Executive Summary

Greenwood Telecommunications Consultants LLC, ("GTC"), Denver, CO seeks issuance of an experimental license to operate on the L1 GPS band in indoor locations to extend GPS mobile reception, navigation and location. Under grant of an experimental license, the company will operate a pre-commercial emitter network (employing sets of 4-6, nanowatt-power emitters) on L1 GPS spectrum strictly inside buildings, which are typically high traffic, multi-story structures. The experimental license research objective is to develop the final RF design, and finalize field installation practices and procedures to create a seamless outdoor-to-indoor mobile GPS coverage experience.

This is novel and is applicable to millions of GPS handset subscribers that visit, live or work inside high traffic urban buildings. To address interior signal leakage of GPS signals, GTC's development partner, Insiteo SA, has designed a distributed network with GPS emitters that rely on outside-mounted GPS sensors to eliminate incidental interference to all nearby GPS receivers. The network continuously manages leakage so as to not exceed the current NTIA interference power limit of -140 dBm across the 24 MHz L1 GPS Band when measured 30 meters from the edge of the building.

The company seeks an FCC Experimental License to operate following compliance with governmental agency regulations as cited under NTIA 8.3.28. The company however seeks a grant on the condition that to meet the same interference level, and undertake research on commercially viable systems, that it be allowed to operate the in-building enclosed emitters up to 10 nanowatts and use outdoor mounted sensors to both regulate leakage and thus ensure GPS spectrum integrity and uncompromised reception at each site.

Public and Private Sector Purposes for Operation under the Proposed Experimental License

The research under the experimental license has the main purpose of developing and demonstrating a continuously operating indoor that is seamless with general outdoor GPS and provides while indoor comparable instant navigation and accurate location using existing conventional assisted GPS ("AGPS") mobile technology, which is common in virtually all mobile handset devices. These devices are well known to the Commission and to the public for E911 location. More than 500M mobile GPS devices have already been sold globally. The forecast is for these to grow well past one billion mobile GPS devices in the coming 3-4 years. Consumers have adopted mobile GPS in many areas of their everyday life, and it is widely believed that indoor coverage poses the last step in all-area location. Once met, this addresses a series of public and private sector mobile location applications, including E911, NG911, which are FCC and DOT initiatives.

In the US, Canada, Japan and other countries, E911 (or E122 in Japan) is mandated for public safety call response. For the US, an estimated 300,000 mobile calls per day[1] enter its 6,180 US E911 call centers[2] at the local, county and state levels. These numbers continue to rise annually are rising as consumers learn and use this service. It is a vital service to rescue and save lives every minute somewhere in the country.

[1] http://www.nena.org/911-statistics
[2] http://www.emergencymgmt.com/safety/911-A-National-Plight.html

E911 is a prominent and successful part of the response backbone in the public safety and response infrastructure of America.

The FCC seeks to have US wireless operators increase their in-building coverage since a large and growing percentage of mobile calls occur where people live, work or travel. Correctly routing the call and pinpointing E911 caller location are critical to a successful and rapid emergency response. Location details also avoid cost of redundant responses, and helps coordinate local first responders efficiently.

To date, comprehensive in-building[3] location has been lacking due to limited direct GPS signal availability since signals must come from far away satellites. GPS was originally designed to operate exclusively outdoors for position, range or timing applications. Clearly the next logical step is to bring GPS operation inside where satellite signals are too few or too weak for position resolution by mobile devices. To maintain seamless operation, inside GPS signals must be provided by pseudolite devices, using emitters that transmit in the same fashion but on separately coded signal carriers. It is important to point out that pseudolites are a terrestrial component of the original GPS navigation system, and use separate, dedicated carrier-codes to provide on-ground continuity of coverage. This will naturally start and evolve from the more travelled offices, public stations, and any place people visit, live or work. Global standards and research has been conducted in Japan, Europe, and to a lesser degree, in N. America.

Commercial location services have followed the lead and operator adoption of E911 in the US and elsewhere. These applications are synergistic and use the same electronic and data processing elements, and help to make it economic to deliver both services through a common, mobile embedded GPS receiver. This is fortuitous since the economic potential is significantly enhanced if the same device and capabilities are used in both applications.

