JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# A Survey of Microstrip Patch Antennas for MIMO Systems in Ultra-Wideband (UWB) Applications

[1] ***Dr.Nagaraj Hanchinamani*** [2] ***Mr Ramalingesha Pyati***

*1 Senior Grade lecturer Sri Channakeshava Government Polytechnic Bankapur Karnataka, India*
*2 Senior Grade lecturer Sri Channakeshava Government Polytechnic Bankapur Karnataka,India*

***Abstract:*** This survey explores the state-of-the-art in microstrip patch antenna design specifically for MIMO systems operating within Ultra-Wideband (UWB) frequency ranges (typically 3.1 GHz to 10.6 GHz). It covers diverse design methodologies such as slot loading, Defected Ground Structures (DGS), Electromagnetic Band Gap (EBG) integration, dual polarization, and compact MIMO arrays. Performance metrics including bandwidth, isolation, Envelope Correlation Coefficient (ECC), gain, and radiation patterns are reviewed. Major challenges like mutual coupling, compactness, and pattern stability are addressed, and future research directions are proposed.

***IndexTerms*** **- MIMO, MICROSTRIP PATCH ANTENNA**

## 1. INTRODUCTION

UWB provides expansive bandwidth for high-data-rate short-range communications, precise positioning, and radar sensing. Combining it with MIMO techniques enhances spectral efficiency and reliability without additional power or spectrum. Ultra-Wideband (UWB) technology, defined by the Federal Communications Commission (FCC) in 2002, operates in the frequency range of 3.1–10.6 GHz. It is widely used in wireless communications, radar, and medical imaging due to its high data rates and low power spectral density. microstrip patch antennas are popular due to their compactness and low cost integrated into MIMO systems for UWB operations, summarizing prominent design techniques and performance outcomes. The following Key Demands such as

- Wideband performance across the entire UWB spectrum.
- High isolation between antenna elements to reduce mutual coupling.
- Low ECC (e.g., ECC < 0.02) for optimal diversity performance.
- Compact footprint suitable for integrated devices

## 2. HISTORY OF MICROSTRIP PATCH ANTENNA

Antenna [1] is a transducer which transmits or receives electromagnetic waves. Microstrip antennas have several advantages over conventional microwave antenna and therefore are used in a variety of practical applications. Microstrip antenna was first introduced in the 1950s. However, this concept had to wait for about 20 years to be realized after the development of the printed circuit board (PCB) technology in the 1970s. Since then, microstrip antennas are the most common types of antennas with wide range of applications due to their apparent advantages of light weight, low profile, low cost, planar configuration, easy of conformal, superior portability, suitable for array with the ease of fabrication and integration with microwave monolithic integrate circuits (MMICs).They have been widely engaged for the civilian and military applications such as radio-frequency identification (RFID), broadcast radio, mobile systems, global positioning system (GPS), television, multiple-input multiple-output (MIMO) systems, vehicle collision avoidance system, satellite communications, surveillance systems, direction founding, radar systems, remote sensing, missile guidance, and so on. Microstrip antenna in its simplest design is shown in Figure 1. It consists of a radiating patch on one side of dielectric substrate (Єr≤10), with a ground plane on other side.

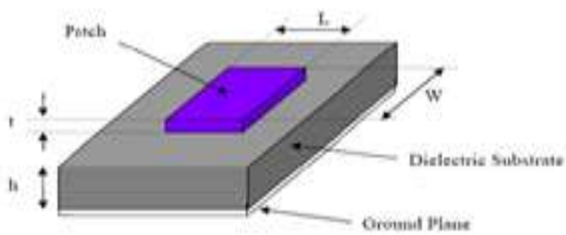
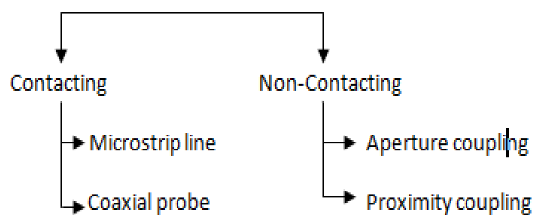



Figure 1: Microstrip antenna configuration

A microstrip patch antenna (MPA) consists of a conducting patch of any non-planar or planar geometry on one side of a dielectric substrate and a ground plane on other side. It is a printed resonant antenna for narrow-band microwave wireless links requiring semi-hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been deeply. The rectangular and circular patches are the basic and most commonly used microstrip antennas.

