Design of Holographic Beamforming Antenna with Slot-Shaped

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ABSTRACT *The future sixth generation (6G) wireless communications expected to construct intelligent network with low-power and high-throughput transmissions. To fulfill such challenging visions in this paper we design Holographic beamforming (HBF) antenna which is developing into a promising solution due to its flexible beamforming capability with lower energy and hardware costs. The HPF consists of an aperture-shaped microwave length array on the metasurfaces (meta-elements) that is different from the conventional phase-controlled antennas. The HPF can control the radiation amplitude and phase of reference wave propagation on the metasurface by leveraging the holographic technique. The PIN diode used in each slot to dynamically tuned between the "on" and "off" states to control the radiation direction. The proposed antenna dimensions are 50mm x 50mm. The substrate used (Rogers 4003, p = 3.38 and tan = 0.0027) and 0.578 mm thick. The feed line coaxial cable in corner to antenna is used to control the air conditioning. The HPF antenna operates at 25.5GHz with a maximum gain of 13dBi and directivity of 15 dBi with antenna efficiency up to 80.8% and achievable bandwidth of 1.4GHz at resonant frequency.*

INDEX TERMS

HPF Metasurface, PIN diode, slot shaped

1. INTRODUCTIONS

The development in wireless networks of communication is increasing that require new techniques to solve problems or reduce complicity in previous networks [1]. The HPF provide comprehensive solutions to the disadvantages of multiple input multiple output (MIMO) and phase array (PA) that used the lowest structure in relation to size, cost and lowest possible power [2]. The great impact was at the end of the twentieth century when meta-surfaces appeared, as that added to both design concepts and materials methodologies, especially materials for the manufacture of antennas, the most important of which are electromagnetic (EM) meta-surfaces, which usually consist of structures with sub-wavelengths that enable electromagnetic properties that are not achieved in materials natural [3]. Due to the suffering of previous MIMO and phase array (PA) technologies and the inability to efficiently match the requirements of the 5G and 6G generation, which requires an increase in the number of components behind each element in these systems, causing an increase in temperature by increasing elements of the antennas used and leads to increase the cost.

HBF is an analog beam former with performance equivalent to analog phased arrays. The HBF technique uses one RF chain that feeds all the elements in the array through a single RF port. Rather than a corporate feed as in phased arrays or digital network in MIMO, HBF uses a series feed that distributes the RF signal along multiple individual antenna elements [2]. In HBF, the control element is semiconductor as varactor tuned feed coupler transfers energy from the distribution network into the antenna element and achieve beam forming is accomplished by using the capacitance shift in the varactor to vary the coupling to selected elements with the proper phase alignment needed to point the beam in the desired direction [4].

In this paper, we choose slot-shaped meta-element technique to demonstrate a reconfigurable coplanar holographic meta-surface aperture to come up with mode-reconfigurable beams in microwave vary. Each slot form of the planned reflective meta-surface will actively engineer the section profile by a PIN diode. Which can be toggled between diverging (ON) and non-radiating (OFF) states by switch a PIN diode, incorporated into the planning, from reverse to forward bias, the pattern is reconfigured that makes pattern manageable, pattern reconfigurable antennas have potential application in wireless communication, that need coincident multiple beams on selective directions.

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The rest of this paper is organized as follows: in Section 2, the design of antennas is presented. Section 3 is dedicated to describe the results and discussion. Finally, the conclusions are given in Section 4.

2. ANTENNA DESIGN

The concept of reconfigurable holographic meta-surface antenna is depicted in Fig. 1. As shown in Fig. 1 is a parallel-plate waveguide, consisting of a dielectric substrate found between parallel plate waveguide (PPW) layout, with dielectric substrate (Rogers 4003, p = 3.38 and tan = 0.0027) and 0.578 mm thick, the feed line coaxial cable in corner to Antenna is used to control the air conditioning. The meta-surface layer is patterned into an array of subwavelength slot-shaped metamaterial elements (or meta-elements) The meta-elements are *λg/2.5* long and *λg/6* wide, where λg is the guided wavelength within the dielectric at 25.5 GHz, 1.13 cm.

