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MICROWAVE CORRELATION THERMOGRAPHY FOR THE IMAGING OF HOT SPOTS IN LOSSY MATERIALS

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Abstract

The imaging of hot spots in homogeneous, lossy materials using a microwave correlation radiometer is investigated. The system utilizes a circular synthetic aperture and a correlation radiometer with an adjustable time delay. Numerical results for various system configurations are presented graphically.

Introduction

For the diagnosis and therapy of certain diseases, like tumors, a technical system for the noninvasiv measurement and supervision of the temperature distribution inside the human body would be of great interest.

One possibility to achieve spatial resolution for the thermal pattern of the body is to apply correlation radiometers, which was proposed in /1/. The correlation technique was combined with synthetic apertures in /2/. In /3/, both experimental and theoretical results for the imaging of hot spots in lossy matter, using a circular synthetic aperture, have been presented. It is the objective of this paper to demonstrate that considerable improvements of this system are possible by applying an additional variable time delay. This component enables one to shift the coherence area with its hyperbolic shape over the object plane by varying the time delay, as was discussed in /4/ for another antenna configuration.

System Description

The region to be imaged is assumed to consist of a homogeneous but lossy material, with one or more noise sources (hot spots). To obtain a 2-dimensional problem, the noise sources are supposed to lie in one plane within a circle (object plane). Two omnidirectional antennas A_m and A_r, positioned on a line through the centre of the object plane, are twisted simultaneously in equispaced steps for a total angle of 180^o to form a circular synthetic aperture, as is indicated in Fig. 1. Noise signals from hot spots, the temperatures of which are presumed to be so high that only their radiation has to be considered, are received by the two antennas, and, if correlated, produce signals at the output of the correlation radiometer. So the 'measurement procedure' is as follows: there are N different antenna positions Am_ν, Ar_ν and for each antenna position M different values τ_μ of the time delay are adjusted. The radiometer is able to produce both the correlated and the orthogonal correlated signals, and therefore a set of 2 MN measurement values has to be stored.

In the reconstruction process a fictitious noise source is moved in small steps over a fictitious plane in the same material as the object space, however, the hot spots of the original scene are removed. If the attenuation coefficient and the phase constant of the lossy material are known, the signals coming from the fictitious noise source can be computed. These signals are compared with those from the 'measurement procedure' for all antenna positions and for all positions of the fictitious noise source. In this way a 2-dimensional ambiguity function can be defined, computed and sketched in a graphical manner.

Computed Results

Results from simulations are shown in Fig.2 to Fig.6. The diameter of the object plane is 15 cm, the midband frequency of the radiometer with a Gaussian frequency response is 1 GHz and its bandwidth is 330 MHz. The attenuation coefficient and the phase constant of the medium are those of tap-water at 1 GHz. In all figures the true positions of the hot spots are indicated by arrows. As can be expected, one antenna position (N = 1) is not sufficient to reproduce the correct source position, on the contrary the ambiguity function extends over several 'mountain-chains' as can be seen from Fig. 2. The reconstruction of Fig. 3 slightly indicates the noise source, nevertheless, for a clear image like in Fig. 4, much more antenna positions are necessary. The ascent of the 'mountain-chains' in Fig. 2 and Fig. 3 at the rim of the object plane seems to be unfavorable, however, this is a consequence of the ambiguity function being formulated to image the power P of different noise sources correctly. The latter fact is illustrated in Fig. 5 with two noise sources.

The efficiency of the variable time delay in connection with a system of moderate or broad bandwidth is clearly demonstrated through the reduction of the sidelobes in Fig. 4 compared to those of Fig. 6.

Conclusion

Provided the parameters of the material of the object space are known exactly, the investigated system has the potential to image correctly the position as well as the power of point-shaped noise sources in homogeneous, lossy material. Due to the circular aperture, the spatial resolution is nearly constant all over the object plane and is in the order of half a wavelength.

