Transparent Patch antenna design using Aluminum-doped Zinc Oxide (ZnO:Al)

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***Abstract* — A transparent antenna using Aluminum-doped Zinc Oxide (ZnO:Al) or AZO as a radiating component and glass with an AZO ground as a substrate. The simulation using CST Microwave software based on a simple micro-strip patch design, calculated to get the resonance frequency of 2.4 GHz for WLAN application. The low resistivity value of AZO (1.44×10^{-4} Ω-cm) when converted to conductivity value, $\sigma = 6.9444 \times 10^5$ S/m will be used in CST Microwave for simulation.**

Keywords— Aluminium-Doped Zinc Oxide (AZO); CST Microwave; Transparent patch antenna; resistivity and conductivity

I. INTRODUCTION

Micro-strip patch antenna is a type of antenna that offers a low profile, i.e. thin, low cost and easy to manufacture or fabricate, which provides a great advantage over traditional antennas. Patch antennas are planar antenna used in wireless links and other microwave applications. The Micro-strip technique is a planar technique used to produce lines conveying signals and antennas coupling such lines and radiated waves.

Using a transparent material as antenna is gaining an interest on investigations. There is several type of transparent material that has low resistivity that is suitable to be used as a radiating element of an antenna. There are Indium Tin Oxide (ITO), Fluorine-doped Tin Oxide (FTO), Aluminum-doped Zinc Oxide (ZnO:Al), Indium-doped Zinc Oxide (ZnO:In) andsilver coated polyester film (AgHT). Applying transparent conductive thin film to construct antennas is a good alternative to meet the space requirement because the transparent antennas can be installed on the surface or the display window of the mobile devices without much visible design problem. The interference from the other electric parts can also be suppressed thanks to the location of the antenna. In this case, Aluminum-doped Zinc Oxide (AZO) have been used as a transparent conductive films as a transparent antenna. This AZO will be attached to transparent glass with an AZO ground mounted.

AZO been considered in this study is due to the increasing of the price of Indium Tin Oxide (ITO). This is because of the high demand for ITO in the rapid development of the flat panels display development. In addition, Zinc Oxide thin films are more stable against hydrogen plasma, more abundant and less expensive and compared to ITO films and also absence of toxicity(6).

There is several methods in preparing the AZO thin film, among them are pulsed laser ablation(2), RF magnetron sputtering, Novel sonicated Sol-Gel(5) and continuous composition spread method(6).

A simple rectangular design with micro-strip patch antenna with inset feed designed to get a dedicated frequency resonance for a suitable application required.

II. ANTENNA DESIGN

A. Antenna dimensioning

In this paper, a simple rectangular micro-strip patch antenna is chosen for a design which is consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side.

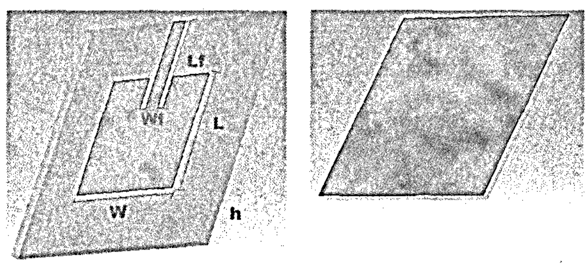

Fig.1

Figure 1 shows design of the patch antenna on the front side of the glass substrate and the ground panel of the other side of the substrate

The dimension calculated based on the basic formula as follow-

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\frac{1}{\sqrt{1+\frac{12h}{W}}}$$

$$\Delta L = 0.412 * h\,\frac{(\epsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{eff}+0.258)(\frac{W}{h}+0.8)}$$

$$L = \frac{c}{2f_r\sqrt{\epsilon_r}} - 2 * \Delta L$$

Where,

W= Width of patch antenna
L = Length of patch antenna
C = the light speed in m/s
εr = dielectric constant
fr = resonant frequency
h = thickness of substrate

B. Aluminium-Doped Zinc Oxide

Aluminum-Doped Zinc Oxide (AZO) is a transparent conductive thin material used as a radiating element and mounting on a glass substrate with an AZO ground. The AZO thin film has thickness of 200nm and the maximum resistivity is $1.44\text{x}10^{-4}$ Ω-cm. This value obtained from pulsed laser ablation technic [2].

This thin film were prepared by ablating the target containing 2 wt% Al2O with ArF excimer laser (λ=193nm). The films were grown at a repetition rate of 10Hz, energy density of 2-3 J/cm2, irradiation time of 10-60 min 96000-36000 laser shots).Electrical properties depends on substrate temperature and oxygen pressure during film deposition.[2]

The conductivity value for material is needed for simulation using CST Microwave. Conductivity and resistivity are inversely proportional to each other. When conductivity is low, resistivity is high. When resistivity is low, conductivity is high [3]. The equation is as follows:

$$\sigma \equiv \frac{1}{\rho}$$

Where,

σ = Resistivity Ohm (Ωm)

ρ = Conductivity Siemens (1/Ωm).

