STANDARD SETTING FOR DIGITAL RADIO

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Introduction

We have been asked by USA Digital Radio Partners, L.P. (USADR) to analyze whether the Federal Communications Commission should initiate a process to select a Digital Audio Broadcasting (DAB), or digital radio, standard.[1] This report begins by explaining why obtaining the benefits of digital radio requires coordinating the decisions of broadcasters, consumer electronics manufacturers, and consumers. Coordination is required so that the digital receivers that manufacturers produce and consumers purchase can receive the digital signals that radio stations broadcast.

We then describe the three principal means for achieving coordination: *de facto* standards, which are set through the market; voluntary standards, which are promulgated through private voluntary standards organizations; and *de jure* or mandatory standards, which are established by the government. Next, we explain why establishing a digital radio standard, whatever the process, requires that the Federal Communications Commission adopt interference rules that protect digital transmissions.

We further explain why the characteristics of the radio broadcasting industry preclude the use of *de facto* standardization to achieve coordination. Finally, we show that many of the industry characteristics that prevent the adoption of a *de facto* digital radio standard make it unlikely that a standard will be developed through private voluntary standards organizations. As a result, the government is likely to have to play a

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[1] This report is submitted in the context of USADR's Petition for Rulemaking to amend Part 73 of the Commission's Rules to permit the introduction of digital AM and FM radio broadcasting (USADR Petition).

significant role in establishing a standard, either by promoting cooperation among industry participants or by directly establishing a digital radio standard itself.

For the purposes of our analysis, we assume that any new digital radio standard will be an In-Band On-Channel (IBOC) system. This means that the new digital signals will occupy both the same range of frequencies and the same dial locations currently used by radio broadcasters, so that the new digital radio signals will overlay the current distribution of AM and FM analog radio stations. Such a system would not require that additional bandwidth be provided to terrestrial broadcasters.[2]

During the transition period proposed by USADR, stations will be allowed to broadcast digital signals simultaneously with their current analog signals without adversely affecting the sound quality of analog programming. In addition, existing analog signals will be protected from digital signal interference through limitations on the allowed power of digital signals.[3] Those stations that choose to offer digital signals will also be able to offer program-associated data as well as some auxiliary digital services, such as information and communications services, within their existing frequency allocations.

During the transition period, broadcasters will be permitted to terminate their analog transmissions. FM stations that do so will continue to be limited in the power of their digital signals. At the end of the transition period, all broadcasters will be permitted

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[2] There may be some performance advantages for a DAB system that does not occupy the same bandwidth as existing analog signals. We are assuming that those advantages are smaller than the cost of obtaining new bandwidth, not maintaining backward compatibility with the installed base of receivers, and displacing the channel locations of existing stations. We have been informed by USADR that the European DAB standard, Eureka, which requires new bandwidth, has no performance advantages over the USADR IBOC DAB system.

[3] We assume that current interference rules for analog signals will continue to be enforced.

to increase the power of their digital signals and, if they so choose, to terminate their analog transmissions. Stations that choose to do so will be able both to improve the quality of their digital broadcast signals and to offer additional auxiliary services. These services will be "interleaved" with the audio signals of these stations.

After the transition, digital signals will be protected from analog signal interference but the reverse will no longer be true. Under the USADR proposal, there is no requirement that broadcasters cease analog transmissions, but there will also be no assurance that the sound quality and coverage of analog signals will be maintained at current levels.

The Need for Coordination

It is clear that improved audio quality is popular with consumers. Consumer acceptance of digital audio disks in the 1980s demonstrates this, as do the projected subscriptions for planned satellite and cable-delivered audio services. Significant advantages will accrue to both broadcasters and consumers from the introduction of a terrestrial digital audio broadcasting system. In particular, listeners will enjoy improved sound quality and a more robust audio signal, and broadcasters will be able to offer auxiliary digital services.

