ARIZONA DEPARTMENT OF PUBLIC SAFETY

2102 WEST ENCANTO BLVD. P.O. BOX 6638 PHOENIX, ARIZONA 85005-6638 (602) 223-2000

"Courteous Vigilance"

JANICE K. BREWER Governor ROBERT C. HALLIDAY Director

Raytheon Missile Systems Experimental License Operations Consent Form

The Arizona Department of Public Safety (AZ DPS), license holder of statewide public safety license WPTZ765, has received a request from Raytheon Missile Systems for its consent to proposed experimental radio operations. The FCC requires Raytheon to secure this consent prior to the FCC's review and processing of the Raytheon experimental license application,

FCC file number: 0077-EX-ML-2014

Raytheon has provided AZ DPS with:

- a copy of the application,
- a copy of the application exhibit
- additional technical information, and
- the opportunity to answer technical questions relevant to DPS

Consent: Upon review of the materials, and after receiving satisfactory responses to AZ DPS technical questions regarding protection of public safety communications, AZ DPS has determined that it will grant consent to the proposed experimental operations. This consent applies to the 384 state channels directly licensed to the Arizona Department of Public Safety per C.F.R. 90.531(b)(5).

Kevin A. Rogers, Manager
Wireless Systems Bureau
Arizona Department of Public Safety

6-30-2014
Date

Attachments:
FCC Form 442 File#:0077-EX-ML-2014
Request Letter dated May 30, 2014

Washington Federal Strategies
Anne Cortez
(520)360-0925
ale@conspecinternational.com

Via e-mail to karogers@azdps.gov

May 30, 2014

Kevin Rogers
State of Arizona
Department of Public Safety
PO Box 6638
MS 2800
Phoenix, AZ 85005-6638

Re: Request for State of Arizona Consent to Raytheon Missile Systems Experimental Operations

Dear Mr. Rogers:

Raytheon Missile Systems, based in Tucson, Arizona, has filed an experimental license application with the FCC, file number 0077-EX-ML-2014, to conduct radar cross section testing to fulfill a number of Department of Defense contracts. In its initial review of the application, the FCC has required Raytheon to seek the consent of the statewide public safety licensee in the 700 MHz band, call sign WPTZ765, which authorizes the State of Arizona to operate on 769-775 MHz and 799-805 MHz. As we discussed yesterday, I am sending this package for your review. Also, I am hoping that it will be possible for you to include this request at the executive committee meeting of state-wide itinerant licensees in Flagstaff in July.

You were kind enough to discuss with me in advance the materials that would be helpful in reviewing this coordination request, so that your office can determine whether to provide its consent to the experimental operations. As with Raytheon's other current experimental coordination, we request that you present this information to the itinerant interoperability executive committee for their consideration and consent as well.

Attached to this letter are the following materials:

- A document containing the technical information submitted in Raytheon's FCC application, 0077-EX-ML-2014
- The exhibit to the application, explaining the operations
- A document containing time calculations showing how little time the spectrum is in use, even when there is testing underway (mostly, the transmitters are off, not on)

Background:

Raytheon Missile Systems is a defense contractor that designs a large number of advanced weapons systems for the US Department of Defense. In order to comply with its DOD contractual

requirements, Raytheon must conduct radar cross section testing on various products to ensure that it is delivering products that meet DOD requirements.

Raytheon has been conducting these radar tests for over 20 years. There have never been any instances of harmful radio interference. The current modification application requests authorization to include spectrum from 100 MHz to 2 GHz, to ensure that the testing fully resolves any concerns about the products.

Raytheon's technologies are dependent on the use of many radio systems, and it has developed a sophisticated spectrum management office which regularly monitors operations on the plant site, works to deconflict spectrum uses, and works in many ways to ensure that it is a non-interfering spectrum user in a congested spectrum environment. The company is committed to continuing to operate cooperatively in the spectrum environment.

Technical Synopsis:

- Test Range: Used for radar cross section testing.
- Frequency usage: Tests step across frequency bands in 10 MHz steps.
- Time of Use: 70 nanoseconds per frequency step, very short pulse duration.
- New spectrum needed: 100 MHz to 2 GHz.
- Range design: Antennas are directional & tilted downward to minimize spatial dispersion of the radiated power.

Testing Explained in Brief:

The system is in use daily, weather permitting. However, even when the system is in use, the radio transmitters are not on for very much time. The time charts attached show how short the radio pulses are, and how much time the radios are off. The duty cycle on a frequency is very low. Further, when all the testing is considered, the amount of time that TTF would use the spectrum for which AZ DPS is licensed is approximately 387 milliseconds per day.

The exhibit to the application, attached here, explains the proposed operations in much greater detail. Further, the exhibit contains spectrum propagation studies generated using Hertz Warfare software. The Hertz Warfare program does not account for the attenuating effect of buildings, so it generally shows more signal propagation than will occur in the actual setting.

Time Reference:

The typical test uses any single frequency step for 0.64 milliseconds at a duty cycle of 1.2% before moving to another frequency. By way of reference, researchers at Harvard Medical School estimate 100-400 milliseconds per human blink.[1] Even at the fastest blink rate, that would be at least 100 tests in the blink of an eye, with a very low duty cycle.

