Application Note 52

Small PCB Antennas for Micrel RF Products

By Carlos Ribeiro

Synopsis

Today there is a high demand for small printed circuit board layouts and antennas that can be enclosed inside of a plastic box without the problem of having the aerial surface touching other objects or being bent reducing its performance and decreasing the overall range of the RF System. The proposed PCB Antennas have the goal to provide the user of Micrel RF products an alternate way to accomplish a good compact RF system design without the need of an external antenna.

Data sheets and support documentation can be found on Micrel's web site at www.micrel.com.

Suitable Applications

- RKE (Remote Keyless Entry)
- TPMS (tire pressure monitor system)
- GDO (Garage Door Opener)
- Alarm Systems
- IPOD Remote Control
- Wireless Keyboard and Mouse
- Set Top Box
- Remote Controlled Toys
- Water Sprinklers
- Light and Fan Control

Description

One antenna, the helical PCB, is intended for 300 to 450 MHz and the other with a multi-element shape for 850 to 950 MHz frequency of operation respectively. The exact frequency is obtained by proper matching with the addition of some discrete components. Both antennas have been tested thoroughly with our transmitters, receivers and transceivers, which gave very good performance and range in comparison to ¼ wave monopole antennas. PCB antennas are depended on manufacturing processes and will vary from PCB house to PCB house. When the design is stable, one should use the same PCB manufacture and always re-check the matching and performance against previous versions.

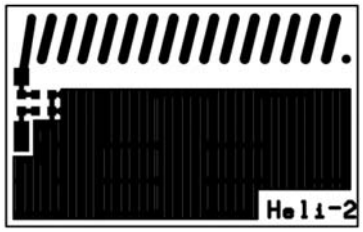

Figure 1 – 300 – 450 MHz PCB Antenna

The helical PCB uses 1.385 x 0.330 inches of PCB area (or 35.2 x 8.4 mm), and the multi-element one uses 1.35 x 0.4 inches of PCB area (or 34.3 x 10.2 mm). Figure 1 and 2 show a picture of both antennas. Gerber files and additional information can be downloaded from Micrel Web Site, under Products / ASKOOK QwikRadio^{R}. The list of reference designs available with these antennas are at the end of each section.

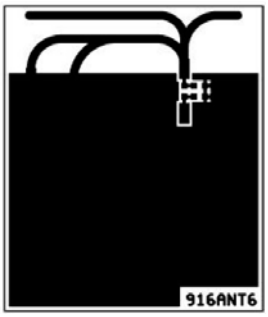

Figure 2 – 850 – 950 MHz PCB Antenna

Heli-2 - Helical PCB Antenna

It resembles a helical antenna. Its behavior is similar in nature and it can be detuned by proximity to conductive objects like metal, human body, etc. When copying the antenna to your Micrel Application, pay very good attention to its dimensions, that is, distance from the ground plane, trace width and length, board thickness (62 mills), copper weight (1 Oz CU), etc. Even when copying exactly as it is, the performance of it may vary slightly due to the manufacturing process being different from the one used at Micrel. Range tests resulted in 10 to 20% less distance in comparison with a ¼ wave whip antenna.

Heli-2 Antenna Impedance

The Heli-2 impedance is capacitive in nature with a resonance frequency at approximately 650 MHz. Table 1 below shows its impedance of the most used frequencies from 300 to 450 MHz.

Freq (MHz)	Z antenna (ohms)
303.825	10.5 – j235
315.0	11.2 – j216.1
345.0	11 – j196.5
390.0	9.2 – j153.8
418.0	8.4 – j134.7
433.92	9.1 – j116.9

Table 1. Heli-2 Antenna Impedance

To bring its impedance close to 50 ohms or any other impedance value, a shunt inductor from the feeding point to ground and a series capacitor from the feeding point to the RF circuit are used. Figure 03 shows the circuit, table 2 the values needed for the 6 frequencies most used and table 3 shows the impedance after the antenna is matched seen from the RF system.

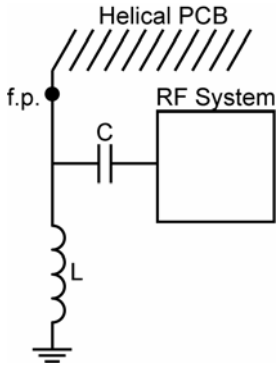

Figure 3 – Antenna Schematic

Freq (MHz)	C (pF)	L(nH)
303.825	**1.2**	82
315.0	**1.2**	75
345.0	**1.2**	62
390.0	**1.2**	43
418.0	**1.2**	36
433.92	1.5	30

Table 2 – Matching Values

Freq (MHz)	Z after matched (ohms)
303.825	41 + j27
315.0	52.3 + j44.3
345.0	49.5 + j32
390.0	42 – j13.5
418.0	45 – j9.5
433.92	46.3 + j15.7

Table 3 – Impedance after matched

As the antenna is tuned, it will present a frequency response as a band-pass-filter which will contribute to the overall selectivity of the RF system. Figure 4 shows an example of its frequency response for the 433.92 MHz matching. The attenuation on the left side of the graphics is more abrupt in comparison to the right side. This is a nice feature to have in this antenna as the dominant outside band noise normally is due to digital clocks and RF systems below 300 MHz, like FM and TV stations, HAM radio, etc, and above 500 MHz the outside band noise comes normally from cellular phones and other RF systems which will also be attenuated as shown in the frequency response.

