Miniaturization Techniques For Next Generation Small Antennas: Review

Geeta Bhatia,
Pusa Polytechnic, Department of Electronics and Communication Engineering

Abstract: The Next Generation Small Microstrip Patch Antennas specification was created to provide miniaturised methodologies for calculating microstrip antenna usage. Several governments and private companies have employed these technologies to overcome antenna fabrication problems in mobile phones, satellites, missiles, radar navigational aids, and military applications.These techniques are used to reduce the physical size of the antenna while boosting its bandwidth and efficiency. Some strategies for antenna downsizing include the use of slots, slits, short meandering, and innovative geometries such as fractals, as well as the use of higher dielectric constants. Miniaturization's impact on antenna properties such as radiation efficiency, gain, and bandwidth is explored. Finally, the study describes how to miniaturise an antenna using appropriate and efficient methods, such as a microstrip patch antenna with a double-layered substrate structure. This authoritative book contains a comprehensive review of contemporary micro antenna literature, as well as the most up-to-date approaches on small antenna theory and assembly.

Keywords: Microstrip patch antenna (MPA), Miniaturization, Microstrip Antenna (MSA).

1. Introduction

Wireless technologies are ubiquitous, and their use is rapidly increasing. These systems include AM and FM radios, Global Positioning Systems (GPS), RFID, and other devices. The performance of these devices is determined by the parameters of the antennas used. As a result, antenna design is the most important feature of any wireless system. Printed antennas have been the most popular alternative for compact electronics and wireless system design due to their low profile and ease of integration. The most common printed antennas are microstrip patch antennas (MPA). Despite the fact that manufacturing technology has reduced the size of most communication system components significantly. Even yet, lowering the size of the antennas is a challenging task. The wavelength of the operating frequency is half the size of standard antennas. Antenna performance is an important issue to consider when reducing the size of an antenna. There has been a lot of research done on antenna performance. Size reduction can be achieved at the expense of antenna bandwidth and gain, according to all theories.

These concepts **(Sievenpiper, D., Dawson, Jacob, 2012)** demonstrate the effect of Q-restriction on antenna performance. Numerous research groups are currently engaged in creating electrically tiny antennas, and many novel antenna structures have developed in miniature form. Among them are microstrip patches, slot antennas, and various sorts of antennas.

Electrically small antennas (ESAs) have been extensively researched and can fit into a half-radian sphere. Small antenna performance limits have been the focus of several theoretical articles, in particular. Every hypothesis has reached the same conclusion: the size of an antenna can only be reduced at the expense of bandwidth and gain **(Sievenpiper, Dawson, Jacob, 2010; Volakis, Chen, Fujimoto, K, 2010)**.

The Microstrip Patch Antenna is the finest fit for the full demand among the many antennas. As a result, it is quite popular among researchers in this field. The following are the key reasons for its popularity: It's a small antenna with a low profile. It's simple to design and make. Monolithic ICS is simple to integrate. It's simple to install on any surface. It is simple to manufacture in large quantities. Because of its inexpensive cost, this antenna can be used in everyday communication equipment.

Material loading **(D. Schaubert and K. Yngvesson,1986)**, shorting and folding **(Porath, 2000)**, reshaping **(Herscovici, Osorio, Peixeiro, 2002)**, modifying the ground plane **(Prabhakar et al., 2007)**, using metamaterials **(Rajab, R. Mittra, Lanagan, 2007)**, and fractal contours have all been used in the miniaturisation of microstrip patch **(Wqrner, Ganguly, 2003)**.

Many bioinspired algorithms have been created and used to improve various antenna shapes **(Kar, 2015)**. **(Cuevas et al., 2013)** Neural networks **(Freni, M. Musetta, Pirinoli, 2012)**, genetic algorithms, and particle swarm optimization are the most commonly utilised **(Robinson, Rahmat-Samii, 2004)**.

This study suggests using a Koch fractal geometry **(Maza, Cook, Jabbour, Shamim, 2012)** in conjunction with a shorting post **(Gianvittorio, Rahmat-Samii, 2002)** to significantly reduce the resonant frequency, allowing for the downsizing of a microstrip patch antenna. The approach focuses on employing a social spider optimization (SSO) algorithm to optimise the shorting post (location and radius) and inset feeding line (width and length) based on spider collective behaviour **(Rodrigues, Lins, Assunço, 2015)**.

For comparison reasons, an antenna prototype was built and tested. It is demonstrated that a compact microstrip patch antenna can be built for usage in the low-frequency bands of 4G mobile communication systems using the proposed technique.

