



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

Central Canada Broadcast Engineers,
Technologists & Technicians Conference
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Nautel Ltd.



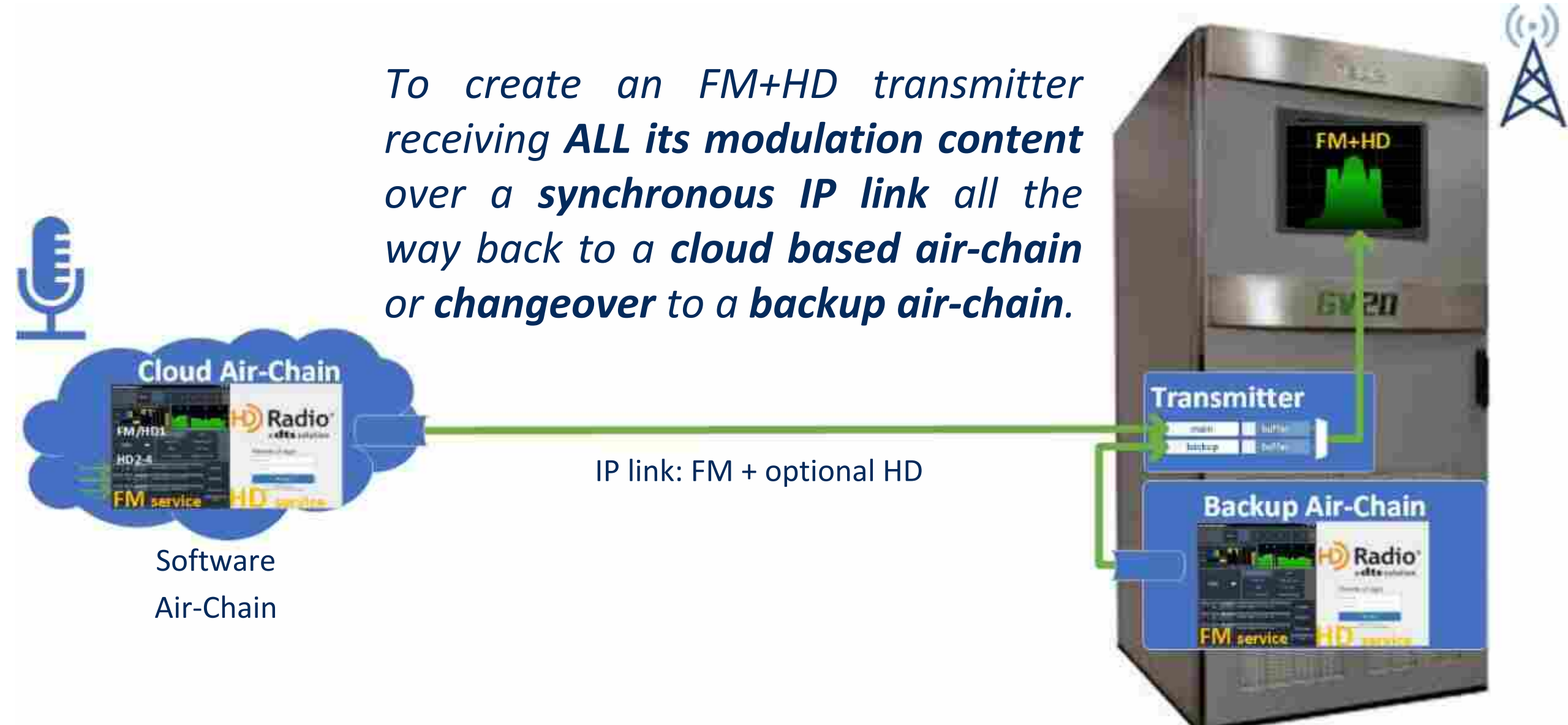
Agenda



- 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**.





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?

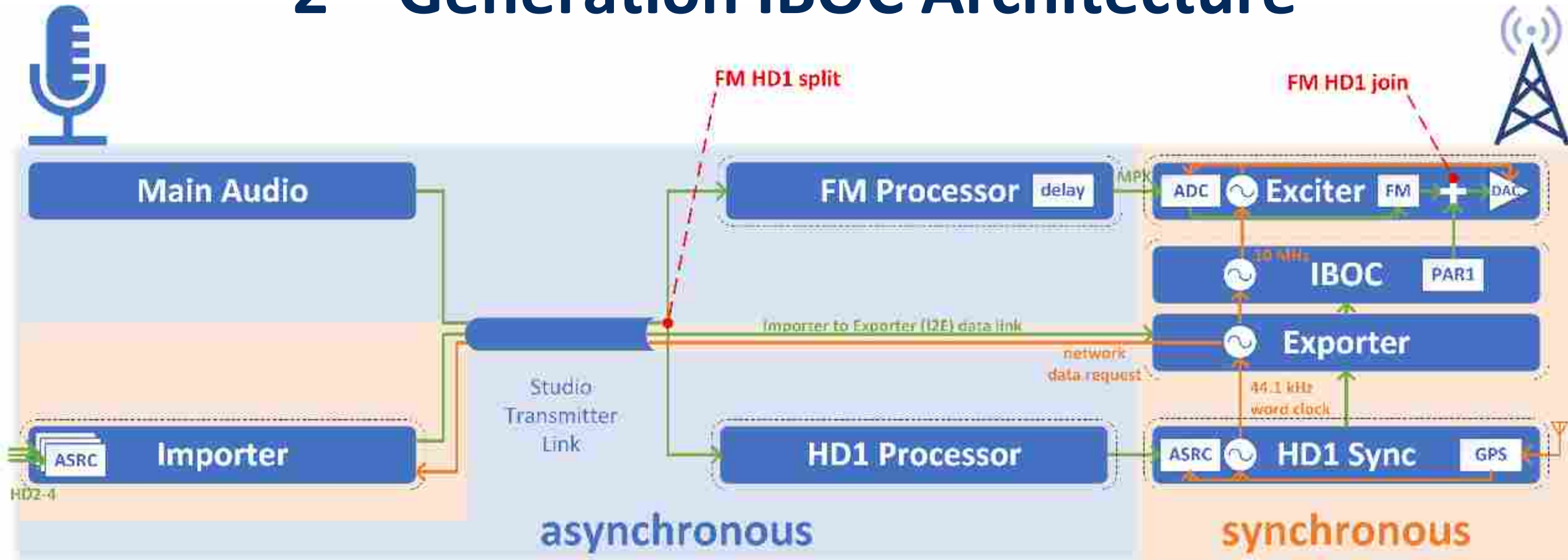
=> Can we improve **IT security** with a new architecture?

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

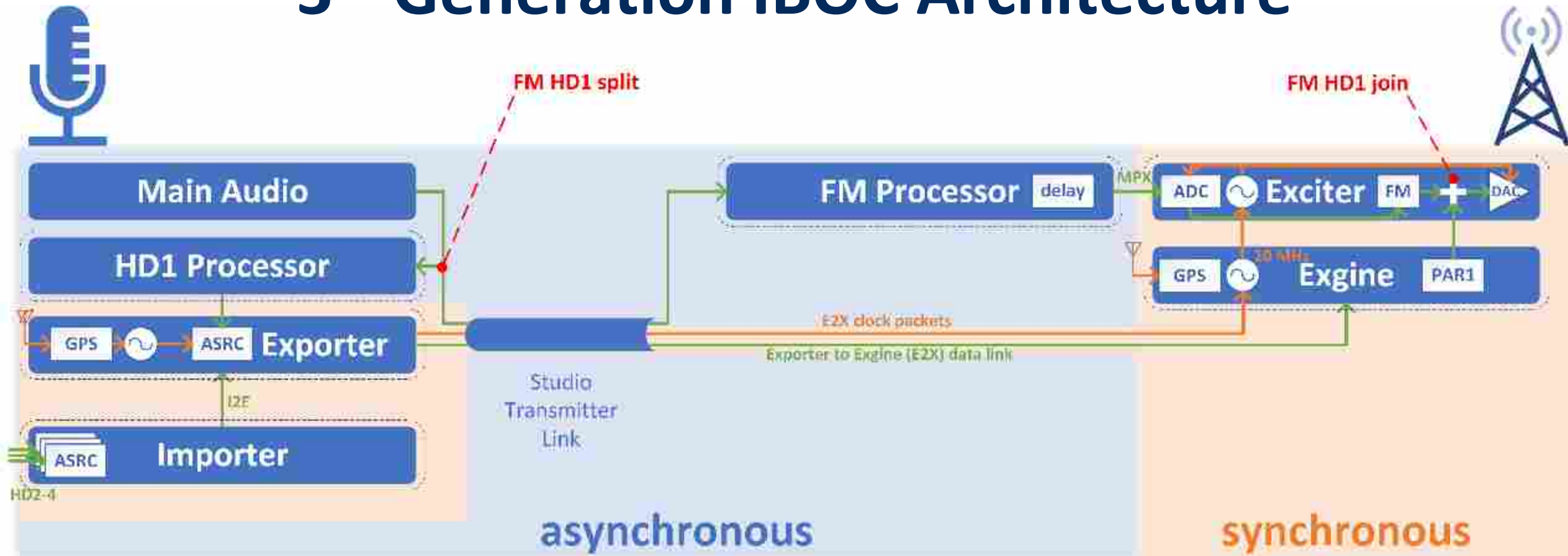
=> Can we reduce **CAPEX** for faster return on investment?

