Hypersensitivity to Electricity: The effect of the current waveform on the perception level.

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Abstract - Hypersensitivity to electricity has been reported many times in the literature. From another point of view, numerous measurements have been performed on perception level. Even if it appears that part of the population has a lower perception level of current, there is no clear link with the so called "hypersensitivity to electricity" which is more related to declared physiological disorders in part of the population (sleeping problem, headache …). Such declared hypersensitivity is currently not yet related to any biological parameter.

Our research team is currently trying to determine a relationship between hypersensitive declared people and the perception level when injecting current in the low frequency range 50-1000 Hz.
We have performed current perception tests with individuals under different conditions (different wave shapes, frequencies, influence of external electric field, male and female…) using a particular protocol and our own designed system for current injection.

This paper will present our test system design (current injector, wave shape converter, safety aspects) and our first results based on both sine wave (different frequencies) and wideband signal.

I. Introduction

Hypersensitivity to electricity, i.e. non-specific health symptoms such as headache, sleep disturbance, nervousness, concentration disturbances or skin arousal, attributed by the patient to the "electromagnetic pollution", has been frequently reported in the literature (Hilert et al, 2002, Leitgeb, 1998) but until now, no clear link has been shown between the electromagnetic field and the symptoms of these persons.

In (Leitgeb and Schrötner, 2003), a subgroup of people with significantly increased electrosensibility was detected. Herein, the electromagnetic sensibility is described as the ability to perceive electric and electromagnetic exposure, and electromagnetic hypersensitivity, developing health symptoms due to exposure to environmental field. The measurements showed a clear difference between men and women. A log-normal law was proved to fit fairy well to their results (see fig 1).

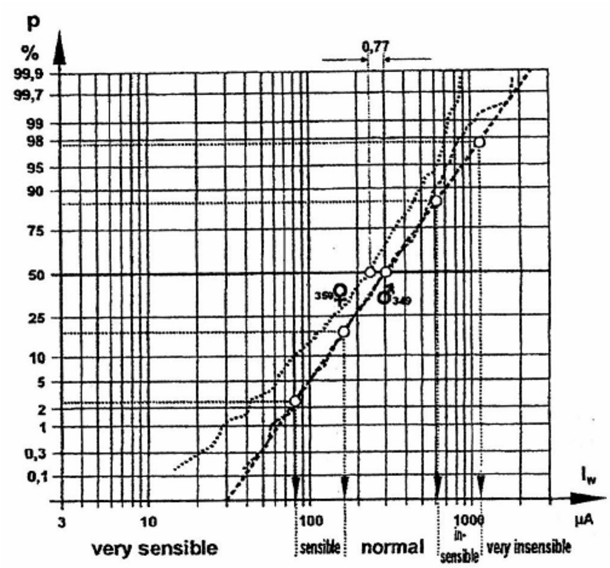

Fig1: Distribution of the cumulative probability perception Threshold current I_w (following Leitgeb-2003)

The existence of the very "electrosensible" subgroup can be seen as the second log-normal distribution on the fig 2.

