# An On-Chip Slot Antenna for ZigBee and IEEE 802.15.4 WPAN Applications

Koen Van Caekenberghe, Nader Behdad, and K. Sarabandi
Radiation Laboratory
Department of Electrical Engineering and Computer Science
University of Michigan, Ann Arbor, MI 48109-2122
saraband@eecs.umich.edu

Electrically small antennas have long been of interest for the compact design of handheld radios and mobile communication systems. In recent years, this subject has gained significantly more attention because there is an increasing demand for miniaturized short-range wireless communication systems. Contemporary multi-band transceivers have stringent size restrictions and miniature antennas are needed to allow for dense packaging while maintaining low mutual and parasitic coupling. Integration of antennas on chip through the System-on-a-Chip (SoC) approach, or on package through the System-on-a-Package (SoP) approach, drives down overall cost as well.

Fundamental limitations of small antennas have previously been explored (R.C. Hansen, "Fundamental Limitations in Antennas", Proc. IEEE, Vol. 69, pp. 170-182, Feb. 1981). Miniaturization increases the antenna radiation quality factor ($Q$), reduces the antenna efficiency, and makes the matching network complex and lossy. Examples of miniaturization techniques include meandering of the wire antenna, using materials with high dielectric constant, and reactive loading (R. Azadegan and K. Sarabandi, "A Novel Approach for Miniaturization of Slot Antennas", IEEE. Trans. Antennas Propagat., Vol. 51, pp. 421-429, Mar. 2006).

In this paper, an electrically short slot antenna ($\lambda_0/35 \times \lambda_0/35$, 5 mm$^2$) for ZigBee and IEEE 802.15.4 WPAN applications is designed, fabricated, and tested. The inductively loaded slot antenna can be matched to any desired input impedance directly without the use of an external matching network, where a very high efficiency is obtained. Miniaturization is achieved through symmetric reactive loading of a very short slot section. The antenna was designed to operate at 2.45 GHz and was fabricated on a low-loss quartz wafer ($\epsilon_r = 3.78$, $h = 20$ mil), using an MCM-D like fabrication process, which lends itself to SoP integration of a wireless transceiver.

At the design frequency, this antenna shows a -10 dB fractional bandwidth of about 0.3%. The return loss and the radiation patterns are measured with a probe station, eliminating the need for wafer dicing and custom-built text fixtures. The wafer is placed on a cavity filled with absorber, located in the far field of the antenna. A probe tip calibration is performed and an on-wafer antenna is connected to port 1 of a vector network analyzer (VNA). Port 2 of the VNA is connected to a movable reference antenna which bends over the probe station. The measured $S_{21}$ is proportional to the gain of the on-wafer antenna, where the measured gain of the antenna is -1.2 dBi and the efficiency is 50%. A comparison is made between the measurement results and method of moments (MoM) simulation results.