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Wood Characterization by Scanning Millimeter Wave Beam

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In the present paper the new possibilities of the technique based on the scanning of a wood sample by millimeter wave beam are discussed. The main idea of the measurement technique operation is the local excitation of millimeter waves in the sample under test and measurement of transmitted wave amplitude and phase at different points of the sample. All measurement processes are computer controlled and the measurement results are compiled in the computer. Some examples of applications of our technique for a wood properties measurement of the plate shape wood samples at millimeter waves are presented.

Keywords: millimeter waves, wood, characterization.

INTRODUCTION

It is well known that millimetre waves can be used for non-destructive characterization of a vide spectrum of materials. Relatively short wavelength of the millimeter waves provides the possibility to utilize them for non-destructive homogeneity characterization of materials [1 – 3]. The application possibilities of the technique based on the scanning of the sample under test by millimeter wave beam was recently discussed for dielectric [3] and semiconductor [4] wafers used in electronics and wood plates [5]. In the present paper the new possibilities of the technique based on scanning of the plate shape wood sample by millimeter wave beam are presented.

MEASUREMENT TECHNIQUE

In essence, we use a millimeter wave bridge consisting of a reference signal and a measuring signal channels. The tested sample is placed between waveguide probes that provide both local excitation and reception of the low power millimeter wave signals (Fig. 1).

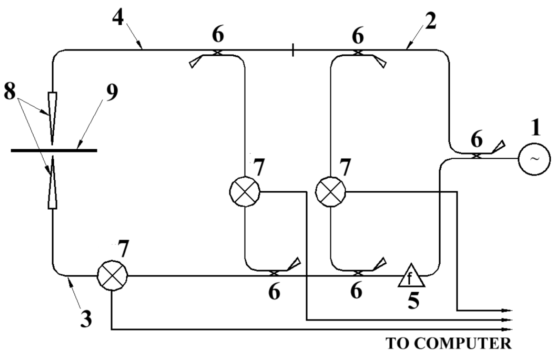

Fig. 1. Schematic diagram of the measurement technique: 1 is millimeter wave oscillator, 2 is reference signal channel, 3 is transmitted signal channel, 4 is reflected signal channel, 5 is frequency converter, 6 are directional couplers, 7 are mixers, 8 are antennas, and 9 is the sample under test

Changes of the electric, dielectric or mechanical parameters in the sample area cause changes in the amplitude and phase of the transmitted signal. By probing the sample at different points with the millimeter wave beam, information about the homogeneity of the sample can be obtained. Measurements were performed in the frequency range 120 GHz – 150 GHz. Open end sections of rectangular waveguide were used for local excitation and reception of millimeter waves. Scanning of the sample was performed using two step motors. One of them serves for the sample rotation and the other one provides its linear motion. Therefore, the scanning process is going on the helix way covering all surface of the sample.

A general view of the measurement technique and the plate shape wood sample placed on the rotating table are presented in the Fig. 2 and Fig. 3, respectively.

Fig. 2. Photo of the measurement technique (in colour on-line)

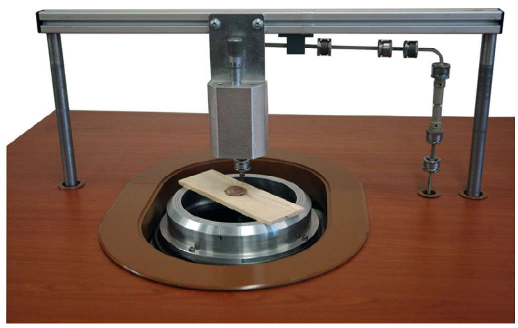

Fig. 3. Photo of the scanning mechanism with rotating table (in colour on-line)

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MEASUREMENT RESULTS

Several plate shape samples cut from the different kinds of wood have been used for the measurement tests. For sensitivity demonstration of our measurement technique to the wood density, anisotropy and moisture content measurements we performed using the pine plate having a branch. Measurement results are presented below. Significant transmitted millimeter wave amplitude and phase variations were observed on the corresponding images presented in Fig. 4. Such variations are related with different density of a wood in the branch and the area around. Dark places in the amplitude image correspond to the fact that wave damping in these areas is higher. Wood density changes causes significant changes in the transmitted wave phase too. All transmitted wave amplitude and phase changes for the same wood plate are better seen in the 3D images presented in the Fig. 5. It is seen that wood density changes cause changes in the wave amplitude more the 100 % and phase oscillations in the range between –120 deg and +180 deg.

