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REGULAR ARTICLE

Multiband Microstrip Patch Antenna Using Artificial Magnetic Conductor with Enhanced Bandwidth and Gain for Wireless Applications

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In this paper, a Multiband Microstrip patch antenna is designed and simulated using Artificial Magnetic Conductor (AMC) as a ground plane. The AMC acting as a High Impedance Surface (HIS) or Frequency Selective Surface (FSS) is a triple band structure constructed on a 3.2 mm thick Rogers RT_Duroid 5880 substrate ($\varepsilon_r = 2.2$) with 00 reflection phase at three different resonant frequencies 5.52 GHz, 11.12 GHz and 14.09 GHz. The return loss characteristics of Microstrip patch antenna with and without Single band and Dual band AG structures are also simulated. The simulation results obtained using Advance Design System (ADS) 2024 shows that the Microstrip patch antenna placed above AMC structure provides better performance characterizations in terms of bandwidth and gain, reduces the size of an antenna and improves radiation patterns. The impedance bandwidths at multiple frequencies obtained by the proposed antenna are 14 % (4.67 – 5.4 GHz), 6.3 % (6.15 – 6.55 GHz), 4.3 % (8.55 – 8.93 GHz), 6.4 % (9.25 – 9.88 GHz) and 2.8 % (12.19 – 12.54 GHz). It is proved that the gain is in-creased from 7.32 dBi to 11.91 dBi when the AMC is used as a ground plane for the microstrip patch antenna. The proposed antenna is suitable for C-band and X-band applications, 5 GHz WLAN and Wi-Fi applications.

Keywords: Artificial magnetic conductor, Frequency selective surface, Gain, High impedance surface, Impedance bandwidth, Radiation pattern, Reflection phase.

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1. INTRODUCTION

Antennas which are operating in more than one frequency band either to transmit or receive electromagnetic waves are called as Multiband antennas [1]. Multiband wireless antenna systems are crucial for various applications, requiring compact size and high efficiency. Microstrip antennas are widely used due to their low profile, lightweight, and cost-effective design. Modern printed circuit technology enables easy fabrication of robust, multi-band wireless systems. However, their limited impedance bandwidth needs to be improved further for multiband and wideband operation. Plenty of the techniques have been stated [1] to provide multiband characteristics and to improve the band-width of an antenna. But the well-organized use of AMC as a ground plane will provide better results in multi-band operation [2] since the AMC reflects the incident Electromagnetic (EM) waves with 00 phase reversal. AMCs are either Electro Magnetic Band gap structures (EBG) or Frequency Selective surfaces (FSSs). FSS is any thin, repetitive surface designed to reflect, transmit or absorb electromagnetic fields based on frequency.

A rectangular loop-slot AMC is designed in [3] with FR-4 substrate operating at 26 GHz which increases the gain and directivity. In [4], AMC based mmWave MIMO antenna is proposed for 5G new radio (NR) networks with high-gain and wider bandwidth. A flexible AMC based dipole antenna for wireless tags operating in the precise frequency range of 2.1 and 2.44 GHz for wireless biomedical applications is presented [5]. In [6] a double microstrip patch antenna is designed with AMC structure which improves bandwidth, gain, return loss, size miniaturization and efficiency.

Design and implementation of AMC structure along with feed line for Microstrip Patch Antenna (MPA) array is proposed in [7]. Polarization rotation technique is very important and commonly employed in the micro-wave and quasi-optical systems to get the polarization rotation of EM wave [8, 10, 11, 13]. A metamaterial structure is used for gain and bandwidth improvement in [9, 16]. Several methods are examined for exploiting higher order resonances of high impedance Frequency Selective Surfaces (FSS) with the goal of designing multiple reflection phase band AMC ground planes [12, 14]. A new type of FSS is developed for gain and bandwidth enhancement in [15]. A small quad-band antenna based

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on electromagnetic band gap (EBG) structure for automotive applications is proposed in [17].

