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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	MM Docket No. 99-25
Creation of a Low Power Radio Service	)	RM-9208 RM-9242

COMMENTS OF USA DIGITAL RADIO, INC.

USA Digital Radio, Inc. ("USADR"), by its attorneys, hereby files these comments in the above-referenced proceeding. The Commission's Notice of Proposed Rulemaking[1] seeks comment on proposals for establishment of new, low power FM ("LPFM") radio service. USADR provides no comment herein on the merits of, need for, or technical parameters of LPFM. Instead, USADR limits its comments to the impact of these proposed rules on the implementation of digital audio broadcasting ("DAB") in the FM bands.

USADR is the inventor of In-Band On-Channel ("IBOC") DAB technology which will permit the upgrade of existing analog broadcasting to digital using the spectrum currently allocated for FM broadcasting. On October 7, 1998, USADR submitted to the Commission a Petition for Rulemaking asking the Commission to adopt rules to permit the introduction of IBOC DAB.[2] That Petition remains pending before the Commission.[3]

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1 *In the Matter of Creation of a Low Power Radio Service*, MM Docket No. 99-25, *Notice of Proposed Rulemaking* (rel. Feb. 3, 1999) ("*Notice*").

2 *Amendment of Part 73 of the Commission's Rules to Permit the Introduction of Digital Audio Broadcasting in the AM and FM Broadcast Services*, RM-9395, *Petition for Rulemaking* (dated Oct.7, 1998) ("USADR Petition").

3 *See Public Notice*, RM-9395 (rel. Nov. 6, 1998).

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USADR's IBOC DAB technology works by inserting digital carriers on both sides of the existing FM analog signal. The USADR system has been engineered based on the interference environment currently existing in the AM and FM bands and seeks to maximize the benefits that can be achieved with the limitations imposed by existing analog broadcasting in these bands. Due to the technical challenges USADR has had to overcome to engineer its system to work in the AM and FM bands and the impact LPFM would have on the FM interface environment, USADR has a strong interest in this proceeding. As is explained in greater detail below, USADR encourages the Commission to wait until it has more information about operation of IBOC DAB in the field before it makes any changes to the existing FM interference environment.

I. Background on IBOC DAB Technology

USADR was established in 1991 for the purpose of developing a digital broadcasting system for AM and FM radio. USADR's goal has always been to create a system that will allow existing broadcasters and listeners to upgrade to digital without the need for new spectrum allocations and without dramatic increases in the cost of transmitting and receiving equipment. The use of IBOC technology has allowed USADR to meet those goals. Because IBOC will permit the introduction of digital radio in the existing broadcasting bands, there will be no need for new spectrum allocations or cumbersome regulatory proceedings to identify new digital spectrum or award digital licenses. Moreover, IBOC DAB will allow stations to retain much of their existing studio and transmission equipment. Because IBOC DAB will allow stations to support both analog and digital broadcasting, existing analog radios will remain useful as consumers acquire DAB receivers in the normal course of equipment replacement cycles. Moreover, USADR projects that DAB receivers will be only incrementally more expensive than analog receivers.

IBOC DAB will significantly enhance the listening experience for AM and FM radio. USADR's FM system will provide near CD-quality sound. The AM system will supply an audio fidelity matching today's FM. In addition to enhanced audio fidelity, IBOC DAB will improve sound quality through additional robustness of the digital signal. This improved robustness will translate to increased resistance to multipath interference, noise and interference from grounded conductive structures. Listeners will perceive greatly enhanced overall quality to increase their enjoyment from radio broadcasting.

Prototype IBOC DAB systems were tested in 1995 in both the AM and FM bands. In the fourth quarter of 1998, 12 of the largest broadcasters in the United States invested in USADR. Subsequently, USADR has announced strategic agreements with 3 transmitter manufacturers[4] and with Kenwood Corporation, one of the largest manufacturers of radio receivers for the U.S. market. Earlier this year, USADR introduced its EASE program, an early adopter program which will allow all radio broadcasters in the United States to participate in the transition to IBOC DAB. More than 500 stations broadcasters have registered to participate in the EASE program. Many of those stations are from small, non-Arbitron rated markets. Most recently, USADR announced a joint commercialization agreement with Texas Instruments whereby TI will integrate USADR's software with TI's programmable digital signal processors.

USADR currently is field-testing its second generation FM system in Columbia, Maryland and its AM system in Cincinnati, Ohio. USADR will field test its system at more than ten locations around the country before the end of the year. It is only after this testing is completed and

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4 USADR was entered into joint technology and marketing agreements with Nautel Limited, QEI Corporation, and Broadcast Electronics, Inc.

subsequent refinements are incorporated into the system will it be possible to fully assess the impact LPFM will have on IBOC DAB. Based on its existing schedule, USADR anticipates that preproduction systems will be operational beginning in early 2000, with commencement of commercial service later that year.

II. LPFM

The Commission's *Notice* proposes the creation of two classes of lower power service within the FM band. The first service would permit the introduction of new 1000-watt stations operating on a primary basis. The second would authorize the operation of 100-watt stations on a secondary basis. The Commission has also requested comment on the need for a "microradio" class operating at 1 to 10 watts on a secondary basis. In order to increase the number of LPFM stations available to be licensed, the Commission has proposed that these stations not be required to meet existing third-adjacent and second-adjacent channel protection criteria.