However, providing the advantages of digital radio broadcasting requires coordination among broadcasters, consumer electronics manufacturers and retailers, and consumers.[4] Broadcasters must transmit signals that can be received by radios that

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[4] Unlike the case of HDTV, where there was also a need to adopt a coordinated production standard, here the existence of a widely accepted digital recording standard eliminates the need to coordinate with program producers.

manufacturers are willing to produce, retailers are willing to carry, and consumers are willing to purchase. Without some form of coordination among these economic actors, there is no incentive for any of the others to adopt digital radio. Thus, consumers will not purchase digital radios unless broadcasters offer digital transmissions. Broadcasters will not install digital transmitters unless they believe that a substantial number of consumers will purchase digital receivers. Manufacturers will not produce digital radios unless broadcasters offer digital transmissions.

In addition, the digital radios that manufacturers produce and consumers purchase must be able to receive the particular types of digital transmissions that stations broadcast. Thus, the designs of broadcast station transmitters and radio receivers must be coordinated in order to effect communication between them. Moreover, for reasons that we develop in detail below, in order to achieve widespread adoption of digital radio, it will be necessary for all radio stations and receiver manufacturers to adopt a common standard. The standard should include whatever technical information is required to ensure coordination between digital transmitters and receivers.

One way to achieve the needed degree of coordination is, of course, for the government to mandate a digital radio standard. However, this is not the only way in which standard setting can occur. The following section describes the various alternatives for achieving coordination and explains why government standard setting is likely to be necessary if digital radio is to be rapidly and widely adopted by American broadcasters and consumers.

Alternative Forms of Standard Setting

Broadly speaking, there are three ways to set technical standards for digital radio. First, *de facto* standards may be established through the workings of the market. These standards result from the interaction of individual consumer, manufacturer, and broadcaster choices and not through any centralized decisionmaking process. Conformity to these standards is based entirely on self-interest, since the only penalty for non-conformity is using a technology that differs from the one used by the majority.[5]

Second, *voluntary* standards may be set through private industry standards organizations, which establish standards through a process that involves information exchange and negotiation, and which typically operate by consensus among interested parties. The interested parties normally conduct most of the technical analysis, but standards bodies occasionally engage in such analysis themselves. The standards are considered "voluntary" in that even those who participate in selecting them are not required to conform to them.

Voluntary standards organizations essentially serve three functions. First, they provide a forum in which individuals can express their views, so that the standards chosen take into account the perspectives of a wide range of interested parties. Second, they permit the parties to engage in "logrolling," in which a party may agree to accept a particular standard in return for an implicit agreement by others to support its preferences at another time. Similarly, a single standard may incorporate design proposals from a number of different proponents in order to achieve consensus. Third, a standard

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[5] Non-conformity would, of course, be a rational choice for those users who value the intrinsic characteristics of a non-standard product more than the benefits of participating in a larger network.

established in this manner provides a "focal point" around which private actions can coalesce, thus reducing the potential that incompatible technologies will be chosen.[6] Although it is possible to depart from the standard that is chosen in this manner, there is a risk that others will not follow. For that reason, those who wish to be part of a dominant network will generally attempt to have a standard changed before departing from it. As in the case of *de facto* standards, conformity results from self-interest.

The third way in which to establish standards is through *mandatory* or *de jure* standards imposed by the government. Because these standards have the force of law, conformity by all parties is ensured; as a result, individuals cannot deviate from them. Unlike *de facto* standards, which can be changed by market processes, or voluntary standards, where the standard effectively changes if enough individuals deviate from it (or if they agree to change it), mandatory standards can be changed only through a formal decision by a governmental body.[7]

When Government Standard Setting is Preferred

Government standard setting will be preferred when two conditions are met. The first is that all producers and consumers derive great benefit when a single standard is widely used. In this case, the benefits of having a single large network exceed the value of the associated reduction in variety. This condition is especially likely to be met when the existence and rapid development of the market itself depends on the existence and promulgation of a common standard.

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[6] The importance of focal points in promoting cooperation is emphasized in T.C. Schelling, *The Strategy of Conflict* (Cambridge, MA: Harvard University Press, 1960).

