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Latest Trends in 5G OTA, A Review

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Abstract:
As 5G technology grows, more access points are needed, which can clutter spaces. Optically Transparent Antennas (OTAs) solve this by blending into the surroundings while meeting communication needs. They integrate into structures without altering designs.

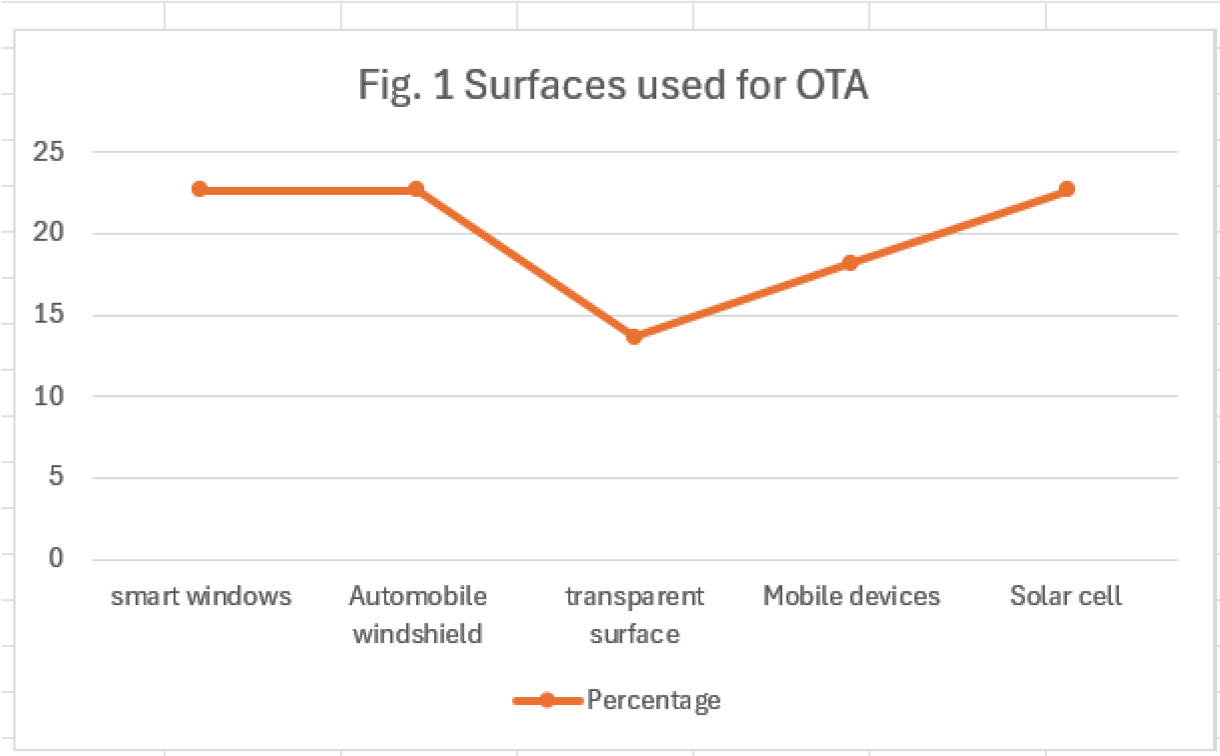
The study explores OTA materials and techniques like Metal Mesh (MM), Transparent Conductive Film, and Transparent Conductive Film (TCF), Transparent Conductive Oxide (TCO). It examines how these affect antenna gain, bandwidth, efficiency, and transparency.

Challenges and limitations of OTAs are discussed, but they are confirmed as a promising solution for future networks, balancing looks with performance.

Keywords: OTA, MM, TCF, TCO, FoM, MM, TCF, TCO, µMM, PVD, AoD ;

1. INTRODUCTION:

Access points are like gateways that help devices to connect to the internet wirelessly. 5G serves fast internet provided there are enough gateways. OTAs serve like gateways and are transparent like clear glass and can be placed on surfaces without being noticed. When using them, the desired communication system requirements should be fulfilled. They are integrated into different infrastructures. For achieving high speed data, due to advancements in wireless communications. This way, IoT, AI, Robotics, Machine Learning have enabled us to full potential. Due to 5G being easily available in all cities, high speed connectivity, device integration and low latency has helped communication become very fast. OTA technology has become the best solution for balancing aesthetics of desired communication [1]. The antenna gain, bandwidth, efficiency, transparency, and materials used are the important parameters that are of concern here. OTA seamlessly integrates into a variety of surfaces like windows, screens, and buildings. The performance is robust, and no compromise is needed to be done in the system design. The access point required for these technologies can be integrated in the antenna itself. The design of antenna is dependent on the application. When antennas are reinforced the surface area increases. For the past 7 years OTA technology has grown leap and bounds. Some of the essential parameters of OTA materials are sheet resistance, transmittance and radiation efficiency [2]. So also, important factors to consider are long term durability, and cost effectiveness. This ensures efficiency and sustainability of OTA in real world situations. Fig.1 displays the different surfaces used for OTA and its percentage.



