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Digital Radio

Common problems in DAB receivers

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Abstract

A large number of DAB receivers have been tested at Kingswood Warren since the test lab was first opened. These have ranged in quality from very good to quite poor, and it has been observed that the worst units have often had very similar defects despite coming from different manufacturers. This document attempts to describe these faults so that all receiver manufacturers can improve their products.

Key words: Digital Radio, DAB, Digital Audio Broadcasting, receiver, common problems

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Authorisation of the Head of Research is required for publication.

Contents

1. Introduction

Over the last two years, a number of DAB receivers have been tested under lab conditions by BBC Research and Development at Kingswood Warren. Some of the receivers tested were commercial products purchased through retail channels, whilst others were submitted by manufacturers in varying stages from breadboard through prototype to pre-production and production units.

As a result of this testing, it has become obvious that a number of different manufacturers, working independently, have developed receivers with surprisingly similar flaws. This document attempts to list the most common of these to provide pointers to all manufacturers so that the quality of DAB receivers can be improved.

One of the first things about a new radio that the user will notice is the quality of the user interface. Historically radios had two very simple controls, one[1] to tune to the desired station, the other a combined control for the volume and turning the receiver on and off.

Relatively recently, push button presets have been added, and the old “pointer and scale” tuning guide has been replaced by a numeric display of the frequency. Some DAB receivers have simply extended with this design, often resulting in easy-to-use radios. Others have added so many multi-function buttons that they are almost impossible to operate even with constant reference to the handbook.

Traditionally home Hi-Fi tuners have received a fairly static range of services, whilst car receivers have had access to a dynamically changing range of services as the receiver moves from one transmission area to another. The Radio Data System, RDS, was developed to allow car radios to automatically re-tune as the vehicle moves from one service area to another.

DAB takes many of the ideas tried out in RDS and makes them much more powerful and useful, making radio an even more desirable and flexible broadcast medium for the 21st century. It is a great shame, therefore, that so many DAB receivers fail to benefit from the potential gains.

With AM and FM radio services, the user is frequently aware of the limitations of such simple systems as the sound squeaks and pops constantly. One of the other core aims during the development of DAB was to allow high quality audio to be received both in the car and on portable receivers. It is encouraging to see that almost all receivers have been able to realise this goal, although some do impose rather low limits on the maximum bitrate (quality) of an individual service, and can exhibit bizarre failure modes if those limits are exceeded.

DAB also adds some pure data capacity, however most receivers are unable to receive these services as specialist decoders are required. As a result it is too soon to list common problems as too few examples have been tested for faults to become common!

It should be noted that this document only lists areas in which a number of receivers have been found to have similar problems. Areas of the DAB standard where most or all receivers are compliant are not referred to. This is not because these areas are unimportant, but because it is felt that individual manufacturers are already handling these aspects in a satisfactory manner.

This document is also not intended to describe the correct way features should be implemented, since there is no one correct way. For almost all aspects of DAB, the receiver manufacturer has a number of valid options to choose between, and it is these choices which will allow receivers to remain distinctive and to gain a competitive advantage in the market place. What is listed are areas where several products exhibit similar features which users will find undesirable and may create a bad impression of DAB in the market place.

1. Possible split into two controls, one for frequency with a separate “band-select” switch

2. Tuning

Fundamental to every use of radio is the concept of selecting the desired service, a process colloquially known as “tuning” the receiver. Both DAB and (to a lesser extent) RDS offer many facilities that can be used to make the task of tuning a modern radio much easier than in the past.

The most significant of these is that both DAB and RDS allow each service can be named, thus allowing the user to identify the desired service much more easily. DAB is able to improve on RDS due to the much greater bandwidth available, which allows information to be sent about services other than the one actually being received.

Receivers can take advantage of this extra information to build up a list of services that are available. This “tuning list” can then be used by the listener to select the desired station quickly and easily.

The choice of services available may change, either because the receiver has been moved to a new location, or because the multiplex has been reconfigured. If the choice of services does change for either of these reasons, a DAB receiver is able to automatically add new services to the tuning list even before the user chooses to receive them.

Unfortunately not all current receivers benefit fully from these improvements for a number of reasons, some of which are listed in the following sections.

2.1 Multiplexes

The DAB spectrum is divided into a number of channels (7 in the UK) each of which carries a multiplex of services, typically somewhere between 6 and 12. These services may optionally be sub-divided into secondary service components. This is obviously a fairly complex structure, and it is one that the majority of users will have no wish to understand. It is likely that, given the choice, most will express the wish to:

- listen to Mogolia Radio

rather than

- listen to Mongolia Radio on the Neptune Multiplex broadcast on 223·936MHz

Once a service has been selected, the user *may* wish to discover which multiplex operator they are using, however most will probably be completely un-interested. There should almost never be a need to know on which frequency[1] a multiplex is broadcast.

It is likely that providing this sort of functionality will require the receiver to maintain a semi-permanent list of possible multiplexes, probably determined by scanning the internationally agreed frequency bands.

Unfortunately receivers do not always hide these technical details from the user, requiring the user to manually select the frequency of the multiplex, then as a separate stage select the desired service. This approach shows a fundamental failure to understand one of the core aims of DAB – to make radios easier to use.

