BLE112, BLE113 AND BLE121LR RANGE ANALYSIS

APPLICATION NOTE

Thursday, 15 May 2014

Version 1.1

VERSION HISTORY

Version	Comment
1.0	Release
1.1	BLE121LR updated, BLE112 carrier measurement added

TABLE OF CONTENTS

1 Introduction

2.4 GHz RF signal is strongly impacted by any obstacles within the RF path. Thus defining a range for a Bluetooth device is more or less question of how to determine the range. For example a radio located in a devices attached to human body has shorter range than a radio that is “floating” in free space because human body has an impact on the RF field. A person usually doesn’t point the device directly towards the transmitter so occasionally the body or other obstacles are within the RF path and will attenuate the received RF signal.

To determine the range for BLE112, BLE113 and BLE121LR, the modules were tested in an airfield using a data connection between the modules. The result does not guarantee practical range for real application. The result should be considered as maximum theoretical range. In a practical application the range can be much shorter because the orientation and height of the antenna can’t be controlled and also typically there are obstacles within the RF path which will attenuate the signal significantly.

In practical application the range is impacted by:

- Persons / obstacles moving close to the antenna. This is because of multipath propagation and will have an impact even if the person is not in line of sight between the two radios.
- Any obstacles within the RF path
- PCB layout around the antenna (depending on the type of the antenna)
- The shape of the PCB (depending on the type of the antenna)
- The mechanical design of the end product

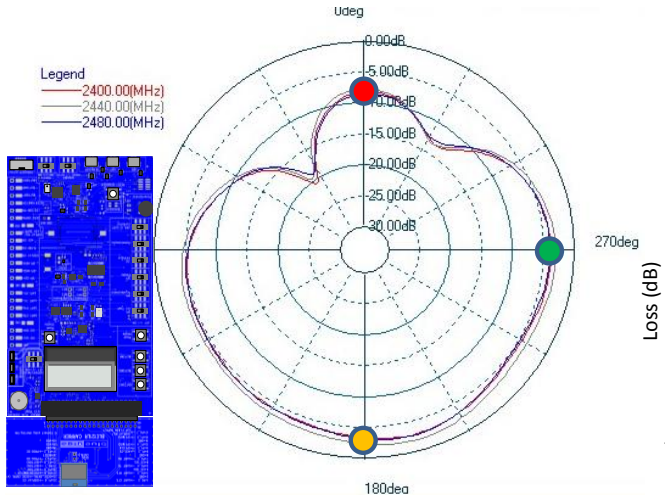
Because the range is impacted by many factors which are difficult to control, the practical range must be tested with the end product and the application should not be design based on the maximum theoretical range because the practical range will always be shorter.

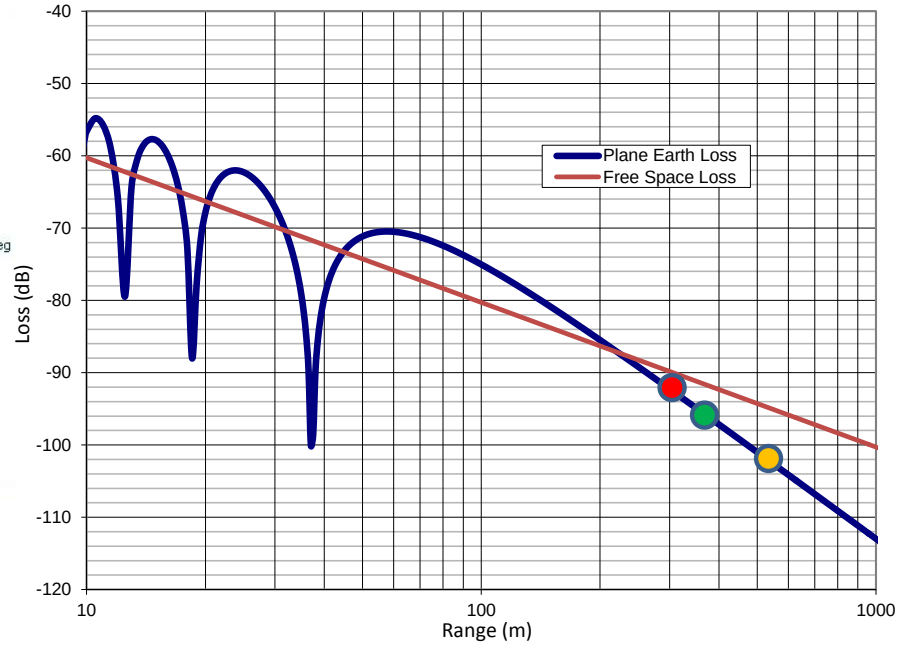
Following chapter shows how the transmit power, receiver sensitivity and the radiation pattern converts to link budget and how the line of sight range can be estimated using plane earth loss calculation. Also the practical test results are shown to compare with the theoretical estimate.

