

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



---

# RFID Textile Antenna and Its Development

---

Lukas Vojtech, Robi Dahal, Demet Mercan and  
Marek Neruda

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/53521>

---

## 1. Introduction

Textile fabric material has become one of the most important things in life. In early times people used to wear the animal skin to cover their body. The advance form of this is all the clothes we wear today. They protect our body from changing environment conditions and keep us warm. As the technology is increasing day by day, it is influencing every sector. With the increase in wireless technology the electromagnetic radiation also increases. This increased radiation may affect human body severely. Thus with invent of problem, cure was also proposed to make a conductive textile material that could be equally wearable but at the same time work as a filter and does not allow the harmful frequency signal to penetrate into the human body. This completely changed the purpose of fabric material which was previously assumed to be used only for keeping human body warm as now it can be used for protection against the harmful electromagnetic radiation.

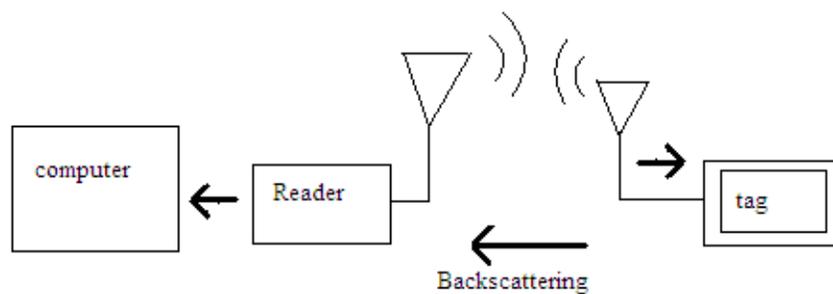
Going one step further ahead, we have tried to explore more advantage of textile fabric. With this new invention of conductive textile, we have designed an antenna for RFID (Radio Frequency Identification) applications made out of conductive textile material.

## 2. RFID basics

The RFID uses wireless technology to identify the objects. It consists of RFID tag and a reader. The bi directional communication between the tag and the reader is accomplished by the Radio Frequency (RF) part of the electromagnetic spectrum, to carry information between an RFID tag and reader. There are two types of RFID tag. Passive RFID tags are the ones that does not require any external power supply and works by receiving the signal from reader and

retransmit the signal back to reader. Active RFID tag consists of external source in them. These are more complex than passive RFID tags and also give long range communication between tag and reader, when compared with passive tag.

The basic block diagram describes the bi directional communication between the tag and the reader, see Figure 1. The tag antenna in the block diagram receives the RF signal from the reader. This signal is received by the tag antenna, rectified and supplied to the chip to power it up. After the chip is powered up, it now acts as a source and retransmits the signal back to the reader. The reader after receiving the signal sends further to the computer to process the data. The method used to send the signal back to the reader from the tag is called back scattering.



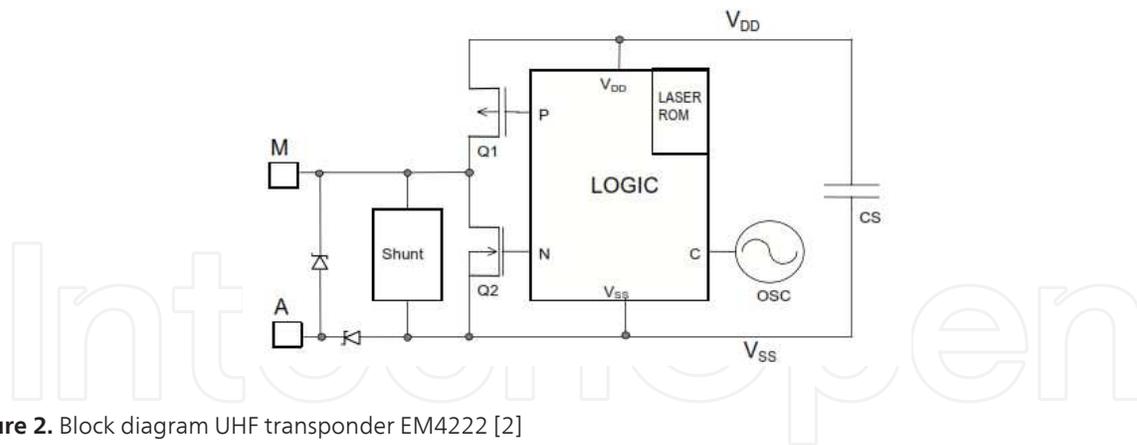
**Figure 1.** Block diagram of RFID system

## 2.1. RFID transponder

RFID Transponder is basically a radio transmitter and receiver. It mainly consists of two parts, antenna and the integrated circuit (IC). The main function of an antenna is to capture the radiated electromagnetic field by the reader at a definite frequency. The received electromagnetic energy is converted to electrical power and supplied to integrated circuit. The IC chip in the transponder has the capability to store the information to be transmitted to the reader, execute the series of command and also sometimes stores new information sent by the reader [1]. The IC chip mainly consists of a rectifier which rectifies the alternating voltage (AC) received by antenna to the continuous voltage (DC) and supplies to the rest of the circuit in the IC chip.

The IC used for the research is EM4222. This is a read only UHF identification device. The EM4222 is used as a passive chip for UHF transponder. It does not have any internal power supply source. The RF beam is transmitted by the reader. The antenna in the transponder receives the signal, rectifies it and supply the rectified voltage to the chip. The basic block diagram is shown in Figure 2.

From the block diagram, it can be seen that the radio beam is received at the terminal A in the chip. This signal is rectified to a DC voltage. The shunt regulator is used to limit the input voltage to the logic circuit. It also protects the Schottky diode which is used as a rectifier.



**Figure 2.** Block diagram UHF transponder EM4222 [2]

The on chip oscillator in the transponder is used to provide the clock pulse to the logic and also defines the data rate. On chip oscillator present in the transponder oscillates at a frequency of 512 kHz.

If the supply voltage is less than the threshold voltage, the oscillator and the logic cannot function properly and thus the transponder cannot be activate. At this condition, the logic is in reset position. This ensures that the transistor Q2 is off during power up and do not let any false operation to act.

Among the two transistors, Q1 is turned on during power up. Q2 is the modulation transistor which when turned on, loads the antenna with the information from the tag. Q2 is active when the data is to be transmitted from transponder to reader.

In order to have a maximum power transferred from antenna to the chip, the antenna should be designed such that the impedance of the antenna is conjugated matched with that of chip for the given frequency. Generally the chip has capacitive impedance so to have a perfect match the antenna impedance should be inductive in nature.

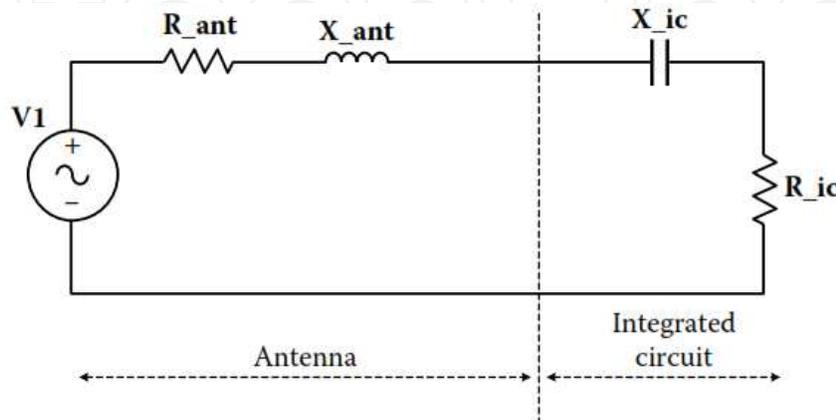
| Parameter                  | Symbol | Test conditions   | Min | Type     | Max | Units |
|----------------------------|--------|-------------------|-----|----------|-----|-------|
| Oscillator frequency       | Fosc   | -40°C to +85°C    |     | 512      |     | KHz   |
| Wake up voltage            | Vwu    | VM-VA rising      |     | 1.4      |     | V     |
| Static Current Consumption | I STAT | VM=1v             | 400 | 1        | 600 | μA    |
| Input Series Impedance     | Zin    | 869 MHz ; -10dBm  | 1.0 | 128-j577 | 5   | Ω     |
| Input Series Impedance     | Zin    | 915 MHz ; -10dBm  |     | 132-j553 |     | Ω     |
| Input Series Impedance     | Zin    | 2.45 GHz ; -10dBm |     | 80-j232  |     | Ω     |

**Table 1.** Electrical characteristics of IC EM4222, VM-VA=2V, TA=25°C, unless otherwise specified [2]

## 2.2. RFID matching

The tag antenna receives RF energy from the reader. The tag antenna works for a definite resonant frequency. So when the reader transmit RF signal with the desired frequency, the tag receives the signal and supplies to the chip which is attached to it in the transponder. The chip

after getting sufficient voltage is able to wake up and hence retransmit the signal at the same frequency to the reader. Thus the purpose of matching an antenna with its load is to insure that maximum power transferred from antenna to chip. To do this, it is needed to have a perfect match between the antenna and the chip. Perfect antenna matching can be achieved by changing the dimension of an antenna, by adding a reactive component or implementing both of them. A mathematical expression can be overviewed as depicted in Figure 3.



**Figure 3.** Series model for transponder chip and antenna [3]

The power delivered from antenna to the load or chip is given as [3]:

$$P_l = \frac{R_{ic}}{2[(R_{ant} + R_{ic})^2 + (X_{ant} + X_{ic})^2]} V_{ant}^2 \quad (1)$$

In the above equation it can be seen that the maximum power can be delivered from the antenna to the IC only if  $R_{ic} = R_{ant}$  and  $X_{ic} = -X_{ant}$ . Thus it can be observed that the maximum power can be delivered from antenna to load only if they are conjugate matched. This gives one of the favorable conditions for antenna designer as generally the antenna impedance is inductive in nature and the impedance of the chip is capacitive.

