# Design of transparent microstrip grid array antenna

**N.I. Mohd Ali[1], N. Misran[2], M.F. Mansor[3]**
[1,2,3]Centre of Advanced Electronic and Communication Engineering (PAKET),
Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, Malaysia
[1]Faculty of Engineering Technology, Universiti Malaysia Perlis, Kampus UniCITI Alam, Malaysia

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**ABSTRACT**

A transparent grid array antenna of 28 GHz frequency is presented. The radiating element of the antenna is made of ITO thin film and printed on glass as the dielectric substrate. The simulation of the antenna executed by using Computer Simulation Technology (CST) Microwave Studio software demonstrated at 28 GHz operating frequency for 5G band applications. This antenna then compared to the rectangular microstrip patch antenna of the same operating frequency. The structural parameters of the proposed antenna were optimized based on parametric studies done. Grid array antenna gives better performance as it gives 35.7% lower return loss with -43.88 dB, better efficiency and gain with a gain of 7.358 dB, which is more than 40% increases.



***Corresponding Author:***

Nur Izzati Mohd Ali,
Centre of Advanced Electronic and Communication Engineering (PAKET),
Faculty of Engineering & Built Environment,
Universiti Kebangsaan Malaysia,
Bangi, Selangor, Malaysia.
Email: nurizzati@siswa.ukm.edu.my

## 1. INTRODUCTION

There are many types of antenna in the world. There are horn, helical, dipole, parabolic, and the most popular among them is microstrip antenna. The typical structure of a microstrip patch antenna consists of a thick metal layer as the radiating patch, and Ground, placed on a dielectric substrate. Transparent antenna normally designed by replacing the metal patch with Transparent Conducting Oxides (TCO) thin film, and clear glass [1-4] or PET film [5, 6] as the dielectric substrate.

Transparent Conducting Oxides (TCO) thin film is a very interesting material that optically transparent material and conductive electrically [7-10]. There are several types of TCO that commonly used; Indium Tin Oxide (ITO), Fluorine-doped Tin Oxide (FTO), silver conductive coated thin film AgHT-4 and AgHT-8. This remarkable combination of transparency and conductivity leads to a great development of electronic components and telecommunication devices, such as touch screens, solar cells, and electrodes for displays, as it can reduce the visual impact and flexibility in terms of installations. Other than that, these features also caught researchers' attention to be explored on and be considered in antenna designing. By replacing the typical thick metal layers of conductors with ITO thin film, the visual impact of the antenna in the system can be minimized [11-13].

Solar antenna is one of the technologies that have been explored by the researcher as it has an interesting benefit which is the ability to power itself by using natural resources. Several researches have been done to integrate the solar and antenna element and basically can be divided to three categories; non-transparent solar antenna, semi-transparent antenna, and transparent antenna.

For non-transparent solar antenna, the problem is the design normally bulky in size and complicated design [14-16]. Some design of the category facing blockade effect [17, 18]. Normally for semi-transparent solar antenna, clear glass or plastic will be used as the substrate but still using solid metal as the radiating element. The structure of the patch improvised to permit sunlight to pass through to the solar cell that normally placed on the bottom as Ground [3, 19, 20] or as the reflector of the antenna [21]. One of the problems of these antennas is the shadowing effect that affecting solar performances as the structure of the antenna itself blocked the sunlight to reach the solar cell due to its material properties. For transparent antenna, all antennas elements are transparent but the design is complicated and the antenna performance is compromised [4, 22].

Grid array antenna was firstly introduced by Kraus in 1964 [23] and then the concept implemented on microstrip by Conti in 1981 [24]. This type of antenna has very interesting characteristics such as traveling wave, frequency scanning, the flexibility of tilting the beam, high gains, and ease of extension and fabrication [25, 26]. There are many techniques to improve the gain of antenna; array techniques, superstrate technique, slotted ground or patch technique, but considering the most suitable one to be implemented on the structure, Grid Array technique is used.

Grid array antenna consists of several grid cells as the radiating element on a dielectric and backed by a ground plane. Figure 1 shows the single element of the cells formed by combining two types of lines, long side, ***l*** and short side, ***s***, which act as the transmission line and the radiation element respectively [27].

