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To cite this article: M A Adnan *et al* 2022 *J. Phys.: Conf. Ser.* **2250** 012005

Biocompatible Sago Aerogel Material as A Substrate for Antenna Application

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Abstract. This paper presents a patch antenna that operates at 2.4 GHz for body communication applications. New biocompatible material is proposed named Sago Aerogel is used as the antenna substrate. As a new substrate material is proposed, a simple patch antenna with a total size of substrate size of 60 mm × 66.2 mm × 1.6 mm size designed and simulated. The antenna performances in terms of S_{11} value, radiation pattern, gain, and input impedance are studied and discussed.

1. Introduction

The use of antennas in this century has grown considerably in both the telecommunications and medical sectors. In the medical sector with the use of an antenna, continuous monitoring of patients can be made and fast transmission of data is possible and more sophisticatedly is by using an antenna in biomedical implants for detecting various illnesses in one's body at every moment. With the introduction of Implantable Medical Devices (IMD) and biomedical implants, the growth of the world population has the potential to be increased and at the same time allow the increase of global aging as well. In IMD, the antenna that is suitable to be implanted must be small in size and biocompatible in characteristics.

To apply an antenna in a biomedical application system, biocompatible material of antenna substrate needs to be used. It is to ensure that the antenna did not produce any harm to the human body. Biocompatible materials are synthetic or natural materials that are used to replace parts of the living system or function in intimate contact with living tissue. Biocompatible materials are intended to connect with the biological system to evaluate, treat, supplement or replace any tissue, organ, or function. Biocompatible materials differ from biological materials such as bone produced by biological systems. Artificial coatings, vascular storage, artificial appliances, and catheters are all made from different biological materials and are made up of different medical devices [1].

Previous work on biocompatible material is reported in [2-9]. The performance antenna in [2] is compared between three different substrates which are Rogers RO 3210, Silastic 0.2 mm, and Alumina. The antennas are intended to be used in intracranial pressure (ICP) monitoring applications. As a result, the Alumina substrate shows the best performance compared to the others substrate. Another reported work using Alumina substrate is presented in [3]. Rogers 3210 also has been used in [4] while using Polydimethylsiloxane (PDMS) as the superstrate. Antenna in [5] used Taconic as a substrate and PDMS as the superstrate. Other reported substrates that have been used for the biocompatible antenna are Kapton polyimide [6], TiN film [7], and ULTRALAM [8-9].

However, new material is proposed in this paper which is Sago Aerogel. Sago is a starch source that can be used for bioplastic synthesis. Sago starch is derived from Metroxylon Sago palm oil, which is a commonly found palm tree exported by countries in Southeast Asia [10]. Aerogel is a synthetic porous ultralight material derived from gels, in which the liquid components of the gel have been replaced with gas. The result is compact with very low density and very low heat conductivity. Other names include frozen smoke, solid smoke, solid air, solid clouds, blue smoke due to its translucent properties and the way it absorbs light in materials [4].

This new material is proposed as a new material since it is easy to be fabricated. The permittivity and tangent loss of the Sago substrate is measured. Then, the patch antenna is simulated using Sago substrate to obtain the antenna performance. The antenna performance using Sago substrate will be compared using the common substrate material which FR-4 and Teflon as the references.

2. Antenna Design and Substrate Details

The material that is being used as substrate can affect the patch antenna's gain, return loss, directivity, resonance frequency, bandwidth as well as the dimension of the patch of the antenna (length of patch, width of patch, and inset depth) [11]. Figure 1 and figure 2 show the proposed substrate that is being used in this project which is by using sago aerogel. The permittivity and loss tangent of the substrate is measured using Vector Network Analyzer (VNA) and the result obtained is shown in table 1.

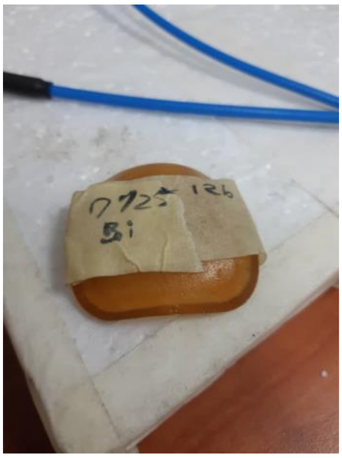


Figure 1. Sago aerogel material (front view).