Conductor material can be placed on both sides of the dielectric substrate material to create microstrip patch antennas. The patch antenna's ground plane will be on one side of the substrate, while the radiating patch will be on the other. **(Sievenpiper, Dawson, Jacob, 2012)** This antenna patch can also be rectangular, round, or any other shape. Because its design is basic and quick to construct, the rectangular and circularly shaped patch is commonly employed. MPAs have several advantages, including being easy to fabricate due to their simple design; they can be fabricated on any cheap substrate material; they are simple to operate; substrate materials are readily available; and they are cost-effective because they can be used with any other circuits in various applications such as GPS receivers, mobile phones, and communication systems. A transmission line model can be used to assess a microstrip patch antenna. The Microstrip antenna is represented by two slots of width W and height h separated by a transmission line of length L in this model. Microstrip is a non-homogeneous line made up of two dielectrics, usually the substrate and air**(Garg, Bhartia, Bhal, Ittipiboon, 2001).**

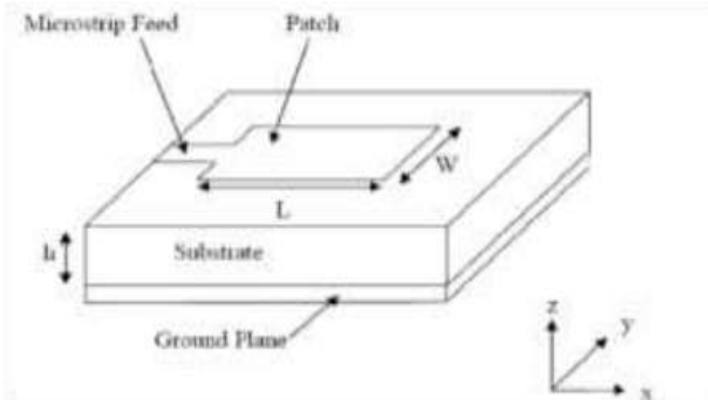

Figure 1

The majority of the electric field lines are found in the substrate, with portions of others found in the air. As a result, the pure transverse electric-magnetic (TEM) mode of transmission is not possible since the phase velocities in the air and the substrate are different. Instead, the quasi-TEM mode would be the dominating mode of propagation. To account for the fringing and wave propagation in the line, an effective dielectric constant (ϵreff) must be determined. Because the fringing fields around the patch's periphery are not restricted in the dielectric substrate but also spread in the air, the value of ϵreff is slightly smaller than r.

$$W = \frac{c}{2f} \times \sqrt{\frac{2}{(\varepsilon_r+1)}}$$

$$L = \frac{c}{2f}\left(\frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{\left[1+12\frac{h}{W}\right]}\right)^{\frac{-1}{2}} - 2\Delta L$$

Miniaturization of Patch Antena

Miniaturization of the patch antenna is an important factor in antenna design, but reducing the antenna's size reduces bandwidth and reduces gain **(Wheeler, 1984)**. However, after several types of research, it has been determined that if a small antenna is enclosed in a sphere of radius "a," the quality factor is given by:

Q = (1/ka) + (1/ka)3

k is the wave number. According to this information, increasing the quality factor increases efficiency and gain while decreasing bandwidth **(Kar, 2015)**.

Techniques for Antenna Miniaturization

Loading of high dielectric material in the substrate of an antenna

Because the wavelength of the high permittivity material employed in the substrate shortens, the antenna physical size shrinks when embedded within it. The permittivity and form of the dielectric will determine the physical dimensions of an antenna. As a result, excessive dielectric loading reduces the antenna's bandwidth while increasing the quality factor. The high concentration of electric field within the high dielectric region is the reason behind this **(Kar, 2015)**.

Using double-layered substrate in microstrip patch antenna

The bandwidth of a microstrip antenna can be increased by increasing the height or thickness of the substrate up to a particular limit in microstrip antenna design. If we want to keep the benefits of having the feed line and radiation patch on the same surface, we'll need to make the substrate and feed line thicker. This will cause issues with feed line dimensions, hence a double substrate geometry is used to boost antenna impedance bandwidth while also providing feed line dimension flexibility. As a result, the dispersion of the transmission line will be decreased. The transmission line's dispersion will be reduced as a result. It does not limit the patch's layer thickness, allowing for a larger impedance bandwidth. As a result, the planar structure of the feed line and patch can be preserved **(Bhattacharya, Chatterjee, 2012).**

1.1 Scope of Study

Antenna miniaturisation is a critical topic in wireless communication these days. The simulated analysis of small planar antennas employing various antenna downsizing approaches is presented in this research. They have contributed to the definition of miniaturisation methodologies for estimating the use of microstrip antennas. These approaches were used by several government and commercial sector firms to solve the problem of antenna fabrication in mobile phones, satellites, missiles, radar navigational aids, and military applications. These strategies are used to minimise the antenna's physical size while increasing its bandwidth and efficiency. Introduction of slots, slits, brief meandering, and new geometries such as fractals, as well as the use of higher dielectric constants, are some methods for antenna downsizing. Miniaturization's impact on antenna properties such as radiation efficiency, gain, and bandwidth is explored. Finally, the study gives a brief description of how to miniaturise an antenna utilising appropriate and efficient approaches, such as a microstrip patch antenna with a double-layered substrate structure.

