NTIA TECHNICAL MEMORANDUM 10-468

INITIAL ASSESSMENT OF THE POTENTIAL IMPACT FROM A JAMMING TRANSMITTER ON SELECTED IN-BAND AND OUT-OF-BAND RECEIVERS

U.S. DEPARTMENT OF COMMERCE • National Telecommunications and Information Administration

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INITIAL ASSESSMENT OF THE POTENTIAL IMPACT FROM A JAMMING TRANSMITTER ON SELECTED IN-BAND AND OUT-OF-BAND RECEIVERS

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U.S. DEPARTMENT OF COMMERCE

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ACKNOWLEDGMENTS

The author would like to thank Frank Sanders and Robert Johnk from the National Telecommunications and Information Administration Institute for Telecommunication Sciences for providing the measurements that were necessary to perform the assessment contained in this technical memorandum.

EXECUTIVE SUMMARY

This technical memorandum examines issues related to the potential interference impact of a specific Cellular Radiotelephone Service (Cellular) and Personal Communications Service (PCS) jammer transmitter on selected out-of-band and in-band receivers. The National Telecommunications and Information Administration (NTIA) Institute for Telecommunication Sciences performed laboratory and field measurements of a specific jammer transmitter and where appropriate these measurements were used in the interference assessment.

Assessment of Out-of-Band Receivers

In the assessment of out-of-band receivers, NTIA considered Federal land mobile radio (LMR) receivers in the 162-174 MHz and 406.1-420 MHz bands and Global Positioning System receivers in the 1559-1610 MHz, 1215-1240 MHz, and 1164-1188 MHz bands most likely to be used in the vicinity of a jammer transmitter at prison facility. NTIA performed laboratory measurements of the equivalent isotropically radiated power (EIRP) levels to characterize the emissions from the jammer transmitter in the LMR and GPS frequency bands and used the measured EIRP levels and established interference protection criteria to compute the distance separations necessary to preclude potential interference. Therefore, based on this method, NTIA can calculate the separation distances required for any jammer transmitter for which the emission characteristics are known. NTIA can then use these distance separations to determine for a particular jammer of known configuration and emission characteristics, whether that jammer will protect Federal receivers at or near a specific site.

Based on the results of NTIA's measurements and this assessment, when operating at full power and jamming in the Cellular and PCS bands, the tested jammer transmitter could cause some impact to LMR receivers at the prison and GPS receiver use in and around the facility. However, the use of a diplexer decreased the potential interference and reduced the required distance separations to such low values as to be negligible. Therefore, the specific jammer tested could be implemented with the diplexer or another appropriate filter without risk to Federal operations. However, because of the limited deployment of the jammer transmitter at the Federal facility, NTIA cannot draw, from the field measurements, any conclusions assessing the potential of aggregate interference to out-of-band receivers if multiple jammer transmitters of this same type were operated throughout the facility.

Variations in jammer configurations, effects of multiple jamming transmitters, structural characteristics of buildings, and propagation factors will be different depending on the installation and the facility making it difficult to fully assess potential interference to Federal operations outside the bands where jamming is performed. Given all of the possible variations in a jammer system installation, on-site measurements to determine the out-of-band signal levels outside of each facility for each installation would be necessary.

Assessment of In-Band Receivers

There are currently no industry adopted standards for in-band interference from other systems to Cellular and PCS handset receivers. In order to assess the potential interference impact to Cellular and PCS handset receivers, the Federal Communications Commission and the wireless industry will need to develop interference protection criteria.

Variations in jammer configurations, effects of multiple jamming transmitters, structural characteristics of buildings, and propagation factors will be different depending on the installation and the facility making it difficult to develop analytical techniques to fully assess potential interference to Cellular and PCS receivers without using very conservative assumptions. Given all of the possible variations in a jammer system installation, on-site measurements to determine the signal levels outside of the facility would be necessary. Based on the field measurements, NTIA observed variations in the measured signal levels of the jammer transmitter outside of the facility. These variations can make it difficult to distinguish the jammer transmitter signal in the environment. Moreover, depending on the relative signal levels it can be difficult to differentiate between the measured jammer transmitter signal and the Cellular and PCS signals. This problem will in all likelihood be exacerbated in areas where there is a high density of Cellular and PCS signals (e.g., metropolitan area). Given the challenges in distinguishing the jammer signal from the Cellular and PCS signals, it may be difficult to accurately measure jammer transmitter signal levels outside of the facility.

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ACRONYMS AND ABBREVIATIONS

EIRP	Equivalent Isotropically Radiated Power
FCC	Federal Communications Commission
GPS	Global Positioning System
IPC	Interference Protection Criteria
ITS	Institute for Telecommunication Sciences
LMR	Land Mobile Radio
NTIA	National Telecommunications and Information Administration
PCS	Personal Communications Service

SECTION 1.0
INTRODUCTION

1.1 BACKGROUND

The National Telecommunications and Information Administration (NTIA) in coordination with the Federal Communications Commission (FCC), the Federal Bureau of Prisons, and the National Institute of Justice, has been directed by Congress to develop a plan to investigate and evaluate how wireless jamming, detection and other technologies might be utilized for law enforcement and corrections applications in Federal and State prison facilities.[1]

Entities in the United States have proposed to operate radio transmitters in United States correctional facilities that produce intentional denial-of-service (jammer) emissions in the Cellular Radiotelephone Service (Cellular) and Personal Communications Service (PCS) handset receiver frequency bands. The NTIA Institute for Telecommunication Sciences (ITS) performed laboratory measurements of a jammer transmitter operating in the handset receiver frequency bands of 869-894 MHz band (Cellular) and 1930-1990 MHz band (PCS) to characterize the emissions as a function of frequency.[2] NTIA also performed field measurements of a jammer transmitter operated at a Federal correctional facility in Cumberland Maryland.[3]

1.2 OBJECTIVE

The objective of this technical memorandum is to examine issues related to the potential interference impact of a specific jammer Cellular and PCS transmitter to selected out-of-band and in-band receivers. The laboratory and field measurements of a specific jammer transmitter performed by ITS will be used where appropriate in the interference assessment.

1.3 APPROACH

NTIA used the following approach in assessing the potential interference impact to in-band and out-of-band receivers.

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1. H.R. Conf. Rep. No. 111-336 at 619 (2009), available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_reports&docid=f:hr366.111.pdf. The language specifically refers to cell phone prevention methods only within prison facilities.

2. National Telecommunications Information Administration Report TR-10-465, *Emission Measurement Results for a Cellular and PCS Signal-Jamming Transmitter* (Feb. 2010) (NTIA Report TR-10-465).

3. National Telecommunications Information Administration Report TR-10-466, *Emission Measurements of a Cellular and PCS Signal-Jammer at a Prison Facility* (Apr. 2010) (NTIA Report TR-10-466).

1. Identify Federal receivers most likely to be operating in the vicinity of a facility where a jammer transmitter is operating.

2. Develop interference protection criteria for selected Federal receivers.

3. Determine system characteristics for selected Federal receivers.

4. Determine the equivalent isotropically radiated power (EIRP) levels of the jammer transmitter in the Federal receiver frequency bands using the laboratory measurements performed by ITS.

5. Compute the distance separations between the jammer transmitter and the selected Federal receivers required to preclude potential interference.

6. Evaluate the field measurements performed by ITS to examine the jammer transmitter emissions in the Cellular and PCS handset receiver frequency bands.

SECTION 2.0
ANALYSIS OF OUT-OF-BAND RECEIVERS

2.1 INTRODUCTION

This section describes the analysis that was performed to compute the distance separations required between a jammer transmitter and selected Federal out-of-band receivers to preclude potential interference.

2.2 SELECTED OUT-OF-BAND RECEVERS

The Federal Government operates, throughout the radio frequency spectrum many different types of receivers such as those used for air traffic control systems, radar systems, and fixed communication systems. In this assessment, NTIA considered land mobile radio (LMR) receivers operating in the 162-174 MHz and 406.1-420 MHz bands and Global Positioning System (GPS) receivers operating in the 1559-1610 MHz, 1215-1240 MHz, and 1164-1188 MHz bands. NTIA selected these receiver types because they are the Federal receivers most likely to be operating in the vicinity of a facility where a jammer transmitter is operating. Prison officials use LMR for prison operations and security. GPS position location technology has become a ubiquitous application in all environments.

NTIA performed the analysis documented in this technical memorandum to compute the distance separations from the jammer transmitter required to preclude potential interference to LMR (base and mobile) and GPS receivers.

2.3 RECEIVER INTERFERENCE PROTECTION CRITERIA

A critical parameter necessary to assess the potential impact to a receiver is the interference protection criteria (IPC). The IPC is a relative or absolute interfering signal level at the receiver input, under specified conditions, such that the allowable performance degradation is not exceeded.

For the Federal LMR receivers an IPC of -143 dBW/10 kHz is used to assess potential interference. NTIA uses this interference threshold in the coordination of LMR systems with Mexico and Canada. It is a worst case value based only on receiver sensitivity and does not take into account the strength of the received signal.[4]

4. If the signal level at the LMR receiver is stronger, higher levels of interference can be tolerated without degrading receiver performance.

An IPC of -147 dBW/MHz is used to assess the potential impact to GPS receivers.[5] This value has been agreed to by NTIA and the FCC for the protection of GPS receivers.

