Commerce Spectrum Management Advisory Committee (CSMAC)
Working Group 5 (WG 5)
1755-1850 MHz Airborne Operations

Air Combat Training System Sub-Working Group Report

FINAL

1. Introduction:

The Commerce Spectrum Management Advisory Committee (CSMAC) Working Group structure was created to explore ways to lower the repurposing costs and/or improve or facilitate commercial wireless industry access while protecting federal operations from adverse impact. Working Group 5 (WG-5) was specifically tasked with studying issues related to airborne operations in the 1755-1850 MHz band. Within WG-5, Sub-Working Group Air Combat Training System (SWG P5 ACTS) was created to focus on issues related to ACTS operating in the band. Pursuant to the working group structure provided by National Telecommunications and Information Administration (NTIA), the expected focus of work for WG-5 would be the 1) determination of protection requirements for federal operations, and 2) understanding of nature and the impact to commercial wireless of government airborne operations.

Based on this guidance, the SWG P5 ACTS met on a biweekly basis, or as required, to develop a common understanding between government and industry regarding the operations and protection requirements for ACTS and to agree on and execute an approach for analyzing the potential for interference both to and from ACTS and commercial 4G Long Term Evolution (LTE) operations. This analysis is intended to form a basis for a recommendation on the feasibility of spectrum sharing and on steps that should be taken, or areas for further analysis, to facilitate sharing if it is determined that sharing appears feasible.

Work was initiated based on information in the NTIA Fast Track report However, significant additional work was accomplished by Government representatives to review the applicable government operations and ensure that the areas of operation and channel assignments were accurate, although none of this information was released to the SWG so it could not be used to inform the discussions within the SWG. The SWG also used information developed in a Technical Committee created as part of WG-1 to provide accurate information on LTE parameters. Finally, the SWG P5 ACTS was also informed by the WG-5 Technical Committee, created as part of WG-5 to consider technical issues related to interference analysis. The SWG ACTS enjoyed broad participation from a range of government and industry representatives. Work was limited to completion of worst case interference analysis for three sample locations; however, there are a significant number of P5 ACTS locations throughout the US, Reference

Appendix 3. As described in this report, a number of proposals have been made and are under consideration to revise and refine the analysis to better understand when harmful interference would occur. Such refinement would allow for a more accurate assessment of sharing opportunities. In addition, because information on channel assignments or more detailed use of ACTS was not provided to the SWG, no consideration of or discussion of methods to cooperatively facilitate sharing have occurred – either on a time basis, arrangement of channel use to meet the needs of both industry and government or other dynamic methods to facilitate sharing. Consideration of assignment information and related discussions would be highly relevant to meeting the goal of CSMAC to "explore ways to lower the repurposing costs and/or improve or facilitate commercial wireless industry access while protecting federal operations from adverse impact." Such information and analysis could have informed consideration of a process to prioritize access to the 1755-1780 MHz portion of the band while ensuring that federal agencies are not adversely impacted. The worst case analysis completed by the group provides only minimal information towards sharing arrangements and is insufficient to fully assess opportunities without additional work.

1.1 Executive Summary of Findings:

The SWG P5 ACTS initiated analysis on two specific work plans to identify the protection distances for: (1) user equipment (UE) to ACTS and (2) ACTS to LTE base stations. Using the randomized real aggregation approach, the overall protection distances observed extend beyond 325 km for the UE to ACTS environment. However, LTE base stations, the protection distances were slightly less but extended to 285 km and beyond depending on the orientation of the base station antenna. It should be noted that variations in base station antenna heights above ground level had small effects on the predicted required separation distances.

1.2 Summary of Observations/Recommendations for Presentation to CSMAC:

The SWG P5 ACTS has performed an analysis of two work plans to determine protection distances for both the UEs to ACTS and ACTS to the LTE base stations based on worst case analysis. To not interfere with P5 ACTS while sharing spectrum, the UEs must restrict its coverage area over which the LTE services are provided. The resulting studies described herein are based on the data noted in Table 1.2, and it appears that sharing may not be feasible without operational and economic impacts to both Government and the commercial wireless industry. However, additional studies may be required to provide a more definitive result, reference paragraph 1.4 below.

From UEs-to-ACTS Receivers[1]	From ACTS Transmitters -to-LTE Base Stations[1]

ACTS Site	Estimated Protection Distance (km)	ACTS Site	Estimated Minimum Distance[2] (km)	Estimated Maximum Distance[3] (km)
Seymour Johnson AFB Ranges	350	Seymour Johnson AFB Ranges		
NAS Key West Ranges	325	NAS Key West Ranges	285	415
Nevada Test and Training Ranges (NTTR)	375	NTTR Ranges		

Table 1.2 Summary of Protection Distances

[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

The above observations were presented to WG-5 for consideration. All comments submitted were reviewed with a response being provided to the initiator.

1.3 Next Steps/Path Forward

1.3.1 Post Report Items: If sharing opportunities are to be fully understood, additional study efforts are required to address the outstanding issues as noted in paragraph 1.4 below. In addition, consideration of assignment information and cooperative mechanisms for sharing would be necessary. However, at this time, further studies may be impacted by budget limitations driven and the final decision to proceed will be dependent on the Defense Budget if enacted by Congress and Administration and Congressional priorities.

1.3.2 Lessons Learned: The creation of a small technical group within WG-5 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 commitment, of disinterested parties. The resulting technical information, in particular LTE characteristics, cumulative power distributions of ensembles of user equipment, and guidance for the randomized "lay-down" of base stations and user equipment, were critical to the ability to perform accurate simulations.

1.4 Promising Opportunities for Future Studies

The SWG P5 ACTS determined there are other possible areas of consideration that could be studied by the P5 ACTS. The following are a list of possible topics identified by the Sub Working Group that may warrant additional study:

1. **Effects of off-tuning of the LTE base station to the P5 ACTS FO –** Off tuning would avoid direct co-channel operation. Commercial wireless industry presented information on innovative spectrum sharing techniques that could exploit the dynamic nature of Government use of spectrum and the advanced features in the LTE standards. These mechanisms would enable commercial wireless industry licensees to dynamically relinquish use of spectrum with minimal impact to users in areas and during times that government users are operating. The economic acceptability of such sharing will depend on the amount of time and the areas impacted. Accordingly, study should include mechanisms to minimize the amount of time and area when a channel would need to be cleared for government operations.

2. **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 channel at times and locations when government agencies are using the spectrum. This mechanism could be used to avoid co-channel operation with minimal impact on private sector users in cases where the government signals are narrow relative to an LTE channel. As with the previous item, the economic acceptability of such sharing will depend on the amount of time and the areas impacted and an effort would be needed to minimize the amount of time and area when a channel would need to be notched to accommodate government operations. This could include real-time monitoring to limit impact to times when government systems are operating rather than scheduled.

3. **Consideration of different interference threshold based on desired signal level desired rather than merely 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 this internationally accepted criterion, 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 could significantly reduce any exclusion or protection zone required.

4. **Possible effects of clutter and terrain –** Current WG-5 analysis does not take into account the effects of clutter and terrain. Greater 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 have the potential to significantly impact protection distances. A proposal under consideration from the technical working group would be to compare measured data to the results of analysis.

5. **Consideration of ACTS assignment information and the potential to prioritize access to markets prioritized by commercial wireless industry –** Prioritizing ACTS assignments in a way that minimizes impact to markets prioritized by commercial wireless industry has the potential to improve the economic viability of sharing while continuing to meet government requirements.

It should be noted that recommendations on a number of these issues have been made in the Technical Working Group and are under consideration.

2 Organization and Functioning of the Sub-Working Group

2.1 Organization and Participation of Sub-Working Group

2.1.1 The SWG P5 ACTS was created under the auspices of WG-5, taking overall direction from the WG-5 Co-chairs. The following were key participating members of the Sub Working Group.:

Co-chairs
- Mr. Joe Giangrosso – Alion Science for DoD
- Mr. Steve Sharkey – T-Mobile USA

Co-Chair Assistant
- Ms. Nena Sandhu, Cricket Communications

FCC Liaisons
- Mr. Mark Settle
- Mr. Michael Ha
- Mr. Chris Helzer
- Ms. Janet Young

NTIA Liaison
- Ms. Renae Carter

P5 ACTS Operational Representatives
- Mr. Thomas O'Reilly (USAF)
- Mr. Patrick Mulligan (USN)

Interference analysis was conducted by:
- Mr. Robert Martin, Alion Science

SWG Report Writing Team
- Mr. Joe Giangrosso – Alion Science for DoD
- Mr. Steve Sharkey – T-Mobile USA
- Ms. Nena Sandhu, Cricket Communications
- Mr. Robert Martin, Alion Science

2.2 Participation: The SWG enjoyed broad participation by government and industry representatives. A full list of the membership is attached, Reference Appendix 1.

2.3 Work Plan

The work plan includes the elements as described below:

1) Overview of ACTS operation and LTE system operation: Government participants provided an overview of the ACTS mission, operations and technical requirements. Industry participants provided an overview of LTE technology and operation.

2) Review of Government Assignments and Operations: Government participants undertook a review to validate and update frequency assignments reflected in the Government Master File (GMF) and were able to eliminate approximately 28% of the records. Updated records have not been made available to the SWG or to industry. Some parts of the information could help to clarify sharing and use requirements if made available.

3) Review of impact to top 100 Cellular Markets: Commercial wireless industry provided a priority list of the Top 100 Cellular markets by population, which have the greatest demand for broadband services and are a priority for gaining access to spectrum. Government participants compared channel assignments and operations to better understand the impact to these markets. This analysis has not yet been released to the SWG and remains under DOD review. Such analysis could facilitate development of sharing options if made available to the SWG for consideration.

4) Analysis locations: ACTS operations take place at a number of locations within the continental US. DOD Services identified three locations to be assessed in this effort. These locations consisted of Warning Area W-122 and the Dare Count Range associated with Seymour Johnson Air Force Base (AFB), NC; Warning Areas W-174 and W-465 associated with Naval Air Station (NAS) Key West, FL; and the Nevada Test and Training Range (NTTR) associated with Nellis and Creech Air Force Bases, NV. A range of operating altitudes was also provided for each of the three training locations to be assessed. A summary of the altitude data provided is shown in Table 2-1 below.

ACTS Base	Associated Training Ranges	Nominal Aircraft Altitudes (ft)
Seymour Johnson AFB	W-122 and Dare County	W-122 – 500 to 50,000
		Dare County – 500 to 18,000
NAS Key West	W-174 and W-465	Both ranges – 500 to 50,000
Nellis AFB	NTTR	Surface to 50,000

Table 2.1 Ranges and Altitudes of Assessed ACTS Locations

2.4 Functioning

The P5 ACTS SWG meetings were held on a bi-weekly basis with broad participation by government and industry. The majority of meetings were conducted via conference call; however, the SWG took advantage of opportunities for face-to-face meetings that coincided with face-to-face meetings of WG-5. Between meetings, P5 ACTS representatives worked as a team to develop and review the work product presented to the industry representatives. Despite individuals being spread across the United States, the teamwork was effective and efficient, with quick turnaround or results, and a minimum of travel expenses.