Figure 2. Sago aerogel material (side view).

The patch antenna is designed as shown in figure 3, using theoretical equations as in reference [3]. By using the value of permittivity, $\varepsilon = 2.72$, and tangent loss, $\tan\delta = 0.057$ as stated in table 1, the calculated parameters for the patch antenna are obtained. The results of FR-4 and Teflon as the reference substrates are needed to compare with Sago. The patch antenna model is shown in figure 3. The calculated parameters for FR-4, Teflon, and Sago are shown in table 1.

3. Results and Discussion

Figure 4 shows the S_{11} results for three different substrates used in this paper. First is S_{11} result with FR-4 substrate is shown in figure 4. As shown in the figure, the antenna can operate at 2.4 GHz (-22.21 dB) with the 70 MHz bandwidth value (2.44 GHz to 2.37 GHz). Then, the S_{11} result using Teflon substrate. The antenna can operate at 2.4 GHz (-15.11 dB) with the 40 MHz bandwidth value (2.42 GHz to 2.38

GHz). Lastly, the S_{11} result using Sago substrate. The proposed antenna can operate in 2.4 GHz (-19.14 dB) with the 40 MHz bandwidth value (2.42 GHz to 2.38 GHz). Comparison of S_{11} results by using three different substrate materials shows that the Teflon and Sago substrates have similar bandwidth values but the Sago substrate has a better S_{11} value compared to the Teflon substrate. By observing the figure, the higher the permittivity of the substrate gives lower return loss for the antenna.

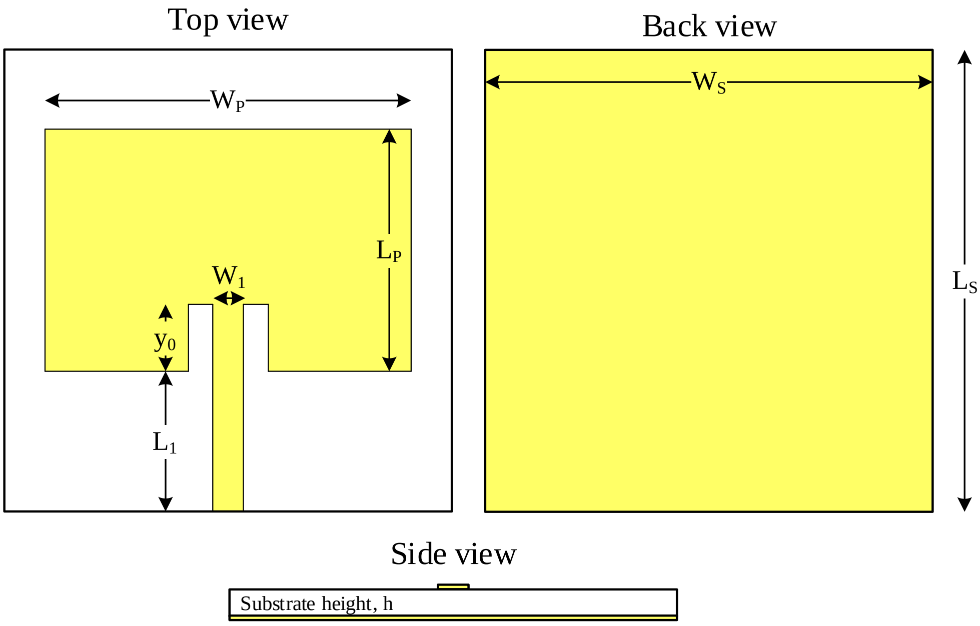


Figure 3. Antenna geometry of the Microstrip Patch Antenna.

Table 1. Design parameters using different types of substrates.

