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Design of Compact Coplanar Waveguide Fed Slot Antenna for RFID Applications

T.Shanmuganantham *, Dr.S.Raghavan

Research Scholar, Dept. of Electronics & Communication Engineering,
National Institute of Technology, Trichy- 620 015, Tamil Nadu, India.
Phone: +91 9486640168, Fax: +91 431 2500133, E-Mail:eck0601@nitt.edu

Abstract:- **In this paper analysis and design of compact capacitive fed Coplanar waveguide slot antenna is proposed for RFID applications. Antenna is fabricated using FR4 substrate with dielectric constant of 4.4. The fundamental parameters of the antenna such as bandwidth, return loss, gain, radiation pattern and polarization are obtained. All meets the acceptable antenna standards. Simulation tool, based on the method of moments (ZELAND IE3D version 12.0) has been used to analyze and optimize the antenna and inductive fed Coplanar Waveguide slot antenna also discussed.**

Index Terms:- **Compact size, CPW, Slot antenna, RFID applications.**

I. INTRODUCTION

Radio frequency identification (RFID) systems have been widely used recently in supply chain management by retailers and manufacturers to identify and track goods. Most RFID systems consist of a reader/writer and a tag [8]. The reader transmits RF power to the tag, which then sends a unique coded signal back to the reader, while the writer can change the information contained within the tag. Several frequency bands have been assigned to the RFID applications, such as 125KHz,13.56,869,902-928 MHz,2.45 and 5.8GHz.As the operating frequency for RFID systems rises into the microwave region, the antenna design becomes more acute and essential [9,10]. In addition to the requirements of the impedance and radiation performances, the conformal structure and compact size are the main concerns within the design process. In this paper CPW fed slot antenna with RF performance suitable for RFID tag use at 5.8GHz is presented. The increasing need for security and visibility of goods and assets in manufacturing companies, and distribution and supply chains has lead to the development of automatic identification systems [1]. Auto-ID and data capture procedures allow identification, data collection, and information storage about assets and goods. Auto–ID technology is implemented in several different ways, including barcodes, lasers, voice recognition, and, biometrics [2]. These techniques suffer from limitations like the need for LOS with the interrogator (lasers and barcodes), low data storage capacities (barcodes), and need for human intervention (voice recognition and biometrics). RFID was developed to overcome these limitations. RFID provides an Auto-ID technology that can operate without a LOS, can store large amounts of user data using integrated technology [3]. RFID proves useful when traceability through process or life cycles is required; data errors are high in material identification or handling [9]; and where business systems need more information than automatic identification technologies like bar coding can provide [10-12] .The RFID concept has been around for decades. The recent reductions of size and cost related to integrated circuits have greatly expanded the range of feasible applications [4]. However, unlike integrated circuits, antennas cost and size has not kept track with Moore's law. Today, antenna and sensor technology is a limiting factor [6]. The requirements of reader and tag antennas are not unlike those for much communication systems. They are driven by the applications and the regulations [5]. Inductive fed Coplanar Waveguide slot antenna results are discussed [2] and it is able to cover 5 GHz – 6 GHz spectrum for RFID applications and this structure and result is discussed in section III. In this paper the analysis and design of compact capacitive CPW-Fed slot antenna for RFID applications are briefly presented.

II. ANTENNA DESIGN AND STRUCTURE

The geometry of the proposed capacitive coplanar waveguide (CPW) fed slot antenna is shown in figure 1 and figure 2 .This antenna has a simple structure with only one layer of dielectric substrate (FR4 Epoxy substrate) and metallization. The feeding CPW, of which the central strip is extended into the slot area to get a better impedance matching condition. For the slot antenna, the resonant conditions arise from the circumference of the slot, which is proportional to the guided wavelength [6]. The input return loss level and the resonant frequency of the proposed design will vary with total length L and width W of the substrate.

