AVR2006: Design and characterization of the Radio Controller Board's 2.4GHz PCB Antenna

Application Note

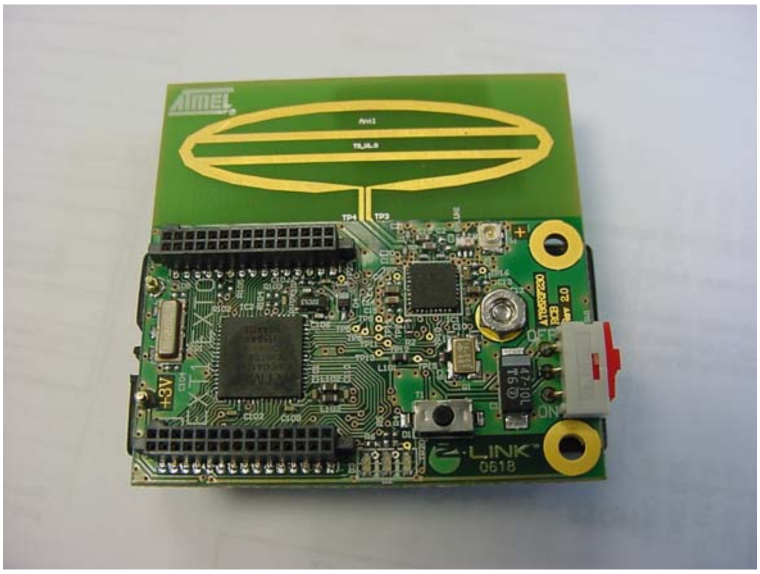
Features

- Radiation pattern
- Impedance measurements
- WIPL design files
- NEC model

1 Introduction

This application note describes the PCB antenna used on the Radio Controller Board as a part of the ATAVRRZ200. This kit is designed for the evaluation of the Atmel® AT86RF230 2.45 GHz radio transceiver. The radio transceiver fully complies with the IEEE® 802.15.4™ standard and targets low-power wireless technologies within homes, buildings and industrial automation such as ZigBee™.

Figure 1-1. ATAVRRZ200's radio controller board



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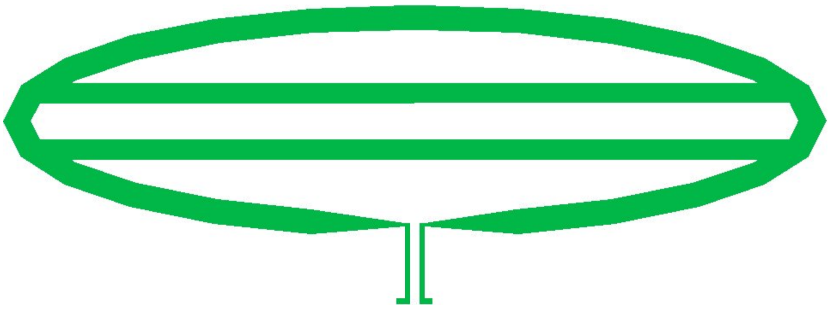
2 Antenna Design

Considering a simple transmitting-receiving-system, the wireless transmission of signals requires the transformation of guided waves into spherical waves by use of an antenna. Therefore the antenna structure converts the guided wave into a propagated wave. The kind and manner of the radiation, depends strongly on the geometry and the environment of the antenna structure. It is essential to choose a design that allows matching either the antenna to the receiver, or to the generator for operation within a fixed frequency range, and to select the geometry for the required radiation.

2.1 Folded Dipole

The designed antenna structure is similar to a dipole. A dipole is a symmetrical antenna of which both lines are being fed in the odd mode, meaning a phase shift of 180°. The input impedance of an ideal dipole is approximately 73 ohm. In the case of one folding of the structure (creating a loop) the input impedance will be modified. The resulting value of the impedance is proportional to the square of the number of foldings used. Therefore a simple folded dipole has an impedance of 2^2*73 ohm. If three lines were to fold to a λ/2 dipole, the impedance would change to 3^2*73 ohm. As the realized antenna structure is being printed on a dielectric layer, the dielectric displacement currents flow between the lines and reduce the impedance considerably. Since the AT86RF230 datasheet states in section 3.5 that the AT86RF230 device has a differential impedance of 100 ohm at a frequency of 2.45GHz, it is now a matter of the geometrical dimensions to find values realizing a matching at the desired frequency. The properties of the antenna connection can be estimated by using electro magnetic (EM) field calculation software. Some programs like WIPL, Sonnet®™ and Microwave Office®™ allow simulating this structure on FR4 PCB material, other's such as the freeware application 4NEC2, only allow one to use free air as a dielectric. But experimenting with 4NEC2 can show the overall behaviour of geometrical changes, keeping in mind that the numerical solution will be wrong for FR4 or other PCB material.

