NON-PERTURBING MICROPROBES FOR MEASUREMENT IN ELECTROMAGNETIC FIELDS

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Abstract

A new generation of non-interfering microprobes is developping. It consists essentially of dielectric microthermometers, named the M.T.D. probes. Their specific temperature range cover -40°C to +150°C in several steps.

The introduced perturbation is very low, inferior to 0.1 db whatever the frequency range is. The M.T.D. probes'medical and industrial applications are very important.

Introduction

Saving energy being crucial, it looks as if the use of microwave energy could solve a certain number of problems pertaining to the fields of industrial processes or of medical applications.

It is therefore necessary to study exactly the conditions of using microwave energy and also the means to couple best this energy to materials to be dealt with.

Research, in every domain, is being carried out on microwave irradiator design. But it seems very difficult to define a suitable optimum irradiator if dosimetry sensors are not available.

These sensors must be "non-interfering probes" with respect to electromagnetic waves.

Two main problems are therefore met : - the first one relative to the knowledge of power density or temperature gradients in a microwave irradiated material: according to each purpose, the respective temperature range could be situated between -50°C to +150°C for industrial applications, and from 20° to 45°C for room temperature range and body temperature range in which we find the studies on biological effects; - the second one concerns the measurement of fields or power firstly in an unloaded oven with the material to be dealt with; or in free space for studying the biological effects; - the second one concerns the measurement of fields or power firstly in an unloaded microwave oven, then in a loaded oven with the material to be dealt with; or in free space for studying the biological effects.

Our department studied both problems. However, in the first case, our studies have well progressed, but in the second case, we are only making the first experiments on such power probes : the results would be published in 1978.

We want to emphasize much more on the necessity of using non-interfering probes in the fields of microwave energy for medical applications (cancer therapy, diathermy, microwave thawing of organs etc..)

Therefore, this paper is a synthesis of the results we obtained in designing these probes and in finding their possible applications.

I. NON-INTERFERING PROBES

We have studied the feasibility of realizing dielectric microprobes non-interfering with electromagnetic waves.

Two types of probes were then defined :

- one operating exclusively in the range of 10°C to 40°C named the cholesterical crystal probe

- another pertaining to industrial application of microwaves which would cover a temperature range of -40°C to +150°C in steps of 40°C, and also the range of 20°C to 40°C. The name of such a probe is the dielectric microthermometer (or M.T.D.) and is essentially a French invention.

Each probe includes :

- a head (different according to the temperature range or density to be measured) comprising, and this is essential, a thermo-sensitive dielectric material

- dielectric light conductors (optical fiber set)

- and associated electronics system.

1.1. Cholesterical crystal probes

This first microprobe, still called "cholesteric crystal and optical fibers probe" was the subject of many conferences (1,2,3,4). Also we will not give any explanation on this, but we would like to make some comments :

- such a probe is only relating to the measurement of temperature in narrow band in the range of 10° to 40°C. Therefore this kind of probe is only devoted to the study of biological effects and cannot give any information in lower or higher temperature range.

- such a probe has a very narrow temperature range inherently due to the physical proprieties of the liquid crystal used.

An important propriety of the cholesterical crystal is to offer a very high rotatory power which is variable from one crystal to another. This rotatory power about 18.000° per mm, varies in amplitude and sign with the wavelength and temperature. This very high rotatory power is due to an ordonnated shifting of the molecular axis of each thin film.

Statistically, in these conditions, it seems impossible that such crystal arrangements find again exactly the same position during a temperature cycle.

This explains the main difficulties encountered in designing such probes which nead to be recalibrated due to liquid crystal aging and instability (5). We then obtain microprobes presenting problems in crystal shift variations, hysteresis effect and difficulty to obtain reliable industrial units. It is for all these reasons that we stopped all the studies in France.

1.2. M.T.D. probes (6), (7)

The second probe, is in fact, a dielectric microthermometer operating within a range of -40°C to +150°C in steps of 40°C.

The principle of the probe is based on the reflexion of a light beam on a thermodilatable liquid contained in a capillary glass pipe of small dimensions

In the glass pipe, the liquid forms a concave reflector meniscus which position and shape vary versus temperature (Figure 1). The quantity of liquid is very small (a few mm3). Therefore the probe thermal inertia is low and the setting in temperature is being rapidly done without any disturbance in the medium.

This time, the head of the probe is composed of

- a conical glass pipe with at the end a small bulb containing the liquid
- a dielectric thermodilatable liquid
- an optical fiber set lighting up the meniscus

The cone aperture is calculated versus the liquid volume at 0°C and the sensitiveness to be obtained. The head of the probe and the optical fibers are within a thermoretractable sheath.