Parameter	FR-4	Teflon	Sago
Dielectric Constant, ε	4.3	2.1	2.72
Loss Tangent, tan (δ)	0.01	0.00028	0.057
Substrate Length, L_S	60 mm	87 mm	66.181 mm
Substrate Width, W_S	50 mm	70 mm	60 mm
Substrate Thickness, h	1.6 mm	1.6 mm	1.6 mm
Patch Length, L_P	29 mm	41 mm	30.18 mm
Patch Width, W_P	28 mm	50 mm	38.46 mm
Inset Length, y_0	9 mm	10 mm	9.365 mm
Microstrip Line Length, L_1	15 mm	22 mm	17 mm
Microstrip Line Width, W_1	2 mm	5.5 mm	3.09 mm

Next, figure 5 (a) shows the radiation pattern results for all three different substrates at 2.4 GHz used in this paper. As seen in the figure, the patterns for all substrates are pointing in an upward direction. A small back lobe is noticed in the pattern results. 3D pattern for Sago substrate is shown in figure 5 (b). As noticed, most of the radiation intensity is pointing upward of the patch antenna whereas the lower radiation intensity is towards the ground plane.

Simulated gain results at 2.4 GHz are tabulated in table 2. The highest total gain of the patch antenna is Teflon with 7.23 dBi. Sago and FR-4 as substrate can also be considered as a good antenna performance because both of the substrates reach the optimum gain.

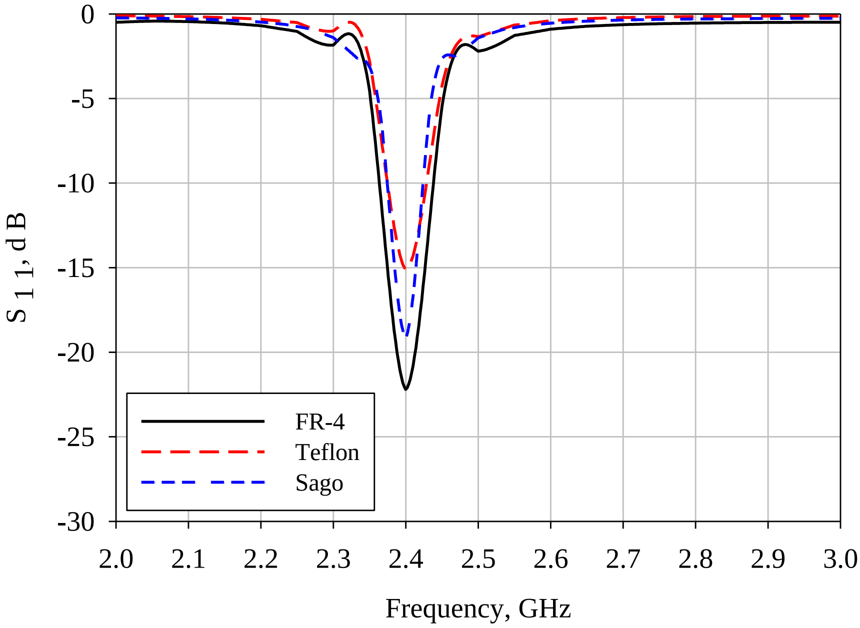


Figure 4. Comparison of simulated S_{11} results between all substrates.

Table 2. Simulated gain results of patch antenna using different types of substrates.

