A Comparative Analysis of Miniaturizing Techniques for Planar Antennas

Vasanthi Yara
Student, Department of Electronics and Communication Engineering
Sreenidhi Institute of Science & Technology, Hyderabad, Telangana, India

R Madhusudhan Goud
Assistant Professor, Department of Electronics and Communication Engineering
Sreenidhi Institute of Science & Technology, Hyderabad, Telangana, India

Abstract- A comparative analysis of different miniaturizing techniques is presented in this paper. Miniature antennas are so called if the dimension of the patch is far less than the fractional wavelength of operation. These are the antennas whose physical dimensions are reduced in output and gain without the degradation. For the following reasons, such as these antennas being compact, light weight, radar purposes, there is a greater need for miniaturized antennas in this advanced world and this allows for a controllable reduction in size. These can be designed by altering structures, loading components, using materials with high permittivity / permeability, and using Meta materials. There are several miniaturization techniques for antenna which can be implemented for planar structures. A quad-band slot antenna, Dual polarization antenna, RFID antenna etc are few miniature antennas which can be used for WLAN/WIMAX, LTE architecture, at ultra high frequencies, satellite navigation systems, etc.

Keywords – Miniaturization, Microstrip Patch Antenna, Metamaterials, Slot, Fractal.

I. INTRODUCTION

The Microstrip based aerial element is a planar printed radio wire which is notable and is all around created in its hypothesis of activity. Because of their points of interest, for example, simple design, weightless, accessible with two dimensional and non-planar arrangements, Patch radiating element turned into an essential piece of remote correspondence networks [1, 2]. Wireless network through progressively needs miniaturized antenna. With the advancement of wireless systems technology becoming increasingly small, the antenna size needs to be reduced. Putting metal components on the two sides of the substrate material with some relative permittivity might be utilized to construct microstrip aerial devices. One side of the foundation will be patch emitting EM waves, and the ground plane of the conducting device will be another hand metal surface. This particular aerial device comprises of a very thin metal stripe placed on a bottom plane with in-between dielectric material. The radiating structure and feed lines are mounted on the dielectric material by photo-engraving process. The patch or microstrip is usually selected to be square, circular or rectangular in design for simplified analysis and manufacture [1, 3].

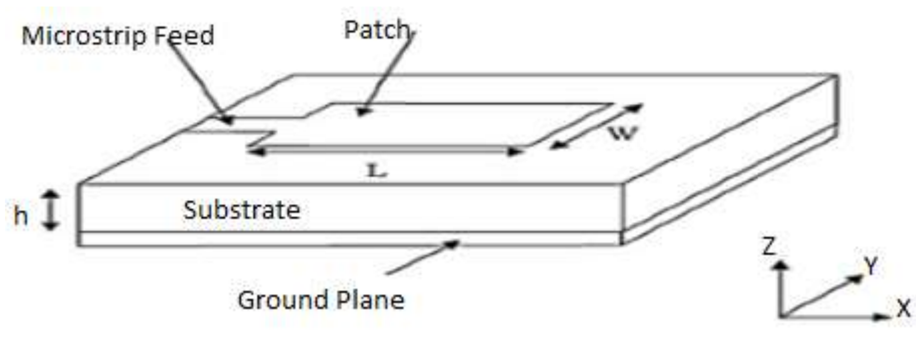

Figure 1. Three Dimensional View of Microstrip Patch Antenna

The pattern of radiation from the microstrip patch antenna is wide. It has low power radiation and narrow bandwidth frequencies. It has less directionality. An array can be built using these patch antennas to provide a greater directivity [1, 4]. A metal patch that is suspended over a ground plane. This assembly included in a plastic substratum which protects the structure against damage. Easy to produce, simple to customize. Support linear as well as circular polarization. Micro strip patch antenna (MPA) size is inversely proportional to its frequency. Input impedance of MPA can be adjusted by probe connection. The different ways of feeding planar element are classified into contacting feeds, non contacting feeds. Contacting feeds uses connection element such as microstrip line or coaxial line and RF power is directly fed to the radiating area. Inset feed, co-axial feed and quarter wave feed comes under this category. Non contacting feeding techniques uses EM radiations to couple power to the radiating patch and the methods are Couple feed and Aperture feed. One of the main issues in usage of these radiating elements in size limited platforms is area occupied by the conducting element of the patch. This drawback can be overcome by applying proper miniaturization techniques by retaining its original radiation characteristics [1,5].

II. Miniaturization

Wireless systems are present everywhere as we live in the advanced world and use of wireless systems is also increasing rapidly. Such systems include AM and FM radios, Global Positioning Systems (GPS), RFID, etc. performance of these devices are determined by the antenna characteristics used. For half a century, the ability to shrink antenna's physical dimensions without major output loss has been of considerable interest. This method of minimizing its size is called miniaturization. A traditional antenna has working frequency dimensions of half wavelength. But, this scale has been decreased in miniaturized antennas. Miniaturization of the antenna can be done with structural modifications and loading of the lumped component using materials and Meta materials of high permittivity or permeability [6].

