DIGITAL RADIO DEPLOYMENT CHOICES

RICH REDMOND
PRESIDENT/MANAGING DIRECTOR - INTERNATIONAL
• Radio in a sea of media options
• Analog and digital standards: FM, HD Radio DRM+, DAB+
• Cost comparison of various radio network topologies
• Main cost factors of radio operation
• New advanced technology impacts network deployment costs
• Snapshot of deployment around the world
• Receiver status
• Conclusion
92%* of Americans 12+ listen to the radio *every week.*

*Nielsen NRD Database Spring 2019.
AM / FM RADIO – THE REACH MEDIUM

SELECTED FIRST-WORLD COUNTRY RADIO REACH (%)

LISTENING TO RADIO EACH WEEK

<table>
<thead>
<tr>
<th>Country</th>
<th>Radio Reach</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>92.3%</td>
</tr>
<tr>
<td>Germany</td>
<td>93.0%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>88.9%</td>
</tr>
<tr>
<td>Finland</td>
<td>92.0%</td>
</tr>
<tr>
<td>Austria</td>
<td>93.9%</td>
</tr>
<tr>
<td>France</td>
<td>89.3%</td>
</tr>
</tbody>
</table>

United States: Nielsen Audio Today 2018 Persons 12+
Germany: ag.ma Winter 2019 Mon-Fri Persons 14+
United Kingdom: RAJAR Q4 2018 Persons 15+
Finland: Kansallinen Radiotutkimus 2018 Persons 9+
Austria: EBU 2017 Persons 12+

Avg. 91.7%
Radio has the highest reach among all media options!

- Listened to Broadcast Radio Past Week: 89%
- Watched Broadcast TV Past Week: 84%
- Watched Any Non-Premium Cable Past Week: 82%
- Used Cellphone to access Internet: 64%
- Visited Facebook Past Month: 60%
- Read Any Newspaper Past Week: 58%
- Visited YouTube Past Month: 41%
- Used Netflix Past Month: 29%
- Visited Pandora Past Month: 27%
- Listened to Satellite Radio Past Week: 12%
- Visited Spotify Past Month: 7%

Scarborough USA+ 2018 Release 2, Persons 18+.
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KEY DIGITAL RADIO STANDARDS

- **HD Radio** – Uses existing AM and FM frequencies to provide audio and multi media services
  - Broadcast in analog and digital simultaneously
  - Uses current AM or FM channel – no new spectrum
  - Supports Multiple Audio channels
  - Offers wide array of data services

- **DAB DAB+** Uses Band III VHF and L-Band to provide a suite of audio and multi media services
  - Common transmission infrastructure
  - Occupies 1.5 MHz RF bandwidth
  - Supports Multiple Audio channels
  - Multiple Video Channels

- **DRM** – Uses existing SW, AM with DRM+ FM to provide audio and multi media
  - Broadcast in analog and digital
  - Uses current AM – or additional FM channel
  - Supports Multiple Audio channels
  - Offers wide array of data services

All using OFDM type of modulation

**New digital Radio receiver necessary in all cases**
## Differences Between DAB+, DRM+ & FM Transmission

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FM</th>
<th>DAB+</th>
<th>DRM+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>87.5 MHz – 108 MHz</td>
<td>174 MHz – 240 MHz</td>
<td>47 MHz – 68 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>87.5 MHz – 108 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>174 MHz – 230 MHz</td>
</tr>
<tr>
<td>Tx Power</td>
<td>Peak</td>
<td>RMS</td>
<td>RMS</td>
</tr>
<tr>
<td>Channel</td>
<td>200 kHz</td>
<td>1.5 MHz</td>
<td>96 kHz</td>
</tr>
<tr>
<td>Programs / Ch</td>
<td>1</td>
<td>typically 9 to 24 (64 max)</td>
<td>1 to 4 (max)</td>
</tr>
<tr>
<td>Data</td>
<td>RDS 1,2 kBit/s</td>
<td>Flexible data rates for Program Associated and Non Program Associated Data rates</td>
<td>Flexible data rates for Program Associated and Non Program Associated Data rates</td>
</tr>
<tr>
<td>Input</td>
<td>Analoge L/R, Stereo Composite, AES -IP (Audio over IP)</td>
<td>Digital ETI 2.048 Mbit/s or EDI (ETI over IP)</td>
<td>Multiplex Data Interface (MDI) 37-186 kBit/s</td>
</tr>
<tr>
<td>Modulation</td>
<td>Single Carrier FM</td>
<td>Multi Carrier (1536) OFDM, type DQPSK</td>
<td>Multi carrier (106) OFDM, 4 QAM or 16 QAM</td>
</tr>
</tbody>
</table>