In this research the antenna is designed to work at 869 MHz. At this frequency the input series impedance of the chip is  $128 - j577 \Omega$ . Thus the requirement is to have antenna impedance of  $128 + j577 \Omega$  such that it is complex conjugate matched with the load and maximum power is transferred.

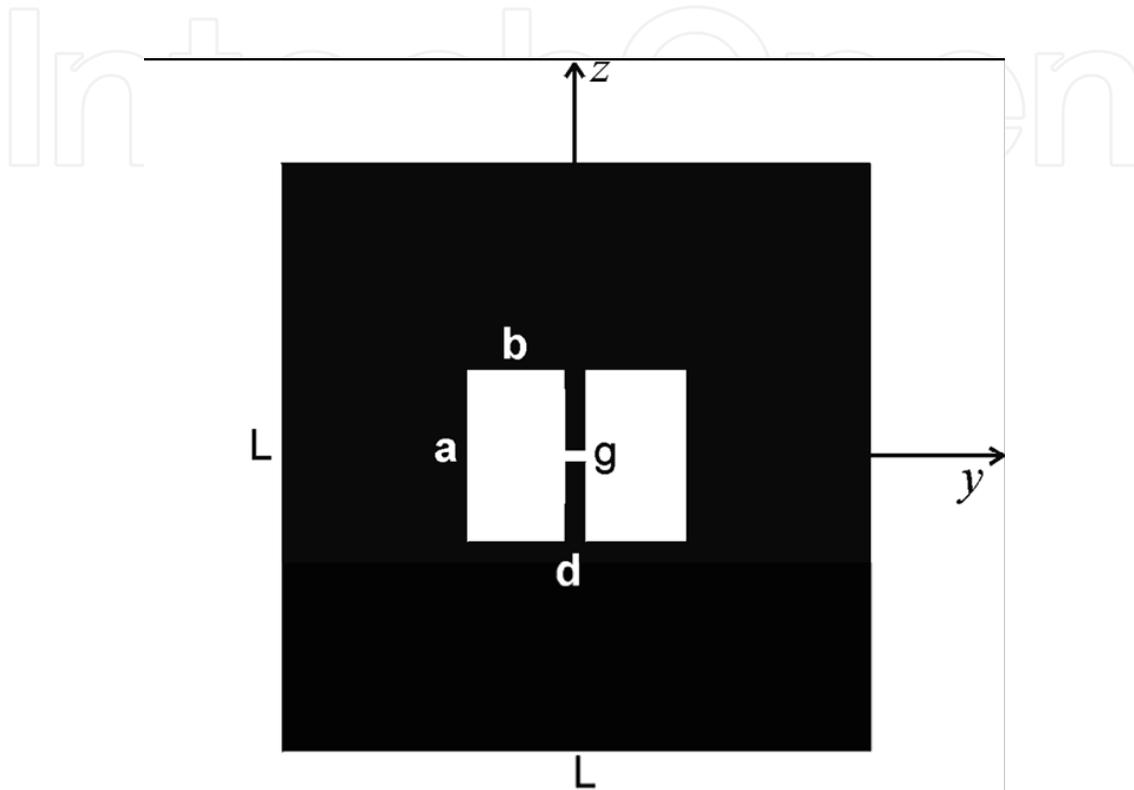
Conjugate Match Factor (CMF) is the factor which tells how good matching is done between the chip impedance and the antenna impedance. It can be described as the ratio between antenna input power with given chip impedance  $Z_s$  and antenna impedance  $Z_a$  assuming  $Z_a$  is complex conjugate of  $Z_s$ .

The value of CMF changes between 0 and 1 in linear. To receive maximum power from the reader and retransmit the maximum power to the reader, the antenna impedance should be complex conjugate match and equaled with that of chip.

### 3. H-slot microstrip patch antenna for UHF RFID

In this section the passive UHF RFID tag design is discussed. This RFID tag is textile made and involving the human body as the object to be tagged.

The designed antenna layout is an H-shape slot place onto a patch, Figure 4.



**Figure 4.** Geometry of nested - slot. The microchip is placed in the central gap of the slot [4]

The patch with H-slot is placed on a substrate and grounded by a conductive material to decouple from the human body. H-slot is a tuning slot for the required conjugate impedance matching between the microchip and the antenna tag. The maximum size of the antenna is 150 mm x 180 mm and the gain is rather poor around -7 dB due to the bidirectional radiation of the slot. But the maximum gain can be increased by increasing width of the tag antenna. And also the impedance matching is done by tuning the internal slot size.

Dielectric material of this patch antenna has a thickness of  $h$  and it has a longer face of it in the lower part which is placed on the human body through the conductive ground plane. It is an advantage to have longer ground plane because it will avoid the effect of human body radiation.

The radiation is produced by the patch open edge and by the slot. To achieve better radiation performance, width of the antenna can be increased depending of available place for tag. The dimension of the central gap is kept fix by the microchip packing but for tuning the other dimensions of the slot are optimized. The perfect conjugate matching should be done between antenna and microchip to obtain the maximum reading distance.

## 4. Observations

### 4.1. Impact on antenna performance with radiating element having different surface resistivity.

While working with textile antenna, it is found that the antenna is not working properly as it should work. This is because the antenna which is generally made of very high conductive material has very good radiation efficiency and gain. However the antenna made of conductive textile material has very high surface resistivity and hence lower conductivity. Because of this property of textile material it is difficult to choose the appropriate conductive textile material for desired gain. Also the height of dielectric constant plays a major role in determining the radiation efficiency.

Because of the problem of higher surface resistivity associated with the conductive textile material, a relation between surface resistivity, gain and radiation efficiency is analyzed. For this purpose the microstrip patch antenna is simulated in simulation software IE3D. First the measurement is performed by simulating two different microstrip patch antenna. Both of these antennas are simulated to work at a frequency of 2.45 GHz but with the radiating element having different surface resistivity.

The surface resistivity for two different radiating elements was chosen to be  $0.02 \Omega/\text{sq}$  and  $1.19 \Omega/\text{sq}$ . Fleece fabric is used as dielectric material which has a dielectric constant of 1.25. The antennas are simulated for reflection loss less than  $-40 \text{ dB}$  and the result is noted.

It is observed from the simulation result that, though all the other antenna parameter are same, the difference in surface resistivity of the two radiating element affect a lot in their radiation efficiency and gain.

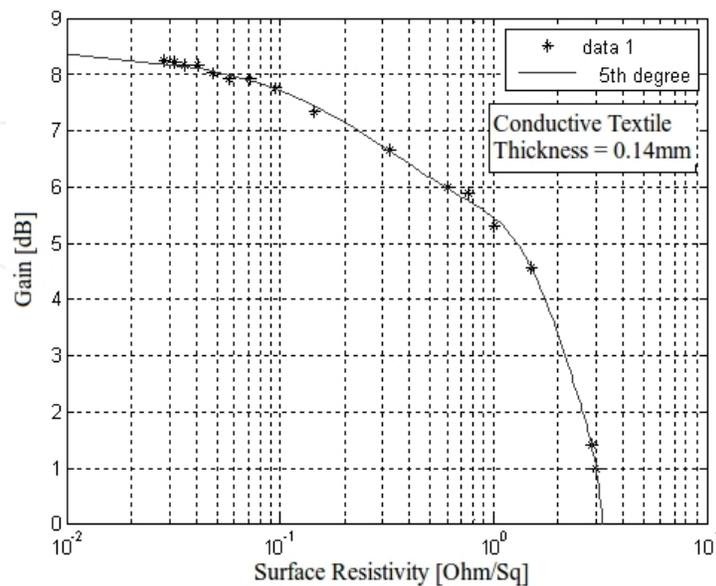
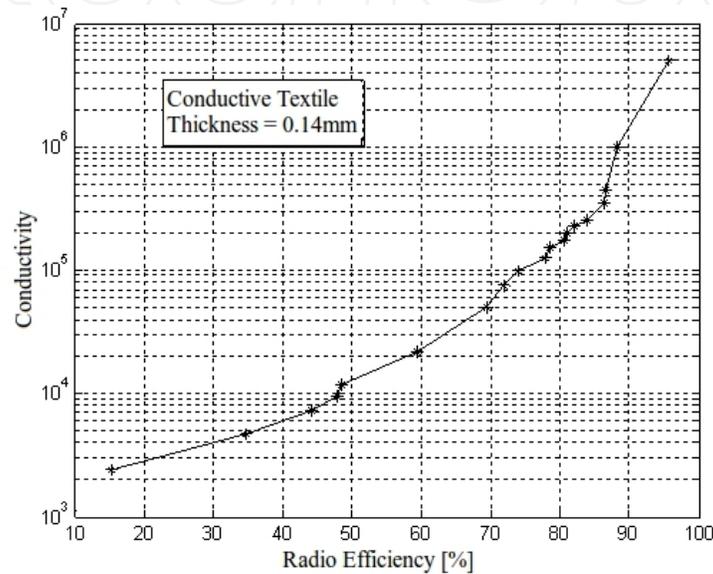


Figure 5. Gain Vs Surface Resistivity Plot

To know the relation between these parameters, a measurement is done for 20 different microstrip antennas keeping other parameters same and only changing the surface resistivity. The result is then plotted in matlab. These measurement results obtained when analyzing different antennas provide valuable information when a conductive textile material is to be used to design an antenna.

Figure 5 depicts that for very low surface resistivity, the gain is maximum. When the radiating element (antenna) surface resistivity is increased, the gain of the antenna starts to decrease.



**Figure 6.** Radiation Efficiency vs. Conductivity Plot

Figure 6 illustrates the relation between the conductivity and the radiation efficiency for above mentioned conductive textile material when used as an antenna. Radiation efficiency is a ratio of power radiated by antenna and power input to antenna. If most of the power input to the antenna is radiated, then the antenna is said to have high radiation efficiency. It can be seen from Figure 7 that conductivity is related to radiation efficiency in logarithmic manner. When the conductivity of radiating element is lower, the radiation efficiency is also very small, and increases as the conductivity increases. However radiation efficiency does not increase in linear way, and to achieve the radiation efficiency in higher percentage, the conductivity of the radiating material should be very high.