1. or channel

2.2 Part-time Services

In most countries, a radio station is typically granted a licence to broadcast for a number of years. Conventionally the station will either broadcast continuously, or, if it is a small station, it might shut down for a period overnight. In the past it has been unusual (although not unheard of) for one radio station to broadcast during the day and the same frequency to be used by a separate station overnight. DAB can be used in the same way as a conventional AM or FM radio, except that a single radio station is usually referred to as a service, and may potentially comprise more than one audio stream, known as Secondary Service Components, of which more later.

In many countries there is pressure on broadcasters to offer as many services as possible via digital delivery mechanisms to encourage people to adopt the new technology. It is becoming more and more likely, therefore, that multiplex operators will offer a range of "part-time" services sharing access to a portion of a DAB multiplex. One example might be a continuous spoken travel news service during the rush-hour sharing capacity with a rolling news service overnight and a book-reading service during the day, as illustrated in figure 1.

DAB carries sufficient information to allow the tuning list to be updated automatically as these changes happen. A service is something which normally persists for some time, although not necessarily continuously. It would therefore be sensible for any new services detected by the receiver to be added to the previously known list of services.

Given that a traditional radio station license usually last for a period of years, it is likely that DAB services that have been removed from the multiplex will probably re-appear in the future. It is therefore sensible for services which are removed from the multiplex to persist in the tuning list, at least for a time.

Inevitably there will be times when the service selected by a user is not actually being broadcast at that instant, and the receiver will be required to display a suitably informative message in this event, for example "Service not currently on-air – try again later" rather than a curt "No service".

Unfortunately many present receivers do not handle this scenario at all well. Most require the user to manually start a re-scan which can take up to five minutes in order to "discover" new time-shared services. Often this re-scan process will wipe the receiver's memory of any previous services, thus making it almost impossible for the receiver to present a complete list of services to the user. Even more confusingly, two friends with identical receivers may end up with different lists of services available depending on the time of day when they initiated the auto-scan, most likely resulting in irate telephone calls.

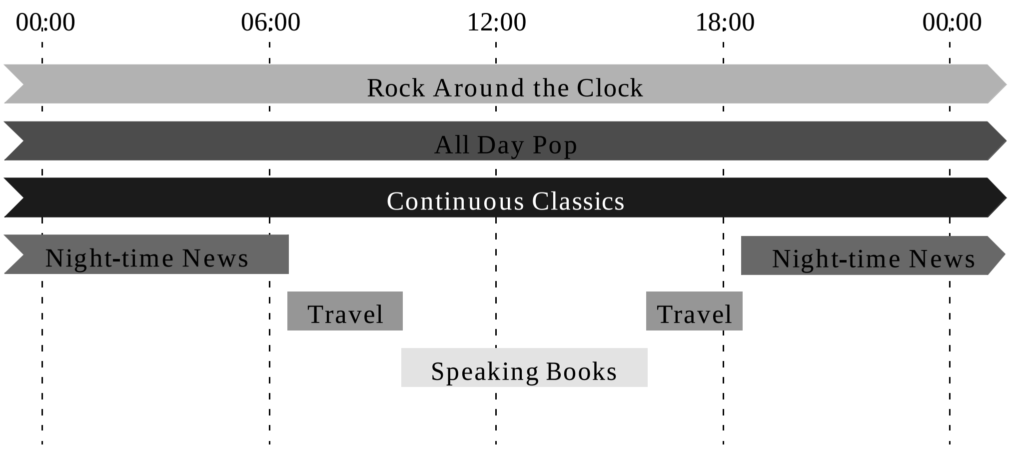

Figure 1: Part-time Services

2.3 Secondary Service Components

Imagine you are the operator of the **World Sport** service (radio station). Tonight there are two really popular football matches being played simultaneously. Which match should you cover, or should your station switch between the two? DAB gives you a third option – cover both matches continuously!

This flexibility is provided in DAB through a mechanism known as secondary service components. Unlike services, secondary service components are intended as strands of programming which exist for a short time and then terminate.

As secondary service components are intended to have a finite lifetime, the receiver should not permanently add components to the tuning list but would only list them when they are actually present in the multiplex, and possibly for a short time (perhaps as long as an hour) after they have been removed.

Most of the time the receiver is only able to determine the presence of a secondary service component when it is actually tuned to the correct multiplex. It is a matter for the receiver manufacturer to decide whether historic secondary service components in non-tuned multiplexes should be displayed or not. This decision may be coloured by the fact that, unlike services, DAB offers no way to uniquely identify a secondary service component, thus making it almost impossible for the receiver to guarantee that the correct secondary service component is selected.

Many current receivers do not realise the full benefit of the flexibility bestowed by secondary service components, although there are several different problems. Some receivers permanently add secondary service components to the tuning list, thus making them appear long after they have been discontinued. Other receivers ignore secondary components completely, denying the user access to audio programming they may wish to receive.

2.4 Presets

Modern analogue radios offer the user a number of presets to rapidly switch between different services. Presets are still very much appropriate to DAB receivers, however they can also be a cause for frustration for users if poorly implemented.

