Boeing St. Louis B105 EMC Laboratory

GPS Re-Radiator Design

04/15/2013

Requirements:

1. Provide range limited GPS repeater capability to the Boeing St. Louis EMC Laboratory facilities, located in building 105 of the Boeing St. Louis facility and centered at the following geodetic coordinates: 38º 45’ 18.014” N x 90º 20’ 48.644” W.
2. Within two adjacent, designated EMI/EMC anechoic chambers, allow limited portability of each chamber’s re-radiating antenna by tethering each re-radiating antenna via its 28 foot flexible RF feed cable to its respective chamber’s wall mounted connection port. See Figure 2 below for the EMC Lab Re-Radiator System Location & Installation Plan.
3. Use the following re-radiator kit equipment (or equivalent), additional LNA and other miscellaneous RF equipment/parts:
    a. Roof-top antenna with built in 40 dB LNA
        i. Part of the L1/L2GHNRR KIT from GPS Networking Inc.
    b. Passive re-radiator antenna
        i. Part of the L1/L2GHNRR KIT from GPS Networking Inc.
    c. Additional Low Noise Amplifier
        i. Part/Model Number ZHL-1217HLN
    d. Miscellaneous RF parts (bias-tee, power splitter, isolators, attenuators, cabling, etc.).

    See Figure 1 below for the proposed EMC Lab Re-Radiator System Block Diagram.

4. Range limitation (Based on an NTIA maximum of -140 dBm/24 MHz at 100 feet):
    a. L1: Total re-radiated power across a 24 MHz band centered at 1572.42 MHz shall not exceed -140 dBm at a distance of 100 feet.
    b. L2: Total re-radiated power across a 24 MHz band centered at 1227.60 MHz shall not exceed -140 dBm at a distance of 100 feet.
5. When either or both re-radiating antennas are not in use the Re-Radiating Antenna and Tether Cable assembly will be removed and stored and the port connecter will be capped with a 50 load.

Physical Design:

