

# A NEW METAMATERIAL PRINTED MICROSTRIP YAGI -ARRAY ANTENNA FOR ISM BAND APPLICATIONS

Amalasofiah S, Preethi.C.

*B.E, Final Year ECE, K.R.C.E, Trichy*

[sofisoosai94@gmail.com](mailto:sofisoosai94@gmail.com), [preethichandru94@gmail.com](mailto:preethichandru94@gmail.com)

**Abstract-** A traditional yagi antenna is used for broadband applications. A New Metamaterial Printed Microstrip Yagi -Array Antenna has been introduced here. This antenna is found to operate at 2.4GHz. The microstrip yagi-array antenna is loaded with artificial split ring resonators (SRRs) which are used for achieving the metamaterial effect in the structure. The overall circuit size of the designed antenna is 11.5\*11.5\*0.25mm<sup>3</sup> with reduced cross polarization and the substrate used is FR4 epoxy with dielectric constant 4.4 which is readily available. The designed antenna achieved about 4dB of gain and it also achieved a high directional characteristic of 5-9dB in the operating band. The designed antenna had a minimum return loss of about -8dB. The achievement of narrowband width for ISM band application enhances the efficiency of the antenna at the specified band and reduces the interference level.

**Index Terms**—Front-to-back (F/B) ratio, gain, SRR, microstrip, yagi array

## I. INTRODUCTION

A New printed microstripyagi-array antenna are becoming very popular due to its increased gain, directivity, reduced cost and ease of fabrication which provides effective communication systems. Yagi-array antennas has omnidirectional pattern with increased efficiency and suppresses unwanted interference and emissions on other side. Yagi antennas are effectively used in Industrial, Scientific and Medical applications at 2.4GHz. Yagi-arrays has the characteristics of providing multiband applications. There have been many printed yagi antennas proposed over past 23 years. Gerald R. Dejean and Mavos proposed a design of microstripyagi-array which consists of seven patch elements in 2007 which produces results of about gain >10dBi and high F/B ratio which is suitable for millimeter wave applications with frequency above 30 GHz.

In this paper with reference to [1] the seven patches are U-slotted to restrict the frequency which suits the ISM band applications. Slotted antenna provides multiband applications. Here the design is provided with split ring resonator metamaterial structure to provide effective results. In addition to the resonant magnetic response SRRs also exhibit excellent resonant electric response [2].

The design is with inset feed structure and reflector elements R which is treated as single element with a gap through the middle to simplify the analysis [4]. This design is easily applicable for lower frequency applications such as ISM band application at 2.4GHz.

## II. ANTENNA STRUCTURE

The entire architecture of antenna consists of seven patch elements. This design has circular slotted reflectors and circular slotted microstrip patch with inset feeding structure. It consists of two U-slot director elements D1 and D2 where D1 has top and bottom elements as D1T and D1B and D2 has its own top and bottom elements as D2T and D2B. The reason behind the spacing between the director elements is analyzed with the reference of [4].

According to this transaction, D1 elements are used to achieve high directionality and to increase the impedance bandwidth and D2 elements are used to increase the gain of an antenna. The spacing between the D1 elements are represented as S1 and spacing between the D2 elements are represented as S2. The design consists of metamaterial structure and the split ring resonator is used here which is illustrated in Fig.2. The substrate used here is FR4 epoxy which has dielectric constant of about 4.4 with size 11.5mm\*11.5mm\*0.25mm.

## III. ANTENNA DESIGN

The proposed design is simulated using HFSS 2011 Version which is a high frequency simulator. The reflectors are size of about 0.5mm\*1.9mm with circular slot of radius 0.2mm. The directors D1, D2 size is about D1=D2=2.814 with U-slot of size -2.6mm\*-2.4mm. The microstrip patch is measured about 2.956mm\*2.956mm in size which also includes circular slot of radius 0.2mm. The feed is designed with size of 1.9mm\*0.2mm. As split ring resonator is used, the outer ring is designed with 11.5mm\*11.5mm and the inner ring is with 9.65mm\*9.65mm. Both the rings has the gap at their opposite end with spacing of 0.62mm. Hence the entire design is of about 11.5mm.

