A Review on Rectangular Microstrip Patch Antennas for Ultra-Wide Band Applications

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Abstract:

As the Federal Communications Commission (FCC) has approved the license free use (for short range & low power) of Ultra-Wide Band (3.1 GHz to 10.6 GHz) on 14th February, 2002, the UWB applications has shown the myriad of challenges and opportunities to researchers for designing of antennas for UWB applications. There are several challenges in designing of UWB Patch antenna. The first and primary requirement is that the proposed antenna should operate in specified UWB frequency band i.e. 3.1 GHz to 10.6 GHz completely. In addition to this it should have good radiation properties with time domain performance for entire proposed frequency band. The shape and geometry of the radiating patch and ground plane is the major concern for planar UWB antenna designs. Various methods like slotted patch, slotted ground, partial ground, modified feed, truncated corner patch, etc. have been used for increasing the bandwidth of patch antenna There are already several wireless standards which operate in the band of 3.1 to 10.6 GHz. These wireless standards includes WiMax (3.3-3.85 GHz), WLAN (5.15-5.85 GHz) and a portion of X band (8-12 GHz). SIW technology is utilized in microstrip patch antennas to increase gain and to improve the directivity of the structure.

Keywords: U*ltra-Wide Band (UWB) antenna, Microstrip Patch Antenna (MPA), Substrate-Integrated Waveguide (SIW), bandwidth, band notched characteristics.*

1. INTRODUCTION

For many practical antenna designs, the main disadvantage of microstrip patch antennas was low bandwidth and low gain. Many methods and techniques have been proposed to improve the bandwidth but slotting technique is the most popular because it enhances the impedance bandwidth and also reduces the size of the antenna. The alphabetical shapes of the patch are very famous in the antenna design. Different types of UWB antennas with and without band rejections are reported in the literature.

2. REVIEW OF LITERATURE

2.1 Microstrip Patch Antenna for Ultra-Wide Band Applications without Band Notched Characteristics

M. Ojaroudi proposed a novel printed monopole antenna which is usable for ultra-wide-band applications. Two slots of rectangular shape and one slot of T shape were inserted on patch and ground plane respectively which gives a bandwidth of more 120% (3.12-12.73 GHz). [1]

M. Ojaroudi propounded a new antenna design which can be utilized for ultra-wide band applications. In the structure the authors has used one T slot and one inverted T slot on patch and ground respectively. It provides a bandwidth of more than 130% covering the frequencies between 2.91 GHz to 14.1 GHz. The author suggested that by using the two T slots on top and bottom of the structure additional resonances are excited and thus provides wide range of bandwidth especially at higher frequencies. [2]

2.2 Microstrip Patch Antenna for Ultra-Wide Band Applications with Band Notched Characteristics

M. Mehranpour presented a square radiating patch on which a pair of L-shaped strip and an E-shaped slot in the centre of the patch was used. In the ground plane a V-shaped strip is placed and due to this strip more bandwidth is achieved even more than 140% (2.89-17.83 GHz). The L-shaped slits generate single band notched function and E-shaped slot in the centre generate dual band notched function. [3]

M. Abdollahvand proposed a compact printed monopole antenna with dual band notched function for ultra-wide band applications. In this antenna, dual band notched function is achieved by a pair of Γ - shaped stubs on the radiating patch and a G-shaped structure in the feed line. And on the ground plane by adding two I-shaped slots both the sides of microstrip feed, additional resonance are excited and bandwidth is increased to 123% . [4]

M. Ojaroudi proposed a printed monopole antenna with band notched function with constant gain for UWB applications. The antenna consists of a ground plane and T-shaped strips in the radiating patch along with a Π- shaped strips and a strip in the ground plane which provides more bandwidth 130% (3.07-14.6 GHz).The T-shaped strip on the radiating patch generate frequency band stop performance like band notch frequency and bandwidth and these can be controlled by electromagnetically adjusting coupling between pair of T-shaped strips. [5]

Nasser Ojaroudi presented a new design of monopole antenna with dual band notches for UWB applications. In this paper the radiating patch consist of a T-shaped slot in the feed line and ground plane consist of two E-shaped slots and a W-shaped conductor backed-plane. Due to E-shaped slot additional resonance are excited and wider bandwidth is achieved which is more than 130% (2.73-13.3 GHz). Single notch function is generated by W-shaped plane structure and dual band notch function is generated by T-shaped slot in the patch and feed line.[6]

