

Design of Ultra-Wide Band TEM Horn Antenna Based on Microwave Imaging

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ABSTRACT: A new ultra wide band (UWB) TEM horn antenna for near-field microwave imaging of dielectric objects are presented together. The focus is on an application in microwave breast tumor detection. The setup employs planar aperture scanning. It consists of an antenna aligned to scan the aperture. The major design requirement is that the antenna couples the microwave energy into the tissue without being immersed itself in a coupling medium. The antenna achieves this requirement by: 1) directing all radiated power through its front aperture and 2) blocking external electromagnetic interference by a carefully designed enclosure consisting of copper sheets and power absorbing sheets. The impedance match of the antenna is satisfactory within the ultra wideband frequency range. The antenna exhibits high tissue coupling efficiency. It has relatively small size front aperture. Proposed antenna is simulated with packages of FEKO EM simulator. The antenna demonstrates over 3-10 GHz.

KEYWORDS: Microwave imaging, ultra wideband (UWB), and TEM Horn antenna.

I. INTRODUCTION

Breast cancer is the leading cause of cancer death for women worldwide. At present, Iran reports around 100,000 new incidence of breast cancer. Breast tumor detection using microwave imaging techniques is a non-ionizing, potentially more certain and low cost alternative. The contrast between the electrical properties of the components of a dielectric body enables its imaging using microwave measurements. In a typical active microwave imaging scenario, microwave power is radiated via an antenna and the scattered power is picked by one or more antennas. The scattered signals are then analysed to detect and evaluate significant scatterers (targets). Microwave detection of breast tumors is based on the significant contrast in the dielectric properties, which is estimated to be greater than 1:2 between normal and tumor tissue. The antenna design for the breast tumor detection is an important part of this technique. Microwave imaging system requires a wide band antenna array capable of producing high-resolution images. However due to the High attenuation losses of breast tissues at higher frequencies the operating frequency has to be limited below 11 GHz

The design of high-performance antennas presents significant challenges in the implementation of all the categories of microwave imaging. Following the guidelines presented in [1], an improved ultra-wide band (UWB) TEM horn antenna is designed and tested. The major design considerations, which distinguish this antenna from the previously proposed antennas for UWB microwave imaging, are: (1) operating in direct contact with the imaged body without the need for coupling liquids, (2) blocking the electromagnetic interference from the surrounding medium, and (3) directing most of the radiated power toward the tissue via the front aperture. The amount of power coupled to the tissue through the front aperture is quantified by a parameter called near-field directivity (NFD). The antenna also features ultra wide impedance bandwidth. It is designed to operate in the UWB range allowed by the Federal Communication Commission (FCC) for indoor applications, i.e., 3.1 GHz to 10.6 GHz.

To satisfy these requirements, a TEM horn antenna seems to be the most suitable one for its inherent wideband, unidirectional radiation, relatively simple construction and easy excitation. Many TEM horn antennas have been reported for UWB applications. However, each has its own merits and drawback. Typical antenna design examples for this application include planar monopole [2], planar "dark-eyes" [3], elliptical tapered slot [4], dielectric filled slot line bowtie [5], and ridged pyramidal horn [6].

This paper presents a new antenna design for microwave imaging application that can operate over the necessary wide bandwidth for this application and has a small size. The performance of the antenna in the coupling medium has been studied by using two antennas as transmitter and receiver, and the sensitivity of the antenna to the size and position of the tumor has been shown

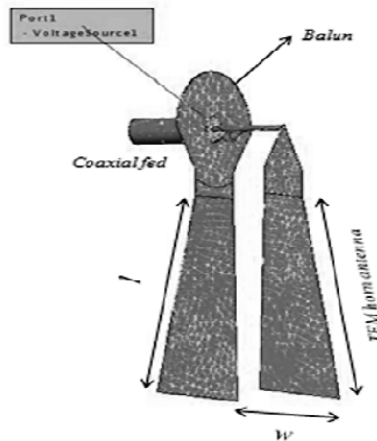


Figure.1. TEM horn with a coaxial feed and the balun.

II. ANTENNA DESIGN

The TEM horn antenna is a travelling-wave structure that consists of two metallic plates. To radiate electromagnetic waves, its flare angle, plate width and plate length must be properly chosen. Since the focus here is on applications of near-field microwave imaging in breast tumor detection, we to operate best when attached to a skin layer backed by a tissue layer with the properties presented in [7]. This influences the selection of the permittivity of the dielectric material used in the antenna structure and ultimately the antenna dimensions.

A microstrip-type balun is used as proposed in [8] and illustrated in Figure 1. The upper plate of the balun is connected to the coaxial core and its width is tapered away from the feed point. The lower plate is connected to the coaxial shield and its width is also tapered. Thus, the impedance of the balun gradually transits from that of the coaxial line to that of the parallel plates. The balun parameters influence significantly the impedance match of the antenna.

