868-MHz Antenna Matrix (WES0030-01-AMS868-01) Measurement Reports

1. Introduction

This document summarizes the measured results of the antennas applied in the Silicon Labs 868-MHz antenna matrix (WES0030-01-AMS868-01).

- The antenna is realized on a 1.55 mm thick FR4
- Target antenna impedance is 50 Ω

Picture of the WES0030-01-AMS868-01 868 MHz Antenna Matrix is shown in Figure 1. For the 868-MHz band 9 different pcb antenna solutions are proposed:

- Medium Size Printed ILA (or optionally IFA) around the PCB circumference (WES0031-01-APL868M-01),
- Ceramic (Chip) Antenna (WES0032-01-ACM868D-01),
- Small Size (Wire) Helical Antenna (WES0033-01-AWH868S-01),
- Medium Size (Wire) Helical Antenna (WES0034-01-AWH868M-01),
- Panic Button IFA (Printed) along the circumference (WES0035-01-APF868P-01),
- Panic Button ILA (Printed) along the circumference (WES0036-01-APL868P-01),
- Printed Meander Monopole (WES0037-01-APN868D-01),
- Small Size Printed ILA (or optional IFA) in dedicated small antenna area (WES0038-01-APL868S-01),
- Printed BIFA in a dedicated bigger antenna area (WES0039-01-APB868D-01),

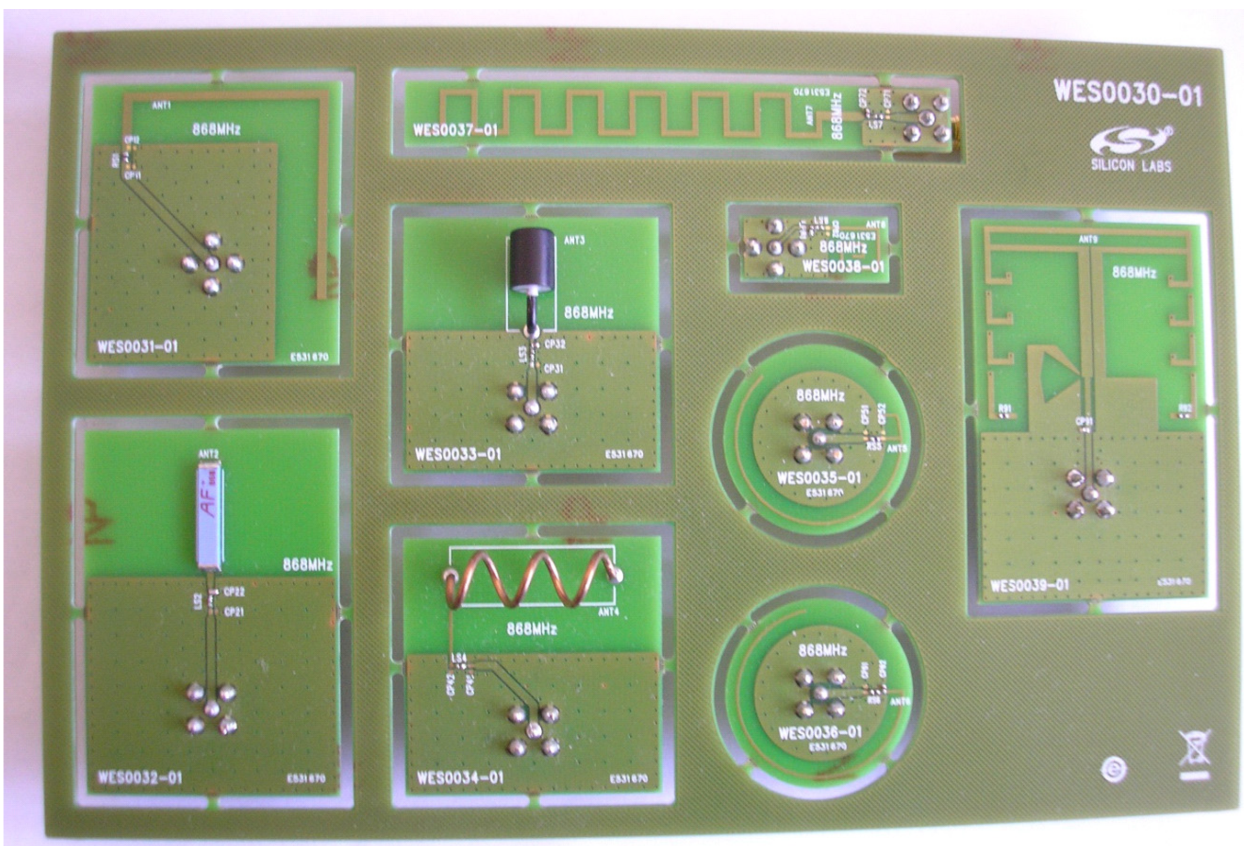


Figure 1. 868M 50 Ohm, Single Ended Antenna Matrix (WES0030-01-AMS868-01)

2. Detailed Antenna Measurement Results

2.1. Medium Size Printed ILA (WES0031-01-APL868M-01)

No external matching is required for this antenna. Although the footprint for a matching Pi section is placed to the layout only a series zero Ohm is used.

The picture of the Medium Size ILA antenna is shown in Figure 1.1.

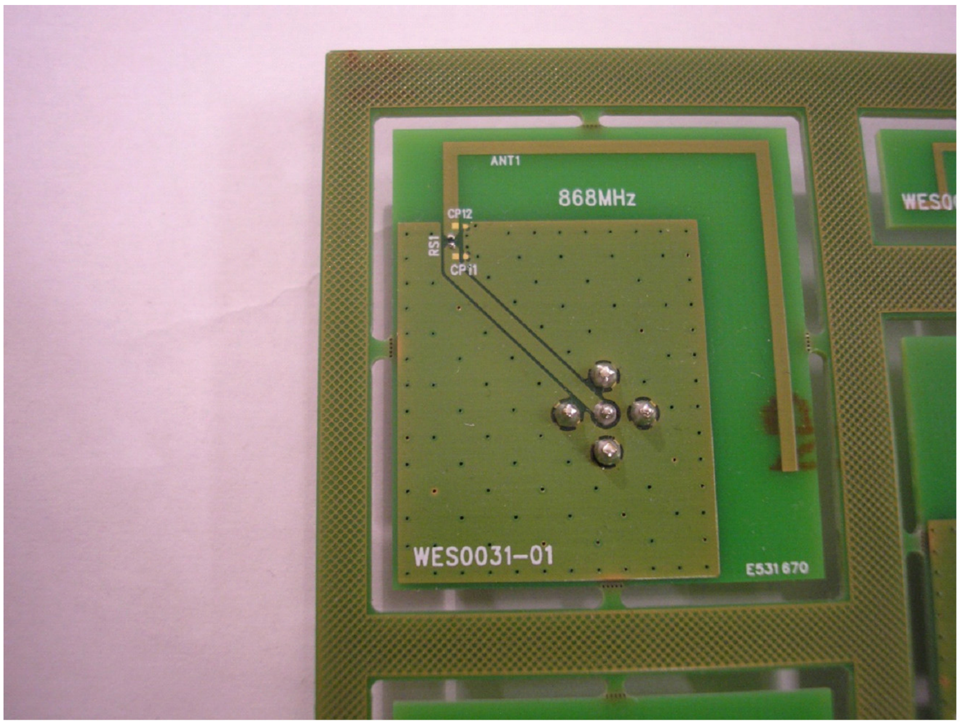


Figure 2. Medium Size Printed ILA Antenna

2.2. Impedance (WES0031-01-APL868M-01)

The measurement setup is shown in Figure 1.2. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 1.3. The measured impedance of the antenna with its external matching network is shown in Figure 1.4 and 1.5 (up to 3GHz) with motherboard hand effect.

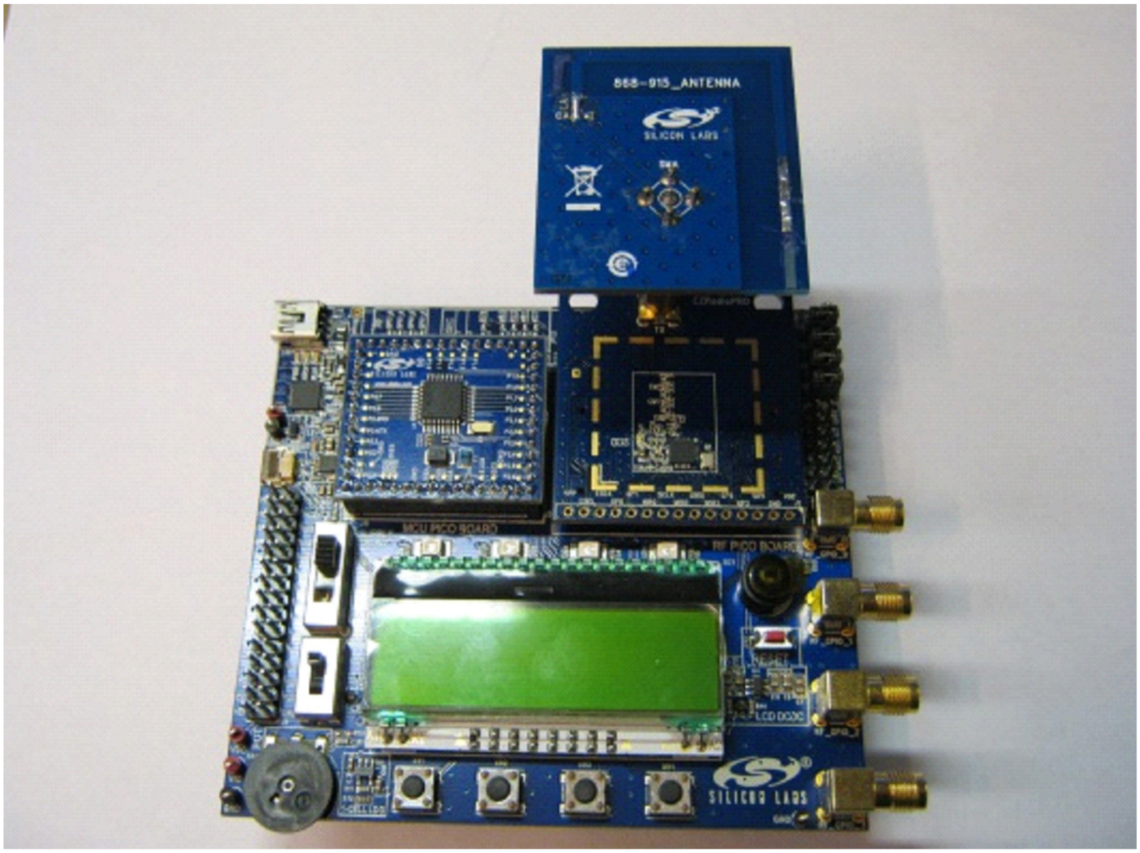


Figure 3. DUT in the final measurement setup

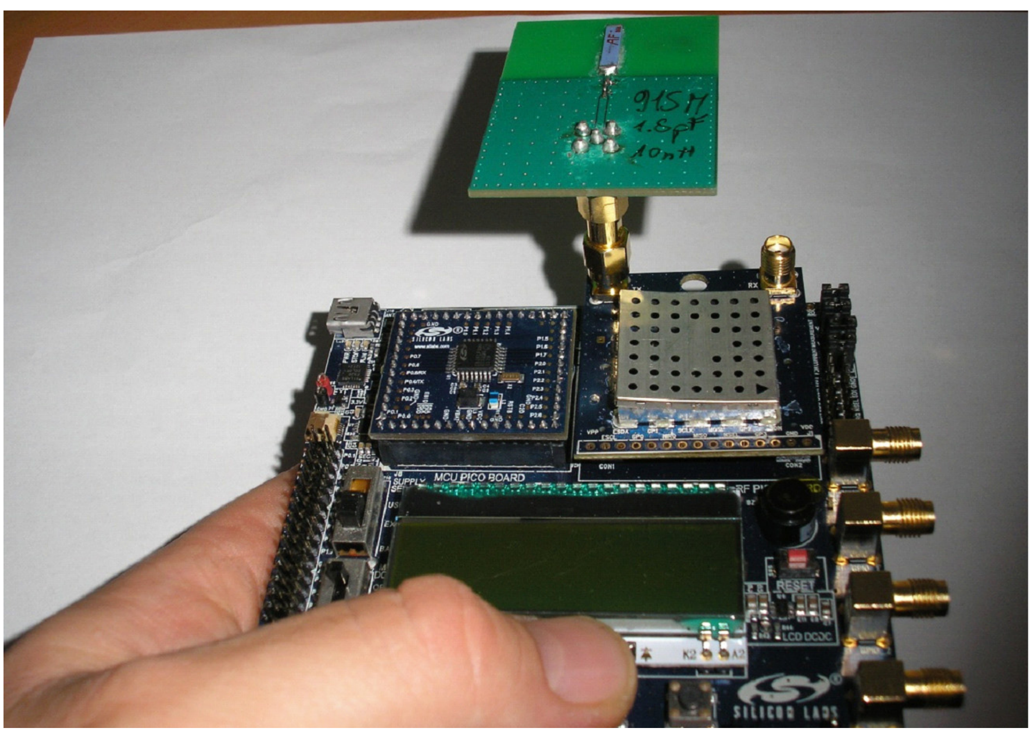


Figure 4. Typical hand effect on the main board during impedance and range measurement

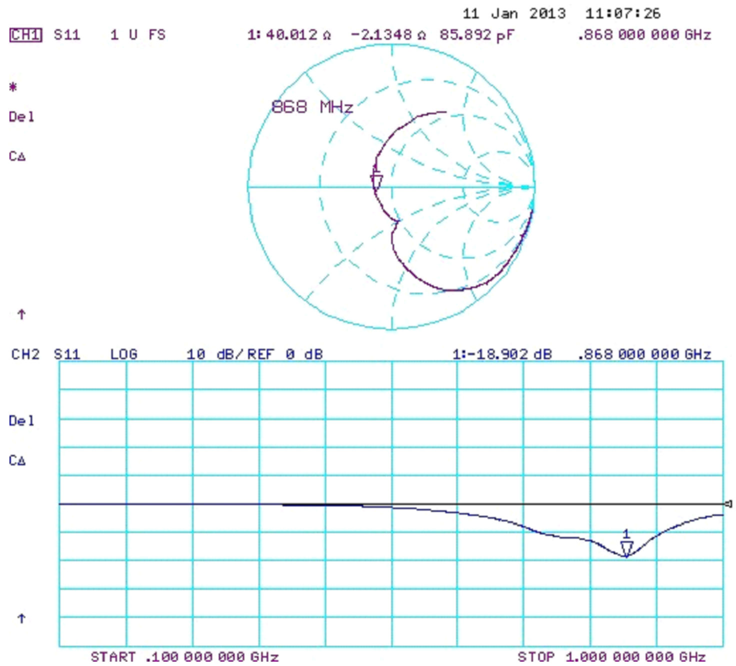


Figure 5. . Measured impedance up to 1GHz with hand-effect on the main board

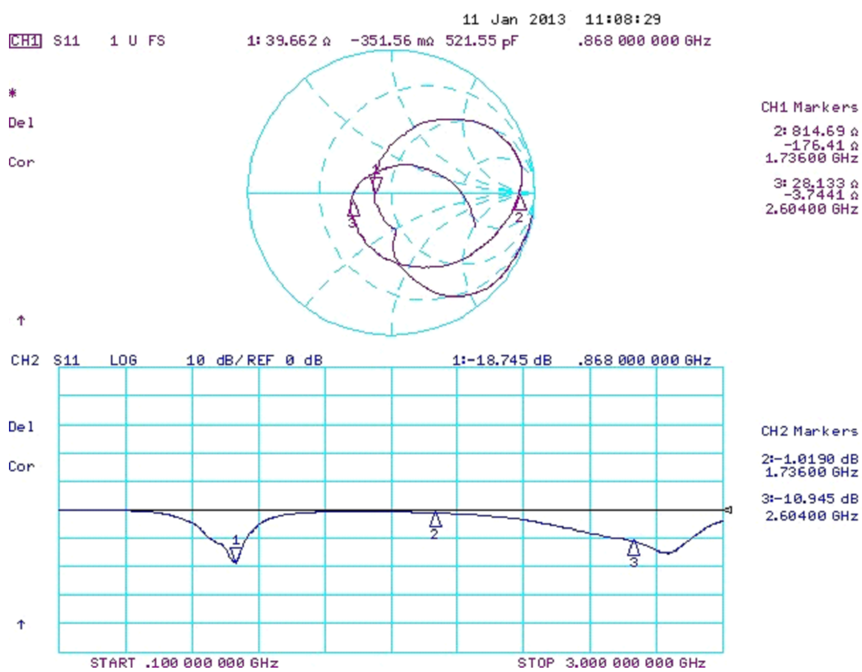


Figure 6. Measured impedance up to 3GHz with hand-effect on the main board

2.3. Antenna Gain (WES0031-01-APL868M-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 1.6). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection loss is negligible.

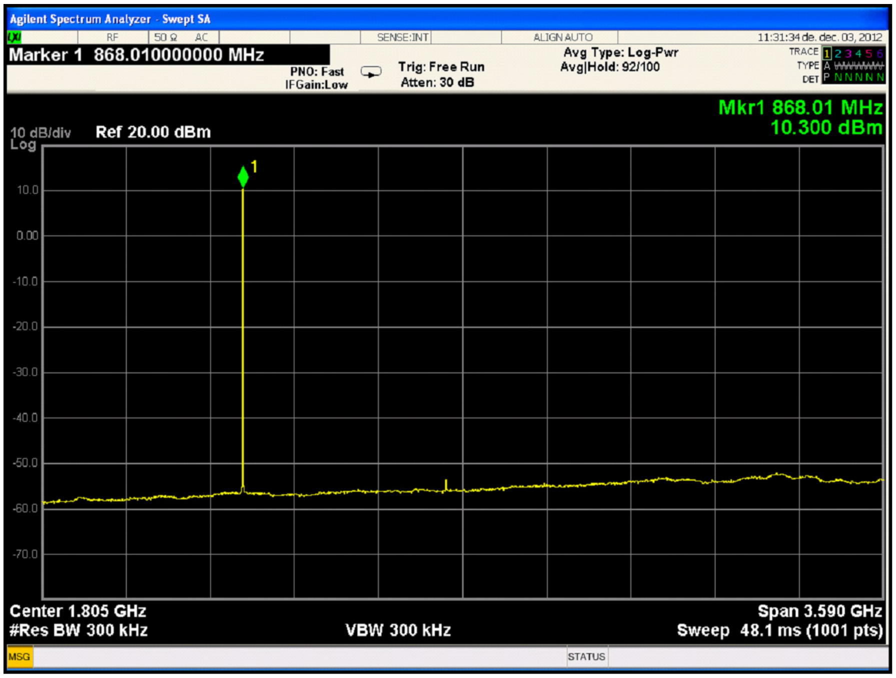


Figure 7. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 1.1). It is around 9.3dBm EIRP so the maximum gain number is ~-1dBi as it is shown in Figure 1.10.

2.4. Radiation Patterns (WES0031-01-APL868M-01)

Radiation patterns of the medium size printed ILA antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture from the DUT with coordinate system under the radiated measurements is shown in Figure 1.7.

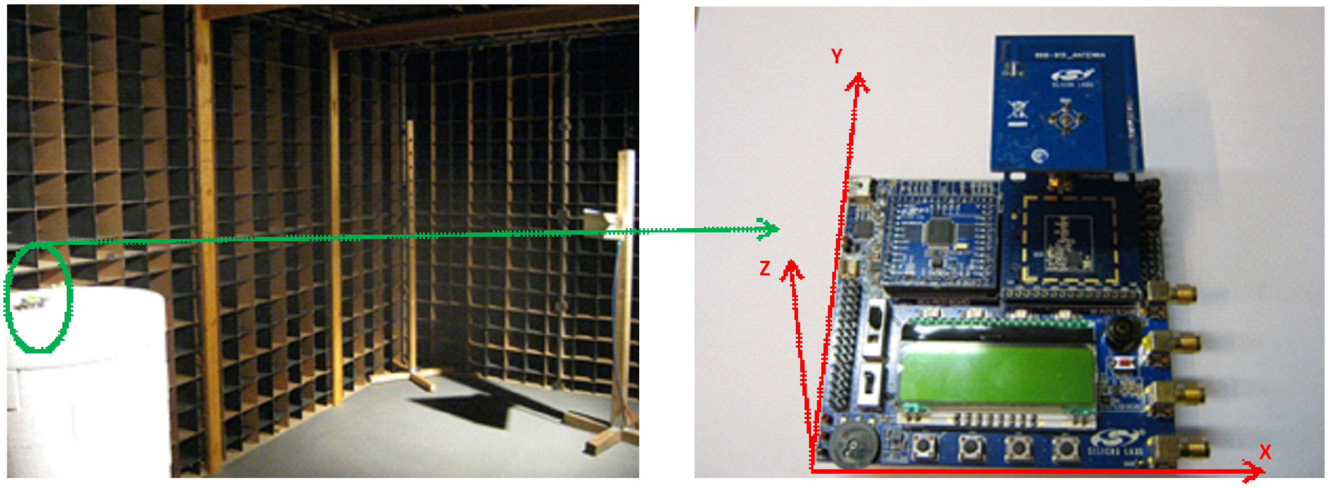


Figure 8. DUT in the Antenna Chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Fig. 1.8-1.13).

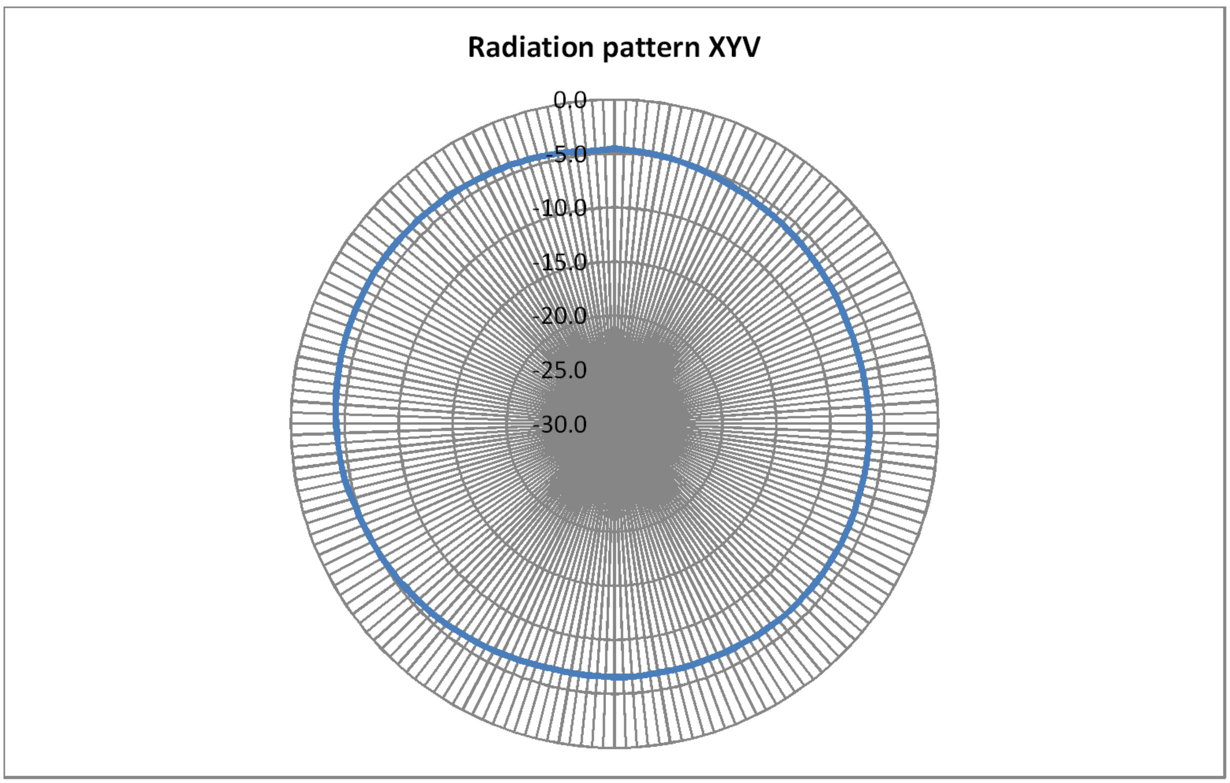


Figure 9. Radiation pattern in the XY cut with Vertical receiver antenna polarization

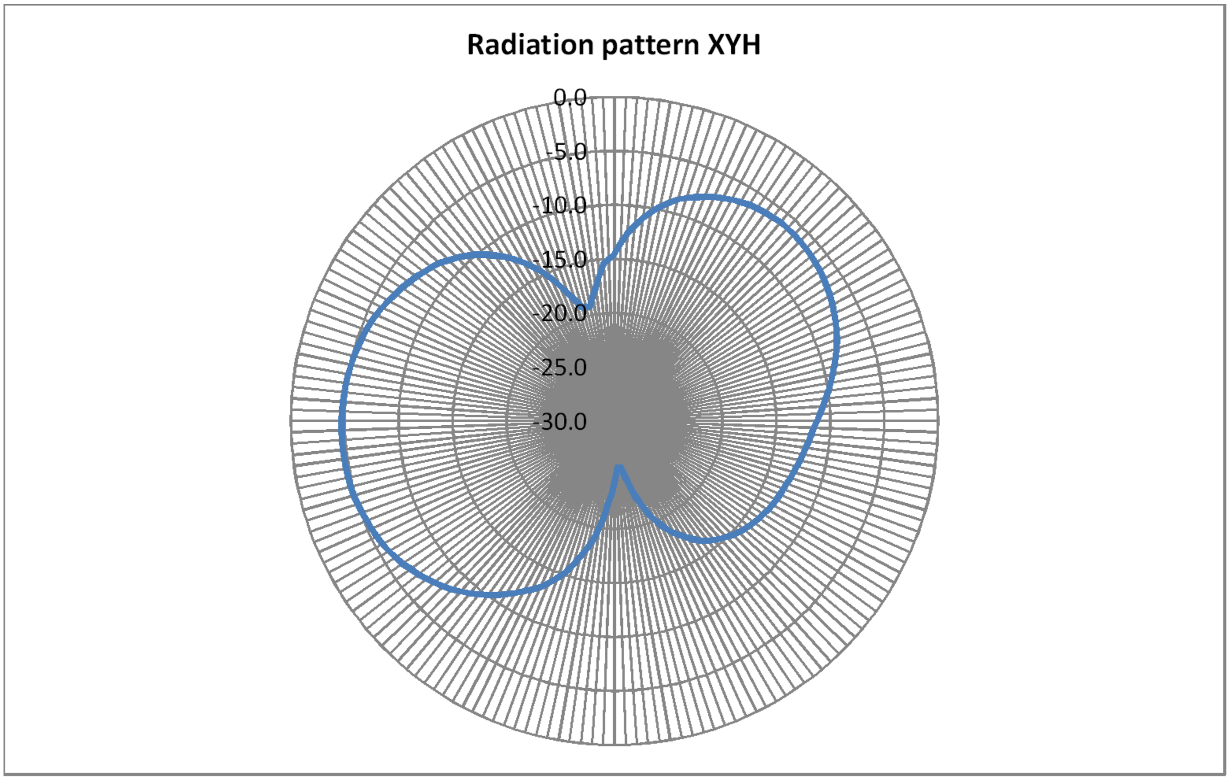


Figure 10. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

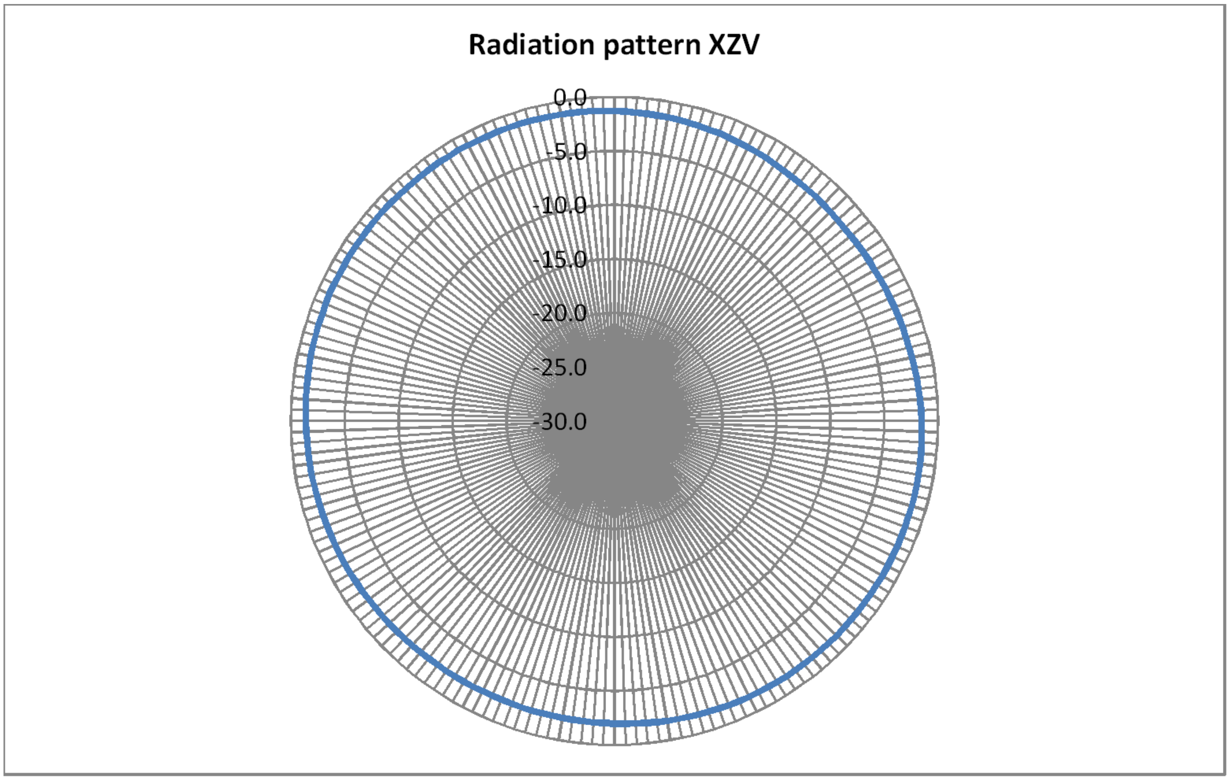


Figure 11. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

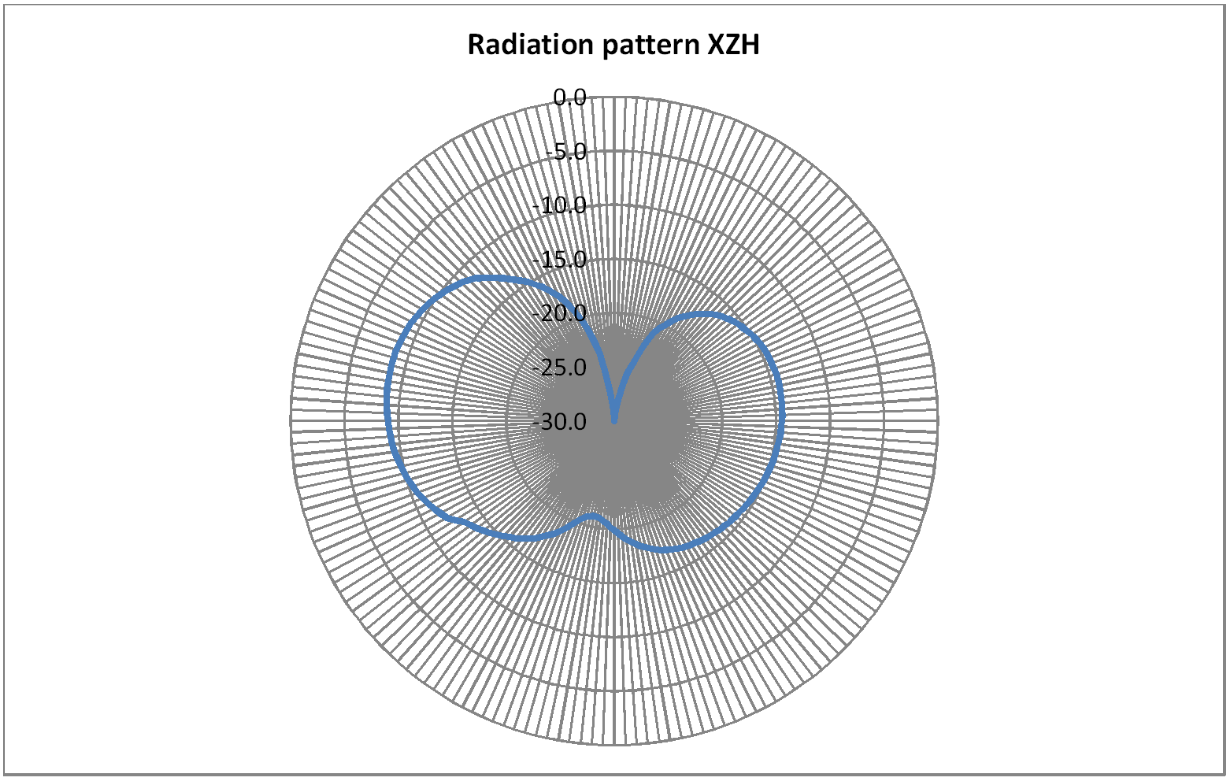


Figure 12. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

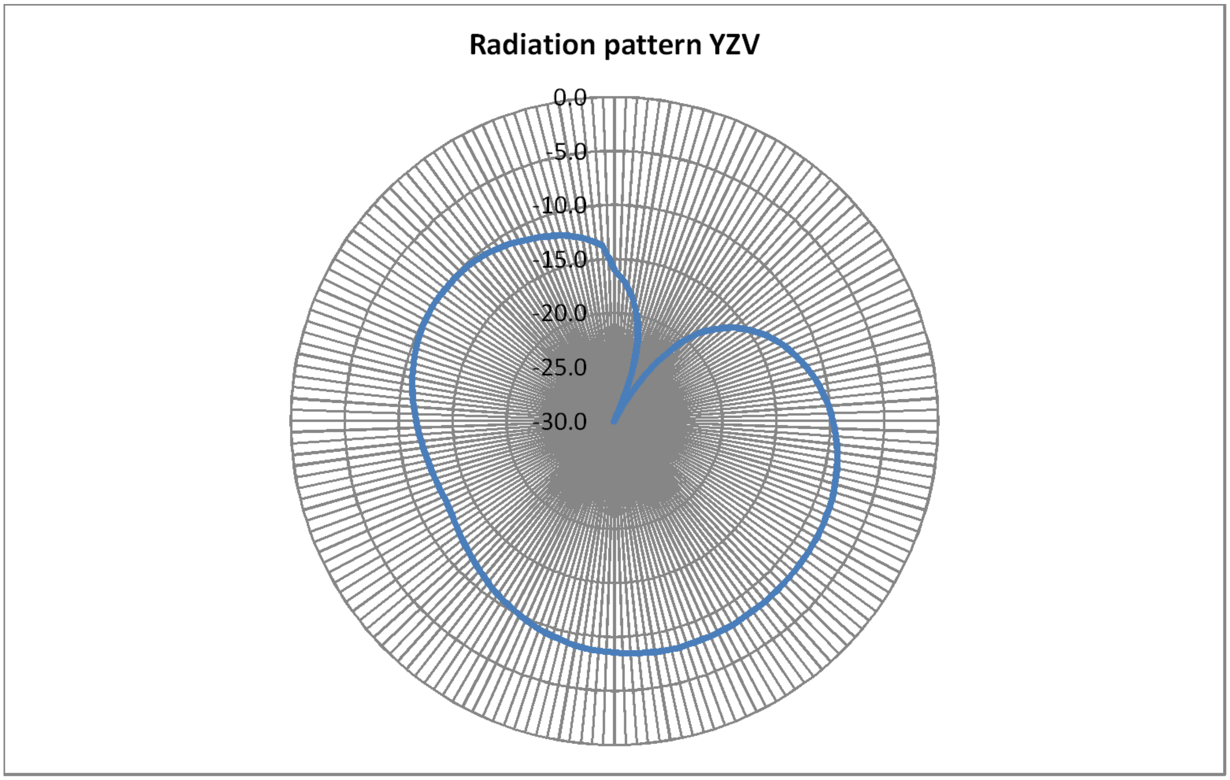


Figure 13. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

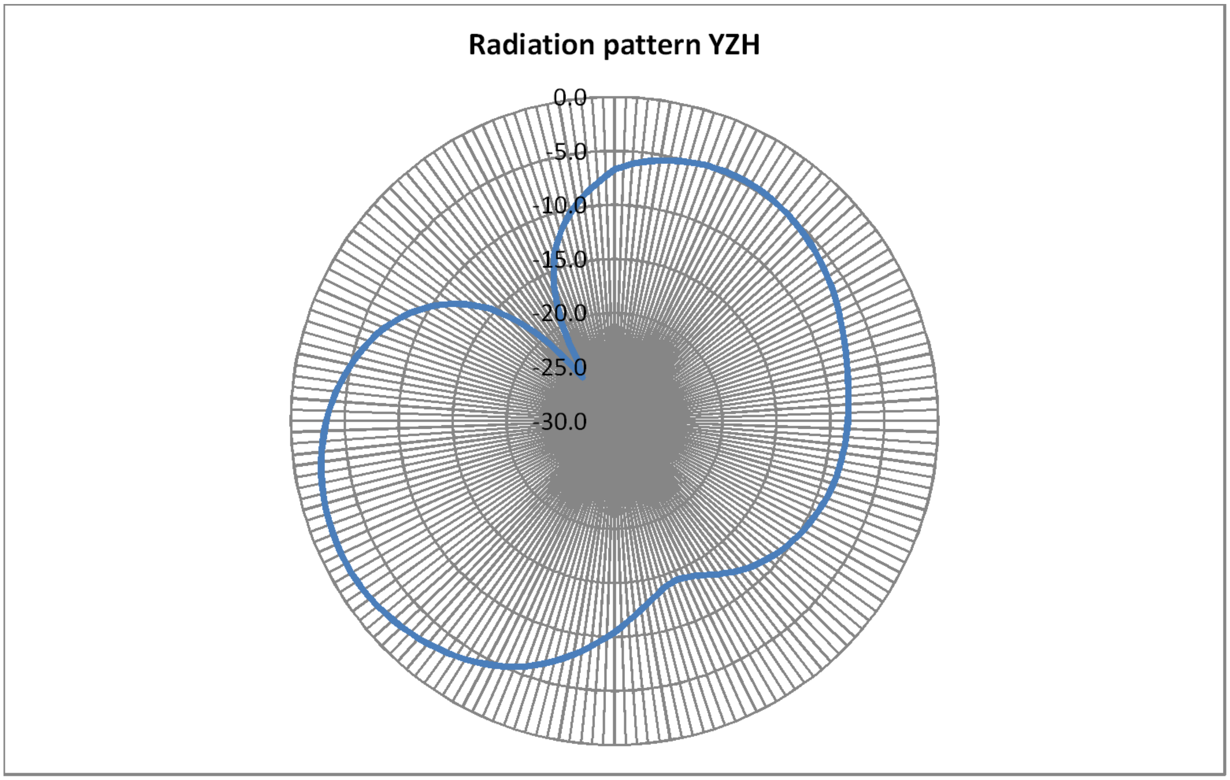


Figure 14. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

2.5. Radiated Harmonics (WES0031-01-APL868M-01)

The radiated harmonics of the medium size printed ILA antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table (Table 1.1.) together with the corresponding standard limits.

The medium size ILA antenna driven by the Si4460 10dBm class E match comply with the ETSI harmonic regulations with margin. Worst is the 6th harmonic which has 2.5dB margin in the YZV cut.

Here it has to be noted that the potential source of the 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 1. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	6.56	10.5
XY	V	2nd	1736	-27.86	-50.39	21.1
XY	V	3rd	2604	-27.86	-49.06	23.0
XY	V	4th	3472	-27.86	-35.49	14.3
XY	V	5th	4340	-27.86	-35.84	13.0
XY	V	6th	5208	-27.86	-37.63	5.8
XY	V	7th	6076	-27.86	-40.73	10.8
XY	V	8th	6944	-27.86	-43.71	16.6
XY	V	9th	7812	-27.86	-39.97	13.4
XY	V	10th	8680	-27.86	-36.05	10.4
XY	H	Fund.	868	16.12	5.62	9.6
XY	H	2nd	1736	-27.86	-48.94	22.5
XY	H	3rd	2604	-27.86	-50.86	21.2
XY	H	4th	3472	-27.86	-42.12	7.6
XY	H	5th	4340	-27.86	-40.91	8.0
XY	H	6th	5208	-27.86	-33.65	9.8
XY	H	7th	6076	-27.86	-38.70	12.9
XY	H	8th	6944	-27.86	-44.44	15.8
XY	H	9th	7812	-27.86	-41.26	12.1
XY	H	10th	8680	-27.86	-38.26	8.2
XZ	V	Fund.	868	16.12	9.25	6.9
XZ	V	2nd	1736	-27.86	-45.31	17.4
XZ	V	3rd	2604	-27.86	-50.87	23.0
XZ	V	4th	3472	-27.86	-34.47	6.6

Table 1. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

XZ	V	5th	4340	-27.86	-34.16	6.3
XZ	V	6th	5208	-27.86	-35.62	7.8
XZ	V	7th	6076	-27.86	-43.66	15.8
XZ	V	8th	6944	-27.86	-43.62	15.8
XZ	V	9th	7812	-27.86	-39.48	11.6
XZ	V	10th	8680	-27.86	-38.95	11.1
XZ	H	Fund.	868	16.12	1.56	14.6
XZ	H	2nd	1736	-27.86	-48.92	21.1
XZ	H	3rd	2604	-27.86	-52.43	24.6
XZ	H	4th	3472	-27.86	-35.33	7.5
XZ	H	5th	4340	-27.86	-33.30	5.4
XZ	H	6th	5208	-27.86	-31.53	3.7
XZ	H	7th	6076	-27.86	-39.31	11.4
XZ	H	8th	6944	-27.86	-44.21	16.4
XZ	H	9th	7812	-27.86	-41.65	13.8
XZ	H	10th	8680	-27.86	-34.63	6.8
YZ	V	Fund.	868	16.12	2.15	14.0
YZ	V	2nd	1736	-27.86	-49.79	21.9
YZ	V	3rd	2604	-27.86	-48.79	20.9
YZ	V	4th	3472	-27.86	-38.65	10.8
YZ	V	5th	4340	-27.86	-40.37	12.5
YZ	V	6th	5208	-27.86	-30.38	2.5
YZ	V	7th	6076	-27.86	-44.53	16.7
YZ	V	8th	6944	-27.86	-43.65	15.8
YZ	V	9th	7812	-27.86	-41.41	13.5
YZ	V	10th	8680	-27.86	-37.00	9.1

Table 1. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

YZ	H	Fund.	868	16.12	8.47	7.6
YZ	H	2nd	1736	-27.86	-42.67	14.8
YZ	H	3rd	2604	-27.86	-49.76	21.9
YZ	H	4th	3472	-27.86	-41.58	13.7
YZ	H	5th	4340	-27.86	-36.85	9.0
YZ	H	6th	5208	-27.86	-33.35	5.5
YZ	H	7th	6076	-27.86	-42.59	14.7
YZ	H	8th	6944	-27.86	-41.65	13.8
YZ	H	9th	7812	-27.86	-41.04	13.2
YZ	H	10th	8680	-27.86	-39.76	11.9

2.6. Range Test (WES0031-01-APL868M-01)

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot (indoor). Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1108m.

The outdoor range test result using two printed ILAs to the front direction (XY plane is horizontal and the Y axes are facing to each other as it is typical in normal remote applications) is 1077m as shown in Figure 1.14.

Also it can be seen from the ILA pattern plots that the antenna gain is at maximum (~-1dBi) at other directions (e.g. XZ cut, vertical polarization, Figure 1.10). With facing the TX-RX pair in this orientation (e.g. in non-remote applications) the range could be even higher by 30…40%%.

Indoor range test is not done, due to the lack of large enough building. But, from the TX power and sensitivity data an indoor range estimation can be given assuming a propagation factor of 4.5, which is a typical value in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -5dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 89m as it is shown in Fig. 1.15.

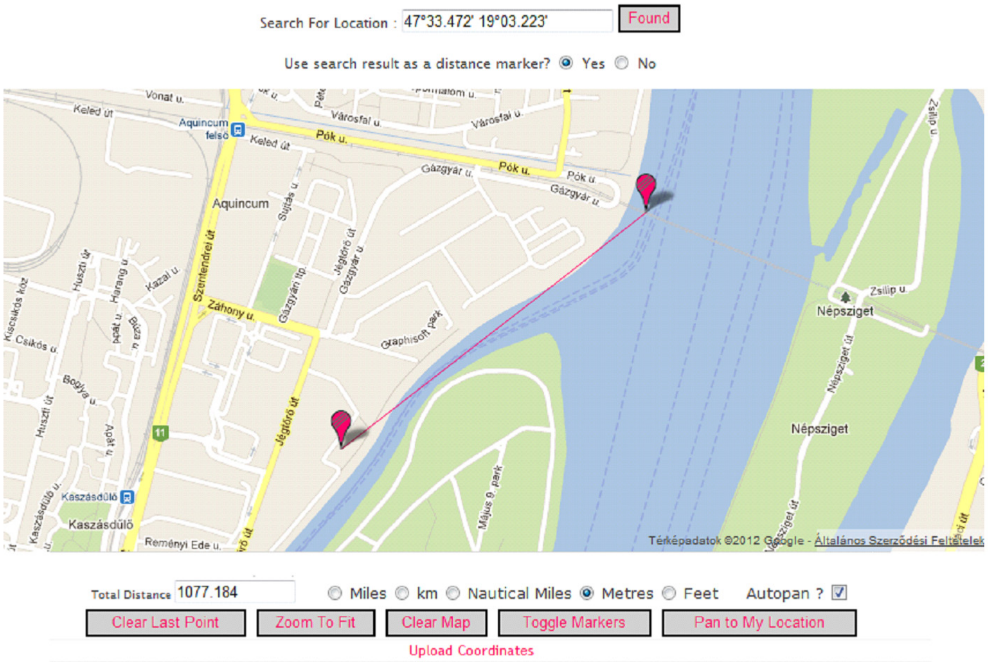


Figure 15. Outdoor range test result with two identical medium size printed ILA antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

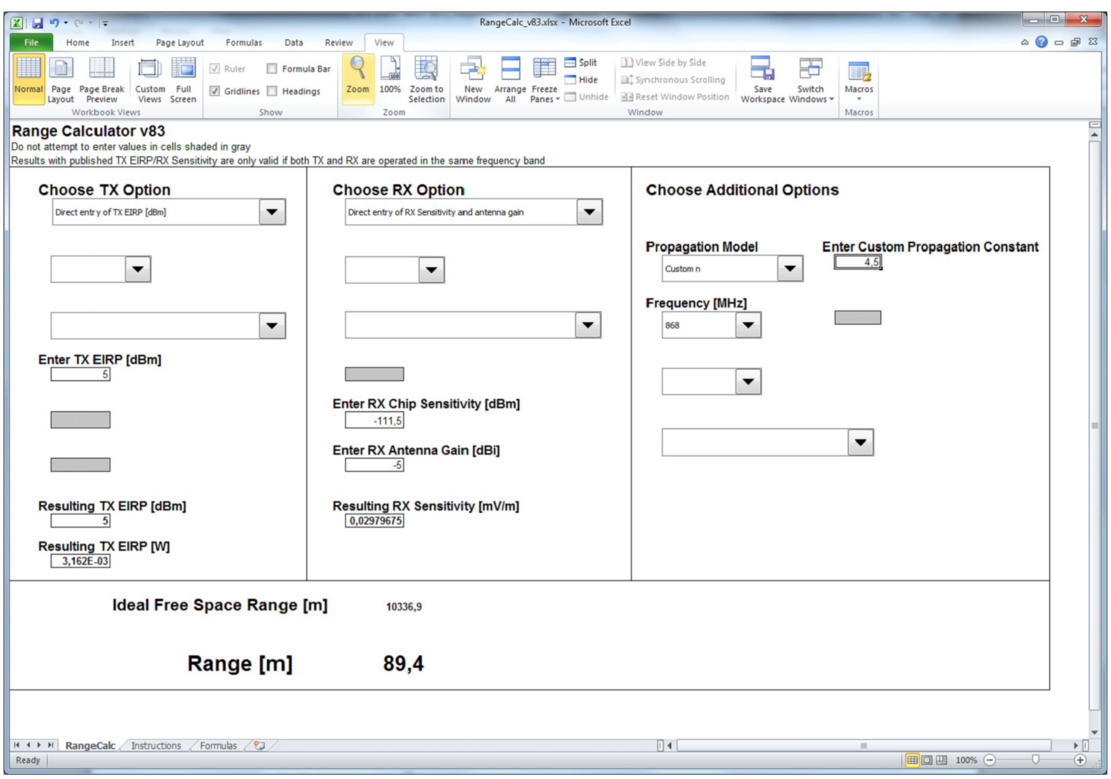


Figure 16. Indoor range estimation with two identical medium size printed ILA antennas and with

the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

3. Ceramic (Chip) Antenna (WES0032-01-ACM868D-01)

The selected chip antenna is: ANT-868-CHP-T, Antenna Factor

https://www.linxtechnologies.com/resources/data-guides/ant-xxx-chp-x.pdf

External matching network (shown in Figure 2.1) is required at the antenna input

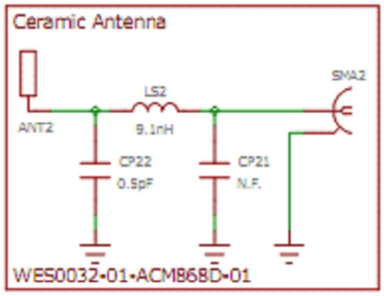


Figure 17. External matching network at 868MHz for the ANT-868-CHP-T ceramic antenna

The picture of the antenna is shown in Figure 2.2.

