AN 0971

Far field antenna design

Rev 1.4 — 4 March 2008

Application note

NXP founded by Philips

Revision history

Rev	Date	Description
1.1	20071019	First, initial release. Author: BarRib
1.2	20080107	Remove Chapter 4. Assembly parameters can be found in "Application Note 0968_Package and Assembly Guideline for the UCODE G2XM_G2XL"
1.3	20080118	Change title from "Application Note 0971_Far Field Antenna Design for UCODE G2XM_G2XL IC" to "Application Note 0971_Far Field Antenna Design"
1.4	20080304	Change Fig 12 "Simulated read range of the original antenna design as shown in Fig 8".

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1. Introduction

This document provides a detailed description of a broadband antenna design.

Form factor: 4* 0.5 inch

The given antenna design in combination with the low quality factor (Q-factor) of the G2XM / G2XL IC results in a very robust and broadband label. This label is optimized for the application on low ε_r materials. The target was to guarantee the best performance for typical UHF RFID applications like on air, cardboard or plastic. Measurements verify the characteristics of this reference design.

2. Design of the Tag Antenna

The basic antenna concept employed is the use of a broadband loop. The loop has to be matched to the impedance of the chip. Combining the loop with a broadband dipole structure will increase the overall performance of the label in terms of read range.

The challenge of this design is to combine two radiating systems with different resonance frequencies in order to increase the bandwidth of the system.

2.1 Loop

The loop based part of the antenna can be depicted with an equivalent circuit as described in Fig 1. The real part of the impedance of the loop consists of the radiation resistance ($R_{radiation}$) and the losses given by the loop conductor (R_{loss}). In general, the radiation resistance for a small circular loop is given by the following equation (1), wherein C denotes the circumference of the loop:

$$R_{loop,radiation} = 20\pi^2 \frac{C^4}{\lambda^4}$$

(1)

Equation 1 clearly shows that the real part of the impedance is dominated by the area of the loop.

The first design condition (based on a matching loop) is given by the chip impedance, which requires a large loop area to compensate the real part and to generate the inductance necessary in order to compensate the imaginary part of the chip impedance.

The functional dependence (approximated form) of inductance and loop dimension is given by equation (2).

- a   Loop radius
- b   Wire radius
- P   Perimeter of the cross section of the conductor (loop)
- σ   Conductivity
- l   Wire length
- L_A.   Inductance of the loop antenna
- L_i Inductance of wire/conductor
- L_{tot} Total inductance

$$L_A = \mu_0 a \left[\ln\left(\frac{8a}{b}\right) - 2 \right]$$

$$L_i = \frac{l}{\omega P} \sqrt{\frac{\omega \mu_0}{2\sigma}}$$

$$L_{tot} = L_A + L_i$$

(2)

The second design condition is bandwidth. An IC with high quality factor Q requires a broadband antenna as to show stable performance. Significant advantages are gained from a broadband antenna design for chips with low Q characteristics (as NXP´s UCODE G2XM / G2XL) as well.