A novel dual band tag antenna that is tolerant of several platforms is suggested for the UHF-RFID bands that are utilized in Europe (850 – 867 MHz) and Japan (950 – 955 MHz) in [18]. To increase the overall gain of the microstrip patch antenna even further, a single layer frequency selective surface (FSS) has been developed to attain the impedance bandwidth of 22.55 GHz and a gain of 3.9 dBi at 19 GHz [19]. In [20], microstrip path with defective ground plane is developed for ISM band applications at 2.45 GHz to improve radiation performance.

2. DESIGN METHODOLOGY

A possible way to overcome the difficulties in antenna design in contemporary wireless contexts is the use of AMCs which increases the bandwidth and gain while preserving the microstrip patch antenna's simplicity and compactness and the suggested system makes the following contributions: **(i)** Base Microstrip Patch Antenna (MPA) design with suitable substrate, and the feeding technique; **(ii)** AMC structure development for improved antenna Performance; **(iii)** Integration strategies for AMC and patch antenna synergy; **(iv)** Optimizing MPA with AMC metasurface for multiband operation.

3. MICROSTRIP PATCH ANTENNA DESIGN

Microstrip antennas consists of a very thin metallic strip (patch) placed a small fraction of a wavelength ($h << \lambda_0$, usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$) above a ground plane. The patch is designed so its pattern maximum is normal to the patch. A simple narrow band microstrip patch antenna is designed above a 0.8 mm thick Rogers RT_Duroid 5880 substrate ($\varepsilon_r = 2.2$) with conventional conducting ground plane to integrate with the AMC. Fig. 1 depicts the geometry of an antenna with the entire dimensions of 40 mm × 39 mm × 0.904 mm and it is excited with a 50 Ω microstrip feed line.

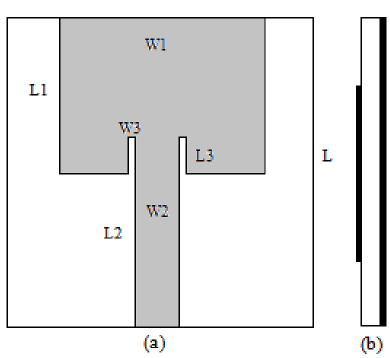


Fig. 1 – Geometry of Patch antenna with $W = 39$, $L = 40$, $W_1 = 27$, $L_1 = 19$, $W_2 = 4.9$, $L_2 = 21$, $W_3 = 0.5$, $L_3 = 3$ (all dimensions are in mm) (a) Top view (b) Side view

4. AMC DESIGN

4.1 Design of AMC Unit cell

The bandwidth and the resonant frequency of the AMC structure depend on the geometry of unit cell. So, there have been two possibilities while designing unit cell geometry: to optimize the dimensions of unit cell for given dielectric substrate or to modify dielectric substrate properties with fixed unit cell dimensions. Different unit cell geometries with various dimensions have been proposed in the literature [7-20]. Genetic Algorithm (GA) optimization technique has also been used to optimize unit cell geometry together with dielectric properties and thickness of dielectric substrate [7]. The suggested AMC structure consists of an array of 6 × 4 AMC unit cells mounted on a thick 3.2 mm Rogers RT_Duroid 5880 substrate ($\varepsilon_r = 2.2$).

4.2 Single band, Dual band and Triple band AMC Design

Single band AMC unit cell shown in Fig. 2.(a) is a rectangular unit cell with the dimension of 9.25 mm × 4.2 mm. An array of 6 × 4 single band AMC unit cells (40 mm × 39 mm) provides 00 reflection phase at the resonant frequency of 5.53 GHz. Dual band AMC structure is constructed using an array of 6 × 4 Dual band AMC unit cells and small rectangular patches are introduced horizontally in between two unit cells. It provides two 00 reflection phase bands at 5.5 GHz and 11.1 GHz. The dual band AMC unit cell is obtained by using two rectangular patches (upper patch: 9.25 mm × 4.2 mm and the inner patch: 1 mm × 1.8 mm). Since the size of the patch is inversely proportional to the frequency, increase in length of inner patch results in reduction of second resonant frequency without altering first band. The removal of inner patch in each individual dual-band AMC unit cell results in triple band AMC unit cell. By neglecting the inner patch, the third 00 reflection phase band is obtained at the resonant frequency 14.08 GHz.

