Keywords: radio, RF, link budget, ISM, industrial, medical, radio frequency, Tx, Rx, ground bounce, free space path, flat earth path loss, link margin

APPLICATION NOTE 5142

Radio Link-Budget Calculations for ISM-RF Products

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Abstract: This application note provides a customizable spreadsheet to help designers using Maxim's industrial, scientific, and medical radio-frequency (ISM-RF) products estimate the range and link margin they can achieve with a given radio design. The spreadsheet accepts inputs for frequency, transmitter and receiver performance, and radio path characteristics. It calculates the link margin and range for free space, outdoor flat earth, and indoor conditions. This spreadsheet also estimates the range and link margin of almost any radio at a carrier frequency between approximately 100MHz and 10GHz.

Introduction

The Link Budget Spreadsheet helps users of Maxim's industrial, scientific, and medical radio-frequency (ISM-RF) products (Tx, Rx, TRx) estimate the range and link margin that they can achieve with a given radio design in several representative environments. The Excel® spreadsheet can also be used to estimate the range and link margin of almost any radio at a carrier frequency between approximately 100MHz and 10GHz. The user can supply the following inputs to the spreadsheet:

Click here for an overview of the wireless components used in a typical radio transceiver.

- Radio carrier frequency
- Transmitter power
- Cable and connector losses
- Antenna gain and efficiency (Tx and Rx)
- Free space and Flat Earth propagation
- Height of Tx and Rx
- Receiver sensitivity
- Obstruction loss
- Multipath loss

The spreadsheet will be upgraded in the future to include new features and increased sophistication of existing features. These will include:

- Connector loss information
- Calculation of multipath loss from scattering models
- Calculation of loss from propagation medium (humidity, conductivity, permittivity, human/animal tissue, foliage, etc.)

This application note briefly describes the major assumptions about the propagation path, some of the mathematics behind those assumptions, and then provides instructions for using the spreadsheet.

Propagation Path Loss

The two fundamental propagation paths in the spreadsheet are the Free Space path and the Flat Earth path. There are additional entries to account for multipath, obstruction, and penetration losses, which are common inside buildings or on urban streets. Maxim's ISM-RF products are used in parking lots, streets, open areas, and buildings where the radio height above ground is small. This means that the Flat Earth path model is usually best suited for estimating the link budget. In applications where both Tx and Rx are located on towers or rooftops, and the antenna beams are narrow, the Free Space model would be more relevant.

A radio signal that transmits very close to the ground relative to the desired distance of the horizontal path consists of two components: the direct, Line-Of-Sight (LOS) signal and the signal that is reflected from the ground. The phase of the ground bounce electric field, with few exceptions, is always opposite the phase of the line-of-sight electric field. In free-space propagation, there is no ground reflection.

The path loss formula for free-space propagation is:

$$P_R = P_T G_T G_R \lambda^2/(4\pi R)^2 \qquad \text{(Eq. 1)}$$

where P_R is the received power, P_T is the transmitted power, G_T is the transmitter antenna gain, G_R is the receive antenna gain, R is the range, and λ is the wavelength.

The path loss formula for flat-earth propagation is

$$P_R = ½P_T G_T G_R \lambda^2/(4\pi R)^2 \, (1 + a^2 - 2a\cos(2\pi\Delta R/\lambda)) \qquad \text{(Eq. 2)}$$

where ΔR is the difference in length of the direct path and the ground reflection path and "a" (≤ 1) is the relative strength of the ground bounce path.

$$\Delta R = \sqrt{(R^2 + (h_2 + h_1)^2)} - \sqrt{(R^2 + (h_2 - h_1)^2)} \qquad \text{(Eq. 3)}$$

Notice that the result in Equation 2 is the product of the free space loss in Equation 1 and a ground bounce loss factor shown below.

$$L_{GB} = ½(1 + a^2 - 2a\cos(2\pi\Delta R/\lambda)) \qquad \text{(Eq. 4)}$$

At close range, where the path loss difference, ΔR, is greater than or equal to about half a wavelength, L_{GB} varies rapidly with R, and the received power fluctuates significantly. At longer ranges (usually 30m or more in handheld applications), L_{GB} exhibits an R^{-2} variation, so that the received power in a flat-earth environment (Equation 2) decreases as the 4th power of R.

