

DESIGN OF COMPACT MICROSTRIP PATCH ANTENNA WITH AND WITHOUT GROUND PLANE SLOT USING NEW NANO-COMPOSITE MATERIALS

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This paper has been enhanced the dimensions of the microstrip antenna namely; the height of the microstrip antenna with and without slot substrate and the width of the patch microstrip antenna, by using nano-composite materials which are composed of RT Duriod 5880 with nanofillers (Fumed Silica, Aluminum Oxide and Graphite). In this research, it has been innovated novel nano-composite materials as a substrate for the microstrip antenna by adding nano-fillers to RT Duriod. Also, it has been demonstrated that the height and width of the suggested model for the microstrip antenna smaller than the conventional rectangular microstrip antenna. The suggested nano-composite material has been investigated efficient and compact microstrip antenna, compact size, simple fabrication and increase radiation, bandwidth and surface wave power of microstrip antenna with and without slot.

1. INTRODUCTION

Antenna is a device that is used to transfer guided electromagnetic waves (signals) to radiating them in an unbounded medium, usually free space, and vice versa (i.e., in either the transmitting or receiving mode of operation) and each antenna is designed for a certain frequency band. Microstrip antennas consist of a metallic patch on a dielectric substrate, which has a grounded metallic plane at the opposite side and the patch has great variety of geometries such as square, rectangular, circular, triangular or elliptical. Microstrip patch antennas have various advantages such as low profile, light weight; easy fabrication and conformability to mounting hosts in addition size reduction and bandwidth enhancement are major design considerations for practical applications of microstrip antennas, but the major disadvantages of this type of antenna are low efficiency, low power, high Quality factor (Q), poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth [1, 2]. In radar and space communication applications patch antennas have attracted much interest due to their compactness and dual-frequency operation. Unfortunately, they have some shortcomings, including relatively low gain, narrow bandwidth, and sensitivity to fabrication errors. Rectangular and circular microstrip resonant patches have been used extensively in a variety of array configurations. As conventional antennas are often bulky and costly part of an electronic system, microstrip antennas based on photolithographic technology are seen as an engineering breakthrough [3, 4].

The antenna performance of microstrip patch antennas varies with different patch configurations and feeding methods. The most popular ones are the microstrip

line, coaxial probe, aperture coupling and proximity coupling. The common structures that used to feed patch antenna are coaxial probe feeds, microstrip line feeds, and aperture coupled feeds. The coaxial-fed structure is often used because of ease of matching its characteristic impedance to that of the antenna; and as well as the parasitic radiation from the feed network tends to be insignificant. In basic aperture coupled patch antenna the radiating microstrip patch element is etched on the top of the antenna substrate, and the microstrip feed line is etched on the bottom of the feed substrate. Microstrip line-fed structures are more suitable due to ease of fabrication and lower costs, but serious drawback of this feed structure is the strong parasitic radiation [2-5]. The microstrip line feed technique is selected in this paper. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a high dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. In order to design a compact microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance [5-7].

Most of materials are polymer/filler composites, and critical materials properties for the device design and packaging include the effective dielectric constant, dielectric loss and their frequency and filler concentration dependence. Models present a systematic theoretical investigation of the effective dielectric constant of polymer/filler composite materials, and its dependence on the filler concentration [8, 12]. A microstrip slot antenna is very small and lightweight, microstrip slot antenna which increases the bandwidth of the antenna. A microstrip slot antennas (slot antennas excited by a strip line) have been extensively used in military (aircraft, spacecraft, satellites, and missiles) and commercial (mobile radio and wireless communication systems) applications. These types of slot antennas have numerous promising features. For instance, they have light weight, small size, and low cost. In addition, they can be easily integrated with planar and nonplanar surfaces and have many degrees of freedom in their design. However, they have significant radiation in some undesired directions, and this radiation is very undesirable in some applications [13-15].

