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Millimeter wave technique for material quality characterization

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Abstract

Millimeter wave bridge technique for non-destructive material quality characterization is described. The idea of this technique is the local excitation of the millimeter waves in the testing material and the measurement of the transmitted or reflected wave amplitude and phase in different places of it, i.e. the material plate is scanned by the millimeter waves beam. Some measurement results of the mechanically non-homogeneous samples are presented.

Key words: millimeter waves, material quality, characterization.

Introduction

It is well known that millimetre waves can be used for non-destructive characterization of a vide spectrum of materials. Usually the bulk or surface resistance as well as the dielectric constant of the material can be measured in this way. In many cases, the quality of the fabricated material depends on spatial distribution of these parameters in the whole area of the sample. This is especially important for large area dielectric substrates and thin films used in electronics. Relatively short wavelength of the millimetre wave provides the possibility to utilise them for non-destructive homogeneity characterization of materials. Recently the method based on the scanning of the material surface by millimeter wave beam and the measurement of transmitted power has been suggested for characterization of dielectric substrates homogeneity [1, 2].

In this paper millimeter wave technique for non-destructive characterization of mechanical non-homogeneities in a material volume and on its surface under pain is described.

Measurement technique

The main idea of the measurement technique operation is the local excitation of millimeter waves in the sample under test and the measurement of transmitted (reflected) wave amplitude and phase at different points of the sample. In essence, we use a millimeter wave bridge consisting of a reference signal and a measuring signal channels (Fig. 1).

The tested sample is placed between special waveguide probes that provide both local excitation and reception of the low power millimeter wave signals. The sample can be moved relative to the exciting and receiving probes by scanning mechanism. Changes of the mechanical in-homogeneities in the sample area cause changes in the amplitude and phase of the transmitted (reflected) signal. By probing the sample at different points with the millimeter wave beam, information about the homogeneity of the sample can be obtained.

Measurement results

For testing of our measurement technique two non-homogeneous samples were used. One of them is door electronic key transponder (Fig. 2) and another one is metallic plate with local destructive surface under paint (Fig.3). First of them serves for inhomogeneity testing in the sample volume using transmitted waves and another one serves for inhomogeneity testing on the metallic surface using reflected waves.

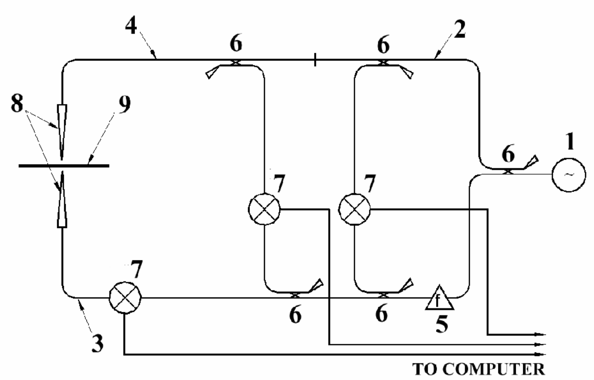

Fig. 1 **Schematic diagram of the device measuring transmitted and reflected electromagnetic wave amplitude and phase: 1 is millimeter wave oscillator, 2 is reference signal channel, 3 is transmitted signal channel, 4 is reflected signal channel, 5 is frequency converter, 6 are directional couplers,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

Fig. 2. **Visible light image of a door electronic key transponder**.

Fig. 3. **Visible light image of a metallic plate surface under paint. Diameter of the plate is 76 mm.**

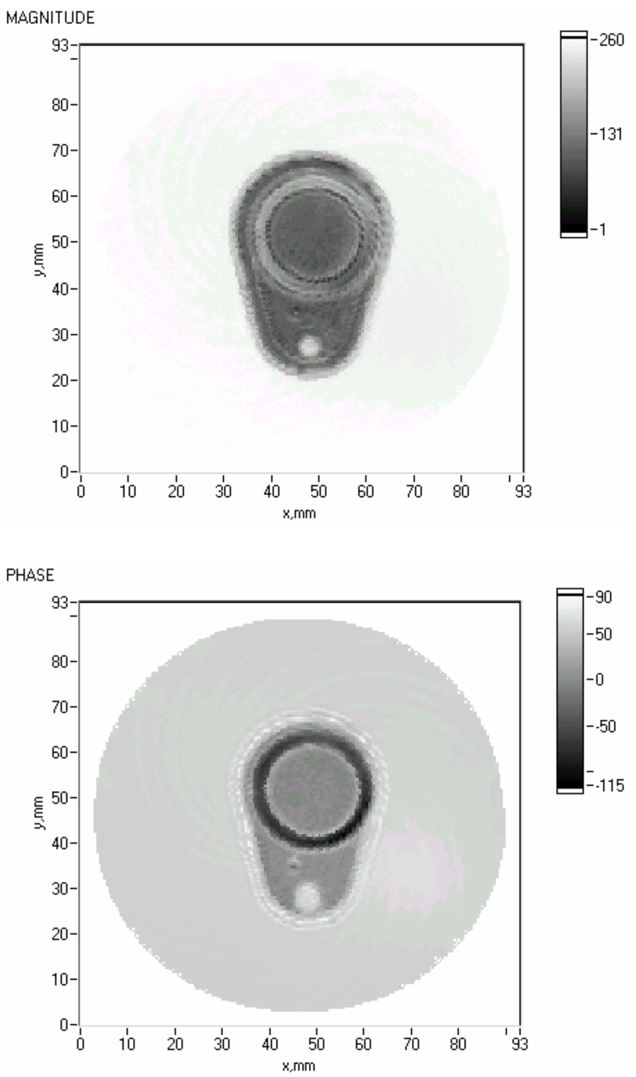

Fig. 4. **Millimetre wave amplitude (top) and phase (bottom) images of the door electronic key transponder. Wave frequency is 120GHz.**

Millimeter wave images of the door electronic key transponder and metallic plate with local destructive surface under paint are presented in the Fig. 4 and Fig. 5, respectively. Inductive coil inside of the electronic key transponder is seen in both amplitude and phase images very clear. In the phase image the microchip and connecting leads are seen too.