[7] As we note below, some standard-setting processes contain elements of both private and governmental standard setting.

The second condition favoring adoption of a government-mandated standard is the desire to avoid the uncertainty and delay that can attend the setting of *de facto* and voluntary standards. Such circumstances may occur, for example, because there is a large number of potential adopters, no one of which is sufficiently large to establish a focal point around which others could conform. The situation may also obtain when sponsors cannot agree because the choice of a standard has a large effect on the distribution of profits among them.[8] If the benefits of a common standard are very great, government action to break the resulting logjam is likely to be desirable. As Farrell and Shapiro point out, "...when compatibility and network externalities are significant, it may be wise to have a central authority pick a technology."[9]

The Problem of Signal Interference

Standardization creates compatibility, which permits *users* to communicate with one another, as in the case of telephone or e-mail standards, and permits a variety of system *components* acquired from different sources to be used together. In addition to ensuring compatibility, however, rules are needed to prevent users of the radio frequency spectrum from interfering with one another. These rules ensure that the activities of different users are *not incompatible* with one another. Interference rules are required regardless of the method employed to establish compatibility standards for digital radio.

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[8] On this point, see the discussions of AM stereo and direct satellite broadcasting standards in S.M. Besen and L.L. Johnson, *Compatibility Standards, Competition, and Innovation in the Broadcasting Industry*, RAND, R-3453-NSF, November 1986. For discussions of the effect of differences among sponsors, see S.M. Besen and G. Saloner, "The Economics of Telecommunications Standards," in R.W. Crandall and K. Flamm (editors), *Changing the Rules: Technological Change, International Cooperation, and Regulation in Telecommunications* (Washington, DC: Brookings Institution, 1989), pp. 179-186.

[9] J. Farrell and C. Shapiro, "Standard Setting in High Definition Television," *Brookings Papers on Economic Activity: Microeconomics*, 1992, p. 26.

In order for consumers to enjoy the benefits of digital radio, radio stations must begin to broadcast digital signals, but broadcasters will not invest the necessary capital in digital broadcasting equipment unless they can be assured that their signals will reach listeners without interference from other stations. An individual broadcaster has an incentive to increase transmission power and spectrum usage in order to reach a greater number of potential listeners, but if all broadcasters are allowed to do this, consumers will not be able to receive any station without some interference. For this reason, the type and strength of signals emitted by broadcasters must be limited by the government. In addition, consumers will expect better-quality reception from new digital receivers, requiring that digital radio signals be protected from interference from other radio stations.

Interference problems are much more pronounced among radio stations than other broadcast media because of the large number of radio stations and the significant variations in their transmission power. In addition, the existence of large numbers of broadcasters in certain areas can exacerbate these interference problems. Finally, since many radio receivers are mobile, signal robustness is much more important to performance than in other broadcast media.

In addition, we have been informed that the possible types of IBOC digital transmissions may cause different levels of interference with current analog transmissions and with one another.[10] For this reason, it is important that the FCC set interference rules now before consumers make substantial investments in digital receivers, some of which could be rendered obsolete after interference rules are adopted. Otherwise, consumers

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[10] See Appendix H of the USDAR Petition for details on interference.

may invest in equipment that receives some digital signals, but will not receive those same signals after the interference rules are adopted. Any uncertainty about the ability of receivers to continue to receive digital signals will slow the adoption by consumers of digital radio receivers. Moreover, the willingness of consumers to purchase new digital radio receivers *after* the interference rules are adopted may be adversely affected if existing digital receivers had been rendered obsolete by these rules.[11]

It is also desirable to adopt interference rules before broadcasters expend considerable resources on digital transmitters whose signals create interference with one another. Unless such rules are set, either some broadcasters may be stranded with transmitters that are incompatible with the rules that are ultimately adopted, or broadcasters will defer purchasing digital transmitters (or upgrading their existing analog transmitters) as long as possible in order to minimize the likelihood that stranding will occur. Finally, rules are necessary to prevent interference between analog and digital transmissions during the transition period. For these reasons, it is important for the Commission to adopt interference rules at the beginning of the transition period.