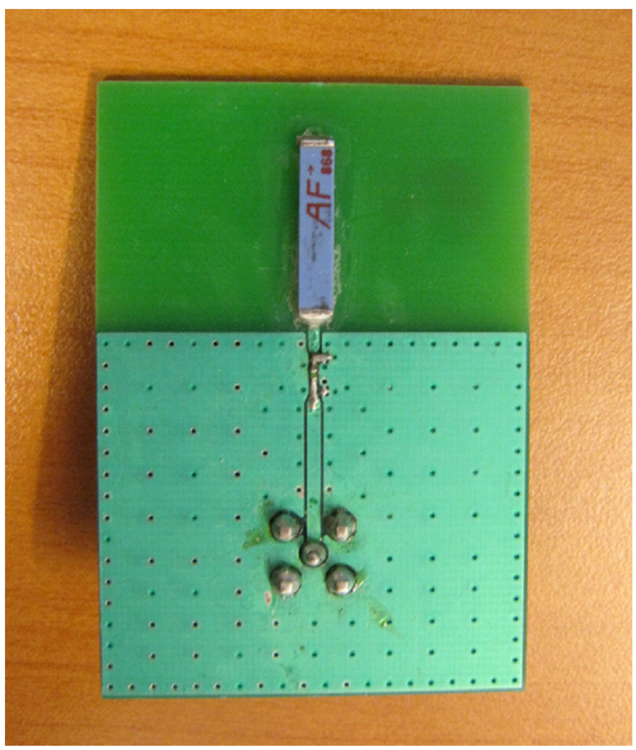


Figure 18. Ceramic (Chip) Antenna

3.1. Antenna Impedance (WES0032-01-ACM868D-01)

The measurement setup is shown in Figure 2.3. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 2.4. The measured impedance of the antenna with its external matching network is shown in Figure 2.5 and 2.6 (up to 3GHz) with motherboard hand effect.

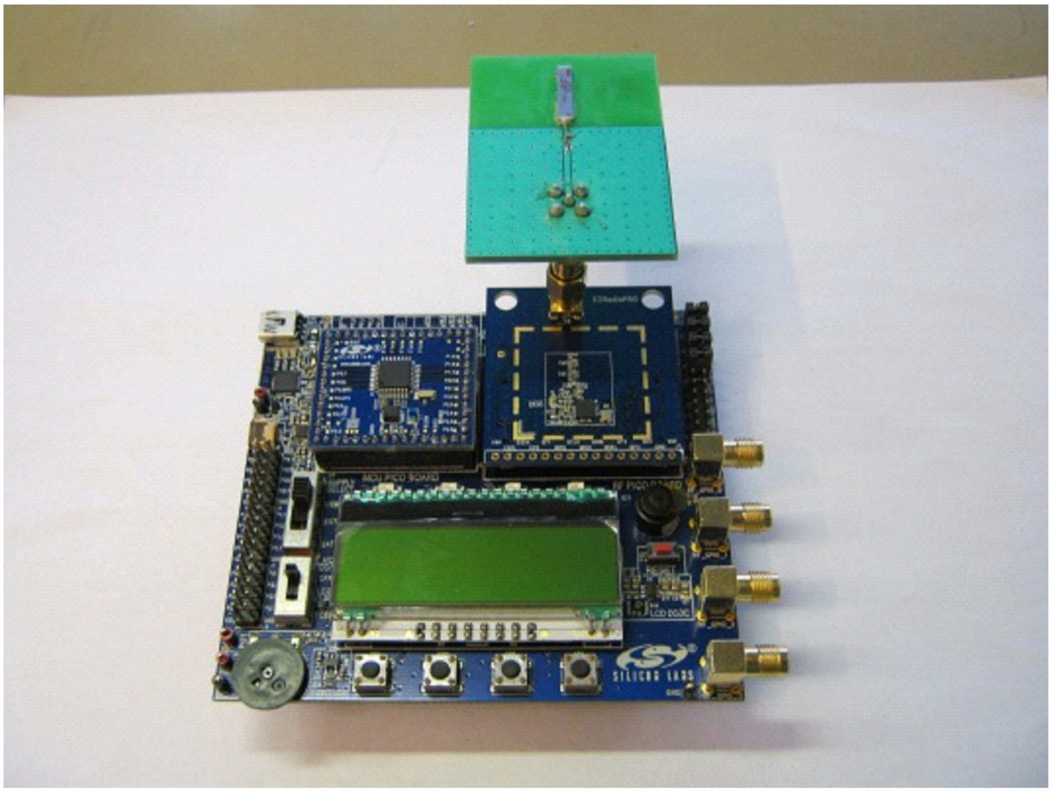


Figure 19. DUT in the Measurement Setup

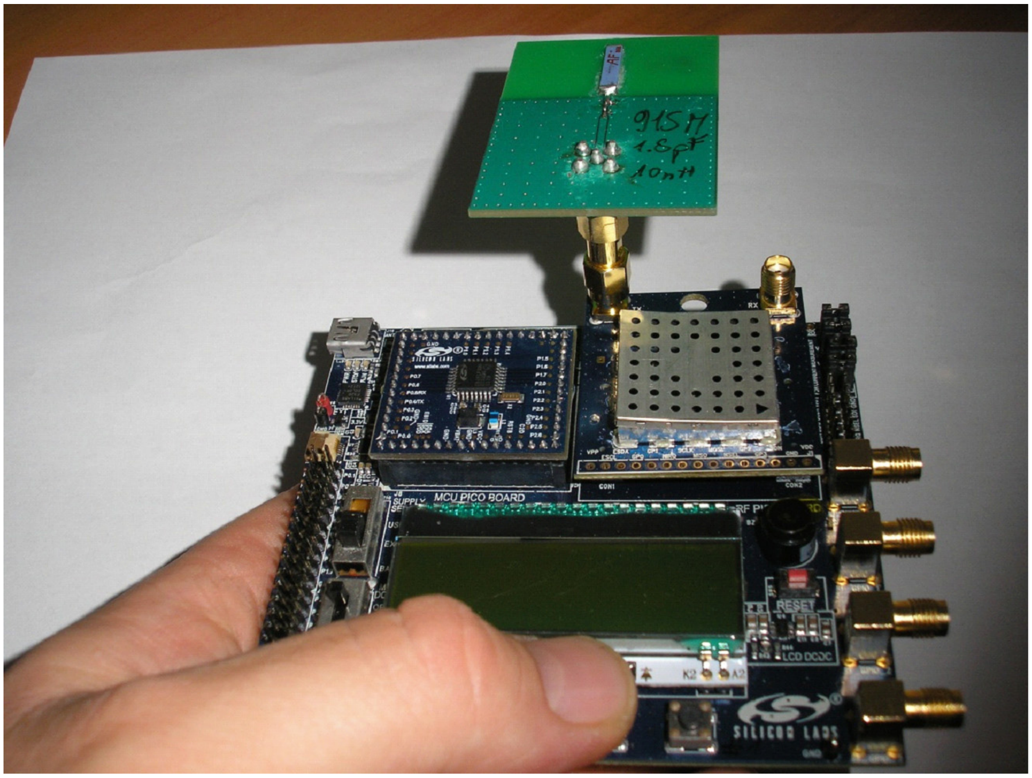


Figure 20. Typical hand effect on the main board during impedance and range measurement

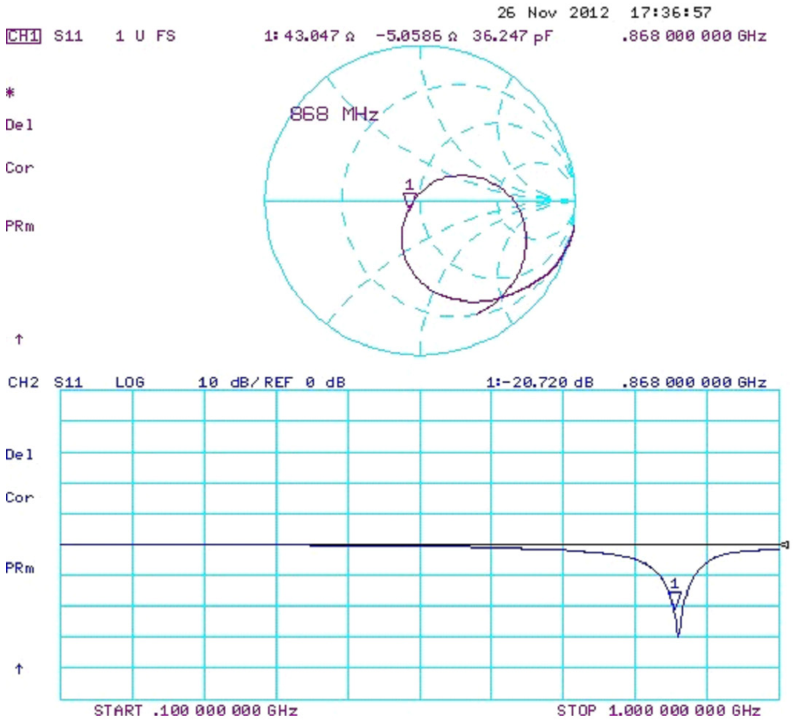


Figure 21. Measured impedance up to 1GHz with hand-effect on the main board

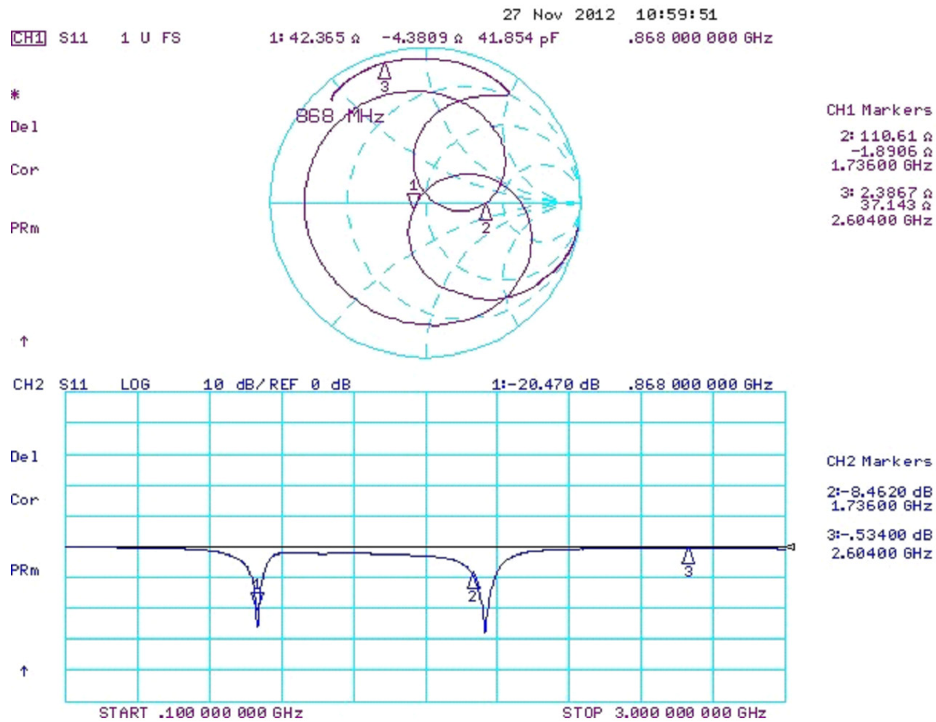


Figure 22. Measured impedance up to 3GHz with hand-effect on the main board

3.2. Antenna Gain (WES0032-01-ACM868D-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 2.7). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection loss is negligible.

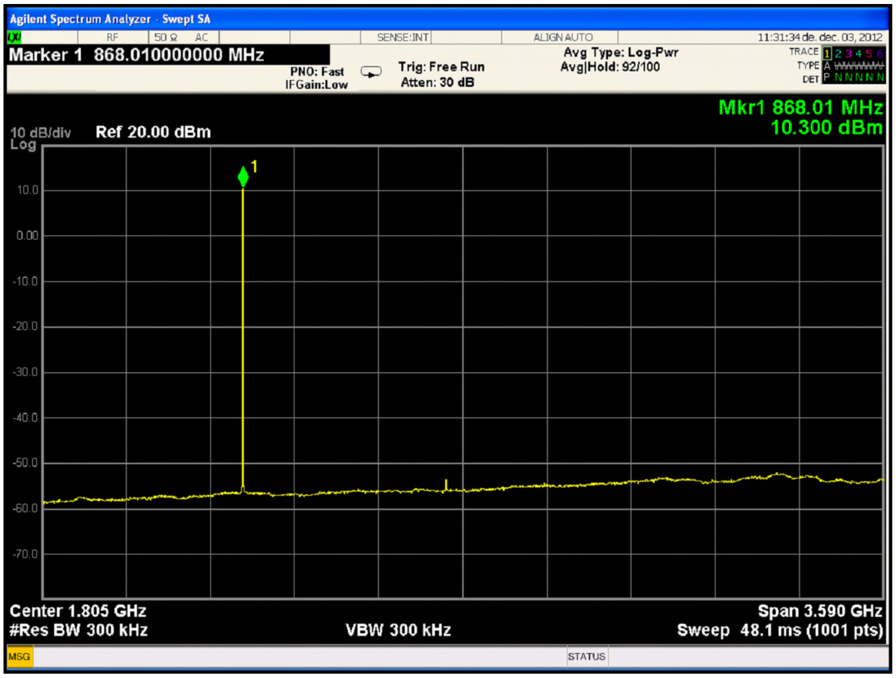


Figure 23. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 2.1). It is around 8.0dBm EIRP so the maximum gain number is ~-2.3dBi as it is shown in Figure 2.11.

3.3. Radiation Patterns (WES0032-01-ACM868D-01)

Radiation patterns of the ceramic antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture of the DUT with coordinate system under the radiated measurements is shown in Figure 2.8.

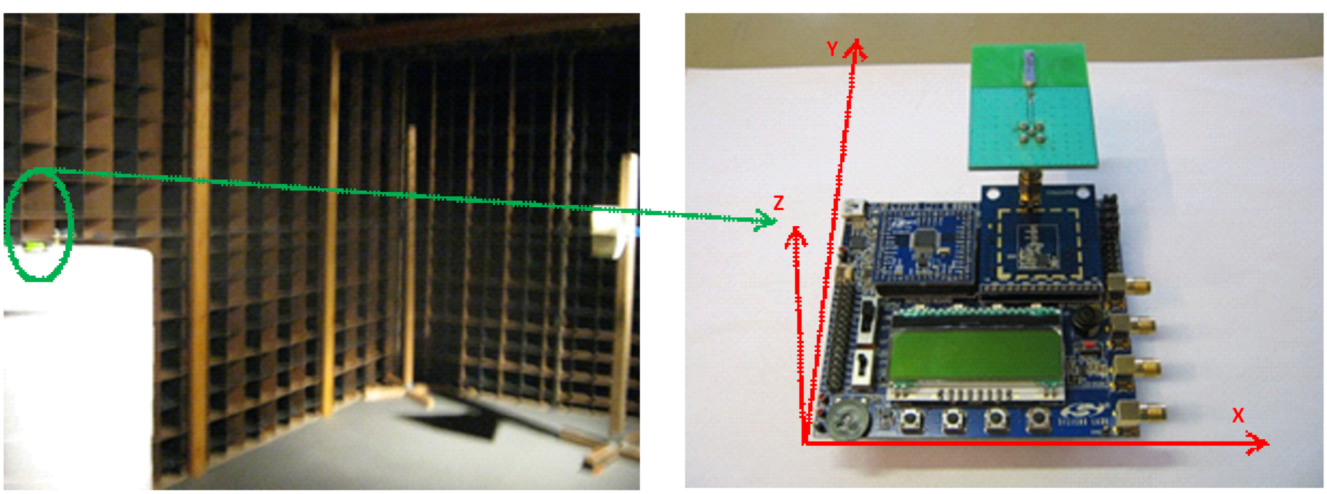


Figure 24. DUT in the Antenna Chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Fig. 2.9-2.14).

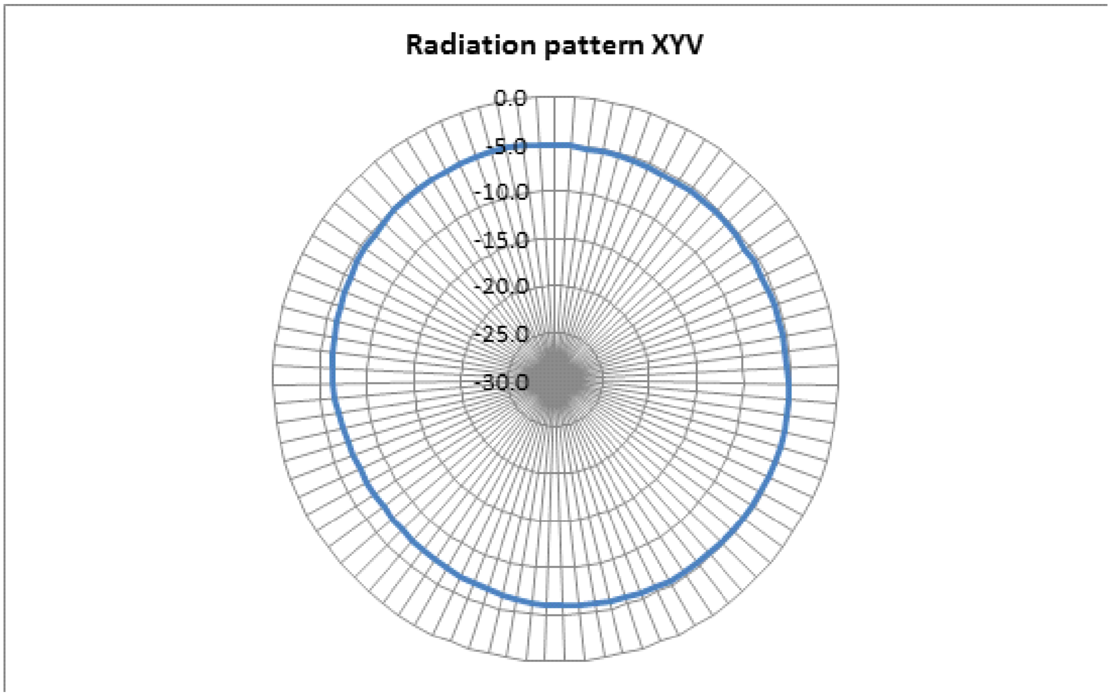


Figure 25. Radiation pattern in the XY cut with Vertical receiver antenna polarization

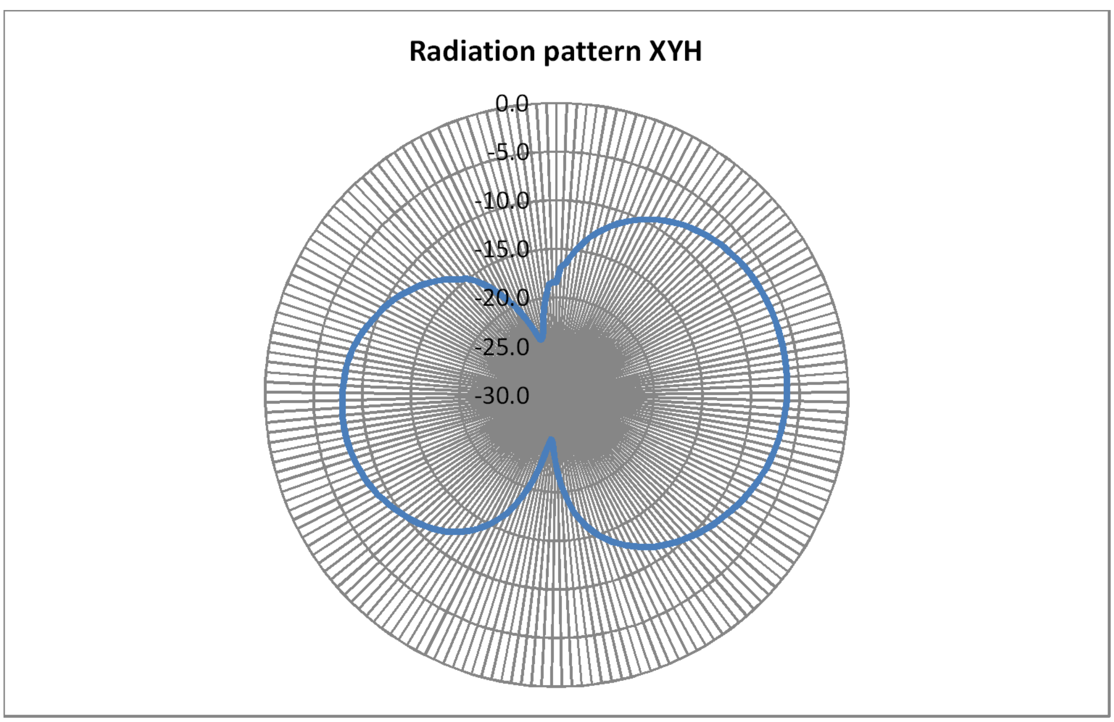


Figure 26. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

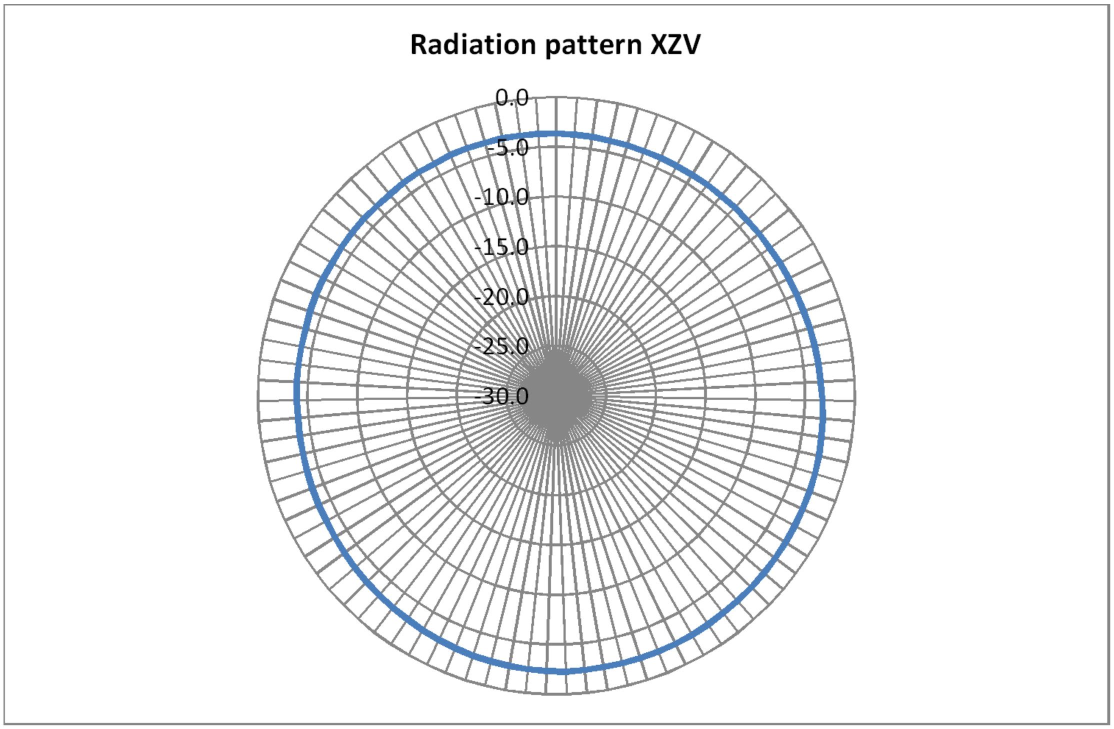


Figure 27. . Radiation pattern in the XZ cut with Vertical receiver antenna polarization

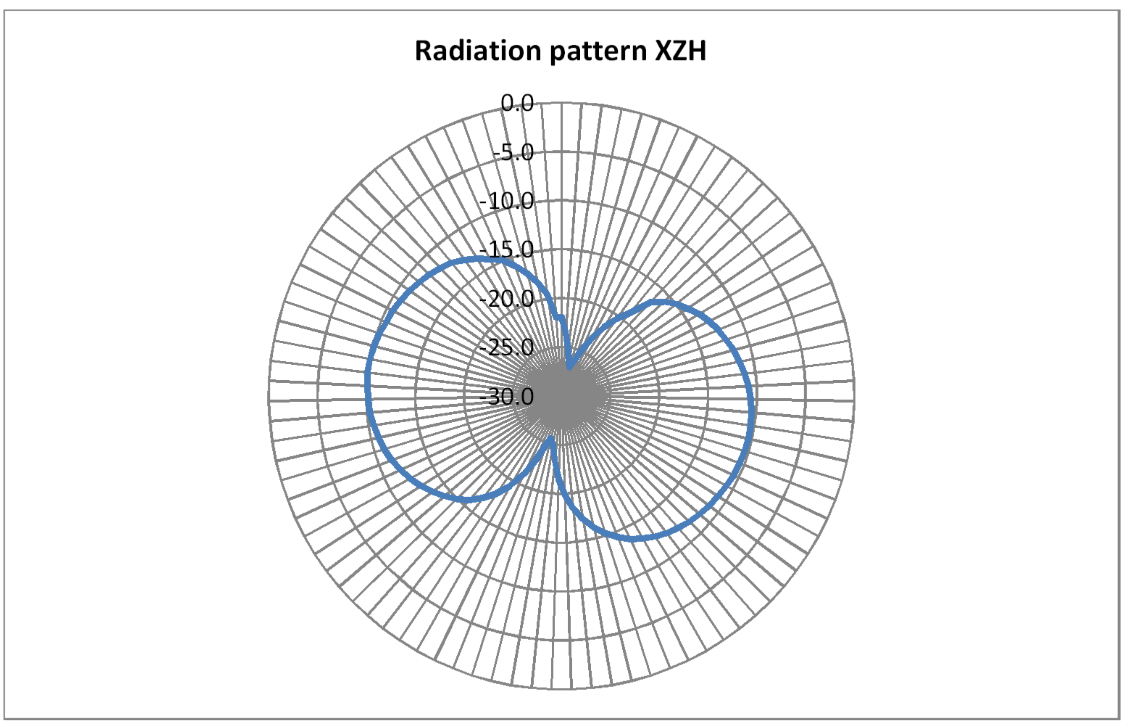


Figure 28. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

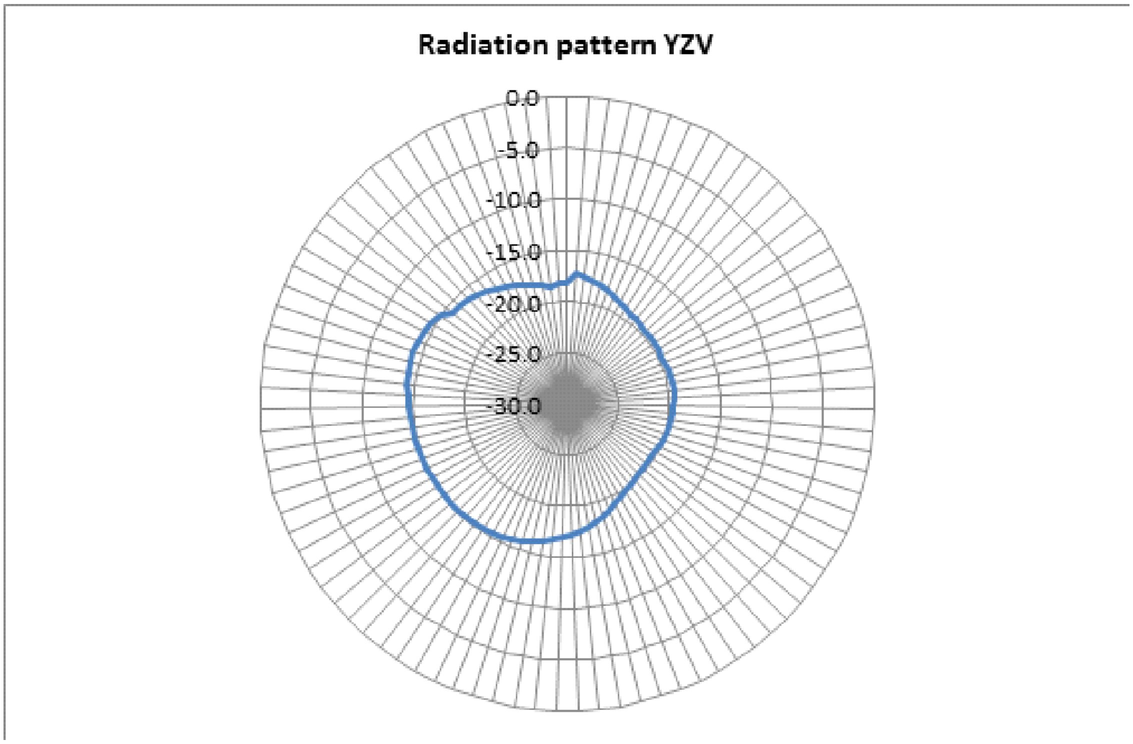


Figure 29. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

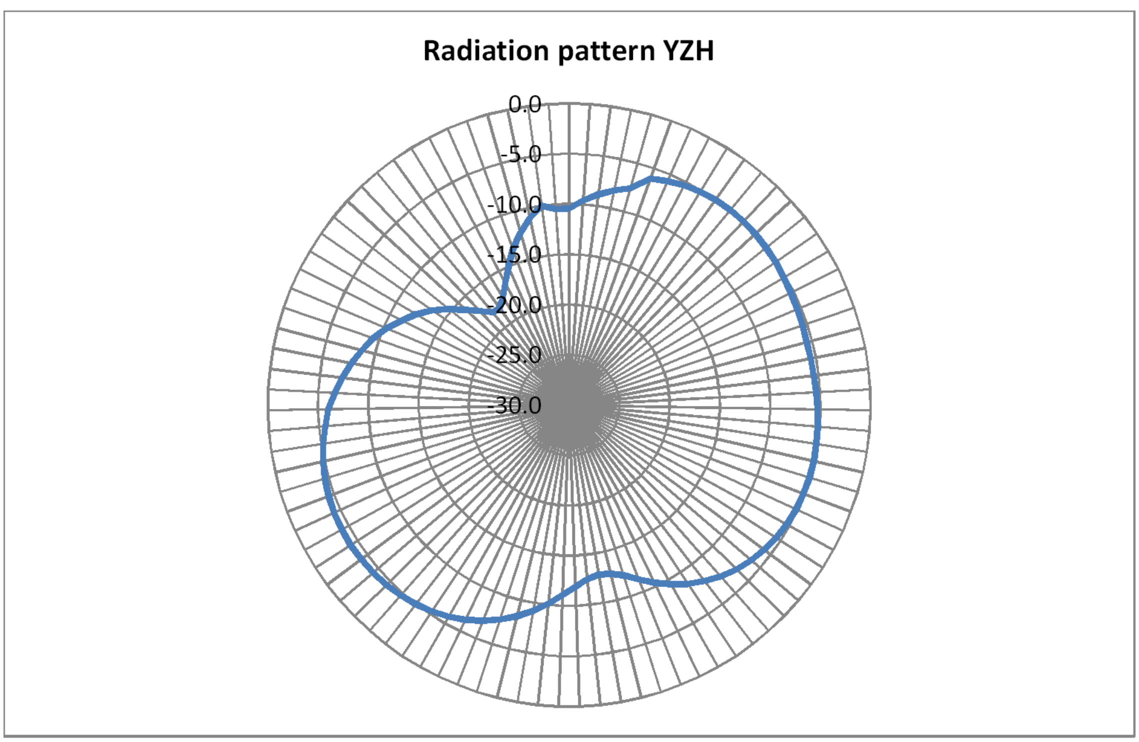


Figure 30. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

3.4. Radiated Harmonics (WES0032-01-ACM868D-01)

The radiated harmonics of the ceramic antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table (Table 2.1) together with the corresponding standard limits.

The Antenna is ETSI compliant, but the 6th harmonic is very close to the limit in some cuts. Here it has to be noted that the potential source of the 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 2. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	5,44	10,7
XY	V	2nd	1736	-27.86	-47,28	19,4
XY	V	3rd	2604	-27.86	-46,35	18,5
XY	V	4th	3472	-27.86	-45,24	17,4
XY	V	5th	4340	-27.86	-35,31	7,5
XY	V	6th	5208	-27.86	-33,38	5,5
XY	V	7th	6076	-27.86	-43,57	15,7
XY	V	8th	6944	-27.86	-43,93	16,1
XY	V	9th	7812	-27.86	-41,46	13,6
XY	V	10th	8680	-27.86	-36,99	9,1
XY	H	Fund.	868	16.12	4,12	12,0
XY	H	2nd	1736	-27.86	-42,30	14,4
XY	H	3rd	2604	-27.86	-46,98	19,1
XY	H	4th	3472	-27.86	-46,70	18,8
XY	H	5th	4340	-27.86	-38,86	11,0
XY	H	6th	5208	-27.86	-28,67	0,8

Table 2. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

XY	H	7th	6076	-27.86	-41,24	13,4
XY	H	8th	6944	-27.86	-44,63	16,8
XY	H	9th	7812	-27.86	-42,05	14,2
XY	H	10th	8680	-27.86	-37,77	9,9
XZ	V	Fund.	868	16.12	8,01	8,1
XZ	V	2nd	1736	-27.86	-37,81	10,0
XZ	V	3rd	2604	-27.86	-53,82	26,0
XZ	V	4th	3472	-27.86	-44,85	17,0
XZ	V	5th	4340	-27.86	-34,61	6,7
XZ	V	6th	5208	-27.86	-31,69	3,8
XZ	V	7th	6076	-27.86	-45,11	17,3
XZ	V	8th	6944	-27.86	-44,30	16,4
XZ	V	9th	7812	-27.86	-42,08	14,2
XZ	V	10th	8680	-27.86	-39,38	11,5
XZ	H	Fund.	868	16.12	0,33	15,8
XZ	H	2nd	1736	-27.86	-47,71	19,9
XZ	H	3rd	2604	-27.86	-51,04	23,2
XZ	H	4th	3472	-27.86	-46,46	18,6
XZ	H	5th	4340	-27.86	-35,97	8,1
XZ	H	6th	5208	-27.86	-33,22	5,4
XZ	H	7th	6076	-27.86	-42,02	14,2
XZ	H	8th	6944	-27.86	-43,91	16,0
XZ	H	9th	7812	-27.86	-40,71	12,8
XZ	H	10th	8680	-27.86	-34,87	7,0
YZ	V	Fund.	868	16.12	-3,76	19,9
YZ	V	2nd	1736	-27.86	-50,55	22,7

Table 2. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

YZ	V	3rd	2604	-27.86	-48,82	21,0
YZ	V	4th	3472	-27.86	-46,00	18,1
YZ	V	5th	4340	-27.86	-35,47	7,6
YZ	V	6th	5208	-27.86	-28,08	0,2
YZ	V	7th	6076	-27.86	-41,63	13,8
YZ	V	8th	6944	-27.86	-43,78	15,9
YZ	V	9th	7812	-27.86	-40,01	12,1
YZ	V	10th	8680	-27.86	-37,70	9,8
YZ	H	Fund.	868	16.12	6,11	10,0
YZ	H	2nd	1736	-27.86	-36,19	8,3
YZ	H	3rd	2604	-27.86	-43,72	15,9
YZ	H	4th	3472	-27.86	-41,55	13,7
YZ	H	5th	4340	-27.86	-31,28	3,4
YZ	H	6th	5208	-27.86	-29,74	1,9
YZ	H	7th	6076	-27.86	-42,35	14,5
YZ	H	8th	6944	-27.86	-44,42	16,6
YZ	H	9th	7812	-27.86	-41,37	13,5
YZ	H	10th	8680	-27.86	-36,95	9,1

3.5. Range Test (WES0032-01-ACM868D-01)

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot (indoor). Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1108m.

The outdoor range test result using two ceramic antennas to the front direction (XY plane is horizontal and the Y axes are facing to each other as it is typical in normal remote applications) is 1077m as shown in Figure 2.15. It is close to the reference whip results.

Also it can be seen from the ceramic antenna pattern plots that the antenna gain is at maximum (~-2.5dBi) at other directions (e.g. XZ cut, vertical polarization, Figure 2.11). With facing the TX-RX pair in this orientation (e.g. in non-remote applications) the range could be even higher by 20…30%.

The indoor range is not measured due to the lack of large enough building. But, from the TX power and sensitivity data an estimation can be given assuming an indoor propagation factor of 4.5, which is typical in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -5dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 89m as it is shown in Fig. 2.16.

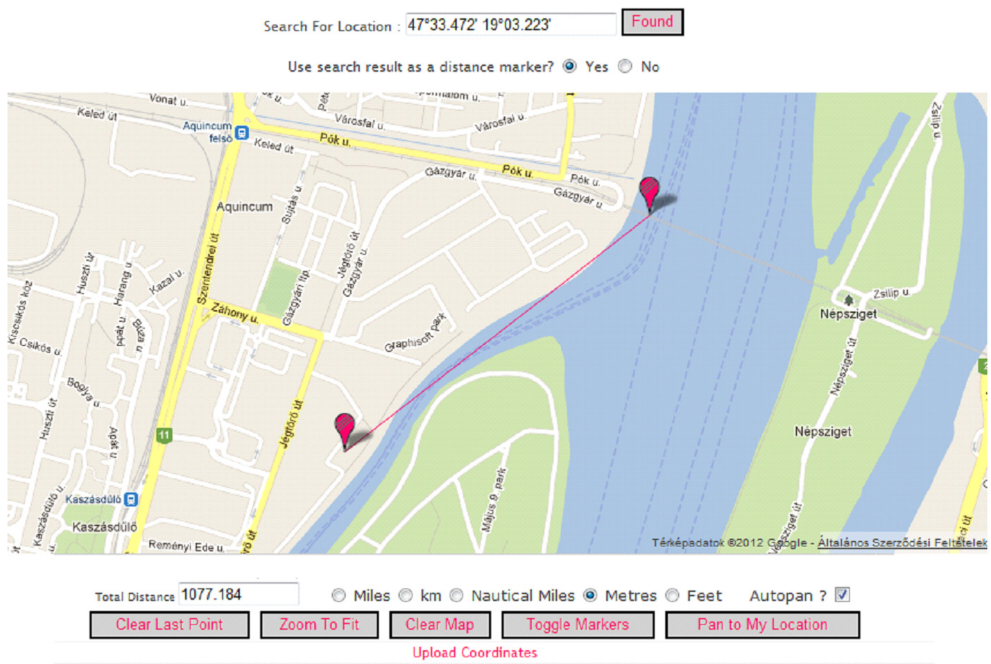


Figure 31. Outdoor range test result with two identical ceramic (chip) antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

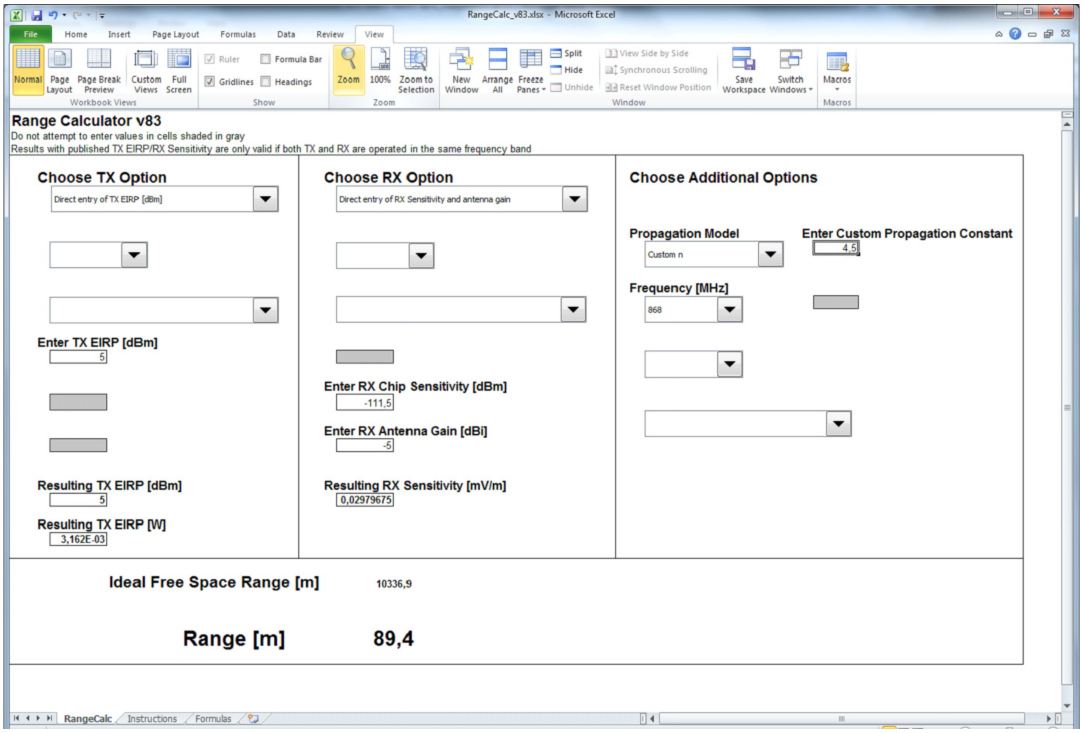


Figure 32. . Indoor range estimation with two identical ceramic (chip) antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

4. Small Size (Wire) Helical Antenna (WES0033-01-AWH868S-01)

- The selected helical antenna is: ANT-868-JJB-RA, Antenna Factor

https://www.linxtechnologies.com/resources/data-guides/ant-868-jjb-xx.pdf

- External matching network (shown in Figure 33) is required at the antenna input

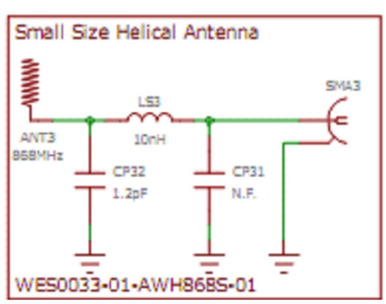


Figure 33. External matching network at 868MHz for the Small Helical Antenna

The picture of the antenna is shown in Figure 34.

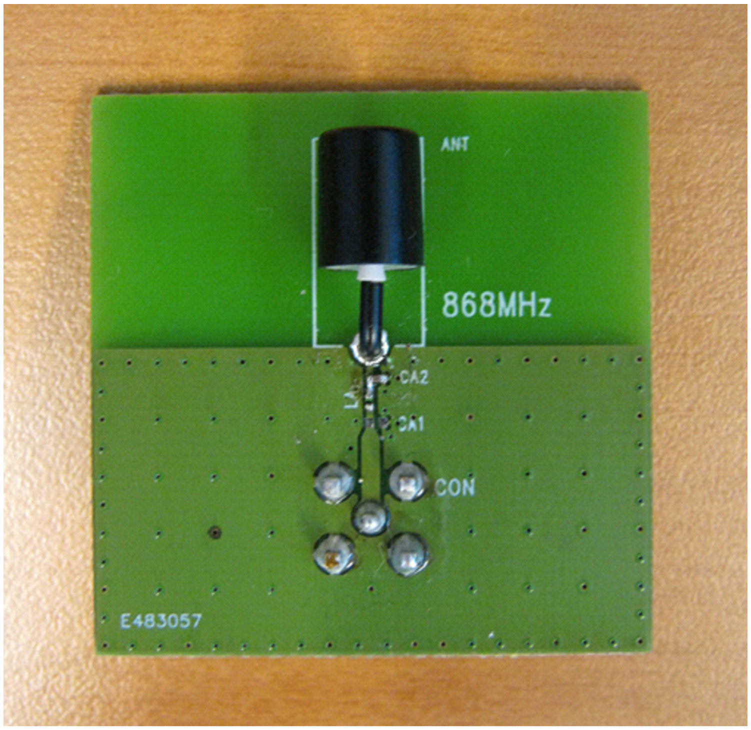


Figure 34. Small Size Helical Antenna

4.1. Antenna Impedance (WES0033-01-AWH868S-01)

The measurement setup is shown in Figure 3.3. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 36. The measured impedance of the antenna with its external matching network is shown in Figure 37 and Figure 38 (up to 3GHz) with motherboard hand effect.