The above structures are designed to reveal 00 reflection phase features at its operating frequency. And these characteristics are affected by the separation between the wave port and the AG surface. Reflection phase characteristics of Single band, Dual band and Triple band AMC structures are given in Fig. 3

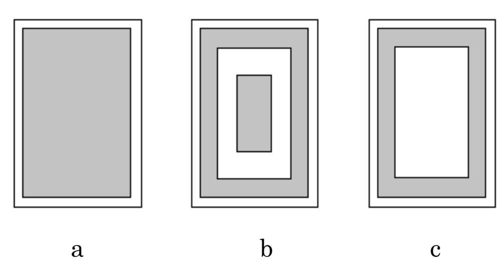


Fig. 2 – AMC unit cell geometry (a) Single-band (b) Dual-band (c) Triple-band (with substrate dimensions 10 mm × 6.5 mm)

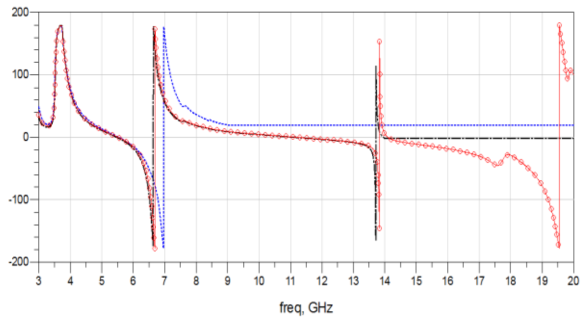
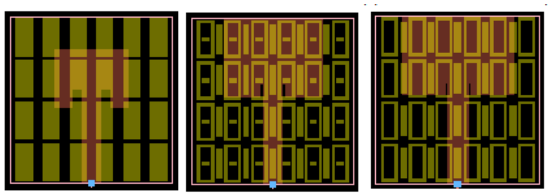


Fig. 3 – Zero degree Reflection phase characteristics



a b c

Fig. 4 – Top view of Microstrip patch antenna with (a) Single band AMC (b) Dual band AMC (c) Triple band AMC

5. DESIGN OF MICROSTRIP PATCH ANTENNA ABOVE AMC GROUND PLANE

5.1 Antenna with AMC

The conventional conducting ground plane of the MPA (as shown in Fig. 1) is replaced with the above designed AMC geometry. Fig. 4 shows the design of MPA with Single band, Dual band and Tri-band AMC structures. When the Single-band AMC is used as a ground plane for the MPA, which resonates at 5.7 GHz, it enhances the bandwidth from 1.6% (5.725 GHz to 5.820 GHz) to 27.2% (4.917 GHz to 6.352 GHz), reduces the size of an antenna and increases the gain at operating frequency. With the presence of Dual band AMC structure as a ground plane, quad band S_{11} characteristics are obtained. The triple band AG structure is used with the same MPA to produce multiple operating frequency bands.

5.2 Reflection Coefficient

The simulated S_{11} values of an antenna with and without single band AMC structure are compared in Fig. 5. Fig. 6 shows that the antenna is capable of operating at multiple resonant frequencies by using triple band AMC structure as the conducting ground plane.

5.3 Radiation pattern

Radiation patterns are simulated in E (XZ) plane and H (XY) plane as shown in Figs. 7 and 8 respectively, for the frequencies 5.18, 6.3 and 8.7 GHz. The antenna using AMC for all the configurations (antenna using single-band, dual-band and triple-band AMC) give better gain than the conventional antenna with a perfectly conducting ground plane. A maximum gain of 11.9 dBi is achieved at 8.7 GHz for triple-band AMC structure.

