1755-1850 MHz
COMPARABLE BAND ASSESSMENT

July 28, 2011

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Executive Summary

The Department of Homeland Security (DHS) remains committed to supporting the President's Spectrum Initiative and submits this band exit evaluation to the National Telecommunications and Information Administration's (NTIA) Policy and Planning Spectrum Committee (PPSG). The evaluation is the result of DHS working closely with the NTIA and other Federal agencies to assess the potential for releasing spectrum in the 1755-1850 MHz band and the potential for relocating operations to alternate spectrum bands. The Department conducted a thorough review of the proposed bands and operations in evaluating possible approaches to exiting the 1755-1850 MHz band. The result is an exit strategy that utilizes spectrum in alternate bands (L, S, and C bands) and more spectrally efficient digital technologies in a phased exit approach.

The Department's phased approach would provide the 1755-1780 MHz spectrum to commercial entities within five years of funding and would provide a pathway for relocating the remaining nationwide operations to other frequency bands. Adopting the Department's approach would allow NTIA to meet the objective of vacating the 1755-1780 MHz band within the 5 years and provide a clear pathway for vacating additional spectrum in the 1780-1850 MHz band.
This strategy provides a pathway for DHS to mitigate operations and provides spectrum in support of the President's Spectrum Initiative. DHS anticipates this strategy will be executed in phases over the 10 + year timeframe at a total cost of approximately $1.67 billion.

The Department's plan utilizes spectrum currently assigned in the 2200-2290 MHz, 4400-4940 MHz, and 1785-1805 MHz band with augmentation of spectrum in the 1675-1695 MHz band. While the current operations in the 1755-1850 MHz band support multiple operational needs, future operations will be transitioned based on operational and physical requirements. Operations requiring deep building penetration will be shifted to the 1675-1695 MHz and 1785-1805 MHz bands. Operations with less stringent building penetration requirements will be shifted to the 2200-2290 MHz and the 4400-4940 MHz band.

This evaluation has multiple assumptions, including timely availability of funding, necessary technology improvements to reduce the spectrum requirements, continuing improvements in miniaturization of devices, updating of policy and rulemaking as necessary, and coordinating of spectrum across the federal users. It is the intent of DHS to initiate the detailed plan for exit of the 1755-1850 MHz band upon approval of the plan by the PPSG and to continue working closely with the other federal agencies, e.g. DOJ, NTIA, to ensure the relocation is completed with minimal impact to operations, within budget, and on schedule.

Relocation Strategy

The Department's strategy to exit the 1755-1850 MHz band utilizes both an operational view of spectrum use and the use of spectrally efficient technologies in a phased approach. The Department's strategy utilizes spectrum currently assigned in the 2200-2290 MHz, 4400-4940 MHz, and 1785-1805 MHz band with augmentation of spectrum in the 1675-1695 MHz band. While the current operations in the 1755-1850 MHz band support multiple operational needs, the transition strategy is based on relocating operations based on operational and physical requirements. Operations requiring deep building penetration will be relocated to spectrum favorable to building penetration, e.g. 1675-1695 MHz and 1785-1805 MHz bands, and operations with less stringent building penetration requirements shifted to the 2200-2290 MHz and the 4400-4940 MHz band. The strategy of relocating to multiple bands aligns with operational needs and affords the opportunity to mitigate risks associated with relocating to a single candidate band. In addition, the strategy relies on the deployment of spectrally efficient digital technologies to fit operations within reduced spectrum. The digital technologies provide a reduced spectral footprint and thus increase the number of potential channels for operational support, mitigating some of the impacts to operations with the proposed exit and relocation of operations.

The strategy takes into account the large number of devices currently deployed across the nation and is based on a phased approach to exiting the spectrum and relocating operations. The phased approach minimizes impacts to on-going operations through alignment of redeployments with product life cycles and reduces risk through alignment of device procurement with vendor development plans. The strategy also provides the 1755-1780 MHz spectrum to commercial entities within five years of funding and would make available additional spectrum in the 1805-1850 MHz range over the 10 year window.

Plan to exit the 1755-1850 MHz band within 10 years

Overview

The Department considered multiple options to exit the 1755-1850 MHz band and views a phased plan to be a cost effective and timely approach to exiting the band while minimizing impacts to critical ongoing operations. This phased plan would primarily employ equipment based on digital modulation technologies and overlay onto operations in bands outside the 1755-1850 MHz band. Currently, deployed systems employ analog based video and audio transmissions with required bandwidths up to 20 MHz and at transmitter power levels up to 5 watts. COFDM (Coded Orthogonal Frequency Division Modulation) digital video systems provide improved narrowband operation and improved interference rejection and offer the potential for additional improvements in spectral efficiency through advanced video coding techniques. The COFDM technologies provide improvement out-of-band rejection compared to analog technologies with manufacturers indicating the CODFM devices requiring approximately 8 MHZ of bandwidth and operate at 1 watt or less. Detailed technical characteristics are provided in the attached appendices.

The plan is based on the use of spectrum currently assigned in the 2200-2290 MHz, 4400-4940 MHz, and 1785-1805 MHz band with augmentation of new channel assignments in the 1675-1695 MHz band. This approach will overlay operations from the 1755-1850 MHz band onto those in the 2200-2290, 4400-4940 MHz, and 1785-1805 MHz band. Current analog based channel assignments based on spectrally inefficient technologies will require replacement with channel assignments based on spectrally efficient digital technologies. Digital channel assignments are anticipated to be assigned on an 8 MHz channel spacing to maximize spectrum use. In addition, channel assignments should be standardized across the Federal law enforcement community and coordinated among agencies to maximize spectrum reuse and limit potential interference issues.

A successful exit will require the Department transition operations to alternate bands based on operation and physical requirements. Operations requiring deep building penetration will be shifted to the 1675-1695 MHz and 1785-1805 MHz bands, currently not standardized for commercial Long Term Evolution (LTE) operations (See Appendix C). While the available spectrum in the 1785-1805 MHz band is only 20 MHz and is less than the initial 30 MHz requested, it will provide operating spectrum that could be used as part of a total solution while allowing commercial entities to operate in bands defined in ETSI TS 136 101 V9.4.0 (2010-06). The Department currently has channel assignments in the 1785-1805 MHz band for analog video systems and can transition these assignments to lower power digital video device assignments. Operations with less stringent building penetration requirements can be shifted to the 2200-2290 MHz where the Department currently has analog based channel assignments and to the 4400-4940 MHz band where the Department has 6 US&P assignments for digital CODFM mesh technologies. Within the 2200-2290 MHz band, the Department currently utilizes eight 17 MHz bandwidth channels across the 2200-2290 MHz band to augment its operations in the 1755-1850 MHz band. The Department's plan will overlay operations currently in the 1755-1850 MHz band on to those in the 2200-2290 MHz band. The current channel assignments, based on analog devices, will be replaced with assignments based on digital COFDM modulation. The reassignment to digital assignments will result in 11 channel assignments in the 2200-2290 MHz spectrum currently occupied by the Department. These eleven channels, in addition to two in the 1785-1805 MHz band, two in the 1675-1795 MHz band, and the six in the 4400-4940Mz band, provide 21 channel assignments for overlaying current operations that exit the 1755-1850 MHz band's 29 channel assignments.

A basic view of DHS's spectrum exit is shown in the figure 1 below.

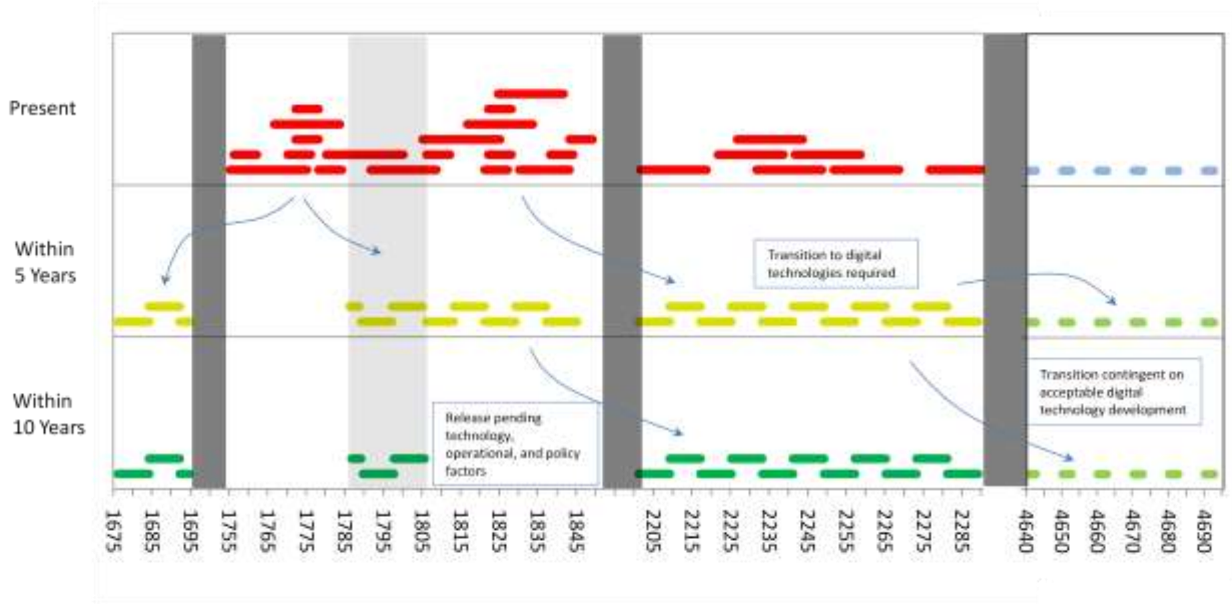

Figure 1 1755-1850 MHz Exit Approach

The Department operates thousands of devices deployed nation-wide and to minimize disruption to operations and secure a successful transition, the Department's plan is based on a phased approach with clear objectives for each phase. Below is a description of the phases for the spectrum exit approach:

Phase 0

This phase will occur prior to the auction of the 1755-1850 MHz spectrum in 2014 and will focus on developing detailed exit plans and evaluation and testing of devices to assure potential interference issues are minimized or mitigated prior to spectrum exit. During this phase the Department will continue to transition legacy analog equipment to digital equipment in support of the 2006 1710-1755 MHz transition[1] and prepare for the next phase of the 1755-1850 MHz exit.

Anticipated activities during this phase include:

- Evaluate and test devices for compatibility and interference limitation
  - Work with ITS Boulder, CO and other labs to verify calculated sharing limits
- Initiate equipment development in alternate bands to develop narrow band and other modulation devices in the 1675-1695 and possibly the 4400-4940 MHz band.
  - Work with the vendor community to develop first article devices based in Department requirements.
- Deploy a limited mesh network in the 4400-4940 MHz band as a next step to current pilot in DC area.
  - Expand to one or two major cities to develop expertise in technology, deployment, and procurement in preparation for transition of operations.

[1] This plan assumes that OMB provides requested funds in Q1 2012 to complete the Department's 1710-1755 MHz transition to digital technologies. Lack of funding at this time will have significant impacts to the plan schedule and costs.

- Limited reprogramming of equipment for test purposes to validate occupying the 1785-1805 MHz band.
- Detailed planning and procurement preparation.
    - Develop detailed project plan for full transition per DHS MD102 directive.

Phase 1

This phase focuses on exit of the 1755-1780 MHz band through reprogramming of existing digital equipment and/or purchase of digital equipment capable of operating in selected bands, e.g. 1675-1695 MHz, 2200-2290 MHz, and 4400-4940 MHz. Based on experience gained during the 1710-1755 MHz transition, the reprogramming and deployment of analog equipment is anticipated to be complete in 3 to 4 years from funding. In addition, the fixed microwave sites operating in the band would exit to higher frequency bands in the 7 GHz range.

Device development in anticipation of relocating operations from the 1805-1850 MHz band would commence with the focus being on devices that can operated in the 1675-1695 MHz band. In addition, development of devices/technologies/methods to address potential issues in the 2200-2290 MHz band and other higher frequency bands would be executed in anticipation of exiting the 1805-1850 MHz spectrum.

Phase 2

This phase will focus on exiting the 1805-1850 MHz band and has the greatest potential for significant operational impacts. During this phase operations will exit the 1805-1850 MHz band and evaluation of alternatives to vacate/share the 1785-1805 MHz band will continue. While it is anticipated that most of the operations would relocate to the 2200-2290 MHz, 1675-1695 MHz, and other bands e.g. 4400-4940 MHz bands unforeseen issues or opportunities may result in use of other bands or technologies. This phase is estimated to require 3 to 4 years following phase 1.

Phase 3

This phase focuses on exit the 1785-1805 MHz band to complete the L band exit. As with the earlier phase of this plan, devices and technologies to address the physical characteristics of the bands, e.g. range limits, building penetration, and the limited bandwidth, e.g. narrow-banding technologies, will need to be developed. This phase is estimated to require 2 years to complete and is contingent upon technologies being developed that would allow operations in the 1785-1805 MHz band to relocate and maintain mission capabilities.

While the Department will require time to develop detailed costing estimates during the planning phase of the exit, should the PPSG determine to exit the spectrum, the Department currently estimates funding requirements at approximately $1.662 billion over the life of the transition to fully vacate the 1755-1850 MHz band. Below and in the attached appendices are detailed estimates.

Cost and Timeline Estimates

DHS detailed costing estimates are below and include pre-auction cost estimates for planning, research & development, testing, and evaluation of technologies as well as evaluation of potential interference with incumbents in the replacement bands. Costs include device developments leading to deployment of new systems and technologies in the 1675-1695 MHz band and other possible bands. Phase 1 and 2 costs include new replacement technologies that

are anticipated to take several years to develop and validate but provide the potential for improved spectral efficiency. Figure 2 provides cost estimate for each phase and Figure 3 provides an annual cost for the project. These estimates should be considered as “rough order of magnitude” (ROM) estimates and subject to change during the planning phase.
(See appendix A for a detailed breakdown of the ROM estimate.)

