

Review On Antenna Design for High Efficiency In UWB

Shijina S

Assistant Professor, Department of ECE

Sarabhai Institute of Science and Technology, Vellanad

doi.org/10.64643/IJIRTV12I10-204547-459

Abstract—Ultra-Wideband (UWB) antenna technology has emerged as a key enabler for high-speed and high-capacity wireless communication systems. This paper presents a comprehensive review of various UWB antenna design techniques aimed at improving antenna efficiency, impedance bandwidth, gain, and overall system performance. The study discusses multiple design approaches, including non-thermal soldering techniques for polymer-based antennas, triangular patch antennas with slot modifications, metamaterial-based antenna structures, combined TEM horn antennas using Klopfenstein impedance tapering, compact shielding can slot antennas, band-notched monopole antennas with defected ground structures, and compact Multi-Input Multi-Output (MIMO) antenna systems.

Index Terms—Ultra-Wideband (UWB) Antenna, Multi-Input Multi-Output (MIMO) Antenna Efficiency Impedance Bandwidth

I. INTRODUCTION

Ultra-Wideband (UWB) antenna technology has gained considerable importance due to its capability to operate over a wide frequency spectrum while supporting high data rates, low power consumption, and reliable performance. The growing need for compact and efficient wireless devices has led to extensive research on antenna designs that can achieve wide impedance bandwidth, high radiation efficiency, stable gain, and minimal distortion across operating frequencies.

However, designing high-performance UWB antennas involves several challenges, including maintaining impedance matching over a wide band, reducing losses, and ensuring consistent radiation characteristics. In addition, practical considerations such as compact size, material constraints, and fabrication techniques significantly influence antenna performance. To address these challenges, various design approaches have been proposed in the

literature.

One effective technique involves improving the feeding mechanism and interconnection methods. Non-thermal soldering using conductive epoxy has been introduced to enhance the efficiency of polymer-based antennas by avoiding thermal damage. Geometrical modifications, such as the use of slots and partial ground planes in patch antennas, have also shown notable improvements in bandwidth and efficiency. For instance, optimized monopole and triangular patch designs can achieve multiple resonant frequencies with good return loss characteristics. Metamaterial-based antenna designs further enhance performance by utilizing unique electromagnetic properties such as negative permittivity and permeability. These structures contribute to improved bandwidth, gain, and radiation efficiency while enabling antenna miniaturization. In addition, configurations such as modified horn antennas and compact slot antennas have been explored to improve radiation performance and enable integration within limited spaces.

Band-notched antennas have also been developed to suppress interference from undesired frequency bands through the use of slots in the radiating patch and ground plane. Furthermore, Multi-Input Multi-Output (MIMO) antenna systems have gained attention for their ability to improve system performance. Techniques such as defected ground structures and optimized element placement are employed to reduce mutual coupling and enhance isolation.

A comparative evaluation of these techniques indicates significant improvements in antenna performance, with reported efficiencies ranging from moderate to very high values, along with wide impedance bandwidth and desirable return loss characteristics.

This paper presents a comprehensive review of UWB antenna design techniques aimed at achieving high

efficiency and improved overall performance. The analysis provides insights into effective design strategies and highlights advancements that can support future developments in UWB antenna systems.

II. REVIEW OF THE EXISTING LITERATURE

(Very T. Peter, R. Nilavalan, H. F. AbuTarboush1 and S.W. Cheung) [1] This paper presents a non-thermal soldering technique to overcome this problem thus eliminating damage to the polymer material of the antenna at the connectors whilst improving the efficiency of the antenna. The use of conductive epoxy to cold solder the connectors to the antenna feed line provides a direct connection in a similar way as thermal soldering the connectors to a feed line on an FR4 antenna. This concept of cold soldering has long been used in the automotive industry and in the last two decades in the surface mount technology to solder heat sensitive electronic components which can be easily damaged through thermal excursions.

The UWB antenna is designed and fabricated using AgHT- 8 for both the monopole and the 50 Ω coplanar waveguide (CPW) feed.