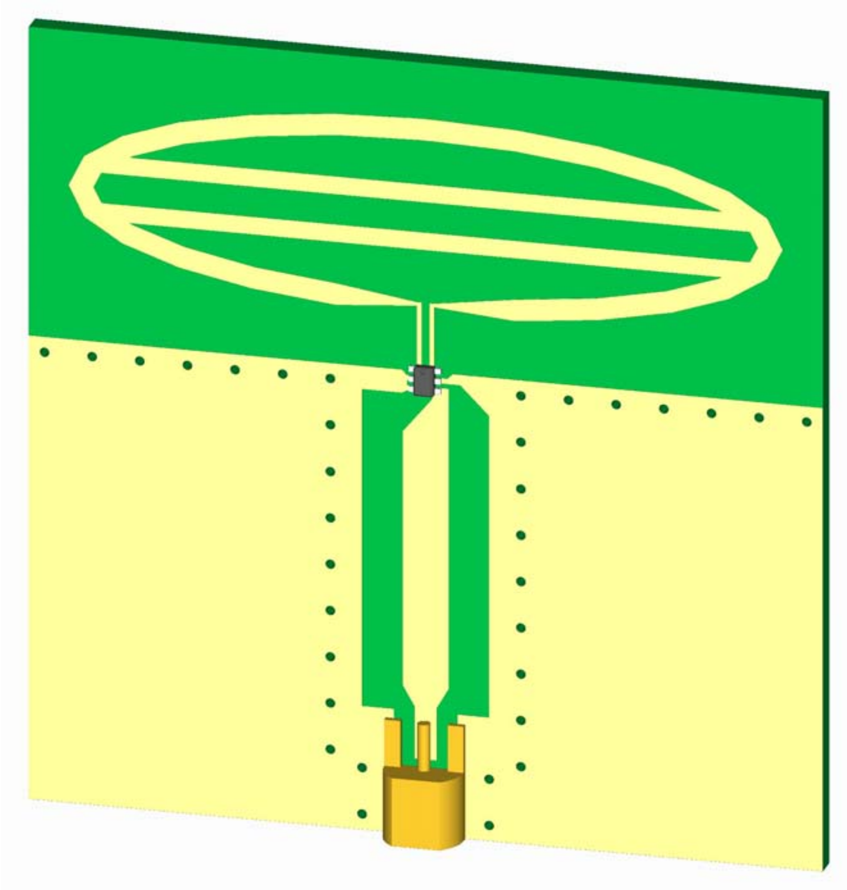
Figure 2-1. Folded dipole consisting of four lines.



2.2 Board Antenna

The finally realized antenna structure considers the symmetrical feeding, the influence of the substrate material, as well as the influence of the adjacent areas of ground on the circuit design. The boundary leading to the ground area should clearly be defined by using wire conductors (vias) between the top and the bottom metal layers. To interface a microstrip to a differential antenna structure, a Chip-Balun "WE-BAL 748421245" is used, allowing single ended measurements. This balun operates between 2400MHz and 2500MHz with an impedance ratio of 1:2. The balun's datasheet should be examined to find values for insertion loss and additional related parameters. The final antenna structure will be connected differentially to the RF port as demonstrated on the Radio Controller Board design. Figure 2.2 depicts the construction of the test board used during the measurements described in section 2.4 thru 2.7 of this application note.

Figure 2-2. Test board.



2.3 Mechanical Dimensions

Figure 2-3. Test board.