The entire simulated antenna has reflection ( $S_{11}$ ) less than -35 dB. However the entire antenna does not have same  $S_{11}$ . This affects the smoothness of the curve obtained in Figure 5 and 6.

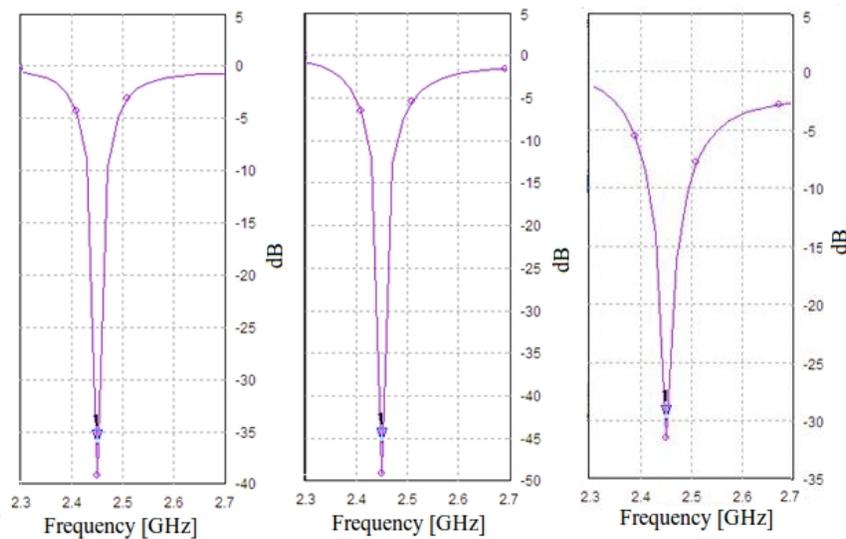
#### 4.2. The impact on antenna performance when the thickness of dielectric material is changed to different values.

When the dielectric material thickness is changed, this affects the radiation efficiency. To analyze this effect, three microstrip patch antenna is designed.

|  |               |                    |
|--|---------------|--------------------|
| Frequency                                | 2.45          | GHz                |
| Surface resistivity of radiating element | 0.02          | $\Omega/\text{sq}$ |
| Thickness of radiating element           | 0.14          | mm                 |
| Dielectric material                      | Fleece fabric | -                  |
| Dielectric constant                      | 1.25          | -                  |
| Height of Dielectric material            | 1, 2, 3       | mm                 |

**Table 2.** Technical specification for the antenna

Three rectangular patch antennas are designed for different height of dielectric material. On doing simulation, various parameters like reflection, gain, radiation efficiency and antenna efficiency for different patch antenna were observed. The obtained results are shown in Figure 7 and 8.

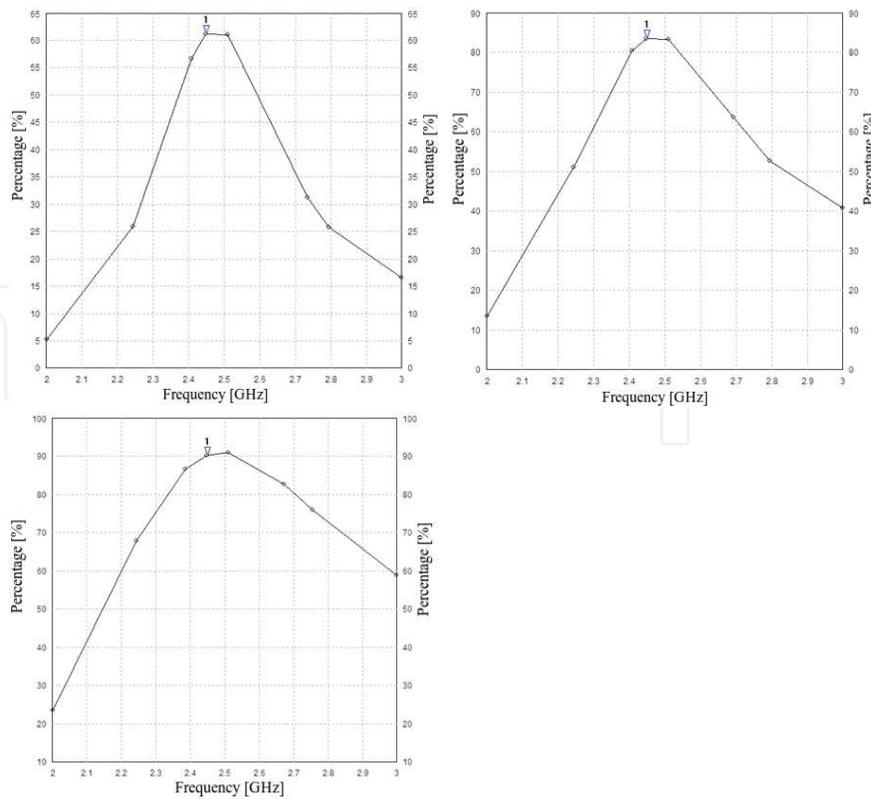


**Figure 7.**  $S_{11}$  for antenna with dielectric thickness 1 mm, 2 mm and 3 mm correspondingly

From above  $S_{11}$  plot it can be seen that the reflection is less than -30 dB for all three antennas with dielectric thickness 1 mm, 2 mm and 3 mm.

For the same specification of antennas, the radiation efficiency is measured with different height of dielectric material.

The above plot gives the measure of radiation efficiency of the antenna with three different thicknesses. It can be seen that for an antenna working at 2.45 GHz and dielectric thickness of 1 mm, the radiation efficiency is 61.2 %, for dielectric thickness of 2 mm, the radiation efficiency is 83.4 % and for dielectric thickness of 3 mm, the radiation efficiency is 90.2 %.



**Figure 8.** Radiation Efficiency for antennas having thickness 1 mm, 2 mm, 3 mm respectively

## 5. Conductive textile materials

The fabric that can conduct electricity is called conductive fabric. The conductivity of the fabric depends on how it is manufactured. Conductive fabric can be made in various ways. They can either be produced by metal inter woven fabric during manufacturing or by metal coated fabric [5] also called electro thread. These conductive textiles have wider application in various fields as they are used for shielding human body and some special equipment from external electromagnetic radiation, and also as pressure sensor or flexible heaters, which are made out of easily wearable conductive textile [6].

For a good design of a textile antenna, the conductive fabric should satisfy some of the conditions as given below.

- The electrical resistance of the conductive textile fabric should be small in order to reduce the ohmic losses in the fabric.
- The surface resistivity should be homogeneous over the entire conductive textile fabric i.e. the variation of resistance should be minimum.
- The fabric should be flexible enough to be able to use as a wearable antenna.

The antenna performs better if the conductive textile fulfills the above given characteristics.

### Non woven fabric

By the name it can be concluded that non woven fabric is prepared by neither knitting process, nor are woven fabric. Thus the non woven fabric does not go through the initial stage of yarn spinning and also a definite web pattern as that of a woven fabric is not obtained. Non woven fabric manufacturing process is similar to that of paper manufacturing process.

The material used is Cu-Ni with the thickness measured in the lab is 0.14 mm.

|                                |   |
|--------------------------------|---|
| <b>Description</b>             | copper + nickel plated non-woven polyamide fabric |
| <b>Roll widths</b>             | 102 cm ± 2 cm                                     |
| <b>Surface resistivity</b>     | Max average 0,02 Ohm/square                       |
| <b>Shielding effectiveness</b> | 70-90 dB from 50 MHz to 1 GHz                     |
| <b>Purpose</b>                 | conductive fabric for general use                 |
| <b>Temperature range</b>       | -30 to 90 (degree centigrade)                     |

**Table 3.** Technical specification of Cu-Ni textile material [7]

These kind of fabric are generally manufactured in three ways namely, drylaid system, wetlaid system and polymer based system. After the fabric is manufactured, it is then strengthened. There are various ways for strengthening fiber web as by using chemical means by spraying, coating. This can also be achieved by thermal means by blowing air or by ultrasonic impact which partially fuses (connects) the fiber thread. Thus finally the metal layer is coated.

### Woven Fabric

Woven fabric is a construction design for lab use at CTU in Prague. The woven fabric consists of silver nano particles attached to the thread of fiber when being constructed and then woven to form a conductive textile, Figure 9.

|   |                                  |
|---|----------------------------------|
| <b>Name</b>                                   | Betex                            |
| <b>Materials Used</b>                         | Shiledex (60%), Polyester (40 %) |
| <b>Number of fiber threads per centimeter</b> | 20                               |
| <b>Surface Resistivity</b>                    | 1.19Ω /sq.                       |

**Table 4.** Technical specification of Betex textile material

## 5.1. Electrical resistance and resistivity of textile materials

Electrical conductivity of textile materials is calculated from electrical resistivity as:

$$\sigma = 1/\rho \quad (2)$$

where  $\sigma$  is electrical conductivity [S/m],  $\rho$  is electrical resistivity [ $\Omega$  m].



