A Structure Review on Calcium Copper Titanate (CCTO) For Enhancement of Dielectric Resonator Antenna

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Abstract. This study critically examines the utilization of Calcium Copper Titanate (CCTO) for enhancing Dielectric Resonator Antennas (DRAs). Against the backdrop of growing demand for efficient wireless communication systems, the integration of advanced dielectric materials like CCTO has garnered significant antion. The problem addressed is the need for improved antenna performance, including enhanced bandwidth, permittivity, and radiation efficiency. By analyzing a comprehensive selection using advanced searching approached on Scopus and Mendeley database found (n=31) final primary data was analysed. These findings have the potential to revolutionize wireless technology applications and stimulate further research in the field. The review concludes with recommendations for policymakers, educators, and institutions to move toward increasingly complex communication needs, these studies provide essential stepping stones toward more efficient, high-performance antenna systems.

Keywords: Dielectric Resonator Antennas, CCTO, Dielectric, Antenna, Enhancement

INTRODUCTION

In recent decades, the realm of wireless communication has experienced an exponential surge in demand for higher data rates, improved signal quality, and enhanced overall performance[1]–[5]. As a result, researchers and engineers have been diligently exploring innovative technologies to push the boundaries of communication systems. Dielectric Resonator Antennas (DRAs) have emerged as a promising avenue due to their exceptional characteristics, including high radiation efficiency, compact size, and compatibility with modern communication frequencies[6].

However, the journey towards unlocking the full potential of DRAs faces certain challenges, particularly in optimizing their dielectric properties. This is where Calcium Copper Titanate (CCTO) comes into the spotlight. CCTO, a perovskite oxide material, has garnered substantial attention for its remarkable dielectric properties, including an extremely high dielectric constant and low loss tangent[7]–[13]. These properties hold the key to revolutionizing the performance of DRAs, paving the way for enhanced signal reception and transmission.

This article embarks on a comprehensive structure review of Calcium Copper Titanate and its application in the context of Dielectric Resonator Antennas. By delving into the intricacies of CCTO's crystal structure, composition, and electrical behavior, we aim to provide an insightful understanding of how this material can be harnessed to augment the capabilities of DRAs. Furthermore, this review underscores the pivotal role of material engineering in reshaping the landscape of wireless communication technology[3], [5], [14].

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As we navigate through the dimensions of crystallography, electrical properties, and practical applications, it becomes evident that CCTO holds immense promise in the pursuit of refining Dielectric Resonator Antennas. By unraveling the synergistic relationship between material structure and antenna performance, we aim to provide a foundation for future innovations in wireless communication technology. This article encapsulates not only the current state of research but also the potential trajectories that lie ahead, where Calcium Copper Titanate could potentially reshape the landscape of Dielectric Resonator Antennas[1], [14]–[17].

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LITERATURE REVIEW

This article discusses the use of one-dimensional multiwall carbon nanotubes (CNTs) and zero-dimensional copper calcium titanate (CCTO) ceramic fillers to enhance the dielectric performance of silicone rubber (SR) composites. The composites showed improved dielectric performance, tensile stress, elongation at break, and elastic modulus. They also had good thermal stability and a wide temperature range up to 400°C[18]. The research focuses on understanding the stability and reproducibility of measured electrical and dielectric properties of CCTO ceramics, which have a large dielectric constant of 104–105 at room temperature. The study uses solid state reaction method and AC impedance spectroscopy to characterize the fundamental electrical properties of CCTO, which can be used to eliminate hysteresis and produce stable and reproducible dielectric properties[19].

Calcium copper titanate (CCTO)/polystyrene–polyethylene–polybutylene–polystyrene (SEBS) dielectric elastomers were prepared via blending method. A capacitive strain sensor using CCTO/SEBS as dielectric layer and polyaniline–dodecylbenzensulfonic acid (PANI–DBSA)/SEBS as electrodes was designed and manufactured by thermoforming process. X-ray diffractometer (XRD), scanning electron microscopy (SEM) and Raman spectra analyses were carried out; no impurities were found in the composite and CCTO particles were well dispersed. The dielectric tests showed that the samples filled with 20 wt% CCTO have their permittivity improved by 70%. The capacitive strain sensors have a stabilized capacitance variety range at different strain ranges or stretch speeds, and could remain synchronized after 500-time-stretching, showing high reproducibility[17].

Ceramic composites with negative permittivity have provoked considerable interests of researchers in electronic and dielectric devices due to the extraordinary electromagnetic performance in radio-frequency (RF) region. Herein, graphene/CaCu3Ti4O12 (GR/CCTO) ceramic composites were spark plasma sintered, of which the dielectric and thermal properties were demonstrated at RF region. An electrical percolation was identified with GR content varying from 10 wt% to 14 wt% which presenting as a dramatic increase of ac conductivity. The conduction mechanism changed from hopping conductivity to metal-like conductivity. Meanwhile, the real permittivity (ε′) turned from positive to negative which indicating an intrinsic transition of dielectric response mechanism. Therefore, Drude model was applied to elucidate the RF negative permittivity ($\varepsilon' < 0$) which manifesting the low-frequency plasmonic state of delocalized electrons in composites. The constructed GR networks in composites also leaded to the enhanced thermal conductivity due to the dominating contribution of phonon vibration in GR sheets. Besides, theoretical models of capacitive and inductive equivalent circuits were used on impedance spectra which successfully clarified the inductive character of negative permittivity. This work benefits expounding the generation and regulation mechanism of negative permittivity and will be favorable to exploring brand-new applications of ceramic composites[20].

