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LEAP AHEAD

INBUILT CONVERGENCE: A Review of Emerging 3GPP and ATSC 3.x Terrestrial Broadcast Offerings

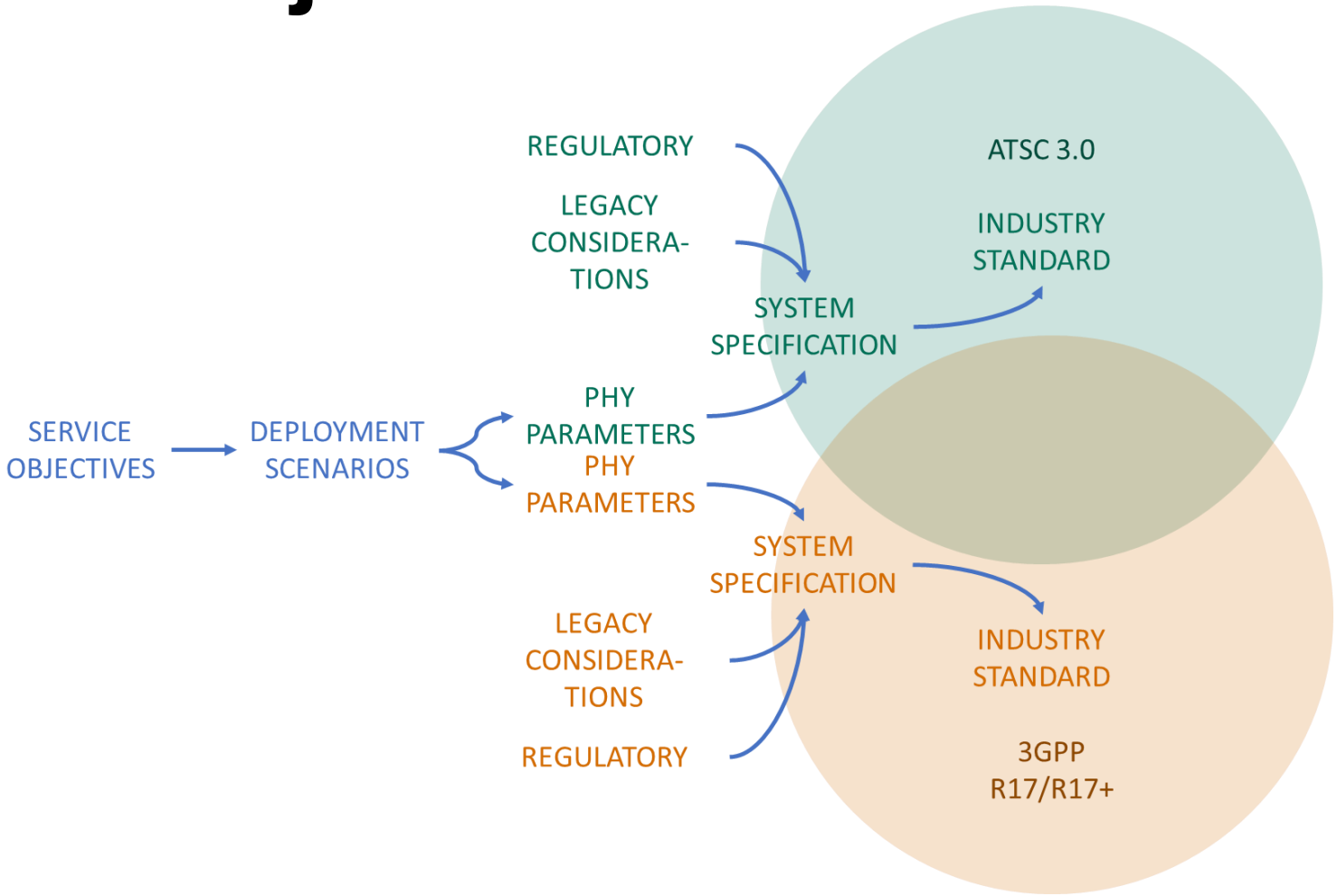
Coherent Logix™

May 13-14, 2020

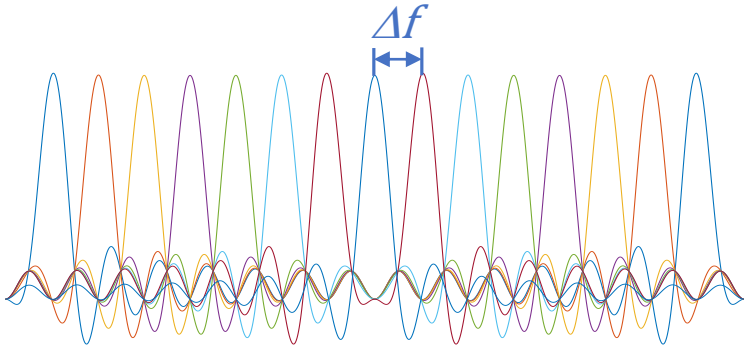
Agenda

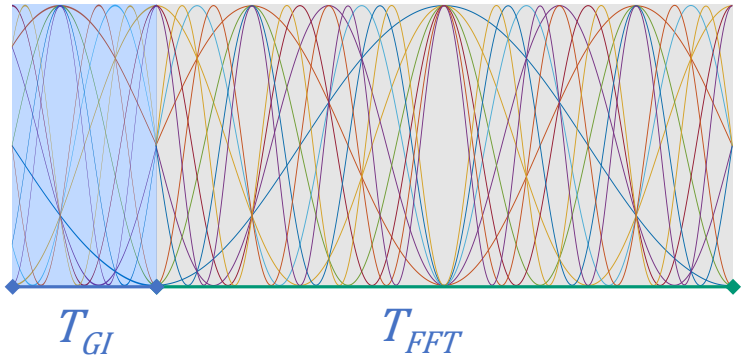
- PHY Layer Convergence
  - Service Objectives
  - OFDM Numerology
- Standards Evolution
- Performance Considerations
- PHY Configurations
- Deployment Scenarios
- System Observations
- Concluding Remarks