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

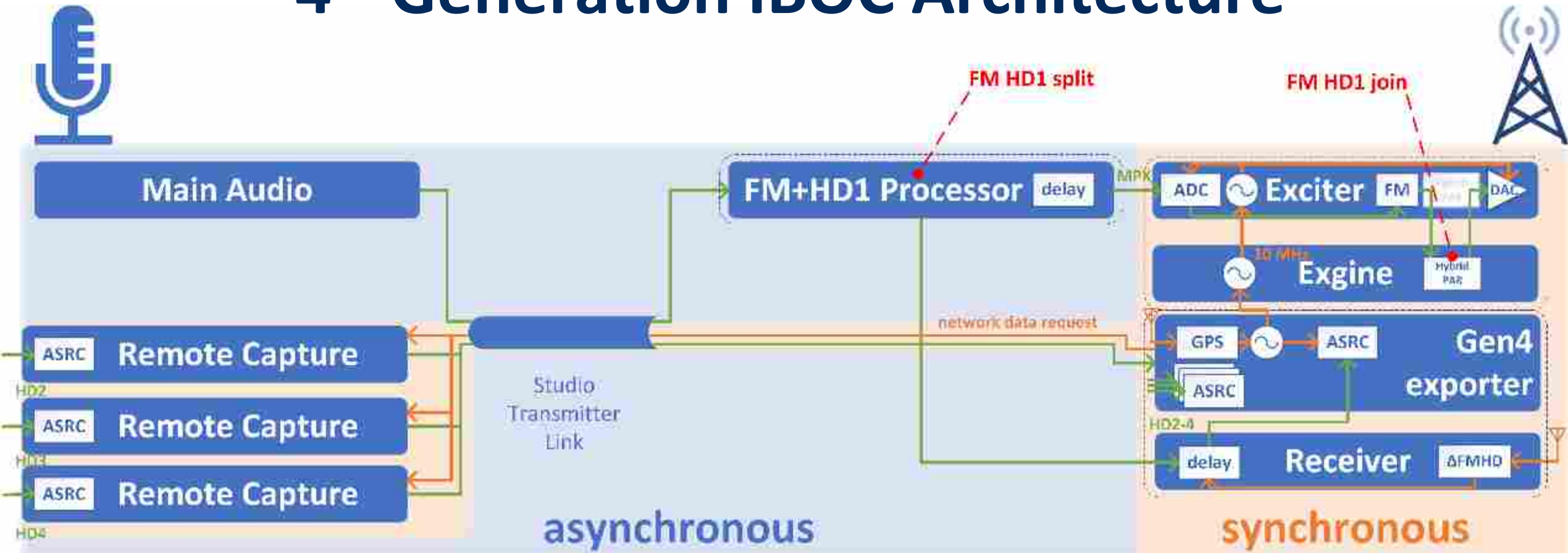
2nd Generation IBOC Architecture



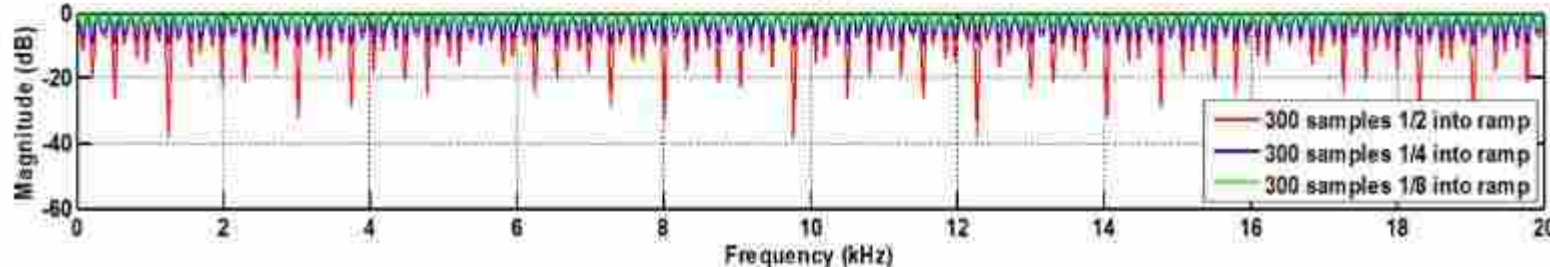
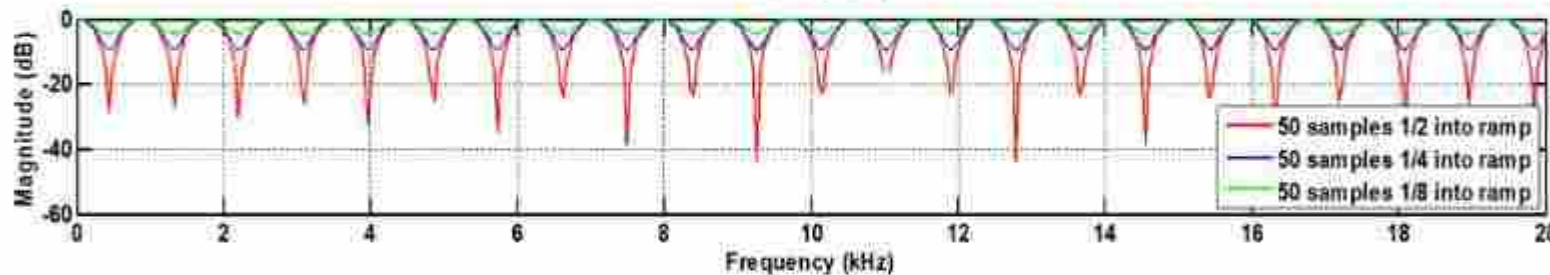
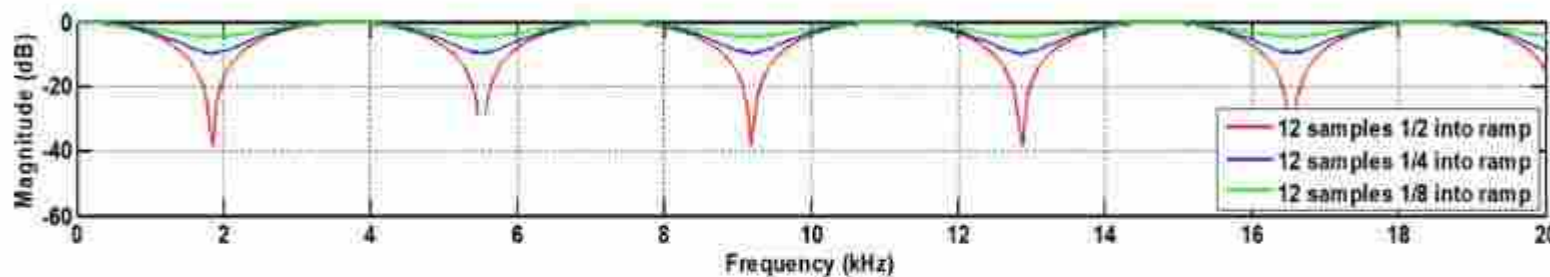
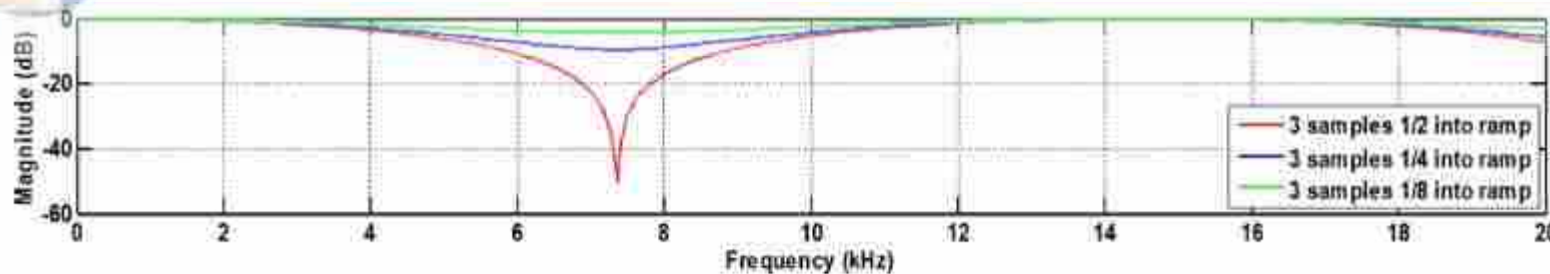
3rd Generation IBOC Architecture



4th Generation IBOC Architecture



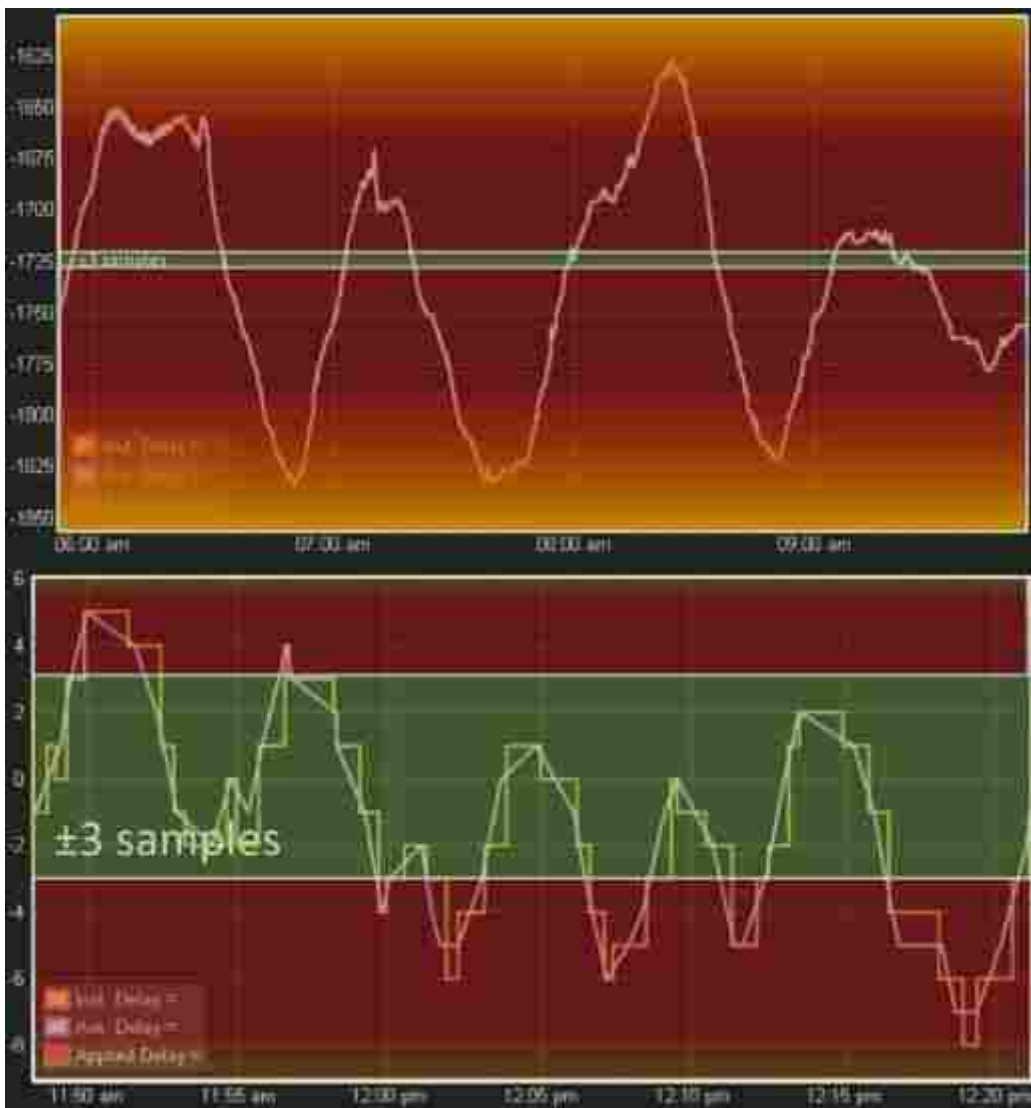
Filtering Effects on HD Blend



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

NRSC spec is ± 3 samples (68 μ s)

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.