	Phase 0	Phase I	Phase II	Phase III
Costs	$ 28,837,179	$ 535,191,157	$ 1,005,794,636	$ 92,698,264
Timeframe	2012-2014	2014-2017	2018-2020	2021-2022

Figure 2 Estimated Cost and Timeframes per project Phase

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Outlays per year	$ 4,456,802	$ 6,162,242	$ 88,330,800	$96,950,374	$ 182,543,901	$ 185,584,215	$ 343,755,168	$ 335,876,235	$ 326,163,233	$ 52,835,005	$ 39,863,260	$1,682,521,236

Figure 3 Estimated Annual Outlays

Assumptions

This plan is based on many technical, operational, and logistic assumptions. Key assumptions are:

- The Department is provided funded in Q1 FY2012 to secured digital COFDM equipment to complete its plan to migration operations from the 1710-1755 MHz band and to regain capabilities lost in the transition through the use of digital technologies and the retirement and disposal of deployed analog devices.
- Phase 0 funds are provided for technological development of capabilities necessary to relocate into alternative frequency bands with the potential to share development costs across the federal law enforcement community.
- Channel assignments for digital video specific channels in the 1675-1695 MHz, 1755-1850 MHz, and 2200-2290 MHz band are granted and will diminish potential interference issues.
- Channel assignments are coordinated across the Federal law enforcement community to diminish the potential for interference with a Federal-wide band plan developed.
- The necessary development of technologies and devices to support of overall surveillance operation relocation will progress to align with transition schedule needs.
- Regulatory criteria will support relocated operations in the alternate bands.
- Regulatory, policy, and legislative change will be made to ensure adequate priority for surveillance operations in the selected bands.
- Incumbents will support interference testing to determine feasibility of co-existence and necessary equipment alterations
- Incumbents will support the relocation plan and equipment deployment as necessary to address interference issues.

Descriptions of required actions

The Department considers several actions key to the successful exit of the 1755-1850 MHz band:

- The Office of Management and Budget (OMB) provides funds for the second and final phase of the Department's 1710-1755 MHz transition plan by no later than Q1 FY2012.
- NTIA will expedite and support the assignment of digital channels in the 1675-1695 MHz, 1780-1850 MHz, and 2200-2290 MHz band.
- Federal law enforcement users and incumbents provide devices for testing in controlled environments as well as real life conditions to evaluate the affects these operations and to augment current technical analysis.
- Other federal agencies will support coordination of channel assignments in the current band and potential alternate bands.

Federal agencies will continue to coordinate technical requirements and collaborate on investments and R&D efforts to obtain the best value for the provided funds and to share research, testing, and deployment knowledge.

Potential Risks and Risk mitigation

The risks associated with this plan are centered on three key areas:

- RF interference as agencies migrated to selected bands and operations are consolidated into reduced available spectrum
- The maturing of digital technologies necessary for a successful exit of the band
- The significant level of nation-wide deployed equipment that must be replaced while maintaining critical mission support.

As federal operations are consolidated into reduced available spectrum, the potential for interference among the systems is increased. To mitigate this risk, the Department's plan includes:

- Migrating to spectrum currently authorized and used by the Department and other Federal law enforcement agencies for analog video surveillance operations. The use of established spectrum should reduced the level of new interference issues and provided for rapidly addressing any interference issue through previous experience in addressing interference in the band
- Re-channelization of the spectrum to completely replace spectrally inefficient analog high power video systems with spectrally efficient digital lower power video systems.
- Continue to program devices and to utilize multiple channels across the band on a case by case basis so that localized interference may be addressed
- Migrate to multiple bands based on operational needs thus dispersing operations across the spectrum and reducing congestion in any one specific frequency band.

Digital technologies, while currently deployed, are maturing to include increased capabilities and improved performance levels to address some of the current technical limitations, e.g. current consumption, heat generation, physical size, etc. To mitigate the risk associated with the level of technology maturity, the Department's plan includes:

- Follow a phased approach that links the available technology to operational needs and secures and deploys equipment as it becomes available in the marketplace.

- Establish and manage a GWAC equipment contract vehicle for video surveillance devices to ensure the Federal law enforcement agencies have access to equipment and technology in a timely manner. This will encourage the use of common equipment across the government and provide rapid access to technology.
- Test and evaluate equipment prior to and during the transition, providing a mechanism to validate equipment performance and provided feedback to the equipment community for further enhancements.

To mitigate the risk associated with replacing the equipment deployed nationwide while maintaining critical mission support, the Department's plan includes:

- Transition operations over several years minimize the impacts to operations
- Aligning equipment replacement with product life cycles where possible, minimizing disruption to operations through alignment with equipment replacement cycles.

Current Operations in the 1755-1850 MHz Band

Overview

In 2007, DHS relocated its 1710-1755 MHz Federal law enforcement operations that support criminal investigations and protective details to the 1755-1850 MHz band, resulting in DHS having extensive and overlapping operations in the 1755-1850 MHz band. The Department is currently migrating operations to more spectral efficient digital technologies and must complete this migration to address the crowding.

The Department uses the band to support two distinct types of systems. The first system is a nationwide system of portable and mobile video surveillance devices supporting Federal law enforcement investigations and protection details. The second system provides microwave data link connecting remote offices. Below is a summary of the Operational and Technical characteristics of the systems.

Video Surveillance

The Department operated a video surveillance system comprised of portable and mobile video devices for the collection of evidence and information during covert and overt law enforcement operations in support of criminal investigations and protection details. The system is supported through the nation-wide deployment of thousands of devices, e.g. RF receivers, transmitters and repeaters.[2] Currently the Department operates equipment based on legacy NTSC[3] "analog" standards as an interim step to a transition of operations to digital technologies. This continuation of analog operations was undertaken as an interim step in the Department's two phase approach to vacate spectrum in the 1710-1755 MHz band.[4]

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[2] Prior to 2007, the Department operated equipment across the 1710-1850 MHz band in support of its law enforcement mission. In 2007, the department identified more than 4000 portable mobile transmitter, receives and repeaters operating in the 1710-1755 MHz band that would have to be relocated to accommodate the transition. These devices were relocated and overlaid with operations in the 1755-1850 MHz band.

[3] National Television System Committee (NTSC) standard

[4] The initial phase of the Department's plan was to vacate spectrum in the 1710-1755 MHz band through relocating operations into the 1755-1850 MHz band through the use of legacy analog equipment until more spectrally efficient digital technologies were available.

Description of Operation

DHS operates two distinct types of systems in the 1755-1850 MHz band. The first system is a nationwide system of covert portable and mobile video surveillance devices that support Federal law enforcement investigations and protection details. The second type of system is a fixed site microwave data-link system for transmission of data to and from field offices.

Covert Video Surveillance System Operation

The system is used for investigating criminal activities, protection of executive staff, and support for joint operations during major national events. The system operates nationwide and is composed of multiple transmitters, receivers and ancillary devices that collect, transport, and store video and audio evidentiary and intelligence information. The nature of the operations requires that the devices be highly concealable, portable, and be capable of rapid deployment.

The covert video system's operation falls into two primary categories:

- **Indoor Operations.** This operation centers on collect audio and video evidence at various types of locations (e.g., hotel rooms, offices, automobiles) during lawfully authorized investigations. Because of the operational nature of the investigations, the equipment must be highly concealable, either on the body or within common room decorations. Further, the equipment must be designed to elude detection by both electronic and physical tools and methods so that neither the officer/agent nor the operation is jeopardized. In addition, the evidence collected must be protected from intercept during transmission to avoid exposing the operation, and it must be safeguarded during storage to conform to established evidentiary safeguarding guidelines.

  The operations are supported through the use of multiple pieces of equipment (e.g., small concealable video transmitters, portable/mobile receivers with recorders) that typically operate for short durations (usually 1-2 hours). The missions typically occur with little advance notice of the operation location, duration, or time of operation; therefore, the equipment must be highly mobile and rugged for rapid deployment.

  Operations typically require a single video transmitter statically RF linked to a single video receiver. The video transmitter consists of a small video camera, microphone, and radio frequency (RF) transmitter, each of which can be easily concealed. The transmitter's emissions are usually monitored and recorded by a receiver located nearby. The receiver usually consists of an RF receiver and video recorder that can be easily transported and installed in investigative equipment, such as surveillance vehicles. Current system transmitters, while capable of being programmed to operate on one of several channels, are simplex devices without capability to be reprogrammed during missions. This simplex operation is of concern to susceptibility to sporadic and unidentified interference at time of deployment.

- **Outdoor Operations.** This operation occurs in public areas and is focused on observation during major national events and during criminal investigations. The transmitting equipment must blend into the surroundings and must operate unattended for long periods of time while transmitting information to receivers at remote collection locations. Information collected must be protected from intercept or corruption.

> The operations are supported by multiple configurations of equipment (e.g., concealable video cameras and transmitters and portable/mobile receivers with recorders) that typically operate for long durations, usually weeks to months. The equipment operates at locations open to the environment; therefore, long-term exposure to the elements and limited access by law enforcement agents adds complexity to their design, operation, and maintenance. Transmitters are programmed in a similar manner to the indoor devices.

The covert video surveillance transmitters are typically low power (less than 1 watt) devices that are paired with nearby receivers that collect evidence and monitor activities for situational awareness. The transmitters are small, covert devices with Omni-directional antennas. The receivers are small portable devices with Omni-directional or low gain antennas.

Technical characteristics of systems

Systems currently operating employ analog based video and audio transmissions with required bandwidths up to 20 MHz and at transmitter power levels up to 5 watts. The move to more spectrally efficient technologies is a key component to the plan for exiting the 1755-1850 MHz band. The COFDM systems selected provide improved interference rejection and the potential to improve spectral efficiency through advanced video coding technologies. The COFDM technologies provide improvement out-of-band rejection compared to analog technologies with manufacturer data indicating the CODFM devices requiring approximately 8 MHZ of bandwidth and operating at 1 watt or less. Detailed technical characteristics are provided in the attached appendices.

For this evaluation the Department analyzed the effects of digital transmitters and receiver propagation on a frequency and physical distance basis for typical use scenarios. While an all encompassing set of use scenarios for the video surveillance operations would be extremely difficult to develop, a set of basic use cases were developed for analysis. The scenarios are: a medium power transmitter (500 mW) transmitting from a height of 2 meters to represent a body-worn device, a higher power transmitter (1 W) transmitting from a height of 10 meters to represent a semi-fixed video transmitter, and a 16 mW transmitter at a height of 20 meters to represent a 500 mW transmitter operating in a high-rise building and attenuated by the building. Each of these transmitter cases was then evaluated for physical and frequency separation based on an initial theoretical model, an urban model with building clutter, an urban model with only topographical parameters included, and finally a smooth earth model removing all clutter and topographical parameters. The propagation model employed for the theoretical work was based on earlier work with the NTIA during the 1710-1755 MHz transition. The other use cases were based on the Hertz warfare NTIA propagation model (derivative of the Longley-Rice model). Results of the analyses are included in the appendices.

Characteristics of System Frequency Use

As a result of the 1710-1755 MHz relocation, the Department utilizes 21 US&P overlapping channel assignments in the 1755-1850 MHz band to support its nationwide video surveillance operations. (See Table 1 and Figure 4) The assignments have channel bandwidths ranging from 6 MHz to 20 MHz with the majority of assignments being 6 MHz which is based on the occupied bandwidth of analog NTSC transmissions.

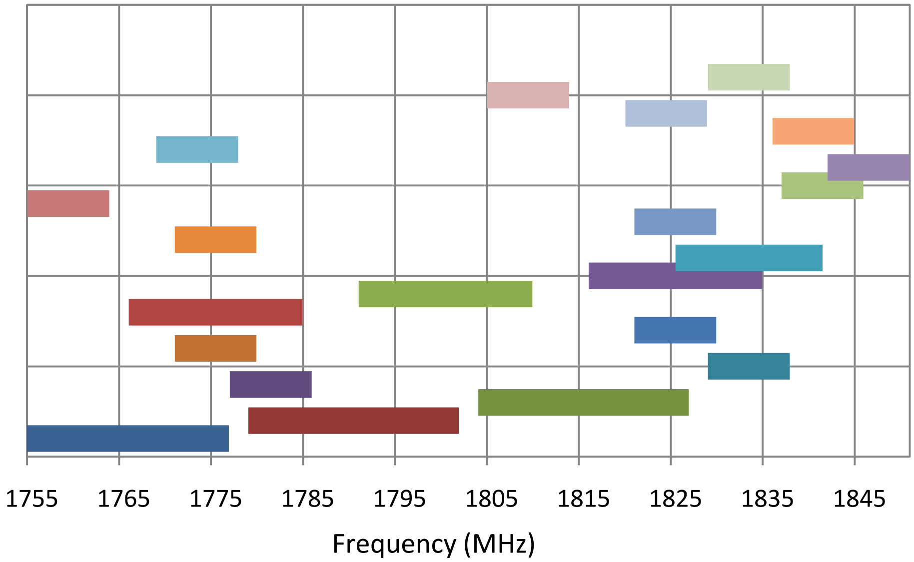


Figure 4 Current Analog based Channel Assignment

SERIAL NUMBER	FREQUENCY	POWER (WATTS)	EMISSION DESIGNATOR	SERIAL NUMBER	FREQUENCY	POWER (WATTS)	EMISSION DESIGNATOR
DHS 070303	1759	5.00	6M00C3F	DHS 070655	1824	5.00	6M00C3F
DHS 028258	1765	5.00	20M00F9W	DHS 038525	1825	5.00	6M00C3F
DHS 070652	1773	5.00	6M00C3F	DHS 038530	1825	2.00	17M00F9W
DHS 038524	1775	5.00	6M00C3F	DHS 038536	1825	1.00	6M00C3F
DHS 038528	1775	2.00	17M00F9W	DHS 035559	1833	5.00	6M00C3F
DHS 038535	1775	1.00	6M00C3F	DHS 038531	1833	2.00	17M00F9W
DHS 035558	1781	5.00	6M00C3F	DHS 070653	1840	5.00	6M00C3F
DHS 028259	1790	5.00	20M00F9W	DHS 070304	1841	5.00	6M00C3F
DHS 038529	1800	2.00	17M00F9W	DHS 070305	1846	5.00	6M00C3F
DHS 070657	1809	5.00	6M00C3F	DHS 033388	1833		6M00C3F
DHS 028260	1815	5.00	20M00F9W				

Table 1 1755-1850 MHz Channel Assignments

While the assignments currently support analog based video and audio transmissions, the bandwidths and assignments provide insufficient protection from interference.[5] The broad bandwidth of the analog devices will need to be replaced with more spectrally efficient devices to utilize the band and any alternate band. Channel assignment realignment will be needed to address the current overlapping assignments to efficiently use the 1755-1850 MHz spectrum during the exit. As part of the Department's 1710-1755 MHz transition plan, the move to more spectrally efficient technologies was seen as a key component to addressing potential interference and maintains current capabilities. The Federal law enforcement community

[5] In support of the 2007 exit from the 1710-1755 MHz, the NTIA, with support from DHS, DOJ, and commercial wireless carriers, conducted an evaluation of potential interference to analog video surveillance systems from commercial transmitters. The results of the evaluation were documented in the ASSESSMENT OF THE POTENTIAL INTERFERENCE FROM ADVANCED WIRELESS SERVICE HANDSETS TO VIDEO SURVEILLANCE SYSTEMS OPERATING IN THE 1710-1755 MHz BAND. The resulting recommendation was for commercial transmitters to limit operation to no closer than 15 MHz to DHS systems and no closer than 20 MHz to DOJ systems.

through the Technical Operations Working Group undertook the task of identifying more robust and spectrally efficient technologies. The result of this effort was the identification of the ETSI-based CODFM technology. The COFDM systems provide improved interference rejection and the potential to improve spectral efficiency through advanced video coding technologies. The COFDM technologies provide improvement out-of-band rejection compared to analog technologies. A key component to migrating operations will be the use of COFDM technologies to increase the efficiency of scarce spectrum. Figure 5 represents the current re-channelization plan for the 1755-1850 MHz band. The initial phase of the transition would focus on transitioning all analog based assignments to digital COFDM assignments, with assignments being made in only the 1795-1850 MHz band. At the completion of the exit of the 1755-1780 MHz band, the spectrum in the 1805-1850 MHz band would be transitioned to the 1785-1805 MHz band and other bands in the 2200-2290 MHz and the 1675-1695 MHz band.

