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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : G01N 22/00

A1

(11) International Publication Number: WO 91/00512

(43) International Publication Date: 10 January 1991 (10.01.91)

(21) International Application Number: PCT/GB90/01013

(22) International Filing Date: 2 July 1990 (02.07.90)

(30) Priority data:
8915323.3 4 July 1989 (04.07.89) GB

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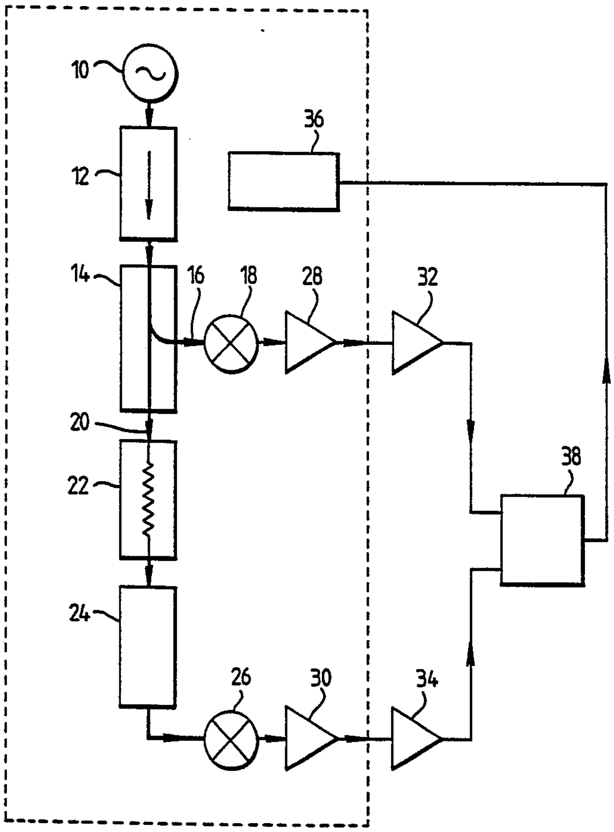
(81) Designated States: AT (European patent), BE (European patent), CA, CH (European patent), DE (European patent)*, DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), NO, SE (European patent), US.

**Published**
*With international search report.*

(54) Title: PORTABLE DEVICE FOR USE IN THE MEASUREMENT OF THE DIELECTRIC PROPERTIES OF MATERIALS

(57) Abstract

A portable device for use in the measurement of the dielectric properties of materials such as fish includes: a microwave circuit comprising a microwave source (10) connected via an isolator (12) to a directional coupler (14), a first output (16) of which is connected to a reference detector (18) and a first pre-amplifier (28) and a second output (20) of which is connected via an attenuator (22) to a sensor (24), an output of which is connected to a signal detector (26) and a second pre-amplifier (30); and further including two amplifiers (32, 34) into which outputs of the first (28) and second (30) pre-amplifiers are connected and a logarithmic/ratio device (38) which provides an output proportional to the logarithm of the ratio of outputs from the two amplifiers (32, 34), wherein an output from the logarithmic/ratio device (38) is calibrated to provide the content of a particular constituent of the material under test.

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PORTABLE DEVICE FOR USE IN THE MEASUREMENT OF THE DIELECTRIC PROPERTIES OF MATERIALS

This invention relates to a portable device for use in the measurement of the dielectric properties of materials and particularly for the measurement of water content of materials and of water and fat content of whole fish. The rapid determination of water and fat content of products is a prevailing problem in the fish industry, since these contents affect various processing operations of the fish, for example, when smoking the fish. In this respect, manufacturers need to determine the fat content of fish so as to assess final product quality - a medium fat content indicates a better quality than either low or high fat content. For similar reasons fish farmers need to assess the fat content of live fish before selling to customers.

In whole fish flesh, such as herring and other pelagic species, the problem is to a certain extent simplified by the fact that a linear relationship exists between the fraction of water and that of fat (Iles and Wood, 1965) so that the measurement of one serves to determine the other within the limits of this relationship. Such a relationship arises from the physiological need of the fish to maintain a slightly negative buoyancy even while the fat content, which is of low density, tends to creat the opposite effect. Variation in fat content arises from seasonal effects of food availability and breeding cycle.

Tests do exist for the measurement of water and fat content of fish but the main disadvantage of these tests is that they are destructive in that the fat must firstly be extracted from the fish, then, after mixing this with a solvent, chemical analysis is used to determine the fat and water contents. These current methods also have the added disadvantage of being very time-consuming, and cannot be used on whole or live fish. Nuclear Magnetic Resonance (NMR) may also be used but is expensive and bulky.