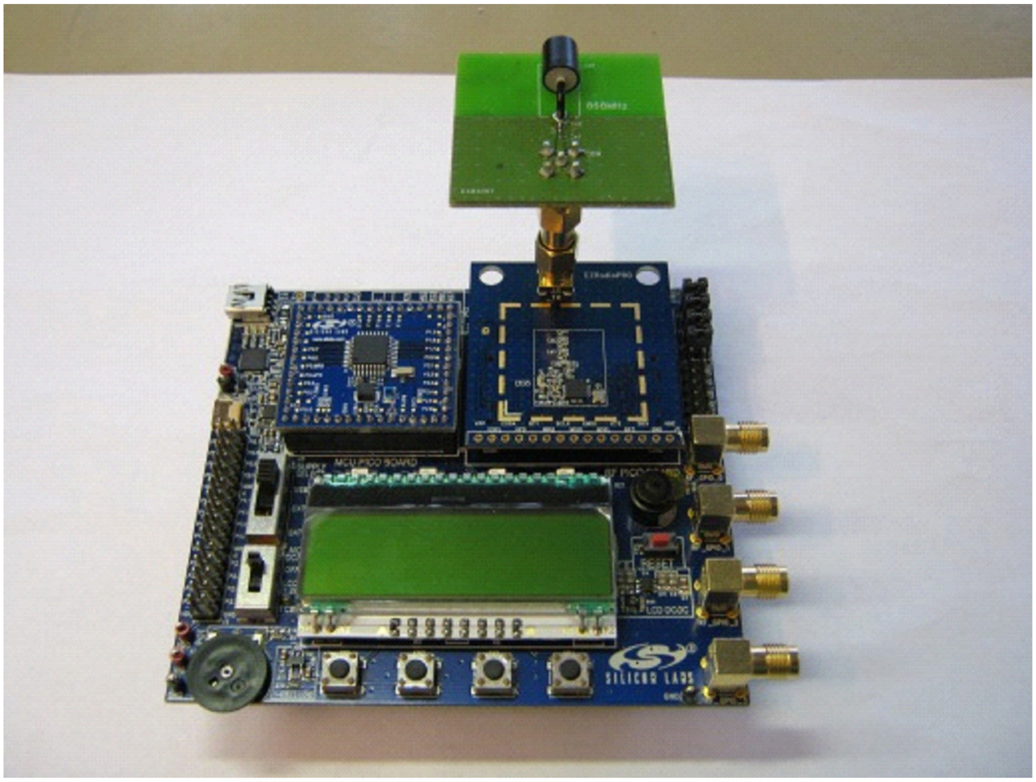


Figure 35. DUT in the final measurement setup

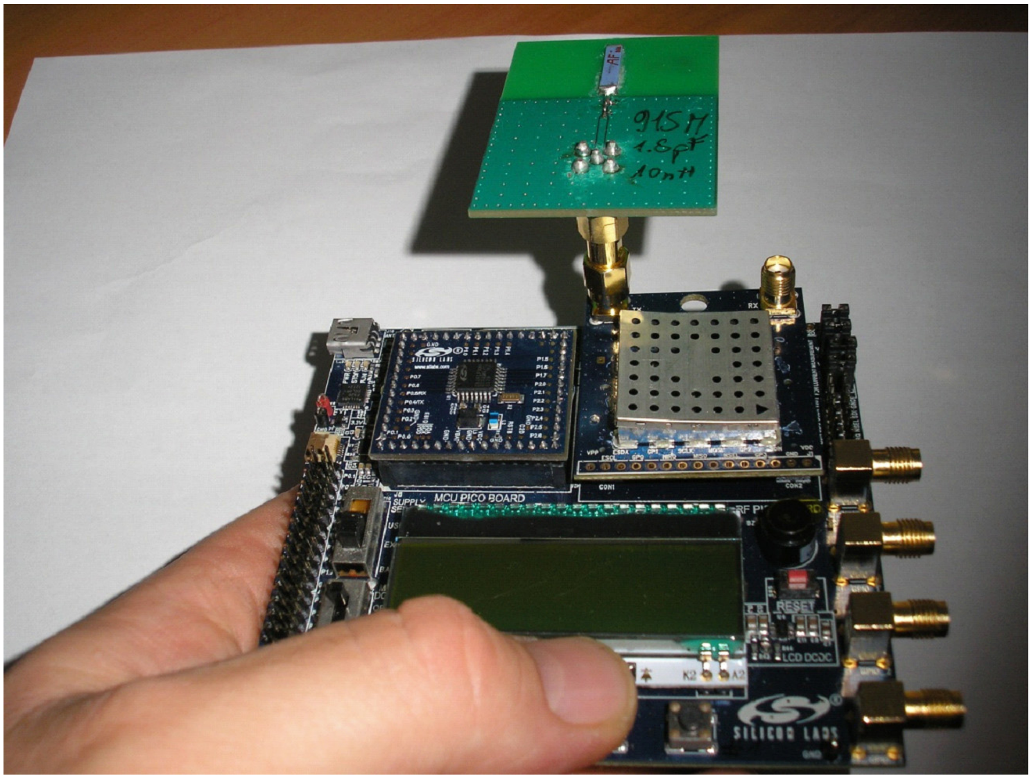


Figure 36. Typical hand effect on the main board during impedance and range measurement

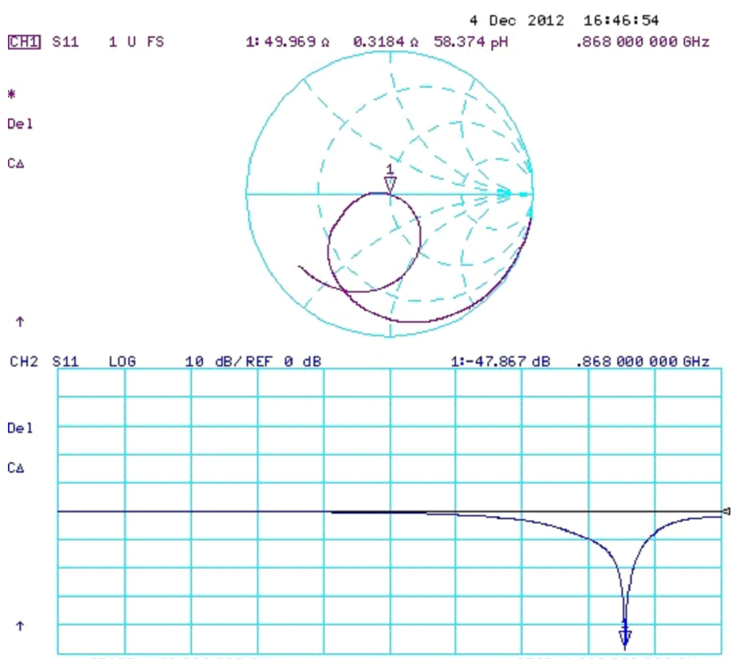


Figure 37. Measured impedance up to 1GHz with hand-effect on the main board

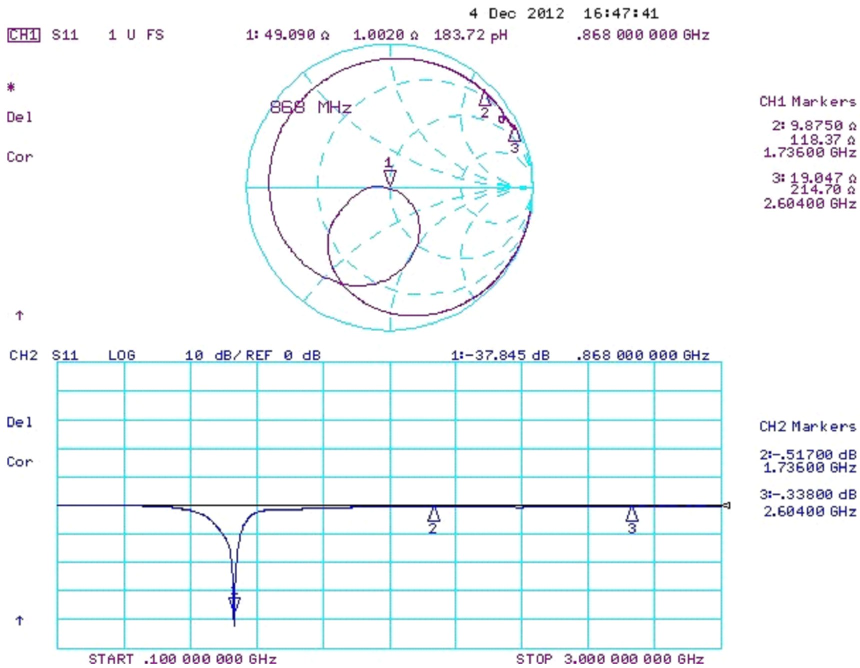


Figure 38. Measured impedance up to 3GHz with hand-effect on the main board

4.2. Antenna Gain (WES0033-01-AWH868S-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 3.7). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection loss is negligible.

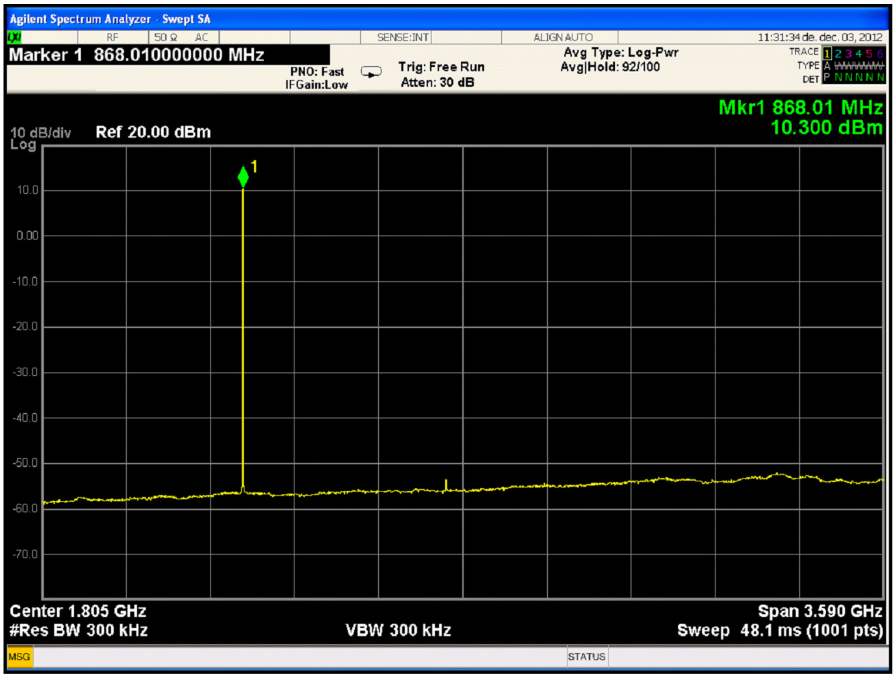


Figure 39. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 3.1). It is around 8.7dBm EIRP so the maximum gain number is ~-1.6dBi as it is shown in Figure 3.11.

4.3. Radiation Patterns

Radiation patterns of the small size helical antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture from the DUT with coordinate system under the radiated measurements is shown in Figure 3.8.

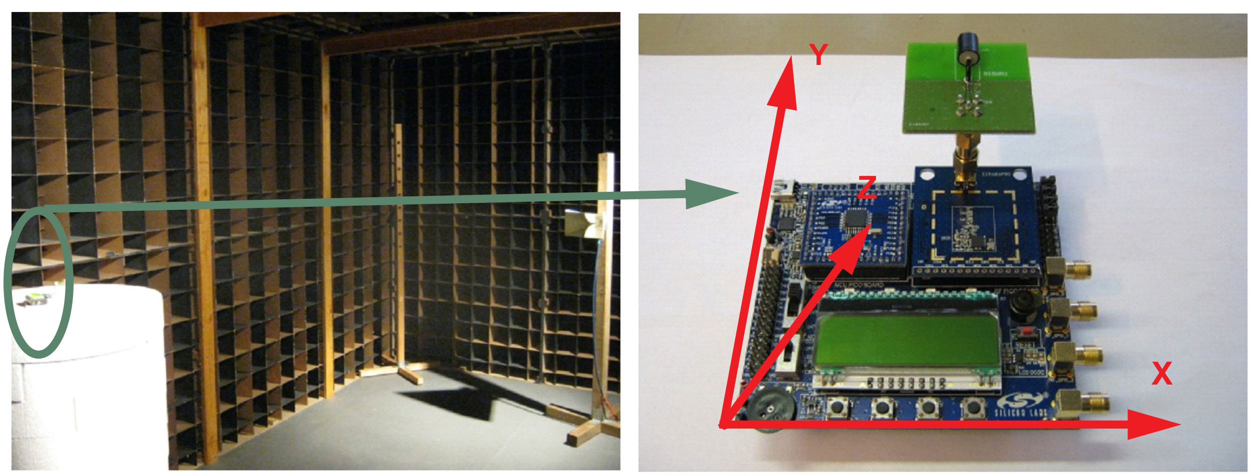


Figure 40. DUT in the antenna chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Figure 41-Figure 46).

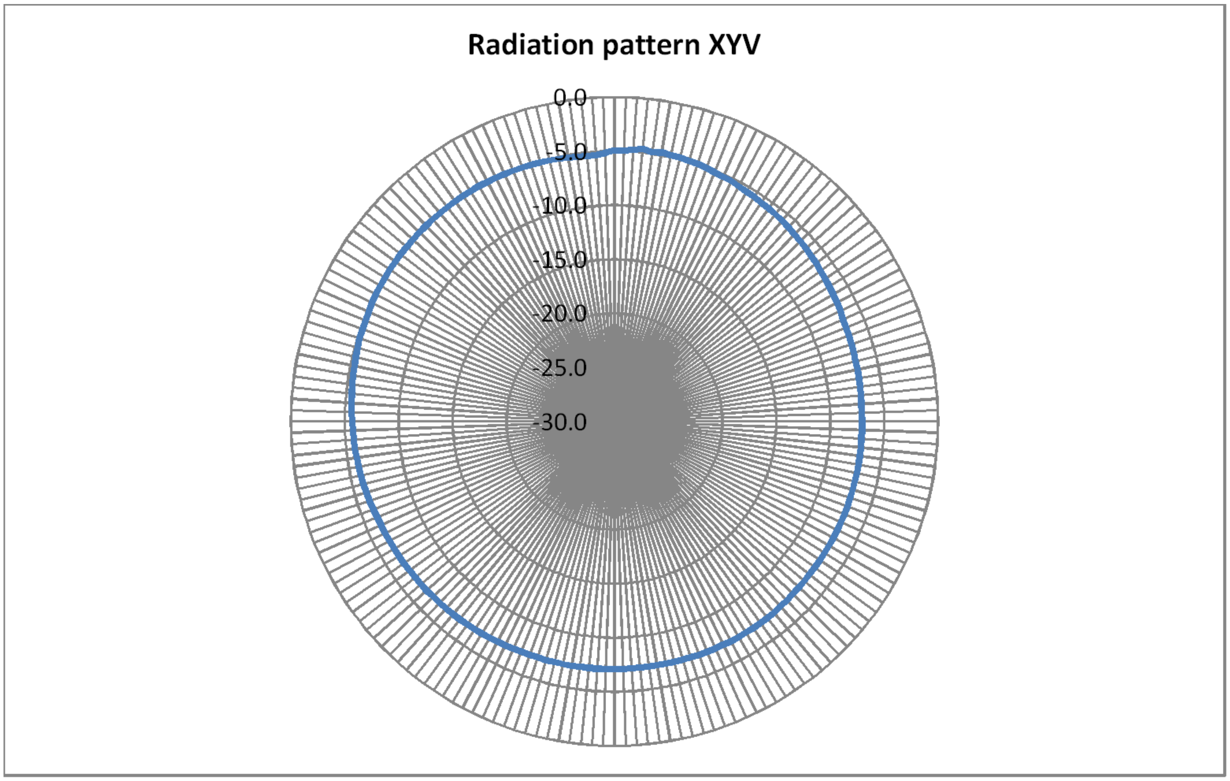


Figure 41. Radiation pattern in the XY cut with Vertical receiver antenna polarization

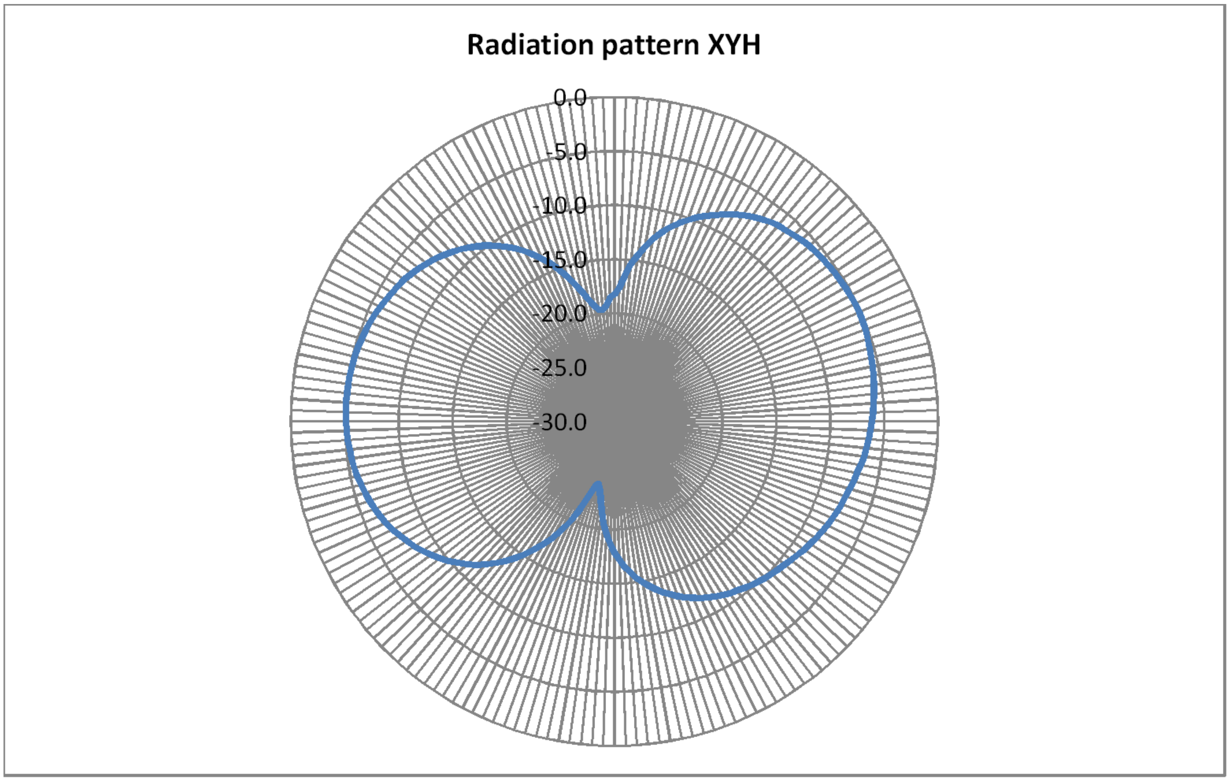


Figure 42. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

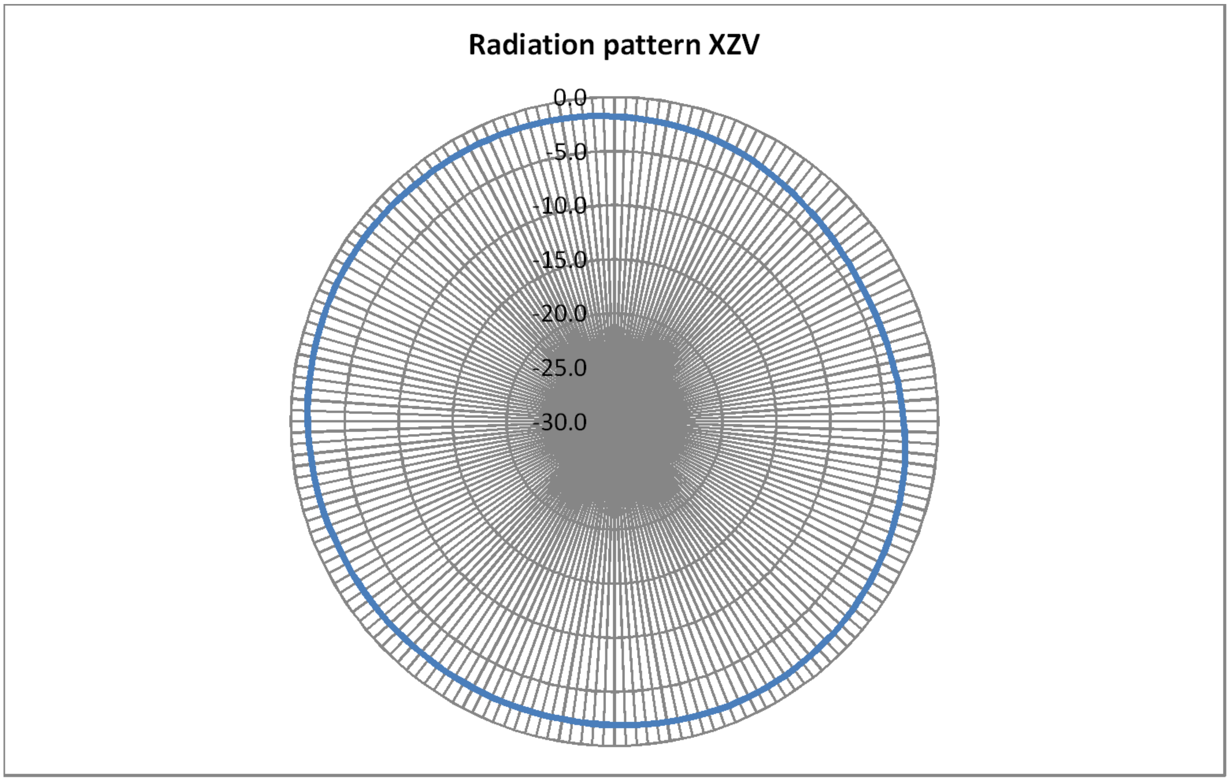


Figure 43. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

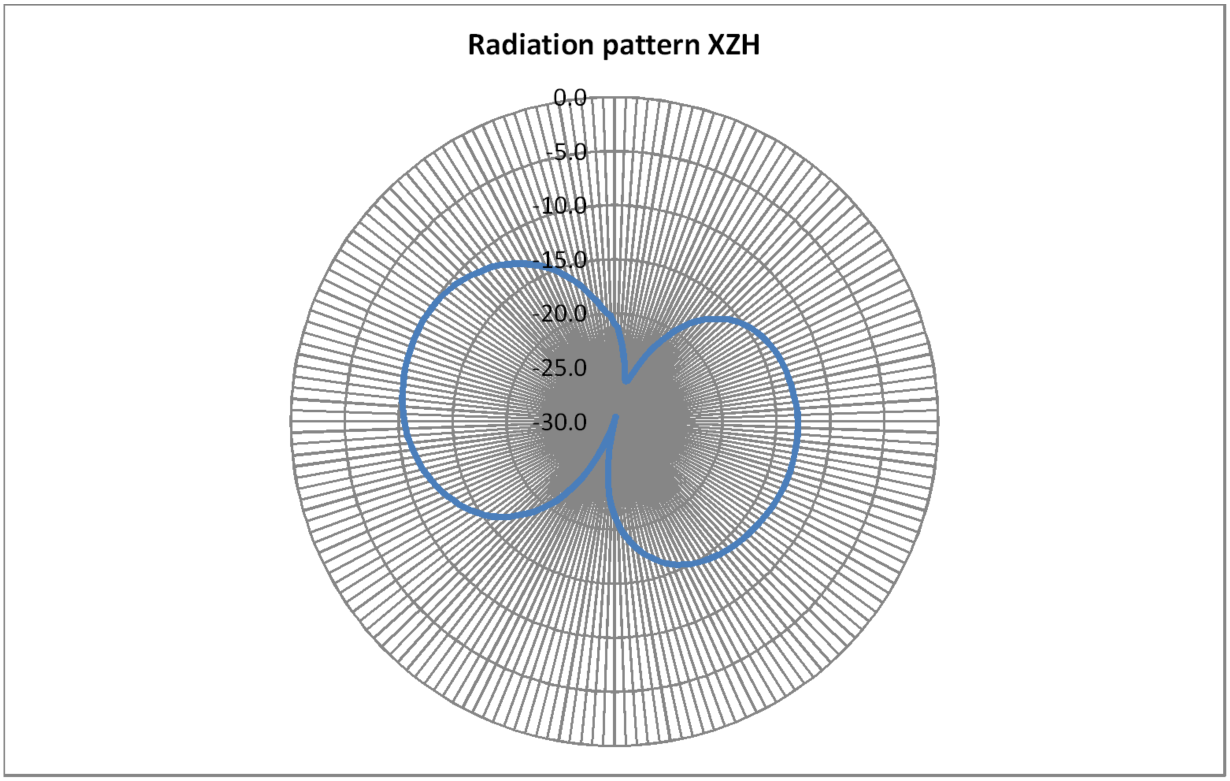


Figure 44. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

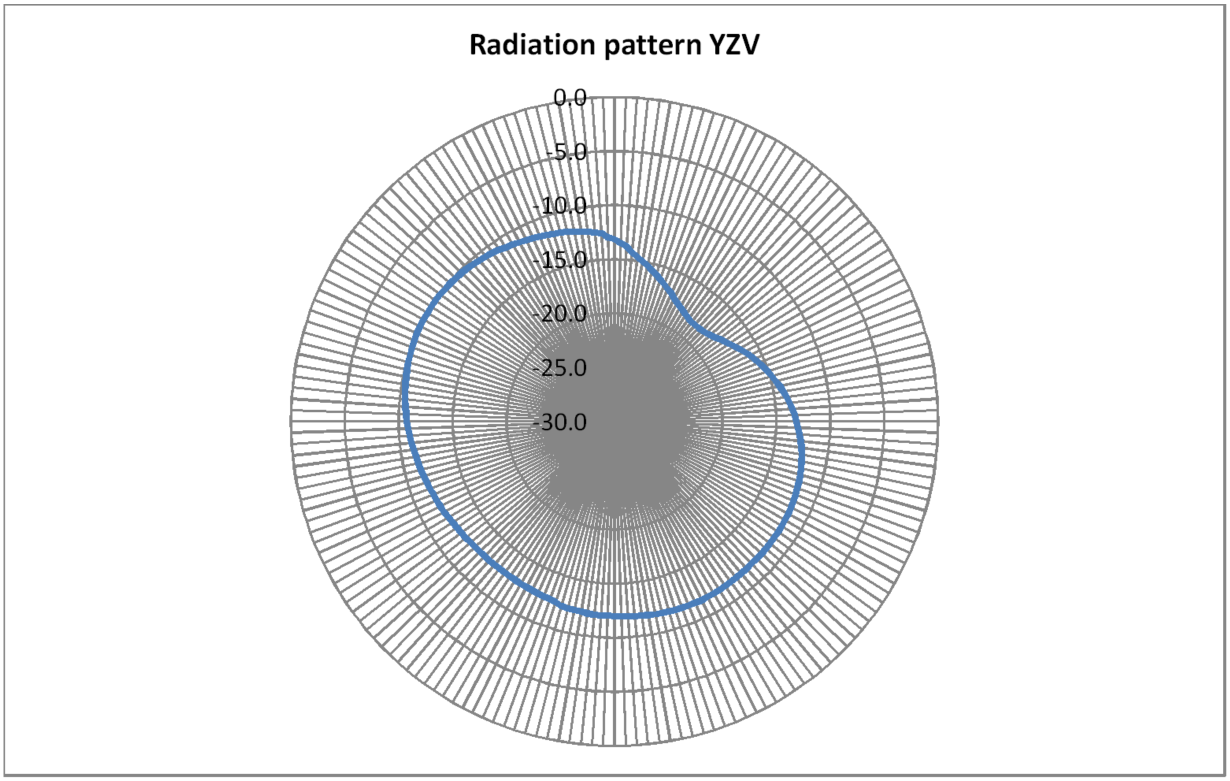


Figure 45. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

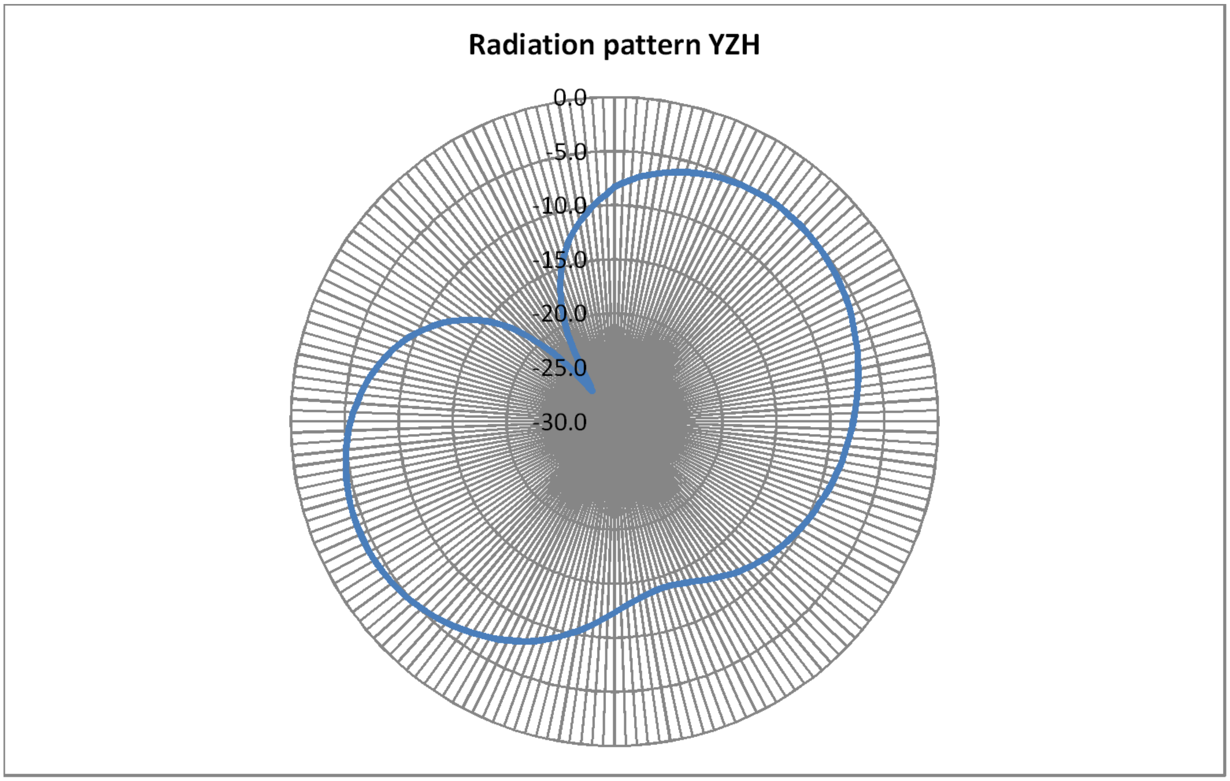


Figure 46. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

4.4. Radiated Harmonics

The radiated harmonics of the small size helical antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table (Table 3) together with the corresponding standard limits.

The Antenna is ETSI compliant, but the 6th harmonic is close to the limit in some cuts. Here it has to be noted that the potential source of the 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 3. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	5.63	10.5
XY	V	2nd	1736	-27.86	-46.56	18.7
XY	V	3rd	2604	-27.86	-48.73	20.9

Table 3. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	4th	3472	-27.86	-43.38	15.5
XY	V	5th	4340	-27.86	-38.01	10.2
XY	V	6th	5208	-27.86	-34.21	6.4
XY	V	7th	6076	-27.86	-44.83	17.0
XY	V	8th	6944	-27.86	-39.94	12.1
XY	V	9th	7812	-27.86	-41.59	13.7
XY	V	10th	8680	-27.86	-39.26	11.4
XY	H	Fund.	868	16.12	5.13	11.0
XY	H	2nd	1736	-27.86	-47.11	19.2
XY	H	3rd	2604	-27.86	-49.54	21.7
XY	H	4th	3472	-27.86	-44.81	17.0
XY	H	5th	4340	-27.86	-41.15	13.3
XY	H	6th	5208	-27.86	-34.44	6.6
XY	H	7th	6076	-27.86	-44.16	16.3
XY	H	8th	6944	-27.86	-44.04	16.2
XY	H	9th	7812	-27.86	-40.90	13.0
XY	H	10th	8680	-27.86	-37.83	10.0
XZ	V	Fund.	868	16.12	8.67	7.5
XZ	V	2nd	1736	-27.86	-41.16	13.3
XZ	V	3rd	2604	-27.86	-50.39	22.5
XZ	V	4th	3472	-27.86	-41.10	13.2
XZ	V	5th	4340	-27.86	-36.77	8.9
XZ	V	6th	5208	-27.86	-34.35	6.5
XZ	V	7th	6076	-27.86	-44.63	16.8
XZ	V	8th	6944	-27.86	-44.01	16.2

Table 3. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XZ	V	9th	7812	-27.86	-41.24	13.4
XZ	V	10th	8680	-27.86	-39.43	11.6
XZ	H	Fund.	868	16.12	0.35	15.8
XZ	H	2nd	1736	-27.86	-45.83	18.0
XZ	H	3rd	2604	-27.86	-50.51	22.7
XZ	H	4th	3472	-27.86	-41.12	13.3
XZ	H	5th	4340	-27.86	-35.76	7.9
XZ	H	6th	5208	-27.86	-30.07	2.2
XZ	H	7th	6076	-27.86	-43.29	15.4
XZ	H	8th	6944	-27.86	-42.27	14.4
XZ	H	9th	7812	-27.86	-41.13	13.3
XZ	H	10th	8680	-27.86	-35.67	7.8
YZ	V	Fund.	868	16.12	0.33	15.8
YZ	V	2nd	1736	-27.86	-51.06	23.2
YZ	V	3rd	2604	-27.86	-52.88	25.0
YZ	V	4th	3472	-27.86	-41.06	13.2
YZ	V	5th	4340	-27.86	-38.77	10.9
YZ	V	6th	5208	-27.86	-30.82	3.0
YZ	V	7th	6076	-27.86	-44.12	16.3
YZ	V	8th	6944	-27.86	-42.24	14.4
YZ	V	9th	7812	-27.86	-41.03	13.2
YZ	V	10th	8680	-27.86	-35.86	8.0
YZ	H	Fund.	868	16.12	6.05	10.1
YZ	H	2nd	1736	-27.86	-41.31	13.5

Table 3. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
YZ	H	3rd	2604	-27.86	-48.81	21.0
YZ	H	4th	3472	-27.86	-39.57	11.7
YZ	H	5th	4340	-27.86	-34.82	7.0
YZ	H	6th	5208	-27.86	-32.63	4.8
YZ	H	7th	6076	-27.86	-42.96	15.1
YZ	H	8th	6944	-27.86	-43.01	15.2
YZ	H	9th	7812	-27.86	-41.13	13.3
YZ	H	10th	8680	-27.86	-39.86	12.0

4.5. Range Test

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot. Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1107m.

The outdoor range test result using two small size helical antennas instead of the whip antennas is 1077m as shown in Figure 47.

Also it can be seen from the ceramic antenna pattern plots that the antenna gain is at maximum (~-2dBi) at other directions (e.g. XZ cut, vertical polarization, Figure 43). With facing the TX-RX pair in this orientation (e.g. in non-remote applications) the range could be even higher by 30…40%.

The indoor range is not measured due to the lack of large enough building. But, from the TX power and sensitivity data an estimation can be given assuming an indoor propagation factor of 4.5, which is typical in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -5dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 89m as it is shown in Figure 48.

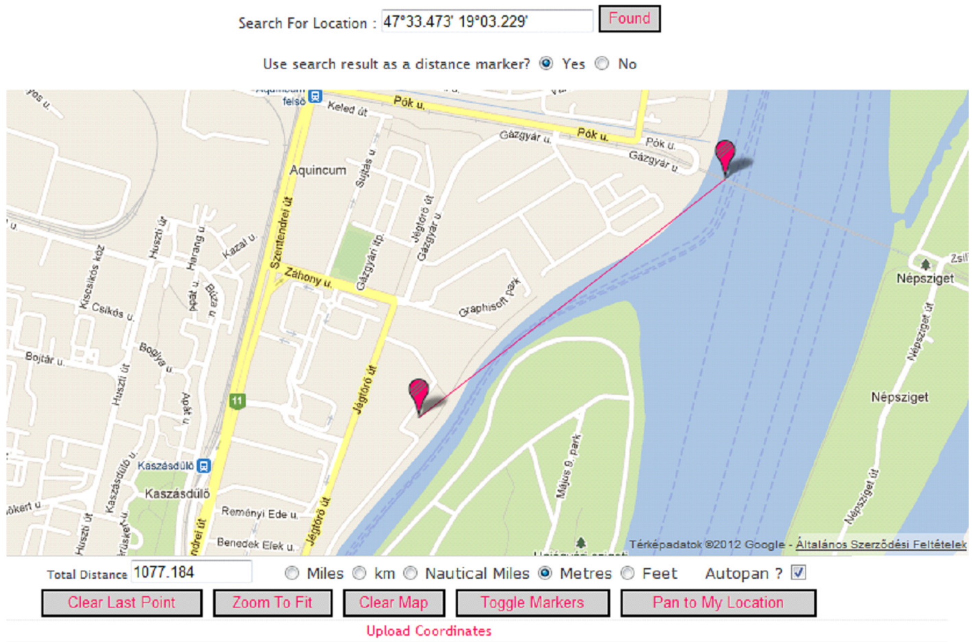


Figure 47. Outdoor range test result with two identical small size helical antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

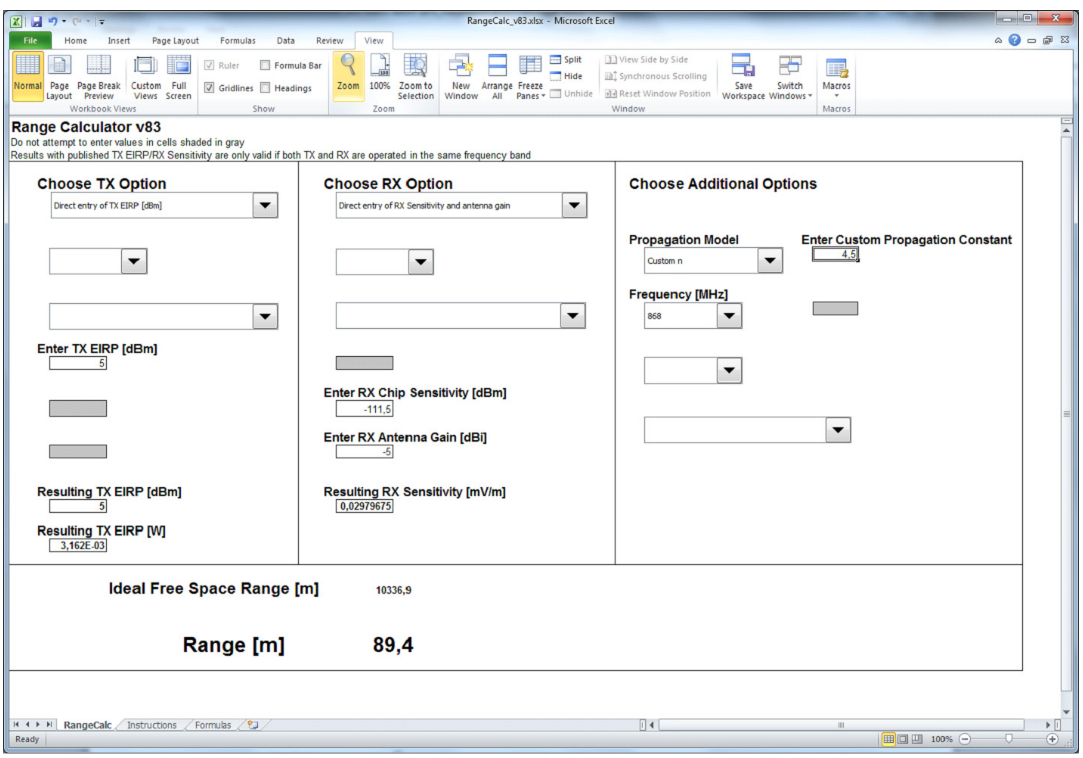


Figure 48. Indoor range estimation with two identical ceramic (chip) antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

5. Medium Size (Wire) Helical Antenna (WES0034-01-AWH868M-01)

- The selected helical antenna is: ANT-916-HETH, Antenna Factor

https://www.linxtechnologies.com/resources/data-guides/ant-xxx-hexx.pdf

- Although the selected antenna is dedicated to 916MHz, it can be easily matched to 868MHz
- External matching network (shown in Figure 4.1) is required at the antenna input

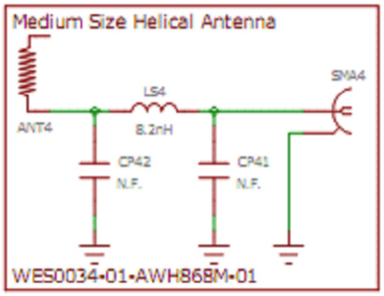


Figure 49. . External matching network at 868M for the Medium Helical antenna

The picture of the antenna is shown in Figure 50.

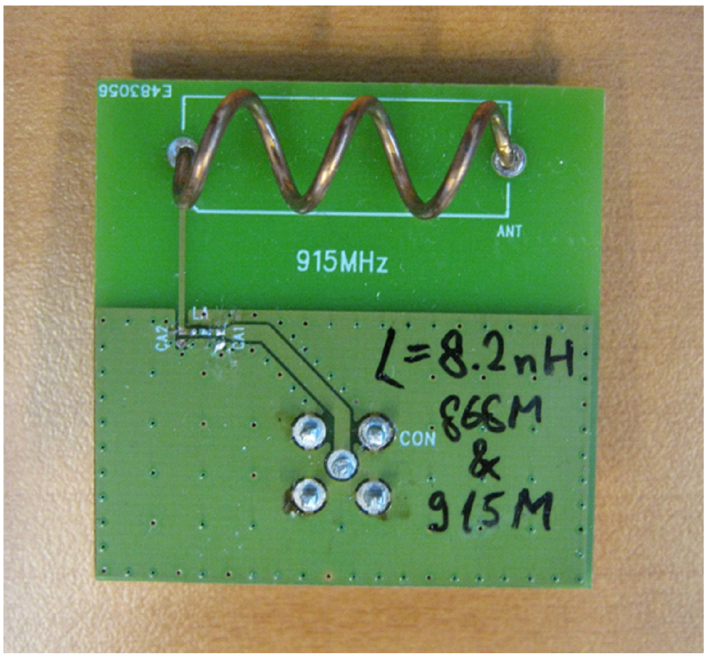


Figure 50. Medium Size Helical Antenna

5.1. Antenna Impedance (WES0034-01-AWH868M-01)

The measurement setup is shown in Figure 51. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 52. The measured impedance of the antenna with its external matching network is shown in Figure 53 and Figure 54 (up to 3GHz) with motherboard hand effect.

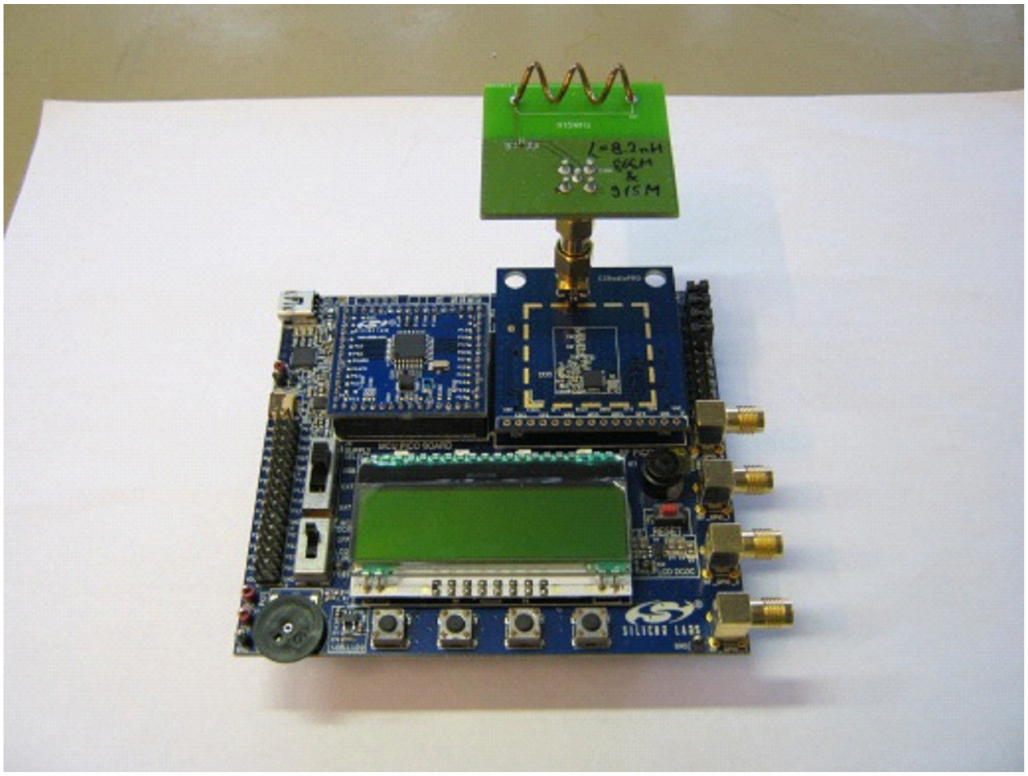


Figure 51. DUT in the Final Measurement Setup

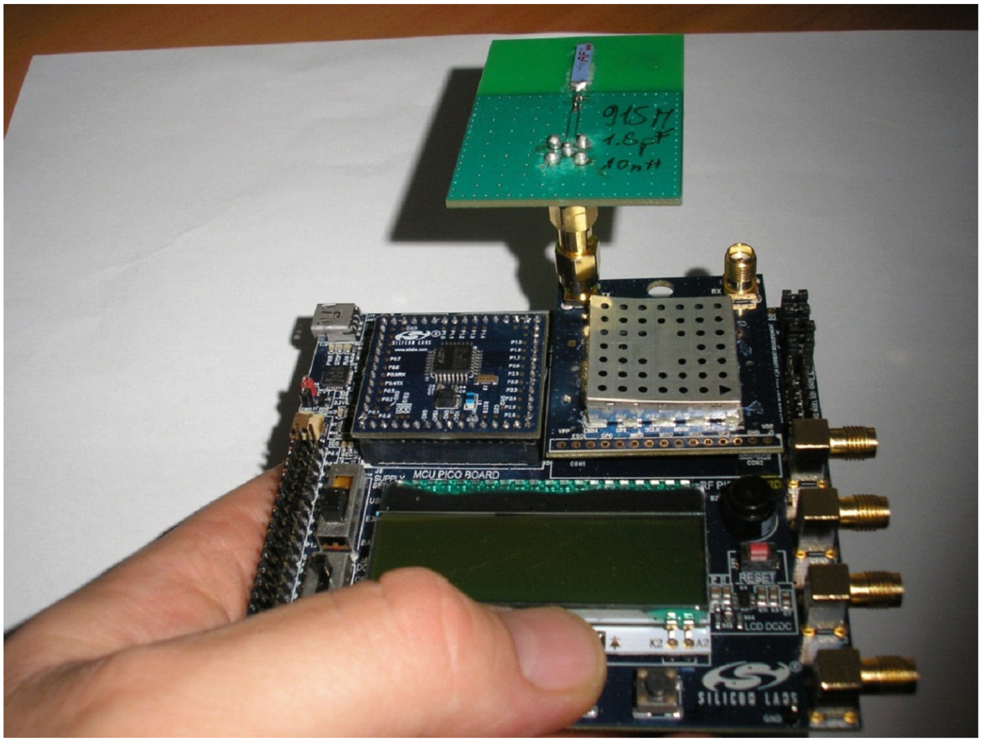


Figure 52. Typical hand effect on the main board during impedance and range measurement

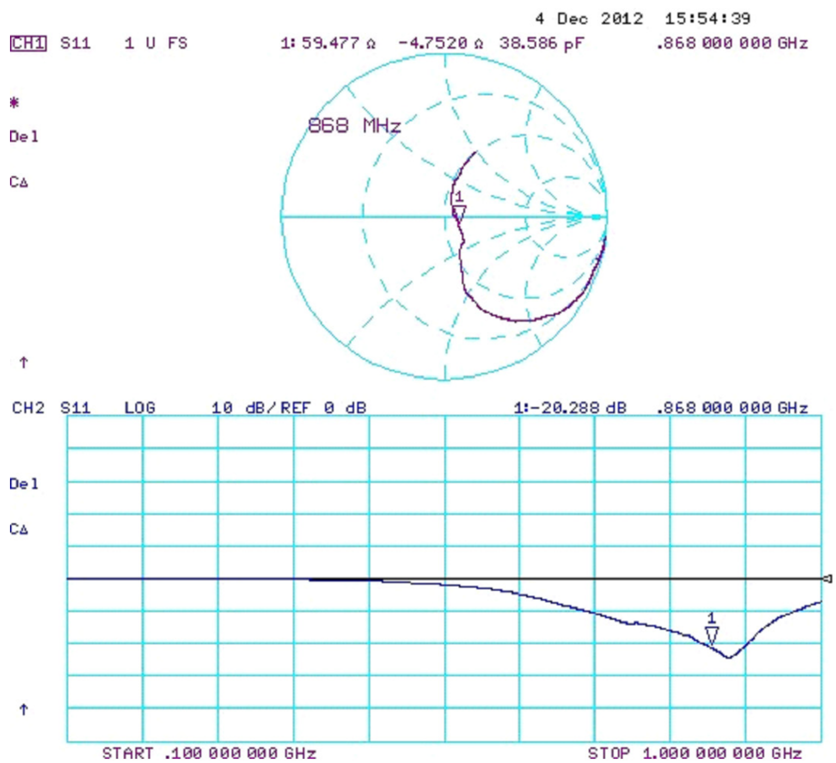


Figure 53. Measured impedance up to 1GHz with hand-effect on the main board

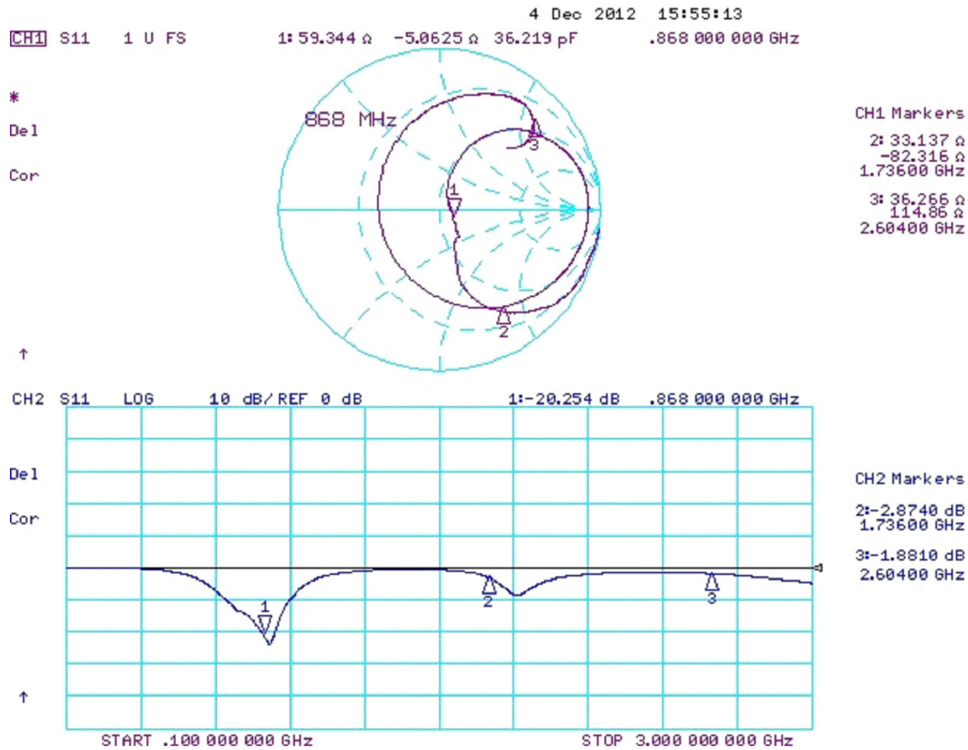


Figure 54. Measured impedance up to 3GHz with hand-effect on the main board

5.2. Antenna Gain (WES0034-01-AWH868M-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 4.7). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection is negligible.

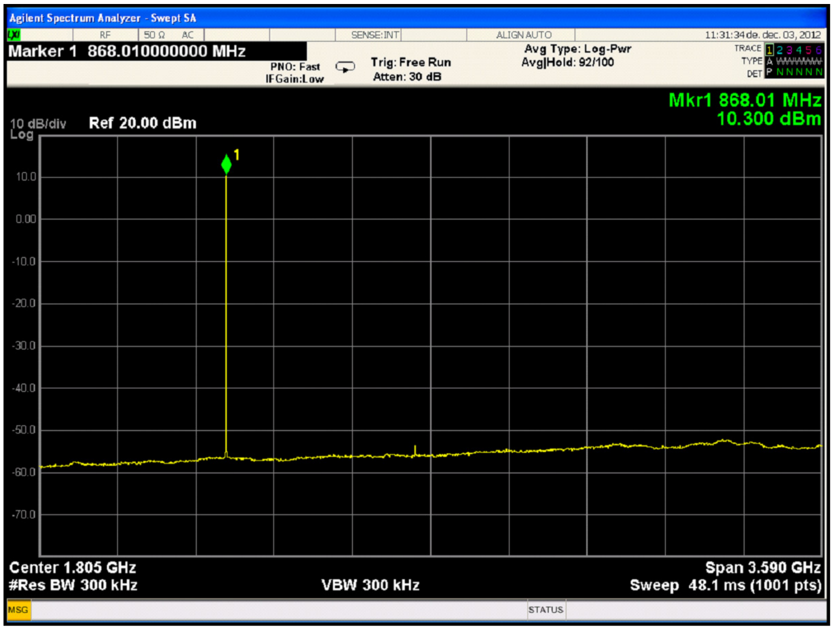


Figure 55. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 4.1). It is around 11.5dBm EIRP so the maximum gain number is ~+1.2dBi as it is shown in Figure 4.11.