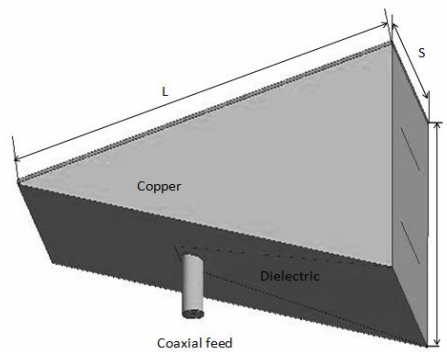


Figure.2. The TEM horn antenna with copper sheets on all outer surfaces expects the front aperture and a microwave absorbing sheet on the top surface.

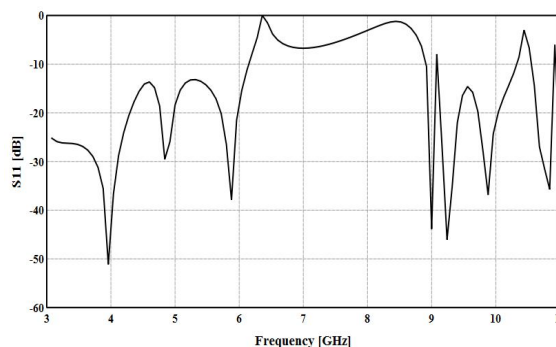


Figure.3. Simulated s11 of the Proposed Antenna

Figure.1. shows the two plates of the TEM horn which is fed by a coaxial cable via a balun ensuring matched transition to the parallel plates of the horn. The TEM horn is embedded in a solid dielectric medium with permittivity of 10 so that it matches closely the weighted average permittivity of the breast tissue of a radiological dense breast in the UWB frequency range. This ensures maximum coupling of the microwave power into the imaged body. The material of the dielectric medium is ECCOSTOCK HiK from Emerson Cuming Microwave Products [9] with and in the frequency range from 1 GHz to 10 GHz. Also, using such dielectric material eliminates the need for coupling liquids, which are often employed in microwave imaging of the breast.

In order to de-couple the antenna from the outside environment (except the front side), the antenna is shielded with patterned copper sheets. The shapes of the apertures on the top copper sheet have a crucial role in matching the impedance of the antenna to that of the coaxial cable. The top plate of the TEM horn is connected to the top copper sheet with a thin wire to suppress propagating modes between these two plates. The thin wire is along the same axis as the inner wire of the coaxial feed; see Figure.2. Then, a microwave absorbing sheet (ECCOSORB FGM-40, Emerson & Cuming Microwave Products) is glued on the top surface of the antenna (on top of the copper Sheet) to prevent the coupling of the antenna to the outside environment.

III. ANTENNA PERFORMANCE

Figure.3.shows the simulation of insertion loss of the designed antenna it shows that the good performance of the whole UWB antenna. Figure.4.shows the Set-up where the antenna is assumed to operate in air while its front aperture is attached to a two-layer medium with a skin layer and

TABLE I

DESIGN PARAMETERS OF THE ANTENNA

Parameter	Value(mm)
l	38
d	5
w	24
h	16
L	74
S	19
T	30

a tissue layer with the parameters shown in Figure.5. The design parameters have been optimized so that the antenna is matched to the 50- coaxial cable in the whole UWB frequency range. We show the performance of the antenna in the frequency domain

Simulations are performed with FEKO 6.0 [10].Table I shows the values for the design parameters of Figures 1 and 2. The parameters L, w, and h, which show the overall size of the antenna, are 74 mm, 19 mm, and 30 mm, respectively. In order to investigate the efficiency of the antenna through simulation computed as

$$e_c = \frac{P_f}{P_{in}}$$

P_f and P_{in} are the radiated power from the front aperture and the power fed to the antenna and P_f is computed as the flux integral of the real part of the pointing vector over the aperture.Figure.5. Shows the variation of efficiency versus frequency over UWB for the proposed antenna in [10].The efficiency over UWB for antenna 0.86. The main reason for this improvement in the efficiency for the proposed antenna is complete shielding of the antenna compared to the partial shielding of the antenna in [10].

IV. IMAGING SET-UP AND RESULTS

Breast tumor detection is one of the most researched application of microwave imaging.The imaging set-up consist of following advantage for breast imaging.(1) The imaging set-updoes not require coupling liquid (2)The image generation is simple.Figure.8. shows the breast model used in simulation.a flat tissue layer with the dimension of 50×50×31.5 is covered by skin and tissue layer and is Figure.9(a)-(d) shows the image obtained from at 3 GHz,7 GHz,

and 9 GHz. These image shows that the tumor simulants can be easily detected especially at 7 GHz and 9 GHz. It is observed that while the tumor simulants have been detected, their shape can not be determined. The tumor simulants are electrically too small.