In the present work, a logical comparison has been carried out for the suggested models with suggested nano-composite materials and conventional rectangular microstrip antenna. Also, this paper has been explained the improvement in height of substrate and width of patch by using novel suggested nano-composite materials which compose of RT Duriod 5880 with nano-filler Fumed Silica, Aluminum Oxide and Graphite.

2. ANTENNA DESIGN

A microstrip antenna consists of conducting patch on a ground plane separated by dielectric substrate with thickness h and relative permittivity ϵ_r , as shown in Fig. 1. The conducting patch can be taken any shape but rectangular and circular configurations are the most commonly used configuration. The most typical substrates have a dielectric constant in range of 2.2 to 12. Thick substrates with high dielectric constant are desirable as they provide better efficiency, larger bandwidth and loosely bound

fields for radiation into space and high dielectric constant substrates are generally preferred for maximum radiation [4, 5].

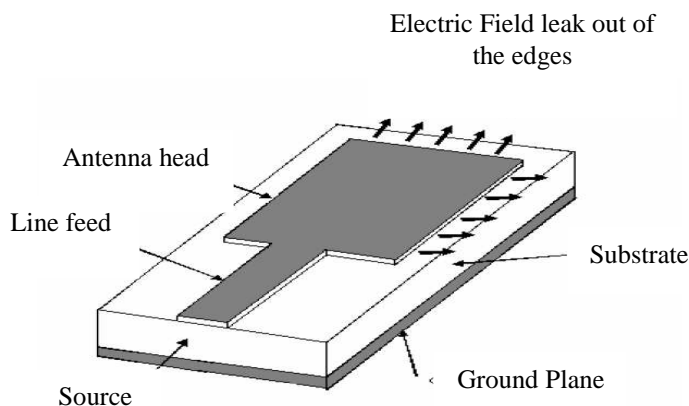


Fig. 1 Microstrip antenna model

Thick substrates with high dielectric constant (2.2-12) are desirable as they provide better efficiency, larger bandwidth and loosely bound fields for radiation into space and high dielectric constant substrates are generally preferred for maximum radiation whatever, at thin substrates with high dielectric constant (2.2-12) are usually applied in microwave circuitry because of their minimized undesired radiation and coupling, and the smaller sizes of their elements [5].

The length and the width of a patch can be found by a mixture of analytical analysis and empirical methods. Patch width has a minor effect on the resonant frequency and radiation pattern of the antenna. A larger patch width increases bandwidth, and radiation efficiency. With proper excitation one may choose a patch width W greater than the patch length L without exciting undesired modes. It can be seen that the width can be calculated from [3, 4]:

$$W = \frac{c}{2 f_r} \left(\frac{\epsilon_r + 1}{2} \right)^{-0.5} \tag{1}$$

Also, the patch length determines the resonant frequency, and is a critical parameter in design because of the inherent narrow bandwidth of the patch. The length is found by calculating the half-wavelength value and then subtracting a small length to present the fringing fields effect. So, the length is given by [3, 4]:

$$l = \frac{c}{2 f_r \sqrt{\epsilon_{eff}}} - 2 \Delta l \tag{2}$$

$$\Delta l = 0.412 h \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h} + 0.813 \right)} \tag{3}$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} - \frac{\epsilon_r - 1}{2} \left(1 + \frac{12t}{W} \right)^{-0.5} \tag{4}$$

An important design step is to choose a suitable dielectric substrate of appropriate thickness h and loss tangent. The substrate dielectric constant ϵ_r plays a role similar to the substrate thickness. A high value of ϵ_r for the substrate will increase the fringing field at the patch periphery, and see the radiated power. Data of microstrip antenna with ground plane slot has been stated in appendix I, and the dimension of slot has been illustrated in figure 2.

