



## **1 Introduction**

This application note is dedicated to the STM32W108 product family from STMicroelectronics.

One of the main reasons to use a PCB antenna is the reduced overall cost of the radio module. Well designed and implemented PCB-printed antennas have a similar performance to the SMD ceramic equivalence. In general, the footprint for a ceramic SMD antenna is smaller than that for a PCB-printed variant. For a PCB-printed antenna solution, the increased size of the PCB in relation to space required for the antenna means that the radio module is larger cost of the PCB increased. The increased cost of the PCB is smaller and less expensive than a SMD ceramic antenna.

The STM32-RFCKIT RF control kit is based on an STM32W108xx RF microcontroller. It implements a PCB-printed antenna to perform RF communications.

---

# Contents

1	Introduction .....	1
1	Coordinate system .....	5
2	Layout specification .....	6
3	Impedance matching .....	8
4	Radiation pattern, 3-D visualization .....	12
5	Radiation pattern, 2-D visualization .....	14
6	Performance .....	25
7	Summary .....	26
8	Revision history .....	27

Table 1. Specification of the recommended substrate ..... 7  
Table 2. Document revision history ..... 27

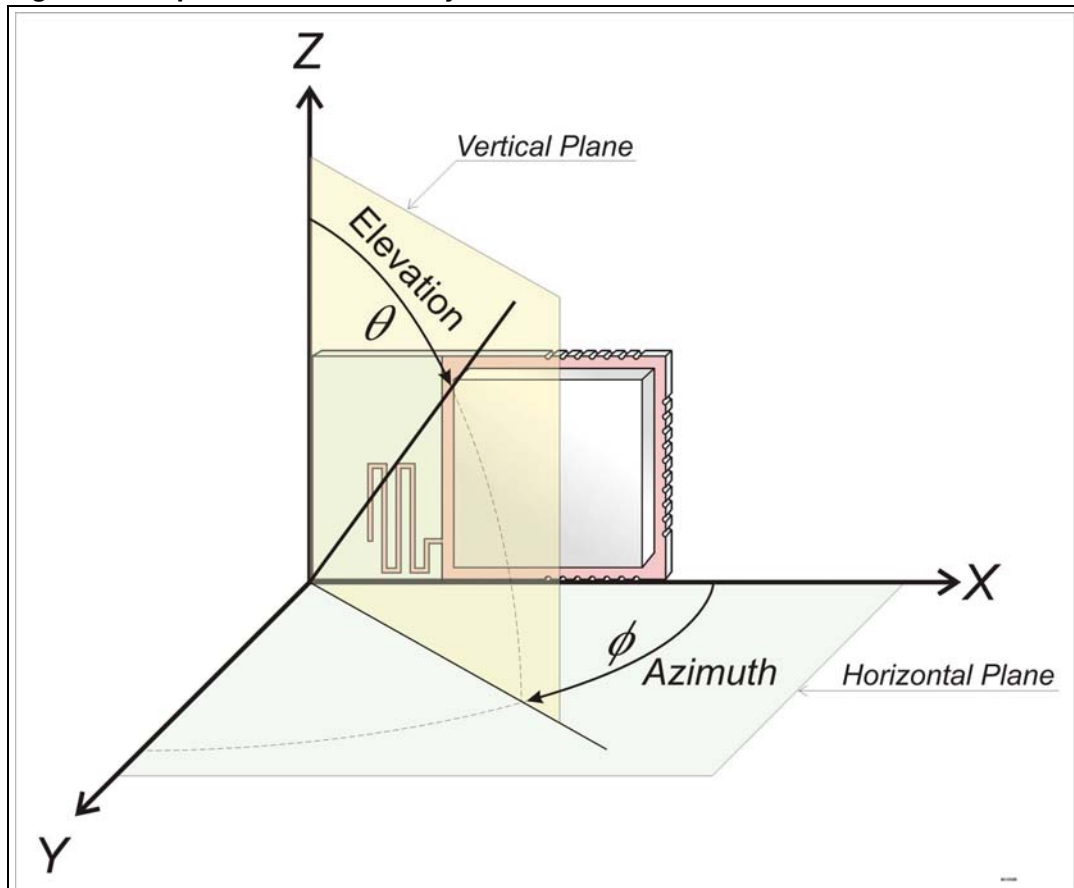
---

Figure 1.	Spherical coordinate system. . . . .	5
Figure 2.	Layout of Meander-like PCB antennae. . . . .	6
Figure 3.	Cross section of the PCB at antennae region. . . . .	7
Figure 4.	Part of the ZigBee module's PCB with Meander-like antenna (around scale 4:1) . . . . .	8
Figure 5.	Bypassing impedance matching circuitry - direct RF connection . . . . .	8
Figure 6.	Complex impedance of the Meander-like antenna on Smith Chart . . . . .	9
Figure 7.	Magnitude of the S11 parameter in logarithmic scale (Cartesian plot) . . . . .	10
Figure 8.	Antenna's Standing Wave Ratio (SWR) . . . . .	11
Figure 9.	Three dimensional (3-D) radiation pattern overview . . . . .	12
Figure 10.	Radiation pattern on Y-Z plane . . . . .	12
Figure 11.	Radiation pattern on X-Z plane . . . . .	13
Figure 12.	Major planes used to visualize 3-D radiation pattern using 2-D plots. . . . .	15
Figure 13.	Far field radiation pattern plotted on Y-Z plane . . . . .	16
Figure 14.	normalized radiation pattern on Y-Z plan (Polar plot) . . . . .	17
Figure 15.	normalized radiation pattern on Y-Z plane (Cartesian plot) . . . . .	18
Figure 16.	Far field radiation pattern plotted on X-Y plane . . . . .	19
Figure 17.	Normalized radiation pattern on X-Y plan (Polar plot) . . . . .	20
Figure 18.	Normalized radiation pattern on X-Y plan (Cartesian plot) . . . . .	21
Figure 19.	Far field radiation pattern plotted on X-Z plane . . . . .	22
Figure 20.	Normalized radiation pattern on X-Z plane (Polar plot) . . . . .	23
Figure 21.	Normalized radiation pattern on X-Z plane (Cartesian plot) . . . . .	24

# 1 Coordinate system

For the purpose of this document, the spherical coordinate system illustrated in [Figure 1](#) is used.

