

# 3.3.2

## **Books/ Conferences/ Book Chapters During Assessment Period 2018-2022**



**Bapatla Women's Engineering College**

Bapatla -522101. Guntur(Dt.), A.P.

(Sponsored by The Bapatla Education Society)

Approved by AICTE- New Delhi, Affiliated to Acharya Nagarjuna University

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(ESTD.2009)

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## Books/ Conferences/ Book Chapters During Assessment Period : 2018-2022

S.NO.	Name of the teacher	Title of the book/chapters published	Title of the paper	Year of publication	ISBN number of the proceeding
1	P. Naga Lakshmi	---	"Power Quality Enhancement in DC Micro grids by Model Predictive Control of Electric Springs"	04.11.2022 to 06.11.2022	Electronic ISBN : 978-1-6654-8057-4 Print on Demand(PoD) ISBN: 978-1-6654-8058-1
2	B.Siva Kumari	Dual Band Hubrid DRA Antenna Design For WLAN	---	01.11.2022	978-81-959356-1-1
3	Divya Gudapati	---	Dual Polarized Planar MIMO Antenna for 5G Base Station Applications	Nov-22	978-1-6654-7100-8
4	O.Sreedevi	---	Evaluation of Removal of Metal Ions from Wastewaters Using Conventional and New Trends	26.09.2022 to 27.09.2022	RFI/SRGBN/2022/304
5	O.Sreedevi	---	Effect of Oxidation of Activated Carbon on Its Enrichment Efficiency of Metal Ions Using Carbon Nanotubes	05.08.2022	RFI/SKCLNCT/2022/137

6	O.Sreedevi	---	Enhanced Removal of Chromium(VI) From Polluted water Using Activated Carbon	10.11.2021	RFI/MR-2021/261
7	O.Sreedevi	---	Synthesis of Low-cost Activated carbons by removal of hexavalent chromium from Aqueous Solution in session III	30.05.2021	RFI/IVC/2021/ABC/392
8	O.Sreedevi	---	A Selective Adsorption of Cr(VI) from Waste water Using Low-Cost Biosorbents	21.02.2021	ICSDCS/2021/252
9	MD.Jareena Begum	---	Enhanced Security for the authentication of Digital Signature from the key generated by the CSTRNG method	Aug-20	978-1-7281-5821-1
10	G. Divya	Asynoptic Review on Dielectric Resonator Antennas	---	Mar-18	978-981-10-7329-8
11	G. Divya	---	Enhancement of isolation in Dual-band Hemispherical DRA using for MIMO Systems	02-03-2018 to 03.03.2018	978-1-5386-3479-0

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IQAC

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PRINCIPAL



# Power Quality Enhancement in DC Microgrids by Model Predictive Control of Electric Springs

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**Abstract**—Electric spring (ES) is an innovative design that can regulate voltage abnormalities developed by intermittent non-conventional power sources (NCPS) connected with smart grid. Renewable power sources are employed nowadays in contemporary power systems worldwide to overcome the fast depletion of fossil fuels. Nonetheless, the infiltration of these NCPS into the power system produces an adverse effect on the power system stability and quality. This research recommends various control schemes and offers a potent approach called as ES which regulates the mains voltage in spite of changes caused by the intermittent NCPS in the DC microgrid (MG) environment. This investigation analyses a Model Predictive Controller (MPC) which is enforced to a DC-DC converter to help in the examination the power quality issues like harmonics reduction, voltage regulation and voltage ripple. In addition, the paper also addresses the battery's lifetime by lessening its storage capacity. The suggested system is simulated using Matlab/Simulink software. The performance specifications of the system are achieved by the MPC controller and the parameters are studied and correlated with the artificial neural network (ANN) based intelligent controller and the conventional PI controller results. The suitability and cogency of the control scheme are affirmed, simulation studies are carried out on the sample test systems, and the simulation results are reported.

**Keywords**— *DC, ES, MPC, ANN, PI control, DC-DC converter.*

## I. INTRODUCTION

The increasing need of distributed generation (DG), like solar panels installed over rooftops and electric vehicles charging causes under and over voltage problems in distribution networks. In the modern power systems, generation of power is often based on estimating load and unified power control. Due to NCPS intermittency, stability issues have become more serious in the recent times as the capacity of energy produced from NCPS and transferred to power system increased greatly. To regulate voltage and control the power flow, FACT systems are utilized. However, the most of them are designed for medium/high-voltage demands. Hence, it is unable to quench the needs of forthcoming low-voltage microgrids with substantial NCPS infiltration, such as wind generators and photovoltaic (PV) systems [1] - [3].

In order to meet the aforementioned requirements, The ES scheme has been suggested which could be employed for the future distributed microgrids. It transfers line voltage variations to non-critical loads (NCL), i.e., NCL tolerates a broad range of supply voltage, to preserve the voltage regulation across critical loads (CL), i.e., CL tolerates a narrow range of supply voltage. This transmission is established by ES's balancing of load requirement automatically with power production [4] - [5]. The smart load is constituted by the ES and NCL (SL) combination. From now on, the voltage across CL and the in-parallel SL is

assigned as grid voltage. An ES and NCL are connected in series to the distribution system (DS) with a single connection point, conflicting a dynamic voltage restorer (DVR) located in series with the DS [6].

MGs are considered as flexible platforms for receiving NCPS without threatening the power quality and reliability of the utility grid [7] where MG is the collection of low-voltage peripheral appliances. The organized NCPS volatility and intermittency leads to voltage swings at the Point of common coupling (PCC). This, in turn, hampers the regular operation of CL's in MG's. Solid spinning reserves and energy storage methods are mostly adopted to deal with this problem, which in compensates for the imbalance between power production and demand. This leads to inefficient, idle generator operations and significant infrastructure investments contrast directly to the basic objective of coordinating NCPS [8], [12], and [17].

ESs are suggested which are both distributed and continuous as a demand side management (DSM) technique. To establish SLs, several kinds of NCL are connected in series with them. The power characteristics of SLs will be adaptively modified to compensate for the power system fluctuations. They possess several advantages like partial power processing, on-site voltage support, and automatic load tracking generation, which make them unique from other DSM systems [9], [12]. The amount of storage capacity required in DC MGs is greatly reduced due to these characteristics. ESs are recommended to secure those significant loads are managed within specific limits while NCLs are influenced by variations, emerging as a novel control scheme where the power generation meets load demand. The major perception and initial iteration of ES, acts mainly in the reactive power compensation. The second interpretation incorporates eight compensating functions, which are explained in detail. The active suspension approach is utilized in bi-directional grid-connected converters that do not have any NCL for the third version [9] [10].

The rising approach of ES scheme is suggested for AC and DC systems, where AC ES technique contribute reactive power and voltage regulation by means of efficient frequency and voltage management. In the DC MG, a DC ES balances DC bus voltage, minimizes harmonics and ripple content. The battery storage present allows for continuous DC supply in supplement to filtering and lessening harmonics. [11]-[14].

## DUAL BAND HYBRID DRA ANTENNA DESIGN FOR WLAN APPLICATION

### Abstract

The Dielectric resonator seems to be a good alternative for Micro-strip Patch Antenna (MPA) due to its ability to resonate at high frequencies more efficiently. When only DRA is used we require high complex structures such as superstrates to get the optimum results at the desired frequencies, so we prefer Hybrid DRA over simple DRA. Hybrid DRA means there is a micro-strip patch which is used for exciting the DR and since the radiating element is DR there will be no conductor losses and surface waves. The impedance bandwidth is improved by 10% when we use Hybrid DRA. The design is simulated using HFSS tool for the two resonant frequencies at 2.8 GHz and 5.6 GHz.

**Keywords:** Dielectric Resonator antenna, Dual Band DRA, Hybrid DRA, Cylindrical DRA, offset well, Dual Band.

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# Dual Polarized Planar MIMO Antenna for 5G Base Station Applications

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**Abstract**— This article presents a low profile dual polarized multi-layered planar MIMO antenna for Sub 6GHz n78 band 5G base station applications. A conventional solution for the severe overload problem in deploying a more significant number of 3D MIMO antennas for base stations is discussed in this paper. A multi-layered planar MIMO antenna system with an element spacing of  $0.5\lambda_0$  is designed to operate at 3.5 GHz with a bandwidth of 130MHz and an isolation level of 20dB. A dual polarization technique is employed to combat the problem of interference and multipath fading. The proposed design provides a reasonable gain value of 8.75 dBi for two-element planar MIMO and makes it suitable for 5G Advanced Antenna Systems (AAS). The performance of the MIMO system is validated by calculating the Envelope Correlation Coefficient (ECC) and Diversity Gain (DG).

**Keywords**— Base Station, Dual Polarized, MIMO, Planar Antenna.

## I. INTRODUCTION

The paradigm shift to 4G technology employs MIMO and massive MIMO technology in the design of base station antennas. 5G MIMO technology [1] is suitable for attaining high channel capacity, a high data rate of 20 Gbps, low latency of 1 ms, improved spectral efficiency of about 30 bit/s/Hz and is 90% more energy efficient than 4G with ubiquitous connections. These behests of 5G are met with its xhaul architecture, where front haul and back haul are integrated [2]. The 5G xhaul architecture of cell towers are evolved with significant improvements from 2G base station antennas. In a conventional 2G GSM digital system, Base Band Unit (BBU) and Remote Radio Head (RRH) are connected to the telecom unit using longer-length coaxial cables, as shown in Fig. 1(a). The radio processing system is connected to the antenna system on the tower with amplifiers via coaxial cables. The efficiency of the base station is reduced as the power consumption is more with the power amplifiers and necessary cooling equipment [3]. The next generation cellular system, 3G/4G, uses distributed networks, which work with C-RAN (Cloud-Radio Access Network), as shown in Fig. 1(b). In this cellular front haul, RRH and amplifiers are separated from the BBU and placed on the tower's top. The RRH is connected to the BBU via optical fibre cables, whereas the antenna system is connected to the RRH via coaxial cables. This technological change in the cellular front haul increases the link gain because RRH is placed next to the antenna system on the tower. The next generation 4.5G / 5G centralized cellular network [4], depicted in Fig. 1(c), uses Radio Access Network (RAN), which brought a technological revolution

in the cellular base station design. The RRH is wholly integrated with the antenna system on the top of the tower, whereas BBU is centralized. The cable losses are reduced, and the passive antenna system is transformed into Active Antenna System (AAS) [5] as all the active electronic components, and RF modules are integrated with the hundreds of antennas. AAS radio [6], a 5G antenna array, is an integration of hardware and software for the transmission and reception of radio signals and signal processing units. The performance of AAS is increased with the increase of a more significant number of antennas, thus forming a Massive MIMO network. As RRH is wholly integrated with the massive MIMO antenna system on the top of the tower, there is a severe space constraint on the size of the antennas. Deploying a more significant number of antennas in a limited space is challenging.

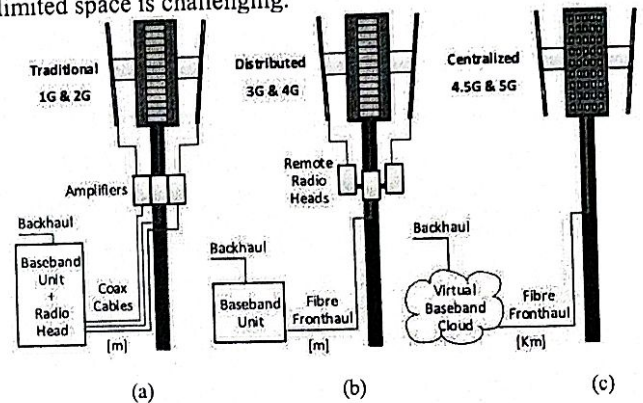


Fig. 1. Evolution of Cellular Infrastructure [7]

The paradigm shift from 4G to 5G demands low-profile antennas, as hundreds of radiating elements are used in the massive MIMO antenna system. The advantage of scaling down the antenna size in massive MIMO is that it significantly improves the throughput, overcomes path losses and improves spectral efficiency with beam forming technique. The antenna array size is reduced considerably by employing the dual polarization technique. Dual polarization [8] refers to simultaneously transmitting and receiving in horizontal and vertical planes (V/H).  $\pm 45^\circ$  dual-polarized antennas are widely preferred over single-polarized antennas because a single dual-polarized antenna can provide the functionality of two separate antennas. V/H dual-polarized antennas are robust and highly reliable, offer high-speed wireless connectivity, reduce interference, improve the signal-to-noise ratio, enhance channel capacity and coverage range, and improve quality of Service by reducing network congestion. Owing to the above-said advantages,  $\pm 45^\circ$  dual-

INTERNATIONAL CONFERENCE On "Recent Trend of Commerce, Arts, Science, Education, Management and Humanities in Present Scenario" (IC-RTCASEMHPS-2022) Date: 26-27 September 2022

Organized By: Shri Rewa Gurjar Bal Niketan College, Sanawad Research Foundation of India & RFI-Care

RFI/SRGBN/2022/304

EVALUATION OF REMOVAL OF METAL IONS FROM WASTE WATERS USING CONVENTIONAL AND NEW TRENDS

Oguri Sreedevi

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Abstract- Heavy metal pollution is one of the most serious environmental issues of our time. Heavy metals must be treated because of their persistence in the environment. In recent years, numerous techniques for removing heavy metals from wastewater have been extensively researched. This paper analyses and reviews the current heavy metal wastewater treatment methods in use. Chemical precipitation, ion exchange, adsorption, membrane filtration, coagulation, flotation, and electrochemical techniques are some of the technologies used in these processes. Sewage that contains heavy metal ions is thought to be a serious threat to air degradation. Heavy metals are serious ecological pollutants because the large percentage of them are harmful, about there-ions really aren't compostable, and they tend to accumulate in the soil and in living organisms. As a result, the water is cleaned and the heavy metal ions are eliminated. Wastewater management is essential for maintaining both the climate and, consequently, population health. Adsorbent is the most widely used technique for extracting the metal ions from substantial quantities of aqueous medium.

Keywords: Heavy Metal Ions, Adsorption, Conventional Adsorbents, Carbon Nano-tubes.



INTERNATIONAL MULTIDISCIPLINARY CONFERENCE On "Recent Research on Management, Science, Pharmacy & Engineering" (IMC-RMSPE-2022) Date: 05 August 2022

Organized By: SKC LNCT Group of Colleges Indore, Research Foundation of India & RFI-CARE

RFI/SKCLNCT/2022/137

EFFECT OF OXIDATION OF ACTIVATED CARBON ON ITS ENRICHMENT EFFICIENCY OF METAL IONS USING CARBON NANOTUBES

Oguri Sreedevi

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Abstract- Researchers studied the use of carbon nanotubes supported by activated carbon to remove chromium (VI) ions from contaminated water. The experimental conditions that favour Cr (VI) adsorption by carbon nanotubes have been studied. The initial Cr (VI) concentration, pH, adsorbent dosage, contact time, and agitation rate are some of these variables. The activated carbon has been characterised using field emission scanning electron microscopy, both by itself and when coated with carbon nanotubes. A fractional factorial design was used to statistically produce a fully random experiment. Adsorption isotherms have been used to determine the adsorbents' adsorption capacities and to analyse the kinetics of the adsorption behaviour. Regression analysis was applied to examine the empirical statistics of the experiment.

Keywords: Carbon Nanotubes, Activated Carbon, chromium (VI) removal.



RFI/MR-2021/261

ENHANCED REMOVAL OF CHROMIUM (VI) FROM POLLUTED WATER USING ACTIVATED CARBON  
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Abstract- Activated carbon made from the stems of the Lantana camara plant is used in batch methods of extraction to remove chromium (Cr) (VI) from contaminated water (ACSLC). pH, initial Cr (VI) concentration, sorbent dosage, temperature, equilibration period, and co-ion presence are the ideal extraction conditions. The discovered adsorption capacity of 26.25 mg/g is greater than that of sorbents previously mentioned in the literature. With just a slight reduction in adsorption capacity, the used adsorbent can be revived and used once more. Field emission scanning electron microscopy (FESEM), X-ray diffraction (XRD), and Fourier-transform infrared (FT-IR) techniques are used to investigate the active carbon. Numerous isotherm models are used to investigate the sorption mechanism, and it is discovered that the Freundlich model adequately captures the adsorption process. Studies on thermodynamics demonstrate that physisorption is spontaneous and endothermic. The pseudo-second-order model accurately describes the adsorption kinetics. The developed methodology is effective when used with effluent samples from various industries.

Keywords: Active Carbon, Adsorbent, Adsorption, Chromium (VI), Polluted Water.

PINTERNATIONAL VIRTUAL CONFERENCE On ““New Challenges & Opportunities in the field of Education, Science, Management, Commerce, Humanities, Agriculture & Technology in the Current Scenario” Date: 30 May 2021

Organized By: Annie Besant College, Indore

RFI/ABC/392

SYNTHESIS OF LOW-COST ACTIVATED CARBONS BY REMOVAL OF HEXAVALENT CHROMIUM FROM AQUEOUS SOLUTION

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Abstract- This paper examines an efficient adsorption method for the treatment of tannery wastewater. Various low-cost activated carbons were made from agricultural waste by processing it, and these carbons were later characterised and used to remove hexavalent chromium from wastewater. Systematic studies on the equilibrium and kinetics of chromium (VI) adsorption by inexpensive activated carbons as well as commercially available activated carbon fabric cloth were carried out at various temperatures, particle sizes, pH levels, and adsorbent doses. The Freundlich and Langmuir models successfully fit the adsorption data. According to pseudo-second-order rate kinetics, Cr(VI) is adsorbed. The evaluation of various parameters, such as the effective diffusion coefficient, activation energy, and activation entropy, served as the basis for these studies in order to identify the INTERNATIONAL VIRTUAL CONFERENCE on “New Challenges & Opportunities in the field of Education, Science, Management, Commerce, Humanities, Agriculture & Technology in the Current Scenario” (30 May 2021) 51 mechanisms. The adsorption capacities of the tested adsorbents were found to be comparable to those of the readily available adsorbents/activated carbons. According to pseudo-second-order rate kinetics, Cr(VI) is adsorbed. The evaluation of various parameters, such as the effective diffusion coefficient, activation energy, and activation entropy, served as the basis for these studies in order to identify the mechanisms. The adsorption capacities of the tested adsorbents were found to be comparable to those of the readily available adsorbents/activated carbons.

Keywords: Hexavalent Chromium Cr (VI); Adsorption, Solid-To-Liquid Ratio, Low cost, Aqueous solution.



INTERNATIONAL VIRTUAL CONFERENCE On "Sustainable Development in Current Scenario:

Social Science, Commerce, Management, Education, Medical, Pharmacy, Agriculture, IT & Engineering and Humanities in Global Environment" (SDCS-2021) Date: 21 February 2021

Organized By: AAFT University Raipur (CG), Christian Eminent Academy of Professional Studies-Indore .Research Foundation of India & JHERF

ICSDCS/2021/252

A SELECTIVE ADSORPTION OF CR (VI) FROM WASTE WATER USING LOW COST BIOSORBENTS

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**Abstract-** The results of a study that looked at the possibility of batch-mode removal of Cr(VI) from aqueous solutions using cheap waste biomaterial are presented in this article. As biosorbents, we used cones from *Fomitopsis pinicola*, as well as peach, apricot, and *Juglans regia* stones, orange peels, and Merino sheep wool. We looked at three grain sizes of biosorbents: fr. 1/2, fr. 0.5/1.0, and fr. 0/0.5 mm. Finding the best biosorbent that could be tested using real samples was the goal. Additionally, the effects of additional factors (such as temperature, rotation speed during mixing, pH value, chemical activation of the biosorbent, and the influence of biosorbent concentration. By using chemical activation and lowering the pH to 1.1 to 2.0, they can have their sorption capacities increased and, in the case of some biosorbents, their exposure times shortened. In order to analyse the experimental data and explain the mechanism of adsorption and its potential speed control steps, pseudo-first-order and pseudo-second-order kinetic models were used. The pseudo-second-order kinetic model seems to best fit the experimental data. The biosorption was likely endothermic and spontaneous, according to the thermodynamic parameters. The Langmuir and Freundlich adsorption isotherms were used to describe the adsorption data in the biosorption equilibrium study. For all biosorbents, the Langmuir model could be used to describe the adsorption data. Both designs work well with peachstones and sheep fleece that has undergone chemical treatment.

**Keywords:** Biosorption; Hexavalent Chromium Cr (VI); Batch Mode; Kinetic; Equilibrium; Thermodynamic Study.

# Enhanced Security for the authentication of Digital Signature from the key generated by the CSTRNG method

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**Abstract**— Security is the most critical feature of the present e-world. Many applications are based on random number generation. In the present situation, it is very difficult to hide the data. So the key-based encryption process is suggested to keep the files secure. The protection of the data depends on the key. Key generation is more important for all cryptography applications, which is entirely dependent on randomness. As long as many designers have been able to develop many Random Number Generator-based keys. Also work is going on to make hacker data more stable. CSTRNG can be suggested in this work. One of the most commonly used technologies in the marketing field is the production of digital signatures. The generation of digital signatures can be generated using many keys that have the property of RNG. The most stable RNG is the Cryptographically Secured True Random Number Generator (CSTRNG). This could generate more unexpected numbers. Work has been built on the Xilinx ISE simulator.

**Keywords**— Random Number Generator, Digital signature, Cryptographically Secured True Random Number Generator, Cryptography.

## I. INTRODUCTION

Security is very critical today, most security systems are focused on authentication. Digital signatures, facial identification, eye detection and fingerprints may be available in many forms. Similar to all authentication methods, a digital signature is one of the easiest and most safe and easy to use anywhere. The greater the size of the key in the digital signature, the higher the authentication [1]. Digital certificates are the exclusive security key for the authentication of messages.

There are several modern ways to produce digital signature authentication keys [2]. In the physical world, hand-written signatures on hand-written or typed messages are popular. They are used to connect the signer to the text. Additionally, a digital signature is a process that links a person/entity to electronic data. If the signature is unique, the chances of hacking are low.

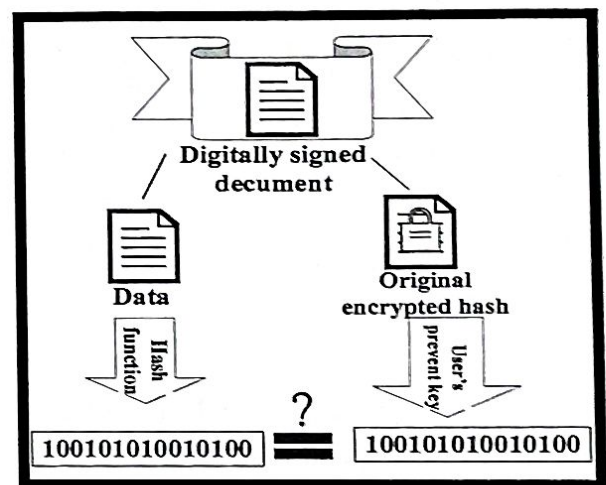


Fig 1. The digital signature generation process

## II. BACKGROUND

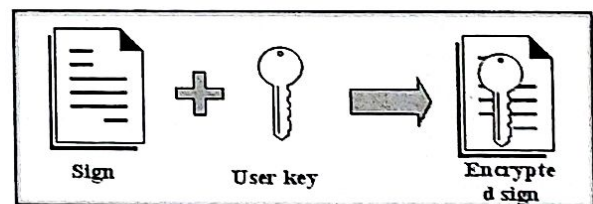


Fig. 2. Process of signature generation

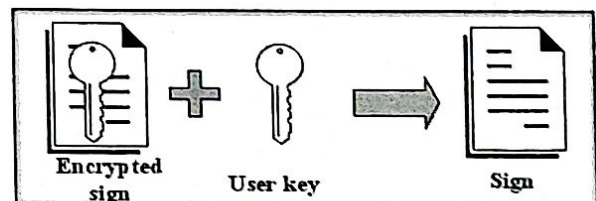


Fig. 3. The verification process of digital signature



# A Synoptic Review on Dielectric Resonator Antennas

G. Divya, K. Jagadeesh Babu and R. Madhu

**Abstract** A brief review of research on dielectric resonator antenna (DRA) is presented in this paper. Basic characteristics of DRA and its comparison with microstrip patch antenna are discussed. Different types of DRAs, excitation mechanisms, various bandwidth enhancement schemes, and isolation improvement techniques are also discussed in this paper. The recent inventions associated with DRA are also included.

**Keywords** Dielectric resonator antenna • Isolation • Excitation  
Glass DRA

## 1 Introduction

Antennas are the essential communication link in the present wireless world. As the new wireless products surface every day, the need for sophisticated antennas is much more demanded in day-to-day life.

