**Commerce Spectrum Management Advisory Committee (CSMAC)**
**Working Group 5 (WG-5)**

**1755-1850 MHz Airborne Operations**

***(Air Combat Training System,***
***Small Unmanned Aircraft Systems, Precision-Guided Munitions,***
***Aeronautical Mobile Telemetry)***

**Final Report**
**(9/16/2013)**

## 1. Introduction

The National Telecommunications and Information Administration (NTIA) through the Commerce Spectrum Management Advisory Committee (CSMAC) established five Working Groups (WGs) "to facilitate the implementation of commercial wireless broadband in the 1695-1710 MHz and 1755-1850 MHz band."[1] Each of the WGs was instructed to "explore ways to lower the repurposing costs and/or improve or facilitate industry access while protecting federal operations from adverse impact"[2] and tasked with producing "written outputs recommending to the CSMAC concerning approaches to sharing, transition and/or relocation of the band that will determine the steps that will have to be taken and any factors that may reduce the projected costs, or limitations or restrictions on spectrum availability."[3]

NTIA through the CSMAC established and tasked four Working Groups with evaluating sharing compatibility between the commercial LTE systems and Federal systems operating in the 1755-1850 MHz band; in particular, Working Group 5 was established to focus on the variety of Federal airborne systems operating in the 1755-1850 MHz band, with expected focus of work on "protection requirements for federal operations"[4] and "[u]nderstanding of periodic nature and the impact to commercial wireless of federal government airborne operations."[5] Because of the range of Federal airborne systems, WG-5 established four Sub-Working Groups (SWG)—SWG-1 Aeronautical Mobile Telemetry (AMT); SWG-2 Small Unmanned Aircraft Systems (SUAS); SWG-3 Air Combat Training System (ACTS); and SWG-4 Precision-Guided Munitions (PGMs) and other miscellaneous airborne systems. WG-5 and each of its SWGs included representatives from the Federal Government and industry (primarily representatives of wireless and other technology manufacturers, commercial wireless service providers and other stakeholders). This report summarizes the reports of the individual SWGs (which are attached in full as appendices to this report).

[1] NTIA "Framework for Work Within CSMAC", May 25, 2012, page 1
[2] Instructions to CSMAC Working Groups, June 28, 2012, page 1
[3] NTIA "Framework for Work Within CSMAC", May 25, 2012, page 2.
[4] NTIA "Framework for Work Within CSMAC", May 25, 2012, page 4.
[5] NTIA "Framework for Work Within CSMAC", May 25, 2012, page 4.

## 1.1 Executive Summary of All SWG Findings

The SWGs conducted analyses to assess the feasibility of commercial Long Term Evolution (LTE) mobile systems sharing the 1755-1850 MHz band with Federal airborne systems and made the findings that are summarized below and set forth in greater detail in the SWGs final reports attached as Appendices.

As an overall summary, Working Group 5's SWGs completed electromagnetic compatibility (EMC) analyses based on an approach and assumptions agreed to as a baseline at the WG-5 level; in addition, at the conclusion of the current SWG efforts, methods for refining the baseline analysis and possible interference mitigation techniques for follow-on efforts were proposed. All of the SWGs' studies, except those addressing PGMs, assumed a randomized real network laydown that was supplied by industry and agreed to be used at the WG-5 level for determining the aggregation of handset powers.[6] The PGM analysis employed a "grid approach", where the base station locations were assumed to be located in the regularized grid pattern that was provided by industry for use in determining LTE handset parameters and included in the LTE baseline technical parameters document provided by CSMAC WG-1.

The results of the SWGs' sharing analyses conducted thus far indicated that separation distances in the order of hundreds of kilometers would be necessary to ensure that Federal and commercial LTE systems would not cause harmful interference to one another. Based on the results of these analyses, several SWGs concluded that band sharing is problematic. In the next steps/path forward section (Section 1.3), WG-5 has compiled a list, developed at the SWG levels, of potential topics that could be researched and analyses that could be performed to refine the feasibility assessments should it be collectively determined that more investigation would be useful. DOD determined that certain DoD systems data could not be released because of the classification level and statute and executive orders requirements for protection of the information, which limited the ability to have fully interactive discussions and analysis between industry and government participants. WG-5 also notes that the CSMAC WGs are established under the CSMAC governed by the Federal Advisory Committee Act, which is focused on sharing all information within the committee publicly. It is also noted that all the WGs are open to anyone, including foreign nationals. The DoD CIO has informed the CSMAC that DoD, working with NTIA, FCC, and industry, have forged a mechanism for DoD to share sensitive but unclassified information with industry and for industry to share proprietary information with DoD to the extent practicable. The information sharing will commence with 12 industry selected individuals in accordance with Nondisclosure Agreements (NDAs) with DoD. DoD has signed the NDAs and industry is finalizing the signatures.

