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Distance assessment in automated butchery by means of microwave sensing

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Abstract - **In this paper, a microwave multi-sensor included in a blade for automatic meat cutting is described. In automatic meat cutting processes, information is needed for local real time control of cutting devices. The lateral information coming from tissues surrounding the blade is necessary to follow meat/fat and meat/bone interfaces. The axial information is needed to avoid collisions with bones during cutting. An original slot antenna geometry has been developed in order to respond to the double criteria of axial and lateral detection. Performance of our multisensor system was measured on a laboratory bench with phantom materials. The results obtained from the experiments achieved the precision required in terms of depth detection and beaming. Bone was detected at a distance of 3 mm in front of the blade, and at 5 mm on either side of the blade.**

Keywords: microwaves, sensor, meat, boning, cutting, dielectric, electrical properties, robotics.

1 INTRODUCTION.

Automatic machines for carcasses cutting and meat debonning are being introduced in slaughterhouses, allowing the automation of tasks performed currently by human operators. Such automation requires information on the location of anatomic parts before and during cutting and debonning tasks to be obtained. In particular, during automatic meat cutting, information is need in order to know precisely the position of the cutting device, and to eventually adapt the cutting path and correctly drive the machine. The sensor must provide information both in the cutting axis and on each side of the blade. The lateral information coming from tissues surrounding the blade is necessary to follow meat/fat and meat/bone interfaces. The axial information is needed to avoid a collision with the bone during cutting movements. This can be done using microwave sensors included in the cutting blade. It has been show in previous study that around 3 GHz the main biological tissues (muscle, fat, bone) are easily identifiable by measuring the value of the real part of the dielectric constant [1]. Furthermore the frequency of 3 GHz perfectly corresponds to dimensional constraints. However, it was established in this earlier study that meat tissues are more readily identified, particularly in the case of industrial processing, by the evaluation of the mismatch of an antenna [2].

2 MATERIALS AND METHODS

2.1 Frequency and shape selection

In this study, several systems of typical coaxial lines and striped lines were designed and tested. Interpretation of the results obtained was difficult, due to the presence of air or liquid gaps and to a poorly controlled pressure. Many techniques for problem solving and analyses were undertaken. A particularly important work focused on the research of a well adapted geometry. However, systems based on coaxial lines were not chosen, although this technology seemed *a priori* to best suit to our problem particularly with regard to dimensional constraints. It was shown that the coaxial probe only explored a very small tissue volume and was therefore particularly sensitive to the heterogeneous structure of biological tissues.
This sensitivity can be explained both by the fact that the coaxial probe is quasi monopolar and by the distribution of the field located in the close field zone.
As a consequence, our studies were carried out on printed lines and slot antennas. These types of antennas integrate a greater scattered volume. However, the use of these antennas induce a loss of precision, thereby resulting in a poor reproducibility. The dispersion is probably due to two causes: the presence of an air or liquid film between the antenna and the meat tissues, and the application of uncontrolled pressure. To overcome these problems the laboratory was provided with a measure bench. This bench was built around a temperature-conditioned measure cell fixed on a stand consisting of a micrometric table equipped with a constraint gauge that allowed the control of the applied pressure.
The entire protocol for the measurement of the dielectric constant was revised by including the pressure applied on the collector as a major influential parameter. The analysis of the results of these experiments clearly showed that the resulting dispersion was not correlated to the application collector pressure. The most probable cause of this dispersion appeared to be the random presence of an air and/or aqueous gap between the collector and tissues under test. This phenomenon was revealed by the installation of a particular manipulation protocol using static and dynamic measurements.

2.2 Performance evaluation using phantom tissues

In order to see inside the material, studies were undertaken on the design of a translucent gel loaded with aluminium powder. Use of this gel which has the same dielectric behaviour as bovine meat, enabled control of the dielectric characteristics. Values of the loss factor were very close to those of considered bovine tissue for the considered frequencies. Gelatine charged with 15% of aluminium has been used to carry out experiments to determine the design of the antenna and evaluation of results. Characteristics vary weakly from 20 to 22°C and have dielectric properties of muscle at the frequency of 3 GHz as shown in figure 2.