A key area of potential confusion is the handling of DAB secondary service components. Secondary components are intended for finite-lifetime programme strand, in comparison with services which should have a relatively long lifetime.

Presets programmed with secondary service components are a cause of confusion to listeners who might be surprised when a preset programmed during a football match later selects a parliamentary debate!

This situation can arise because the DAB specification does not assign a long-term identifier to secondary service components[1]. As a result it is impossible for the receiver to determine whether the component currently on-air is the same as the one that was being broadcast last time the receiver was turned on.

In some countries, creating a secondary service component is a decision entirely within the control of the multiplex operator, but government approval must be sought to create a new programme service. Secondary service components are therefore a very attractive alternative to part-time services in some circumstances, and their use is likely to increase in the future.

Unfortunately some receivers do allow a user to programme a preset with a secondary service component, thereby causing confusion for some users and limiting the use broadcasters can make of secondary service components.

1. The ECC+SId+SCIdS combination is only guaranteed to be retained while the component is on-air and can be re-used (see volume 2 of the DAB Guidelines[3] paragraph 3.3.1.9.2).

2.5 Scanning

In order to fully benefit from all the facilities of DAB described this far, it is almost inevitable that most receivers will sometimes need to scan the frequency band to update the list of services available. This scanning is probably best done in the background. If this is not possible for technical reasons (e.g. on a portable receiver where battery life is an important concern) then a scan should only be performed in response to a user selection.

When scanning the band it is important to only add services to the list. By definition, part-time services may not be broadcast all of the time, and losing a service that wasn't on-air at the instant the scan was performed is probably a bad idea!

That said, it is equally important that a means is provided to prevent the service list filling up with services that are no longer broadcast. It is therefore highly desirable that the user has some way to remove these services. This could be achieved in a number of ways, for example:

- automatically prune services which have not been received for a long time
- provide a function which removes a single service from the list
- provide an optional "wipe memory" function when re-scanning the multiplexes

Most of the current receivers take a considerable time to scan the UK DAB band of seven channels, and to cover the worldwide spectrum allocation currently takes many minutes. This is obviously unacceptable to most users, so it is important to find ways which allows the receiver to perform these scans more quickly and/or in the background.

One solution might be for the receiver to scan periodically when in stand-by mode. The regularity of such background scans would have to be tailored to the power consumption and power source of the receiver – a portable DAB receiver running on a pair of AA-cells scanning every 30 minutes is probably a bad idea, but might be acceptable[1] for a Hi-Fi tuner plugged into a mains power source. A car radio will undoubtedly require more complex algorithms to handle, for example, the loss of signal while parked in an underground car park without draining the car battery.

2.6 Simulcast Services and Multiplexes

Although uncommon at present, the DAB specification allows for a single service to be simulcast as parts of two different multiplexes, or even for a single multiplex to be simulcast on two frequencies. If identical services are being simulcast, they should have the same SId value (ServiceID). Similarly, if identical multiplexes are being simulcast, they should have the same EId value (EnsembleID).

This situation is already known to exist in the England/Scotland border region where the Digital One multiplex is broadcast on different channels in the two geographic regions.

Some receivers have implemented a tuning model which works against the potential benefits of simulcasting a service or ensemble. When performing an auto-scan, only one possible location for each SId value is stored, usually either the one with the lowest or the highest frequency. These receivers might be just able to decode one of the two signals, yet the other may be much better quality. If the weaker one is stored in the tuning list, the user will effectively be unable to obtain good quality reproduction of the service despite a good signal being available on another frequency.

1. Ignoring environmental considerations

2.7 Centre Frequency

The current DAB specification allows for the multiplex to be broadcast at any frequency in the ranges

- 47 – 68MHz (Band-I)
- 88 – 108MHz (Band-II)
- 174 – 240MHz (Band-III)
- 470 – 590MHz (Band-IV)
- 598 – 862MHz (Band-V)
- 1452 – 1492MHz (L-Band)
- 784kHz – 3GHz (cable and satellite only)

In all cases, the centre frequency is specified to be on a 16kHz lattice plus or minus half the carrier spacing for the mode in use (±500Hz in Mode-I rising to ±4kHz in Mode-III).

Frequencies below 150MHz are likely to pose significant practical problems (e.g. fractional bandwidth of filters) and are unlikely to be used, however band-III and L-band are very commonly used for DAB services. International agreements have been put in place which list 87 “recommended frequencies”[5] covering Band-III and L-band, and coverage of these should be regarded as a minimum requirement for all receivers.

The UK currently only uses a small subset of the 87 agreed frequencies, and almost all receivers have been able to decode this subset. Unfortunately several receivers cannot decode all 87 recommended frequencies. It has also been observed that, unlike analogue receivers, the fault may exist only at a single frequency, usually due to an incorrect value being programmed into the tuner. As a result it is no longer sufficient to check a receiver using spot frequencies at the top, bottom and middle of the desired band – all channels must be checked individually[1].

2.8 Multiplex Size

The DAB specification is rather lax in specifying the maximum number of services in a multiplex, although it does define a maximum of twelve components (primary and secondary) in a single audio (programme) service, or eleven for data services, and a maximum of 64 subchannels. In theory the number of services in a single multiplex is approximately 4·3 billion!