Nonlinear electric conductance of reinforced insulation can homogenize electric field distribution and suppress local electric field distortion inside high-voltage direct current cable accessories. To achieve a significant nonlinear electric conductance in ethylene–propylene–diene misch–polymere (EPDM) used for reinforced insulation of cable accessories, the inorganic micron crystal powder of calcium copper titanate (CCTO) is synthesized by the sol–gel method, which is filled into EPDM to prepare 5∼15 wt% CCTO/EPDM composites by melting blend and hot-press molding methods. Microscopic structure, electric conductivity, direct current (DC) dielectric breakdown strength, and charge trap characteristics of CCTO/EPDM composites are tested to reveal the underlying derivation of electric conduction nonlinearity. Scanning electron microscopy and X-ray diffraction (XRD) demonstrate that CCTO micron fillers are uniformly dispersed in the EPDM matrix. Dielectric breakdown strength of CCTO/EPDM composites gradually decreases with the increase in CCTO content while persisting qualified for electrical insulation of DC cable accessories. CCTO crystal macron fillers introduce shallower charge traps than the intrinsic charge traps derived from the structural defect EPDM matrix, which initiates the percolating conductive channels between charge traps under high electric fields, accounting for the significant nonlinearity in the profile of electric current density versus electric field strength. Finite-element simulations and analyses on the electrostatic field in DC cable terminals prove that employing 15 wt% CCTO/EPDM composite as reinforced insulation can efficiently homogenize the electric field at the interface between the main insulation and accessory

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insulation of power cables, which is of great interest to develop insulation materials used for DC cable accessories in severe environments[20].

Calcium copper titanate (CCTO) powders associated with the chemical formula Ca1−xSrxCu3−yZnyTi4−zSnzO12 (where x, y, z varying from 0 to 0.1) were synthesized via a solid-state reaction route. Dense ceramics (>96% of theoretical density) were obtained by sintering these powders comprising micrometer-sized grains at appropriate temperatures. X-ray powder diffraction studies confirmed the formation of monophasic CCTO cubic phase, with no traceable secondary phases present. The lattice parameter 'a' was found to increase on increasing the dopant concentration. The microstructural studies performed on these ceramics confirmed a decrease in mean grain size (18 μm to 5 μm) with the increase in Sr, Zn and Sn doping concentrations as compared to that of undoped CCTO ceramics though they were sintered at the same temperature and duration (1100 °C/15 h). The dielectric studies (dielectric constant (ϵ′) and the dielectric loss (D)) conducted in a wide frequency range (102-107 Hz) demonstrated an increase in ϵ′ and a decrease in D on increasing the doping concentration. Impedance analysis (Nyquist plots) performed on these ceramics revealed a significant increase in grain boundary resistance. The highest value of grain boundary resistance (6.05 × 108 Ω) (in fact this value was 100 times higher than that of pure CCTO) was obtained for the composition corresponding to x = y = z = 0.075 and intriguingly the ceramic pertaining to this composition exhibited enhanced ϵ′ (1.7 × 104) and lower D (0.024) at 1 kHz. Further, these co-doped CCTO ceramics exhibited substantial improvement in breakdown voltages and nonlinear coefficients (α). The temperature independent (30 -210 °C) dielectric response of these samples qualifies them to be suitable dielectric materials for the fabrication of multilayer ceramic chip capacitors[21].

AC electrical measurements were carried out on iodine doped, CaCu3Ti4O12-xIx (x = 0, 0.005, 0.05 and 0.2) ceramic specimens sintered at 1100 °C for 12 h in the temperature (300–450 K) and frequency (20 Hz - 1 MHz). The crystalline structure, microstructure, and oxidation state of various ions of pure and iodine-substituted sintered specimens were carried out through XRD, SEM, and XPS, respectively. The dielectric relaxations in grains, grain boundaries, and sample-electrode interfaces for different compositions were investigated through impedance and modulus spectroscopic techniques and were reported in the first part of the investigation. It revealed the involvement of similar types of charge carriers in conduction and relaxation processes in grains and grain boundaries, respectively. This second section emphasizes the dielectric and conduction properties of CaCu3Ti4O12 (CCTO) with iodine doping at the anion site. The XPS study reveals that the concentration [VO••] is reduced, and [VM″] gets increased with increasing concentration of iodine from x = 0.05 to 0.2. This observation also supports the point defect model as reported earlier for charge compensation of impurity defect IO• i.e., with increasing substitutions of iodine, the charge on IO• change from electronic to cationic vacancies, VTi//// or copper VCu// or both to keep electrical charge neutrality. The metal ions get segregated at grain boundaries. This, in turn, will minimize hopping due to electrons between Ti4+ and Ti3+ or Cu2+ and Cu1+. As a result, it increases resistivity and minimizes dielectric losses for the higher concentration of iodine doping. Thus, a high concentration of iodine doping at the oxygen site promotes the formation of a barrier layer capacitor[22].

