MICROSTRIP RING RESONATOR AS A MOISTURE SENSOR FOR WHEAT GRAINS

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Abstract: Microwave resonant frequency and quality factor of a ring resonator are measured with a single wheat grain as an overlay on the ring and are found to vary with the moisture content independent of the weight of the kernel.

Introduction:

The moisture content of wheat grain is an important factor for the storage of the grain, determination of the time of harvesting, marketing and processing[1,2]. The standard gravimetric laboratory tests are tedious and require several hours and days for completion. Conventional electronic moisture meters measure average moisture in bulk grain sample. The average does not provide any information on the range of moisture in the individual grains or seed moisture content[3]. Different low frequency laboratory measurement techniques have been developed to perform non destructive moisture measurements within a few minutes. Resonant cavity techniques are widely used for the determination of complex permittivities of dielectric samples as well as to perform nondestructive moisture measurement within individual kernels of wheat/peanuts[2,3]. The waveguide cavity measurement technique is associated with the difficulties of loading and unloading of individual kernels and placing them accurately inside the cavity. Microstrip being a miniature and planar microwave component, has been characterized in the present research for the prospective use as a resonant cavity sensor to offer nondestructive and relatively faster moisture measurement within individual kernels of nuts, seeds and grains.

Principles of the present method:

The present paper describes characterization of microstrip ring resonator in the presence of a single wheat kernel kept as a partial cover on a ring resonator on a alumina substrate. It has been reported in several theoretical and experimental studies that the effective permittivity, characteristic impedance and losses in a single microstrip vary due to the presence of a dielectric cover on a microstrip[4-7]. At the same time resonant frequency and transmission and quality factors of microstrip resonators change due to the change in the basic microwave properties due to partial or full overlays on it. The change in the resonant frequency is governed by the relation

$$\frac{f_o^2}{f_s^2} = \frac{\epsilon_{effs}}{\epsilon_{effo}} \qquad \textbf{(1)}$$

where suffices '*o*' and '*s*' indicate resonant frequency(*f*) and effective permittivity(ε_{eff}) without and with sample grain as an overlay on the ring resonator respectively.

$$\Delta f_o = f(\epsilon_{rs}) \qquad \textbf{(2)}$$

$$\Delta Q = f(\epsilon'_{rs}, \epsilon''_{rs}) \qquad \textbf{(3)}$$

where ε_{rs} is the relative permittivity of the grain and ε' and ε'' indicate real and imaginary parts of the complex permittivity ε. Dry wheat grain has low dielectric constant (between 2-3) compared to the dielectric constant of water(75-80). Resonant frequency of the ring resonator is highly sensitive to the

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moisture level of the wheat grain due to the difference in the relative permittivities of dry wheat and water. Whereas Q factor is sensitive to both ε' and ε'' of the overlay material as conductor loss of the microstrip with cover is also subject to the changes in the inductance per unit length of the microstrip[5,6].

Experimental details:

About 100 wheat grains of a high quality "Lokawan" variety grown in GUJRAT state of India were selected for the study. They were classified into four weight groups: (a)0.045±0.005 gm, (b)0.055±0.005 gm, (c)0.065±0.005 gm and (d)0.075±0.005 gm. Individual grains were kept on the ring at different orientations viz. 0^0, 45^0, -45^0 and 90^0. The change in the resonant frequency and change in the quality factor of the ring were recorded. Moisture levels were varied from -15% to 40% by oven drying and soaking in water; considering the starting level as reference moisture level.

Results and discussion:

It has been observed that the resonant frequency of the ring resonator is highly sensitive to the presence of the overlay grain sample. Q factor of the lowest weight group viz ±0.045 decreased by 51% when the moisture content of the grain was increased by 36% whereas when the moisture was decreased by 4% the *Q* factor increased by 15%. The lowest sensitivity has been observed in 0^0 orientation and 90^0 orientation has been found to give the highest sensitivity. Fig.1 shows variation in the *Q* factor for different weight groups and four different orientations. Fig.2 shows *Q* factor variation for four different weight groups at 90^0 orientation. Fig.3 shows variation of resonant frequency with percentage moisture content for 0.045 g weight group with different orientations. Fig.4 shows variation of resonant frequency with percentage moisture for four different weight groups at 90^0 orientation.