2.5 Abstract of Sub-Working Group Report

The P5 ACTS SWG originally developed three work plans for this analysis. These included analyses to (1) assess distances required to protect ACTS receivers; (2) assess applicability of the required distances for all ACTS sites, and (3) assess distances required to protect LTE base station receivers for P5 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 main goal was to assess the Electromagnetic Compatibility (EMC) between the P5 ACTS and the LTE equipment. The study considered the EMC of the LTE UE to the P5 ACTS receivers, both airborne and ground-based and the EMC of the P5 ACTS airborne emitters to LTE base stations. The DOD used the technical parameters provided to determine the EMC effects. The modeling effort was performed by the Visualyse Model technology through Alion Science and Technology for the purpose of these assessments. 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 described in referenced documents. 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 assessment was made principally using the Visualyse automated analysis software. We recognized that a number of alternative analysis tools are available and independent analyses may be valuable. A number of assumptions were made in performing the assessment and in almost all cases such assumptions represented worst-case system and environmental configurations. Further analysis using less conservative assumptions may be warranted if interest in sharing continues. Table 2.2 below is provided as a summary of initial suggested protection distances based on the worst-case analysis for the representative ACTS locations considered and analyzed.

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

Table 2.2 Summary of Initial Distance Assessment

[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.

3 Work Plan (Tasks and Objectives)

3.1 Work Plan Item 1 and Observations/Recommendations: RF Interference Analysis of UEs to P5 ACTS System, to include the airborne ACTS receiver and the ACTS Remote Range Unit (RRU).

3.1.1 Objective:

The overall objective of this Work Plan Item was to assess the EMC of the LTE UE handset environment to the P5 ACTS receivers, whether airborne or ground-based. This effort would provide observations as to the typical distances required to protect P5 ACTS receivers. In order to assess these distances, we selected three P5 ACTS operating sites that are typical urban scenario driven sites to best obtain the needed data for an overall analysis. The technical information of the P5 ACTS is noted in Appendix 2 and the LTE information is noted in Appendix 5. The main scope of this work plan was to provide an observation as to the initial estimated Protection Distance assessment of UEs to the P5 ACTS at each of the three selected sites; (1) Seymour Johnson AFB, NC, (2) NAS Key West, Key West, FL, and (3) Nellis AFB, Las Vegas, NV.

3.1.2 Technical Approach:

The technical approach for this work plan item is to consider the effects of the P5 ACTS receiver as an interference victim. In performing this analysis, the following are the assumptions for this analysis:

The P5 ACTS technical data for the P5 ACTS was derived from the P5 CTS white paper, Reference Appendix 2, and J/F-12/07971/4 certification document. The LTE and UE technical information data was provided by Working Group One (WG-1), Reference Appendix 5.

1. Assess three designated P5 ACTS ranges noted as being typical training site.

2. Assess a single aircraft within the range.

3. Assess a single RRU within the range.

4. The UE transmit power modeled using urban and rural Cumulative Distribution Function (CDF)

5. UEs modeled as being physically located at the base of urban/rural base station (three per UE carrier frequency at each base station)

6. UE geographic distribution according to “randomized” real network

7. UE interference modeled as a single 1.67 MHz UE emitter per sector base station

In addition to the parameters, we used a standard interference power calculation formula for determining the interference power at the victim receiver antenna output which was modeled into the program. The interference power calculations were calculated by the Visualyse automated software tool with the following parameters:

1. UE power was set not exceed 20 dBm

2. Propagation loss calculated using ITU-RP.528 for air to ground interactions

3. Clutter was not considered

4. Longley-Rice and terrain data used for ground/ground interactions

5. Additional P5 ACTS receiver system loss of approximately 2 dB for cable loss

6. Base station cable, insertion, and other receiver losses assumed at 2 dB

7. Only on-tuned cases were considered

Technical parameters for the LTE equipment are provided in Appendix 5. Several items are noteworthy; the LTE baseline document provides a description of the geographic distribution of LTE base stations as being in a grid pattern with separate and distinct grids for urban and rural environments. However, during the course of the ACTS assessment, the Comsearch Company (engaged to provide “spectrum management and wireless engineering solutions to the global market for fixed, mobile, and broadband wireless applications”) developed a different distribution following agreement among commercial wireless industry representatives to provide a distribution based on an actual network configuration of a major carrier as deployed in an adjacent band. The distribution consisted of a national laydown of carrier base stations whose locations as defined by their latitudes and longitudes had been slightly altered in a random fashion. In the analysis described here, UEs were associated with base station locations provided by Comsearch and separated into urban and rural groups according to their base station location with respect to urban centers. The top 100 US urban centers were identified and the latitude and longitude of each urban center was used to define a 30 km radius about each city. UEs within such a radius were considered urban UEs and their EIRP in all Visualyse simulations were defined according to the urban UE cumulative distribution function (CDF) in Appendix 5. Similarly, any UE outside a 30 km radius of an urban center was assigned an EIRP as defined by the rural UE CDF in Appendix 5.

Network loading was not considered in the simulations performed for this assessment. That is, for each simulation step, any active UE that represented a possible interference source was considered to be radiating during the entire simulation, resulting in 100% network loading. It is recognized that this represents an extreme worst-case assumption that may be reviewed if further analysis is pursued.

Generally in the assessments done for WG-5 it was assumed that six UEs, evenly spaced in frequency, operated in a single 10 MHz LTE channel as stated in Appendix 5. A single UE channel was taken to be 1.67 MHz wide. Each base station was assumed to have three sectors and each sector contained a UE on each of the six UE frequencies. UE antenna height was 1.5 m. For the ACTS assessment, the 3 dB second IF bandwidth of an ACTS receiver is less than the bandwidth of a single UE, consequently, for all of the ACTS scenarios examined, the worst case occurs when a single UE is co-tuned with an ACTS receiver. As such, all ACTS receiver simulations were performed with each base station in the associated environment having three UEs, rural or urban, co-tuned with the ACTS receivers being analyzed.

Once the model was ran and the data provided, we reviewed the calculated interference power and compared it to the receive system interference threshold of the P5 ACTS. The interference power calculated for positions of simulated flight paths around operation area boundaries and locations of the RRUs were reviewed to develop the protection areas based on the I/N of -6dB required threshold for the P5 ACTS. This data is noted below as part of our observations.

3.1.3 Observations/Recommendations

The Visualyse tool was used to predict the interference power levels at ACTS receivers from UEs in the common environment. An analysis was performed for each ACTS operating area identified in table 2.2 above. In each analysis, ACTS receivers were placed at points on the edges of the operating areas that represent points of closest approach that an aircraft, operating with the designated training area, might encounter an electromagnetic environment generated by introduced LTE base stations and UEs. ACTS altitudes were set at a nominal 10,000 meter height above sea level except for the points associated with Dare County which were set to 5,500 meters. These flight altitudes were selected as a representative mean altitude. Additionally, the protection distance is directly related to flight altitudes and by varying these altitudes, the protection distances would vary. The LTE environment was defined by selecting base station locations within at least 500 kilometers of each ACTS location in a simulation. Figures 3.1 through 3.3 show the configurations of ACTS systems and LTE base stations for the ACTS facilities. It should be noted that the radio horizon for an ACTS antenna at 10,000 meters for a smooth 4/3 earth is approximately 412 kilometers.

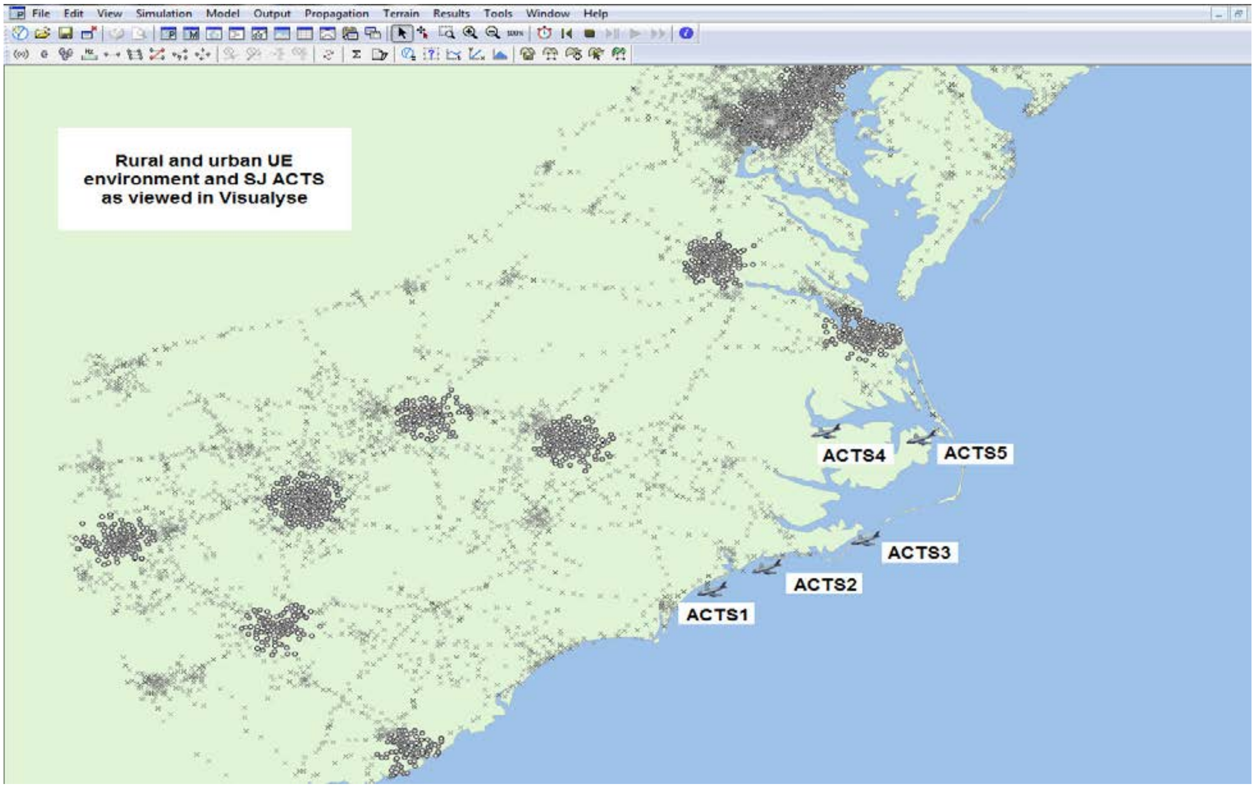

Figure 3.1. Seymour Johnson AFB environment as configured in Visualyse.