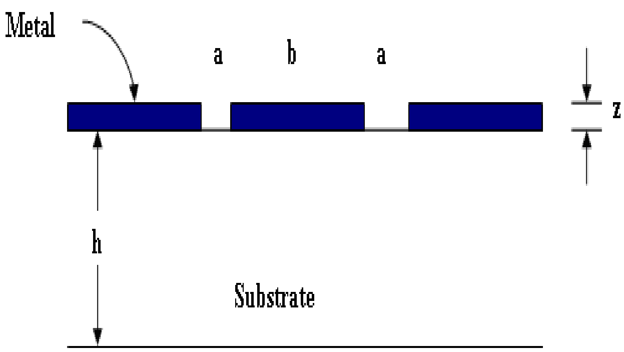

Fig. 1 CPW-Fed Slot Antenna Front View

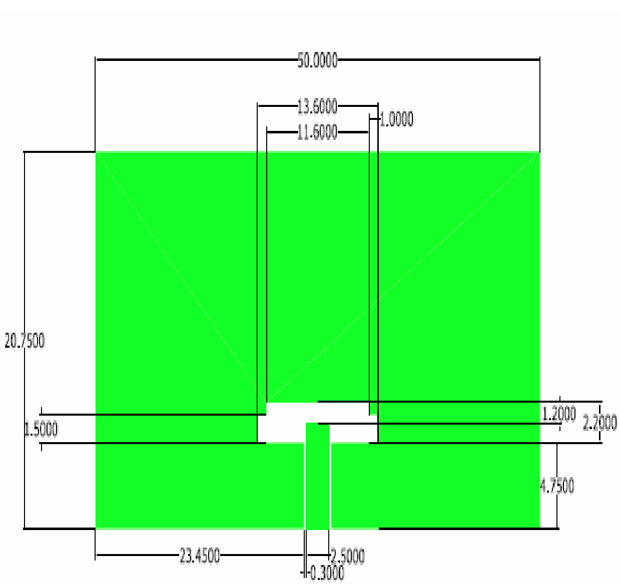

Fig. 2 Proposed CPW-Fed Slot Antenna Top View (Capacitive Fed Antenna)

Substrate details:
Dielectric Constant ε_r = 4.4,
Loss tangent Tan δ = 0.02, h=3.2mm

Antenna dimensions:

a=0.3, b=2.5, z=0.03mm
Where,
All dimensions are in mm
Shaded area denotes metal
Remaining area denotes slot

Inductive fed Coplanar Waveguide slot antenna structure is shown in figure 3.

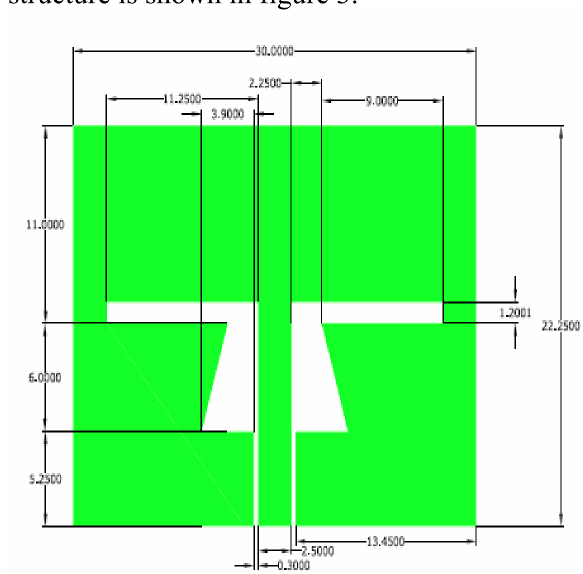

Fig. 3 Inductive Fed CPW slot Antenna (From Reference [2])

First, the dimensions of the antenna by simulation with the aid of IE3D electromagnetic software were studied and then adjusted them by experiment. The dimension of the slot antenna is referred to the guide wavelength (λ_g) which is given in equation (1),

$$\lambda_g = \frac{c/f}{\sqrt{\varepsilon_{eff}}} \qquad (1)$$

Where, ε_{eff} is an effective constant $\varepsilon_{eff} \approx (\varepsilon_r + 1)/2$

In this case $\varepsilon_{eff} \approx (4.4+1)/2 \approx 2.7$

λ_g = 31.47 mm (for f = 5.8 GHz)

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Total length of the slot structure is approximately (33.66 mm) 1 λ_g of the slot line at resonance. Free space wavelength of this antenna at resonance is equal to 51.72 mm. The length and width of the antenna were initially chosen to be 50 mm (approximately one λ). But to make the accepted antenna parameters, the width of the antenna dimension is reduced to 20.75 mm. The width of the center strip and slot of the 50 ohm CPW feed line are chosen to be 2.5 mm and 0.3 mm respectively.

