A Cloud-Capable Synchronized Transport Architecture for FM and HD Radio Broadcasting

Central Canada Broadcast Engineers,
Technologists & Technicians Conference
August 27, 2022

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Nautel Ltd.

Agenda

- Motivation
- Evolution of today's HD Radio Broadcast Architecture
- FM HD1 Time Alignment
- A new HD Radio Architecture
  - Synchronizing the Air-Chain
  - Buffer Control Algorithm
- Air-Chains with Constant FM HD1 Time Alignment
  - Change Over Demonstrations
- Air-Chains for Fleet distribution
- IT Security Consideration

Our Vision

To create an FM+HD transmitter receiving ***ALL its modulation content*** *over a* ***synchronous IP link*** *all the way back to a* ***cloud based air-chain*** *or* ***changeover*** *to a* ***backup air-chain****.*

Software Air-Chain

IP link: FM + optional HD

Motivation

Broadcasters tell us their HD Rack is very complex …

=> How can we **simplify HD Radio** installations?

Traditional studios are going away and often get centralized …

=> Can we create **platform agnostic** HD Radio air-chains?

=> Can we create **location agnostic** HD Radio air-chains?

=> Can we define an **analog only** architecture ***ready*** for HD Radio?

On-Air Broadcast reliability is suffering …

=> Can we create **hot/cold standby air-chains** for failover?

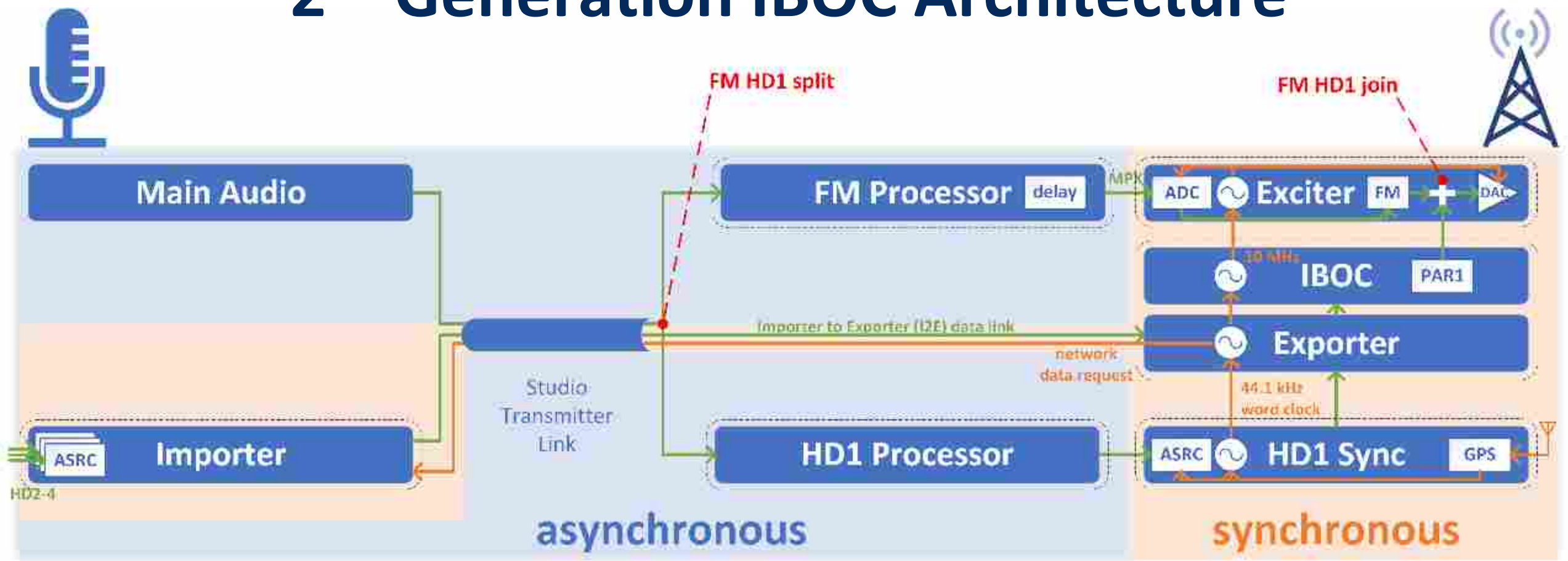
=> Can we improve **IT security** with a new architecture?

HD Radio business models are emerging, but CAPEX is high …

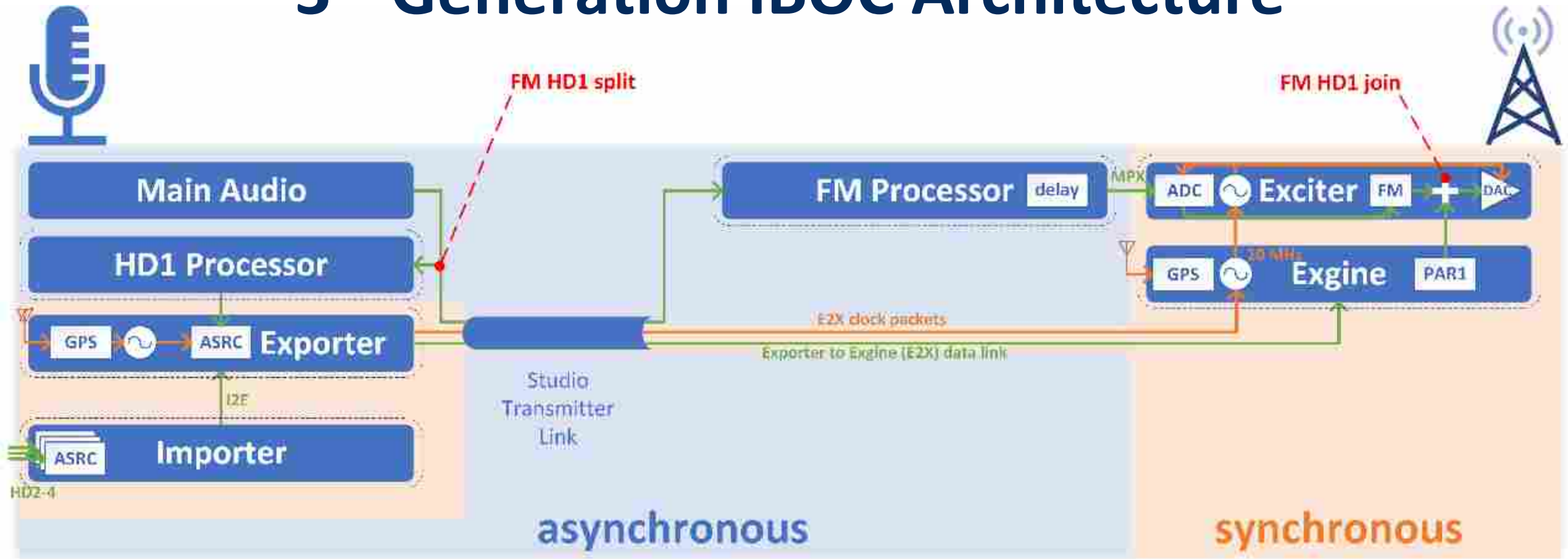
=> Can we reduce **CAPEX** for faster return on investment?

=> Can we offer **OPEX business models** to ease entry into HD Radio?

