# Design of Stair and Slotted UWB Antenna using Stepped-Feed with Modified Slotted Ground Plane

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## ABSTRACT

A modified design of an ultra-wide band antenna (UWB) using stepped feed, partial slotted ground, two level stairs with notches in patch and ground plane is simulated with band rejection feature. The enhanced frequency range (3.2 to 14.0 GHz) is covered by the proposed antenna with the overall dimensions of 25.0 (L) x 20.0 (W) x 1.60 (H) mm3. The voltage standing wave ratio (VSWR) is less than 2.0 for entire operating frequency range. The proposed antenna operating on 5.2/5.8 GHz wireless local area network (WLAN), 3.5/5.5 GHz WiMAX, X-band and partial range (12.0 to 14.0 GHz) of Ku-band finds its applications to secure military communication, radar, medical applications and home appliances.

## Keywords

Ultra-wide band, voltage standing wave ratio, wireless local area network, WiMAX.

## 1. INTRODUCTION

The United States and the Federal Communications Commission (FCC) frequency allocation for UWB in February 2002, the Electronic Communications Committee Task Group (ECC TG3) is progressing in the elaboration of a regulation for the UWB technology in Europe. From an implementation point of view, several solutions have been developed in order to use the UWB technology in compliance with the FCC's regulatory requirements. The ultra wideband system covers the frequency range from 3.1 to 10.6 GHz, which based on narrow pulses to transmit data at extremely low power. UWB has recent attracted much attention as an indoor short range high speed wireless communication. One of most exciting characteristics of UWB is that its bandwidth is over 110 Mbps (up to 480 Mbps). UWB antennas have better efficiency in energy consumption. Required minimum bandwidth is 500MHz and $S_{11}$ parameter is less than -10 dB [1].

From the Shannon-Hartley theorem, the ultra wideband provides high data rates using very low power at very limited range, which will lead to the applications well suited for wireless personal area network (WPAN). These advantages provide the high data rate for short distance electronic devices. For example; electronics consumers like digital cameras, video cameras, MP3 players, televisions, personal video recorders, automobiles and DVD players will experience high data rate in home and for their personal entertainment [2].

Ultra Wideband (UWB) devices can be used for precise measurement of distances or locations and for obtaining the images of objects buried under ground or behind surfaces. UWB devices can also be used for wireless communications, particularly for short-range high-speed data transmissions suitable for broadband access to the Internet. UWB devices can be used for a variety of communications applications involving the transmission of very high data rates over short distances without suffering the effects of multi-path interference. UWB devices can be used to measure both distance and position. UWB positioning systems could provide real time indoor and outdoor precision tracking for many applications. Some features of UWB for medical applications are given below Penetrating through obstacles, High precision ranging at the centimeter level, Low electromagnetic radiation, Low processing energy consumed, medical monitoring, Patient motion monitoring, Vital signs monitoring of human body [3]. UWB technology has been used for some time in Ground Penetrating Radar (GPR) applications and is now being developed for new types of imaging systems that would enable police, fire and rescue personnel to locate persons hidden behind a wall or under debris in crises or rescue situations. By bouncing UWB pulses, rescuers can detect people through rubble, earth or even walls using equipment similar to radar. Construction and mineral exploration industries may also benefit [5, 6]. The US military has already been using this technology for military radars and tracking systems for the last 15 years. UWB technology can make intelligent auto-pilots in automobiles and other crafts a reality one day. Some potential home safety uses include intrusion detection systems that are less susceptible to false alarms, and space heaters that turn themselves off when a child comes nearby.

## 2. RECTANGULAR MICROSTRIP PATCH ANTENNA

The rectangular and circular patches are the basic and most commonly used microstrip antennas. In high-performance aircraft, spacecraft, satellite, and missile applications, where size, weight, costs, performance, ease of installation, aerodynamic profile are constraints, and low-profile antennas may be required. To meet these requirements, microstrip antennas can be used. These antennas are low profile, conformable to planar and no planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and when the particular patch shape and mode are selected, they are very versatile in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed

Major operational disadvantages of microstrip antennas are their low efficiency, low power, high Q (sometimes in excess of 100), poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth, which is typically only a fraction of a percent or at most a few percent [4]. Design of microstrip patch antenna using transmission line model. In the designing process of rectangular microstrip patch antenna using transmission line model we have to first specify the operating resonant frequency 'f', the permittivity of the dielectric substrate material '$\varepsilon_r$' and the thickness or height of the substrate 'h'. Then by using the equation given below, the width 'W' of the patch is calculated.

$$W = \frac{c}{2f}\left[\sqrt{\left(\frac{2}{\varepsilon_r+1}\right)}\right] \qquad \dots (2.1)$$

In the above equation 'c' is the free-space velocity of light. After calculating the width, the value of effective dielectric constant '$\varepsilon_{reff}$' is calculated by using the equation given below

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left\{\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}\right\} \qquad \dots (2.2)$$

Now the calculation of extension in length of the patch 'ΔL' is required which can be easily done by using the equation given below

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad \dots (2.3)$$

In the last the length of the patch 'L' is calculated by subtracting the extension in length on both sides of the patch which is calculated in equation given below. The pictorial representation of the extension in length 'ΔL' is shown in figure given below

$$L = \frac{c}{2f} - 2\Delta L \qquad \dots (2.4)$$

Dimension of waveguide port are 6H and 5W where H is height of patch and W width of feeding line.

