

An RF-over-fiber system for reliable signal injection in ERETIC spectroscopy

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Introduction: Quantification of absolute metabolite concentration is a key requirement for the assessment of pathologic alterations and for a better understanding of biochemical processes in vivo. To facilitate signal quantification the ERETIC method [1] relies on a reference RF signal, synthesized by an electronic device, which is injected during the acquisition of spectroscopy data. Ensuring safety and maintaining sufficiently low signal coupling between the actual receive coil and the ERETIC setup presents significant engineering challenges due to inevitable cable interactions and parasitic grounding loops. Great care must also be taken when positioning coaxial cables of the ERETIC system in the MR room because the routing can strongly affect the transmitted signal [2]. If the signal is injected inductively potential loading of the injector loop is another source of error in the reference signal.

Materials and Methods: The alternative solution proposed in this work is to transmit the reference signal via an optical fiber link based on nonmagnetic components including a directly modulated light-emitting diode (LED). The optical signal is guided through a plastic optical fiber (POF), converted back to an electrical signal by means of a photodiode and then inductively coupled into the receive coil. LED senders (Hamamatsu L9534) were chosen rather than semiconductor lasers because they are less sensitive to temperature changes, inexpensive, do not need special biasing circuits and do not emit potentially dangerous coherent radiation. POFs (1 mm PMMA) are easy to handle and have a large numerical aperture for efficient coupling between the LED and the fiber. A PIN photodiode (Infineon SFH250) was used to detect the modulated optical signal. A low noise amplifier (Avago MSA0886) was included in the link to decrease its noise figure and net attenuation. The signal is coupled into a 3T proton birdcage coil (127.8 MHz) via a 0.84 cm² loop. The injector loop is placed behind the RF mirror of the birdcage coil to assure a stable reference signal for various coil loading conditions. The ERETIC signal is generated by the broadband tune channel of the system in the service room; the signal then travels through a fiber of 10 m in length and enters the scanner room's Faraday shield through a waveguide. This setup guarantees patient safety since the optical fiber is a perfect electrical isolator. The link was used with a 3T Philips Achieva system (Philips Healthcare, Best, NL).

Results: The attenuation of the link (consisting of preamplifier, LED, POF, and detector diode) at 127.8 MHz is -14 dB, the noise figure is 24.48 dB and the 3rd order intercept point is -35 dBm. Even though the attenuation and the noise figure of the link are high, the reference signal presents a very good signal-to-noise ratio, which further improves when the signal is averaged during spectroscopic acquisitions. In-vivo feasibility of the signal injection is demonstrated in Fig. 3, showing a sample 1H brain spectrum with prominent water and reference peaks. The key requirement for use in ERETIC is the amplitude stability of the reference signal over time. It was first checked on the bench by monitoring the gain of the link over 12 hours, followed by a test in the MR system, measuring the amplitude of the reference signal with the MR spectrometer, again for 12 hours, of which the first 180 minutes are displayed in Fig. 4. The ERETIC signal remained highly stable after a warm-up phase of 30 minutes. Assuming a moderate number of signal averages (N=130) the standard deviation of the reference signal was 0.66% over 3 hours and 2.16% over 12 hours.

Discussion and Conclusion: Using an optical link solves a key problem in the ERETIC method by ensuring a stable and safe reference signal. It is thus expected to facilitate high-fidelity quantitative measurements of metabolite concentrations. It also greatly simplifies the handling of the ERETIC setup by overcoming all issues related to cable routing. Since the temperature of the MR room is kept constant the LED's sensitivity to temperature changes is not an issue. Nevertheless the setup needs a warm-up phase of 30 minutes after being switched on.

References

[1] Barantin et al., A New Method for Absolute Quantitation of MRS Metabolites. *MRM* 38, p.197 (1997) [2] Marro et al., Synthetic signal injection using inductive coupling, *Journal of Magnetic Resonance* 194(1), p.67 (2008)[3] Schweizer et al., Advances in the ERETIC method for the quantification of in-vivo 1H and 31P spectra, *Proc. 16th ISMRM*, p.193 (2008)

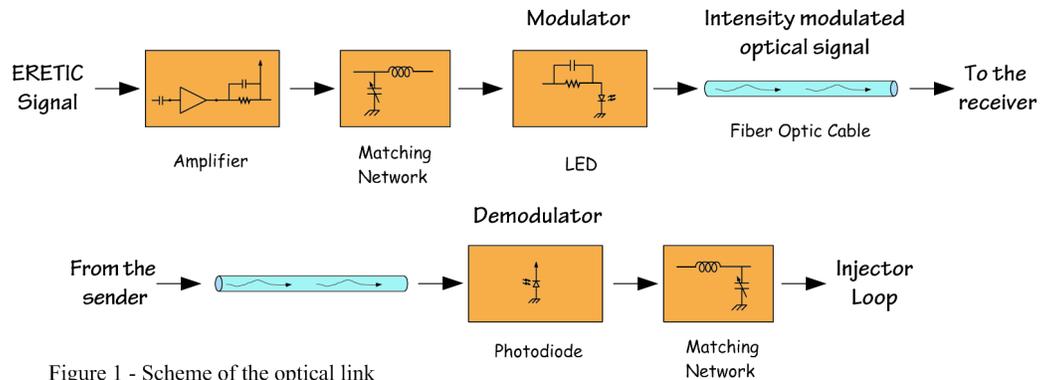


Figure 1 - Scheme of the optical link

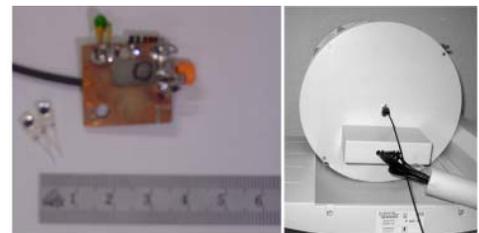


Figure 2 - The modified birdcage coil (right) and its injector loop (left)

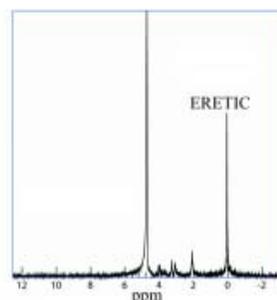


Figure 3 - In vivo spectroscopy

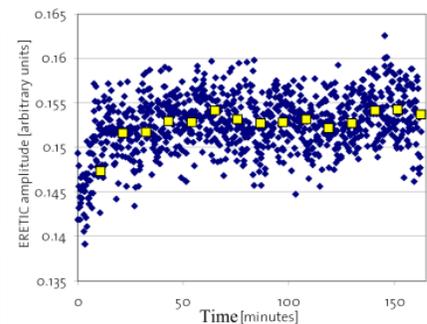


Figure 4 - Stability measurement, the yellow dots represent the mean (averaging factor of 130)