A Review of Recent Patents on Ultra Wide Band (UWB) Antennas

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Abstract: In this article, recent patents on UWB antennas are reviewed; different geometries, design parameters and their experimental results are discussed. Several types of UWB antennas including special horn, patch and array antennas in recent patents are explained together while comparing their measured return loss, gain and radiation patterns. Projections to the future developments of UWB antenna technology are also given.

Keywords: Ultra wide band (UWB) antenna, patch antenna, horn antenna, Vivaldi antenna.

1. INTRODUCTION

Ultra Wide Band (UWB) systems are defined as the systems which use electromagnetic signals having greater than 500MHz bandwidth or 20% bandwidth around its center frequency [1]. UWB systems provide high data rates for wireless communications, accurate radar and geolocation systems [2, 3]. Since the allocation of unlicensed various frequency bands (0-960 MHz, 3.1-10.6 GHz, 22-29 GHz) to UWB systems [1] by Federal Communications Committee (FCC), research on UWB has gained much attention by academia and industry [1-19].

High data rates and low power requirements of UWB systems make them feasible for portable commercial applications. In various applications, UWB technologies utilize different modulation methods such as orthogonal frequency division multiplexing (OFDM) or pulse-based methods. It is apparent that the antenna requirements of UWB systems would vary due to the utilized modulation types. Such requirements for MB-OFDM and pulse systems are summarized in [2] and listed in Table **1**. As clear from Table **1**, there are many requirements for designing UWB antennas depending on the modulation scheme. Due to the wide bandwidth, the antenna parameters become frequency dependent in UWB systems, thus complicating the analysis and design.

There are various patents filed on UWB antennas with enhancing different properties of antennas such as being omni-directional or employing microstrip type, horn geometry, or so. In this paper, we review patents on UWB antenna technology and various antenna designs together with their parameters.

2. SELECTED FILED PATENTS ON UWB ANTENNAS

There are different geometries for UWB antennas in the literature. The key factor of the proper geometry selection is to minimize the gain and the phase errors exhibited at different frequencies and also to stabilize the antenna parameters over the whole bandwidth while maintaining low cost feature [11]. For example, if the transverse electro-magnetic (TEM) antenna with horn antenna geometry of Fig (**1**) is considered, it is filed as the patent "Compact, High-Gain, Ultra-Wide Band (UWB) Transverse Electromagnetic Planar Transmission-Line Array Horn Antenna" [11], it is argued that, the utilization of binary-tree design resulting to multiple number of paralleled horns and radiation apertures, the phase error is minimized. Fig. (**2**) shows measured continuous wave directivities (gains) of conventional TEM antenna (solid line) and the reported equivalent two-stage

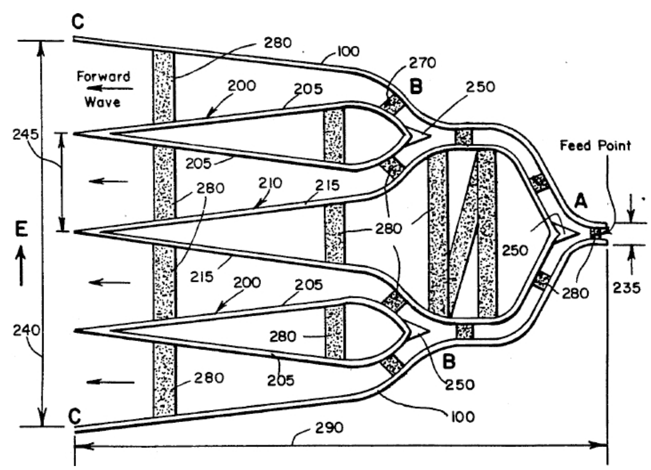

Fig. (1). UWB horn antenna [11].

binary-tree TEM horn antenna (dashed-line). The binary-tree horn antenna employs 35% smaller aperture area than the conventional TEM antenna [11]. The resulting advantages of this design are; a stronger and less distorted, radiated waveform with much higher gain and directivity over most of its intended frequency range. Also, the ability to output a given level of short-pulse, UWB power in a more compact, smaller antenna than a conventional horn antenna. The disadvantages of this configuration are that it is harder to build than a conventional horn antenna and structure losses at the lowest frequencies cause significant loss of gain in that region [11].

