

SECOND EDITION

world **dab**

Establishing DAB+

Digital Broadcast Radio

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Preface

The process of adopting and deploying a new digital radio standard is complex and includes wide-ranging activities and stakeholders. In this updated second edition we provide additional information in several sections, including details about the new Automatic Safety Alert (ASA), new Hybrid radio features, more examples on regulation and licensing models, additional details of site equipment, a cost minimisation method for transmitter sites, and more.

We view the overall goal of rolling out DAB digital radio as a set of interacting processes to allow stakeholders to better understand the complexities of the activities which are required. We intend this guide to be primarily used as an introduction to the overall process, but which can also be referred to for later reference. It is suitable for both new adopters in countries wishing to implement DAB+ digital radio as well as for countries which have already started the process.

The overall adoption process includes several sub-processes which cover education and demonstrations, business case, regulation, network planning and design, and rollout, each of which also has its own set of processes and activities, many of which are interlinked and have strong dependencies. This document provides guidance and examples to all stakeholders in the radio ecosystem, including:

- Broadcasters and content producers where we show the benefits of using DAB+ digital radio technology in terms of business case and technical capabilities;
- Regulators in terms of possible ways to introduce DAB+ to provide efficient use of spectrum and ways to license DAB+ radio aspects such as spectrum ownership, content, equipment and transmissions;
- Network and transmission engineers and organisations in terms of the activities which need to be undertaken to design, deploy and operate DAB+ systems;
- Commercial and marketing organisations and individuals in terms of educating the ecosystem, including broadcasters and the public, provision of receivers in domestic and automotive settings, the development of new content and the ongoing operation of DAB systems.

While this ebook covers many of the technical aspects of designing and implementing DAB+ networks and systems, it also covers the most important aspect of stakeholder communications and interaction and the business case, with emphasis on the vision required by industry champions to ensure success.

This ebook contains input from many leading industry experts through both contributions as well as feedback, guidance and many discussions. We thank them all for their hard work in the DAB world and for providing their expertise and guidance to future champions.

This ebook is also available in French, see www.worlddab.org.

Acknowledgements

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Finally, I thank the WorldDAB Steering Board for their support for this on-going educational body of knowledge.

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1. Introduction

DAB+ has evolved to become the preeminent broadcast digital radio standard, with many countries around the world adopting it. While adoption is spearheaded in Europe, where most countries now have permanent transmissions, there are many other countries which are just beginning the journey.

This ebook provides a guide for the steps that are usually followed to adopt and roll out DAB+ as a national standard and primary digital radio service. It provides a guide for all stakeholders in the radio ecosystem, including broadcasters and content providers, regulators and government organisations, network infrastructure equipment and service providers, receiver manufacturers and suppliers, including the automotive market and other service providers.

Every country is different and consequently the order and duration of the development phases described below vary considerably. The activities, however, are consistent while the interaction between phases is flexible.

An important theme across all phases of the adoption process is stakeholder engagement, which is critical to ensuring that the entire radio ecosystem achieves the wide range of benefits that DAB+ digital radio offers.

This ebook provides a structured approach to the adoption process, from the initial investigations that broadcasters and regulators undertake, through demonstrations, business case development, formal adoption, including legislation and licensing, system design, including multiplexing and transmission networks, rollout and finally the long-term operating perspective.

The status of DAB adoption is provided in the map shown in Figure 1-1. While most European countries now have DAB+ services, coverage and services numbers continue to grow. There are increasing activities for adoption in the Asia-Pacific, Middle East and African regions.

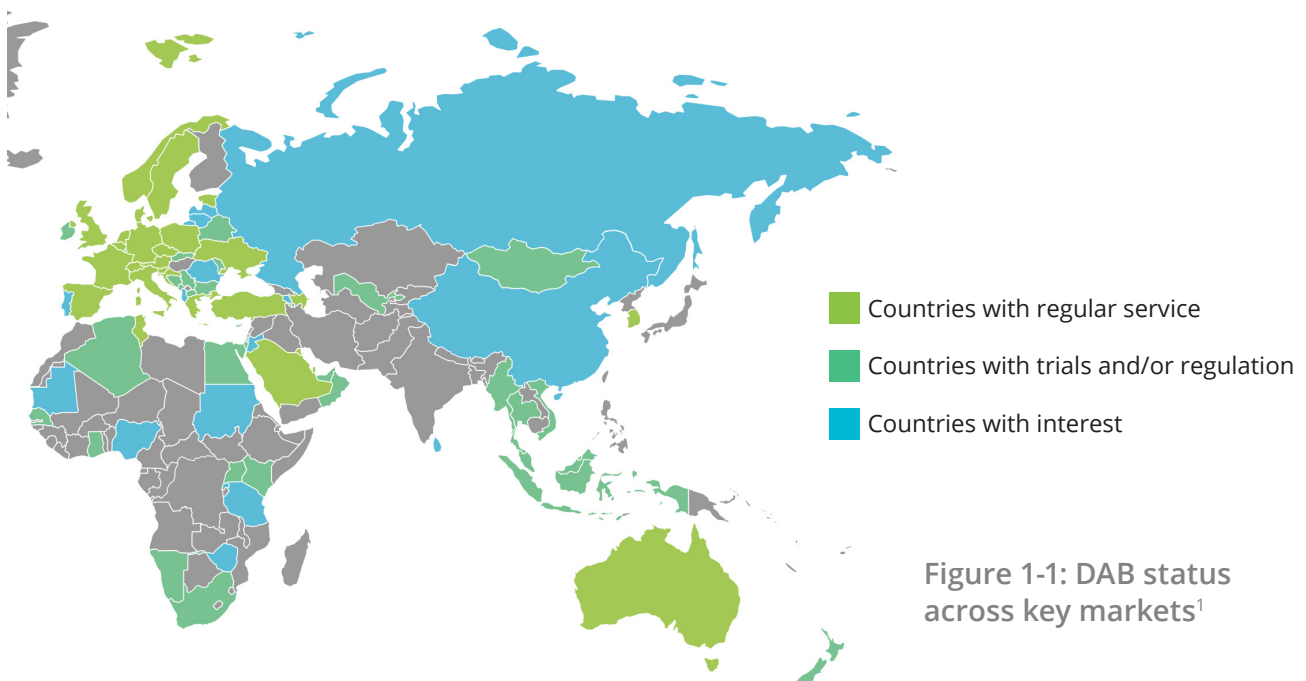


Figure 1-1: DAB status across key markets¹

¹ WorldDAB infographic, www.worlddab.org

2. Overview of DAB+ features

The features discussed in this section are supported by the suite of DAB+ standards defined in ETSI Technical Specifications. A full list of the Technical Specifications can be found in §15.

2.1 Audio

Audio can be delivered in two ways using DAB and DAB+. The original DAB audio encoding used MPEG-2 while DAB+ audio encoding uses HE-AAC v2. DAB+ audio encoding also includes additional concatenated Forward Error Correction through a Reed-Solomon code along with a virtual interleaver which provides additional error protection. DAB+ is the preferred audio encoding solution as for most audio types the required bit rate to achieve suitable audio quality is 40% to 50% less than the original DAB MPEG-2 encoding.

2.2 Metadata

Metadata is becoming increasingly important to both listeners and broadcasters. DAB provides a range of metadata, including text (Dynamic Labels), images (SlideShow), programme information (PI) and service information (SI), such as logos.

Metadata is essential to ensure that modern graphical user interfaces provide a suitable range of features which are easily viewed and used. This is particularly the case for new cars, many of which have large colour screens.

Metadata is delivered both through Programme Associated Data (PAD) incorporated into the audio service as well as through data services and can also be delivered via IP connections. Metadata is particularly important in vehicles; see the WorldDAB metadata explainer video on the WorldDAB website.²



Figure 2-1: Dynamic Label text delivery³

² See the WorldDAB website at www.worlddab.org

³ Image courtesy of Telestar



Figure 2-2: SlideShow image delivery⁴

2.3 Features

DAB digital radio includes a wide range of features to provide services and enhance the listening experience:

- Service Following

Service Following provides the ability to switch to a different audio source when the current signal becomes too weak to deliver error-free audio reliably. The Service Following feature can be used to switch to other DAB ensembles, DRM or FM-RDS. See [27]

- Programme Information

The EPG is a Programme Information (PI) feature which provides the ability for broadcasters to inform their listeners of the programmes that they offer, for example the daily or weekly schedule of programmes.

- Service and Programme Information

A range of Service and Programme Information can be delivered by broadcast and/or IP. Information includes service logos (multiple sizes), geolocation, programme type, genre, service names and groups, keywords, phenomes and IP links.

This metadata can add considerable functionality for hybrid DAB Broadcast / IP connected radio receivers, particularly in vehicles.

See [14] for details of SI for both broadcast and hybrid delivery.

⁴ Image courtesy of Technisat (left) and Albrecht (right)

2.4 Automatic Safety Alert

WorldDAB announced the launch of the “Automatic Safety Alert (ASA)” system in 2024 after two years of intensive collaboration. This pioneering innovation in DAB+ digital radio technology aims to protect the public during emergencies by delivering reliable safety alerts without requiring an internet connection.

Benefits for listeners

Listeners will benefit from an alerting system that warns them without relying on mobile or internet connections. ASA operates automatically in the background, can be regionally adjusted for the location, and boasts high resilience thanks to the robust DAB+ radio transmission network. New standards for operation and testing have been published through ETSI for the EWS system operation [28] and the receiver test specification [29]. Receivers must pass the tests specified in [29] to be able to claim conformance and be able to use the ASA logo on product packaging.

The EWS/ASA system was initially demonstrated and tested for the IFA Berlin and the nationwide Warntag in Germany in September 2024 and was further demonstrated at the Paris Radio Show in February 2025. In mid-2025, new generations of DAB+ radios are in production supporting the ASA standard. These products were tested during the German Warntag event in September 2025 and will become publicly available in late 2025 in electronics retailers⁵.

Collaboration of public and private organisations

Public and private radio broadcasters, device manufacturers, and German safety authorities such as the Federal Office of Civil Protection and Disaster Assistance (BBK) joined forces to create a critical component for crisis communication using DAB+ digital radio. With powerful transmitters covering large distances, DAB+ can send regionalised warnings, ensuring people in affected areas receive timely and accurate alerts.

The catastrophic flood in the Ahr Valley, Germany in 2021 which resulted in numerous fatalities spurred this development in Germany. Given the current global instability and climate change, ASA holds significant international importance as DAB+ is available in over 70% percent of Europe and increasingly around the globe. ASA allows radio broadcasters worldwide to enhance the safety of their listeners.

Enhanced warning clarity

Additional text and image information accompanying spoken alert messages make warnings clearer and more understandable for affected individuals. International standardisation and resource-efficient programming further ensure the system’s future viability on a global scale.

⁵ See <https://www.dabplus.de/2025/09/12/dab-radio-am-warntag-erfolgreicher-test-des-automatic-safety-alert-asa-mit-zertifizierten-empfaengern/>

ASA functionality

- **Alerts:** Spoken alert messages convey all relevant information about the emergency.
- **Wake-up Function:** Radios can be activated by DAB+ signals, crucial for future generations of radio alarm clocks and receivers in general.
- **Switch Function:** Receivers analyse references to alerts on other radio stations, increasing the flexibility and reach of warnings.
- **Location Codes:** The DAB+ signal indicates warning areas accurately, with the ASA target area being as small as 1 square kilometre for localised emergencies, e.g. major building fires, or as large as multiple ensemble coverage areas for large scale emergencies such as floods or earthquakes, ensuring only those in affected regions are notified.
- The location of home receivers needs to be entered into ASA capable receiver products. The user can find their location code using the website <https://asa.radio/>. An example of the code representing the area where the WorldDAB head office is located is shown in Figure 2-3.
- **Synchronisation:** Wake-up cycles are very short, reducing power consumption and conserving battery power for portable receivers. Synchronisation with the radio signal ensures that all devices activate simultaneously and receive alerts concurrently.

The WorldDAB ASA Factsheet⁶ provides a further overview with additional technical details being provided at <https://www.worlddab.org/dab/asa-emergency-warnings>.

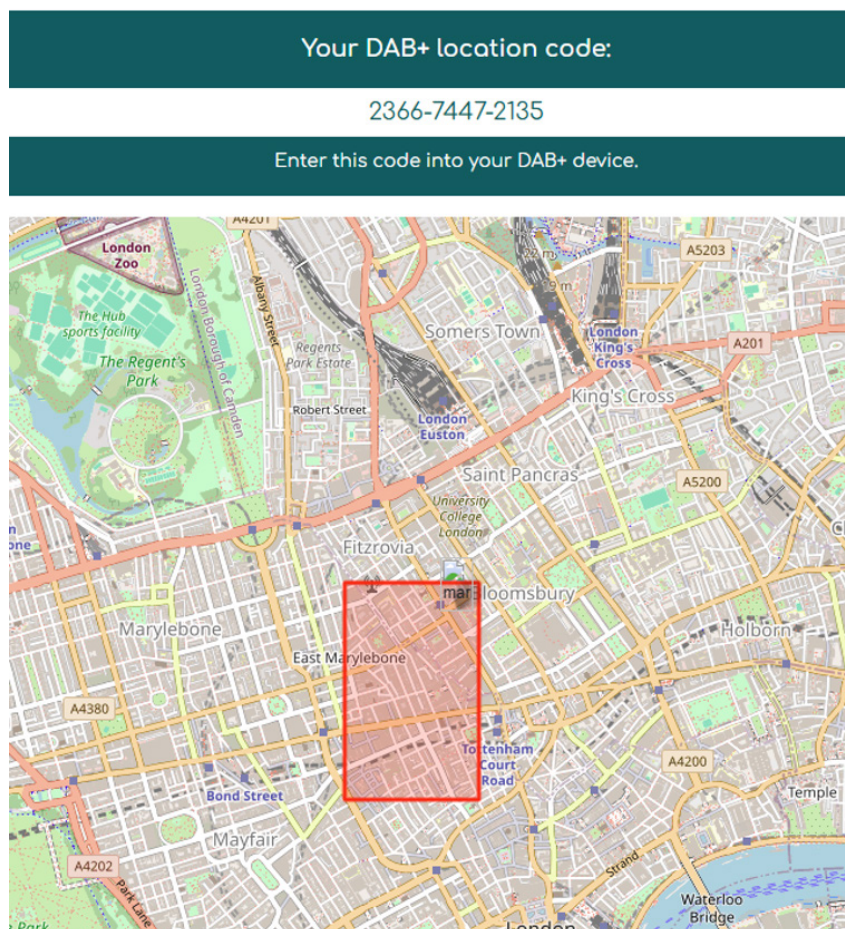


Figure 2-3: The ASA location code for the WorldDAB head office in London

⁶ See https://www.worlddab.org/public_document/file/1648/ASA_Fact_Sheet.pdf?1725031512

2.5 Transmission and multiplexing

DAB is transmitted in a Time Division Multiplexed format using Orthogonal Frequency Division Multiplexing with concatenated Forward Error Correction coding. As such, it is a robust signal which was specifically designed to provide radio services in difficult environments which are predominantly shadowed from the transmission site.

DAB+ has several different FEC code rates that can be used to trade delivered data capacity with robustness, with the inner convolutional code rates ranging from $R=1/4$ (strongest) to $R=4/5$ (weakest). For DAB+ the most commonly used FEC code rate is $R=1/2$, also called Equal Error Protection level 3A (EEP-3A), which results in a total user data capacity of 1.152 Mbps per ensemble.

The DAB broadcast system has considerable flexibility and can deliver up to 64 services, each of which can be defined independently in terms of sub-channel bit rate, audio mode and the amount of PAD to carry metadata such as Dynamic Label and SlideShow. There is no such thing as a typical DAB+ ensemble; there are many variations across established DAB markets. For example, the Australian market initially had a general configuration of 18 services at the same 64 kbps coding rate. That configuration has been adjusted considerably with the evolution of services and now has a mixture of sub-channel bit rates for different types of audio content, as is also the case in Europe. We observe classical, jazz and folk music usually being delivered at higher sub-channel bit rates due to the more frequent presence of pure music tones, and pop music and speech usually delivered at lower sub-channel bit rates, due to the ease of coding.

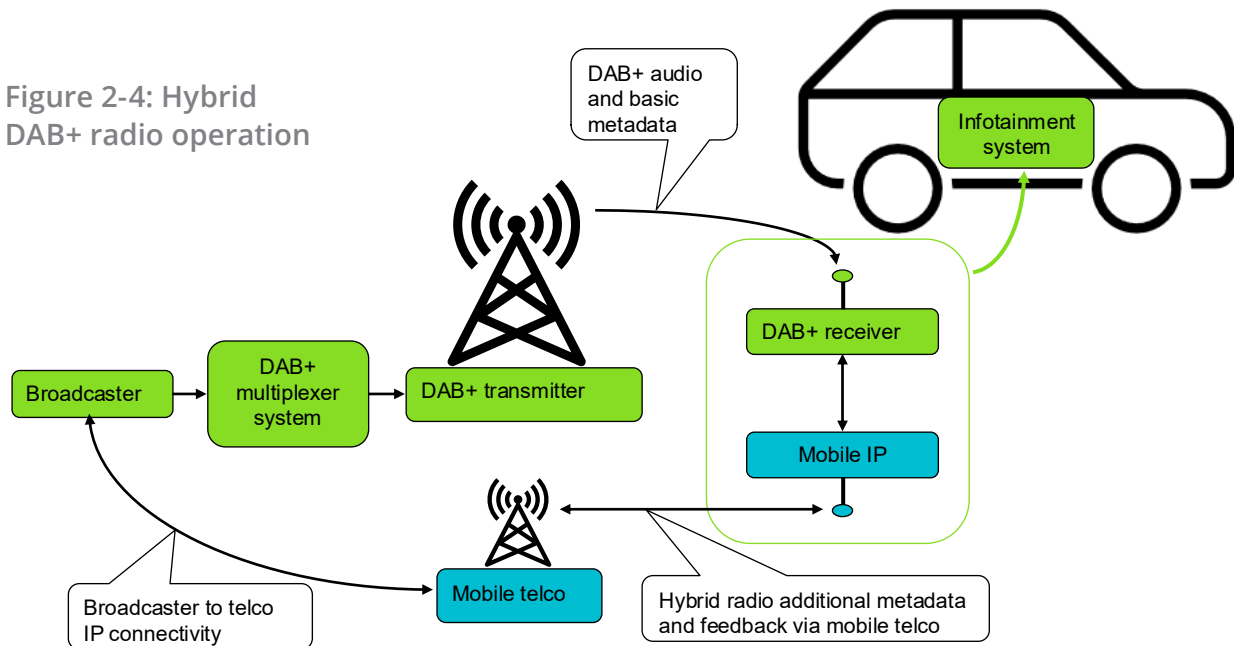
Multiplexing systems can allow ensemble capacity to be grouped by Service Provider (SP) who can control their capacity independently from other SPs. For example, an ensemble may have three SPs which have 256, 256 and 512 kbps of capacity assigned respectively. Each SP is free to define the number of services which will be delivered using their allocated capacity and can change the configuration of services, including the number of services and their bit rates, at any time they choose.

2.6 Hybrid DAB+ radio

Hybrid DAB+ radio is the combination of DAB+ digital broadcast radio for the delivery of audio and basic metadata and IP connectivity for the delivery of additional metadata, features and the return of listener information, as shown in Figure 2-4. This mode of operation is currently mainly limited to vehicle based systems and has been implemented by many automotive bands. It can also be implemented in home products where the IP connectivity is typically provided via WiFi.

The IP connectivity is typically provided by the RadioDNS system which uses a Domain Name System (DNS) approach to link the broadcast DAB+ service to the broadcaster's internet domain. The RadioDNS organisation operates the DNS root server for radiodns.org to a published trust model as described in [14]. Once the IP connection is established the broadcaster you can choose which functionality to provide to their listeners.

Figure 2-4: Hybrid DAB+ radio operation



Hybrid DAB+ radio features include:

- **Visuals and Dynamic Metadata**

Visual images can be higher resolution than the standard DAB+ broadcast QVGA format with better quality to better suit large in-car screen displays.

- **Service and Programme Metadata**

While DAB+ broadcast can deliver station logos, names, descriptions and basic genre information by using a data carousel mechanism, hybrid radio can usually deliver specific information more quickly via IP. IP connectivity also allows links to websites and social media as well as geofencing information.

- **Analytics**

The connection provided over IP can provide insight into how listeners are using broadcast radio. By capturing and reporting significant events, logging and analytics can be built up similar to those provided by streaming audio servers.

- **Interaction**

When the listener wants to know more about what's on, radio tagging allows the simple tap of a button to record their interest, with the ability to revisit the content later, on an associated mobile phone, tablet or desktop device at a time to suit them.

A number of organisations provide hybrid radio services and products including:

- **RadioDNS⁷** – This is a free service from the member based not-for-profit RadioDNS organisation. It can be used by automotive manufacturers as well as domestic product manufacturers.
- **Radioplayer⁸** – This is a paid service that is provided to automotive manufacturers.
- **Xperi's Autostage⁹** – This is a paid service that is provided to automotive manufacturers.

⁷ See <https://radiodns.org/>

⁸ See <https://radioplayer.co.uk/node/2>

⁹ See <https://dts.com/autostage/>

3. DAB adoption overview

3.1 The basic process

DAB adoption is a process for the formal adoption and establishment of DAB+ digital broadcast radio. It has seven distinct phases, which have some overlap and often significant interaction. DAB+ adoption requires a broad range of skills in a multidisciplinary team environment. The key to success is collaboration between stakeholders and the different teams which all help deliver the process, including technical research, system design and construction engineering, content development and production, product provisioning for both infrastructure and receivers, regulators and legislators, marketing, management and finance.

The seven phases can be summarised as follows:

1. Initial investigations and research
 - Gain a good understanding of what DAB+ digital radio provides in terms of content delivery, features, business case, design and construction (theory);
 - Ongoing education and research as the process unfolds.
2. Demonstrations
 - Experiment with DAB+ transmissions to get hands-on experience to improve understanding and expand knowledge for system planning and design and to allow stakeholders to experience DAB+ digital radio in familiar surroundings;
 - Can also be used as a pre-permanent service to help establish an initial listener base.
3. Formal adoption: Regulations and licensing
 - Across the radio ecosystem, agree the conditions for the successful establishment of DAB+ and the supporting business case;
 - Through stakeholder discussions, establish DAB+ as an approved and formally legislated digital radio broadcasting standard;
 - The regulations provide the legal basis for providing DAB+ spectrum, transmission systems and content provision licenses.
4. High-level planning and costing
 - Service requirements – how many services should be provided in each area;
 - Coverage requirements – what field strengths are required to deliver content in each area;
 - Allotment planning – this is essentially a high-level transmission plan which defines what frequency blocks are assigned to each area;
 - A multiplexer network design including decisions on the type of network architecture and the location of the multiplexing systems;
 - A cost analysis to estimate the cost of the DAB+ system in terms of CAPEX for establishment, OPEX for ongoing operations and the Total Cost of Ownership (TCO) to determine indicative Access Fees.

5. Detailed design and tendering

- Using the High-Level Plan as a basis a detailed design can be developed with a view to tender for the required equipment and services;
- Design the system needed to deliver the services, includes:
 - i. Transmission systems – at actual transmission sites with realistic antenna patterns, this includes an updated coverage plan and interference analysis;
 - ii. Multiplexing systems – including agreed network architecture and multiplexing centre sites;
 - iii. Contribution and distribution networks – including the use of Telco and possibly private communication networks and facilities;
 - iv. Operations and monitoring – including a Network Management System (NMS), its location and operations and maintenance programs.
- Production of documentation including detailed technical specifications for use in tendering, equipment and service selection and purchasing readiness.

6. Rollout

- Start the equipment and service purchasing process – this is often over a period of years;
- Construct the DAB system from studio to transmission sites;
- Developing additional content;
- Receiver provisioning including engagement with Retailers and the Automotive industry for home/portable and automotive receivers;
- Marketing content generation initially focused on the launch of DAB+ but also including an ongoing marketing plan.

7. Operations

- Technical systems operations and maintenance;
- Content production, including audio and metadata;
- Ongoing marketing;
- Ongoing cross-industry support.

8. Analogue switch-off (ASO)

- Through cross-industry stakeholder discussions, establish a methodology to transition to DAB+ and switch off analogue radio systems.

The overall timeline is summarised in the Gantt chart in Figure 3-1. The period for the full process for Norway, which achieved ASO in 2017, was 22 years from first involvement in the standards development process and initial transmissions in 1995.

Today, that process can be shortened due to the maturity of the DAB+ standard and the availability of low-cost infrastructure and receiver products. The overall process is, however, quite typical of the introduction and adoption of a new digital technology, whether it be radio, television or mobile telecommunications systems.

The period spent in each phase will vary depending on the stakeholders' appetite to move forward. In some countries, the early stages of adoption move forward very quickly. Some have extended periods of demonstrations while the formal adoption legislation is debated, and some countries may start the rollout with major population centres before proceeding to lower population areas.

One of the most important aspects of the overall process is the vision of the driving stakeholders and their long-term belief in the benefits of DAB+ to society and business.

Norway is again a good example where the stakeholders were faced with either refreshing a very large fleet of FM transmitters or moving the entire country to digital radio. Their leadership was visionary, and they now enjoy significant improvements in the overall radio ecosystem with much more content availability, lower operating costs and the ability to incrementally add new digital features to ensure the ongoing viability of the broadcast radio medium.

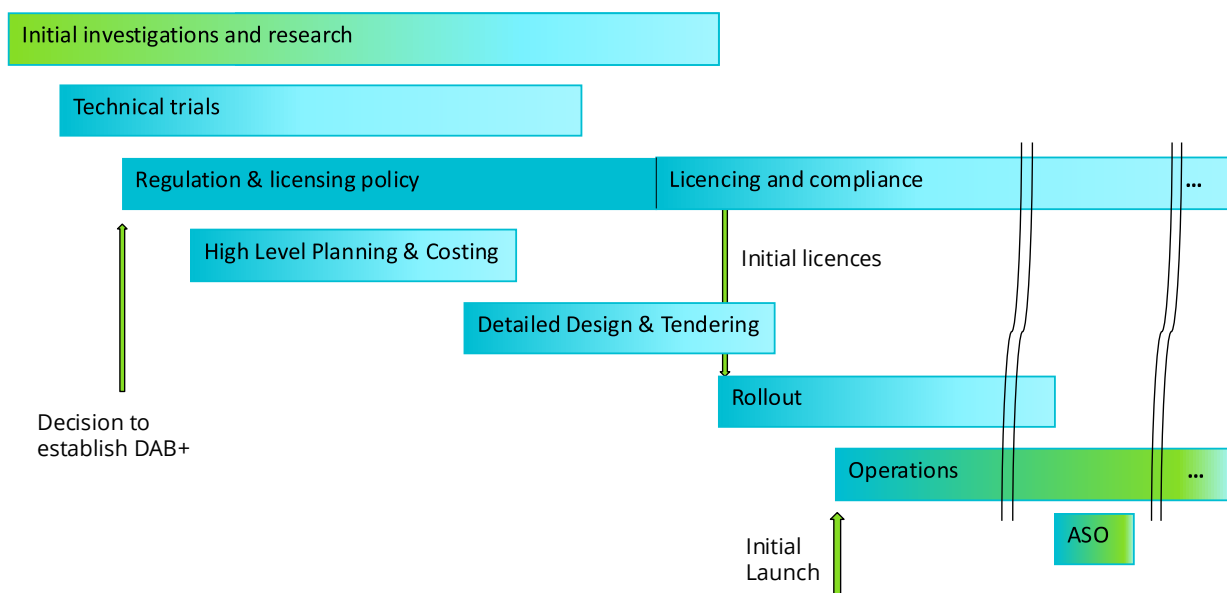


Figure 3-1: DAB adoption process: typical Gantt chart

A word of warning, however. Some stakeholders have difficulty seeing the long-term benefits and struggle to commit, citing reasons such as “DAB will not add listeners”, “the cost is too high” or “the payback period is too long”. The future is bleak for such a view, with multiple digital platforms already taking slices of listeners (or content consumers) from the existing analogue listener base. This may be through multinational offerings such as Spotify, Apple Music and others, podcasts or simple streaming. The long-term evolution of digital delivery

will ensure that analogue radio will decline significantly in many developed countries in the next 10 to 20 years; indeed, a UK government report released in April 2022 states: “Projections from Mediatique prepared for the Review suggest that FM listening will still account for 12–14% of listening in 2030 and 8–10% in 2035.”¹⁰ This decline is due to the demand for “modern” features, multiple content types and genres and costs. Countries that do not adopt digital broadcast radio will face the need to transition to mobile IP delivery in that timeframe and pay the price that is demanded by third-party network providers to do so, effectively limiting their control of the delivery of the content they produce.

Overall, those countries with the long-term vision and the courage to commit to DAB+ digital broadcast radio will enjoy the benefits of the most cost-effective and vibrant radio industry. We see evidence of this approach in Switzerland, with their planned ASO having a target completion date of 2024 and increasing discussions in other countries in Europe.

3.2 Accelerating the process

The Gantt chart in Figure 3-2 shows the accelerated steps for the overall adoption process, where we maximise task parallelism in order to minimize the time to Launch.

Each step has a set of pre-requisite activities within the previous step to allow it to start. We also know that a task contains many sub-tasks and threads of tasks. Many of those threads are “relatively” independent and can start once their prerequisites have been fulfilled. Such planning requires a moderately detailed approach, however it also provides the opportunity to take advantage of parallelism and minimise the time to Launch.

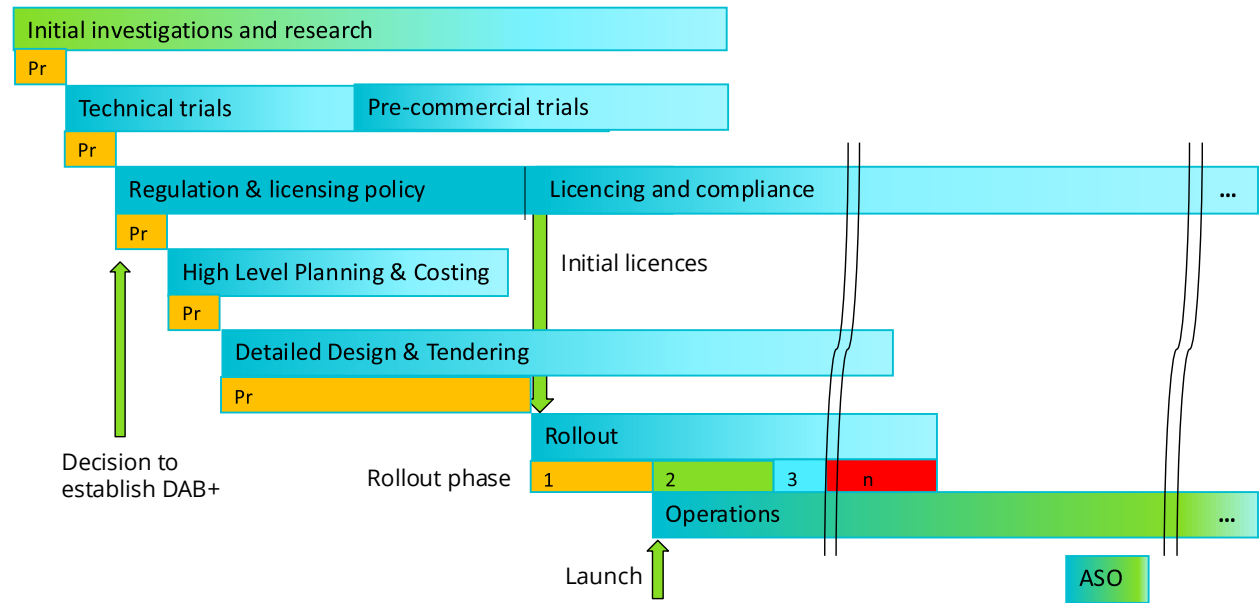


Figure 3-2: The accelerated adoption process

¹⁰ Source: <https://www.gov.uk/government/publications/digital-radio-and-audio-review/digital-radio-and-audio-review#chapter-3---the-future-of-radio-and-audio-listening-to-devices-used-in-home>

We must also be aware that the adoption process costs money, not only for equipment and network design and construction, but also for the resources required in regulation and overall organisation. In this respect, we recommend the establishment of a DAB+ champion organisation to assist the industry and to undertake common tasks. The use of a Champion organization will minimise the time to launch as well as the cost to establish DAB+ systems, as discussed further in §4.2.

As shown in Figure 3-2, each step consists of the prerequisite activities that need to be completed before starting the next step PLUS several ongoing activities. The ongoing activities are usually much larger than the prerequisite activities to start the next step, so emphasis in each step should be to complete the prerequisite tasks first and allow the next step to start before then embarking on additional activities.

Table 3-1 shows typical prerequisite activities within each step to allow the next step to commence. For example, we see within the “Research” step that the prerequisites to start the next step “Trials” are for the development team to “Understand the technology, country benchmarks, initial High Level requirements”. Once those basic requirements are fulfilled, the Trials, or Pilot systems, step can start while the “Research” step focuses on other activities such as “Additional studies on technical and regulation aspects e.g. Initial deployment targets, emergency support, tunnels”.

Similarly, within “Trials” step the initial targets to allow the next step on “Regulation” to commence are “...activities which are essential to system understanding and decision making including coverage capabilities, feature demonstrations”.

The accelerated process promotes a timely and coordinated approach which allows each step to commence as soon as possible using, where possible, centralised common support through a Champion organisation which in turn will minimise overall costs and maximise overall network quality.

Step	Prerequisite activities for <u>next step</u>	Additional activities
	Industry and Government desire to establish DAB+ to deliver improved and additional radio services Spectrum availability	
Research	Understand the technology, country benchmarks, initial HL requirements <i>WorldDAB resources: Country factsheets</i>	Additional studies on technical and regulation aspects e.g. Initial deployment targets, emergency support, tunnels <i>WorldDAB resources: Fact sheets, Technical support, Guidelines</i>
Trials	Target trial activities which are essential to system understanding and decision making including coverage capabilities, feature demonstrations <i>WorldDAB resources: Field testing factsheet</i>	SFN operation, coverage estimation accuracy, base planning parameters to determine field strength targets
Regulation	Initial decisions on service layers, population and area coverage, allotment planning approach, initial deployment areas (HL rollout plan)	Broadcaster types capacity assignment, licensing processes, forms and fees, operational rules and requirements
HL design	Initial deployment areas and surrounding areas completed in Allotment plan, initial areas HL cost analysis	Provide templates for equipment at different sites to drive commonality Completion of phase 2+ deployment areas
Detailed design	Initial deployment areas frequency allotments assigned, detailed design for phase 1 installations, tender document templates, Phase 1 rollout tender docs completed	Equipment tendering for Phase 1 deployment Frequency allotments and detailed design for Phase 2+ areas Equipment tender documents for phase 2+
Rollout	Initial Phase 1 deployment areas installed and tested	Rollout of equipment to phase 2+ areas
Operations	Provide ongoing status of rollout to completion timing to allow ASO timing assessment and process to be established	Continue with operations as the DAB+ network grows
ASO		Gradually turn-off and dismantle legacy analogue transmission systems

Table 3-1: Prerequisite activities for next steps, and on-going activities for each step

3.3 WorldDAB support

WorldDAB is the global industry forum for DAB digital radio. WorldDAB facilitates the adoption and implementation of broadcast digital radio based on DAB, the digital radio standard adopted by broadcasters across Europe, the Middle East, Asia-Pacific, Africa and beyond.

WorldDAB delivers tailored solutions and advice on all aspects of the switch from analogue to digital radio, including regulation, licensing, demonstrations, network build-out, marketing and production of new digital radio content.

WorldDAB also provides regular workshops and targeted support for countries embarking on the adoption of DAB+ digital radio. Workshops have been delivered to many countries outside of Europe, including at the ABU Digital Broadcasting Symposium in Malaysia and targeted workshops for countries such as Thailand, Malaysia, Indonesia, Vietnam, Jordan, Algeria, Uganda and South Africa and Southern African Development Community (SADC) countries. Such workshops have also included live demonstrations where a temporary low-power DAB+ transmission is established, typically around 100 W ERP, and field testing is then used to demonstrate the features and capabilities of DAB+.

WorldDAB continues to provide this support and encouragement around the globe. To find out more, please contact the WorldDAB Project Office at projectoffice@worldddab.org.

WorldDAB continues to evolve the DAB+ standards with new features and capabilities through its committees and task forces covering all aspects of the DAB ecosystem, from standards updates (Technical Committee) to automotive implementation (Automotive Working Group), and ensuring that communities know about DAB (Marketing Committee). WorldDAB member organisations contribute in these forums to ensure that DAB+ digital radio provides current and relevant capabilities.

A full description of the WorldDAB organisation and activities is provided in §17.

4. Initial investigations and research

This section provides a guide to activities that are generally undertaken to establish a good understanding of what DAB+ can provide and how it is planned across the various stakeholder sectors. Several educational activities are used to provide the necessary information and skills to allow local planning and implementation. A transmission demonstration is usually undertaken to provide hands-on experience with DAB systems and reception demonstrations, as discussed in §5. While there will always be some ongoing educational activities due to new features or situations, once the foundations are completed each country should be able to decide what further activities are required to allow decisions on whether to adopt DAB+ as a national broadcasting standard and to then be able to commence the adoption and planning processes.

4.1 Establishing stakeholder interest

When broadcasters and/or the regulator become interested in DAB+ as an alternative to analogue broadcast services, it is usual to discuss possible ways forward both within their own organisations and with stakeholders across the broader radio ecosystem. This step will often result in establishing a digital radio action plan. In some cases, the stakeholders may simply be the Public Service Broadcaster(s) (PSB), while in other cases it could be a combination of the PSB(s), commercial broadcasters and the regulator.

Once a good understanding of the DAB+ system has been gained, typically through workshop sessions, stakeholders can discuss the next steps on how to move forward. This is often a critical point which has vested interests; for example, Public Service Broadcasters may wish to increase their service offerings to the general public, while some commercial radio operators may be opposed to the introduction of new services as they may feel commercially threatened. It is important to ensure that all stakeholders are heard and that a clear plan of action to decide how to move forward is developed which includes how to deal with any issues identified. To successfully adopt and rollout DAB+ most stakeholders need to be in positive agreement to move forward.

It is usually useful to create an organisation to champion DAB+ either as an independent entity or a committee within an existing organisation. Examples include Digital Radio UK and DigiMig in Switzerland. The DAB+ organisation should provide an inclusive and positive environment and establish general working practices to move forward through the adoption process.

In these early stages, stakeholders will typically include the Public Service, commercial and community broadcasters, the regulator and relevant government departments. Representation from the retail and automotive industry will be needed, particularly through the design, rollout and operations phases, along with representatives of transmission and multiplex network providers.

Meetings of the stakeholders should be scheduled at regular intervals, with formal actions and an agreed timeline of activities which may also require the formation of sub-committees to undertake specific areas of interest, such as commercial, technical and marketing, as

shown in Figure 4-1. Each part of the DAB+ champion organisation will be active at different times during the adoption process, often with significant overlap and interaction, as discussed below.

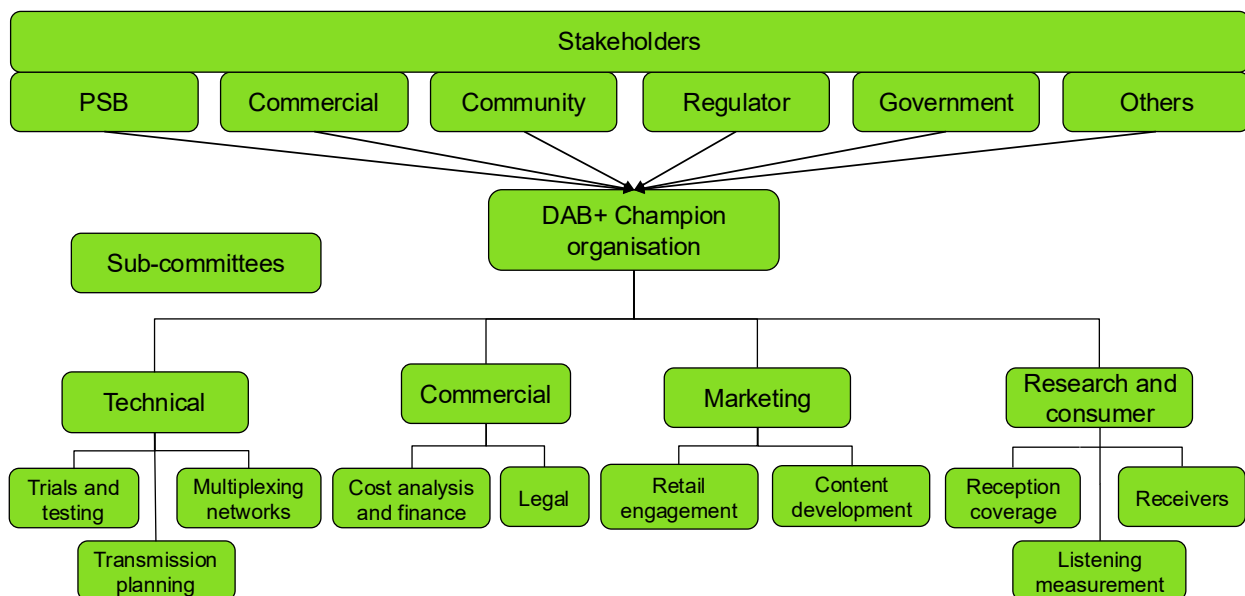


Figure 4-1: DAB+ champion organisation and stakeholder involvement

4.2 Digital radio champion organisation

We discussed above that a Digital Radio Champion organisation can help the entire radio industry within each country to move forward with DAB by undertaking responsibility for some common tasks, such as technical guidance, legal assistance and marketing. Figure 4-1 shows a typical organisational chart. The Champion organization is usually led by a CEO under the guidance and direction of a Steering Board which is composed of representatives from the principal stakeholders.

Digital Radio Champion organisations are often run as Not-for-Profit companies with funding being provided by member organisations.

Examples include Digital Radio Netherlands, Digital Radio UK, Digital Radio Deutschland, DigiMig in Switzerland, The Digital Technical Advisory Committee (DTAC) in Australia, and the Southern African Digital Broadcasting Association (SADIBA) in South Africa, all of which undertook various roles to assist industry during DAB establishment and continue to provide industry support.

The role of the Champion organisation evolves with time as each country moves through the adoption process, as discussed in §3. This means the staff required within the organisation will change over time. For example, early in the overall adoption process there is a higher emphasis on technical and regulatory aspects, whereas after the initial launch the emphasis will generally shift to minor technical support and more emphasis on listener support and take-up measurements, along with on-going marketing activities to encourage new listeners. The profile on the number of staff required usually peaks around the time of initial launch.

4.3 Stakeholder education

The educational programme shown below is an example covering the key aspects of DAB+ to allow an in-country study to provide guidance on the benefits, costs and next steps. Such workshops can be tailored to the needs of the participants and focus on specific areas of interest, some of which may not be listed in the example below.

- a. Workshop / webinar 1 – general capabilities and business case
 - i. What is digital audio broadcasting?
 - ii. The features provided and advantages gained
 - iii. Commercial and technical business cases
 - iv. The overall adoption process
- b. Workshop / webinar 2 – implementation components
 - i. Overall system operation
 - ii. Head end systems and options
 - iii. Transmission systems and options
- c. Workshop / webinar 3 – services and receivers
 - i. Service implementation – bit rates, metadata, hybrid operation
 - ii. Content and metadata sources
 - iii. Home and portable receivers
 - iv. Automotive receivers
 - v. Whole of industry approach
- d. Workshop / webinar 4 – system design, and allotment and transmission planning
 - i. Overall system design and requirements, number of services and their location
 - ii. Allotment planning methodologies
 - iii. Transmission planning – coverage and interference

The initial training programme will need to be followed up with further activities as the stakeholder group expands and activities gather momentum.

The initial stakeholders are likely to be the larger broadcasters, the regulator / government and possibly parties interested in providing network facilities. This group will grow once interest increases to include the automotive industry, receiver manufacturers and retailers, as well as additional broadcasters and equipment providers.

Ongoing education is usually provided when the demand is established, for example once demonstrations have been at least started or planned and decisions to move forward have been made.

5. Demonstrations and pilot transmissions

Demonstrations involve the physical design, implementation and testing of DAB+ systems and transmissions so as to develop the necessary skills for adoption and provide stakeholders with experience of DAB+ in their own locale. Ideally the design, construction and testing are undertaken by the local broadcasters / stakeholders with the assistance of international experts and equipment providers. Demonstrations may be undertaken over an extended period and often merge into full-time or permanent operation. Demonstrations may be very low power, for example 100 W Effective Radiated Power (ERP), or be up to several kW ERP. The activities that are usually undertaken during DAB+ demonstrations are discussed below.

5.1 System requirements

The DAB+ trial system requirements are usually defined through discussions between the stakeholders, although it is not uncommon for a major stakeholder to take the lead. High-level decisions on a range of aspects need to be agreed prior to commencement, including:

- a. When can the DAB+ demonstration be done, given spectrum availability?
- b. What funding is available from what sources?
- c. Where will the DAB+ demonstration be done?
- d. What services will be included?
- e. What tests and demonstrations will be included?
- f. What specific objectives should be included, such as coverage analysis?
- g. What test results are needed for decision-making on future activities?

5.2 System design

The demonstration system design covers the complete system from audio and metadata inputs, the multiplex system setup and the transmission system, including the transmitter, filters and antenna system.

The coverage requirements are usually to provide either an indicative coverage of a city or town or a low-power limited area transmission. The coverage area decision is strongly influenced by the desires of the stakeholders to move forward, or be more cautious and review the results before committing to larger and more costly transmissions.

The expected coverage is usually modelled prior to specifications sign-off to provide stakeholders with an understanding of the likely area that will receive service and can be tested in the field. In some cases, the equipment specification may be adjusted to ensure that the expected coverage includes specific areas, such as the city centre / Central Business District (CBD) or areas that may experience shadowing.

5.3 Equipment sourcing

The amount and type of equipment depends on the scale of the demonstration. Small demonstrations of less than 1 kW ERP have been undertaken using loaned equipment with only some ancillary equipment and the antenna system being the primary expense. An example low-power demonstration system is shown in Figure 5-1. Larger demonstrations which involve significant transmitter powers, e.g. over 1 kW transmitter power, usually require more significant antenna, feeder and filter systems and hence are more expensive. Higher-power demonstrations provide more opportunities to test reception under different conditions and to obtain more test measurements which can be used to “tune” coverage models. An example high-power demonstration system is shown in Figure 5-2. Such high-power systems may later become part of a permanent transmission network.

The demonstration process from specifications through design and implementation provides significant hands-on experience for later system designs and deployments.

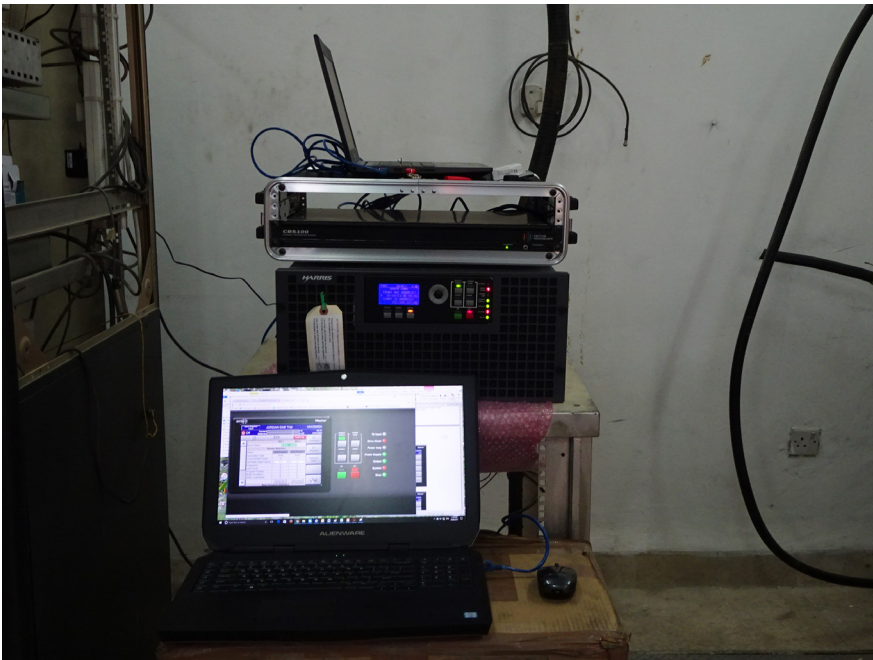


Figure 5-1: Example low-power DAB+ demonstration system



Figure 5-2: Example high-power DAB+ demonstration system

5.4 Demonstration activities and testing

Demonstration activities are usually undertaken in two groups: field strength and coverage testing, and feature testing.

Field strength coverage is usually predicted using modern propagation prediction tools which take into account accurate Digital Terrain Maps (DTM) and building and foliage clutter. Field testing is used to check the prediction and tune the models used. This is particularly the case for cities with significant high-rise buildings, which can cause areas of low field strength due to shadowing effects. This is a very important aspect of demonstrations as prediction is often used to help design the power and antenna patterns for permanent services during the allotment planning phase, and in the case of cities with many high-rise buildings a Single Frequency Network (SFN) of a number of transmission sites may be required to achieve the required coverage. It is sometimes also useful to do demonstrations in multiple different terrain types. Figure 5-3 (upper) shows an example field strength prediction and Figure 5-3 (lower) shows a correlation analysis between the predicted field strength and field strength measured along the route marked on Figure 5-3 (upper). The colour palette of the field strengths is shown in Figure 5-4.

Indoor testing is also useful to check in-building field strengths and building entry loss values and the consequent field strength reference levels for different classes of coverage, for example rural/open, suburban, urban and dense urban. The values used differ from country to country due to differences in terrain, building structures and urban densities.

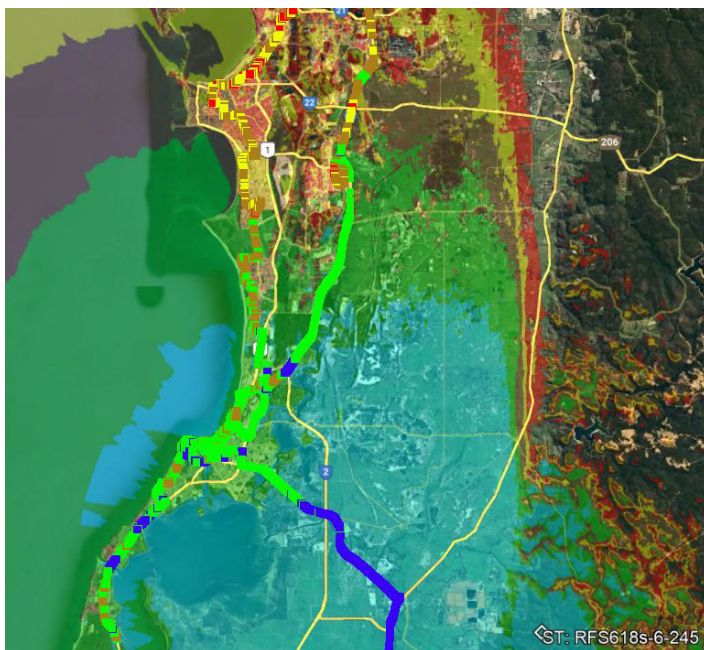
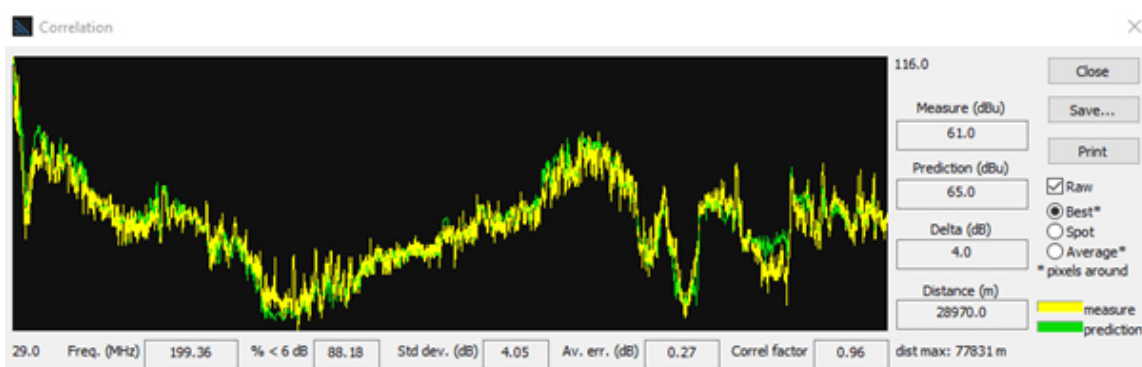


Figure 5-3: Example field strength prediction and drive test verification (top) and the analysis of prediction accuracy (bottom)



>=dBu/OAA	Label	
45	poor vehicle	Red
50	vehicle	Yellow
54	suburban	Brown
60	urban	Green
70	dense urban	Cyan

Figure 5-4: Australian field strength coverage palette

Feature testing demonstrates the capabilities of the system and can include testing of multiple receiver types, including car receivers and the demonstration of audio quality for different content types, metadata delivery and features such as Emergency Warnings (ASA) and Service Following. Hybrid radio is also now becoming common place and should also be demonstrated.