**Figure 1. Spherical coordinate system**

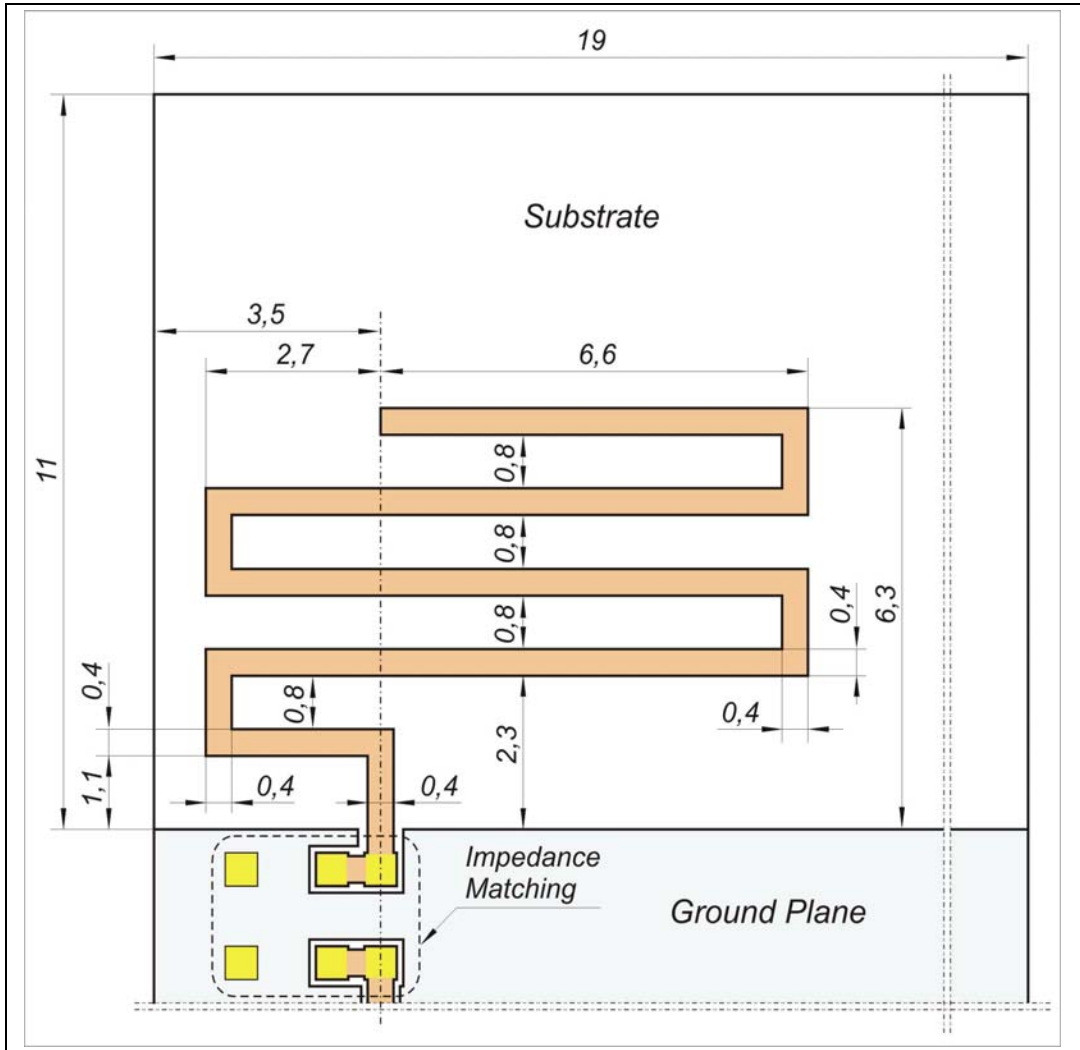


The PCB module is orientated vertically (plane X-Z), and located in proximity to the origin of the coordinate system. The azimuth angle radiates from the X-axis towards the Y-axis, and the elevation angle radiates from the Z-axis towards the horizontal plane, X-Y. Sometimes, as with geographical and navigational systems, the X-axis is called the "Nord-axis", the Y-axis is called the "East-axis" and the Z-axis is called the "Zenith-axis".

## 2 Layout specification

PCB antennas, including the electrical parameters of PCB materials used, are layout sensitive. STMicroelectronics recommends using a layout as close as possible to that shown in [Figure 2](#).

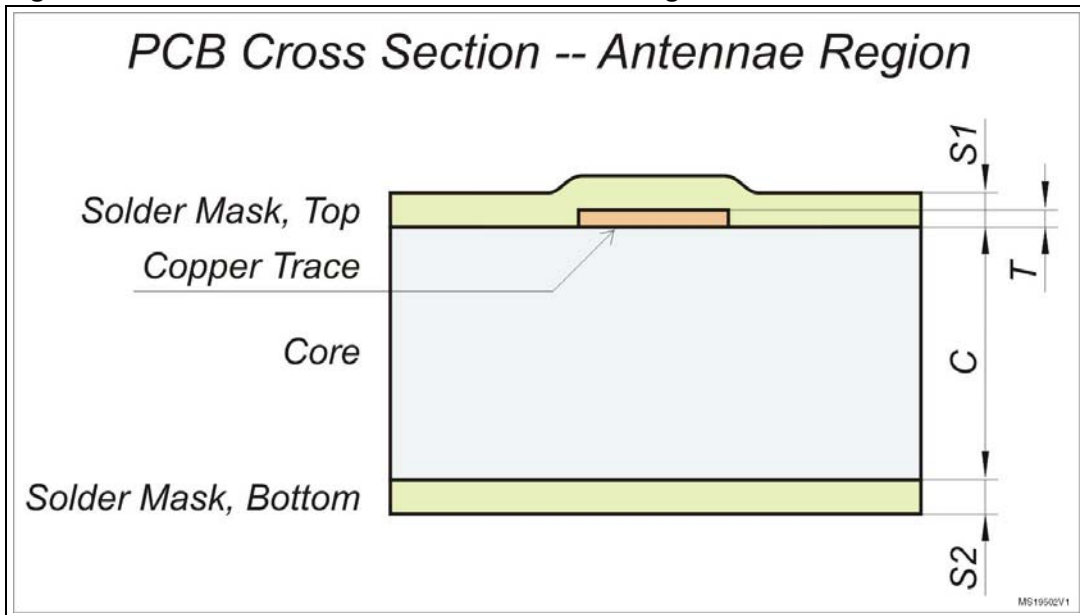
**Figure 2. Layout of Meander-like PCB antennae**



The electrical parameters and performance of the PCB antenna are also determined by the substrate used, in particular the thickness of the core and dielectric constants  $\epsilon_R$ .

[Figure 3](#) illustrates a typical cross-section of the substrate in a PCB-antennae area.

Figure 3. Cross section of the PCB at antennae region



A substrate with the parameters in [Table 1](#) is recommended:

Table 1. Specification of the recommended substrate

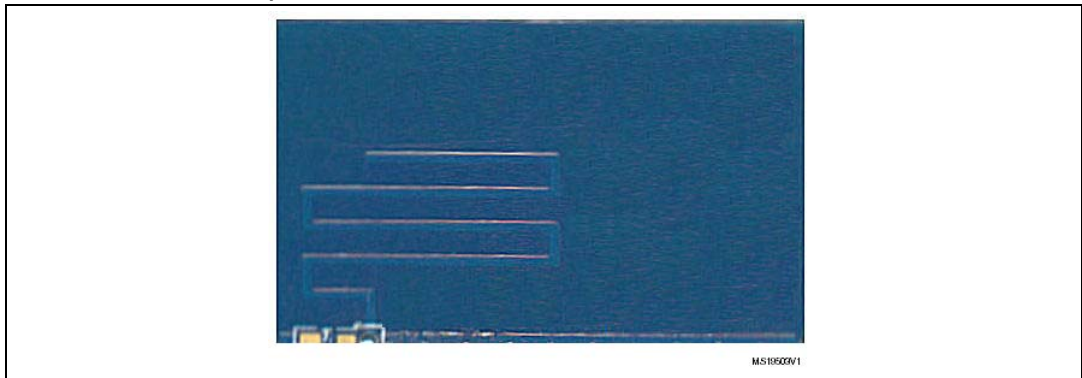
Pos.	Layer	Dimension					Dielectric Constant $\epsilon_R$
		Label	Value	Unit	Value	Unit	
1	Solder Mask, Top	S1	0.7	mil	17.78	$\mu\text{m}$	4.4
2	Copper Trace	T	1.6	mil	40.64	$\mu\text{m}$	---
3	Core	C	28	mil	711.2	$\mu\text{m}$	4.4
4	Solder Mask, Bottom	S2	0.7	mil	17.78	$\mu\text{m}$	4.4

### 3 Impedance matching

Meander-like PCB antenna can be tuned to the required 50 Ohm impedance by matching the impedance circuitry with the  $\pi$  topology. In *Figure 2* the impedance matching area is marked with a dashed line. Under nominal conditions, this antenna should exhibit impedance very close to the required nominal impedance (50 Ohm).

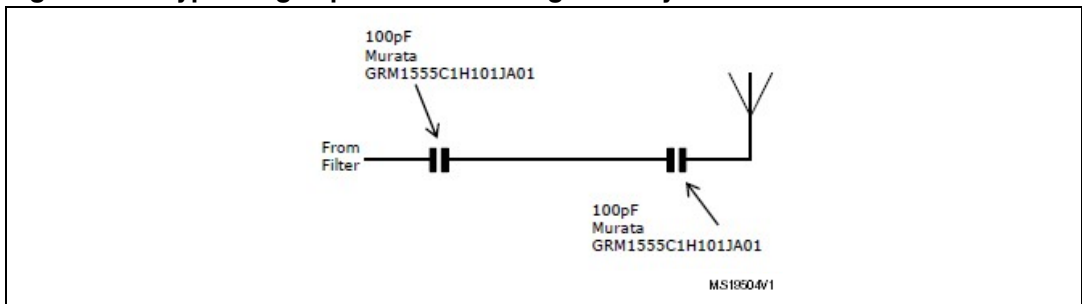
To check the performance of this design, a sample antenna was manufactured (according to the specifications covered by this document). *Figure 4* shows this antenna.

**Figure 4. Part of the ZigBee module's PCB with Meander-like antenna (around scale 4:1)**



Assuming that the manufactured sample exhibits the expected performance (no impedance matching necessary), the impedance matching circuitry was bypassed by two 100 pF capacitors connected in series, as shown in *Figure 5*:

**Figure 5. Bypassing impedance matching circuitry - direct RF connection**



All electrical parameters of the meander-like antenna have been measured at connection to the Band Pass Filter with the frequency span covering frequencies from 2.4 GHz to 2.5 GHz.

