Measurements to Characterize Land Mobile Channel Occupancy for Federal Bands 162–174 MHz and 406–420 MHz in the Washington, D.C., Area

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This report describes field measurements to characterize Land Mobile Radio (LMR) channel occupancy of Federal bands 162–174 MHz and 406–420 MHz at a single central location in the Washington, D.C., area. This is part of the National Telecommunications and Information Administration effort to evaluate the spectrum efficiency in the Federal frequency bands. Measurements of the received signal levels in LMR frequency bands 162–174 MHz and 406–420 MHz were performed over an eight day period for the purpose of determining channel usage within the measurement system's coverage area of approximately 100-km radius for base stations, 50-km radius for mobile units, and 25-km radius for portable units. The measurements were made using new equipment and techniques that digitize as much as a 5-MHz segment of spectrum and process it to obtain simultaneous signal levels of up to 400 individual LMR channels. These techniques provided faster measurements, but also allowed enhanced post-processing of the data to remove effects of impulsive noise.

Key words: channel occupancy; channel usage; Federal radio usage; Land Mobile Radio (LMR); measurements; spectrum efficiency

1 INTRODUCTION

In May 2003, President Bush established the Spectrum Policy Initiative to promote the development and implementation of a United States spectrum policy for the 21st century. In response to the Spectrum Policy Initiative, the Secretary of Commerce established a Federal Government Spectrum Task Force and initiated a series of public meetings to address policies affecting spectrum use by the Federal, state, and local governments, and the private sector. The recommendations resulting from these activities were included in two reports released by the Secretary of Commerce in June 2004. Based on the recommendations contained in these reports, the President directed the Federal Agencies on November 30, 2004, to plan the implementation of the 24 recommendations contained in the reports. One of the recommendations directed the National Telecommunications and Information Administration (NTIA) to develop analytic approaches, software tools, and engineering techniques for evaluating and improving the efficiency and effectiveness of Federal spectrum use.

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As discussed in the Spectrum Policy Initiative reports, the radio frequency spectrum is a critical resource that is used by the Federal Government to perform congressionally mandated missions. Efficient use of the spectrum is one of the cornerstones for obtaining maximum usage of the available spectrum. NTIA and the other Federal Agencies realize that the primary way to satisfy the growing demands for spectrum in the Land Mobile Radio (LMR) frequency bands is to employ more spectrum efficient technologies.

As part of the effort to meet these objectives, NTIA performed a study that created a database of frequency assignments from the Government Master File (GMF) in the 162–174 MHz band within a 100-mile radius of Washington, D.C. The Washington, D.C., metropolitan area was selected because it is believed to be representative of a spectrally congested environment. Licensed data from Federal Agency radio systems and agency interviews were used to understand the services provided by Federal radio systems in this frequency band, including the coverage areas and other aspects of each radio system. This information was used to produce "signal capacity" maps that showed the cumulative coverage areas of all Federal radios in this band, including the number of simultaneous messages that could be carried at various locations within 100 miles of Washington, D.C. Results of this work were compiled in a report titled "Federal Land Mobile Operations in the 162-174 MHz Band in the Washington, D.C., Area" [2].

NTIA's Institute for Telecommunication Sciences (ITS) then undertook a series of channel occupancy and usage measurements in Washington, D.C., in the LMR bands of 162–174 and 406–420 MHz, the results of which are described in this report. The results of these channel occupancy measurements can further be used to specify the overall performance objectives of LMR systems employing different technologies (e.g., trunking).

1.2 Objective

There were two objectives for this project. The first objective was to monitor each assignable 12.5- and 25-kHz channel in the 162–174 MHz and 406–420 MHz bands in the Washington, D.C., area to determine the amount of time those channels contained power above specific thresholds, and to present statistical analysis of channel occupancy based on number of occurrences exceeding the threshold. The second objective was to develop channel occupancy and usage measurement techniques for LMR bands using the latest in technology.

1.3 Approach

Using the Radio Spectrum Measurement Science 4th generation measurement system (RSMS-4), the measurements were performed during the course of eight consecutive days, including the Presidential Election Day (October 26 to November 3, 2004). The measurement system was designed for a receiver coverage of approximately 100-km radius for base stations and repeaters, 50-km radius for mobile units, and 25-km radius for portable units.[2] Data were acquired continuously, 24 hours per day, over the course of the eight-day period and then analyzed for Federal bands 162–174 MHz and 406–420 MHz to furnish channel loading statistics.

