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Composite based metasurface for surface wave excitation in HF band

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Abstract: This paper describes the design of a low profile inductive surface for High Frequency Surface Wave Radars (HFSWR) in HF-band. We discuss about reducing the thickness of the metasurface by designing an adapted dielectric support. The metasurface is then exploited to highly increase the electric field near the ground when illuminated by a quarter-wave monopole in TM polarization. This enhancement of the electric field is necessary in order to excite a surface wave.

Being able to detect ships up to 200 nautical miles, High Frequency Surface Wave Radars (HFSWR) constitute a major asset for maritime surveillance of Exclusive Economic Zone (EEZ), which is an area up to 200 nautical miles from coastal baseline where a sovereign state has special rights such as fishing and oil extraction exclusivity. ONERA, the French Aerospace Lab, has been developing radars (Graves, Nostradamus) and more specifically HFSWR for several years. First, an installation has been successfully tested [1], but interferences due to sky waves reflecting on ionosphere have been acknowledged [2]. Later, a metamaterial structure placed in front of the emitting antenna has been proposed in order to reduce ionospheric sky wave interferences and to increase the propagating energy near the ground in the forward direction [3, 4]. However, it has been observed that the structure is too high, typically $\lambda/10$ (3 m at 10 MHz), to withstand strong sea winds and due to regulation in protected natural area. A reduced profile metasurface of height $\lambda/30$ designed on a Rogers TMM6 substrate has been proposed and tested in the L-band at about 1.1 GHz [5]. Here, we make a step forward to design a new surface wave exciting structure that is compact and realizable in HF-band.

The metasurface is composed of resonant square metal rings printed on a dielectric substrate. The transposition of the previously designed L-band metasurface to the HF-band would require a very large size of the commercial Rogers TMM6 dielectric substrate, which is unrealizable in practice. Hence, it is highly desirable to find a natural material that has similar properties to the TMM6 substrate. We thus propose a composite material based on air and distilled water.

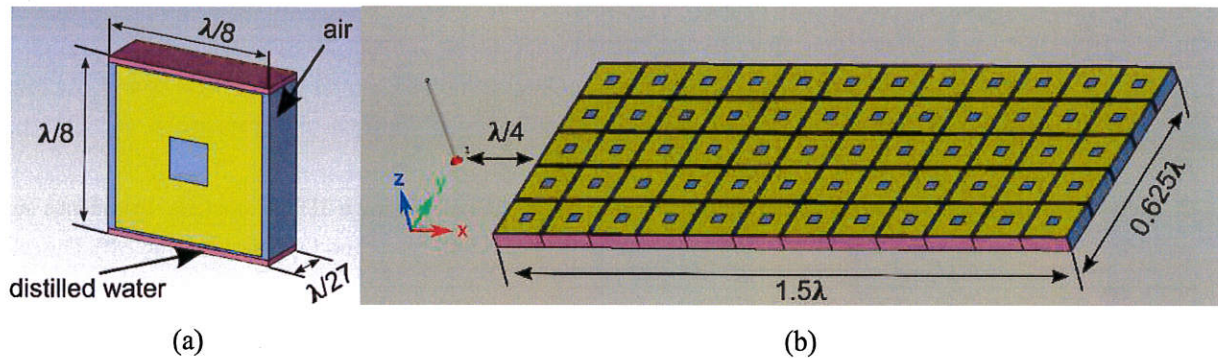


Figure 1. (a) Unit cell designed using a composite dielectric material made of air and distilled water. (b) HF-band metasurface-based antenna.

Different designs of dielectrics, based on the shape of the composite and the materials used, can be considered. Their dielectric properties are obtained using the Nicholson-Ross-Weir parameter extraction method. An example of such design is made of 90% of air in distilled water to obtain an effective permittivity $\epsilon_{\text{eff}} = 6$, see Fig. 1(a). An analytical study of the unit-cell using transmission line theory allows to tune the shape of the dielectric to get the desired inductive behaviour [5].

The performance of the metasurface is evaluated thanks to the vertically radiated electric field $E_{\text{metasurface}}$. The gain of the metasurface antenna is defined as $\text{Gain} = 20 \log_{10} \left(\frac{E_{\text{metasurface}}}{E_{\text{inc}}} \right)$, where E_{inc} is the amplitude of the electric field radiated by the monopole source. A gain enhancement of more than 10 dB (Fig. 2(a)) is observed at the extremity of the metasurface and most of the field is located at ground level ($Z=0$) (Fig. 2(b)), which is mandatory to excite a surface wave.

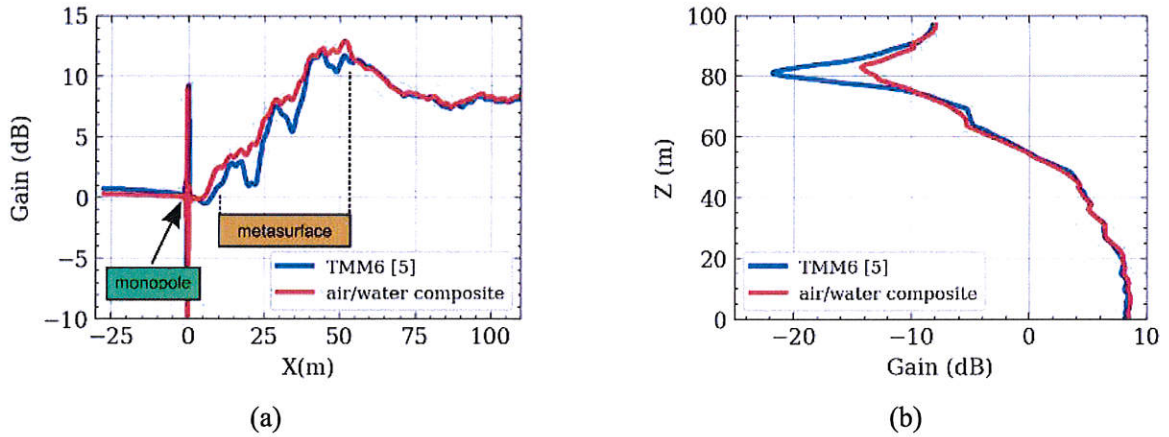


Figure 2. (a) Simulated gain of the SIS and the novel composite metasurface at 10MHz along a line in the horizontal plane. (b) Simulated gain of the SIS and the novel composite metasurface at 10MHz along a line in the vertical plane.

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