2.4 LABORATORY MEASUREMENTS OF A JAMMER TRANSMITTER

NTIA performed laboratory measurements to obtain a set of emission spectrum data, in the form of EIRP levels, of a jammer transmitter that can be used to characterize the radiated emissions between 100 MHz to 6 GHz.[6] The EIRP measurements shown in Figure 2-1 for the 100 to 2000 MHz frequency range reflect the jammer transmitter operating at full power, with jamming signals swept across both bands (Cellular and PCS), and, no diplexer at the output of the jamming transmitter.[7]

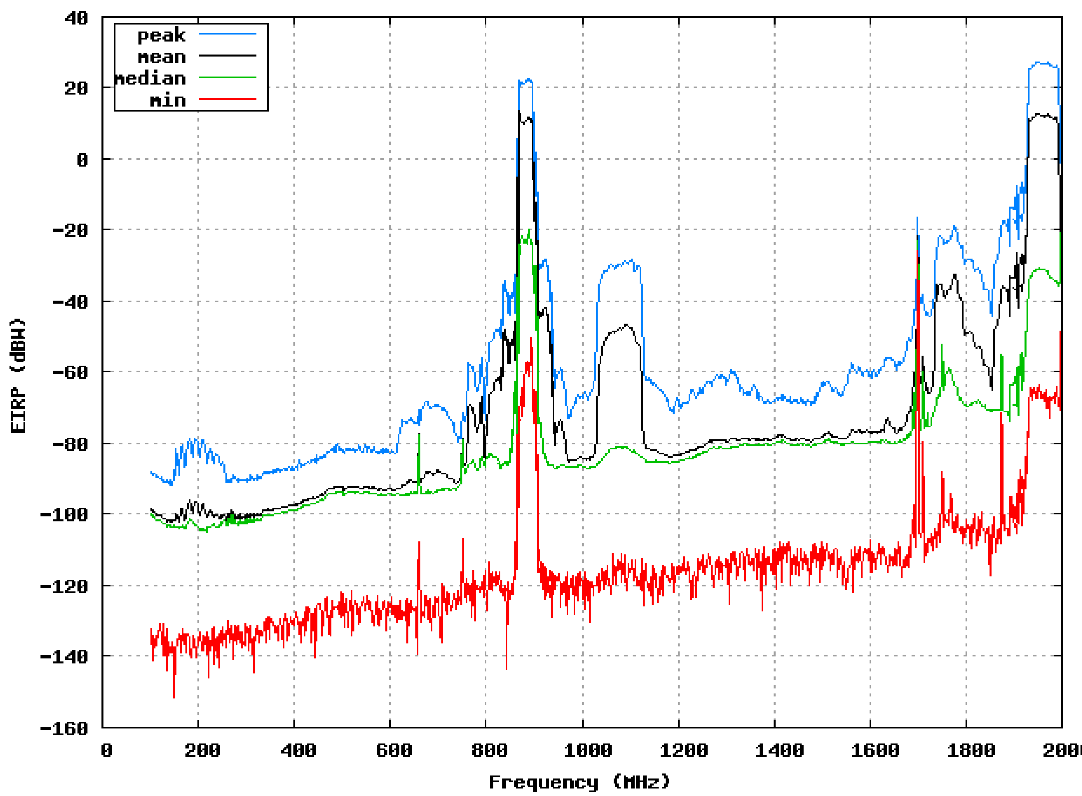

Figure 2-1. EIRP Measurements in the 100 MHz to 2000 MHz Frequency Range (Without Diplexer)

5. The IPC value is based on a 1 dB increase in the receiver system noise for a receiver with a bandwidth of 1 MHz and a noise figure of 3 dB.

6. The laboratory measurements characterized the emissions varying the following jammer transmitter parameters: output power; frequency range; output filtering; and antenna type.

7. NTIA Report TR-10-465 at Figure 10.

The jammer transmitter operates by repetitively frequency-sweeping (referred to as chirping) a carrier wave signal across the bands to be jammed. The measurement bandwidth was tailored to achieve an optimal signal-to-noise ratio in the measurement results. For this jammer, the combination of its chirp bandwidth and its chirp rate resulted in an optimum measurement bandwidth of 2 MHz.[8]

For the jammer transmitter measured by NTIA, a standard Cellular-PCS band diplexer was used as a filter.[9] This diplexer is not integral to the jammer; instead, can be manually connected to the output of the jammer transmitter. Figure 2-2 shows the measured frequency response of the diplexer.[10]

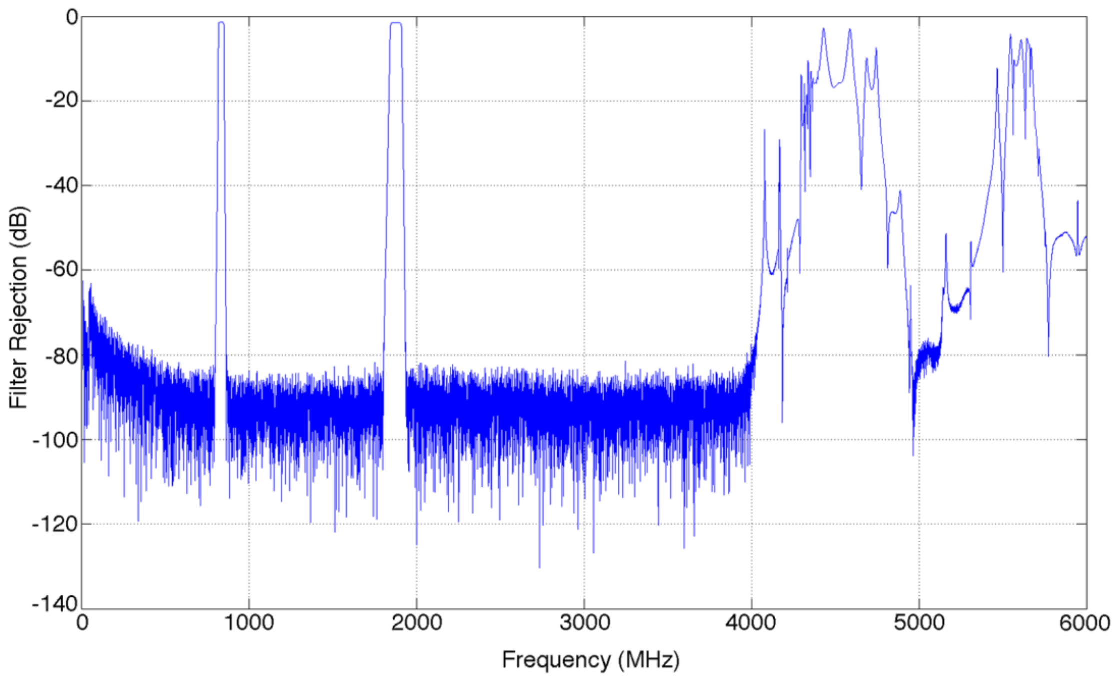

Figure 2-2. The Power-Rejection Characteristic of the Diplexer as a Function of Frequency

As shown in Figure 2-3, when implemented as a filter, the diplexer reduces the jammer's emission levels outside its intended bands of operation (e.g., signals at 1100 MHz are reduced to the noise floor of the measurement system).

8. *Id.* at 5.

9. A diplexer is a passive device that implements frequency domain multiplexing.

10. NTIA Report TR-10-465 at Figure 7.

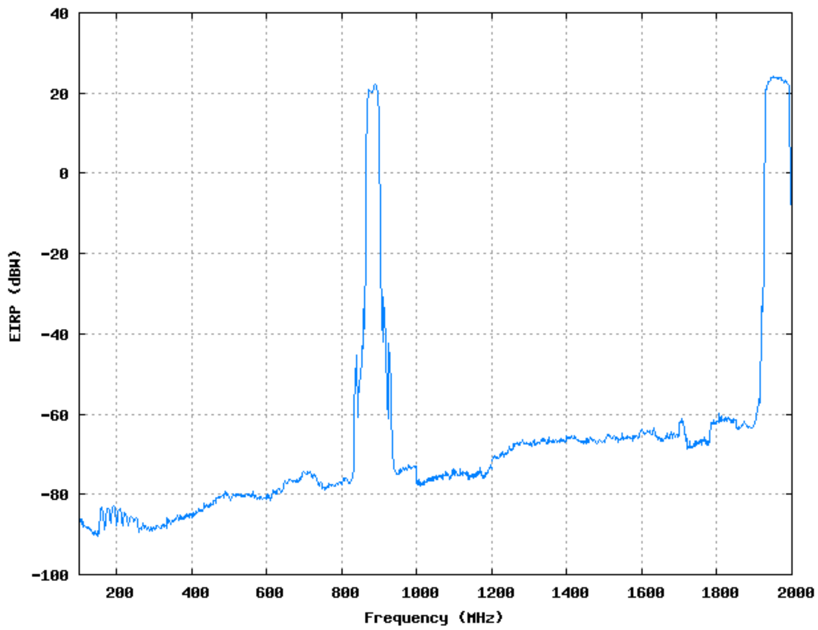

Figure 2-3. EIRP Measurements in the 100 MHz to 2000 MHz Frequency Range (With Diplexer)

Figures 2-4 and 2-5 show more detailed emission measurements in the 162-174 MHz and the 406.1-420 MHz bands with the diplexer using a hardline connection.[11] The emission levels from the jammer transmitter in Federal LMR frequency bands are below the noise floor of the measurement system.

