Design of Compact Printed RFID Reader Dipole Array Antenna for 5G –IoT Applications

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Abstract - *The article presents a compact Radio Frequency Identification (RFID) reader antenna for 5G- Internet of Things applications. The proposed antenna consists of array of four double sided printed dipoles (DSPD) to be operated at 60GHz unlicensed band. The designed array fed by integrated 1:4 power divider significantly meets the specifications required for RFID application at millimeter wave range to be used in upcoming 5G communication systems. Taconic TLX-8 substrate has been used to satisfy the dielectric properties at millimeter wave frequency. The proposed RFID antenna is designed and simulated using full wave EM solver Computer Simulation Technology (CST) Microwave studio. After the parametric study and analysis, comparison of the designed printed array for RFID reader has been done with that of existing literature and found better in terms of gain and bandwidth with reduction in size of antenna.*

***Key Words*: RFID, Printed dipole Array, Double sided printed dipole, Millimeter wave, 5G communication.**

1. INTRODUCTION

The omnipresent paradigm of traditional Internet enhances into a smart Internet of Things (IoT), created around intelligent interconnections of various objects in the physical world, such as vehicles, cell phones, habitats, and habitat occupants [1]. 5G technology, the next generation mobile communication technology, is expected to be a backbone to connect the billions of devices for future IOT and will be implemented beyond 2020 [2]. IoT consists of low-cost information gathering and dissemination devices, such as sensors and RFID tags that facilitate quick communication among the objects themselves as well as the objects and persons in any place and at any time. To make IoT a reality, significant research needs to be conducted within and across these technological aspects of IoT. The demand of compact antennas has been increasing for connecting all the electronic systems, including smallest possible devices, into an IoT. Most of the RFID applications work with a bandwidth of around 180 to 300 MHz for different bands such as Low Frequency (LF) band of 120-150KHz, High Frequency (HF) band for 13.56 MHz, Ultra High Frequency (UHF) for 860 MHz to 960MHz and Microwave (MW) band for 2.45 GHz or 5.8 GHz [3]. Below 6 GHz, the 5G systems will interwork and co-exist with 4G systems [4]. The microwave bands are popular than other RFID bands in many areas because of its high readable range, fast reading speed, large information storage capability [5]. Many attempts have been made in recent times to reduce the antenna size. Chip less RFID systems became new interest of research in 2009 and are among those applications that have envisaged to expand their operation in the millimeter-wave range for high data encoding capacity chipless RFID systems [6]. Zomorrodi and Karmakar [7], [8] have proposed a 60-GHz electromagnetic (EM) image-based chipless RFID system

Owing to variety of beneficial properties printed antenna including light weight, low profile, low cost with wider bandwidth, lower loss, and less parasitic radiation of the feed lines [9-14] and better performance of DSPD as compared to single sided printed dipole [15], [16] ,in this paper a compact printed RFID reader array antenna for 5G-IoT application is presented which operates at millimeter wave range frequency i.e. 60 GHz. DSPD is considered as array element in this research. After parametric optimization of the designed antenna, various simulated results have been discussed.

2. ANTENNA DESIGN

The RFID reader antennas operated at millimeter wave frequency are required to meet the following specifications.

- The antenna must operate on a frequency band that is between 57 and 64 GHz.
- The antenna must have a high axial ratio (>20 dB) in the bore sight direction.
- The antenna must have a fan-shaped radiation on azimuth (>150°) and limited elevation Beam width (< 15°).
- The antenna must be lightweight and have a small structure for handheld applications of the reader.

Four elements printed dipole array is sufficient to meet the above said specifications for RFID reader antenna [17]. The geometry of the designed 4-element printed dipole array is shown in fig.1.To excite the array elements a power divider is used the geometry of which is shown in fig. 2.