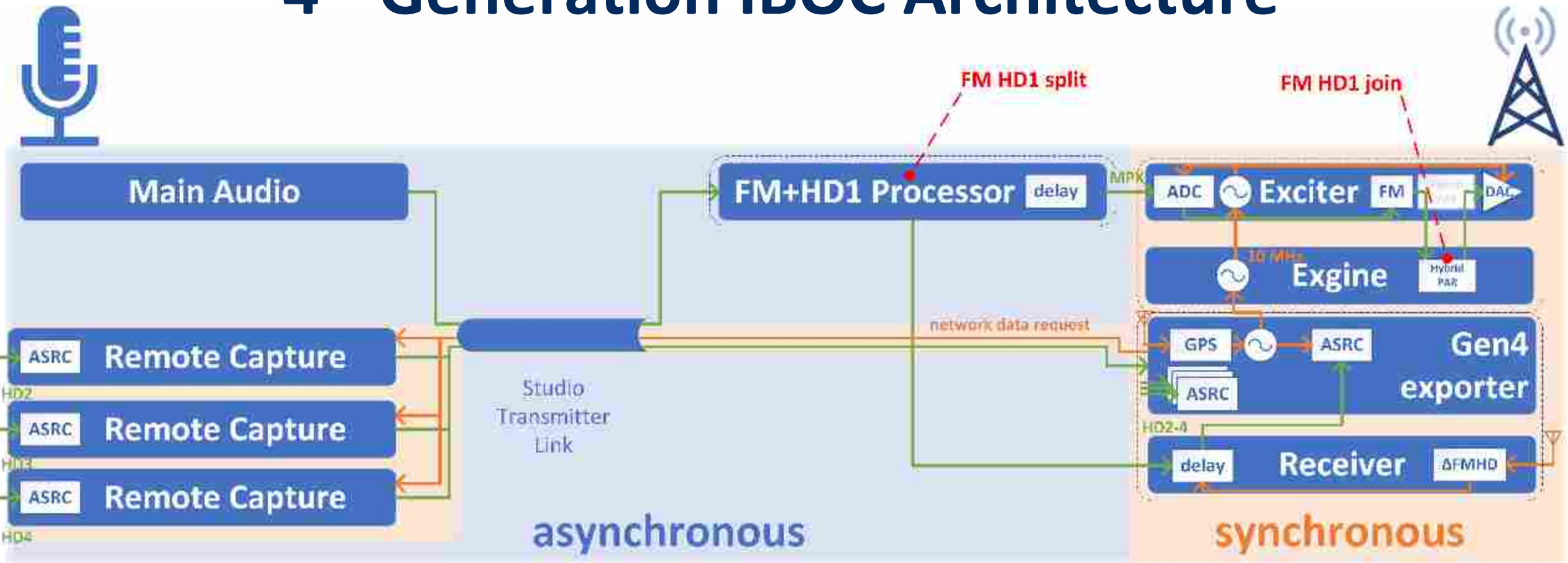
2nd Generation IBOC Architecture



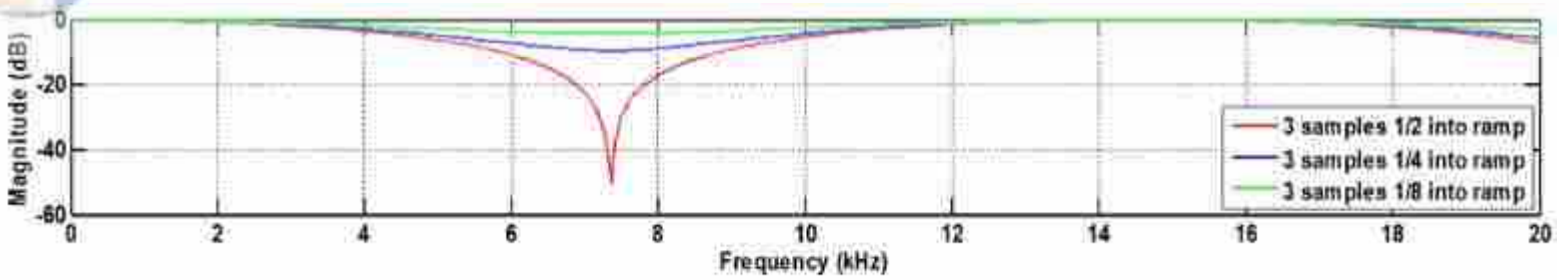
3rd Generation IBOC Architecture

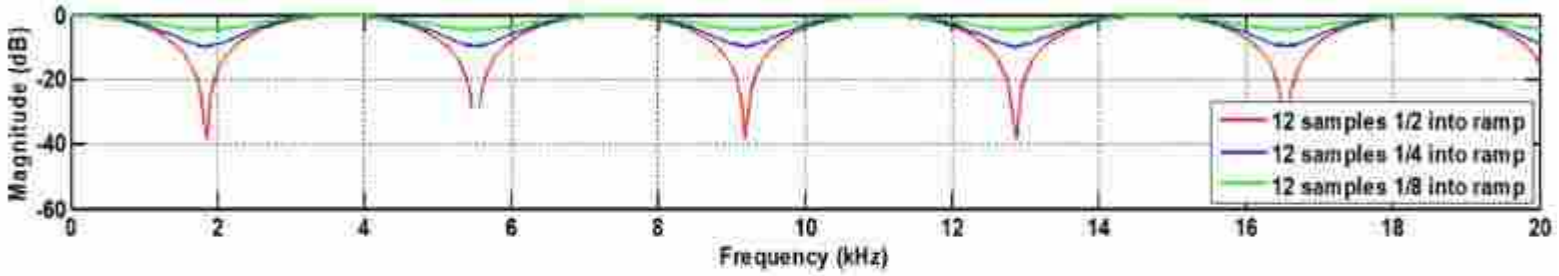


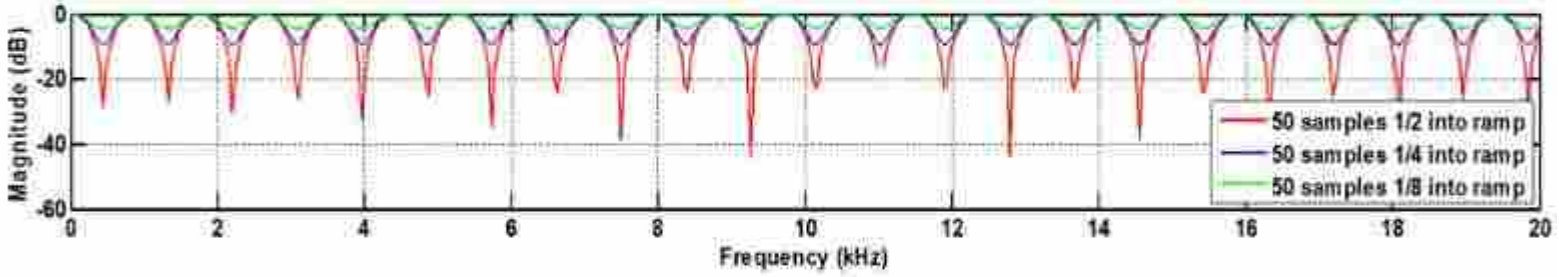
4th Generation IBOC Architecture

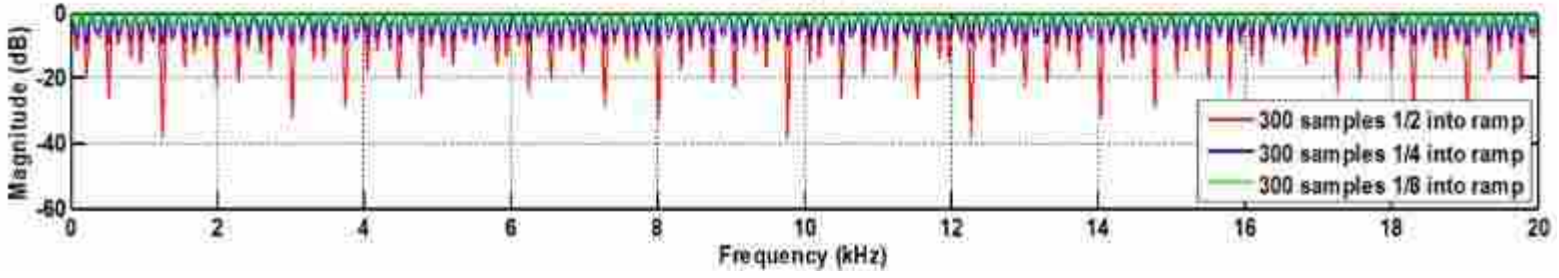


Filtering Effects on HD Blend





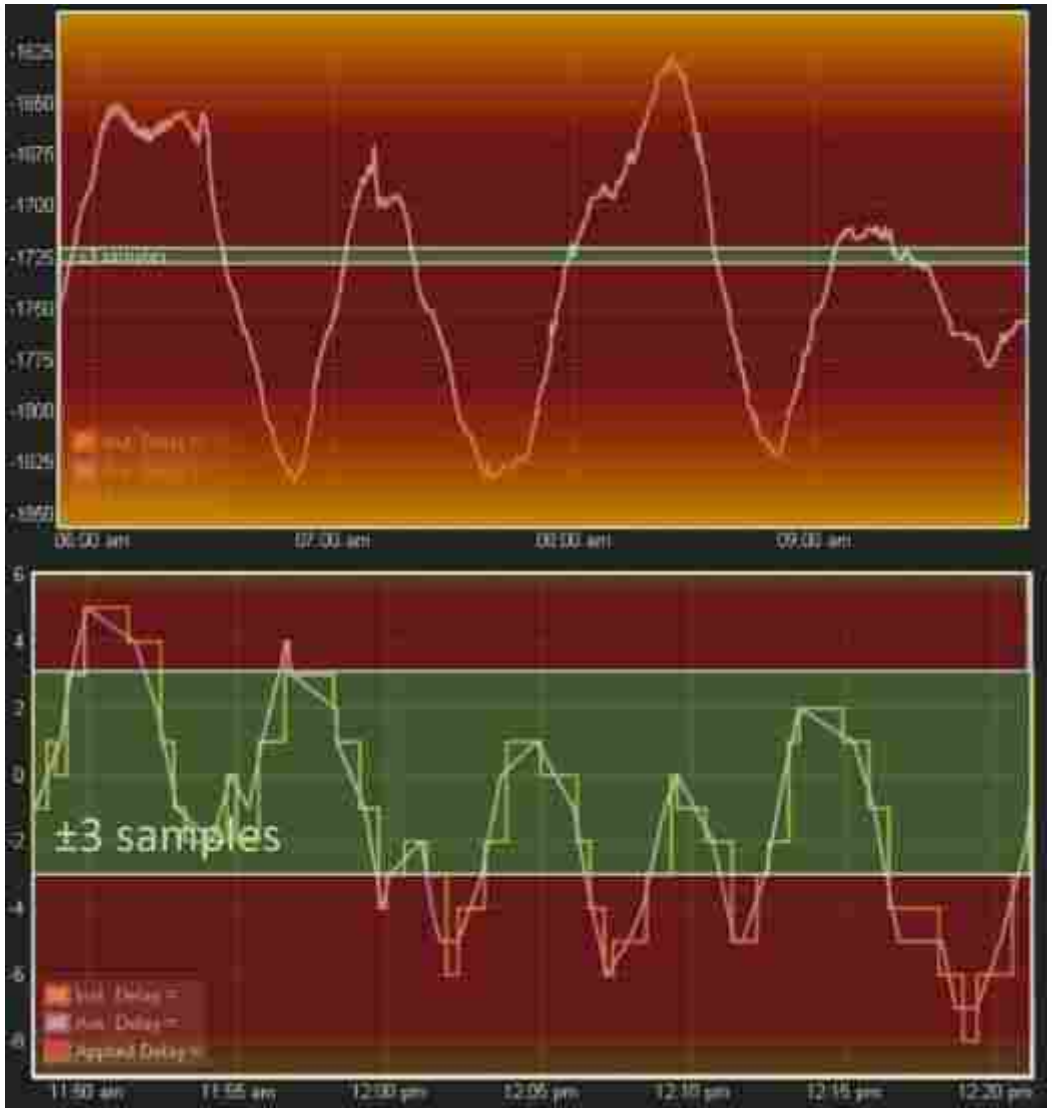




The larger the delay, the lower the impacted audio frequencies but notches become more selective

NRSC spec is +-3 samples (68 µs)

Typical Alignment Results



Challenging to maintain E2X alignment across an STL either without GPS 10 MHz (top) or even with GPS 10 MHz (bottom).

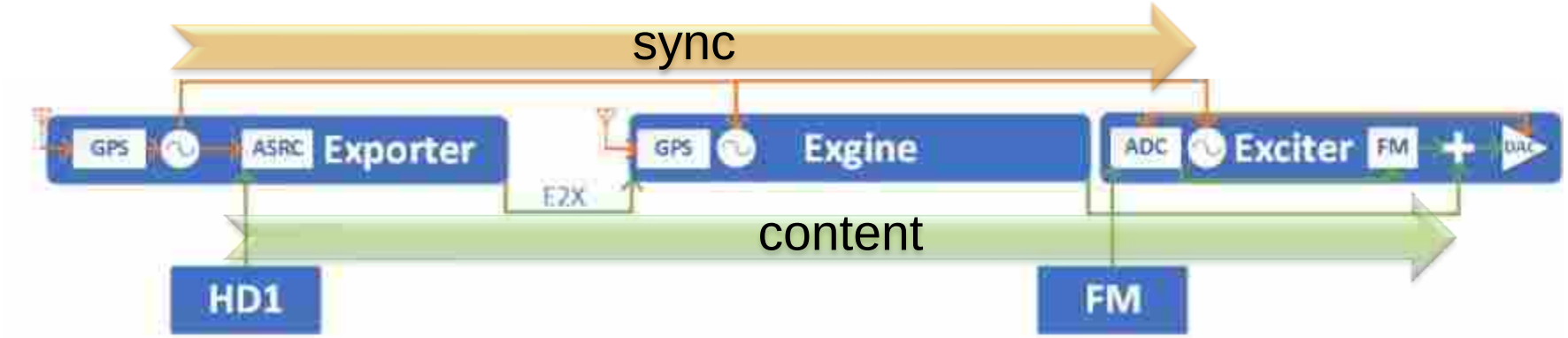
NRSC recommendation: Keep HD equipment at the TX site.

Reactive off-air receivers can compensate, but rapid delay adjustments can impact new self correction receivers.

