Broadband IQ CMOS transceivers for compact and ultra-compact NMR probes.

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CMOS technologies allow for the miniaturization of the electronics needed for a pulsed NMR probe. Recently, use of single-chip transceivers was demonstrated for both compact NMR tools implementation and realization of ultra-compact high sensitivity sub-nL probes [1-4]. Due to their low power operation, CMOS transceivers are particularly versatile and performing solutions for the implementation of probes having small active volumes. For instance, Fig. 1A shows a single-chip ultra-compact NMR probe having a 200 pL active volume and a spin sensitivity of $1.5{\cdot}10^{13}$ spins/Hz$^{1/2}$, together with the spectra of individual sub-nL intact ova of microorganisms [5]. In this work we mainly focus on a new single-chip transceiver capable of broadband (3 MHz - 1 GHz) IQ demodulation (Fig. 1B), interfaced with external resonators, and demonstrate its use in combination with a modified version of a commercial teslameter. We also implement a 2-channel compact probe for high resolution and simultaneous high field magnetometry, showing that probes employing acrylic-embedded water samples of 500 nL are capable of resolutions as high as 0.06 ppb/Hz$^{1/2}$ at 7 T, and that magnetic noise due to field fluctuations can be directly measured at this precision level (Fig. 1C).

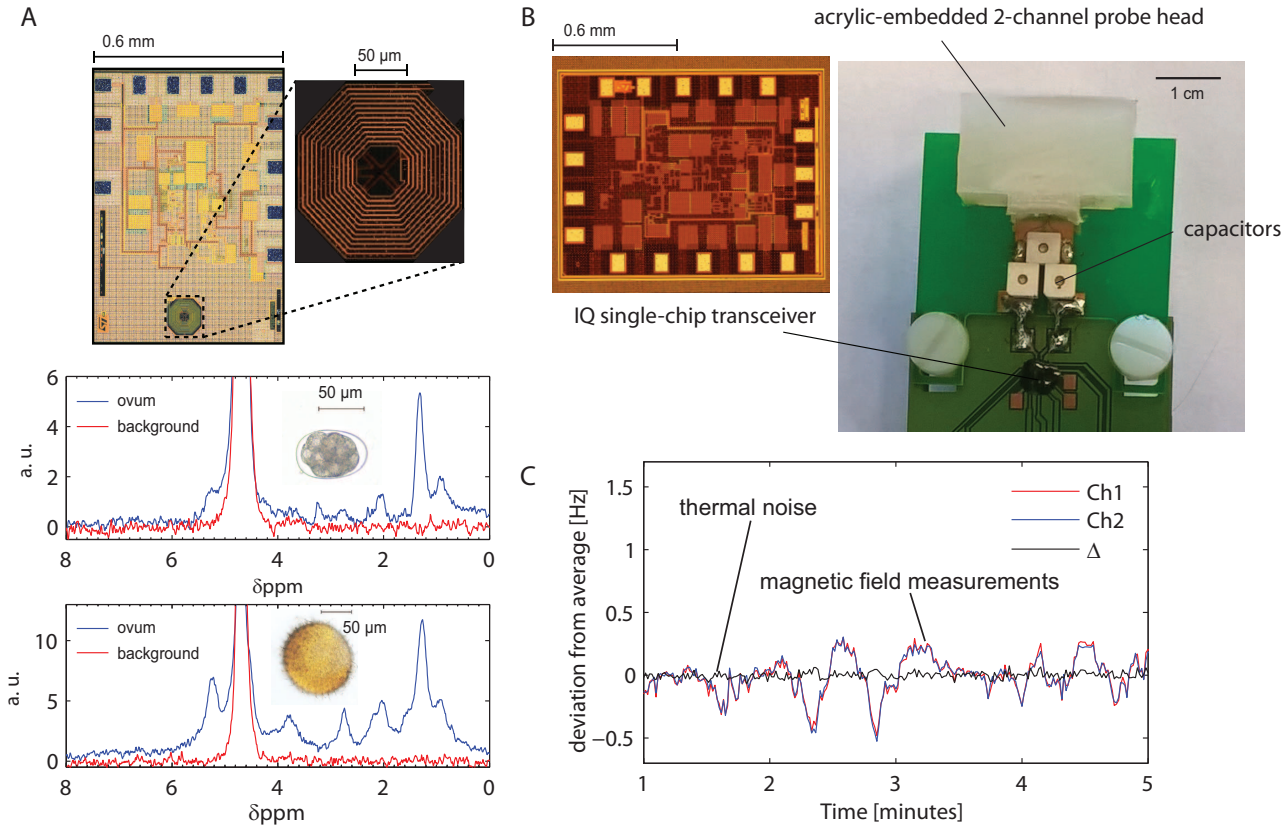

Figure 1: (A) Photograph of a ultra-compact single chip probe (a single-chip transceiver co-integrated with a micro-coil) and spectra of single intact sub-nL ova of microorganisms obtained with the same device. (B) Photographs of the broadband IQ single-chip transceiver and the resulting 2-channel compact probe head for simultaneous high field magnetometry. The 500 nL water samples are contained in acrylic capillaries. Two solenoids are wrapped around the capillaries, which are then embedded in acrylic resin. An identical circuit on the other surface of the PCB implements the second channel. (C) Channel 1 (red), channel 2 (blue), difference Δ among channels (black), resulting from a 5 minutes series of magnetic field measurements (taken every 1 s) in a Bruker 7T cryo-magnet.

[1] B. Blümich, *TrAC Trends in Analytical Chemistry*, 2016, **83A**, 2-11. [2] N. Sun, et al., *IEEE J. Solid-State Circuits*, 2001, **46**, 342-352. [3] D. Ha, et al., *Proc. Natl. Acad. Sci. U.S.A.*, 2014, **111**, 11955-11960. [4] M. Grisi, G. Gualco and G. Boero, *Review of Scientific Instruments*, 2015, **86**, 044703. [5] M. Grisi, B. Volpe, R. Guidetti, N. Harris and G. Boero, *arXiv:1511.06719*, 2015.