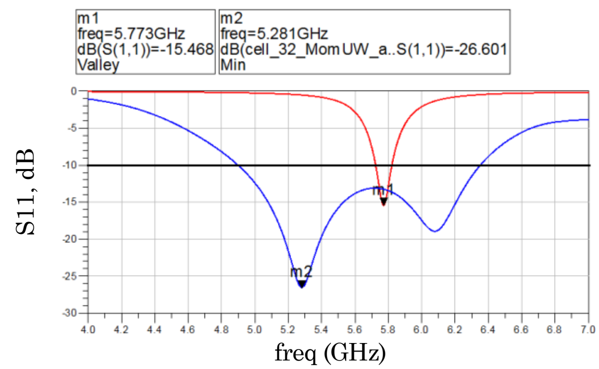


Fig. 5 – S_{11} of Antenna with Single band AMC

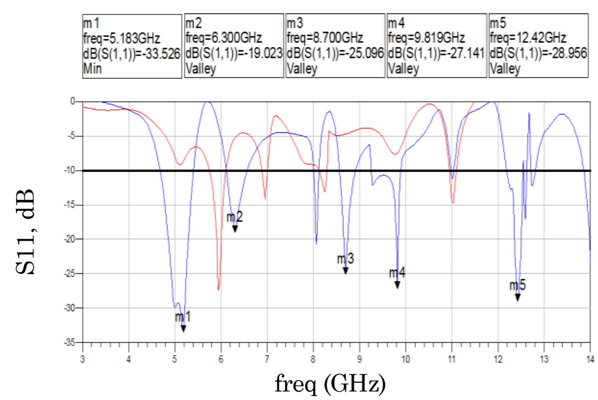


Fig. 6 – S_{11} of Antenna with Dual band and Triple band AMC

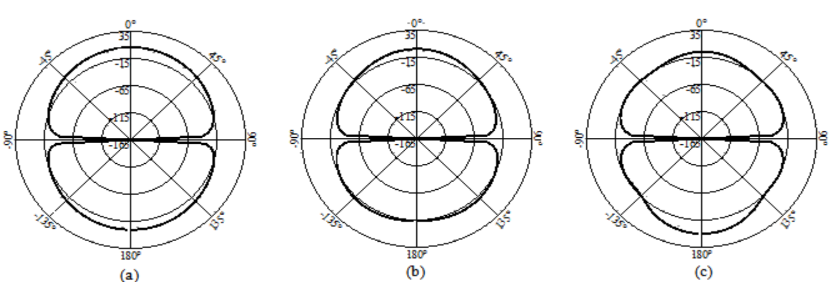


Fig. 7 – Simulated Radiation pattern in E-plane at (a) 5.18 GHz (b) 6.3 GHz (c) 8.7 GHz

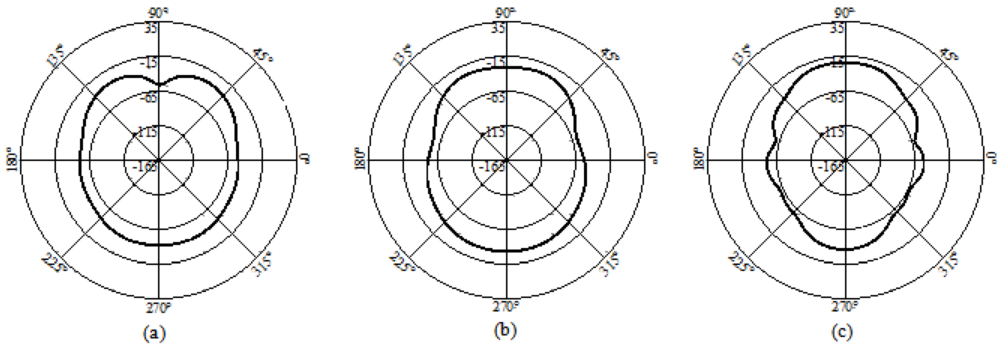


Fig. 8 – Simulated Radiation Pattern in H-plane at (a) 5.18 GHz (b) 6.3 GHz (c) 8.7 GHz

Table 1 – Comparison of Simulation Results of Antenna with Single band, Dual band and triple Band AMC structures

