A Transparent Dual-Polarized Antenna Array for 5G Smartphone Applications

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***Abstract*—Future 5G applications at mm-wave frequencies require antenna arrays which consume large PCB area. A transparent antenna array in which the radiating elements are made visually transparent and integrated with mobile phone rear glass is proposed as a solution for saving enormous PCB area giving an additional degree of freedom for mobile phone system design engineers. A new antenna array configuration is proposed which consists of dual polarized meshed capacitive fed patch antennas with feed section in mobile phone PCB and radiating patch integrated into mobile phone rear glass. Indium tin oxide is used as the transparent conducting oxide. The radiating patch is meshed to further improve the visual transparency. The antenna array has a 10 dB return loss over 23.5-32 GHz and achieves a minimum realized gain of 12.1 dBi making it suitable for 5G smartphone applications.**

***Index Terms*—5G, antenna, dual-polarization, ITO, mesh antenna, mm-Wave, patch antenna, phased array, smartphone, TCO.**

I. Introduction

One of the key motivators for 5G is to provide ubiquitous, high-speed, high-quality wireless broadband coverage to meet societal and industrial needs beyond 2020. The frequency band around 28 GHz is considered as one of the prospective bands for mm-wave 5G smartphone applications [1].

Recently, several researches are focused on developing mm-wave phased antenna arrays at 28 GHz for 5G mobile phone applications. In [1], researchers at Samsung America developed a mesh type patch antenna with dual feeds to achieve dual polarization around 28 GHz. The antenna array was placed in the plane normal to the PCB as opposed to the conventional PCB plane placement to save space. But the bandwidth was 2 GHz which was not sufficient. In [2], the authors proposed a compact PIFA with defected ground structure with a wide bandwidth of 6 GHz. However, the design did not provide dual polarization. In [3], four linear sub-arrays of 12 capacitive fed patch antennas each was integrated into mobile phone PCB for providing 360^0 coverage. The design provided good coverage and sufficient bandwidth but occupied large space in the PCB and provided only single linear polarization.

This work focuses on developing a novel two dimensional transparent dual polarized antenna array with wide bandwidth and minimum PCB footprint by integrating the radiating element in the mobile phone rear glass. The antenna is made visually transparent using transparent conducting oxide and antenna meshing technique to preserve the mobile phone aesthetic properties.

In Section II, the proposed antenna array configuration and performance is described. The design principle of the antenna element is also discussed. Some conclusions are given in Section III indicating the achievements of this research.

II. Antenna Array Configuration and Performance

A. Antenna Array Configuration

The proposed 2×2 antenna array consists of dual polarized meshed capacitive coupled patch antenna elements in which the radiating patches are integrated into the mobile phone rear glass of dielectric constant (ε_{r2}) 4.82 and the capacitive feeds are printed in the PCB as shown in Fig. 1. The 4-element antenna array is located at the middle of the mobile phone chassis. Rogers RT5880 Duroid of a relative dielectric constant (ε_{r1}) 2.2 at mm-Wave frequencies is used as the substrate for printed circuit board of size 150 mm × 74 mm which models a 5-inch mobile phone. The antenna elements are placed with a separation of 0.64λ between each element to ensure good isolation between the antenna elements and minimize the grating lobes.

Transparent Conducting Oxide (TCO) film is a thin film that is conductive electrically and transparent optically. Indium tin oxide (ITO) coating of conductivity 2.4×10^5S/m is used as the transparent conducting oxide to achieve a transparency of 80% for the radiating patch [4]. The patch is meshed in the form of a net to further improve the visual transparency.

The patch antenna is probe fed at two locations using two 50Ω SMPM connectors to achieve dual polarization. The feed locations are such that the TM_{10} and TM_{01} orthogonal patch modes are effectively excited. The patch has an edge length of approximately 2.3 mm which is $0.2\lambda_{eff}$ at 28 GHz. The bandwidth of micro-strip patch antennas can be widened by increasing the substrate thickness. However, the use of very thick substrates leads to an increase in the inductive component of the input impedance which ultimately prevents

