CHARACTERIZATION OF AUDITORY EVOKED POTENTIALS RECORDED IN RADIOFREQUENCY FIELDS

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ABSTRACT

This paper deals with the analysis of auditory evoked potentials recorded in presence of radiofrequency fields emitted by a mobile phone. During measurements, spurious frequencies appear on the one hand at 50, 100, 150 Hz but and on the other hand around 83.3, 133.4 and 216.7 Hz. The first ones are due to the mains and that at 216.7 Hz comes from the GSM modulation. We show that the two others (83.3 and 133.4 Hz) are related to the 216.7 Hz component and to the sampling frequency. In order to get rid of these parasitic components, a low-pass filtering is applied before further analysis. A study of the acquisition system behavior in the band [0; 40 Hz] is carried out to conclude on the validity of this analysis.

1. CONTEXT

The frequency range used for mobile telephony varies according to companies and their technologies, ranging from 850 to 1900 MHz. The range will be extended to 2200 MHz with the new UMTS technology, and to the 400 MHz waveband with the TETRA system, currently under development. These are part of the much wider range of radiofrequencies present everywhere in our environment, at home, at work, or in public, especially in urban areas.

Two features characterize radiofrequency associated with mobile telephony, causing a legitimate interrogation of the public: for mobile phones, the question concerns the immediate proximity of the antenna and cranium, during conversation; for the telecommunications transmitters, it concerns the multiplication of antennas relays in our close environment.

The development of telecommunications has been followed by research into the effects of radiofrequency electromagnetic fields on biological systems. This research focused particularly on mechanisms that could link exposure of human cells to the development of cancers. The highly-complex physical and biological involved phenomena necessitated the development of new experimental, measuring, and observation procedures that were not always completely controlled in the early research projects. Some research evidenced short-term modifications in certain physiological or biochemical parameters, or even fine neuro-sensory functions, while other work contradicted these results. The significance of these observations in predicting the occurrence of long-term effects is debatable.

The public are naturally concerned by this difficulty in drawing conclusions. The issue of potential health hazards resulting from exposure to radiofrequencies takes on a very special importance when it is considered that 30 million people are users of mobile telephone in France. Even if the individual risk was very small, the great number of people involved would produce a considerable impact in terms of public health.

During the recent period, several scientific authorities produced reports aiming at apprehending the knowledge state on the biological and medical effects of the radiofrequencies.

In France, the COMOBIO project ("COmmunications MObiles et BIOlogie"), funded by the Ministries of Industry and Research within the National Network for Research on Telecommunications, aims to contribute a significant share to the process of installation of the mobile telephones certification, to improve the reliability of the systems of exposure for the animals and to carry out biological experiments targeted to bring answers to the questions which remain posed on the medical effects of the mobile telephones.

The sub-project 3 of COMOBIO project relates to the study of auditory evoked potentials (AEPs) under influence of radiofrequencies emitted by a mobile telephone.

The characterization of the functional implications of radiofrequencies passes in priority by the examination of the cerebral structures close to the radiation source, in other words, the auditory system and the temporal areas. Therefore, the radiofrequencies repercussions are studied through the observation of auditory evoked responses.

This analysis is associated to a study on imagery and dosimetry. The access to the morphological information provided by the Imagery by Magnetic Resonance makes it possible to individualize the anatomical structures of the brain. Then, we can be interested in the 3D dosimetry estimation by taking into account the environment heterogeneity.

AEPs recorded in presence of radiofrequencies emitted by a mobile phone exhibit, in addition to components due to the mains, frequential components at 83.3, 133.4 and 216.7 Hz. To avoid these disturbances in our analysis, a low-pass filtering is carried out insofar as the auditory evoked activity is low-frequency. Nevertheless, the presence of these different disturbing frequencies forced us to wonder about the validity of this choice. In this paper, our aim is *i)* to give some answers to the origin of the disturbing frequencies and *ii)* to show that the low-frequency band we retained only reveals the auditory activity, that can be modified by the radiofrequency fields.

2. PROTOCOL

Two populations are considered: the first one consists of 14 healthy subjects, the second one is a population of 14 subjects presenting a temporal epilepsy.