Ref	**Structure**	**Antenna Type**	**Resonant frequency (GHz)**	**Bandwidth (MHz)**	**% Bandwidth**	**Gain (dBi)**
Proposed AMC	Single band	Without AMC	5.773	95 (5.820 – 5.725 GHz)	1.6 %	7.32
		With AMC	5.281	1435 (4.917 – 6.352 GHz)	27.2 %	7.64
	Dual band	Without AMC	5.773	95 (5.820 – 5.725 GHz)	1.6 %	7.32
		With AMC	5.938	354 (5.750 – 6.104 GHz)	5.96 %	7.89
			6.951	116 (6.885 – 7.001 GHz)	1.67 %	7.82
			8.250	167 (8.125 – 8.292 GHz)	2.02 %	11.58
	Triple band	Without AMC	5.773	95 (5.820 – 5.725 GHz)	1.6 %	7.32
		With MAC	5.183	730 (4.67 – 5.4 GHz)	14 %	7.06
			6.3	400 (6.15 – 6.55 GHz)	6.3 %	8.64
			8.7	380 (8.55 – 8.93 GHz)	4.3 %	11.91
[3]	Single band	Without AMC	26.496	460 (26.49 – 26.95 GHz)	1.74 %	4.77
		With AMC	26.439	319 (26.28 – 26.599)	1.2 %	8.52
[6]	Single band	Without AMC	16	–	–	< 5
		With AMC	16	494	3.125 %	7.5
[19]	Single band	With FSS	20.395	22.55 GHz (9.12 – 31.67 GHz)	111 %	3.9
[20]	Single band	With DG and EBG	2.47	256	10.3 %	3.84

6. COMPARITIVE PERFORMANCE ANALYSIS OF THE SUGGESTED ANTENNA WITH THE RELATED WORKS

Impedance bandwidths of an antenna for various proposed AMC configurations and its corresponding gain values are compared with the related works as shown in Table 1. The MPA proposed in [3] achieves a high gain of 8.52 dBi. However, it has a single band of operation with a very minimum bandwidth of 460 MHz. In [6], the antenna achieves a peak gain of 7.5 dBi with the presence of a single band AMC. But this structure also provided a single narrow band operation with 494 MHz. Although the antennas proposed in [19, 20] provided an acceptable bandwidth at the required operating frequencies, the maximum gain obtained is very low comparing with the suggested antenna structure and also these designs are capable of operating at one desired frequency. The proposed antenna gives multi-band operation with wide bandwidth and highest gain values which makes the system suitable for wireless applications such as C-band and X-band applications, 5 GHz WLAN and Wi-Fi applications.

7. CONCLUSION

In this paper, a microstripfed patch antenna with a triple-band AMC ground plane is designed and simulated for improved performance. The proposed AMC structure enhances bandwidth from 95 MHz to 730 and 1435 MHz while increasing gain from 7.32 dBi to 11.91 dBi. The antenna also achieves reduced back radiation and acceptable radiation patterns in both E and H planes. Antenna with single band AMC is suitable for WLAN applications of IEEE 802.11a, IEEE 802.11n & IEEE 802.11ac and IEEE 802.11 WiMAX standard at 5.5 GHz. The patch antenna with tri-band AMC resonates at 5.183 GHz, 6.3 GHz, 8.7 GHz, 9.819 GHz and 12.42 GHz with Bandwidth of 730 MHz, 400 MHz, 380 MHz, 637 MHz and 350 MHz at corresponding frequencies. And it finds operations in C band (4 – 8 GHz) and X band (8 – 12 GHz) applications where the proposed antenna can be used for satellite and RADAR applications, in WLAN (IEEE 802.11a & n) & Wi-Fi applications and also finds applications for defense and secure communication.

