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TV NETWORK PLANNING

SFN DESIGN GUIDELINES, GAP FILLERS, SFN'S APPLICATIONS

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TV Systems Applications Engineer

PRESENTATION AGENDA

- Regulatory Guidelines
- Single Frequency Network (SFN)
- SFN Timing / Synchronization
- SFN Coverage
- On channel (SFN) Gap Filler application

SINGLE FREQUENCY NETWORK REGULATORY GUIDELINES

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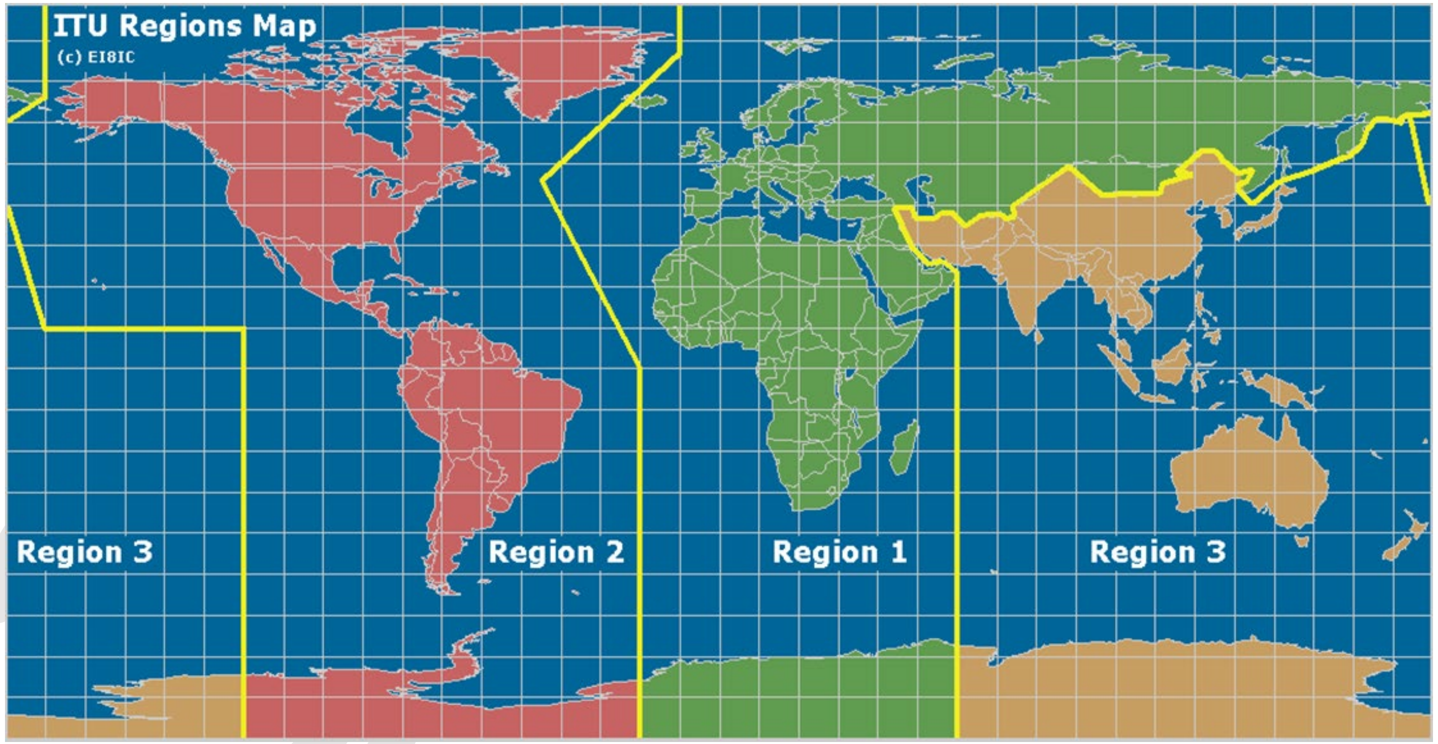
REGULATORY GUIDELINES

The ITU (International Telecommunications Union) has technical standards for TV and Radio broadcast. The standards / recommendations are regional based. Each Country within each region has regulations derived from these standards /recommendations.

In the USA the Broadcasters predominantly follow the standards, recommendations, and regulations provided by the FCC (Federal Communications Commission) and the NTIA (National Telecommunications and Information Administration). In additional to bi-lateral agreements with bordering neighbors.



REGULATORY GUIDELINES

The ITU Guideline for Single Frequency networks:

Digital terrestrial broadcasting: Design and implantation of single frequency networks (SFN)

https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-BT.2386-2015-PDF-E.pdf

For USA ATSC 3.0 Recommended Practice: Techniques for Signaling, Delivery and Synchronization.

https://www.atsc.org/wp-content/uploads/2019/08/A351-2019-Signaling-Delivery-RP.pdf

ATSC Recommended Practice: Conversion of ATSC 3.0 Services for Redistribution.

https://www.atsc.org/wp-content/uploads/2019/12/A370-2019-Conversion-and-Redistribution-1.pdf

SINGLE FREQUENCY NETWORK

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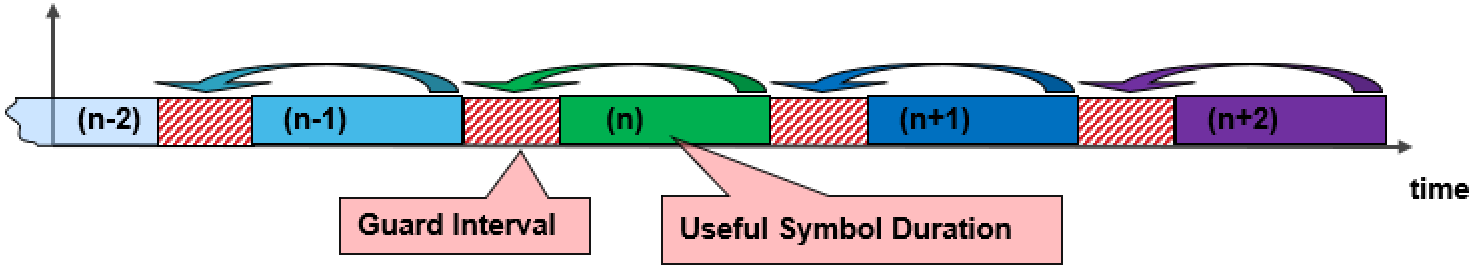
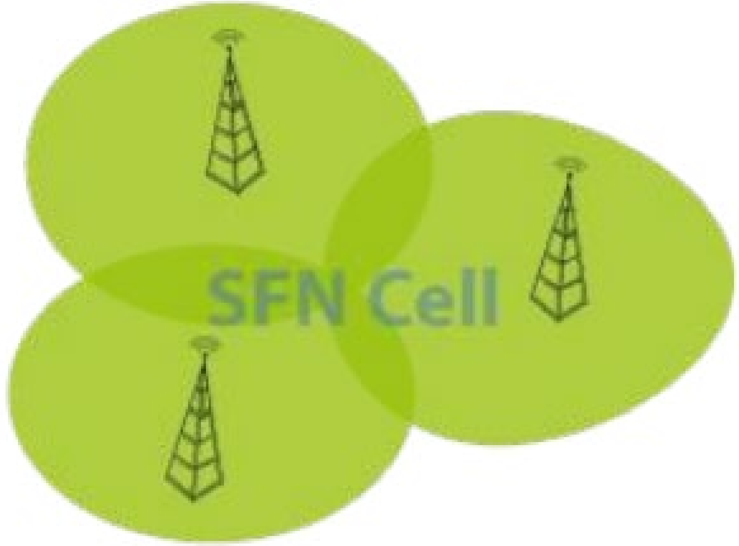
SINGLE FREQUENCY NETWORKS