Why a Government-Mandated Digital Radio Standard May Be Required

We explained above why a digital radio standard is needed to coordinate the behavior of broadcasters, equipment manufacturers, and consumers. This section identifies a number of characteristics of radio broadcasting that may significantly retard the pace of adoption of digital radio if a government-mandated digital radio standard is

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[11] Apparently, a major reason why consumers were unwilling to purchase FM radio receivers after World War II was that the FCC had changed the location of the FM band, rendering useless FM receivers that had previously been purchased, and consumers feared being "stranded" again. See S.M. Besen, "AM

not adopted. These characteristics explain why a *de facto* digital radio standard is unlikely to emerge from the independent behavior of consumers, manufacturers, and broadcasters. They also explain why establishing a standard through private standards organizations is likely to be especially difficult. It should also be noted, however, that the existence of a government-mandated standard may be a necessary, but not sufficient, condition for achieving widespread and rapid diffusion of digital radio. The pace and extent of adoption will also depend on the underlying demand for the service as well as on other actions taken by the government.[12]

Consumer Electronics Manufacturers Will Not Produce Digital Receivers Without a Standard

The major developers and sponsors of digital radio systems are not consumer electronics manufacturers. For this reason, digital radio receivers (and transmitters) will have to be supplied by third parties, which will license the technology from developers. Consumer electronics manufacturers, whose cooperation is critical in creating the market for digital radio, have in the past indicated that they are reluctant to incur the costs necessary to begin production of new broadcast receivers in the absence of a standard.[13]

Many of the costs of producing digital radio receivers must be incurred prior to the point at which any sales to consumers are made. A large percentage of the total costs of producing any digital product involves the costs of writing the needed software and

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versus FM: The Battle of the Bands," *Industrial and Corporate Change*, 1992, for an analysis of this experience.

[12] Besen, *ibid.*, provides an analysis of the case of FM radio, where adoption was long delayed despite the existence of a standard.

[13] See Comments (dated July 11, 1996) and Reply Comments (dated August 12, 1996) of Electronics Industries Association and EIA Advanced Television Committee in MM Docket No. 87-268 (the proceedings on Advanced Television Systems).

designing the microprocessors in which the software is embodied. In order to produce digital receivers, a manufacturer must incur these costs.[14] Because these costs are sunk, meaning that they cannot be recovered if the product is unsuccessful, manufacturers are reluctant to begin development unless they have some assurance that consumers will purchase the receivers that are being designed. As long as there is some question as to which digital standard will be used by broadcasters, so that consumers may be unwilling to purchase receivers, receiver manufacturers will remain reluctant to incur the large fixed costs of development. Moreover, if manufacturers have to incur the design and setup costs for a number of different digital broadcast standards, they will be less likely to produce for any particular standard.[15]

On the other hand, if manufacturers are certain that the equipment they produce will receive all digital radio signals, they will be more likely to enter the market and promote the sales of digital radios. Although the existence of a standard does not by itself guarantee that a manufacturer's costs of development will be recovered, it does increase the probability.[16]

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[14] During most of the transition period, new receivers will be capable of receiving both analog and digital transmissions since, presumably, not all stations will have converted to digital transmission. Moreover, existing receivers will be able to continue to receive analog transmissions throughout the transition period.

[15] An example may be coding of the digital signal. In order for receivers to translate the radio waveform into the correct audio signal, the receiver must know how the data bits are coded into the carrier signal. Although it may be possible to build receivers that "understand" different coding systems, this will add to their cost and slow their adoption. Thus, it may be necessary for the standard to specify how coding should occur.

[16] See the USADR Petition, Section VIII, for a discussion of the additional complexity of digital AM and FM receivers.

