PARTIALLY LOADED PERIODIC MICROSTRIP LINES

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Abstract – In this paper, partially loaded periodic microstrip lines are studied. Floquet's theorem and spectral domain approach (SDA) are used to formulate coupled integral equations. Method of moments is then applied to convert the coupled integral equations to a matrix equation. Numerical results show that the loading factor of the periodic structures can be used to adjust the bandwidth of the first two stopbands. Leakage in the radiation region is also observed.

1 Introduction

Microstrip lines are commonly used in microwave and millimeter-wave circuits. They are easy to fabricate and integrate with other passive and active components. Slow-wave phenomena and frequency selective properties are observed in periodic microstrip line. Various kinds of periodic microstrip lines are investigated for applications like delay lines and filters [1-4].

In [1], a capacitively loaded microstrip loop resonator is studied, in which periodically spaced fingers are added along the loop to create a slow wave structure. It has smaller size and higher Q factor than the conventional half-wavelength resonators. In [2], an edge coupled microstrip resonators with periodical slot loading is proposed. Adding more slots increases the Q factor and reduces the resonance frequency. In [3], a two-dimensional photonic bandgap structure is studied using FDTD method. It is comprised of metal pads etched in the ground plane and connected by narrow strips to form a distributed LC network. Such a structure can be used to suppress spurious surface waves in conductor-backed coplanar waveguides, microstrip bandpass filters, microstrip antanna, and so on. In [4], the slow-wave structure proposed in [3] is used in small microstrip patch antennas to reduce its size without affecting its performance.

In [5], periodic microstrip lines with width sinusoidally modulated are analyzed using the effective dielectric constant (EDC) method to obtain the dispersion curves and frequency response. In [6], spectral domain approach (SDA) is used to analyze shielded periodic microstrip lines with width sinusoidally modulated. In [7], the dispersion characteristics of notch-loaded periodic microstrip lines are observed to have two passbands, one stopband, and a radiation region. Leaky wave is excited above certain frequency in the radiation region.

In this paper, open and partially loaded periodic microstrip lines will be investigated using Floquet's theorem and spectral domain approach. The loading factor of the periodic structures is studied for its effect on the second stopband. The occurrence of leaky waves in the radiation region will also be studied.

2 Formulation

Figure 1 shows the configuration of a periodic microstrip line with width sinusoidally modulated. To formulate an integral equation, we apply the Floquet's theorem and express these potential functions to satisfy the wave equations in each layer. Then the electric and magnetic fields in each layer can be calculated in terms of the potential functions. Next, apply the boundary conditions that the tangential electric fields are continuous and the tangential magnetic fields are discontinuous due to the surface current on the air-dielectric interface. Finally, impose the boundary condition that the tangential electric fields vanish on the strip surface to obtain coupled integral equations.

Next, apply method of moments to solve the coupled integral equations. Two sets of global vector basis functions with edge conditions are chosen to expand the surface current on the nonuniform

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microstrip line [6]. Then the coupled integral equations are converted to a matrix equation. The propagation constant along the line is then obtained by searching the zeros of the determinantal equation.

3 Results and Discussions

Figure 1 shows both partially protruded and indented periodic microstrip lines with sinusoidal width modulation. The width-modulated microstrip lines analyzed in [5] and [6] are special cases of those shown in Figure 1. The dispersion curves of the fully loaded periodic microstrip lines with sinusoidal width modulation are calculated using both the SDA and the EDC methods as shown in Figure 2. Since the effective dielectric constant used in the EDC method is a constant for a given geometry and is frequency-independent, the results obtained by using these two methods match well only in the low frequency range, the difference becomes larger when the frequency is increased. Because the electric field becomes more concentrated in the substrate when the frequency is increased, the effective dielectric constant increases with frequency. Also notice that leaky wave is excited at the intersection of the n=-1 space harmonic and the TM_0 mode of the slab waveguide. The EDC method cannot predict leakage.

Define the loading factor, r, as the ratio of modulation length, P_r, to the period, P. Figure 3 shows the dispersion curves of the partially protruded periodic microstrip line with a sinusoidal width modulation. When the loading factor is varied from 1.0 to 0.6, attenuation and bandwidth of the second stopband increase, but the first stopband is only slightly affected.

The dispersion curves of the partially indented periodic microstrip line with sinusoidal width modulated are shown in Figure 4. The attenuation and bandwidth of the stopbands of the structure with indent are larger and wider than those with protrusion. To obtain similar attenuation and bandwidth of stopbands, the one with indent occupies less area than the one with protrusion. Larger modulation amplitude will result in larger attenuation and bandwidth of the stopbands. By tuning the combination of the modulation amplitude and the loading factor, the attenuation and bandwidth of both the first and the second stopbands can be adjusted.

4 Conclusions

Partially loaded periodic microstrip lines are analyzed by using Floquet's theorem and spectral domain approach. Global basis functions are chosen to expand the unknown surface currents on the strip, then the moment method is applied to convert the coupled integral equations to a matrix equation. The EDC method is used to verify this approach in the low frequency range. The occurrence of the leaky wave is observed at the intersection of the n=-1 space harmonic and the TM_0 mode of the slab waveguide. The dispersion curves of protruded and indented periodic microstrip lines with sinusoidal width modulation are also shown to analyze the effects of the loading factor.

References

[1] J. S. Hong and M. J. Lancaster, "Capacitively loaded microstrip loop resonator," *IEE Electron. Lett.*, vol.30, no.18, pp.1494-1495, Sept. 1994.

