MICROWAVE ELECTRONICS

DEVELOPMENT AND ANALYSIS OF A DRUM-SHAPED COMPACT MICROSTRIP ANTENNA

A thesis submitted by

JACOB GEORGE

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COCHIN 682 022, INDIA

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To my Parents, my Brother
and
to my Teachers

CERTIFICATE

This is to certify that this thesis entitled "**DEVELOPMENT AND ANALYSIS OF A DRUM-SHAPED COMPACT MICROSTRIP ANTENNA**" is a bona fide record of the research work carried out by Mr. Jacob George under my supervision in the Department of Electronics, Cochin University of Science and Technology. The results presented in this thesis or part of it have not been presented for any other degree.

Dr. P. MOHANAN
(Supervising Teacher)
Reader
Department of Electronics
Cochin University of Science and Technology

Cochin 682 022
26th June 1998

DECLARATION

I hereby declare that the work presented in this thesis entitled "**DEVELOPMENT AND ANALYSIS OF A DRUM-SHAPED COMPACT MICROSTRIP ANTENNA**" is based on the original work done by me under the supervision of Dr. P. Mohanan, in the Department of Electronics, Cochin University of Science and Technology, and that no part thereof has been presented for the award of any other degree.

Cochin 682 022
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JACOB GEORGE

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Jacob George

CONTENTS

Chapter 1

INTRODUCTION

In 1886, Heinrich Rudolph Hertz, the father of electromagnetics, in his Karlsruhe laboratory, generated, transmitted and received electromagnetic energy by means of an end loaded half-wave dipole as transmitter and a resonant square loop antenna as receiver. This was the birth of a new field called antennas. "*Antennas are like electronic eyes and ears*" [18]. They act as interface between free space and circuitry. According to Institute of Electrical and Electronics Engineers (IEEE) an antenna is defined as "*a means for radiating or receiving radio waves*" [4]. Hertz has observed that when sparks were produced at a gap at the centre of a dipole, sparking also observed at a gap in the nearby loop. This was a memorable event in the history of science and this invention triggered talented scientists all over the world to generate and transmit electromagnetic waves efficiently.

In 1897, J.C. Bose, the talented Indian Scientist, experimented at very short waves with a new type of antenna called electromagnetic horn. The works of Hertz and Bose, inspired Guglielmo Marconi and he erected large monoconical wire antennas for longwave transatlantic communication. In 1901, he succeeded in transmitting the first wireless signal across the Atlantic. Since then, many researchers around the world conducted brain storming work towards the development of various types of antennas to meet different applications. The early history of electromagnetic waves before 1900 is well reviewed by Ramsay [12].

According to Prof. J.D. Kraus[18, 5], antennas can be classified on the basis of the material from which it is made of as

a. antennas made of conductors of wire or tubing

b. antennas made of sheet conductors

c. antennas made of dielectrics

d. array antennas

Different types of helices, linear conductor antennas and loops are coming in group (a). Category (b) consists of reflectors, guiding, slotted and microstrip antennas. Group (c) is constituted by lenses, polyrods and slabs. The last group is divided into driven, parasitic, adaptive, interferometric and digital beam forming arrays.

The rapid developments in the present day communication systems (personal communication systems, mobile satellite communication systems, etc.) demand planar low profile and conformal antennas. Microstrip antennas are satisfying all the above requirements and therefore they are fast replacing conventional antennas in the above areas.

1.1 MICROSTRIP ANTENNAS

The microstrip antenna concept was first proposed by Deschamps [19] in 1953. Since then, it took nearly 20 years for the first practical microstrip antennas to come up. The first practical microstrip antennas were developed by Howell [22] and Munson [23] in the early 1970's and this set the pace of research and development in the area of microstrip antennas all over the world.

The basic configuration of a microstrip antenna is shown in Figure 1.1. It consists of a planar radiating structure of any geometrical shape over a ground plane separated by a thin dielectric substrate. Commonly used microstrip radiating geometries are rectangular and circular. However, other shapes are also considered depending upon the application. These antennas have got many advantages like light weight, low volume, low profile planar configuration that can be made conformal, low fabrication cost, etc., compared to conventional microwave antennas. However, they have some serious drawbacks like narrow bandwidth, low gain, radiation in one half plane, poor isolation between the feed and the radiating element, etc.

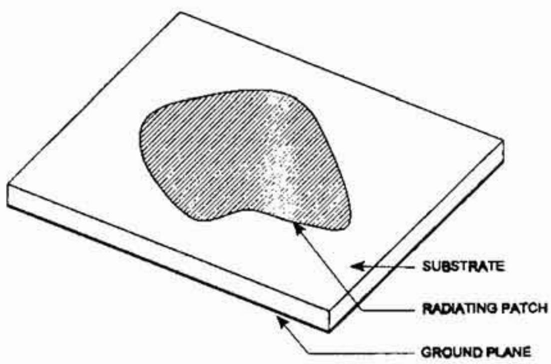

FIGURE 1.1 Basic microstrip antenna configuration

1.1.1 Radiation from a Microstrip Antenna

The radiation from microstrip antennas occurs from the fringing fields between the edge of the microstrip antenna conductor and the ground plane. For a rectangular microstrip antenna fabricated on a thin dielectric substrate and operating in the fundamental mode, there is no field variation along the width and thickness. The fields vary along the length, that is about half a wavelength long. These electric field configurations are shown in Figure 1.2.

