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MANIPULATING MICRO-SIZED COUPLING GAPS FOR RECONFIGURABLE ANTENNA APPLICATIONS

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ABSTRACT: Synthetically arranged micro-lines (width $\leq 1\text{mm}$) have been considered for antennas and radiating structures at microwave frequencies. Finite-difference time-domain (FDTD) simulations show how the electrical size of the structure and multiple resonances can be controlled by carefully introducing micro-sized gaps.

Key Words: Reconfigurable antennas, micro-lines, coupling gaps, FDTD

1. INTRODUCTION

Wireless communications are ubiquitous in today's society and there are ever growing commercial factors that demand greater frequency coverage with increasingly challenging physical constraints. A space efficient method of creating multiple antennas is to use reconfigurable antennas which use switches to extend the electrical lengths of parts of the radiating structure [1-4].

The frequency of the antenna can therefore be tuned with the aid of tuning pin-diodes [2], micro-electro-mechanical systems (MEMS) [1, 3] or photoconducting switches [4]. These electronic components and switches will continue to decrease in size as the technology progresses. Recent advances in micro and nanotechnology mean that new structures can be fabricated with greater accuracy and repeatability. These developments will enable micro-sized and yet precise coupling gaps to be added to a metallic structure [5]. Note, this work is part of a larger project to investigate the feasibility of fabricating antennas and integrated substrates using nanomaterials.

2. SIMULATION METHODOLOGY

EMPIRE XCell™ FDTD software was used in this work (www.empire.de). A vertically polarized E_z , H_y plane wave propagating in the X direction was created by using a parallel plate waveguide. The cut off frequency of the cavity, $f_c=c/\text{MAX}(W \text{ or } H)$ and therefore, using height and width of the waveguide as $7500\mu\text{m}$, the maximum frequency is 40GHz. Perfect electric conductors and perfect magnetic conductors are used at the two sides and top and bottom boundaries respectively; so the sample is infinitely periodic in two dimensions. When the structure is meshed very finely to include micro-sized structures, computational limitations become apparent and the above compact plane wave excitation is advantageous. The radiating structures in this paper are all passive objects and re-radiate the incident plane wave source travelling between the two ports along the waveguide. However, the same analysis would apply to excited antennas. A metallic loop was added at the centre of the waveguide. The loop had exterior dimensions $6500\mu\text{m}$ in the Y and Z directions and had a thickness of $1\mu\text{m}$. The geometry is shown in Fig. 1. In this paper, the switching devices have not been included in the model.