Service Objectives



OFDM Numerology



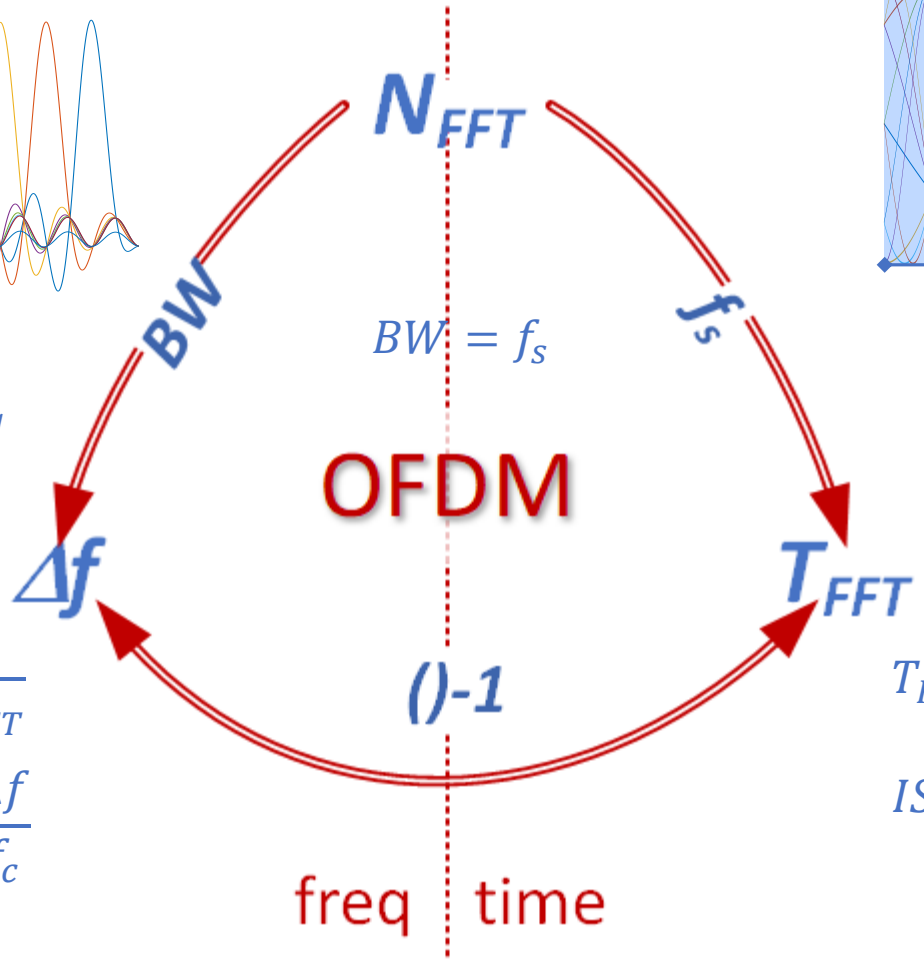


Δf: subcarrier spacing
→ Doppler Tolerance

f_c: carrier frequency

$$\Delta f = \frac{BW}{N_{FFT}} = \frac{1}{T_{FFT}}$$

$$v_D \propto c \cdot \frac{\Delta f}{f_c}$$



T_{FFT}: useful symbol duration

T_{GI}: guard interval duration
→ Delay Spread Tolerance

$$T_{FFT} = \frac{N_{FFT}}{f_s} = \frac{1}{\Delta f}$$

$$ISD = c \cdot T_{GI}$$

$throughput \leftarrow ModCod \rightarrow 1/range_{SNR}$

Standards Evolution

Standard	DVB	DVB	DVB	ATSC	3GPP	3GPP	3GPP	3GPP
Release	*T*	*T2*	*NGH*	*3.0*	*9 - eMBMS*	*14 - FeMBMS*	*16 – 5G Broadcast*	*17+ - 5G-NR (TB)*
Date	*Q1 1997*	*Q3 2009*	*Q2 2013*	*Q3 2016*	*Q1 2010*	*Q2 2017*	*Q1 2020*	*2021+*
Service Objectives	fixed reception to roof-top antennas	Increased Capacity, ruggedness, flexibility	Hybrid (terrestrial with satellite) broadcast to handheld terminals	Increased spectral efficiency, added mobility, improved resiliency for indoor rx.	Enables Broad-/multicast alongside 4G LTE unicast.	4G LTE based. Larger SFN ISDs. Receive-only-mode which enables free-to-air reception, i.e. SIM free.	Based on LTE.	Added subcarrier spacings for terrestrial broadcast in new bands based on 5G-NR.
Features	Uniform constellations	Rotated constellaions	Non-uniform constellations	**Non-uniform constellations**	Uniform constellations	Uniform constellations	Uniform constellations	TBD
	Variable GI duration	New FEC, high order mod	4D rotated constellation	Higher mod orders	**40/60 unicast/MBMS**	**Cell Acquisition SF (CAS)**		
	Multiple (2) subcarrier spacings	Additional subcarrier spacings	Hierarchical modulation for local service insertion	multiplexing arrangement including LDM		**Added subcarrier spacings (7.5, 1.25) KHz**	**Added subcarrier spacings (2.5 , 0.37) KHz**	**Even more subcarrier spacings**