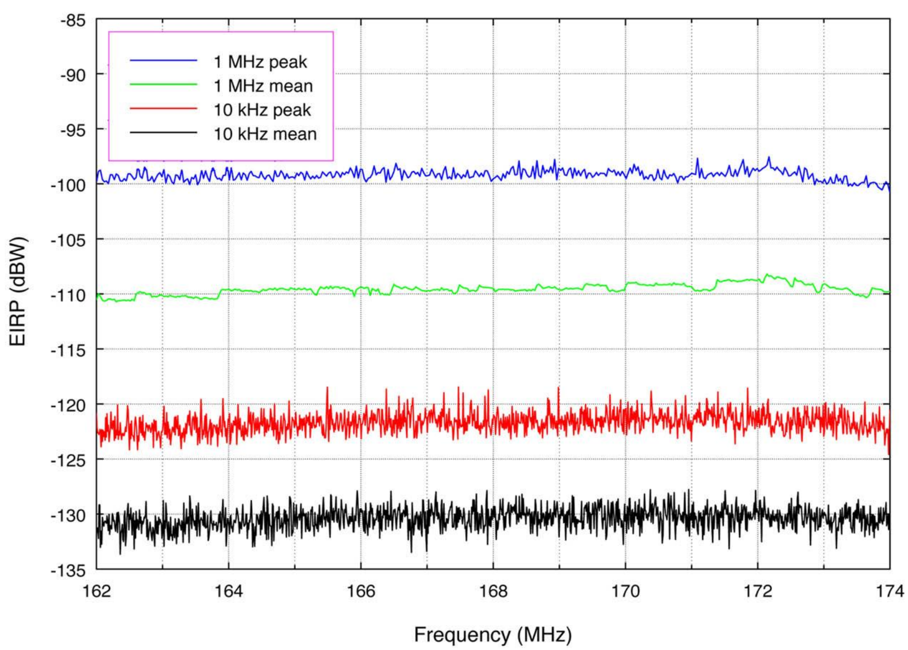

Figure 2-4. Detailed 162-174 MHz Band Emission Measurements

11. *Id.* at Figures 38 and 39.

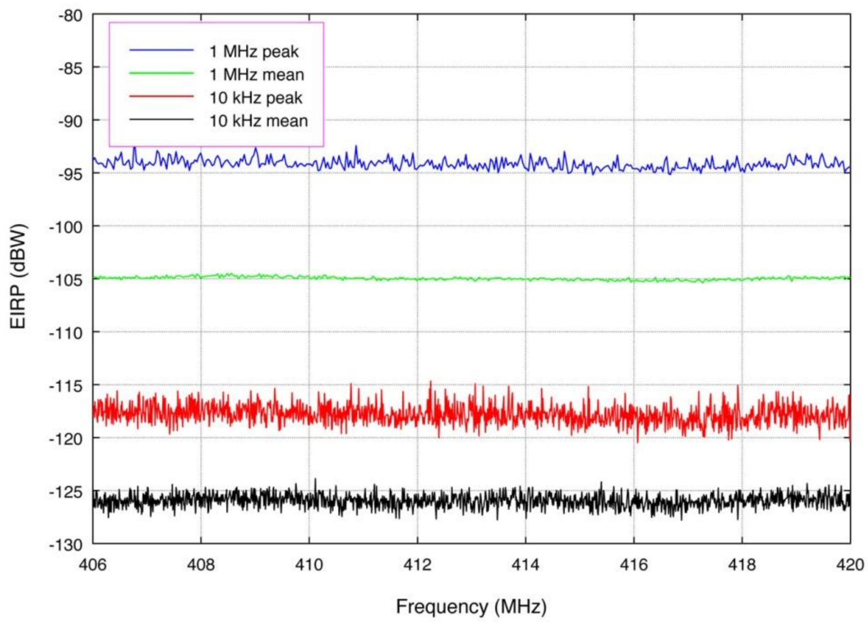

Figure 2-5. Detailed 406.1-420 MHz Band Emission Measurements

Figures 2-6 through 2-8 show more detailed emission measurements in the GPS frequency bands with the diplexer using a hardline connection.[12] The emission levels from the jammer transmitter in GPS frequency bands are below the noise floor of the measurement system.

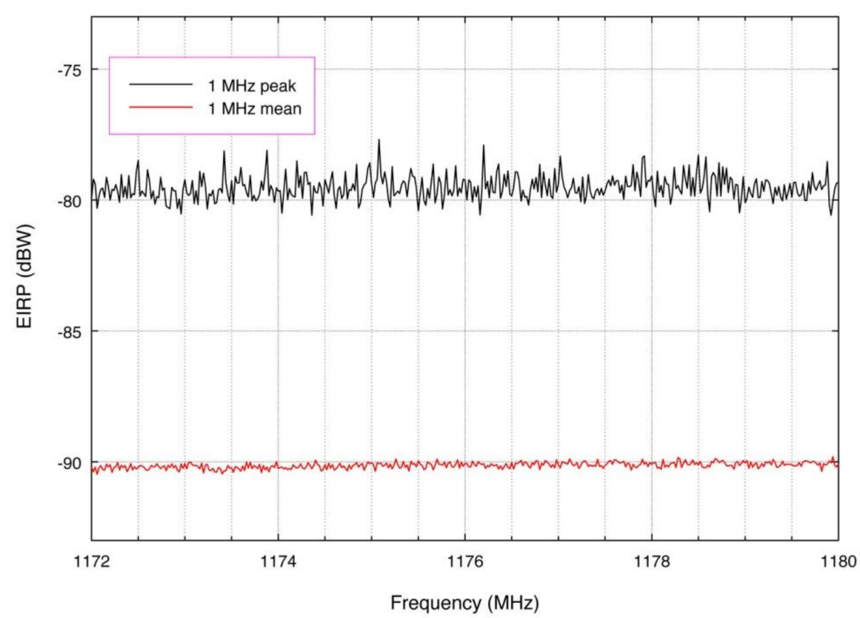

Figure 2-6. Detailed 1172-1180 MHz Band (L5) Emission Measurements

12. *Id.* at Figures 44, 45, and 46.

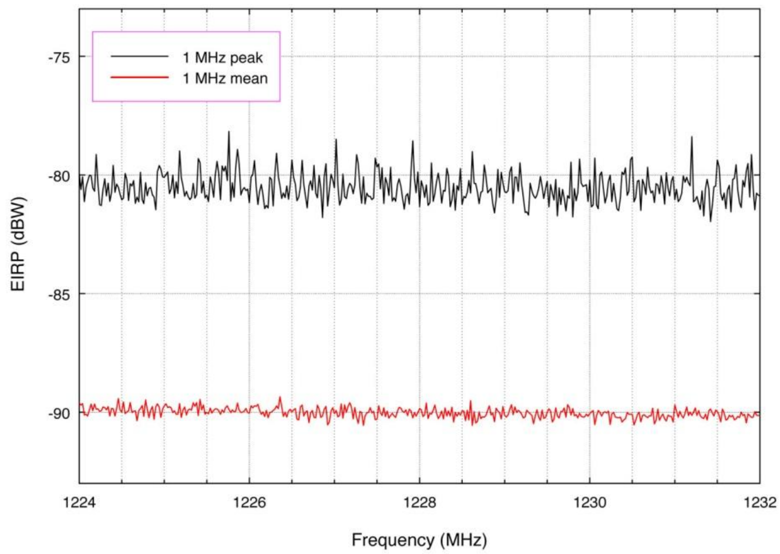

Figure 2-7. Detailed 1124-1232 MHz Band (L2) Emission Measurements

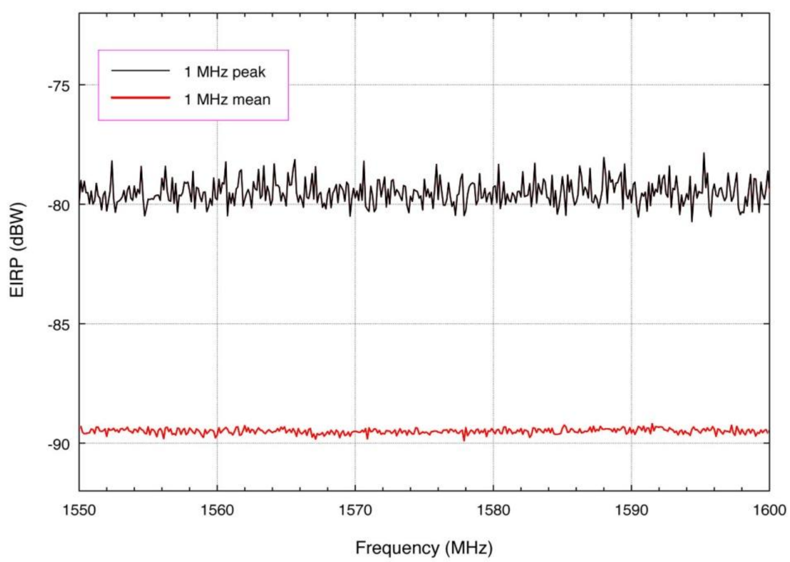

Figure 2-8. Detailed 1550-1600 MHz Band (L1) Emission Measurements

2.5 FIELD MEASUREMENTS OF A JAMMER TRANSMITTER

ITS performed field measurements of a jammer transmitter operated inside a Federal correctional facility located in Cumberland, Maryland.[13] The targeted jamming area was limited to the interior of a two-floor reinforced cinderblock structure measuring

13. The same jammer transmitter characterized at the ITS laboratory was installed at the Federal correctional facility, with the exception of a different filter to control the out-of-band and spurious emissions.

