7. Appendix

7.1. Indoor Test

Indoor tests show that we have different behaviors according to the wall composition.

In fact electromagnetic waves are reflected by materials thus there is an attenuation of signal. Reflection depends on peculiarities of the material such as rugosity , shape and type.

In particular steel and aluminum produce a strong signal's attenuation so walls covered with steel , aluminum and cement cause a great packet loss (see Figure 7.1-1).

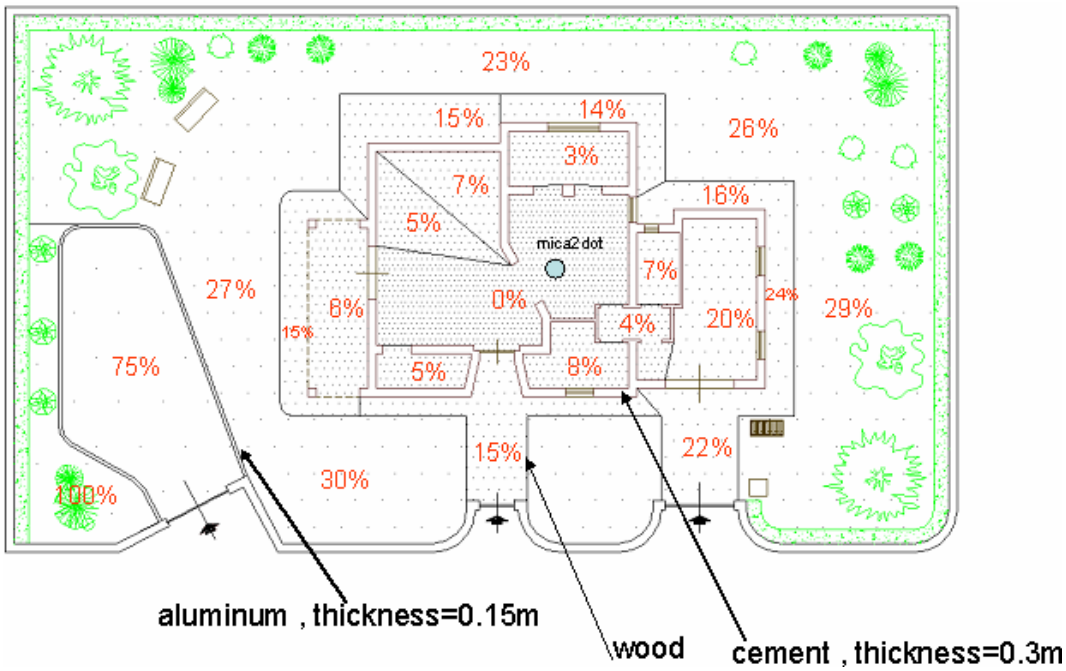


Figure 7.1-1

7.2. Rayleigh Fading

The primary source of performance degradation is thermal noise generated in the receiver. Often , external interference received by the antenna is more significant than thermal noise. If a radio channel's propagating characteristics are not specified , one usually infers that the signal attenuation versus distance behaves as if propagation takes place over ideal free space. The model of free space treats the region between the transmit and receive antennas and being free of all objects that might absorb or reflect radio frequency (RF) energy. It also assumes that , within this region, the atmosphere behaves as a perfectly uniform and non-absorbing medium. Furthermore the earth is treated as being infinitely far away fom the propagating signal (or equivalently as having a reflection coefficient that is negligible. For most practical channels , where signal propagation takes place in the atmosphere and near the ground the freespace propagation model is inadequate to describe the channel. In a wireless mobile communication system , a signal can travel from transmitter to receiver over multiple reflective paths , this phenomenon is referred to as *multipath propagation*. The effect can cause fluctuations in the received signal's amplitude, phase, and angle of arrival, giving rise to the terminology *multipath fading*.

Fading channel manifestations start with two types of fading effects that characterize mobile communications: large-scale and small-scale fading.

Large-scale fading represents the average signal power attenuation or path loss due to motion over large areas. This phenomenon is affected by prominent terrain contours (hills, forests, billboards, clumps of buildings) between he transmitter and the receiver. The receiver is often represented as being shadowed by such prominences.

Small-scale fading refers to the dramatic changes in signal amplitude and phase that can be experienced as a result of small changes in the spatial separation between receiver and transmitter. Small-scale fading is also called Rayleigh Fading because if the multiple reflective paths are large in number and there is no

line-of-sight signal component, the envelope of the received signal is statistically described by a Rayleigh probability density function.

A detail block description of small-scale and large-scale fading is in Figure 7.2-1.