**ACTS:** The SWG ACTS conducted analyses to identify the protection distances for: (1) LTE user equipment (UE) to ACTS and (2) ACTS to LTE base stations. The separation distance requirements calculated for each location analyzed are summarized in Table 1

[6] The randomized real network laydown consisted of a carrier's actual nationwide base station locations that were shifted random distances up to one mile in a random direction.

below. Variations in base station antenna heights above ground level had small effects on the predicted required separation distances. WG5 did not make conclusions as to whether sharing arrangements between ACTS and LTE are possible based on the analysis results. Section 1.3 identifies a list of proposed potential items to refine the EMC analysis as well as potential alternative means to assess opportunities for sharing.

**Table 1. Summary of Protection Distances for ACTS**

| From UEs-to-ACTS Receivers[1] | | From ACTS Transmitters[1] -to-LTE Base Stations | |
|---|---|---|---|
| ACTS Site | Estimated Protection Distance (km) | Estimated Minimum Distance[2] (km) | Estimated Maximum Distance[3] (km) |
| Seymour Johnson AFB Ranges | 350 | 285 | 415 |
| NAS Key West Ranges | 325 | | |
| Nevada Test and Training Ranges (NTTR) | 375 | | |

[1] - Assumes ACTS platform can be anywhere on perimeter of range.
[2] -Assumes Base Station antenna is 180 degrees off-azimuth from ACTS range area with downtilt of 3 degrees.
[3] -Assumes Base Station antenna is zero degrees off-azimuth from ACTS range area with downtilt of 3 degrees

**PGM and Miscellaneous Systems:** The SWG PGM analyzed PGM and a wide variety of DoD airborne datalink systems. The two types of analyses performed for these systems were the DoD system receiver as potential victim of interference from LTE UEs and the DoD system transmitter as potential source of interference to LTE base stations. The estimated protection distances for the various DoD systems assessed in the SWG PGM effort are provided in Table 2 below:

**Table 2: Summary of Protection Distances for PGM and Miscellaneous**

| DoD System | Estimated Protection Distances[1] (km) | |
|---|---|---|
| | UEs to DoD Receiver | DoD Transmitter to LTE Base Station |
| PGM | 290 | 43 - 423 |
| TactiLink Eagle | Not applicable | 145 - 230 |
| JTRS AMF | 130 - 165 | 180 - 245 |
| Navy TTNT | 330 - 360 | 291 - 440 |
| Army/USMC TTNT | 350 (air), 25 (gnd) | 260 - 415 |
| LITENING CMDL | 80 - 300 | 40 - 280 |
| Sniper CMDL | 80 - 300 | Not applicable |
| Dragoon | 45 - 94 | 145 - 325 |
| VORTEX | 80 - 300 | 160 - 420 |
| ROVER | 5 - 30 | Not modeled – characteristics similar to CMDL |

[1]Distances are for the sites included in the assessment

Based on the results of the analyses, SWG PGM concluded that it is not feasible for LTE systems to share the 1755-1850 MHz band with these DoD systems within the sites and protection distances provided unless mutually agreeable technical and operational mitigation approaches are developed.

**SUAS:** The main goal of the SUAS SWG was to assess the Electromagnetic Compatibility (EMC) between the SUAS and the LTE equipment. Studies were considered of interference from LTE UEs to the SUAS receivers, both airborne and ground based, as well as the interference from the SUAS airborne emitters to LTE Base stations.

During the initial meetings between industry and DOD, industry representatives requested the following information about each SUAS system: (1) the frequency assignment; and (2) the location of the assignment. However, because of classification of the information, DoD was not able to publicly release the information (Paragraph 2.5.3 infra).