Complex impedance of the antenna is shown in the Smith diagram in *Figure 6*:



Figure 6. Complex impedance of the Meander-like antenna on Smith Chart

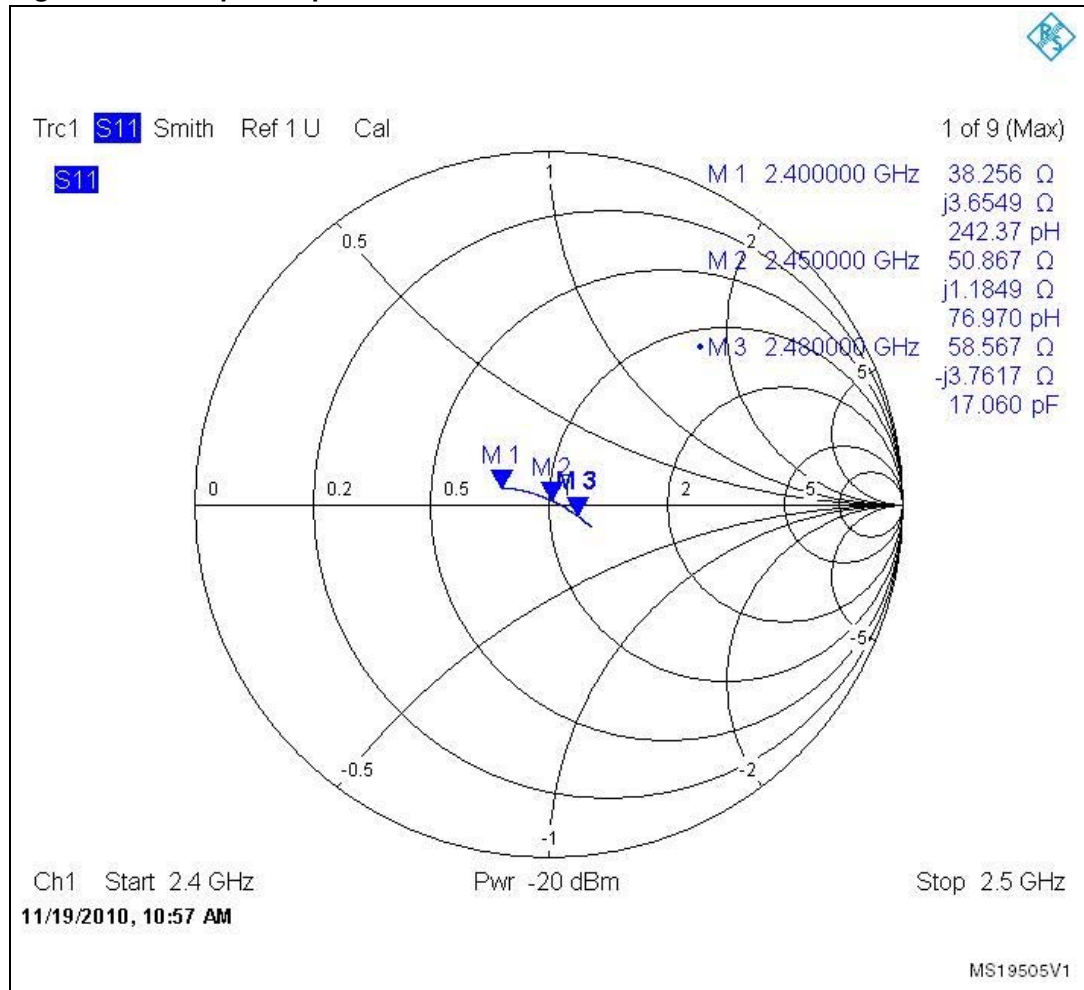


Figure 7 shows the magnitude of the S11 parameter (in log scale).

Figure 7. Magnitude of the S11 parameter in logarithmic scale (Cartesian plot)

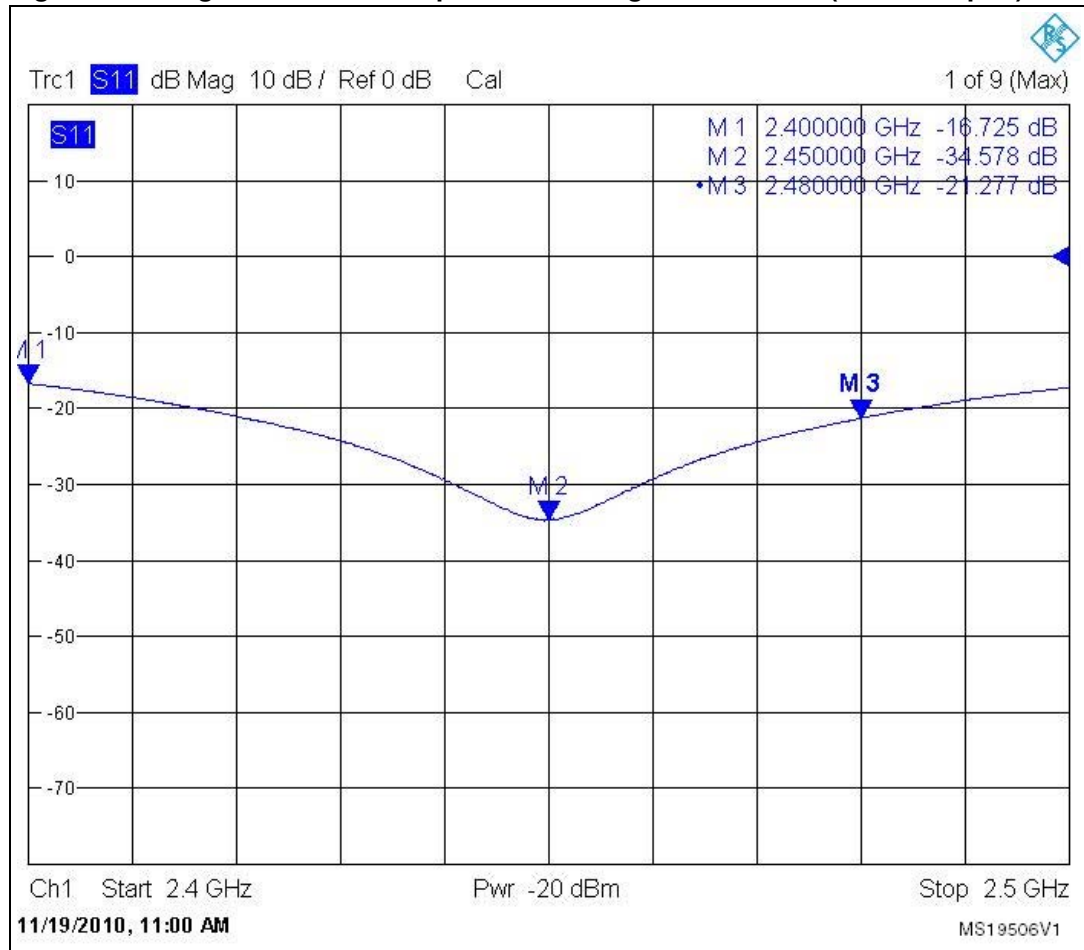
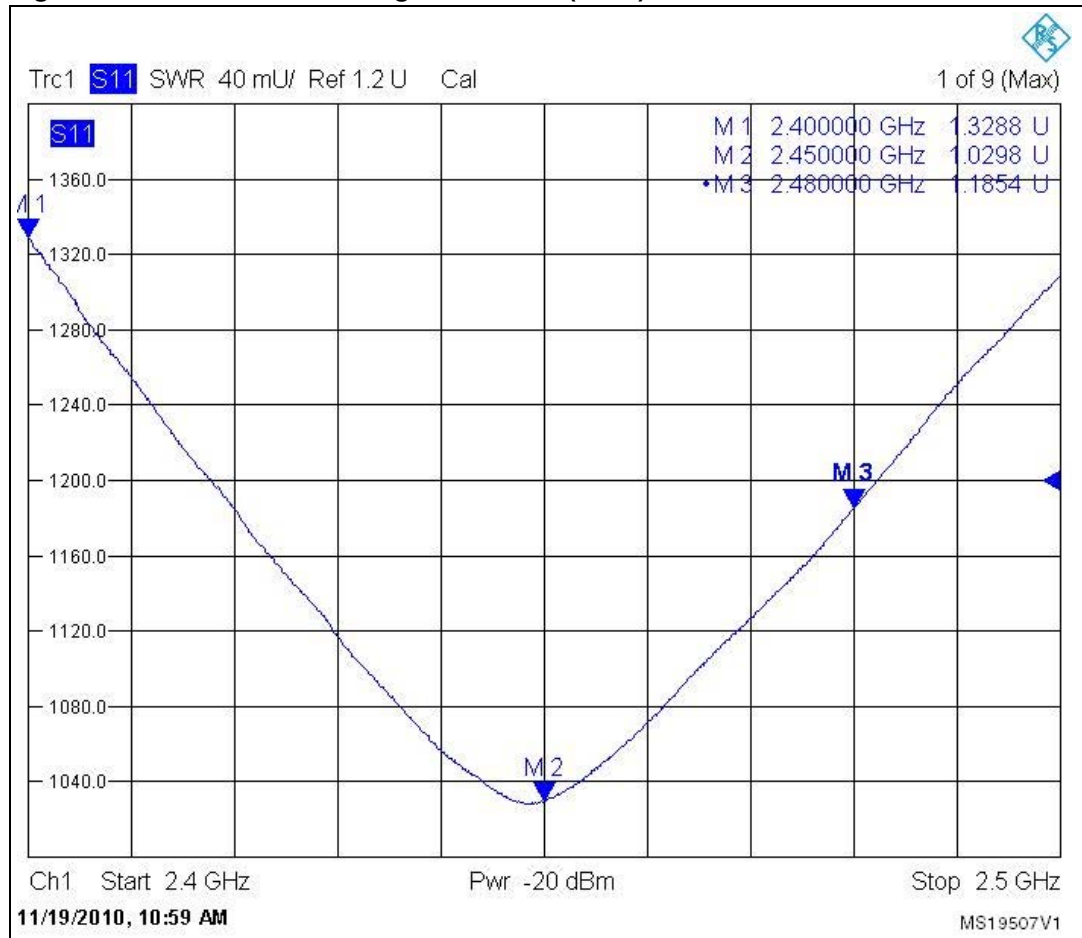