30 meters long by 8 meters wide.[14] Measurements with the jammer transmitter turned on and off were performed both inside and outside of the facility.

Figure 2-9 shows the measured emission levels in the 162-174 MHz band.[15] As shown in Figure 2-9 there are no detectable emissions from the jammer transmitter measured at a distance of approximately 26 meters line-of-sight to the facility.[16]

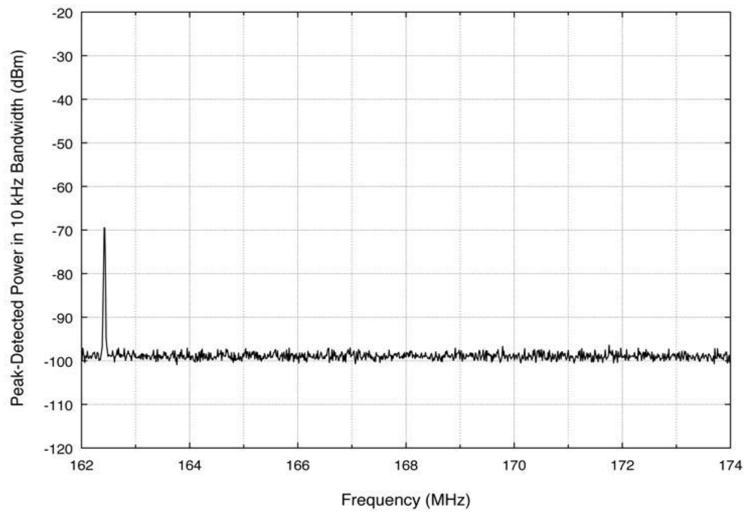

Figure 2-9. Measured Emissions in the 162-174 MHz Band

Figure 2-10 shows the measured emission levels in the 406.1-420 MHz band.[17] As shown in Figure 2-10 there are no detectable emissions from the jammer transmitter measured at a distance of approximately 26 meters line-of-sight to the facility.[18]

14. NTIA participated in the site selection process and assisted in coordination of the use of the site, but did not participate in or direct any aspect of the jammer installation or configuration.

15. NTIA Report TR-10-466 at Figure 25.

16. The only signal detected was a weather radio signal.

17. NTIA Report TR-10-466 at Figure 26.

18. Two LMR signals were detected.

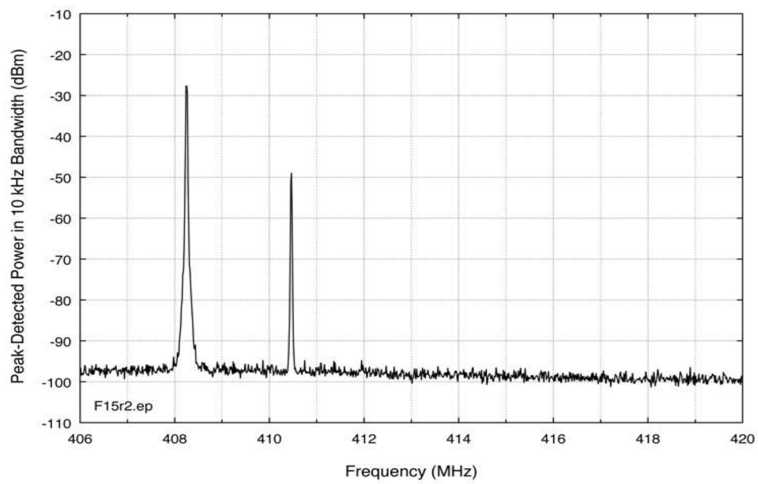

Figure 2-10. Measured Emissions in the 406.1-420 MHz Band

Figures 2-11 through 2-13 show the measured emission levels in the GPS L1, L2, and L5 frequency bands.[19] As shown in these figures there are no detectable emissions from the jammer transmitter measured at a distance of approximately 26 meters line-of-sight to the facility.

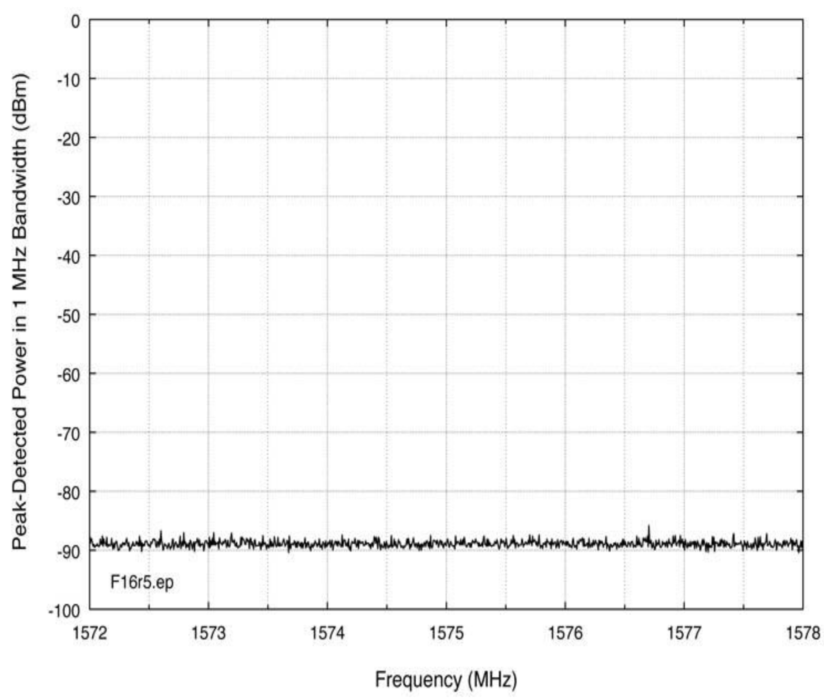

Figure 2-11. Measured Emissions in the GPS L1 Band

19. NTIA Report TR-10-466 at Figures 27, 28, and 29.

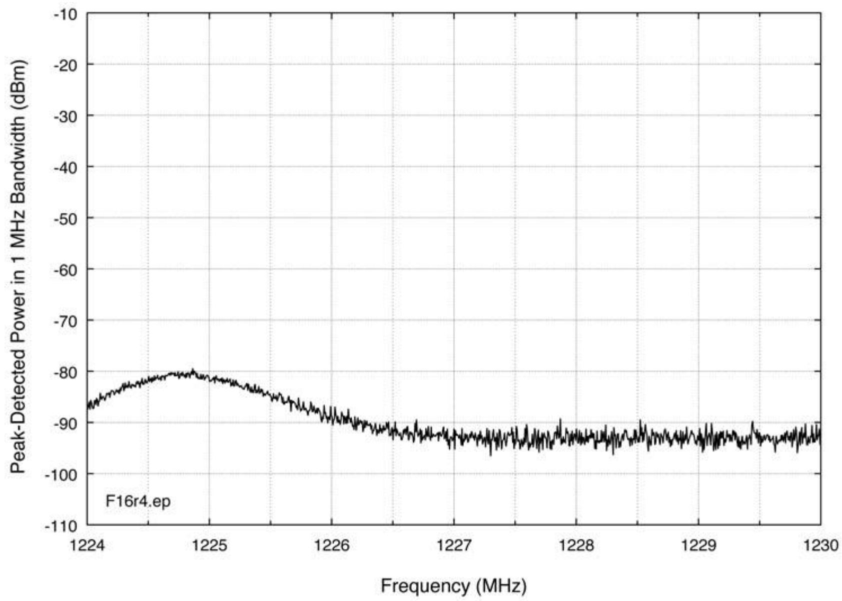

Figure 2-12. Measured Emissions in the GPS L2 Band

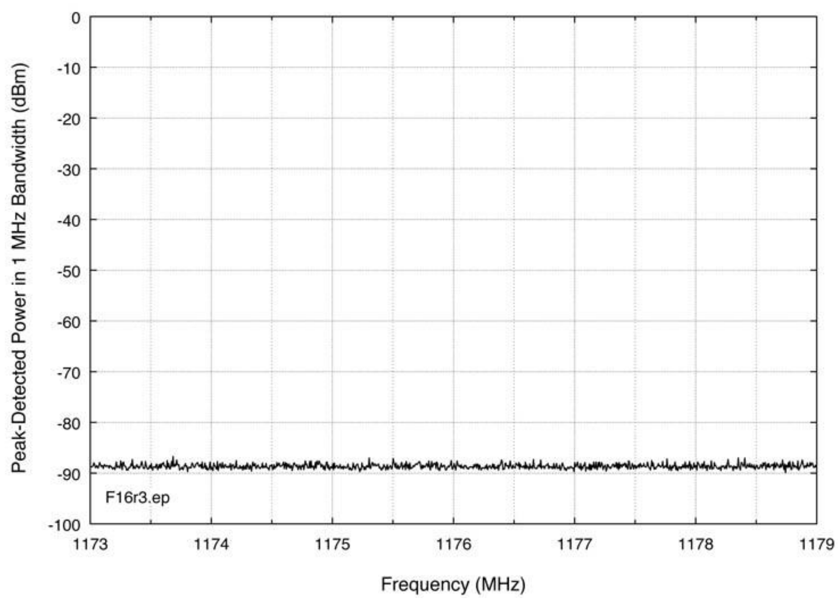

Figure 2-13. Measured Emissions in the GPS L5 Band

2.6 REQUIRED SEPARATION DISTANCES FOR LMR RECEIVERS

The following analysis provides the approximate separation distances required between a jammer transmitter and Federal base and mobile LMR receivers operating in the 162-174 MHz and 406.1-420 MHz bands to preclude potential interference.