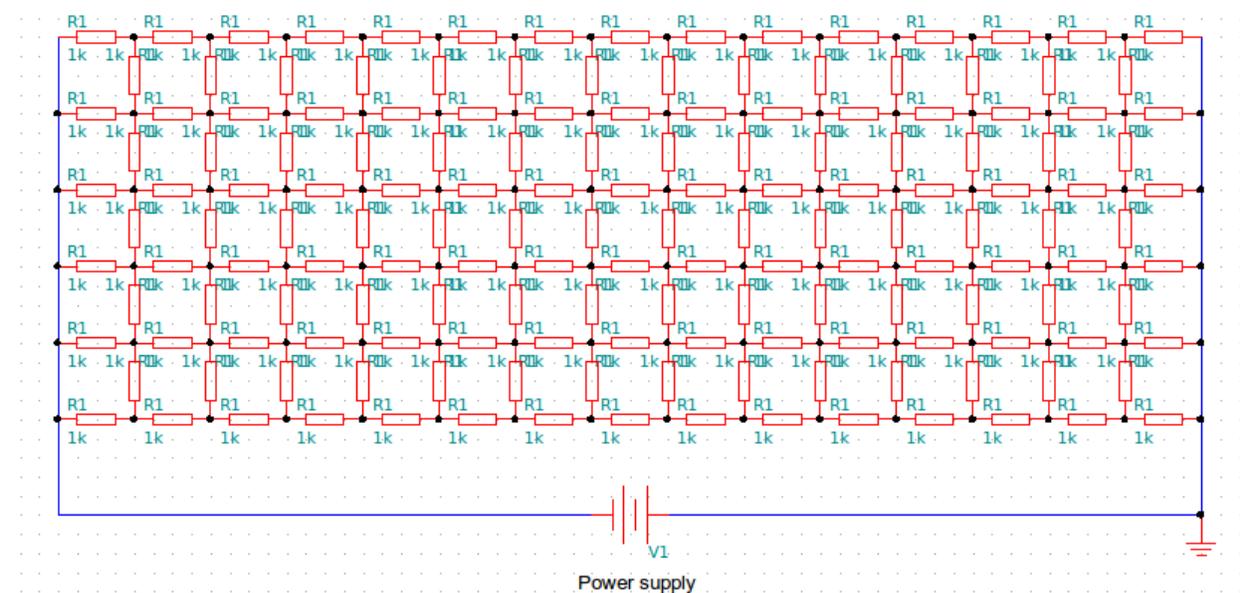
**Figure 9.** Photo of woven Betex textile material

Electrical resistivity can be obtained via resistance measurement [8-10]. We differentiate surface and bulk electrical resistance. Surface resistance is defined as the ratio of a DC voltage  $U$  to the current  $I_s$  which flows between two specific electrodes. The electrodes are placed on the same side of measured material and it is assumed all currents flows only between electrodes and do not penetrate into the bulk of material [8].

Bulk resistance or electrical resistance takes into account all currents flowing in the material, not only on the surface. It can be measured by RLCG bridge or DC power source (showing voltage and current values).

## 5.2. Resistance modelling

The textile material can be modelled as finite grid of resistors. However, it assumes only woven fabric [11]. The example is depicted in Figure 10.



**Figure 10.** Equivalent circuit diagram of Betex textile material

Measurement of resistance (bulk or surface) is based on placing two square electrodes on two ends of the woven textile material. The structure can be interpreted as series-parallel connection of resistors. The battery represents electrodes and resistors the textile fibres.

The equivalent circuit diagram can be simplified with respect to basic physical laws. Equipotential points in this diagram are in all individual „vertical” resistor connections. The resistors placed between the points with same potential can be eliminated because they are equalled to zero. The voltage probes are placed in the equipotential points in Figure 11. The results are depicted in Figure 12. All probes reach the same value and therefore the resistors can be eliminated.

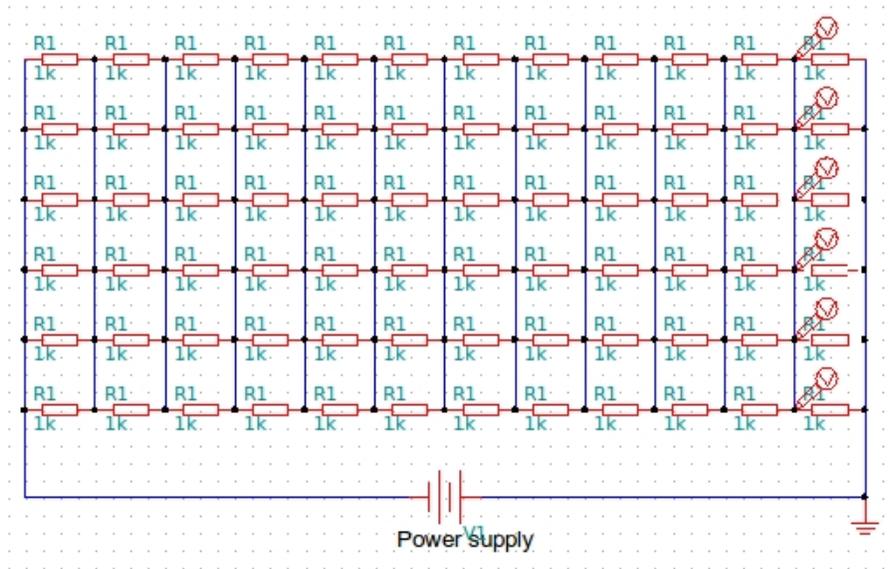


Figure 11. Simplified equivalent circuit model

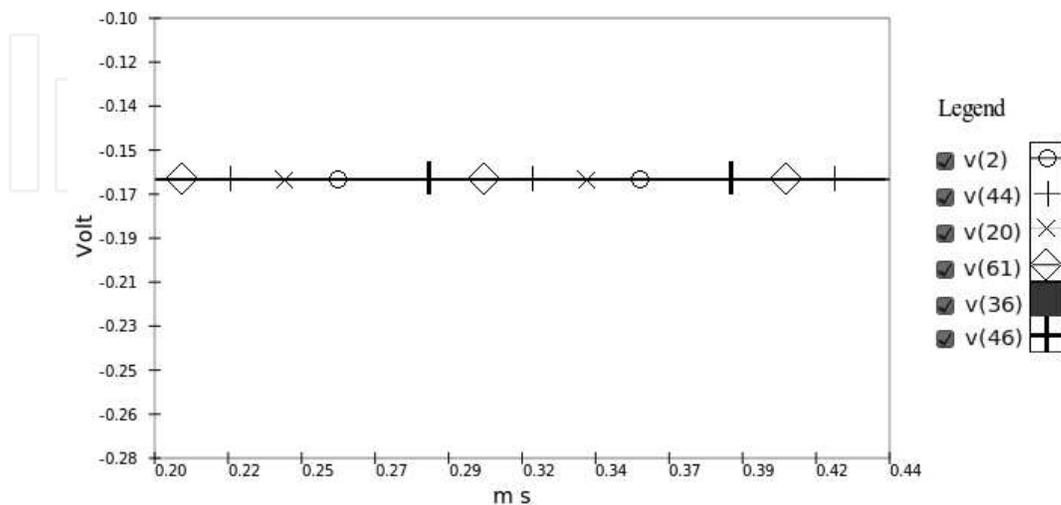


Figure 12. Result values of placed voltage probes.

The resultant resistance of this model can be calculated as series-parallel connection of resistors as:

$$R = \sum_1^{12} \frac{R1}{6} = \frac{12 R1}{6} = 2R1 \quad (3)$$

Formula (3) can be generalized as:

$$R = \sum_{n=1}^r \frac{R1}{s}, \quad n, r, s \in \mathbb{N} \quad (4)$$

where  $n, r$  represents number of squares in „horizontal“ direction and  $s$  in „vertical“ direction.

Considering Betex sample and setup measurement, the Betex sample reach dimensions 10 x 3 cm, 25 threads/cm in warp and 20 threads/cm in weft. Parameters  $n$  and  $s$  are then equalled to:

$$r = 10 \cdot 25 - 1 = 249 \quad (5)$$

$$s = 3 \cdot 20 - 1 = 59 \quad (6)$$

Resultant resistance is equalled to:

$$R = \sum_{n=1}^r \frac{R1}{s} = \sum_{n=1}^{249} \frac{R1}{59} = \frac{249R1}{59} = 4.22R1 \quad (7)$$

The parameter  $R1$  represents a resistance element of used fiber which forms the whole fabric. It can be calculated from the dimensions of textile structure with the aid of fiber diameter measurement.  $R1$  is set to  $0.97\Omega$  and  $R=4.09\Omega$ . It means the structure is very conductive.



**Figure 13.** Measurement setup

### 5.3. Resistance measurement

The Betex sample is measured by RLCC bridge with respect to its calculated resistance. DC power source can cause sample damage at low voltage values (10 V corresponds to approx. 10 A). The measurement setup is depicted in Figure 13.

The measurement of Betex sample shows the resultant resistance is approx.  $4\Omega$  which confirms the modelling results.

## 6. Simulations

In this chapter different two antenna types are designed for the conductive textile material. The two designed antennas are H-slot antennas for RFID having an IC chip EM4222 at 869 MHz with the impedance  $128-j577$ , microstrip patch antenna for RFID having T-match. Manual calculations and simulation results for all the antennas are presented below.

### 6.1. Simulation of H-slot patch RFID tag antenna

The wearable tags are designed on IE3D, fabricated and tested in real conditions. The overall size of the H-slot antennas is 180 mm x 200 mm. This big dimension of the antennas can be smaller by using a substrate which has a high dielectric constant, because the antenna size depends on the dielectric constant  $\epsilon_r$  of the substrate and also the design frequency. In this design a fleece fabric is used as a substrate which has a dielectric constant of 1.25. This fabric is chosen because of its better radiation performance. When a substrate has low dielectric constant and small thickness then the designed antenna has good radiation performance. But if a small tag is requested then a substrate with high dielectric constant can be used.

Three different substrate materials are used for comparison. The first substrate is Polyethylene ( $\epsilon_r = 2.25$ , thickness  $h = 1.7$  mm). This design gives smaller dimensions (145 mm x 160 mm) than fleece fabric.

Later on this substrate replaces with the fleece fabric to increase the radiation performance because of fleece's low dielectric constant.

Third design is made by a substrate material which has a very high dielectric constant  $\epsilon_r$  to reduce the antenna size. The material is silicone slab. Silicone slab is chosen because it is elastic, hydrophobic material and this property gives an advantage of avoiding the water absorption into the substrate, this is important property of silicone slab because when water absorbed into the substrate, the dielectric constant of the substrate changes. This also gives homogeneous connection between the substrate and radiating patch. The antenna design with silicone slab is giving as a size of 57 mm x 78 mm, much smaller than other designs. But a decreasing in the radiation performance is achieved. Thus there is a trade of between antenna performance and size of the antenna.

