

## **Technical Analysis of the Low Power FM Service**

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## 1 Summary

The Federal Communications Commission has proposed a new class of low power FM radio stations (LPFM). A critical element of this proposal is consideration of whether the proposal is technically feasible. Specifically, a key issue is whether these new low power radio stations will cause unacceptable levels of interference to the current FM broadcast stations. Wireless Valley Communications, Inc. was commissioned to provide objective, critical technical analysis of the technical studies submitted by several commenters in the FCC's proceedings.

Our mission in this report is three-fold: 1) to critique and referee various submissions for fair and accurate technical representation; 2) to compile accurate technical models and trends from various submissions that can be used to analyze the impact of LPFM on current and future station owners and listeners; and 3) to use the technical data from the public comments and the FCC's NPRM to determine the viability and limitations on LPFM and its potential impact on existing and emerging FM broadcast services and the listening public. In this report, we point out incorrect assumptions, inappropriate models, and erroneous results which do not properly model the impact which LPFM may have on incumbent FM broadcasters or emerging digital radio services in the FM band. Where possible, we suggest alternative and more objective techniques for postulating the technical arguments, and recompute the results.

Our analysis concludes that LPFM will not cause unacceptable levels of interference to existing FM broadcast stations. The receiver studies submitted in this proceeding imply that the true "real world" FM interference environment for household radios is benign, due to the FCC's unnecessarily high interference protection ratios. The receiver studies offer very strong support for LPFM as a viable service without the need for 2nd and 3rd adjacent protection ratios, because today's fixed and portable FM radios operate successfully with much less interference protection than what the FCC provides in its present station licensing process. The small additional interference induced by LPFM is miniscule in comparison to already existing levels of interference in the FM band.

Moreover, in reviewing these studies, we have uncovered a clear bias on the part of certain constituencies to overstate the potential interference problems of LPFM. Many commenters who conducted FM receiver studies skewed their results when contemplating how LPFM would impact the listening public. For example, the National Association of Broadcasters commissioned an extensive receiver study of 28 FM radios<sup>1</sup> but then omitted automobile radios (which make up over 20% of the FM radios sold and over 44% of the radios listened to by the

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<sup>1</sup> "Comments of the National Association of Broadcasters in MM Docket 99-25," Volume Two of Three and Volume Three of Three, August 2, 1999.

public)<sup>2</sup> from its LPFM impact study. Omitting car radios from an LPFM system impact study greatly biases the results for maximum susceptibility to interference (i.e. worst performance). In other comments, a “worst-case” radio, most susceptible to interference, was fabricated from the worst-case measured data of two different radios, even though no such physical FM receiver was found to exist in any of the public comments. Numerous other examples of data manipulation, such as double and triple counting of interference events, portray LPFM in an unfair and non-objective light. Our intention is to expose these incidents and offer more credible methods for extrapolating results to properly quantify the impact of LPFM.

In addition to a review of the submitted studies, we conduct an extensive spectrum simulation to demonstrate that hundreds of LPFM stations may indeed be deployed in the U.S. with minimal impact to incumbent and future digital FM radio stations. We use the FCC’s FM radio license database, the FCC radio propagation programs, and Part 73 interference and coverage rules for FM radio stations, to show that properly certified LPFM transmitters with radiated power levels between 1 and 100 Watts and no 2<sup>nd</sup> or 3<sup>rd</sup> adjacent channel protection requirements can serve tens of millions of neighborhood listeners in the U.S.,

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<sup>2</sup> “Comments of the Consumer Electronics Manufacturers Association in MM Docket 99-25,” p. 10, August 2, 1999.

while having minimal interference impact on a few tens of thousands of listeners at most.

Our analysis shows that between 64 and 680 times as many citizens are able to receive LPFM programming over small distances (i.e. within neighborhoods) as those who may rarely experience some level of interference or degraded service. Even those listeners experiencing some degradation of service will likely be able to augment their reception by simply relocating their radio or adjusting their antenna. We also present maps to demonstrate suitable locations of LPFM stations in several representative cities. All of the models, assumptions and techniques used to carry out the analysis and simulations are documented for corroboration by others, and computer source code based on the original FCC LPFM code is provided in this filing.

Finally, we analyze the concerns of IBOC digital radio technology, and study some of the cost/performance tradeoffs that digital radio manufacturers make in product design. We show that, regardless of the specific radio implementation, IBOC will be able to coexist with LPFM in the same manner it will with standard FM broadcast stations, due to the very small interference footprint of LPFM.

## 2 Preliminary Statement

The compelling case for minimal LPFM interference regulation is due to the fact that LPFM station contours for coverage and interference are much smaller than those of primary FM broadcast stations. However, much of the debate has, to date, not addressed this issue. NAB and CEMA premise their FM receiver tests on a supposition that LPFM will be possible only if receivers offer the same interference rejection as provided by the FCC interference protection ratios. This premise is completely wrong. The radio receiver studies demonstrate that there is significant room to relax the FCC's protection standards and that most consumers today are satisfied with FM receivers that tolerate a much greater level of interference than what is provided for in the FCC FM station licensing rules. In other words, the current protection ratios provided by the FCC offer much greater interference protection than is required for fixed and portable household receivers, and may thus be relaxed to accommodate LPFM.

The receiver studies submitted show that, while technology may have improved, this improved technology has not increased the interference rejection capabilities of modern FM radios to the level of FCC protection ratios. Why is this the case? Because the FCC's protection standards produce a significantly sheltered environment for even very low quality receivers. The proliferation of poor quality receivers that satisfy consumers, in fact, demonstrates that the FCC's protection ratios are far more stringent than necessary and that the interference environment is benign. The FCC protection ratios are aimed at

protecting against the worst-case interference situation, which occurs when adjacent-channel stations are strong enough to capture or blanket the receiver. Early FM receivers used discrete electronic components which made mass-production of tight RF front end filters more difficult than today, (Rappaport, Wireless Communications, Prentice Hall (1996), p.4) and relied upon Automatic Frequency Control (AFC) circuitry to fine tune the receiver for best reception. As a result, older FM receivers were much more susceptible to drift, adjacent channel capture, and adjacent channel overload than are modern receivers, which by contrast use integrated RF circuitry, digital frequency synthesis, and phase lock loop (PLL) detection. Today's modern FM receivers can tolerate much closer adjacent channel transmitter spacings than present FCC rules provide. By using overly stringent adjacent channel protection ratios, the FCC guarantees that FM broadcast stations will be properly spaced to avoid adjacent signals sufficiently powerful to disturb older FM receivers, but does not recognize the remarkable improvement in adjacent channel interference resistance for modern FM receivers. Thus, providing such a high level of interference protection for modern receivers wastes a great deal of spectrum. The addition of LPFM stations will create insignificant interference levels while greatly increasing the spectrum utilization of FM.

It is critically important to note the FCC did not premise its LPFM proposal on the improvement of receiver technology. The Commission mentions receiver

improvement in a footnote<sup>3</sup> of the NPRM, but the three reasons given for waiving 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel protections for LPFM are 1. "...these protections would limit substantially the number of channels available for low power radio generally...",<sup>4</sup> 2. "In most instances, we believe the actual effects of such interference might well be insignificant"<sup>5</sup> and 3. "We found only a small risk of interference in (the context of grandfathered short-spaced FM stations), which was outweighed by improved service."<sup>6</sup> As shown below, our computer simulations support these rationales.

In addition to adopting overly cautious interference protection standards for fixed and portable FM receivers, other FCC policies do not maximize the total number of authorized stations in the United States today. An even greater number of FM licenses (i.e. improved spectral efficiency) could be provided by the Commission if more accurate, site-specific radio propagation models (which account for signal attenuation due to foliage, buildings and terrain) were used to predict interference for fixed and portable radio receivers in lieu of curves presented in Part 73 of the Commission's rules. Site-specific models that use

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<sup>3</sup> "Notice of Proposed Rule Making In the Matter of Creation of a Low Power Radio Service," FCC 99-6, Federal Communications Commission, February 3, 1999, paragraph 42, page 17.

<sup>4</sup> FCC 99-6, paragraph 42, page 17.

<sup>5</sup> FCC 99-6, paragraph 45, page 18.

<sup>6</sup> FCC 99-6, paragraph 46, page 18.

real-world databases have been the topic of intense research,<sup>7</sup> and are becoming practical.<sup>8</sup>

In this report, Wireless Valley Communications responds to comments filed in MM Docket 99-25 by the National Association of Broadcasters (referred to as the NAB Study)<sup>9</sup>, which includes the Carl T. Jones report, "FM Receiver Interference Test Results Report (The NAB Carl T. Jones Report) and the MLJ reports (NAB MLJ Reports), the Consumer Electronics Manufacturing Association (referred to as the CEMA Study)<sup>10</sup>, USA Digital Radio (referred to as the USADR Study).<sup>11</sup> We also examine FM receiver test reports by the FCC's Office of Engineering and Technology (referred to as OET Study)<sup>12</sup> and Broadcast Signal Labs, LLC (referred to as BSL Study).<sup>13</sup> Comments from other parties, such as corporations, associations of broadcasters, and broadcasting consultants were also reviewed, but are not subjects of this analysis. We chose to respond to the NAB Study, the

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<sup>7</sup> T.S. Rappaport: *Wireless Communications: Principles & Practice*, Prentice Hall, 1996, ch. 3

<sup>8</sup> See for example, *SitePlanner™*, a site-specific wireless system design program, www.wvcomm.com

<sup>9</sup> "Comments of the National Association of Broadcasters in MM Docket 99-25," August 2, 1999.

<sup>10</sup> "Comments of the Consumer Electronics Manufacturers Association in MM Docket 99-25," August 2, 1999.

<sup>11</sup> "Comments of USA Digital Radio, Inc. in MM Docket 99-25," August 2, 1999.

<sup>12</sup> "Second and Third Adjacent Channel Interference Study of FM Broadcast Receivers", Project TRB-99-3 Interim Report, July 19, 1999, Technical Research Branch, Laboratory Division, Office of Engineering and Technology, Federal Communications Commission.