The developed technique is very sensitive to moisture content in a wood volume due to large absorption of the millimeter waves by water. For demonstration of this proposition we partially inserted the pine plate to glass with water for several minutes and measured the transmitted wave amplitude and phase images again. Measurement results are presented in the Fig. 6 and Fig. 7, respectively. Dark area in the amplitude image is related with higher moisture content in a wood volume. Drastic changes of the phase demonstrate moisture distribution in the branch and the area around.

Due to annual rings wood is highly anisotropic material. Rotation of the wood plate cut parallel to annual rings with respect to exciting millimeter wave electric vector direction a wood anisotropy can be observed. This is clearly demonstrated in the Fig. 8. The absorption is different when wave electric vector lies parallel or perpendicular to annual rings. Due to the fact that scanning process is starting from the center of the sample under test sector of low absorption (light area) is splay out in the periphery. Obviously that wood anisotropy can not be observed for wood plate cut perpendicular to annual rings (Fig. 9 and Fig. 10). In this case only annual rings and mechanical crack in the amplitude image is observed.

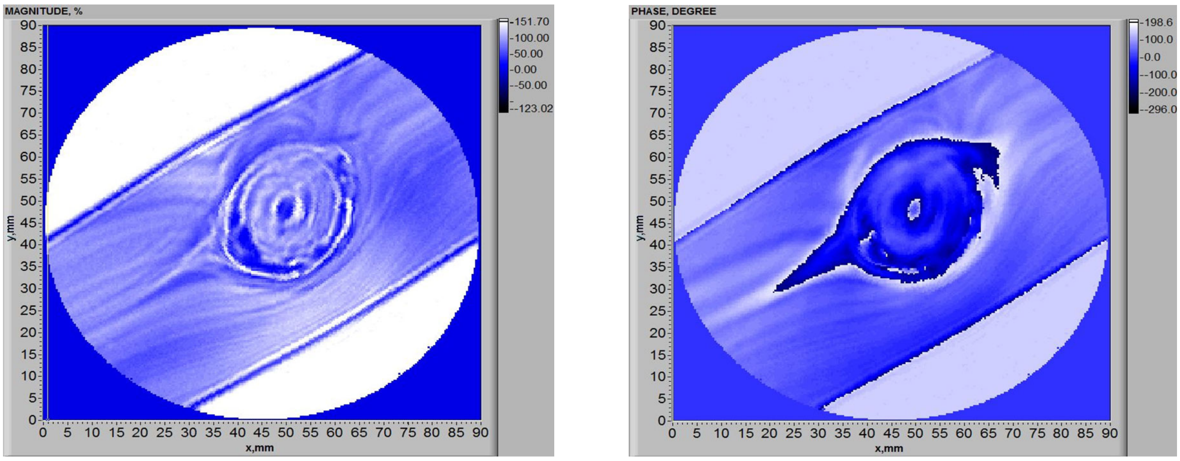

Fig. 4. 2D millimeter wave amplitude (left) and phase (right) images of the pine plate having a branch. Thickness of the plate is 4.0 mm. Diameter of the scanning area is 90 mm. Changes in amplitude are in percents and changes of phase are in degrees (in colour on-line)