SWG SUAS conducted an analysis of co-channel operations to determine required separation distances between SUAS and commercial LTE operations. SWG SUAS focused on identifying the required protection distances for: (1) LTE UEs to SUAS and (2) SUAS to LTE base stations. The analysis modeled the LTE network using the randomized real aggregation provided by industry after discussions and agreement within the WG-5 technical working group whether to use randomized versus the grid network approach. It should be noted that variations in base station antenna heights above ground level had small effects on the predicted required separation distances. A summary of the separation distance results for the locations assessed is provided in Table 3 below.

**Table 3. SUAS Protection Distance Summary**

| SUAS Site | Predicted Protection Distance (km) | | Predicted Distance[2] (km) | |
|---|---|---|---|---|
| | From UEs-to-SUAS Receivers[1] | From UEs-to-GCS Receivers[1] | From SUAS Transmitters[1]-to-LTE Base Stations | From GCS Transmitters[1]-to-LTE Base Stations [3] |
| Eglin AFB | 100 | 40 | 235 / 215 / 160 | 90 |
| Dahlgren | 130 | 45 | 165 / 154 / 137 | 127 |
| Ft. Irwin | 100 | 45 | 190/170/140 | 150 |
| Twenty-Nine Palms | 120 | 25 | 155/138/95 | 125 |
| Bridgeport | 100 | 80 | 154/141/96 | 114 |
| Camp Pendleton | 110 | 140 | 153/138/95 | 130 |
| Charleston | 110 | 20 | 153/139/95 | 52 |

[1] – Assumes SUAS platform can be anywhere on the perimeter of the designated flight area at the sites.
[2] – Assumes the Base Station antenna is 0° /60° /180° off-axis from SUAS sites with a down tilt angle of 3°.
[3] – Assumes the Base Station antenna is pointed on-axis

**AMT**: The SWG AMT initiated analysis on two specific work plans to identify the protection distances for: (1) LTE UE to AMT ground station receivers and (2) AMT transmitters to LTE base stations. Based on an analysis of three representative sites, models and simulations were developed with the results being applicable to similar DoD AMT sites throughout the US. In accordance with the details and parameters identified in the appendices to the SWG AMT report, the computed protection distances are summarized in Table 4 below. The SWG AMT concluded that sharing between these two disparate applications is problematic given the significant geographic distances required to protect both services.

**Table 4: Summary of Protection Distances for AMT**

| **From UEs-to-AMT Receivers**[1] | | **From AMT Transmitters**[1] **-to-LTE Base Stations** | |
|---|---|---|---|
| AMT Site | Estimated Protection Distance (km) | Estimated Minimum Distance[2] (km) | Estimated Maximum Distance[3] (km) |
| Atlantic Test Ranges (at or near Patuxent River, Maryland) | >80 | 100 km from the AMT ground stations for the corresponding aircraft | >560 km from the same ground stations |
| Pt. Mugu | 140 | | |
| Eglin | >75 | | |

[1] **-** Specific antenna locations at the various sites are provided in the AMT SWG Report.
[2] - Assumes Base Station antenna is 180 degrees off-azimuth from AMT range area with downtilt of 3 degrees.
[3] Assumes Base Station antenna is zero degrees off-azimuth from AMT range area with downtilt of 3 degrees.

### 1.2 Summary of WG-5 Recommendations for Presentation to CSMAC

The following section summarizes the recommendations from WG-5. More detail on specific SWG recommendations can be found in the individual SWG reports (see Section 3).

1. The recently agreed-upon mechanism for release of sensitive but unclassified information regarding the Federal systems in the band to industry representatives and vice versa via an appropriate mechanism that ensures protection of the information needs to be implemented to enable both industry and government to have access to the same information for discussions to assess next step options.

2. If it is determined that it would be useful to refine the technical feasibility analysis the SWGs conducted, an evaluation of the topics for further study outlined in the next steps/path forward section (Section 1.3) should be undertaken to determine which items should be assessed.

3. Relocation of some of the federal airborne systems that cannot share with commercial users to alternative frequency band(s) will need to be considered. However, identification and consideration of impact (i.e., sharing, cost and system performance) of any particular bands for relocation of any system was not part of the scope of the WG.

