MM 99-25

SUNSHINE PERIOD

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 word" 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[1] 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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[1] "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)[2] 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 2nd or 3rd adjacent channel protection requirements can serve tens of millions of neighborhood listeners in the U.S.,

[2] "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[3] of the NPRM, but the three reasons given for waiving 2nd and 3rd adjacent channel protections for LPFM are 1. "...these protections would limit substantially the number of channels available for low power radio generally...",[4] 2. "In most instances, we believe the actual effects of such interference might well be insignificant"[5] 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."[6] 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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[3] "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.

[4] FCC 99-6, paragraph 42, page 17.

[5] FCC 99-6, paragraph 45, page 18.

[6] FCC 99-6, paragraph 46, page 18.

real-world databases have been the topic of intense research,[7] and are becoming practical.[8]

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)[9], 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)[10], USA Digital Radio (referred to as the USADR Study).[11] We also examine FM receiver test reports by the FCC's Office of Engineering and Technology (referred to as OET Study)[12] and Broadcast Signal Labs, LLC (referred to as BSL Study).[13] 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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[7] T.S. Rappaport: Wireless Communications: Principles & Practice, Prentice Hall, 1996, ch. 3

[8] See for example, *SitePlanner*™, a site-specific wireless system design program, www.wvcomm.com

[9] "Comments of the National Association of Broadcasters in MM Docket 99-25," August 2, 1999.

[10] "Comments of the Consumer Electronics Manufacturers Association in MM Docket 99-25," August 2, 1999.

[11] "Comments of USA Digital Radio, Inc. in MM Docket 99-25," August 2, 1999.

[12] "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.

[13] "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."[14] 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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[14] NAB Study, Executive Summary.

CEMA explains "Receivers are designed with intentional design and cost tradeoffs that are made by manufacturers to meet market needs."[15] 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 2nd or 3rd 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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[15] "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 2nd and 3rd 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.[16]

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.[17] 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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[16] Discussions between T. S. Rappaport and research and design engineers at cellular phone manufacturers Nokia, Ericsson, Motorola, and Qualcomm, 1995 – 1999.

[17] 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 2nd or 3rd 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 1st adjacent channels be at least 25 dB below the main carrier.[18] The Association of Federal Communications

[18] FCC 47 CFR 73.317.

Consulting Engineers (AFCCE) found in a small study[19] 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.[20] Given the FCC's care in assigning primary FM radio licenses, and the good quality of FM radio reception

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[19] "Comments of the AFCCE on Notice of Proposed Rulemaking", August 2, 1999, page 11.

[20] 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,[21] 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[22] must also be protected to avoid interference, just as standard FM stations are required to do.

[21] 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.

[22] 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 2nd and 3rd 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

LPFM Power (Watts)	Interference Radius (mi)	Interference Area (sq mi)	Serving Radius (mi)	Serving Area (sq mi)
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 2nd and 3rd 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

Station Class	Blanketing distance[23] (mi)	Blanketing Area (sq. mi)
A	0.6	1.1
B1 or C3	1.2	4.7
B or C2	1.7	9.4
C or C1	2.5	18.9

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 2nd and 3rd 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

[23] Calculated according to the FCC 47 CFR part 73.319 formula: D(in mi.)=0.245x√P(in kW) for 115 dBu.