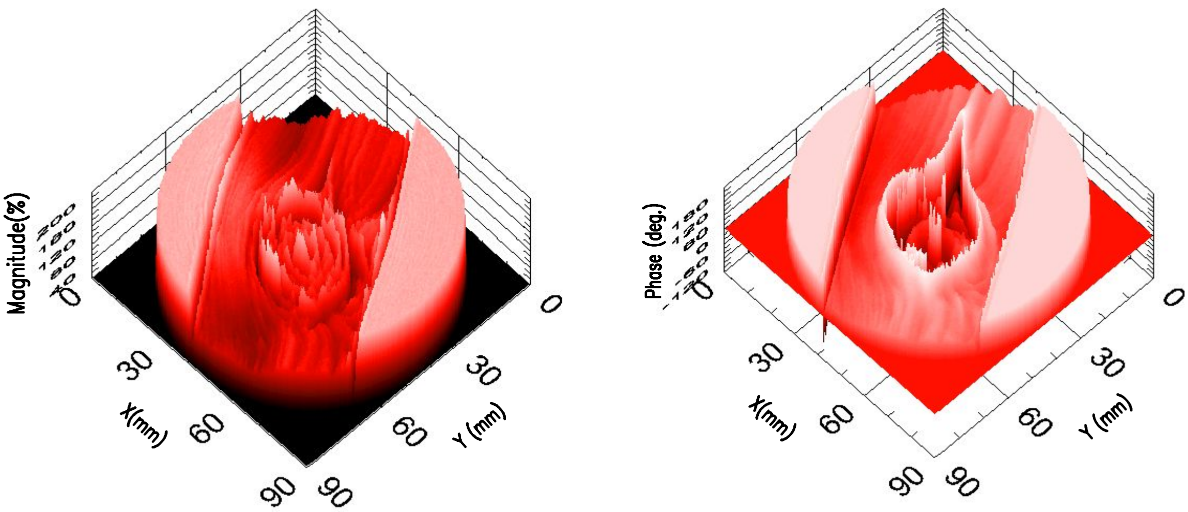

Fig. 5. 3D millimeter wave amplitude (left) and phase (right) images of the pine plate having a branch (in colour on-line)

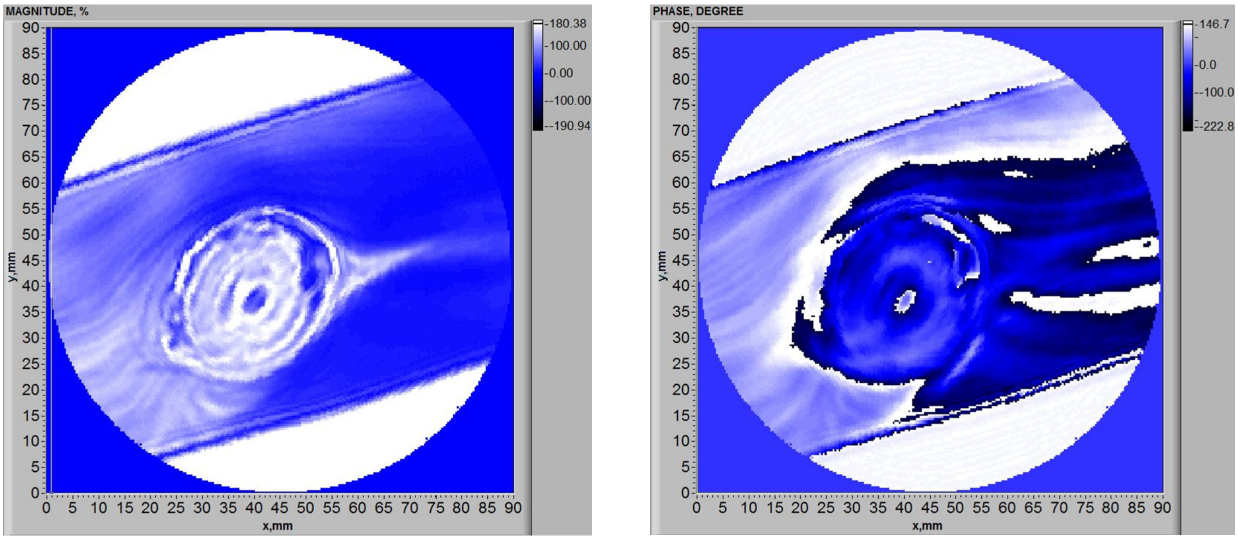

Fig. 6. 2D millimeter wave amplitude (left) and phase (right) images of moisture distribution in the pine plate having a branch (in colour on-line)