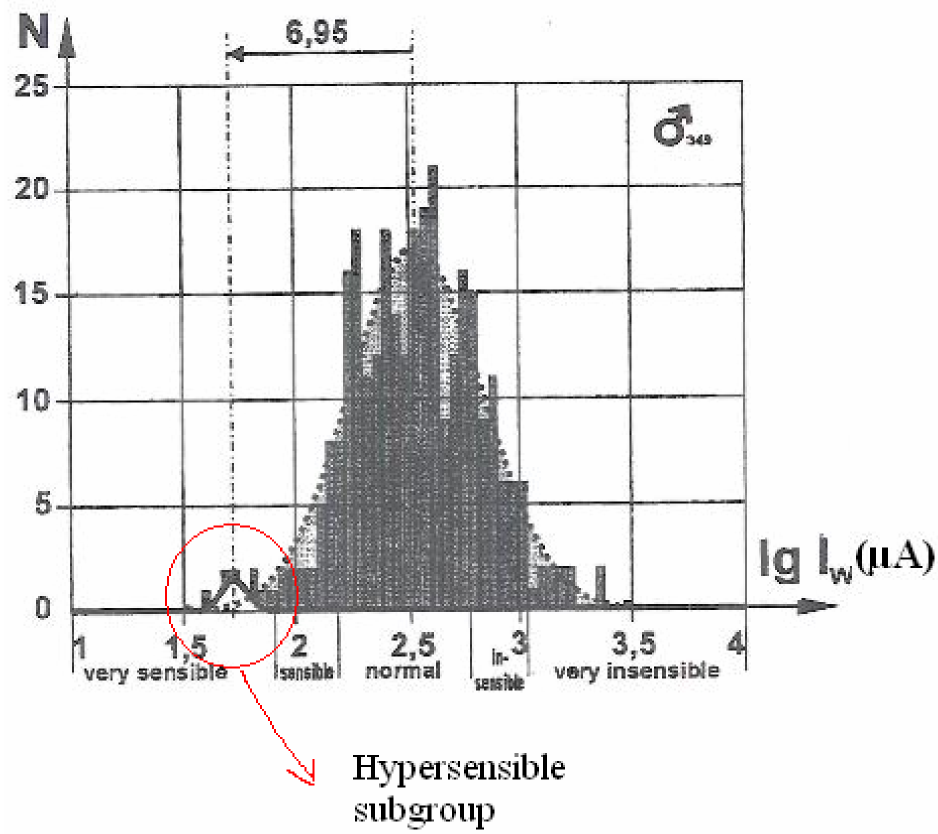

Fig 2: Best least square fit of two ideal log-normal distributions with the frequency distribution of measured electric current perception thresholds of men (following Leitgeb-2003.

Similarly to the work in (Leitgeb and Schrötner, 2003), but in a wide band of frequency, and signal shape, we try to determine a link between the "hypersensitivity to electromagnetism" and the sensibility to electricity. Our aim is to measure the smallest current intensity that a given person can feel when electrical current is flowing between two electrodes placed on the forearm of this person.

A home-made device, that allows injecting any waveform current within the frequency range 50Hz-1kHz, has been designed. This injector will be described in detail hereafter.

This paper will be focused on the sensitivity to electricity of a person according to the frequency. The first results of measurements will be shown for two different frequencies (50Hz and 1 kHz).

II. Measurements method

The developed experimental system is composed of a computer, a current injector and an external supply (see fig 3).

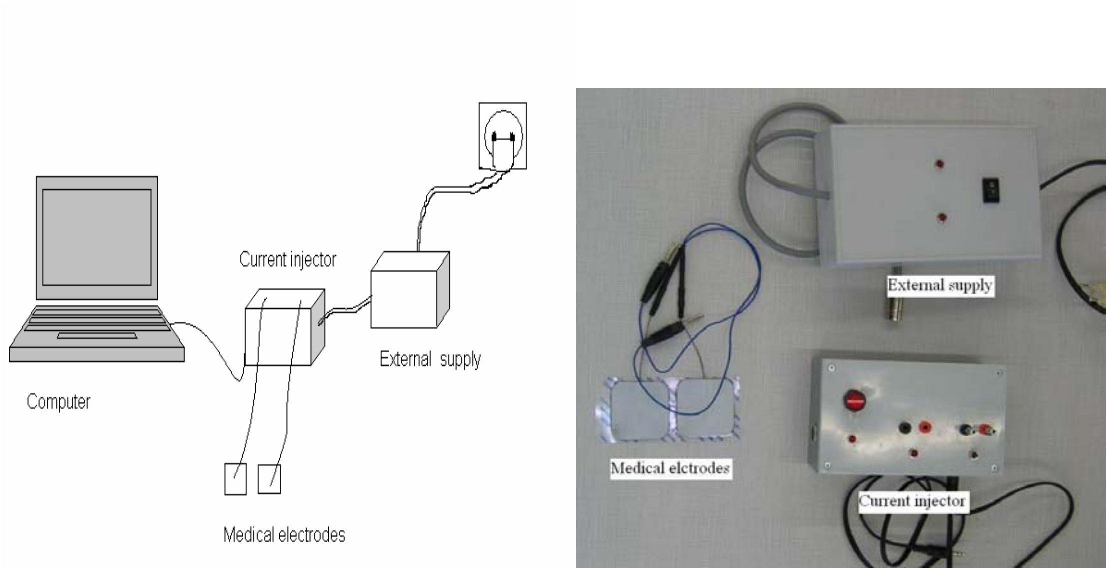

Fig3: Experimental System

A home-made program creates an audio signal (wave file) which is transmitted via the sound card to the current injector. The latter converts the voltage in a stable current flowing between the two electrodes through the body of the volunteer. For safety reasons and to prevent any electric current pathways across the heart, the investigations were done on the forearms on the volunteers. The complete description of the current injector can be found on the Section 3.