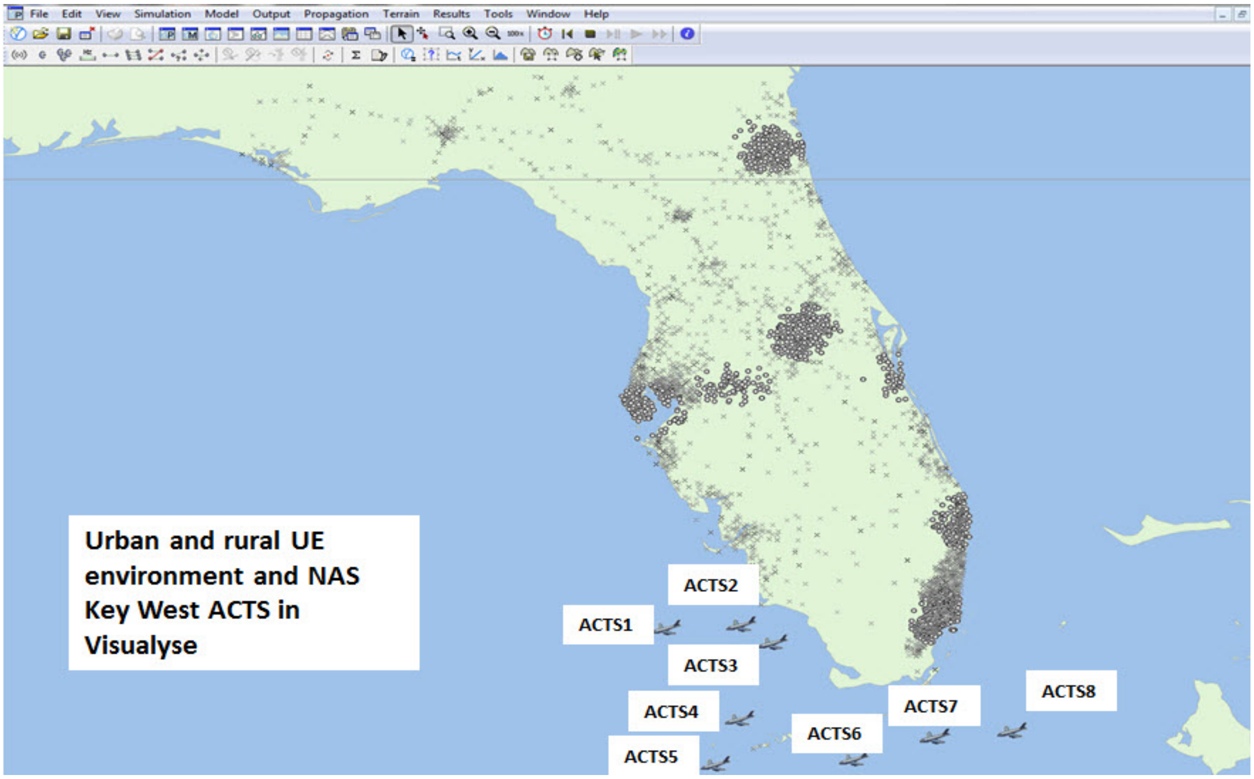

Figure 3.2. NAS Key West environment as configured in Visualyse.

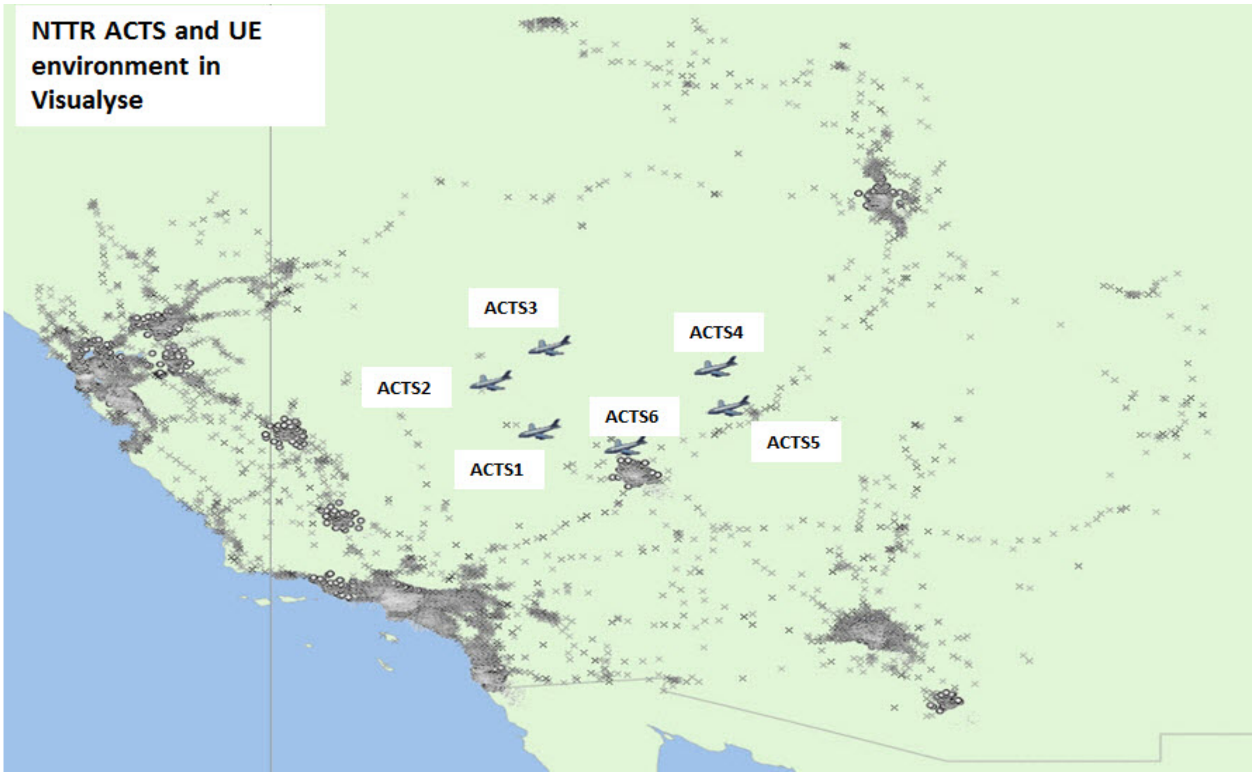

Figure 3.3. Nellis AFB environment as configured in Visualyse.

The interference power from a single UE at an ACTS receiver is calculated using Equation 1 below.

$$I = Pt + Gt + Gr - Lp - Lsys - OTR \quad (1)$$

Where,

I = Interference power at the input to the ACTS receiver (dBm)

Pt = UE transmitter power (dBm)

Gt = Transmitter antenna gain in the direction of a victim receiver (dBi)

Gr = Victim receiver antenna gain in the direction of the interferer (dBi)

Lp = Propagation loss (dB)

Lsys = Receiver system loss (dB)

OTR = On-tune rejection (dB)

The sum of Pt and Gt represent the EIRP of a UE. Possible values of UE EIRP are defined by the CDF curves provide in the LTE baseline document. In the Visualyse simulations, each base station location has three UEs associated with it representing the three sectors of the base station. Further, because of the large number of UEs in the simulations the three UEs at any one base station were treated as a single equivalent UE with the EIRP determined by the CDF increased by the value of 10 log(3). A 10,000 step simulation was performed to determine the appropriateness of this approximation. In that simulation 182 base station locations were created where 91 sites had three UEs at each base station and 91 sites had one UE with the EIRP adjusted by 10 log(3). All other factors in the simulation were identical – CDF category, single receiver location, and propagation model. In that test the difference in mean received aggregate power was approximately 0.114 dB and the difference in the standard deviations of the samples was 0.334 dB. This approximation seemed reasonable given the additional assumptions in the overall assessment. In all UE-to-ACTS simulations, the EIRP of each UE was randomly determined by the category of the UE, urban or rural, and the associated CDF.

The antenna gains for the ACTS receivers are provided in the ACTS White Paper. These gains are 0 dBi for the airborne unit and 11 dBi in the horizontal plane for the RRUs.

Values for propagation loss for ground-to-air interactions were predicted using the methods contained in ITU-R Recommendation P.528-3. The TWG agreed to use this model for ground-to-air interactions at this level of analysis recognizing that the model does not address possible additional propagation losses due to clutter and terrain. The effects of additional losses may be addressed in further analyses, however for this effort, given the lack of agreement within the TWG on how to treat clutter, a demanding schedule, and the goal of identifying initial protection distances, it was agreed to use ITU-R P.528-3. Propagation loss for each UE-to-ACTS receiver was predicted using ITU-R P.528-3 set to calculate loss not to be exceeded 50% of the time. For the ground-to-ground analysis used to assess RRU issues, the Visualyse Longley-Rice module was used with both Confidence and Reliability values set for 50%. USGS 30 second terrain data was used with the Longley-Rice model.

Technical staff supporting the ACTS program noted that nominal ACTS receive systems losses are approximately 2 dB.

Typically Equation 1 includes the effects of Frequency Dependent Rejection (FDR) which includes both On-Tune Rejection (OTR) and Off-Frequency Rejection (OFR). OTR is the rejection offered when there is a mismatch in receiver bandwidth and emission bandwidth and is considered to occur when the emission bandwidth is wider than the receiver bandwidth. In this analysis OTR is defined as in Equation 2 below.

$$\text{OTR} = 10\log(B_t/B_r)\ \text{dB} \qquad \text{for } B_t > B_r \qquad (2)$$

$$= 0\ \text{dB} \qquad \text{for } B_t \leq B_r$$

Where,

B_t = 3 dB emission bandwidth (MHz)

B_r = 3 dB receiver IF bandwidth (MHz)

OFR results from detuning between an interfering transmitter and a victim receiver. The effects of OFR were not included in this assessment since every base station in a simulation included the equivalent of three UEs co-tuned with the ACTS receivers. The interference contribution of non-overlapping UEs emissions was considered negligible compared to the interference power of the on-tune UEs.

The approach described above was used to calculate the interference power from a single equivalent UE at an ACTS receiver. The aggregate interference was determined by adding algebraically the interference power from all of the UEs in a simulation using Equation 3. Note that when there were multiple ACTS receivers in a simulation, aggregate interference power would be different at each receiver and was calculated at each accordingly.

$$I_a = 10\log\{\textstyle\sum_{j=1}^{N} Ij\} + 30 \qquad (3)$$

Where,

I_a = Aggregate interference power at victim receiver (dBm)

N = Number of UEs

I_j = Interference power at victim receiver from a single UE, Watts

As provided by technical staff supporting the ACTS program, the interference criterion for the ACTS receivers was an I/N of -6 dB. For any single ACTS receiver, the predicted interference power was that determined for the aggregate interference at the receiver as in Equation 3. The receiver noise power was approximated using Equation 4

$$N = -114 + 10 \log(B_r) + NF \quad (4)$$

Where,

N = Receiver noise power (dBm)

NF = Receiver noise figure (dB)

A fundamental goal of this effort was to make a conservative estimate of the distances at which an aggregate environment of UE emitters would not be likely to exceed the -6 dB I/N threshold to ACTS receivers at their training facilities. Visualyse was used to apply the steps described above to a large scale UE environment and ACTS receivers at the listed facilities and determine protection distances for each facility. In the Visualyse simulations for the airborne ACTS receivers the receivers where placed at the points of closest approach previously described and at altitudes of 10,000 m unless noted otherwise. The UE environment was set up such that each UE radiated according to a random sampling of the appropriate CDF and each UE EIRP was independent of all other UEs. A simulation consisted of multiple time steps with each UE varying on each step. An overall protection distance was determined by setting up a series of protection distances around each of the ACTS receivers. A series of simulation steps would be run at one distance and after a fixed number of steps the protection distance would be increased for all ACTS receivers by a fixed incremental distance. For example, a simulation might start with all UEs within 50 km of a receiver being turned off. After a fixed number of steps the distance at which all UEs are turned off would be increased to 75 km. This simulation typically would run successively turning off UEs until distances were reached out to anywhere between 350 to 500 km depending on the density and distribution of the UE environment. At each distance and during each simulation step, I/N values at each ACTS receiver would be calculated and written to a file that could be retrieved as a spreadsheet. The simulations would be run until predicted I/N values at all ACTS receivers were below the interference threshold of -6 dB I/N. All simulations were run with both the ACTS receivers and the UEs having a center frequency of 1760 MHz. A typical simulation consisted of anywhere from five to ten ACTS receivers and thousands of UEs. Typical run times for the simulations were overnight, although some took several days to run.

The data gathered during the Visualyse runs described above was then used to generate plots showing the predicted I/N values at ACTS receivers for the various distance increments used in the simulations. For example, for the configuration of ACTS receivers and UE environment shown in Figure 3.1 a plot was developed and is shown in Figure 3.4 below. The figure has two vertical axes, a primary axis on the left showing predicted I/N values and a secondary axis on the right showing the effective number of interfering UEs. The horizontal axis shows the protection distance increments.