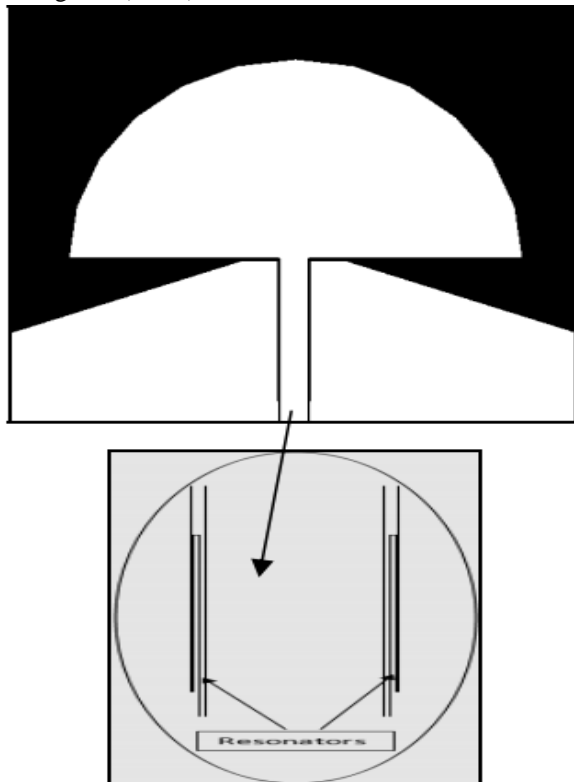


Fig 1. Proposed antenna as per reference [1]

A non-thermal soldering technique was proposed to improve the efficiency of polymer-based antennas made of transparent conductive materials by applying conductive epoxy to solder the SMA connectors to the CPW feed instead of indirectly connecting them through copper pads to avoid thermal excursion.

For ultra-wide bandwidth applications (Khaled B. Suleiman, Fatima A. Alazraq, Ahmed M. Alkrewi) [2] The antenna design process begins with an initial resonant frequency of 6.85 GHz. The triangular patch antenna is isolated from the ground plane by a 1.58 mm thick 'Roger RT5880' substrate. The dielectric constant of the substrate material is 2.2 in this design. The efficiency of the patch antenna is improved due to the inclusion of two rectangular slots and partial ground plane, and also due to variation of parameters, including dimensions. The concept proposed is fed with the regular 50ohm microstrip line, the microstrip line width is set at $W_f = 4,908$ mm to achieve an impedance of 50 ohm. It can be observed that, the maximum efficiency of the proposed antenna with respect to frequency is 86 % at 11 GHz.

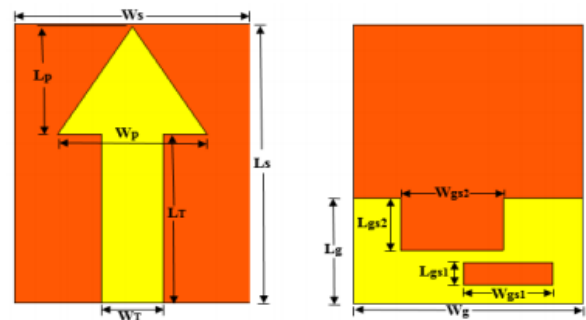


Fig 2. Proposed antenna as per reference [2]

(YahieaAlnaiemy Nagy Lajos) [3] In this section two different UWB antennas based on metamaterial was studied, the first antenna design is started with circular patch antenna and the fractal metamaterial unit cell which is shown in Fig. 2. The main reason to choose this type of topology attributed to its sub-wavelength properties wide application and its simple architecture. The resonance frequency is affected by several antenna parameters, such as size of circular patch, substrate material and the slotted ground plane, therefore, in this paper we studied and presented the effect of these parameters to the antenna performance, the simulation is performed using CST MW.