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Table 1. Comparison of Requirements for UWB Antennas Using Different Schemes [2]

	Modulation scheme	
Constituent	**MB-OFDM**	**Pulse-based**
Electrical	• wide impedance bandwidth covering all sub-bands • steady directional or omni-directional radiation patterns • constant gain at directions of interest • constant desired polarization • high radiation efficiency	• wide impedance bandwidth covering the bandwidth where most of the energy of the source pulse is concentrated • steady directional or omni-directional radiation patterns • constant gain at directions of interest • linear phase response • constant desired polarization • high radiation efficiency
Mechanical	• small size/low profile/embeddable • low cost (materials/maintenance/fabrication)	

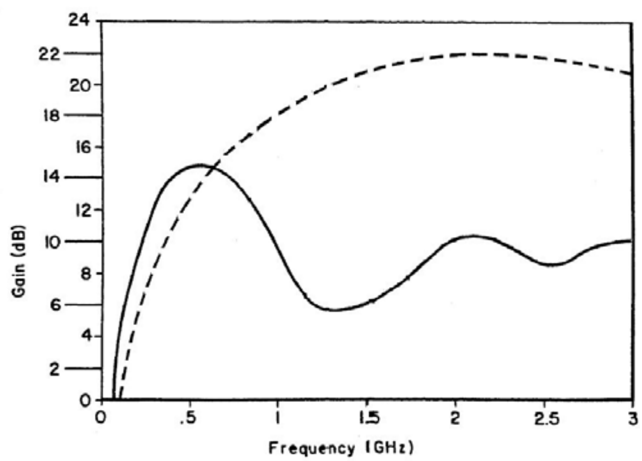

Fig. (2). Measured gains of conventional horn antenna and UWB horn antenna [11].

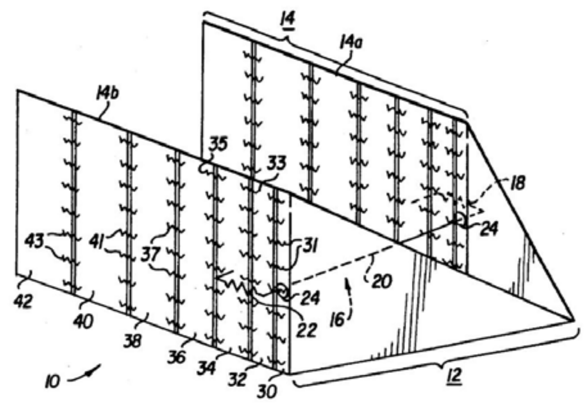

Fig. (3). Low VSWR UWB antenna [12].

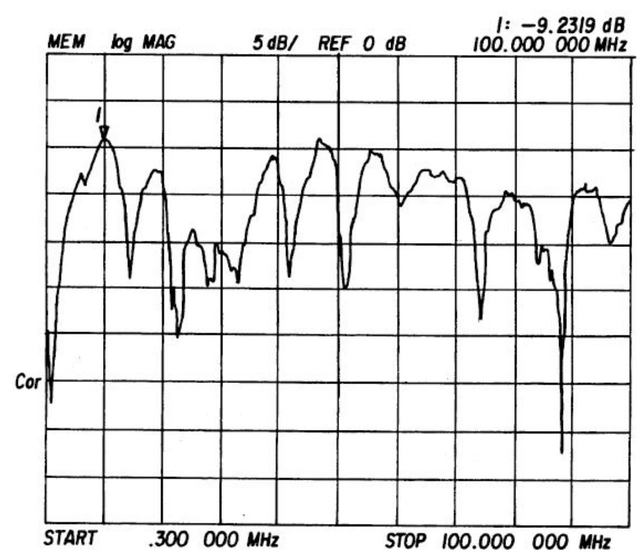

Fig. (4). Measured S_{11} of UWB antenna [12].