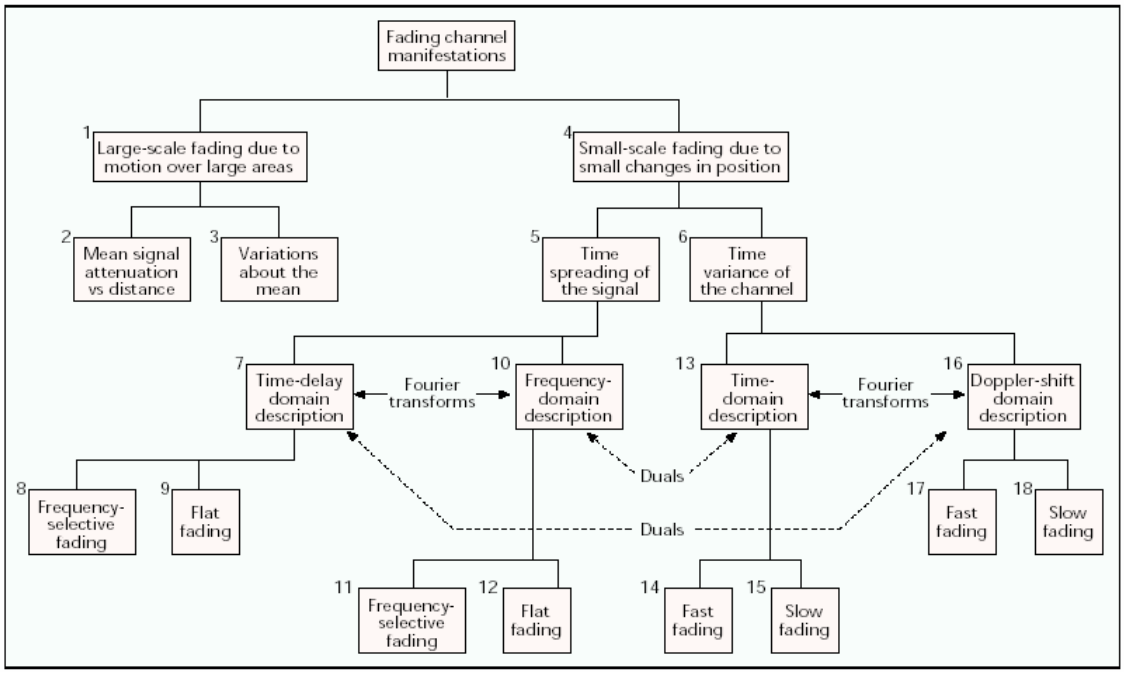


Figure 7.2-1

A mobile radio roaming over a large area must process signals that experience both types of fading: small-scale fading superimposed on large-scale fading. There are three basic mechanisms that impact signal propagation in a mobile communication system. They are reflection, diffraction and scattering:

- reflection occurs when a propagating electromagnetic wave impinges on a smooth surface with very large dimensions compared to the RF signal wavelength.
- diffraction occurs when the radio path between the transmitter and receiver is obstructed by a dense body with large dimensions compared to signal wavelength , causing secondary waves to be formed behind the obstructing body.
- scattering occurs when a radio wave impinges on either a large rough surface or any surface whose dimensions are on the order of signal wavelength or less, causing the reflected energy to spread out (scatter) in all directions. In a urban

environment typical signal obstructions that yield scattering are lampposts, street signs, and foliage.

During an experiment we have seen that even if sender and receiver are at 100 m distance (so with a small percentage of packet loss).In fact radio waves from the sender can take different paths and cancel each other when the waves are of opposite phase.

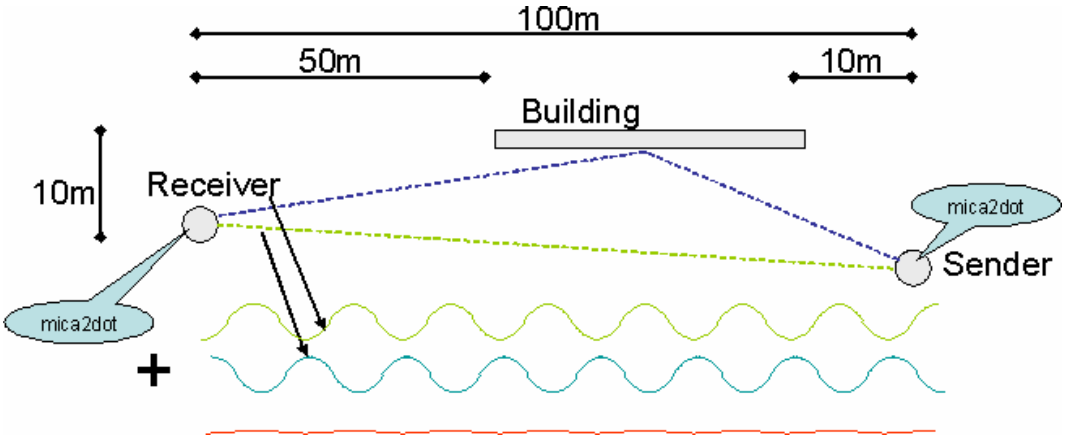


Figure 7.2-2

7.3. Minimum horizontal distance

The radio on the MICA2 has an extremely sensitive receiver, which can be interfered with by an adjacent local oscillator from another MICA2. A distance of at least 50 cm should be maintained between MICA2 units to avoid local oscillator interference.