It is known (Mudgett et al (1974), J Food Sci, 39, 632-635) that in the microwave frequency region the dielectric properties of materials are dominated by those of water especially if the water fraction is large. Thus the attenuation of microwave enegy by a material provides a measure of the moisture content of the material. It is also known (Ohlsson et al (1974) J Food Sci, 39, 1153-1156) that both the fat and water contents of meat emulsions could be determined from various dielectric measurements in the microwave range. However, in those data no correlation existed between the fate and water contents.

It is further known (Kent 1989) that there is a good correlation between the water content of the fish and the real part of the dielectric permittivity at all frequencies in the microwave range. There exists many methods for the measurement of the dielectric properties of materials, one such method being the subject of UK Patent No 1354474. This method depends on the dielectric sensitive properties of a form of transmission line known as a microstrip or stripline sensor.

However, those known methods of the measurement of the dielectric properties of materials all use apparatus which are large and bulky, inconvenient and not portable.

There is therefore a need for a portable device for the measurement of the dielectric properties of materials, in particular the water content of materials and the fat and water content of whole or live fish which has the advantages of being both convenient and easy to use.

According to the present invention there is provided a portable device for use in the measurement of the dielectric properties of materials which includes; a microwave circuit which comprises a microwave source connected via an isolator to a directional coupler, a first output of which is connected to a reference detector and a first preamplifier and a second output of which is connected via an attenuator to a sensor, an output of which is connected to a signal detector and a second pre-amplifier; and further includes two amplifiers into which outputs of the first and second pre-amplifiers are connected and a logarithmic/ratio device which provides an output proportional to the logarithm of the ratio of utputs from the two amplifiers, wherein an output from the logarithmic/ratio device is calibrated to provide the content of a particular constituent of the material under test.

The microwave circuit is housed in a hand held probe, whilst the rest of the device plus batteries and switches are in a separate unit connected to the probe. Thus the device is portable and easy to use. For laboratory use, however, the device may be modified to run on an available main electrical supply.

The output of the logarithmic/ratio device is preferably fed directly to a digital voltmeter in the hand held part of the instrument. The instrument is preferably pre-calibrated to give a reading of the content of a particular constituent of the material under test. This is preferably water, but could also be fat, in the case of fish, or indeed any constituent in any material whose dielectric properites are affected by that constituent.

The sensor used in the device may take a number of different forms. Preferably a microstrip or stripline sensor is used as disclosed in UK Patent No 1354474. Alternatively a directional coupler or a circulator could be used, feeding an open-ended coaxial line in a reflectometer mode.

The microwave source may be any suitable low-current drain microwave source, but is preferably a Gunn diode.

The microwave circuit may be made up of discrete components, alternatively it may be made from stripline with all components on one substrate.

The device preferably has a microprocessor to perform a number of operations, for example storing calibration equations and providing a facility for averaging a predetermined number of readings. This latter function would allow, for example, the mean fat content of a batch of fish to be estimated.

The present invention will now be described by way of example only, with reference to the accompanying diagrammatic drawings in which:

Fig 1 is a block circuit diagram of a device according to the present invention;

Fig 2 is a circuit diagram of a pre-amplifier of Fig 1;

Fig 3 is a circuit diagram of the logarithmic/ratio amplifier of Fig 1;

Fig 4 is a side view in section of the stripline sensor used in the present invention; and

Fig 5 shows the device according to the present invention being used to test the dielectric properties of whole fish.

As shown in Fig 1 a device for use in the measurement of dielectric properties of materials has a microwave circuit which measures the insertion loss or attenuation of power comprising of a microwave source 10, preferably a Gunn diode, connected via an isolator 12 to a directional coupler 14. One output 16 of the directional coupler 14 is connected to a reference detector 18 and the other output 20 is connected via an annenuator 22 to a stripline sensor 24, the output of which is connected to a signal detector 26. Outputs of the reference detector 18 and the signal detector 26 are each connected to low gain voltage follower-type pre-amplifiers 28 and 30 (circuit diagram at

Fig 2). Each of these are connected to further amplifiers 32 and 34, respectively. The output of these are then connected to a logarithmic/ ratio amplifier 38 (circuit diagram at Fig 3). The output of the logarithmic/ratio device 38 is fed directly to a digital voltmeter 36. The boxed area of Fig 1 is that part of the device housed in a hand held probe. The rest plus batteries and switch (not shown) are in a separate unit connected to the proble by multicore cable.