The radiation mechanism may be explained by resolving the fringing fields at the open circuited edges into normal and tangential components with respect to the ground plane. The normal components are out of phase (as the patch is half wavelength long) and hence the far field produced by them cancel each other. Whereas, the tangential components are in phase and the resulting fields are combined to give maximum radiation in the broadside direction.

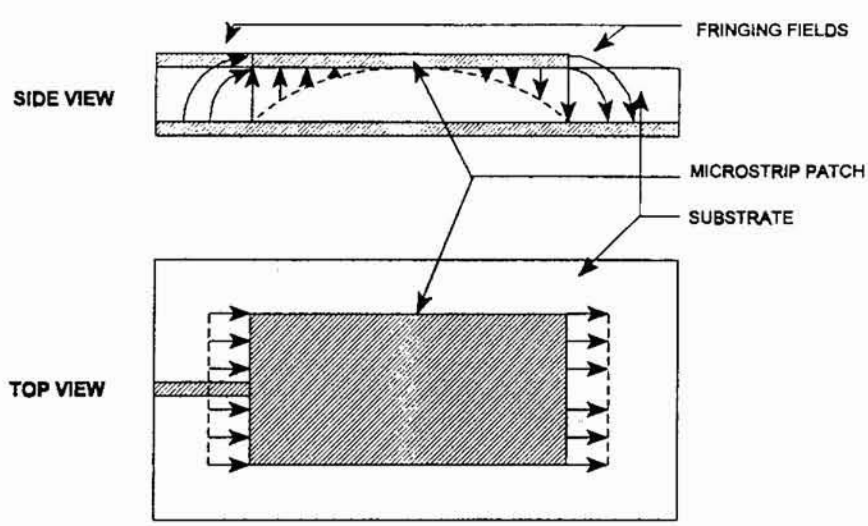

FIGURE 1.2. Field variation along the length and width of a rectangular microstrip antenna

1.1.2 Excitation techniques

The selection of an appropriate feeding mechanism to couple power to a microstrip antenna is as important as the selection of a suitable geometry for a particular application. A variety of feeding mechanisms are available and some important techniques are explained here.

1.1.2.1 Microstrip feed

This is the simplest way to feed electromagnetic power to a microstrip antenna. Here, the antenna and the feed line are fabricated simultaneously on the same side of the substrate as shown in Figure 1.3 and this makes it very attractive in array environments. The most undesirable feature of this feeding mechanism is the spurious radiation from bends, transitions, junctions, etc. These radiations adversely affect the side-lobe level and cross-polarisation characteristics of the antenna. This drawback may be compensated by suitably selecting a high dielectric constant substrate. In fact, this will reduce the radiation efficiency of the antenna. A compromise between the two is to be made depending upon the applications.

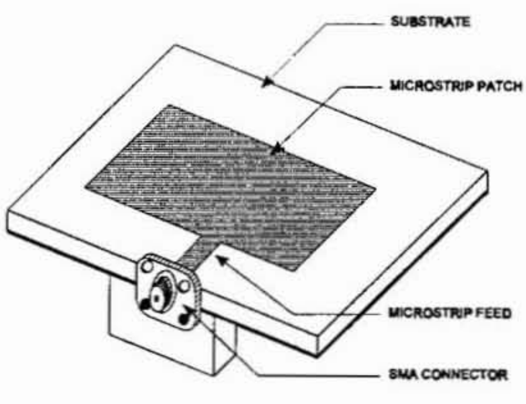

FIGURE 1.3. Microstrip feeding arrangement

1.1.2.2 Coaxial feed

It is a convenient method of feeding a single patch. Here, the coaxial connector is attached to the backside of the printed circuit board and the centre conductor is attached to the antenna at the desired point. The coaxial (probe) feeding arrangement is shown in Figure 1.4. Here, as the feed lies behind the radiating surface, there is no question of unwanted radiation from the feed for thin substrates. In fact, for thick substrates, the coupling between adjacent feeds may deteriorate the performance. In array environment, the complete antenna and feeding arrangement cannot be etched simultaneously. This increases the feeding complexity, especially in large arrays. At high frequencies, it becomes very difficult to realise these types of feeding as it involves drilling holes through the substrate and proper soldering of the centre conductor to the patch.