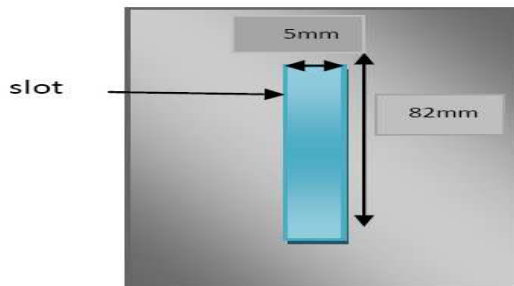


Fig. 2 Bottom view of the antenna With GPS.

3. SELECTED NANO-PARTICLES

In this research, it has been selected the following nano-particles for enhancing the performance of microstrip patch antenna:

- Fumed Silica is one of the most important filler that used in insulating materials, integrated circuits, electric components, conductors, and many other applications. Main advantages of Fumed Silica are costless and have a great effect on properties such as viscosity, stiffness and strength. Suggested nano-composite Fumed Silica with RT Duriod 5880 has been got high dielectric constant for compact size, simple fabrication and increase radiation.
- Aluminium Oxide is the family of inorganic compounds with the chemical formula Al_2O_3 . It is an amphoteric oxide and is commonly referred to as alumina, corundum as well as many other names, reflecting its widespread occurrence in nature and industry. Its most significant use is in the production of aluminium metal, although it is used as abrasive due to its hardness and as a refractory material due to its high melting point.
- Graphite is an electrical conductor (semimetal). It is, consequently, useful in such applications as arc lamp electrodes, and it is the most stable form of carbon under standard conditions. Therefore, it is used in thermo chemistry as the standard state for defining the heat of formation of carbon compounds. Graphite may be considered the highest grade of coal, just above anthracite and alternatively called meta-anthracite, although it is not normally used as fuel because it is hard to ignite [8, 12]. Data of all selected materials has been illustrated in appendix I.

4. RESULTS AND DISCUSSION

In this paper, all results and performance optimizations have carried out by using the commercial CST Microwave Studio and FDTD technique. Simulation results with CST

Microwave Studio are verified with FDTD technique. From the simulation of a Patch antenna with FDTD, it has been seen that the 3D FDTD method is a good technique for predicating electric field propagation. The FDTD technique can be used to generate wide frequency responses with no change in modeling. Also it provides a near complete solution of Maxwell's equations in a 3D model.

4.1 Effect of Nano-Composite Materials on Microstrip Patch Antenna

Table 1. Parameters of conventional and suggested models

Substrate material	ϵ	Radiation efficiency dB	Directivity dBi	Frequency MHz
RT Duriod 5880 conventional without slot	2.2	0.5099	7.763	1800
RT Duriod 5880 with wt 20% fumed silica without slot	2.6	0.4867	7.562	1674
RT Duriod 5880 with wt 20% Aluminum Oxide without slot	3.76	0.8304	7.043	1414.8
RT Duriod 5880 with wt 20% Graphite without slot	4.48	0.9782	6.930	1303.2
RT Duriod 5880 conventional with slot	2.2	0.6595	5.281	915
RT Duriod 5880 with wt 20% fumed silica with slot	2.6	0.7452	4.566	855.6
RT Duriod 5880 with wt 20% Aluminum Oxide with slot	3.76	0.5399	4.181	735.9
RT Duriod 5880 with wt 20% Graphite with slot	4.48	1.209	4.247	683.33

Table 1 shows a comparison between conventional and suggested antenna models which composed RT Duriod 5880 with 20% wt nano-fillers (Fumed Silica, Aluminum Oxide and Graphite).

4.2 Effect of New Nano-particle Fumed Silica on Microstrip Antenna at Conventional Resonant Frequency

Figure 3 displays the return loss $S_{1,1}$ of microstrip antenna by using new nano-composite material (RT Duriod 5880 with 20% wt Fumed Silica), at the same resonant frequency 1800 MHz of microstrip antenna with slot and at the same resonant frequency 915 MHz of microstrip antenna without slot. It is noticed that, using suggested nano-composite materials have been enhanced, the radiation efficiency, bandwidth and surface wave power of microstrip antenna. Also, the dimensions of microstrip antenna have decreased as shown in table 2.