In this work, two different conductive textiles are used to design and fabricate two different tags, TAG1 and TAG2.

|                            |                    |                    |
|----------------------------|--------------------|--------------------|
| <b>Parameter</b>           | Cu-Ni              | BETEX              |
| <b>Frequency</b>           | 869 MHz            | 869 MHz            |
| <b>Surface resistivity</b> | 0.02 $\Omega$ /sq. | 1.19 $\Omega$ /sq. |
| <b>Thickness</b>           | 0.14 mm            | 0.35 mm            |
| <b>Conductivity</b>        | 357143 S/m         | 2381 S/m           |

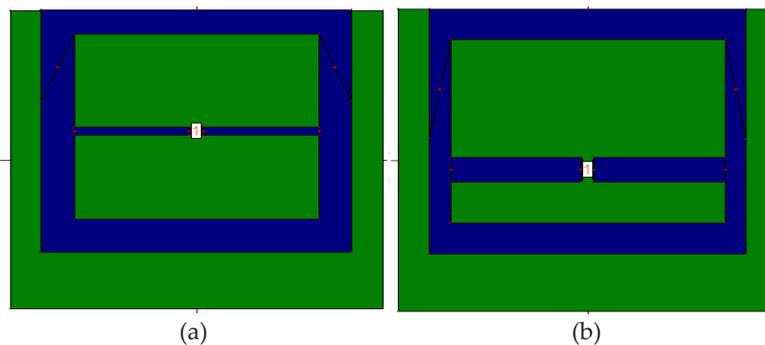
**Table 5.** Specifications for the conductive textile radiating element

| <b>Parameter</b>                  | TAG1                              | TAG2                            |
|-----------------------------------|-----------------------------------|---------------------------------|
| <b>Conductive Material</b>        | Cu-Ni, conductivity of 357143 S/m | BETEX, conductivity of 2381 S/m |
| <b>Substrate Material</b>         | Fleece Fabric                     | Fleece Fabric                   |
| <b>Thickness of the Substrate</b> | 4 mm                              | 4 mm                            |

**Table 6.** Specification for simulating antenna (TAG1 and TAG2)

### 6.1.1. Antenna layouts and designs

Cu-Ni conductive textile has high conductivity and the designing with this conductivity gives better radiation performance than Betex textile which has low conductivity. The simulation of two antennas with two different materials having same dielectric substrate and the same dielectric constant is shown in Figure 14.



**Figure 14.** Simulated H-slot antenna for radiating element having surface resistivity = 0.02(a), and surface resistivity =1.19(b)

As expected, the tag with high conductive material is giving better radiation performance. When a comparison made between this two tag's simulations, a high reading distance and high radiation efficiency are achieved from TAG1 which is designed with high conductive textile. This can be shown by the plot obtained from the simulation, Figure 15.

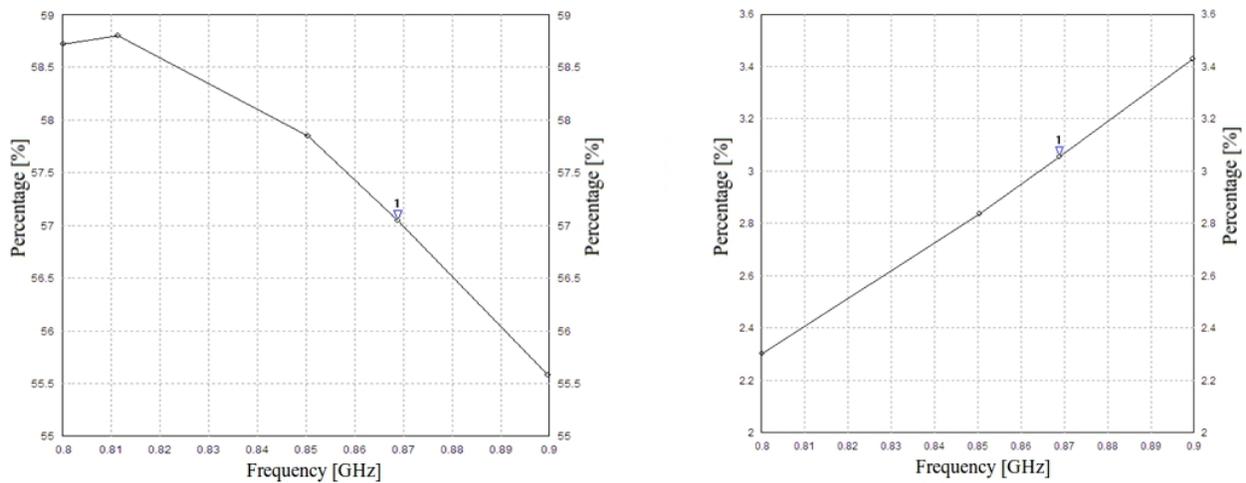


Figure 15. Radiation efficiency Vs Frequency plot for TAG 1 and TAG 2 respectively

It can be seen that radiation efficiency obtained for TAG1 is 57.1% and that for TAG 2 is 3.05%. As it is concluded before that the radiation efficiency is directly proportional to the surface resistivity of the radiating patch. Therefore, higher radiation efficiency is obtained for the TAG having lower surface resistivity. If the antenna were designed from copper material the simulated efficiency would be very high because copper has high conductivity then these conductive textiles. This is shown in later case. Therefore, this value of 57% radiation efficiency is quite good result for this conductive textile.

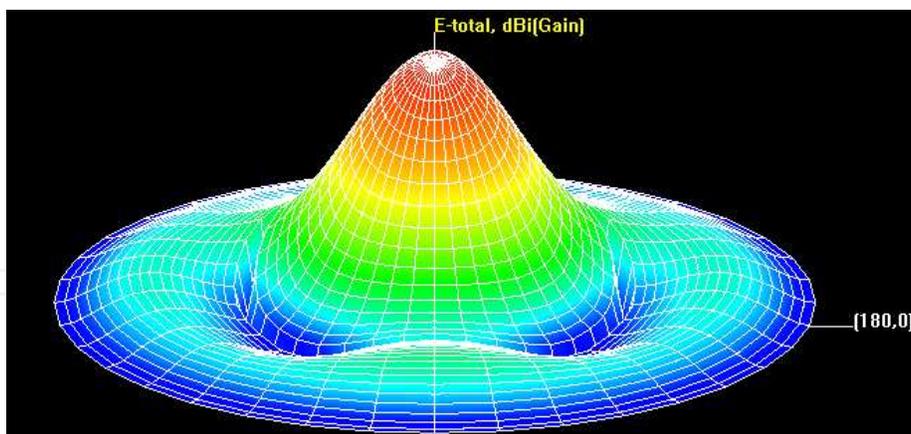


Figure 16. pattern of TAG1

The value of CMF is used to find how good the matching is in between the antenna impedance and chip impedance. The plot obtained for TAG 1 and TAG 2 is depicted in Figure 18.

From the above figure it can be observed that the CMF for TAG1 is 0.975 and that for TAG2 is 0.874. It can be considered that both of the tag antennas has good matching with the chip, however TAG 1 shows better match among the two.

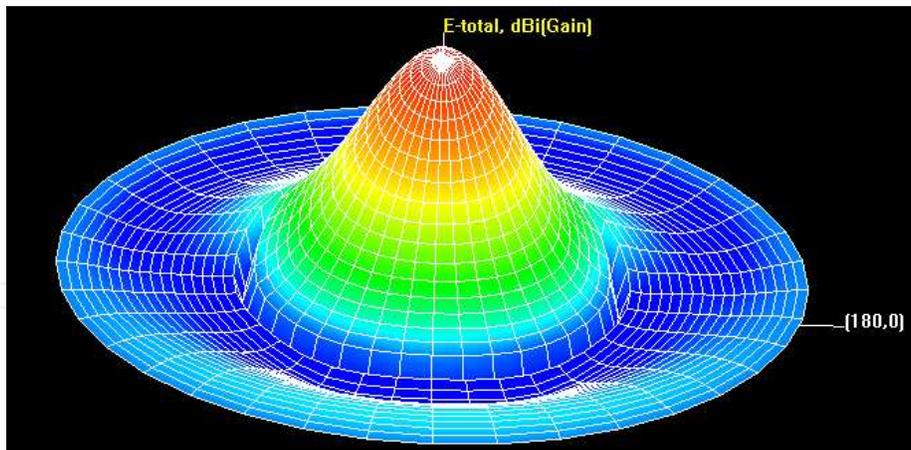


Figure 17. pattern of TAG2

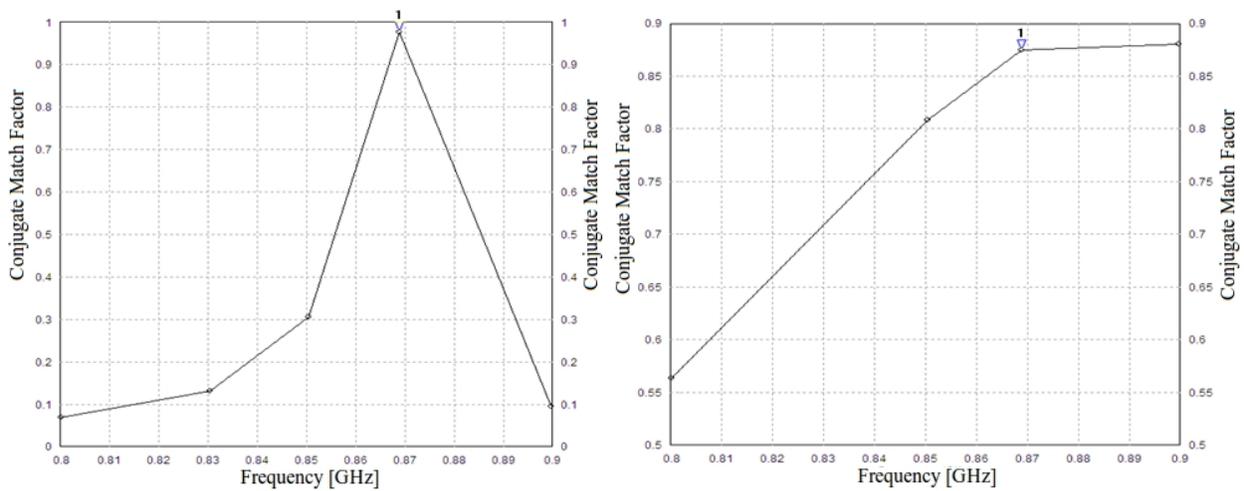


Figure 18. Conjugate match factor plot for TAG 1 and TAG 2 respectively

| @869Mhz                           | TAG1      | TAG2       |
|-----------------------------------|-----------|------------|
| Radiation Efficiency,             | 57.1%     | 3.05%      |
| Conjugate Match Efficiency        | 28.5%     | 1.52%      |
| CMF                               | 0.975     | 0.874      |
| Gain                              | -8.46dBi  | -15.25 dBi |
| Directivity                       | 7.89dBi   | 8.47 dBi   |
| Size of the Tag Lg x Wg           | 180x200mm | 180x200mm  |
| Antenna impedance, Z <sub>a</sub> | 100+j597  | 206+j472   |