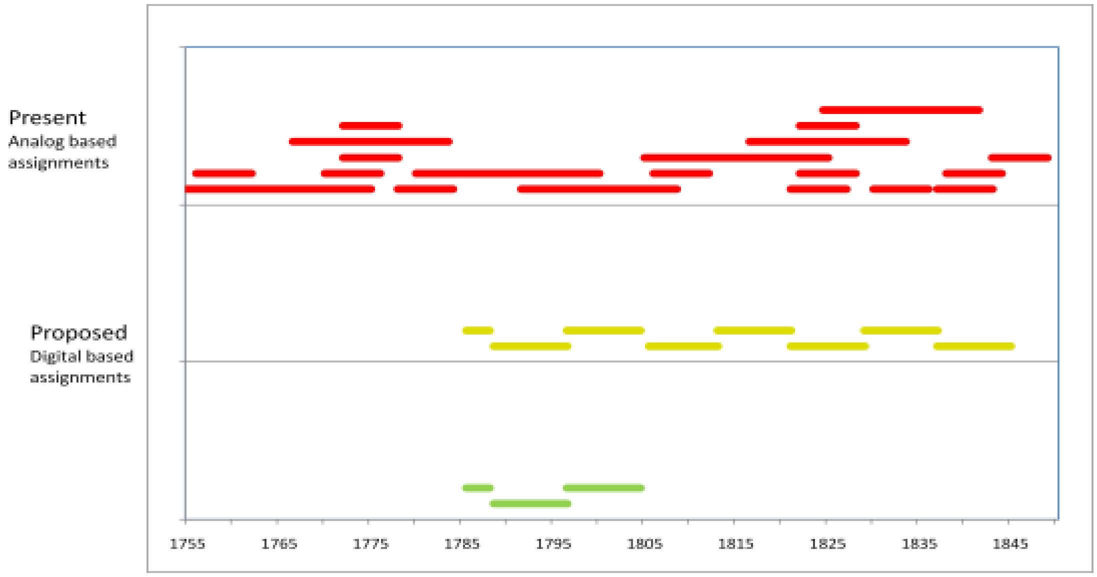


Figure 5 Migration to Digital Technology-based Channels

This transition is made possible as a result of improved spectral efficiency of the COFDM transmission compared to legacy NTSC based system. This improvement in the spectral mask points to the potential for improved channel separation as well as physical proximity. The Figures below present typical 8 MHZ COFDM transmitter spectral mask.

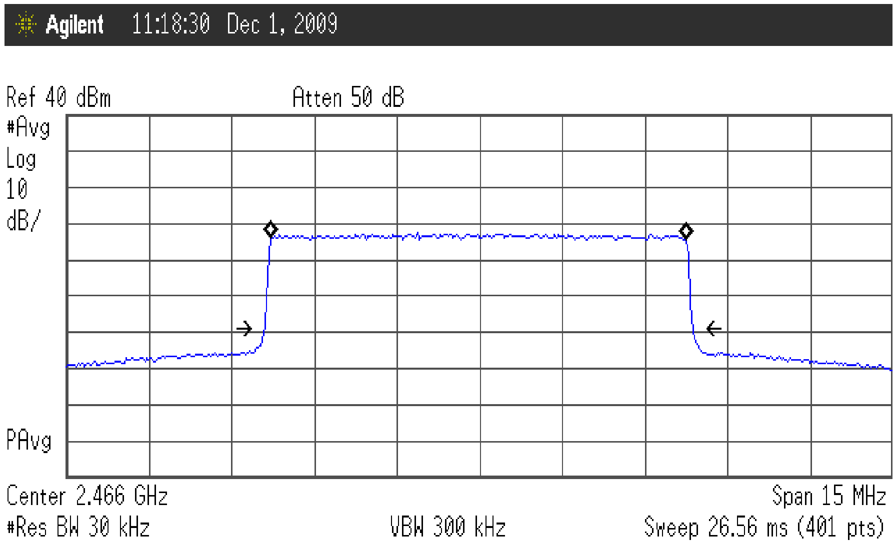


Figure 6 COFDM 8 MHz transmitter Spectrum

The Department analyzed the effects of digital transmitters and receiver propagation on a frequency and physical distance basis for typical use scenarios. While an all encompassing set of use scenarios for the video surveillance operations would be extremely difficult to develop, a set of basic use cases were developed for analysis. The scenarios are: a medium power transmitter (500 mW) transmitting from a height of 2 meters to represent a body-worn device, a higher power transmitter (1 W) transmitting from a height of 10 meters to represent a semi-fixed video transmitter, and a 16 mW transmitter at a height of 20 meters to represent a 500 mW transmitter operating in a high-rise building and attenuated by the building. Each of these transmitter cases was then evaluated for physical and frequency separation based on an initial theoretical model, an urban model with building clutter, an urban model with only topographical parameters included, and finally a smooth earth model removing all clutter and topographical parameters. The propagation model employed for the theoretical work was based on earlier work with the NTIA during the 1710-1755 MHz transition. The other use cases were based on the Hertz warfare NTIA propagation model (derivative of the Longley-Rice model).

Below are the results of the theoretical evaluation for the three transmitter scenarios.

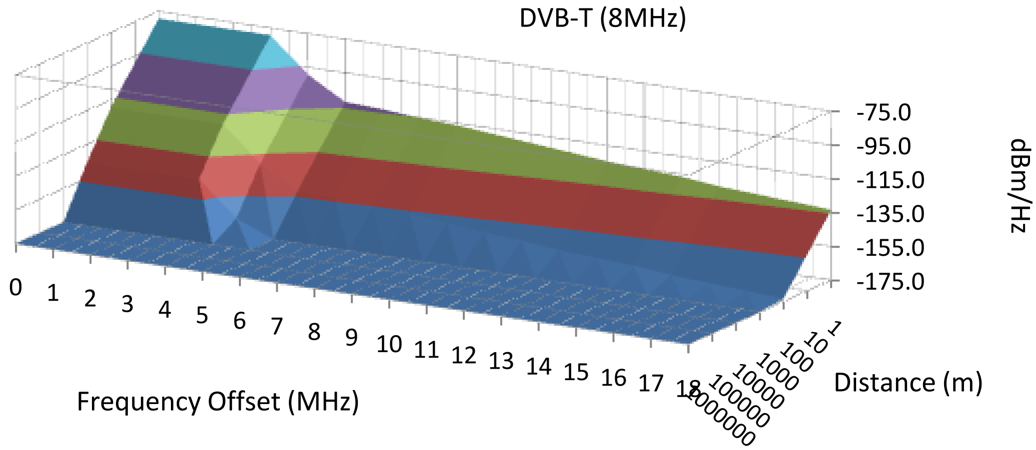


Figure 7 500 mW Transmitter at 2 meter Height

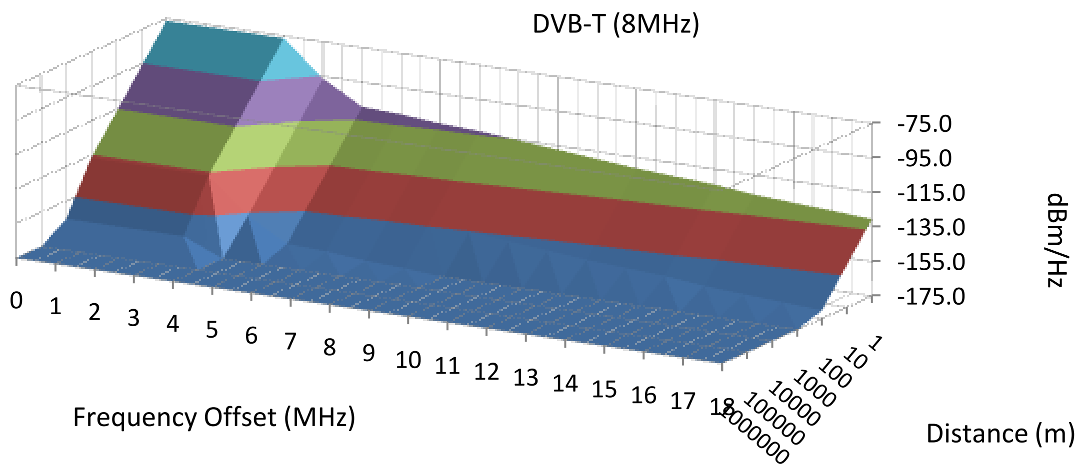


Figure 8 1 Watt Transmitter at 10 meter Height

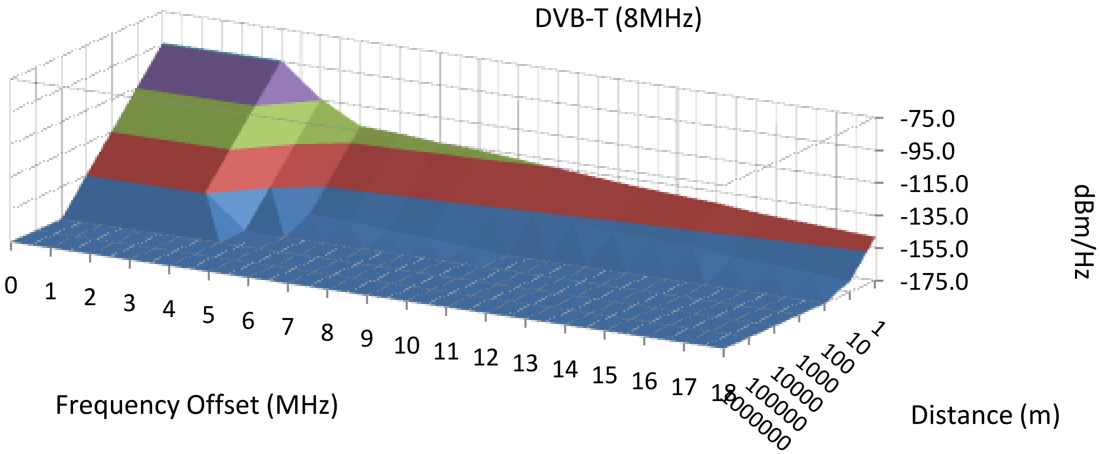


Figure 9 500 mW Transmitter attenuated by Building and at 20 meter Height

As can be seen from the figures above, the narrow band and low power nature of the transmitters limit the operational footprint both spectrally and physically. Channel reuse within 10 KM should be possible and operations with channel separation of 8 MHz operating within 1 KM may be possible.

Also, the transmitters were evaluated using Hertz Warfare for various scenarios indicating transmitter signals are limited to a 5 KM range for the test cases evaluated. See figures below.

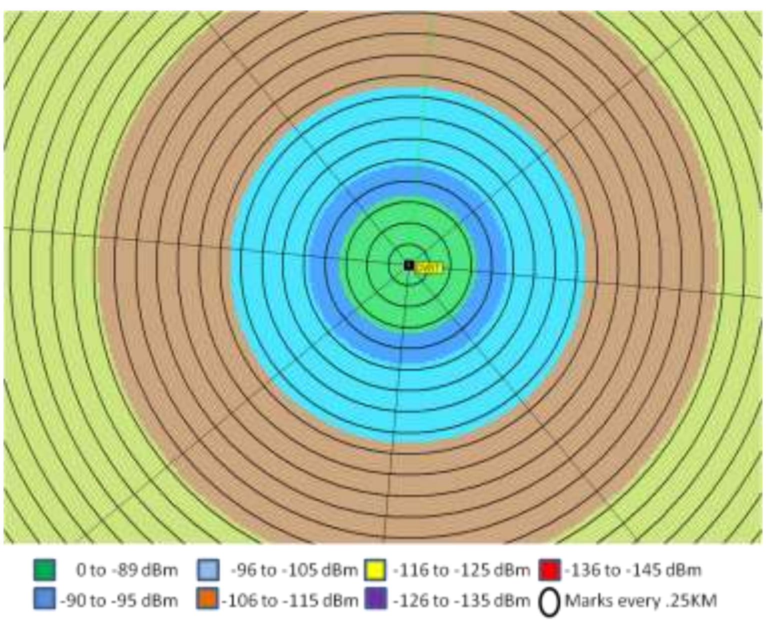


Figure 10 500 mW Transmitter at 2 meter Height on smooth earth in 8 MHz Bandwidth

(Note: Thermal Noise limitation equal to -105 dBm. TX equivalent signal level at approx. 2 KM from Transmitter)

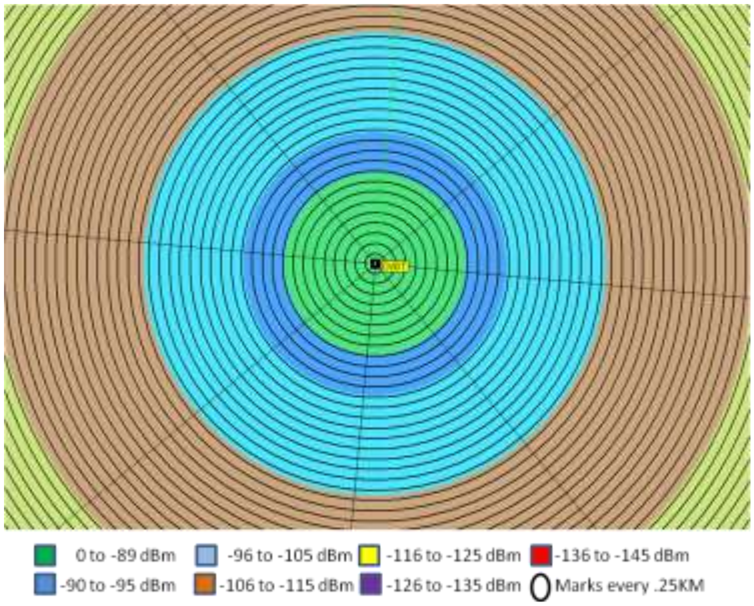


Figure 11 1 W Transmitter at 10 meter Height in 8 MHz Bandwidth

(Note: Thermal Noise limitation equal to -105 dBm. TX equivalent signal level at approx. 2 KM from Transmitter)