Consumers Expect Portability

Consumers currently can purchase an AM or FM receiver and be confident that it will receive the signal of any AM or FM station in the country as long as the consumers are located within the broadcast contour of the station. Without a digital radio broadcast standard, however, an individual broadcaster or broadcast network can only guarantee that consumers will be able to receive its own digital broadcasts. Thus, without a standard, consumers cannot be assured that they will be able to receive all signals as they travel from city to city. This is especially important for radio receivers that are used in automobiles, which represent a large percentage of radio receiver purchases.[17] Because no single broadcaster or network can fulfill consumers' expectations regarding portability, a single standard is needed to hasten the penetration of digital receivers.

Consumers Expect Universal Reception

In addition to portability, consumers expect universal reception. Currently, consumers who purchase an AM or FM receiver can receive all AM or FM broadcasts within the area in which they reside. However, if consumers must instead choose equipment that can receive some local AM or FM digital broadcasts but not others, they will be less likely to invest in new equipment. Significant network benefits will not be available if different digital standards are being employed by different broadcasters in the same market.

The example of AM stereo demonstrates this consumer expectation. One of the main reasons cited for the lack of broad adoption of AM stereo is the lack of universal

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[17] According to the CEMA Research Center, 27 percent of all radio receivers sold in 1997 were placed in automobiles.

reception. Although one might expect that, at least within a single city, broadcasters would choose a single standard, this has not been the case. When AM radio was first introduced, most radio markets with more than one stereo AM station employed more than one stereo broadcast standard.[18] When consumers realized they could not pick up a particular AM stereo broadcast with their new receivers, they blamed the receiver and not the lack of compatibility between different AM stereo standards.[19] The lack of universal reception may have slowed the adoption of AM stereo receivers and, therefore, AM stereo transmitters.

The Problem of Open Systems

Broadcasters purchase, install, and operate transmitters under the assumption that all consumers will have equipment that can receive their signals. Listeners purchase equipment under the assumption that they will be able to receive all local radio broadcasts and will continue to receive all radio broadcasts as they travel among areas. Because these purchase decisions are made by different entities (i.e., because the system is "open"), a standard is required to ensure that the assumptions on which they are based are mutually consistent. In contrast, operators of "closed" systems, e.g., cable and subscription satellite systems, can coordinate the choice of transmitter and receiver themselves.[20]

Because of the open and non-subscription characteristics of radio broadcasting, broadcasters cannot dictate which equipment listeners should purchase. The necessity of

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[18] See Besen and Johnson, *op. cit.*, p. 46.

[19] *Id.*, pp. 49-50.

[20] Cable operators typically lease consumer equipment, thus ensuring compatibility with their transmissions. Although consumers purchase the equipment used to receive most Direct Broadcast

coordination between broadcasters and listeners, who experience different benefits and costs from different technologies, makes the selection of a single broadcast standard critical. Because of the characteristics of this market, described in detail below, a government-mandated digital broadcast standard may be needed to achieve this coordination.

The Effect of the Large Number of Radio Station Owners

Because willingness on the part of consumers to purchase a radio receiver depends on the number of stations they can receive, there are benefits to stations if they all employ the same transmission standard. However, the AM stereo example demonstrates that even stations in the same city can have difficulties coordinating on a single standard. This lack of coordination among stations can result from significant differences among them regarding such factors as programming format, broadcast power, interference environment, network affiliation, and profitability. Each station must perform its own cost/benefit analysis when deciding which technology to adopt, and this analysis may yield different results for different stations. In order for stations to enjoy the benefits of coordination, a single digital broadcast standard is needed.

Although stations could attempt to coordinate their actions through negotiation, this is likely to prove difficult given the very large number of stations that must agree.[21] There are more than 10,000 commercial radio stations in the United States and the

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Satellite services, they typically intend to receive only a single service, and thus purchase the reception equipment that is compatible with the transmissions of that service.

[21] Clearly, consumers are too numerous to dictate the adoption of a standard. Conceivably, equipment manufacturers could dictate a standard but they are apparently reluctant to do so without assurances that broadcasters will adhere to the same standard

number of stations in some individual markets is very large.[22] Moreover, no single broadcast station group, or small collection of such groups, is large enough to dictate a standard to which others would have to conform.[23] Of the almost 4,500 different commercial radio station owners, the largest station group owns only about 3 percent of all stations, and the ten largest groups together own only about 13 percent of the total. Finally, the owners of USA Digital Radio own fewer than 2 percent of all commercial radio stations.