The square form damage of the surface and the straight line scratch with 0,5 mm width is seen in the amplitude and phase images of the metallic plate surface under paint (Fig. 5). Dark places in the amplitude image around the damage area demonstrate thicker layer of the paint that cause a stronger absorption of the reflected wave. Periodic dark and light arc form lines observed on the damage area in the phase image are due to wave reflected from the damage area boundaries interference.

Measurement results presented above demonstrate that our developed millimeter wave technique can be successfully applied for material quality characterization and in some cases can serve as alternative to ultrasonic defectoscopy.

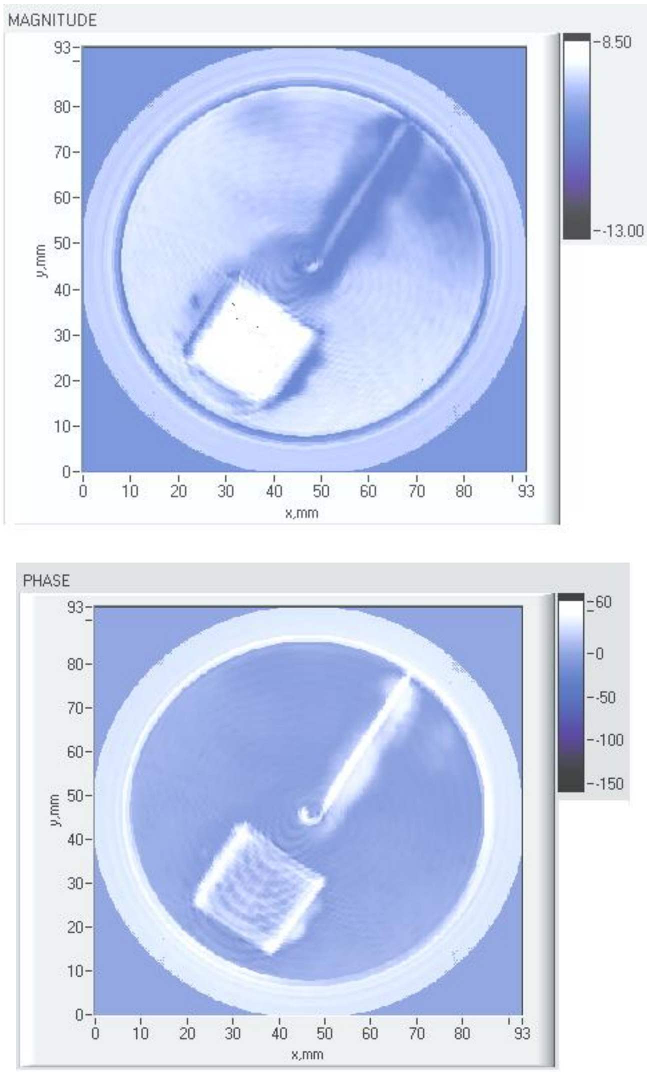

Fig. 5. **Millimetre wave amplitude (top) and phase (bottom) images of the metallic plate with local destructive surface under paint. Wave frequency is 120 GHz.**

Conclusions

Millimetre wave bridge technique for nondestructive material quality characterization is presented. The idea of this technique is the local excitation of the millimetre waves in the sample under test and the measurement of the transmitted or reflected wave amplitude and phase in the different its places. Some measurement results of the mechanically non-homogeneous samples are presented. The space resolution of the measurement technique is about 1 mm^2. Wave frequency operation range is 120 – 150 GHz.

Acknowledgment

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References

1. **Laurinavičius A., Anbinderis T., Martjanova O., Prishutov J., Abrutis A., Teišerskis A.** Non-destructive material homogeneity characterization by millimeter waves. Intern. J. Infrared and Millimeter Waves. 2001. Vol.22. No.7. P. 961 – 964.
2. **Laurinavičius A., Anbinderis T., Prishutov Yu., Martjanova O.** Material homogeneity mapping by millimeter waves. Electronics Lett. 2003. Vol.39. No.18. P.1315 – 1316.

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Medžiagų kokybės tyrimas milimetrinių bangų technika

Reziumė

Aprašyta neardomosios medžiagų homogeniškumo kontrolės matavimo metodika ir prietaisas, kuris veikia milimetrinių bangų tiltelio principu. Pagrindinė matavimo metodikos idėja yra ta, kad milimetrinės bangos yra lokaliai žadinamos tiriamosios medžiagos plokštelėje ir matuojama praėjusios arba atsispindėjusios bangos amplitudė ir fazė skirtingose jos vietose, t. y. plokštelė skenuojama milimetrinių bangų spinduliu. Pateikti dviejų plokštelių su mechaniniais netolygumais homogeniškumo matavimo rezultatai. Matavimo prietaiso skiriamoji geba pagal plotą yra apie 1mm^2. Prietaisas dirba 120–150 GHz dažnių ruože.

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