Both formulas for the propagation loss are calculated in the spreadsheet. You can choose which one to use to determine link margin.

User Tabs Descriptions

There are five tabs in the spreadsheet that perform calculations or have information to guide the user in making entries:

- Link Budget
- Link Plot
- Ground Multipath
- Cable Loss
- Obstructions

Of these tabs, only the **Link Budget** and **Ground Multipath** tabs require inputs from the user. The **Cable Loss** tab contains insertion loss specifications from commonly-used coaxial cables and connectors. The **Obstructions** tab contains estimated losses for walls and windows inside buildings, and for forests, vegetation, and structures outside. These numbers can be used to determine the entries in the Link Budget tables for cable and obstruction loss. Connector losses are usually less than 1dB and can be entered without the use of an additional tab. The **Link Plot** tab depicts the radio link loss contributions from the hardware and the channel (propagation path) from start to finish.

The **Ground Multipath** tab requires user inputs for the transmitter and receiver height, and contains a useful plot of path loss vs. distance, including (in some scenarios) the deep transmission fades associated with terrestrial radio links.

The entries in the spreadsheet are color-coded to identify their source.

Black: Direct entry from the user
Dark Red: A constant, e.g. the speed of light
Blue: Calculated number
Green: Values obtained from another tab

Using the Spreadsheet

Open the **Link Budget** tab of the spreadsheet. A screen shot of this tab is shown at the end of the instructions.

1. Enter the carrier frequency of the radio in megahertz. The spreadsheet will calculate the wavelength.
2. Enter the PA power of the transmitter. This is the power level estimated or measured as close to the PA output pin of the transmitter circuit as possible.
3. Enter the Tx match loss (if any). Most transmitters need a few passive components to transform the antenna impedance to the optimum impedance for the transmitter.
4. Enter any significant connector and cable losses between the transmitter circuit and the antenna. At this point, the spreadsheet shows the power at the Tx antenna input.
5. Enter the Tx antenna gain. This includes the efficiency of the antenna, losses in any additional impedance transformation networks, and allowance for variation in the directional pattern of the antenna. Antennas whose dimensions are less than 0.1 wavelength will have a loss rather than a gain.
6. Enter the distance in meters that you wish to cover with the radio link.
7. Enter the loss from the medium, if applicable. Examples are propagation through media other than air or propagation at higher frequencies (> 2GHz) where moisture or molecular absorption may occur.
8. Go to the **Ground Multipath** tab on the spreadsheet and enter the height of the transmitter antenna and receiver antenna.
9. Return to the **Link Budget** tab. At this point, the spreadsheet calculates the path loss for both Free Space and Flat Earth at the distance you have chosen.
10. The received power at the antenna for Free Space Loss appears a few rows above the received power for Flat Earth Path Loss. If the link is a free space link, the Free Space Loss is used and there is no need to calculate the Flat Earth Loss.
11. Enter the anticipated Multipath Loss (from reflecting and scattering objects in the path). This is usually at least 20dB, unless the path is flat and empty (an open field or a deserted parking lot, for example).
12. Enter the anticipated Obstruction Loss (from walls or buildings).
13. The received power at the antenna for Flat Earth Loss appears a few rows below the Free Space Path Loss.
14. Enter the Rx antenna gain. The same rules for efficiency apply as for Tx antenna gain.
15. Enter any significant connector and cable losses between the antenna and the receiver circuit. The final Rx

power at the receiver input is shown for both Free Space path loss and Flat Earth path loss.

