Eurasian Journal of Analytical Chemistry
ISSN: 1306-3057 OPEN ACCESS 2017 12 (3): 144-151

Microstrip Patch Antenna Miniaturization Using Magneto Dielectric Ferrite Substrates

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Received: 10 November 2016 ▪ Revised: 13 December 2016 ▪ Accepted: 12 January 2017

Abstract: Antenna miniaturization with enhanced radiation performance is a contemporary problem with application in RF and wireless systems. The substrate and ground plane of the antenna play a very important role in achieving the desired antenna characteristics. The synthesis of substrate electronic nano material is going to play a very important role for achieving the desired antenna parameters in GHz and THZ range. The prime objective here is miniaturize the size of the antenna and increase the values of other desired parameters. Microstrip patch antenna is proposed, to reduce the interaction of the antenna with its ground and design a miniaturized wideband antenna system. We presented a detailed survey upon the most recent research efforts associated with those metamaterials based antennas. It is found that magneto dielectric substrate can be used for both the antenna miniaturization as well as band width enhancement; however periodic magneto- dielectric is basically to maximize the bandwidth of the miniaturized antenna. It has been realized that the emergence of metamaterials has implications to nearly all branches of science and engineering exploiting the EM radiation.

Keywords: EM Radiation, Voltage Standing Wave Ratio (VSWR), VSM (Vibrating Sample Magnetometer).

INTRODUCTION

The Substrates used in microstrip antenna is primarily provide mechanical strength to antenna, the dielectric medium allows surface waves to propagate through it which will extract some part of total power available for radiation which degrades the electrical properties of antenna. The cost of antenna design is also effected by dielectric material, hence it require intelligent decision while selecting substrate. Generally a dielectric substrate is defined by its two prime parameters one is its permittivity (It describes the materials with high polarizability) and another is loss tangent (It explains the dissipation of electromagnetic energy), $\varepsilon=\varepsilon_r\varepsilon_0(1-J\mathrm{Tan}\delta)$. for loss less materials there is no loss tangent ($\mathrm{Tan}\delta=0$) the permittivity is real and is $\varepsilon=\varepsilon_r\varepsilon_0$ In present paper rectangular micro strip antenna in its simplest form consisting of sandwich of two conducting layers separated by single thin dielectric substrate is considered, where lower conductor function as ground plane and upper conductor function as radiator. Larger ground plane gives better performance but makes the antenna size bigger.

This is excited with coaxial feed. At resonate frequency of 2.0420GHz. The frequency bandwidth of a micro strip patch antenna depends primarily on both the thickness and dielectric permittivity of substrate. A thick substrate with low dielectric permittivity can increase the band width of printed patch. If the thickness of substrate increases create 1) difficulty in integration of antenna with other microwave circuits, 2) surface wave propagation and the large inductive image part of input impedance of antenna which makes its resonance unfeasible. Hence a reasonable band width of 1.56mm used in present project common for simulation all substrates.

In its most basic form, a micro strip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. A 2 rectangular patch is used as the main

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radiator. There are several advantages of this type of patch antenna, such as being planar, small in size, simple in structure, low in cost, and easy to be fabricated. Thus, it is attractive for practical applications like Bluetooth, Wi-Fi, Microwave oven, GPS.

The most important advantage of ferrites is their very high degree of compositional variability. Most of the original intrinsic properties on ferrites are made on the simple ferrites such as MnFe2O4, CoFe2O4 and MgFe2O. However, most commercially important ferrites are of the mixed variety and actually consist of solid solutions of the various simple ferrites with infinite number of combinations possible. Depending on the requirements of the ultimate application, various combinations of different properties can be obtained by blending a judicious choice of the simple ferrites in a appropriate ratio.

In recent years, a lot of work has been done on nano crystalline materials because of their unusual properties compared to the properties of bulk materials. Several research groups are attempts to improve the electrical properties have been made by doping it with rare earth elements such as lanthanum (La), Praseodymium (Pr) Samarium (Sm), Gadolinium (Gd), Terbium (Tb) and Cerium (Ce) Dysprosium (Dy) etc. The dopant can be at the A site or the B site. A site being the edges of the perovskite cell and the B site being the centre of the perovskite cell. The present work is to Design Micro strip Antenna with a novel dielectric substrate (Lanthanum, Cerium doped Magnesium ferrite and study the effect of antenna parameters.

