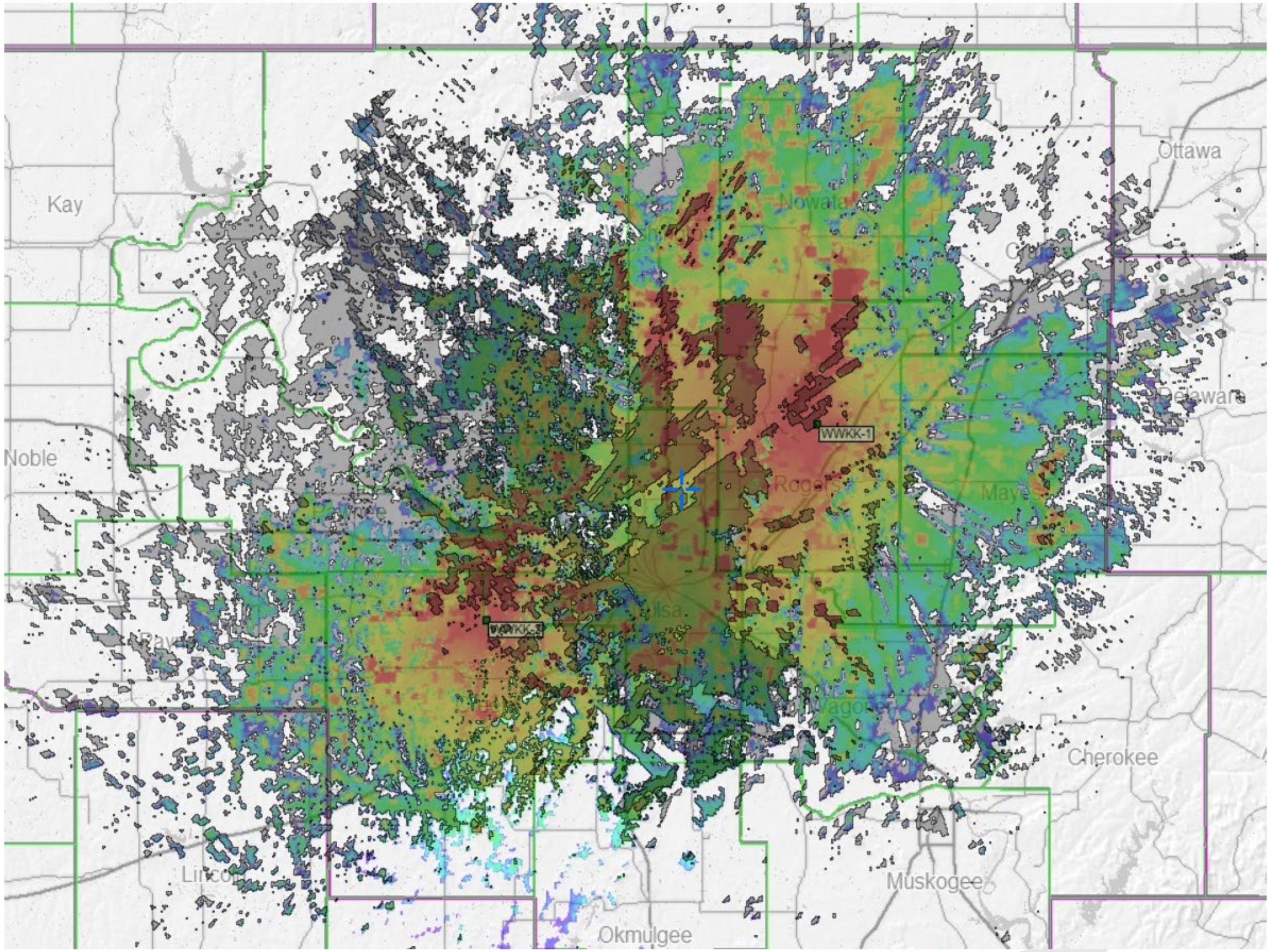
Multi path signals received outside the guard interval are destructive interference.

SFN SERVICE PLANNING MODULATION PARAMETERS



ATSC 3.0
64QAM
10/15 Code Rate
FFT size 16k
Occupied Bandwidth: 5.83Mhz
Guard Interval : GI 6_1536
Guard Interval Time 222.2µs
Maximum distance 66.6km (41.4Miles)