16. The entry immediately to the right of the Rx power is the sensitivity of the receiver. This is the minimum signal level at which the receiver will process information correctly from the radio link. When the received signal level for the path of interest (Free Space or Flat Earth) is equal to the sensitivity, the distance entered is the maximum achievable range of the radio link. Adjust the range as needed to match the received signal level with the sensitivity.
17. To determine the proper sensitivity number to enter in the cell, use the Receiver Sensitivity Calculations section of the **Link Budget** tab or select a value from the Maxim RX table on the **Link Plot** tab. The three numbers to enter for calculating the sensitivity and SNR of the receiver are the noise figure, the receive bandwidth, and the operating temperatures.

Example 1: Remote Keyless Entry (RKE) Control Link

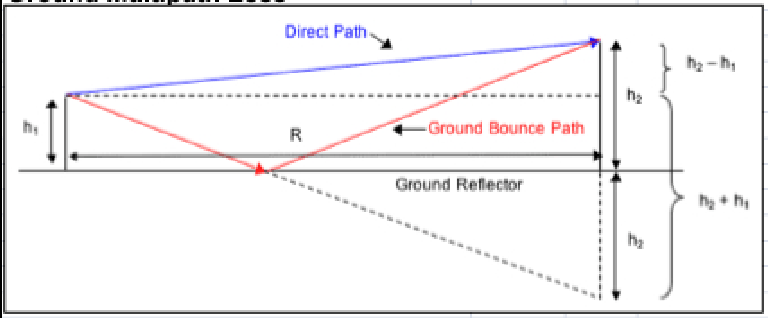
Figure 1 is a screen shot of the **Link Budget** tab filled out for an RKE control link at 315MHz. **Figures 2** and **3** show the **Ground Multipath** tab with entries for Tx and Rx height and the path loss vs. distance from the radio link. Discussion of the results appears after the screen shots.

RF System (Link Budget) Calculations

System Variables	Variable	Units	Equation	Value		
Frequency	f_0	MHz		315		
Speed of Light	c	m/s		299792458		
Wavelength	λ	m	$\lambda = c/f_0$	0.951722089		
Block		**Units**	**Equation**	**Value**		
PA Power	P_{PA}	dBm		10		
TX Match Loss	L_{MatchT}	dB				
TX source	P_{TX}	dBm		10		
TX connector loss	L_{ConT1}	dB	(from Connector Loss sheet)	-0.57		
TX cable loss	L_{CabT}	dB	(from Cable Loss sheet)			
TX connector loss (remote antenna)	L_{ConT2}	dB	(from Connector Loss sheet)			
TX power	P_T	dBm	$P_T = P_{TX}$(C&C Loss)	9.43		
TX antenna gain	G_T	dBi		-15		
Effective (Isotropic) Radiated Power	EIRP	dBm	$EIRP = P_T G_T$	-5.57		
Distance	d	m		175		
Channel Medium Loss Factor	L_0	dB	(from Medium Loss sheet)	0		
Free Space Loss	L_{FS}	dB	$L_{FS} = (\lambda/4\pi d)^2$	-67.27475527		
Power at RX Antenna, Free Space Path	P_{ChanFS}	dB	$P_{ChanFS} = L_{FS} L_0 EIRP$	-72.84475527		
Flat Earth Loss (Includes Ground Bounce)	L_{FE}	dB	(from Ground Multipath sheet)	-92.73416576		
Multipath Loss	L_{MP}	dB				
Obstruction Loss	$L_{Obs\text{-}Total}$	dB		0		
Power at RX Antenna, Flat Earth Path	P_{ChanFE}	dB	$P_{ChanFE} = L_{FE} L_0 L_{MP} L_{Obs} EIRP$	-98.30416576		
RX antenna gain	G_R	dBi		-15		
RX connector loss	L_{ConR1}	dB		-0.57		
RX cable loss	L_{CabR}	dB				
RX connector loss (remote antenna)	L_{ConR2}	dB				
RX power, Free Space Path	P_{RFS}	dBm	$P_{RFS} = P_{ChanFS} G_R$(C&C Loss)	-88.41475527		
RX power, Flat Earth Path	P_{RFE}	dBm	$P_{RFE} = P_{ChanFE} G_R$(C&C Loss)	-113.8741658		-114
					Sensitivity of Rx	
Receiver Sensitivity Calculations	**Variable**	**Units**	**Equation**	**Value**		
RX Noise Figure	NF	dB		7		
Operating Temperature	T_0	K		290		
Effective Noise Temperature	T_e	K	$T_e = T_0(NF - 1)$	1163.442978		
Boltzmann's constant	k	J/K		1.38E-23		
Receive Bandwidth	BW_{RX}	MHz		0.012		
Antenna Temperature	T_{Ant}	K		300		
Noise Power (at RX)	P_n	dBm	$P_n = k(T_{Ant} + T_e)BW_{RX}$	-126.1556386		
Signal to Noise Ratio	SNR_{RX}	dB	$SNR_{RX} = P_{RX}/P_n$	12.15563863		

