Simulation of Wideband Inverted Suspended Patch Antenna

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Abstract - The radio spectrum is finite, but bandwidth utilization for wireless communication is increasing exponentially due to the emergence of new standards driven by the rapid growth in information services provided by the Internet. Therefore, there is a need for new technology that can open a new door to wireless communication. Ultra wideband (UWB) technology based on the use of very narrow pulses on the order of nanoseconds, covering a very wide bandwidth in the frequency domain, could be a possible solution to this problem. UWB has had a substantial effect on antenna design. This paper presents a wideband inverted suspended patch antenna design for UWB applications. The designed antenna is simulated using Advanced Design System (ADS). For initial result, this antenna obtains 5 GHz of bandwidth at frequency 4.5 GHz to 9.5 GHz with maximum VSWR of 2.

1. Introduction

Ultra wideband is a wireless technology developed to transfer data at high rates over very short distances at very low power densities and an area of immense current interest, with numerous potential applications. A UWB frequency allocation has been made by the US Federal Communication Committee (FCC) between 3.1 and 10.6 GHz at a limited transmit power of –41.3 dBm/MHz, and work is underway by regulatory bodies to achieve the same in Europe and Asia [1].

UWB has had a substantial effect on antenna design. UWB antennas are specifically designed to transmit and receive very short time durations of electromagnetic energy. Currently modern telecommunication systems require antennas with wider bandwidth and smaller dimensions than conventionally possible. This has initiated antenna research in various directions, one of which is by using UWB antennas. Some research projects on UWB antenna have been reported in recent years [2]-[6].

Among the most important advantages of UWB technology are low system complexity and low cost. UWB systems can be made nearly "all-digital", with minimal RF or microwave electronics. Because of the inherent RF simplicity of UWB designs, these systems are highly frequency adaptive, enabling them to be positioned anywhere within the RF spectrum. This feature avoids interference to existing services, while fully utilizing the available spectrum.

This paper presents a wideband inverted suspended patch antenna design for UWB applications. The designed antenna is simulated using Advanced Design System (ADS) simulation software. The basic structure of this antenna consists of a rectangular conductive plate and foam with inverted suspended configuration as shown in Figure 1. This configuration is chosen in order to obtain broad bandwidth.

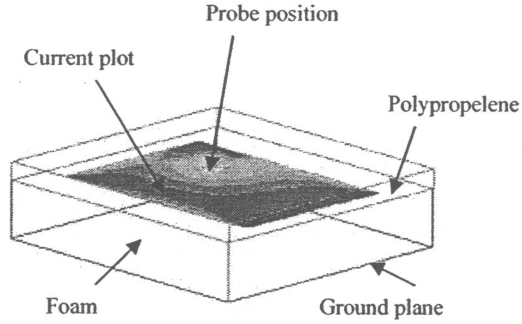

Figure 1: Inverted suspended configuration of UWB antenna (3D View)

2. UWB Antenna Requirements

There are two vital design considerations in UWB radio systems. Firstly, radiated power density spectrum shaping must comply with certain emission limit mask for coexistence with other electronic systems [7]. Another consideration is that the design source pulses and transmitting/receiving antennas should be optimal for performance of overall systems [8]. Emission limits will be crucial considerations for the design of source pulses and antennas in UWB systems.

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For many years, the idea of an UWB antenna that would allow stable pattern control over many frequency decades seemed elusive at the best. UWB antennas require the phase centre and voltage standing wave ratio (VSWR) to be constant across the whole bandwidth of operation. A change in phase centre may cause distortion on the transmitted pulse and worse performance at the receiver. The antennas are significant pulse-shaping filters. Any distortion of the signal in the frequency domain (filtering) causes distortion of the transmitted pulse shape, thereby increasing the complexity of the detection mechanism at the receiver [9].

Other consideration that must be taken into account is group delay. Group delay is given by the derivative of the unwrapped phase of an antenna. If the phase is linear throughout the frequency range, the group delay will be constant for the frequency range. This is an important characteristic because it helps to indicate how well a UWB pulse will be transmitted and to what degree it may be distorted or dispersed. It is also a parameter that is not typically considered for narrowband antenna design because linear phase is naturally achieved for narrowband resonance.

