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Dielectric Properties of Antarctic Ices and Soils at 5 GHz Frequency

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ABSTRACT

Microwave Remote Sensing is a powerful technique for Geological applications. Information about the dielectric properties of any material is important for calculating their emissivity. These parameters are significant for interpretation of remote sensing data. Therefore, the laboratory validation of these parameters is an important aspect of study in case of Antarctic Geophysical materials like ices and soils.

The dielectric properties of these materials are measured during the XXIInd Indian Scientific Expedition to Antarctica. An automated C-band Microwave Bench Setup was used to measure these properties.

THE EXPERIMENTAL SETUP

The college in a RESPOND project of ISRO procured the setup. It is effectively used for detennination of these properties of soils of different texture and moisture, different water samples and sea water samples. However the equipment could not be used for measurement of the dielectric properties of ices due to lack of suitable laboratory facilities for maintaining zero and subzero temperature in our laboratory. Therefore the setup was taken to Antarctica for measurement of dielectric properties of Antarctic ices and soils.

The setup consists of a low power microwave source,VTO-7089(Avantek Inc.US A) and other components as isolator, coaxial connector, attenuator, slotted-line section, sliding screw tuner,detector,probe and a dielectric cell .The bench if interfaced with a PC through an add-on card. Microwaves of 10 mW power generated by the VTO are propagated through the rectangular wave-guide components of the bench to the dielectric cell. Tuning the VTO at 7.0 volts generates the frequency of 5 GHz. The attenuator is used to maintain the desired power in the line. A tunable probe containing 1N23 crystal detector sits on a movable mount so that it can be moved forward and backward in the slotted line. The crystal detector is connected to the PC to read and record the measured microwave power (current in micro ampere).An empty dielectric cell with a polished metallic reflector at the back end is attached to the slot-line. The position of the probe in the slot line and the microwave current at that position are recorded. This data can be acquired and stored in a file through an interfacing software. The bench is tuned by adjusting the attenuator for a desired level of microwave power in the bench and tuning the probe and the s. s. tuner for obtaining a symmetrical standing wave pattern in the slot-line. Similar data is obtained by filling the cavity of the dielectric cell with samples (ice or soil) of different thickness. The dielectric properties of the material are calculated from the wave parameters of the waves in the empty cell and those in the samples and obtaining their best fit values. Block diagram of the setup is shown in Figure 1.

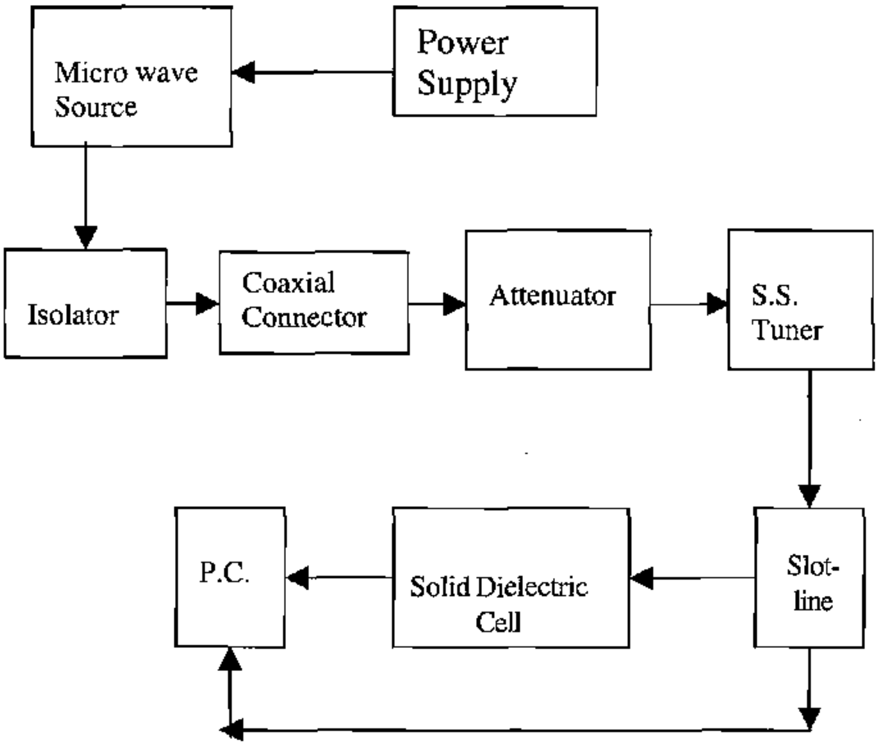

Fig. 1: Block Diagram of C-Band Microwave Bench

THEORETICAL FORMULAE AND CALCULATIONS

The distance between the two minima in the standing wave pattern gives the value of λ_0 and $\lambda_{c=2a}$, a being the broad side of the wave guide.