<sup>13</sup> "National Lawyers Guild Committee on Democratic Communications Receiver Evaluation Project", June 30, 1999, by Broadcast Signal Labs, LLP.

**CEMA Study, the USADR Study and the OET and BSL studies because they raise the technical issues most important to LPFM.**

### 3 The State of FM Radio

This section discusses the relations between FM receiver quality, FM radio station placement rules, and FM interference levels.

In Section 3.1 we find that receiver performance is unrelated to FCC interference separation rules or protection ratios. Section 3.2 covers the forces governing FM interference levels and reception quality, showing that FCC protection ratios do not describe actual interference levels. The FCC interference protection guidelines are much more rigorous than actually needed and implemented. Therefore a small additional amount of interference from LPFM stations will not noticeably deteriorate reception for the vast majority of FM radio listeners.

#### 3.1 *The State of Consumer FM Receivers*

NAB and CEMA's radio tests appear to have been designed to show how poorly FM receivers perform compared with the FCC interference protection ratios. However, this comparison itself is illogical and has no merit. FCC protection ratios were developed to ensure that FM stations were not built too close together, thereby providing acceptable reception by early generations of FM radios with discrete RF components and AFC tuning. Today's FM receivers drift less, have more reproducible electrical characteristics and better detection capabilities. They are designed for excellent performance in today's FM-band interference environment. Modern radio designs are not based on the FCC's

protection ratios. The fact that modern FM receivers do not meet the FCC protection ratios while still providing good consumer performance demonstrates the protection ratios are overly stringent. Even car radios, which use stringent filtering because they may travel close to an arbitrary FM transmitter, often fail to meet the FCC ratios.

Commenters noted that FM receivers as a group don't work very well compared to any expectations implicit in the FCC interference protection ratios. The NAB states that the "majority of receivers do not perform even as well as the Commission's existing standards assume."<sup>14</sup> This is true, but *supports* adoption of LPFM. This statement is sensible and not at all surprising. The FCC interference protection ratios adequately protect against the most difficult situation for early generation FM radios – nearby adjacent channel signals much stronger than the desired signal. The majority of receivers today use much more effective RF front end filtering and phase lock loop (PLL) tuning mechanisms. In virtually all reception situations today, adjacent channel FM signals do not come close to interfering with the proper detection of the desired signal, whereas this was not the case a few decades ago. Therefore, an enormous amount of excess (i.e. wasted) interference protection and untapped spectrum utilization is freely available to all modern FM radio receivers.

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<sup>14</sup> NAB Study, Executive Summary.

CEMA explains “Receivers are designed with intentional design and cost tradeoffs that are made by manufacturers to meet market needs.”<sup>15</sup> Maximizing the profit on radio sales by adjusting the price/performance tradeoff for each category of receiver is simply good business. It does not mean the quality of receivers is declining. It does mean radio consumers’ cost and quality expectations are being met more precisely. There is no reason to hold household receivers to extremely high interference-rejection standards in light of the FCC’s overly protective interference environment, and no compelling reason to require 2<sup>nd</sup> or 3<sup>rd</sup> adjacent interference protection for LPFM transmitters, given the minute level of additional interference that would be produced.

Note that FM radio receiver performance is based on the actual real world environment, the tolerance of the consumer, and the design/cost tradeoffs made by the manufacturer, and has absolutely nothing to do with how the FCC assigns FM broadcast station licenses. This crucial point is vital for understanding the implications of the FM receiver studies, and illuminates several flaws made by commenters who attempt to tie FM receiver performance with FCC protection ratios.

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<sup>15</sup> “Comments of the Consumer Electronics Marketing Association”, August 2, 1999, page 17.

The receiver studies clearly document that the intended FCC interference protection levels, as computed by its propagation models and computer programs used to assign primary FM broadcast licenses, are much more stringent and have very little to do with the actual interference protection needed for today's household FM receivers. The data show that radio manufacturers have sensibly exploited a lack of interference in the FM band (i.e. the presence of margin) to design and manufacture radios that handle much less adjacent channel interference (i.e. are less expensive to manufacture) than the FCC interference protection rules would imply. Even with such poor interference protection, household radios satisfy the consumer. Since LPFM induces a small amount of additional interference (as we show in Section 6), this should logically lead the FCC to approve LPFM stations without adjacent channel protection requirements, since its present policy for licensing primary FM stations for a high level of 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel protection contour (i.e. -40 dB D/U) has already manifested itself in consumer acceptance of FM radios that handle much less interference than the protection ratios imply.

The concept of designing the least expensive receiver for the particular interference environment is not new, nor is it restricted to FM radio. In the cellular and PCS wireless communications industries, portable handsets are built for minimal interference rejection when the wireless service is new and has relatively few base station transmitters which are separated by large distances. In this phase of the system, the spectrum not used efficiently. Then, as the

number of wireless subscribers increase, the wireless operators add more base stations which are closer together, the interference environment worsens, and the handset manufacturers then build “better” next generation handsets with greater interference rejection capabilities more in line with the original interference specification for a “fully deployed” system.<sup>16</sup>

The handset manufacturer enjoys the limited interference environment since it is able to manufacturer its products at the least cost. The LPFM concept is, technologically, similar in some respects to the addition of small base stations, called microcells, in a cellular radio system, which offer increased cellular capacity and service coverage at the expense of slightly more interference near the microcell.<sup>17</sup> For LPFM, however, the additional interference will be so minute that existing FM receivers will perform just as well for virtually all listeners.

Several receiver studies incorrectly assert that, because many FM radios tolerate less interference than the FCC protection ratios, LPFM must be subjected to the same interference prevention guidelines as standard FM broadcast stations. On the contrary, the studies show that consumers are pleased with FM radios that have much less protection immunity than assumed by the FCC protection guidelines, and thus LPFM will be easily assimilated.

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<sup>16</sup> Discussions between T. S. Rappaport and research and design engineers at cellular phone manufacturers Nokia, Ericsson, Motorola, and Qualcomm, 1995 – 1999.

<sup>17</sup> Rappaport. *Wireless Communications: Principles and Practice*, Prentice Hall, c. 1996, ch. 2.

### 3.2 *The State of FM Reception*

The FM reception environment is not as harsh as might be assumed solely from the FCC's regulations. This will leave room for LPFM stations placed without regard to 2<sup>nd</sup> or 3<sup>rd</sup> adjacent channel protection, provided their power is no greater than 100 Watts.

With FM stations, the most restrictive separation rule takes precedence over all the others. This means only one of the many protection ratios established for these rules is ever built into the radio environment. Consequently, actual FM reception conditions are far better than the laboratory tests assume, allowing the "poor-performing" radios to satisfy listeners' sound quality expectations.

Clearly the FCC licensing procedure uses a propagation model which is cautious and which, in fact, overestimates the needed separation distances between transmitting stations to achieve a useful level of interference protection for household FM receivers.

In addition, FM radio transmitters are required to have emission masks that limit the energy radiated in adjacent FM channels. For example, these so-called emission mask regulations require power on 1<sup>st</sup> adjacent channels be at least 25 dB below the main carrier.<sup>18</sup> The Association of Federal Communications

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<sup>18</sup> FCC 47 CFR 73.317.

Consulting Engineers (AFCCE) found in a small study<sup>19</sup> that the out-of-band emissions of FM stations in good repair were 30 dB *below* the regulated amount. In other words, the component of FM interference due to off-channel transmissions is well below what the FCC regulations would lead one to expect. If LPFM transmitters are certified for proper operation, as suggested by the FCC in its NPRM, there is no reason to expect adjacent channel bleedover except for blanketing conditions. We believe the requirement for transmitter certification, in fact, is necessary to ensure spectral protection to adjacent channel subcarrier transmissions for the blind, background music and other SCA services, and for emerging digital radio services. With such certification, LPFM broadcasters will be as cautious as other FM broadcasters, and will not generate interference to subcarrier transmissions or to In Band, On-Channel Digital Audio Broadcasting (IBOC DAB) services.

While the FCC propagation models for FM station licensing are clearly not perfect, they do a remarkably good job as there has not been a public outcry with regards to interference in today's FM band, and few commenters criticized the interference conditions that exist today.<sup>20</sup> Given the FCC's care in assigning primary FM radio licenses, and the good quality of FM radio reception

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<sup>19</sup> "Comments of the AFCCE on Notice of Proposed Rulemaking", August 2, 1999, page 11.

<sup>20</sup> In some select regions, interference can indeed occur. See "Comments of the North Carolina Association of Broadcasters and the Virginia Association of Broadcasters", Vol. 1 of 3, August 2, 1999, p. 22

experienced by citizens, it is clear that the present state of FM radios is well matched to consumer expectations and level of satisfaction in today's FM spectrum.

The FCC interference protection guidelines are much more rigorous than actually needed and implemented. This suggests that a small additional amount of interference from LPFM stations will not noticeably deteriorate reception for the vast majority of FM radio listeners.

### *3.3 Under the Proposed Protection Rules, Fears of LPFM Interference are Unwarranted*

The location of new FM stations is restricted by several interference protection rules that place a conservative limit on spacing between other stations.

LPFM must be certain to avoid interference with primary FM stations, and must be certain to avoid interfering with subcarrier transmissions (known as SCA services) such as broadcasts for the blind. Furthermore, LPFM must offer transmission integrity as good as existing FM stations. For this reason, we assert that LPFM must obey co-channel and first adjacent interference guidelines of 20 dB D/U and 6 dB D/U,<sup>21</sup> respectively, just as current FM stations are required to do. This requirement would assure that LPFM transmitters are sited properly with

respect to other co-channel and adjacent channel transmitters. Furthermore, FM translators, TV stations using channel 6, and FM stations 53 or 54 channels away<sup>22</sup> must also be protected to avoid interference, just as standard FM stations are required to do.

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<sup>21</sup> D/U stands for the ratio of Desired signal power to Undesired (or interfering) signal power. For convenience, it is expressed in decibels, abbreviated dB. 20 dB D/U means the desired signal power is 20 dB greater than the power of the interfering signal.

