DESIGN OF A WIDEBAND REDUCED SIZE MICROSTRIP ANTENNA IN VHF/ LOWER UHF RANGE

Manish Kumar [(1)], Manish Kumar Sinha[(2)], L. K. Bandyopadhyay[(3)], Sudhir Kumar[(4)]

Central Mining Research Institute, Dhanbad; Instrumentation div., CMRI, Barwa Road, Dhanbad – 826 001, Jharkhand (India)

E-mail: [(1)]laxmikb@yahoo.com; [(2)] er_mksinha@yahoo.co.in; [(3)]laxmikb@yahoo.com; [(4)]sudhir_46@yahoo.co.in

ABSTRACT

The paper presents a Wideband Helical Microstrip Antenna, with particular attention to high bandwidth, size reduction and low back lobe radiation in VHF (Very High Frequency)/ lower UHF (Ultra High frequency) band. The antenna inserted with shorting post, is double probe-fed having a minimum VSWR (Voltage Standing Wave Ratio) of 1.025 at a resonating frequency of 321.25 MHz, and a 2:1 VSWR bandwidth of 183.5 MHz. The antenna structure is finally arrived at after studying various dimensional effects on bandwidth and frequency of operation. The simulations are conducted using IE3D (commercial software) based on Method of Moments (MoM) and results of the simulation study have been discussed in the paper.

1. INTRODUCTION

The official IEEE definition of an antenna as given by Stutman and Thiele [1] says: “That part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves.” Microstrip antenna is only one such type of antenna.

The concept of Microstrip antenna though introduced in the early 1950’s in USA by Deschamps and in France by Gutton and Baissinot, it was in the 1970’s only that with the advent of printed-circuit technology [2,3], some serious advancements in this research area had begun resulting in the development of first practical antennas.

A Microstrip device in its simplest form is a sandwich of two parallel conducting layers separated by a single thin dielectric substrate. The upper conductor is a thin metallic patch (usually Copper or Gold), which is a small fraction of a wavelength [1]. The lower conductor is a ground plane which should be infinite theoretically. The patch and ground-plane are separated by a di-electric substrate which is usually non-magnetic. The dielectric constant of the substrate ranges from 1.17 to about 25, with the loss tangent ranging from 0.0001 to 0.004. The patch can assume any shape, be it rectangular, circular, triangular, elliptical, helical, circular ring, etc. The variety in design that is possible with Microstrip antennas probably exceeds that of any other type of antenna element. Microstrip antennas are used where size, weight, cost, better performance, compatibility with microwave and millimeter wave integrated circuits (MMICs), robustness, ability to conform to planar and non-planar surfaces, etc. are required [2,5].

Bandwidth and efficiency of a Microstrip antenna depends upon patch size, shape, substrate thickness, dielectric constant of substrate, feed point type and its location, etc.. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable for higher bandwidth, better efficiency and better radiation, leading to a larger antenna size. Designing a compact antenna requires higher dielectric constant, leading to narrower bandwidth, lesser efficiency and higher loss tangents (dissipation factors) [2]. Another effective technique to reduce antenna size is to insert shorting post which would be used in the proposed antenna. Hence final design requires a trade-off between antenna dimensions and antenna performance, depending on the system requirement. The upper conducting layer, i.e., the patch of the Microstrip antenna is the source of radiation and it radiates primarily because of the fringing fields between the patch edge and the ground plane. The lower conducting layer acts as a perfectly reflecting ground plane, bouncing energy back through the substrate and into the free space.

Microstrip antennas are high Q (Quality factor) devices, sometimes reaching 100 for thinner elements. But high Q elements have lower bandwidth and lower efficiency. One solution can be to increase the substrate’s thickness, but there are limits beyond which an increased fraction of the total power delivered by the source goes into surface wave. Surface wave, an unwanted power loss, is scattered at dielectric bends and discontinuities which is shown in the fig. 1. However, the quantitative presence of surface wave being governed by the rules of total internal reflection, must be included to extract power from the direct radiation pattern, resulting in increased side lobe levels, antenna loss and decrease in efficiency. The two techniques available to feed or transmit electromagnetic energy, i.e., induce excitation to a Microstrip antenna are contacting and non-contacting types. In the contacting technique, feeding is done directly via a connecting element such as Microstrip transmission line and co-axial probe. In the non-contacting technique like aperture coupling and proximity coupling, electromagnetic field coupling is done to transfer power between the Microstrip line and the upper conductor [2,3].