Private Voluntary Standardization Is Likely To Be Difficult

In principle, of course, a private agreement, either through an established standards organization or an *ad hoc* agreement, might be used instead of a government-mandated standard to overcome the problems discussed above. However, there may be factors in this case that make voluntary standardization difficult.

First, if there are substantial differences among the technologies that are competing to become the standard, private voluntary standardization is likely to be a contentious process. Although this problem may be overcome if there are relatively few users, or if users share all the same interests, those conditions are not satisfied here. In the same way that a single radio broadcaster is not large enough to impose a *de facto* standard, a single broadcaster (or small group of broadcasters) may not be able to direct a voluntary standards process to successful conclusion. The wide diversity in interests among station owners exacerbates this problem. For example, different standards may

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[22] For example, 8 markets have more than 50 stations, 26 markets have at least 40 stations, and 64 markets have at least 30 stations. These and subsequent data are drawn from BIA Research, Inc., *Media Access Pro*.

[23] Besen and Saloner, *op. cit.*, p. 182, note that "The stalemate may also be broken if there is a dominant firm." For an example where the choice of a standard by a single large buyer induced other

have very different benefits for a station owner depending on whether it operates at high or low power, is in an urban or rural location, or has a music or talk format.

Second, not only must a voluntary process coordinate the preferences of broadcasters with significantly different characteristics, it must also coordinate these interests with those of manufacturers and consumers. For example, a standard that imposes high manufacturing costs would slow the adoption of digital receivers and, therefore, the introduction of digital broadcasts. Although a voluntary process should, in principle, reflect the interests of manufacturers and consumers, there is no guarantee that these interests will be fully represented. Similarly, even if all consumer electronics manufacturers could agree on a standard, they will not be able to create a market if broadcasters do not adopt the same standard.

Third, reaching agreement on a voluntary standard is difficult if the choice has significant consequences for the distribution of profits among sponsors. In such cases, sponsors may have difficulty in agreeing on a standard and may instead choose to compete *for* the market rather than agreeing to a standard and then competing *within* the market.[24] As a result, sponsors may attempt to delay or disrupt the private standard-setting process.[25]

Fourth, private voluntary standards processes may be subject to significant antitrust scrutiny, which can substantially increase the cost, and slow the progress, of

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buyers to choose the same standard, see the discussion of the television program scrambling standard in Besen and Johnson, *op. cit.*, pp. 99-113.

[24] See S.M. Besen and J. Farrell, "Choosing How to Compete: Strategy and Tactics in Standardization," *Journal of Economic Perspectives*, 1994, for an analysis of this choice.

[25] J. Farrell, "Choosing the Rules for Formal Standardization," mimeo, UC Berkeley, 1993, observes that the rules chosen for the selection of a standard will be more likely to affect the speed of the process adversely if product vendors prefer not to have a standard at all.

standardization. In the extreme, private bodies may become so paralyzed by the threat of antitrust litigation that they are unwilling to adopt any standards at all.[26]

Fifth, there is no guarantee that, once a voluntary standard has been set, it will actually be adopted by broadcasters. For example, Japanese broadcasters and European satellite broadcasters resisted various HDTV standards, which significantly slowed the introduction of that new technology.[27]

Finally, the distinction between private voluntary and government standard setting may be too strong. In most cases, government standard setting has involved the participation of both private standard-setting bodies and industry members. Similarly, private standards organizations often request government endorsement of the standards they have selected.[28]

The Benefits of a Transition Period

As part of the process of creating a market for digital radio, it is important to have a transition period during which digital services begin to be offered but analog receivers and transmitters continue to provide service. In the following section, we describe the benefits to consumers and broadcasters of having a transition period.