CCTO ceramics are known for their high dielectric constant and low loss, making them potential candidates for use in various electronic and energy storage applications. The dielectric properties of CCTO ceramics can be tuned by doping of various elements. In addition to the dielectric properties, Co–Ni substitution has also been found to affect other properties of CCTO ceramics, such as the thermal and electrical conductivity. Therefore, Co–Ni substitution can be a useful strategy for tailoring the properties of CCTO ceramics for specific applications. In this research work, the sol–gel auto-combustion technique is used for the synthesis of Co–Ni-substituted calcium copper titanate, Ca(1-x)Co(x)Cu3Ti(4-y)Ni(y)O22 (x = 0.0/y = 0.0, x = 0.1/y = 0.3 and x = 0.2/y = 0.4). X-ray diffraction, Fourier transform infrared spectroscopy, field emission scanning electron microscopy, and impedance analyzer have all been used to examine the structural and dielectric properties of synthesized samples. X-ray diffraction study shows the presence of crystalline structure of calcium copper titanate. The presence of peaks at 422 cm−1, 503 cm−1, and 506 cm−1 in FTIR spectra also confirms the presence of CCTO. The Debye-type relaxation technique and Maxwell–Wagner model describe dielectric characteristics. The grain boundary resistance (R gb) significantly contributes to the dielectric properties of synthesized calcium copper titanate as seen by the Cole–Cole plot[22].

Calcium copper titanate (CCTO) was made into sub-micrometer-sized (0.33 m) polycrystalline powders using the solgel technique. To make porous (80% density) pellets, calcined powders were sintered at 900 °C for 2 hours. The pellets were then coated with ZnO or SnO2 pastes (10 m grain size) and sintered for 15 hours at 1100 °C, producing dense (>95% density) ceramics. The majority of the CCTO ceramics contain residues of ZnO or SnO2, according to X-ray structural analyses. The transport and segregation of these oxides at the grain boundaries were confirmed by experiments using energy dispersive spectroscopy and scanning electron microscopy. The ZnO or

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SnO2 diffused samples were found to have better dielectric and varistor properties than pristine CCTO ceramics. As an illustration, the dielectric[22].

MATERIALS AND METHODS

Identification

The systematic review process consists of three basic phases that were used to choose many relevant papers for this study. The first phase entails the identification of keywords and the search for associated, related terms using thesaurus, dictionaries, encyclopedias, and prior research. Following the selection of all pertinent keywords, search strings on the Scopus and Science Direct databases (see Table 1) have been developed. The current study project was able to successfully obtain 160 papers from both databases during the first stage of the systematic review process.

TABLE 1. The search strings.

Scopus	TITLE-ABS-KEY (("Calcium Copper Titanate" OR dielectric) AND ("Dielectric Resonator Antenna")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "MATE") OR LIMIT-TO (SUBJAREA , "MATH")) AND (LIMIT-TO (EXACTKEYWORD , "Dielectric Resonators") OR LIMIT-TO (EXACTKEYWORD , "Dielectric Resonator Antennas")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))
Science Direct	ccto and dielectric antenna

Screening

During the screening stage, the collection of potentially pertinent research items is checked for content that corresponds to the established research question(s). The selection of research items based on content-related criterion that is routinely applied during the screening phase. All duplicate papers will be eliminated from the list of papers to be searched in this stage. 78 papers were assessed in the second stage of the screening process based on various inclusion and exclusion criteria for this study, while 82 publications were rejected in the first stage (see Table 2). The first criterion used was literature (research articles), which is the main repository of useful advice. Reviews, meta-synthesis, meta-analyses, books, book series, chapters, and conference proceedings that were omitted from the most current study are also included. The review was also limited to English-language publications. It is critical to keep in mind that the approach was limited to the period from 2021 to 2023.

Eligibility

The third level, called eligibility, has a total of 73 items ready. At this point, all article titles and important content were carefully examined to make sure they met the criteria for inclusion and complemented the current study's objectives. 42 papers were thus excluded because they were out of field, the title did not significantly relate to the goal of the study, the abstract did not correspond, and there was no full text access based on empirical data. 31 articles are available for review as of this writing (see Table 2).