The stripline snsor 24 is shown in Fig 4 and consists of a piece of microstrip having a base plate 40, a substrate 42 and a strip conductor 43. A protective layer 44 of preferably polytetrafluoroethylene (ptfe) material is fixed directly over the strip 44. The substrate 42, is preferably made of a ptfe and ceramic mixture with a permittivity of 10 and very low loss. The sensor is shown with transitions from stripline to coaxial line 46, the transition being made by feeding the centre conductor 47 of a coaxial line jack type connector 46 through the substrate 42 and soldering to the surface of the strip 44 at 48. The stripline sensor allows a flat surface 50 to be presented to the material under test.

Fig 5 shows the device in operation. In use, the sensor 24 is placed directly on top of the material to be tested and the Gunn diode 10 is switched on. Power from the Gunn diode 10 is fed via the isolator 12 to the 10 dB directional coupler 14. The purpose of the isolator is to prevent any reflected power from interferring with the operation of the Gunn-diode. The directional coupler feeds 10 dB of the power to the reference detector 18. the major part of the power is fed through the 10 dB attenuator 22 to the stripline sensor 24. The attenuator 22 reduces the power to a level comparable with that in the reference arm. This level is also low enough to ensure square law operation of the detectors given the input power of a few milliwatts. It also reduces the effect on both the Gunn-diode 10 and the directional coupler 14 of reflected power from the various mismatches in the sensor. Apart from the obvious mismatch of the sensor impedance there are also reflections from the coaxial-to-stripline transitions which are difficult to eliminate entirely. After passing through the sensor 24 the remaining power is detected by another signal detector 26.

The Gunn diode 10 oscillates at 10 GHz with a supply voltage of - 7.5V and delivers about 10 mW of power. The current drawn from the power supply for this is around 200 mA so, in order to conserve battery energy and life the Gunn-diode 10 is only switched on for the duration of the measurement. Since it never achieves thermal equlibrium it is therefore most probable that both the frequency and the power output are to some extent time dependent. This is where the value of the reference system 18 is demonstrated since the ratio of the power in the signal detector to that in the reference detector is always measured. Thus variations in power level during this transient operation are not important. The frequency shift that takes place is small enough to render negligible any frequency dependent changes that might occur in the various components. All components have fairly broadband characteristics (8-12 GHz). Although the system described operates in this particular frequency range (X-band) it can be constructed to function at any microwave frequency. For some applications it might in fact be better to make the measurements at 1-2 GHz.

The output from the reference detector 18 is about 100 mV while that from the signal detector 26 ranges from 100 μV up to 100 mV depending on the loss in the sensor 24. These two dc signals are each fed to the low gain voltage follower type pre-amplifiers 28, 30. The amplified signals are then fed through a further stage of amplification 32, 34 to the logarithmic/ratio device 38 which provides an output proportional to the logarithm of the ratio of the two signals. This signal is proportional to the decibel ratio of the signals and is calibrated against the content of the desired constituent of the material. In this case, the constituent would be the fat or water content of the fish. This signal is fed to a digital voltmeter 36 in the hand held part of the probe. This will dispay the content of the desired constituent. The device is preferably pre-calibrated to measure a particular constituent. For exmaple, for calibration to measure the fat content of herring the following equation relates the microwave attenuation A and fat content F as:

$$\log_e (F) = a - bA$$

where $a = 5.05$

and $b = 0.166$

The device also preferably contains a microprocessor (not shown) to perform a number of operations, such as storing calibration equations and providing a facility for averaging a predetermined number of readings. This latter function allows, for example, the mean fat content of a batch of fish to be estimated.

The device is not restricted for use with fish alone. Indeed, any material may be tested for water content including liquids such as cement and slurries. Also, the constituent measured is not restricted to water but also fat in the case of fish, as mentioned above, because of the linear relationship between fat and water content of fish. Additionally, the amount can be measured of a particular constituent in any material whose dielectric properties are affected by that constituent.

Hence a device has been described for the measurement of the dielectric properties of materials which can be mains driven or portable, is convenient and easy to use, in particular for testing whole or live fish for fat content.