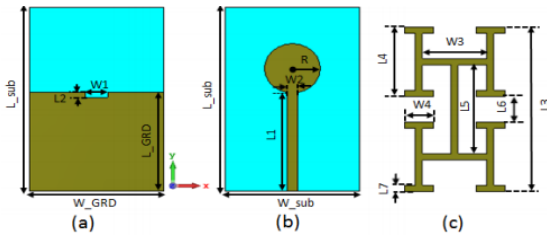


Fig 3. The proposed antenna geometry; (a) bottom view, (b) front view and (c) unitary fractal cell. [3]

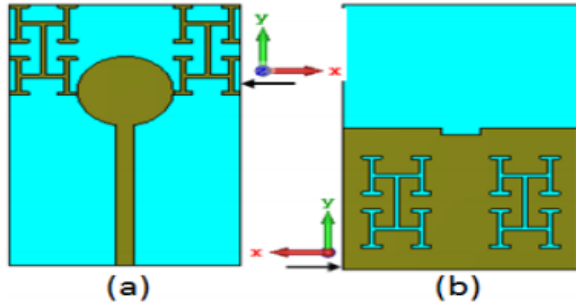


Fig 4. The proposed antenna geometry with proposed metamaterial (a) front view (b) back view, green zone represents the metallization [3]

The second UWB antenna design made of four metamaterial unit cells, SRR, CLS and wire (see Fig. 4), this design simultaneously exhibits both a negative magnetic permeability and a negative electrical permittivity. the proposed antenna with and without metamaterial. Finally, from the obtained results we conclude the UWB antennas based on metamaterial exhibit improvement in antenna performance, such as bandwidth, gain, return loss, efficiency, radiation pattern compares with the conventional UWB antennas.

(Shao-fei Wang and Yan-zhao Xie) [4] Conventional TEM horn antenna exhibits capacitive impedance in the low-frequency range, which means that a lot of energies are stored around the antenna instead of being radiated to the free space. As aforementioned, the principle of the combined antenna is to short out the reactive energy stored around the TEM horn to make a magnetic dipole. In the low-frequency range, the electric dipole and the magnetic dipole can work together to improve the performance of the antenna. In order to demonstrate the effect of the combination of the electric and magnetic dipoles, simulation models for conventional TEM horn and combined antenna are created with the same length of 30 cm, as is shown in Fig. 5. Apertures of both antennas are of 30 cm × 30

cm, and the structure of the plates of the horns is the same and designed based on the Klopfenstein impedance taper. the gain of the antenna array. In addition, conventionally, the characteristic impedance of the TEM horn antenna at the aperture is designed to match the wave impedance in the free space. In this paper, the designed antenna is a cubic one, whose impedance at the aperture of the horn is much smaller than the conventional one. The research results indicate that the designed antenna works even better than the conventional one. So, in the design of the UWB antenna with a structure similar to TEM horn, the aperture impedance could be flexibly adjusted according to the design objective.

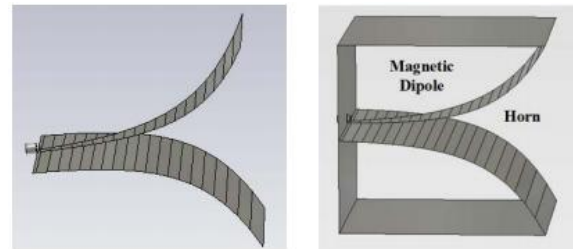


Fig 5. Proposed antenna as per reference [4]

(Shaobo Chen, Hongwi Liu) [5] Figure 6 demonstrates the 3D structure of the proposed shielding can slot antenna and Figure 7 gives the side view of the design. The slot antenna is placed on the top surface of the shielding can by excavating some hollow areas, where the antenna is composed of three slot sections and they are designated as slot section L1, L2 & L3. For the feeding realization, the antenna is excited by a coaxial cable located near section L3 and the cable is assembled inside the shielding can. At the feeding position shown in Figure 1, the outer conductor of the coaxial cable is stripped and the inner conductor of the cable is placed across slot section L2. For the other end of the coaxial cable, it will be assembled with a SMA connector and the cable will go across the bottom module PCB, where these arrangements are for test purpose only. In practice, the other end of the coaxial cable could be assembled with some microminiature board to board connector for RF connection with the UWB RF front-end. For the three sections of the slot antenna, the length of section L1 & L2 mainly control the resonant frequency of the antenna which could be used to tune the antenna to the target operating band. Meanwhile, sections L3 mainly influences the impedance matching of the antenna. The size of the

shielding can is 14.7mm*19.7mm which is a typical size for the circuit part of a UWB module. And the height of shielding can is 2mm. Overall, we can see that this antenna doesn't need clearance which is necessary for many PCB antenna or ceramic antenna designs.

