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DESIGN AND CALIBRATION OF THE H_{10}-MODE ABSORPTION CELL FOR 10- cm WAVELENGTH BAND AND THE MEASUREMENT OF VARIATION OF ABSORBED POWER WITH TEMPERATURE BY WATER COLUMN OF DIFFERENT LENGTHS

Mohammed Gazim Uddin

College of Science, Physics Department, University of Basrah, Basrah, Iraq

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An absorption cell has been designed to study the dielectric properties of pure liquid water at 10-cm wavelength band. The dimensions of the cell are such that when filled with water only the H_{10}-mode can be transmitted. It is found that the energy absorbed/cm of the experimental water column inside the cell is approximately 10 dB.

For a fixed length of water column the amount of power absorbed is reduced with the increase of its temperature. The rate of change of absorbed power with the temperature is lower at higher temperature than that of at low temperature.

INTRODUCTION

The absorption cell designed according to: $\lambda_g = \lambda_o/\sqrt{\epsilon}$ (where ϵ, λ_g and λ are respectively the dielectric constant, guide and free space wavelengths) is a similar one developed and used by Collie, Hasted and Ritson [1]. In the present investigation a direct method of measuring the variation of absorbed power by a given length of water column with temperature is developed. The power I_o is fed into the absorption cell with the help of magnetic loop-probe and after passing through the given length of water column the power I is picked up with another loop-probe and taken out to the measuring device. The input power level I_o is kept constant during the measurement. The variation of output power I is recorded with temperature. Now if the dimensions of the absorption cell are well above the cut-off, the absorption coefficient $\mathcal{H}$ is given by [2]:

$$I/_{Io} = \text{Exp}\,(-2\pi\mathcal{H}/\lambda),\text{i.e.} -\ln\,(I/Io) \propto \mathcal{H}.$$

According to the above equation the temperature variation of I represents that of the absorption coefficient $\mathcal{H}$. $I \approx F(T)$ curves at different water-filled cell lengths show that the rate of change of $\mathcal{H}$ with temperature ($d\mathcal{H}/dT$)may not be uniform in the temperature range under investigation.

Design of the 10-cm Absorption Cell. The details of the absorption cell [3] and its connections with the microwave-source and the detection systems are shown in Fig.1 (a) (b) and (c). The power is fed from the microwave line into the cell with the help of a magnetic loop-probe fitted with the bottom fixed plunger. In the H_{10}-mode the magnetic lines of force formed closed loops; the planes of which are parallel with the broad face of the rectangular guide. In order to get best feed in and pick–up of power, the plane of the loop–probes are kept perpendicular to the broad face of the cell, so that, they link the magnetic lines of force well. After passing through the given length of water filled cell the power is again picked–up with another loop fitted with the movable plunger and taken to the detection system.

The micrometer head (total movement 7.5 cm), micrometer rest, cell-holder and the cell are fitted as shown in the Fig. 1(a). A brass block is fitted on the narrow portion of the spindle support and the whole head can be rested on a rectangular brass–tubing with the help of two screws. The brass–block is made push–fit inside the holder, so that it can be taken out whenever needed. Another similar brass

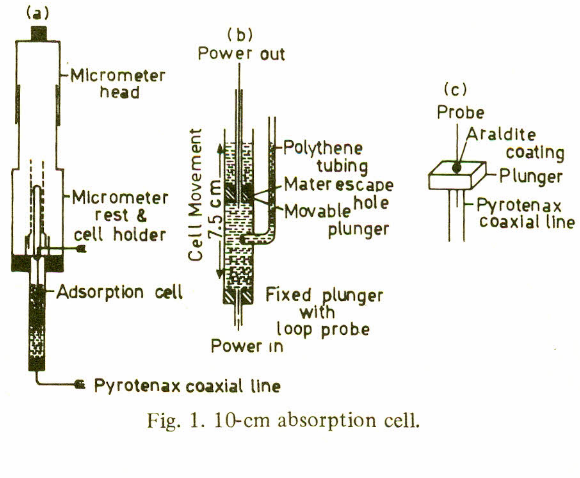

Fig. 1. 10-cm absorption cell.

block with a rectangular hole to fit the cell is fixed at the top end of the cell with set–screws. The cell is then held at the other end of the brass–tube. A slot is cut along the length of the cell holder to pass the pyrotenax cable with the movable plunger into the cell and to provide the facilities for up and down movements of the plunger. Fixed lenght pyrotenax cable is held from the micrometer–adjustment–thrust–barrel which is fitted at the end of spindle to obtain the linear motion of the plunger.

