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Beam width estimation of microwave antennas using lock-in infrared thermography

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HIGHLIGHTS

- A fast method for determining beam widths of microwave antennas in E- and H-planes using lock-in thermography is proposed.
- Amplitude images are used to determine the half power points in both E- and H-planes.
- From these E- and H-plane beam widths the directivity is then calculated.

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ABSTRACT

The beam width of microwave antennas can be easily determined using infrared thermography. A thin absorption screen made up of some carbon loaded polymer is placed in front of a microwave antenna. The electromagnetic waves impinging the screen are partially absorbed by it, resulting in temperature rise of this screen. This temperature rise is monitored by an infrared camera. These infra red images of the temperature distribution are identical to the power distribution of the incident electromagnetic field at the screen location. The distance between half power points on the main lobe of the radiation pattern at the screen location in two orthogonal directions (E- and H-planes) can be easily found. From these distances the half power beam widths in both E- and H-planes can be calculated. Further from these beam widths, directivity is also calculated.

The experiments were carried with a patch antenna radiating at 2.45 GHz. In order to show the repeatability of the results, experiments were carried for different distances between patch antenna and absorption screen. A great agreement is seen between simulation, measurement and experimental (thermographic) results.

The microwave source is modulated at a low frequency so as to avoid the lateral spread of heat on the absorption screen and to permit lock-in detection of temperature distribution.

1. Introduction

The visualization of electromagnetic field intensity on a plane can be easily achieved by infrared thermography using a microwave absorption screen made of carbon loaded polymers. The electromagnetic waves falling on the absorption screen increase its temperature as per joules law. This temperature rise is monitored by an infrared camera. This monitored temperature profile can further be correlated to the electric field intensity.

Electromagnetic field measurement by measuring the temperature change on an absorption screen has been reported by Nogard et al. [1–5], Will et al. [6,7] and Sega [8,9]. However these methods were used for measurement of temperature changes greater than 1 K on the screen, requiring electromagnetic waves of power of more than 10 W. For lower temperature change measurements (corresponding to weak electromagnetic fields) lock-in infrared thermographic technique is used [10–15]. In this technique the electromagnetic wave source is modulated at a low frequency (few Hz) and the thermal images of the temperature distribution on the absorption screen are taken by an IR camera. Fourier transformation of the recorded thermal movie gives the amplitude image corresponding to temperature change at each pixel location on the screen. The phase images are of no significance for such application as reported by Balageas et al. [10].

The mathematical equation relating magnitude of electric field strength (E) and temperature change (ΔT) on the screen, reported in [15] is given by

$$E = k\sqrt{\Delta T} \quad (1)$$

where k is a constant.

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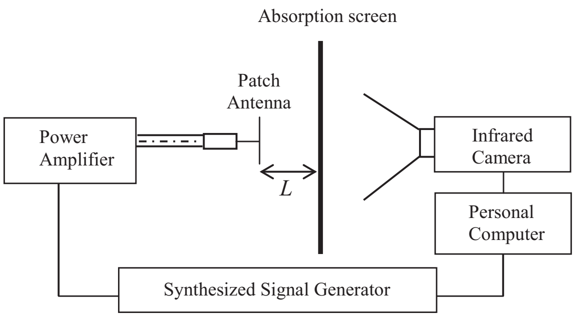

Fig. 1. Block diagram of the experimental set up.

2. Measurement principle

The principle of this measurement technique can be understood from Fig. 1. The patch antenna radiating at 2.45 GHz is connected to a synthesized signal generator which is turned ON/OFF at a frequency of 1 Hz. The temperature distribution on the screen is monitored by an IR camera. The infrared camera is taking thermal images of the screen at a frame rate of 25 Hz. The data captured by the camera is stored in a computer attached to it. Fourier transformation of the recorded thermal movie at 1 Hz gives an amplitude image corresponding to the temperature change (ΔT) at each pixel location on the screen. This temperature change (ΔT) is proportional to square of electric field magnitude as per