Figure 8 shows the Standing Wave Ratio (SWR).

Figure 8. Antenna's Standing Wave Ratio (SWR)



The following changes will affect the radiation impedance of the PCB antenna:

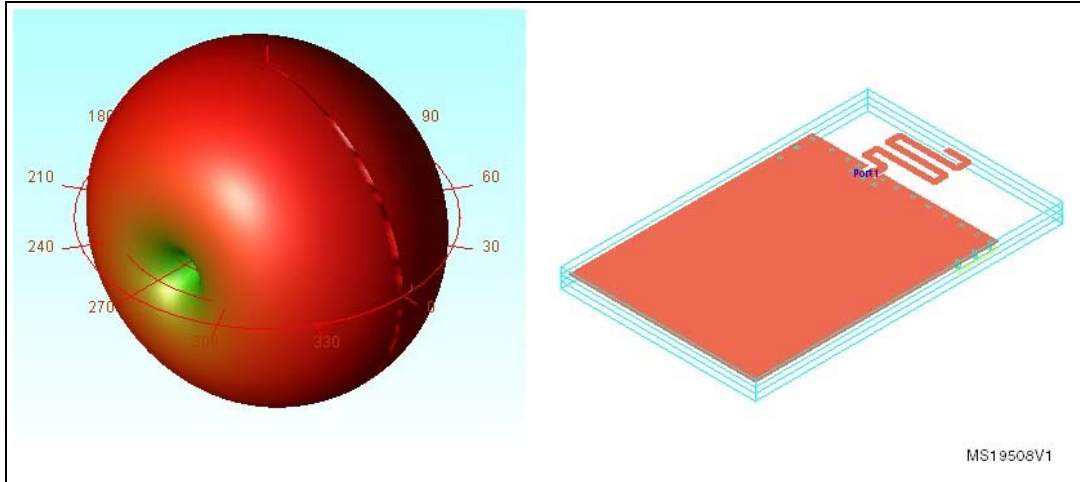
- slight board size variation
- metal shielding
- use of plastic cover
- presence of other components in proximity of the antenna

The best performance impedance matching circuitry will compensate these effects so that for operating frequencies, the optimum 50 Ohm impedance is achieved.

## 4 Radiation pattern, 3-D visualization

A three-dimensional (3-D) visualization of the radiation pattern (magnitude of the electrical far field  $|E|$ ) is done for the center ISM band frequency 2.44175 GHz.

**Figure 9. Three dimensional (3-D) radiation pattern overview**



**Figure 10. Radiation pattern on Y-Z plane**

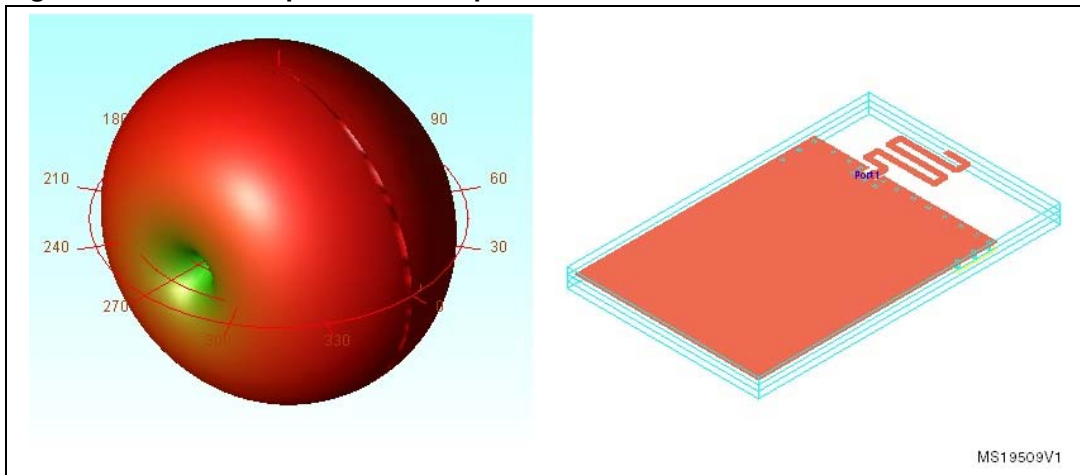
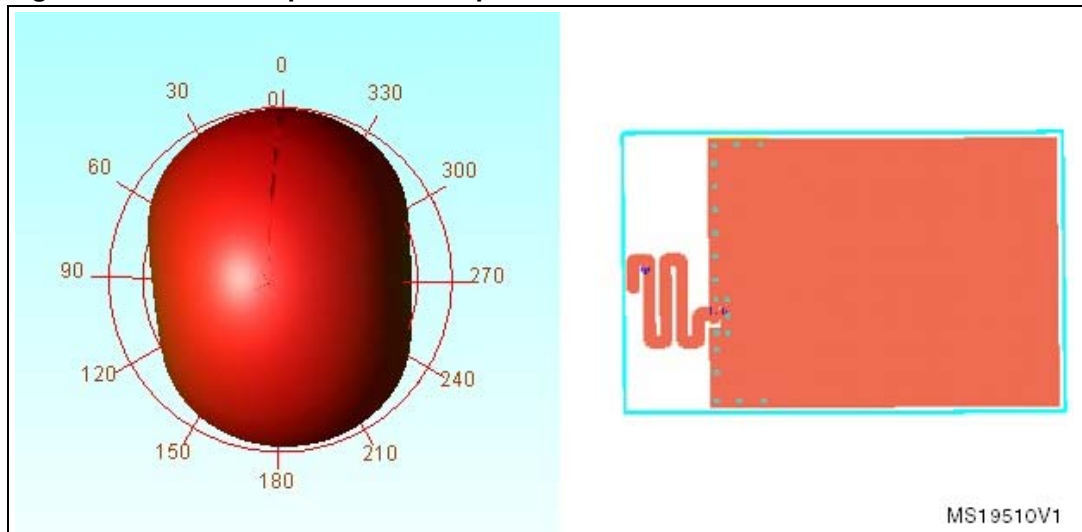


Figure 11. Radiation pattern on X-Z plane



## 5 Radiation pattern, 2-D visualization

In this chapter all radiation patterns are related to the magnitude of electrical far field  $E$ , which is normalized and shown in the logarithmic scale (in dB). This means that the maximum global radiation pattern (maximum magnitude of the electrical far-field  $E$ ) is represented by 0 dB level. To show antenna radiation patterns in detail, three two dimensional (2-D) major cuts are presented. Consider the orientation of the module in the spherical coordinate system as shown in [Figure 1](#).

