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High Gain UWB Horn Antenna for Concealed Metal Detection and Microwave Imaging Application

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Abstract: In this paper, the examination of recognition technology along with imaging system intended for the identification of metallic object inside or in the middle of two walls. The UWB frequency is used by ground–penetrating radar (GPR). The working mechanism of illuminating structure is centered on Time Domain Reflectrometry (TDR) by means of through wall imaging (TWMI). This paper describes an exceptional concept of recognition of barrier and distance between these barriers. The instrument Vector Network Analyzer (VNA) is used to produce very diminutive length pulses for to revealing the barrier, behind and between two barriers under examination with UWB probe antenna array system. The simulation outcomes of horn antenna have represented a massive potential for penetration in order to recognize a concealed metallic object positioned in the middle of two barriers and capable to estimate the gap width with well precision. Now it is considered to be an attractive expansion in the detection and imaging technology. For further improvement and to enhance the resolution of an image, improved quality filters have been industrialized.

Keywords: UWB; UWB Antenna Probe; SSL; VNA; TWMI; GPR; TDR and CST

1. INTRODUCTION

Detection of wall gap between two barriers by means of ultra-wide band antenna array for the formation of recognition and imaging system has been considered an optimum choice of many researchers. Microwave imaging system is being used extensively as an effective tool for detection.

For the sake of safety, presently many scientists are heavily involved in this current technology and generating better results as paralleled to ordinary electromagnetic recognition systems. They design rapid, stable and efficient tool for revealing of buried metallic objects.

The first metal detector was presented in 1920 by Fisher, which can be used as a very effective instrument for armaments detection till at the moment (Wikipedia, 2013). Imaging system, which has been playing a vital role in the development of security (Suksmono *et al.,* 2010) and medical technology accompanied by the development of new tendencies of GPR via UWB technology (Chun-lin *et al.,* 2010).

Especially in medical technology, we have need of precise detection and measurements of well-defined entities. For vibrant investigation, so this current technology is given a better impact to breast cancer diagnostic system (Zhou, 2010) enabling initial stage detection of breast cancer (Conceição *et al.,* 2009).

Recently, it has been used to help military forces to perceive the presence of any object or person behind the barrier (Yemelyanov *et al.,* 2009). Many mathematical examinations have been carried out for estimating through wall imaging (Lubecke *et al.,* 2007) including geometrical optics (GO) (C. Thajudeen *et al.,* 2012), ray tracking (Buonanno *et al.,* 2010) and 2D method for assessing moment (MoM) (Nikolic *et al.,* 2007).

In this study the predictable scheme of GPR and imaging systems (Shaikh *et al.,* 2017) which contained antenna sensor embedded with TDR (Elboushi *et al.,* 2013) has been discussed. The used of ultra-wide band horn antenna for metallic objects recognition (Shaikh *et al.,* 2018) and wall distance estimation, UWB and TWMI sensors equally cover projected working mechanism of UWB microwave imaging by (Chang *et al.,* 2005) depend on the transmission of small cycle interval pulses shaped by transmit continuous cycle wave signals at intermediate frequencies. It almost satisfies and covers the complete mentioned frequency range. The ranges produced by VNA both of the above systems are listed in **(Table- 1)**. The Time domain depiction of the small pulses be able to acquired by execution of Inverse Fast Fourier Transform on transmit signal as well as reflected back signals and it is used for image re-construction of scanned objects. All the simulations are carried out from computer simulation microwave studio (CST Microwave Studio, Ver. 2015).

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Table: 1 Operating Frequency

Name	Frequency Range	Applications
Low Frequency (LF)	30-300kHz	Time standards, Navigation
High Frequency (HF)	3-30MHz	Amateur radio
Very High Frequency (VHF)	30-300MHz	FM/TV broadcasting
Ultra-High Frequency (UHF)	to 3GHz	Cell phones,WLAN,GPR
Ultra-Wide Band Frequency (UWB)	3.1-10.6GHz	Detection and Imaging application
Extremely High Frequency (EHF) "MMW'	30-300GHz	Imaging and Detection application,5G mobile

2. ANTENNA DESIGN AND CONFIGURATION

The geometrical configuration of the proposed antenna is presented in **(Fig.1)**. The selection of antenna element for any recognition system is measured as mainly imperative design. The horn antenna accessible in (Elboushi *et al.*, 2014) is measured as a good alternative to be implement in this system (Elboushi, *et al.*, 2014) because of its better concert together with the high gain (Elboushi *et al.*, 2012) the wide operating frequency band that convene the whole ultra-wide band requirements and the low side lobe level.