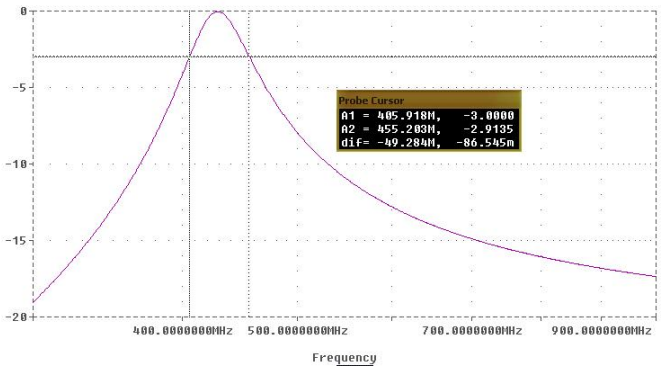

Figure 4 – ANT-HE2 Frequency response at 433.92 MHz

Heli-2 Dimensions

The total PCB area required for the antenna besides the outside surroundings is 1.385 x 0.330 inches. When copying the antenna for the Micrel RF application, use the exact dimensions shown at figures 5 and 6 and use the files provided as the ultimate reference. There are 16 parallel traces (80 mills apart), with 32 vias having 20 mills in diameter (1 inch = 1000 mills = 25.4 mm).

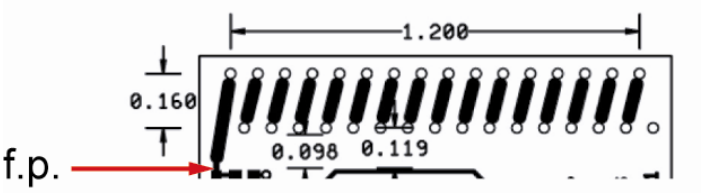

Fig. 5 – Dimensions on the top layer (inches)

The center of the vias closer to the ground plane, top and bottom, are 119 mills away from each other. The edges of the traces are 98 mills from the ground plane – see figure 5.

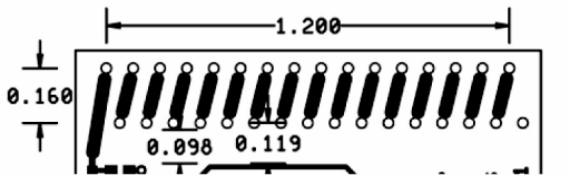

Fig. 6 – Dimensions on the bottom layer (mirror image)

Keep the feeding point (f.p.) and the first PCB antenna trace as shown without increasing or decreasing its size (309 mills) and width (40 mills). The first trace coming out of the feeding point is not exactly parallel to the other ones. The remaining 15 smaller traces are 206 mills long, and 40 mills wide. On the bottom layer there are 16 parallel traces like the 15 small ones on top. Also keep at least 30 mills from the edges of the board, and do not make holes or place components in the area between the antenna and RF circuit (area in red below). The antenna needs free space without anything around it in order to have good performance (figure 7).

Figure 7 – Avoid objects in the red area

Ideally the antenna should be away as far as practical from any objects; however a minimum of 200 mills (~5mm) outside distance should be kept and any objects close to the antenna will change its behavior, performance and matching.

Reference Designs available with Heli-2 Antenna

Several evaluation boards are available with Heli-2 antenna. They are,

1. Heli-2 board, no RF IC's
2. QR009HE1, MICRF009 receiver with band-pass-filter front-end
3. QR009HE2, MICRF009 receiver with high-pass-filter front-end
4. QR009HE3, MICRF009 receiver with wide band SAW filter front-end.
5. QR009HE4, MICRF009 receiver with narrow band SAW filter front-end.
6. QR009HE5, MICRF009 receiver with wide band SAW filter + LNA (low noise amplifier) front-end.
7. QR009HE6, MICRF009 receiver with narrow band SAW filter + LNA (low noise amplifier) front-end.
8. TX102HE2, MICRF102 transmitter.
9. QR010_102HE1, QwikRadio^{R} transceiver board with MICRF009 receiver + MICRF102 transmitter.

For ordering the boards, contact the nearest Micrel Office, Rep. or Dist.