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[1] Schiffman, H.R., Sensation and Perception. An Integrated Approach, New York: John Wiley and Sons, Inc., 2001

Conclusion:

Thank you for your consideration of this request. Raytheon Missile Systems looks forward to working cooperatively with you and your team as you evaluate the experimental spectrum uses Raytheon requires to develop and deliver innovative products to the federal government and other authorized customers. We welcome your questions, and if there is anything further that you need, please do not hesitate to ask.

Sincerely,

Anne E. Cortez, Esq.
On behalf of Raytheon Missile Systems

Attachments

Cc: Geoff Anderson, Esq. senior counsel, Raytheon Missile Systems
Thomas J. Fagan, spectrum manager, Raytheon Missile Systems

FCC FORM 442 - FEDERAL COMMUNICATIONS COMMISSION
APPLICATION FOR NEW OR MODIFIED RADIO STATION UNDER PART 5 OF FCC RULES - EXPERIMENTAL RADIO SERVICE (OTHER THAN BROADCAST)

Approved by OMB 3060 - 0065 Expires 09/30/98

Applicant's Name (company): Raytheon Missile Systems **File No.:** 0077-EX-ML-2014

Mailing Address

Attention: Thomas J. Fagan
Street Address: 1151 E. Hermans Road, Bldg. M02, M/S T16
P.O. Box: 11337
City: Tucson
State: AZ
Country: United States
Zip Code: 85734-1337
E-Mail Address: tjfagan@raytheon.com

Application Purpose

Application is for: MODIFICATION OF LICENSE

For Modification indicate below

File No.: 0102-EX-RR-2013 **Callsign:** KA2XAG

Government Contract

Is this authorization to be used for fulfilling the requirement of a government contract with an agency of the United States Government? If "YES", include as an exhibit a narrative statement describing the government project, agency and contract number. No

Foreign Government Use

Is this authorization to be used for the exclusive purpose of developing radio equipment for export to be employed by stations under the jurisdiction of a foreign government? If "YES", include the contract number and the name of the foreign government concerned as an exhibit. No

Research Project

Is this authorization to be used for providing communications essential to a research project? (The radio communication is not the objective of the research project)? If "YES", include as an exhibit the following information:

a. **A description of the nature of the research project being conducted.**
b. **A showing that the communications facilities requested are necessary for the research project involved.**
c. **A showing that existing communications facilities are inadequete.**

No

Exhibit Information

If all the answers to Items 4, 5, 6 are "NO", include as an exhibit a narrative statement describing in detail the following items:

a. **The complete program of research and experimentation proposed including description of equipment and theory of operation.**
b. **The specific objectives sought to be accomplished.**
c. **How the program of experimentation has a reasonable promise of contribution to the development, extension, expansion or utilization of the radio art, or is along line not already investigated.**

Estimated Duration

Give an estimate of the length of time that will be required to complete the program of experimentation proposed in this application: 24 Months

Environmental Impact

Would a commission grant of this application come within Section 1.1307 of the FCC Rules, such that it may have a significant environmental impact? If "YES", include as an exhibit an Environmental Assessment as required by Section 1.1311. No

Manufacturer

List below transmitting equipment to be installed (if experimental, so state) if additional rows are required, please submit equipment list as an exhibit :

Manufacturer	Model Number	No. Of Units	Experimental
Electronic Navigation Industry	P/N 550L	1	No
Applied Systems Engineering	167S/XTWTA	1	No
Electronic Navigation Industry	P/N 601L	2	No
Applied Systems Engineering	167x/KuTWTA	1	No
Varian	P/N 69006	1	No

Station ID

Is the equipment listed in Item 10 capable of station identification pursuant to Section 5.115? No

Applicant Type

Applicant is: Corporation

Foreign Government

Is applicant a foreign government or a representative of a foreign government? No

License Denied or Revoked

Has applicant or any party to this application had any FCC station license or permit revoked or any application for permit, license or renewal denied by this Commission? If "YES", include as an exhibit a statement giving call sign of license or permit revoked and relate circumstances. No

Owner and Operator

Will applicant be owner and operator of the station? Yes

Contact Information

Give the following information of person who can best handle inquiries pertaining to this application: **First Name:** Anne E
Last Name: Cortez
Title: Counsel
Phone Number: 520-360-0925
E-Mail Address: alc@conspecinternational.com

Drug Abuse Question

APPLICANT ANTI-DRUG ABUSE CERTIFICATION: By checking "YES", the individual applicant certifies that he or she is eligible for this license. This requires that he or she is not subject to a denial of federal benefits, including FCC benefits, as a result of a drug offense conviction pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C. 862. A non-individual applicant, e.g., corporation. partnership or other unincorporated association, certifies that no party to the application is subject to a denial of federal benefits, pursuant to that section. For definition of a "party" for these purposes, see 47CFR 1.2002(b). Yes

Certification

THE APPLICANT CERTIFIES THAT:

a. Copies of the FCC Rule Parts 2 and 5 are on hand; and
b. Adequete financial appropriations have been made to carry on the program of experimentation which will be conducted by qualified personnel; and
c. All operations will be on an experimental basis in accordance with Part 5 and other applicable rules, and will be conducted in such a manner and at such a time as to preclude harmful interference to any authorized station; and
d. Grant of the authorization requested herein will not be construed as a finding on the part of the Commission:
    1. that the frequencies and other technical parameters specified in the authorization are the best suited for the proposed program of experimentation, and
    2. that the applicant will be authorized to operate on any basis other than experimental, and
    3. that the Comission is obligated by the results of the experimental program to make provision in its rules including its table of frequency allocations for applicant's type of operation on a regularly licensed basis.

