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Titre : Surface ondulée à ondes millimétriques pour la réduction du couplage mutuel entre antennes dipôles

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Résumé : La réduction du couplage mutuel entre les antennes dipôles à ondes millimétriques en utilisant une surface ondulée est présentée. La surface ondulée présente une bande interdite dans la direction de propagation vers l'antenne adjacente. Le couplage mutuel est réduit de 4 à 20 dB lorsque la surface ondulée est placée entre les antennes. De plus, la surface ondulée proposée n'a pas d'impact significatif sur le diagramme de rayonnement de l'antenne.

Mots-clés : Diagramme de rayonnement des antennes, Direction de propagation, Antennes dipôles à ondes millimétriques, Réduction du couplage mutuel, Surface ondulée à ondes millimétriques

Millimeter-Wave Corrugated Surface for Mutual Coupling Reduction Between Dipole Antennas

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Abstract—The mutual coupling reduction between mm-wave dipole antennas using a corrugated surface is presented. The corrugated surface has a bandgap along the propagation direction toward the adjacent antenna. The mutual coupling is reduced between 4 to 20 dB when the corrugated surface is placed between the antennas. Moreover, the proposed corrugated surface does not have significant impact on the antenna radiation pattern.

Keywords—corrugated surface; mutual coupling; mm-wave Antenna; MIMO

I. INTRODUCTION

Reducing the mutual coupling between radiating element in an antenna array, which in most cases results in a degradation of the expected radiation features, has been investigated by several authors [1]–[5]. Mutual coupling has an impact on antenna array performance through changing the input impedance of the radiating elements, increasing the sidelobe level and degradation of the radiation pattern shape [1]. In MIMO systems [2], for maximizing the channel capacity and improving the signal-to-noise ratio, the maximum inter-element spacing in an array must be half of the wavelength. Moreover, in phased antenna arrays an optimum distance between elements is less than half of the wavelength in order to eliminate the harmonic of the main lobe (Grating Lobe) to contribute in the array factor. However, this condition yields strong mutual coupling.

There are several techniques to reduce mutual coupling, including confocal elliptical metasurface cloaks [3], parasitic element slots [4], cavity backed resonator [5], and electromagnetic band-gap (EBG) structures [1]. Because of fabrication limitation at mm-wave frequencies, these methods are not practical. Inter-element spacing in an mm-wave arrays are less than a few millimeters.

In this paper, a corrugated surface is proposed for reducing the mutual coupling. The proposed corrugated surface has a bandgap along the propagation direction toward the adjacent antenna. The proposed structure does not degrade the radiation pattern at mm-wave bands, but at lower frequency it has significant impact on the radiation pattern.

II. ANTENNA DESIGN AND CORRUGATED SURFACE STRUCTURE

The schematic diagram of used 1×2 dipole antenna array is shown in Fig. 1. Each antenna is fed by a microstrip line. The ground plane ended at the middle of L_2 -line to operate as a balun and drives the dipole ports with 180 degree out of phase. The dipole antenna is not grounded and radiates in both half spaces. The antenna distance is half of the free space wavelength.

The conventional corrugated surface and the proposed corrugated surface are shown in Fig. 2. The conventional corrugated surface operates like as soft surface along the X-direction [6], and the surface impedance can be obtained as

$$Z_x = \frac{E_x}{H_y} = j \left(\frac{W}{P} \right) \eta \tan k_g d \quad (1)$$

The surface impedance is infinite when $d = \lambda_g/4$, which corresponds to a surface made of parallel thin strip of PEC and PMC oriented in Y-direction (Fig. 2c). The usable bandwidth is within the range of $0 < k_g d < \pi$, although surface waves may exist when $d \neq \lambda_g/4$. In practice a usable relative bandwidth is up to 3%, although the best soft E-Plane performance is when $k_g d = \pi/2$.

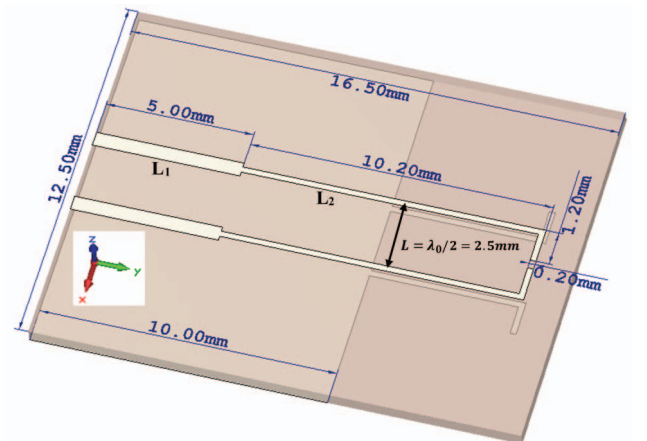


Fig. 1. Schematic diagram of 1×2 dipole antenna array.