2. METHODOLOGY ADAPTED

2.1 Antenna Shape Selection

Designing an antenna in the VHF (Very High Frequency)/ lower UHF (Ultra High Frequency) band meant that the antenna dimensions could be bulky which is unwelcomed. Keeping this in mind, with the objective to design a reduced-size wideband Microstrip antenna, the design idea was taken from broadband antennas to make the antenna work in a large band of frequencies. Of the many broadband antennas, helical antenna was chosen. Hence, the chosen shape of the patch was that of the shape of a 2D (two-dimensional) helical antenna, with an aim to combine the advantage of both the helical as well as that of the Microstrip antenna. It was, thus, possible to reduce the size of patch thereby reducing the size of Microstrip antenna with increased bandwidth.

2.2 Feeding Type Selection

To induce excitation, co-axial or probe feed technique was used as its main advantage was that the feed can be placed at any place in the patch to match with its input impedance (usually 50 ohm). The front view of this arrangement is shown in the fig. 2. Also in the non-contacting techniques, there was an undesirable complexity and increase in the overall thickness of antenna. Hence the probe feed technique was used for its easiness of fabrication as well as low spurious radiation. But the problem arises when the height of the dielectric substrate increases, making the input impedance more inductive, thereby inviting undesirable matching problem [4]. Care was, therefore, taken not to increase the height of substrate beyond a certain limit. The equivalent RLC (Resistance-Inductance-Capacitance) circuit for the probe feed is shown in the fig. 3 [3]. The parallel RLC circuit symbolizes the patch, illustrating its resonant structure. The resistance R corresponds to the loss associated with the conductors (ground plane and patch) and the substrate (loss tangent). The co-axial probe feed line is represented by probe inductance L_p. It is to be noted that initially the feeding was done at a single point, but the results were not very encouraging. It was, therefore, at this juncture only that decision was taken to feed at two points.

2.3 Dielectric Substrate Selection

Considering the trade-off between the antenna dimensions and its performance, it was found suitable to select a thin dielectric substrate with low dielectric constant. Thin substrate permits to reduce the size and also spurious radiation as surface wave, and low dielectric constant – for higher bandwidth, better efficiency and low power loss. The simulated results were found satisfactory.

2.4 Use of Shorting Post

It was felt necessary to insert shorting post for further reduction of the antenna dimensions. This technique uses the fact that the electric lines of force existing between the patch and the ground plane has a maximum value at the two edges and zero at the middle plane. Hence shorting a few points at the middle zero-potential plane was always possible without affecting the basic operations of the antenna [5].

2.5 Software Selection for Simulation

The software used to model and simulate the helical Microstrip antenna was Zeland Inc's IE3D [6]. IE3D is an integrated full-wave electromagnetic and simulation package based on the method of moments for the analysis and design of 3D (three-dimensional) Microstrip antenna, high frequency printed circuits and digital circuits such as MMICs and high speed printed circuit boards (PCBs). It can be used to calculate and plot RL (Return Loss), VSWR (Voltage Standing Wave Ratio), Radiation pattern (Azimuth & Elevation), Smith Chart and various other parameters.

3. ANTENNA DESIGN

Fig. 4 shows the proposed helical Microstrip antenna with its dimensions being mentioned in the table 1 [7].

The double probe-fed helical Microstrip antenna, with crossing loops and inserted with shorting post, is the proposed antenna. Each dimension, i.e., L (length), B (breadth), W (width), D (outer diameter), d (inner diameter) and n (number of loops) of the antenna was varied in accordance with the other dimensions of the same, observing the changes in bandwidth, frequency of operation and back lobe radiation. But the results of the proposed antenna dimensions as mentioned in the table 1 were found to be better in comparison to the results of other antenna dimensions of the similar structure. The size of the proposed antenna is acceptable considering the fact that the size could have been even larger because of its application in the VHF/ lower UHF range.

Table 1 : Dimensions of the proposed antenna

L (total length of patch)	270 mm
B (breadth of patch)	145 mm
W (width of patch)	5 mm
D (diameter of bigger loop)	180 mm
d (diameter of smaller loop)	120 mm
n (number of loops)	2
h (height of substrate)	1.6 mm
ε_r (dielectric constant of substrate)	2.2
Loss tangent of substrate	0.001
First feeding point	(3 mm, 0 mm)
Second feeding point	(3 mm, 5mm)

4. RESULTS & DISCUSSION

The proposed antenna has been simulated using Zeland Software's IE3D simulation package. Fig. 5 shows the variation of VSWR with frequency. From frequency 222.5 MHz to 406 MHz, the input VSWR and RL are <= 2 and <= –9.5 db respectively. The total input impedance bandwidth of 183.5 MHz is available from the proposed antenna. Fig. 6 shows the variation of return loss with frequency with centre frequency of 321.25 MHz. Minimum –41 db RL and minimum 1.025 VSWR are available from the proposed antenna which is significant. Fig. 7 shows the 2D radiation pattern (elevation) at 321.25 MHz; the same radiation pattern has been obtained throughout the operating frequency band. Fig. 8 shows the 2D radiation pattern (azimuth). Fig. 9 shows the input impedance loci using Smith Chart.