THE APPLICANT FURTHER CERTIFIES THAT:

e. All the statements in the application and attached exhibits are true, complete and correct to the best of the applicant's knowledge; and
f. The applicant is willing to finance and conduct the experimental program with full knowledge and understanding of the above limitations; and
g. The applicant waives any claim to the use of any particular frequency or of the electromagnetic spectrum as against the regulatory power of the USA.

Name of Applicant: Raytheon Missile Systems
Signature (Authorized person filing form): Thomas J Fagan
Signature Date (Authorized person filing form): 04/22/2014
Title of Person Signing Application: Spectrum Manager
Classification: Authorized employee

WILLFUL FALSE STATEMENTS MADE ON THIS FORM ARE PUNISHABLE BY FINE AND/OR IMPRISONMENT (U.S. CODE, TITLE 18, SECTION 1001), AND/OR REVOCATION OF ANY STATION LICENSE OR CONSTRUCTION PERMIT (U.S. CODE, TITLE 47, SECTION 312(A)(1)), AND/OR FORFEITURE (U.S. CODE, TITLE 47, SECTION 503).

NOTIFICATION TO INDIVIDUALS UNDER PRIVACY ACT OF 1974 AND THE PAPERWORK REDUCTION ACT OF 1980

Information requested through this form is authorized by the Communications Act of 1934, as amended, and specified by Section 308 therein. The information will be used by Federal Communications Commission staff to determine eligibility for issuing authorizations in the use of the frequency spectrum and to effect the provisions of regulatory responsibilities rendered by the Commission by the Act. Information requested by this form will be available to the public unless otherwise requested pursuant to 47 CFR 0.459 of the FCC Rules and Regulations. Your response is required to obtain this authorization.

Public reporting burden for this collection of information is estimated to average four (4) hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden to the Federal Communications Commission, Records Management Branch, Paperwork Reduction Project (3060-0065), Washington DC 20554. DO NOT send completed applications to this address. Individuals are not required to respond to this collection unless it displays a currently valid OMD control number.

THE FOREGOING NOTICE IS REQUIRED BY THE PRIVACY ACT OF 1974, P.L. 93-579, DECEMBER 31, 1974, 5 U.S.C. 552a(e)(3), AND THE PAPERWORK REDUCTION ACT OF 1980, P.L. 96-511, DECEMBER 11, 1980, 44 U.S.C. 3507.

Station Location

	City	State	Latitude	Longitude	Mobile	Street (or other indication of location)	County	Radius of Operation
0	Tucson	Arizona	North 32 6 6	West 110 56 49		1151 East Hermans Road, Bldg. 846C	PIMA	0.16

Datum: NAD 83

Is a directional antenna (other than radar) used? No

Exhibit submitted: No

(a) Width of beam in degrees at the half-power point:

(b) Orientation in horizontal plane:

(c) Orientation in vertical plane:

Will the antenna extend more than 6 meters above the ground, or if mounted on an existing building, will it extend more than 6 meters above the building, or will the proposed antenna be mounted on an existing structure other than a building? No

(a) Overall height above ground to tip of antenna in meters:

(b) Elevation of ground at antenna site above mean sea level in meters:

(c) Distance to nearest aircraft landing area in kilometers:

(d) List any natural formations of existing man-made structures (hills, trees, water tanks, towers, etc.) which, in the opinion of the applicant, would tend to shield the antenna from aircraft:

Action	Frequency	Station Class	Output Power/ERP	Mean Peak	Frequency Tolerance (+/-)	Emission Designator	Modulating Signal
Modified	100.00000000-2000.00000000 MHz	FX	100.000000 W 28119.000000 W	P		2M00P0N	pulsed radar
New	2000.00000000-4000.00000000 MHz	FX	100.000000 W 66222.000000 W	P		2M00P0N	pulsed radar
New	4000.00000000-8000.00000000 MHz	FX	100.000000 W 36392.000000 W	P		2M00P0N	pulsed radar
New	8000.00000000-12000.00000000 MHz	FX	100.000000 W 58884.000000 W	P		2M00P0N	pulsed radar
New	12000.00000000-18000.00000000 MHz	FX	100.000000 W 62517.000000 W	P		2M00P0N	pulsed radar
New	32000.00000000-39000.00000000 MHz	FX	10.000000 W 2884.000000 W	P		2M00P0N	pulsed radar

Raytheon Missile Systems
Experimental License KA2XAG Modification Application
File No: 0077-EX-ML-2014

Tucson Test Facility
Explanation of Experiment and Use of Spectrum

Background:

This application is filed to modify experimental license KA2XAG to expand the radio frequencies that can be used at the radar cross section testing facility operated by Raytheon Missile Systems (RMS) in Tucson, Arizona. This application is for RMS to use this spectrum for independent research and development (IRAD) of products. The same facility is used for identical testing by RMS pursuant to government contracts. The use of the facility for government contractual purposes is the subject of a Navy frequency assignment request. After numerous meetings with both the Navy and the Federal Communications Commission (FCC) in 2008, 2009, and 2011, RMS was instructed that this facility requires both the Navy frequency assignment and an FCC experimental license, as it has in the past. A parallel modification is being requested for the Navy Frequency Assignments.