Figure 1. The Link Budget tab filled out for an RKE control link at 315MHz.

Ground Multipath Loss



Reference Maxim Application Note AN3586

Ground Reflection Path Loss

System Variables	Variable	Units	Equation	Value
TX height	h_{TX}	m		1
RX height	h_{RX}	m		1
Distance	d	m	(from Link Budget sheet)	175
Direct Path	d_1	m	$d_1 = (d^2 + (h_{TX} - h_{RX})^2)^{1/2}$	175
Reflection Path	d_2	m	$d_2 = (d^2 + (h_{TX} + h_{RX})^2)^{1/2}$	175.0114282
Reflection Path Δ	Δd	m	$\Delta d = d_2 - d_1$	0.011428198
Estimated Reflection Path Δ	Δd_e	m	$\Delta d_e = 2h_{TX}h_{RX}/d$	0.011428571
Wavelength	λ	m	(from Link Budget sheet)	0.951722089
Normalized Ground Bounce Amplitude	a	none		1
Loss From Ground Bounce Cancellation	L_{GB}	dB	$L_{GB} = 10\log_{10}(0.5(1 + a^2 - 2a\cos(2\pi\Delta d/\lambda)))$	-25.45941048
Free Space Loss	L_{FS}	dB	$L_{FS} = 10\log_{10}(\lambda/4\pi d)^2$	-67.27475527
Flat Earth Loss	L_{FE}	dB	$L_{FE} = L_{GB} + L_{FS}$	-92.73416576

Ground Reflection Path Loss Approximation (for $d > 5(h_{TX} + h_{XR})$)

System Variables	Variable	Units	Equation	Value
Estimated Flat Earth Loss*	L_{FEe}	dB	$L_{FEe} = 10\log_{10}(h_{TX}^2 h_{RX}^2/2d^4)$	-92.7318219
Estimated Ground Bounce Cancellation Loss	L_{GBe}	dB	$= L_{FEe} - L_{FS}$	-25.45706663

* Introduction to RF Propagation, John S. Seybold, p.172

Figure 2. The Ground Multipath tab displaying flat earth loss calculations vs. Tx and Rx height for an RKE control link.