Fortunately practical limitations (primarily the bitrate available in the FIC to carry all the information) mean that it is impossible to build such huge multiplexes and still comply with the minimum repetition rates defined in the Guidelines[3].

In any practical multiplex, there are unlikely to be more than thirty services and a total of fifty components. An individual service could easily have up to the maximum twelve components (primary plus eleven secondary).

Unfortunately some of the receivers tested have limitations well below these figures, sometimes allowing only eight services with one secondary each. These receivers are unable to decode multiplexes from some of the more adventurous DAB broadcasters, and the situation is unlikely to improve. In some cases the receiver may be able to decode parts of the multiplex, but in a couple of cases the receiver has simply given up and has been unable to reproduce any of the audio in the multiplex.

2.9 Audio and Data

The DAB specification allows a data service to contain secondary service components carrying audio. No practical applications have yet been developed which rely on this functionality, however.

Many receivers are unable to decode such services. Although not a problem for self-contained receivers, those units equipped with RDI interfaces for connection to external data decoders may wish to offer data service selection as a configurable option.

1. Spot-checks are acceptable for production testing, but the full sweep tests must be conducted during the prototype testing.

2.10 Subchannels

From the user point of view, a DAB multiplex is broken down into a number of services, some, all or none of which may have secondary service components. However, from the receiver's point of view, there is a second way of breaking a multiplex down – into a number of subchannels.

Subchannels are the parts of the DAB multiplex which actually carry the audio, whilst the services and components form a directory to allow the correct subchannel to be selected. Once the user has chosen a service, the receiver will begin to decode the subchannel corresponding to the primary component. As a result of a multiplex reconfiguration, the mapping from services through to subchannels may be changed, and the receiver may be required to stop decoding the original subchannel and start decoding a new one. In almost all cases this change can be made without the user being aware of the change.

A typical, albeit simplified arrangement showing the entire "tree" from RF channel through to subchannels is shown in figure 2.

This shows a relatively small multiplex carried in RF channel 12B. In it, the receiver can see three services, two of which have secondary service components. The primary component of the **Music** service is the same audio as the secondary component of the **Country** service, and to maximise the capacity in the multiplex, these two components both refer to the same subchannel. Notice also that the primary component may at the option of the broadcaster be omitted, as for **Capital** and **Country**, in which case the receiver should, if needed, assume that the primary component has the same name as the service and an SCIdS value of zero.

It has been noticed that not all receivers correctly distinguish between the service structure and the subchannel structure, resulting in receivers that decode the wrong audio after a multiplex reconfiguration. Some even become confused when two services simply refer to the same audio content, possibly with the service name flashing on the display, or with one of the two services disappearing completely. Obviously, neither is acceptable to a consumer.

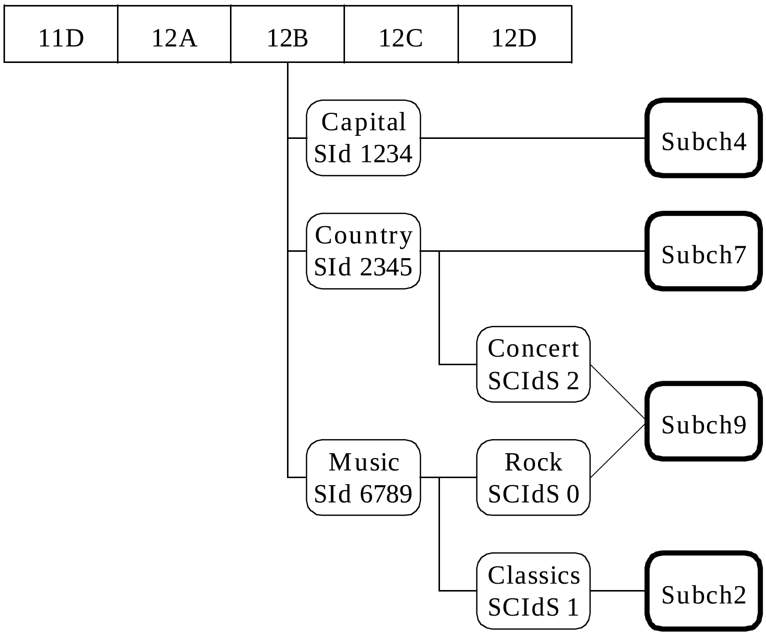

Figure 2: Services, Secondary Service Components and Subchannels

3. Multiplex Reconfiguration

In days gone by life was simple: you tuned to an AM or FM service and you got some audio. If the receiver moved out of the transmission area, the quality steadily degraded until the service was “lost”. This was an inconvenience to many people, primarily those undertaking long journeys by motorway who found it necessary to re-tune the radio repeatedly. RDS was added to FM as one way around the problem. RDS provided the radio with just enough information to allow it to re-tune itself, however the basic principle of the service either being there or not being there remained.

DAB has changed the situation somewhat in that services can be added to or removed from the multiplex at any time, the bitrate and protection profiles can be changed, perhaps to free up bitrate for other services, or to take advantage of bitrate freed up by other services.

