Dual-Stacked Transparent Patch Antenna using AgHT-8 for Wireless Application

M. Awalludin[1], M. T. Ali[1], R. A. Awang[1] and M. H. Mamat[2]
[1]*Antenna Research Group (ARG),*
[2]*NANO-ElecTronic Centre (NET),*
Faculty of Electrical Engineering, Universiti Teknologi Mara, Shah Alam, Selangor 40450, Malaysia.
mardhiahawalludin@gmail.com

***Abstract*—A dual-stacked transparent patch antenna using silver coated polyester (AgHT-8) thin film as radiating element and perspex acrylic dielectric substrate as mechanical support is proposed. Employing an air gap between the stacking structure is proven to exhibit better performance in terms of bandwidth and gain compared to a single structure patch antenna. The dual-stacked antenna was also experimentally verified, achieving reasonable agreement between the simulation and measurement results. The proposed antenna has the potential to be adopted in any transparent devices where invisibility of physical appearance is inherent.**

***Index Terms*—Aght-8; Air Gap; Stacked Antenna; Transparent Antenna.**

I. Introduction

In recent years, conventional metal like copper for radiating element and ceramic/polymer dielectric materials for mechanical support are commonly used in microstrip patch antenna fabrication. The opaque physical appearance factor makes the conventional patch antennas unsuitable for some applications because it could be easily seen with naked eyes. Hence, suitable transparent materials/substrates are necessitated to realize the transparent devices.

Generally, implementing transparent conducting material films as radiating element on glass or windows will result in transparent or invisible. These transparent conducting materials have been actively engaged in a wide range of applications such as solar cells transparent electronics and touch-panel controls [1]–[3].

The most widely used transparent conductive material is constructed from indium tin oxide (ITO) [4]. Although it has several advantages such as excellent stability and compatibility with both wet and dry device processes but the cost of ITO is unpredictably and substantially increased due to relatively rare element of the indium [5]. Thus, an investigation for alternative materials to replace ITO is required.

Alternatively, silver coated polyester (AgHT-8) also can be used as a transparent conducting element. It has been reported that AgHT-8 thin film has high transparency which is above 80 % [6] and it has a conductivity of σ = 1.25 x 105 S/m [7]. An optically transparent conducting material with high conductivity is required in fabricating the transparent antenna. In 1997, the first transparent microstrip antenna was made from AgHT-8 and clear polyester sheet has been reported by R. N. Simons and R. Q. Lee [8]. Transparent antennas have tremendous potential applications such as radio-frequency identification (RFID) [6][9], wearable [10] and small satellite [11].

The motivation of the research in this paper lies in the utilization of a transparent radiating material (AgHT-8) and a transparent substrate (Perspex) to realize transparent antenna at working frequency of 5 GHz. A dual-stacked patch antenna with an air-gap structure is presented. The proposed antenna with intervening of air gap between the stacked structures is capable to enhance the bandwidth and gain.

II. Antenna Design

A. A Single Transparent Patch Antenna

The investigation of the dual-stacked transparent antenna begins with the design of a single structure of transparent microstrip patch antenna. The antenna consists of a single rectangular patch radiating element and a ground made from AgHT-8 material. They are glued in between perspex (dielectric constant, Ɛr = 2.007, loss tangent = 0.0265) substrate as shown in Figure 1. The rectangular patch structure was chosen in this work due to its simplicity and well-established design. A coaxial feeding technique is employed in this design. A representation of the fronts, back and side view of antenna structure can be seen in Figure 2. The antenna is simulated using CST Microwave Studio software.

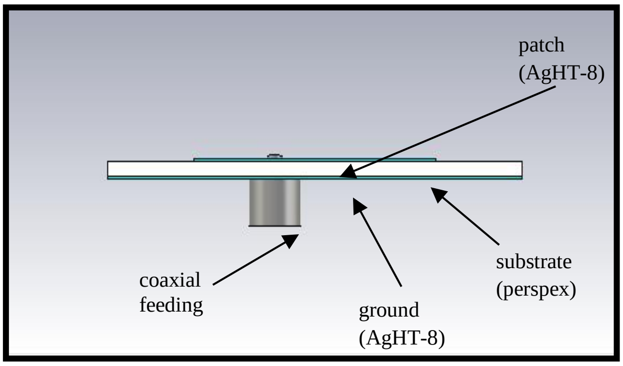

Figure 1 : A cross-sectioned view of the single transparent patch antenna

The optimization process is carried out to achieve required resonant frequency and better performance results. In this design, parameters such as length of the patch (Lp) and width of the patch (Wp) play a significant role in the determination of the resonant frequency. The length Lp varied whilst keeping the other parameters constant. From Figure 3, increasing patch length creates a corresponding decrease in the resonant frequency. The depth of the S_{11} increases significantly with increasing patch length.