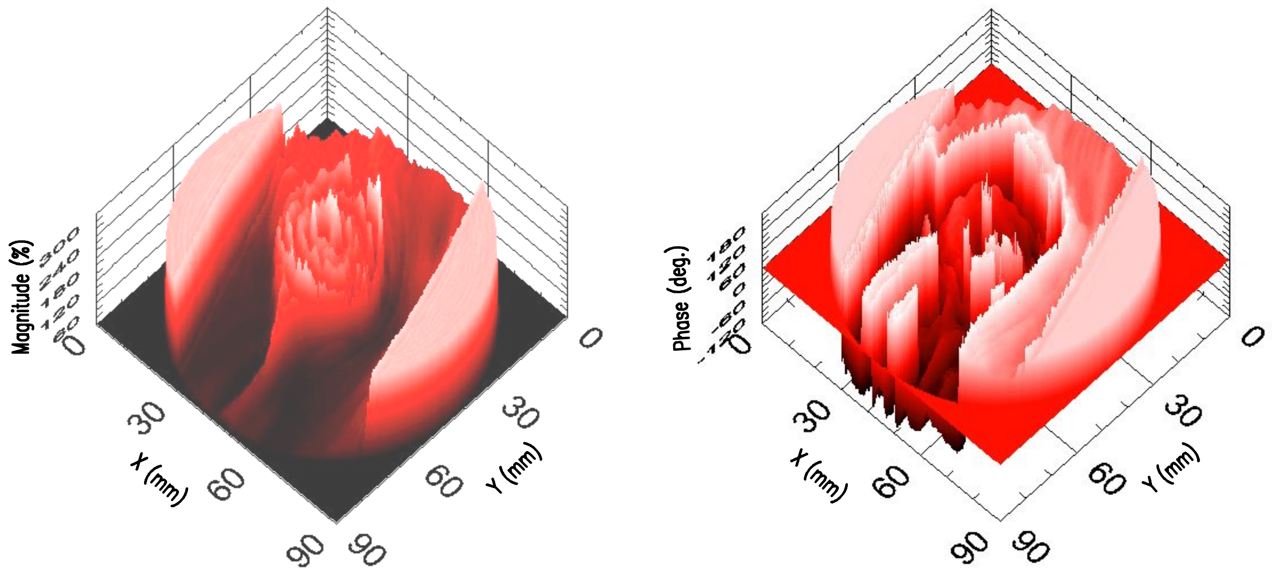

Fig. 7. 3D millimeter wave amplitude (left) and phase (right) images of moisture distribution in the pine plate having a branch (in colour on-line)