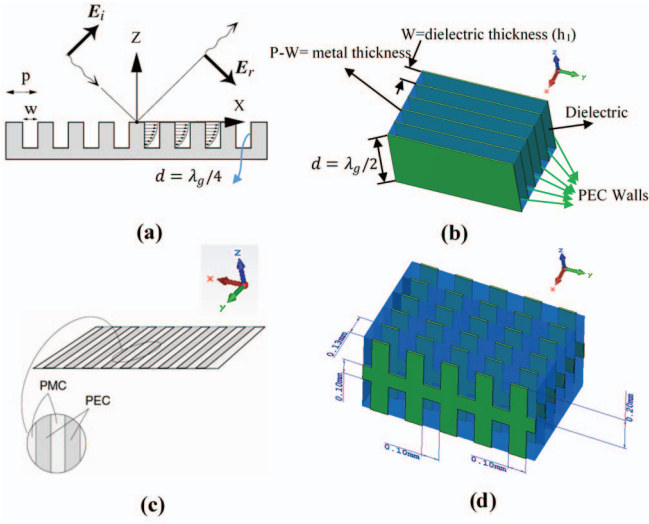


Fig. 2. Corrugated surfaces. (a) Conventional corrugated surface. (b) Proposed corrugated surface. (c) Equivalent model of corrugated surface. (d) Proposed dual-band corrugated surface.

The surface impedance of the proposed corrugated surface (Fig. 2b) can be obtained as

$$Z_X = \frac{E_X}{H_Y} = j \left(\frac{W}{P} \right) \eta \cot k_g d \quad (2)$$

The surface impedance is infinite when $d = \lambda_g/2$, which corresponds to a surface made of parallel thin strip of PEC and PMC oriented in Y-direction (Fig. 2c). As it has been said, this corrugated surface is very narrow band, in practice the usable relative bandwidth is up to 3%. To improve the bandwidth of the proposed corrugated surface, a dual-band corrugated surface (Fig. 2d) was designed to cover the frequency band of 57 GHz to 64 GHz (6% relative bandwidth).

The proposed corrugated surface is placed between the antenna elements and is shown in Fig. 3. This structure can be used only at mm-wave frequency bands. At microwave frequency bands, up to 20GHz, $d = \lambda_g/2$ is big and thus embedding this structure between the antennas has significant impact on radiation pattern and will load the input impedance of the individual antenna element through blocking the antenna radiation, and thus is not useful at these frequency bands. At

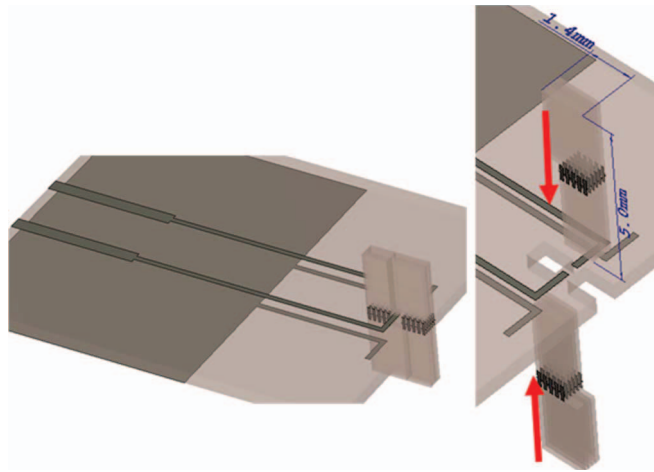


Fig. 3. Proposed 1x2 dipole antenna array with corrugated surface.

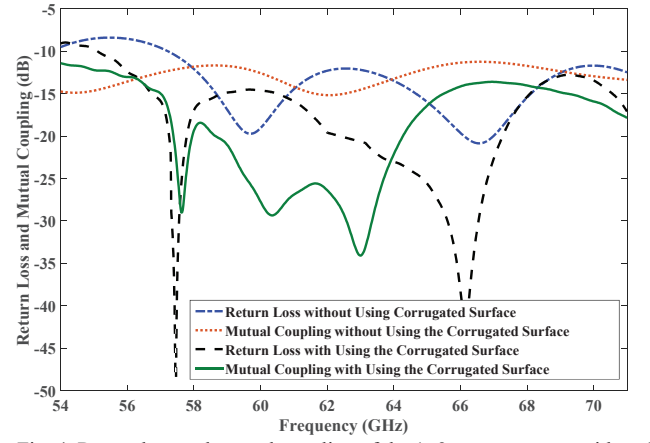


Fig. 4. Return loss and mutual coupling of the 1x2 antenna array, with and without the corrugated surface.

mm-wave frequency bands, $d = \lambda_g/2$ is in range of the host dielectric thickness and does not have significant impact on the radiation pattern and input impedance of the individual antenna elements.

The proposed antenna array with the corrugated surface and without the corrugated surface are simulated using HFSS. The scattering parameters of proposed antenna are shown in Fig. 4. The mutual coupling is reduced between 4 to 20 dB when the corrugated surface are placed between the antennas.

III. CONCLUSION

A new type of soft surface that can be used at mm-wave frequencies has been designed. The proposed soft surface has a bandgap along the propagation direction perpendicular to the coagulation. The corrugated surface has been used between two dipole antennas for reducing the mutual coupling. The proposed corrugated surface does not have significant impact on the radiation pattern and input impedance of the individual antenna elements.

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