<sup>22</sup> Stations exactly 10.6 or 10.8 MHz away from the desired station's frequency can cause interference in the IF (intermediate frequency) section of the receiver. Longstanding separation rules prevent this from happening.

#### **4 Interference Impact of LPFM will be Minimal Compared to Population Served**

We recommend authorizing only 100 Watt and weaker stations for LPFM service, except where LP 1000 stations can be authorized without any change to current interference protection regulations. By limiting LP 1000 stations, there is very little danger of unacceptable interference. LP1000 stations are not viable in most large cities, any more than are additional standard-class stations, because the FM band in these areas is too crowded. If LP1000 stations can be added with the same protections as primary FM stations, they should be allowed. LP1000 stations serving small towns or rural areas should cause no undue interference. In smaller radio markets, LP1000's should be easy to place without relaxing the current protection rules.

##### *4.1 Potential For LPFM Interference is Low*

The potential interference area of LPFM stations will be extremely small, and therefore affect very few people. Many conditions would have to be met before a listener lost service from an incumbent station due to an LPFM station.

Low power stations of 100 Watts and less will interfere with very few radios on very few stations because their interference footprints are so small. Table 1 lists the 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel interference areas of LPFM stations, calculated according to FCC's Part 73 interference curves (100 dBu contour for D/U = -40 dB at the edge of a high powered station's protected 60 dBu service contour).

**Table 1. Predicted Interference and Serving Distances and Areas for LPFM Stations with 30 meter Antenna Height**

<b>LPFM Power (Watts)</b>	<b>Interference Radius (mi)</b>	<b>Interference Area (sq mi)</b>	<b>Serving Radius (mi)</b>	<b>Serving Area (sq mi)</b>
1	0.04	0.01	1.1	4.0
10	0.14	0.06	2.0	12.1
100	0.44	0.60	3.5	38.5

People listening inside the interference area would experience interference to an incumbent station's signal if and only if *all* of the following conditions applied concurrently:

- If the LPFM station were placed near the coverage fringe of the incumbent station,
- If the incumbent station transmits on a channel 2 or 3 channels above or below the LPFM station's assigned frequency,
- If the listener only wishes to listen to the incumbent station out of the dozens of stations available, and
- If their radio happens to be a poor-performing model like a clock radio.

In many instances, the listener would be able to "tune" out the LPFM interference by moving the FM receiver. It is quite common for people to adjust

the position of their clock radio or boom box for good reception. Such adjustment could cause the LPFM interferer to fade while maximizing the desired signal.

Some interference from existing FM stations is already acceptable under FCC rules. For example, blanketing interference occurs when a nearby FM station's signal overloads a receiver such that it cannot receive *any* other station on *any* other frequency. The FCC already considers blanketing interference to be acceptable from existing FM stations. As shown in Tables 1 and 2, the coverage areas of LPFM stations are much smaller than the blanketing areas of even the smallest of existing FM stations. Furthermore, interference from LPFM will only affect one or two FM stations, at most, and then only if all the conditions are just right, as opposed to blanketing which impacts all of the FM channels within the band. Yet the size of the blanketing areas of incumbent stations are larger than the largest interference areas of LPFM stations.

In other words, primary FM stations are allowed to interfere with *all* other stations within a certain distance of their transmitting site, whereas relaxing 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel separation rules for LPFM will cause interference with, at most, only one or two stations within a much smaller radius.

**Table 2. Blanketing Interference Area for Primary FM Stations**

<b>Station Class</b>	<b>Blanketing distance<sup>23</sup> (mi)</b>	<b>Blanketing Area (sq. mi)</b>
<b>A</b>	<b>0.6</b>	<b>1.1</b>
<b>B1 or C3</b>	<b>1.2</b>	<b>4.7</b>
<b>B or C2</b>	<b>1.7</b>	<b>9.4</b>
<b>C or C1</b>	<b>2.5</b>	<b>18.9</b>

*4.2 Many More Listeners Will Benefit From LPFM than will Experience Interference from LPFM*

A large number of people could be served by LPFM stations, especially in large cities with high population densities. Even with 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel separation rules relaxed, the maximum number of people who might experience interference from an LPFM station is very small compared to the potential audience.

By performing a detailed computer analysis we calculate the projected number of individuals served and the number who may experience interference.

Some listeners experiencing interference will tune out the interferer by moving the receiver antenna, others will substitute another station, possibly the

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<sup>23</sup> Calculated according to the FCC 47 CFR part 73.319 formula:  $D(\text{in mi.})=0.245 \times \sqrt{P(\text{in kW})}$  for 115 dBu.

new low power station. Most will simply never notice. In any case, the benefit of each new LPFM station far outweighs the potential for interference.

Using results in Tables 1 and 2, it is possible to determine the average number of people who will receive LPFM coverage versus the number of people who would be affected by adjacent channel interference from LPFM stations. We computed the average population density (population per square kilometer) for the 60 cities the FCC studied in the NPRM to be 1843 people per square kilometer. We computed this value using the following method:

1. Divide the population of each city by the square area<sup>24</sup> of the city for population density.
2. Sum the population density of all 60 cities.
3. Divide the result by 60.

Table 3 outlines the potential audience for each type of low power station and the number of listeners who could potentially experience interference if all the conditions were just right (as discussed above), assuming an average (uniform) population density. These figures were computed by multiplying the average population density by the interference area or service area of the LPFM

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<sup>24</sup> Population and city square area from 1990 US Census data.

station.<sup>25</sup> It is important to bear in mind that these values are averages, and results will vary from city to city. Also, specific propagation conditions may vary from city to city, but the standard FCC protection guidelines, when applied to the specific transmitter power levels and 30 m height above average terrain (HAAT), yield values which show an overwhelming number of citizens will benefit from LPFM as opposed to receive interference from it. It is important to realize that the number of people experiencing interference is a worst case, since many listeners may not ever receive interference, and in fact it is doubtful that all LPFM stations will use 30 m antenna heights.

**Table 3. Estimate of Population Affected by and Served by LPFM Stations**

LPFM Power (Watts)	Maximum Population Affected by Interference	Population Served by One LPFM Station	Percent of Those Served Who Might Experience Interference
1	48	19,536	0.24%
10	286	58,423	0.49%
100	2912	186,512	1.56%

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<sup>25</sup> Service radii were calculated using the FCC's (50,50) curves program at 60 dBu for HAAT of 30 meters. Interference radii were calculated using the FCC's (50,10) curves program at 100 dBu for HAAT of 30 meters. The program used to find these values was <http://www.fcc.gov/mmb/asd/bickel/curves.html>. Area was computed using the standard formula for area:  $A=\pi r^2$

## 5 FM Receiver Tests

Receiver studies commissioned by the Consumer Electronic Manufacturers Association (CEMA) with National Public Radio (NPR) and the National Association of Broadcasters (NAB), were conducted inappropriately and presented with unfair bias against LPFM.

In section 5.1 we find the set of receivers selected by CEMA does not match the population of receivers in use, invalidating any claim or assumption that the receiver test results represent actual FM listening.

In section 5.2 we present a method of weighting receiver results by sales and listening data. If NAB and CEMA had used this simple method, their test results would have painted a more accurate picture of the state of FM listening.

Section 5.3 covers the selection of audio quality criteria used in the NAB, CEMA and OET studies. Over half of the radios tested by NAB did not meet their own quality criteria in perfect reception conditions, throwing serious doubt on the validity of the NAB test results and the selection of the sample.

The lack of sufficient input level range for all 4 tests is explained in Section 5.4. Radios operate at a much wider input signal level range than the NAB, CEMA, OET and BSL studied them for, so the tests give us only a narrow snapshot of receiver performance.

Section 5.5 outlines the receiver test results compared to FCC protection ratios. As one would expect, a very large proportion of the tested radios does not provide as much interference protection as the FCC ratios provide. We explain why testing radios in comparison to FCC interference protection ratios completely misses the mark. CEMA and NAB certainly must know fixed and portable receivers do not need to offer interference rejection anywhere close to the overly cautious protection ratios the FCC has adopted for FM station licensing, but use this pretense as a flawed reason to claim radio receivers cannot function with LPFM.

Also in Section 5.5, we discuss why FCC separation rules for FM stations are poor predictors of overall interference conditions.

Interpretation of test results is covered in Section 5.6. Without explanation, the NAB over-counted affected population in their mapping study, indicating intent to skew results toward a predefined conclusion.

#### *5.1 Sample Selection*

Neither the NAB nor CEMA chose receivers for their sample which accurately reflect the proportions of receiver types in use.

A sample is meant to represent the entire population under consideration. When the population is very large, for practical reasons a representative sample must be chosen. If the sample is representative, fairly accurate conclusions about the population can be drawn from the results of testing the sample. If the

sample is not representative, no conclusions can be drawn about the population. Moreover, selecting a biased sample can artificially produce a predetermined conclusion about the population.

In this case, a varied sample of test radios is important because FM receivers differ widely in their ability to reject interference. Less expensive radios are less able to pull stations in clearly because additional circuits are needed in the radio "front end" to accomplish very good interference rejection. Good reception at highway speeds is more difficult to engineer, so car radios cost more but reject interference very well. The tradeoff of price for performance and features is different for each receiver sales category. For example, clock radios do not need excellent sound quality at highway speeds, so they can cost less.

Neither CEMA's nor NAB's sample attempted to mimic the proportion of listening that occurs in vehicles as opposed to fixed locations. Clearly if people use one type of radio more often than another, the proportion of radios of that type in the test should be higher.<sup>26</sup>

#### 5.1.1 CEMA Test Sample

CEMA is a respected authority on the market penetration of the various types of FM receivers. In choosing the sample of receivers to test, however, CEMA did

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<sup>26</sup> BSL and OET also tested FM receivers, but did not describe their radios such that they could be placed in comparable categories. This prevented us from analyzing their samples in the same way.

not use their information on receiver types in use to make the sample representative.