USADR was gratified that the *Notice* explicitly stated the Commission "will also be wary of any provisions that would limit the development of future terrestrial digital radio services."[5] Moreover, the separate statements of the Commissioners which accompanied the *Notice* each expressed concern that LPFM not impede the introduction of terrestrial DAB in the FM band.

III. The Commission Should Not Adopt LPFM Rules Until More Information About IBOC Systems Is Available

The Commission should wait until it has detailed information about the performance of IBOC DAB in field tests and the final design of the IBOC DAB system before it makes any changes

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[5] Notice at ¶ 1.

in the FM interference environment. Adopting final LPFM rules before that information is available would be premature and an inefficient allocation of Commission resources.

USADR's IBOC DAB system was designed based on the existing interference environment for the AM and FM bands. The system's design maximizes the quality of the digital signal without causing harmful interference to the existing analog signal. The system has been exclusively modeled and tested in the lab, and field tests currently are ongoing. USADR currently plans to complete this stage of its field-testing by the end of 1999.

By the end of this year, the Commission should have a thorough analysis of the performance of IBOC DAB in a variety of locations and interference environments. Moreover, in early 2000 USADR should make any necessary modifications to the IBOC DAB system to design full production models. Until that time, it will be impossible for the Commission to fully assess its ability to accommodate both IBOC and LPFM in the current FM bands.

Adopting LPFM rules now, before full IBOC information is available, is an unnecessary use of Commission resources. It would be inefficient to adopt rules today which may need to be modified in less than six months when additional information on IBOC DAB becomes available. Moreover, it may ultimately slow the introduction of LPFM if the Commission devotes resources this year to finalizing rules which will need to be reformulated early next year. It would be more efficient for the Commission to use 1999 to complete the record for both IBOC DAB and LPFM and to proceed with final rules after more detailed information is available.

IV. Eliminating Second Adjacent Channel Interference Protections Will Impact IBOC DAB

Eliminating the requirement that LPFM stations comply with existing second adjacent channel interference protections will create new and more significant instances of interference for DAB. This will increase the number of instances that listeners will lose digital audio radio program service. Although the design of the digital receiver front end and the High Power Amplifier ("HPA") stage of the digital transmitter will determine the extent of the interference, USADR's studies indicate the digital signal will be harmed by the LPFM signal.

The strength of the LPFM signal and the location of the transmitter will determine the specific impact the introduction of LPFM will have on the digital signal. The stronger the LPFM signal and the farther the transmitter from the full power station's transmitter, the greater the impact of the LPFM station on the digital signal.

The USADR system must continue to deliver DAB in the presence of co-channel interferers that are 20 dB lower in signal strength than the signal of interest ("SOI") and first adjacent channel interferers that are less than 6 dB weaker than the SOI. Second adjacent channel interferers present the most difficult case because they are authorized to be 40 dB higher, in the commercial band, and 20 dB higher, in the non-commercial band, than the SOI.

The bandwidth of a hybrid IBOC transmission is +/-199 kHz with its second adjacent channel beginning at +/- 201 kHz, allowing for a 2 kHz guard band. The design of the IBOC system includes techniques to insure that there will be a minimal overlap of the digital information between second adjacent channels. The IBOC exciter employs root raised cosine function and a large number of OFDM carriers to cancel these out-of-band emissions. These techniques are effective at cancellation

of out-of-band digital information into the second adjacent channel and into the region where the host analog signal is transmitted. Although those techniques will help to reduce the impact of LPFM on the IBOC DAB signal, some degradation of the digital signal is inevitable.

USADR commissioned a study, attached to these comments as Exhibit A, to examine the impact on IBOC DAB of the elimination of second adjacent channel protection. That study looked at the worst case scenario of LPFM stations located at the edge of coverage of the full power FM station. The study concluded that a 1000-watt LPFM station will create an interfering signal 39 dB stronger than the desired signal at the 44 dBu contour. This will create a predicted radius of interference of 3.8 kilometers. Multiple second adjacent channel LPFM stations assigned around a full power FM station would only exacerbate the problem by increasing the number of "cut outs" or dropped signals from the full power station's coverage area. USADR's analysis indicates there are enough variables impacting compatibility that it cannot fully predict at this time the impact of LPFM on DAB. Until there is actual implementation of DAB in the field, it is not possible to determine the potential for interference. Therefore, USADR believes it is premature to adopt final rules for LPFM at this time.

V. The Design of Production Grade Digital Receivers Will Significantly Impact Compatibility with LPFM

Although USADR can predict the impact of LPFM on DAB assuming the use of certain types of transmitters and receivers, the transmitter and receiver designs developed by equipment manufacturers ultimately will determine how susceptible DAB will be to interference from LPFM. It is USADR's assumption that market forces will drive the production of extremely low cost DAB receivers which may be susceptible to significant interference from LPFM.

A receiver's "front end" consists of a radio frequency ("RF") amplifier and a local oscillator and mixer. This circuitry will differ from receiver to receiver and will impact both performance and price. In order to lower costs, manufacturers could choose to trade performance for price. The tradeoff could include the use of a less expensive adjacent channel rejection filter or a front end amplifier with a less dynamic range.