### Diagrams
- **Modulation**
  - **FM**
    - Single Carrier FM
    - Peaks: -100 kHz, +100 kHz
  - **DAB+**
    - Multi Carrier (1536) OFDM, type DQPSK
    - Peaks: -768 kHz, +768 kHz
  - **DRM+**
    - Multi Carrier (106) OFDM, 4 QAM or 16 QAM
    - Peaks: -48 kHz, +48 kHz
HD RADIO TECHNOLOGY USES IN-BAND, ON CHANNEL (IBOC) METHOD

- Enables simultaneous transmission of analog and digital signals
- Analog receivers continue to function normally – digital channels “invisible” to analog receivers
- Digital transmissions immune to multipath distortion, adjacent channel interference and static
- IBOC technology makes the PPM watermark more robust

Frequency kHz

(Digital Signal)

(Protected FM Mask)

Existing FM Analog Signal

(Not to scale)
### TYPICAL OPTIONS

- **P1 Partition** (96 kb/s bandwidth)
  - **A**: 64 kb/s
  - **B**: 48 kb/s
  - **C**: 48 kb/s
  - **D**: 32* kb/s

- **P3 Partition** (24 kb/s bandwidth)
  - **A**: 32 kb/s
  - **B**: 48 kb/s
  - **C**: 24 kb/s
  - **D**: 32 kb/s

* * 32 kb/s minimum bandwidth required for HD1 channel

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Allocate 120 kb/s channel bandwidth according to program content and user preference.

All bandwidth above 96 kb/s (P3 partition) must be treated as a single stand-alone unit – it cannot be combined with lower 96 kb/s (P1 partition).
TRANSMISSION SYSTEM DAB+ VS. FM

1 single Radio program

Up to 18 Radio programs (64kbps) of good audio quality
HD Radio-Capable Transmitter

HD Radio Exciter/Exgine

HD Radio Exporter

HD Radio Importer

Needed to generate HD1 signal

Needed to generate HD2 – HD4 signal

DRM+ has a similar topology
Cost efficiency of FM, DAB+ and DRM+

Example: 18 Radio Programs same coverage

**FM**
- Tx 1, 2, 3, ..., 16, 17, 18
- 18x FM Transmitter
- 18x Frequencies
- 18x Frequency License fee
- 18x Studio-Transmitter Link (STL)
- 18x RDS encoder/Data
- 18x Large antenna

**DAB+**
- Tx 1 carries 18 programs
- 1x DAB+ Transmitter
- 1x Frequency
- 1x Frequency License fee
- 1x Studio-Transmitter Link (STL)
- 1x DAB+ Play-out
- 1x Medium antenna system

**HD Radio**
- Tx 1, ..., 5
- 5x HD Radio Transmitter
- 5x Frequency
- 5x Frequency License fee
- 5x Studio-Transmitter Link (STL)
- 5x HD Radio Head-End
- 5x Large antenna system

NOTE: Antenna system aperture for DAB+ around 200MHz is approximately 1/2 that of FM and DRM+ around 100MHz for the same gain.

NOTE: DRM+ typically uses 3 channels per transmitters
- 10 times less RF power in DAB+ for same coverage as FM
- Due to higher losses in Band III (Filter, RF line) the effective transmitter power of DAB+ is ¼ to FM (conservative)
Efficiency, what does it mean?