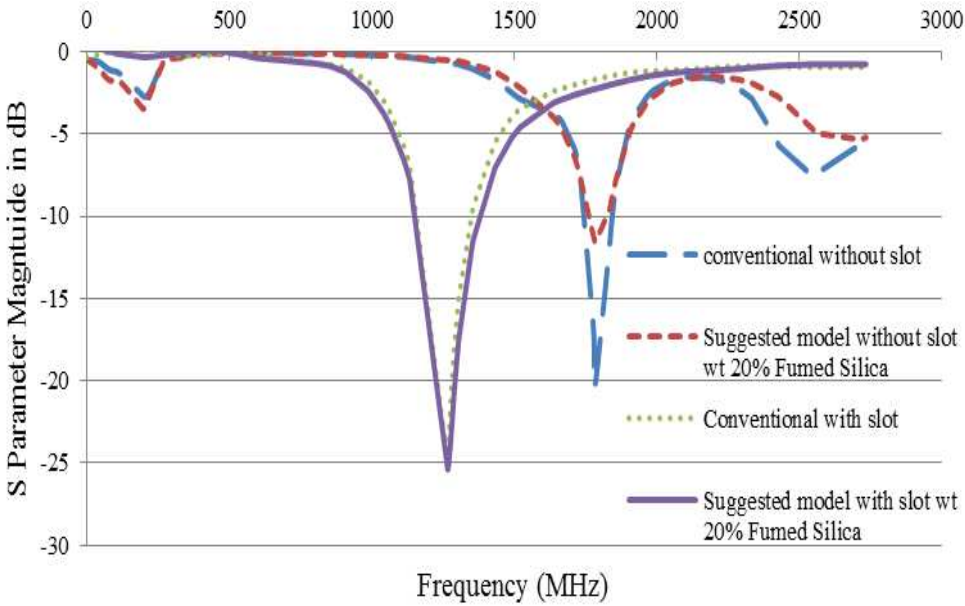


Fig.3. $S_{1,1}$ of suggested compact antenna with novel nano-composite materials

Table 2. Parameters of conventional and suggested models

Substrate material	ϵ	h mm	w mm	L mm	f MHz	Radiation efficiency
RT Duriod 5880 without slot	2.2	5.51465	74.6529	87.5783	1800	0.5470
RT Duriod 5880 with 20% wt fumed silica with slot	2.6	4.6	71	83	1674	0.4867
RT Duriod 5880 with slot	2.2	5.5146	74.653	87.578	915	0.6595
RT Duriod 5880 with 20% wt fumed silica with slot	2.6	5.3	68	72.1	855.6	0.7452

Using nano-composite materials (RT Duriod 5880 with Aluminum Oxide and Graphite) have been enhanced the radiation, bandwidth and surface wave power of microstrip antenna with slot. Nano-composite materials (RT Duriod 5880 with Fumed Silica and Graphite) have been enhanced the radiation, bandwidth and surface wave power of microstrip antenna without slot. The sizes of suggested models are lower than conventional model sizes at these frequencies.

4.3 Effect of New Nano-particle Aluminum Oxide on Microstrip Antenna at Conventional Resonant Frequency

Figure 4 illustrates the return loss $S_{1,1}$ of microstrip antenna by using new nano-composite material (RT Duriod 5880 with 20% wt Aluminum Oxide), at the same resonant frequency 1800 MHz of conventional microstrip antenna with slot and at the same resonant conventional frequency 915 MHz of microstrip antenna without slot.