With reference [4], the parasitic element placed next to the driven element which is D1 elements whose distance has to be small for effective coupling.

The D2 element plays an important role to enhance the gain of the antenna. In this design every single cell of SSR has a square shaped enclosed loops in which opposite ends has a splits with small gaps between them. As a result of these splits this structure highly supports resonant wavelength which is greater than the diameter of the ring. This is the major difference between the split ring and the closed ring. The rings are etched on the dielectric substrate. The complete design is illustrated in Fig.1

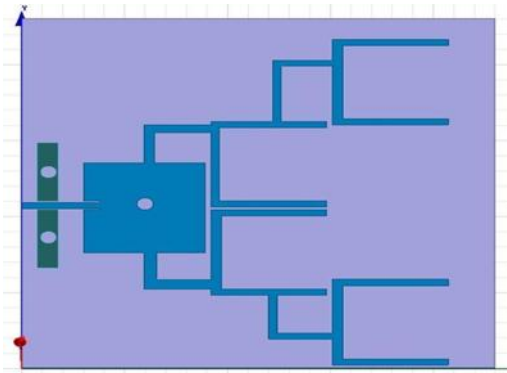


Fig.1 complete design with all the patch element

All the patch elements are united as a single element as shown in Fig.1 to achieve high current distribution and effective results.

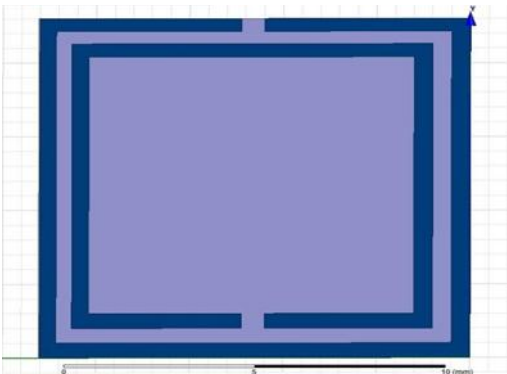


Fig.2. split ring resonator illustration

#### IV. PARAMETRIC ANALYSIS

There are many parameters are to be analyzed. In this section the director elements and the split rings are analyzed briefly with respect to frequency band.

##### A. With Single Un-slotted Director Element

The effects of director elements are given in table 1. With the use of one director element in the patch the frequency band obtained is 8GHz with current distribution 5.49V/m.

##### B. With Two Un-slotted Director Elements

With the use of this two un-slotted director elements high frequency is achieved which is of about 32.5GHz with current distribution 2.51V/m.

##### C. With U-Slot in Single Director Element

By introducing slot in the second director element the frequency has been reduced to 23GHz with current distribution 3.58V/m.

##### D. With U-Slot in Two Directors and Circular Slot in Reflectors and Patch

By introducing U-slot in second director element the frequency is reduced to 3-5 GHz and the current distribution is about 4.45V/m. To Achieve the required results the circular slots are introduced in reflectors and driven element. Hence the frequency is reduced to 2.4Ghz. But the gain is not attained.

##### E. Introducing Split Ring Metamaterial Structure

By introducing split ring the desired results are achieved. With one split ring the frequency of 2.4GHz is achieved with gain of 4dB. To increase the gain and current distribution two split rings are introduced with frequency 2.4GHz and gain of 5dB is achieved. The current distribution achieved is 8.1V/m.

TABLE-I

CONTENT		FREQUENCY (GHz)	E-FIELD (V/m)
Single	Un-slotted Director	8	5.49
Two	Un-slotted Directors	32.5	2.51
Single slotted director		23	3.58
Two slotted directors		3-5	4.41
Using split rings		2.4	8.1

#### V. SIMULATION RESULTS

To verify the analysis the entire simulation results are provided below. The achieved gain, directivity, E-field distribution are discussed below. The multiband output obtained below which suits for various applications. Hence the design is not only restricted to ISM band.