There are several solutions for the bandwidth issue. A bandwidth higher than that of a normal circular loop can be achieved by using a triangular loop (top driven or bottom driven with θ = 60°) see Fig 2, a rectangular loop with W/H = 0.5 (see Fig 3) and a rhombic loop with β = 120° in Fig 4.
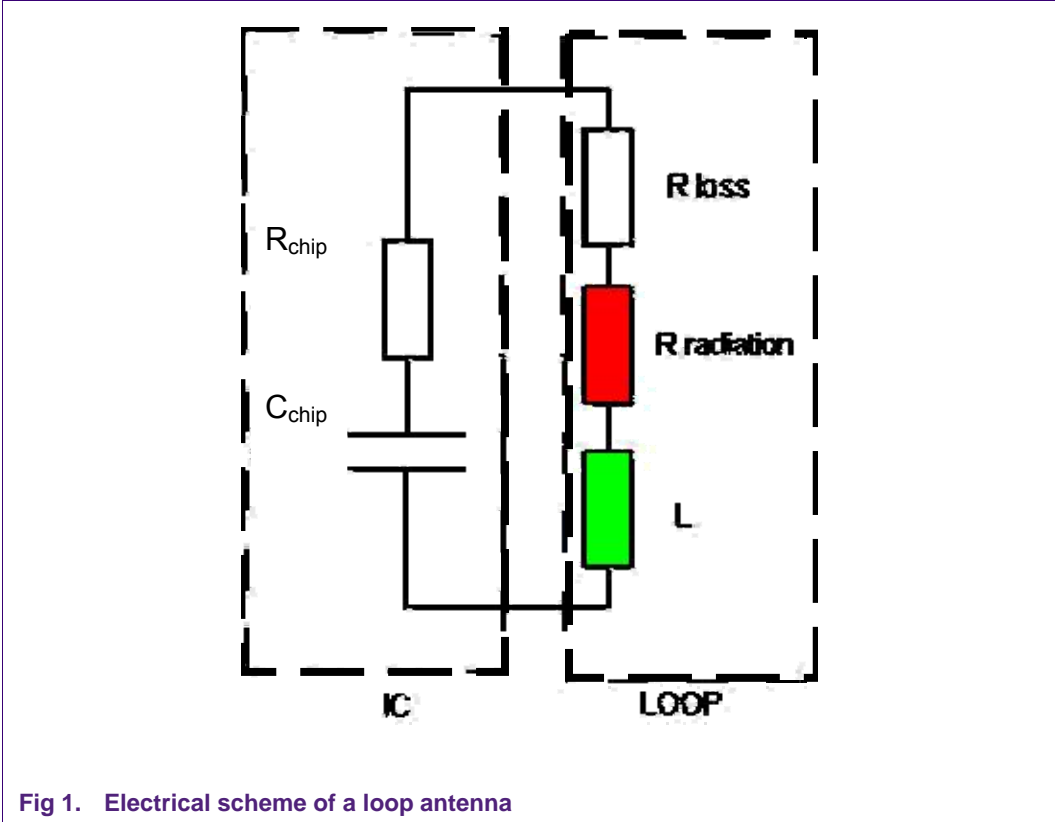
Fig 1.   Electrical scheme of a loop antenna
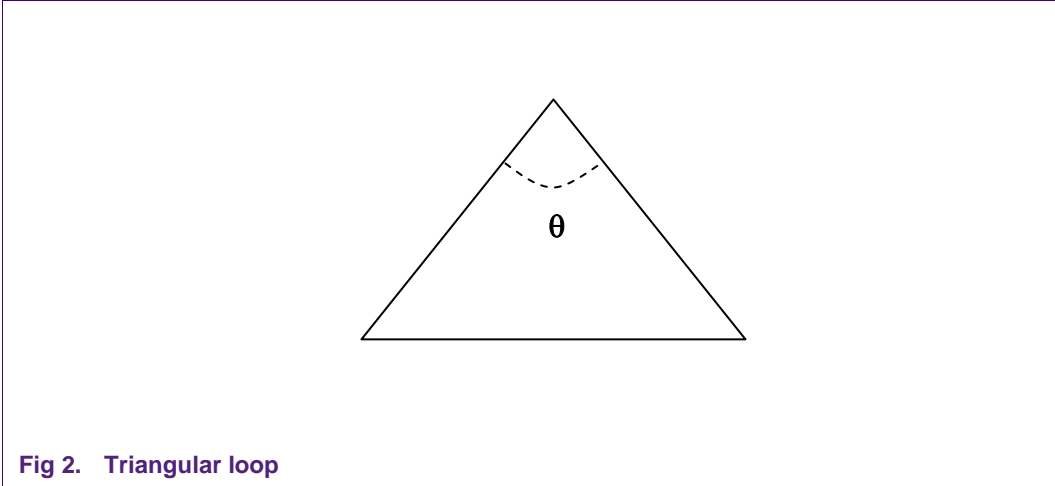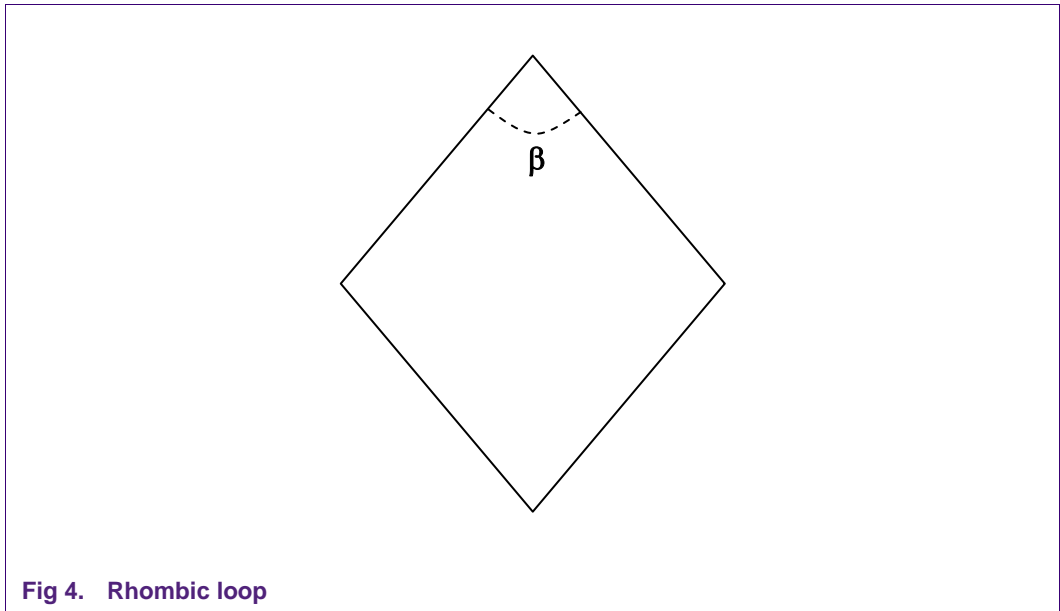

Fig 2.   Triangular loop
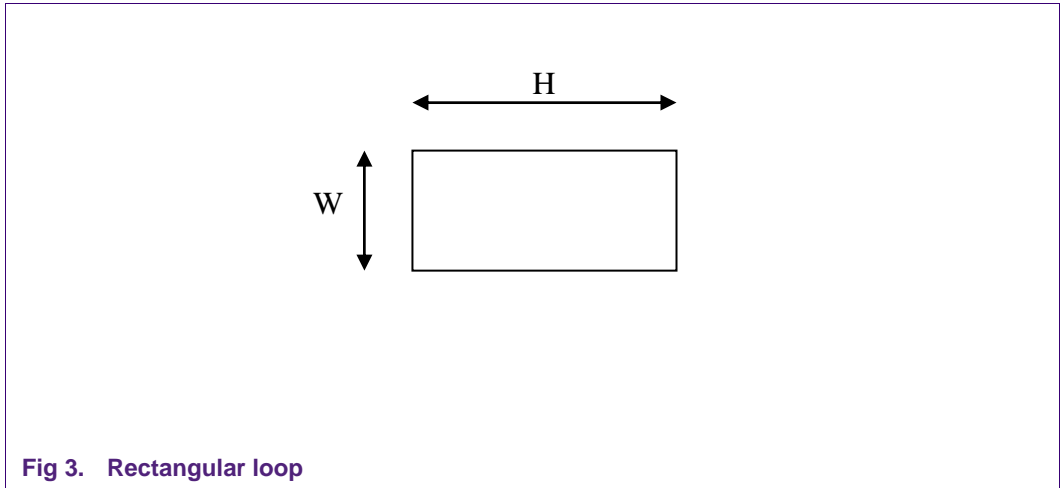
Fig 3.   Rectangular loop

Fig 4.   Rhombic loop

2.2   Dipole

The equivalent circuit of a dipole is given by a series L-C resonant circuit shown in Fig 5.