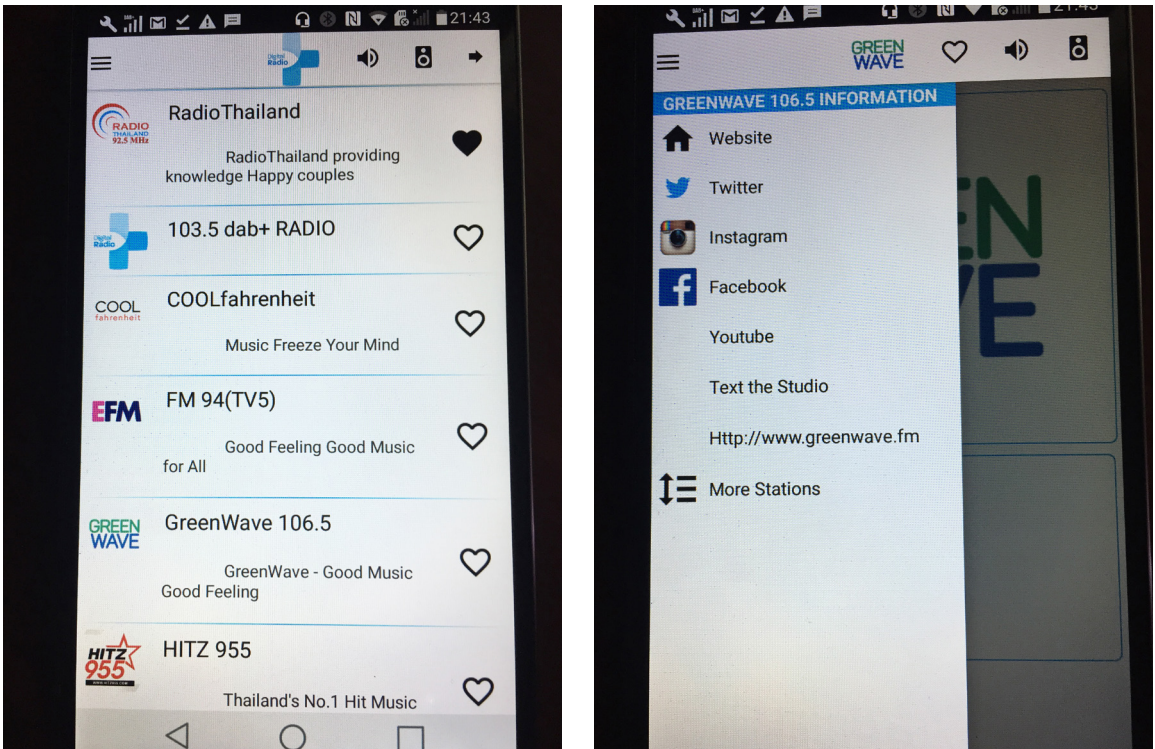


Figure 5-5: Example hybrid radio metadata

5.5 Reporting

The results of the testing are usually compiled into a report for all stakeholders to review. The report will also include recommendations regarding different aspects of the system, such as coverage deficiencies, the use of features and the availability of receiver types. The report is usually accompanied by a seminar presentation which allows stakeholders to enquire about aspects of the demonstration and the system performance.

The results of the education programme and the field demonstrations are critical inputs to the next steps in the process – formal standards adoption and system planning. The demonstration transmissions will often continue after the initial reporting and the decision to proceed to the next steps to allow further testing and demonstrations and in some cases help to “seed” the market with early adopters acquiring receivers. Early adopters are very important as broadcasters can try out new service concepts and music genres and get feedback.

An example Gantt chart of the initial investigations and technical demonstrations phases is shown in Figure 5-6.

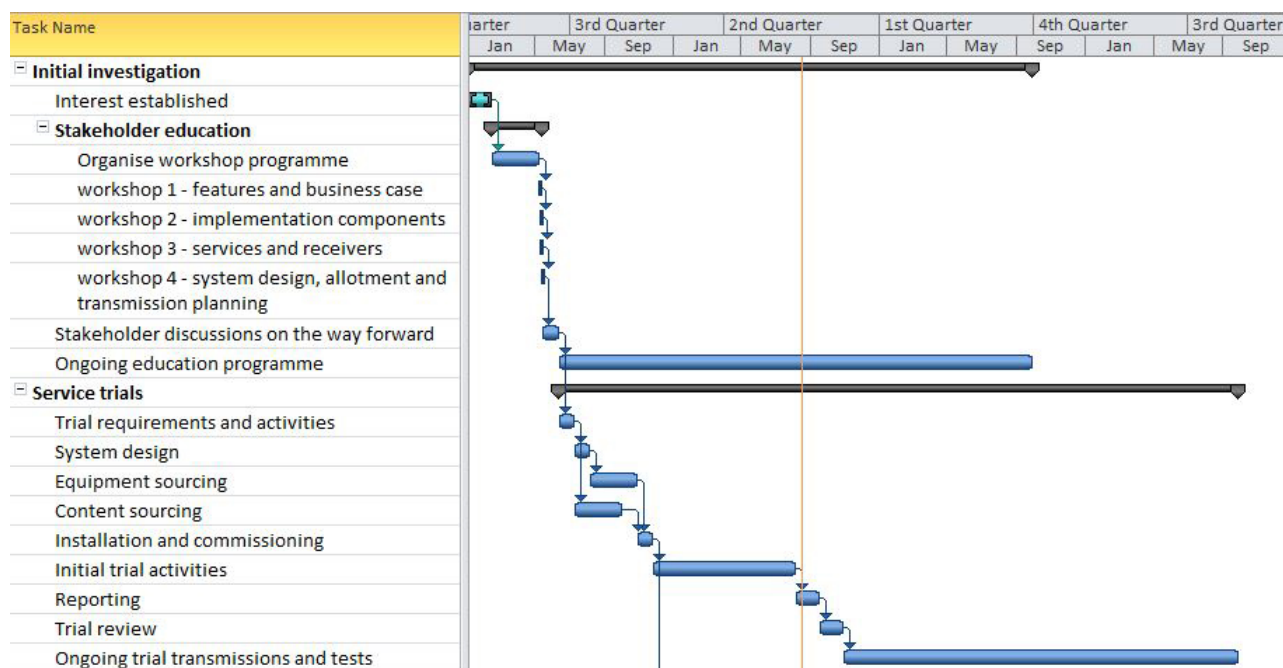


Figure 5-6: Example Gantt chart for Phases 1 and 2

6. Formal DAB Standard adoption

The adoption of DAB as a national radio broadcasting standard usually requires several formal steps and often includes legislation that supports the ongoing licensing process for the use of radio frequency spectrum. In order to complete this phase, it is essential that the regulator and the majority of the stakeholders believe in a positive business case for DAB+ digital radio and that the ecosystem works as a whole to establish the most appropriate business and operating conditions to ensure future success.

6.1 Structure and control

In most countries, there is a top-down approach to the licensing and regulation structure. A common structure is shown in Figure 6-1, with the responsible government department at the top, typically called the Ministry of Communications and Information Technology (or similar). The ministry is responsible for the establishment of legislation which controls the issuing and use of radio frequency spectrum, for example in Australia the Broadcast Services Act 1992 (as amended) or in the United Kingdom the Communications Act 2003 (as amended) and the Broadcasting Act 1996 (as amended). The Acts are the principal legislation that sets out the bulk of the regulatory environment and can be amended from time to time to accommodate new technology, political environments and business evolution.

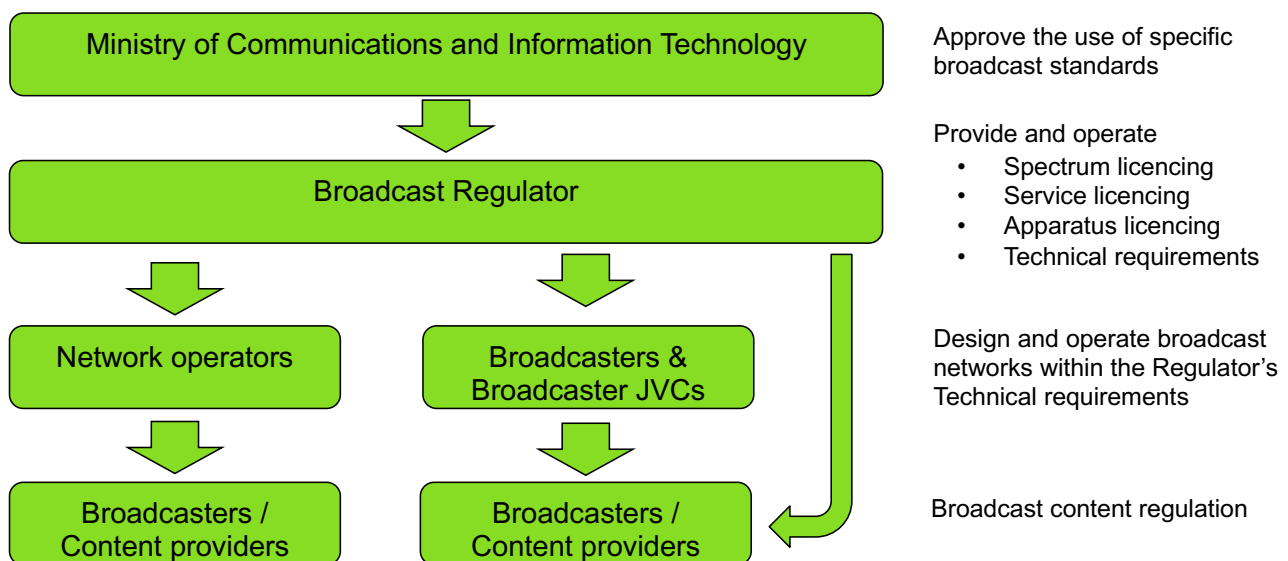


Figure 6-1: Typical regulatory structure

6.2 Stakeholder roles

6.2.1 Regulators' responsibilities and approaches

The regulations are supported and usually developed by “The Regulator”, which is a government authority with powers to grant or remove spectrum and service licences. Examples include the ACMA¹¹ in Australia, Ofcom¹² in the UK and the NBTC¹³ in Thailand. The regulator usually has many roles in addition to broadcasting, including telecommunications (mobile and fixed telephone, data networks, satellite communications, etc.), electronic security and often content regulation. The regulator is responsible for ensuring that radio spectrum is used efficiently and maximises the overall socio-economic benefit to society, which is generally the overarching requirement for spectrum use and management.

Regulators regularly undertake planning activities regarding the future use of radio spectrum given ongoing changes in technological use, public and commercial demands, and international trends. It is common for regulators to issue Spectrum Outlook documents, typically for three to five year periods, which outline the current plans and expectations over the foreseeable future. While this applies to the entire spectrum (i.e. DC to light) there are also considerations for broadcasting. The global use of spectrum is within the remit of the International Telecommunications Union (ITU), which is a United Nations organisation, although the specific use of particular frequencies is the responsibility of the national frequency regulators, ensuring that cross-border interference issues are addressed with neighbouring countries.

Regulators will generally be involved in planning or at least reviewing new transmissions (or changes to existing assignments and installations) to ensure that they will provide fit for purpose coverage without causing excessive interference into other services. As such, they are also responsible for setting the operating guidelines for broadcast transmissions, including maximum and minimum field strengths, coverage expectations and interference Protection Ratios (PRs). For DAB+ these technical planning parameters are provided through recommendations and guidelines such as the EBU Tech 3391 [1] and the ITU BS.2241 [6]. While these documents provide recommendations, it is common to find that individual regulators will provide their own adjustments to the base-level technical parameters¹⁴ with the result of slightly different required minimum median field strengths for different classes of service and coverage area types.

Modern regulators will generally undertake public consultations and industry discussions to ensure that they have a clear understanding of the positions of various broadcasting industry sectors; unsurprisingly, there are often differing opinions. To resolve conflict situations, regulators will sometimes set up industry committees to work through the issues and arrive at mutually acceptable conclusions. An example of such a process was the Australian Digital Radio Planning Committee, which was tasked with determining how to plan DAB+ frequency allotments in Australia. The task was complicated by the availability of only two VHF Band III television channels, resulting in only eight DAB+ frequency blocks being available for the

¹¹ ACMA is the Australian Communications and Media Authority

¹² Ofcom is the Office of Communications, UK

¹³ NBTC is the National Broadcasting and Telecommunications Commission, Thailand

¹⁴ Base-level technical parameters include antenna gain for different receiver types, location variation standard deviation, building entry loss for different clutter classes and man-made electrical noise in different environments.

entire country. To complicate matters further, the Public Service Broadcasters (PSBs), the ABC and SBS, required that they have their own ensemble with no sharing of frequency blocks (or equivalently multiplex ensembles) with the commercial and community broadcasters who do share capacity. The outcome was the formulation of a set of Planning Principles [7] which defined the number of frequency blocks to be provided to the PSBs and the commercial and community broadcasters and the technical parameters which would be used to determine the allotment of frequency blocks to commercial licence areas. Such an approach can be used by other countries to resolve cross-industry issues and allow the broadcasting sector to move forward.

6.2.2 Broadcasters' role

Broadcasters often have a significant input to the overall development of the regulation and licensing structure. It is important that a forum is provided for the broadcasters to have input to the regulator on their preferences as there are several aspects which can have significant cost and operational impacts. These areas include the types of licence that are issued, the level of control that network service providers have, for example do they own the spectrum licence or just provide transmission services, as well as the ability to provide increased services, e.g. digital-only services.

There is often debate between the various broadcaster / content provider sectors as to which broadcasters should be included on wide area DAB+ ensembles and the capacity which is allocated to existing broadcasters. The regulatory decisions made early can impact the broadcaster and network provider business decisions and their level of commitment moving forward. There are also several incentives that the regulator and government can provide to entice broadcasters to participate in the DAB+ adoption process; these are discussed in more detail in §6.7.6.

6.3 Operating models

Infrastructure providers operate beneath the regulator, as shown in Figure 6-1. There are many models for operating DAB+ networks. These models are based around the commercial operating structure, essentially which companies own each part of the infrastructure. The basic models are:

- Network Operator (NO), or service provider – a non-content providing third party provides most of the DAB+ system's infrastructure
- Broadcaster-owned – a broadcaster or a group of broadcasters own the majority of the DAB+ system's infrastructure.

6.3.1 Network and transmission service providers

Network Operators are companies that provide transmission and/or multiplexing facilities and services. These can be either public or private but tend to be commercialised private companies in Western-style political systems. They can, but don't always, own the spectrum licence for the transmissions and may simply lease tower space to broadcasters.

Transmission services include the provision of transmitters, tower aperture (vacant vertical

space on the tower), antenna systems and the associated infrastructure. Their operating model revolves around the delivery of DAB+ ensembles to air with a specified Service Level Agreement (SLA) based on the required Effective Radiated Power (ERP) and antenna radiation pattern, and reliability requirements.

The multiplexer network provider operates multiplexer and audio and PAD encoder systems to allow broadcasters (content creators) to deliver their content in the form of services within a DAB+ ETI/EDI stream to the transmission sites required. The multiplexer network provider then charges for their services based on the DAB+ multiplex capacity used and the provision of enhanced service features such as Programme Associated Data (PAD), Service Following, Emergency Warnings (ASA) and hybrid radio. They may also provide IP network connectivity through either their own telecommunications networks or leased services. Their service charges are typically competitive and based on demand.

In many cases the same organisation will supply a combined service where they provide both the multiplexer network and transmission system network. As per the multiplex network operator, combined multiplex and transmission Network Operators charge Access Fees, the cost of which are dependent on the multiplex capacity used (for one or more services) as well as the number, types and power of the transmission sites used to deliver the multiplex to air.

Example network operators include:

- Arqiva in the UK, which provides both multiplexing and transmission services and also owns¹⁵ the spectrum licence for commercial operators; the BBC owns their spectrum licence. Telenor in Norway operates in a similar manner.
- TXA and BAI in Australia, which provide transmission services only and do not own the spectrum licence, and Telstra Broadcast Services in Australia, which provides multiplexing services, including IP contribution and distribution networks.

Network and transmission service providers have specialist knowledge to help ensure that the technical basis of DAB is correctly established by the regulator. To that end, they can provide input or feedback to the regulator on planning and operations aspects, such as coverage field strength requirements, particularly in difficult terrain and urban environments, protection ratios to avoid interference, and operational requirements (if relevant).

The disadvantage of this approach is that the NO can set the Access Fee for ensemble capacity in accordance with their view of required operating profit. This may make access comparatively expensive when there is limited capacity and especially when there is no opportunity to expand capacity through new ensembles, as in the case when spectrum is limited. This can cause the Regulator to require specific and reportable maximum profit margins to ensure the ecosystem remains healthy.

Profit limitations have been imposed in Australia to ensure that the community radio sector is able to access ensemble capacity at the same rate as commercial broadcasters.

¹⁵ Note that the term “owns the spectrum licence” is actually referring to the exclusive use of a specific part of the radio frequency spectrum for a specific period of time. In reality, the government in each country owns the RF spectrum and they lease that spectrum to users under the established regulatory system.

6.3.2 Broadcaster-owned/operated networks

Broadcaster-based DAB+ transmissions are usually either by the Public Service Broadcaster or for commercial/community broadcasters via a Joint Venture Company (JVC) or equivalent business structure. In Australia, the commercial and community broadcasters have formed JVCs in the populous metropolitan cities and some large regional centres where they lease facilities, and in some instances transmission and multiplexing equipment from site owners. On the other hand, in Vietnam, radio transmissions are controlled by the state-owned broadcaster, the Voice of Vietnam.

The JVC is usually formed on a per ensemble basis with shareholding being related to the ensemble capacity used. In some cases, broadcasters may wish not to become owners within the JVC scheme and be simple access seekers where they pay for access to ensemble capacity just as in the NO approach.

The setting of Access Fees can be contentious, as it can give rise to price gouging where the JVC operator business partners charge more for non-shareholders to access capacity. This can be controlled through the mandatory use of Access Fee calculation methods. Such methods may also be legislated to limit JVC profits to a specific amount, usually in the range of 15% to 30% of operating cost.

Small-scale DAB (SS-DAB) is another example of broadcaster-owned / operated networks. For example, in the UK there are now many SS-DAB networks (usually consisting of a small number of low-power transmission sites) which provide local community broadcast services. These systems are usually very low-cost implementations and are owned by multiplexing companies which may or may not include broadcaster ownership.

6.3.3 Country examples

Table 6-1 shows a number of operating model examples. We observe that in most cases the Network Operator is a commercial organisation which does not produce any content but is usually the multiplex provider as well as the transmission network provider. They range in scale from national to regional and sometime city area based. Usually the NO also holds the spectrum licence and then leases capacity to the radio broadcaster/content provider on an annual fee basis. The main exception being some Public Service Broadcasters who are assigned spectrum licenses.

The JVC model where the broadcasters own the spectrum licence is mainly limited to Australia, although some small scale-DAB community radio operators also use that model.

Country	Broadcaster type	Network operator	Spectrum licensee	Comments
Australia	PSB (ABC & SBS)	BAI / Telstra BS	PSB	
	Commercial	TXA	Commercial stations	
	Community	TXA	Allocated capacity on Commercial ensembles	
France	PSB	Various commercial NOs TDF	NO	Most services operate at 88 kbps EEP-3A
	Commercial	Various commercial NOs Radiomux, Towercast etc	NO	
Germany	PSB	Media Broadcast	DR Deutschland	
	Commercial national	Antenne Deutschland	Antenne Deutschland	
	Commercial regional	Various regional NOs	NO	Federal state based
Norway	PSB (NRK)	Norkring	Norkring	
	Commercial	Various commercial NOs	NO	
Switzerland	PSB (SSR-SRG)	SSR-SRG	SSR-SRG	
	Commercial regional	Swiss Mediacast Digris AG	NO	
	Commercial local	Various NOs	NO	
	Community			Maybe SS-DAB based
UK	PSB (BBC)	Arqiva	BBC	
	Commercial National	Arqiva	Arqiva	Digital One owned by Arqiva Sound Digital developed by Arqiva with Bauer and Wireless
	Commercial local	Various NOs	NOs	
	Community	Various commercial NOs	Broadcaster JVCs	SS-DAB based

Table 6-1: Example Network Operators

6.4 Content regulation

The broadcasters (content providers) must produce content which conforms to the country's broadcasting content regulations. These can include how much local area content is required, how much national content is delivered (that is content generated within the country, whether it is music, current affairs or other content), the type of content to ensure suitability in terms of the country's general ethical and religious basis and the amount and type of commercial advertising.



Figure 6-2: A live radio studio showing multiple presenter and guest capabilities as well a control panels and desk¹⁶

While the content that is to be broadcast is regulated directly through licensing by the regulator which allows the broadcaster to deliver their content, that licence is subject to the broadcaster observing the rules that apply to the content. Each country will have different content requirements depending on their cultural and political systems.

Third-party transmission and multiplex service providers are generally not subject to the content regulations as they are simply “carriers”. They do, however, have to provide the broadcast transmissions according to the requirements and restrictions applicable in transmission and apparatus licences. In cases where the broadcaster operates their own transmission system, they are also subject to those transmission and apparatus licences.

Broadcasters have critical input to the regulation process as they will provide context for the digital broadcasting scheme as a whole. They should provide input to the regulation evaluation process in the form of the number of services required in each area, as this will impact spectrum requirements, the types of content, as this can impact licensing types, and coverage and overspill allowances and preferences. Without this input, the regulator may inadvertently assign too little spectrum or define requirements which make implementation overly expensive.

¹⁶ Credit: A Capital studio at Global's headquarters in London, UK

6.5 Business case

The business case for DAB has many facets, some of which are commonly accepted and some of which are prone to scepticism. As with all new systems that are introduced, there need to be clear advantages for the providers and the users. In the case of DAB+ there are many compelling factors, all of which have differing impact depending on the state of radio broadcasting in the individual country. The business case for DAB can be summarised as shown in Figure 6-3, where the case for both the listeners and society is the responsibility of the regulator and government.

Listeners	Broadcasters	Society
• Increased choice • Superior audio • Text and images	• Opportunities to innovate (grow audience / revenues) • Cost-effective distribution • No gatekeeper	• Protect national culture • Green distribution • Reliable in emergencies

Figure 6-3: Business case fundamentals

From a regulator perspective, the efficient use of spectrum is often a critical part of decision-making due to the increasing value of RF spectrum. However, it is also recognised that the ability to provide the general public with additional services is beneficial to society. In most countries around the globe, most major cities have congested FM bands to the extent that there is no spectrum available for new services. This limits the ability to deliver additional services which can benefit society in general through:

- Increased languages, most societies are multicultural so the ability to deliver information in multiple languages is beneficial to listeners, as well as providing more opportunity for government messaging, particularly in times of crisis
- More entertainment options, whether through the delivery of more music genres or additional news, weather and current affairs programmes.
- Educational opportunities, particularly in countries with poor internet infrastructure; educational classes can be supplemented with content via DAB+.
- Data services, including traffic and travel information.
- Emergency warnings to help protect people from danger in critical situations such as natural disasters.

While increased choice of content has been demonstrated to be a critical factor in the public's decision to invest in purchasing a DAB+ radio, other factors, such as superior audio quality in areas of FM congestion, and metadata, such as text and images, are also important.

For regulators, the assessment of the necessary number of services in an area is a high priority. The ability to meet the expected service number requirement is directly impacted by the available Band III spectrum and the RF efficiency of DAB+. It has been shown over the last decade that when DAB+ is introduced to a country, the number of services typically increases by between approximately three and six times overall, and seven times for national services, as demonstrated in Figure 6-4. This is particularly the case for both PSBs and commercial services.

National radio services

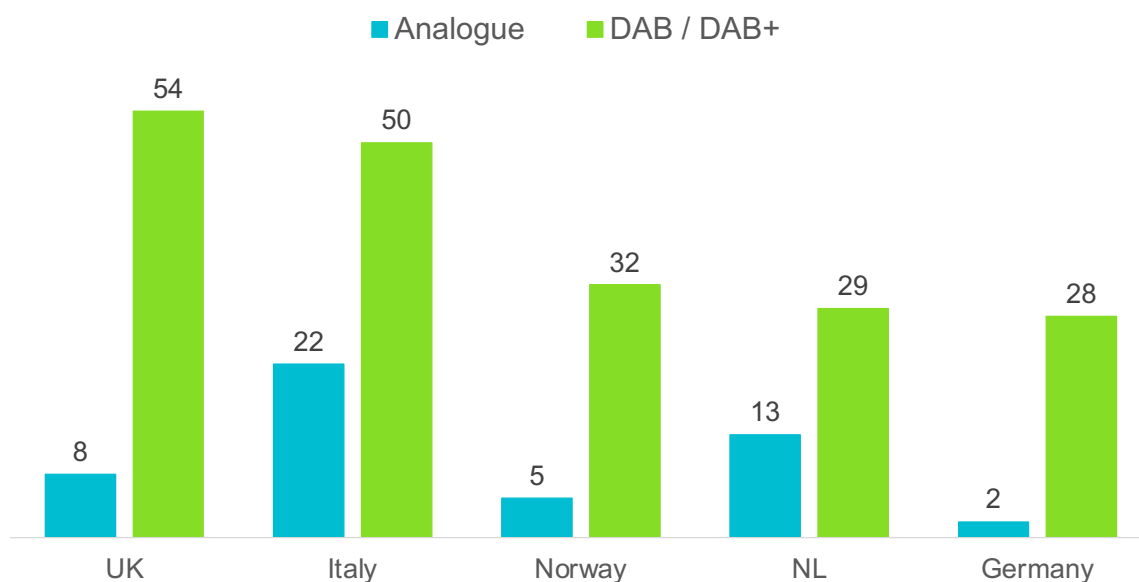


Figure 6-4: Increased numbers of national radio services in selected European countries¹⁷

Some countries may already have very large numbers of active FM transmissions in an area, many of which interfere with each other causing coverage limits and reception difficulties. In this case, DAB+ offers increased coverage areas and interference-free reception and delivers more services in a particular location.

Without access to spectrum-efficient digital delivery, it is difficult for broadcasters to innovate while providing new services through cost-effective broadcasting. Some broadcasters, however, see the provision of additional services as a threat and a way to reduce or dilute their listening audience. This negative argument has been largely shown to be false and indeed it is not the additional broadcast services that are the competition, it is digital streaming giants such as Spotify, Apple and Google who seek to take advantage of IP delivery systems to expand their own international businesses. This is usually countered by local broadcasters through arguments about live and local content, especially news and current affairs; however, even that area is now under threat.

¹⁷ Source: WorldDAB 2022

Overall regulation should encourage the development of radio in the digital age, as summarised in Figure 6-5.

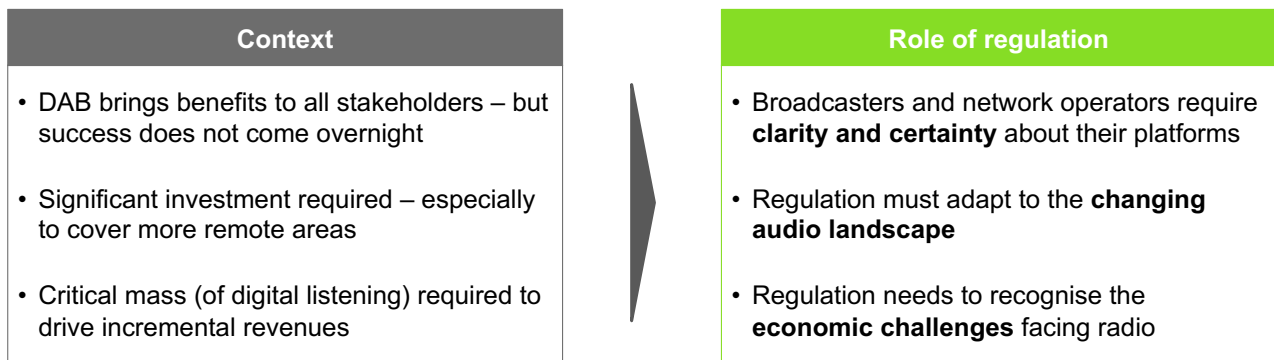


Figure 6-5: Summary of the high-level role of regulation

For broadcasters, there are two primary commercial considerations: 1) How can they grow revenues? and 2) How can they manage costs?

The key to growing revenues for commercial radio networks is the ability to reach increased audiences cost-effectively: more listeners equate to more revenue. Therefore, there are regular surveys of listeners to determine which station or programme is reaching the highest audience.

One example of how to grow your audience is Absolute Radio in the UK. They embarked on a strategy to provide decade-based and genre-based music content. Starting from one analogue service, they now deliver 10 DAB services in the UK with the result of tripling their audience over 10 years, from 1.7m (Q1 2012) to 5.3m (Q4 2021). This is known as the Brand Extension strategy, as demonstrated in Figure 6-6, and has been successfully copied by many radio networks around the globe.

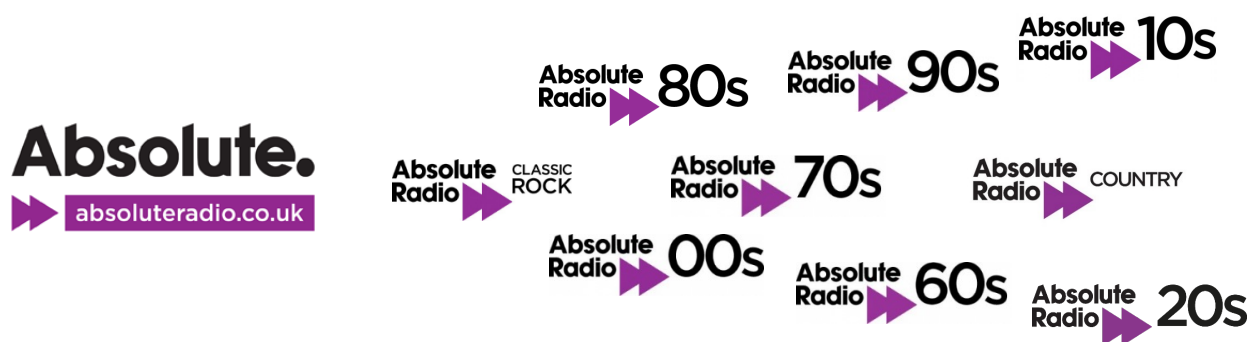


Figure 6-6: Absolute radio Brand Extension strategy services.

Another example is to increase the geographic coverage of the service, which is what the London FM current affairs station LBC (Leading Britain's Conversation) did. LBC joined the UK national commercial multiplex in 2014 with a London-based listening audience of 1.1m people. By 2022, the number of listeners was 2.5 times higher at 2.6m people as shown graphically in Figure 6-7.

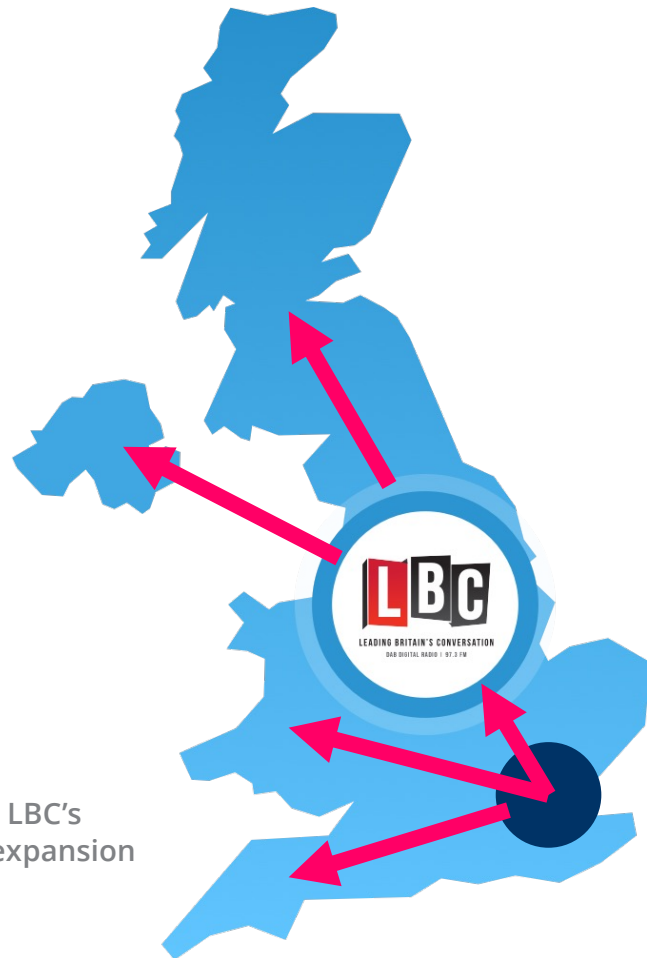


Figure 6-7: LBC's geographical expansion

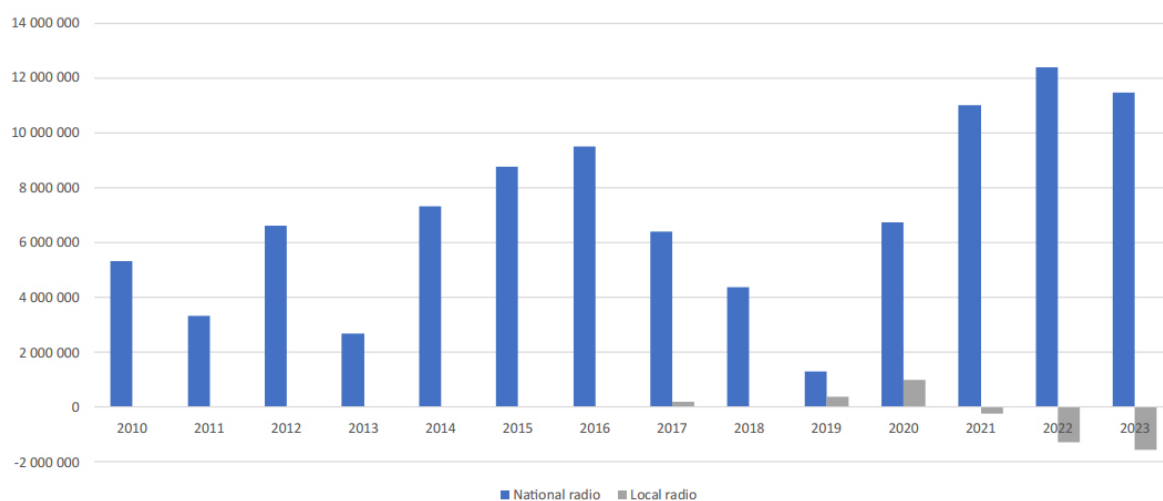
When it comes to the actual cost of operations, there is no doubt that DAB is much lower cost than AM and FM; this has been shown in many studies, e.g. [15] and [16]. Indeed, DAB+ has been shown to have positive "green" credentials in many studies [18].

Perhaps the bigger issue is the amount of time that analogue and digital services are simulcast. In Europe, the European Electronic Communications Code (EECC)¹⁸ requires that from the end of 2020 all new cars must be capable of receiving and reproducing digital terrestrial radio. This directive applies to all EU countries regardless of their DAB rollout status. This directive provides an ongoing expansion of the DAB listening base and effectively encourages broadcasters and countries to consider analogue switch-off (ASO) more quickly. Such an initiative in countries newly adopting DAB+ will provide a ready listener base prior to DAB+ system deployment.

While §11 has more about the mechanics of ASO, it is worth noting the success of the Norwegian radio industry after its ASO. As shown in Figure 6-8 the Norwegian commercial radio industry has had ongoing profitability - although somewhat variable - over the pre-ASO years. Since the ASO which was completed in December 2017, the profit margin has increased significantly even through the effects of the 2020 pandemic and as of 2022 was at an all-time high.

¹⁸ See the WorldDAB factsheet for more information: https://www.worlddab.org/public_document/file/1759/Global_DAB_receiver_regulation_factsheet_Oct_2025.pdf?1761226434

Operating profit (Euro) – commercial radio



Sources:

- The Brønnøysund Register Center (figures for Viaplay and Bauer Media).
- Local Radio Association (comparable figures available from 2017).



Figure 6-8: Norwegian commercial radio profit before and after ASO

All broadcasters are aware of the threats to their business and as such a risk analysis of not implementing DAB+ to secure their future as a digital radio service provider is essential. This is particularly the case considering the rise of multinational digital streaming giants and the increasing value and delivery of metadata, such as logos, images and links.¹⁹

In addition, DAB provides an Emergency Warning System / ASA feature which can automatically switch from the currently selected service to the Emergency Warning service, thereby providing very rapid warning information for fast moving disaster situations such as bushfire, tsunami and floods.²⁰

To ensure the success of digital radio, five critical factors known as the 5Cs have been observed, as shown in Figure 6-9. Policy and regulation needs to consider these critical factors and the radio industry stakeholders need to collaborate to ensure success. The 5Cs are:

1. Coverage – is critical to demonstrate that the industry is serious about adopting DAB+ as the next generation of radio delivery. Increasing coverage promotes the uptake of DAB+ radio devices and encourages new content to be distributed in a cost-effective manner.
2. Content – is King! New content has been found to be the biggest driver for listeners to adopt DAB+.
3. Consumer devices – are needed to receive and reproduce the audio content and associated data services. They need to be available widely at affordable prices: bigger listener numbers drive lower prices.

¹⁹ E.g. see WorldDAB metadata explainer video <https://www.youtube.com/watch?v=f7BqIC2NGLU>

²⁰ See www.worlddab.org for the Emergency Warning factsheet

4. Cars – are where many people consume radio content; in some countries in-car listening is the highest of all locations. It is critical for rollout success to have cars available with DAB+ as standard and aftermarket devices for cars which do not have DAB+ capability.
5. Communication – is arguably the most important aspect: it covers all areas, from broadcaster / regulator discussions to marketing campaigns. The value of a common voice for all broadcasters cannot be underestimated. It is often the case that a cross-industry organisation is established to encourage discussions and policy direction.

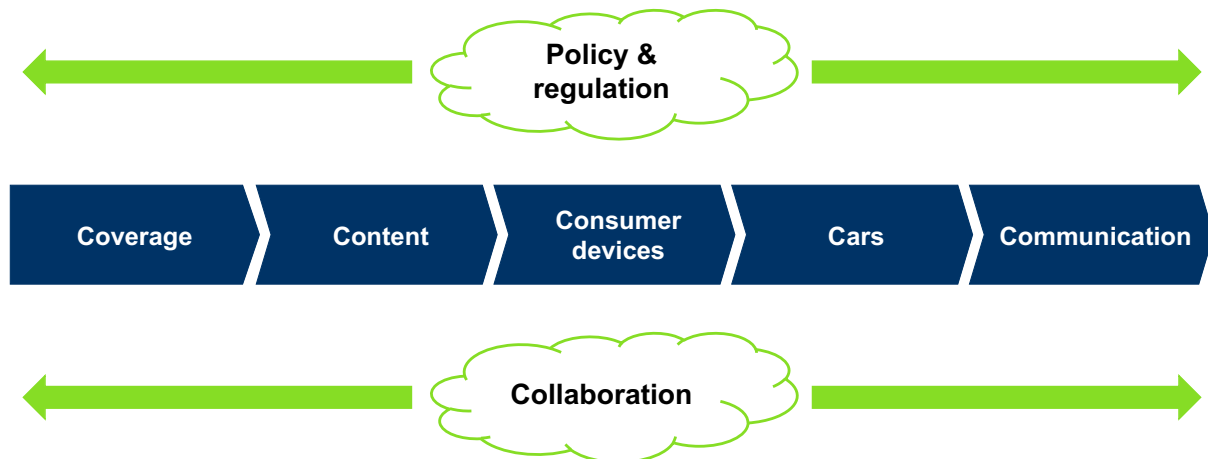


Figure 6-9: The 5Cs

6.6 Conditions for success

As there are many competing desires within the radio ecosystem, it is important to consider the conditions which will encourage success and how to create them. It is the role of the regulator to mediate with the broadcasters to ensure the most viable operating model and conditions in each country. Each country will be different as they all have different political and socio-economic approaches along with established approaches to analogue broadcast regulation. In some cases, there may be lessons learned from the digitisation of television. However, we note that DTT multiplexes are usually focused on individual television broadcasters while DAB multiplexes often have content from multiple broadcasters.

The primary areas to consider for creating the conditions for success are:

- Give broadcasters an incentive to invest
- Ensure that multiplex operators have an effective business model
- Ensure that broadcaster economies support sustained development of DAB+
- Consider regulation to accelerate the take-up of DAB+ in cars and homes

6.6.1 Incentives to invest

Regulators can provide incentives for broadcasters to engage with the development of DAB services and infrastructure through licensing initiatives.

Broadcasters' most valuable asset is their existing FM or AM licence, which provides long-term positive cashflows. In most markets, licences are issued for a fixed period, typically 10 to 15 years, with no guarantee that the licence will be renewed. Licence renewal is often assessed against the service that the broadcaster has provided and any infringements of content or delivery rules. Licence renewal also attracts fees.

Regulators can provide an incentive to broadcasters who (at least) simulcast their analogue service of DAB+ by offering an automatic FM licence extension if they do so. The regulator may also limit the fee for FM licence renewal to an administrative fee or even make it free. They may also not charge for DAB capacity that is assigned to the "joint FM DAB+" licence. This removes risk from losing future profits and promotes long-term broadcaster sustainability.

An example of this approach is from the UK, where a new law was passed in December 2020 which provides automatic renewal of national analogue licences for 10 years under the condition that those services were simulcast on DAB / DAB+. The licence fee was set at a nominal figure of 10,000 GBP with no added proportion of revenues, thus making FM broadcasting cheaper to allow those derived funds available to support DAB. All three national licence holders accepted this approach.

In Australia, broadcasters were offered the incentive of effectively free spectrum capacity of one-ninth of a multiplex per AM or FM service, along with a non-competition period of seven years where no new broadcasters could enter the market.²¹

6.6.2 Effective multiplex operator business model

There are two main models for spectrum allocation and multiplex operation. In each case, the multiplex operator owns the spectrum rights:

1. Vertically integrated
 - a. A single broadcaster, or broadcast network, with multiple services operates the multiplex; or
 - b. There is a partnership of broadcasters whose services will be carried on the multiplex
2. Stand-alone
 - a. An independent, non-content producing organisation will operate the multiplex, usually referred to as the network operator

²¹ This was confined to the initial round of development in the five main metropolitan cities of Sydney, Melbourne, Brisbane, Adelaide and Perth.

Both of these models are used successfully; for example, the network operator Arqiva in the UK provides pay-for-capacity DAB broadcasting services for commercial services. The BBC owns the spectrum rights for their services; however, they sub-contract the delivery to Arqiva.

In Australia, the commercial broadcasters have formed Joint Venture Companies (JVCs) which own the spectrum rights based on a combination of initial free capacity allocated and further capacity purchased. Initially, the JVCs operated their own multiplex and transmitter systems and leased the transmission tower space. Over time, the JVCs moved to an outsourcing model where the multiplex and transmission systems were provided under long-term contracts with third-party network operator TX Australia.

6.6.3 Support sustained development

DAB+ offers opportunities to grow audiences and revenues while better competing with external content providers, such as streaming services, particularly from multinational players such as Spotify, Apple and Google. The first step is the investment in infrastructure and new services. However, it takes time to build the DAB+ audience from launch and also grow revenues, indeed to reach a critical mass can take several years.

Regulators can assist the economics of investing in DAB+ through support measures including:

- More attractive licence terms
- Relaxation of regulation rules
- Public funding

In the UK, Ofcom makes regular consultations with the radio industry to ensure that regulations are suitable to the operating environment and have consequently made a number of changes over time, including²²

- Ownership: in 2011, the government removed rules regarding the ownership of radio services
- Formats: in 2017, commercial radio stations were given greater freedom to deliver the content and genres they believed were best for their service
- Localness: in 2018, broadcasters were given greater freedom regarding local content, where it can be produced and how many hours of specific local content were required per week.

These rules were changed to improve the economics of local radio stations and help ensure the sustainability of local news provisioning.

²² See <https://www.gov.uk/government/consultations/commercial-radio-deregulation-consultation>
<https://www.gov.uk/government/publications/digital-radio-and-audio-review/digital-radio-and-audio-review#executive-summary>

Public funding can also help make the initial economics of DAB+ more attractive. For example:

- In Switzerland, the government provided funding to private broadcasters to subsidise the cost of simulcast transmission
- In France, the government has offered to co-fund broadcasters' marketing of DAB+
- In the UK, government, public and private broadcasters co-funded the rollout of local multiplexes

6.6.4 Regulatory support

The ability of broadcasters to generate revenues from DAB+ is driven by the size of the audience. The key driver is the number of DAB+ receivers that the listening audience have, and use, in both cars and at home.

Support for strong marketing will encourage retail presence and product variety and availability; this is a focus in France.

Governments can also significantly accelerate adoption through regulations requiring the presence of DAB+ reception capability in both cars and domestic products. In the EU, the European Electronic Communications Code (EECC) was passed in December 2018 and was effective from 21 December 2020. This ensures that all new cars in the EU now have DAB+ capability regardless of the status of the DAB+ network in each EU country. This regulation has now pushed the number of new cars with DAB+ close to 100%, as shown in Figure 6-10.

Additionally, several individual EU countries have applied their own rules for domestic radio receivers. For example:

- Germany, all radios able to display a station name must be digital (DAB+ capable)
- Italy, all receivers must have DAB+ capability
- In France, all radios able to display a station name must be digital (DAB+ capable)

The examples above provide guidance for countries seeking to adopt DAB+ as their digital radio system. Regulations can be established ahead of launching DAB+ to provide both incentives for broadcasters to invest as well as establishing an initial listener capability. Such actions will significantly accelerate the take-up of DAB+ and lead to earlier analogue switch-off, further improving the economics of radio broadcasting.

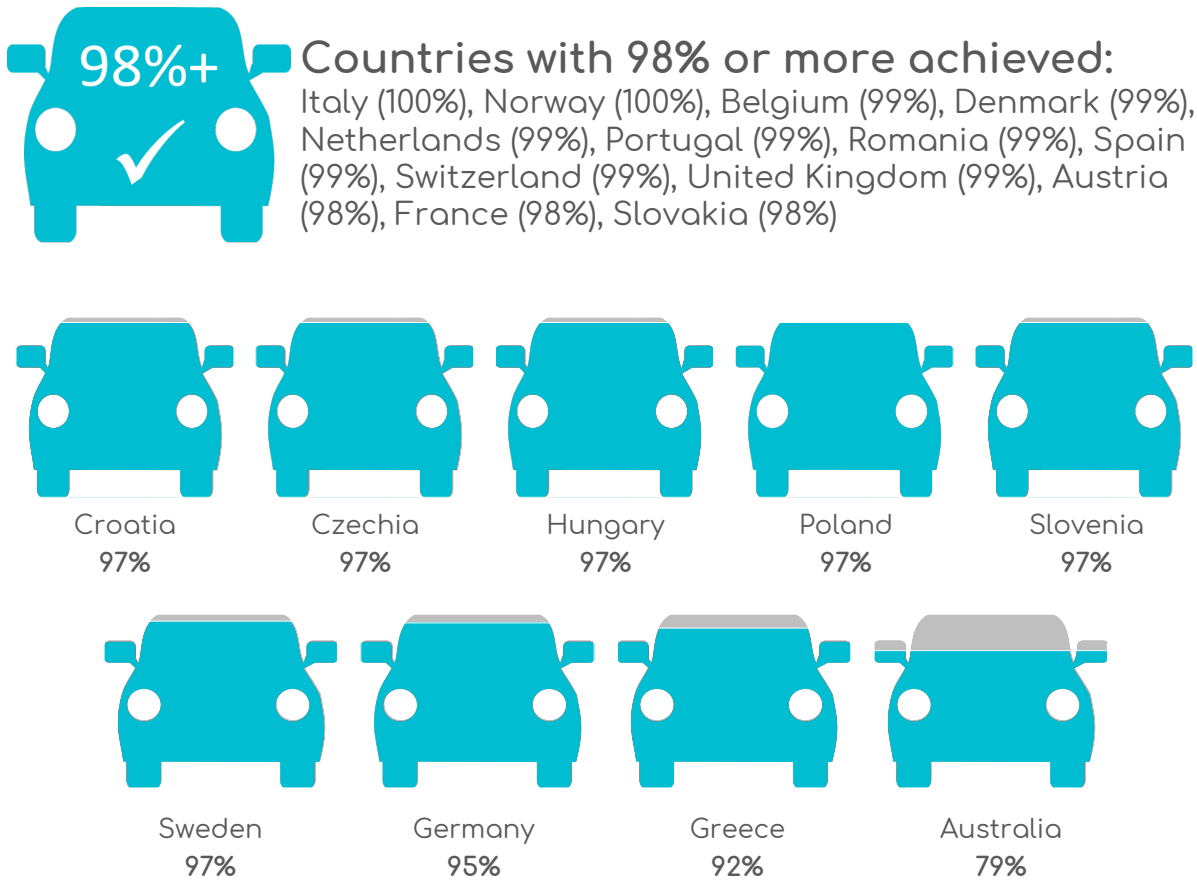


Figure 6-10: Percentage of new cars with DAB+ as of 02/2025

6.7 Regulation and licensing

The formal adoption process has several activities which are interrelated but can also run in parallel. When implementing the adoption process, there are roles for all stakeholders in the radio ecosystem. An example Gantt chart is shown in Figure 6-11, with each aspect discussed below. Note that the time periods for each activity are indicative only.

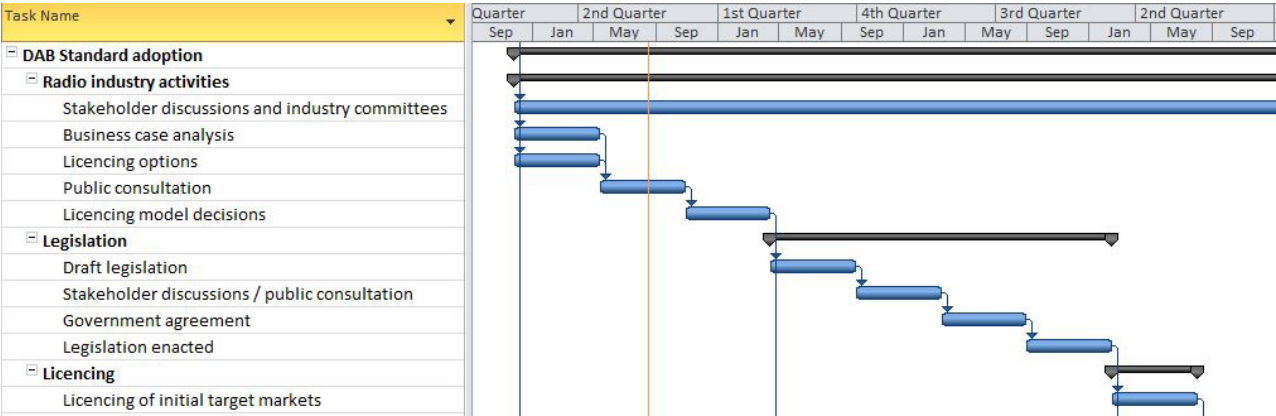


Figure 6-11: Example Gantt chart for formal DAB adoption

6.7.1 Stakeholder discussions and industry committees

These generally involve as many stakeholders as are interested. It is not uncommon for the regulator to ask the stakeholders, including the broadcasters, to suggest their preferred operating model in terms of transmission provisions and spectrum licensing. It is important to ensure a clear connection between the broadcasters, network operators and the regulator, with regular communications and clear and transparent decision-making processes. It is not unusual for the broadcasters to form an Industry Committee to allow all broadcasters' opinions to be heard as well as inputs from the greater radio ecosystem. Such Industry Committees may eventually resolve into a Digital Radio champion organisation, as discussed in §4, or may be temporary for a specific purpose such as Allotment planning.²³

Gaining initial agreement on the “shape” of the licensing system and the timelines to rollout are critical to success. This process can be strongly influenced by the availability of VHF Band III spectrum as limited spectrum will also limit the number of services that can be delivered. The timing of the availability of spectrum²⁴ will also strongly influence the ongoing timing of a DAB rollout and in some cases then influence the overall time available to develop licensing policies and enact them. It is important that the regulator tempers discussions and plans to ensure that the general public gains the maximum benefit of the introduction of digital radio broadcasting and the ability to receive additional content and features.