Because LPFM stations will appear to the IBOC DAB system as new second adjacent interferers, USADR has studied the impact of second adjacent interferers on less expensive filters in use today. These types of filters are commonly found in portable and personal radios. USADR looked at a +40 dB interferer, which would be a typical interference level received from an LPFM station. In the receiver, filters of this class attenuate the second adjacent interferer by only 40 dB. As a result, the interfering signal presents the same signal power to the receiver as the SOI. The studies indicate a LPFM station acting as a second adjacent interferer would impact the digital reception of receivers using this class of filters.[6]

For receivers employing this class of filters dynamic range tradeoffs result in negligible changes in the performance of the digital and analog reception in the presence of second adjacent channel interference. However, it will have a dramatic impact on the ability of the IBOC receiver to receive DAB signals in the presence of high power interferers elsewhere in the FM band.

VI. LPFM Will Degrade the DAB Listening Experience

Listener expectations for high sound quality have risen due to the introduction of CDs and other digital delivery systems. DAB is designed to enhance the overall listening experience to more

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6 The USADR study was conducted using a Murata filter, model number SFE10.7MS3-Z. This filter is used in numerous radios sold today.

similarly replicate the experience of listening to a CD. A significant attribute associated with CD quality is freedom from interruptions to the audio signal. IBOC DAB's enhancements to signal robusters will greatly improve resistance to interference, noise and other interruptions. LPFM will increase interference to full power stations, creating a loss of the digital audio signal in certain areas. Even if these 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.

VII. LPFM Will Impact Auxiliary Services

The introduction of new interferers, particularly the potential for co-location of new second adjacent interferers, through the commencement of LPFM broadcasts, will create simultaneous first adjacent channel interference that will impact both hybrid and all-digital broadcasts. Hybrid and all-digital IBOC transmissions rely on sideband diversity to operate in the presence of multipath and first adjacent channel interference. Increasing the likelihood for simultaneous first adjacent channel interference reduces the robustness of the digital transmission and ultimately leads to the failure of the digital signal.

USADR's all-digital system will place low level data channels in the area formerly occupied by the analog signal. These digital carriers will support new auxiliary data services for the public. The low power level of these carriers (-26 dB), however, leaves them vulnerable to interference. Although USADR has designed its system to maintain the integrity of these data channels in the existing interference environment, these auxiliary services will be severely compromised in the presence of simultaneous first adjacent channel interference. Diminishing the performance of these

auxiliary services will deny the introduction of new data casting services to the public and may eliminate a significant opportunity to provide a means to upgrade existing subcarrier services.

VIII. Conclusion

USADR appreciates this opportunity to present its views on the Commission's proposal. USADR believes it will be difficult to fully assess the impact of LPFM systems until complete information about IBOC DAB is available. Any attempt to adopt final LPFM rules before that time would be inefficient. USADR's analysis already indicates that LPFM may cause interference to DAB. USADR respectfully requests that the Commission refrain from adopting LPFM rules until IBOC DAB is more thoroughly tested and details of the final production designs are available to ensure LPFM does not negatively impact the implementation of IBOC DAB.

Respectfully submitted,

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Counsel for USA Digital Radio, Inc.

Dated: August 2, 1999

EXHIBIT A

ENGINEERING STATEMENT

IN SUPPORT OF THE COMMENTS OF

USA DIGITAL RADIO, INC.

IN

MM DOCKET NO. 99-25

July 30, 1999

ENGINEERING REPORT

USA Digital Radio, Inc.
Columbia, Maryland

Engineering Statement
In support of the Comments of
USA Digital Radio, Inc.
MM Docket No. 99-25

Introduction

The firm of MLJ, Inc. has been retained by USA Digital Radio, Inc. (USADR) to conduct engineering studies in support of the USADR comments on the Notice of Proposed Rule Making in MM Docket No. 99-25. In this proceeding the Commission proposes to create a new class of aural broadcasting service, the low power FM (LPFM) service. Because USADR is developing a digital aural broadcasting (DAB) system to operate in theFM broadcasting band, USADR is concerned over interference to DAB coverage from new LPFM stations that could operate under the Commission's proposed rules. The USADR DAB system enables FM stations to transmit digital signals on a station's operating channel by using low levels of emissions within channels adjacent to the station's channel. The DAB signals fit within the emission specifications or "mask" of the Commission's rules. The USADR system is thus characterized as in-band, on-channel (IBOC).

Because of the present levels of interference in the FM band, the USADR IBOC systems relies on several techniques to improve robustenss of the system. These techniques include Orthogonal Frequency Division Modulation (OFDM), cancellation of potentially interfering first adjacent channel analog signals, and redundant digital information in the upper and lower adjacent channels. Although such techniques are used, there is some vulnerability to interference because

of the low level of the digital information. Initially it is expected that FM stations will operate with the USADR DAB system in a "hybrid" mode. That is, both digital and analog information will be transmitted simultaneously. Ultimately, it is expected that stations will transition to digital only transmissions. Hybrid receivers will be capable of switching to the detected analog signal when the low level digital signal cannot be decoded because of noise or interference. Interference studies considered in this statement are based upon hybrid operation.

USADR has filed a petition for rulemaking, RM-9395, which requests that the Commission adopt standards for an FM IBOC system. Specifications of the USADR system are contained in the petition. Although USADR is designing its IBOC system to minimize the potential for DAB interference, no system is immune to interference. The focus of this study is on DAB interference, not on interference to analog only reception that LPFM stations will cause.

