

# A Ultra High Frequency (UHF) RFID Antenna Design for Food Quality and Safety



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**Abstract** — In this proposed review paper an antenna design for Ultra High Frequency Radio Frequency Identification (RFID) is presented. We discuss various applications of RFID antenna: meat freshness monitoring application, RFID card, RFID bracelets, in food containers for catering business and methods to measure dielectric properties on agri food materials. Modeling and simulation results are also presented.

**Index Terms** — Antennas, UHF Radio Frequency Identification (RFID), Dielectric properties, Tags

## I. INTRODUCTION

RFID (Radio Frequency Identification) uses radio signals to identify the presence of an object, calculating the timing of sports events or for controlling an inventory. RFID is designed for complementing the bar code and for finding the long range reading of codes. Using the RFID technology we can able to identify a person or packaging an item [1]. For achieving this operation it uses RFID Tags. These tags are small combination of radio transmitter and receiver that transmits the signal above a short distance. An RFID tag can be incorporated into product, animal or a person for identification, this can be achieved by tracking of radio waves [2]. The tags can also be read from several distance, continuing after the line of sight. Due to the complications in direct reading and the failure of radio waves the tags support a plain text inscription along with a barcode [3]. The RFID tags have two parts within the first part have an integrated circuit used for storing, processing information, modulating and demodulating a radio frequency signal. The second part of an antenna is used for transmitting and receiving the signal. RFID is classified into passive and active types [4]. In active RFID tags, it works with the help of batteries whereas the passive RFID tags works without the help of batteries.

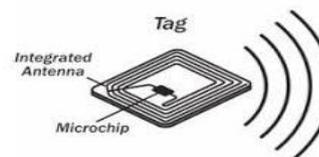
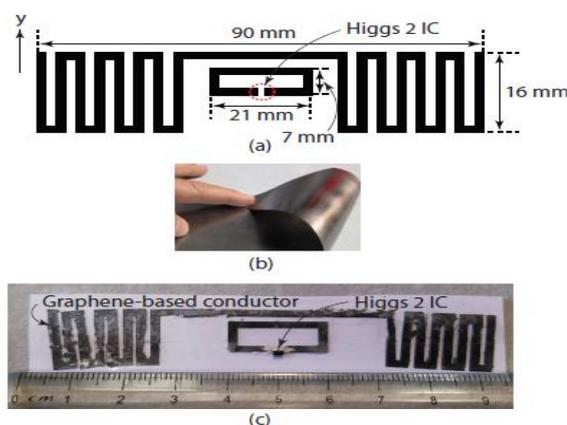


Fig. 1.RFID Antenna

The above fig.1. represents an basic integrated RFID antenna along with a microchip. In recent years, the studies related to radio-frequency identification has been increasing. The RFID system can be employed for several frequencies from few kilohertz to few gigahertz. The UHF RFID applications is mainly used for tracing the quantity of supplies of mass retailed products [5]. The UHF RFID frequency band extends from 860- 960 MHz, but the regulated frequencies may vary according to the country. The UHF RFID are generally of three categories as: 865-868 MHz for Europe, 902-928 MHz for America, and 952-954 MHz for Japan [6]. RFID tag antenna need to be in an broadband to work in every country. Since the requirement of tags has been in an increasing order the production cost has to be as low as possible. The production cost of an tag can be decreased by making the possibility of working an antenna independently on which it is mounted [7]. We can able to create a multiple number of tags for different applications when antennas printed on a substrate with a ground plane [8]. Using the technology cost and the performance make a huge number of RFID tags [9]with low cost .In some cases the antenna could be paper-based, and the conductor could be composed of silver ink.

## II. ANTENNA DESIGN

### A . Passive UHF RFID tag with conformal antenna



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Fig. 2. (a)Dimensions of UHF RFID tag antenna ;(b)Antenna on carbon content graphene based material which is 97% available and (c)UHF RFID tag with paper substrate and graphene based conductors[10].

In this method, graphene based material is placed to reduce conductor failure [11]. Simulations and read range measurements for 2.1 meters of passive UHF RFID tag with dimensions and graphene based conductors and also commercially available copper based designs are shown in the below figures.



Fig. 3. RFID reader antenna in the full anechoic chamber meanwhile measurements of read range

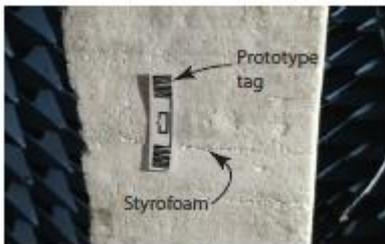


Fig. 4. The prototype tag's read range measured in the full anechoic chamber.

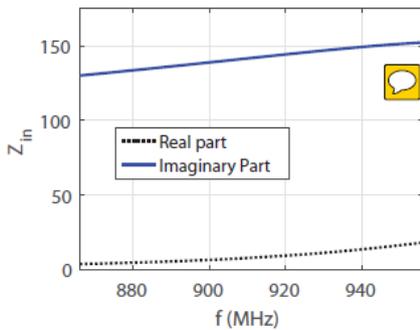


Fig. 5. Simulated input impedance of the antenna with graphene based conductors.