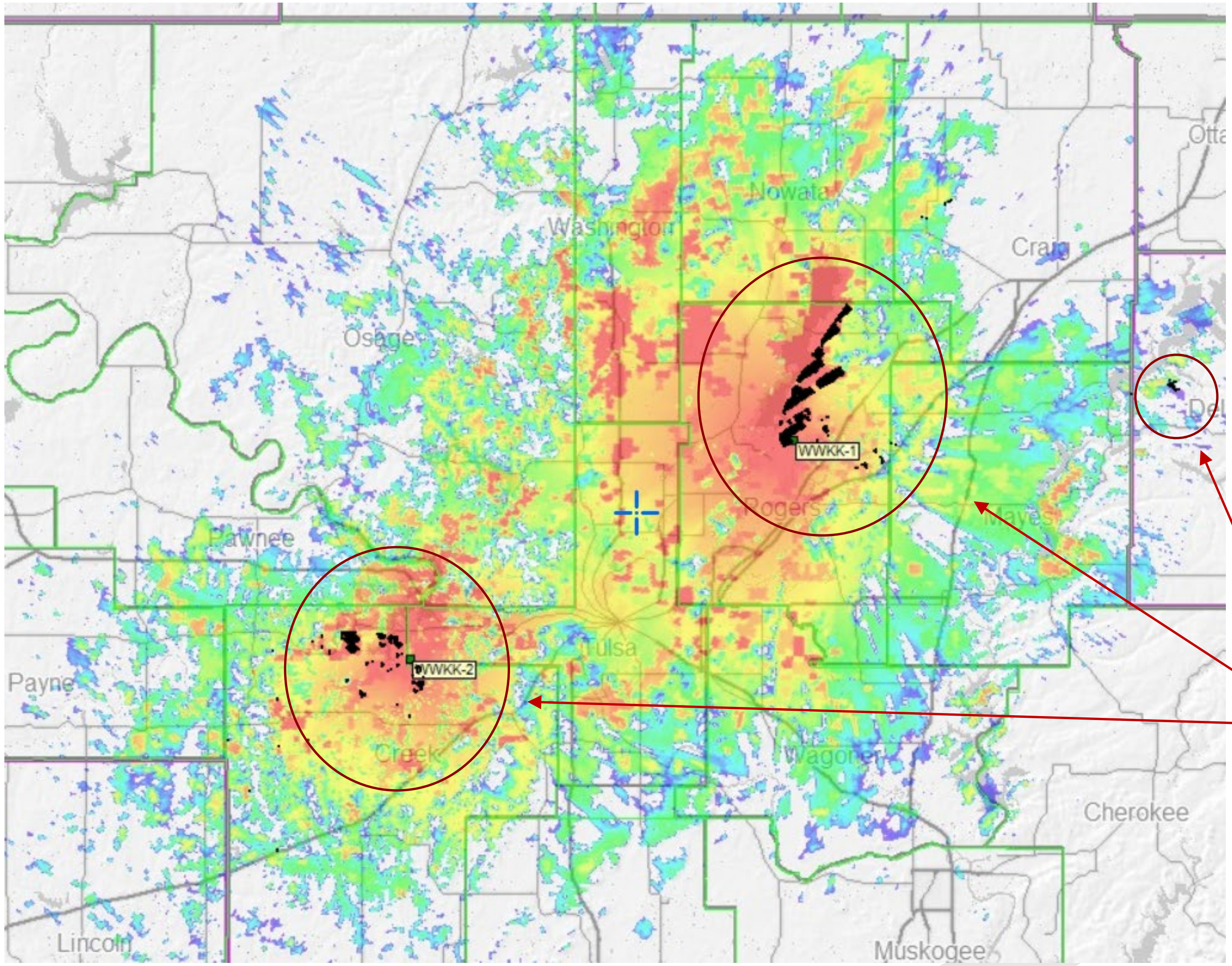
SFN SERVICE PLANNING OVERLAPPING COVERAGE



ATSC 3.0
64QAM
10/15 Code Rate
FFT size 16k
Occupied Bandwidth: 5.83Mhz
Guard Interval : GI 6_1536
Guard Interval Time 222.2µs
Maximum distance 66.6km (41.4Miles)

Adding Signal strength to the locations within the overlap.