The resonance frequency of the dipole is a function of inductance and capacitance. For a series L-C resonant structure, resonance frequency is given by equation (3).

$$\omega_{res} = \frac{1}{\sqrt{LC}} \tag{3}$$

The quality factor and bandwidth of the dipole are a function of $\sqrt{L/C}$ and of $1/Q$ respectively (see Fig 5).
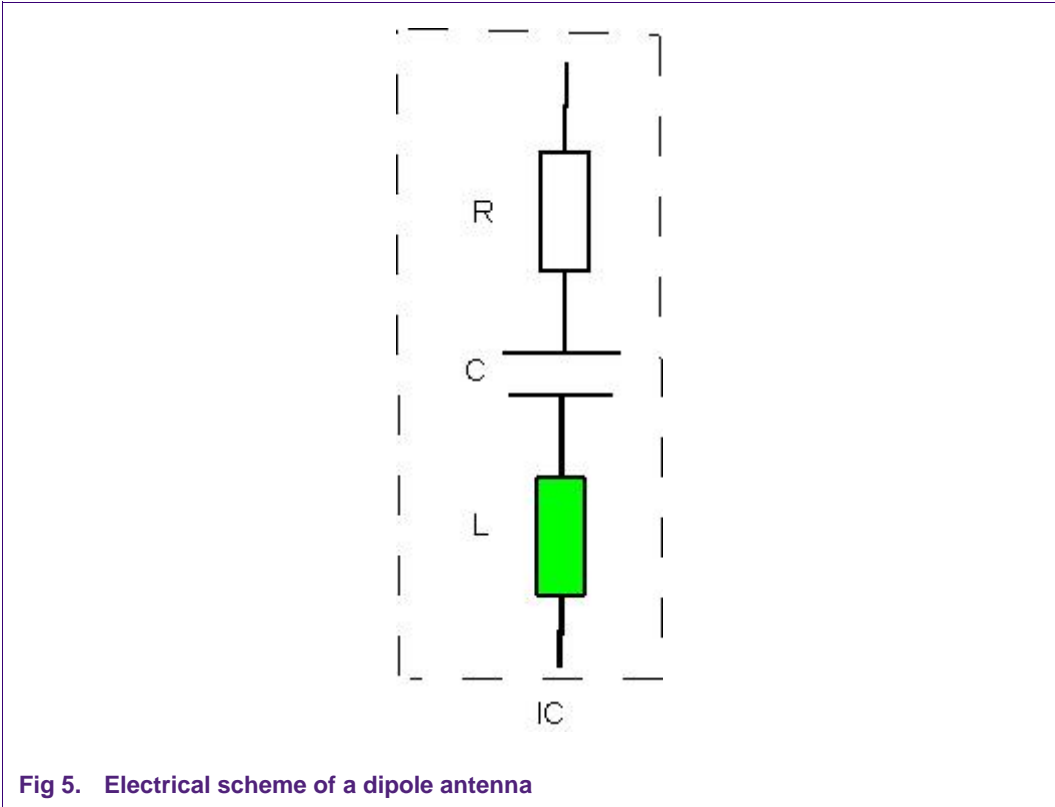
Fig 5. Electrical scheme of a dipole antenna

2.3 Dipole-Loop Coupling

The essential question to be answered for a system based on a loop and a dipole antenna is how to couple the two radiating structures. Basically there are two possibilities:

- Inductive and / or capacitive coupling

The two radiating structures are galvanically isolated. The energy transfer either takes place via the electrical field between the components (capacitive coupling) and/or via a shared magnetic field (inductive coupling).

- Conductively connected

The two methods are depicted in Fig 6 (magnetic coupling) and Fig 7 (conductively connected).

Fig 6.   Magnetic coupling

Fig 7.   Conducted coupling – physical connection
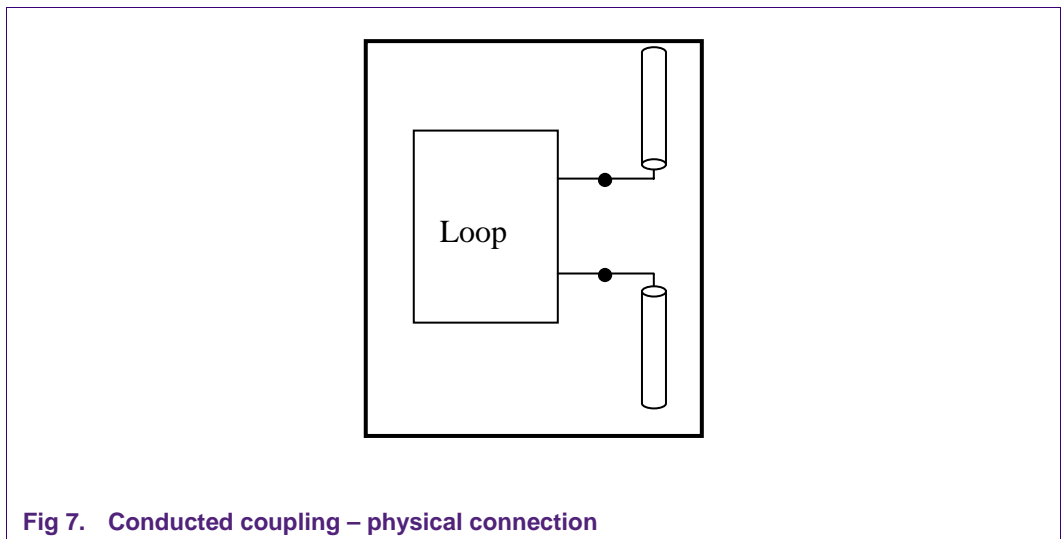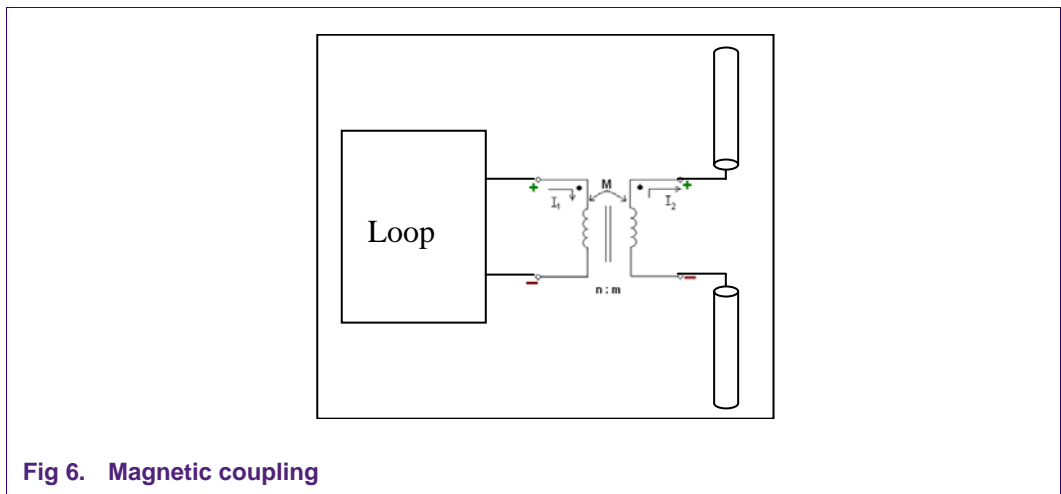
The design described in this document is based on conducted coupling of the loop and the dipole.