The FCC Proposal

Three classes of LPFM stations are proposed by the Commission. The classes are defined in terms of effective radiated power (ERP) and antenna height above average terrain (HAAT). The maximum facilities of the classes are shown in the following table:

Class	ERP (Watts)	Antenna HAAT (meters)
LP1000	1000	60
LP100	100	30
Microradio	1	30

The Commission's notice includes a series of distance separation requirements comparable to those of the non reserved FM band to allocate new LPFM stations. Few LPFM allotments, particularly, LP1000 allotments, can be dropped into major markets. Therefore, the Commission has suggested that it may be feasible to delete the second and third adjacent channel separations presented in the proposed rules. Under this scenario. second and third adjacent channel LPFM stations could locate throughout an FM station's service area.

Potential Interference

The proposed distance separations are based upon "protection" of FM stations' standard protected contour[1]. It is thus assumed that no loss of service would result from LPFM stations if the separations are adopted. This is not the case; FM service does not end at the protected contour. Decades ago, the field strength of 34 dBu (50 μV/m) was used to depict the extent of noise-limited FM coverage. This value may be appropriate in some cases, but general use of the 34 dBu contour appears to overstate coverage. Therefore, USADR sought to identify a more realistic noise-limited coverage contour. A value of 44 dBu was used in the USADR petition. The derivation of this value is shown in Appendix A which was taken from the USADR petition with only editorial changes. Predicted distance to the protected contour and the 44 dBu contour is shown in the following table for the various classes of FM stations:

[1] 54 dBu for commercial class B stations 57 dBu for commercial class B1 and 60 dBu for all other classes

Distances to Predicted Contours

Class	Protected Contour (km)	44 dBu Contour (km)	Difference (km)
A	28.3	58.7	30.4
B1	44.7	73.3	28.6
B	61.1	88.6	27.5
C3	39.1	73.3	34.2
C2	52.2	88.6	36.4
C1	72.3	111.9	39.6
C	91.8	137.7	45.9

Many stations provide service to significant portions of the area near the 44 dBu noise limited contour. This is evident from studies conducted for the USADR petition; sample nation wide channel maps of interference were included in the petition. The USADR DAB system is designed to operate when receivers are exposed to first adjacent channel interference by employing redundant data transmission. The system, however is susceptible to second adjacent channel interference when the interfering signal is 39 dB stronger than the desired signal (D/U = -39 dB). This ratio is based upon laboratory simulations that identify the threshold of audibility (TOA) of interference. The difference between the TOA and the point of failure (POF) is negligible. This is because there is a pronounced signal-to-noise or signal-to-interference threshold in digital systems. Below threshold, failure is abrupt.

In this study the focus is on the LP1000 because such stations pose the greatest threat of interference and are likely to be the most desirable by LPFM operators. For a maximum

powered LP1000 at the 44 dBu contour this represents a predicted radius of interference of 3.8 kilometers. If the LP1000 station were at the 50 dBu contour, the radius would be reduced but remains significant at 2.7 kilometers. The predicted area of interference is only approximately a circle. Figure 1 is a schematic drawing showing the example of an LP1000 within a station's 44 dBu contour. The area of lost service in the example is 37.8 square kilometers (14.6 square miles).

Multiple second adjacent channel LP1000 stations could be assigned around an FM station within the station's 44 dBu contour, and within protected contours if second adjacent channel requirements are not adopted. The co-channel LP1000 separation is 65 kilometers. Seven LP1000 stations on each second adjacent channel could be dropped in within the 44 dBu contour of a Class B station. There is no restriction between the upper and lower second adjacent channel LPFM stations. Figure 2 is a drawing showing the predicted 44 dBu contour and the protected contour (54 dBu) of a Class B station and hypothetical locations of second adjacent channel LP1000 stations. Figure 2 shows that there is the potential for up to sixteen second adjacent channel LP1000 stations that can cause loss of service to a class B station and up to six such stations within the protected contour if there are no second adjacent channel LPFM requirements. Even if the Commission retains the second adjacent channel LP1000 distance separation requirements fourteen LP1000 second adjacent stations could locate within the 44 dBu contour and "protect" the station's 54 dBu contour. This scenario is shown on

Figure 3. Assuming each LP1000 causes loss of service area of 37.8 square kilometers, the total loss from the fourteen LPFM stations is 529 square kilometers.

In the above calculations deriving predicted interference areas, it is assumed that the desired to undesired ratio is not a function of desired field strength. Measurement of the interference susceptibility of contemporary analog receivers indicates that there are "non-linear" effects in some receivers. In such cases, the required desired to undesired ratio does not remain constant as the desired signal strength changes; the change in interference ratio may be approximately equal to an increase in desired signal. In this case, the radius of interference for such receivers is nearly constant and relatively independent of desired field strength. There is concern that some new digital receivers will respond to interference in such a fashion. In summary, reliance on constant interference ratios may lead to the erroneous conclusion that interference from LPFM stations will be negligible for high desired station field strengths.

Simultaneous Second Adjacent Channel LPFM Stations

The rules proposed in the NPRM do not contain distance spacing requirements between second adjacent channel LPFM stations. Therefore, such LPFM stations could locate in the same area or even at the same site. If there is service from an FM station that is between the LPFM stations in frequency, there is potential for loss of DAB service from the affected FM station because both of the redundant IBOC sidebands could be affected. In this case, the LPFM

stations would be first adjacent channel to the FM station. Although, the proposed first adjacent channel separations would prevent such interference within protected contours, there is potential for loss of DAB service outside of the protected contours. To avoid such interference, it is necessary to prevent LPFM second adjacent channel stations from delivering strong signals to the same area. Thus, interference can be controlled by avoiding overlap of the LPFM interfering contours. A desired to undesired ratio of -6 dB is considered appropriate analog reception for first adjacent channel interference and this ratio is used herein, however, it must be pointed out that the IBOC digital is signal is weaker (19 dB) than its analog interferer. Generally, first adjacent channel interference can be avoided by taking advantage of system redundancy, however this is not possible when two strong first adjacent channel signals are present. To protect service in the vicinity of a desired 54 dBu contour, overlapping LPFM 48 dBu contours are used. The following table shows proposed separations (rounded to the nearest kilometer) for second adjacent channel LPFM stations:

	LPFM Second Adjacent Channel Distance Separation (kilometers)		
	LP1000	LP100	Microradio
LP1000	55	39	32
LP100	39	23	15
Microradio	32	15	7

The above separations were derived using the F(50,50) curves of the Commission's rules. The F(50,50) curves were used rather than F(50,10) curves because both signals must be simultaneously strong, not ten percent of the time, to cause interference.

Summary

LPFM separation distances designed to protect the standard contours will not prevent loss of service to the public including loss of digital service because reliable reception extends well beyond the protected contour, This extent of usable service beyond the protected contour is substantial, as great as approximately 46 kilometers for a full facilities Class C station. The loss of service can be substantial as shown in the above example, even if the Commission adopts distance separations rules designed to protect FM service from second adjacent channel interference. If rules are adopted that do not contain protection of FM stations from second adjacent channel interference, numerous low power stations could cause interference to a stations DAB service. Even with protection as proposed by the commission, fourteen LP1000 stations could locate in the area where a class B station provides service and cause loss of coverage to an area in excess of 500 square kilometers. Distance separations between second adjacent channel LPFM stations are necessary to control interference to DAB service. Proposed separations for second adjacent channel LPFM stations are included in this report.

USA Digital Radio, Inc.
Columbia, Maryland

AFFIDAVIT

COUNTY OF ARLINGTON)
) SS:
COMMONWEALTH OF VIRGINIA)

JOSEPH W. STIELPER, being duly sworn upon oath deposes and says:

That he is employed as a Senior Engineer by the firm of JMS Worldwide, Inc. d/b/a MLJ consulting telecommunications engineers;

That this firm has been retained by the USA Digital Radio, Inc. to prepare this engineering statement;

That he has either prepared or directly supervised the preparation of all technical information contained in this engineering statement; and that the facts stated in this engineering statement are true of his knowledge, except as to such statements as are herein stated to be on information and belief, and as to such statements he believes them to be true.

Joseph W. Stielper

Subscribed and sworn to before me this 30th day of July, 1999

Commonwealth of Virginia, County of Arlington

Jacqueline Marie Richardson

Jacqueline Marie Richardson, Notary Public

My commission expires October 31, 2001.

USA Digital Radio, Inc.
Columbia, Maryland

Appendix A

Analog FM Noise-Limited Coverage
Derivation of FM Noise-limited Coverage Contour

Values for coverage contours may be derived for various assumptions for type and grade of service. For example, receivers may be indoors or outdoors, stationary or mobile, and may operate in a high or low RF noise environment. Service even depends on whether the receiver is in monaural or stereo mode. There is a substantial signal to noise ratio (S/N) penalty for stereo operation; the theoretical loss is 22 dB.[2]

Unfortunately, there is very little data that can be used to derive a noise-limited contour value and such data often shows wide ranges in values. This is particularly true for factors such as ambient noise level which varies substantially between locations. In this study, for noise-limited coverage it is assumed that receiving antennas are outdoors; no allowance is made for indoor antennas. The general formulas and factors used to calculate the contour value for particular conditions are shown later in this supplement. Required field strength is first calculated for the FM threshold without a noise margin for the standard temperature (290° K). Field strength may then be adjusted upward for various conditions and grades of service.

[2] NAB Engineering Handbook, Eighth Edition, p 1145

Automobile reception is very important to FM radio broadcasting. The most varied experience with FM radio also is with such reception; the derived contour should be appropriate for such reception and should agree with experience. The threshold for monaural reception is used as the standard because of the functioning of the car receivers, the noisy interior environment of a vehicle and reasonable assumptions regarding listener behavior. Modern car receivers "blend" from stereo to mono and operate in mono at the service limit. Occasional short bursts of noise are tolerated by the listener. For service to fixed receivers stereo reception is assumed.

To perform calculations, noise factors are taken from Reference Data for Engineers[3], location factors from the CCIR and time factors from the Commission's propagation curves. Time and location reliability are assumed to be log-normally distributed. Short-term Rayleigh or multipath fading is based on data contained in section 2.1 of Appendix H of the USADR petition. For reception in homes with outdoor antennas net antenna system gain is assumed to be 3 dB, the value used by the Commission in the recent DTV planning for low VHF TV. The reliability factors are added independently as is traditional for planning broadcasting services. These factors may be independent, particularly time and location reliability, and it would be more appropriate to root sum square (rss) the standard deviations and derive the standard deviation for overall reliability. The method used is more conservative and results in a higher coverage value.

[3] Jordan, E. C., ed. Reference Data for Engineers, Radio, Electronics, Computer and Communications, pp 34-5 to 34-9

Table A-1 shows the field strength calculations for three coverage conditions:

1) Rural Mobile with Fading
2) Suburban - median location and 90% of the time
3) Outdoor Stereo Median location 90% of the time

Derived field strength varies from 39 to 51 dBu. The middle value, 44 dBu, appears to be a good compromise to depict the extent of noise-limited coverage. It represents the coverage limit for car receivers suffering a Rayleigh fade at the worst 10 % of rural locations and lowest 10% of the time.