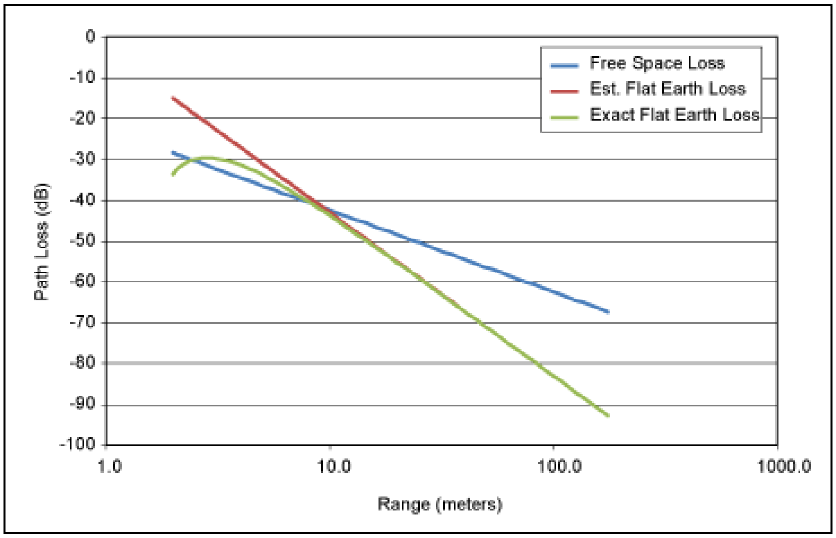


Figure 3. Graph of flat earth loss vs. range for an RKE control link.

RKE Example Observations and Analysis

Entries in the Link Budget spreadsheet are characteristic of RKE applications, which have very low antenna gains of -15dB for the Tx and Rx and transmitter power levels of +10dBm or lower. The size of the key fob antenna is usually no more than 1in × 1in (40mm × 40mm), which is tiny compared to the 950mm wavelength, so the antenna is *very* inefficient. The receive antenna can be larger, but allowance needs to be made for shadowing and blockage inside the car or behind the dashboard. The transmitter power at the IC is typically +10dBm to minimize drain on the battery and to keep the peak radiated power from the antenna below the allowable FCC limit. This maximum value is given in terms of the peak field strength 3 meters away from the transmitter. This can be as high as 60mV/m (equivalent to +0.4dBm radiated power from the antenna) if the duty cycle of the transmitter is kept low enough.

The entries that are needed in the **Ground Multipath** tab are the height of the transmitter and the height of the receiver. These determine the effect of the ground bounce. In the example, the height of both transmitter and receiver are 1m, which is typical for the person holding the key fob and for the location of the receiver in the vehicle.

Under the conditions entered in the spreadsheet, including the -114dBm sensitivity of the receiver, the maximum range in an open area is approximately 175m. This result was found by changing the value of the Distance entry in the **Link Budget** tab, until the received signal power equaled (within a few tenths of 1dB) the sensitivity.

Example 2: Home Automation Sensor and Keypad

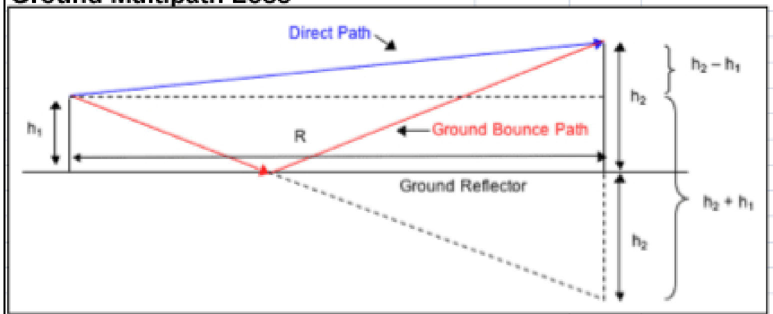
Figure 4 is a screen shot of the **Link Budget** tab filled out for a home automation link at 433.92MHz. **Figures 5** and **6** show the **Ground Multipath** tab with entries for Tx and Rx height and the path loss vs. distance from the radio link. This link could be between an occupancy detector and wall-mounted keypad in a home security system, a remote thermostat control, and a thermostat in another room, or a remote dimming control and a lighting fixture. In this example, unlike the RKE Control Link, there are obstructions and multipath losses, which add to the path loss and therefore reduce the range. Contrastingly, the antenna efficiency is higher (antenna is a larger fraction of a wavelength), and the radios are placed at slightly greater heights above the ground, which increase the range. The net result in this example is a reduction in range.