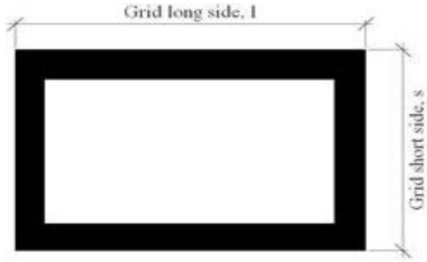


Figure 1. Single element of grid array

In this paper, a design of transparent microstrip grid array antenna will be presented and discussed. The performance will be compared to a reference antenna which is a rectangular microstrip patch and both antennas are operating at 28 GHz frequency of 5G band application. The dielectric of the antenna is made of glass and the radiating element, as well as the ground plane, is made of Indium Tin Oxide (ITO) thin film.

## 2. RESEARCH METHOD

Figure 2 shows the rectangular microstrip patch antenna which as a reference antenna of 28 GHz operating frequency. ITO thin film with sheet resistance, $R_S$ of 10Ω/sq used as the radiating patch material, and the thickness of the layer determined based on the equation discussed in [28-31]. The material of the substrate layer is glass with dielectric constant, $\varepsilon_r$ and thickness of 4.82 and 1.10 mm respectively. Table 1 shows the optimized dimension of the reference design based on equations in [32].

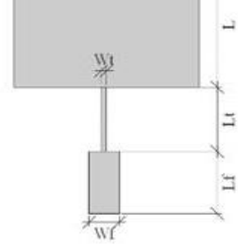


Figure 2. Reference antenna

Table 1. Optimized Dimensions of Rectangular Microstrip Patch Antenna

| Parameter | Length(mm) |
|---|---|
| L | 3.285 |
| W | 4.235 |
| Wt | 0.200 |
| Lt | 1.805 |
| Wf | 0.783 |
| Lf | 1.958 |

For grid array antenna, the loop dimensions are approximately half of guided wavelength vertically ($s=\lambda_g/2$) and one full guided wavelength horizontally ($l=\lambda_g$) [27]. Figure 3 shows the front view of the transparent Grid Array Antenna with 8 optimized loops.

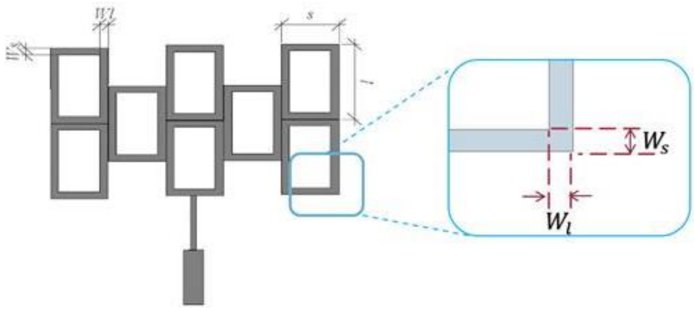


Figure 3. Top view of the transparent grid array antenna

Figure 4 and Figure 5 show the study of parameter $W_L$ and $W_S$ respectively. For the short arm, $W_S$ is varied from 1.00mm with 0.05mm increment and shows that the resonance frequency, $f_r$ shifted to the right side as the width of the short arm, $W_S$ gets wider, whereas the effects on the return losses are insignificant. Contrary with the width of the long arm, $W_L$, which varied starting from 0.5mm with the step size of 0.1mm, and as it increases, the return loss will be decreased together with the frequencies, $f_r$ until it reaches 0.9mm, then the changes are minimal. Table 2 shows the optimized dimension of the design.