The design parameters of the DSPD element are shown in fig.1. The length *Lp* of the dipole arm is a function of the thickness and dielectric constant of the substrate. The initial value of the dipole length comes from the following:

Dipole length (Lp) = 0.47v/f

Where $v = \frac{c}{\sqrt{\varepsilon_{reff}}}$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \left(\frac{\varepsilon_r - 1}{2}\right)\left[\sqrt{1 + \frac{12h}{w}} + 0.04\left(\frac{1 - Wp}{h}\right)^2\right]$$

This initial length is entered in full-wave EM solver CST Microwave Studio, and the design is optimized to meet the specification requirement. The simulated dipole arm length is 0.98 mm.

After parametric study of the antenna designed for 60 GHz resonating frequency the dimensions of the printed antenna are obtained and are detailed in table I. The geometry of complete structure of the array is shown in fig.3

Table I Dimensions of Single Element of Printed Antenna

Total Size	L	2mm
	W	4mm
PCB Substrate	Thickness	0.127 mm
	ε_r	2.55
	tan δ	0.0018 mm
Dipole Arm and Ground Plane	Lp	0.98mm
	Wp	0.19mm
	L1	1.008mm
	L2	0.9 mm
	Wf	0.385mm

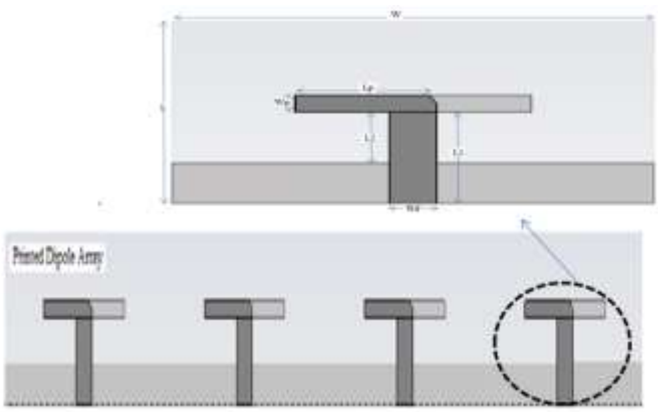

Fig.1. Geometry of 4-element Printed array.

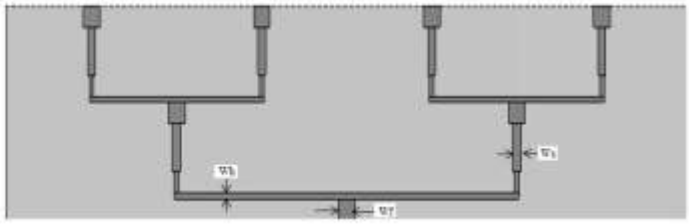

Fig.2 Geometry of Power divider with Wf=0.385mm, Wh=0.1mm and Ws=0.205mm.

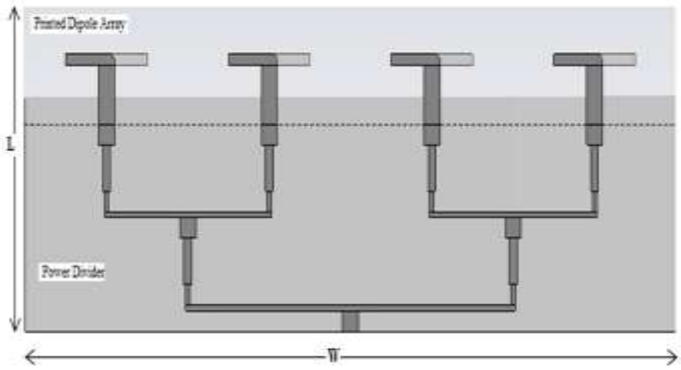

Fig.3 Geometry of complete structure of the array

3. RESULTS AND DISCUSSION

The s-parameter curve of the designed antenna is shown in fig.4 which shows that the designed antenna is resonating at 59.5 GHz. the return loss is -20.1 dB. Fig 4 also shows that the bandwidth achieved is 9.7527GHz which is approximately 12%. The bandwidth enhancement is due to the reduced ground plane of the proposed design of the printed dipole array. Fig.5 shows the radiation pattern of the designed array in E-plane; it is clear from the Fig. that the designed antenna is having gain of 8.07dBi in E-plane. The elevation beam width achieved is 14.9^0 which satisfy the elevation beam width requirement for RFID reader antenna application.

