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Reconfigurable Antenna for Medical Applications

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Abstract: Microwave imaging systems offer much promise for biomedical applications such as cancer detection because of their good penetration, non invasive and non ionizing nature and low cost. The resolution is one of the major problems faced in such systems, which can be improved by applying signal processing techniques. The key element for the microwave imaging system is the antenna. This paper present a fractal antenna which has low profile, light weight and is easy to be fabricated. It has been successfully demonstrated to have multiband characteristics. The simulated results show that the proposed antenna has very good radiation characteristics suitable for imaging applications. *Copyright © 2009 IFSA.*

Keywords: Microwaves, Imaging, Dielectric property, Sierpinski antenna

1. Introduction

The application of microwave technology in the field of biomedical engineering is increasing both in diagnostic and therapeutic areas. Microwave imaging has a great potential in the area of diagnostics. This technique promises non destructive evaluation of biological medium based on the dielectric property variation. Changes in the dielectric properties of tissues can be related to their physiological condition. Therefore microwave imaging can be used as a diagnostic indicator. Several applications of microwave imaging have been proposed in the medical field and one of them is microwaves for breast cancer detection [1].

Breast cancer is the most common form of cancer found in woman. Early detection and timely treatment are key factors that affect long term survival. X-ray mammography is currently the popular screening method for breast cancer. Mammography has been proved to be quite sensitive to the presence of lesions in the breast. However, association of this diagnoses method with uncomfortable breast compression and exposure to ionizing radiation prevents patients to undergo early stage examination which is the best and effective phase for medical treatment [2]. These concerns provide motivation to develop a supplement to the existing technique.

Microwave imaging can be defined as seeing the internal structure of an object by illuminating the object with low power electromagnetic fields at microwave frequencies. An antenna is used to illuminate the object with microwaves which travels through the object and is then detected with the receiver antenna. Another technique is to use reflections which are detected with the same transmitter that is illuminating the object. The measured data can be processed using reconstruction algorithm to give information on the complex dielectric permittivity of the scattering object [3].

Microwave imaging system relies on the fundamental property that malignant tumor has higher water content and hence have higher dielectric properties than normal breast tissues which have low water content. Therefore, strong scattering takes place at the boundary between normal tissues and lesions.

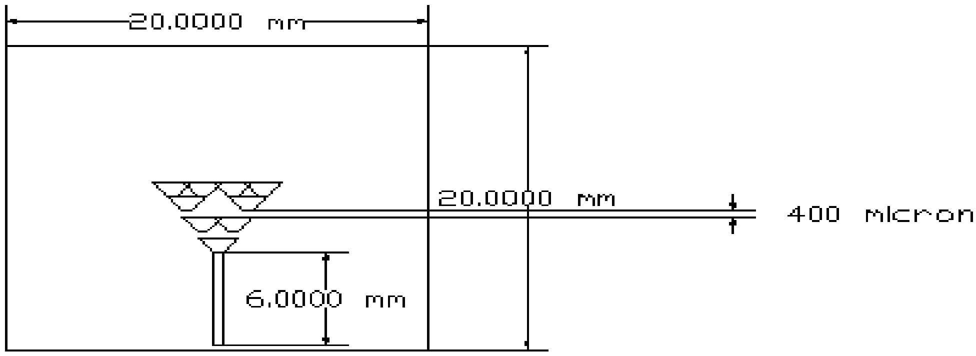
The key component of a portable imaging system requires antenna with multiband operation and smaller dimension. Several UWB antenna designs have been proposed for use in medical imaging systems [4]. Some of the proposed antennas have non-planar structure while others have low gain and poor return loss. Majority of the compact UWB antenna presented in literature exhibit omni directional radiation patterns with relatively low gain [5-7]. These types of antennas are suitable for the short range indoor and outdoor communication. However, for radar systems, such as microwave imaging systems for detection of tumor in women's breast a moderate gain antenna is preferred. Among few alternatives, a microstrip antenna was chosen due to the ease in design and fabrication and can be used in a planar gap coupled array configuration for imaging applications.