CEMA says, “CEMA believes that the test receiver sample used in its laboratory testing is representative of in-use receiver designs.”<sup>27</sup> This statement is contradicted by CEMA’s own FM receiver sales figures.<sup>28</sup> Table 4 compares the proportion of radios in use by the public with the proportion of radios selected for the test, grouped in categories with similar uses and circuitry.

**Table 4. Proportion of Radios, In Use and In the CEMA Receiver Test Sample, by Sales Category**

Receiver Category	In Use (%)	CEMA Sample (%)
Table	16.8	0
Personal	24.2	6.3
Portable	21.2	18.8
Component	15.4	43.8
Auto	22.4	31.3

CEMA did not test table radios at all, yet one in six radios in use are of this type. More examples of component radios, the smallest category, were tested

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<sup>27</sup> CEMA Study, page 17.

<sup>28</sup> CEMA Study, page 9-10.

than any other type.<sup>29</sup> Therefore this sample is not representative, and invalidates any conclusions drawn about the total population of FM receivers from the results.

One reason for the discrepancy could be that radios were chosen for particular performance measures. We believe table radios were eliminated because none could meet the test's audio quality threshold (discussed in Section 5.3). Whatever the reason, the fact that CEMA claims its sample is representative when it clearly is not suggests the test may be flawed and the results should be taken with a grain of salt.

#### 5.1.2 NAB Test Sample

The selection of receivers used in the NAB receiver study more closely matches receivers in use, as shown in Table 5.

Without changing the total number of radios tested, NAB could have come much closer to the proportion of radios in use. If they had tested 6 Auto, 7 Personal, 6 Portable, 5 Table and 4 Component radios, the proportions would be as shown in Table 6.

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<sup>29</sup> The sales percentages here do not exactly match those in the table on p. 10 of the Comments. CEMA has added the sales figures for FM radios sold with vehicles to the sales of aftermarket car radios. Clearly, a more accurate picture of receivers *in use* would require ignoring the number of aftermarket car radios that simply replace the radio bought with the vehicle. We adjusted the sales figures to reflect this difference and recalculated the percentages for radios in use.

**Table 5. Proportion of Radios, In Use and In the NAB Receiver Test Sample, by Sales Category**

Receiver Category	In Use (%)	NAB Sample (%)
Table (clock)	16.8	17.9
Personal	24.2	17.9
Portable	21.2	17.9
Component	15.4	17.9
Auto	22.4	28.6

**Table 6. Proportion of Radios, In Use Compared to a Theoretical Distribution of 28 Radios, by Sales Category**

Receiver Category	In Use (%)	Theoretical Sample (%)
Table (clock)	16.8	17.9
Personal	24.2	25.0
Portable	21.2	21.4
Component	15.4	14.3
Auto	22.4	21.4

## 5.2 Weighting Results

Neither NAB nor CEMA weighted their results based on proportions of radios by type or proportion of time various radio types are used by listeners. Such a weighting system would have been proper and more objective. As shown below, by neglecting to weight the test results to account for the proportion of listening that occurs in vehicles NAB and CEMA over-emphasized the poor performance of radios.

No small sample of radios would perfectly reflect the proportion of radios in use. The proper procedure would be to design the sample for as close a match as possible, and then apply weighting factors to the test results to correct the remaining error.

Using sales figures supplied in CEMA's report, and their figures for car radio listening,<sup>30</sup> we find weighting factors by category as shown in Table 7.

**Table 7. Proposed Weighting Factors for FM Receiver Test Results**

Category	Weighting Factor <sup>31</sup>
Table	0.120
Personal	0.174
Portable	0.152
Component	0.110
Auto	0.444

Note that since car radios are listened to 44.4% of the time (and comprise 22.4% of FM radios in use), the better performance of car radios would raise the overall performance of radios if the measurement data were weighted by sales and listening data. This was not done.

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<sup>30</sup> CEMA Study, pages 9-10.

<sup>31</sup> CEMAs listenership figures give 44.1% auto, 55.2% home. These do not add up to 100%, so we added half the difference to each proportion for 44.4% and 55.6%. We found the percentage of non-auto radio sales, and multiplied by 0.556 to obtain the weighting factors for each non-auto category. This assumes people listen to each category of non-auto radios equally. While these weighting factors do not

### 5.2.1 NAB Mapping Study

The NAB's mapping study of potential LPFM interference completely left out automobile radios from consideration. Including auto radios would have shown that LPFM would have a much smaller impact on interference than the NAB claims.

After conducting their receiver tests, the NAB examined the size of potential LPFM interference areas in a mapping study. A fair evaluation would have employed the receiver test results weighted for sales and listenership by category. Instead, the NAB excluded car radios from the mapping study entirely. This skews their sample away from representing the population of FM radios to a tremendous degree, utterly destroying any hope of applying the results to FM listening as it exists today.

The NAB gives three reasons for excluding automobile radios from their mapping analysis of potential LPFM interference.<sup>32</sup> We address each in turn:

1. Car radios perform better than FCC protection ratios would assume.

Auto radios account for over 20% of all radios in use. Car radios are in use for 44% of all listening to FM radio. Eliminating them for good performance indicates a clear intent to slant the report toward a pre-decided conclusion. Even

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represent reality perfectly, we believe that using them will paint a more accurate picture of FM radio use by the public.

if the car radio interference contours are small on the maps, their inclusion is essential because the tabular analysis is derived from the mapping calculations. Without car radios, the tabular analysis of affected population is inaccurate.

2. Any interference areas for car radios would be contained within interference areas for other types of radios.

This reason applies to all radios. Because signal power, and therefore interference levels, fall off with increasing distance, the interference areas for each type of radio are contained within that of the next-worse radio. For example, the interference area for Home/Stereo radios is entirely inside the interference area for Clock & Personal radios. All the interference areas are nested. Nested interference areas cannot be a valid reason for excluding any particular radio category.

3. The objective of the study is to determine the impact that relaxing the existing Commission protection ratios would have.

NAB's third reason has nothing to do with car radios. Relaxed protection ratios could affect all radios.

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<sup>32</sup> NAB Study, Volume 3, "Interference From Low Power FM Stations to Existing Stations", p. 10.

### 5.3 *Selection of Quality Criteria*

We do not believe the quality criteria selected for the recent FM receiver tests were formulated with enough objective rigor to offer sufficient input to any FM regulatory process.

In this section we discuss two criteria for evaluating audio quality: signal to noise ratio (SNR) and distortion. Section 5.3.1 critiques specific SNR thresholds chosen by CEMA and NAB. Section 5.3.2 discusses inherent difficulties in selecting a specific SNR threshold at all.

Testing FM receivers for interference rejection requires a quantitative measurement of the audio quality produced under various interference conditions. Two measurements are normally used: signal to noise ratio and distortion.

To enable comparison from one receiver to the next, a threshold of audio quality is needed. All receivers in the test are "stressed" with interference until the measured audio quality drops to the threshold. The threshold may be defined in terms of SNR or distortion.

We compare the 4 receiver test samples for this threshold in Section 5.3.1 and note that many more of NAB's radios failed. In fact, NAB chose a quality criterion threshold that was impossible for 54% of its tested receivers to meet. This suggests that either the performance metric was unrealistic, or that there was an intentional effort made to select inferior radios.

All of CEMA's receivers were able to meet the quality threshold they chose. By comparison to the other receiver test samples, this may mean that CEMA pre-selected receivers as well, but for different reasons. A desire for a valid test procedure may have driven CEMA's selection, yet it ruined any chance of the sample accurately representing the population of FM radios.

None of the radio studies used the common quality criteria value for radio troubleshooting (40 dB SNR). This is a widely known and used threshold for quality in the technical end of the radio business. Why NAB or CEMA never mentions it is unexplained.

OET tested for a 1% or 3% rise in distortion. This is very different from setting a predetermined threshold for quality and then testing a radio against it. This method allows testing of radios in a wide range of quality levels, without concern as to whether they will meet the threshold in the presence of no interference. As such, this method would have helped CEMA avoid the temptation of handpicking radios for testing.

### 5.3.1 Signal to Noise Ratio

Both CEMA and NAB chose quality standards by which to test FM receivers that can never be achieved by a sizeable proportion of existing radios.

One of the principle ways to characterize audio quality is to measure the relative volume of the desired sound to the noise. Noise manifests itself as hissing or static behind the program audio. No audio system is completely

immune from noise, but analog radio systems are particularly susceptible to bothersome noise levels.

Signal to noise ratio (SNR) is measured in decibels (dB), a logarithmic way of expressing the difference of two numbers which is convenient for quantities with wide ranges. For example, the power ratio 1/10000 or 0.0001 is equal to -40 dB.

A higher S/N number indicates better audio quality (the noise is much lower in volume than the program audio). A lower S/N means noisier-sounding audio.

The NAB used 50 dB S/N for the standard threshold of FM reception quality.<sup>33</sup> By choosing this standard, the NAB required the acoustic power of the program audio to be greater than that of the noise by a factor of 100,000 in order for a radio's reception to be considered acceptable. This is an extraordinarily high standard for sound quality from FM broadcasts.

Table 8 summarizes the noise performance of radios in perfect reception conditions (no interference) from the four recent FM receiver tests.

Over half the radios chosen by the NAB did not meet the 50 dB signal to noise ratio criteria for acceptable audio quality in perfect reception conditions with zero interference. If the samples were all representative in terms of radio quality, we would expect about the same proportion to fail *any* given audio

quality threshold. Table 8 seems to demonstrate that NAB chose a larger proportion of poor quality receivers to include in their test sample.

**Table 8. Proportion of FM Radios in Each Test Sample That Could Never Produce 50 dB S/N on Audio.**

Tester	Radios with < 50 dB S/N <sup>34</sup>	Total Radios Tested	Failure Rate
NAB	15 <sup>35</sup>	28	54%
BSL	2 <sup>36</sup>	11	18%
OET	6 <sup>37</sup>	21	29%
CEMA	3 <sup>38</sup>	16	19%
Overall	26	76	34%

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<sup>33</sup> "Standard of Service for FM Receiver Tests In Support of the Comments of The National Association of Broadcasters MM Docket No. 99-25", July 21, 1999, pages 6-10.