6.7.2 Licensing options

When formulating licensing options, there are several aspects to be resolved.

1. The technical basis of planning

This provides the basis for acceptable and unacceptable transmissions. It is important that DAB+, like any radio technology, is able to be received in the required areas, for example for commercial broadcasters their licensed coverage areas. To do that, the transmission design needs to fulfil specific field strength targets in the coverage area. The EBU and ITU publications provide a good starting point for the establishment of network planning requirements. However, it is usual for individual countries to customise the field strength requirements based on their own needs, such as due to different in-building entry losses and man-made noise issues [1] and [6].

²³ The Digital Radio Planning Committee (DRPC) in Australia is an example of this, it existed for approximately 2 years for the purpose of national allotment planning.

²⁴ E.g. due to the process of analogue television switch-off and migration to the UHF band.

2. Broadcaster licence types

There are several different licence types which are used by countries around the world. These are related to the type of content that is transmitted and the type of broadcaster. Typical licence 'classes' include:

- PSB licences, which are often wide area or country-wide and may be subject to limited commercial activity.
- Commercial broadcasters, who are often limited to specific areas and allowed to transmit commercial content, such as advertising.
- Community broadcasters, who are focused on specific areas, community groups served or content types.
- Narrowcast broadcasters, who are restricted to specific content types, for example only sports radio, and who usually also have coverage area limits.
- Other broadcast types, such as international or subscription-based services.

Commercial Radio licence

Public Service Broadcaster radio licence

Community Service Broadcaster radio licence

Narrowcast Service Broadcaster radio licence

Low Power Broadcaster radio licence

All of these licence types have their own specific legal definitions which are defined by the ministry in conjunction with the regulator.

Each has their own allowances, restrictions and costs defined through legislation. The number of services in an area will be a mixture of these basic types. The type of licence often also impacts the likelihood of additional DAB+ services. We find that PSBs typically increase their number of services by two to three times, commercial by four to six or more times and community generally less than two times. This demonstrates the value of DAB+ to commercial radio broadcasting. In some countries, new services may be new market entrants after the introduction of DAB+ rather than the expansion of services from existing radio networks.

3. Periods and costs

Each licence type will attract a different cost due to the different nature of the broadcaster. However, we generally see that in most countries the DAB licensing is either associated with existing AM or FM licences or is a low fee which is basically for administrative costs. The important point is that each licence has its rules of operation, as is usually established in the "Broadcasting Services Act"²⁵ for each country, which requires the broadcaster to conform with the content and transmission rules to maintain their licence to operate.

4. Coverage

Regulators often require that the broadcaster in each specific licence area provides their services to a minimum percentage of the area's population and possibly also a percentage of the licence area and/or specific roads, such as main motorways.

²⁵ E.g. for Australia the Broadcasting Services Act 1992: <https://www.legislation.gov.au/Details/C2021C00042>

5. Content

The content that is allowed to be broadcast has two basic aspects: the actual licensed content types, for example commercial advertising, but also the content itself in terms of the “norms of society”. Hence we see that different countries have different requirements for the content itself in terms of religious, political, language and the content itself (such as profanity limits).

Some countries also require specific amounts of locally generated content to ensure that local industries are supported; this particularly applies to music and news.

6.7.3 Regulatory licence types

Regulators usually have multiple licence types based on the activities involved.

Broadcast content licence

A licence to produce radio content: this is more commonly called a broadcaster licence. It generally defines what content that can and cannot be delivered. For example, a commercial content licence allows advertising, while a narrowcast licence only allows specific content types, for example sport or religious. In all cases, there are general content rules regarding public acceptability of language, such as profanities and sometimes political content, for example extremist propaganda.

Scientific licence

This is a transmission and spectrum access licence which allows organisations to demonstrate and experiment with new transmission technologies. It is usually for a limited period of time, e.g. 1 year, and often comes with numerous limitations in terms of transmission power and coverage area, content types (sometimes content must be looped and not real-time), and reporting on outcomes.

Spectrum access licence

A licence to deliver content to air in a specific frequency band: in the case of DAB, this is a frequency block. The frequency block may be shared with other broadcasters, in which case the access may also specify the capacity within the ensemble that is allocated to a broadcaster. For transmission network providers who own the spectrum frequency block licence, they allocate the capacity to broadcasters based on demand and the associated commercial arrangements.

Apparatus licence

This is a licence to own and operate transmission equipment, such as transmitters.

Transmission licence

This is a licence to deliver transmissions to air. This licence has provisions for the maximum (and often minimum) power that can be delivered in each direction, such as through a

radiation pattern requirement. For example, it is very common to restrict power in some directions to less than the maximum power assigned to protect other transmissions from interference.

Network Operator licence

This is essentially the combination of Spectrum, Apparatus and Transmission licenses.

Each country will have its own version of these licence types and in some cases, they may be combined.

When deciding on licensing options and requirements, the regulator takes into account the feedback from the stakeholders provided through public consultation and develops licensing structures and the technical basis which will provide the best benefits to both the public and the broadcasters' businesses, including the PSB(s).

While the regulator typically develops the technical basis and also makes recommendations on licence types and constraints, it is usually the ministry that will develop the actual legislation.

6.7.4 Public consultation

Following discussions between the ministry and regulator and with stakeholders, it is usual, but not essential, for a public consultation to be held where the regulator will present their recommendations and options for a licensing model and request feedback from the stakeholders.

The broadcasters and other stakeholder businesses then can formally state their preferred options and give the reasons why those options are beneficial to both themselves and the community in general.

In some cases, public consultations may be supplemented with public hearings, industry briefings and industry working groups.

6.7.5 Legislation

Once the regulator has developed its preferred licensing system, it will discuss it with the relevant government departments who have the responsibility to develop the actual legislation that will enable DAB to be formally licensed and deployed.

It is not uncommon for that legislation to take a few iterations to be developed from initial drafts to the final formal documentation, which will be agreed by the political system before being passed into law and then be able to be formally used to grant and manage licences.

6.7.6 Licensing the initial markets and incentives

Once the formal legislation is passed into law, the regulator has the authority to issue licences. Those initial licences may be either allocated under a prearranged scheme or acquired through a selection process, such as an auction or beauty contest, where content type and other factors are also assessed during licensing assessments.

In some countries, incentives are provided to encourage broadcasters to establish DAB broadcasting services and protect those that have invested in the development of the DAB systems from premature competition. These incentives are due to the common situation where there are no, or at least few, receivers in the market and hence the listener market needs to be established, which can take some time, typically years. Fortunately, there are now many car models with receivers fitted as standard due to the European Electronic Communications Code (EECC)²⁶ and which can then flow on to other countries in the form of cars with DAB receivers built in as standard.

Typical incentives include (essentially) free spectrum allocations, for example DAB ensemble capacity assigned based on existing analogue transmissions,²⁷ minimal if any initial fees, non-competition periods during which no new commercial broadcasters can establish operations, and financial inducements such as the waving of licence fees for analogue services for participants that invest in DAB+ infrastructure and/or new service developments.

6.7.7 Licence examples

Every country has slightly different licensing arrangements due to the history of each individual country. We see that licensing processes for DAB are similar to those of DTT and hence most country's Regulator will have some experience of the transition from single programme ATV to multi-programme DTT where service multiplexing on a single broadcast transmission was first introduced.

The UK regulator, Ofcom, has an operating model where broadcasters / content providers are required to have "service" licences while Network Operators have "Multiplex" licences. The UK's Ofcom provides an open view of their licensing processes, and we provide several links below to different aspects of their licensing requirements.

Ofcom Sound Programme licences

In the UK for sound (audio) services on a multiplex Broadcasters need to obtain a Digital Sound Programme Service (DSPS) licence, these may be associated with existing FM services which are to be simulcast on a DAB multiplex.

²⁶ See <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L1972>

²⁷ E.g. in Australia, existing AM/FM broadcasters were allocated one-ninth of ensemble capacity for each existing AM/FM service.

To deliver a Digital Sound Programme Service (DSPS) in the UK, broadcasters need to apply using the form and information found at <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/dsp-application-form.docx?v=216014>. Guidance notes can be found at <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/dsp-notes-of-guidance-for-applicants.pdf?v=328808>. A sample DSPS licence can be found at <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/dsps-sample-licence.pdf?v=335114>.

For new digital services the Broadcaster needs to also apply for a Digital Additional Sound Service (DAS) using the form and information found at https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/das_app.docx?v=216029. Guidance notes can be found at <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/das-notes-of-guidance-for-applicants.pdf?v=328807>. A sample DAS licence can be found at <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/das-sample-licence.pdf?v=323582>.

Ofcom Multiplex licences

There are three main types of Multiplex licence, National, Local and small scale-DAB for community broadcasters. The Network Operator needs to apply for the Multiplex licence which is in effect a licence to utilise a specific DAB Frequency Block in a specific location using defined technical parameters such as ERP and antenna HRP.

Multiplex licence applications are often considered from both financial viability and community good perspectives. When this is in the context of a public call for offers or bids we often see the assessment methodology based in some form of "Beauty Contest".

UK Ofcom requires assessment of the financial arrangements proposed for Local and National multiplexes and as such requests that applicants complete Financial Templates when applying for either, examples are:

- DAB Local Radio Multiplex Licence https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/financial_template_local.xls?v=217061
- DAB National Radio Multiplex Licence https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/financial_template_national.xls?v=217078

An example UK Ofcom Local Radio Multiplex Licence can be found at https://webarchive.nationalarchives.gov.uk/ukgwa/20160702165230mp_/http://licensing.ofcom.org.uk/binaries/radio/digital/localmultiplex.pdf

An example licence for the small-scale DAB multiplexes in the UK can be found at <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/small-scale-dab/supporting-data/small-scale-mux-sample-licence.pdf?v=326772>. Corresponding guidance notes can be found at <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/small-scale-dab/supporting-data/small-scale-radio-multiplex-licence-guidance-24.pdf?v=389970>.

“Sound Digital” is a company that was formed to bid for a national commercial multiplex licence. “Sound Digital” is composed of two leading broadcasting networks, Bauer Media Group and UTV Media along with the UK’s largest Network Operator Arqiva. Their application form provides a good example of the details that can be required in order to bid for a national multiplex licence. It shows that both financial stability and suitable content as well as strong governance are all required to be successful. Their application form can be found at https://webarchive.nationalarchives.gov.uk/ukgwa/20160702174259mp_/http://licensing.ofcom.org.uk/binaries/radio/digital/nationalradio/SoundDigital.pdf.

Ofcom Technical guidance

The UK Ofcom also provides the “Technical policy guidance for DAB multiplex licensees” document to help Network Operators design their transmission systems, see <https://www.ofcom.org.uk/siteassets/resources/documents/tv-radio-and-on-demand/broadcast-guidance/dab-technical-policy-documents/technical-policy-guidance-for-dab-multiplex-licensees.pdf?v=335554>.

Other countries

Luxembourg in Europe is currently undertaking the establishment of DAB+ digital broadcast radio. As Luxembourg is a relatively small country at 80 x 55 km, the first multiplex to be established will be a national multiplex. The second will be for local radio stations / services. DAB+ repeaters will also be established in road tunnels. A roadmap for the establishment of DAB+ was released in March 2023, see <https://smc.gouvernement.lu/dam-assets/feuille-de-route-dab.pdf> (only available in French language).

The public call for applications started on 19 August 2024 with submissions due by 11 October 2024 with a view to have DAB+ services on air in 2025. The public call information can be found at https://gouvernement.lu/fr/actualites/toutes_actualites/communiqués/2024/08-aout/19-smc-dab.html. This contains the application process and documentation for both “DAB+ sound radio services” and “Multiplex Operator”.

In addition, a number of African countries are currently establishing licensing frameworks and procedures including Ghana, Kenya and Uganda. Contact with the Regulators in those countries may be useful.

6.7.8 Spectrum licence fees

In many countries the licence fees reflect regulatory management costs with Radio generally not being targeted for significant government revenue making. We note however that it is not unusual for media companies to be taxed on their profits with specific levies such as 3% of revenue being applied to FM services. As analogue switch-off has not yet been widespread we will see if the FM revenue fee approach is transferred to DAB+ in the future.

We provide examples of the licensing fees for several countries below. We examine

- Cost of acquiring spectrum and/or ensemble capacity
- Licence processing fees, both initially and long term
- Operational fees and taxes above the standard company profit tax approach

Australia

The licensing of DAB+ services, apparatus and spectrum is undertaken by the ACMA, see <https://www.acma.gov.au/digital-radio-licences>. Initial licences were granted prior to the DAB+ launch in August 2009.

The PSBs were allocated two ensemble frequencies nationwide (8B and 9C).

Commercial AM and FM licensees were granted access to 128 kbps (EEP-3A) per existing services. The remaining capacity on the assigned ensembles in each area was then auctioned. That auction occurred for the five major capital cities where DAB+ was launched approximately one year after the launch and within the moratorium of no new broadcasters which covered a period of seven years from launch. The bidding for the excess capacity varied from city to city dependent on the city's population but were typically in the range of \$50-200k AUD per 64 kbps of capacity.

Applications to establish new commercial ensembles (Cat.1 and Cat.2) in additional cities, of which five have now occurred, attract an application fee of \$1,130 AUD. There are also Apparatus licence fees to be paid on an annual basis.

UK

Here we provide examples of DAB licensing fees charged by the UK regulator Ofcom.

Ofcom Radio multiplex fees

There are fees for both applications for new multiplexes as well as annual fees for existing multiplexes. The fees for licence applications for national and local multiplexes are shown in Table 6-2. The fees charged are dependent on the population covered by the proposed multiplex.

Licence type	Population (Aged 15+)	Tariff for 2023–24 (£)
National licences		
All licences		50,000
Local licences		
Category A	4,500,000+	25,000
Category B	1,000,000–4,500,000	15,000
Category C	400,000–1,000,000	5,000
Category D	0–400,000	1,000

Table 6-2: Ofcom fee table for DAB Multiplex applications

Annual fees also apply to ongoing multiplexes as shown in Table 6-3.

Licence	Tariff for 2023–24 (£)
National radio multiplex	10,000
Local radio multiplex	500

Table 6-3: Ofcom annual multiplex licence fees

Community broadcasting via Small-scale radio multiplex licence is shown in Table 6-4 with the fees for community Digital Sound Programme licence (C-DSP) being shown in Table 6-5.

Fee	Tariff for 2023–24 (£)
Application fee	500
Annual licence fee	500

Table 6-4: Ofcom fees for Small-scale DAB+ multiplex licences

Fee	Tariff for 2023–24 (£)
Application fee	250
Annual licence fee	100

Table 6-5: Ofcom fees for Community Digital Sound Programme licence

The fees that Ofcom charge are essentially processing costs and only cover the effort that Ofcom needs to exert in order to prepare a new licence or process an ongoing licence each year.

Turnover tariff

In addition to the licence fees, Ofcom also charges a tariff based on the turnover of the radio service. This applies to analogue services which are usually the base station from which digital only services expand. The annual licence fees are shown in Table 6-6. For example the fee for an FM station with £1m GBP in turnover is £1,390 while if the turnover is £10m then the fee is £20,800.

Bands	Tariff for 2023-24 (% of relevant turnover)
£0m – £1m	0.092
£1m – £5m	0.139
Over £5m	0.208

Table 6-6: National and local radio licence fees

Netherlands

In December 2020, the Dutch government announced plans to auction a third national multiplex, aiming to expand DAB+ accessibility. Licences from this auction are valid for 12 years (2021-2033), with a starting bid of €50,000 per licence.²⁸

²⁸ https://www.worlddab.org/countries/netherlands/history/current-situation?utm_source=chatgpt.com

6.7.9 Access fees

Access fees vary depending on the ensemble capacity used (bit rate and FEC code rate) as well as the population covered. Many countries do not publicly disclose their access fees as they are negotiated between the broadcaster / content provider and the multiplex Network Operator. Some countries require publication of the multiplex Network Operators rate card, e.g. Arqiva in the UK, or have a specific business operations cost basis, e.g. in Australia for Commercial Cat.1 multiplexes.

Some examples:

Switzerland

Digris AG operates in Switzerland and charges from 6,000 CHF (6,500 USD) per year and higher depending on bitrate and location – see <https://www.digris.ch/verbreitung/vorgehen-und-kosten/>

UK

UK – 2nd National Commercial DAB Transmission Service Reference Offer

Arqiva own and operate this national DAB ensemble and have provided a reference Rate Card.²⁹ On that Rate Card we see that the total fee is a combination of Network Access Fees, Managed Transmission Fees, Electrical charges and Pass-through costs. The total fee varies dependent on the transmission site used and the corresponding coverage area within the range of £22.6k GBP to £143.2k GBP. There are also a range of additional fees for application for service, administration fees, legal fees, site fees for space and mast access.³⁰ Part of the rate card is shown in Figure 6-12 where we see both the application fees and the ongoing costs. In the reference there are also some examples which demonstrate that the cost of the antenna can vary significantly, with the cost of exclusive use being roughly half of the annual fee.

Australia

The application processing fee for a new DAB+ multiplex set by the Australian regulator the ACMA is \$1,130 AUD. Once a multiplex licence is obtained there is an annual apparatus licence fee of \$41.86 AUD. This is essentially for keeping track of transmission apparatus. Access fees are determined from the operating costs of the multiplexes plus a profit margin of 15% and vary from city to city. In Perth, the fee has been reported as \$7,453 per 32 kbps per quarter in 2017 which indicates that the annual operating cost of a full ensemble is around \$1.073 m per annum.³¹ Operating costs include tower site and mast access, power, equipment upgrades, network operations and maintenance.

²⁹ <https://www.arqiva.com/documentation/reference-offers/broadcast-radio/N2%20Reference%20Offer%20-%20Per%20Station%20breakdown%20of%20indicative%20total%20fee%20v1.pdf>

³⁰ The Arqiva radio rate card for network access is updated annually and available under 'reference offers' at: <https://www.arqiva.com/documentation/>

³¹ <https://www.mediarealm.com.au/articles/digital-radio-australia-dabplustechnical-overview/>



Arqiva Radio Rate Card for Network Access 2024/25

Subject to Contract																	
1. Application Fee (One-off) One-off Fee to process the Customer Enquiry. The charge applies to requests for access to a single site. Requests for access to multiple sites will be separately costed and advised to the Applicant. This fee should be paid at the time of submitting an enquiry for Network Access.	£ 6,298																
2. Contract Administration Fee Fee to maintain ongoing contract administration. As a contract can cover many sites, this is a fixed charge per contract, and does not vary with the number of sites required. Reduced charges will apply to contract renewals. This is recovered over the life of the contract allowing a 7.5% pa real rate of return plus 'provision of service' charge.	£ 6,032																
3. Legal Fee Fee for Legal costs incurred in preparing the Customer Contract and also a contribution towards the cost of preparing the Framework Reference Offer for Network Access. As a contract can cover many sites, this is a fixed charge per contract, and does not vary with the number of sites required. Reduced charges will apply to contract renewals. This is recovered over the life of the contract allowing a 7.5% pa real rate of return plus 'provision of service' charge.	£ 10,667																
4. Annual Charge for Site Accommodation																	
a) Arqiva Site - Freehold Tenure	£ per sq m pa																
i Accommodation Area in Arqiva Building or Cabin	540																
ii Ground Area for Customer's Cabin (to include ground satellite and other sterilized areas)	87																
iii GPS Antenna x 1	586																
iv Earth Mat for MF Antennas	7																
b) Arqiva Site - Other Tenure	£ per sq m pa																
i Accommodation Area in Arqiva Building or Cabin	540																
ii Ground Area for Customer's Cabins (to include ground satellite and other sterilized areas) to cover cost of site maintenance only	27																
iii GPS Antenna x 1	586																
iv Earth Mat for MF Antennas	7																
c) Site not owned or managed by Arqiva (i.e. Third Party Site) Cost included in Site Rental charged by third party Landlord in 6a below	-																
5. Annual Charge for use of Mast / Tower																	
a) Mast/Tower owned by Arqiva Antenna Windload charge for exclusive use by sharer: <table> <tr> <th>Mean Height a.g.l</th><th>£ per sq m pa</th></tr> <tr> <td>i Less than 20m</td><td>2159</td></tr> <tr> <td>ii 20m to less than 50m</td><td>3454</td></tr> <tr> <td>iii 50m to less than 100m</td><td>3886</td></tr> <tr> <td>iv Equal to or greater than 100m</td><td>4318</td></tr> </table> Feeder Windload Charge per Antenna: <table> <tr> <th>Feeder Length charge for exclusive use of sharer:</th><th>£ per m pa</th></tr> <tr> <td>i Feeder diameter less than 3.125"</td><td>44</td></tr> <tr> <td>ii Feeder diameter equal to or greater than 3.125"</td><td>57</td></tr> </table> Small feeders with a total diameter equal to or less than 3.125" feeding one antenna will be counted as one.	Mean Height a.g.l	£ per sq m pa	i Less than 20m	2159	ii 20m to less than 50m	3454	iii 50m to less than 100m	3886	iv Equal to or greater than 100m	4318	Feeder Length charge for exclusive use of sharer:	£ per m pa	i Feeder diameter less than 3.125"	44	ii Feeder diameter equal to or greater than 3.125"	57	
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ii Feeder diameter equal to or greater than 3.125"	57																
b) Mast/Tower not owned by Arqiva Cost included in Site Rental charged by third party Landlord in 6a below	-																

Figure 6-12: Arqiva rate card for 2024/25³²

³² The Arqiva radio rate card for network access is updated annually and available under 'reference offers' at: <https://www.arqiva.com/documentation/>

7. DAB+ requirements and allotment planning

The development of the requirements for the deployment of a new radio system can be a complicated process. It is essential that all stakeholders are engaged in the process and that all have a flexible position to ensure an overall positive result.

7.1 Prerequisites

The prerequisites to starting the detailed planning process are:

- The broadcast industry has decided to move forward and implement DAB+
- The regulator is agreeable to developing (or has developed) the licensing framework
- There is (or will be) VHF Band III spectrum available

The overall process to be undertaken is shown in the flowchart in Figure 7-1, which starts with the determination of the service requirements and concludes with the allotment plan being complete.

The overall goal is to determine the allotment plan which will achieve the best long-term benefits for the country. The process is generally iterative and requirements may need to be refined on an area basis. For example, the number of services that can be delivered in a specific area will be impacted by the spectrum that is available, the coverage requirements and ultimately the technical basis which will define the coverage field strength targets and interference protection ratios.

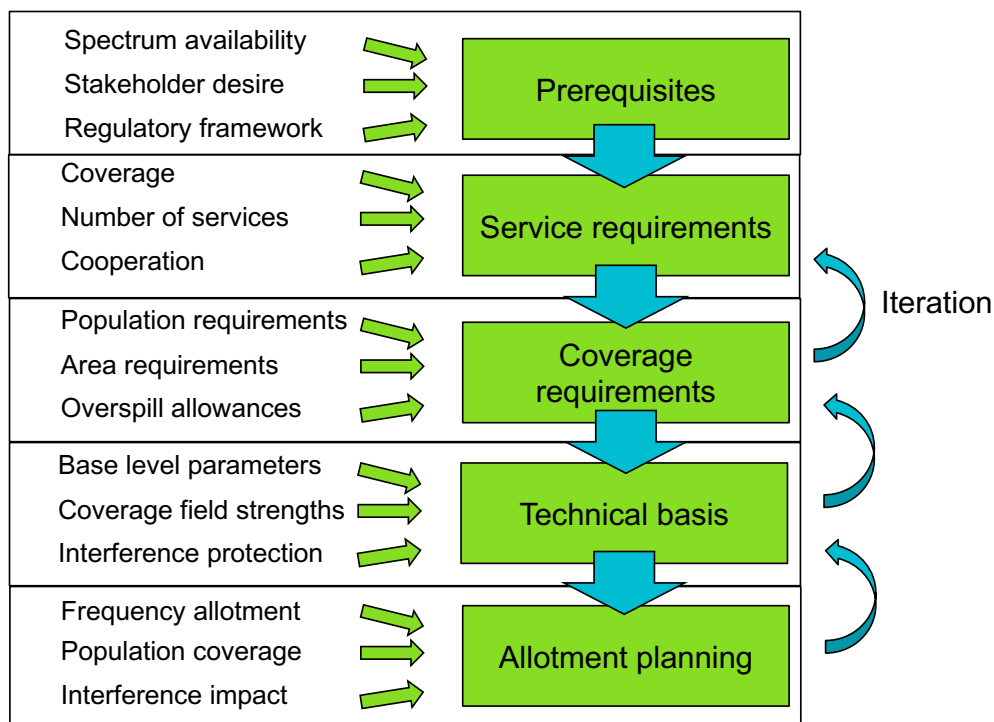


Figure 7-1: Requirements planning steps

In some cases, the process flow will have existing constraints, for example when several transmission sites have already been constructed and are operational, providing DAB+ services to the public. This was the case for the allotment planning in Australia, which was undertaken some years after the initial five main cities had established DAB+ transmission services.

7.2 Service planning

The starting point for DAB+ system planning is the number and types of services which already exist and the expectations for future new services. The development of DAB+ across Europe during the last 20 years has shown that where spectrum is available, services will follow. The result is an expansion in the number of services that are available to the public, with typical increases in mature DAB+ countries being between three and six times the number of pre-DAB+ analogue services. It is therefore very important to factor into the planning requirements not only the digitisation of existing services but an allowance for future new services.

Services are planned by their coverage area. National services are those provided consistently across an entire country, regional services cover a significant part of the country, and local services provide content only within a local licence area. In many cases, the number of national, regional and local services provided in an area have similar numbers as shown in Table 7-1, where the current service numbers are derived from <https://www.wohnort.org/dab/>. We see that each area has a significant number of services, all having more than 60, with London having the most with 126. The services by area type are reasonably balanced; however, we see the UK examples showing relatively more national services due to the UK’s small size and reasonably evenly distributed population, while Australia has relatively few national services due to its large size and population distribution being focused on urban centres.

	Service types			
Location	National	Regional	Local	Total
Sydney	11	30	33	74
London	57	47	22	126
Bristol	57	12	20	89
Munich	27	22	20	69
Oslo	17	20	23	60

Table 7-1: Example number of services in an area

Services are also divided by the content and licence types, where we often see Public Service Broadcasters (PSB), commercial broadcasters and community broadcasters.

Coverage by area is generally separated into national, regional and local layers, where regional includes several local areas and national covers all regional areas and in many cases most of the country. Figure 7-2 shows an example of the 34 commercial licence areas in the state of New South Wales in Australia. Community licence areas tend to be smaller and more focused on individual communities; however, some may be the same as commercial licence areas, particularly in the metro cities. PSB coverage areas are typically regional and encompass multiple commercial licence areas.

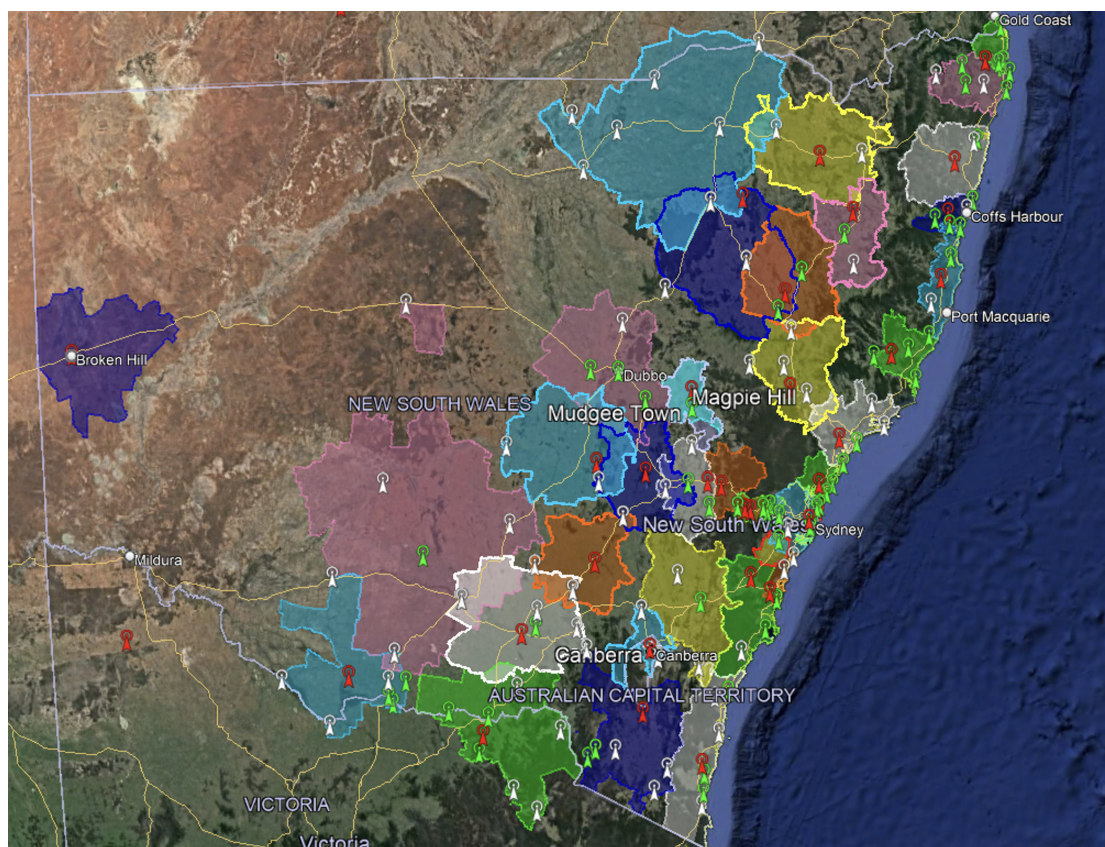


Figure 7-2: Commercial licence areas in the state of New South Wales in Australia

7.3 Coverage requirements

Regulators will often require network providers to comply with coverage targets in terms of both the percentage of people who can receive DAB+ and the percentage of the country's area where DAB+ can be received at specific grades of service. This is to fulfil Universal Access and Service (UAS) obligations that ensure that no one is disadvantaged. Countrywide rollout is usually undertaken in a phased approach over several years; for example, see the rollout phasing in Tunisia shown in Figure 7-3. Here, we see an extended test and demonstration period where services were established in the capital Tunis and then a countrywide rollout plan in four phases from 2018, with final completion targeted in T3 2023.

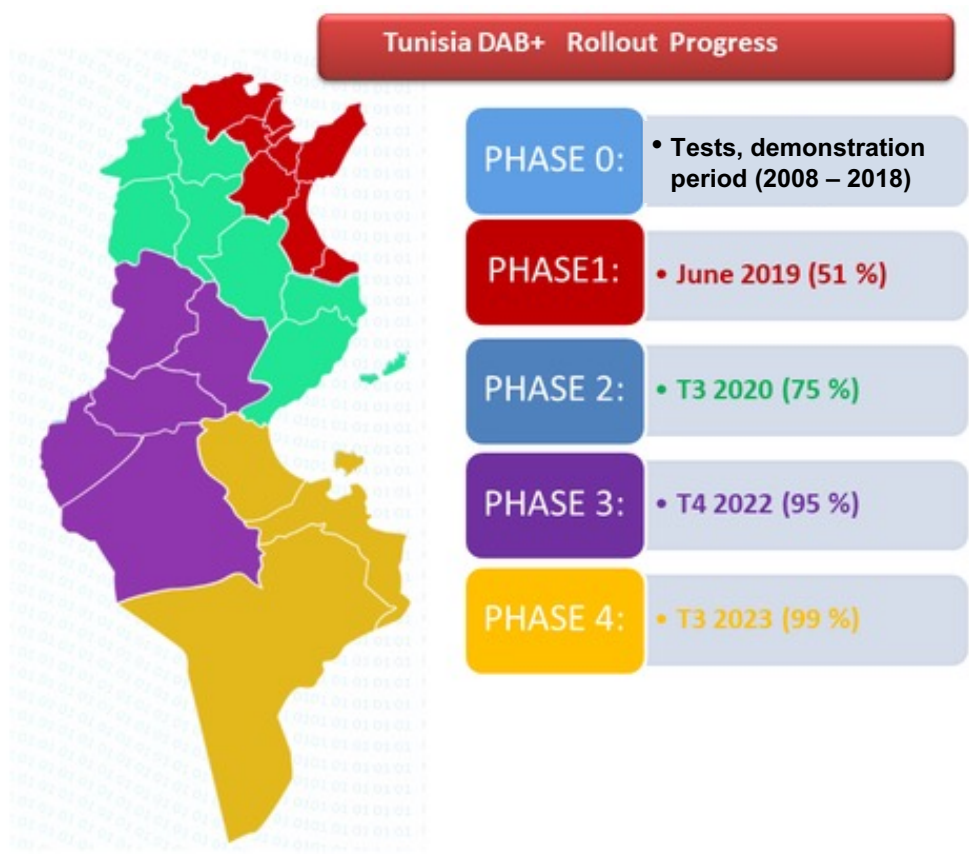


Figure 7-3: The rollout phasing in Tunisia³³

While coverage is critical, when planning DAB+ networks it is also critical to control interference to ensure that the correct grade of service can be delivered.

Most countries have land or sea borders with other countries which will require cross-border coordination to ensure that cross-border interference is limited to acceptable levels. The ITU Radio Regulations [25] provide guidance on the recommended processes.

³³ Source: <https://www.worlddab.org/countries/tunisia>

7.4 Spectrum requirements

DAB+ operates in the VHF Band III spectrum band of 174 to 230 MHz (and up to 240 MHz in some countries) which has traditionally been used for analogue television (ATV). The clearing of ATV from this band with its DTV replacement being made in the UHF bands allows band III to be used for DAB+. Band III was extensively cleared and planned for DAB+ in Europe in the late 1990s and early 2000s, culminating in the landmark ITU planning conference GE06, which undertook extensive planning in VHF Band III and UHF Bands IV and V for Region 1³⁴ in 2006. This included Europe, Africa, Russia, parts of central Asia and the Middle East but did not include the Asia-Pacific region. See [24] for more information.

VHF Band III provides 32 DAB frequency blocks from frequency block 5A with centre frequency 174.928 MHz to 12D at 229.072 MHz. In some countries, the Band III extension in Channel 13, or part of, is also available from 13A at 230.784 to 13F at 239.200 MHz although Channel 13 is often used for military communications and is not widely implemented. Each frequency block provides 1.712 MHz of bandwidth for the 1.536 MHz signal, so the guard band between adjacent frequency blocks is 176 kHz and requires post-transmitter filters, usually mechanical cavity filters, to ensure that Adjacent Channel Interference (ACI) does not cause performance loss. The details are provided in the main DAB Standard EN 300 401 [2].

The conversion of ATV to DTV is still under way, with some countries yet to embark on the implementation of DTV while others have completed the DTV installation programme but have not yet completed the ASO process. The DAB+ planning process can begin before Band III spectrum becomes available for permanent services but a date for its availability is needed for industry certainty. The availability date of spectrum, or even the start of the ASO process, provides the earliest target dates for permanent system rollout.

DAB+ can be established before ATV switch-off. However, due to high Protection Ratios (PRs), the DAB+ power may need to be reduced relative to planned ERP levels. This can allow systems for demonstration and training activities and such sites can be increased in power as the adjacent ATV services are switched off.

In some countries, Band III spectrum will also be used for DTV, for example Australia and South Africa, due to its ability to deliver signals over longer distances than the UHF bands for the same ERP. This requires spectrum-sharing plans which will determine how many frequency blocks will be available for DAB+ across the country. As we have seen in both Australia and South Africa, the provision of only two TV channels, or eight DAB frequency blocks, is the absolute minimum for most countries to ensure a suitable range of regional services. When cross-border coordination is required, flexibility with the choice of frequency blocks will be necessary.

³⁴ GE06 also included Iran which is in ITU region 3

7.5 Technical basis

It is very important that the field strengths used for planning in different reception scenarios are suitable for the country planning DAB+. As shown in Figure 7-4, there are variations in the required minimum median field strength targets for different reception scenarios in different European countries. This is due to variations in the “base level parameters” used to calculate the coverage target field strengths. The physical equations are well known and example calculations are shown in the EBU document Tech 3391 [1]. Typical examples of variations are:

- **Building entry loss:** the amount of building entry loss is dependent on the type of building and the materials used for its construction. Radio frequency waves are attenuated more by steel-reinforced concrete than timber, so areas which are dominated by high-rise buildings will need higher external field strengths to ensure suitable indoor reception than timber homes.
- **Man-made noise:** the rise of electronic devices ensures that the background MMN level is higher in dense urban areas than in rural settings. MMN impacts receiver sensitivity and is often higher in areas which have a significant quantity of electronic equipment, such as radio studios, PC-dominated office environments and industrial sites.
- **Vehicle antenna characteristics:** vehicle antennas have evolved from roof-mounted whip antennas which have good omnidirectional gain characteristics to in-glass antennas which have lower gain and often non-omnidirectional patterns. This has occurred due to the aesthetics of modern vehicles becoming more important than radio performance. Some countries have elected to redefine their vehicle antenna gain values to lower values to ensure that the required probability of reception in vehicles is achieved.

The establishment of the correct values for such parameters is essential to ensure that suitable reception probabilities can be achieved in the environments to be covered.

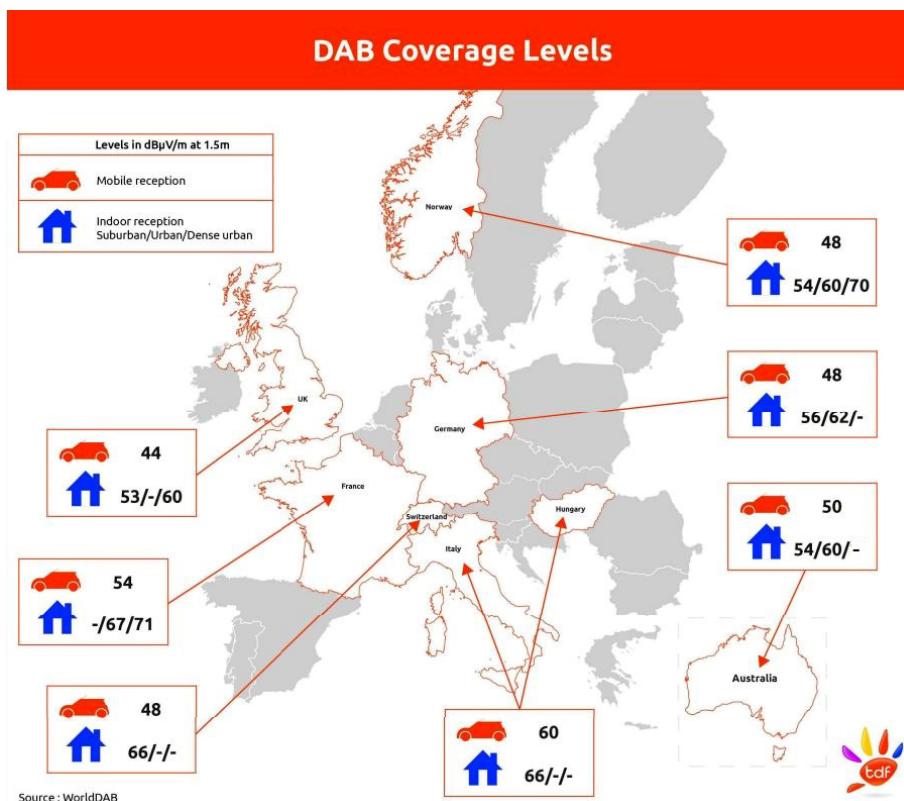


Figure 7-4: Example field strength targets,
Source: Jerome Hirigoyen, TDF

It is also important to select suitable values for the Protection Ratios (PRs) for both Co-Channel Interference (CCI) and Adjacent Channel Interference (ACI). However, these are well understood, and the values used are quite universal (see EBU Tech 3391 [1]).

The issue of minimum service quality should also be considered. Most countries allow the market to decide what service characteristics are delivered through a listener acceptance approach where if the quality of a service is too poor then people will not listen to it and hence the viability of the service will be questionable. This is more the case for commercial broadcasters than PSBs, who tend to prefer higher quality. Some countries, however, prefer to define the minimum service quality through minimum service bit rates and Forward Error Correction (FEC) capability. Slovenia is an example where they have defined the minimum sub-channel delivery requirements of a bit rate of 48 kbps and FEC = EEP-3A for stereo services.

Services can be delivered at low bit rates, for example 32 kbps. However, the quality of the audio reproduction, particularly in new vehicles which tend to have excellent sound systems, can be quite poor for some types of content, especially when pure tones are delivered in music such as classical, jazz, folk and some modern styles.

7.6 Allotment planning

Allotment planning is the task of deciding which frequency blocks will be available for use in each area to be covered. The allotment planning process considers the combination of the required number of services in an area and then determines the “best” frequency blocks for each area when planning over a group of areas, where “best” means the maximum number of assignable frequency blocks with the minimum amount of interference, usually CCI. The process complexity is driven by the required number of available services, remembering that typical numbers of DAB+ services are three to six times greater than the number of existing analogue services. It is also driven by the size of the areas to be allotted, with sets of smaller areas being more complex due to the reach of signals from other areas causing CCI.

7.6.1 Role of the regulator

Regulators are responsible for a wide variety of technical and licensing aspects for radio system design and operation. Those responsibilities include the allocation of frequencies to broadcast areas, that is allotment planning, and the assignment of frequencies to transmission apparatus, that is assignment planning. See the ITU Radio Regulations [25], Volume 1 Articles, items 1.16 to 1.18 for formal definitions.

As discussed in §7.4, the GE06 conference [24] resulted in the allotment and/or assignment of frequencies for broadcasting largely throughout region 1. It also, however, defined a set of procedures to be used for variations, additions and cross-border coordination. While the GE06 conference results are generally still relevant today, due to emphasis on DTT there are situations where insufficient spectrum has been allowed for T-DAB services. In those cases there may be opportunities to use vacant DTT VHF band III frequencies or coexist with DTT services with suitable CCI mitigation coordination.

As there has been no ITU coordination conference for Region 3, current planning for DAB+ is done on a country by country basis with cross-border coordination being done directly between the regulators of the involved countries who need to agree the allotment planning process, which is typically based on ITU recommendations. The complexity of that process is dependent on the demand for services, which is usually driven by the countries' population and regional radio areas and the amount of Band III spectrum that is either required or available. As Band III has been extensively used in the past for ATV, existing cross-border channel agreements may still exist.

When spectrum is not limited and demand for services is low, the allotment planning can often be done manually. If the demand is moderate and the amount of spectrum is reasonable, then it is often necessary to use automated allotment planning methods based on agreed planning principles. If the demand for services is high but the available spectrum is low, interference issues will cause either the number of services and/or the served areas to be limited. The allotment planning complexity is shown diagrammatically in Figure 7-5.

Degree of difficulty

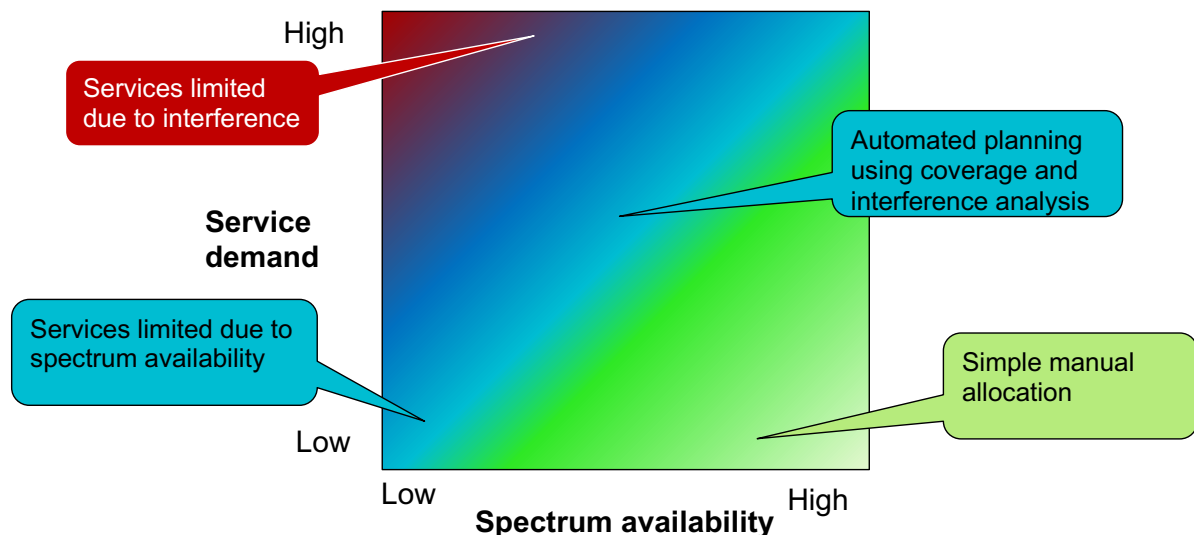


Figure 7-5: Allotment planning complexity

7.6.2 Planning principles

The approach to allotment planning should be agreed between the major stakeholders, usually the broadcasters and the regulator. This ensures an agreed approach for all types of broadcaster. This is particularly important when spectrum is scarce and/or demand is high. See also ITU-R BT.2140-12 [26], section 4.2.

The Australian Digital Radio Planning Committee³⁵ developed a set of planning principles [7] due to only eight frequency blocks being available across Australia and demand for two frequency blocks to be available in each commercial radio licence area; those blocks were one for the PSBs and one for the commercial and community broadcasters. The planning principles can be summarised as:

1 – Overall planning approach

- Plan for all areas in advance of any implementation to ensure balanced opportunities for first movers and late adopters.

2 – Proposed frequency allotment planning approach

- Define and agree how much spectrum will be available for each broadcasting sector.
- Initial main site transmission powers may need to be limited to ensure an overall solution.

3 – Licence area aggregation

- When there are specific coverage licensing areas for commercial and community broadcasters, it may be necessary to combine some to achieve a realistic overall plan.

4 – Transmitter site selection

- Use existing sites where possible. This will minimise costs and interference between DAB+ and any DTV which may exist in VHF Band III.

5 – RF planning parameters

- Select the planning parameters appropriate to your country in each class of reception.
- This includes minimum coverage field strength to be protected, CCI and ACI PRs.
- This may require some testing and experimentation, especially with respect to vehicle antenna gains and patterns, in-building entry losses and man-made noise in cities.

³⁵ The Digital Radio Planning Committee was a cross-industry committee which included representatives from the ACMA, CRA, ABC, SBS, CBAA and the Department of Communications.

The planning principles should result in a balanced allotment process. We start with the general requirement of the maximum interference that one coverage area cell is allowed to cause into another cell in terms of people affected. The limit is typically selected as a percentage of the population of the interfered cell, for example no more than 5%, with the expectation that the final allotment plan will result in less than this nominal value for all cells. The coverage requirements are generally considered secondary as they can be increased by adding low-power transmitters later. The overall process is:

1. The stakeholder team defines the baseline ERPs and antenna patterns (HRP/VRP) for each cell
 - a. Only one main transmitter site in a cell is provided with typical ERP of 5 to 10 kW, with some exceptions for remote and very dense areas. The ERP must be low enough to be able to obtain a solution for frequency allotments for all coverage areas.³⁶
 - b. Typical antenna HRP is omnidirectional, VRP down tilt = 0°.
 - c. Antenna locations are usually chosen from existing broadcast transmission sites with antenna tower height being the same as previous/existing ATV antennas.
 - d. At this stage, we are not interested in the transmitter systems themselves, only the radiated power and pattern.
2. For a set of assigned powers, calculate the field strength coverage for all areas using the same frequency
 - a. Typically use the centre frequency of the available frequency band
3. Determine the CCI between all sites
 - a. The initial planning is done for CCI; ACI is considered as a secondary issue.
 - b. CCI is generally assessed as the number of people in the affected cell who will lose reception due to interference, where interference is defined as the unwanted signal is greater than the wanted signal in the area being interfered with by greater than the CCI PR.
4. Assign candidate allotment frequencies to each area
 - a. Typically using a cellular approach where co-channel assignments have maximum distance between them. This can be done manually or use an automated approach.
 - b. The assigned frequencies should minimise the overall interfered population.
5. If the interfered population in each cell is less than the target then finish, else reduce/adjust the ERP and HRP of sites which cause the most interference.
 - a. Higher elevation sites will radiate further due to larger areas of line of sight coverage.
 - b. Problematic main sites may need to be significantly reduced in power and have low-power repeaters added to ensure suitable area coverage.

³⁶ See [26] section 4.2.2 which also includes the use of SFNs with multiple transmitters. However, this can make the overall process more complex and time-consuming and often will not result in any significant difference in the allotted frequencies if the cell is dominated by a single HPHT transmission.

- c. Repeat from step 2 where coverage and interference are reassessed for sites with changed ERP/HRP.
- d. If the initial interference is too high, it may be necessary to reduce most/all site ERPs.

This process can be quite complex when there are a lot of individual coverage area cells and will often mean that it is not feasible to manually select the set of frequency assignments which meets the local interference limits.

The complexity of allotment planning can be reduced by using a few rules, such as:

- Limit the number of cells in the area to be planned to limit the number of possible combinations.
- Use large pixel sizes when running coverage and interference simulations, for example 100 m × 100 m or larger.
 - The impact on the initial analysis of clutter will be small.
 - Higher resolution analysis can be done for specific cases when the allotment plan is starting to converge to an overall solution, that is all cells have interference of less than the target when using a selected set of allotted frequency blocks.
- Some cells may have preassigned frequencies, for example cells which have already been planned/implemented or in a set of adjacent cells, whether in-country or across borders.
- Do not allocate the same frequency in adjacent blocks; have at least one intervening cell between co-channelled cells.

Once a set of allotments has been successfully planned, the coverage in each cell can be assessed and adjusted through fine adjustment of ERP, HRP and VRP and the possible addition of low-power SFN repeater sites to ensure that over time adherence to population and area coverage targets can be met.

8. System planning and design

This chapter covers the design of the DAB+ system with emphasis on transmission system design and network design. In both cases, the designs are focused on fulfilling the requirements established in the planning phase at minimum cost.

The implementation of new services to add to the digitised analogue services is covered in §9 Rollout.

8.1 Transmission design

The requirements for services and coverage per area were defined in the planning stage, which then led to an allotment plan which specifies which frequency blocks can be used in each area and usually provides an initial transmission design.

8.1.1 Tools and methodology

Transmission design usually involves the use of propagation prediction tools which can calculate the estimated field strength within a coverage pixel, that pixel being part of a Digital Terrain Map (DTM).

The predicted coverage is based on the site(s) transmission parameters which were determined in the allotment planning process or subsequently adjusted. The allotment planning process itself will have been undertaken using such tools. The transmission site parameters are:

- The site location, usually specified as latitude and longitude against a specific reference datum
- ERP in kW (This is the power transmitted from the antenna and not the power output of the transmitter.)
- Antenna HRP and VRP, although in some case a radiation pattern mask³⁷ is used as a best-case coverage scenario³⁸
- Antenna height, the height of the centre of the antenna above ground level (AGL).
- The operating frequency

There are several propagation models that can be used; most of these originate from the ITU. Empirical models such as ITU P.1546 were originally used for planning and are still used as the basis for cross-border coordination. However, for coverage prediction deterministic models are now generally used as they are more accurate.

While interference and coordination are still done using a receiving antenna height of 10 m, it is more typical now to use an antenna height of 1.5 m for reception coverage as this is more representative of actual user conditions for both cars and personal use.

³⁷ Such radiation pattern masks are often specified by regulators; they can be used when there is no available actual HRP and VRP specified.

³⁸ And consequently also a worst case CCI scenario.

Empirical methods such as ITU-R P.1546 [9] are based on propagation measurements under a range of conditions with interpolation and extrapolation to give a set of predicted coverage field strengths against propagation distance for a set of conditions including antenna height, frequency, percentage of time as well as whether the propagation path is over land or sea (warm or cold) and also includes corrections to account for terrain clearance and terminal clutter³⁹ obstructions. This method is intended for use on tropospheric radio circuits. An example propagation loss curve set is shown in Figure 8-1.