A conformal broadband microstrip antenna is suitable for this kind of application. The conventional microstrip antenna suffers from a major disadvantage that it has a narrow bandwidth. This has initiated research in different directions, one of which is by using fractal shaped antenna elements. The relation between antenna dimensions and wavelength λ states that, if the antenna size is less than $\lambda/4$, then antenna is not effective because radiation resistance, gain and bandwidth is reduced and therefore antenna size is increased [8]. Fractal geometry is a good solution for these problems. These structures have self similar properties and fractional dimensions.

The space filling property of these fractal antennas lead to curves that are electrically long but confine into compact physical space. This property leads to miniaturization of antenna. In this paper, a sierpinski fractal antenna fabricated on a FR4 substrate is presented. The self-similar property of fractals makes them especially suitable to design multi-frequency antennas. The antenna has multi-frequency operation, good return loss and radiation characteristics.

2. Antenna Characteristics

Fig. 1 shows a picture of the 20 x 20 mm antenna designed on FR4 substrate with $\varepsilon_r = 4.8$ and height h = 2.4mm with a 50 Ω micro strip feed. The thicker the material, the more bandwidth, particularly at the low frequency end. However, if the substrate becomes too thick, surface waves are generated and array scanning performance and efficiency is lost [9]. The sierpinski antenna considered is triangular with a side of 8mm. Inter connecting tabs are 400 x 200 microns. The reconfigurable sierpinski antenna was actually designed as 3 separate prototypes namely open configuration, partially closed configuration, and fully closed configuration for testing in the laboratory.



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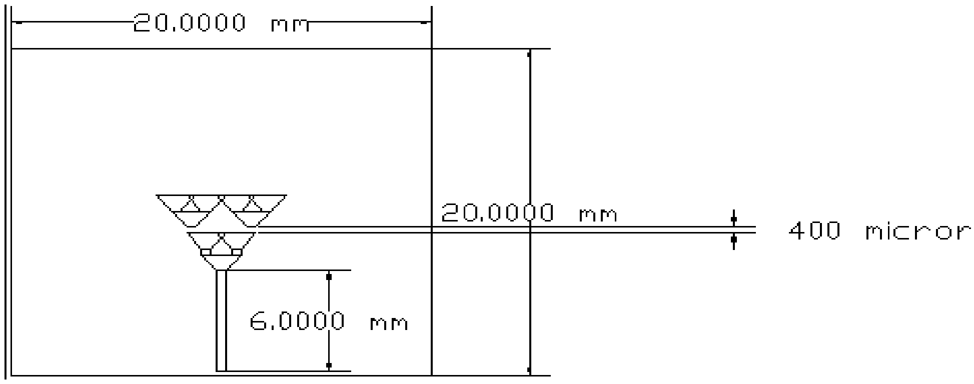

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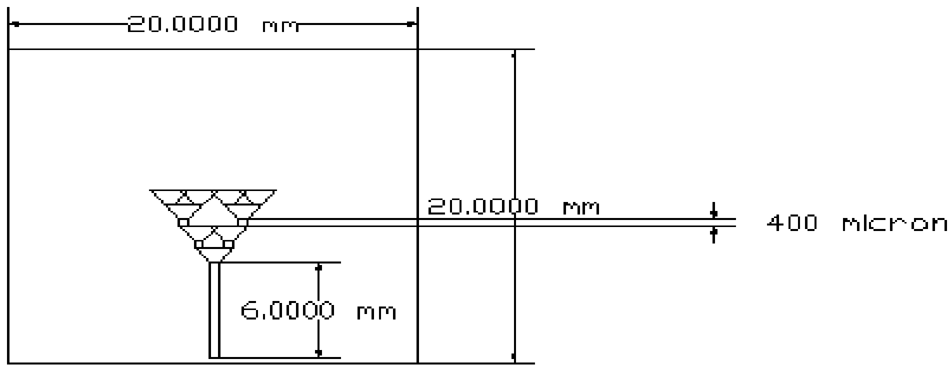

