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Fault detection of antenna arrays using infrared thermography

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HIGHLIGHTS

- A fast method for fault detection of antenna arrays using lock-in thermography is proposed.
- Temperature distribution on a thin microwave absorption screen helps in finding the faulty elements.
- Amplitude images are used for detecting the faulty elements.

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ABSTRACT

A fast and easy method for fault detection in antenna arrays using infrared thermography is presented. A thin, minimally perturbing, microwave absorption screen made of carbon loaded polymer is kept close in front of the faulty array. Electromagnetic waves falling on the screen increase its temperature. This temperature profile on the screen is identical to electric field intensity profile at the screen location. There is no temperature rise observed on the screen corresponding to non-radiating (faulty) elements and hence can be easily detected by IR thermography. The array input power is modulated at a low frequency which permits thermography to detect even weak fields. It also improves the resolution of thermal images. The power fed to the array is only 30 dBm. In order to show the utility of this technique, an example of 14 GHz 4×4 patch antenna array is given. The simulations are carried in CST Microwave Studio 2013. A good agreement between simulation and experimental results is observed.

1. Introduction

Infrared thermography has been used for the visualization of electric fields [1–14]. This technique uses a thin absorption screen of carbon loaded polymer. Such screens are commercially available. The electromagnetic waves impinging on this absorption screen are partially absorbed by the screen. The power absorbed by the screen is given by

$$P_{abs} = \frac{1}{2}\frac{E^2}{Z_s} \tag{1}$$

where E is electric field strength, Z_s is the surface impedance of the absorption screen. The absorbed radiations increase the temperature of the screen by joule heating. This temperature rise is monitored by an IR Camera. The temperature rise (ΔT) at each pixel location is related to modulus of electric field strength E by Eq. (2) as reported in [10]

$$E = k\sqrt{\Delta T} \tag{2}$$

where k is a constant. Therefore the temperature rise at each pixel location on the screen is proportional to square of electric filed strength.

Infrared thermography has been used earlier for array diagnostics [11]. Our technique differs from the earlier approach as we are modulating the array input. The advantages of our approach are as:

1. Modulation eliminates the convection effects of heat on the screen and helps even in the detection of weak electromagnetic fields [12].
2. The lateral diffusion of heat on the screen is inversely proportional to square root of modulation frequency of the electromagnetic wave source [12]. Therefore modulation improves the resolution of the thermal images.
3. For quantification of electromagnetic field values on thin screens using Lock-in thermography we need only amplitude images of the temperature distribution on the screen, the phase images are of no significance for such an application [12].

Further for antenna arrays radiating at higher frequencies the individual elements are closely spaced and the dimensions of the array elements are also small. In absence of modulation, the lateral

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diffusion of heat on the screen hinders the detection of faulty elements precisely. Therefore it gets imperative to modulate the array input for fault detection using thermography for better accuracy.

2. Measurement setup

The principle of our method can be understood from Fig. 1.

The antenna array is fed by synthesized signal generator through a coaxial SMA connector from the back side. The power input to the array is only 30 dBm. The absorption screen is kept in front of the array at a distance of 2 mm. The signal generator, controlled by computer is turned ON/OFF at a frequency of 1 Hz. The Infrared Camera connected to the Computer is taking thermal images of the screen at a frame rate of 20 Hz. Fourier transformation of the recorded thermal movie at 1 Hz gives the amplitude

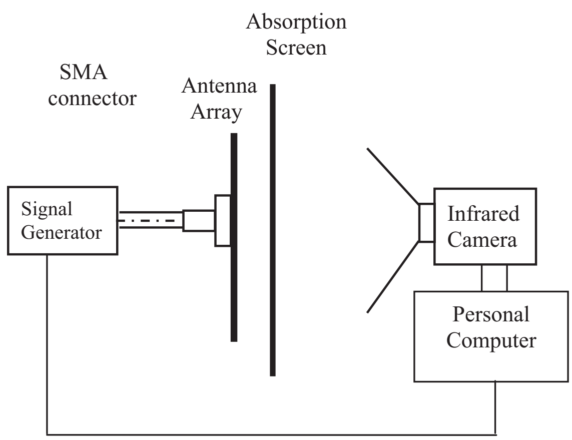

Fig. 1. Experimental setup for fault detection of arrays.