What is this Application Seeking beyond NTIA 8.3.28; Why is this Necessary?

This application seeks approval to operate its emitters at 10 nanowatts, or -50 dBm, based on comprehensive tests by its supplier. This is also in collaboration with a dedicated European CEPT standard body organization that rigorously shows no degradation to satellite navigation and avionics systems when operating at these levels indoors at the minimum building loss factor. The applicant recognizes that while this turns out to be 24 dB above the emission level indicated by IRAC (25 pW), *it is able to guarantee that it will not exceed the most important limit, the -140 dBm outdoor leakage limit*. The applicant believes that the NTIA and other agencies' primary interest is to restrict outdoor leakage and to enable government agency, military and civilian equipment to progressively work inside indoor places as well (where outfitted with this equipment). This application seeks to show government agencies and others that outdoor leakage can best controlled to stay below the NTIA leakage limit by actively sensing the indoor signal leakage outside the building. Based on level of indoor signals the system can quickly reduce or shut off leakage should it arise.

[3] Mobile AGPS often successfully works inside residential homes that have light construction, but not multistory, heavy construction buildings, which are home to about 25M residents and 50M workers nationally.

The table below shows that this will have the same safeguards and compliance norms to operate as NTIA prescribes in 8.3.28 (Rev 9/2009).

Specification	This Application	NTIA 8.3.28 Re-Radiator Equipment
Bandwidth	24 MHz, centered at 1575.42MHz	24 MHz, centered at 1575.42MHz
Usage	Indoor use only	Indoor use only
Interference Area	User must manage	User must manage
Maximum leakage (at 30 m)	-140 dBm measured, calibrated, continuously and automatically controlled	-140 dBm calculated
Limited use	Experimental license research, demonstration purposes of GPS RNSS	Purpose of testing RNSS equipment/systems
Control of system	Multiple methods, including "stop buzzer" point of contact	"Stop buzzer" point of contact
Places of test operation	Site specific as filed following FCC Experimental filing procedures Away from airfields, military and other sensitive locations.	Site specific, filed in the GMF
Method of assuring compliance	Active measurement of leakage energy outside illuminated building sites. Maximum power emission: 10 nW.	Calculation using inverse free space law path loss with no building loss factor.
Site control	Building owner with security and other administrative controls present.	Federal facility must be under control of the user.
Protection of this use	Not protected, is shut off at discretion of FCC	(assumed) Not protected

10 nW ERP indoor emitter power is necessary to ensure economy, that is, it uses the fewest emitters per interior area covered, while also ensuring minimum outdoor signal leakage levels. This economical solution will support more installations than installing less powerful emitters having less range and accuracy. The company developing the indoor equipment has product development plans underway to make emitters less expensive and less costly to install. These developments will make for more ubiquitous installations, and therefore the system will be more affordable to install across many building locations throughout the US and other countries. This helps E911 compliance by the industry comprised of operators, mobile service specialists, and the nation's public safety operations. Given the system uses direct sensing to limit outdoor leakage, actual interference protection is stronger method to assure interference-free operation compared to the field calculation method currently prescribed in the NTIA regulation. Re-radiators do not change once installed and could persistently leak due to moving RF reflections or people. There is no mitigation method for these fixed, uncontrolled systems.

Why Should this Experimental License Application Be Approved?

The GPS signals are precious and the spectrum in which these signals radiate must be carefully protected from both in- and out of band RF emissions. At the same time, consumer and public safety uses of GPS can be most effective if the GPS receiver works where people congregate indoors. The GTC experimental operation of a pre-commercial GPS indoor network provides a safe way to inform DoD, FAA, FCC, NTIA and other interested agencies on how to support GPS operations for its public safety counterparts using modern methods to control the interior power levels safely, effectively and without degrading all traditional civil, government, aeronautical, space or military GPS missions.

Each building test site and GPS emitter will have precisely controlled power levels based on sensing and limiting outdoor leakage. Based on the proximate outdoor GPS measured signal levels, the pre-commercial network can in real time sense leakage to prevent interference well below the current NTIA leakage limit, and either cut back or shut down the interior emitters even if a transient event might create momentarily high outdoor leakage.