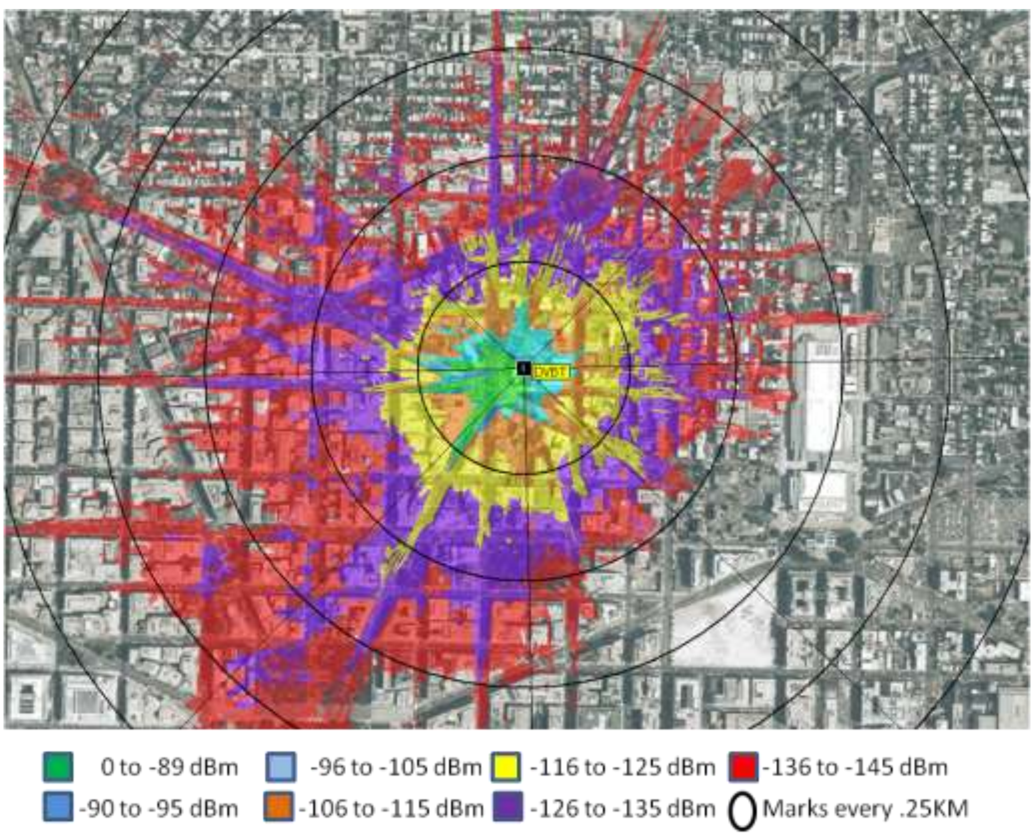


Figure 10 500 mW at 2 meter height in Urban Environment

1785-1805 MHz Band

DHS will continue to utilize the 1785-1805 MHz band to maintain operations that employ miniature and covert transmitters including body-worn video surveillance activities and receivers operating in close proximity around specific points. It is anticipated that as the equipment community develops smaller, power efficient devices the 1785-1805 MHz spectrum may be exited.

The Department currently has two US&P assignments for analog video surveillance, one assignment with a bandwidth of 20 MHz and a maximum TX power of 5 watts and the other with a bandwidth of 17 MHz and a maximum TX power of 2 watts. These assignments will be replaced with narrow-band (8 MHz) lower power (1 watt) assignments to accommodate digital COFDM devices. This narrow-banding and reduction in transmitter power will reduce the potential for interference with systems currently sharing the band with DHS operations.

Fixed Microwave Data link

In addition to the expansive deployment of video surveillance devices, DHS has several microwave data links at fixed locations operating continuously (24/7). These systems operate on 25 spot assignments in the 1755-1850 MHz band. The fixed site microwave data-link systems are used for transmission of data to and from field offices. These systems route communications media, voice from tactical radios, video imagery from remote video surveillance systems, and data from ground sensors to the key decision makers in central command and communications centers. Transmitter powers vary from 2 to 10 watts with directional antenna gains from 28 to 33 dB. (See table below)

POWER IN WATTS	ANTENNA GAIN (dB)	EMISSION DESIGNATOR	POWER IN WATTS	ANTENNA GAIN (dB)	EMISSION DESIGNATOR
10.00	30	3M75D7W	3.00	31	1M60D7W
10.00	30	3M75D7W	10.00	30	3M75D7W
10.00	30	3M75D7W	10.00	30	3M75D7W
10.00	30	3M75D7W	3.00	31	3M20D7W
10.00	30	3M75D7W	3.00	30	3M75D7W
3.00	33	1M60D7W	3.00	28	1M60D7W
3.00	31	5M00W7D	3.00	31	5M00W7D
10.00	30	3M75D7W	10.00	30	3M75D7W
3.00	28	3M75D7W	3.00	31	1M60D7W
10.00	30	3M75D7W	3.00	31	1M60D7W
3.00	31	1M60D7W	10.00	28	3M75D7W
2.00	28	3M20F9W	10.00	30	3M75D7W
2.00	28	3M20F9W			

Feasibility of relocating to spectrum band(s) for each category/operation.

2200-2290 MHz

Summary

The Department currently utilizes the 2200-2290 MHz band to augment its operations in the 1755-1850 MHz band through the use of 8 US&P assignments. Technical characteristics of devices, e.g. occupied bandwidth and modulation format, planned to be deployed during the transition will be similar to those digital systems in the 1755-1850 MHz band. However, the 20 percent reduction in transmitter and receiver separation resulting from the physical characterizes of the band present challenges. To increase the utilization of the band the Department will need to carefully monitor the increased potential for interference from increased use and sharing of operations with current DHS operations and incumbent services, e.g. Satellite and Space Operations.

The reduced spectral footprint of the digital devices and the reduced transmitter power compared the current higher power wide bandwidth analog systems should reduce potential for interference issues. As technology developments allowing for more intelligent sharing of the frequency and the reduction in required channel bandwidth for video surveillance operations, the potential exists for further band sharing and/or use of the band.[6]

Technical Considerations

While the Department has devices that operate in the 2200-2290 MHz band, the use of the band will increase as operations migrate to the band and the number of devices operating in the band increase. It is anticipated that device physical size and weight would slightly improve or remain the same as the 1755-1850 MHz devices. The quality of the video would remain relatively consistent assuming interference issues are avoided, but physical separation between transmitters and receivers would degrade.

The band will require re-channelization to replace current analog assignments with narrower digital assignments. The Department currently has 8 analog channel assignments that span the 2200-2290 MHz band as depicted in figure 6 and Table 2 below.

[6] The GMF identifies over 2895 assignments for transmitters in the band with the majority being low power devices for applications such as test beds, telemetry, and point to point communications. This is in contrast to the 1755-1850 MHz band which has approximately 3150 assignments with the majority of transmitters being low power (< 10 watt) devices and those of significant power being associated with high gain (approx 40 dB) directional antennas for space telecommand.

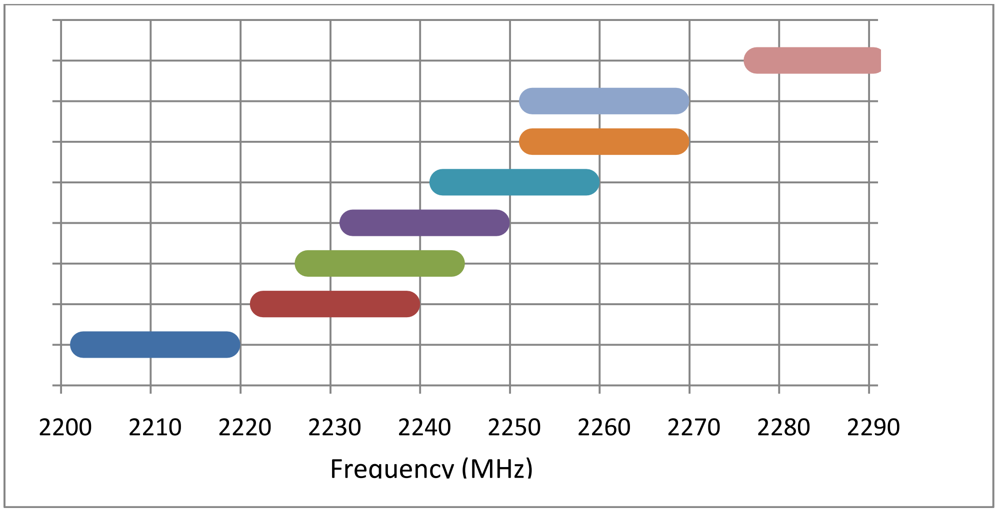


Figure 6 Current 2200-2290 MHz Assignments

SERIAL NUMBER	FREQUENCY	EMISSION	SERIAL NUMBER	FREQUENCY	EMISSION
DHS 038438	M2230	17M00F9W	DHS 038496	M2210	17M00D7W
DHS 038439	M2240	17M00F9W	DHS 038497	M2235	17M00D7W
DHS 038440	M2250	17M00F9W	DHS 038498	M2260	17M00D7W
DHS 038441	M2260	17M00F9W	DHS 038499	M2285	17M00D7W

Table 2 2200-2290 Current Analog Assignments

A possible re-channelization of the 2200-2290 MHz band would be to remove the current analog channel assignments and assign eleven 8 MHz channel assignments across the band. The assignments would be for video surveillance operations in the band and coordinated across the Federal law enforcement community. Figure 7 depicts a possible approach to channelizing the band.

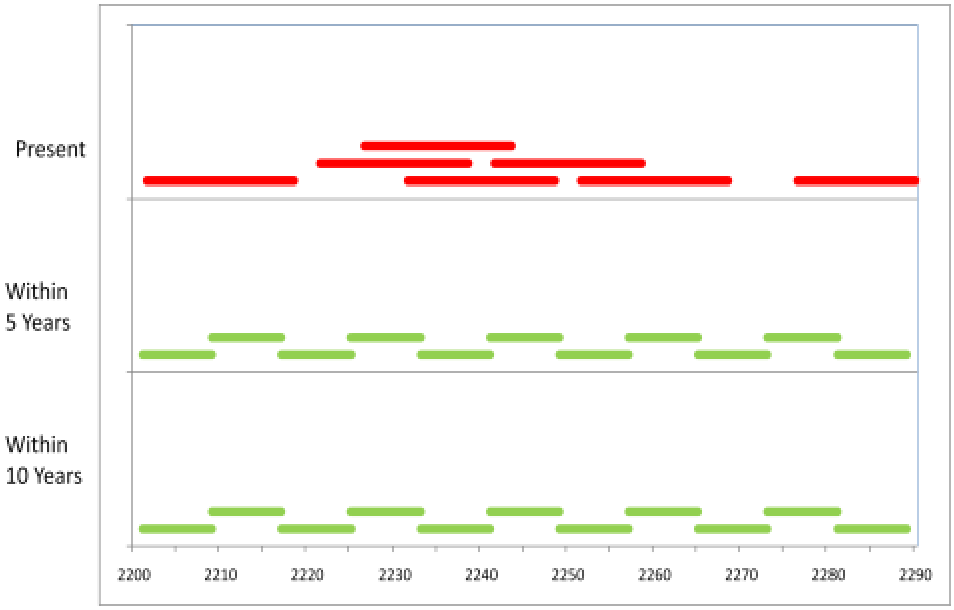


Figure 7 Migration to Digital Technology based Channels

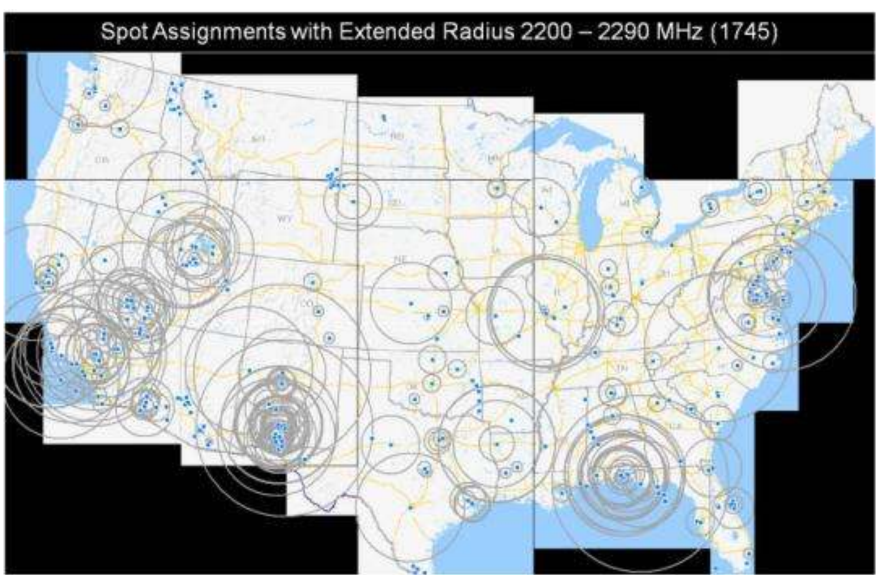
Estimates for COFDM transmitter signal power and CODFM receiver interference versus physical distance from the transmitter and spectral separation indicate transmitters operating at low heights (2 meters) produce radiated power that falls off rapidly as physical and spectral separation increase. Signal levels at 1 km or greater and 8 MHz from center frequency from transmitters would appear to be below thermal noise levels. While further analysis and testing are required, the current analysis suggests that digital devices may operate at reduced separation (physical and spectral) compared to analog devices. See appendices for detailed analysis.

Overall, the digital equipment available in this band has comparable capabilities with the exception of minor differences in size and Supply current for the transmitters. The available spectrum in the band and the availability of COFDM devices suggest that the quality of information would be similar to that in the 1755-1850 MHz band assuming interference levels do not increase significantly as devices migrate into the band.