In another patent entitled "Low VSWR High Efficiency UWB Antenna", which describes an antenna that minimizes losses while maintaining high return loss which has a particular application with impulse radar systems is presented [12]. The diagram showing the implementation of the proposed antenna is shown in Fig. (**3**). The operation of the antenna is accomplished by providing a network structure across the output of TEM horn. The network at the output of the horn consists of two parts; a resistively plated section and a shunt network of a wire connected in series with a resistor at each end of the antenna. The duty of the parallel plate is to launch the high frequency waves without reflecting any electromagnetic energy, and the shunt network behaves like a distributed inductance having resistive loads such that low frequency waves are vanished by the antenna. The measured return loss (S_{11}) of the antenna is given in Fig. (**4**) which was measured using a network analyzer [12]. As it can be seen from Fig (**4**), energy given to the antenna is either terminated or radiated. On the other hand, UWB antennas have to fulfill the requirement of having a phase center that does not change with frequency so that radiated and received waveforms are not distorted. In most of the antennas, the antennas emit high and low frequency components from different portions of the geometry, so the radiated waveforms are highly distorted, which is not suitable for impulse radio applications [13]. The correction of this distortion requires the use of RF blocks and signal processing tools, thus resulting in a cost-ineffective system. The distortions in horn UWB antennas are lower than the other geometries; however, they require a larger geometry. In the patent named "Ultra Wide Bandwidth (UWB) Antenna and Feeding Circuit" [13], a small omni-directional dipole antenna that radiates energy with minimal reflection and distortion is filed. The proposed antennas use elliptical elements and having feed structures of special geometries to inject the waveforms which are given in Fig. (**5**) and Fig. (**6**), respectively. The novel coupling structure permits better transformation in the feed region compared to the previously reported structures. The feeding part constitutes an impedance matching region that can be varied directly. That is to say, this antenna completes the two basic challenging requirements of UWB antenna having an omni-directional pattern (having more circular antenna elements) and having good impedance matching (having more eccentric elements). In fact, the latter requirement is realized by the so-called "feeding part of the antenna" rather than antenna elements, which is the main goal of this patent [13].

A recent invention, "Broadband Compact Slot Dipole/ Monopole and Electric Dipole/Monopole Combined Antenna", proposes a broadband compact antenna using an electric dipole/monopole coupled or connected in parallel to a slot antenna [14]. The perspective view of this patent is given in Fig. (**7**). It comprises of two antenna parts, slot and dipole antenna elements, which are shown in Fig. (**8a**) and Fig (**8b**), respectively. The slot antenna may be flat square or rectangular conducting sheet with a slot of various shapes and fed from the center by a coaxial line. The monopole or dipole antenna of the forms wire, flat strip or other shapes is put close to the slot to increase bandwidth [14]. The return loss, impedance chart and radiation pattern of the UWB antenna of Fig. (**7**) are shown in Fig. (**9**), Fig. (**10**) and Fig. (**11**), respectively.

Also, an UWB patch antenna which has an upper dielectric, a lower dielectric and a conductive pattern sandwiched between the upper dielectric and lower dielectric is presented in [15]. The front and side views of this antenna are shown in Fig. (**12a**) and Fig. (**12b**), respectively. The conductive part, which is comprised of a reversed triangular portion having a right-hand tapered part and a left-side tapered part widening from the feeding point at a predetermined angle toward a right-hand side and a left-hand side. The rectangular part of the conductive layer has a base side being in contact with the reversed triangular region. The predetermined angle is between 40° and 60° and a slit on the rectangular region may be added. The bandwidth of the antenna is determined by the predetermined angle [15]. Fig. (**13**) shows the measured S_{11} of the antenna for various predetermined angles. In this antenna, optimal results are obtained especially at $\theta=45^o$ and $\theta=50^o$.

An electrically small planar UWB antenna that can be arrayed in 2D or 3D is filed in [16]. The antenna can be implemented on the dielectric substrate with feeding circuits to eliminate losses of the transmission lines, thus providing an integrable solution. This antenna with low voltage standing wave ratio (VSWR), symmetrical pattern, mass producible without line losses is designed using a tapered clearance area (clearance slot) within a sheet of conductive material, where the feed is with the clearance area [16]. The clearance area may have different shapes and may be filled with various dielectric materials such as fiberglass, air, Teflon or FR4. The presented antenna structure utilizing an oval clearance shape is given in Fig. (**14**). The E and H field patterns of this antenna are given in Fig. (**15**).

Another small and planar UWB antenna structure is reported in [17] that is mostly suitable for Wi-Fi communications of laptops. The antenna is given in Fig. (**16**). This antenna has a 270 degrees of coverage and implemented on a dielectric substrate with two Vivaldi horn radiators attached to substrate and a single radiator coupled to Vivaldi radiators. This antenna structure can be easily attached to portable devices as shown in Fig. (**17)**. The communication error rates are also given in Table **2** [17], when conventional dipole and the newly introduced antennas are used for data transmission. As it can be seen from Table **2**, the error rates are decreased by using this antenna rather than conventional antenna especially for central and right directions.