Synchronous Air-Chain

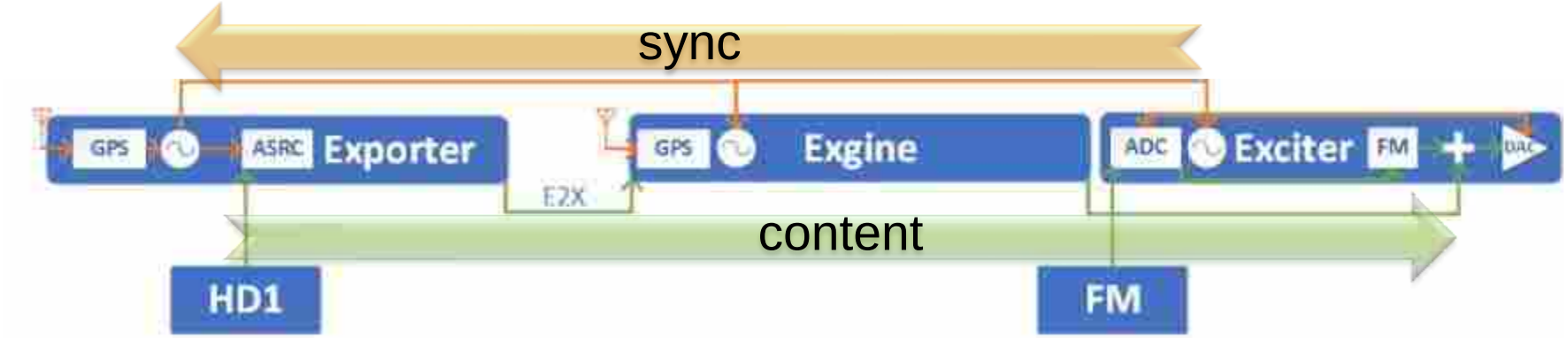
	Ratio	Sample Rate	
GPS produces a 1 pulse per second		1	Hz
This drives a 10 MHz voltage-controlled crystal	$\frac{10e6\ cycles}{1\ PPS}$	10	MHz
This drives a 44.1 kHz word clock	$\frac{44100\ samples}{10e6\ cycles}$	44.1	kHz
This generates L1 frames (65536 audio samples)	$\frac{1\ L1\ frame}{65536\ samples}$	0.67291	Hz
This generates 512 IBOC symbols of 2160 IQ samples	$\frac{1105920\ IQ\ Samples}{1\ L1\ frame}$	744187.5	Hz
The 10 MHz drives the exciter MPX ADC sample rate	$\frac{1\ MPX\ Samples}{2\ IQ\ Samples}$	372093.75	Hz
The 10 MHz drives a direct-to-channel exciter DAC	$\frac{640\ DAC\ Samples}{1\ IQ\ Sample}$	476.28	MHz

Synchronous Air-Chain



- Today's air chain has two entry points: FM and HD1
  - GPS lead ASRC in exporter is a hardware dependency today
- Today's synchronization is feed forward along with content

Synchronous Air-Chain



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- Reverse synchronization following high quality exciter crystal

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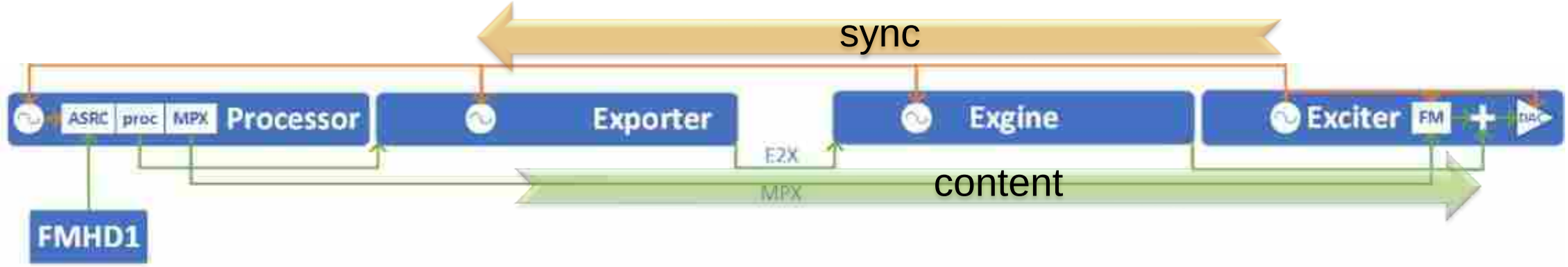

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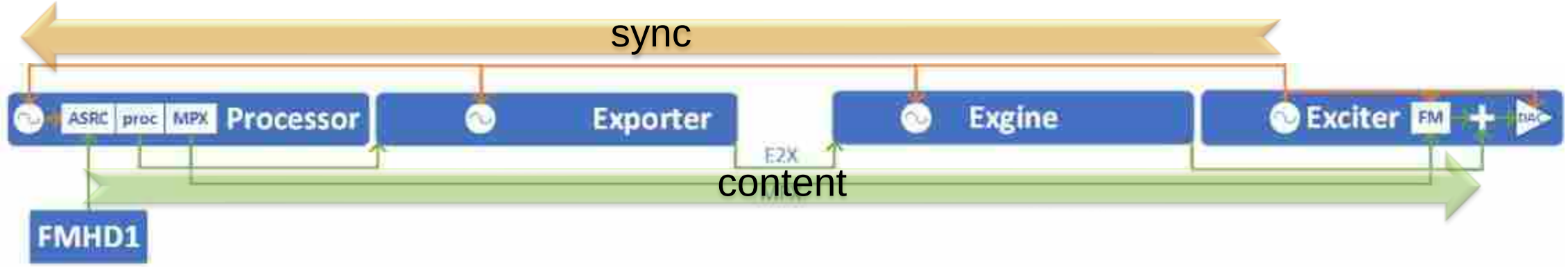
Synchronous Air-Chain



- Today's air chain has two entry points: FM and HD1
  - GPS lead ASRC in exporter is a hardware dependency today
- Today's synchronization is feed forward along with content
- Reverse synchronization following high quality exciter crystal
- Extend content and sync to common FMHD1 entry: split to join
  - Eliminated exporter ASRC, common ASRC for FM/HD1
  - Hardware dependency solved: **software-based HD Radio Air-Chain**

Air-Chain Integrated Transport

Studio Automation | **Audio Processing** | **HD Radio Coding**

Air-Chain Integrated Transport

Studio Automation

Audio Processing

HD Radio Coding

- HD1
- HD2
- HD3
- HD4
- PSD
- Album Art
- Station Logo

Exporter 2 Exgine (E2X)

- L+R audio
- 19 kHz Pilot
- L-R audio
- RDS
- (67 kHz SCA)

Composite (MPX)

Air-Chain Integrated Transport

Studio Automation

FMHD1-HD4

Audio Processing

HD1-HD4

HD Radio Coding

- HD1
- HD2
- HD3
- HD4
- PSD
- Album Art
- Station Logo
- L+R audio
- 19 kHz Pilot
- L-R audio
- RDS
- (67 kHz SCA)

Exporter 2
Exgine (E2X)
4096 44.1 KHz
Audio Samples

MPX | E2X | MPX | E2X

Composite (MPX)
16384 176.4 kHz
MPX Samples
4:1 Ratio

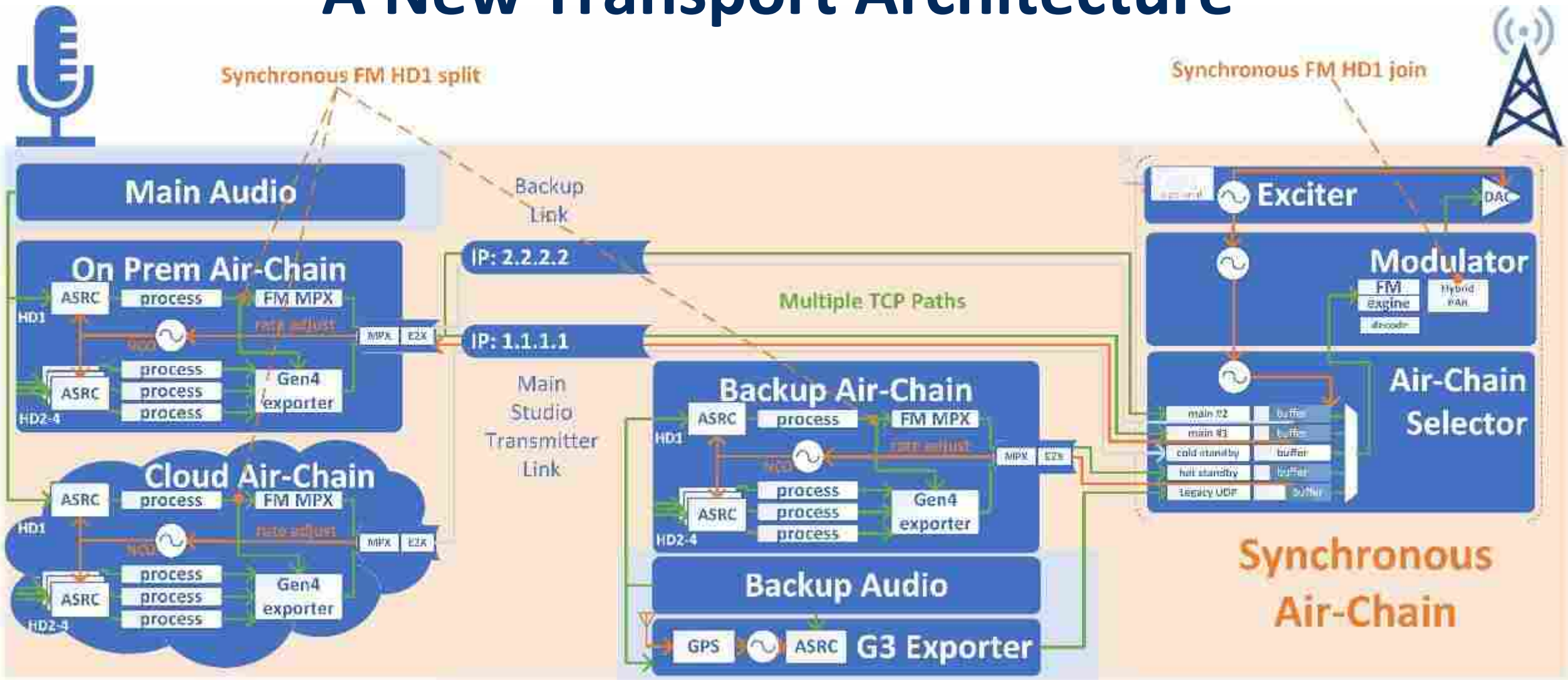
FM+HD Modulation

FM+HD Locked

Transport Comparison

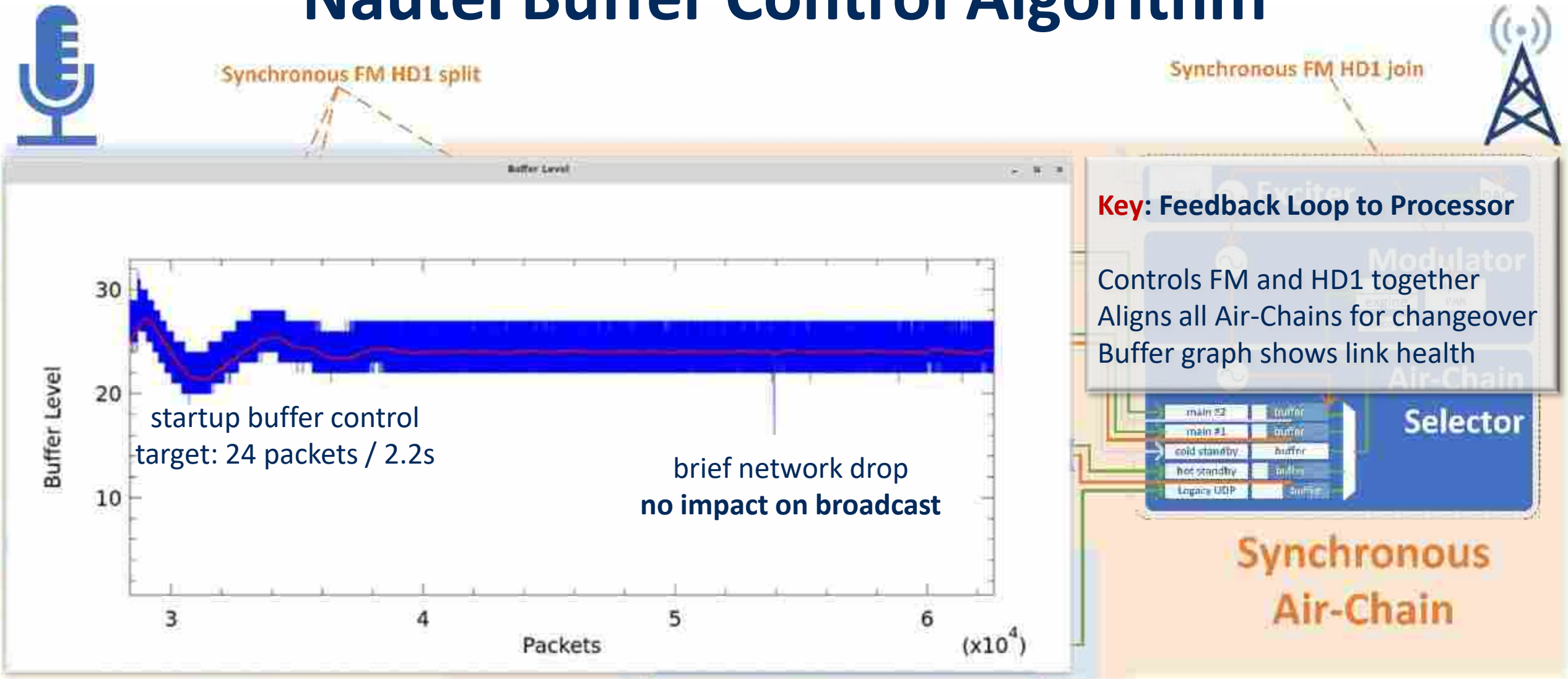
	Gen2	*Gen3*	*Gen4*	*Sync Air-Chain*
Transmitter Site Equipment	5 boxes	2 or 3 with external GPS	4 including delay receiver	1 transmitter plus optional backup audio
STL Bandwidth	**1.6 – 4.6 Mbps**	**1.7 Mbps**	**1.6 – 4.6 Mbps**	**0.8-3.0 Mbps**
FM Bandwidth	1.0 - 1.5 Mbps	1.0-1.5 Mbps	1.0 - 1.5 Mbps	2.8 Mbps 600 kbps (compressed)
HD Bandwidth	3-4.5 Mbps (discrete audio) <60 kbps (importer at studio)	~200 kbps	3-4.5 Mbps (discrete audio) <60 kbps (remote capture client)	~200 kbps
Studio Impact	low	high	medium	high
Content flow	forward	forward	forward	forward
Session connection flow	forward	forward	forward	reverse
Sync flow	forward	forward	forward	reverse
Authentication flow	none	none	none	reverse