2 Range Comparison

2.1 BLE121LR Mounted to DKBLE

Module	Typical TXP	Sensitivity	Direction	Antenna Attenuation	Link Budget	Calculated Range	Tested Range
BLE121LR	8 dBm	-98 dBm	Front	-3 dB	100 dB	470m	450m
BLE121LR	8 dBm	-98 dBm	Back	-7 dB	92 dB	300m	300m
BLE121LR	8 dBm	-98 dBm	Side	-5 dB	96 dB	370m	340m





2.2 DKBLE112

Module	Typical TXP	Sensitivity	Direction	Antenna Attenuation (*	Link Budget	Calculated Range	Tested Range (**
BLE112	3 dBm	-91 dBm	Front	-14 dB	70 dB	20- 30 m	20 m
BLE112	3 dBm	-91 dBm	Back	-6 dB	82 dB	160 m	150 m
BLE112	3 dBm	-91 dBm	Side	-2 dB	90 dB	260 m	-

*) The radiation pattern of a monopole chip antenna is strongly dependent on the motherboard layout. These numbers are measured with the DKBLE112

**) The range was tested with BLE112 carrier mounted to the DKBLE. Thus the radiation pattern does not necessarily match with the pattern measured with DKBLE112

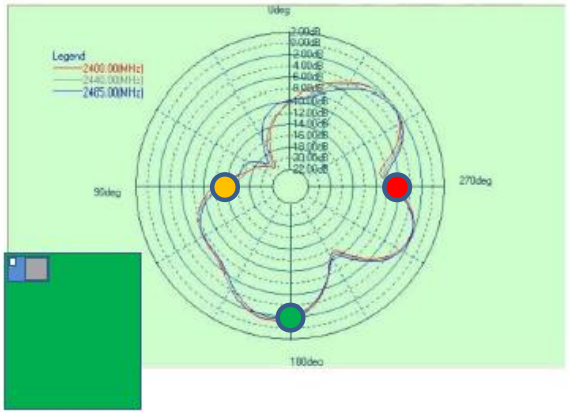
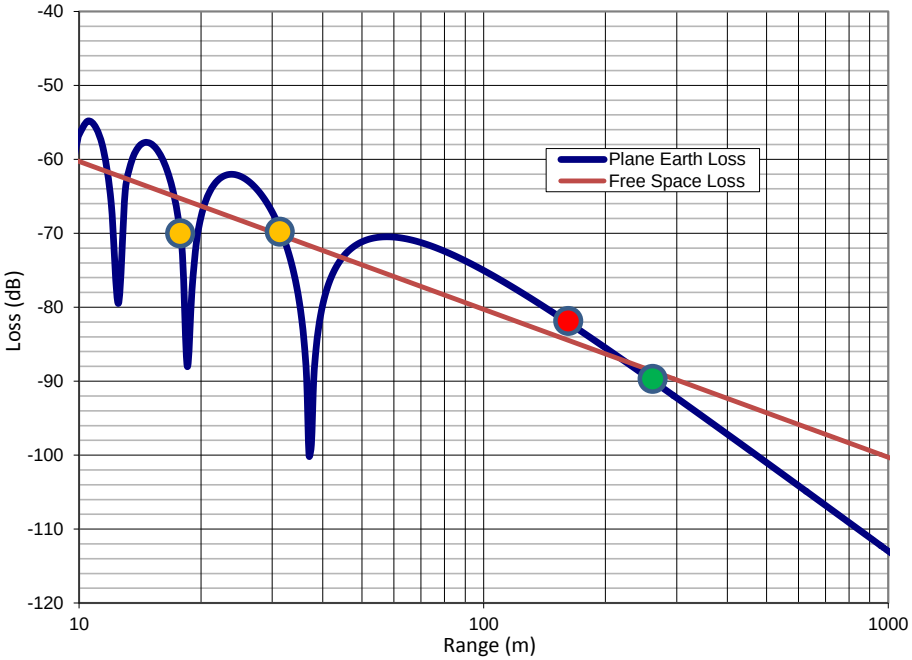


