Raytheon Missile Systems
Outdoor Antenna Test Range
Application for Renewed Experimental License
Call Sign: WF2XLH
File No: 1130-EX-ST-2019

Explanation of Experiments and Need for Renewed Experimental License

Overview:

Raytheon Missile Systems has been operating an outdoor antenna test range at its Tucson facility since 1993. In 2010, the FCC granted an experimental license for those operations after the expiration of a Frequency Assignment granted by the DoD Area Frequency Coordinator Arizona. This outdoor antenna test range supports all programs and contracts for the Navy, Air Force, and the Army. In addition, Raytheon Missile Systems conducts independent research and development at the same range. This license was renewed in 2012 and 2014 and 2016. The FCC's computer system dismissed the 2018 renewal application while it was pending despite a request for additional time to complete external coordinations, and this application is being filed to restore operations at the range. The need to determine the characteristics of the antennas installed on Raytheon's missiles and other products is ongoing, and so Raytheon is seeking to continue use of the range.

Synopsis:

- Spectrum in use: 200 MHz to 18 GHz
- Operational Power level: 30 milliwatts
- Time of spectrum use: 3.2 milliseconds per frequency step, 10 MHz steps, 200 Hz of occupied bandwidth, 1.2% duty cycle
- Directional antenna: Azimuth 270, at desert, with scatter fence behind
- Minimal testing each day: 15 tests conducted per day, not all frequencies used

Description of operations:

The outdoor antenna test range operates two antennas that test by stepping across a range of frequencies. The test range transmit antennas are:

- Q-Par Dual Polarized Quad Ridge Horn: steps across frequency range 2-18 GHz in 10 MHz increments
- Sunol Sciences Quad LP-1 Antenna: steps across frequency range 200 MHz to 2 GHz in 10 MHz increments

The test range transmit antennas are used to conduct tests to determine three-dimensional (3D) far-field radiation patterns with full scale mockups mounted on the motorized Dual-Mount Tower (DMT), and tested in azimuth and roll over a full sphere. For each unique azimuth and roll increment, the directional antenna gain relative to that of an isotropic

radiator (gain in dBi) is measured.

The horn antennas are mounted on the rooftop of the Outdoor Range. The horn antennas transmit and the Antenna Under Test (AUT) mounted on the DMT receives the signal. Due to the principle of reciprocity, the radiation pattern obtained when the AUT receives the signal is identical to the radiation pattern of the AUT when it transmits. So, testing the receive characteristics provides the required information on the antenna pattern.

In Figure 1 below, Raytheon shows data for some sample test frequencies, antennas, polarization, azimuth and roll resolutions, and other parameters for a typical 3D far-field pattern test:

Antenna	Frequency Band	Number of points	Az, Roll Resolution	Polarization	Wings folded	Wings extended
Link-16	960-1216 MHz	8 (every 40 MHz)	2° x 4°	V & H	Yes	Yes
FTS	424-426 MHz	5 (every 500 kHz)	2° x 4°	RHCP	Yes	Yes
TM	2.2-2.3 GHz	5 (every 25 MHz)	2° x 4°	RHCP	Yes	Yes
Beacon	5.6 - 5.8 GHz	2 (Trans & Rcv)	2° x 4°	V & H	Yes	Yes
UHF	200 - 260 MHz	5 (200, 222, 232, 242, & 260 MHz)	2° x 4°	V & H	No	Yes
GPS L1	1565 - 1586 MHz	11 (every 2 MHz)	2.5° x 5°	V & H	No	Yes
GPS L2	1217 - 1238 MHz	11 (every 2 MHz)	2.5° x 5°	V & H	No	Yes

Note: GPS antenna testing is not performed outdoors within 10 MHz of center frequency.

Figure 1: Sample test parameters

The sample frequencies shown here describe how testing is conducted. As is evident in Figure 1, the antennas tested in column 1 are not all tested across all frequencies on the license. Some antennas are tested across much more limited spectrum. Further, the steps between frequencies vary for each antenna to accommodate the information required on the antenna being tested.