A New Transport Architecture

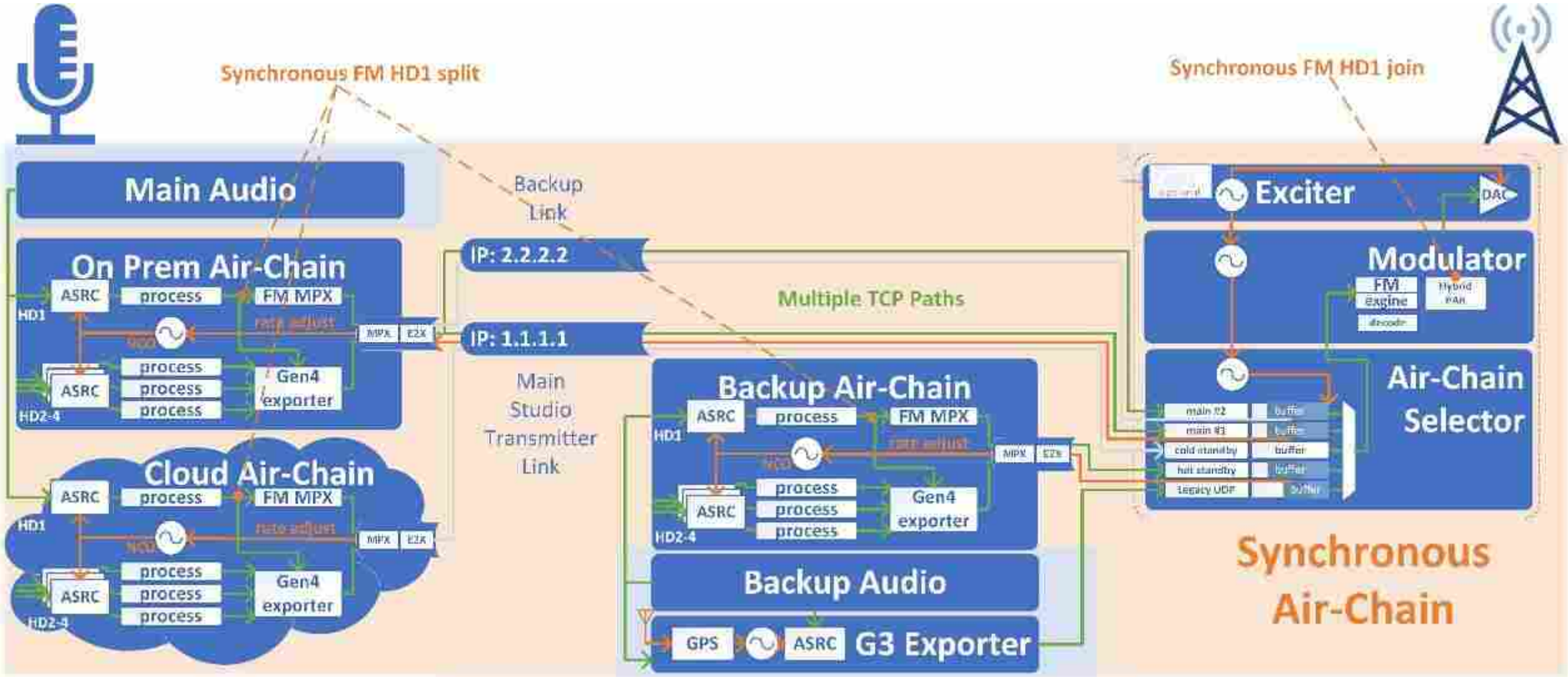


All Air-Chains are Synchronous with Exciter and Each Other

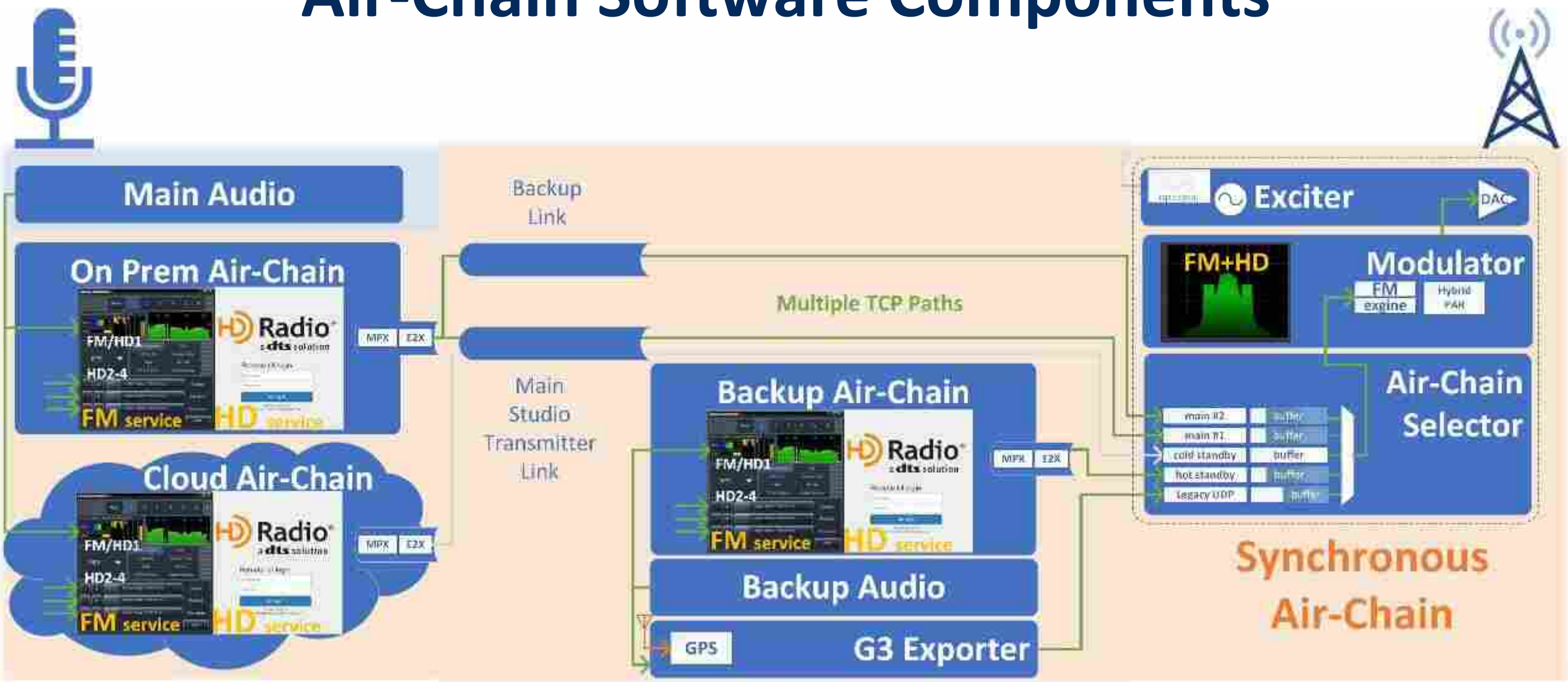
Nautel Buffer Control Algorithm



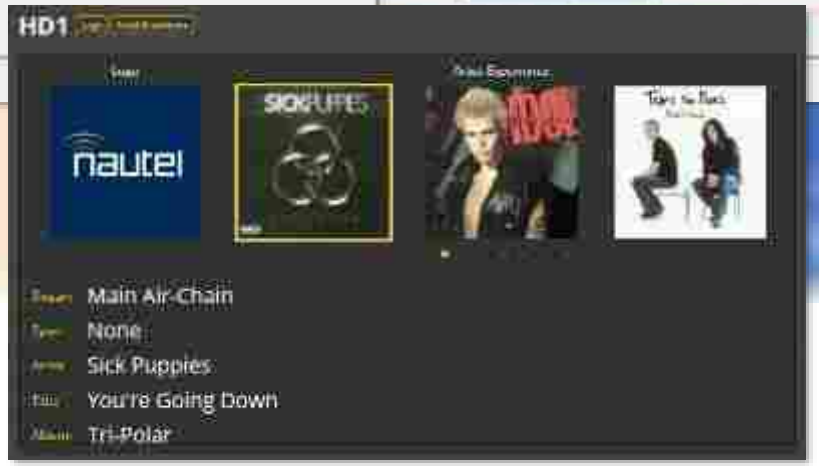
Air-Chain on MaxxKonnect Wireless Modem (approx. 100 min)


Synchronous FM HD1 split
Synchronous FM HD1 join
Main Audio
Backup Link
On Prem Air-Chain
ASRC
process
FM MPX
HD1
MPX
E2X
IP: 2.2.2.2
Multiple TCP Paths
IP: 1.1.1.1
process
process
process
Gen4 exporter
ASRC
HD2-4
Main Studio Transmitter Link
Backup Air-Chain
Cloud Air-Chain
Backup Audio
GPS
ASRC
G3 Exporter
Exciter
DAC
Modulator
Air-Chain Selector
cold standby
buffer
Synchronous Air-Chain