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



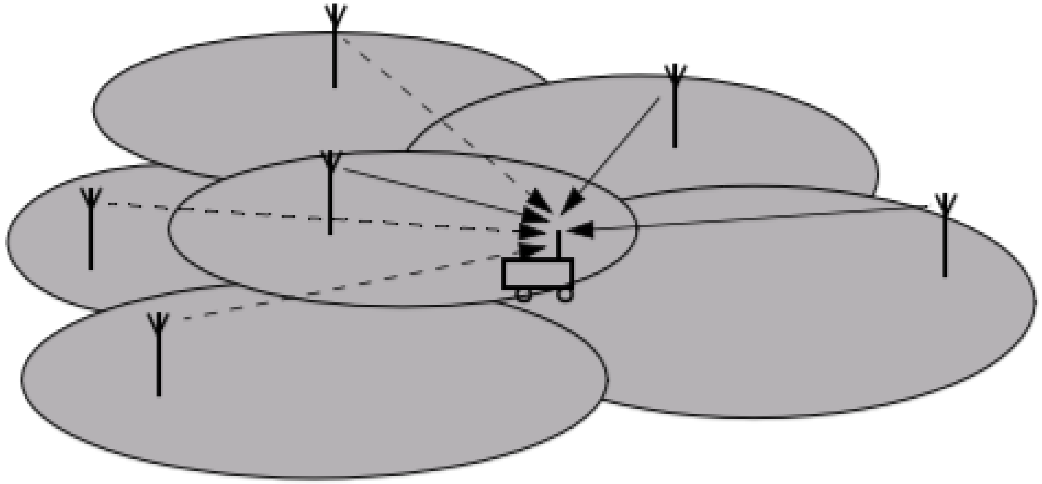


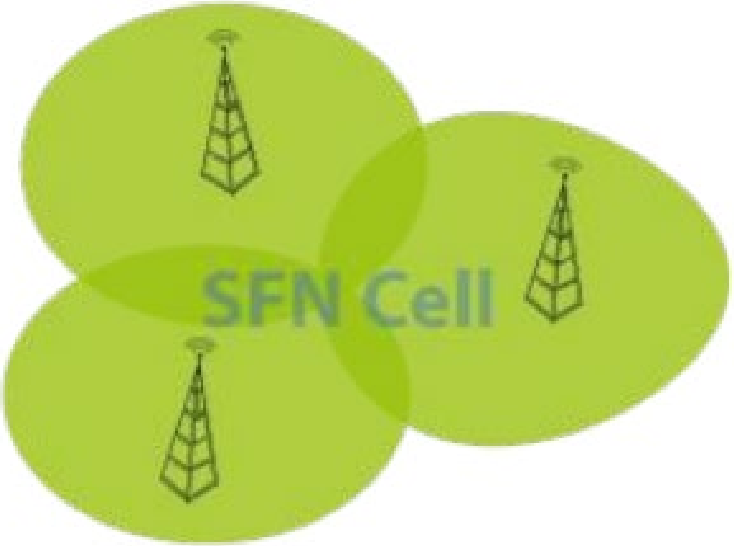
SINGLE FREQUENCY NETWORKS

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.





SINGLE FREQUENCY NETWORKS

BENEFITS OF AN SFN

The Benefits of using an 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.

Signal - Higher Receive signal strength, receivers making use of signals from multiple transmitters.

Helps with indoor coverage requirements.

Network Planning- progressively adding or changing the network to meet new needs or coverage requirements.

LIMITATIONS OF A SFN

Limitations using an SFN:

Signal 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).

The 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)= **222.2us (Gius)**

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

Example Parameters:
ATSC 3.0 (6MHz bandwidth)
64QAM
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 NETWORKS

Calculating the Maximum Distance between Sites in an
SFN for DVB-T, DVB-T2 or ISDB-T:

Bandwidth kHz / Number of Carriers (FFT size) = Carrier Spacing Hz (cs)
7.61 MHz * 10e6 / 13633 (16k Mode) = **558.2 Hz (cs)**

1 / carrier spacing (cs) = Total Symbol Duration (Tu)
1 / 558.2 Hz = .001791 seconds = **1791us (Tu)**

Tu * Guard Interval (Gi) = Guard interval in Microseconds (Gius)
1791us * (1/8) = 1791 * .125 = **223.87us (Gius)**

Guard Interval * Velocity of Light (Vo) = The distance in km
223.87us * (300*10e3) = .00022387 * 300000 = **67.161 km**

Example Parameters:
DVB-T2 (8MHz bandwidth)
64QAM
16k Mode
Bandwidth: 7.61Mhz
Guard Interval : 1/8

Note: For Modulation specific Guard internals see the Modulation specific specifications

SINGLE FREQUENCY NETWORK TIMING / SYNCHRONIZATION

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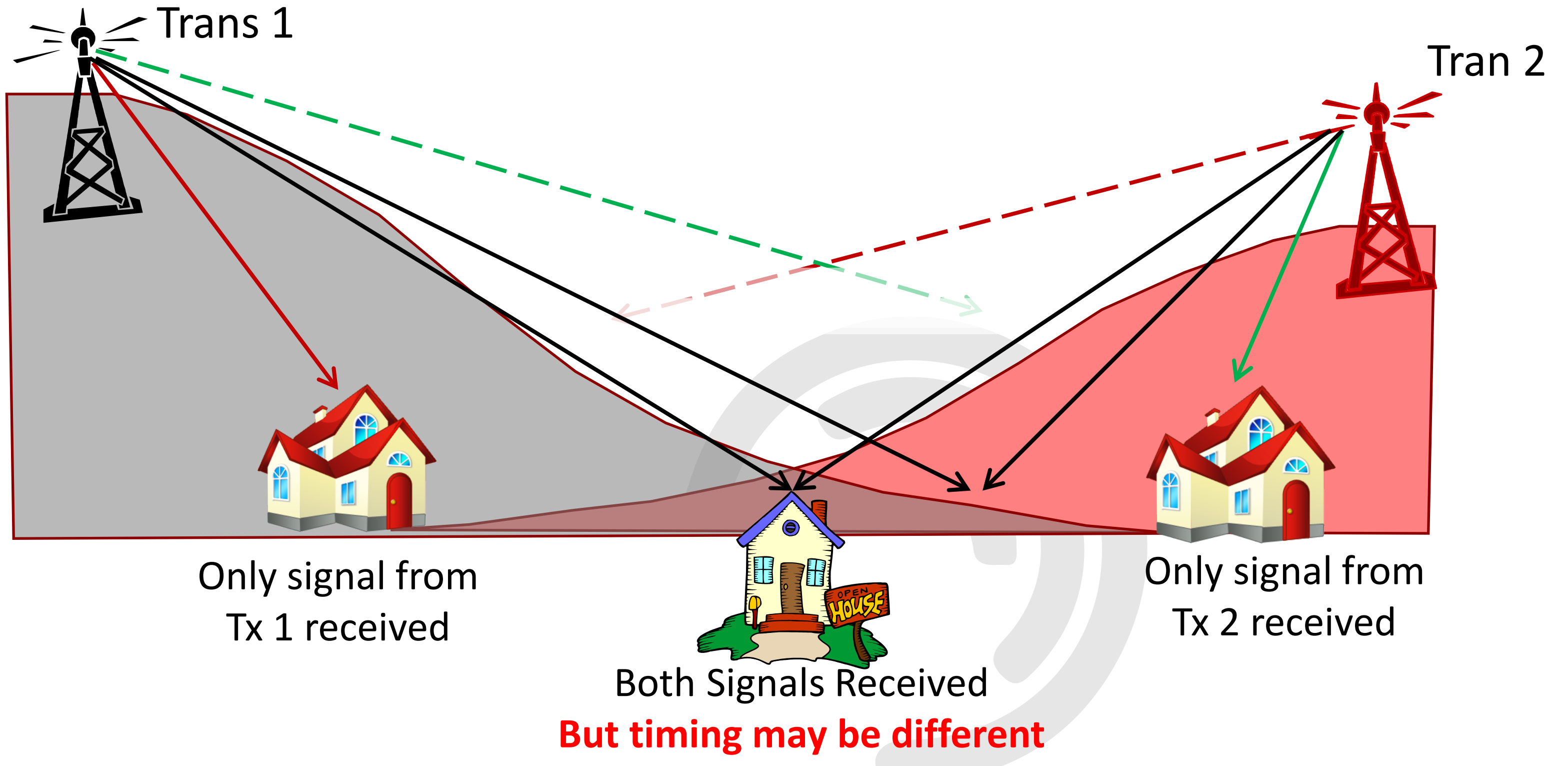
TIMING / SYNCHRONIZATION

Transmitters in an SFN all work together and can not operate independently, the data transmitted must be Identical, and at the 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).

