DIGITAL RADIO AND MARKET FAILURE: A TALE OF TWO COMPLEMENTARY PLATFORMS

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Introduction

Over a decade and a half of rolling-out digital audio systems have left the global digital radio market in disarray, mainly due to platform[1] fragmentation and non-committal positions taken by its main players. Service providers seem to await the coming of mass-produced equipment before committing more contents to specific platforms. Manufacturers on the other hand require the branding and provision of a large range of digital services and some certainty about platform convergence before committing to large-scale production. This stalemate is hurting the market prospects of the two most technically efficient terrestrial digital platforms designed for broadcast services outside the US and Japanese markets[2]: DAB (Digital Audio Broadcasting) and DRM (Digital Radio Mondiale). Although the ageing DAB standard has, over the years, scored some successes in a handful of European countries, neither DAB+ (its more recent and more efficient upgrade) nor DRM (its main alternative) have seen much market deployment so far.

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[1] In this paper, 'platform' refers to a technology that enables the creation of products such as fixed and mobile receivers.

[2] The US and Japanese standards, HD and ISDB, are not the subject of this study: neither standard is affected by the platform complementarity issues discussed here, nor have they made much market progress beyond their respective borders. HD radio is the digital standard developed in the United States in the early 2000s (earlier known as In-Band-On-Channel, or IBOC). Unlike other digital standards, HD radio is proprietary and generally as 'conservative' (i.e. better suited for large broadcasters) as the European DAB standard (Ala-Fossi and Stavitsky 2003). The Japanese digital radio standard known as ISDB - Integrated Services Digital Broadcasting – is by contrast quite radical but technologically not dissimilar to DAB. Because HD radio was developed to digitise both FM and AM (with little success so far) the question of platform complementarity discussed in this paper does not arise in the US (where AM is in strong decline anyway).

DAB+ and DRM both use the same advanced audio coding system and operate with single frequency networks[3] to provide more services at higher sound quality and lower transmission cost. However, these two families of technologies are far from being perfect substitutes. They differ markedly in how they operate, in the markets they are aiming to reach, in the production cost of their respective equipment, and most notably in their current marketability. In many ways DAB+ (which digitises FM) and the initial DRM30 standard (which digitises AM) complement each other, and their respective consortiums (the World DMB Forum and the DRM Consortium, two non-proprietary organisations) initially conducted several joint projects in the pursuit of synergies.

Although these potential synergies remain, the will to pursue and realise them appears to be slowly evaporating. Recent extensions to the DRM standard (known as DRM+, i.e. DRM technology designed to digitise FM rather than AM radio) have turned DRM into a potential competitor to DAB/DAB+[4] Although it is by no means clear that DRM+ necessarily aims at substituting DAB/DAB+ in digitising FM transmissions, there is nevertheless a sense that opportunities for convergence between these two complementary platforms are being squandered.

This evolution is troubling. The digital radio broadcast[5] market as a whole is experiencing many difficulties in its transition to market. Technology markets often fail to take off due to uncertainty and risk aversion. In this case digital radio markets fail to

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[3] A single frequency network is a group of synchronised broadcast transmitters (for instance a DAB multiplex) that operates transmissions *efficiently* by sending the same signal at the same time and on the same frequency. The COFDM modulation techniques of digital radio technologies are highly compatible with these synchronised transmissions whereas analogue transmissions are not.

[4] DRM+ has recently, been successfully trialled on Band III (Steil et al. 2010) but is not yet ETSI- or ITU-standardised.

[5] The focus of the paper is firmly on broadcasting rather than streaming radio platforms. Internet radio is not currently in a position to overtake AM/FM or DAB/DRM due to physical constraints on servers capacity. Since the bandwidth required to deliver the radio streams increases linearly with the number of listeners, Internet radio is best suited for small audiences. Serving large audiences will result in increasingly higher distribution costs for internet radio stations. A hybrid solution, consisting of broadcasting radio programs to GSM/3G cell phones equipped with antennas and a digital radio receiver did not make much progress, radio operators preferring to carry the traffic on their own networks. As a consequence, smart phones remain a streaming rather than a broadcasting radio device. A third alternative, satellite radio, failed to expand much beyond the US and Canadian markets. It is probably the most economically vulnerable radio platform and has not proved very successful. The merger between Sirius and XM was driven by high debts and slowing penetration rates, partly due to competition by internet radio.

internalise a positive externality - whereby the benefits to society (and technology developers) of adopting a high-profile complementary standard are not internalised by risk-averse markets (broadcasters, manufacturers, and their consumers). The industry can ill afford to ignore potential complementarities and perpetuate the current fragmentation of standards. Somehow, terms of trust will have to be established in an industry that badly needs to deal with the market failures inhibiting its main players.

It is fair to say that multi-platform approaches are a vexed theme in digital radio policy. Intuitively, the higher the degree of competition amongst separate and mutually incompatible standards the harder it becomes for the digital radio industry as a whole to make progress in the radio broadcasting market. In some (mainly European) countries, policy concerns arise from the multiplication of digital radio platforms competing with one another for a small share of the listening market. By contrast, in other large and sparsely inhabited countries (Australia, Canada, Russia) and in well populated countries hosting a number of sparsely inhabited regions (Brazil, China, India) the main concern remains the lack of currently adopted technologies that could complement the Eureka 147 family of FM-digitising standards (DAB/DAB+/DMB) to serve communities in rural areas.

This paper argues that these complementarities exist, particularly for geographically large countries with an established AM service, but there are neither harnessed nor exploited. . A single digital solution to market uncertainty, insufficient rural coverage and disenfranchised community radio stations potentially exists, but it require reactivating the initial search for synergies between the DAB and DRM projects. To illustrate this proposition, the paper reviews recent market development with respect to DAB+ and DRM to discuss the suitability of adopting combined DAB+/DRM platforms in large countries with significant rural populations, where sole reliance on the deployment of DAB / DAB+ is not an affordable option. The nature of the various market failures affecting the digital radio market are discussed and a way forward for digital radio broadcast technologies is suggested.

Digital Audio Broadcasting

DAB is a digital platform designed for audio wireless reception. DAB belongs to a family of digital radio standards known as Eureka 147[6]. All three Eureka 147 platforms (DAB, DAB+, DMB) are premised on the transmission of services through multiplexes (also known as ensembles), whereby a group of services (signals) are mixed together on a single transmission channel for broadcasting. Radio receivers then disentangle individual signals from the combined signal to offer separate channel selection to listeners. Because digital transmissions are much more spectrally efficient than analog, a multiplex can contain up to several times the number of stations of an analog channel while occupying the same spectrum bandwidth. This new transmission mechanism allows radio broadcasters to increase considerably the diversity of their programming.