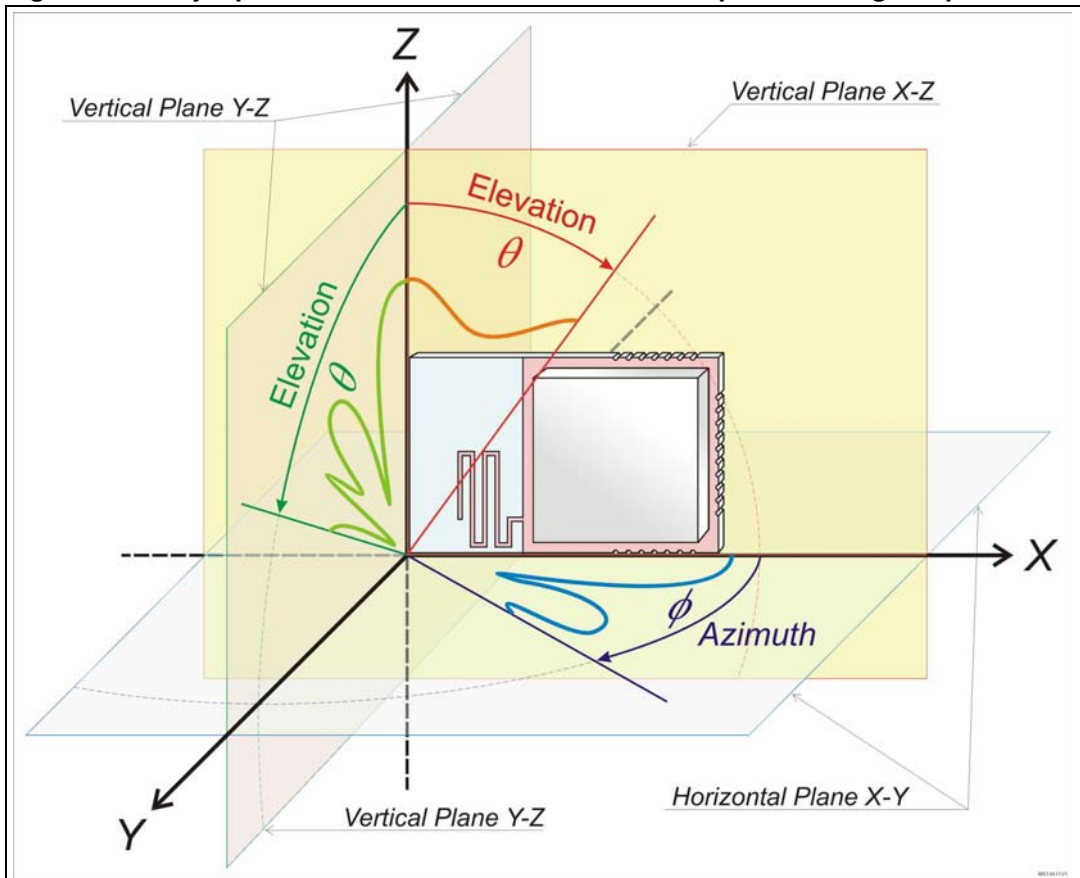
A three dimensional (3-D) far field radiation pattern is visualized as three two dimensional (2-D) cuts through a 3-D pattern. Three major planes are used for these cuts ([Figure 12](#)):

- One horizontal X-Y plane
- Two vertical planes: X-Z plane and Y-Z plane.

For the colors of the plots in [Figure 12](#):

- The "Blue" plot is drawn on the horizontal X-Y plane, where azimuth  $\phi$  radiates from  $0^\circ$  on the X-axis towards the Y-axis until it reaches  $360^\circ$  on the X-axis.
- The "Red" plot is drawn on the X-Z plane, where elevation  $\theta$  radiates from  $0^\circ$  on the Z-axis towards the positive part of the X-axis until it reaches  $180^\circ$  on the negative part of the Z-axis. In this plot (cut by X-Z plane), elevation  $\theta$  is negative for  $X < 0$ .
- The "Green" plot is drawn on the Y-Z plane, where elevation  $\theta$  radiates from  $0^\circ$  on the Z-axis towards the positive part of the Y-axis until it reaches  $180^\circ$  on the negative part of the Z-axis. For this plot (cut by Y-Z plane), elevation  $\theta$  is negative for  $Y < 0$ .

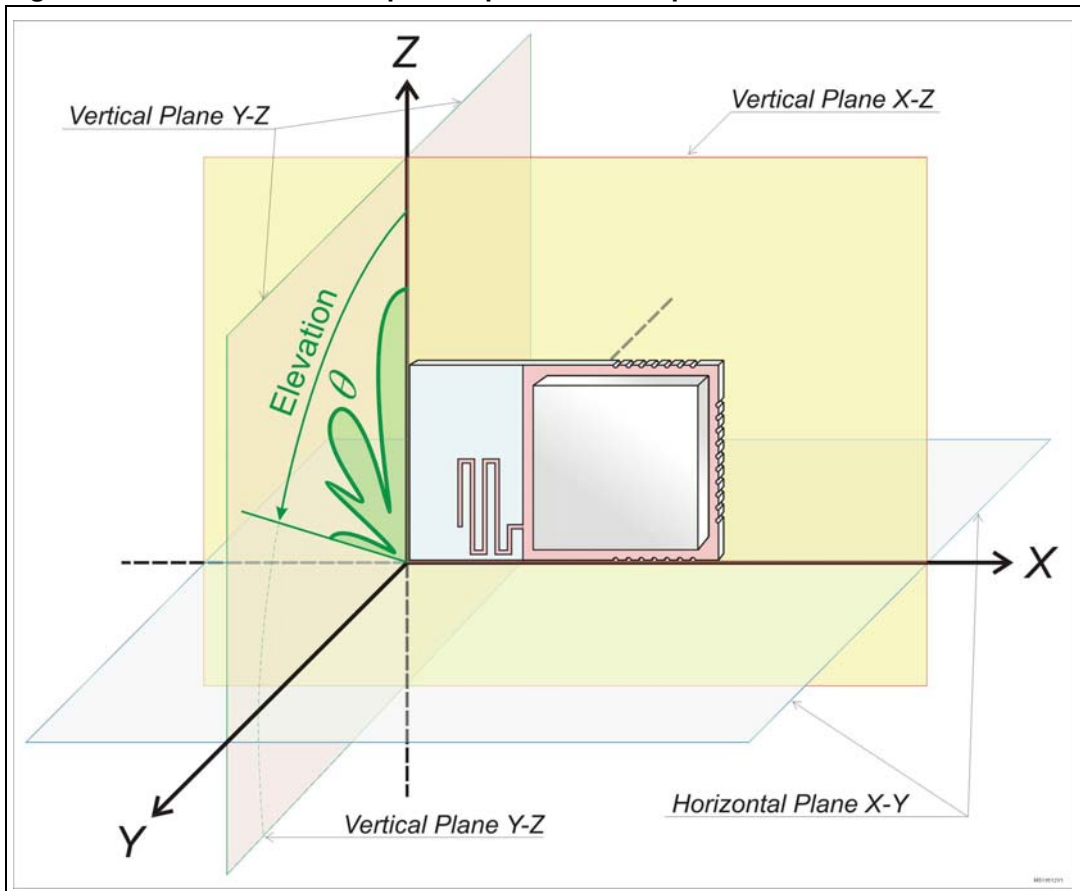
Figure 12. Major planes used to visualize 3-D radiation pattern using 2-D plots



This chapter uses short dipole for comparison and clarification purposes only.

The first radiation patterns in [Figure 14](#) and [Figure 15](#) show a normal electrical field radiation pattern  $|E|$  (far field) on the Y-Z plane. The module orientation versus Y-Z plane and this plot is shown in [Figure 13](#).

Figure 13. Far field radiation pattern plotted on Y-Z plane



Notice the nearly constant level of the radiation—nearly omni-directional radiation on this plane. For a vertically orientated dipole, this pattern is equivalent to the horizontal radiation.