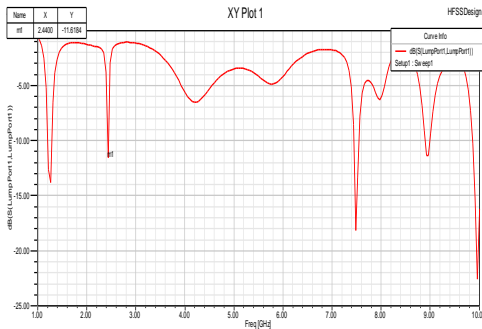


Fig.3. Frequency (GHz)

From Fig.3. The band obtained is 2.4GHz which is suitable for ISM band applications. Lumped port is used to provide the required current distribution. The radiation pattern obtained is omnidirectional which provides high directionality and front-to-back ratio.

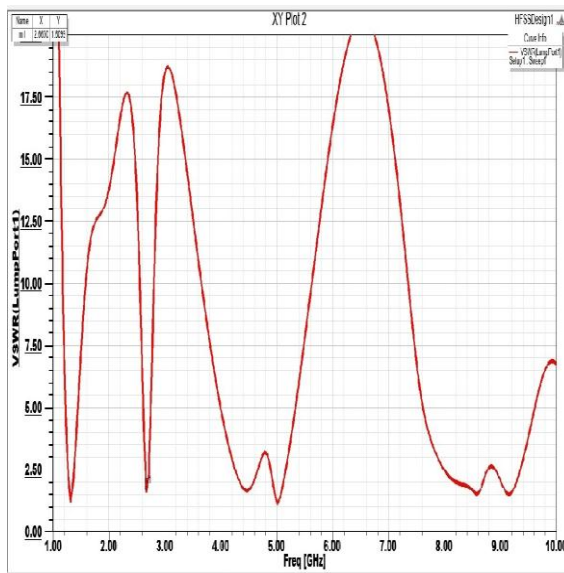


Fig.4. VSWR Measurement

The VSWR illustration is shown in Fig.4. The measured VSWR is about 1.80. Radiation pattern determines the entire radiation characteristics of the designed antenna. For an effective antenna front side radiation should be greater than the backside radiation or should be neglected. The radiation pattern obtained for E-Field and H-Field of the design is illustrated separately.

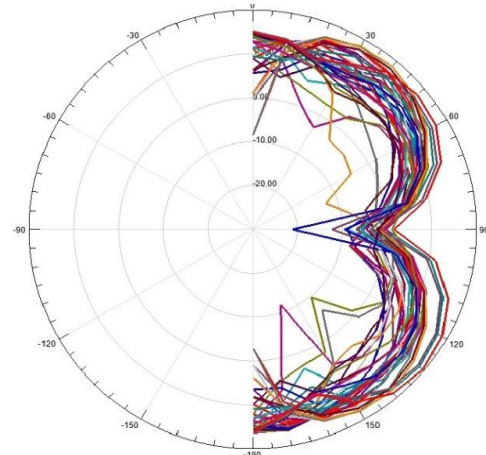
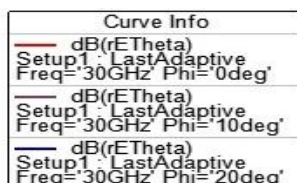


Fig.5. Radiation Pattern1 for E-Field

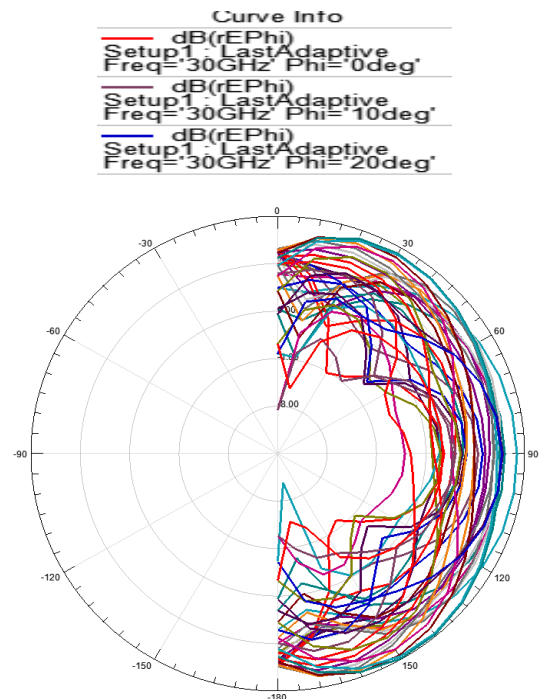


Fig.6. Radiation Pattern 2. For H-Field

Gain is increased by introducing two split rings. The total gain of about 4dB is achieved. As it provides omnidirectional pattern directivity of about 9dB is achieved. The total gain and directivity is illustrated below.