As the P.1546 model is based on empirical measurements, it does not always provide the most accurate prediction of field strength, particularly when there is complex terrain or clutter conditions. Modern propagation prediction tools use deterministic methods where the propagation from the transmitter to a DTM pixel⁴⁰ is calculated individually considering the path loss and diffraction over, and around, clutter objects, such as buildings. Such deterministic methods are often called ray-tracing methods as the overall wide area field strength prediction is based on a collection of propagation paths to individual DTM pixels.

The ITU provides a number of models that can be used in deterministic coverage prediction, including recommendations P.525 [10], P.526 [11] and P.1812 [12]. These recommendations can be used as fully implemented in propagation analysis tools or they can be mixed with other methods, such as the Deygout or Bullington diffraction methods.

The receiver height was originally set as 10 m due to the use of rooftop antennas for both radio and television. The use of deterministic models has allowed more accurate results to be calculated directly at a receiver height of 1.5 m (or other heights if needed).

Propagation prediction provides us with a tool to gain an understanding of the expected coverage of a proposed, or existing, transmission. Accuracy ensures that we can use the resulting coverage prediction with confidence for a range of purposes, such as knowing the population that is covered, or not covered, analysing interference and overspill issues. To ensure that the prediction is as accurate as possible, we generally tune the model using measured field strength data, as discussed in §5.4.

An example of this process was undertaken during the testing of the NBTC DAB+ demonstration in Bangkok.⁴¹ Extensive field measurements were undertaken, and the results used to tune the model in terms of clutter and diffraction losses. The clutter was particularly significant as Bangkok had approximately 30 very tall buildings in the CBD area over 200 m AGL which were higher than the transmission tower itself at 185 m AGL. A Google Earth 3D buildings plot providing some insight into the extent of the very tall building clutter, with emphasis on the N Sathon Rd, is shown in Figure 8-2. The results of the coverage prediction are shown in Figure 8-3 using the same field strength palette as shown in Figure 5-4. The detailed clutter of the CBD is shown in Figure 8-5 along with the clutter classes and assumed heights in

³⁹ Clutter is a collective term for objects on the ground between the transmitter and receiver which include natural objects such as trees/forests of different heights as well as buildings of different heights. Accurate clutter is particularly important when the receiver is shadowed from the transmitter by such objects.

⁴⁰ A DTM pixel is the smallest square area within a digital terrain map. Typical pixel sizes used in coverage field strength prediction are between 20 and 100 m. Smaller pixels allow more accurate representation of the clutter and generally result in higher accuracy predictions.

⁴¹ The results shown are courtesy of the National Broadcasting and Telecommunications Commission of Thailand (NBTC).

Figure 8-6. The results in Figure 8-3 show the impact of the tall buildings on coverage, with shadow lines emanating to the southeast of the city being supported by the field test data.

The results of coverage prediction and field testing provide valuable information regarding both areas which will be covered with suitable field strengths as well as those which may be compromised by either terrain or clutter shadowing, allowing the system designer to then determine solutions to ensure appropriate coverage. Those solutions may be a combination of increased ERP, alternative HRP/VRP or SFN repeaters.

6

Rec. ITU-R P.1546-6

FIGURE 1
100 MHz, land path, 50% time

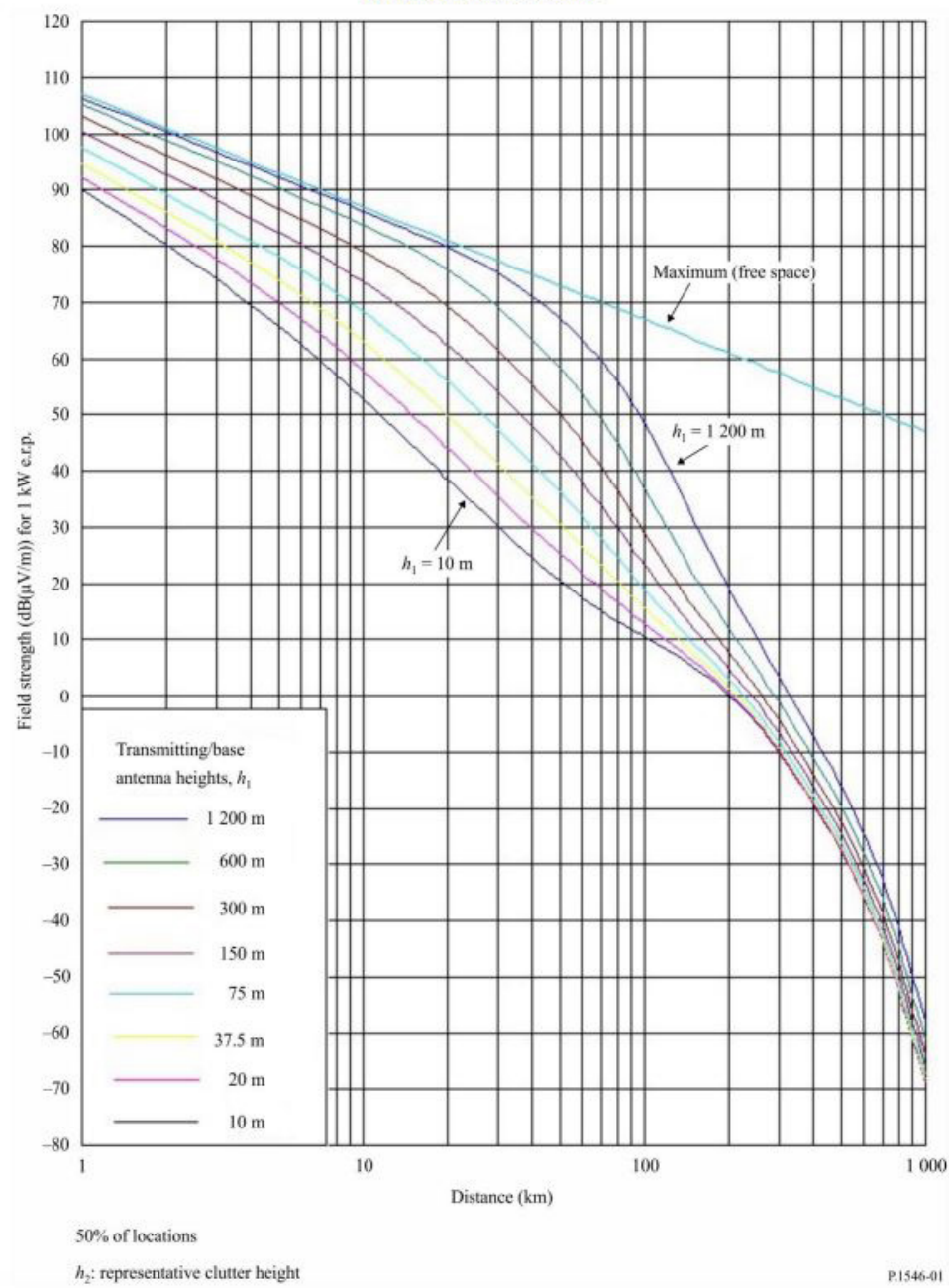


Figure 8-1: Example field strength prediction curves from ITU-R P.1546

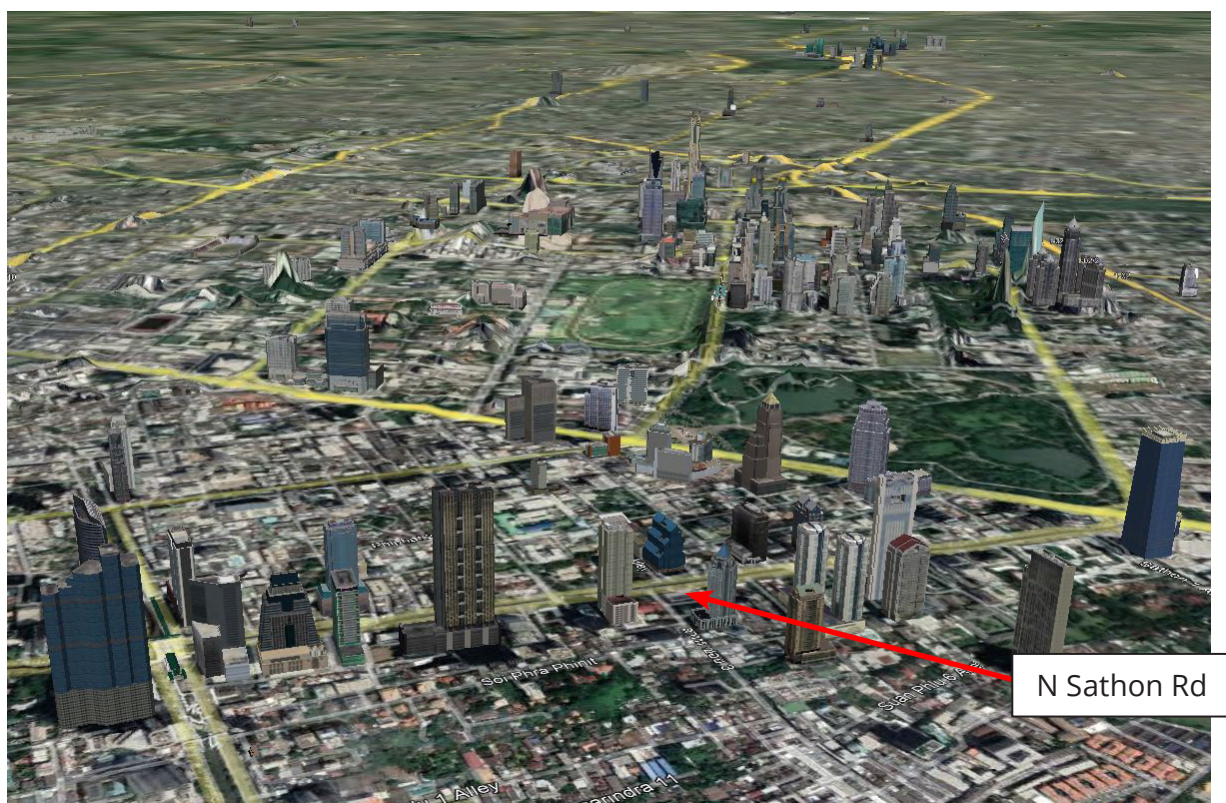


Figure 8-2: Google Earth map of the Bangkok CBD showing 3D buildings in 2019

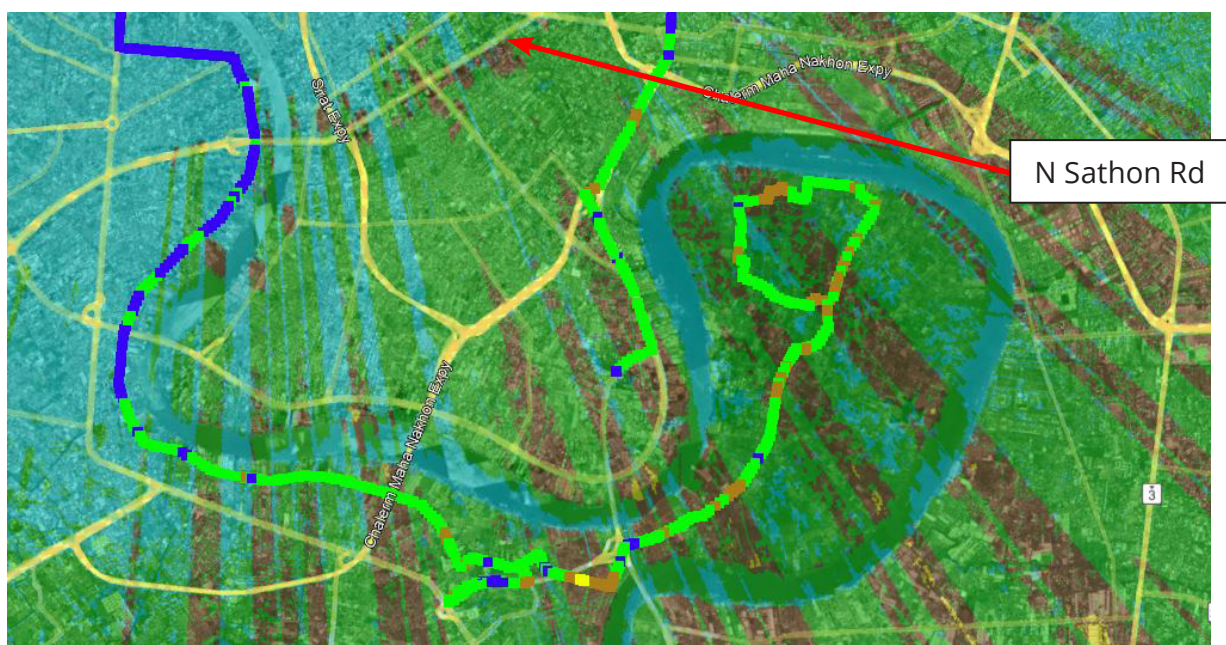


Figure 8-3: Example coverage prediction and field test results for the 2019 Bangkok trial

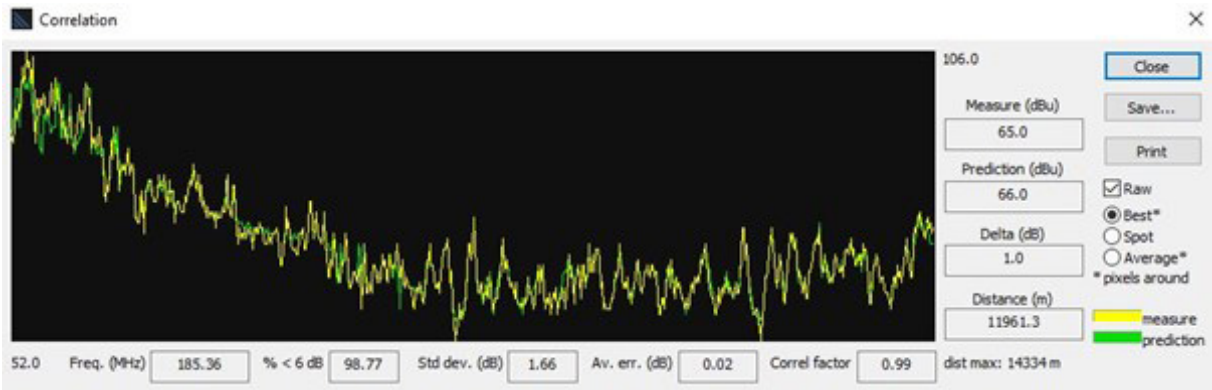


Figure 8-4: Correlation analysis of the field test data south of the Bangkok CBD



Figure 8-5: Clutter map for the Bangkok CBD

Clutter code		Name	dB/km - Atten (dB)		Clutter height
0		open	0.0	0.0	0
1		Extreme urban	0.0	0.0	200
2		suburban	0.0	0.0	8
3		urban	0.0	0.0	15
4		dense urban	0.0	0.0	30
5		forest	0.0	0.0	12
6		hydro	0.0	0.0	0
7		high urban	0.0	0.0	50
8		park/wood	0.0	0.0	4
9 *		very high urban	0.0	0.0	100
10		rail	0.0	0.0	0
11		road	0.0	0.0	0
12		airport	0.0	0.0	0
13		port	0.0	0.0	0
14		open rural	0.0	0.0	0
15 *		vv high urban	0.0	0.0	150

Figure 8-6: Clutter classes used in Bangkok

8.1.2 Extending the initial allotment planning design

The transmission plan in the allotment planning process includes the nominal selection of the transmission sites to be used in an area along with their power and antenna pattern characteristics. The nominal characteristics may in some case be conservative, particularly in terms of the ERP and antenna patterns to simplify the allotment planning process. This is particularly the case when there are many licence areas to be considered due to the complexity of determining the best frequency blocks for each licence area, which increases exponentially with increasing Licence Area (LA) density.

When allotment planning is undertaken on a nominal basis, the coverage is often not optimum with areas of poor coverage. In many cases, the initial nominal transmission ERP and antenna patterns can be adjusted to ensure much more appropriate coverage, typically through increases in ERP and antenna height as well as HRP and VRP optimisation.

The optimisation of the antenna characteristics is often crucial to ensuring both minimum overspill into adjacent commercial licences areas as well as minimising CCI with LAs using the same frequency block.

The process of establishing new transmission characteristics is usually overseen through an application process with the regulator, who defines the allowable level of overspill and CCI interference limits, often in terms of the populations or percentage populations impacted. These parameters may vary between areas and be based on the population distribution in the candidate areas. They will also be likely to use existing FM overspill and interference situations as historical guidance.

This process is most likely to only be used for the main sites in a LA where such sites have ERPs of 5 kW or more. Infill sites are usually lower power, for example <1 kW, and have little impact except in situations where the LAs are small and tightly connected, or the infill site is close to the LA boundary.

8.1.3 Site selection

The main transmission site in an LA will usually already be determined by either current high-power FM or DTV transmissions. These are usually located at the highest physical point which is close to the population to be served, e.g. the city to be served, or in a rural situation that has a dominant view of the surrounding area.

In some cases, the DAB transmission provider may have choices between multiple sites within the area to be covered. This ideal scenario is useful as it provides a competitive basis and hence helps reduce the cost of site rental to near minimum. In some cases, those multiple sites may be on the same mountain.

Infill sites may also be similar to DTV and FM repeater sites for the same reasons. However, we know from experience that coverage in large cities can be significantly impacted by tall buildings and often necessitates the use of relatively high-power SFNs to ensure appropriate coverage. It is often the case that the use of multiple medium-power sites will provide better coverage than a single high-power site.

If new “green fields” sites are the preferred solution, then the site construction will need to consider:

- road access
- tower height requirements, including other distribution systems such as DTT and IMT
- power supply, both main distribution feed and local genset backup power
- emergency operations requirements, for example operations in sub-zero and blizzard conditions, high wind / cyclone conditions and fire risks
- IP access, such as single or redundant fibre or microwave connectivity
- overall cost of construction and operation
- security, both physical and electronic / IP

8.1.4 Transmission design

Once the transmission site(s) have been selected, the transmission design can be undertaken based on the population distribution in the area to be covered and overspill and interference limits. For example, if the main transmission site is in the centre of the city to be covered, an omnidirectional HRP may be used. This, however, is often not the case, with many cities having adjacent high terrain or mountains, in which case the transmission HRP will often be focused from the transmission site towards the major population area using a Directional Antenna (DA) where the Horizontal Radiation Pattern (HRP) will vary in different azimuthal directions, e.g. see Figure 8-8.

DAB+ transmissions are always planned using vertical polarisation. This is in contrast to DTV transmissions in VHF Band III which always use horizontal polarisation. The difference in polarisation between DAB+ and DTV provides additional co and adjacent channel protection when both DAB+ and DTV are transmitted in VHF Band III as is found in Australia and many African nations.

The selection of the HRP will also be impacted by the use of a SFN to cover the area. This is particularly useful when the coverage area has multiple terrain obstacles, for example local high hills or mountains, or large multi-storey buildings. When designing a SFN to cover a city, multiple coverage analysis iterations may be needed to ensure the best coverage versus cost solution. While the use of sites in addition to the designated main site will improve coverage, it is important to minimise the number of sites to minimise both Capex and Opex.

During the design, both the overspill into neighbouring LAs and interference with more distant LAs which are co-channelled need to be considered, as discussed in §8.1.2.

The antenna VRP may also be used to limit overspill and interference by applying down-tilt. However, it is usual to have the same down-tilt on all sides of the antenna so this option may be limited in some situations.

An example antenna system is shown in Figure 8-7. The original four-bay dipole antenna is shown below the new eight-bay / four-panel array which was installed after the field testing during the Bangkok DAB+ demonstration showed coverage deficiencies both in and behind the CBD to the southeast and also suffered significant rear losses towards the northwest due to the dipole array rear HRP gain and shadowing caused by the tower itself. The new antenna system, coupled with an ERP increase of almost 3 dB, largely rectifies these deficiencies.

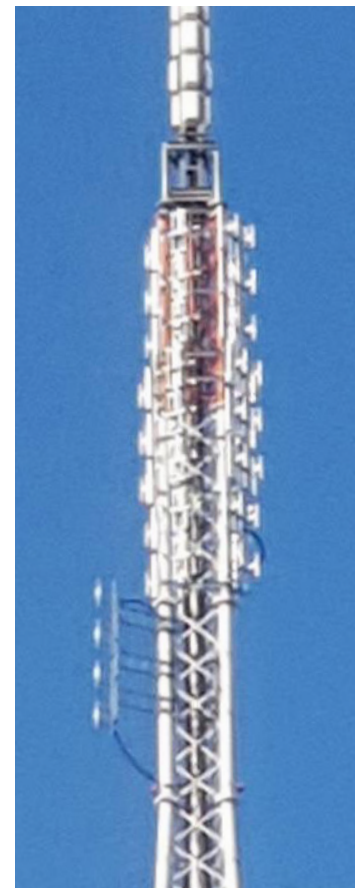


Figure 8-7: The DAB+ transmission antenna in Bangkok

It is common that the regulator will require the transmit antenna to meet specific horizontal radiation characteristics to minimise interference into other transmissions. The site operator may also use shaped HRP and VRP to maximise efficiency by not radiating into areas with no population or out to sea. An example is shown in Figure 8-8, where the shaped HRP shown in blue meets the required radiation pattern mask shown in red.

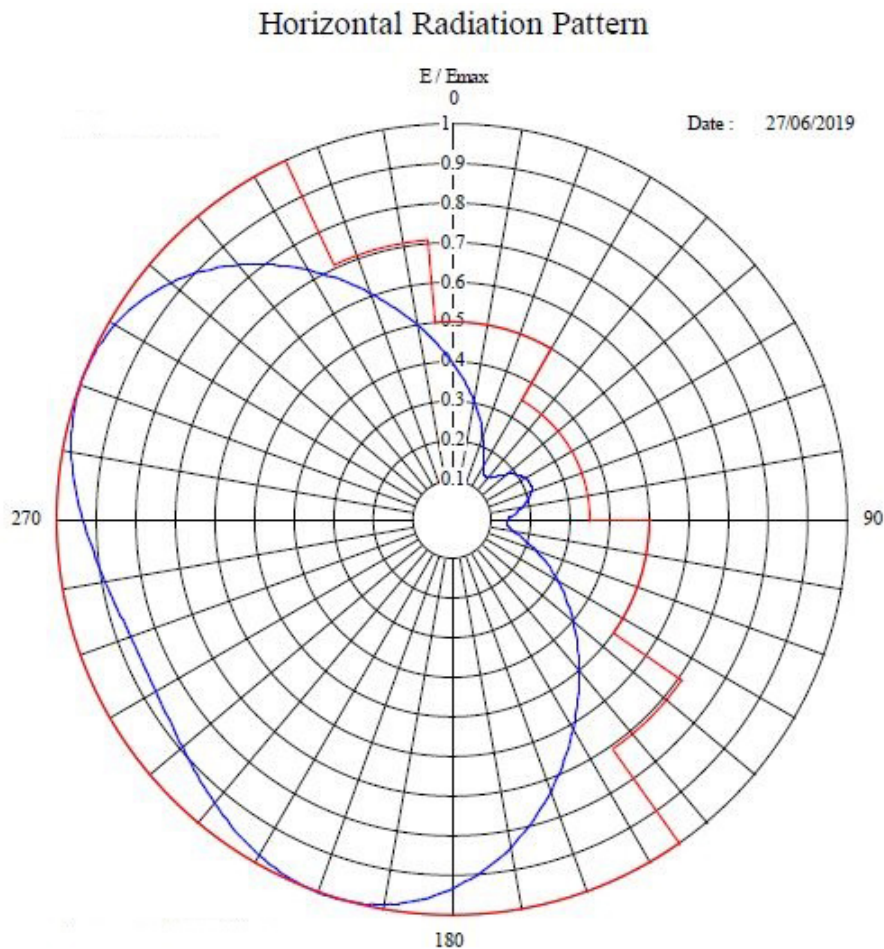


Figure 8-8: A shaped HRP (blue) which directs the transmission power within a required radiation limit mask (red)

The design of the systems used at transmitter sites is often based on an initial template, an example is shown in Figure 8-9. The specific equipment included at a transmission site will depend on the site's purpose, e.g. primary of infill repeater, and may also vary over time e.g. redundant equipment may be installed once a specific DAB+ listening percentage is achieved.

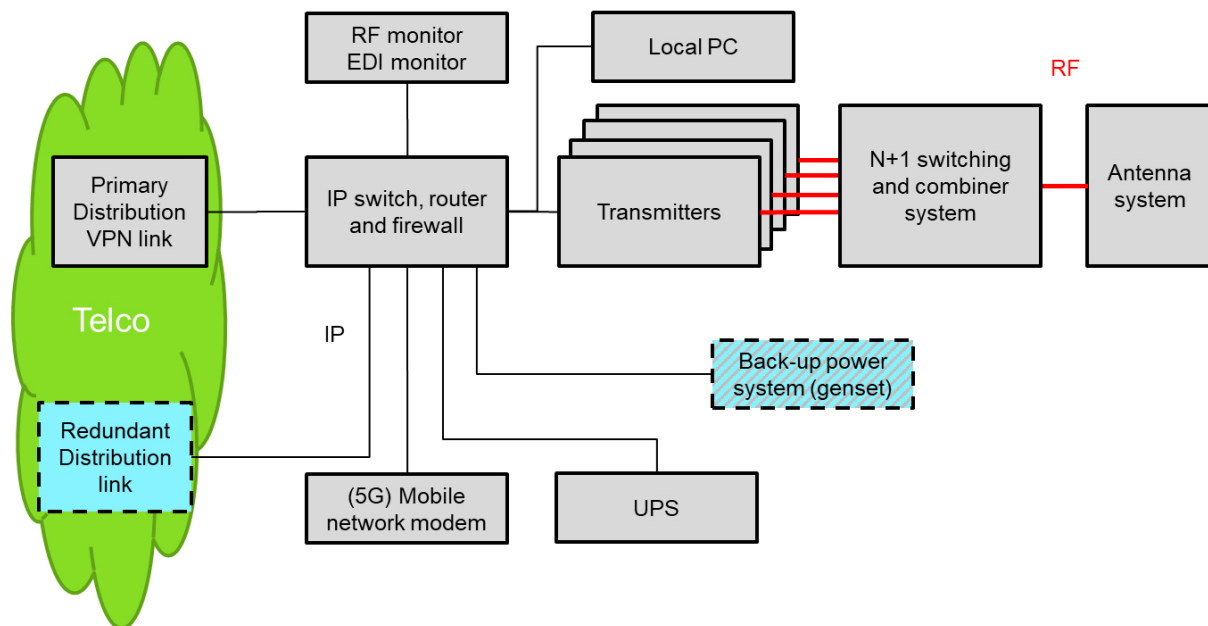


Figure 8-9: An example equipment template for a transmitter site

During the High Level Design phase the transmitter site will often have baseline ERPs e.g. a specific range of options such as 1, 2, 4, 10 kW and the HRP will be assumed to be OD. When the design moves to the Detailed Design stage then these baseline assumptions are reviewed and specific antenna characteristics established based on coverage and interference requirements.

The template of equipment is often used in cost analysis as most transmission sites will be very similar in terms of the equipment required but with specific variations for ERP, HRP and antenna size often being dependant on the site itself. The cost of the equipment can however be minimised by the judicious choice of antenna size and transmitter power as discussed in the following §8.1.5.

8.1.5 Trade-off between antenna size and transmitter power

The cost of the transmission system is often a high percentage of the overall Capex and Opex, for example for wide area networks this can be around 90%. We wish to minimise the Total Cost of Ownership (TCO) of the transmission system over its lifetime.

The minimisation of the TCO for transmission sites is described in detail in Annex C: Transmitter site cost minimisation which provides the equations and a process which can be used to determine the minimum TCO Per Annum (PA). It also provides more examples for both panel and dipole based antenna systems derived from real world costs as obtained from commercial RFIs and discusses sensitivity to costs and amortisation periods. Here we provide a preview of some example results.

Typically, the antenna system will have a lifetime of 20 to 30 years while the transmitter itself is between 10 and 15 years.

The Capex is impacted by the size of the antenna, that is the number of vertical bays and the number of panels or elements per bay with Omni Directional (OD) HRPs generally using four sides. We wish to determine the antenna size which when balanced by a suitable transmitter power will minimise the TCO for a specified ERP. The total cost of the antenna system is typically close to a linear multiple of the total number of panels / elements and their associated feeder cables.

The cost of the antenna system can be traded with the cost of the transmitter system, where we know that for a specific ERP the transmitter power required (kW RMS) can be reduced by increasing the gain of the antenna system by increasing the number of antenna bays. Correctly balancing the transmitter power and the antenna size will then provide the lowest TCO over the lifetime of the system. The analysis can be used in the two main design phases of the overall transmission system design:

1. High Level Design

The HLD usually includes the transmission Allotment Plan which defines the sites to be used for transmissions, and their basic characteristics including the ERP, antenna height and in some cases the HRP. The HLD usually also undertakes a system implementation cost analysis which includes both the Capex to build the network as well as the Opex costs to run it. It is common to use templates for the transmitter systems based on a range of ERPs, e.g. 1, 2, 4, 10 kW. We can use the cost minimisation process to minimise the TCO for each type of site template. That in turn will provide cost estimates which minimise the DAB+ network overall TCO.

2. Detailed Design

During the DD phase we have access to the details of each transmission site including the actual tower height, the aperture available for the antenna, more detailed requirements of the HRP and VRP, sites lease costs and so on. These details narrow the scope of the template that was used for the site in the HLD phase. For example, to minimise TCO for a 10 kW Directional site for 3 ensembles we require a dipole array antenna with 8 bays, however if the tower is already congested with other antenna systems it may have limited aperture which can accommodate a maximum of 6 bays.

In Figure 8-10 we see some TCO PA examples for 4 sided panel array antennas as a function of the number of antenna bays used for a range of ERP values. The top graph is for a single ensemble with a 1+1 redundant transmitter, while the bottom graph is for 3 ensembles with N+1 transmitter redundancy (3+1).

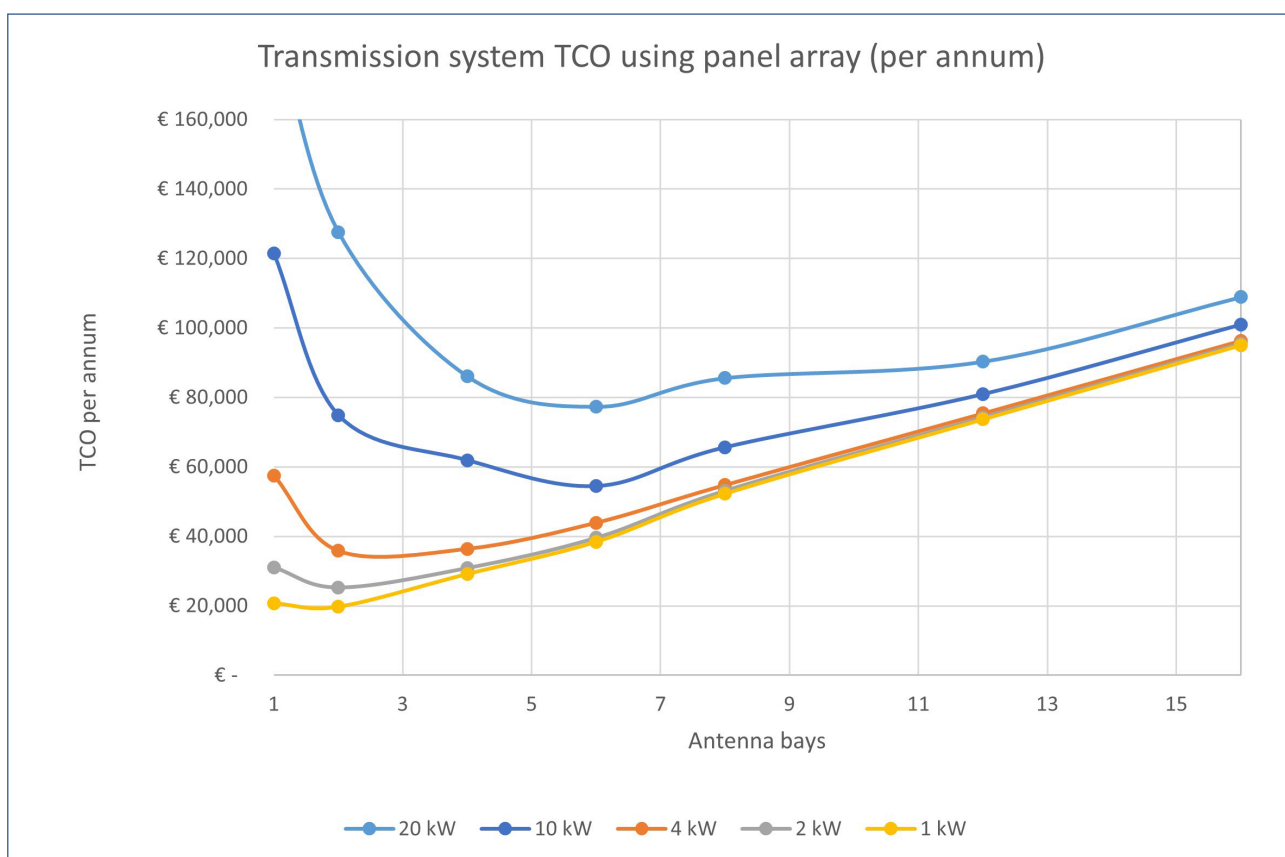
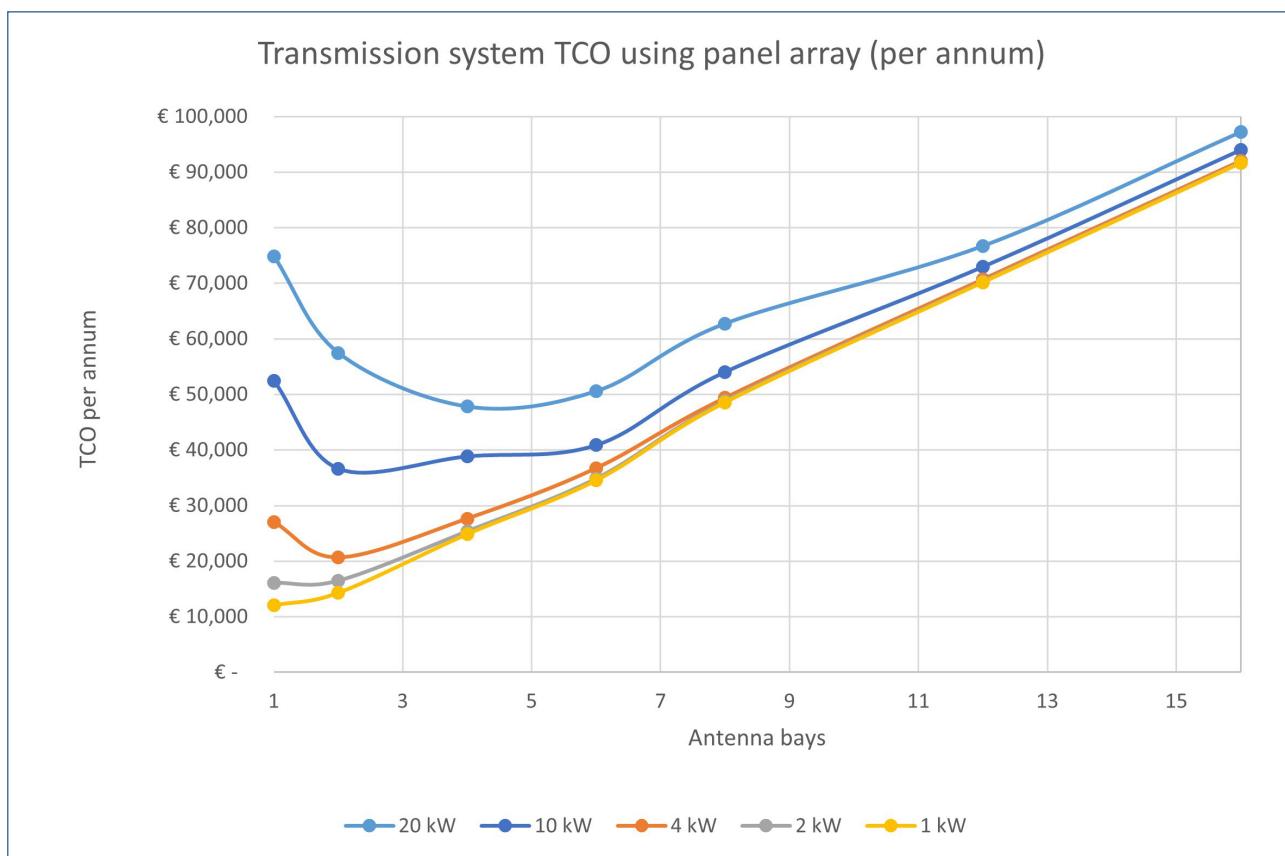


Figure 8-10: TCO PA for a single ensemble top, three ensembles bottom.

We observe that in both cases there are distinct minima for each ERP. For the high power case of 20 kW ERP we see that for a single ensemble the optimum number of bays is 4, while for 3 ensembles the minimum is achieved using 6 bays. We can compare this with the medium power case of 4kW ERP where the minimum cost for 1 ensemble is 2 bays, and for 3 ensembles it is also 2 bays. So we see that generally the antenna size required to minimise the TCO PA increases with both ERP and the number of ensembles. Annex C shows the same trend for dipole-based antenna systems albeit with the minimum TCO PA usually requiring a different number of bays.

The minimum TCO PA for the panel antenna examples versus required ERP is shown in Figure 8-11. We observe that the minimum TCO PA value is not linearly related to either the ERP or the number of ensembles. This is due to the sharing of the antenna system between ensembles and to the quantised nature of the cost of the antenna and transmitter systems. The quantisation of the transmitter system cost is due to the modular nature of those systems where the Power Amplifier (PA) capability is typically set at maxima of 0.3, 0.6, 1.2, 2.4, 3.6 ... kW (RMS). For example, if the minimum TCO PA requires a transmitter power of 1.4 kW then the transmitter system will require a 2.4 kW PA system which is more expensive than a 1.2 kW system. The minimum TCO PA may however then be obtained by using a 1.2 kW transmitter but with a larger antenna to provide increased gain, however every situation is slightly different. Note that the equations provided in Annex C do not take into account the variation of transmitter efficiency for different power levels relative to the maximum capability, however that minimum TCO is not highly sensitive to that variation as it often only varies by a few percent between full power and half power operation.

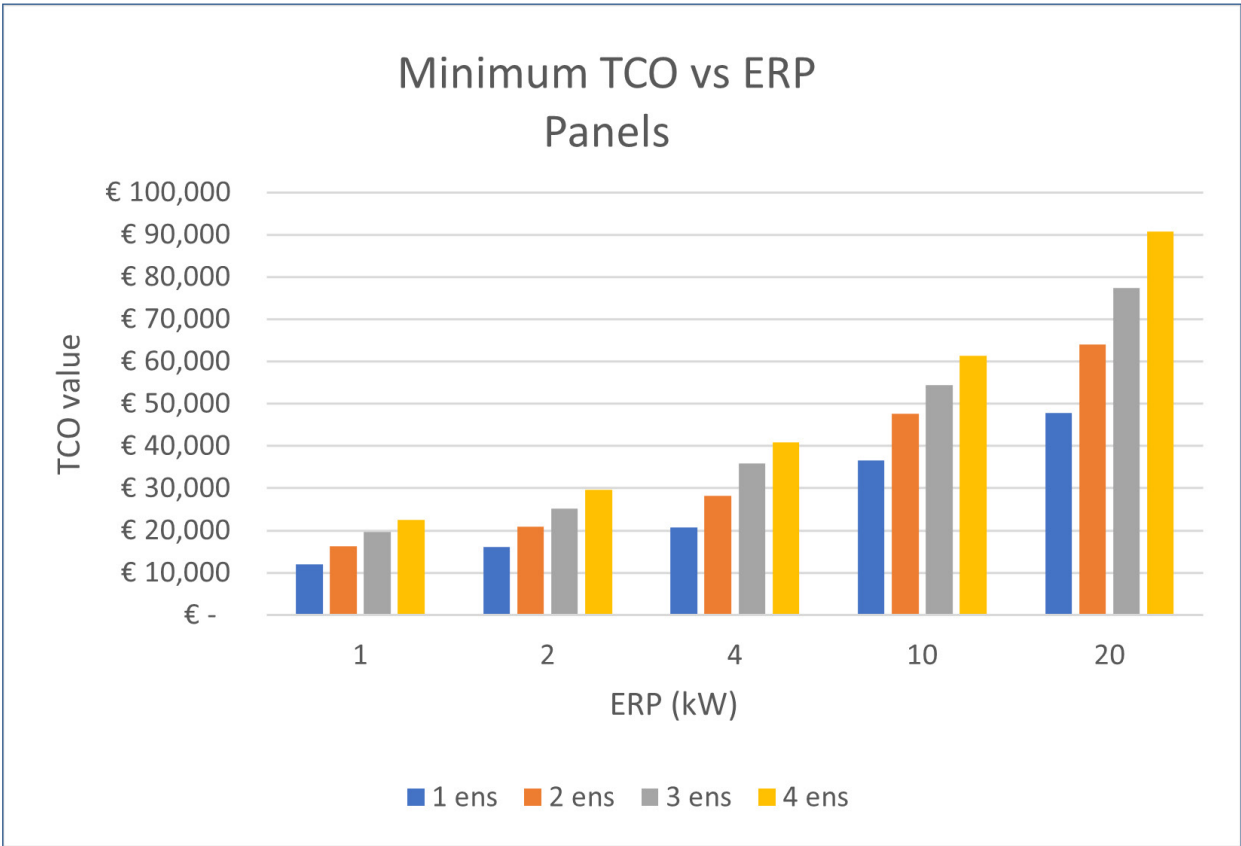


Figure 8-11: Minimum TCO vs ERP

Figure 8-12 shows the minimum TCO PA per ensemble for the range of ERPs. This graph demonstrates the significance of the number of ensembles sharing the same antenna system and transmitter redundancy system for N+1 configurations. Using three ensembles as an example we see that for a 1 kW ERP the minimum TCO PA is €6k but for 10 kW it is €18k, that is 10 times the power for three times the cost. This is not unusual as the cost of transmitters is non-linear as their power increases. Similarly, using a medium sized 4 kW ERP for an example we see that the cost of one ensemble is €21k per ensemble while for three ensembles it is €12k per ensemble. This is due to the sharing of the antenna system.

So not only does DAB+ help reduce costs through the sharing of a transmission by multiple services and often multiple broadcasters on an ensemble, there are also additional savings that can be made when sharing site facilities such as antenna systems. Indeed for that case of a 4 kW ERP for three ensembles, and considering 18 services per ensemble we see the TCO PA per service is only €666. While this seems like a great price we must also recognise that the cost of bit rate capacity also includes many other costs which are not considered in these equations, such as transmitter site ancillary systems (IP, power, control etc), the multiplexer network and associated telco connection costs, and operations and maintenance costs.

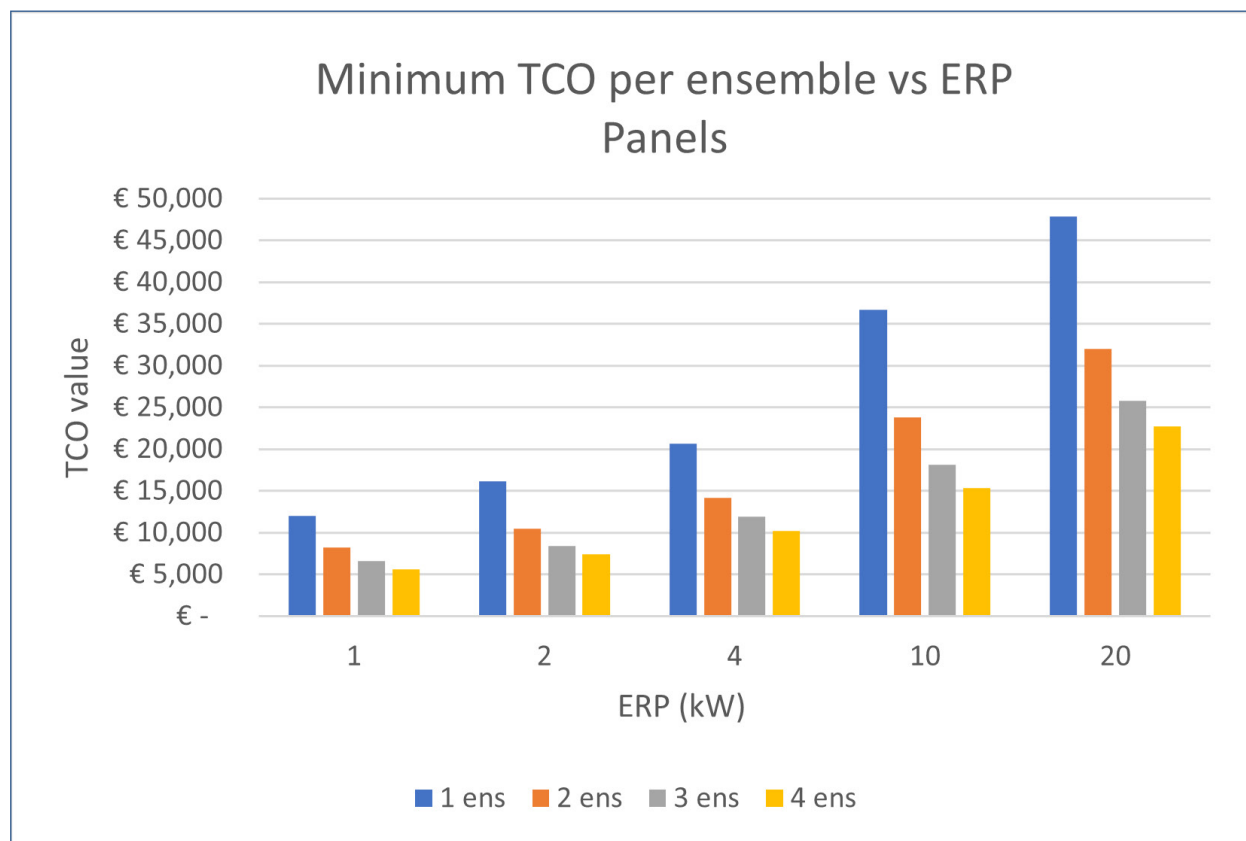


Figure 8-12: Minimum TCO per ensemble vs ERP

Overall, it is clear that using larger antennas will generally result in a lower TCO per annum. However, care needs to be taken with lower-power sites to get the correct cost balance and optimal configuration. The lower-power sites are more likely to be repeater sites, where there may also be restrictions on what antenna systems can be mounted on existing tower infrastructure.

8.1.6 Use of Single Frequency Networks

The design of the Orthogonal Frequency Division Multiplexing (OFDM) system for DAB+ allows the implementation of wide area Single Frequency Networks (SFNs). This is a key feature of DAB+ networks providing high spectral efficiency as all transmitters in a coverage area can use the same frequency, whereas analogue FM networks must use repeaters in a Multi Frequency Network (MFN) architecture.

There are many examples of SFNs covering wide regional areas and even entire countries. To do this, the design of the networks must obey transmitter site separation rules to ensure that transmitters within the network do not deliver higher than allowable signal power outside of the OFDM Guard Interval (GI). The GI for DAB+ is 246 μ S which translates to a maximum transmitter spacing of 73.8 km.

The other principal of SFN operation is the requirement for the signal that is transmitted from each site within the SFN to be identical. Consequently, a SFN delivers the same content to the entire area and there is no way to “insert” a different service into a part of the SFN.

SFNs are commonly used within an MFN design where the MFN is required to be able to deliver different content / services in different areas, for example adjacent LAs. Within each LA, it is typical to have one or more high-power sites which are supplemented with several lower-power infill sites. Those infill sites deliver the same content as the main site(s).

SFNs are commonly implemented using EDI delivery to each transmitter from the same multiplexer via IP infrastructure, such as fibre or microwave. For lower-power sites, typically less than 300 W ERP On-Channel Repeaters (OCR) can also be used. OCRs receive their input directly off-air using a directional antenna and then amplify it to be retransmitted to cover a local area. To allow operation at ERPs such as 300 W, the use of receive-to-transmit antenna separation along with digital echo cancellation techniques are required to limit RF feedback issues. OCRs have a lower maximum distance from the main transmitter site due to round trip delays and equipment processing times. In some cases, this may be reduced to around half of the maximum value of 73.8 km and is often terrain and/or clutter related. As the cost of IP connectivity to repeater sites continues to reduce we see OCR site operators are increasingly preferring EDI delivery.

Wide area SFNs are often used to deliver national services. An example from Italy is shown in Figure 8-13, where large areas receive the same “national” content.



Figure 8-13: National SFN layers in Italy⁴²

The design of SFNs needs to consider both in-country interference and cross border interference. In-country interference can be either from transmissions within the target SFN or from transmissions from another SFN on the same frequency block.

When the transmissions are in-country the potential CCI is analysed using propagation models such as ITU-R P.1812 and sometimes ITU-R P.1546. The signal variations considered typically considers the wanted signal using 50% of time reception probability while the potential interference uses 10% of time interference as shown in Table 8-1.

	Useful signal (condition <i>steady</i>)	Interfering signal (condition <i>tropo</i>)	
		National territory	Foreign country territory
Time probability	50%	10%	1%
Location probability	50%	50%	50%

Table 8-1: Time and location probabilities used in interference modelling⁴³

For international cross-border coordination the ITU-R P.1546 model is preferred as stipulated by the ITU-R. In this case, all signals are modelled using a receiver height of 10 m and with a potential interferer time probability of 1%. This is to minimise the potential cross-border impact of services.

⁴² Courtesy Hanns Walter, DAB Italia

⁴³ Courtesy Mauro Martino, AGCOM, Italy from his presentation "DAB+ coverage planning from a spectrum regulator's perspective", delivered at the WorldDAB SNIC workshop 20 March 2024.

Italy is a very good example of such cross-border coordination considering they have many neighbouring countries across both land and sea borders. Indeed, we see in Figure 8-14 that Italy has ten international coordination zones. Much of that coordination was done under the ITU-R GE06 project, however there have since been several adjustments as the rollout of DAB+ gathers pace in those neighbouring countries.

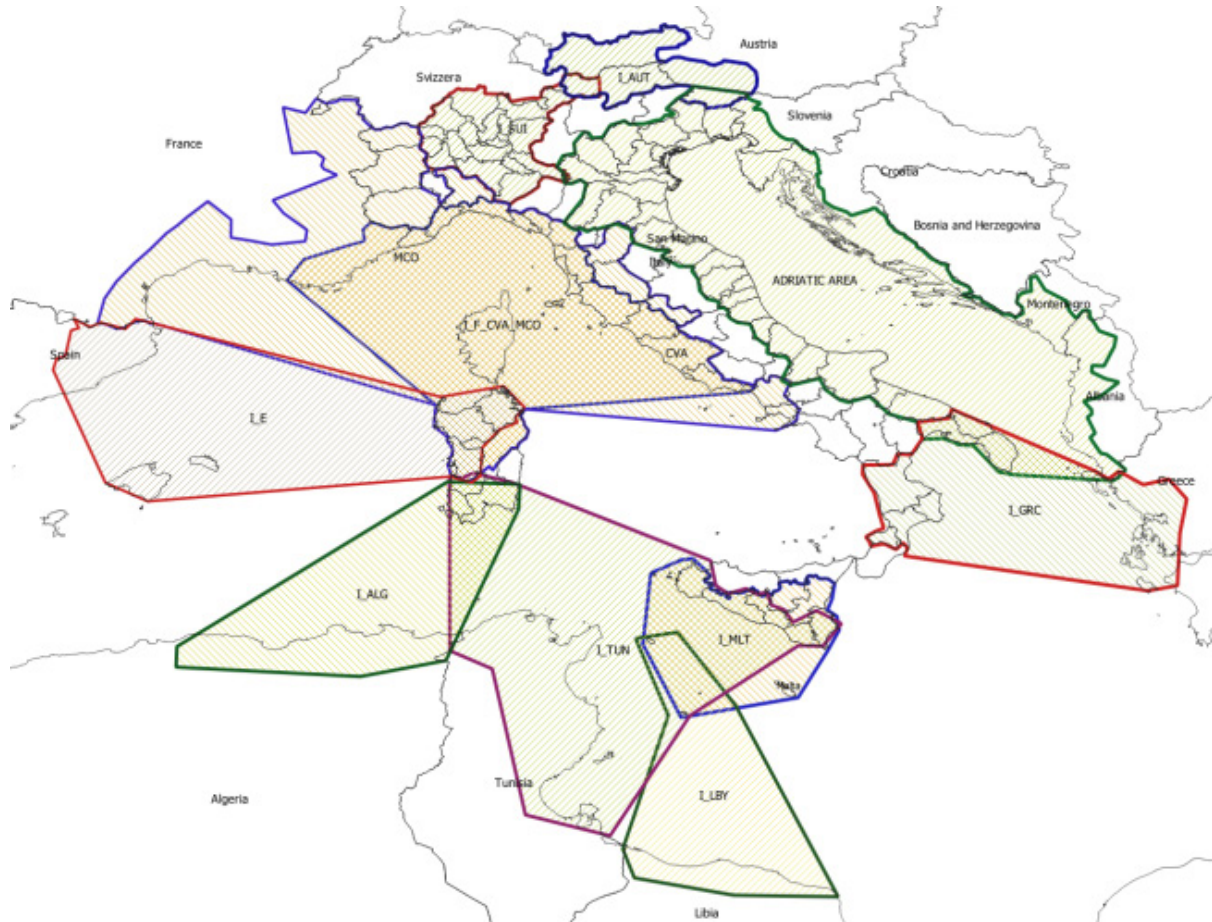


Figure 8-14: Cross-border coordination zones between Italy and neighbouring countries⁴⁴

We see a further example from Italy in Figure 8-15 where the transmissions from the central Italy area of Lazio need to be coordinated with both in-country and cross-border transmissions on the same 12A frequency block. In this case, there are 15 different transmission paths to be considered, including both land and sea-based propagation. Note that these potential interfering situations must be considered in both directions. In this case, the Lazio area may be a local area or be part of a larger MFN or SFN. If it is part of a larger SFN, the other regions within that SFN will also need to be considered.