Air-Chain Software Components



Xperi Gen4 HD Radio Encoder

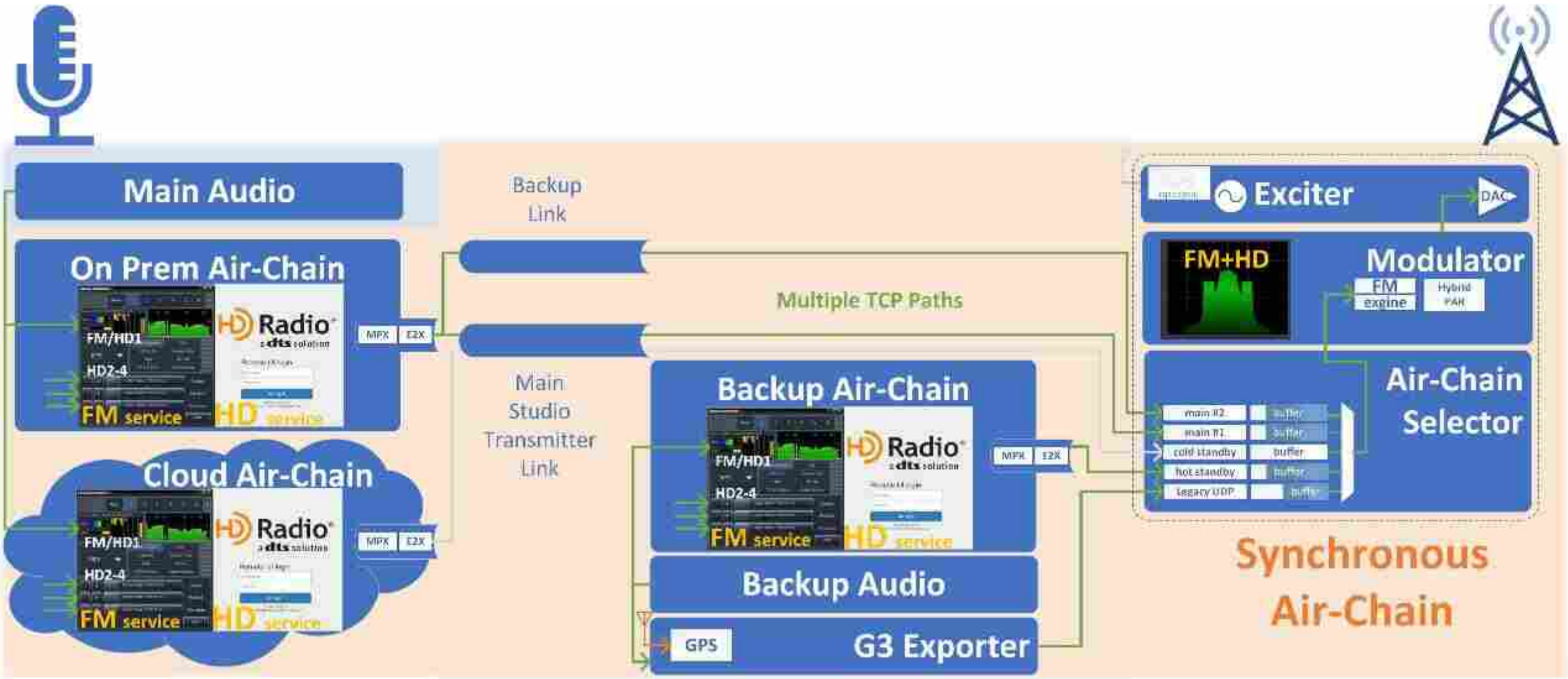


Key: Synchronous Nautel Audio Interface

Encodes HD1-HD4 audio
Adds Station Logo and Artist Experience
Guaranteed HD Radio standardization

Runs in the Cloud

Artist Experience sourced by Xperi Rapid


Main Audio
On Prem Air-Chain
FM/HD1
HD2-4
FM service
HD service
Radio
dts solution
MPX
E2X
Cloud Air-Chain
Backup Link
Multiple TCP Paths
Main Studio Transmitter Link
Backup Air-Chain
Backup Audio
GPS
G3 Exporter
Exciter
DAC
FM+HD
Modulator
FM engine
Hybrid PAR
Air-Chain Selector
main #2
main #1
cold standby
hot standby
Legacy UDP
buffer
Synchronous Air-Chain

Omnia for Nautel

Key: Dual FM+HD1 processing on common input
Processing cores for HD2, HD3, HD4
Livewire AES67, Shoutcast/Icecast inputs
Built-in RDS Generator
Confidence monitor: listen to your audio remotely
Advanced Processing: Undo, Phase Processing, Final Limiter, Downward Expanders, Input AGC, Wideband AGC 1/2/3, Parametric EQ, Stereo Enhancer, Multiband AGC/Limiters, Band Mix

Omnia for Nautel and Xperi Gen4 in AWS

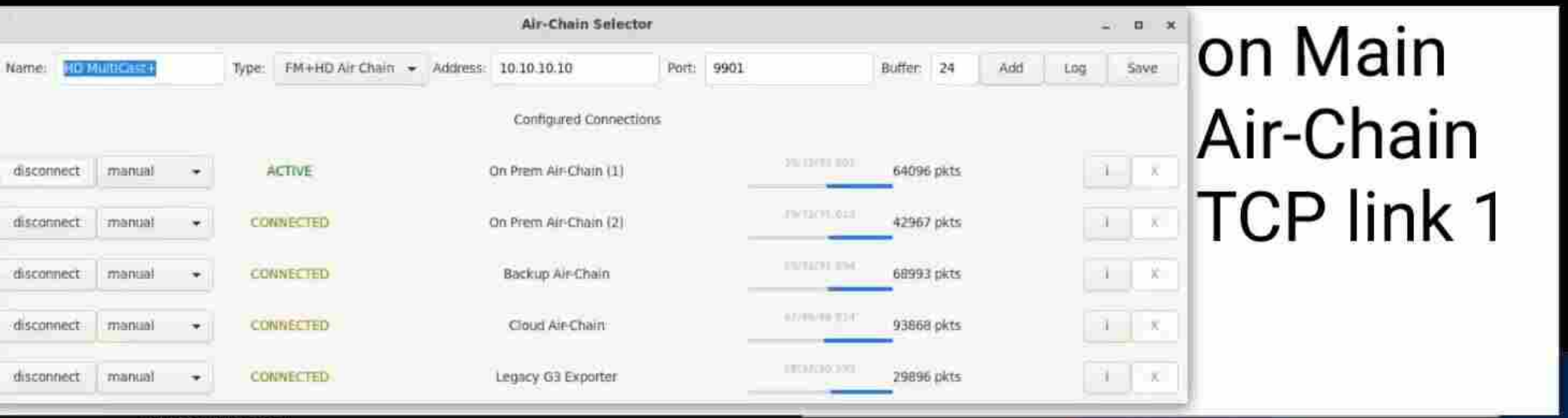
Air-Chain Selector

Air-Chain Selector

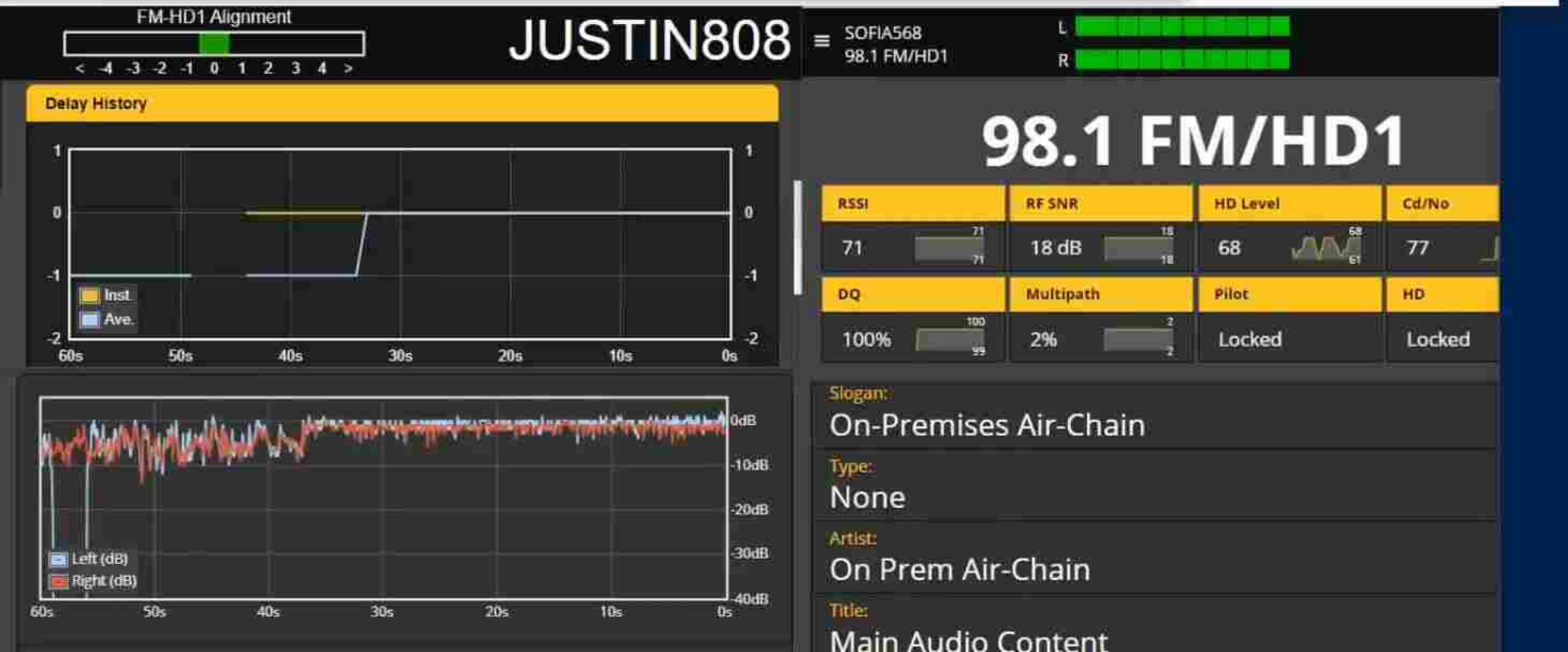
4 Types of Connections
Manual: full control
Cold Standby: connects when needed
Hot Standby: active connection
Multiple TCP: use 2 or more IP paths

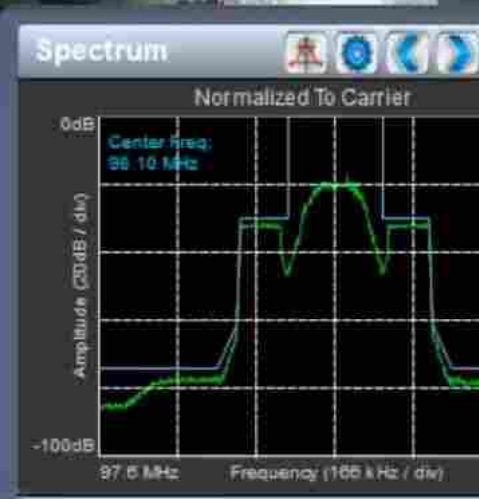
Fixed FM-HD1 Delay across Change Overs

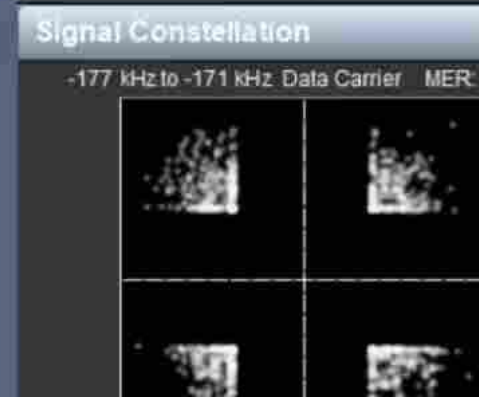
- First changeover with cold standby requiring a new connection to be established
  - May cause silence (not RF drop) if slow to establish
- Second changeover with hot standby
  - Graceful blend to new air chain using receiver blend, no FM interruption
- An integrated transport fixes FM HD1 delay
  - No GPS used
- Buffer alignment offers improved changeover



on Main
Air-Chain
TCP link 1







Air-Chain Selector

Name: HD MultiCast+ Type: FM+HD Air Chain Address: 10.10.10.10 Port: 9901 Buffer: 24 Add Log Save