The sinusoidal current is applied by trains of constant rms (root mean square) value with dead time of 5 ms between each of them. Between two sequences, the rms current level is increased following a given law, which has been chosen in these experiments as exponential. Our system can easily handle any dead time or increasing law at a given frequency. Currents were increased by step until the program was interrupted by the volunteer’s push of the computer’s space bar (or any other computer’s button) when perceiving the current flow. To minimize random influences, measurements were performed six times with 5 seconds break between each. The mean value of this first test was considered as the first evaluation of the perception level. After 30 sec, the measurements were performed six more times, but with a more precise range of current, according to the first evaluation. The tests evaluated the sensitivity to a 50 Hz sinusoidal wave and 1 kHz sinusoidal wave. The value of 1 kHz was arbitrary chosen to compare the sensibility at two different frequencies. Recruitment method of volunteer was done essentially on the student of the University of Liège; they were informed about the procedure and explicitly expressed their consent to the measurements.

III. Technical specification and safety aspect

The electronic scheme of the current injector is shown on the Fig.4. It is composed of seven “blocks”.

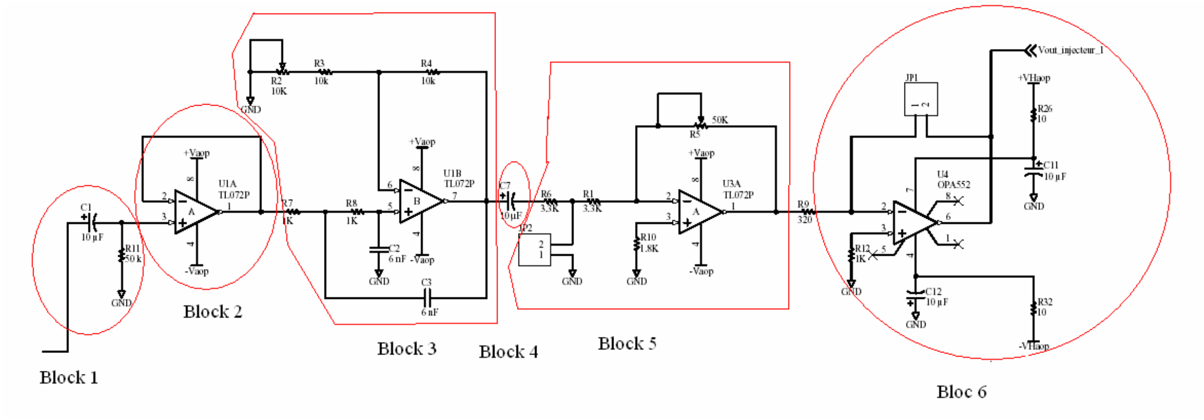

Fig4: Scheme of the current injector

- *Block 1: RC high pass filter:*

Its role is to eliminate the DC component of the signal. The value of the cut down frequency is 0.3 Hz. The DC part has to be eliminated because it could damage the tissues of the volunteer.

- *Block 2:Follower circuit*

It makes sure that there is no interference between the part one and the part three of the circuit.

- *Block 3: Butterworth low pass filter,*

This block eliminates the high frequency parasites. Its cut down frequency is 25 kHz

- *Block 4: RC high pass filter*:

It serves to eliminate the DC component of the signal. Indeed, the signal can have been perturbed by the precedent part of the circuit and have again a DC component. Its cut down frequency is the same than the block 1's : 0.3 Hz.

- *Block 5:Amplifier with variable gain*:

This part of the circuit is used to adjust the output (calibration) of the device.

- *Block 6: Current injector circuit* :

This part of the circuit is the current injector itself; it uses the human body resistance as feedback resistance.

We have characterized the bandwidth of the device in order to be sure that our signals are not altered (attenuated). The results are shown on the following figure (voltage peak to peak taken on the output of the device in function of frequency). The results measurements showed that in the range of our experiment, i.e. 50 Hz to 1 kHz, the signals are not altered.