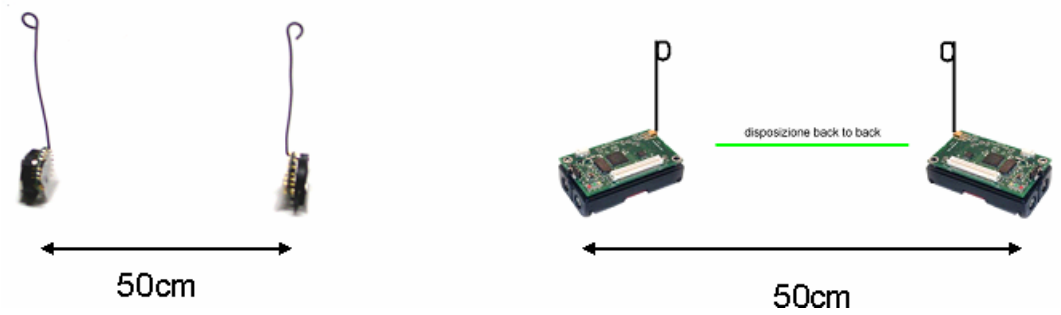


Figure 7.3-1

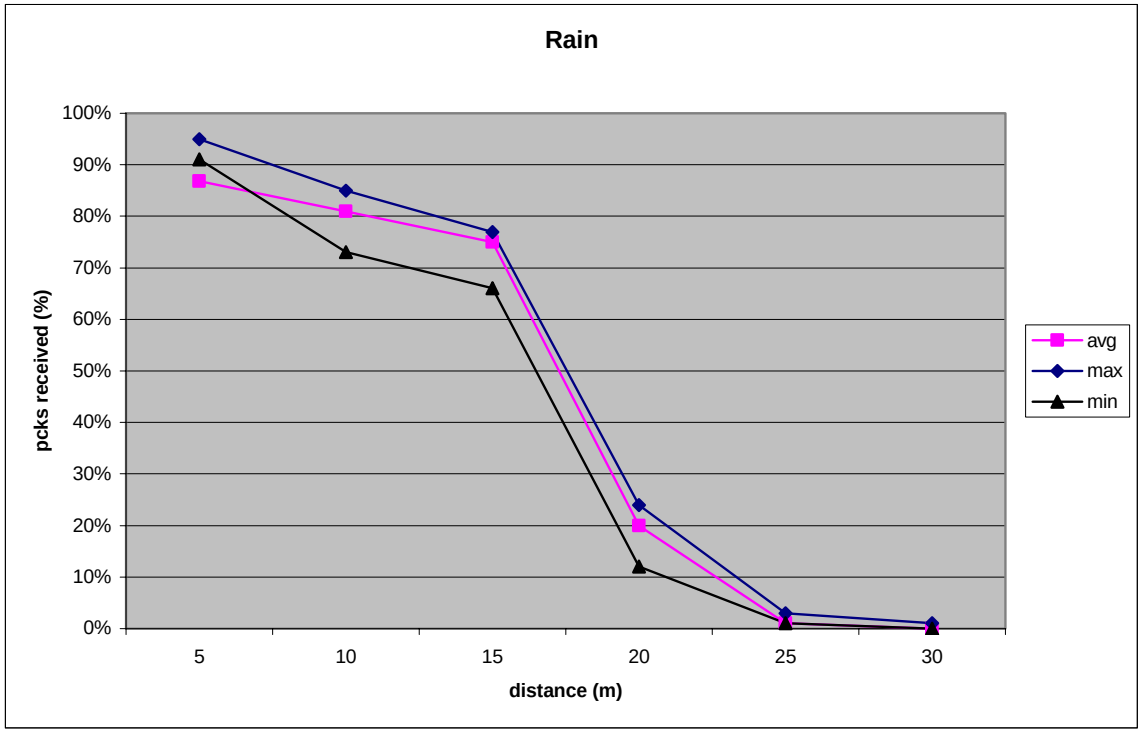
7.4. Rain

Test's conditions:

Transmitter	Mica2
Receiver	Mica2
Height from ground (m)	1
Relative humidity	65%
Temperature (C)	12
Time	10 am
Atmospheric conditions	Rain
Antenna disposition	Back to back
Power out(db/mW)	0 (default)
Duty Cycle	100% (default)

Tool for measurement	pluviometer
Fall rain intensity (mm/h)	30
Rain type	intense rain
Particles diameter (mm)	4
Speed of fall(m/sec)	2

Results:

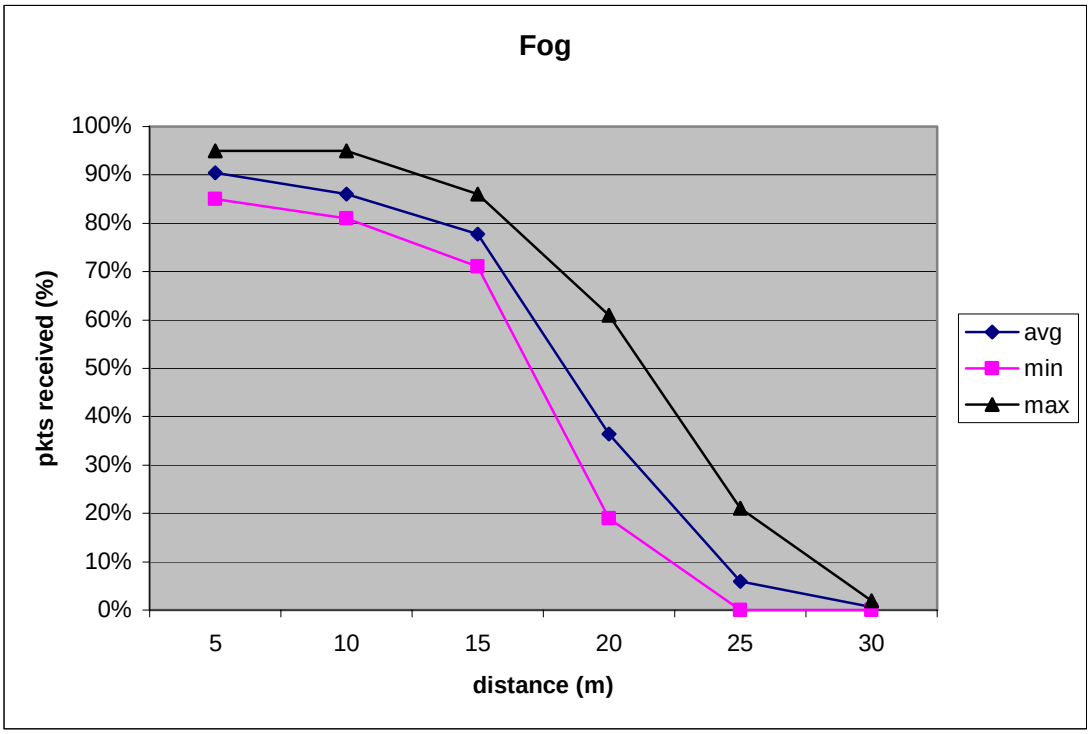


7.5. Fog

Test's conditions:

Transmitter	Mica2
Receiver	Mica2
Height from ground (m)	1
Relative humidity	83%
Temperature (C)	6
Time	9 am
Atmospheric conditions	fog
Antenna disposition	Back to back
Power out(db/mW)	0 (default)
Duty Cycle	100% (default)

Results:

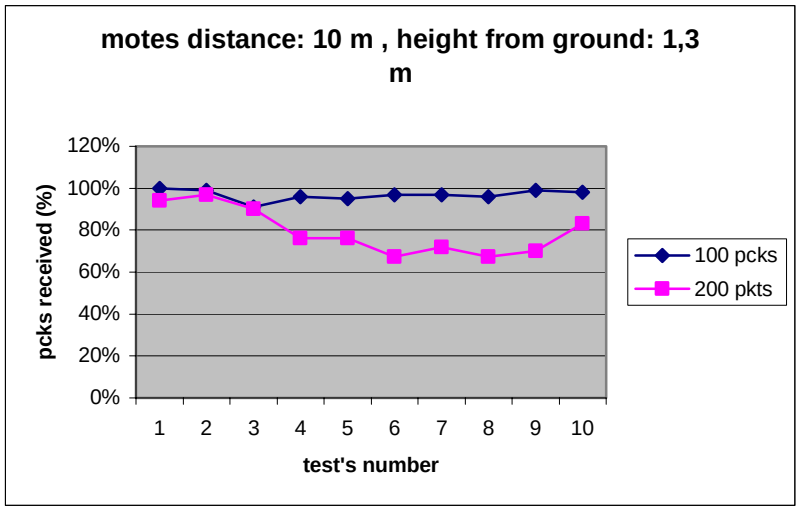


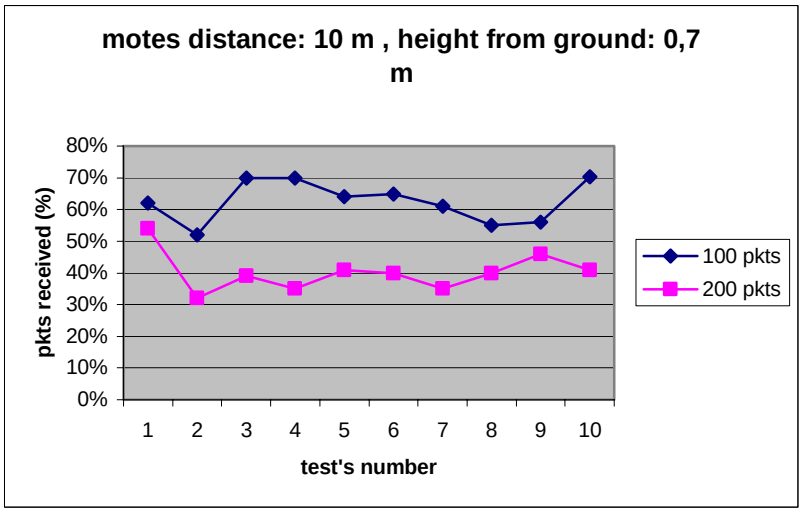
7.6. Height from ground

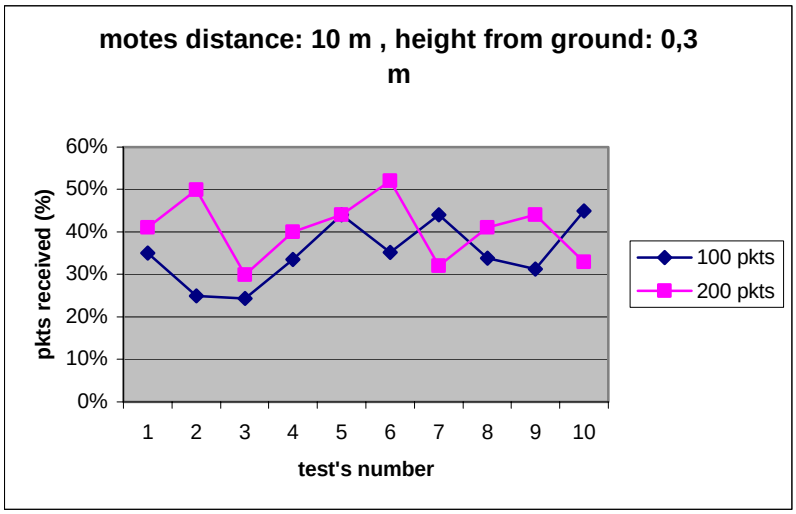
Test's conditions:

Transmitter	Mica2
Receiver	Mica2
Height from ground (m)	0.2 , 0.7 , 1.3
Vertical distance (m)	10
Relative humidity	55%
Temperature (C)	18
Time	11 am
Atmospheric conditions	normal
Antenna disposition	Back to back
Power out(db/mW)	0 (default)
Duty Cycle	100% (default)

Results:





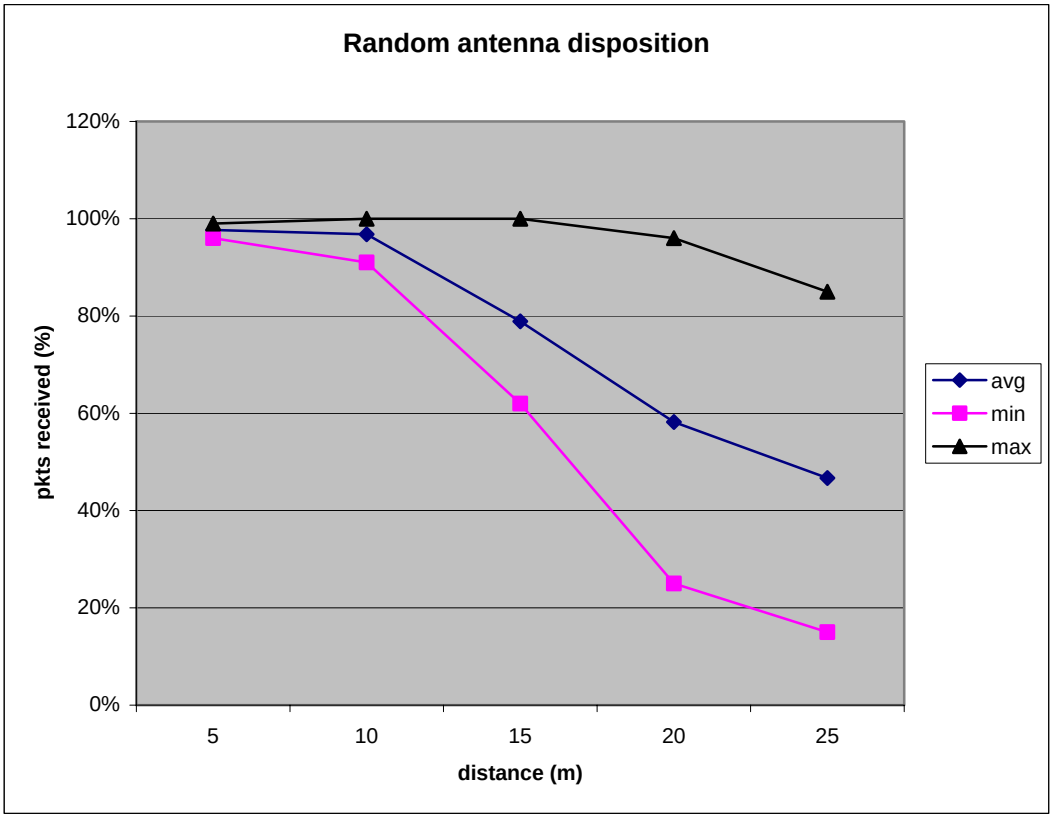

motes distance: 10 m , height from ground: 0,3 m
pkts received (%)
60%
50%
40%
30%
20%
10%
0%
1
2
3
4
5
6
7
8
9
10
test's number
100 pkts
200 pkts

7.7. Random Antenna Disposition

Test's conditions:

Transmitter	Mica2
Receiver	Mica2
Height from ground (m)	1
Relative humidity	57%
Temperature (C)	16
Time	10 am
Atmospheric conditions	normal
Antenna disposition	random
Power out(db/mW)	0 (default)
Duty Cycle	100% (default)

Results:

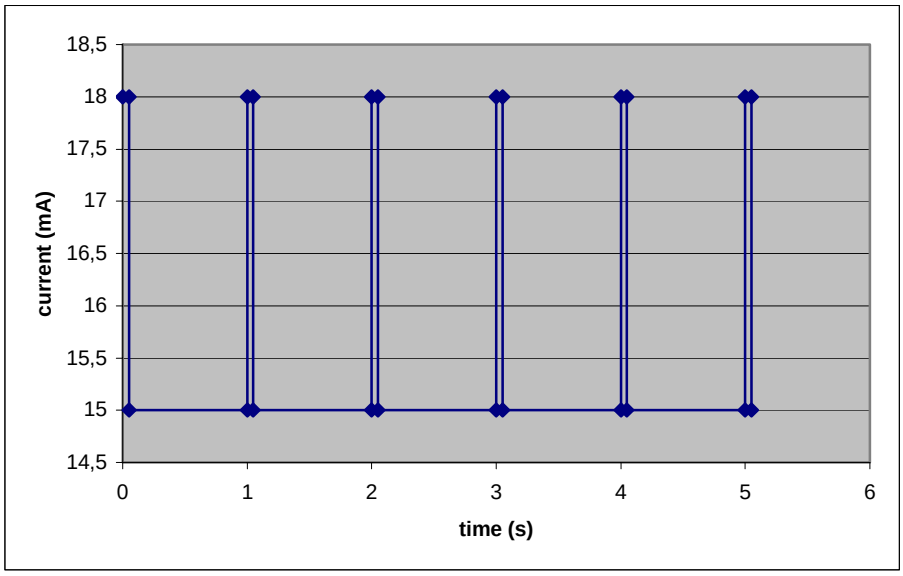


7.8. Power Consumption

Test's conditions:

Mote type	Mica2
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	indoor
Frequency	900 Mhz
Application	Transmits an 8-byte packet through radio. Radio is always in transmission mode

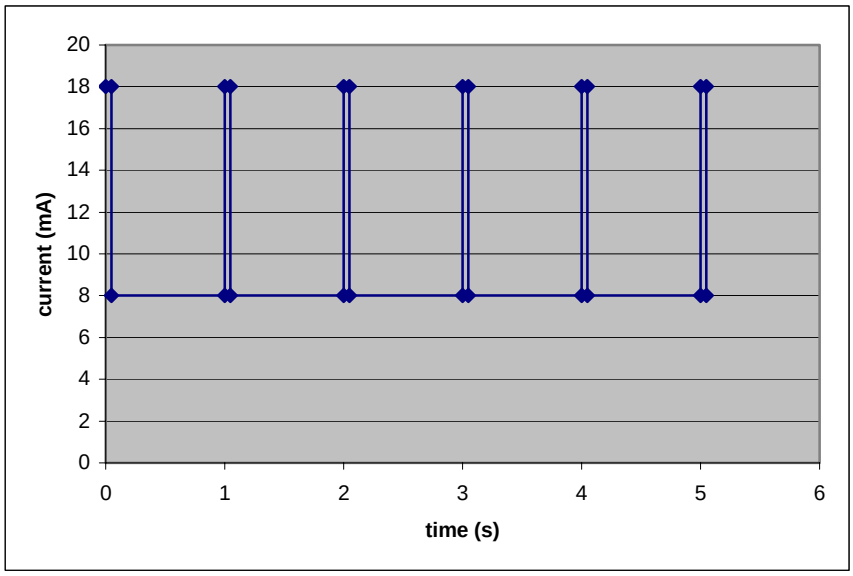
Results:



Test's conditions:

Mote type	Mica2
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	indoor
Frequency	900 Mhz
Application	Transmits an 8-byte packet through radio. Radio is off when unused.