REFERENCES

1. C. Balanis, Antenna Theory, *Analysis and Design; 2nd Edition* (New York: Wiley publishing: 1997)
2. Frank B. Gross, *Frontiers in Antennas: Next Generation Design and Engineering* (New York: 2011)
3. Z.I. Othman, S.A. Hamzah, K.N. Ramli, S.M.Shah, S. Saiman, *J. Electron. Voltage Appl.* **3** No 1, 105 (2022)
4. A.A. Ibrahim, W.A.E. Ali, *Int. J. Electron. Commun.* **142**, 153990 (2021)
5. Angel and Rajeev Thakur, *Int. J. Res. Trend. Innov.* **5**, 85 (2020)
6. N. Bahari, M.F. Jamlos, M.M. Isa, *Bull. Elect. Eng. Inform.* **8** No 1, 166 (2019)
7. R.E. Vaishali, P.L. Zade, *IEEE Global Conference on Wireless Computing and Networking* **51** (2014)
8. X.C. Zhu, W. Hong, K. Wu, H.J. Tang, Z.C. Hao, J.X. Chen, H.X. Zhou, H. Zhou, *IEEE Trans. Antennas Propag.* **62** No 2, 940 (2014).
9. O. Mahri, N. Guebgoub, A. Khalfallaoui, T.A. Denidni, *J. Nano-Electron. Phys.* **16** No 2, 02016 (2024).
10. M. Zhao, G. Zhang, X. Lei, J. Wu, J. Shang, *IEEE Antennas Wireless Propag. Lett.* **12**, 356 (2013)
11. S.M. Anwar, R. Sauleau, G. Valerio, L.L. Coq, H. Legay, *IEEE Trans. Antennas Propag.* **61** No 3, 1032 (2013).
12. W. Yang, W. Che, H. Wang, *IEEE Antennas Wireless Propag. Lett.* **12**, 1172 (2013)
13. E. Doumanis, G. Goussetis, J.L.G. Tornero, R. Cahill, V. Fusco, *IEEE Trans. Antennas Propag.* **60** No 1, 212 (2012).
14. D. Nashaat, H.A. Elsadek, E.A. Abdallah, M.F. Izkander, H.M. Elhenawy, *IEEE Trans. Propag. Lett.* **59** No 5, 1528 (2011).
15. T. Tewary, S. Maity, A. Mukherjee, A. Roy, S. Bhunia, *J. Nano-Electron. Phys.* **15** No 3, 03015 (2023)
16. T. Nakamura, T. Fukusako, *IEEE Trans. Antennas Propag.* **59** No 6, 2103 (2011).
17. V.R. Rentapalli, B. Roy, *J. Nano- Electron. Phys.* **16** No 4, 04020 (2024)
18. A. Bansal, S. Sharma, R. Khanna, *Int. J. RF Microwave Comput. Aid.-Eng.* e21695 (2019).
19. T. Tewary, S. Maity, A. Roy, S. Bhunia, *J. Microwave., Optoelectron. Electromagn. Appl.* **22** No 2, 329 (2023)
20. D. Singh, A. Thakur, V.M. Srivastava, *J. Commun.* **13** No 12, 730 (2018)

Багатодіапазонна мікросмужкова патч-антена з використанням штучного магнітного провідника зі збільшеною пропускною здатністю та коефіцієнтом підсилення для бездротових застосувань

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У роботі розроблено та змодельовано багатодіапазонну мікросмужкову патч-антену з використанням штучного магнітного провідника (АМС) як заземлювальної площини. АМС, що діє як високоомна поверхня (HIS) або частотно-селективна поверхня (FSS), являє собою тридіапазонну структуру, побудовану на підкладці Rogers RT_Duroid 5880 товщиною 3,2 мм (ε_r = 2,2) з фазою відбиття 00 на трьох різних резонансних частотах 5,52; 11,12 та 14,09 ГГц. Також змодельовано характеристики втрат на відбиття мікросмужкової патч-антени з однодіапазонною та дводіапазонною структурами та без них. Результати моделювання, отримані за допомогою Advance Design System (ADS) 2024, показують, що мікросмужкова патч-антена, розміщена над структурою АМС, забезпечує кращі характеристики з точки зору пропускної здатності та коефіцієнта підсилення, зменшує розмір антени та покращує діаграми спрямованості. Діапазон імпедансу на різних частотах, отриманий запропонованою антеною, становить 14 % (4,67-5,4 ГГц), 6,3 % (6,15-6,55 ГГц), 4,3 % (8,55-8,93 ГГц), 6,4 % (9,25-9,88 ГГц) та 2,8 % (12,19-12,54 ГГц). Доведено, що коефіцієнт підсилення збільшується з 7,32 до 11,91 дБі, коли АМС використовується як заземлююча площина для мікросмужкової патч-антени. Запропонована антена підходить для застосувань у С-діапазонах та Х-діапазонах, а також для WLAN та Wi-Fi на частоті 5 ГГц.

Ключові слова: Штучний магнітний провідник, Частотно-селективна поверхня, Коефіцієнт підсилення, Високоомна поверхня, Смуга пропускання імпедансу, Діаграма спрямованості, Фаза відбиття.