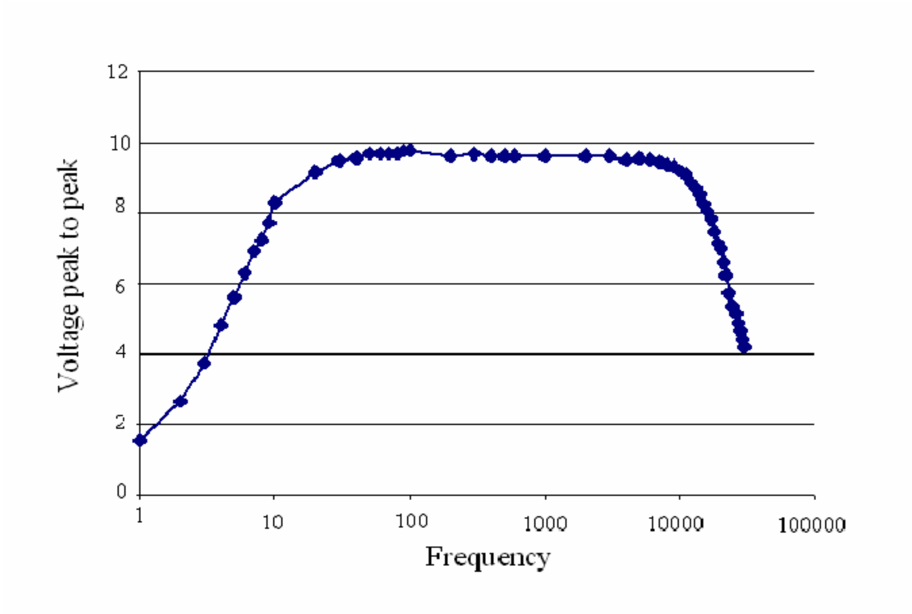

Fig 5: Frequency response of the current injector

On such a kind of device, the safety aspect is crucial. In order to be sure that any perturbation of the electric network is rejected, a system of low pass filter, in the external supply, has been designed to eliminate the high frequency component, as the perturbation can be seen as a high frequency signal, it is thus eliminated. The device is also limited with a maximum output current of 5mA.

As already mentioned, we have ensured, by a system of high pass filter, that the signal injected in the body does not have a continuous (DC) component, as a DC component would be dangerous for the tissues.

The last feature that guarantees the security of the person tested is a stop button that disconnects immediately the person from the current injector. When the user pushes the button, the entry of the amplifier (Block 5) is forced to the mass, so the entry of the amplifier is zero.

IV Results and discussion

It was possible to perform measurement on 150 persons. These persons were aged between 17 and 60 years, in order to avoid bias by including possibly more sensitive children or less sensitive elderly. As the persons were generally students of the university, almost all of them were under 25 years old.

Our first data clearly show a difference to the perception level at 50 Hz and 1 kHz. It has already been shown that the sensitivity to electricity varies according with the frequency (Dalziel & Manfield, 1950) of the signal; but our study is focused on the low frequency range.