The collection of the auditory evoked potentials consists in recording electroencephalographic (EEG) signals on the surface of the scalp in response to a given stimulus using a helmet of 32 or 64 electrodes (Figure 1).

Figure 1. Helmet of 32 electrodes.

The continuous signal collected and described as "gross" is sampled at 1 kHz and is treated by the "Neuroscan" system. This system uses a pre-amplification stage on the level of the box head, and digitizes the analogic signal on 16 bits. The detection impedance of this system lies between 0 and 20 kΩ , and the input tension must be in the range [1 μV; 20 mV].

The subject is installed in a soundproofed Faraday screen room, which allows completely satisfactory conditions of signal acquisition.

The stimuli emitted by the loudspeaker of the portable telephone are pure tones at 500 Hz and 1 kHz randomly sent. The control of the emission power of the radiofrequencies is carried out by a communication simulator ("Hemibox").

The continuous recorded signal is split up into epochs of 820 ms. An artifact rejection allows to get rid of epochs distorted by external disturbances such as eyes blinking. An averaging on about 250 epochs after synchronization on the stimulus allows to increase the signal-to-noise ratio and supplies the averaged AEP.

During one experimental session there exist 4 successive recording phases: during the first phase, there is no emission of radiofrequency; in the second phase, the emission power is minimal; the third phase is performed with an emission in maximal power and the last one is identical to the second one.

Each subject takes part in 2 experimental sessions, during which the mobile phone is alternately located close to the right ear and close to the left ear.

For some subjects, a third session is saved to study the placebo effect. It is also composed of 4 during which no radiofrequency is emitted.

3. PARASITIC COMPONENTS

Figure 2 shows an example of an averaged AEP obtained during a maximal radiofrequency emission.

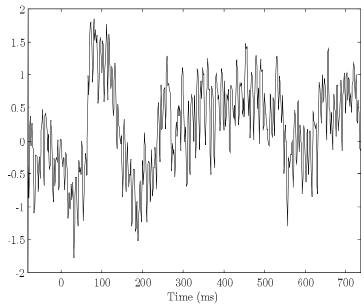

Figure 2. Averaged AEP.

To know the frequential contents of individual responses, we represent in Figure 3 the average of all individual spectra.

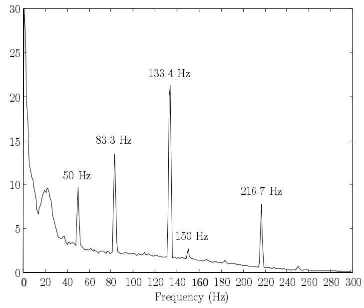

Figure 3. Average of 250 spectra with radiofrequencies in maximal emission.

This figure exhibits some activity in the low frequencies but also spectral lines at 50, 83.3, 133.4, 150 and 216.7 Hz. The components at 50 and 150 Hz are disturbances due to the mains.

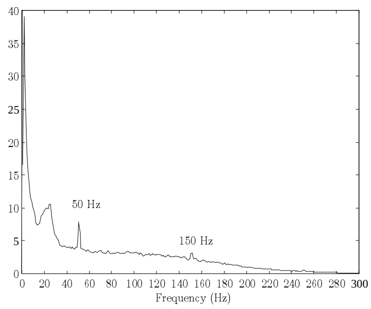

Figure 4. Average of 250 spectra without radiofrequency.

The average of spectra relative to signals recorded without any emission of radiofrequency is represented in Figure 4. In addition to the normal activity it emphasizes frequency bins only at 50 and 150 Hz. Consequently, the three other spurious frequencies (83.3, 133.4 and 216.7 Hz) are probably dependent on the radiofrequencies emission.

3.1 Origin of the 216.7 Hz component

The GSM portable uses the band from 890 to 915 MHz with a maximal emission power of 2 W. To increase the number of communication channels, 2 techniques of which the temporal multiplexing, Time Division Multiple Access (TDMA), are employed simultaneously. A 4,615 ms old frame is divided into 8 intervals of equal duration (577 µs). The GSM infrastructure actually functions in modulated pulsated mode, since, for each channel, a set of 8 frequencies is actually used. That means there are 1733 changes of frequencies a second, and we have 8 different frequencies, qualified as pulsated, each one emitted 216.68 times per second. The spectrum of this pulsated signal is represented Figure 5 and comprises harmonics of the 216.684 Hz component except multiples of 8×216.684 Hz.