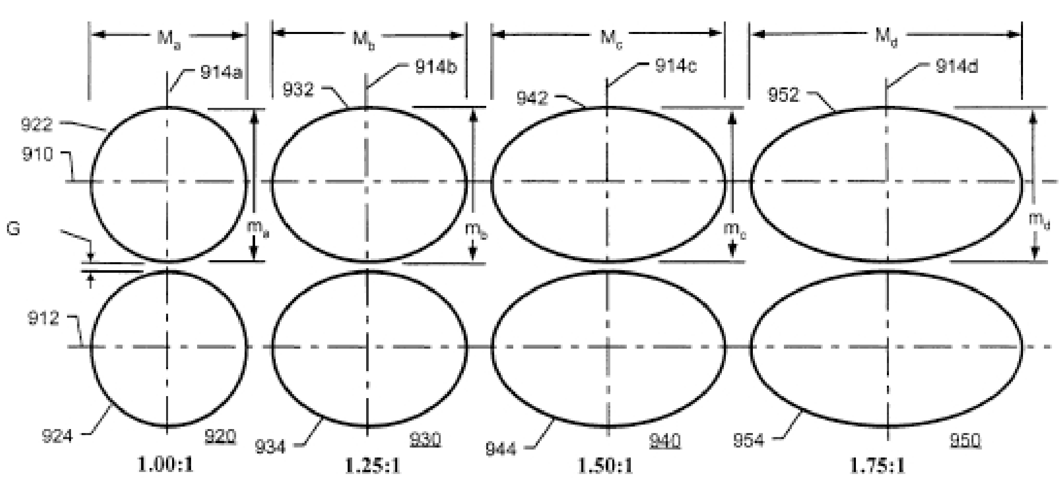

Fig. (5). The front view of UWB antenna [13].

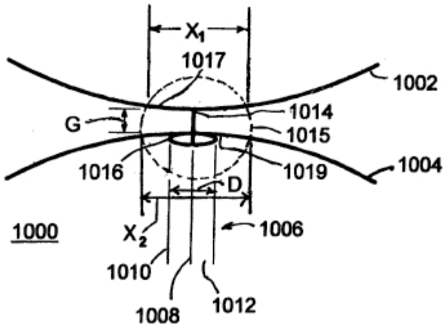

Fig. (6). Side view of UWB antenna [13].

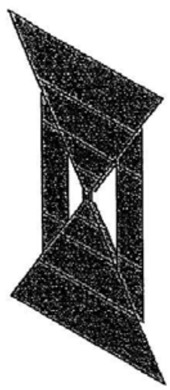

Fig. (7). Broadband antenna [14].

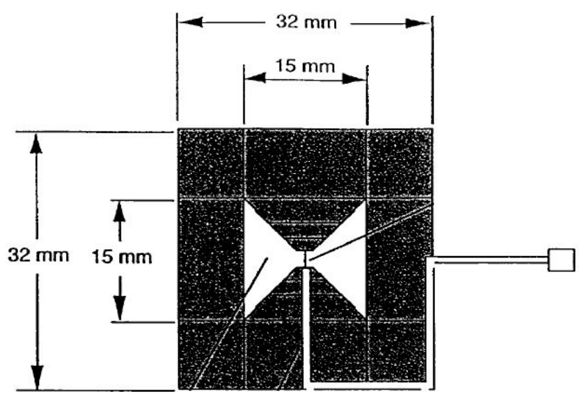

Fig. (8a). First element of the antenna [14].

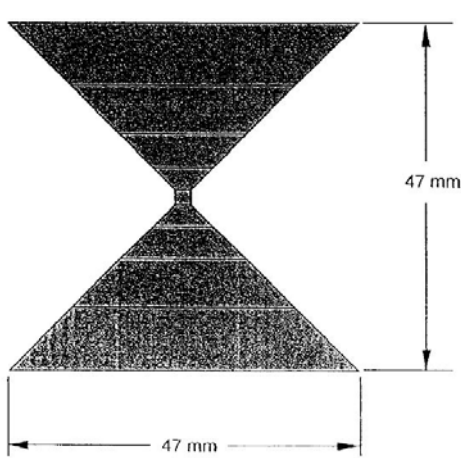

Fig. (8b). Second element of the antenna given [14].

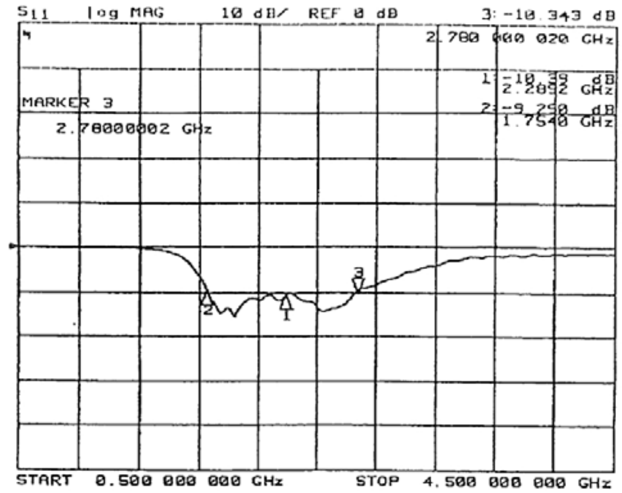

Fig. (9). Measured return loss of the UWB antenna [14].