FFT Sizes	2K, 8K	1K, 2K, 4K, 8K, 16K	1K, 2K, 4K, 8K [extended], 16K [extended]	**8K, 16K, 32K**	2K, 4K	2K, 4K, 24.6K	2K, 4K, 12.3K, 24.6K, 41.5K	9.2K, 12.3K, 15K, 30K, 24.6K, 49.2K, 60K, 73.8K, 141.3K, 147.5K, 295K
Modulation formats	QPSK, 16/64QAM	QPSK, 16/64/256QAM	QPSK 2D/4D rotated, 16/64QAM 2D rotated, NU-64QAM 2D rotated, 256QAM, NU-256QAM	QPSK, 16/64/256QAM NUC, 1024/4096QAM	QPSK 16/64QAM	QPSK 16/64/256QAM	QPSK 16/64/256QAM	TBD
Scattered Pilots	8% of total	1%, 2%, 4%, 8% of total	DX = [3,6,12,24] DY= [2,4]	DX = [3,4,6,8,12,16,24,32] DY= [2,4]	PSS|SSS	(DX, DY) = (3,7) , (3,6), (1,8), (2,4), (3,2)	DX = [1,2,3] DY= [2,4,6,7,8]	DMRS
Continual Pilots	2.6% of total	0.35% of total	CP1, CP2, CP3, CP4, CP5	CP32, CP16, CP8	4.8% of total	7.1% of total		PT-RS
Error Correction	Convolutional Coding + Reed Solomon	LDPC + BCH	LDPC + BCH	**LDPC [+CRC or BCH]**	Parallel Concatenated Convolutional Coding	Parallel Concatenated Convolutional Coding		**LDPC, Polar**
Code Rates	1/2, 2/3, 3/4, 5/6, 7/8	1/2, 3/5, 2/3, 3/4, 4/5, 5/6	5/15, 6/15, 7/15, 8/15, 9/15, 10/15, 11/15	2/15, 3/15, 4/15, 5/15, 6/15, 7/15, 8/15, 9/15, 10/15, 11/15, 12/15, 13/15	1/3 (others derived via rate matching)	1/3 (others derived via rate matching)		
GI Durations	1/4, 1/8, 1/16, 1/32	1/4, 19/128, 1/8, 19/256, 1/16, 1/32, 1/128	1/32, 1/16, 1/8, 1/4, 1/128, 19/256, 19/128	3./[512,256,…,8], 1./[64,32,…,2], 19./[256,128, …,32], 57./[512,256,128]	**1/4**	7%-25%	7%-25%	2%-25%
Multiplexing Arrangement	TDM	TDM	TDM + H-LSI	TDM, FDM, TFDM, **LDM**	TFDM	**SF containing no unicast Read-only-Mode (ROM)**	TDM, FDM	TDM, FDM (CBP)
Frame Availability	100%	100%	100%	100%	**60%**	**100%**	100%	100%