## 3. UWB ANTENNA DESIGNS AND SIMULATIONS

### 3.1 An Antenna with Partial Ground and patch:

Microstrip antenna design using above equations for specific resonant frequency response for the proposed antenna. Microstrip antenna can be converted into UWB antenna through many techniques like as adding a step beneath the patch, using partial ground, using of tuning stub, etc. First we use partial ground (only less than 40% of total ground), the size of patch is C= 13.0 mm, D=12.8 mm and it is made of annealed copper. Substrate length L=25.0 mm, width W=20.0 mm, dielectric constant is 2.2 (Rogers RT 5880), height 1.6 mm (there are same for all three antennas).Partial ground is made of annealed copper (lossy metal) and dimension of ground R=10.0mm, H=3.5mm, J=2.5mm. Stepped-feed dimension are A= 3.0mm, B= 1.4mm, E= 5.5mm, F= 6.0mm (these are same for all antennas) shown in figure given below.

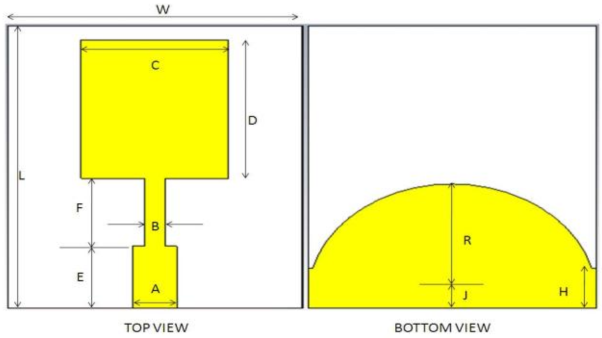


**Fig. 1. An Antenna with Partial Ground and patch.**

### 3.2 An Antenna with Partial Ground & Addition of Stairs in patch

A rectangular patch antenna was designed and optimized with partial ground. After partial grounding, stairs have been introduced in order to achieve ultra wideband. The steps are added in lower end of the patch antenna. It can be observed that adding one or more steps with certain dimension in the patch antenna, there has been a sudden increment in the bandwidth of the antenna. This configuration is based on the research works done previously. To determine the dimensions of stairs, one stair with length 1.2 mm is introduced and then the width of stair was optimized by parameter variation. The additional second stair yielded very small increment in the bandwidth as well as shifting the frequency to the rights. The optimization was done to have better return loss compared to width dimensions. The simulation results of designed and optimized antennas for patch with full ground and partial ground, partial ground without stair and with single stair and partial ground with single stair and double stairs. Dimension of two stepped stairs are A1and A2=1.2mm, M=4.7mm, N=5.3mm from end corner of patch. The proposed antenna is shown in figure given below.

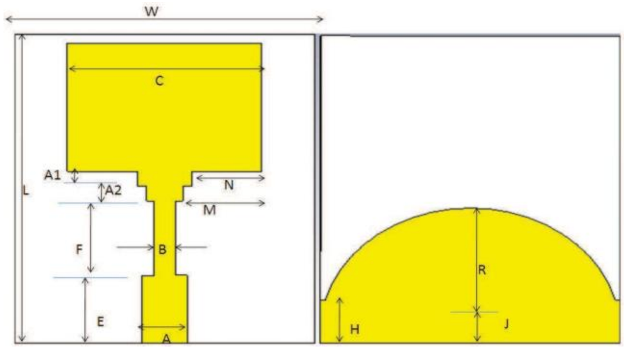


**Fig. 2. An Antenna with Partial Ground & Addition of Stairs in patch.**

### 3.3 An Antenna with Partial Slotted Ground with Addition of Stair & Stub for notch (band reflections)

All dimension and materials are same in this antenna as two stepped stair patch, stepped-feed, ground and substrate. If we want a band rejection in UWB range then cut a optimize stub on patch and on partial ground on above antenna then a band rejection will be start, we can reject a band up to 1.20 GHz. We can vary frequency range of notch (Band Rejection) through size of stubs on patch and partial ground by moving the stub along the length of patch and ground in UWB range. Stub dimension on patch are variable which are optimized by parameter variation method.