The derived values may be compared to the low VHF TV (54 MHz - 88 MHz) Grade B value which is also intended to be noise-limited contour. The value is 47 dBu which is the service limit for the TV visual signal. TV aural carriers are FM, however the stations are limited to an ERP of about 7 dB less than the visual. Thus, TV aural Grade B corresponds to a field strength of approximately 40 dBu.

General Assumptions:

1) Carrier to noise ratio (C/N): The standard should be the threshold for monaural reception. May be adjusted for stereo reception of higher required S/N.
2) Ambient Noise factor = F_a Noise environment may be equivalent to rural or suburban; receiver noise contribution is negligible. Noise reference temperature = T_0.
3) Base Antenna Gain on a half wave dipole receiving antenna. G = Antenna gain
4) Noise equivalent bandwidth = B

Formulas:

F_a = Ambient Noise in dB above kT_0B (dBW)[4]

[4] Reference Data For Engineers: Radio, Electronics, Computers and Communications, 7th Ed. p. 34-5 to 34-9

N = Noise level = $10 \log(B) + F_a - 204$ (dBW)
P_r = Required received power = $N + C/N$ (dBW)
F = Field Strength = $P_r + 20 \text{ Log } (F_{mhz}) - 105 + G$ (dBu)

Assumed Values:

B = 200 kHz
T_0 = 290° K
F_{mhz} = 98 MHz
C/N = 13 dB[5]

Threshold Field Strength (all values rounded to nearest dB) for $F_a = 0$
$N = 53 + - 204 = -151$ dBW
$P_r = -151 + 13 = -138$ dBW
$F = -122 + 40 + 105 = 7$ dBu

Other Factors Included in Contour Calculation:
Height Factor 9.1 m to 1.5m = 9 dB [6]
Long term Fading = Based FCC curves assuming log normal distribution
Rayleigh Fading = Fading caused by multipath [7]
Terrain Reliability Factor = Log Normal Fading e.g. 11 dB (90% of locations) [8]
Stereo Operation = 22 dB[9]

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[5] Often assumed to be 10 dB for wideband FM, 13 dB yields S/N ≅ 45 dB including pre-emphasis & de-emphasis. See Schawrtz, M; Information Transmission Modulation and Noise,
[6] Based on TASO see NAB Handbook 7th Ed. p339 & FCC Report R -6406 "Technical Factors Affecting the Assignment of Facilities in the DPLMRS", (Carey Report). Note : Plane Earth loss = 20 Log (9.1/1.5) = 15.7 dB
[7] See Section 2.1 of Appendix H
[8] CCIR Recommendation 370-5, Geneva , 1986
[9] NAB Engineering Handbook, 7th Ed., p1145

USA Digital Radio, Inc.
Columbia, Maryland

Table A-1
Noise-limited Field Strength Calculations

1. Rural Mobile - 90% of Time & Locations with Rayleigh Fading

Factor	Condition	Field Strength Calculation	
Field Strength	Threshold	7	dBu
Ambient Noise (Fa)	Rural (quiet locations)	6	dB
Height Factor	9.1m to 1.5 m	9	dB
Long Term Fading	90% of Time (60 km)	4	dB
Rayleigh Fading		7	dB
Location Reliability Factor	90% of locations	11	dB
System antenna Gain		0	dB
S/N Adjustment		0	dB
Coverage Contour		44	dBu

2. Suburban Mobile - Median Location, 90% of theTime & Rayleigh Fading

Factor	Condition	Field Strength Calculation	
Field Strength	Threshold	7	dBu
Ambient Noise (Fa)	Suburban	24	dB
Height Factor	9.1m to 1.5 m	9	dB
Long Term Fading	90% of Time (60 km)	4	dB
Rayleigh Fading		7	dB
Location Reliability Factor	50% of Locations	0	dB
System antenna Gain		0	dB
S/N Adjustment		0	dB
Coverage Contour		51	dBu

3. Outdoor Stereo - Median Location & 90% of the Time

Factor	Condition	Field Strength Calculation	
Field Strength	Threshold	7	dBu
Ambient Noise (Fa)	Rural (quiet locations)	6	dB
Height Factor	9.1 m	0	dB
Long Term Fading	90% of Time (100 km)	7	dB
Rayleigh Fading		0	dB
Location Reliability Factor	50% of locations	0	dB
System antenna Gain		3	dB
S/N Adjustment	Stereo	22	dB
Coverage Contour		39	dBu