Description of the Research Project:

RMS builds systems used for national security and defense. Creating products and systems that are difficult to detect is an important part of developing new technologies that keep our nation safe. While much of the company's work is performed on government contracts, some work is done independently to develop new ideas that may be useful to RMS's customers. That IRAD testing requires use of the Tucson Test Facility, and an experimental license is required for operation. The nature of the research is to determine the radar cross section of various objects under test. Radar pulses are narrowly focused to bounce off those objects, and the radar returns are evaluated to determine the profile of the object. There is no way to measure the radar cross section of an object without using a radar, the purpose of the facility for which this license modification is being filed.

This facility has had an experimental license, KA2XAG, from the FCC for over 20 years. This application proposes to expand ongoing operations at the TTF to include frequency bands covering the spectrum from 100 MHz to 2.0 GHz, providing enhanced spectral range to supersede the previously used spot frequencies at 155 MHz, 815 MHz, and 1300 MHz.

The spectrum requested in this modification application will used in the same way as the existing, stepped frequency radar testing that currently is authorized from 2 GHz – 18 GHz and from 32 GHz to 39 GHz. The object under test is placed on a pylon down range from the radar transmitter; the pylon rotates in 0.1 degree azimuth increments, and at each increment the radar systems step through the authorized frequencies, measuring both polarizations to determine the return from the object.

The signal generator requires some measurable time between pulses to avoid overheating, and each pulse has a maximum duration of 70 nanoseconds. Table 1 below presents information on total test time, total time on a frequency, and other data that helps to illustrate the brevity of the RF signal use.

At its most efficient the range can only test six to eight objects per day, allowing for changing the object aspect, cooling the signal generator, and performing the requisite computations that must be run between pulses.

Synopsis:

- Test Range: Used for radar cross section testing.
- Frequency usage: Tests step across frequency bands in 10 MHz steps.
- Time of Use: 70 nanoseconds per frequency step, very short pulse duration.
- New spectrum needed: 100 MHz to 2 GHz.
- Range design: Antennas are directional & tilted downward to minimize spatial dispersion of the radiated power.

Technical Details of Testing:

TTF operates a low power instrumentation test range. Most testing currently steps across the 2-18 GHz and 32-39 GHz bands. The transmissions are made in 10 MHz steps, with a pulse width of 70 nanoseconds and the beam narrowly focused to illuminate the test objects. Although the power level and antenna gain for these transmissions appear to be high, the narrow beamwidth and downward tilt of the antennas serve to minimize any potential interference effects associated with the test transmissions; furthermore, the duration of the pulses is so short that they will not be detected by typical radio receivers.

As far as the measurement procedure is concerned, the test object is put on a turntable down range from the radar, and the transmitter is pulsed to capture complete data on the return from the object. The radar receiver acquires the reflected signal, which is subsequently processed to determine the time-domain response of the object under test.

This modification request seeks to augment the license – from use of three discrete frequencies at 155, 815, and 1300 MHz – to include stepping across the frequency band from 100 MHz to 2.0 GHz. This will provide a continuous extension of the measurement capability of the existing license.

Test Time:

Tables 1 and 2 below show how Raytheon calculated the maximum time of use for any frequency used on one day as well as the maximum total amount of time that RF may be emitted within a single day. Regardless of how many frequencies are being tested, the total amount of time that any frequency would be in use on a single day is never more than 387 milliseconds.

Table 1 shows the total amount of time spectrum is in use while testing is being conducted across the combined range consisting of the existing licensed spectrum and the spectrum requested under this modification application: that is, 100 MHz – 18 GHz and 32 – 39 GHz. Table 2 shows the total amount of time of spectrum would be in use when testing is conducted only on the additional spectrum requested under this modification application, 100 MHz to 2 GHz.

All testing steps through authorized frequencies, pulsing at 10 MHz intervals, with each pulse being 70 nanoseconds in duration.