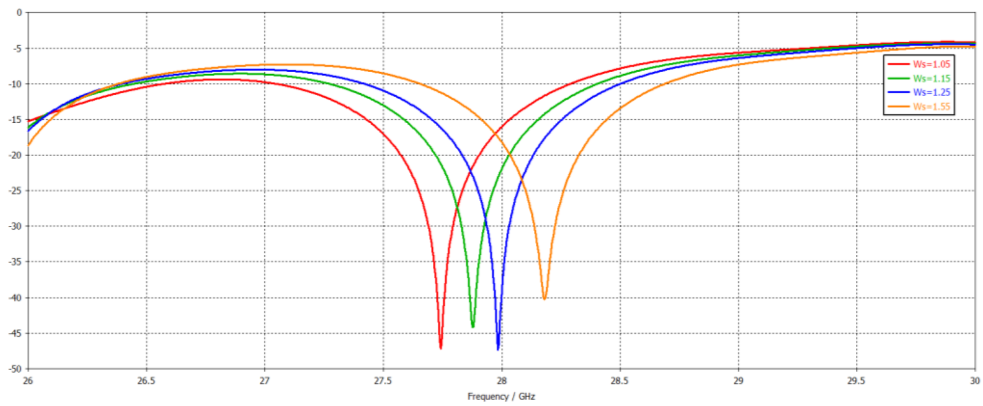


Figure 4. Parametric study of short arm width, $W_S$

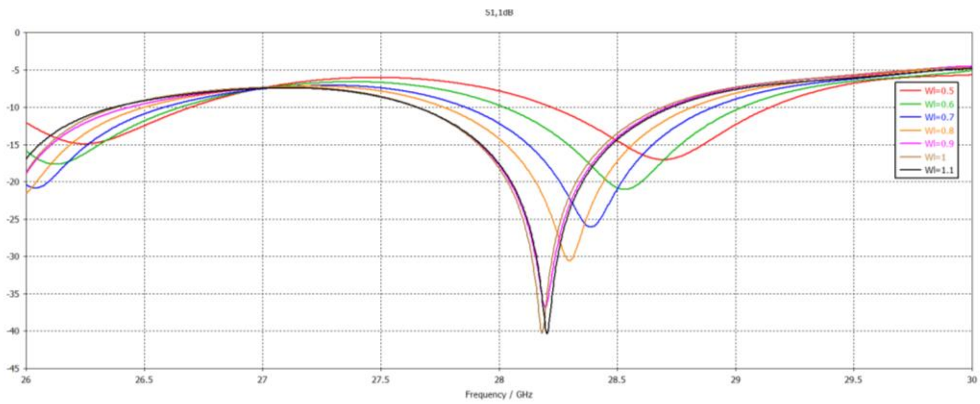


Figure 5. Parametric study of long arm width, $W_L$

Table 2. Optimized Dimension of Transparent Grid Array Antenna

| Parameter | Length (mm) |
|---|---|
| *l* | 4.814 |
| *s* | 2.438 |
| $W_L$ | 1.000 |
| $W_S$ | 1.250 |

## 3. RESULTS AND ANALYSIS

Figure 6 shows the frequency response of both reference and transparent grid array antennas with a resonance frequency of 28GHz and **Error! Reference source not found.** shows the results summary of return loss and bandwidth of the design. From the results shown, the transparent grid array antenna gives better performance in terms of efficiency as it has 35.7%. lower return loss. Whereas, as predicted, the reference antenna gives wider bandwidth compare to the grid array as discussed in [33]. Besides that, the size of the reference antenna is also a concern as it will be difficult to do the realization due to its small size compare to the Grid Array antenna.

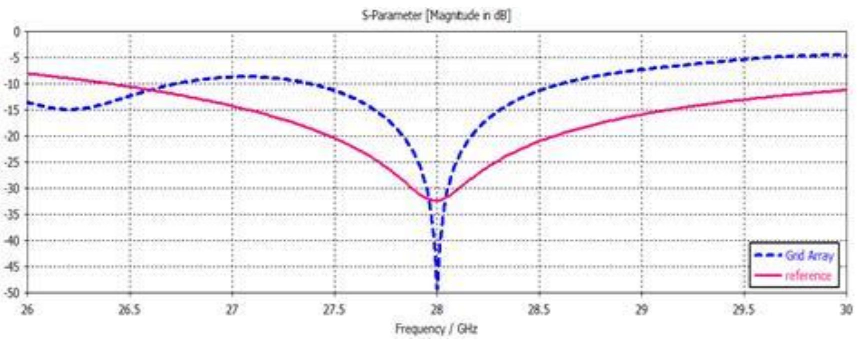


Figure 6. Frequency response

Table 3. Return Loss & Bandwidth Results

| Parameters | Reference | Grid Array |
|---|---|---|
| Return loss | -32.335 | -43.88 |
| Bandwidth (GHz) | 4.018 | 1.253 |
| Bandwidth (%) | 14.35 | 4.48 |