<sup>34</sup> For NAB and BSL: As measured with a desired signal level at or near -55 dBm, which is approximately the level expected at the edge of the 60 dBu protected service contour of most FM stations. The CEMA test recorded a "best S/N" without test details, so the input desired signal level is unknown. For OET: from the quieting levels they recorded in characterizing their radio sample.

<sup>35</sup> "FM Receiver Interference Test Results Report", Prepared for: the National Association of Broadcasters, NAB Study Volume 2, August 2, 1999, page 24.

<sup>36</sup> "National Lawyers Guild Committee on Democratic Communications Receiver Evaluation Project", June 30, 1999, by Broadcast Signal Labs, LLP, Appendix G.

<sup>37</sup> "Second and Third Adjacent Channel Interference Study of FM Broadcast Receivers", Project TRB-99-3 Interim Report, July 19, 1999, Technical Research Branch, Laboratory Division, Office of Engineering and Technology, Federal Communications Commission, p. 4.

<sup>38</sup> "FM Receiver Interference Tests, Laboratory Test Report", RMC Technologies for National Public Radio, Consumer Electronics Manufacturers Association and Corporation for Public Broadcasting, July 27, 1999, Appendix B, page 1.

For the purposes of their test, CEMA adopted an earlier suggestion from a National Public Radio (NPR) report that the reference quality level be 45 dB SNR on audio.<sup>39</sup> Table 9 shows how well the tested radios fared against this standard.

**Table 9. Proportion of FM Radios in Each Test Sample That Could Never Produce 45 dB S/N on Audio.**

Tester	Radios with < 45 dB S/N <sup>40</sup>	Total Radios Tested	Failure Rate
NAB	11 <sup>41</sup>	28	39%
BSL	1 <sup>42</sup>	11	9%
OET	6 <sup>43</sup>	21	29%
CEMA	0 <sup>44</sup>	16	0%
Overall	18	76	24%

Only CEMA’s sample met the “45 dB S/N without interference” specification universally. Since only CEMA was concerned with 45 dB S/N performance, we

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<sup>39</sup> “Comments of the Consumer Electronics Marketing Association”, p. 10.

<sup>40</sup> For NAB and BSL: As measured with a desired signal level at or near –55 dBm, which is approximately the level expected at the edge of the 60 dBu protected service contour of most FM stations. The CEMA Study recorded a “best S/N” without test details, so the input desired signal level is unknown. For OET: from the quieting levels they recorded in characterizing their radio sample.

<sup>41</sup> See note 16.

<sup>42</sup> See note 17.

<sup>43</sup> See note 18.

<sup>44</sup> See note 19.

believe they chose only receivers which could provide that level of audio quality or better. That may explain why they tested no table radios – perhaps none could be found that met their stringent quality criteria.

Typically in a receiver study, if a fixed quality threshold is chosen, the radios should meet the quality criteria before interference is applied. On the other hand, no conclusion can be drawn from a technically accurate test of a non-representative sample of radios.

Over half the radios tested by NAB failed to meet their own quality criteria at the outset. For the radios that could not meet the quality threshold in the no-interference condition, NAB tested for a 5 dB decrease in SNR. Because they used two different testing methods, NAB should have reported the test results for each subset of radios separately. Or, NAB could have chosen to test all receivers for a 5 dB decrease in SNR. The fact that they held onto the 50 dB SNR threshold wherever possible indicates it had an importance to them outside it's utility as a test benchmark.

Unfortunately, none of the radio receiver tests used a lower SNR threshold, say 40 dB SNR or 38 dB SNR, which was achievable by all measured radios. By using a benchmark that was common, it would have been possible to consider a reasonable “go, no-go” threshold for deciding whether a given receiver is functioning properly.

The above observations illustrate the problems with choosing a fixed quality threshold for radio testing. BSL avoided these problems by testing radios at fixed D/U ratios and recording both SNR and distortion, hoping to find a general D/U at which radios began to fail rapidly. OET chose to test for a 1% and 3% rise in distortion, starting at whatever distortion the radio could produce in perfect reception conditions. With these methods, the question of how many receivers are capable of meeting the quality threshold does not arise.

### 5.3.2 Choice of Quality Standard

Choosing a fixed audio quality threshold creates testing or sampling problems, as outlined in Section 5.3.1. To arrange for all receivers to meet the threshold in perfect reception conditions, the sample or the threshold must be adjusted. Tweaking the sample removes any hope of applying the test results to the entire population of receivers. Picking a threshold slightly below the quality level of the worst receiver in the sample (measured in a no-interference situation) brings with it no troublesome consequences for sampling validity or test objectivity.

Rather than choose a fixed quality threshold, defining the extent of the change in audio quality for a given change in interference levels or ratios is a far more objective approach to radio testing. This is what OET did, and what NAB did for the radios in their sample that failed to meet the 50 dB S/N on audio with no interference. Unfortunately, mixing methods within the same test prevents

comparing the results from radios tested in different ways. In choosing a fixed threshold, NAB and CEMA created testing problems for themselves that were not solved to our satisfaction. In an academic setting, the design of NAB's and CEMA's tests would be considered flawed and the results from such tests would be disregarded.

#### *5.4 Range of Desired Input Levels*

None of the four receiver tests repeated their procedures for a wide variety of desired input signal levels. Receivers cannot be accurately characterized without this step. The tests do not give a complete picture of receiver performance in the real world.

Radio receiver performance varies widely with input signal levels. Thoroughly testing receivers for susceptibility to interference requires repeating the procedures with a wide range of desired signal input levels and for a few different output levels. For FM reception, an acceptable input signal range would be 0 to -90 dBm, and output SNR levels of 40 dB and 45 dB.

Each of the four receiver testing organizations applied a desired signal at different levels. Table 10 summarizes these levels.

The NAB's test properly attempted to examine the effects of a range of input signal levels, but did not employ a wide enough range of input levels to determine anything more than a vague trend, particularly given the fact they

used an output metric (50 dB SNR) which was not achievable in more than half of their test sample.

**Table 10. Desired Signal Levels at Which FM Receivers Were Tested**

Testing Organization	Desired Signal Level(s)	Desired Signal Level(s)
	In dBu at 100 MHz	In dBm
BSL	61	-54
OET	58	-57
NAB	50, 60, 70	-65, -55, -45
CEMA	65, 45	-50, -70

Though touted as complete and representative receiver tests, we consider the lack of a common output metric and the narrow range of input levels used to be problematic.

A more complete test from which better conclusions could be drawn would have used several different input signal levels (i.e. 0 dBm to -90 dBm) and two output SNR levels (i.e. 40 dB and 45 dB).

NAB uses their receiver test results to generalize that "...the interference susceptibility of contemporary receivers has generally not improved since the (FCC) rules were adopted in the 1940's."<sup>45</sup> However, the lack of a limited range

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<sup>45</sup> "Selection of Receivers for FM Receiver Testing and Analysis of Test Results In Support of the Comments of the National Association of Broadcasters in MM Docket 99-25", Moffet, Larson & Johnson, Inc., July 21, 1999, page 16.

of input signal levels (among other test problems) prevents any accurate generalization.

#### *5.5 Receiver Performance Compared to FCC Interference Regulations*

By testing FM receivers against the FCC protection ratios, CEMA and NAB posited that FM receivers should perform as well as assumed by the FCC protection ratios governing radio station licensure. Holding the performance of modern FM receivers to the FCC protection ratio standard completely misrepresents the purpose of the FCC interference protection ratios, and could be an attempt to deceive the public about FM reception conditions. The FCC protection ratios were designed to provide simple and conservative spacings to prevent early FM radio receivers from undesired retuning to strong adjacent stations.

Reasonably, a large proportion of CEMA's and NAB's tested receivers did not perform as well as the FCC interference protection ratios would predict. The FCC protection ratios were designed around early FM radios and the RF filtering and frequency synthesis available at that time. Early FM receivers tended to retune themselves to a strong adjacent channel signal. Today's FM receivers have never needed to perform as well as the FCC ratios would predict because modern radios resist adjacent signals better than older radios. In fact, a commercial FM receiver designed using the FCC protection ratios would produce an extremely expensive radio, far beyond the needs of FM radio consumers.

While it's difficult to compare the different receiver studies, they demonstrate car radios are much more robust to interference, and are typically designed to come close to the FCC 2<sup>nd</sup> and 3<sup>rd</sup> adjacent protection ratios ( $D/U = -40$  dB), whereas all other types of FM receivers can be designed much less stringently. Manufacturers design car radios with better adjacent filtering capabilities because of signal fading and the ability to travel arbitrarily close to an interfering broadcaster – if an interference signal rises while the desired signal level dips, a poorly designed receiver will have unintelligible output, whereas a well designed receiver will still be able to detect the desired signal. No such interference protection buffer is needed for household FM receivers because they do not experience severe fading nor move rapidly towards an interfering station.

FCC protection ratios do not reflect the actual FM interference environment. In fact, the interference environment is much more forgiving than the FCC ratios would indicate, which is why modern receivers are designed less stringently than the ratios indicate. The FCC ratios are the basis for a conservative calculation of the required separation distances for FM stations. Thus, the ratios tell us how close FM stations can be to each other, but very little about the actual resulting interference.

The spacing of new FM stations is governed by multiple separation rules, in such a way that the most stringent rule (i.e. the most rigorous co-channel or adjacent protection ratio) predominates. This means for a given adjacency, just a

few pairs of potentially interfering stations are as close together as the rules would allow. Therefore in most cases the interference is much less than the FCC ratios would indicate.

In the receiver tests, the proportion of receivers that failed to perform as well as FCC ratios for 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel interference would predict is quite revealing. Clearly, the FCC protection ratios and/or the chosen quality thresholds have no bearing on real world receiver performance. Table 11 shows the percent of radios in each category of the CEMA and NAB tests that could not receive a signal with a D/U of -40 dB and output audio with 50 or 45 dB S/N. In other words, the radios tallied here could not receive a signal of acceptable quality (as defined by the tester) in the presence of the FCC protection ratio level of interference.