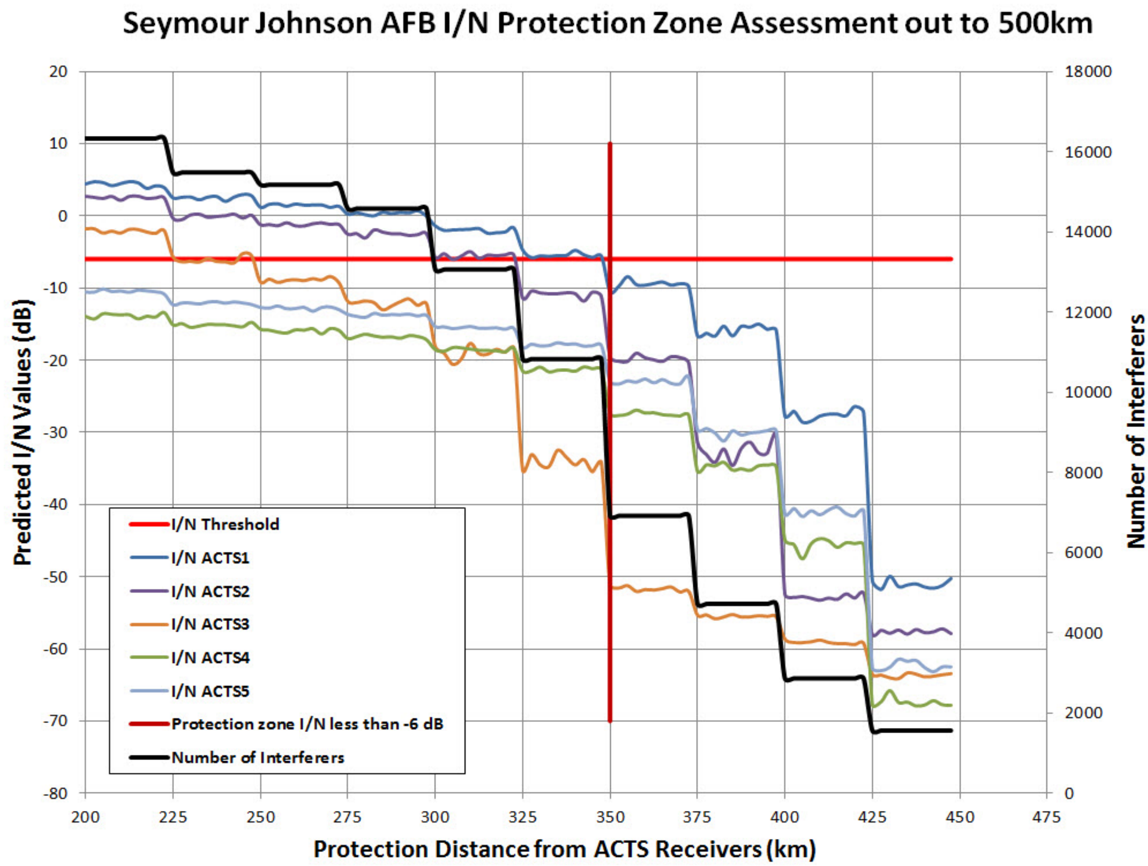

Figure 3.4. Predicted I/N versus protection distance for ACTS receiver operating near Seymour Johnson AFB

For each ACTS receiver, predicted values of I/N from the aggregate UE environment are plotted. It should be noted that in the figure, the values of predicted I/N between any two distance increments represents the bin of calculated I/N values for the smaller distance. For example, for the I/N ACTS1 plot, the section of the curve between 200 and 225 km represents the various values calculated in multiple simulation steps for the protection distance increment of 200 km, not values for distances of 201 km, 202 km, etc. A simulation for any one ACTS location was run until predicted I/N values were less than -6 dB for all of the ACTS receivers. In Figure 3.4 it can be seen that for the ACTS ranges associated with Seymour Johnson AFB, 350 km is the protection distance at which all ACTS receivers experience predicted interference below the ACTS receiver interference threshold. Different ACTS receivers will have different predicted I/N curves resulting from their different positions relative to the UE environment. Similar plots were developed for NAS Key West and NTTR as shown in Figures 3.5 and 3.6 below. The suggested protection distance for the ranges associated with NAS Key West is 325 km and for NTTR the distance is 375 km.

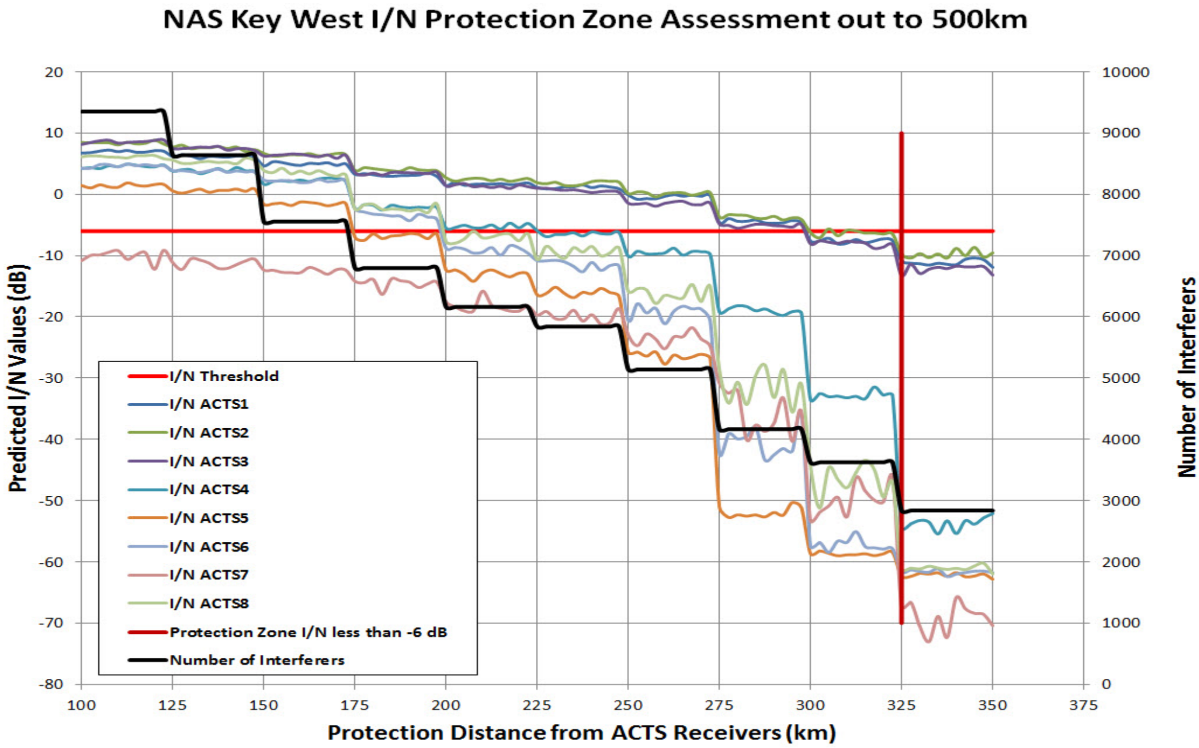

Figure 3.5. Predicted I/N versus protection distance for ACTS receivers operating near NAS Key West.

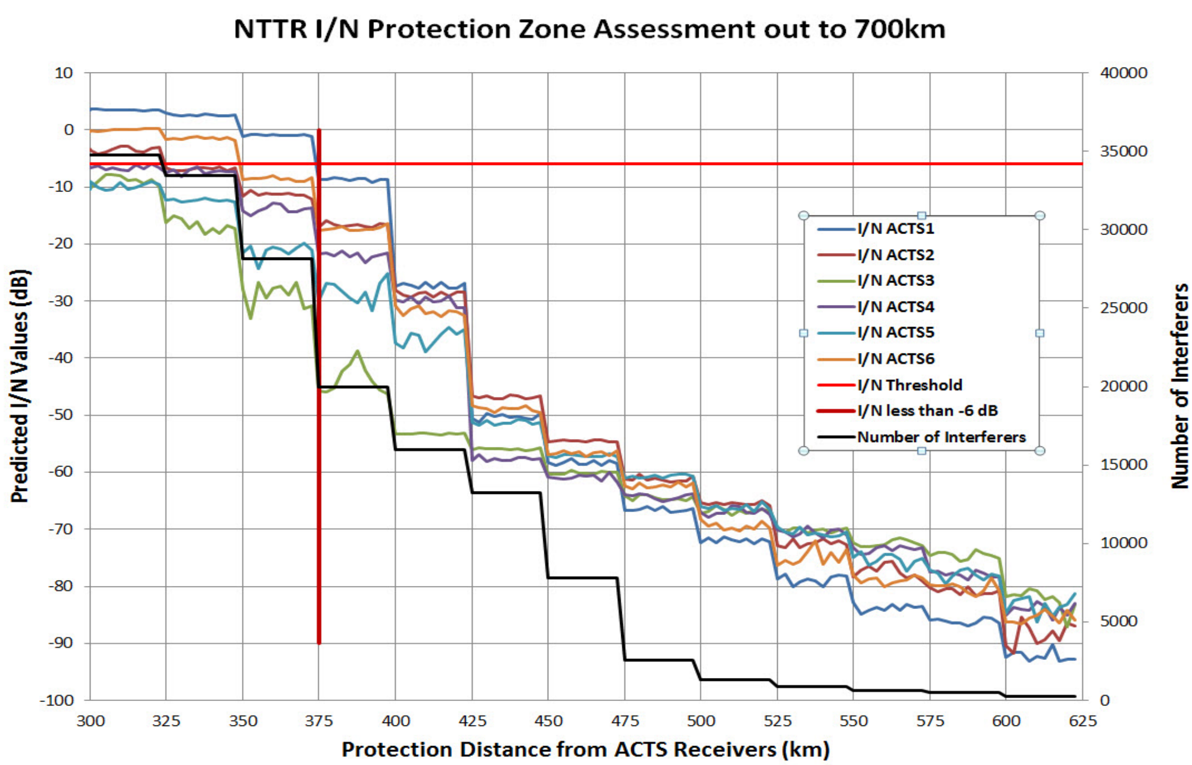

Figure 3.6. Predicted I/N versus protection distance for ACTS receiver operating near NTTR.

As has been noted, almost all ACTS ranges include ground-based units that interface directly with ACTS-equipped aircraft and may be considered participating units in an ACTS exercise. While it is generally the case that range-specific protection distances for ACTS airborne receivers would encompass associated RRUs, the technical staff supporting the ACTS program asked that the RRU at Marco Island, Florida be analyzed as it is some distance from the NAS Key West ranges. Figure 3.7 below shows Visualyse representation of the Marco Island RRU and the UE locations from the randomized real network data.