- Definition: \((RF\ \text{Power Out} \div AC\ \text{Power In}) \times 100\%\)

Increased efficiency: reduces power consumed and reduces energy wasted
ENERGY CONSUMPTION – ANALOG & DIGITAL

<table>
<thead>
<tr>
<th>Transmitter</th>
<th>FM</th>
<th>DAB+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>10 kW</td>
<td>2.5 kW rms</td>
</tr>
<tr>
<td>Efficiency</td>
<td>72%</td>
<td>50%</td>
</tr>
<tr>
<td>Consumption per Transmitter</td>
<td>13.9 kW</td>
<td>5 kW</td>
</tr>
<tr>
<td>Transmitters</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>Energy all Transmitters</td>
<td>250 kW</td>
<td>5 kW</td>
</tr>
<tr>
<td>Annual cost of energy</td>
<td>328,500</td>
<td>6,570</td>
</tr>
</tbody>
</table>

- **Energy costs over 10 years of operation**
- **DAB+ energy savings over 10 years**
  - 3,219,300 USD compared to FM

- **DAB+ energy savings**
  - 50x lower compared to FM
- **Power consumption in kW**
- **Assumes 0.15 USD per kWh**

**Example:** 18 Radio Programs same coverage
Drastic cost reductions using DAB+ compared to FM and DRM+ for areas which have 18 or more services.

<table>
<thead>
<tr>
<th>Transmitter</th>
<th>FM</th>
<th>HD Radio - DRM+</th>
<th>DAB+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of transmitters</td>
<td>18</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>CAPEX: Cost of transmitters</td>
<td>900</td>
<td>270</td>
<td>80</td>
</tr>
<tr>
<td>OPEX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td>328</td>
<td>20</td>
<td>6.57</td>
</tr>
<tr>
<td>Cooling</td>
<td>92</td>
<td>12</td>
<td>3.333</td>
</tr>
<tr>
<td>Total OPEX</td>
<td>420</td>
<td>32</td>
<td>~10</td>
</tr>
</tbody>
</table>

Note: Opex per year
The approximate OPEX cost **SAVINGS** of operating 18 services over a **10 year** period using Digital radio:

<table>
<thead>
<tr>
<th></th>
<th>DAB+ vs. FM</th>
<th>HDRadio - DRM+ vs. FM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEX Savings</td>
<td>4.1M USD</td>
<td>3.9M USD</td>
</tr>
</tbody>
</table>

Note that we have not considered further savings from:
- Rental of floor and antenna space if site is not owned by broadcaster
- Higher cost of keeping spares and the amount of maintenance effort
NORTH AMERICA HD RADIO ADOPTION

U.S. Totals
- Stations On-Air: 2,298
- Total Digital Channels On-Air: 4,495

Mexico Totals
- Stations On-Air: 117
- Total Digital Channels On-Air: 190

Canada Totals
- Stations On-Air: 33
- Total Digital Channels On-Air: 80

As of January 2020.
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As of January 2020.

Adopted - Approved

Experimental Approval

Interested - Testing

HD RADIO GLOBAL ROLLOUT
ALL MAJOR BRANDS OFFER FACTORY-INSTALLED HD RADIO TECHNOLOGY

NEW CARS DELIVERED IN THE U.S. IN 2019 WITH FACTORY-INSTALL HD RADIO RECEIVERS

49.2 Percent

CARS ADDED ANNUALLY IN U.S. WITH HD RADIO RECEIVERS (INCLUDING AFTERMARKET)

8.9 Million

RUNNING TOTAL U.S. HD RADIO-EQUIPPED CARS ON THE ROAD (INCLUDING AFTERMARKET)

60.9 Million

As of December 2019.
HD RADIO AND THE BATTLE FOR THE DASHBOARD

All major brands offer factory-installed HD Radio

- Vehicle Brands (Chevy, Ford etc.)
- Vehicle Models (Malibu, Focus etc.)

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</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>86</td>
<td>109</td>
<td>154</td>
<td>166</td>
<td>198</td>
<td>212</td>
<td>216</td>
<td>247</td>
<td>263</td>
<td>298</td>
</tr>
<tr>
<td>36</td>
<td>21</td>
<td>61</td>
<td>67</td>
<td>76</td>
<td>92</td>
<td>109</td>
<td>114</td>
<td>150</td>
<td>163</td>
<td>182</td>
</tr>
</tbody>
</table>

As of January 2020.