Table 1		All Spectrum: 100 MHz - 18 GHz and 32 - 39 GHz		Calculations show use of a single frequency and total time of spectrum use per day
Factor:		Amount		Notes
# of test angles		3600		
# of radar sweeps through all frequencies/angle		128		Multiple Sweeps needed for Fast Fourier Transform
total number of sweeps/pattern		460800		a pattern is the full set of sweeps through every angle and at each frequency
Number of polarizations		2		vertical and horizontal
pulse width (sec) - per frequency		0.00000007		70 ns pulses, time of use of the frequency per sweep
Time (sec) on a frequency per pattern (all 460800 sweeps)		0.064512		
maximum number of patterns run each day (different objects or different parts of an object)		6		Typical use is 6 patterns per day
Total time per day on a single frequency, in seconds (maximum use is 6 patterns per day)		0.387072		387 milliseconds total use per day
interval between frequencies tested (MHz)		10		testing steps across spectrum, pulsing for 70 ns every 10 MHz
Number of frequency steps for all spectrum		2490		the system steps through the frequencies in 10 MHz steps, for a total of 2490 steps
Maximum spectrum use per day - all frequencies included (sec)		963.80928		Total spectrum time used during a day of testing
Maximum spectrum use per day, including all frequencies (minutes)		16.063488		

Table 2		Spectrum in use: 100 MHz - 2 GHz		Calculations show use of a single frequency and total time of spectrum use per day
Factor:		Amount		Notes
# of test angles		3600		
# of radar sweeps through all frequencies/angle		128		Multiple Sweeps needed for Fast Fourier Transform
Total number of sweeps/pattern		460800		a pattern is the full set of sweeps through every angle and at each frequency
Number of polarizations		2		vertical and horizontal
Pulse width (sec) per frequency		0.00000007		70 ns pulses, time of use of the frequency per sweep
Time (sec) on a frequency per pattern (all 460800 sweeps)		0.064512		460,800 sweeps and 2 polarizations
Maximum number of patterns run each day (different objects or different parts of an object)		6		Typical use is 6 patterns per day
Total time on a single frequency, in seconds (maximum use is 6 patterns per day)		0.387072		387 milliseconds total use per day
Interval between frequencies tested (MHz)		10		testing steps across spectrum, pulsing for 70 ns every 10 MHz
Number of frequency steps for this sub-spectrum		190		the system steps through the frequencies in 10 MHz steps, for a total of 190 steps
Maximum spectrum use per day - all frequencies included (sec)		73.54368		73.54 seconds of total spectrum use in a day, if 6 patterns are collected on the 100 MHz to 2 GHz sub-band.
Maximum spectrum use per day, including all frequencies in the sub-band (minutes).		1.225728		Total time of RF use for a day, in minutes

Description of the Test Plan:

The time of RF use for data collection for any given test object is short. An object is placed on the test range 520 feet from the transmitting antennas; and for most of the testing, the transmitter is pulsed at each frequency, from 100 MHz to 18 GHz and 32 to 39 GHz, in 10 MHz steps (as noted above, each pulse is 70 nanoseconds in duration). The sweep is repeated 128 times for the system to correlate the signal using a Fast Fourier Transform (FFT). After a complete set of frequency sweeps has been performed, the polarization is changed and the frequency stepping is repeated at the same angle. The object on the turntable is rotated thru 360 degrees in 1/10 degree increments, with the frequency stepping at both polarizations repeated at each angle.

Depending upon the weather, up to 6 items, or patterns, can be tested each day. This application proposes to add to the stepped testing the spectrum extending from 100 MHz to 2.0 GHz. It is expected that there will be times when the radar testing will only use the frequency range from 100 MHz to 2.0 GHz. The test time calculations for this specific usage are shown in Table 2. Typically,

six patterns are completed in a day. The RF is in use, across all frequencies, for a total of 16 minutes. The total time of RF use for any single frequency is only 387 milliseconds spread across an entire day.

Evaluation of Interference Potential

Raytheon has run tests using a spectrum analyzer to measure the signals from the TTF range, and the spectrum analyzer did not register use of spectrum at all, because the pulse width of the signals is so short.

Geography Limits Interference Potential:

TTF is located in a relatively unpopulated area, which also minimizes the possibility of any potential interference. At the request of the FCC and others, RMS researched numerous questions, including whether there was potential impact on FM radio reception from test. RMS was also requested to provide additional theoretical analyses of the signal strength in the surrounding area.

Voice Communications Equipment and FM Receivers Receive No Interference:

Raytheon's research indicates that voice communication equipment will not respond to 70 nanosecond signals because the signal duration is too short for a typical receiver to process. In addition, FM receivers normally reject pulsed signals, and the squelch on most commercial receivers rejects signals that are shorter than one millisecond in length. One frequency sweep from the TTF has less effect on a voice communications radio than a lightning strike. FM receivers are designed to reject amplitude variations in the received signals, which further reduces the likelihood of interference. Motorola, which makes a variety of handheld and fixed-location voice communication products, stated that voice communications equipment will not respond to 70 nanosecond RF bursts.

This modification requests authorization to shift from the use of the spot frequencies, 155 MHz, 815 MHz, and 1300 MHz, to the use of stepped testing from 100 MHz to 2.0 GHz. In the past, Raytheon has verified that TTF does not interfere with voice communications equipment operating on or near the spot frequencies. RMS engineers tested using a Motorola handheld radio on the TTF range. The radio was tuned to 155 MHz and placed in the TTF main antenna beam with the TTF transmitter also set to 155 MHz. As expected, the radio did not respond to the maximum-power emissions from TTF's test system. The tests were repeated on 815 and 1300 MHz, and in all cases the radios registered absolutely no response to the transmitted signals. Because of the stepped nature of the proposed testing, no interference is expected in the frequency bands 100 MHz to 2 GHz. The pulse width of 70 nanoseconds is so short that it will not affect receivers on these frequencies.