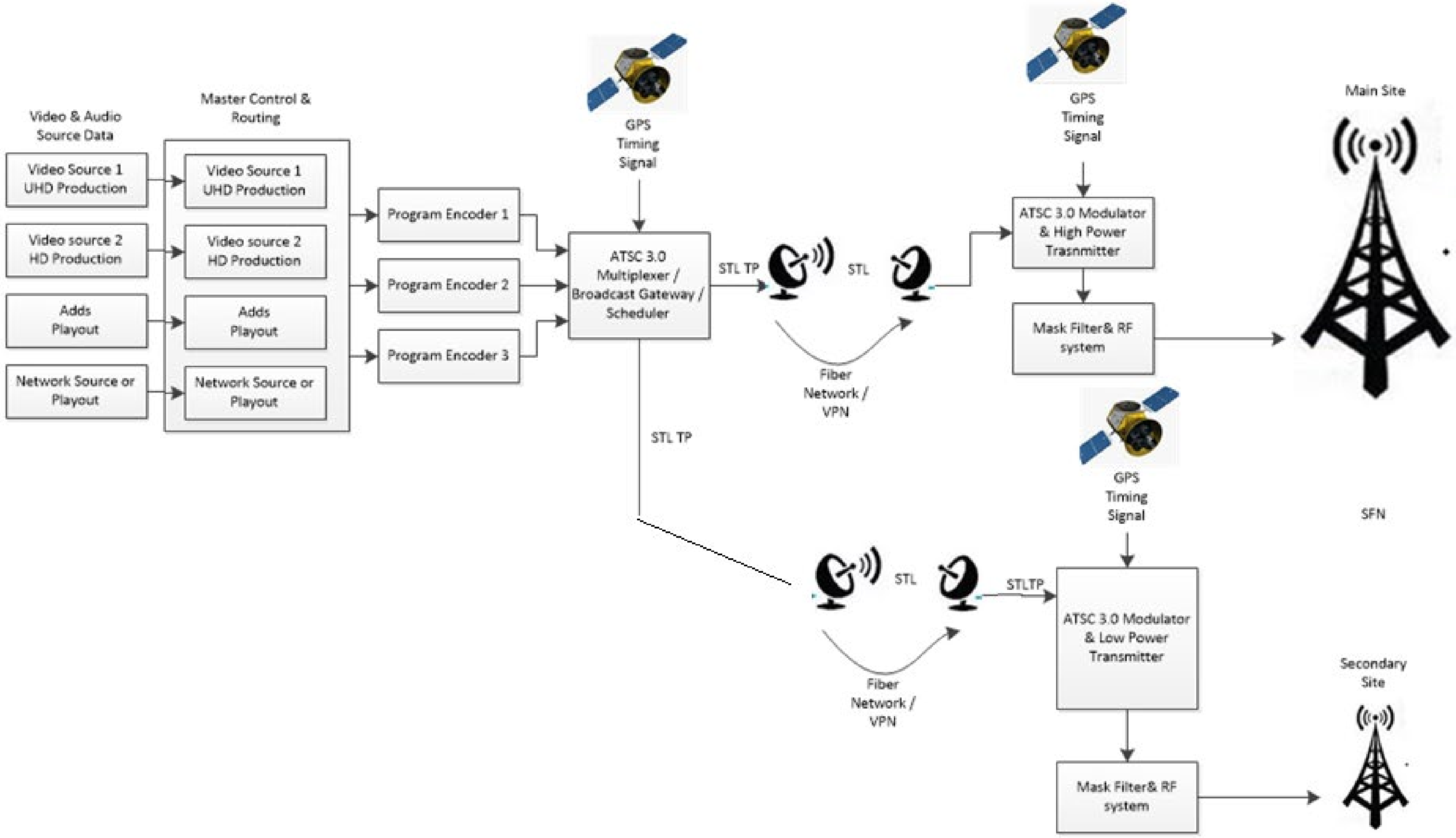
SFN SERVICE PLANNING SELF-INTERFERENCE



ATSC 3.0
64QAM
10/15 Code Rate
FFT size 16k
Occupied Bandwidth: 5.83Mhz
Guard Interval : GI 6_1536
Guard Interval Time: 222.2µs
Maximum distance 66.6km (41.4Miles)

Self-interference cause by Multipath reception, outside the selected Guard interval , This can be resolved by adjusting the Guard interval size or moving transmission sites closer.

STANDARD ATSC 3.0 SFN SIMPLE FLOW DIAGRAM



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ATSC 3.0 SINGLE FREQUENCY NETWORK ON CHANNEL GAP-FILLER APPLICATION

ON CHANNEL GAP-FILLERS

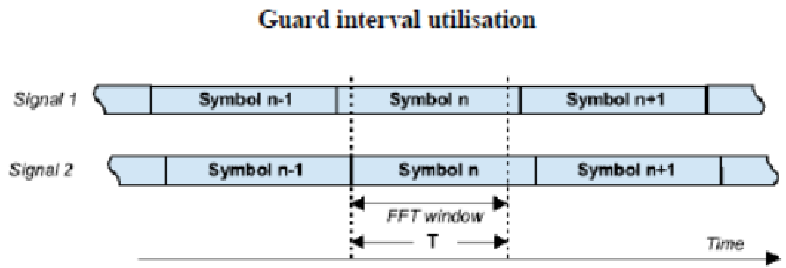
ATSC 3.0 on channel gap-fillers become a great option for filling in areas that have weak or no coverage within a specified coverage area or increasing signal strength in urban areas for better indoor coverage.

The term Gap-filler is normally associated with a transmission system that receives RF in on the same channel as the RF out. On Channel Gap-filler.