TABLE 2. The selection criterion is searching

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Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2021 – 2023	< 2021
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Subject		Besides Social science

Data Abstraction and Analysis

An integrative analysis was used as one of the assessment strategies in this study to examine and synthesise a variety of research designs (quantitative, qualitative, and mixed methods). The goal of the competent study was to identify relevant topics and subtopics. The stage of data collection was the first step in the development of the theme. Figure 2 shows how the authors meticulously analysed a compilation of 27 publications for assertions or material relevant to the topics of the current study. The authors then evaluated the current significant studies related to cervical cancer cell classification. The methodology used in all studies, as well as the research results, are being investigated. Next, the author collaborated with other co-authors to develop themes based on the evidence in this study's context. A log was kept throughout the data analysis process to record any analyses, viewpoints, riddles, or other thoughts relevant to the data interpretation. Finally, the authors compared the results to see if there were any inconsistencies in the theme design process. It is worth noting that, if there are any disagreements between the concepts, the authors discuss them amongst themselves. The produced themes were eventually tweaked to ensure consistency. The analysis selection was carried out by two experts, one in public health (Khairul Shakir Ab Rahman—expert medical doctor in pathology) and the other in biomedical science (Wan Azani Mustafa—expert in biomedical computing), to determine the validity of the problems. The expert review phase ensures the clarity, importance, and suitability of each subtheme by establishing the domain validity

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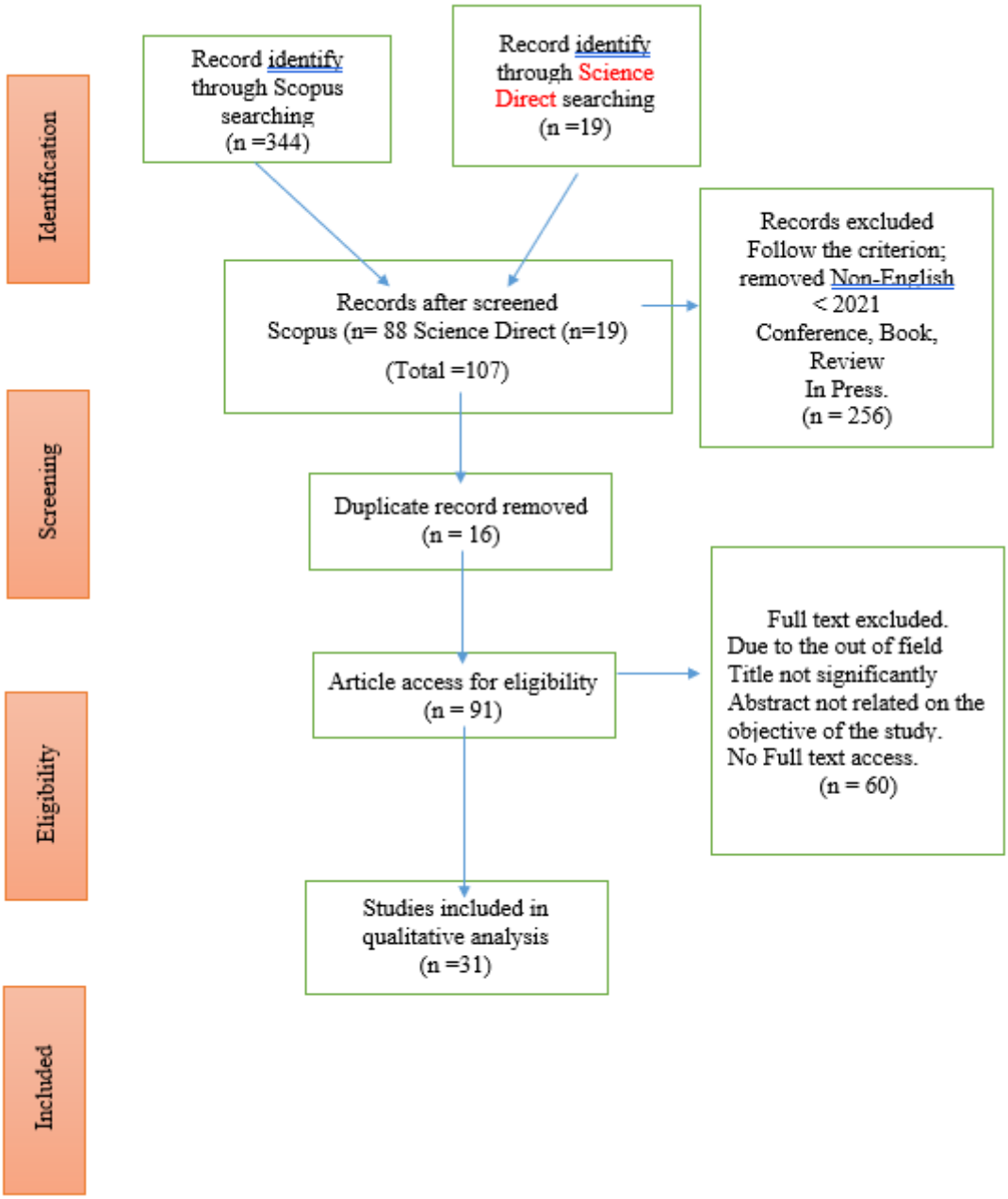

FIGURE 2. Flow diagram of the proposed searching study [4]

