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Wideband All-Dielectric Reflector at 100 GHz for 6G Communications

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***Abstract*—Power-efficient systems are required for 6G communications. Part of a window real-state can be used as placement of a reflecting metasurface, which can provide coverage to users in scenarios, where there are no line-of-sight links. In this contribution, we propose a wideband all-dielectric metasurface at 100 GHz that consists of alumina posts on plastic and does not depend on the angle of incidence. The design has been manufactured and measured, with good agreement between measurements and simulations.**

I. Introduction

The current roll out of the fifth generation of mobile communications (5G) has marginally eased the demand for network capacity, with the incorporation of some frequency bands in the millimeter-wave (mm-wave) spectrum. However, the demand continues to grow exponentially, and with the inclusion of applications with augmented reality in the following years, 5G will also face a capacity shortage [1]. The future sixth generation of mobile communications (6G) will benefit from the inclusion of frequency bands from 100 GHz to 1 THz [2]. Data rates of 100 Gbit/s can only be achieved with very high spectral efficiencies or with bandwidths of unregulated spectrum of more than 10 GHz. The former is extremely challenging and the latter one, can only be found from 300 GHz [3].

Higher-gain antenna systems are employed in 5G to compensate the larger propagation attenuation. In [4], an average cell radius of 72 m is obtained for a coverage probability of 95 % in a 30 GHz network 6G will improve the energy consumption of 5G networks, by reducing the number of base stations per km^2 needed, in conjunction with other solutions. One of the methods to increase the sustainability of the communications consists in the inclusion of reflective elements, which can provide a propagation link between base station and user, when there is no line-of-sight connection. Their function is to act as relays, and they can either be passive or enhance the signal strength. Reconfigurable or large intelligent surfaces (RIS, LIS) are considered passive, as they are made of simple reflectors, but they are software-controlled to achieve the required phase. The software controller requires minimal power for operation [1], [5]. The majority of these reflecting surfaces are made of two metal layers separated by a dielectric [6]–[8], or full metal, as in [9]. Reflective all-dielectric surfaces have also been proposed in literature [10], [11].

In order to achieve high reflection of two dielectric substrates stacked together, Mie theory can be used to generate magnetic and electric resonances close to each other [12]. The Mie scattering efficiency can be improved embedding high-permittivity particles in a low-permittivity medium. The size of the particles should be comparable to the wavelength. At the resonance of the multipolar modes, there is a strong confinement of the fields inside the particle and the performance is comparable to the metallic counterpart [13]. The ratio of the refractive indexes of the two substrates controls the reflection bandwidth [10]. Therefore, high-index contrast is required for wideband applications. It is possible to find transparent ceramics made of yttrium oxide and laser host materials with high permittivity [14].

In this work, we have proposed and manufactured an all-dielectric reflective metasurface at 100 GHz. The metasurface is supposed to be mounted on the windows of buildings and is quite robust to the incidence angle. The material characterization kit (MCK) from SWISSto12 has been employed to perform the transmission/reflection measurements at 100 GHz.

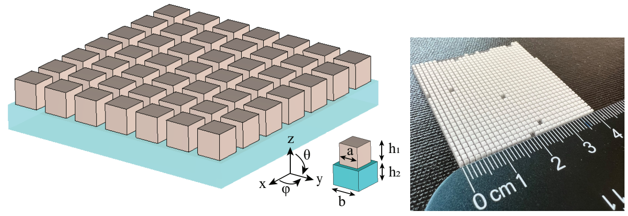
II. Proposed Design

The materials chosen to make the manufacturing easier are alumina (material 1) and plastic (material 2). The metasurface dimensions and measured material properties can be found in Table I. The fabricated design is shown in Fig. 1.

TABLE I
Design parameters of the manufactured all-dielectric reflector.

Parameter	Value [mm]	Parameter	Value [$\cdot$]
a	1	ϵ_{r1}	9
b	1.42	$\tan\delta_1$	0.004
h_1	1.02	ϵ_{r2}	2.97
h_2	0.98	$\tan\delta_2$	0.008

Fig. 2 shows the s-parameters comparison between measurements and simulation. An extra trace with the reflection coefficient of the full substrates (alumina and plastic) before dicing the posts has also been included as a reference. At 100 GHz, the full substrates stacked together have a reflection coefficient of -6 dB. However, when the posts are diced with the appropriate dimensions, a reflection coefficient of -0.4 dB can be achieved. Good agreement can be seen between measurements and simulations. As a note, the measurement results above 110 GHz, are outside the measurement range of the MCK. Therefore, they might not be accurate.



(a) (b)

Fig. 1. (a) Proposed design. (b) Manufactured metasurface with alumina posts on plastic. During fabrication, 2 % of the posts fell off, mainly on the sides, which do no affect the overall performance, as the measured area is smaller.

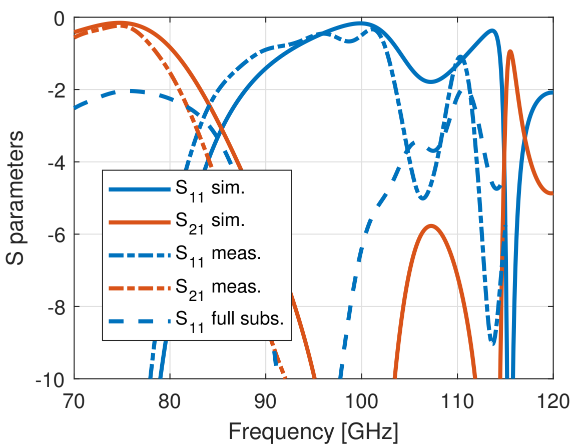


Fig. 2. S parameters comparison of the simulated and manufactured all-dielectric reflector. The last trace corresponds to the measurement of the full alumina substrate glued on top of the plastic one.

The simulated reflection coefficient as a function of the angle of incidence has also been plotted in Fig. 3. The combination of alumina and plastic provides a quite robust performance to the angle of incidence, with only a reflection zero around $40°$.

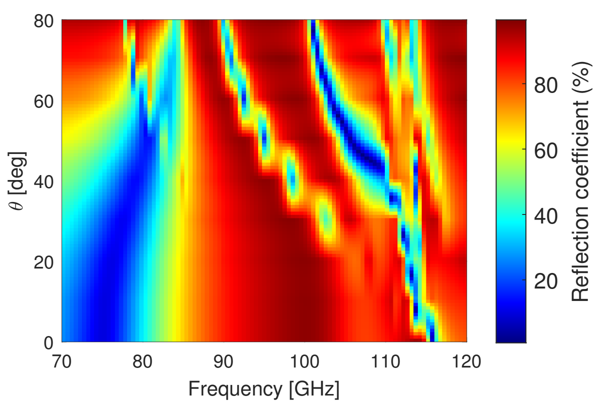


Fig. 3. Reflection coefficient depending on the angle of incidence.

III. Conclusion

An all-dielectric metasurface has been designed by enhancing the scattering of the substrates with Mie theory. With high-refractive index contrast and coupling the electric and magnetic dipole moments, broad reflection bandwidths can be achieved. To be able to manufacture the metasurface with the available in-house tools, alumina and plastic have been employed for the fabrication. The simulation and measurements show good agreement.

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