SUSTAINABLE DUAL-BAND MICROSTRIP PATCH ANTENNA WITH PAPER-BASED SUBSTRATE AND ALUMINUM FOR MULTIPOINT DISTRIBUTION SYSTEMS AND WiMAX APPLICATION

by

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In this study, a microstrip patch antenna design with a U-shaped patch and a paper-based substrate is presented. Metallic parts such as the patch, ground plane and microstrip line feed are designed in aluminum. Utilization of recyclable paper and aluminum yields a sustainable and environmentally friendly design. The dual-band antenna operates between 1.950-2.125 GHz and 2.650-2.825 GHz with a bandwidth of 0.175 GHz for both frequency ranges. It is suitable for multipoint distribution systems (2.076-2.111 GHz) and WiMAX application (2.700--2.800 GHz). Monopolar radiation patterns are obtained for the operation frequencies of both frequency ranges. Maximum gain values are 5.009 dBi and 5.413 dBi for the operation frequencies of multipoint distribution systems and WiMAX application, respectively. While the antenna can be used indoors and outdoors, radome design is not considered in the structure. No parasitic elements or slots are included in the antenna. All simulations are carried out by using ANSYS HFSS software package.

Key words: *antenna design, environment, microstrip patch antenna, sustainability, sustainable engineering*

Introduction

Sustainability is defined as a capability of a system to endure and maintain itself. Various disciplines may apply this term differently. Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1, 2].

Engineering is the application of scientific and mathematical methods for practical purposes such as the design, manufacture, products and processes, while taking into account constraints of economics, environment and other sociological factors. Many technological advances are introduced by engineering, which significantly improves society and standards of living. It also affects culture and environment positively [3]. Recently, many researchers have indicated the importance of sustainable development in engineering education and practice, which has yielded the concept of sustainable engineering as an area of multidisciplinary research. Sustainable engineering can be defined as the integration of sustainability topics in the broad activities related to engineering [4]. Sustainable engineering maximizes advantages in

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favor of individuals, society and ecosystems. It is vital to specify the associated sustainability issues at the beginning of the engineering designs [5].

Antennas form the basis of modern communications and antenna design is one of the largest application areas in engineering. Moreover, sustainable antenna designs are of great importance within the context of sustainable engineering. Using recycled, non-hazardous materials, reducing scrap through increased simulation cycles and virtual prototyping, designing directional antennas and improving antenna efficiency for energy use minimization are several methods in sustainable antenna design. Few studies on sustainable antennas have been reported. Ibanez-Labiano *et al.* [6] examine a multi-layer graphene-based soft antenna in which graphene is used as an alternative to metal parts. The antenna covers a frequency range of 3-9 GHz with a maximum gain of 2.83 dBi. In another study [7], radiation shielding materials of copper, tungsten, lead and stainless steel are used in a microstrip patch antenna that resonates at 2.4 GHz and 26 GHz. By comparison of these materials, it is concluded that tungsten is a viable choice for the antenna structure and is more environmentally friendly compared to the other options. Ying *et al.* [8] propose a flexible coplanar waveguide fed antenna with organic substrate which is Basalt composite for 2.4 GHz and 5 GHz WLAN applications. Dimensions of the antenna is 49.9 × 51.15 mm. It exhibits dipole radiation patterns.

Microstrip patch antennas are commonly utilized in many areas such as wireless communications, navigation, space research as well as telemedicine as they are compact, low-profile, and low-cost. [9]. Ample research has been reported for different microstrip patch antenna geometries in a number of studies [10-20]

In this article, a microstrip patch antenna with a *U*-shaped patch and a paper-based substrate is designed. Aluminum is utilized for the metallic parts including the patch, ground plane and microstrip line, which is used for feeding. Antenna performance parameters such as return loss, radiation pattern and maximum gain are presented. It is suitable for both multipoint distribution systems (MDS) and WiMAX application as it is a dual-band antenna. It is an example of sustainable antenna designs as the paper and aluminum can be recycled and are non hazardous for the environment. Simulations are carried out by using ANSYS HFSS, a finite element method based software.