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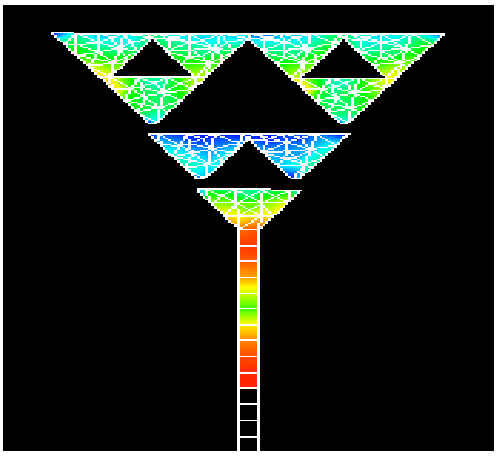
Fig. 1. Reconfigurable serpinski antenna: (a) open configuration; (b) partially closed configuration; (c) fully closed configuration.

The switches are modeled in two ways. First, they were simplified to a 400 x 200 μm gap in the OFF position and by a metal pad of the same size in the ON position. The antenna was simulated using IE3D, a method of moment electromagnetic solver. The current distribution in the antenna is shown in Fig. 2. The simulated return loss is shown in Fig. 3.

We were able to achieve a bandwidth of 1.8GHz, 1.5GHz, and 1.3 GHz at the operating frequencies of 14 GHz, 12 GHz, and 11 GHZ respectively. The effective bandwidth is found to be 4.2 GHz.



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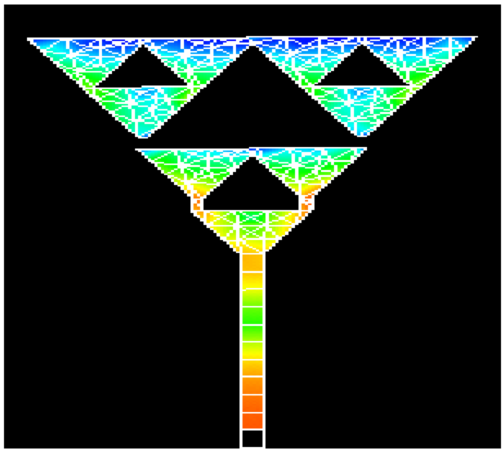

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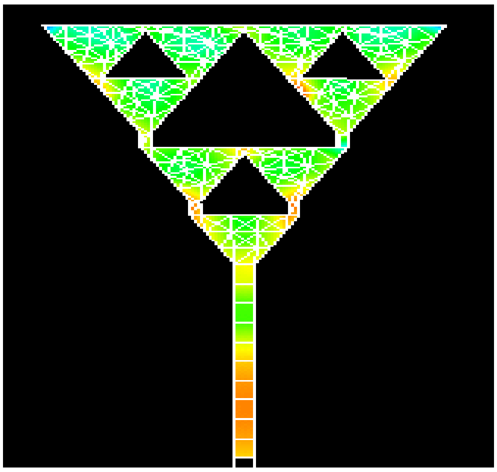

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Fig. 2. Current distributions (a) in the open configuration; (b) in the partially closed configuration; (c) in the fully closed configuration.