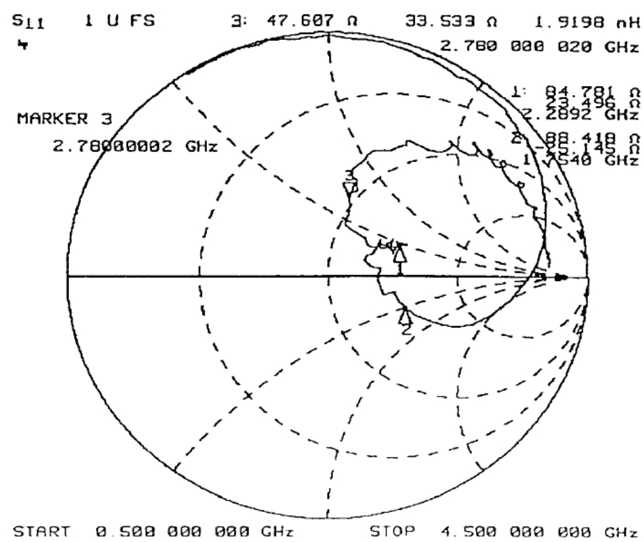

Fig. (10). Measured impedance chart of the UWB antenna [14].

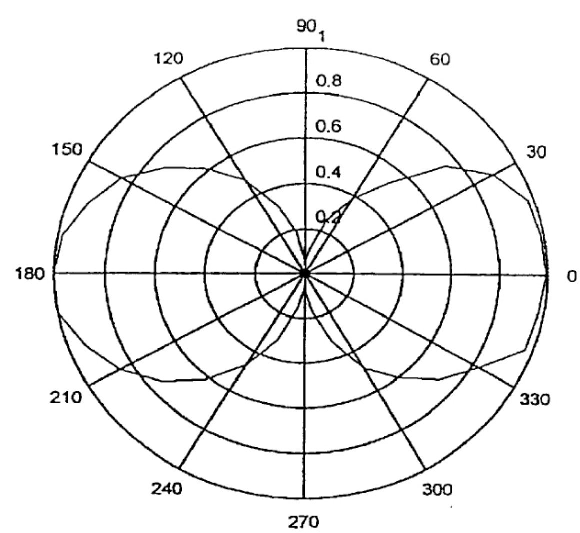

Fig. (11). Measured radiation pattern of the UWB antenna [14].

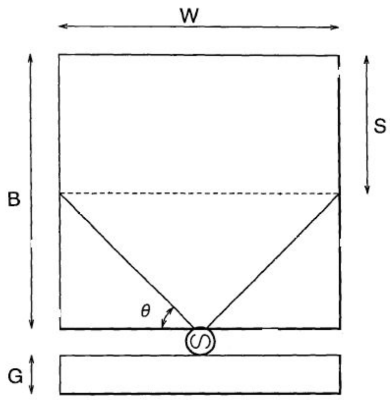

Fig. (12a). First element of the antenna [15].

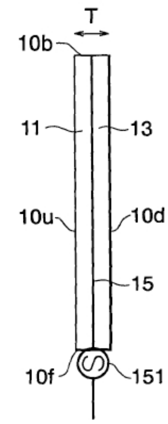

Fig. (12b). Second element of the antenna [15].