This type of conformal antenna has the advantage of conformality of graphene based conductors and conducting properties which is used for developing UHF RFID passive antenna[12]. Tags on thin conformal paper substrates and its Read ranges 2.1 could be achieved for 2.1 metres are shown by measurements .

**B.Design of UHF RFID tag antenna for food systems**

In this method, a tag antenna is constructed for radio frequency identification (RFID) food system.

Based on the concept of rectangular loop used in UHF band (Korean and Japanese standards from 916.7 to 923.5 MHz) the antenna for RFID tag is designed and fabricated. The designed tag antenna is together with sensor tag chip,

radiation patch, temperature sensor , oscillator and battery [13].U-shaped stub is used to obtain conjugated matching between the sensor tag and antenna . Because of different fields(the military ,environmental monitoring and health care),the active RFID can obtain long range data transmission. Increase in importance of food safety problems causes the growing of food management requirement system.The freshness of the meat ,vegetable or diary product is very important.An active RFID tag is placed on the product which can be vegetable,meat or diary product.Product spoilage can be prevented by requiring refrigeration and monitoring the temperature or process of distribution.In this method ,a semi active sensor tag antenna for RFID food system is designed and it covers the range of 916.7 to 923.5MHz.

By using high frequency simulator (HFSS) software, the simulations of the antenna were carried out.

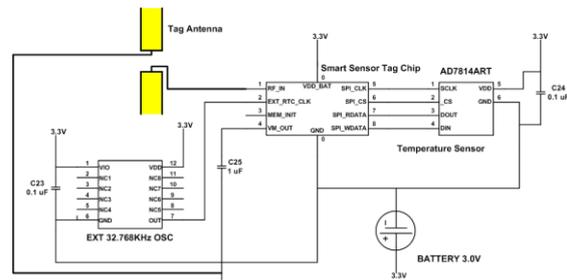
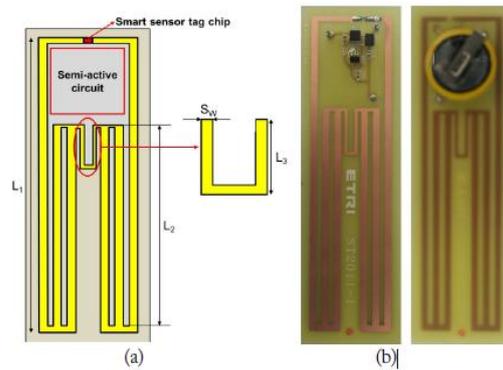


Fig. 6.Geometry of the designed semi-active tag antenna. (a) Tag antenna (b)photograph and (c) semi active circuit

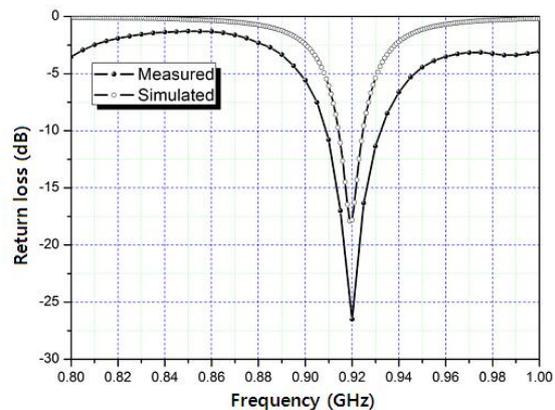


Fig. 7.(a)

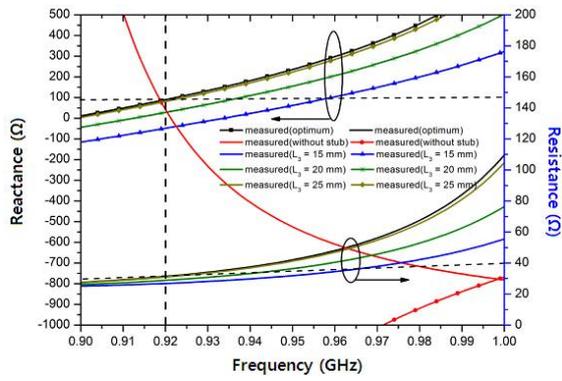


Fig. 7.(b)

Fig. 7. Measured results of the semi active tag antenna. (a) Return loss and (b) input impedance

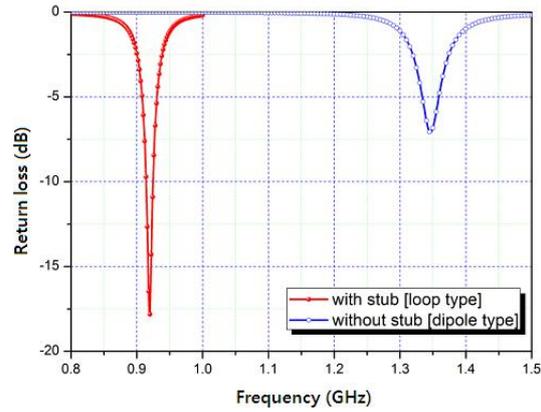


Fig. 9. Simulated with and without the U-shaped stub.