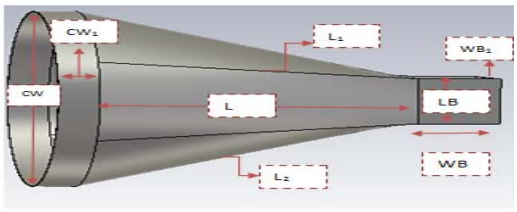

Fig.1: Geometrical Structure of the UWB Horn Antenna

Table 2: Optimized measurements for the UWB Antenna

Parameter	Dimension
L	50mm
L_1	50mm
L_2	50mm
CW(outer radius)	25.4mm
CW_1(thickness)	6.35mm
WB	12.7mm
LB	12.7mm
WB_1	25.4mm

The optimized measurements of UWB horn antenna are specified in **(Table 2)**. This structure present a substantial performance in a capacity of operating bandwidth from 3.5GHz to 9.7GHz and it is perceived that reflection coefficient (S_{11}) is below -10dB. As depicted in **(Fig. 2).**

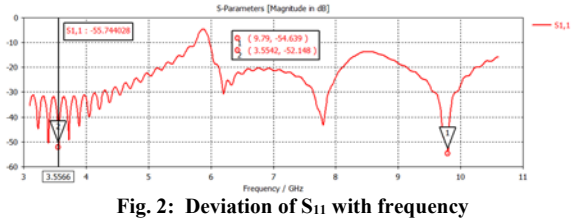

Fig. 2: Deviation of S_{11} with frequency

3. UWB-TWMI HIDDEN TARGET DETECTION SYSTEM

The recognition of concealed objects positioned in the middle of the two walls the UWB-TWMI detection is introduced. The channel 1 of the VNA (Elboushi *et al.*, 2013) is linked with input port of an array antenna system. In this system an absorber which is vertically mounted and retained behind the antenna to counter undesired reverse reflections. The used of power amplifiers along array elements intended for providing the sustainable power according to requirement of an antenna. An antenna array system is situated in pinpoint to look the primary barrier in y-z plane. Distance between the starting wall and antenna should be calculated vigilantly for functioning in far-field section of an antenna. An undesired reflection which are consider as a heavy obstacle specially in imaging systems. To counter this problem and center of attention an example which images the object via synthesized pulse recognized by means of sending constant signals at intermediate frequencies over the essential frequency bandwidth. As represented into **(Fig. 3).**

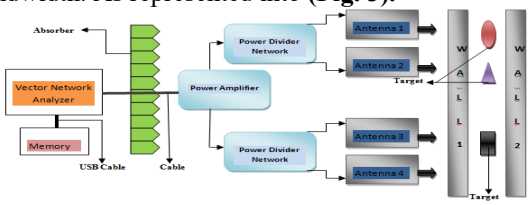

Fig. 3: Imaging System

4. HIDDEN OBJECT DETECTION ALGORITHUM

The concealed object algorithm initiates by analysis the S_{11} (Reflection Coefficient) via calibrated VNA. The assessment procedure is conceded out at every position in the region under assessment. The frequency domain representation is used to process the obtained data and the same domain representation is considered for barriers and object reflections *G(f).* The instrument VNA using the technique of inverse Fast Fourier Transform or with fixed regulations in time domain is used to obtained the reflection coefficient at every position *g(t).* For counter the effect of array system which contains antenna array, feeding network, cables, effects of connectors and decrement in clutter signals received from redundant objects, so take recognized reflection *g(t)* is subtracted from the array antenna system and reaction received in front of an absorber *a(t).* In an investigation the resultant signal *s(t)* just kept the information about the walls and the hidden targets. In the next stage the multiplication of *s(t)* by diminutive structure factor Kaiser window *k(t)* focuses that region which exist in between the two barriers and only the object details can be find through *m(t).* In a further part the image

restoration can be completed by correlating 2D data of the point location to the area under the *m(t)* curve (integration of *m(t)*). The flow chart of the concealed object recognition algorithm is representing **(Fig. 4).**

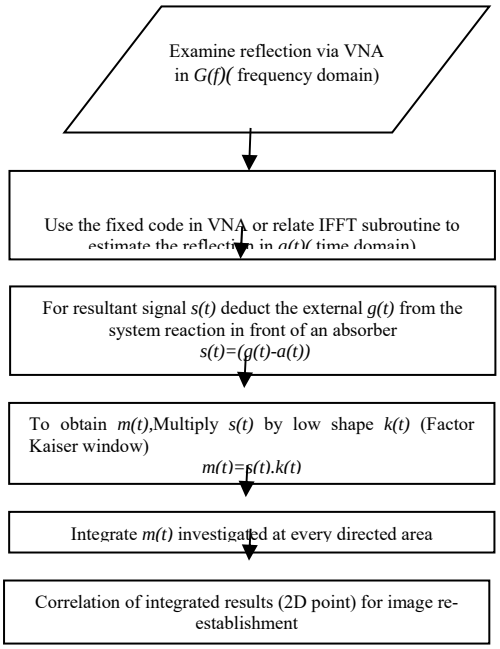

Fig. 4: Algorithm of Recognition System

5. SIMULATION ANALAYSIS AND DISCUSSION

A. 3D Radiation Patterns

The representation of radiation patterns in 3-dimention of an ultra-wide band horn antenna at different frequencies are depicted in **(Fig. 5)**. End fire radiation patterns have been observed by means of low side-lobe and back-lobe levels. A high gain is established at lower frequency side and gain is gradually increases with respect to frequency and utilize entirety ultra-wideband, for example, it is 11.13 dBi at 6.85GHz with good arrangement of radiated efficiency which is 2.98 dB and total efficiency around 2.50 dB.