Antenna

Designed antenna and dimension notations are shown in fig. 1. The antenna consists of a *U*-shaped patch, a ground plane and a substrate material in between. It is fed centrally by a microstrip line. Microstrip line calculations are carried out according to Garg *et al.* [21]. Antenna dimensions are given in tab. 1. Substrate material is blank paper with a relative dielectric constant of 3.1 and a loss tangent of 0.065 [22]. Substrate height is abbreviated as H. Aluminum is used in the metal parts for the patch, the ground plane and the microstrip line.

Results and discussion

In this section, simulation results for the antenna performance parameters such as return loss, radiation pattern and gain along with the overall evaluation are presented.

Table 1. Antenna dimensions

A	W	L	M_W	M_L	P	T	H
60.60	7.98	30.91	1.43	15.00	22.93	14.59	0.25

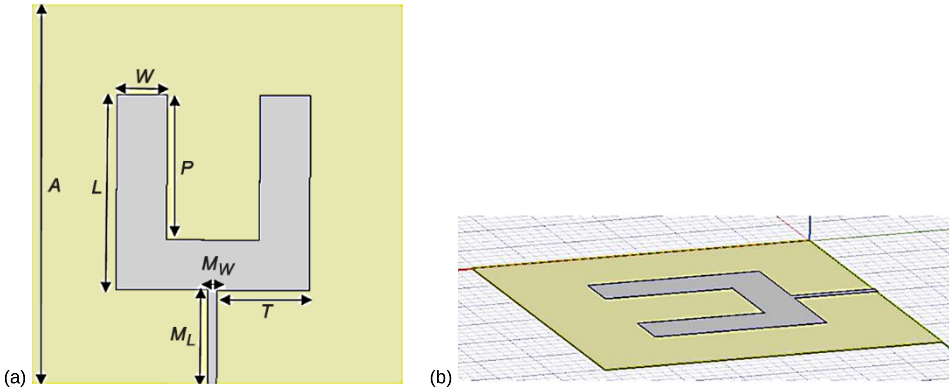

Figure 1. Designed antenna top view (a) and side view (b)

Figure 2 shows the return loss as a function of frequency. The antenna operates between 1.950-2.125 GHz with a resonant frequency of 2.050 GHz, and 2.650-2.825 GHz with a resonant frequency of 2.750 GHz. The –10 dB impedance bandwidth is 0.175 GHz for both frequency ranges. One frequency band for Wi-MAX application is 2.700-2.800 GHz. Hence, the designed antenna is suitable for WiMAX application. It is also suitable for MDS because the frequency band for MDS is 2.076-2.111 GHz.

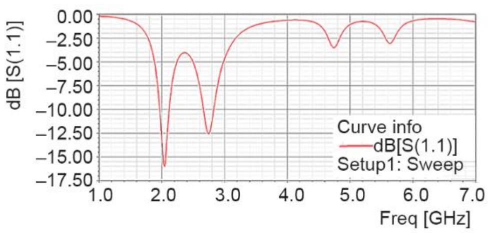

Figure 2. Return loss *vs.* frequency

Radiation patterns for ϕ = 0º and ϕ = 90º planes at the resonant frequency of 2.050 GHz are illustrated in fig. 3. Maximum radiation values are 22.15 dB and 22.30 dB for ϕ = 0º and ϕ = 90º planes, respectively. They occur at boresight for both planes. Maximum gain value is 5.009 dBi.