## CLAIMS

What is claimed is:

1. A portable device for use in the measurement of the dielectric properties of materials including; a microwave circuit comprising a microwave source connected via an isolator to a directional coupler, a first output of which is connected to a reference detector and a first pre-amplifier and a second output of which is connected via an attenuator to a sensor, an output of which is connected to a signal detector and a second pre-amplifier; and further including two amplifiers into which outputs of the first and second pre-amplifiers are connected and a logarithmic/ratio device which provides an output proportional to the logarithm of the ratio of outputs from the two amplifiers, wherein an output from the logarithmic/ratio device is calibrated to provide the content of a particular constituent of the material under test.

2. A portable device as claimed in Claim 1 wherein the microwave circuit is housed in a hand-held probe.

3. A portable device as claimed in Claims 1 or 2 wherein the device further includes batteries on which the device runs.

4. A portable device as claimed in Claims 1 or 2 wherein the device is adapted to run on a main electrical supply.

5. A portable device as claimed in any previous claim wherein the output of the logarithmic/ratio device is fed directly to a digital voltmeter housed in the hand-held probe.

6. A portable device as claimed in any previous claim wherein the sensor is a stripline sensor.

7. A portable device as claimed in any one of claims 1 to 5 wherein the sensor is a directional coupler.

8. A portable device as claimed in any one of Claims 1 to 5 wherein the sensor is a circulator.

9. A portable device as claimed in any previous claim wherein the microwave source is a Gunn diode.

10. A portable device as claimed in any previous claim wherein the microwave circuit is made from stripline with all components on one substrate.

11. A portable device as claimed in any previous claim wherein the device further includes a microprocessor.

12. A portable device as claimed in Claim 11 wherein the microprocessor states calibration equations.

13. A portable device as claimed in Claim 11 wherein the micro-processor provides a facility for averaging a predetermined number of readings.

14. A portable device as claimed in any previous claim where the constitutient is any constituent in any material whose dielectric properties are affected by that constituent.

15. A portable device as claimed in any previous claim wherein the constituent is water.

16. A portable device as claimed in any previous claim wherein the fat content of fish is measured.

17. A portable device substantially as herein described with reference to the accompanying drawings.

Fig. 1.