Raytheon put FM radios on the pylons on the range, turned on the TTF transmitters, and there was no interference.

Raytheon also tested aircraft radios, AM radio receivers, and commercial band radios in the 400 MHz band: there was no interference to any of those radio receivers from operation of the TTF range.

Need for Continuous Spectrum:

RMS needs continuous spectrum for its testing to be valid because it is not possible to gain essential information concerning the radar cross section of its new products if the testing cannot be conducted at 10 MHz intervals.

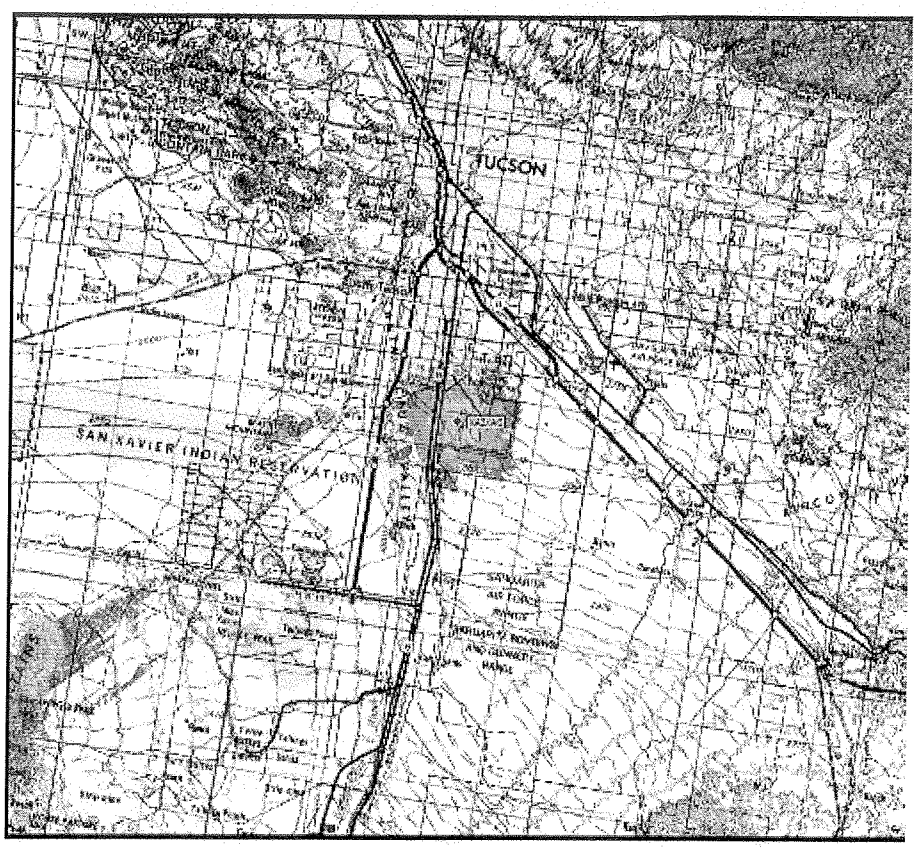
Spectrum Plots Show Very Weak Signals Beyond the Test Range:

To illustrate the rapid drop off of the signal in all frequency bands, RMS ran theoretical spectrum analyses using Hertz Warfare software. The Hertz Warfare plotted predictions do NOT take into account the attenuating effect of buildings around the transmitters. The plots show significantly more signal propagation than actually occurs in the real world, because the surrounding buildings absorb signal power and attenuate propagation.

The spectrum plots, three of which are below, indicate that the signal levels would never be greater than -70 dBm beyond the test range. The signal levels, unattenuated by buildings, are seen to be very low, and, with the short pulse width, the possibility of harmful interference to any other radio use is minimal. Moreover, because the spectrum analyses do not take into account the attenuating effects of buildings, they predict much stronger signals than will actually be present during a test. RMS ran spectrum plots at 200 MHz intervals to get an accurate estimate of signal propagation.