916ANT6 – PCB Antenna

The 916ANT6 is a multi-element PCB antenna that works well in the 900 MHz frequency band, which covers 868.35 MHz in Europe and 902-928 MHz in the United States and other Countries. It has a radiation pattern similar to a dipole, even though the radiation pattern will change due to proximity of other objects and should not be considered absolute, especially in small tuned antennas.

916ANT6 Antenna Impedance

The 916ANT6 impedance is capacitive in nature with a resonance frequency at approximately 2 GHz. Table 4 shows its impedance of the most used frequencies.

Freq (MHz)	Z antenna (ohms)
868.35	13 – j166
915.0	13 – j188

Table 4, 916ANT6 Antenna Impedance

To bring its impedance close to 50 ohms or any other impedance value, a series capacitor from the feeding point to the RF circuit and a shunt capacitor from the RF circuit to ground are used. Figure 8 shows the circuit, table 05 the values needed for the 2 frequencies most used.

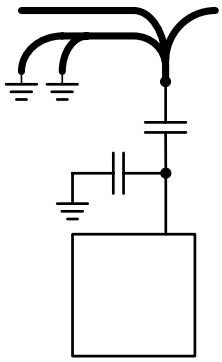

Figure 8 – Antenna Schematic

Freq (MHz)	Cseries (pF)	Cshunt(pF)
868.35	1.5	2.7
915.0	1.2	2.7

Table 5 – Matching Values

916ANT6 Dimensions

The total PCB area required for the antenna besides the outside surroundings is 1.35 x 0.4 inches. Its detailed dimensions are shown in figure 9. As mentioned before, avoid any proximity to foreign objects as they decrease the antenna performance. Any small changes in the dimensions will change the antenna behavior.

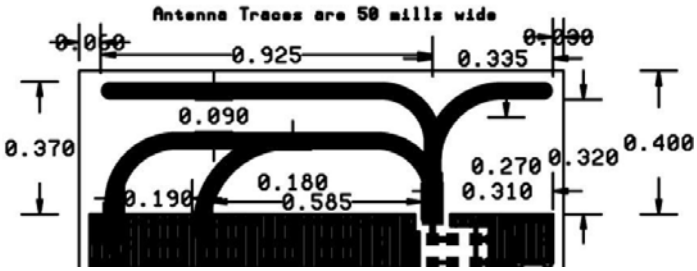

Figure 9 – 916ANT6 Dimensions (inches)

Reference Designs available with 916ANT6 Antenna

Several evaluation boards are available with the 916ANT6 antenna. They are,

1. 916ANT6 board, no RF ICs.
2. Q5ANTLNA, MICRF005 receiver with a wide band SAW filter in the front-end and a low noise amplifier.
3. T103ANT1, MICRF103 transmitter.
4. T103ANT2, MICRF103 transmitter and power amplifier to boost gain.
5. There is also some reference designs with the MICRF505.

For ordering the boards, contact the nearest Micrel Office, Rep. or Dist.

Testing the Antennas

Antenna gain measurement can be made by comparing the signal amplitude from an antenna under test with a standard one like the ¼ wave monopole antenna. Simple ways to measure the signal amplitude are using the RSSI (received signal strength indicator) of a receiver tuned for the frequency of interest, or by using specialized equipment like a power meter or a spectrum analyzer. As variations can exist from PCB houses, the matching proposed must be verified and retuned accordingly using the same measurement process as described above (figure 10).

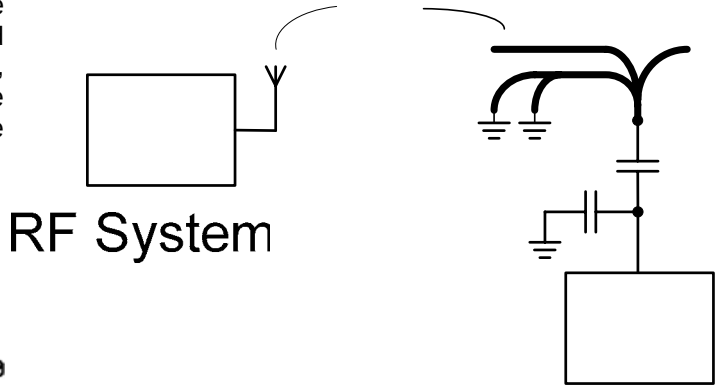

Figure 10 – Example how to measure the antenna gain

Reference Material

Many antenna books are available and should be used to further enrich the knowledge of the material covered here. Some of them are,

1. The ARRL Antenna Book
2. Small Antennas, K. Fujimoto
3. Practical Antenna Handbook, Joseph J. Carr
4. Antenna Impedance Matching, Wilfred N. Caron

MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA
TEL +1 (408) 944-0800 FAX +1 (408) 474-1000 WEB http://www.micrel.com