Figure 14. normalized radiation pattern on Y-Z plan (Polar plot)

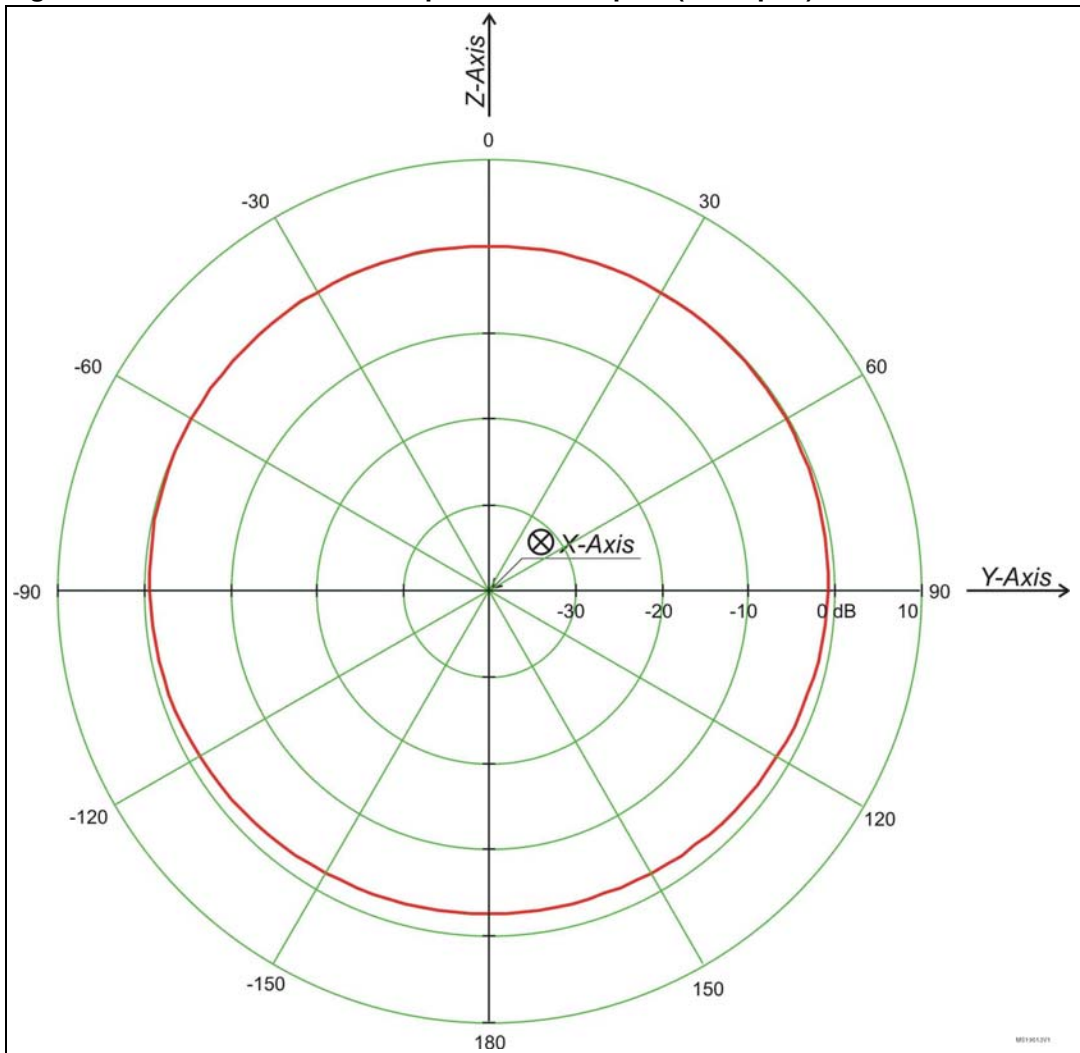
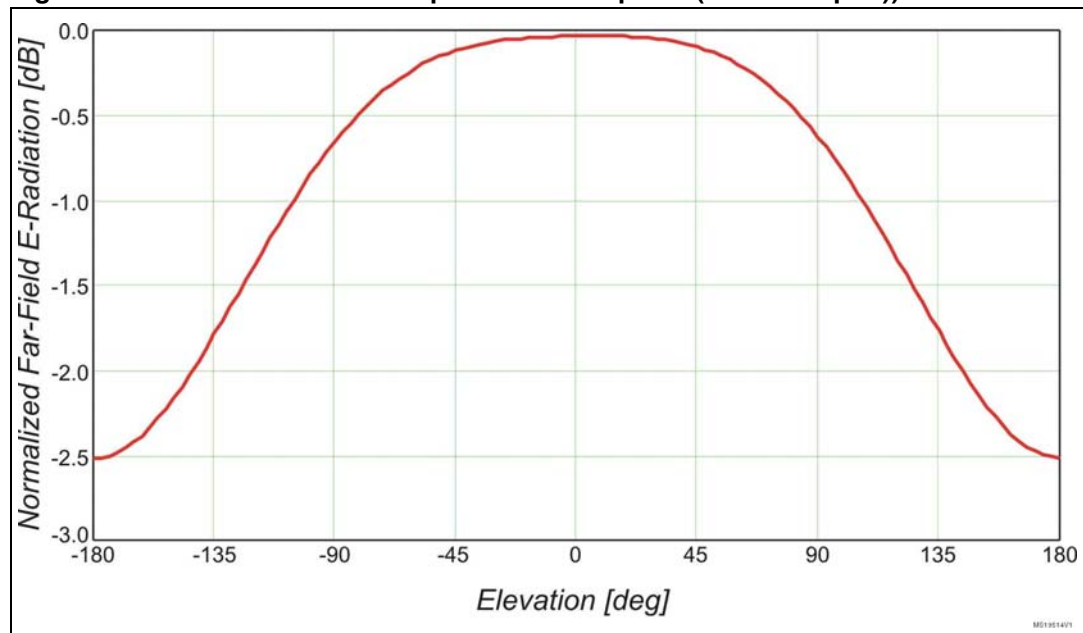
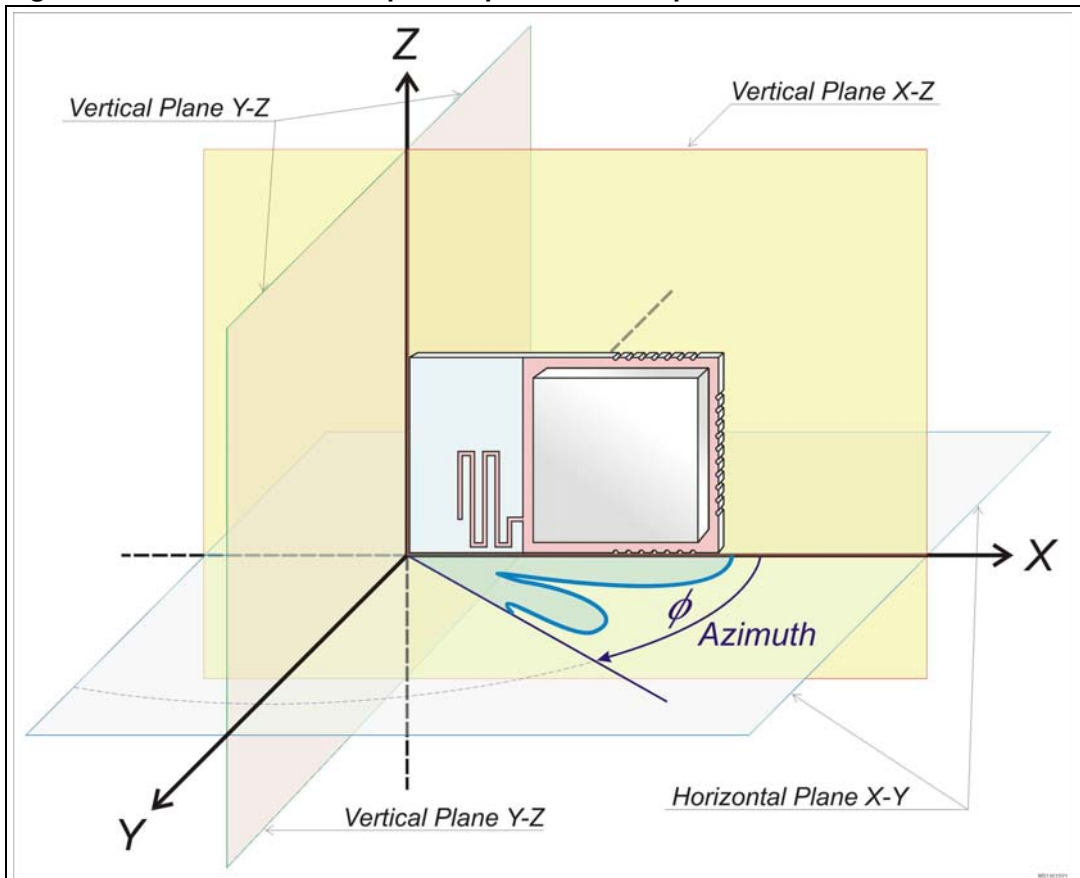


Figure 15 shows the same radiation pattern as in Figure 14, presented as a Cartesian plot.

**Figure 15. normalized radiation pattern on Y-Z plane (Cartesian plot)**

The second far-field radiation pattern ([Figure 17](#) and [Figure 18](#)) represents a normalized magnitude of the electrical field  $|E|$  plotted on the X-Y plane. The module orientation versus the X-Y plane and this plot is shown in [Figure 16](#).