Qing-Xin Chu presented a compact printed ultra-wide band (UWB) monopole antenna with dual band-notched characteristics. By inserting two I-shaped notches in both sides of the microstrip feed line on the ground plane, additional resonances are excited, and hence the bandwidth is increased up to 123%. Two notched frequency bands are achieved by embedding a pair of (Ґ) shaped stubs in the radiation patch and a modified G-slot defected ground structure in the feeding line. The designed antenna has a small size of 20.0 × 18.0 mm2 and operates over the frequency band between 2.8 and 11.8 GHz for VSWR < 2.0, with one notch frequency band at 3.3–3.8 GHz (WiMAX band) and the other at 5.1–6.0 GHz (WLAN band). The VSWR and radiation patterns of the fabricated antenna are presented, which prove that the designed antenna is a good candidate for various UWB applications.[7]

Wen Tao Li proposed a new antenna that covers 3G, Bluetooth, WiMAX, and the UWB bands with dual band notched characteristics. Quasi complementary split ring resonator (CSRR) in the feed line is etched that achieve dual notched frequency bands at 5.3 GHz and 7.4 GHz, and lower resonance over 3G band is achieved by the transmission line based meta material.[8]

Mohammad Ojaroudi presented a small printed monopole antenna with dual band notches for UWB applications. Ground plane is cut by a fork-shaped slit and due to this additional resonance is excited and wider bandwidth is achieved. A U-shaped strip on the radiating patch is used to generate dual band notched function. This antenna covers all the 5.5/5.8-GHz WLAN, 3.5/5.5-GHz WiMAX, and 4.0-GHz C-bands.[9]

J. Xu a small novel ultra wideband (UWB) antenna with dual band-notched functions. The dual band rejection is achieved by etching two C-shaped slots on the radiation patch with limited area. A single band-notched antenna is firstly presented, and then an optimized dual band-notched antenna is presented and analyzed. The measured VSWR shows that the proposed antenna could operate from 3.05 to 10.7 GHz with VSWR less than 2.0, except two stop bands at 3.38 to 3.82 GHz and 5.3 to 5.8 GHz for filtering the WiMAX and WLAN signals. Radiation patterns are simulated by HFSS and verified by CST, and quasi omnidirectional radiation patterns in the H-plane could be observed. Moreover, the proposed antenna has a very compact size and could be easily integrated into portable UWB devices.[10]

A. Ghazi proposed a modified square monopole antenna with multi-resonance performance, for UWB applications. The proposed antenna consists of a square radiating patch with a pair of T-shaped slots and a ground plane with a pair of rectangular sleeve and a T-shaped resonator which provides a wide usable fractional bandwidth of more than 125% (3.05-13.57 GHz). By optimizing dimension of rectangular sleeves, T-shaped slots and resonator, the total bandwidth of the antenna is greatly improved. The designed antenna has a small size of 14.0 × 22.0 mm2. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and experimental results are presented to demonstrate the performance of a suggested antenna.[11]

S. Yazdanifard proposed a novel printed monopole antenna for ultra wideband applications with variable frequency band-notch characteristic. The proposed antenna consists of a stepped square radiating patch with modified W-shaped slot and a ground plane with rectangular sleeve and pair of L-shaped resonator which provides a wide usable fractional bandwidth of more than 130% (3.05-14.3 GHz). By cutting a modified W-shaped slot with variable dimensions on the radiating patch frequency band-stop performance is generated and it can control its characteristics such as band-notch frequency and its bandwidth. The designed antenna has a small size of 12.0 × 18.0 mm2 while showing the band rejection performance in the frequency band of 5.08 to 5.91 GHz.[12]

M. Ojaroudi presented a novel printed monopole antenna (PMA) for ultra wideband (UWB) applications with variable frequency band-notch characteristic. The proposed antenna consists of a stepped square radiating patch with two U-shaped slots and a notched ground plane with a T-shaped sleeve that provides a wide usable fractional bandwidth of more than 140% (2.85–16.73 GHz). By cutting two modified U-shaped slots with variable dimensions on the radiating patch, frequency band-stop performance is generated, and it can control its characteristics such as band-notch frequency and its bandwidth. The designed antenna has a small size of 12.0 × 19.0 mm2 while showing the band rejection performance in the frequency band of 5.02–5.97 GHz.[13]