Figure 7 shows the 3D radiation pattern of both antennas designed and Table 4 shows the summarization of gain, VSWR, and the radiation efficiencies. As shown in the table, VSWR and radiation efficiency of both antennas are satisfactory which are near to 1 and higher than 50 percent respectively. But Grid Array antenna gives better efficiency compared to the reference one. The fact that grid array antenna is one of the methods used for enhancing gain, then, as expected the gain of the Transparent Grid Array antenna is almost 42% higher compared to the basic rectangular antenna.

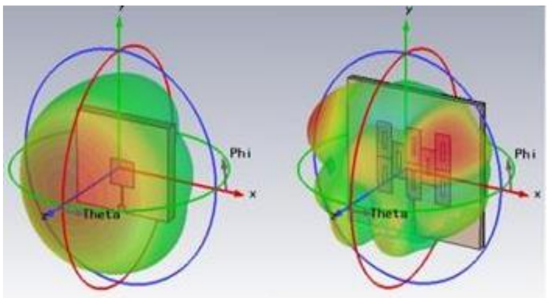


Figure 7. 3D radiation pattern

Table 4. Gain, VSWR, and Radiation Efficiency Result

| Parameter | Reference | Grid Array |
|---|---|---|
| Gain (dB) | 5.192 | 7.358 |
| VSWR | 1.05 | 1.01 |
| Rad. Efficiency (%) | 77.88% | 83.68% |

## 4. CONCLUSION

This paper compares two types of transparent antenna that operate in 28 GHz frequency, which are using ITO thin film as the radiating material. The designs that have been discussed are transparent microstrip grid array antenna and a basic rectangular microstrip patch antenna. Basic rectangular patch antenna gives wider bandwidth, but Grid Array antenna gives better performance in terms of higher radiation efficiency and gain with much lower return loss.

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## BIOGRAPHIES OF AUTHORS

Nur Izzati Mohd Ali received B. Eng degree in Electronic Engineering (Telecommunication Electronic) in 2011 from Universiti Teknikal Malaysia Melaka (UTeM) and a Master degree in Electronic Engineering (Telecommunication System) in 2012 from the same university. She is Ph.D. student of Universiti Kebangsaan Malaysia (UKM) specifically under the Centre of Advanced Electronic and Communication Engineering (PAKET), and her current research work includes the transparent solar antenna for 5G band application. Nur Izzati is also a graduate member of The Institution of Engineers, Malaysia, and a member of the Board of Engineers Malaysia (BEM).

Professor Dr. Norbahiah binti Misran received her bachelor's degree from Universiti Kebangsaan Malaysia (UKM) and Ph.D. from Queen's University Belfast. Currently, she is a Professor and the Chair of the Centre of Advanced Electronic and Communication Engineering (PAKET) in UKM. Her expertise is in Reflectarray antenna, Multiband and wideband planar antenna, and Electromagnetic absorption reduction. She is also a member of the Board of Engineers Malaysia (BEM), member of The Institute of Electrical & Electronics Engineers (IEEE) and member of IEEE Antenna and Propagation Society. Her current research works include wireless communication engineering, RF device, and antenna design, and engineering education.

Dr. Mohd Fais Bin Mansor, senior lecturer in Universiti Kebangsaan Malaysia (UKM), received his Master from UKM and University of Duisburg-Essen and his Ph.D. from University of Surrey. His expertise is in Antenna and Propagation, RF circuit and systems, and Wireless Communication. His current research work includes MIMO Antenna and RF circuits, Reconfigurable mm-Wave antenna array, Reconfigurable dielectric resonator antenna, Active reflectarray system, Solar integrated reflectarray system, and mm-Wave system using LTCC fabrication technology. Dr. Mohd Fais is the graduate member of the Board of Engineers Malaysia (BEM), and member of The Institute of Electrical & Electronics Engineers (IEEE).