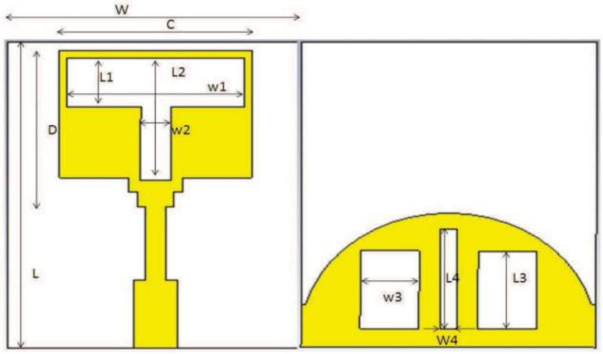


**Fig. 3. An Antenna with Partial Slotted Ground with Addition of Stair & Stub for notch (band rejections)**

## 4. RESULTS AND DISCUSSIONS

TABLE 1

**Comparison among the three proposed designs.**

| S.No. | Parameters | Design-I | Design-II | Design-III |
|---|---|---|---|---|
| | **Name of antenna** | **Antenna with Partial Ground and patch** | **Antenna with Partial Ground & Addition of Stair in patch** | **Antenna with Partial Slotted Ground with Addition of Stair & Stub for notch (band reflections)** |
| 1 | Max. Surface Current | 36.30 A/m (f=6.85) | 33.81 Aim (f=11.55) | 29.35 Aim(f=8.55) 36.24Aim(f=11. 55) |
| 2 | Bandwidth | 3.486GHz | 10.428 GHz | 3.34 and 5.39 GHz |
| 3 | Directivity (Abs) | 3.435 dBi | 3.663 dBi | 3.0 dBi |
| 4 | Gain (Abs) | 2.857 dB | 3.328 dB | 2.426 dB |
| 5 | Peaks($S_{11}$) | -28.0 dB at 5.31 GHz | -51.98 dB at 7.663 GHz | -35.87 dB at 9.20GHz |
| 6 | Notch | NA | NA | 1.166 GHz between 6.76 to 7.933 GHz |

The above table demonstrates the three proposed design results. The Maximum surface current is 36.30 A/m at f=6.85 GHz for the first design. The second design gives the highest valve of gain and directivity. In the third design one notch is observed ranging from 6.76 GHz to 7.933 GHz.