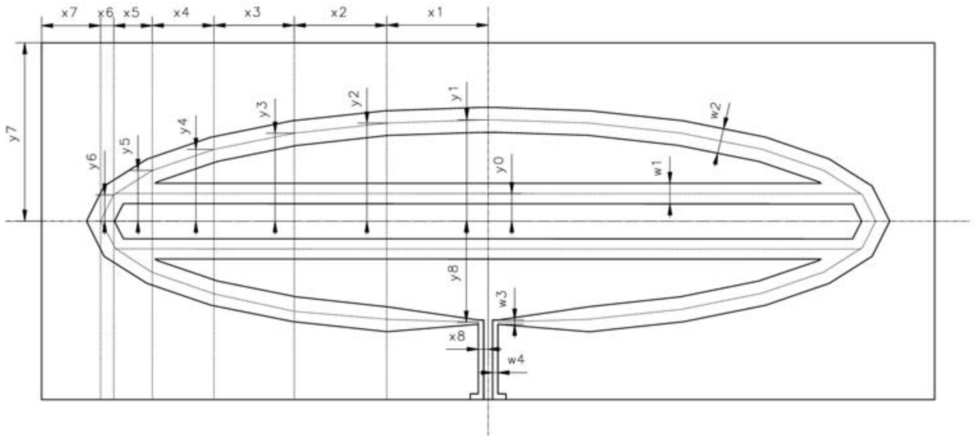


Table 2-3. Mechanical dimensions.

Dimension	[mm]	[mil]
x1	5.6750	223.42
x2	5.1790	203.90
x3	4.4940	176.93
x4	3.4520	135.90
x5	2.1620	85.12
x6	0.7380	29.05
x7	3.2980	129.84
x8	0.3836	15.10
y0	1.5480	60.94
y1	5.6750	223.43
y2	5.5000	216.54
y3	4.9330	194.21
y4	4.0240	158.43
y5	2.8450	112.00
y6	1.4720	57.95
y7	10.0000	393.70
y8	5.6590	222.79
w1	1.1470	45.16
w2	1.4110	55.55
w3	0.2400	9.45
w4	0.3011	11.85

2.4 Port Impedance

Figure 2.4-1 and 2.4-2 show the measured impedance of the antenna on the test board. The goal is it to reach a matching loss of 0dB in the desired frequency band. The measured value at 2.45GHz is Z = 38 ohm / -15° so the antenna has an input impedance without balun of |ZAntenna| = 76 ohm, which creates a matching loss of 0.4 dB. Reference plane for the following measurements is the SMA connector.

Figure 2-4-1. Measured magnitude of port impedance.

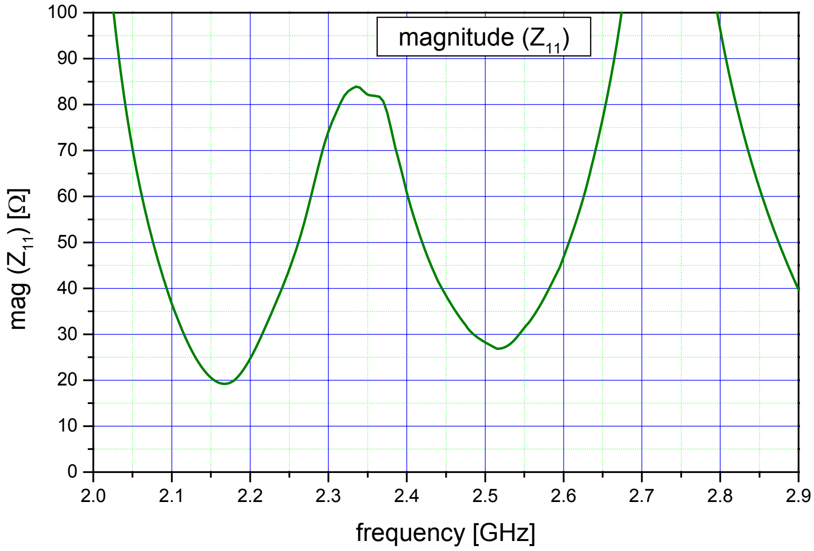
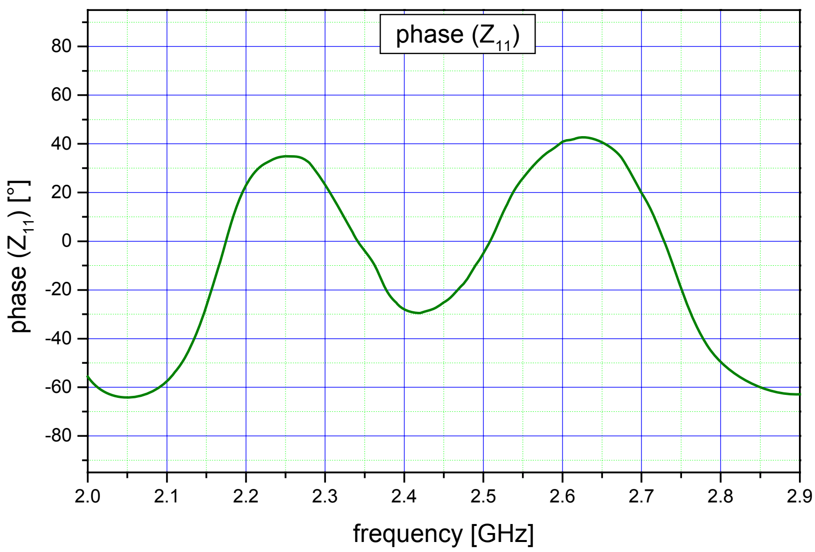