Table 7. The combined results obtained from the simulation of two tag antenna

### 6.1.2. Reading range calculation

The read range is obtained as:

$$d_{max} = \frac{c}{4\pi f} \sqrt{\frac{EIRP_R}{P_{chip}}} \tau G_{tag} \quad (8)$$

$$\tau = \frac{4R_{chip}R_a}{|Z_{chip} + Z_a|^2} \leq 1 \quad (9)$$

Here, chip sensitivity is -10 dBm and the maximum radiated power by the reader is 3.2 W EIRP. Thus from the formula the transmission power coefficient for TAG1 and TAG2 is equal to,

$$\tau_1 = 0.97 \quad (10)$$

$$\tau_2 = 0.87 \quad (11)$$

Thus the maximum range obtained is  $d_{max} = 2$  m for TAG1 and  $d_{max} = 1.2$  m for TAG2.

## 6.2. Comparison when different dielectric substrate used

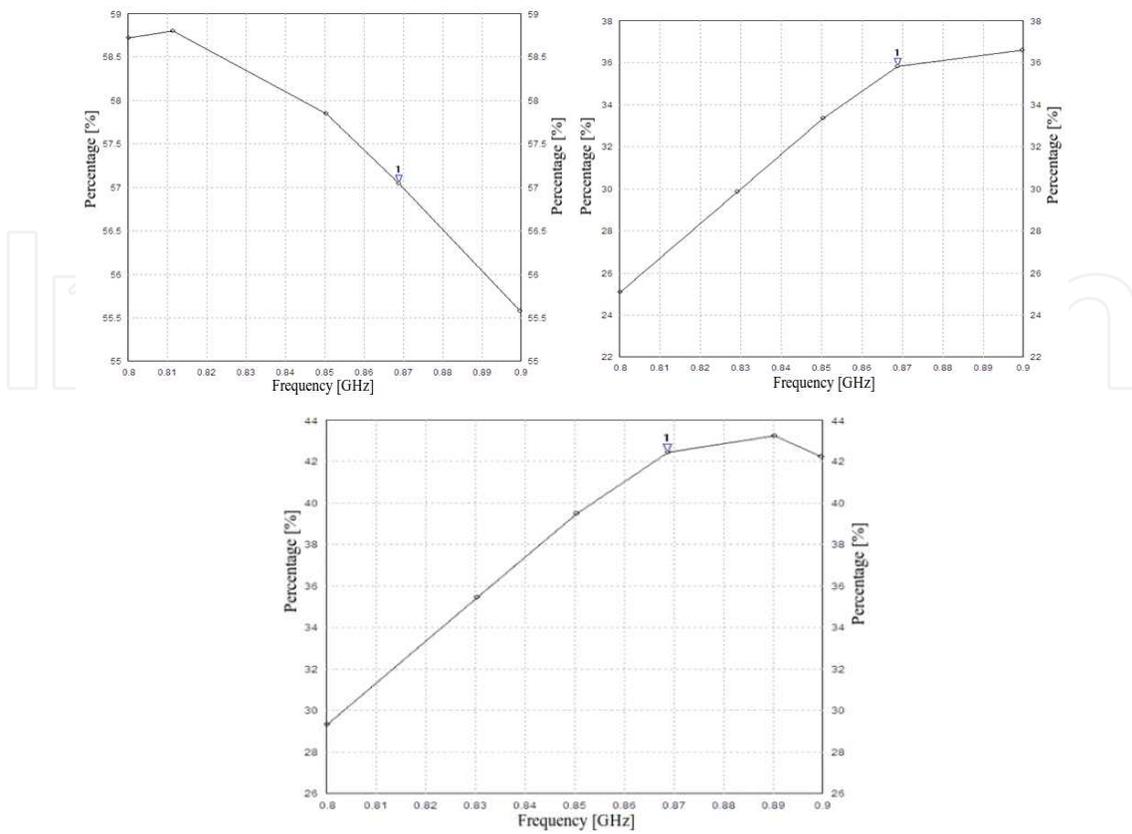
A comparison is performed in simulation to compare the radiation efficiency of H-slot antenna, when the conductive textile (Cu-Ni) is used as radiating element. The comparison is made by changing the thickness of dielectric substrate (fleece fabric) to 2 mm, 2.56 mm and 4 mm. The simulation is performed for the conductor having the surface resistivity  $0.02 \Omega/\text{sq}$  to resonate at the frequency 869 MHz. For three different thickness values, three different antenna geometry and CMF and radiation pattern is achieved. The CMF for all the designs were measured to be more than 0.95 when measured in linear scale.

Figure 19 depicts the radiation efficiency obtained from 4 mm thick dielectric substrate is the highest and obtained to be 57.1 %, for 2.56 mm thick dielectric substrate is 43.4 % and that for 2 mm thick dielectric substrate is 35.8 %. The better performance is achieved with the antenna having thicker dielectric substrate.

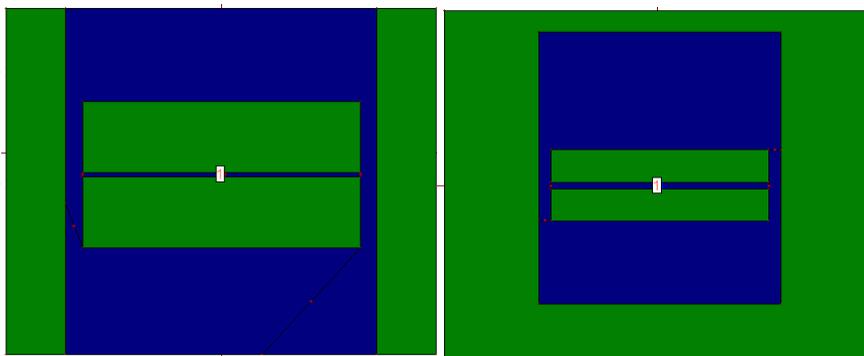
## 6.3. Comparison when different dielectric material used

In this case the two dielectric materials are used. One is the fleece fabric with the dielectric constant 1.25 and the other is silicone slab with dielectric constant 11.9. The silicone slab with high dielectric constant is used to reduce the size of antenna and also hydrophobic in nature. This is very useful characteristics of silicon slab. The two antennas with two different materials are depicted in Figure 20 and 21.

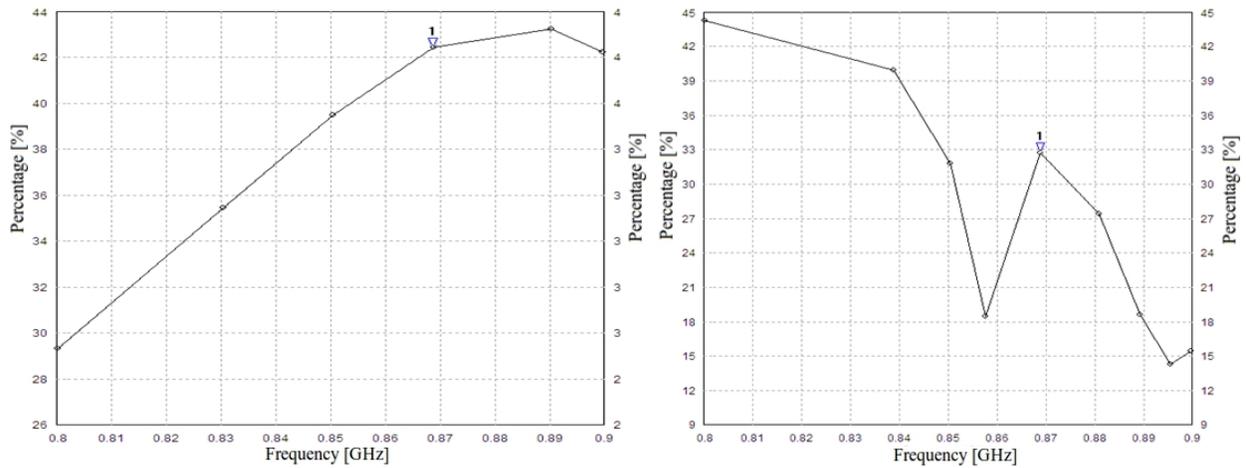
As seen from the graph, the radiation efficiency of antenna using silicone slab and having higher dielectric constant, is reduced compared with the one using fleece fabric. Though the



**Figure 19.** Simulation result of Radiation efficiency plot for Cu-Ni, with the height of dielectric substrate 2 mm, 2.56 mm and 4 mm.