The use of GPS receivers in an SFN is called **Dynamic Delay Compensation**. GPS are also used to Frequency lock each transmitter in an SFN for frequency stabilization.

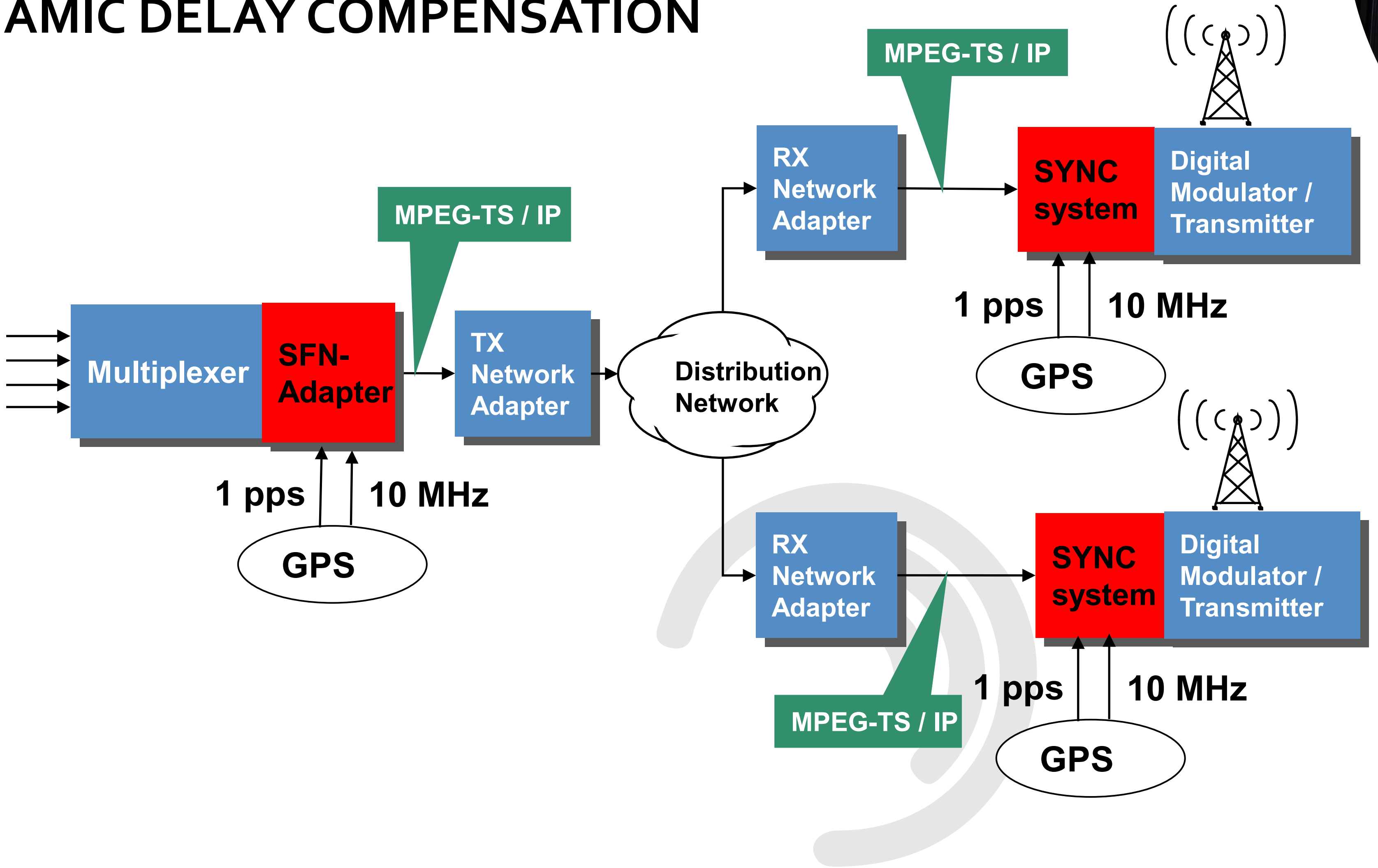
Additional delay compensation can be added in the transmitters systems where the modulators have different processing times or different manufactures are used , this is due to differences in modulator (exciter) processing times, additional delay is typically called **Static Delay Compensation**.

Static Delay Compensation can also be used to delay the propagation of a specific site to reduce or move SFN self interference to locations that have no population (example; over water)

In many cases Dynamic delay compensation and Static delay compensation are utilized in large SFN's.

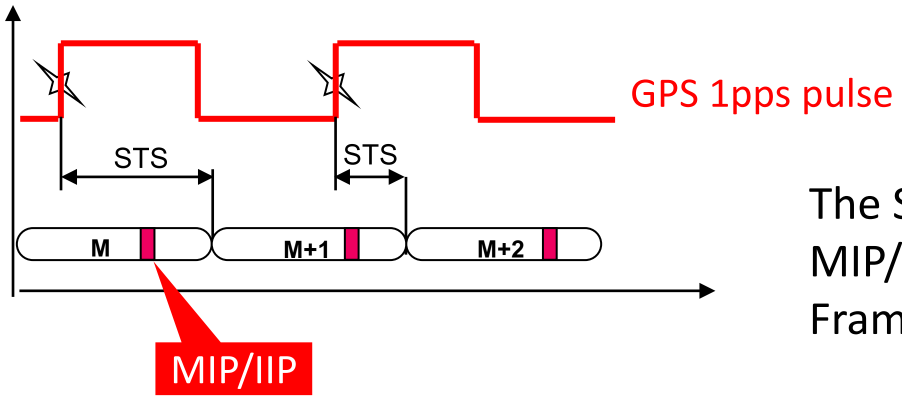
TIMING / SYNCHRONIZATION

DYNAMIC DELAY COMPENSATION



TIMING / SYNCHRONIZATION

Modulation Information Packet (MIP) / ISDB-T Information packet (IIP)



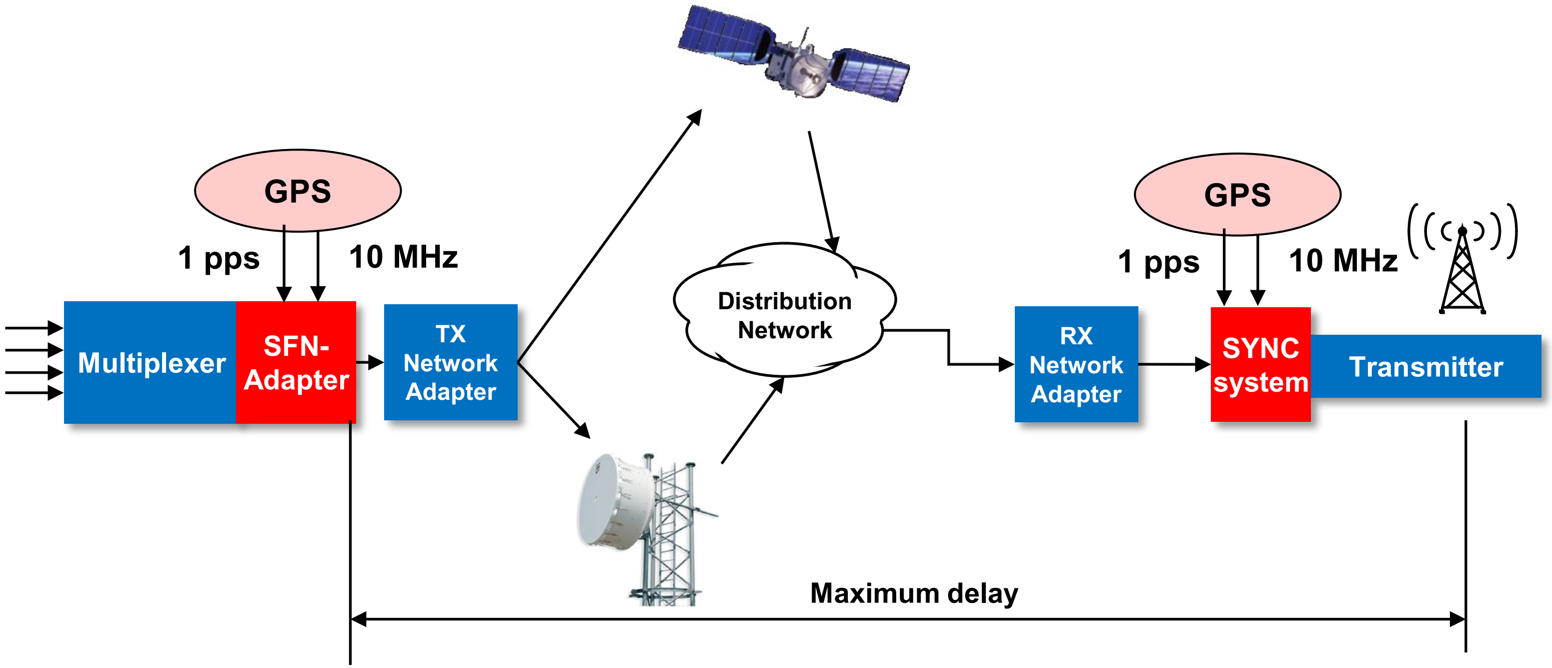
Synchronization Timestamp (STS)
The synchronization timestamp value is the difference in time between the rising edge of the 1pps Symbol and the beginning of a modulation super / mega-frame

