GPS Re-Radiation (Re-Rad) System to Support Military Aircraft Production

The Boeing Company
St. Louis, MO
Lambert Field, Bldg. 73-75

GPS L1 1575.42 MHz
Emission 24M0G1D
Power at antenna: Maximum -98.6 dBW or 72 Pico watts
Reference to an existing license: WB9XXP File Number 0357-EX-ST-2004

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by

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The purpose of this application is to extend operations as authorized by WB9XXP (STA) by applying for a full 2-year experimental license. This system has been constructed and operates as described in the technical description documents and application for the STA. The system performs as designed. There have been no reported incidents of interference.

Boeing - St. Louis has built a new production hanger (Building 73-75) to replace the 1950's era production/flight test operation and to make way for the St. Louis Lambert Field International Airport Expansion. The building is located at 38-45-4.1 N 90-21-23.8 W NAD83. The facilities are used to manufacture military aircraft (F-15E, F/A-18E/F, and T-45C.)

The following are the contract numbers:

N00019-99-C-1226 (F/A-18)
F33657-00-C-0013 (F-15)
N00019-03-C-6528 (T-45)

No proprietary or classified programs/contracts are connected with work done in Building 73-75.

No Research and Development (work) programs are conducted out of Building 73-75.

The facility also supports many other military programs that make use of the flight test operations co-located with the production operations. The ability to perform GPS avionics checkout and troubleshooting inside the production hanger is an important and cost effective aspect for production operations.

Refer to exhibit 1. The system collects the GPS signals from a roof top antenna and re-transmits the signals inside the hanger to allow our aircraft production and flight test personnel to perform testing and troubleshooting of the aircraft's GPS based systems.

The roof mounted antenna has a built-in band-pass filter with 60 dB skirts at +/- 1.0 MHz and provides 38 dB gain. A low loss cable connects the output to a line amplifier and a variable attenuator to fine tune the total system gain and help maintain the "No GPS Re-Rad Zone" perimeter of no more than –161 dBW.

The line amplifier is connected to a 1 to 8 signal splitter. 6 ports are used, one for each antenna. The other 2 ports are terminated spares but can be used as needed for a maximum of 8 antennas. The splitter also contains a fixed gain amplifier of 14.5 dB. Boeing Manufacturing Engineering located each re-rad antenna so that they are positioned 30 feet over an aircraft test station in the area encircled by the red dashed line shown in exhibit 2. As needed, flat pieces of metal where used as reflectors to block the RF energy from reaching levels above –161 dBW in the "No GPS Re-Rad Zone."

The RF budget for the system is listed in exhibit 1. The optimum level at each aircraft test station is about –155 dBW, the same as it would be at the earth's surface. Again, the system gain is adjusted using the variable attenuator.

All equipment was purchased from GPS Networking Inc., www.gpsnetworking.com.

Refer to exhibit 2. The all metal building is 450 long and 250 feet wide. There are 9 metal hanger doors on each side. The doors are 50 feet wide and 30 feet high. Weather permitting, the doors are opened. The following analysis shows how the GPS re-radiating system is used with the doors open and be safe.

Boeing Engineering has designed a GPS re-radiation system that confines the signal to a spot beam on the floor where the aircraft test station is located. The GPS re-rad antenna is suspended above the aircraft test station about 30 feet from the floor. The directional beam of the antenna is aimed directly at the floor. Each antenna provides a radius of about 50 feet of signal coverage. The 90 degree downward gain of the antenna is about 3 dB. There is a slight null point at 90 degrees. The antenna has about –7.5 dB of gain at 5 degrees of "negative elevation."

At installation testing and calibration of the system coverage, the signal was adjusted so that a -155 dBW signal level was measured directly below the antenna at the floor level and -160 dBW was measured at the aircraft station perimeter about 50 feet away. The starting point for the system level in testing and calibration was with the minimum amount of signal (maximum variable attenuation.) The system gain was increased to pass a "2 GPS Walk Around Test."

The test involved using 2 GPS receivers that are the same. The reason two receivers are used is for redundancy and reduce ambiguous measurements that might be observed with just one receiver. The receivers were walked around a perimeter as shown by the green dashed line. The system gain was increased to a level where the receivers detect the re-radiated signal at the red line. The following is a summary of the calculations to establish the signal levels.

First, we must consider that the radiation arriving at the red, green and hanger door edge is at an angle. The angle to these points varies and the antenna gain to these points is also different. To best analyze the signal levels is to start at the antenna. But, the signal levels are too low to measure with reasonable confidence. So, by placing two GPS receivers directly below the antenna and slowly increasing the system gain we can reasonably measure the signal level at the floor directly below the antenna. When the receivers just begin to detect and lock onto the re-radiated signal, the signal must be about -160 dBW. By increasing the signal just a little more to where the receivers obtain a solid lock, the signal is then approximately -155 dBW.

At a 50 foot radius of the aircraft test station, as indicated by the red line, the slope of the radiation is approximately 45 degrees from the antenna. 45 degrees is half of 90 degrees and the

half way point between +3 dB (90 degrees) and – 7 dB (-5 degrees) is roughly -2.0 dB. The path length from the antenna to the red line is about 58 feet for about –60 dB of loss.

So, working backward from known points and references we can calculate the RF signal level at the red, green and hanger door edge.