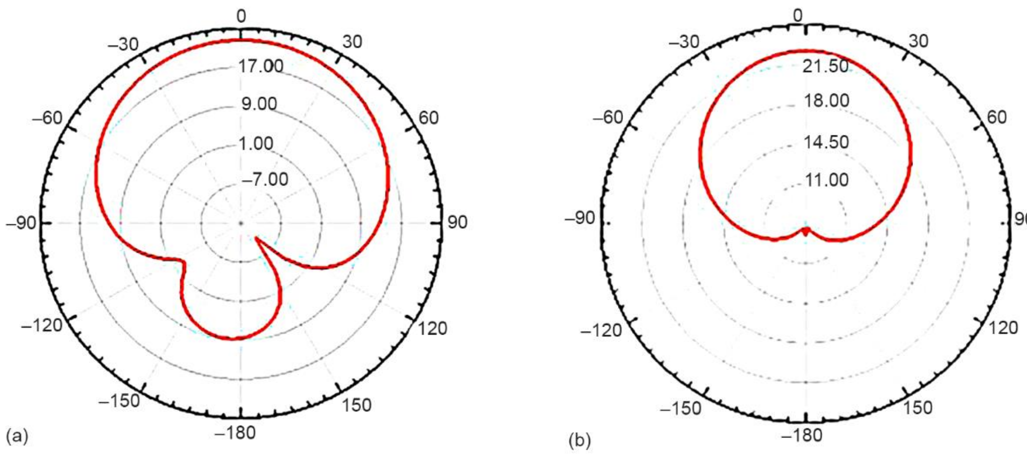

Figure 3. Radiation patterns for ϕ = 0º (a) and ϕ = 90º (b) planes at 2.050 GHz

Radiation patterns for ϕ = 0º and ϕ = 90º planes at the resonant frequency of 2.750 GHz are shown in fig. 4. Maximum radiation values are 22.76 dB and 23.47 dB for ϕ = 0º and ϕ = 90º planes, respectively. They occur at boresight for both planes. Maximum gain value is 5.413 dBi.

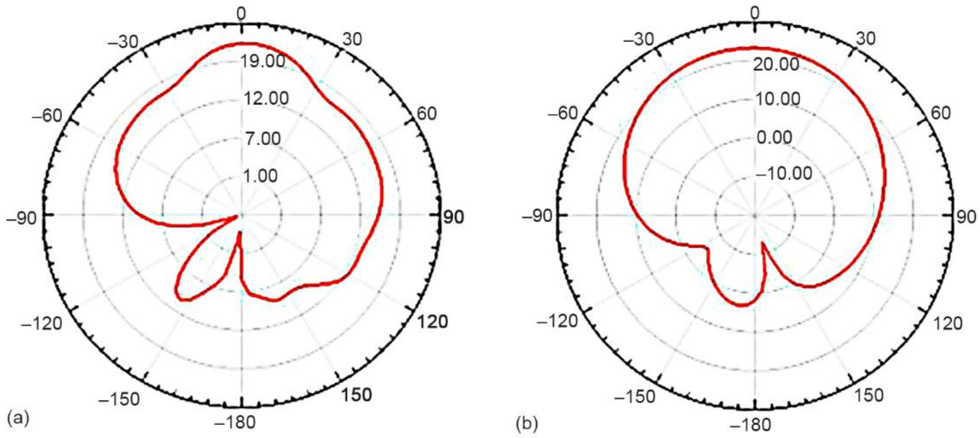

Figure 4. Radiation patterns for ϕ = 0º (a) and ϕ = 90º (b) planes at 2.750 GHz

The designed antenna has a monopolar radiation pattern, and high maximum gain. It enables simultaneous operation for two wireless technologies as it is a dual-band antenna.

In addition to the antenna design requirements, environmental issues should also be taken into consideration. Material selection is an important criterion during the design process. Copper is generally preferred in microstrip patch antenna designs and productions as it is ductile and inexpensive. However, it is a significant pollutant in the environment. Aluminum is an infinitely recyclable metal, and it is more effective to recycle it than to produce primary aluminum, which contributes to the environmental protection. Usage of aluminum, which is a much lower pollutant, instead of copper in the design yields a more environmentally friendly structure. Furthermore, no difference is observed in the simulations when copper is replaced by aluminum.

Paper has many advantages that lead to environmentally friendly electronics. It is basically cellulose, which is a renewable resource. Today, a large portion of the paper in use is recycled. Moreover, it can be easily processed resulting in low manufacturing costs. Using paper as a substrate leads to a simple, eco-friendly, easily-supplied and inexpensive antenna design.

Issues that need to be taken into account for the design are as follows. Firstly, it is challenging and cost-inefficient to apply photolithography techniques to paper. Secondly, a radome might be needed if the antenna is operated outdoors. Radome design is not included in this article. Usage of the radome with the antenna would change the antenna performance parameters.

Conclusion

A microstrip patch antenna with a *U*-shaped patch, centrally-fed by a microstrip line is presented. It is dual-band, and is suitable for multipoint distribution systems and WiMAX application. Blank paper is used as a substrate, and aluminum is utilized for the metallic parts. The design is simple, sustainable, environmentally friendly, and low-cost. Monopolar radiation patterns and high gains are achieved. No parasitic elements or slots are present in the design. In the future, a radome that might be necessary for outdoor use could be considered along with the etching techniques on paper substrate.

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