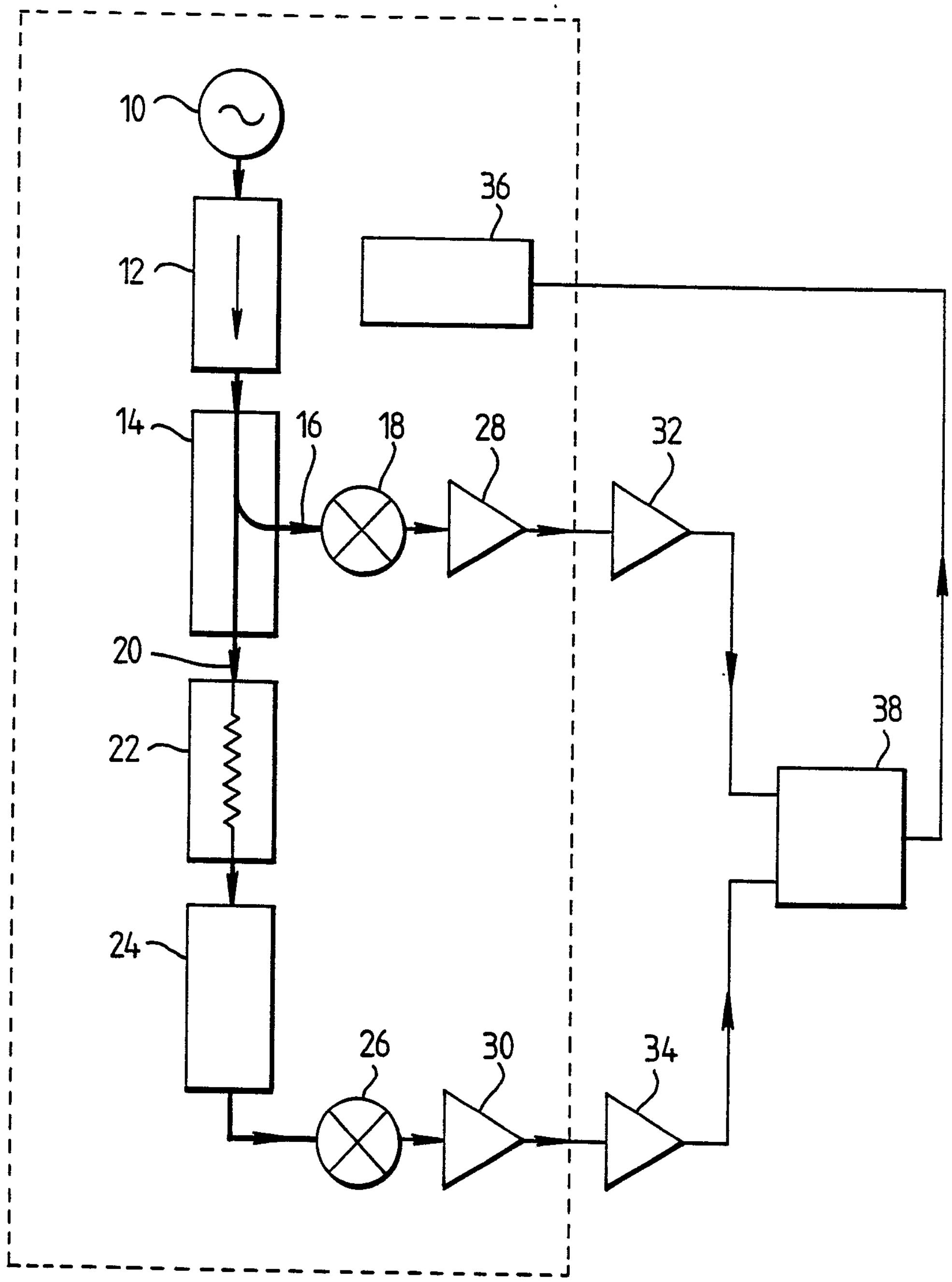
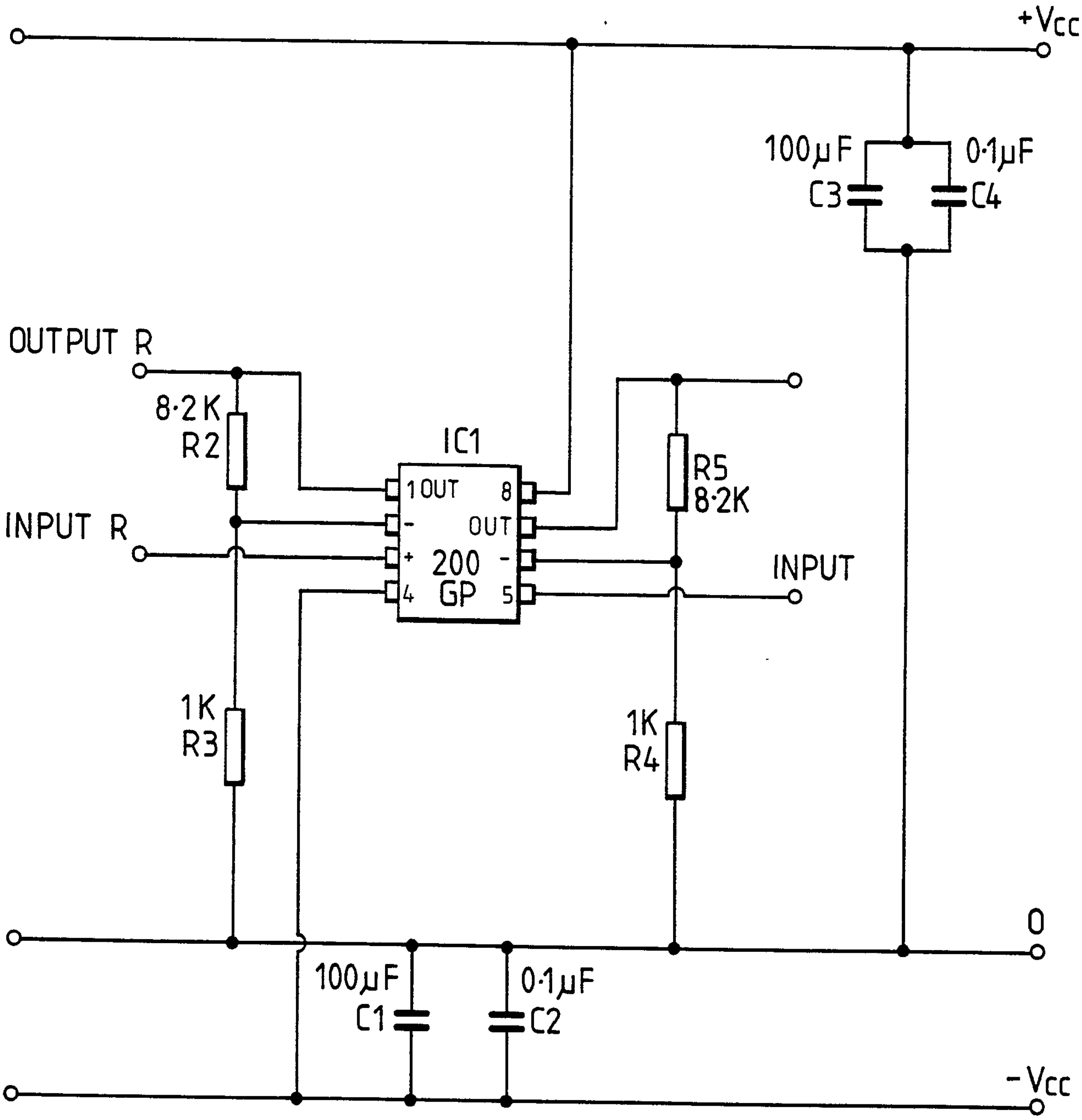


