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λ/4 printed monopole antenna for 868/915MHz

1.   Preface

Taking the demand for easy fabrication and low cost into account in the development of low-power radio devices for 868/915MHz applications, a quarter wavelength monopole antenna implemented on the same printed circuit board as the radio module is a good solution. A printed quarter wavelength monopole antenna is very easy to design and can be tuned simply by slight changes in length.

This article presents basic guidelines on how to design such an antenna for use together with the nRF905 and nRF9E5 Single chip Transceivers operating in the 900MHz frequency range.

The described antenna should be fabricated on standard 1.6mm, low cost FR4 printed circuit board (PCB).

2.   Basic properties of a quarterwave monopole antenna

A quarterwave monopole is a ground plane dependent antenna that must be fed single-ended. The antenna must have a ground plane to be efficient, and ideally the ground plane should spread out at least a quarter wavelength, or more, around the feed-point of the antenna. The size of the ground plane influences the gain, resonance frequency and impedance of the antenna.

The length of the monopole PCB trace mainly determines the resonant frequency of the antenna, but because of the very wide gain bandwidth of a quarterwave monopole, the antenna length is not too critical. But like any other antenna types, the gain of a quarterwave monopole will vary if parameters in the surroundings, such as case/box materials, distance to the ground plane, size of the ground plane, width and thickness of the PCB trace are varied. If any of these parameters are changed, a retuning of the monopole PCB trace length may be necessary for optimum performance in each application.

3.   Determining the length of the printed monopole antenna

For an application operating both in the 868-870MHz and 902-928MHz bands, the antenna can be tuned to a frequency in between the two bands. Because of the very wide gain bandwidth of the antenna, the antenna will show good overall performance in the whole frequency range 868-928MHz when tuned to 900MHz.

The antenna is fabricated on a standard 1.6mm FR4 substrate material with a typical dielectric constant ε_r of 4.4 at 900MHz.

The width of the monopole trace is W = 1.5mm. The wavelength in free air is $\lambda_0 = 333$mm. It may be approximated that the guided wavelength λ_g on the FR4 substrate is about

$$\lambda_g \tilde{\ } \ 0.75 \cdot \lambda_0 = 0.75 \cdot 333\text{mm} \tilde{\ } \ 250\text{mm}$$

The approximate, physical length of a printed quarterwave monopole antenna is then

$$L = 250/4 = 62.5\,\text{mm}$$

provided that the size of the available ground plane is close to the ideal as discussed above and that the antenna trace is uniformly surrounded by the FR4 substrate.

When implementing the monopole as a trace on the PCB, the length of the trace should be extended somewhat to allow for some fine-tuning of the antenna to resonance at 900MHz. If the size of available ground plane is approaching the ideal size and the antenna trace is uniformly surrounded by the FR4 substrate, then the length of the trace should be extended by about 20%.

If the ground plane size is considerably smaller than the ideal size and/or much of the antenna trace is routed close to the edge of the PCB, then the length of the antenna trace should be extended by about 30%. For an example, see Figure 1b.

4.   Combining the printed quarterwave monopole with the nRF905/nRF9E5 RF-layout

The quarterwave monopole must be fed single-ended, hence a differential to single-ended matching network must be used between the nRF905/nRF9E5 antenna interface ANT1/ANT2 and the monopole feed-point. A suggestion on a differential to single-ended matching network can be found in the nRF905/nRF9E5 datasheet.

Figure 1 shows two examples on how a printed quarterwave monopole can be combined with the nRF905 RF-layout on the same PCB. Figure 1a shows the optimum placement of the antenna trace. With this placement, the antenna is allowed to radiate freely in all directions. The monopole has maximum radiation in the plane normal to the antenna axis, and minimum radiation along the axis. To be omni-directional, the monopole antenna should be placed vertically.

Figure 1b shows a more compact layout of the antenna trace. This layout may have lower antenna gain in the direction of maximum radiation than for the layout shown in Figure 1a, but it will exhibit a more uniform radiation in the horizontal plane if vertical placement is not possible.

When bending the antenna trace like in Figure 1b, be sure to keep the distance (d) between the open end of the antenna trace and the ground plane as large as possible, preferably 25mm or more. Reducing this distance will reduce the gain of the antenna.