The results indicate that the *Q* factor measurements are weight independent as the Q factors lie in the same range even though the changes in the weight of the kernels are 45%. The sensitivity factor dQ/dM is found to vary for different orientations where M indicates percentage moisture. The highest value of sensitivity has been found to be 1.4 at the 90^0 orientation of the wheat grain with respect to the feed line. As the measurements have been performed on the HP 8757C Scalar Network Analyzer the uncertainty in the frequency measurements is taken to be 25 MHz as quoted in the manufacturer's manual. Modern instruments have improved frequency uncertainties to the order of 1Hz which can reduce the basic uncertainty in quality factor and resonant frequency measurements.

Conclusion:

The Q factor and frequency shift measurements of a microstrip ring resonator may be used to perform highly sensitive moisture measurements independent of the volume and weight of the individual grain. The resolution of better than 1% has been obtained in the very wide range of moisture percentage. A very fast instantaneous measurement technique can be developed with a very fast loading and unloading of the sample procedure.

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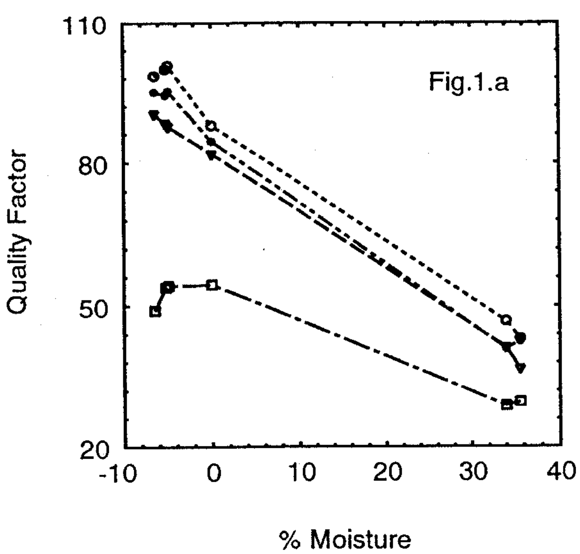