Figure 5: Radiation pattern of BLE112, top view

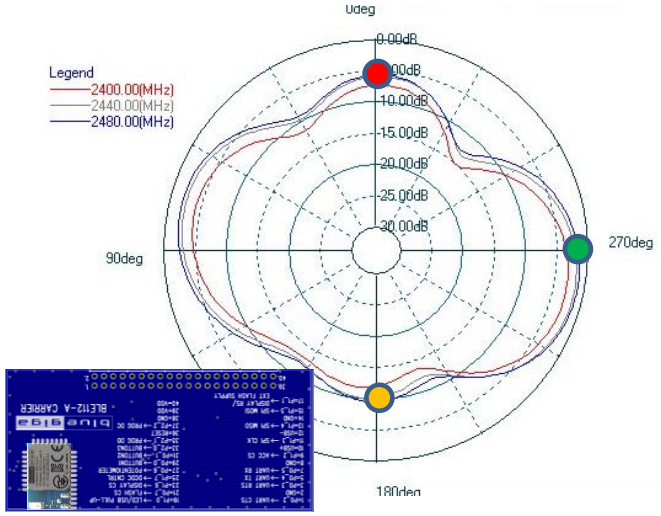


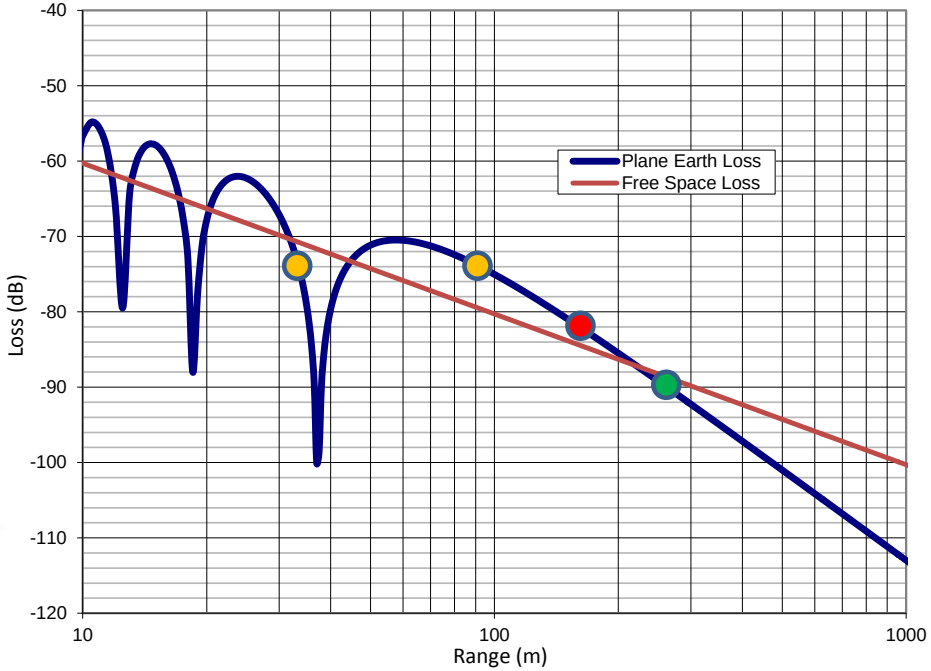
2.3 BLE112 Mounted to a Carrier Board

Module	Typical TXP	Sensitivity	Direction	Antenna Attenuation (*	Link Budget	Calculated Range	Tested Range (**
BLE112	3 dBm	-91 dBm	Front	-10 dB	74 dB	30 - 90 m	-
BLE112	3 dBm	-91 dBm	Back	-6dB	82 dB	160 m	-
BLE112	3 dBm	-91 dBm	Side	-2 dB	90 dB	260 m	-

*) The radiation pattern of a monopole chip antenna is strongly dependent on the motherboard layout. These numbers are measured with the DKBLE112

**) The range was tested with BLE112 carrier mounted to the DKBLE. Thus the radiation pattern does not necessarily match with the pattern measured with DKBLE112





2.4 DKBLE113

Module	Typical TXP	Sensitivity	Direction	Antenna Attenuation (*	Link Budget	Calculated Range	Tested Range (*
BLE113	0 dBm	-93 dBm	Front	-14 dB	69 dB	20-30 m	-
BLE113	0 dBm	-93 dBm	Back	-6 dB	81 dB	150 m	-
BLE113	0 dBm	-93 dBm	Side	-2 dB	89 dB	230 m	-

*) The radiation pattern of a monopole chip antenna is strongly dependent on the motherboard layout. These numbers are measured with the DKBLE112. The radiation pattern of DKBLE113 can be asumed to be identical with DKBLE112 because of the same antenna in a similar layout.