Figure 16. Far field radiation pattern plotted on X-Y plane



For a vertically orientated dipole, this pattern is equivalent to the vertical radiation. Note that the "dips" (between -10 and -14 dB) are much less critical than for the dipole.

Figure 17. Normalized radiation pattern on X-Y plan (Polar plot)

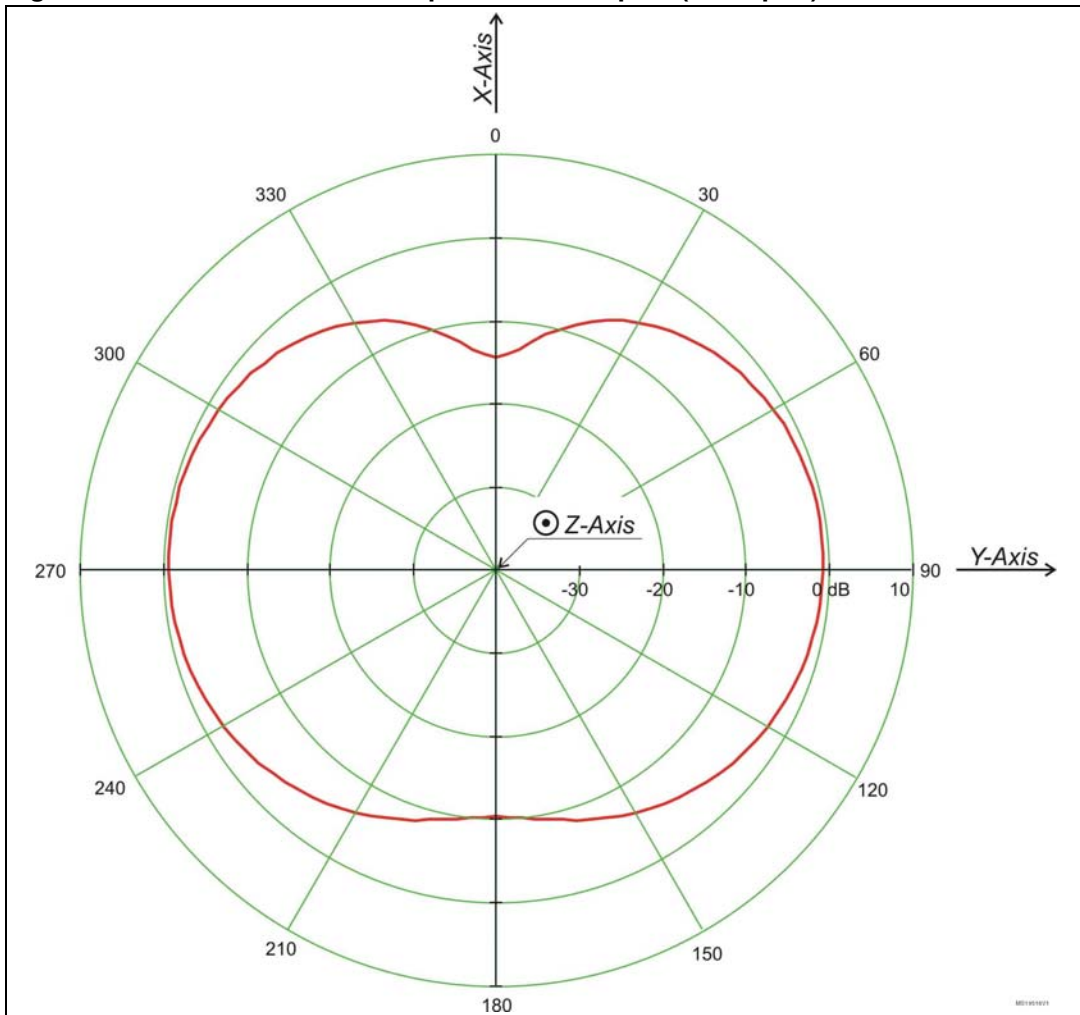
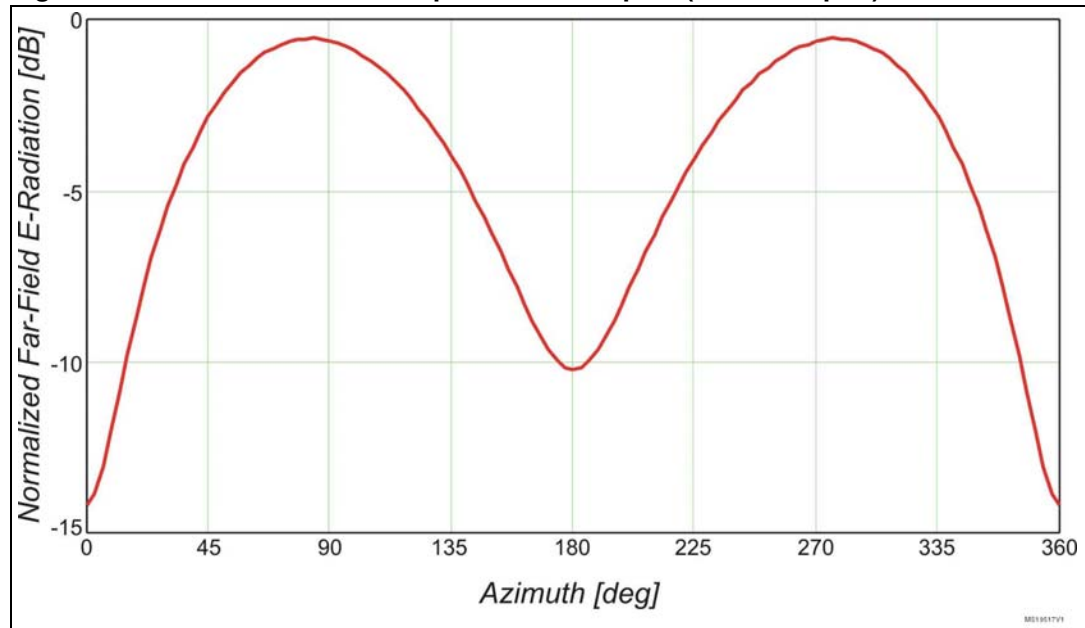
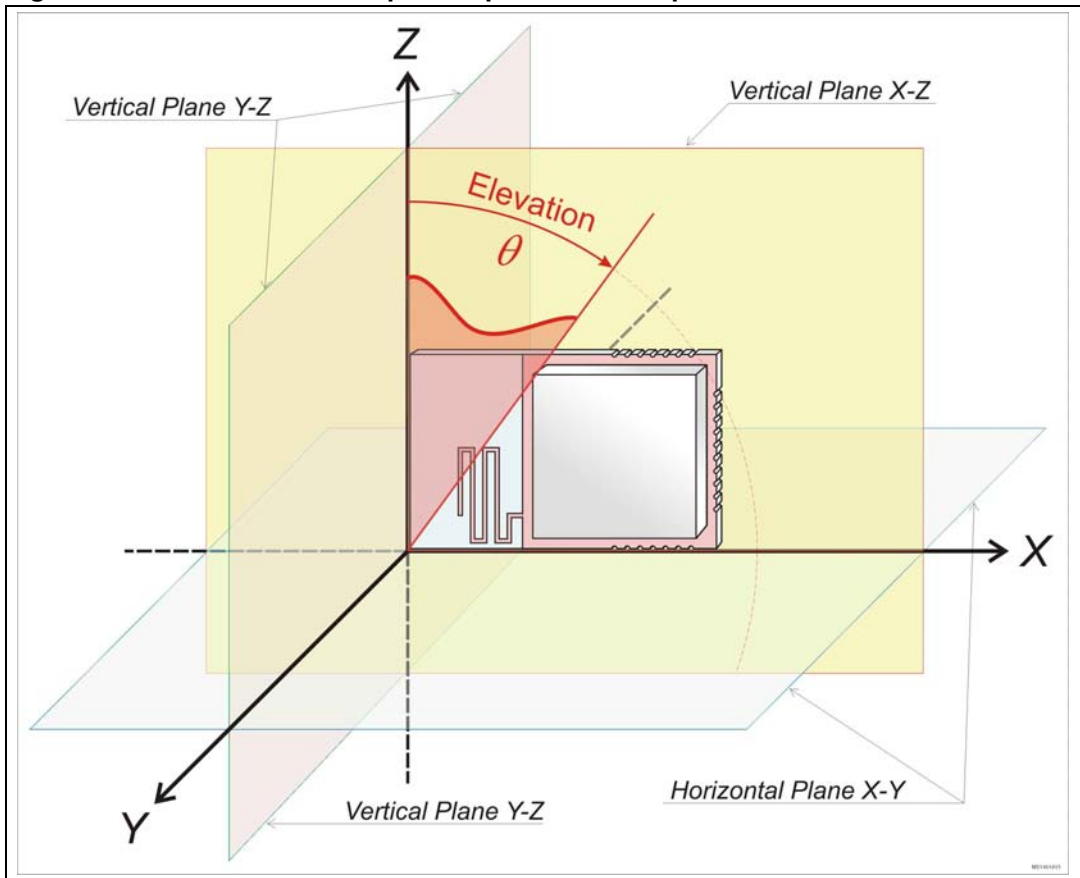


Figure 18 show the same far |E|<sub>rms</sub> field radiation pattern on the X-Y plane as in Figure 17, presented as a Cartesian plot.