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Result and Finding

TABLE 4. The research article finding based on the proposed searching criterion

Authors	Title	Year	Source title	Method	Result/Advantages
Huang T.; Liu H.; Xu H.; Geng L [21].	3-D printed dual-band, dual-sense circularly polarized dielectric resonator antenna with a bandstop filtering response using planar via-free D-CRLH feeding network	2023	AEU - International Journal of Electronics and Communications	A novel concept to design a dual-band, dual-sense circularly polarized (CP) antenna with a bandstop filtering response is presented by adopting an elaborate-designed irregular-shaped dielectric resonator (ISDR) and a dual-composite right/left-handed (D-CRLH)-based feeding network. First, the TEy111 and TEy113 modes of a rectangular DR (rDR) are simultaneously excited using an offset feeding slot, to realize the dual-band, linearly polarized (LP) operation in the x-direction. To eliminate the effects of the offset feeding on antenna performance, two types of edge-cuts and an impedance transformer are introduced. Secondly, another microstrip line and offset feeding slot are utilized to excite TEx111 and TEx113 modes of the DRA, obtaining dual-LP in two bands, and the corner truncation is introduced to reduce the cross-polarized field. Accordingly, a dual-band, dual-LP	The measured results show that the proposed antenna obtains a 3-dB axial ratio (AR) bandwidth of 9.3 % for the left-hand circular polarization (LHCP) at the lower band and 3.6 % for the right-hand circular polarization (RHCP) at the upper band. Moreover, the proposed antenna also features good suppression between two bands as the D-CRLH resonator offers a stopband filtering effect.

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				DRA with boresight radiation and low cross-polarization is achieved. After that, building on this design, a dual-band feeding network based on the D-CRLH resonator is employed to further implement the dual-sense CP operation. Finally, the ISDR is manufactured using 3-D printed technology for demonstration.	
Soltanmohammadi H.; Jarchi S.; Soltanmohammadi A .	Tunable dielectric resonator antenna with circular polarization and wide bandwidth for terahertz applications	2023	Optik	A tunable wideband circularly polarization (CP) dielectric resonator antenna (DRA) is designed and simulated. The antenna is fed by slot coupling and circular polarization is achieved by the design of the slot configuration and by the excitation of different modes. The tunable response is provided by coating graphene on the top of the radiating dielectric resonator	The proposed antenna provides a wide 10 dB impedance bandwidth of 49% (2.7–4.46 THz) and an overlapped axial ratio bandwidth of 17.34% (2.87–3.43 THz).
Huda S.; Saha A.; Karmakar A [22].	Ultra wideband (UWB) dielectric resonator antenna using fractal-inspired feeding mechanism	2023	International Journal of Communication Systems	A compact dielectric resonator antenna (DRA) for UWB applications. Here a composite feeding structure excites a dielectric resonator which in tern provides the resonant modes TE111, TE121, TE212, and TE222. The dielectric resonator (DR), built of alumina ceramic (εr, DR = 9.8), is mounted on	The measured outcome demonstrates that the suggested antenna has a frequency range of 3.38–10.71 GHz (104%) for S11 < −10 dB and provides a maximum gain of 7.23 dBi at 8 GHz along with highest possible

				a fractal triangular patch, inspired by Sierpinski Gasket. The suggested DRA is supported by a FR4 substrate (εr, sub = 4.4) and measures compactly 40 × 30 × 8.5 mm3. To confirm the results of its simulations, the proposed antenna's prototype is prepared and measured up to the second iteration.	simulated efficiency of 98%.
Mohapatra S.; Barman R.; Das T.K.; Badapanda T.; Bennett E.L.; Tripathy S.N .	Exploration of MgTiO3-CaTiO3 Ceramic-Based Dielectric Resonator Antenna for Sub-6 GHz 5G Communication Application	2023	ECS Journal of Solid State Science and Technology	There has been extensive research on microwave dielectric materials considering their applications in 5G communication technologies. In this work, the microwave dielectric performances of 0.95MgTiO3−0.05CaTiO3 (MCT) ceramic for sub-6 GHz frequency 5G application have been reported. The solid-state reaction technique was used to develop the MCT ceramic. The structural as well as dielectric properties of MCT were systematically examined. X-ray diffraction (XRD) was used to examine the crystalline phase of the MCT sample. The microwave dielectric properties, including relative permittivity, temperature coefficient of resonant frequency, and quality factor of	Using MCT ceramic as the resonator, a dielectric resonator antenna (DRA) has been simulated using HFSS software, which realizes that the S11 curve is in good accordance and that efficiency is high at 5.22 GHz. The extraordinary performances indicate that MCT ceramic is a potential candidate for 5G application.

