Infrared Thermography for Characterization of Microwave Fields: A Brief Overview and Review

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Abstract : This first half of this paper gives a basic understanding of thermal imaging of microwave fields over plane surfaces. The electromagnetic radiations emanating from a microwave source are made to fall on a thin absorption (resistive) screen. These waves are amplitude modulated. The waves falling on the screen result in temperature rise of the screen. Thermal images of the screen are taken by an IR camera at some fixed frame rate and hence a thermal movie is recorded. Amplitude images of the thermal movie determine the power pattern of these waves at the screen location cameras or more popularly known as infrared cameras. This second half of this paper gives a brief review of thermal imaging of microwave fields over plane surfaces gives a basic understanding of thermal imaging of Microwave fields over plane surfaces.

IndexTerms – IR Camera, Thermography, Microwave fields, Absorption screen

I. INTRODUCTION

Infrared thermography based techniques for electromagnetic field characterization provide many advantages like non-contact approach, fast data evaluation, simple system design etc. to name a few. Electromagnetic waves are widely used for a large number of applications as in communication devices like mobile phones, wireless LAN, non-contact type IC card systems etc. Measurement and visualization of electromagnetic field distribution around such devices is very useful. Measurement of electromagnetic field strength is typically done by a small scanning antenna, which involves a series of repetitive and time consuming probe measurements. Furthermore the scanning antenna may itself disturb the measurement process. On the other hand, in case of a thermographic measurement, a single thermograph gives the distribution of electromagnetic field strength over a plane. Moreover the absorption screen can be kept close to the electromagnetic wave source without disturbing the electromagnetic field distribution. Therefore fields near the electromagnetic wave source can also be visualized and measured using thermographic measurement system. Further, while the dimensions of the scanning antenna depend on the wavelength i.e. a probe antenna with certain dimensions can be used for specific wavelengths only, this is not the case with a carbon loaded polymer screen as it can absorb electromagnetic waves over a wide band.

The technique is based on the heating produced by incident electromagnetic radiation on a thin resistive screen, the temperature of which is visualized by an IR camera.

Due to the desired characteristics, IR thermographic techniques are suitable to study electromagnetic field strength distribution in real time, with the possibility of its continuous monitoring. Moreover the lack of repetitive sampling and moving elements (like test probe) can reduce the complexity, cost, and human resources required by standard techniques. Therefore this technique provides the possibility of a simpler and more accessible system for electromagnetic field strength determination.

II. REVIEW

This type of work was first reported by T. Hasegwa [1] in 1955. The technique used a filter paper impregnated with cobalt chloride. This paper turned blue from pink colour after exposure to microwaves. Lizuka [2] used the same idea; he exposed a polaroid film to microwaves during the developing stage. The developed reagent absorbed microwave energy. If the development stage is stopped prematurely, only the microwave heated regions are fully developed. So it is possible to relate the regions corresponding to stronger microwave fields

Augstine et.al [3] used microwave absorbers painted with liquid crystals. Microwaves absorbed in the absorber produce heat causing colour change in the liquid crystal. Lizuka [4] carried the work using a photochromic film which is transparent to visible light. On illumination to ultraviolet (UV) light, this film turns blue. If the UV light is stopped from falling on the film, the colour of the film fades to transparent again. The rate of fading of the colour is accelerated by increasing the temperature. Thus if the film is placed on a microwave absorber and illuminated by UV light, when the UV light is stopped, the colour of the film fades more quickly in regions of more intense microwave fields.

In 1973 IR thermography was finally introduced by Lizuka and Gregoris [5]-[6]. Because of various advantages associated with thermography, it has overshadowed the previous mentioned techniques. The various advantages are: non-contact, fast, possible reversibility of the phenomenon and easy data handling. Thermography is used for mapping microwave fields in open space conditions or in cavities [7]-[8], surface current distribution on conducting structures [9]-[10] and also for finding power absorption in microwave absorbing materials [11]-[12]. The quantification of electromagnetic fields using IR thermography in free space was initially done by Russel [13], Martin [14], Wetlaufer [15] and Metzger [10]. All these authors characterized the electromagnetic fields in the steady state regime i.e. they measured the temperature of the absorption screen in equilibrium state. The accuracy obtained was relatively poor and there were some limitations like it takes long time to reach to the equilibrium state , there are convective and radiation losses and thermal conduction on the absorption screen can change the temperature distribution which deteriorates the spatial resolution of the temperature distribution.

The problems mentioned above are solved largely by avoiding the steady state regime. The key lies in producing dynamic electromagnetic fields resulting in dynamic thermal fields on the absorption screen. The thermal effects produced by such fields are detected by lock in technique. It is therefore possible to combine the advantages of IR thermography and lock in detection. This type of technique has been used in photothermal experiments [16-18] and vibrothermography [19-21]. The theory of lock in is discussed by Krapez [11]. In 1992 such a technique was introduced by Leveseque et. al [14] for electromagnetic fields. Finally in 1993 such a technique was used by Balageas et. al [26] for visualization of electromagnetic fields. The lock-in IR thermographic system eliminates the influence of heat losses and enhances the spatial resolution [26]-[27]. The lock-in IR thermography was also used by the author for finding beam width estimation of patch antenna [28], for determination of polarization of microwave signals [29] for fault detection of antenna arrays [30]

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