3. Antenna Overview

This chapter describes the antenna model.

The label antenna is designed to be used with an FR4 substrate of 0.5 mm thickness and with a conductive copper trace of 0.035 mm.

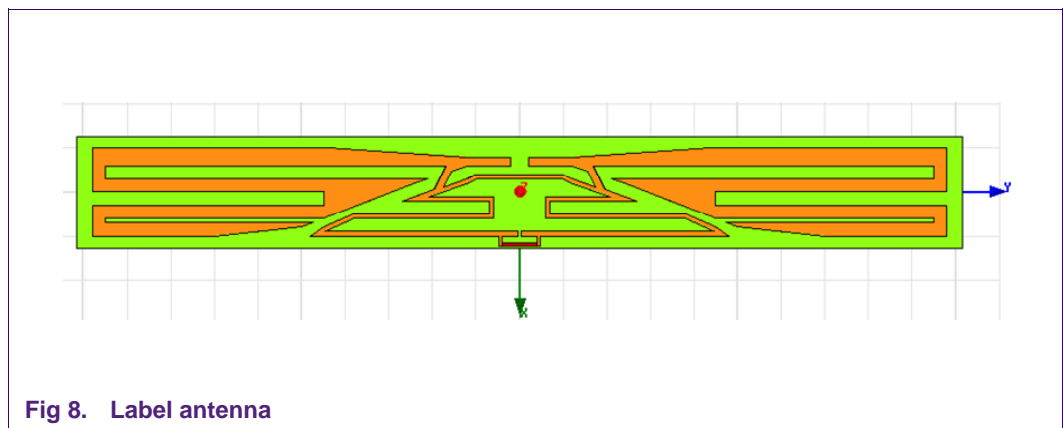The form factor of the designed antenna label is 4* 0.5 inch (Figure 8).

Fig 8. Label antenna

Figure 9, Figure 10 and Fig 11 provide a basic understanding of the concept this label antenna design is based upon. The label consists basically of the loop, the dipole and the connection between loop and dipole. Fig 9 depicts the detailed loop; Fig 10 shows the resonant dipole and Fig 11 details of the connection between dipole and loop.
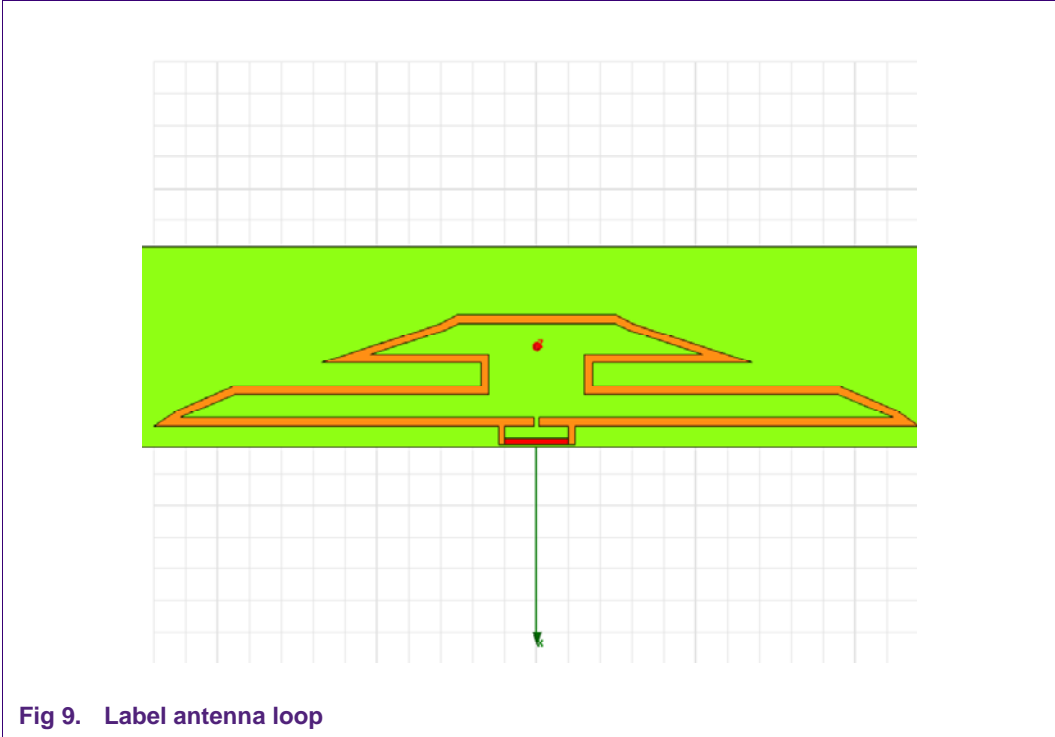
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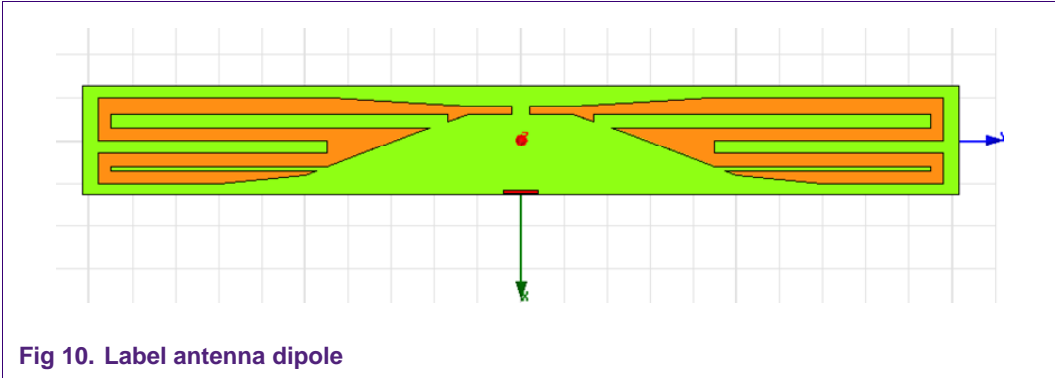**9 of 19**