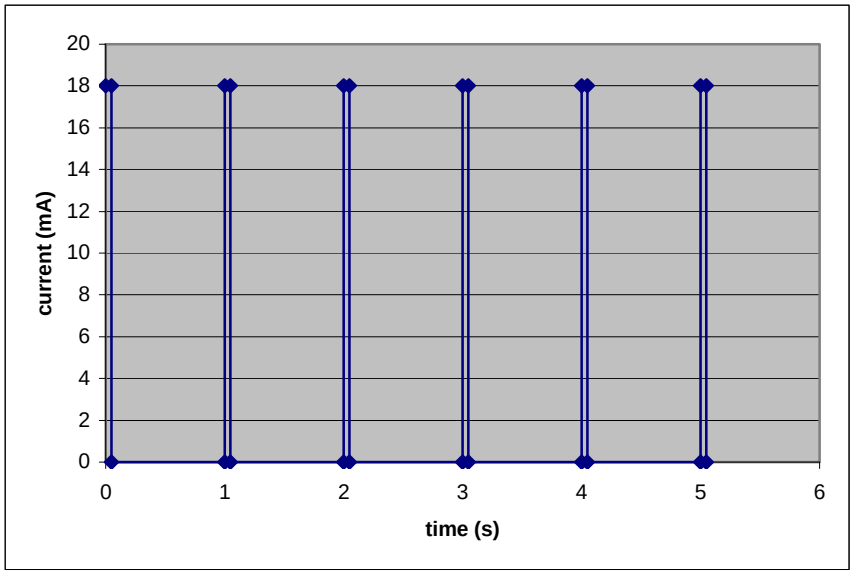
Results:



Test's conditions:

Mote type	Mica2
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Transmits an 8-byte packet through radio. When radio is idle it's is activated power down mode.

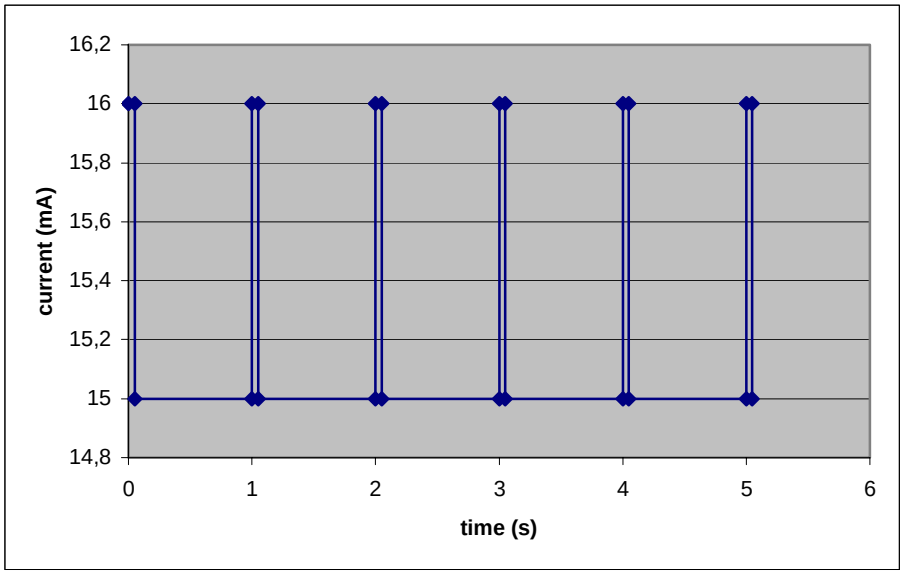
Results:



Test's conditions:

Mote type	Mica2
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Mote waits for packets ; when it receives something blinks the red led.

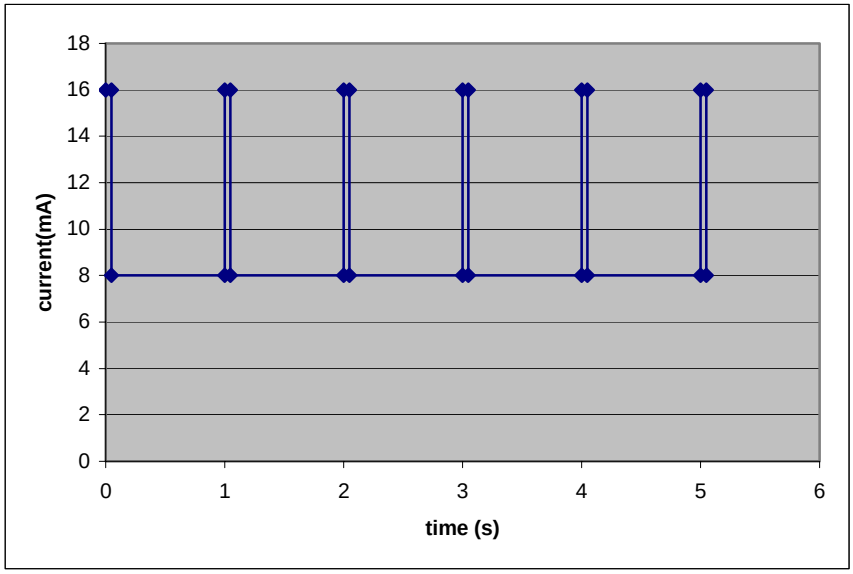
Results:



Test's conditions:

Mote type	Mica2
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Mote waits for packets; when it receives something blinks the red led. Radio is off when unused

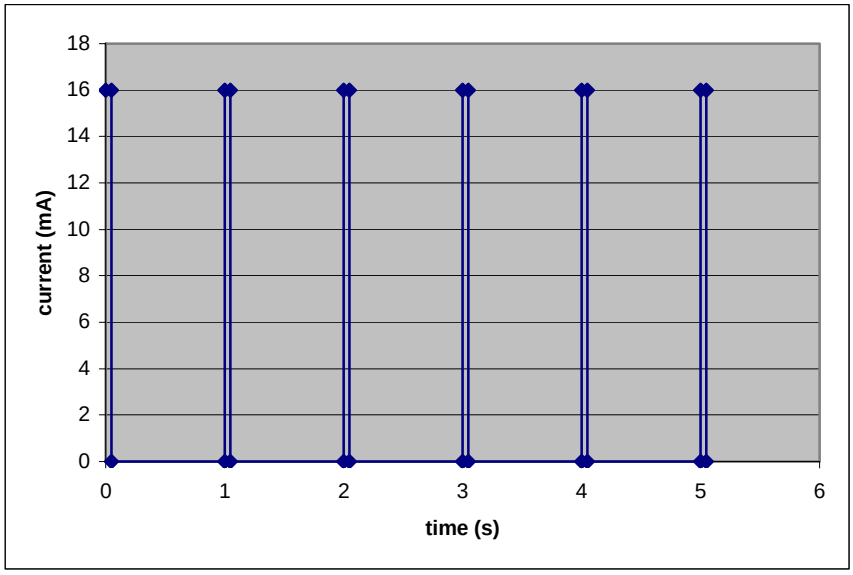
Results:



Test's conditions:

Mote type	Mica2
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Mote waits for packets; when it receives something blinks the red led. Radio is put in power down mode when idle.

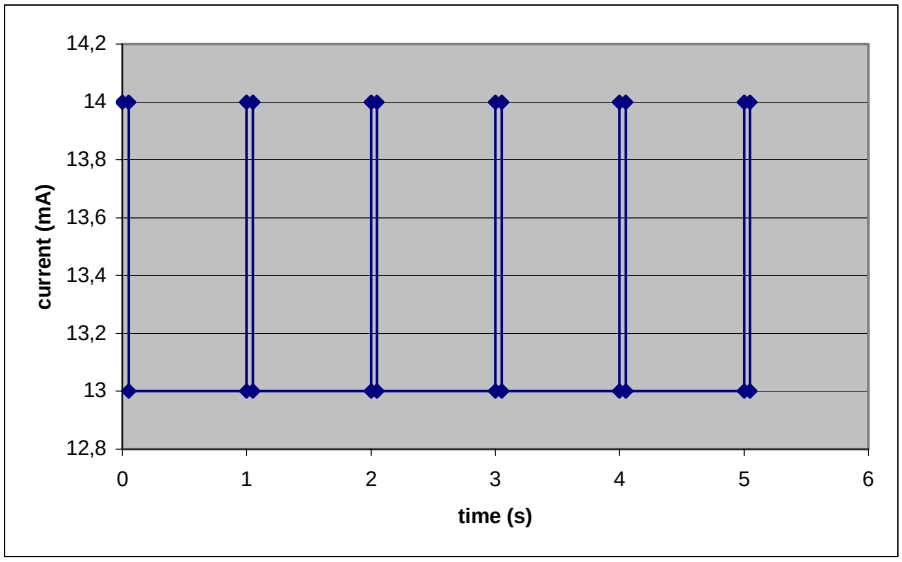
Results:



Test's conditions:

Mote type	Mica2dot
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Transmits an 8-byte packet through radio. Radio is always in transmission mode

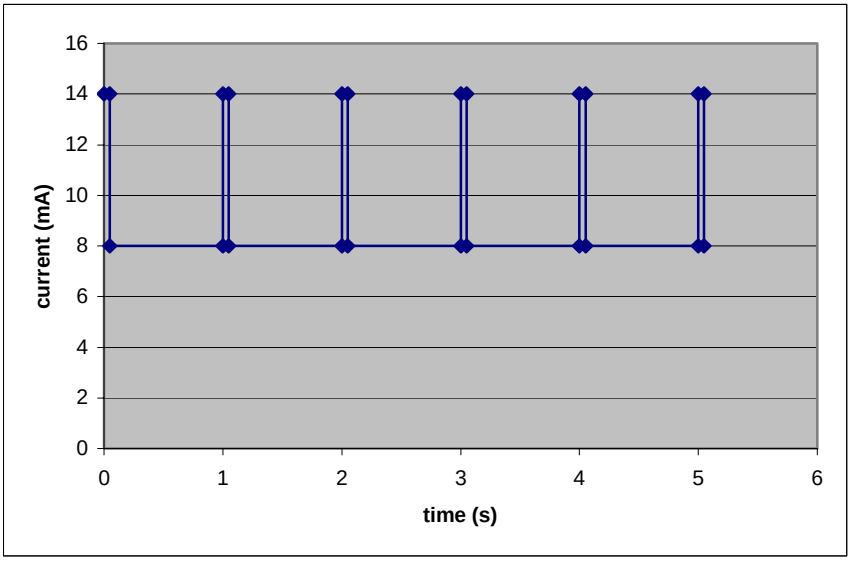
Results:



Test's conditions:

Mote type	Mica2dot
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Transmits an 8-byte packet through radio. Radio is off when unused.

