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Design of Millimeter MEMS-Based Reconfigurable Front-End Circuits Using the Standard CMOS Technology

可重置毫米波 CMOS-MEMS 前端電路之設計

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作品摘要

微機電（MEMS）技術發展至今已廣泛地存在我們的生活之中，而智慧型手機的發明提供了非常精彩的整合平台，更成為MEMS元件急遽成長的動能。即便如此，其仍面臨與其他晶片電路的整合挑戰，額外的傳輸損耗及封裝優劣都將影響電路特性，也因此「混合製程」的概念順勢提出。MEMS元件可利用現有標準製程相容工序與其他電路整合製作在單一晶片上，其中又以CMOS 製程最受青睞。主因是CMOS積體電路製程發展成熟，具有高良率、低成本及微小化之各項優點，也容易與現有無線通訊晶片整合設計。

此外因應高速數據傳輸的急迫需求，無線通訊應用已逐步邁入毫米波頻段。為了實現更輕薄短小的系統裝置，可兼具多項通訊標準和功能智慧型可重置多工的微波前端電路需求大增，然當頻率升高，半導體元件特性會受到寄生效應影響而產生退化。相較之下，MEMS元件具有極佳的優勢，包含低損耗、寬頻操作、高截止頻率和良好的功率承受能力，使其在毫米波前端電路的應用上更具潛力。

本作品利用TSMC 0.35-μm及TSMC 0.18-μm CMOS-MEMS製程，成功設計並製作四種毫米波前端電路，包含帶拒濾波器、濾波整合開關、頻率可重置晶片天線及切換式相移器。透過適當的電路架構評估與選擇，並加以電路縮小化（如H型諧振，步階阻抗，接地浮升等技術），使其巧妙與致動器整合而不致影響微波特性。我們亦提出一新型靜電驅動式致動器，可生成多種狀態進行電路重置，而平行魚骨架構可增加靜電吸附力，故能在合理的驅動電壓下提供更大的位移量。這些電路的實現，成功驗證了CMOS-MEMS製程在毫米波頻段的可用性。由於兼具了MEMS元件之優勢，使得電路特性與傳統CMOS電路相比更具競爭力，可重置性也更高，提供未來在毫米波前端晶片電路設計的另一項選擇。

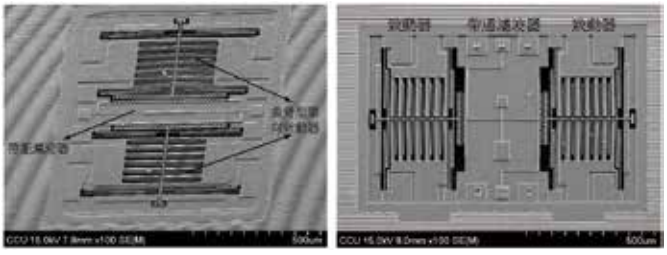

圖1 > 帶拒濾波器（左）與濾波器整合開關（右）之晶片照相圖

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交通大學電信工程學系學士學位，2003 年取得加州大學戴維斯分校電機工程博士學位，隨後加入中正大學電機工程學系與通訊工程學系任教至今。

研究領域

微波與毫米波元件與電路、CMOS-MEMS 可重製毫米波晶片電路、相位陣列天線系統、微波生醫感測系統、無線室內定位系統以及雷達應用之開發。

Abstract

Recent trends significantly increase the demands of millimeter-wave wireless communication systems. The potential applications include 60 GHz high-speed wireless data link, 77 GHz automotive radar, 94 GHz radar imaging, etc. In order to enable low-cost consumer devices, integration for multiple standards and functions, which requires smart and reconfigurable radio transceivers, becomes highly desired.

The solid-state tuning elements, such as p-i-n diodes or varactors, have been considered the territory of III–V compound or silicon–germanium (SiGe) technology when the frequency reaches the millimeter-wave region. However, for those components fabricated in the CMOS process, the performance is often severely degraded. MEMS devices provide another solution with many advantages including low loss, broadband operation, high cutoff frequency and good power handling capability. Moreover the MEMS devices fabricated in standard CMOS technology can lead to high circuit compatibility and economical manufacturing and packaging.

In this work, four reconfigurable CMOS-MEMS front-end circuits, including a bandstop filter, a filter-integrated switch, a slot antenna and a switchable phase shifter, are implemented using standard 0.35-μm and 0.18-μm CMOS processes. Those circuits are designed in V-/W-band to demonstrate their capabilities for high-frequency operation. Additionally, a new-type of electrostatic laminated actuator driven by fishbone beams is introduced to provide dual-state/multi-state reconfigurations, wherein the electrodes consist of a set of lateral cantilever beams, attached to a longitudinal fixed–fixed pole resembling a fishbone. The actuation voltage can be reduced due to the increase of electrostatic force. The success of these CMOS-MEMS circuits demonstrates the great potential for future low-cost, single-chip RF multiband transceivers with improved performance and functionality.

Fig.3 > Application of MEMS

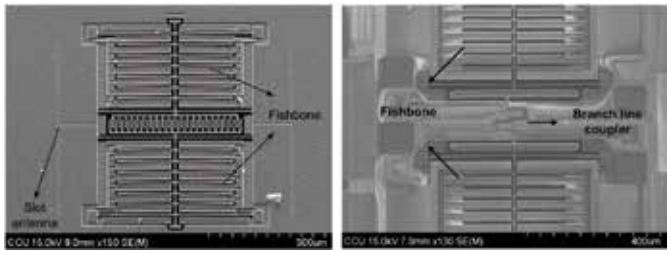

Fig.2 > The photographs of the proposed slot antenna (left) and a switchable phase shifter (right)

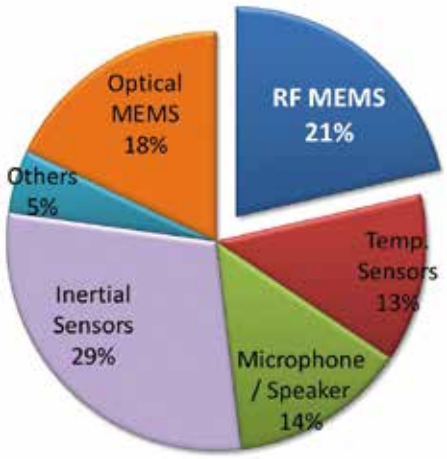

Fig.4 > MEMS foreseeing market in cell phone/tablets @ Yole Development