The STS is carried in the MIP/IIP of each Multiplex-Frame.

The STS carried in the Multiplex-Frame (M) describes the beginning of the Multiplex-Fame (M+1)

The STS carried in the Multiplex-Frame M+1 describes the beginning of the Multiplex-frame M+2

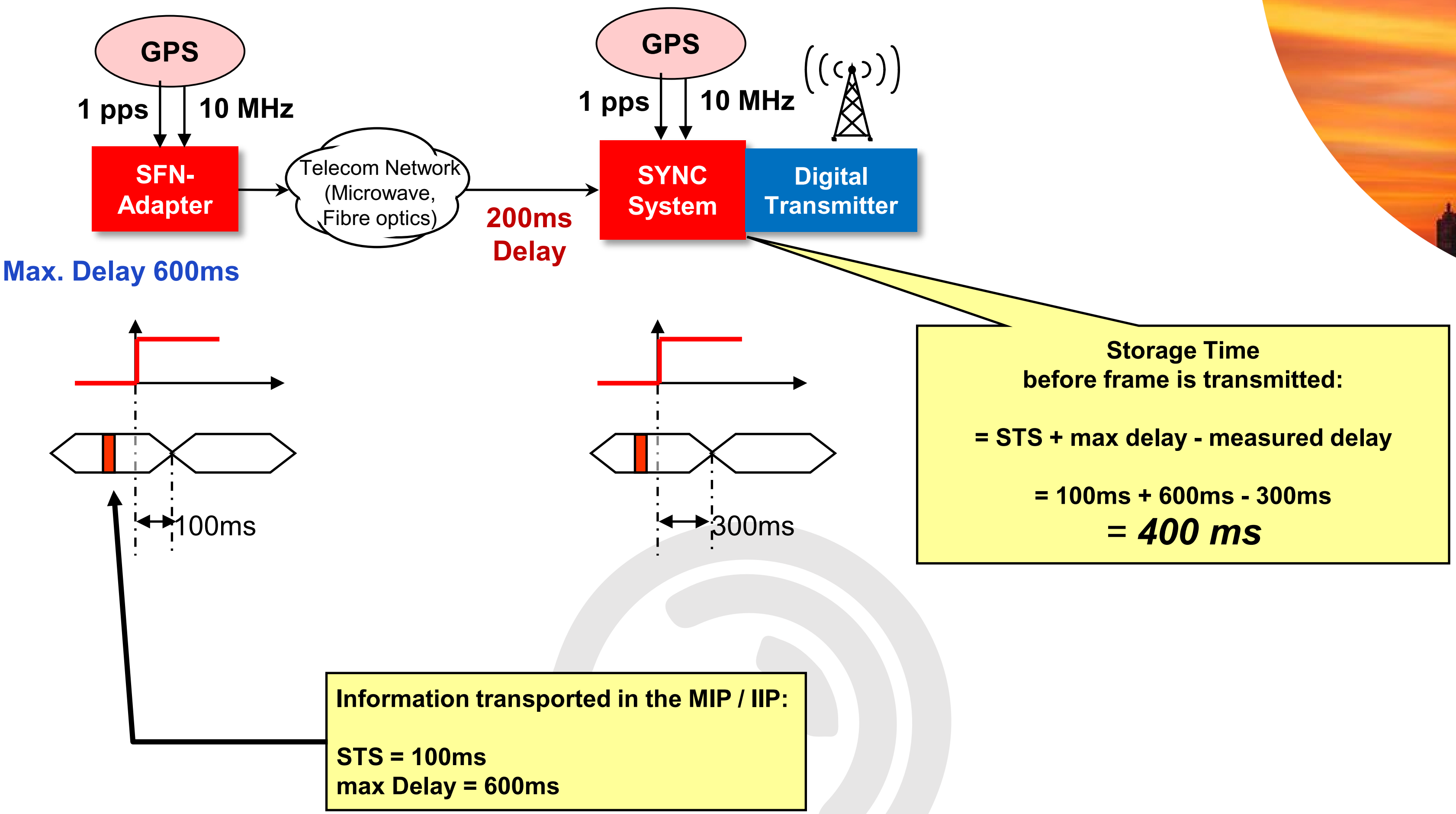
TIMING / SYNCHRONIZATION



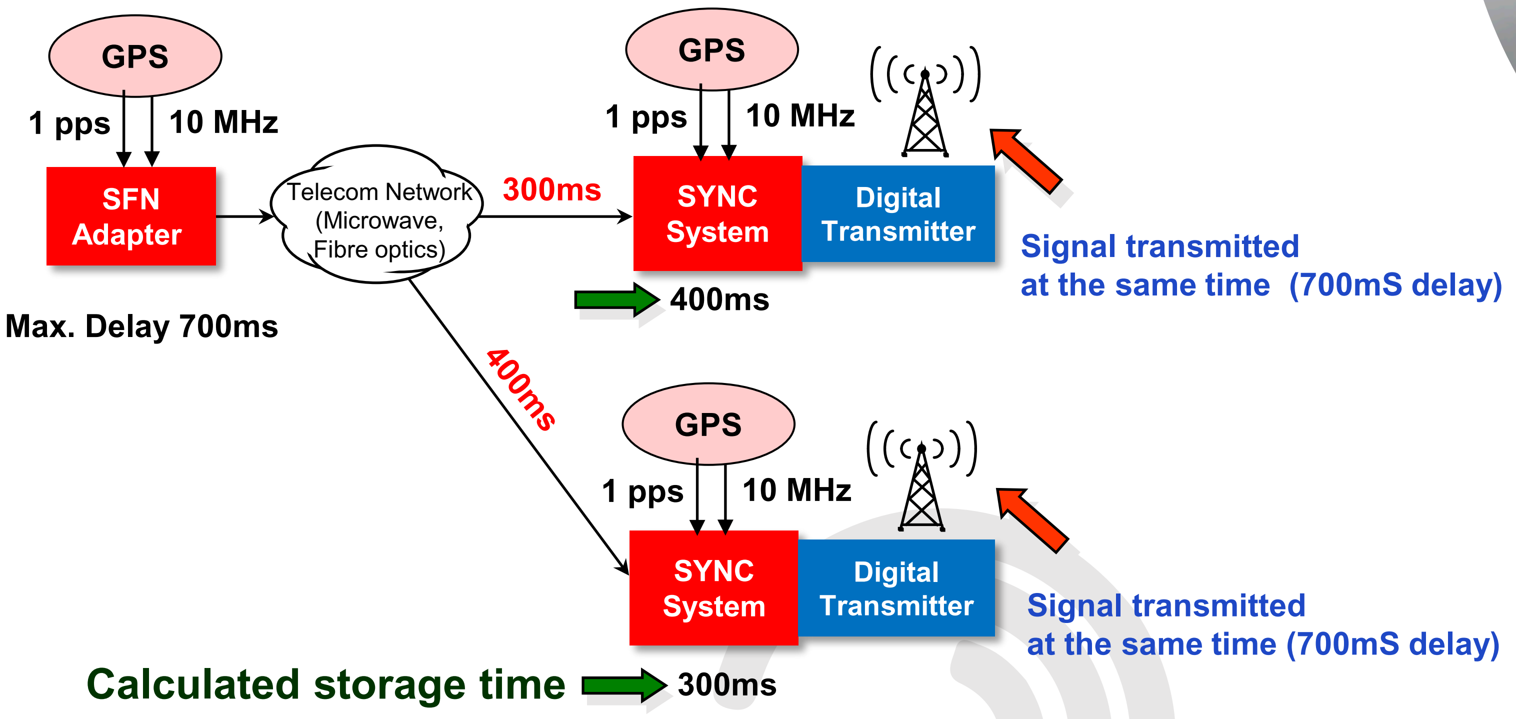
Maximum delay: (reference synchronization)
The maximum delay describes the difference in time between a specific Multiplex-Frame leaving the SFN adapter and the corresponding COFDM Super / Mega-frame available at the antenna output of each Transmitter in the SFN.