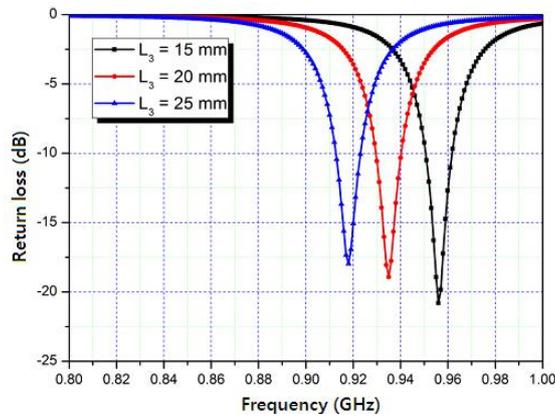


Fig. 8.(a)

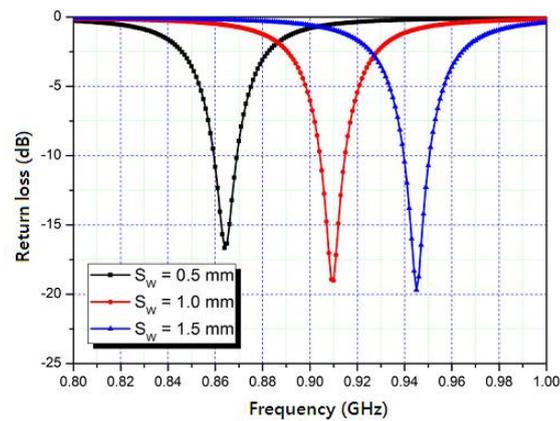


Fig. 8.(b)

Fig. 8. Return losses with respect to frequency for different sizes of U-shaped stubs. (a)  $L_3$  and (b)  $S_w$ .

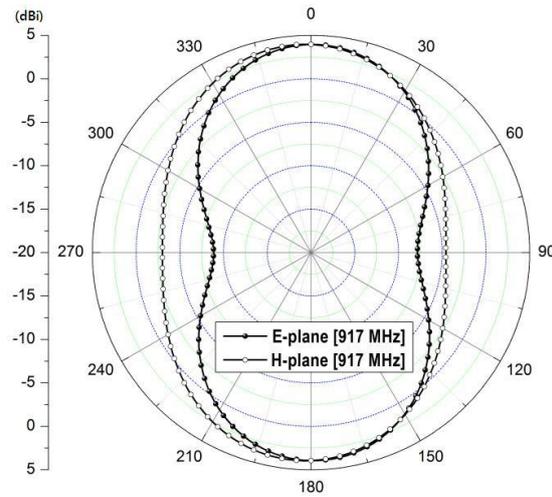


Fig. 10.(a)

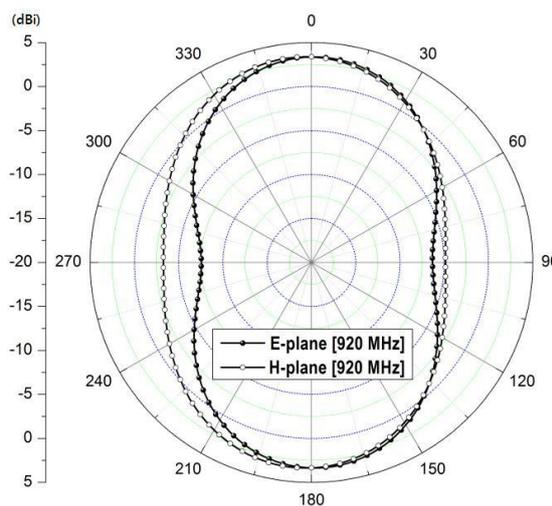


Fig. 10.(b)

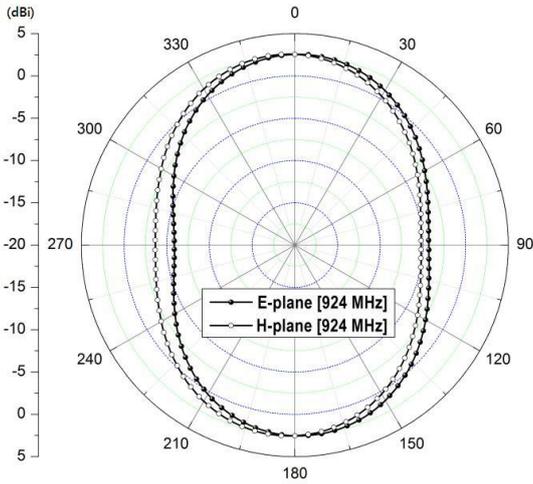


Fig. 10.(c)

Fig. 10. Measured radiation patterns. (a) 914MHz, (b) 920MHz and (c) 924MHz.