Predicted Area of Interference from 1000 Watt LPFM

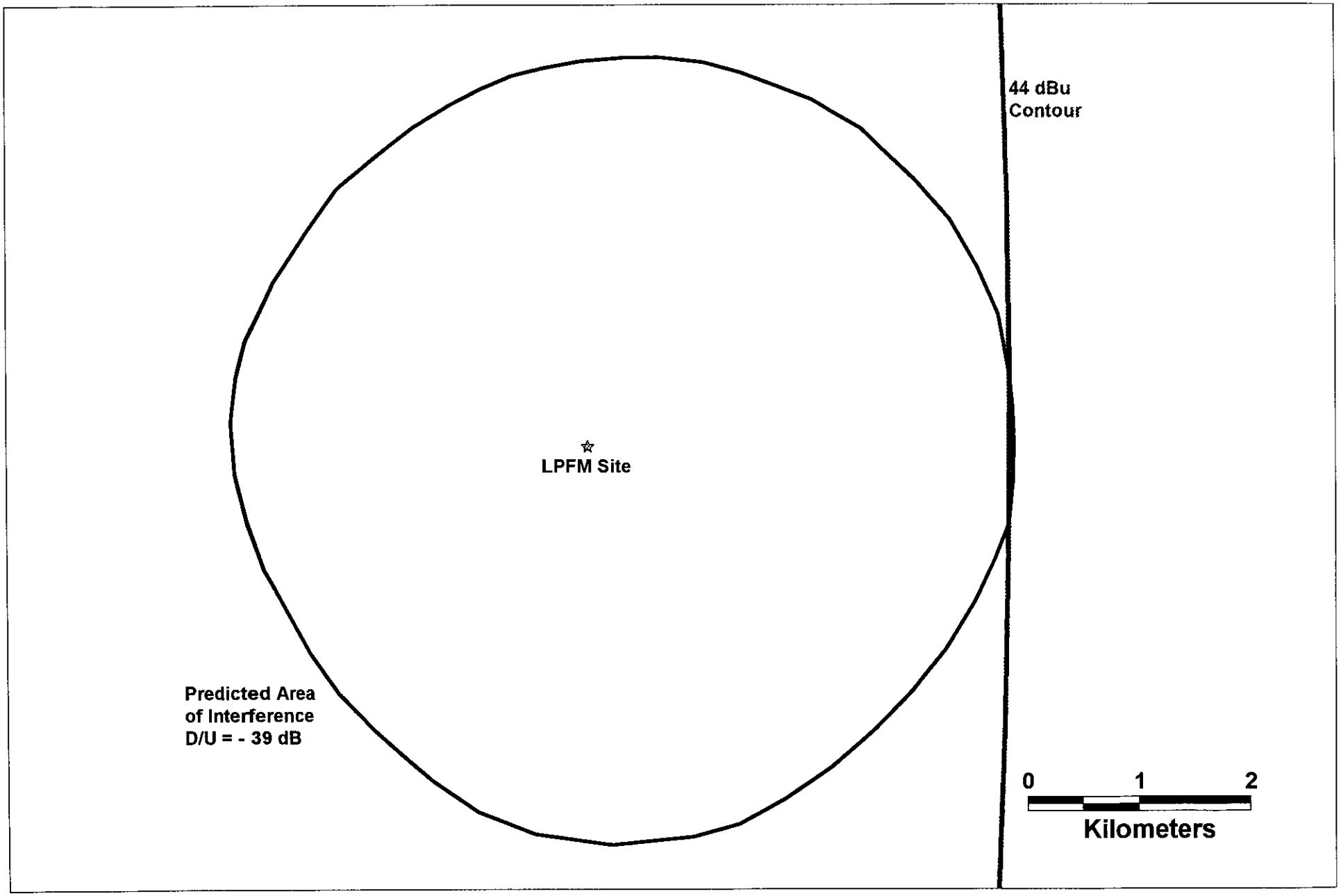

Figure 1

LP 1000 Stations without Second Adjacent Channel FM Separations

