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CHARACTERIZATION OF A TUNABLE MEMS RF FILTER

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ABSTRACT

We present a reduced-order analytical model to describe the response of a tunable MEMS RF filter to an input signal whose frequency is in the neighborhood of the passband. It extends our earlier model by allowing for the application of independent DC voltages in addition to an AC input signal. The model is obtained by discretizing the distributed-parameter system using a Galerkin procedure. It consists of two second-order nonlinearly coupled ordinary-differential equations. Using the method of multiple scales, we determine four first-order nonlinear ordinary-differential equations describing the amplitudes and phases of the modes.

We found that mismatch between the natural frequencies of the resonators modifies the global modes significantly, leading to localization of the response in either the input or the output beam. We found that the filter can be tuned to operate linearly for a wide range of V_{AC} by choosing a DC voltage that makes the effective nonlinearities vanish. Amplifying the input signal V_{AC} to improve the filter performance creates multi-valued responses beyond a threshold in the case of non-zero effective nonlinearities.

1 Introduction

The evolution of MEMS technology has led to a new generation of small, high-performance, low-power RF-MEMS components, such as switches, phase shifters, tunable capacitors, inductors, and mechanical resonators and filters. Miniaturization, while allowing for the integration of transmitters and receivers on the same chip, puts severe constraints on the circuit power dissipation and electromagnetic compatibility (EMC) requirements. Consequently, filtering is indispensable for both transmitters and receivers to ensure that they do not interfere with each other [1].

The successful implementation of high-Q micromechanical resonators in many on-chip systems suggests a method for miniaturizing and integrating highly selective mechanical filters alongside other IC components. These filters are composed of two or more mechanical resonators coupled mechanically. Lin *et al* [2] were the first to present a mechanical filter based on polysilicon interdigitated comb resonators with a double-folded support structure. Banon *et al* [3] were the first to demonstrate filters comprised of two clamped-clamped beams (resonators) coupled mechanically by a soft mechanical spring.

Johnson [4] discussed in details the design process of macroscopic mechanical filters. Bannon *et al* [5] described, step-by-step, the design process of a micromechanical filter comprised of two capacitive resonators made of clamped-clamped beams and coupled by a flexural beam. Electromechanical analogies were used to model the mechanical device via equivalent electric circuits. They reported a filter center frequency around 8 MHz, a quality factor (Q) between 40 and 450, a bandwidth of 0.23–2.5%, and an insertion loss less than 2 dB.

Tilmans [6] presented a simple method to obtain a first-order approximation of the dynamic behavior of mechanical filters. In this approach, the mechanical portions of the transducer are represented by their electrical equivalents, however only the steady-state small-signal frequency response of the circuit is considered.

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