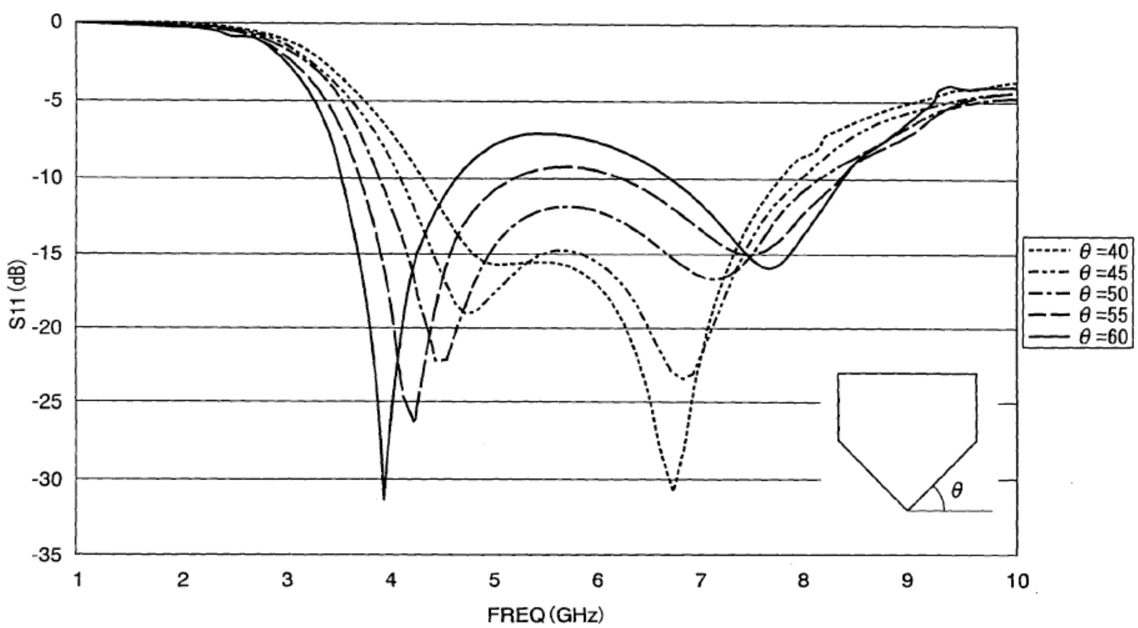

Fig. (13). Measured S_{11} of UWB antenna [15].

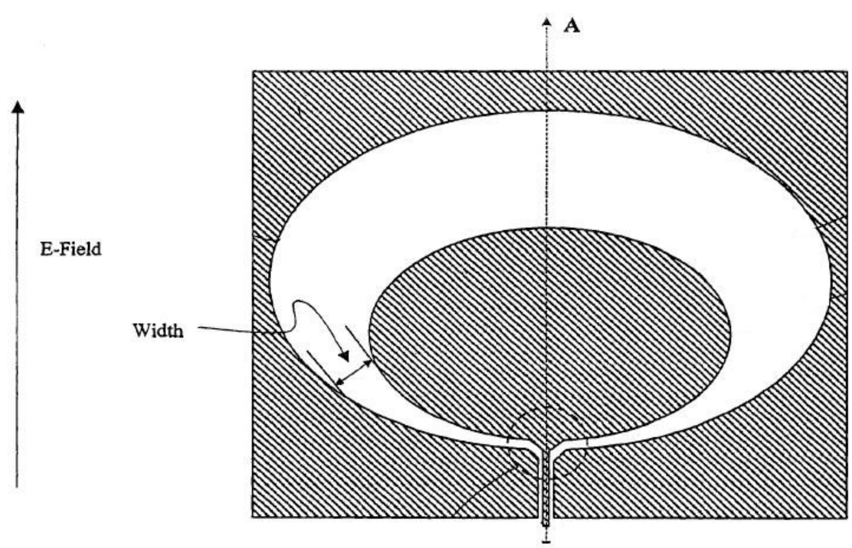

Fig. (14). Small UWB antenna [16].

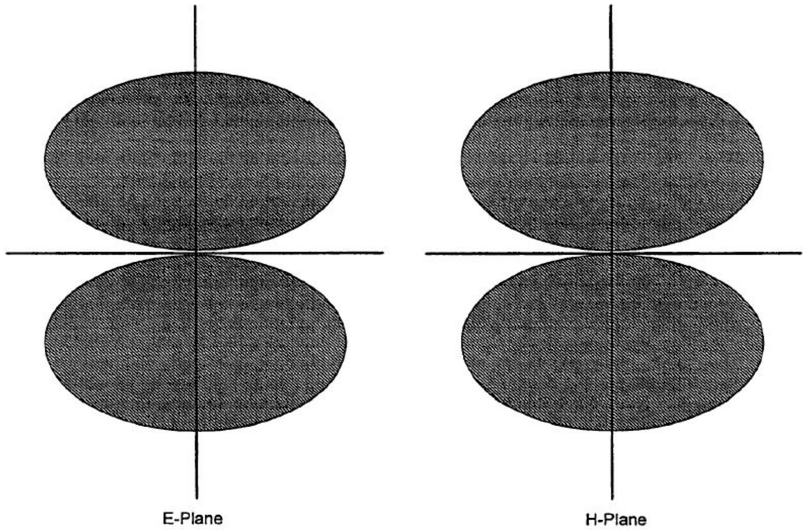

Fig. (15). E and H field patterns of the antenna [16].