The above examples are demonstrations that while SFNs are very useful and spectrally efficient, they also need to be designed very carefully to ensure that they are compatible with other planned networks, both in-country and in neighbouring countries.

⁴⁴ Courtesy Mauro Martino, AGCOM, Italy from his presentation "DAB+ coverage planning from a spectrum regulator's perspective", delivered at the WorldDAB SNIC workshop 20 March 2024.



Figure 8-15: Internal and cross-border areas which need to be considered for the DAB transmissions from central Italy (Lazio)⁴⁵

8.1.7 Main transmitters

There are several aspects that need to be considered when designing the main transmitter system.

Transmitter redundancy: modern transmitter systems have very good N+1 redundancy switching to minimise the cost of transmitters when there are multiple ensembles being delivered. Control units can reconfigure the redundant transmitter to have the same configuration as the failed unit and switch it to air at full power in only a few seconds. This relieves the need for 1+1 redundancy requiring only one redundant transmitter for N ensembles, as shown in Figure 8-16.

⁴⁵ Courtesy Mauro Martino, AGCOM, Italy from his presentation "DAB+ coverage planning from a spectrum regulator's perspective", delivered at the WorldDAB SNIC workshop 20 March 2024.

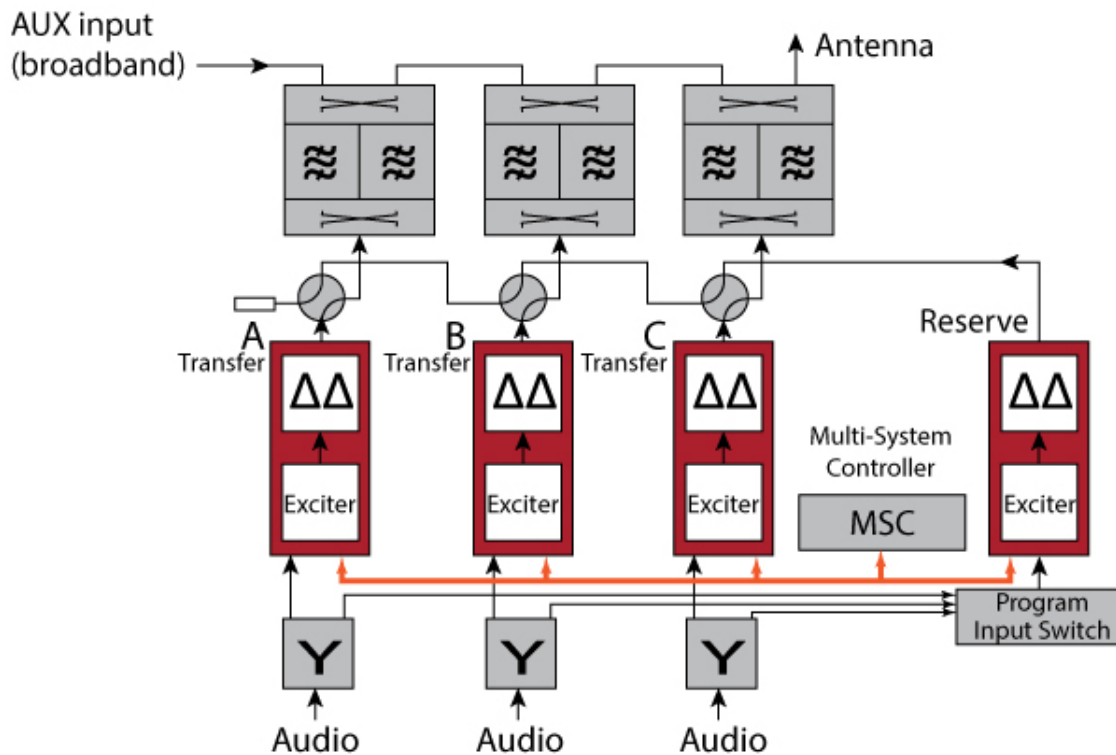


Figure 8-16: An example N+1 redundancy configuration⁴⁶

Redundancy of IP feeds: modern network architectures are completely IP-based, with ETI streams being delivered over EDI (ETI over IP) [4], monitoring using SNMP and control via TCP/IP-based protocols. The issue is now how to protect the incoming IP from distribution failures. This can be done by providing redundant IP connections which may be achieved by separate IP connections in separate site entries and by mixing the IP delivery between fibre, microwave and satellite delivery systems. It is important to ensure maximum independence, for example separate routers and switches on each feed, and using separate delivery paths, for example do NOT put the main and redundant fibre in the same conduit and route.

Redundancy of power systems: reliable power systems are essential to allow broadcast facilities to keep operating under extreme conditions. The mains power supply can be compromised when natural disasters occur, so the site must provide local power generation capability. This is usually in the form of a Genset, which can provide enough power for all systems on the site for several days, usually via diesel fuel storage. For critical sites, redundant Gensets are often provided, with regular start-up and testing protocols to ensure that they are always maintained in good working order.

8.1.8 Monitoring, control and ancillary systems

It is essential to always know the operational status of all transmission site equipment. This is often done via SNMP-based remote control and monitoring systems which are centralised at a Network Operations Centre (NOC). In most cases, a NOC which is responsible for one or more major broadcast networks will be staffed 24/7 even though the actual transmitter sites

⁴⁶ Source: Gates Air: <https://www.gatesair.com/products/transmit-radio/dab-transmitters/maxiva-vaxte-with-powersmart-plus>

are not. In many cases, even major sites are staffed in the day, when system changes and maintenance operations take place, but are not staffed at night. When a system component fails, it is likely that the NOC operator will detect the issue before the local site staff. At night, the NOC staff may need to switch systems “manually” and run Gensets remotely if a major issue such as a power supply failure occurs.

This means that to ensure appropriate reliability, or continuity of service, which is typically stated at 99.96% uptime, or only three hours per year off-air, the ability of the monitoring and control systems is critical to the overall system performance. This is a clear reminder of the need for diversified IP feeds to transmission sites.

Ancillary systems also play key roles, particularly when the environment is extreme; whether hot or cold, windy or dry, systems to control temperature are generally needed for both the staff and the equipment. The remote monitoring and control system needs to monitor these site “vital signs” as well as the details inside the equipment.

8.2 Network design

The starting point of the network design is the locations of the transmission sites, both main and infills, and the content production studios of the broadcasters. The aim of the network design is to minimise the TCO of the multiplexing system infrastructure and the contribution and distribution communication networks. The multiplexing system(s) costs are dominated by the initial Capex costs while the communications networks costs are often dominated by the Opex costs. The TCO is typically calculated over the expected operational period of the multiplexing system, for example 10 years. After such a period, the multiplexing equipment will usually become out of date due to technological creep, such as hardware platform and support software capability enhancements and cost reductions.

8.2.1 Multiplexing systems

The multiplexer system is the heart of the overall DAB system. It ingests the audio content from broadcasters along with the PAD information and other metadata and produces a Time Division Multiplexed (TDM) data stream in the Ensemble Transport Interface (ETI) format for delivery to transmission and other distribution sites.

Modern multiplexer systems are software-based and usually run on standard computing server platforms, often being hosted within a Virtual Machine (VM) environment.

An example block diagram is shown in Figure 8-17, where the audio and PAD source is shown on the left in orange. Those sources are typically audio and PAD playout systems which deliver the audio content to the DAB+ audio encoder. The audio format may be analogue, AES digital or more commonly AES67-based Audio over IP (AoIP). The PAD is often collected by a PAD server and delivered either to the multiplexer or the audio encoder for embedding in the X-PAD component of the audio stream.

The multiplexer system receives the DAB+ encoded audio along with the PAD from the various sources and assembles them into a set of services which are then assigned to sub-channels in the signal to be transmitted. The resulting ETI stream also includes the Fast

Information Channel (FIC) which contains the necessary configuration information to allow the receiver to understand the structure of the ETI stream and its contents. That configuration information includes parameters such as the assigned sub-channel, the service label, the sub-channel bit rate and the amount that is reserved for X-PAD, the audio encoding parameters, and so forth. Full details of the system can be found in the main DAB Standard [2] with the DAB+ audio encoding being defined in [3]. The ETI stream produced by the multiplexer system is usually encapsulated within an IP stream using the methods defined in [4].

DAB can also deliver data services in a similar manner, typically using enhanced packet mode. Those services can include EPG, TPEG and a range of other data services, including custom applications.

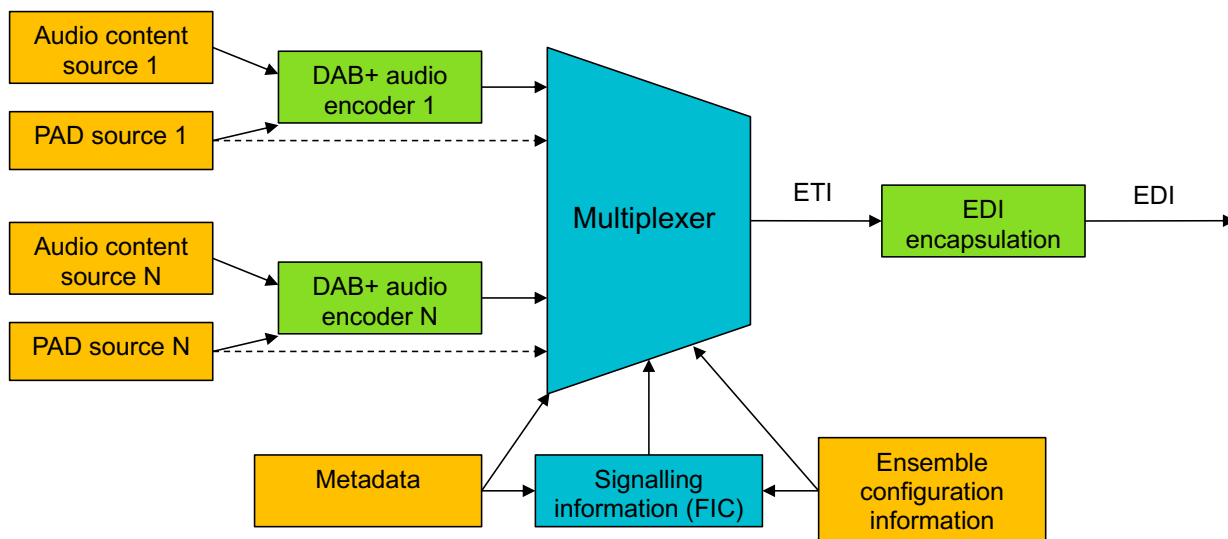


Figure 8-17: Basic components of the multiplexer system

DAB+ encoding and multiplexing systems are provided by several commercial infrastructure system manufacturers in a range of formats, from custom hardware-based to standard computing server platforms, with or without VM architectures, to cloud-based implementations.

To ensure a high degree of availability, multiplexer systems are usually constructed as 1+1 redundant systems where the main and redundant multiplexer system is hosted on a physically different platform and usually fed by different IP and power systems. See §8.2.5 below for more details.

PAD server systems are usually provided as separate software systems but may be hosted on the same server platform as the multiplexer system.

Audio encoders may similarly be hosted on the same server platform for the case where the audio delivery is economically practical, typically using AoIP. Otherwise, they can be hosted on separate and often remote platforms, particularly where the multiplexer system serves several different broadcasters.

8.2.2 Network architecture

Multiplexing networks generally have a contribution network which delivers the audio and PAD from the studios to the multiplexer and a distribution network which delivers the resulting ETI / EDI stream to the transmission sites. Figure 8-18 shows an example of the use of star networks for both the contribution and distribution networks. This type of network is often used for coverage of a specific area, whether a local, regional or a national network licence area.

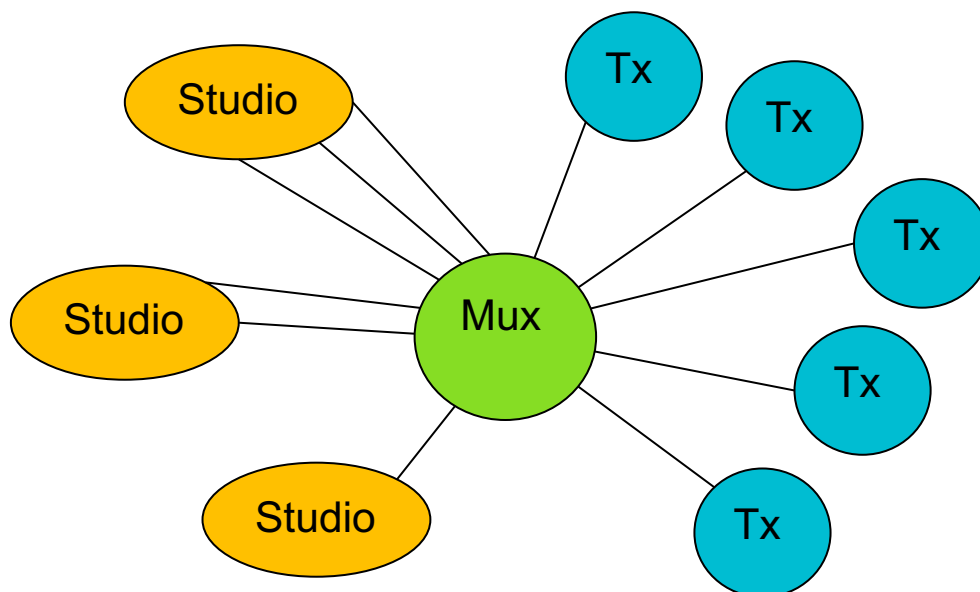


Figure 8-18: An example of a star network

When operating across multiple coverage areas which have their own local content, the contribution network may also be a mesh or partial mesh network. Figure 8-19 shows the case where content from a studio in a coverage area is also used in other areas; this can be the case where national content is produced in different locations. The cross-coverage area links are shown in red from the network of studios coloured light orange to each individual multiplexer. Using this approach leads to many contribution links, the number of which grow quickly as the number of areas increase. Figure 8-20 shows an alternative where the studios are interconnected, and the studio located in the coverage area delivers content to the local multiplexer. This approach can reduce the number of individual links and save contribution network costs.

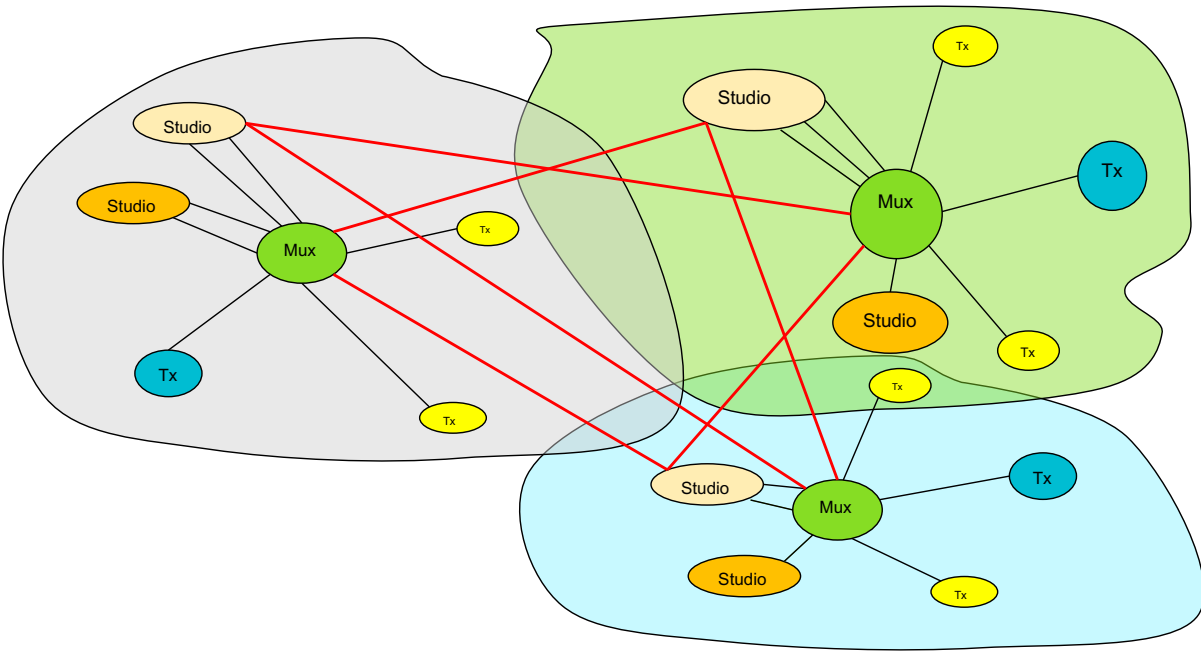


Figure 8-19: Cross-coverage area contribution using direct to multiplexer delivery

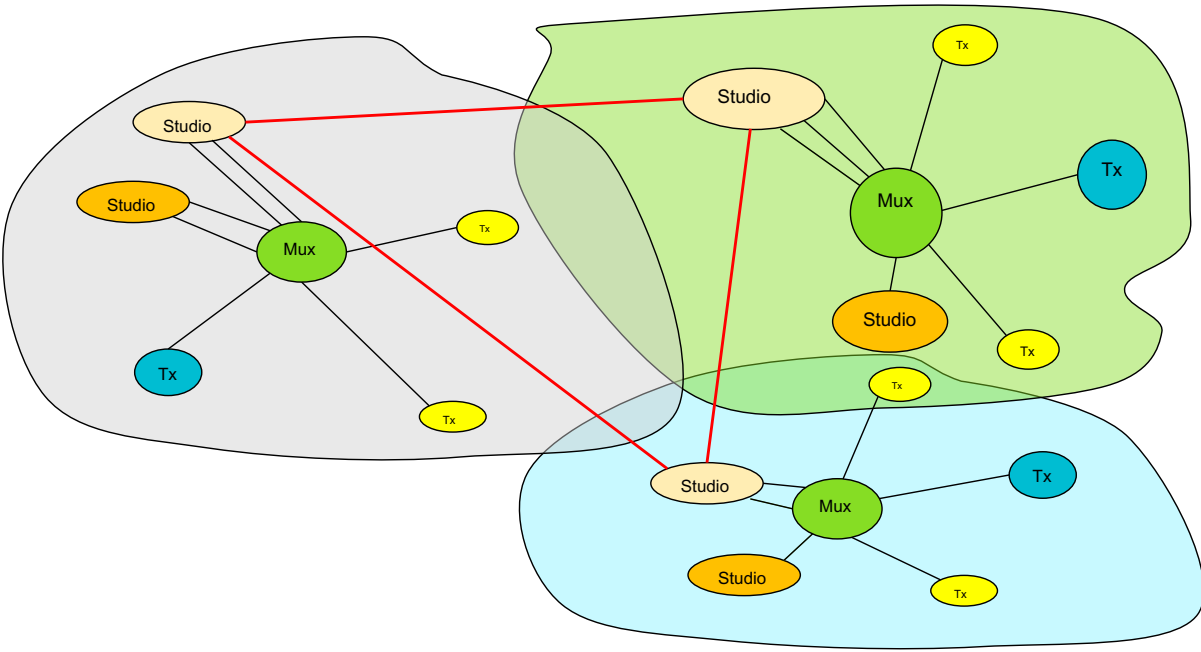


Figure 8-20: Cross-coverage area contribution using inter-studio content delivery

In some cases, it can be more economic and operationally easier to gather all multiplexing and encoding systems at a single operations site. Such a network will typically have a star architecture where all contributing audio and PAD sources are delivered to the central multiplexing site which then delivers the resulting EDI streams to the transmission sites as shown in Figure 8-18. The biggest concern with such an approach is the cost of the contribution and distribution links, which may stretch across a country. In some cases, however, this may not be a big issue, especially for broadcasters who also produce television services, such as many Public Service Broadcasters like the BBC and the ABC. This is because in many cases the links for DAB require low capacity relative to those required to distribute television streams, often to the same transmission sites, and hence the DAB contribution and distribution comes at little or no cost as the capacity used sits in the spare capacity of high-capacity links, often a fibre optic-based network.

At the opposite end of the scale are regional commercial and community transmissions which serve communities in regional and rural settings. In this case, it is often more economic to site the multiplexer at the main transmitter site and use low-cost microwave links or public internet to deliver the audio and PAD content to that site. The multiplexer can then connect directly to the transmitter via a site-based IP network. The approach using public internet is often used in the implementation of SS-DAB+ systems in the UK as described further in §8.2.5 below.

Both the contribution and distribution networks have their highest capacity requirements in one direction, that being the forward direction from broadcaster site to multiplexer site and then from the multiplexer site to the transmission sites. In the case of EDI distribution which is typically used from the multiplexer site to the transmission sites, forward error correction can be applied within the EDI stream and also further encapsulating layers to protect the payload content from errors. Satellite distribution systems can be a very cost-effective distribution method for national or wide area distribution. For example, DVB-S2 [8] can be used to distribute EDI streams on encapsulated satellite links. The planned network for Algeria is a good example of this, where the central studio content made in Algiers can be delivered to many tens of transmitter sites across the country using only a few MHz of satellite capacity.

While we have focused on the primary content delivery, we must also remember that DAB+ networks also require monitoring and operational control. This is done through bidirectional networks which are often based on the TCP/IP protocol. Operation and control are performed through equipment web interfaces while system monitoring is done primarily through SNMP-based network management systems. The network management system is responsible for observing the status of all equipment in the overall network. This includes encoder status, hardware platform status and performance, network equipment, multiplexers and PAD services. For transmitter site equipment it includes the transmitters, power monitors and antenna switch-frames, EDI and transmission signal monitors and the ancillary systems such as power, air-conditioning and IP network equipment.

The amount of traffic in network management can be significant and when summed from all sites can be several Mbps, so it is important to dimension those systems carefully and consider the impact of system failures, which can cause a surge in control traffic to multiple systems, as well as monitoring of the individual devices through web interfaces.

8.2.3 Broadcaster site equipment

The broadcasters' site equipment is shown in Figure 8-21 for a fully redundant system. The blocks in "grey" are the essential system functional blocks. Those in "blue" are redundant system with options being shown with a dashed outline.

The equipment at the broadcasters studio is:

- DAB+ audio encoder
 - ▶ This is assumed to be a hardware unit which can receive input from analogue, AES3 digital audio or AES67 based AoIP network systems.
 - ▶ The unit hardware is assumed to be able to encode multiple audio sources, typically up to 4.
 - ▶ Cost of the unit is based on the hardware platform and the number of encoder licenses required.
- DAB+ or other encoder IP connectivity
 - ▶ The primary IP route to the multiplexer site is assumed to be via a low capacity VPN IP link, e.g. 128 kbps per service to be transmitted
 - ▶ The IP network equipment will typically require an IP switch, Layer 3 router with firewall and the Customer Premises Equipment (CPE) of the Telco providing the VPN service. In some cases these IP systems will be integrated.
- Redundant encoder
 - ▶ There are two main options for providing audio encoder redundancy, they are shown in "blue" with a dashed outline in Figure 8-21
 - The first option is to have a redundant audio encoder at the studio site. Ideally that encoder system will run on different hardware to the primary encoder system. Its IP output can be delivered through the main encoder VPN however it is often better to use an alternative IP route so in this case we show it as being delivered over the public internet.
 - The redundant audio path may also be delivered via webstream over the public internet, the webstream should be at least 128 kbps for AAC+ and 256 kbps for MP3 based encoding.
 - ▶ The IP network equipment will typically require an IP switch, L3 router with firewall and the CPE of the Telco providing the network service. No VPN is provided only access to the public internet but should have a dedicated IP address. We assume that this equipment already exists for the delivery of existing web streaming service.
- Service provider capacity controller
 - ▶ This will generally only be needed when the broadcaster needs to be able to control the use of their allocated capacity for multiple services. This is to allow the broadcaster to adjust their number of services and associated bit rates and can be used to deliver pop-up services. Some DAB network providers provide this functionality via web based interface for operation by the broadcasters, others require a change request process which can take time and may have additional cost.

- PAD delivery
 - ▶ PAD such as text and images is assumed to be delivered directly from the broadcaster's playout system to a common PAD server software application which will run on the same server as the multiplexer software. Alternatively, the broadcaster could have a PAD server application which runs on their internal platforms and connects to either the multiplexing system or to the DAB+ encoder.
 - ▶ If there is no PAD automation, i.e. dynamic text and images for now playing information, then static PAD can be delivered from the multiplexer system. Static PAD would typically include a slide carousel containing images depicting the popular programmes delivered by the broadcaster along with a static tagline in the text.

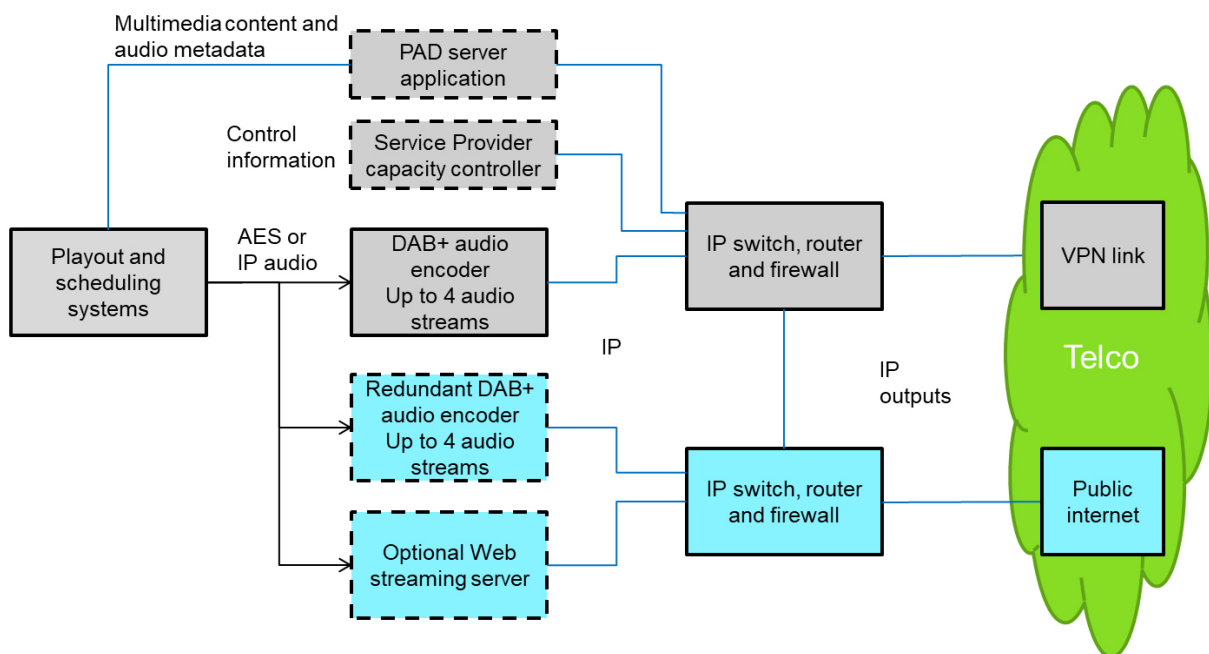


Figure 8-21: Broadcaster site equipment using DAB+ encoders

The baseline configuration is 1 service per broadcaster. DAB+ studio encoders can usually provide up to 4 DAB+ services, each service in addition to the initial service will usually attract additional encoding licence fees.

While it is common to provide the DAB+ audio encoding at the broadcaster's studio site to minimise the contribution network traffic to the multiplexer site some network designs provide all DAB+ encoding at a centralised multiplexer site. In this latter case the broadcaster needs to deliver their audio to that multiplexer site usually either by AoIP via a VPN or via a public internet connection where the transport of the audio includes alternative audio encoding e.g. MP3 and may also include error correction mechanisms to help overcome data dropouts⁴⁷.

IP connectivity and UPS equipment is assumed to already be available at the broadcaster's studio and has no additional costs.

⁴⁷ The Factum Radioscope SRT system is a good example of this approach, see the presentation by Mr. James Waterson at <https://www.worlddab.org/events/detail/685#presentations>

8.2.4 Multiplex site equipment

It is recommended that all multiplexer systems be 1+1 redundant at all main sites. This is due to the critical nature of the multiplexer system with any failure or maintenance activities requiring off-air time. 1+1 redundancy will ensure that all services have maximum on-air time. When Disaster Recovery (DR) sites are implemented, they may, or may not have, 1+1 redundancy. Site equipment overviews for Main and Disaster Recovery sites are provided in Figure 8-22 and Figure 8-23 respectively, where the main and redundant systems are shown as (main) and (alt). Non-essential redundant equipment is shown in “blue”.

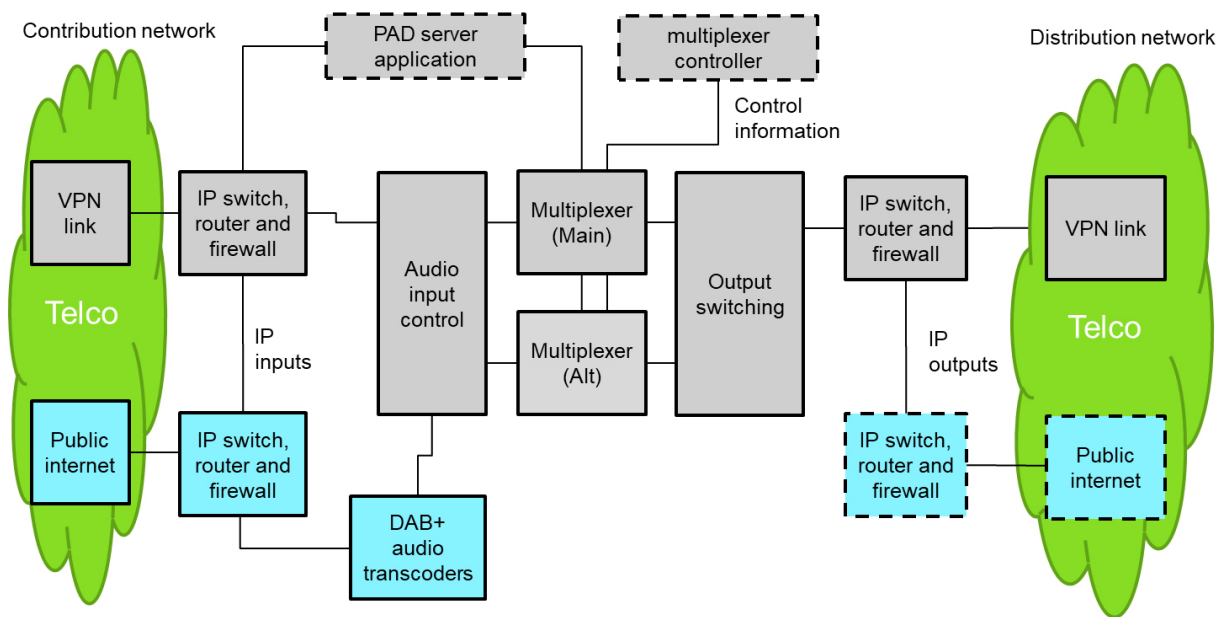


Figure 8-22: Main multiplexer site equipment overview – redundant multiplexers

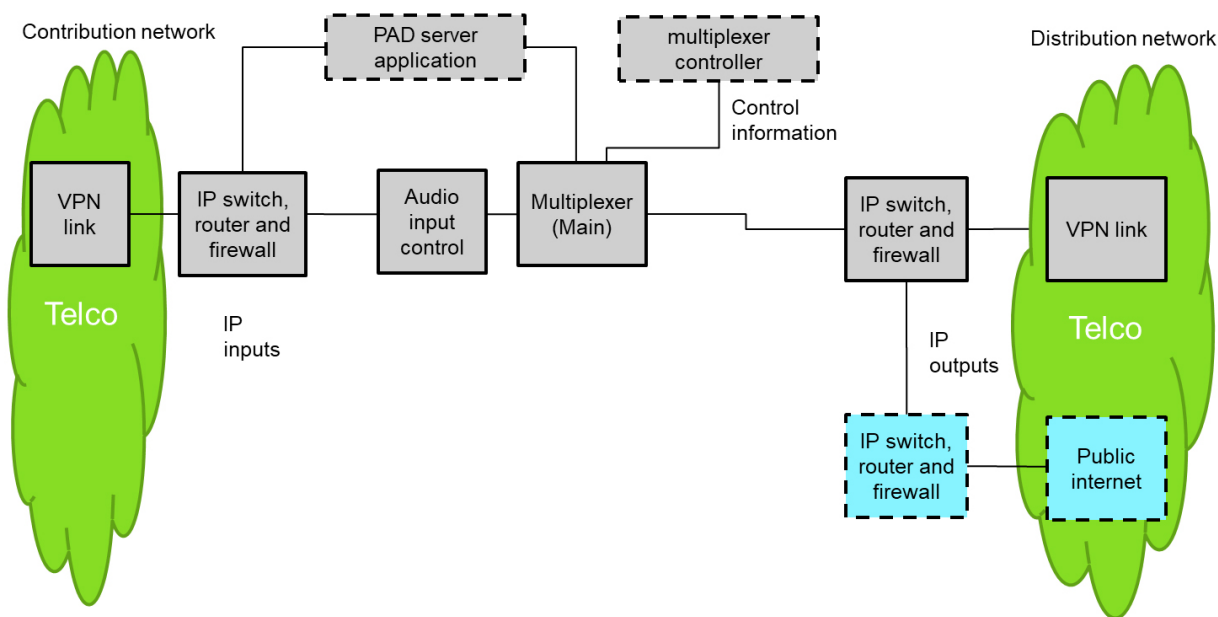


Figure 8-23: Disaster Recovery multiplexer site equipment overview – non-redundant multiplexers

The systems and software used at typical multiplexer sites is provided below. Site capabilities and equipment will vary depending on the selected location of the audio encoder and PAD systems. The lists below tend to be inclusive so some implemented systems may not have all the equipment shown.

- Multiplexer system equipment
 - ▶ Multiplexer system software instances
 - 2 per ensemble implemented. This can be for multiple layers. Each ensemble is implemented as a 1+1 redundant system each running on different server platforms.
 - Additional instances for DR site if used
 - ▶ Input audio handling
 - This only applies when the audio is delivered to the multiplexer site by a non-DAB transport system.
 - This software can often accommodate multiple audio streams.
 - Can be implemented in a redundant arrangement as input to 1+1 redundant multiplexers running on 2 physically separate server platforms.
 - ▶ DAB+ encoder software instances (if not implemented in the broadcaster's studios)
 - Main encoders coupled with the main multiplexer instances
 - Redundant encoders coupled with the redundant multiplexer instances
 - 1 per service per platform, e.g. 2 per service when using 1+1 multiplexer redundancy
 - Note that audio encoders are also implemented in separate hardware units, as often seen in studios, however here we emphasise the use of common server platforms as they usually have lower costs.
 - ▶ Output EDI redundancy switching
 - 1 per redundant multiplexer pair
 - ▶ Server platforms
 - Typically this is around 1 per 10 individual multiplexer instances but is also dependent on the implementation of encoders and other functionality
 - Server platforms are often setup using virtual machine methodologies.
- PAD equipment (PAD server, data services)
 - ▶ PAD systems are software based and will generally run on the same server hardware platforms as the multiplexer system
 - ▶ PAD servers are often not seen as mission critical in which case they may not be redundant
 - 1 PAD server per ensemble (some implementations can deal with multiple ensembles).
 - 1 licence per service (depending on supplier).

- Monitoring
 - ▶ EDI monitor
 - 1 per ensemble
 - ▶ Studio monitor
 - 1 per layer
 - ▶ NMS
 - 1 per site
- Ancillary equipment
 - ▶ IP switches and routers
 - 2 each per site
 - Depending on the size of the multiplexer site multiple IP switches may be required
 - ▶ Uninterruptable power supplies
 - 2 per rack
 - ▶ Air-conditioning
 - supplied by the site owner

8.2.5 New Approaches to DAB+

New Approaches to DAB+ have emerged over the last few years for very low-cost implementations of DAB+ multiplex and transmission systems. This has gained momentum in the UK where it is called Small-scale DAB+ (SS-DAB+) to provide DAB+ coverage, typically to serve defined communities, towns, smaller cities, parts of conurbations etc. Although providing smaller-scale coverage than that offered by established UK multiplexes, the term “small-scale” is perhaps somewhat misleading here. Although early experiments tended to cover small community areas, typically a few kilometres radius, a recent examination of Ofcom data revealed “small-scale” multiplexes with nominal coverage areas ranging from under 100 km² to well over 2,000 km², and containing adult (15+) populations ranging from just under 30,000 to approaching 1,000,000 individuals. The services carried are usually existing local community radio stations but it is not uncommon for new services to be established as well. In addition, networking of services across a number of multiplexes is permitted, with stations such as Radio Caroline taking advantage of these opportunities to expand coverage.

The New Approaches methodology was initially spawned through the development of open source software for the implementation of multiplexing and encoding functionality by the Communications Research Centre (CRC) in Canada. It was then used for example transmissions in Switzerland circa 2012 and then championed by Rashid Mustapha of Ofcom in the UK in 2013 as a way to provide low-cost community-based DAB radio services [22]. Since then, there has been great support for the concept in the UK and other European countries. In the UK, Ofcom proceeded with the seventh and eighth rounds of SS-DAB+ licensing in 2025.

The early, so-called, SS-DAB tests, dating back to over a decade ago (from 2012 onwards), all employed multiplexer and encoding systems based on open-source software from the

Opendigitalradio.org organisation, which champions the software development through the provision of ODR-mmbTools.⁴⁸ The ODR-mmbTools include software for multiplexing, audio encoding and PAD services, and signal modulation, and is provided through GitHub.⁴⁹

The software is usually run on standard PC or computing platforms under the Linux operating system. The transmission system is typically composed of a Software Defined Radio hardware unit, such as an Ettus USRP unit,⁵⁰ to perform the modulation, coding and RF conversion and a low-cost upconverter and RF power amplifier. A DAB RF mask filter may also be required to ensure a suitable radiated signal bandwidth. Antennas are usually low cost with maximum ERP rating of 100 to 400 W, typically a dipole or colinear type.

Although various new smaller local DAB multiplexes continue to employ open-source multiplexer and encoding systems, others have opted for commercially sourced solutions. Some even combine ODR-based transmitters and commercial alternatives working in the same SFN (for example Future Digital Norfolk, based in Norwich).⁵¹ The emergence of licensing opportunities for new, more localised, DAB+ multiplexes has provided additional opportunities for commercial companies to invest in the development of lower-powered DAB+ transmission equipment, such that, over recent years, the options open to the operators of such services has greatly increased.

Future Digital Norfolk, a non-profit-distributing Company Limited by Guarantee, began operating its Norwich multiplex on an experimental basis in 2015. At that time, it was licensed to operate a single 100 Watt e.m.r.p. omni-directional DAB transmitter located just to the North of the city. This ODR based installation was established on top of a residential tower block using a domestic ADSL connection to send individual programme streams to the multiplex encoder which was co-located at the transmitter site. Because the weak link in the system, proved to be the ADSL connection, during the first two years of operation an additional ADSL feed, further backed up by a 5GHz “ethernet first mile” microwave link were both added to provide redundancy and thereby improve reliability.

In 2020, Future Digital Norfolk Limited was given the opportunity to apply for a long-term DAB multiplex licence, which was subsequently awarded in June 2021. This licence gave the company the opportunity to enhance its coverage by adding an additional transmitter, this time located on an office tower block to the South of the city. Delivering omni-directional coverage at 200 Watts e.m.r.p. resulted in the provision of expanded geographical coverage, together with enhanced building penetration, particularly in the narrow streets of the medieval city centre. Because the two transmitters are geographically quite close to each other, (in the suburbs to the North and South of the City Centre) coverage now benefits not only from the resultant single frequency network gain, but also from the fact that multiplex signals are delivered into the city from two distinctly different directions, thus providing enhanced clutter penetration, often a crucial benefit where less than optimal transmitter sites are used on the basis of cost. Ofcom calculates that the residential population served (aged 15+) by the two transmitters is now 300,000.⁵²

⁴⁸ See <https://www.opendigitalradio.org/>

⁴⁹ See <https://github.com/Opendigitalradio>

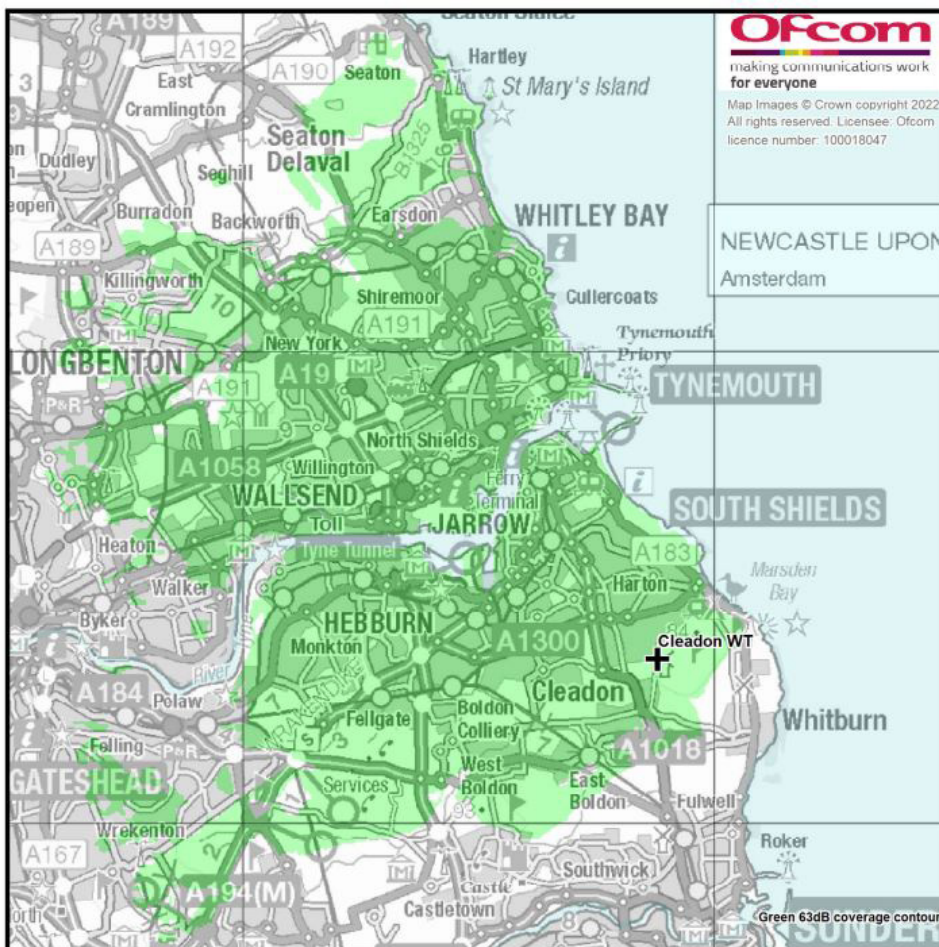
⁵⁰ See <https://www.ettus.com/>

⁵¹ See <https://futuresdigital.info/>

⁵² See <https://www.ofcom.org.uk/siteassets/resources/documents/tv-radio-and-on-demand/radio-ops/coverage/ssdab-coverage-maps/norwich.pdf>

When installing the second transmitter for Norwich, it was decided that, instead of duplicating the existing ODR installation, some elements would be obtained from a commercial supplier. In the event, the company selected was GatesAir and, specifically, its Maxiva VAXT150G2DA rack mount design. The primary driver of this decision related to the need for readily available technical support, for example in relation to either updates or technical failures etc. To provide additional redundancy a Fibre To The Premises (FTTP) data feed is provided at the new site and there is a bi-directional 5 GHz line between the two sites. Station feeds are sent to both transmitter sites, with a duplicate live instance of the multiplex being created at each, such that, in case of the failure of one instance, the other can automatically take over to ensure continuity of service. Real-time service monitoring is achieved using a combination of Inovonics 662 web-accessible 'Site-Streamers', and the desk-based QIRX SDR monitoring software. Various Linux network monitoring and alarm software systems are also employed, overall reliability being broadly similar to that of the existing larger multiplexes that cover the city.

For smaller operators, the decision as to which technical equipment might be most suitable, typically relates to the availability of particular in-house resources, not least including capital and technical competences. If available capital is minimal, this might encourage the use of open-source approaches. However, these then require the availability of high-level technical skills, either in-house or easily accessible locally, particularly in the areas of Linux coding and networking skills. If, as is often the case within smaller transmission providers, such resources are not readily available, then commercial solutions might be the preferred option, any additional outlay being justified on the basis of the operational value of support provided by the commercial supplier.



Tynemouth and South Shields small-scale DAB - predicted coverage - February 2022

Figure 8-24:
Tynemouth and South
Shields predicted
coverage

Another UK example is that of the area of Tynemouth and South Shields, which is part of Greater Newcastle upon Tyne, as detailed in the Ofcom document [23]. The coverage area is shown in Figure 8-24 and corresponds to a population of approximately 270,000 people. This particular implementation is operated by MuxOne.⁵³ Similar community-based companies have been formed to provide similar services across the UK.

While the cost of implementing SS-DAB is low relative to commercial grade systems, the implementations often come with some constraints, such as:

- Because carriage charges are typically based on data capacity used (e.g. number of Capacity Units required for delivery), some stations choose to operate at a low bit-rate, e.g. 32 kbps DAB+ at EEP-3A. As a result, audio quality of some audio services may be compromised.
- Some multiplex operators set their own minimum standards to minimise such audio quality issues. 32 kbps availability may, for example, only be made available for speech-based (mono) services. Typically, music-based services operate at 48 kbps, 40 kbps transmissions being less common. Although original MP2 DAB transmissions are permitted, these are few and far between, simply on the basis of their higher data rates and, therefore operational costs.
- The systems may not be redundant and hence off-air events due to system failures can be more frequent than for commercial grade systems.
- Siting of the transmission may not be optimal due to the preference for low-cost sites, hence the antenna height may be lower than desired. Typical sites include buildings such as tower blocks, smaller communications masts and water towers.
- There may be minimal system monitoring software to oversee, control and maintain the systems, although this is an area of development. For example, the SDR-based QIRX⁵⁴ software provides a broad range of monitoring capabilities at low cost and includes TII for real-time SFN network oversight.

This form of radio delivery is gaining significant momentum, with multiple operations now running in the UK, Switzerland, Italy, the Netherlands and Denmark, and more soon. See the WorldDAB presentations at IBC2022 for more information.⁵⁵ Trial broadcasts commenced in the Republic of Ireland early in 2025.⁵⁶

A more detailed examination of smaller-scale DAB+ implementations can be found in the report, 'New approaches to DAB: Developments in DAB+ Delivery Technology and Techniques' prepared by Dr Lawrie Hallett, for WorldDAB in 2024.⁵⁷ What is apparent, judging by the increasing implementation of new approaches to DAB+ delivery, is that such developments are succeeding in providing access to DAB transmissions by an increasing number of smaller broadcasters and in providing expanded choice for listeners. Moreover, the roll-out of such services also creates increased commercial opportunities for equipment manufacturers and service providers, in the form of a new market for the supply and support of lower-power DAB transmitters, simpler multiplexers and various ancillary equipment and operational support services.

⁵³ See <https://www.facebook.com/MUXONEUK/>

⁵⁴ See <https://qirx.softsyst.com/>

⁵⁵ See www.worlddab.org

⁵⁶ See <https://failedab.ie/>

⁵⁷ See https://www.worlddab.org/public_document/file/1748/240530_New_approaches_to_DAB.pdf

8.2.6 Hybrid radio

As discussed in §2.6, Hybrid radio is the delivery of content to listeners using both broadcast and IP connectivity. Typically, the DAB broadcast delivers the audio content and some limited metadata while the IP link delivers advanced metadata, including station logo images, high resolution SlideShow images suitable for modern car screens, tag lines, service information, IP service linking and geolocation information.

Some hybrid radio services also provide tools for analysing listener behaviour and additional functionality such as personalised radio.

The RadioDNS organisation is a provider of hybrid radio services through its global standard [13]. Figure 8-25 and Figure 8-26 provide a graphic of the basic content and description of typical capabilities. There are also several private organisations who are competing for the provision of hybrid radio services in vehicles.