The application requests renewed authorization to conduct tests on discrete frequencies across wide frequency bands so that it is possible to test in accordance with parameters such as those in Figure 1. The tests use very narrow, continuous wave signals with side lobes suppressed. Therefore, the actual spectrum use is far less than the application would seem to request on its face.

The operations proposed here continue to be at a secure facility (campus) with restricted access and even more tightly controlled access to the transmit area. The test range is used during the work week, intermittently. In the event of any emergency situation, all of Raytheon's experimental operations are shut down as part of plant security, so the antenna test range would never be in use during an emergency requiring first responders to be in the area.

Tests conducted by the spectrum management staff at Raytheon have shown that there is no interference experienced at the secure facility, not even near the secured area where the antenna tests are being conducted. The results of the testing by Raytheon spectrum management show that there is minimal chance of any entity experiencing harmful interference adjacent to Raytheon's secured campus. Operational testing under the frequency assignment has been coordinated with nearby facilities such as the Air National Guard, Davis-Monthan Air Force Base, Tucson International Airport, Kitt Peak Observatory, and the University of Arizona. No interference issues have arisen from past and ongoing operations. The operations proposed in this experimental license renewal application are identical to the currently authorized operations, and so there is no anticipated new interference.

Operations are highly directional:

The beamwidth of the antenna is normally narrow, as low as 10 degrees at 18 GHz and is pointed due west into the desert and sparsely populated Indian Reservation. The sidelobes are suppressed by the building and a steel scatter fence, see Figure 2. The scatter fence diffuses the RF energy in many directions, reducing the potential for interference.

Antennas are directional with a very narrow beam, the transmitters point to the desert & sparsely populated Indian reservation land.

Figure 2: Outdoor Antenna Test Range

Interference Analysis Shows No Likelihood of Harmful Interference

This test range has been in operation, first under a federal frequency assignment and then under WF2XLH for years, without causing harmful interference to other radio operations. Nevertheless, Raytheon has used Hertz Warfare software to run theoretical studies of the interference potential from use of this antenna test range. As is evident from Figures 3 (close up) and 4 (wide view) below, the signal levels off the range are very low. The use of scatter fencing protects the area behind the transmitter from any effects of backlobe radiation, as it was intended to do. When the low power of the signals is combined with the low duty cycle and short pulse duration of the transmitted signals, the prospect of interference is even less. Figure 3 below shows in a close-up view of the signal on the Raytheon plant site using a 1 km scale. The Raytheon plant site is runs all the way from the outdoor antenna test range to Interstate 19, and the signals off the plant site are very low. Figure 4 uses a 5 km scale showing the area around the plant site, to give greater context to the statement that the signal levels off the plant site are unlikely to result in any harmful interference.