Nasser Ojaroudi presented a novel printed monopole antenna for ultra wideband applications with dual band-notched function. The antenna consists of a square radiating patch with an inverted T-shaped ring slot, surrounded by a C-shaped slot, which provides a wide usable fractional bandwidth of more than 125% (2.71–12.06 GHz). In this structure, by cutting an inverted T-shaped slot, the impedance bandwidth is effectively improved at the upper frequency. In order to generate single band-notched characteristics, the author used an inverted T-shaped slot, surrounded by a C-shaped slot, in the radiating patch. By adding an inverted T-shaped parasitic structure inside the inverted T-shaped slot on the radiating patch, a dual band-notched function is achieved, and also by inserting this parasitic structure, additional resonance is excited, and hence much wider impedance bandwidth can be produced, especially at the higher band. The measured results reveal that the presented dual band-notch monopole antenna offers a wide bandwidth with two notched bands, covering all the 5.2/5.8-GHz WLAN, 3.5/5.5-GHz WiMAX, and 4.0-GHz C-bands. The designed antenna has a small size of 12.0 × 18.0 × 0.8 mm^3.[14]

M. Ojaroudi proposed a new band-notched tapered monopole antenna for ultra-wideband applications. The antenna structure is etched on a 1.0 mm-FR4 epoxy substrate with dielectric constant ε_r = 4.4. The ground plane and radiating patch are tapered to obtain good wide impedance matching performance. Inserting two slots in the ground plane causes to greatly widen the impedance bandwidth. By embedding a folded trapezoid in an inner hole of the patch, the band-notch function can be achieved. The fabricated antenna has a small size of 18.0 × 20.0 mm2 and operates over the frequency band between 3.0 to 13.0 GHz for VSWR < 2.0, rejecting the undesired frequency band from 5.1 to 5.85 GHz. [15]

2.3 Microstrip Patch Antenna using SIW Technology

Many researchers have used Substrate-Integrated Waveguide (SIW) technology either to increase the gain or to confine the directivity for specific applications. This technology is a way to make efficient connection between planar and non-planar structures. By means of using SIW the electromagnetic energy is guided to the radiating patch beneath the microstrip line in the dielectric substrate. This increases the gain of the structure and it also narrows down the radiation pattern and thus improves the directivity. SIW is he technique of inserting metallic vias or empty periodic cylindrical structures in the substrate. [16-20]

3. METHODOLOGY

Most of the researchers have proposed slotting either on the radiating patch or on the partial / truncated ground plane. By virtue of partial ground plane, bandwidth enhancement is achieved whereas with the help of slotting on the radiating patch band rejection (s) or additional improvement in the bandwidth is achieved. The detailed comparison of the reviewed literature is shown in table 1.

Table 1: Microstrip Patch Antennas for UWB Applications with and without Band Notched Characteristics.

Published Literature	Key Issue	Solution Approach/ Methodology used	Results	Limitations
Ref. [1]	Covers entire said UWB specified by US-FCC	Two rectangular slots on radiating patch and T notch on ground plane gives additional bandwidth so that it is greater than 7.5 GHz	Provides wide usable bandwidth more than 120% (3.12-12.73 GHz)	Interference from the nearby interfering bands lying within the UWB frequency range.

Ref. [2]	Covers entire said UWB specified by US-FCC	One T slot and one inverted T slot on patch and ground respectively is used to provide 7.5 GHz bandwidth	Provides wide bandwidth of more than 130% (2.91-14.1 GHz)	Interference from the nearby interfering bands lying within the UWB frequency range.
Ref. [3]	Covers entire said UWB specified by US-FCC dual band rejections	A pair of L-shaped strip and an E-shaped slot in the centre of the patch is presented, also in the ground plane a V-shaped strip is placed	Due to this strip more bandwidth is achieved even more than 140% (2.89-17.83 GHz). The L-shaped slits generate single band notched function and E-shaped slot in the centre generate dual band notched function	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [4]	Covers entire said UWB specified by US-FCC dual band rejections	In this antenna dual band notched function is achieved by a pair of Ӷ - shaped stubs on the radiating patch and a G-shaped structure in the feed line. And on the ground plane by adding two I-shaped slots both the sides of microstrip feed,	Bandwidth is increased to 123%	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected

		additional resonance are excited		
Ref. [5]	Covers entire said UWB specified by US-FCC dual band rejections	The proposed antenna consists of a ground plane and T-shaped strips in the radiating patch and also a Π-shaped strips and a strip in the ground plane	Provides more bandwidth 130% (3.07-14.6 GHz). The T-shaped strip on the radiating patch generate frequency band stop performance like band notch frequency and bandwidth and these can be controlled by electromagnetically adjusting coupling between pair of T-shaped strips.	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [6]	An antenna which can cover entire said UWB specified by US-FCC with dual band rejections	Radiating patch consists of a T-shaped slot in the feed line and ground plane consist of two E-shaped slots and a W-shaped conductor backed-plane. Due to E-shaped slot additional resonance are excited and wider bandwidth is achieved	Wider bandwidth is achieved which is more than 130% (2.73-13.3 GHz). Single notch function is generated by W-shaped plane structure and dual band notch function is generated by T-shaped slot in the patch and feed line.	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [7]	An antenna which can cover entire	By inserting two I-shaped notches in both sides of the microstrip	The designed antenna has a small size of 20.0 × 18.0 mm2 and	Interference from the nearby

	said UWB specified by US-FCC with dual band rejections	feed line on the ground plane, additional resonances are excited, and hence the bandwidth is increased up to 123%. Two notched frequency bands are achieved by embedding a pair of tau shaped stubs in the radiation patch and a modified G-slot defected ground structure in the feeding line.	operates over the frequency band between 2.8 and 11.8 GHz for VSWR < 2.0, with one notch frequency band at 3.3–3.8 GHz (WiMAX band) and the other at 5.1–6.0 GHz (WLAN band). The VSWR and radiation patterns of the fabricated antenna are presented, which prove that the designed antenna is a good candidate for various UWB applications.	interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [8]	An antenna which can cover entire said UWB specified by US-FCC with dual band rejections	A new antenna is presented that covers 3G, Bluetooth, WiMAX, and the UWB bands with dual band notched characteristics. Quasi complementary split ring resonator (CSRR) in the feed line is etched	Dual notched frequency bands at 5.3 GHz and 7.4 GHz, and lower resonance over 3G band is achieved by the transmission line based meta material.	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [9]	An antenna which can cover entire	Ground plane is cut by a fork-shaped slit and due to this additional	This antenna covers all the 5.5/5.8-GHz WLAN, 3.5/5.5-GHz	Interference from the nearby

	said UWB specified by US-FCC with dual band rejections	resonance is excited and wider bandwidth is achieved. A U-shaped strip on the radiating patch is used to generate dual band notched function	WiMAX, and 4.0-GHz C-bands.	interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [10]	An antenna which can cover entire said UWB specified by US-FCC with dual band rejections	The dual band rejection is achieved by etching two C-shaped slots on the radiation patch with limited area. A single band-notched antenna is firstly presented, and then an optimized dual band-notched antenna is presented and analyzed.	The measured VSWR shows that the proposed antenna could operate from 3.05 to 10.7 GHz with VSWR less than 2.0, except two stop bands at 3.38 to 3.82 GHz and 5.3 to 5.8 GHz for filtering the WiMAX and WLAN signals.	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [11]	An antenna which can cover entire said UWB specified by US-FCC with dual band rejections	radiating patch consist of a T-shaped slot in the feed line and ground plane consist of two E-shaped slots and a W-shaped conductor backed-plane. Due to E-shaped slot additional resonance are excited and wider bandwidth is achieved	Wider bandwidth is achieved which is more than 130% (2.73-13.3 GHz). Single notch function is generated by W-shaped plane structure and dual band notch function is generated by T-shaped slot in the patch and feed line.	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [12]	An antenna	By inserting two I-	The designed antenna	Interference