Manufactures currently offer video systems in this band and are working to enhance their devices' operation with narrowband technologies. The development of intelligent avoidance of interference is less clear and an area of potential focus by the community. If additional consolidation of operations is required then technical solutions to address the impacts of the reduction in TX/RX separation and the intelligent avoidance of harmful interference among the systems may be required. In addition, evaluation of the use of narrow channels, e.g. 2.5 MHz, would be required.

Geographic extend of operations

The geographic extend of 2200-2290 MHz band fixed locations is below. The Department has coordinated with incumbents for the fixed and satellite systems and continues to consider the increased level of 2200-2290 MHz band use a viable option. Fixed site avoidance is less of an issue as depicted in the following figure.



The extent to which these limits impact mission effectiveness
A concern for relocating DHS systems into the 2200-2290 MHz band is the extent of the space operations and the interaction with mobile devices. Preliminary estimates for mutual interference on an aggregate basis suggest no significant interference issues.

Potential for sharing
The potential for sharing of this band is high. The Federal law enforcement agencies currently have operations in the band utilizing high bandwidth (20 MHz) and high power (5 watt) devices. Relocating to this band and replacing existing analog devices with newer narrow bandwidth (8 MHz) and lower power (1 watt) will ease the potential for interference among the other incumbent users.

1675-1695 MHz

Summary
The 1675-1695 MHz band presents an option to migrate some of the video surveillance devices from the 1755-1850 MHz band. Some of the smaller body-worn devices and concealed devices could be accommodated in the band on two 8 MHz channel assignments and a 2.5 MHz channel assignment (potential for future modulation narrow-banding). Sharing of operations with incumbent services, e.g. meteorological aids (radiosonde) and meteorological Satellite (space-to-earth) services[7] will need to be evaluated in detail, but the current evaluation indicates that sharing is a strong potential based on the limited power and time of operations of the radiosondes. Users of radiosondes may require technological advances to reduce potential interference and should consider development of improved, narrow-band systems to further reduce the potential for interference.

The band is approximately 6.5 percent below that of the current 1755-1850 MHz range resulting in minor improvements to estimated received RF power at a given physical separation (approximately 0.59 dB) or a slight improvement to distance of operation (approximately 7 percent). With the exception of an increased antenna length requirement, the overall device characteristics are estimated to be sufficiently close to current equipment, resulting in limited DC power, size, and weight impacts. Currently the vendor community does not offer produces in this band and the Department would have to work with the vendors to secure devices.

Technical Considerations
The proximity of the 1675-1695 MHz band to the 1755-1850 MHz band makes its physical characteristics suitable for supporting current law enforcement covert operations/missions; however, the limited overall spectrum severely restricts the amount and level of operations which could be supported in the band without major efforts to develop technologies that could address the need for more spectrally efficiency transmissions and interference avoidance.
The 1675-1695 MHz band currently has frequency assignments for operation of a meteorological aide (radiosonde) and meteorological satellite (space-to-earth) stations. To migrate DHS video

[7] The GMF identifies 159 assignments for transmitters with power up to 90 watts and applications such as radiosondes and Satellite downlinks. This is in contrast to the 1755-1850 MHz band which has approximately 3150 assignments with the majority of transmitters being low power (< 10 watt) devices and those of significant power being associated with high gain (approx 40 dB) directional antennas for space telecommand.

surveillance operations to the 1675-1695 MHz band, the current authorized use will require expansion to provide for allocation of fixed and mobile station class operations.

Potential interference with the meteorological satellite services is centered on the potential for interference from video surveillance transmitters to the meteorological earth stations. This potential interference has been analyzed and it is anticipated that the relatively low transmitter power and localized RF footprint of the video surveillance transmitters and the earth station's upward pointing antenna's high side-lobe rejection will significantly diminish the real world potential for harmful interference that can be further reduced by the use of basic protection zones around primary earth station receivers. Furthermore, the potential for interference to the meteorological satellites is considered as remote. The 188 dB free space path loss, the low RF power of the surveillance transmitters (< 1 watt), and the estimated low density of simultaneous nation-wide user (< 500) suggests a maximum aggregate interfering signal of approximately 53 dB below earth's thermal noise (-173.8 dBm/Hz) at the satellite's receiver, well within the -12.2 dB I/N requirements for satellite operations.

An addition source for potential mutual interference is between radiosondes and DHS systems. In general, the radiosonde operations are assumed to consist of airborne low power transmitters and ground-based receivers. The transmitters transmit sensor data during short duration (4 hours typical) missions from altitudes up to 30,000 feet through a 138 KHz bandwidth channel operating at power levels up to 238 mW. (See appendix)

Radiosonde transmitters' interference to DHS video surveillance receivers was analyzed in multiple scenarios. Analysis of radiosonde transmitters and video surveillance receivers suggests that the potential for interference is greatest for radiosondes operating within 4 MHz of the video surveillance device center frequency and in close proximity to video receivers during ascent and descent. The analysis considered multiple scenarios including smooth earth, urban, and rural environments. In general, radiosonde transmitters operating at greater than 4 MHz from the video surveillance receiver center frequency and physically separated by 1 Km or more have little potential to cause interference with video surveillance devices. Transmitters operating within the bandwidth of the video surveillance receivers have a greater potential to produce interference; however, the impacts of the surrounding terrain and the close proximity of the video surveillance transmitters reduce the potential for harmful interference, e.g. urban environment separation distance less than 1km.

The interference potential from DHS video transmitters to radiosonde receivers was analyzed based on an 8 dB I/N threshold. Analysis based on a smooth earth model suggest that on channel operations be physical separated by approximately 8 Km and operations with a 4 MHz offset be separated by 2 Km. The inclusion of real world terrain into the analysis reduces the separation distance significantly, with urban environment separation at approximately 1 km.

While this analysis strongly suggests the potential for spectrum sharing, specific field testing should be conducted to validate the analysis. In addition, options to mitigate the potential for interference should be included in deployment plans and should include a structured operational model among the spectrum users to include geographic and time-of-use channel selection.

The proximity of the 1675-1695 MHz band to the 1755-1850 MHz band makes its physical characteristics suitable for supporting current law enforcement covert operations/missions; however, the limited overall spectrum severely restricts the amount and level of operations which could be supported in the band without major efforts to develop technologies that could address the need for more spectrally efficiency transmissions and interference avoidance. There are approximately 158 frequency assignments resident within the 1675-1695 MHz band and relocating all of the 1755-1850 MHz operations into this band has the potential to increase significantly the potential for interference.

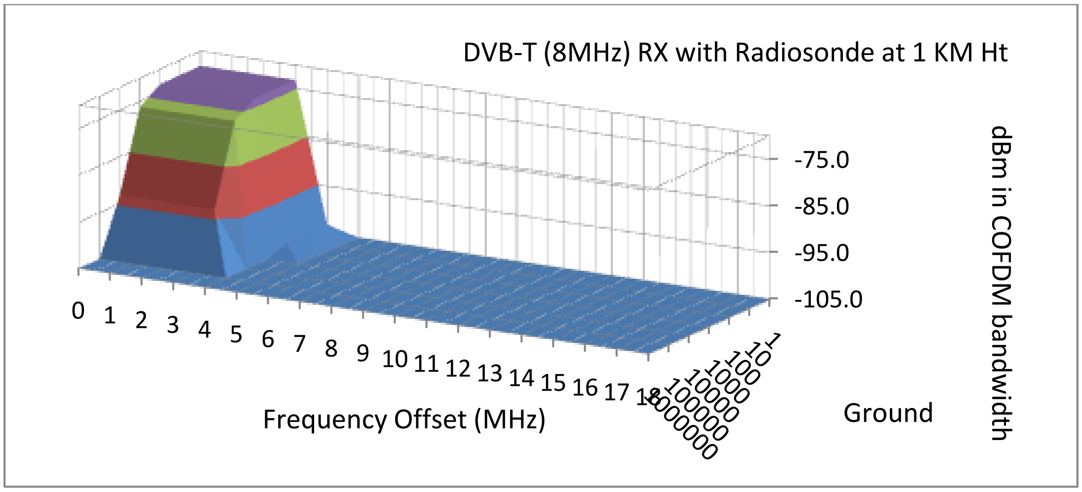


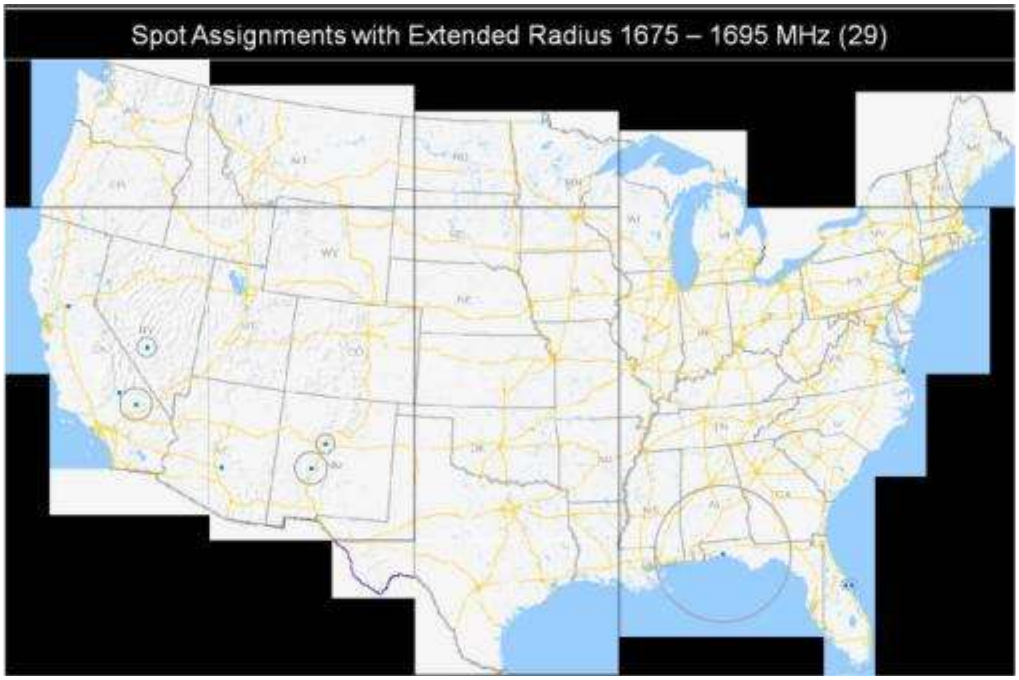
Figure 8 Estimate of Received Interference from Radiosondes vs. Frequency Offset vs. Distance Smooth Earth

Currently devices are offered in bands close to the 1675-1695 MHz band and would have to be modified to work in this band. From discussion with vendors, this is seen as a minor point.

Geographic extend of operations

The geographic extend of current operation in the 1675-1695 MHz band that are of interest is driven primarily from satellite assignments and radiosondes. The number of earth station and their locations has yet to be ascertained. A full accounting of the locations and the significant RF characteristics of the locations would have to be conducted to determine potential geographic sharing of the frequency band. For the radiosondes, a better understanding of the devices operations and significant RF characteristics would have be required to estimate the potential for geographic sharing of the frequency band. Technical information for the radiosondes indicate the transmitters emit +23.8 dBm (240mW) in a 3dB bandwidth of 135 KHz with emissions falling to 58 dBc at 1 MHz offset.

Fixed site avoidance is less of an issue as depicted in the following figure.



Spot Assignments with Extended Radius 1675 – 1695 MHz (29)

A more viable option is to use the band as part of an overall comprehensive transition including the 1785-1805 MHz, 2200-2290 MHz, and 4400-4940 MHz bands, allowing the Department to match operational needs to band physical characteristics.

The physical characteristics of the band align well with the operational needs of some of the current devices operating in the 1755-1850 MHz band. In addition, the vendor community provides products operating in bands close to the 1675-1695 making the near-term availability of devices a possibility. In addition, the transmitter power level and anticipated physical separation of operations reduces the level of anticipated harmful interference. These factors make the band a candidate for limited use to support a portion of the DHS operations as a part of the overall comprehensive transition including the 1785-1805 MHz, 2200-2290 MHz, and 4400-4940 MHz bands, allowing the Department to match operational needs to band physical characteristics.

4400-4940 MHz

Summary

The Department will continue to utilize its assignments in the 4400-4940 MHz band for expansion of its digital mesh network to off load operations in other bands to reduce the potential for interference and reduce operational burdens with future spectrum exits, e.g. 2200-2290 MHz. The Department current has six US&P assignments for low-power, narrowband COFDM operations and anticipates increasing the usage of these assignments. These assignments will be used for portable and point-to-point links where operational requirements allow. As the Department expands the use of its assignments in the 4400-4490 MHz band, it is anticipated that integration of new point-to-point spectrally efficient capabilities will result in increased efficiencies in overall spectrum efficiencies.

Assumptions made for assessing the potential for operational usage within the 4400-4940 MHz band are that overall congestion in the 4400-4940 MHz band will continue to increase as Federal activities exit other bands; however, technologies currently being evaluated for use in the band will become available to allow for more spectrally efficient use of the band

Technical Considerations

While the Department has US&P assignments in the 4400-4940 MHz band and other Federal law enforcement agencies have video surveillance assignments in the band, the use of the band by the Department has been limited. As operations migrate out of the 1755-1850 MHz band, the number of devices operating in the 4400-4940 MHz band will increase and raise the potential for interference. However, it is anticipated that relocating to multiple bands, using digital modulation, limiting the transmitter power of devices, and coordinating across the Federal law enforcement community will limit the potential interference.

Other Frequency bands (1350-1390 MHz, 1435-1525 MHz, 2025-2110 MHz, 2360-2395 MHz)

In addition to the 1675-1695 MHz band, 1785-1805 MHz band, 2200-2290 MHz band, and 4400-4940 MHz bands, the Department considered four other bands for relocations operations. While each offer potential for relocation a portion of the operations, no single band provided a better alternative considering cost, operational impacts, and technology development than the mixed band strategy recommended. Below is a brief discussion of each of the proposed bands.

1350-1390 MHz

Summary

The 1350-1390 MHz band presents a limited option for migrating all video surveillance from the 1755-1850 MHz band. Significant obstacles to overcome before utilizing the band include addressing the limited bandwidth (40 MHz total compared to 95 MHZ) and the relocation or sharing of operations with incumbent services, e.g. radiolocation service systems[8]. Of primary technical concern is the potential interference from the incumbent high power/high bandwidth radar transmitters (Up to 258 mW power/10 MHz BW) on the video surveillance receivers. While the COFDM video systems provide some protection to pulsed interference through the use of block forward error correction (FEC) coding, the system's symbol block lengths are relatively short. The duration of radar pulse interference may be sufficient to corrupt an entire symbol block negating FEC improvements.[9] Transmitter power, bandwidth, pulse duration, and

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[8] GMF identifies 593 assignments for various transmitters with power up to 258 Megawatts and applications such as radar test beds, UAV control, and air traffic control. This is in contrast to the 1755-1850 MHz band which has approximately 3150 assignments with the majority of transmitters being low power (< 10 watt) devices and those of significant power being associated with high gain (approx 40 dB) directional antennas for space telecomm and.