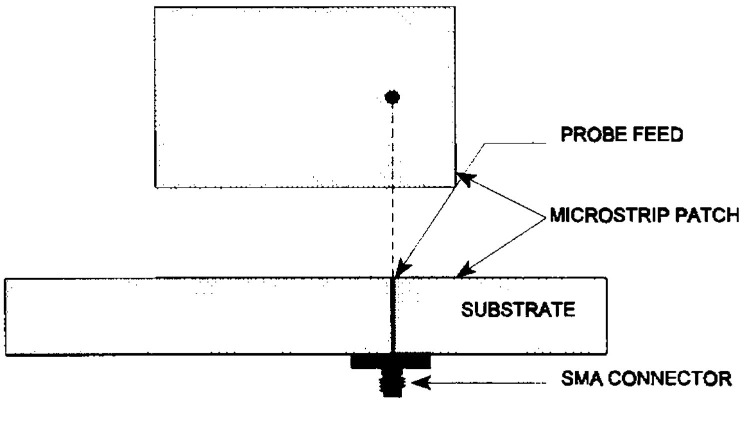

FIGURE 1.4 Coaxial(probe) feeding of a microstrip antenna

1.1.2.3 Buried feed(electromagnetic coupling)

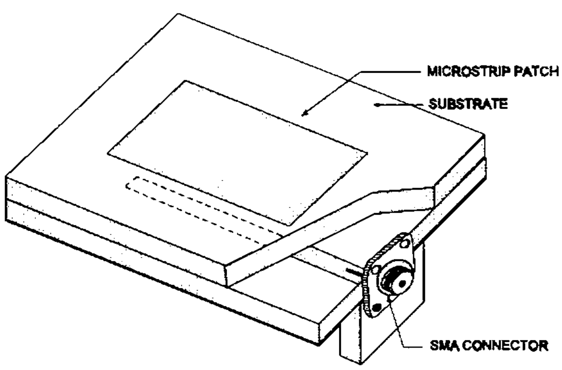

FIGURE 1.5 Buried feeding arrangement

In this type of feeding, the antenna and the feed are placed at different levels. i.e., the feed system is a covered microstrip line and the radiating element is etched on the covering substrate immediately above the open-ended feed line. The radiating element is thus parasitically coupled to the feed line. The system can be considered as a microstrip patch on a double layered substrate sharing a common ground plane with the feed as shown in Figure 1.5. Like the microstrip feed system, this arrangement also suffers from spurious radiation from the feed network. This may be minimised by using substrates of high dielectric constant for the feedline.

1.1.2.4 Slot feed (aperture coupling)

This feeding arrangement utilises a common ground plane to separate the feed and the radiating geometry. The coupling between the two is provided by a slot etched on the ground plane. The aperture should be placed accurately below the patch and above the feed line as shown in Figure 1.6. Here, spurious radiation from the line is physically separated from that of the patch and can be completely avoided by enclosing the feed within a box. To avoid radiation towards the backside of the antenna, the slot must not resonate within the operating frequency band of the patch and should be placed far enough from the edge of the patch.

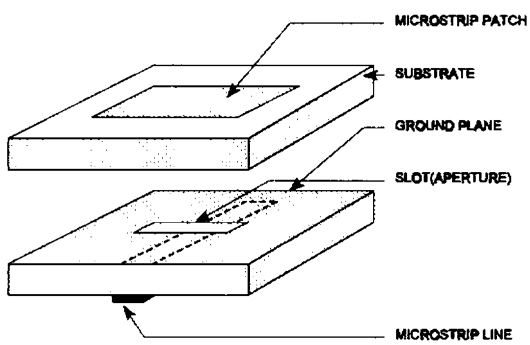

FIGURE 1.6 Slot (aperture) feeding arrangement

1.1.3 Broadband microstrip antennas

One major drawback of microstrip antennas, which limits its widespread application, is the narrow impedance bandwidth. There are different approaches for improving the impedance bandwidth of microstrip antennas. They include: using thicker substrates with low dielectric constant, addition of a parasitic patch on top of the original patch by using a separate dielectric substrate as support, using multiple patches in one plane and by means of proximity coupling of feed line to the patch antenna.

The use of thicker substrates for bandwidth enhancement is limited by the excitation of surface waves. In the case of using parasitic patches, each element resonates at adjacent frequencies and as a result the impedance bandwidth improves. The parasitic loading will usually increase the overall surface area. In Appendix C, one new method for the enhancement of impedance bandwidth of microstrip antennas is described in detail. Appendix B demonstrates the enhancement in impedance bandwidth through proximity coupling.

1.1.4 Compact microstrip antennas

Depending upon the application, microstrip antennas having different geometrical shapes are used [7]. Commonly used geometries are rectangular and circular. However, recent developments in Personal Communication Systems (PCS), demand more and more compact microstrip antennas. This is clear from the review presented in the next chapter. The important approaches for reducing the size of microstrip antennas include: the use of new geometrical shapes, use of shorting posts, use of a high dielectric constant substrate, etc. A detailed review of the works towards the development of compact microstrip antennas is also included in Chapter 2.

1.1.5 Models/techniques used in the analysis of microstrip antennas

Different methods are available in literature for the analysis of microstrip antennas. For antennas having regular geometrical shapes (rectangular), analytical techniques like cavity model and transmission line model can be applied. For geometries which can be readily divided into few regular geometrical shapes, these analytical techniques could be applied along with segmentation technique. These techniques are unsuitable in the case of arbitrary shaped patches. Here numerical techniques like Finite Element Method (FEM), Finite Difference Time Domain