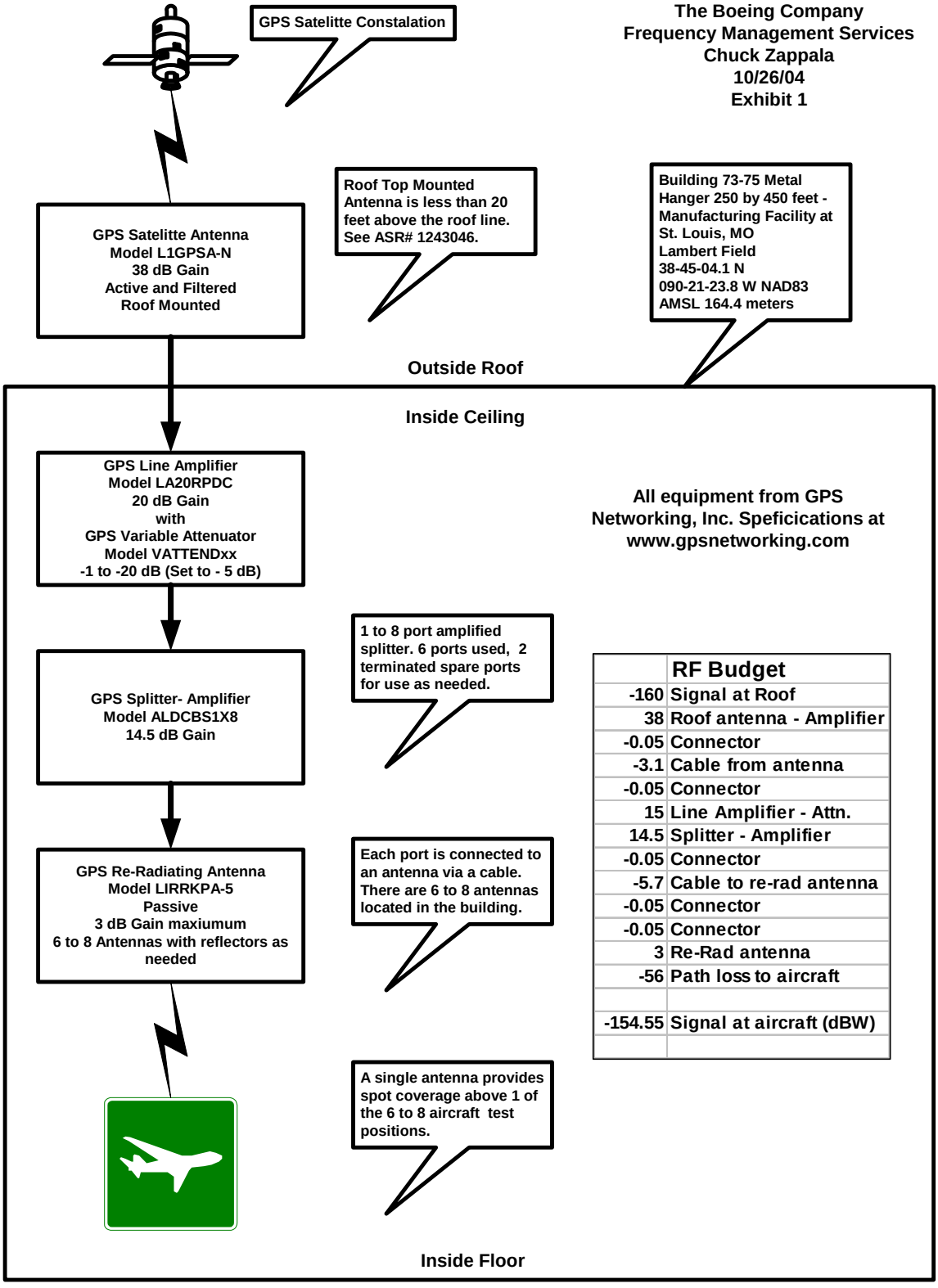
If the signal level at the floor is set at –154 dBW, and the 30 feet of vertical path loss is subtracted (-56) and the antenna gain at 90 degrees (+3) is subtracted then the red line edge should be computed as –101 (level at antenna) + (-2) (gain at 45 degrees) + (-60) (path loss) = -163 dBW.

A minimum detectable signal is about –160 dBW. So, these numbers are close enough to estimate the distance of the radius of 50 feet when the antenna is placed 30 feet above the floor and RF levels are set accordingly. As needed, an antenna reflector were used to decrease the signal in the direction of the open door.

The circumference of the zone (green line) about 2 feet further out from the –160 dBW red line perimeter is calculated to be approximately –161 dBW. 25 feet further out the signal level is calculated to be an additional -4 dB of free space path loss plus at least another –1 dB (conservative) due to the loss from the antenna gain approaching –7 dB. The signal level at the door edge is calculated to be about –166 dBW. This insures at least a better than -161 dBW (non-signal) area that is 25 feet inside the hanger door area. This makes opening the hanger door very safe to do.

Adjustment or replacement of antennas, reflectors or other system components is not permitted without performing a “2 GPS Walk Around Test.” The test will also be performed monthly to verify the “No GPS Re-Rad Zone. The GPS receivers are tested for proper operation by walking the receivers with a valid and locked-fixed signal from the natural satellite constellation area outdoors, through the “No GPS Re-Rad Zone” where it will be noted where the receivers fail to receive the natural signal and the re-rad signal. The tester will then continue to walk into the re-rad area and observe that the receivers will lock onto the re-rad system signal at the red line. The tester should be able to walk back to the green line and again verify all signal loss. The system will be shut down if the system RF levels for installation, modification or annual testing are not obtained.

The intent is to have the GPS signal available 24/7 with or without hanger doors open.



	RF Budget
-160	Signal at Roof
38	Roof antenna - Amplifier
-0.05	Connector
-3.1	Cable from antenna
-0.05	Connector
15	Line Amplifier - Attn.
14.5	Splitter - Amplifier
-0.05	Connector
-5.7	Cable to re-rad antenna
-0.05	Connector
-0.05	Connector
3	Re-Rad antenna
-56	Path loss to aircraft
-154.55	Signal at aircraft (dBW)

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Exhibit 2