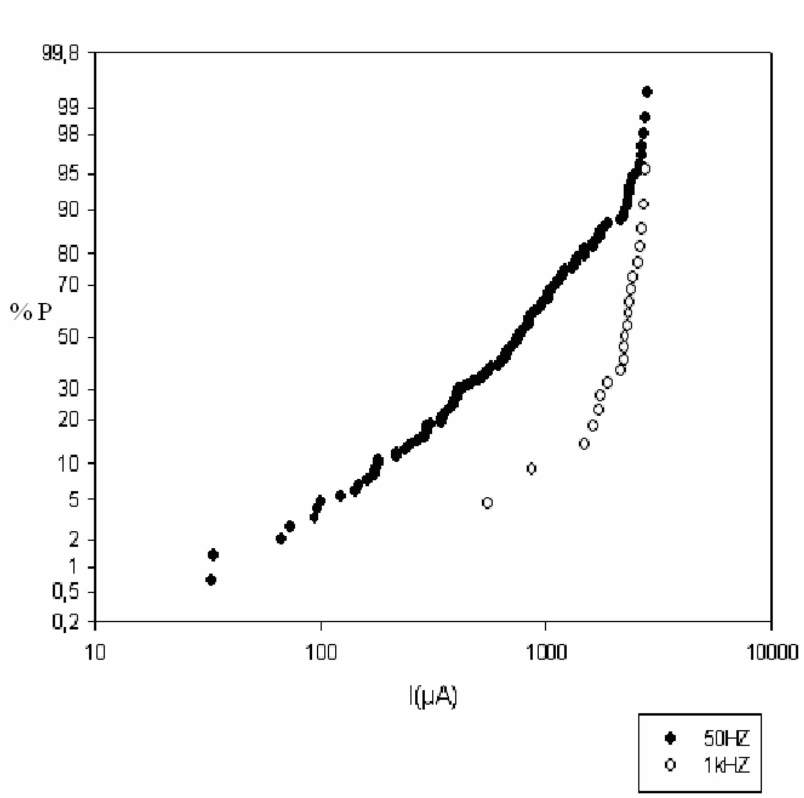

Fig 6: distribution of the cumulative frequency

We have compared our data concerning the 50Hz sinusoidal current to Leitgeb's results (Leitgeb and Schrötner, 2003). Our results superpose to their results are shown on the Fig 7. The mean value of the perception threshold in our study (760.23 µA) is higher than the mean value they found (for men, near 300µA). Nevertheless the mean value we found is still lower than the related mean value (Reilly, 1998). It seems also that the mathematical law is different; the kind of frequency distribution of perception level was analyzed by Kolmogorov-Smirnov testing. The null hypothesis of log-normal distribution data was rejected by a significance P<0.01. Until now, we hadn't found a proper law to fit our results. The histogram of the frequency distribution of measured electric current perception threshold is shown on the Fig 7

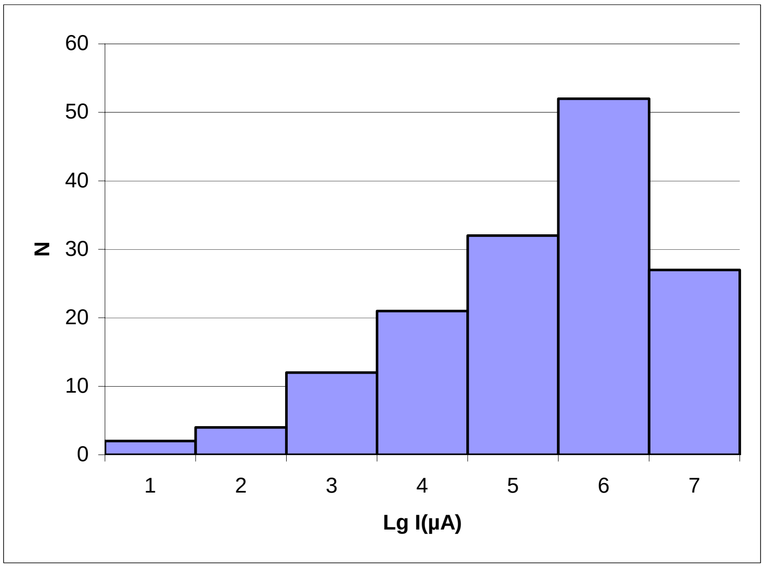

Fig 7: histogram of the frequency distribution of measured electric current perception threshold

It is possible that the observed differences are due to the differences in the measurements protocol, Leitgeb (Leitgeb and Schrötner, 2003) increased their current linearly, but we increased it exponentially, they also took six measurements, but did not proceed to a refining like us and take a break of 3min after each measurement whereas we took only 5sec. Two other differences are the facts that our volunteers were almost all under 25 years old. The results are not separated between male and female because we had only 19 percent of female volunteers. It has to be said that the two "weak perception volunteers" were male.