There shall be no ground plane on the PCB layer(s) beneath the antenna trace. No ground plane, PCB traces or components should be placed close to the antenna trace.

a)

b)
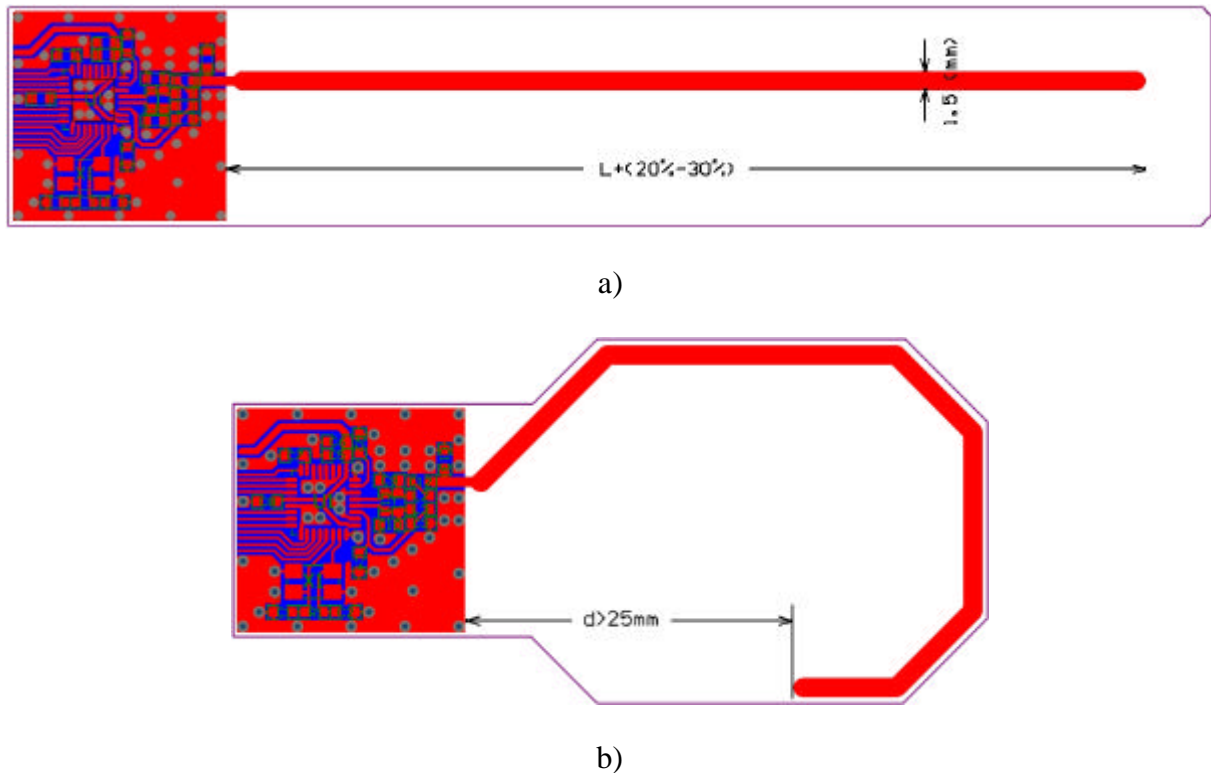
Figure 1. Examples of nRF905 RF-layout combined with a printed λ/4 monopole antenna.

Tuning of the antenna is done simply by cutting the length of the PCB antenna trace until resonance at 900MHz is obtained. The antenna must be tuned with the PCB placed inside the case/box (if any) and hand-held/body-worn (if this is a hand-held/body-worn application).

For applications where range performance is not critical the antenna can be tuned by measuring radiated power from the antenna with a spectrum analyzer. For more accurate tuning a vector network analyzer must be used for impedance and SWR (Standing Wave Ratio) measurements.

As shown Figure 1 the PCB antenna trace should be made 20%-30% longer than the estimated theoretical length in order to make tuning possible on prototypes. For the production version of the PCB, the optimum antenna length found on the prototype should be used.

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