### 1.3 Next Steps/Path Forward

The SWGs were able to identify a number of items for potential follow-up work and research, as well as "lessons learned" that can be considered for future assessments. The paragraphs below identify these items and observations as determined by each SWG. As a general matter, WG-5 has not prioritized the items below, and each would require further study to determine their feasibility as well as economic acceptability of the specific proposal.

As far as "lessons learned," the ACTS and AMT SWGs found that the creation of a small technical group to address the technical characteristics of the involved systems was very helpful. It provided the forum for detailed technical discussions by all interested parties, without requiring the involvement, or time and expense of commitment, of disinterested parties. The resulting technical information, in particular LTE characteristics, cumulative power distributions of ensembles of UEs, and guidance for the randomized real aggregation of base stations and UEs, were critical to the ability to perform more refined simulations.

**1. Possible Effects of Clutter and Terrain –**

The ground-to-ground analyses conducted in WG-5 took into account terrain effects via the features included in the Irregular Terrain Model (ITM) in conjunction with a USGS terrain database. The air-to-ground analyses, using ITU-R Recommendation P.528, did not take into account terrain effects. As discussed and agreed by WG5 at the outset of the work, clutter and terrain effects were not considered in any of the baseline interference analyses because timely agreement could not be reached on how they should be applied.[7] Whether to do so, and how to do so, in future analyses remains under discussion. In particular, additional study of the impact that clutter and terrain have on propagation, particularly in air-to-ground analysis, would provide greater confidence in the analysis and may impact protection distances.

To take into account terrain and clutter effects into the analysis, a validated model is necessary. The technical working group has been considering proposals to account for terrain and clutter effects including, a proposal to compare measured data of aggregation of power from LTE to the airborne systems with the model currently being used for the analysis to understand the difference in loss, understanding that such measurements must be based on the ground truth of what an actual LTE network deployment for the band would be and the actual airborne systems that operate in the band. That process was not concluded.

**2. Time-Based Sharing –** The commercial wireless industry presented information on proposed innovative spectrum sharing techniques (e.g., time-based sharing or real time monitoring via Licensed Shared Access) that could exploit the advanced features in the LTE standards to enable use of spectrum assigned to government users without impact to operations. These mechanisms have the potential to facilitate sharing by enabling commercial wireless licensees to dynamically relinquish their use of the shared spectrum with minimal impact to users in areas during times that government users are using the band. The proposal did not include the implementation details and would need further study. Both government and industry interests writ large should work together to further study these approaches, including providing as much information as practicable about the systems and operational aspects that are envisioned to share using such mechanism as well as the projected economically acceptable conditions, to determine feasibility of sharing without a negative impact to both government and commercial operations. This study should include the feasibility of the time-based sharing Licensed Shared Access regulatory construct. This study should also include the potential impact on government operations and proposed commercial operations in this band, and the implementation details on the real-time/near real-time information requirements for both government and commercial wireless licensees, whether it is via a database or some other secure means. Further, the study should consider the economic acceptability of the proposal.

**3. Effects of frequency off-tuning –** Frequency off-tuning would avoid co-channel operation of the commercial systems on channels the government systems are using. The implementation details of frequency off-tuning, via dynamic techniques (e.g., described in item 1 above) or static methods, to enable commercial use of the band while ensuring protection of federal operations and the magnitude of protection distance reduction would require study.

**4. Possible notches in wireless use of frequencies at selected locations –** Commercial wireless industry provided information on innovative spectrum sharing techniques that take advantage of advanced features in LTE technology to notch out a portion of an LTE UE uplink channel at times and locations when government agencies are using the spectrum. This mechanism could be used to avoid co-channel operation with potentially minimal impact on private sector users in cases where the government signals are narrow relative to an LTE channel. The implementation details of how the LTE technology would notch out spectrum to enable commercial use of the band while ensuring protection of federal operations and the magnitude of any reduction of separation distances due to notching requires study. Further, the economic acceptability of such sharing will also need to be considered. Requirements and mechanisms for coordination between government and commercial operations to facilitate notching should be developed if this approach is considered.