The dielectric substrate (Lanthanum, Cerium doped magnesium ferrite) was prepared be sol gel route method because the sol gel auto combustion synthesis process was used to syntheses pure and substituted magnesium ferrites. This process has the advantages of inexpensive precursors, low external energy consumption, a simple preparation method as well as simple equipment requirement that result into nano-sized, homogeneous, highly reactive powders. Auto combustion synthesis, also called self-propagating synthesis, was initially developed in Russia by Merzhanov and had been successfully used to speed up the synthesis of complex oxide material such as ferrites and high temperature superconductors.

Microstrip antennas are popular and are getting increased attention due to their advantages. Depending upon the application, microstrip antennas having different geometrical shapes are used .Nowadays, researchers are interested in the design and development of compact microstrip radiating elements. In literature, the authors have experimentally demonstrated the development of compact microstrip antenna. Many techniques have also been studied in order to overcome the narrow impedance bandwidth of microstrip patch antenna.

Among the various techniques, there have been the popular ones such as use of increased substrate thickness, the use of a low dielectric constant substrate, the use of air filled dielectric medium, use of various impedance matching and feeding techniques, the use of multiple resonators, and the use of slot antenna geometry and so on. In particular, the slot technique shows excellent improvement characteristics suitable for microstrip antennas with air as dielectric substrate medium. Since coaxial probe feeding technique is adopted and it introduces capacitance between the feed and the radiating patch and this capacitance cancels out the inductance due to a probe itself, this effect makes it possible to improve the impedance bandwidth of the microstrip patch antenna and the improvement in gain is also achieved.

PROPOSED SYSTEM

Microstrip patch antenna used to send on board parameters of article to the ground while under operating conditions. The aim of the thesis is to prepare a novel material for satisfying the conditions to obtain a desire epsilon r and tan delta for designing E shaped micro strip patch antenna. To design Microstrip patch Antenna and study the effect of antenna dimensions Length (L), Width (W) and substrate parameters relative Dielectric constant (εr), substrate thickness (t) and Antenna parameters Return Loss, Voltage Standing Wave Ratio (VSWR), Directivity, Gain and Efficiency, on the Radiation parameters of Bandwidth and Beam-width.

Selection of proper substrate material is prime important task in microstrip patch antenna design. Because the limitations of micro strip antenna such as low gain, low efficiency and high return loss can overcome by selecting proper substrate materials, because permittivity of substrate is critical parameter in controlling band width, efficiency, and radiation pattern of patch antenna. The substrate materials have two basic properties such as dielectric constant and loss tangent.

Present paper comprehensive study of various dielectric materials and its effect on radiation characteristics of rectangular patch antenna such as resonance frequency, bandwidth, gain, return loss,

input impedance, radiation pattern, and current distributions are investigated. The dielectric materials selected here having zero loss tangent.

The frequency bandwidth of a micro strip patch antenna depends primarily on both the thickness and dielectric permittivity of substrate. A thick substrate with low dielectric permittivity can increase the band width of printed patch. If the thickness of substrate increases create 1) difficulty in integration of antenna with other microwave circuits, 2) surface wave propagation and the large inductive image part of input impedance of antenna which makes its resonance unfeasible. Hence a reasonable band width of 1.56mm used in present project common for simulation all substrates.

In our project main objective is reduced the return loss and increase the operating frequencies up to GHZ range. The nano powder is suitable for the application in multilayer chip inductor due to its low temperature sinter ability, good magnetic properties and low loss at high frequency. The antenna performance to best the others as the return loss achieves a greater negative value, voltage standing wave ratio achieves a value closer to the ideal value of 1 and the bandwidth achieved being maximum.