[9] DISA JSC Communications Receiver performance Degradation Handbook 7.4 TEMPORAL FLUCTUATIONS "If an undesired signal is intermittent, bit errors tend to be more numerous during the interference dwells, and less numerous between the dwells. If the interference is of sufficient strength and duration, the FEC decoder may be overloaded and the BER may approach ½ during a dwell, which means the decoder output is completely random."

geographic separation need to be considered. Since video systems are predominantly operated within or in very close proximity to major metropolitan areas but operate in rural areas as well, evaluation of the potential interactions between the video and radar systems would be required to determine required physical separation, frequency separation and power limits as well as operational modifications before a full operational transition could occur.

The band is approximately 24 percent lower in operating frequency compared to the current 1755-1850 MHz range presenting the potential for slight improvements in receiver (RX) and transmitter (TX) separation (31 percent) or reduce RF transmitter power (approximately 2.4 dB) assuming a larger antenna for a given physical separation.[10] Unfortunately, the benefits of increased RX/TX separation or reduced RF-TX power are tempered by the necessity to increase the physical size of the transmitter antenna to maintain antenna matching characteristics, reducing the covertness of the devices. With the exception of an increased antenna length requirement, the overall device characteristics are estimated to be sufficiently close to current equipment, resulting in limited DC power, size, and weight impacts. The greater concern with migrating to the 1350-1390 MHz band is the potential interference from systems currently occupying the band. As identified for current operations in the 1755-1850 MHz band, legacy video surveillance systems require 15 to 20 MHz receiver to interfering transmitter to avoid harmful interference. Digital encoding techniques employed in currently available digital video systems have further advanced the receiver selectivity to the point where it is estimated the channel separation possibly may be reduced to 5 to 6 MHz. While these technology developments have the potential to reduce the need for spectrum, the significant reduction of the current available 95 MHz bandwidth in the 1755-1850 MHz band to the 40 MHz made available in this band makes the potential to relocate all operations unlikely.

Technical Considerations

The separation of the 1350-1390 MHz band from the 1755-1850 MHz band makes its physical characteristics increasing less suitable to support current law enforcement covert operations/missions. As the wavelength of the operating frequency increases so does the physical size of the radiating structure if comparable RF and DC power levels are to be maintained. While these issues may not be insurmountable, significant technology development to redesign systems to operate in this band would be required. A more significant challenge would be in addressing the reduction in available bandwidth on information quality and potential interference from incumbent radar operations.

Technical solutions required to overcome such limitations

Devices would need to be developed for operation within the 1350-1390 MHz band that are capable of supporting the miniaturized or low-profile operations required by DHS US&P assignments. As a consequence, R&D would have to be initiated to develop, procure, and deploy these devices. Technical solutions to address the impacts of the reduction in available bandwidth on video quality and the intelligent avoidance of interference may be required.

[10] Propagation model used ITS model for propagation loses employed in AWS interference analysis 2007.

Regarding State of availability and maturity of the technology necessary to transition

The reduction of available bandwidth, manufactures are currently offering video systems that operate in 2.5 MHz of bandwidth and are developing 1.25 MHz bandwidth systems. Detailed and careful evaluation of these narrowband technologies will be required before adoption by the law enforcement community. The development of technologies for the intelligent avoidance of interference is less clear and an area of potential focus by the community.

Operational Considerations

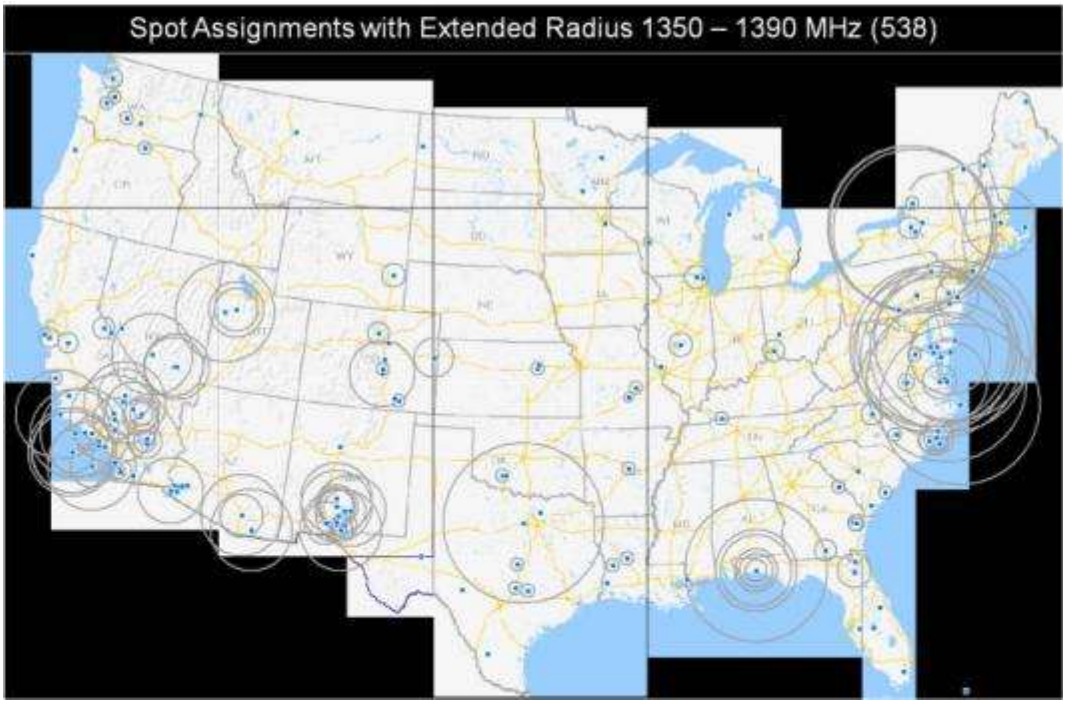
The primary concern for DHS system relocations into the 1350-1390 MHz band is the potential for detrimental interference with radiolocation systems already resident within the band. From an operational standpoint, fixed point-to-point data link operations under some circumstances might be addressed with incumbent radiolocation activities, but the mobile US&P operations presents a more difficult challenge. US&P based operations as stated earlier are dynamic and potentially less than 24/7 in duration, placing a high degree of uncertainty on location and timing of the operations. In addition, the operations does not lend to the coordination prior to start of operations. Currently the operation model utilizes clear bandwidth with immediately available, where and when mission conditions dictate. To provide comparable capabilities, assuming no technology advance to address the sharing issues, a similar operating model would be required in the 1350-1390 MHz band

In addition, the limited bandwidth in the band (40 MHz total) would reduce DHS US&P operations to less than half of the currently available spectrum to address required channel separation and bandwidth for information quality. While DHS already experiences an "overlay" of assignments within the 1755-1850 MHz band, the reduction in available bandwidth has the potential to impact operations and reduce the total available channels compared to the 1755-1850 MHz band, increasing the potential for overlay of assignments from other agencies, and interference among system operations.

Geographic extend of operations

The geographic extend of current operation in the 1350-1390 MHz band that are of interest is driven primarily from Radiolocation services. As depicted in the following chart, the coverage area of individual systems and number of systems located near major metropolitan areas across the United States is of concern, specifically the systems along the southwest border and the northeast United States. A full analysis of the systems along with the significant RF characteristics of the locations would have to be conducted to determine potential geographic sharing of the frequency band.

Fixed site avoidance is less of an issue as depicted in the following figure.



1435-1525 MHz

Summary

The 1435-1525 MHz band presents a potential option for migrating all video surveillance from the 1755-1850 MHz band. The total available bandwidth is similar to that provided in the 1755-1850 MHz band and the device challenges associated with the physical characteristics of the band, while presenting challenges to the redesign of equipment, may be possibly addressed through equipment development. The overall device characteristics are of concern if intelligent interference rejection circuitry is required. While there are no current devices or technologies known to address these issues for video surveillance system, it is reasonable to assume that significant DC power, size, and weight impacts would need to be considered in the receiver design.

The potential for aeronautical telemetry devices to be operating at altitudes from near ground level to high altitudes with an associated large RF foot print, the expanse of devices deployment, and the concentration of devices being roughly proportional to population concentrations across the United States raises concerns of potential interference issues.[11]

[11] The GMF identifies 998 assignments for various transmitters with power up to 100 watts and applications such as telemetry system and antenna test beds. This is in contrast to the 1755-1850 MHz band which has approximately 3150 assignments with the majority of transmitters being low power (< 10 watt) devices and those of significant power being associated with high gain (approx 40 dB) directional antennas for space telecommand.

The primary concern for relocating DHS systems into the 1435-1525 MHz band is the anticipated need to reduce operating bandwidth and the incompatibility and mutual interference DHS systems would incur from and present to the incumbent systems already resident and operating within the band. Even if DHS were able to obtain equipment that provided acceptable information quality in a significantly reduced bandwidth, sufficiently clear spectrum would still not be available in many key areas of the country. As a consequence, R&D would have to be initiated to develop, procure, and deploy devices that are capable of operating in the 1435-1525 MHz band. Significant time would be required, but it is estimated that the potential for a total solution in the limited bandwidth is low.

Technical Considerations

The proximity of the 1435-1525 MHz band to the 1755-1850 MHz band makes its physical characteristics closer to being suitable for supporting current law enforcement covert operations/missions than other low frequency bands; however, the interference potential with incumbent operations would need to be carefully considered prior to relocation.

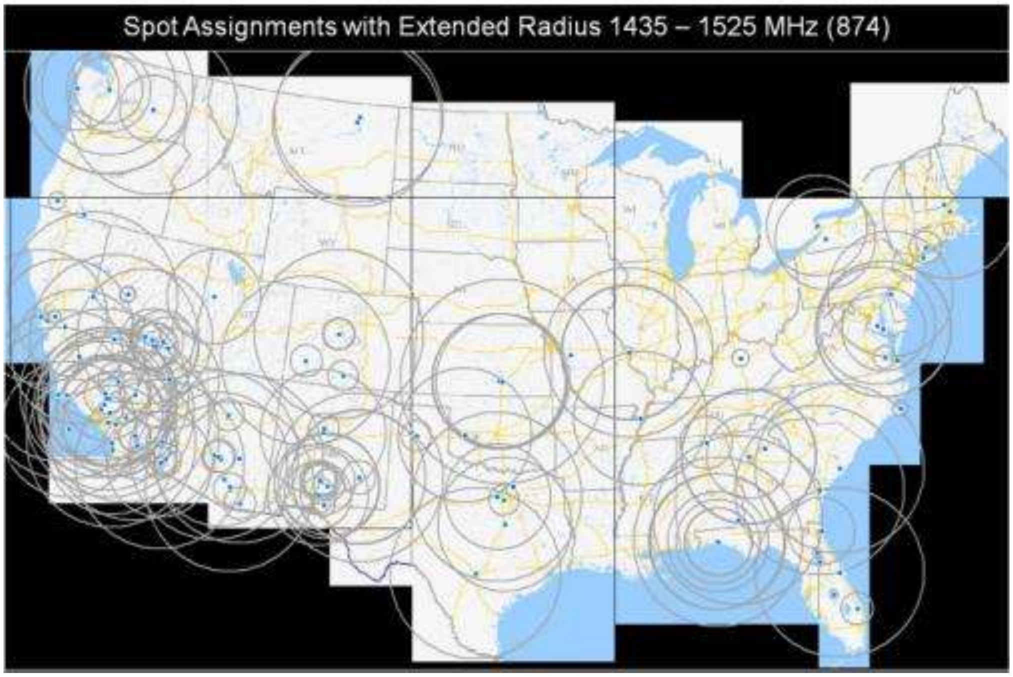
Operational Considerations

The primary concern for systems relocation into the 1435-1525 MHz band is the mutual interference systems would experience with aeronautical telemetry systems operating in the band. The dynamic nature of the DHS US&P operations, e.g. unpredictable in location and time, makes pre-coordination unlikely. The approach currently used in the 1755-1850 MHz band to maintain multiple US&P channels to address static localized interference may not be sufficient in this band where interference would be more sporadic.

Geographic extend of operations

The geographic extend of current operation in the 1435-1525 MHz band that are of interest is driven primarily by telemetry devices operating in the band. The number of devices, the dynamics of the operations, and the transmitter locations would need to be ascertained to account for the significant RF characteristics to determine potential geographic sharing of the frequency band.

Fixed site avoidance as depicted in the following figure would need to be addressed.



2025-2110 MHz

Summary

The 2025-2110 MHz band presents an option for migrating video surveillance from the 1755-1850 MHz band. The total available bandwidth is similar to that provided in the 1755-1850 MHz band. However, the primary areas of concern are the reduced RF propagation characteristics in the band and the number and diversity of incumbent systems currently in the band. Calculations indicate that transmitter and receiver distances would decrease by approximately 12%. While the physical separation would be degraded, requiring 12% additional devices to roughly provide comparable aggregate operations coverage, the potential for interference from current incumbent operations is of more concern. The potential interference with and from the systems in the band, e.g. earth exploration satellite and space operations/research, radar, microwave links, experimental, and the significant number of low power TV broadcast, with maximum transmitter powers of 500W raises concerns.[12]

The primary concern for relocating DHS systems into the 2025-2110 MHz band is the magnitude of commercial, private, and/or non-government licenses already within the band. Most of these assignments are for high bandwidth (10-20 MHz), many are "broadcast" in nature, and the transmit power is significant. While most of the incumbent assignments are fixed, the "mobile" DHS US&P operations make it problematic to de-conflict system within specific geographic

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[12] The GMF identifies 333 assignments for transmitters with power up to 501 megawatts in Alaska and applications such as satellite control uplinks, and antenna and sensor test beds. In addition, more than 7000 FCC licenses exist in the band. This is in contrast to the 1755-1850 MHz band which has approximately 3150 assignments with the majority of transmitters being low power (< 10 watt) devices and those of significant power being associated with high gain (approx 40 dB) directional antennas for space telecommand.

areas. In addition, since most of the licenses are non-federal, the process to de-conflict would require high level coordination between the FCC and NTIA.

The full impact of the incumbent systems would need to be examined in detail prior to any relocation. As with other bands in this study, the potential development of interference avoidance systems may be required. While there are no current devices or technologies known to address these issues for video surveillance systems, it is reasonable to assume that significant DC power, size, and weight impacts would be encountered in the receiver design.