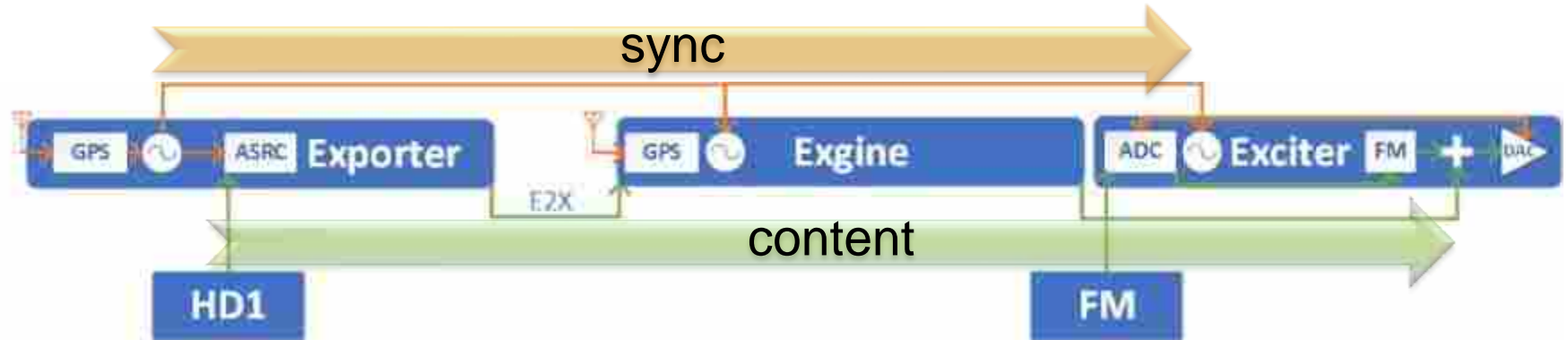
Reactive off-air receivers can compensate, but rapid delay adjustments can impact new self correction receivers.

Synchronous Air-Chain



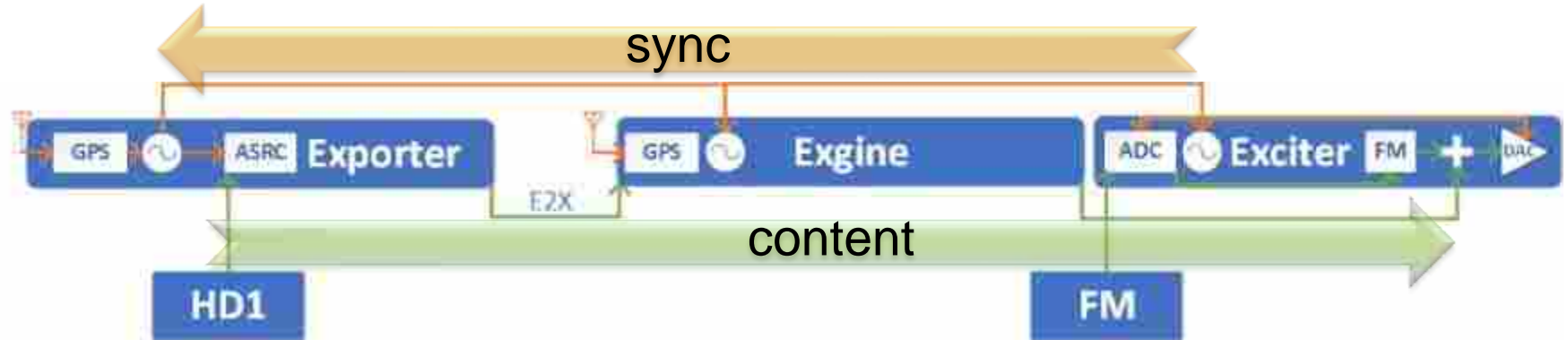
	Ratio	Sample Rate
GPS produces a 1 pulse per second		1 Hz
This drives a 10 MHz voltage-controlled crystal	$\frac{10e6 \text{ cycles}}{1 \text{ PPS}}$	10 MHz
This drives a 44.1 kHz word clock	$\frac{44100 \text{ samples}}{10e6 \text{ cycles}}$	44.1 kHz
This generates L1 frames (65536 audio samples)	$\frac{1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

Synchronous Air-Chain



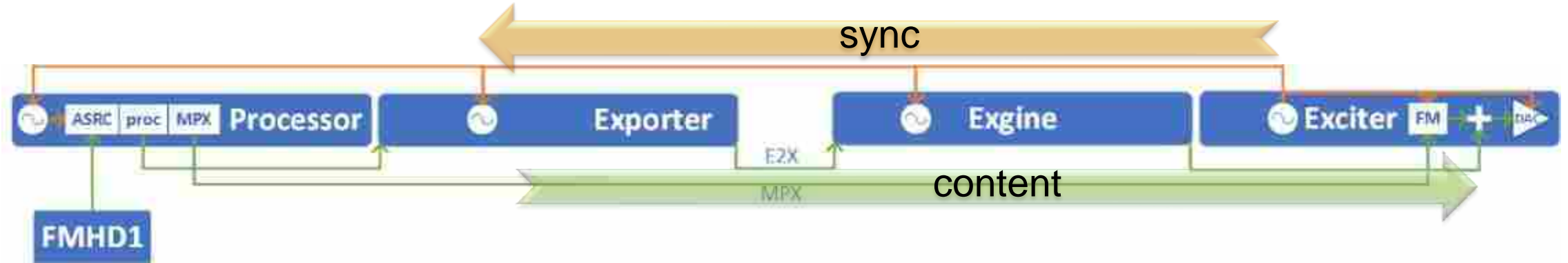
- Today's air chain has two entry points: FM and HD1
 - GPS lead ASRC in exporter is a hardware dependency today
- Today's synchronization is feed forward along with content

Synchronous Air-Chain



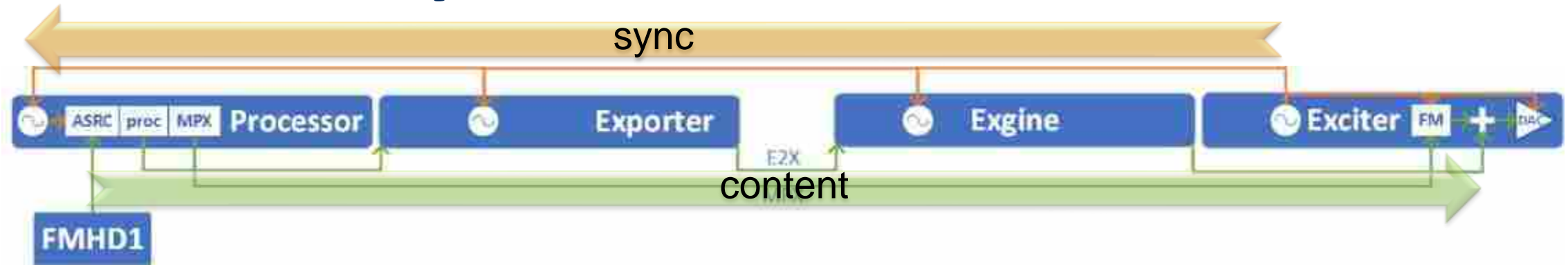
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- Reverse synchronization following high quality exciter crystal

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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



Air-Chain Integrated Transport



Studio Automation

Audio Processing

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)

Composite (MPX)



Air-Chain Integrated Transport



Studio Automation

Audio Processing

HD Radio Coding

- HD1
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- L-R audio
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Exporter 2
Exgine (E2X)
4096 44.1 KHz
Audio Samples