Table 2. Communication Error Rates of the Antenna Reported in [17]

	Left direction	Left 45 degrees direction	Central direction	Right 45 degrees direction	Right direction
Conventional antenna	0.13%	1.13%	0.83%	1.77%	39.71%
Presented invented antenna	0.33%	0.45%	0.0357%	0.0215%	0.0371%

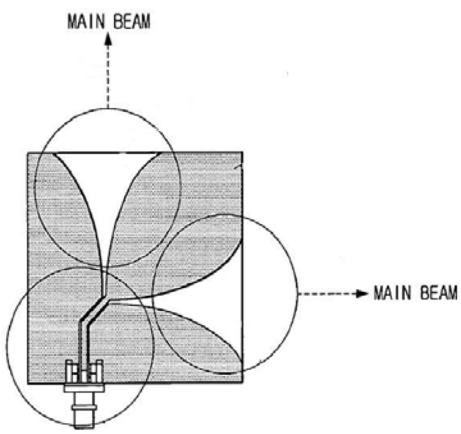

Fig. (16). Compact UWB antenna [17].

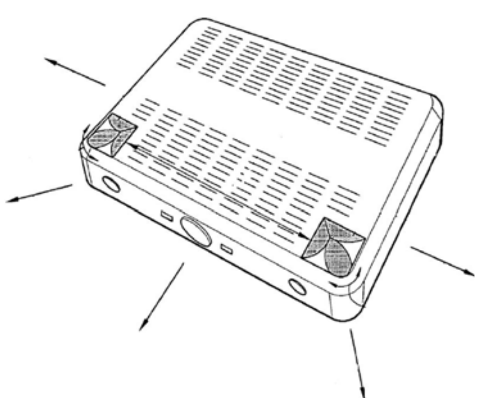

Fig. (17). Application of the compact UWB antenna [17] in a laptop.

Another UWB antenna with unidirectional radiation pattern is presented in [18]. The geometry of this antenna is shown in Fig. (**18**). This antenna provides electromagnetic radiation perpendicular to antenna plane. The UWB antenna system is composed of a feeding point, a dipole part and a loop section. The feeding can be implemented as microstrip lines, or coplanar waveguides [18]. The VSWR and gain graphics of the antenna are shown in Fig. (**19**) and Fig. (**20**), respectively.

The last antenna structure to be given is shown in Fig. (**21**) [19]. This antenna is also a microstrip-type antenna that is suitable for laptops or any other mobile devices with preferably light weight and low production cost features. The patch can be of different shapes including circle, triangle, rectangle, etc. The key point of this invention is to insert an air gap slot in the patch to control the bandwidth. Also, double matching stubs are implemented between patch and feeding point to achieve the best impedance matching performances. Stubs are made of microstrip by taking the advantage of being on circuit board material. The measured return loss of the invented antenna structure is given in Fig. (**22**). As it is seen from Fig. (**22**), the antenna exhibits a large bandwidth more than 8 GHz, thus being suitable for UWB communication systems.

3. CURRENT & FUTURE DEVELOPMENTS

Several UWB antenna designs with various properties are discussed in this paper. The UWB antenna research is mostly directed by the short range high data rate low power communication systems such as laptops and personal digital

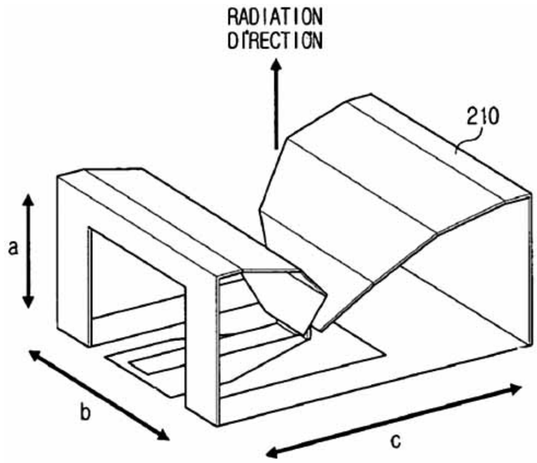

Fig. (18). Unidirectional UWB antenna [18].