RF System (Link Budget) Calculations

System Variables	Variable	Units	Equation	Value	
Frequency	f_0	MHz		433.92	
Speed of Light	c	m/s		*299792458*	
Wavelength	λ	m	$\lambda = c/f_0$	0.690893386	
Block	**Variable**	**Units**	**Equation**	**Value**	
PA Power	P_{PA}	dBm		10	
TX Match Loss	L_{MatchT}	dB			
TX source	P_{TX}	dBm		10	
TX connector loss	L_{ConT1}	dB	(from Connector Loss sheet)	-0.57	
TX cable loss	L_{CabT}	dB	(from Cable Loss sheet)		
TX connector loss (remote antenna)	L_{ConT2}	dB	(from Connector Loss sheet)		
TX power	P_T	dBm	$P_T = P_{TX}$(C&C Loss)	9.43	
TX antenna gain	G_T	dBi		-10	
Effective (Isotropic) Radiated Power	EIRP	dBm	$EIRP = P_T G_T$	-0.57	
Distance	d	m		80	
Channel Medium Loss Factor	L_0	dB	(from Medium Loss sheet)	0	
Free Space Loss	L_{FS}	dB	$L_{FS} = (\lambda/4\pi d)^2$	-63.25777632	
Power at RX Antenna, Free Space Path	P_{ChanFS}	dB	$P_{ChanFS} = L_{FS} L_0 EIRP$	-63.82777632	
Flat Earth Loss (Includes Ground Bounce)	L_{FE}	dB	(from Ground Multipath sheet)	-72.18814948	
Multipath Loss	L_{MP}	dB		-25	
Obstruction Loss	$L_{Obs\text{-}Total}$	dB		-10.2	
Power at RX Antenna, Flat Earth Path	P_{ChanFE}	dB	$P_{ChanFE} = L_{FE} L_0 L_{MP} L_{Obs} EIRP$	-107.9581495	
RX antenna gain	G_R	dBi		-5	
RX connector loss	L_{ConR1}	dB		-0.57	
RX cable loss	L_{CabR}	dB			
RX connector loss (remote antenna)	L_{ConR2}	dB			
RX power, Free Space Path	P_{RFS}	dBm	$P_{RFS} = P_{ChanFS} G_R$(C&C Loss)	-69.39777632	
RX power, Flat Earth Path	P_{RFE}	dBm	$P_{RFE} = P_{ChanFE} G_R$(C&C Loss)	-113.5281495	-114
					Sensitivity of Rx
Receiver Sensitivity Calculations	**Variable**	**Units**	**Equation**	**Value**	
RX Noise Figure	NF	dB		7	
Operating Temperature	T_0	K		290	
Effective Noise Temperature	T_e	K	$T_e = T_0(NF - 1)$	1163.442978	
Boltzmann's constant	k	J/K		*1.38E-23*	
Receive Bandwidth	BW_{RX}	MHz		0.012	
Antenna Temperature	T_{Ant}	K		300	
Noise Power (at RX)	P_n	dBm	$P_n = k(T_{Ant} + T_e)BW_{RX}$	-126.1556386	
Signal to Noise Ratio	SNR_{RX}	dB	$SNR_{RX} = P_{RX}/P_n$	12.15563863	

Figure 4. The Link Budget tab filled out for a home automation link at 433.92MHz.