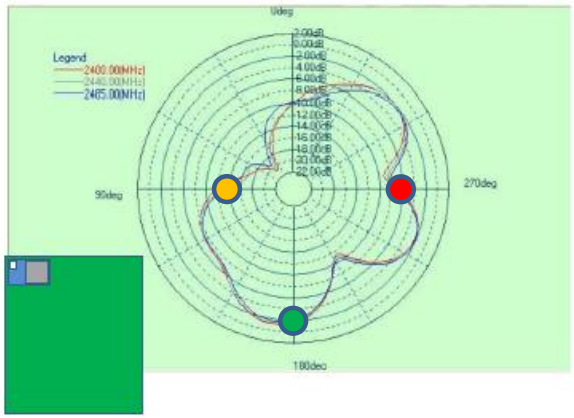
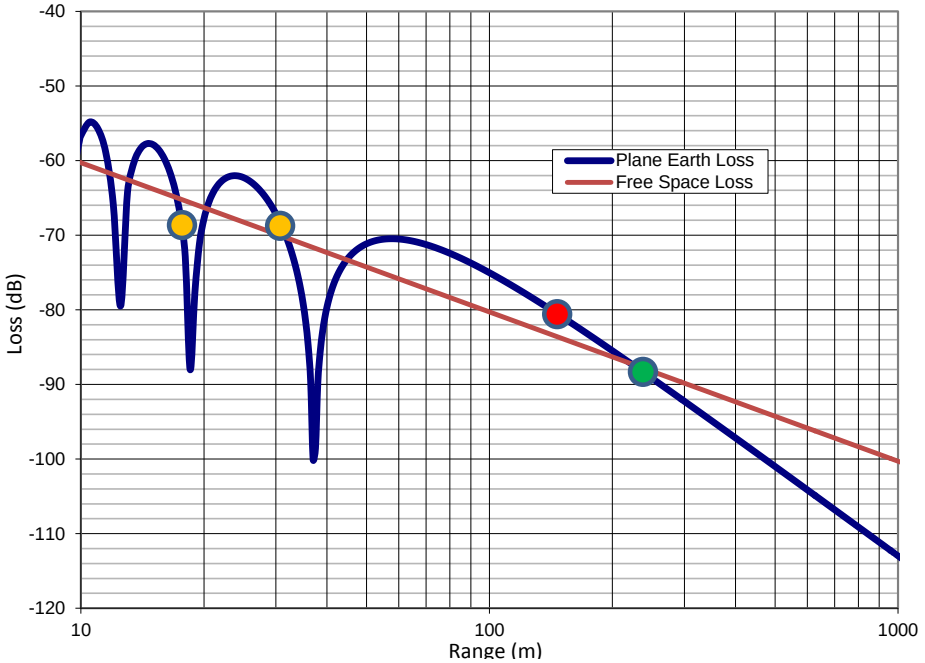


Figure 5: Radiation pattern of BLE112, top view



2.5 Module vs Phone Range

Following ranges were measured in an open field with antennas 1.5 meter above ground using the Heart Rate example. The range is the distance at which the remote device was able to still connect and remain the connection to the module.