**Figure 18. Normalized radiation pattern on X-Y plan (Cartesian plot)**

The third and last radiation pattern ([Figure 20](#) and [Figure 21](#)) represents a normalized electrical field radiation pattern  $|E|$  (far field) on the X-Z plane. The module orientation versus the X-Z plane and this plot is shown in [Figure 20](#).

Figure 19. Far field radiation pattern plotted on X-Z plane



For a horizontally orientated dipole, this pattern is equivalent to the vertical radiation. Note that the "dip" (about -18 dB in worse case) is not as deep, in comparison to the dipole radiation pattern.

Figure 20. Normalized radiation pattern on X-Z plane (Polar plot)

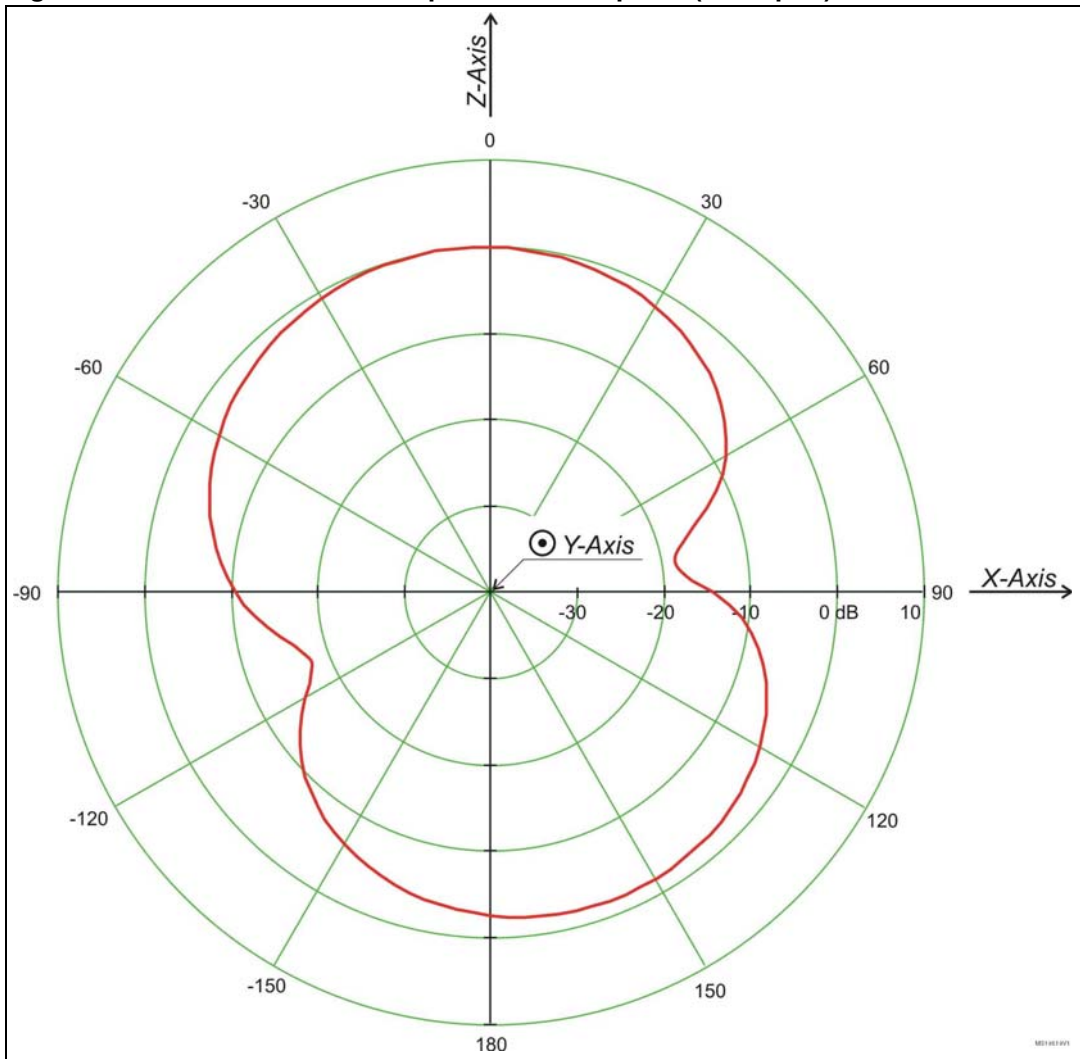
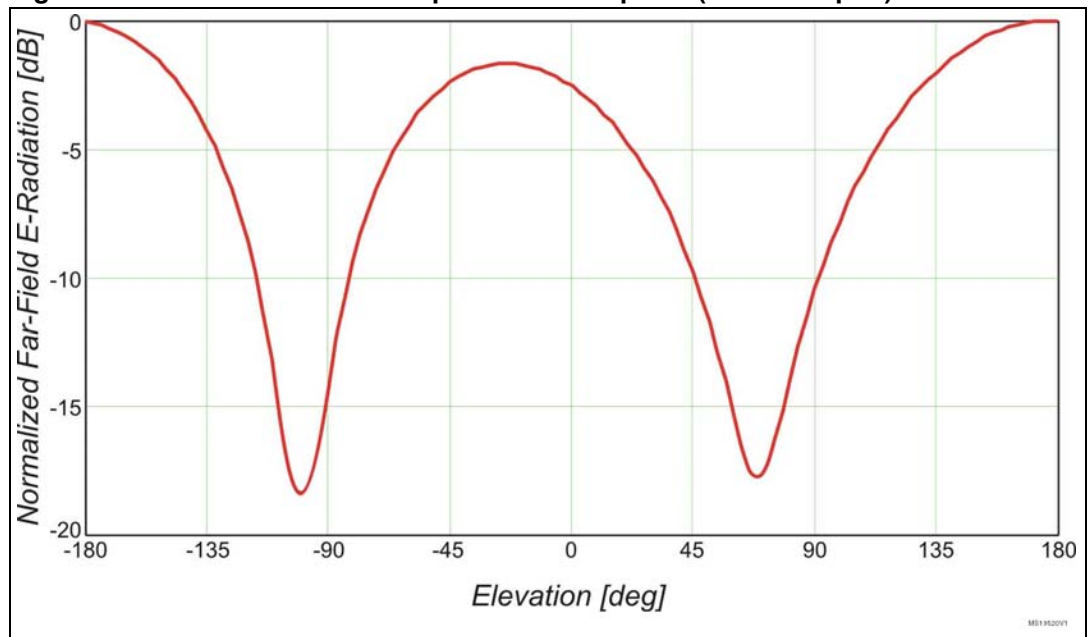


Figure 21 shows the same far electrical field radiation pattern on the X-Z plane (Figure 20), presented as a Cartesian plot.

Figure 21. Normalized radiation pattern on X-Z plane (Cartesian plot)





## 6 Performance

At center ISM Band frequency 2.44175 GHz, antennae show the following key performance parameters:

- Directivity 2.21 dB
- Gain 1.95 dBi
- Maximum intensity 0.125 W/Steradian

## 7 Summary

The designed antenna occupies a small part of the module's PCB. It is inexpensive and simple to produce and shows very good performances, confirmed by measurements of the manufactured samples. Keeping the manufacturing process as close as possible to the specification detailed in this document produces an antenna that does not need any of the additional components usually required for impedance matching circuitry (cost reduction, increased reliability). In addition, a no tuning procedure or similar is required. The antenna impedance is close to the nominal 50 Ohm value, with excellent SWR < 1.35 together and wideband capabilities, where  $\log(|S_{11}|) < -10$  dB is satisfied for more than 150 MHz.

## 8 Revision history

**Table 2. Document revision history**

Date	Revision	Changes
17-Mar-2011	1	Initial release.

**Please Read Carefully:**

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

**UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.**

**UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.**

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2011 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

[www.st.com](http://www.st.com)