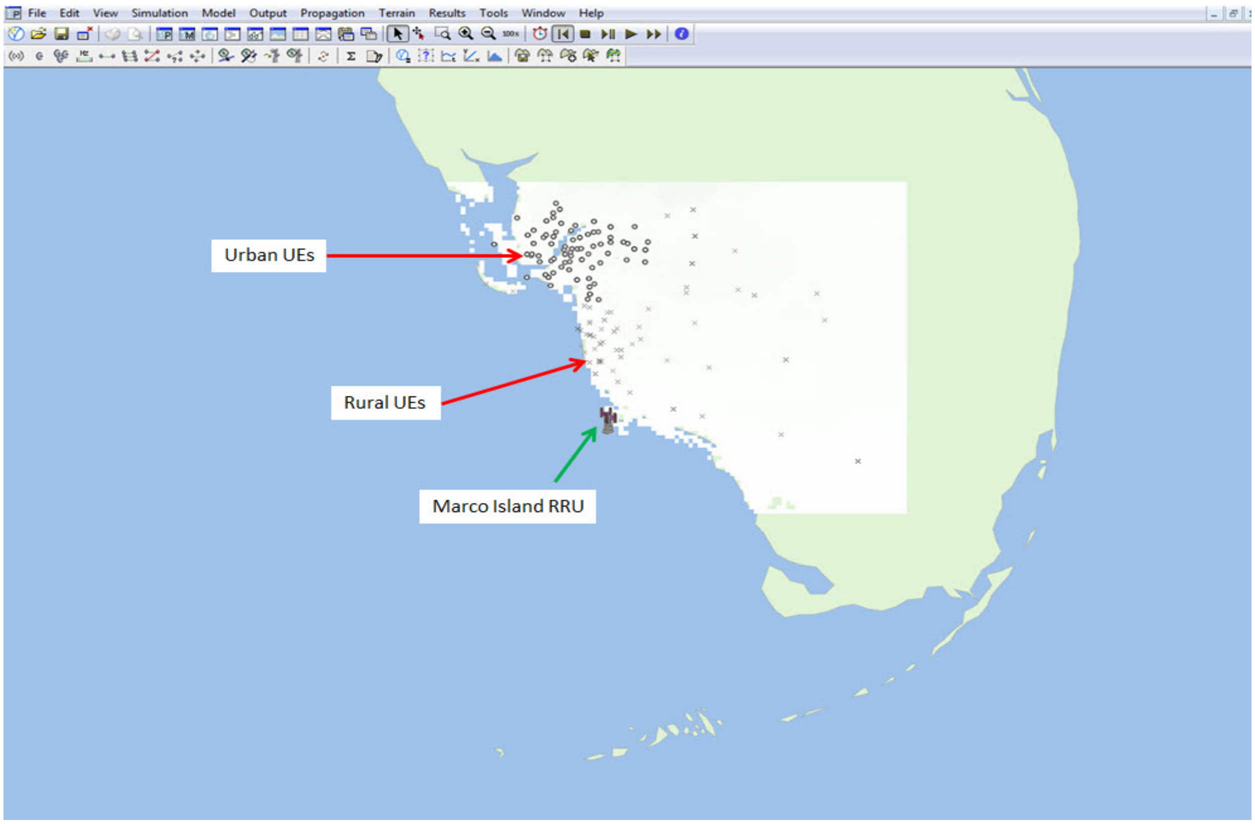

Figure 3.7. Marco Island RRU environment as configured in Visualyse.

The receiver characteristics for an RRU are the same as those of the units on aircraft. However the RRUs have antennas that are Omni-directional in the horizontal plane, have a vertical pattern, and have a gain in the horizontal direction of approximately 11 dBi. Technical staff supporting the ACTS program provided the Marco Island RRU antenna height. In the Visualyse simulation performed for the Macro Island RRU the UEs were grouped into urban and rural categories as with the airborne analysis, all UE antenna heights were 1.5m, and the EIRP of each UE varied each simulation step according to the appropriate CDF. Interference power at the Marco Island RRU receiver was aggregated as described in the section above. For this terrain-dependent analysis the Longley-Rice propagation module in Visualyse was used to predict propagation losses. The Visualyse implementation of this model uses code supplied by the Institute of Telecommunication Sciences of the Department of Commerce. As with the airborne analysis, a simulation was run with incrementally increasing protection distances. Multiple simulation steps were run at each distance and I/N values from each simulation step were recorded and plotted. For this simulation the plotting capabilities of Visualyse were used to display the data as seen in Figure 3.8 below. In the figure it can be seen that a protection distance of approximately 40 km would be recommended for the Marco Island RRU. This distance is well inside the suggested distances for the overall NAS Key West range

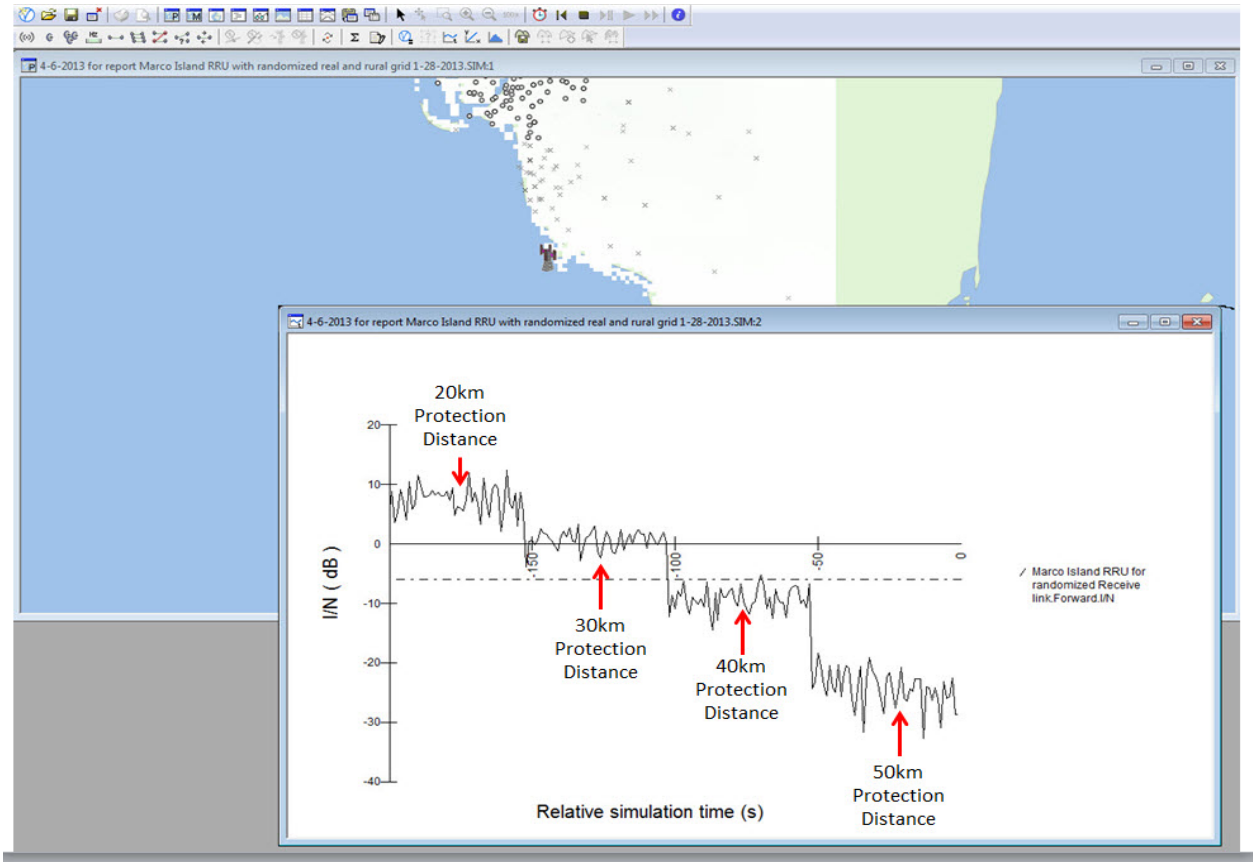

Figure 3.8. Predicted I/N versus protection distance for Marco Island ACTS RRU receiver

The P5 ACTS Sub Working Group was tasked to provide observations based on the results of the modeled calculations as documented in the analysis briefing. These observations are noted in Table 3.1 below:

From UEs-to-ACTS Receivers[1]	
ACTS Site	Estimated Protection Distance (km)
Seymour Johnson AFB Ranges	350

NAS Key West Ranges	325
NTTR Ranges	375

Table 3.1 Summary of Initial Distance Assessment from UEs to P5 ACTS

1 - Assumes ACTS platform can be anywhere on perimeter of range.

3.1.4 Outstanding Issues

The P5 ACTS SWG determined there are other possible areas of consideration that could be studied for additional "Observations" for the P5 ACTS. The following are possible study topics determined by the Sub Working Group that may warrant additional investigation; however, additional items may be considered:

1. Effects of off-tuning of the LTE base station to the P5 ACTS FO
2. Possible notches in wireless use of frequencies at selected locations
3. Consideration of different interference threshold based on desired signal level desired
4. Possible effects of clutter

<u>3.2 Work Plan Item 2 and Observations/Recommendations:</u> RF Interference Analysis of P5 ACTS to LTE Base Stations

3.2.1 Objective: The overall objective of this Work Plan Item was to assess the EMC of the P5 ACTS airborne emitters to the LTE base station. This effort would provide observations as to the typical distances required to protect LTE base station receivers. In order to assess these distances, we selected three P5 ACTS operating sites that are typical Urban scenario driven sites to best obtain the needed information for an overall analysis. The technical information of the P5 ACTS is noted in Appendix 2 and the LTE information is noted in Appendix 5. The main scope of this work plan was to provide an observation as to the initial estimated Protection Distance assessment of the P5 ACTS to the LTE Base Station at each of the three selected sites; (1) Seymour Johnson AFB, NC, (2) NAS Key West, Key West, FL, and (3) Nellis AFB, Las Vegas, NV.

3.2.2 Technical Approach

The technical approach for this work plan item is to consider the effects of the P5 ACTS airborne emitter as an interference source to the LTE base station. In performing this analysis, the following assumptions were made:

1. The P5 ACTS technical data was derived for the P5 ACTS white paper and J-12 certification document

2. The LTE technical information was the data provided to us by the Technical Working Group of Working Group 1 (WG-1)

3. Assess three designated P5 ACTS ranges noted as being typical training site

4 Assess a single aircraft or RRU within the range

5 Base station antenna height at 30 meters

6. Interference assessed for on-azimuth

7. Addressed mitigation of 60 degree off axis and 180 degree off axis interference source

8. Site locations and parameters are documented in Table 2.1

In addition to the parameters, we used a standard interference power calculation formula for determining the interference power at the victim receiver antenna output which was modeled into the program. The interference power calculations were calculated by the Visualyse automated software tool with the following parameters:

1. P5 ACTS transmitters simulated at multiple boundary locations

2. Visualyse used to determine distances beyond which the base stations not expected to receive interference

3. Clutter was not considered

Technical characteristics of LTE base station receivers used in this effort were taken from Appendix 5. Included in Appendix 5 is an I/N interference threshold for the base station receiver of -6 dB, this was used in the ACTS-to-LTE base station analysis.

The LTE (FDD) Base Station Receiver Characteristics table in Reference 1 indicates that the base station should be modeled using antennas that cover three sectors each 120 degrees wide and these antennas should have a down tilt of 3 degrees. Further, the ACTS-to-base stations configurations considered three orientations of the base station antenna. One ACTS-to-base station configuration modeled the base station as always pointed in the direction of the ACTS emitters, one with the base station antenna always pointed 60 degrees away from the ACTS emitters, and one with the base station antenna always pointed 180 degrees away from the ACTS emitters – in all of these configurations the base station also had a down tilt of 3 degrees. The base station antenna pattern was modeled using the ITU-R Recommendation F.1336-3 as suggested in Appendix 5.

3.2.2.2 Airborne ACTS-to-LTE Base Station Analysis

The Visualyse software was also used to model the airborne ACTS-to-LTE base station interactions. The ACTS and base station parameters were gathered as mentioned above. Equation 1 above was used to predict interference levels in the base station receiver although in the ACTS-to-base station case the OTR value was taken to be 0 dB as the ACTS emission bandwidth is less than the base station receive bandwidth provided in Appendix 5.