Configured Connections

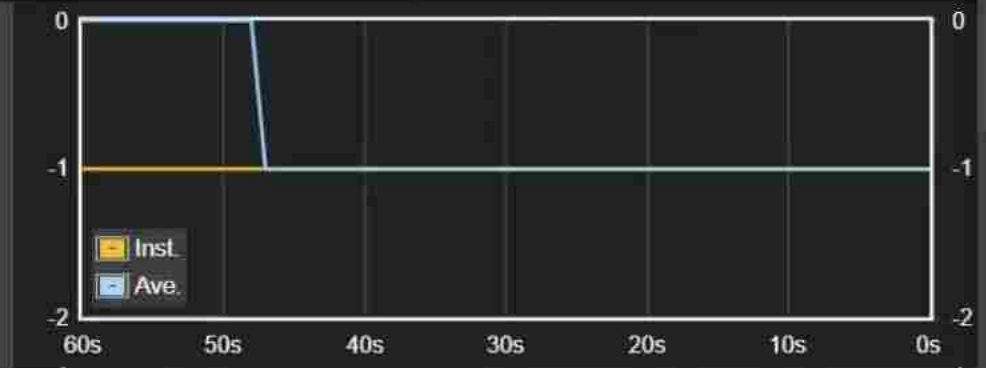
disconnect	hot standby	ACTIVE	On Prem Air-Chain (1)	34684 pkts	i	X
disconnect	hot standby	CONNECTED	On Prem Air-Chain (2)	36494 pkts	i	X
disconnect	hot standby	CONNECTED	Backup Air-Chain	37286 pkts	i	X
connect	manual	READY	Cloud Air-Chain	0 pkts	i	X
connect	manual	READY	Legacy G3 Exporter	0 pkts	i	X

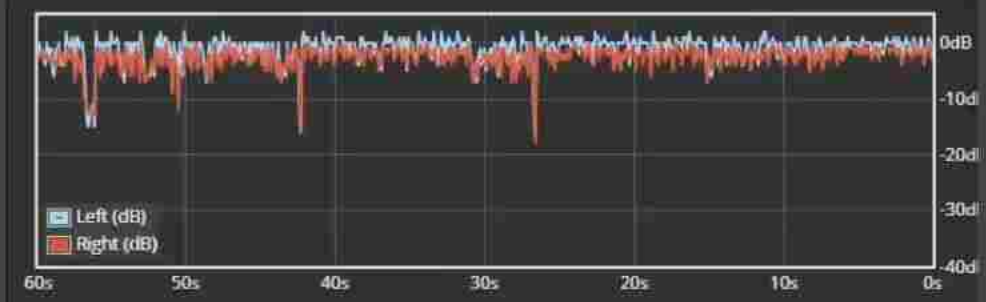
98.1 HD

FM-HD1 Alignment

< -4 -3 -2 -1 0 1 2 3 4 >

JUSTIN





RSSI	RF SNR	HD Level	Cd/No
71	17 dB	62	76

DQ	Multipath	Pilot	HD
100%	3%	Locked	Locked

HD1

Slogan:
On-Premises Air-Chain

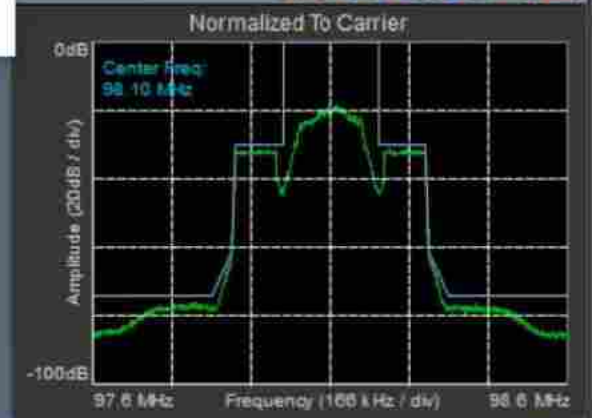
Type:
None

Artist:
On Prem Air-Chain

Title:
Main Audio Content

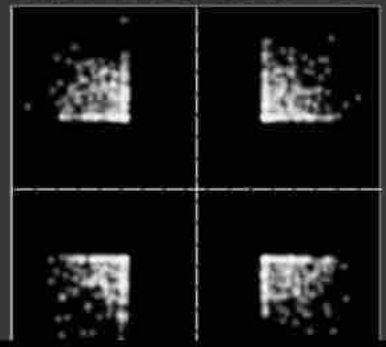
Album:
Dual Ethernet TCP

Spectrum



Signal Constellation

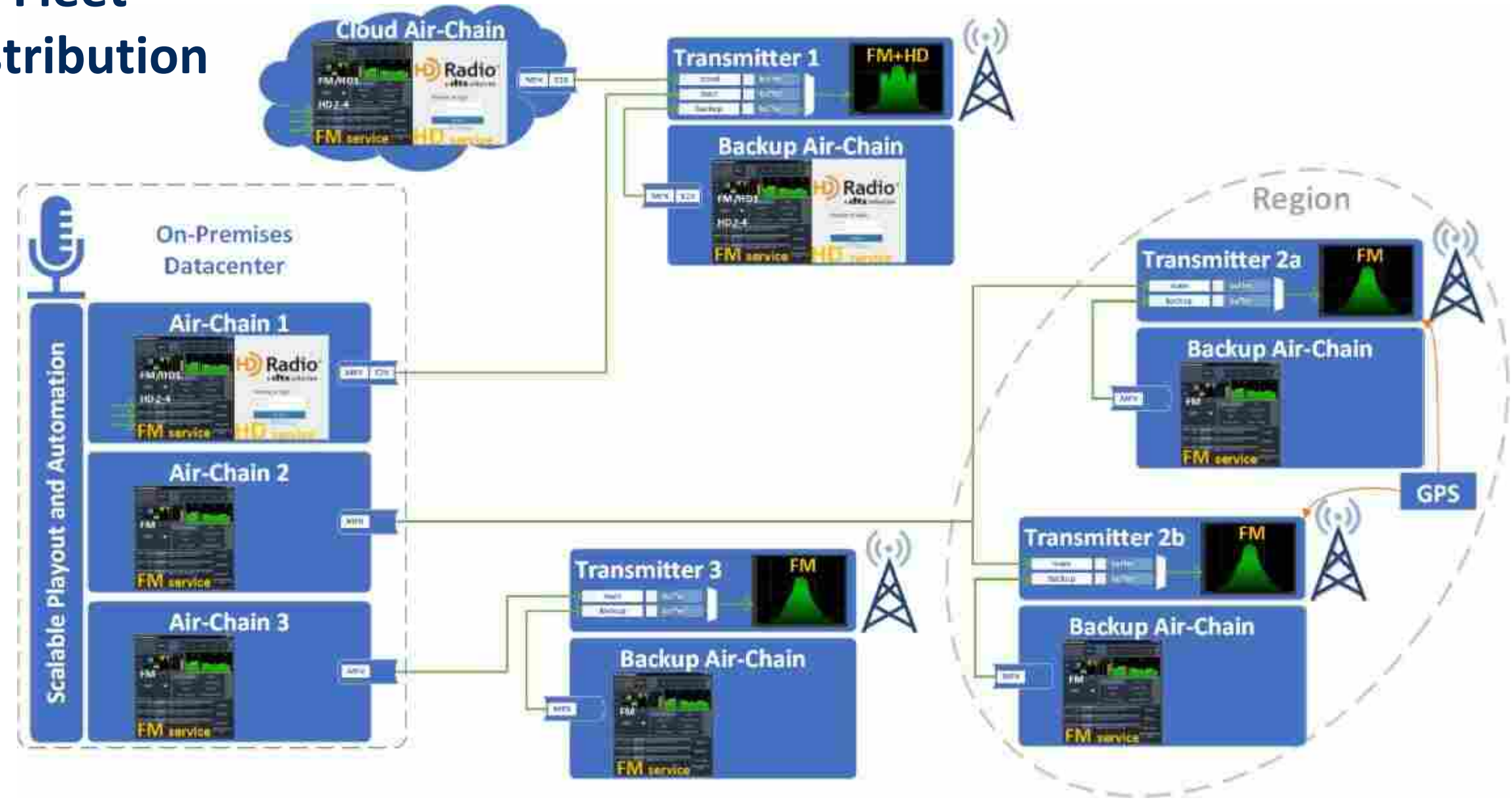
-177 kHz to -171 kHz Data Carrier MER: 14.49



Changeover Comparison

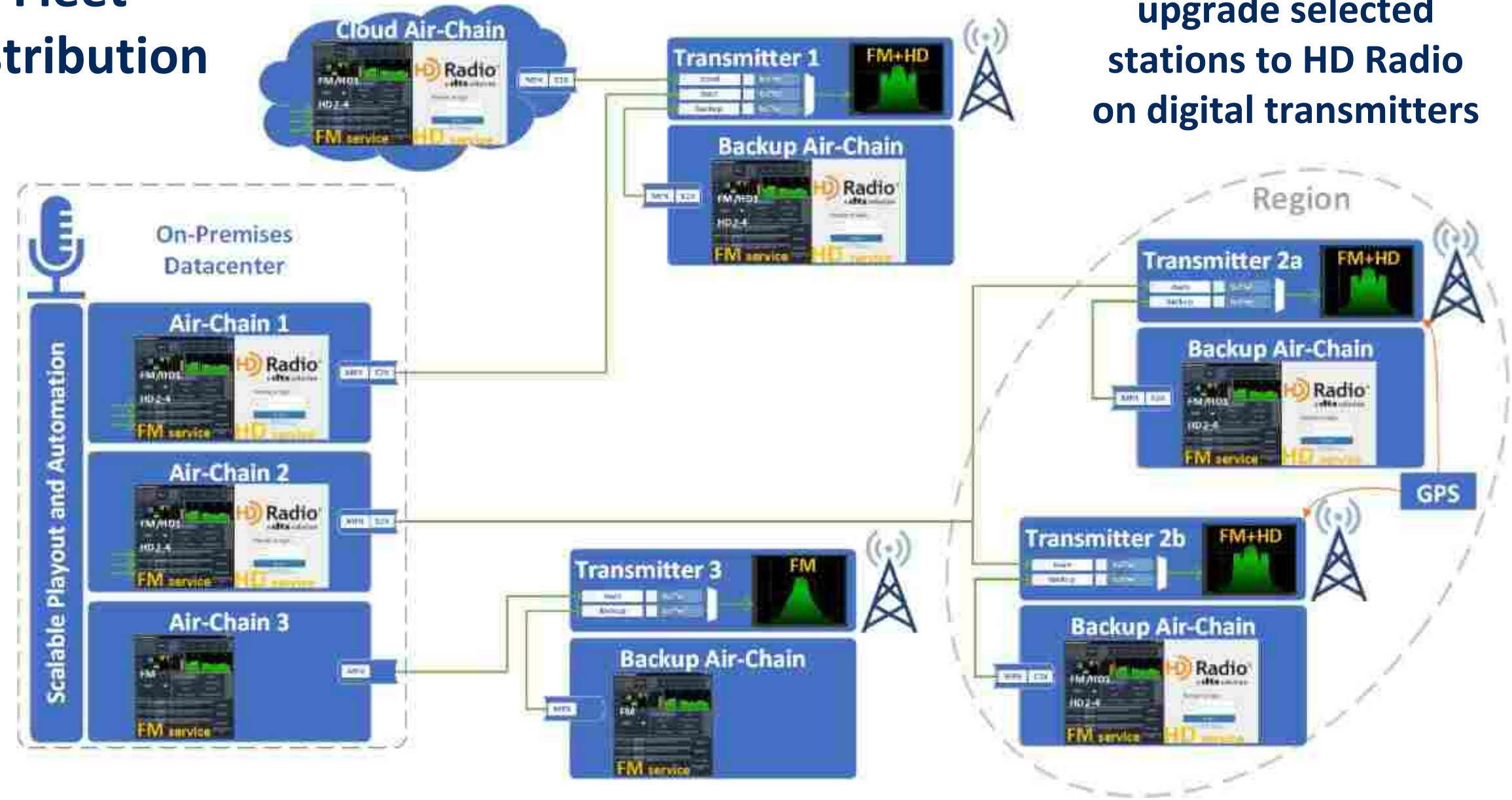
	Dual Exciter	*Cold Standby*	*Hot Standby*	*Multiple Path TCP*
Backup Air-Chain	Yes duplicate equipment	Yes	Yes	No
RF	1-10s to RF on	Not affected	Not affected	Not affected
FM	Initial static	some silence	Instant switch	Hitless
HD1	FM blend 10s-70s	FM blend (short silence)	3-5s FM blend (blends to new)	Hitless
HD2-4	10s-70s silence	<10s silence	3-5s silence	Hitless
FM-HD1 Alignment	No	Yes	Yes	Yes
Supported	All generations	HD Air-chain G3/4 Manual	HD Air-chain	HD Air-chain Bit splicing