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



FM+HD Modulation



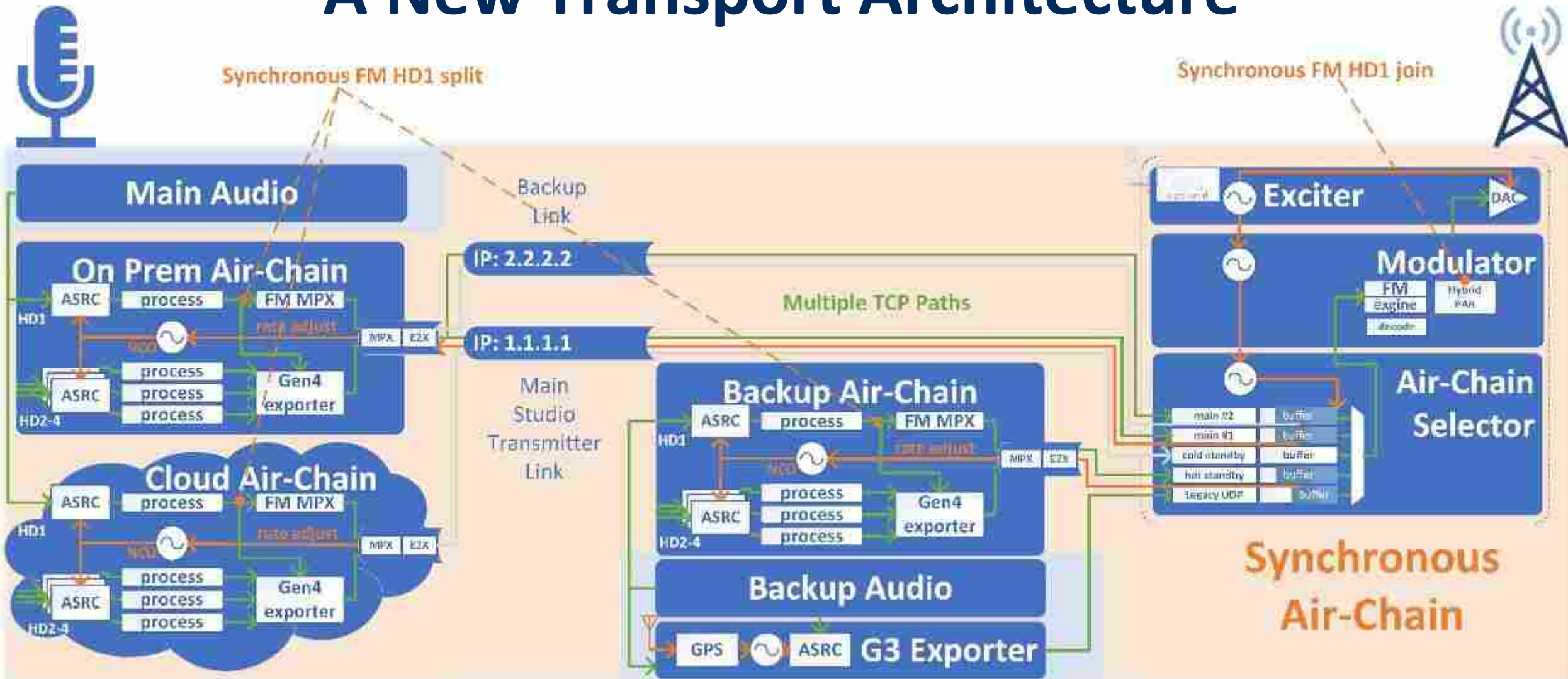
FM+HD Locked

Transport Comparison



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

A New Transport Architecture



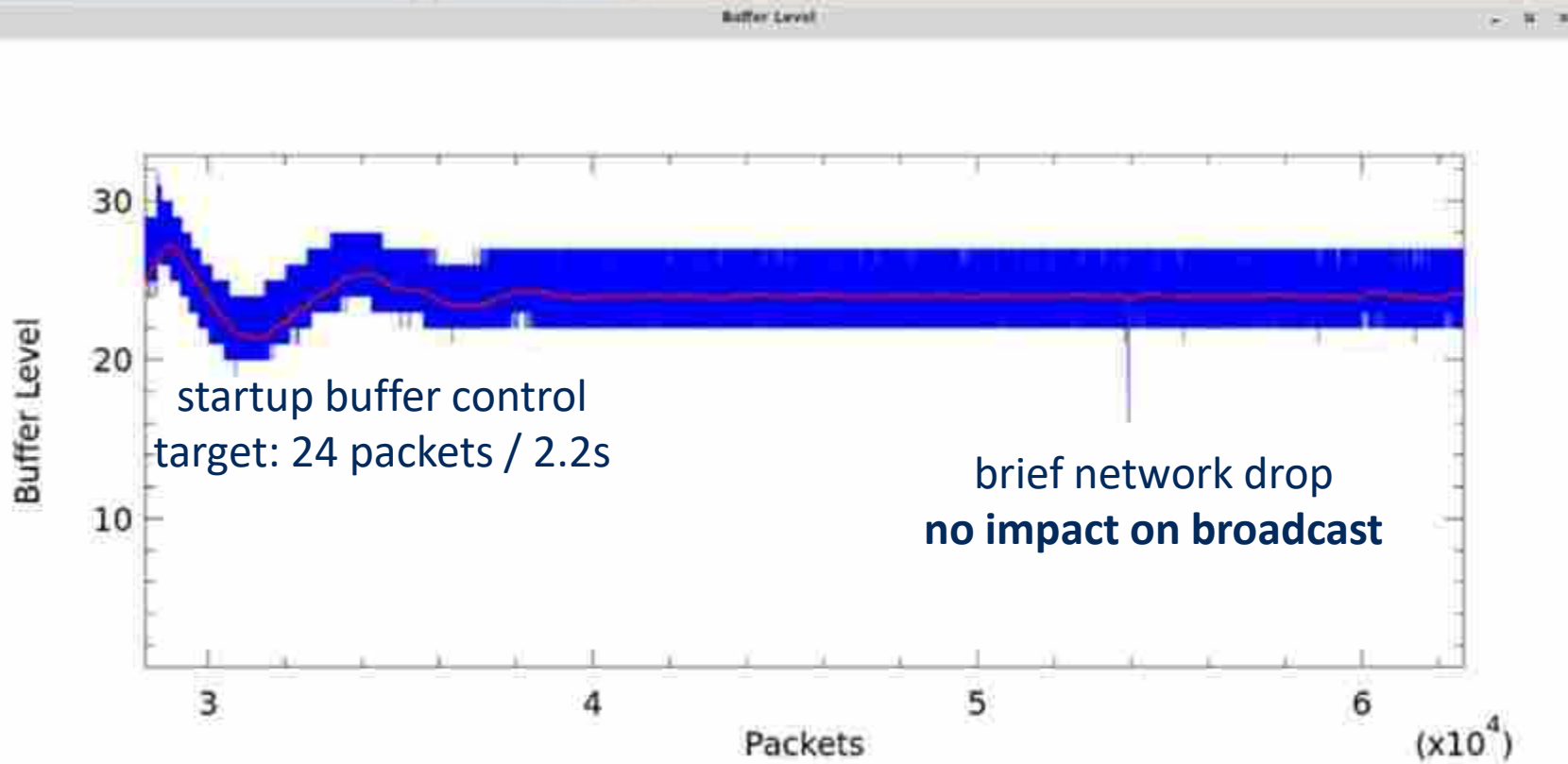
All Air-Chains are Synchronous with Exciter and Each Other

Nautel Buffer Control Algorithm



Synchronous FM HD1 split

Synchronous FM HD1 join



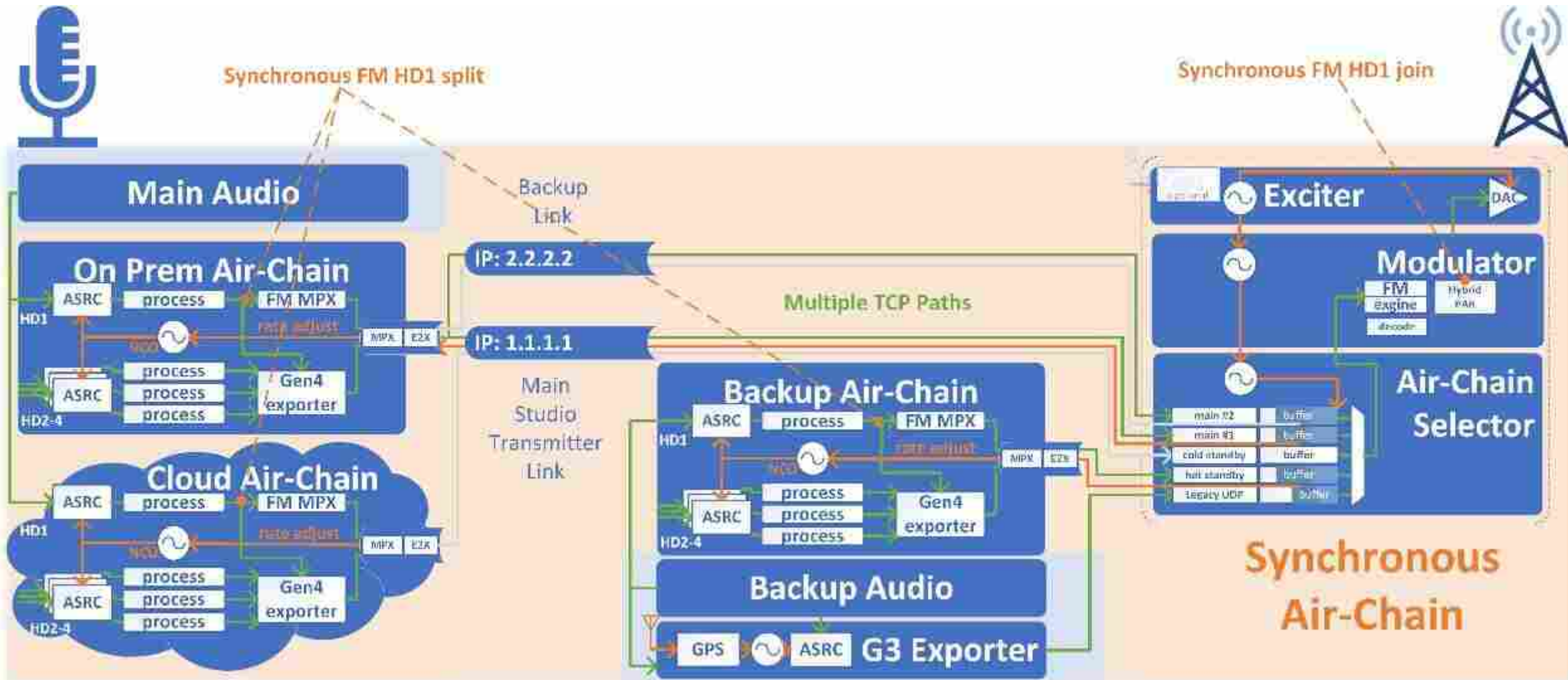
Key: Feedback Loop to Processor

Controls FM and HD1 together
Aligns all Air-Chains for changeover
Buffer graph shows link health

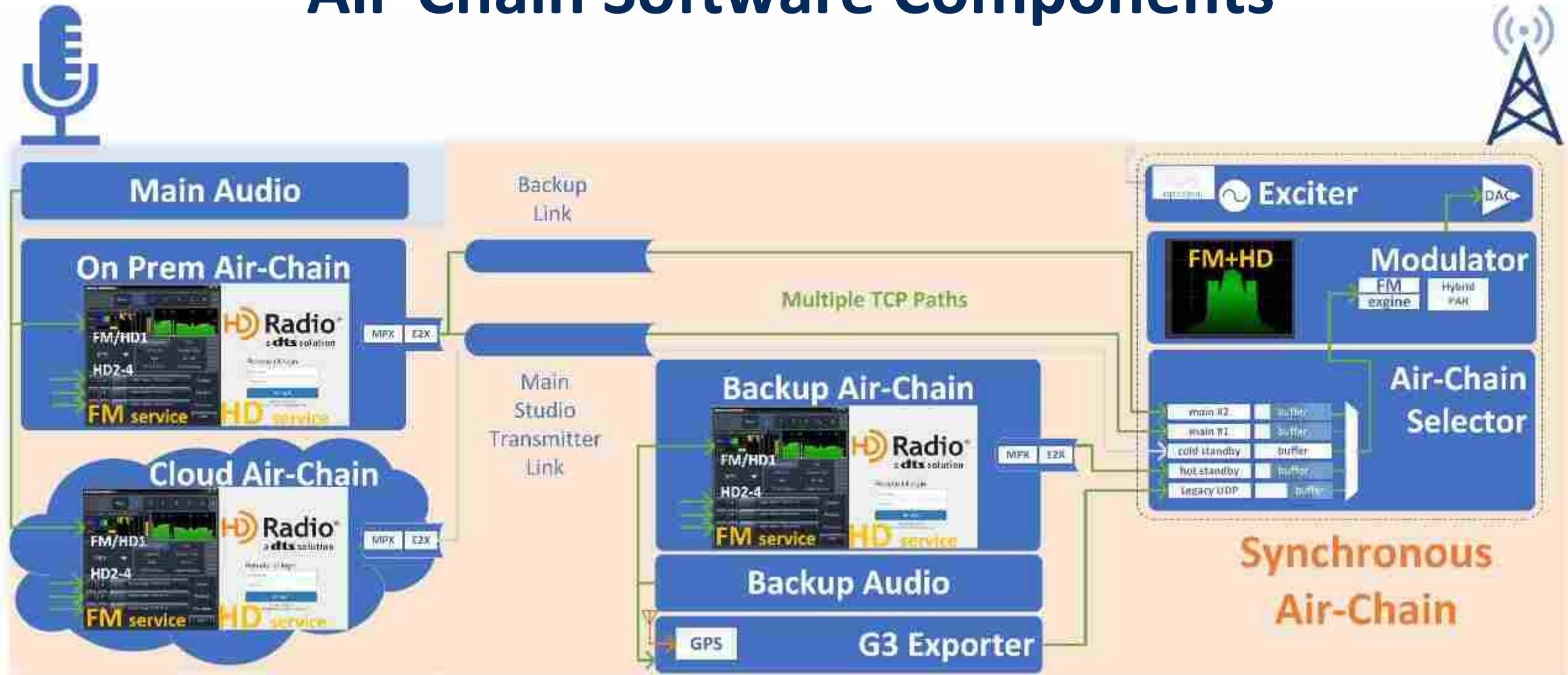


Synchronous
Air-Chain

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



Air-Chain Software Components



Xperi Gen4 HD Radio Encoder

The screenshot displays the HD Radio control interface. On the left, there is a login section with the text "Remote UI login" and fields for "Username" and "Password", followed by a blue "Login" button. The main area on the right contains system controls: a "Comm Panel" with a "Reload Page" button, a "User Message" area, an "Engine IP" field with a "Set IP" button, a "Sync State" indicator showing three green lights and the word "SYNCHRONIZED", an "Active Configuration" section with a "Set Active Config" button, and a "Run State" indicator showing three green lights and the word "STARTED", with "Start" and "Stop" buttons. A menu bar at the top includes "File", "GUIs", "AudioClients", "MscClients", "Layout", and "Help".

Key: Synchronous Nautel Audio Interface

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

Runs in the Cloud



The screenshot shows the HD1 artist experience interface. At the top, it says "HD1" and "Main Air Chain". Below this, there are four album covers: "nautel", "SICK PUPPIES", "You're Going Down", and "Tri-Polar". A track list is visible at the bottom: "Main Air Chain", "None", "Sick Puppies", "You're Going Down", and "Tri-Polar".