A nearly omnidirectional radiation pattern is desirable in that it enables freedom in the receiver and transmitter location. This implies maximizing the half power beamwidth and minimizing directivity and gain.

Conductor and dielectric losses should be minimized in order to maximize radiation efficiency. High radiation efficiency is imperative for an UWB antenna because the transmit power spectral density is excessively low. Therefore, any excessive losses incurred by the antenna could potentially compromise the functionality of the system. The physical constraints require compatibility with portable electronic devices. As such, a small and compact antenna is required.

3. Wideband Inverted Suspended Patch Antenna

Extremely wideband antennas intended for UWB applications have to be designed very carefully with all the antenna parameters to be taken into consideration. The design of the UWB antenna involves calculating the dimension of rectangular antenna, simulating and optimising the design using ADS Simulation Software. Other geometries such as triangular, circular and elliptical are considered for the next simulation.

3.1 Numerical Analysis

There are many methods for broadening the bandwidth of antennas. One of methods is by increasing the substrate thickness, which is applied in this preliminary antenna design.

From [10], the bandwidth increases with an increase in substrate thickness h and decrease in effective dielectric ε_r. The effect of the increase in h and the decrease in ε_r can also be realized using the suspended-microstrip configuration or inverted suspended-microstrip. The suspended configuration consisting of two dielectric layers can be replaced by a single layer of equivalent dielectric constant ε_q of thickness $\Delta + h$, where Δ is gap spacing.

Parameters value for this proposed UWB antenna is summarized in Table 1.

Table 1: Parameters value for wideband inverted suspended patch antenna

	Parameters	Value
Foam	Δ	0.7 cm
	ε_r	1.07
	Tan δ	0.0009
Polypropelene	h	0.167
	ε_r	2.18
	Tan δ	0.003

Antenna dimension calculation can be derived from equation 1 to 4 as below [10]:

$$L_e = L + 2\Delta L \quad (1)$$

$$\Delta L = \frac{h}{\sqrt{\varepsilon_e}} \quad (2)$$

$$L_e = \frac{15}{f_0\sqrt{\varepsilon_e}} \quad (3)$$

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (4)$$

Where L_e, ΔL is effective length and extension length respectively in cm, f_0 is in gigahertz. By substituting the given parameters from Table 1 into the equations thus results antenna dimensions such width W of 2.05 cm with length L of 1.583 cm.

As shown in Figure 1, the patch is fabricated on one side of the dielectric substrate, and it is suspended in foam gap. An inverted suspended configuration, the top dielectric substrate acts as a protective layer with the current plot. The preciseness on the construction of the feedpoint is a major concern, as it will affect the performance of the antenna. Antenna dimensions and feed position are optimised using optimisation ADS software to obtain a broader bandwidth.

3.2 Simulation Results

The aim of this design is to obtain the bandwidth of 7.5 GHz. The effect of feed point location to centre frequency and gap spacing (Δ) was also studied. For feed location of x = 0.417 cm and y = -0.268 cm from the centre of the patch was found to be optimum for minimal effects on the input bandwidth. For initial result, this antenna obtains 5 GHz of bandwidth at frequency 4.5 GHz to 9.5 GHz as shown in Figure 2 with maximum VSWR of 2.

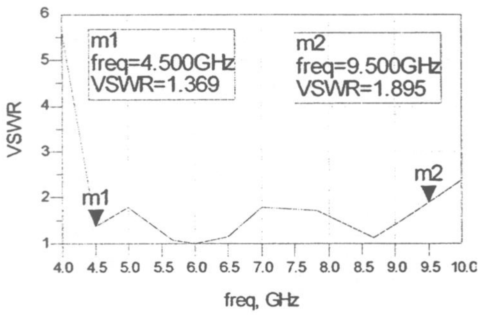

Figure 2: Simulated result of VSWR for initial antenna design

Gain, directivity and radiated power are described in Figure 3 and Figure 4, respectively. Both graphs are in 2D plot. For the planar cut, the angle phi, which is relative to the x-axis, is kept constant. The angle theta, which is relative to the z-axis, is swept to create a planar cut. Theta is swept from 100 to –100 degree. As shown in Figure 3, the gain is 9.124 dB with radiated power of 0.002 watts (see Figure 4).