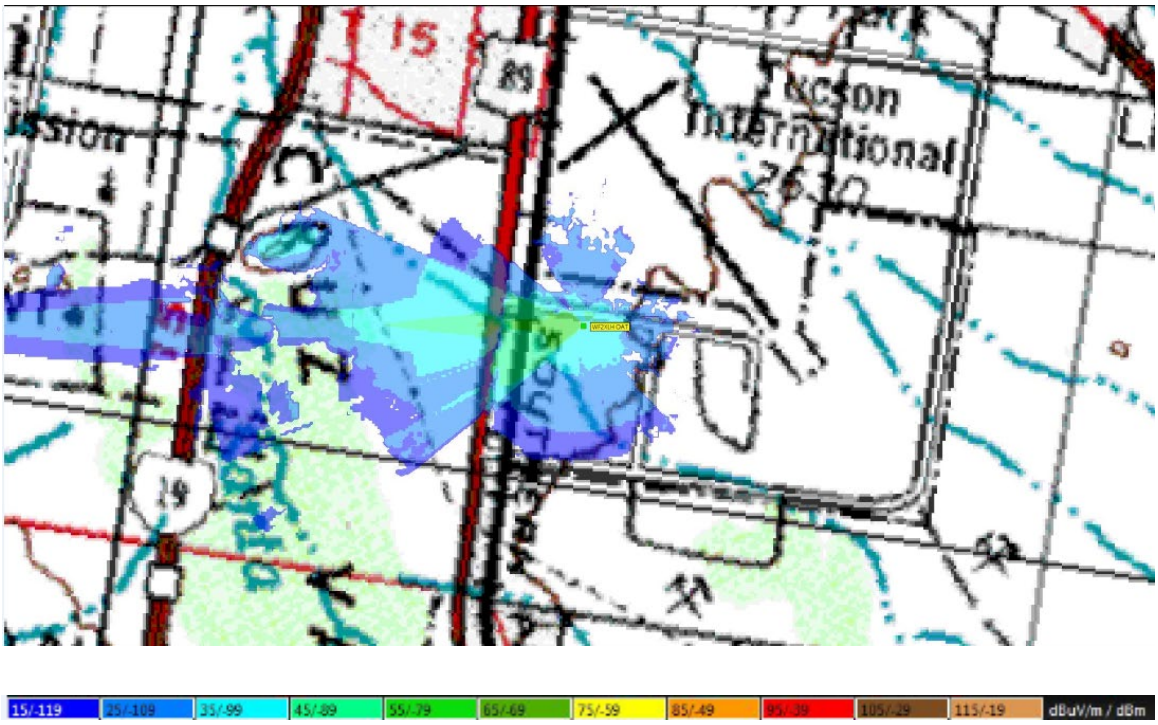

Figure 3: 760 MHz Spectrum Plot from Hertz Warfare at 1 km scale
(Note: color scale goes down to -119 dBm)