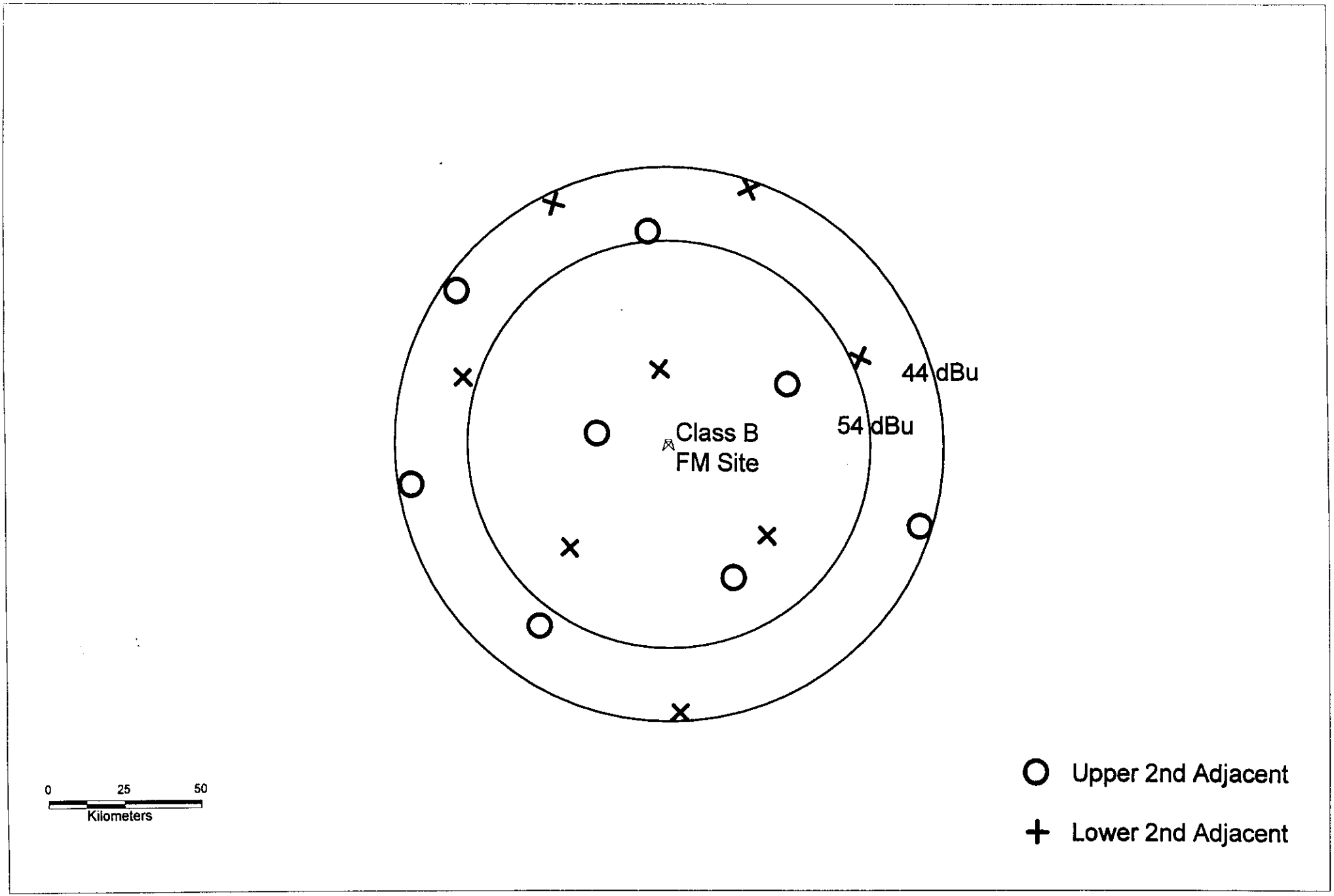

Figure 2

LP 1000 Stations with Second Adjacent Channel FM Separations

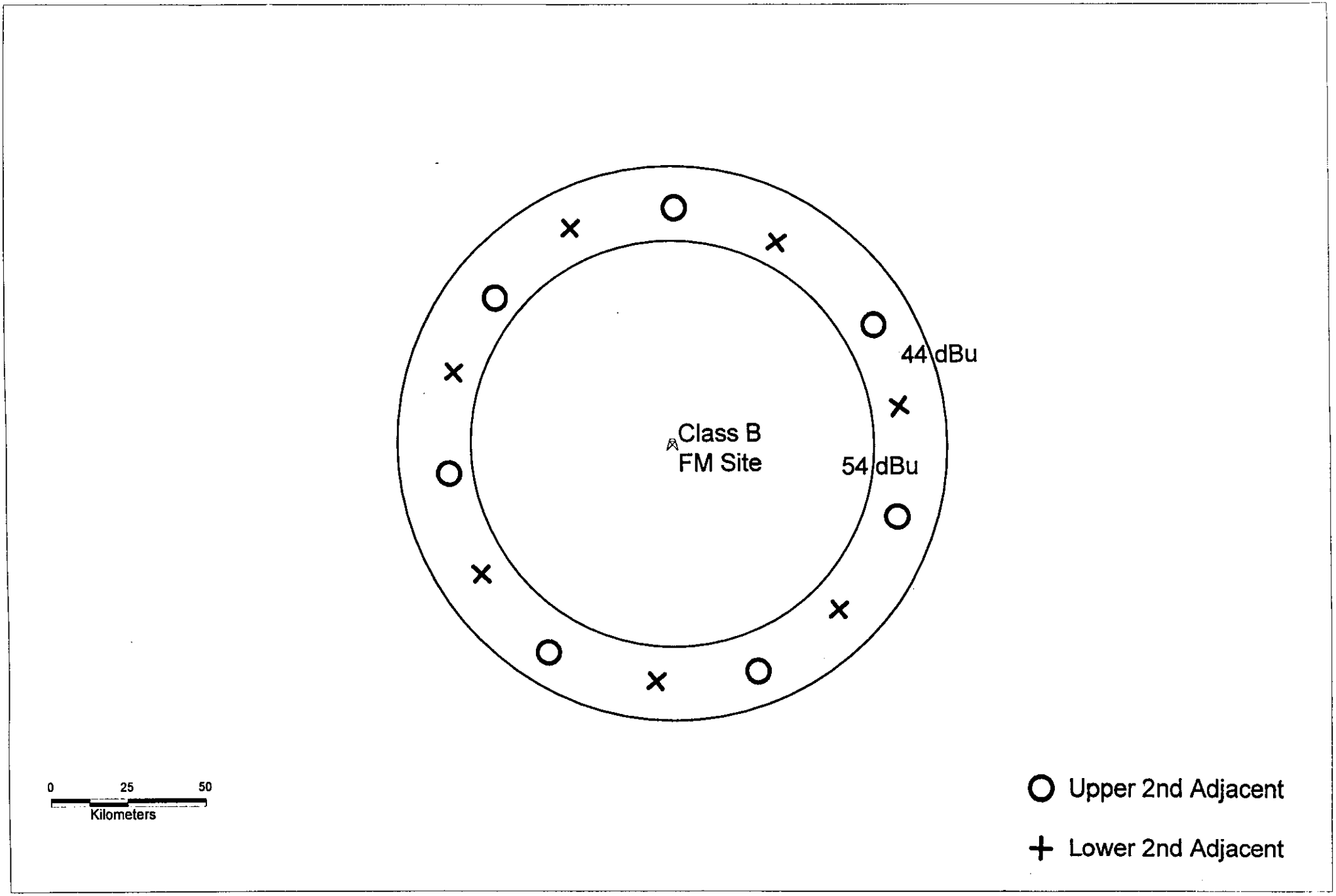

Figure 3