We still must keep in mind that Gap-fillers are a single frequency network, even with RF in from a receive antenna, so utilizing a GPS or some other timing reference to lock the transmitter on frequency is important, but not necessarily required for a gap-filler.

There is also additional processing delay that will need to be accounted for as a part of the SFN design.

As with any SFNs we still need to use modulation parameters that allow for any multipath reception to be received within the guard interval.

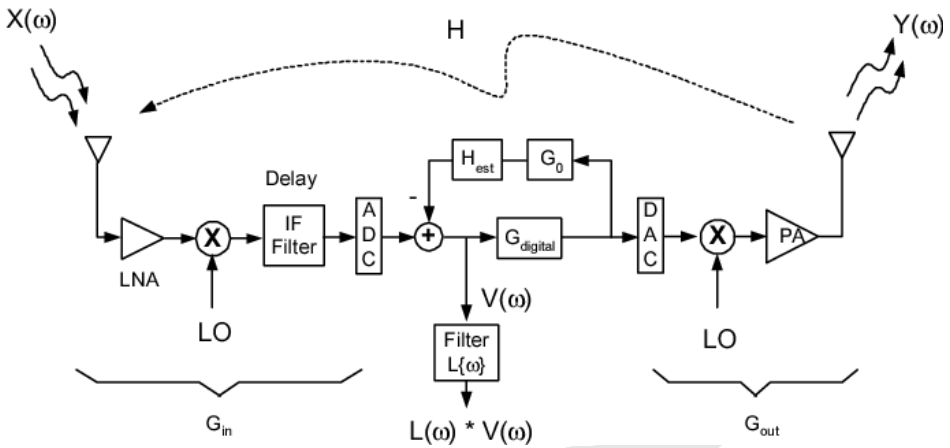


ON CHANNEL GAP-FILLERS

On channel, RF in gap-fillers have an inherent issue, because an RF in gap-filler is transmitting on the same channel it could receive the same signal it is transmitting, causing an Echo effect, which we have all encountered when the microphone is too close to the output speaker.

To help reduce this echo effects gap-fillers employ echo cancellation this involves first recognizing the originally transmitted signal that re-appears, with some delay in the transmitted or received signal.

Once the echo is recognized, it can be removed by subtracting it from the transmitted or received signal.

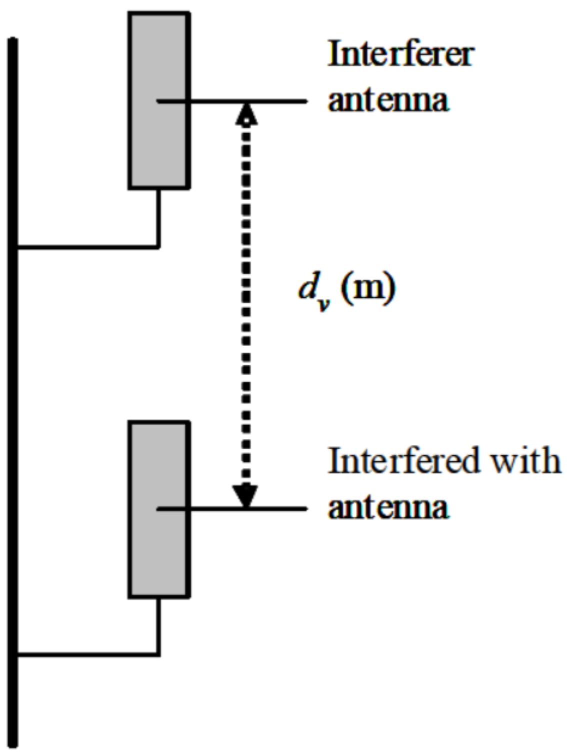


Typical Echo cancelation in a RF broadcast gap-filler/transmitter is approximately 40dB

ON CHANNEL GAP-FILLERS

Another way of helping reduce the Echo effect is space Isolation.
Vertical spacing between the receive antenna and the transmit antenna can add isolation, reducing echoes.