DAB+, which recently upgraded the DAB standard developed in the 1980s, facilitates the provision (and potential substitution) of FM-type services on non-FM bands (either VHF Band III or UHF L-Band). DAB+ is particularly suited for efficient nationwide or region-wide coverage in relatively small countries with high population density, such as England, Denmark or Norway, where indeed its predecessor, the DAB standard saw much market progress.

DAB+ was introduced as a response to a growing stalemate between countries, which were interested in adopting DAB but were increasingly aware of its ageing audio coding, and countries, which had successfully rolled out the DAB standard (UK, Denmark) but could not recall millions of DAB receivers sold (as DAB is not forward compatible with audio coding used by DAB+). Adoption of DAB+ was therefore a win-win strategy for countries with no or limited pre-established DAB networks, such as Australia, Switzerland. Broadcasters could transmit at a lower cost per bit rate than DAB, consumers could receive more services and regulators could save more radio spectrum (Herrmann et al. 2007). However the adoption of DAB+ did not resolve fundamental policy issues inherent to the DAB approach, particularly the need for large countries to

[6] Eureka 147 was named after a European project (later turned consortium) started in the early 1980s[6] by the research arms of German and French broadcasters and telecommunications organisations - later including equipment manufacturers as well.

ensure universal coverage within their borders. The policy questions that followed the roll-out of Australia's DAB+ network provide an excellent illustration of this dilemma.

Problems with DAB+

In July 2009, Australia became the first country to adopt and deploy DAB+ as its single[7] digital radio standard operating on VHF Band III (174–230 MHz) and providing services in the five largest metropolitan areas (Warner 2009). There are now plans to extend DAB+ coverage to smaller metropolitan areas as well. For instance, DAB+ trials conducted in Canberra and Hobart come with no guarantee of a permanent digital service thereafter[8].

The exclusive reliance on DAB+ to digitise analog audio broadcasting raises a number of significant issues for the provision of digital radio services to rural communities[9]. There are currently no DAB+ services in non-metropolitan Australian areas nor any prospects of service deployment in these areas in the near future. The stalemate raises issues of equitable treatment (universal service obligations, missed economic benefits for rural audiences and stations), and of business capacity constraints (lack of penetration opportunities for new commercial and national / public broadcasting services). Above all, the lack of access to rural areas produces a risk of failure for the digital radio industry as a whole, as both rural and inter-areas mobile audiences lose faith in the new services for lack of adequate coverage.

Why should it be difficult to provide DAB+ services in rural areas, when other countries such as Malta and Switzerland appear to do this quite successfully? The reason has to do with the meaning of 'rural' in a geographically big but sparsely populated country, such as Australia. In small, densely populated countries, where FM has near nation-wide coverage, such as Malta and Switzerland, there is no particular issue with the digital

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[7] Malta and Switzerland adopted DAB+ in 2008, but alongside DAB and DMB, i.e. they did not adopt it as a single standard.
[8] 'Canberra digital radio trial update' (14-Jul-10), http://digitalradioplus.com.au/
[9] Australian broadcast legislation on digital radio only distinguishes two types of areas; metropolitan and regional. In other countries (e.g. UK) non-metropolitan regions are referred to as provincial areas. This paper uses the term 'rural' to encompass all non-metropolitan areas.

coverage of rural areas (as evidenced also by near 100 percent DAB coverage in Belgium, Denmark and in the UK).

However, in large, low-density countries such as Australia, Canada, Norway and Russia , which have traditionally relied on AM services for rural coverage of national services, there are considerable issues of cost, coverage and spectrum availability hampering the deployment of digital radio services, such as DAB+. First there are *Spectrum constraints*. DAB+ in Australia is designed to operate on VHF Band III, where spectrum is in very short supply almost everywhere. It is therefore unlikely that there will be enough available spectrum to accommodate all current AM/FM services in the event of an analog radio switch-off (let alone to significantly expand the number of DAB+ digital services in the future).

Second, there are *no real alternatives* to these capacity constraints. Although International Telecommunications Union Recommendations (ITU-R) allocated UHF L-Band spectrum to DAB/DAB+ services as a way to alleviate the VHF Band III spectrum constraint, dual Band III/L-Band receivers are expensive to make and are not mass-manufactured. In addition, L-Band is far less suited for the operations of Single frequency networks for wide-coverage networks than Band III. The L-Band option is losing support among broadcasters. Third, *DAB+ is no solution for digitising AM transmissions*. Although DAB+ is well-designed to replace FM services in case of analog radio switch-off, it offers no substitute for AM services. In particular, it is not suited for long or ultra-long distance transmissions.

Fourth, DAB+ is not well designed to accommodate the needs of operators with differing coverage areas. It is often the case that large public and commercial operators on the one hand, and local or community stations on the other hand will diverge in their coverage areas, thus providing few incentives for coordination amongst the two groups. Finally, DAB+ licensing requires shared transmission infrastructure, which is costly to join whilst providing few benefits to local radio operators. Hence DAB+ serves the interest of public and commercial broadcasters in a cost-effective manner, but fails to do so for local and community stations.

Spectrum scarcity

Spectrum availability is therefore a major consideration for wide-area coverage. Because DAB+ is not an 'in-band' technology it cannot operate alongside analog services on FM Bands. DAB+ requires its own spectrum. As per ITU-R allocations, DAB+ can only use spectrum in VHF Band III or in the UHF L-Band. The international experience with VHF Band III is very encouraging, but this spectrum is in very short availability in some large countries such as Australia and Canada (where most of it is allocated in rural licence areas for analog and digital television).

In spite of (or alternatively due to) its attractive transmission properties VHF Band III is a band characterised by chronic spectrum scarcity, which severely limits any future expansion of DAB+ services at the present time. Consequently, there will be no additional spectrum available for DAB+ in most of the rural areas until analog TV switch-off releases a digital dividend[10] in 2013. Even then the size of the digital dividend and competition from the TV sector will impact on how much VHF Band III spectrum will actually be available for DAB+ services.