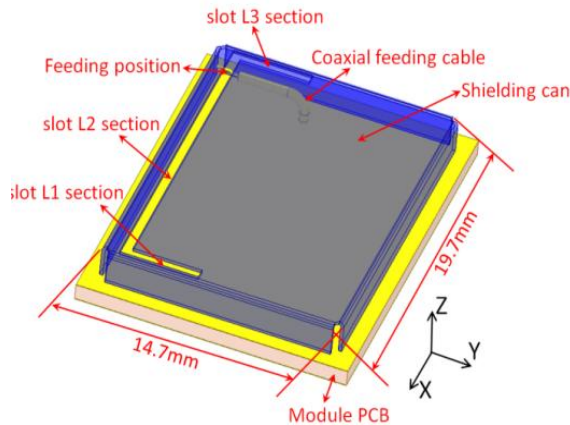


Fig 6. 3D structure of the proposed shielding can slot antenna [5]

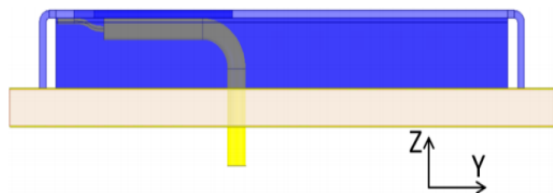


Fig 7. side view of the proposed shielding can slot antenna [5]

(Sunil kumar Gupta, Rajan Mishra) [6] Proposed dual band notched antenna is imprinted by containing FR4 (Flame Retardant material) Epoxy dielectric substrate. FR4 Epoxy dielectric substrate has $\tan \xi$ 0.025, permittivity of 4.3 and height of 1.6 mm. Feedline width of 2.5 mm is used to provide the perfect matching between the patch and the feed strip of the designed antenna. The substrate dimensions are $(16.5 \times 16.5 \times 1.60)$ mm. In the specified frequency band, the band rejection property is achieved by inserting three U slots and one I slot into the radiation patch and micro strip feed line and two inverted U slots into the ground plane structure. By calculating the exact value of every parameter of various slots, antenna band notched characteristics of 3.5-5.3, 5.4-7.0, and 8.1-8.9 GHz can be Obtained.

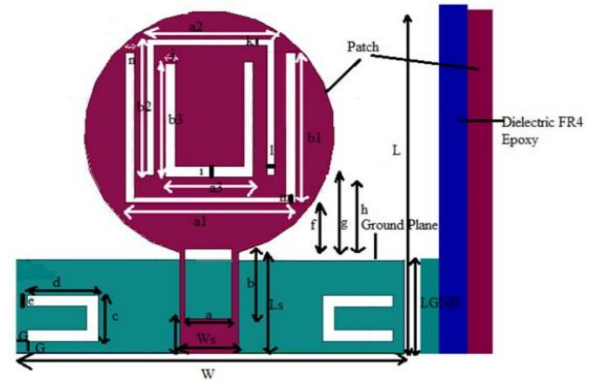


Fig 8. Proposed antenna as per reference [6]

By inserting the two inverted U slots into the ground surface structure and one I slot into the radiation patch, proposed antenna bandwidth is increased. One U slot in the center of radiation patch is used to reject the ITU band. Second inverted U slot in radiation patch is used to reject WLAN and U-NII band. Then third U slot in radiation patch is used for rejection of WIMAX and C band. For the better rejection of desired WiMAX, C, WLAN, ITU and UNII band, U slot dimensions may be selected properly as per requirement.