Ground Multipath Loss



Reference Maxim Application Note AN3586

Ground Reflection Path Loss

System Variables	Variable	Units	Equation	Value
TX height	h_{TX}	m		1.5
RX height	h_{RX}	m		1.5
Distance	d	m	(from Link Budget sheet)	80
Direct Path	d_1	m	$d_1 = (d^2 + (h_{TX} - h_{RX})^2)^{1/2}$	80
Reflection Path	d_2	m	$d_2 = (d^2 + (h_{TX} + h_{RX})^2)^{1/2}$	80.05623024
Reflection Path Δ	Δd	m	$\Delta d = d_2 - d_1$	0.056230239
Estimated Reflection Path Δ	Δd_e	m	$\Delta d_e = 2h_{TX}h_{RX}/d$	0.05625
Wavelength	λ	m	(from Link Budget sheet)	0.690893386
Normalized Ground Bounce Amplitude	a	none		1
Loss From Ground Bounce Cancellation	L_{GB}	dB	$L_{GB} = 10\log_{10}(0.5(1 + a^2 - 2a\cos(2\pi\Delta d/\lambda)))$	-8.930373157
Free Space Loss	L_{FS}	dB	$L_{FS} = 10\log_{10}(\lambda/4\pi d)^2$	-63.25777632
Flat Earth Loss	L_{FE}	dB	$L_{FE} = L_{GB} + L_{FS}$	-72.18814948

Ground Reflection Path Loss Approximation (for $d > 5(h_{TX} + h_{XR})$)

System Variables	Variable	Units	Equation	Value
Estimated Flat Earth Loss*	L_{FEe}	dB	$L_{FEe} = 10\log_{10}(h_{TX}^2 h_{RX}^2/2d^4)$	-72.09024907
Estimated Ground Bounce Cancellation Loss	L_{GBe}	dB	$= L_{FEe} - L_{FS}$	-8.832472755

* Introduction to RF Propagation, John S. Seybold, p.172

Figure 5. The Ground Multipath tab displaying flat earth loss calculations vs. Tx and Rx height for a home automation link.

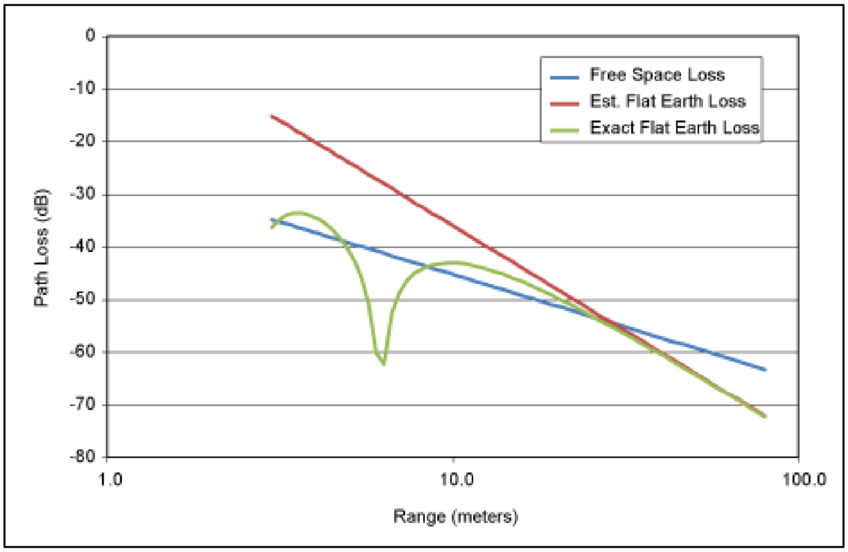


Figure 6. Graph of flat earth loss vs. range for a home automation link.