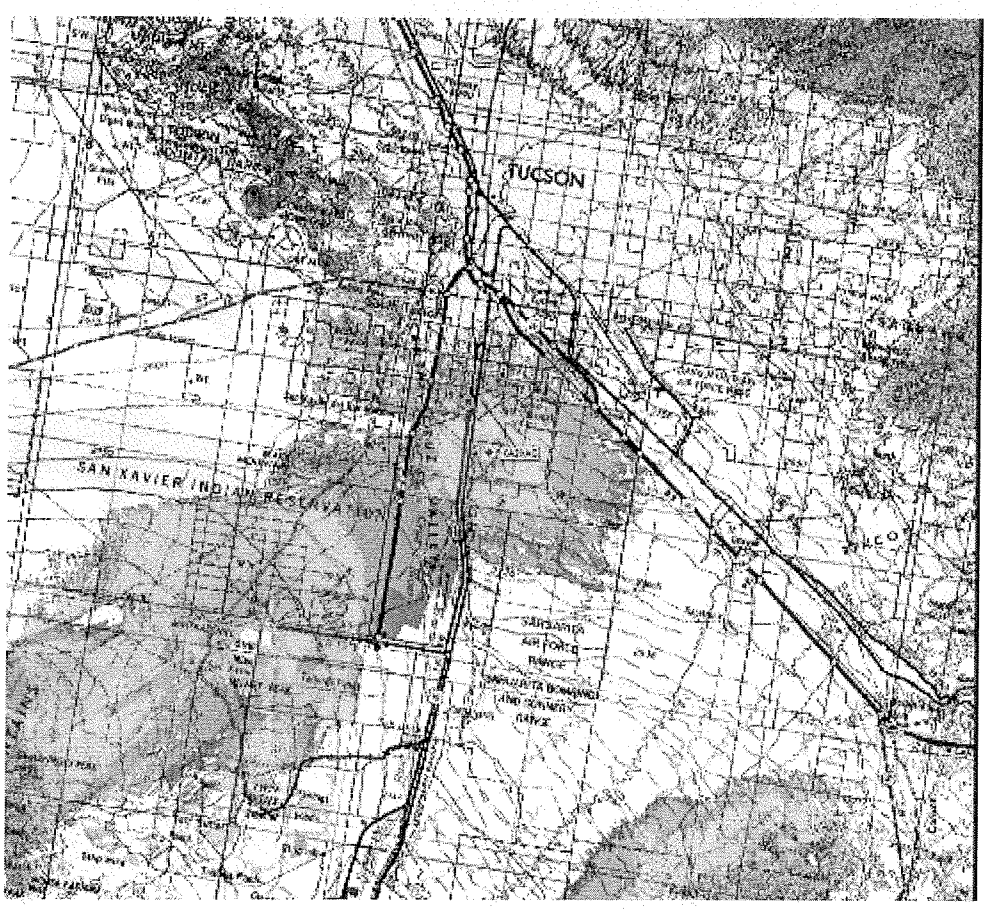
On each of the spectrum plots shown below, the scale varies due to the nature of the software. A note regarding the scale is presented below each plot.

200 MHz signal levels:



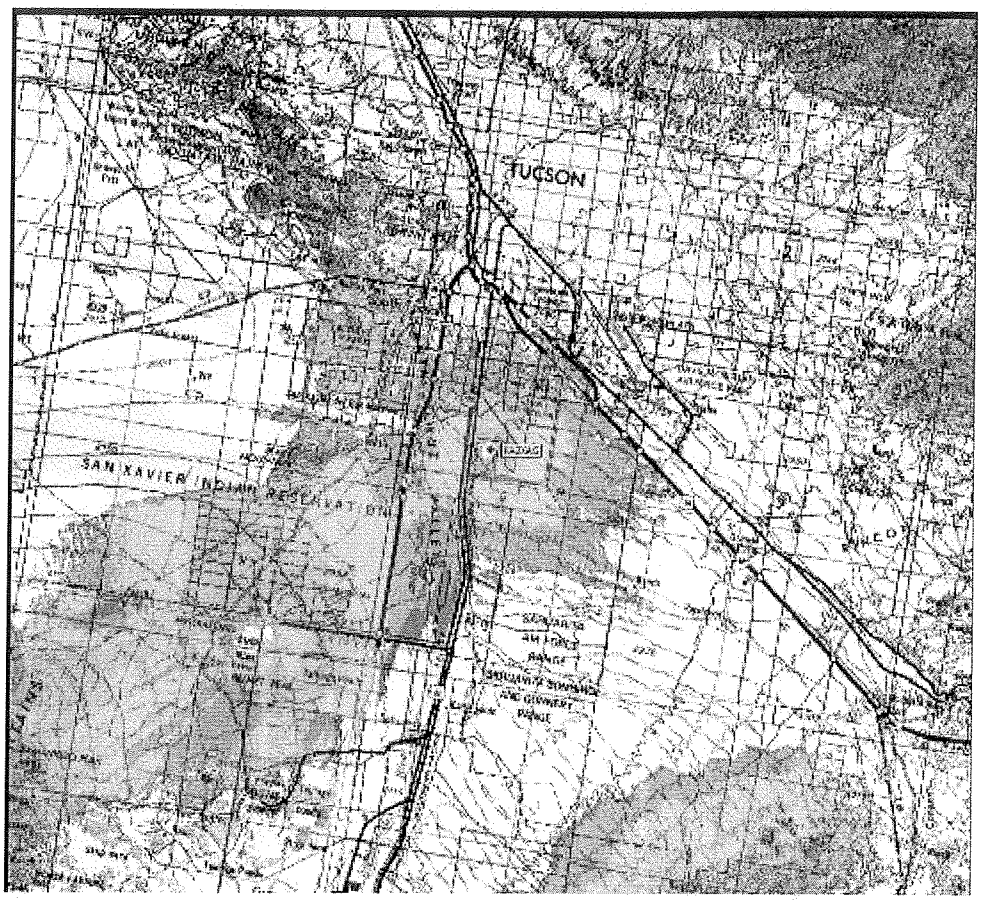
Note on Scale: dark blue is -108 dBm

800 MHz Signal Levels:



Note on Scale: dark blue is at -120 dBm

1400 MHz Signal Levels:



Note on Scale: dark blue is at -125 dBm

The Hertz Warfare plots indicate that the signal strength from the TTF operations is never stronger than -70 dBm once the signals go beyond the TTF range. Analysis of the spectrum plots, coupled with Raytheon studies of radio noise floor data, indicate that the TTF signal will blend into the local radio noise. As shown in previous applications RMS has filed for operations at this test range, the radar returns used at the range are down in the noise, which has led to the extensive testing performed to use correlation data to discern the real signals from the radio noise. Given the predicted weakness of the proposed radio signals, it would be reasonable to expect that a grant of this request will not lead to harmful interference to any of the surrounding area.