$$\lambda_g = \frac{300}{f(GHz)\sqrt{\varepsilon_{eff}}} \quad (1)$$

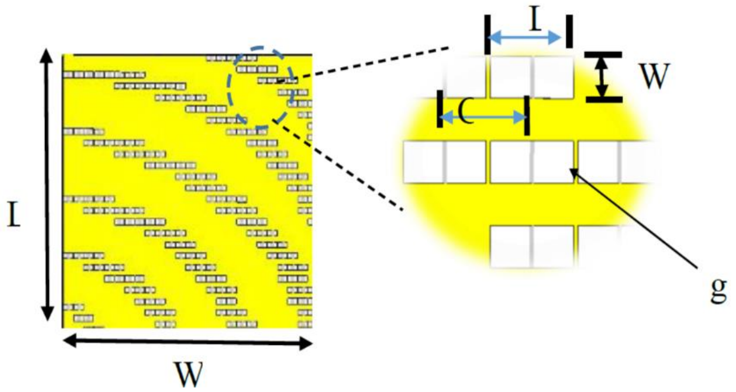

Figure 1. Stricter of Metasurface

The gab is used to control the value of the impedance, since by changing the gab value by increasing or decreasing, result that the impedance value change, this is very useful because it allows us control the surface impedance Z just varying the values of gaps the surface impedance of the sub-wavelength sized would increase with gap size decreasing. from which the following equation is fitted using cubic polynomials to describe the relationship between surface impedance and gap size [5].

$$\lambda_g = -1.2763\,.10-9.\ Z_s3 + 8.509.\,10-7.\ Z_s2 - 1.9586.\,10-4.\ Z_s + 0.0158 \quad (2)$$

use the surface impedance (Z_s) to control the phase of a wave through the metasurface by controlling gab between the slot, such meta-surface is called holographic meta-surface (HMS), we can calculate the expression that relates the surface impedance and the phase through a slot cell:

$$Z_s = Z_o\sqrt{1-(\phi C/(aW))^2} \quad (3)$$

Where: Z_o is the impedance in free space, the phase difference across the unit $\emptyset = kta$ the surface wave vector kt passes through a unit cell, a is the period of the unit cell, where $C$is the light speed in free space and w is the surface angular frequency [6]. We use PIN diodes loaded in meta-surface antenna technology, used to control the resonance frequency, and therefore the coupling response of the elements to the guided mode. Each unit cell coupling response of the elements to the guided mode. Each unit cell element patterned onto the front surface of the holographic metasurface aperture includes a PIN diode in the center, as depicted in Fig.2 for which we assume the circuit model of the PIN diode. When forward-biased, the PIN diodes are modeled as an RL circuit with a negligible forward resistance in parallel with the junction capacitance, and an inductor in series [7].

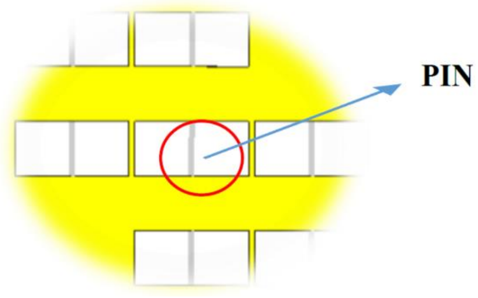

Figure 2. PIN diodes loaded

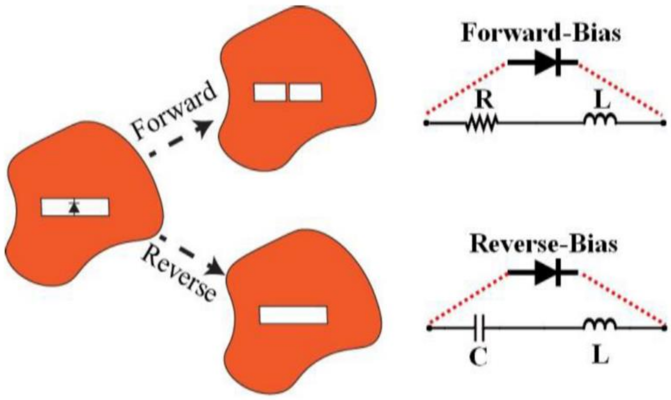

Figure 3. Element configuration for forward and reverse bias

When reverse Unit cell loaded with a PIN diode Fig 3 element configuration for forward and reverse bias states biased, the PIN diodes can be modeled as an LC circuit, exhibiting a high reverse resistance (effectively open-circuit), leaving the junction capacitance connected in series with the inductor. to analyze the achievable contrast in the power level radiated by the OFF and ON unit cells, in CST Microwave Studio.