In regulatory terms, the only substitute for Band III is UHF L-Band, which offers less attractive and less efficient transmission properties and has generally been ignored by broadcasters and equipment manufacturers. The lack of adequate L-band equipment played a significant role in the failure of the DAB roll-out in Canada (O'Neill 2007; O'Neill 2010). Hence, DAB technologies require spectrum that is scarce and non-substitutable.

Mandatory and costly multiplex operations

Multiplex management presents yet another conundrum. DAB+, like all Eureka 147 platforms, distribute services through multiplexes. In Australia for instance, the *Radiocommunications Act 1992* requires all mutliplexes to be operated by a joint

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[10] Technically a digital dividend in AM-FM spectrum is a possibility (similarly to the one just realised in the UHF band for TV). Yet, analog switchoff in radio is politically sensitive and has not been discussed much beyond the few countries with established DAB markets (UK, Norway). Clearly a digital switchover and dividend would help the digital radio industry, but without convergence between DAB and DRM it will leave many issues unresolved

venture company with shares held by the incumbent licensees who share a common coverage area. The joint venture companies are controlled mainly by commercial operators as it is somewhat complex and costly for community radio industry to be part of a joint venture company [11]. Similarly, the costs of setting up a DAB+ multiplex in many rural areas of Australia may also be prohibitive for commercial and public broadcasters if there are few operators to share the financial burden with.

The benefits of DAB+ (more spectrally efficient, more robust and more flexible[12]) really only accrue when groups of radio broadcasters *with similar coverage areas* join the multiplex[13] (EBU 2009). These gains in coordination and spectrum savings are harder to obtain with broadcasting multiplexes including (or consisting of) local and community station operators. Local broadcasters will generally have no or little interest in large coverage areas and will therefore not be willing to meet the high costs[14] of joining a DAB+ multiplex, which in turn raises concerns about the future of community radio and the guarantee of diversity in broadcast contents (Hallett 2010), and concerns that the technology is too premised on commercial applications (Dunaway 2000).

Exclusion of community radio services

In practice, this framework therefore excludes local-area community radio services as they do not serve the same coverage areas as commercial broadcasters. This is problematic, because rural audiences are a different type of market, with different tastes

[11] Although there are formal legal requirements regarding the operations of joint venture companies (JVCs), *access* to a JVC does not require holding JVC *shares*. For instance, an incumbent station is not required to hold shares in a JVC in order to access capacity. Access is a *right* for incumbents (stations with same licence areas) and only incumbents can access the multiplex. Problems of differential coverage targets therefore become an issue if the DAB+ framework is expanded to non-incumbent 'local stations', such as local-area community broadcasters, who would be excluded under the current arrangement.
[12] For instance, multiplex operators can modify the number of channels in the multiplex, the bit rates for each channel, etc.
[13] In an Australian context this will always consist of one DAB+ transmitter transmitting many services (Herrmann et al. 2007; Crawford and King-Smith 2008; Hoeg and Lauterbach 2009; Warner 2009).
[14] These costs will include (i) transmission fees for large coverage areas where broadcasters' target audiences will mostly not reside – more costly because requiring more transmitters, (ii) equipment costs for interleaving and synchronising program streams and (iii) costly maintenance and upgrades for mainstream digital infrastructure (whereas community broadcasters' transmitters are traditionally serviced in-house). In addition, there is (iv) the cost of simulcast transmissions (analogue / digital) until the take-up of digital receivers by community radio audiences is large enough that analogue transmission can cease (possibly a very long-term perspective).

for program variety and different readiness (or capacity) to purchase equipment than their urban counterparts. Therefore, mandated multiplex operations through joint-venture corporations make it difficult to deliver the degree of flexibility needed to serve these different audiences.

In that sense, multiplexing has changed the whole organisation of broadcasting services because it requires a very high degree of coordination amongst the actors involved. This technologically innovative (efficient) but socially conservative (restrictive) business model favours large public and commercial broadcasters (Ala Fossi 2010b) and there are indeed some examples of either entirely publicly-managed or commercially managed DAB multiplexes in the UK (Lax 2003), but there are no such examples for community radio.

Community radio fulfils an important information role in democratic societies. Community radio provides information (crime reports, council announcements, school closures, local emergencies, traffic information, etc.) that differs markedly from the nationwide contents of the other two ‘tiers’ of radio broadcasting - public broadcasters and commercial stations (Hallett and Hintz 2010). However, beyond this humble role as provider of local news, community radio also acts as a vector of deliberative democracy expression, driven by varying objectives of social inclusion, decentralised rule, public interest, community cohesion, local advocacy, ethnic diversity, etc. (Lewis 2006; Lewis 2008). What perhaps most characterises community radio is its higher degree of independence from political interference or from compromises with vested interests (Tridish and Coyer 2005; Corominas et al. 2006). This high degree of independence relies critically on the technological environment (Tabing 2002; Hallett 2010). Because they are modestly resourced and wish not to overly rely on external funding sources, community radio stations require transmission facilities that are affordable to acquire, simple to operate, and adjustable to their (usually) narrow coverage needs. Whereas AM and FM technology met those needs, DAB/DAB+ does not and in addition imposes a ‘gate keeper’ (the multiplex manager), thus further threatening community radio’s most coveted asset – its independence.

The digital challenge on community radio is an unwanted effect from the Eureka 147 project. Excluding community radio from the benefits delivered by digital radio was never the intention of DAB developers. The fundamental issue is that DAB, is an already old technology that was developed at a time when local and community broadcasting was little developed[15] in Europe or elsewhere (Ala-Fossi 2010b: 47-8). The primary objective of the Eureka 147 project was to reach mass audiences through large-scale national/rural areas via terrestrial transmissions (T-DAB) and rely on satellite DAB (S-DAB) for international broadcasts (Hallett and Hintz 2010). This architecture was ideally suited to the provision of public broadcasting services (with multiple programming) and large commercial operators (with wide advertising targets), but not for smaller commercial operators (Lax et al. 2008) and even less for local and community broadcasters (Hallett 2010). In large countries with significant rural populations such as Australia, Brazil, Canada, India and various others, the problem is compounded by the lack of digital solutions for the conversion of their AM networks[16].