Figure 4 shows the return loss (S_{11}) response when the patch width is varied from 16 mm to 22 mm, and all other parameters are kept constant. As the patch width is increased, the resonance frequency is shifted to the lower frequency with the depth of the resonance increased substantially. A summary of the selected parameters after optimization is listed in Table 1.

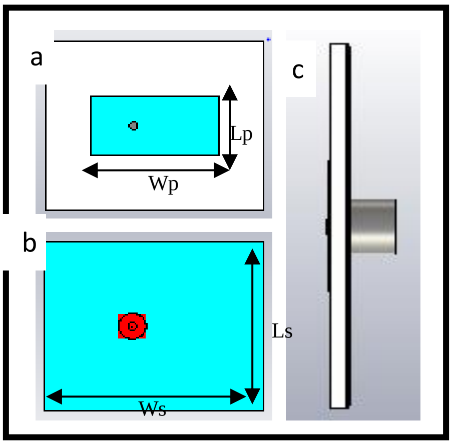

Figure 2: A single patch antenna: (a) Front view, (b) back view (c) side view

Table 1
Dimensions of a single transparent patch antenna

Parameter	Dimensions (mm)
Wp	20.05
Lp	10
Ws	34
Ls	28

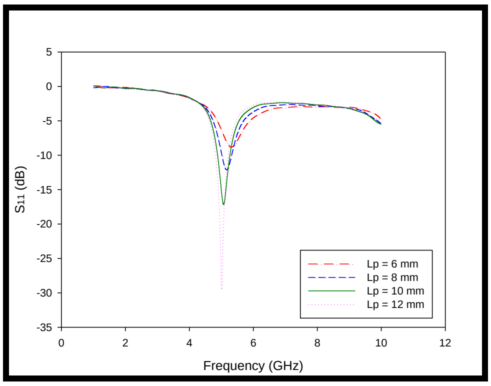

Figure 3: Optimization process for length of the patch

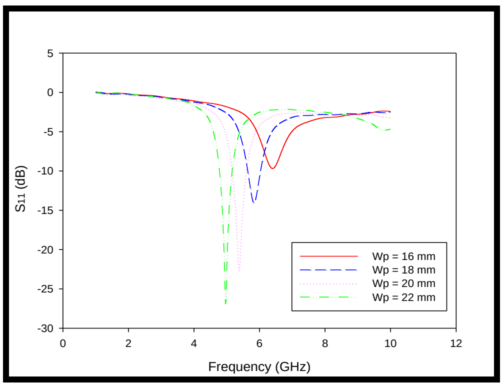

Figure 4: Optimization process for width of the patch

B. Dual-Stacked Transparent Patch Antenna

In the second design, the single patch antenna is stacked with another layer of perspex substrate introducing air-gap of 2 mm separated between the stacking structure as illustrated in Figure 5. The idea of adding air gap in this design is to enhance the bandwidth of the antenna. To achieve required resonant frequency, the length and width of the patch has been optimized. After optimization process, the patch width and length is 21.8 mm and 12 mm, respectively. The substrates dimensions for this design are similar with the single antenna design. The front, back and side view of the antenna is shown in Figure 6 with the related dimensions is tabulated in Table 2.