**Table 11. Proportion of FM Receivers Unable to Meet Quality Thresholds at FCC Protection Ratios**

Category	CEMA 2 <sup>nd</sup> Adj.	NAB 2 <sup>nd</sup> Adj.	NAB 3 <sup>rd</sup> Adj.
Automobile	60%	38%	38%
Component	100%	80%	80%
Personal	100%	100%	80%
Portable	100%	100%	100%
Table	100%	100%	100%

For comparison, between 10 and 29% of OET's radios performed worse than FCC protection ratios, albeit using a 1% rise in distortion as the audio quality threshold. (BSL did not test their receivers in a comparable way.)

In other words, in an interference scenario where the radios under test must successfully reject an undesired 2<sup>nd</sup> or 3<sup>rd</sup> adjacent signal which is 10,000 times as strong as the desired on-channel signal, nearly all the radios tested could not meet the stated quality threshold. The tests reveal commercial household radios are not built to reject a level of adjacent channel interference anywhere close to the FCC station protection ratios. Obviously the same radios are successfully sold to the public, so clearly there is no need for receivers to have anywhere close to this level of interference rejection in the real-world environment.

In the receiver tests, the FCC station licensing procedure's rules were assumed to reflect the actual FM reception environment. This is a flawed assumption, because it is clear that there is a huge discrepancy between FCC protection guidelines for FM station licensing, and the real-world interference rejection requirements of household FM receivers. We believe a combination of factors leads to this result.

First, the FCC interference protection guidelines stem from the need to avoid strong adjacent channel signals, so that the early generation FM radios would remain tuned to the desired station. Assuming the receiver remains locked to the desired station, the prescribed signal strength ratios are much greater than are

actually required for good quality reception using modern FM receivers. The receiver studies indicate modern FM receivers may operate properly with much less adjacent channel interference filtering.

Second, and most important, the FCC protection ratios do not represent the actual interference environment for FM receivers. FM stations must be spaced at least as far apart as the specified separation distances given in Part 73, but practical matters and conservative margins for fading and interference in the FCC's propagation model ensure that radio stations are more widely spaced than necessary for virtually all potential interference cases. This is a key result of the receiver studies and shows that the FCC can eliminate some interference protection requirements for LPFM radio service.

#### *5.6 Specific Biased Errors in NAB's Interpretation of Its Results*

In the following sections we discuss evidence of a non-objective approach taken by the NAB in estimating the impact of LPFM. In particular:

1. In the tabular analysis of their mapping study (contained in NAB Study, Volume 3) the NAB seriously over-counted the number of people affected by potential LPFM interference.
2. The NAB mapping study was so poorly documented that reviewers cannot reproduce their results.

3. Of the three sets of receiver tests (at -65, -55 and -45 dBm desired input signal strength) in the Carl T. Jones report for NAB (contained in NAB Study, Volume 2) the set of receiver tests chosen showed the worst possible receiver performance.
4. The NAB invents a “worst radio” in order to show much greater potential LPFM interference than would be experienced by any real receiver.
5. The NAB omits a comparable map of calculated interference from incumbent FM stations.

All these actions are evidence of the NAB’s attempt to portray potential interference from LPFM as much worse than it would look in an objective analysis.

#### 5.6.1 The NAB Over-Counted Affected Population

The NAB shows inflated figures for population affected by LPFM interference in the tabular analysis of their mapping study.<sup>46</sup>

Without any mention of underlying assumptions or methods of calculation, the NAB presents Tables 4 through 9 with columns labeled “Population Experiencing Interference with Different 2<sup>nd</sup>/3<sup>rd</sup> Adjacent Channel Protection Ratios.” These tables appear to be calculations of the population covered by the

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<sup>46</sup> NAB Mapping Study, pages 14-19.

interference areas shown on the maps. NAB says only "After plotting the interference areas for each of the markets...Dataworld then calculated the number of people who would be affected by this interference based on the 1990 US Census Data. Tables 4 through 9 summarize this data."<sup>47</sup>

The four columns are sub-labeled "FCC Ratios", "Clock/Personal", "Portable" and "Home Stereo." The first refers to a theoretical radio that would have the same interference rejection capability as the FCC interference protection ratios would predict – a radio that performs significantly better than most radios in use, according to studies. The last 3 refer to categories of radio types.

A careful review reveals that the population totals are greatest for Portable, next greatest for Clock/Personal, followed by Home Stereo and FCC Ratios in that order. This is true for all 6 tables. It's also true for individual rows of the tables in cities where more than one LPFM station was proposed.

The radio types, in descending order of performance, are FCC Ratios, Home Stereo, Clock/Personal, and Portable. This is the same order as the column totals, and the same order as the nested interference areas on the maps.

Thus, we see that each of the interference regions shown on the NAB's maps is nested, with the inner part representing interference to the best radios. The

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<sup>47</sup> NAB Mapping Study, page 13.

outer part represents interference for the poorest radio. In other words, better radios can get closer to LPFM stations before they experience severe interference on incumbent stations' frequencies.

The only way the NAB could count the affected population to show the pattern of decreasing population with increasing radio performance would be to accumulate population with each nested interference area. Thus, "FCC Ratios" has only the people inside the FCC Ratios area, "Home Stereo" has all the people inside the Home Stereo area *and* the FCC Ratios area, and so on. The series ends with "Portable" including the population for every other radio type as well as the population under the green-shaded "Portable" areas on the maps.

Interpreting the Portable column as well as we can with limited information, it seems these totals assume:

- Every person in the largest interference area (Portable) has one of each of four types of radios,
- They listen to all four at the same time,
- They somehow know which radio stations they should receive based on protected contours, and
- They know whether or not they receive each station at a quality level of 50 dB S/N.

Another way to look at it is that the NAB has counted certain sets of the population four times, other sets three times, and so on. Since the methodology is not explained, these methods can only be interpreted as an attempt to inflate the NAB's case against LPFM without technical justification.

#### 5.6.2 The NAB Failed to Document the Methods Used to Produce Their Mapping Study

An objective study would contain all calculations, source code, and methods clearly explained so that others could duplicate the results, if desired. The NAB seems to have avoided including their methods in the Volume 3 of their Comments, thus arousing suspicion that the maps and tables presented are not what they appear to be.

As reviewers, we require full disclosure of calculation methods and data inputs in order to make an objective analysis. The NAB has not provided the methods or assumptions behind the interference that they predict for LPFM. In particular, the report lacks:

- Propagation model details.
- How the affected population was calculated.
- Details of any Geographic Information System (GIS) data used in the analysis.
- What protections were assumed in the placement of the LPFM stations.

- Which of the 9 scenarios run by the FCC to discover how many LPFM stations might be placed in major cities was used in reconstructing the list of LPFM stations mapped.

Ordinarily a technical report of this type includes enough information about the methods and formulas used that other researchers can reproduce the work independently. Omitting this information invites doubt as to the actual source of the results: calculations and scientific analysis, or wishful thinking. It also limits the utility of the work for further research, because others cannot determine exactly how applicable the work is to a new problem.

For example, there are many propagation models that estimate the signal power of a radio wave. Some are more accurate at FM frequencies than others. Since they are not detailed, we cannot assess the accuracy of the interference predictions on the NAB's maps.

### 5.6.3 Choice of Receiver Test Results

The NAB chose to use the worst of 3 sets of receiver test results when another set would have been the obvious fair and objective choice.

The NAB performed receiver tests with three different desired input signal level settings to three different power levels: -45 dBm, -55 dBm and -65 dBm. At the fringe of an FM stations' protected coverage area, signal power should be about -55 dBm. But for the mapping analysis, NAB chose receiver test results for

–45 dBm desired signal power, rather than those at –55 or –65 dBm. Their reasons for this choice are unclear.

It should be noted that measurements for the more logical choice of –55 dBm desired signal power show better receiver performance. We believe the –45 dBm results were used because they are the worst.

#### 5.6.4 The NAB Invents a “Worst Radio”

The NAB used a fictional “worst radio” to inflate the size of potential LPFM interference areas.

Appendix B<sup>48</sup> contains maps with an additional contour called the “worst radio.” The worst 2<sup>nd</sup> adjacent interference rejection performance found for any of the 28 tested radios was combined with the worst 3<sup>rd</sup> adjacent performance of any radio. The two measurements were taken from different receivers.<sup>49</sup> Therefore the “worst radio” does not exist. Given that we have already demonstrated that NAB’s test sample was biased towards lower-quality radios, this invention of a worst radio is extraordinary. NAB tries to explain this approach by stating, “There may be receivers, new or old, that do not perform as well as our ‘worst radio’ data.”<sup>50</sup> The logical extension of this argument ends with radios

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<sup>48</sup> NAB Mapping Study.

<sup>49</sup> NAB Mapping Study, page 12.

<sup>50</sup> NAB Study, Volume 3, page 12.

that do not work at all, but no one suggests making communications policy based on the presence of non-functional radios.

We find a serious conflict between the assumption of a “worst radio” and the NAB’s assertion that the 28 receivers tested were a broad, representative sample.

Taken together, the “worst radio” concept and the exclusion of car radios from the mapping analysis (see Section 5.2.1) point clearly to the NAB’s intention to exaggerate potential LPFM interference beyond any levels indicated by realistic assumptions.

#### 5.6.5 No Map of Current FM Interference Provided

Although the NAB produced maps of potential interference after the introduction of LPFM, it did not produce a map of current FM interference for comparison. Showing only LPFM interference implies that no FM interference exists now, which is impossible. We believe this was omitted because it would have weakened the NAB’s contention that LPFM stations will cause more interference than FM listeners have yet been exposed to.

An objective analysis of this type would include maps and calculations showing the interference caused by existing FM stations solely to each other. Such a plot would serve as an experimental control and baseline reference for evaluating maps of interference caused by only LPFM stations. NAB does not

include any mention of existing FM interference – though the tested FM receivers would see plenty of interference in the current environment without LPFM.

