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Design of compact pentagonal slot antenna with bandwidth enhancement for multiband wireless applications

Pratap N. Shinde*, Jayashree P. Shinde[1]

Deapartment of Electronics and Telecommunication, Sinhgad Academy of Engineering, Pune, India

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ABSTRACT

The compact design of a microstrip feed pentagonal shaped slot antenna with electromagnetically coupled pentagon parasitic patch is proposed in this paper for bandwidth enhancement. An aligned self-similarity pentagonal shaped structures, for slot and parasitic patch, at its vertex are used to broaden the bandwidth. The proposed antenna gives a wide bandwidth of 4.17 GHz (3.281–7.45 GHz), which corresponds to FRB 77.72%. The rotational behaviour of slot antenna illustrates good impedance matching over the wide bandwidth. Over the entire operating bandwidth, the antenna gain remains constant about 4.24 dBi and group delay is less than 0.5 ns. The simulated and measured results show its use in wireless applications.

1. Introduction

Today's wireless consumer devices, designed for indoor communication needs high data rate. In addition, the wireless communication system like Bluetooth, WLAN, WiMAX, HIPERLAN/2 needs the compact antenna with wide bandwidth. The channel capacity with increase in bandwidth improves the data rate of compact antennas. Slot antennas have attractive features such as wide frequency bandwidth, low profile, lightweight, easy integration with microwave monolithic integrated circuits, low cost and ease of fabrication.

Researchers in the past has carried out the parametric analysis of slot antenna using same shaped geometry for radiating patch as well as slot [1–4]. The dimensions of the antennas followed by these researchers are very large, more than 72 mm × 72 mm. The antennas designed with geometry of square slot with CPW feed [5] and rotated square slot [6] with microstrip feed uses the size of 70 mm × 70 mm each, for bandwidth of 1.41 GHz (1536–2500) and 2.2 GHz (3400–5600 MHz) respectively. These antennas are highly susceptible to mismatch during fabrication process and can cause drift in desired results. A microstrip line feed antenna with parasitic square patch and same shaped slot around it [7] use size of 37 mm × 37 mm and gives bandwidth of 3.13 GHz (2225–5355 MHz). The antennas reported in [6,7] are considered as reference antenna in this research. Design of triple band slot antenna using pentagonal tuning stub for WLAN and upper UWB application is studied [8]. Printed cone antenna and elliptical slot antennas designs [9,10] yields wide bandwidth, but not compact enough for wireless handheld devices. In addition, some of these antennas use low thickness substrate like RO3003 and RT Duroid, which is special, costly and likely to result into wide band operation. A survey of recent research papers show the use of metamaterial to enhance the performance of single as well as multiple band antennae with respect to bandwidth, gain, radiation pattern selectivity and polarization diversity, and compactness [11–14]. Left handed metamaterial have dramatically increased bandwidth and gain of microstrip antenna using planar complementary double ring [11]. In [12] two dimensional artificial metamaterial transmission line, composed of complementary split ring resonators (CSRRs) etched in the ground plane and a capacitive gap embedded in the stepped-impedance conductor line, was used in design of compact microstrip antenna to obtain radiation pattern selectivity and polarization diversity feature over triple band. The multifrequency monopole antennas design were investigated for various communication standards using set of complementary metamaterial transmission line (CMTL) unit cells [13]. Recently low profile and small size circularly polarized antenna is numerically and experimentally reported using the Hilbert shaped reactive impedance surface (HRIS) structure and Wunderlich shaped fractal complementary split ring resonator (WCSRR) [14] for WiMAX application.

* Corresponding author at: Sinhgad Academy of Emgineering, Sr. No. 41, Kondhwa-Saswad Road, Pune 411 048, India. Tel.: +91 2026934441.
E-mail addresses: shinde.pratap07@gmail.com (P.N. Shinde), jpspaper10@ymail.com (J.P. Shinde).
[1] Postal address: Sinhgad Academy of Emgineering, Sr. No. 41, Kondhwa-Saswad Road, Pune 411 048, India.

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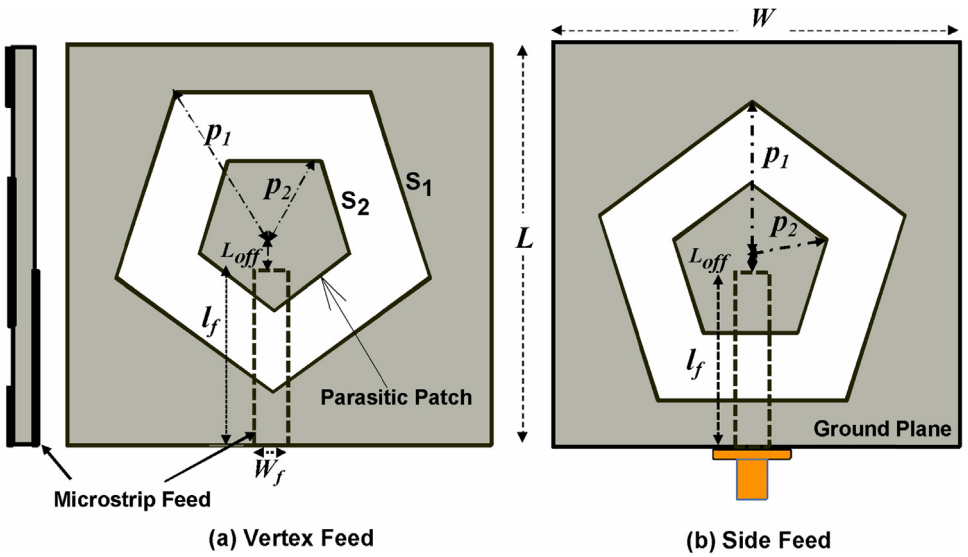

Fig. 1. Pentagoanal slot antenna configuration (a) vertex feed, (b) side feed.