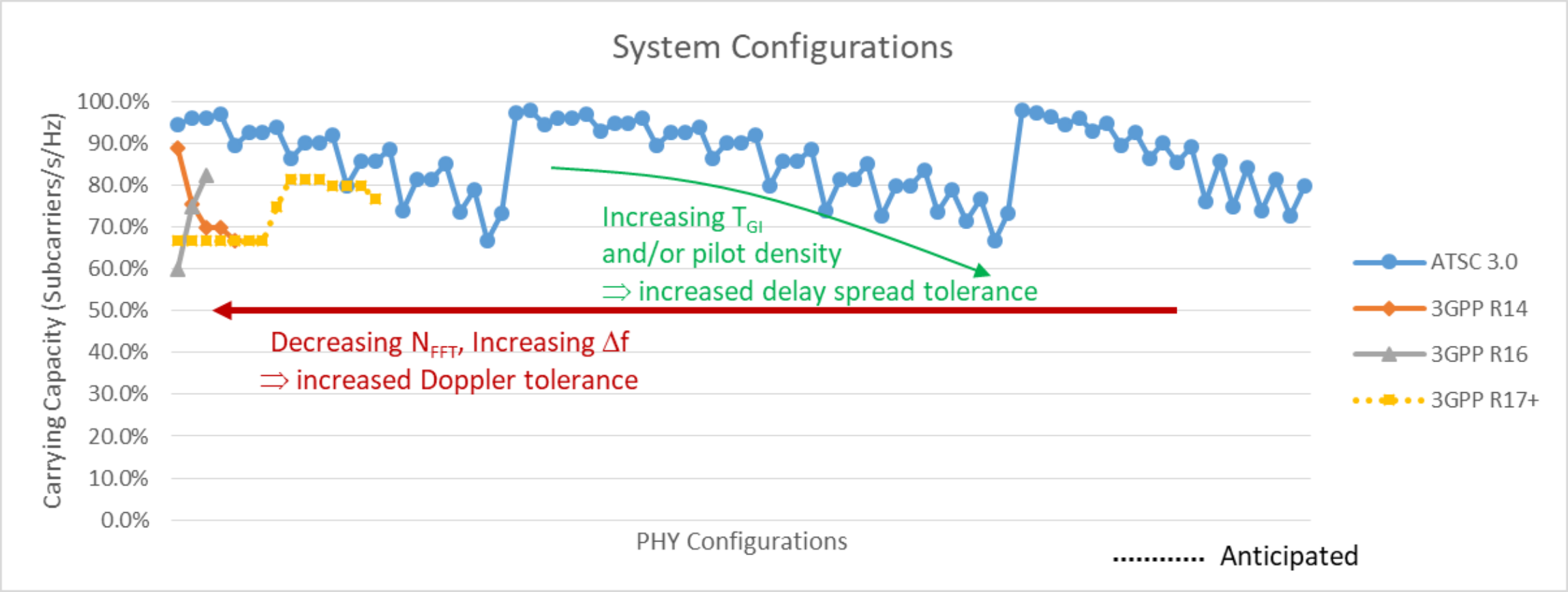
Performance Considerations

	ATSC 3.0	3GPP – Rel 16
Coverage – ISD (Km)	8 - 211	1.4 - 90
Mobility - Doppler Limit (Hz)	46 - 206	42 - 1000
BICM spectral efficiency (bpc)[1]	10.36	7.09

$$\text{Doppler Limit} = 1/(2 \times D_t \times T_{sym})$$

[1]Manuel Fuentes, De Mi, Hongzhi Chen, Eduardo Garro, Jose Luis Carcel, David Vargas, Belkacem Mouhouche, David Gomez-Barquero, "Physical layer performance evaluation of LTE-advanced pro broadcast and ATSC 3.0 systems," IEEE Transactions on Broadcasting, vol. 65, no. 3, 2018.

PHY Configurations



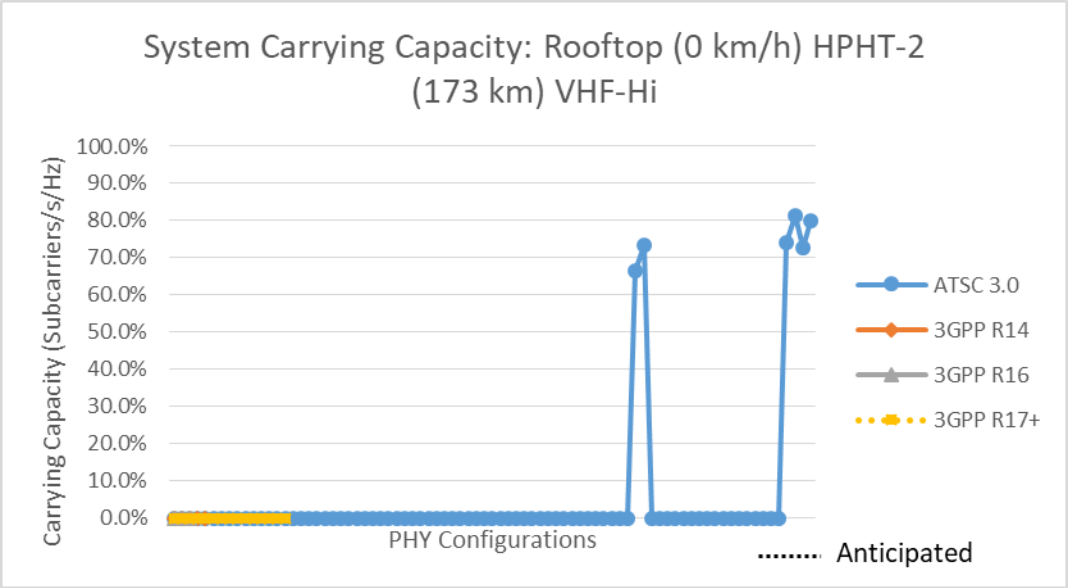
Deployment Scenarios[1]