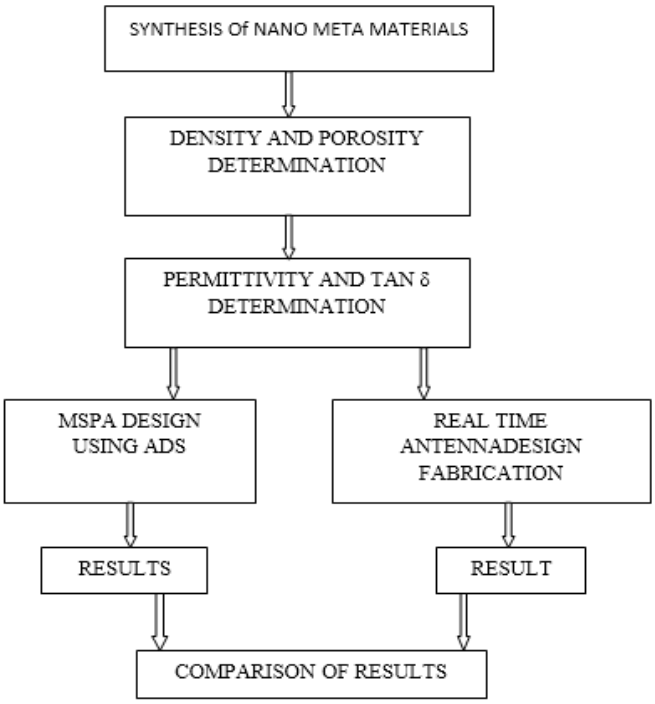
The return loss achieved for MSPA is of the minimum value of -26.66 dB and SWR value as 1.097 closest to the ideal value of 1. Very low return loss indicates that maximum amount of inputted power is converted into electromagnetic waves and very less amount of it is reflected back.

The microstrip patch antenna designed to enhance the electrical and magnetic properties and enhance the antenna parameters. The impedance bandwidths of reduced size patch antennas loaded with dispersive magneto dielectric substrates and high-permittivity substrates are compared. It is shown that unlike substrates with dispersion-free permeability, practically realizable artificial substrates with dispersive magnetic permeability are not advantageous in antenna miniaturization.

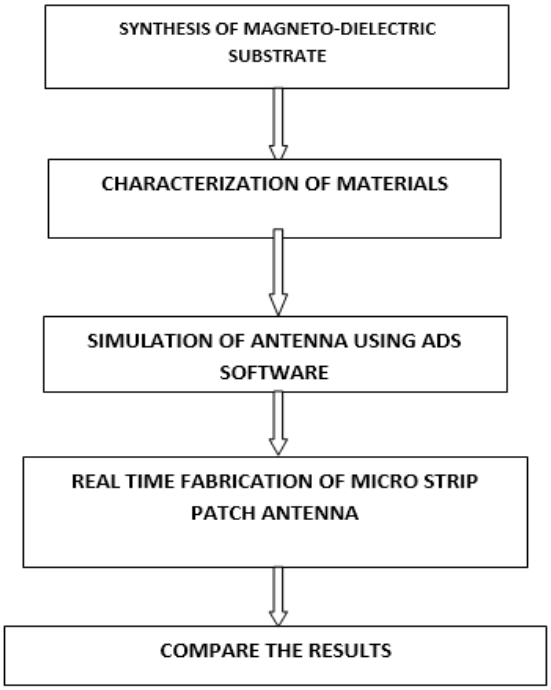
The sinter ability of combustion synthesized powder (≈900oC) is much better than that of conventional solid-oxide route powder. The composition of nano materials highest permeability, magnetization and lower loss factor among all the compositions studied here. The composition is highly suitable for application up to 4MHz frequency. Considering all the advantages, especially sinter ability below 960oC, the composition may be suggested as a better material for MLCI applications.

In its most basic form, a micro strip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. A rectangular patch is used as the main radiator. There are several advantages of this type of patch antenna, such as being planar, small in size, simple in structure, low in cost, and easy to be fabricated. Thus, it is attractive for practical applications like Bluetooth, Wi-Fi, Microwave oven, GPS.

METHODOLOGY



Work Plan



Simulation Software – ADS

Advanced Design System (ADS) is an electronic design automation software system produced by Agilent EEs of EDA, a unit of Agilent Technologies. It provides an integrated design environment to designers of RF electronic products such as mobile phones, [2] pagers, wireless networks, satellite communications, radar systems, and high- speed data links. Agilent ADS supports every step of the design process—schematic capture, layout, frequency-domain and time-domain circuit simulation, and electromagnetic field simulation—allowing the engineer to fully characterize and optimize an RF design without changing tools. Agilent EEs of has donated copies of the ADS software to the electrical engineering departments at many universities, and a large percentage of new graduates are experienced in its use. As a result, the system has found wide acceptance in industry.

