Raytheon IIS
Experimental STA Request
File No: 0931-EX-ST-2015

Explanation of Experimentation and Need for STA

Raytheon IIS is the intelligence, information, and services division of Raytheon Company. It develops a number of defense systems including advanced voice and data communications systems for the US military.

Need for an STA:

Raytheon is working on the development of advanced Troposcatter communications signal processing and equipment/systems for the U.S. Department of Defense and foreign military customers as well as commercial long range communications applications. The goal is to develop fixed and mobile Troposcatter point to point stations with high data throughput.

Raytheon has already successfully demonstrated to the Department of Defense a prototype of this system with data rates of up to 100Mb/s. The prior demonstration testing was conducted at Ft. Bliss, Texas, at government direction. This STA is needed to allow testing of customer suggestions to refine hardware improvements/upgrades and to study Tropospheric effects. After the demonstration to the Department of Defense, they have established some testing and development timelines that they would like to see Raytheon meet. That requires testing to start as soon as possible.

Background

Troposcatter communications systems emerged during the 1950s prior to the advent of satellite communications. Such systems were extensively deployed by the US and the Soviets to provide C3 channels typically in sparsely populated areas as shown Figure 1.

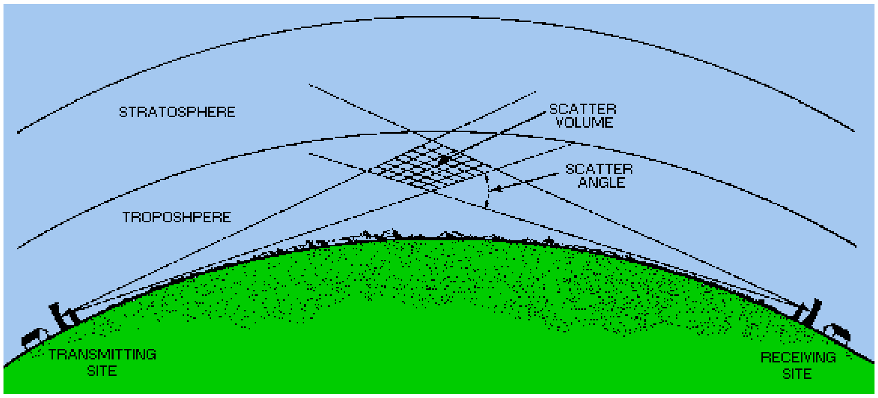

Figure 1 Troposcatter communications concept

Troposcatter communications is an offshoot of early radar technology. Troposcatter technology was constructed using elements of the same technology base, but also exploited technology used in analogue telephony, and later digital telephony.

The physics underpinning Troposcatter communications is most interesting, and remains the subject of academic research.

In a conventional microwave relay communications network, a transmitter must have a direct line of sight to a receiver. While refraction of the signal, due to the gradient in atmospheric refractivity (due to density lapse rate with increasing altitude), can "bend the beam" over the horizon slightly, it typically cannot increase range beyond the line of sight (BLOS) to any significant extent.

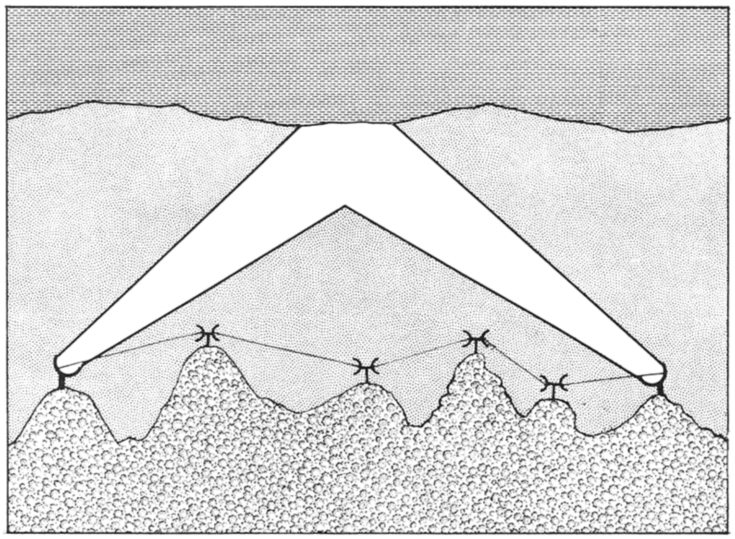

Figure 2 Troposcater vs line of site

In a Troposcatter system, the beam is bounced off the upper Troposphere, providing a true BLOS point to point communications capability as shown in Figure 2. These systems rely on the irregularity of the refractivity gradient at such altitudes, resulting in impinging microwave power being scattered forward in an irregular fashion.