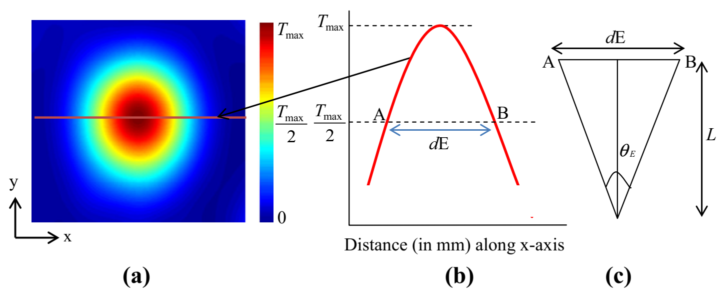

Fig. 2. (a) Temperature distribution on absorption screen kept at a distance (L) from patch antenna and (b) temperature distribution over a line along X-axis (representing E-plane distribution) passing through T_{max}. (c) Geometrical diagram for calculation of E-plane beam width.

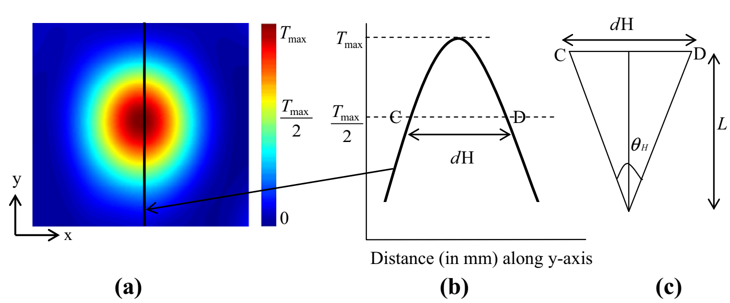

Fig. 3. (a) Temperature distribution on absorption screen kept at a distance (L) from patch antenna, (b) temperature distribution over a line along Y-axis (representing H-plane distribution) passing through T_{max}, (c) geometrical diagram for calculation of H-plane beam width.

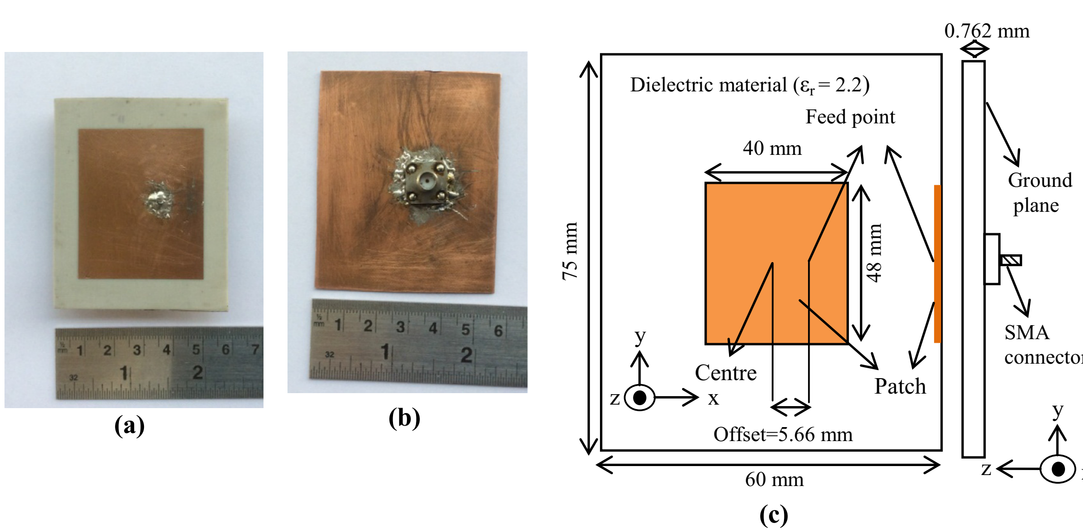

Fig. 4. Photographs of the 2.45 GHz patch antenna used in the experiment. (a) Front side, (b) back side, (c) geometrical details of the patch antenna.