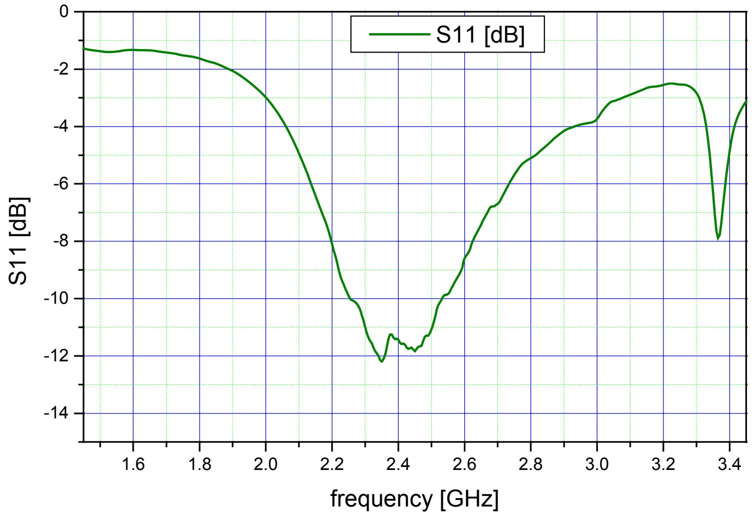
Figure 2-4-2. Measured phase of port impedance.



2.5 Matching

The impedance matching of this antenna is shown in figure 2.5. Between 2.4GHz and 2.5GHz the return loss is less than -10 dB, which is equivalent to the behavior without a balun. The design goal here is it to reach an equal value of |S11| than the generator delivers, which was reached here.

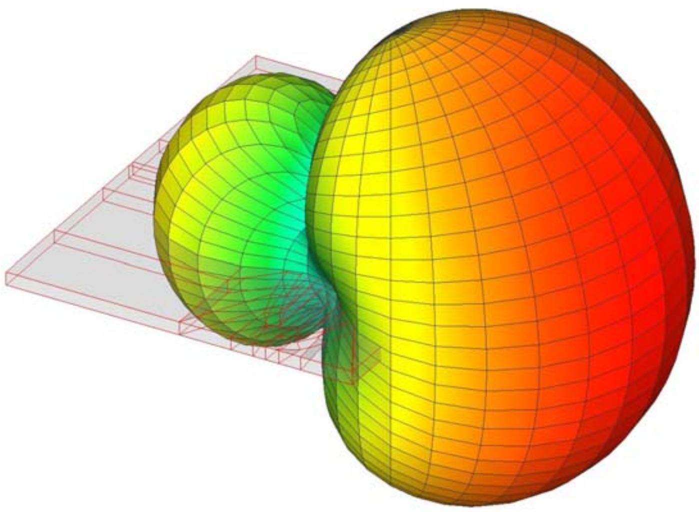
Figure 2-4-3. Measured matching.



2.6 3D Radiation Pattern

Figures 2.6, 2.7-1 and 2.7-2 show the radiation pattern in a spherical, horizontal and vertical view. The spherical view shows with the red intensity that the most intensive radiation direction is along the x-axis, with a direction gain of 6.5dBi and a 3dB-beamwidth of about 100°. So the other communication end point should also be in that direction to make use of the antenna gain and prolong the transmission range.

Figure 2-6-1. Calculated radiation pattern.



