Measurement of Dielectric Properties of various Decorative Stones at X-band Microwave Frequencies

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ABSTRACT
The natural reservoirs of decorative stones in India have extreme commercial importance. The decorative stones possess a wide variety of colours and textures. The present paper envisages the dielectric behavior of such variety of stones specific to this region at X-band microwave frequencies. A measurement setup at X-band was setup for the experimental determination of relative dielectric constant of various decorative stones. The regular pattern of the relative dielectric constant varying with microwave spectrum is revealed. The Relative dielectric constant is correlated with the type; structure and chemical composition of marble are discussed. The results show that the relative dielectric constant is related to the frequency when measured in the frequency range of 8.8 – 12.2 GHz. The real part of the relative dielectric constant among different type of stone changes in the range of 3.5000 – 8.0194. The regular decrease in relative dielectric constant with increase in frequency. The chemical composition gives somewhat complex relation as the impurities are different in different colour stones. The imaginary parts of relative dielectric constant shows that loss tangent also decreases with increase in frequency in the range of 0.11088 – 0.131975. The loss tangents are different for different types of stones as their chemical composition varies. Further, the relative dielectric constants (both real and imaginary) were determined for wet stones also, smooth decline of dielectric constant with increase in frequency. The measurement data may be of vital importance for microwave remote sensing applications.

Keywords
Dielectric constant, dielectric loss, Marble, X-band frequency.

1. INTRODUCTION
To estimate the existence of natural resources beneath the ground surface, now a days Microwave remote sensing techniques are adopted. The laboratory measurements of dielectric properties of earth's forming rocks and minerals have played an important role in developing electrical and electromagnetic prospecting method of mineral exploration. In view of the growing importance of laboratory measurements of electrical properties and also keeping in view the scarcity of such data on Indian rocks, we have carried out measurement of dielectric constant and loss Tangent of Marbles stones, granite stones and sand stones in the Microwave frequency range from 8.8 GHz to 12.2GHz using two point method. In the present paper, we have reported the results of measurements of dielectric constant and loss tangent of nine samples of marbles, two samples of Granite stones and two samples of Sand stones We have further studied the influence of moisture content of the samples on these properties.[1-3]

2. EXPERIMENTAL DETAILS
2.1 Materials
Marble samples of nine different colours and varieties were obtained from the different marble mines of Rajasthan (India). White marbles from Agaria mines of Rajsamand, Pink Marbles from Babarmal, Udaipur and Green Marbles from Keshriya ji, Udaipur. Two samples of Granites and Two samples of Sand stones were taken.

2.2 Samples Preparation and Dielectric Measurements
All stones blocks were cut by a diamond wheel cutter and sample of marbles and other stones were prepared to the size of dielectric cell 68x23x10mm. Surface of sample were made smooth and were inserted in dielectric cell. The values of ϵ' and ϵ'' at x-band frequencies were determined by employing the short circuited two point method for rectangular wave guide operating at TE10 mode at room temperature. [4,5] We have also measured the values of ϵ' and ϵ'' after dipping these samples in water for 2-3 days so that they absorb the water completely.

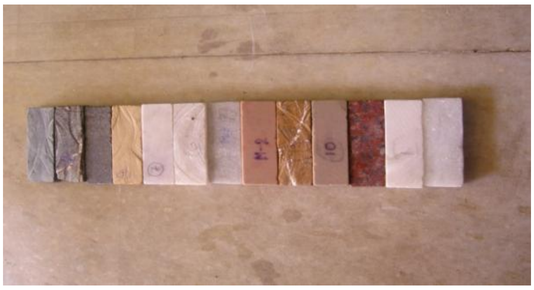

Figure 1: Samples of decorative stones

Figure 2: Experimental Setup

Table 1: Values of dielectric constant of different marble samples at X band frequency (dry)