Vertical isolation



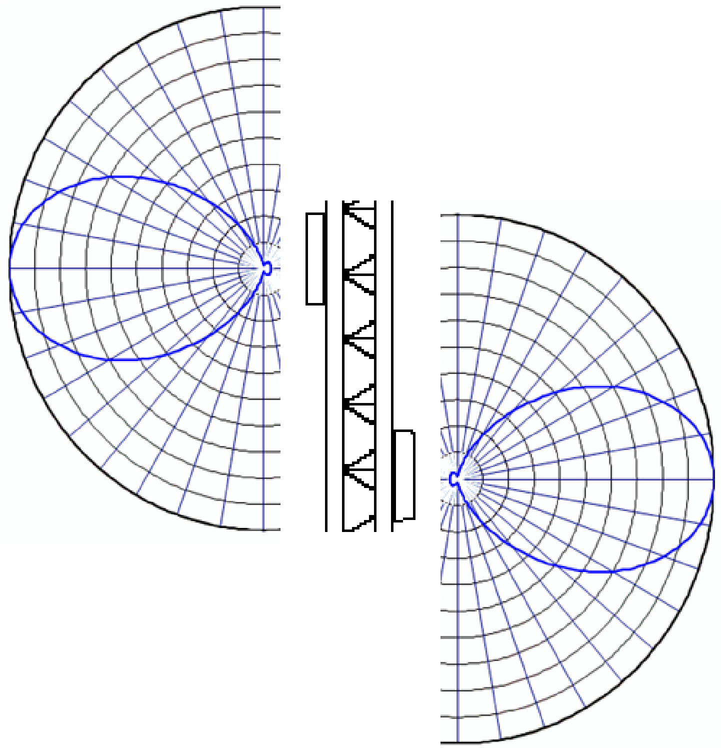
$$Iv[dB]=(28+40)*Log(dv/l)$$

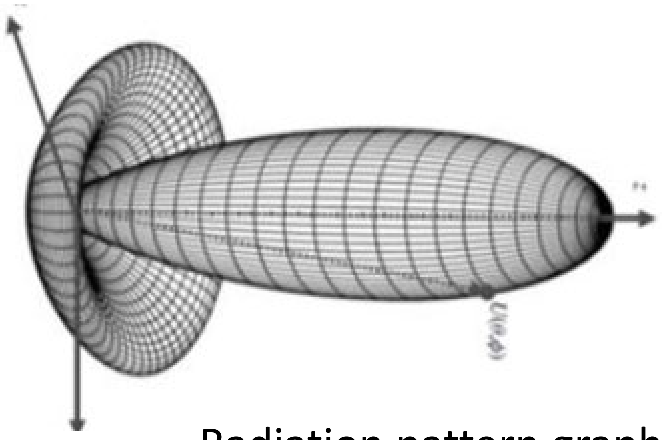
Where:

- I_v[dB]: isolation between vertically separated transmitter and receiver antennas
- d_v[m]: the vertical distance from the interferer antenna to the interfered with receiver antenna, measured from radiation centre-to-radiation centre
- λ [m]: the wavelength of the interfered with system frequency band.

ON CHANNEL GAP-FILLERS

Antenna patters and the use of directional antenna also adds isolation between antenna.
All antenna have back radiation and that small amount of gain on the back potion of a directional antenna should be considered, there are also additional lobes created in the elevation pattern that adds a small amount of gain.

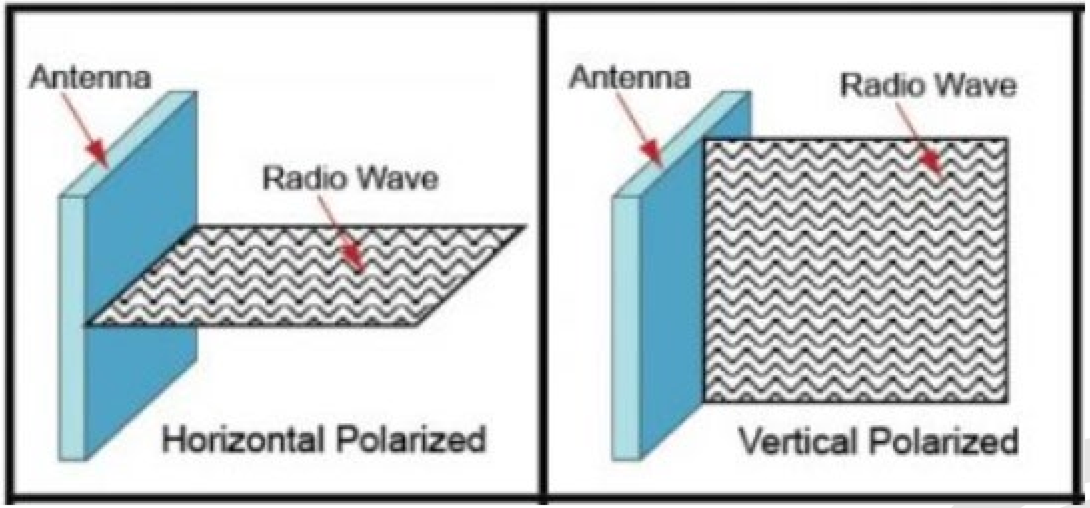




Radiation pattern graphical representation

ON CHANNEL GAP-FILLERS

Antenna polarization is another way of adding additional isolation between the receive antenna and the transmit antenna.