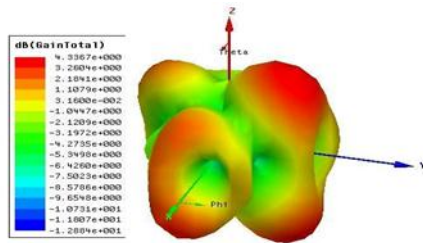


Fig.7.Total gain

When front-to-back-ratio is greater than 4dB then the impedance bandwidth and the radiation bandwidth will be equal. When the spacing between the enclosed rings decreases gain increases as per the analysis.

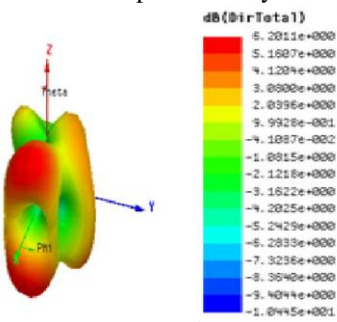


Fig.8. Total directivity

The current distribution is increased by varying the feed width and the obtained E-field is illustrated below. The E-field distribution is obtained separately for the split rings and the patched elements and illustrated below.

TABLE -II

FREQUENCY	GAIN	DIRECTIVITY	VSWR
2.4Ghz	4dB	9dB	1.80

Table-II shows the entire achieved results of the design.

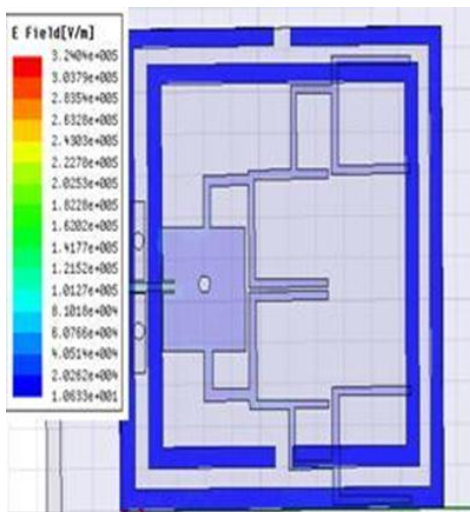


Fig.9. E-Field in Split rings

From Fig.9 the E-Field in split ring is provided with maximum of 4.05V/m. E-field in patch elements is provided with maximum of 8.10V/m which is illustrated in figure.10. The proposed yagi array antenna was analysed for its negative effects by using MATLAB simulator. The required negative values for permeability and permittivity were plotted in figures 11 and 12. From the plots it is evident that the yagi array structure achieved the left-handed metamaterial effect, i.e., it achieved both permeability( $\mu$ ) and permittivity ( $\epsilon$ ) values as negative at the desired ISM band.