S. No.	Stone	Storage Factor(e')	Loss Factor(e")
1	Kesariyaji Green (serpentine)	6.8306	0.111220
2	Bidasar Green Fossile Stone)	6.811358	0.11088
3	Banswara Marble	7.9073	0.13009
4	Agariya Brown	7.1592	0.11697
5	Agariya (Rajnagar)	8.0032	0.131362
6	Pink Babarmal	7.54800	0.12371
7	Bidasar Brown	6.9700	0.130654
8	Salumber ONYX	7.9614	0.130954
9	Agariya White(Fine Grain)	8.019990	0.131975

Table 2: Values of dielectric constant of different Granite samples at X band frequency (dry)

S. No.	Stone	Storage Factor(e')	Loss Factor(e")
1	Black Granite	7.3432	0.120029
2	Jhansi Red	6.8537	0.111622

Table 3: Values of dielectric constant of different Marble samples at X band frequency (dry)

S. No.	Stone	Storage Factor(e')	Loss Factor(e")
1	Jaisalmer Lime	3.500	0.11761
2	Sand Stone Karoli	5.6232	0.112332

Table 4: Values of dielectric constant of different Granite samples at X band frequency (Moist)

S. No.	Stone	Storage Factor(e')	Loss Factor(e")
1	Black Granite	7.3432	0.120029
2	Jhansi Red	6.9700	0.113654

Table 3: Values of dielectric constant of different Marble samples at X band frequency (Moist)