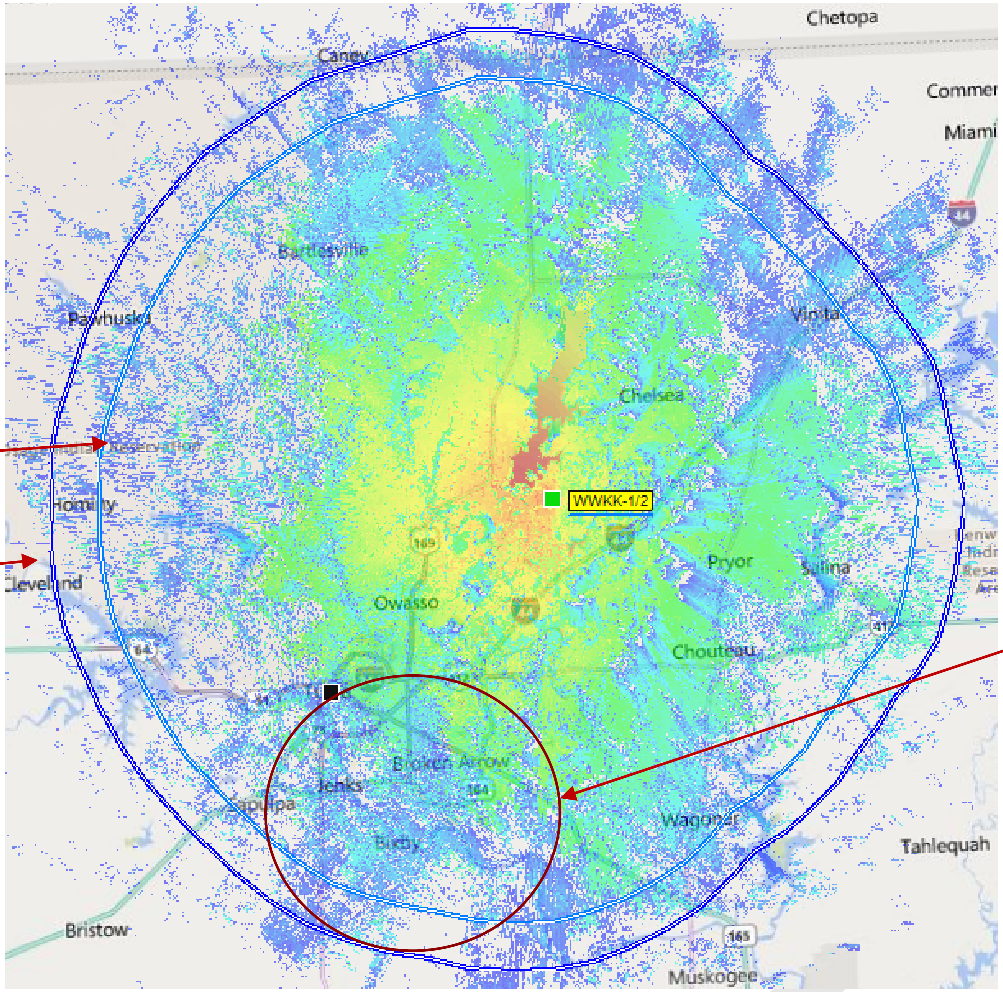


Polarization isolation can be as much as 30dB of isolation between receive and transmit antenna

The two polarizations shown would be considered linear or orthogonal to each other. This allows a given polarization of an antenna to only receive on its intended polarization, isolated from the transmit polarization, thus the receive avoids interference from energy on the transmit polarization antenna. This is the case even if the two linear polarizations are operating within the same frequency.

ON CHANNEL GAP-FILLERS

Coverage: Possible Gap-filler application

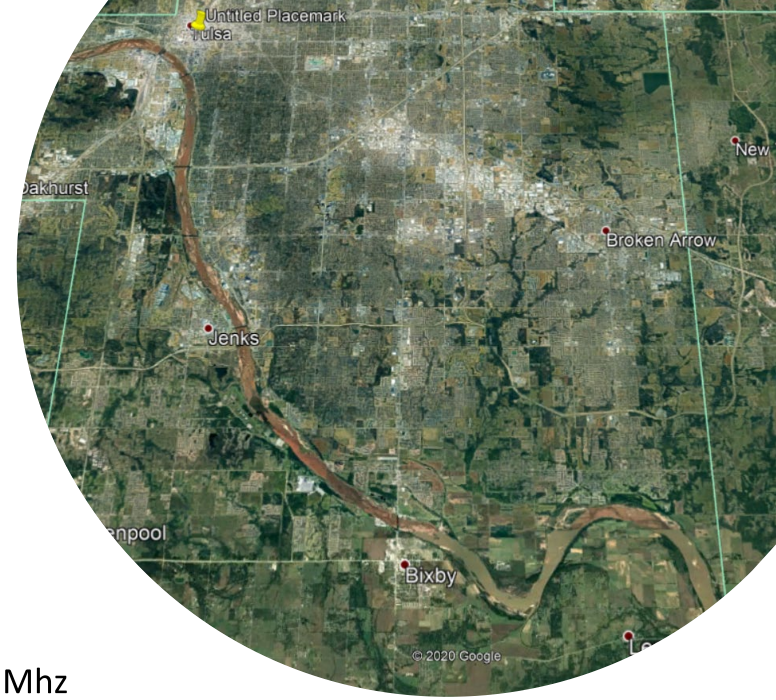


Note: shown are the vertically polarized contour as well as the horizontally polarized contours, this customer has an elliptically polarized main transmit antenna