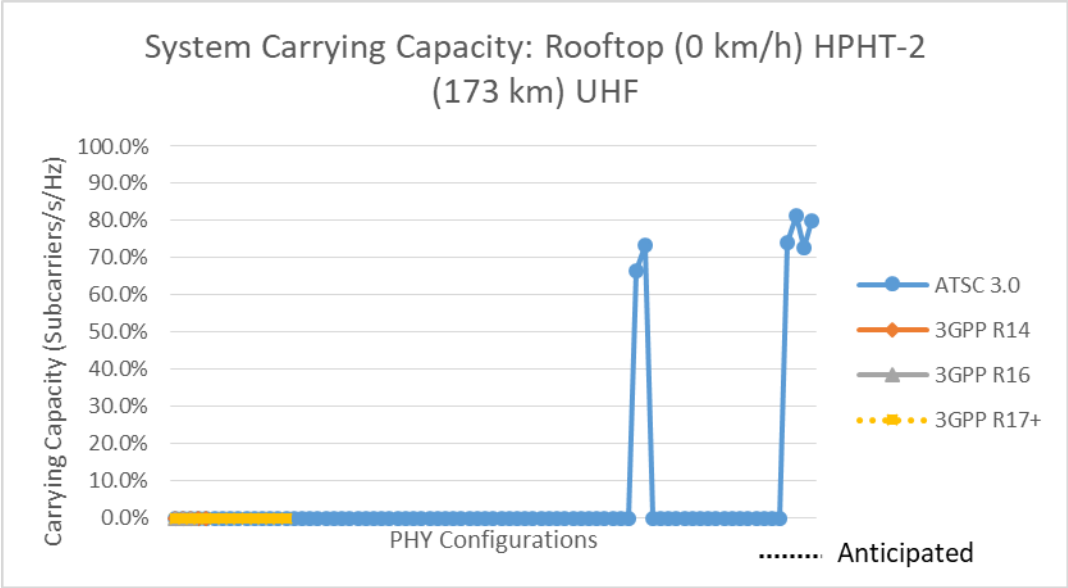
Scenario	LPLT	MPMT	HPHT-1	HPHT-2
ISD	15 km	50 km	125 km	173 km

Scenario	Rooftop	Indoor	Car-mounted-1	Car-mounted-2
Rx Velocity	0 km/h	3 km/h	125 km/h	250 km/h

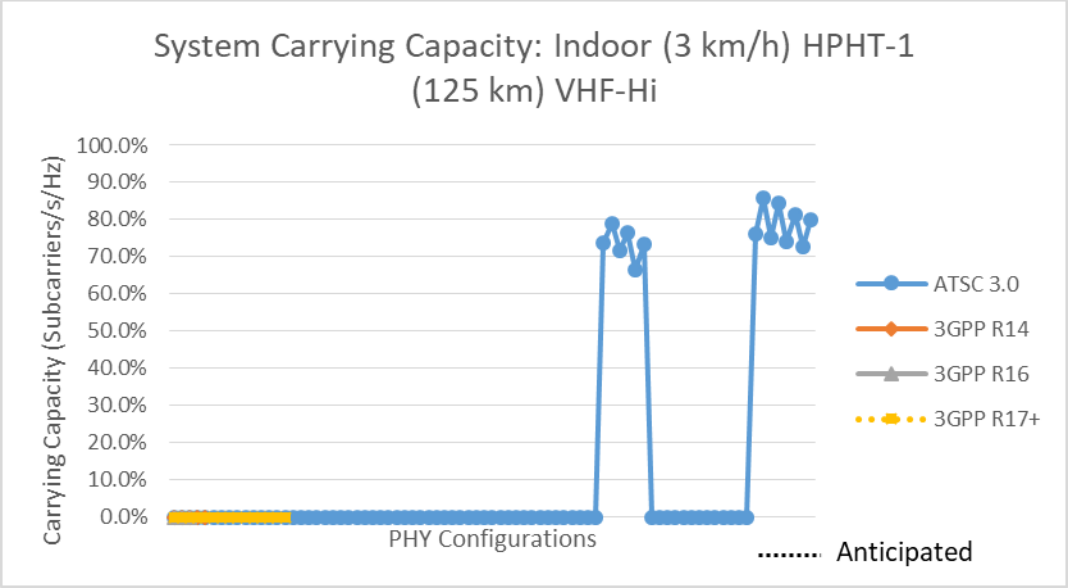
[1]3GPP R1-1811728, “Chairman’s notes of AI 6.2.4 Study on LTE-based 5G Terrestrial Broadcast,” 2018.