The measurements were made using new equipment and techniques that digitize as much as a 5-MHz segment of spectrum and process it to obtain simultaneous signal levels of up to 400 individual LMR channels. These techniques provided faster measurements, but also allowed enhanced post-processing of the data to remove effects of impulsive noise.

In this report, channels are considered to be occupied (i.e., in use) whenever the channel contains Radio Frequency (RF) power above a certain received threshold level. The measurements were made and recorded so that variable threshold levels could be used for purposes of analyzing the effects of external noise and other factors. This definition of occupancy is generally consistent with other definitions of usage, although the choice of received power detection threshold levels is not necessarily uniform among researchers. By some definitions a channel may be considered "in use" even if no traffic is being carried during the time of measurement. For instance, a channel being used by a Secret Service agent protecting the President may not carry traffic (not occupied) unless there is an emergency. However, the channel is "in use" in the sense that personnel are monitoring the channel and ready to take action should a situation require it. In this report, "usage" is used interchangeably with the term "occupancy," which means carrying traffic – not simply being monitored.

[2] Typical reuse distances for base stations and repeaters is approximately 100 km.

2 LMR SIGNAL CHARACTERISTICS AND EMISSION ENVIRONMENT

This section provides an overview of the LMR signal characteristics and the other emissions in the RF environment that were a factor in determining the parameters of the system for measuring the 162–174 MHz and 406–420 MHz frequency bands. The two LMR signal characteristics that determine measurement parameters are: channelization (how the frequencies are assigned in each band), and adjacent channel power ratio (how much a signal must be attenuated at the adjacent channel). The former determines preselector filter characteristics, center frequency assignments, the degree of decimation of digitized data, and the manner in which frequencies are grouped for acquisition. The latter determines the windowing requirements and data acquisition length (which ultimately determine the resolution of individual LMR signals that can be measured). The other environmental emission factors that must be considered in determining the measurement system parameters, include the range of in-band signal levels, out-of-band signal levels, and the nature of RF noise.

2.1 Channelization

Table 1 summarizes the center frequencies of possible channel assignment in the 162–174 MHz and 406–420 MHz bands. While frequencies in these bands were originally assigned using a 25-kHz channel spacing scheme (referred to in this report as "the old 25-kHz channels"), frequencies assigned in these bands are now required to use a 12.5-kHz channel spacing (referred to in this report as "the new 12.5-kHz channels"). To do so requires that the emission bandwidth of any existing LMR systems be reduced to half the original bandwidth so that the new 12.5-kHz channels can be inserted between the original channels, spaced 25 kHz apart. In the 406–420 MHz band, the center frequencies of the old 25-kHz channels are assigned according to the following equation:

$$(406.125 \text{ MHz}) + (N \times .025), \text{ where } N = 0 \text{ to } 554.$$

The new 12.5-kHz channelization scheme adds channels midway between the old 25-kHz channels so that these channels occur at:

$$(406.1125 \text{ MHz}) + (N \times .025), \text{ where } N = 0 \text{ to } 555.$$

In the 162–174 MHz band, the center frequencies of the old 25-kHz channels and the new 12.5-kHz channels are assigned according to the equations given in Table 2 and Table 3 respectively [3].

Table 1. Center Frequencies for LMR Measurements

Frequency	Measurement Center Frequencies
162–174 MHz	Multiples of 12.5 kHz starting at 162.0125 MHz
406–420 MHz	Multiples of 12.5 kHz starting at 406.1125 MHz