In terms of achievable range performance, smaller Troposcatter systems are able to repeatedly achieve 100 - 150 km ranges between a pair of stations. Larger systems, with 10+ meter antenna diameters and kilowatt class transmit powers levels, have been reported successful communications across links of up to 400 km between a pair of stations. It is this range performance which has underpinned the popularity of Troposcatter technology for use in undeveloped or underdeveloped regions, as it permits use of a microwave channel in terrain where the cost of both deploying and maintaining a conventional microwave relay would be prohibitive. In land warfare contingencies, Troposcatter stations deployed by an advancing force permit the maintenance of a chain of relays back to the initial staging area, providing voice and data connectivity, with no dependency on airborne or satellite relays.

Achievable channel capacity and thus data rates for Troposcatter systems were quite poor in comparison with direct line of sight (LOS) microwave systems operating in the same bands due to:

- relatively low power levels caused by forward scatter off the Troposphere;

- byproduct of the irregularities in the scattering mechanisms, and
- variations in pathlength arising from the propagation path.

A range of design techniques have been adopted since the introduction of this technology, to reduce the adverse impact of the medium. These innovations in design techniques include:

- frequency diversity, including the use of adaptive techniques,
- modulation techniques which are better suited to dispersive media have been used, and
- robust Forward Error Control (FEC) techniques.

Explanation of Experimentation:

Raytheon is proposing to use utilize commercial off the shelf (COTS) technology with specialized Raytheon-developed software. The idea is to set up experimental test sites for equipment checkout, customer/government demonstrations and Troposcatter propagation studies and system performance validations.

The system is designed to be modular so subcomponents can be changed out and tested as they become available from the COTS manufacturers.

The frequency band selected is already in use for Troposcatter communications. Given the distance and path loss, the power levels are necessary for reliable high data rate communications.

Concept of Operations

Raytheon will set up two sites for experimentation. The first/main site will be in Indianapolis and the second site will be one of the locations proposed on this application. Only two sites will be in use at a time. The remote site may be moved to any of the locations shown in Figure 3.

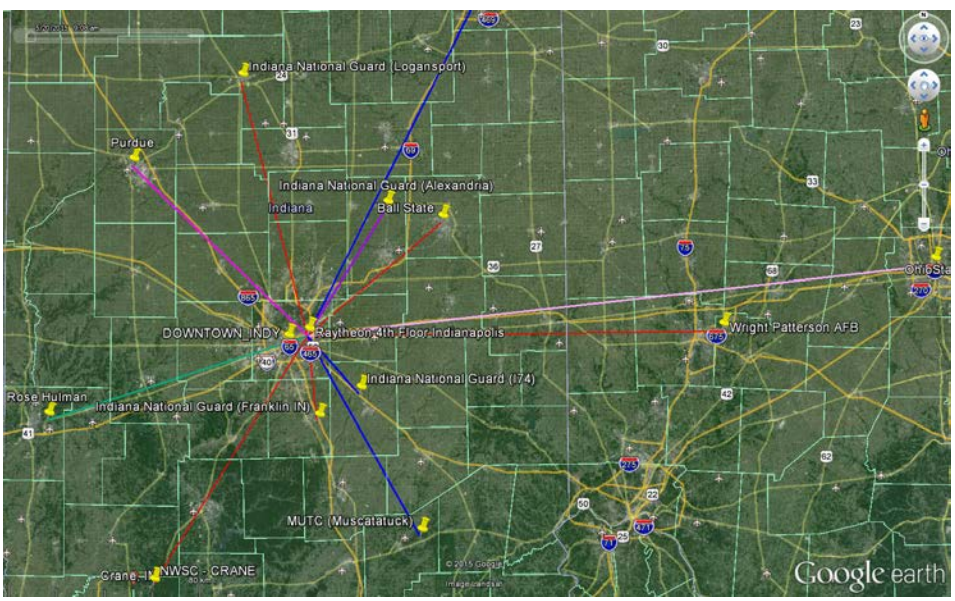

Figure 3 Proposed Troposcatter site locations

Raytheon needs at least four test frequencies/channels with a bandwidth of at least 20MHz each. Each site will transmit on two frequencies and receive on two frequencies.
At each test site, the spacing between transmit and receive frequencies must be at least 150 MHz and the spacing between transmit frequencies must be 50 MHz as shown in Figure 4.

