

High- Q Substrate-Integrated-Waveguide Resonator with Degenerate Band Edge

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The novel concept of degenerate band edge (DBE) has been recently proposed by Figotin et al., in the framework of their study of slow wave propagation in photonic crystals [1]. The degenerate band edge is a special dispersion condition near the edge of the Brillouin zone ($k_d = \pi/p$, p is the spatial period) where four degenerate Bloch modes coalesce at a same frequency f_d (two propagating modes and two evanescent modes). The dispersion relation is locally described by a quartic curve

$$f - f_d = -\alpha(k - k_d)^4 \quad (1)$$

where f_d is the DBE frequency and α is a positive constant that depends on the parameters of the structure.

A DBE condition provides a strong dispersive behavior and, therefore, it leads to an extremely low group velocity and a strong field enhancement in the waveguide. This can be used in pulse compression, oscillators, filters and slow-wave structures. It has been introduced into a circular waveguide [2], coupled transmission lines [3], and other structures. Moreover, it has been experimentally verified that a giant resonance and high Q -factor can be obtained with this condition. Substrate-integrated-waveguide (SIW) technology can offer good solutions for resonant structures at mm-waves: for this reason, we achieve here a DBE condition in a periodic SIW line for the first time. A Bloch analysis based on the unit cell is presented, and a truncated SIW resonator supporting the DBE is proposed to achieve a giant resonance and a high Q -factor.

In order to enforce a DBE condition, the waveguide should support two different modes and couple them in a suitable way. The unit cell for SIW with DBE is shown in Figure 1 (a). Two parallel waveguides provide two modes, and the coupling gap and oblique line of vias couple the modes properly. For a truncated SIW line, the Q -factor is shown in Figure 1 (b) vs. the number of cells. It is proportional to the fifth order of the number of cells, which means we can get a high- Q resonator with a relatively small number of periods.

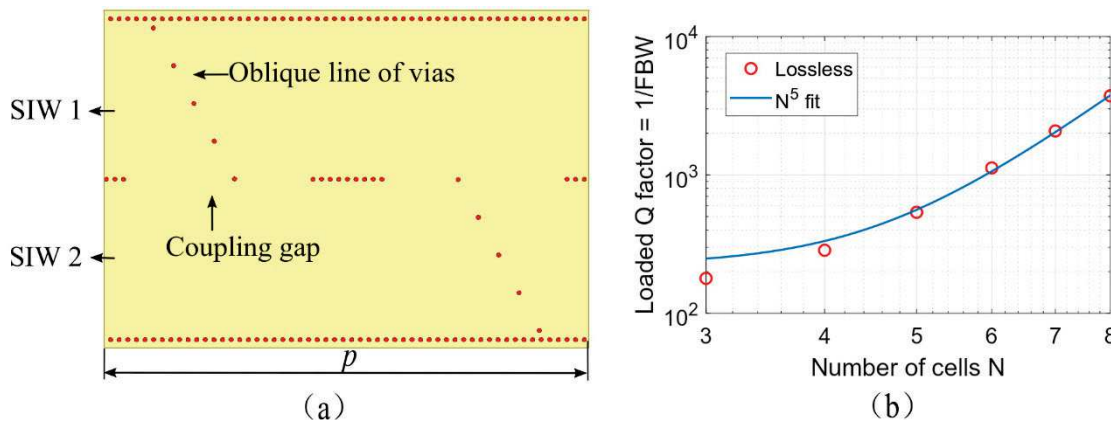


Figure 1. (a) The unit cell of the periodic substrate-integrated waveguides with DBE. (b) Loaded Q -factor for truncated SIW lines with different length of the cells.

1. A. Figotin, I. Vitebskiy, "Gigantic transmission band-edge resonance in periodic stacks of anisotropic layers," *Phys. Rev. E*, vol. 72, 2005, p. 036619.
2. M. A. K. Othman, F. Capolino, et al, "Experimental demonstration of degenerate band edge in metallic periodically loaded circular waveguide," in *IEEE Trans. Microw. Theory Techn.*, vol. 65, no. 11, 2017, pp. 4037–4045.
3. G. W. Hanson, F. Capolino, et al, "Exceptional Points of Degeneracy and Branch Points for Coupled Transmission Lines—Linear-Algebra and Bifurcation Theory Perspectives," in *IEEE Antennas Propag. Mag.*, vol. 67, no. 2, Feb. 2019, pp. 1025-1034.