**5. Consideration of different interference threshold based on the desired signal to noise plus interference level desired rather than defining interference as a rise in the noise floor –** Current WG-5 analysis uses long-standing interference criteria established by the ITU. While there is no desire to modify the internationally accepted criterion, the wireless industry believes that the study of interference relative to a desired carrier taking into account actual system operations would be beneficial to understand how government and LTE systems would interact in a shared environment with close coordination between users, and believe that could significantly reduce required separation distances. DoD asserts that airborne systems often operate at maximum range from their ground stations, and hence the corresponding receivers are operating under noise-limited conditions. DoD believes that the current interference criteria are appropriate for all the systems that are operating in the band. Further, DoD believes that any consideration of changes in interference protection criteria (IPC) on a system by system basis is risky and inappropriate. This is because IPCs are developed over a long period of time to ensure that protection criteria are based on underlying physical phenomena rather than on short-term technological specifications of individual systems. As a result, these long standing IPCs successfully form the basis for many national and international spectrum use agreements, including allocation and reallocation decisions, despite the often rapid evolution and improvement of new and incumbent systems.

**6. UE Antenna Height and Network Loading –** In the LTE Baseline document, the WG-1's LTE parameters document defined the antenna height for UEs to be 1.5 meters above ground level and the WG-5 analyses were completed using this height. In a realistic deployment, a number of UEs in urban and rural environments could be at different heights above ground level. For follow-on analysis to refine the protection distances, it may be necessary to define and agree on a realistic range of antenna heights, above and beyond the data provided by WG1, for urban and rural environments. Appropriate UE power distribution functions should be used for the assumed UE heights. The analysis also assumed 100 percent network loading for the LTE systems, per the WG1 LTE technical parameters document. Industry notes that they provided a 100% network loading assumption as a way forward because timely agreement could not be reached on applying more realistic loading. Therefore, industry has expressed the view that the assumption does not represent the actual loading of an LTE network. As analysis is refined, industry agreement will need to be reached on how to apply realistic parameters for network loading and operation.

**7. Consideration of government assignment information and the potential to prioritize access to markets prioritized by commercial wireless industry –**The wireless industry has proposed consideration of making government frequency assignments in a way that minimizes impact to markets prioritized by the commercial wireless industry, which has the potential to improve the economic viability of sharing for commercial users. However, some of the federal operations are right on top of the market areas industry has prioritized; therefore such an approach could have an adverse impact on the ability of the federal agencies to meet their missions. For this technique to be effective, the Government would need to determine the feasibility and cost of moving frequency assignments in high-priority commercial markets, which will need to consider the potential requirement for comparable spectrum to move federal operations to where it is not feasible to move frequency assignments within the existing 1755-1850 MHz band in order to provide commercial access to high-priority markets with no impact to federal operations. NTIA and/or the FCC would need to make available the additional comparable spectrum for federal use. This proposal would need further study to understand its feasibility and implications.

## 2. Organization and Functioning of the Working Group

### 2.1 Organization of WG-5

The leadership of WG-5 was composed of the following members:

**Co-Chairs**

Fred Moorefield, Air Force Spectrum Management Office (AFSMO) (prior to October 2012)
Col. Donald Reese, AFSMO (since October 2012)
Sanyogita Shamsunder, Verizon

**CSMAC Member Liaisons**

Jennifer Warren, Lockheed Martin
Bryan Tramont, Wilkinson Barker Knauer LLP

**CSMAC Member Participants**

Tom Dombrowsky, Wiley Rein LLP
Kevin Kahn, Intel
Michael Calabrese, New America Foundation
Mark Gibson, Comsearch
Mark McHenry, Shared Spectrum
Janice Obuchowski, Freedom Technologies
Carl Povelites, AT&T

**NTIA Point of Contact**

John Hunter, NTIA (until March 2013)
Gary Patrick, NTIA
Renae Carter, NTIA

**FCC Representatives**

Mark Settle, FCC
Michael Ha, FCC
Chris Helzer, FCC
Janet Young, FCC

## 2.2 Participation in WG-5

WG-5 enjoyed broad participation by government and industry representatives. A full list of the membership is attached to this report. Because WG-5 was tasked with developing recommendations regarding a diverse group of airborne operations, WG-5 was divided into four SWGs as described above.