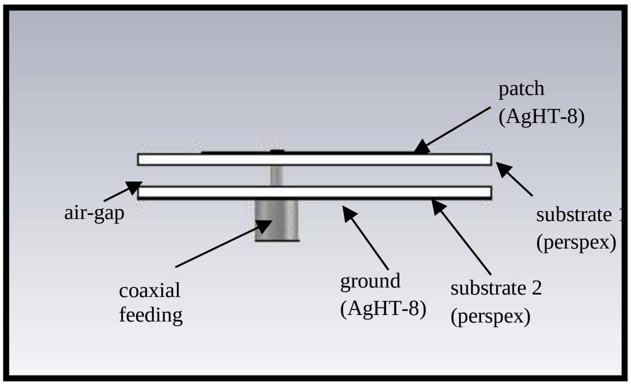

Figure 5: A cross-sectioned view of the stacked transparent patch antenna

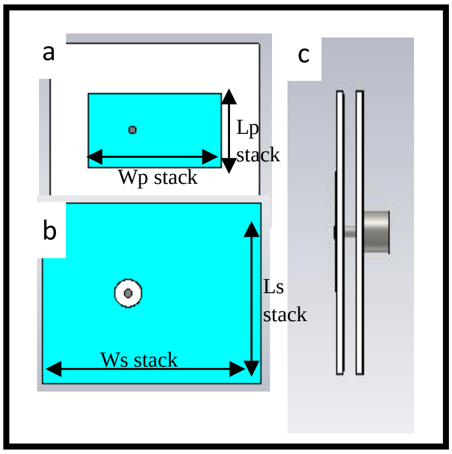

Figure 6: A dual-stacked patch antenna: Front view (a) Front view, (b) back view and (c) side view

Table 2
Dimensions of a dual-stacked patch transparent antenna

Parameter	Dimensions (mm)
Wp stack	21.8
Lp stack	12
Ws stack	34
Ls stack	28
H_{airgap}	2

III. RESULTS AND DISCUSSION

A. Simulation Results of a Single Transparent Patch Antenna

Figure 7 shows a S_{11}= -34.36 dB for simulation result of a single transparent patch antenna at 5 GHz. It produces only 210 MHz of 10-dB bandwidth. The simulated radiation pattern is shown in Figure 8. The simulated gain and directivity is 1.606 dB and 7.014 dBi, respectively. The gain is quite low compare to acceptable value gain for a microstrip antenna.

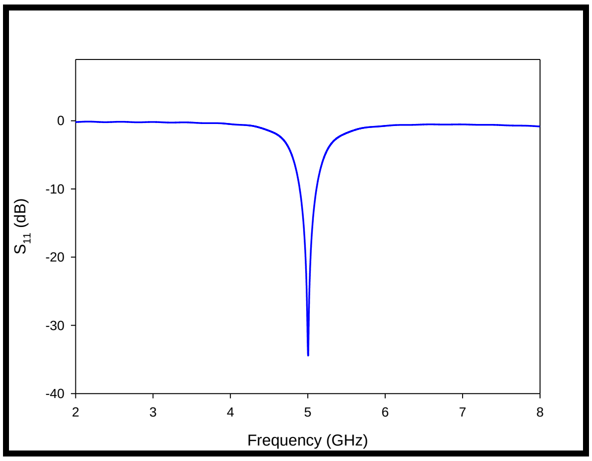

Figure 7: Simulated return loss of a single transparent patch antenna

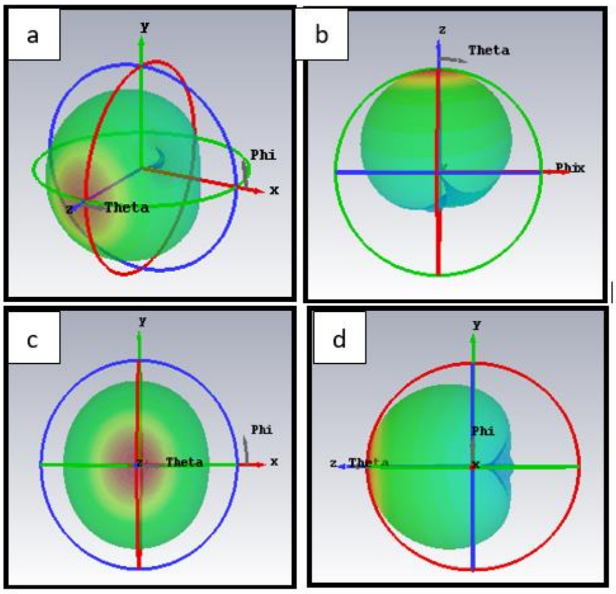

Figure 8: Simulated radiation pattern for a single transparent patch antenna: (a) Perspective view, (b) top view, (c) front view and (d) side view

