Novel Substrate-independent Broadband Micromachined Antennas for mm-wave Cognitive Radio Applications

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Abstract: In this paper, novel U-slot and Yagi-Uda micromachined patch antennas were designed based on the "micromachined elevation" technique to improve the performance of mm-wave cognitive radios in terms of gain, weight and bandwidth. The elevated antennas were fed with a micromachined probe connected to a CPW line on top of a high ε_r substrate. By elevating the antenna from the high ε_r substrate, high-performance antenna designs can coexist with compact feed networks in 3D module configurations. A 10dB impedance bandwidth of 31% and 25% were obtained for the U-slot and Yagi designs, respectively.

I. Introduction

With the continuous quest for high data rate, low power, low cost, lightweight and compact communication systems with cognitive capabilities, the easy integration of components into a single package becomes increasingly important [1]. To achieve higher compactness and higher thermal dissipation, the signals are often carried through high-index substrates. However, the antenna performance is greatly compromised on these substrates due to high surface waves.

Micromachining techniques compatible with the MMIC process have been already demonstrated in [2]-[4], exhibiting a significant improvement in the antenna performance on top of high-index substrates that is suitable for SOP design. Specifically in [3], an impedance bandwidth of 9.4% was achieved in a single elevated patch antenna with epoxy posts. In this paper, the bandwidth of micromachined elevated patch antenna in [3] and [4] is further improved by designing mechanically stable U-slot and Yagi-Uda antennas on these elevated topologies. The two antennas demonstrated high bandwidth around 25 and 70 GHz suitable for truly cognitive Local Multipoint Distribution Service (LMDS) and Wireless Personal Area Network (WPAN) applications.

II. Antenna Design and Performance

The U-slot patch antenna uses an additional slot to introduce another resonance to a regular patch antenna[5]. The antenna is fed with a metal coated micromachined probe connected to a CPW line above soda-lime glass of ε_r =8.1. It is elevated 200um (0.046λ) above the ground metal with epoxy posts of ε_r =3 and its dimensions are shown in Fig. 1. In Fig 2, the simulated return loss obtained from HFSS shows a 10dB bandwidth from 58GHz to 82 GHz achieving a 10dB fractional bandwidth of 34%. The maximum gain observed at the zenith is 9.74 dBi showing high radiation efficiency of the structure. A 10 dB fractional bandwidth with an almost frequency-independent radiation pattern is under optimization and will be presented at the conference.

An elevated microstrip Yagi-Uda antenna was also designed. It consists of one reflector, one feeder and two identical directors to tilt the main radiation beam 30 degree away from the zenith. All the metal patches are supported by 2 to 4 epoxy based pillars of 600um height. It has a broad bandwidth from 21.5 GHz to 27.5 GHz, corresponding to a 25% fractional bandwidth, which is shown in Fig. 4. Its radiation pattern, as plotted in Fig. 5, demonstrates a high directivity of 10.4 dBi and a tilt angle which can be modified to a variety of values depending on the cognitive application by changing the patch sizes and the element spacings. The enhanced bandwidth and high directivity of this design enables LMDS systems to sense interfering channels, migrate to neighboring frequencies and transfer high data rate in a large range.

Both introduced antennas take advantage of the “micromachined elevation” technique to eliminate surface waves and obtain better radiation performance and improved bandwidth [2]-[4]. For example, in the case of the U-slot antenna, a maximum gain of 9.74 dBi was achieved for the elevated antenna which is much higher than the 3.14 dBi maximum gain from a similar antenna built on top of high ε_r substrate of the CPW feeding line.

The feeding network of the above antennas was built on top of a 0.6-mm thick soda-lime glass. The seeding layer Ti/Cu/Ti was deposited using a DC sputterer. Negative photoresist of NR-9 8000 was deployed above the Ti layer to cover the slot of the feeding CPW-line. Copper was then electroplated on the Ti layer to form the current probe and the ground. An epoxy of SU-8 was dispensed on top of the copper layer to the designed elevated height and patterned to form the post and the feeding probe of the antennas. To guarantee good electrical conductivity between the probe and the antenna, a silver paste was pre-applied on the patch at the point of contact before the patch is attached to the post and the probe.

III. Conclusions

Two novel micromachined antennas, fabricated following the “micromachined elevation” approach, have been designed and featured a significantly improved bandwidth compared to conventional patch antenna on high dielectric substrates. The U-slot antenna achieved a 10dB fractional bandwidth of 31%, while the Yagi-Uda patch antenna had 25%, around 70 and 24 GHz respectively. This paper demonstrated the capability of fabricating complex high performance antenna designs in a MMIC compatible process for a wideband mm-wave range, something that could set the foundation for truly cognitive mm-wave radios with high data throughput, low cost, low weight and compactness.