OTAs can be placed on the surface of buildings, ceilings, mirrors, windows and screens.

2. IMPLEMENTATION OF OTAs:

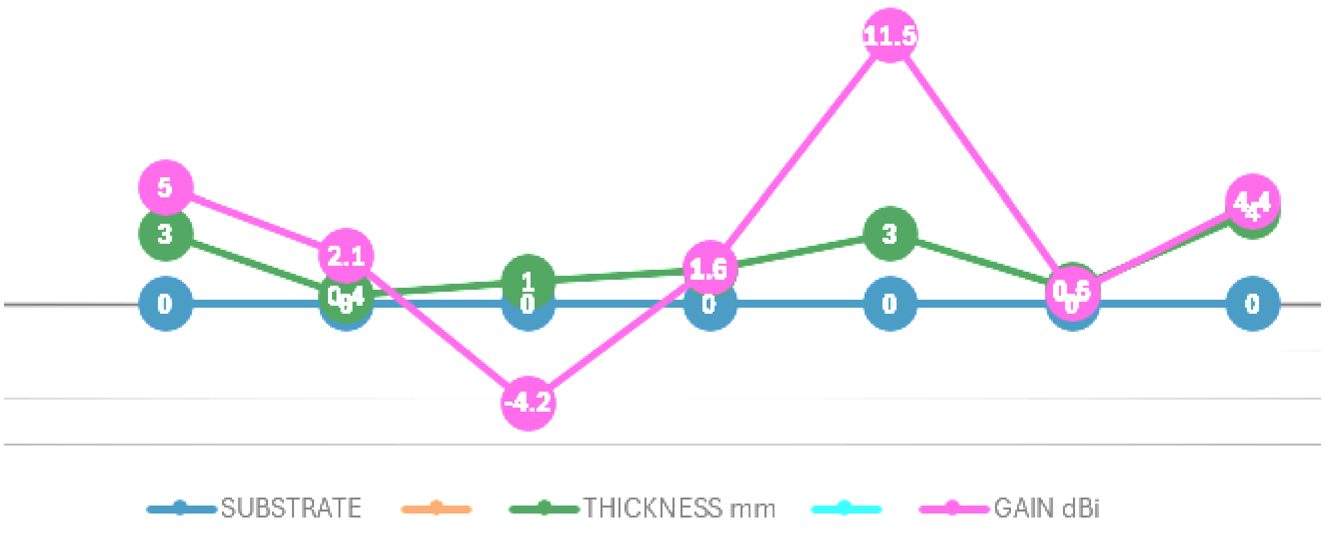
Implementation of OTA is like microstrip antenna [3]. It is classified into three parts, ground plane, substrate, and conductive area. The last being on the top. The characteristics of these elements express the electromagnetic behavior of the OTA. The width, length and thickness of the conductive material affects the working frequency. The height expresses the bandwidth. The entire system is transparent unlike that of a microstrip antenna. It is expected to have higher conductivity except for few ohmic loss. Optical transparency is an ability to transmit wavelength from UV to longwave infrared. Correlation percentage is a percentage obtained from ratio of transmittance of the conductor and sheet resistance. Higher the correlation better is the performance of OTA. If transparency is high, the sheet resistance is low. An ideal transparent conductor has a hundred percent optical transmittance and infinite conductivity. The correlation factor is a figure of merit (FoM), used to quantify electrical and optical character of the material [4]. This helps in comparing OTAs and decide for its application suitable. Humidity and temperature of the environment does affect the performance of an OTA. The dielectric constant changes the resonant frequency. To avoid these problems the height of substrate is increased at the cost of OT. Substrate is made of glass, polyethylene terephthalate (PET) and polyethylene naphthalate (PEN) [5]. OTA should allow visible light frequency to pass through. Techniques like Metal Meshes (MM), Transparent conductive films (TCFs) and Transparent Conductive Oxides (TCOs) are used [6].

3. MANUFACTURING TECHNIQUES OF OTA:

Tradeoff between transparency and conductivity is always existing here. In MM technique of manufacturing [7]. A metal sheet is made as a mesh by perforation. A periodic metal pattern is created on it and is placed on a transparent substrate for radiation. The sheet is either of copper, silver or aluminum whose thickness say is ‘t’. The antenna is more effective if has lower resistivity. Mesh characteristics