## 3.FEEDING TECHNIQUES

Microstrip patch antennas can be fed by a variety of methods. The methods can be classified into two categories contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques are




### 3.1 Microstrip Line Feed

In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. This method is advantageous due to its simple planar structure.

### 3.2 Coaxial Probe Feed

The Coaxial probe feed is a very common technique used for feeding Microstrip patch antennas. The inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance.

### 3.3 Proximity coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme. Two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%) due to overall increase in the thickness of the microstrip patch antenna. This method is advantageous to reduce harmonic radiation of microstrip patch antenna implemented in a multilayer substrate

### 3.4 Aperture coupled feed

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane and variations in the coupling will depend upon the size i.e. length and width of the aperture to optimize the result for wider bandwidths and better return losses. The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration.

## 4. ANTENNA DESIGN TECHNIQUES

### 4.1 Slot-Loaded & Annular Slot Patch Designs

A 4×4 MIMO antenna using a microstrip annular patch with rectangular slots design achieves a 3–7 GHz frequency coverage, with an isolation of 19 dB and an antenna gain of approximately 4.5 dBi, all within a compact 51 × 51 × 0.8 $mm^3$ package.

### 4.2 Defected Ground Structures (DGS) & EBG Integration

An Ultra-Wideband (UWB) microstrip MIMO antenna utilizing EBG-loaded structures and stepped-impedance resonators (SIRs) achieves a broad frequency band of 2.4–6.5 GHz for WLAN and Sub-6G applications. This configuration significantly suppresses mutual coupling, demonstrating isolation of approximately 20 dB and an Envelope Correlation Coefficient (ECC) less than 0.02 across the operating range. The use of electromagnetic band-gap (EBG) structures in conjunction with defected ground structures (DGS) in UWB MIMO systems is an effective method for reducing mutual coupling without sacrificing antenna performance.

### 4.3 Dual-Polarized Patch Designs

Dual-polarized microstrip patches combining two frequency bands, such as 3.1–5.2 GHz and 4.9–11.5 GHz, can enable full ultra-wideband (UWB) coverage with effective bandwidth management. The technique uses multiple patches designed for different frequency bands to cover the entire UWB range from 3.1–10.6 GHz. The dual-polarization feature adds another layer of versatility by allowing for polarization diversity, which improves signal quality.

### 4.4 Compact & Diversity UWB MIMO Systems

Compact UWB (Ultra-Wideband) MIMO antenna designs for the 3.1–10.6 GHz band achieve low mutual coupling by using techniques like T-shaped ground stubs, orthogonal orientation of radiating elements, ground slots, decoupling stubs, or metal strips placed between elements. These methods, such as the one proposed by TechRxiv, aim to reduce the interaction between the antenna elements to achieve isolation below –16 dB, which is crucial for high-performance MIMO systems in portable applications. An 8-element monopole-based MIMO antenna (2–12 GHz) adds rejection capabilities (4.85–6.35 GHz), achieves >17 dB isolation, low ECC, stable radiation—compact at 50 × 50 $mm^2$ arXiv.

### 4.5 Graphene-Based & Terahertz MIMO Patches

Graphene-based micro-sized circular patch Yagi-like MIMO antennas targeting UWB frequency extensions into the THz range offer ultra-compact form for emerging high-frequency domains MDPI. A graphene-based, circular patch, Yagi-like Multiple-Input Multiple-Output (MIMO) antenna is a numerically investigated, ultra-wideband (UWB) antenna designed for terahertz (THz) wireless communication. By utilizing microstrip technology, this micro-sized device offers a compact form factor for emerging high-frequency wireless domains

## 5.PERFORMANCE METRICS COMPARISON

| Design Approach | Bandwidth (GHz) | Isolation / ECC | Gain / Patterns |
|---|---|---|---|
| **Slot-loaded 4×4 patch array** | 3–7 | ~19 dB isolation | ~4.5 dBi |
| **EBG-loaded symmetric elements** | 2.4–6.5 | ~20 dB / ECC < 0.02 | Not specified |
| **Dual-polarized patches** | 3.1–5.2, 4.9–11.5 | – | – |
| **Compact planar MIMO patches** | 3.1–10.6 | < –16 dB | – |
| **8-element monopole MIMO** | 2–12 (notched) | >17 dB isolation | Stable patterns |
| **Graphene Yagi-like patches (THz)** | UWB Terahertz range | – | – |

## 6. KEY DESIGN CHALLENGES

- **Mutual Coupling:** Achieving high isolation between closely packed elements (via EBG, DGS, or geometric techniques).
- **Isolation vs. Compactness:** Balancing antenna size and performance in tight form factors.
- **Impedance Stability:** Maintaining wideband impedance matching across UWB.
- **Radiation Pattern Consistency:** Maintaining omnidirectional or consistent patterns over wide frequencies.
- **Complex Fabrication:** Complex feeding and ground structures may complicate manufacturing.