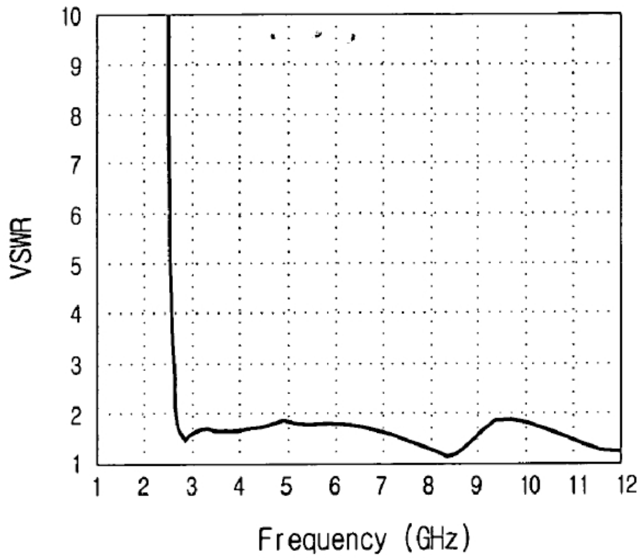

Fig. (19). Measured VSWR graphics of the UWB antenna [18].

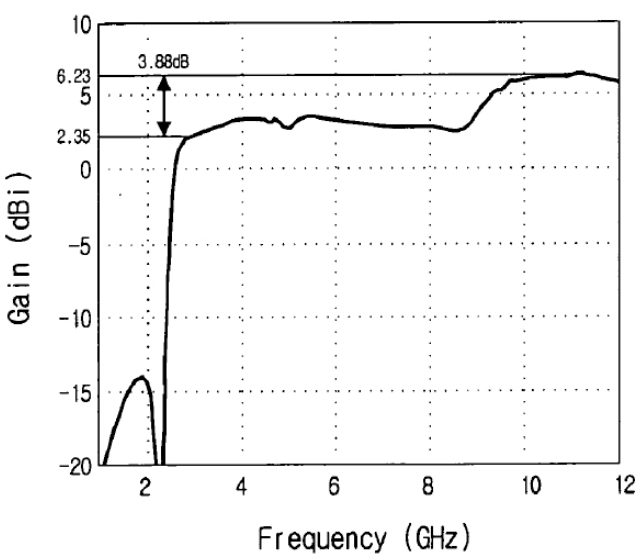

Fig. (20). Measured antenna gain of the [18].

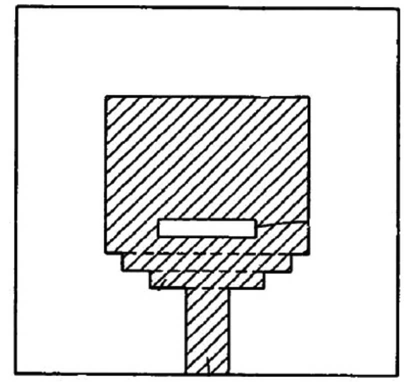

Fig. (21). Compact patch antenna [19].

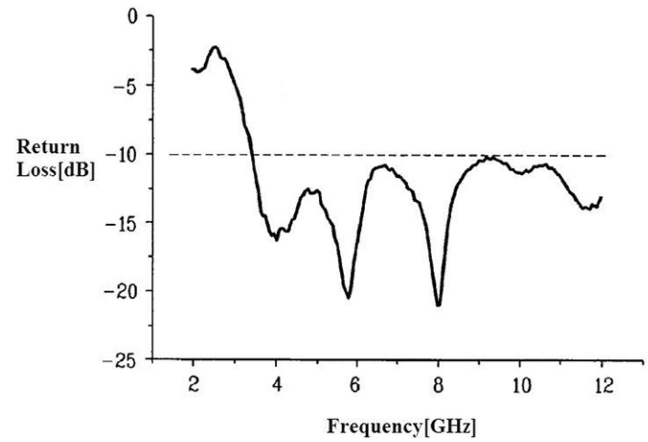

Fig. (22). Measured return loss of the UWB antenna of [19].

assistants (PDAs). UWB antenna designs have continuously evolved to be more compact and more cost-effective since the last fourteen years [11-19]. Currently, state of the art UWB antennas comprise the most of the unlicensed permitted band (i.e. 3.4 GHz to 12 GHz) with a negligible group delay (2ns) with a minimum gain of 6.67dBi [19]. Future developments of UWB antennas are expected to have challenge on the modeling, simulation and design which have a complicated nature due to the wide bandwidth and highly frequency dependent parameters. Optimization of UWB antennas will include both technical and economical aspects, mostly will be influenced by the channel coding. Also, 2D and 3D UWB antenna arrays will have application areas especially in impulse GRP (ground penetrating radar) and UWB patch antenna array systems on a single substrate are expected to gain much interest.

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