The required propagation loss necessary to preclude potential interference to LMR receivers is determined by:

$$L_{required} = EIRP_{Jammer} – L_{LMR} + G_{LMR} - I_T \qquad (2\text{-}1)$$

Where:

$L_{required}$ is the required propagation loss between the jammer transmitter and the LMR receiver necessary to preclude potential interference (dB);
$EIRP_{Jammer}$ is the peak EIRP of the jammer (dBW/10 kHz);[20]
L_{LMR} is the additional losses associated with the LMR receiver (dB);
G_{LMR} is the receive antenna gain of the LMR in the direction of the jammer transmitter (dBi); and
I_T is the LMR receiver IPC (dBW/10 kHz).

The measured levels shown in Figure 2-1 (without diplexer) and Figures 2-4 and 2-5 (with diplexer) will be used to estimate the EIRP levels in the Federal LMR bands.[21]
The receive antenna gain of a LMR mobile in the direction of a jammer transmitter is assumed to be 0 dBi.

A factor of 3 dB is included for additional losses associated with the LMR receiver (e.g., insertion loss, body losses).

The required separation distance is determined using the free space propagation loss model:

$$D_{required} = 10^{[(Lrequired - 20 \text{ Log } F + 27.55)/20]} \qquad (2\text{-}2)$$

Where:

F is the frequency (MHz); and
$D_{required}$ is the required separation distance between a transmitter and a receiver (m).

Using Equations 2-1 and 2-2, Table 2-1 provides the required separation distances for LMR mobile receivers when the jammer transmitter is operating at full power, the jamming signal is swept across the Cellular and PCS bands, and no diplexer.

Table 2-1.

LMR Center Frequency	$EIRP_{Jammer}$ (dBW/10 kHz)	L_{LMR} (dB)	G_{LMR} (dBi)	I_T (dBW/10 kHz))	$L_{required}$ (dB)	$D_{required}$ (m)
168 MHz	-103[a]	3	0	-143	37	10
413 MHz	-108[a]	3	0	-143	32	2
a - EIRP level determined from Figure 2-1 with bandwidth adjustment of 23 dB.						

20. The peak EIRP levels considered in this analysis provide a worst case representation of the jammer transmitter signal.

21. In the 162-174 MHz and 406.1-420 MHz bands the emission measurements shown in Figure 2-1 are essentially at the noise floor of the measurement system. In this case the EIRP is adjusted by a factor of 10 Log ($10 \times 10^3 / 2 \times 10^6$) reducing the measured emission level by 23 dB.

For a base station receive antenna, a gain of 6 dBi and 5 dB of insertion loss enable the computation of the separation distances required to preclude interference. Table 2-2 provides the required separation distances for LMR base stations when the jammer transmitter is operating at full power, the jamming signal is swept across the Cellular and PCS bands, and no diplexer.

Table 2-2.

LMR Center Frequency	$EIRP_{Jammer}$ (dBW/10 kHz)	L_{LMR} (dB)	G_{LMR} (dBi)	I_T (dBW/10 kHz)	$L_{required}$ (dB)	$D_{required}$ (m)
168 MHz	-103[a]	5	6	-143	41	16
413 MHz	-108[a]	5	6	-143	36	4
a - EIRP level determined from Figure 2-1 with bandwidth adjustment of 23 dB.						

Table 2-3 provides the required separation distances for LMR mobile stations when the jammer transmitter is operating at full power, jamming in the Cellular and PCS bands, the jamming signal is swept across the Cellular and PCS bands with the diplexer installed.

Table 2-3.

LMR Center Frequency	$EIRP_{Jammer}$ (dBW/10 kHz)	L_{LMR} (dB)	G_{LMR} (dBi)	I_T (dBW/10 kHz))	$L_{required}$ (dB)	$D_{required}$ (m)
168 MHz	-120[a]	3	0	-143	20	1
413 MHz	-115[b]	3	0	-143	25	1
a - EIRP level determined from Figure 2-4. b - EIRP level determined from Figure 2-5.						

Table 2-4 provides the required separation distances for LMR base stations when the jammer transmitter is operating at full power, the jamming signal is swept across the Cellular and PCS bands, with the diplexer installed.

Table 2-4.

LMR Center Frequency	$EIRP_{Jammer}$ (dBW/10 kHz)	L_{LMR} (dB)	G_{LMR} (dBi)	I_T (dBW/10 kHz)	$L_{required}$ (dB)	$D_{required}$ (m)
168 MHz	-120[a]	5	6	-143	24	2
413 MHz	-115[b]	5	6	-143	29	1.6
a - EIRP level determined from Figure 2-4. b - EIRP level determined from Figure 2-5.						

2.7 REQUIRED SEPARATION DISTANCES FOR GPS RECEIVERS

The required propagation loss required to preclude potential interference to a GPS receiver is:

$$L_{required} = EIRP_{Jammer} + G_{GPS} - I_T \qquad (2\text{-}3)$$

Where:

$L_{required}$ is the required propagation loss between the jammer transmitter and a GPS receiver necessary to preclude potential interference (dB);
$EIRP_{Jammer}$ is the peak EIRP of the jammer (dBW/MHz); [22]
G_{GPS} is the GPS receive antenna gain in the direction of the jammer transmitter (dBi); and
I_T is the GPS receiver IPC (dBW/MHz).

The GPS receive antenna gain in the direction of the jammer transmitter is 0 dBi.

The measured EIRP shown in Figure 2-1 and the diplexer frequency response shown in Figure 2-2 will be used to estimate the EIRP levels in the GPS frequency bands.[23] The EIRP is determined by using the peak EIRP of -62 dBW/MHz from Figure 2-1 and the 85 dB of rejection in the GPS frequency bands from the diplexer as shown in Figure 2-2. The resulting EIRP used in the analysis is -147 dBW/MHz.

The required loss when the jammer transmitter is operating at full power, jamming signals in both the Cellular and PCS bands, full jamming across each band and no diplexer is:

$$L_{required} = -62 + 0 - (-147) = 85 \text{ dB}$$

Using Equation 2-2, the required separation distances necessary to preclude potential interference to GPS receivers is:

$$D_{required} = 240 \text{ meters (L1)}$$

$$D_{required} = 308 \text{ meters (L2)}$$

$$D_{required} = 321 \text{ meters (L5)}$$

The required loss for the jammer transmitter operating at full power, jamming in both the Cellular and PCS bands, full jamming across each band, with the diplexer is:

$$L_{required} = -147 + 0 - (-147) = 0 \text{ dB}$$

The required separation distance necessary to preclude potential interference to GPS receivers is:

$$D_{required} = < 1 \text{ meter}$$

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22. The peak EIRP levels considered in this analysis provide a worst case representation of the jammer transmitter signal.

23. In the GPS bands the measurements shown in Figure 2-1 are essentially at the noise floor of the measurement system. In this case the EIRP is adjusted by a factor of 10 Log ($1x10^6/2x10^6$) reducing the measured emission level by 3 dB.

SECTION 3.0
EXAMINATION OF IN-BAND JAMMER TRANSMITTER EMISSIONS

3.1 INTRODUCTION

This section examines the emissions from a jammer transmitter in the frequency bands used by Cellular and PCS handsets receivers.

The purpose of the jammer transmitter is to disrupt Cellular and PCS communication service within the prison while not disrupting communication outside of the prison. Figure 3-1 shows a high level diagram portraying the general issues and areas associated with assessing potential in-band interference from a jammer transmitter.

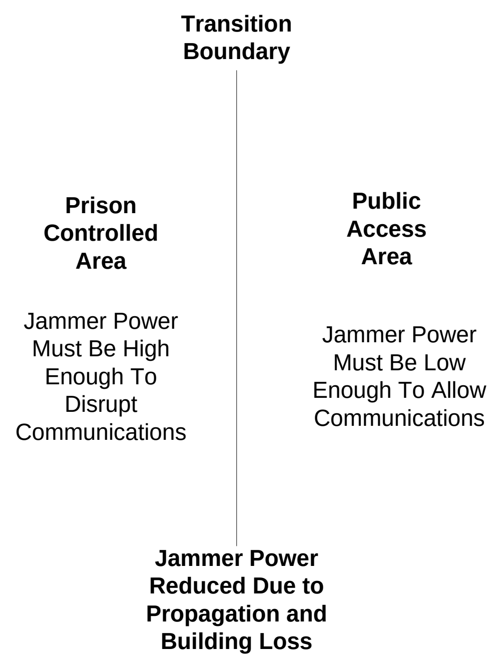

Figure 3-1. General Model for In-Band Interference

The general model is based on a representative prison scenario consisting of land that is under prison control and land outside the prison grounds that is accessible to the public. The prison land can contain buildings and prison yards that can extend to the boundary of the prison land and analysis must assume that the radio services will be jammed in the area of the prison, including the prison yard. The jamming signal is provided by antennas located on towers (in the yard) and/or the outside of the prison buildings. The strength of the jamming signal drops off as the distance from the antennas increases.