## 7. FUTURE RESEARCH DIRECTIONS

- **Reconfigurable Designs:** Frequency-, pattern-, or polarization-tunable antennas for dynamic adaptation
- **Advanced Materials:** Exploring graphene or metamaterials for ultra-compact and high-frequency MIMO arrays.
- **Machine Learning in Design:** Automated sizing and tuning of multi-parameter antenna systems.
- **THz & Beyond Applications:** Expanding into extremely high-frequency regimes for next-gen communications.

---

## 8. Conclusion

Microstrip patch antennas remain a compelling choice for UWB MIMO applications due to their compactness, cost-effectiveness, and performance scalability. Surveyed methods—slot loading, EBG/DGS structures, polarization diversity, compact array layouts—offer viable means to satisfy UWB bandwidth, low coupling, and diversity needs. Ongoing innovation in materials, reconfigurate architectures, and optimization techniques will define the future of MIMO-UWB antenna systems.

## 9. REFERENCES

[1] C. A. Balanis, "Antenna Theory, Analysis and Design" John Wiley & Sons, Inc, New York 1997.

[2] Hamid Reza Dalili., "Design of New Compact Ultra Widband Microstrip antenna for MIMO application". International journal of Natural and Engineering Science 7(2),pp no 22-26,2013.

[3] Ghyda'a M Al-Maani and Mohamed K Abdelazeez., "Enhancement of Slot Antenna Parameters for Wideband Applications'' Antennas " International Journal of Electrical, Computer, Electronics and Communication Engineering Vol: 8, No: 6, pp-945-948, 2014.

[4] K. Jagadeesh Babu, Dr.K.Sri Rama Krishna, Dr.L.Pratap Reddy "A Multi Slot Patch Antenna for 4G MIMO Communications" ,International Journal of Future Generation Communication and Networking Vol. 4, No. 2, June, pp.105-112, 2011.

[5] Rezaul Azim , Mohammad Tariqul Islam ,Norbahiah Misran, “Printed Planar Antenna for Wideband Applications”, Journal of Infrared, Millimeter and Terahertz Waves, 31:969-978, 2010.

[6] Henridass Arun, Aswathy K. Sarma, Malathi Kanagasabai, “Deployment of Modified Serpentine Structure for Mutual Coupling Reduction in MIMO Antennas”, IEEE Antennas and wireless propagation letters, vol. 13, pp: 277-280, 2014

[8] Pradeep Kumar et al., “Dual polarized microstrip patch antennas for ultra-wideband applications,” Microw. Opt. Technol. Lett., Jun. 2014 Wiley Online Library.

[9] M. Saeed Khan et al., “Ultra-Wideband Antenna with MIMO Diversity for 5G Wireless Communication,” arXiv, Jul. 2020 arXiv

[10] A.G. Alharbi & V. Sorathiya, “Ultra-Wideband Graphene-Based Micro-Sized Circular Patch-Shaped Yagi-like MIMO Antenna for THz…,” Electronics, 2022 MDPI

**[11] Aminu, S.; Zheng, H.** *Design of Circular Slot Antenna for UWB Applications. Proc. of the 2015 Int. Conf. on Management, Education, Information and Control*, vol. *Advances in Intelligent Systems Research* (June 2015), pp. 153–157. DOI: 10.2991/meici-15.2015.30.

[12] Ramya, P., Valarmathi, R.S., Poongodi, C., Hamsagayathri, P. (2020). Slotted Microstrip Patch 4 × 4 MIMO Antenna for Ultra Wide Band Applications. In: Smys, S., Bestak, R., Rocha, Á. (eds) Inventive Computation Technologies. ICICIT 2019. Lecture Notes in Networks and Systems, vol 98. Springer, Cham. https://doi.org/10.1007/978-3-030-33846-6_2

[13] Poonam Kadam, Amit A. Deshmukh, "Analysis of Compact Dual Band Defected Ground Microstrip Patch Antenna for WLAN Application", *Proceedings of International Conference on Wireless Communication*, vol.36, pp.21, 2020