Raytheon Missile Systems
Experimental License Modification Application
File Number: 0044-EX-ML-2012
Call sign: WF2XVV

Exhibit I – Explanation of Need to Use Radio Spectrum

Raytheon Missile Systems (Raytheon) is requesting authorization to modify its experimental license WF2XVV to add the frequency band 1435-1525 MHz, to increase the radius of operations, and to increase the authorized power on the currently licensed bands of 1755 to 1850 MHz and 4500 to 4700 MHz. Raytheon continues to experiment in these radio bands to develop improved interference resistance for command and control signals used when its products are in flight.

Raytheon builds missiles used by the US military. Those products 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. The experimentation proposed here is intended to further the development of radio system and transmissions that will be robust and reliable even in a crowded RF environment to ensure that vital command and control signals are received, without harmful interference.

Synopsis:

- Frequencies requested: 1435-1525 MHz, 1755 – 1850 MHz, and 4500 – 4700 MHz
- Testing is to develop enhanced command and control signals that will not cause nor receive interference in a crowded RF environment
- Testing is on missiles; there is airborne use in a 120 km radius around the Raytheon Tucson facility.
- After waveform analysis, testing will be listen-before-transmit and use frequency hopping.
- Frequency bands requested are needed for comprehensive testing and development required.

Description of experimentation:

This modification application proposes to use three frequency bands: 1435-1525 MHz, 1755-1850 MHz and 4500-4700 MHz. The power levels currently proposed, based on what Raytheon has learned from the first six months of testing, are a modest increase from what was originally authorized. The current proposed power level is high enough to test out operations that mimic real-world conditions for when the missiles would be in use. The bandwidth per transmission is 6 MHz. The ongoing experimentation proposed here will help Raytheon determine what type of

transmission will guarantee that the command and control signal is received and will withstand interference from the operation of other radios in the area and on or near the same frequency.

Raytheon is proposing to add the use of 1435-1525 MHz to its existing operations. The proposed use will operate on frequencies that are often used for flight test, and Raytheon will coordinate its proposed use through AFTRCC. The reason for including this frequency band in the development of advanced datalink technology development is that this program of experimentation could lead to the development of significantly improved radio communications that are essential to aeronautical mobile telemetry. The proposed experimentation is expected to lead to the development of technologies that are more reliable, more efficient, and carry more data than some of the telemetry technologies currently in use. In seeking to experiment on spectrum that is currently used for telemetry, Raytheon hopes to hone its designs to the exact propagation characteristics of this spectrum band.

The 1755 to 1850 MHz band experimentation continues to use off-the-shelf technologies that are readily available. The purpose of testing in this band is to use easy-to-access technologies to learn as much as possible about designing an interference-resistant transmission before migrating the experiments to the 4500 to 4700 MHz band. In the 4500 to 4700 MHz band, Raytheon has been designing and building equipment. It has begun to test the nature of the transmission of command and control signals. Using 1755 to 1850 first minimizes the variables to be explored in any one test, and therefore it maximizes the efficiency of the testing. 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. In the early phases of testing, the program has been testing waveforms, and it has not 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.

Once the waveforms have been analyzed, then the program begins to incorporate frequency hopping and listen-before-transmit technologies. At that point, the program will always use 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 of cable for most of the analysis, except that there will be about two days of field-testing per month.

Request for full bands is necessary for adequate experimentation:

Raytheon is well aware that the new band it proposes to add to its experimental license, and both of the bands for which it is currently authorized, are highly occupied by other users. 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.

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 experimental license is needed.

In an effort to maximize the effectiveness of the testing, Raytheon is proposing to test across all three, but 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.

Raytheon is moving from strictly lab experimentation into field trials of some of the technology under development. 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 asking for the ability to work across the three designated spectrum bands, Raytheon is trying to allow 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:

Raytheon began its experimentation under the existing license WF2XVV in the fourth quarter of 2011. After the initial 5 months of testing, it became clear that additional work was needed, additional spectrum bands needed experimentation, and the power levels currently authorized did not permit experimentation in a radius of operations that would be adequate for the effective development of these technologies. The experimentation is scheduled to continue for at least four (4) 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. Initially, Raytheon sought authorization to operate within a 25 mile radius around its Tucson facility, however, after the initial work was done under its current license, Raytheon learned that its flight testing needed to show how the radios would operate when they were in use at a greater distance. That is why it is seeking authorization to increase the radius of operations to 120 km. The currently proposed radius is more representative of the actual distances across which these radios will need to be used when the final product is incorporated into Raytheon's products.

Stop Buzzer Point of Contact:

Thomas J. Fagan, Spectrum Manager
Raytheon Missile Systems
(520) 794-0227 (office)
(520) 465-7087 (cell)
tjfagan@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.

The proposed testing here is intended 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 Thomas J. Fagan, Spectrum Manager, Raytheon Missile Systems, 520-794-0227 or tjfagan@raytheon.com or Anne L. Cortez, Washington Federal Strategies, 520-360-0925 alc@conspecinternational.com.