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Triple band E-shaped Microstrip Antenna

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Abstract

The triple frequency design of E-shaped Microstrip antenna backed by E-shaped ground plane is proposed. The pair of rectangular slots that realizes E-shaped structure in patch as well as the ground plane reduces the resonance frequencies of TM_{02} and TM_{12} modes and along with fundamental TM_{10} mode yields triple frequency response. At each frequency, proposed antenna yields 1 to 2% of VSWR bandwidth. The slots in ground plane and patch modify the surface current distribution at higher order modes to give broadside radiation pattern at each frequency. To increase the gain suspended variation of defected ground plane backed radiating patch is proposed which gives more than 1 to 5 dBi of gain at each frequency. The proposed works clearly explains the functioning of defected ground plane triple band antenna in terms of patch resonant modes. This will be useful as similar work to get an insight into functioning of defected ground plane backed antenna is not available in the literature.

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Keywords: Rectangular microstrip antenna; Multi-band microstrip antenna; E-shaped microstrip antenna; Rectangular slot; Higher order mode; Defected ground plane patch

1. Introduction

Since its invention for the first time in 1969, due to numerous advantages like low cost low profile planar configuration, Microstrip antenna (MSA) finds many applications in the design of wireless communication systems[1 – 3]. In the application wherein the transmission and reception of the signal is needed at closely spaced frequencies, dual and triple band antennas are needed. In these applications as against other antenna variations like dipole and horn antennas, MSAs are widely preferred[1 – 3].

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In conventional regular shaped half wavelength MSAs, dual band response can be obtained with respect to fundamental and next higher order mode resonance frequency. However in these MSAs pattern characteristics do not remain constant over two frequencies. For identical radiation pattern characteristics and tunable frequency ratio, dual and triple band MSAs is realized by cutting the slot inside the MSA [4 – 9]. In most of the literature it is reported that slot length equals either half wave or quarter wave in length to realize multiple frequencies. However recent study showed that slot reduces resonance frequency of higher order orthogonal patch mode that yields multiple frequencies[10]. The broadband MSAs are realized when the coupling between two resonant modes is controlled such that the loop is formed inside VSWR = 2 circle in the smith chart[1 – 3]. Instead of cutting the slots on the radiating patch, broadband or dual band configurations have been realized by cutting the slots in the ground plane, i.e. by using defected ground plane structure[11, 12]. However the reported work on defected ground plane MSAs does not provide any insights into the functioning of broadband or dual band response in terms of patch resonant modes.

In this paper, a design of defected ground plane multi-band MSA, an E-shaped MSA backed by E-shaped ground plane in 900 MHz frequency band is proposed. The proposed configuration is studied using glass epoxy substrate (ε_r = 4.3, h = 0.16 cm, tan δ = 0.02). The pair of rectangular slots was cut on one of the radiating edges of the rectangular MSA (RMSA) as well as on one of the edges of rectangular shaped ground plane. By studying the resonance curve plots, simulated surface current distribution and radiation pattern plots for increasing slot length, a detailed study that explains the realized triple frequency response is presented. The slots in patch and the ground plane reduce the resonance frequencies of patch higher order orthogonal TM_{02} and TM_{12} modes and along with fundamental TM_{10} mode yields multi-band response. The multi-band MSA yields VSWR BW of 1 to 2 % at each of the frequencies. The radiation pattern at TM_{10} mode in RMSA is in the broadside direction whereas that at TM_{02} mode, it is conical. The pattern at TM_{12} mode is in the broadside direction but shows higher cross polar levels. The slots in patch and ground plane re-orients surface currents at TM_{02} and TM_{12} modes and align them in the same direction as that of the currents at TM_{10} mode. This yields broadside radiation pattern over the triple frequencies. As the proposed MSA is optimized on thinner lossy substrate it has lower gain. To increase the gain, a suspended configuration of proposed triple band MSA is proposed which gives broadside gain of more than 1 to 5 dBi across three frequencies. The proposed triple band modified ground plane MSA is first optimized using IE3D software followed by the measurements. The antenna is fed using SMA panel type connector of inner diameter 0.12 cm. In experimental validation, antenna was fabricated on glass epoxy substrate and the impedance measurements were carried out using ZVH-8 vector network analyzer. The radiation pattern was measured in antenna lab using RF source (SMB 100A) and spectrum analyzer (FSC 6). Here novelty of the proposed work lies in providing detailed explanation about functioning of defected ground plane multi-band MSA in terms of patch resonant modes as the similar work providing the explanation is not available in the literature for defected ground plane MSAs.

2. Triple band E-shaped MSA backed by E-shaped ground plane

The E-shaped MSA backed by E-shaped ground plane is shown in Fig. 1(a, b). Using reported resonance frequency equation for RMSA[1 – 3], dimensions of equivalent patch are calculated such that its TM_{10} mode frequency is around 900 MHz. For this frequency patch length (Lp) was found to be 8 cm. To realize lower TM_{01} mode frequency and higher gain, patch width (Wp) is selected to be 10 cm. The ground plane dimensions are selected as Lg = 10 cm and Wg = 12 cm as shown in Fig. 1(a). For x_f = 2.0 cm, RMSA is simulated using IE3D software and its resonance curve plot is shown in Fig. 1(c). The plot shows three resonant peaks which are due to TM_{10} (896 MHz), TM_{02} (1439 MHz) and TM_{12} (1719 MHz) modes. The surface current distribution at these modes is shown in Fig. 1(d – f). At TM_{10} mode current shows one half wavelength variation along patch length, hence the radiation pattern shows E-plane directed along $\Phi = 0^0$ as shown in Fig. 2(a). At TM_{02} mode currents show two half wavelength variation along patch width[1 – 3] hence it shows conical radiation pattern with E-plane directed along $\Phi = 90^0$ as shown in Fig. 2(b). At TM_{12} mode, as current shows half wavelength variation along patch length and two half wavelength variation along patch width, pattern shows broadside radiation with higher cross polarization levels and E-plane is directed along $\Phi = 0^0$, as shown in Fig. 2(c). The field/surface current distribution on the ground plane is complementary to the field/current distribution that is present on the radiating patch. In Fig. 1(d – f), fields on the patch are denoted by using black colour whereas the fields on ground plane are marked using blue colour.