influence transparency and effectiveness of antenna. Important among them is gap size 'g', gap shape and number of gaps. The width of gap line is taken as 'w'. The ratio of area of gaps and total area of sheet is termed as fill factor φ, which is a percentage representing OT of the metal sheet.
φ = w/(g+w). The factors φ and OT are interrelated. Conductive material is dependent on φ. Lower the φ and OT, greater is the efficiency of antenna. Transmittance T is open area of the mesh such that: $T = (1-\varphi)^2$ The gaps are usually in square lattice form, but diamond shapes and honey comb also are prevalent. MM uses mesh of millimeter size. It gives lower OT but better conductivity. Another version called as mesh of micrometer size µMM has low conductivity but higher OT. Ink-jet printing can also be used in MM and so also physical vapor deposition (PVD) is useful along with electroplating. They are more complex and costly procedures. For RF application lower sheet resistance is desirable. All 5G antennas should operate at mmWave frequencies. B5G is an emerging 5G technology. AoD is Antenna on Display is integration of antenna with OLED screen. Here device screen is used as a substrate and MM is used as a radiating element. Use of meta surfaces and other materials have been used for MM technique. Ag can be deposited on polymethyl methacrylate (PMMA), making more transparency and better electromagnetic performance for mobile applications.
Transparent conductive film (TCF) technique uses fully transparent material, for antenna, conductor, substrate and ground plane [8]. Flexibility can be achieved by combining this with MM. Examples of such designs are AgHT-4, AgHT-8. Graphene, polymers and metamaterials. Their conductivity is lower than metals. Antennas with AgNWs are smaller in size. Conductivity is high in them [9]. Here a balance needs to be there in between thinner material for OT and thicker to minimize ohmic losses. At high frequency Skin effect becomes prevalent because of losses. Theus the current density is concentrated near the surface of the conductor. The skin depth $\partial = \sqrt{(1/(\pi f \mu \sigma)}$ where $\mu\ is\ permeability\ of\ free\ space$ $\sigma\ is\ electrical\ conductivity,$ 'f ' is operating frequency.
The technique of Transparent Conductive Oxide uses doping metal oxides. The OT is high and has better electrical conductivity. Monolayer substrates are used and hence are fragile. The film of TCO has refractive index n, attenuation coefficient α, extinction coefficient k, thickness t, and transmission T = $e^{-\alpha t}$ If λ is wavelength and k is the extinction coefficient then $\alpha = \frac{4\pi k}{\lambda}$ Here Indium tin oxide (ITO) is commonly used [10]. It has health risk in extraction and prolonged exposure. Indium is a scarce material, instead Gallium doped Zinc oxide (GZO0 and Aluminum Zinc oxide (AZO), Fluoride Tin oxide (FTO) may be used.
Multilayer Film like TCO is obtained using different transparent material. Comparing various materials like Glass, Quartz, Acrylic, and PET, for the past 4 years, and comparing the thickness, type of metal used, and other characteristics, and comparing them with copper and silver, there is trend towards using advance materials for better performance. The most transparent is Glass. With 95% transparency, 1.1 mm thick, and the conductive coated material used is ITO (Indium Tin Oxide). This is useful for displays. It creates clear visuals and has the best electrical performance. The best efficiency is that of Pyrex glass. Glass has the highest gain of 25.8 dB.

Fig. 2 Comparison of OTA using TCF



4. FINDINGS:

MM and TCF are good in terms of OT and are helpful for integrating in wireless technologies, preserving aesthetics. TCF antennas are invisible to the human eye and can be integrated on glass, touchscreens and solar panels [11]. MM based antennas are useful where the need of superior electrical performance. They are best suited for larger surfaces. It does not have full transparency and is not suitable for smartphone displays. TCFs enable transparent conductors maintain OT and conductivity in μm and mm regions. MMs function as High Pass Filter, reflect certain frequencies but allowing transmission based on structural characteristics. The sheet resistance is dependent on the material used. MM technique has better efficiency. Performance is based on sheet resistance, thickness, and conductivity. The physical parameters are altered in the presence of humidity and temperature. Thermal stress rate is mechanical stress, which is caused by temperature variations from 1% to 2%. MM technique is superior to FoM in terms of performance. As the metal area decreases, OT increases and conductivity and efficiency decreases. If transmittance is 1, the material is considered fully transparent, and if it is zero it is opaque. If φ decreases material becomes more transparent. The skin effect varies with frequency [12]. When frequency increases, skin depth decreases. If thickness is increased, conductivity increases, reducing OT. Ratio t/δ should be about 3 for minimizing the skin depth loss. For low frequency skin effect is negligible. Material innovation and optimization strategies is important in addressing the challenges in OTA design. High OT is always desirable, with low resistance at HF [13].

5. CONCLUSION:

In future several base stations are needed, so access points should increase to have a high data rate. OTA is the best solution for this demand, keeping in mind easy integration of that to the surfaces like glass, OLED displays, Solar panels and building structures. OTA provides a perfect balance between OT and electrical performance, without changing the aesthetic environment. The most important characteristics to be concerned about here are OT, gain, bandwidth, operating frequency, and radiation frequency. The transparent material should be so chosen that it satisfied the needs of the application. Every technique of OTA manufacture has its advantages and disadvantages. MM technique is good for electrical performance, but the transparency is not good. TCF is good at high optical transmittance, but the electrical performance is not that good. TCFs are fragile. MLF OTA are more flexible and durable. OTA helps high speed, low latency communication for the given data rate, particularly at 5G, and beyond. Using OTA there is no scenery disruption, and the performance is also desirable.

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