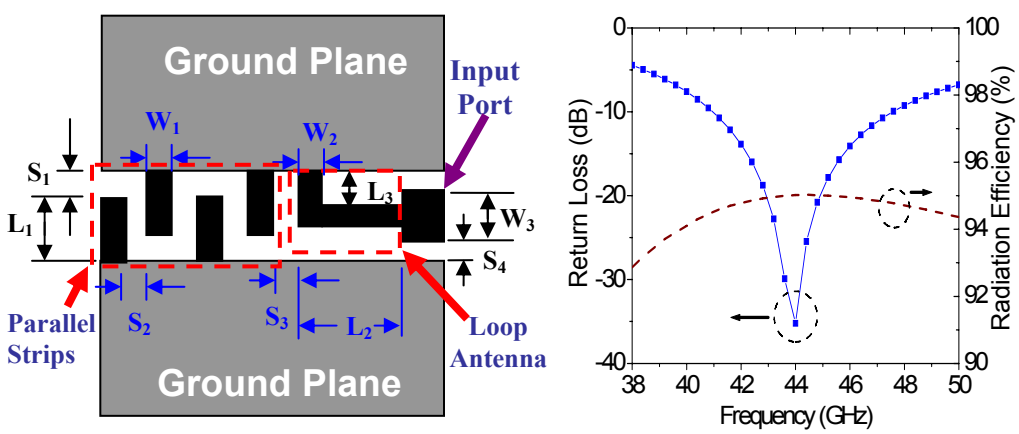
Metamaterial-based Compact CPW-Fed Antenna for 44 GHz Applications

Hualiang Zhang, Hao Xin*, and Richard W. Ziolkowski
ECE Department, University of Arizona, Tucson, AZ 85721-0104, USA

Metamaterials (MTMs) are artificial materials which feature engineered electromagnetic properties that are not readily available in nature. Recently, many applications have been proposed that take advantage of the unusual properties of metamaterials. Among them, the MTM-based electrically small antenna (A. Erentok and R. W. Ziolkowski, IEEE Antenna and Propagation Symp., 1309-1312, 2007) has drawn much attention, since it can provide a very compact antenna design with very high radiation efficiency. Inspired by this kind of antenna, a compact CPW-fed antenna is proposed for millimeter wave frequencies at 44 GHz. Simulation results show that this antenna achieves size reduction, high efficiency, and good bandwidth. Moreover, its uni-planar structure has made it easy to integrate with other circuits.

The design of the proposed antenna is shown in Fig. 1(a). It basically is a semi-loop antenna with one end of the loop shorted to the ground plane. Based on the metamaterial concepts, four interdigital strips are then added and arranged to be parallel with the original loop antenna. The working principles of this antenna can be explained as follows. Physically, the loop antenna as a driven element generates a magnetic flux which is captured by the interdigital strips, a very near field parasitic element. Since the magnetic fields are time-varying, large currents will be induced on the surface of these strips. As a result, strong electric fields are produced between the gaps of the strips, which introduce a large capacitance to the antenna system. This capacitance along with the original loop antenna (which can be treated as an inductor) forms a resonant metamaterial-inspired antenna system (it may be thought of as an LC resonator or as a composite right/left-handed transmission line). Based on this design concept, a 44 GHz antenna was built on a quartz substrate that has a dielectric constant of 3.78, a substrate thickness of 350 μm, and a loss tangent of 0.0004. The design parameters of the antenna (as labeled in Fig. 1(a)) are: L_1 = 193 μm, L_2 = 150 μm, L_3 = 83 μm, W_1 = 50 μm, W_2 = 60 μm, W_3 = 190 μm, S_1 = 33 μm, S_2 = S_3 = 25 μm, S_4 = 18 μm. The metal thickness is 1μm throughout. The total length of the proposed antenna is 450 μm, which is about $\lambda_0/15$ (λ_0 being the free space wavelength at 44 GHz, 6.818 mm), demonstrating the fact that this antenna is electrically small, i.e., ka=0.232. The simulated performance of the antenna is shown in Fig. 1(b). The -10 dB (return loss, S_{11}) antenna bandwidth is 6.5 GHz. In Fig. 1(b), the radiation efficiency of the antenna is also given It is observed that the radiation efficiency is higher than 94% over the whole operating band.



(a) (b)

Figure 1. (a) General topology of the proposed CPW antenna, (b) simulated performances of the antenna.