The area shown in red indicates an area within the customers FCC coverage area that has low spotty signal strength, or a gap in coverage, within a large populated area. This gap in coverage can be terrain or man-made obstructions, or a combination of both.

ON CHANNEL GAP-FILLERS

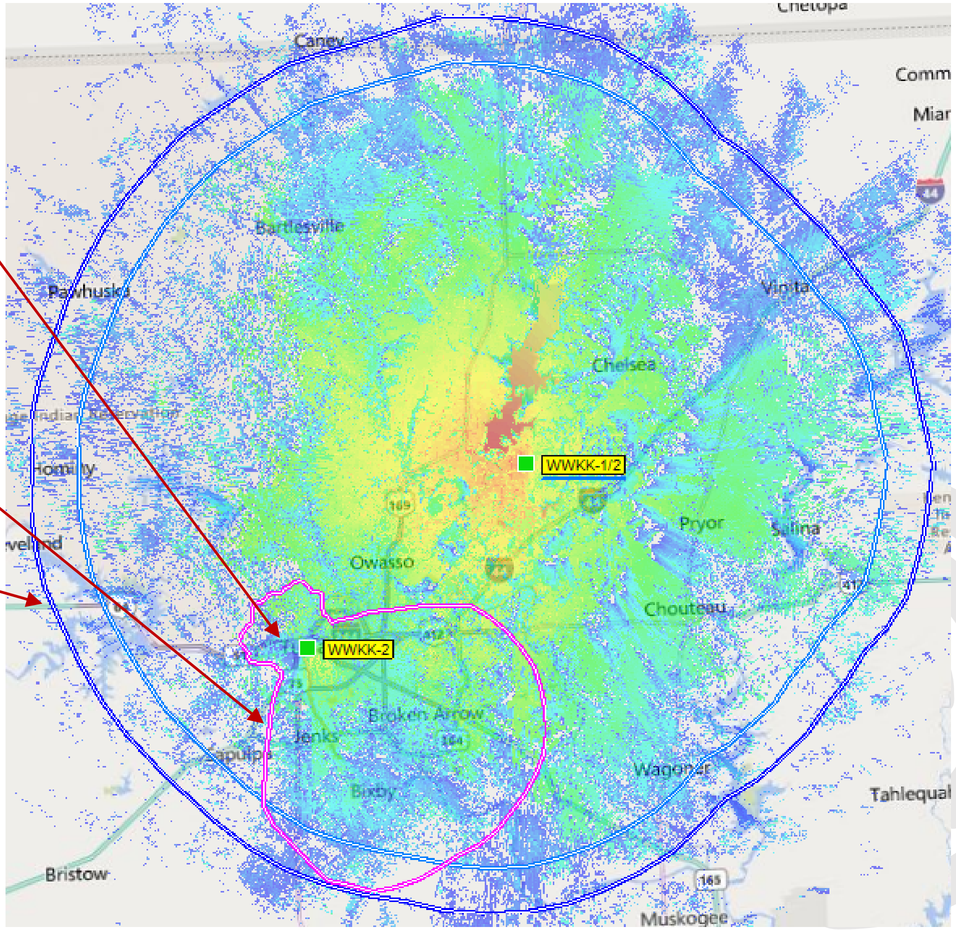
Employing a 125W on channel Gap-filler transmitter with Echo cancelation, space isolation of the receive and transmit antennas, directional receive and transmit gap-filler antenna (9.5dB peak gain), and polarization isolation (Vertically polarized receive antenna Horizontally polarized transmit antenna), the area with no or little coverage can be filled.