Artist Experience sourced by Xperi Rapid



Main Audio

On Prem Air-Chain

Radio **dts** solution

MPX E2X

Cloud Air-Chain

Radio **dts** solution

MPX E2X

Backup Link

Main Studio Transmitter Link

Multiple TCP Paths

Backup Air-Chain

Radio **dts** solution

MPX E2X

Backup Audio

GPS

G3 Exporter

Exciter



Modulator

FM engine Hybrid PAH

Air-Chain Selector

main H2	buffer
main H1	buffer
cold standby	buffer
hot standby	buffer
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

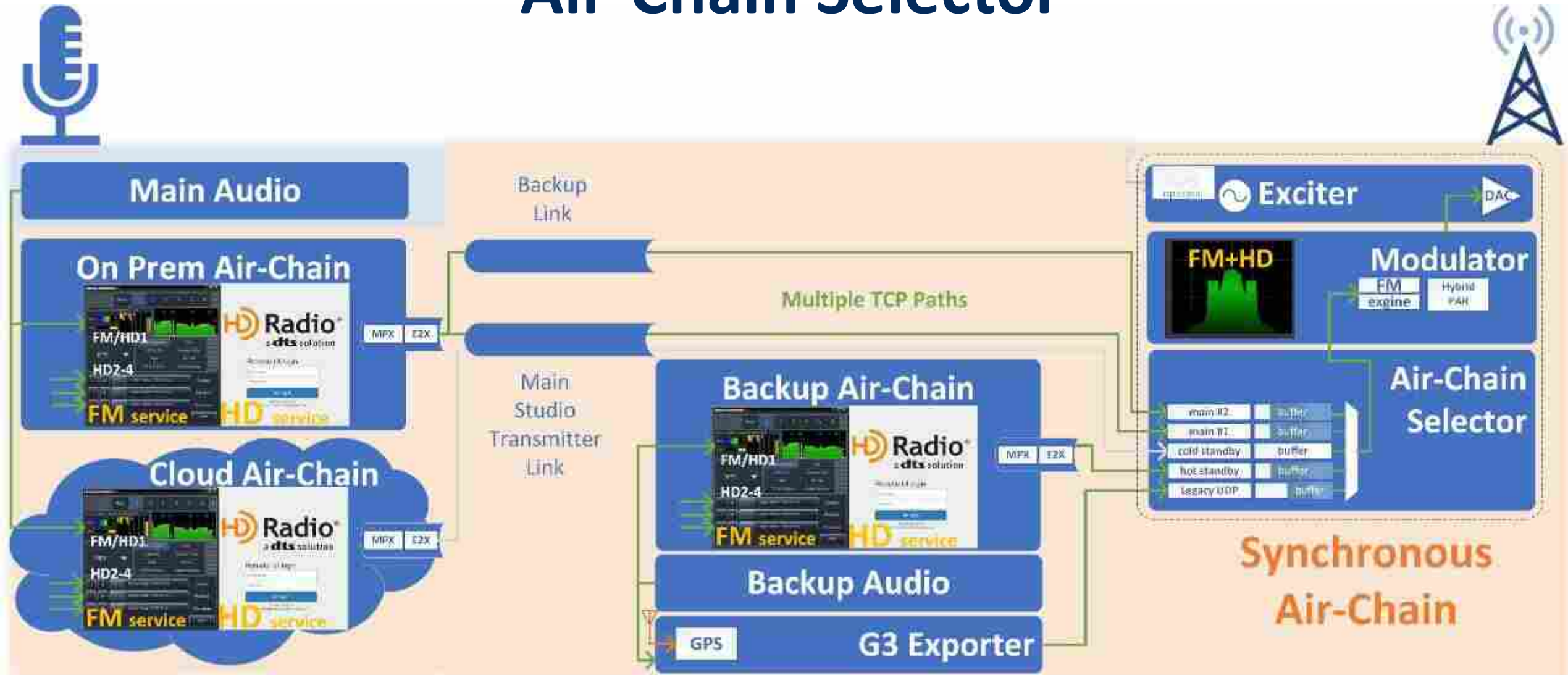
The image displays the AWS Management Console interface for EC2 instances. The main table shows three instances:

Name	Instance ID	Instance state	Instance type	Status check	Alarm status	Availability Zone	Public IPv4 DNS	Public IPv4 ...	Elastic IP
Cloudporter-1-old	i-0e9009fb942b29504	Stopped	c5.xlarge	-	No alarms +	us-east-2b	ec2-3-137-78-48.us-east...		
Cloudporter-2	i-099476fa4a24ff8f5	Stopped	c5.xlarge	-	No alarms +	us-east-2a	ec2-3-12-42-249.us-east...		
Cloudporter-1	i-04b5cc0f943de190f	Running	c5.xlarge	2/2 checks passed	No alarms +	us-east-2b	ec2-3-15-124-9.us-east...		

Overlaid on the console are two windows from the HD Radio software:

- HD Radio Control Panel:** Shows various performance metrics and graphs, including CPU usage, memory usage, and network activity. The interface includes tabs for Activity, HD1, HD2, HD3, Config, Client Audio, Overview, Video, Recording, MP3, and Streaming.
- Remote UI login:** A window titled "Remote UI login" with fields for Username and Password, and a "Log in" button. Below the login fields, it displays "Version: v0.3.12" and "© 2018 DTS, Inc. All Rights Reserved".
- HD Radio System Status:** A window showing the system's operational status. It includes a "File" menu, "Sys UI", "Menu", and "SysCfg" options. The "Comm Panel" shows "Reload Page" and "User Message: Run Status Changed From: STOPPED To: S...". The "Engine IP" field has a "Set IP" button. The "Sync State" is "SYNCHRONIZED" with a green indicator. The "Run State" is "STARTED" with a green indicator. There are buttons for "Get Active Config", "ChangeSysRunState", "Start", "AutoRun (on restart)", and "Stop". A green message at the bottom reads "ChangeSysRunState message completed".

Air-Chain Selector



Air-Chain Selector

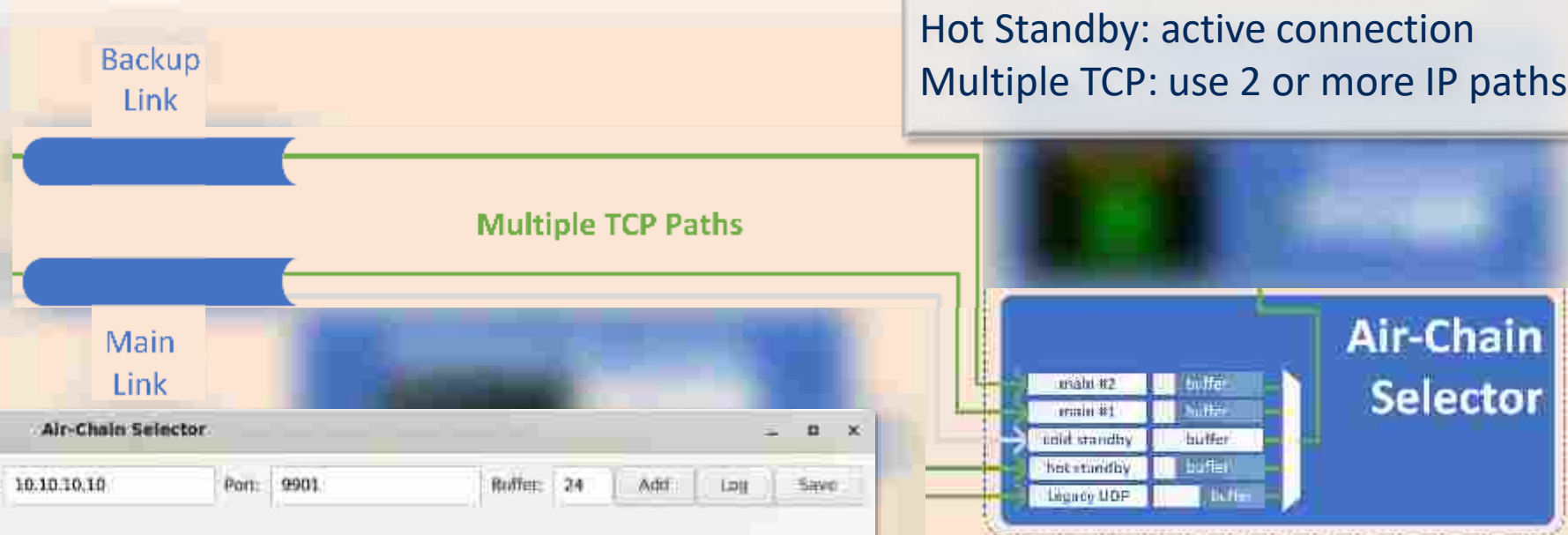
4 Types of Connections

Manual: full control

Cold Standby: connects when needed

Hot Standby: active connection

Multiple TCP: use 2 or more IP paths



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

Control	Status	Connection Name	IP Address	Packet Count	Actions
disconnect hot standby	ACTIVE	On Prem Air-Chain (1)	30.13.172.104	67763 pkts	X
disconnect hot standby	CONNECTED	On Prem Air-Chain (2)	20.12.13.104	48660 pkts	X
disconnect hot standby	CONNECTED	Backup Air-Chain	20.13.132.104	80351 pkts	X
connect cold standby	READY	Cloud Air-Chain	199.11.100.0	95768 pkts	X
connect cold standby	READY	Legacy G3 Exporter	172.16.0.0	106582 pkts	X

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

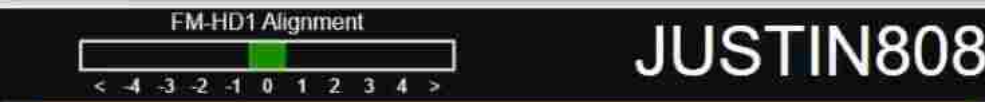
Air-Chain Selector

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

Configured Connections

Connection	Status	PKT/SEC	PKTS
On Prem Air-Chain (1)	ACTIVE	70/1270 802	64096 pkts
On Prem Air-Chain (2)	CONNECTED	70/1270 802	42967 pkts
Backup Air-Chain	CONNECTED	80/1270 804	68993 pkts
Cloud Air-Chain	CONNECTED	67/9648 834	93868 pkts
Legacy G3 Exporter	CONNECTED	88/1230 330	29896 pkts

on Main
Air-Chain
TCP link 1



JUSTIN808

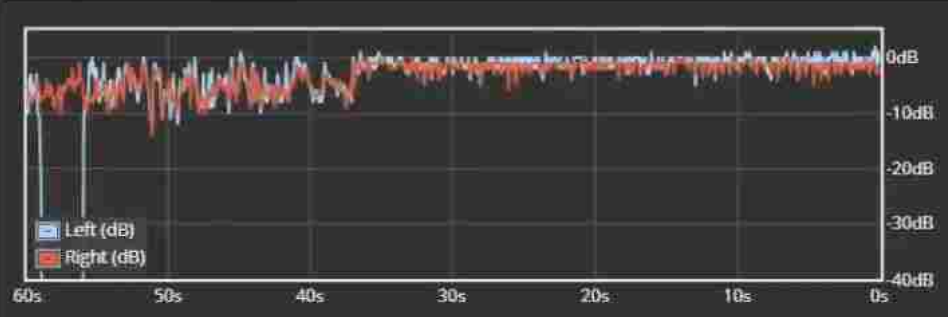
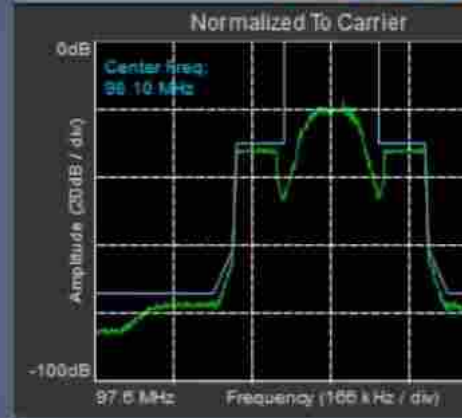
SOFIA568
98.1 FM/HD1
L [Green Bar]
R [Green Bar]