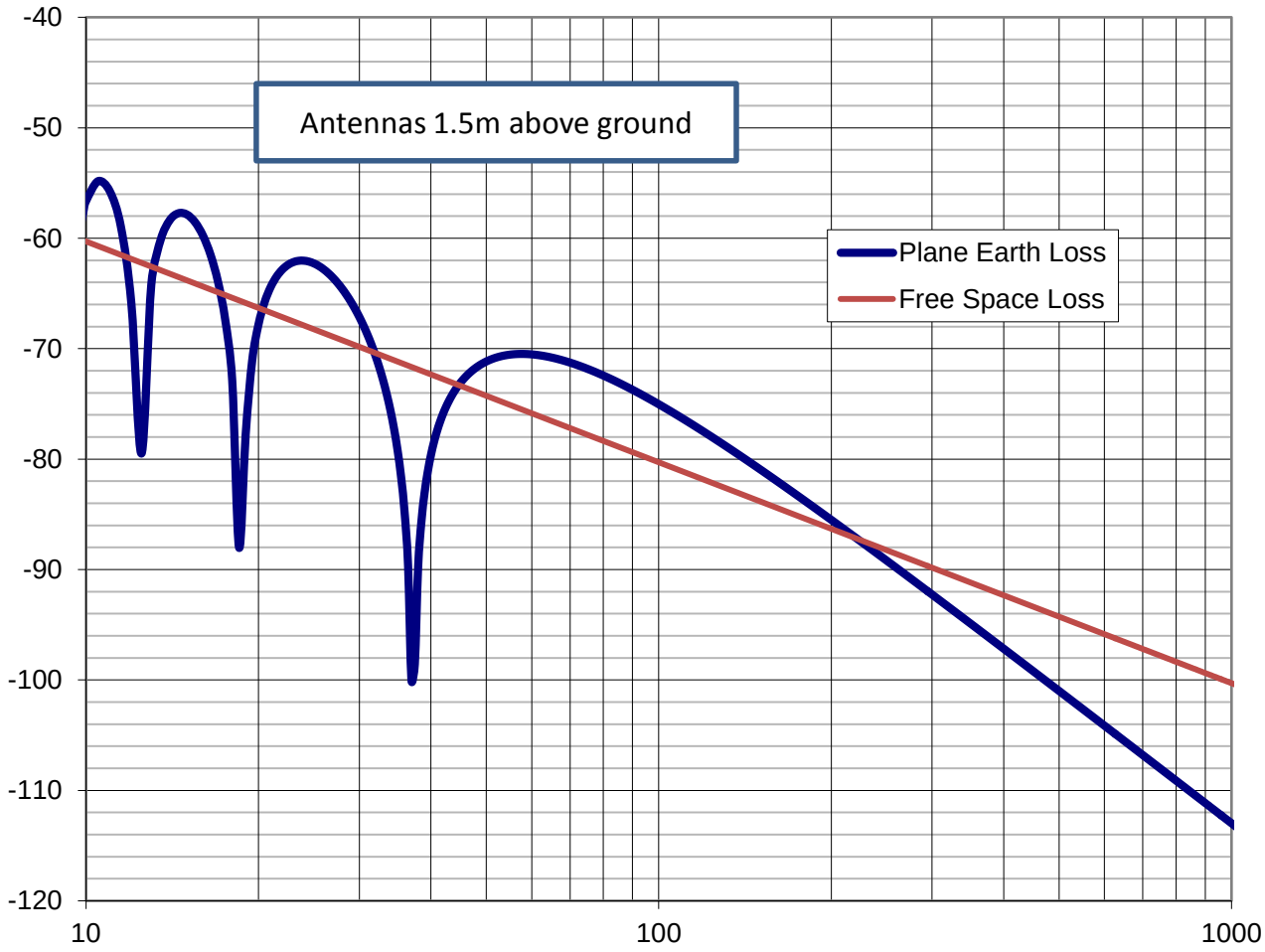
Setup	Tested Practical Line-of-Sight Range
BLE121LR vs iPod	250m – 300m
BLE121LR vs Nexus7	~430m
BLE113 vs iPod	60m – 80m
BLE113 vs Nexus7	~170m