5.3. Radiation Patterns (WES0034-01-AWH868M-01)

Radiation patterns of the medium size helical antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture of the DUT with coordinate system under the radiated measurements is shown in Figure 56.

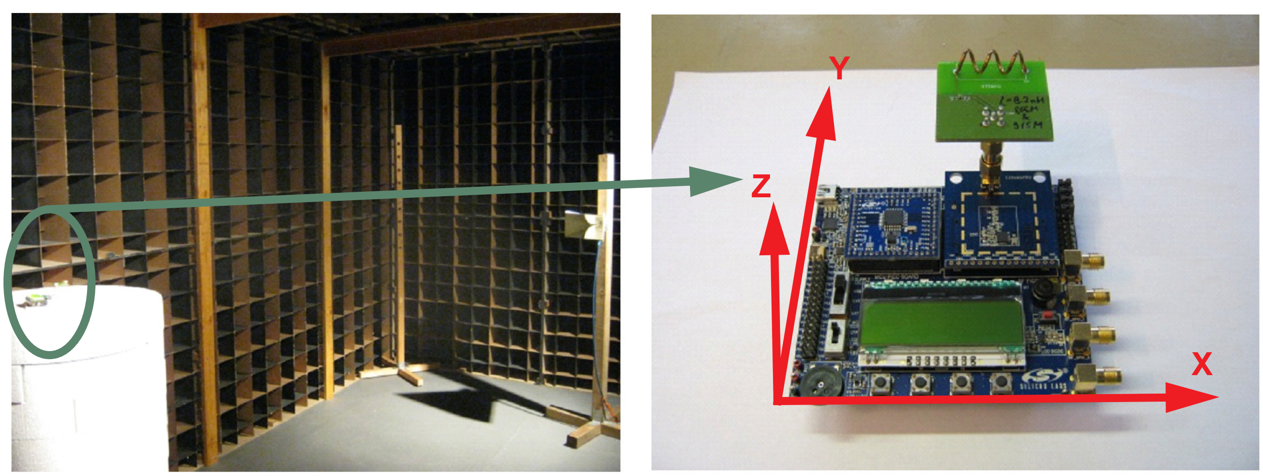


Figure 56. DUT in the Antenna Chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Figure 57-Figure 62).

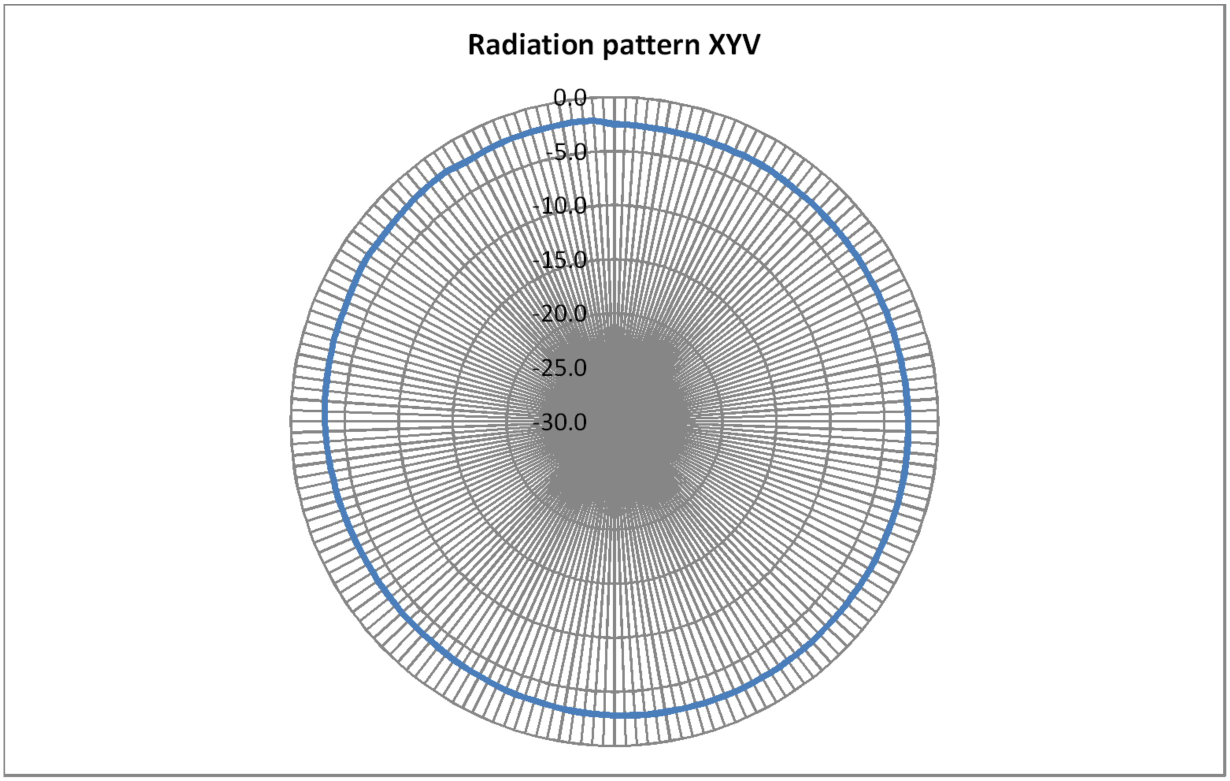


Figure 57. . Radiation pattern in the XY cut with Vertical receiver antenna polarization

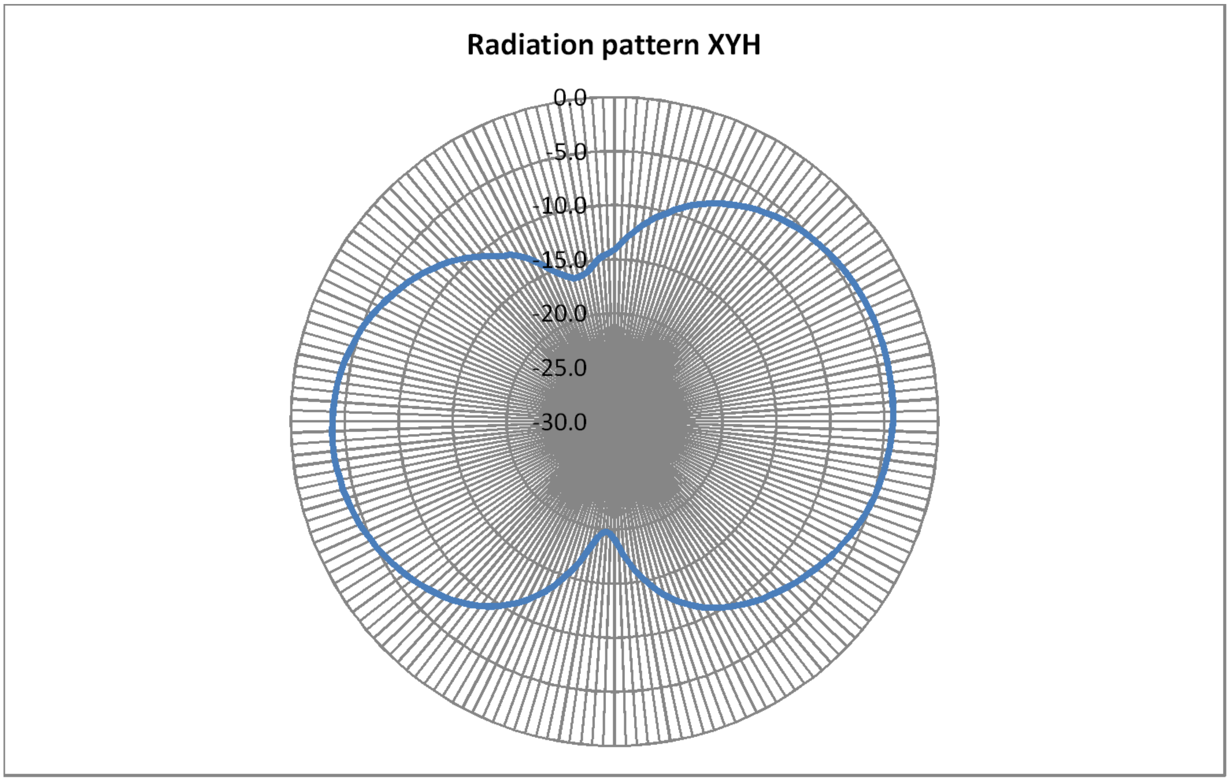


Figure 58. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

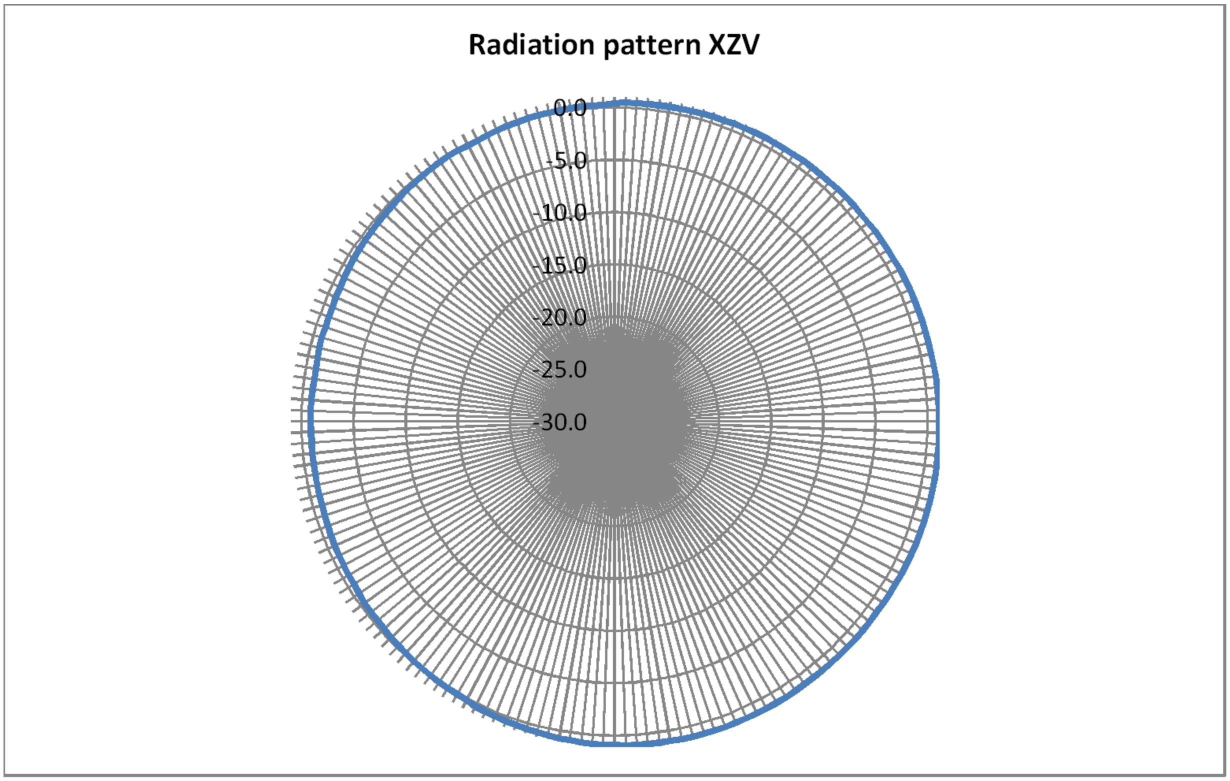


Figure 59. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

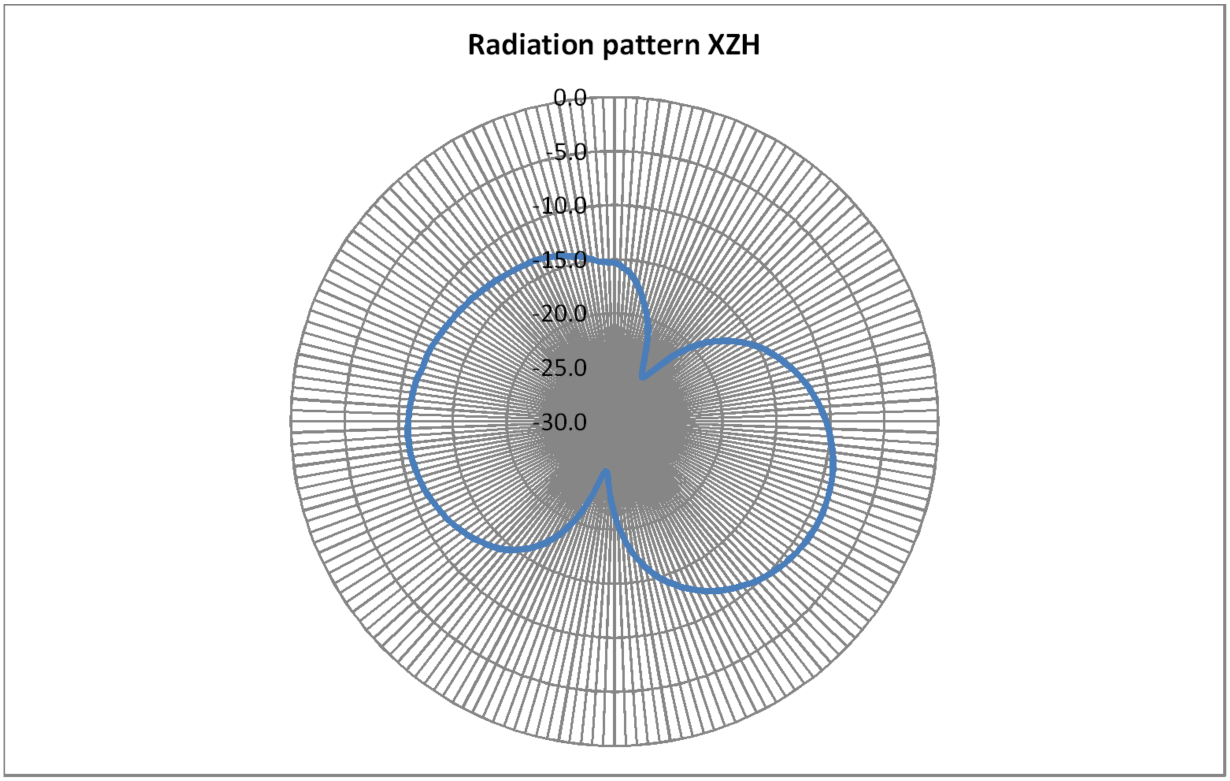


Figure 60. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

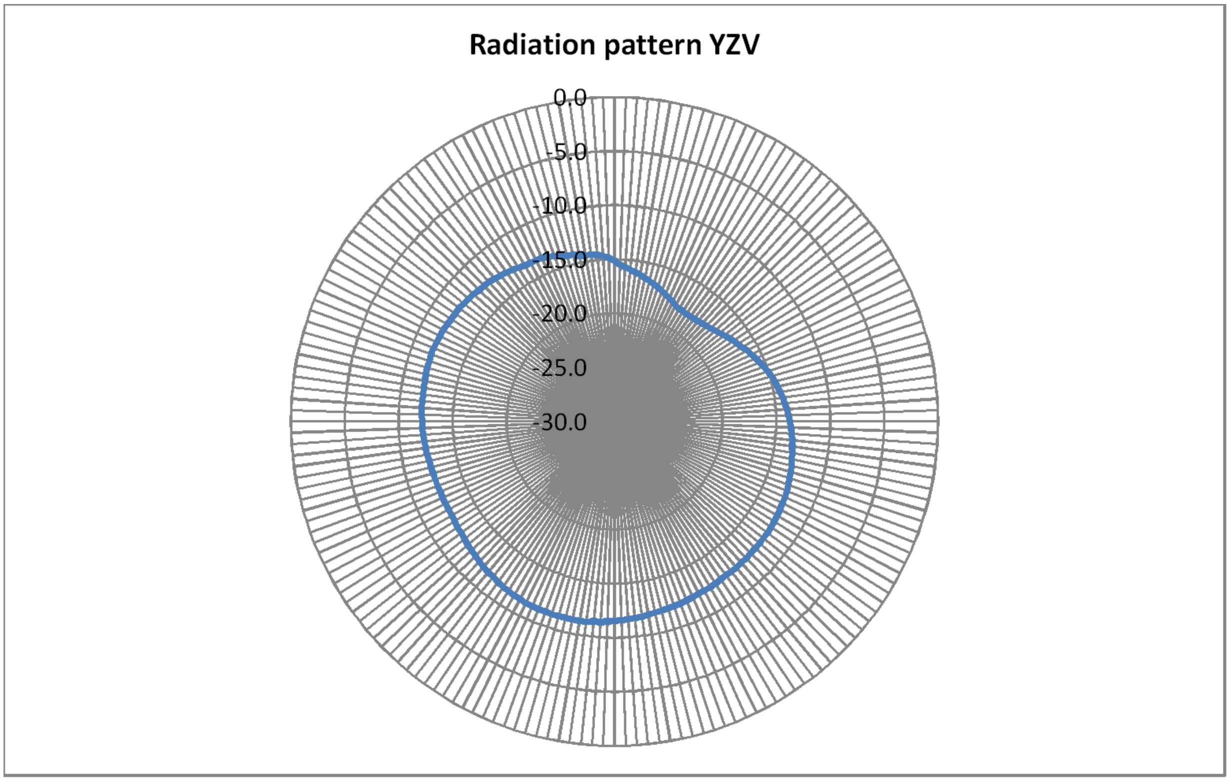


Figure 61. . Radiation pattern in the YZ cut with Vertical receiver antenna polarization

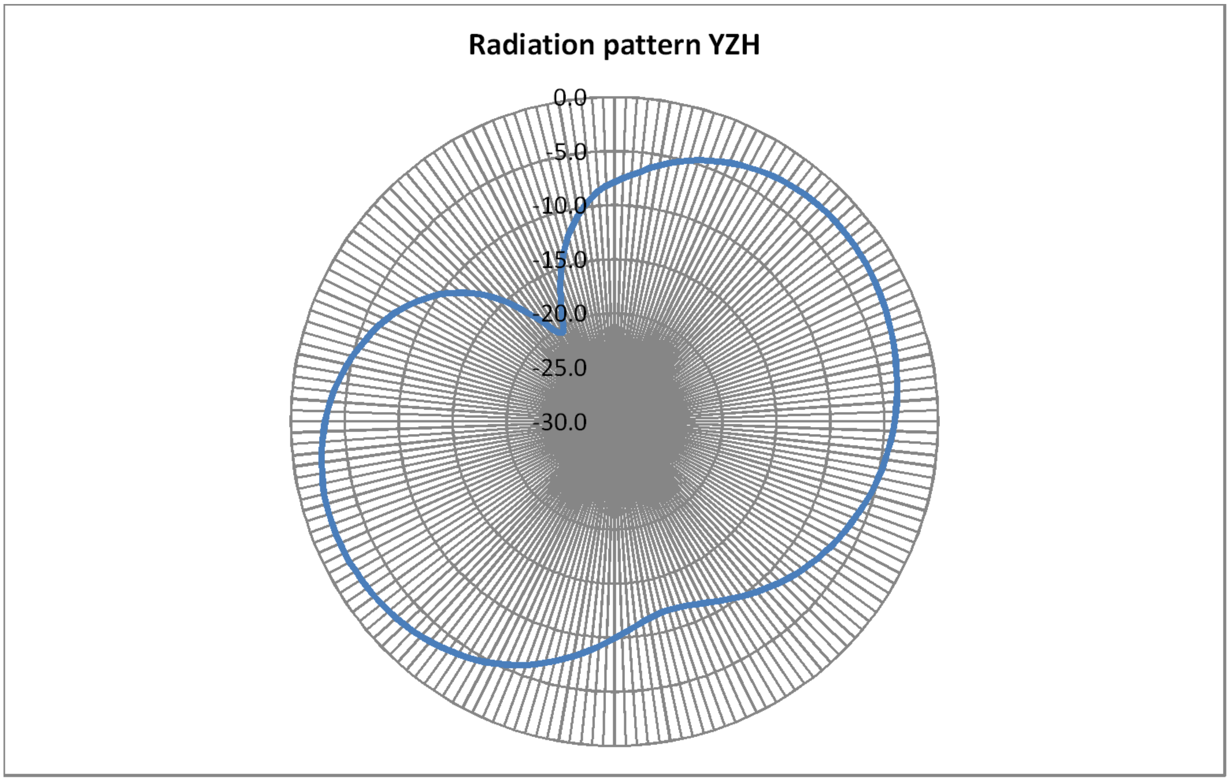


Figure 62. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

5.4. Radiated Harmonics (WES0034-01-AWH868M-01)

The radiated harmonics of the medium size helical antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table together with the corresponding standard limits.

The Antenna is ETSI compliant, with large enough margin. Here it has to be noted that with the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 4. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	8.22	7.9
XY	V	2nd	1736	-27.86	-46.17	18.3
XY	V	3rd	2604	-27.86	-47.77	19.9

Table 4. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	4^{th}	3472	-27.86	-38.66	10.8
XY	V	5^{th}	4340	-27.86	-39.17	11.3
XY	V	6^{th}	5208	-27.86	-41.00	13.1
XY	V	7^{th}	6076	-27.86	-41.96	14.1
XY	V	8^{th}	6944	-27.86	-43.09	15.2
XY	V	9^{th}	7812	-27.86	-40.11	12.2
XY	V	10^{th}	8680	-27.86	-36.32	8.5
XY	H	Fund.	868	16.12	6.49	9.6
XY	H	2^{nd}	1736	-27.86	-51.14	23.3
XY	H	3^{rd}	2604	-27.86	-49.59	21.7
XY	H	4^{th}	3472	-27.86	-43.23	15.4
XY	H	5^{th}	4340	-27.86	-41.45	13.6
XY	H	6^{th}	5208	-27.86	-40.51	12.6
XY	H	7^{th}	6076	-27.86	-39.67	11.8
XY	H	8^{th}	6944	-27.86	-44.25	16.4
XY	H	9^{th}	7812	-27.86	-41.84	14.0
XY	H	10^{th}	8680	-27.86	-38.97	11.1
XZ	V	Fund.	868	16.12	11.47	4.6
XZ	V	2^{nd}	1736	-27.86	-43.29	15.4
XZ	V	3^{rd}	2604	-27.86	-51.46	23.6
XZ	V	4^{th}	3472	-27.86	-37.30	9.4
XZ	V	5^{th}	4340	-27.86	-36.58	8.7
XZ	V	6^{th}	5208	-27.86	-38.78	10.9
XZ	V	7^{th}	6076	-27.86	-43.49	15.6
XZ	V	8^{th}	6944	-27.86	-43.26	15.4

Table 4. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XZ	V	9th	7812	-27.86	-41.65	13.8
XZ	V	10th	8680	-27.86	-36.79	8.9
XZ	H	Fund.	868	16.12	1.37	14.8
XZ	H	2nd	1736	-27.86	-46.91	19.0
XZ	H	3rd	2604	-27.86	-52.08	24.2
XZ	H	4th	3472	-27.86	-39.18	11.3
XZ	H	5th	4340	-27.86	-36.83	9.0
XZ	H	6th	5208	-27.86	-36.63	8.8
XZ	H	7th	6076	-27.86	-40.37	12.5
XZ	H	8th	6944	-27.86	-42.90	15.0
XZ	H	9th	7812	-27.86	-40.15	12.3
XZ	H	10th	8680	-27.86	-33.22	5.4
YZ	V	Fund.	868	16.12	-0.94	17.1
YZ	V	2nd	1736	-27.86	-49.35	21.5
YZ	V	3rd	2604	-27.86	-51.02	23.2
YZ	V	4th	3472	-27.86	-38.22	10.4
YZ	V	5th	4340	-27.86	-37.54	9.7
YZ	V	6th	5208	-27.86	-35.80	7.9
YZ	V	7th	6076	-27.86	-40.77	12.9
YZ	V	8th	6944	-27.86	-42.31	14.5
YZ	V	9th	7812	-27.86	-40.37	12.5
YZ	V	10th	8680	-27.86	-34.54	6.7
YZ	H	Fund.	868	16.12	8.14	8.0
YZ	H	2nd	1736	-27.86	-42.51	14.6

Table 4. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
YZ	H	3rd	2604	-27.86	-48.85	21.0
YZ	H	4th	3472	-27.86	-37.52	9.7
YZ	H	5th	4340	-27.86	-35.88	8.0
YZ	H	6th	5208	-27.86	-37.53	9.7
YZ	H	7th	6076	-27.86	-39.16	11.3
YZ	H	8th	6944	-27.86	-42.88	15.0
YZ	H	9th	7812	-27.86	-41.13	13.3
YZ	H	10th	8680	-27.86	-38.58	10.7

5.5. Range Test (WES0034-01-AWH868M-01)

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot (indoor). Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1108m.

The outdoor range test result using two medium size helical antennas to the front direction (XY plane is horizontal and the Y axes are facing to each other as it is typical in normal remote applications) is 1077m as shown in Figure 63.

Also it can be seen from the medium size helical antenna pattern plots that the antenna gain is at maximum (~1.2dBi) at other directions (e.g. XZ cut, vertical polarization, Figure 59). With facing the TX-RX pair in this orientation (e.g. in non-remote applications) the range could be even higher by 30…40%.

Indoor range test is not done, due to the lack of large enough building. But, from the TX power and sensitivity data an indoor range estimation can be given assuming a propagation factor of 4.5 (which is a typical value in normal office environment). Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -2.5dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 115m as it is shown in Figure 64.

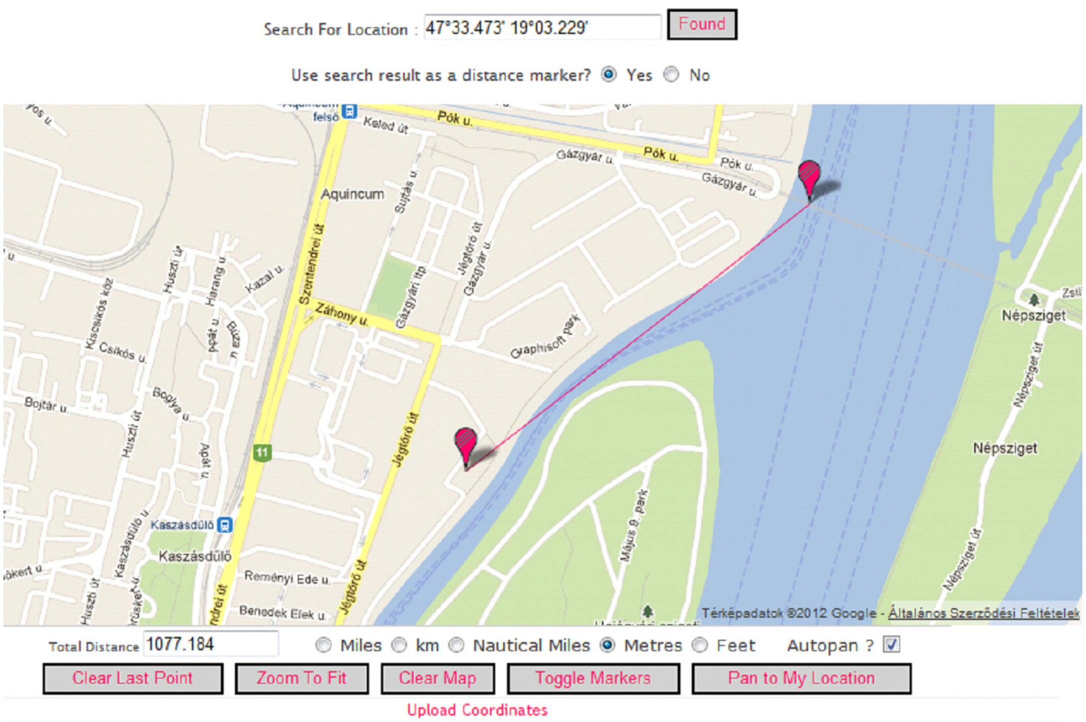


Figure 63. Outdoor range test result with two identical medium size helical antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

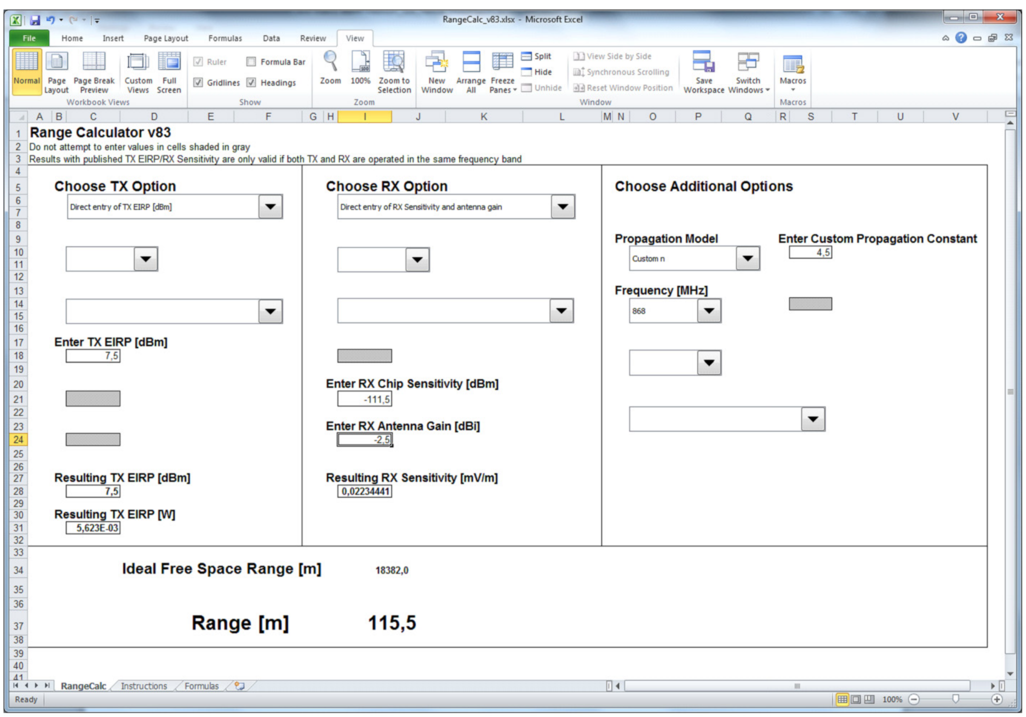


Figure 64. Indoor range estimation with two identical medium size helical antennas and with the

4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

6. Panic Button IFA (WES0036-01-APF868P-01)

- The antenna trace width is 0.5mm.
- The distance between the antenna trace outer edge and the PCB cutting edge is 1.5mm.
- The distance between the antenna trace inner edge and ground metal is 2mm.
- No capacitance (Ctop) at the end of the antenna required
- No parallel capacitance at the antenna input required

The picture of the antenna is shown in Figure 65.

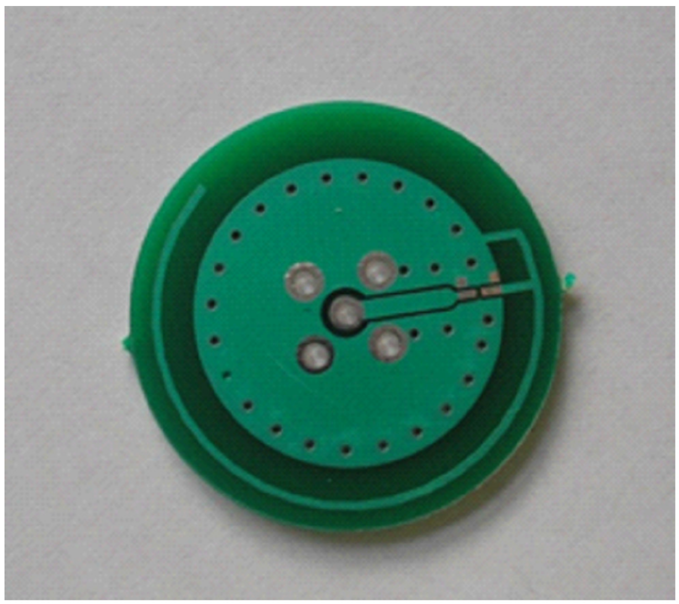


Figure 65. Small IFA antenna for panic button applications

6.1. Antenna Impedance (WES0036-01-APF868P-01)

The measurement setup is shown in Figure 66. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 67. The measured impedance of the antenna with its external matching network is shown in Figure 68 and Figure 69 (up to 3GHz) with motherboard hand effect.

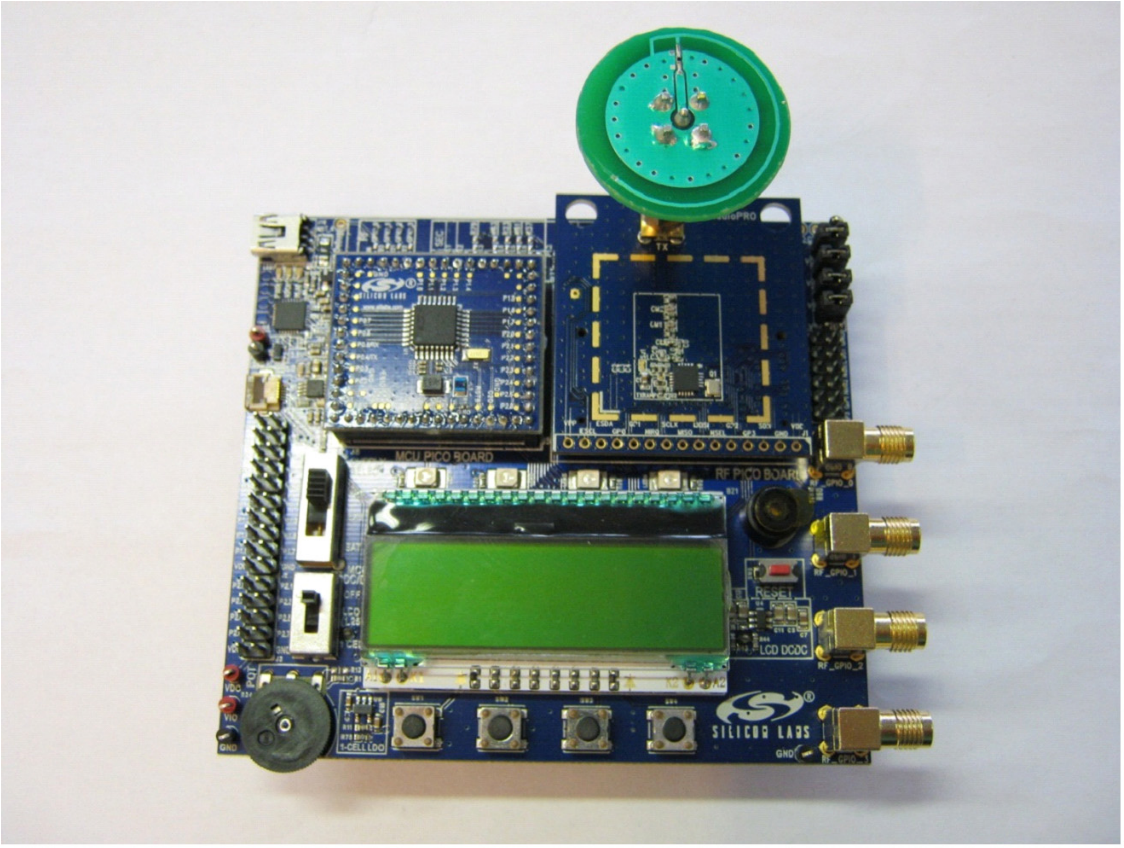


Figure 66. DUT in the final measurement setup

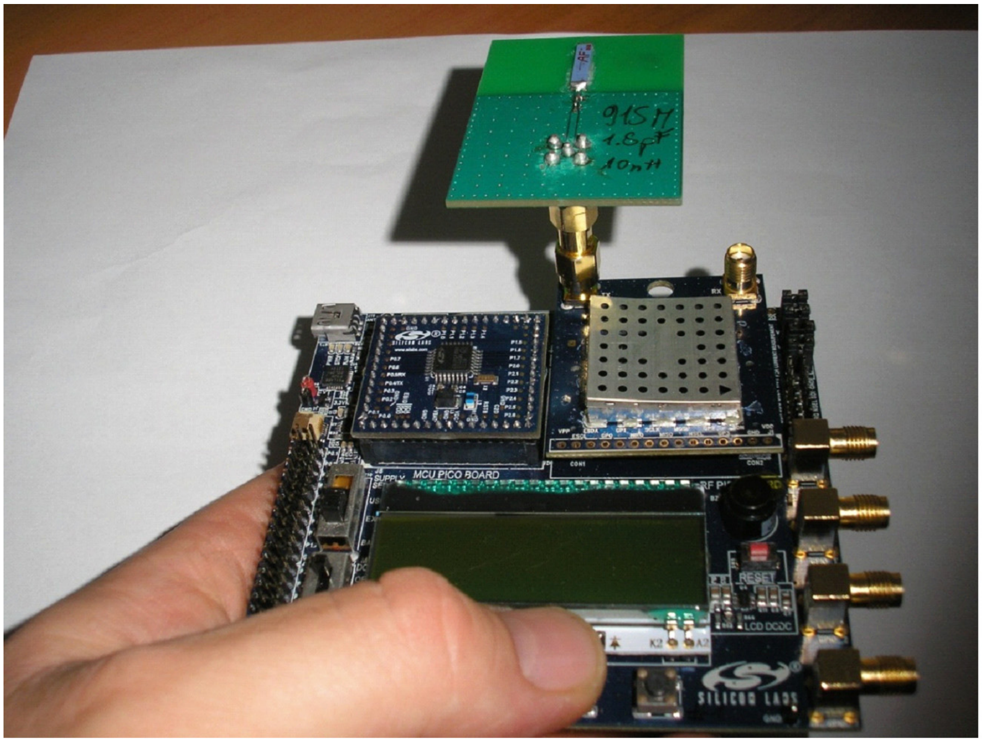


Figure 67. Typical hand effect on the main board during impedance and range measurement

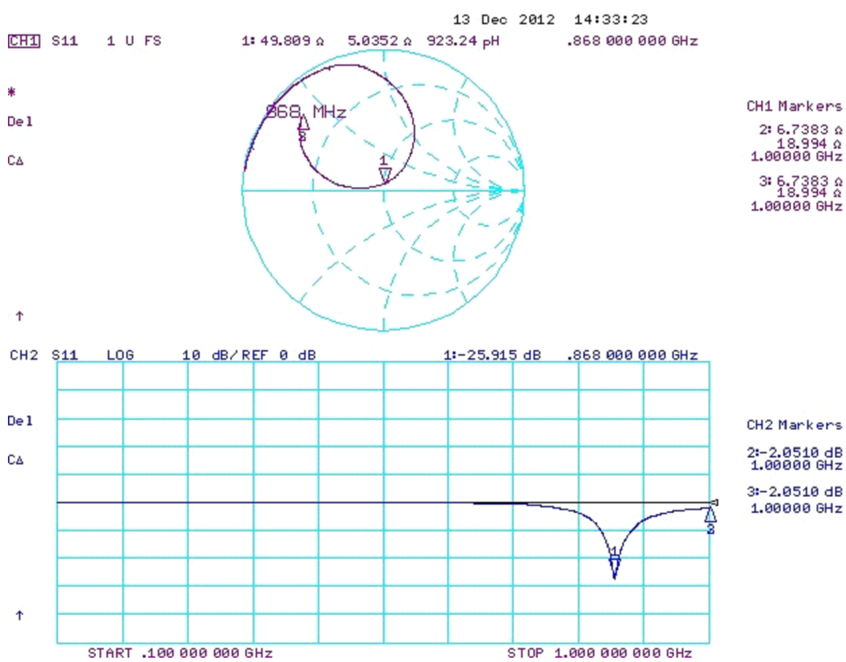


Figure 68. Measured impedance up to 1GHz with hand-effect on the main board

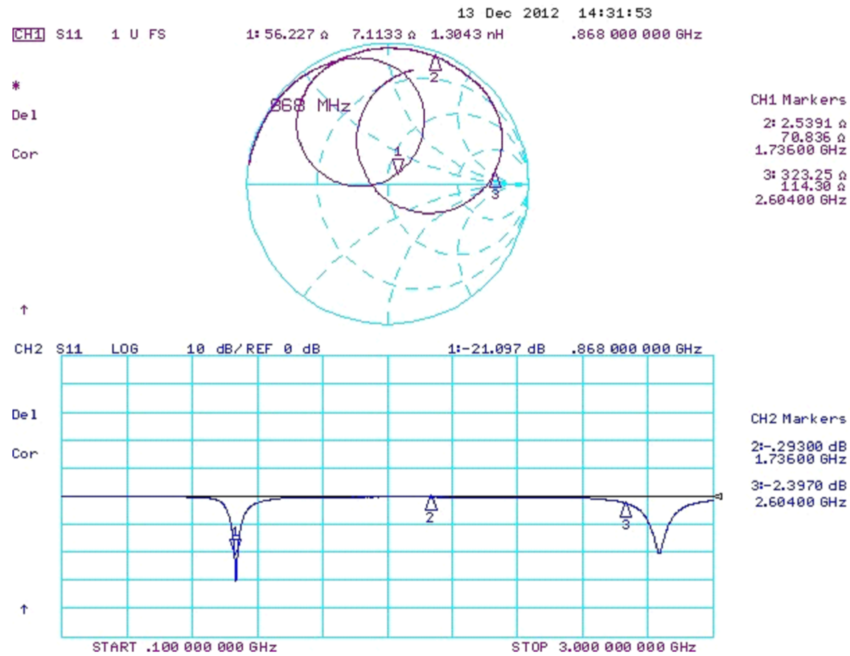


Figure 69. Measured impedance up to 3GHz with hand-effect on the main board

6.2. Antenna Gain (WES0036-01-APF868P-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 70). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection is negligible.

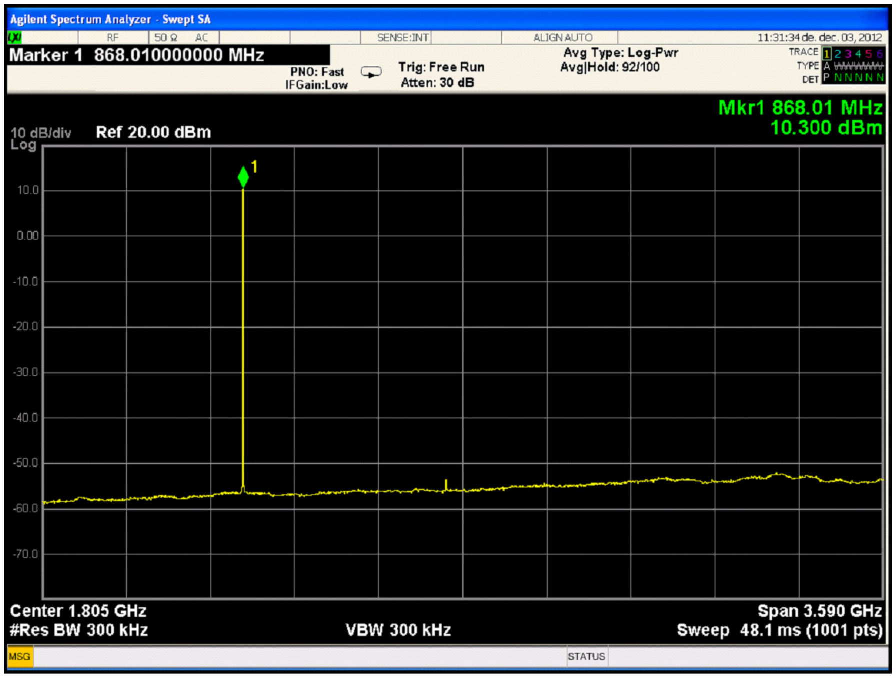


Figure 70. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 5.1). It is around 10.4dBm EIRP so the maximum gain number is ~0dBi as it is shown in Figure 5.10.

This gain number is surprisingly high for a panic button antenna. It should be emphasized that in typical panic button applications the grounding environment and the strength of the hand effect is different. In real panic button applications (instead of the SMA connector, SMA male-male transition, Pico Board and Wireless Motherboard) only a lithium coin battery is applied and the achievable antenna gain is much weaker.

Also in wrist applications the very close parallel hand has strong detuning effect. In these applications further impedance tuning of the antenna required and the radiation efficiency degrades strongly (please refer the “Antenna Design Guide for Single Ended 50 Ohm Antennas” document).

6.3. Radiation Patterns (WES0036-01-APF868P-01)

Radiation patterns of the small IFA antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture from the DUT with coordinate system under the radiated measurements is shown in Figure 5.7.

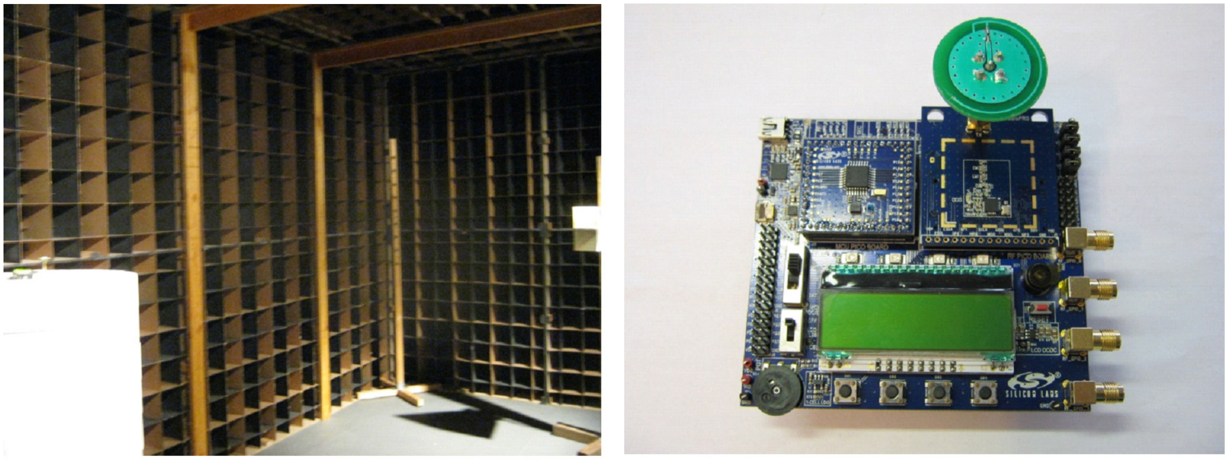


Figure 71. DUT in the antenna chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Fig. 5.8-5.13).