Metallic structure miniaturization has made a state of difficulty that needs to be resolved for sophisticated fabricating companies. The upcoming and innovative areas of technology need to work upon the small areas to be implemented to meet the increasing requirements in various highly developing areas such as automotive , aerospace, electronics , medical devices, and optics. This exciting and highly awaited complexity area attracts today’s innovators to propose appropriate and correct methods in the manufacture of very small and nano features to keep up with the increasing industry developments and commercial applications. In present scenario, there is a huge requirement from populations which made the researchers to incorporate tiny parts into different types of commercial goods. There different methods for miniaturization of planar radiating elements. Some of the most efficient techniques which can be implemented without changing the directional characteristics are usage of high permittivity components, fractal methods, shorting ground and radiating conductors [3, 6]

21.. Usage of high permitivity components –

Permitivity plays a vital role in the design of planar structures. A substance’s permittivity is the substance's ability to store energy in an electric field. Using high dielectric constant (ϵr) material is the easiest way to cut down the area occupied by the radiating structure. Dimensions of the aerial device, such as length and width, are inversely related to the material's dielectric constant. And if we use materials with high permittivity we may reduce the antenna dimensions. By using higher dielectric constant materials, surface wave propagation will increase inside the substratum, resulting in lower radiation efficiency due to increased losses, and also decreasing bandwidth. Size reduction in the ground plane results poor polarization as well as changes the performance characteristics of patch antenna. Size reduction was achieved by 50 % with respect to conventional antenna for FR4 substrate. Impedance bandwidth of 1.1% achieved at 1573 MHz frequency. Magneto-dielectric substrate was also used for miniaturization of micro strip patch antenna. By using this method 65% size reduction was achieved at 2.45 GHz with respect to conventional antenna [6, 7].

2.2. Sierpinski Carpet Fractal Method –

The fractals usually have the property of filling space. This attribute of the geometrical arrangement allows the electrical range, where it is applied to minimize the antenna conducting area, to increase effectively [8]. The physical dimension of the radiating aerial device was reduced by using Sierpenski carpet fractal approach with different iterations. In this method initially the metal surface was separated into nine geometrically similar structures and central structure was replaced. As we know that electric field distribution is maximum at the edges and

minimum (nearly equal to 0) at the center of the rectangular patch antenna, even though if we remove the center part antenna performance is not affected [9]. The remaining eight rectangles in the further iterations were repeated in similar way where it is further fractioned into another nine similar rectangular structures, and central rectangular structures were repeated the same dispatched from these rectangular structures. The same procedure is followed for other iterations. By using this method 32 % size reduction was achieved at 2nd iteration. The section which comprises of exciting feed was not disturbed by the Sierpinski carpet geometrical pattern to acquire a proper exciting input impedance matching.
The formulae for the iterations are

$$N_n = 8^n$$
$$L_n = (1/3)^n$$
$$A_n = (8/9)^n$$

Where n is the number of iterations, Nn is the count of rectangular structures emanating the em waves from the conducting element, Ln is the longest physical dimensional ratio which is the ratio for geometrical arranged pattern [10, 11].

2.3. Usage of shorting pins between radiating element and the ground conducting layer –

The aerial device area minimization can be accomplished using the shorting pins among the top conducting element and bottom conducting plane. It makes antennas electrically small. E-field distribution for a half wavelength rectangular patch antenna is maximum at the radiating edges and zero at the middle. So we can subtract half of that distribution and also can get the same Q performance at the same resonant frequency that is called quarter wavelength antenna. Higher size reduction was achieved by adapting shorting pins between top and bottom conducting plane but directivity was reduced. Therefore antenna gain was reduced as well. By using this technique the size reduction with the conventional antenna was achieved by factor 3 [12, 13].