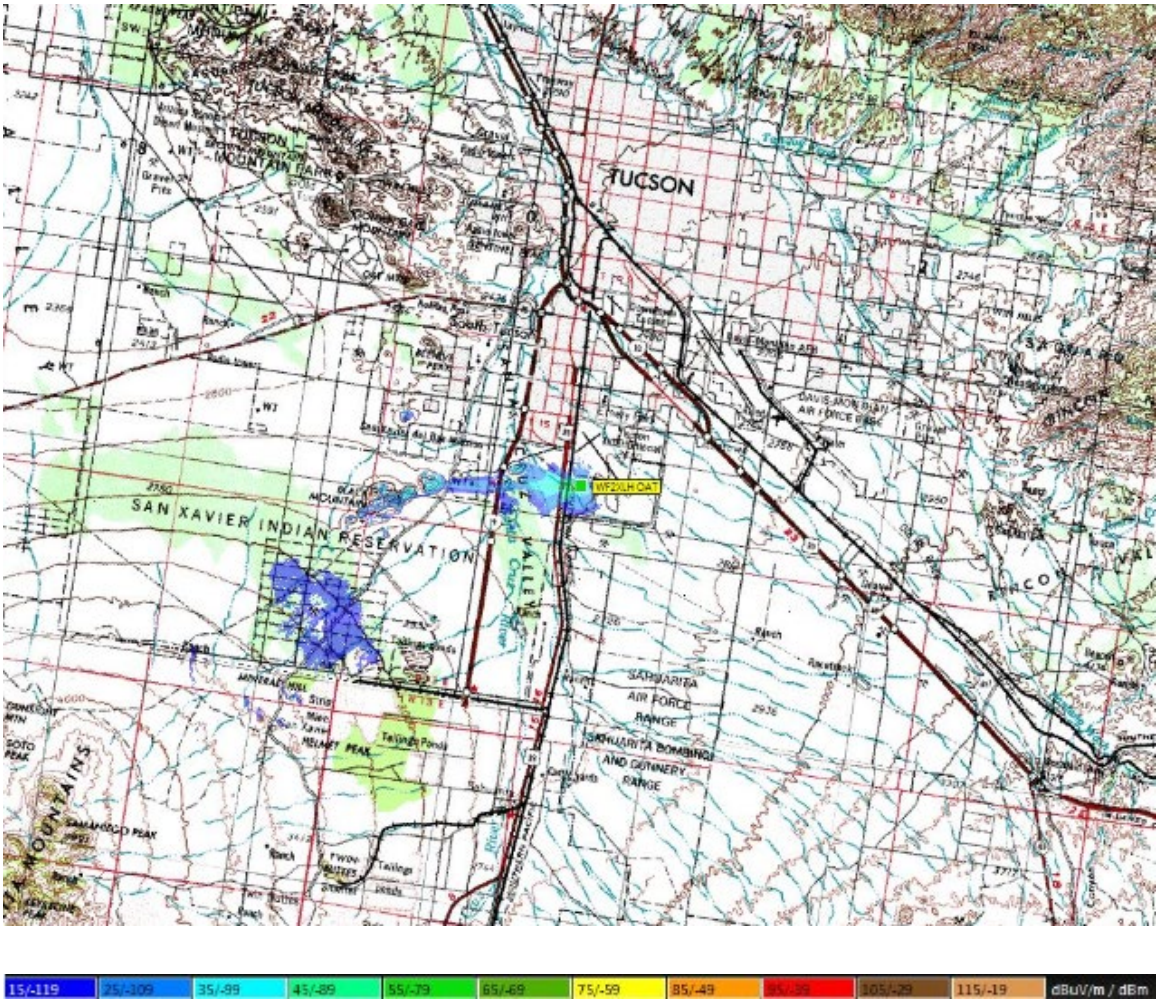

Figure 4: 760 MHz Spectrum Plot from Hertz Warfare at 5 km scale
(Note: color scale goes down to -119 dBm)

In **Figures 5 and 6** below, Raytheon shows the results of additional interference analyses at higher frequencies that are sometimes used by this antenna test range. As the frequency being analyzed increases, the scale shifts, because higher frequency transmissions do not propagate as far as lower frequency transmissions. As a result, the shaded areas may appear bigger, but the signal strengths being illustrated are much lower.

Raytheon has never received any complaints of interference from the ongoing operations of this test range.