A photograph of this prototype antenna is shown in figure 4. FR4 substrate mounted SMA connector with 50 ohm is used in fabrication.

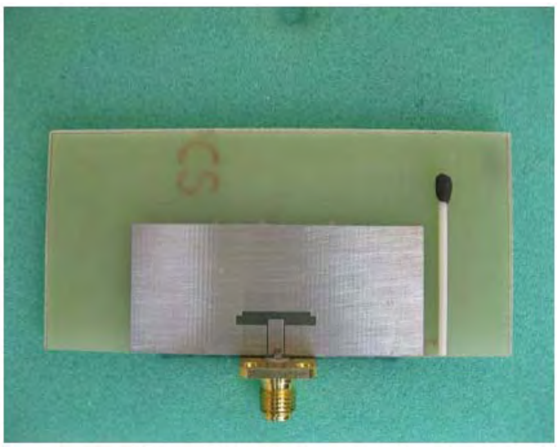

Fig.4 Photograph of the proposed CPW-Fed Slot Antenna

III. RESULTS AND DISCUSSION

Throughout the design process, simulations were carried out on package software IE3D from Zeland Corporation which is based on Method of Moment [7]. The first concept to understand regarding antennas is that they are passive devices. To operate, they require no supply voltage. They do not alter nor process RF signals and they do not amplify RF energy. If they are 100% efficient, they radiate no more power than is delivered to their input terminal [8]. The basic properties that are used to describe the performance of an antenna include impedance and VSWR (Voltage Standing Wave Ratio), amplitude radiation patterns, 3 dB beamwidth, directivity, gain, polarization and bandwidth. Here the following parameters of the proposed antenna are discussed. In order to achieve maximum energy transfer between a wire or coaxial transmission line and an antenna, the input impedance of the antenna must identically match the characteristic impedance of the transmission line. If the two impedances do not match, a reflected wave will be generated at the antenna terminal and travel back towards the energy source. This reflection of energy results in a reduction in the overall system efficiency. This loss in efficiency will occur if the antenna is used to transmit or receive energy.

The resultant voltage wave on the transmission line is the combination of both the incident (source) and reflected waves. The ratio between the maximum voltage and the minimum voltage along the transmission line is defined as the Voltage Standing Wave Ratio or VSWR. The VSWR, which can be derived from the level of reflected and incident waves, is also an indication of how closely or efficiently an antenna's terminal input impedance is matched to the characteristic impedance of the transmission line. An increase in VSWR indicates an increase in the mismatch between the antenna and the transmission line. Typically, most wireless communications systems operate with a 50 Ohm impedance and therefore, the antenna must be designed with an impedance as close to 50 Ohms as possible. The antenna VSWR is then an indication of how close the antenna impedance is to 50 Ohms. The Return Loss (RL) is a parameter which indicates the amount of power that is "lost" to the load and does not return as a reflection. The RL is given as by $RL=-20\log_{10}^{|\Gamma|}$ (dB). The relationship between VSWR and reflection coefficient (Γ) is given by VSWR= |Γ |Γ+|1-|1.For practical applications, a VSWR of 2 is acceptable, since this corresponds to a RL of -9.54 dB.

The return loss (S_{11}) in dB (-24.04 decibel at 5.8 GHz) Vs Frequency measurement is shown in fig. 5. This is achieved by properly calculating the fundamental parameters of CPW and the spacing between the centre and inner slot structure. The simulated bandwidth is 460MHz (5.62GHz to 6.08 GHz with 2: 1 VSWR). This is meet the standard values of VSWR and return losses. Inductive fed Coplanar Waveguide slot antenna measured and simulated return loss is shown in figure 6. Other parameters like radiation pattern, gain and polarizations are given in the reference [2] for inductive fed Coplanar Waveguide slot antenna.