3.2 RECEIVER INTERFERENCE PROTECTION CRITERIA

There are currently no industry adopted standards for in-band interference from other systems to Cellular and PCS handset receivers. The IPC values for the handset receivers will depend on received signal level which varies in relationship to the distance between the base station transmitter and handset receiver.[24] For example, if the area of concern (outside prison land) for the handset receiver is relatively far from the base station, the signal level at the handset can be assumed as constant over relatively short distances. However, if the prison jamming transmitter location is close to the base station transmitter then the handset receivers may experience significantly different interference impact depending on where they are located with respect to the base station and the jammer transmitter. Without established IPC values, NTIA cannot assess the potential interference impact to Cellular and PCS handset receivers operating outside of the area being jammed.

3.3 LABORATORY MEASUREMENTS OF A JAMMER TRANSMITTER

The laboratory measurements performed by NTIA do not provide any insight as to the interference impact of a jammer transmitter to in-band Cellular and PCS handset receivers. The measurements performed by NTIA only examined jammer transmitter signal levels. The effectiveness of the jammer transmitter to actually disrupt Cellular or PCS signal reception was not examined.

3.4 FIELD MEASUREMENTS OF A JAMMER TRANSMITTER

The field measurements were performed with the jammer transmitter operated inside the prison facility. The targeted jamming area was limited to the interior of a two-floor reinforced cinderblock structure measuring 30 meters long by 8 meters wide. Measurements with the jammer transmitter turned on and off were performed both inside and outside of the facility.

Figures 3-2 and 3-3 provide examples of the measured field strength levels of the jammer transmitter inside the facility in the Cellular and PCS bands.[25]

24. IPC values can be developed based on worse case assumptions regarding received signal level (e.g., edge of coverage), but this can limit the allowable power level and possibly the overall effectiveness of the jamming system.

25. NTIA Report TR-10-466 at Figures 3 and A-8. The measurement resolution bandwidths of 100 kHz for the Cellular signals and 1 MHz for the PCS signals were used because they are consistent with the receiver bandwidths of 200 kHz used by Cellular handsets and 1.25 MHz used by PCS handsets.

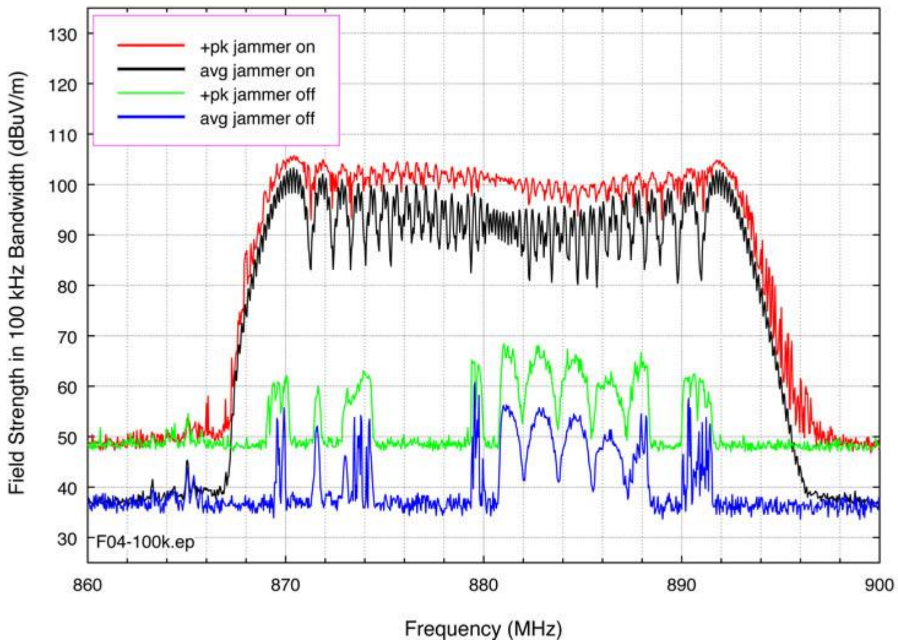

Figure 3-2. Indoor Field Strength Measurements in the Cellular Band

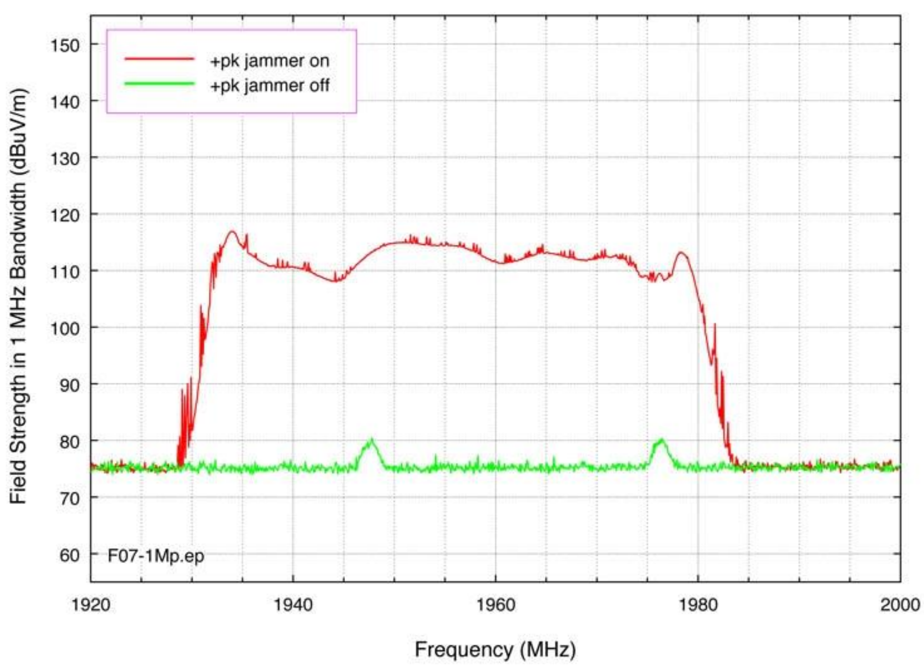

Figure 3-3. Indoor Field Strength Measurements in the PCS Band

As shown in Figures 3-2 and 3-3, the large difference between the measured signal levels makes it possible to differentiate between the jammer signal and the Cellular and PCS signals received inside of the facility. The measurements in Figure 3-2 show Cellular signals at the following frequencies: 869 MHz, 872 MHz, 874 MHz, 880 MHz, 881 MHz, 883 MHz, 885 MHz, 886 MHz, 888 MHz, and 891 MHz. The measured peak levels of the jammer transmitter are approximately 35 to 40 dB higher than those of the

Cellular signals. The measurements in Figure 3-3 show PCS signals at 1947 MHz and 1976 MHz. The measured peak levels of the jammer transmitter are approximately 30 to 35 dB higher than those of the PCS signals.

Figures 3-4 through 3-6 provide the measured field strength levels of the jammer transmitter in the Cellular band at various points outside of the facility.[26] As shown in Figure 3-4, while the measured differences seen in the jammer transmitter and Cellular peak signal levels are less than 10 dB at a separation distance of approximately 26 meters (80 feet) from the facility, they are still distinguishable. At a distance of approximately 131 meters (400 feet) line-of-sight from the facility the measured signal levels from the jammer transmitter cannot be distinguished from the Cellular signals as shown in Figure 3-5. A similar situation occurs for a non-line-of-sight path to the facility approximately 52 meters (156 feet), as shown in Figure 3-6.[27] Here again, the signal levels from the jammer transmitter cannot be distinguished from the Cellular signals.