Fig 9.   Label antenna loop
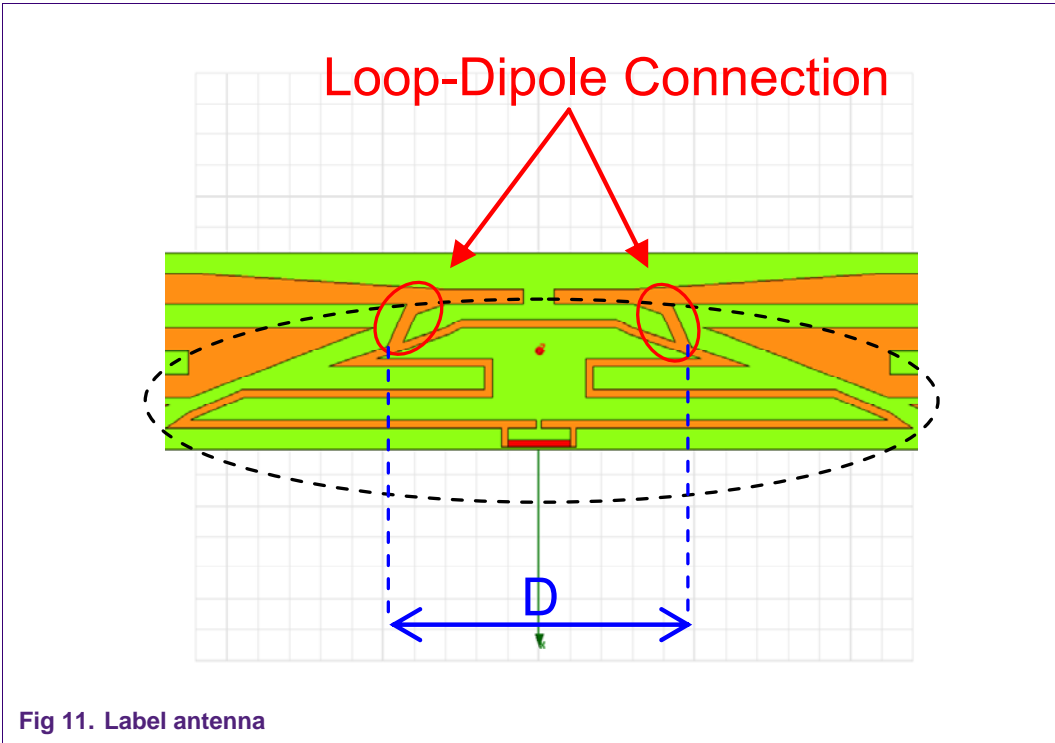

Fig 10. Label antenna dipole

Fig 11. Label antenna

3.1 Antenna Tuning

This antenna design has one fundamental advantage: It can be tuned to different frequencies, depending on the requirements of the end application.
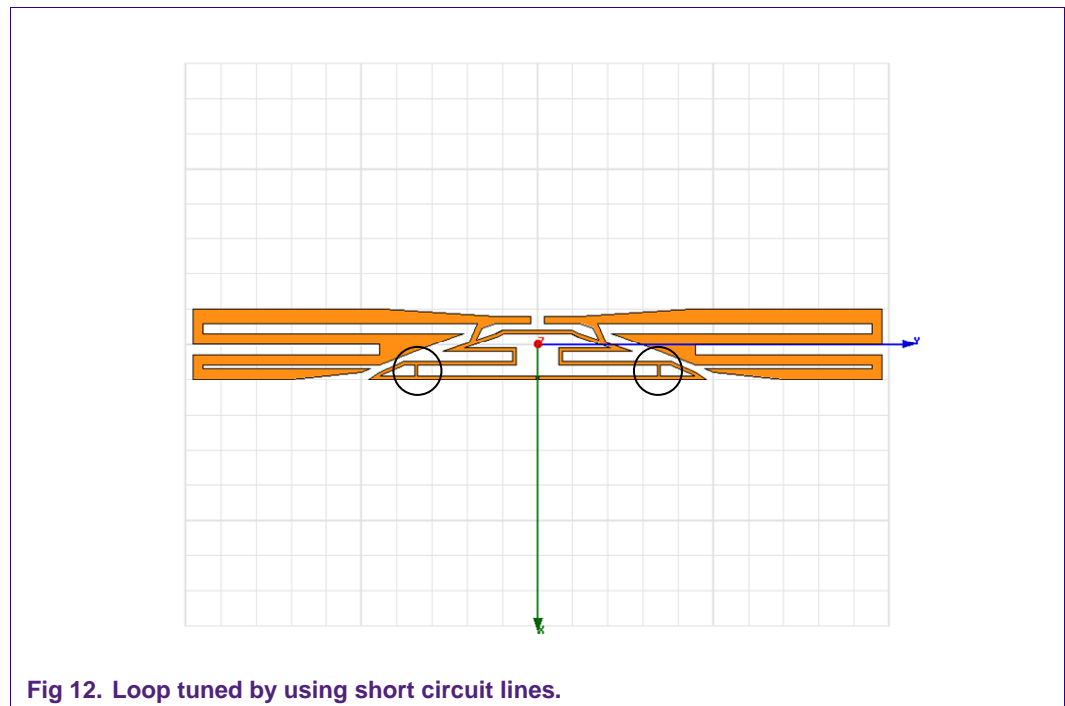
A change of the resonance frequency can be achieved by varying geometrical parameters of the design such as:

- Loop length and area (see Fig 9)
- Distance D between arms connection (see Fig 11)
- Electrical area and length of the dipole (see Fig 10)

The following chapters give examples on the impact of the change.

3.1.1 Influence of Loop Area and Loop Length

In this example the area of the loop is modified by introducing two short circuits on the loop (Fig 12), resulting in a rise of the resonance frequency of the system approximately by 30 MHz.

Fig 12. Loop tuned by using short circuit lines.

The impact of these two short circuits on the resonance frequency is shown in Fig 133 (read range plot).
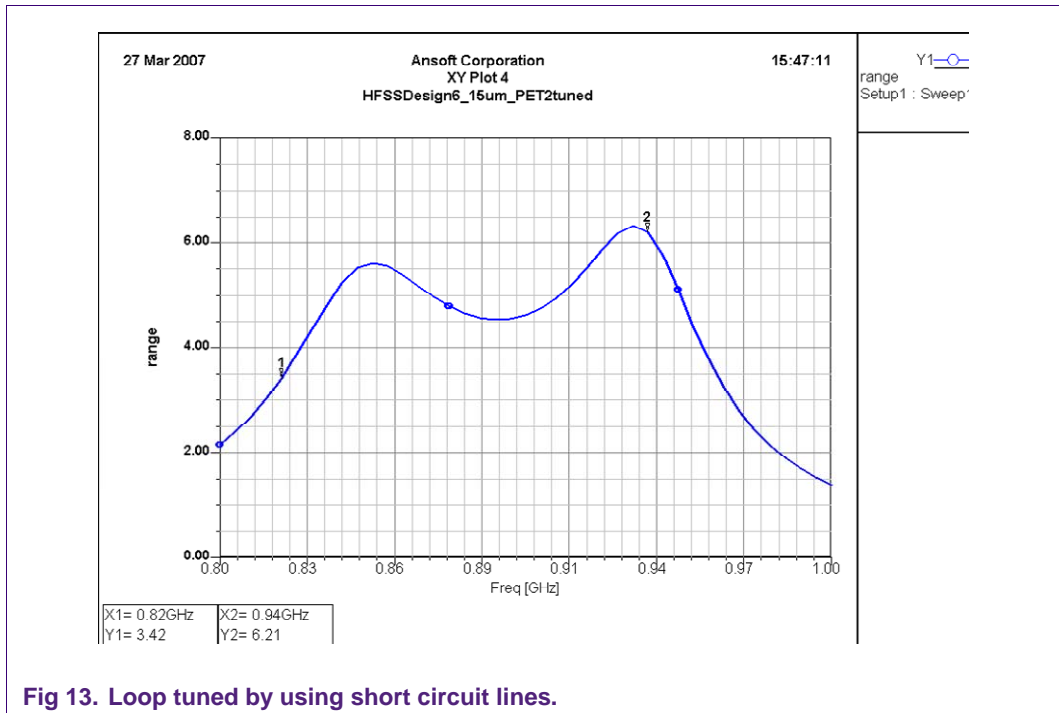
Fig 13. Loop tuned by using short circuit lines.
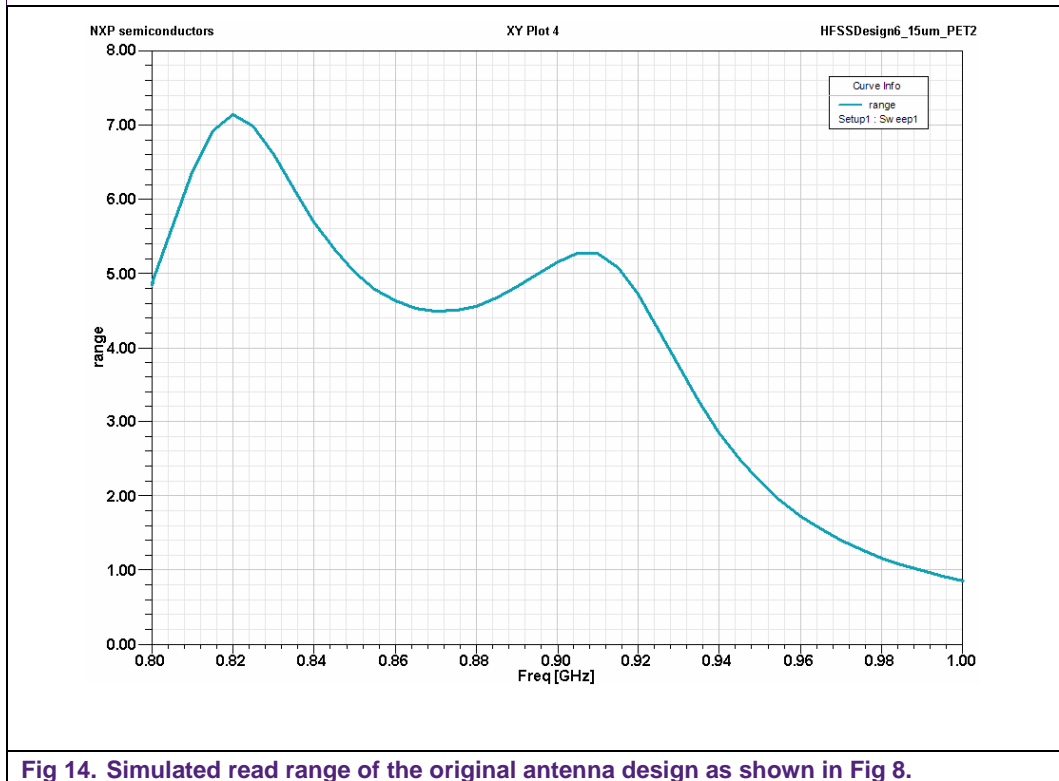