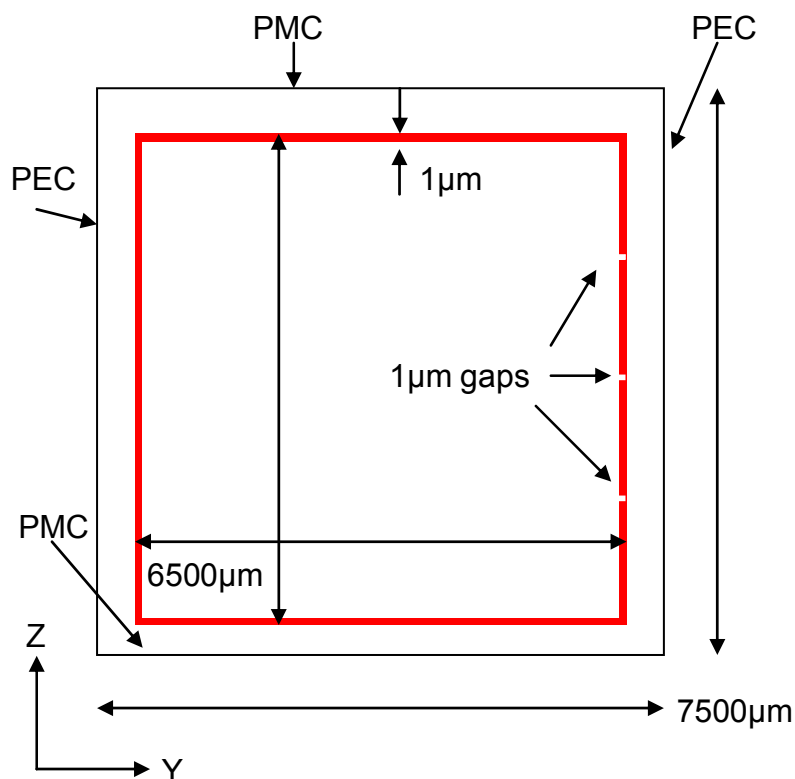


Fig. 1. The geometry of the loop with three gaps evenly spaced on the right hand side (not to scale).

3. RESULTS

In this paper, evenly spaced $1\mu\text{m}$ gaps were inserted into the top or side sections of the continuous loop. The continuous loop resonates at 12GHz. The maximum currents are on the side sections of the loop with a vertically polarized excitation. When increasing number of gaps were added to the top section of the loop, the behavior changes from a loop (12GHz) to a \sqsubset -shaped radiating structure (16GHz). As the current is a minimum on the top section of the continuous loop, adding gaps in this region has a relatively small and predictable response.

Evidence of the behavior of micro-lines is visible when gaps are introduced into the side section of the loop as the current in the continuous loop is a maximum here. When the side section is removed, the loop becomes a \square -shaped structure and resonates at 7GHz, see Fig. 2. When one $1\mu\text{m}$ gap was inserted in the side section, the resonant frequency increased. In addition to this behavior, a second resonance develops at a lower frequency. The addition of further gaps increased both resonant frequencies. When five gaps were added, the S_{21} at the lower frequency resonance increased in magnitude while the S_{21} at the high frequency resonance decreased in magnitude. When more than 10 gaps were added, the current in this section was negligible, the original resonance has virtually disappeared and the structure behaves like a \square -shaped structure. Of particular interest is the case, when three

gaps were added to the side, the structure developed a triple resonance at 6, 18 and 20GHz.

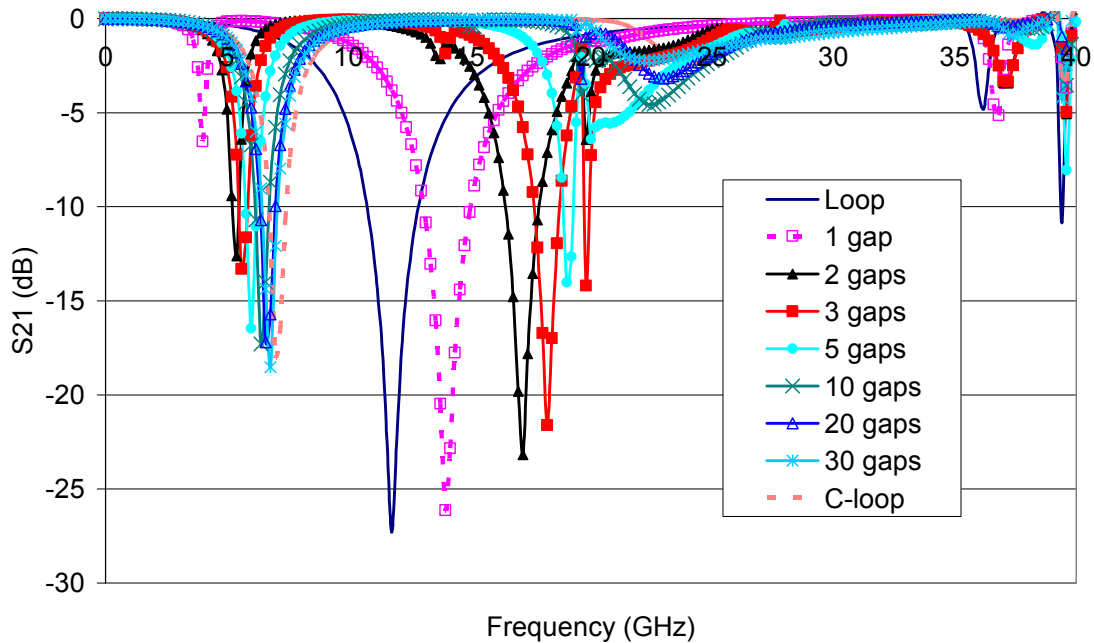


Fig. 2. The transmission coefficients of loops with increasing number of gaps in the right hand side section of a loop.

