Electronically Tunable Dielectric Resonator Reflectarray

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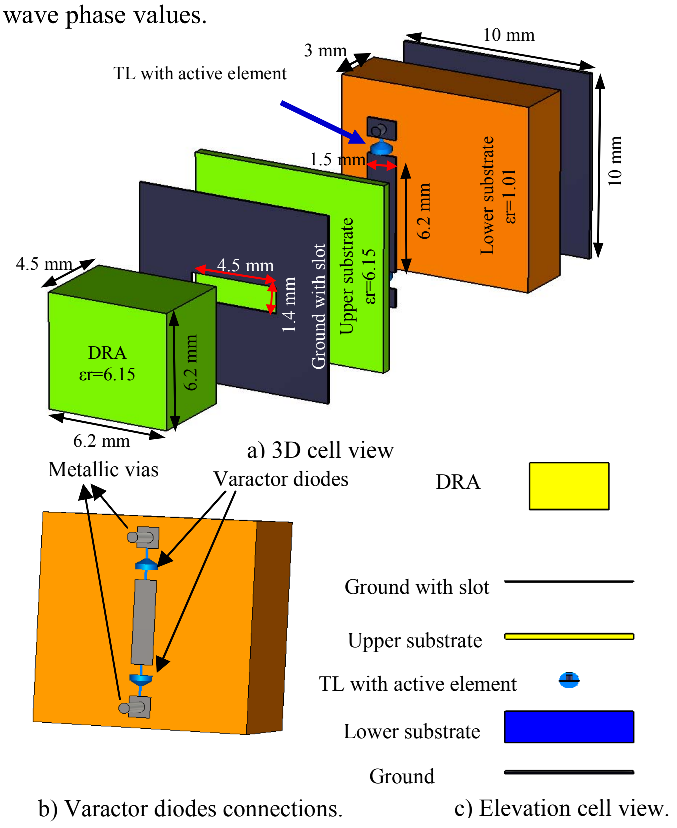
Abstract— An electronically tunable reflectarray of aperture coupled square dielectric resonator antenna (DRA) elements is designed with a 230 × 230 mm^2 size. The DRA phase is controlled via a capacitive varactor. The results show that the beam scanning within ± 60° range can be realized. The reflectarray is center-fed by a linearly polarized pyramidal horn antenna. At 10.6 GHz, the antenna provides a 3-dB beamwidth of 6 degrees with a gain of 25.5 dB. The antenna bandwidth within 1.5 dB gain variation is found to be 9% with stable radiation patterns.

Keywords— Aperture coupled DRA; Reflectarray; Waveguide method; Beam scanning.

Printed reflectarray is attractive alternative to conventional parabolic reflector antenna because of its compactness, lightweight and low manufacturing cost. Reflectarrays have found several attractive applications, such as direct broadcast satellite (DBS) services or application in micro spacecraft missions, where high-gain antennas with small volume and low mass are needed [1]. In radar and satellite antennas applications, beam scanning is mainly required. Some active reflectarrays using varactor diodes, electronic switches and liquid crystal substrates are investigated [2-6].

I. ACTIVE ELEMENT DESIGN AND ALANYSIS

The DRA reflectarray element consists of multilevel aperture coupled DRA with fixed sizes supported on a ground plane with fixed slot length and transmission line length attached to the ground plane with slot through metallic vias and the active element is implemented at the same level of transmission line. Each reflectarray element is square (10 mm × 10 mm) with DRA dimensions, L = 6.2 mm, W = 6.2 mm, height = 4.5 mm and ε_r = 6.15. The slot dimensions on ground plane are 4.5 mm × 1.4 mm, the upper substrate have a thickness of 0.5 mm with ε_r = 6.15. The transmission line strip is 6.2 mm × 1.5 mm with two gaps of dimension 1 mm × 1.5 mm for the varactor location. The lower substrate with thickness of 3 mm made of foam with ε_r = 1.01 to support all structure above ground plane as shown in Fig.1. An SMV2019 hyper-abrupt varactor diode is used with a capacitance range from 2.25 pF to 0.16 pF when the applied voltage is 20V [7]. According to the characteristic of varactor diode, the changing of reversed applied volts led to nonlinear changing in varactor values, which affect the performance of active array that limits the bandwidth. Changing the varactor's capacitance will change the reflected wave phase values.



a) 3D cell view
b) Varactor diodes connections.
c) Elevation cell view.

Fig.1 Tunable reflectarray cell configuration.

In this paper, a periodic infinite array concept is used to compute the reflection phase of one element against varactor capacitance value changes based on the waveguide method. The incident wave is a linear y-polarized plane wave. The electrical length of transmission line is changed by varying varactor diode capacitance and as a result, the total reflected phase from cell element is changed. The variation of varactor capacitance values leading to changing the reflection phase coefficient of the periodic cell at 10.6 GHz is shown in Fig.2.

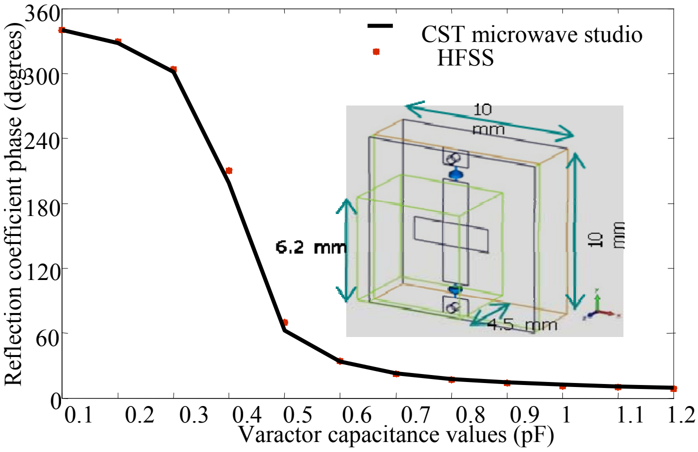


Fig. 2 Reflection coefficient phase versus varactor capacitance values at f=10.6 GHz.

II. TUNABLE REFLECTARRAY DESIGN AND LANYSIS

The reflectarray antenna size is 7.66 $\lambda_o \times$ 7.66 λ_o with element spacing of 10 mm and its focal length-to-diameter ratio F/D = 0.79 for -15 dB amplitude edge taper at 10.6 GHz. The reflectarray is fed by y-polarized pyramidal horn with aperture area of 70 × 48 mm^2 with length of 80 mm. The reflectarray provides a wide range of beam scanning with suitable stability of gain all over the range with some degradation in pattern due to decreasing of the projected area. The field patterns of H-plane (x-z plane) are illustrated in Fig.3 with beam scanning range from -60° to 60° at 10.6 GHz. The radiation pattern at 10.6 GHz has a 3-dB beamwidth of 6°. The peak gain is 25.5 dB at $\theta = 0^o$ indicating 9% bandwidth for gain variation of 1.5 dB as shown in Fig.4.

III. CONCLUSIONS

A beam scanning DRA reflectarray antenna was designed for wide scanning range from -60° to 60° at X-band. A 23 × 23 elements reflectarray antenna was presented. At 10.6 GHz, the antenna provides a 3-dB beamwidth of 6° with a gain of 25.5 dB with 1.5 dB gain bandwidth variation of 9%.

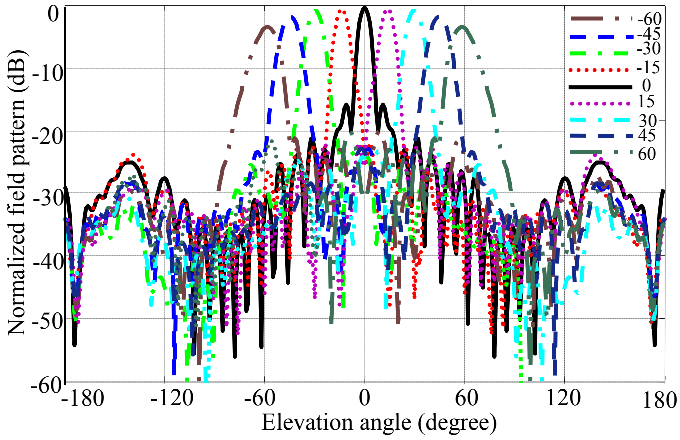


Fig.3 Gain patterns at various beam angles at 10.6 GHz.

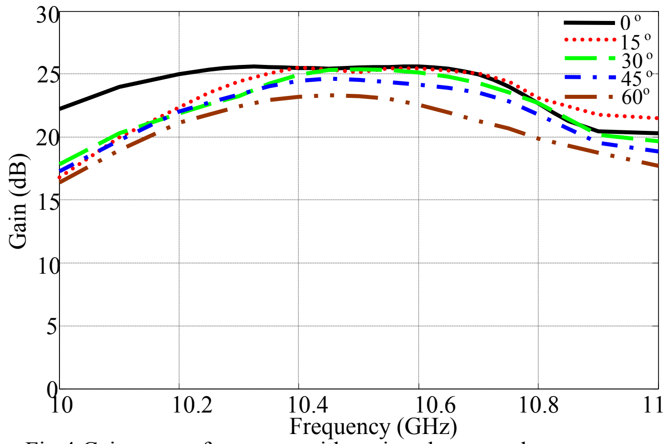


Fig.4 Gain versus frequency with various beam angles.

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