Since conductivity is the measure of how easily electricity flows, electrical resistivity measures how much a material resists the flow of electricity.

From the equation, the conductivity of the AZO is $6.9444\text{x}10^5$ S/m [3]

III. SIMULATION RESULTS

The dimensions of transparent antenna are shown in Figure 1. For the initial dimension, the transparent thin film AZO as a radiating element and ground was mounted on glass substrate with the thickness of 1mm. The AZO has a thickness of 200nm and conductivity $6.9444\text{x}10^5$ S/m

Initially we are using the value from the calculation to get the frequency resonance of 2.4GHz and we get the length of AZO, L=28mm, width of AZO W=36.6mm. The ground attached to the glass substrate with the thickness, h=1mm with the dimension 2 times L and W.

For the feeding line, the width has to be set at 1.88mm to get 50 ohm line impedance.

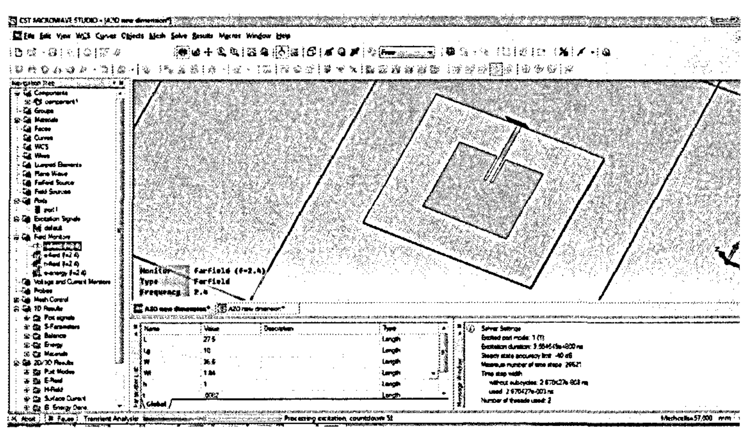

Fig. 2

Figure 2 shows the CST Microwave that used for the simulation process of the transparent antenna design using the initial value from the calculation

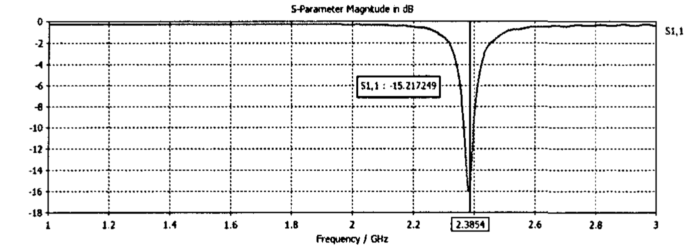

Fig 3

Figure 3 shows the return loss S11 with the thickness h=1mm

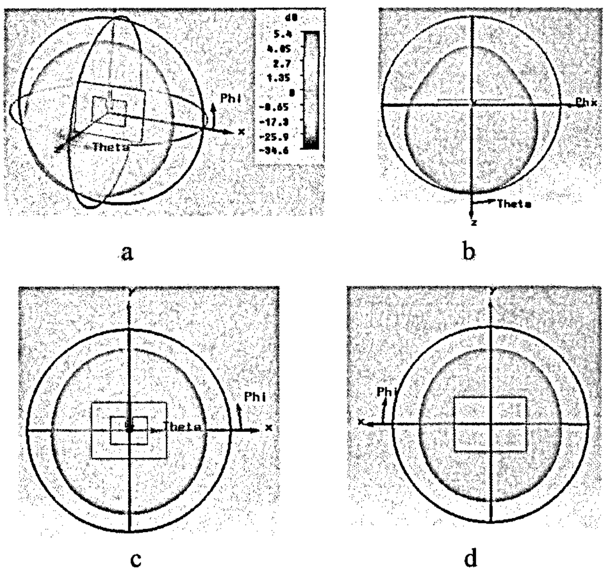

Fig. 4

Figure 4 shows the simulated 3D radiation pattern with the thickness, h=1mm. (a) Perspective view (b) Top view (c) Front view (d) back view