98.1 FM/HD1

RSSI	RF SNR	HD Level	Cd/No
71	18 dB	68	77
DQ	Multipath	Pilot	HD
100%	2%	Locked	Locked

Spectrum



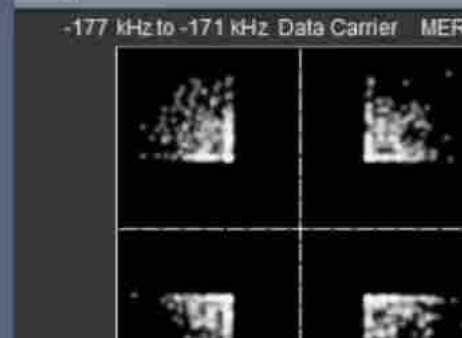
Slogan:
On-Premises Air-Chain

Type:
None

Artist:
On Prem Air-Chain

Title:
Main Audio Content

Signal Constellation



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 JUSTIN

FM-HD1 Alignment <-4-3-2-1 0 1 2 3 4>

RSSI	RF SNR	HD Level	Cd/No
71	17 dB	62	76
DQ	Multipath	Pilot	HD
100%	3%	Locked	Locked

HD1

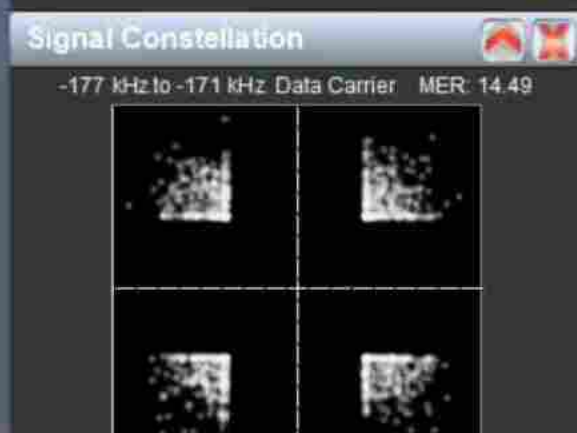
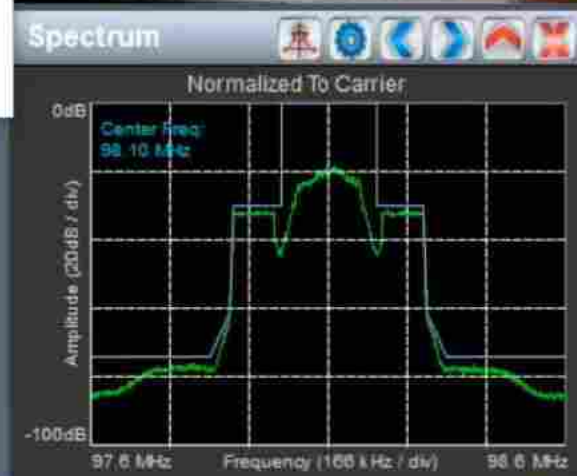
Slogan: **On-Premises Air-Chain**

Type: **None**

Artist: **On Prem Air-Chain**

Title: **Main Audio Content**

Album: **Dual Ethernet TCP**



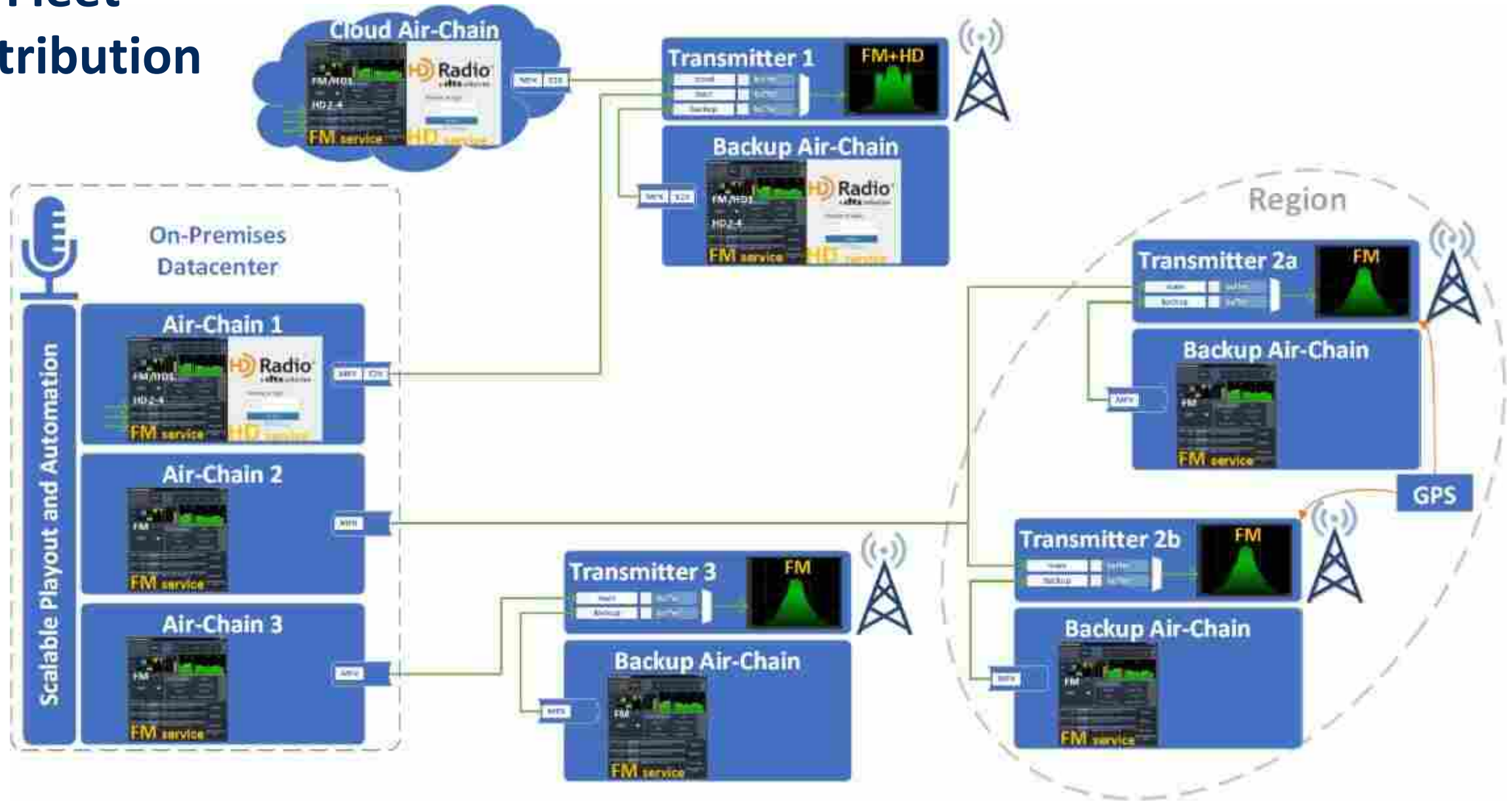


Changeover Comparison

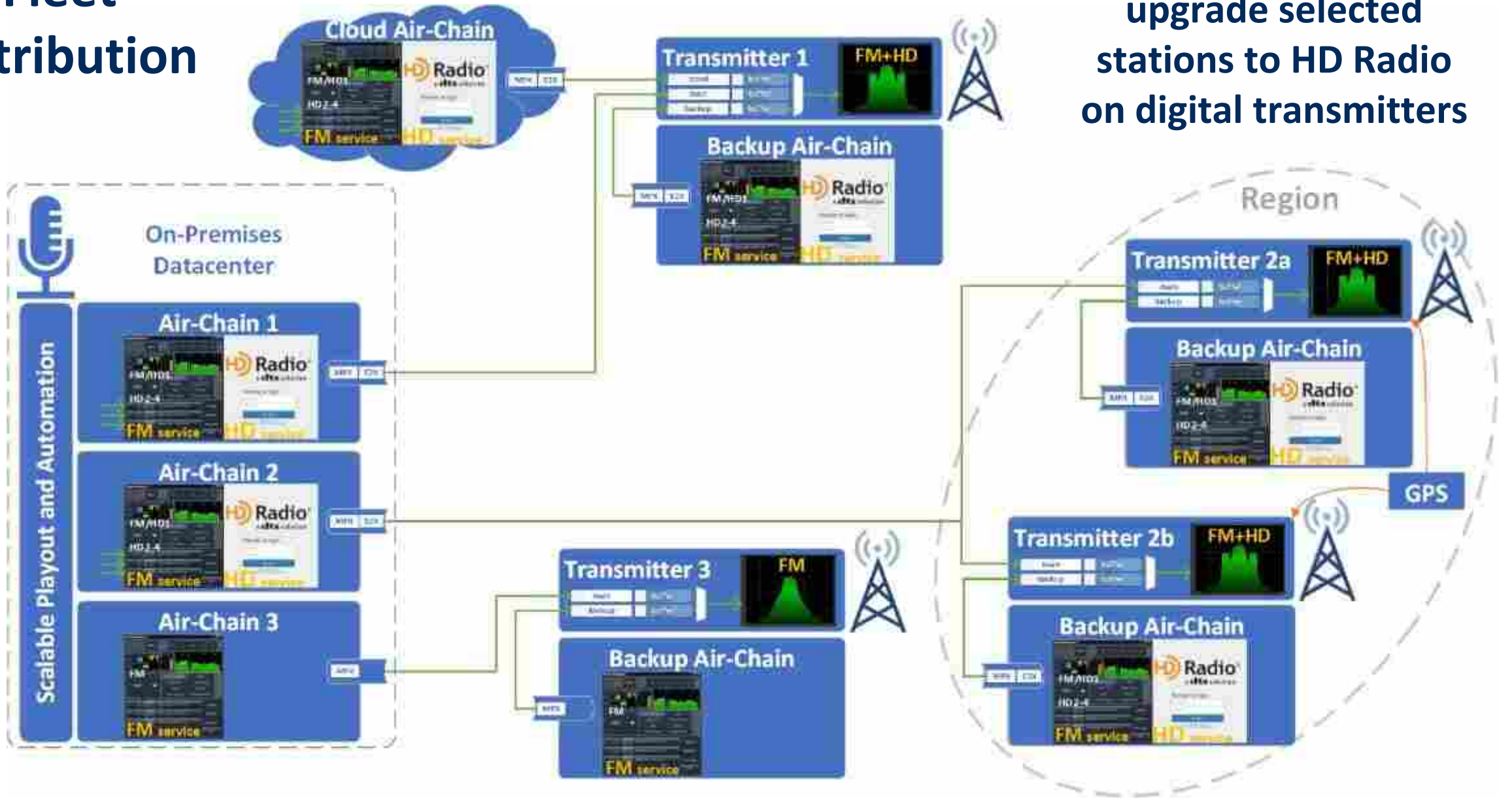


	<i>Dual Exciter</i>	<i>Cold Standby</i>	<i>Hot Standby</i>	<i>Multiple Path TCP</i>
<i>Backup Air-Chain</i>	Yes duplicate equipment	Yes	Yes	No
<i>RF</i>	1-10s to RF on	Not affected	Not affected	Not affected
<i>FM</i>	Initial static	some silence	Instant switch	Hitless
<i>HD1</i>	FM blend 10s-70s	FM blend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