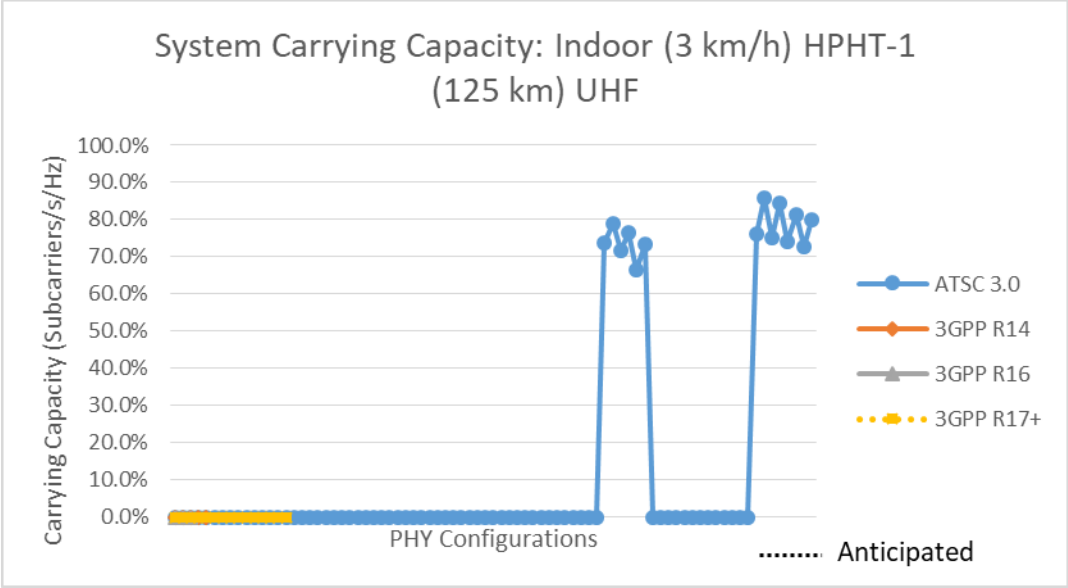
Scenario 1: Rooftop/HPHT-2



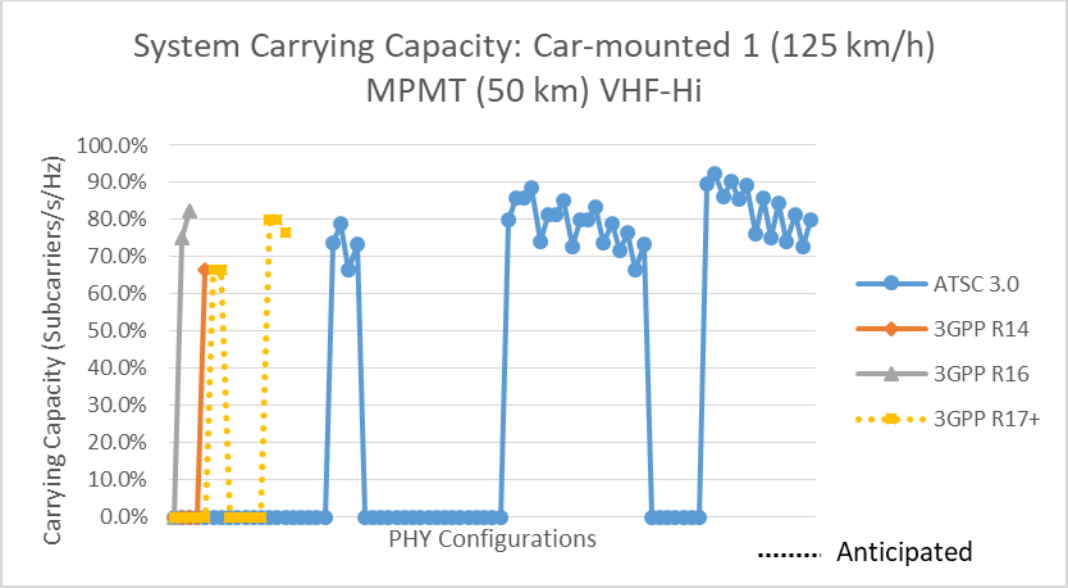


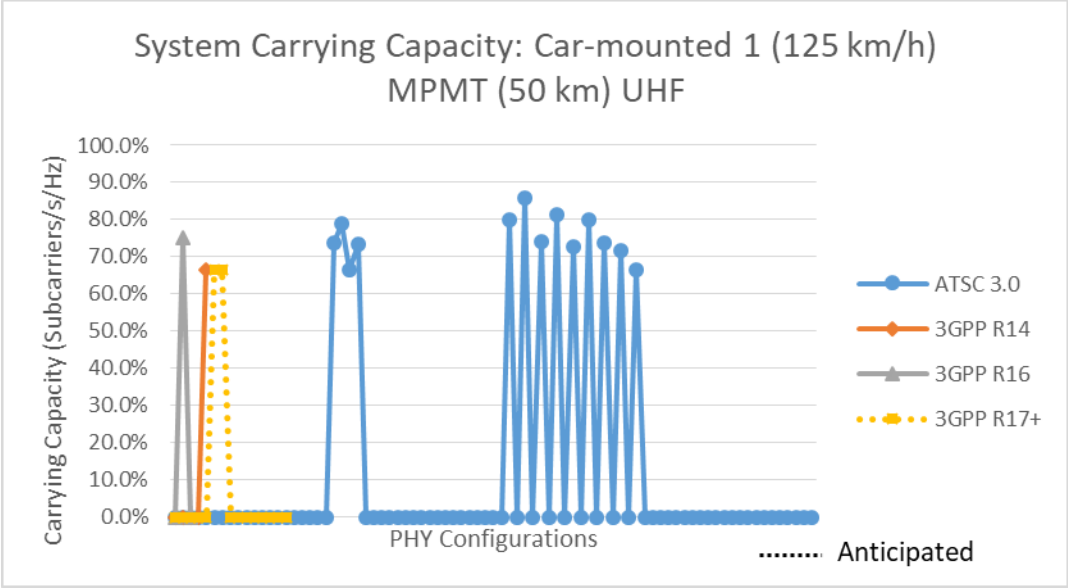
Scenario 2: Indoor/HPHT-1



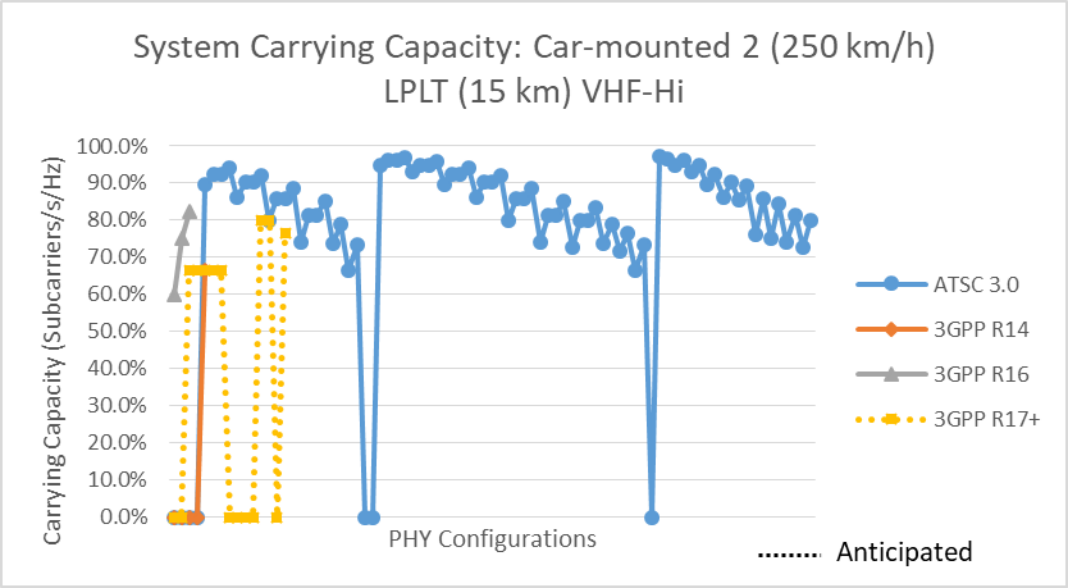


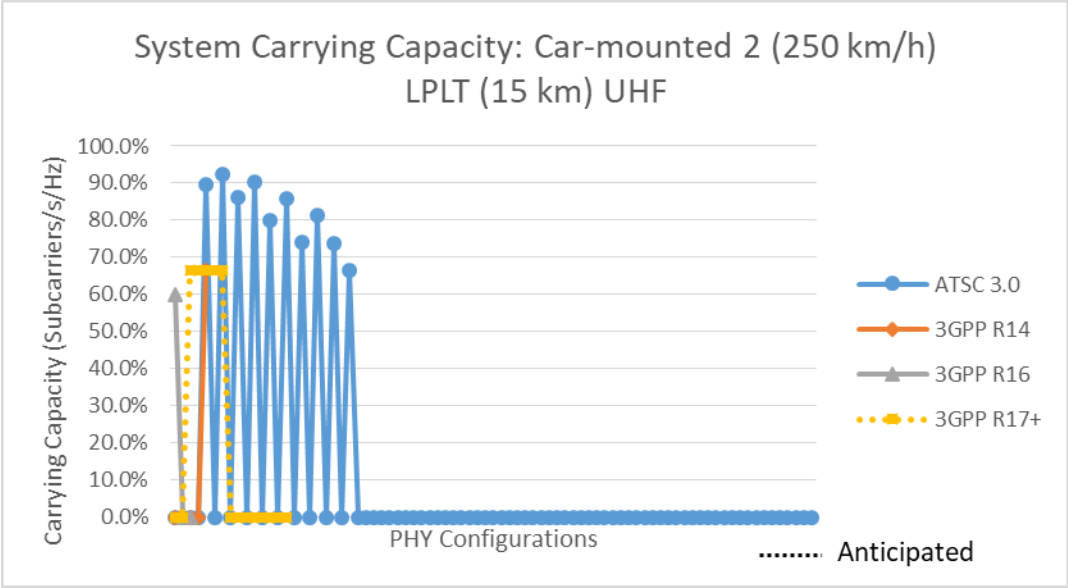
Scenario 3: Car-Mounted-1/MPMT





Scenario 4: Car-Mounted-2/LPLT

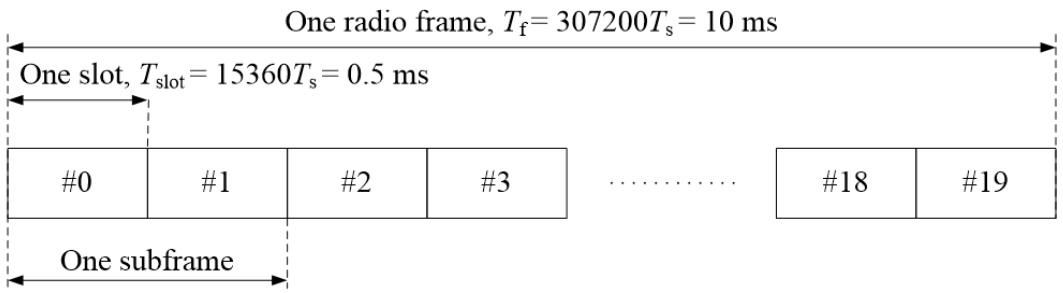


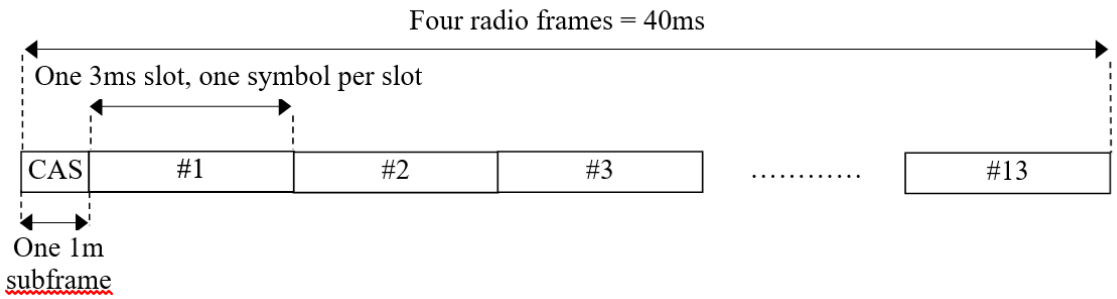


System Observations – ATSC 3.0

- Support new system bandwidths of 5, 10, 20 MHz.