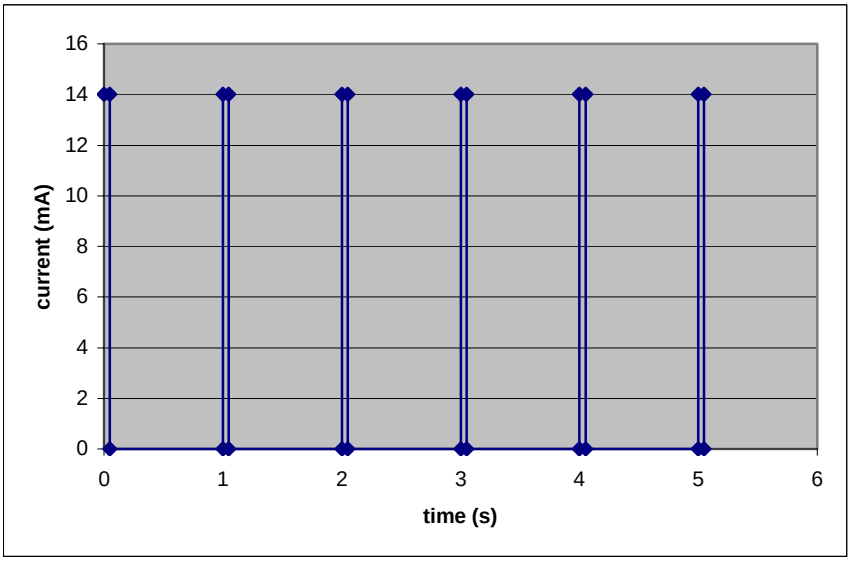
Results:



Test's conditions:

Mote type	Mica2dot
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Transmits an 8-byte packet through radio. When radio is idle it's is activated power down mode.

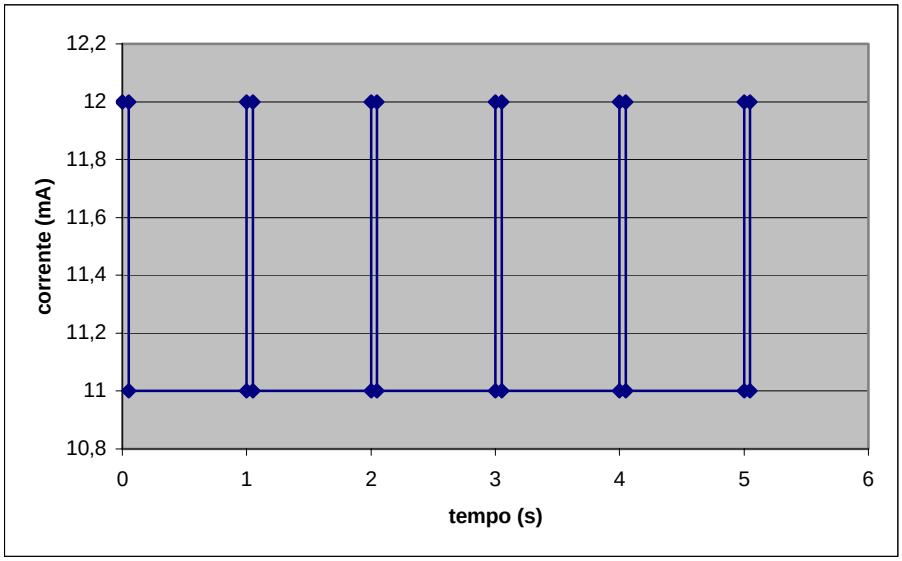
Results:



Test's conditions:

Mote type	Mica2dot
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Mote waits for packets; when it receives something blinks the red led.

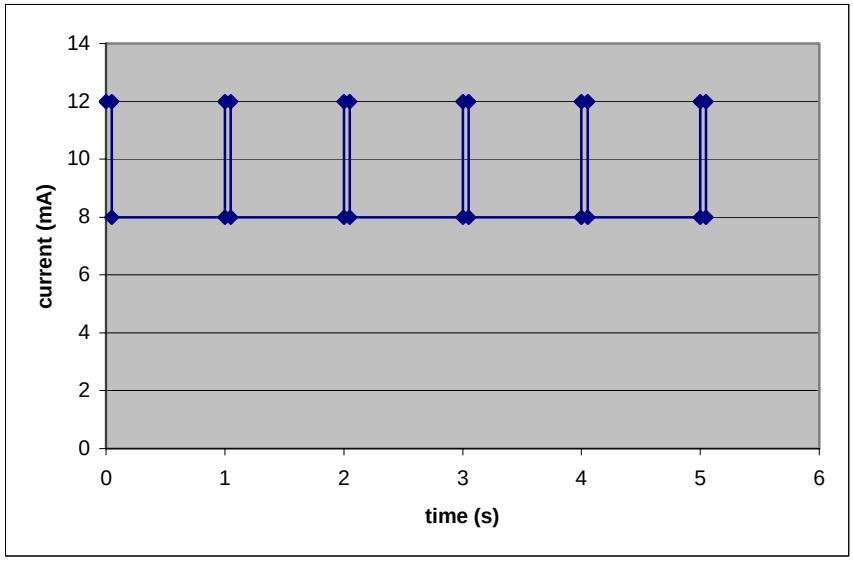
Results:



Test's conditions:

Mote type	Mica2dot
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Mote waits for packets; when it receives something blinks the red led. Radio is off when unused

Results:



Test's conditions:

Mote type	Mica2dot
Battery	Panasonic AM-3PI (alkaline , 1.5 V)
Power out (dB/mW)	0 (default)
Duty Cycle	100% (default)
Environment	Indoor
Frequency	900 Mhz
Application	Mote waits for packets; when it receives something blinks the red led. Radio is put in power down mode when idle.

Results: