Active tunable 1D periodic leaky wave antenna

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Abstract

In this paper a novel periodic leaky wave antenna is introduced. Active devices inside the antenna give an additional degree of freedom to control the periodicity of the structure and thereby control the radiation angle. Proposed leaky wave antenna scans the forward quadrant from 50^o to 70^o for a given switching pattern when all the patches are grounded. Radiation in the same frequency band is not present when switches are turned off.

1. Introduction

Emerging wireless technologies demand smart reconfigurable antennas in order to improve their performance [1]. In this paper we introduce a one dimensional periodic microstrip leaky wave antenna that steer the beam in the forward quadrant. The radiation mechanism of periodic leaky wave antennas is well researched over the last few decades [2]. Directivity of an antenna is mainly determined by the aperture size. Most of the work on changing the directivity is done by changing the geometry of the antenna. Recently several new means of controlling the beam steering is studied by means of electronic control [3], [4] and optical illumination [5].

In general periodic microstrip leaky wave antennas provide a narrow fan beam that scans with the frequency. Leakage occurs due to the periodic variation along the microstrip line [6]. This can be obtained by lumped loads[7] or periodically variation of the dielectric constant [8] alongthe microstrip line.The leakage occurs because of the complex wave number, with a phase constant β and a leakage constant α, characterizing propagation of wave at frequencies above the light-line.Leakage occurs over the entire length of the microstrip or only when periodicity allows it in a more complex realisation of quasi-periodic structures.

Introducing periodicity, characterized by the periodicity step d, it generatesan infinite number of space harmonics related to each other. The phase constant β_n is related to its phase constant of the fundamental dominant mode $\beta_0$by the equation

$$\beta_n d=\beta_0 d+2n\pi \tag{1}$$

For a continuous microstrip line the dominant mode is a guided wave; higher order modes contribute to the radiation. Angle of main beam (θ_n) radiation from the broadside direction ($\theta=0^o$) is given by

$$\sin\theta_n = (\beta_n /k_0) \tag{2}$$

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Replacing β_n by (1)

$$\sin\theta_n = (\beta_0 / k_0) + 2n\pi / k_0 d \quad (3)$$

Therefore, changing the periodicity(d) allows the control of radiation characteristics. Free space wavenumber (k_0) is given by

$$k_0 = 2\pi f / c \quad (4)$$

where c is the speed of light.

Here we will consider a low frequency structure similar those in [7], where additionally to the frequency the unit cell characteristics can be changed dynamically and this allows an additional degree of freedom. The structure is described in the following section.

2. Geometry of the leaky wave antenna

A microstrip is place on the top of agrounded two layer of Nelco substrates (ε_r=3.4) each with thickness of 60 mils and 12 mils respectively. Between the substrates an array of patches with the dimensions (450 mils x 80 mils) is patterned. Each single patch has two vias on the sides to connect it to the ground which is at the bottom of the 60 mil thick substrate. Connection between the via and the ground is controlled by two FET switches which are located in between via ground path as shown in Fig.1. The microstrip line on the top is 50 mils in width. A unit cell of dimension 550 mils x 120 mils in this structure contains the above described patch, vias, two FET switches and the microstrip. Here we are considering a structure of 24 unitcells (with a periodicity of 120 mils along the longitudinal direction). Antenna is excited from one end of the microstrip line running orthogonally to thepatches.

As opposed to traditional 1D periodic microstrip lines which change the geometry of the microstrip line this structure keeps the same microstrip width but locally changes the effective dielectric constant (ε_{eff}) along the propagation direction x. Effective dielectric constant is changed by selectively connecting the patches in the unit cell by biasing the FET switches. The microstrip above the patch shows a $\varepsilon_{eff} = \varepsilon_1$ when the FET switches are in on state and $\varepsilon_{eff} = \varepsilon_2$ when FET switches are off. Therefore the presence of the FET switches allows the control of changing the effective dielectric constant and thus changes the main beam direction. For further discussions when the switches in a unit cell are on that state is referred as “1” and when they are off state is referred as “0”.

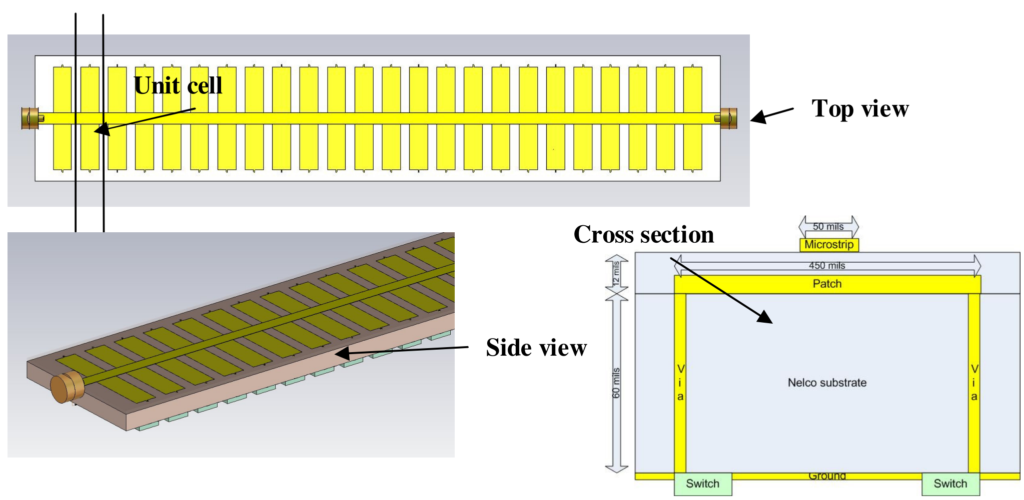

Fig.1: CAD model of the proposed leaky wave antenna

Fig. 2indicates the beam scanning from 5.6GHz to 6.2GHz. The extracted results are for "…1111…" configuration or when all the patches are grounded in the periodic structure. Beam scans from 50°to 70°degrees in the forward quadrant when changing the frequency from 5.8 GHz to 6.1 GHz as shown in Fig. 2. When switches are in off state, the bandgap is moved to higher frequencies [9]. Consequently the first bounded mode will extend over the previously considered frequency band and no radiation from the structure will be present. Changing the states of the diodes,we can control the radiation properties of the device. The effects of the control for the bounded waves have been described in [10].

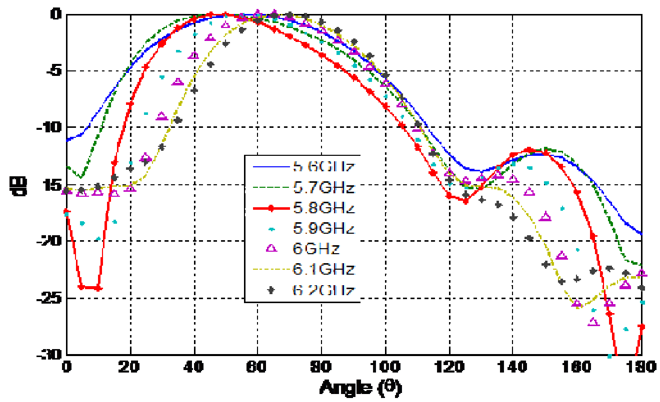

Fig.2: Normalized main beam angle for different frequencies for all on state switches configuration

4. Conclusion

The one dimensional active periodic leaky wave antenna studied here can operate in two different modes: when the active devices are turned on no radiation exists. When the switches are polarized in on state, a beam scanning from 50°to 70°has been observed.

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