Fleet Distribution

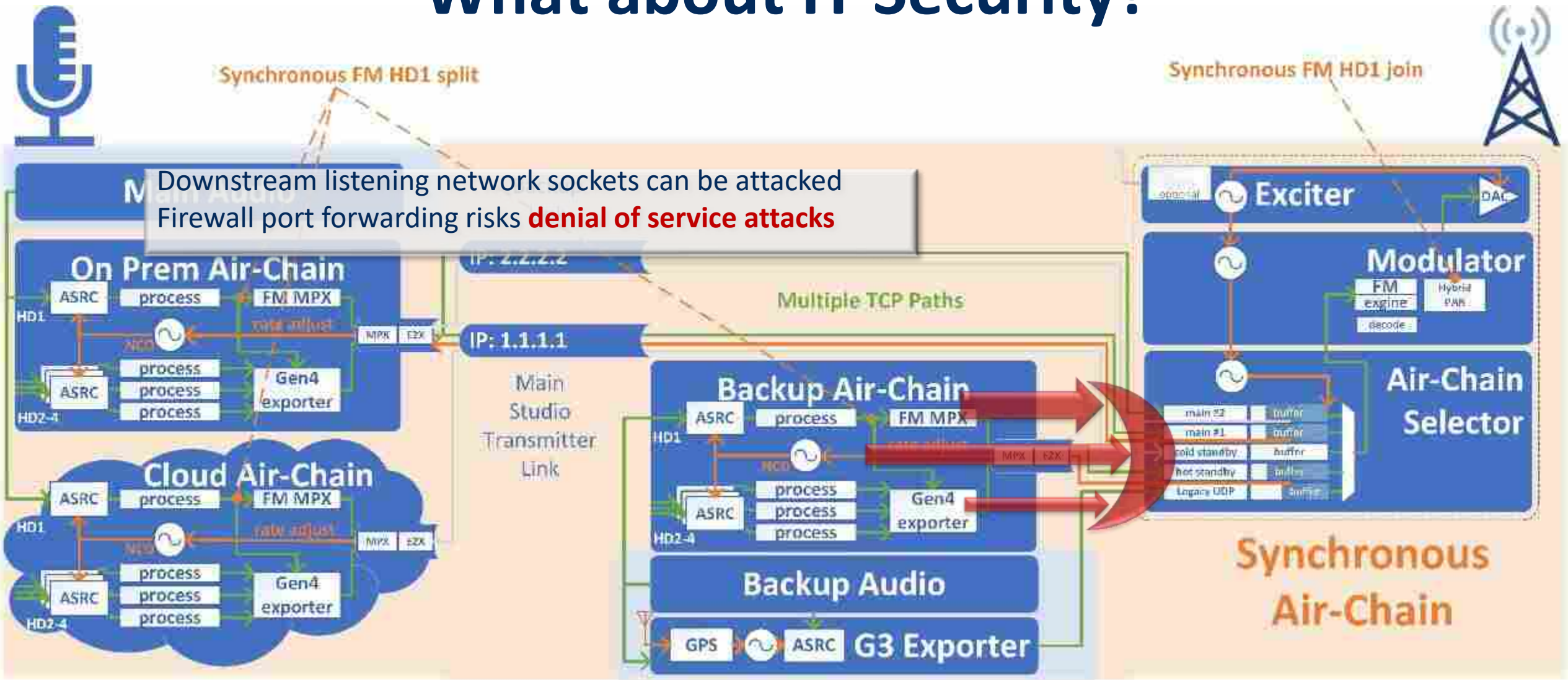


Fleet Distribution

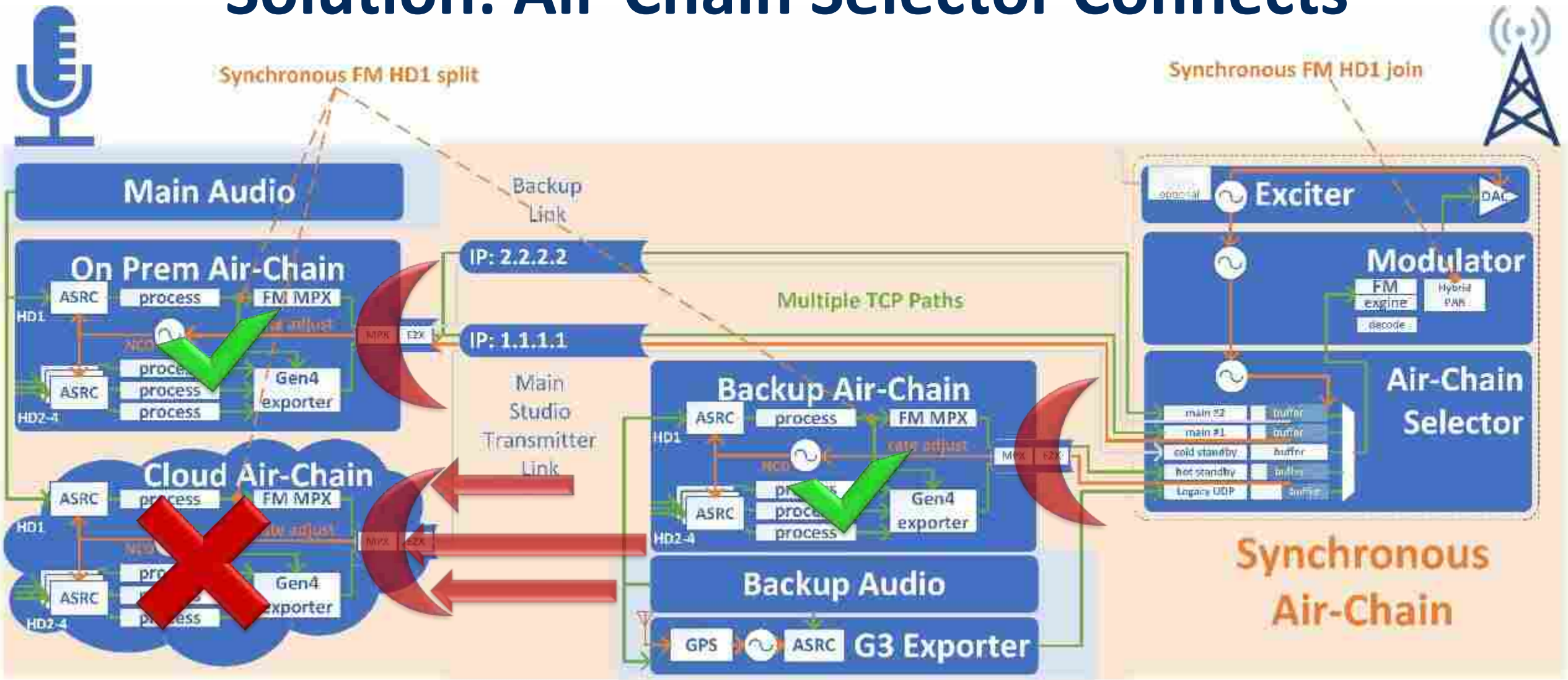
upgrade selected stations to HD Radio on digital transmitters



What about IT Security?