The dielectric properties of various samples of the ice and soil can be calculated using the relations

$$\varepsilon' = \lambda_0^2\left[\frac{1}{\lambda_c^2} + \frac{\alpha^2 - \beta^2}{4\pi^2}\right]$$

and

$$\varepsilon'' = \frac{\lambda_0^2\alpha\beta}{2\pi^2}$$

where λ_0 is the free space wavelength which can be calculated using the formula

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

where the cut off wavelength $\lambda_c = 2a = a \times 4.73 = 9.46$ cm, 'a' being the broader side of the rectangular wave-guide.

α = Attenuation constant

β = Propagation constant

The dielectric constant is calculated by using the least square-fitting program. The best is obtained using the parameters α,β, p_0,δ;where p_0 is maximum power and δ is phase constant.

RESULTS AND CONCLUSIONS

The values of the dielectric constant and dielectric loss for different samples of ice and soil are given in Tables 1 and 2.The emissivity of most of the ice samples is very high . The significant variation in these values can be observed if the measurements are taken at lower microwave frequencies i.e. at L and S band frequencies. The ice sample containing soil shows comparatively less emissivity. The dielectric constant of Antarctic soils (5 – 6) in some what higher than the same for average Indian soil (3 – 4), however that of some of the samples at Antarctica is like those of Indian soil . The textural composition of the Antarctic soil is not measured.

Table 1: Dielectric Properties of Ice Samples Collected from Antarctica

S. No.	Sample Name	Dielectric Constant ε'	Dielectric Loss ε''	Emissivity e	Location
1	Snow1	3.1624	3.3387E-002	0.9215	new fern
2	Snow2	3.2138	1.1401E-002	0.9194	old fern
3	Snow3	2.9670	1.0438E-002	0.9295	old fern
4	Snow4	3.2904	7.6004E-003	0.9163	fresh snow(lake)
5	Snow6	3.1938	1.6217E-002	0.9202	Ice cored moraine
6	Blueice1	3.2750	2.0755E-002	0.9169	Near Maitree ice wall
7	Blueice2	3.2762	2.5372E-002	0.9513	GSI drilling site
8	Blueice4	3.1897	1.6516E-002	0.9204	GSI drilling site
9	Coreice1	3.1900	2.2012E-002	0.9203	GSI Camp 16.7m deep
10	Coreice2	3.1880	2.2870E-002	0.9204	GSI Camp 22.4m deep
11	Coreice3	3.1105	1.8681E-002	0.9236	GSI Camp 26.7m deep
12	Coreice4	3.1903	2.3254E-002	0.9203	GSI Camp 48.0m deep
13	Coreice5	3.2031	9.9326E-003	0.9198	GSI Camp 51.0m deep
14	Coreice6	3.1911	2.2200E-002	0.9203	GSI Camp 52.0m deep
15	Fastice1	3.0721	1.6028E-002	0.9251	New shelf site
16	Fastice2	3.0373	1.9613E-002	0.9266	New shelf site
17	Ferncore	3.1989	2.5908E-002	0.9200	Fern core GSI site 0.3m
18	Fern	3.1915	2.0886E-002	0.9203	Fresh fern (packed)
19	Loose fern	3.1884	1.9477E-002	0.9204	Fresh fern (loose)
20	Icy Soil 1	6.1911	4.2277E-002	0.8179	Near Maitree Ice Wall

Table 2 : Dielectric Properties of Soil Samples Collected from Antarctica

S. No.	Sample Name	Dielectric Constant ε'	Dielectric Loss ε''	Emissivity e	Location
1	Soil 1	6.35	1.05E-002	0.8135	Near Maitree Station
2	Soil 2	5.13	7.82E-003	0.8499	Near Lake L51
3	Soil 3	6.19	1.82E-002	0.8181	Near Priyadarshini Lake
4	Soil 4	3.36	2.48E-002	0.9136	10 m from ice wall
5	Soil 5	3.19	6.81E-003	0.9203	Bottom of ice wall
6	Sand 1	4.96	8.46E-003	0.8554	Aeouean sand
7	Sand 2	6.19	3.93E-002	0.8181	Sand near Nova Station

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