The Design of Miniature Antenna and RF Powering Circuit for Implantable Intraocular Pressure Sensor

Chin-Lung Yang[1], Eric Y. Chow[2], Sungwook Moon[1],Yuehui Ouyang[1], Pedro P. Irazoqui[2], and William J. Chappell[1]

[1]IDEAS Microwave Laboratory and [2]BCI Laboratory

[1]Department of Electrical & Computer Engineering and
[2]Weldon School of Biomedical Engineering, Purdue University
465 Northwestern Avenue, West Lafayette, IN 47907 USA.

Email: {cyang, eychow, moon8, ouyangy, pip, and chappell}@purdue.edu

Glaucoma is a detrimental eye disease where elevated levels of intraocular pressure (IOP) cause permanent damage to the optic nerve. It is projected to affect about 60.5 million people by 2010 and cause bilateral blindness in 4.5 million. We are developing a device that provides internal ocular pressure measurements to help detect and treat elevated levels of IOP. The device will be inserted into the suprachoroidal space and has a stringent size restriction of just a few millimeters on each side and less than 300 µm in thickness. The implant is composed of an IC, MEMS capacitive sensor, miniature antenna, RF powering module, and capacitive array for on-board power storage. The chip consists of a sensor interface, a/d converter, on-chip memory, and wireless transmitter to provide the capability for 24-hour IOP monitoring.

One of the major difficulties with this miniature implant deals with the wireless data acquisition from the device. We designed various antenna types on both multilayer low temperature co-fired ceramics (LTCC) and silicon substrates using Ansoft HFSS™. Our wireless transmitter, designed and fabricated on the AMIS 0.6 µm process, was integrated with the different antenna types. The various devices were implanted in the eyes of New Zealand white rabbits and the *in vivo* experiments allowed us to quantify the attenuation through the tissue and demonstrate the feasibility of low-power wireless telemetry (E. Y. Chow, et. al, TMTT, Dec 2008). To determine the required receive power for successful data transfer, our minimum detectable signal (MDS) is estimated from the noise floor and calculated to be -108 dBm. From our measurements, the power received at a distance of 12 inches with a transmitter current consumption of 3 mA is still at least 10 dB greater than the MDS, and allows us to achieve successful wireless data transfer.

Supplying remote power to this implant is another significant challenge due to the size restrictions and biological effects. We explored an RF powering technique to transfer sufficient power to charge the on-board capacitor array in a matter of seconds. This method for wireless power transfer is not as directionally dependent and allows for greater ranges than the traditional low-frequency inductive link. RF powering also allows us to use the same antenna which is very beneficial given our size restriction. In addition to the antenna design, a high-frequency rectifier is required to generate the DC supply. We used a complementary 2-stage voltage multiplier to produce our desired voltage and we also incorporated a switched circuit technique to separate passive and active loads, which reduced the recharging time. A novel impulsive powering technique is explored to take advantage of the nonlinear region of the rectifier diodes, which improves the ratio of DC power produced to average power supplied. We explored the use of anisotropic conductive adhesive (ACA, developed by Nexaura Inc.) to provide a thin bonding solution for the electrical connections from our IC and components to the substrate. In our i*n vivo* experiments, this RF powering module was able to charge up the 20 µF array to 4 volts in 850 ms using an average transmission power of 1 mW.

The already stringent requirements on size, power, and wireless capabilities for most biomedical devices are even more severe for ocular implants. Our work demonstrates the feasibility for using RF frequencies for both wireless data and power transfer in a 24-hour continuous glaucoma IOP monitor.