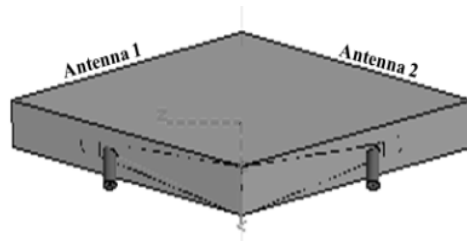


Figure.4. Attaching Two Antennas Front-front To Measure Efficiency

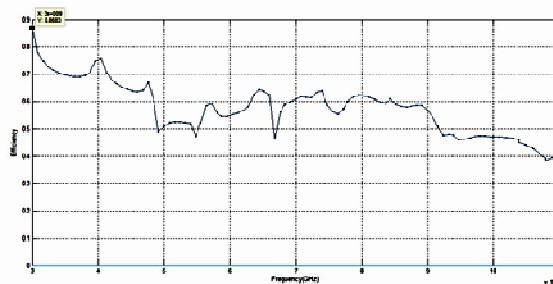


Figure.5. Efficiency of antenna

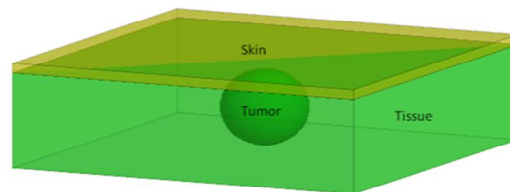
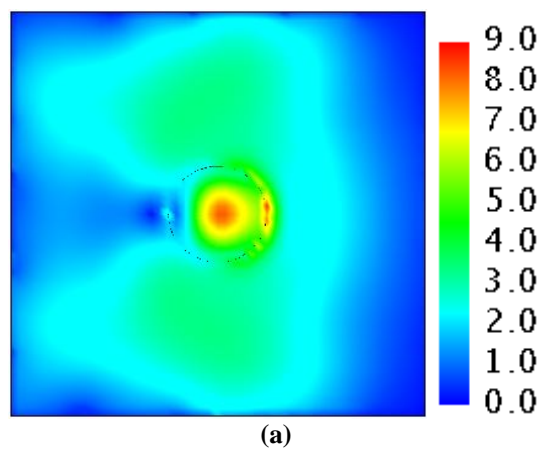


Figure.6. Breast model



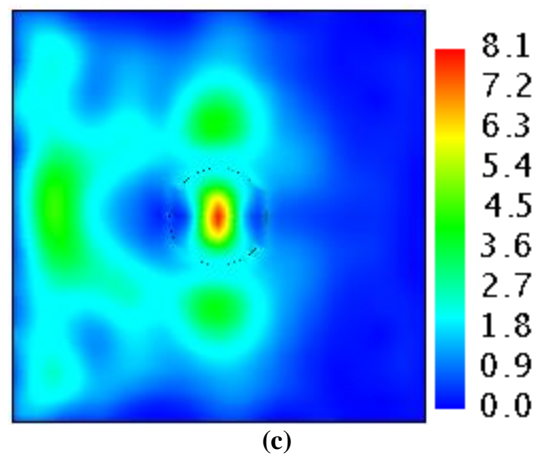
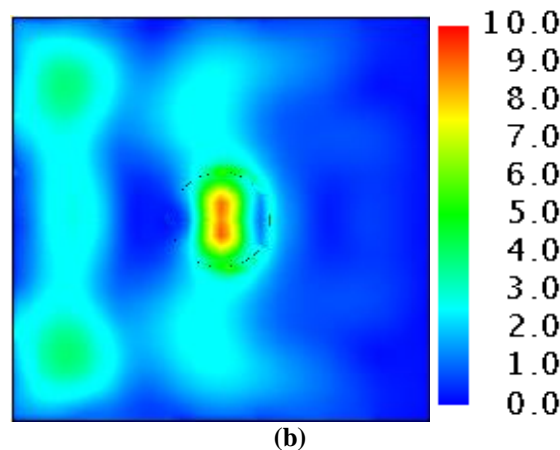


Figure.7.Simulated image at (a)3 GHz, (b)7 GHz and (c)9 GHz

V. CONCLUSION

A UWB TEM horn antenna is proposed for microwave imaging of the tissue. This ensures maximum radiation of microwave power toward the tissue. Also, the outer surface of the dielectric enclosure has been covered by copper sheet and a microwave absorbing sheet to decouple the antenna from surrounding interference. The investigated parameters of the antenna included dielectric constant and coupling efficiency. Excellent coupling efficiency is achieved that would increase the dynamic range of the raster scanning microwave imaging setup an effort has been made to achieve small size while maintaining good impedance match. Future work includes the study of other biological tissue models and the design of a suitable microwave imaging system

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