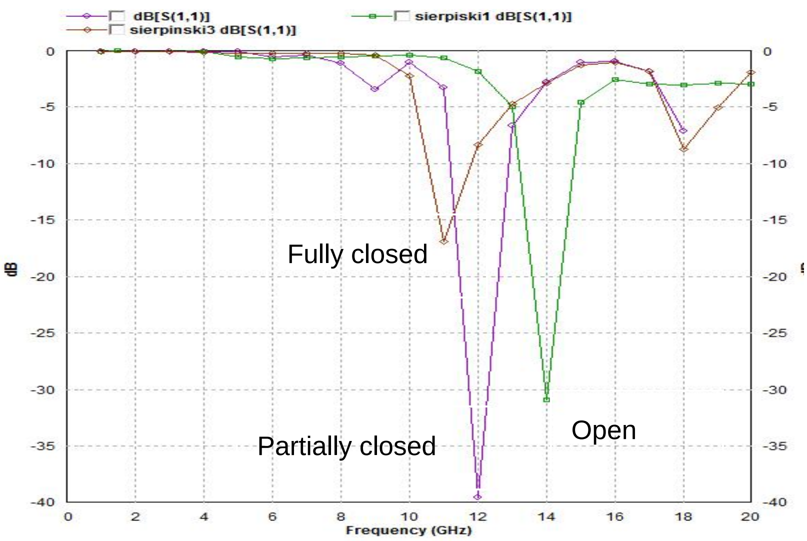
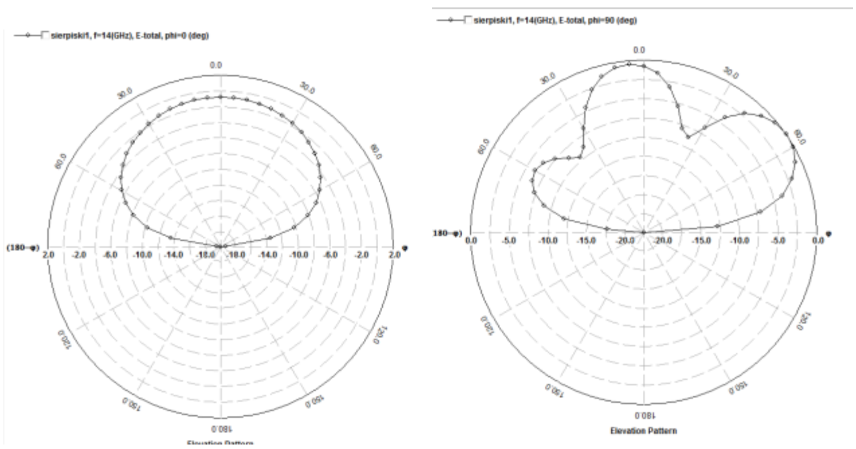


Fig. 3. Simulated return loss of the sierpinski antenna.

The radiation patterns of three stages of antenna are shown in Fig. 4.



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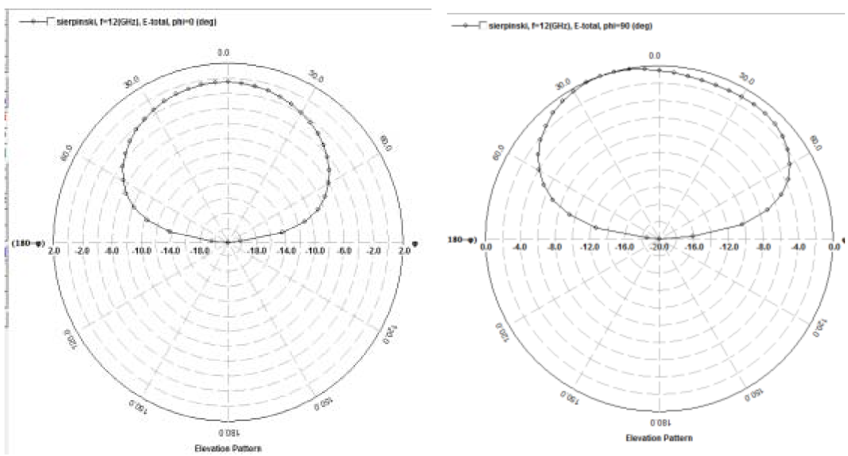