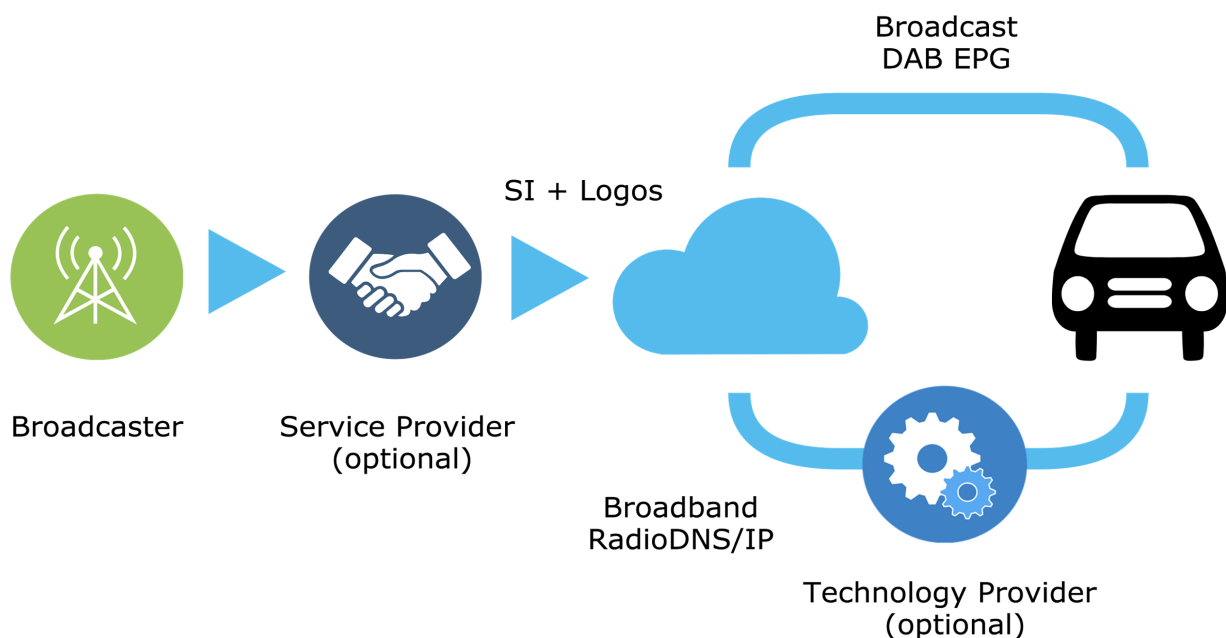
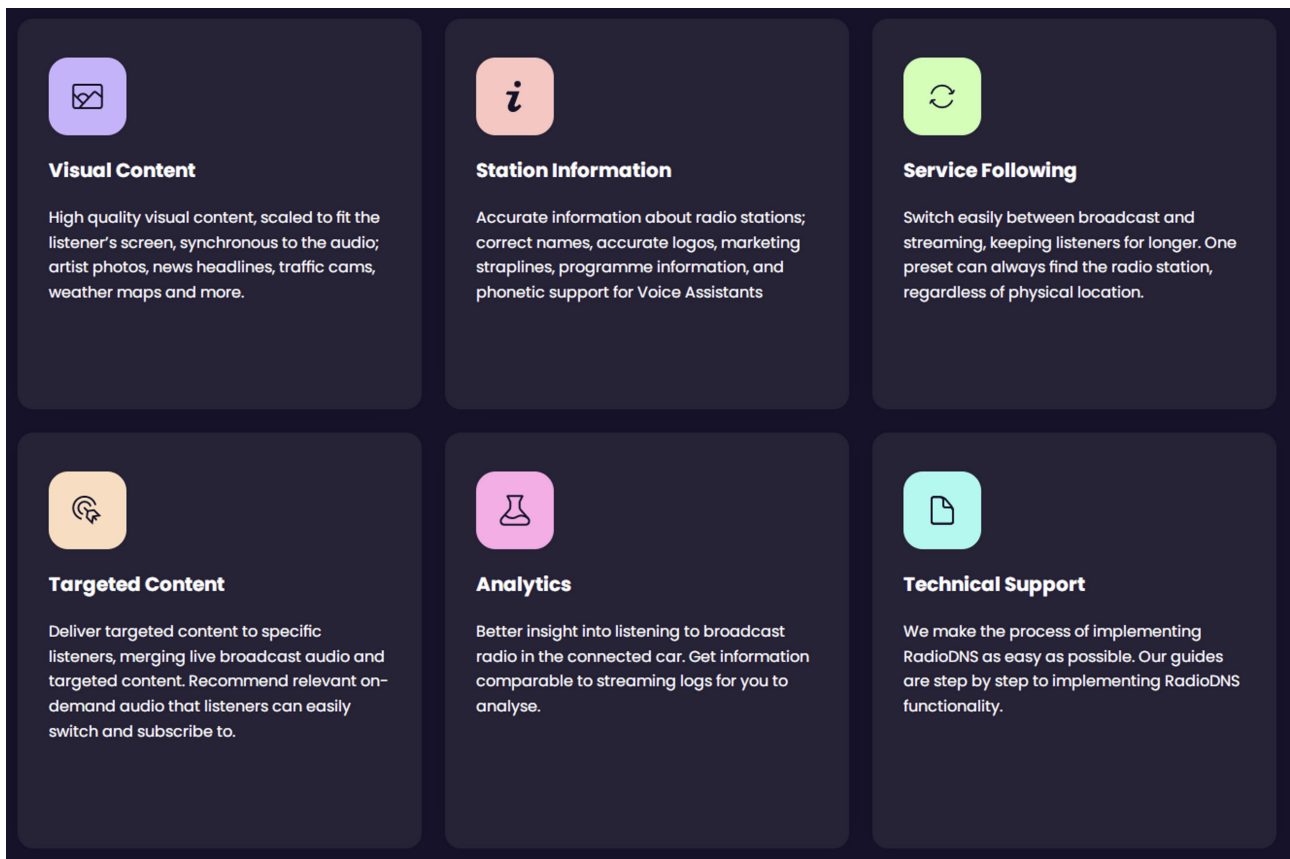


Figure 8-25: Hybrid radio⁵⁸

Radioplayer also provide automotive solutions for hybrid radio, see Figure 8-27 as per their website <https://radioplayer.org/>.

Similarly Xperi provide automotive hybrid radio solutions, see Figure 8-28 as per their website <https://dts.com/autostage/>.

⁵⁸ Source: https://radiodns.org/wp-content/uploads/2020/04/StationLogosDoc_FINAL_2019.pdf

Figure 8-26: RadioDNS overview⁵⁹

Why carmakers partner with Radioplayer

Seamless Hybrid Radio

Our hybrid technology blends FM, DAB, and IP streams for uninterrupted listening, switching automatically to the best available signal.

Optimized for the Dashboard

We design intuitive, driver-friendly interfaces that make radio easy to discover and enjoy —no distractions, just great radio.

Global Reach, Local Expertise

We support over 10,000 stations worldwide, delivering rich metadata (logos, images, program info) for a premium in-car experience.

Future-Proof Technology

Constantly evolving to integrate with the latest connected car ecosystems and software standards.

Figure 8-27: Radioplayer hybrid radio for cars

⁵⁹ Source: <https://radiodns.org/>

Your Customers' Favorite Entertainment. All In One Place.

DTS AutoStage unifies the connected car in-dash experience.

Bringing together radio, audio, video, and gaming content, DTS AutoStage is the first global, personalized, content-first entertainment platform designed to address the unique needs of automotive OEMs and their customers.

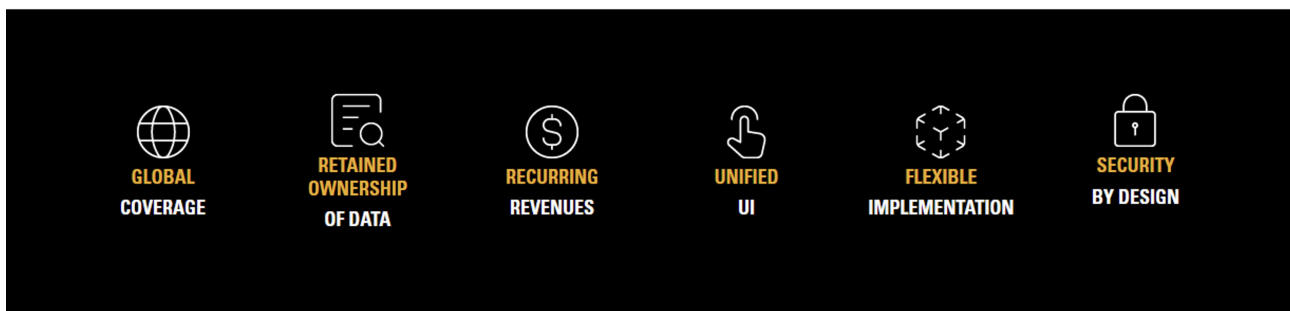


Figure 8-28: Xperi hybrid radio for cars

With the increasing availability of hybrid radio in cars, coupled with the fact that listening in cars is a dominant mode of radio content consumption, hybrid radio should be planned along with the other aspects of a DAB+ network rollout.

This is often not a difficult aspect of rollout planning and involves ensuring that the broadcasters have suitable assets available to deliver to the cars via IP connectivity. Typical assets which may or may not also be broadcast include:

- Station logos – very important for image-based service lists, and important in maintaining a recognisable brand image.
- Hi-resolution SlideShow images - Broadcast is usually limited to QVGA (240 x 360) for capacity reasons whereas many new cars have HD or better resolution. Delivering hi-res images looks much better on such screens.
- Linking and geo-fencing information – DAB+ broadcast may already include Service Following and other DAB links in its FIC signalling, hybrid can provide geo-fencing and IP linking information.
- More information about the current service

Assets such as high resolution images can be delivered in real time from metadata servers, while information such as logo images, service linking and geo-fencing are contained in .SI files which are maintained by broadcasters on their servers. This ensures that all broadcaster information is kept up to date.

While the three methods discussed above are all competing for use in new car dashboards, we see the need for broadcasters to support all of them to ensure that the broadcaster's user experience is most consistent across all hybrid DAB+ delivery platforms. This will usually require the broadcasters and/or the DAB country champion organisation to coordinate, to

ensure that the radio industry uses all the tools available to provide the best experience to listeners and best compete with on-line streaming-only competition.

While hybrid radio services are not currently mainstream in domestic receivers, the increasing addition of IP connectivity, particularly through WiFi, may see that change in the future.

8.2.7 Ancillary systems

DAB multiplexer networks and transmitter systems require a range of ancillary systems to support them, including:

- Monitoring and Network Management Systems (NMS) to monitor and control the network
- IP systems to provide IP connectivity across the network. As IP links are single points of failure, they are often redundant in critical systems
- Mains Power and Unbreakable Power Systems (UPS) ensure that power is always available to the network equipment. This often includes backup power generator sets, both at transmission sites and studio sites.
- Air-conditioning systems to ensure that both equipment and operations staff are provided with a suitable operating environment. Some such systems need to operate in extreme environments, such as snow-bound mountains and hot arid desert regions.

An example of IP and power system redundancy design is shown in Figure 8-29.

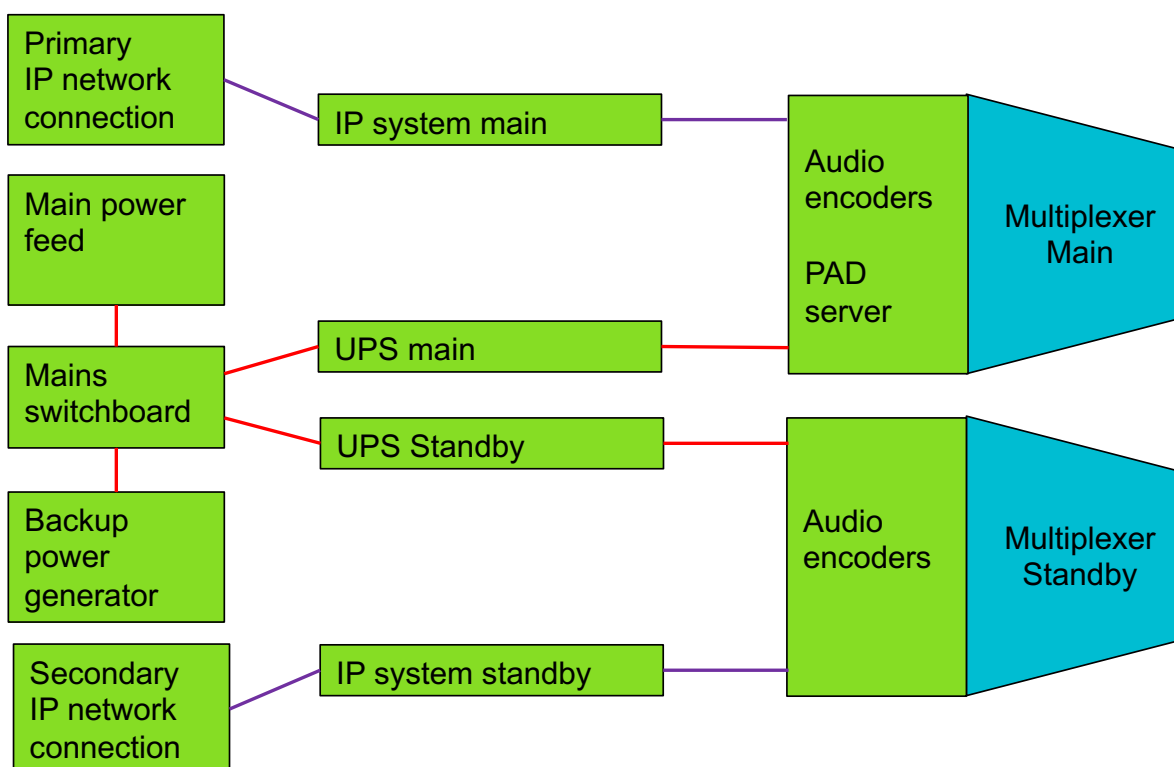


Figure 8-29: Example main and standby multiplexers and ancillary power and IP systems

8.2.8 DAB coverage in road tunnels

Road tunnels have been used for many years to provide connecting roads through mountainous areas, for example the European Alps and Norway. Road tunnels are now becoming commonplace in many cities to provide higher-speed transport in areas where overground highways are not feasible. This is particularly the case in large and dense modern cities.



Figure 8-30: Example infrastructure in a road tunnel which includes power distribution, lighting and communications via leaky feeder coax systems⁶⁰

DAB+ systems have been developed to provide in-tunnel radio broadcasting which is seamless with the above-ground transmissions, allowing drivers to listen to their preferred service uninterrupted during their in-tunnel journey.

Such in-tunnel DAB+ systems also play an important safety role through the ability to provide vocal break-in to deliver critical information in time of emergency, such as accidents or fires. We now find such tunnels retransmission and break-in systems are required by local law in many countries in Europe, and around the world.

An example of a break-in system is shown in the system diagram from Paneda, Figure 8-31. Here the off-air signal is received through a suitably placed antenna and fed to the re-distribution system which is then amplified and delivered to the tunnel environment, usually through a leaky feeder antenna system, similar to what is used for similar FM-based systems. In time of emergency, the local tunnel control staff can interrupt the off-air broadcast and replace it with either live or recorded messages to direct the tunnel users to appropriate safe locations.

⁶⁰ Source: Paneda: <https://paneda.no/products/break-in-systems-for-tunnels/>

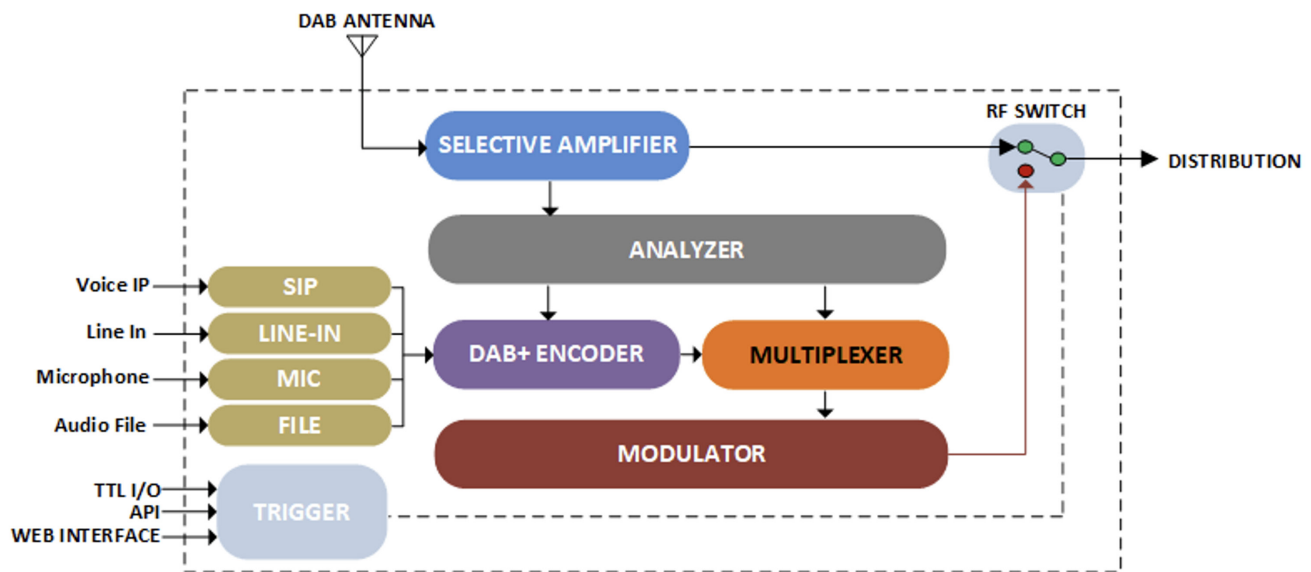


Figure 8-31: Block diagram of the Paneda tunnel break-in system⁶¹

Most multiplex system providers also provide products for in-tunnel rebroadcast systems.

When road, or rail, tunnels are used in a country that is establishing DAB+, it is important to discuss when and how existing tunnels can be updated to include DAB+ rebroadcast. Indeed, there may already be local rules / legislation requiring such rebroadcast and emergency break-in capabilities for FM systems to ensure the safety of drivers. The same should also apply to new tunnels built after the rollout of DAB+ networks.

8.3 Example implementations

Below are some example implementations of DAB in a range of settings. It is particularly important to understand the impact of terrain and building clutter, especially tall buildings when designing the transmission network.

8.3.1 European overview

European Union countries have embraced DAB+ as the basis of the next generation of radio broadcasting, with most having implemented or in the process of doing so. We see in the map in Figure 1-1 that the vast majority of European countries have regular services with only a few still in development e.g. Portugal, Ireland, Romania and the Baltic and Balkan states.

The introduction of the EEC legislation which requires all radio receivers to include DAB+ in cars is playing a key role in encouraging take-up and expansion of DAB+ services across EU countries.

⁶¹ Source: Paneda: <https://paneda.no/products/break-in-systems-for-tunnels/>

In Figure 8-32, we see that the coverage of Norway by the PSB NRK reaches 99.7% of the population, while the RIKS commercial radio network reaches over 92.8%.

Figure 8-33 shows the DAB+ layering in Italy with the National DAB+ networks being composed of SFNs. The national layer covers multiple regional areas. The local networks have smaller areas but still often cover multiple local community areas. This demonstrates that national layers can be constructed to cover broad areas of country with common interests, while the local layer can be as small as a single community area, as shown by several coverage areas in the bottom row of Figure 8-33.

The number of DAB services available in Germany in 2020 is summarised in the map shown in Figure 8-34. The number of services available continues to grow. As of 2025 the First Nationwide DAB+ multiplex on Frequency Block 5C provides service to all of Germany as shown in Figure 8-35. The details of the services provided on this national ensemble can be seen at <https://www.wohnort.org/dab/germany.html?PageSpeed=off>.

The use of small-scale DAB for community and local services is also expanding across Europe, with multiple countries now implementing SS-DAB, for example the UK, Switzerland and the Netherlands and several others in early stages. Figure 8-36 shows a map of several of the SS-DAB systems across the UK in 2024, where Ofcom is undertaking an ongoing licensing programme.

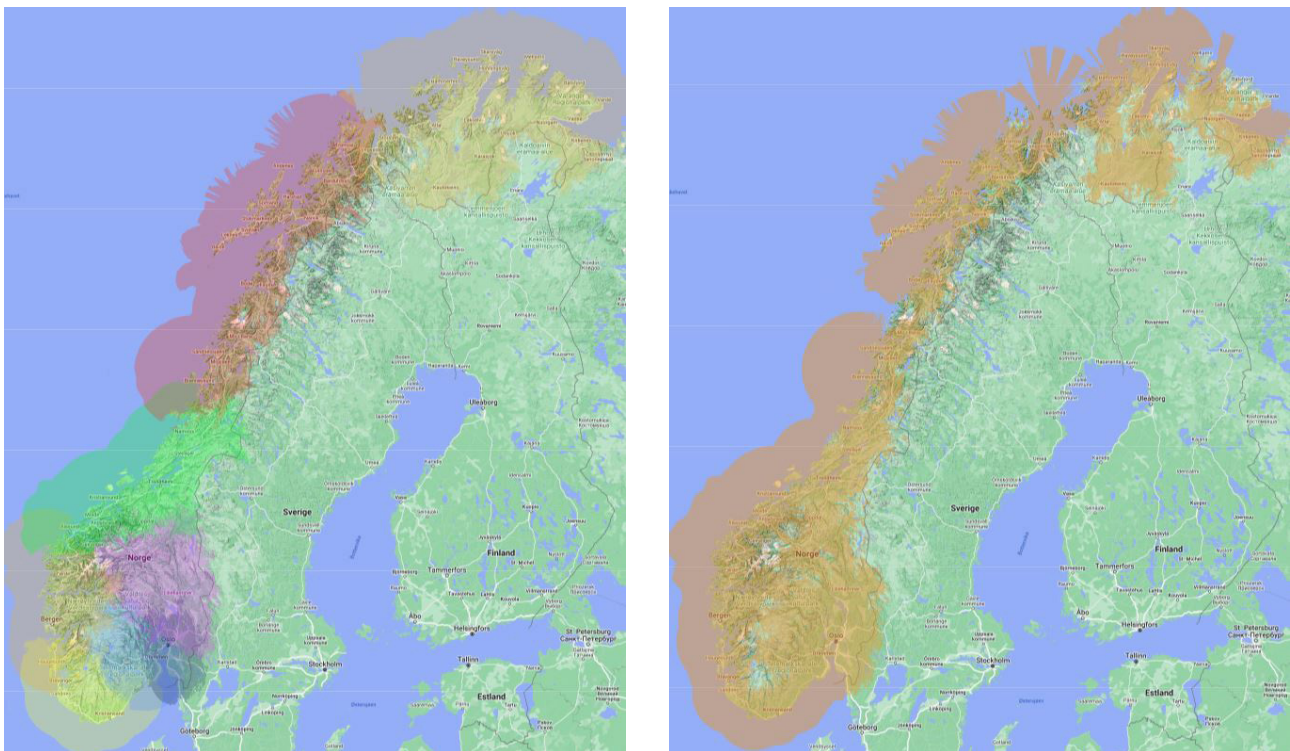


Figure 8-32: Coverage of Norway by NRK, the Norwegian PSB (left), and the Norwegian commercial radio services (right)⁶²

⁶² Source: <https://radio.no/dekning/>

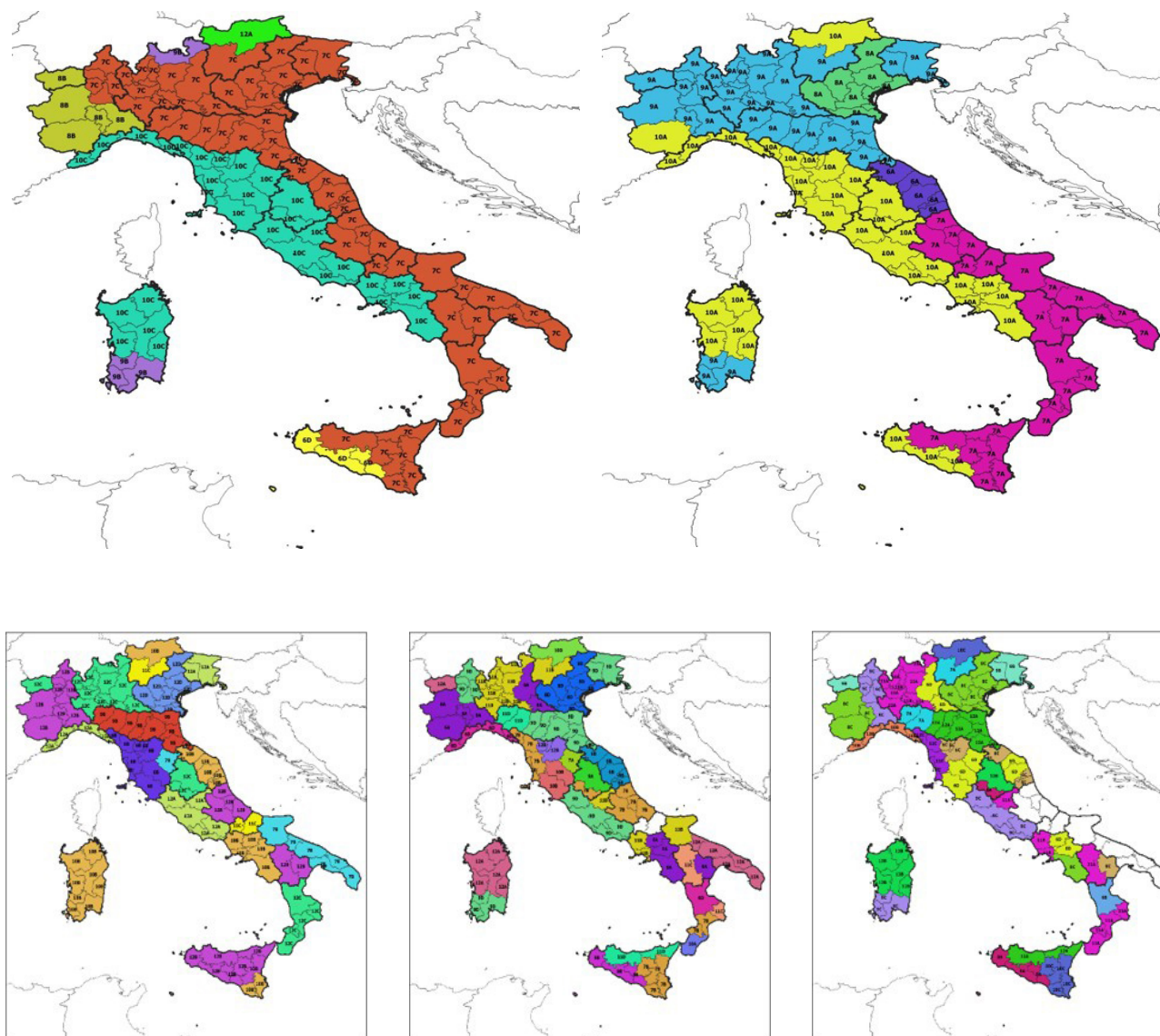


Figure 8-33: DAB+ in Italy, national Layers (top) and local layers (bottom)⁶³

⁶³ Source: Hanns Wolter, DAB Italia

DAB+ Anzahl deutscher Programme Stand: Sept 2020

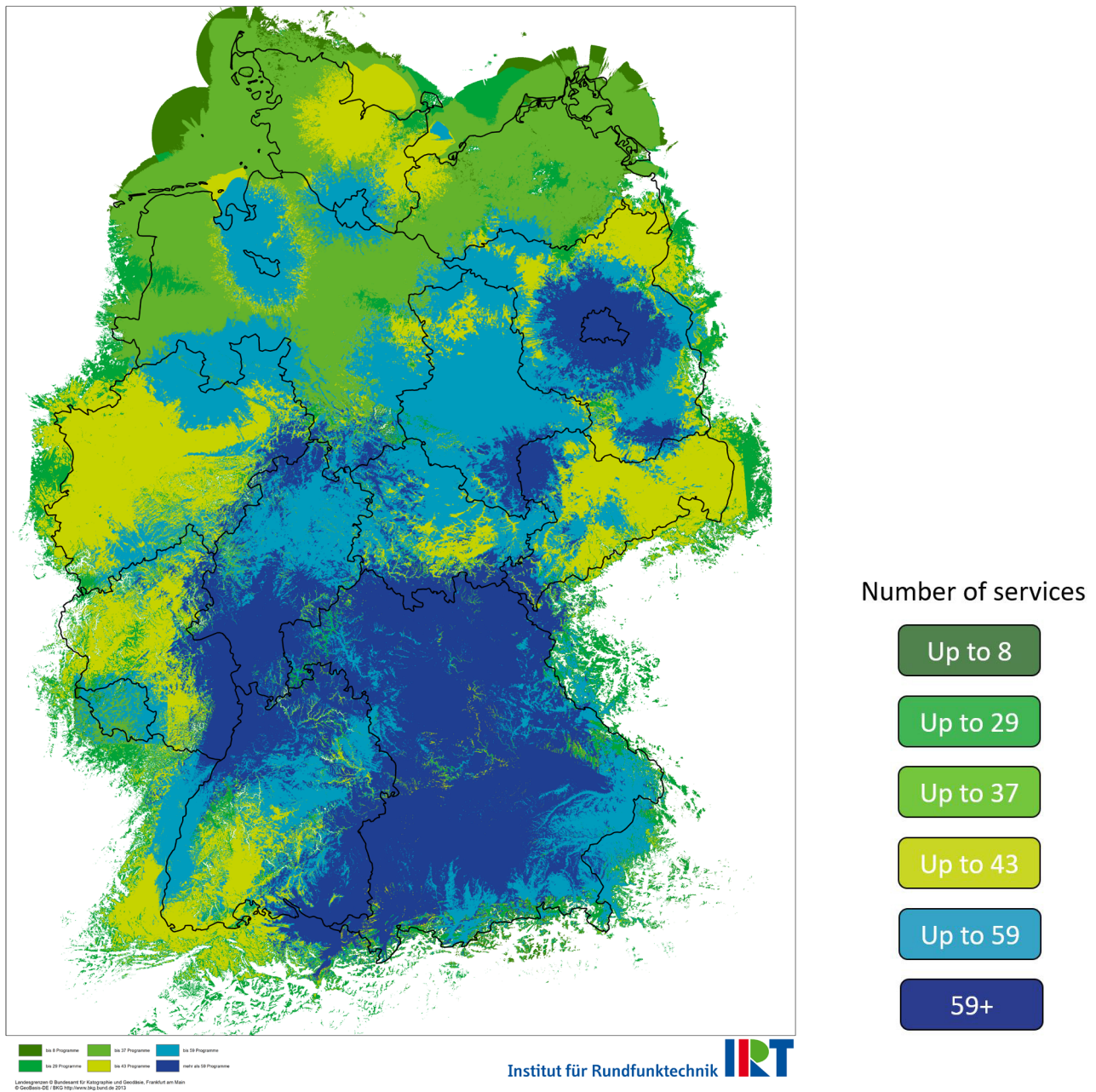


Figure 8-34: The number of DAB services available in 2020 in different areas of Germany⁶⁴

⁶⁴ Source: IRT 2020



Figure 8-35: Estimated 2025 coverage for the First Nationwide DAB+ multiplex on Frequency Block 5C

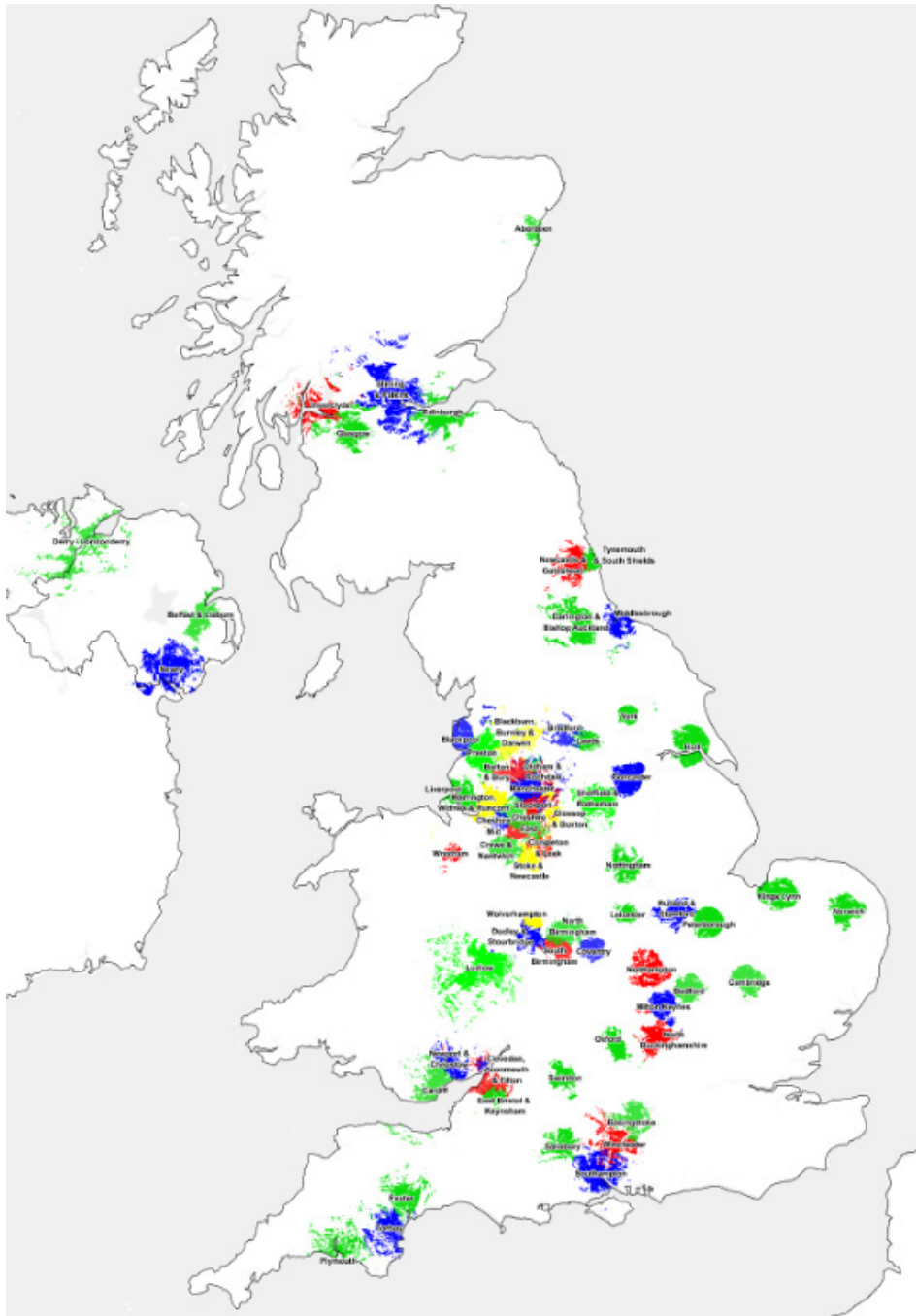


Figure 8-36: An example of the expansion of small-scale DAB across the UK⁶⁵

⁶⁵ Source: <https://www.ofcom.org.uk/siteassets/resources/documents/manage-your-licence/digital-radio/small-scale-dab/ssdab-progress-report-2024.pdf?v=383726>

8.3.2 Germany

Networks

In Germany, the DAB+ broadcasting network comprises two national programme platforms and around 100 regional and local multiplexes. These networks transmit over 300 regionally varied DAB+ programmes, including approximately 100 that are broadcast exclusively on DAB+. Mobile coverage extends across more than 97 percent of the country. Along major transport routes (such as motorways), coverage exceeds 99 percent, effectively representing full coverage. As a result, around 77.7 million residents (91% of the population) can receive DAB+ programmes at home using an indoor antenna.

Receivers

At present, around 30 million DAB+ radios are in use across Germany. Half of these are in cars. Among new vehicles, 94 percent come factory-fitted with a DAB+ radio.

Usage

According to “ma 2025 audio II”, DAB+ reached a new all-time high in summer 2025, accounting for around one third of the total extended listenership – that is, people who listen to radio at least once every four weeks (WHK). The strongest growth is seen among 30- to 59-year-olds, where the share is just under 40 percent. Figure 8-37 shows a listener breakdown by service based on the number of listeners per average hour from Monday to Friday, 06:00 – 18:00.

Use Case: Radio BOB!

Niche broadcasters with clearly defined target audiences benefit economically from DAB+, as it enables them to achieve nationwide distribution that FM never offered. Examples include Radio BOB! and sunshine live.

Radio BOB! (a rock format) originally operated on a regional level but now reaches a nationwide audience via the national DAB+ multiplex. According to *ma 2025 audio II*, BOB! attracts 4.601 million daily listeners (+14.5% year-on-year) – more than any other private radio station in Germany. An average of 720,000 people tune in during any given hour. This makes BOB! both the largest rock radio station and the leading private radio brand nationwide. Its total reach (WHK) stands at 9.86 million, with an above-average increase driven by DAB+. For advertisers, this opens access to a nationwide rock community with strong purchasing power.

Use Case: sunshine live

sunshine live (electronic music) also began as a regional broadcaster. Founded in 1997, the station is now transmitted terrestrially across Germany exclusively via DAB+. Across all digital distribution channels – including DAB+ – its daily reach has grown to 1.949 million listeners. Compared to last year, this marks a 19.6 percent increase.

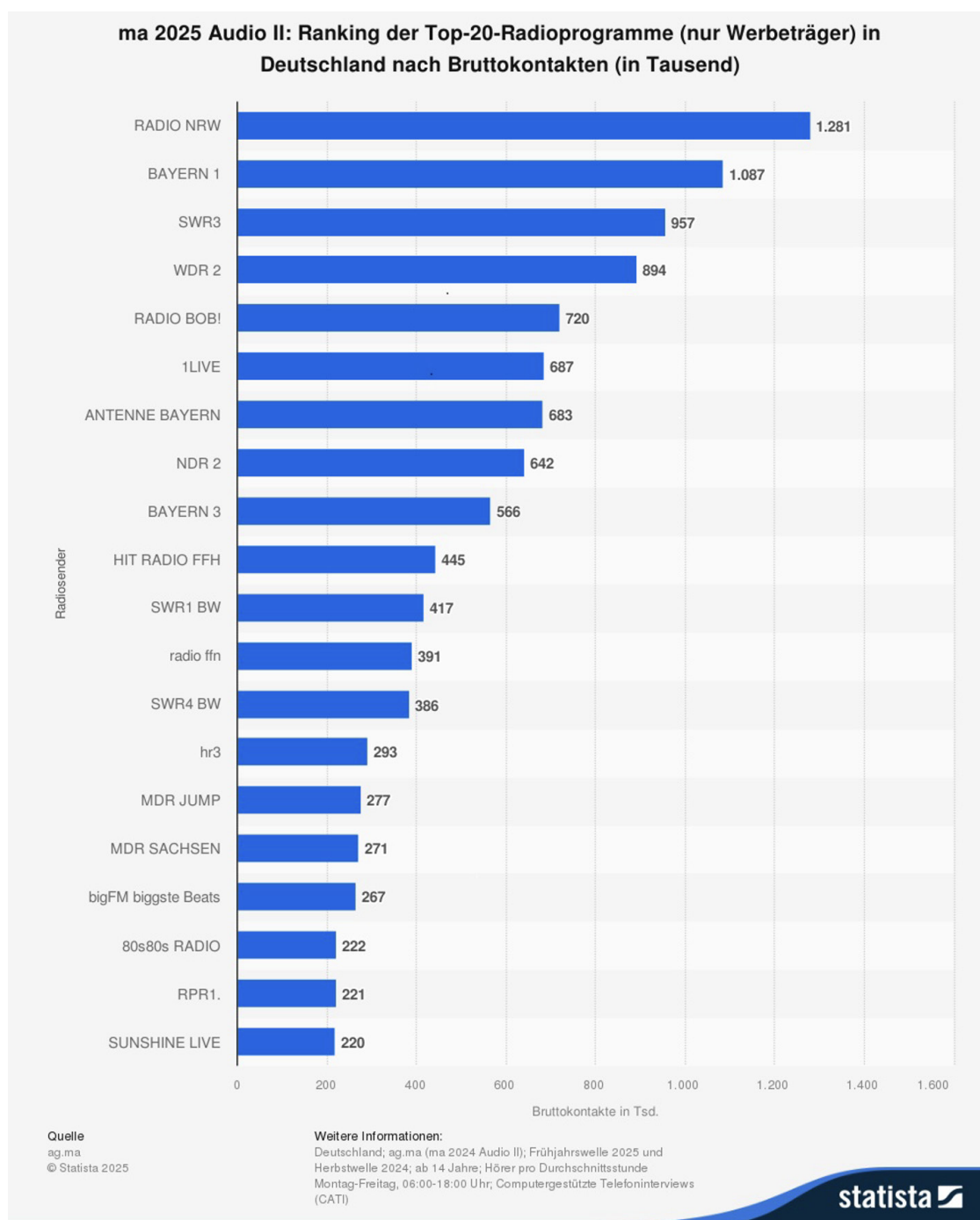


Figure 8-37: Ranking of the Top 20 Radio Programs (advertising broadcasters only) in Germany by Gross Contacts (in thousands) from ma 2025 Audio II:

8.3.3 London, UK

London, in the United Kingdom, has coverage from several transmission sites using an SFN. According to RAJAR,⁶⁶ in May 2022 41% of all radio listening in the UK is via DAB, with 69% of all households having a DAB receiver. In London, DAB digital radio coverage reaches almost 100% of the population and roads.

According to Ofcom [20] the transmitter site details for the London 1 CE multiplex are shown in Table 8-2, where the Power column shows the transmitter power and not the transmission ERP. London has two main transmitters: Croydon (5 kW) and Wrotham (4.5 kW); four medium transmitters: Alexandra Palace (0.8 kW), Bluebell Hill (1.0 kW), Guildford (1.0 kW) and Reigate (1.3 kW); as well as nine additional low-power sites. The ERP from Croydon site is 33.55 kW,⁶⁷ indicating an antenna system gain of 8.3 dB. Each site has an individual purpose, such as wide area coverage from sites like Croydon or targeted coverage at High Wycombe.

Site Name	NGR	Site Height (m)	Aerial Height (m)	Power (kW)	Antenna & Bearing
Alexandra Palace	TQ 296 900	92	100	0.8	Dipoles
Bluebell Hill	TQ 757 613	193	41	1.0	Panels
BT Tower	TQ 292 819	27	192	0.8	Dipoles on 340°
Caterham Old Park Wood	TQ 335 533	226	48	0.14	Dipoles on 10°
Croydon	TQ 332 696	114	128	5.0	Panels
Guildford	SU 974 486	142	39	1.0	Dipoles on FM panels
High Wycombe	SU 856 942	156	53	0.01	Yagis on 0° & 180
Hungry Hill	SU 824 490	179	50	0.08	Dipoles on 350°
Kenley	TQ 329 592	152	38	0.008	Collinear
Leatherhead Stoke d'Abernon	TQ 135 590	60	51	0.01	Dipoles on 160°
Maidenhead Hyde Farm	SU 850 840	85	32	0.08	Dipoles on 220°
Pimlico	TL 088 045	137	69	0.40	Panels
Pin Green	TL 249 256	133	28	0.06	Dipoles on 300°
Reigate	TQ 256 521	234	51	1.3	Dipoles on FM panels
Wrotham	TQ 595 604	219	150	4.5	Dipoles on 318°
Zouches Farm	TL 044 210	207	62	0.5	Dipoles on 160°

Table 8-2: Transmitters used for the London 1 digital multiplex on frequency block 12C

⁶⁶ <https://www.worlddab.org/countries/united-kingdom>

⁶⁷ See <https://www.radiodns.uk/transmitters/tq332696>

The predicted indoor coverage for 95% of locations is shown in Figure 8-38, with the mobile coverage for 99% of locations being shown in Figure 8-39. Note that Ofcom does not provide the reference field strengths for either of these predictions in the document. However, these are expected to correspond with the data shown in Figure 7-4, which indicates 53 dBµV/m for indoor and 44 dBµV/m for mobile reception.

The use of the SFN in the London area provides very good coverage for both wide area and identified areas which have shadowed reception from the main transmitters, for example terrain issues at High Wycombe and shadowing due to tall buildings in central London being assisted by the BT Tower transmission.

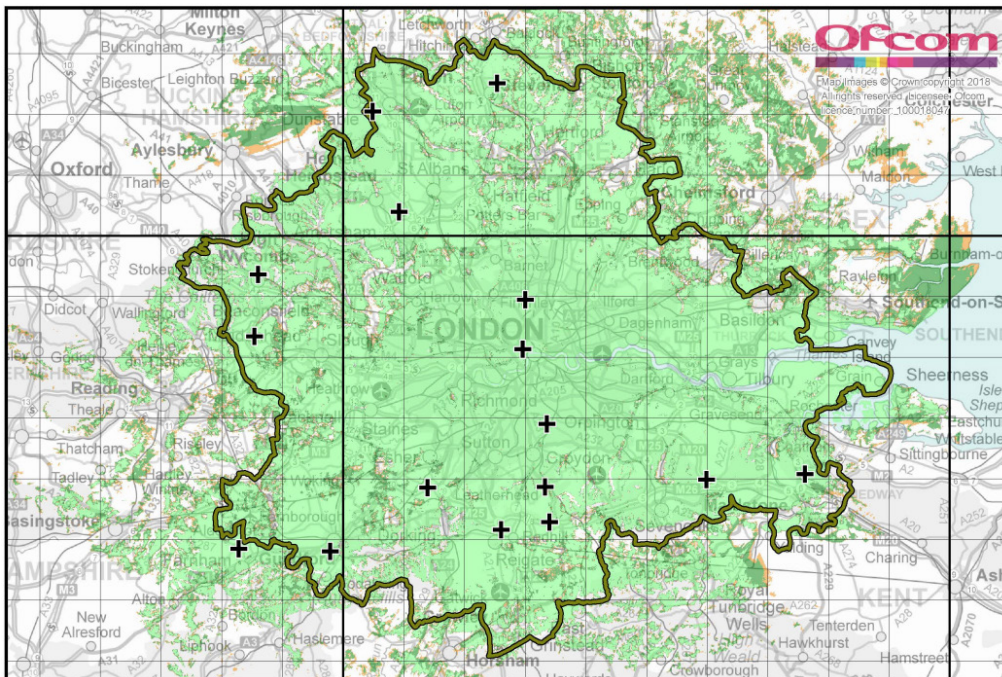


Figure 8-38:
London 1 local
DAB multiplex
(CE Digital),
indoor coverage,
normal
propagation
conditions.

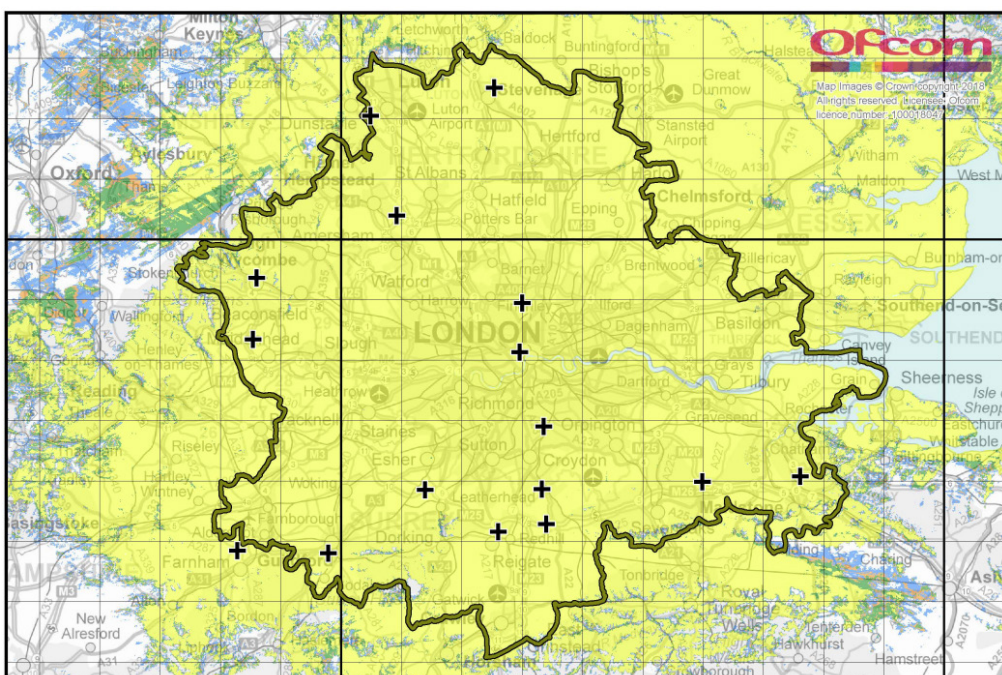


Figure 8-39:
London 1 local
DAB multiplex
(CE Digital),
mobile coverage,
normal
propagation
conditions.

8.3.4 Sydney, Australia

The coverage of the city of Sydney, Australia started with the launch of DAB+ in 2009 with 45 kW ERP from the main transmission site of Artarmon. After the launch of DAB, the evaluation of the coverage in the outer parts of the licence area were shown to have insufficient coverage field strength and a suite of repeaters were proposed and installed over a 10-year period from 2010 to 2019. Initially, all repeaters were On-Channel Repeaters (OCRs), which have limited ERP due to feedback issues (see §8.1.6). However, the more distant sites at Hawkesbury Heights and Gregory Hills were converted to Link Fed Repeaters (LFR) using microwave systems for EDI delivery to allow better timing control and to minimise RF feedback issues. The transmissions are shown in Table 8-3.

Site	ERP (kW)	HRP	Site height (m ASL)	Antenna height (m AGL)	Area covered / Comments
Artarmon	45	Near OD	106	196	Main site
Sydney Tower	0.3	OD	30	311	City centre / OCR
Hawkesbury Heights	0.3	DA (East)	289	42	West / LFR
Gregory Hills	0.5	DA (Southeast)	104	42	Southwest / LFR
Collaroy Plateau	0.3	DA (North)	111	32	North / OCR
Bilgola Plateau	0.3	DA (South)	148	37	North / OCR
Bonnet Bay	0.3	DA (East)	98	32	South / OCR

Table 8-3: Sydney transmission site parameters

As shown in Figure 8-40, the main site at Artarmon provides good coverage to the majority of the Sydney licence area. However, there are a number of areas which do not receive suitable coverage due to distance from the Artarmon site, e.g. the west and southwest, terrain issues in the northern areas, or in the city due to clutter shielding. The addition of the repeaters has largely resolved the problem areas. The predicted coverage when the repeaters are operating is shown in Figure 8-41. The field strength palette is shown in Figure 8-42.



Figure 8-40: Sydney DAB+ coverage – Artarmon main site only



Figure 8-41: Sydney DAB+ coverage – all sites

>=dBu	dBu/dBm labels	
50	1.5m-ACMA vehicle coverage	
54	Suburban	
60	Urban	
70	Dense urban = urban + 10dB	

Figure 8-42: Australian DAB+ field strength classes

9. Rollout

9.1 DAB system construction

Once the high-level planning process and in particular the allotment planning has been completed, the rollout can commence with the design of the actual delivery systems. It is important to note that rollout planning should start before the entire country is planned. This is quite common, with initial construction in major cities becoming full-time services before the whole country is planned. This approach provides the advantage of gaining early momentum and capability for a range of stakeholders, including the broadcasters, receiver providers, including the automotive industry, and general content production.

Phased approach

1. VHF Band III spectrum availability
 - a. The availability of spectrum, and in particular the spectrum defined in the allotment plan, is a key milestone for the start of rollout. Although spectrum might not be available during the system design period, it must be available to allow the turn-on of transmitters for testing and ongoing service provision.
2. Transmission and network system design
 - a. The rollout will usually be conducted in phases, with the main cities being the first to receive coverage, then secondary cities and finally the remaining areas. Note that some areas may not warrant the deployment of DAB+ if there is insufficient population to be served, such as deserts or rugged mountain areas.
 - b. It is important to consider the system design in a holistic manner, especially for national networks, to ensure a cost-effective overall solution.
3. Systems testing
 - a. As areas roll out DAB+, it is important to do field testing to thoroughly understand the coverage that is provided and then tune the prediction models. This will allow the network provider and broadcasters a clear guide to who can receive coverage and what areas have any issues and may require a repeater to be deployed.
 - b. In some cases, the antenna pattern may be compromised in the initial rollout to protect areas with ATV if the process of DSO is under way. The antenna pattern can usually be adjusted through appropriate design of the antenna element phasing networks or possibly simply by operating at a lower initial power, e.g. 1 kW ERP for the first six months and then full power, e.g. 10 kW ERP thereafter.
4. Ongoing deployment
 - a. As rollout is usually a phased approach, it is not uncommon to do the detailed design of areas as they arise. This also ensures that the system design is the most cost-effective as network architectures change as different technologies evolve. For example, depending on the capability of the country's IP network, centralised multiplexing may be more cost-effective than distributed systems.

9.2 Developing additional content

The initial rollout of DAB usually includes the launch of new services to provide a significant point of interest to the listening public and an incentive to acquire DAB receivers.

New content types include:

- delivery of content already existing in other areas, for example adjacent licence areas, or regional content
- jukebox stations, such as extended playlist on random selection – no DJ/presenter
- partially curated with a presenter
- new fully curated station

Each of these categories can include internal station advertising, for example other shows on the same or different services, as well as advertising for commercial broadcasters.

Such new content needs associated facilities to be operational by the time of the launch to ensure appropriate content availability and quality.

Some examples of how existing stations have increased their service offerings are:

- Expanding music offerings based on decades, such as the Absolute radio network, see Figure 9-1
- Expanding genres of music, for example the Southern Cross Austereo (SCA) network in Australia has added several genre-specific services on DAB+ to support their FM service TripleM and also the Hits network supporting the 2Day FM service; see Figure 9-2
- An example of the range of services offered nationally in Norway is shown in Figure 9-3. Many of these stations were established as digital-only services in the 2000s and 2010s as well as after the FM switch-off was completed in Norway in 2017.