The current on the structure was investigated to understand the reason for this multiple resonance. Fig. 3 shows the current at 6, 18 and 20GHz with three gaps added to the side of the loop. The current distribution shows that the structure behaves like a \square - shape antenna at the lower frequency (6GHz) with the maximum current predominantly on the left hand side and along the two horizontal sections; see Fig. 3(a). Whereas, the current distribution at 18 and 20GHz has equal magnitudes on the two vertical sections, see Fig 3. (b) and (c) which means the structure is behaving in the same way to a loop exposed to a vertically polarized plane wave. Therefore, by carefully choosing the number and size of the gaps, a structure can be designed where metallic micro-lines and gaps can perform both like a continuous and a discontinuous object depending on the frequency and the geometry.

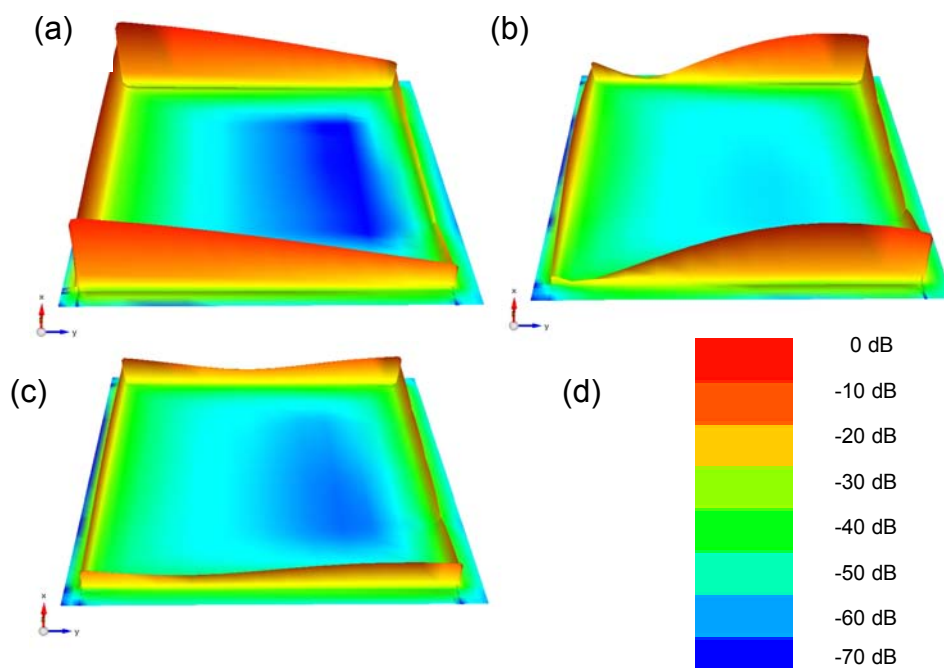


Fig. 3. The current on a loop with three $1\mu\text{m}$ gaps on the right hand side at (a) 6GHz; (b) 18GHz; (c) 20GHz and (d) scale. The current is physically extrapolated away from the surface to aid visualization.

4. CONCLUSIONS

This paper has introduced a new approach to adjust the frequency resonance of loops. Adding micro-sized gaps to a metallic loop radiating structure meant the two sections can couple. This ability to control the behaviour is an alternative to adding a secondary loop for dual resonance. By carefully controlling the number and size of the gaps, it is possible to create a dual or even triple resonance where the same structure behaves both like a loop and a \square - shape at different frequencies. The application of this work will enable an extra degree of control to the operating frequency.

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