The process of adding a service, or shifting bitrate from one subchannel to another is known as multiplex reconfiguration. In a properly implemented receiver it is almost always possible to continue to decode all of the services with no audible disturbance.

3.1 Subchannel Changes

DAB allows quite a large amount of flexibility in the handling of the subchannels used to carry the audio. Subchannels can be increased and decreased in both bitrate and protection level (ruggedness), and their location within the multiplex can be adjusted.

Subchannels can also be added to the multiplex, or removed from the multiplex. The addition or removal of a subchannel will be matched by a change to the service information, but does not necessarily mean that a service has been added or removed.

The sort of changes that might be expected in a typical DAB multiplex are shown in figure 3. Assuming full-rate audio is used, changes of this sort should be completely invisible to the user of the radio.

Unfortunately some receivers have proved unable to cope with changes to the subchannels in the multiplex. Sometimes it is simple changes in the subchannel position, size or protection level which cause problems, in other cases it is the addition and removal of subchannels.

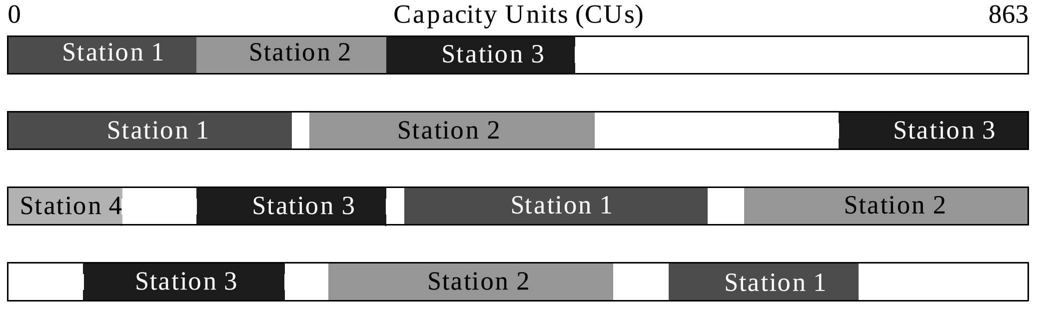

Figure 3: Subchannel reconfigurations

3.2 Services Changes

As mentioned in section 2.10, the receiver should select a single component and follow it during multiplex reconfigurations. Consider the multiplex reconfiguration shown in figure 4.

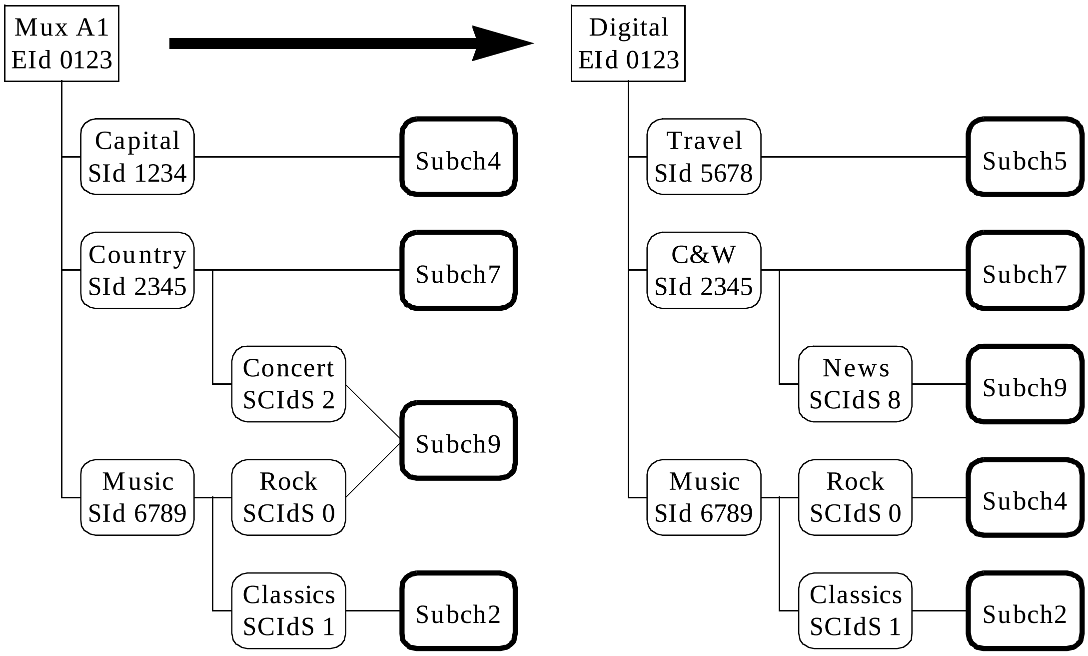

Figure 4: Service reconfiguration

Several things have changed during this reconfiguration:

i) The ensemble has been renamed **Digital**

ii) The **Capital** service has ended, but is likely to return and should not be removed from the tuning list.

iii) The **Travel** service has been added to the multiplex and should be added to the tuning list.

iv) The **Country** service has changed its name and is now known as **C&W**. The tuning list and any presets should be updated to reflect this change.

v) The **Concert** secondary component has been discontinued and may or may not return in the future. It should be removed[1] from the tuning list.

vi) The **News** secondary component has been added to the renamed **C&W** service and should be added to the tuning list.

vii) The primary component of the **Music** service, **Rock**, is now carried in subchannel 4 instead of subchannel 9.