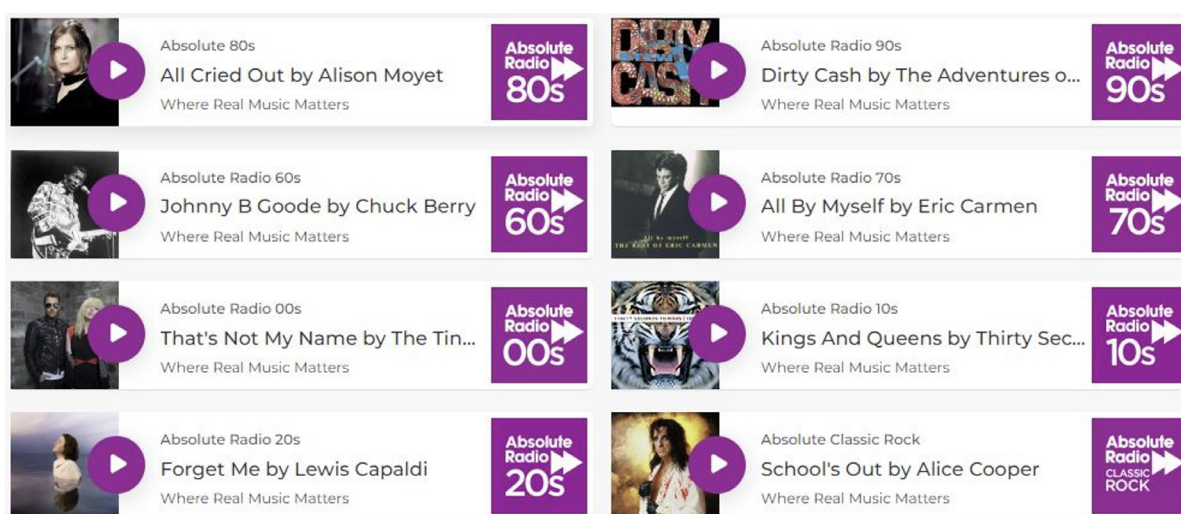


Figure 9-1: Examples of decade-based radio stations from the Absolute Radio Network in the UK⁶⁸

⁶⁸ Source: <https://planetradio.co.uk/absolute-radio/>

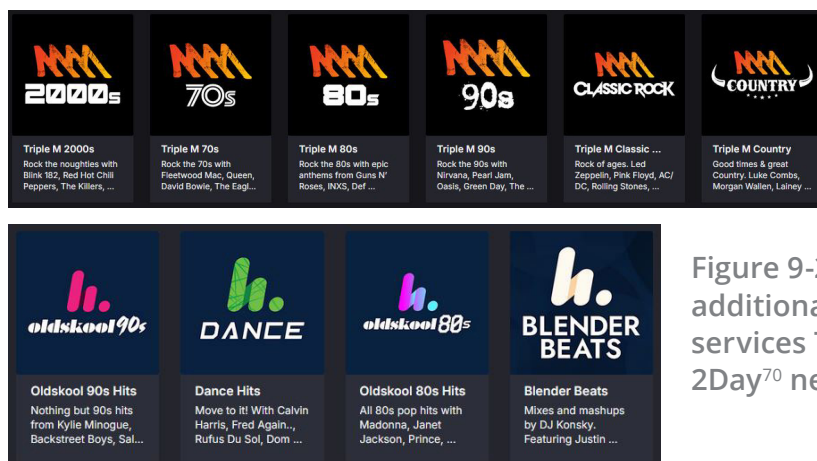


Figure 9-2: DAB+ only services additional to the primary FM services TripleM⁶⁹ and Hits / 2Day⁷⁰ networks

Coverage	Channel	Major owner	Financing	Penetration	Distribution	Year established	
Nationwide	NRK P1	State	Tax	100/99	DAB+	1933	
	NRK P2	State	Tax	99	DAB+	1984	
	NRK P3	State	Tax	99	DAB+	1993	
	NRK Klassisk	State	Tax	99	DAB+	1995	
	NRK Alltid Nyheter	State	Tax	99	DAB+	1997	
	NRK Sápmi	State	Tax	99	DAB+	1999	
	NRK mP3	State	Tax	99	DAB+	2000	
	NRK Super	State	Tax	99	DAB+	2007	
	NRK Sport	State	Tax	99	DAB+	2007	
	NRK Jazz	State	Tax	99	DAB+	2008	
	NRK P1+	State	Tax	99	DAB+	2013	
	NRK P13	State	Tax	99	DAB+	2014	
	NRK Vær	State	Tax	99	DAB+	2007	
	NRK Trafikk	State	Tax	99	DAB+	2017	
	NRK Folkemusikk	State	Tax	99	DAB+	2004	
	P4	Nordic Entertainment Group	Commercials	93	DAB+	1993	
	P5	Nordic Entertainment Group	Commercials	93	DAB+	2010	
	P6 Rock	Nordic Entertainment Group	Commercials	93	DAB+	2014	
	P7 Klem	Nordic Entertainment Group	Commercials	93	DAB+	2011	
	P8 Pop	Nordic Entertainment Group	Commercials	93	DAB+	2015	
	P9 Retro	Nordic Entertainment Group	Commercials	93	DAB+	2017	
	P10 Country	Nordic Entertainment Group	Commercials	93	DAB+	2017	
Regional	NRJ	NRJ/Nordic Entertainment Group	Commercials	93	DAB+	2010	
	Radio Norge	Bauer Media	Commercials	93	DAB+	2004	
	Radio Rock	Bauer Media	Commercials	93	DAB+	2013	
	Kiss	Bauer Media	Commercials	93	DAB+	2012	
	Radio Norsk Pop	Bauer Media	Commercials	93	DAB+	2016	
	Radio Vinyl	Bauer Media	Commercials	93	DAB+	2017	
	Radio Topp 40	Bauer Media	Commercials	93	DAB+	2017	
	P24-7 Mix	Bauer Media	Commercials	93	DAB+	2018	
	BIG Hiphop & RnB	Bauer Media	Commercials	93	DAB+	2019	
	P24-7 Kos	Bauer Media	Commercials	93	DAB+	2019	
Local	Podplay Radio	Bauer Media	Commercials	93	DAB+	2021	
	15 regional channels	State	Tax	100/99	DAB+	From 1957	
	78/57 local channels	Various	-	-	FM/DAB+	From 1982	

Figure 9-3: Norwegian radio channels in 2021⁷¹

⁶⁹ See <https://www.triple.com.au/sydney>

⁷⁰ See <https://www.hit.com.au/2day>

⁷¹ See <https://medienorge.uib.no/english/?cat=statistikk&page=radio&queryID=313>

9.3 PAD and metadata

Metadata is becoming increasingly valuable as part of the digital radio service offering. Due to the presence of large colour screens in cars, there is significant focus on delivering metadata to cars. The WorldDAB AWG is working with both broadcasters and car manufacturers to develop guidelines and standards that support a range of metadata, including logos, programme information and other service information. To date, a number of the standards, such as TS 102 818 [14], have been updated as well as implementation guidelines being published, for example the Automotive User Experience Guidelines.⁷²

While the increasing size and availability of large colour screens may be driving much of the metadata impetus, we also see increasing numbers of domestic receivers with colour screens. This is a clear sign that visual information is increasing in importance. Consequently, when rolling out new DAB systems it is now essential to provide both PAD in the form of Dynamic Label text and SlideShow images as well as metadata, such as station logos, along with the audio content. The addition of visual information allows a much more contemporary experience in line with what streaming delivery can provide. It is not uncommon for the PAD and metadata for a service to be common to both broadcast and streaming delivery.

If broadcasters do not deliver PAD and metadata, particularly to cars:

- The dashboard screen could be blank, with no information on your station, no branding and no easy-glance information for the driver
- Your competitors will have a better in-car User Experience (UX)
- You could lose listeners – over 25% of listening takes place in the car, in some countries over 50%
- Incorrect station logos provided by third party suppliers may be shown
- A third party could potentially monetise your space in the dashboard
- Listeners will find it easier to get information like artist and title when they listen to songs from streaming music services

PAD and metadata enrich the user experience and will increase in value as receiver devices are increasingly colour screen based. It is an essential part of the radio product and needs to be planned for alongside the other systems and functionality. Indeed, PAD and metadata, just like transmitters, has a lead time for development and integration and in this case on the content playout systems. This is often an additional part of the delivery which does take some effort to set up and maintain. Ideally, it would be integrated with streaming delivery so there is no duplication of resources required.

9.4 Analytics

Analytics is a term used for the gathering of information about listener behaviour, such as the time spent listening to different radio services and reactions to the content delivered by those services. This information can provide broadcasters with increased understanding of their audience's preferences, allow targeting of new types of content and allow targeted advertising.

⁷² See <https://www.worlddab.org/automotive/user-experience-guidelines>

While the current DAB+ broadcast does not provide analytics directly, the use of hybrid radio where the receiver includes an internet connection can provide analytic information. The RadioDNS organisation, along with several commercial companies, is currently actively developing these capabilities in line with the analytics that are possible for streaming audio services.

9.5 Receiver provisioning

9.5.1 Domestic and car aftermarket receivers

There is a very wide variety of DAB+ radio receivers for all types of environments and applications. These include domestic radios in the home which can include kitchen radios, water-proof radios for bathrooms, clock radios for bedrooms and HiFi radios for living rooms.

Portable radios are also very common and usually can be powered from mains electricity as well as batteries, often rechargeable, so that they can be used in the home as well as the garden or other outside areas. There are also personal or handheld models which are compact and ideal for use when travelling, exercising or working.



Figure 9-4: Example home receiver products⁷³

⁷³ Clockwise from top left, images courtesy of Bush, Telestar, Sangean and Tivoli



Figure 9-5: Example portable receiver products⁷⁴

⁷⁴ Clockwise from top left, images courtesy of Roberts, View Quest and View Quest



Figure 9-6: Example handheld portable receiver products⁷⁵

While there has been a considerable effort to ensure that new cars have DAB+ receivers, there remain many cars on the road which do not have DAB+ installed. To provide DAB+ in those cars, a range of aftermarket products have been developed by companies such as Sony, JVCKenwood, Pioneer and others.⁷⁶



Figure 9-7: Example car aftermarket receiver products⁷⁷

⁷⁵ Images courtesy of Sangean (left) and View Quest (right)

⁷⁶ See the WorldDAB website for more information on aftermarket product developers: www.worlddab.org

⁷⁷ Clockwise from top left, images courtesy of JVCKenwood, Alpine and Pure

The WorldDAB Aftermarket Devices working group was formed to work on improving the performance of devices for receiving digital radio in the car. The focus of the group is on improved performance, improved antennas, guidance on installation, marketing and all other areas to ensure that all aftermarket devices give the driver the best digital radio listening experience.

9.5.2 Supply chain considerations

The block diagram in Figure 9-8 shows a typical supply chain for domestic receivers. This includes home and portable products but also includes car aftermarket products. The diagram helps identify the complexities in the supply chain and the number of different actors involved.

The development and production process begins with the receiver standards, such as TS 103 461 Minimum Receiver requirements [5].

Receiver product manufacturers define product specifications based on functionality and target price point. Most domestic receivers are based on DAB+ modules with or without additional motherboards and functionality; for example, WiFi connectivity may be a function additional to the module selected. Most products are designed by parent companies in Europe and Japan and manufactured in China. The products are then distributed internationally to warehouses for delivery to retailers.

Broadcasters and retailers want to maximise the number of DAB+ listeners and often collaborate for DAB+ launches with special offers and pricing to start the market moving. This collaboration is usually through joint marketing campaigns and can continue over many years.

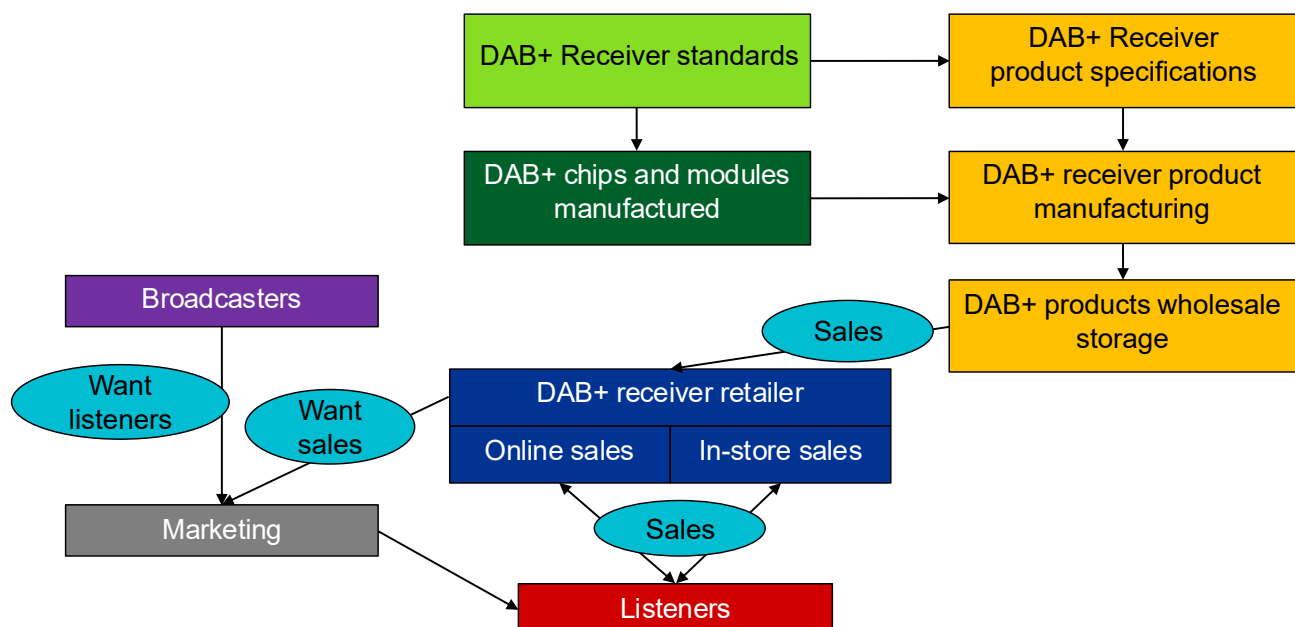


Figure 9-8: Domestic and car aftermarket supply chain

9.5.3 Factory fit car receivers

Factory fit DAB is currently a hot topic, with virtually all car brands now providing DAB+. It is important that the broadcast industry engages with the car industry as early as possible to ensure that new cars will have DAB+ receivers, preferably as standard fit. Indeed, if possible, car receivers should be included in new cars years before the actual launch of DAB+ to provide an existing listener base at launch.

At launch, most cars will not have DAB capabilities, hence it is very important to establish supply chains for aftermarket car receivers just like domestic receivers. In addition, it has been demonstrated in several countries, for example Norway, UK and Switzerland, that providing car product outlets with installation training significantly improves the quality of the installations. It is critical to get the aftermarket product antenna correctly positioned to ensure good reception as well as suitable cabling so as not to upset the aesthetics of the car dashboard.

The WorldDAB Automotive Working Group provides a forum for car manufacturers to work with DAB+ radio developers to ensure that radio has the most appropriate place in the car dashboard as well as collaboratively providing guidance on functionality, User Experience (UX) and performance.



Figure 9-9: Example car dashboard displays with DAB+ radio⁷⁸

⁷⁸ Image courtesy of P4 Norway



Figure 9-10: Car manufacturers and brands which provide factory fitted DAB+ receivers⁷⁹

9.6 Marketing for DAB+ launch

9.6.1 The role of marketing

Marketing is an often underestimated but essential component to a positive DAB+ launch and ongoing listener number increases.

It is essential that the launch campaign is a cross-industry initiative which provides support for all sectors. Marketing for launch is aimed at listener education and the encouragement to purchase a receiver and listen to DAB+. Launch campaigns should be across all forms of media, including TV, online, billboards, bus-sides, taxi-backs and most importantly on radio itself.

Marketing is often coordinated by a cross-industry marketing committee and is an excellent example of the 5Cs discussed in §6.5 where all of the radio industry should participate to ensure that the listening audience expands. Marketing is initially focused on listener education, to inform the audience about what DAB+ can provide, including more content, coverage and features to encourage them to invest in a receiver and start listening to DAB+. While the marketing push is often initiated by broadcasters, the receiver retailers, the car industry and government all have a role to play.

The marketing committee plays a critical role during the initial country launch and then ongoing expansion into new areas. As such, it is typically composed of several full-time staff to run the activities of the committee while being driven by a “steering board” composed of CEOs from public and commercial broadcasters and possibly government representatives if there is financial support from the government for marketing activities, as we have seen in France. The steering board will also engage with other stakeholders, such manufacturers, retailers and the car industry, to develop the high-level targets and agreements to ensure that launch campaigns have suitably broad impact.

⁷⁹ Source: WorldDAB

Marketing has an ongoing role in the long-term success of DAB+. We focus here on campaigns for initial country launches, which are usually confined to the most populated cities and areas, as well as new area launches. Established markets also benefit from ongoing marketing, as discussed further in §10.4.

9.6.2 Marketing campaign design

Launch campaigns are usually coordinated by a cross-industry marketing committee which includes all stakeholders – commercial, public service and community broadcaster representatives as well as retail and car industry representatives.

Launch campaigns are usually designed by marketing professionals and need to cover a wide range of topics, such as:

- Why you should listen to DAB+, and what's in it for me?
- Where to buy a receiver? This is often accompanied by a postcode-driven website which can show what stores are in the listeners' areas.
- What types of receiver are available?
- What DAB means to car drivers and their passengers.

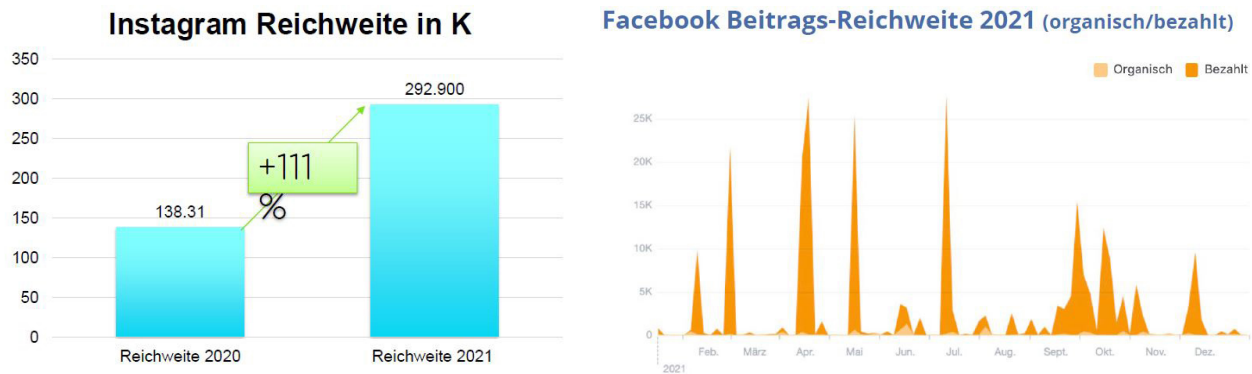
The marketing team under the direction of the marketing committee steering board makes sure that the plan of approach, the goals, the KPIs and management of the diverse stakeholders are being followed up and managed.

Marketing campaigns need to use a variety of delivery platforms, including:

- Radio (AM / FM / DAB+ / streaming) – this should be included in the broadcasters' programming, cross-promoting simulcast services and announcing new services.
- Social media – is a strong advertising medium and can be used by broadcasters to push notifications to listeners who subscribe or follow their services.
- TV and video streaming can include video marketing campaigns which can provide strong visual aspects.
- Outdoors, there are a range of opportunities such as billboards, bus and train sides, taxi-backs and so forth.
- In some cases, campaigns can include physical activities, such as shopping mall booths, to foster direct discussion with potential listeners and give-away events. Both can feature specific receiver brands and also lottery style give-away radios to encourage engagement.

All campaigns will have a specific budget and objective, so the choice of delivery platforms needs to be carefully considered to ensure the best outcome for the resources spent.

It is also useful to be able to measure the response to the marketing campaign. For example, a campaign in Austria was monitored using social media Instagram and Facebook, as shown in Figure 9-11. The results indicate that the response to the regular campaign over the period of one year was a 111% increase in DAB+ receiver sales.

Figure 9-11: Marketing campaign monitoring⁸⁰

9.6.3 WorldDAB Marketing support

WorldDAB provides a free marketing toolkit to help ensure that the styling and logos used internationally are consistent.

- The DAB+ logo and branding kit are free to use for industry stakeholders; see <https://www.worlddab.org/resources/logo>
- Factsheets can help educate stakeholders and listeners: <https://www.worlddab.org/resources/factsheets-and-reports>
- The WorldDAB style guide is shown in Figure 9-12.

The marketing toolkit also includes design elements and strategies for:

- on-air radio spots
- online distribution, such as www.dabplus.de, social media, banners
- off-air design, with point of sale and trade fairs

The WorldDAB Marketing Committee undertakes regular activities and has meetings typically three times a year where members can observe what each country is doing to promote the uptake of DAB+. The Marketing Committee:

- includes marketing specialists from multiple countries
- provides examples of DAB+ marketing best practice through reports from multiple countries
- and WorldDAB membership is NOT a prerequisite to join the Marketing Committee



⁸⁰ Source: WorldDAB Marketing Committee meeting, February 2022 – Austrian presentation



Figure 9-12: WorldDAB international style guide

9.6.4 Example campaigns

In France, several launch campaigns are in progress. Figure 9-13 shows an educational campaign to inform listeners of coverage along the route from Paris to Nice with emphasis on listening to DAB+ in cars while travelling and DAB+ coverage expansion in the Côte d'Azur region.

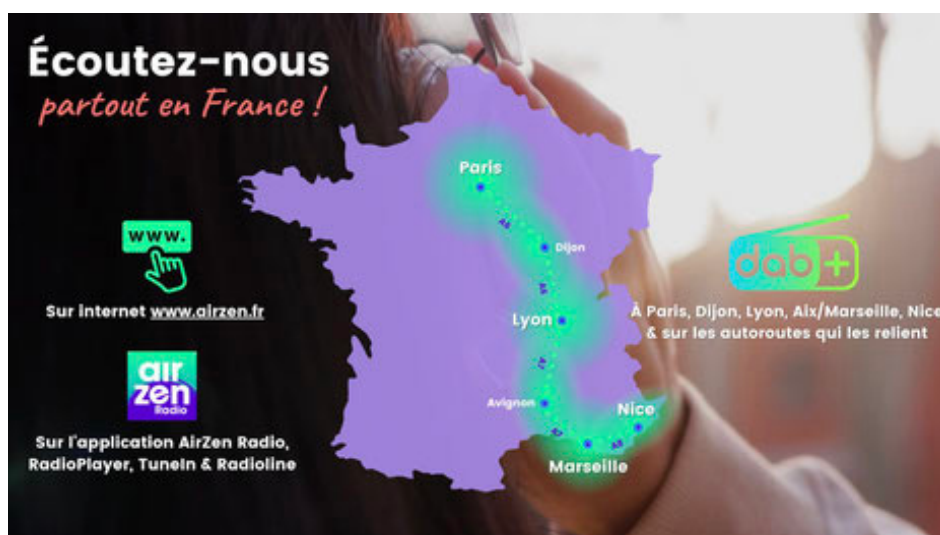


Figure 9-13: Example images of marketing launch campaigns⁸¹

In September 2022, the DAB+ station DanceOne expanded its coverage from Paris to Marseille and Nice with a campaign starting on 8 September. DanceOne is the 20th radio station in the audio-digital bouquet of La Maison FG, which also operates three other stations licensed to broadcast in DAB+: Radio FG, FG Chic, with lounge and nu-disco programmes and

⁸¹ Courtesy of www.dabplus.fr in 2023

Maxximum, focused on discovery and techno. Radio FG is available in several cities across France, while FG Chic and Maxximum are broadcast on DAB+ in the Paris region.

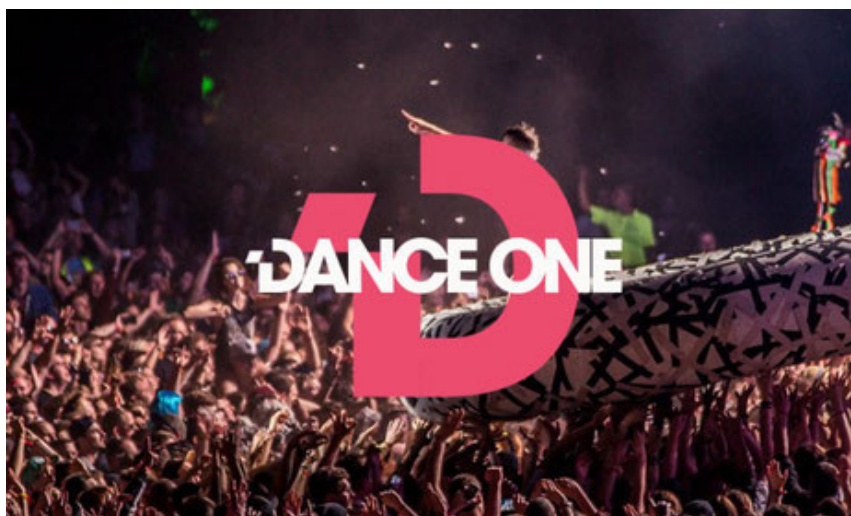


Figure 9-14: DanceOne expansion to new areas launch campaign⁸²

Another example is the expanding coverage in the Czech Republic as shown in Figure 9-15. In this case, the promotion is publicising the expansion of commercial DAB+ services into new areas. This promotion is from the Czech Radio website, showing another way to promote DAB+ as such stories are also then picked up by social media, radio news services and news outlets in both the Czech Republic and beyond.

The decisive period for the development of DAB+ in the Czech Republic is to be next year, commercial radios need regionalization

© September 22, 2022



The coverage of the ČRo DAB+ multiplex will be expanded by nine new transmitters this year | photo: České Radiokomunikace

Figure 9-15: DAB+ expansion in the Czech Republic⁸³

⁸² Courtesy of www.dabplus.fr in 2022

⁸³ Source: <https://digital.rozhlas.cz/rozhodujicim-obdobim-pro-rozvoj-dab-v-cesku-ma-byt-pristi-rok-komerčni-radia-8832429>

10. Operations

10.1 Systems operations and maintenance

Radio is a real-time system, often with 24/7 delivery being a critical part of the service offering. Such systems need constant monitoring to ensure that when a system failure occurs, first the redundant system takes over and second the failed system is restored.

Systems operations are usually conducted via a 24/7 Network Operations Centre (NOC), whether internal or a contracted external provider. It is also often coupled with a service contract with a defined Service Level Agreement (SLA) to monitor equipment status and correct failures when they arise within agreed parameters. New techniques are being employed to help predict and prevent system failures, such as Machine Learning / Artificial Intelligence systems, which can predict failure likelihood, such as for a transmitter power amplifier module or an IP network router.

As DAB+ networks grow over time, the operations and maintenance activities must also be adjusted accordingly; indeed, they need to be integrated with the overall programme of works to ensure that when they go live, they are fully integrated.



Figure 10-1: A modern Network Operations Centre⁸⁴

As the standards evolve and new features emerge, they too need to be integrated and tested. This can also be part of the NOC responsibilities, for example the updating of Service Linking information when a new area starts transmission, or the control of the Emergency Warning (ASA) alerts.

The ASA alerting system is likely to be connected to other Emergency Warning systems to ensure an integrated approach across multiple platforms, such as television and mobile phone

⁸⁴ Source: <https://www.saravalindustries.com/network-operations-centers-faq/>

text alerts. The NOC has the responsibility to ensure that connectivity and configuration are correct to allow operation 24/7.

In most cases, it is usual to have regular testing of system operations to ensure that all is working correctly, including for example transmitter redundancy switchover, on-site power generator operation and service linking feature operation.

10.2 Content production

The production of new content is an ongoing process as the appetite of the audience evolves over time. New music evolves, audiences age and new younger generations emerge with different tastes, and news and current affairs interest varies according to political and environmental events. This drives new service offerings to keep radio content “fresh” and attractive. As such, the development of new offerings is an ongoing task for radio broadcasters, whether it be a new programme on an existing service or new services.

The capabilities of DAB+ are continually evolving to meet the demands of the audience and broadcasters and we will soon see the emergence of features such podcast links and on-demand audio that is provided by broadcasters to help keep their audience loyal.

10.3 Coverage expansion

The rollout of DAB+ across a country is usually undertaken in phases, for example the phasing shown for Tunisia in Figure 7-3. The initial launch will usually concentrate on the major population centres and capital cities, both national and internal states and provinces. The initial rollout as described in §9 will lift the knowledge base of the industry stakeholders and put them in a good position to assess the success of the rollout and then adjust expansion plans accordingly. This applies to all activities, from the technical planning and detailed design of future coverage areas to the operational aspects and the overall Capex and Opex costs.

10.3.1 Blackspot remediation

The measurement of the coverage achieved in the initially rolled out areas will often find areas where the coverage is not as good as expected or desired. The unexpected results may be due to specific attributes of the clutter and terrain of the area that were not initially captured. Feedback from both the listening public and from field testing surveys is important to ensure a clear and accurate understanding of the actual coverage delivered.

Once the details of blackspots and poor coverage areas are well known, plans can be formulated to provide additional coverage through the establishment of repeater transmitters forming an SFN with the main transmission.

An example of this situation is the initial DAB+ coverage of the southwest of Sydney in Australia. The initial rollout was planned around high-powered main sites of typically 50 kW ERP.⁸⁵ The trials undertaken in Sydney provided some measurement data for coverage model tuning. However, as the trial was low power with a lower antenna height and at a different

⁸⁵ Sydney main site at Artarmon is 45 kW ERP

location than the planned site, the trial coverage did not reach the Campbelltown area, which is 45 km to the southwest. Measurements of the coverage after construction revealed that the Campbelltown area and the expanding suburb of Camden had poor coverage and required an infill repeater. A 500 W ERP repeater was subsequently deployed at the Gregory Hills site to provide improved coverage (see Figure 10-2). In Sydney, due to the large coverage area size (85 km N-S by 60 km E-W) a total of six repeaters have been deployed to cover a range of poorly served areas over a period of 10 years.

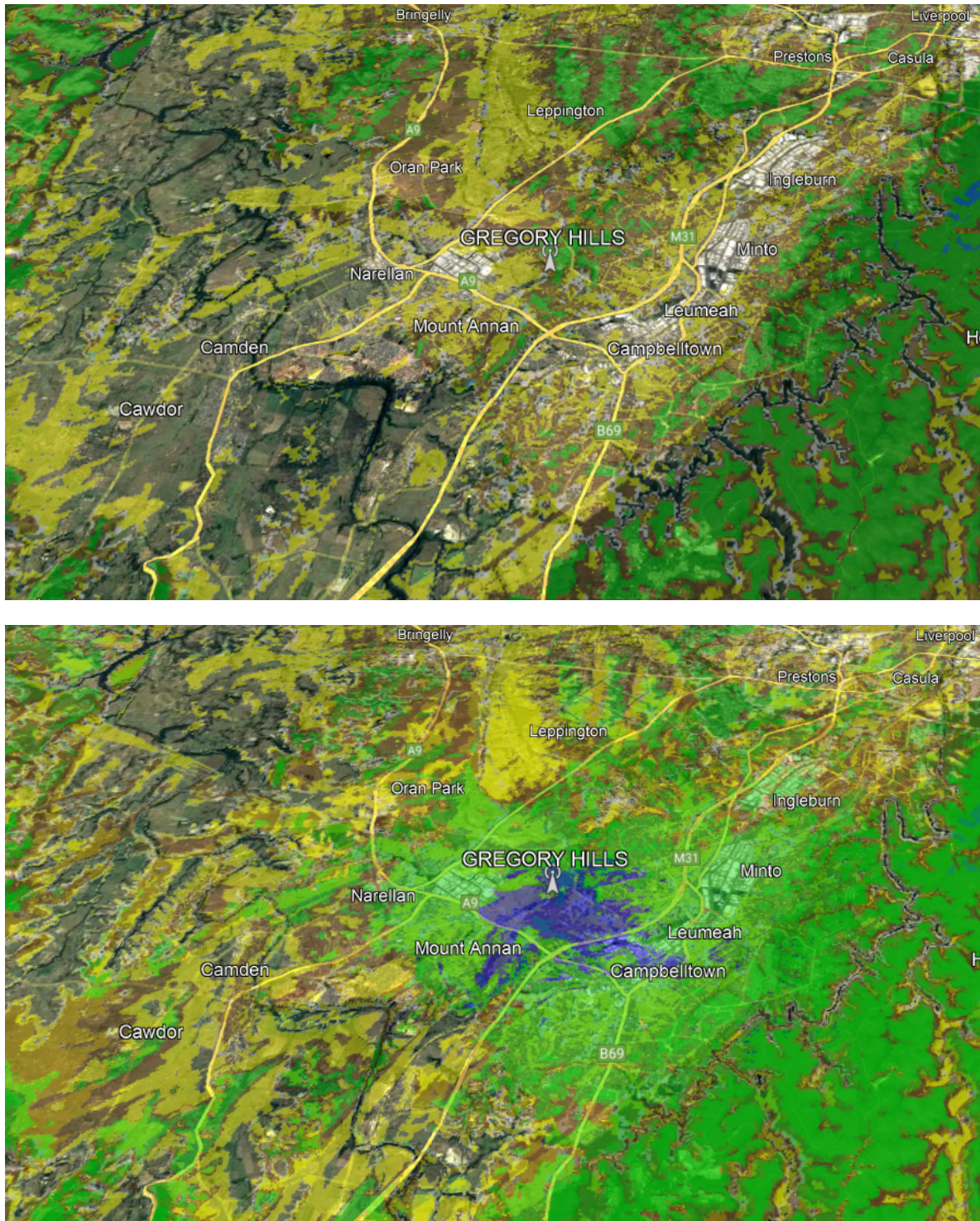


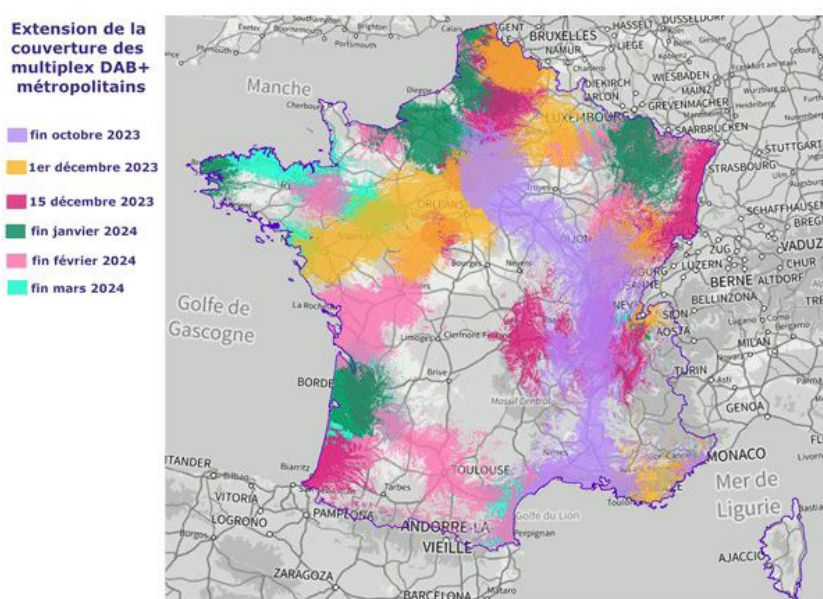
Figure 10-2: Coverage of the Campbelltown and Camden areas without the Gregory Hills repeater (top) and with the repeater (bottom)

10.3.2 Adding coverage areas

Expansion of coverage to new areas will generally be planned to be undertaken over a number of years to spread the Capex cost burden. The deployment will often focus on both the national and the local layers, with both being expanded simultaneously, possibly in different areas.

An example of ongoing expansion of services comes from the UK, which has established both national and regional layers over many years. There was still, however, a need for additional DAB+ services, particularly for local community broadcasters. Their issue comes in two parts; first, their coverage area was often smaller than the distribution provider's transmission coverage, and second, the community broadcasters have very low budgets and are often run through local supporters and government grants and could not afford the prices that were asked by distribution providers. The solution came in the form of small-scale DAB (SS-DAB), where the multiplexing and encoding systems are based on open source software using Software Defined Radio hardware platforms and transmission systems are low power, e.g. 100–200 W ERP with no redundancy. This innovation, also discussed in §8.2.3, allowed affordable systems to be implemented. The UK Ofcom subsequently developed a plan for phased deployment of SS-DAB systems across the UK, as shown in Figure 8-36, where the programme is now focused on Round 4 areas.

An example of a complementary rollout philosophy comes from France, where the initial rollout was focused on local broadcasts and highways. The initial local areas launched in 2014 were Paris, Marseille and Nice, which only included local broadcasters. In 2017, the “Nodes and Arcs” plan was formulated, which included focus on the main highways, e.g. the north–south motorway from Paris through Lyon to Marseille. In January 2020, the regulator CSA published a roadmap⁸⁶ for calls for applications for local allotments for the period 2020 to 2023, with the initial areas allotted in 2020, including local broadcasters in the regions of Dijon, Lyon, Marseille and Rennes; see Figure 10-3 for the status at the end of 2020. In 2021, two national multiplexes were announced with deployment being undertaken in parallel with the local DAB+ allotments.



These examples show that there are a diverse range of methods to deploy DAB+; every country has its own specific needs and will formulate the best approach to move forward with DAB+.

Figure 10-3: France rollout progress as of the end of 2020⁸⁷

⁸⁶ Feuille de route 2020- de la poursuite du déploiement du DAB+, csa_roadmap-2020.pdf

⁸⁷ Source: <https://www.arcom.fr/actualites/deploiement-en-france-de-la-radio-numerique-terrestre-dab>

10.4 Ongoing marketing

The initial country launch of DAB+ is usually confined to the most populated cities and areas. After the initial launch, DAB+ expands to new areas across each country over time. Each area will have its own launch and often we will see the expansion of services in already established areas.

To ensure the ongoing take-up of DAB+ listening, regular marketing campaigns are needed to remind listeners who have not switched to DAB+ of the benefits they could receive. These campaigns are usually conducted during times of gift giving, such as Christmas or family days, and can also be associated with new services.

Most countries develop their campaigns together with advertising agencies. Some countries work with a marketing team consisting of creative employees from both public and commercial broadcasters.

In The Netherlands, more than 60 stations joined the campaign, and the most famous DJs and radio presenters were deployed as DAB+ ambassadors, encouraging the listeners to make the switch from FM to DAB+.



Figure 10-4: Popular DJs and radio presenters participating as DAB+ ambassadors in The Netherlands⁸⁸

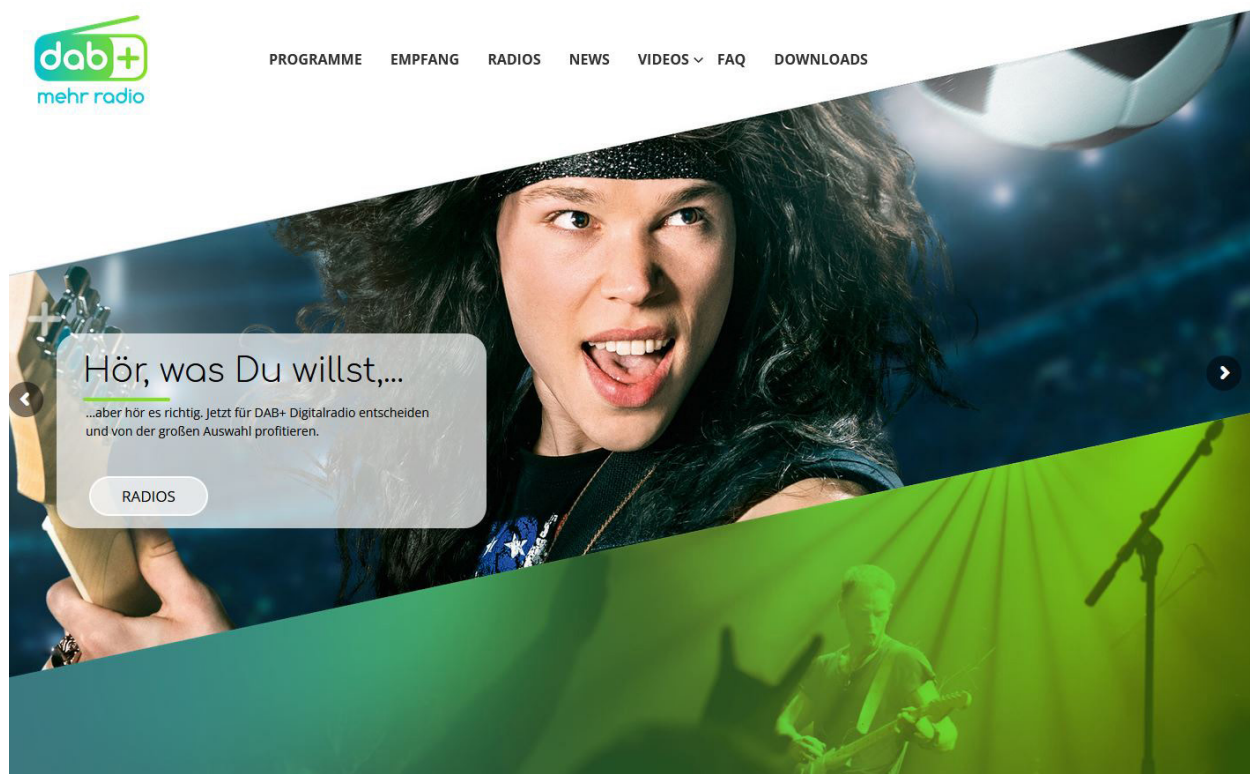
Austria has developed a year-long marketing campaign plan, as shown in Figure 10-5. The campaign runs in 11 out of 12 months, with each month having a different focus. For example, February is “World Radio Day” while September is “Back to School” and each month promotes different receiver products.

⁸⁸ Source: DAB+ marketing presentation for Indonesia by Jacqueline Bierhorst, May 2022

Kampagne												
Radio												
Reich												
Cost												
Status												
01	02	03	04	05	06	07	08	09	10	11	12	
Wellness @ Home	World Radio Day	Eastern		DIY	On the bike		Fresh Kick	Back to School		Black Friday	Merry Christmas	
												
TechniSat Digitradio 370 CD BT	TechniSat, pure Digitradio 3, Viola 2C	TechniSat, pure Techniradio RDR, Pure StreamR Splash		TechniSat Digitradio 2300D	TechniSat Digitradio Bike 1		Pure StreamR	TechniSat Technifant		TechniSat, pure, Dual	Noch offen	
108.000	70.000	122.000		30.000	120.000		90.000	110.000		200.000	50.000	
€ 2.000	€ 700	€ 2.500		€ 2.000	€ 3.000		€ 2.000	€ 2.500		€ 3.000	€ 2.000	
Abgeschlossen	Abgeschlossen	Abgeschlossen		Abgeschlossen	Abgeschlossen		Abgeschlossen	Verschoben		Abgeschlossen	Abgeschlossen	

Figure 10-5: Austrian campaign plan for 2022⁸⁹

A DAB+ website is another tool which helps guide the listeners with information about receiver availability, what areas can receive DAB+, car receivers, both factory fit and aftermarket products, and general statistics on the take-up of DAB, such as listening numbers and growth and the percentage of new cars with DAB+ radio. A good example is the DAB+ website for Germany, as shown in Figure 10-6.

Figure 10-6: The German DAB+ website⁹⁰

⁸⁹ Source: WorldDAB Marketing Committee meeting, February 2022 – Austrian presentation

⁹⁰ See <https://www.dabplus.de/>

10.5 Cross-industry communications

Stakeholder communications, cooperation and commitment have been repeatedly demonstrated to be the key for the successful rollout of DAB+. It is only when all stakeholders have a positive “can do” attitude that DAB+ will be designed, licensed and operated in a manner which provides positive outcomes for all. Stakeholders include:

- content producers / broadcasters
- regulators and government
- network builders, operators and maintainers
- infrastructure equipment providers
- the retail providers of receivers, both domestic and in vehicles

The stakeholders will often have a representative body which will facilitate discussions through regular dialogue, for example Digital Radio UK in the UK, and DigiMig in Switzerland.

One of the critical aspects is often the communication between the broadcasters and the regulator, bearing in mind that the broadcasters can be composed of multiple types, including Public Service Broadcasters, e.g. the BBC, commercial broadcasters such as Bauer, and community broadcasters who tend to be either smaller-area commercial operators or community sponsored, depending on the country. Each broadcaster sector has their own desires and financial constraints; however, in general all must work together to be able to develop and operate cost-effective DAB systems. This is often a difficult task and one which usually demands compromise on all sides. Such compromise may be encouraged by the regulator through incentives in the form of licensing, e.g. free spectrum to existing AM and FM operators in Australia, non-competition periods or discounts on existing analogue service licence fees.

Where systems are implemented through joint ventures, there is also a role for sensible capacity access fees which can be regulated. Indeed, this is the case in Australia, where the access to DAB+ capacity is regulated through the Australia Competition and Consumer Commission (ACCC) through a specific formula which allows the Joint Venture Company (JVC)⁹¹ to make a profit but also controls the cost of access to ensure equity, particularly for the small community broadcasters.

⁹¹ The Australia regulatory approach requires the use of JVCs when a multiplex has two or more different owners.

11. Analogue switch-off

The switching off of analogue services is the ultimate event in the adoption process. This is a very significant step which allows broadcasters to reap the financial benefits of digital-only transmissions.

11.1 Benefits and barriers

ASO has now been completed by Norway. Switzerland is in the final stages of planning and expected to complete ASO by 2024 and there are serious considerations by other countries.

ASO ensures that the TCO of the transmission network is minimised. Many studies have shown that the cost of operating an FM network is significantly more than that of a DAB+ service, even when the broadcasters deliver more content / services than in analogue alone. See [15], [16] and [17].

Apart from the lower operating costs, we see from the ASO experience in Norway that the increased services and their availability is driving an increase in radio listening and hence value for both commercial radio broadcasters and PSBs.

The environmental impacts of DAB are summarised in the WorldDAB factsheet [18]. The data in that document was produced prior to the recent dramatic upturn in energy prices and hence the environmental impact of moving to DAB+ is even more now than stated in that document.

We note, however, that there are some broadcasters who do not wish to pursue DAB+ for reasons such as:

- They believe that delivering more content will simply dilute their existing services and not result in any additional overall revenue after expenses. These are often broadcasters operating in solus markets, that is they are the only commercial broadcaster operating in a specific region or licence area.
- They believe that by deploying DAB+ the opportunities for other broadcasters will be greater than those for themselves and hence want to maintain the status quo. This is sometimes the case when a broadcaster has a dominant commercial radio share in a country.
- The broadcasters believe that IP streaming will dominate radio soon, so it is a waste of time deploying DAB+ and they are better focusing on IP delivery alone.

While it is not essential to plan for ASO during the rollout phase of DAB+, an indication that there will be an eventual switchover will encourage all stakeholders to move forward. We also note that some countries will be more capable of making the shift quicker than others, usually due to size and population. The quicker the ASO occurs, the quicker the reduced ongoing cost of service provision can be achieved.

11.2 Example ASO planning mechanisms

11.2.1 Norway

The switching off of analogue services is a difficult task unless it is embraced by the majority of radio ecosystem stakeholders. Norway made a bold decision in 2015 to move forward with DAB+ and switch FM off. Although there were some dissenting individuals and organisations, the Norwegian government authorities could see the overall advantages of undertaking an ASO in terms of cost, as their existing national PSB NRK's FM transmitters were due for a full replacement, as well as the efficient use of spectrum and the number of services which could be offered using DAB being vastly larger than on FM. The Norwegian Ministry of Culture produced a study [19] in 2011 where they proposed that an analogue switch-off date would be set once at least 50% of Norwegian households had acquired a digital radio set. They further stated that *"Analogue switch-off may not be completed until the following additional criteria have been fulfilled: (1) the population as a whole has access to digital radio (2) digital radio must offer added value to listeners."* The study included further requirements, including population coverage targets to demonstrate capability.

With the required targets being met, Norway started turning off analogue FM radio in January 2017 and completed the ASO in December 2017. An overview of the ASO plan was delivered to the WorldDAB General Assembly on 10 November 2016 by Line Langnes [21] where he outlined the decision-making process, the ASO process and target date and the challenges to be faced. The environmental and financial gains of the ASO are summarised in the relative number of transmitters required for the required DAB coverage being 1,160 for both NRK and commercial radio relative to approximately 3,000 for FM. The most challenging aspect was the number of DAB radio receivers, which in 2016 was only 30% for cars and 70% for households. Extensive marketing and education campaigns supported the ASO.

11.2.2 Switzerland

The approach of Norway to require specific DAB+ listening levels before establishing a date for ASO is also used in other countries such as Switzerland. In 2014, the Swiss broadcasters decided that FM transmissions would cease at the end of 2024 along with all licences. The Swiss DigiMig working group delivered a press release⁹² on 26 August 2021 stating: *"In 2014, Swiss radio stations agreed to switch off FM broadcasting of their programmes by 2024 at the latest. Since almost three-quarters of radio usage was digital at the end of last year, the radio industry came to the conclusion that under these conditions an early and staggered shutdown of FM stations in August 2022 (SRG) and in January 2023 (private radio stations) would be responsible. 42 out of 44 radio broadcasters and the SRG agreed on this."*

To support the switchover to DAB+ an ongoing marketing campaign is in progress featuring the animated DAB+ radio character "Dabsy" as shown in Figure 11-1. This campaign promotes DAB+ in a fun way while still providing information about better sound, more services and other features as well as the fact that FM radio transmissions will stop by the end of 2024.

⁹² <https://www.presseportal.ch/de/pm/100086886/100876267>

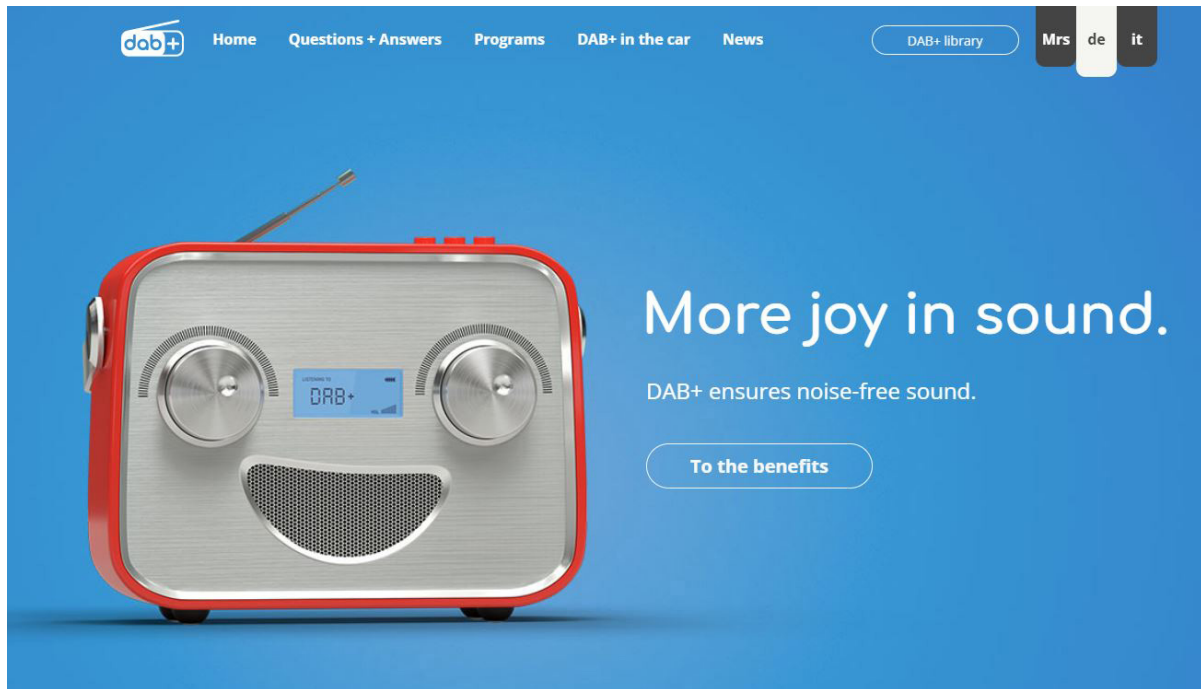


Figure 11-1: DAB+ promotional campaign in Switzerland⁹³

On 31 December 2024, the Swiss public broadcaster SRG SSR ceased FM broadcasting. For private radio stations, depending on the radio station, individual FM transmitters in a broadcasting area will be switched off in stages from 1 January 2025 (fade-out process) or in their entirety at the end of 2026. The Association of Swiss Private Radios (VSP) has [more details on its website](#). It is understood that as of January 2025, three local stations have switched FM off completely: Radio Stadtfilter, Radio 3fach, and Radio GOAT. Most stations in German-speaking areas have turned off some FM transmitters, especially smaller ones, while they plan to keep one or two high-power transmitters on until 2026, to keep urban areas covered. In French-speaking areas, most radio stations plan to continue until the end of 2026.

In autumn 2024, just before SRG SSR's FM switch-off, the Digital Migration working group once again collected figures on radio usage. The results show that the majority of the Swiss population has already switched over to digital radio: at the last measurement in autumn 2024, only 8% of listeners listened to the radio exclusively via FM.

⁹³ See <https://dabplus.ch/>

11.2.3 Germany

Radio stations in Germany's northernmost federal state are gradually transitioning from FM to DAB+ in multiple phases. The switchover is set to be completed by mid-2031 at the latest. From then on, radio in Schleswig-Holstein will only be available via DAB+ broadcast or, as is already the case, over the internet.

