On the Efficiency Measurement of Microstrip Antennas Using the Wheeler Cap Method

Hosung Choo*, Robert Rogers[+] and Hao Ling
Department of Electrical Engineering
University of Texas at Austin
Austin, TX 78712 U.S.A

[+]Applied Research Laboratory
University of Texas at Austin
Austin, TX 78713 U.S.A.

The Wheeler cap method is a simple and well-known technique for measuring antenna efficiency. The method involves making only two input impedance measurements of the antenna under test, one with a conducting cap enclosing the antenna and one without. The antenna efficiency is then estimated based on either a parallel or a series RLC circuit model for the antenna. Pozar and Kaufman reported on the use of this method for measuring the efficiency of microstrip antennas (*IEEE Trans. Antennas Propagat.*, 36, 136-139, 1988). Even though it is generally believed that a microstrip antenna should be modeled as a parallel circuit, their measurement results did not support the parallel RLC model, and they concluded that the loss mechanism in the microstrip is similar to that of a series RLC circuit. In this work, we revisit the Wheeler cap method for microstrips and show that the parallel RLC model is indeed a more appropriate model to use than a series one for the microstrip. Our Wheeler cap measurement is verified by two different simulations using the commercial software ENSEMBLE: (i) simulation of the Wheeler cap method by modeling the conducting cap, and (ii) gain simulation with and without losses.

As a test, we use a standard square microstrip (patch dimension of 40.5 mm operating at 1.8 GHz) built on FR-4 substrate. A conducting rectangular cap (17cm× 17cm×8.5cm) is used to completely enclose the test microstrip. The input impedance of the antenna is measured with and without the cap. Based on the parallel RLC model, the radiation conductance G_a and the conductance due to losses G_l are extracted. The efficiency is calculated by $\eta = G_a /(G_a+G_l)$. The resonant frequency of the capped antenna is slightly shifted from the original resonance due to the cap effect. The conductance at the new resonant frequency is used to compensate for this effect. Based on the parallel RLC model, the Wheeler cap measurement shows an efficiency value of 32%. This result is checked against two different simulation results. From the simulation of the Wheeler cap method, the efficiency is found to be 39%, while the gain simulation with and without dielectric and metal losses shows an efficiency of 30%. The same methodology is applied to microstrips on other substrate materials, and the resulting efficiencies are investigated. The interior cap modes, which may prevent accurate efficiency measurements, are discussed. Furthermore, optimal shapes and dimensions of the Wheeler cap are studied.