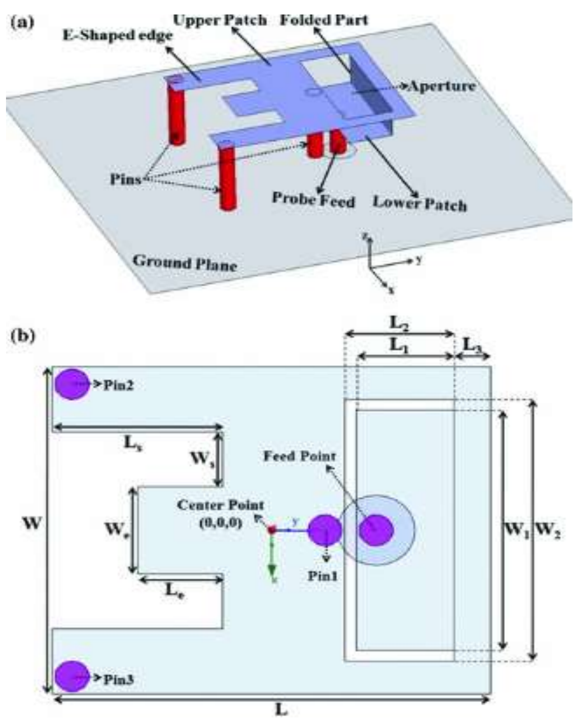

Figure 2. Microstrip radiating patch with shorting pins

2.4. Placing slots on the top conducting layer of the patch –

A technique commonly used to miniaturize the microstrip patch antenna is to introduce the slots on the patch or to change the patch shapes. By using this technique electrical paths for current increases and this can be done in high-performance computing method using genetic algorithm. In this method, various slots of the different lengths were introduced on the patch of antenna [14].

Also U and L shaped slots were introduced on the ground plane. Here patch and ground plane were shortened by shorting pin, resulting in increased length of electrical path for current flow. Using this technique, the size reduction was achieved up to 86 per cent. Through this, antenna was operated on several frequency bands.

Another method of using slots, where they use irregular shapes and size of the slots on the patch of the micro strip patch antenna using genetic algorithm [15].

Miniaturization using this method suffers from ohmic losses, resulting in reduced antenna gain and micro strip patch antenna radiation efficiency. Artificially engineered conductors were used to solve this problem. Separately laminated varying layers here. Artificially engineered conductor had the same thickness as conventional conductor [16, 17].

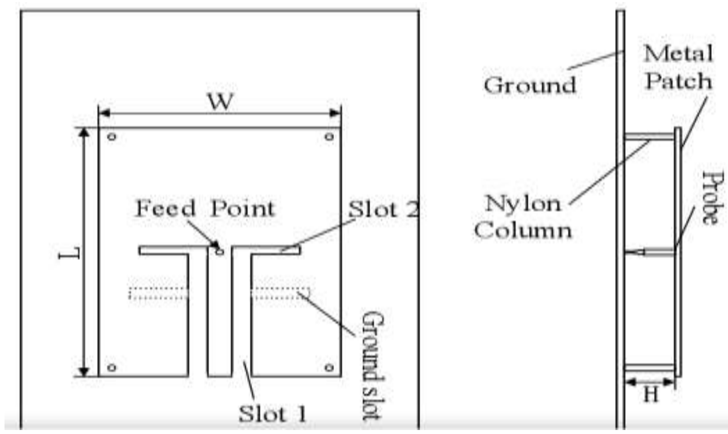

Figure 3. Microstrip patch with slots on the top layer

2.5. Comparison

The use of high permitivity materials has an advantage of high size reduction. The percentage of area reduction is less than 50 percent. But the drawback with this approach is limited operational bandwidth and also the cost of implementation is very high. With the use of fractal approach , the antenna perforamance like radiation characteristics is not changed. The impedance and pattern characteristics of the antenna will remain same. The drawback of this approach is the number of iterations to be performed to obtain the required radiation characteristics is highly complex. On the other hand higher size reduction with reduced cost is obtained with shorting pins between the top conducting layer and the bottom conducting plane is highly advantageous but there is no standard procedure for the same. By placing slots on top layer of the patch, the bandwidth of the patch can be increased , but polarization of the antenna is very poor and the design complexity is very high.

IV.CONCLUSION

This paper briefly provides the basic knowledge on the fundamental design of the Microstrip radiating device and its miniaturization techniques. Some of the methods provided greater miniaturization, while the other methods provided moderate miniaturization with antenna performance and radiation efficiency. Some methods can be applied very easily where some are very complex miniaturization methods. We may go for that particular miniaturization technique and design the antenna based on our requirement.

REFERENCES

[1] D. M. Pozar, "Microstrip antennas," in *Proceedings of the IEEE*, vol. 80, no. 1, pp. 79-91, Jan. 1992, doi: 10.1109/5.119568.

[2] Choon Sae Lee, Pi-Wei Chen and V. Nalbandian, "Electrically small microstrip antennas," *IEEE Antennas and Propagation Society International Symposium. Transmitting Waves of Progress to the Next Millennium. 2000 Digest. Held in conjunction with: USNC/URSI National Radio Science Meeting (C*, Salt Lake City, UT, 2000, pp. 778-781 vol.2, doi: 10.1109/APS.2000.875325.