USADR has proposed a transition period during which all broadcasters could overlay digital radio transmissions on their existing analog signals. During this period, consumers who chose to purchase digital receivers would receive improved signal quality from those stations that provided digital transmissions, and those stations could also offer

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[26] We understand that this was a consideration in the decision by the National Association of Broadcasters not to adopt an AM radio standard.

[27] See Farrell and Shapiro, *op. cit.*, pp. 8, 12.

[28] Farrell and Shapiro, *id.*, p. 29, make this point

some digital information and communications services. After the transition period, stations could increase the power of their digital signals and, if they so choose, eliminate their analog transmissions. Stations that terminated their analog transmissions would offer improved digital radio signal quality and could expand their offerings of information and communications services. There are a number of benefits to this approach.

The Sound Quality of Analog Radio Service Would Be Unaffected During the Transition

Under the USADR proposal, the sound quality of existing analog radio services would be unaffected during the transition.[29] Not only would stations continue to broadcast analog signals but those signals would be accorded the same degree of protection as at present. This means that the existing installed base of analog receivers would be backward-compatible even for the signals of stations that chose to provide digital transmissions during the transition period.[30] Consumers would presumably begin to purchase digital-capable receivers at a pace dictated by their expectations about the availability and value of digital transmissions.[31] In addition, most consumers will have replaced their current radios within the proposed transition period.[32]

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[29] Indeed, there may be improved performance on analog receivers.

[30] Consumers would be free to continue purchasing analog-only receivers, although we believe that most would not do so. This is in contrast to the All-Channel Receiver Act of 1962, which mandated that all televisions sold in the U.S. be able to receive both VHF and UHF signals. The benefits to consumers of the Act's mandatory inclusion of UHF tuners are questioned in D.W. Webbink, "The Impact of UHF Promotion: The All-Channel Television Receiver Law," *Law and Contemporary Problems* 34, 1969, pp. 535-561.

[31] We understand that the digital receivers employed during the transition period will also be able to receive the improved signals of those stations that terminate analog service after the transition period. Although providing for backward compatibility may reduce the incentive to purchase digital receivers, this is likely to be offset by the existence of a fixed transition period.

[32] Consumer surveys have shown that most radios are replaced within 10 years. For example, see *Appliance Magazine*, September 1998.

Broadcasters Can Provide Digital Transmissions at Different Times

Under the USADR transition proposal, the timing of the adoption of digital broadcasting is left to each individual station. Some stations, particularly smaller, financially constrained stations, are likely to wish to upgrade to digital broadcasts only when they need to replace their transmitters, and they are permitted to do so under the proposal.[33] Indeed, under the USADR proposal, stations would never be required to adopt digital broadcasting. Other stations might choose to upgrade their existing transmitters quickly, or to accelerate their replacement, in order to take advantage of the benefits of offering digital service.

The pace at which adoptions would occur would presumably depend on the age and condition of existing analog transmitters, but it would also depend on the benefits that individual stations expect from employing digital radio. The factors that influence that choice might include a station's programming format, the topographic conditions in the area in which it operates, whether competing stations offer digital transmissions, and the expected demand for auxiliary digital services. Some stations might employ digital radio transmissions early in the transition period while others might do so much later, or, conceivably, not at all. In any event, the choice would be left entirely up to the stations but, of course, there would be no expectation that their analog transmissions would be protected and free of interference after the end of the transition period.

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[33] We have been informed that between 4 and 10 percent of all radio stations replace their transmitters in any given year; see USADR Petition, Section IX.C.

A Fixed Transition Period Would Promote Adoption

Although the existence of a transition period would give both consumers and broadcasters considerable flexibility in converting to digital radio, there is a danger that an excessively long or indeterminate transition period would retard adoption. This is because consumers, or broadcasters, might adopt a "wait and see" attitude, moving to adopt only after a substantial number of others had adopted. But, of course, if everyone employs such an approach, no one will ever adopt, with the result that the benefits of the new technology will never be realized, even if those benefits are great. This phenomenon, which is called "excess inertia," is an important factor in industries where the benefits that any consumer obtains depends on the number of other consumers who have made the same decision but where it is difficult to coordinate their actions.[34] The existence of a fixed transition period is intended to overcome this phenomenon.