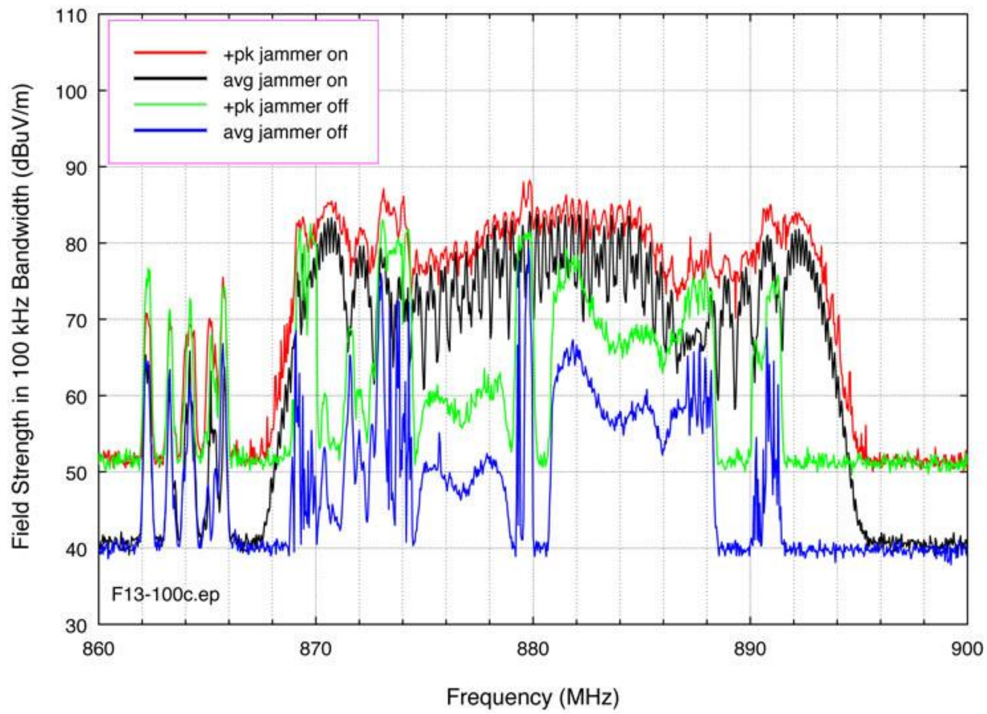

Figure 3-4. Field Strength Measurements in Cellular Band (26 Meters Line-of-Sight from Facility)

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26. *Id.* at Figures 11, 19, and 21.

27. The non-line of sight condition occurs as a result of terrain and building blockage.

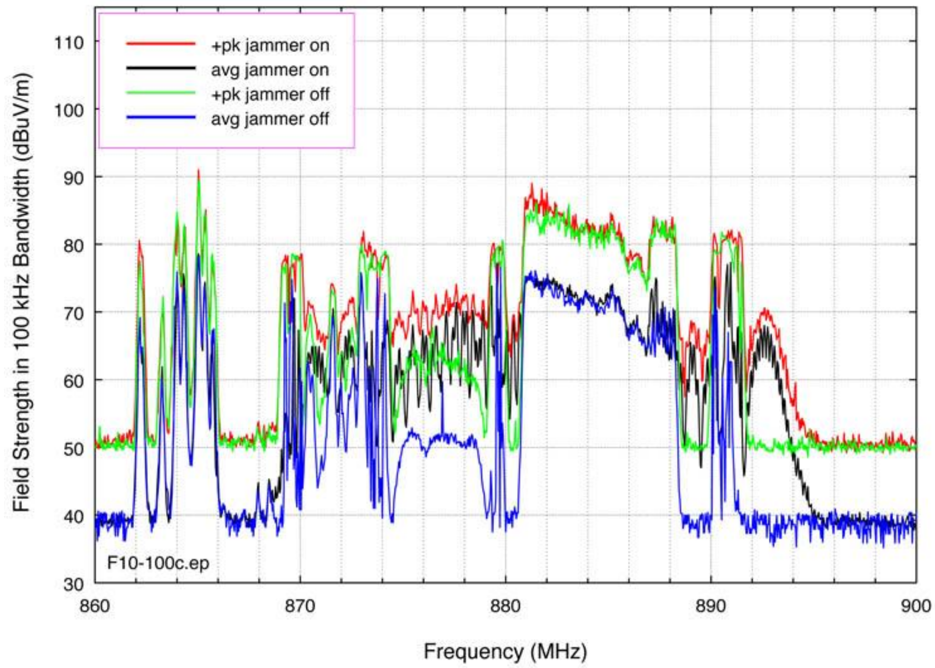

Figure 3-5. Field Strength Measurements in Cellular Band (131 Meters Line-of-Sight from Facility)

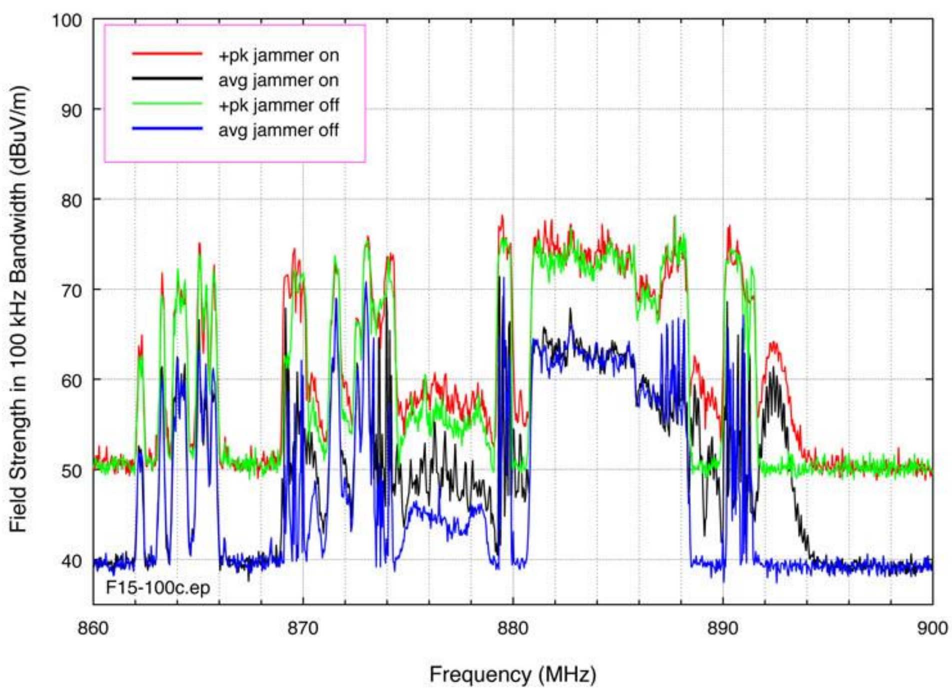

Figure 3-6. Field Strength Measurements in Cellular Band (52 Meters Non-Line-of-Sight from Facility)

Figures 3-7 through 3-9 provide the measured field strength levels of the jammer transmitter in the PCS band at various points outside of the facility.[28] As shown in Figure 3-7, the measured signal levels of the jammer transmitter range from approximately 2 to 10 dB higher than the levels of several PCS signals (1937 MHz, 1947 MHz, 1967 MHz, and 1977 MHz) at a distance of 26 meters (approximately 80 feet) line-of-sight from the facility. At a distance of 131 meters (approximately 400 feet) line-of-sight from the facility the difference between the measured jammer transmitter signals is large enough that it can be distinguished from the PCS signals. The measured jammer transmitter signals are approximately 2 to 5 dB higher than the levels of the PCS signals as shown in Figure 3-8. For a non-line-of-sight path to the facility 74 meters (220 feet), as shown in Figure 3-9 the measured field strength levels from the jammer transmitter cannot be distinguished from the PCS signals.[29]

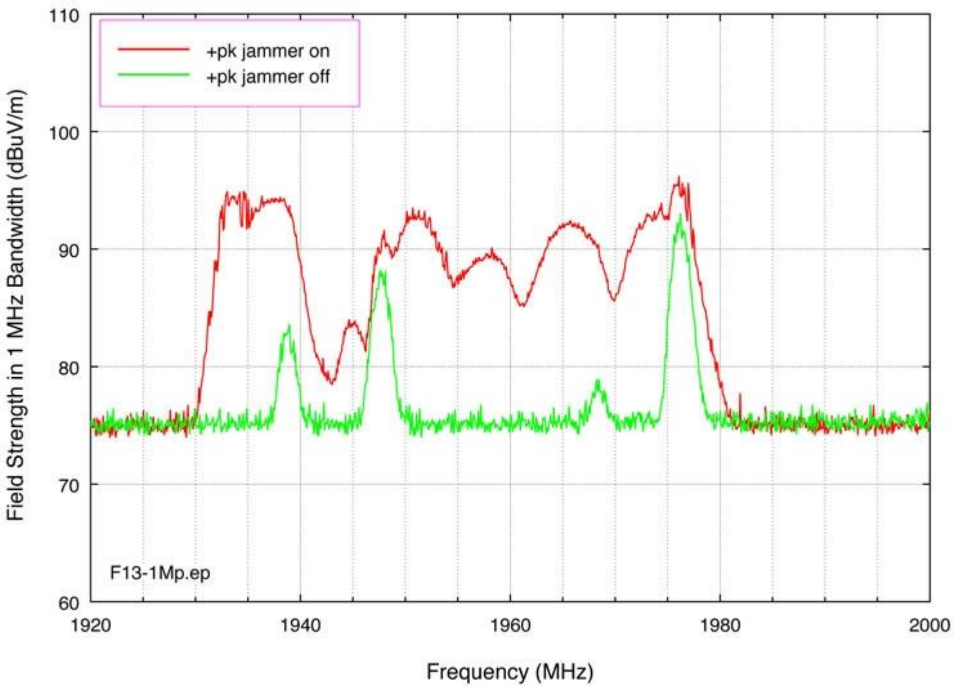

Figure 3-7. Field Strength Measurements in PCS Band (26 Meters Line-of-Sight from Facility)