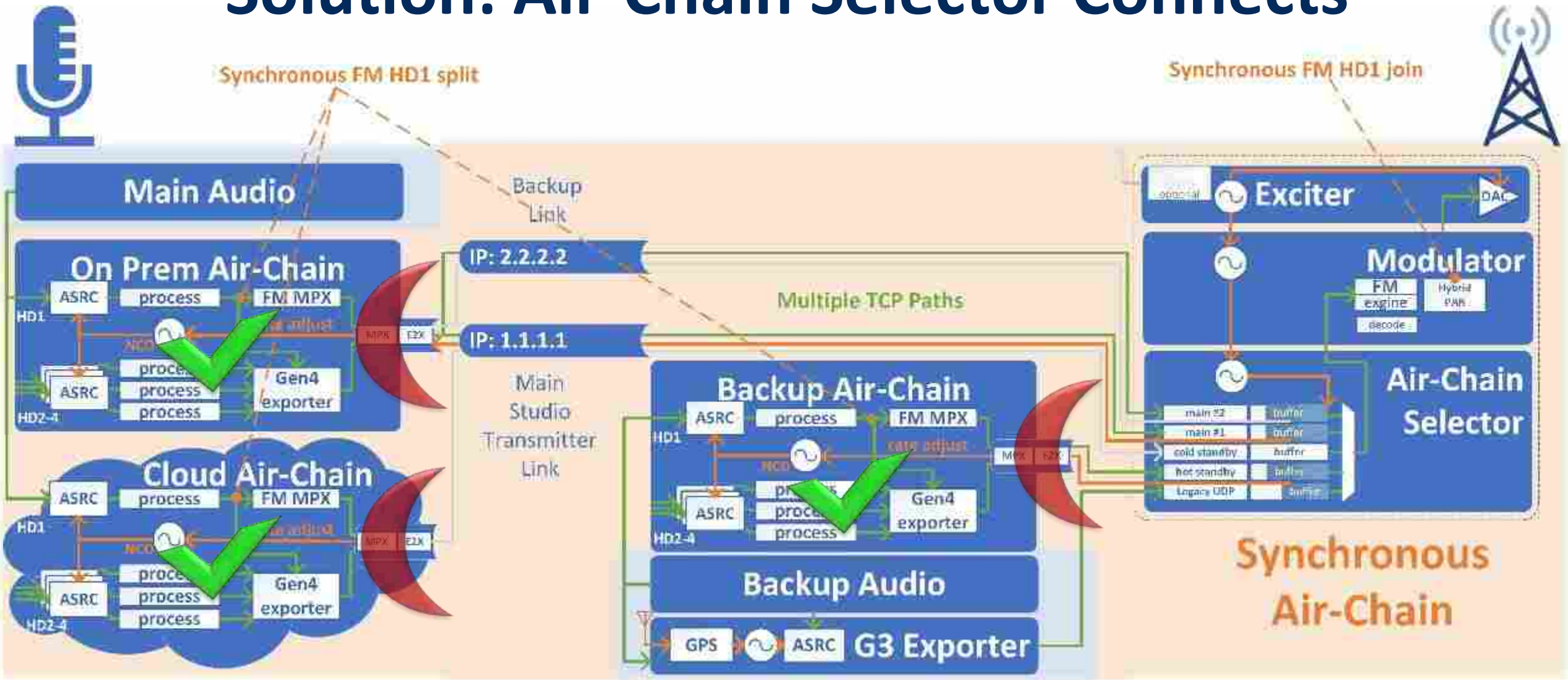


Solution: Air-Chain Selector Connects



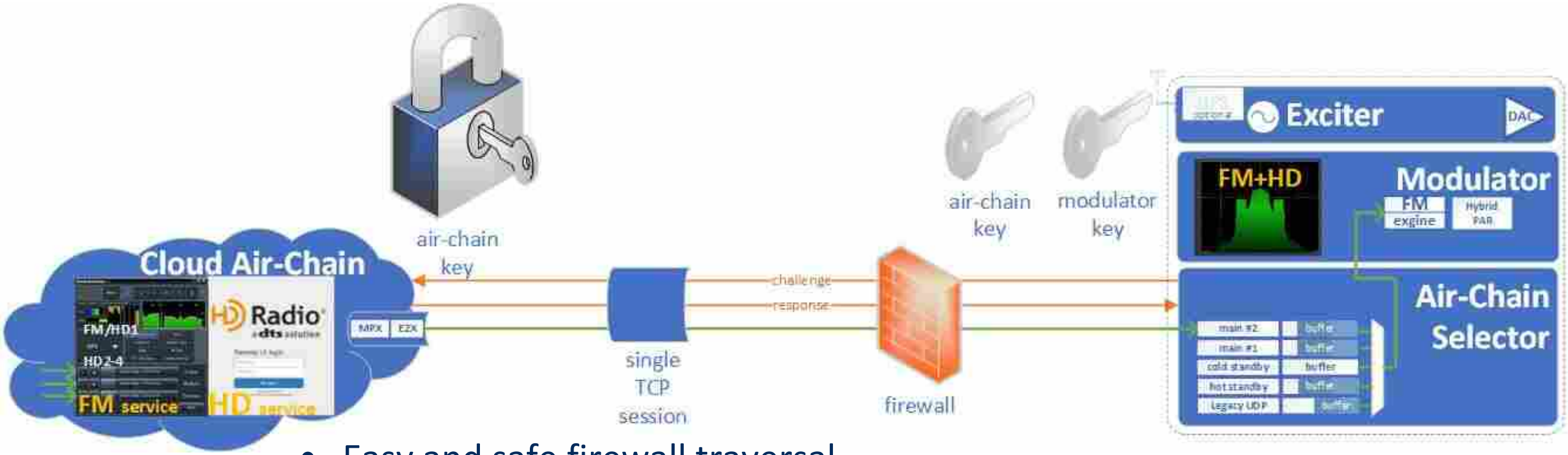
Can we still be attacked? Yes, but other Air-Chains remain OK

Solution: Air-Chain Selector Connects



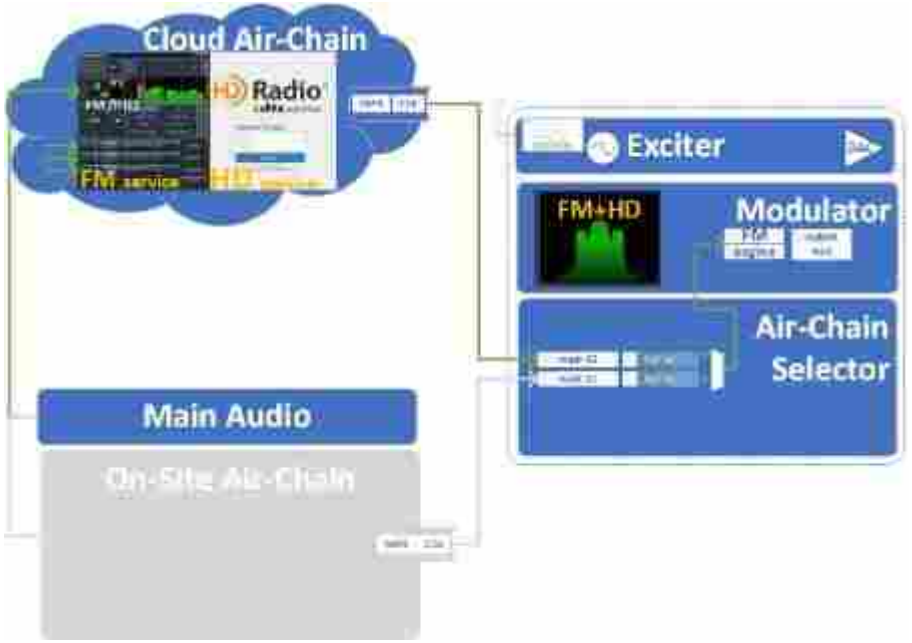
Fix attack vector, restore air-chain from backup, go back on-air

Future Work: Authentication



- Easy and safe firewall traversal
- Must defend against Air-Chain imposter, Man-in-the-Middle
- Air-Chain key creates and check challenge/response
- Modulator key locks to hardware and can identify itself to air-chain
- Content encryption optional, broadcast will be public in seconds

Current Work and Status



- April 2022: On-air at KVSC, St. Cloud MN both local and AWS Air-Chain

Current Work and Status

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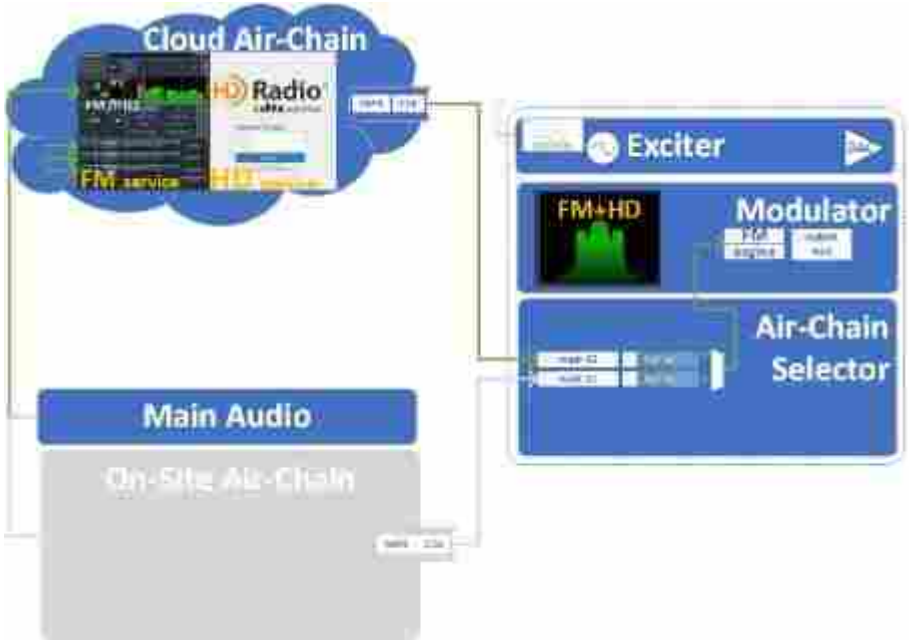
- NAB Show Demonstration

Current Work and Status

- April 2022: On-air at KVSC, St. Cloud MN both local and AWS Air-Chain
- NAB Show Demonstration and BEITC Paper
- **Omnia for Nautel** shipping for HD2-4
  - Supported on HD MultiCast+ platform

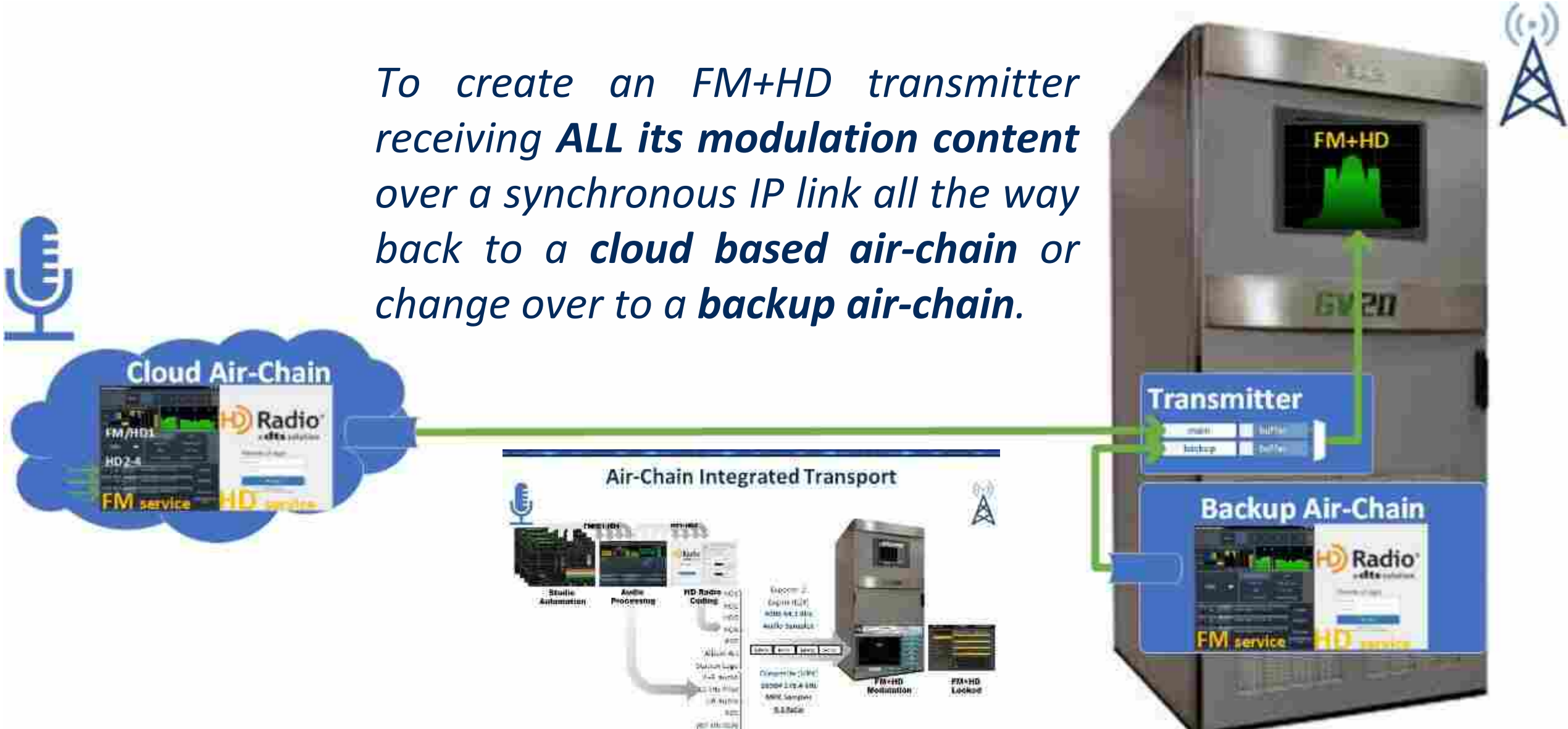
Current Work and Status



- April 2022: On-air at KVSC, St. Cloud MN both local and AWS Air-Chain
- NAB Show Demonstration
- **Omnia for Nautel** shipping for HD2-4
  - Supported on HD MultiCast+ platform
- Fall: Further On-Air trials
- On-going: Standardization work with NRSC

Vision Accomplished

To create an FM+HD transmitter receiving ***ALL its modulation content*** *over a synchronous IP link all the way back to a* ***cloud based air-chain*** *or change over to a* ***backup air-chain****.*



Thank You