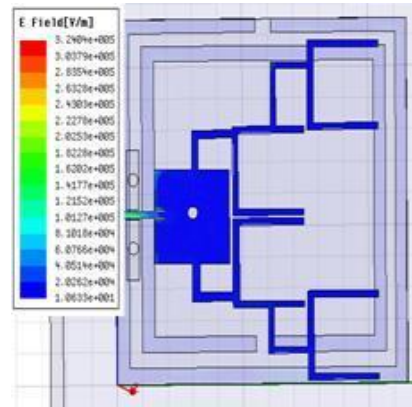


Fig.10. E-Field in patch elements

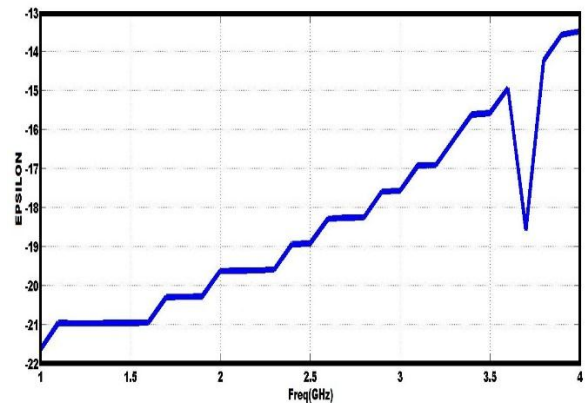


Fig.11. Plot for negative epsilon

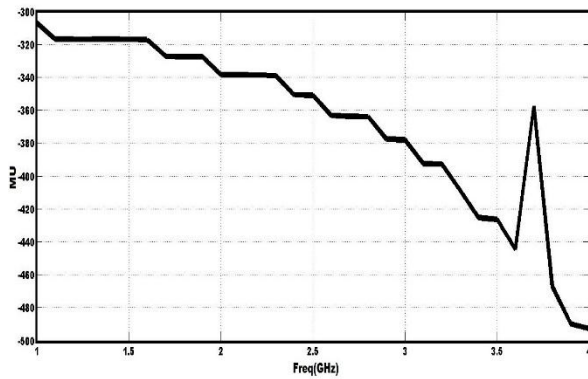


Fig 12. Plot for negative  $\mu$ .

## VI. CONCLUSION

The designed Microstripyagi-array antenna has a split ring shaped metamaterial structure with reduced cross polarization with reduced return loss of -8dB. This design provides total gain of about 4dB and total directivity of about 9dB. This antenna perfectly suits for ISM band applications which is not only restricted to WLAN applications but also covers various applications by providing multibands effectively. The cost of fabrication is very less as FR4 epoxy substrate is used which provides dielectric constant 4.4 and perfectly suits for low frequency applications. High directional pattern i.e, omnidirectional pattern is achieved with greater directionality. By modifying the director elements various bands for various applications are achieved with high efficiency and also provides ease of fabrication.

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## REFERENCES

- [1] M. Bemani and S. Nikmehr, " A Novel Wide-band Yagi-Uda Array Antenna For WLAN Application," Progress In Electromagnetics Research B, Vol. 16, 389-406, 2009.
- [2] N. Katsarakis, T. Koschny, and M. Kafesaki, " Electric coupling to the magnetic resonance of split ring resonators," Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology Hellas (FORTH), vol-84, 2004.
- [3] Satyandra Singh Lodhi & P.k. Singhal, "Microstrip Yagi-Uda Antenna At 2.45GHz For ISM band Applications," International Journal of Research in Engineering & Technology (IJRET) Vol. 1, Issue 2, July 2013, 151-154.
- [4] Omar M. Khan, Zain U. Islam, Qamar U. Islam, and Farooq A. Bhatti, "Multiband High-Gain Printed Yagi Array Using Square Spiral Ring Metamaterial Structures for S-Band Applications," IEEE Antennas and Wireless propagation letters, vol 13, 2014.
- [5] P.K. Singhal, Bimal Garg, "Design and Characterization Of Compact Microstrip Patch Antenna Using Split ring Shaped Metamaterial Structure," International Journal of Electrical and Computer Engineering (IJECE) Vol.2, No.5, October 2012, pp. 655-662.
- [6] EiThae Aye \*, Chaw Myat Nwe \*\*, "Rectangular Microstrip Patch Antenna Array For RFID Applications Using 2.45GHz Range." International Journal of Scientific and Research Publications, Volume 4, Issue 6, June 2014.
- [7] Juhua Liu, 1,2 Yue Kang, 1,2 Jie Chen, 1,2 and Yunliang Long, 1,2, " Yagi Array of Microstrip Quarter-Wave Patch Antennas with Microstrip Lines Coupling," Hindawi Publishing Corporation International Journal of Antennas and Propagation Volume 2014, Article ID 102362.