Fig 14. Simulated read range of the original antenna design as shown in Fig 8.

This method is very suitable for antenna fine tuning.

If a resonance frequency change of more than 50 MHz is required, the loop area and the length of the dipole have to be changed.

3.1.2 Distance D between the Dipole Arms

By changing the distance D (see Fig 11) between the two dipole arms the bandwidth of the antenna can be adapted. Basically Δf between the two resonance points on the read range curve (two peaks with the maximum read range) can be decreased/ increased by reducing/ increasing distance D.

This is a very sensitive tuning method. Modifying distance D also has an impact on the frequency position of the resonance, as explained with the following example:

The layout in Fig 15 has the distance "D" diminished from 19.5 mm (standard design Fig 8) to 11.6 mm.

D = 11.6 mm

Fig 15. Layout loop with smaller D.
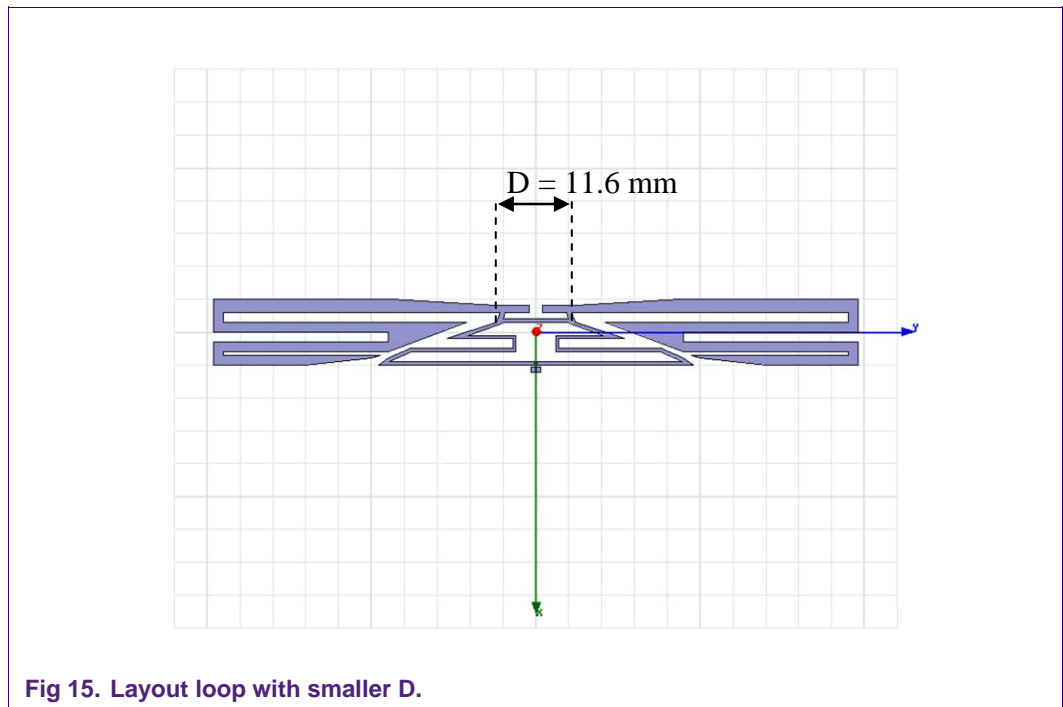
The reduction of "D" causes the two resonance points to converge and the resonance frequency to decrease (Fig 16)
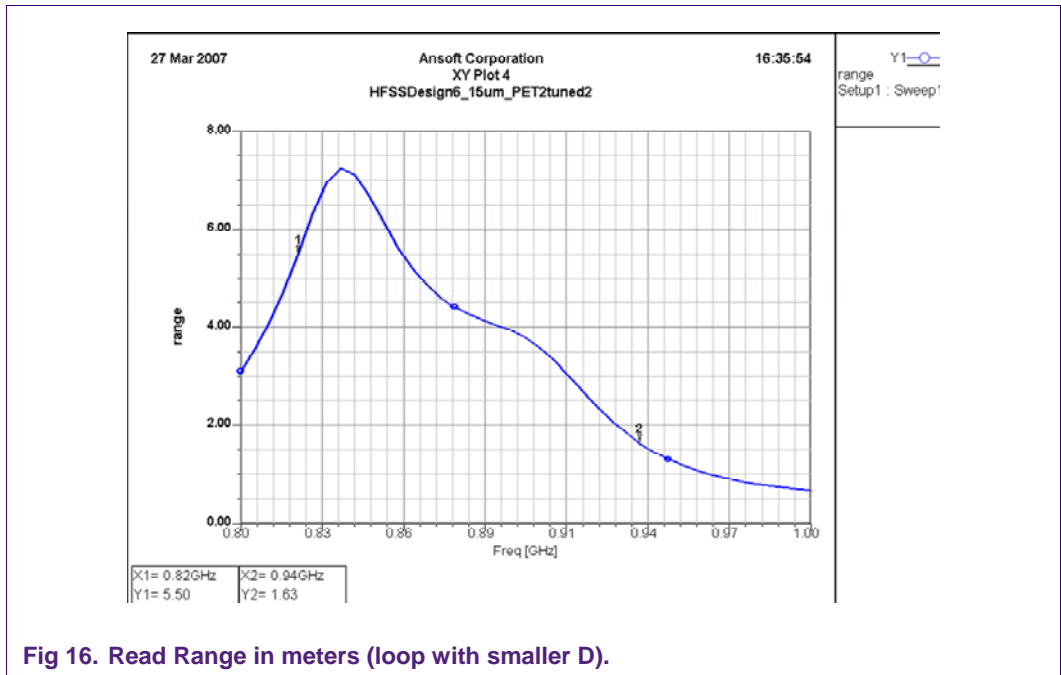
Fig 16. Read Range in meters (loop with smaller D).