Consumers will purchase receivers that are digital-capable if they perceive that the benefits of such receivers exceed their costs.[35] However, all consumers would know during the transition period that there is no guarantee of interference-free analog transmissions at the end of the period. This knowledge would presumably increase the

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[34] See J. Farrell and G. Saloner, "Standardization, Compatibility, and Innovation," *Rand Journal of Economics*, 1985, pp. 70-83, for an analysis of this phenomenon. Farrell and Shapiro, *op. cit.*, p. 29, point out that "Reliance on the market may lead to a prolonged period of confusion or uncertainty during which multiple systems compete and many consumers wait until they think they can see who will win the market bandwagon contest. Market competition also may leave some consumers – the bold ones – stranded with abandoned, incompatible equipment."

[35] Because we expect that the incremental costs of adding digital capability to analog receivers will be small (see USADR Petition, Section VIII), we do not expect that analog-only receivers will continue to be offered. Relatively few consumers purchased AM-FM receivers for an extended period after the FM standard was adopted following World War II since AM-only receivers continued to be offered. On this point, see Besen, *op. cit.* Also, since most consumers own multiple radios, some of these units may be digital but not others.

rate of adoption of digital-capable receivers,[36] providing two benefits. First, other consumers would be induced to purchase digital receivers as the "bandwagon" picked up speed. Second, broadcast stations would increase their rate of conversion in order to offer service to the growing number of consumers with digital receivers.[37] Further, this process would provide feedback whereby the growth in the number of stations broadcasting digital signals increased the purchases of digital receivers by consumers.

A similar process works to influence the behavior of broadcasters. Each FM broadcaster would know that its analog signal might be subject to interference at the conclusion of the transition period. In order to avoid this possibility, a broadcaster would be more likely to purchase a digital transmitter during the transition period than if it remained confident that the analog signal would be indefinitely protected from interference.

Stations Could Continue to Offer Analog Service Indefinitely

At the end of the transition period, each broadcaster would decide whether to continue analog transmissions, in order to reach those listeners who have not purchased digital receivers, or cease analog transmissions, in order to improve service to those listeners who have. Although the setting of a date after which consumers will have no guarantee that analog signals will be protected encourages the purchase of digital receivers, there may be some markets in which most or all stations continue to provide

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[36] There are two basic reasons why the knowledge that analog service will be degraded at the end of the transition period will induce consumers to replace analog radios more quickly. First, consumers are less likely to incur the costs of repairing damaged or malfunctioning analog radios because they know they have only a limited useful life. Second, consumers will want to enjoy the benefits of digital service sooner if they expect to have to convert to digital at the end of the transition period in any event.

[37] It is also likely that, in the instances where a consumer wishes to continue using an analog radio (e.g., antique radio collectors), digital-to-analog converters will be made available.

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analog transmissions. Although these situations would be rare if digital radio receives widespread acceptance, the possibility that some stations will continue to offer analog transmissions indefinitely is taken into account in the proposed transition mechanism.

The existence of the proposed transition period to digital radio provides two benefits. First, it affords both consumers and broadcasters considerable flexibility in the timing of their conversion to digital broadcasting. Second, with the length of the transition fixed, incentives will be created that can overcome the inertia that sometimes plagues adoption decisions in network industries.

Summary

A digital radio standard is necessary to ensure coordination among consumers, broadcasters, and equipment manufacturers and, therefore, create a market for digital radio. The characteristics of the digital radio market are such that a *de facto* standard is unlikely to arise. Moreover, for many of the same reasons, private voluntary standard selection is also unlikely to produce a digital radio standard. As a result, it is likely that government involvement will be necessary in the standard-setting process in order to bring the benefits of digital radio to consumers. This can take the form of promoting cooperation among broadcasters and equipment manufacturers as well as within these groups, but it may also require that the government itself select the standard.