The user experience at the moment of the reconfiguration will naturally depend on the service they were listening to at the moment of reconfiguration.

- **Capital** listeners will obviously lose the service they were listening to. The receiver may choose to select an alternative service based upon other criteria (e.g. programme type (PTy) information, previous user selection, …) or may simply mute and display a message along the lines “This service is not currently being broadcast. Please select another service.”
- **Country** listeners should not hear any disturbance to their service, although the service label, if being displayed, should be updated to reflect the new name **C&W**.
- **Concert** listeners should automatically be moved to the **C&W** service. The service label, if displayed, should be updated appropriately.
- **Music** and **Rock** listeners should start to receive audio from subchannel 4 instead of subchannel 9. This may involve a short audio mute of up to 360ms due to the emptying and re-filling of the time-interleaving stores.
- **Classics** listeners should not be able to determine than a reconfiguration has taken place until they next try to tune the receiver, when they would observe the new and renamed services.

1. Removal of secondary components should arguably be performed after a couple of hours delay.

4. Programme Associated Data

DAB allows a small amount of data to be carried alongside the audio. The most common application for this is to carry Dynamic Labels, a short piece of text which can be changed periodically, or Dynamic Range Control information.

4.1 Fixed PAD (F–PAD)

The F-PAD comprises a pair of bytes at the end of each audio frame. These two bytes actually fulfil a number of different roles, including:

- The type of X-PAD, if any
- The presence or absence of DRC values
- The content type of the audio (music / speech / uncoded)

In order that all of these functions can be used simultaneously, the F-PAD is effectively Time Division Multiplexed. For example, if one frame of audio carries F-PAD signalling short X-PAD, all subsequent audio frames should be assumed to contain short X-PAD until an F-PAD frame signals variable X-PAD or no X-PAD.

Some receivers have been implemented in such a way that this time division multiplexing does not work correctly. These receivers can get confused when two or more of the possible F-PAD functions are present simultaneously. Typically the result is that one or more of the functions (X-PAD, DRC etc.) fail to work correctly, if at all.

4.2 Extended PAD (X–PAD)

X-PAD occurs in two distinct types, short and variable length. The short X-PAD is only able to carry one application per audio frame, whilst variable length X-PAD can potentially carry four applications per frame.

At present the only application in common use is Dynamic Labels, however it is likely in the future that other applications will become more common, and it is important that current receivers should ignore applications for which they do not have the correct decoder.

Given that the X-PAD is carried in the audio frame, the data rate is obviously linked to the sampling frequency of the audio: low sampling frequency audio subchannels have half the number of frames per second. Some receivers are unable to cope with this, and fail to correctly decode applications carried in X-PAD in a half-rate audio subchannel.

In total there are four common modes for the carriage of X-PAD applications:

- 48kHz sampling, short X-PAD
- 48kHz sampling, variable length X-PAD
- 24kHz sampling, short X-PAD
- 24kHz sampling, variable length X-PAD

Very few receivers are currently able to decode all four of these combinations correctly. Even fewer are able to handle situations where two or more applications share the X-PAD data capacity.

4.3 Dynamic Labels

Dynamic Labels are, broadly speaking, an improved version of RDS Radiotext. A short piece of text, up to 128 characters long, is transmitted alongside the audio which is intended to be displayed to the user.

Dynamic Labels are carried as an application within X-PAD at the end of the audio frame. Even if the entire X-PAD was available for this one application, the number of bytes available is not high enough to allow the entire 128 character Dynamic Label to be carried in a single frame. The receiver will therefore have to combine chunks of data (known as “segments”) from a number of frames in order to form the complete label.

Although many receivers do manage to correctly assemble the segments, a few can present “half-received” labels, resulting in amusing and/or embarrassing labels being displayed! Other receivers fail to handle special-cases correctly, for example labels which are short enough to fit into only one or two segments, or where the “clear label” command code is sent rather than a piece of text to be displayed.

Sufficient signalling is present in the X-PAD application data to allow all these problems to be avoided.

4.4 Dynamic Range Control

Dynamic Range Control has been known under a different name for a very long time: as audio compression. The big difference in DAB is that the receiver performs the compression rather than the transmitter. This allows the compression to be turned off by the user when it is not needed, unlike analogue radio where the control is in the hands of the broadcaster. This allows users in quiet environments (e.g. listening at home) to benefit from the full dynamic range of the music while listeners in more noisy environments (e.g. in a car) can artificially increase the volume of quiet portions above the ambient noise level.

Of course, the broadcaster must still have some control over the compression applied by the receiver in order that the highest possible quality is maintained across all the receivers available in the market place. In DAB this is achieved by sending a helper signal in the F-PAD of each audio frame known as the DRC signal. This exactly defines how much compression should be applied to the next audio frame.

According to the DAB specification, the DRC range will be 0·00…+15·75dB in steps of 0·25dB. A few receivers offer alternative ranges **in addition to** the standard range with the choice as to the degree of compression being given to the user. Unfortunately some receivers **only** offer non-standard ranges, and this is can give rise to undesirable artefacts (e.g. clipping) which the user cannot choose to disable.