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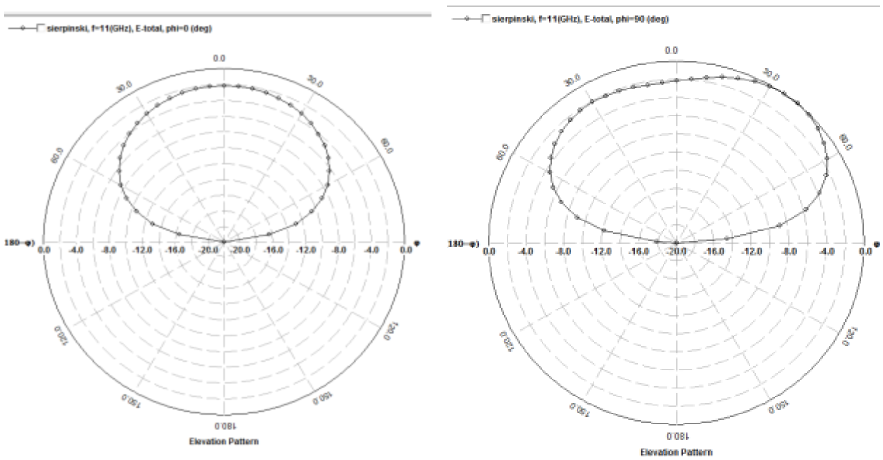

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Fig. 4. Radiation pattern of the sierpinski antenna (a) at 14 GHz ($\varphi = 0$ and $\varphi = 90$), (b) at 12 GHz ($\varphi = 0$ and $\varphi = 90$), (c) at 11 GHz ($\varphi = 0$ and $\varphi = 90$).

3. Antenna Fabrication and Testing

The reconfigurable antenna was fabricated using PCB technology on a FR4 substrate with dielectric constant 4.8 and height 2.4mm, as three separate prototypes (open, partially closed and closed configuration) for testing in the laboratory. The return loss measurements were taken with Agilent N5230A Vector Network Analyzer.

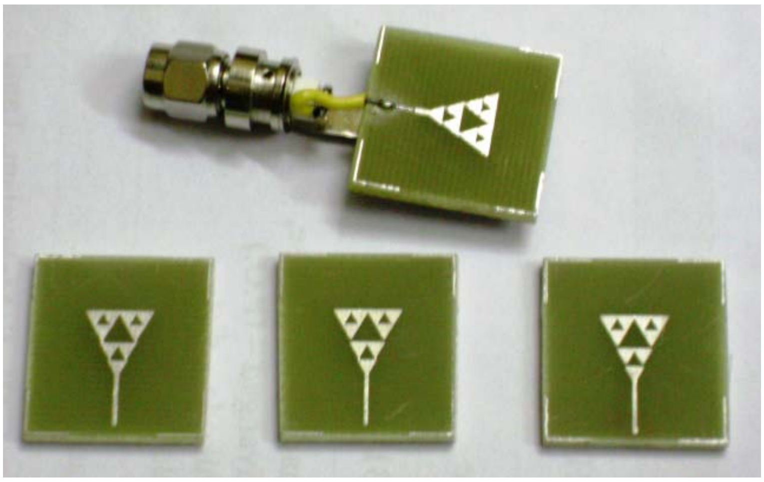


Fig. 5. Picture of the fabricated antenna in open, partially open and fully closed configurations.

The return loss measurement results are shown in Fig. 6. The resonant frequencies decrease as the antenna size increases.

4. Results and Conclusion

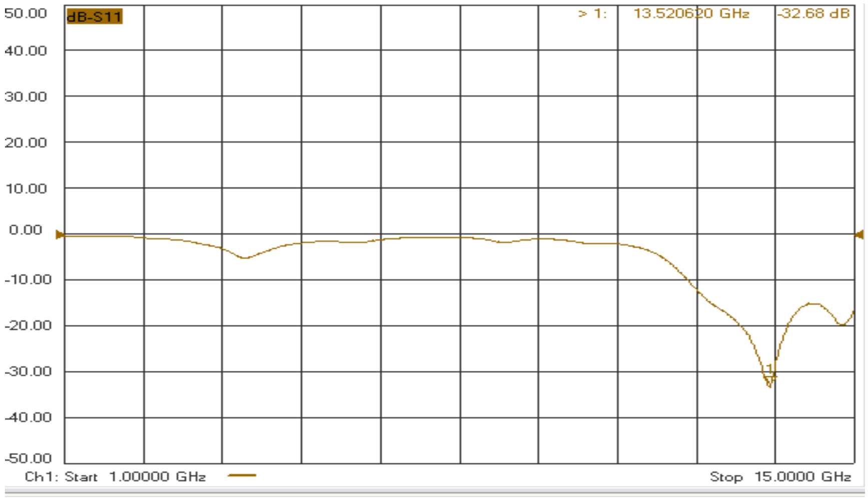
A sequentially reconfigurable multiband antenna was designed, fabricated and tested. The purpose of this paper was to illustrate how the antenna performance can be enhanced by increasing the number of resonant frequencies. The antenna exhibits three principle resonant frequencies with good radiation characteristics. The resonant frequencies of operation are 14 GHz, 12 GHz, and 11 GHz. The measured and simulated results are summarized in Table 1 and Table 2.