## 2.3 Work Plan

The expected focus of WG-5's work was to perform interference analysis in both directions, government systems to LTE and LTE to government systems to determine separation distance requirements to protect both LTE and government operations. Individual work plan items were delegated to the SWGs and are outlined in the individual SWG reports.

### 2.4 Functioning of WG-5

WG-5 meetings were held on a bi-weekly basis, as necessary, with broad participation by government and industry representatives. The majority of meetings were conducted via conference call; however, the WG also had several face-to-face meetings.

WG-5 was also divided into four SWGs as described above. Each SWG held its own meetings. Like WG-5, each SWG met biweekly or as needed, typically via conference call. On many occasions, SWGs took advantage of opportunities to hold their own face-to-face meetings that coincided with the face-to-face meetings of the larger WG-5. Each SWG had its own co-chairs and FCC/NTIA liaisons.

## 2.5 Abstracts of SWG Reports

### 2.5.1 Air Combat Training System (ACTS)

The SWG conducted analyses to: (1) assess distances required to protect ACTS receivers from UEs; and (2) assess distances required to protect LTE base stations receivers from ACTS operations. The analyses were cooperative efforts between DoD and commercial wireless interests as technical information for both systems were required to perform this effort. The analysis was performed by Alion Science and Technology (Alion) utilizing Visualyse modeling tool, as agreed by WG5. The analysis report provides a high-level description of a technical assessment of the impact of co-channel operation in the 1755-1850 MHz frequency range between current incumbent ACTS units and LTE systems. As agreed by WG5, the analysis considered three representative ACTS locations in the continental US: (1) Seymour Johnson AFB, NC, (2) NAS Key West, Key West, FL, and (3) Nellis AFB, Las Vegas, NV. The SWG recognized that a number of alternative analysis tools are available and that independent analyses may be valuable, but agreed to proceed with use of Visualize for the analysis. The analysis took into account assumptions and methodologies agreed to by WG5. Further analysis using refined assumptions about system and environmental configurations may be warranted if interest in sharing continues, and is reflected in the items identified in section 1.3 of this report for consideration for potential future analysis.

### 2.5.2 Precision-Guided Munitions (PGM) and Miscellaneous Systems

The required separation distances of LTE systems sharing the 1755-1850 MHz band with each DoD system evaluated by SWG PGM was determined by performing analyses of potential interference between LTE systems and the DoD systems.

Two different types of analyses were performed: the DoD system receiver as potential victim of interference from UEs, and the DoD system transmitter as potential source of interference to LTE base stations.

#### 2.5.2.1 UE Transmitters to DoD Receiver

For the analysis of potential interference from UEs to a DoD receiver, locations for urban/suburban and rural base stations were defined. For the PGM analyses, the base station locations were assumed to be located in the regularized grid pattern that was provided by industry for use in determining LTE handset parameters and included in the

LTE baseline technical parameters document provided by CSMAC WG-1. For all the other systems considered in the analyses, the locations were from a commercial wireless industry-provided randomized real network laydown.

At each base station location, UE transmitters were assumed to be positioned at the coordinates of the base station with an antenna height for each UE of 1.5 m AGL.

The undesired received power at the DoD receiver due to each UE was computed as follows. A random value for the EIRP of each UE transmitter was determined from cumulative distribution function data in the LTE baseline document for all studies except for the PGM study where EIRP was modeled as fixed mean values: -3 dBm urban, 8 dBm rural (statistical output power not used). The propagation loss along the path between antennas was evaluated using an appropriate model agreed to by WG5: Recommendation ITU-R P.528-3 for ground-air paths or Recommendation ITU-R P.452-14 for ground-ground paths. Receiving system data was either based on measured data or was obtained from the DD Form 1494, Application for Equipment Frequency Allocation (also known as the J/F-12) for the system. The frequency dependent rejection (FDR) of the UE signal due to the bandwidth of the receiver IF stage was computed using the ratio of the transmitter and receiver bandwidths.

The analysis was many-on-one where the sources consisted of the collection of UE transmitters, and the level of aggregate undesired received power was calculated by summing the individual received power values in Watts, and then converting the value into dBm or dBW.

For each receiver, a threshold interference to noise (I/N) ratio of -6 dB was selected as the value for which operational impact to the receiver would be minimal. The aggregate I/N in dB was computed by subtracting the receiver system noise level from the aggregate undesired received power, both in dBm or dBW.