In this study, a novel patch antenna optimized for simplicity in design and feeding is proposed. It has characteristic which will meet radar system application. Parameters of the antenna such as return loss, impedance bandwidth, radiation patterns and gains are discussed in this paper. This paper shows extensive benefits of 3D view of radiation pattern facility provided by the ADS software.

Design Specifications

The three essential parameters for the design of a rectangular Microstrip Patch Antennas are

- Frequency of operation (fo): The resonant frequency of the antenna must be selected appropriately. The military application uses the frequency range at 3 GHz. Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for my design is 3 GHz.
- Dielectric constant of the substrate (εr): The dielectric material selected for my design is Lanthanum Cerium coated with RT duroid substrate which has a dielectric constant of 2.219. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna.

Height of dielectric substrate (h): For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.82 mm

RESULT AND DISCUSSION

XRD(X-Ray Diffraction study)

A careful analysis of the XRD patterns helps to determine the respective planes and face centered cubic structure of these ferrites. Well resolved peaks in XRD pattern clearly indicates the single phase and polycrystalline nature of the samples.

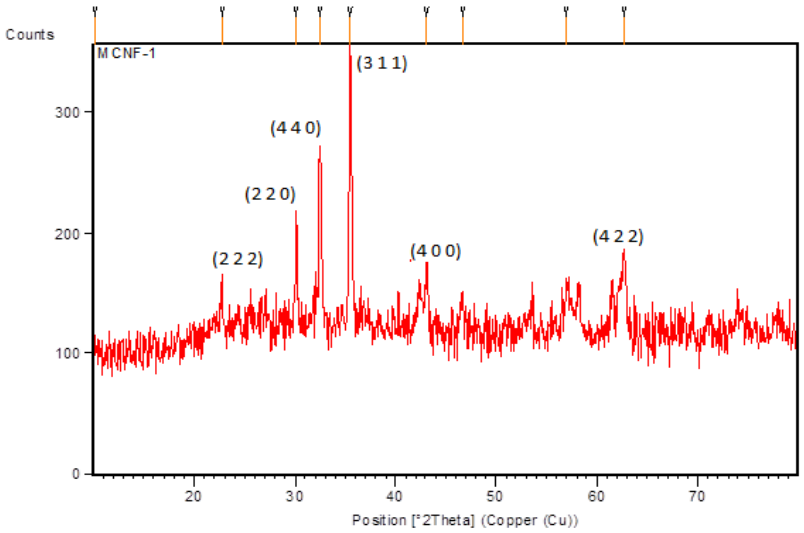


Fig. 1: XRD patterns of $MgCe_xNd_yFe_{2-x-y}O_4$

Figure shows XRD patterns of the $MgCe_xNd_yFe_{2-x-y}O_4$ sample. The diffraction patterns and relative intensities of all diffraction peaks are matched well with those of JCPDS card 22-1086 for $MgCe_xNd_yFe_{2-x-y}O_4$ and the Ce diffraction peaks matched well with those of JCPDS card 34-0394. The peaks appeared at around 28º, 33.555º, 42.47º, 56.535º, 59.087ºand 69.402ºfor Mg and Ce. These peaks were well indexed to the crystal plane of spinel ferrite (220), (311), (400), (422), (333) and (440) respectively.

The figure confirms that the diffraction peaks were sharp because of the micrometer size of the crystallite. The single-phase cubic spinel structure was clearly indicated by the XRD patterns of these pure $MgFe_2O_4$. The patterns also show that all the samples had formed the cubic single spinel phase. The lattice parameter a (Aº) was determined using Bragg's law.

$$a = d_{hkl}\sqrt{h^2 + k^2 + l^2}$$

Here h, k, l are the indices of mentioned planes. The crystal size was evaluated by measuring the FWHM of the most intense peak (311) from XRD figure. The size of the crystal was determined by using the Debye Scherrer's formula [16] , given as

$$D = \frac{0.94\lambda}{\beta cos\theta}$$

The lattice constants for all samples prepared in investigation are listed in Table 1. It was also seen that the lattice constants of individual phases did not show a large variation by the inclusion of Cerium.