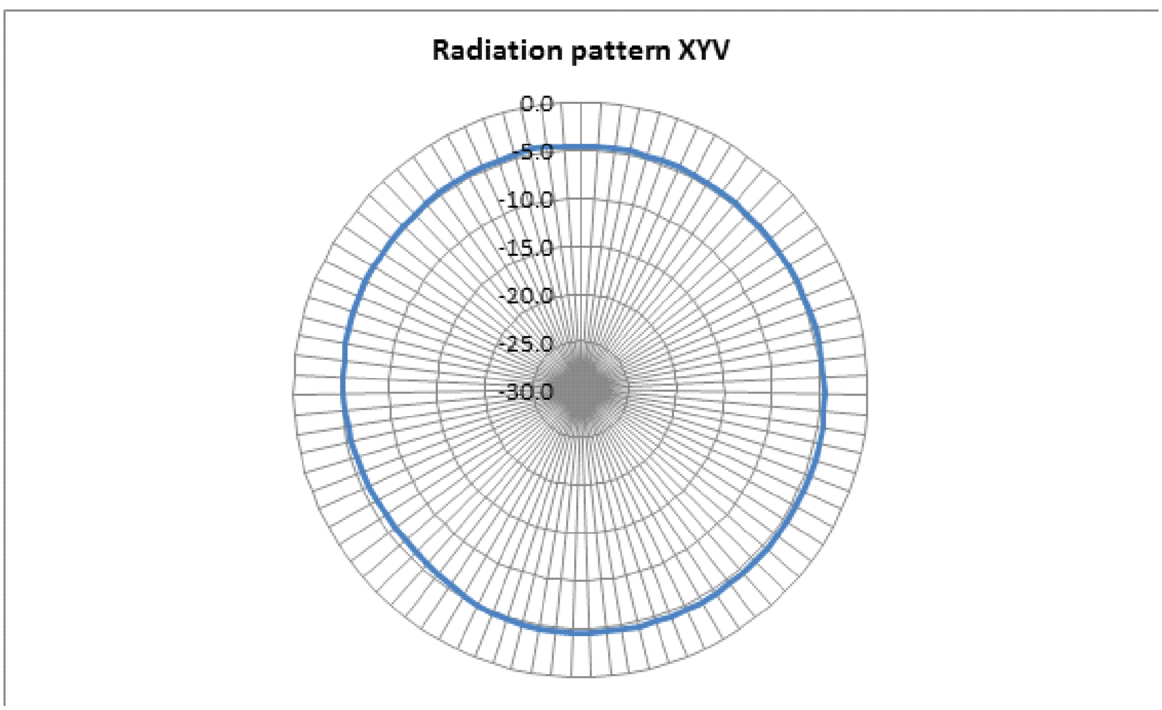


Figure 72. Figure 5.8. Radiation pattern in the XY cut with Vertical receiver antenna polarization

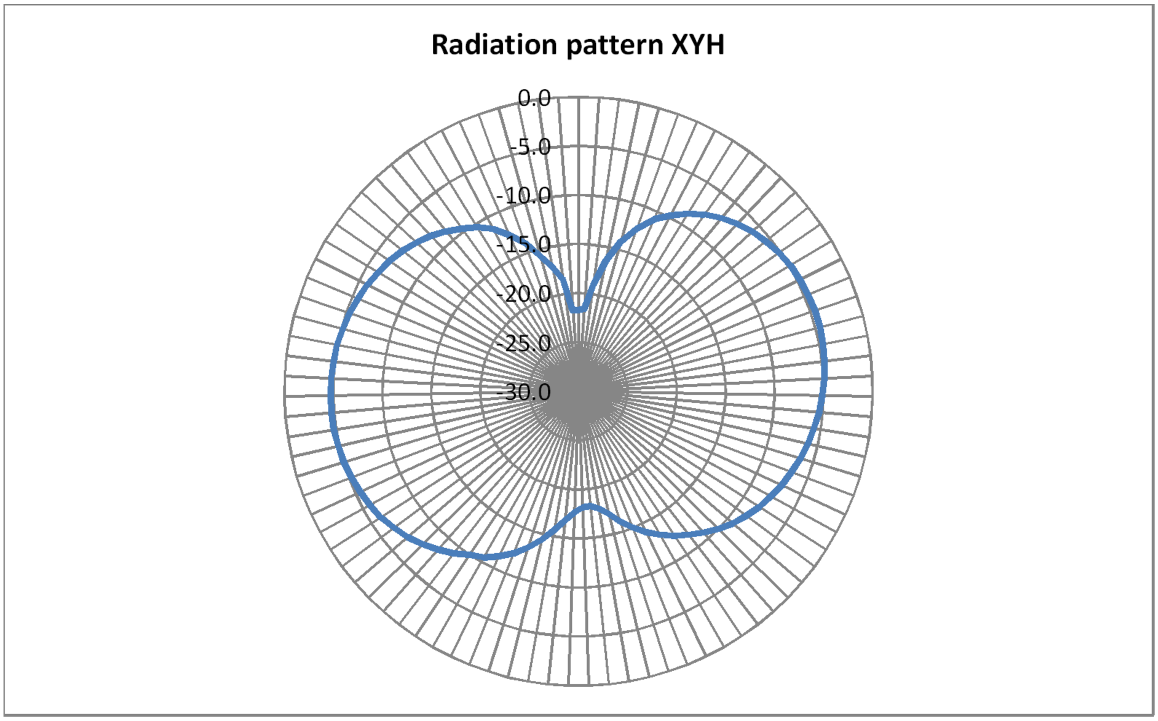


Figure 73. Figure 5.9. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

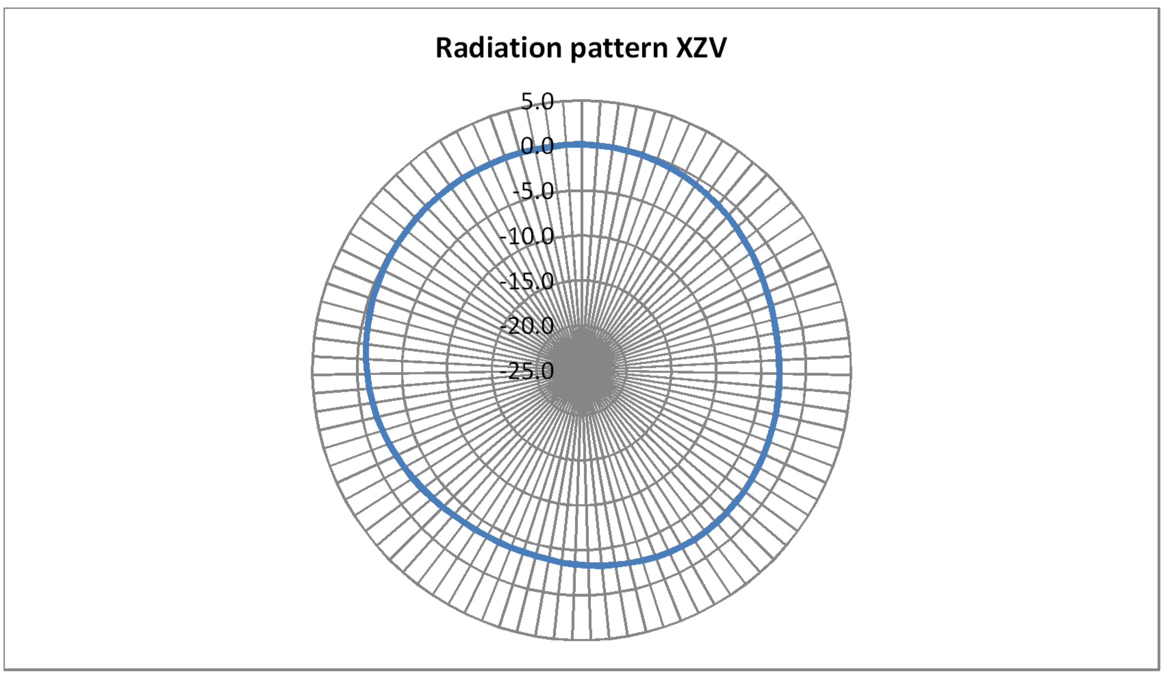


Figure 74. Figure 5.10. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

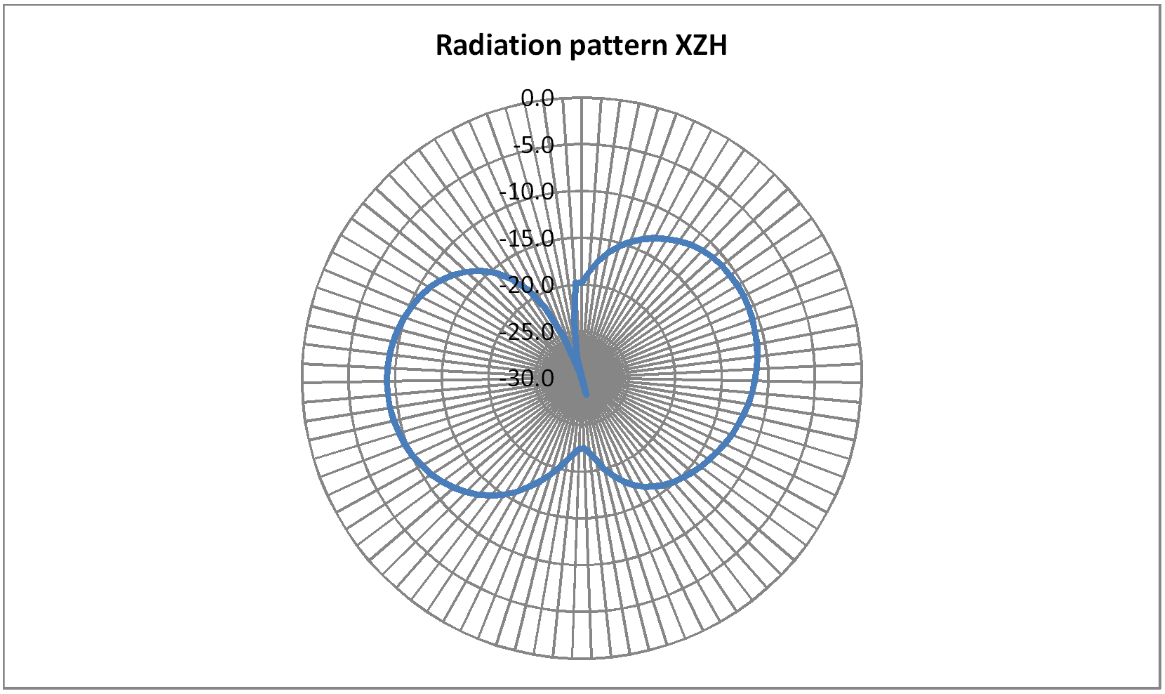


Figure 75. Figure 5.11. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

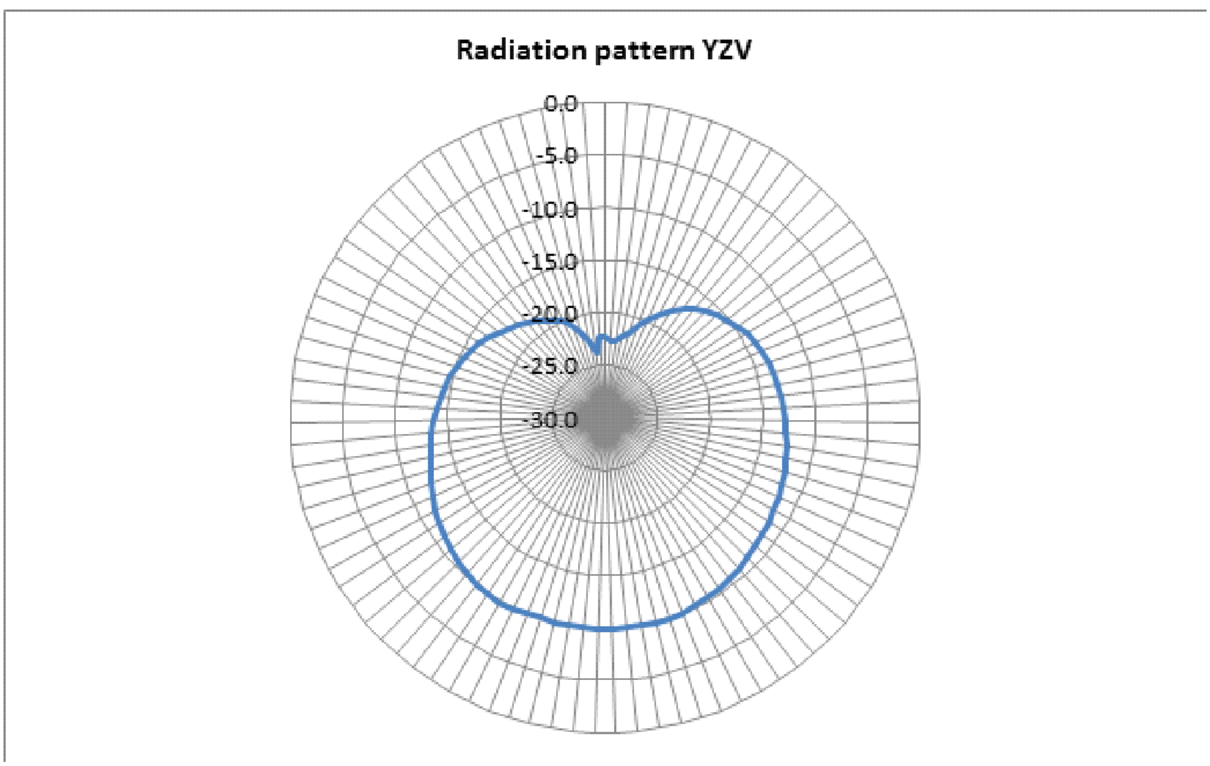


Figure 76. Figure 5.12. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

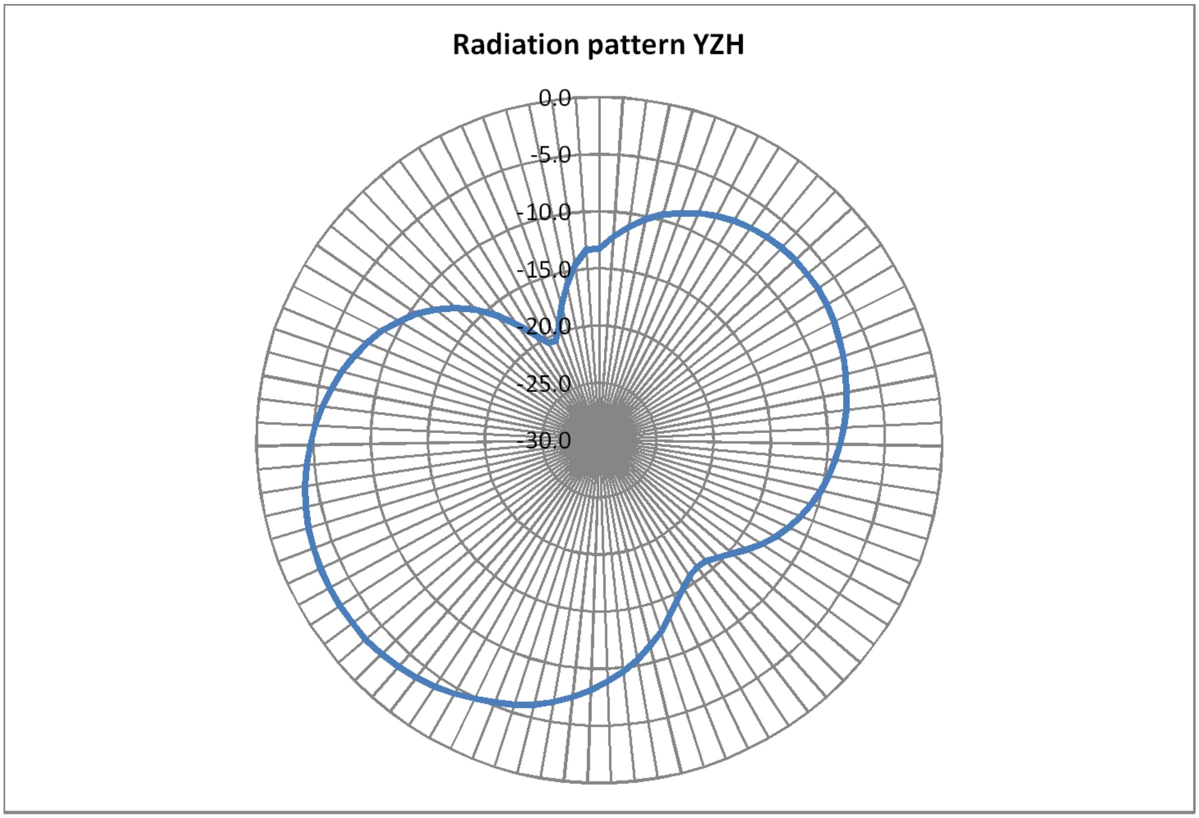


Figure 77. Figure 5.13. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

6.4. Radiated Harmonics (WES0036-01-APF868P-01)

The radiated harmonics of the small Panic IFA antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table together with the corresponding standard limits.

The small size panic button IFA antenna driven by the Si4460 10dBm class E match comply with the ETSI harmonic regulations. However, the margin is small at the 6th and 5th harmonic, in the YZ cuts.

Here it has to be noted that the potential source of the 5th and 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 5. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	5,92	10,2
XY	V	2nd	1736	-27.86	-44,59	16,7
XY	V	3rd	2604	-27.86	-51,00	23,1
XY	V	4th	3472	-27.86	-42,34	14,5
XY	V	5th	4340	-27.86	-33,75	5,9
XY	V	6th	5208	-27.86	-36,59	8,7
XY	V	7th	6076	-27.86	-45,25	17,4
XY	V	8th	6944	-27.86	-41,00	13,1
XY	V	9th	7812	-27.86	-41,50	13,6
XY	V	10th	8680	-27.86	-39,32	11,5
XY	H	Fund.	868	16.12	5,80	10,3
XY	H	2nd	1736	-27.86	-48,22	20,4
XY	H	3rd	2604	-27.86	-52,06	24,2
XY	H	4th	3472	-27.86	-43,12	15,3
XY	H	5th	4340	-27.86	-37,60	9,7
XY	H	6th	5208	-27.86	-34,93	7,1
XY	H	7th	6076	-27.86	-46,08	18,2
XY	H	8th	6944	-27.86	-43,07	15,2
XY	H	9th	7812	-27.86	-41,85	14,0
XY	H	10th	8680	-27.86	-38,23	10,4
XZ	V	Fund.	868	16.12	10,43	5,7
XZ	V	2nd	1736	-27.86	-42,22	14,4
XZ	V	3rd	2604	-27.86	-54,13	26,3
XZ	V	4th	3472	-27.86	-41,25	13,4

Table 5. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XZ	V	5th	4340	-27.86	-31,50	3,6
XZ	V	6th	5208	-27.86	-36,78	8,9
XZ	V	7th	6076	-27.86	-46,02	18,2
XZ	V	8th	6944	-27.86	-43,97	16,1
XZ	V	9th	7812	-27.86	-41,86	14,0
XZ	V	10th	8680	-27.86	-35,75	7,9
XZ	H	Fund.	868	16.12	1,17	15,0
XZ	H	2nd	1736	-27.86	-44,79	16,9
XZ	H	3rd	2604	-27.86	-55,16	27,3
XZ	H	4th	3472	-27.86	-42,23	14,4
XZ	H	5th	4340	-27.86	-31,77	3,9
XZ	H	6th	5208	-27.86	-34,95	7,1
XZ	H	7th	6076	-27.86	-45,79	17,9
XZ	H	8th	6944	-27.86	-41,73	13,9
XZ	H	9th	7812	-27.86	-40,92	13,1
XZ	H	10th	8680	-27.86	-32,72	4,9
YZ	V	Fund.	868	16.12	0,52	15,6
YZ	V	2nd	1736	-27.86	-48,02	20,2
YZ	V	3rd	2604	-27.86	-50,11	22,2
YZ	V	4th	3472	-27.86	-42,97	15,1
YZ	V	5th	4340	-27.86	-32,94	5,1
YZ	V	6th	5208	-27.86	-30,93	3,1
YZ	V	7th	6076	-27.86	-44,71	16,9
YZ	V	8th	6944	-27.86	-42,70	14,8
YZ	V	9th	7812	-27.86	-39,90	12,0

Table 5. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
YZ	V	10^{th}	8680	-27.86	-37,39	9,5
YZ	H	Fund.	868	16.12	7,22	8,9
YZ	H	2^{nd}	1736	-27.86	-40,43	12,6
YZ	H	3^{rd}	2604	-27.86	-44,86	17,0
YZ	H	4^{th}	3472	-27.86	-41,19	13,3
YZ	H	5^{th}	4340	-27.86	-28,50	0,6
YZ	H	6^{th}	5208	-27.86	-33,74	5,9
YZ	H	7^{th}	6076	-27.86	-45,31	17,4
YZ	H	8^{th}	6944	-27.86	-45,15	17,3
YZ	H	9^{th}	7812	-27.86	-41,97	14,1
YZ	H	10^{th}	8680	-27.86	-38,99	11,1

6.5. Range Test

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot (indoor). Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1108m.

The outdoor range test result using two panic button IFAs to the front direction (XY plane is horizontal and the Y axes are facing to each other as it is typical in normal panic button applications) is 1077m as shown in Figure 5.14. As it was mentioned in chapter 2 in real wrist applications where strong hand effect is present the achievable gain, and thus the achievable range can be much shorter.

Also it can be seen from the small panic button IFAs plots that the antenna gain is at maximum (~0dBi) at other directions (e.g. XZ cut, vertical polarization, Figure 5.10). With facing the TX-RX pair in this orientation (e.g. in non-panic applications) the range could be even higher by 40…50%. Of course it is valid without hand effect. With hand effect the pattern and the gain is different (weaker)

Indoor range test is not done, due to the lack of large enough building. But, from the TX power and sensitivity data an indoor range estimation can be given assuming a propagation factor of 4.5, which is typical value in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -

5dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 89m as it is shown in Fig. 5.15.

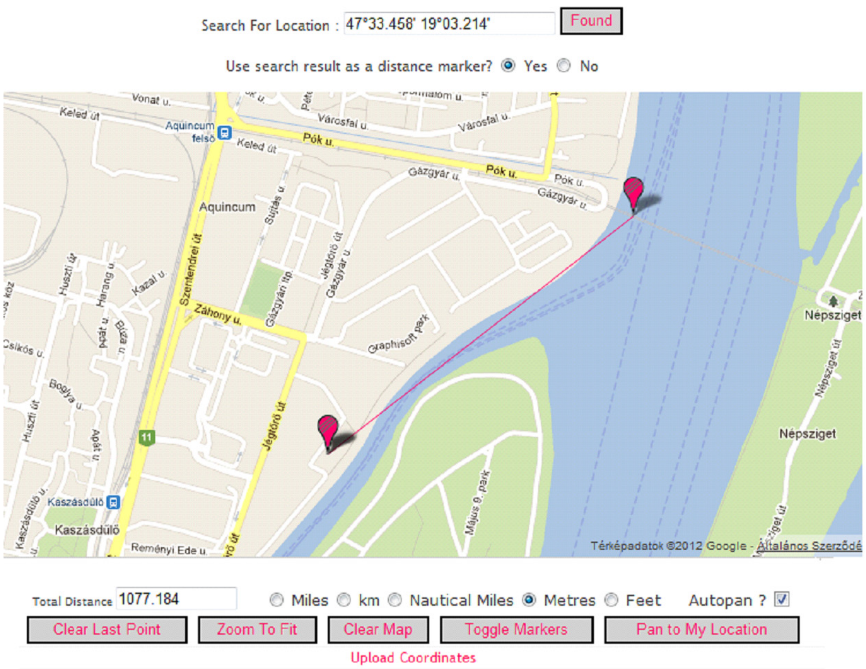


Figure 78. Figure 5.14 Outdoor range test result with two identical IFA panic button antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

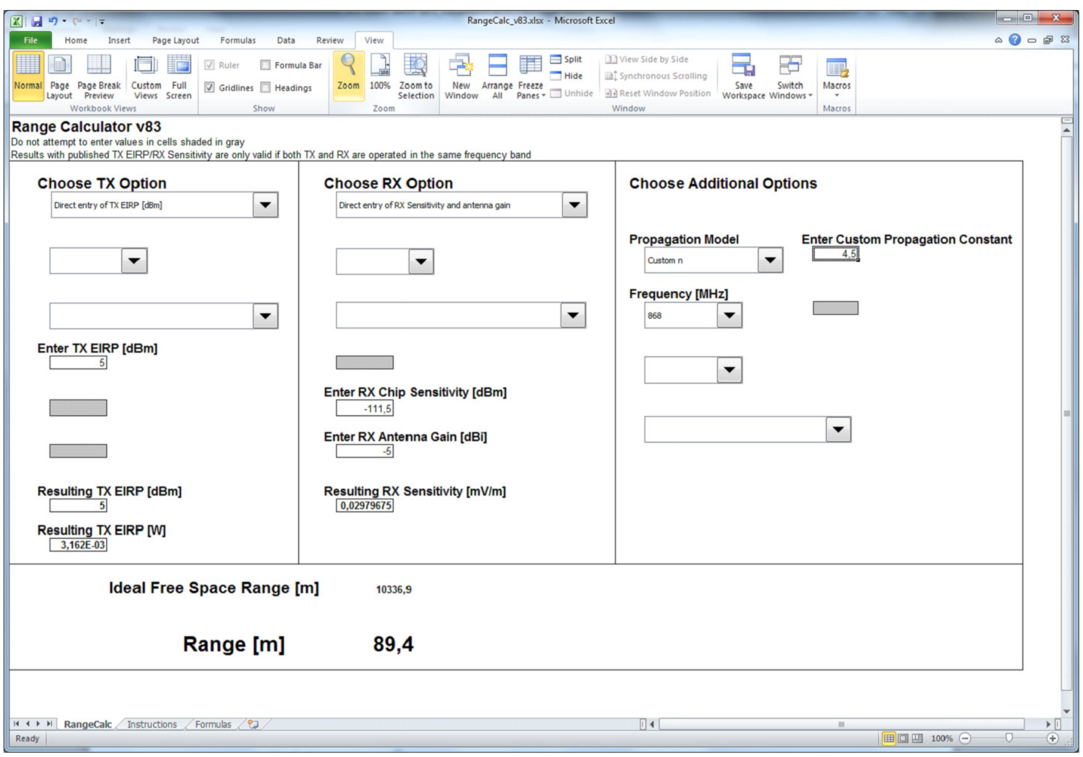


Figure 79. Figure 5.15. Indoor range estimation with two identical IFA panic button antennas and with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

7. Panic Button ILA (Printed) along the circumference (WES0036-01-APL868P-01)

- The antenna trace width is 0.5mm.
- The distance between the antenna trace outer edge and the PCB cutting edge is 1.5mm.
- The distance between the antenna trace inner edge and ground metal is 2mm.
- External matching network (shown in Figure 6.1) is required at the antenna input

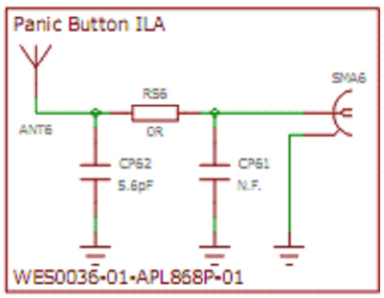


Figure 80. Figure 6.1. External matching network at 868MHz for the Panic Button ILA antenna

The picture of the antenna is shown in Figure 6.2.

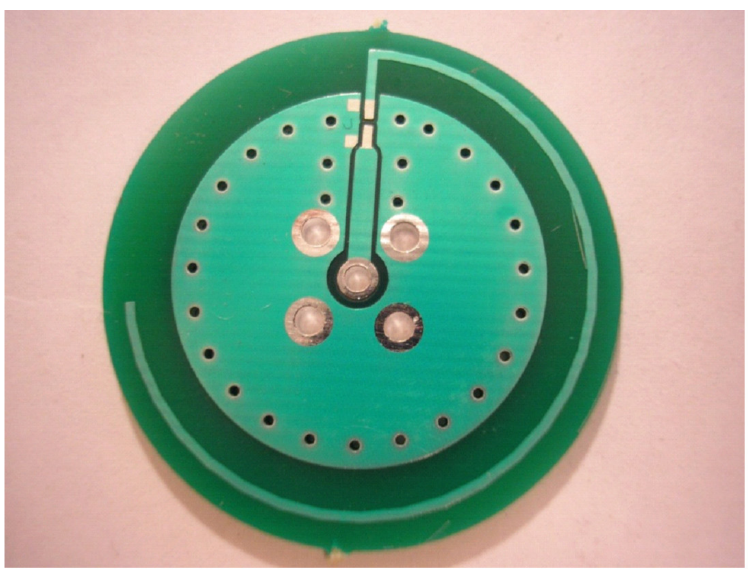


Figure 81. Figure 6.2. Small ILA antenna for panic button applications

7.1. Antenna Impedance (WES0036-01-APL868P-01)

The measurement setup is shown in Figure 6.3. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 6.4. The measured impedance of the antenna with its external matching network is shown in Figure 6.5 and 6.6 (up to

3GHz) with motherboard hand effect.

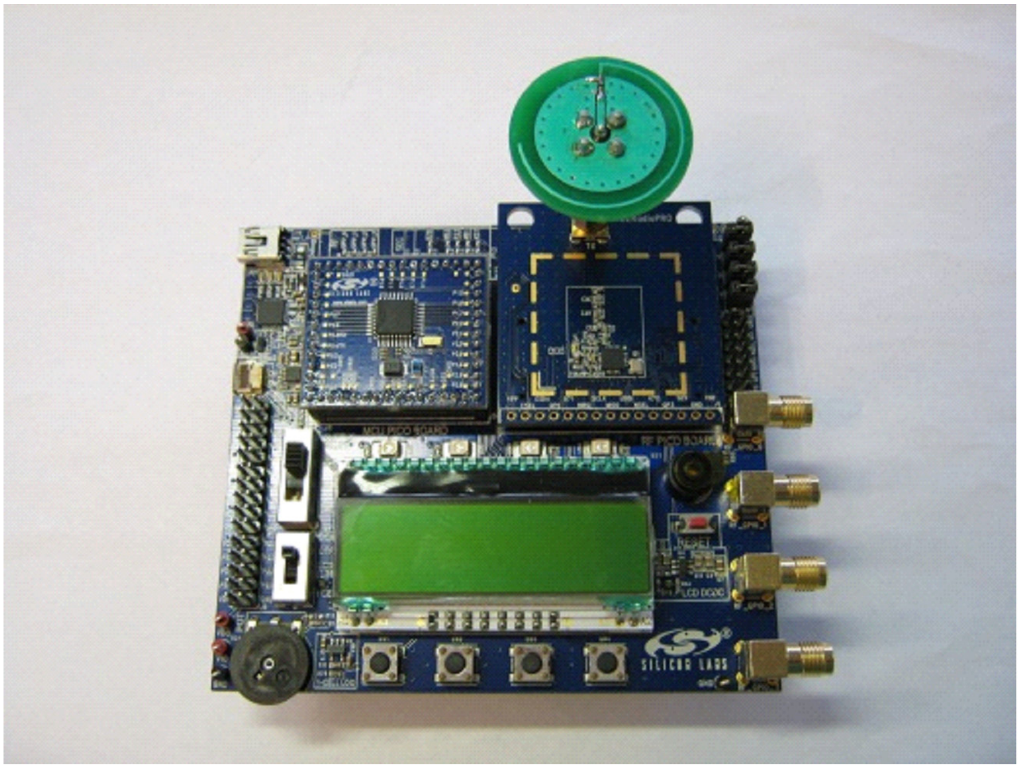


Figure 82. Figure 6.3. DUT in the final measurement setup

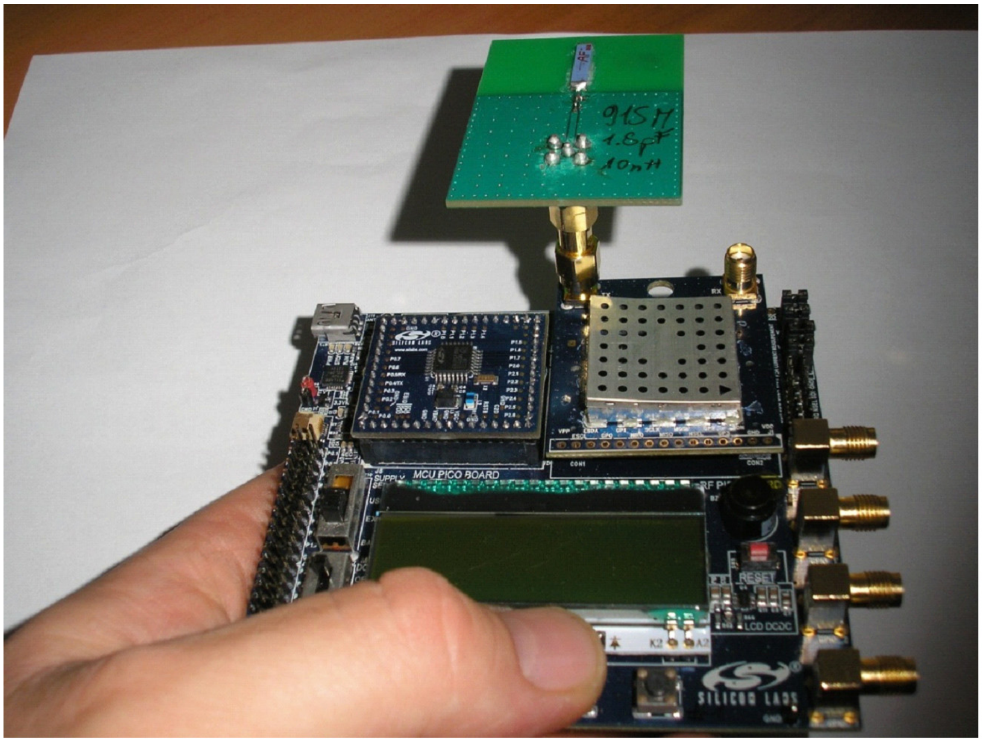


Figure 83. Figure 6.4. Typical hand effect on the main board during impedance and range measurement

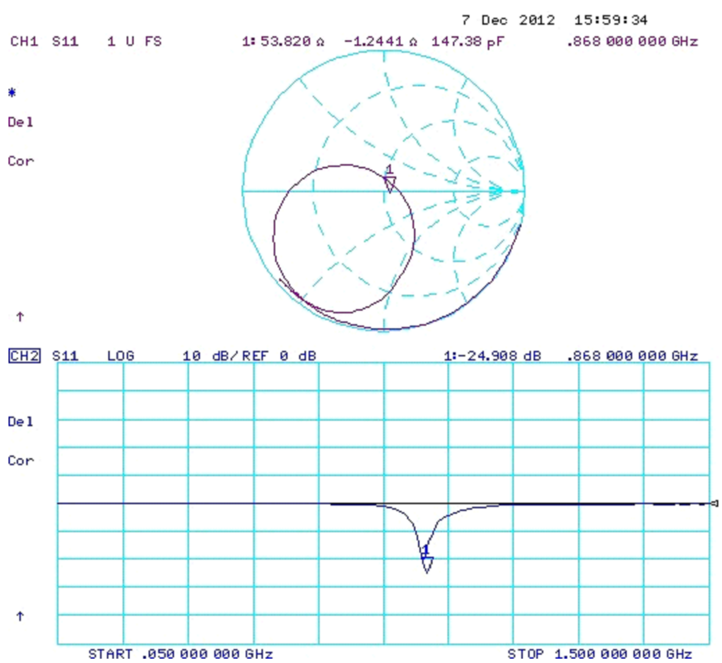


Figure 84. Figure 6.5. Measured impedance up to 1.5GHz with hand-effect on the main board

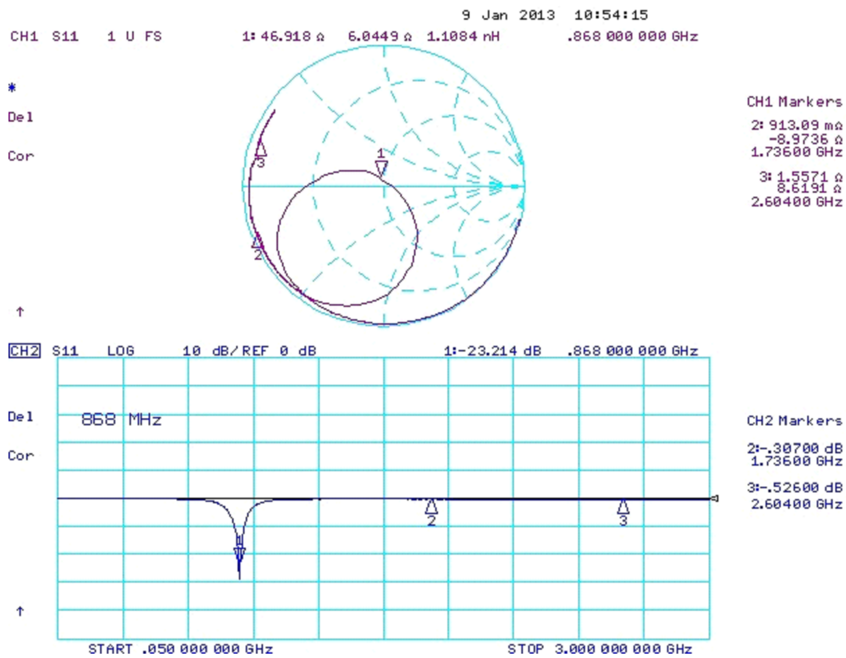


Figure 85. Figure 6.6. Measured impedance up to 3GHz with hand-effect on the main board

7.2. Antenna Gain (WES0036-01-APL868P-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 6.7). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection loss is negligible.

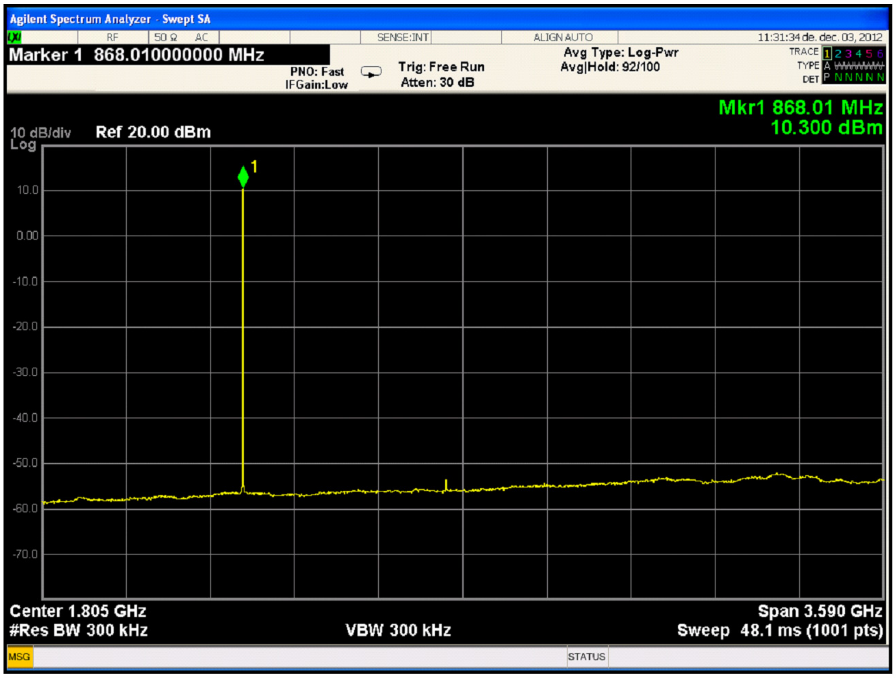


Figure 86. Figure 6.7. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 6.1). It is around 11.6dBm EIRP so the maximum gain number is ~1.3dBi as it is shown in Figure 6.11.

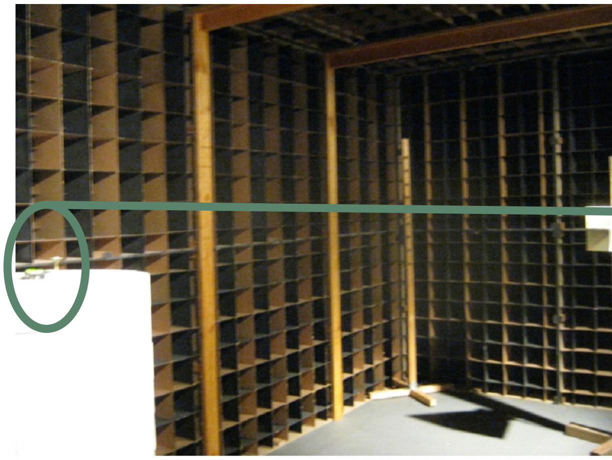
This gain number is surprisingly high for a panic button antenna. It should be emphasized that in typical panic button applications the grounding environment and the strength of the hand effect is different. In real panic button applications (instead of the SMA connector, SMA male-male transition, Pico Board and Wireless Motherboard) only a lithium coin battery is applied and the achievable antenna gain is much weaker.

Also in wrist applications the very close parallel hand has strong detuning effect. In these applications further impedance tuning of the antenna required and the radiation efficiency degrades strongly (please refer the “Antenna Design Guide for Single Ended 50 Ohm Antennas” document).

7.3. Radiation Patterns (WES0036-01-APL868P-01)

Radiation patterns of the small ILA antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture from the DUT with coordinate system under the radiated measurements is shown in Figure 6.8.



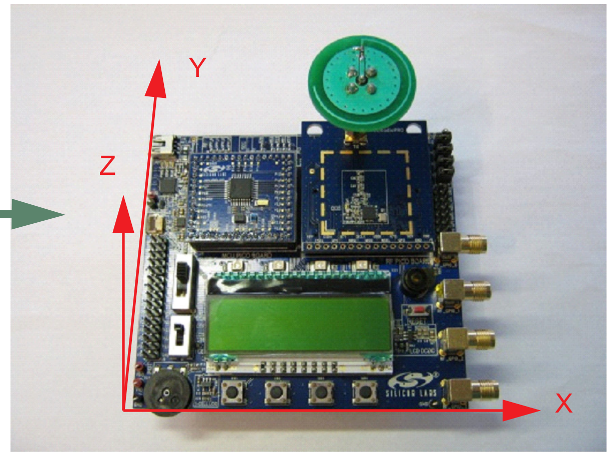


Figure 87. Figure 6.8. DUT in the antenna chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Fig. 6.9-6.14).

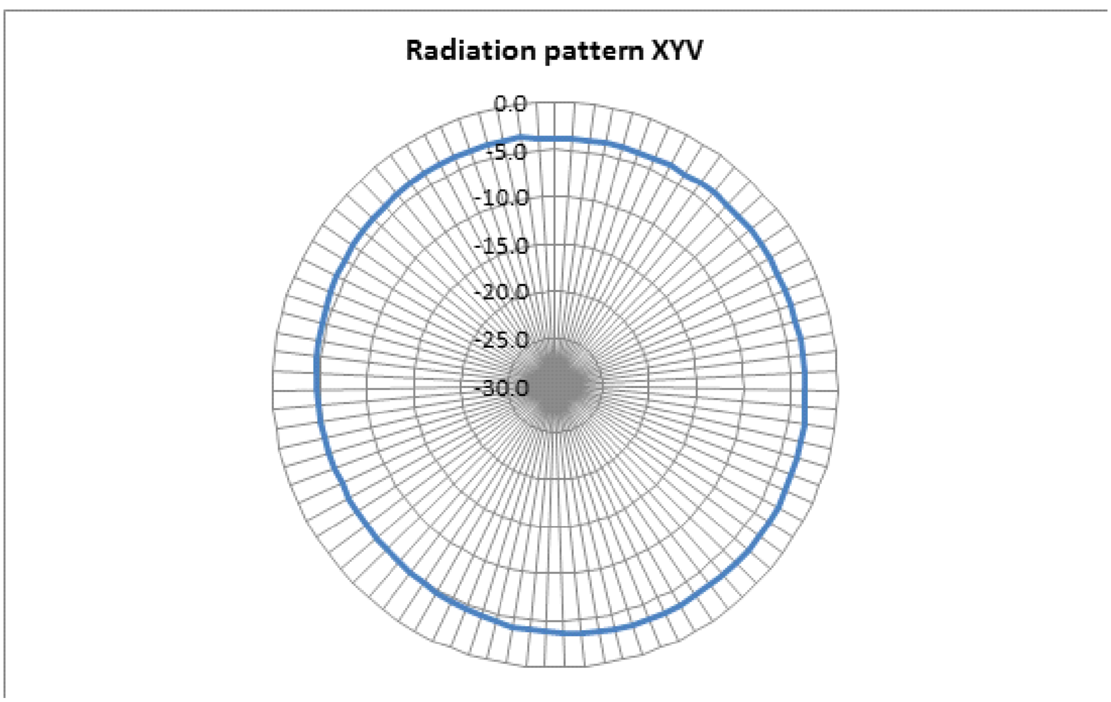


Figure 88. Figure 6.9. Radiation pattern in the XY cut with Vertical receiver antenna polarization

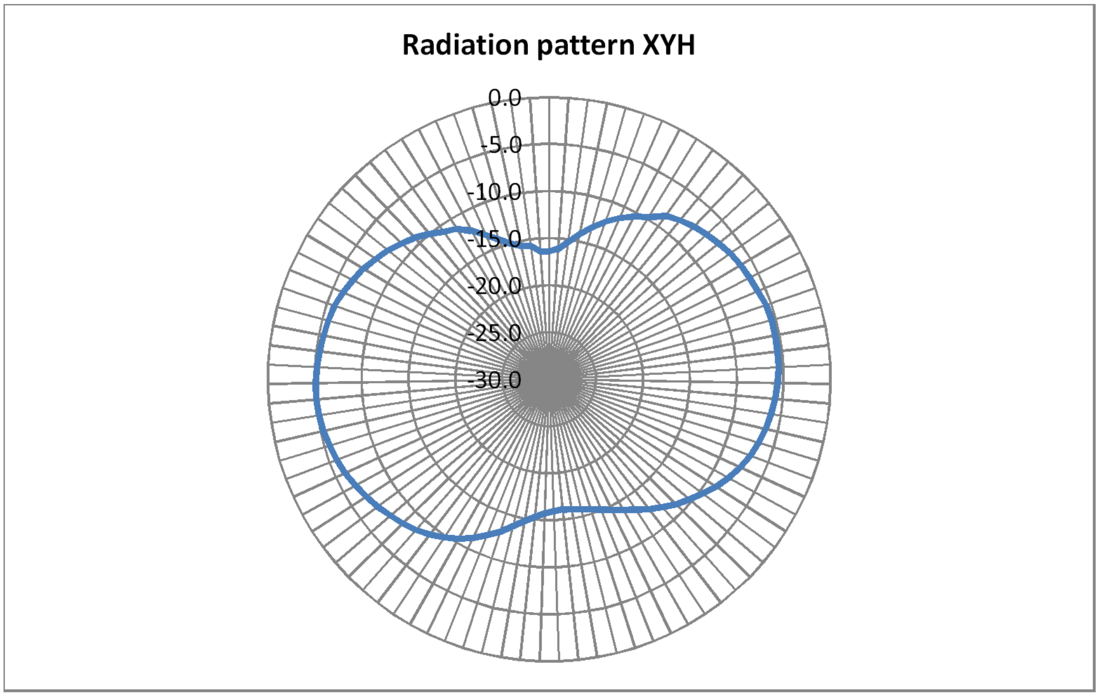


Figure 89. Figure 6.10. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

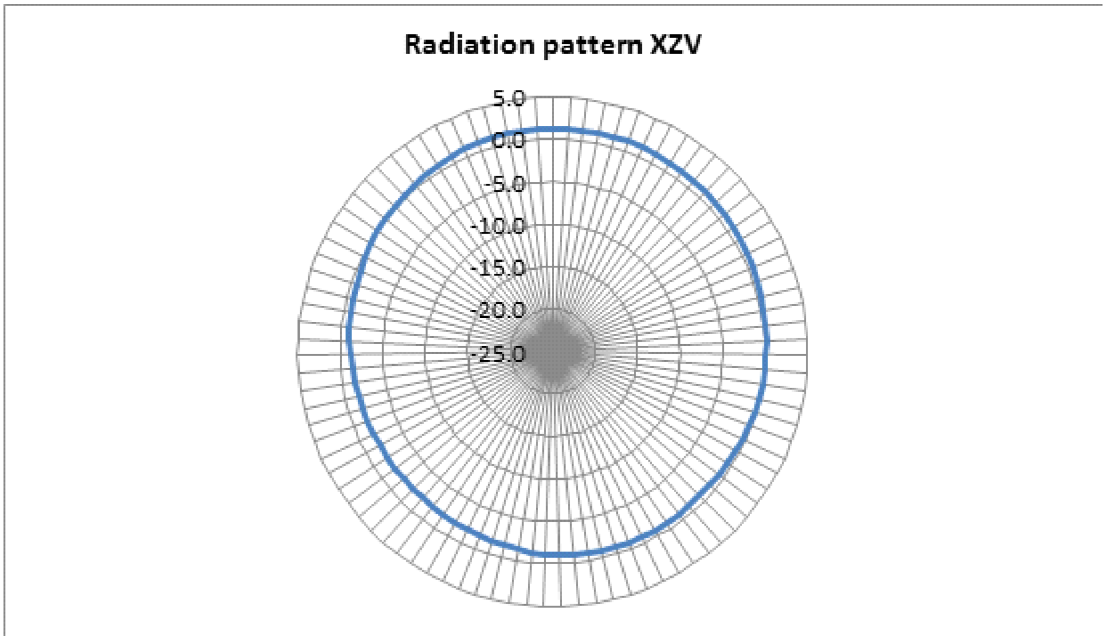


Figure 90. Figure 6.11. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

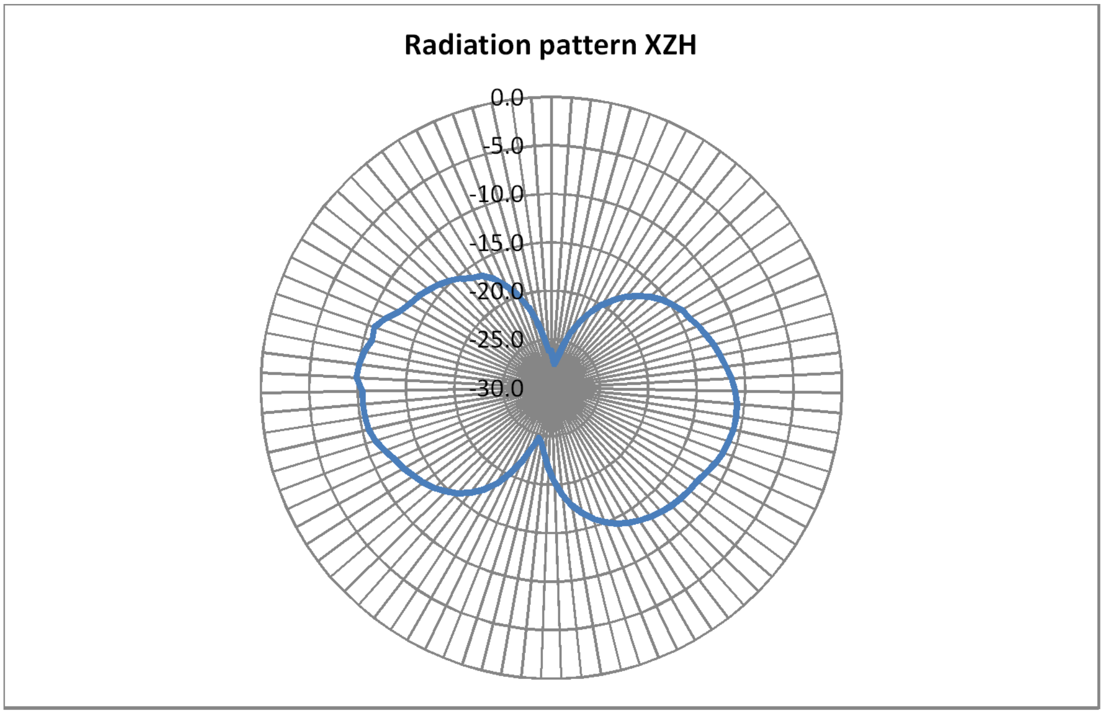


Figure 91. Figure 6.12. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

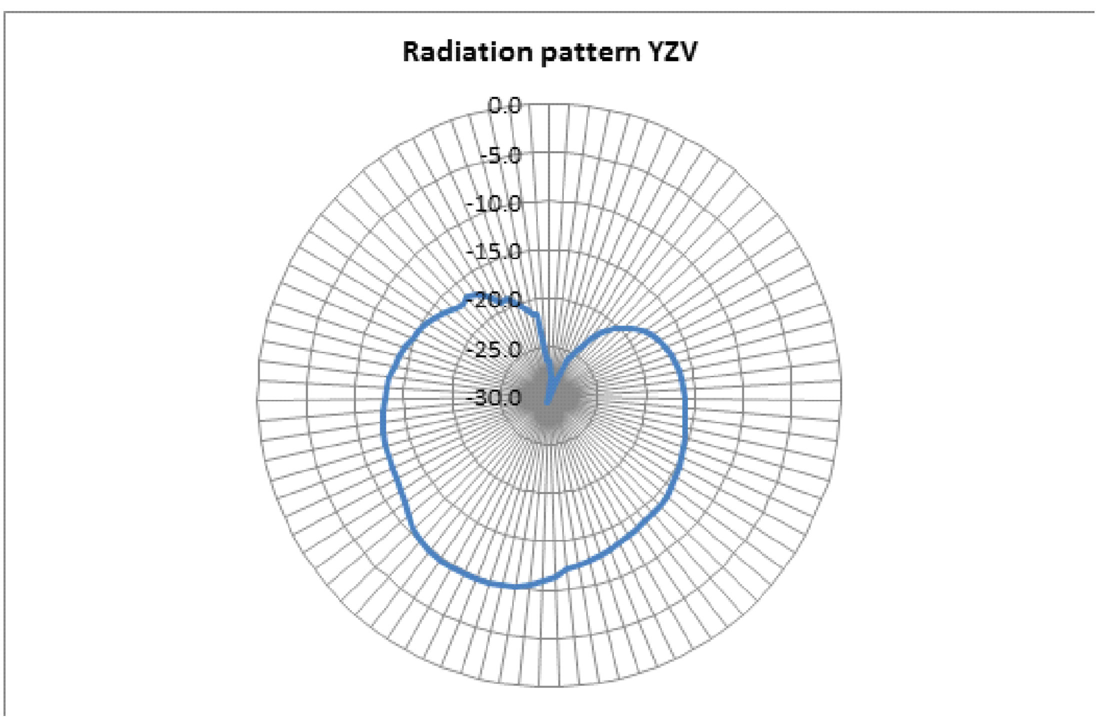


Figure 92. Figure 6.13. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

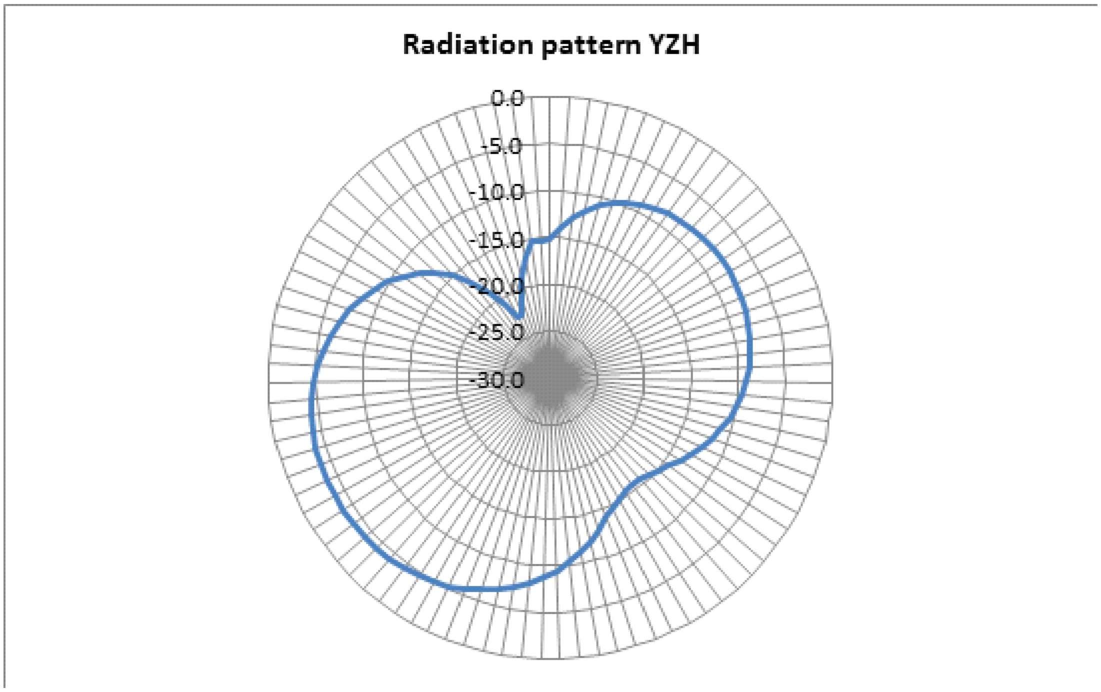


Figure 93. Figure 6.14. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

7.4. Radiated Harmonics (WES0036-01-APL868P-01)

The radiated harmonics of the small ILA antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table together with the corresponding standard limits.