Inadequate coverage of rural areas

Even if legislative provisions were readjusted to facilitate multiplex participation by local-area community stations at an acceptable cost, there would still be no certainty that DAB+ could offer a suitable platform to address the needs of rural audiences. Transmission of digital signals to sparsely populated areas imposes a difficult technical and infrastructure challenge to DAB+ broadcasters, because DAB+ is not designed for long-distance transmissions. For instance, The Australian Broadcast Corporation's (ABC) AM radio services on MF bands provide very wide coverage of large rural areas at very low infrastructure cost. Achieving similar services through DAB+ networks would be prohibitively expensive because the number of transmission towers would have to increase considerably, and because the technology has not been designed to operate on AM frequencies. As a reference, even those European countries, which adopted the DAB standard still leave a few sparsely inhabited rural areas uncovered by digital transmissions due to cost and suitability of service issues (Harwood and English

[15] Local and community broadcasting only really took off in the late 1980s in Europe.
[16] See (Hendy 2000; Lax 2003; Rudin 2006; Hallett 2010)

2006). Thus the threat from digitisation through DAB/DAB+ to rural audiences is twofold: marginalisation (or loss of independence) of their community radio stations, *and* loss of reception of public broadcasters' transmissions on AM frequencies.

Finally, using DAB+ as a single digitising option for nationwide coverage is not only detrimental to the interests of rural audiences and their service providers, it also prevents the realisation of significant economic benefits through the operations of single frequency networks on AM bands. Spectrum availability on AM bands is a lesser issue than on FM for the purpose of rolling-out digital radio services to rural audiences, but the technology must then be designed for AM and this is clearly not the case with any of the Eureka 147 technologies. Providing audio services to rural audiences in a geographically large but demographically sparse country raises considerable challenges for the DAB+ platform and calls for a complementary approach.

The four issues just defined (spectrum constraints, multiplex cost, conservative technology, and infrastructure cost for rural coverage) resonate with the dilemmas faced by other large countries such as Canada, Russia, Brazil or India, which, unlike Australia, have not adopted DAB+ but also need solutions to digitise their AM transmissions. The lack of cost-effective opportunities to bring the benefits of digital technology to rural areas affect both local and community radio stations and national and commercial broadcasters. It is timely then to take stock and examine alternatives for digital radio transmission in rural areas.

Digital Radio Mondiale

Digitising AM transmissions

Introduced in 1998 by the DRM Consortium, Digital Radio Mondiale (DRM) is a response to these concerns, although its initial purpose was merely to digitise digital broadcasts on LF, MF and HF frequencies (30kHz – 30 MHz)[17] – together known as the AM frequencies. , Due to their very large coverage and propagation properties, the AM

[17] Note, though, that 26 MHz is the highest AM frequency assigned to radio broadcasting.

frequencies were the very first radio waves adopted for analog radio broadcasting in the early 1930s, but they were subsequently and gradually dethroned in the 1970s by better quality FM transmissions in the higher VHF Band II. Yet, AM broadcasts remain popular —particularly in the developing and emerging economies: Africa, Russia, India, Brazil, etc. Consequently, the DRM project initially merely aimed at co-existence with analog AM transmissions, expecting to progressively take over through analog phase-out and eventual switch off. The advantages of DRM30 ('30' stands for 'up to 30 MHz') mode over analog transmissions on AM bands are significant:

- near-FM audio quality: no fading, noise or interference
- flexibility of configuration to varying bandwidth (automatic frequency tuning)
- text and data services (pause/rewind/record functions and electronic program guides)
- energy-efficiency: transmitters use up to 50% less power[18] than AM for same coverage
- health benefits: lower-power transmitters also mean lower radiations around AM sites
- spectrum efficiency: supports channel re-use through single frequency networks
- Low infrastructure cost; DRM30 re-uses existing AM transmitters , antennas and sites[19]

Trials on various AM bands have proved the performance and robustness of the DRM30 platform in frequency bands below 30 MHz (Freyens 2010). DRM30 is also a cost-effective solution since it does not require its own infrastructure (DRM30 operates on legacy AM infrastructure with only very minor adjustments)[20]. Furthermore, DRM30 can be operated with AM-like transmission diversity techniques (transmitting the same

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[18] This is particularly the case for HF bands (Harwood and English 2006).

[19] DRM30 can use the same sites as AM. AM Transmitters just need adding a front-end (a digital modulator, a multiplexer, a sound card etc.). These adjustments do not usually take much time. In any case, the transmitter needs to be accompanied by a DRM Content Server (i.e. audio and data encoder and DRM multiplex generator), and a DRM Modulator (sometimes called a DRM Exciter).' DRM30 is also compatible with existing AM antennas, but may require adjustments in payload distribution over the sub-carriers.

[20] By contrast adapting legacy FM transmitter for OFDM-modulated transmissions, whether DAB+ or DRM+, would not be economical compared to using new digital transmission infrastructure instead.

signal on several channels to improve the chances of good reception) that offer an additional way of dealing with indoor multipath issues.

Complementing Digital Audio Broadcasting

How does DRM30 enters our previous analysis? First, by digitising AM transmissions, DRM30 offers a natural complement to the Eureka 147 family of standards. AM frequencies being lower than VHF frequencies, they provide enhanced propagation and coverage properties at the expense of weaker carriage properties and accrued interference potential (both affecting audio quality). Although DRM's use of these frequencies remains exposed to interferences (particularly at night) the intrinsic quality of signal is no longer an issue. Thus, DRM resolves the fourth issue affecting DAB transmissions (inadequate coverage of rural areas). Combining the two technologies (DRM/DAB) into a single receiver could enable full digitisation of analog, AM/FM services, offering FM-type services to urban areas and AM-type broadcasts to rural areas.

Second, although DRM30 uses the same modulation technique and audio coding as DAB+ (and is therefore superior to DAB in terms of quality audio coding), DRM30[21] was developed to digitise AM transmissions 'in-band' (ie. on the same frequency, directly adjacent to AM channels) and under a large array of testing circumstances (tropical bands, ultra-distance transmissions, rural and local broadcasting). By contrast, DAB/DAB+ was developed with a view of replacing FM services (operating on Band II) on a separate VHF band (Band III). This means that DRM30 does not require new allocations (or reallocations) of frequencies and is therefore not subject to the first issue identified in the previous section (spectrum constraints).

Third, the operations of a DRM30 platform are not premised on the distribution of services through multiplex structures (as are DAB and DAB+), which greatly simplifies access to transmission infrastructure for local and community radio broadcasters. DRM

[21] DRM30 was so named because it was designed to operate on bands below 30 MHz (the 'AM bands')

is bandwidth-compatible with both AM and FM[22] with which it shares channels without any need for a multiplex. DRM operations therefore remove our second concern with DAB operations (required and costly multiplex operations), as well as our third issue (similar coverage areas and implicit convergence towards the business models of public broadcasters).