The maximum delay is a value adjustable in the SFN-Adapter. The set value must be higher than the longest actual network delay. The value is transported in each MIP / IIP with the STS.

TIMING / SYNCHRONIZATION



TIMING / SYNCHRONIZATION



SINGLE FREQUENCY NETWORK COVERAGE

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COVERAGE PLANNING

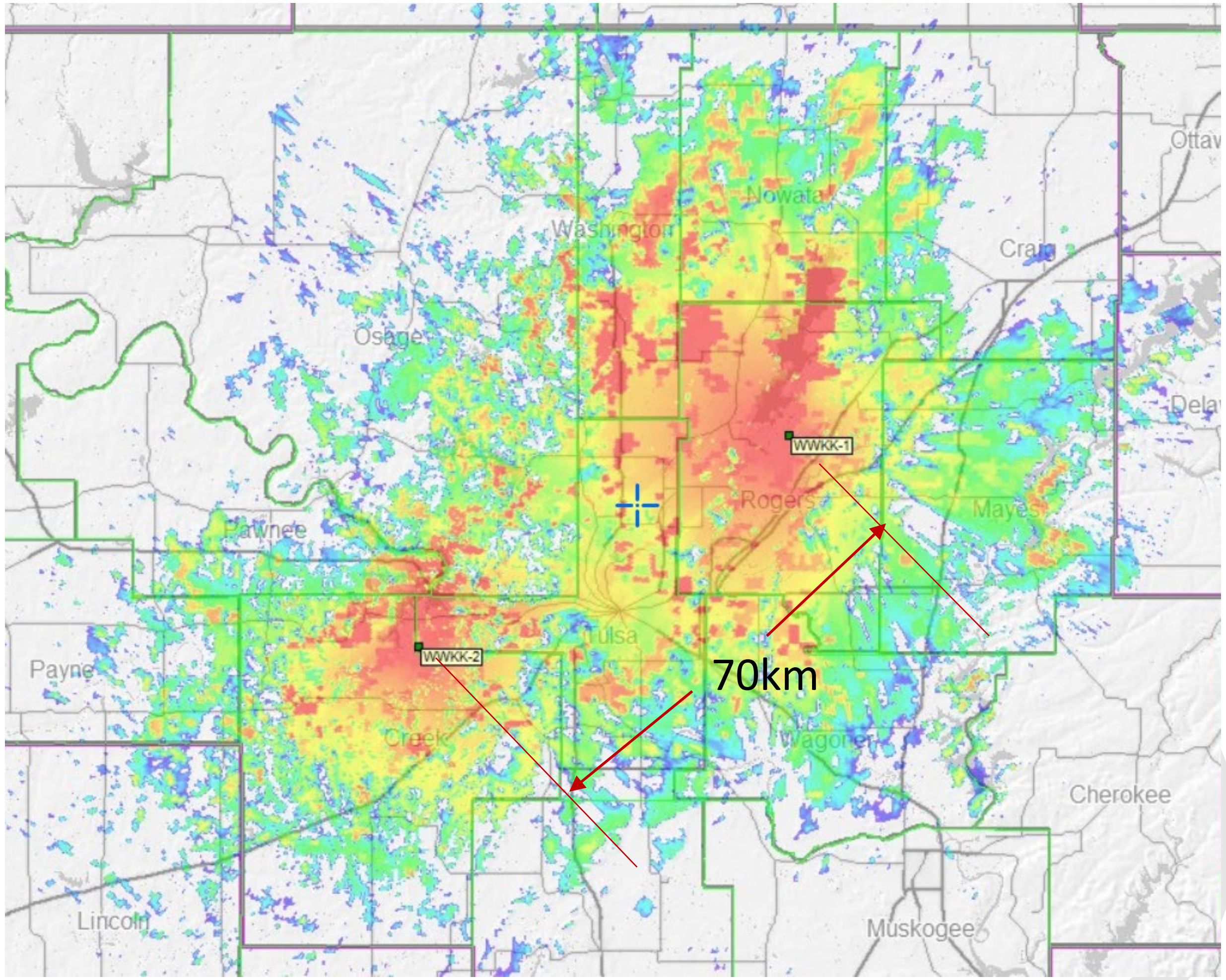
SFN coverage is a balance of the following parameters:

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 coverage from the planning stage of any SFN network, transmitter sites that cause self-interference or reflections (multipaths) outside the selected guard interval can be determined before the network is constructed.

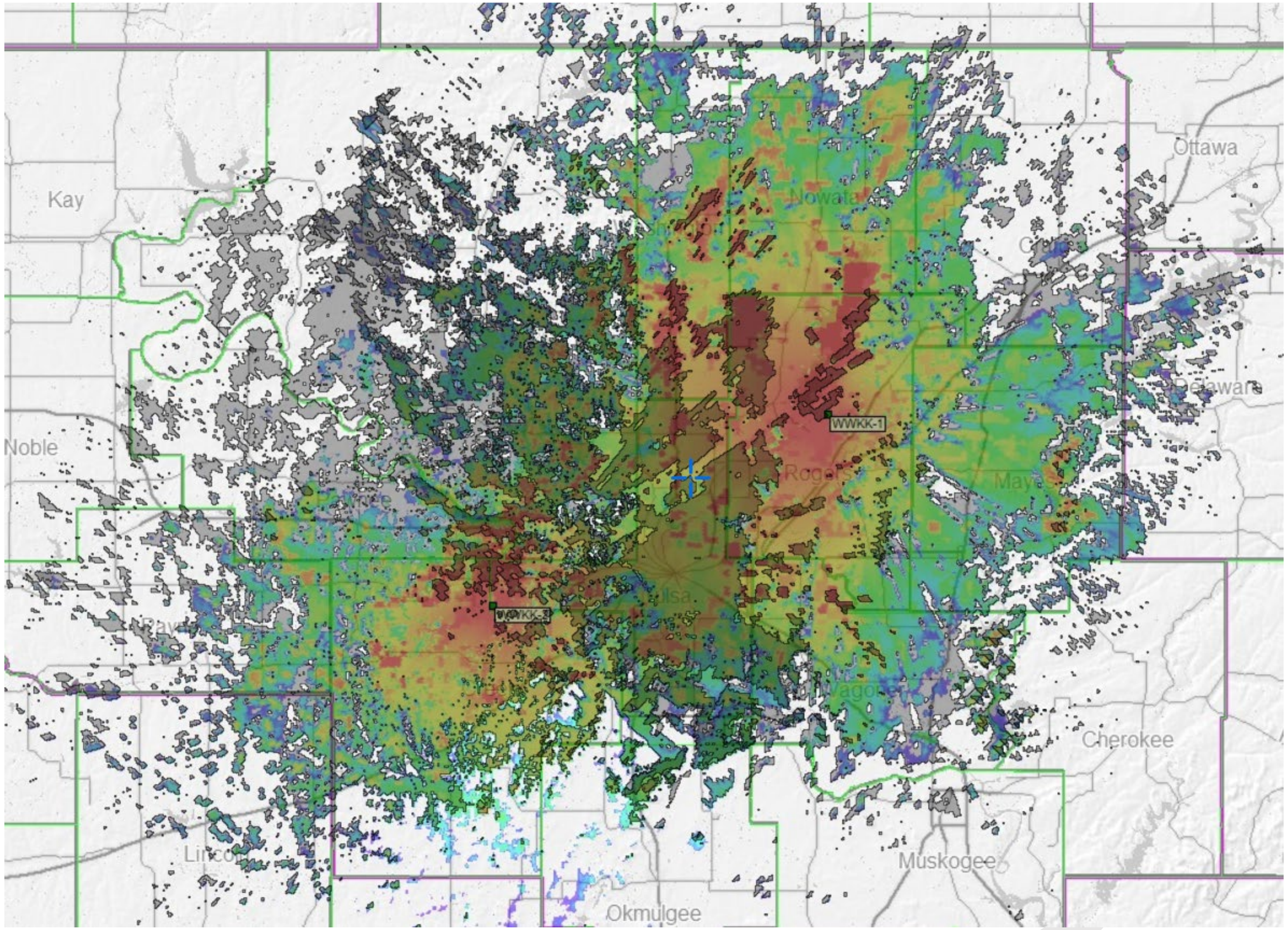
In general it is the highest power sites that cause the most interference within an SFN. However, Adjusting the timing (launch delay) of the lower ERP sites may be the best way to reduce self-interference.