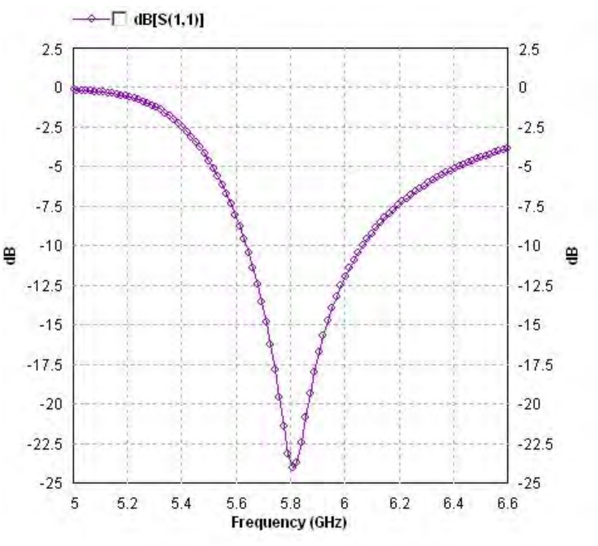

Fig.5 Proposed Antenna Return loss measurement

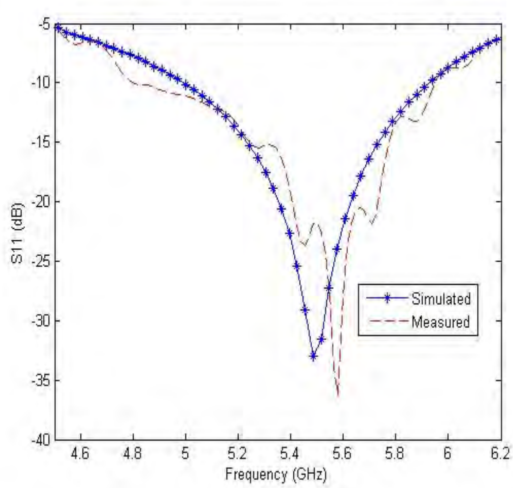

Fig.6. Return loss Vs Frequency (Inductive CPW-Fed slot Antenna)

Antenna gain is a measure of directivity properties and the efficiency of the antenna. It is defined as the ratio of the radiation intensity in the peak intensity direction to the intensity that would be obtained if the power accepted by the antenna were radiated isotropically. Antenna gain is measured in dBi, i.e. decibels relative to isotropic antenna. Directivity is a measure of how strongly the antenna favors the particular direction of its maximum transmission (reception) sensitivity comparing to other directions. More specifically, it is defined as the ratio of the radiation intensity in the peak intensity direction to the averaged radiation intensity in all other directions. Antenna Efficiency is defined as the ratio between the radiated power to the power put into antenna (incident power). Ideal perfectly matched lossless antenna has efficiency of 1 (or 100%).Radiation Efficiency is defined as the ratio between the radiated powers to the input power. Maximum gain at each frequency is graphically shown in figure 7. The radiation pattern measurements of E-plane is shown in figure 8 and H-plane measurement is shown in figure 9.