Technical Considerations

The 2025-2110 MHz band has physical characteristics that limit the propagation range between transmitters and receivers. However, this is offset to some extent by the possible reduction in device size. However, other limiting factors associated with battery size and heat dissipation may significantly impact devices. In addition, the interference potential from incumbent operations would need to be carefully considered prior to relocation. The technologies for the intelligent avoidance of interference such as Dynamic Frequency Selection are not mature at this time and have not been introduced into the video surveillance equipment. In addition, the vendor community is working to increase transmitter power while managing the associated heat and battery consumption.

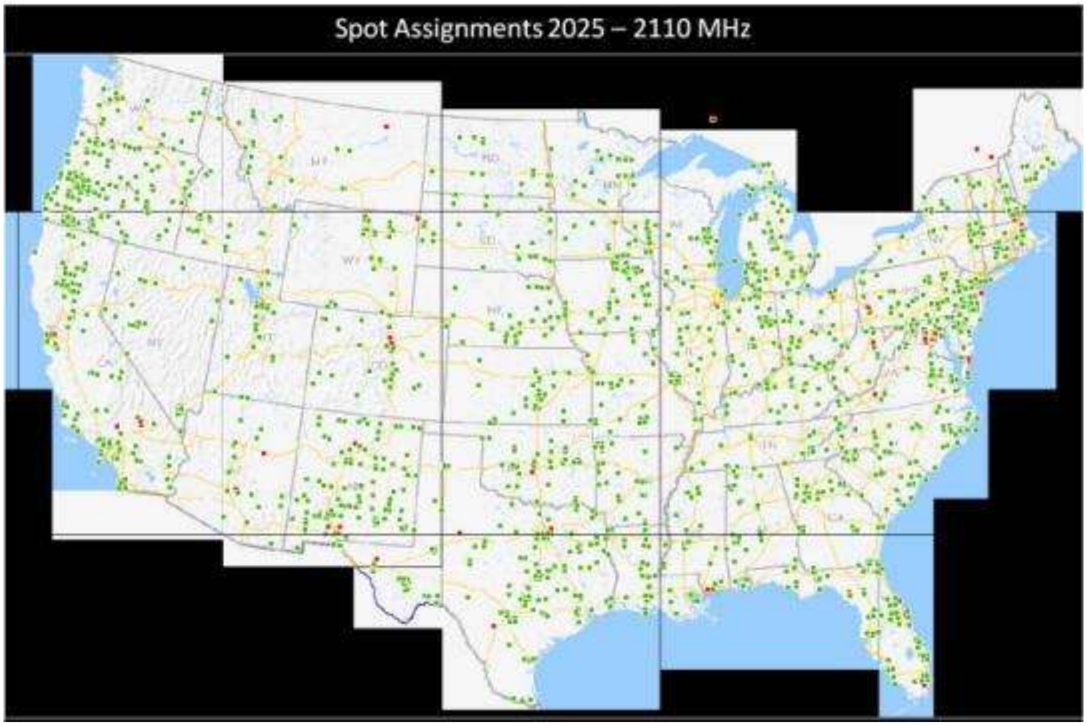
Operational Considerations

The primary concern for systems relocation into the 2025-2110 MHz band is the mutual interference that systems would experience with incumbent systems. In addition, the reduced propagation characteristics would result in the need for additional transmitter/receiver pairs to maintain aggregate coverage.

Geographic extend of operations

The geographic extend of operation in the 2025-2110 MHz band include over 400 Government frequency assignments, of which over 25% are identified as being in support of Non-Government (NG) services. The FCC database on commercial and private licenses includes 7187 licenses within the band.

Fixed site avoidance is less of an issue as depicted in the following figure.



2360-2395 MHz

Summary

The 2360-2695 MHz band presents a limited option for migrating all video surveillance from the 1755-1850 MHz band. Significant obstacles to overcome before utilizing the band include addressing the limited available bandwidth (35 MHz total compared to 95 MHZ) and the relocation or sharing of operations with incumbent services, e.g. telemetry systems. While technology developments that would allow more intelligent sharing of the frequency may be possible, the significant reduction on available bandwidth limits the utility of this band for a full transition. While it is doubtful that all video surveillance operations could be relocated to the 35 MHz provided, the physical performance perspectives of the band make it a candidate for a limited set of video channels assuming the potential interference to telemetry systems is addressed.[13]

The band is approximately 48 percent above the current 1755-1850 MHz range resulting in significant reductions in RF propagation. Devices are estimated to be similar to those currently available since the limitation to device size, weight, and power are related to characteristics other

[13] The GMF identifies 590 assignments for transmitters with all but three assignments for transmitters with TX power less than or equal to 100 watts for applications such as telemetry and test beds. This is in contrast to the 1755-1850 MHz band which has approximately 3150 assignments with the majority of transmitters being low power (< 10 watt) devices and those of significant power being associated with high gain (approx 40 dB) directional antennas for space telecommand.

than antenna size. The greater concern with migrating to the 2360-2695 MHz band is the reduction of total available spectrum and the potential interference with systems currently occupying the band and those entering the band. As identified for current operations in the 1755-1850 MHz band, legacy video surveillance systems require 15 to 20 MHz receiver to interfering transmitter to avoid harmful interference. Digital encoding techniques employed in currently available digital video systems have further advanced the receiver selectivity to the point where it is estimated the channel separation may be reduced to 5 to 6 MHz, and systems in development may reduce this. While these technology developments have the potential to reduce the need for spectrum, the significant reduction of the currently available 95 MHz bandwidth in the 1755-1850 MHz band to the 35 MHz makes the potential to relocate all operations highly unlikely. It is more reasonable that a portion of the operations in the 1755-1850 MHZ may be relocated to this band to offset reductions in the 1755-1850 MHz spectrum.

Technical Considerations

The limited overall spectrum severely restricts the number and level of operations which could be supported in the band without major efforts to develop technologies that could address the need for more spectrally efficiency transmissions and interference avoidance.

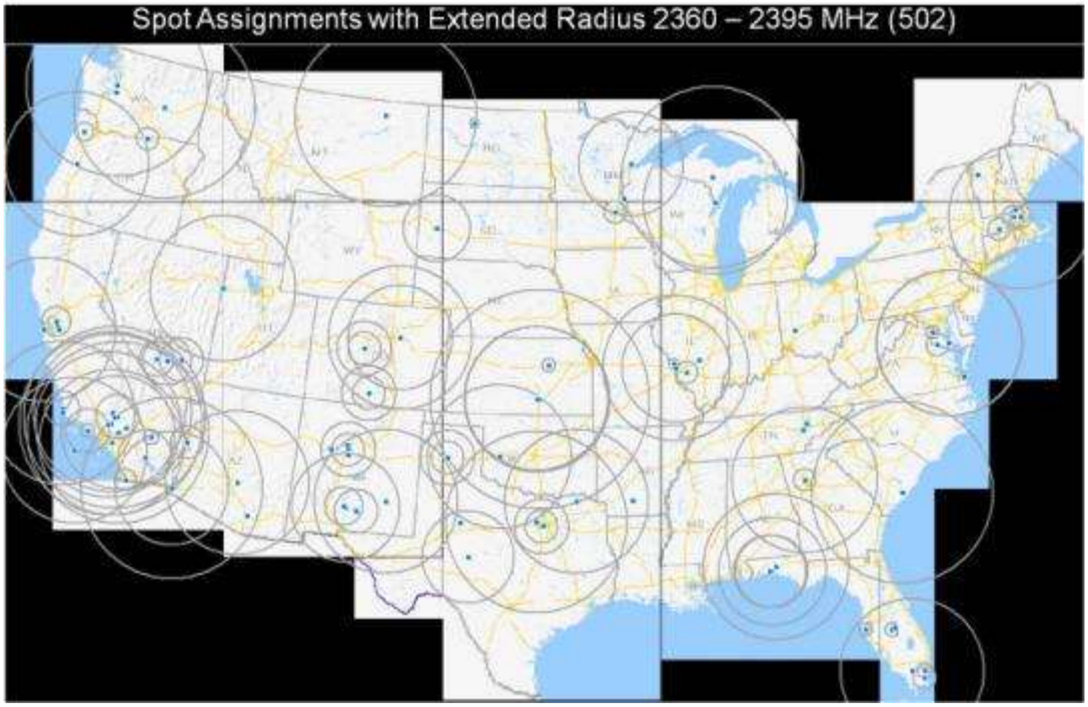
Operational Considerations

The primary concern for DHS system relocations into the 2360-2395 MHz band is the potential for detrimental interference with telemetry system resident in the band and the limited available bandwidth. US&P based operations are dynamic, placing a high degree of uncertainty on location and timing of the operation. Coordinating in an environment where the expanse of radio telemetry systems is significant and uncertain suggests coordination prior to start of operations would be extremely difficult.

Geographic extend of operations

The geographic extend of current operation in the 2360-2395 MHz band that are of interest is driven primarily from telemetry systems. The number of systems and their locations has yet to be ascertained. An evaluation of the locations and the significant RF characteristics would have to be conducted to determine potential geographic sharing of the frequency band.

Fixed site avoidance is less of an issue as depicted in the following figure.


Spot Assignments with Extended Radius 2360 – 2395 MHz (502)

Appendix A ROM Funding and Schedule Estimate

	2012		2013		2014		2015		2016		2017	
	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
Pre-Exit Tasks												
Phase 0 -- Pre-migration												
Test and Evaluation	$500,000		$500,000		$125,000							
COFDM device development	$250,000		$500,000		$100,000							
Digital mesh FOA	$600,000		$1,800,000		$600,000							
Equipment reprogramming	$-		$-		$250,000							
Planning	$750,000		$500,000		$250,000							
EQUIPMENT												
Digital Migration Phase I												
Body-worn/Concealment	-	$-	-	$-	1,005	$12,502,298	406	$5,055,582	396	$4,931,122	412	$5,130,259
Receivers	-	$-	-	$-	755	$16,762,331	248	$5,500,834	244	$5,412,003	254	$5,634,080
Repeaters	-	$-	-	$-	331	$9,059,470	77	$2,102,016	67	$1,828,316	77	$2,102,016
Custom Covert Enclosures	-	$-	-	$-	319	$9,593,179	97	$2,925,409	97	$2,925,409	91	$2,745,199
Ancillary Equipment	-	$-	-	$-	1,306	$1,492,735	371	$423,948	474	$541,711	460	$525,704
	-	$-	-	$-								
IP Camera Enclosures	-	$-	-	$-	115	$247,250	80	$172,000	80	$172,000	50	$107,500
IP Cameras	-	$-	-	$-	115	$327,750	38	$108,300	38	$108,300	38	$108,300
Phase I Equipment Total	-	$-	$-	$-	3,945	$49,985,013	1,317	$16,288,089	1,396	$15,918,861	1,382	$16,353,058
Fixed Sites	-	$-	-	$-	9	$6,678,153	9	$6,678,153	7	$5,194,119	-	$-
Mobile Platforms	-	$-	-	$-	43	$4,945,000	32	$3,680,000	32	$3,680,000	15	$1,725,000
Digital Migration Phase II & III												
Body-worn/Concealment	-	$-	-	$-	-	$-	-	$-	-	$-	300	$1,500,000
Receivers	-	$-	-	$-	-	$-	-	$-	-	$-	300	$4,500,000
Repeaters	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
Custom Covert Enclosures	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
Ancillary Equipment	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
IP Mesh enclosures					-	$-	25	$750,000	400	$12,000,000	400	$12,000,000
Mesh IP nodes					-	$-	50	$2,500,000	400	$20,000,000	400	$20,000,000
Surveillance Platform refit					-	$-	2	$120,000	13	$780,000	35	$2,100,000
EQUIPMENT TOTAL	-	$-	-	$-	3,997	$61,608,166	1,435	$30,016,241	2,248	$57,572,980	2,832	$58,178,058
Technology First Article for Phase III												
Portable IP Mesh system	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
Fixed IP system	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
EQUIPMENT TOTAL	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
Technology Mesh Deployment												
IP Mesh DC expansion	-	$-	-	$-	-	$-	-	$-	-		-	$-
IP Mesh 2	-	$-	-	$-	-	$-	-	$-	-	$-	-	

Top 20 city LE Mesh	-	$-	-	$-	-	$15,346,570	-	$56,270,655	-	$56,270,655	-	$56,270,655
Top metropolitan area LE Mesh	-	$-	-	$-	-	$-	-	$-	-	$57,549,638	-	$57,549,638
Mesh total	-	$-	-	$-	-	$15,346,570	-	$56,270,655	-	$113,820,293	-	$113,820,293
Project contingency		$1,000,000		$1,000,000		$1,000,000		$1,000,000		$1,000,000		$2,500,000
Contract Services												
Training	-	$-	-	$-	25	$325,000	50	$250,000	100	$677,600	100	$597,600
Shipping	-	$-	-	$-	-	$46,000	-	$77,600	-	$77,600	-	$70,600
Spectrum	2	$500,000	2	$515,000	2	$530,450	3	$819,545	4	$1,125,509	4	$1,159,274
Admin	1	$163,200	2	$336,192	2	$386,278	4	$758,332	4	$779,732	4	$801,774
Logistics Support	1	$288,000	2	$593,280	4	$3,765,717	4	$3,014,262	3	$2,453,400	5	$3,150,315
SERVICES TOTAL	4	$951,200	6	$1,444,472	8	$4,728,445	11	$4,669,739	11	$4,436,241	13	$5,181,963
Project Staff												
	1	$215,450	1	$221,914	3	$726,454	3	$748,248	3	$770,695	3	$793,816
	1	$190,152	1	$195,857	7	$1,472,461	8	$1,761,456	8	$1,751,581	8	$1,920,674
	-	$-	-	$-	7	$1,317,104	8	$1,563,855	9	$1,824,227	10	$2,065,553
	-	$-	-	$-	3	$481,601	4	$670,180	4	$690,285	3	$526,258
Total Project staff	2	$405,602	2	$417,770	20	$3,997,620	23	$4,743,739	24	$5,036,788	24	$5,306,302
Totals		$4,456,802		$6,162,242		$88,330,800		$96,950,374		$182,543,901		$185,584,215

