

REDUCING THE EFFECT OF ELECTRIC AND MAGNETIC FIELDS ON AUDITORY EVOKED POTENTIALS (506)

Isaac Kurtz¹, M.H.Sc. P.Eng., Yuri Sokolov¹, Ph.D.

¹Vivosonic Inc., 56 Aberfoyle Cres., Suite 620, Toronto, ON, Canada, M8X 2W4, 1-416-231-9997, 1-877-255-7685 (Canada & US), www.vivosonic.com

Objectives

- 1) Quantify the relationship between measured field levels in the environment and noise in Auditory Evoked Potential (AEP) measurements.
- 2) Quantify the relationship between magnetic field levels and the repeatability of AEP measurements.
- 3) Evaluate the effect of in-situ amplification on noise and repeatability in AEP measurements.

Background

- While clinical AEP measurements are ideally acquired in rooms that are electrically and magnetically shielded, it is often necessary to acquire AEP's in unshielded environments such as operating rooms, nurseries and hospital wards.
- The National Institute of Occupational Safety and Health survey on extremely low frequency (ELF) magnetic fields in the range of 3-3000 Hz is summarized in Table 1.

Table 1. NIOSH survey of magnetic field exposure in hospitals and offices (mG)

Intensive care unit	0.1 - 220	Measured at nurse's chest
Post-anesthesia care unit	0.1 - 24	
Magnetic resonance imaging (MRI)	0.5 - 280	Measured at technician's work locations
Desk work locations	0.1 - 7	Peaks due to laser printers
Desks near power center	18 - 50	
Power cables in floor	15 - 170	
Computer center	0.4 - 6.6	
Can opener	3000	
Desktop cooling fan	1000	Appliance fields measured 6 in. away
Other office appliances	10 - 200	
Building power supplies	25 - 1800	

- Electric fields are introduced into AEP measurements through capacitive coupling of the electrode inputs and the surrounding electric field. Based on National Research Council data, typical electric fields in home environments are 5-10 V/m, with most of the energy at power line frequency and its harmonics.

Theoretical Considerations

Electric Field

For a first order approximation of AEP noise due to electric fields assume:

- a uniform electric field
- capacitive coupling of the signal leads to the surrounding environment is predominantly through the head

Following Heron (1977):

$$C_H = \epsilon_0 \pi^2 4 r^2$$

• where r is the radius of the head and ϵ_0 is the permittivity of air.

$$V_H = E * r$$

• where E is the electric field.

$$I_E = C * 2 * \pi * f * V_H$$

• where I_E is the noise current induced into the system due to the electric field and f is the frequency of noise.

Ferree et al. expressed the relationship between I_E and the noise voltage at the amplifier input (V_E) as:

$$V_E = I_E (Z_1 - Z_2)$$

• where $Z_1 - Z_2$ is the scalp-electrode impedance imbalance between the two signal electrodes.

Example

Head radius = 10 cm
Noise frequency = 60 Hz
Electric field = 5 V/m
Impedance mismatch = 1 kΩ
Noise induced by Electric field = 2.1 μV

Magnetic Field

From Faraday's Law:

$$V_M = 2 * \pi * f * A * B$$

• where f = frequency, A = area of loop, B = magnetic field.

Example

$B = 3$ mGauss
 $A = .1$ square meters (i.e., 2 meter long signal leads separated by an average distance of 5 cm)
Noise induced by Electric field = 11 μV

Realities

- 1) Household levels of electric and magnetic fields produce significant noise in AEP measurements.
- 2) At these levels, magnetic fields will have a more significant effect than electric fields.
- 3) Magnetic fields are proportional to loop area.
- 4) Shielding and impedance matching does not reduce magnetic noise.

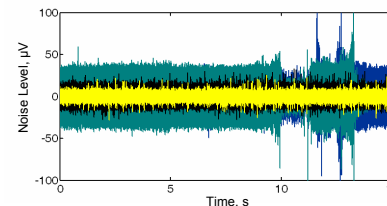
Experimental Method



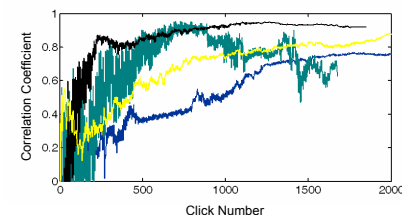
Example of an in-situ amplifier, Vivosonic's Amplitrode™.

- EEG signal recordings obtained with no applied stimulus while varying the magnetic field and keeping the electric field constant (~5 V/m)
- Idealized ABR (0.5 mV peak) added to EEG noise
- Conventional EEG recording:
 - Signal loop area = .18 square meters
 - @ 3 mG (green), 9 mG (blue)
- In-situ recording (Amplitrode™):
 - Signal loop area = .05 square meters
 - @ 3 mG (yellow), 9 mG (black)

Results

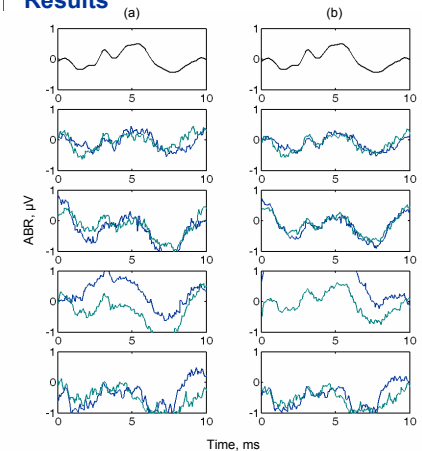


15s sample of measured noise. Conventional recording at 3 mG (green) and 9 mG (blue). In-situ at 3 mG (yellow) and 9 mG (black).



Comparing correlation with click number for the four measured EEGs.

Results



Comparing ABR received signals for the different EEG noises at (a) click 500 and (b) 1200. The top row displays the idealized ABR, rows 2 & 3 processed ABR from the in-situ amplifier at 3 and 9 mG, respectively, and 4 & 5 processed ABR from the conventional leads at 3 and 9 mG, respectively.

Conclusions

- 1) Moderate magnetic field levels significantly affect the quality of the processed ABR signal.
- 2) These effects are reduced when using in-situ amplification.
- 3) In-situ amplification is less sensitive to higher magnetic fields.

References

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- Heron M.L. Capacitance and Static Electricity in the Human Body. *Phys. Med. Biol.*, 22: 1208-1209, 1977.
- National Research Council. Possible Health Effects of Exposure to Residential Electric and Magnetic Fields. Washington DC: National Academy, 1997.