Since an aggregation of emitters is not appropriate for this configuration a slightly different approach was taken with Visualyse. An Area Analysis capability was used to determine contours that would define the distances at which the interference threshold in a model base station would be exceeded if the base station was placed at a series of test points within a large area, largely defined by the locations of the ACTS emitters and the associated distance to the radio horizon. The propagation loss was modeled using ITU-R P.528-3. At each test point a predicted I/N value is calculated in the base station receiver and a contour is drawn showing the distances at which an I/N of -6 dB is expected to occur. For each ACTS location considered three contours were drawn, one each for the base station antenna pointing directions described above. Also, Appendix 5 notes that base station antenna heights may vary. Initial airborne ACTS-to-LTE base station interactions were done for base station heights of 30 m and 60 m, however for an ACTS emitter at 10,000 m the curves for these two heights are virtually indistinguishable and the curves presented below show only the contours for a 30 m base station antenna height. Figures 3.9 through 3.11 below show suggested separation distances required to protect base station receivers to the interference threshold provided in Appendix 5.

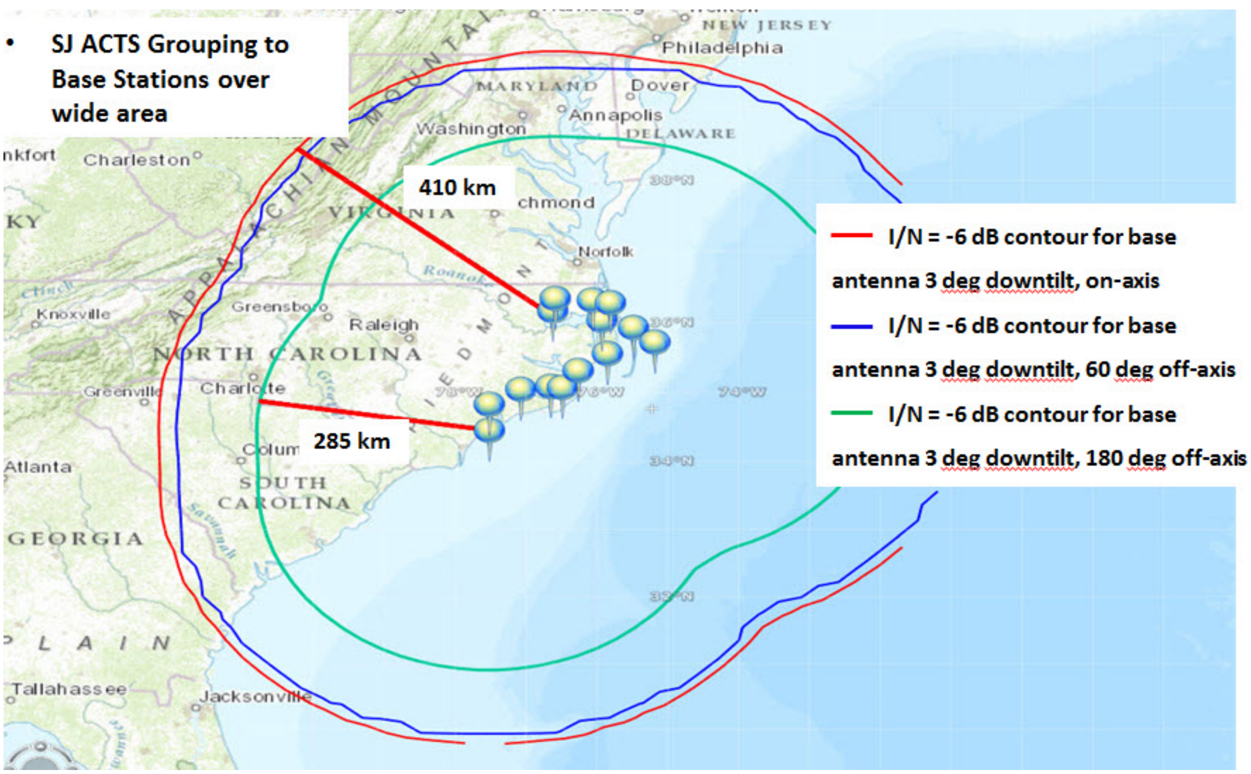

Figure 3.9. Suggested protection distances for LTE base stations around Seymour Johnson AFB.

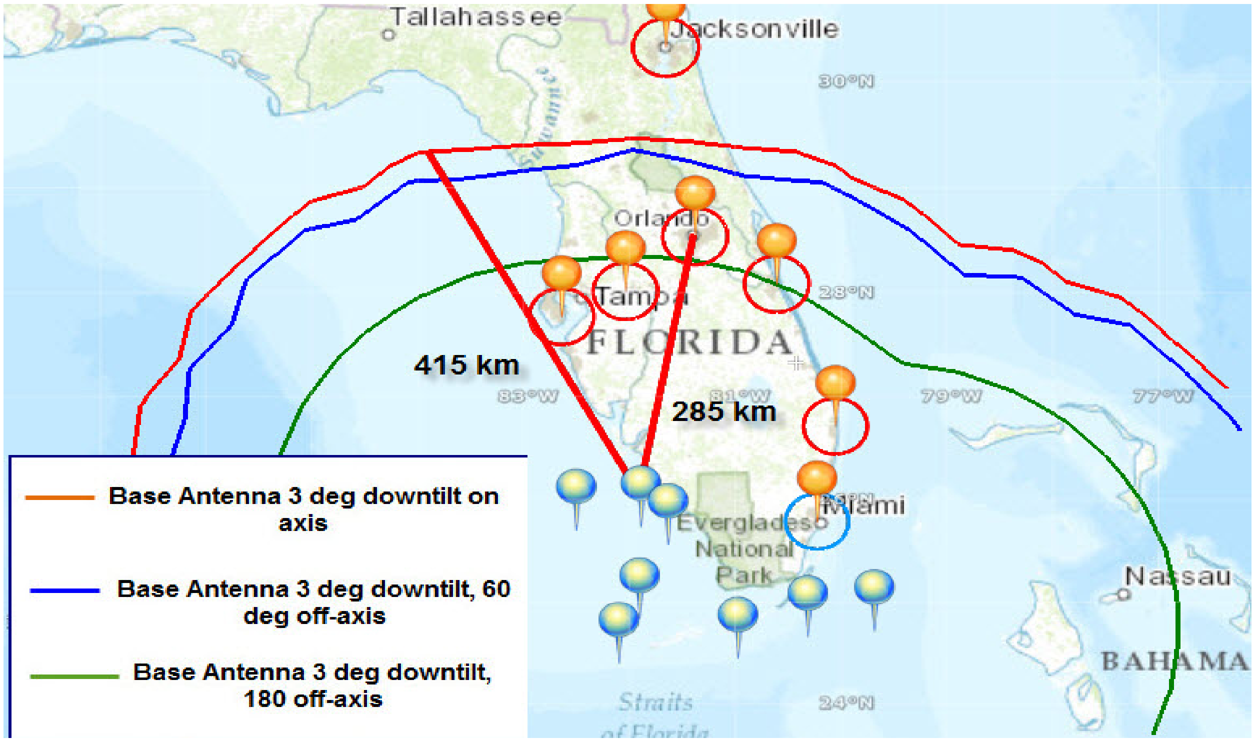

Figure 3.10. Suggested protection distances for LTE base stations around NAS Key West.

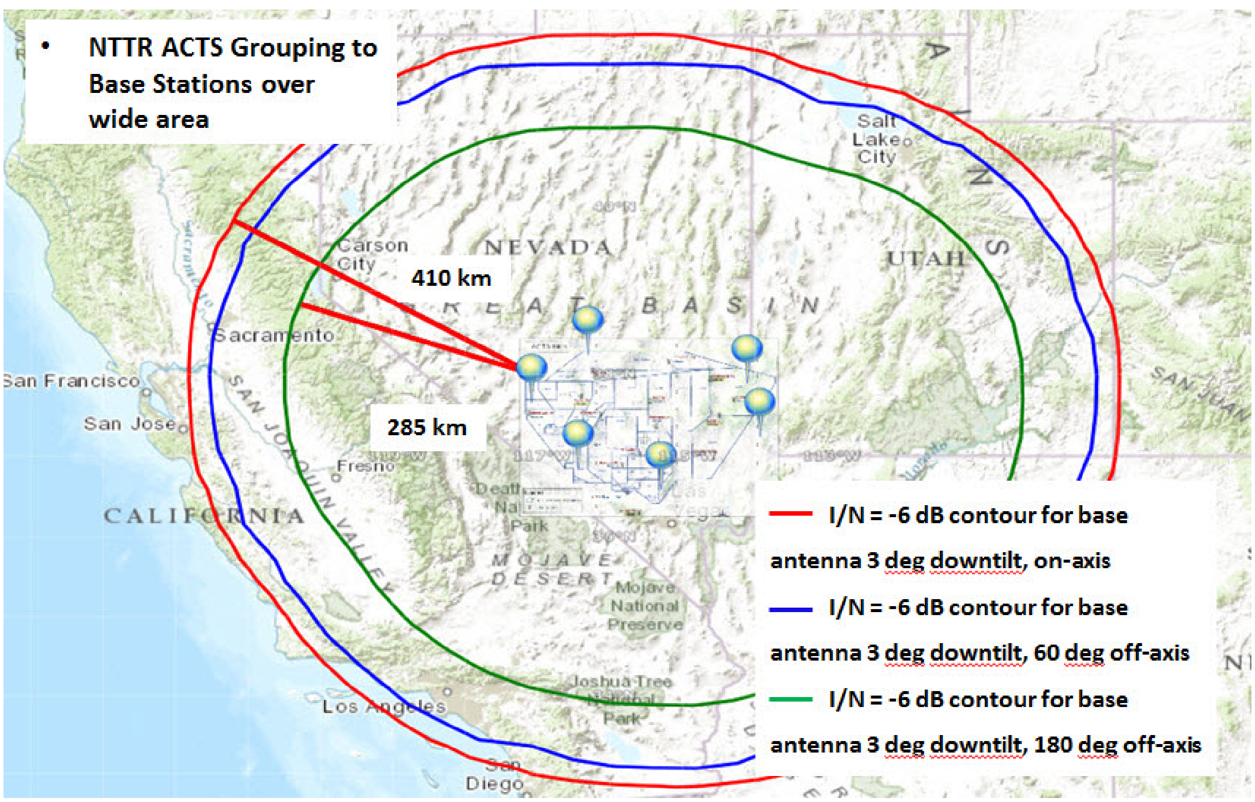

Figure 3.11. Suggested protection distances for LTE base stations around the NTTR

3.2.2.3 Remote Range Unit-to-LTE Base Station Analysis

The Visualyse Area Analysis capability described above was used to develop contours for the ACTS RRU located at Marco Island, Florida. In this case the ACTS emitter was at a single point on Marco Island and contours were drawn for a grid of test points over a large area somewhat greater than the radio line-of-sight between the Marco Island RRU and a base station antenna at 60 m above local terrain. Propagation loss was predicted using the Visualyse Longley-Rice module with settings as described above and 30 second terrain data was used. Base station parameters were as described in Sections 3.2.2.1 and 3.2.2.2 and contours were developed for base station antenna heights of 30 m and 60 m. The three base station antenna pointing orientations described above were considered. Figure 3.12 shows the contours around the Marco Island RRU for the various base station antenna configurations considered. As a comparison Figure 3.13 shows the contours around the Marco Island RRU and the best-case contour for the ACTS airborne points-of-closest approach for the NAS Key West ranges. As might be expected, for the configurations described here all of the contours for the Marco Island RRU location are well within the best-case contour for the airborne case.