Table 2. Old 25-kHz Channel Assignments in the 162–174 MHz Band

162.025 MHz + N x 0.025, where N = 0–22
162.6125 MHz + N x 0.025, where N = 0–7
162.825 MHz + N x 0.025, where N = 0–22
163.4125 MHz + N x 0.025, where N = 0–7
163.625 MHz + N x 0.025, where N = 0–6
163.8125 MHz + N x 0.025, where N = 0–7
164.05 MHz + N x 0.025, where N = 0–31
164.8625 MHz + N x 0.025, where N = 0–37
165.825 MHz + N x 0.025, where N = 0–23
166.4375 MHz + N x 0.025, where N = 0–8
166.675 MHz + N x 0.025, where N = 0–20
167.2125 MHz + N x 0.025, where N = 0–23
167.825 MHz + N x 0.025, where N = 0–135
171.2375 MHz + N x 0.025, where N = 0–6
171.425 MHz + N x 0.025, where N = 0–70
173.4125 MHz + N x 0.025, where N = 0–23

Table 3. New 12.5-kHz Channel Assignments in the 162–174 MHz Band

162.0125 MHz + N x 0.025, where N = 0–23
162.6 MHz + N x 0.025, where N = 0–7
162.8375 MHz + N x 0.025, where N = 0–22
163.425 MHz + N x 0.025, where N = 0–7
163.6125 MHz + N x 0.025, where N = 0–7
163.825 MHz + N x 0.025, where N = 0–6
164.0375 MHz + N x 0.025, where N = 0–32
164.85 MHz + N x 0.025, where N = 0–37
165.8375 MHz + N x 0.025, where N = 0–23
166.45 MHz + N x 0.025, where N = 0–7
166.6625 MHz + N x 0.025, where N = 0–21
167.225 MHz + N x 0.025, where N = 0–22
167.8375 MHz + N x 0.025, where N = 0–135
171.25 MHz + N x 0.025, where N = 0–5
171.4125 MHz + N x 0.025, where N = 0–71
173.425 MHz + N x 0.025, where N = 0–22

2.2 Adjacent Channel Power Ratio

Adjacent channel power ratio (ACPR) is the ratio in decibels (dB) between the total transmitter power that lies within its authorized channel bandwidth and the part of the output power that falls within the bandwidth centered around the frequency assignment of the adjacent channel (expressed in units of dBc). Chapter 5 of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management specify the ACPR standards for Federal LMR systems in the 162–174 MHz and 406–420 MHz bands [4]. The ACPR standards are specified for analog and digital wideband (25 kHz channels) and narrowband (12.5 kHz channels) operations as shown in Table 4. The NTIA ACPR standards are consistent with those specified by the Telecommunications Industry Association for analog [5] and digital [6] LMR systems.

Table 4. Minimum ACPR Requirements for Analog and Digital Federal LMR Systems

	Channel Spacing	
Frequency Range	Wideband Operation	Narrowband Operation
162–174 MHz	50 dBc	70 dBc
406–420 MHz	70 dBc	70 dBc

2.3 Emission Environment

Factors associated with the RF emission environment must also be taken into consideration in determining the parameters for the measurement system. These factors include range of in-band signal levels, out-of-band signal characteristics, and the nature of RF noise. Because LMR systems by their very nature are mobile, the signal power received at the measurement system can be time varying and span a range as great as 100 dB in received power – the weakest signals coming from distant transmissions and the stronger signals coming from nearby base stations and local mobile and hand-held units that approach the measurement system. Not only can a single frequency assignment vary greatly in power from time to time, but power can vary greatly between adjacent frequencies. Because of this broad range of received signal powers, depending upon the degree of sensitivity of the measurement system, the system must have a wide instantaneous dynamic range (i.e., be able to resolve the individual signals without varying the sensitivity of the measurement system across the band of acquisition).

To prevent overload of the measurement system front-end amplifiers, out-of-band emissions must be attenuated through proper filtering. The most significant out-of-band emissions that affect the measurement system requirements are those due to TV station channel 7; this channel occupies the spectrum between 174 and 180 MHz. This is a very strong signal, and not only can it saturate the front-end amplifiers of a sensitive system, but it also has strong enough adjacent channel emissions within the 162–174 MHz LMR band to be detected significantly above the noise floor of the measurement system (10 dB or more depending upon the measurement system noise figure).

The other factor in the emission environment that has to be addressed is RF noise. Preliminary investigation shows that in the spectrum region of interest, the mean of the Gaussian RF background noise power usually lies well enough below the measurement system noise power so as not to be detected. However, impulsive noise can occur well above the measurement system noise, and therefore techniques have to be employed to differentiate this emission source from the LMR signals.