Using an existing building in the City 120m height (about 393.7 ft)

Note: the Gap-Filler Horizontal contour stays within the 41dBµV/m licensed contour

DTS rules were changed in January 2021 it is no longer necessary to limit coverage contour

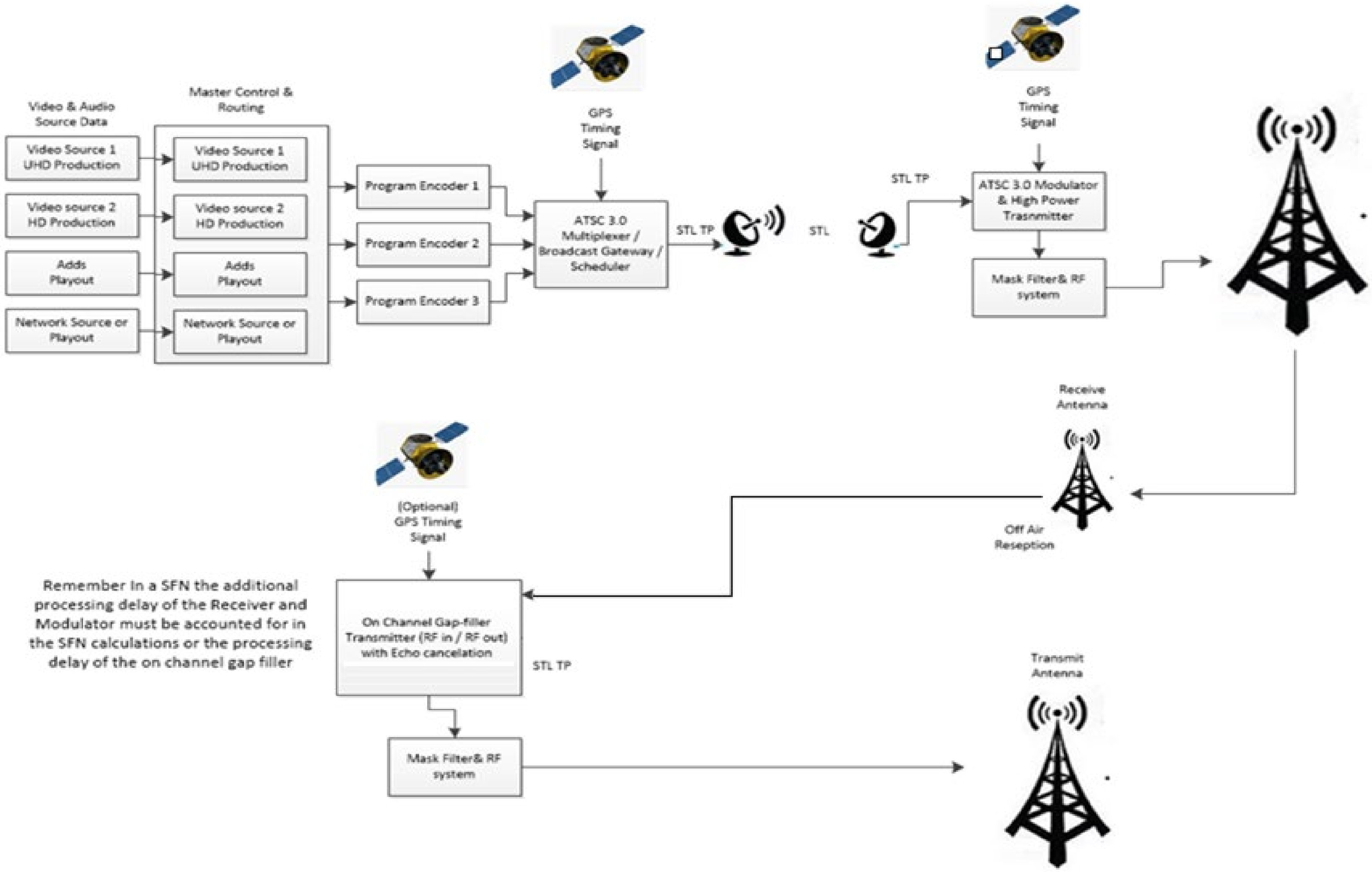


ATSC 3.0 Parameters:
64QAM
10/15 Code Rate
FFT size 16k
Occupied Bandwidth: 5.83Mhz
Guard Interval : GI 6_1536
Guard Interval Time 222.2µs
Maximum distance 66.6km (41.4Miles)

Distance between site 1 (main) & Site 2 (Gap-Filler) 54km (33.5miles)
Gap-Filler Processing delay 10µs
40dB Echo cancellation
-75.6dB of antenna space isolation (30m)
3db gain from directional antenna patterns (1.5 dB receive, 1.5 dB Transmit)
-28dB of Polarization Isolation

-75.6dB+3dB-28dB = -100.6dB + 40dB Echo cancelation = -140.6dB
222.2µs – 10µs Processing delay = 212.2µs*(300*10e3)= 63.66km (39.5miles)

ATSC 3.0 GAP-FILLER SFN FLOW DIAGRAM



Remember In a SFN the additional processing delay of the Receiver and Modulator must be accounted for in the SFN calculations or the processing delay of the on channel gap filler

THANK YOU

Connecting for the Future