Table-I: Comparison with other tag antennas

Tag antennas	Structure	size	Read Range (m)	Frequency (MHz)
CAEN A927Z	Semi passive	130×23.4×12.7	10	860-928
TMT-8500	active	94×58×14	100	902-928
Power TMP SL	active	85×54×0.9	40	860-960
Proposed	Semi active	100×30×0.8	30	900-950

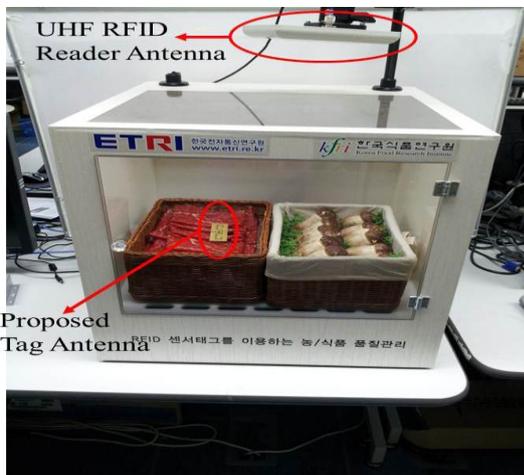


Fig.11.(a)

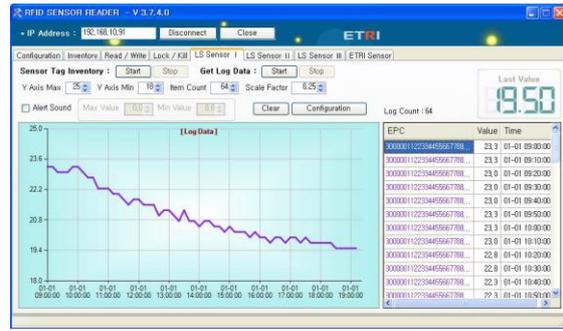


Fig.11.(b)

Fig.11.Measured results for tag identification. (a) Grocery temperature monitoring setup environment and (b) obtained results for the grocery temperature. The proposed antenna for semi active tag was stucked to the top of meat and this allowed real-time measurement of the meat temperature [14]. This tag antenna will be useful in systems for real-time grocery location and for maintaining freshness.

C. Broad band UHF RFID antenna tag with quasi-isotropic radiation performance

To obtain an omnidirectional and broadband performance simultaneously, design of microstrip antenna and electromagnetic radiation, a bent meandered dipole antenna and two short circuited strip is examined in ultra high frequency (UHF) bands. For low cost production, the designed antenna was composed with thin copper layer and printed on thin lossy PET substrates..This type of antenna can be used for all different UHF RFID tags in passive RFID applications.

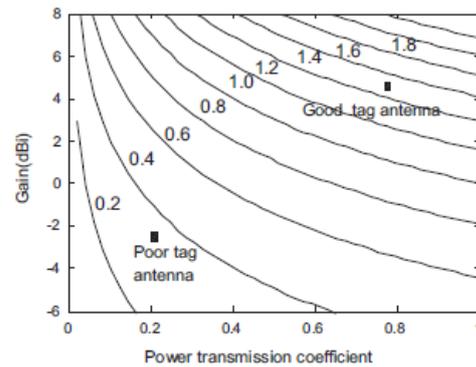


Fig. 12. Tag antennas performance chart

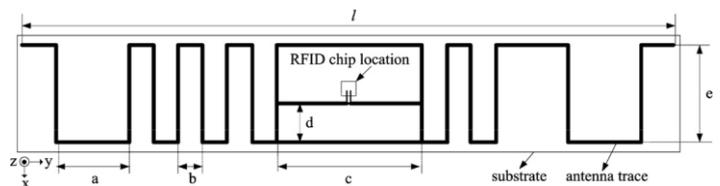


Fig.13. Physical outline of the designed antenna

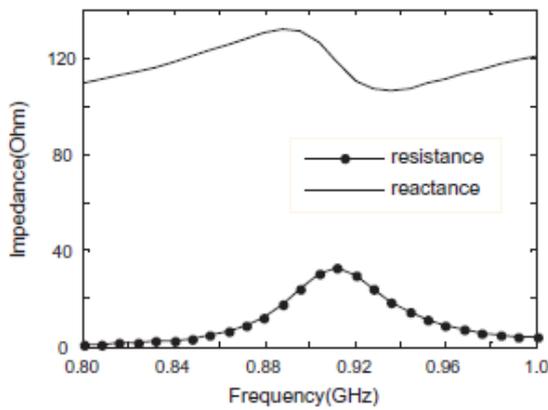


Fig. 14. Simulated impedance for proposed antenna with  $l=88$  mm.