S. No.	Stone	Storage Factor(e')	Loss Factor(e")
1	Jaisalmer Lime	4.500	0.2231
2	Sand Stone Karoli	5.9261	0.11365

2.3 Graphical Observations

2.3.1 Marble (dry samples)

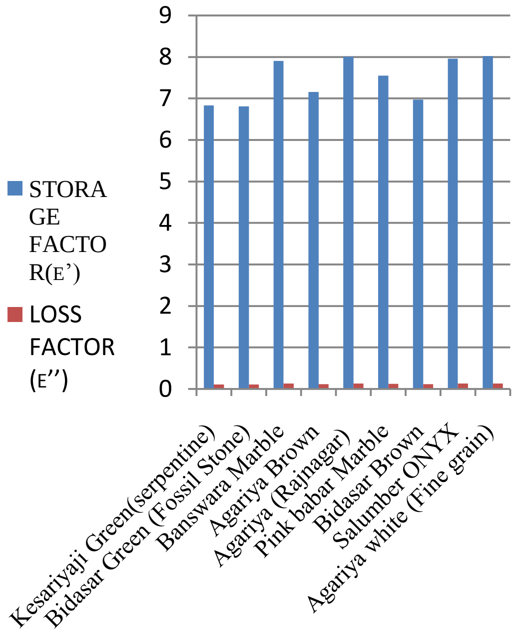

Figure 4: Dielectric constant for Marble stones

2.3.2 Granite (dry samples)

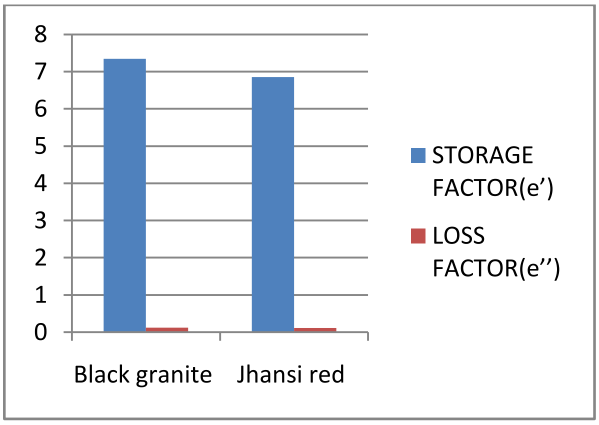

Figure 5: Dielectric constant for Granite stones

2.3.3 Sandstone and limestone (Dry samples)

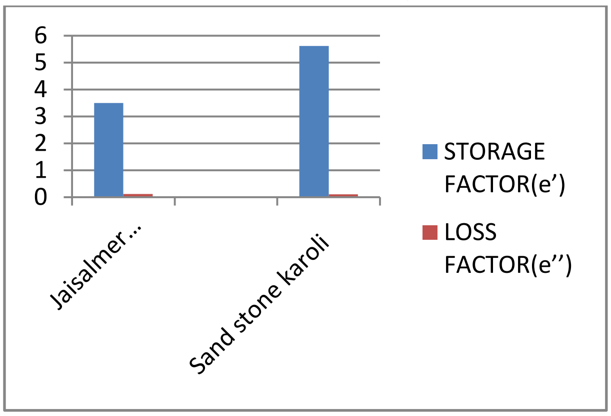

Figure 6: Dielectric constant for Sand stones

2.3.4 Marbles (Moist samples)

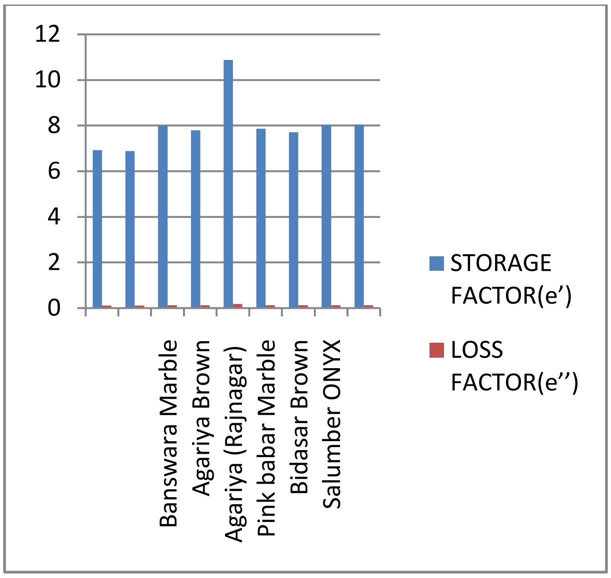

Figure 7: Dielectric constant for Marbles stones

2.3.5 Granite (moist samples)

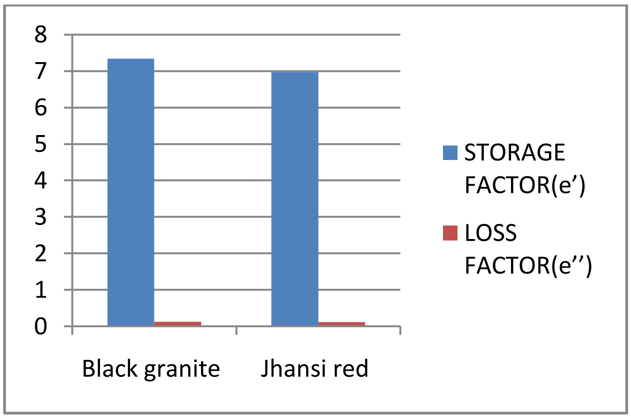

Figure 8: Dielectric constant for Granite stones

2.3.6 Limestone and sandstones (Moist samples)

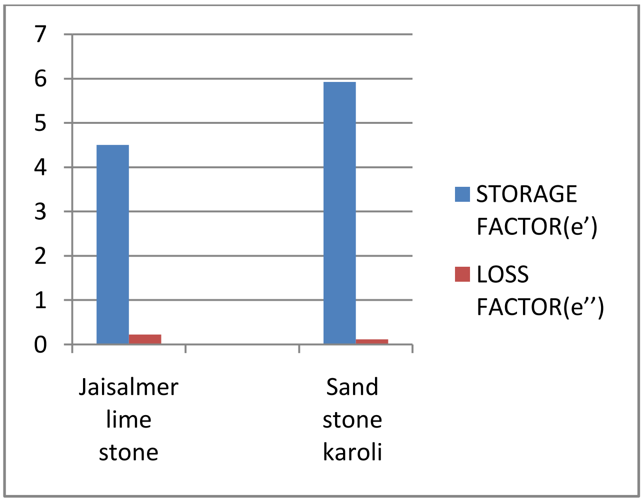

Figure 9: Graphs for different samples

3. DISSCUSION

We observed that the dielectric constant which compromises of two parts storage factor and loss factor behave as following:

3.1 With Marbles Stone Surface

Case 1: With Dry Samples Referring Figure 4

AGRIYA MARBLE (FINE GRAIN) has highest dielectric constant due its compact nature and less amount of impurities associated with it. Generally the marble with white texture has maximum dielectric constant as compare to other marble because the impurities associated with them is very less therefore the storage factor is greater. These show the dielectric constant in range of 7.5 to 8.5.[5,6]

All the marbles that having brown texture like Agriya brown and Bidasar brown etc. they attends moderate values in range of 6.9 to 7.5.