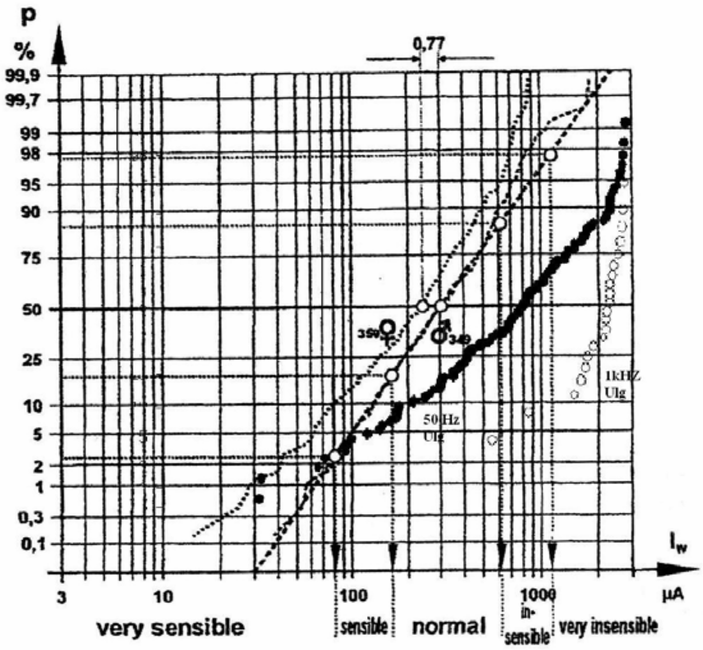

Fig 8: Our results superposed to Leitgeb's data

The current injector and its program can be used to generate a more complex waveform than a sinus. The Fig 8 and 9 show a typical waveform used during the last year in our study. Even if our device is now able to generate any whished waveform, the problem is to have a comparison point between two waveforms. Up to now, we have chosen to compare the RMS (Root Mean Square) value, but we have doubts about the validity of this approach. A value linked to a biological characteristic such as the Action Potential of the nervous cells would certainly be more suitable.

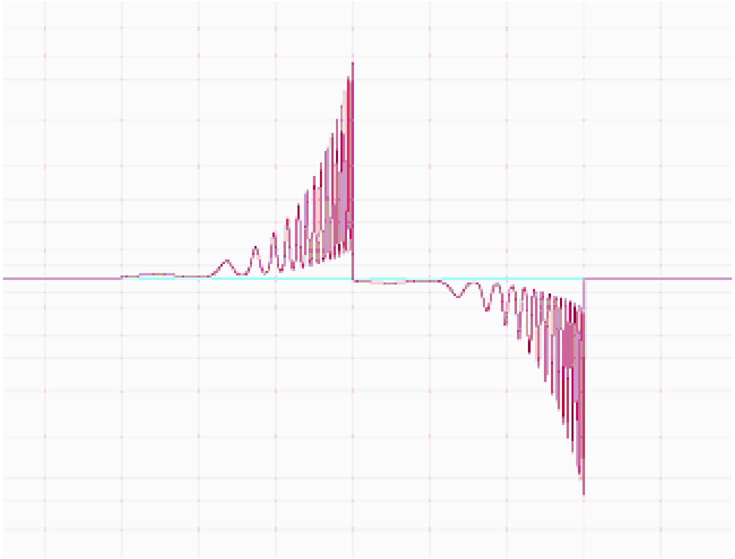

Fig 9: Wideband signal

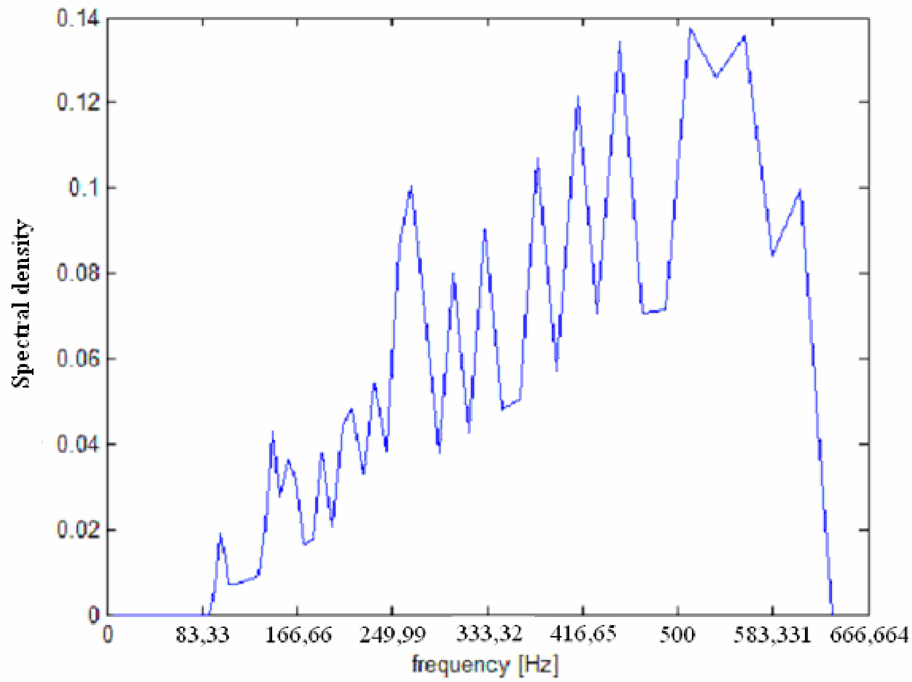

Fig10. Frequential analysis by the wavelet method of the wideband signal.