Table 1: Parameters of XRD in MCNF with different samples

Pos.[°2Th.]	Height[cts]	FWHM Left [°2Th.]	d-spacing[A⁰]
10(1)	16(152)	1(9)	8.72263
22.75(6)	37(190)	0.2(4)	3.90600
30.10(2)	79(41)	0.16(9)	2.96677
32.46(2)	114(77)	0.2(1)	2.75615
43.1(2)	168(85)	0.19(8)	2.52958
47(3)	51(335)	0(1)	2.09627
57.0(4)	40(1507)	1(22)	1.94450

VSM (Vibrating Sample Magnetometer)

The permeability of this material also calculated by using the magnetic saturation obtained from the hysteresis curves. Fig.3 show the variations in saturation magnetization (M_S) for the different x values of nano composite $MgNd_xCe_yFe_{(2-x-y)}O_4$, the saturation magnetization (M_S) value increases with the increase in value of x.

This is due to the increasing Cerium content, which induced a polar-to-non polar phase transition. It is also seen that the Ce substitution resulted in the appearance of spontaneous magnetization, which was significantly enhanced upon the composition-driven transition from a rhombohedra to an orthorhombic phase.

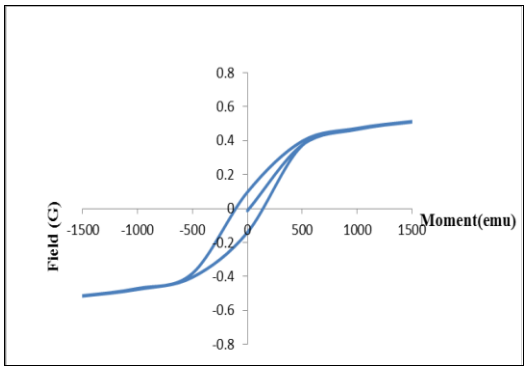


Fig. 2: Hysteresis loop of $MgCe_xNd_yFe_{2-x-y}O_4$

The coercive force show linear increase initially and later shows a gradual decrease with the increase in the doping concentration. The values of magnetic parameters such as M_S, H_C, M_R of nano particles of $MgNd_xCe_yFe_{(2-x-y)}O_4$obtained from the VSM data. Therefore the increase in saturation magnetization can be attributed to the effect of nano regime on it. The difference in the value of M_S can be explained in the light of cation distribution. Any change in the concentration and nature of the ions in A and B site should cause resultant magnetization to be different.

CONCLUSION

The observation of antenna parameters table and radiation pattern diagrams we can conclude that the increment of substrate dielectric constant in antenna design, results degradation of performance characteristics. Antenna parameter table the gain, directivity radiation efficiency. A single slot rectangular microstrip antenna consists of a substrate patch with slot embedded on patch and placed above the ground plane, developed for various wireless applications. Compared with a conventional patch antenna, it has a better omni directional radiation pattern and provides an increase in bandwidth up to 9.41 % (320 MHz) with a compactness of 21 %. Hence, the proposed antenna is quite easy in design, fabrication and implementation and uses low-cost dielectric material as cost effective method. The reduction of surface waves due to lowering of effective dielectric constant can reduce the end fire radiation, decreasing interference with devices in proximity to the antenna and may lead to more compact structure. The real time antenna testing was done in GHz ranges due to shortage of instruments. Or else the antenna can be worked in THz range also.

REFERENCES

[1] Krishnamoorthy, P., & Jayalakshmi, T. (2012). Preparation, characterization and synthesis of silver nanoparticles by using phyllanthusniruri for the antimicrobial activity and cytotoxic effects, *Journal of Chemical and Pharmaceutical Research, 4*(11), 4783-4794.

[2] Amir, M., Gungunes, H., Slimani, Y., Tashkandi, N., El Sayed, H.S., Aldakheel, F., Sertkol, M., Sozeri H., Manikandan A., Ercan, I., & Baykal, A. (2019). Mössbauer studies and magnetic properties of cubic CuFe 2 O 4 nanoparticles. *Journal of Superconductivity and Novel Magnetism*, *32*(3), 557-564.