No Harmful Interference to GPS:

The proposed license modification requests authorization to step across spectrum that is used for GPS. RMS includes GPS receivers in most of its products, and the company pays particular attention to avoiding interference to GPS signal reception. There are several reasons why the proposed operations will not cause interference to GPS: (1) the GPS signal processor is searching

for a signal that has a pulse width of 130 – 150 milliseconds long, and the 70 nanosecond pulse of the radar transmitter will be rejected by the GPS receiver as radio noise; (2) the waveform of the signal emitted by the radar is different from the encoded GPS signal and will not be acquired by the GPS; (3) since the proposed testing steps through the spectrum at 10 MHz intervals, the most signal use in any of the GPS bands could be three 70 ns steps, then the radar sweep will have moved into other spectrum. Not only is 210 nanoseconds shorter than the shortest signal accepted by GPS receivers, the individual pulses are spaced at intervals, ensuring that each individual pulse will be rejected by the GPS receiver.

The pulsed radar system needs a settling time of 10 milliseconds between each pulse to allow the signal generator to reset and not overheat. Therefore, the spectrum use will have an on-time of 70 nanoseconds, off time of 10 milliseconds, step to the next frequency, pulse for 70 nanoseconds, then be off, etc. The pulse is so short that GPS will not react to it, and with 10 milliseconds delay before the next pulse, the GPS receiver would reject any signal that is not received within 2.5 milliseconds of the first pulse. In sum, because of noise rejection, different signal coding, and the spacing of the radar pulses, a GPS receiver will not be affected by this proposed testing.

System configuration will also help to ensure that the radar pulses will not cause any harm to GPS reception. Because of the nature of GPS, the signals are generated in space and the receive antennas are typically configured for optimal reception of a space-based signal. The TTF radar pulses are low to the ground, very narrow-beam, ground-bounced signals; therefore, if the energy from a TTF radar pulse were to reach a GPS receiver the pulse would typically illuminate a low-level side lobe of the GPS receive antenna. GPS receiver technology is designed to reject multipath and will eliminate signals coming from the wrong direction, which minimizes any potential impact from the proposed operations.

Occupied Bandwidth and Pulse-Width:

The calculated occupied bandwidth of 10 MHz is used for most of the transmissions at the test facility. The measurement system was designed to ensure that each test gives an accurate picture of the radar cross section of the test object for each specified 2 MHz of spectrum. The transmissions were tested to show that the radar pulses use very narrow bandwidth, about 1 MHz at 3 dB down from peak power and less than 2 MHz at 20 dB down from the peak power.

A 70 nanosecond pulse-width was selected to ensure an accurate measure of the object being tested. The pulse needs to be wide enough to create an RF envelop that illuminates the extent of a typical test object, and it must be narrow enough to ensure that the return signals arrive within a specified time window. All of the calculations presented in this filing are based upon a pulse-width of 70 nanoseconds. There are some objects for which the pulse-width used is actually shorter, as little as 30 nanoseconds. Typically, the pulse-width is 60 ns, but Raytheon based its calculations on a "worst case scenario."

Stop Buzzer Point of Contact:

Should there be any instances of interference, the stop buzzer point of contact is:

Thomas J. Fagan, Spectrum Manager
Raytheon Missile Systems

520-794-0227 (office)
520-465-7087 (cell)

Conclusion:

In order to acquire the directional RF transmission radiated by the TTF radar, a receiver would actually have to be looking for it: the receiver would have to be located in the forward plane of the transmitting antenna, with a major antenna lobe facing toward TTF. The receiver would also need to be looking to acquire the radar pulse at precisely the frequency and instant that the radar is transmitting, and it would need to be sufficiently sensitive to detect the short duration and extremely attenuated signal. Standard radio receivers are not designed to process signals at the pulse width used by the test facility, thus any detected RF signal will be filtered out by receivers that are sensitive enough to detect signals at such low levels.

- Total potential RF On-time – for any day that the facility is in use (worst case).
- Antenna parameters –
- Hertz Warfare Spectrum analyses – not accounting for the attenuating effects of buildings
- Test results from the measurements taken to determine the occupied bandwidth
- Measurements of radio noise in the vicinity of TTF showing why the power levels requested are necessary to conduct the tests and experiments at this facility.

For questions about this application, please contact Tom Fagan, 520-794-0227 or tjfagan@raytheon.com, or Anne Linton Cortez, 520-360-0925 or alc@conspecinternational.com.