Link Budget Calculations

Equipment

Part	Description	Gain or Loss
L1/L2GPSA-T	Active Roof Antenna	40dBm
L1/L2GRRKPA-T	Passive Antenna. dBi depends on angle	3 dBi to -6 dBi
RRKAMP	Line Amplifier	30 dBm
RG214/U	Cabling	10.3 dB per 100ft

Formulas

The formula for the maximum EIRP in dBm as given in NTIA Redbook 8.3.27.f:

$$P_{Tmax} = P_R + 20\log_{10} f + 20\log_{10}(30 + d) - 27.55$$

Where: P_{Tmax} is the maximum permissible EIRP in dBm

P_R is the power received at 30 meters from the building (-140 dBm/24 Mhz)

f is the frequency in MHz

d is the distance between the radiator and the closest exterior wall of the building in meters.

The formula for the system's radiated broadcast power in dBm is:

$$R_p = G_R + L_C + G_A + G_P + R_A$$

Where: R_p is the radiated power in dBm

G_R is the gain provided by the roof antenna

L_C is the loss caused by cable and adapters

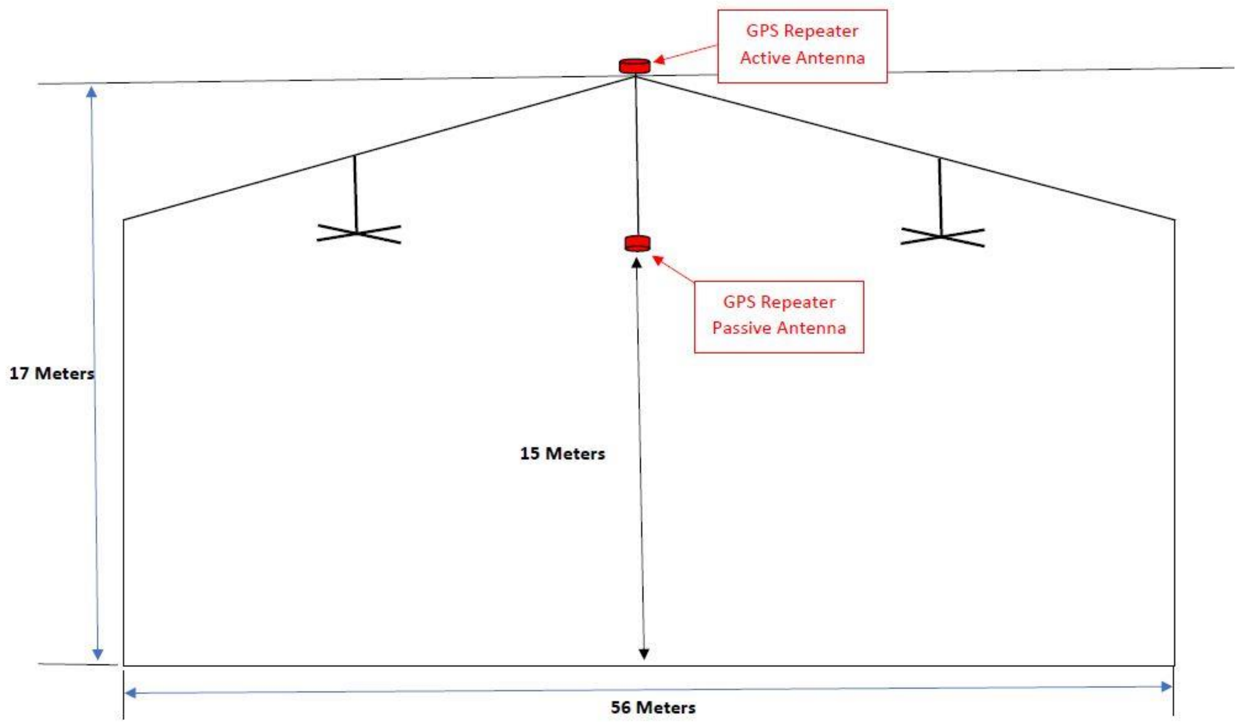
G_A is the gain from the reradiating amplifier

G_p is the gain provided by the passive antenna

R_A is the average receive power for a given frequency in North America

Installation

The installation environment is a 56 x 54 meter rectangle as shown in this drawing:



The radiating antenna is suspended 15 meters above the ground in the center of the hangar. The nearest wall is 27 meters away (54/2). In order to comply with NTIA regulations, the received signal power must be less than -140 dBm at a range of 57 meters from emissive antenna. Please note that emissive antenna is aiming down at the floor of the hangar.

Proof

First, we will compute the radiated power that this system will provide for the L1 and L2 signals.

The radiated power at the emissive antenna can be obtained by summing the gains and losses of the broadcast system as shown in the formula section.

$$R_p = G_R + L_C + G_A + G_P + R_A$$

For the L1 signal we will set:

- G_R as 40dBm for the gain provided by the roof antenna
- L_C as -2dBm for the loss caused by cable and adapters
- G_A as 30 dBm for the gain from the reradiating amplifier
- G_p as -5 dBi for the gain provided by the passive antenna[i]
- R_A as -130 dBm for the average receive power for L1 in North America

$$R_p = 40 - 2 + 30 - 5 - 130 = -67\ dBm$$

For the L2 signal we will set

G_R as 40dBm for the gain provided by the roof antenna
L_C as -2dBm for the loss caused by cable and adapters
G_A as 30 dBm for the gain from the reradiating amplifier
G_p as -6 dBi for the gain provided by the passive antenna [ii]
R_A as -132 dBm for the average receive power for L2 in North America

$$R_p = 40 - 2 + 30 - 6 - 132 = -70\ dBm$$

Now that we have the radiated power levels, we can compute the maximum allowed power level per NTIA Redbook 8.3.27.f for L1 and L2:

$$P_{Tmax} = P_R + 20\log_{10} f + 20\log_{10}(30 + d) - 27.55$$

For L1, Let:

P_R = -140dBm
f = 1575 MHz
d= 27

$$P_{Tmax} = -140 + 20\log_{10}(1575) + 20\log_{10}(30 + 27) - 27.55 = -68.5\ dBm$$

For L2, Let:

P_R = -140dBm
f = 1227 MHz
d= 27

$$P_{Tmax} = -140 + 20\log_{10}(1227) + 20\log_{10}(30 + 27) - 27.55 = -70.6\ dBm$$

Results

Signal	Max Allowed Power	Computed Power	Difference
L1	-68.5 dBm	-67 dBm	1.5 dBm
L2	-70.6 dBm	-70 dBm	0.6 dBm

By this analysis, both signals will be slightly above the required power level at a range of 30 meters. This issue will be rectified by the inclusion of a 3 dBm fixed RF attenuator between the roof antenna and repeater amplifier.

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[i] At an antenna height of 15 meters and a measurement distance of 57 meters, we create a right triangle to estimate the minimum angle between the emissive antenna and isotropic measurement antenna. Considering that the average measurement antenna will be held at least 1 meter above the ground, we can reduce the effective height of the emissive antenna to 14 meters.

$$\theta = tan^{-1}\left(\frac{14}{57}\right) = 13.8°$$

The datasheet for the L1/L2GRRKPA-T specifies a gain of -5 dBi at 10° for the L1 frequency.

[ii] The datasheet for the L1/L2GRRKPA-T specifies a gain of -6 dBi at 10° for the L2 frequency.