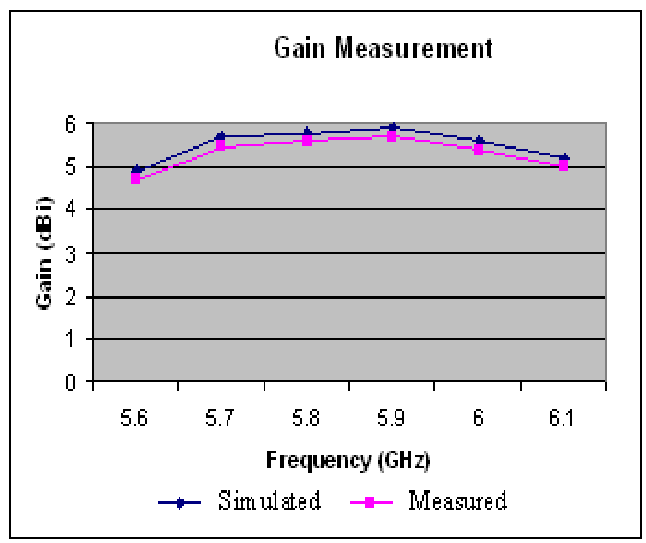

Fig. 7 Comparison of Gain measurement of the proposed antenna

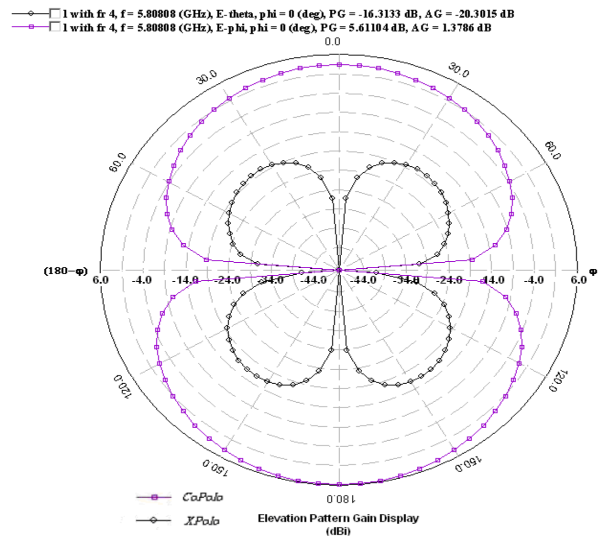

Fig.8 Radiation Pattern Measurement of E-plane

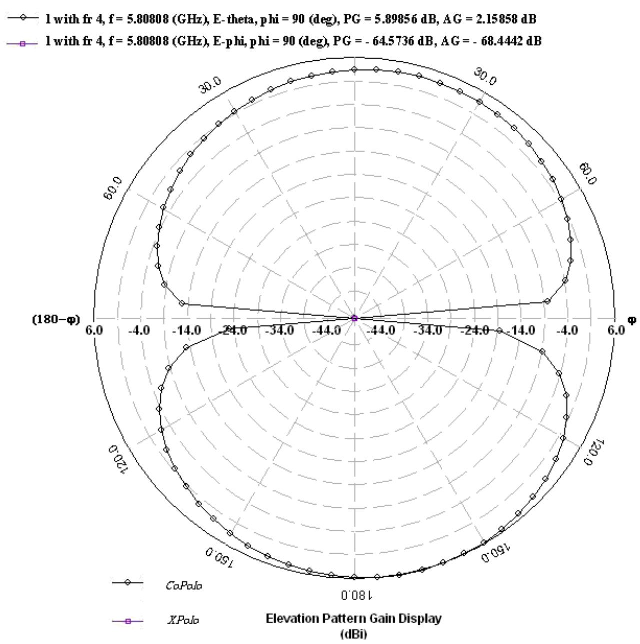

Fig.9 Radiation Pattern Measurement of H-plane

IV. CONCLUSION

Inductive fed wideband antenna is able to cover the 5 to 6 GHz spectrum along with the RFID applications. When an antenna is suitable to provide multipurpose applications, it is suggested to use the inductive fed antenna for practical applications. If the purpose is to cover only the 5.8 GHz RFID band then capacitive fed RFID antenna is the better choice. The antennas are designed and fabricated with standard materials available in market. Since the antennas are fabricated with atmost care, the simulated results will result in good agreement with the measured results. The antennas show no significant variations in radiation pattern characteristics over the bandwidth of operation. The designed antennas are well suited for RFID applications. Moreover, the simple and uniplanar structure makes it ease of design and mass production.

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REFERENCES

[1] K.L. Wong, *Compact and Broadband Microstrip Antennas*. New York, NY: John Wiley and Sons Inc., 2002.

[2] K.Manikandan, S.Raghavan and T.Shanmuganantham, "CPW Fed Tapered Slot Antenna for 5 GHz Band Applications" ,International Journal of Microwave and Optical Technology , U.S.A., Vol. no. 3, No.1, pp.22 – 26,Jan'2008.