Fig. 2.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100μF
0·1μF
C3
C4
OUTPUT R
8·2K
R2
IC1
1OUT
8
OUT
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GP
4
5
R5
8·2K
INPUT R
INPUT
1K
R3
1K
R4
0
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C1
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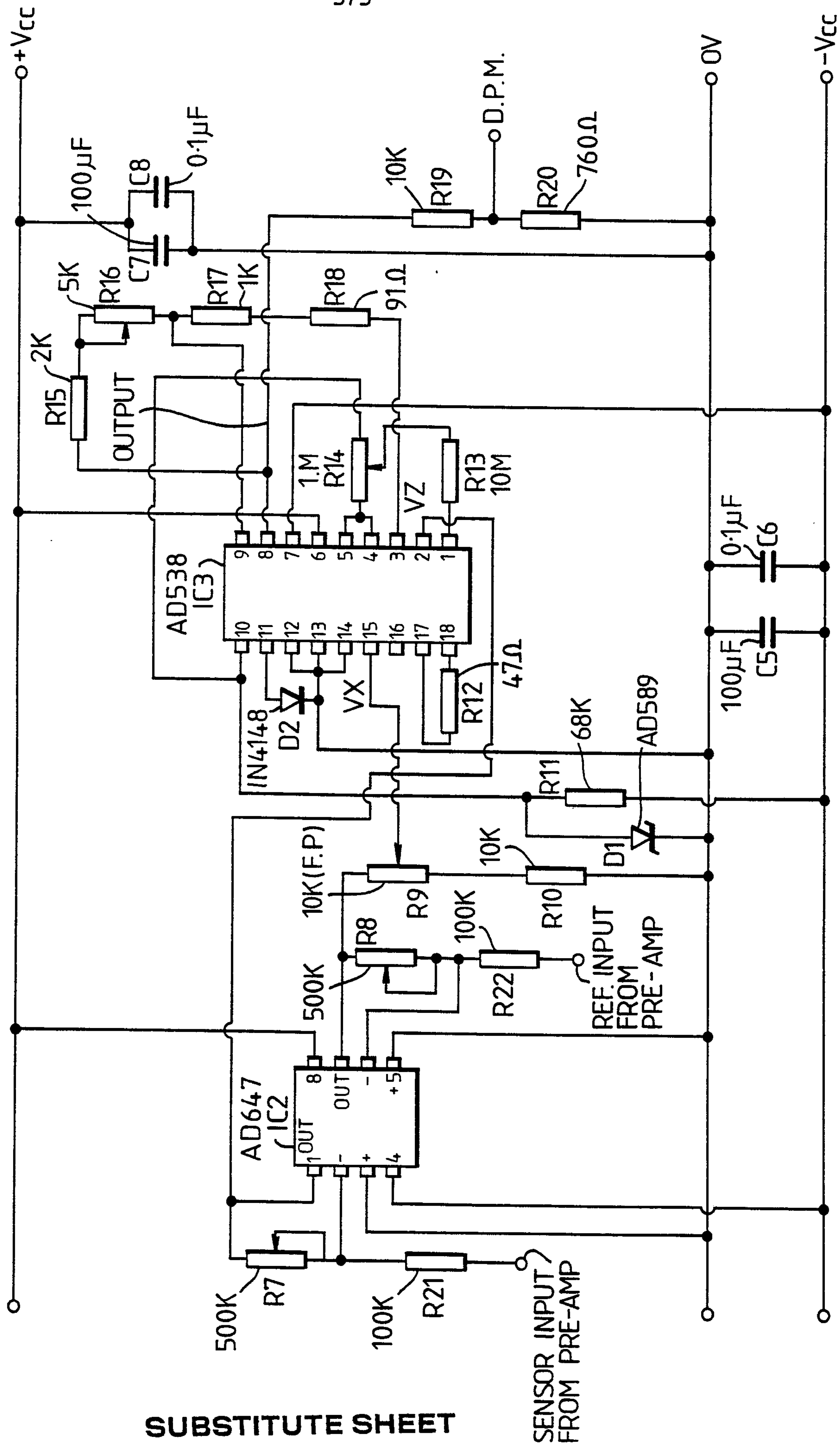
C2
-Vcc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R16
5K
R17
1K
R18
91Ω
R15
2K
OUTPUT
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1.M
R13
10M
VZ
AD538
IC3
R12
47Ω
D2
IN4148
VX
R11
68K
AD589
D1
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C6
100µF
C5
R9
10K(F.P)
R10
10K
R8
500K
R22
100K
REF. INPUT FROM PRE-AMP
AD647
IC2
R7
500K
R21
100K
SENSOR INPUT FROM PRE-AMP