[3] Annie, J.P., Dr. Paul, S., & Dr. Ponmary Pushpalatha, D. (2014). Decision Tree Analysis to Predict Traffic Congestion in Transport Routing. *International Scientific Journal on Science Engineering & Technology, 17*(10), 905-910.

[4] Asha, R.S., & Dr.Jayasree V.K., (2015). Simulative Investigation of Coherent Optical OFDM Communication with Gbits/s Data Rates. *Bonfring International Journal of Research in Communication Engineering, 5*(3), 22-26.

[5] Tsai, C.I., & Lo, C.H., (2014). Integrating Phosphorylation and Catalytic Sites Information into AH-DB. *The SIJ Transactions on Computer Science Engineering & its Applications, 2*(4), 54-58.

[6] Bhasker, B., & Dr.Murali, S. (2019). Networks Flaws and Filtering Using KNOD Algorithms. *Bonfring International Journal of Software Engineering and Soft Computing, 9*(2), 36-39.

[7] Chávez, J.J.G., & Rodrigues, C.K.D.S. (2015).A Simple Algorithm for Automatic Hopping among Pools in the Bitcoin Mining Network. *The SIJ Transactions on Computer Networks & Communication Engineering (CNCE), 3*(1), 6-11.

[8] Beena Ullala Mata, B.N., & Dr. Meenakshi, M. (2018). Mammogram Image Segmentation by Watershed Algorithm and Classification through k-NN Classifier. *Bonfring International Journal of Advances in Image Processing, 8*(1), 01-07.

[9] Dr.Prabavathy, K. (2018). Enhanced Information Retrieval System (E-IRIS) for Named Entity Recognition. *Journal of Computational Information Systems, 14*(3), 108 - 112.

[10] Maalini, D., & Balraj, E. (2018). Secured and Energy Efficient Packet Transmission in Wireless Sensor Networks using Flooding protocol and AES Algorithm. *Journal of Computational Information Systems, 14*(4) 7 - 13.

[11] Dr.Kathirvelu, M., Sethuramalingam, N., Vignesh, M., Vijayakumar, K., & Vasudevamoorthy, L.(2015). Low Cost Music Mixture Module for Entertainment Industry. *International Journal of Advances in Engineering and Emerging Technology, 7*(3), 152-155.

[12] Chandrakala, K., Meenakshy, L., Nivedha, S., Priyanka, P., & Punithalakshmi, R. (2015). A Cross Layer Based Modern Handover Algorithm for Mobile WiMAX. *International Journal of Advances in Engineering and Emerging Technology, 7*(4), 225-236.

[13] Raj, M.S., Saravanan T., & Srinivasan, V. (2014). A modified direct torque control of induction motor using space vector modulation technique. *Middle - East Journal of Scientific Research, 20*(11), 1572-1574.

[14] Khanaa, V., & Thooyamani, K.P. (2013). Using triangular shaped stepped impedance resonators design of compact microstrip quad-band. *Middle-East Journal of Scientific Research*, *18*(12), 1842-1844.

[15] Asiri S., Sertkol M., Güngüneş H., Amir M., Manikandan A., Ercan I., & Baykal A. (2018). The Temperature Effect on Magnetic Properties of NiFe 2 O 4 Nanoparticles. *Journal of Inorganic and Organometallic Polymers and Materials, 28*(4), 1587-1597.

[16] Thaya, R., Malaikozhundan, B., Vijayakumar, S., Sivakamavalli, J., Jeyasekar, R., Shanthi, S., Vaseeharan, B., Ramasamy, P., & Sonawane, A. (2016). Chitosan coated Ag/ZnO nanocomposite and their antibiofilm, antifungal and cytotoxic effects on murine macrophages. *Microbial pathogenesis*, *100*, 124-132.

[17] Kolanthai, E., Ganesan, K., Epple, M., & Kalkura, S.N. (2016). Synthesis of nanosized hydroxyapatite/agarose powders for bone filler and drug delivery application. *Materials Today Communications*, *8*, 31-40.