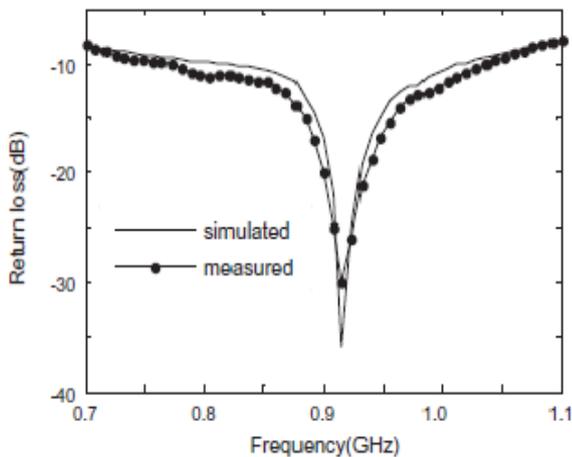


Fig. 15. Return loss of designed antenna at 915 MHz.

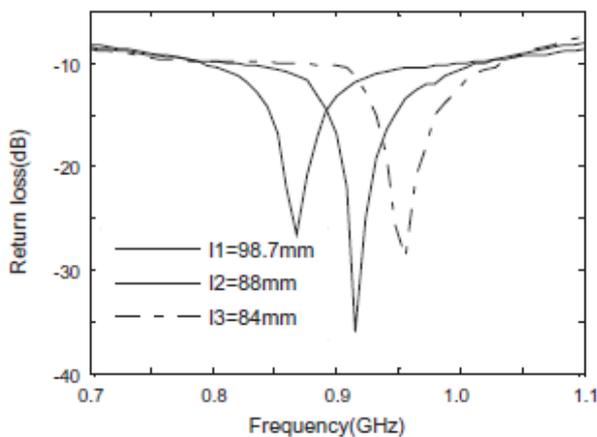


Fig.16. Simulated return loss of designed antenna with different  $l$  values.

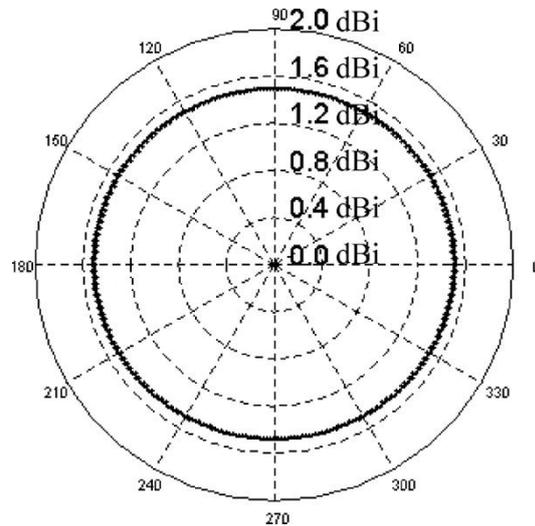


Fig.17. The designed antenna's gain in XZ plane at 915 MHz.

As a result, the designed antenna provides high gain for all UHF RFID tag with omni directional performance. The designed antenna's radiation pattern is shown in fig.18. Thus the quasi isotropic radiation pattern is achieved. Therefore, the designed antenna obtains a good radiation performance [16]. Fig.18 displays that the tradeoff among the impedance matching and the gain of the antenna is very close to the tradeoff performance of good tag antennas. Measured and simulated results show that the designed antenna provides high gain and good radiation performance.

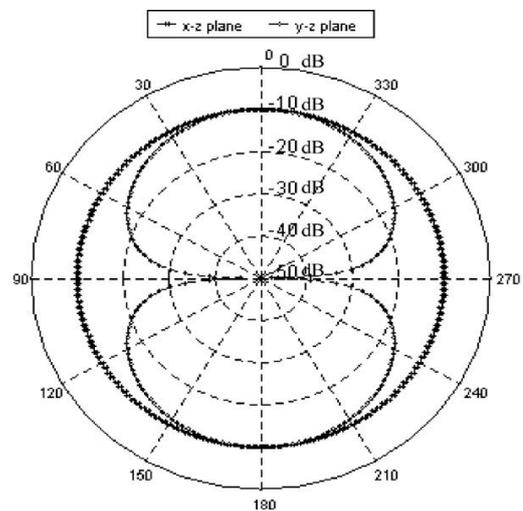


Fig.18. Radiation pattern of designed antenna in E Plane and H plane.

The above measured and simulated results display that the bandwidth of designed antenna is varying from 840 MHz to 0 MHz and it is greater than 20%. The above designed antenna also has the good radiation performance and high gain. Therefore, the designed antenna has the good tradeoff between gain, impedance and antenna bandwidth used in the applications of UHF RFID.

**D. Compact UHF RFID MIMO Tag Antenna for Platform Tolerant Applications**

In this method, an antenna is designed with compact UHF RFID MIMO for platform tolerant applications. The antenna structure consists two bent-loop feeding networks between two substrates, a square patch and a folded radiator [17]. The antenna is reduced to a volume of 35 mm×35 mm×6 mm (due to the folded structure and 3D cross slot). In order to provide isolation between two ports, the feeding networks placed orthogonally are introduced. Between the antenna and the chip, conjugate matching is realized by proximity coupling feed besides the loop matching network. The -3dB impedance bandwidth for the antenna in free space, mounted on water and mounted on metal are 96 MHz (902-998 MHz), 93 MHz (900-993 MHz) and 92 MHz (905-997 MHz) respectively are shown by the simulated results. It means the band of 902-928 MHz can be covered by the tag antenna in various platforms. The isolation is greater than 30 dB in three platforms and two ports have mutually orthogonal radiation characteristics, satisfying the polarization diversity of the MIMO antenna.