The rectangular waveguide piece used as the absorption cell is a British Standard Waveguide No. 20 for 1.66 to 1.13 cm waves with a=1.067 cm and b=0.432 cm. The loops are made out of the inner conductor of the pyrotenax cable by spot–welding with the plungers. The magnesium oxide filling of the cable is prevented from coming in contact with the experimental water by coating with high–stress araldite. The radius of the loop is about 1.25 mm and is held central in the waveguide by means of the plungers.

The pick–up and feed–loop are fitted with the movable and the fixed plunger respectively which are made water tight with araldite coating. A small hole is drilled through the movable plunger which acts as a water–escape–hole. The polythene side tubing from the broadface of the cell provides the facility for indicating the level of the experimental water inside the cell.

Description of the Apparatus and Procedure of Measurement. The apparatus used for absorption measurement is shown in the block diagram of Fig 2. The I0-cm radiation is generated by the Reflex Klystron oscillator (valve type No. CV–2116) of variable frequency (2.7–3.5 GH_Z). The Klystorn fed by a stabilised power–pack is stable with regard to frequency and output power once it reaches a steady working temperature.

Two variable attenuators and an isolator are used in the microwave–circuitry. The combination of isolator and attenuator is inserted in front of the Klystron and only the attenuator after the standing–wave–indicator. The combination provides enough attenuation and insertion loss to isolate the Klystron from the load on the remainder of the line and protect it from reflection and frequency pulling. The role of this combination is important; because at high frequency the power output of the valve is low and very sensitive to impedance offered by the load. The other attenuator is used to control the output power from the system in order to keep the power level within the available range of the synchronous amplifier.

The standing–wave indicator is used to measure the standing–wave–ratio of the microwave system. The output from the standing–wave–indicator is taken to the spot–galvanometer *via* a crystal detector (CV–2145). The microwave line is matched with the help of the three–screw–tuner by varying the depth of penetration of the screw inside the waveguide.

A coaxial–to–waveguide transformer leads out the power from the waveguide to the coaxial line and fed to the absorption cell. After passing through the water column the wave is again picked–up by a probe and taken to the amplifier *via* a square–law detector housed inside an expanded polystyrene.

Standard BNC 50–ohms plugs and sockets are used in all the junctions. The coaxial leads are made out of commercial pyrotenax which is very suitable for the transmission line. The continuous outer coating facilitates the very high degree of screening and can be used at high temperature. Since the pyrotenax cable is lossy (about 10 dB/metre) by using few metres long cable it is possible to damp out the standing waves due to inevitable mismatches at the plug and junctions.

The synchronous amplifier (Elliott Brothers Ltd., type B-801) used in the measurement is a special precision instrument (sensitivity $1\mu V$ for FSD) and has 106 dB total attenuation in steps of 20 dB, 2 dB and a continuous variable attenuator from 0 to 6 dB. It is possible to read 0.05 dB from the continuous attenuator. The overall accuracy of