**Figure 20.** Antenna with Dielectric substrate fleece and antenna with dielectric substrate silicone slab respectively



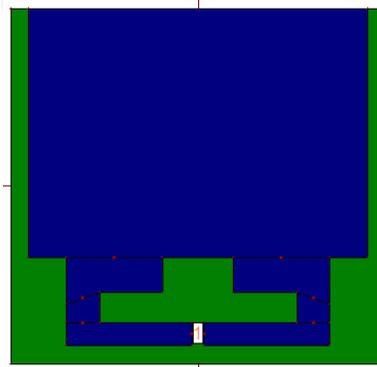
**Figure 21.** Radiation efficiency of antenna using dielectric substrate fleece (43.4%) and silicone slab (32.7%)

size of antenna was reduced, the efficiency was also decreased drastically. It is due to this reason fleece fabric is preferred.

#### 6.4. Simulation of microstrip patch antenna for RFID application

This is another technique of designing RFID tag antenna. A rectangular patch antenna is used as a tag antenna for RFID. The microstrip patch antenna for RFID is designed for 869 MHz. The manual calculation of microstrip patch is calculated in the similar ways as for the rectangular microstrip patch in chapter 3, however the feeding is different. A T-match is used to match the impedance of the antenna to the chip. The calculated length is 150 mm and the width is 190 mm.

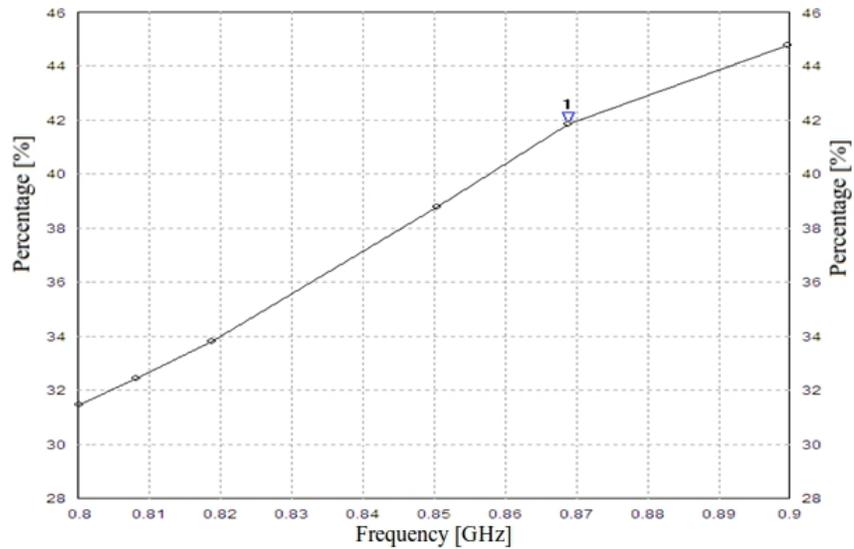
The dielectric material used is Fleece fabric with dielectric constant 1.25 and dielectric height of the substrate 2 mm. The radiating element is simulation of conductive textile material having surface resistivity 0.02 Ω/sq.



**Figure 22.** Microstrip patch antenna using T match

|                            |          |
|----------------------------|----------|
| Frequency(869 MHz)         | TAG3     |
| Radiation Efficiency       | 41.82%   |
| Conjugate Match Efficiency | 20.91%   |
| CMF                        | 0.956    |
| Gain                       | -7.99dBi |
| Directivity                | 8.162dBi |
| Size LxW                   | 150x190  |
| Imput Impedance , Za       | 92+j547  |
| Reading distance           | 2m       |

**Table 8.** Simulated output results for TAG 3



**Figure 23.** Radiation Efficiency Vs frequency plot for the tag antenna

Figure 23 shows the radiation efficiency obtained is 41.8 %.

## 7. Fabrication and measurement of H-Slot and patch RFID antenna

### 7.1. Results of fabrication and measurements of TAG1 and TAG2

For fabrication of these two tag antenna, the available fleece fabric had a thickness of 2 mm, so to have 4 mm thickness two layer of fleece is overlapped by using glue. The conductive material also attached to the substrate by using glue.

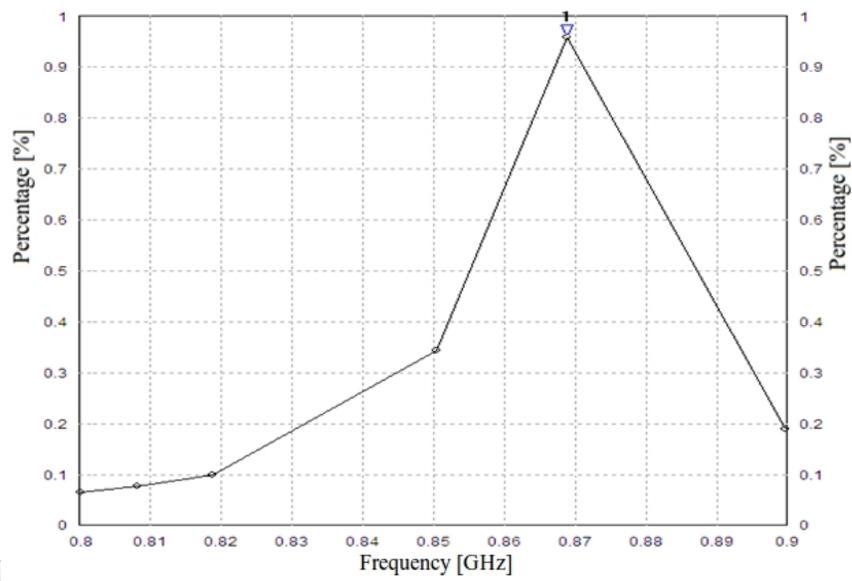


Figure 24. Conjugate match vs frequency for TAG 3 ( $CMF_{max}=0.956$ )

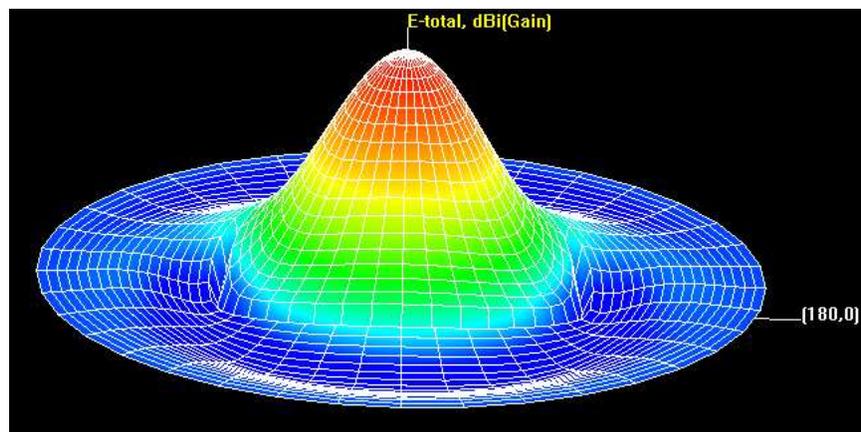


Figure 25. radiation pattern for TAG 3



Figure 26. Fabricated antenna (a), chip connection to slot arm (b) for TAG 1



**Figure 27.** Fabricated antenna for TAG 2 and chip connection



**Figure 28.** Fabrication and Chip connection for TAG 3

As can be seen from the Figure 27 TAG 2 is constructed from Betex and being very difficult to connect chip by soldering, an alternative way is used. First a copper tape is attached, similar to that with microstrip patch and then the chip is soldered on top of it as shown in Figure. This not done with TAG 1, as it was not necessary.

To measure the tag performance, an RFID reader is connected to the computer.

The reader shown in the above figure generates the frequency signal which is captured by the tag antenna, and retransmit signal back to reader. This signal is received by the reader and is sent to the computer for further processing of the signal.

The RFI21 RFID Reader Demo application program is used in the computer to read the reader. This application uses Python 2.6 programming language in the computer to accomplish this task. The reader is manufactured by METRA BLANSKO a.s.

During the measurement, the reading distance of the TAG1 and TAG2 is measured. Tags are moved towards the reader's antenna till the reader detects the signal from the tag.

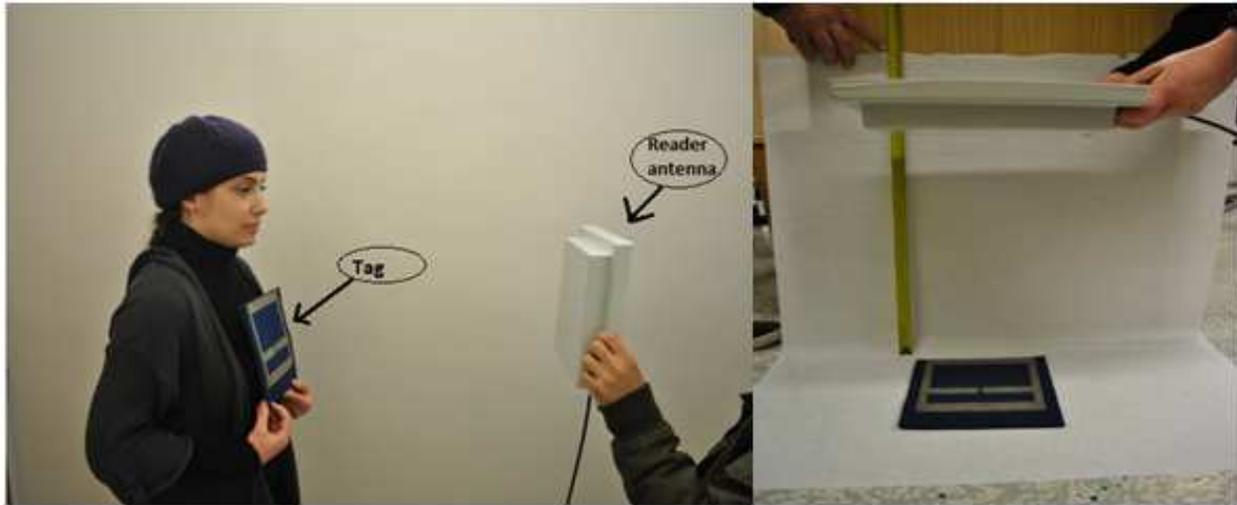


Figure 29. Measuring Reading distance of TAG1

As soon as RFID tag is detected by reader's antenna, the information is displayed on the computer.