[3] David M. Pozar; Daniel H. Schaubert, "Basic Microstrip Antenna Elements and Feeding Techniques," in *Microstrip Antennas: The Analysis and Design of Microstrip Antennas and Arrays* , IEEE, 1995, pp.57-104, doi: 10.1109/9780470545270.ch2.

[4] S. A. Bokhari, J. -. Zurcher, J. R. Mosig and F. E. Gardiol, "A small microstrip patch antenna with a convenient tuning option," in *IEEE Transactions on Antennas and Propagation*, vol. 44, no. 11, pp. 1521-1528, Nov. 1996, doi: 10.1109/8.542077.

[5] D. R. Jackson, J. T. Williams, A. K. Bhattacharyya, R. L. Smith, S. J. Buchheit and S. A. Long, "Microstrip patch designs that do not excite surface waves," in *IEEE Transactions on Antennas and Propagation*, vol. 41, no. 8, pp. 1026-1037, Aug. 1993, doi: 10.1109/8.244643.

[6] Y. Hwang, Y. P. Zhang, T. K. C. Lo, K. M. Luk and E. K. N. Yung, "Miniaturization on planar antennas with very high permittivity materials," *Proceedings of 1997 Asia-Pacific Microwave Conference*, Hong Kong, 1997, pp. 217-220 vol.1, doi: 10.1109/APMC.1997.659343.

[7] T. Kin-Chung Lo and Yeongming Hwang, "Microstrip antennas of very high permittivity for personal communications," *Proceedings of 1997 Asia-Pacific Microwave Conference*, Hong Kong, 1997, pp. 253-256 vol.1, doi: 10.1109/APMC.1997.659352.

[8] M. F. Abd Kadir, A. S. Ja'afar and M. Z. A. Abd Aziz, "Sierpinski carpet fractal antenna," *2007 Asia-Pacific Conference on Applied Electromagnetics*, Melaka, 2007, pp. 1-4, doi: 10.1109/APACE.2007.4603961.

[9] Nan Lu and XiaowenXu, "Sierpinski carpet fractal antenna in third iteration," *2013 IEEE INTERNATIONAL CONFERENCE ON MICROWAVE TECHNOLOGY & COMPUTATIONAL ELECTROMAGNETICS*, Qingdao, 2013, pp. 164-167, doi: 10.1109/ICMTCE.2013.6812412.

[10] A. R. Sankhe and U. P. Khot, "Optimization of Iteration Order and Iteration Factor in Sierpinski Carpet Fractal Patch Antenna," *2018 International Conference on Smart City and Emerging Technology (ICSCET)*, Mumbai, 2018, pp. 1-5, doi: 10.1109/ICSCET.2018.8537388.

[11] S. Shrestha, S. Han, S. Noh, S. Kim, H. Kim and D. Choi, "Design of modified Sierpinski fractal based miniaturized patch antenna," *The International Conference on Information Networking 2013 (ICOIN)*, Bangkok, 2013, pp. 274-279, doi: 10.1109/ICOIN.2013.6496389.

[12] R. Porath, "Theory of miniaturized shorting-post microstrip antennas," in *IEEE Transactions on Antennas and Propagation*, vol. 48, no. 1, pp. 41-47, Jan. 2000, doi: 10.1109/8.827384..

[13] K. F. Tong, K. F. Lee and K. M. Luk, "On the effect of ground plane size to wideband shorting-wall probe-fed patch antennas," *2011 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications*, Torino, 2011, pp. 486-486, doi: 10.1109/APWC.2011.6046774.

[14] R. Azadegan and K. Sarabandi, "Design of miniaturized slot antennas," *IEEE Antennas and Propagation Society International Symposium. 2001 Digest. Held in conjunction with: USNC/URSI National Radio Science Meeting (Cat. No.01CH37229)*, Boston, MA, USA, 2001, pp. 565-568 vol.4, doi: 10.1109/APS.2001.959526.

[15] B. Ghosh, S. K. M. Haque and N. R. Yenduri, "Miniaturization of Slot Antennas Using Wire Loading," in *IEEE Antennas and Wireless Propagation Letters*, vol. 12, pp. 488-491, 2013, doi: 10.1109/LAWP.2013.2255857.

[16] C. Ko, M. Chiang and J. Sze, "Miniaturized Planar Annular Slot Antenna Design Utilizing Shorting Conducting Strip," in *IEEE Antennas and Wireless Propagation Letters*, vol. 8, pp. 1360-1363, 2009, doi: 10.1109/LAWP.2009.2039190.

[17] A. Shackelford, Kai-Fong Lee and D. Chatterjee, "On reducing the patch size of U-slot and L-probe wideband patch antennas," *2000 IEEE-APS Conference on Antennas and Propagation for Wireless Communications (Cat. No.00EX380)*, Waltham, MA, USA, 2000, pp. 35-38, doi: 10.1109/APWC.2000.900136.