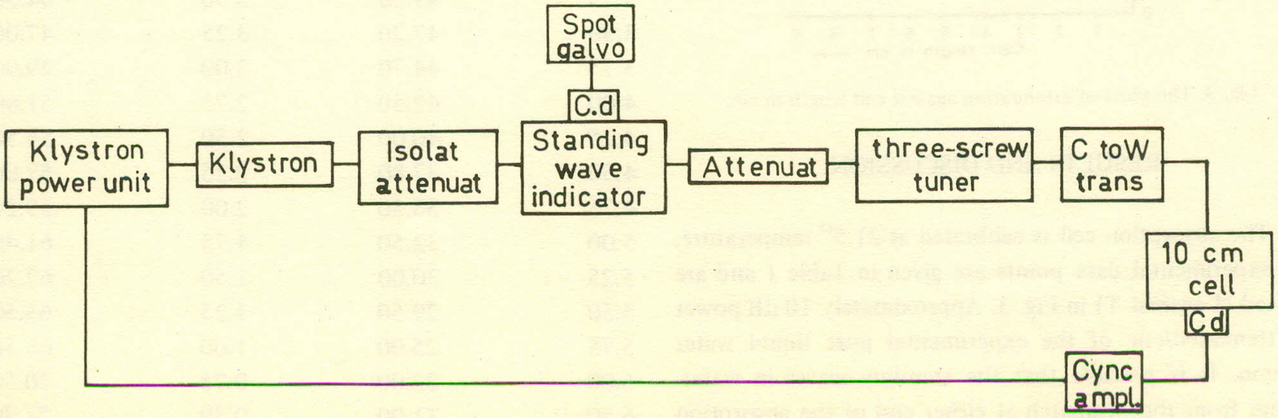

Fig. 2. Block diagram of the apparatus for the measurment of absorption.

the attenuation measurement is approximately ± 0.025 dB.

The instrument is switched on about an hour before recording any measurement, so that, it may reach a steady working temperature. Proper voltages are applied to the electrodes of the Klystron and the frequency is adjusted accordingly; the thermostat bath is set for the desired temperature. The matching of the system is checked and if necessary adjusted to make the standing wave ratio as close possible to one ($D_{max}/D_{min} \approx 1.005$; where D_{max} and D_{min} are the maximum and minimum galvanometer deflections). The value of D_{max} is kept constant as a measure of constant power–input to the absorption cell.

After allowing about 2-hr for steady and equilibrium distribution of temperature of the experimental water inside the cell, three observations are recorded for the temperature and the output power at 5 min interval. The recorded variations between the observations at the same temperature is well within ± 0.003° and ± 0.025 dB) the estimated accuracy of measurement. The following measurements are made:

1. Calibration of the Absorption Cell: The output power is recorded with cell length at constant temperature. The experimental data points are presented in the Table 1 and plotted in the Fig. 3.
2. Measurement of Output Power: The output power is recorded with temperature at different cell–lengths in the temperature range from 25° to 70°. The data points are given in the Table 2 and plotted in the Fig. 4.

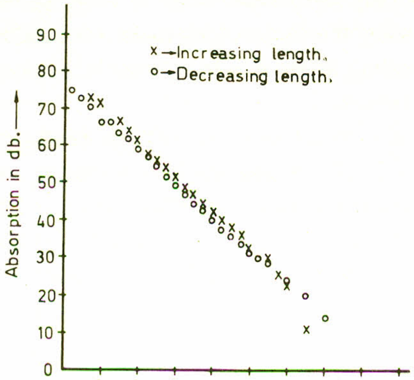

Fig. 3. The plots of attenuation against cell length in cm.

RESULTS AND DISCUSSION

The absorption cell is calibrated at 21.5° temperature, the experimental data points are given in Table 1 and are plotted (I against T) in Fig. 3. Approximately 10 dB power is attenuated/cm of the experimental pure liquid water column. It is possible that the standing waves in water, arising from the mismatch at either end of the absorption cell may interfere in this measurement. In order to over-

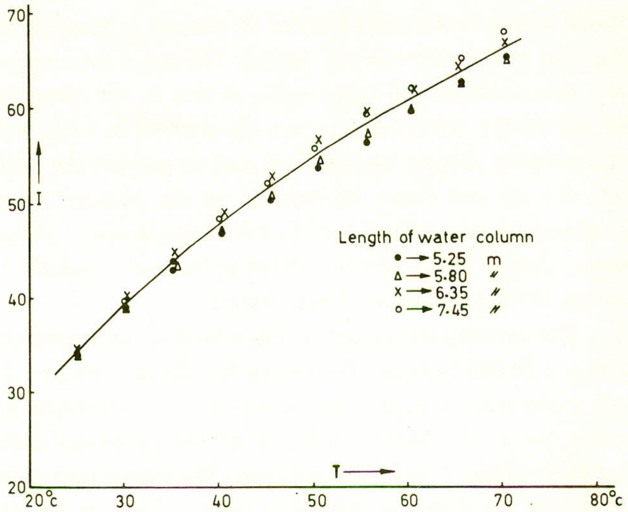

Fig. 4. Plots of I (T).

Table 1. Calibration of absorption cell. Cell–length in cm and output power in decibels at 21.5°.