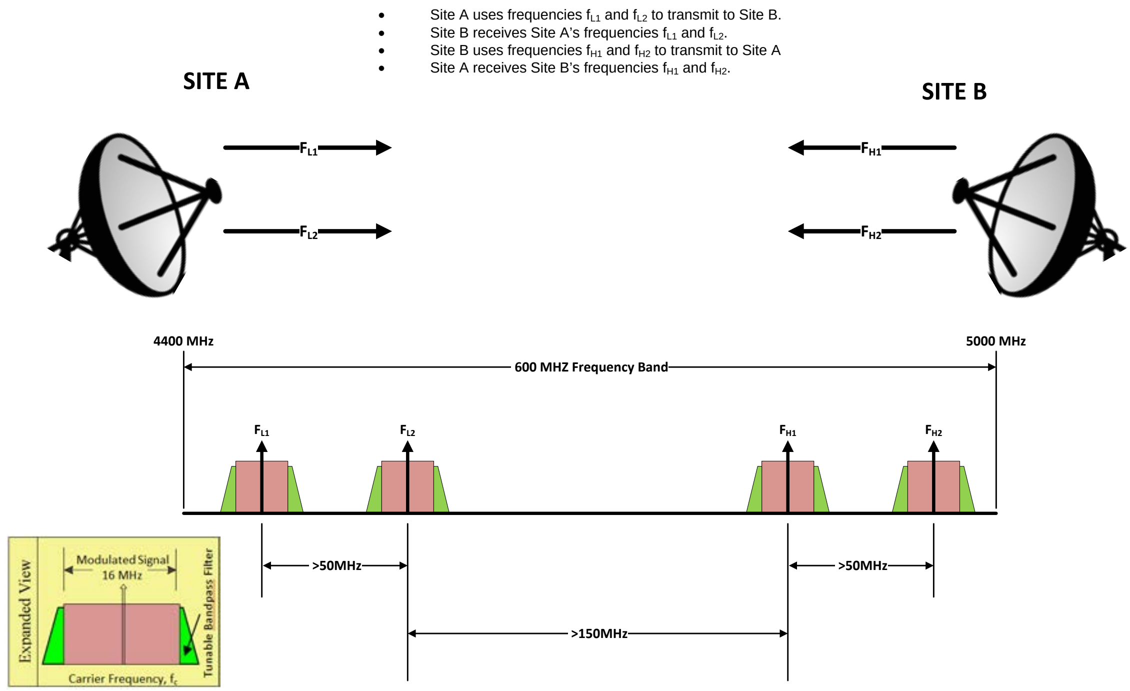

Figure 4 Frequency spacing

Spectrum Band Needed, or Channel Configuration Requirements:

Raytheon's application seeks authorization for use of the band between 4400 MHz and 5000 MHz. However, Raytheon would accept any channel configuration that will accommodate its requirements, if the Commission is unable to authorize use of the entire band requested.

One example of a possible channel configuration could be:

<u>Location A:</u>

- Transmit Channel 1: 4400-4420 MHz
- Transmit Channel 2: 4450-4470 MHz

<u>Location B:</u>

- Transmit Channel 3: 4500-4520 MHz (at least 150 MHz higher than the highest transmit channel at location 1, because it is a receive channel at Location B)
- Transmit Channel 4: 4550-4570 MHz

Any channel configuration that separates the transmit channels at a location by 50 MHz and separates the transmit channels from the receive channels by 150 MHz would be viable.

Setup/alignment

The antenna/systems are pre-aligned based GPS coordinates. Once pre-aligned, a test signal is transmitted by each station. Each station is then either manually or auto-aligned using Raytheon developed software. With this additional alignment, the signal transmission is optimized.

Antenna elevation angle/position

Given the low height of the Troposphere and the height of the antennas, the antenna elevation angle/position can vary slightly above or below 0 degrees as shown in Figure 5. Sites/heights were selected to mitigate any unintentional radiation to the public or any structures which could interfere/attenuate the transmit signal.