IV. Acknowledgements

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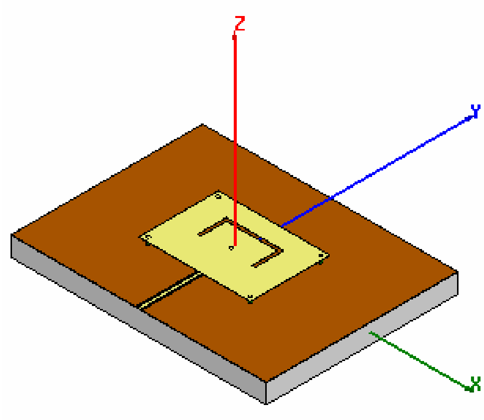
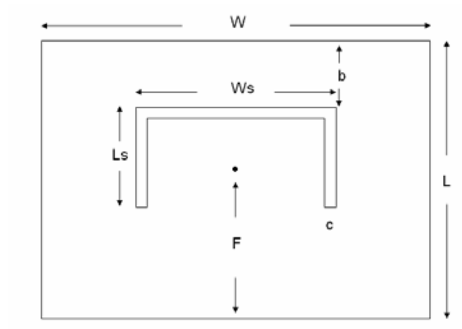


(a)



W=3.5mm, L=2.5mm, Ws=2.2mm,
Ls=1.0mm, c=0.05mm, b=0.9mm, F=1.1mm

(b)

Fig. 1 (a) Micromachined U-slot antenna and (b) antenna dimensions.

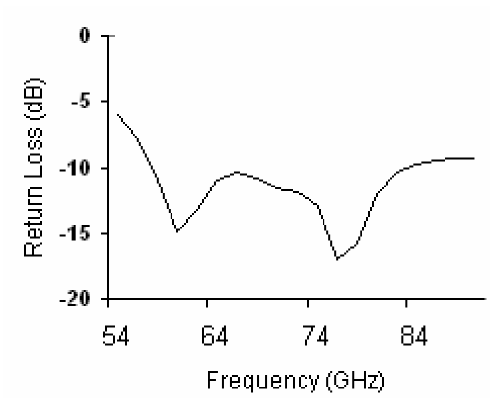


Fig. 2 S11 of U slot antenna.

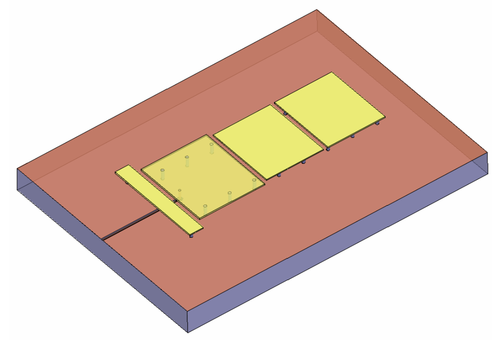


Fig. 3 Micromachined elevated Microstrip Yagi

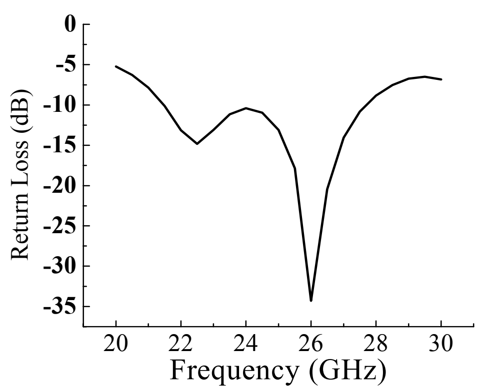


Fig. 4 S11 of elevated Yagi antenna

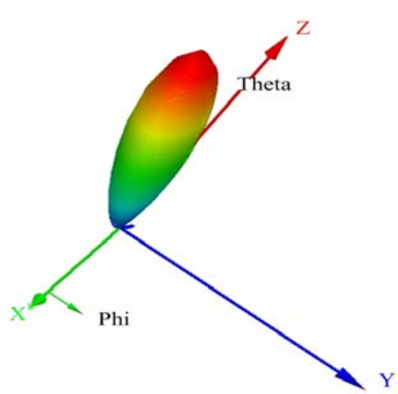


Fig. 5 Radiation pattern of elevated Yagi antenna