[18] Thilagavathi, P., Manikandan, A., Sujatha, S., Jaganathan, S.K., & Arul Antony, S. (2016). Sol–Gel Synthesis and Characterization Studies of NiMoO4 Nanostructures for Photocatalytic Degradation of Methylene Blue Dye. *Nanoscience and Nanotechnology Letters*, *8*(5), 438-443.

[19] Thamotharan C., Prabhakar S., Vanangamudi, S., & Anbazhagan, R. (2014). Anti-lock braking system in two wheelers. *Middle - East Journal of Scientific Research, 20*(12), 2274-2278.

[20] Thamotharan C., Prabhakar S., Vanangamudi, S., Anbazhagan, R., & Coomarasamy C. (2014). Hydraulic rear drum brake system in two wheeler. *Middle - East Journal of Scientific Research, 20*(12), 1826-1833.

[21] Vanangamudi, S., Prabhakar S., Thamotharan C., & Anbazhagan, R. (2014). Collision control system in cars. *Middle - East Journal of Scientific Research, 20*(12), 1799-1809.

[22] Vanangamudi S., Prabhakar S., Thamotharan C., & Anbazhagan R. (2014). Drive shaft mechanism in motor cycle. *Middle - East Journal of Scientific Research, 20*(12), 1810-1815.

[23] Anbazhagan R., Prabhakar S., Vanangamudi S., & Thamotharan C. (2014). Electromagnetic engine. *Middle - East Journal of Scientific Research, 20*(3), 385-387, 2014.

[24] Kalaiselvi, V.S., Prabhu, K., & Mani Ramesh, V.V. (2013). The association of serum osteocalcin with the bone mineral density in post-menopausal women. *Journal of clinical and diagnostic research: JCDR*, *7*(5), 814-816.

[25] Kalaiselvi, V.S., Saikumar, P., & Prabhu, K. (2012). The anti mullerian hormone-a novel marker for assessing the ovarian reserve in women with regular menstrual cycles. *Journal of clinical and diagnostic research: JCDR*, *6*(10), 1636-1639.

[26] Arul, K.T, Manikandan, E., Ladchumananandasivam, R., & Maaza, M. (2016). Novel polyvinyl alcohol polymer based nanostructure with ferrites co-doped with nickel and cobalt ions for magneto-sensor application. *Polymer International*, *65*(12), 1482-1485.

[27] Das, M.P., & Kumar, S. (2015). An approach to low-density polyethylene biodegradation by Bacillus amyloliquefaciens. *3 Biotech*, *5*(1), 81-86.

[28] Vanangamudi S., Prabhakar S., Thamotharan C., & Anbazhagan, R. (2014). Turbo charger in two wheeler engine. *Middle - East Journal of Scientific Research, 20*(12), 1841-1847.

[29] Vanangamudi S., Prabhakar S., Thamotharan C., & Anbazhagan, R. (2014). Design and calculation with fabrication of an aero hydraulwicclutch. *Middle - East Journal of Scientific Research, 20*(12), 1796-1798, 2014.

[30] Saravanan, T., Raj, M.S., & Gopalakrishnan, K. (2014). VLSI based 1-D ICT processor for image coding. *Middle-East Journal of Scientific Research*, *20*(11), 1511-1516.

[31] Ajona, M., & Kaviya, B. (2014). An environmental friendly self-healing microbial concrete. *International Journal of Applied Engineering Research*, *9*(22), 5457-5462.

[32] Hemalatha, R., & Anbuselvi, S. (2013). Physicochemical constituents of pineapple pulp and waste. *Journal of Chemical and Pharmaceutical Research*, *5*(2), 240-242.

[33] Langeswaran, K., Revathy, R., Kumar, S.G., Vijayaprakash, S., & Balasubramanian, M.P. (2012). Kaempferol ameliorates aflatoxin B1 (AFB1) induced hepatocellular carcinoma through modifying metabolizing enzymes, membrane bound ATPases and mitochondrial TCA cycle enzymes. *Asian Pacific Journal of Tropical Biomedicine*, *2*(3), S1653-S1659.