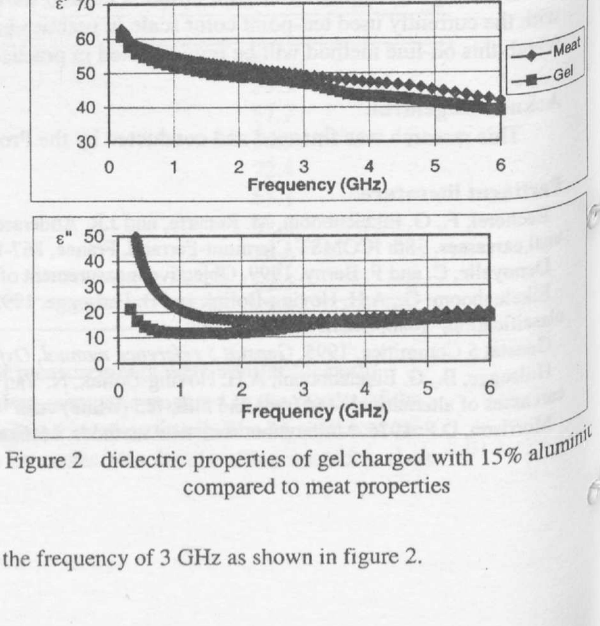

Figure 2 dielectric properties of gel charged with 15% alumini
compared to meat properties

3 RESULTS AND DISCUSSION

A plate used to mimic a blade wearing antennae was plunged into a gel. A block of bone, with known dimensions, was put in the aquarium containing the gel. The antennae were precisely positioned by a micrometric table.
The evolution of the response of each antenna was correlated to the distances from the bone. Figure 3 represents reflection measured in free space in the gel and close to a bone during a lateral detection with the help of a slot antenna. The input reflection coefficient S_{11}^{*} of the sample is equal to :

$S_{11}^{*} = S_{11}e^{j\phi} = \dfrac{Z_i/Z_0 - 1}{Z_i/Z_0 + 1}$ where Z_i is the input impedance of the antenna in the gel, and Z_0 is the characteristic impedance of the antenna.

Measurements of the reflection coefficient were performed using one or two antennae, simply by measuring the power amplitude of the reflected and transmitted signals.
The incident power (P_i) is partly reflected (P_r) and partly dissipated so that $P_r = |\Gamma|^2 P_i$ where Γ is the reflection coefficient.

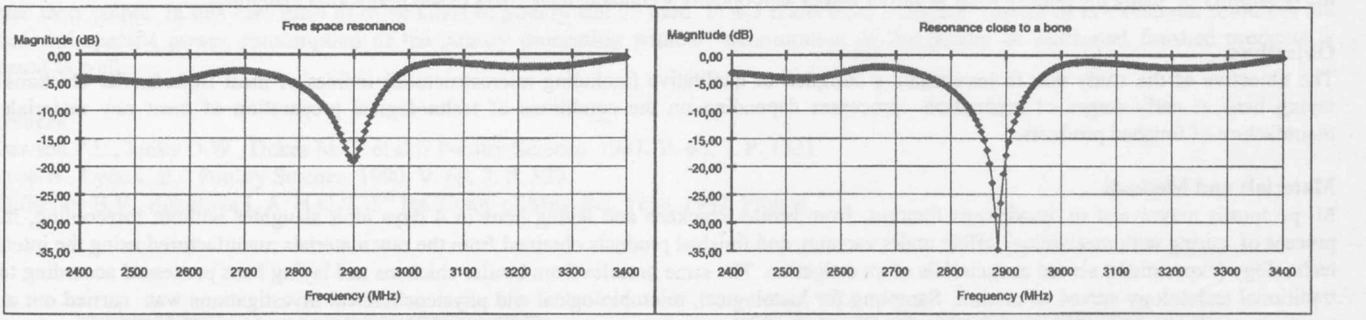

Figure 2 Frequency and magnitude comportment near the resonance in free space and close to a bone

Evolution of frequency and magnitude at the resonance in free space or with the presence of an obstacle were evaluated. Using the measuring device, performance in terms of distance detection was evaluated. Distances of detection of a bone were 3mm in the direction of the movement of the tool and 5mm on either side of the tool. These results were obtained by the measurement of magnitude and frequency shift.
We obtained similar results using the observation of the Standard Wave Ratio (S.W.R) measured in each antenna feed line and with the coupled antennae system.

4 CONCLUSION

A microwave multisensor included on a blade for a local adjustment in automated meat cutting is described. Sensors were used to obtain two sets of information: a measurement on each side of the knife to obtain the lateral information, and from both sides with coupled antennae to obtain the axial information. Several systems with coaxial lines and striped lines have been designed and tested. Engraved antennae give the best result for frequencies situated in a range around 3 GHz. Bone was detected at a distance of 3 mm in front of the blade, and at 5 mm on either side of the blade.

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