RADIO BOB! A rock station in Schleswig-Holstein ceased its statewide FM broadcasting on 9 April 2025, followed by N-JOY (NDR), which shut down its transmitter site in Niebüll. Deutschlandradio and has also largely ended its FM transmissions in Schleswig-Holstein. As of 30 June, Deutschlandfunk and Deutschlandfunk Kultur have fully switched from FM to DAB+ at twelve locations, covering a total of 16 transmitters. This autumn, delta radio (a sibling station to Radio Bob) will also complete its transition to DAB+ digital radio. All current developments are detailed on the dedicated page: www.dabplus.de/sh

By the end of the year, additional FM transmitters will be decommissioned, bringing the total number of FM transmitters taken out of service – including those in other federal states like Bavaria, Saxony-Anhalt, and Saxony – to as many as 100 in Germany in one year.

In Bavaria, the State Media Authority is actively supporting the transition. Under the “Audio Strategy 2025”, FM licences are being extended in stages – but only for those committed to DAB+. A full FM phase-out is scheduled for no later than 2035. Broadcasters such as Klassik Radio and egoFM are taking advantage of market-based incentives and benefiting from a clear strategic framework for the transformation.

11.2.4 Other initiatives

In Italy, the Radio Director Robert Sergio of the PSB RAI proposed on 17 March 2022 that FM would be shut down starting in 2025, with the goal of being all digital and shuttering FM broadcasting entirely by 2030.⁹⁴

⁹⁴ <https://www.radioworld.com/global/rai-radio-director-proposes-2030-fm-shutdown-for-italy>

11.3 Discussion

The introduction of the EECC requirement for all car radio receivers in 2020 to include DAB+ has made a huge reduction to the degree of difficulty for undertaking an ASO, as over several years the receiver base across EU countries has increased dramatically, making ASO decisions easier and likely sooner.

We now also see some FM broadcasters voluntarily switching off FM in preference for DAB+ only in Italy and Germany. This is primarily due to the combination of increased digital listening and increasing electricity costs.

We expect to see this trend increasing over the coming years making a clear statement that DAB+ is the future of broadcast radio.

11.4 Other uses for MW and VHF Band II

Once analogue services are switched off, the MW and FM spectrum can be cleared for future uses. It is, however, very early to look towards what services might use the vacated spectrum due a few reasons:

- FM in VHF Band II is only 20 MHz of spectrum in most countries, 88 to 108 MHz
- MW from 531 to 1602 kHz (Europe, Asia, Africa) has just over 1 MHz of spectrum

The small amount of spectrum makes it a small prize relative to the GHz of bandwidth that are being targeted by Telcos for 5G and beyond.

In addition, as the spectrum is not yet cleared and in most countries there is no plan for such clearance at this stage, the exceptions being Norway, Switzerland and Italy, there is no global initiative for this spectrum. On the other hand, we know that RF propagation in those bands is very power-efficient so it could possibly be used for a variety of Internet of Things systems, such as rural asset management and control of energy and utilities delivery monitoring amongst other applications.

12. Conclusions

The DAB+ standard is increasingly being adopted around the globe, with Europe leading the charge in establishing it as the standard of choice for the delivery of multiple radio services to an area. We also see growth in adoption in the Asia-Pacific region, the Middle East and Africa. Many of those countries are only just embarking on the journey to develop and deliver digital radio services. This ebook has been developed to provide guidance to new adopters to help them move forward with the hindsight of previous experiences.

Radio broadcasting is a very long-term business, and one which provides essential information and entertainment delivery to the population of every country. It is considered an essential service to the extent that every country has a Public Service Broadcaster and generally also commercial and community operators.

Radio has grown in popularity to the point that in most major cities around the world the spectrum provided in the FM band is insufficient to provide new opportunities and to allow the sustainability of local radio delivery in the light of international competition from streaming giants. DAB+ offers a solution to that challenge where it has been shown to be the best backbone to a multi-service delivery scenario which also includes local IP streaming and on-demand services such as podcasts and audio selection.

The radio ecosystem is complex, making the adoption, establishment and ongoing operation of DAB+ digital radio a challenging exercise. Of all the aspects of that exercise one stands apart as the most crucial, that being communication between the stakeholders. Only when there can be clear dialogue, understanding of differing perspectives and compromise on all sides can the road to success be navigated both successfully and rapidly.

While this ebook provides guidance on the many and varying aspects of DAB+ every country has its own needs and preferred outcomes. Seeking guidance from like-minded countries is a great source of knowledge which can make the journey easier. Indeed, there are many organisations that can assist along the way, most importantly the WorldDAB organisation, which promotes DAB+ and provides assistance and guidance to the global family of adopters.

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[28] [TS 104 089](#): “Emergency Warning System (EWS); Definition and rules of behaviour”

[29] TS 104 090, “Emergency Warning System (EWS); Minimum requirements and test specifications for receivers”

14. Annex A: Glossary of terms

The following terms are used in this document. They may not be fully aligned with the terms used in some countries.

Broadcaster: An organisation which develops and publishes audio content and any associated metadata. Broadcasters are sometimes also called content providers; in this document, we use the terms interchangeably. The broadcaster in many countries also provides the transmission services/facilities; however, the transmission facilities may also be provided by third-party transmission network providers.

Transmission network provider: Also simply called network provider, an organisation which provides transmission services in the form of analogue or digital RF transmissions. In some cases, the network provider will also provide service multiplexing facilities. Network providers do NOT generate content.

Regulator: There is usually only one regulatory body for broadcasting in each country. The regulator is part of the country's government structure but may be an independent organisation which is bound by government guidelines in its scope and power. The regulator is usually involved with the preparation and recommendation of ways of licensing and operating broadcast services.

Stakeholders: Stakeholders are any organisation which has an interest in the establishment and operation of DAB+ services and systems. This includes broadcasters, network providers, regulators, receiver manufacturers and suppliers, network and transmission system providers, the automotive industry and others who provide ancillary equipment and services.

The acronyms used in this document are shown in Table 14-1.

Acronym	Meaning
ABC	Australian Broadcasting Corporation
ACI	Adjacent Channel Interference
ACMA	Australian Communications and Media Authority
AoIP	Audio over IP
AGL	Above Ground Level
ASL	Above Sea Level
ASO	Analogue Switch-Off
ATV	Analogue TeleVision
AWG	(WorldDAB) Automotive Working Group
Backchannel	An information channel from the DAB+ radio receiver to another service, typically SMS, voice or a bidirectional data service to a web portal.
BBC	British Broadcasting Corporation
Capex	Capital expenditure
CBAA	Community Broadcasting Association of Australia
CBD	Central Business District
CCI	Co-Channel Interference
CRA	Commercial Radio & Audio (formerly Commercial Radio Australia)
DSCTy	Data Service Component Type
DAB+	Digital Audio Broadcasting using the AAC+ audio encoder
DSO	Digital Switchover
DTM	Digital Terrain Map
DTT / DTV	Digital Terrestrial Television / Digital Television
DTTB	Digital Terrestrial Television Broadcasting
DVB	Digital Video Broadcasting; DVB-T2 is second generation DVB
EECC	European Electronic Communications Code
e.m.r.p.	Effective Monopole Radiated Power
EPG	Electronic Programme Guide
ERP	Effective Radiated Power (with respect to a dipole) dBd
EDI	Encapsulation of DAB Distribution Interfaces
ETI	Ensemble Transport Interface
EU	European Union
EWS	Emergency Warning System
FEC	Forward Error Correction
GBP	Great Britain Pound
GI	Guard Interval
HPHT	High-Power High Tower (transmission site)
HRP	Horizontal Radiation Pattern (of an antenna system)
IMT	International Mobile Telecommunications
IP	Internet protocol
ITU	International telecommunications Union
JPEG	An image encoding method developed by the Joint Photographic Experts Group.

Acronym	Meaning
JVC	Joint Venture Company
LA	Licence Area
LFR	Link Fed Repeater
LPLT	Low-Power Low Tower (transmission site)
MCMC	Malaysian Communications and Multimedia Commission
MMN	Man-Made Noise
MMS	Multimedia Message Service as used in GSM and 3G
MOT	Multimedia Object Transfer
NMS	Network Management System
NOC	Network Operations Centre
OCR	On-Channel Repeater
OD	Omnidirectional (antenna HRP)
ofcom	UK Regulator, the Swiss Regulator acronym is also OFCOM
OFDM	Orthogonal Frequency Division Multiplexing
Opex	Operational expenditure
PNG	Portable Network Graphics (an alternative to JPEG)
PR	Protection Ratio
SADC	Southern Africa Development Community
SBR	Spectral Band Replication
SBS	Special Broadcasting Service (of Australia)
SFN	Single Frequency Network
SLA	Service Level Agreement
SMS	Short Message Service as used in GSM and 3G
SNMP	Simple Network Management Protocol
SP	Service Provider
SS-DAB	Small-Scale DAB (UK)
TC	WorldDAB Technical Committee
TCO	Total Cost of Ownership
TDM	Time Division Multiplexing
TF	Task Force
TPEG	Transport Protocol Experts Group
TX	Transmitter
UAS	Universal Access and Service
UPS	Unbreakable Power Supply
VM	Virtual Machine
VPN	Virtual Private Network
VRP	Vertical Radiation Pattern (of an antenna system)
WAP	Wireless Access Protocol as used over GPRS and 3G packet data services
WRC	World Radio Conference
X-PAD	eXtra Program Associated Data

Table 14-1: Acronyms used in this document

15. Annex B: Standards overview

The DAB system is defined through a suite of ETSI Technical Specifications (the Standards) as described below. In addition to the ETSI standards, there are other supporting documents from the ITU and EBU.

The DAB family of standards is available for free download from the [ETSI website](#).

A useful starting point is to read the guide to DAB Standards: [TR 101 495](#).

All the current standards can be accessed using the following links.

DAB system

[EN 300 401](#): DAB system standard

[TS 101 756](#): Registered Tables

[TS 103 176](#): Rules of implementation

[TS 102 367](#): Conditional access

[TS 104 089](#): DAB emergency warning system: definition and rules of behaviour

Audio coding

[TS 102 563](#): DAB+ audio

[TS 103 466](#): DAB audio

[TS 101 757](#): DAB audio testing

Data transport coding

[EN 301 234](#): MOT

[TS 101 759](#): TDC

[TS 102 427](#): MPEG-2 TS

Contribution, distribution and networks

[EN 300 797](#): STI

[TS 101 860](#): STI Levels

[EN 300 798](#): DIQ

[ETS 300 799](#): ETI

[TS 102 693](#): EDI

Data applications

[TS 101 499](#): SlideShow

[TS 102 818](#): Hybrid Digital Radio (DAB, DRM, RadioDNS); XML Specification for Service and Programme Information (SPI)

[TS 102 371](#): SPI binary

[TS 103 177](#): Filecasting

[TS 102 980](#): Dynamic Label Plus

[TS 102 979](#): Journaline

[TS 102 428](#): DMB

[TS 103 270](#): RadioDNS Hybrid Radio; Hybrid lookup for radio services

[TS 103 551](#): TPEG

[TS 103 689](#): Filtered Information Service

Receivers

[TS 103 461](#): Minimum requirements for receivers

[TS 104 090](#): Emergency Warning System (EWS); Minimum requirements and test specifications for receivers

Further information can be obtained from the WorldDAB [website](#).

16. Annex C: Transmitter site cost minimisation

16.1 Motivation

The cost of establishing a DAB+ network is usually dominated by the cost of the transmission system. Studies have shown that for large networks the cost of the transmission system network is around 90% of total Capital Expenditure (Capex) and Operational Expenses (Opex). The costs for each transmission site are dominated by the Capex for the transmitter and antenna systems and Opex costs for the transmission tower access and electrical power.

The choice of the antenna size (number of bays and type) has a significant impact on the antenna gain and hence the required transmitter power to achieve the target Effective Radiated Power (ERP) which is usually established during Frequency Block allotment planning. The higher the antenna gain, the lower the required transmitter power but the higher the antenna system costs. Hence there is a cost minimisation situation which for a specified transmission ERP balances the increased antenna cost as the number of antenna bays increase against the lower Capex and Opex costs of a less powerful transmitter.

In this analysis we use the Total Cost of Ownership (TCO) which is the combination of the Capex cost and Opex cost over a specified amortisation period, that is the replacement time for the antenna and transmitter equipment.

If the transmitter power and antenna characteristics are not optimised to ensure the minimum TCO over the lifetime of the system, both the cashflow of the Network Operator and the access fees paid by Broadcasters can be significantly higher than necessary. The optimisation focuses on individual sites but should be used for the entire transmission network to ensure minimum transmission network TCO.

There are also other costs to take into account including the transmitter site costs (this is primarily for access to the aperture on the transmission tower), the cost of power, the number of transmitters (including redundancy) given the number of ensembles to be transmitted, the transmitter efficiency and the feeder/combiner system losses.

While transmission sites also have other equipment such as IP, power and control systems as well as operations and maintenance costs, these are independent of the transmitter and antenna systems and hence do not need to be considered in the cost minimisation.

In this analysis we generally use costs which have been obtained through commercial Requests For Information (RFIs) or extrapolations when needed.

16.2 Cost analysis

The cost analysis considers two types of antenna system:

1. Four-sided panel arrays which are often used for high power sites, e.g. greater than 4 kW ERP. These can also have a shaped Horizontal Radiation Pattern (HRP) and Vertical Radiation Pattern (VRP) to suit the transmission network requirements;
2. Dipole arrays which are somewhat directional with typical HRP front to back ratio of 6 dB. Such arrays are often used for lower power transmissions, e.g. from 1 to 10 kW

The amortisation period for transmitters is typically 10 to 15 years, while for antenna systems it is typically 20 to 30 years. Hence, we adopt an overall amortisation period where two transmitter systems will be supplied within the lifetime of the antenna system. We then analyse the cost implications for total amortisation periods of 20 and 30 years.

The antenna system cost is calculated as:

$$Capex_{AS} = \text{Antenna cost} + \text{feeder cost} + \text{combiner cost} \times \text{number of ensembles} \quad (1)$$

The antenna TCO per annum is calculated considering the Opex for the transmitter site costs as:

$$TCO_{AS} = \frac{Capex_{AS} \times (1 + \text{Antenna system instalation \%})}{\text{Amortisation period}} + \text{Tx site cost PA} \quad (2)$$

where PA means "Per Annum".

The transmitter system cost using N+1 redundancy is calculated as:

$$Capex_{Tx} = \text{Transmitter cost} \times (\text{number of ensembles} + 1) + \text{Redundancy system cost} \quad (3)$$

The transmitter system TCO per annum is calculated considering the Opex for the transmitter power costs as:

$$TCO_{Tx} = \frac{2 \times Capex_{Tx} \times (1 + \text{Transmitter instalation \%})}{\text{Amortisation period}} + \text{Tx power cost PA} \quad (4)$$

The total TCO per annum is then

$$TCO_{total} = TCO_{AS} + TCO_{Tx} \quad (5)$$

We wish to find the Tx and antenna system configuration which minimises TCO_{total} . To determine the minimum TCO configurations we calculate for a range of optional implementations.

16.3 Cost calculations

All costs are calculated using Euros. We explore the TCO considering the following parameter variations:

- ERP = 1, 2, 4, 10, 20 kW
- Ensembles per site = 1, 2, 3, 4
- Amortisation periods = 20, 30 years
- Power costs of €0.20 and €0.40 / kWhr

We use the following pricing for the system components:

- Transmitters
 - One transmitter per ensemble plus one redundant transmitter, i.e. N+1 redundancy
 - Tx cost is based on RFI responses obtained in 2023, see Table 16-1
 - Transmitter system Capex cost is calculated using equation (3)
 - Tx installation cost is set at 10% of the cost of the system
 - Tx efficiency = 45%⁹⁵

Power (kW rms)	Single Tx	N+1 Redundancy system
0.3	€ 9,101	€ 9,722
0.6	€ 13,655	€ 11,400
1.2	€ 21,910	€ 12,100
2.4	€ 47,312	€ 17,500
3.6	€ 59,422	€ 17,500
6.0	€ 100,000	€ 25,000

Table 16-1: Transmitter system costs

- Antenna systems
 - ▶ Dipole antennas assume a linear array, see example in Figure 16-1. Dipole antenna arrays are typically Directional (DA) with approximately a 4 to 6 dB front to back ratio.
 - ▶ Panel antennas assume 4 sides for omni-directional HRP, see example in Figure 16-2. Such 4 sided panel arrays are usually considered to be Omni-Directional (OD) but do exhibit some gain variation “ripple” dependent on azimuthal direction of up to around 3 dB.
 - ▶ Antenna system costs are based on RFI responses obtained in 2023
 - Antennas, feeders, combiner / filters

⁹⁵ The figure of 45% is based on modern Doherty technology for DAB+ transmitters, however we note that there are significant efforts to increase the efficiency with expectations of achieving 50 to 55% in the near future.

- ▶ Antenna system installation cost is set at 50% of the cost of the total antenna system
- ▶ No antenna redundancy included, e.g. the ability to split stacks
- ▶ Antenna site cost is based on the effective antenna height above ground level and equivalent wind loading surface area
- ▶ See Table 16-2 and Table 16-3 for antenna system characteristics and costs

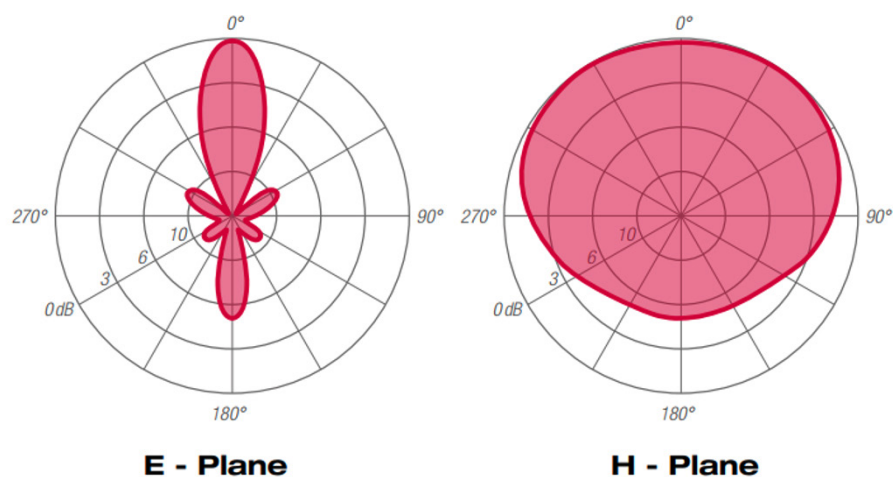


Figure 16-1: Example dipole array VRP, HRP and example⁹⁶

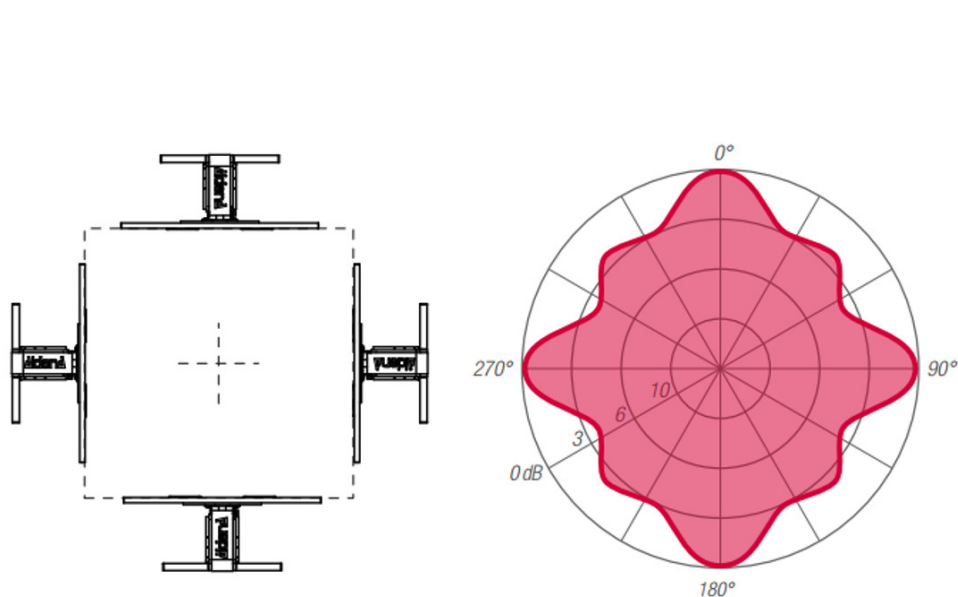


Figure 16-2: Example omni-directional panel array configuration, HRP and example⁹⁷

⁹⁶ HRP and VRP examples are courtesy of Aldena, see <https://www.aldena.it/products/vhf-band-iii/adb-02-04-23x/>

⁹⁷ Four sided array diagram and HRP are courtesy on Aldena, see <https://www.aldena.it/products/avp-02-04-43x/>

Dipole antenna bays	Antenna gain (dBd)	Antenna system gain (dBd)	Operational height (m)	Wind loading area (m ²)	Antenna Capex Cost	Opex cost for tower use PA
1	2.2	0.94	50	0.5	€ 2,500	€ 2,000
2	5.4	4.14	50	1	€ 4,320	€ 4,000
4	8.5	6.77	100	2	€ 6,282	€ 9,000
6	10.3	8.57	100	3	€ 8,289	€ 13,500
8	11.6	9.41	150	4	€ 10,000	€ 20,000
12	13.4	11.21	150	6	€ 14,000	€ 30,000
16	15.1	12.91	150	8	€ 16,000	€ 40,000

Table 16-2: Directional dipole array options

Panel antenna bays	Antenna gain (dBd)	Antenna system gain (dBd)	Operational height (m)	Wind loading area (m ²)	Capex Cost	Opex cost for tower use PA
1	2.4	1.14	50	1	€ 6,120	€ 4,000
2	5.3	4.04	50	2	€ 11,830	€ 8,000
4	8.3	6.57	100	4	€ 23,760	€ 18,000
6	10.1	8.37	100	6	€ 35,433	€ 27,000
8	11.4	9.21	150	8	€ 47,322	€ 40,000
12	13.1	10.91	150	12	€ 70,000	€ 60,000
16	14.4	12.21	150	16	€ 90,000	€ 80,000

Table 16-3: Omni-directional panel array options (4 panels per bay)

We make the following assumptions due to their minor impact on the overall results:

- All feeders are 1 5/8", feeder loss is set at 0.93 dB / 100m
- Combiner / filter loss is set at 0.8 dB
- Antenna installation cost is 50% of the antenna system cost
- The transmitter installation cost is 10% of the transmitter system cost

The TCO is calculated as follows.

The ERP per ensemble is selected from the range 1, 2, 4, 10 or 20 kW, the transmitter power for each ensemble is then calculated considering the gain of each antenna system option where the Antenna System gain is calculated as:

$$G_{AS} \text{ (dBd)} = G_{\text{antenna}} \text{ (dBd)} - L_{\text{Feeder}} \text{ (dB)} - L_{\text{Combiner}} \text{ (dB)} \quad (6)$$

The transmitter output power is calculated as

$$P_T = \frac{P_{ERP}}{\frac{G_{AS}}{10^{10}}} \quad (W \text{ rms})$$

where P_{ERP} is the desired transmission ERP. The total transmitter power consumed is calculated as:

$$P_{T-total} = \frac{P_T \times \text{Number of ensembles}}{\text{Transmitter efficiency}} + P_{T-standby} \quad (W) \quad (7)$$

where the power used by the standby transmitter is set to $P_{T-standby} = 0.5 \text{ kW}$. $P_{T-total}$ is then used to calculate the cost of transmitter power based on the selected power cost per kWhr. The transmitter system TCO is then calculated using equation (4).

The antenna system cost is as shown in equation (1), with the antenna system TCO being calculated using equation (2).

The total TCO is simply the sum of the transmitter system TCO and antenna system TCO as shown in equation (5). We then calculate the total TCO per annum for each power option for the range of dipole and panel array antennas.

16.4 Results

The results of the total TCO PA calculated for the number of ensembles based on power costs of €0.20 / kWhr are shown below in Figure 16-3 to Figure 16-6.

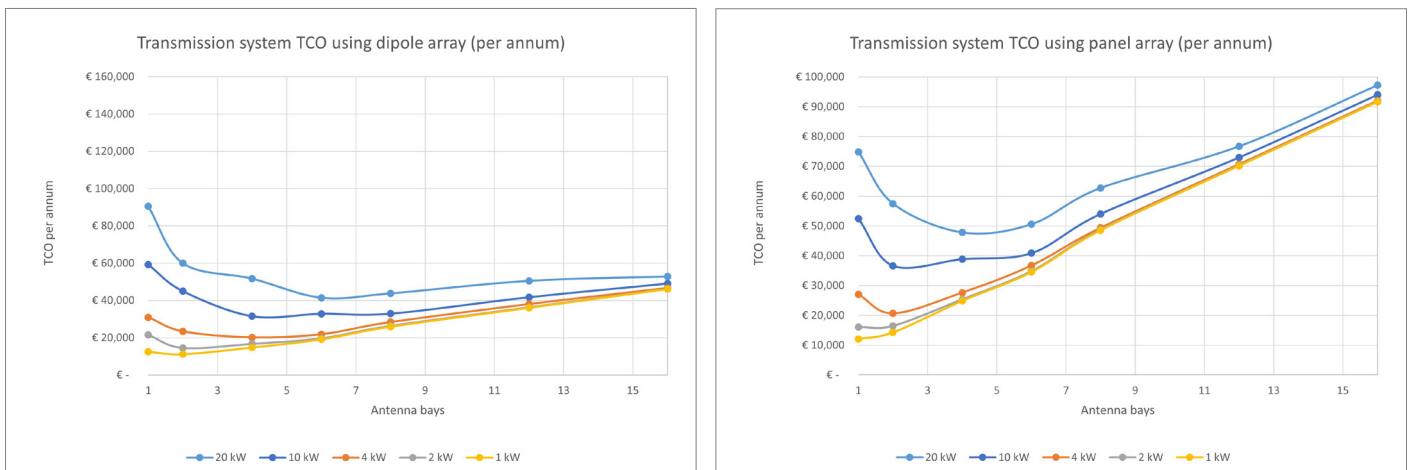


Figure 16-3: Total TCO PA for 1 ensemble (Dipole left, Panel right)

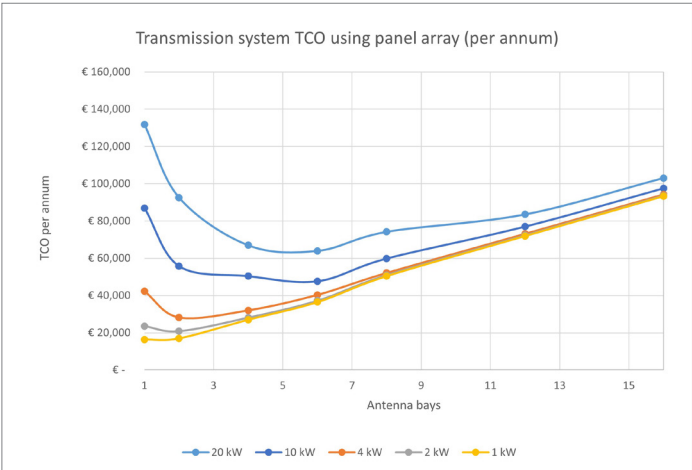
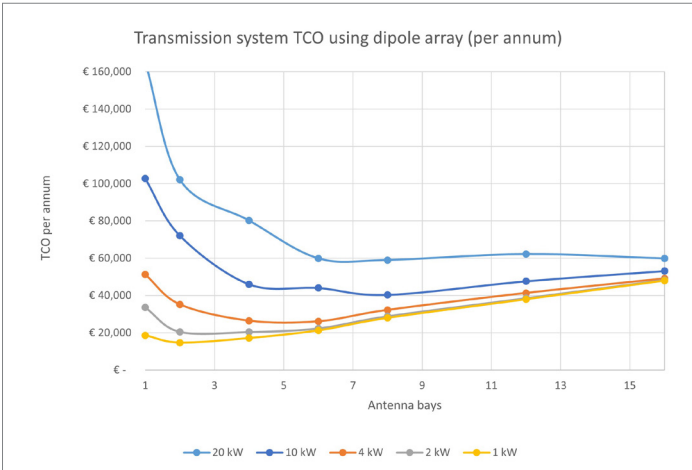


Figure 16-4: Total TCO PA for 2 ensembles (Dipole left, Panel right)

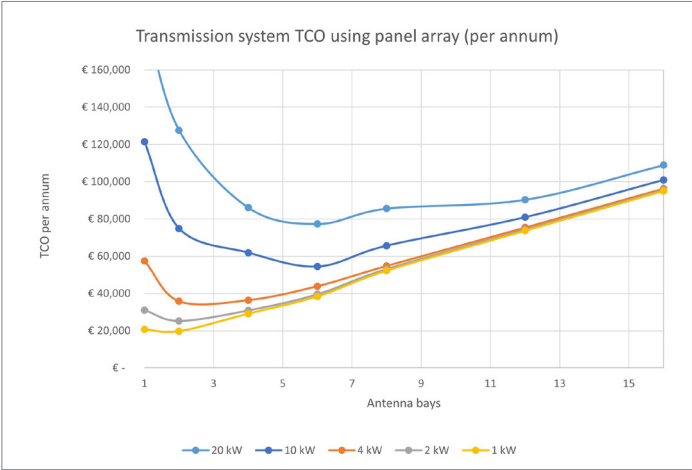
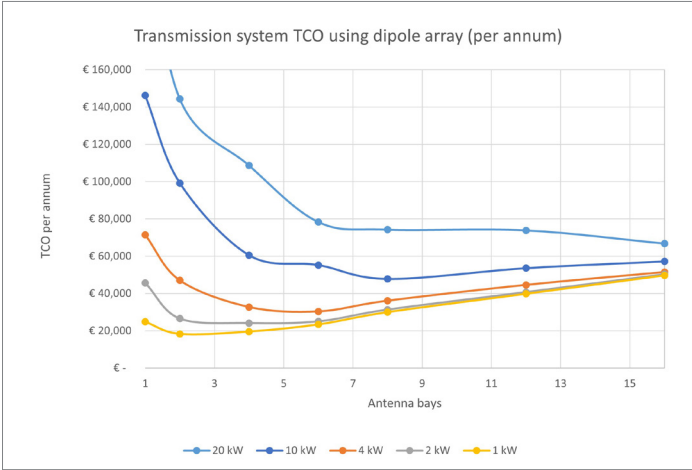


Figure 16-5: Total TCO PA for 3 ensembles (Dipole left, Panel right)

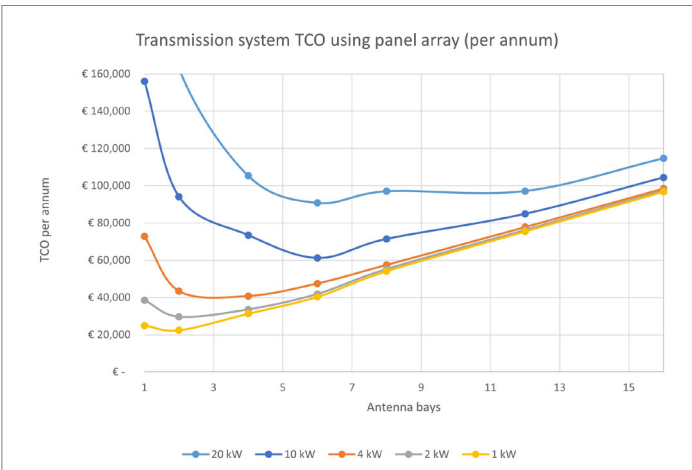
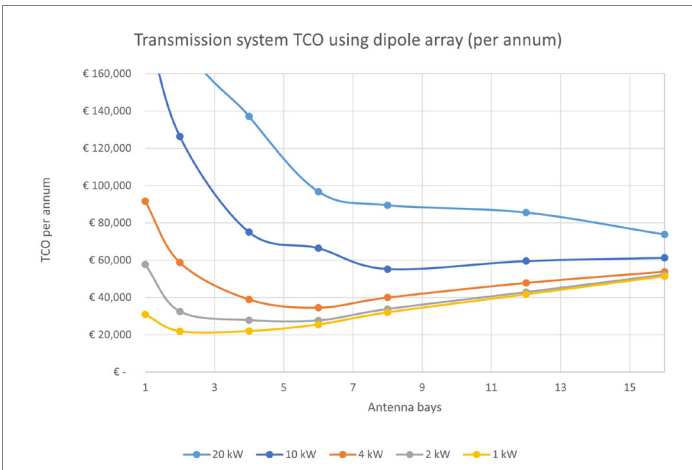


Figure 16-6: Total TCO PA for 4 ensembles (Dipole left, Panel right)

Observing Figure 16-3 to Figure 16-6, we see the general trend that there is an optimum number of antenna bays to minimise the overall TCO. The TCO is sensitive to the number of ensembles being transmitted with the impact being greater as both the number of ensembles and transmission ERP increases. If only one ensemble is being transmitted, then the minimum cost requires a smaller number of antenna bays for both dipole and panel antennas.

We also observe that lower power sites will have minimum TCO with fewer antenna bays for both dipole and panel antennas with the impact being most distinct for lower numbers of ensembles. A comparison of the number of antenna bays is shown in Figure 16-7, where we see that the panel array solution uses fewer bays than the dipole solution. The number of bays gradually increases as both the ERP and number of ensembles increase as expected. We have 2 outlier scenarios for dipole antennas for 20 kW ERP for 3 and 4 ensembles where the number of bays has jumped to 16 relative to 8 bays for 10 kW ERP. This is because the cost of the additional antenna bays to deliver 3 dB additional gain is less than the cost of power without the additional bays. In general, we see the minimum TCO when the TCO for the antenna system is close to the TCO for the transmitter system.

We compare the individual transmitter power for each scenario in Figure 16-8 where we see that in most cases the transmitter power is less than 1.2 kW. This has two cost impacts, first the transmitter system is cheaper and second the cost of the combiner system is about half of that when the individual transmitters have an output greater than 2 kW. We see a couple of outliers for the dipole case of 1 ensemble with 10 and 20 kW ERP. In these scenarios, the use of the smaller antennas results in significantly smaller antenna site costs which offsets the higher power costs. This is a very good example of being aware that site costs for tower use are very influential on overall cost minimisation.

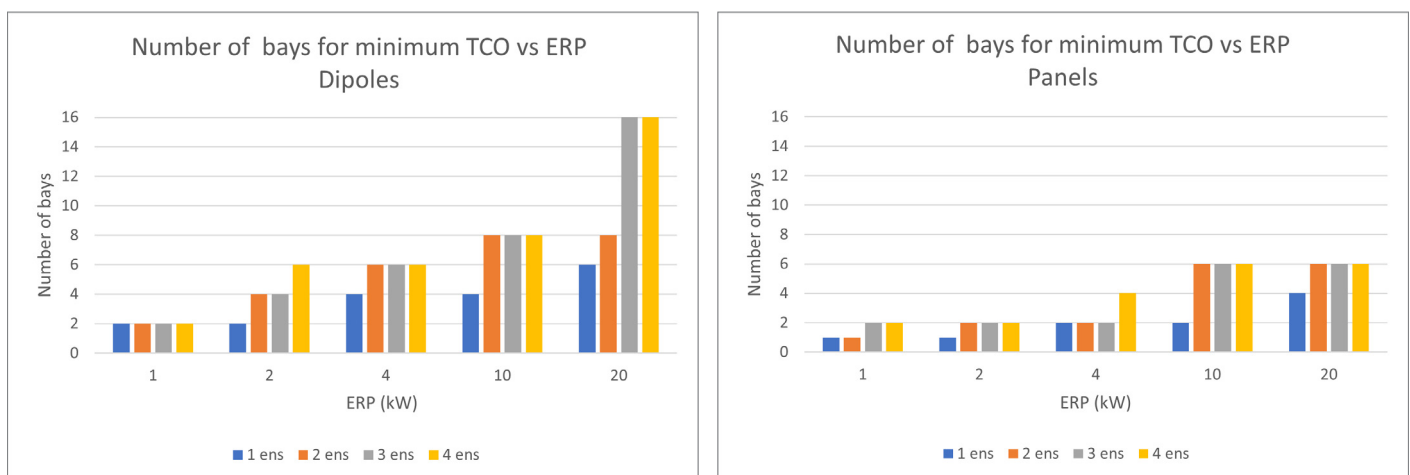


Figure 16-7: Number of bays for minimum TCO vs ensemble ERP, for 1 to 4 ensembles

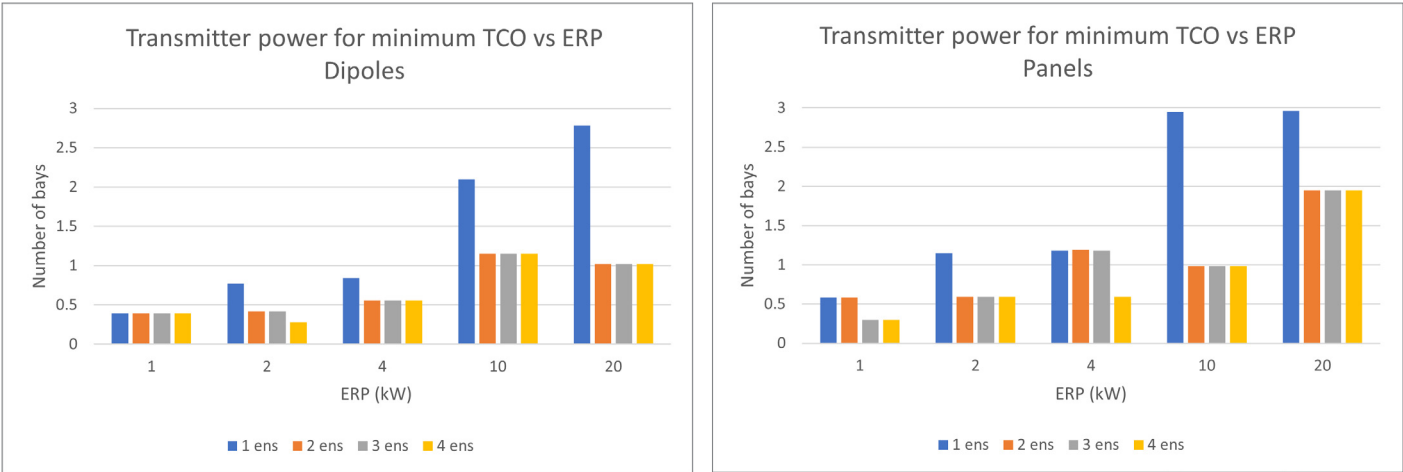


Figure 16-8: Transmitter power for minimum TCO vs ensemble ERP, 1 to 4 ensembles

We can also compare the minimum TCO value as shown in Figure 16-9. Here we see that cost difference between dipoles and panels is not high, with the example calculations showing that the TCO of panel arrays is around 13% higher than for dipole antennas but with a reduced coverage area due to the directionality of the dipole antenna array.

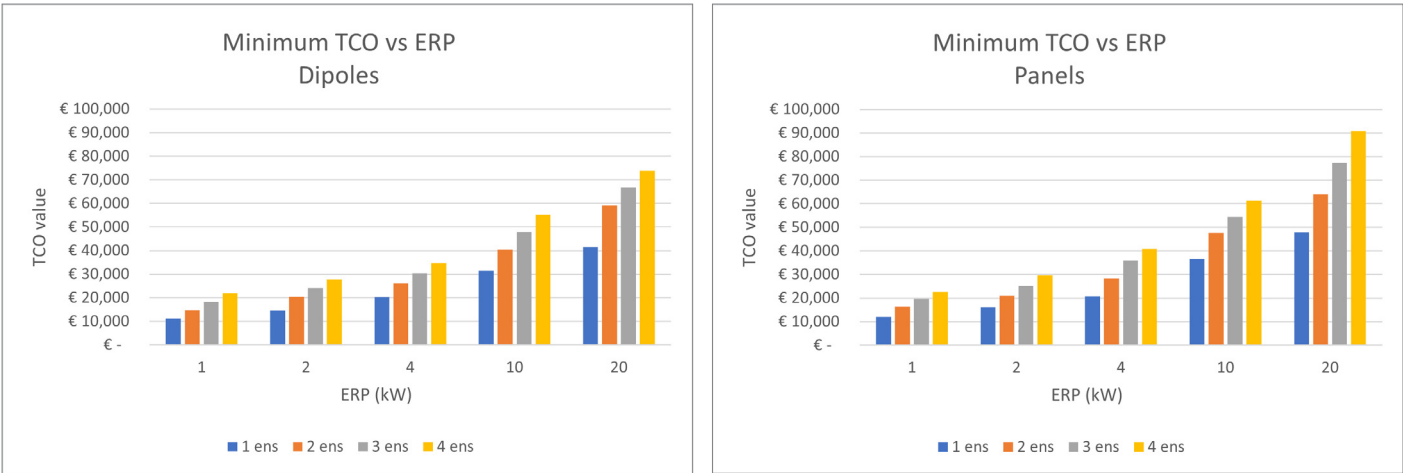


Figure 16-9: Minimum TCO vs ensemble ERP, for 1 to 4 ensembles

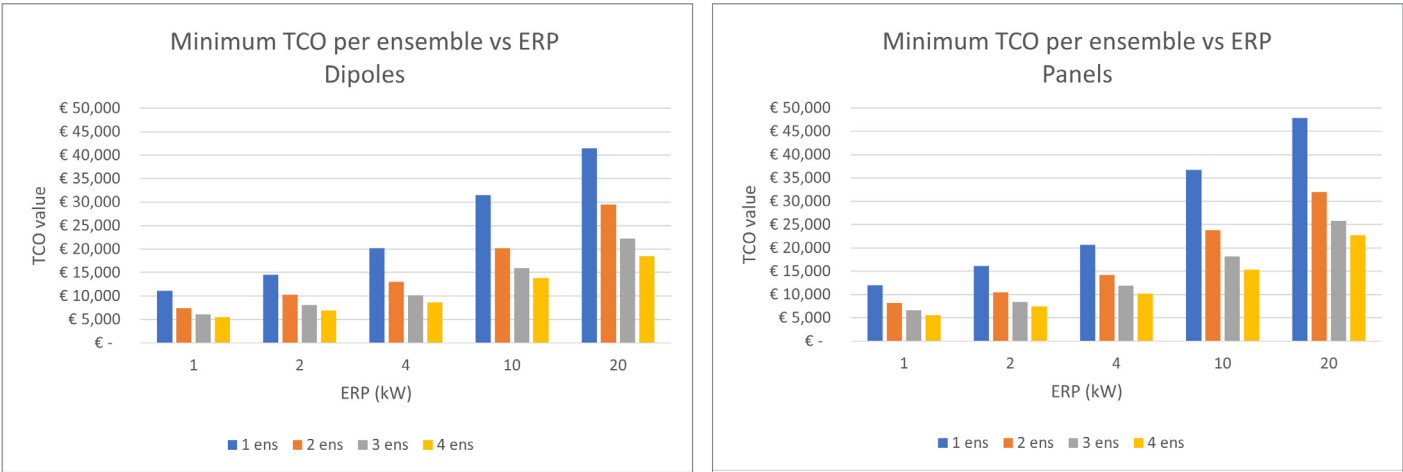


Figure 16-10: Minimum TCO per ensemble vs ensemble ERP, for 1 to 4 ensembles

In general, the TCO for sites using panel antennas is slightly greater than for dipole antennas with the percentage difference ranging from around 3% to 20% depending on the scenario with an average of around 13%. We also note that the panel antennas provide greater coverage than the dipole antennas. Comparing the -3 dB contour of the HRP in Figure 16-1 and Figure 16-2 shows that the panel antennas have approximately 40% increased area coverage. The minimum difference is for the 1 ensemble with 4 kW ERP per ensemble scenario, the largest being for the 4 ensembles with 20 kW ERP per ensemble scenario. This variation is due to the quantized price points for both transmitters in terms of power stages generally being available in steps of 1.2 kW and antennas having steps of 2 to 4 bays. We expect dipole arrays to have a lower TCO due to their lower cost, however in this comparison they also have approximately 40% smaller coverage footprint than panel arrays for the same ERP.

Figure 16-10 shows the minimum TCO per ensemble. The TCO per ensemble is usually used to set the access fees for services, plus an additional allowance for other ongoing costs. As expected, the TCO per ensemble reduces as the number of ensembles increases, due to the fact that each ensemble shares the same antenna system. As an example, considering the site costs only we see the cost per ensemble for a dipole-based system for one ensemble being around €20,000 PA while for three ensembles it is €10,000 PA. Given 20 services on the ensemble, this equates to €500 PA per service. This is a very low figure, however Network Operators also have to take into account multiple other additional costs such as for the multiplexing network, telecommunications costs and ongoing operations and maintenance costs. This example does however provide a demonstration of why it is very important to ensure that the most expensive part of the DAB+ network — the transmission system — is designed to achieve the minimum TCO.

Looking at the sensitivity to power cost, we find that as the cost of power increases, the number of bays required to minimise the TCO also increases. For example, if the cost of power is increased from €0.20 to €0.40 / kWhr we see the optimum number of bays increase as shown in Table 16-4. Here we see that even though the power cost has doubled, most scenarios do not have any difference in the number of bays required to minimise the TCO. The TCO value has of course increased, however only in cases where the minimum for €0.20 / kWhr is close to the upper cost threshold of increasing the number of bays does the number of bays increase. This is due to the quantized nature of the costs for transmitters and antenna systems.

		Number of ensembles	ERP				
			1	2	4	10	20
Dipole	1	0	2	0	2	0	
	2	0	0	0	0	8	
	3	2	2	0	0	0	
	4	2	0	0	8	0	
Panel	1	0	1	0	2	2	
	2	1	0	2	0	0	
	3	0	0	2	0	0	
	4	0	2	0	0	6	

Table 16-4: The increase in the number of bays required to minimise TCO for power cost of €0.40 / kWhr compared to €0.20 / kWhr.

Looking at the impact of the amortisation period we see that increasing it from 20 to 30 years causes a small reduction in the overall TCO PA for all scenarios. For example, for 3 ensembles using a dipole array at 10 kW per ensemble, the ensemble TCO PA reduces from €47,791 to €43,284 or 11%. While all cost reductions are welcome, we generally do not see that the amortisation period has a significant impact on the system requirements to minimise the TCO.

16.5 Discussion

Overall, we see that the use of dipole antenna arrays incurs a slightly lower overall TCO per annum, however we also note that there is a difference in the coverage area for the same ERP. Dipole arrays typically have around a 6 dB front to back ratio making them slightly directional, they also often suffer from shadowing notches at the rear of the antenna (at 180°) due to the impact of the tower they are mounted on.

On the other hand, 4 panel arrays as shown in Figure 16-2, can have near omni-directional HRPs typically with around 3 dB ripple, but also can be shaped using appropriate phasing between elements on different sides. This allows the generation of complex HRPs to help minimise both overspill into different licence areas and interference with co-channelled transmissions.

16.6 Conclusions

This study demonstrates that by careful selection of the primary elements at a transmitter site, those being the antenna and its gain through the number of bays, and the transmitter power, that the Total Cost of Ownership can be minimised.

The examples shown should be used for guidance only, as costs will vary for equipment and sites depending on the individual site requirements and cost drift over time.

This study provides the equations and methodology which can be used to generate comparative studies, which can then be applied during DAB+ network high level and detailed design to ensure that the TCO of both individual sites, and eventually the entire transmission network, are minimised in the long term.

17. Annex D: About WorldDAB

WorldDAB is the global industry forum for digital radio, facilitating the adoption and implementation of broadcast digital radio based on DAB / DAB+.

WorldDAB provides advice and support on all aspects of the switch from analogue to digital radio including regulation, licensing, technical trials, network build-out, marketing and production of new digital radio content.

WorldDAB is a not-for-profit association with legal personality governed by Swiss law and by its Statutes.

WorldDAB membership

WorldDAB has over 110 members from 33 countries representing companies and organisations from across the radio ecosystem, including broadcasters, network operators, car makers, device manufacturers and technology providers.

WorldDAB membership is open to companies and organisations considering the use of the DAB family of standards for the broadcast of digital radio. Companies considering WorldDAB membership must first agree to the WorldDAB Statutes before being considered for WorldDAB membership.

A reduced fee is available to companies with fewer than 10 employees, broadcasters, academic institutions and governmental bodies from lower-income countries. Please email the Project Office at projectoffice@worldadab.org to find out more.

How WorldDAB works

WorldDAB is a membership organisation which operates for the benefit of its members.

WorldDAB has several committees that are governed by its members. Working groups and task forces focus on specific areas related to the deployment of DAB. The operational day-to-day running of WorldDAB is undertaken by the WorldDAB Project Office.

WorldDAB General Assembly

The WorldDAB General Assembly is an annual member meeting where members make decisions on the strategic direction of WorldDAB. The General Assembly provides an opportunity for members to share their experiences and insight on all aspects of digital radio rollout.

Steering Board

The Steering Board comprises elected representatives from WorldDAB member organisations who oversee the operational and financial management of the organisation, implementing strategic measures to ensure the successful rollout of DAB+.

Marketing Group

The Marketing Group helps broadcasters develop a DAB+ marketing strategy by sharing resources, case studies and best practice from countries and regions where broadcasters are already informing their listeners about DAB+.

Asia-Pacific Committee

The Asia-Pacific Committee addresses the unique needs and concerns of broadcasters in the APAC region, offering support and assistance in the successful rollout of DAB+. Working under the guidance of this committee is the Asia-Pacific Technical Group, which gives guidance on the technical aspects of implementing DAB+ digital radio, with help and advice that is tailored specifically to the needs of the region. The Group works in tandem with the WorldDAB Technical and Spectrum & Network Implementation Committees.

Finance Committee

The WorldDAB Finance Committee is responsible for developing, in conjunction with the President and Project Director, an annual budget for approval by the General Assembly. It proposes broad financial policy objectives to carry out the activities of the Forum. It ensures appropriate processes exist to monitor and oversee the management of all aspects of risk as well as oversee revenue generation and business processes.

Technical Committee

The Technical Committee oversees the DAB technical standards, ensuring that receiver equipment and broadcast technologies are compatible, upgrading and advancing the DAB Standards in line with other technical developments, and future proofing broadcast radio equipment for broadcasters and manufacturers.

Spectrum and Network Implementation Committee

The Spectrum and Network Implementation Committee provides guidance on DAB network implementation, including how to build a transmission site, multiplexing and sound processing, monitoring and signal distribution and data service implementation. The Committee also monitors and lobbies to ensure frequency availability for DAB+.

Automotive Working Group

The Automotive Working Group brings together the broadcast and automotive industries to collaborate on the optimum implementation of DAB+ digital radio in the car to benefit the driver. The Group's work is focused on three specific areas: improving the user experience for in-car digital radio, ensuring optimal performance of all areas of the DAB radio in the car, including performance of the antenna within this experience. This group also works on the same goals for all aftermarket DAB devices, both line fit quality and stand-alone devices.

How DAB Family of standards are maintained

Based on the needs of the market, the Steering Board, Technical Committee and its Task Forces draw up a set of user requirements that outline the market parameters such as user functions, timescales and price range. Once consensus on the user requirements is reached, the Technical Committee and relevant Task Force develop the specifications.

This will include examining the technological implications of the user requirements and examination of the technologies available. Once the Technical Committee reaches consensus on the resulting specification, and the Steering Board's support for it has been ensured, the specification is put forward to the Steering Board.

The Steering Board gives the final approval of the specification. It is then offered for standardisation to the relevant international standards body (i.e. ETSI or CENELEC) through the EBU/ETSI/CENELEC Joint Technical Committee or the International Telecommunication Union (ITU-R or ITU-T).

18. Annex E: About the author



Dr. Les Sabel

Les is a member of the WorldDAB Technical Committee and also Chair of the WorldDAB Asia-Pacific Technical Group.

He has over 35 years of experience in communications systems, including broadcast digital radio (DAB/DAB+/DMB and DRM/DRM+), 2G to 5G mobile communications, wireless broadband and satellite communications.

Les founded S-Comm Technologies Pty. Ltd. in 2008 to work with the global radio industry on the development and implementation of digital broadcast radio. S-Comm has provided services to many Australian and international companies and

has provided independent engineering consultancy to WorldDAB, the ITU, and public service and commercial radio networks and regulators in numerous countries across the globe.

Previously, Les has held senior positions in companies including RadioScape Ltd. (UK), Verticalband (UK), Lucent Technologies (USA/UK) and the Institute of Telecommunications Research at the University of South Australia. His expertise covers the development of state-of-the-art communications infrastructure and receiver equipment, systems engineering, business development, product and project management, and education and training. He has worked with companies across the globe to deliver new products and services. He has authored numerous journal and conference papers and been granted eight patents.

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