Fleet Distribution

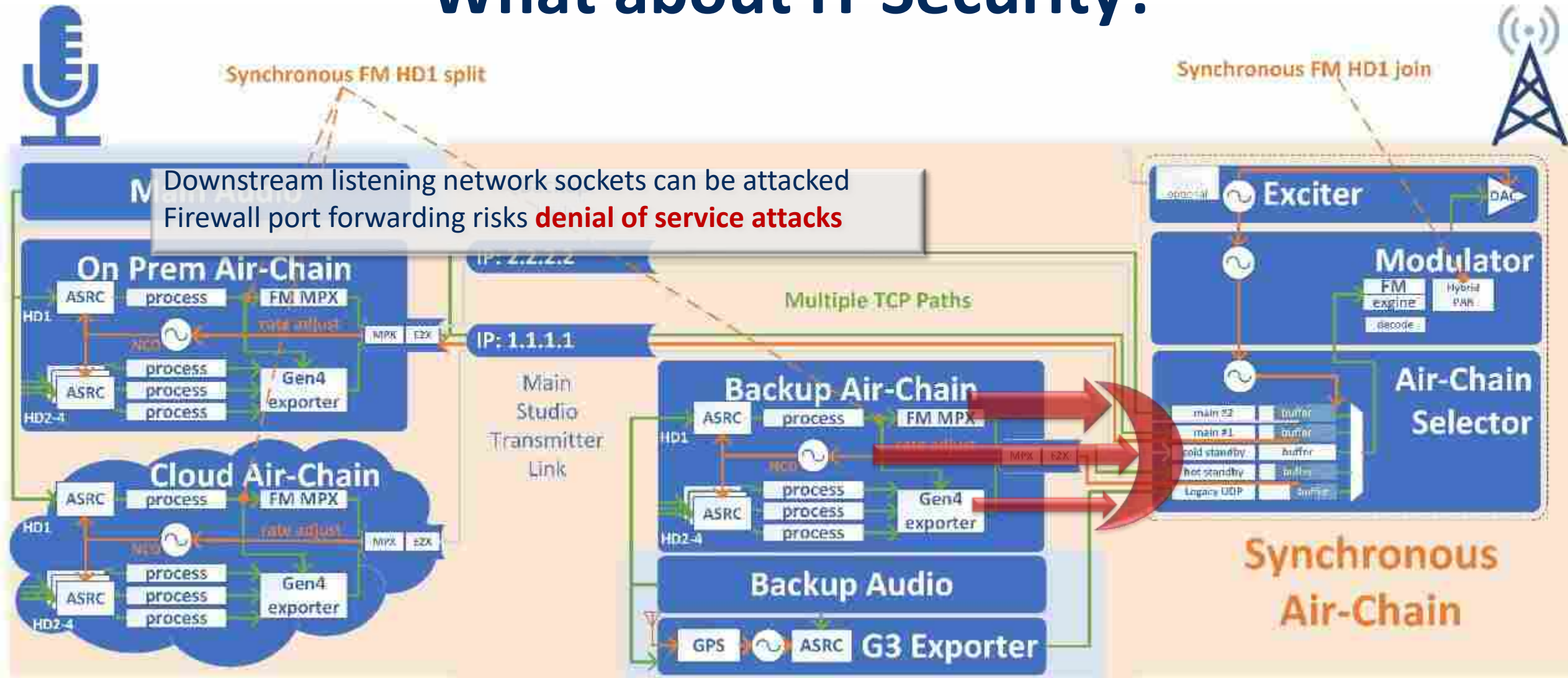


Fleet Distribution

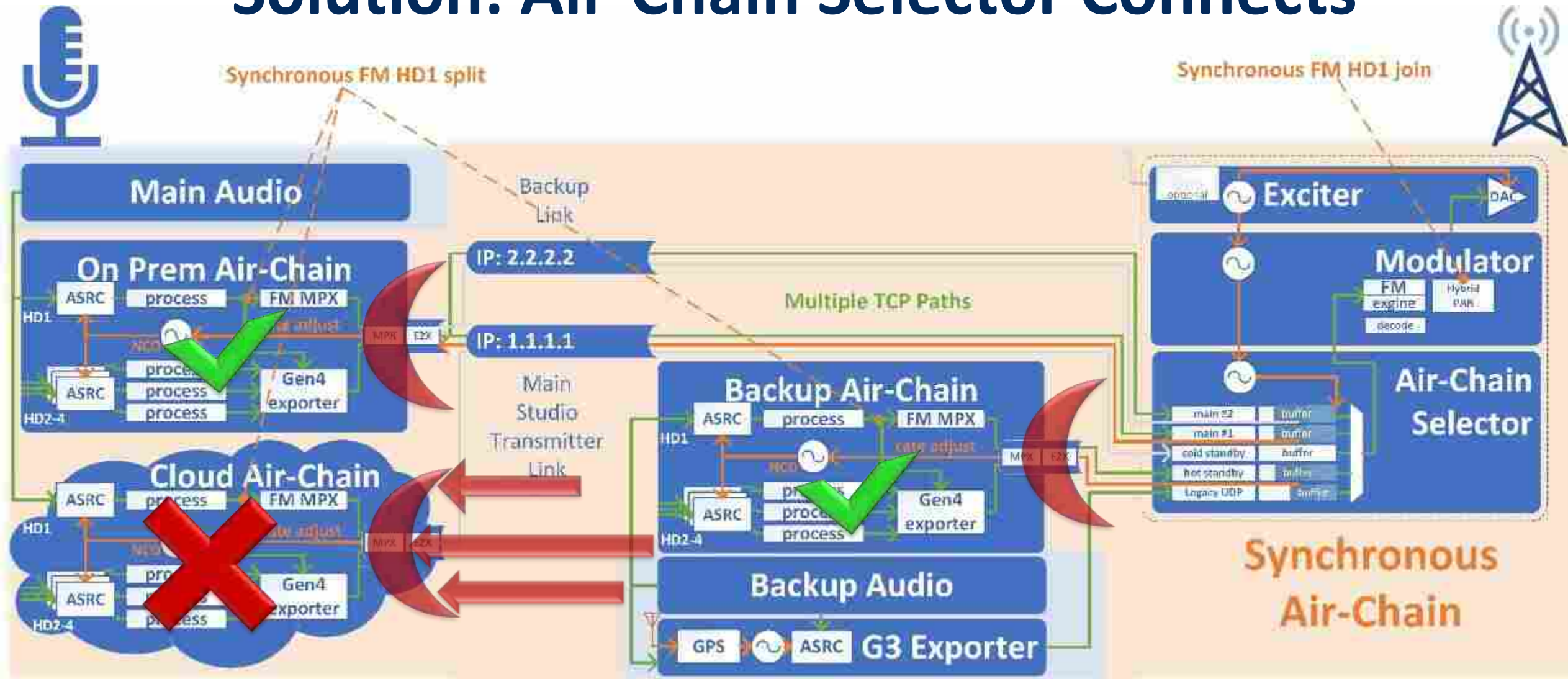


upgrade selected stations to HD Radio on digital transmitters

What about IT Security?

