Raytheon Missile Systems
Experimental License Renewal Application
File Number: 0136-EX-CM-2018
Call sign: WF2XVV

Exhibit I – Explanation of Requested Modification

Raytheon Missile Systems (Raytheon) is requesting a modification to its experimental license WF2XVV to expand testing in the 4700-5000 MHz bands. Raytheon is trying to expand its experimentation in these radio bands to develop improved interference-resistance for the command and control signals used when its products are in flight.

Raytheon missiles are used in an increasingly crowded RF environment. Various command and control signals are used when the missiles are in flight to ensure their proper operation. This modification will allow for broader experimentation to further the development of radio systems and transmissions to make the products robust and reliable in crowded RF environment, ensuring vital command and control signals are received, without harmful interference.

Technical Synopsis:

- New frequencies to be utilized: 4700-5000 MHz
- Testing of advanced command and control signals that will not cause nor receive interference in a crowded RF environment
- Testing is on missiles; operations will be airborne using a 120 km radius around the Raytheon Tucson facility.
- After waveform analysis, testing will be listen-before-transmit and frequency hopping.
- Frequency bands requested are needed for comprehensive testing and development required.

Description of experimentation:

This application proposes to add the frequency band: 4700-5000 MHz. The current power level is just enough to test operations that mimic real-world conditions for when the missiles would be in use. The bandwidth per transmission is 6 MHz. The ongoing experimentation will help Raytheon fine-tune its radio use so that the command and control signals that are legitimately sent are also received and will withstand interference from the operation of other radios in the area, on or near the same frequency.

Raytheon has been testing in lower bands to learn as much as possible about designing an interference-resistant transmission before migrating the experiments to the 4500 to 4700 MHz band. At this point,

the need to migrate operations to the higher bands means that Raytheon needs to include the 4700-5000 MHz band to have sufficient spectrum for the testing required.

In the 4500 to 4700 MHz band, Raytheon has been designing and building equipment. That design now needs to expand from 4700-5000 MHz. In its design phase and for further development, Raytheon has begun to test the nature of the transmission of command and control signals. Raytheon has discovered that for it to develop effective radio technologies, aimed at delivering the robust data required, it must employ a higher powered antenna, shifting from an ERP of no more than 49 W to an antenna that has an ERP of 100 W. This allows for transmission of key data over a greater radius of operations, and it also allows for the more efficient transmission of the data, because data throughput can slow significantly with distance, if there is no power increase.

Use of Frequency Hopping and Listen-Before-Transmit Technologies

As Raytheon stated in its original application, for much of the field testing, the radios will listen for a clear channel and transmit only on a clear frequency. The radios will change to clear channels if a signal appears on the frequency to be used. The program has been testing waveforms, and so far it has not fully focused on the use of frequency hopping technologies. Raytheon's work on the waveforms to date has proven fruitful, and the experimentation is moving more into the field. Field testing of the waveform analysis is expected to last only two (2) days per month.

For each test, once the waveforms have been analyzed, the program begins to incorporate frequency hopping and listen-before-transmit technologies. At that point, the program uses listen-before-transmit technologies, unless it needs to debug a system or undertake additional waveform analysis. In the event the program must debug a system or analyze a new waveform, the program will again return to the lab and use cable connections for most of the analysis. After the lab work, there will be about two days of field-testing per month.

Full band usage is necessary for adequate experimentation:

Raytheon will continue full band usage as authorized in its current license. It is important to repeat that almost all of the proposed operations will either be in the lab over a cable or will be "listen-before-transmit" to ensure that there is no chance of harmful interference. Furthermore, testing in a crowded RF environment is key to developing the sort of robust radio system that is needed for safe operation of the command and control systems on the missiles. If this testing is successful, then Raytheon's products will be able to send and receive signals in any crowded RF environment and work

successfully, without disrupting any other essential communications, but also without being detected or disrupted.

The radio systems that Raytheon hopes to develop through these experiments should be able to transmit command and control signals without suffering – or **causing** – interference. These systems will be used by Raytheon's customers in crowded RF environments. Raytheon is aware that its customers will be operating other radio systems on the same spectrum at the same time, and the new systems under development must not cause interference to those other vital communications. At the same time, the new system must be able to withstand the radio traffic and still communicate effectively. This is a great engineering challenge, which is why this renewal license is needed.

In an effort to maximize the effectiveness of the testing, Raytheon is testing across all three bands on the license. It will not be operating across all these spectrum bands continually. In the initial phases, testing will be primarily in the lab on a cable, with only two days of field testing per month. This application seeks to expand the testing into the 4700-5000 band to make the radio transmissions more effective.

The proposed testing will be sporadic, with short bursts of radio use, when and where there is clear spectrum, based on the listen-before-transmit technology. The occupied bandwidth of the transmission will be only 6 MHz, to ensure minimal spectrum occupancy. Based on Raytheon's experience in developing new radio systems, the most effective way of developing a system is to design a test that incorporates flexibility to allow for the engineers to test, learn, adapt, redesign, and repeat the process. By continuing the ability to work across the three designated spectrum bands, Raytheon is allowing its engineering team flexibility to design a system that can be used effectively and to do so in a cost-effective manner.

Time Schedule for Experiment:

The experimentation is scheduled to continue for at least three (3) more years, to allow sufficient time to explore and test waveforms, test frequency hopping and listen-before-transmit technologies, re-analyze waveforms, and refine the systems being developed to ensure that they achieve optimal performance – neither causing nor receiving interference while operating in a crowded RF environment.

Area of Test:

The operations will be used within a 120 mile radius of the Raytheon Missile Systems main facility in Tucson, Arizona. The experimental radios will be used on a mobile basis, probably in aircraft that will fly at a maximum altitude of 10,000 ft.

Stop Buzzer Point of Contact:

Bart Turner Spectrum Manager
Raytheon Missile Systems
(520) 794-0227 (office)
Bartholomew.d.turner@raytheon.com

Conclusion:

Raytheon continues its work in building on other, ongoing experimentation with radio systems to enhance the quality of frequency hopping technologies as well as to develop interference-resistant command and control radio systems to make the use of Raytheon missiles more secure. This application seeks to add the frequency band 4700-5000 MHz to the existing license.

This license is used to develop robust, interference-resistant command and control radio transmissions that will enhance the safety and effectiveness of Raytheon's missile systems. The testing has been designed to minimize the power needed, limit the occupied bandwidth, and produce an efficient, effective radio system. The testing will all be "listen-before-transmit" both to protect existing users in these bands as well as to improve the quality of the product under development.

Should there be any questions about the proposed application, please contact Anne L. Cortez, Washington Federal Strategies, 520-360-0925 alc@conspecinternational.com.