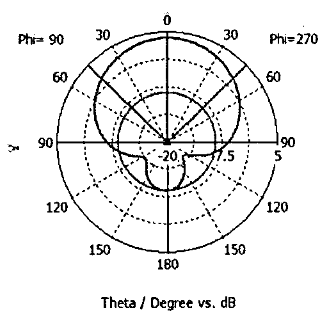

Fig. 5

Figure 5 shows the radiation pattern with thickness, h = 1mm

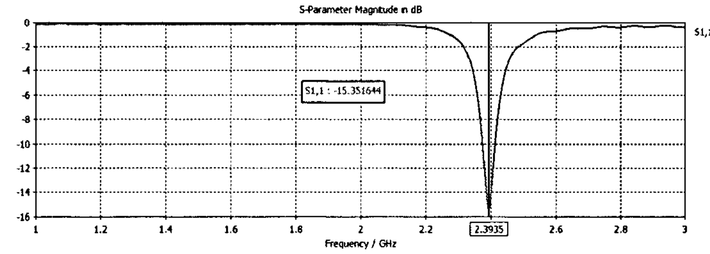

Fig 6

Figure 6 shows the return loss S11 with the thickness h=1mm

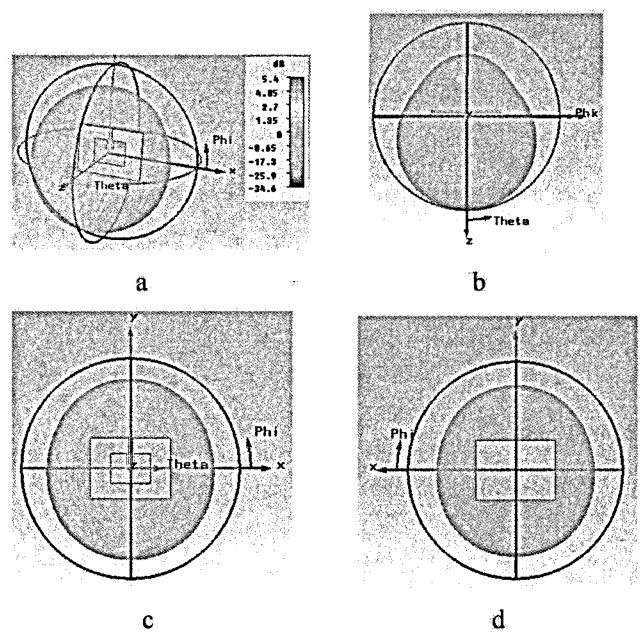

Fig. 7

Figure 7 shows the simulated 3D radiation pattern with the thickness, h=2mm. (a) Perspective view (b) Top view (c) Front view (d) back view

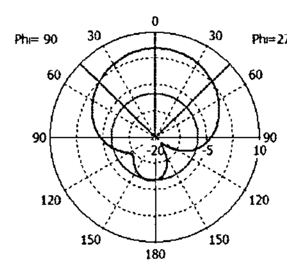

Fig. 8

Figure 8 shows the radiation pattern with thickness, h = 2mm

IV. CONCLUSION

From the result of simulation, we find that the Electrical Characteristic of Aluminum-doped Zinc Oxide (ZnO:Al) or AZO namely the low resistivity value is suitable to be used a radiating element in a transparent antenna. The simulation result of 2.4GHz is suitable for WLAN application

The preparation method of Aluminum-doped Zinc Oxide (ZnO:Al) also give an effect of the resistivity value.

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REFERENCES

[1] Alyaa S. Azini, Muhammad R. kamarudin, Tharek A. Rahman, Hashimu U. Iddi, Amuda Y. Abdulrahman and Mohd F. Jamlos, "Transparent antenna Design for WiMAX Application" Progress In Electromagnetics Research, vol. 138, pp. 133-141, 2013

[2] A. V. Singh, Manoj Kumar, R. M. Mehra, Akihiro Wakahara and Akira Yoshida, "Al-doped zinc oxide (ZnO:Al) thin films by pulsed laser ablation", J. Indian Inst. Sci., vol. 81, pp.527-533, 2001

[3] Electrical Conductivity and Resistivity, Heaney, Michael, Electrical Measurement, Signal Processing, and Displays. Jul 2003

[4] Ming-Hung Liu, Shih-Chang Shei, and I-Tseng Tang, "A new coplanar waveguide fed transparent antenna at 2.4 GHz," International Journal of Science and Engineering Vol.2, No.4, 7-16, 2012

[5] M. H. Mamat, M. Z. Musa, N.D.M. Sin, Z. Khusaimi and M.Rusop, "Characteristics of aligned aluminum-doped zinc oxide nanorod arrays via a novel sonicated Sol-Gel immersion," 2011, IEEE Symposium on Industrial Electronics and Applications (ISIEA2011), September 25-28, 2011, Langkawi, Malaysia

[6] Keun Jung, Dong Wook Shin, Seok-Jin Yoon and Ji-Won Choi, Won-Kook Choi, Han Song and Hyun Jae Kim, "Electrical and Optical Properties of Al-doped Zinc-oxide Thin Films Deposited at Room Temperature by Using the Continuous Composition Spread Method" Journal of the Korean Physical Society, Vol. 57, No. 4, pp. 1092-1095, October 2010

[7] A. V. Singh I, R. M. Mehra, A. Wakahara and A. Yoshida, "Optimization and characterization of highly conductive and transparent Al-doped ZnO films for solar cell applications," 3rd World Conference on Phorovolroic Energy Conversion May f-l8,2003 Osaka, Japan

[8] Rajeshwar Lal Dua, Himanshu Singh, and Neha Gambhir "2.45 GHz Microstrip Patch Antenna with Defected Ground Structure for Bluetooth," International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-1, Issue-6, January 2012

[9] T. Yasin, R. Baktur, and C. Furse, "A comparative study on Two Types of Transparent Patch Antennas," General Assembly and Scientific Symposium, pp. 1-4, 2010