Multipurpose Optically Transparent Planar High-gain Passive Antenna

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CSEM designed, prototyped and characterized a high-gain antenna array operating at 2 GHz-5 GHz that is passive and optically semi-transparent. It is used for relaying the RF signal through high attenuation glass structures, while preserving the properties of the glass. The concept uses a semi-transparent conductive material, which is deposited on window glass. It allows for relaying and focusing an RF signal and improving the RF link budget through the window by 7 dB to 10 dB at 2.45 GHz.

The use of a transparent antenna in combination with relatively large unused glass surfaces, such as windows (e.g. on buildings, cars, trains), or even smaller surfaces (e.g. a watch glass or a light bulb) can increase the effective area of the antenna and thus the gain and performance of a wireless device. To this end, CSEM integrates flexible and semi-transparent antennas into devices of all shapes and sizes in order to benefit from unused areas and volumes. This allows for the budget link to be improved, while reducing the impact of the antenna on the device size.

There are several candidate materials suited for making transparent antennas such as spray-on conductive substances or metallic conductive films. Thin film deposition techniques, such as Physical Vapor Deposition (PVD), can be used to produce high conductivity transparent multilayer Transparent Conductive Oxide (TCO), or highly conducting ZnO/silver. This technology, widely used in solar cells, can be employed to develop high performance transparent antennas. Many transparent (physically or electromagnetically) materials, including glass and plastics with curved or flat surfaces, can be processed to integrate an efficient transparent antenna. In addition to improved performance, this technology also offers an increased flexibility in design integration and an efficient use of pre-existing device surfaces.

The transparent antenna solution developed by CSEM is based on the deposition of a conductive layer on a glass window. The antenna can either be completely passive or active when connected to an RF transceiver. It can also comprise several antenna elements assembled into an array. A passive antenna array consists of many small elements distributed so that it forms a beam, increases directivity, etc. For example, the additional directivity and gain provided by forming a beam via a smart window may be used to improve the propagation (link budget of RF signal) inside a building, to relay GPS satellite signals or to drastically improve GSM communications inside the building.

The proposed design serves as a generic basis for developing transparent antennas that may be used for many applications and systems (5G, GPS, GSM, Wi-Fi) operating in various frequency bands:

- Smart buildings (transparent window antenna solutions, PV cell antenna…)
- Automotive (communication, energy harvesting system)
- Security: sensors integrated into the window, e.g. for security and environment monitoring

In the example of Figure 1, the concept is based on the phase gradient of frequency selective surface (right) and an externally place low gain source antenna ("external antenna"). Circular shaped elements with a diameter ranging from 1cm to 6cm have been used (Figure 1, left). In real life an external antenna is any antenna built into a portable (e.g. cell phone) or stationary (e.g. WiFi or GSM / LTE routers) devices.

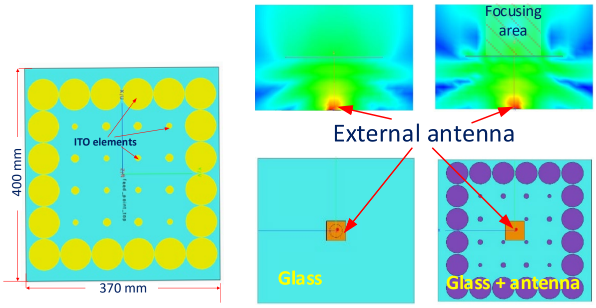

Figure 1: Antenna array theoretical model.

The complexity of the structure (e.g. the number of elements) depends on the application and the required characteristics. All elements are placed on one side of the 3 mm thick glass plate. In this case, the glass plate measures 400 mm by 370 mm. The transparent antennas were designed, manufactured and tested using only CSEM facilities. The measurement results are presented in Figure 2. By comparison with a conventional antenna operating in free space, the passive glass antenna provided an additional 3-4 dB of gain. Considering the losses in the glass and the limitations in the achievable coating thickness, the smart window antenna still increases the gain from 5 dBi to 10 dBi.

A large passive transparent antenna array can potentially improve communication channel budget by up to 15 dB.

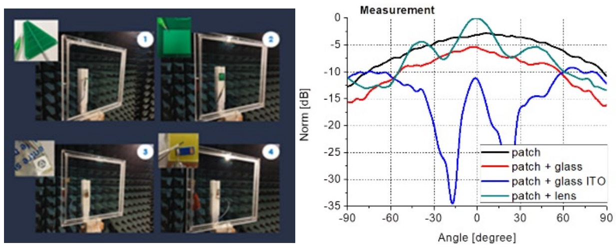

Figure 2: Window antenna characterization with different source antennas (left) and normalized measured antenna gain (right).

The proposed transparent antenna designs leverage and combine the multidisciplinary expertise of CSEM (i.e., antennas, wireless systems, materials) to provide a unique set of mechanical, visual and electro-magnetic properties. The advanced RF antenna can be combined with other aspects (e.g. transparent PV cell antennas) of a smart window, to support multiple functionalities, such as energy-saving, energy harvesting and RF communication.