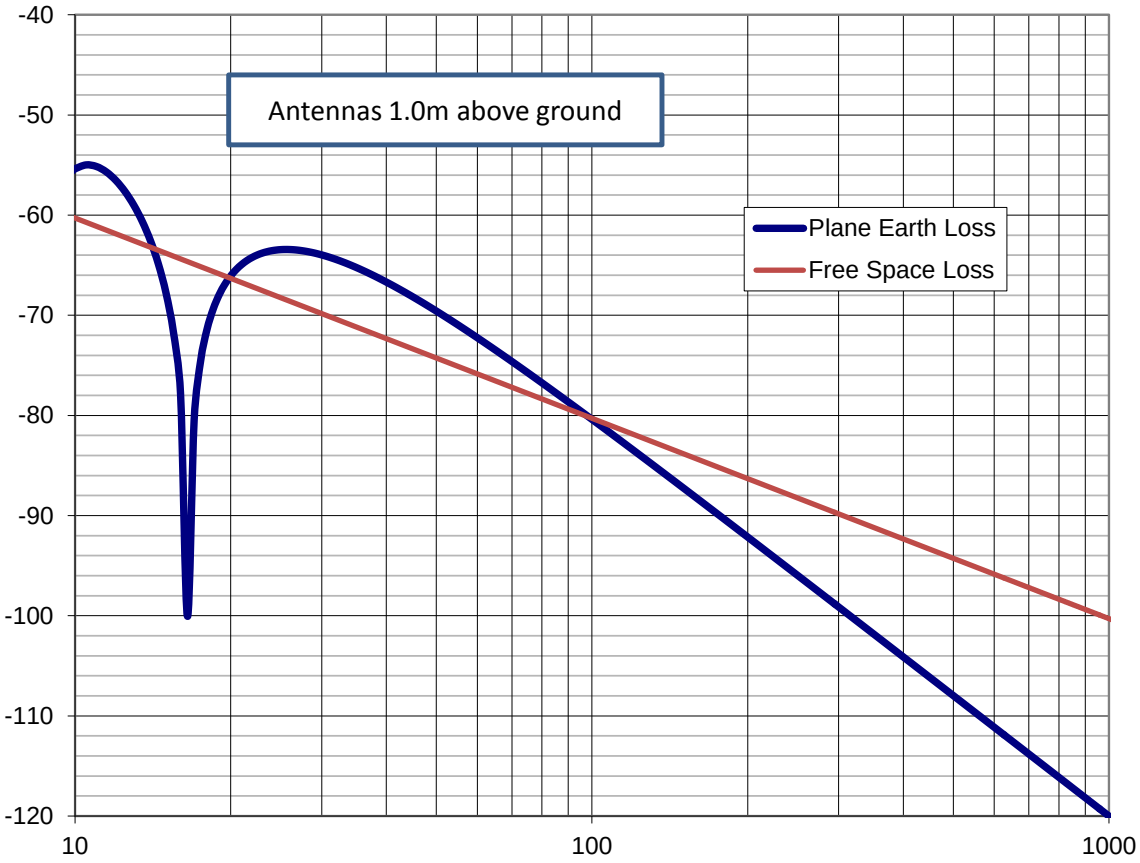
Table 1: Tested practical ranges

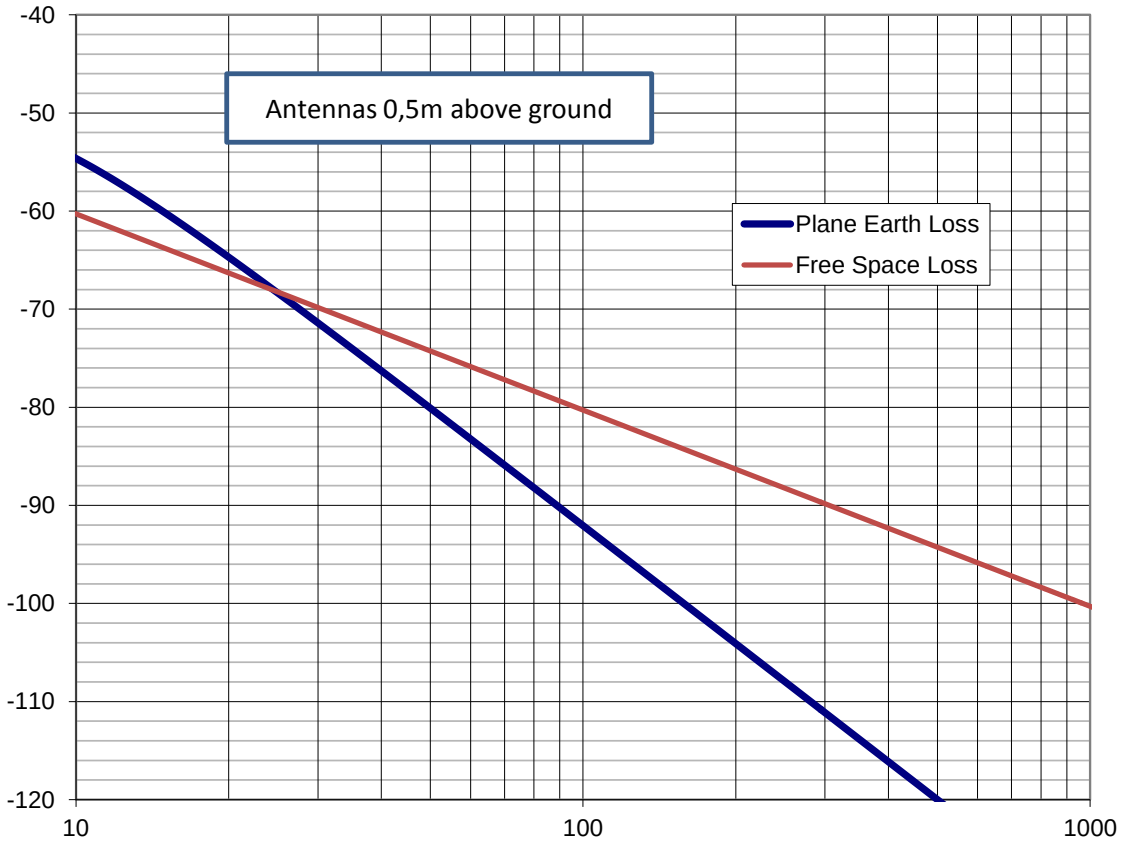
2.6 How the Antenna Height from Ground Effects on the Range