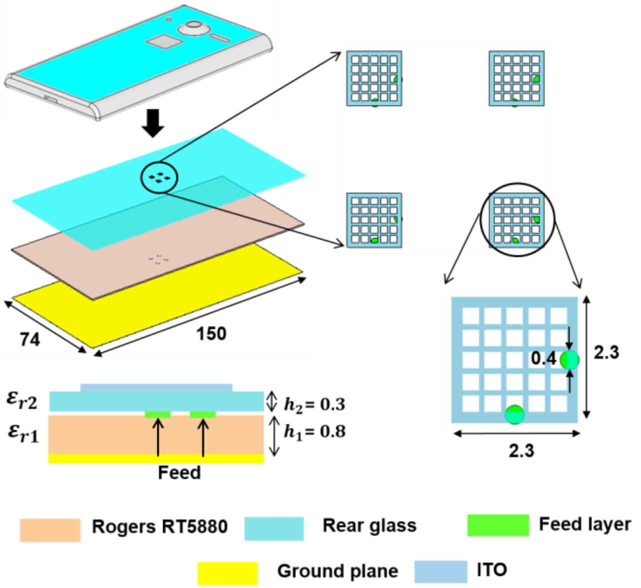

Fig. 1. Proposed 2D transparent antenna array configuration for mobile phone with a zoomed view of the antenna element (dimensions are in mm).

a match being obtained. A capacitive feeding technique in which the capacitance due to the gap between the feed and the radiating patch is used to cancel out the inductive component to obtain broadband impedance matching. Meshing the patch away from the patch edges will not significantly deteriorate the patch performance as the strong currents are seen at the patch edges due to the skin effect.

B. Antenna Array Performance

The simulated reflection coefficient of the antenna array is shown in Fig. 2. Only the most significant reflection coefficient data has been shown. The results indicate a 10 dB return loss over an 8.5 GHz bandwidth from 23.5-32 GHz. A worst-case isolation of 17.5 dB is seen between feed 1 and feed 3 of the adjacent dual polarized patch antenna elements. A worst-case isolation of 15 dB is seen between the two feeds of the dual polarized patch antenna.

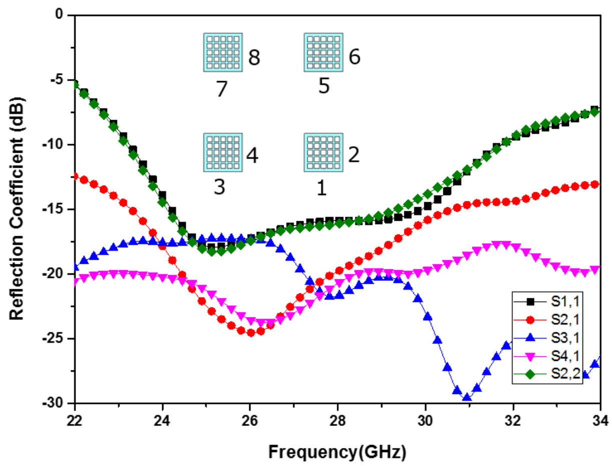

Fig 2. Simulated reflection coefficient of the antenna array.

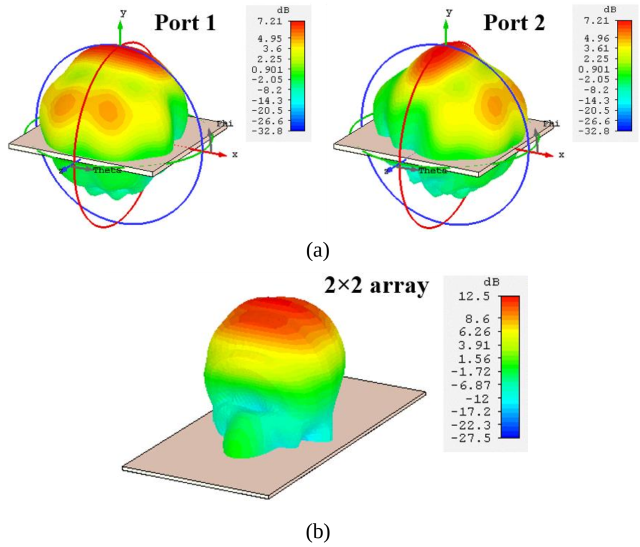

Fig 3. Radiation pattern at 28 GHz (a) Single element patch antenna (b) 2×2 antenna array.

The radiation pattern of two feeds of the single patch antenna element and the 2×2 array is shown in Fig. 3(a) and Fig. 3(b) respectively. The antenna element exhibits a broadside radiation pattern with realized peak gain around 7.21 dBi for both the feeds at 28 GHz. The array gain at boresight is around 12.5 dBi which is sufficient for 5G smartphone applications.

III. CONCLUSION

A transparent antenna array in which the radiating element is integrated in the mobile phone rear glass has been proposed as a solution for saving enormous PCB area. A dual-polarized meshed capacitive-fed patch antenna has been used as the radiating element with feed section in PCB. ITO has been employed as the transparent conducting oxide. The antenna array achieved a 10 dB return loss over a wide frequency band of 23.5-32 GHz and obtained a minimum realized gain of 12.1 dBi making it suitable for 5G smartphone applications. The antenna will be fabricated, and the measurement results will be presented.

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