It has also been observed that some receivers introduce a 15·75dB attenuation whenever DRC is activated by the user, presumably in an attempt to prevent the digital audio exceeding 0dBFS. This choice is obviously a matter for individual manufacturers, however it is likely that most users would be confused if activating DRC (labelled “loudness” on some receivers) actually makes the sound quieter! The guidelines for DAB actually state that:

> *The gain values transported as DRC data should be coordinated with the associated audio levels in a way that will eliminate the possibility of digital full scale clipping in receivers using DRC, taking into account the existence of both interpolating and non-interpolating receivers.*

This allows a receiver to merely increase the gain, and any clipping introduced as a result is a cause for complaint against the broadcaster and is not a concern for the receiver manufacturer. That said, a receiver must simply clip the signal should DRC cause an audio sample to exceed full-scale – “wrapping” large positive values around to negative values (or vice versa) causes really quite unpleasant noises to be produced!

4.5 DRC Timing

The timing of the DRC helper signal and the raw audio is obviously critical. The DAB specification defines the timing relationship between the DRC signal and the decoded audio as described in the figure 5.

It can be seen that the DRC value carried in MPEG frame *n–1* is applied to the audio samples decoded from MPEG frame *n*. Since the MPEG decoder includes a filter bank with a delay of 240 samples, the DRC value must by delayed in the receiver by a similar amount.

During testing, it has often been found that this delay has been omitted, giving rise to the DRC being applied 5ms too early.

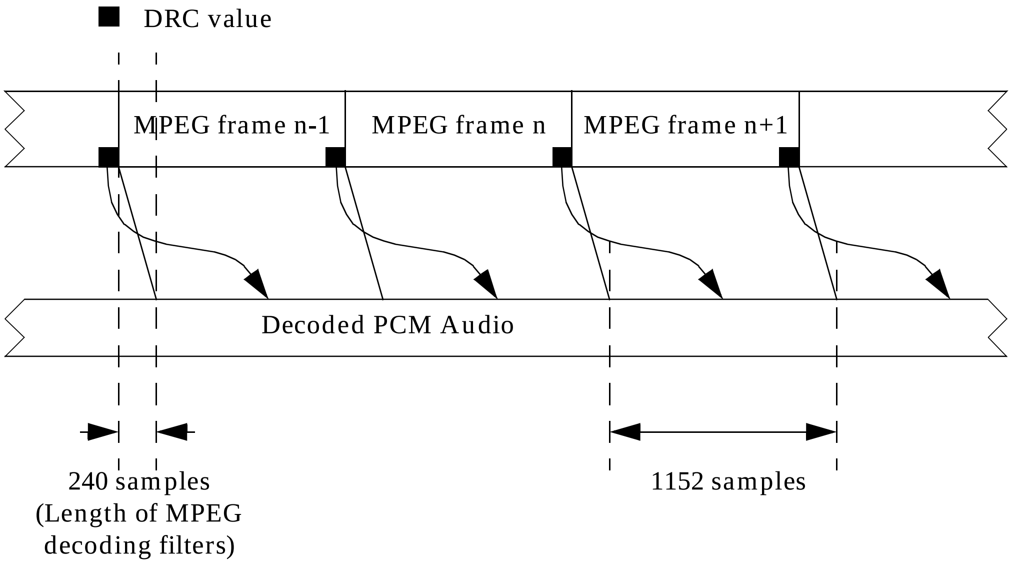

Figure 5: Dynamic Range Control timing

5. Miscellaneous

Although most of the faults identified can be fitted into the earlier categories, a few refuse to be pigeon-holed so easily. This section addresses these issues.

5.1 Display

When RDS was developed, it was assumed that, for cost reasons, receivers would have a very limited ability to display text. As such service labels were kept to only 8 characters, and "star-burst" displays capable of displaying upper case letters only were just about acceptable.

Ten years later, a disappointing number of manufacturers still fit poorly back-lit 8-character LCD star-burst displays to their new, £1,000 DAB receivers. Other manufacturers fit bright, smooth-scrolling graphic-capable multi-line displays to lower cost receivers – in a retail environment it is obvious which will be sold first.

5.2 DAB Character Set

The DAB character set is very similar to the ASCII character set, however there are a number of characters even in the so-called "core 7-bit set" which are different. Many receivers do not correctly display these characters. The characters shown in table 1 are displayed incorrectly by many receivers.

In addition, many alternative character sets are defined for the character codes above 128. These definitions are common to RDS and are shown in Annex E of the RDS Specification, EN50067.