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Virtually all (98%) HD Radio Technology users surveyed are satisfied with their HD Radio Technology experience.

91% of listeners said they are “completely” or “very” satisfied.

55% indicated they are “completely satisfied” with the HD Radio Experience.

Those under 40 years old and heavy users (listen to radio >15 hours a week) have the highest satisfaction with HD Radio Technology.

Among HD Radio Technology users, 98% are satisfied.
TEN YEARS AGO, FOUR DAB MARKETS IN EUROPE

Established markets

- UK
- Norway
- Sweden
- Germany
- France
- Italy
- CH
- DK
- Poland
- Czech
- Austria
- Ireland
- Portugal
- Slovenia
- Estonia
- Latvia
- Lithuania
FIRST COUNTRIES ARE SWITCHING OFF FM

Norway: 2017

Switzerland: 2024
STRONG PROGRESS IN MAJOR MARKETS

UK: 58% of listening is digital

Germany: Launching 2nd national multiplex this year

Italy: All receivers must have DAB+ from 2020

Switzerland: Switch-off FM by end 2024
SIGNIFICANT NEW LAUNCHES ACROSS THE CONTINENT

Belgium:
Flemish & French launches (2018/19)

Austria:
National DAB+ (May 2019)

Sweden:
40% population coverage (2019)

France:
Regional services on air - national DAB+ next to launch

Tunisia launched 2019; Algeria trial in 2020
• Over 529 million people are within reach of a DAB/DAB+ signal

• DAB/DAB+ is now available in 45 countries/territories worldwide*

• Countries that have put DAB+ services on air in the last 12 months:
  
  Azerbaijan, Serbia, Thailand, Tunisia, Vietnam

*Includes Gibraltar, Holy See and Monaco in that total as territories
National radio services

DAB+ OFFERS GREATER CHOICE – UP TO SIX TIMES AS MANY SERVICES

* Will double with launch of second national multiplex – expected September 2020
Source: dabplus.de
RECEIVERS ARE NOW MASS MARKET

• Over 80 million receivers sold*

• Prices from €20

*Source WorldDAB
GROWING NUMBER OF NEW CARS WITH DAB

- Norway: 100%
- UK: 95%
- Switzerland: 91%
- Australia: 73%
- Italy: 46%
- Germany: 40%
- Netherlands: 43%
European Electronic Communications Code (Dec 18)

- From end 2020, all new car radios in EU must be able to receive digital terrestrial radio
- Member States free to introduce own legislation for consumer radios
MULTI CARRIER DAB SOLUTIONS REDUCE COSTS, AND INCREASE ROI

2 non adjacent channels

3 adjacent channels

3 non adjacent channels
OUTDOOR TRANSMITTER SYSTEM MAKE COVERAGE EXPANSION MORE COST EFFECTIVE

MAIN FEATURES:
• 70W RMS power or one analog signal (130 W p.s.) with amazing efficiency
• No need for servicing blowers and filters
• Enable complete remote control via SNMP/Web interface through a standard Ethernet connection or integrated 4G modem
• Compact chassis: just 18.9x14x6.7 in (480x360x170) mm.
• Several Input interfaces:
  · ASI input (TS, BTS, T2MI, SMPTE-310M, ETI)
  · GbE port (TS over IP or EDI)
  · Optional: DVB-S/S2 Satellite Receivers
    (up to 4, including CAM interface and multi-stream capabilities)
  · Optional: RF receiver input for repeater/gap-filler configuration
• DVB-T/H/T2, ISDB-T/Tb, DAB/DAB+/T-DMB, ATSC modulations
• Adaptive pre-correction circuits
• High stability GPS / GLONASS receivers with battery
• Consumers demand more and different types of content – Radio still most used
• Digital Radio lowers deployment cost per channel
• Key technologies deliver superior green footprint
• Additional savings are realized from facility space, cooling, construction and maintenance costs
• Advancements in multi channel and outdoor system reduce the cost to expand network coverage
• Digital radio receivers are widely available for HD Radio and DAB – especially in cars
• Digital Radio is a cost-effective mobile content delivery platform