Superconducting Glide-Symmetric Bifilar Transmission Lines for Tunable Stop-Band and Filtering Applications

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***Abstract*—This work shows a glide-symmetric corrugated transmission line, based on previous studies, but this time implemented using superconductive characteristics. The scope is to investigate if stop-bands are still present when the transmission line has superconductive features. The simulations demonstrate that stop-bands are indeed observed, opening the possibility of using them in superconducting circuits, particularly in traveling-wave kinetic-inductance parametric amplifiers.**

***Keywords*— Glide-symmetry, metasurface, superconductor.**

I. Introduction

SUPERCONDUCTING circuits are essential in state-of-the-art fields such as quantum computing and radioastronomy [1]. In both cases, noise plays a major role thus the need of superconducting devices capable of operating up to quantum-level noise constraints. In order to come up with superconducting devices, for example parametric amplifiers and resonators, microstrip transmission lines are frequently used hence the importance of exploring their topologies and properties.

When symmetry considerations are added to non-superconducting transmission lines, new properties can emerge, for instance low-dispersive transmission lines and tunable stop-bands. Furthermore, non-superconducting symmetric strip lines have been previously studied as periodic structures [2]. Longitudinal and translational symmetries were considered to design stub-loaded microstrips to produce group delay changes and, consequently, achieve a tunable band gap filter [3]. In this work, we present a glide-symmetric line, based on [4], that includes a simulated superconducting condition. We demonstrate that the tunable stop-band property achieved for the non-superconducting case, can be obtained while imposing the superconducting condition to the strip line.

II. Glide Symmetry with Superconducting Condition

Glide symmetry enables the control of dispersion characteristics of the transmission line. Though this condition can be achieved by different means, we have considered a geometry in which the symmetry property is realized from added corrugations to the main line in a double-sided bifilar line. To study the effect of symmetry breaking in the band structure, simulations were performed using Ansys HFSS commercial software. A unit cell with a period p=400 μm was defined, as presented in Fig. 1. This cell also represents the Irreducible Brillouin Zone containing the whole information of the wave vector $\vec{k}$. The corrugations are set such that symmetry can be broken by either altering the corrugation heights and the widths at each side of the bifilar line or altering the separation between corrugations [2]. The glide-symmetric state is the one in which the corrugations are separated half period apart, while a longitudinal symmetry is that in which there is no separation in between.

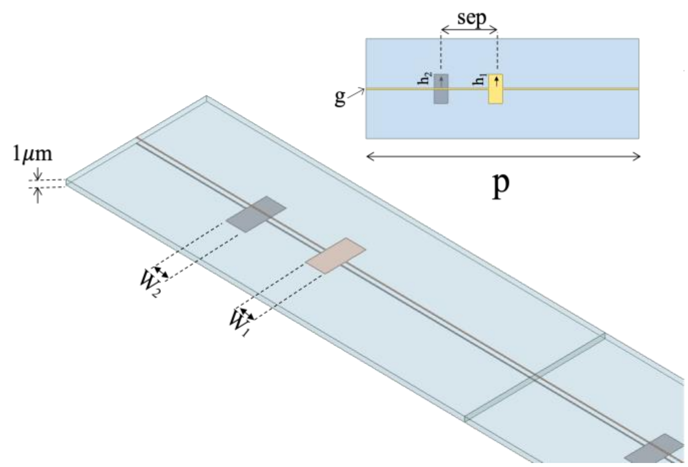

Fig. 1. Glide-symmetric bifilar line with a SOI substrate with 1 μm height. It is used along with a line width of 1 μm. The separation parameter, is measured between the front and rear corrugations as fractions of the period p.

Here we present the propagation analysis of a periodic glide symmetric bifilar with a superconducting condition on the surface impedance of the conductor [4],

$$Z_s = 2\,\pi\,j\,f\,\mu_0\,\lambda\coth(t/\lambda), \tag{1}$$

The penetration depth was set to $\lambda = 314$ nm [5] and the conductor thickness to $t = 60$ nm. The lengths of the

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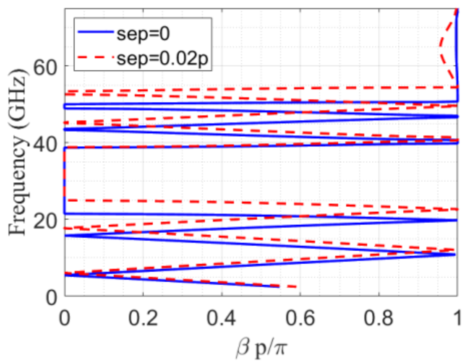
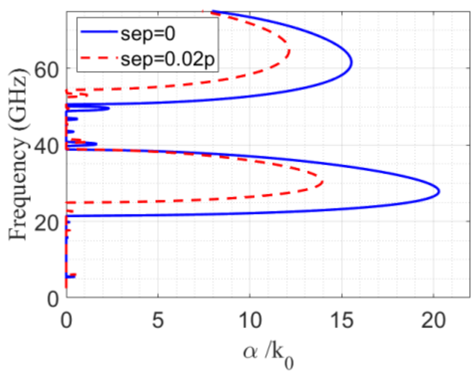


a)



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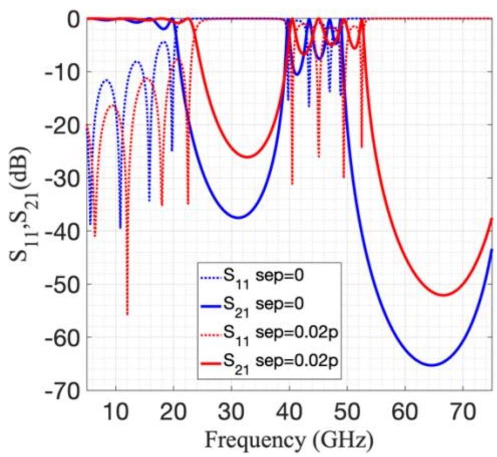

c)

Fig. 2. Simulated results of the proposed structure under superconductor surface impedance condition. (a) normalized β and (b) normalized α obtained for two separations between corrugations. (c) S-parameters obtained for the same separation values.

corrugations were set to $h_1 = h_2 = 20\ \mu$m and their widths to $w_1 = w_2 = 20\ \mu$m, as well.

III. Results

First, we have obtained the dispersion diagram of the glide symmetric structure under the superconductive condition using the Multimodal Transfer Matrix method [6]. We can see the presence of stop-bands, which is demonstrated on the propagation and attenuation constants shown in Fig. 2.a. and Fig. 2.b. Moreover, varying the separation between corrugations yields a tunable stop-band. The transmission and reflection coefficients S_{11} and S_{21} are presented in Fig. 2.c. The tunable stop-band was confirmed with a full-wave simulation. By modifying the separation to zero hence breaking the glide symmetry, the transmission is modified thus moving the stop-band.

IV. Conclusions

This article presented a tunable superconductive glide-symmetric bifilar line. The tunable stop-band property was achieved under superconducting conditions. The tuning was realized by varying the separation between corrugations, though further tuning can be achieved by modifying other parameters of the unit cell. A superconducting device with such capability provides benefits for low-noise applications under cryogenic conditions, for instance radioastronomy, parametric amplification, and quantum computing. Future work will show the validation of the structure in higher frequency bands and explore properties of other non-superconducting microstrip designs under superconducting conditions.

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