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SIMULATION OF A MEMS RF FILTER

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ABSTRACT

We simulate the motions in a MEMS bandpass Radio-Frequency (RF) filter. The filter model is obtained by discretizing the Lagrangian of the distributed-parameter system using a Galerkin procedure. The Euler-Lagrange equations are then used to obtain a two-degree-of-freedom model consisting of two nonlinearly coupled ordinary-differential equations of motion. We use the model to study the transmission characteristics of a bandpass filter made up of two coupled resonators. Three distinct response regimes, separated by two critical amplification levels V_{cr1} and V_{cr2}, are identified in the filter response. For amplification levels up to V_{cr1}, the pass signal is artifact free. Two types of artifacts due to the filter dynamics appear and distort the signal for amplification levels beyond V_{cr1} .

INTRODUCTION

Evolution in MEMS technology has led to a new generation of high-performance, small, low-power RF-MEMS components/devices, such as switches, phase shifters, tunable capacitors, inductors, and mechanical resonators and filters. In modern communication systems, there is a continuous trend to miniaturization to allow for the integration of transmitters and receivers on the same chip. To ensure that they do not interfere with each other, narrow-band filtering is required. Electromechanical filters, such as quartz-crystal filters and ceramic filters, are widely used in RF and intermediate frequency (IF) applications. Being off-chip components necessitates interfacing them with integrated electronics at board level and hence conflicts with the miniaturization process. However, the successful implementation of high-Q micromechanical resonators in many micro on-chip systems suggests a method for miniaturizing and integrating highly selective filters alongside other IC components. A mechanical filter is composed of mechanically coupled multiple mechanical resonators, and it allows bi-directional signal propagation within the filter [1].

A mechanical filter based on polysilicon interdigitated comb resonators with a double-folded support structure was first presented in [2]. Filters comprising of two clamped-clamped beams (resonators) coupled mechanically by a soft mechanical spring were first demonstrated in [3].

The design of a mechanical filter involves basic principles of physics, electromechanical transducer concepts, vibration theories, and filter circuitry. Johnson [4] discussed in details the design of macroscopic mechanical filters. Bannon et al. [5] presented a step-by-step description of the design process of a micromechanical filter comprised of two clamped-clamped beams coupled by a flexural-mode beam. Electromechanical analogies were used to model the mechanical devices via equivalent electric circuits. They reported a filter with center frequency around 8 MHz, a quality factor (Q) between 40 and 450, 0.23–2.5% bandwidth, and an insertion loss of less than 2 dB. A comprehensive treatment for the design of higher-order (more than two resonators) micromechanical filters was illustrated in [6]. A center frequency of around 340 kHz with 0.1% bandwidth and an insertion loss of 0.1 dB was demonstrated.

A device comprised of interlinked micromechanical res-

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