Low-Cost Phased-Array Antenna Technology Enabled by Macro-Electro-Mechanical Systems (MÆMS)

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In recent years, there has been an exponential growth of the use of millimeter-wave (MMW) frequencies for various communications, sensing, and imaging applications. One contributing factor to this growth is the exhaustion of the available radio-wave spectrum that can be used for high-speed wireless communications at lower microwave frequencies. Consequently, the 5th generation cell phones are planned to operate at MMW frequencies to provide the high-speed data rates required for streaming video and voice applications. The efficient utilization of MMW frequency bands for the new emerging applications, however, requires the development of affordable phased-array antennas that can provide video-frame rates of scanning. A phased-array antenna is a high-gain antenna that can rapidly and dynamically change the direction of its radiated beam (e.g., to track a moving receiver). While various phased-array antennas operating at microwave frequencies have been developed, their extreme cost and complexity has limited their application only to the most expensive pieces of military hardware. Indeed, the development of affordable phased-array antenna technology remains an unaddressed challenge in the applied electromagnetic area.

In this paper, we present the concept of MAcro-Electro-Mechanical System (MÆMS) based phased arrays. MÆMS-based phased array concept is expected to offer a means of developing affordable phased-array technology and be particularly useful for microwave and MMW systems that operate at frequencies higher than a few GHz. We discuss a specific design example where MÆMS tuning techniques are applied to a reflectarray antenna to achieve a high-gain, beam-steerable structure. We demonstrate that beam-scanning in this reflectarray antenna can be achieved without the need for integrating individual electronic tuning elements (e.g. varactors, switches, etc.) within each unit cell of the structure. Rather, small mechanical movements over a larger area are exploited to achieve the same effect that would have been provided by those individual tuning elements on a macro scale. This concept makes the task of designing large-scale tunable reflectarray and transmitarrays considerably simpler and more practical, since it eliminates the need for integrating hundreds or even thousands of individual varactors and biasing them to achieve beam steering. Additionally, because the mechanical movements involved are very small and the parts of the structure that need to be moved are light weight, mechanical movements can be performed very rapidly. Thus, the proposed MÆMS-based phased arrays are expected to be capable of providing video-frame rates of scanning. Details of the proposed concept along with simulation and measurement results of a prototype will be presented and discussed at the symposium.