[34] Masthan, K.M.K., Babu, N.A., Dash, K.C., & Elumalai, M. (2012). Advanced diagnostic aids in oral cancer. *Asian Pacific Journal of Cancer Prevention*, *13*(8), 3573-3576.

[35] Asiri S., Güner S., Demir A., Yildiz A., Manikandan A., & Baykal, A. (2018). Synthesis and Magnetic Characterization of Cu Substituted Barium Hexaferrites. *Journal of Inorganic and Organometallic Polymers and Materials,* 28(3), 1065-1071.

[36] Vellayappan, M.V., Jaganathan, S.K., & Manikandan, A. (2016). Nanomaterials as a game changer in the management and treatment of diabetic foot ulcers. *RSC Advances*, *6*(115), 114859-114878.

[37] Vellayappan, M.V., Venugopal, J.R., Ramakrishna, S., Ray, S., Ismail, A.F., Mandal, M., Manikandan, A., Seal, S., & Jaganathan, S.K. (2016). Electrospinning applications from diagnosis to treatment of diabetes. *RSC Advances*, *6*(87), 83638-83655.

[38] Bavitra, K., Sinthuja, S., Manoharan, N., & Rajesh, S. (2015). The high efficiency renewable PV inverter topology. *Indian Journal of Science and Technology*, *8*(14), 1.

[39] Vanangamudi, S., Prabhakar, S., Thamotharan, C., & Anbazhagan, R. (2014). Design and fabrication of dual clutch. *Middle-East Journal of Scientific Research*, *20*(12), 1816-1818.

[40] Sandhiya, K., & Kaviya, B. Safe bus stop location in Trichy city by using gis. *International Journal of Applied Engineering Research*, *9*(22), 5686-5691.

[41] Selva Kumar, S., Ram Krishna Rao, M., Deepak Kumar, R., Panwar, S., & Prasad, C.S. (2013). Biocontrol by plant growth promoting rhizobacteria against black scurf and stem canker disease of potato caused by Rhizoctonia solani. *Archives of Phytopathology and Plant Protection*, *46*(4), 487-502.

[42] Sharmila, S., & Jeyanthi Rebecca, L. (2012). GC-MS Analysis of esters of fatty acid present in biodiesel produced from Cladophora vagabunda. *Journal of Chemical and Pharmaceutical Research*, *4*(11), 4883-4887.

[43] Ramkumar, M., Rajasankar, S., Gobi, V.V., Dhanalakshmi, C., Manivasagam, T., Thenmozhi, A.J., Essa, M.M., Kalandar, A., & Chidambaram, R. (2017). Neuro protective effect of Demethoxycurcumin, a natural derivative of Curcumin on rotenone induced neurotoxicity in SH-SY 5Y Neuroblastoma cells. *BMC complementary and alternative medicine*, *17*(1), 217.

[44] Selvi, S.A., & Sundararajan, M. (2016). A Combined Framework for Routing and Channel Allocation for Dynamic Spectrum Sharing using Cognitive Radio. *International Journal of Applied Engineering Research*, *11*(7), 4951-4953.

[45] Krupaa R.J., Sankari S.L., Masthan K.M.K., & Rajesh E. (2015). Oral lichen planus: An overview. *Journal of Pharmacy and Bioallied Sciences, 7,* S158-S161.

[46] Srividya, T., & Saritha, B. (2014). Strengthening on RC beam elements with GFRP under flexure. *International Journal of Applied Engineering Research*, *9*(22), 5443-5446.

[47] Kumar, J., Sathish Kumar, K., & Dayakar, P. (2014). Effect of microsilica on high strength concrete. *International Journal of Applied Engineering Research*, *9*(22), 5427-5432.

[48] Saraswathy, R., & Saritha, B. (2014). Planning of integrated satellite township at Thirumazhisai. *International Journal of Applied Engineering Research*, *9*(22), 5558-5560.

[49] Saritha, B., Ilayaraja, K., & Eqyaabal, Z. (2014). Geo textiles and geo synthetics for soil reinforcement. *International Journal of Applied Engineering Research*, *9*(22), 5533-5536.

[50] Iyappan, L., & Dayakar, P. (2014). Identification of landslide prone zone for coonoor taluk using spatial technology. *International Journal of Applied Engineering Research*, *9*(22), 5724-5732.