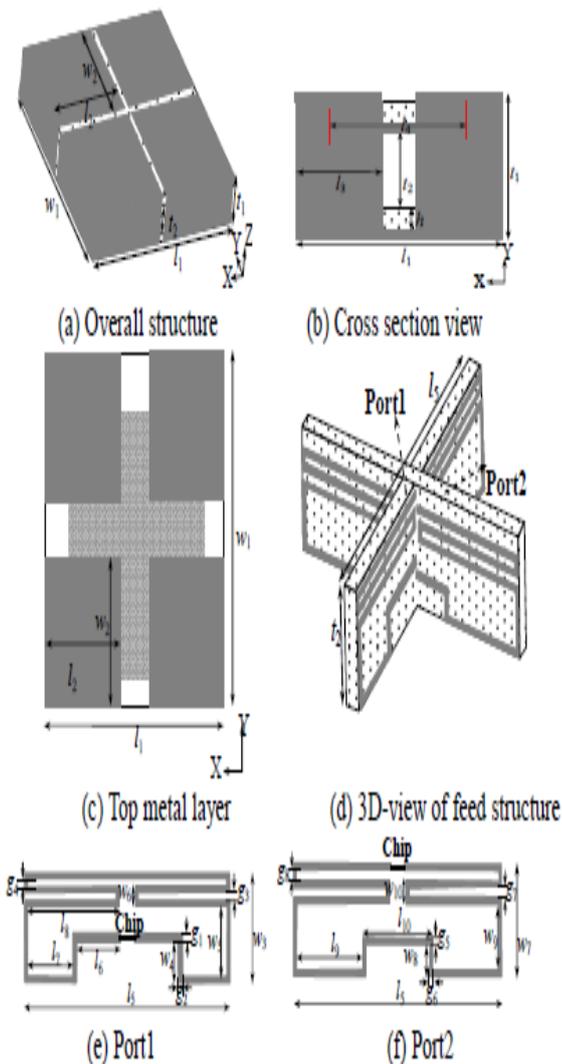


Fig.19. Designed antenna's structural configuration

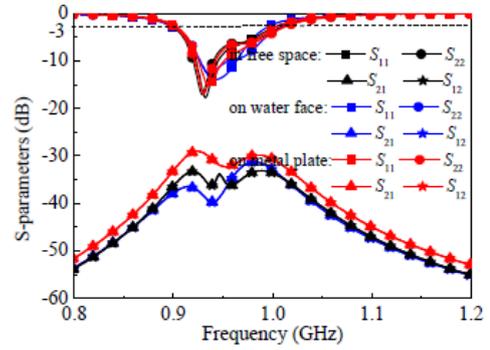


Fig.20. S parameters in three platforms

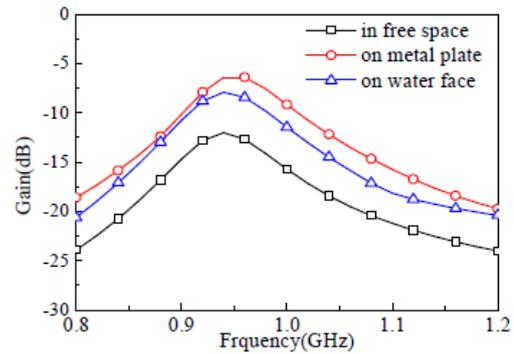


Fig.21. Realized gains in three platforms

Compared to the similar size or even larger antennas, the designed tag antenna is a candidate with good performance and compact size. The metal platform achieves the maximum gain -6dB, and the antimetal feature is quite good.

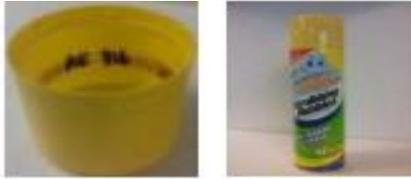
**III. RFID TAGS IN VARIOUS APPLICATIONS**

RFID antenna in temperature based applications. During the transportation or storage of large number of goods, temperature change must be taken into account for quality assurance. In this method, a passive UHF RFID-enabled sensor system to operate at higher temperature levels for detection has been explained. The components included here are an RFID reader, disposable temperature sensor comprising an UHF antenna, chip and temperature sensitive unit are used. The design and simulation of UHF antenna was carried out using an IE3D software. From the obtained temperature level, the properties were examined and the packaging mechanism will be changed accordingly by placing suitable antenna substrate[1].