SFN COVERAGE PLANNING MODULATION PARAMETERS



ATSC 3.0
64QAM
10/15 Code Rate (2/3 if DVB-T2)
FFT size 16k
Guard Interval Time 222.2us
Maximum distance 66.6km (41.4Miles)

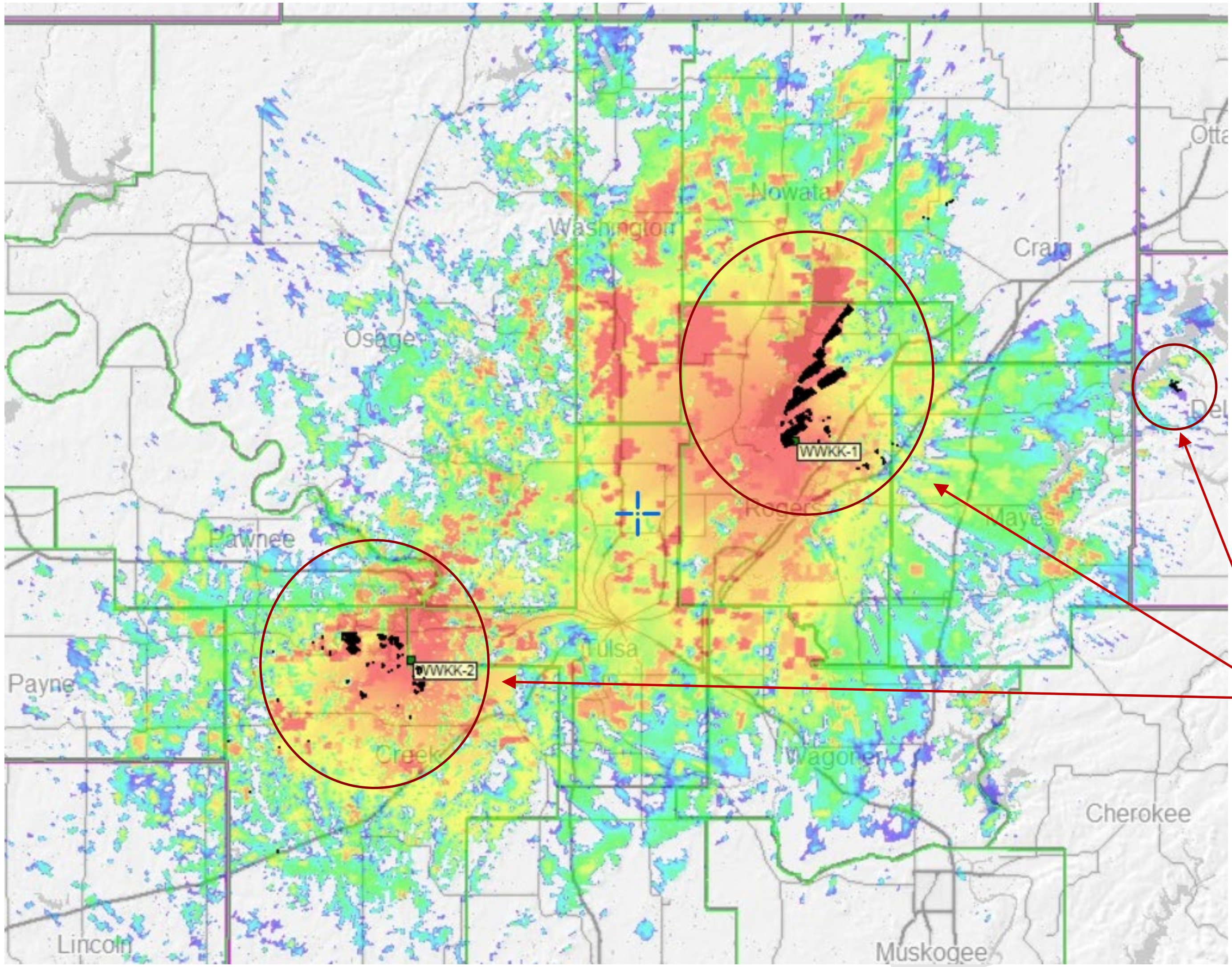
SFN COVERAGE PLANNING OVERLAPPING COVERAGE



ATSC 3.0
64QAM
10/15 Code Rate (2/3 if DVB-T2)
FFT size 16k
Guard Interval Time 222.2us
Maximum distance 66.6km (41.4Miles)

Adding Signal strength to the locations within the overlap.

SFN COVERAGE PLANNING SELF-INTERFERENCE



ATSC 3.0
64QAM
10/15 Code Rate (2/3 if DVB-T2)
FFT size 16k
Guard Interval Time: 222.2us
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.

SINGLE FREQUENCY NETWORK
ON CHANNEL GAP-FILLER APPICATION

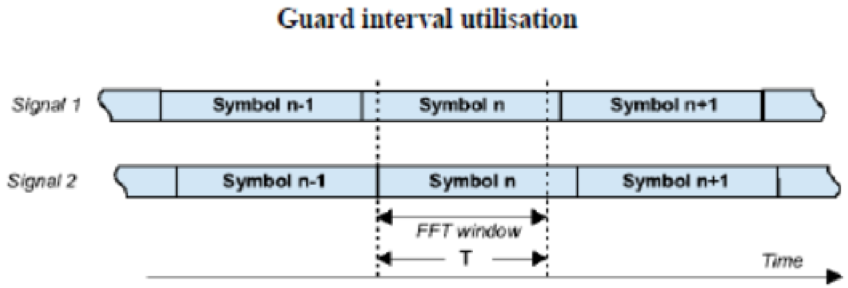
ON CHANNEL GAP-FILLERS

With COFDM Modulations like ISDB-T, DVB-T2 and 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 frequency lock is still an important part of the system synchronization.