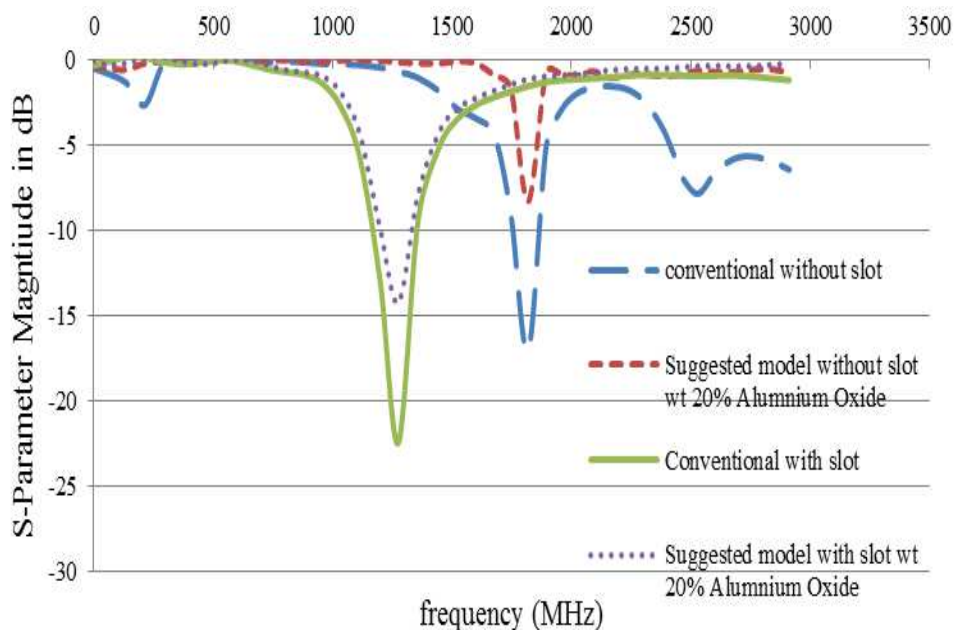


Fig. 4. S_{11} for suggested compact antenna with novel nano-composite materials

Table. 3 Parameters of conventional and suggested models

Substrate material	ϵ	h mm	w mm	L mm	f MHz	Radiation efficiency
RT Duriod 5880 without slot	2.2	5.5146	74.6529	87.5783	1800	0.5470
RT Duriod 5880 with 20% wt Aluminum Oxide without slot	3.76	5 2	68	62.6	1414.8	0.8304
RT Duriod 5880 with slot	2.2	5.5146	74.653	87.578	915	0.6595
RT Duriod 5880 with 20% wt Aluminum Oxide with slot	3.76	1.6	60	49.85	735.9	0.5399

It is cleared that the suggested material has reduced the height, width and length of the patch antenna for the substrate as shown in table.3.

4.4 Effect of New Nano-particle Graphite on Microstrip Antenna at Conventional Resonant Frequency:

Figure 5 illustrates the return loss S_{11} of microstrip antenna with new nano-composite material (RT Duriod 5880 with 20% wt Graphite), at the same resonant frequency 1800 MHz of microstrip antenna with slot and at the same resonant frequency 915 MHz of microstrip antenna without slot.

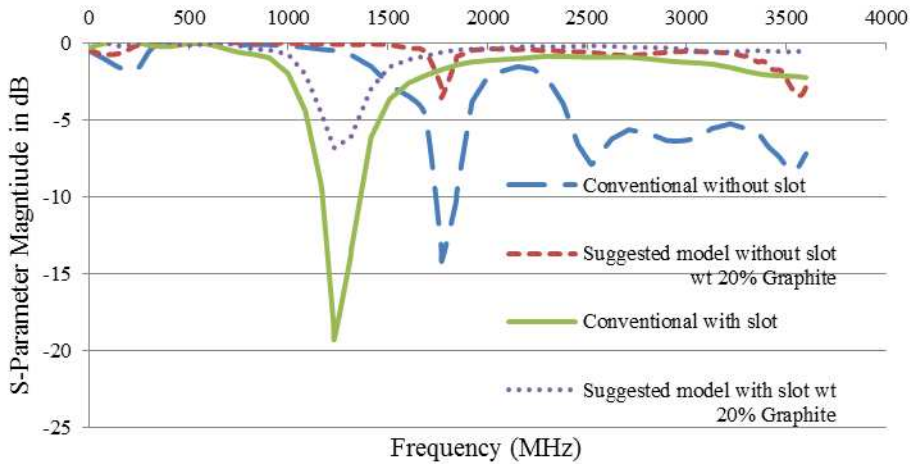


Fig. 5. $S_{1,1}$ of suggested compact antenna with novel nano-composite materials