In a first step, we designed a microprobe working from -30°C to +20°C. We are now able to design microprobes in every range within steps of 40°C covering the -40°C to +150°C temperature range.

Measurements effected within the ranges 900 to 915 MHz, 2400 to 2500 MHz and 8.2 to 12.4 GHz show that the perturbation caused by the thermometer is very low (inferior or equal to 0,1 db) and whatever the orientation of the probe in terms of the electric field. Furthermore, the V.S.W.R. due to the probe is less than 1.1 The microprobe contribution is therefore negligible and we can say that it does not disturb the electromagnetic waves, being transparent to the microwave spectrum.

Figure 2 shows a response curve for one of these probes in the range 5° to 45°C.

This device has been the object of a patent registered by ANVAR (ANVAR n° 9211, Deficis probe) and was extended to several foreign countries.

1.3. Electronic units

For each probe described above, electronics is similar and relatively simple.

In a first step, we used a white light source which lights up the optical fibers and lightsup then the dielectric meniscus. The reflected light is collected by a photomultiplier driven by a power supply. The analysis of the reflected light is then done either by recording on a plotter or by any other process

We are using now, as light receptor, a phototransistor followed by its amplifier. This allows us to try to integrate both the white light source and the phototransistor on the same support and reduce the cost of the device.

1.4. The M.T.D. probes ' performances

In experimental tests of the unit operating in the range of -30°C to +20°C, we have obtained records of a microwave thawing process of a chopped beef piece of about 2 kilos, then another of about 50 kilos. Figure 3 shows one of these curves; this shows that we can record continuously the microwave thawing process.

This fact is very important in industrial applications but also in medical applications of microwave energy. By using such probes, we can know exactly where is located the microwave power in biological materials. We can think of many applications of such probes in the dosimetry related to diathermy or cancer therapy process for instance.

In all cases, these probes working alone or simultaneously can be used to make an exact temperature cartography during a microwave process .

The microthermometer main characteristics are, at present, as follows :

. temperature ranges : -40°C to +150°C by steps of 40°C special serie in 10°C to 40°C

. sensitiveness : about 0,5°C presently

. response time : < 15 seconds

. output voltage of the electronic : 0 to 5 V
  - average sensitiveness : 200 mV/d°
  - electronic noise : < 20 mV

. dimensions :
  - length of the probe : from centimeter to some meter lengths
  - probe diameter : 2 mm
  - sheath diameter : < 3 mm

. performances between DC to 12 GHz
  V.S.W.R. : 1.1 and insertion losses : 0.1 db

. presentation : rack : 5/25 3 U

. Analogical output on B.N.C. connector

. possibilities of driven many units by microprocessor

The future developments envisaged in our microwave department in liaison with an industrial firm are :

. design microprobes with $\Delta T = 60°C$
$\Delta T = 100 ° C$ - $\Delta T = 200°C$ with respectively an average sensitiveness of about $\pm$ 1.5 °C, $\pm$ 2.5°C and $\pm$ 5°C

. improve the M.T.D. probe in the range of the biological effects to obtain sensitiveness of about $\pm$ 0,1°C in temperature steps of 10 or 15° in the range of 30° to 45°C.

Figure 4 shows a photography of the M.T.D. probe with the electronic unit.

II. PRACTICALAAPPLICATIONS OF THESE M.T.D. PROBES

Two main application fields can be foreseen :

2.1 Medical field :

(from +20°C to 40°C with a great sensitiveness of ± 0.1°C in the 10°C range)

- measuring the biological effects : study of the E.M. penetration and absorption by biological media
- local dosimetry applications such as diathermy - studies of microwave thawing of frozen organs or granulocytes)
- in every place, where the measurement of the temperature is difficult (small areas, etc)
- continuous control and regulation processes of the microwave penetration (hyperthermia, cancer therapy) detection of overheating points

2.2 Industrial field :

We would like to give some complementary informations about the usefulness of such probes :

- in the temperature range of -40°C to +150° it is now possible :

. to control exactly the inside microwave penetration as for large pieces of beef

. to aid for processing simulation such as thawing simulation

. to participate to continuous control and regulation process such as for pasteurization, sterilization and lyophilisation of food products

. to insure a continuous control of distribution of the microwave power

The large range of applications makes us forecast a very good market and we think that these probes or by-products will become the laboratory and industry main tools.

Conclusion

We are thinking that the M.T.D. probes could be considered as the second generation of non-interfering microprobes in front of the cholesterical crystal probes. They can operate from -40°C to +150°C in steps of 40°C and they can be used in the range of 10° to 40°C with good accuracy.

We also think that we need to make many efforts in the next years to improve either such kind of probes or to develop new type of probes devoted to specific temperature range measurements.

Furthermore, it seems very useful to design field or power density probes that can be used near a microwave applicator, working units in its near field zone as those employed in the medical branch.