Thus, the 216.7 Hz component corresponds to the GSM modulation which is not supposed to induce any component at 83.3 and 133.4 Hz.

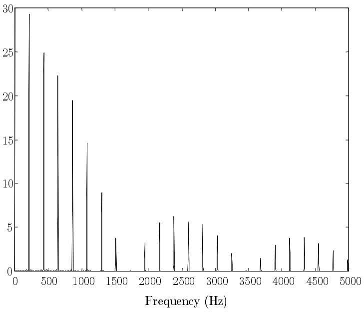

Figure 5. Spectrum of GSM the modulation signal

3.2 Origin of the 83.3 and 133.4 Hz components

To find the origin of the components at 83.3 and 133.4 Hz, we must take account of all elements which play a role in the AEPs collection.

The first parameter is the cerebral activity. Recordings are taken on a "phantom" to free oneself from the presence of the electroencephalographic signals. The phantom used in the dosimetry measurements consists of mannequins whose electromagnetic characteristics are adjusted according to the dielectric biological fabric properties.

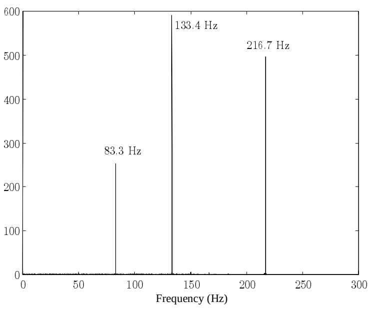

Figure 6. Spectrum of a signal recorded on a phantom in maximal emission power.

The spectrum of the signal recorded by electrodes placed on this phantom in maximal radiofrequencies power is represented Figure 6. The frequencies at 83.3 and 133.4 Hz appear distinctly. As a consequence, they do not result from a physiological reaction to the presence of the component at 216.7 Hz.

The second parameter is the communication simulator which allows the remote control of the emission power. To test the influence of the "Hemibox" simulator, experiments are done by activating the manual test procedure to put the radiotelephone in maximal emission.

The presence of both frequencies (83.3 and 133.4 Hz) is visible on Figure 7, and indicates that they are not generated by the communication simulator.

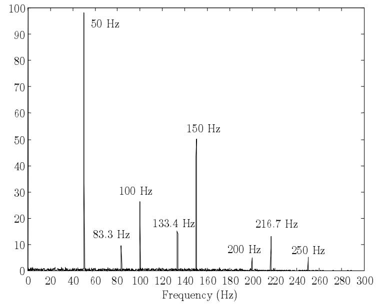

Figure 7. Spectrum of a signal recorded with no communication simulator in maximal emission power.

The third parameter to analyze is the acquisition system. Electrodes are connected directly to a low frequency generator which delivers a sinusoidal electric signal at 216.684 Hz corresponding to the GSM frequency whose amplitude is 523.25 µV.

A ten-second acquisition is carried out and the spectrum of the recorded signal is represented in Figure 8. In addition to the component at 216.684 Hz, this figure exhibits the two spurious frequencies at 83.3 and 133.4 Hz.

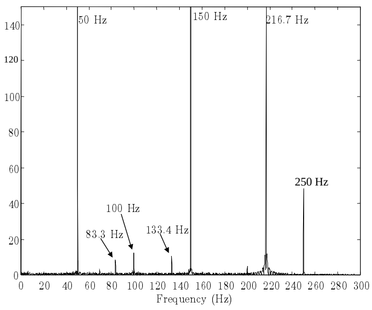

Figure 8. Spectrum of the signal recorded using a sinusoid generator at 216.684 Hz.

This result tends to prove that the components at 83.3 and 133.4 Hz found in the previous recordings are due to the acquisition system and are related to the 216.7 Hz frequency.

To check if these disturbances are due to a problem involved in sampling, two recordings in maximal emission power are considered for two different sampling rates respectively equal to 1 kHz and 10 kHz. The spectrum of the signal sampled at 1 kHz is represented in Figure 6 and contains the spurious frequencies at 83.3 and 133.4 Hz. As for the spectrum of the signal acquired at 10 kHz and illustrated on Figure 9, it does not contain these parasitic components.