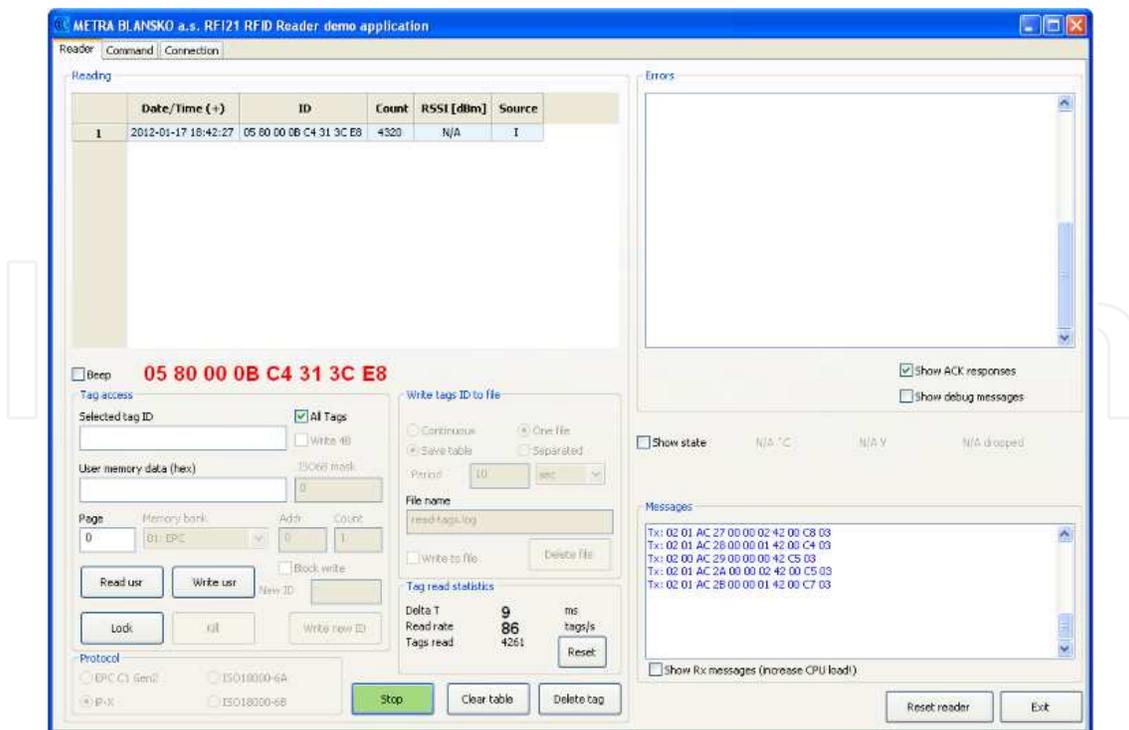


Figure 30. Application program detecting the EM4222 chip ID (in red)

EM4222 chip is used in the tag antenna. When the tag is detected by the reader the tag ID is displayed in the computer. This can be seen in the figure which is the ID of the chip in red color.

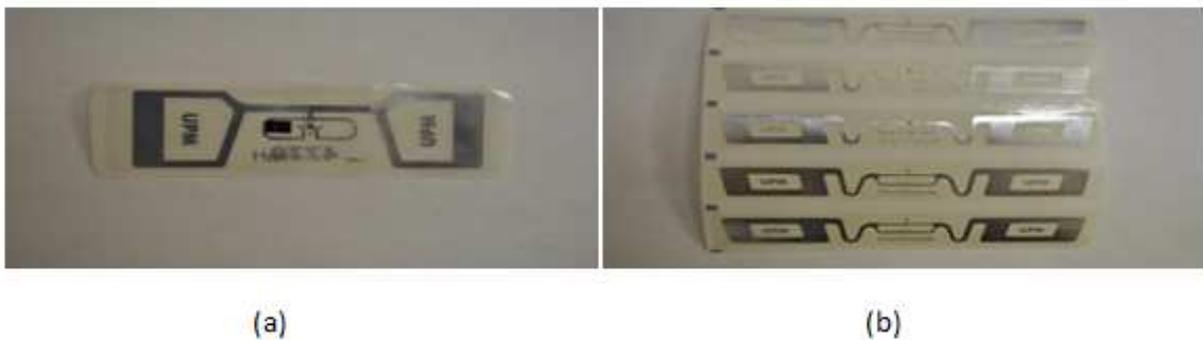
From the measurement results, the reading distance for TAG1 is measured to be 50 cm. This is quite smaller than simulated results because of the change in dielectric material due to non-precise determination of permittivity and also soldering process.

The reading distance for TAG2 is quite close the simulation results, 90 cm. The simulated reading distance for this tag is 1.2 m. Thus TAG 2 gave better performance and was very close to simulated values.

| Range         | TAG1  | TAG2  | TAG3  |
|---------------|-------|-------|-------|
| Reading range | 50 cm | 90 cm | 60 cm |

**Table 9.** Measured read range from the three designed tag

A short experiment was done to compare working of the fabricated tag and the tag available in the market. To make a comparison of reading distance, two different UHF RFID tag's reading distance were measured. The tags used were UPM Hammer 258-1 and UMP short dipole 211\_2. These are the commercially available tag in the market.



**Figure 31.** UPM Hammer 258-1RFID tag (a), UMP short dipole 211\_2 RFID tag (b)

| Parameter        | UPM Hammer 258-1 RFID tag | UMP short dipole 211_2 RFID tag | H-slot TAG2 |
|------------------|---------------------------|---------------------------------|-------------|
| Reading Distance | 98 cm                     | 152cm                           | 90cm        |
| Chip Protocol    | EPS S1 Gento              | EPS S1 Gento                    | IP-X        |

**Table 10.** Comparison of read range of manufactured tag with commercially available tag

The measurement was performed in open space in the lab.

## 8. Conclusion

Implementation of textile antennas for RFID tags represents a realistic developmental assignment, and as shown and practically proved, this arrangement yields good results. The successful operation of such textile antennas mainly requires the mechanical stability of the textile composite, which realizes a RFID tag antenna. A good function of the antenna and thus the sensitivity of the complete tag can be provided for just compliance with the mechanical construction and stability of required dimensions. A good choice of textile material for both electrically conductive structures and the insulating layer of the resultant fabric composite is the most important prerequisite for the successful implementation.

Textile RFID tags find its use at both person marking (marking of athletes, protective clothing and other functional ready-made textile products) and stock-in-trade marking in hospitals, packaging, etc.

## Acknowledgements

This work was supported by the project Kompozitex FR– TI4/202 - Composite textile materials for humans and technology protection from the effects of electromagnetic and electrostatic fields. The work was conducted in the Department of Telecommunication Engineering at the Czech Technical University in Prague in the scope of thesis called “Design and performance analysis of purely textile antenna for wireless applications” [12] and other research projects.

## Author details

Lukas Vojtech, Robi Dahal, Demet Mercan and Marek Neruda

\*Address all correspondence to: lukas.vojtech@fel.cvut.cz

Department of Telecommunication Engineering, FEE, CTU in Prague, Prague, Czech Republic

## References

- [1] Kennedy T.F. et al. Body-Worn E-Textile Antennas: The Good, the Low-Mass, and the Conformal, *IEEE Transaction on Antennas and Propagation* 2009; 57(4) 910-918.
- [2] EM Microelectronic Data Manual, Marina SA. Company of the Swatch Group, Data Sheet EM4222, 2003.

- [3] Lozano-Nieto A. RFID Design Fundamental and Application. Boca Raton: CRC Press; 2011.
- [4] Occhiuzzi C. et al. Modeling, Design and Experimentation of Wearable RFID Sensor Tag, *IEEE Transactions on Antennas and Propagation* 2010; 58(8) 2490-2498.
- [5] Aniolczyk H. et al., Application of Electrically Conductive Textile as Electromagnetic Shields in Physiotherapy, *Fibers and Textiles in Eastern Europe* 2004; 12(4) 47-50.
- [6] Vojtěch, L. and Neruda, M. Application of Shielding Textiles for Increasing Safety Airborne Systems - Limitation of GSM Interference. In *The Ninth International Conference on Networks (ICN 2010)*. Los Alamitos: IEEE Computer Society 2010, 157-161.
- [7] Constantine A.B. *Antenna Theory Analysis and Design*. New York: John Wiley; 1997.
- [8] Maryniak W.A., Uehara T., Noras M. A. Surface Resistivity and Surface Resistance Measurements Using a Concentric Ring Probe Technique, *Trek Application Note* 2003; 1005: 1-4. [www.trekinc.com/pdf/1005\\_Resistivity\\_Resistance.pdf](http://www.trekinc.com/pdf/1005_Resistivity_Resistance.pdf) (accessed 16 August 2012).
- [9] IEC 61340-5-1 Standard. *Electrostatics – part 5-1: Protection of Electronic Devices from Electrostatic Phenomena - General Requirements*, 2001.
- [10] ASTM Standard D 257-99. *Standard Test Methods for D-C Resistance or Conductance of Insulating Materials*, 1999.
- [11] Neruda, M. and Vojtěch, L. Verification of Surface Conductance Model of Textile Materials. *Journal of Applied Research and Technology* 2012; 10(4), 579-585.
- [12] Dahal, R. and D. Mercan. Design and performance analysis of purely textile antenna for wireless applications. Sweden, 2012. 64 p. Diploma thesis. Czech Technical University, University of Gävle, Sweden. [hig.diva-portal.org/smash/get/diva2:504525/FULLTEXT01](http://hig.diva-portal.org/smash/get/diva2:504525/FULLTEXT01) (accessed 16 August 2012).

IntechOpen