  - 20 MHz could be supported via the channel bonding of two adjacent 10 MHz RF channels.
- Carrier spacing might need to be increased in order to maintain sufficient Doppler tolerance at higher carrier frequencies than the typical television broadcast frequencies.
- Support new FFT sizes.
  - Either 4K (to support a wider carrier spacing) or 64K (to support a wider system bandwidth).

System Observations – 3GPP





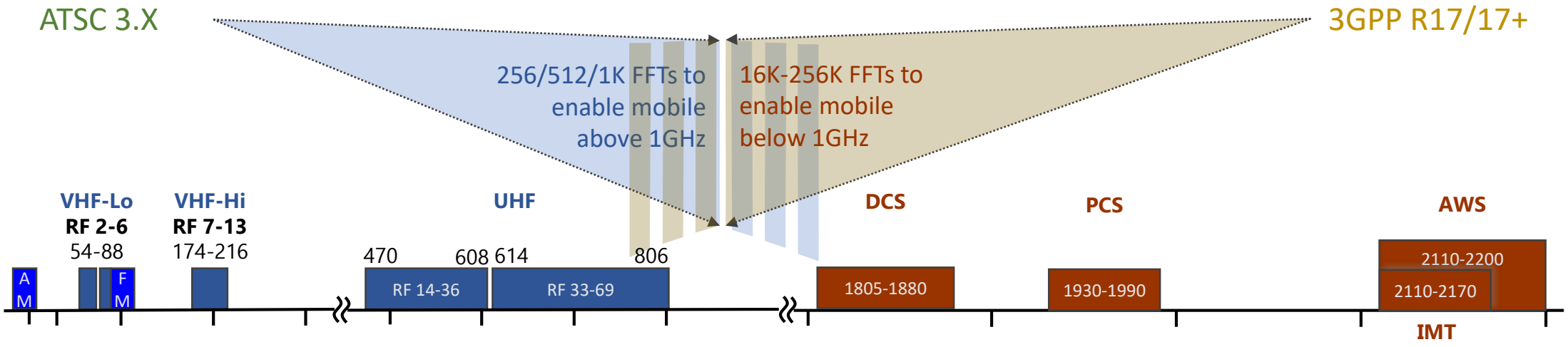
Frame structure type 1 for subframes using any subcarrier spacing <u>except</u> $\Delta f = 0.370$ kHz[1]

Frame structure type 1 for subframes using subcarrier spacing $\Delta f = 0.370$ kHz[1]

Subcarrier Spacing (KHz)	15	2.5	1.25	0.37
Channel Bandwidth (MHz)	20			
FFT Size	2048	12288	24576	41472

[1] 3GPP TR 36.276 v0.2.0, "LTE-based 5G terrestrial broadcast; Overall Description," 2019.

Concluding Remarks



Thank You

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