Modelling of Travelling-Wave Kinetic-Inductance Parametric Amplifiers Implemented with Artificial Transmission Lines

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The use of the kinetic-inductance present in superconductors has bring about sensitive devices for use in diverse applications including radio astronomy. One of the most recent of such devices is the travelling-wave parametric (TKIP) amplifier. In this amplifier the superconducting material is fabricated (over a substrate) in the form of a transmission line that, owing to the kinetic inductance of the superconductor, has a nonlinear inductance. In such a medium a nonlinear parametric process can occur where several waves can exchange energy. Amplification results if only a limited number of waves is allowed to travel in the line. This is achieved by introducing adequate periodic perturbations in the line that produce stop bands at the selected frequencies.

Since it is relatively easy to fabricate, a CPW line was selected for the first implementation of a TKIP amplifier [1]. Despite of the promising results, one problem arose due to this particular selection of line. Given the high kinetic inductance needed to produce amplification, only lines with high impedance could be fabricated. Although efforts were made in matching the line, its connection to an external 50-Ω line resulted in large in the gain that render the device impractical.

One way to reduce the impedance, but maintaining the use of CPW lines, is to construct them in the form of artificial transmission lines [2]. In this kind of line, small sections of a CPW are used to recreate a transmission line made of lumped-elements. Here we will present, first, a model to construct such lines. The validity of the model was confirmed with the use of HFSS and Sonnet. We will also present designs of TKIP amplifiers using this lines. Table 1 and Fig. 1 show some of the results that will be presented at the conference.

Table 1. Two different designs of unperturbed lines.

	Design 1		Design 2	
	Impedance	$f_{\text{cut-off}}$	Impedance	$f_{\text{cut-off}}$
	Ω	GHz	Ω	GHz
Model	53.2	1287	36.3	898
Sonnet	58.8	---	43.0	---
HFSS	57.6	---	46.4	---

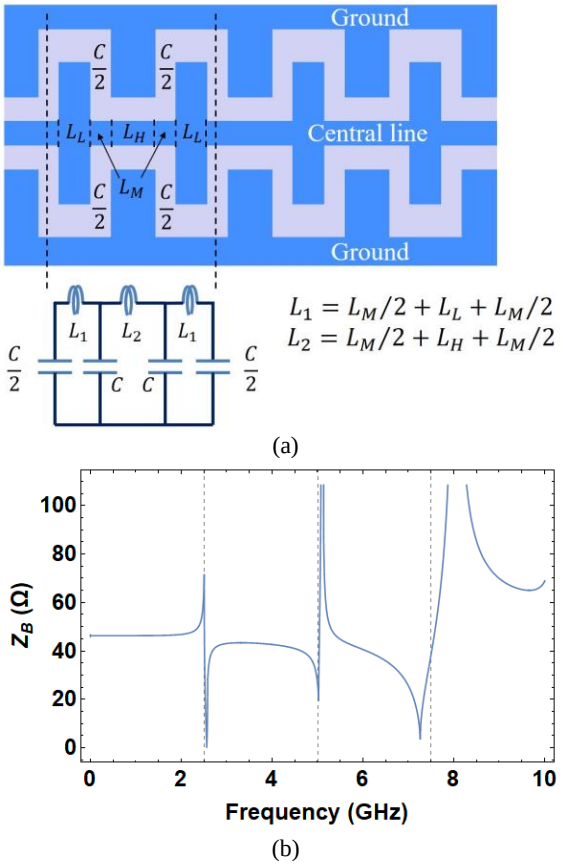

Fig. 1. (a) Circuital model of a unit cell of a (non-perturbed) superconducting artificial line made of CPW sections. (b) Bloch impedance of a perturbed line that can be used to implement a TKIP amplifier using four-wave mixing. Its dimensions were chosen as to obtain a Bloch impedance close to 50 Ω in the intended operational range (0–5 GHz).

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References

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