Table 1. Simulated characteristics of the sierpinski antenna.

Resonant Frequency (GHz)	Return Loss (dB)	Directivity (dB)
14	-32	8.2
12	-40	8.4
11	-18	10.5

Table 2. Measured return loss of the sierpinski antenna.

Resonant Frequency (GHz)	Measured Resonance Frequency (GHz)	Measured Return Loss (dB)
14	13.5	-32
12	11.6	-20
11	10.8	-18



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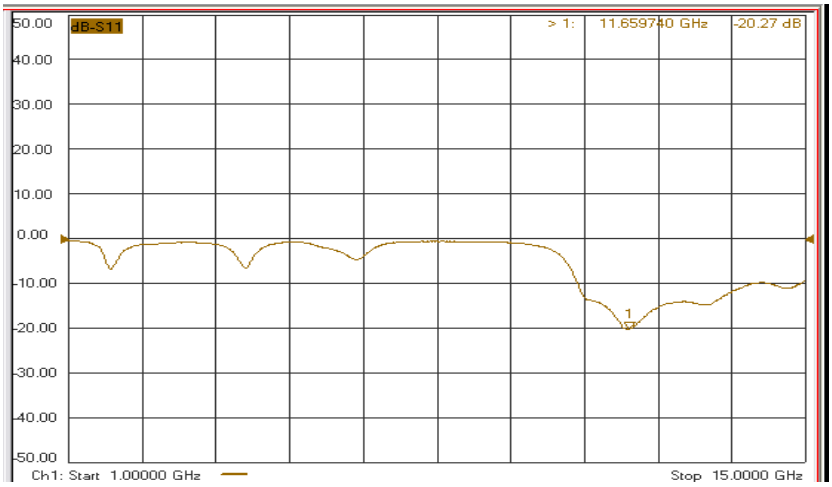

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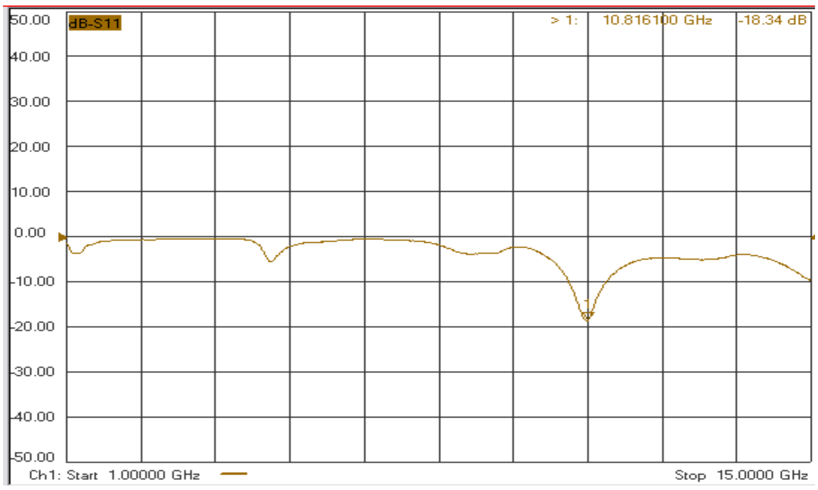

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Fig. 6. Measured return loss of the fabricated antenna (a) open configuration; (b) Partially open configuration; (c) closed configuration.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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