Broadband Stacked Patch Antenna for Bluetooth Applications

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Abstract—Microstrip patch antennas are well suited for wireless Local Area Network (LAN) application systems due to their versatility, conformability, low cost and low sensitivity to manufacturing tolerances. Conventionally patch antennas have showed a narrowband response, implicating low bit rate transfer. Recently the importance has been placed upon creating patch antennas that show broadband properties, capable of high-speed data transfer. The aim of this paper is to design efficient and reliable broadband patch antenna for adequate area coverage and sufficient bandwidth usage.

A parasitically coupled broadband patch antenna for the broadband wireless LAN application systems is designed. The proposed structure has been initially optimized using the Method of Moments based commercial software IE3D followed by experimental verification on Agilent Vector Network Analyzer, E5062A. The active bandwidth for VSWR $\leq 1.5$ is observed around 195 MHz (8%). Other important characteristics of the antenna structure such as antenna gain, antenna efficiency, radiation efficiency and average current distribution are also studied.

Index Terms—Wireless LAN, parasitic elements, electromagnetically coupled, Bluetooth

I. INTRODUCTION

A Microstrip Antenna (MSA) is a narrowband, wide-beam antenna. It is fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate. The ground plane is formed with a continuous metal layer bonded to the opposite side of this substrate. Common microstrip antenna radiator shapes are square, rectangular, circular and elliptical, however, any continuous shape can be possible. Some patch antennas uses a dielectric substrate and suspend a metal patch in air above a ground plane using dielectric spacers; the resulting structure is less robust but provides better bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be conformable, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices [1][7-9]. Microstrip antennas are also relatively inexpensive to manufacture and design because of the simple two-dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency. A single patch antenna provides a maximum directive gain of around 6 to 9 dBi. It is relatively easy to print an array of patches on a
single (large) substrate using lithographic techniques. Patch arrays can provide much higher gains than a single patch at little additional cost. The ability to create high gain arrays in a low-profile antenna is one of the reasons that patch arrays are common on airplanes and in other military applications [1][7-9].

A wireless LAN is a flexible data communication network used as an extension to, or an alternative for, a wired LAN. Primarily they are used in industrial sectors where employees are on the move, in temporary locations or where cabling may hinder the installation of wired LAN. Increasingly more and more wireless LANs are being setup in home and or home office situations as the technology is becoming more affordable. The increasing popularity of indoor wireless LAN capable of high-speed transfer rate is prompting the development of efficient broadband antennas [3-4].

The broadband antennas are required to be compact, low-profile, directive with high transmission efficiency and designed to be discreet. Due to these well met requirements coupled with the ease of manufacture and repeatability makes the microstrip patch antennas very well suited for broadband wireless applications[3-4].

II. GEOMETRY OF PROPOSED STACKED PATCH

Recently, several microstrip slot antennas [5-6] and planar monopole geometries such as circular, square, rectangular, elliptical, hexagonal and pentagonal, have been analyzed, providing wide impedance bandwidth. Stacked multi-resonators which are electromagnetically coupled microstrip antennas can also widen the bandwidth. In this paper a parasitically coupled broadband patch antenna for the broadband wireless LAN application systems is designed, simulated and experimentally verified. The proposed antenna uses a glass epoxy dielectric with dielectric constant of 4.5 and loss tangent of 0.002. Overall area of the antenna can be reduced by increasing the dielectric constant, but this results in reduced bandwidth and gain[2][4].

Figure 1 shows the geometry of electromagnetically coupled stacked MSA. The driven patch has a length of \( L_1 = 30 \) mm and a width of \( W_1 = 30 \) mm. The two parasitic patches are added together with \( L_2 = 35 \) mm, \( W_2 = 35 \) mm, and \( L_3 = 40 \) mm, \( W_3 = 40 \) mm. The center frequency of this stacked antenna is 2.45 GHz. which is specifically designed to make the antenna suitable for bluetooth applications.

![Fig. 1. Geometry of proposed stacked patch](image-url)
III. RESULTS AND DISCUSSIONS

The proposed structure has been initially optimized using IE3D software followed by experimental verification on Agilent Vector Network Analyzer, E5062A. The experimentation has been done in the open air condition, however, testing in an anechoic chamber is recommended. Figure 2 and Figure 3 show the measured and simulated VSWR response of stacked patch for 2.4 – 2.5 GHz band (VSWR ≤ 1.5) and 1.8 – 4 GHz (VSWR ≤ 2) respectively. Measurement results are well agreed with the simulated results. The center frequency of the structure is 2.45 GHz. The Bluetooth range is from 2.4 to 2.5 GHz, it means that 100 MHz is the minimum bandwidth requirement for bluetooth applications. The proposed antenna gives 195 MHz bandwidth at VSWR ratio of 1.5:1. The matching frequency range is observed from 2.2 GHz to 2.7 GHz. The stacked patch is also matched from 1.8 to 4.1 GHz with an impedance bandwidth of 69.79 % as shown in Figure 3.

![Figure 2. Simulated and measured VSWR (1.5:1)](image1)

![Figure 3. Simulated and measured VSWR (2:1)](image2)

Figure 4 shows the measured and simulated return loss plot of stacked patch antenna. Matching frequency range of patch antenna is from 2.25 to 2.60 GHz with impedance bandwidth 350 MHz (14%) at the center frequency of 2.45 GHz. Figure 5 shows simulated antenna efficiency and radiation efficiency response of the proposed stacked patch antenna. Antenna efficiency and radiation efficiency are found 62 % and 64 % respectively at the center frequency. Antenna gain is found to be 6.2 dBi as shown in Figure 6. Figure 7 shows the average current distribution in the patches and it observed that maximum current distribution is along the edges of the radiating patch.

Figure 8 shows simulated radiation pattern response of the proposed stacked patch antenna at 2.45 GHz. The main gain in both E-plane and H-plane are presented. The beamwidth read on the average pattern, which should be considered as the mean beamwidth. This beamwidth is relatively large and suits for bluetooth application. From the radiation characteristics it is clear that the antenna provides a stable gain, good front to back ratios and almost unchanging half power beamwidth across the well matched bandwidth. These features completely meet the demands for bluetooth application.
Fig. 4. Simulated and measured return loss

Fig. 5. Simulated antenna efficiency and radiation efficiency.

Fig. 6. Simulated antenna Gain.

Fig. 7. Average current distribution

Fig. 8. Simulated radiation pattern (\(\theta=0^\circ\), \(\theta=90^\circ\))
IV. CONCLUSION

A parasitically coupled broadband patch antenna for the broadband wireless LAN application systems is presented. It is observed from the simulated and experimental results that the suggested patch antenna can be deployed for broadband Bluetooth applications in the ISM band. The active bandwidth of 195 MHz is obtained with this configuration. The performance of the antenna can be further improved by using substrates with low insertion losses as well the emergence of an improved implementation technique.

ACKNOWLEDGMENT

The Authors would like to thank Dr. K. P. Ray, Head of Antenna Division, SAMEER IIT Campus Mumbai for making available the test facilities. The authors would also like to thank Mr. Loenymoon, Signet Instruments Mumbai for making available the required dielectric and fabrication of the antenna.

REFERENCES