*Fig. 3.*

Fig. 4.

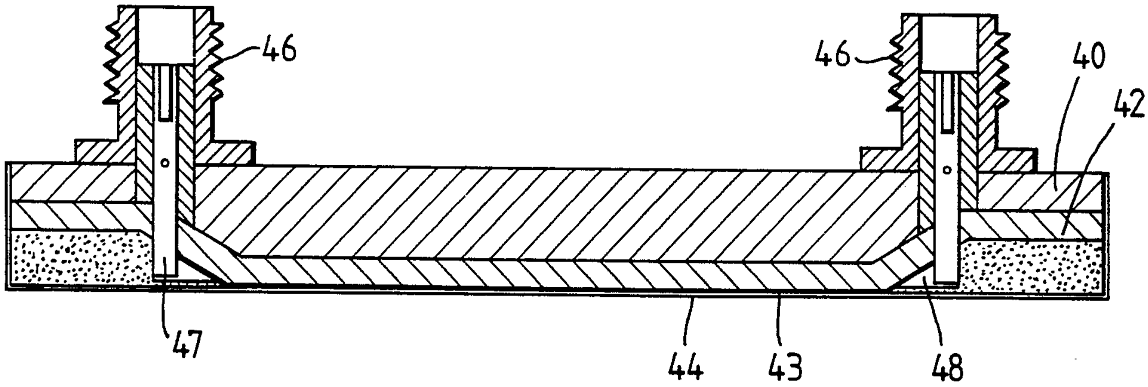
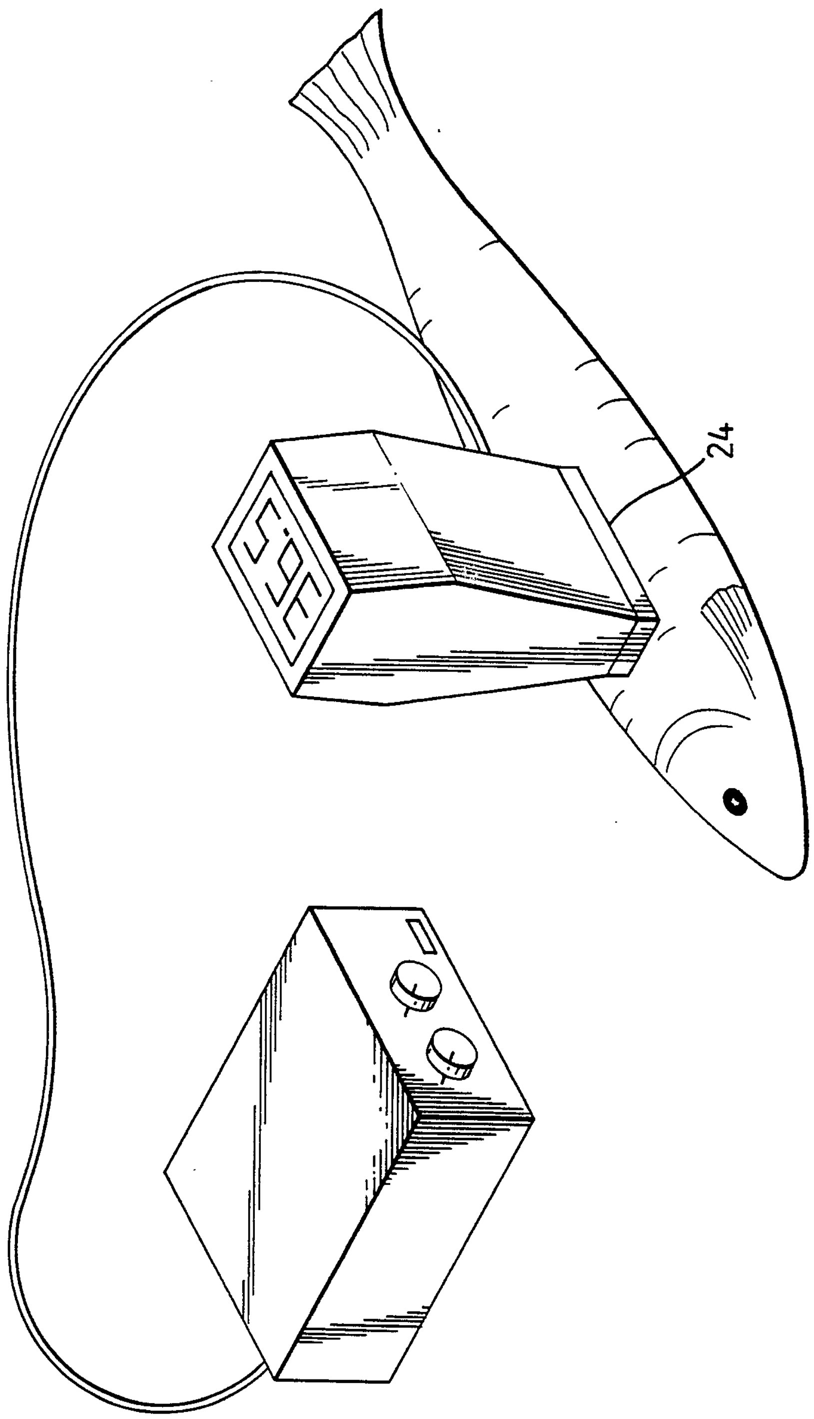