The small size panic button ILA antenna driven by the Si4460 10dBm class E match (4060-PCE10B868 Pico Board) comply with the ETSI harmonic regulations. However, the margin is small (~3.5dB) at the 6th harmonic, in the YZV cut.

Here it has to be noted that the potential source of the 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 6. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	7,22	8,9
XY	V	2nd	1736	-27.86	-44,17	16,3
XY	V	3rd	2604	-27.86	-49,71	21,8
XY	V	4th	3472	-27.86	-38,59	10,7
XY	V	5th	4340	-27.86	-37,86	10,0
XY	V	6th	5208	-27.86	-36,55	8,7
XY	V	7th	6076	-27.86	-45,91	18,1
XY	V	8th	6944	-27.86	-43,25	15,4
XY	V	9th	7812	-27.86	-42,30	14,4
XY	V	10th	8680	-27.86	-39,60	11,7
XY	H	Fund.	868	16.12	5,20	10,9
XY	H	2nd	1736	-27.86	-47,21	19,3
XY	H	3rd	2604	-27.86	-51,42	23,6
XY	H	4th	3472	-27.86	-43,04	15,2
XY	H	5th	4340	-27.86	-38,84	11,0
XY	H	6th	5208	-27.86	-34,58	6,7
XY	H	7th	6076	-27.86	-46,42	18,6
XY	H	8th	6944	-27.86	-44,54	16,7
XY	H	9th	7812	-27.86	-41,41	13,5
XY	H	10th	8680	-27.86	-38,15	10,3
XZ	V	Fund.	868	16.12	11,60	4,5
XZ	V	2nd	1736	-27.86	-43,39	15,5
XZ	V	3rd	2604	-27.86	-54,77	26,9
XZ	V	4th	3472	-27.86	-38,55	10,7

Table 6. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XZ	V	5th	4340	-27.86	-34,02	6,2
XZ	V	6th	5208	-27.86	-35,35	7,5
XZ	V	7th	6076	-27.86	-45,34	17,5
XZ	V	8th	6944	-27.86	-44,27	16,4
XZ	V	9th	7812	-27.86	-42,07	14,2
XZ	V	10th	8680	-27.86	-38,60	10,7
XZ	H	Fund.	868	16.12	0,41	15,7
XZ	H	2nd	1736	-27.86	-44,94	17,1
XZ	H	3rd	2604	-27.86	-52,02	24,2
XZ	H	4th	3472	-27.86	-41,79	13,9
XZ	H	5th	4340	-27.86	-34,95	7,1
XZ	H	6th	5208	-27.86	-34,48	6,6
XZ	H	7th	6076	-27.86	-45,57	17,7
XZ	H	8th	6944	-27.86	-41,27	13,4
XZ	H	9th	7812	-27.86	-41,38	13,5
XZ	H	10th	8680	-27.86	-35,22	7,4
YZ	V	Fund.	868	16.12	0,63	15,5
YZ	V	2nd	1736	-27.86	-47,82	20,0
YZ	V	3rd	2604	-27.86	-50,58	22,7
YZ	V	4th	3472	-27.86	-41,33	13,5
YZ	V	5th	4340	-27.86	-37,71	9,9
YZ	V	6th	5208	-27.86	-31,25	3,4
YZ	V	7th	6076	-27.86	-43,41	15,6
YZ	V	8th	6944	-27.86	-43,39	15,5
YZ	V	9th	7812	-27.86	-41,33	13,5

Table 6. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
YZ	V	10th	8680	-27.86	-39,10	11,2
YZ	H	Fund.	868	16.12	6,54	9,6
YZ	H	2nd	1736	-27.86	-41,71	13,8
YZ	H	3rd	2604	-27.86	-47,00	19,1
YZ	H	4th	3472	-27.86	-39,88	12,0
YZ	H	5th	4340	-27.86	-34,19	6,3
YZ	H	6th	5208	-27.86	-34,53	6,7
YZ	H	7th	6076	-27.86	-44,62	16,8
YZ	H	8th	6944	-27.86	-44,02	16,2
YZ	H	9th	7812	-27.86	-41,80	13,9
YZ	H	10th	8680	-27.86	-39,60	11,7

7.5. Range Test (WES0036-01-APL868P-01)

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot (indoor). Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1107m.

The outdoor range test result using two panic button ILAs to the front direction (XY plane is horizontal and the Y axes are facing to each other as it is typical in normal panic button applications) is 1077m as shown in Figure 6.15. As it was mentioned in chapter 2 in real wrist applications where strong hand effect is present the achievable gain, and thus the achievable range can be much shorter.

Also it can be seen from the small panic button ILAs plots that the antenna gain is at maximum (~+1.2dBi) at other directions (e.g. XZ cut, vertical polarization, Figure 6.11). With facing the TX-RX pair in this orientation (e.g. in non-panic applications) the range could be even higher by 40…50%. Of course it is valid without hand effect. With hand effect the pattern and the gain is different (weaker)

Indoor range test is not done, due to the lack of large enough building. But, from the TX power and sensitivity data an indoor range estimation can be given assuming a propagation factor of 4.5, which is typical value in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -4dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 99m as it is shown in Fig. 6.16.

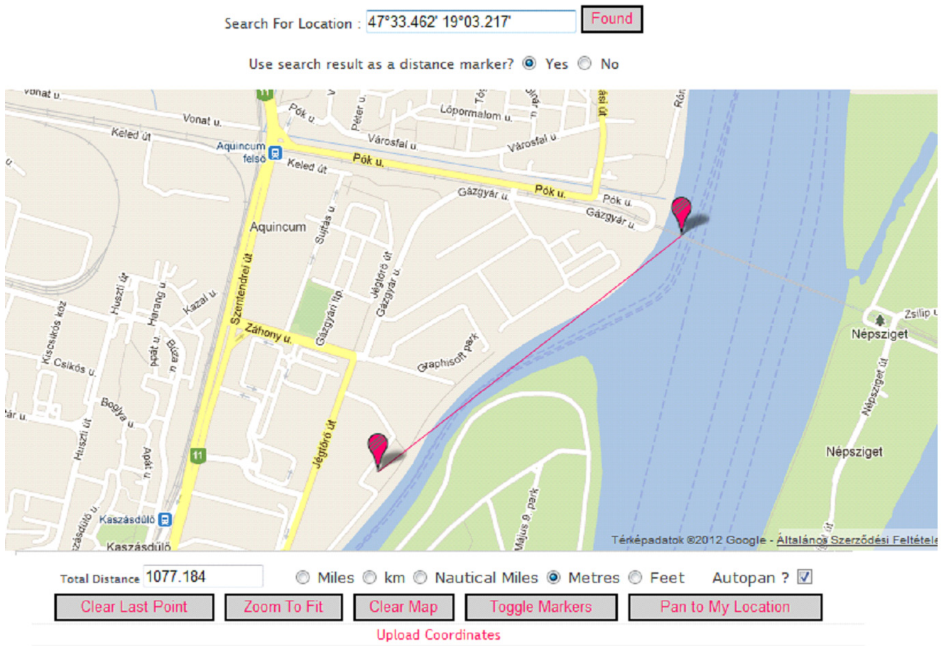


Figure 94. Figure 6.15. Outdoor range test result with two identical ILA panic button antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

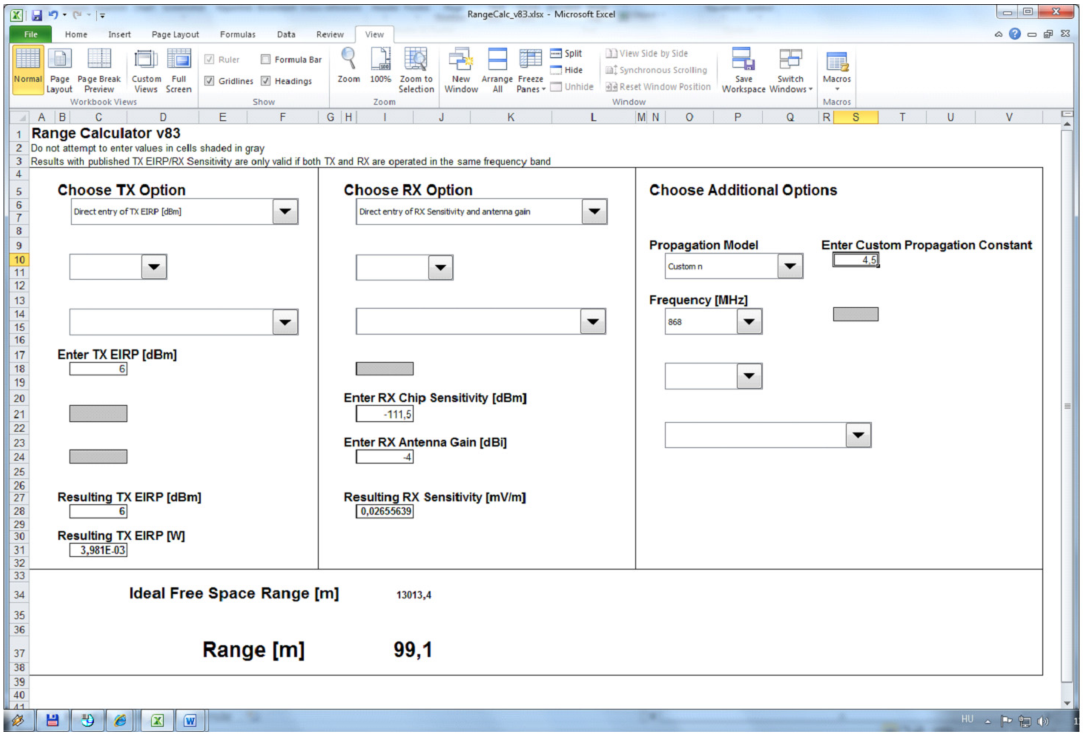


Figure 95. Figure 6.16. Indoor range estimation with two identical ILA panic button antennas and with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

8. Printed Meander Monopole (WES0037-01-APN868D-01)

External matching network (shown in Figure 7.1) is required at the antenna input.

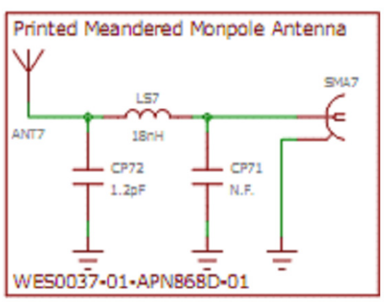


Figure 96. Figure 7.1. External matching network at 868M for the Printed Meander antenna

The picture of the antenna is shown in Figure 7.2.

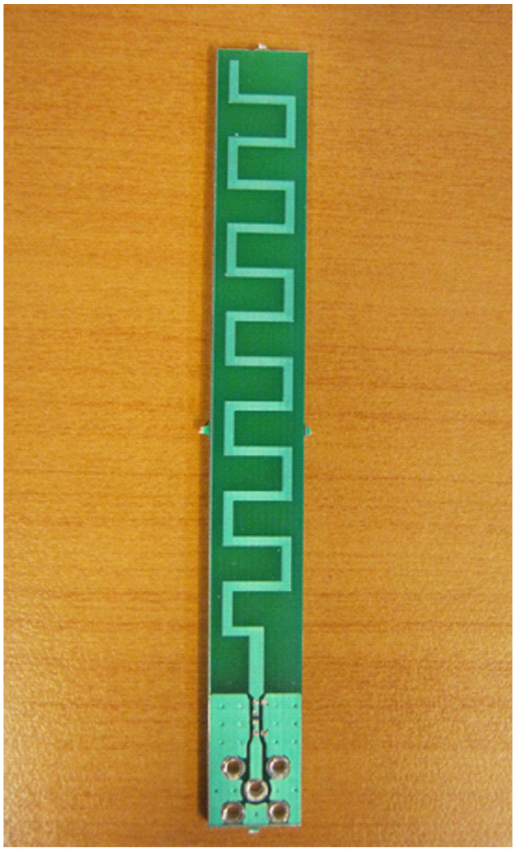


Figure 97. Figure 7.2. Printed Meander Monopole antenna

8.1. Antenna Impedance (WES0037-01-APN868D-01)

The measurement setup is shown in Figure 7.3. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 7.4. The measured impedance of the antenna with its external matching network is shown in Figure 7.5 and 7.6 (up to 3GHz) with motherboard hand effect.

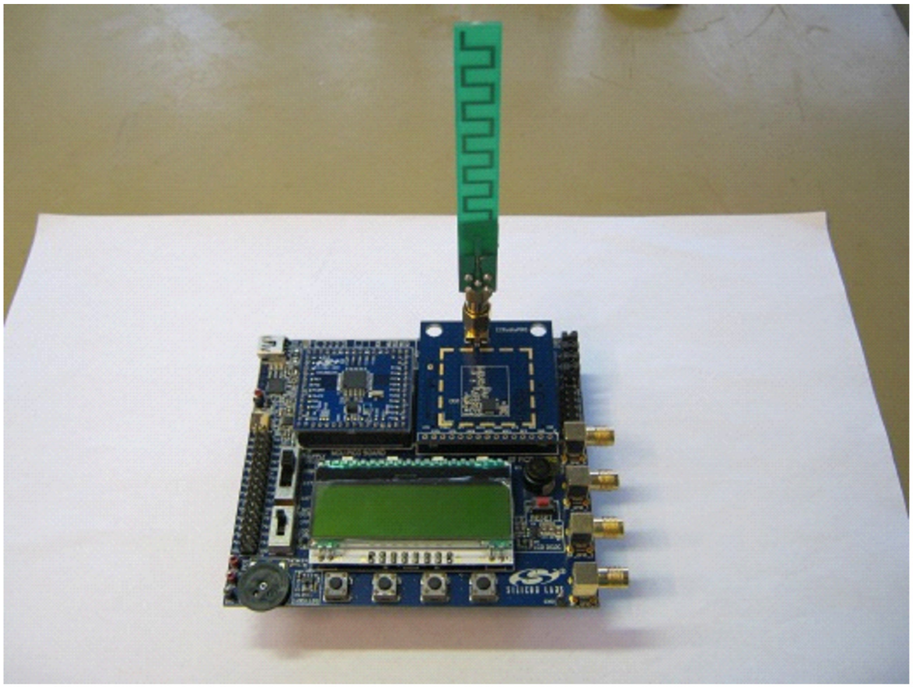


Figure 98. Figure 7.3. DUT in the final measurement setup

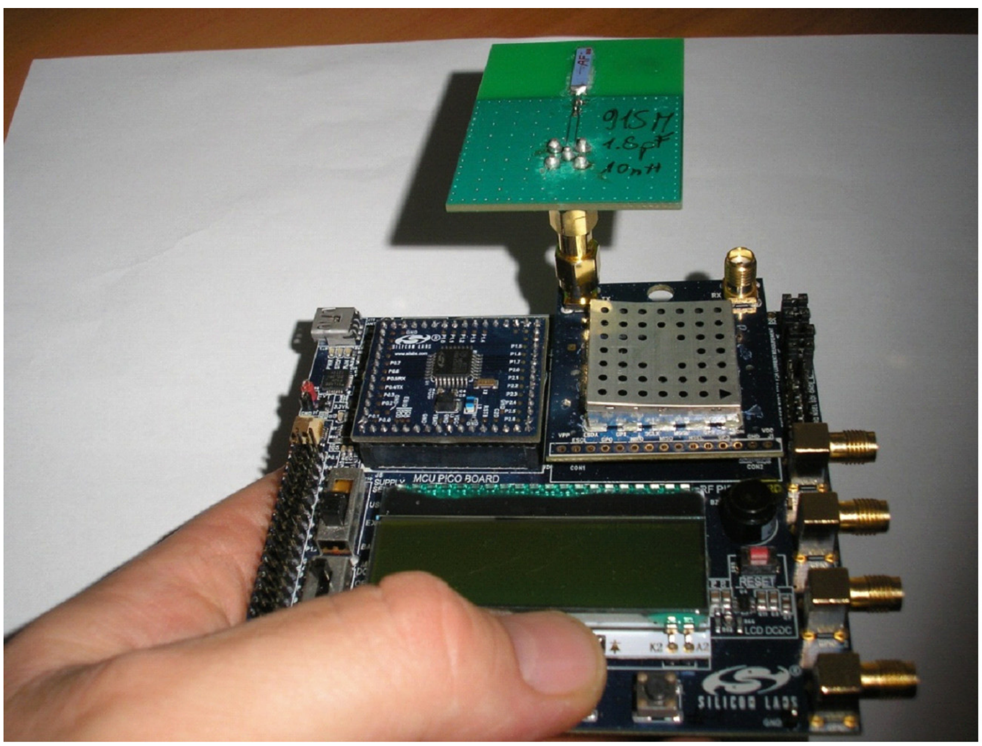


Figure 99. Figure 7.4. Typical hand effect on the main board during impedance and range measurement

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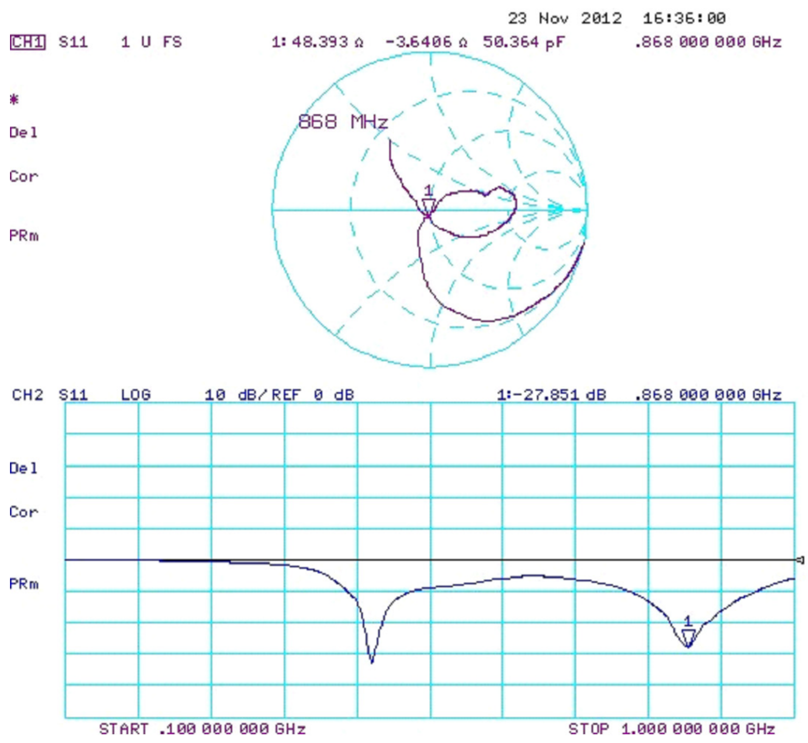


Figure 100. Figure 7.5. Measured impedance up to 1GHz with hand-effect on the main board

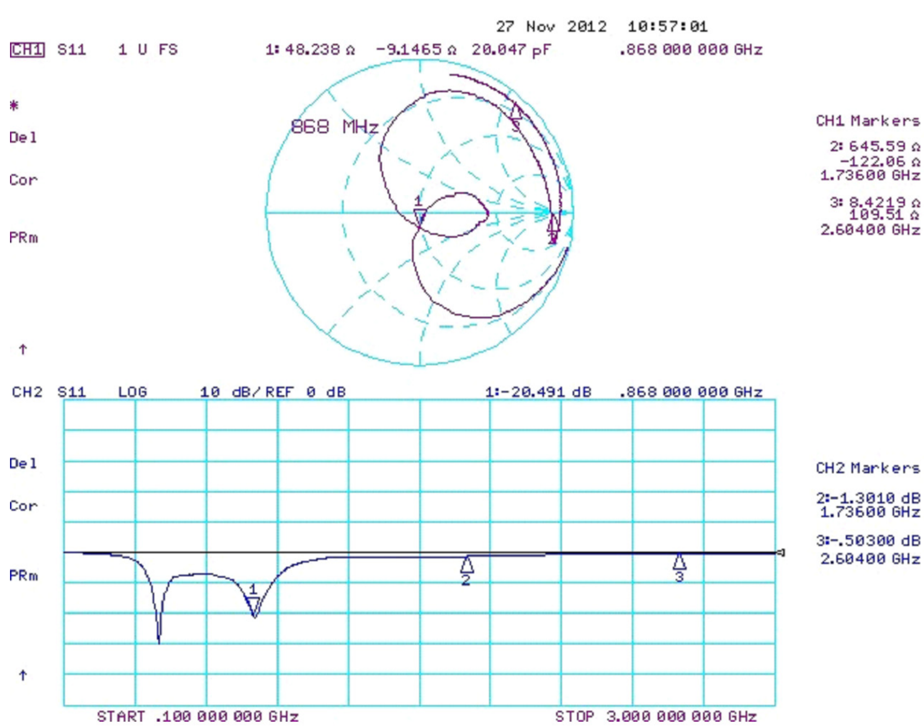


Figure 101. Figure 7.6. Measured impedance up to 3GHz with hand-effect on the main board

8.2. Antenna Gain (WES0037-01-APN868D-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 7.7). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection is negligible.

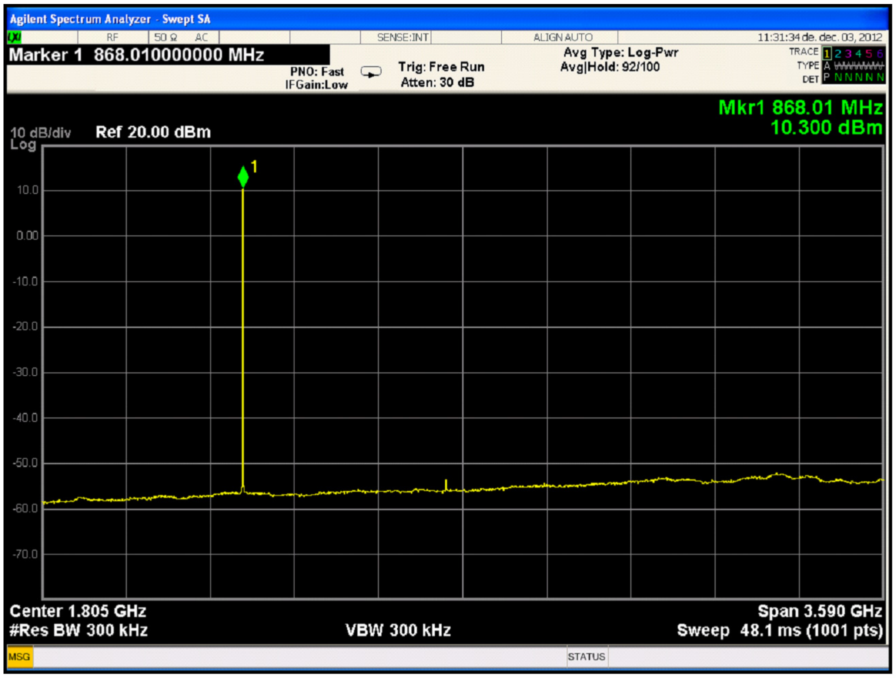


Figure 102. Figure 7.7. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XY cut (Table 7.1). It is around 9.3dBm EIRP so the maximum gain number is ~-1dBi as it is shown in Figure 7.8.

8.3. Radiation Patterns (WES0037-01-APN868D-01)

Radiation patterns of the printed meander antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture from the DUT with coordinate system under the radiated measurements is shown in Figure 7.8.

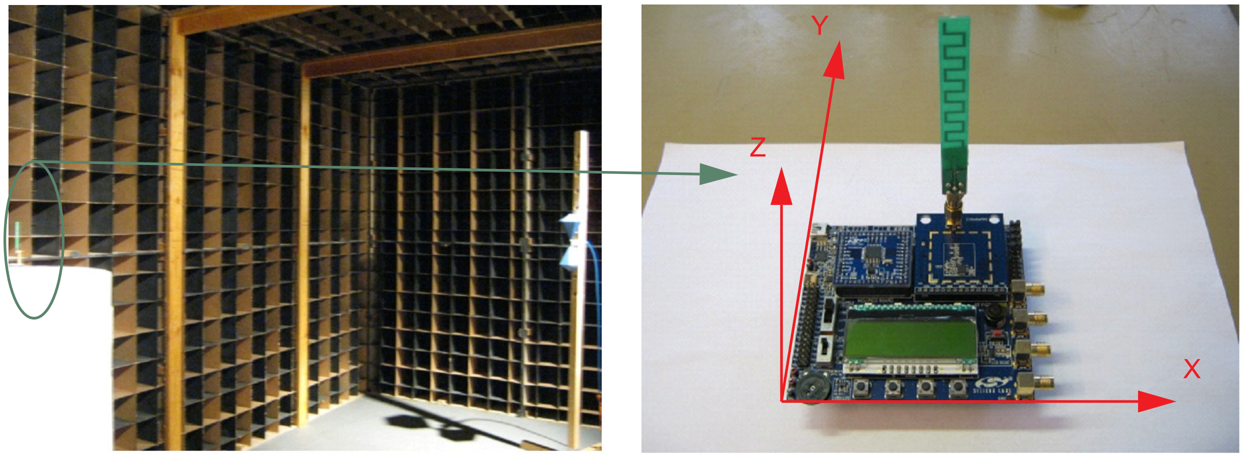


Figure 103. Figure 7.8. DUT in the antenna chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Fig. 7.9-7.14).

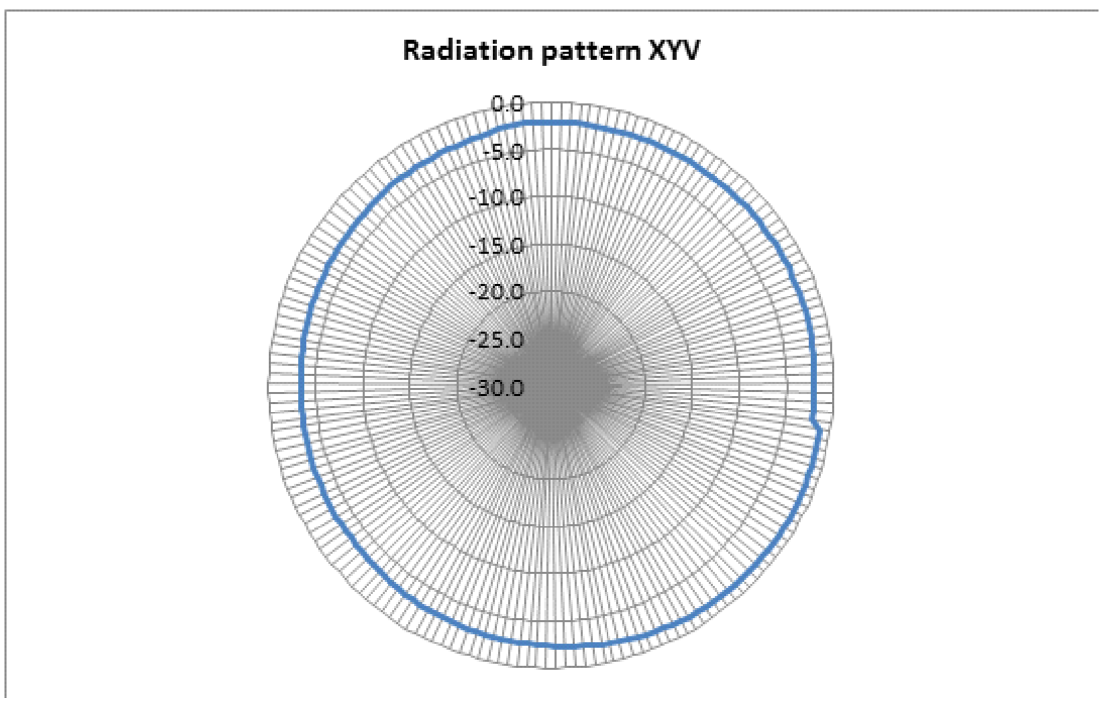


Figure 104. Figure 7.9. Radiation pattern in the XY cut with Vertical receiver antenna polarization

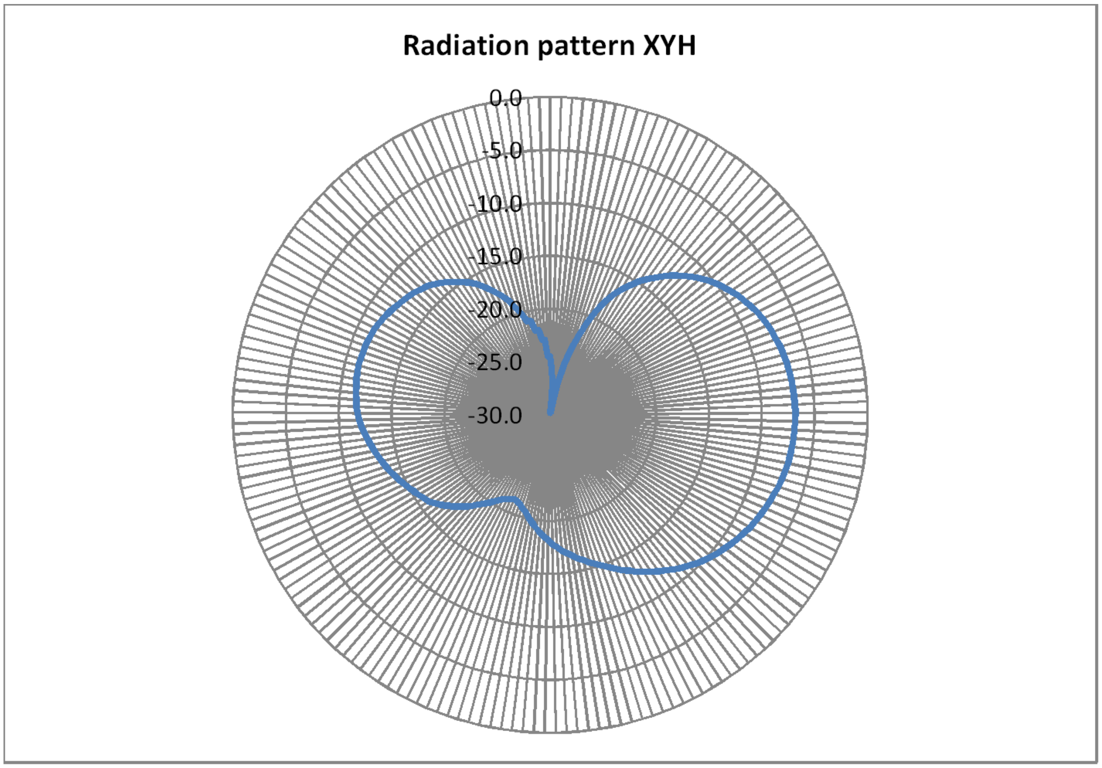


Figure 105. Figure 7.10. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

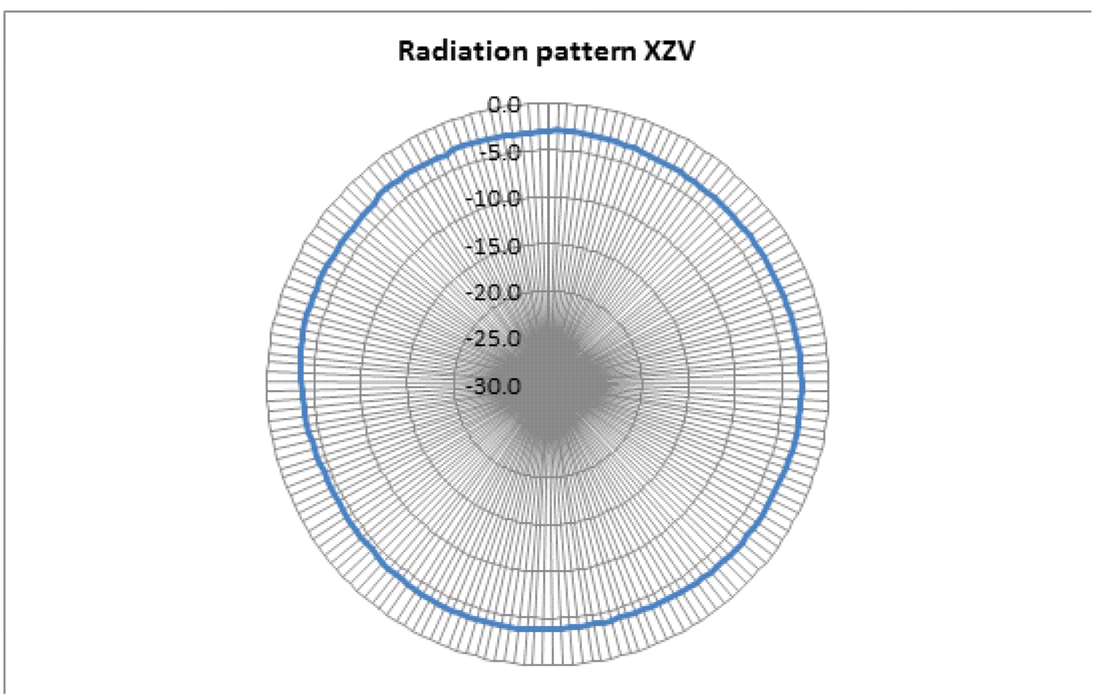


Figure 106. Figure 7.11. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

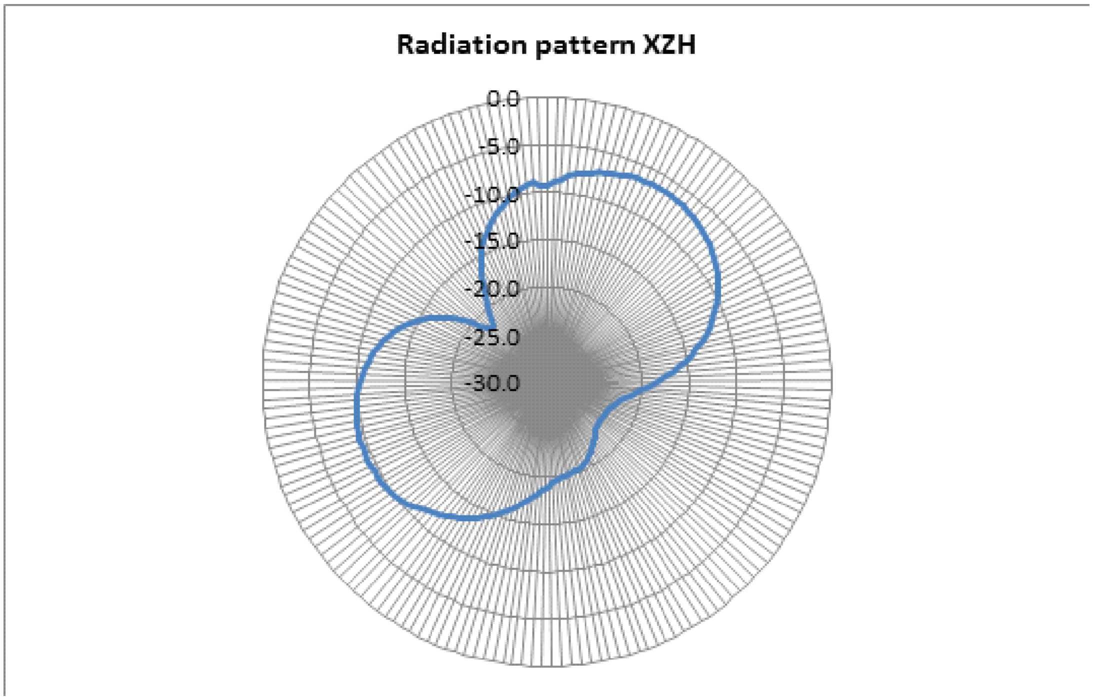


Figure 107. Figure 7.12. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

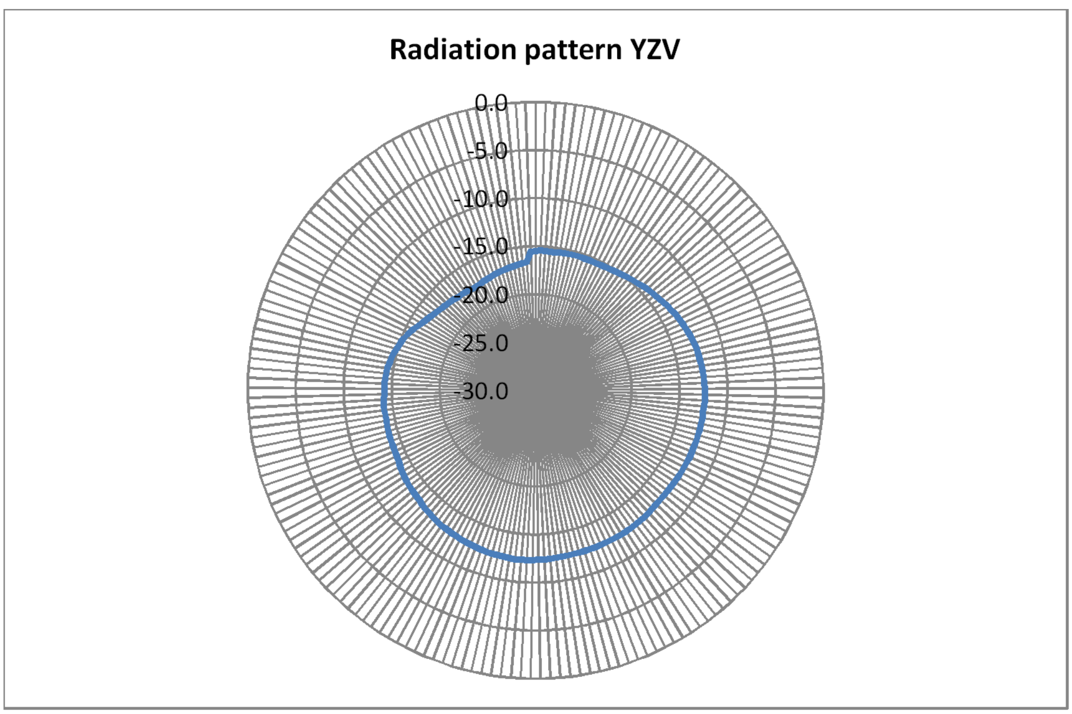


Figure 108. Figure 7.13. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

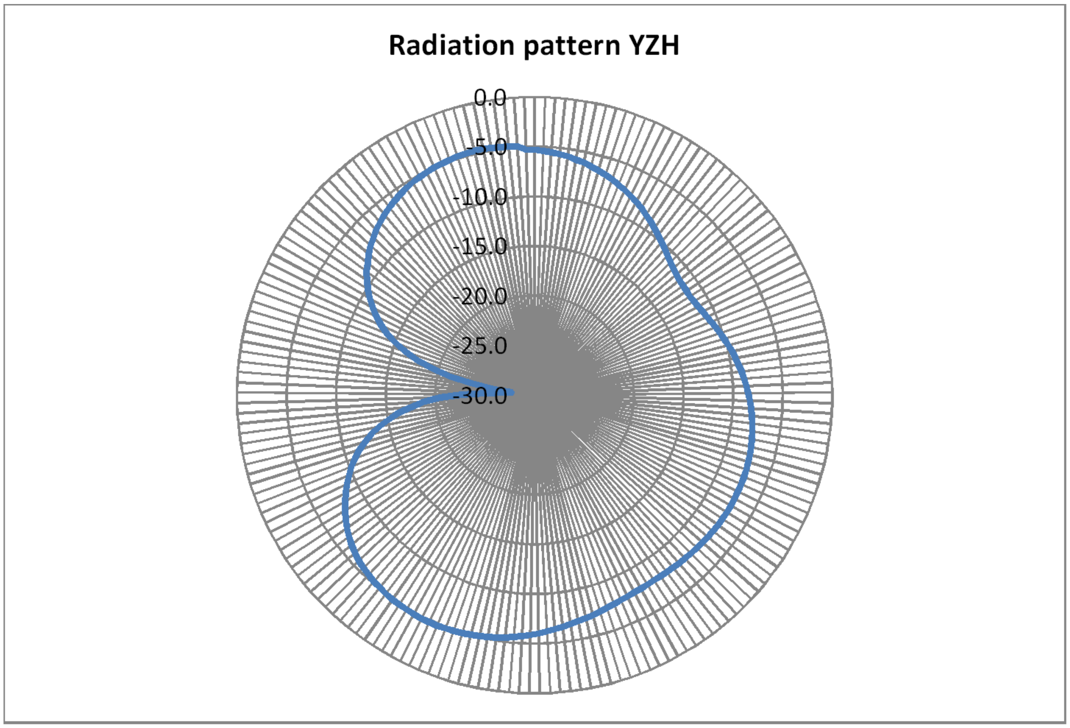


Figure 109. Figure 7.14. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

8.4. Radiated Harmonics (WES0037-01-APN868D-01)

The radiated harmonics of the printed meander antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table together with the corresponding standard limits.

The Antenna is ETSI compliant, but the 6th harmonic is very close to the limit in some cuts. Here it has to be noted that the potential source of the 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 7. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	9,25	6,9
XY	V	2^{nd}	1736	-27.86	-49,20	21,3

Table 7. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	3rd	2604	-27.86	-45,64	17,8
XY	V	4th	3472	-27.86	-44,82	17,0
XY	V	5th	4340	-27.86	-34,48	6,6
XY	V	6th	5208	-27.86	-31,40	3,5
XY	V	7th	6076	-27.86	-41,79	13,9
XY	V	8th	6944	-27.86	-44,28	16,4
XY	V	9th	7812	-27.86	-40,90	13,0
XY	V	10th	8680	-27.86	-36,33	8,5
XY	H	Fund.	868	16.12	3,48	12,6
XY	H	2nd	1736	-27.86	-48,54	20,7
XY	H	3rd	2604	-27.86	-49,29	21,4
XY	H	4th	3472	-27.86	-45,72	17,9
XY	H	5th	4340	-27.86	-36,63	8,8
XY	H	6th	5208	-27.86	-33,47	5,6
XY	H	7th	6076	-27.86	-41,26	13,4
XY	H	8th	6944	-27.86	-44,26	16,4
XY	H	9th	7812	-27.86	-40,76	12,9
XY	H	10th	8680	-27.86	-38,61	10,8
XZ	V	Fund.	868	16.12	7,41	8,7
XZ	V	2nd	1736	-27.86	-41,29	13,4
XZ	V	3rd	2604	-27.86	-51,63	23,8
XZ	V	4th	3472	-27.86	-43,47	15,6
XZ	V	5th	4340	-27.86	-31,67	3,8
XZ	V	6th	5208	-27.86	-31,08	3,2
XZ	V	7th	6076	-27.86	-43,65	15,8

Table 7. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XZ	V	8th	6944	-27.86	-43,82	16,0
XZ	V	9th	7812	-27.86	-41,22	13,4
XZ	V	10th	8680	-27.86	-38,71	10,9
XZ	H	Fund.	868	16.12	3,90	12,2
XZ	H	2nd	1736	-27.86	-43,48	15,6
XZ	H	3rd	2604	-27.86	-50,00	22,1
XZ	H	4th	3472	-27.86	-47,94	20,1
XZ	H	5th	4340	-27.86	-31,73	3,9
XZ	H	6th	5208	-27.86	-30,83	3,0
XZ	H	7th	6076	-27.86	-39,27	11,4
XZ	H	8th	6944	-27.86	-42,40	14,5
XZ	H	9th	7812	-27.86	-41,33	13,5
XZ	H	10th	8680	-27.86	-34,25	6,4
YZ	V	Fund.	868	16.12	-2,00	18,1
YZ	V	2nd	1736	-27.86	-47,84	20,0
YZ	V	3rd	2604	-27.86	-49,48	21,6
YZ	V	4th	3472	-27.86	-46,46	18,6
YZ	V	5th	4340	-27.86	-34,44	6,6
YZ	V	6th	5208	-27.86	-30,60	2,7
YZ	V	7th	6076	-27.86	-39,97	12,1
YZ	V	8th	6944	-27.86	-43,33	15,5
YZ	V	9th	7812	-27.86	-41,39	13,5
YZ	V	10th	8680	-27.86	-35,01	7,1
YZ	H	Fund.	868	16.12	5,58	10,5

Table 7. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
YZ	H	2nd	1736	-27.86	-42,27	14,4
YZ	H	3rd	2604	-27.86	-47,67	19,8
YZ	H	4th	3472	-27.86	-48,49	20,6
YZ	H	5th	4340	-27.86	-38,56	10,7
YZ	H	6th	5208	-27.86	-31,91	4,0
YZ	H	7th	6076	-27.86	-44,20	16,3
YZ	H	8th	6944	-27.86	-44,00	16,1
YZ	H	9th	7812	-27.86	-41,69	13,8
YZ	H	10th	8680	-27.86	-38,86	11,0

8.5. Range Test(WES0037-01-APN868D-01)

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot (indoor). Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1108m.