In this paper, a novel compact (25 mm × 25 mm) design of microstrip feed pentagonal slot antenna is proposed for multiband wireless applications. The proposed antenna design is based on [7]. The antenna design uses uncommon pentagon shaped parasitic radiating patch and same shaped slot in ground plane, printed on same side of substrate for bandwidth enhancement. The study of vertex feed antenna configuration in comparison with side feed is presented. The entire bandwidth enhancement in vertex feed configuration is achieved by impedance matching occurred from tuning coupling effect between parasitic patch, pentagonal slot and the feed line. This design illustrates bandwidth enhancement more than 1 GHz compared with reported antennas [6,7] and compactness greater than 50% with respect to the ground plane dimension. The wide impedance bandwidth (3.24–7.45 GHz) of proposed antenna suits for wireless applications such as WiMAX, based on IEEE 802.16d standards operating at bands 3.5/5.5 GHz in point to multipoint radio operation and IEEE 802.11a WLAN operating at 5.2/5.8 GHz bands. The succeeding sections contribute the analysis of antenna with respect to reflection coefficient, radiation pattern, gain, radiation efficiency and group delay.

2. Design of the pentagonal slot antenna

A compact pentagonal slot antenna designed on a commercially available FR4 substrate, 25 × 25 × 1.6 mm^3 in size, with dielectric constant $\varepsilon_r = 4.4$ and loss tangent 0.02. The geometrical configuration of the antenna is shown in Fig. 1. The antenna comprises of a ground plane of length L and width W with a pentagonal shaped slot cut from the ground plane. The pentagonal slot has side length S_1 and the distance from its centre to the vertex of the slot is p_1. There is an electromagnetically coupled pentagonal parasitic patch of side length S_2 with the distance from its centre to the vertex being p_2 printed on the same substrate. The parasitic patch is positioned at the origin, which is surrounded by a wide pentagonal shaped slot. The area of this slot ring is controlled by either variation in p_1 or p_2. The pentagonal slot antenna is excited from a microstrip line placed beneath it, l_f in length and W_f in width. The gap between the centre of the parasitic patch and the upper end of the projected microstrip line feed is termed as L_{off}. The microstrip feed line excites the parasitic patch electromagnetically through the pentagon shaped slot ring. The impedance matching condition for maximum transmission of signal from the feed line to the parasitic patch, is achieved by optimization of the parameters p_2, feed length l_f and gap L_{off}.

3. Parametric study of vertex feed pentagonal slot antenna

The electromagnetically coupled pentagonal parasitic patch located at centre and fed by microstrip line excites resonating frequencies. These resonating frequencies overlap each other to broaden the bandwidth by lowering the lower edge frequency f_1

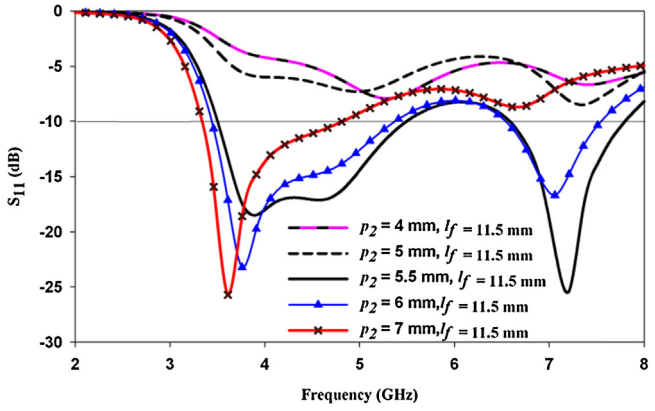

Fig. 2. Simulated reflection coefficient of pentagonal slot antenna with various p_2, at $W = L = 25$ mm, $p_1 = 10.5$ mm, $w_f = 1.6$ mm, $L_{off} = 1$ mm, and $l_f = 11.5$ mm.

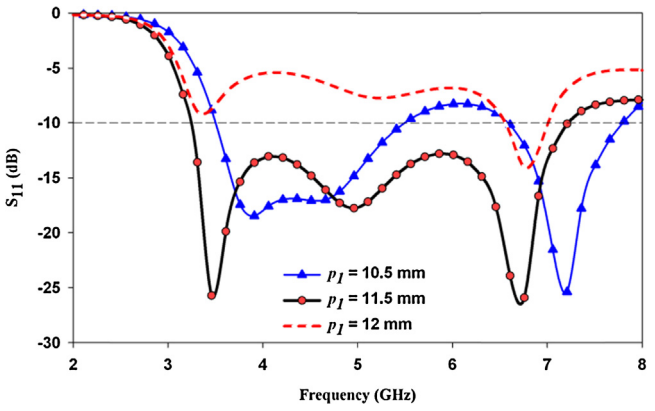

Fig. 3. Simulated reflection coefficient of pentagonal slot antenna with different p_1, at $W = L = 25$ mm, $p_2 = 5.5$ mm, $w_f = 1.6$ mm, $L_{off} = 1$ mm, and $l_f = 11.5$ mm.