Other technical research under this license will be done to further verify interference immunity of modern GPS receivers, especially in scenarios where they come into range of interior building GPS coded signals. Early information suggests that the industry has progressed in areas of interference immunity such that it is much higher than previously thought.

The initial test site will be at Stanford University, Palo Alto, CA which is a primary center for GPS knowledge and academic research globally. The particular test site will be one of the Linear Accelerator laboratory buildings, which has substantial shielding to contain all RF interference. Once satisfied that our design assumptions are met, we plan to migrate testing to representative public buildings including convention center (later Moscone Center, San Francisco, or San Jose Convention Center) and into other public venues as time and commercial research interest permits. For instance, plans are underway to operate in the major ground transportation centers such as Penn Station or Union Station, Washington DC.

Properly regulated in-building GPS emission works but it must be demonstrated and witnessed firsthand to secure the interest of operators, building owners, the GPS industry at large, public safety, who all seek to serve the mobile public interest without compromising the primary GPS mission. Feasibility rests in showing a system that extends GPS operation inside buildings but not to the extent it goes over an interference threshold. While this is early in terms of an industry, it is also important to note that European and Asian countries are developing interior GPS solutions for public safety and commercial purposes, and it makes sense to be at parity with these markets.

We propose further, in an appending document, a compliance protocol to provide additional assurances to the IRAC agencies in service to guard the spectrum and assuring safe operation on the GPS L1 spectrum at sites installed under this application.

Appendix

Compliance Protocol: Field Installation and License Log Procedures

1. The selected site shall not be near airfields, military or other sensitive public safety areas. Record lat and long data into the EL on-line application file following FCC procedures.
2. Once equipment is ready for activation, follow these steps in sequence:
   - Set up the sensor measurement element to receive the outdoor signals, measure levels and confirm sensor receiver is properly calibrated.
   - Mount temporarily an antenna (using a long cable and built in LNA) designed to receive interior signals with enough sensitivity to trigger the emitter control loop. Have the cable long enough to move to sensitive locations and enable two-point calibrations (the mounting location and one or more points at 30 m distance from the building walls).
   - Set all emitters at 25 pW output (NOTE: this is the reverse-calculated NTIA power figure with a free space link and no building loss factor)
   - Measure at the outdoor antenna perimeter signals directly proximate and 30m from the building perimeter, starting emitter power output at the currently prescribed 25pW level.
   - Record levels and antenna position (using pictures and other tools) into license file.
   - Raise emitter power gradually, taking care to not exceed -50 dBm ERP until the interior floor coverage levels are served.
   - Record the final emitter levels into the license file.

     CAUTION: Do not set emitters higher than -50 dBm.
   - Using the external calibrated GPS reference sensor, connect and monitor the power control element.
   - Ensure power control element properly regulates the interior emitters continuously by entering a small leakage cable from inside the building (using a known, measured signal level that is < -140 dBm), or a GPS simulator instrument that introduces power into the sensor antenna port. Measure corresponding interior power decreases as leakage power outside increases.
   - Record control loop response data, and take sufficient sample of measurements at different sensor antenna locations where there is power detected from inside the building.
   - Make a final antenna mount location where the interior power can be sensed and using a separate receiver take proximate and 30m perimeter measurements of the interior signals.
   - Calibrate the sensor such that it reduces power where the outside 30m measurements are below -140 dBm detected.
   - Mount the antenna and repeat the procedure, ensure the control loop is operating correctly.
   - Test final operation by opening all doors, windows (if applicable) between the illuminated floor area and the outside to exercise leakage opportunity under these conditions.
   - Record measurements under this condition, noting characteristics of leakage and safety margin at each position relative to the -140 dBm leakage criterion.
   - Once automatically operating, test that the system enters all power control events over a threshold level into the license log.
   - Store time-tagged sensor receiver measurements into a disk log for later retrieval and license auditing.
   - Test the system kill switch locally and remotely for proper operation.
   - Test back up power if applicable to shut down system if remote kill switch is inoperable.
   - Test remote management dashboard verifying all operational indicators.