2.7 Radiation Diagrams

Figure 2-7-1. Measured horizontal radiation pattern.

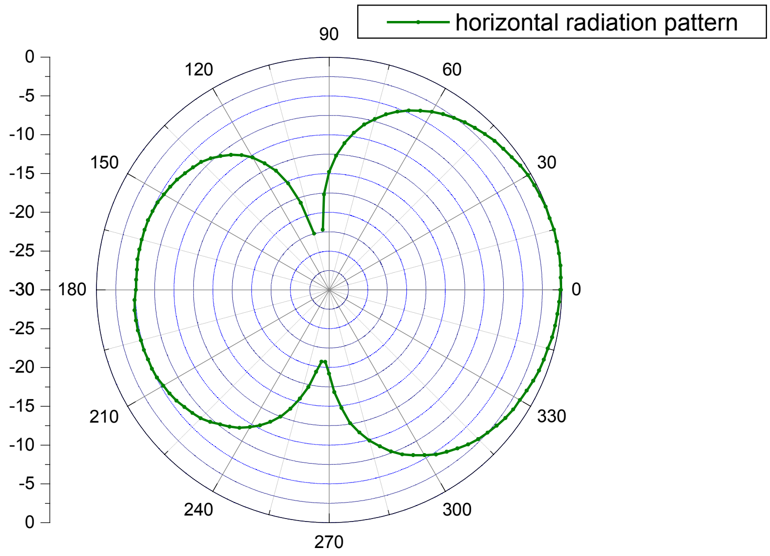
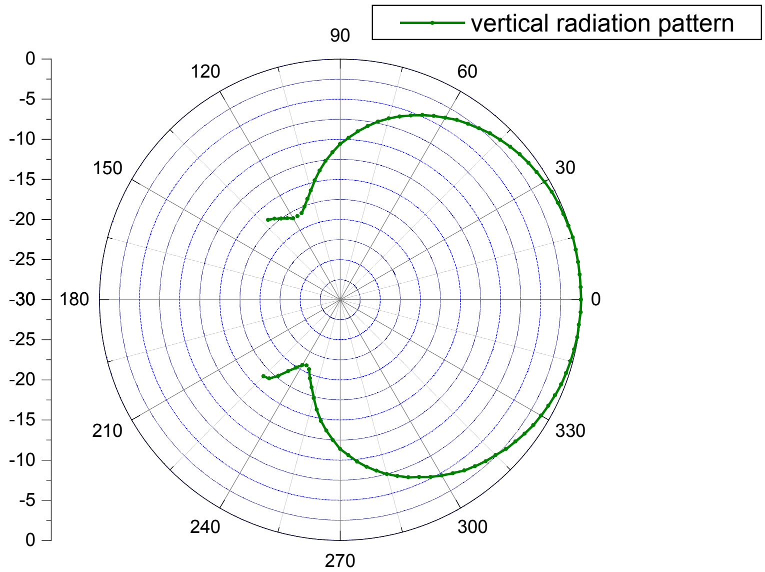


Figure 2-7-2. Measured vertical radiation pattern.



2.8 Software

The EM-field calculation software WIPL used in the design of this antenna can be found on http://www.wipl-d.com. The simulation files for this antenna can be found on www.atmel.com as "T3_WIPL.ZIP". Another EM-field calculator in the same league is Sonnet (http://www.sonnetusa.com/). Sonnet also offers a free version, which is limited to the calculated unknowns and PCB area.

Those, who want to learn more about antenna simulation, may take a look at http://home.ict.nl/~arivoors/ to find the freeware 4NEC2. A geometrical model can be found on www.atmel.com as T3.NEC file.

One should understand as a general note that the electromagnetic field solving software out in the market will never replace years of experience of antenna and PCB designers. It can only be a tool to calculate modeled behavior. The common antenna design process is a loop of creating and measuring an antenna object, since a lot of antenna properties cannot be modeled easily. Such properties are i.e. the antenna environment, distance to disturbing objects in the neighborhood and many more. All of those items may be add to the calculator's input, but it would take months to find results. So the appropriate tool concerning development time is it to include these parameters in the design loop for iterating and measuring parameters as shown in this document.

2.9 Gerber Files

The Gerber files of this antenna and the Radio Controller Board can be found on www.atmel.com in the ATAVRRZ200 kit.

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