[3] T.Shanmuganantham, K. Balamanikandan, and S. Raghavan, "CPW-Fed Slot Antenna for Wideband Applications," International Journal of Antennas and Propagation, Vol. 2008, pp.1 - 4, Hindawi Publication, U.S.A., 2008.

[4] K. L. Wong and W. H. Hsu, "Broadband triangular Microstrip antenna with U-shaped slot," *Electron. Lett.,* vol. 33, pp. 2085-2087, 1997.

[5] K. F. Tong, K. M. Luk, K. F. Lee, and R. Q. Lee, "A broad-band U-slot rectangular patch antenna on a microwave substrate," *IEEE Trans. On Ant. Prop.*, vol. AP-48, no. 6, pp. 954-960, June 2000.

[6] Rainee N. Simons, *Coplanar Waveguide Circuits, Components, and Systems*. New York, NY: John Wiley & Sons, Inc., pp. 1-6, pp. 422-424, 2001.

[7] Strassner, B., and Chang, K.: 'Integrated antenna system for wireless RFID tag in monitoring oil drill pipe'. IEEE Antennas and Propagation Society Int. Symp., Columbus, OH, USA, 2003, Vol. 1, pp. 208–211

[8] Foster, P., and Burberry, R.: 'Antenna problems in RFID systems'. IEE Colloquium on RFID Technology, London, UK, 1999, pp. 31–35.

[9] Marrocco, G.: 'Gain-optimized self-resonant meander line antennas for RFID applications', IEEE Antennas Wirel. Propag. Lett., 2003, 2, (21), pp. 302–305

[10] Yu-De Lin and Syh-Nan Tsai, "Coplanar waveguide-fed uniplanar bowtie antenna," *IEEE Trans. On Ant. Prop.*, vol. AP-45, no. 2, pp. 305-306, Feb. 2000.

[11] A. A. Eldek, A. Z. Elsherbeni, C. E. Smith and K-F Lee, "Wideband slot antennas for radar applications," *Proc. IEEE Radar Conf.*, Huntsville, AL, pp. 79-84, May 2003.

[12] A. A. Eldek, A. Z. Elsherbeni and C. E. Smith, "Wideband bow-tie slot antennas for radar applications," *2003 IEEE Topical Conference on Wireless Communication Technology,* Honolulu, Hi, October 2003.

BIOGRAPHY

Mr.T.Shanmuganantham received B.E. degree in Electronics and Communication Engineering from University of Madras, M.E. degree in Communication Systems from Madurai Kamaraj University and pursuing Ph.D. degree in the area of Microwave Integrated Circuits under the guidance of **Dr.S.Raghavan** from Department of Electronics and Communication Engineering, National Institute of Technology, Tiruchirappalli, India. He has 10 years of teaching experience in various reputed Engineering Colleges in Tamil Nadu, India. His research interest includes Microwave Integrated Circuits, Computational Electromagnetics, Numerical Techniques of Microwave and Millimeter wave transmission lines, CAD of MICs and Antennas. He has published 20 research papers in various Conferences and Journals. He is a member in IEEE, Life Member in IETE , ISTE and IE.

Dr.S.Raghavan having 26 years of Teaching (U.G., P.G. and Research) experience in the National Institute of technology, Tiruchirappalli, India as a Senior Professor. Developed Microwave and Microwave Integrated Circuits Lab. Obtained B.E.(Electronics and Communication Engineering) degree from College of Engineering , Guindy. M.Sc.(ENGG.)Microwave Engineering from College of Engineering, Trivandrum and Ph.D.(Microwave Integrated Circuits) from I.I.T., Delhi, India under the guidance of **Prof.Baharathi Bhat** and **Prof.S.K.Koul**. Senior Member of IEEE in MTT and EMBS. Life Fellow in BES. Fellow in IETE and IE, Life member in ISSS, MRSI, ISTE, EMC/EMI, IELTS and ILA. Referee for MTT journal. Carried out two Research and Development projects of Coplanar Waveguide and RF-MEMS. Has contributed more than fifty papers in international conference and twenty international journals. Conducted two tutorials in IEEE preconference tutorials.