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				MCT were measured.	
Lai Q.X.; Pan Y.M.; Zheng S.Y.	A Self-Decoupling Method for MIMO Linear and Planar Dielectric Resonator Antenna Arrays Based on Transmission Characteristics of Feeding Structure	2023	IEEE Transactions on Antennas and Propagation	A novel self-decoupling method for the multi-input multi-ouput (MIMO) dielectric resonator antenna (DRA) arrays is investigated. This method is based on the transmission characteristics of the conformal strip that feeds the DRA. It is found that when the strip-fed DRA operates in the higher order mode, e.g., TE113 mode, the E -field coupled to the metal strip of the adjacent passive DRA presents a standing-wave distribution. By appropriately adjusting the dimensions of the feeding strip, the E -field can form a node with zero amplitude at its bottom where a coaxial probe is connected, preventing the energy from getting into the receiving port and hence achieving a high isolation level without requiring any extra decoupling structure. This self-decoupling method is applicable not only to 1-D H- and E-plane coupled MIMO linear arrays but also to 2-D MIMO planar arrays. To verify its feasibility, a prototype of 2 × 2 MIMO planar DRA	The results show that a usable bandwidth (vert S ii vert < -10 dB and vert Sij\vert < -20 dB) of 10.8% is achieved, and the maximum isolation is over 40 dB within the passband.

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				array is simulated, processed, and tested.	
Yang C.; Leung K.W.	3-D-Printed Wideband Circularly Polarized MIMO Dielectric Resonator Antenna	2023	IEEE Transactions on Antennas and Propagation	A 3-D-printed wideband circularly polarized (CP) multiple-input-multiple-output (MIMO) antenna is proposed. This antenna consists of two CP dielectric resonator antennas (DRAs) which are covered by a dielectric decoupler. With this decoupler, the center-to-center distance between the two DRAs can be made as small as 0.33 λ 0 with a high isolation, where λ 0 is the operating wavelength in air. To verify the simulation, a prototype operating in X-band was designed, fabricated, and measured. Its measured -10-dB impedance bandwidth is 21.7% (8.88-11.04 GHz), within which the axial-ratio (AR) bandwidth and mutual coupling are less than 3 and -21.4 dB, respectively. The impedance and AR have a wide overlapping bandwidth of 21.7%.	
Liu Y.-T.; Zhao W.; Ma B.; Huang S.; Ren J.; Wu W.; Ma H.-Q.; Hou Z.J.	1-D Wideband Phased Dielectric Resonator Antenna Array With Improved	2023	IEEE Transactions on Antennas and Propagation	A 1-D wideband phased array of the rectangular ring dielectric resonator antenna (RRDRA) is presented for millimeter-wave (mmWave)	Reasonable agreement between the measured and simulated results is observed.

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	Radiation Performance Using Characteristic Mode Analysis			applications. By using the characteristic mode analysis, it is found that the unwanted higher order mode (HOM) of the RRDRA results in severe gain degradation and high cross-polarization when the array scans. To remedy the problem, each RRDRA is loaded with a pair of silver strips. They can suppress unwanted HOM and enable good scanning performance in a wide frequency range. To demonstrate the idea, a 1 × 4 phased RRDRA array was designed, fabricated, and measured for the licensed mmWave bands (24.25-29.5 GHz).	
Parvathi V.L.; Rajput A.; Raut R.B.; Mukherjee B.	A Novel Low-profile Rectangular Dielectric Resonator Antenna with enhanced gain for 5G New Radio band applications	2023	Microwave and Optical Technology Letters	A wideband low-profile chamfered rectangular dielectric resonator antenna (RDRA) with high gain is proposed for sub-6 GHz 5G new radio band applications. RDRA is excited with microstrip cross-slot aperture coupling which is employed on the substrate. The dielectric resonator antenna with low-profile produces unwanted back radiation. The reflector placed at the bottom side of the RDRA is accountable for gain	The proposed antenna offers 2.74–4.35 GHz impedance bandwidth and 9.1 dBi peak gain. The proposed design is fabricated and experimentally verified.

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				improvement on boresight direction by reducing back radiation. Slits, introduced on the copper layer, help to control the phase difference between direct waves and reflected waves. A rectangular stub is added to microstrip feed to enhance the impedance matching between excitation port and the antenna.	
Cheh Lin I.K.; Jamaluddin M.H.; Gaya A.	A Triple Band Substrate Integrated Waveguide with Dielectric Resonator Antenna for 4G and 5G Applications	2023	Micromachines	A triple-band substrate integrated waveguide (SIW) with dielectric resonator antenna (DRA) for fourth-generation (4G) and fifth-generation (5G) applications is proposed and analyzed in this paper. Loading SIW with DRA allows for a wide bandwidth, low losses, and fabrication ease. The proposed antenna can transmit and receive data independently by covering LTE Band 3 at 1.8 GHz, LTE Band 8 at 2.6 GHz, and 5G n77 at 3.7 GHz. A U-shaped cut is applied to achieve the targeted multi-resonance frequencies. The antenna obtains high bandwidths of up to 19.50% with 4.9 dBi gain and 81.0% efficiency at 1.8 GHz, 6.58% bandwidth with 4.4 dBi and 72.7% efficiency at 2.6 GHz, and 8.21%	. The simulated and measured results agree well. The proposed antenna is feasible for 4G and 5G applications.