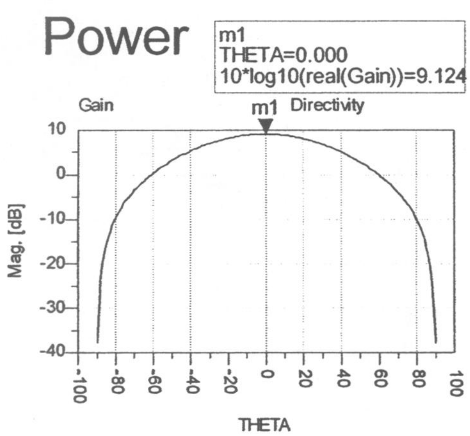

Figure 3: Gain and directivity simulation result

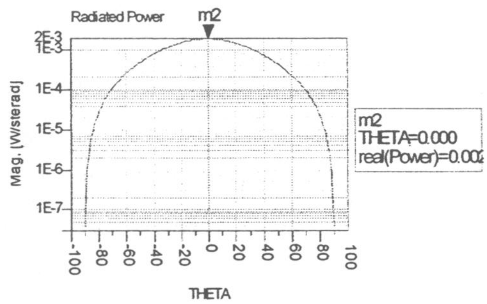

Figure 4: Radiated power simulation result

4. Summary

This paper presents the wideband inverted suspended patch antenna design for UWB application using ADS simulation software. Some parameters such bandwidth, gain, directivity, and radiated power are determined in order to ensure the antenna's performance meet the international standards (FCC and ETSI). From simulation result, the bandwidth of 5 GHz is achieved. This bandwidth is smaller than the required bandwidth of 7.5 GHz defined by FCC. Gain and directivity are 9.12 dB with radiated power of 0.002 watts. These results are still higher than normally UWB gain value of 4.2 dB [11].

Since the bandwidth doesn't meet the FCC requirement. Optimisation bandwidth performance and antenna development are proposed for future work.

References

[1] Kazimierz Siwiak and Debra Mc. Keown, *Ultra Wideband Radio Technology*, John Wiley & Sons, Ltd., 2004.

[2] Kamya Y.Y. and Ryuji Kohno, "Ultra Wideband Antenna," *IEEE Radio Communications*, June 04.

[3] Hans Gregory Schantz, "A Brief History of UWB Antennas," *IEEE A&E System Mag.*, April 04.

[4] Albert K.Y. Lai, et al, "A Novel Antenna for Ultra Wideband Application," *IEEE Transactions on Antennas and Propagation,* vol. 40, no.7, July 92.

[5] Anatoliy Boryssenko, "Time Domain Studies of Ultra Wideband Antennas,"in *Proceedings of the 1999 IEEE Canadian Conference on Electrical and Computer Engineering Conference Centre,* Edmonton, Alberta, Canada, May 1999.

[6] Debatosh Guha, "Broadband Design of Microstrip Antenna: Recent Trends and Developments," *Facta Universitatis, series: Mechanics, Automatic Control and Robotics,* vol. 3, pp. 1083-1088, 03.

[7] Federal Communications Commission (FCC), "First Report and Order, ET Docket 98-153, FCC 02-48," *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*. April 2002. http://www.fcc.gov.

[8] Zhi Ning Chen, et al, "Considerations for Source Pulses and Antennas in UWB Radio Systems," *IEEE Transactions on Antennas and Propagation*, vol. 52, no. 7, July 2004.

[9] Siwiak, "Impact of UWB Transmission on Generic Receiver," in *Proceedings of the 2001 IEEE Vehicular Tech. Conference (VTC)*, May 2001.

[10] Girish Kumar and K.P. Ray, *Broadband Microstrip Antenna*, Artech House Inc., 2003.

[11] Hyungkuk Yoon, et al, "A Study on The UWB Antenna with Band Rejection Characteristic," *IEEE Radio Communications*, 2004.