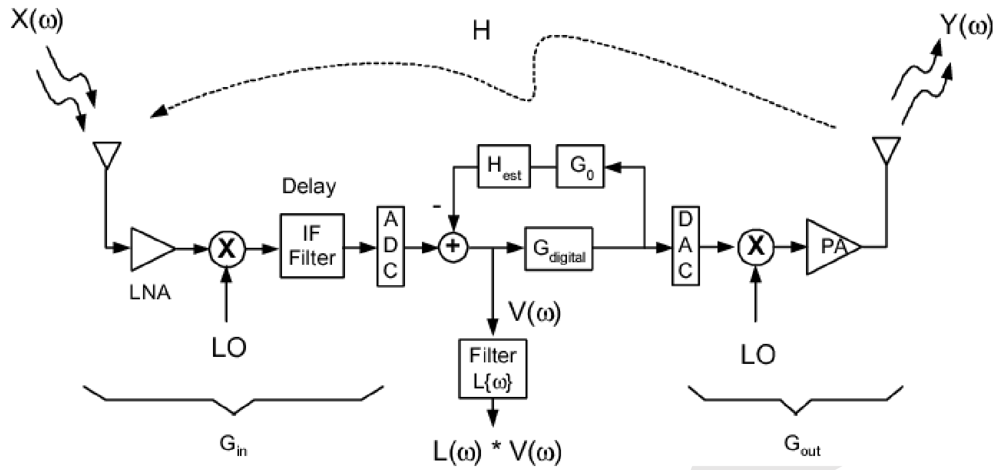
As with any SFNs we still need to use modulation parameters that allow for any multipath reception to be received within the guard interval.



ON CHANNEL GAP-FILLERS

On channel, RF in Gap-fillers have one 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 to close to the output speaker.

To help reduce this echo effect RF in 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.

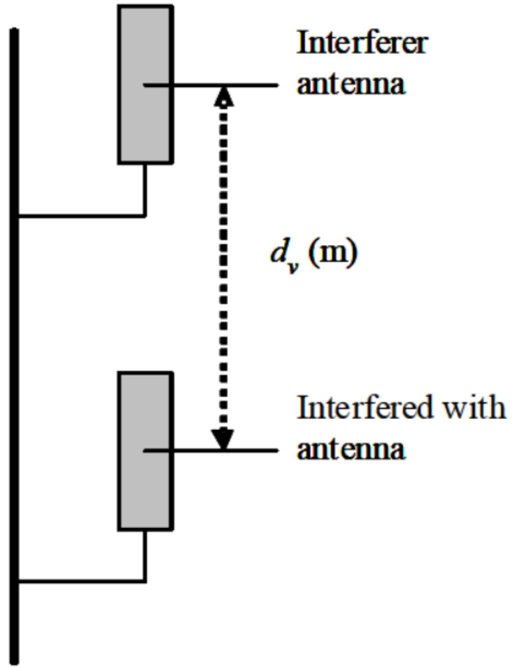


Typical Echo cancelation in a RF broadcast gap-filler/transmitter is between 10 and 15dB

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:

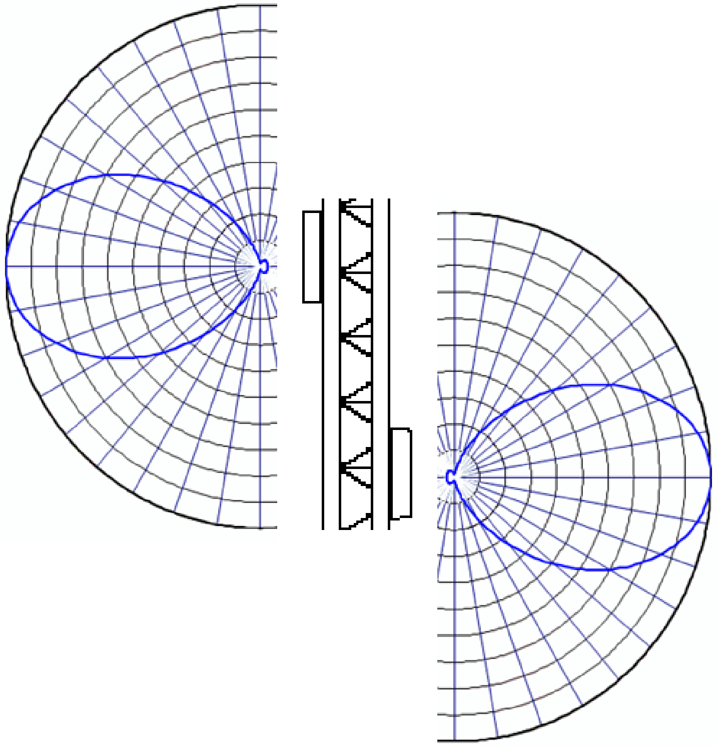
I_v[dB]: isolation between vertically separated transmitter and receiver antennas

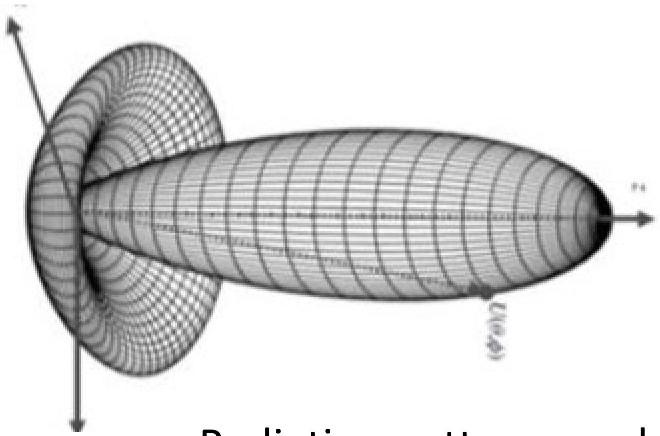
d_v[m]: the vertical distance from the interferer antenna to the interfered with receiver antenna, measured from radiation centre-to-radiation centre

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.