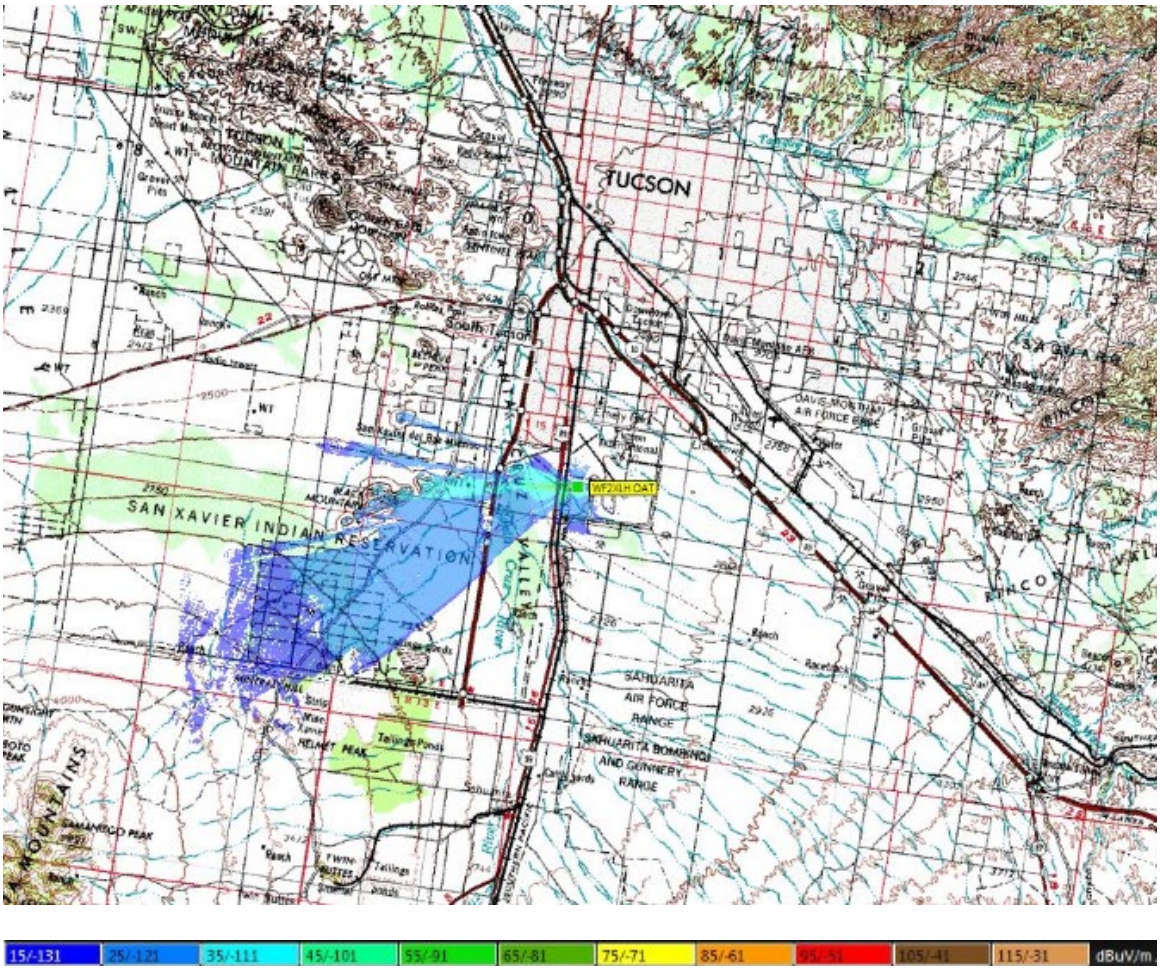

Figure 5: 3000 MHz Spectrum Plot from Hertz Warfare at 5 km scale
(Note: color scale goes down to -131 dBm)

