PROJECT III.4: CIRCUITS & DEVICES FOR SENSOR NETWORKS & SYSTEMS

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Objectives

The main objective of the activity is the development of the necessary technologies for future sensor networks and systems. In the context of this objective the research targets of sensor readout, wireless telemetry, RF remote powering in the near as well as the far field are pursued. Special consideration is given in operation within a spacecraft environment as well as in integration and packaging.

Funding

ESA Contract No. 21339/08/NL/GLC “Remote RF Powering and Passive Telemetry Link for a Wireless Strain Sensor System”

Subcontracting under ESA Contract No. ESTEC 22322/09/NL/CBI entitled “Hardware architecture development for FEC encoding/decoding support” with Analogies S.A

MAIN RESULTS IN 2010

Wireless telemetry and RF remote powering of sensor tags

Remote monitoring networks often require the development of batteryless sensor nodes that harvest energy from the environment, i.e vibration and incident RF power. RF power harvesting tags have the advantage that RF fields can be generated by controlled base stations, thus providing a more stable power supply. In this activity a passive smart sensor tag is being developed. The tag comprises a power harvesting unit that accumulates energy for the circuitry to operate. Each node accommodates a low power microcontroller that is responsible for sensor measurement and data transmission. The system (Fig. 1.) operates in the 430MHz band requiring a minimum input RF power of -5.8dBm.

The antenna of the tag is a slotted PIFA-type geometry connected to the PCB bottom metal (ground) through a shorting pin and fed with a properly designed microstrip on the top PCB metal. The feed and shorting pins support the antenna very close to the ground plane, only at a distance of 1 cm. This approach results in a very compact antenna which is embedded within the system’s PCB and the whole device can be conformally packaged. At the same time the antenna has been optimized, by minimizing size in conjunction with optimizing the slots’ positions, width, length and shape as well as pin coordinates, for broadband operation, eliminating the danger of detuning when the system is in close contact with other entities. Thus the tag could be attached to metal and concrete structures in infrastructure monitoring applications for example.

The performance of the system was simulated using the commercial Method-of-Moments (MoM) full wave simulator Designer. The system’s simulated return loss is shown in Fig. 2, along with the corresponding measurement performed using an Anritsu Lightning Vector network Analyzer and a 50-Ohm RF port. It should be noticed that there is excellent agreement between simulations and measurements throughout the frequency range covered. In addition the bandwidth of the antenna, at the demanding level of -10 dB, is 60 MHz, or 14%. This is about twice the bandwidth achievable with a patch antenna, while the latter is much larger than the system of this sensor tag in all dimensions.

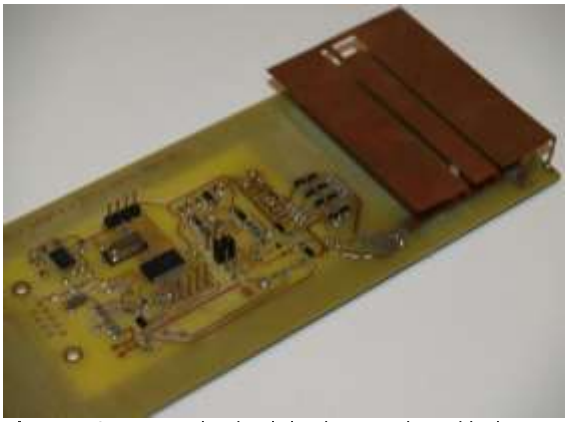

Fig. 1. Sensor node circuit implementation with the PIFA antenna attached to it.

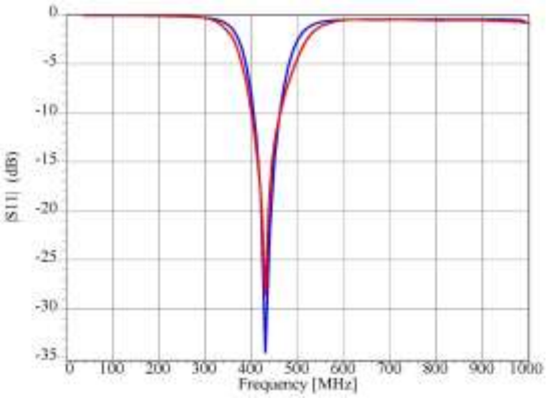

Fig. 2. Simulated (1) and measured (2) return loss of the optimized antenna

In order to evaluate the remote powering link in open space a room that is 11 m long, 3 m high and 8.6 m wide was selected. A commercial transceiver that outputs 200 mW (23 dBm) at 430 MHz was attached to a 430 MHz resonant dipole antenna in order to power the tag with the PIFA antenna remotely. The tag controller was programmed to output a pulse train with a 32 kHz clock as in bench measurements. The transceiver and the tag were placed in line in the middle of the room. Then an oscilloscope was used in order to capture the output pulse trains. It should be noted that at distances longer that 4 m the microcontroller outputs only one pulse between charging cycles. At such distances the storage capacitor charging rate is lower than capacitor discharging due to microcontroller operation. Thus, the voltage controlled switch is turned off quickly. At distances from 4 to 2 meters the tag operates for time intervals of 20 ms between charging cycles and at distances lower than 2 meters the controller is continuously on due to ample power available at the antenna terminals.