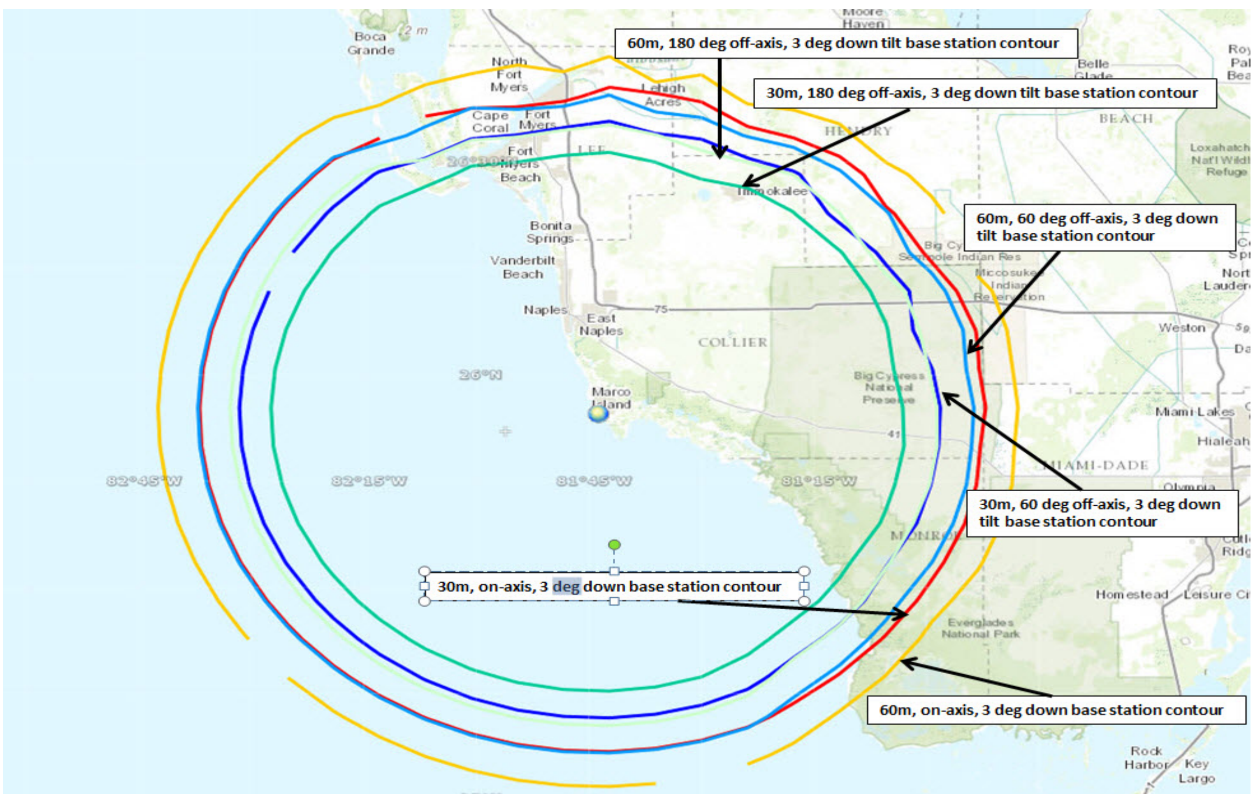

Figure 3.12. Suggested protection distances for LTE base stations around Marco Island RRU.

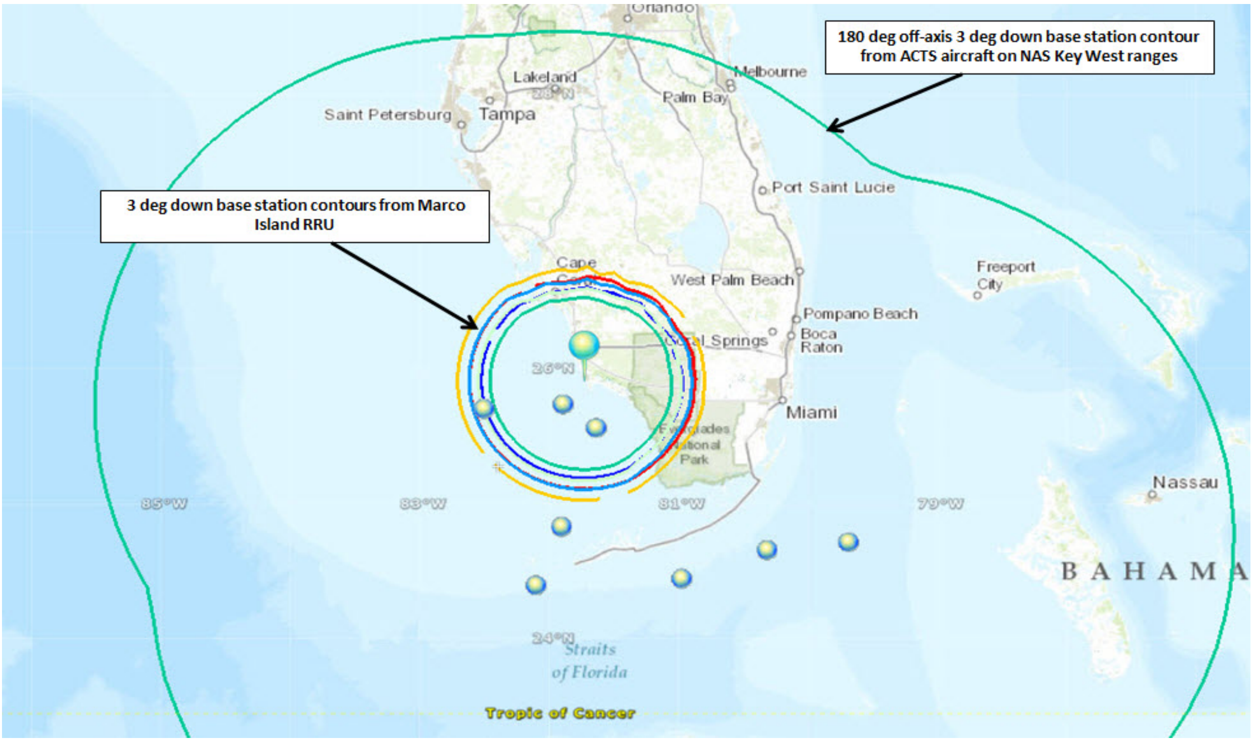

Figure 3.13. Comparison of Marco Island RRU protection contours and 180 degree off-axis contour for NAS Key West ranges.

Once the model was ran and the data provided, we reviewed the calculated interference power and compared it to the receive system interference threshold of the LTE base station. The interference power calculated for positions of simulated flight paths around operation area boundaries and locations of the LTEs were reviewed to develop the protection. This data is noted below as part of our observations.

3.2.3 Observations/Recommendations

The sections above provide a high-level description of a technical assessment of the incumbent ACTS units and LTE systems as described in Appendix 5. The assessment considered three representative ACTS locations in the continental US. The assessment was made principally using the Visualyse automated analysis software. It is recognized that a number of alternative analysis tools are available and independent analyses may be valuable. A number of assumptions were made in performing the assessment and in almost all cases such assumptions represented worst-case system and environmental configurations. Further analysis using less conservative assumptions may be warranted if interest in sharing continues. Table 3.2 below is provided as a summary of initial suggested protection distances for the ACTS locations considered.

From ACTS Transmittersto-LTE Base Stations		
ACTS Site	Estimated Minimum Distance [2] (km)	Estimated Maximum Distance [3] (km)
Seymour Johnson AFB Ranges	285	415
NAS Key West Ranges		
NTTR Ranges		

Table 3.2 Summary of Initial Distance Assessment From P5 ACTS to LTE Base Station

[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.

3.2.4 Outstanding Issues

The SWG P5 ACTS determined there are other possible areas of consideration that could be studied for additional "Observations" for the P5 ACTS. The following are a list of possible study topics determined by the Sub Working Group that may warrant investigation, however, additional items may be considered:

1. Possible notches in wireless use of frequencies at selected locations
2. Consideration of different interference threshold based on desired signal level desired rather than a rise in noise floor
3. Possible effects of clutter
4. Consideration of channel assignments to minimize impact of ACTS use on Top 100 markets

4.0 Detailed Technical Information

Below is the technical information associated with the P5 ACTS analysis.

4.1 Detailed Technical Analysis Approach: The approach was to determine the interference power at the victim receiver from the P5 ACTS to the LTE base station and to determine the interference power at the victim receiver from the UEs to the P5 ACTS receivers, both on the ground as well as its airborne component. As agreed by CSMAC WG-5, the interference power calculations would be performed using the Visualyse automated software model software tool to perform the multi-function calculations with the P5 ACTS and LTE/UE characteristics as reference. One key point was the clutter was not considered as key performance model characteristics were not defined or provided by the Technical Working group. In this analysis, only on-tuned cases were considered. The calculated interference power results were compared to the receiver system interference threshold as provided by the P5 ACTS Program Office and by the LTE Baseline document provided by WG 1.

The interference power from a single UE at an ACTS receiver is calculated using Equation 1 below.

$$I = Pt + Gt + Gr - Lp - Lsys - OTR \quad (1)$$

Where,

I = Interference power at the input to the ACTS receiver (dBm)

Pt = UE transmitter power (dBm)

Gt = Transmitter antenna gain in the direction of a victim receiver (dBi)

Gr = Victim receiver antenna gain in the direction of the interferer (dBi)

Lp = Propagation loss (dB)

Lsys = Receiver system loss (dB)

OTR = On-tune rejection (dB)

The sum of Pt and Gt represent the EIRP of a UE. Possible values of UE EIRP are defined by the cumulative distribution function (CDF) curves provide in the LTE baseline document. In the Visualyse simulations, each base station location has three UEs associated with it representing the three sectors of the base station. Further, because of the large number of UEs in the simulations the three UEs at any one base station were treated as a single equivalent UE with the EIRP determined by the CDF increased by the value of 10 log(3). A 10,000 step simulation was performed to determine the appropriateness of this approximation. In that simulation 182 base station locations were created where 91 sites had three UEs at each base station and 91 sites had one UE with the EIRP adjusted by 10 log(3). All other factors in the simulation were identical – CDF category, single receiver location, and propagation model. In that test the difference in mean received aggregate power was approximately 0.114 dB and the difference in the standard deviations of the samples was 0.334 dB. This approximation seemed reasonable given the additional assumptions in the overall assessment. In all UE-to-ACTS simulations, the EIRP of each UE was randomly determined by the category of the UE, urban or rural, and the associated CDF.

The antenna gains for the ACTS receivers are provided in the ACTS White Paper. These gains are 0 dBi for the airborne unit and 11 dBi in the horizontal plane for the RRUs.

Values for propagation loss for ground-to-air interactions were predicted using the methods contained in ITU-R Recommendation P.528-3. The TWG agreed to use this model for ground-to-air interactions at this level of analysis recognizing that the model does not address possible additional propagation losses due to clutter and terrain. The effects of additional losses may be addressed in further analyses, however for this effort, given the lack of agreement within the TWG on how to treat clutter, a demanding schedule, and the goal of identifying initial protection distances, it was agreed to use ITU-R P.528-3. Propagation loss for each UE-to-ACTS receiver was predicted using ITU-R P.528-3 set to calculate loss not to be exceeded 50% of the time. For the ground-to-ground analysis used to assess RRU issues, the Visualyse Longley-Rice module was used with both Confidence and Reliability values set for 50%. USGS 30 second terrain data was used with the Longley-Rice model.

Technical staff supporting the ACTS program noted that nominal ACTS receive systems losses are approximately 2 dB.