3. RESULT AND DISCUSSION

In this section study the effect of changing a number of elements on Antenna performance, which It includes all of the S-parameter, gain, directivity, bandwidth ‹radiation pattern and efficiency. in addition to studying the effect of the diode in controlling the phase and increasing the gain and directivity in the antenna.

A. *Impact of Gap Between Cells*

The influences of the gaps width on both gain and S-parameters are studied as shown in the Fig.4(a) Can observe the increase in the width of the gap to increases S-parameters and gain Fig.4(b) It has got the best value for the gain and consequently obtaining the best antenna performance as a result of the improve radiation efficiency.

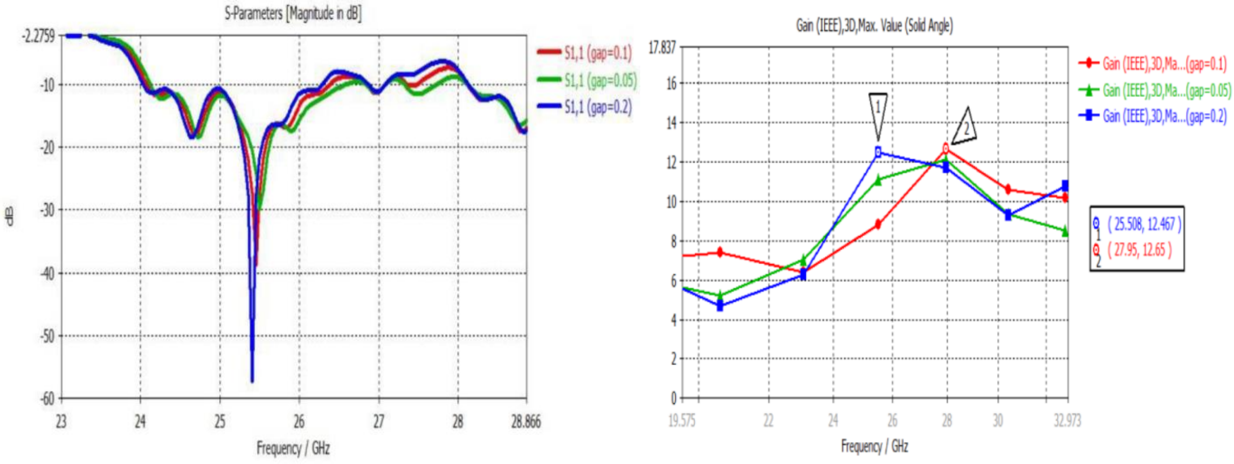

Figure 4. **(a) S11 on gaps between unit cell (b) Gain and gap between unit cell**

B. *The Impact of Diode on phase*

To make Metasurface as reconfigurable metasurface, we use control elements such as diode. The PIN diode used to control in the direction of radiation, decrease and increase on directivity. From results in Fig.5, we note that in the case of forward biased as ON diodes the resonant frequency in s-parameter is 25.5GHz , the phase of radiation pattern equal to 60 degree , directivity value is 14.7dBi and gain is 13 dBi as Fig.6.