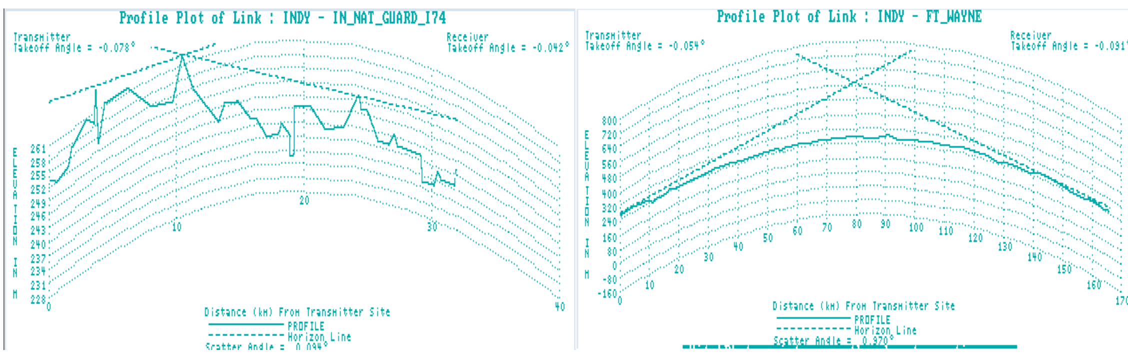

Figure 5 Typical profile model with earth curvature

Antenna parameters

Antennas are commercial off the shelf items that are typically used in commercial point to point and satellite communication systems. Because those applications require low sidelobes, the antennas used will have low sidelobes.

<u>Technical Synopsis:</u>

- Power level proposed: 500 W
- Location: Raytheon Indianapolis fourth floor building to one of multiple test sites identified above
- Spectrum Requested: 4400 - 5000 MHz
- Radios: Raytheon
- Planned Use: Used for R&D testing

<u>Antenna Beamwidth:</u>

The proposed testing will use directional antennas, with gain from 36 to 44 dBi.

Vertical Orientation: the antennas will be oriented ± 1 degree from horizon to achieve the tropospheric bounce illustrated in Figures 1 and 2.

Horizontal orientation: the orientation will depend on the link being tested. The link orientations are set out in Figure 6 below:

Site	Name	Antenna Azimuth True (°)	Name	Antenna Azimuth True (°) and reciprocal
1 to 2	Indianapolis	50.36	Ball State University – Muncie, IN	230.78
1 to 3	Indianapolis	138.79	Indiana National Guard – Shelbyville, IN	318.95
1 to 4	Indianapolis	27.07	Raytheon – Ft Wayne, IN	207.66
1 to 5	Indianapolis	314.4	Purdue University – Lafayette, IN	133.86
1 to 6	Indianapolis	32.22	Indiana National Guard – Alexandria, IN	212.47
1 to 7	Indianapolis	345.68	Indiana National Guard, Logansport, IN	165.47
1 to 8	Indianapolis	151.15	Muscatatuck Training Center, Butlerville, IN	331.48
1 to 9	Indianapolis	84.06	Ohio State University – Columbus, OH	266.06
1 to 10	Indianapolis	89.81	Wright Patterson AFB, Dayton OH	271.08
1 to 11	Indianapolis	212.43	NSWC – Crane, IN	31.95

Figure 6: Table of Horizontal Orientation Angles

The half power beamwidth information is:

Vertical: 1.2 – 2.0 degrees
Horizontal: 1.2-2.0 degrees

<u>Locations of testing:</u>

Raytheon is proposing to conduct tests on the Troposcatter data link from the rooftop of its plant site in Indianapolis, Indiana to the rooftop of at least one other site mentioned above. These sites were picked based on the distance from Raytheon Indianapolis and the terrain.

Raytheon, Indianapolis is a secure facility, with no open access to the public and only limited rooftop access to Raytheon authorized personnel.

All other sights military/government, private companies and colleges have, as a minimum, restricted access to the transmitter sites (rooftops). Some of the sites (military/government/Raytheon) may also restrict access to authorized personnel only.

<u>Test Time:</u>

During the initial setup/construction, the program will be working through the regular workday. To achieve the best, quickest test results, the program would like to conduct ongoing testing 24 hours a day, 7 days a week. This will allow us to study the effects that the environment has on the Tropo system performance.

To ensure that other users of the spectrum are able to conduct operations without interference, Raytheon is willing to arrange to interrupt communications, if required. Raytheon will coordination operations as necessary.

Stop Buzzer Point of Contact:

Jeff Au
317-460-9948 (mobile)
jeff_au@raytheon.com

Conclusion:

Raytheon is proposing to use COTS equipment for rapid development of Tropospheric communications system for its customers. The use of COTS technology will both expedite the new technology development and keep costs low in the early design and testing phase of this research.

If there are any questions, please contact Brian Kavalar, Spectrum Manager, Raytheon IIS, at 317-517-9989 or brian_r_kavalar@raytheon.com or Anne Cortez, Counsel, Washington Federal Strategies, 520-344-8525 or alc@conspecinternational.com.