Developments in Norway offer a good illustration of the complementary nature of the DRM standard. Norway is a sparsely populated and mountainous country, where the cost of providing extensive FM and DAB coverage is particularly high and could be reduced by switching off analog FM services. However, household penetration of DAB remains well below the 50 per cent of the population needed to vindicate a wholesale digital switchover for radio. Even if customers' adoption of DAB receivers improves, there remains the matter of deciding how local and community radio stations will migrate to digital. L-band is the preferred option in the urban areas, but DAB is not a cost-effective solution for rural areas where there might sometime only be one radio station. In this context, DRM is the obvious alternative and Norwegian network operators have recently acquired licences to test DRM transmissions in non-metropolitan areas.

…or a substitute?

In March 2005, at its General Assembly in Paris, the DRM Consortium decided to increase the spectrum range of the DRM standard to cover bands from 150 kHz up to 120 MHz[23]. This effectively opened up the use of several VHF Bands for DRM-digitised audio transmissions. The new standard was at the time referred to as DRM mode E, or DRM120 but is now more commonly known as DRM+. DRM+ uses the same AAC+ audio codec as DRM30, same OFDM modulation design, same multiplex and signalling

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[22] Unlike DAB and DAB+, DRM does not require specific alternative frequency allocation with respect to AM (DRM30) and FM (DRM+, see next sub-section). Compared to FM, DAB/DAB+ is more robust to co-channel interferences because multiplex operations spread the combined signals over a large VHF spectrum space (VHF 'blocks' of about a quarter of 7MHz each) thus reducing multi-path and local fading problems. This approach is of course incompatible with the channel raster for FM transmissions (100 to 200 kHz wide) and AM (10kHz wide) thereby forcing the allocation of DAB/DAB+ services further up on Band III. By contrast, DRM's 'on channel' narrowband nature makes it bandwidth-compatible with both AM and FM (which removes the need for large spectrum spaces and therefore the need for multiplex operations).

[23] Later, in 2009, the IEC/ETSI/ITU-certified spectrum range for DRM+ was extended further to 174 MHz.

scheme, and along with DRM30, DRM+ can transmit up to four applications, audio, video or data in a single channel. The difference between the DRM modes resides in main channel bandwidth (which is 9 or 10kHz for DRM30 and 100kHz for DRM+) and coverage area (a function of the spectrum used).

The decision to increase the spectrum range of DRM operations beyond AM frequencies was momentous because it also meant that DRM ceased being perceived by the broadcasting industry (including equipment manufacturers) as a complementary technology to the Eureka standards. Until then, DRM was limited to digitising AM frequencies whilst Eureka was digitising FM. After March 2005, it was now quite possible that both sets of standards would now compete as alternatives platforms vying for the right to eventually replace analog FM broadcasts, albeit not necessarily on the same VHF bands.

Does DRM solve the shortcomings of Digital Audio Broadcasting?

The last couple of years have seen successive rounds of extensive trials for the DRM standard, followed by international certification and high-profile endorsements by some large countries with important AM networks, such as India and Russia[24]. Australia and Brazil are currently trialling the technology and pondering a similar endorsement for coverage of their rural areas (DBCDE 2010). These developments seem to indicate that DRM is coming of age not only technically but also in terms of political support in a number of geographically large countries. This evolution is not surprising. Although DRM30 and DRM+ are as advanced as DAB+ in terms of digitisation techniques, they never strayed much from the traditional concept of broadcasting. As with analog FM and AM, DRM is characterised by a decentralised, almost tailored-made environment, emphasising flexibility with respect to coverage area, independence (stand-alone transmissions), affordability (use of low-cost transmitters) and universal access (both in terms of transmission - community broadcasters - and reception - rural audiences).

[24] China adopted DAB in the mid 2000's for its urban areas (both VHF Band III and L-Band) but relies heavily on analog SW to serve rural areas, which suggests a role for DRM to serve rural areas in the future.

As discussed, DRM stations do not need to share or synchronise their transmitters, nor do they need to operate on the same frequency, or combine their programs in a multiplex. DRM+ offers the option to local broadcasters of combining up to 4 services (audio and data) in a multiplex (i.e. a much less complex and smaller size multiplex than those required by DAB+) but this is no way a mandatory or even recommended course of action (Waal 2009; Ala Fossi 2010b).

Finally, there is the question of spectrum availability. The lack of available Band II spectrum for FM transmissions has often been alleged to be the main constraint on the size of the community broadcasters industry. The promise of large spectrum dividends from digitising FM through efficient transmissions on Band III offered a chance to reallocate the released spectrum to community broadcasting, but this is only an option if FM transmissions are to be kept in the future rather than switched-off and replaced by digital services. If this is the case, the only viable alternative for community broadcasters is to join multiplexes at a high cost and for few benefits. For policy makers, the main issue with using the DAB/DAB+ standard for rural transmissions lies with the spectrum requirements in VHF Band III[25]. For public broadcasters the main issue is the infrastructure cost of setting up DAB transmitters in a large number of rural areas (a costly approach for large countries with low population density).

For all these reasons DRM is a more likely candidate to meet the needs of small (local, rural) broadcasters - due to its non-reliance on multiplexing, whilst also meeting the needs of large (national) broadcasters - due to its initial focus on AM frequencies (Ala-Fossi 2010 : 50). A recent survey of mainly European[26] industry experts, revealed that most respondents viewed the DAB/DAB+ platform as expensive and uneconomic for *both* commercial and community broadcasting (Ala Fossi 2010a). The major reported drawbacks of rolling out the DAB/DAB+ standard country-wide was not the matter of

[25] Alternatively the L-Band could be used for local DAB+ radio but to the extent that the L-Band is not used in urban area, that its higher frequency range implies much smaller coverage areas (which increases the need for repeater stations), and that the availability of joint Band III / L-Band receivers is very low, use of L-Band increasingly appears as a costly and unviable option for DAB+ (Warner 2009).