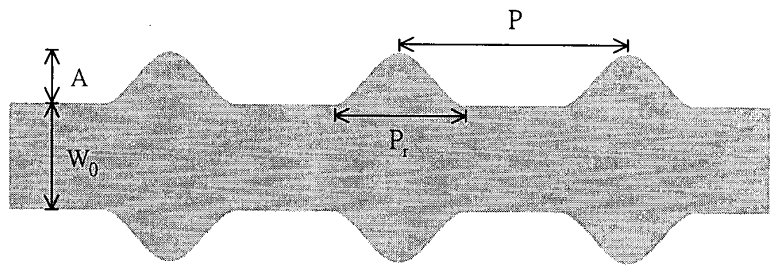
[2] J. S. Hong and M. J. Lancaster, "Edge-coupled microstrip loop resonators with capacitive loading," *IEEE Microwave Guided Wave Lett.*, vol.5, no.3, pp.87-89, March 1995.

[3] F. R. Yang, K. P. Ma, Y. Qian, and T. Itoh, "A uniplanar compact photonic-bandgap (UC-PBG) structure and its applications for microwave circuits," *IEEE Trans. Microwave Theory Tech.*, vol.47, no.8, pp.1509-1514, Aug. 1999.

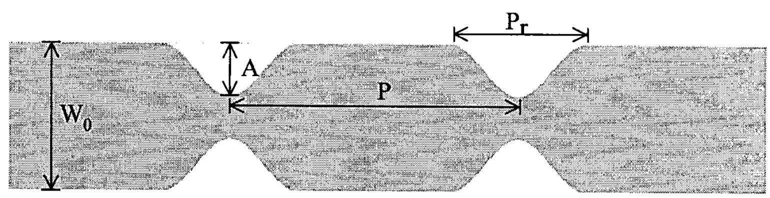
[4] M. K. Fries and R. Vahldieck, "Small microstrip patch antenna using slow-wave structure," *IEEE MTT-S*, pp.770-773, 2000.

[5] N. V. Nair and A. K. Mallick, "An analysis of a width-modulated microstrip periodic structure," *IEEE Trans. Microwave Theory Tech.*, vol.32, no.2, pp.200-204, Feb. 1984.

[6] F. J. Glandorf and I. Wolff, “A spectral-domain analysis of periodically nonuniform microstrip lines,” *IEEE Trans. Microwave Theory Tech.*, vol.35, no.3, pp.336-343, March 1987.
[7] C. K. C. Tzuang and Y. C. Chen, “Dispersion characteristics of microstrip with periodic perturbations,” *IEEE MTT-S*, pp.1537-1540, 2000.



(a)



(b)

Figure 1. Layouts of partially loaded periodic microstrip lines with sinusoidal width modulation: (a) protrusion and (b) indent.

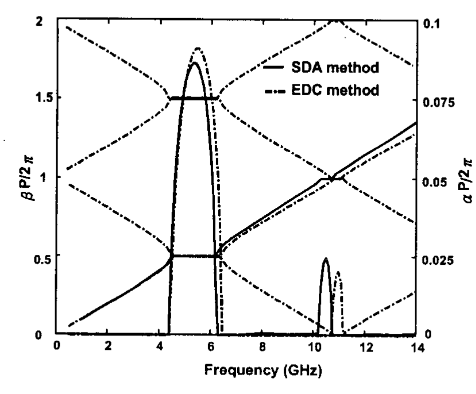


Figure 2. Dispersion curves of fully loaded periodic microstrip line with sinusoidal width modulation, ε_r=10.2, h=0.635mm, P=10.0mm , P_r=10.0mm , W_0=1.0mm , A=1.0mm.

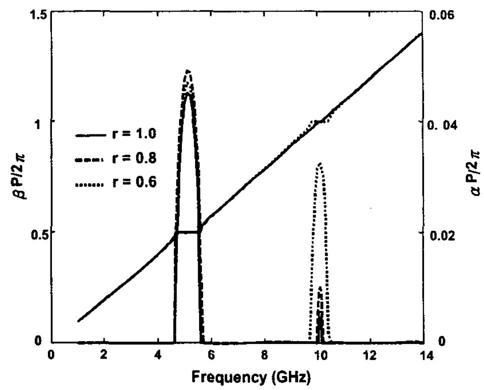


Figure 3. Dispersion curves of partially protruded periodic microstrip line with sinusoidal width modulation, ε_r=10.2, h=0.635mm, P=10.0mm, W_0=3.0mm, A=1.0mm.

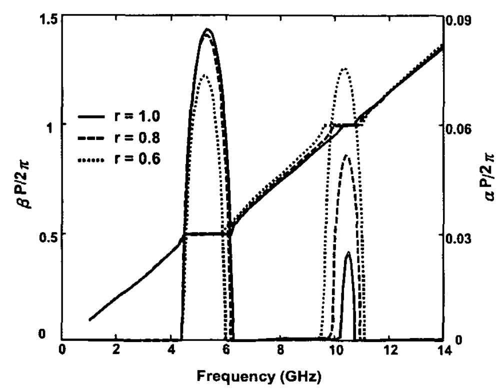


Figure 4. Dispersion curves of partially indented periodic microstrip line with sinusoidal width modulation, ε_r=10.2, h=0.635mm, P=10.0mm, W_0=3.0mm, A=1.0mm.