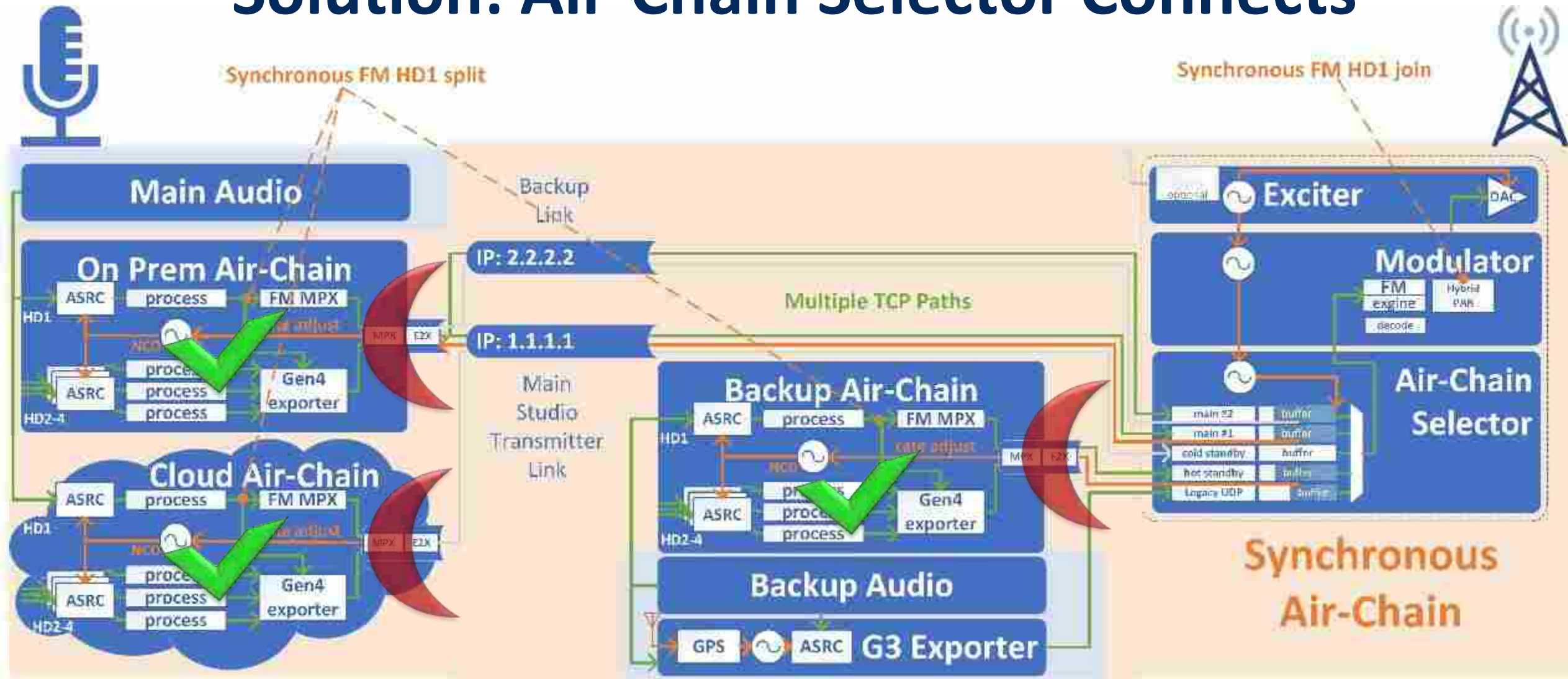


Solution: Air-Chain Selector Connects



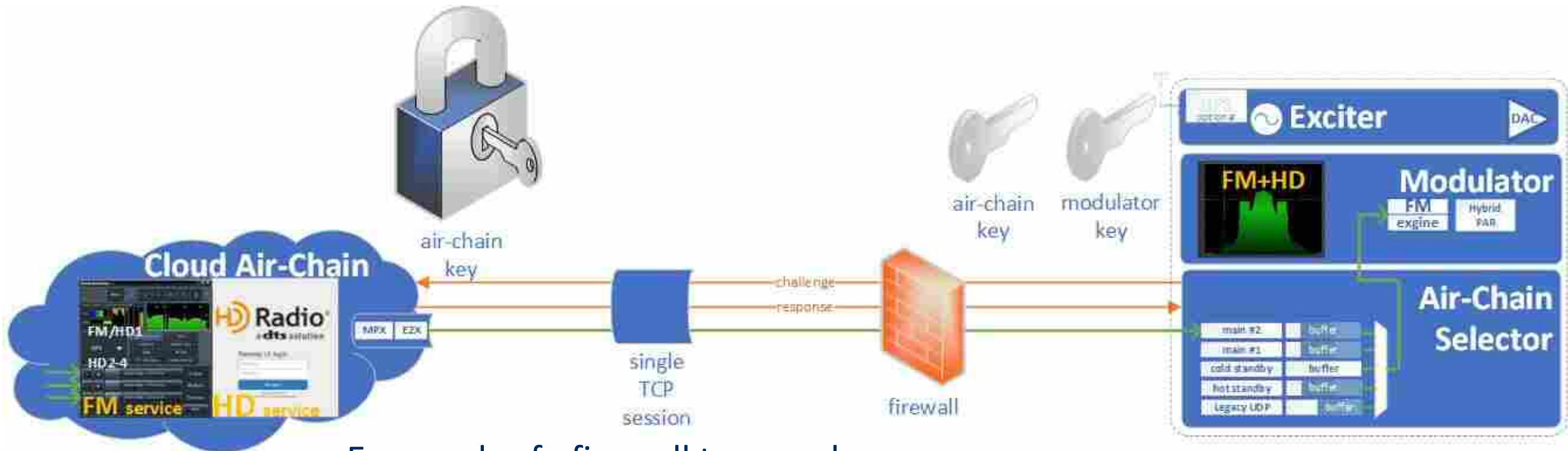
Can we still be attacked? Yes, but other Air-Chains remain **OK**

Solution: Air-Chain Selector Connects



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

Future Work: Authentication

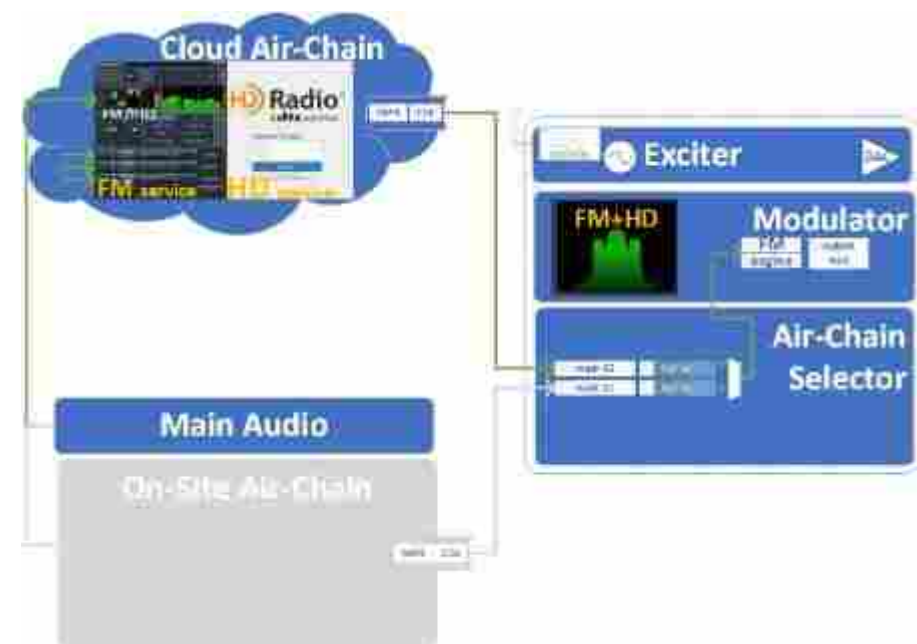


- Easy and safe firewall traversal
- Must defend against Air-Chain imposter, Man-in-the-Middle
- Air-Chain key creates and check challenge/response
- Modulator key locks to hardware and can identify itself to air-chain
- Content encryption optional, broadcast will be public in seconds

Current Work and Status



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



Current Work and Status



Radio Air-Chain
INNOVATION

Visit Nautel at NAB to see Radio Air-Chain Innovation In Action

Software-Based Air-Chain

Free & open source software for the industry's most advanced and
flexible Air-Chain architecture

HD MULTICAST Import/Export

The industry's first Flexible
Implementation!
• HD Audio Processing
for HD 2-3 & more than

Call your Nautel Rep today
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NABSHOW
Audio Content Summit 2022

Visit Nautel at
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Radio
nautel.com/HD nautel

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

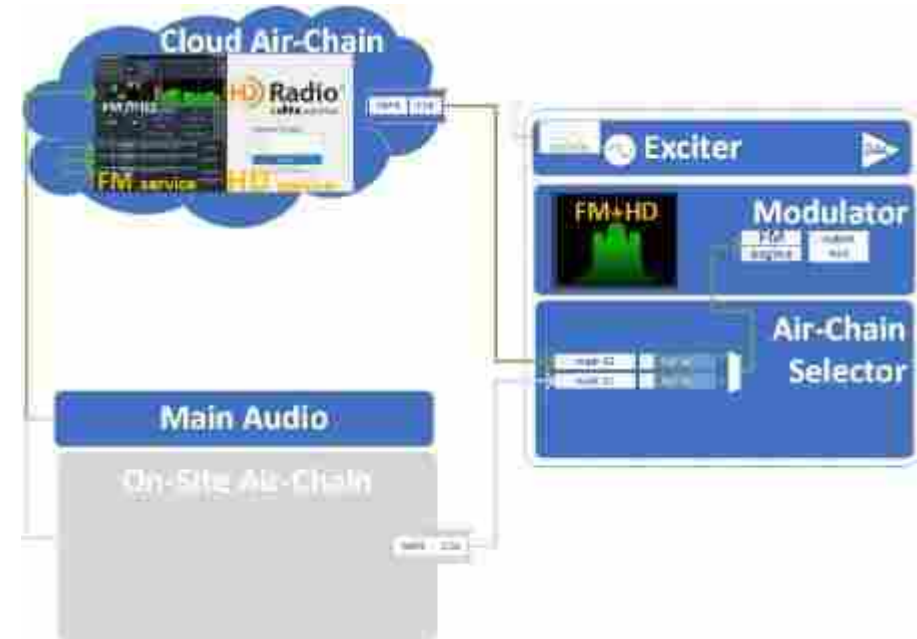
Current Work and Status



- 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



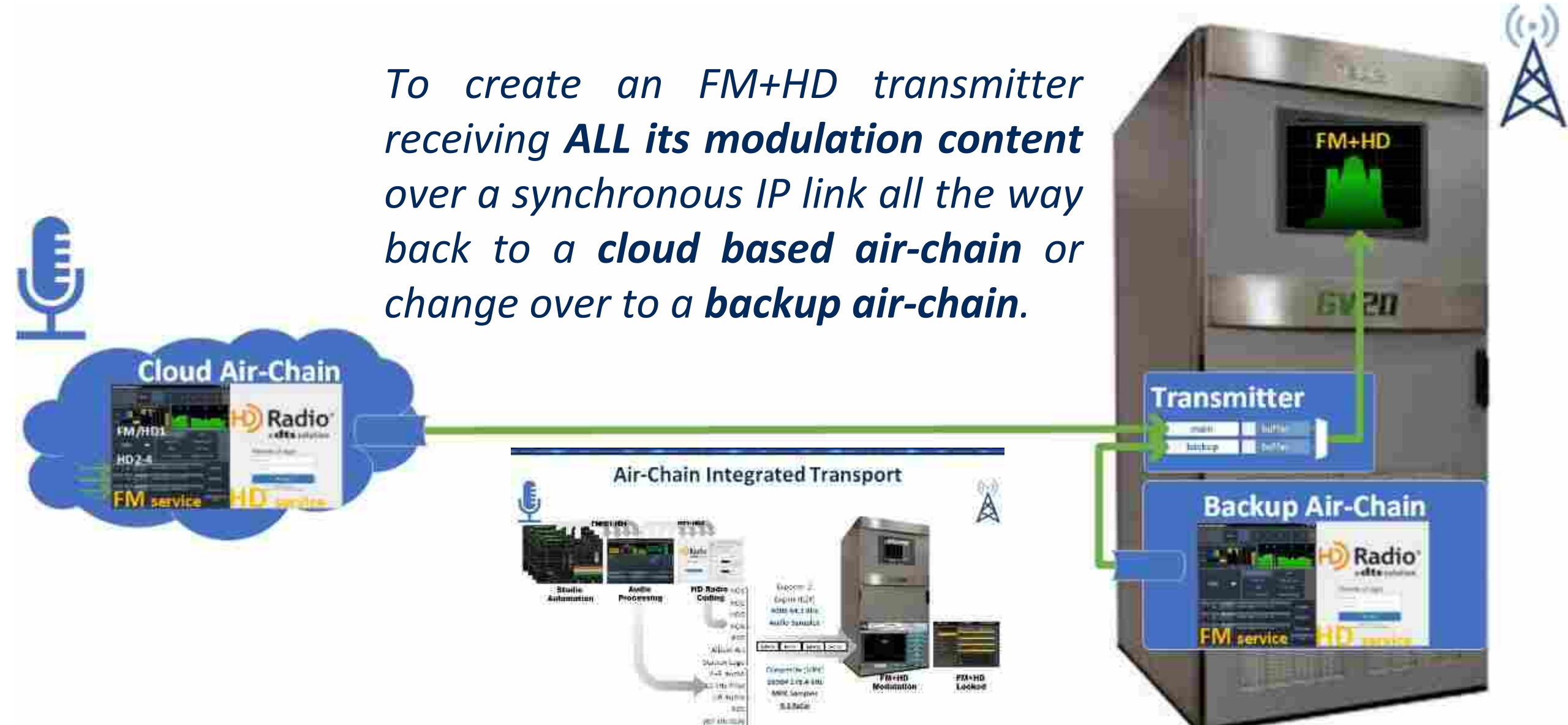
Current Work and Status



- 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