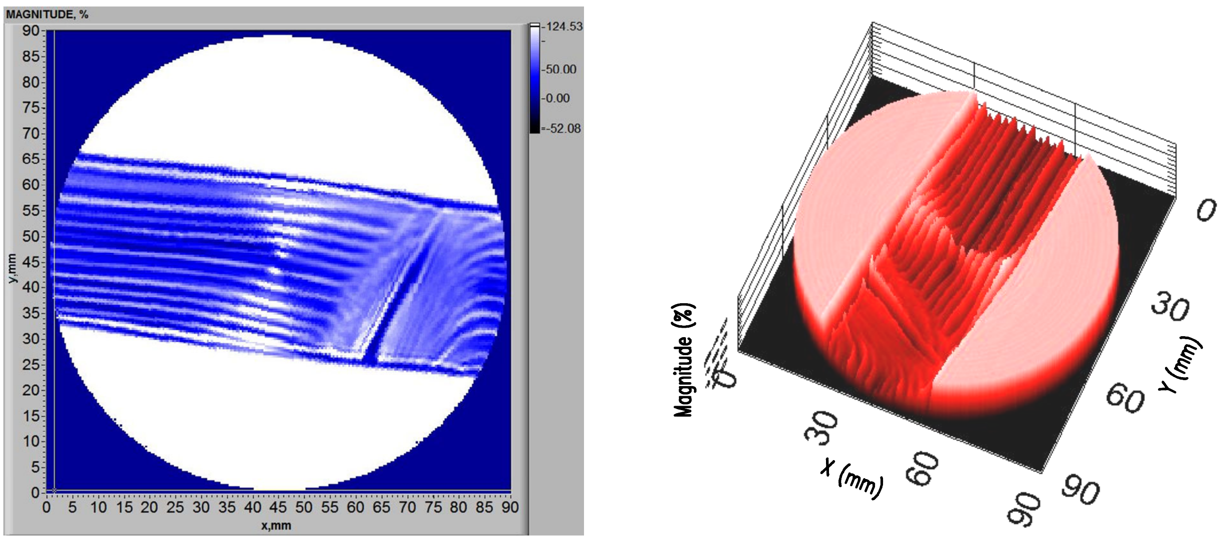

Fig. 8. 2D (left) and 3D (right) amplitude images demonstrating a wood anisotropy of the pine plate having a branch (in colour on-line)

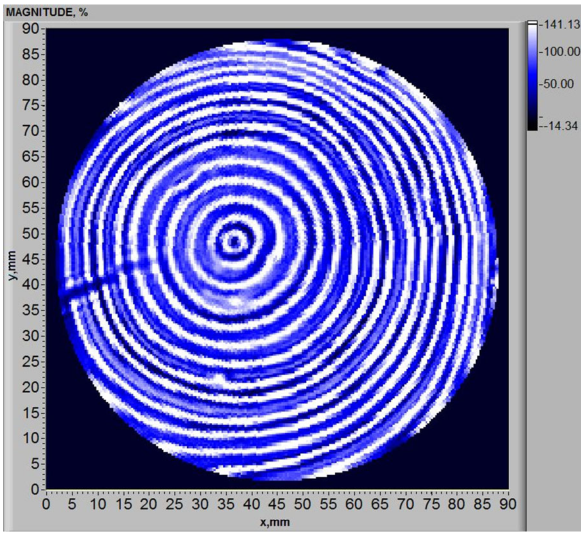

Fig. 9. 2D millimeter wave amplitude images of the pine plate cut perpendicular to the annual rings. Both annual rings and mechanical crash are seen in the image (in colour on-line)

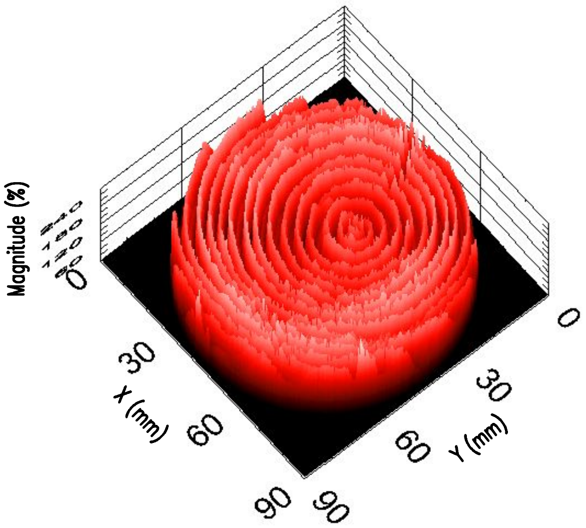

Fig. 10. 3D millimeter wave amplitude images of the pine plate cut perpendicular to the annual rings (in colour on-line)

CONCLUSIONS

Possibilities of the millimeter wave technique for a wood properties examination are presented. Operation of the technique is based on the scanning of a wood sample under test by millimeter wave beam. It is shown that wood density, moisture content and anisotropy can be study using this technique. Different plate shape pine samples were used for experiments. All experiments were performed at frequency range 120 GHz – 150 GHz. The space resolution of the technique is less than 1 mm^2. Wood homogeneity image measurement and mapping time is about 1 min.

Acknowledgments

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