[26] The survey was conducted over 2005-2006 and covered the UK, Ireland, Denmark, Finland and Canada (Ala-Fossi et al. 2008; Ala Fossi 2010a). The survey consisted of semi-structured interviews with 43 digital radio professional working as public or commercial broadcasters, regulators, technology developers, and media electronics professionals.

multiplex pricing policy (a sensitive matter for local broadcasters only) but the economic cost, relative to both analog and alternative digital platforms such as DRM, arising from the design of DAB implementation (i.e. the *necessity* to use multiplexes).

The same set of surveys of the radio broadcasting industry also indicates that even in countries with advanced take-up of DAB technology, such as the UK and Denmark, a majority of respondents saw a need for a complementary approach through platforms such as DRM, the main reason being the lack of compatibility between DAB and community radio (Ala-Fossi et al. 2008; Ala Fossi 2010a). These views have been re-emphasised strongly at a recent Symposium on the use of DRM+ in Band III in May 2010 (Ory 2010).

Collaboration – competition tradeoffs

There was early recognition of the complementarities that DRM could bring to the DAB project and the WorldDMB Forum decided in 2005 to join forces with the DRM Consortium in an attempt to combine DAB and DRM transmissions on VHF Band III (Hallett 2005). Over time though, the idea lost its momentum. Omission of the DRM standards in the 2007 WorldDMB profiles and prolonged absence of combined DAB+/DRM+ equipment (none exists at this stage) have generated much scepticism about the exact intentions behind the consortiums' pledge of joint work.

Part of the problem is that DRM is now technically able to replace AM and FM in the absence of any other platform, and it does not necessarily need access to VHF Band III. Certainly, the availability of a single digital platform to first simulcast transmissions in-band, than later replace FM and AM stations by using legacy analog bands appears a more attractive and efficient solution than a fragmented approach. Is it the goal pursued by the DRM Consortium though? Even if wholesale analog replacement was its stated objective, is DRM capable of achieving this objective?

Realistically, DRM is a far too recent system to catch up with the market head start taken by Eureka 147 technologies. DAB has developed an impressive receiver basis in several European countries and is on its way to achieving the same in Australia with

DAB+. DAB is also a far more experienced platform than DRM with an established record of high field strengths developed through high power and SFN operations.

Just a year after the release of the World DMB receiver profiles (which, as mentioned above, ignored DRM), the DRM Consortium released its own DRM Digital Radio Receiver Profiles at IBC[27] in September 2009. The announcement followed the certification of DRM+ a few weeks earlier, in August 2009. Like the WorldDMB profiles, the DRM receiver profiles provide a set of minimal features and functions for all DRM receivers. The profiles are mainly addressed at manufacturers and designed at ensuring (i) interoperability between DRM receivers, and (ii) move DRM out of its 'niche' market by establishing the basic requirements for a price-sensitive range of receivers (profile 1 – standard radio receiver) as opposed to existing 'high-end' devices (now profile 2 – rich media radio receiver). The distinction between DRM profiles 1 and 2 is very reminiscent of the distinction between DAB/DAB+ and DMB profiles, where:

- profile 1 offers high quality DRM30/DRM+ audio services plus data and text services, but keeps design costs low;
- profile 2 adds colour screen and various video/multimedia enhancements (as does DMB within profile 3 of the WorldDMB profiles).

The similarities between the two sets of profiles (WorldDMB and DRM) are not fortuitous as the DRM study group in charge of developing the profiles scrupulously followed the WorldDMB's approach, consulting with broadcasters, network providers, regulators, equipment manufacturers, technology developers and academics.

However, by contrast with the WorldDMB profiles, the DRM profiles were also created with a view to alleviate concerns about market fragmentation by complementing the set of WorldDMB profiles for a multi-standard approach to receiver manufacturing (Flynn 2010). Although the profiles focus only on DRM in terms of specifications and functionality, they also address compatibility with Eureka 147 platforms in an attempt to

[27] IBC (International Broadcasting Convention) is Europe's largest broadcasting trade show, annually gathering broadcasters, equipment manufacturers and various professional associations in Amsterdam – Netherlands.

encourage a universal approach. The DRM profiles minimise the set of options (to keep cost low) and reiterate the commitment to a single DRM standard[28]. Thus, the profiles do not distinguish between DRM30 and DRM+ but merely set mandatory reception in MF[29], HF and international FM bands, whilst advising reception in all bands up to 174 MHz. Of course, mandatory bandwidth requirements are different between DRM30 (9kHz to 10kHz) and DRM+ (100kHz) but this is built into the band channel decoding requirements.

In issuing this recent set of profiles, the DRM Consortium sent several signals to the market, namely that:

- DRM receiver technology is ready for mass market manufacturing and consumption, and;
- DRM is now ready to operate on both AM and VHF bands I and II (with strong hints about future Band III possibilities);
- DRM is committed to reducing market fragmentation and confusion through interoperability with WorldDMB standards (its emulation of WorldDMB profiles specifications being evidence of its harmonisation efforts).

Market deployment and combined platforms

In view of the significant obstacles to rolling out DAB+ services nationwide in large but sparsely populated countries, it would seem sensible to consider a complementary approach that would fill the gaps left by DAB+ transmissions. A dark horse since its inception, DRM30 is well positioned, technologically, to adequately complement the gaps left by the DAB/DAB+ approach, but its market position remains an uphill struggle. Despite all the positive developments and trial results, DRM is still perceived as a lab / trial technology with a niche market outlet, not a mass market option. As

[28] As explained earlier, the distinction between DRM30 and DRM+ made in this report is artificial and only meant to facilitate the reading. The DRM Consortium only recognises one standard (DRM) and the DRM+ standardisation achieved by mid-2009 is an enhancement of the earlier DRM30 standard, not a separate standard.

[29] Inclusive of LF bands in ITU region 1.

experiences in a number of countries have shown, the digital radio market is new and fragile and there is consequently little market readiness to give DRM a fair go.

Although DRM30 has been officially market-ready since 2003, by June 2010 receivers were still very few and expensive with no model designed to be operated in conjunction with DAB+ receivers. There are a few combined DAB/DRM30/AM/FM receivers available on the market but none of them includes DAB+ reception- and yet, DAB+ and DRM utilise the same audio coding system. A chipset (and ultimately a receiver) that combined both these technologies would support the flexible future use of both standards in one country.

