A Low-Cost Broadband 60 GHz Beamforming Array with Integrated CMOS Components

William F. Moulder*[(1)], John L. Volakis[(1)], and Rudy M. Emrick[(2)]
(1) ElectroScience Lab, The Ohio State University, Columbus, OH, USA
(2) Motorola Labs, Tempe, AZ, USA

A. Introduction

The unlicensed spectrum around 60 GHz (57-64 GHz in the United States) is being considered for short-range multiple Gbits/sec. wireless communications systems. High gain beamforming antennas are necessary for such systems to overcome high path loss while maintaining uninterrupted connections with mobile devices. Fabrication of the active components on silicon would allow for low-cost mass production. However, this raises challenges for antennas and other RF components as doped silicon is extremely lossy.

In this paper, we propose a low-cost broadband beamforming array to satisfy the requirements of commercially viable antennas for 60 GHz communications systems. The array uses silicon-based active components but minimizes losses due to silicon by employing cheap, low loss polymer substrates for the antenna elements and feed.

B. Unique Aspects of System

The proposed system is the first to integrate low loss polymer substrates with low cost CMOS active components. PTFE, LCP, and fluoropolymer-ceramic composites are the most attractive substrates for the array, as they offer low loss ($\tan\delta < 0.0001$, 0.004, 0.001 at 60 GHz for the three materials, respectively) and high melting points. The latter feature allows the polymer-based components to be soldered to the CMOS components in a flip-chip configuration, minimizing interconnect losses. This proposed scheme overcomes silicon loss limitations without expensive micromachining techniques. Unlike all-dielectric arrays, the proposed integrated array allows for spatial power combining (where each element is mated with an amplifier), a critical design aspect at millimeter wave frequencies

The integration scheme allows the system to employ a new true time delay beamformer. The beamformer consists of three delay lines (on polymer) which are switched in and out of the circuit by discrete switches, soldered to the polymer lines. The proposed beamformer thus offers eight states, and is more compact than other true time delay beamformers at 60 GHz. Further, it is the only one which uses low cost polymer as its main material. The true time delay device does not place any theoretical limitations on bandwidth, as it does not restrict the array to the phase shift approximation.

C. Design

The proposed array contains 16 (4x4) patch elements, that, according to simulations, each offer 7-8 dBi realized gain (giving 19-20 dBi gain for the array). Because the elements are aperture coupled, such a square array can be built without the construction of vias through thick substrates, which would cause considerable loss at millimeter wave frequencies. Each element is mated with a CMOS amplifier and a switched-line beamformer. Power is distributed to the elements via corporate feed.