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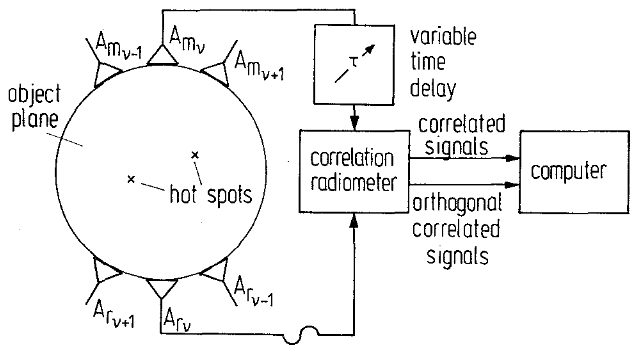

Fig. 1: Block diagram of the imaging system

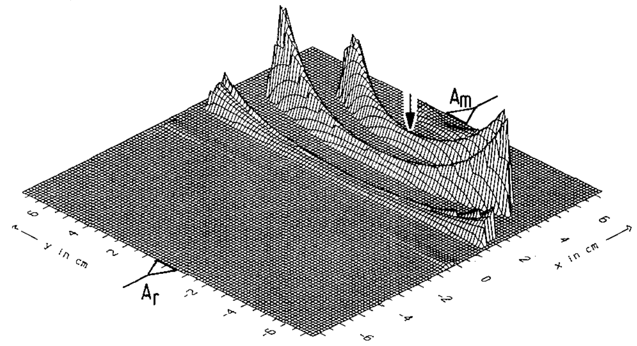

Fig. 2: Reconstruction of one hot spot; number of antenna positions N = 1; number of time delay adjustments M = 31

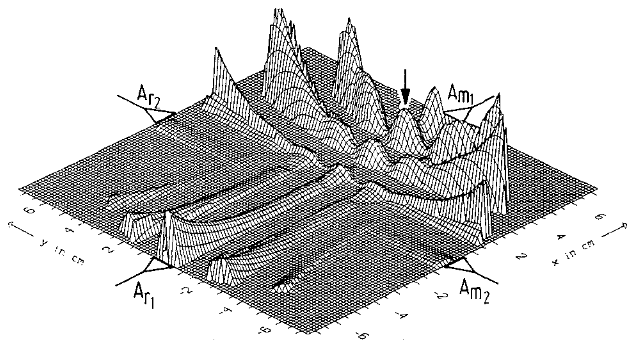

Fig. 3: Reconstruction of one hot spot: N=2, M=15

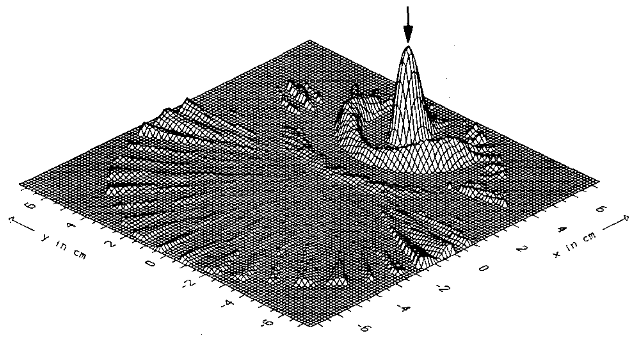

Fig. 4: Reconstruction of one hot spot: N=25, M=21

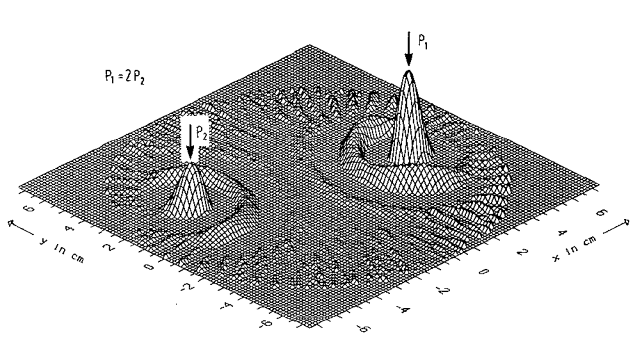

Fig. 5: Reconstruction of two hot spots: N=25, M=21

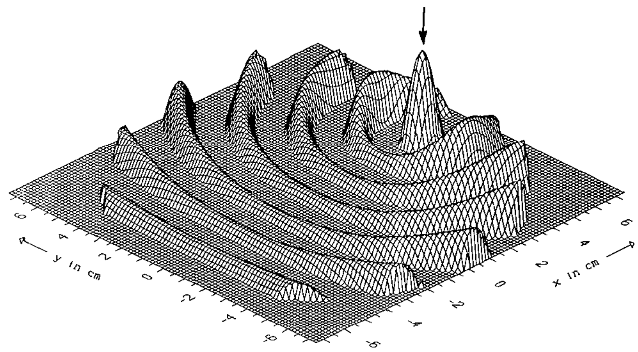

Fig. 6: Reconstruction of one hot spot: N=25, M=1