3.2 Dipole Length Reduction

This chapter discusses the impact of dipole length modifications.

Fig 17 shows the layout of the label with a shorter dipole, resulting in a decreased peak height of the main resonance whereas the secondary resonance peak is subjected to a frequency position shift (Fig 18).

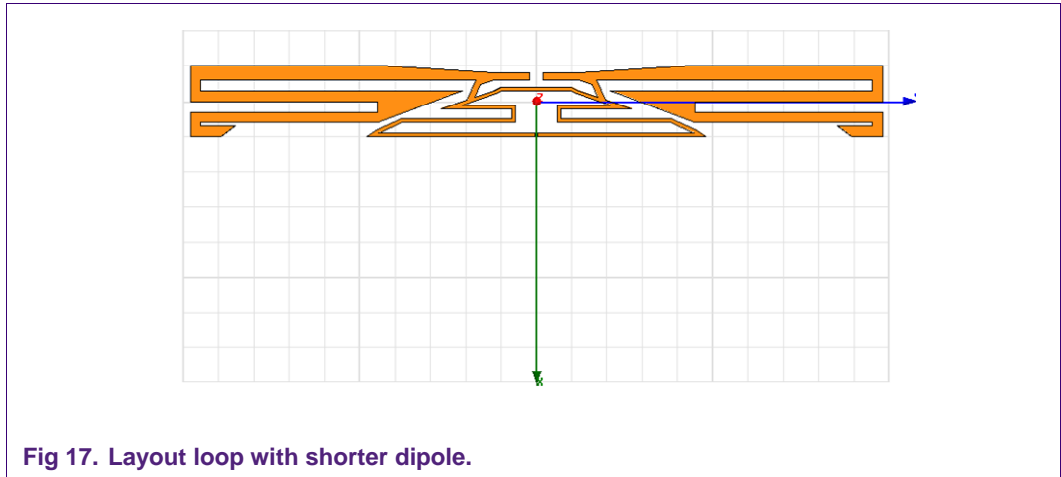Bottom line: an increased bandwidth of the system results.

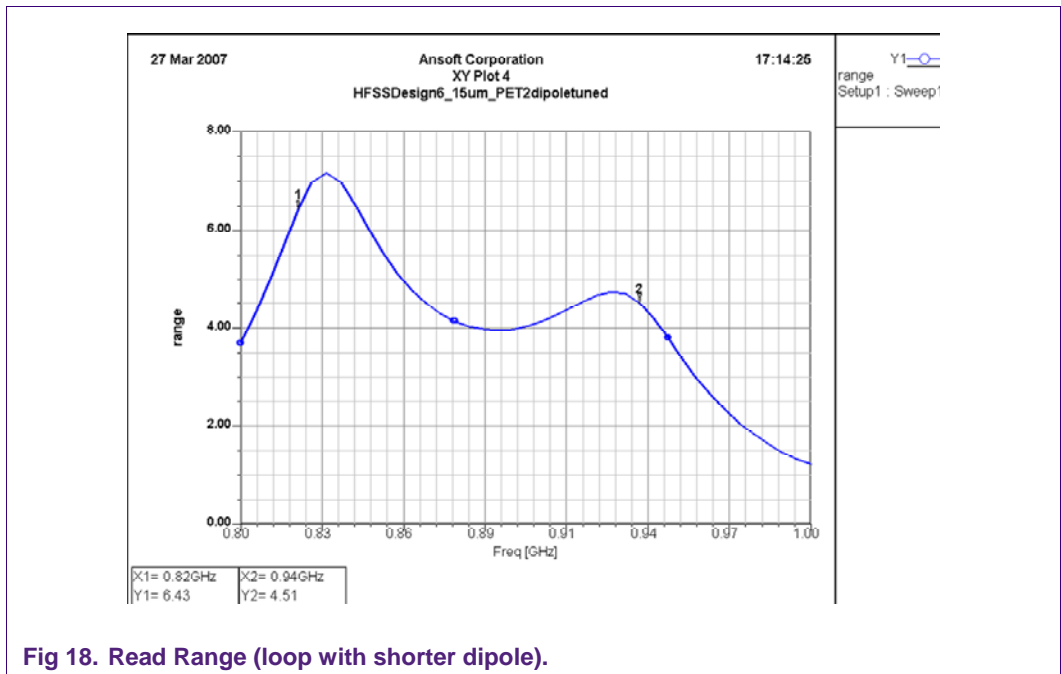**Fig 17. Layout loop with shorter dipole.**

Fig 18. Read Range (loop with shorter dipole).

4. Conclusions

This document provided general principles of designing a UHF label antenna. A reference design guide, including assembly parameters and a far field antenna, which is exactly matched to the impedance of the NXP UCODE G2XM and the NXP UCODE G2XL IC is provided in the "Application Note 0969_Reference Antenna Design for the UCODE G2XM_G2XL IC".

This label design has the following advantages:

        a) tunable to a required resonance frequency

        b) adaptive bandwidth

Fine tuning as well as significant changes in the resonance behavior can be achieved by minor modifications of the design.

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