Substrate Materials	Simulated Gain, dBi
FR-4	3.75
Teflon	7.27
Sago	4.97

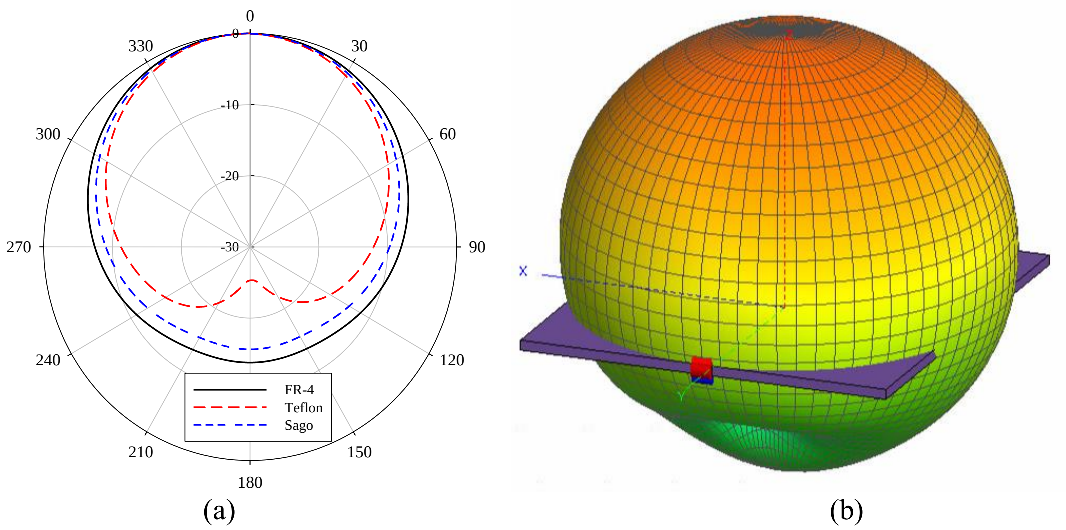
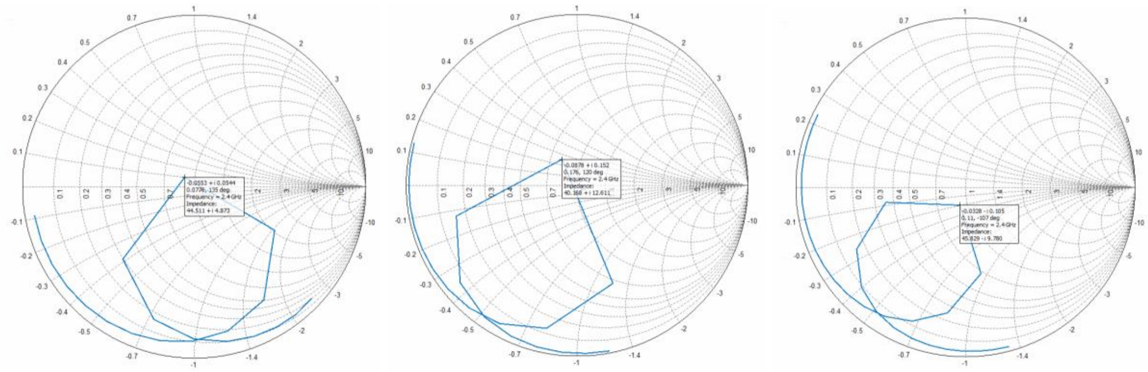


Figure 5. (a) Simulated radiation pattern results for all substrates (b) 3D radiation pattern for Sago substrate.

Figure 6 shows the input impedance results for three different substrates used in this paper. The ideal input impedance for the patch antenna is 50 Ω with 0 imaginary value. Input impedance at 2.4 GHz using FR-4, Teflon, and Sago substrates is 44.51+4.87j, 40.17+12.61j, and 45.83+9.78j, respectively. Although it is impossible to get the ideal input impedance, getting the closest value to the ideal can be considered as a good antenna. From the figures, all substrates attained a closed value to the ideal input impedance.



(a) (b) (c)

Figure 6. Simulated input impedance using (a) FR-4 (b) Teflon (c) Sago substrates

4. Conclusion

The results obtained from the research shows that Sago as a substrate is suitable to be used as a biocompatible antenna. The results of the Sago substrate compared to commonly used substrates such as FR-4 and Teflon are on the same level of performance. Good antenna performance results when using Sago substrate is obtained in terms of S_{11} value, radiation pattern, gain and input impedance. However, a detailed simulation study needs to be carried out since it is a challenge to have a flat surface of Sago substrate in real environment. Fabricating a patch antenna using Sago substrate is required to test the antenna in a real environment.

5. References

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Acknowledgments
The authors would like to thank the Ministry of Higher Education (MOHE), Japan International Cooperation Agency (JICA), Communication Systems and Network (CSN i-Kohza) Research Group, Malaysia-Japan International Institute of Technology (MJIIT), and Universiti Teknologi Malaysia (UTM), Kuala Lumpur. This research is supported by JICA Joint Research Grant 2021.