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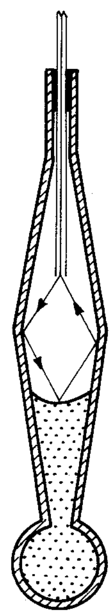


SONDE A THERMOMETRE DIELECTRIQUE

M.T.D. PROBE

FIGURE 1

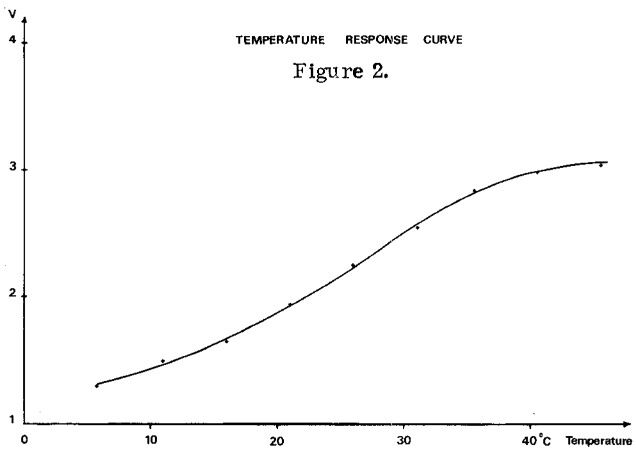
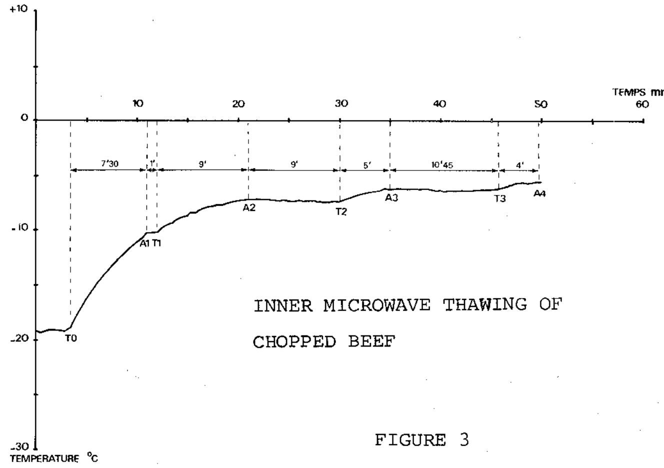


Figure 2.



INNER MICROWAVE THAWING OF CHOPPED BEEF

FIGURE 3

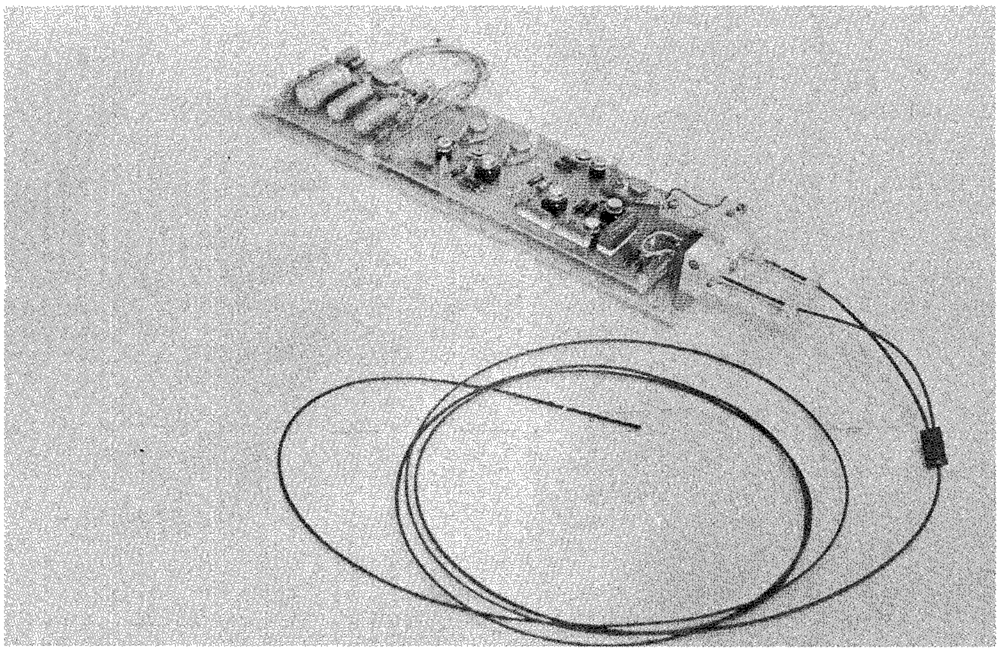


Figure 4. M.T.D. Probe