However, there are very few developments in that area. The most comprehensive multi-platform receivers available in the market now still consist of DAB (rather than DAB+) combined with DRM30 (and AM/FM) – all based on the Radioscape RS500 chipset, which is costly and supports neither DAB+ nor DRM+ (Owen 2009c). The WorldDMB profiles standardised norms for chipset and module manufacturing across Eureka 147 standards such as DAB, DAB+ and DMB, but it did not solve the fundamental incompatibilities amongst equipment. DAB receivers cannot decode DAB+ signals, which hinders the adoption of DAB+ in highly developed DAB markets (e.g. UK, Denmark).

In addition, most European countries broadcast only DAB and DRM30 services (the latter for international broadcasts). There is therefore no perceptible broadcasters demand for a combined DAB+/DRM chipset although this may change soon as more European countries launch or upgrade to DAB+. DAB+ countries (Australia, Malta, Switzerland, Italy) have so far shown little interest in DRM either, although this may change as DRM30 trials are underway in both Australia and Italy in the 26 MHz band.

The situation is worse still in the crucial in-car receiver market. In-car reception equipment is the least developed segment of the digital radio market for both the WorldDMB group and the DRM Consortium. The availability of in-car digital radio receivers is a fundamental aspect of the successful deployment of any digital radio technologies and the commitment of car manufacturers to equip their vehicles systematically with digital radio receivers is critical to the long-term viability of digital radio platforms.

Unfortunately, obtaining these commitments has traditionally been difficult to achieve in countries, which have rolled-out digital radio platforms. On the on hand, car manufacturers are doubtful about their consumers' interest in digital radio. On the other hand, where the demand exists, manufacturers view the asking price of a digital upgrade as exceeding consumers' willingness to pay. There is a consensus amongst many car manufacturers that most motorists are satisfied with FM/AM receivers (Owen 2010).

The low DAB take-up rates in most Western European countries together with the worldwide fragmented nature of digital radio standards have certainly contributed to this state of affairs.. To make matters worse, digital audio coverage and signal quality remain insufficient on most roads and arteries, even in high population density countries such as the UK[30].

The UK government has recently imposed a 2013 deadline to the car industry to fit all new vehicles with DAB receivers as standard - with existing vehicles retrofitted using convertors by 2015. The car manufacturing industry's peak body stressed the difficulty of implementing this strategy for vehicles whose development cycle started prior to 2009. As large-scale retrofit programs would be difficult to implement the industry suggested an optional reliance on aftermarkets instead. In the light of these numerous hurdles, it is understandable that there are very few in-car digital receivers currently on the market.

In fact, there are very few in-car DAB+ receivers currently available – all expensive and coupled with FM reception only. There are no in-car DRM30 receivers available on the market (let alone DRM+) although some display-like prototypes and portable 'plug-in' options do exist. Russia seems to manufacture in-car DRM30 receivers but these are not

[30] Note that the situation is significantly better in smaller countries such as Belgium, Switzerland and Denmark, where outdoor DAB coverage has reached 100%, 93% and 90% respectively (see http://www.worlddab.org/country_information accessed 01 June 2010).

exported to Western markets and there is no information on their presumed retail price. Several in-car DRM30 prototypes (also offering FM and AM) have been presented at the IFA trade fair in Berlin for some years now, but the manufacturer's commitment to bring them to the market remains unclear[31]. Needless to say, there are no combined DAB+/DRM in-car receivers currently on the market. Except for the UK market, driven by regulation, there are no clear commitments from the car manufacturing industry to standard-fit their line-products with digital radios.

It seems that at this stage, the main hurdle facing DRM in-car prototypes is the lack of commitment and/or conviction from both equipment and car manufacturers. The DRM prototypes remain a bit of a mystery, having been tested, presented and demonstrated at various consumer fairs but none of them having been made available for purchase.

Market Failure and Regulatory Intervention

The absence of a coordinated approach between the WorldDMB Forum and the DRM Consortium (despite earlier statements of future collaboration) is generating large opportunity costs, particularly in large countries. Spectrum is a finite, highly demanded public resource, which requires to be governed efficiently and fairly by regulators. A sole DAB+ approach for nationwide broadcast transmissions cannot meet expectations of allocative spectrum efficiency and universal coverage in those countries. Since DRM operates 'in-channel' and targets both FM and AM it offers different prospects. First, DRM propagates digital signals alongside analog ones without the need for additional spectrum allocations (hence no need for additional VHF or UHF spectrum allocations, existing FM and AM spectrum is sufficient). Second, DRM30 generates significant spectrum savings through the efficient operations of single frequency networks on AM frequencies. Third, DRM potentially meets the needs of local and community stations because it does not require multiplexing. Fourth, but not least, the cost of DRM transmission infrastructure is relatively low because DRM30 signals can be transmitted using modified legacy AM equipment (this option is too expensive for either

[31] Questions to Anne Fechner, DRM Project Director, September 2007, http://mt-shortwave.blogspot.com/2007/08/where-can-i-get-receiver-for-drm.html

DAB/DAB+ or DRM+ use of FM transmitters). Hence DRM generates efficiencies over and above those created with FM-digitising technologies, and does so without requiring broadcasters to harmonise their coverage areas and business models, attributes of considerable importance to large but sparsely populated countries.

Unfortunately, time is running out for DRM due to the expanding DAB+/DMB market, and due to increasing competition from other platforms such as satellite or internet-based radio. DRM is short of market drivers, of market footholds, its current equipments are expensive and few public broadcasters are convinced that DRM-transmitted will ever reach an audience[32]. Even fewer manufacturers are convinced that DRM equipment will ever be profitable.

To many consumers and manufacturers the standard indeed brings little that is new. The real benefits accrue at a much higher level, in the education benefits of digitising AM contents, in the spectrum efficiencies of developing single frequency networks for digitised AM programs, in the efficiency gains of operating low-cost equipment, and perhaps most of all in the capacity to digitise analog audio broadcasts in a seamless way, maintaining or expanding the AM/FM coverage area and the whole range of programs offered by AM/FM.

Many of these benefits accrue to society at large (productive efficiency, spectral efficiency, universal access, education benefits) but these gains are not obvious to market players. In a recent article on the DAB standard, O'Neill (2009) deplores a:

"…liberal market approach, where it has been left largely to market forces to decide the fate of particular technologies. As with previous technological developments in the sector, this has resulted in long delays in new technology development, competing solutions, confusion for the radio and audiences, and an uncertain environment for future planning" (p. 245).

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[32] RTL Luxembourg, an earlier unique commercial DRM broadcaster has recently stopped its transmissions - it seems by lack of conviction over the future of DRM.

