Electrical Characterization Of Operating Table Mattresses
L Bellomo, C Calí, R Vitrotti

Citation

Abstract
In this article, we will analyze electrical properties of operating table mattresses. These ones are used as mechanical support for patient and, during surgical operations, they could interact with high frequency electrosurgery devices. These interactions may result in a patient burn.

I. MEASUREMENTS AND INSTRUMENTS
The purpose of this experiment is to define an electric model that represents electrical properties of operating table mattresses.

To observe mattresses behaviour referring to different working frequencies, we made many impedance measurements using a vectorial impedance meter that autonomously scans all selected frequencies.

Generally electrosurgical devices working around kilohertz but, analysing the complete signal spectrum generated by this devices, we can observe many spurious frequencies with significant power around Megahertz.

So, the selected measurement range starts at 100 Hz (Direct Current) and stop at 10 MHz with a 300 pti logarithmic step. Besides we decided to work with 1 V measurement voltage.

Instrumentation:

- Vectorial impedance meter HP-4192A
- two 13x21 mm rigid composite glass-base epoxy dielectric copper boards (figure 1)
- a 5 kg reference mass to perform a better contact between boards and mattresses.
- two copper wires to connect boards and impedance meter: diameter 1 mm and length 300 mm

Figure 1
Figure 1: Copper board

Figure 2
Figure 2: Measurement schematic
II. SETUP

We defined a standard measurement method to be able to repeat measurement, minimizing significant acquisition errors.

To avoid the creep problem (structural yielding of an object loaded with a mass) we decided to wait 1 minute before start with the first acquisition.

Because of possible polarization of internal mattresses structures or partial copper boards oxidation, measures could be instable. So, we defined to make three free acquisitions before starting with real measurement.

Besides it's very important to observe graphical representation of data, before using acquired values for estimate model parameters. This is the main point because data could be corrupted by external interference (like power supply placed near measurement site).

Setup requires to:

- place boards on mattress
- wait 1 minute
- make three free acquisition
- make 4th measure and verify graphical result. If they're corrupted, repeat the acquisition

MATTRESSES PROPERTIES

Used mattresses come from three new mattresses set. Differentiation between sets is made by progressive numeration from 1 to 3. Each set is composed of 3 parts: one for nape - section A, one for body - section C (supple, to allow bed movements – figure 4) and one for feet - section B.

Table 1 contains the codification used to classify sets and sections of mattresses. In this table, SET represents used mattress set, SECTION represents each part of mattress and SIDE represents measured mattress side.

Dimensions of each section are available in table 2.

![Figure 3: Workbench](image)

**Figure 3**

**Figure 4**

<table>
<thead>
<tr>
<th>SET</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SECTION</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>SIDE</td>
<td>X</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1**

<table>
<thead>
<tr>
<th>Section</th>
<th>h (mm)</th>
<th>l (mm)</th>
<th>w (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>30</td>
<td>295</td>
<td>475</td>
</tr>
<tr>
<td>B</td>
<td>30</td>
<td>550</td>
<td>475</td>
</tr>
<tr>
<td>C</td>
<td>30</td>
<td>1000</td>
<td>485</td>
</tr>
<tr>
<td>Cx (ref.fig.4)</td>
<td>30</td>
<td>275</td>
<td>485</td>
</tr>
<tr>
<td>Cy (ref.fig.4)</td>
<td>30</td>
<td>260</td>
<td>485</td>
</tr>
<tr>
<td>Cz (ref.fig.4)</td>
<td>30</td>
<td>70</td>
<td>485</td>
</tr>
<tr>
<td>Ck (ref.fig.4)</td>
<td>30</td>
<td>115</td>
<td>485</td>
</tr>
</tbody>
</table>

**Figure 5**
Electrical Characterization Of Operating Table Mattresses

Figure 6

Figure 4: Overview of section C

A graphical representation of a mattress section impedance course is available in figure 5.

Figure 7

Figure 5: Impedance - Frequency curve

III. MODEL

Model that better describes mattresses behaviour is the RC model (figure 6). This one describe properties of all analysed sections.

Figure 8

Figure 6: RC Model

The model parameters values estimation requires to find optimal matching between measured and model parameters. So, we compared these data (Zmeasured and Zmodel) to be able to calculate the standard deviation, using the following relation:

Figure 9

where N represent the number of available measured data.

Parameter Zmeasured is composed by:

Figure 10

RC impedance is represented by:

Figure 11

Rewriting the relation we obtain:

Figure 12

Minimization function requires a starting vector as input, which contains the starting values of R and C to evaluate the function's minimum.

The chosen starting vector is:
because these values of R and C are very close to the ones that minimize our function.

Referring to the figure 7, the blue curve represents the impedance of the mattresses at different frequencies, measured by the impedance meter, while the red one represents the impedance evaluated by the RC model. In every measurement set, we observed that the two curves cross each other at least in one point: this means that our fitting is correct. Some fittings result very precise, while other ones show a clear shifting between the red and the blue curve; since the minimization function is very sensitive to the input values of R and C.

**Figure 14**

Figure 7: Graphical result of model data (red curve) and measured data (blue curve) fitting

So we can say that mattresses are electrically indefinable neither as conductors nor as insulators: in fact their behaviour changes with the frequency of the applied waveform.

However we can make a comment about C values. In the three mattresses sets the minimization function appraised a capacitance of about 5n F for A sections and about 10n F for B sections. We can't do the similar statements for C sections: capacitance values don't result comparable probably because of their particular shape.

There isn't any correlation between the R values we found, as it's possible to see in Table 8.

This means that the model's impedance has a great variability for different analyzed mattress set or section. For these reasons we can assert that operating table mattresses have bad electric characteristics. They also can be the cause of problems using HF electrosurgery devices during surgical operations.

**IV. CONCLUSIONS**

We can evaluate the data variability for different sections of operating table mattresses in the figures 8 and 9. They doesn't follow a precise behaviour both for the R and C values, as we can easily understand looking at the bar plots.
The real problem is the variability of the impedance values estimated (by the model) and measured (by the impedance meter). If we would find impedance values independent from the mattress set or the section measured, we could study a solution performing a better system. In the case we cared, it's very difficult to formulate a solving hypothesis, because of different behaviour of the mattresses sets.

We can only affirm that small low impedance areas in contact with the patient could represent alternative paths for HF currents. These paths may produce burns.

Old mattresses could produce more problems, so it could be useful to make new measurements on the same sets we analyzed after using themselves for about 6 months. We should find that electrical characteristics of used mattresses perform a worst electrical behaviour: it could increase the probability of problems during surgical operations.

References
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