Character code (decimal/hex)	DAB glyph	Notes
10 / 0A	Control code – not to be displayed	Dynamic Label control code for "preferred line break"
11 / 0B	Control code – not to be displayed	Dynamic Label control code for "end of headline"
31 / 1F	Hyphen if word is broken, otherwise not to be displayed	Dynamic Label control code for "preferred word break"
36 / 24	¤	International currency symbol
94 / 5E	—	Full-width line, mid-height (similar to an em-dash)
96 / 60	‖	Full-height double vertical line
126 / 7E	‾	Full-width line, top of character cell

Table 1: DAB character set

5.3 Subchannel Size

The quality of audio in DAB is primarily dictated by the bitrate allocated to the carry the subchannel. Typically this might range from 48kbit/s for a mono speech service up to 256kbit/s for a service carrying a high-quality stereo concert, although the specification allows for bitrates up to 384kbit/s. Some early DAB receivers had limitations on the amount of data they could process, typically of the order of 192kbit/s. This limitation was largely imposed by the cost of producing silicon capable of decoding more of the multiplex, and thanks to Moore's Law should now be remembered as a sad fact of history.

Unfortunately even relatively modern receivers often have problems decoding high-quality services. The failure modes can be quite bizarre, in some cases requiring the user to unplug the power cord before any services, even low quality ones, can be decoded. Other receivers have been seen to display random characters on the display when attempting to decode high-quality services. Even when the chipsets available were unable to handle such large quantities of data, such behaviour would have been unacceptable to most users. To see such problems in modern receivers is inexcusable.

5.4 Forward Error Correction

To cope with errors in the received signal, DAB includes a significant amount of forward error correction. Three different types of error protection are defined, known as UEP, EEP-A and EEP-B, with each type having four or five different "code-rates" (strengths).

Typically in current multiplexes, audio is transmitted using the UEP-3 protection profile, although any of the 13 currently defined profiles can be used. In most cases, data services will use EEP profiles, although this is also not mandated.

Some receivers incorrectly assume that audio will only be transmitted using a small subset of the 13 possible protection profiles, and are unable to decode services transmitted using profiles outside of that subset.

The most common assumptions are that all audio must be transmitted using UEP, or that full-rate audio must use UEP while half-rate must use EEP. Neither assumption is true: any subchannel may use any profile.

6. Future Enhancements to DAB

This document has, for the most part, assumed that the receiver is capable of decoding a single audio strand and has little or no data decoding capability. As DAB matures, this assumption will increasingly be incorrect. This section attempts to describe some of the ways in which more advanced receivers could operate.

6.1 Multiple Subchannel Decoders

Decoding a second subchannel is likely to become more important in the near future. This is partly a result of the increasing number of data services available, but may also be required even if the receiver only wishes to provide applications carried in X-PAD.

One application currently under discussion is an Electronic Programme Guide. An EPG for an entire multiplex, or even a group of multiplexes, could be carried in a single data subchannel, requiring the receiver to decode one audio and one data subchannel simultaneously.

Alternatively, the EPG data for each service could be carried in the X-PAD of that service, requiring the receiver to decode at least two audio subchannels simultaneously.

The provision of an EPG is likely to make a big difference to the usability of future DAB radios, especially those incorporating some form of storage. The chipsets used in these products will need to be able to decode multiple subchannels in order to fully benefit from these features

6.2 Multiple Audio Decoders

Future receivers may well offer the user the chance to decode more than one strand of audio at a time, perhaps to feed speakers in different parts of the house, or for car passengers to listen to using headphones.

Possibly the hardest aspect of handling multiple audio decoders is implementing the user-interface in a satisfactory manner. As already described, some single-audio DAB tuners present the user with so many buttons they are very difficult to operate.

Adding even one extra audio decoder makes the user-interface design that much more demanding. One solution might be that a simplified user interface is provided for each headset in a similar way to that commonly found on MiniDisc and MP3 players.

6.3 Data Decoders

The carriage of data services either as subchannels in their own right or as part of the X-PAD will only increase in the future. At present the range of data applications proposed is increasing, and to fully benefit from these developments, receivers will need to be upgraded.

Work is under way to develop a common application framework which could allow over-air upgrades to be performed in the future. The current reality, however, is that users will need to upgrade their equipment to benefit from new applications.

The overhead in managing these upgrades may make DIY upgrades using a home PC and data from the Internet a more attractive option, and has already been implemented on a few DAB receivers.

6.4 Recorders

The cost of data storage is falling all the time, and the flexibility of such storage is increasing simultaneously. DAB already uses a highly compressed audio format, and it is easy to see how a significant amount of audio storage could be added to a radio receiver with minimal cost. The current popularity of MP3 players is one indicator of how popular such a system might be.

Any DAB product incorporating storage will immediately have problems with the copyright of the material broadcast. Fortunately the DAB audio format already incorporates SCMS which declare the audio to be copyright, original etc. It will become increasingly important that the SCMS is honoured by DAB receivers producing the output audio in the digital domain (e.g. S/P-DIF) or incorporating any means of recording of material.

Appendix A References

1	ETSI EN 300 401	"Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) to mobile, portable and fixed receivers"
2	ETSI TR 101 496-1	"Digital Audio Broadcasting (DAB); Guidelines and rules for implementation and operation; Part 1: System outline"
3	ETSI TR 101 496-2	"Digital Audio Broadcasting (DAB); Guidelines and rules for implementation and operation; Part 2: System features"
4	ETSI TR 101 496-3	"Digital Audio Broadcasting (DAB); Guidelines and rules for implementation and operation; Part 3: Broadcast network"
5	EN 50248	"Characteristics of DAB Receivers"