28. NTIA Report TR-10-466 at Figures A-10, A-18, and A-22.

29. The non-line of sight condition occurs as a result of terrain and building blockage.

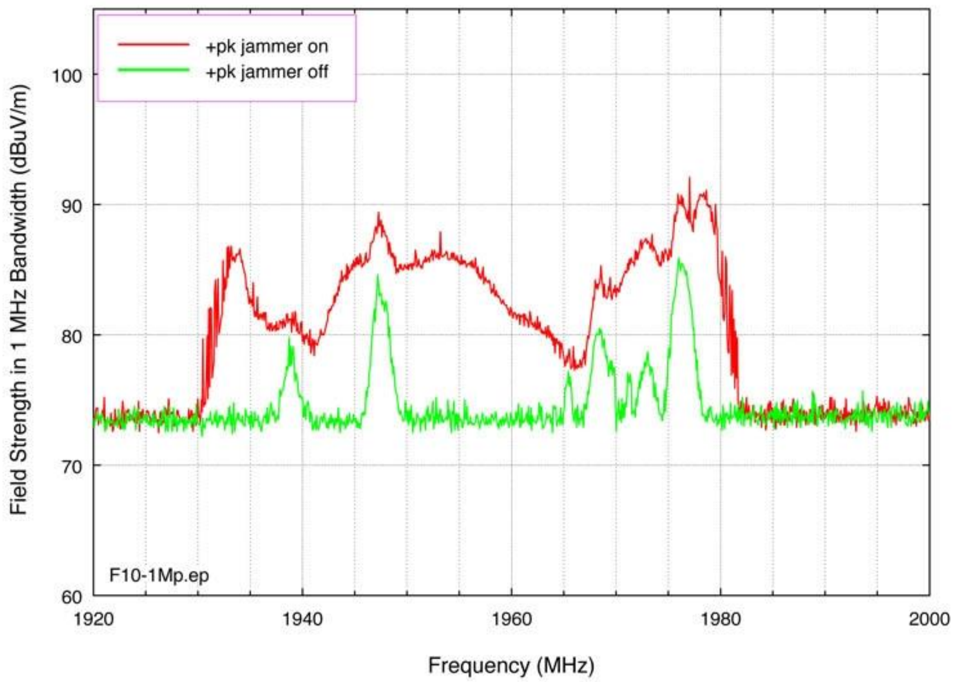

Figure 3-8. Field Strength Measurements in PCS Band (131 Meters Line-of-Sight from Facility)

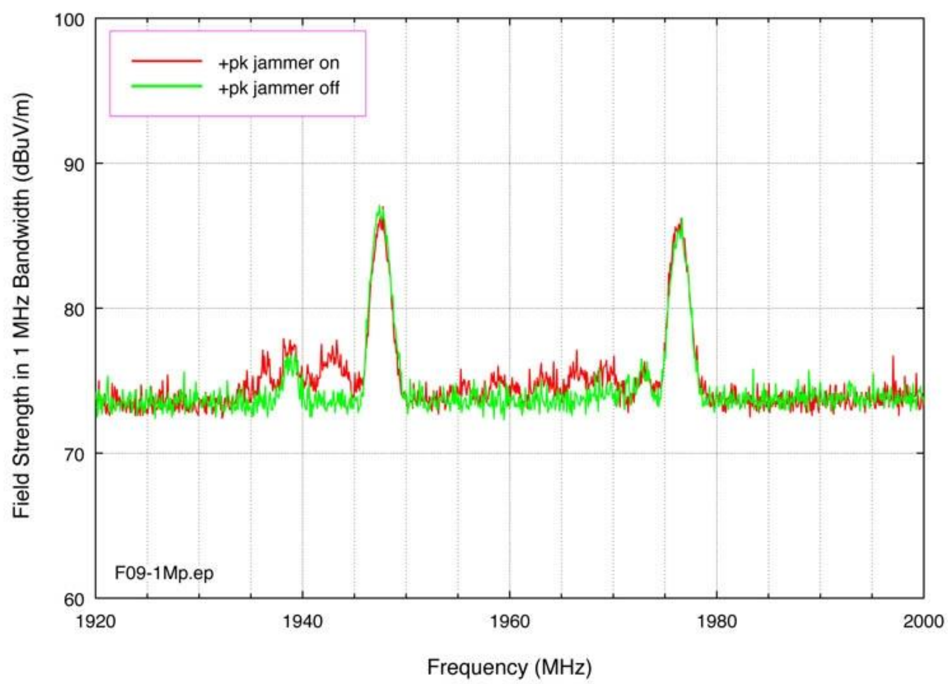

Figure 3-9. Field Strength Measurements in PCS Band (74 Meters Non-Line-of-Sight from Facility)

SECTION 4.0
SUMMARY

4.1 INTRODUCTION

This section provides a summary of the issues related to the potential interference impact of a specific Cellular and PCS jammer transmitter on selected out-of-band and in-band receivers.

4.2 ASSESSMENT OF OUT-OF-BAND RECEIVERS

A summary of the required separation distances for LMR and GPS receivers based on the laboratory measurements performed by NTIA to characterize the emissions of a specific Cellular and PCS jammer transmitter is provided in Table 4-1.

Table 4-1.

Receive Frequency Band	Receiver Type	Jamming Frequency Range	Jammer Output Power	Bands Jammed	Diplexer	Required Separation Distance
162-174 MHz	LMR Mobile	Full Band	Maximum	Both	No	10 m
406.1-420 MHz	LMR Mobile	Full Band	Maximum	Both	No	2 m
162-174 MHz	LMR Base	Full Band	Maximum	Both	No	16 m
406.1-420 MHz	LMR Base	Full Band	Maximum	Both	No	4 m
162-174 MHz	LMR Mobile	Full Band	Maximum	Both	Yes	1 m
406.1-420 MHz	LMR Mobile	Full Band	Maximum	Both	Yes	1 m
162-174 MHz	LMR Base	Full Band	Maximum	Both	Yes	2 m
406.1-420 MHz	LMR Base	Full Band	Maximum	Both	Yes	1.6 m
1559-1610 MHz 1215-1240 MHz 1164-1188 MHz	GPS L1 GPS L2 GPS L5	Full Band	Maximum	Both	No	240 m 308 m 321 m
1559-1610 MHz 1215-1240 MHz 1164-1188 MHz	GPS L1 GPS L2 GPS L5	Full Band	Maximum	Both	Yes	<1 m

As shown in Table 4-1, when operating at full power and jamming in the Cellular and PCS bands, the tested jammer transmitter could cause some impact to Federal LMR receivers at the prison and GPS use in and around the prison facility. However, the use of the diplexer or appropriate filtering can decrease the potential interference and reduce the required distance separations to such small values as to be negligible.

The field measurements in the Federal LMR and GPS frequency bands are consistent with the laboratory measurements, indicating there are no detectable emissions from the jammer transmitter.

The laboratory measurements only examined one type of jammer transmitter, thus the results of the measurements and analysis cannot be broadly applied to all jammer transmitters. Moreover, because of the limited deployment of the jammer transmitter at the Federal facility it is not possible to draw any conclusions from the field measurements assessing the potential of aggregate interference to out-of-band receivers if multiple jammer transmitters were operated throughout the facility. The results of the field measurement are idiosyncratic to this particular jammer installation and facility. Variations in jammer characteristics, structural characteristics of buildings, and propagation factors will produce different results for different installations at different facilities.

4.3 ASSESSMENT OF IN-BAND RECEIVERS

In order to assess potential interference to in-band receivers (e.g., establish distance from a facility where communication is not disrupted) IPC values for Cellular and PCS handsets are required.

The field measurements only examined one type of jammer transmitter, thus the results of the measurements and analysis cannot be broadly applied to all jammer transmitters. For example, the measurements did not examine the in-band emission levels outside targeted jamming areas that would result from jamming inside different building structures or jamming inside larger building interiors. Due to the limited deployment of the jammer transmitter at the Federal facility, NTIA cannot draw conclusions from the field measurements assessing the potential of aggregate interference to in-band receivers if multiple jammer transmitters were operated throughout the facility.

Variations in jammer configurations, effects of multiple jamming transmitters, structural characteristics of buildings, and propagation factors will be different depending on the installation and the facility making it difficult to develop analytical techniques to assess potential interference to in-band receivers without using very conservative assumptions. Given all of the possible variations in a jammer system installation and assuming IPC values are developed for Cellular and PCS handset receivers, on-site measurements to characterize the signal levels outside of each proposed facility are necessary before conclusions can be reached regarding compatibility with wireless services.

As shown in the NTIA field measurement report, inside the facility the signal levels of the jammer transmitter can be accurately measured. Outside of the facility, variations in the measured levels of the jammer transmitter signal may make it difficult to distinguish it from the Cellular and PCS signals in the environment. The variations in the measured jammer transmitter signal levels are likely due to propagation effects and building attenuation losses that will be different at each facility and for each jammer installation.

Depending on the relative signals levels, it may be difficult to differentiate between the measured jammer transmitter signal and the ambient Cellular and PCS signals. This problem will be exacerbated in areas where there is a high density of Cellular and PCS signals. Given the variations in the measured signal level and the inability to distinguish the jammer signal from the environmental Cellular and PCS signals under conditions that cannot be controlled (e.g., turning off Cellular and PCS signals) it may be difficult to accurately measure the jammer transmitter signal levels outside of the facility.