The outdoor range test result using two printed meander monopoles to the front direction (XY plane, the LCD baseboard and the picoboard is horizontal while the antenna board is vertical) is 1107m as shown in Figure 7.15. It is nearly the same as the reference whip results.

Also it can be seen from the printed meander pattern plots that the antenna gain is at maximum at the used cut.

The indoor range is not measured due to the lack of large enough building. But, from the TX power and sensitivity data an indoor range estimation can be given assuming an indoor propagation factor of 4.5, which is a typical value in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -2dBi antenna gain (front direction) the estimated indoor range is 121m as it is shown in Fig. 7.16.

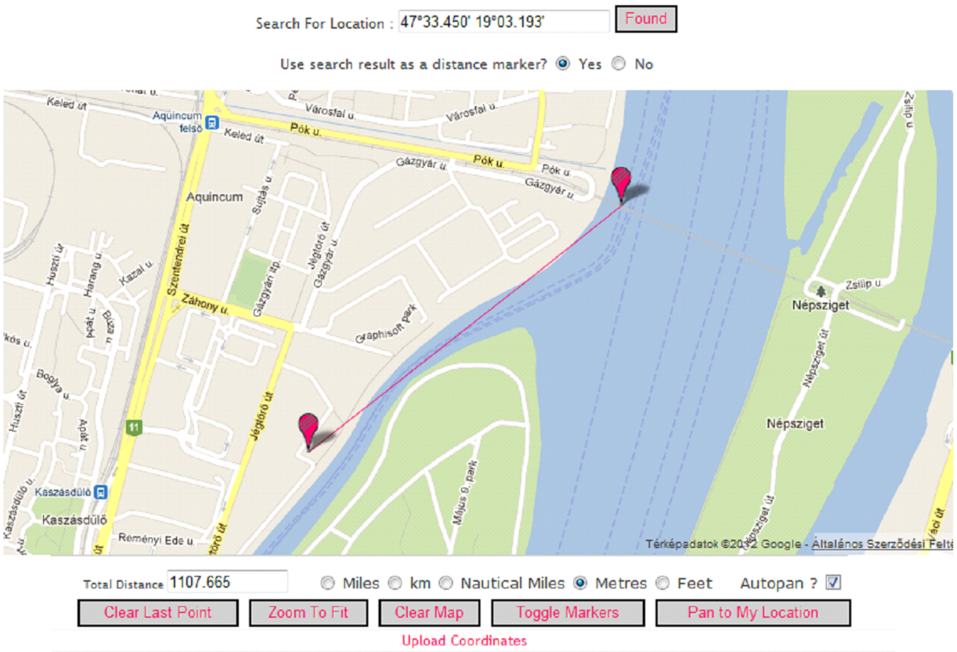


Figure 110. Figure 7.15. Outdoor range test result with two identical printed meander monopole antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

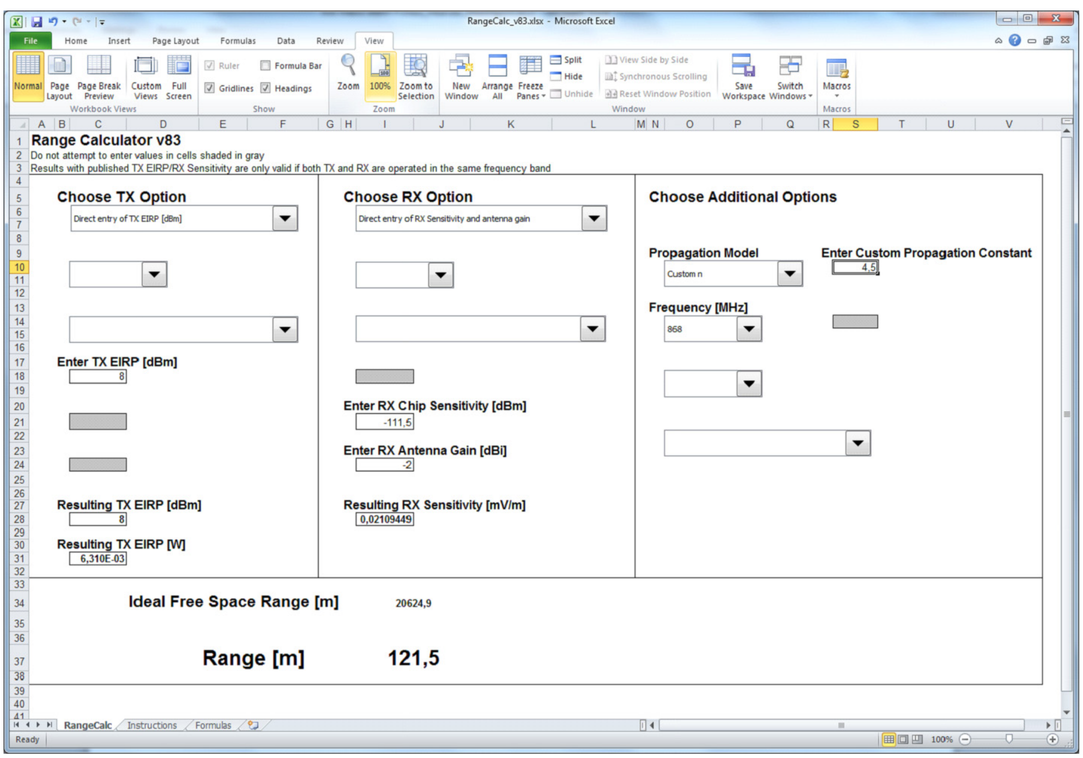


Figure 111. Figure 7.16. Indoor range estimation with two identical printed meander monopole

antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

9. Small Size Printed ILA antenna (WES0038-01-APL868S-01)

- The distance between the antenna trace outer edge and the PCB cutting edge is 1.5mm
- The size of the separated PCB antenna area is 10x10mm
- External matching network (shown in Figure 8.1) is required at the antenna input

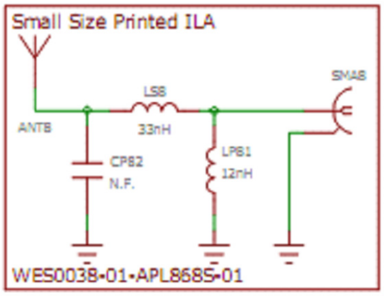


Figure 112. Figure 8.1. External antenna matching network at 868M for the small ILA antenna

The picture of the antenna is shown in Figure 8.2.

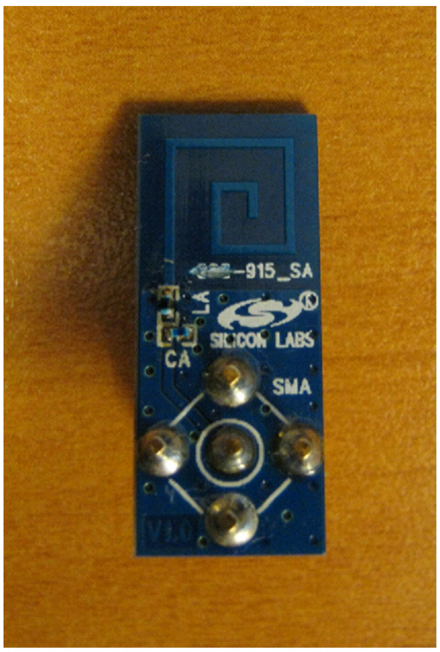


Figure 113. Figure 8.2. Small Size Printed ILA antenna

9.1. Antenna Impedance (WES0038-01-APL868S-01)

The measurement setup is shown in Figure 8.3. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 8.4. The measured impedance of the antenna with its external matching network is shown in Figure 8.5 and 8.6 (up to

3GHz) with motherboard hand effect.

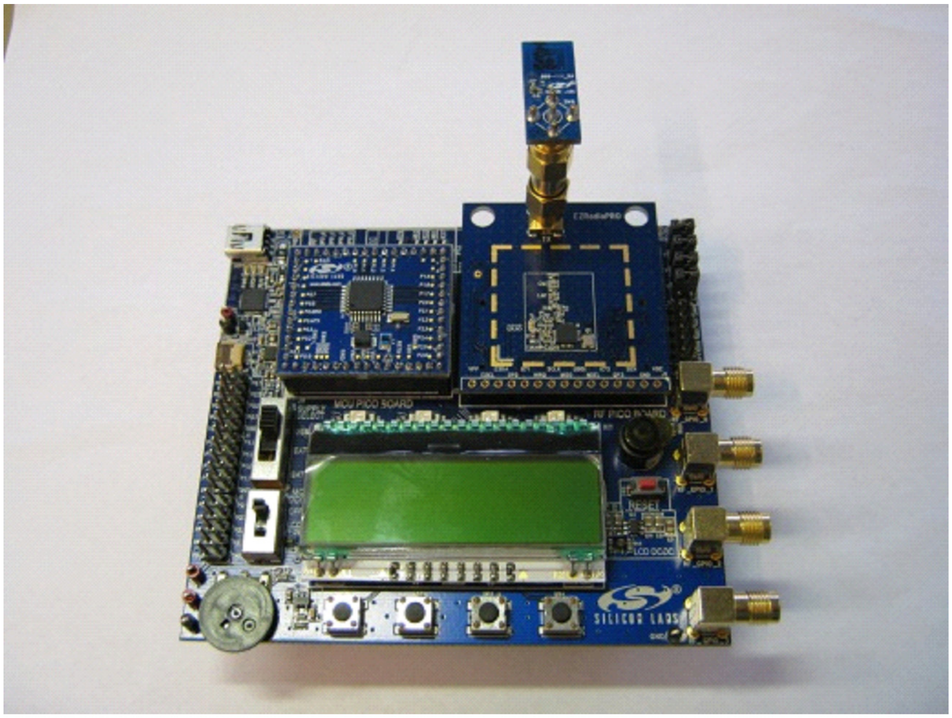


Figure 114. Figure 8.3. DUT in the final measurement setup

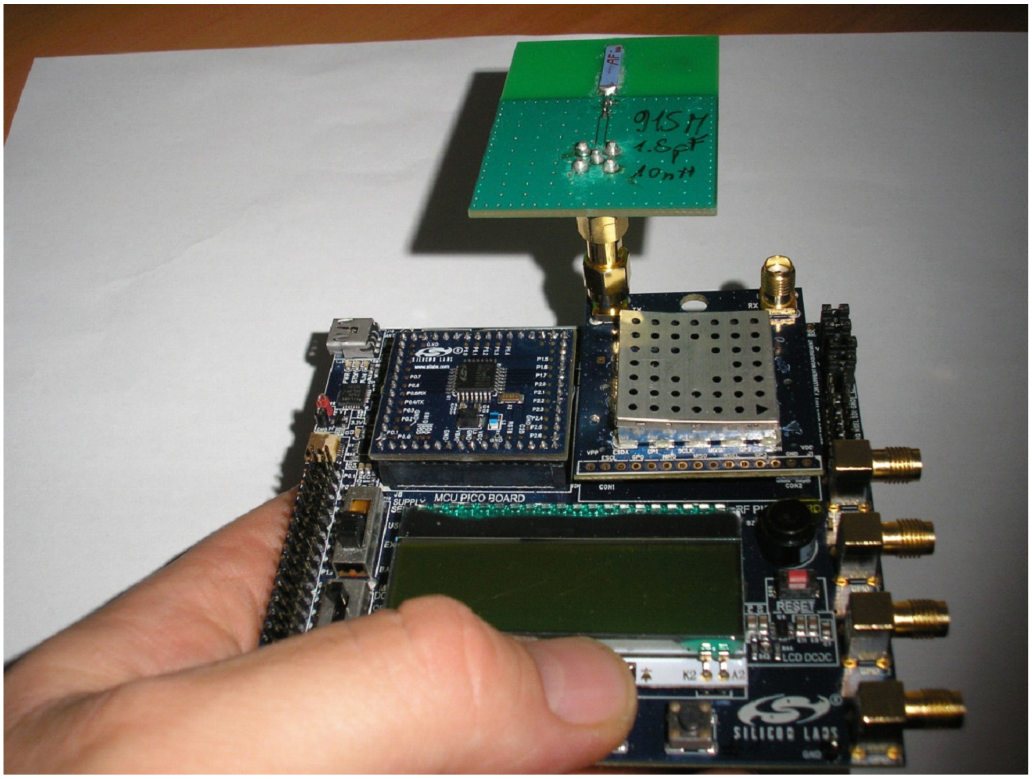


Figure 115. Figure 8.4. Typical hand effect on the main board during impedance and range measurement

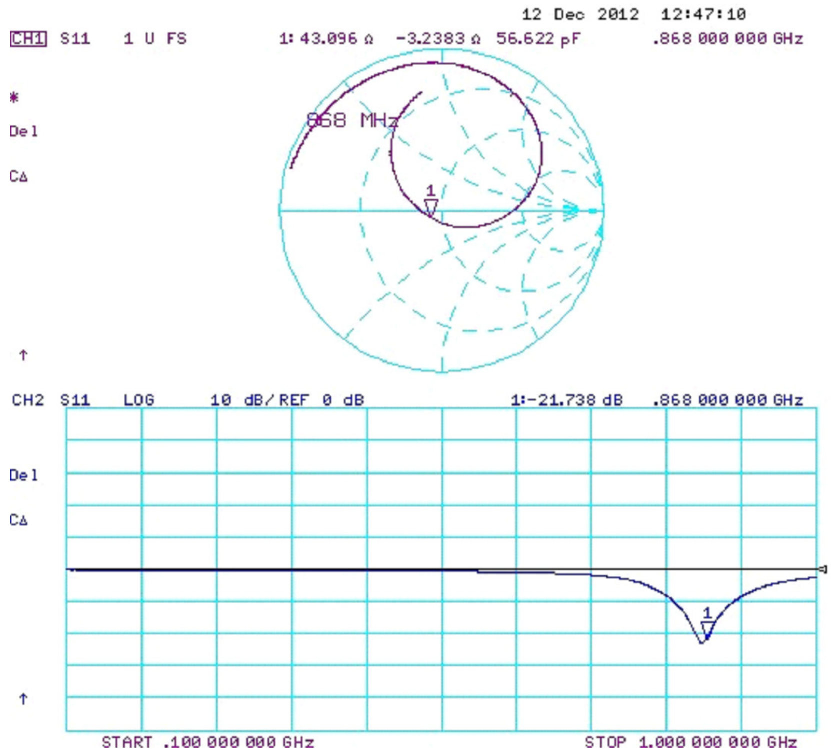


Figure 116. Figure 8.5. Measured impedance up to 1GHz with hand-effect on the main board

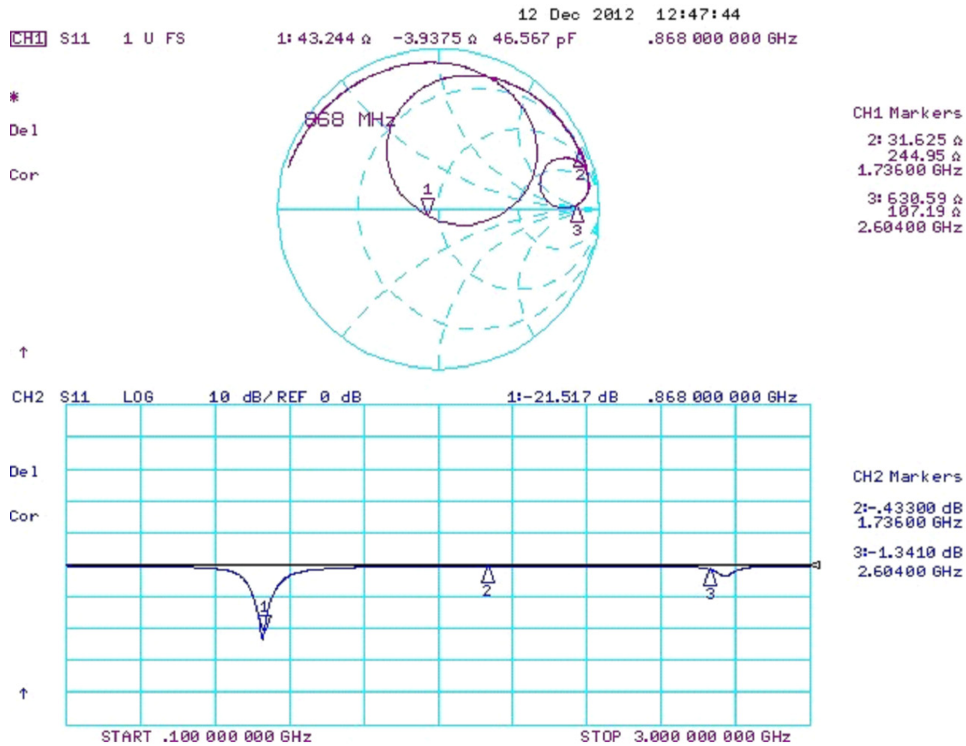


Figure 117. Figure 8.6. Measured impedance up to 3GHz with hand-effect on the main board

9.2. Antenna Gain (WES0038-01-APL868S-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 8.7). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection is negligible.

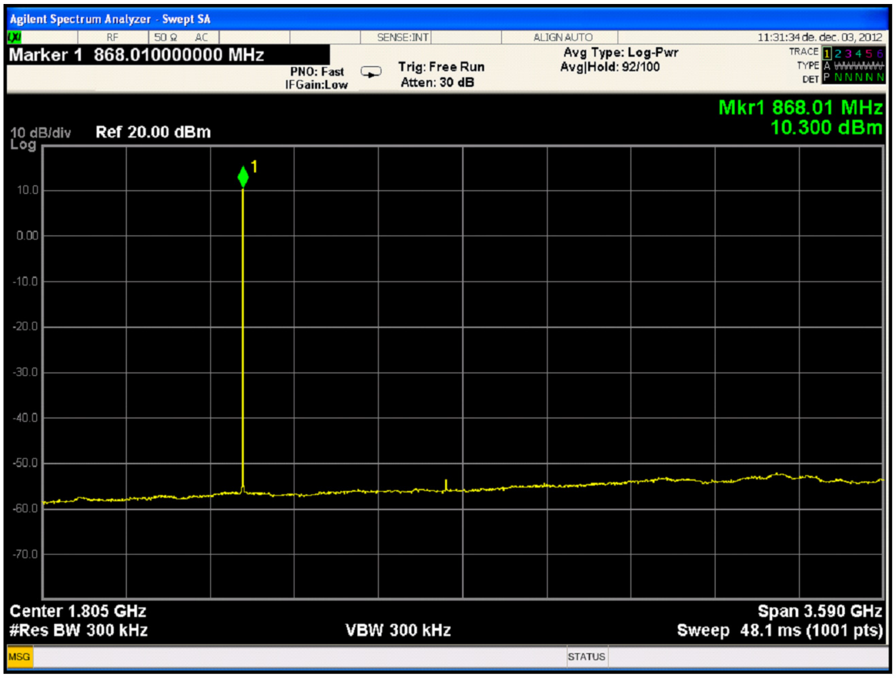


Figure 118. Figure 8.7. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 8.1). It is around 7.6dBm EIRP so the maximum gain number is ~-2.7dBi as it is shown in Figure 8.11.

This gain number is surprisingly high for such a small antenna. It should be emphasized that in typical small remote applications the grounding environment and the strength of the hand effect is different. Without the SMA connector, SMA male-male transition, Pico Board and Wireless Motherboard the achievable antenna gain is much weaker.

9.3. Radiation Patterns (WES0038-01-APL868S-01)

Radiation patterns of the small size printed ILA antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture from the DUT with coordinate system under the radiated measurements is shown in Figure 8.8.

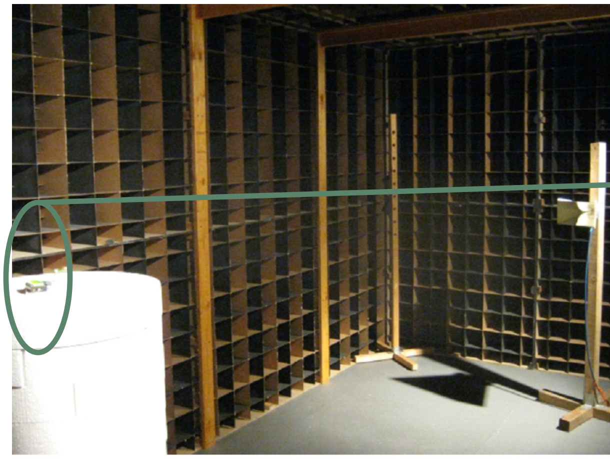
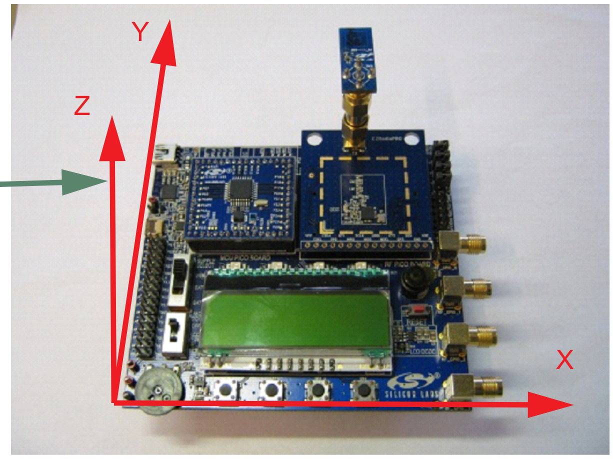



Figure 119. Figure 8.8. DUT in the antenna chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Fig. 8.9-8.14).

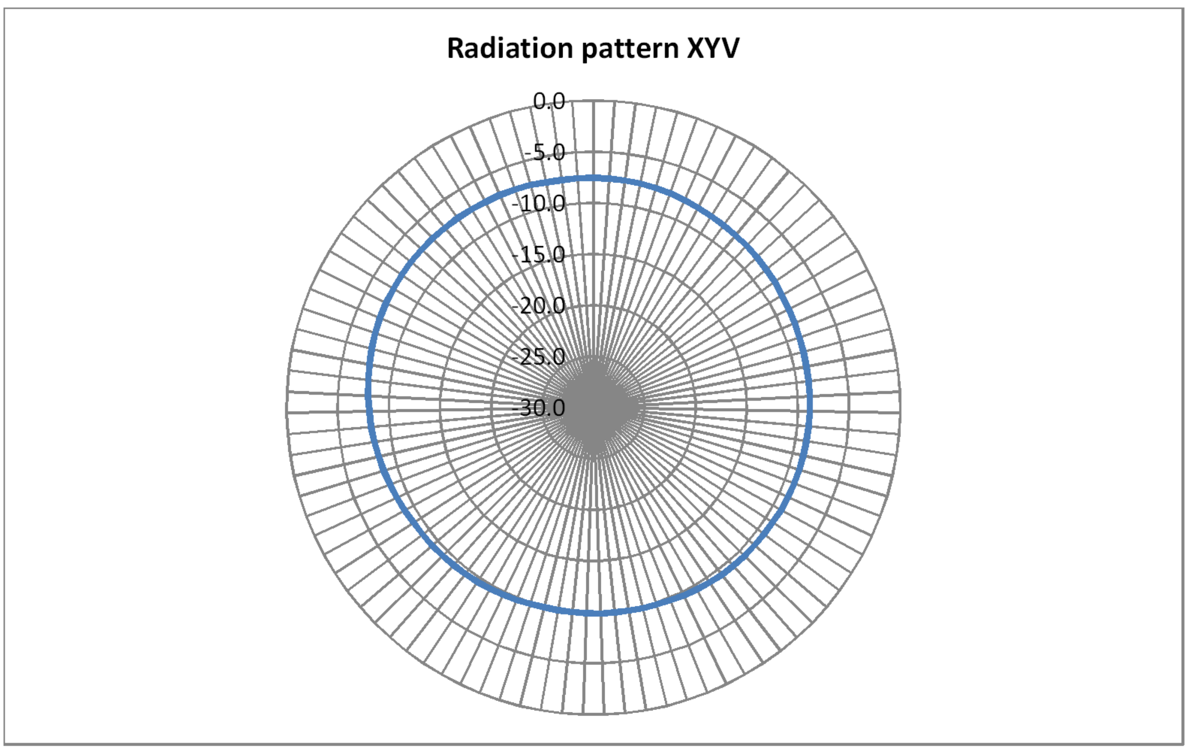


Figure 120. Figure 8.9. Radiation pattern in the XY cut with Vertical receiver antenna polarization

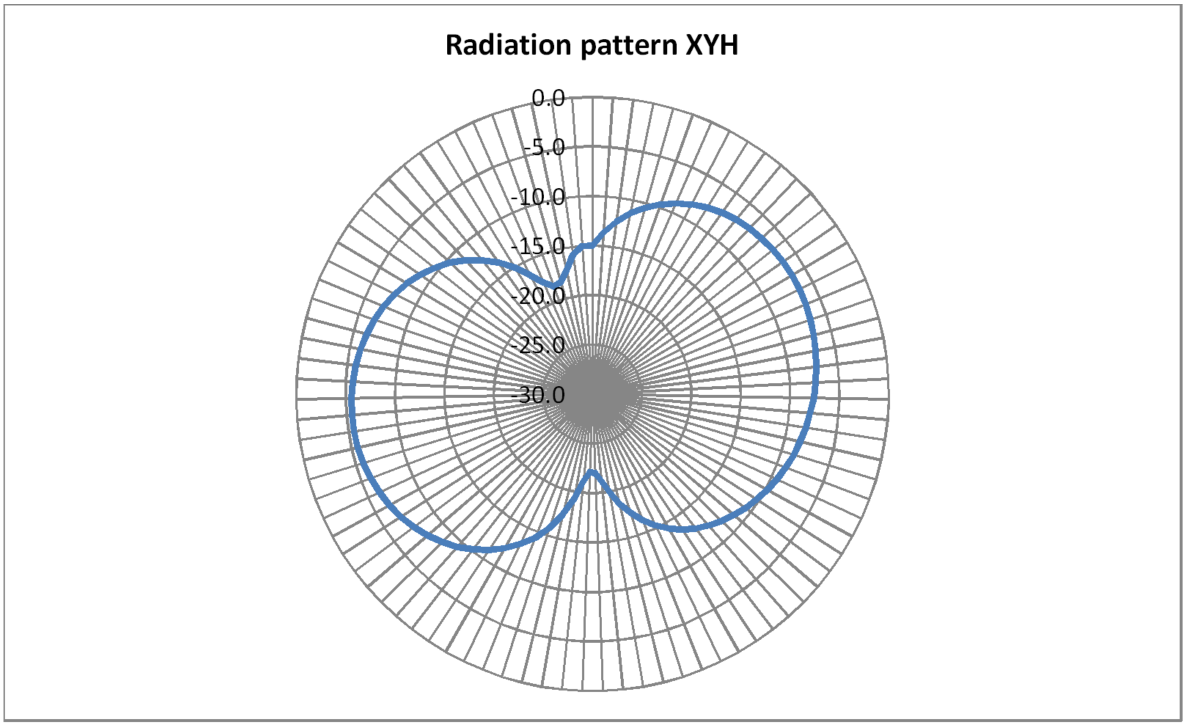


Figure 121. Figure 8.10. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

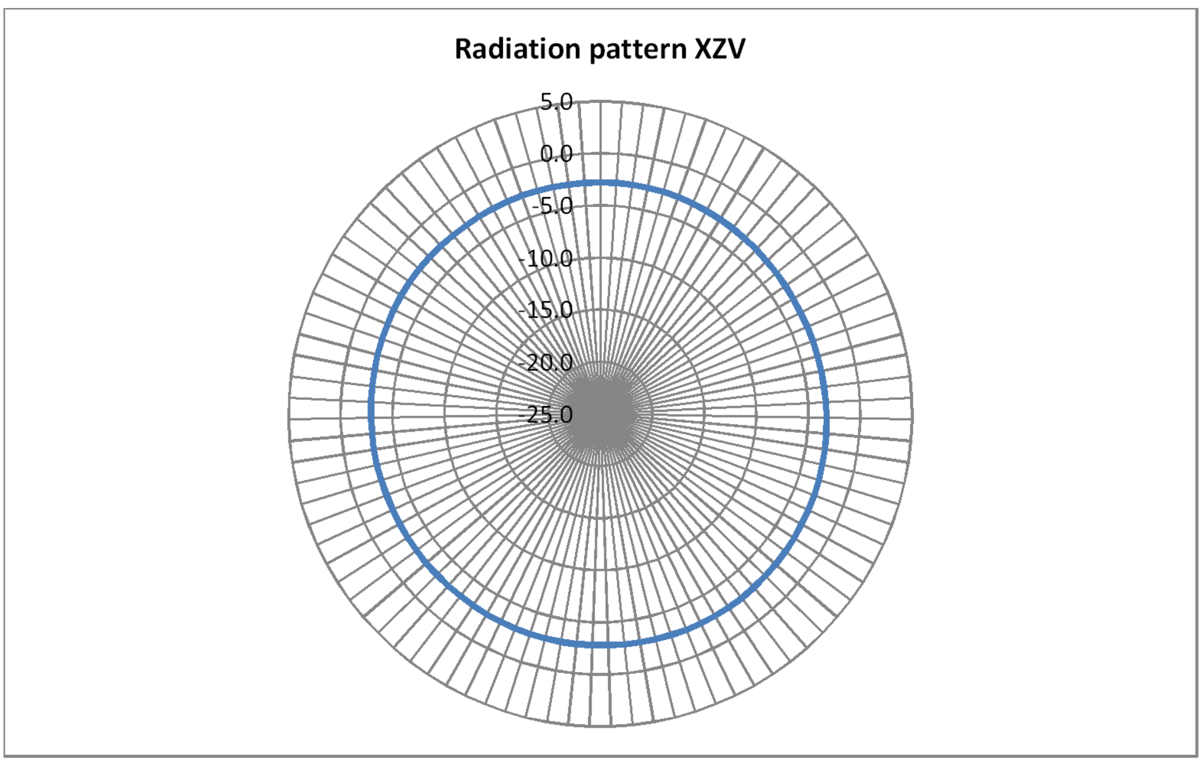


Figure 122. Figure 8.11. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

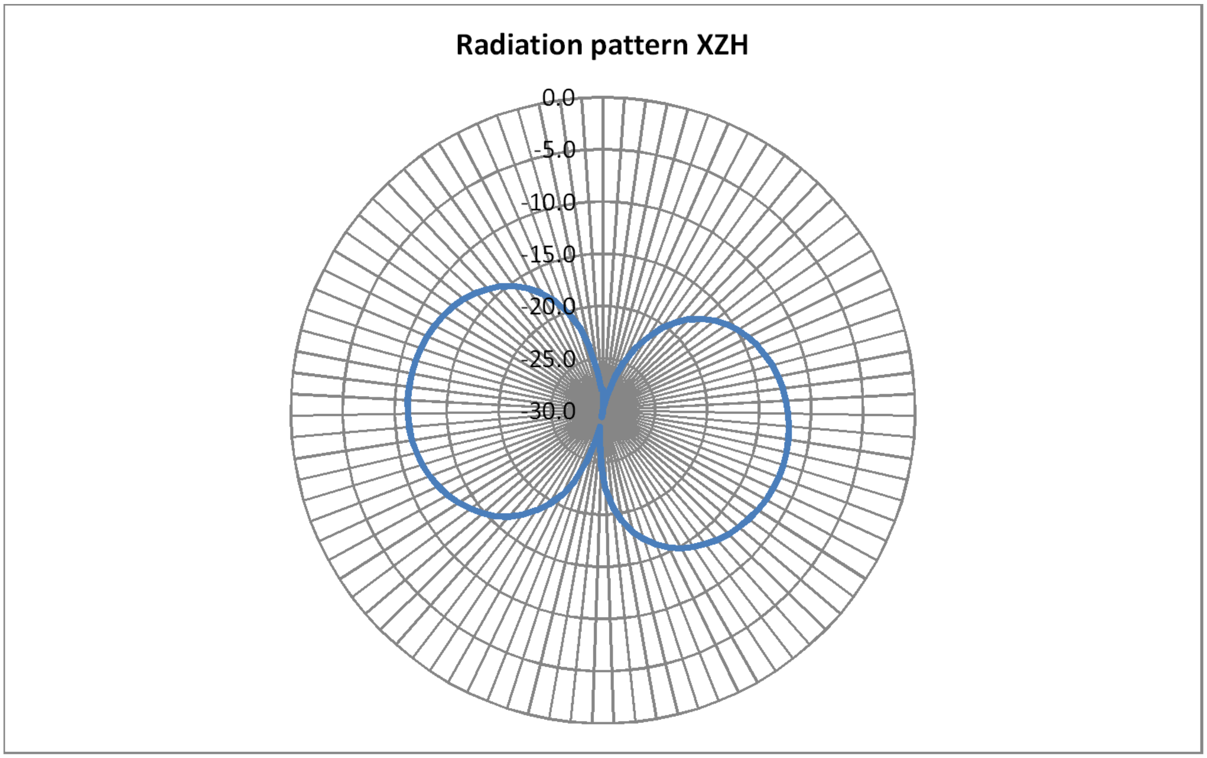


Figure 123. Figure 8.12. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

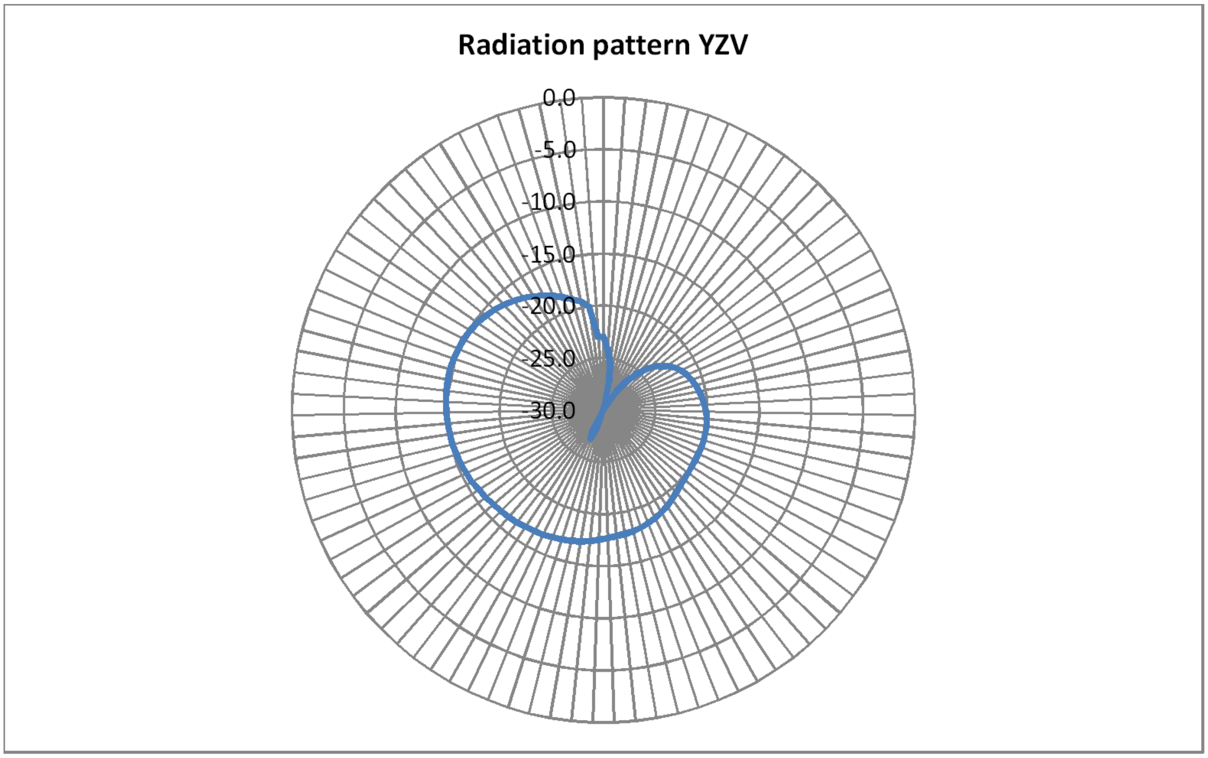


Figure 124. Figure 8.13. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

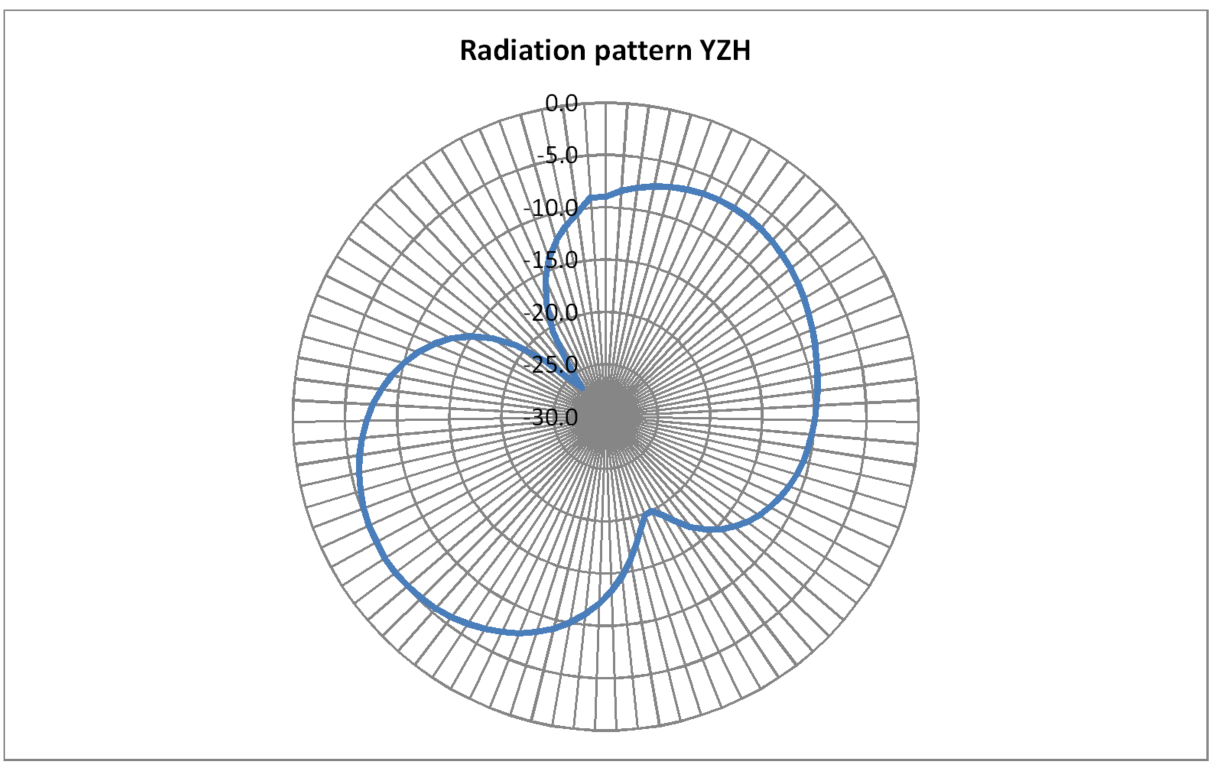


Figure 125. Figure 8.14. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

9.4. Radiated Harmonics (WES0038-01-APL868S-01)

The radiated harmonics of the small size printed ILA antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table together with the corresponding standard limits.

The small size ILA antenna driven by the Si4460 10dBm class E match (4060-PCE10B868 Pico Board) comply with the ETSI harmonic regulations with margin. Worst is the 6th harmonic, which has only 2.5dB margin in the YZ cuts.

Here it has to be noted that the potential source of the 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 8. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	3,11	13,0
XY	V	2nd	1736	-27.86	-42,48	14,6
XY	V	3rd	2604	-27.86	-49,00	21,1
XY	V	4th	3472	-27.86	-42,65	14,8
XY	V	5th	4340	-27.86	-33,90	6,0
XY	V	6th	5208	-27.86	-35,90	8,0
XY	V	7th	6076	-27.86	-43,69	15,8
XY	V	8th	6944	-27.86	-41,60	13,7
XY	V	9th	7812	-27.86	-42,15	14,3
XY	V	10th	8680	-27.86	-37,52	9,7
XY	H	Fund.	868	16.12	4,74	11,4
XY	H	2nd	1736	-27.86	-43,14	15,3
XY	H	3rd	2604	-27.86	-51,27	23,4
XY	H	4th	3472	-27.86	-43,34	15,5

Table 8. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	H	5th	4340	-27.86	-36,98	9,1
XY	H	6th	5208	-27.86	-36,25	8,4
XY	H	7th	6076	-27.86	-45,58	17,7
XY	H	8th	6944	-27.86	-43,65	15,8
XY	H	9th	7812	-27.86	-41,39	13,5
XY	H	10th	8680	-27.86	-39,13	11,3
XZ	V	Fund.	868	16.12	7,63	8,5
XZ	V	2nd	1736	-27.86	-42,60	14,7
XZ	V	3rd	2604	-27.86	-53,48	25,6
XZ	V	4th	3472	-27.86	-39,37	11,5
XZ	V	5th	4340	-27.86	-30,86	3,0
XZ	V	6th	5208	-27.86	-36,66	8,8
XZ	V	7th	6076	-27.86	-46,33	18,5
XZ	V	8th	6944	-27.86	-42,40	14,5
XZ	V	9th	7812	-27.86	-42,23	14,4
XZ	V	10th	8680	-27.86	-38,70	10,8
XZ	H	Fund.	868	16.12	-0,92	17,0
XZ	H	2nd	1736	-27.86	-43,09	15,2
XZ	H	3rd	2604	-27.86	-53,08	25,2
XZ	H	4th	3472	-27.86	-43,86	16,0
XZ	H	5th	4340	-27.86	-33,13	5,3
XZ	H	6th	5208	-27.86	-35,88	8,0
XZ	H	7th	6076	-27.86	-45,01	17,1
XZ	H	8th	6944	-27.86	-40,29	12,4
XZ	H	9th	7812	-27.86	-41,13	13,3

Table 8. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XZ	H	10th	8680	-27.86	-33,86	6,0
YZ	V	Fund.	868	16.12	-4,43	20,6
YZ	V	2nd	1736	-27.86	-49,27	21,4
YZ	V	3rd	2604	-27.86	-49,63	21,8
YZ	V	4th	3472	-27.86	-43,53	15,7
YZ	V	5th	4340	-27.86	-33,52	5,7
YZ	V	6th	5208	-27.86	-30,45	2,6
YZ	V	7th	6076	-27.86	-45,28	17,4
YZ	V	8th	6944	-27.86	-40,85	13,0
YZ	V	9th	7812	-27.86	-42,07	14,2
YZ	V	10th	8680	-27.86	-34,84	7,0
YZ	H	Fund.	868	16.12	5,41	10,7
YZ	H	2nd	1736	-27.86	-38,00	10,1
YZ	H	3rd	2604	-27.86	-47,17	19,3
YZ	H	4th	3472	-27.86	-40,19	12,3
YZ	H	5th	4340	-27.86	-30,45	2,6
YZ	H	6th	5208	-27.86	-35,13	7,3
YZ	H	7th	6076	-27.86	-44,41	16,5
YZ	H	8th	6944	-27.86	-44,61	16,7
YZ	H	9th	7812	-27.86	-41,62	13,8
YZ	H	10th	8680	-27.86	-38,67	10,8

9.5. Range Test (WES0038-01-APL868S-01)

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot. Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done with two Pico Boards and two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1108m.

The outdoor range test result using two small printed ILAs to the front direction (XY plane is horizontal and the Y axes are facing to each other as it is typical in normal remote applications) is 982m as shown in Figure 8.15. As it was mentioned in chapter 2 in real small remote applications the achievable gain, and thus the achievable range can be much weaker.

Also it can be seen from the small ILA pattern plots that the antenna gain is at maximum (~-2.5dBi) at other directions (e.g. XZ cut, vertical polarization, Figure 8.11). With facing the TX-RX pair in this orientation (e.g. in non-remote applications) the range could be even higher by 40…50%.

Indoor range test is not done, due to the lack of large enough building. But, from the TX power and sensitivity data an indoor range estimation can be given assuming a propagation factor of 4.5, which is typical value in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -7.5dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 69m as it is shown in Fig. 8.16.

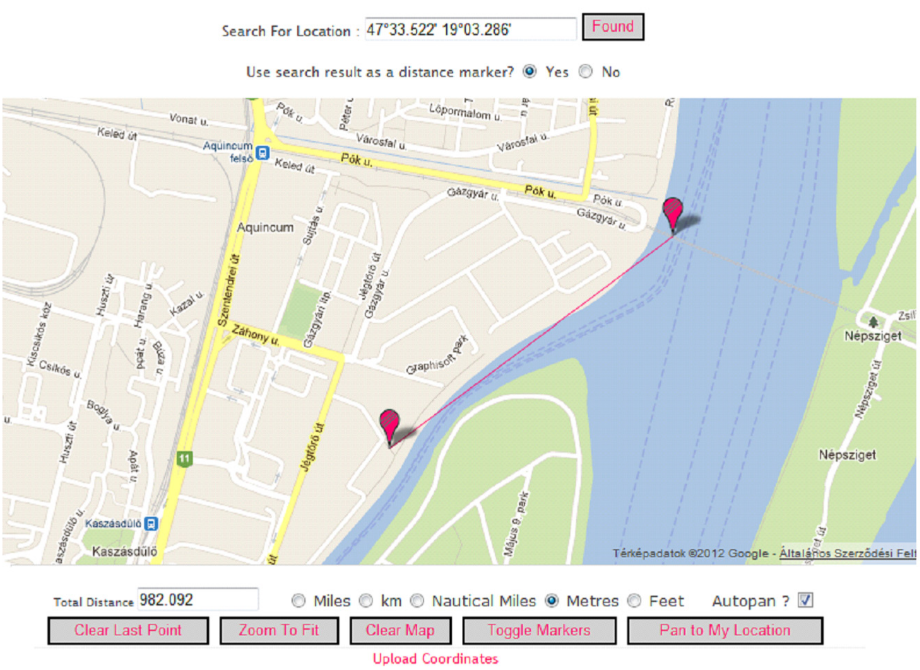


Figure 126. Figure 8.15. Outdoor range test result with two identical small size printed ILA antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

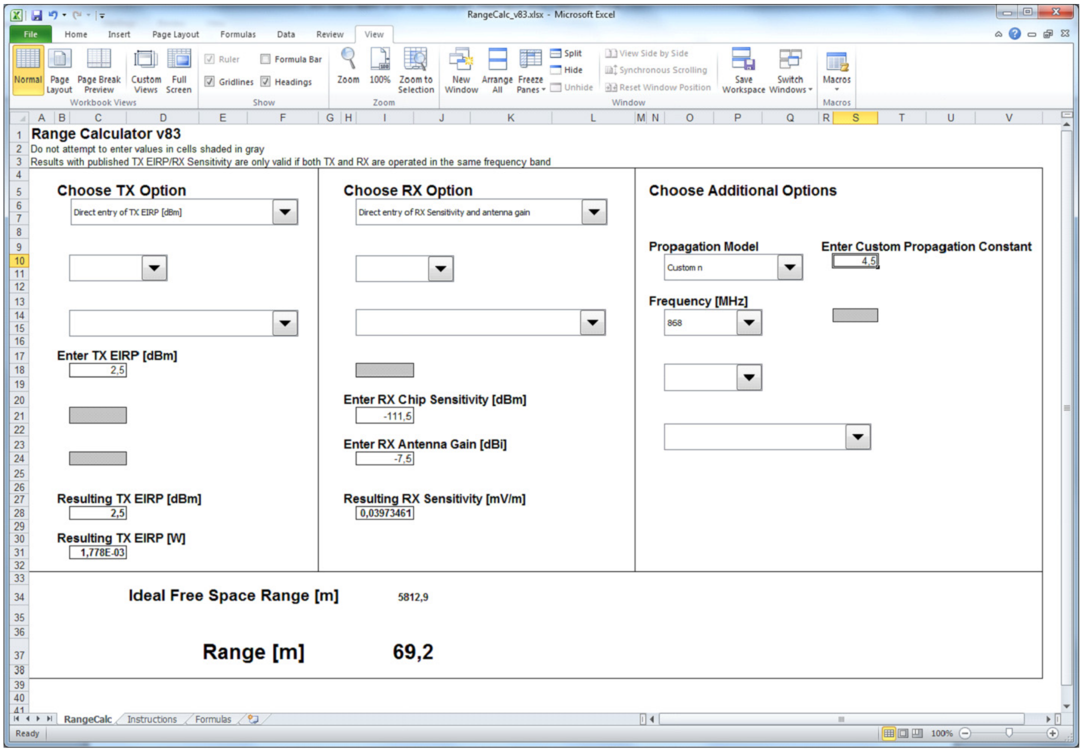


Figure 127. Figure 8.15. Indoor range estimation with two identical small size printed ILA antennas and with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

10. Printed BIFA (WES0039-01-APB868D-01)

External matching network (shown in Figure 9.1) is required at the antenna input.