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				bandwidth with 6.7 dBi and 73.5% efficiency at 3.7 GHz.
Qasaymeh Y.	An eight-element sequentially rotated crescent-slot-coupled dielectric resonator antenna array for WIFI applications	2023	International Journal of Communication Systems	In this communication, the author presents an eight-element sequentially rotated (SR) circularly polarized (CP) dielectric resonator antenna (DRA) for operation in the IEEE 802.11a standard. A novel resonating element composed of a crescent slot (CS) used to excite a rectangular dielectric resonator (RDR) is proposed that has two orthogonal modes (Formula presented.) and (Formula presented.) as required for CP radiation. An SR series–parallel geometry is used to prototype the array feed network to allocate the array elements to symmetrical positions. The phase progression of each element was 45° along the array, and the signal magnitude was distributed evenly based on the binomial theory to enhance the antenna performance. The prototyped SR array had a size of (Formula presented.) mm3 and was measured and characterized in order to authenticate the design. The

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	resonance bandwidth (S11 < −10 dB) was found to be 14.28% with a 3 dB axial ratio (AR) of 17.7% for right-hand CP. The gain varied from 15.71 to 16.26 dBi within the operating band. The size, gain, and impedance bandwidth of the proposed array make it a potential candidate for devices operating in the IEEE 802.11a band. © 2023 John Wiley & Sons Ltd.

ANALISIS AND DISCUSSION

The results of dielectric properties of CCTO always vary when different techniques had been used. It is hope that after using plasma spray method, it can give a better result in term of microstructure and dielectric properties of CCTO. Recent developments in millimeter-wave DRA technology have been presented and discussed in detail in this survey.Furthermore, useful design guidelines have been provided to RF front-end designers in order to control circuital characteristics and radiation properties of this class of antennas. Different feeding techniques for DRAs have been first introduced, while outlining the relevant advantages and disadvantages. Furthermore, design approaches useful to achieve size reduction of DRAs have been discussed in detail. By using high permittivity materials or by placing conducting plates along specific symmetry planes of the resonator body, one can make DRAs considerably smaller. On the other hand, the gain of a DRA can be increased either by exciting therelevant higher-order modes (electrically large DRAs), or by integrating horn-like structures. Particular attention has been put on hybrid design techniques which rely on the combination of DRAs and radiating patch/slot antennas. In this way, the antenna impedance bandwidth can be easily tuned in such a way as to synthesize a dual-band rather than wide-band frequency response. Circular polarization of the electromagnetic field radiated by DRAs can be achieved by using various design methodologies.

In this respect, the cross-shaped feeding slot-based approach provides different benefits in terms of high coupling to the DR and additional degrees of freedom to control the polarization purity (axial ratio) of the DRA, in combination with ease of manufacturing and integration. Finally, advances in the application of DRA technology at millimeter-wave frequencies have been presented, and the most recent implementation of onchip DRAs and off-chip DRAs has been reviewed. It has been shown that DRAs realized on silicon substrates with standard CMOS process can be characterized by good efficiency and gain, thus proving the good potential of dielectric resonator antennas for said applications. Expected outcomes include a deeper understanding of CCTO's influence on DRA enhancement, a synthesis of diverse findings, and the identification of key factors influencing the performance of CCTO-enhanced DRAs. The review's conclusion will consolidate the observed outcomes, highlighting the progress made, challenges encountered, and potential avenues for further exploration in this burgeoning field of research, thus providing valuable guidance for researchers and practitioners in advancing dielectric material integration for
enhanced antenna technologies.

In this study, a novel approach to designing a dual-band, dual-sense circularly polarized (CP) antenna with a bandstop filtering response is presented. This is achieved through the integration of an irregular-shaped dielectric resonator (ISDR) and a dual-composite right/left-handed (D-CRLH)-based feeding network. Initially, the rectangular dielectric resonator (rDR) is employed to create dual-band, linearly polarized (LP) operation through

the excitation of TEy111 and TEy113 modes using an offset feeding slot. Techniques like edge-cuts and an impedance transformer are introduced to mitigate the effects of offset feeding. Subsequently, a second microstrip line and offset feeding slot are utilized to excite TEx111 and TEx113 modes of the dielectric resonator antenna (DRA), enabling dual-LP in two frequency bands, with the addition of corner truncation to reduce cross-polarized fields. The design then evolves to achieve dual-sense CP operation using a D-CRLH resonator-based feeding network. The resulting antenna is manufactured using 3D printing technology for practical demonstration.Additionally, a tunable wideband CP dielectric resonator antenna (DRA) is designed, with circular polarization achieved through slot coupling and the excitation of different modes. Graphene coating on the radiating dielectric resonator enables tunability. Another compact DRA is proposed for ultra-wideband (UWB) applications, utilizing a composite feeding structure to excite resonant modes on a dielectric resonator placed on a fractal triangular patch. The prototype of this antenna is validated through measurements.Furthermore, the research reports on the microwave dielectric properties of 0.95MgTiO3−0.05CaTiO3 (MCT) ceramic for sub-6 GHz frequency 5G applications. The solid-state reaction technique is employed to develop the MCT ceramic, and its structural and dielectric properties are thoroughly examined. X-ray diffraction is used to analyze the crystalline phase, while microwave dielectric properties, such as relative permittivity, temperature coefficient of resonant frequency, and quality factor, are measured.In conclusion, these studies showcase innovative approaches to antenna design, including dual-band, dual-sense CP operation, tunable CP operation, and UWB applications, as well as the exploration of microwave dielectric materials for 5G communication technologies, contributing to the advancement of wireless communication systems