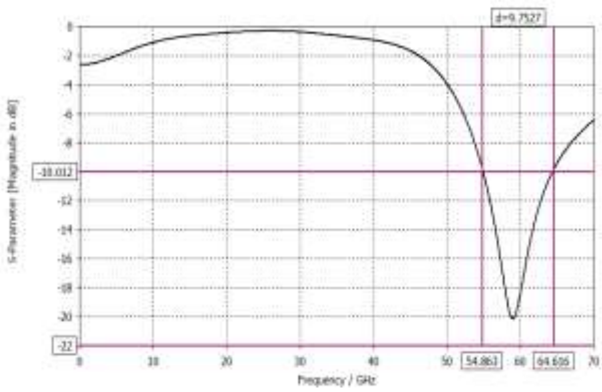

Fig. 4 S-parameter of printed dipole Antenna Array

Also the azimuth radiation pattern in H-plane of the designed antenna is shown in Fig. 6 which shows that the gain of the designed antenna in h-plane is 10.9dBi with the azimuthal beam width of 175^0 which also fulfills basic requirement of the RFID reader antenna.

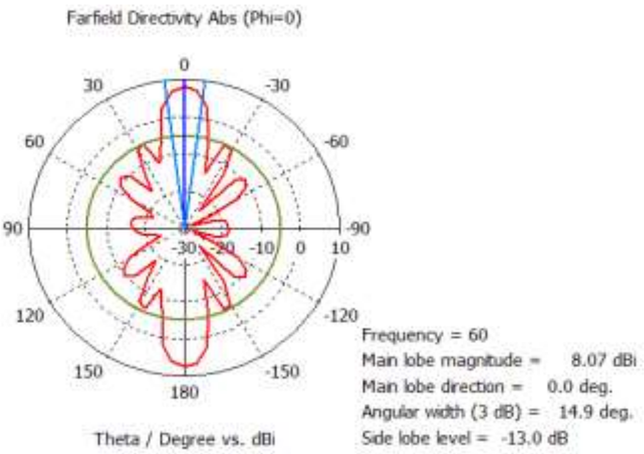

Fig. 5 E-plane Radiation Pattern of Printed dipole Array

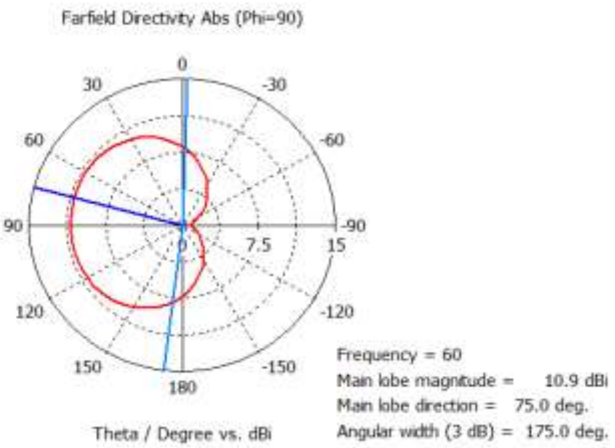

Fig. 6 H-plane Radiation Pattern of Printed dipole Array

The comparison of the designed printed array for RFID reader done with that of existing in literature [17] is shown in table II.

Table II Comparison of the Designed RFID antenna with Existing RFID antenna

Antenna Design At 60 GHz	Dimension (mm)	SLL (dB)	HPBW (⁰)	Gain (dBi)	Band width (GHz)
Ref[17]	22x14	----	E-plane-15 H-plane-150	5.5 -7	7
This Work	16x5.5	-20.1	E-plane-14.9 H-plane-175	E-plane-8.07 H-plane -10.9	9.7527

CONCLUSION

A printed antenna is designed at millimeter wave frequency. After the successful simulation analysis of single DSPD an array antenna of 4- DSPD elements is designed and thoroughly investigated at 60 GHz for RFID reader antenna to be operated for 5G-IoT application. The antenna was design using Taconic TLX-8. The compact and simple structure of the array also makes it suitable for many applications in the mm-wave region for low-range wireless communication systems.

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