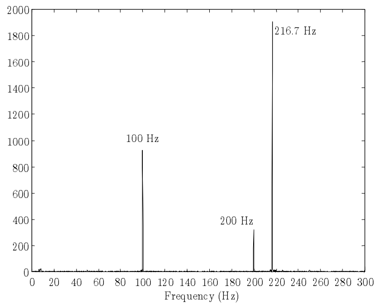

Figure 9. Spectrum of the signal sampled at 10 kHz in maximal emission power.

Thus, the two spurious frequencies at 83.3 and 133.4 Hz are partly due to the sampling rate. In fact, the first one corresponds to the aliased 5th harmonic (equal to $5 \times 216.684\,\text{Hz} - 1\,\text{kHz}$) while the second one corresponds to the aliased 4th harmonic (equal to $1\,\text{kHz} - 4 \times 216.684\,\text{Hz}$).

According to the Neuroscan acquisition system, the signals collected on the electrodes are pre-amplified and filtered using an analog filter with an insufficient slope to remove the 216.7 Hz harmonics. So, some aliasing appears for a sampling rate equal to 1 kHz. The signals are then filtered numerically with a second order pass-band filter [0.15 Hz; 200 Hz].

To circumvent this problem, a low-pass filtering with a cut-off frequency at 40 Hz is applied to the auditory evoked potentials.

Of course, other harmonics are close to multiples of the sampling frequency, and so the aliasing creates disturbing components in the band [0; 40 Hz]. Except the 4th and 5th harmonics, those which give aliased frequencies in the previous band are the 14th (3033 Hz) and the 23rd (4983 Hz) harmonics; however, they are sufficiently reduced by the analog filtering so as not to disturb the band [0; 40 Hz]. This is illustrated on Figure 10.

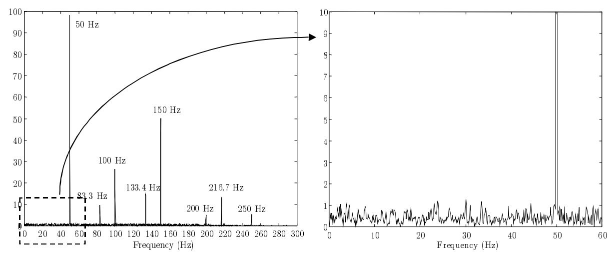

Figure 10. Spectrum of a signal recorded in maximal emission power.

3.3 Acquisition system behavior in the frequency band [0; 40 Hz].

Since the influence of radiofrequencies on human cerebral activity [1] [2] is tested in the band [0; 40 Hz], we have to demonstrate that no problem occurs in this band. To this end, we check the behavior of the acquisition system in the range [0; 40 Hz].

As an example, Figure 11 represents the spectrum of a signal recorded using two sinusoid generators at 5 and 11 Hz and does not reveal any decomposition of the two components.

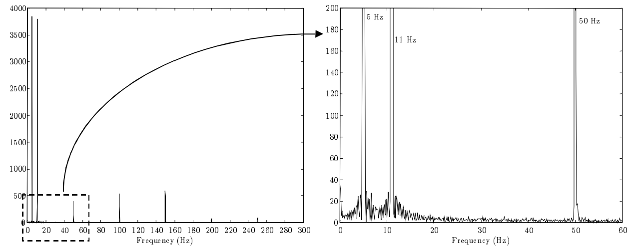

Figure 11. Spectrum of a signal recorded using two sinusoid generators at 5 and 11 Hz.

Consequently, low frequencies that can be viewed as auditory evoked components do not create disturbances.

4. CONCLUSION

The spurious frequencies at 50, 150 and 250 Hz observed on AEPs recorded on surface electrodes are due to disturbances relative to the mains. The 216.7 Hz component is linked to the GSM modulation frequency. It comes out that the components at 83.3 and 133.4 Hz do not correspond to a physiological phenomenon and are not emitted by the system of remote control of the radiofrequency emission power. To overcome this problem a low-pass filtering has to be applied to individual AEPs before further analysis in terms of radiofrequency influence on human cerebral activity.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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