**RFID ANTENNA in location sensing application.**

In this method, RFID tags are used for sensing the locations, to achieve this process they placed an RFID tag designed antenna reader inside the product. Here, the reader is accessed through internet allowing us to identify the presence of an object anywhere around the world. This helps us in reducing the labour costs. Due to the RFID constrains such as short range, narrow bandwidth and low power outputs they have developed an location sensing algorithm..

Here, huge number of reader antennas are placed and from the received signal level indicator the values are incorporated into a mean-square error testing function[18]. The minimization does not depend upon the tag type and orientation and hence the proposed method is friendly compared with other methods. For more accuracy they used conventional UHF RFID readers, antennas, and passive tags .

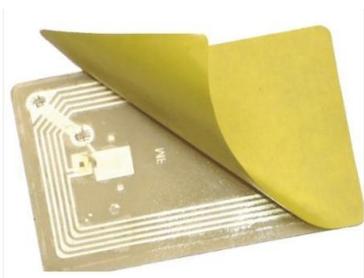


**Fig.22. Mounting of an RFID Tag inside the plastic lid of a metal spray can.**

**A. RFID ANTENNA in meat freshness monitoring application**

In real time it is necessary to know the quality of the packaged food especially for meat products. By knowing the status of the product before packing it enables the distributors to alter their packaging or preserving mechanisms such as freezing thereby increasing their productivity. In this method, they will be displaying the expiry date of the product using an RFID tag. This system compresses of an RFID tag, temperature sensor, humidity sensor, gas sensor, RFID reader, and server. The meat is composed of water, protein, fats and carbohydrates and the enzymes decompose the meat into volatile gases as days passes. Using the gas sensor, it measures the gas emitting from the meat and it transmits the output signal to an MCU and the MCU transmits the signal to the RFID reader and a PC determines the freshness and expiry date using the data from the reader. This process is simultaneously saved by the server. The server analyses the ammonia data and shows the result directly to the customer. By combining the RFID technology along with gas sensor and temperature and humidity sensor they have obtained the relationship between meat freshness and gas released from the meat.

**A. RFID Label**



**Fig.23. RFID smart label**

The above figure is an RFID tag that is in the form of label, this tag enables us to add additional information on its non-sticky side such as barcode and other necessary information about the product[19].

**B. RFID card**

It is often used in large enterprises, the RFID chip with an antenna is mounted on a plastic card which can allow its owners to open doors, also used to support attendance systems. It may be also a key case to open garage doors, etc.



**Fig.24. RFID smart tag**

**C. RFID bracelets**

The RFID bracelets are used as wristbands to identify patients in hospitals instead of the original plastic tape, which have patient's name and identification number marked on it.



**Fig.25. RFID bracelets**

**D. RFID Tag antenna in food containers for catering business**

In this system, the containers with RFID tags was aimed to store fresh products in industrial kitchens at restaurants and hotels. With the help of RFID tags placed in these containers, the information of the product such as its usage time limits can be obtained accurately. In old systems they have placed a sticker and mentioned the product details due to exposure of the containers to external substances like water, washing detergents they have moved on to RFID tag Mounted Containers.



**Fig.26. RFID Tag placed in an container**

#### IV. RFID ANTENNA IN FOOD INDUSTRY

##### A. Advantages of using RFID antenna in food industry

The RFID tag antennas are disposable cheap transponders, easy to recycle. It can be easily mounted in small areas, manufacturing products. It can be able to withstand higher temperatures, humidity and environmental conditions.

##### B. Effects of using RFID antenna in food industry

It is impossible to identify the food items at critically high temperatures, reliability is less. It can also affect tag antenna impedance matching when the tag and the reader are placed nearer to it. Thereby reducing the minimum power delivered to activate the tag, affects signal modulation, bandwidth and the backscattered signal.

#### V. MEASUREMENT OF RFID ANTENNA

##### A. Dielectric Property

Dielectric properties is finding an utilization, as rapid and developing technology is altered to be used in their relevant industries and research laboratories. To find grain moisture content permittivity measurement concept was used and it also depends on dc electrical resistance [23]. In 1991 Nelson observed when temperature decreases there occurs a non linear increase in the resistance of the grain. But, no significant data were described by von Hippel in 1954.

Later on, The capacitance change is measured, so ac measurements were engaged commonly and acceptable illustrative stock capacitors were expanded by Nelson in 1998. Most important application is the measurement of Grain Wetness based on properties of Dielectric data. The electrical equipment design has been related with the Materials's dielectric Properties, where diverse dielectrics are worn for insulating conductors and further units of electric equipment [24-27]. Bulk dielectric properties (dielectric constant, dielectric loss factor) measurement is not close up to itself. Rather, these possessions are an midterm vehicle for certain physio-chemical properties of the trial material.