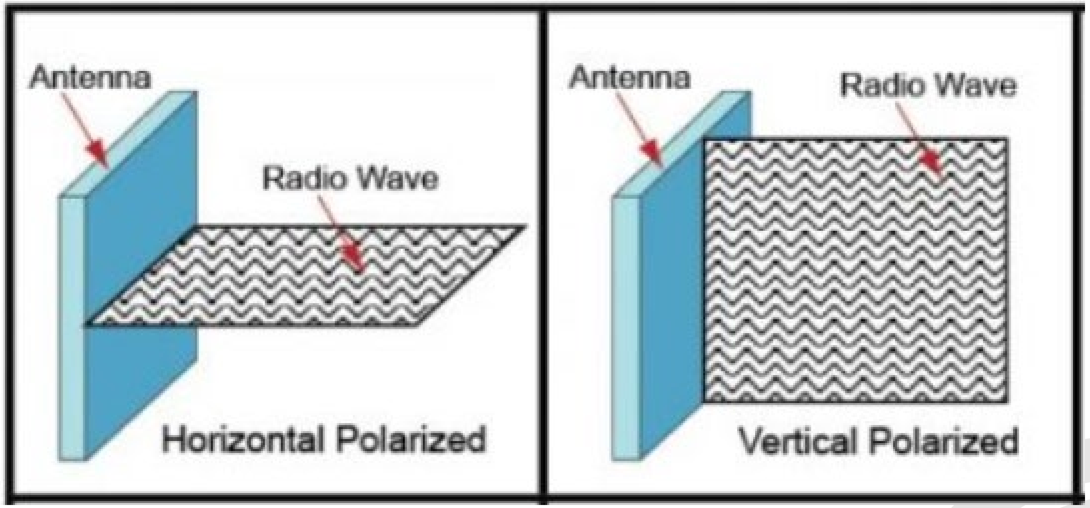




Radiation pattern graphical representation

ON CHANNEL GAP-FILLERS

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

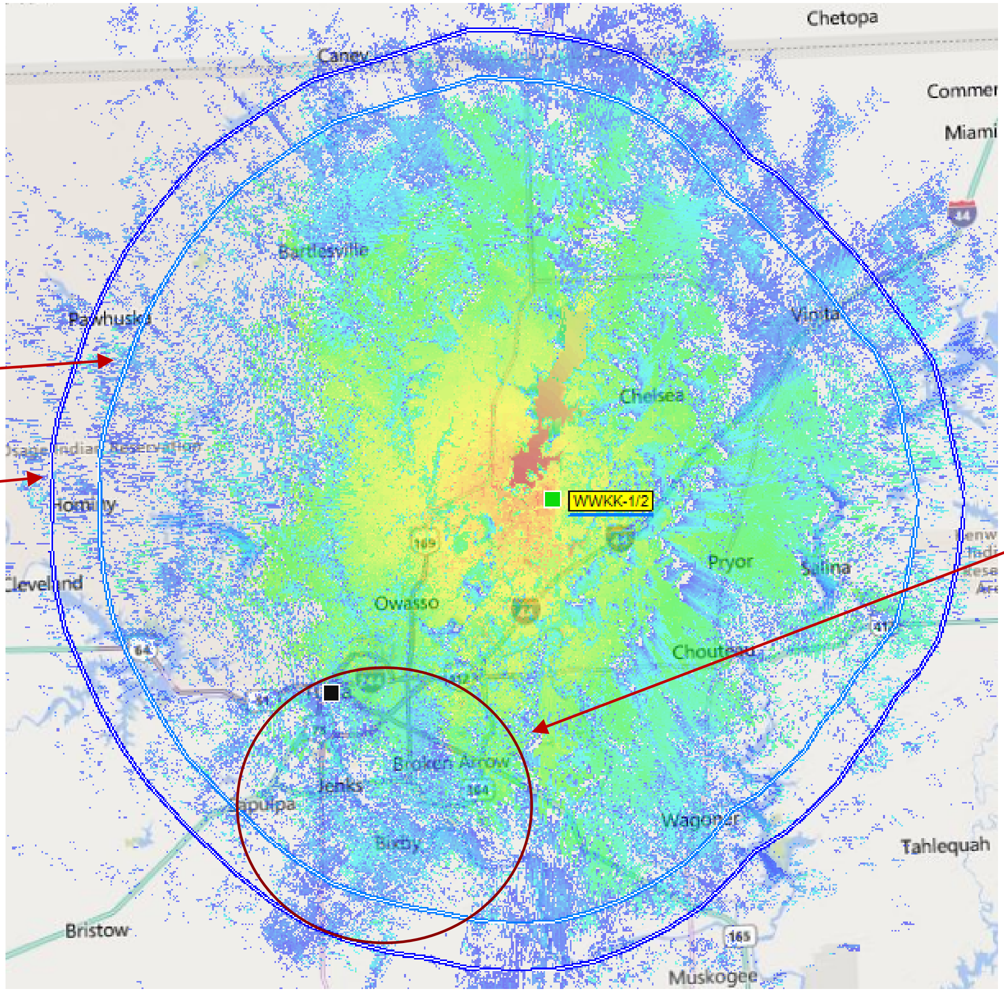


The two polarizations shown would be considered linear or orthogonal to each other. This allows a given polarization of an antenna to only receive on its intended polarization, isolated from the transmit polarization, thus the receive avoids interference from energy on the transmit polarization antenna.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

Polarization isolation can provide up to 30dB of isolation between receive and transmit antenna

ON CHANNEL GAP-FILLERS

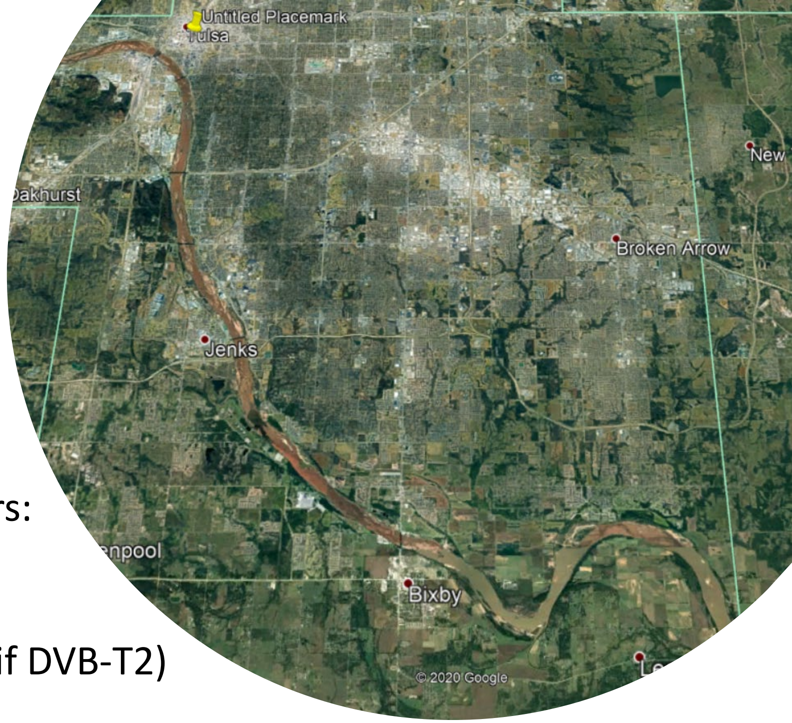
In practice looking a customer in the Tulsa, Ok area has a blank area of coverage, within the Tulsa residential area.



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 of Tulsa. This gap in coverage can be terrain or man-made obstructions, or a combination of both.

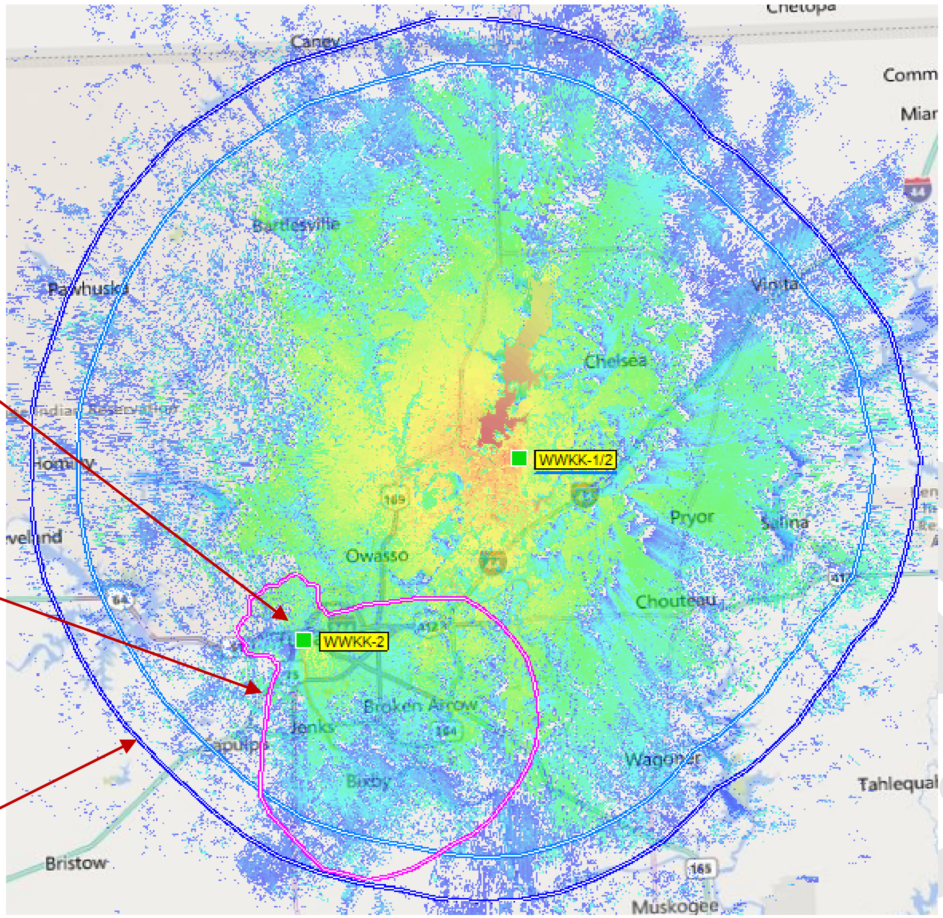
ON CHANNEL GAP-FILLERS



Employing a GatesAir 125W 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 Center (120m)

Note: the Gap-Filler contours stay within the approved customer FCC 41dBuV/m licensed contour



Modulation Parameters:
ATSC 3.0
64QAM
10/15 Code Rate (2/3 if DVB-T2)
FFT size 16k
Guard Interval Time 222.2us
Maximum distance 66.6km (41.4Miles)

Gap-Filler Processing delay 10us
15dB 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 + 15dB Echo cancelation
222.2us – 10us Processing delay = 212.2us*(300*10e3)= 63.66km (39.5miles)

QUESTIONS ?