Decibels above 0.5 μV		Decibels above 0.75 μV	
Cell-length in cm increasing order	I in dB.	Cell-length in cm decreasing order	I in dB.
0.25	78.50	7.50	12.00
0.50	74.80	7.00	14.00
0.75	73.00	6.50	20.00
1.00	71.50	6.00	24.00
1.25	65.00	5.50	28.50
1.50	66.00	5.25	30.00
1.75	63.60	5.00	31.50
2.00	62.00	4.75	33.40
2.25	58.50	4.50	35.50
2.50	57.00	4.25	37.50
2.75	54.60	4.00	40.00
3.00	52.00	3.75	42.20
3.25	49.50	3.50	44.50
3.50	47.20	3.25	47.00
3.75	44.70	3.00	49.00
4.00	42.50	2.75	51.60
4.25	40.00	2.50	54.50
4.50	37.80	2.25	57.00
4.75	35.50	2.00	59.20
5.00	32.50	1.75	61.40
5.25	30.00	1.50	62.20
5.50	29.50	1.25	65.50
5.75	25.00	1.00	66.50
6.00	22.00	0.75	70.50
6.50	11.00	0.50	73.30

Table 2. Bath temperature in degrees centigrade and I in dB. Temperature range from 25° to 70° at about 5° interval.

Cell length 5.25 cm		Cell-length 5.8 cm		Cell-length 6.35 cm		Cell-length 7.45 cm	
Temp. $^{\circ}$	I dB	Temp. $^{\circ}$	I dB	Temp. $^{\circ}$	I dB	Temp. $^{\circ}$	I dB
25.02	34.00	25.02	34.00	25.13	34.30	25.02	34.00
30.24	39.05	30.26	39.20	30.57	40.20	30.10	39.70
35.32	43.25	35.59	43.60	35.61	45.00	35.17	44.00
40.32	47.00	40.32	47.30	40.48	49.05	40.15	48.60
45.43	50.50	45.52	50.95	45.44	53.00	45.35	52.30
50.41	53.90	50.65	54.70	50.46	56.90	50.11	55.90
55.52	56.65	55.77	57.45	55.67	59.90	55.32	59.55
60.25	59.90	60.24	60.05	60.41	61.95	60.32	62.35
65.28	62.85	65.51	62.80	65.16	64.50	65.44	65.50
69.92	65.45	70.17	65.25	69.78	66.90	69.95	68.20

come this difficulty, few metres of pyrotenax coaxial cables are used which help to damp out the standing waves. Moreover, the propagation of the 10-cm wave in water takes place with an attenuation of many decibels in few centimetres [4]. Any standing waves that may arise from the reflection at the surface of the cell are damped out in a very short distance. The standing–wave–ratio in the guide is made as small as possible by keeping the microwave line well matched which also helps to maintain a constant power level.

The plots of I in dB against temperature in $^{\circ}$C for various cell lengths between 25° and 70° at about 5° interval are shown in Fig. 4 and the experimental data–points are presented in the Table 2. All these curves show a noticeable general curvature which is much more prominent at higher temperature, especially above 55°. Above this temperature dI/dT is lower than that of at low temperature end. It was observed by Collie, Hasted and Ritson [5] that at higher temperature i.e. above 60°, between 60° and 90° the change in $\mathcal{H}$ absorption coefficient with temperature is about 0.11 while between 20° to 50° is nearly 0.4.

It is seen that I increased with the increase of the temperature of the experimental water; that is to say, the power absorbed in the liquid column is decreased with the increase of its temperature. The radial distribution function derived from X-ray diffraction and scattering data and neutron–diffraction experiments showed that as the temperature increases (from 4° to 100°) the number of neighbours next to the reference molecules increases (by approximately 10%). If it is so, it is no doubt, a remarkable situation that as the absorption of microwavespower by the experimental water column decreases with the increase of the temperature the degree of molecular crowding increases. Clearly, simple versions of the–kinetic–molecular–theory do not apply to water in its liquid state; this is another anomalous property of water amongst its all the other well known anomalies.

In spite of all the above described precautions taken to damp out the standing wave inside the absorption cell and to avoid their possible interference with the measurements, a number of cell–lengths are used, so that by taking the average of all the runs the results free of any interference can be obtained.

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