In today's wireless era, a low cost, more gain, highly efficient, broadband antennas are a major challenge for the antenna designers. Over the last three decades, an extensive research shows that microstrip antenna (MSA) and dielectric resonator antenna (DRA) are suitable for modern microwave and wireless communications because of lightweight, low profile, inexpensive, and compatibility with integrated circuits. In contrast to MSA, DRA is considered as the viable solution to the traditional conductor antennas at millimeter-wave frequencies.

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# Enhancement of Isolation in Dual-band Hemispherical DRA using DGS for MIMO Systems

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**Abstract** - A simple compact novel hemispherical DRA (HDRA) for isolation improvement with rectangular shaped slot Defected Ground Structure (DGS) is proposed. Length of the slot on the ground plane plays a vital role to enhance the isolation. An optimized length of the slot of  $b=4.5\text{cm}$  on PEC ground plane offers an isolation of  $-30\text{dB}$  and impedance bandwidth ( $S_{11} < -10\text{dB}$ ) of  $15.6\%$  with return loss  $-42.5\text{dB}$  at  $2.412\text{GHz}$  and  $-23.3\text{dB}$  isolation with  $-18\text{dB}$  return loss at  $4.216\text{GHz}$ . The proposed geometry resonates at two bands, primarily at ISM band and it is best suitable for Bluetooth, Wi-Fi, WiMax, WLAN and Satellite and radar applications in S-band.

**Keywords** - DRA, Isolation, Dual band, DGS

## I. INTRODUCTION

Cutting-edge MIMO technology demands highly efficient antennas with improved isolation and enhanced bandwidth. Microstrip antennas (MSA) and Dielectric Resonator Antennas (DRA) comply with the demands of MIMOs. From the past two decades, DRAs have gained significant interest because of its wide impedance bandwidth as it radiates through its whole 3-dimensional surface, low conduction losses because of the absence of a conductor, high gain and high radiation efficiency. This 3D technology overcomes many snags of planar technology particularly microstrip antennas. The characteristics of MSA and DRA are compared in [1]. Several DRA geometries like rectangular, cylindrical, triangular, hemispherical, conical, hexagonal etc [2-5] have been explored. In [6] transparent hemispherical DRA for optical applications is discussed. A novel swastika shaped DRA is discussed in [7]. Each geometry has its own advantage. The hemispherical DRA offers many advantages like design flexibility, wide bandwidth, and high isolation. The fundamental modes of hemispherical DRA are  $TE_{111}$  and  $TM_{101}$ . The DRA performance can be improved in terms of bandwidth enhancement [8, 9], isolation improvement [10, 11] and gain improvement [12].

The performance of MIMO systems is effectively improved by enhancing the isolation between the adjacent

antenna elements in an array. Mutual coupling affects various parameters like radiation pattern, resonant frequency, and bandwidth. Numerous techniques have been employed for enhancing the isolation. Defected Ground Structures (DGS) [13], Parasitic elements, Electromagnetic Band Gap structures, Decoupling networks, Neutralization lines and Metamaterials [14].

Defected ground structures and metamaterials provide good isolation. Defected ground structures have gained much importance because of its simplicity in design, good spatial diversity, and less correlation coefficient. DGS is actualized by etching slits and slots on the ground plane. Slots act as a band stop filter and suppress the coupled fields between the neighboring antenna elements by reducing the current on the ground plane. Better isolation is achieved by varying the slot length and space between the slots. First DGS with dumbbell shape was proposed by Kim & Park [15]. Various DGS shapes like the spiral, Arrowhead dumbbell, concentric ring, Circular head dumbbell, open loop dumbbell etc have been explored.

In this paper, a novel half-hemispherical DRA with 3 rectangular slots is proposed. This enhances the isolation by  $30\text{dB}$  at  $2.412\text{GHz}$  and  $23\text{dB}$  at  $4.216\text{GHz}$ .

## II. PROPOSED DESIGN

The proposed structure consists of an array of  $2 \times 2$  MIMO with hemispherical DRA cut at its center vertically at  $90^\circ$ . Hemispherical DRA with removed left portion is shown in Fig1. Schematic diagram of the proposed design is shown in Fig 2.



Fig. 1: Hemispherical DRA