Home Automation Example Observations and Analysis

Entries in the Link Budget spreadsheet that are characteristic of a home automation application are low antenna gains of -10dB for the Tx and -5dB for the Rx, and the transmitter power of +10dBm. The size of the remote Tx antenna depends on the package constraints of the sensor (occupancy detector, thermostat mount, etc.), but it is usually larger than the antenna in a key fob. In addition, the wavelength is smaller at 433MHz than it is at 315MHz. For these reasons, the antenna gain in this application is higher than it is in an RKE application, but the antenna is still very inefficient. The receiver antenna can be larger, because the receiver enclosure (usually mounted on a wall) has more room, but it is not likely to be as large as one-fourth of a wavelength (17.5cm, or 7in). Therefore, the receiver antenna gain is still less than 0dB. The transmitter power is typically +10dBm to minimize drain on the battery (some home automation transmitters may be able to use "house power") and to keep the peak transmitted power below the allowable FCC limit. Again, this maximum value, which is higher at 433MHz than at 315MHz, is given in terms of the peak field strength 3 meters away from the transmitter. This level can be up to 110mV/m if the duty cycle of the transmitter is kept low enough. The power needed to produce this field strength is +5.6dBm. In both this example and the previous RKE example, the transmitted power entered into the spreadsheet is not at the FCC limit, because the antennas are small and inefficient. If a larger antenna can be deployed, you can easily improve the range.

The entries that are needed in the **Ground Multipath** tab are the height of the transmitter and the height of the receiver. These determine the effect of the ground bounce. In the example, the height of both the transmitter and receiver is 1.5m. Even the small added height, compared to the RKE example (1.5m vs. 1.0m), will improve the range. This is because the ground bounce approximation for path loss improves as the square of the height of each antenna. Depending on the particular home automation application, each height may vary. For instance, an occupancy sensor may be mounted on the ceiling, which would increase its height in the spreadsheet.

The indoor environment adds loss from multipath (reflections and scattering from objects in a house or building) and blockage (walls and ceilings). The multipath loss is estimated at 25dB and allowance for 3 walls (10.2dB blockage loss) has been made through the entries in this spreadsheet.

Under the conditions entered in the spreadsheet, including the -114dBm sensitivity of the receiver, the maximum range in an indoor area is approximately 80m. This result was found by changing the value of the "Distance" entry in the **Link Budget** tab until the received signal power equaled (within a few tenths of a dB) the sensitivity. This example shows how the multipath and blockage losses associated with the inside of a building dramatically reduces the range of indoor radio links.

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Related Parts		
MAX1470	315MHz Low-Power, +3V Superheterodyne Receiver	Free Samples
MAX1471	315MHz/434MHz Low-Power, 3V/5V ASK/FSK Superheterodyne Receiver	Free Samples
MAX1472	300MHz-to-450MHz Low-Power, Crystal-Based ASK Transmitter	Free Samples
MAX1473	315MHz/433MHz ASK Superheterodyne Receiver with Extended Dynamic Range	Free Samples
MAX1479	300MHz to 450MHz Low-Power, Crystal-Based +10dBm ASK/FSK Transmitter	Free Samples
MAX7030	Low-Cost, 315MHz and 433.92MHz ASK Transceiver with Fractional-N PLL	Free Samples
MAX7031	Low-Cost, 308MHz, 315MHz, and 433.92MHz FSK Transceiver with Fractional-N PLL	Free Samples
MAX7032	Low-Cost, Crystal-Based, Programmable, ASK/FSK Transceiver with Fractional-N PLL	Free Samples
MAX7033	315MHz/433MHz ASK Superheterodyne Receiver with AGC Lock	Free Samples
MAX7034	315MHz/434MHz ASK Superheterodyne Receiver	Free Samples
MAX7036	300MHz to 450MHz ASK Receiver with Internal IF Filter	Free Samples
MAX7042	308MHz/315MHz/418MHz/433.92MHz Low-Power, FSK Superheterodyne Receiver	Free Samples
MAX7044	300MHz to 450MHz High-Efficiency, Crystal-Based +13dBm ASK Transmitter	Free Samples
MAX7049	High-Performance, 288MHz to 945MHz ASK/FSK ISM Transmitter	Free Samples
MAX7057	300MHz to 450MHz Frequency-Programmable ASK/FSK Transmitter	Free Samples
MAX7058	315MHz/390MHz Dual-Frequency ASK Transmitter	Free Samples
MAX7060	280MHz to 450MHz Programmable ASK/FSK Transmitter	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 5142: http://www.maximintegrated.com/an5142
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