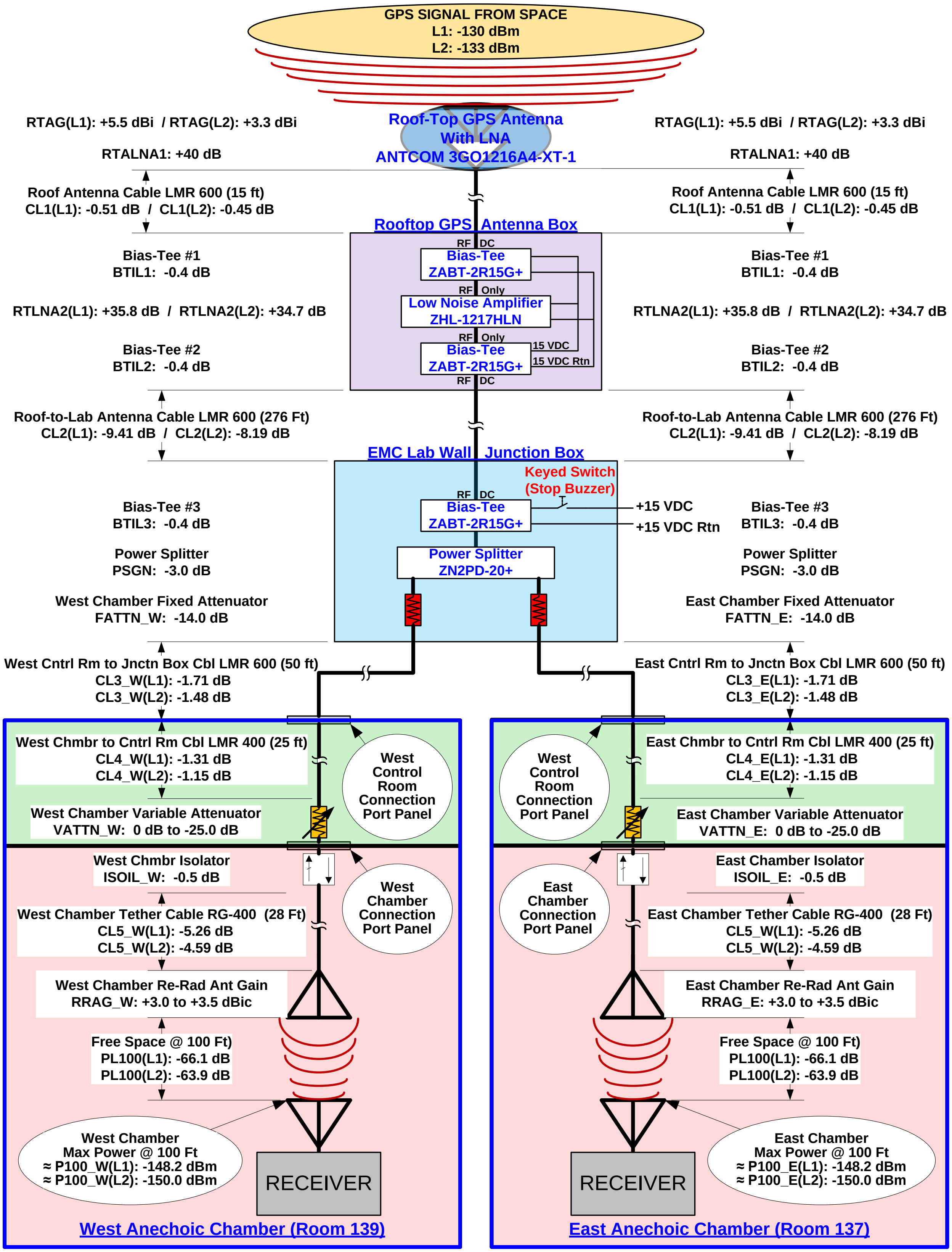

Figure 1 EMC Lab Re-Radiator System Block Diagram

Description:

GPS Satellite signals received and amplified by the roof-top antenna are conducted through a 276 foot transmission line (coaxial cable) into the EMC Lab wall mounted junction box. The wall mounted junction box contains a Bias-T to provide DC power to the roof-top antenna's built-in LNA and the additional LNA required for this application. It also contains a power splitter to provide the GPS signal to the re-radiators located in two separate anechoic chambers. In addition there is a fixed 8 dB attenuator in each chamber re-radiator path to reduce the re-radiated signal levels below the target GPS receiver's maximum input. The 8 dB attenuator also ensures re-radiated power levels at 100 Feet are 8 to 10 dB below the NTIA maximum of -140 dBm/24 MHz.

For each anechoic chamber there is an existing chamber connection port panel where the respective re-radiating antenna is tethered by a 28 foot flexible cable. This cable allows the re-radiating antenna to be portable within the chamber where movement of the antenna is constrained by the tether cable and the chamber walls. With power levels at 100 foot distance from the re-radiating antenna set to less than -148 dBm (-178 dBW), the likely-hood of interference with other systems beyond 100 feet is effectively reduced to zero.

Although this re-radiator design does compensate for some of the frequency dependent attenuation in the cabling and some RF components, it does not provide re-radiated power levels that ideally match the typical power level difference between L1 C/A, and L/2 P/Y power levels as received on earth from the satellites. Picking antenna and LNA components with gains that favor the L1 over L2 is used to compensate for some of the frequency dependent attenuation which favors L2 over L1 in the cabling and the re-radiated free space loss. This design compensates for these frequency dependencies well enough to meet the anticipated test objectives within the anechoic chambers.

Below are the calculations demonstrating NTIA compliance at 100 Feet.

Re-Radiator Power Level at 100 Ft. Range

P100 = Tx - PL

P100: Re-Radiated Power at 100 Ft. (dBm)
Tx: Re-Radiating Antenna Power (dBm)
PL: Free Space Path Loss (dB)

Tx = GPS + RTAG+ RTLNA1 + CL1 + RTLNA2 + CL2 + BTIL + PSGN + FATTN + CL3 + CL4 + VATTN + ISOIL + CL5 + RRAG

GPS: Satellite Signal (dBm)
RTAG: Roof-Top Antenna Gain (dBi)
RTLNA1: Roof-Top Antenna Low Noise Amplifier (dB)
CL1: Cable Loss, Roof-Top Antenna to Additional Roof-Top LNA (dB)
BTIL1: Roof-Top Antenna Box Roof Antenna Bias-Tee Insertion Loss (dB)
RTLNA2: Additional Roof-top Low Noise Amplifier (dB)
BTIL1: Roof-Top Antenna Box Roof Antenna & LNA Bias-Tee Insertion Loss (dB)
CL2: Cable Loss, Roof-Top LNA to Lab Junction Box Bias-Tee (dB)
BTIL3: EMC Lab Junction Box Bias-Tee Insertion Loss (dB)
PSGN: EMC Lab Junction Box Power Splitter Loss (dB)
FATTN: EMC Lab Junction Box Fixed Attenuator (dB)
CL3: Cable Loss, Lab Junction Box Fixed Attenuator to Control Room Panel (dB)
CL4: Cable Loss, Control Room Panel to Control Room Variable Attenuator (attached to Chamber Panel) (dB)
VATTN: Control Room Variable Attenuator (attached to Chamber Panel (dB)
ISOIL: Chamber Isolator Insertion Loss (attached to Chamber Panel (dB)
CL5: Cable Loss, flexible cable from Isolator to Re-Radiating Antenna (dB)
RRAG: Re-Radiating Antenna Gain (dBi)

Tx determined for L1 and L2:

	L1	L2
GPS (dBm)	-130	-133
RTAG (dBi)	+5.5	+3.3
RTLNA1 (dB)	+40	+40
CL1 (dB)	-0.51	-0.45
BTIL1 (dB)	-0.4	-0.4
RTLNA2 (dB)	+35.8	+34.7
BTIL2 (dB)	-0.4	-0.4
CL2 (dB)	-9.41	-8.19
BTIL3 (dB)	-0.4	-0.4
PSGN (dB)	-3.0	-3.0
FATTN (dB)	-8	-8
CL3 (dB)	-1.71	-1.48
CL4 (dB)	-1.31	-1.15
VATTN (dB)	0	0
ISOIL (dB)	-0.5	-0.5
CL5 (dB)	-5.26	-4.59
RRAG (dBi)	+3.5	+3.5
Tx (dBm)	-82.10	-86.06

$PL = K + 20\log(f_{MHz}) + 20\log(d_{Ft})$

K: -37.88 dB when range is in Ft.