Fig. 5.



# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/01013

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: G 01 N 22/00

**II. FIELDS SEARCHED**

Minimum Documentation Searched[7]

| Classification System | Classification Symbols |
|---|---|
| IPC5 | G 01 N |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT**[9]

| Category * | Citation of Document,[11] with indication, where appropriate, of the relevant passages[12] | Relevant to Claim No.[13] |
|---|---|---|
| X | US, A, 4674325 (SEIICHIRO KIYOBE ET AL) 23 June 1987, see figure 3; claim 1 | 1-15 |
| Y | | 16-17 |
| | -- | |
| X | US, A, 4104584 (YUKIO MIYAI ET AL) 1 August 1978, see figure 5; claim 1 | 1-15 |
| Y | | 16-17 |
| | -- | |
| Y | GB, A, 1354474 (NATIONAL RESEARCH DEVELOPMENT CORPORATION) 30 May 1974, see page 3, line 102 - line 109 | 16-17 |
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**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
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| 27th September 1990 | 11. 10. 90 |
| **International Searching Authority** | **Signature of Authorized Officer** |
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| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) | | |
|---|---|---|
| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No |
| Y | JOURNAL OF FOOD SCIENCE, Vol. 39, 1974, Thomas Ohlsson et al: "DIELECTRIC PROPERTIES OF MODEL MEAT EMULSIONS AT 900 AND 2800 MHz IN RELATION TO THEIR COMPOSITION ", see page 1153 - page 1156<br>--<br>-------- | 16-17 |

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/GB 90/01013

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The members are as contained in the European Patent Office EDP file on 28/08/90
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| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US-A- 4674325 | 23/06/87 | CA-A- 1222397 | 02/06/87 |
| | | DE-A-C- 3413852 | 11/07/85 |
| | | JP-A- 60135752 | 19/07/85 |
| | | NL-A- 8403905 | 16/07/85 |
| | | SE-B-C- 455024 | 13/06/88 |
| | | SE-A- 8402289 | 24/06/85 |
| US-A- 4104584 | 01/08/78 | AU-B- 500624 | 24/05/79 |
| | | AU-D- 2202877 | 17/08/78 |
| | | CA-A- 1078923 | 03/06/80 |
| | | JP-A- 52096096 | 12/08/77 |
| GB-A- 1354474 | 30/05/74 | NONE | |

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