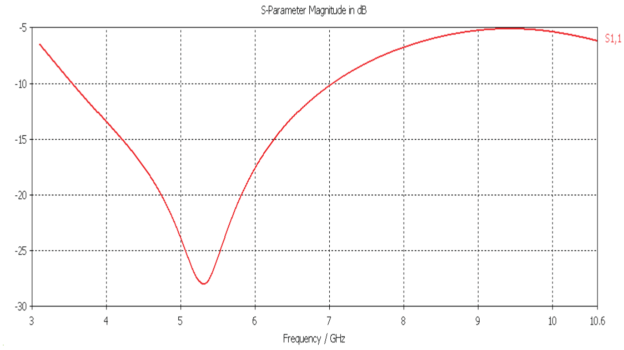


**Fig. 4. $S_{11}$ parameter for first design.**

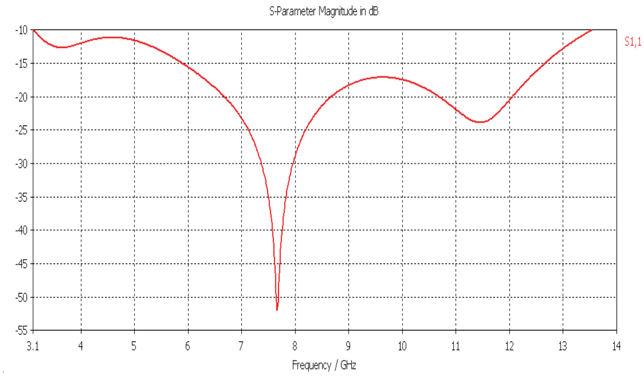


**Fig. 5. $S_{11}$ parameter for second design.**

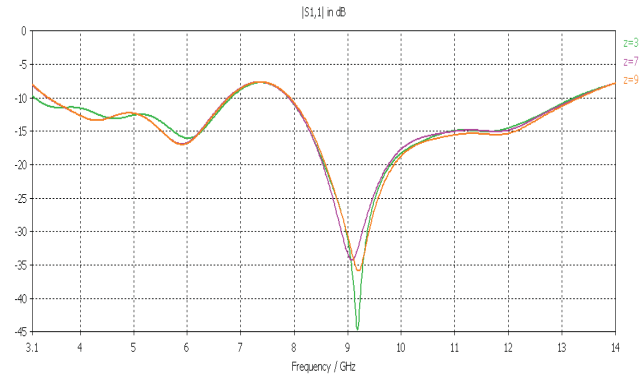


**Fig. 6. $S_{11}$ parameter for third design.**

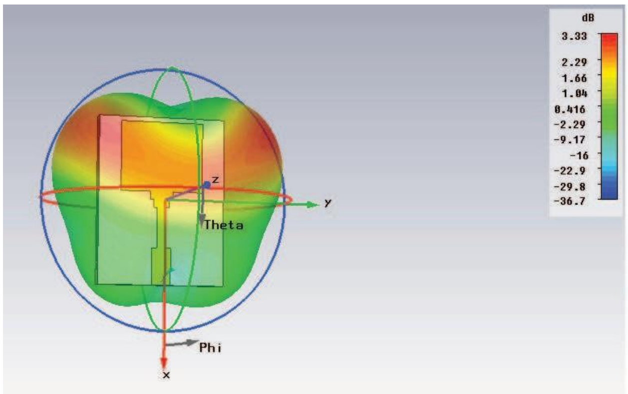


**Fig. 7. Phi-Theta curve for second design.**

## 5. CONCLUSIONS

In this paper, three antennas are presented which are designed and simulated by integrating slotted partial ground with stair and addition of tuning stub with rectangular patch antenna. The designed antennas can operate from 3.1 — 10.5 GHz and above frequency bands with more than 10.4 GHz band width. The maximum gain and maximum directivity obtained with "antenna with slotted partial ground & addition of stair" design. The main problem of this design is it needs very accurate feeding. The goal of this antenna was to design a low cost, highly directional antenna that was low profile and easy to manufacture. The antenna designing and simulation is achieved by using CST. Various techniques have been used to enhance the proposed antenna characteristics. These techniques are: adding a step beneath the patch, using partial ground, using of tuning stub.

## 6. REFERENCES

[1] Jin-Shyan Lee, Yu-Wei Su, and Chung-Chou Shen "A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi" Information & Communications Research Labs Industrial Technology Research Institute (ITRI) Hsinchu, Taiwan jin-shyan-lee, the 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON), Nov. 5-8, 2007, Taipei, Taiwan.

[2] Islam Md. Rafiqul, Member IEEE, Alam AHM Zahirul, Senior Member IEEE, M. Feroze Akbar J. Khan and Shaker Alkaraki" Design of Microstrip Patch Antenna Using Slotted Partial Ground And Addition Of Stairs And Stubs For UWB Application" Cyber Journal: Multidisciplinary Journal in Science and Technology , JSAT, May Edition 2012

[3] Jianli pan (A survey paper written under guidance of Prof. Raj Jain)"medical application of ultra —wideband (UWB)".

[4] Constantine A. Balanis "Antenna Theory & Analysis Design‘, Third Edition, by ISBN 0-471-66782-X Copyright 2005 John Wiley & Sons, Inc. 811.

[5] Mohammed AL Husseini, Ali Ramadan, Ali EL Haji and Karim Kablan "Design of a Compact and Low-Cost Fractal-Based UWB PCB Antenna".

[6] K.-S. Lim, M. Nagalingam, and C.-P. Tan, Multimedia University, 63100 Cyberjaya, Malaysia. "Design and construction of microstrip uwb antenna with time domain analysis" progress in electromagnetic research m, vol. 3, 153—164, 2008.

[7] Hazem H.A wadalla, Shoukry I. shams, AMMA Allam "A Compact Symmetric U-shaped Monopole for Ultra Wide band Operation" 28th National Radio Science Conference (NRSC 2011) April 26-28,2011, National Telecommunication Institute, Egypt.

[8] Raj Kumar and Pranotibansode "On the Design of Ultra Wide-Band Antenna based on Fractal Geometry" 92-61-13171-9/CFP1038E.

[9] Werner Wiesbeck "Basic Properties and Design principles of UWB Antennas", Proceedings of the IEEE, Vol.97, No.2, February 2009.

[10] Hans Gregory Schantz "A Brief History of UWB Antennas". The Proceedings of the 2003 IEEE UWBST Conference.

[11] Shiran Wang, Qi Wu, and Donglin Su "A Novel Reversed T-Match Antenna with Compact Size and Low Profile for Ultra-wideband Applications" IEEE Transactions On Antennas And Propagation, Vol. 60, No. 10, October 2012.

[12] Ian Gresham, Alan Jenkins, Robert Egri, Channabasappa Eswarappa, Noyan Kinayman, Nitin Jain, Richard Anderson, Frank Kolak, Ratana Wohlert, Shawn P. Bawell, Jacqueline Bennett, and Jean-Pierre Lanteri. "Ultra-Wideband Radar Sensors for Short-Range Vehicular Applications", IEEE Transactions On Microwave Theory And Techniques, Vol. 52, No. 9, September 2004.