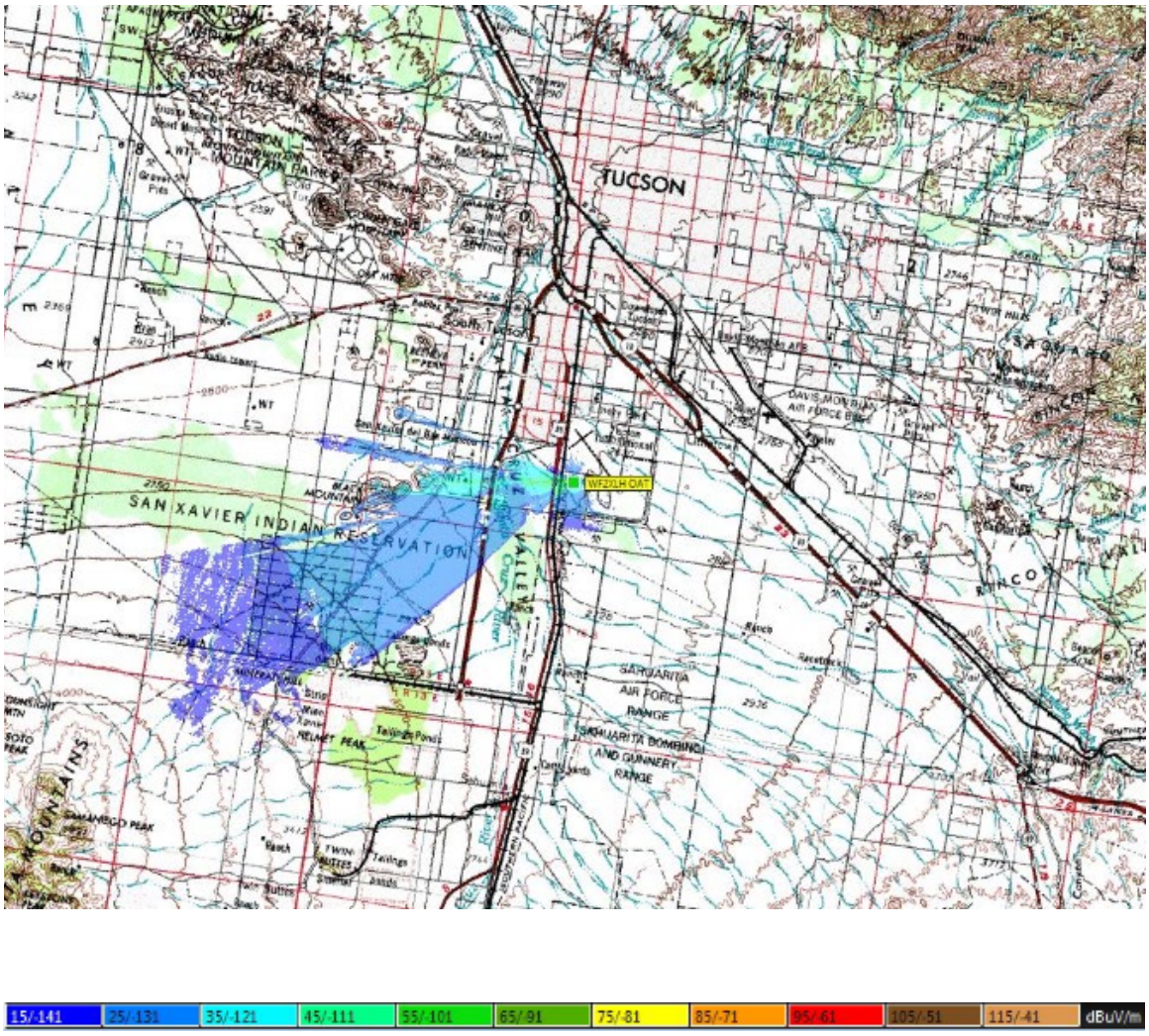

Figure 6: 9000 MHz Spectrum Plot from Hertz Warfare at 5 km scale
(Note: color scale goes down to -141 dBm)

Need for Outdoor Antenna Test Range:

Because of the nature of work being done, it is important to test the characteristics of a number of different antennas operating across a range of frequencies. Those antennas are installed on various pieces of equipment that Raytheon builds. That equipment and the way that its antennas work must be tested in a free space environment. Therefore, it is necessary to operate this outdoor antenna test range.

Given the sensitive nature of the tests, Raytheon transmits on a number of discrete frequencies across a wide range of frequencies. Those tests are limited in time, and for highly sensitive frequencies, Raytheon continues to be willing to operate according to a strict schedule to minimize any potential interference issues.

Limitations on Use:

Low Power testing: Review of the operations of the outdoor antenna test range have shown that the power level of the transmissions is merely 30 milliwatts.

Limited Time of Use of Spectrum: Raytheon has studied the operations of the test range. For any antenna test, each frequency is only in use less than ***3 minutes***, which is a short amount of RF use. That estimate is the accumulated time of transmitted pulses that last only 3.2 milliseconds each, less than half of what it was only 2 years ago, with the signal off for a long period between pulses. The duty cycle is only 1.2%. Each day of testing normally only tests 15 of the stepped frequencies. The RF usage on any given day is minimal.

Detailed time of use calculations will be submitted in a second exhibit.

Stop Buzzer:

Jim Ortega, Spectrum Manager
Raytheon Missile Systems
520-794-0227
James.e.ortega@raytheon.com

Conclusion:

Raytheon seeks continued authorization for operations at its outdoor antenna test range. The purpose of the range is to determine the antenna patterns of the Antennas Under Test (AUTs). Those antenna patterns are tested by using transmitters which step across many discrete frequencies, record the receive patterns of the AUTs, and because of reciprocity the testing provides the transmit patterns of the AUTs. The testing is extensive – looking at the AUT in three dimensions. The power is low, and the time on any single frequency is very brief.

If there are any questions, please contact Anne Linton Cortez, 520-360-0925, alc@conspecinternational.com.