	which can cover entire said UWB specified by US-FCC with dual band rejections	shaped notches in both sides of the microstrip feed line on the ground plane, additional resonances are excited, and hence the bandwidth is increased up to 123%. Two notched frequency bands are achieved by embedding a pair of tau shaped stubs in the radiation patch and a modified G-slot defected ground structure in the feeding line.	has a small size of 20.0 × 18.0 mm2 and operates over the frequency band between 2.8 and 11.8 GHz for VSWR < 2.0, with one notch frequency band at 3.3–3.8 GHz (WiMAX band) and the other at 5.1–6.0 GHz (WLAN band). The VSWR and radiation patterns of the fabricated antenna are presented, which prove that the designed antenna is a good candidate for various UWB applications.	from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [13]	An antenna which can cover entire said UWB specified by US-FCC with dual band rejections	A new antenna is presented that covers 3G, Bluetooth, WiMAX, and the UWB bands with dual band notched characteristics. Quasi complementary split ring resonator (CSRR) in the feed line is etched	Dual notched frequency bands at 5.3 GHz and 7.4 GHz, and lower resonance over 3G band is achieved by the transmission line based meta material.	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [14]	An antenna	Ground plane is cut by	This antenna covers all	Interference

	which can cover entire said UWB specified by US-FCC with dual band rejections	a fork-shaped slit and due to this additional resonance is excited and wider bandwidth is achieved. A U-shaped strip on the radiating patch is used to generate dual band notched function	the 5.5/5.8-GHz WLAN, 3.5/5.5-GHz WiMAX, and 4.0-GHz C-bands.	from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [15]	An antenna which can cover entire said UWB specified by US-FCC with dual band rejections	The dual band rejection is achieved by etching two C-shaped slots on the radiation patch with limited area. A single band-notched antenna is firstly presented, and then an optimized dual band-notched antenna is presented and analyzed.	The measured VSWR shows that the proposed antenna could operate from 3.05 to 10.7 GHz with VSWR less than 2.0, except two stop bands at 3.38 to 3.82 GHz and 5.3 to 5.8 GHz for filtering the WiMAX and WLAN signals.	Interference from the nearby interfering bands lying within the UWB frequency range as only two bands are rejected
Ref. [16]	Integration of cascaded SIW filter and MSA	SIW is a bridge between planar and non planar device to reduce the volume of the structure	Gain and directivity of the antenna is improved. Front to back ratio of the antenna is narrowed.	Fabrication is a bit complex and measured results deviates due to non ideal environmental conditions.
Ref. [17]	MSA using SIW	SIW is a bridge between planar and non	Gain and directivity of the antenna is	Fabrication is a bit complex

	technology	planar device to reduce the volume of the structure	improved. Front to back ratio of the antenna is narrowed.	and measured results deviates due to non ideal environmental conditions.
Ref. [18]	MSA using ESIW for 5G applications	Using ESIW around the feed line the energy is confined to the substrate	ESIW is less complex SIW technique by which Gain and directivity of the antenna is improved.	Fabrication is a bit complex and measured results deviates due to non ideal environmental conditions.
Ref. [19]	MSA using QMSIW for WLAN / WBAN applications	Using QMSIW the size of the overall microwave	Gain and directivity of the antenna is improved. Front to back ratio of the antenna is narrowed.	Fabrication is a bit complex and measured results deviates due to non ideal environmental conditions.
Ref. [20]	SIW Antenna for 5G applications	SIW is bridge between planar and non planar device to reduce the volume of the structure	Gain and directivity of the antenna is improved. Front to back ratio of the antenna is narrowed.	Fabrication is a bit complex and measured results deviates due to non ideal environmental conditions.

4. STRENGTHS

Most of the reviewed antenna designs are planar and less complex which is most important for the ease of fabrication. The frequency bands of rejections can be shifted by changing the dimensions and positions of the slots which in terms changes the capacitance at that point. SIW reduces the losses which in term enhances the gain.

5. CONCLUSIONS

In this paper, a review on microstrip patch antennas for ultra-wide band applications with & without band notched characteristics along with the SIW technology is presented. It was found that, the design should be simple so that the fabrication of the structure is easy. In addition to this, band rejections can be achieved by using slotting techniques in different shapes whereas partial ground plane is used enhancing the bandwidth.

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