V. Conclusion

We have designed a device that has shown to be a useful tool to study the human sensibility to electricity. One of our priorities was to ensure the security of the volunteers.

The measurements obtained with our device were quite different from those published in a similar work. We concluded that the protocol chosen influences considerably the results.

A study on the effects of the frequency and the waveform on the perception level has begun. The first results, even if few measurements have been done, clearly show that the human sensibility decreases with the frequency. This effect is maybe due to a "relaxation effect" of the neurons. Our device is able to generate any waveform, but the problem is to have or select a comparison magnitude between two waveforms. This magnitude could maybe be linked to a biological characteristic like the Action Potential of the nervous cell.

Acknowledgments

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Appendix I: Results (table)

Person number	Sensibility(µA)	Person number	Sensibility(µA)	Person number	Sensibility (µA)	Person number	Sensibility (µA)	Person number	Sensibility (µA)
1	32,98	31	348,03	61	644,38	91	918,47	121	1496,1
2	33,76	32	349,17	62	665,58	92	952,13	122	1501,41
3	67,68	33	358,22	63	669,33	93	957,31	123	1633,51
4	74,22	34	372,24	64	672,67	94	963,44	124	1641,22
5	94,8	35	379,69	65	673,03	95	969,53	125	1658,06
6	96,79	36	382,21	66	680,98	96	996,15	126	1716,69
7	101,82	37	388,82	67	689,03	97	1031,19	127	1741,75
8	124,12	38	392,52	68	696,02	98	1033,52	128	1761,12
9	143,2	39	402,25	69	699,17	99	1036,11	129	1766,01
10	147,57	40	404,86	70	717,8	100	1037,6	130	1838,65
11	162,86	41	409,32	71	723,5	101	1044,95	131	1895,77
12	174,75	42	410,17	72	738,21	102	1047,75	132	2141
13	176,58	43	413,25	73	744,01	103	1081,14	133	2219,56
14	177,48	44	415	74	760,14	104	1097,02	134	2230,09
15	181,05	45	416,23	75	760,23	105	1109,5	135	2251,5
16	181,35	46	438,42	76	765,18	106	1125,08	136	2323,71
17	216,51	47	451,58	77	774,43	107	1136,47	137	2328,3
18	218,93	48	471,99	78	781,19	108	1158,31	138	2332,96
19	240,99	49	477,37	79	805,99	109	1178,81	139	2336,15
20	248,03	50	502,34	80	813,27	110	1185,21	140	2360,27
21	258,5	51	529,54	81	823,39	111	1200,55	141	2401,14
22	270,14	52	532,75	82	837,5	112	1207,93	142	2432,56
23	292,25	53	538,85	83	840,67	113	1320,73	143	2578,9
24	293,9	54	552,89	84	840,67	114	1331,47	144	2642,4
25	295,99	55	553,71	85	848,9	115	1341,86	145	2664,78
26	298,27	56	562,55	86	850,2	116	1354,68	146	2700
27	298,71	57	579,62	87	853,4	117	1361,42	147	2743,05
28	309,97	58	615,64	88	855,8	118	1381,65	148	2783,27
29	345,11	59	636,58	89	870	119	1489,26	149	2820,93
30	345,55	60	637,53	90	895,29	120	1495,92	150	3000

Table1: electrical sensibility to a 50Hz sinusoidal current.

Person number	Sensibility (µA)	Person number	Sensibility
1	552,89	12	2328,3
2	870	13	2332,96
3	1495,92	14	2336,15
4	1633,51	15	2401,14
5	1716,69	16	2432,56
6	1761,12	17	2578,9
7	1895,77	18	2642,4
8	2141	19	2700
9	2219,56	20	2743,05
10	2230,09	21	2783,27
11	2251,5	22	3000

Table 2: Electrical sensibility to a 1 kHz current.