#### *5.7 FM Receiver Test Equipment and Connections*

The radio tests themselves, as described in the reports, were straightforward. We found no faults in the connections or choice of measurement equipment. Implicit in all of the tests was the assumption that the receiver would be stationary, since no fading of any kind was injected into the desired or undesired signals.

Any differences in choice of peak, quasi-peak or weighted quasi-peak readings were small and tend to be swamped by the original choice of test assumptions or data manipulation. BSL took care to evaluate receiver performance in a wide range of modulated signal formats, including formats similar to digital radio, and found little overall difference in most of the receivers.

## **6 Simulation to Determine Viable LPFM Stations**

Following FCC techniques, we determine the available channels, possible locations, and interference and coverage contour radii for LPFM transmitters of varying transmit powers in 60 representative markets. We are then able to estimate the average number of listeners who will be able to receive programming or who might receive adjacent channel interference from LPFM stations of four different power levels.

We conclude that LP1000 stations are hard to place in crowded FM markets because very little of the FM band remains unused. New FM stations are authorized each month, lessening the spectral space available to LPFM.

LP100 stations can be placed more easily, due to their shorter required separation distances. The same is true to a greater extent with LP10 and LP1 stations. Our analysis probably underestimates the number of possible LP100 to LP1 stations because we assume that antenna heights for 100, 10 and 1 Watt stations are 30 meters HAAT. In practice, most LPFM antennas are likely to be much closer to the ground, thereby reducing the interference and coverage areas below those of stations with 30-meter high antennas.

In the 60 cities considered here, a total population of 38.5 million citizens is represented. If LPFM is instituted with all standard FM protection ratios with the exception of 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channels, 626 100-Watt LP stations can be made available. These stations would provide alternative programming coverage to 81.1 Million citizen-channels, where one citizen-channel represents the ability of one person to receive a single LPFM station. These 626 100-Watt LP stations could potentially interfere with a maximum of 1.2 million citizen-channels, providing a public service to interference ratio of about 64. We use the term "citizen-channel" because the modified FCC LPFM program and the maps in the appendix show there are numerous locations in each city where more than one LPFM station may be placed. Consequently, many citizens will be able to receive

more than one LPFM station at some locations, and may also receive interference from more than one LPFM station at some locations, and thus the number of citizen-channels exceeds the actual population in some cases. Nevertheless, the *ratio* of citizens served by LPFM to citizens interfered with by LPFM is exactly the same as the ratio of citizen-channels.

Alternatively, 766 10-Watt LP stations could be made available to serve 31.6 million citizen-channels, while interfering with 158 thousand citizen-channels. This yields a public service to interference ratio of about 200. Or, 797 1-Watt LP stations could be made available to 11.1 million people while providing interference to only 16,300, thus yielding a service to interference ratio of about 680. It would also be possible to mix various LP power levels. Modifying the program to accommodate a mix of LPFM powers would not be difficult. In conclusion, it can be seen that between 64 and 680 times as many people gain access to LPFM broadcasts as may rarely experience interference from LPFM (Table 12). As a worst case, only 1.6% of the public would experience some type of adjacent channel interference from LPFM, and that would only be from LP100 stations and only if all conditions occurred as described earlier. We believe the actual percentage of the population experiencing any kind of trouble would be significantly less than 1.6%.

**Table 12. Summary of LPFM Simulation Results, Showing Proportion of Newly Served Population Who May Be Affected By Interference. The LP1000 stations have full protection, and LP100 – LP1 have full protection except for no 2<sup>nd</sup> adjacent and 3<sup>rd</sup> adjacent channel protection.**

LPFM Power (Watts)	New LPFM Station Count	Maximum citizen-channels affected by Interference	Maximum citizen-channels served by all LPFM Stations	Percent of Those Served Who Might Experience Interference
1	797	16,262	11,052,430	0.1%
10	766	157,911	31,634,873	0.5%
100	626	1,262,455	81,066,457	1.6%
1000	34	0	23,160,193	0%

Table 12 illustrates the tradeoff between the number of new radio voices enabled by LPFM, the size of the newly served population, and the proportion of those who may be affected by interference. (LP1000 calculations were based on full interference protection and thus would not interfere with any other existing FM stations.)

In preparing their NPRM, the FCC developed a computer program for estimating the number of LPFM stations of 1000 and 100 Watts that could be placed in each of 60 major US cities. The FCC has relied on such analysis and computer simulation methods over the past several decades to successfully assign licenses to nearly ten thousand FM broadcasters, as well as in its NPRM.

The program draws upon the ever-changing database of FM stations, Channel 6 TV stations and FM translators and applications for all of the above maintained by the FCC. It calculates the possible positions and channels for LPFM stations on a grid square with 1 minute by 1 minute spacing, based on the regulations for coverage and interference given in Part 73. Options for the overall area include 10x10, 20x20 and 30x30 minute grid squares.

We obtained from the FCC the source code for this program as well as the database of FM transmitter stations dated August 9, 1999. In addition, files with the Mexico and Canada transmitters, and water files for 16 cities were obtained from the FCC. We expanded the capabilities of the program by adding the following options:

- The ability to place LP10 and LP1 stations in the city of interest.
- Increased the granularity to half-minute by half-minute grid size and quarter-minute by quarter-minute grid size in order to more accurately discretize the contours of LPFM stations.
- Increased area of 60x60 grid squares (except for cities near water) to expand the coverage region of the analysis within a particular city.

Our version of the program was verified for accuracy in a test to find the number of LP1000 stations for Phoenix, AZ. Using the current version of the FM database and the same input conditions, the same results were obtained by us

and by FCC engineer Jordan Brinn, who ran the original version of the program at the FCC.<sup>51</sup>

Inputs to the modified program include:

1. Name of city to be analyzed (spelling must be exact to match FCC station database).
2. Geographical coordinates of the center of the city (these were obtained from the FCC).
3. Area of analysis (specified in terms of grid squares).
4. Granularity (size of a single grid "bin").
5. Transmit power of LPFM station to be placed in the city.
6. Yes/No options for retaining 2<sup>nd</sup> and 3<sup>rd</sup> adjacent protection.
7. Population and square area of each city.

Outputs from the program include:

1. Number of available channels.
2. A list of the available channels.

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<sup>51</sup> Conversation between Roger Skidmore, Vice President of Engineering, Wireless Valley Communications and Jordan Brinn, Engineer, Audio Services Division, Mass Media Bureau, Federal

3. The grid bin locations in which a LPFM transmitter for a particular FM channel may be placed.
4. The average population per square mile.
5. The total audience reached by all allowable LPFM stations in the city.
6. The maximum (worst case) possible number of people who would experience interference from all LPFM stations in the city (assuming 100 dBu interference boundary for each LPFM station).

The number of stations calculated by our program does not exactly match those listed in the NPRM because the version of the FM database used last January when the NPRM was prepared is no longer available from the FCC.

A small sample of the program output, using a collection of 30x30 grid squares, each with 30-seconds per side is presented in Table 13. 2<sup>nd</sup> and 3<sup>rd</sup> adjacent protections were ignored for this example. The table shows the number of LPFM stations that could be placed. See Appendix B for results for all 60 cities and Appendices C and D for a complete printout of computed results for a wide range of inputs in all 60 cities. Appendix E contains user instructions for the Wireless Valley LPFM program that generated these results.

It is worth noting that depending upon the granularity selected by the user, it is possible to get a +/- 1 difference in the number of available channels for LPFM in a particular market.

Appendix A contains color-coded maps of 10 cities, showing the possible locations for LP100 and LP10 stations. Calculations for these maps came directly from the modified FCC LPFM program, assuming a 30 x 30-minute grid using 1-minute resolution, and no 2<sup>nd</sup> or 3<sup>rd</sup> adjacent channel protection. All other protections were retained.

**Table 13. Count of Allowable LPFM Stations in 5 Cities**

<b>City</b>	<b>LP1000</b>	<b>LP100</b>	<b>LP10</b>	<b>LP1</b>
Los Angeles	0	0	1	2
San Francisco	0	0	5	5
Phoenix	4	12	19	20
Detroit	2	4	4	4
Boston	2	5	5	6

## **7 IBOC DAB and LPFM**

In-Band, On Channel Digital Audio Broadcasting (IBOC DAB) proponents' concerns about LPFM are significantly based on the cost of future hybrid digital-analog receivers. This cost-performance tradeoff is no different from the cost-performance tradeoff of any new category of radio receiver.

To the extent that IBOC proponents concerns are about the technical limits of their developing technology, their concerns are focused on the potential loss of 2<sup>nd</sup> adjacent channel interference protection. We find these concerns to be unwarranted.

Second adjacent protection for LPFM stations of 100 Watts and lower is not necessary to protect IBOC DAB transmissions. Digital radio has been engineered to perform acceptably well in the current FM interference environment. LPFM will not significantly change that environment, and therefore will have an insignificant impact on digital broadcasting.

Section 7.1 below discusses the background and issues surrounding digital audio broadcasting as it is envisioned by USA Digital Radio and others.

The cost pressures on IBOC DAB receivers is discussed in Section 7.2

Sections 7.3 and 7.4 explain what impact LPFM will have on digital radio.

Section 7.5 concerns assertions made about the incumbent FM service contour radius and demonstrates why one particular LPFM placement configuration examined in the USADR Study should be of no concern to digital radio.

### *7.1 Digital Audio Broadcasting Background*

IBOC DAB can potentially transmit two different programs on the same FM channel: one analog and one digital. Broadcasters plan to continue analog FM service while duplicating their programming on the digital portion of the signal. In decades to come, when DAB receivers have replaced nearly every one of the 700+ million FM receivers currently in use, the service will convert wholly to digital.<sup>52</sup>

Digital broadcasters intend to try datacasting on digital subcarriers, again within the same FM radio channel. Digital broadcasters and DAB receiver manufacturers are concerned that FM interference will limit the usability (and therefore profit potential) of subcarrier data services. It should be noted that analog subcarriers have been used for background music services and reading services for many years, and operate very well in the current FM interference environment. Our proposed enforcement of 1<sup>st</sup> adjacent channel protection will

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<sup>52</sup> No technical reason prevents broadcasters from transmitting a completely separate program on the recovered analog portion of their FM channel. DAB, therefore, represents a potential for "free spectrum." Spectrum, like land, is valuable because it is ultimately a limited resource. The value of radio spectrum is

maintain good performance for DAB. Since the IBOC DAB subcarrier services are engineered for the existing FM environment, they should be robust enough to succeed.