(Syeda Wafa Zehra, Muhammad Zahid) [7] Structure of ground in proposed MIMO design is kept different from single element because in MIMO there is need to reduce the mutual coupling between the elements of the MIMO antenna. It can be done with help of decoupling structures or by placing the elements at reasonable distance. By making the unique ground structure as depicted in Fig.9 (b) the ECC value and mutual coupling has been reduced and isolation is increased.

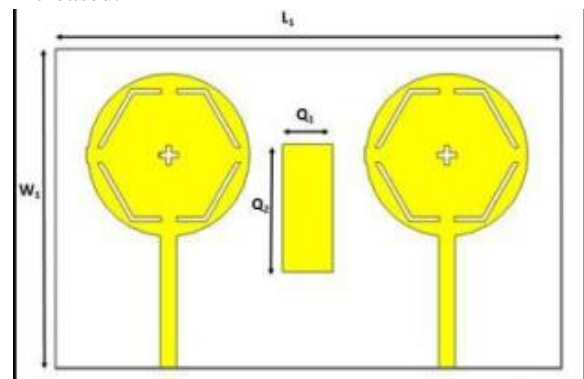


Fig 9: (a) Patch and Parasitic Element

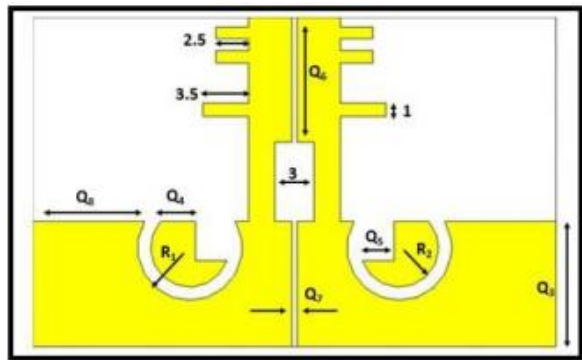


Fig 9: (b)Ground Plane of Proposed MIMO

The gain and total efficiency of proposed design and total efficiency value of the proposed system is over 80 % and is maximum at 4.5 GHz which is 93 %. The realized gain is over 2 dBi for whole operating band and is maximum at 7.3 GHz that is 4.6 dBi.

III. COMPARATIVE ANALYSIS

Finally, a comparative table is be developed based on the techniques discussed above with respect to the design technique, type of antenna and performance in table 1.

Table 1 Comparative analysis of literature review

Ref.	Design Technique	Efficiency	Performance
1	A Non-Thermal Soldering Technique to Improve Polymer Based Antenna Performance	62%	2.45 to 10.65 GHz with VSWR less than 2,
2	A triangular patch feeding by a 50 Ω standard microstrip line.	86%	Good return loss (<-10 dB) over BW of 17.6GHz (2.9 GHz – 20.5 GHz). Five different resonant frequencies at 5.85 GHz, 8.51 GHz, 11.97GHz,14.68GHz and 18.37 GHz
3	UWB antennas based on metamaterial of miniaturized geometries	98.7%	Excellent enhancements are found in the directivity, radiation efficiency and total efficiency of the proposed antenna with metamaterial compare with the conventional antenna.
4	UWB Combined Antenna Based on Klopfenstein Impedance Taper	76.1%	The impedance bandwidth [voltage standing wave ratio (VSWR) < 2] of the antenna is 180 MHz to 7 GHz
5	shielding can slot antenna	96.3%	7.0% fractional impedance bandwidth for VSWR < 3 and the corresponding operating frequency range is from 7.73 GHz to 8.29 GHz
6	Band Notched Monopole Antenna with Defected Ground Plane	90%	multi band notched properties in the WiMAX band (3.5 / 5.5 GHz), C band (4 GHz), WLAN band (5.2 / 5.8 GHz) and operates from 3.2973 to 11.9310 GHz frequency range.
7	Compact 2 Element MIMO Antenna	93%	S11 and S12 < -10 dB from 3.39 GHz to 9.1 GHz reflecting UWB characteristics, observed realized gain is > 2.5 dBi

IV. CONCLUSION

This paper presented a comprehensive review of various UWB antenna design techniques with a focus on improving efficiency, impedance bandwidth, and overall performance. The comparative analysis highlights that antenna performance is strongly influenced by the adopted design methodology, material selection, and structural modifications.