5. CONCLUSION

The design has demonstrated that a double probe-fed helical shaped patch with inserting post can be used to form an antenna with a bandwidth of 57.12% working in the VHF/ lower UHF band. Due to its compactness and wideband property, diverse applications of such antenna can be anticipated. The designed wideband antenna could be used in wireless devices. Reduced back lobe radiation is obtained which is an added advantage for the application of the antenna if used in wireless handsets since this minimizes the amount of electromagnetic energy radiated towards the user's head. Further development work could be carried out regarding design of a dichroic or trichroic microstrip patch antenna which would operate at two or three frequencies to serve multiple applications.

There is every possibility that the overall performance of the proposed antenna can be improved in terms of size, shape, thickness of substrate, type of substrate, power loss, bandwidth, etc. Some of the techniques have been developed [8] for further improvement in the antenna performance, like the use of parasitic elements, stacked elements, better impedance matching techniques, electromagnetic-coupling, cavity-backed antennas, micro-machining technology, photonic crystals, etc.

ACKNOWLEDGEMENT

The authors are thankful to the Director, Central Mining Research Institute, Dhanbad for his kind support and permission to publish this paper.

REFERENCES

[1] Stutzman, W. L. and Thiele, G. A., *Antenna Theory and Design*, John Willey & Sons, Inc., 1998.
[2] C. A. Balanies, *Antenna Theory : Analysis & Design*, John Willey & Sons, Inc., 1997.
[3] Pozar and Schaubert, "Microstrip Antennas," *Proceedings of the IEEE*, vol. 80, 1992.
[4] Kumar, G. and Ray, K. P., *Broadband Microstrip Antennas*, Artech House, Inc., 2003.
[5] Waterhouse, R. B., Targonski, S. D., and Kokotoff, D. M., "Design and Performance of small Printed Antennas," *IEEE Trans. Antennas and Propagation*, 1998, vol. 46, pp. 1629-1633.
[6] IE3D Software Release 7.0 (*Zealand Software Inc.*, Fremont, California, USA).
[7] A. K. Roy, A.G. Sharma, Manish Kumar, "Design of reduced size Wide-band Microstrip antenna for VHF & Lower UHF application using IE3D," *B. Tech. project*, NERIST, Arunachal Pradesh (India).
[8] Zurcher, J. F., and Gardiol, F. E., *Broadband Patch Antennas*, Artech House, London and Boston, 1995.

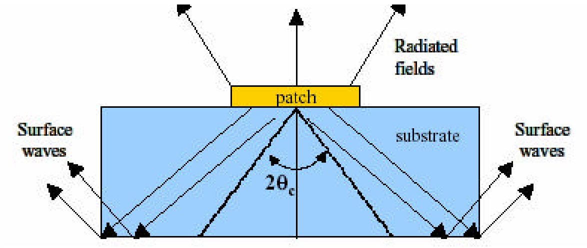

Fig. 1 : Field lines radiating from patch antenna; illustrates the formation of surface waves (θ_c = Critical angle)