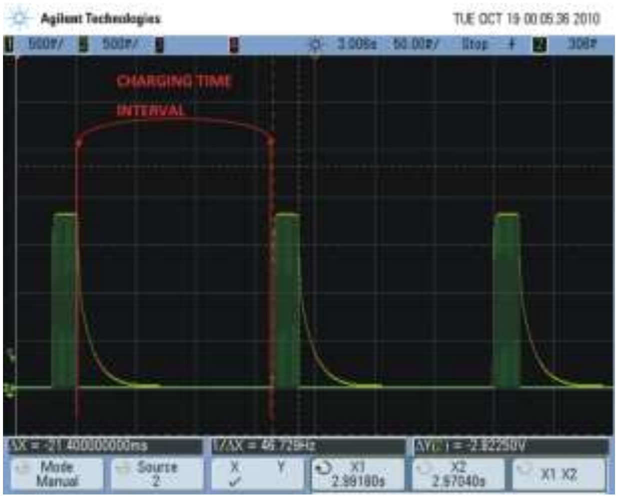

Fig. 3. Demonstration of charging and operation cycles at an input power level of -2.5 dBm. The envelope of the pulse trains corresponds to the voltage level at the regulator output.

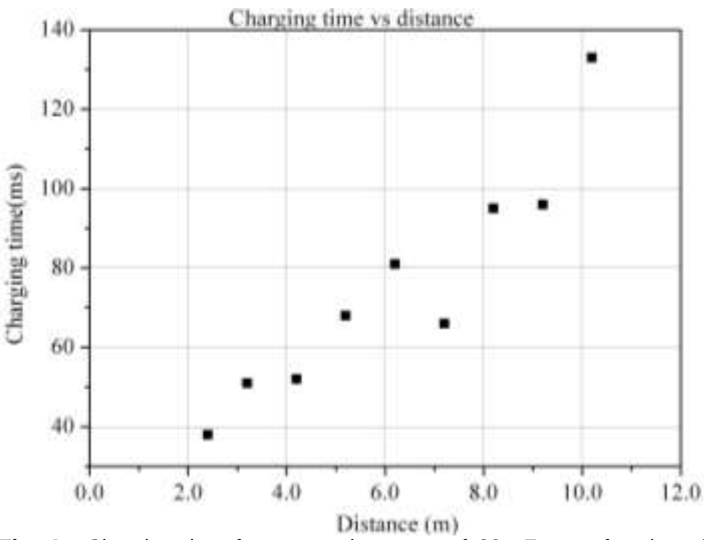

Fig. 4. Charging time for a capacitor array of 20 uF as a function of distance. The reader station emits 23dBm at 430 MHZ with a resonant dipole antenna.

FPGA implementation of embedded and complex systems

A Reconfigurable capacitive sensor array interface comprised of a subsystem able to read an array of capacitive type sensors and an embedded processor has been designed and implemented.The system is intended to be a smart interface for capacitive sensor arrays. Each sensor is connected to a ring oscillator, which translates capacitive changes into a variable frequency pulse train. Analysis of the oscillator behavior including all parasitic elements has been performed and the use of a Schmitt trigger at the inverter chain is proposed to assure oscillation for capacitance values ranging from 1 pF to 1500 pF. The oscillation frequency is estimated by using a 16-bit counter and the appropriate user-defined counting interval ranging from a few microseconds to several seconds in order to achieve maximum accuracy within the entire capacitance range. The two byte word thus produced can be sent to a host computer through a serial or parallel interface for further processing. To demonstrate the concept a 16-channel interface has been described in a Hardware Description

Language (HDL) and implemented on a Complex Programmable Logic Device (CPLD). Measurement of two different capacitive pressure sensors developed in-house reveals frequency sensitivity values of –252.1 Hz/fF and –9.54 Hz/fF, which are in good agreement with the expected values derived by the analytic relations.

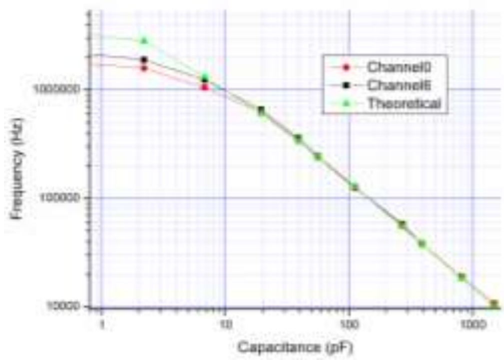

Figure 5. Oscilation frequency versus capacitance Cs

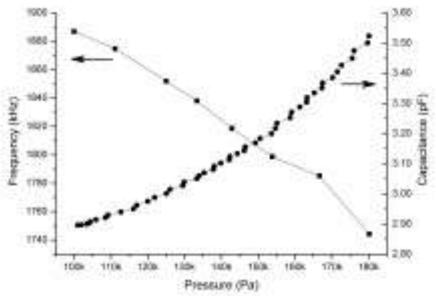

Figure 6. Sensor capacitance and oscillation frequency vs pressure for two in-house developed capacitive-type pressure sensors.

PROJECT OUTPUT IN 2010

Publications in International Journals and Reviews

1. E. D. Kyriakis-Bitzaros, N. A. Stathopoulos, S. Pavlos, D. Goustouridis and S. Chatzandroulis, "A Reconfigurable, Multi-Channel Capacitive Sensor Array Interface", IEEE Transactions on Instrumentation & Measurement, accepted for publication