Among the reviewed techniques, non-thermal soldering methods improve reliability and provide moderate efficiency (~62%) while ensuring better integration for polymer-based antennas. Slot-loaded and geometrically modified patch antennas demonstrate enhanced bandwidth and good return loss, achieving efficiencies up to 86%. Metamaterial-based designs exhibit the highest performance, with efficiencies reaching approximately 98.7%, along with

significant improvements in gain and radiation characteristics. Similarly, compact shielding can slot antennas offer high efficiency (~96.3%) and practical advantages such as minimal space requirements.

Combined antenna structures based on impedance tapering improve low-frequency radiation but show comparatively moderate efficiency (~76.1%). Band-notched monopole antennas effectively suppress interference across multiple frequency bands while maintaining wideband operation, achieving efficiencies around 90%. In addition, compact MIMO antenna configurations demonstrate high efficiency (up to 93%) with improved isolation and reduced mutual coupling, making them suitable for multi-element systems.

Overall, the comparison indicates that advanced techniques such as metamaterial integration, optimized slot structures, and MIMO configurations significantly enhance UWB antenna performance.

ACKNOWLEDGMENT

Author would like to thank her gratitude to Dr. Rojin R K for his technical and moral support. My sincere thanks to Sarabhai Institute of Science and Technology also, for providing support for writing this paper. Author would also like to thank for friends for motivating to write the review paper.

REFERENCES

- [1] V. T. Peter, R. Nilavalan, H. F. AbuTarboush, and S. W. Cheung, "A non-thermal soldering technique to improve polymer-based antenna performance," *IEEE Antennas and Wireless Propagation Letters*, vol. 11, pp. 411–414, 2012.
- [2] K. B. Suleiman, F. A. Alazraq, and A. M. Alkrewi, "Enhanced UWB triangular microstrip patch antenna based on ground plane modification," in *Proc. IEEE Conf.*, 2021.
- [3] Y. Alnaiemy and N. Lajos, "Design and analysis of ultra-wide band (UWB) antennas based on metamaterial," BME Artificial Intelligence FIKP Grant of EMMI (BME FIKPMI/SC).
- [4] S.-F. Wang and Y.-Z. Xie, "Design and optimization of high-power UWB combined antenna based on Klopfenstein impedance taper," *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, Dec. 2017.
- [5] S. Chen and H. Liu, "UWB slot antenna on shielding can for high accuracy positioning application," in *Proc. GMC-ElecEng*, 2020.
- [6] S. K. Gupta and R. Mishra, "A compact band notched monopole antenna with defected ground plane for UWB applications," in *Proc. 5th IEEE Uttar Pradesh Section Int. Conf. Electrical, Electronics and Computer Engineering (UPCON)*, 2018.
- [7] S. W. Zehra and M. Zahid, "A compact 2 element MIMO antenna for UWB applications," in *Proc. IEEE Asia Pacific Conf. Wireless and Mobile (APWiMob)*, 2021.
- [8] V. K. Sambhe, R. N. Awale et al., "Compact multi-band novel shaped planar monopole antenna for DCS, Bluetooth, and ultrawide-band applications," *The Journal of Engineering*, no. 5, pp. 119–123, 2016.
- [9] B. Cadilhon, B. Cassany, P. Modin, J.-C. Diot, V. Bertrand, and L. Pécastaing, "Ultra-wideband antennas for high pulsed power applications," in *Ultra-Wideband Communications, Novel Trends—Antennas and Propagation*, Rijeka, Croatia, 2011, pp. 278–306.
- [10] M. Gopikrishna, D. D. Krishna, C. K. Anandan, P. Mohanan, and K. Vasudevan, "Design of a compact semi-elliptic monopole slot antenna for UWB systems," *IEEE Transactions on Antennas and Propagation*, vol. 57, pp. 1834–1837, 2009.
- [11] Z. N. Low, J. H. Cheong, and C. L. Law, "Low-cost PCB antenna for UWB applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 4, pp. 237–239, 2005.