Table 4. Parameters of conventional and suggested models

Substrate material	ϵ	h mm	w mm	L mm	f MHz	Radiation efficiency
RT Duriod 5880 without slot	2.2	5.51465	74.6529	87.5783	1800	0.5470
RT Duriod 5880 with 20% wt Graphite without slot	4.48	1.8	62.6	65	1303.2	0.9782
RT Duriod 5880 with slot	2.2	5.5146	74.653	87.578	915	0.6595
RT Duriod 5880 with 20% wt Graphite with slot	4.48	1.6	52.15	75.6	683.33	1.209

Also, it is cleared that, using the suggested material has reduced the height, width and length of the antenna as shown in table.4. The radiation efficiency, bandwidth and surface wave power of microstrip antenna have been increased, and so dimensions of microstrip antenna have been decreased. Compact microstrip antenna has been investigated high performance, light weight, easy fabrication and low cost.

5. CONCLUSIONS

- Novel nano-composite materials which are composed of RT Duriod 5880 with nanofillers Aluminum Oxide and Graphite have been enhanced the design of microstrip antenna with slot.
- Novel nano-composite materials which are composed of RT Duriod 5880 with nanofillers Fumed Silica and Graphite have enhanced the design of microstrip antenna without slot.
- Height and width of the suggested microstrip antenna models are smaller than these of the conventional rectangular microstrip antenna with and without slot.

- The radiation efficiency, bandwidth and surface wave power of microstrip antenna have been enhanced by using suggested new nano-composite materials with easy fabrication, high performance and low cost.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

- [1] Rathod, J. M., "Comparative Study of Microstrip Patch Antenna for Wireless Communication Application", *International Journal of Innovation, Management and Technology*, Vol. 1, pp.194–197, 2010.
- [2] Cui, Y., "Antenna Design For On-the-body Sensors", *International Journal on Electrical Engineering and Informatics*, Vol. 2, pp. 1–92, 2010.
- [3] El-Dein, A. Z., "Interaction between the Human Body and the Mobile Phone", LAP Lambert Academic Publishing, 2010.
- [4] Behera, S. K., Reddy, C. V., Vand Rana, R., "Design Of Linearly Polarized Rectangular Microstrip Patch Antenna Using IE3D/PSO", *National Institute of Technology*, pp. 1-66, 2009.
- [5] Sharma, V., Sharma, B., Sharma, K. B., Saxena, V. K., Bhatnagar, D., "A Novel Dual Frequency S-Band Rectangular Microstrip Antenna for Radar and Space Communication", *Journal of Theoretical and Applied Information Technology*, pp. 129–135, 2010.
- [6] Singh, G., "Design considerations for rectangular microstrip patch antenna on electromagnetic crystal substrate at terahertz frequency", *Infrared Physics & Technology*, Vol. 35, pp. 17–22, 2010.
- [7] Islam, M. T., Shakib, M., Nand Misran, N., "Broadband Microstrip Patch Antenna", *European Journal of Scientific Research*, Vol 27, pp. 74-180, 2009.
- [8] Vo, H., and Tand Shi, F.G., "Towards Model-Based Engineering of Optoelectronic Packaging Materials, Dielectric Constant Modeling", *Microelectron Journal*, Vol.33, pp. 409 – 415, 2002.
- [9] Lutz M., and Zimmerman, R.W., "Effect of an Inhomogeneous Interphase Zone on the Bulk Modulus and Conductivity of a Particulate Composite", *International J Solids Struct*, Vol. 42, pp. 429-437, 2005.
- [10] Gouda, O., Thabet, A., and Abdrabo. M., "Developing Dielectric Properties of Industrial Materials by Using Nano-Technology Technique", *IEEE Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10)*, pp. 157-161, 2010.
- [11] Lou, J., Hatton, T.A., and Laibinis, P.E., "Effective Dielectric Properties of Solvent Mixtures at Microwave Frequencies", 37:123-30, 2005.
- [12] Lombardo, N., "A Two-Way Particle Mapping for Calculation of the Effective Dielectric Response of Graded Spherical Composites", *Composites Science and Technology*, Vol.67, pp. 728-736, 2007.