##### B. Dielectric properties on agri food materials

Food dielectric properties measurements were published advancedly by Dunlap and Makower in 1945 for carrots at frequencies in the range of 18 kHz to 5 MHz. The factors such as wetness content used for dielectric constant and conductivity as affected by Particle size, temperature, frequency and particle size. The dielectric constant was crucially constant at moisture contents up to 6-8% and increased quickly at larger moistures was perceived for calculated conductivities. In 1949, Shaw and Galvin measured dielectric properties of carrot, potato, apple, and peach tissue at frequencies from frequencies 1 to 40 MHz. In 1968 Pace et al observed raw potato's dielectric properties at frequencies from 300 to 3000 MHz dropped leisurely with raising frequency. In 1971, Thompson and Zachariah observed the apple's dielectric properties at frequencies of 300 to 900 MHz and it is vary with dropping, maturity unhurriedly in the operation of aging. Peaches, Pears, Beef steak, and Beef fat values acquired appeared that as frequency increased or as temperature decreased, loss factors decreased [28].

Different types of fishes and meat including herring, pork fat, codfish, raw beef, pork beef and codfish, and measurement were observed in 1974 by Ohlsson et al at the frequency range from 10 to 100 MHz. He establish huge contrast in the dielectric properties of chilled and unchilled samples and extreme dissimilarity between test with fibril aligned at right angles or side by side to the field, i.e., aeolotropic behavior. In 1966, de Looand Meijboom measured the Potato starch's and milkfat's dielectric possessions at little frequency range from 1.2 to 18 GHz. In 2000 to inquire into the effectiveness of capacitive (RF) dielectric heating, Zhao et al used radio frequency (RF) heating to pasteurize surimi seafoods as well as radish seeds and alfalfa. In 1993, Kent et al considered the effect of solid content variation during processing of milk products using a freshly evolved on-line microwave based sensor.

In 1968 Pace et al think about the possibilities for microwave complete drying of potato pieces and establish that energy absorption at 1.0 and 3.0 GHz developed at larger moisture contents and temperature. Measurement of Oils were done above an extended frequency range from 100 Hz to 80 GHz and was setup to have a dispersion region from about 19 MHz to 1 GHz. In 1969, van Dyke et al calculated the ground beef's dielectric property of restored ground beef at 0.915 GHz to learn the properties of wetness, cinders and Plump contents. Less difference in dielectric loss occurs when Moisture content below 20% came. When moisture increases from 20 to 45%, Loss factor of Dielectric raises rapidly and then more decreasing at increasing Wetness, loss factors and clinkers content increases and fat content decreases. In 1994, Nelson mentioned the Methods of calculating the grainy and crushed or dust material's dielectric possessions at the frequency range of microwave and the elements affecting the materials's dielectric properties, such as moisture content, frequency, temperature, and bulk density. For growing predictive sterilization models, Dielectric measurements of foods at rising temperatures and pressures, To reduce the availability of nutrients, the high temperature short time (HTST) processes has been designed. At microwave frequencies Dipole losses occurs in large and mid moisture foods are prioritized at less temperature and at larger temperature ionic losses become highly dominant at larger temperature where penetration depths become rapidly shallow or lower moisture, where penetration depths become increasingly large.

##### C. Methods of calculating dielectric properties

To calculate the dielectric properties of cultivating food materials there are different techniques tried by Sucher and Fox in 1963; and by de Loo and Meijboom in 1966; and by Bengtsson and Risman in 1971; by Thompson and Zachariah in 1971; and by Metaxas and Meredith in 1983). By using different methods, in the region of microwave the dielectric properties of nutriment materials can be identified by making use of variable microwave calculating sensors in Kraszewski at 1980. At submicrowave frequencies, penetration depth and ionic

losses are much larger, and at below 0.1GHz frequency for high, intermediate, and low moisture foods are negligible. Dielectric Properties calculation has been collected significance because it can be used for observing the non-destructive of particular properties of materials which go through solid or synthetic changes[29]. To find the effectiveness of capacitive (RF) dielectric heating, dielectric possessions of food substance can be calculated. Vector Network Analyzer is very expensive and versatile and much useful. Scalar Network Analyzer is little expensive, but nowadays mostly people aimed to buy the less expensive even though versatile occurs. For little Purpose Radio Frequency and Microwave Measurement equipments were used.

#### D. Perturbation Technique

The Dielectric properties of Homogeneous Food substance is calculated, so this technique has been used. It can be also be worn for low dielectric loss materials[30]. By placing the sample in the middle of the waveguide that can be made into cavity, so the centre frequency and width gets changed by using this information dielectric constant can be calculated. For easy measurement and for automatic display changes in width and frequency, the vector network analyser can be used. Several Techniques Dielectric properties are indirectly estimated by using these measured parameters phase and amplitude part of the signal, reflection coefficient, difference in resonant frequency and attenuation and Q-factor etc.

## VI. CONCLUSION

Radio frequency identification is a emerging technology for identifying the objects automatically. In this paper, we presented an antenna design for UHF RFID tags. We discussed various applications of RFID antenna such as meat freshness monitoring application, RFID card, RFID bracelets, in food containers for catering business and methods in measuring dielectric properties on agri food materials. We also presented modeling and simulation results are also which were in good agreement with measurement data. The analysis presented here can also be applied to active tags and passive tags operating at other frequencies.

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