Different methods have been proposed for the investigation of anal sphincter muscles, often related to the assessment of incontinence. Intra-anal EMG has been proposed as an additional technique for the investigation of the external anal sphincter (EAS). In previous works signals have been detected by either longitudinal or ring-shaped pairs of electrodes incorporated into intra-anal probes or perianal pairs of electrodes. Multi-channel intra-anal EMG systems have been proposed for high-resolution detection of EMG from EAS [1]. A recent result in the investigation of intra-anal EMG signals from EAS muscle is the estimation of monopolar from single differential (SD) signals [2].

2. Objectives
Detection of monopolar signals, computation of the corresponding SD signals, estimation of monopolar signals from the SD and evaluation of the error of reconstruction. This error reflects the geometry of motor units around the anal canal and is minimal in case of arrangements along circular arcs [2].

Evaluation of the relationship between error of reconstruction and the fiber geometry.

3. Methods
Signals were detected using a rectal EMG probe developed at LISIN in collaboration with the company OT-Bioelettronica. Intra-anal EMG signals were acquired in monopolar derivation using the EMG-USB amplifier (LISIN OT-Bioelettronica). Twelve volunteer subjects participated to the experiment. The probe was lubricated with a drop of glycerol and inserted in the anal canal. Single MUAPs were identified from intra-anal EMG signals by a recently developed decomposition method based on the CCK [3]. Averaged monopolar MUAPs were obtained by triggering the averaging of a 30 ms time window from the raw EMG signals. All the detected occurrences in the 50 s long contractions were used for the averaging. In each contraction, only the MUs for which at least 30 action potentials were identified were considered for further analysis. The monopolar estimation error of each MUAP was computed as the difference between the original monopolar signal (ARV), and the reconstructed signal (ARV obtained from the SD signals) divided by the ARV of the monopolar signal and expressed as a percentage.

The average rectified value (ARV) of MUAP templates was computed for each channel and averaged along each of the three arrays, obtaining the average amplitude at the three depths within the anal canal.

3. Results
A preliminary classification was based on MU location: A) MUs which are clearly visible only in one of the three arrays (CoV of the three ARVs > 0.7), which are very likely superficial and close to that array; B) MUs which are visible in two of the three arrays (0.4 < CoV < 0.7); C) MUs which are visible in each of the three arrays (CoV < 0.4), which are very likely deep in the muscle. The error of monopolar reconstruction is larger when the MUAP template is visible from more arrays, which means when MUs are deep in the muscle. This indication is further investigated in Figure 5, where the scatter plot of the estimation error versus CoV of MUAP amplitude is shown. A significant dependency between the two variables was observed (Pearson correlation coefficient R = -0.75, p<0.001). The estimation error also depends on the longitudinal location of the MU (i.e. along the anal canal). This property is shown in Figure 6. The locations of the three arrays were considered the MU depth within the anal canal was estimated as that of the array for which the corresponding MUAP had higher amplitude. The MUAPs which were located close to the third array (i.e., the most external one) had significantly lower estimation error with respect to those located in the proximity of the other two arrays (non parametric one way Kruskal-Wallis ANOVA, Chi = 17.3, p<0.001).

4. Conclusions
Monopolar intra-anal EMG signals from EAS were recorded using an anal probe carrying three arrays of 16 electrodes placed at three depths within the anal canal 15 mm apart. Single MUAPs were identified. The contribution of common mode components to single MUAPs is lower for MUs located superficial in the muscle and at a lower depth within the anal canal. This finding is related to the geometry of the fibres that, as confirmed by anatomical studies, are circular and parallel to the detection array in such a location. A large contribution of common mode components is present in the interference signal, suggesting that there is crosstalk from far and large co-contracting muscles (e.g. puborectalis, glute).

5. References

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