- [13] Aijaz, Z., and Shirvastava, S.C., "An Introduction of Aperture Coupled Microstrip Slot Antenna", International Journal of Engineering Science and Technology, Vol 2(1), pp. 36-39, 2010.
- [14] Rao, Q., Denidni, T. A., and Johnston, R. H., "A New Aperture Coupled Microstrip Slot Antenna", IEEE Transactions on Antennas and Propagation, Vol. 53, pp. 2818-2826, 2005.
- [15] Islam, M. T., Shakib, M. N, Misran, N., and Sun, T. S., "Broadband Microstrip Patch Antenna", European Journal of Scientific Research, Vol.27, pp.174-180, 2009.

تحسين سلوك الهوائى مع و بدون فتحة فى الطبقة الارضية باستخدام مواد نانومترية مركبة جديدة

هذا البحث توصل الى مواد جديدة مركبة من اراتى درايود مع (اكسيد الالمونيوم و السليكا و جرافيت) لتقليل حجم وابعاد الهوائى و بدون فتحة فى الطبقة الارضية و المتمثلة فى ارتفاع و عرض الهوائى وذلك لزيادة اشعاع الهوائى و عرض النطاق الترددى للهوائى. كما تم التوصل الى تقليل حجم الهوائى و زيادة الاشعاع عن طريق تقليل السماحية للهوائى المستخدم و ذلك باضافة حبيبات نانومترية من مواد (اكسيد الالمونيوم و السليكا و جرافيت) على طبقة الهوائى المصنوعة من اراتى درايود. بالاضافة الى انة تم دراسة تاثير السماحية و النفاذية على حجم الهوائى.

APPENDIX I

Antenna	ϵ	h mm	W mm	L mm
Antenna dimension	2.2	5.5146	74.653	87.578
Fumed Silica	4.5	-	-	-
Aluminum Oxide	9.5	-	-	-
Graphite	15	-	-	-

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Ahmed Thabet was born in Aswan, Egypt in 1974. He received the BSc (HIE) Electrical Engineering degree in 1997, and MSc (HIE) Electrical Engineering degree in 2002 both from High Institute of Energy, Aswan, Egypt. PhD degree had been received in Electrical Engineering in 2006 from El-Minia University, Minia, Egypt. He joined with Electrical Power Engineering Group of High Institute of Energy in South Valley University as a Demonstrator, Lecturer, and as Assistant Professor from 1999 up to date. His research interests lie in the areas of analysis and developing electrical engineering models and applications, investigating novel nano-technology materials via addition nano-scale particles and additives for usage in industrial branch, electromagnetic materials, electroluminescence and the relationship with electrical and thermal ageing of industrial polymers. A lot of mobility's has investigated for supporting his research experience in UK, Finland, Italy, and USA ...etc. On 2009, he had been a Principle Investigator of a funded project from Science and Technology development Fund "STDF" for developing industrial materials of ac and dc applications by nano-technology techniques. He has been established first Nano-Technology Research Centre in the Upper Egypt (http://www.ghson.net/FOLDERS_INDEX/nano/index.htm). He has more than 40 publications which have been published and under published in IEEE journals and conferences and held in Nano-Technology Research Centre website (http://www.ghson.net/FOLDERS_INDEX/nano/dr_athabet.htm).



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