When uncertainty and risk aversion drive uncoordinated approaches in technology markets the outcome often consists of still-born solutions. Standardisation is the logical response, but if the market will not adopt it, who will? . Risk-averse digital radio markets (broadcasters, manufacturers, and their consumers) have so far shown no inclination to internalise the positive externalities that would arise from adopting a complementary standard . It is symptomatic that commercial operators, who face significant difficulties converting their audiences to the DAB+ standard, see DRM as unwelcome competition rather than as a potential source of convergence and market integration.

To succeed the market way, DRM would need to provide attractive new (digital-only) services (as DAB+ successfully did). To do this the DRM consortium needs to convince broadcasters to adopt fashionable new contents that will be broadcast DRM-only. Furthermore, DRM needs to convince manufacturers[33] to build low-cost DRM+ receivers (for fixed, mobile, and in-car usage). This is not a trivial task at a time when marketing research keeps pointing at new developments in internet radio and/or satellite-based radio. The DRM consortium has consistently underachieved in that area, considering that prototypes (including in-car receivers) have been displayed at electronics consumer fairs for several years now.

The way ahead is to alleviate markets' doubts both about digital radio as an analog substitute and about which platform will eventually succeed. Clearly this requires separate DAB+ and DRM transmissions while supplying markets with combined DAB+/DRM equipment. Although this question requires further research, the matter appears as a classic case of market failure whereby the positive externalities of rolling out a complementary, spectrally-efficient technology with low-transmission costs are not internalised by market agents. As a consequence, society settles for too little service provision, too few transactions and welfare-enhancing opportunities elsewhere are not exploited.

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[33] A point often made is that equipment manufacturers have been too focused on the production of IBOC/HD receivers to supply the US market where ambiguities about multiple terrestrial digital platforms are not present http://www.usdrm.com/drm_news3.html

Economists typically characterise such situations as basket cases for regulatory control. For instance, relevant authorities could subsidise the commodity generating the positive externalities (e.g. subsidising the production of combined receivers), or remove the barriers to trade that prevent its expansion (exchanging information, providing guarantees or insurance, lowering risk, mandating new standards). To gain industry / consumer support for DRM broadcasting there is a need to remove uncertainties about market fragmentation, foster collaboration between technology developers, and clarify the large benefits of a combined approach to consumers.

There is nothing untoward in calling for government intervention in situations where markets fail to produce efficient outcomes. Digital radio is a market characterised by positive externalities (unrealised benefits accruing to society from combining DRM and DAB+) and lingering uncertainties about market direction due to platforms fragmentation. There is therefore an important role for policy to reduce the transaction costs involved with the provision of combined programs by public and commercial broadcasters and the manufacturing of mass-market combined DAB+/DRM equipment (inclusive of in-car equipment).

Most experts are convinced that the future of radio remains terrestrial over-the-air (Ala Fossi et al. 2008, O'Neil 2010, Oweb 2010), but this future needs to be secured by a comprehensive rather than fragmented solution. There is much promise that a combined DAB+/DRM+ standard would offer such complementarities as to make the introduction of any other standard largely irrelevant and unlikely in the future, resolving the fragmentation problem that has plagued digital radio in the last decade. And there is a strong role for governments to help achieve this outcome.

Conclusion

Unilateral adoption of commercially-designed platforms to digitise analog radio, such as recently observed in Australia, are risky strategies for large, sparsely populated countries. The main drawbacks from this unilateral approach consist of its exclusive focus on commercial services, its large demands on scarce VHF radio spectrum, its sole focus on digitising FM (offering no alternatives for AM), and its costly yet mandatory multiplex operations. Unsurprisingly, such strategies result in market fragmentation and contribute to long-term stagnation in digital radio markets. Although there are various sources of market fragmentation, part of the problem lies with failure to provide a cost-effective solution to covering large rural areas, to digitising community radio services and to formulate a comprehensive replacement solution for AM and FM services.

In this article I examined the two main policy issues arising from this unbalanced development; market stagnation / fragmentation, and marginalisation of community radio and rural audiences. First, the lack of market progress for the alternative terrestrial platform, DRM, is quite unfortunate in view of its complementarities with DAB+, its flexibility, its adequacy for digitising AM radio, its mild spectrum requirements and its cost-effective transmissions. However, most of these benefits are of a positive externality nature, which, combined with other market failure arguments (uncertainty, transaction costs, terms of trust, etc.) explains why broadcasters, equipment manufacturers and consumers have so far failed to embrace this new technology.

The second problem, sidelining of community radio and its audiences through adoption of an expensive standard, is similarly disturbing. Community radio fulfils important information, social and political roles in modern societies, particularly for rural areas. Community radio operations had long been stifled by lack of sufficient access to radio spectrum, but the digital era brought high hopes that these constraints would ease and that the community radio sector could find new technical resources to expand. This promise is unlikely to be met unless a significantly different approach is taken. Currently, community radio is bound to either remain on increasingly outdated analog channels and forego the digital promise of additional spectrum, or significantly compromise their independence by seeking the financial resources to join multiplexes managed and operated by other types of broadcasters.

If market failure prevents market players to converge towards a better standard, there is scope for regulatory intervention. Governments have so far contributed little to these policy debates, so there remains much scope for policy to reduce the transaction costs preventing manufacturers to invest in the production of combined equipment, for broadcaster to air their program contents in combined digital mode, and for consumers to purchase combined digital equipment trusting that they will still be able to receive broadcast contents in the foreseeable future. Encouraging the development of a digital platform combining the DAB and DRM standards would therefore go a long way not only toward alleviating the concerns of rural and community broadcasters and their frustration with current digital radio developments, but also in addressing the non-committal position of other market players (manufacturers and national broadcasting services).

A combined standard would make the introduction of any other terrestrial digital standard unnecessary, and would help resolve some of the chronic uncertainty affecting digital radio markets since their inception. A combined platform is highly needed because beyond the issues of quality, coverage, and spectral efficiency, which a combined standard would address, loom other important market fragmentation challenges for the radio broadcasting industry (such as non-terrestrial and non-broadcast digital radio platforms). Even with a combined terrestrial broadcasting standard, full migration of analog services to digital radio, if it is ever to occur, would probably still follow a long and windy road, due to the risks and uncertainties imposed by other content delivery platforms. The task ahead for governments and the digital radio industry is to shorten and straighten the road.

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