2. Conclusion

This paper discusses the numerous microstrip patch antenna shrinking approaches, as well as the basics and many aspects of antenna size, bandwidth, and gain. Mobile, military, marine, land mobile telemetry, fixed telemetry, digital multichannel system, satellite (downlink), and aeronautical applications all benefit from this antenna design. For nearly 70 years, antenna shrinking has been the topic of various investigations. Early research found that shrinking an antenna's size reduces its bandwidth and efficiency (hr). The size restriction places a lower limit on the possible radiation quality factor (Q factor) and, as a result, on the maximum impedance bandwidth. Many new studies have recently been carried out in order to minimise the form factor (or total size) of various types of antennas while maintaining appropriate matching qualities and operational bandwidth. The electrical and physical parameters of an antenna are often changed using these shrinking techniques.

3. References

D. H. Wqrner and S. Ganguly, "An overview of fractal antenna engineering research," *IEEE Antennas and Propagation Magazine*, vol. 45, no. 1, pp. 38–57, 2003.

D. Schaubert and K. Yngvesson, "Experimental study of a microstrip array on high permittivity substrate," *IEEE Transactions on Antennas and Propagation*, vol. 34, no. 1, pp. 92–97, 1986

Garg, R., Bhartia, P., Bhal, I., Ittipiboon, A.: ‘Microstrip antenna design handbook’ (Artech House, MA, USA, 2001)

H. V. Prabhakar, U. K. Kummuri, R. M. Yadahalli, and V. Munnappa, “Effect of various meandering slots in rectangular microstrip antenna ground plane for compact broadband operation,” *Electronics Letters*, vol. 43, no. 16, p. 848, 2007.

J. P. Gianvittorio and Y. Rahmat-Samii, “Fractal antennas: a novel antenna miniaturization technique, and applications,” *IEEE Antennas and Propagation Magazine*, vol. 44, no. 1, pp. 20–36, 2002.

J. Robinson and Y. Rahmat-Samii, “Particle swarm optimization in electromagnetics,” *IEEE Transactions on Antennas and Propagation*, vol. 52, no. 2, pp. 397–407, 2004.

M. U. Khan, M. S. Sharawi, and R. Mittra, “Microstrip patch antenna miniaturization techniques: a review,” *IET Microwaves, Antennas & Propagation*, vol. 9, no. 9, pp. 913–922, 2015.

N. Herscovici, M. F. Osorio, and C. Peixeiro, “Miniaturization of rectangular microstrip patches using genetic algorithms,” *IEEE Antennas and Wireless Propagation Letters*, vol. 1, pp. 94–97, 2002.

R. L. Haupt and D. H. Werner, *Genetic Algorithms in Electromagnetics*, John Wiley & Sons, Inc., 2007.

R. Porath, “Theory of miniaturized shorting-post microstrip antennas,” *IEEE Transactions on Antennas and Propagation*, vol. 48, no. 1, pp. 41–47, 2000.

Samir Dev Gupta, M.C. Srivastava, “Multilayer microstrip antenna quality factor optimization for bandwidth enhancement”, vol. 7, No. 6, pp.756-773, 2012

S. Chatterjee, A Bhattacharya “Active rectangular patch antenna”, IJECET, vol. 3, pp. 220-228, January-June 2012

Sievenpiper, D., Dawson, D., Jacob, M., et al.: ‘Experimental validation of performance limits and design guidelines for small antennas’, IEEE Trans.Antennas Propag., 2012, 60, (1), pp. 8–1

Sumit Gupta and Toolika Srivastava, *“A Review on Microstrip Patch Antenna and its Miniaturisation Techniques.“*

W. C. de Araújo, H. W. C. Lins, A. G. D'Assunção Jr, J. L. G. Medeiros, and A. G. D'Assunção, “A bioinspired hybrid optimization algorithm for designing broadband frequency selective surfaces,” *Microwave and Optical Technology Letters*, vol. 56, no. 2, pp. 329–333, 2014.

Wheeler, H.A.: ‘Fundamental limitations of small antenna’, Proc. IRE, 1947, 35,no. 12, pp. 1479–1484.