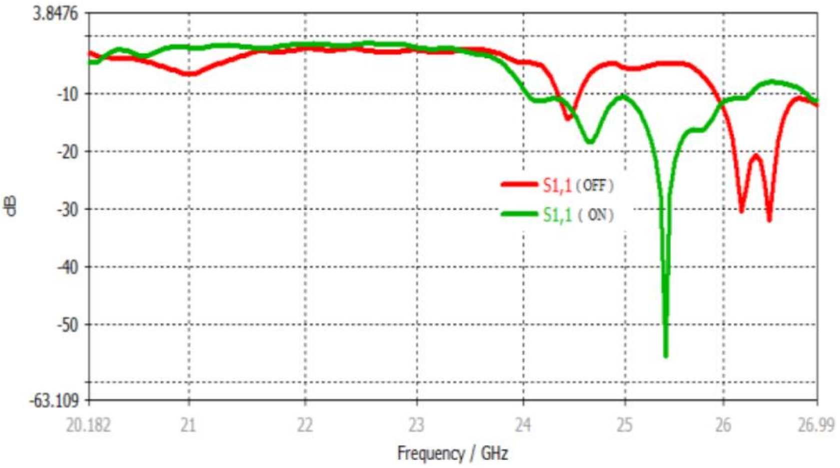

Figure 5. **S-parameter with diode "on" and "off"**

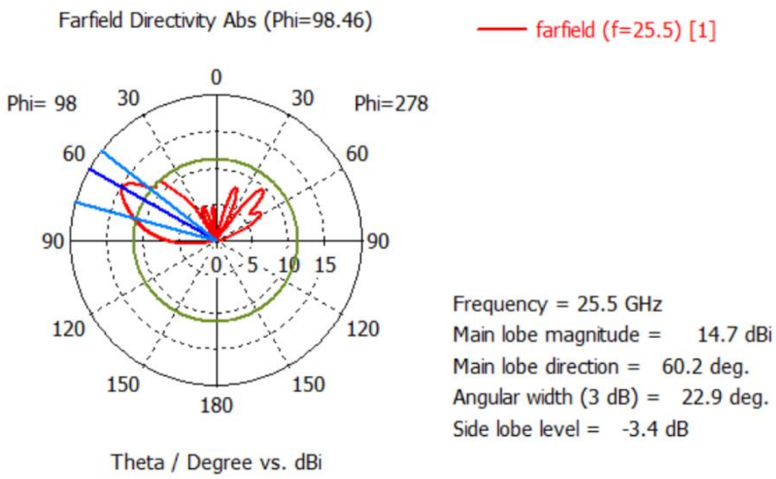

Figure 6. Radiation pattern in ON diode

So, in case of reverse biased as OFF diodes, we note that no radiation and the phase angle to radiation is 65.0 degree and directivity value is 5 dBi and gain is 3.84 dBi as Fig.6.

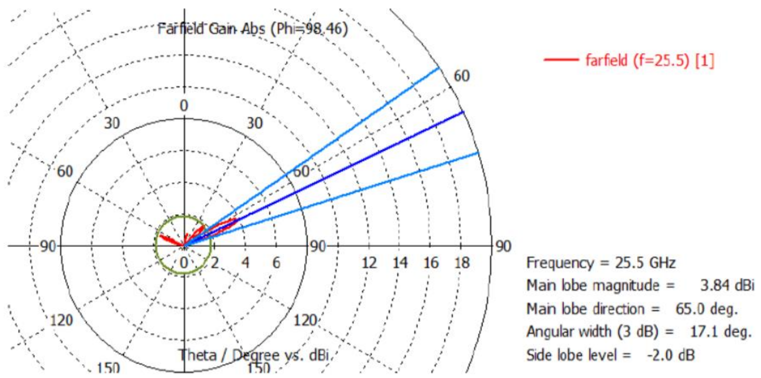

Figure 7. Radiation pattern in OF diode

When we consider some of diodes ON and OFF in each row from slot shape we have 6 row slots on antenna of surface, we getting as figure 4.7 change in phase direction, increase in radiation of directivity and gain resulting decrease in angular width and increase in side lobe level.

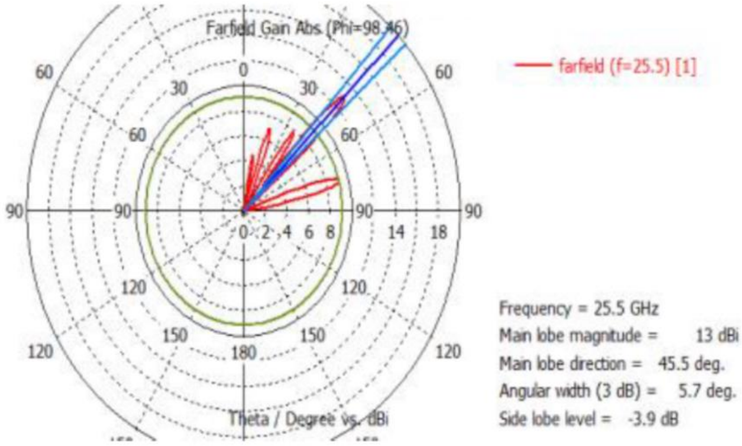

Figure 8. Radiation pattern in some of ON, OFF diode

4. CONCLUSION

This paper investigates the radiation characteristics of HPF antennas derived by be toggled between radiating (ON) and non-radiating (OFF) states by switching a PIN diode, incorporated into the design, from reverse to forward bias. The PIN diode used to control in the direction of radiation, decrease and increase on directivity. A parametric study of several parameters that impact antenna performance, (thickness of substrate, radius of feeding, length and width of gaps) was performed using CST simulator. As these parameters are required to obtain the best antenna performance, they are set by tight mathematical relationships.

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