	2018		2019		2020		2021		2022		TOTAL	
	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
Pre-Exit Tasks												
Phase 0 -- Pre-migration												
Test and Evaluation												$1,125,000
COFDM device development												$850,000
Digital mesh FOA												$3,000,000
Equipment reprogramming												$250,000
Planning												$1,500,000
EQUIPMENT												
Digital Migration Phase I												
Body-worn/Concealment	257	$3,203,860	10	$124,460	-	$-	10	$124,460	-	$-	2,497	$31,072,042
Receivers	87	$1,923,626	10	$222,076	-	$-	10	$222,076	-	$-	1,607	$35,677,026
Repeaters	141	$3,852,054	10	$273,700	-	$-	10	$273,700	-	$-	712	$19,491,272
Custom Covert Enclosures	71	$2,125,277	6	$180,210	-	$-	6	$180,210	-	$-	688	$20,674,893
Ancillary Equipment	267	$305,430	6	$6,860	-	$-	6	$6,860	-	$-	2,889	$3,303,248
											-	$-
IP Camera Enclosures	18	$38,700	-	$-	-	$-	-	$-	-	$-	343	$737,450
IP Cameras	18	$51,300	-	$-	-	$-	-	$-	-	$-	247	$703,950
Phase I Equipment Total	859	$11,500,247	42	$807,307	-	$-	42	$807,307	-	$-	8,983	$111,659,881
											-	$-
Fixed Sites	-	$-	-	$-	-	$-	-	$-	-	$-	25	$18,550,424
Mobile Platforms	-	$-	61	$1,830,000	32	$960,000	32	$960,000	-	$-	247	$17,780,000
											-	$-
Digital Migration Phase II & III											-	$-
Body-worn/Concealment	500	$2,500,000	675	$3,375,000	675	$3,375,000	375	$1,875,000	275	$1,375,000	2,800	$14,000,000
Receivers	500	$7,500,000	700	$10,500,000	750	$11,250,000	450	$6,750,000	350	$5,250,000	3,050	$45,750,000
Repeaters	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
Custom Covert Enclosures	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
Ancillary Equipment	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
											-	$-
IP Mesh enclosures	350	$10,500,000	300	$9,000,000	300	$9,000,000	325	$9,750,000	225	$6,750,000	2,325	$69,750,000
Mesh IP nodes	400	$20,000,000	400	$20,000,000	400	$20,000,000	425	$21,250,000	325	$16,250,000	2,800	$140,000,000
Surveillance Platform refit	60	$3,600,000	50	$3,000,000	-	$-	-	$-	-	$-	160	$9,600,000
											-	$-
EQUIPMENT TOTAL	2,669	$55,600,247	2,228	$48,512,307	2,157	$44,585,000	1,649	$41,392,307	1,175	$29,625,000	20,390	$427,090,305
											-	$-
Technology First Article for Phase III											-	$-
Portable IP Mesh system	40	$2,000,000	20	$1,000,000	-	$-	-	$-	-	$-	60	$3,000,000
Fixed IP system	5	$750,000	-	$-	-	$-	-	$-	-	$-	5	$750,000
EQUIPMENT TOTAL	45	$2,750,000	20	$1,000,000	-	$-	-	$-	-	$-	65	$3,750,000
											-	$-
Technology Mesh Deployment											-	$-
IP Mesh DC expansion	-	$-	-	$-	-	$-	-	$-	-	$-	-	$-
IP Mesh 2	-		-		-		-		-	$-	-	$-
Top 20 city LE Mesh	-	$-	-		-		-		-	$-	-	$184,158,536

Top metropolitan area LE Mesh	-	$268,564,977	-	$268,564,977	-	$268,564,977	-		-		-	$920,794,207
Mesh total	-	$268,564,977	-	$268,564,977	-	$268,564,977	-	$-	-	$-	-	$1,104,952,743
											-	$-
Project contingency		$5,000,000		$5,000,000		$2,000,000		$2,000,000		$1,000,000		$22,500,000
											-	$-
Contract Services											-	$-
Training	100	$677,600	200	$1,080,000	50	$250,000	-	$160,000	-	$-	625	$4,017,800
Shipping	-	$70,600	-	$42,000	-	$60,000	-	$60,000	-	$46,000	-	$550,400
Spectrum	4	$1,194,052	3	$922,405	3	$950,078	2	$652,387	1	$335,979	30	$8,704,679
Admin	4	$814,477	4	$822,862	2	$453,474	1	$252,939	1	$259,327	29	$5,828,587
Logistics Support	5	$3,200,395	8	$4,105,629	6	$3,740,979	4	$2,801,099	4	$2,915,192	46	$30,028,266
SERVICES TOTAL	13	$5,279,525	15	$5,892,896	11	$5,204,530	7	$3,766,424	6	$3,556,498	105	$45,111,933
											-	$-
Project Staff											-	$-
	3	$817,631	3	$842,160	3	$867,424	4	$1,224,668	4	$1,261,408	31	$8,489,867
	9	$2,205,346	9	$2,271,506	9	$2,339,651	7	$1,869,407	7	$1,925,489	74	$17,903,580
	10	$2,127,519	9	$1,958,096	8	$1,776,593	8	$1,829,890	8	$1,884,787	77	$16,347,624
	4	$732,323	4	$754,293	3	$575,057	3	$592,309	3	$610,078	31	$5,632,384
Total Project staff	26	$5,882,819	25	$5,826,055	23	$5,558,725	22	$5,516,274	22	$5,681,762	213	$48,373,455
											-	$-
											-	$-
Totals		$343,755,168		$335,876,235		$326,163,233		$52,835,005		$39,863,260		$1,662,521,236

Appendix B 1755-1850 MHz Propagation Analysis

1755-1850 Video TX
coverage Analysis coı

(Double click to open)

Appendix C 1675-1695 MHz Analysis

1675-1695 Video TX
coverage Analysis coı

(Double click to open)

Appendix D 2200-2290 MHz Analysis

2200-2290 Video TX
coverage Analysis coı

(Double click to open)

Appendix E 1435-1525 MHz Analysis

1435-1525 Video TX
coverage Analysis coı

(Double click to open)

Appendix F 2025-2110 MHz Analysis

2025-2110 Video TX
coverage Analysis coı

(Double click to open)

Appendix G 2360-2395 MHz Analysis

2360-2395 Video TX
coverage Analysis coı

(Double click to open)

Appendix H 4400-4940 MHz Analysis

4400-4940 Video TX
coverage Analysis coı

(Double click to open)

Appendix I LTE Operating Bands

From ETSI TS 136 101 V9.4.0 (2010-06)

5.5 Operating bands

E-UTRA is designed to operate in the operating bands defined in Table 5.5-1.

Table 5.5-1 E-UTRA operating bands

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) operating band BS transmit UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894MHz	FDD
6[1]	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	FDD
10	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	FDD
11	1427.9 MHz – 1447.9 MHz	1475.9 MHz – 1495.9 MHz	FDD
12	698 MHz – 716 MHz	728 MHz – 746 MHz	FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
15	Reserved	Reserved	FDD
16	Reserved	Reserved	FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	FDD
18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
19	830 MHz – 845 MHz	875 MHz – 890 MHz	FDD
20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
21	1447.9 MHz – 1462.9 MHz	1495.9 MHz – 1510.9 MHz	FDD
...			
33	1900 MHz – 1920 MHz	1900 MHz – 1920 MHz	TDD
34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
35	1850 MHz – 1910 MHz	1850 MHz – 1910 MHz	TDD
36	1930 MHz – 1990 MHz	1930 MHz – 1990 MHz	TDD
37	1910 MHz – 1930 MHz	1910 MHz – 1930 MHz	TDD
38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
Note 1: Band 6 is not applicable			

Appendix K Radiosonde Transmitter Parameters

Parameter	GPS Radiosonde Transmitter
Emission 3 DB Bandwidth (MHZ)	135KHZ
Tuning Range (MHZ)	Operates on four channels with center frequencies of 1676 MHZ, 1676 MHZ, 1680 MHZ, and 1682 MHZ
Power (Peak)(DBM)	23.8 (.2399 Watts)
Emission Spectrum Relative Attenuation (DB) as a function of Frequency Offset (MHZ)	36DB@.2MHZ 48DB@.4MHZ 52DB@.6MHZ 56DB@.8MHZ 58DB@1MHZ
Modulation	FSK
Duty Cycle(percent)	100
Data Rate (bit/s)	9600
Antenna Gain (main beam)(DBI)	4.3 (Vertical plane, pointed downward)
Azimuth Off-Axis Antenna Pattern (1)(2) (DBI as a function of off-axis angle in degrees)	Same as Elevation Pattern
Elevation Off-Axis Antenna Pattern(2) Antenna Gain(DBI) As a function of off-axis angle (degrees)	+2.9DBI@20 degrees +1.8DBI@40 degrees -0.4DBI@60 degrees -2.6DBI@80 degrees -4.4dbi@90 degrees
Antenna Height (meters)	1 to 33000 m
Antenna Polarization	Left Hand Circular
Antenna Horizontal Sector (degrees)	360
Antenna Down Tilt Angle (degrees)	90 Once launched, the antenna is pointing towards the earth
Cable, Insertion, or Other Losses (DB)	N/A

The radiosonde antenna is oriented in an earthward in vertical plane. The 0 degree angle is equivalent to -90 degrees for an antenna that is oriented horizontally. Angles above 0 degrees would have further gain reductions as it is in the backplane, which has not been measured, and are considered irrelevant as they would be pointing upward on a system that is airborne, thereby radiating away from earth-based stations and handsets.

Appendix J Technical Characteristics of Digital Video Systems

Parameter	**Value**
System	
Brief Description of System	DHS operates a nationwide system of covert portable and mobile video surveillance devices that support Federal law enforcement investigations and protection details. The system is used to investigate criminal activities, protect executive staff, and support joint operations during major national events. The system and is composed of multiple transmitters and receivers that collect, transport, and store video and audio evidentiary and intelligence information. The nature of the operations requires that the devices be highly concealable, portable, and be capable of rapid deployment.
Does System have multiple transmitters and/or receivers?	YES
System Deployment	
Geographic Area(s) of Operation. Indoor/outdoor operation? If applicable number of units/km^2	US&P operations both indoor and outdoor
Provide data below for each transmitter/receiver in system	
Transmitter	
Emission 3 dB Bandwidth (MHz) [i]	7.5021 MHz
Power (dBW) Peak[ii] Average	 Up to +30 dBm peak Up to +30 dBm average
Duty Cycle (%)	100 %
*Emission Spectrum[iii] (Relative Attenuation (dB) as a Function of Frequency Offset from Center Frequency (MHz))	See table below

Attenuation	Frequency Offset
20	4
33	5
34	6
36	7
37	8
39	9
41	10
43	11
45	12
46	13
48	14
50	15
51	16
53	17

	54 | 18 55 | 19
*Emission Roll-Off (dB/decade)	20 dB/decade
Antenna Gain (Mainbeam) (dBi)[iv]	2.15 dBi
Azimuth Off-Axis Antenna Pattern (dBi as a function of off-axis angle in degrees)[v]	0 dB
Elevation Off-Axis Antenna Pattern (dBi as a function of off-axis angle in degrees)	0 dB
*Polarization	Linear
Cable, Insertion, or Other Losses (dB) [vi]	N/A
Transmitter location(s) (lat/lon if fixed; geographic area of operation and altitude if airborne; geographic area of operation if land mobile)	Portable transmitters operating on a US&P basis
Transmitter antenna boresight pointing	NA
Transmitter antenna height (m)	Ground level (2M) and greater
Receiver	
Receiver 3 dB Intermediate Frequency (IF) Bandwidth (MHz)	Matched to TX bandwidth
*Receiver IF Selectivity (Relative Attenuation (dB) as a Function of Frequency Offset from Center Frequency (MHz))[vii]	Attenuation Frequency Offset 20 dB 10 MHz 60 dB >= 15 MHz
Receiver Noise Figure (dB) or Receiver Temperature (K)	4 dB
Antenna Gain (Mainbeam) (dBi)	2.15 dBi (dipole)
Azimuth Off-Axis Antenna Pattern (dBi as a function of off-axis angle in degrees)	Dipole characteristics
Elevation Off-Axis Antenna Pattern (dBi as a function of off-axis angle in degrees)	Dipole characteristics
Polarization	Linear
Cable, Insertion, or Other Losses (dB)	0.5 dB
Interference Criteria Interference to Noise Ratio (dB) *Signal-to-Noise-Plus-Interference (dB) Percentage of time that above criteria may be exceeded (%)	 -6 dB 0 %
*Interference Threshold (dBW)[viii]	Varies depending on receiver mode of operation, interference signal spectral characteristics, and measurement method. See endnote for additional information.
Receiver location(s) (lat/lon if fixed; geographic area of operation and altitude if airborne; geographic area of operation if land mobile)	Portable transmitters operating on a US&P basis for non-airborne missions
Receiver antenna boresight pointing	NA

Receiver antenna height (m)	2m or greater (limited by surrounding structures

* Optional: only provide if readily available

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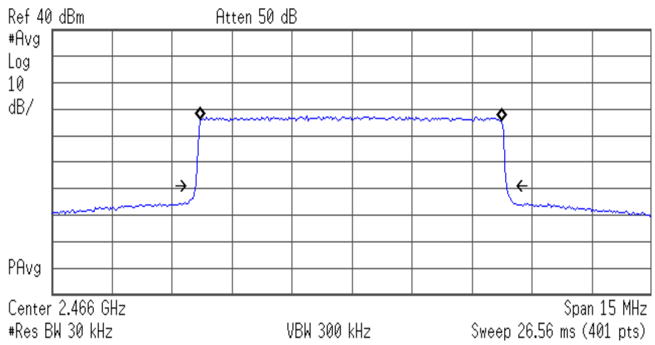
i Example of measured transmitter power spectral mask:



ii Transmitters operate on a continuous basis at power levels up to 1 watt. Modulation peak to average per COFDM sub-carrier would align with QPSK, 16QAM and 64QAM theoretical limits.

iii FCC required spectral mask

iv Antennas are dipole but in close proximity to conductive materials with potential to distort radiation pattern

v Antennas subject to operating at various angles depending upon application

vi Antenna integrated with transmitter

vii Receiver Selectivity values per vendor test specification.

viii Receiver threshold sensitivity -89 dBm QPSK mode, -83 dBm 16 QAM mode, and -77 dBm 64 QAM mode.

From Communication Receiver Performance Degradation Handbook (JSC-CR-10-004)

" **2.4.2.4 Subjective Performance Measures** Measures of signal power or BER do not directly address the quality of communication as perceived by users of the system. Some subjective performance measures have been defined that do address that quality of communication. ….. The Television Allocation Study Organization (TASO) score is a similar evaluation of television picture quality by a viewer panel…. It is possible to establish a correspondence between objective performance and subjective performance by extensive, careful testing and polling. It is very difficult, however, to extrapolate subjective test results beyond the parameter set used for the tests."