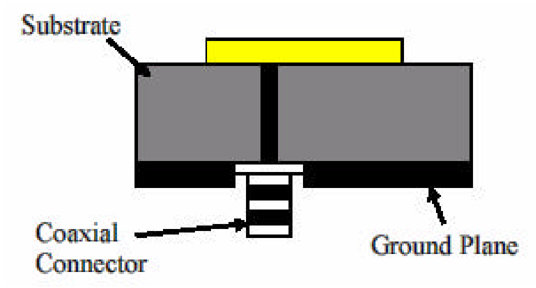

Fig. 2 : Probe – fed patch antenna (front view) feed configuration

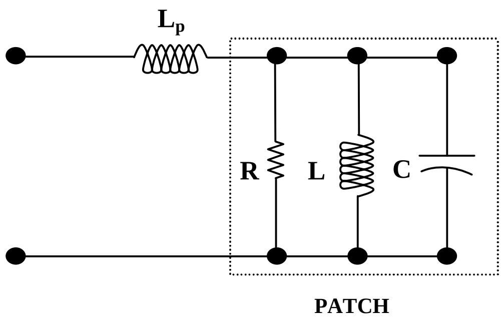

Fig. 3 : Equivalent RLC circuit of Co-axial Probe

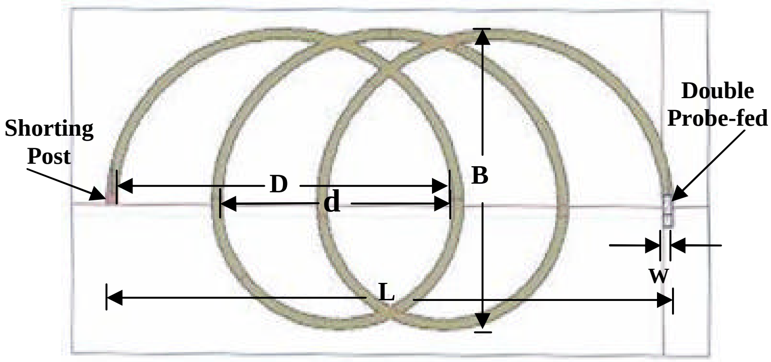

Fig. 4 : Proposed Double Probe-fed Helical Microstrip Patch Antenna with Shorting Post

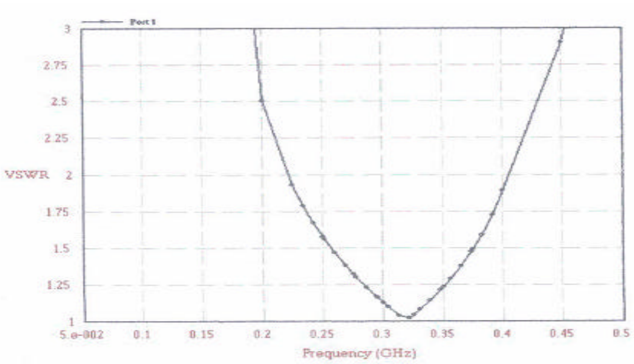

Fig. 5 : Variation of VSWR with frequency

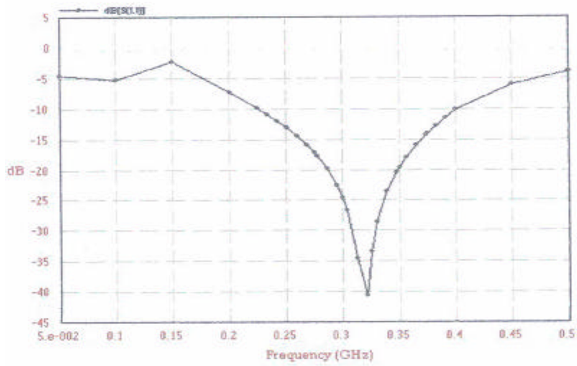

Fig. 6 : Variation of Return Loss with frequency

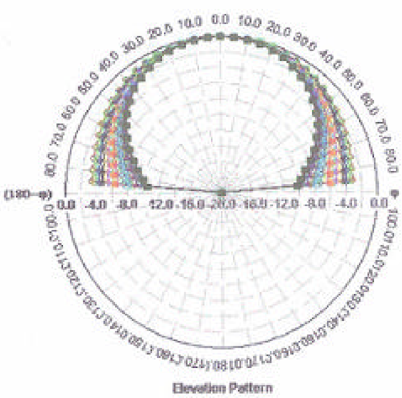

Fig. 7 : 2D Radiation Pattern (Elevation)

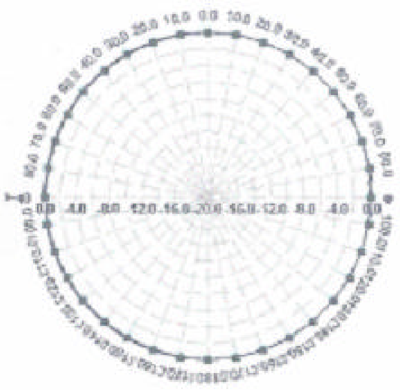

Fig. 8 : 2D Radiation Pattern (Azimuth)

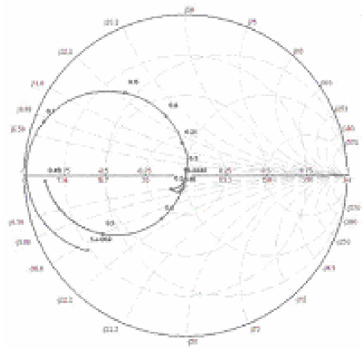

Fig. 9 : Input Impedance Loci