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The research article presents two innovative approaches in the realm of dielectric resonator antenna (DRA) arrays, focusing on multi-input multi-output (MIMO) configurations. The first investigation introduces a novel self-decoupling method for MIMO DRA arrays. This method capitalizes on the conformal strip feeding the DRA and exploits the transmission characteristics of this setup. Notably, when the strip-fed DRA operates in a higher order mode, such as the TE113 mode, a standing-wave distribution of the E-field occurs, coupled to the metal strip of an adjacent passive DRA. By meticulously adjusting the dimensions of the feeding strip, an E-field node with zero amplitude is established at the strip's bottom. This node corresponds to the location where a coaxial probe is connected. This ingenious configuration effectively hinders energy from reaching the receiving port, achieving a remarkable isolation level without necessitating supplementary decoupling structures. This self-decoupling methodology is versatile, as it applies to both 1-D H- and E-plane coupled MIMO linear arrays as well as 2-D MIMO planar arrays. The feasibility of the approach is substantiated through simulations and practical testing of a 2 × 2 MIMO planar DRA array prototype.

In the second investigation, the study proposes a 3-D-printed wideband circularly polarized (CP) MIMO antenna, comprising two CP dielectric resonator antennas (DRAs) enveloped by a dielectric decoupler. The decoupler's introduction allows for a close center-to-center distance between the two DRAs, achieving a remarkable isolation even at small separation distances of 0.33 λ 0 (where λ 0 is the operating wavelength in air).

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The article showcases the design, fabrication, and measurement of a prototype operating in the X-band. The achieved results highlight a significant -10 dB impedance bandwidth of 21.7% (8.88-11.04 GHz), with axial-ratio (AR) bandwidth and mutual coupling staying below 3 and -21.4 dB, respectively. Remarkably, the impedance and AR display a wide overlapping bandwidth of 21.7%, reinforcing the effectiveness and practical viability of the proposed design.

In conclusion, the two presented studies offer innovative solutions to the challenges in MIMO DRA arrays. The first study's self-decoupling method offers a promising avenue for achieving high isolation without additional complex decoupling structures, while the second study's approach to 3-D-printed CP MIMO antennas underscores the feasibility of achieving robust performance in a compact design. These findings contribute to the advancement of MIMO antenna technology, opening doors to enhanced wireless communication systems and applications.

The two research articles discussed in this comprehensive overview showcase novel and ingenious approaches to designing advanced dielectric resonator antenna (DRA) arrays, with a particular focus on multi-input multi-output (MIMO) configurations. These studies contribute significantly to the field of wireless communication systems and antenna technology, offering innovative solutions to enhance performance, isolation, and bandwidth in various applications.

The first study introduces a pioneering self-decoupling method for MIMO DRA arrays. This method leverages the unique transmission characteristics of a conformal strip that feeds the DRA. The authors demonstrate that by operating the strip-fed DRA in a higher order mode, such as the TE113 mode, a standing-wave distribution of the E-field is generated, interacting with the metal strip of an adjacent passive DRA. Through careful adjustments of the feeding strip's dimensions, a strategically positioned E-field node with zero amplitude is established at the bottom of the strip. This spatial configuration, where a coaxial probe is connected, effectively prevents energy from entering the receiving port. The result is a remarkable isolation level achieved without the need for extra decoupling structures. Importantly, this method's versatility extends to both 1-D H- and E-plane coupled MIMO linear arrays, as well as 2-D MIMO planar arrays. The feasibility of this approach is validated through simulations and practical testing of a 2 × 2 MIMO planar DRA array prototype.

In the second study, the researchers propose an innovative 3-D-printed wideband circularly polarized (CP) MIMO antenna, featuring two CP dielectric resonator antennas (DRAs) covered by a dielectric decoupler. This decoupler allows for a remarkably close center-to-center distance between the two DRAs, ensuring high isolation even at a minimal separation distance of 0.33 λ 0 (where λ 0 is the operating wavelength in air). The study presents the comprehensive design, fabrication, and measurement of a prototype operating in the X-band. The achieved results impressively demonstrate a substantial -10 dB impedance bandwidth of 21.7%, coupled with an axial-ratio (AR) bandwidth and mutual coupling levels maintained below 3 and -21.4 dB, respectively. Notably, the overlapping bandwidth of 21.7% between the impedance and AR highlights the effectiveness of this design in achieving superior performance.

CONCLUSIONS

In conclusion, both research articles exemplify the continual advancement of antenna technology, particularly in the realm of MIMO DRA arrays. The proposed self-decoupling method and the innovative 3-D-printed CP MIMO antenna offer distinct contributions to enhancing wireless communication systems. These findings have the potential to revolutionize wireless technology applications and stimulate further research in the field. As we move toward increasingly complex communication needs, these studies provide essential stepping stones toward more efficient, high-performance antenna systems.

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