B. Simulation and Measurement Results of a Dual-stacked Transparent Patch Antenna

To validate the proposed dual-stacked transparent patch antenna, a prototype antenna as shown in Figure 9 is fabricated and measured. Figure 10 shows a comparison of the measured and simulated S11 of the dual-stacked antenna. The measured S11 has reasonable congruence with the simulated results. The measured S11 is slightly shifted to the higher frequency (5.6 GHz) due to the fabrication tolerance. In comparison with the single patch antenna, the dual-stacked antenna has wider 10-dB bandwidth (390 MHz) with an increment of 86 %. Figure 11 displays a simulated radiation pattern for the dual-stacked antenna with the gain and directivity is 6.55 dB and 7.45 dBi, respectively. The simulated gain of the dual-stacked antenna is significantly increased than a single patch antenna. However, the measured gain (3.77 dB) and directivity (3.93 dBi) for the dual-stacked antenna are slightly lower than simulation results but still in acceptable range. Therefore, employing air gap between two stacked-substrates is proven in increasing the gain and the bandwidth of the proposed antenna.

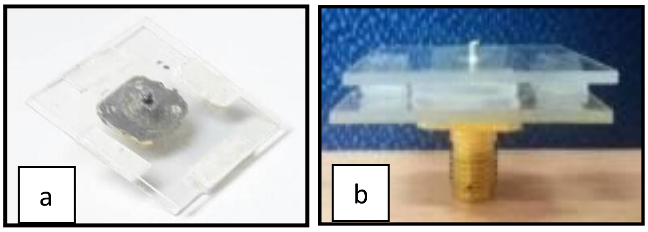

Figure 9: Prototype of dual stacked transparent patch antenna; (a) Front view and (b) side view.

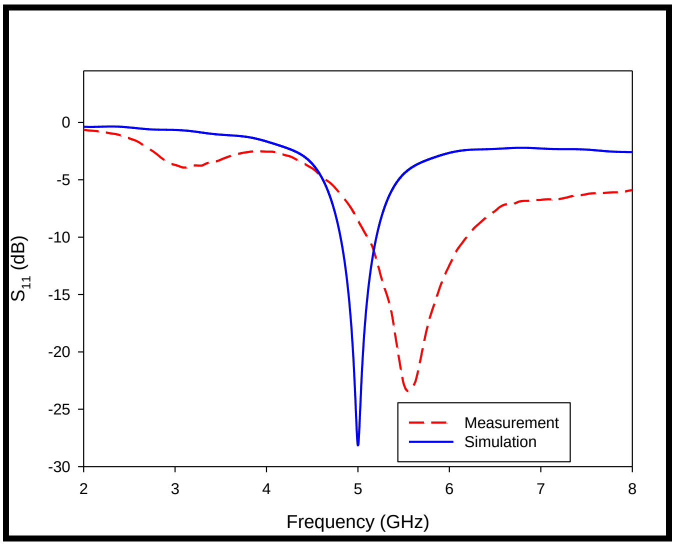

Figure 10: Simulated and measured results of return loss for a dual-stacked transparent patch antenna.

IV. CONCLUSION

A dual-stacked transparent patch antenna using silver coated polyester (AgHT-8) and perspex materials is successfully presented. Measured return loss shows a reasonable agreement with the simulated results. The presence of air gap between the stacked substrates produces higher gain and wider bandwidth than a single transparent patch antenna. Owing to its transparent structure as well as good performance, the proposed antenna has the potential to be implemented in the system/devices where physical structure invisibility is concerns.

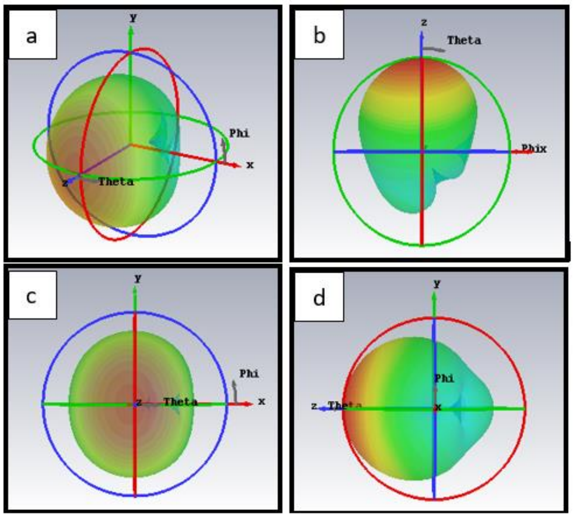

Figure 11: Simulated radiation pattern for a dial-stacked transparent patch antenna: (a) Perspective view, (b) top view, (c) front view, (d) side view.

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