The kesariyaji green marble known as serpentine and Bidasar green (fossil stone) attends the least value in marble group in range of 6.0 to 6.9. This is due to serpentine that include hydrous magnesium iron phyllosilicate ($(Mg, Fe)_3Si_2O_5(OH)_4$) minerals; they may contain minor amounts of other elements including chromium, manganese, cobalt and nickel. So due to increased impurities the value of storage factor decreases.

In case of pink Baber marble the dielectric constant is 7.5480 that is between the white and green range.[7-10]

Case 2: With Moist Samples Referring Figure 7

With moist samples the we observe that the dielectric constant increases due to increase in hydration ions and storage factor is directly proportional to the hydration factor hence increase in storage factor occurs. In case of Agriya (Rajnagar) the dielectric constant increases mostly up to 10.881 which is due to property of this marble to absorb large amount of water. Hence the increment in dielectric constant is directly proportional to amount of water it absorbs. All other marble also shows some amount of increase in dielectric constant.[9,10]

3.2 With Granite Stone as Sample

Case 1: With dry sample: Referring Figure 5

With dry granite as sample the reading comes in range of 6.8 to 7.0 in range which is in higher side which is also due to more compactness in case of graphite.

The black granite has 7.044 dielectric constant more than that of Jansi red due to fewer amounts of impurities associated with it. Jansi red has dielectric constant of 6.8537.

Case 2: With moist sample: Referring Figure 8

With moist granite as sample the dielectric constant increases due absorption of water molecules. The increment is less due to compactness of inter granite molecules due to which it absorb less amount of water, hence increase is less.

3.3 With Sandstone and Limestone as Sample

Case 1: With dry sample: Referring Figure 6

The sandstone and limestone they shows least dielectric constant among all dielectric decorative surfaces .Sandstone Karoli has dielectric constant of 5.6232 and limestone Jaisalmer has dielectric constant of 3.50 . Less amount of dielectric constant is due to greater intermolecular distances in case of limestone and sandstone due to which the storage factor comes in fewer amounts. We know that the limestone and sandstone are brittle therefore it supports the result. [11-14]

Case 2: With moist sample: Referring Figure 8
The sandstone and limestone absorb quit appreciable amount of water, increased value of dielectric constant supports this above fact .the limestone shows the increment of unit factor due to its porous nature.
In case of loss factor it shows random behavior due to different ferrite ion concentration and correctness in sample. [15-17]

4. CONCLUSION

The ε′ values of decorative stones in microwave region are almost independent of the frequency, the observed variance in the ε′ values, whereas the loss factor ε″ is very poorly correlated with the bulk density. Similar to bulk density, constituents of chemical composition of the decorative stones equally affected the values of microwave dielectric permittivity. Due to different values of ε′ and ε″ of these oxides at microwave frequency, the variation in dielectric constants of these oxide bearing geologic materials is expected with the percentage change in their chemical composition constituents.
The increase in percentage of impurity in the chemical composition of marbles also affects permittivity values in low frequency region. Similar to other geologic rocks and minerals, these decorative stones obey the Cole-Cole dielectric dispersion behavior. Microwave dielectric permittivity of these marble specimens of nearly equal bulk density is governed by the variance in percentage of chemical composition of different oxides in the sample. The detailed study of different marbles will contribute significantly in high frequency electromagnetic waves dielectric sensing technique because the radar investigation of the Earth's geology depends on the average dielectric constant of the area under investigation. Further, the dielectric constant of marble samples along with their chemical composition can be used to estimate the individual contribution and interaction contribution of the sample constituents to the dielectric constant using the volumetric dielectric mixing equations.

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