In an open field the received power is a sum of the line-of-sight wave and the ground-reflected wave. Depending on the phase of the ground-reflected wave, it either amplifies or attenuates the total received power. For details, see chapter 3.

Following figures demonstrate how the actual plane earth loss (the path loss in an open field) behaves compared to the free space loss.


Antennas 1.5m above ground
Plane Earth Loss
Free Space Loss
-40
-50
-60
-70
-80
-90
-100
-110
-120
10
100
1000


Antennas 1.0m above ground
Plane Earth Loss
Free Space Loss
-40
-50
-60
-70
-80
-90
-100
-110
-120
10
100
1000


Antennas 0,5m above ground
Plane Earth Loss
Free Space Loss
-40
-50
-60
-70
-80
-90
-100
-110
-120
10
100
1000

3 How to Calculate the Range

RF power propagates in free space within a virtual “pipe” which can be defined by so called Fresnel ellipsoid. Any obstacles within the area of this “pipe” will attenuate the RF power and thus decrease the actual range of the link. The radius of the “pipe” can be approximated by

$$R = \sqrt{\frac{D \times \lambda}{12}}$$

Where R is the radius, D is the distance between the antennas and lambda is the wave length (12.2 cm).

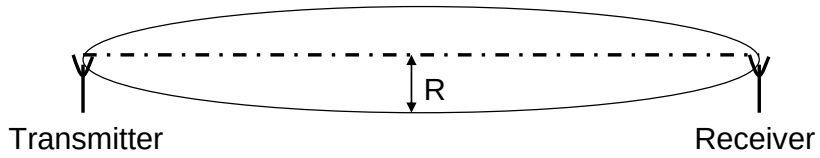


Figure 1: RF propagation area between TX and RX

The free space loss can be approximated by

$$L_P(dB) = 92{,}45 + 20\log F + 20\log D$$

Where F is frequency in GHz and D is Distance in kilometers. This approximation however does not apply to actual case where the signal is reflected from the ground. More realistic approximation can be calculated by

$$\frac{P_R}{P_T} = 2\left(\frac{\lambda}{4\pi r}\right)^2 \left[1 - \cos\left(k\,\frac{2h_1 h_2}{r}\right)\right]$$

Where h_1 and h_1 the height of the antennas respectively, k is the free space wavenumber and r is the distance between the antennas. The equation is expressed with the blue line in the figures showing the Plane Earth Loss. From these figures one can see that at Bluetooth frequencies simple approximation -20dB/decade can be used in free space and -40dB/decade once the ground starts to dominate the power loss. The distance where the ground starts to effect can be calculated by

$$d_m = \frac{(12 \times h_1 \times h_2)}{\lambda}.$$

The total range can be approximated once the output power from the antenna (transmitter output power + antenna gain) and the receiver sensitivity (receiver sensitivity + antenna gain) is defined. As an example using antenna heights 1 m, 2 m and 3 m, TX power 3 dBm, receiver sensitivity -91dBm and antenna attenuation 5 dB (5 dB loss in both TXP and RX sensitivity) one can approximate the total ranges assuming an open field without obstacles within the RF path.

h = 1 m → D = 125 m

h = 2 m → D = 235 m

h = 3 m → D = 305 m

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