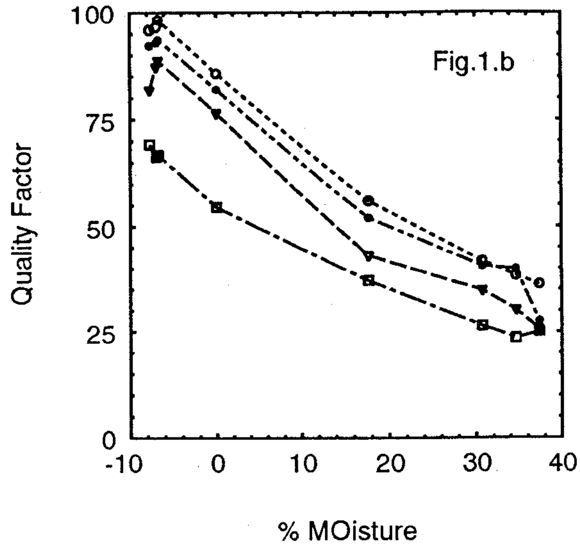

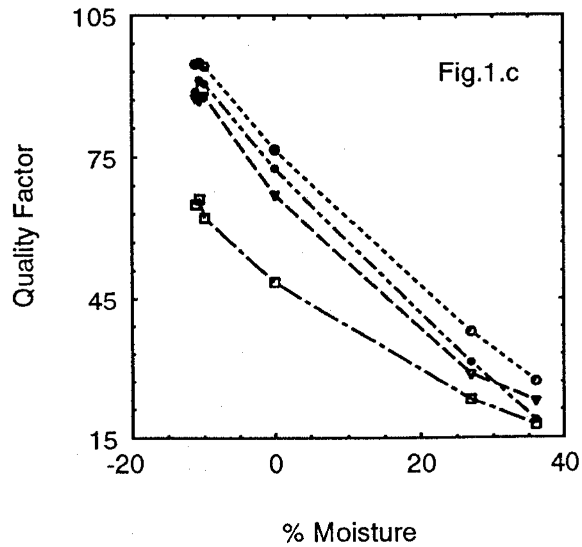

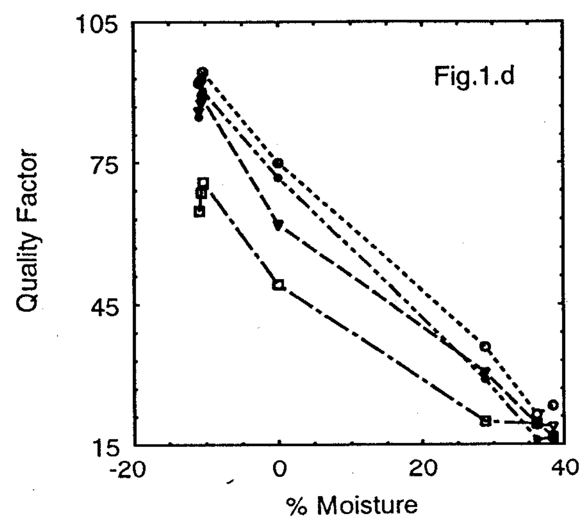

Fig.1 Variation in *Q* factor for different weight groups and four different orientations. a)0.045gm b)0.055gm c)0.065gm d)0.075gm

Fig.2

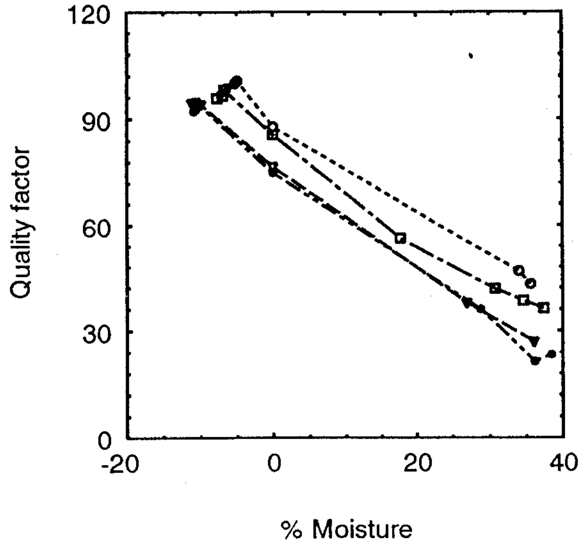

Fig.2 Variation of Q factor for four different weight groups at 90^0 orientation.

Fig.4

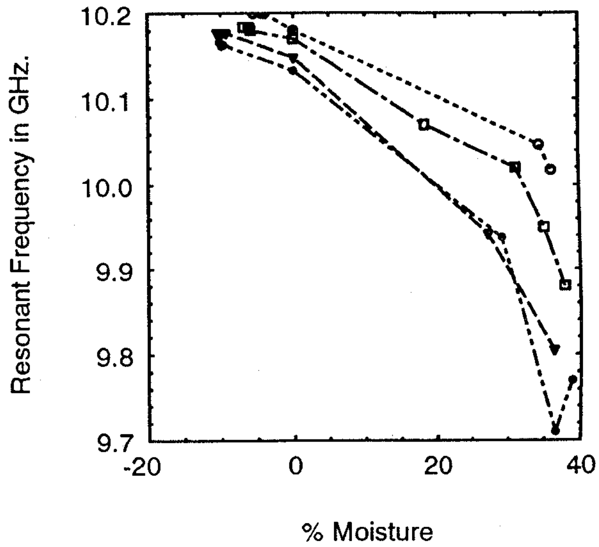

Fig.4 Variation of resonant frequency with % moisture for four different weight groups at 90^0 orientation.

Fig.3

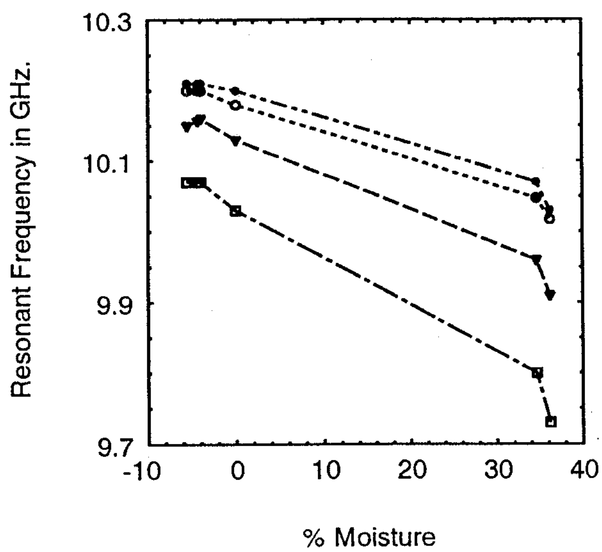

Fig.3 Variation of resonant frequency with % moisture content for 0.045gm weight group with different orientations.