Typically Equation 1 includes the effects of Frequency Dependent Rejection (FDR) which includes both On-Tune Rejection (OTR) and Off-Frequency Rejection (OFR). OTR is the rejection offered when there is a mismatch in receiver bandwidth and emission bandwidth and is considered to occur when the emission bandwidth is wider than the receiver bandwidth. In this analysis OTR is defined as in Equation 2 below.

$$OTR = 10 \log(Bt/Br) \text{ dB} \quad \text{for } Bt > Br \qquad (2)$$

$$= 0 \text{ dB} \quad \text{for } Bt \leq Br$$

Where,

Bt = 3 dB emission bandwidth (MHz)

Br = 3 dB receiver IF bandwidth (MHz)

OFR results from detuning between an interfering transmitter and a victim receiver. The effects of OFR were not included in this assessment since every base station in a simulation included the equivalent of three UEs co-tuned with the ACTS receivers. The interference contribution of non-overlapping UEs emissions was considered negligible compared to the interference power of the on-tune UEs.

The approach described above was used to calculate the interference power from a single equivalent UE at an ACTS receiver. The aggregate interference was determined by adding algebraically the interference power from all of the UEs in a simulation using Equation 3. Note that when there were multiple ACTS receivers in a simulation, aggregate interference power would be different at each receiver and was calculated at each accordingly.

$$I_a = 10 \log\{\sum_{j=1}^{N} I_j\} + 30 \qquad (3)$$

Where,

Ia = Aggregate interference power at victim receiver (dBm)

N = Number of UEs

Ij = Interference power at victim receiver from a single UE, Watts

As provided by technical staff supporting the ACTS program, the interference criterion for the ACTS receivers was an I/N of -6 dB. For any single ACTS receiver, the predicted interference power was that determined for the aggregate interference at the receiver as in Equation 3. The receiver noise power was approximated using Equation 4.

$$N = -114 + 10 \log(Br) + NF \quad (4)$$

Where,

N = Receiver noise power (dBm)

NF = Receiver noise figure (dB)

A fundamental goal of this effort was to make a conservative estimate of the distances at which an aggregate environment of UE emitters would not be likely to cause interference to ACTS receivers at their training facilities. Visualyse was used to apply the steps described above to a large scale UE environment and ACTS receivers at the listed facilities and determine protection distances for each facility. In the Visualyse simulations for the airborne ACTS receivers, the receivers were placed at the points of closest approach previously described and at altitudes of 10,000 m unless noted otherwise. The UE environment was set up such that each UE radiated according to a random sampling of the appropriate CDF and each UE EIRP was independent of all other UEs. A simulation consisted of multiple time steps with each UE varying on each step. An overall protection distance was determined by setting up a series of protection distances around each of the ACTS receivers. A series of simulation steps would be run at one distance and after a fixed number of steps the protection distance would be increased for all ACTS receivers by a fixed incremental distance. For example, a simulation might start with all UEs within 50 km of a receiver being turned off. After a fixed number of steps the distance at which all UEs are turned off would be increased to 75 km. This simulation typically would run successively turning off UEs until distances were reached out to anywhere between 350 to 500 km depending on the density and distribution of the UE environment. At each distance and during each simulation step, I/N values at each ACTS receiver would be calculated and written to a file that could be retrieved as a spreadsheet. The simulations would be run until predicted I/N values at all ACTS receivers were below the interference threshold of -6 dB I/N. All simulations were run with both the ACTS receivers and the UEs having a center frequency of 1760 MHz. A typical simulation consisted of anywhere from five to ten ACTS receivers and thousands of UEs. Typical run times for the simulations were overnight, although some took several days to run.

The data gathered during the Visualyse runs described above was then used to generate plots showing the predicted I/N values at ACTS receivers for the various distance increments used in the simulations. For example, for the configuration of ACTS receivers and UE environment shown in Figure 3.1 above, a plot was developed and is shown in Figure 3.4 above. The figure has two vertical axes, a primary axis on the left showing predicted I/N values and a secondary axis on the right showing the effective number of interfering UEs. The horizontal axis shows the protection distance increments. For each ACTS receiver, predicted values of I/N from the aggregate UE environment is plotted. It should be noted that in the figure, the values of predicted I/N between any two distance increments represents the bin of calculated I/N values for the smaller distance. For example, for the I/N ACTS1 plot, the section of the curve between 200 and 225 km represents the various values calculated in multiple simulation steps for the protection distance increment of 200 km, not values for distances of 201 km, 202 km, etc. A simulation for any one ACTS location was run until predicted I/N values were less than -6 dB for all of the ACTS receivers. In Figure 3.4 above, it can be seen that for the ACTS ranges associated with Seymour Johnson AFB, 350 km is the protection distance at which all ACTS receivers experience predicted interference below the ACTS receiver interference threshold. Different ACTS receivers will have different predicted I/N curves resulting from their different positions relative to the UE environment. Similar plots were developed for NAS Key West and NTTR as shown in Figures 3.5 and 3.6 respective, above. The suggested protection distance for the ranges associated with NAS Key West is 325 km and for NTTR the distance is 375 km.

For the UE to RRU, almost all ACTS ranges include ground-based units that interface directly with ACTS-equipped aircraft and may be considered participating units in an ACTS exercise. While it is generally the case that range-specific protection distances for ACTS airborne receivers would encompass associated RRUs, the technical staff supporting the ACTS program asked that the RRU at Marco Island, Florida be analyzed as it is some distance from the NAS Key West ranges. Figure 3.7 above shows the Visualyse representation of the Marco Island RRU and the UE locations from the randomized real network data. The receiver characteristics for an RRU are the same as those of the units on aircraft however the RRUs have antennas that are omni-directional in the horizontal plane, have a vertical pattern, and have a gain in the horizontal direction of approximately 11 dBi. Technical staff supporting the ACTS program provided the Marco Island RRU antenna height. In the Visualyse simulation performed for the Marco Island RRU, the UEs were grouped into urban and rural categories as with the airborne analysis, all UE antenna heights were 1.5m, and the EIRP of each UE varied each simulation step according to the appropriate CDF. Interference power at the Marco Island RRU receiver was aggregated as described in the section above. For this terrain-dependent analysis, the Longley-Rice propagation module in Visualyse was used to predict propagation losses. The Visualyse implementation of this model uses code supplied by the Institute of Telecommunication Sciences of the Department of Commerce

As with the airborne analysis, a simulation was ran with incrementally increasing protection distances. Multiple simulation steps were accomplished at each distance and I/N values from each simulation step were recorded and plotted. For this simulation the plotting capabilities of Visualyse were used to display the data as seen in Figure 3.8 above. In the figure, it can be seen that a protection distance of approximately 40 km would be recommended for the Marco Island RRU. This distance is well inside the suggested distances for the overall NAS Key West range as seen in Figure 3.5 above.

4.2 Analysis Assumptions: The analysis assumptions for the P5 ACTS were evaluated and agreed upon by the CSMAC WG-5 and are documented below (It should be noted that there are a number proposals under consideration in the Technical Working Group for further refining the analysis)**:**

4.2.1 P5 ACTS as interference victim: See paragraph 3.1.2 above.

4.2.2 P5 ACTS as interference source: See paragraph 3.2.2 above.

4.3 Model Description.

Visualyse Professional is commercial off-the-shelf software that can be used to build simple or complex simulations of radio frequency interactions between multiple units in an electromagnetic environment. The software uses models of simple objects such as antennas, stations, carriers, and links to build the simulation scenarios. Objects contain data either entered by the user or parameters derived from the input data. Once input data and derived parameters are available as objects, multiple simple objects are combined to form complex simulations. For simulations with a large number of objects such as those developed for this effort, objects with certain similar attributes can be managed as a group. Once a simulation is fully defined, it is executed by starting a series of simulation steps. The simulation steps are typically defined by time increments of a specific duration and the simulation will run for a designated number of steps. During the simulation, data can be both displayed and collected for post processing.

For the simulations associated with this effort, a particular set of the basic inputs are of interest. First, several different types of antennas were modeled. Visualyse has over ninety different antenna patterns available as default choices as antenna objects. Most of these patterns are defined in ITU documents and are available, with several user-defined parameters such as frequency of operation, height, feeder loss, efficiency and other parameters. Users can also fully define an antenna by entering specific measured or calculated data points. For the ACTS analysis, the Visualyse omnidirectional antenna pattern with 0 dBi of gain used for the UEs and ACTS receivers. An individual pattern was developed for the RRU antenna and ITU-R Recommendations F.1336-3 was used to develop patterns for the base stations.

Antennas are associated with individual stations and in the Visualyse simulations several distinct station types were used. UEs, ACTS-equipped aircraft, an RRU, and base stations were modeled as station types with associated antennas, locations, heights above terrain or sea level, and feeder losses. For each type, multiple individual stations were developed and deployed in an environment according to the parent simulation.

Stations are then grouped into links to allow for the RF calculations. Typically, UEs were grouped into transmit links, i.e., were treated only as transmitting sources. A traffic module was used to associate the urban and rural transmit EIRP values with individual UE stations in a transmit link and to vary these values for every simulation step for every transmitting station according to the appropriate urban or rural CDF. The ITU-R Recommendation P.528-3 propagation model for the air/ground/air interactions is assigned as a transmit link parameter. A version of the Longley-Rice propagation model was used to model ground-to-ground interactions. A transmit frequency, emission bandwidth, and baseline transmit power is also defined in a transmit link. Victim receivers are defined in receive links or receive link groups depending on the number of stations to be considered. In receive links, receiver frequency, bandwidth, and noise parameters are defined. In general, transmit and receive links are used to more completely define the various system and environmental parameters needed to complete an interference analysis.

A final step in Visualyse is to define the interference path. This step establishes the receive links to be addressed in a simulation and the transmit link, or links in most cases, to be used as the interference sources. Additional issues such as polarization loss may be established in this last step although that was not used in this effort. For all of the simulations performed in this effort, the values for various parameters of the simulations were recorded for all simulation steps. Recording of this data allowed for the development of I/N plots and the plotting of the number of interferers associated with each protection distance considered.

4.4 Publicly releasable Federal systems general description and characteristics of operation to include:

4.4.1 P5 Combat Training System (CTS) Data Link Transceiver (DLT) Operational Characteristics", 7 August 2012, CSMAC WG-5, SWG ACTS-P5. (See Appendix 2)

4.4.2 P5 ACTS Operating locations and geographic areas of operation. (See Appendix 3)

4.4.3 P5 ACTS Operational Profiles for the Model Analysis (See Appendix 4)

4.5 LTE systems description, characteristics, and parameters

The LTE information was cross-referenced to work coming out of theWG-1 spin off group that identified LTE characteristics and identify any deviations or additional LTE characteristics and parameters considered by Sub-Working Group. These are referenced in the following document:

Baseline LTE Uplink Characteristics", 12 November 2012 – Rev2, LTE Technical Characteristics group of CSMAC Working Groups (See Appendix 5)

4.6 Findings/Results

4.6.1 Associated technical considerations and regulatory concepts and components required to support the recommendations.

This Sub Working Group was tasked to provide a summary of "Observations" for the analysis performed for this effort. We did not develop any recommendations or regulatory language for the P5 ACTS.

5.0 Full Participant Lists for Sub-Working Group Report Preparation/Reviewers

Appendix 6 is a full list of participants, subdivided by Federal Agency and Industry.

6.0 **Web Location of Archival Documents/Exhibits**

TBD

The undersigned has jointly prepared and approves the content of the P5 ACTS analysis report and hereby submits this report to Working Group 5

______________________________	______________________________
Joe P. Giangrosso Date	Steve Sharkey Date
Alion Science and Technology for DoD	T-Mobile
P5 ACTS Co-Chair	P5 ACTS Co-Chair