The protection distance is the minimum distance between a DoD system receiver and the laydown of UEs at which interference to the DoD receiver would not be expected to occur. For each location of the DoD system receiver, the protection distance between the receiver and the laydown of UEs was determined iteratively so that the predicted aggregate I/N was approximately equal to the threshold I/N. Plots of predicted results were generated where the urban/suburban and rural LTE locations were depicted along with the protection distance for each DoD receiver location.

#### 2.5.2.2 **DoD Transmitter to LTE Base Station Receiver**

The analysis of potential interference from a DoD system to an LTE base station receiver was essentially the same as that described above except that the analysis was one-on-one (i.e., the DoD system transmitter to one LTE base station receiver). The analyses were done for the same specific locations that were considered for the UEs to the DoD receiver analysis.

The undesired received power and the I/N for the LTE BS receiver due to each DoD system transmitter was computed in a fashion similar to that described previously, with the following differences. The EIRP for the DoD transmitter was set to the maximum with system loss at the transmitter (e.g., cable loss, insertion loss, etc.) included where appropriate. The bandwidth for the LTE base station receiver was set at 10.0 MHz. Receiver system loss was 2 dB from the Baseline LTE document. The FDR of the DoD systems signal due to the bandwidth of the receiver IF stage was computed using the ratio of the transmitter and receiver bandwidths. The base station sectoral antenna off-axis angle was defined as the difference between the azimuth angle for an antenna's maximum gain and the azimuth angle for the transmitter-receiver path. The analyses were performed for several antenna off-axis gain values. Given parameters from the WG1 LTE Baseline document, off-axis gain values for the LTE base station sector antenna were obtained using a model of the antenna.

A color-coded contour representing the transmitter-receiver distance at which the I/N at the LTE receiver is equal to the I/N threshold (e.g., -6 dB) was generated and plotted. This contour represents the protection distance within which interference to LTE base station receivers would not be expected.

Recommendations can be found in the PGM SWG Report.

### 2.5.3 **Small Unmanned Aircraft Systems (SUAS)**

The main goal of the SUAS SWG was to assess the Electromagnetic Compatibility (EMC) between the SUAS and the LTE equipment. Studies were considered of interference from LTE UEs to the SUAS receivers, both airborne and ground based, as well as the interference from the SUAS airborne emitters to LTE Base stations. The analysis considered seven locations within the US where the SUAS typically operates in an urban environment. The locations were: (1) Fort Irwin (NTC), CA, (2) Twentynine Palms, CA, (3) Eglin AFB, FL , (4) Dahlgren, VA, (5) Bridgeport, CA, (6) Camp Pendleton, CA, and (7) Charleston, SC. The analysis was performed by Alion using the Visualyse modeling tool, as agreed by WG5.

### 2.5.4 **Aeronautical Mobile Telemetry (AMT)**

The AMT Sub Working Group performed EMC analyses to: (1) assess distances required to protect AMT receivers from the emissions of the aggregation of LTE UEs; and, (2) assess distances required to protect LTE base station receivers from telemetry transmissions of AMT flight test aircraft.

The studies considered EMC of the LTE UE with respect to emissions into the AMT ground station receivers, and the EMC of the AMT airborne emitters into LTE Base Station receivers, for three sites, as agreed to by WG5, thought to be representative of the large trade space for the entire country. A summary of the observations is noted in the full AMT SWG Report at Table I and described in greater detail there.

Protection levels for AMT ground stations are those defined in ITU-R M.1459. Protection levels for LTE base stations were provided by the WG-1 technical working group.

Operating characteristics for airborne AMT transmitter systems are those provided in Recommendation ITU-R M.1459. Operating characteristics of LTE UEs are those developed by the technical WG-1 working group. Table 1 of the AMT SWG Report provides a summary of the results of the corresponding analyses and simulations.

## 3. Appendices

### 3.1 ACTS SWG Final Report

### 3.2 PGM SWG Final Report

### 3.3 SUAS SWG Final Report

### 3.4 AMT SWG Final Report

## 4. Full Participant Lists for WG-5

Attached as Attachment 1.

## 5. Web Location of Archival Documents/Exhibit