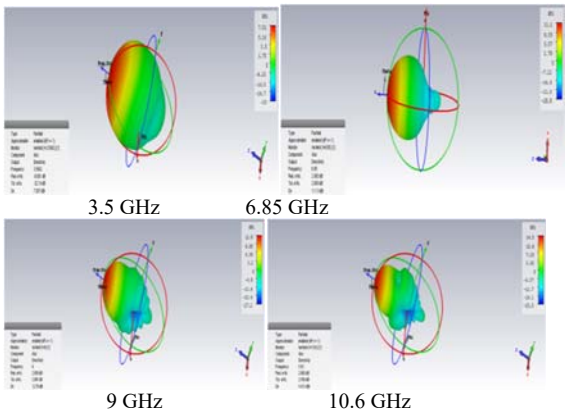

Fig.5: Far-field radiation patterns

B. 3D Polar Representation

The representation in 3-dimentional polar plots of ultra-wideband horn antenna has been derived through simulation software CST with special frequencies. At frequency of 6.85GHZ low side lobe with reasonable gain is achieved as exposed in Figure 6. We have observed a fine agreement of horn antenna among UWB detection system as well as microwave imaging application.

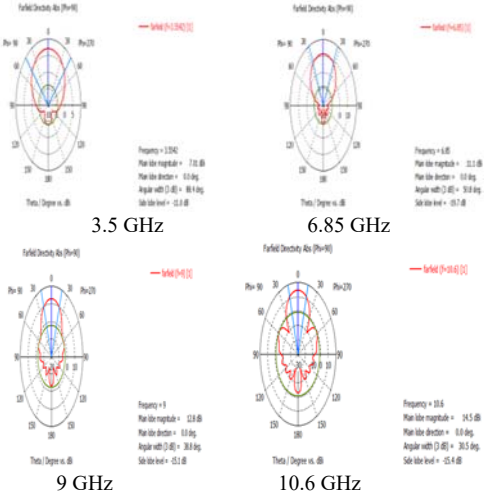

Fig. 6: 3D Polar Representation

C. Surface Current Distribution

The surface current distributions at different frequencies (3.5GHz, 5.5GHz, 6GHz and 6.85GHz) are presented in fig.7.From the different current distribution plot, it is observed that maximum amount of high current are present within range of 5.5GHz to 6GHz as shown **(Fig. 7)**, which is suitable for penetration and different imaging applications.

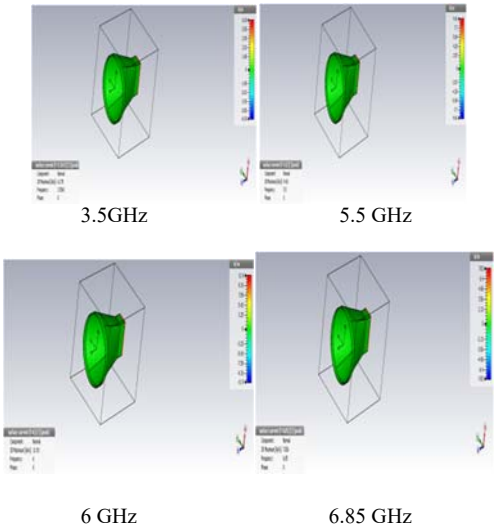

Fig. 7: Surface Current Distribution

6. CONCLUSION

GPR and TWI application has been deliberated fabricated and presented. An accurate UWB through wall metal detection system based on Step frequency synthesized pulse technique and TDR approach has been offered. The proposed antenna almost covered the UWB defined bandwidth. The investigational outcomes illustrate a well conformity with the simulation and intended array antenna system circularizes a enormous capability especially recognition of a metal between two walls and gap between them. The several simulation outcomes of UWB horn antenna have represented an improved diffusion power and achieved high gain with particular choice of defined frequency. The current distribution and 3-diementional radiation pattern of an antenna has been plot and it is clearly understand the antenna operating principal. The projected scheme has produced a high-quality performance and be able to be used in radar application and is a good contender of microwave imaging application.

7. RECOMMENDATION

The projected TWMI system is capable of using different UWB antenna. The UWB tapered slot antenna can also be an appropriate antenna for recognition and measurement of width between two walls.

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