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Design and Analysis of High Beam forming MIMO Antenna for 5G Applications

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Abstract—in upcoming days wireless communication products and electronic gadgets are becoming a necessity to human life. Communication systems need antennas that work with multiband and wide band with required parameters like polarization and gain. The main motto of this work is to produce high beam forming with the aid of mutual coupling among the four antenna elements in order to encourage enhanced transit capacity and empower the communication bandwidths at very large data rates for 5G Technology. In the view of mitigating the multipath fading with above mentioned principles. The designed antenna is developed a MIMO patch antenna with wide characteristics. It operates the frequency band from 2.2 GHz to 4.8 GHz. The antenna is developed with FR4 material with a dielectric consistent of 4.4, loss tangent of 0.02 and a density of 1.6mm. The recommended design has 4 monopole antennas. Each monopole antenna has a circular patch with radius of 5mm to avoiding interference. The simulation results s- parameter, VSWR, TARC, ECC, CCL and diversity gain are obtained and verified with the aid of Ansys HFSS and CST studio.

Keywords—Beam forming, MIMO, Mutual Coupling, 5G applications.

I. Introduction

In the 21st century, most of the electronic gadgets operation covers vast sector to the cellular mobile phones. In the daily life a common man wherever they go on an average carries one or more than one antennas with them (For instance: In cell phones GPS system is linked with multiple antennas). This indicates as wireless communication systems become an important part of everyday life. In extension, to the RFID devices advise that the number of antennas used may extend to one antenna per object in the world. The structure of a four element and three lumped components, high-separated dual-element MIMO antenna is to reduce the mutual coupling drastically [1]. It is analyzed with the coverage frequency band limit from 3.4GHz to 3.6GHz, in the C-band. An 8-elements hybrid array antenna is composed with two- antenna arrays, these two are operating at GSM and LTE [2] bands to achieve the better envelope correlation coefficient value. The monopole parasitic inverted-L striped [3] MIMO antenna abide of four elements arranged perpendicular to one another to attain the good impedance matching and diversity capability of polarization. The coupling among the antenna arrays can be reduced to increase the performance of the MIMO structure as well as the discriminating the desirable cross polarization [4]. When compared with the uncorrelated antennas the MIMO antenna systems are produced a good ergodic [5] channel capacity, efficacy and good radiation pattern to support the 5G Communication. The size of the antenna should be relatively small to maintain high-isolation in the design of dual band [6] MIMO array antenna. By selecting suitable coupling slot and 90^{o} phase difference with equal amplitudes in the antenna array, we can easily obtain the circular polarization and beam forming [7-8]. Similarly the dual conformal strip [9-10] method is also maintaining circular polarization and cost effective with ease of excitation. To meet the broadband service the bandwidth characteristics [11] and omnidirectional pattern must be improving in the monopole antenna. Wide coverage of elevation and azimuth angles must be maintain [12-15] to achieve a good beamforming mechanism. This principle is more suitable for 5G mobile communications. A compact sized doughnut slot MIMO configured antenna will enhance the gain as well as lower ECC (Envelope correlation coefficient) at all frequencies [16-17]. In order to minimize the mutual coupling and boost the separation among the ports, U- slots and the dual polarized radiators plays a pivotal part in the performance of the system [18-19]. The proposed MIMO antenna supports and plays a crucial role in the mobile communications to overcome the overall shortage bandwidth in the wireless cellular networks and the 5G intelligence system. This paper is arranged in the consecutive manner. The sector 2 explains the antenna geometry and the design evolution. The section 3 discusses the result analysis obtained from the simulation. Section 4 concludes the paper with the improvements, applications of the advised skeleton. The suggested MIMO antenna is shown in the figure 1(a) & (b).

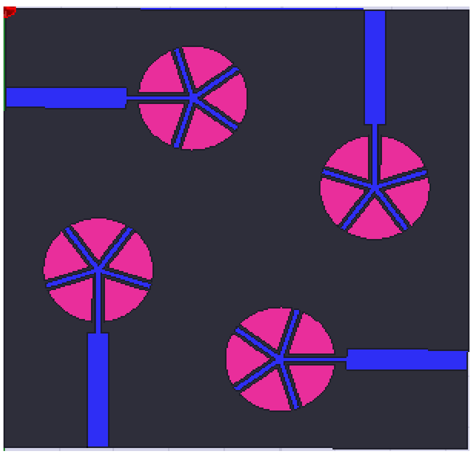

Fig.1. (a) 4- Elements of Proposed MIMO Antenna

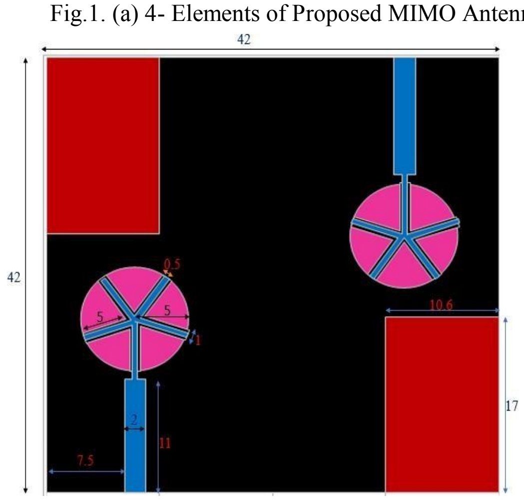

Fig.1. (b). Designed view of the suggested Antenna

II. FOUR ELEMENTS OF MIMO ANTENNA DESIGN STRUCTURE

In this part clearly stated that the design calculation of recommended antenna is given and also the step wise design evolution is presented. The proposed antenna is designed on an FR4 substrate which has ε_r=4.4 and loss tangent of 0.02. The recommended antenna each and every parameter is calculated as per the required formulas and patch dimensions (width and length) are obtained from the basic formula mentioned in the below equations. The substrate which is has dimensions of length and width is equal (42x 42) mm and has thickness of 1.6mm.

Width of the strip calculation done based on eq-1

$$W = \frac{c}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

Where C= velocity of the light (3x10^{8}m/s)

f_r = Resonating Frequency

ε_r =Dielectric constant (4.4)

The patch length is derived from the following equation

$$L = L_{eff} - 2\Delta L \quad (2)$$

Where $$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{reff}}} \quad (3)$$

The tapered ground of each monopole antenna has no slots and has the dimensions 10.6x17 mm^2. This type of ground plane will enhance the bandwidth of the structure. The circular patch is has a radius, r=5mm and width of the strip lines in the circular patch is 1 & 0.5mm. The space from the input feed line to the substrate is 7.5mm.

In this situation, if the antennas are arranged parallely side by side at that time the mutual coupling is not satisfactory. So, by providing an orthogonal phase quadrature fed to four accesses to get purity of the circular polarization and the symmetry of radiation pattern. It gives a good axial ratio in the antenna. Therefore, this type of structure is more suitable for 5G communications. For this antenna, the emission element consists of a simple strip line. This slot aperture is stimulated by a line tag along with the axes, which is united to the 50 Ω strip line with fw = 2 mm.

III. EXPERIMENTAL ANALYSIS OF THE MIMO ANTENNA

This section mainly intent to discuss the simulation waveforms and its analysis. These are obtained with the aid of different simulation tools, such as: ANSYS HFSS and Microwave CST studio. Here we explained each and every parameter in detailed, those are S-parameter, VSWR, radiation pattern, 3-D polar plot, envelope correlation coefficient (ECC), TARC, channel capacity loss and diversity gain.

A. S-Parameter

The return loss state that the ratio of the approaching signal to the reproduced signal as it enters a component. Sometimes the return may also define as change between stimulated signal

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power and the re bounced signal power due to the deviation in the link and channel mismatch. The return loss waveform specifies over a range of frequencies how well the link and channel impedance matches. In general, higher return loss value will give larger variation between the power of the radiated and echo signal. The suggested MIMO antenna has a return loss of -34.49 at 3.48GHz. The return losses are measured at four ports those are represented in the figures 2(a) & 2(b).

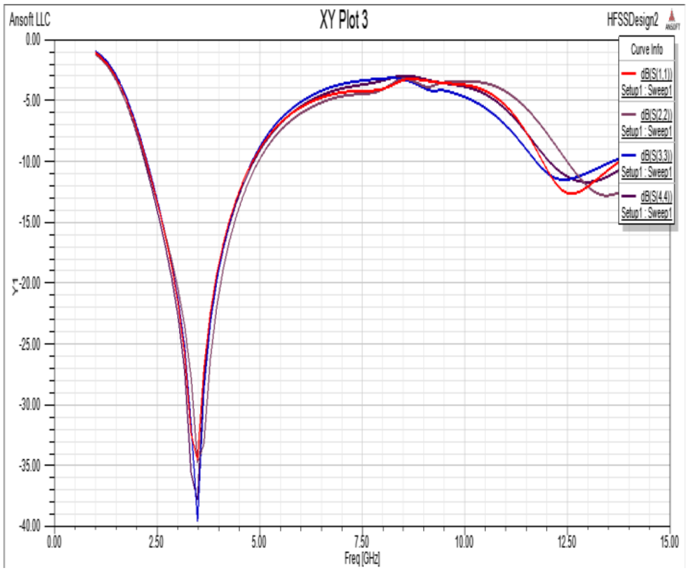

Fig.2. (a) .Four port S-Parameter (S_{11} S22 S_{33} S_{44})

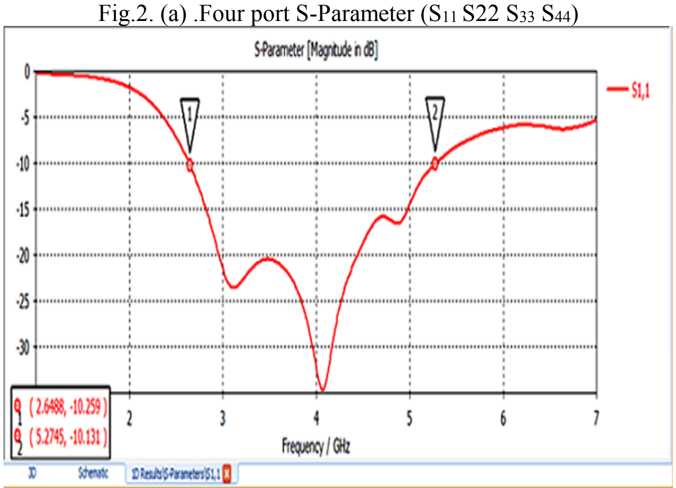

Fig.2. (b) S_{11} Parameter obtained in CST MWS

B. VSWR

VSWR calculates the how much of power is effectively radiated from the origin to load, through transmission medium. To maintain good VSWR, the system requires an identical match among the source, load, all its connectors and the chacteristics impedances of the transmission medium. Reflections are occurs along the line due to the interference, dominant peaks and valleys in the voltage at different time instants. It is calculate the voltage variation in the transmission line. It is defined as the ratio of maximum peak voltage to minimum peak voltage. Whenever the VSWR value should be low, then the antenna must be matched to transmission line and its delivers major power. In this proposed article the VSWR is 1.2 at 3.5GHz. The pictorial graph is presented in the figure 3.

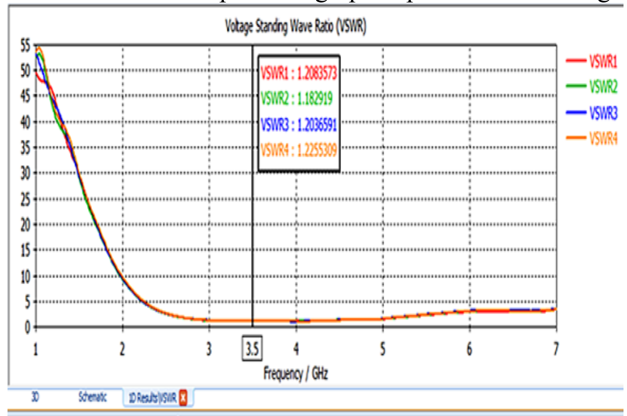

Fig.3. VSWR Characteristics

C. Gain & Radiation Pattern Characteristics

Power gain is the pivotal factor in the antenna theory. Which combines the directivity of the antenna and electrical efficiency? The gain decides how much of power is delivered in the required direction. Similarly the received antennas express how the antenna transforms the radio waves in to electrical power. The deviated power emitted by the proposed antenna is measured at different planes. The E-plane exists at 0deg and H-plane occurred at 90deg with a good results. The radiation characteristics for the given frequency is shown in the Fig.4 at 3.5 GHz for both Phi=0deg and 90 deg. Similarly the gain plot is presented in the figure 5.

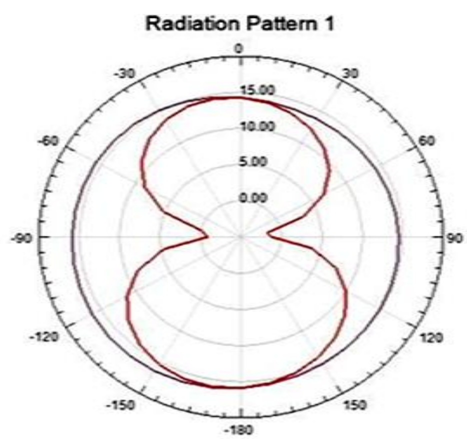

Fig.4. 2-D Radiation pattern characteristic for both Phi= 0 and 90 deg at 3.5 GHz

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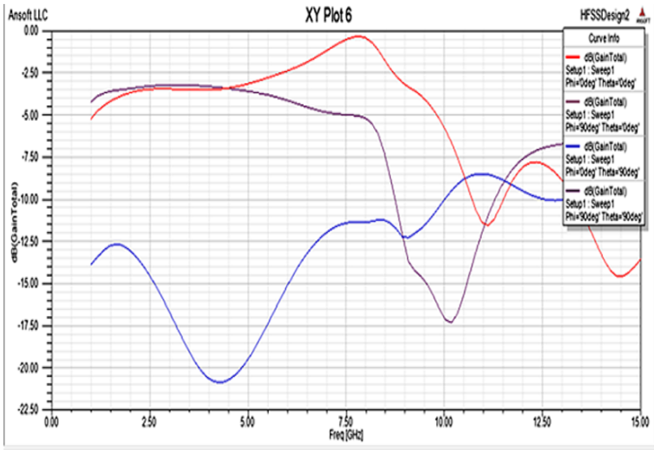

Fig.5. Gain Characteristics Plot

D. *Total Active Reflection Coefficient (TARC)*

The total active reflection coefficient (TARC) is defined as the proportional to square root of the total reflected power is split by the square root of the incident power. Based on the below equation we can find out the TARC. The Frequency versus TARC waveform is presented in the figure 6.

$$TARC = \sqrt{\left|S_{11} + S_{12}e^{j\theta}\right|^2 + \left|S_{21} + S_{22}e^{j\theta}\right|^2} \Big/ \sqrt{2}$$

Where θ is varied from 0 to 2π

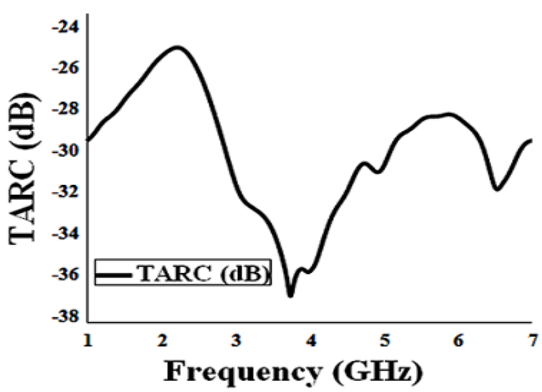

Fig.6. TARC versus frequency plot of MIMO antenna

E. *Envelope Correlation Coefficient (ECC)*

The ECC is used to assess the diversity of the MIMO system. For greater isolation and broad diversity gain, we need lower ECC value. In general, for mobile applications the envelope correlation coefficient value should be lesser than 0.5, those systems have excellent diversity. The suggested MIMO antenna is has '0' ECC at 3.5GHz. Therefore, this system is more suitable for 5G communications. The simulated waveforms of the ECC and diversity are shown in the below figure 7 (a) and (b).

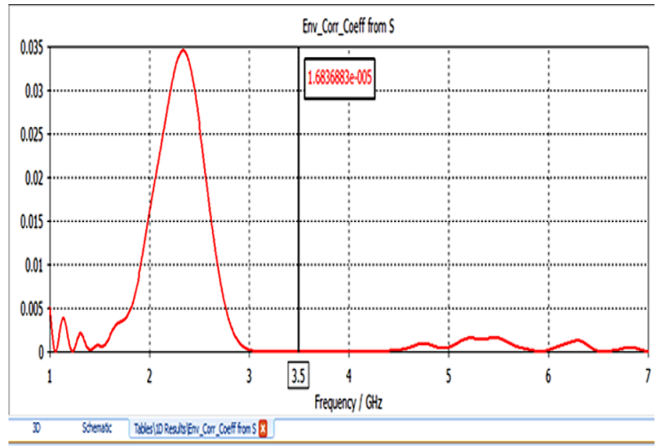

Fig.7 (a). Simulated waveform of ECC at port 1 and port 2

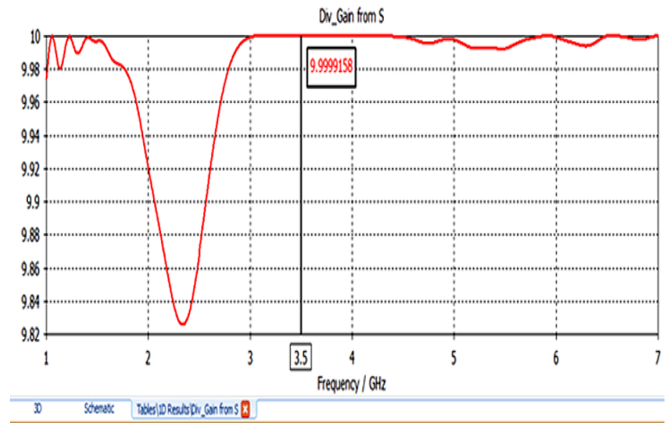

Fig.7 (b). Diversity gain plot at port 1 and port 2

F. *Channel Capacity Loss (CCL)*

The channel capacity loss is retrieve in the presence of higher signals to noise ratio. At transmit end the data is scattered among the channels and united after the reception, in such cases the total channel capacity is boost. The simulated graphs of the CCL and the mutual coupling among the antennas are presented in the below figures 8, 9(a) & (b). This shows very satisfactory results for MIMO antenna system. The surface current distribution at 3.5GHz for monopole antenna and 3-D polar plots are shown in the figure10 & 11 respectively. In the table 1 presented the performance evaluation of the proposed work with existed works.

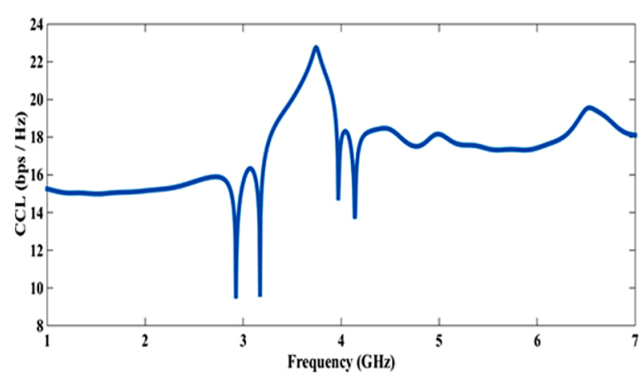

Fig.8 CCL versus frequency plot of MIMO design

Referen	No.of	Opera	ECC at	Subst

ces	antenna elements	ted freque ncy GHz	3.5GHz	rate
[1]	4	3.4~3. 6	-	FR4
[2]	8	3.4~3. 6	0<ECC <0.35	FR4
[3]	4	3.4~3. 6	0<ECC <0.05	FR4
[4]	8	3.4~3. 6	0	FR4
[5]	10	3.4~3. 6	0<ECC <0.2	FR4
[6]	4	3.4~3. 6	0	FR4
Propose d Antenna	4	2.2~4. 8	0	FR4

Tab. 1.Compariion with Existed 5G MIMO antennas

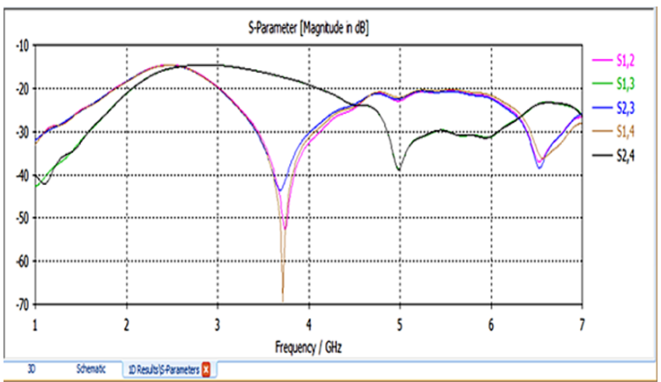

Fig.9 (a) Mutual coupling curve obtained in CST MWS

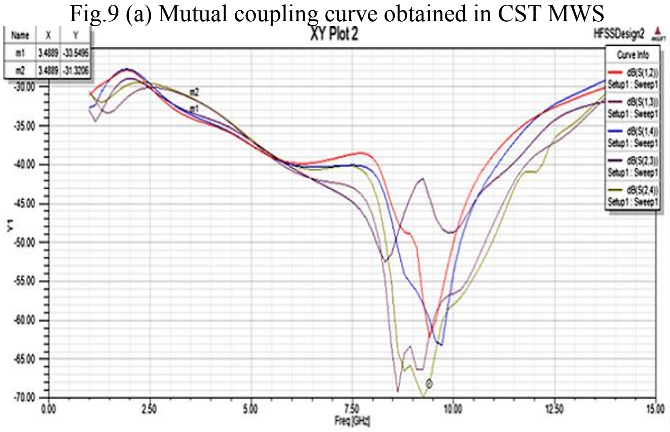

Fig.9 (b) Mutual coupling curve obtained in HFSS

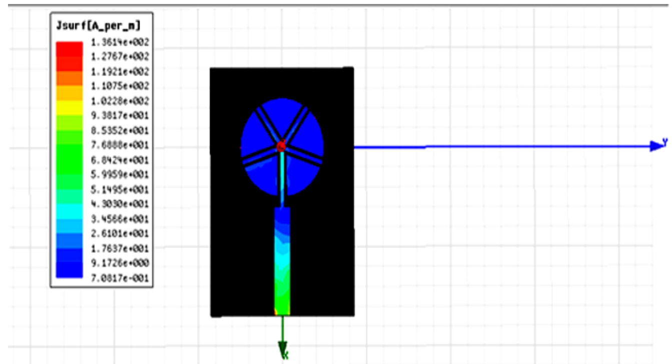

Fig.10. Current flow in monopole antenna

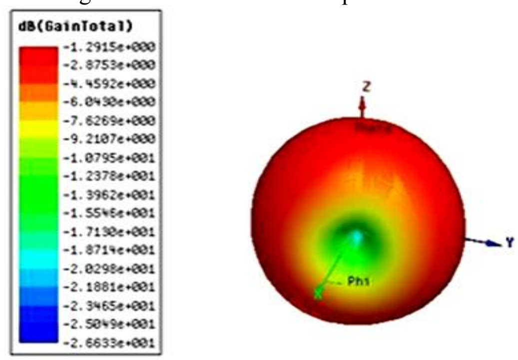

Fig.11. 3-D Polar plot

IV. Conclusion

The stated work is successfully reported and composed a four–port novel MIMO patch antenna for future 5G applications, which is designed with very smaller dimensions. The designed system shows satisfactory results and provides high gain and beam forming characteristics. The bandwidth of designed antenna is around 2.5GHz which is very large when correlated to those of already existed MIMO-5G antennas. The ECC is 0 and diversity gain is 9.99. The VSWR of all four ports is about 1.2. As the design is with very smaller dimensions and provides promised results. We hope this antenna design can be among the first standing members for a good reliable MIMO-5G antenna system designs. Therefore, the designed antenna is more suitable for forthcoming 5G mobile applications.

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Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

Author Contributions: Please, indicate the role and the contribution of each author:
Example
Dr.A.PramodKumar carried out the simulation, report writing and the optimization.
N.Suman has implemented the proposed design and its analysis of simulation measurement.
Y.V.Koteswararao has organized and executed the experiments of Section 3.
In general, please, follow
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