IBOC DAB works with a reduced guard band between FM channels. A guard band is like the median area of a divided highway: it provides a needed separation between channels in which no one is allowed to broadcast.

The size of the guard band is driven purely by receiver filter capability. Practical analog filters require a guard band larger than the one intended for DAB, but digital filters can easily handle the smaller channel spacing. The tradeoff is that the hardware for implementing the digital filter is more expensive.

IBOC DAB has been designed to work best with all stations converted to digital. Special filtering takes place in the transmitter to reduce the amount of signal "leaking" into the adjacent channels. Less energy in the adjacent channels means digital radios can decode more distant transmissions, enhancing the digital coverage of all FM stations.

Analog FM stations also place a small amount of unwanted energy in adjacent channels, because transmitters will always be imperfect. However,

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growing with the public's desire to be unwired: free from the traditional stationary telephone and computer connections.

according to the AFCCE,<sup>53</sup> modern stations emit far less power in adjacent channels than FCC regulations require.

### *7.2 Digital Receiver Cost Pressures Drive Concerns Over Interference*

IBOC proponents are concerned about LPFM, in part, because it costs more money to manufacture radios that reject interference well, and an increased radio cost may delay or decrease consumer acceptance. The cost of DAB receivers will be driven by 2 factors. First is the processor capability of the digital filters and second is whether hybrid DAB receivers will employ a single analog front end or both digital and analog front ends. The interference level impacts both of these factors, but the interference levels and price/performance tradeoffs for DAB receivers are the same as for analog receivers.

USADR comments do not mention 3<sup>rd</sup> adjacent interference. This is because the digital filters already designed for DAB receivers reject 3<sup>rd</sup> adjacent interference very well. The effectiveness of any filter increases with channel separation, but this is especially true for digital filters. Inexpensive digital filters for rejecting power on 3<sup>rd</sup> adjacent channels can be made in a variety of ways.

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<sup>53</sup> "Comments of the AFCCE on Notice of Proposed Rulemaking", August 2, 1999, page 11.

Interference on 2<sup>nd</sup> adjacent channels is more difficult to filter out than 3<sup>rd</sup> adjacent channels. It can be done effectively with digital filters implemented on faster digital signal processor (DSP) chips or microprocessors specially designed for baseband detection and filtering. Faster DSP chips, like faster computer processors, cost more.

It is possible that digital radio manufacturers intend to structure their products around poor quality analog front ends, rather than digital filters implemented using DSP. USADR studied RF filters "...commonly found in portable and personal radios."<sup>54</sup> Portable and personal radios were found to be the worst performing of any category by several independent tests of FM receivers.

Digital radio manufacturers are in a position to make several cost/performance tradeoffs. From a hardware point of view, an analog front end could be seen as more cost-effective. Hybrid models will make up the first generation of DAB receivers, capable of decoding the digital portion of the broadcast until it degrades too much, then switching to analog mode in difficult reception conditions. A single analog front end can feed both the analog and digital sections of the radio. The more expensive option is to build separate analog and digital front end circuits. Even though similar concerns surround

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<sup>54</sup> Comments of USA Digital Radio, Inc., August 2, 1999, p. 8.

today's analog FM car radios, USADR asserts that "Even if... areas of interference are limited to a specific geographic area, repeated loss of the signal as a mobile user enters and exits various LPFM service areas will significantly degrade the listener's experience."<sup>55</sup> USADR does not account for the fact that most car radios today already perform to high specification levels and cost significantly more than other radios.<sup>56</sup> Nothing will prevent manufacturers from making and selling high quality expensive car radios for IBOC DAB, just as they have for analog FM.

Digital radio manufacturers will simply be able to repeat the pattern they established for analog FM radio manufacturing. That is, cheap radios will receive fewer DAB stations than more costly ones and the market will find the right balance of cost and quality in each receiver category.

IBOC DAB has been designed to work in the current FM interference environment. Any concerns over greater interference need to be addressed to all additional FM stations, not just LPFM. The addition of LPFM, which will impact a very small percentage of the listening public, and in very small zones, is a miniscule interference source when compared to the current FM environment.

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<sup>55</sup> Comments of USA Digital Radio, Inc., August 2, 1999, p. 9.

<sup>56</sup> Car radios face a more challenging reception environment because they move at high speed through the peaks and valleys of FM signal power. To provide acceptable reception quality, they must incorporate more expensive filtering and better-performing circuit designs. This makes them more expensive than personal and portable radios.

### 7.3 IBOC DAB and LP1000 Stations

If LP 1000 stations are granted interference protection responsibilities similar to other primary FM stations, we conclude that LP1000 stations pose no threat to IBOC DAB.

DAB will be most challenged in dense radio markets where LPFM stations are hardest to place. Certainly DAB receivers will be designed with sufficient quality for consumer acceptance in New York and Los Angeles, where no LP1000 stations can be located. Adding LP1000 stations to smaller radio markets will *at worst* bring the interference levels up to equal that of the biggest markets.

### 7.4 IBOC DAB and LP100 to LP1 Stations

LPFM stations of 100W or less will not significantly change the interference level in any market if they are placed according to reasonable separation rules which take into account the co-channel and first adjacent channel neighbors, as well as the standard FM transmission spectrum mask rules.

Because LPFM can be introduced into the present analog FM environment and IBOC DAB is designed to work in the present analog FM environment, digital FM broadcasting should not be harmed by LPFM.

7.5 *Review of Engineering Statement Submitted with Comments of USA Digital Radio, Inc. (USADR)*

The Engineering Statement<sup>57</sup> submitted as part of USADR's comments claims relaxing 2<sup>nd</sup> adjacent protection rules for LPFM stations could disrupt IBOC DAB transmissions in areas outside the protected contour of the primary station. They assume the "real" service contour of incumbent FM stations is near the 44 dBu contour. FCC rules protect the service contour of most stations to 60 dBu, except commercial class B1 stations to 54 dBu and commercial class B stations to 57 dBu. However, we doubt many FM stations have been unwise enough to base their business plans on the unprotected 44 dBu contour.

The statement authors envision two LPFM stations on channels that are 2<sup>nd</sup> adjacent to each other and first adjacent to a primary station. Further, they assume the LPFM stations will be close to each other, and that they are also inside the 44 dBu contour of the primary station.

Given the scarcity of FM channels available for LPFM and the varied purposes for which community broadcasters can use LPFM, even if we considered the 44 dBu contour protected (which has no basis in any FCC rule), USADR's worries seem extreme. Further, the USADR study focuses on LP1000 stations, for which we recommend retaining full adjacent channel protections. The threat from

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<sup>57</sup> Engineering Statement In Support of the Comments of USA Digital Radio, Inc., Moffet, Larson & Johnson, Inc., August 2, 1999.

LP100 – LP1 stations co-located inside the 44 dBu contour of a primary FM station on 2<sup>nd</sup> adjacent channels and first adjacent to the primary FM station is very small.

The reason this rare circumstance is of concern to USADR has to do with the way the digital portion of the IBOC signal is transmitted. IBOC transmits redundant information in upper and lower sidebands of the FM channel, leaving the center for the standard analog FM transmission. If interference temporarily interrupts the data stream from the upper sideband, the program can be reconstructed from the lower sideband data stream and vice versa. Sideband redundancy is a major feature of the robustness of IBOC DAB because simultaneous interference to both upper and sidebands is much less likely than interference bursts from each adjacent channel singly. Sidebands are most threatened by first adjacent channel interference. If two stations interfere, one on the upper first adjacent channel and the other on the lower adjacent channel, IBOC will not work.

Since interference areas are so small for LPFM stations, and since channels available for LPFM are so rare, IBOC DAB proponents need not fret over potential “pockets” of two-sided first adjacent interference.

## 8 Conclusions

LP1000 stations should be authorized if and where they can adhere to the existing FCC separation rules for FM stations, including full protection for 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel interference.

LPFM stations of 1 to 100 Watts should be licensed if and where they can adhere to all existing FCC separation rules for FM stations *except* those for 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel interference. The benefit of such stations far outweighs the small potential for 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel interference to incumbent stations.

Our calculations show that many hundreds of LPFM stations could be introduced, providing new FM service to tens of millions, in all but the most FM-congested cities. The number of served citizens versus citizens who might experience interference from LPFM is greater than 64 times, and can be as much as 680 times.

Radio receiver tests by NAB and CEMA comparing FM receiver performance to FCC interference protection ratios miss the point on two counts: 1. The FCC's proposal to relax 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel protection for LPFM is strengthened by evidence that modern FM receivers perform acceptably with much more severe interference environments than assumed by the FCC protection ratios, and 2. The FCC protection ratios were designed for early generation FM receivers, which were more susceptible to frequency drift and

adjacent capture than today's FM receivers. As a result, today's FM receivers tolerate the existing FM interference environment very easily, and a minute increase in 2<sup>nd</sup> and 3<sup>rd</sup> adjacent channel interference, due to the relatively small number of LPFM stations, will have a negligible effect on radios used by the listening public.

It is unclear how NAB computed the population potentially affected by LPFM interference in its mapping study and may have misrepresented the population affected. In contrast, we have presented here a detailed analysis regarding the affected population, with all assumptions clearly disclosed for replication and validation of results.

The quality criteria selected by CEMA and NAB for their FM receiver tests were not formulated with enough objective rigor to offer sufficient input to the FM regulatory process regarding licensing regulations for adjacent channel interference.

LPFM will have no significant deleterious effects on the reception of incumbent FM stations, subcarrier services, or future IBOC DAB services.