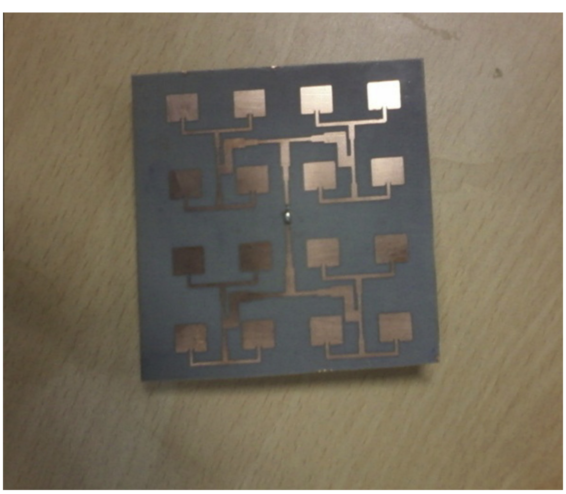

Fig. 2. Front side of the 14 GHz 4 × 4 array.

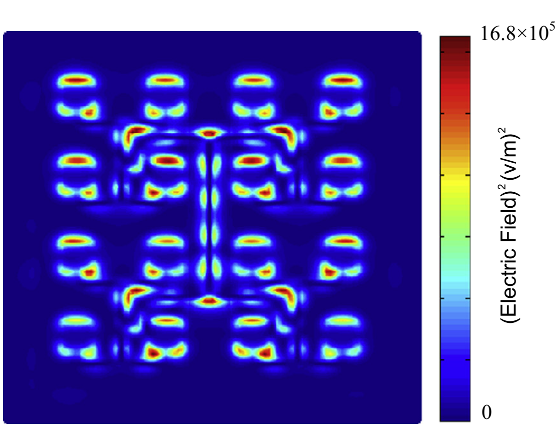

Fig. 3. No element blocked.

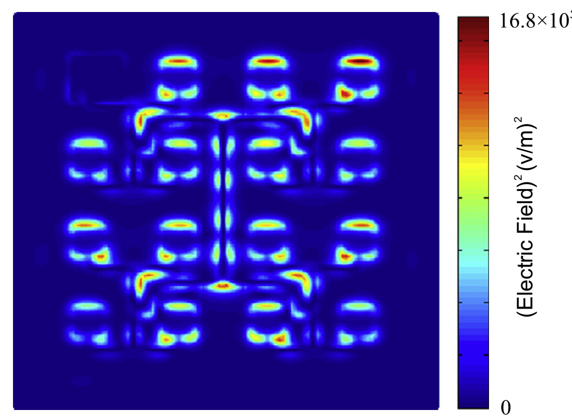

Fig. 4. Single corner element in the 1st row blocked.

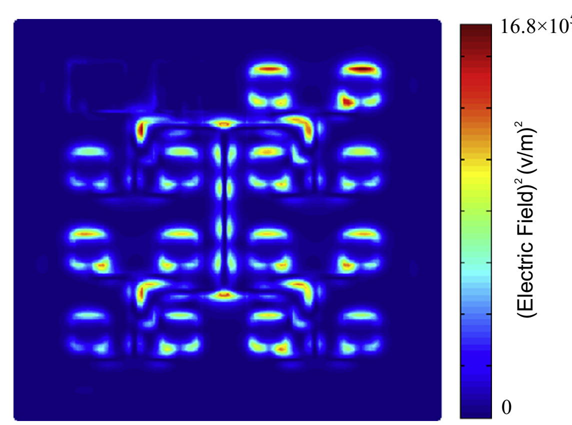

Fig. 5. Two elements (1st and 2nd) in the first row blocked.

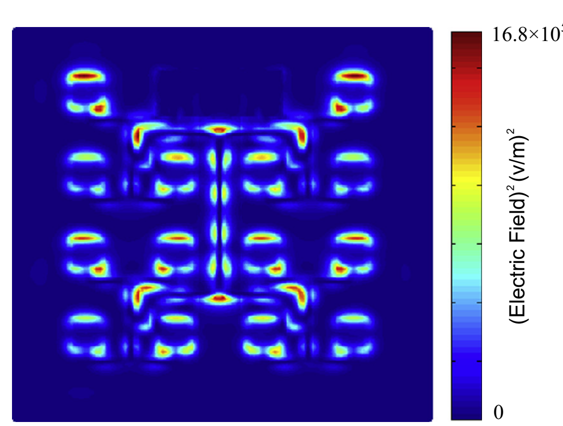

Fig. 6. Two elements (2nd and 3rd element) in the first row blocked.