$PL_{L1} = -37.88 + 20\log(1575.42) + 20\log(100)$
$= 66.07$ dB

$PL_{L2} = -37.88 + 20\log(1227.60) + 20\log(100)$
$= 63.90$ dB

$P100_{L1} = -82.10 - 66.07$
= **-148.2 dBm**

(≈8.4 dB below the NTIA maximum of -140 dBm/24 MHz at 100 feet)

$P100_{L2} = -86.86 - 63.90$
= **-150.0 dBm**

(≈10.2 dB below the NTIA maximum of -140 dBm/24 MHz at 100 feet)

Boeing St. Louis B105 Level 1 EMC/EMI Lab GPS Re-Radiators' Locations

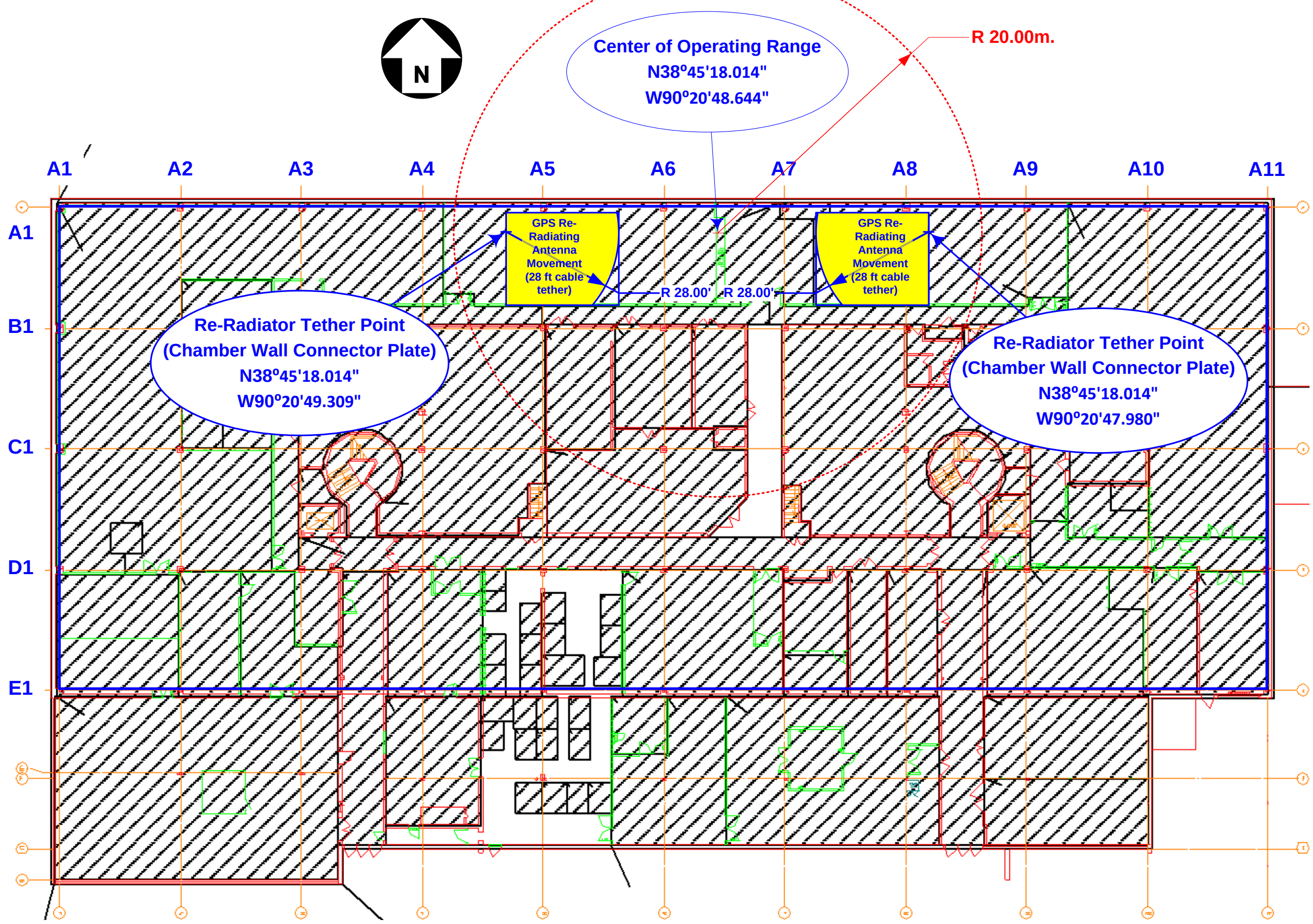

Figure 1 EMC Lab Re-Radiator System Location & Installation Plan