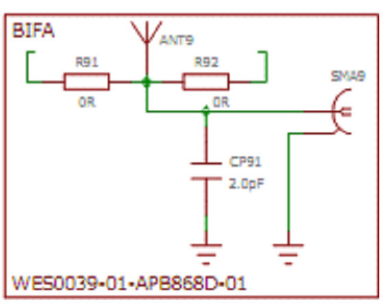
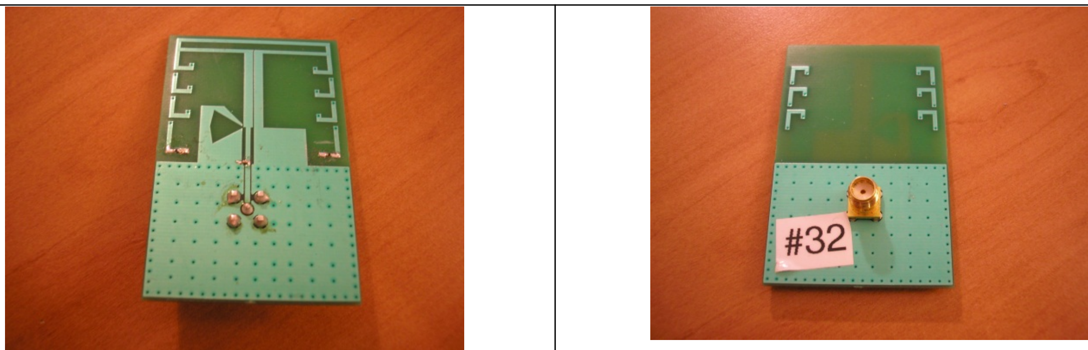


Figure 128. •Figure 9.1. External matching network at 868MHz for the BIFA antenna

The picture of the antenna is shown in Figure 9.2.



Top layer	Bottom layer

Figure 129. Figure 9.2. Printed BIFA antenna

10.1. Antenna Impedance (WES0039-01-APB868D-01)

The measurement setup is shown in Figure 9.3. The antenna board is connected to the 4060-PCE10B868 Pico Board through a male to male SMA transition and also the WMB-930 Wireless Motherboard driving the Pico Board.

During range test the users hand holds the motherboard. Typical hand position is shown in Figure 9.4. The measured impedance of the antenna with its external matching network is shown in Figure 9.5 and 9.6 (up to 3GHz) with motherboard hand effect.

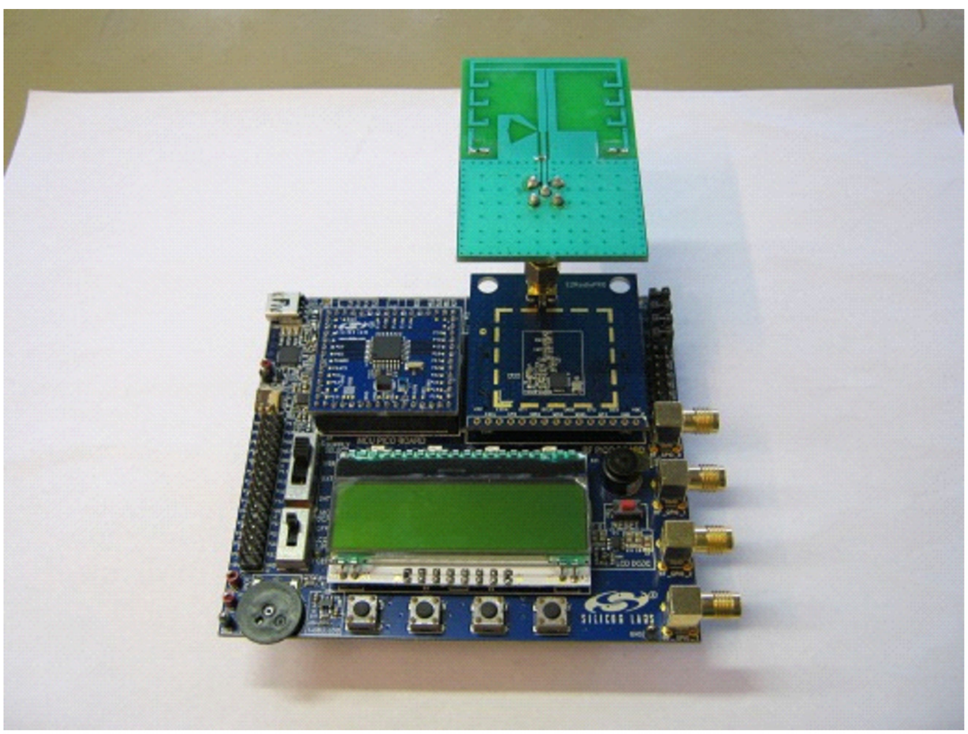


Figure 130. Figure 9.3. DUT in the final measurement setup

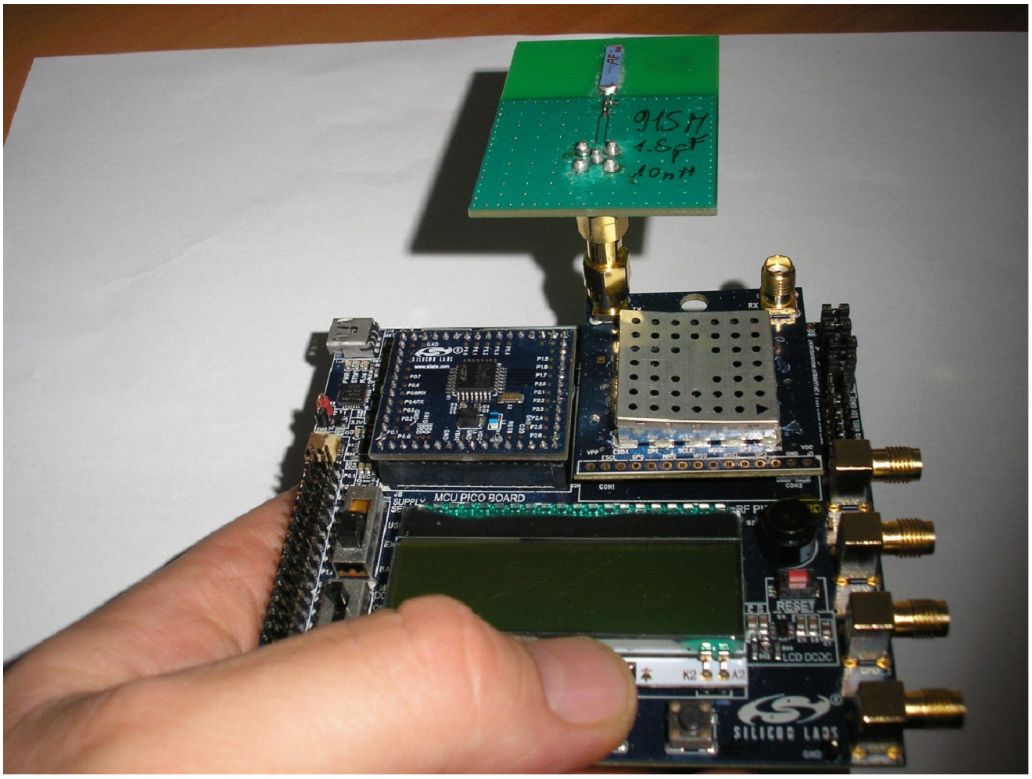


Figure 131. Figure 9.4. Typical hand effect on the main board during impedance and range measurement

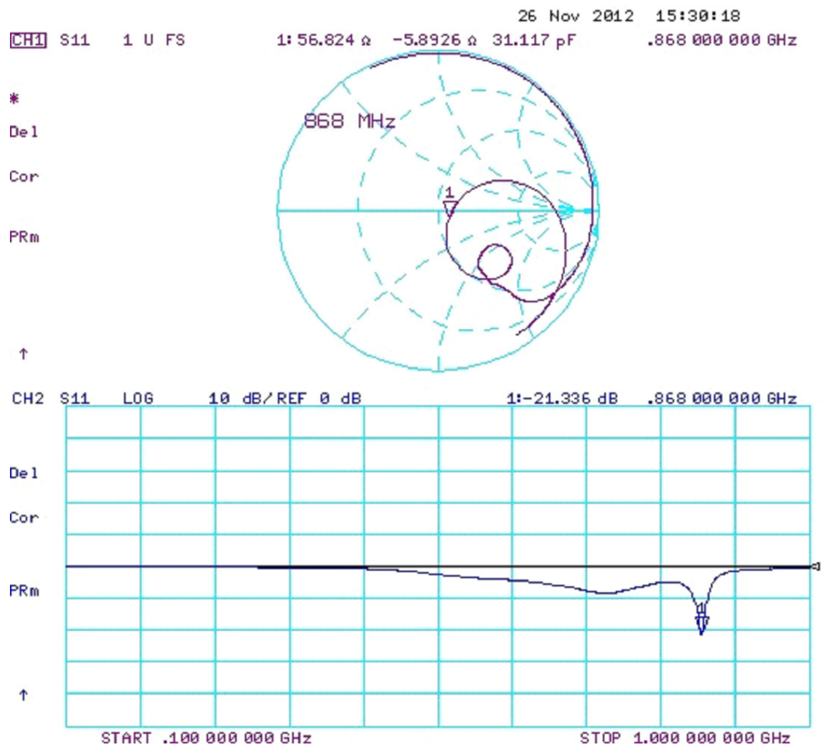


Figure 132. Figure 9.5. Measured impedance up to 1GHz with hand-effect on the main board

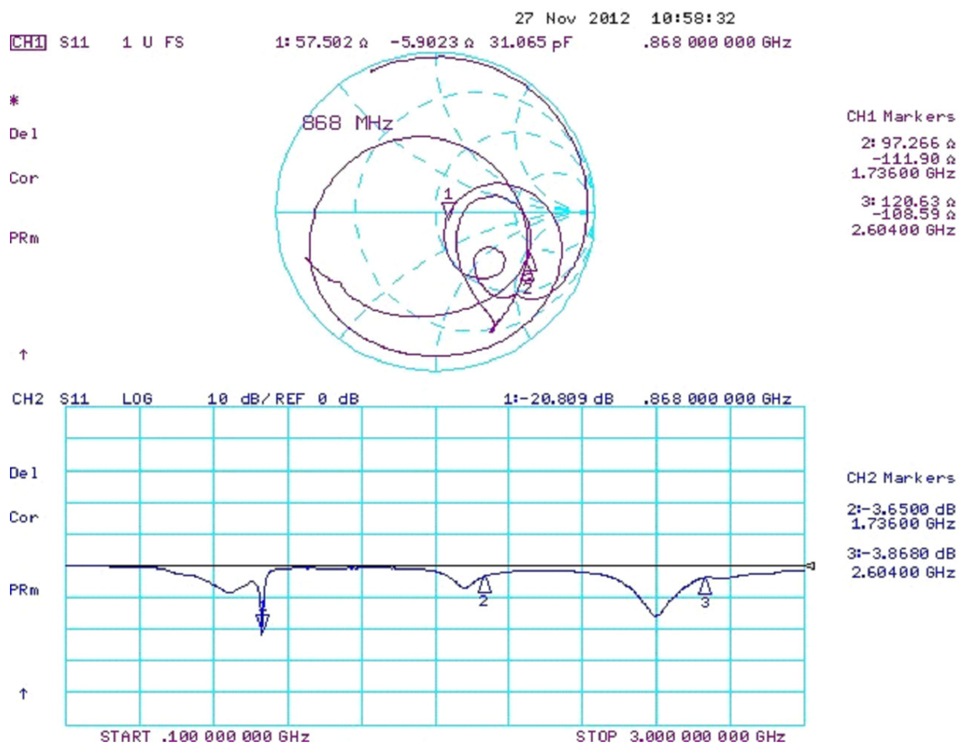


Figure 133. Figure 9.6. Measured impedance up to 3GHz with hand-effect on the main board

10.2. Antenna Gain (WES0039-01-APB868D-01)

The antenna gain is calculated from the measured radiated power at the fundamental and from the delivered power to the antenna (from conducted SA measurements on 50 Ohm termination shown in Figure 9.7). This method can be effectively applied due to the fact that the S11 of the antenna is much better than -10dB so the reflection loss is negligible.

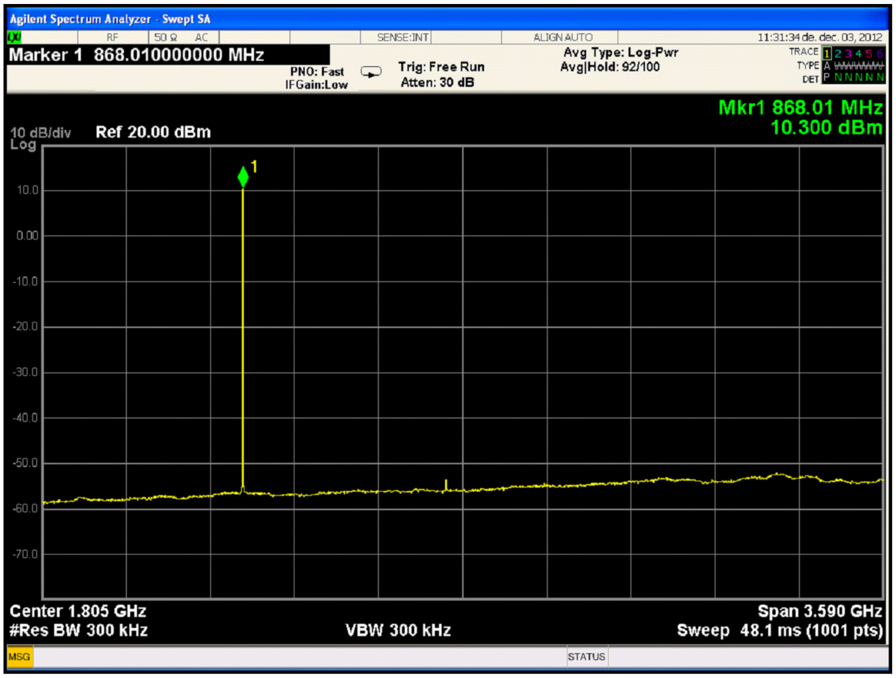


Figure 134. Figure 9.7. Conducted measurement result, 4060-PCE10B868

The measured radiated power maximum is at XZ cut (Table 9.1). It is around 10.1dBm EIRP so the maximum gain number is ~0dBi as it is shown in Figure 9.11.

10.3. Radiation Patterns (WES0039-01-APB868D-01)

Radiation patterns of the printed BIFA antenna were measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the WMB-930 Wireless Motherboard driving the Pico Board. The radiation patterns at the fundamental frequency in XY, XZ, YZ cut both with horizontal and vertical receiver antenna polarization are shown in this chapter. Resolution 2 deg. Results are in 6 separate plots.

A picture from the DUT with coordinate system under the radiated measurements is shown in Figure 9.8.

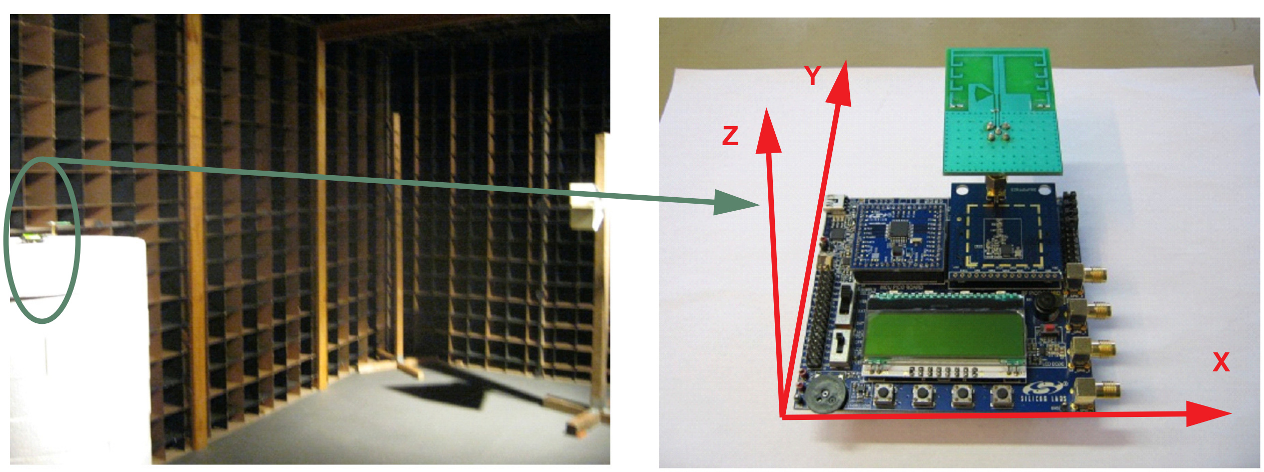


Figure 135. Figure 9.8. DUT in the antenna chamber

The measured radiation patterns (antenna gain in dBi) are shown in the following 6 figures (Fig. 9.9-9.14).

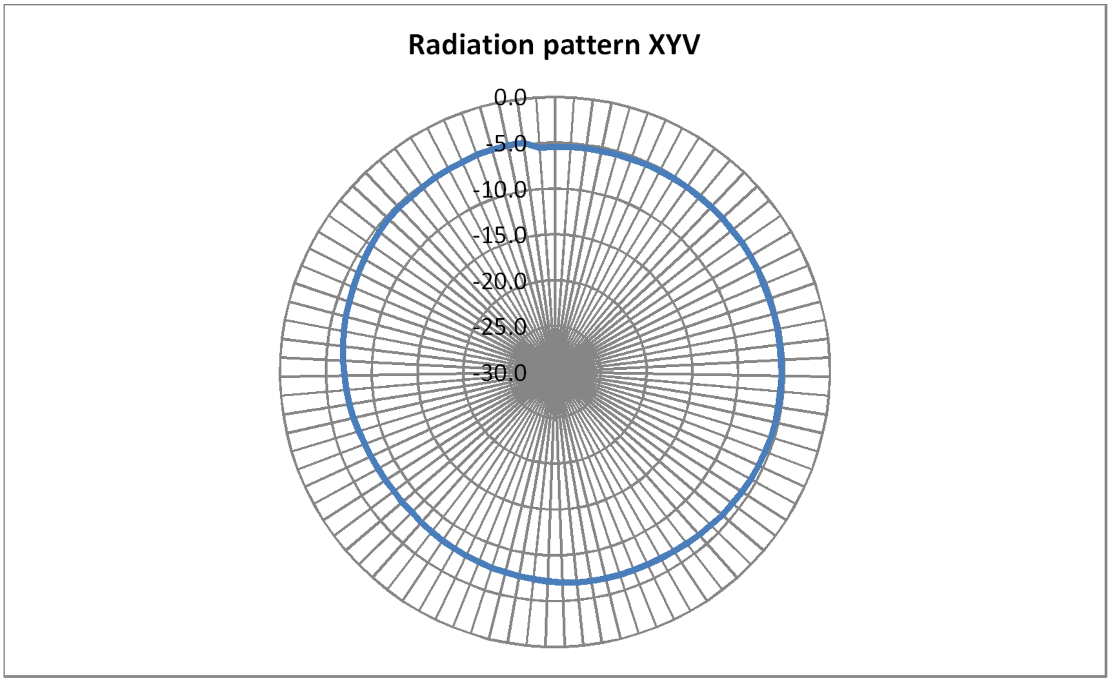


Figure 136. Figure 9.9. Radiation pattern in the XY cut with Vertical receiver antenna polarization

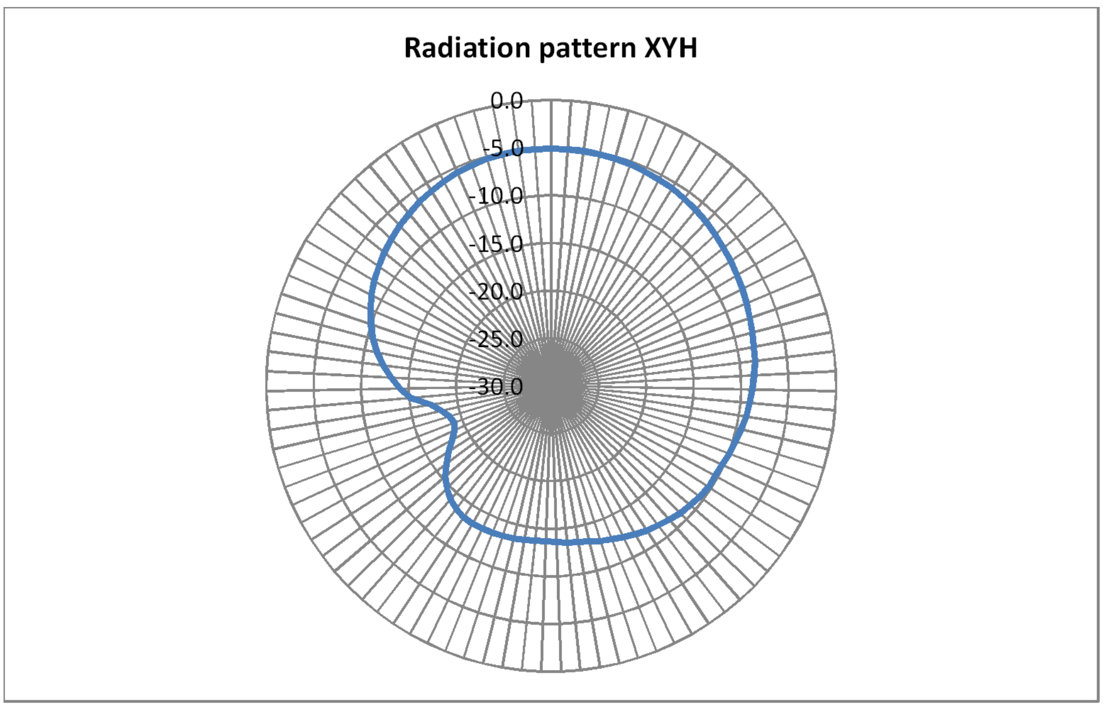


Figure 137. Figure 9.10. Radiation pattern in the XY cut with Horizontal receiver antenna polarization

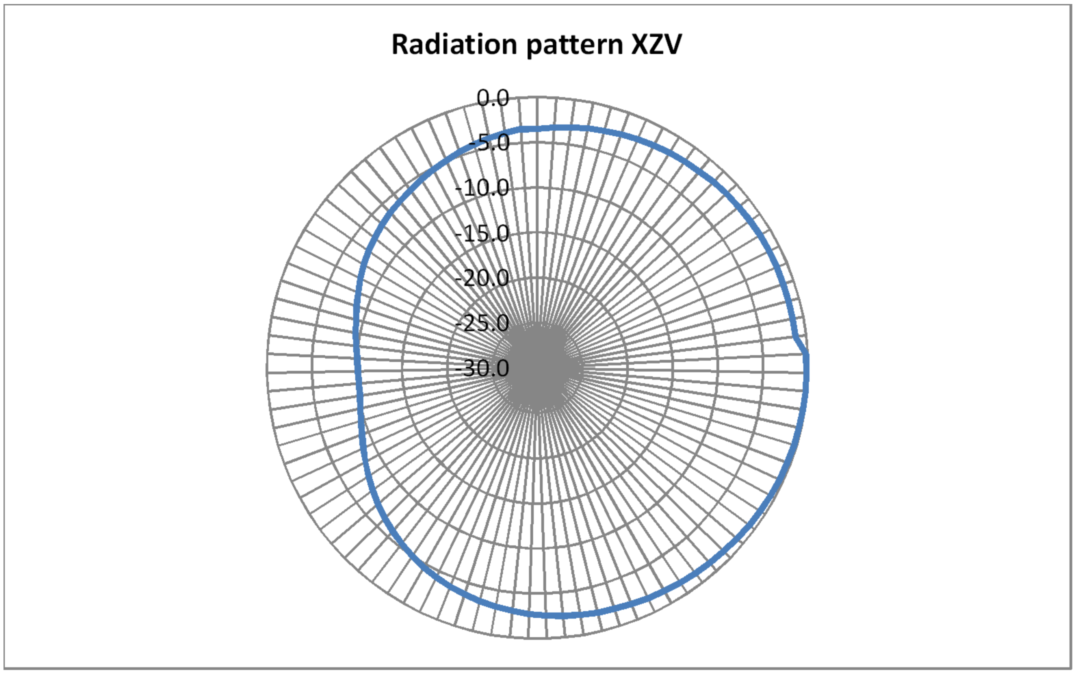


Figure 138. Figure 9.11. Radiation pattern in the XZ cut with Vertical receiver antenna polarization

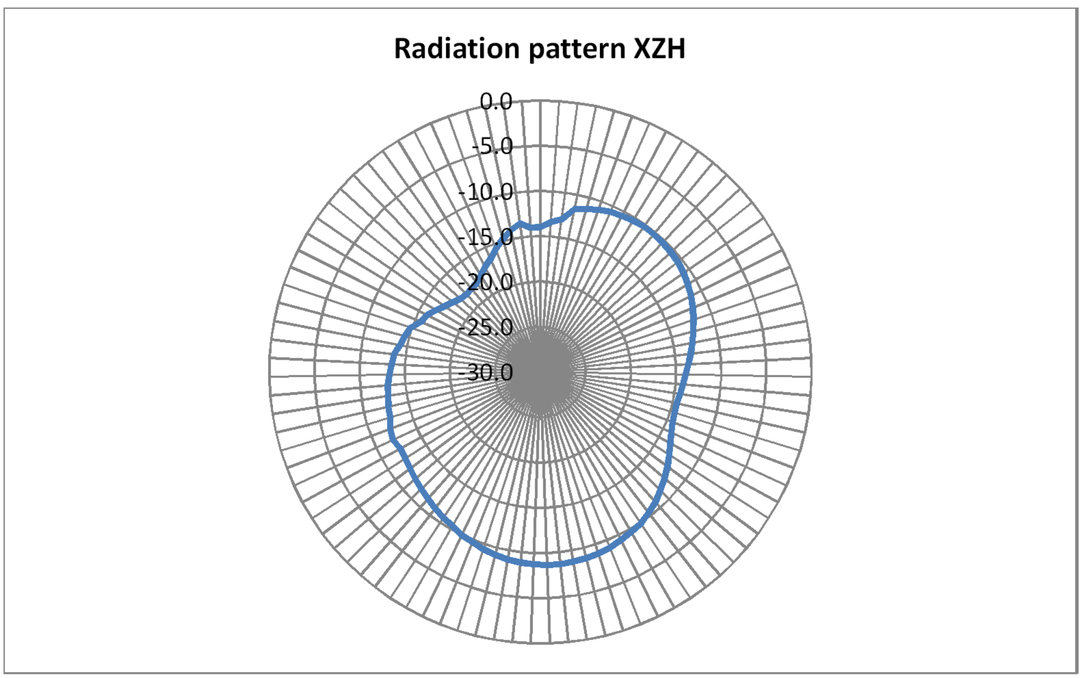


Figure 139. Figure 9.12. Radiation pattern in the XZ cut with Horizontal receiver antenna polarization

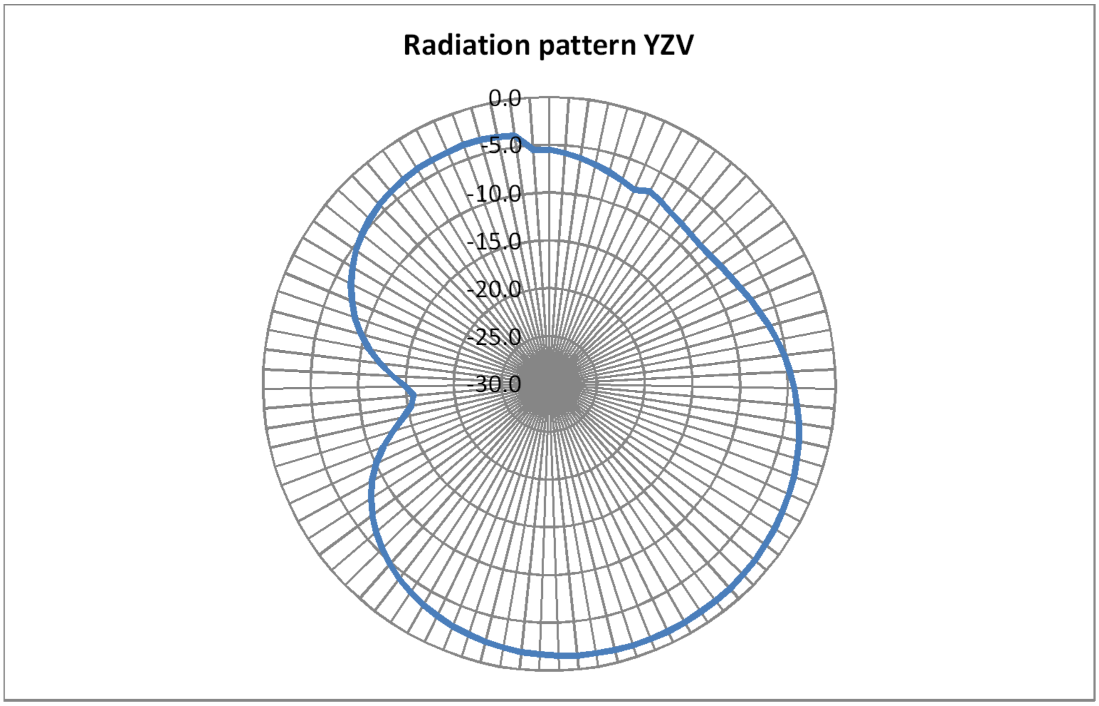


Figure 140. Figure 9.13. Radiation pattern in the YZ cut with Vertical receiver antenna polarization

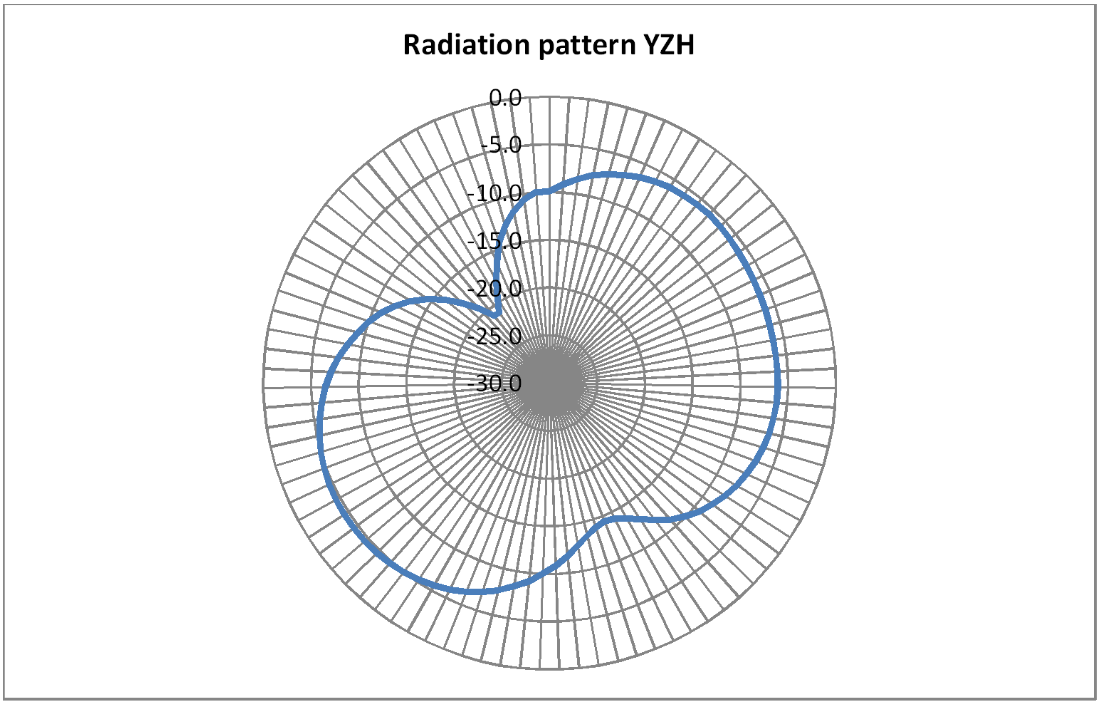


Figure 141. Figure 9.14. Radiation pattern in the YZ cut with Horizontal receiver antenna polarization

10.4. Radiated Harmonics (WES0039-01-APB868D-01)

The radiated harmonics of the BIFA antenna were also measured in an antenna chamber with using the 4060-PCE10B868 Pico Board connected through a male to male SMA transition and also with the MSC-LCDBB930-AES Wireless Motherboard driving the Pico Board. The maximum radiated power levels up to the 10th harmonic were measured in XY, XZ and YZ cut both with horizontal and vertical polarized receiver antenna. Results are shown in the following EIRP table (Table 9.1) together with the corresponding standard limits.

The BIFA antenna driven by the Si4460 10dBm class E match (4060-PCE10B868 Pico Board) comply with the ETSI harmonic regulations with large margin. Only exception is the 6th harmonic, which has only 3dB margin in the YZV cut.

Here it has to be noted that the potential source of the 6th harmonic radiation is the MSC-LCDBB930-AES Wireless Motherboard (leakage through the SDN, GPIO1 and GPIO2 connectors). With the newer WMB-930 Wireless Motherboard the harmonic radiation is 4-5dB lower. Moreover, in typical battery operated final applications where the Wireless Motherboard is eliminated and the Pico Board layout is unified with the antenna the harmonic radiation is even lower.

Table 9. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	V	Fund.	868	16.12	5,51	10,6
XY	V	2nd	1736	-27.86	-47,37	19,5
XY	V	3rd	2604	-27.86	-48,27	20,4
XY	V	4th	3472	-27.86	-38,55	10,7
XY	V	5th	4340	-27.86	-39,09	11,2
XY	V	6th	5208	-27.86	-37,98	10,1
XY	V	7th	6076	-27.86	-43,03	15,2
XY	V	8th	6944	-27.86	-43,81	15,9
XY	V	9th	7812	-27.86	-40,81	13,0
XY	V	10th	8680	-27.86	-38,01	10,1
XY	H	Fund.	868	16.12	5,20	10,9
XY	H	2nd	1736	-27.86	-44,94	17,1
XY	H	3rd	2604	-27.86	-50,13	22,3
XY	H	4th	3472	-27.86	-41,31	13,5
XY	H	5th	4340	-27.86	-42,30	14,4

Table 9. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
XY	H	6th	5208	-27.86	-35,00	7,1
XY	H	7th	6076	-27.86	-40,46	12,6
XY	H	8th	6944	-27.86	-44,51	16,7
XY	H	9th	7812	-27.86	-41,33	13,5
XY	H	10th	8680	-27.86	-39,08	11,2
XZ	V	Fund.	868	16.12	10,14	6,0
XZ	V	2nd	1736	-27.86	-41,83	14,0
XZ	V	3rd	2604	-27.86	-52,88	25,0
XZ	V	4th	3472	-27.86	-39,29	11,4
XZ	V	5th	4340	-27.86	-38,43	10,6
XZ	V	6th	5208	-27.86	-37,16	9,3
XZ	V	7th	6076	-27.86	-45,15	17,3
XZ	V	8th	6944	-27.86	-44,52	16,7
XZ	V	9th	7812	-27.86	-42,11	14,2
XZ	V	10th	8680	-27.86	-39,41	11,5
XZ	H	Fund.	868	16.12	1,63	14,5
XZ	H	2nd	1736	-27.86	-46,89	19,0
XZ	H	3rd	2604	-27.86	-52,39	24,5
XZ	H	4th	3472	-27.86	-41,58	13,7
XZ	H	5th	4340	-27.86	-39,89	12,0
XZ	H	6th	5208	-27.86	-36,76	8,9
XZ	H	7th	6076	-27.86	-43,70	15,8
XZ	H	8th	6944	-27.86	-44,13	16,3
XZ	H	9th	7812	-27.86	-39,38	11,5
XZ	H	10th	8680	-27.86	-35,52	7,7

Table 9. Radiated harmonics, 4060-PCE10B868 driven by the MSC-LCDBB930-AES Wireless Motherboard (Continued)

Cut.	Pol.	Freq.	f [MHz]	ETSI limit in EIRP [dBm]	Measured radiated power in EIRP [dBm]	Margin [dB]
YZ	V	Fund.	868	16.12	9,04	7,1
YZ	V	2nd	1736	-27.86	-48,96	21,1
YZ	V	3rd	2604	-27.86	-51,19	23,3
YZ	V	4th	3472	-27.86	-39,10	11,2
YZ	V	5th	4340	-27.86	-36,03	8,2
YZ	V	6th	5208	-27.86	-30,61	2,7
YZ	V	7th	6076	-27.86	-41,02	13,2
YZ	V	8th	6944	-27.86	-44,09	16,2
YZ	V	9th	7812	-27.86	-41,11	13,2
YZ	V	10th	8680	-27.86	-37,75	9,9
YZ	H	Fund.	868	16.12	5,81	10,3
YZ	H	2nd	1736	-27.86	-39,43	11,6
YZ	H	3rd	2604	-27.86	-46,53	18,7
YZ	H	4th	3472	-27.86	-38,19	10,3
YZ	H	5th	4340	-27.86	-34,10	6,2
YZ	H	6th	5208	-27.86	-31,45	3,6
YZ	H	7th	6076	-27.86	-38,38	10,5
YZ	H	8th	6944	-27.86	-42,68	14,8
YZ	H	9th	7812	-27.86	-41,45	13,6
YZ	H	10th	8680	-27.86	-36,19	8,3

10.5. Range Test (WES0039-01-APB868D-01)

Result is the range number in [m] with Google map distance plot (outdoor) or with building map plot (indoor). Proposed bit rate is 9.6kbps, frequency deviation is 30 kHz (2-level GFSK, H=6.25), standard Pico Board packet error test. Output power (conducted) is 10dBm; receiver sensitivity is –111.5 dBm (1e-3 BER).

Two outdoor range test is done.

1. Outdoor range test with two units using the reference monopole
2. Outdoor range test between two identical units using the investigates antenna board

The reference outdoor range test was done two whip antennas (ANT-868-CW-HWR-SMA type from Lynx Technologies). The delivered TX power to the antenna was ~10dBm. The reference range with this was 1108m.

The outdoor range test result using two printed BIFAs to the front direction (XY plane is horizontal and the Y axes are facing to each other as it is typical in normal remote applications) is 1107m as shown in Figure 9.15. It is very close to the reference whip results.

Also it can be seen from the BIFA pattern plots that the antenna gain is at maximum (~0dBi) at other directions (e.g. XZ cut, vertical polarization, 90 degree, Figure 9.11). With facing the TX-RX pair in this orientation (e.g. in non-remote applications) the range could be even higher by 40…50%.

Indoor range test is not done, due to the lack of large enough building. But, from the TX power and sensitivity data an indoor range estimation can be given assuming a propagation factor of 4.5, which is a typical value in normal office environment. Using the Silabs range calculator (can be found in the webpage, e.g. here: http://www.silabs.com/support/pages/document-library.aspx?p=Wireless&f=EZRadioPRO&pn=Si4460) and assuming -5dBi antenna gain (front direction, Y axes facing) the estimated indoor range is 89m as it is shown in Fig. 9.16.

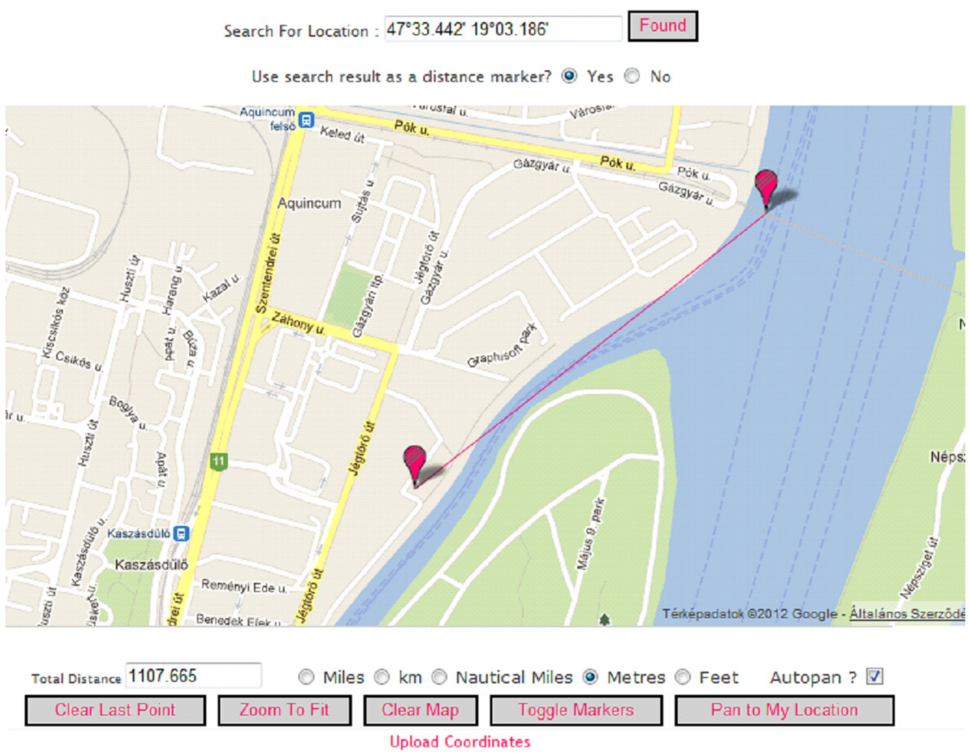


Figure 142. Figure 9.15. Outdoor range test result with two identical printed BIFA antennas with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

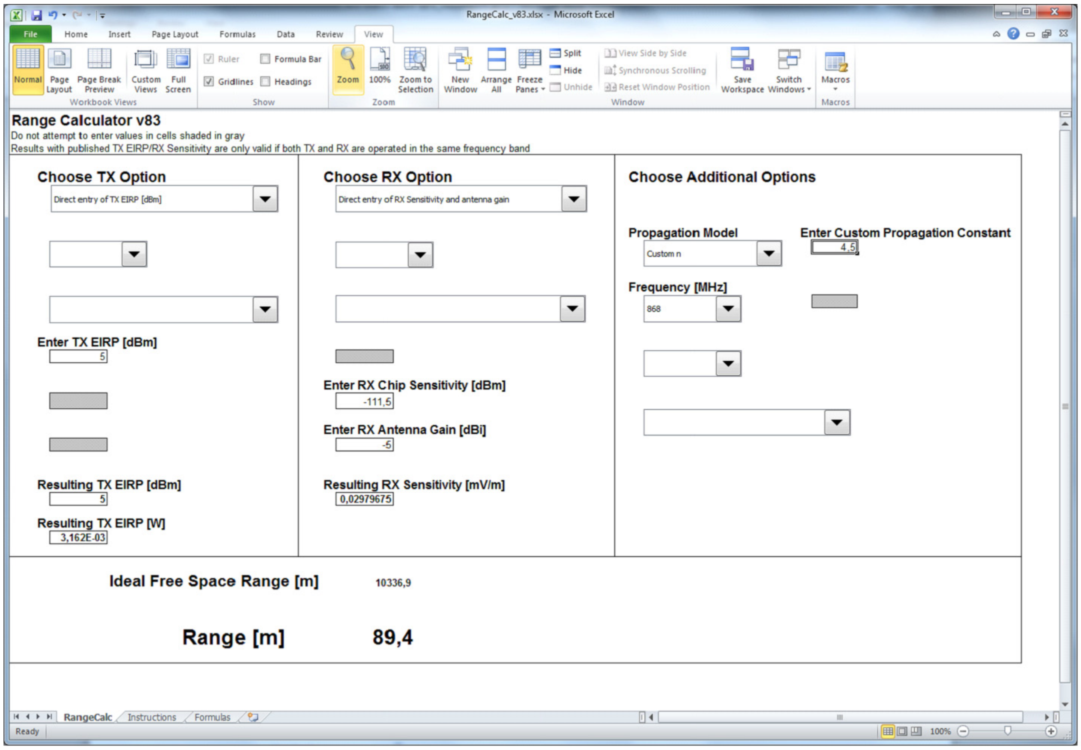
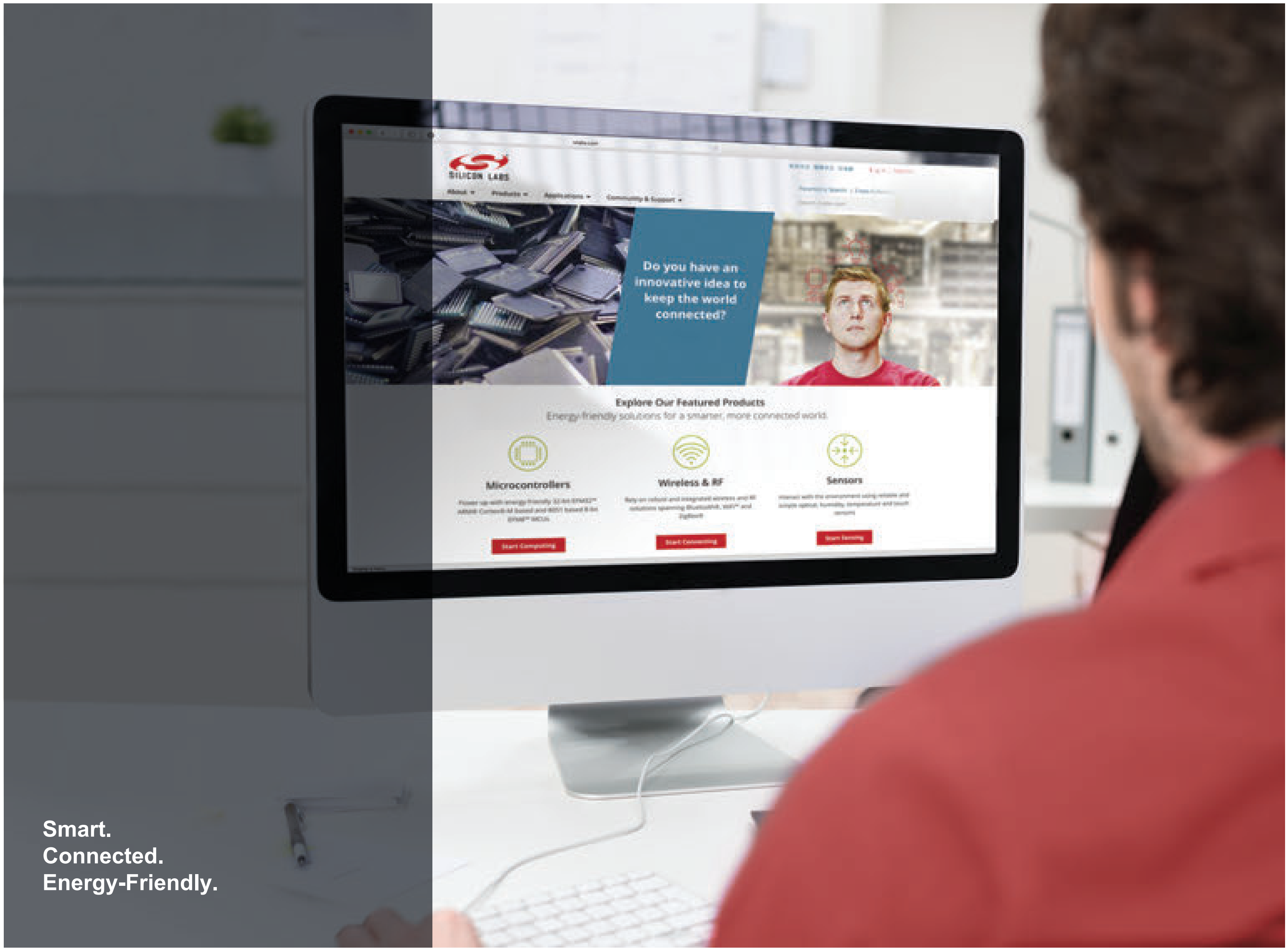


Figure 143. Indoor range estimation with two identical printed BIFA antennas and with the 4060-PCE10B868 Pico Board driven by the MSC-LCDBB930-AES Wireless Motherboard

NOTES:



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