Dual Band Dual Linear Polarization Elliptical Microstrip Ring Antenna

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Abstract

An analysis is presented for an aperture coupled microstrip elliptical ring antenna. Results demonstrate that the antenna has a dual resonance and the separation between resonances is controlled by the eccentricity of the ring. The antenna is excited by two independent perpendicular microstrip feeds parallel to the minor and major axes of the elliptical ring and which are located on a dielectric slab below the common ground plane. The orthogonality of the feeds creates two orthogonal linear polarized radiated fields. Theory demonstrates resonant frequencies from 12.0 GHz to 16.5 GHz, VSWR < 2 bandwidth of 6%, and isolation of 15-30 dB. The antenna radiates a single main beam with a 3 dB beamwidth of 90° and cross-polarization greater than 30 dB. The elliptical ring antenna is small (D/\lambda0 = 0.315) at the lower resonance and the two layer design produces a completely planar antenna system which is compatible with microwave and millimeter, MIC, and monolithic MMIC integrated circuits.

Keywords

Microstrip, dual polarised, dual band, aperture coupled antenna.

I. INTRODUCTION

VARIOUS communication systems require dual frequency band capabilities with dual linear or dual circular polarizations. For planar topologies, the first requirement is usually met using two individual antennas elements in a uniplanar or multiplanar geometry [1], [2], [3]. The second requirement is satisfied by exciting the antennas such that they radiate orthogonal fields [4], [5]. Recently, dual linear polarization with dual frequency band separation was demonstrated using a single element and two orthogonal feeds [6].

This paper introduces a single element that can produce dual frequency bands and dual linear polarizations. The basic radiator geometry is a ring antenna. The dual band nature is created by modifying the circular ring to an elliptical ring. The eccentricity of the ring creates two fundamental modes, each resonating along the major and minor axes. The amount of eccentricity controls the separation between the two resonant frequencies. We demonstrate frequency separations between 5% and 20%. The antenna is fed by two independent microstrip feedlines, thus eliminating frequency duplexers, which is preferred for transmit/receive applications. The apertures are placed orthogonal to each other creating two orthogonal linearly polarized radiated fields. The antenna is located on a low relative permittivity dielectric, \epsilon_r = 2.2, and the microstrip feeds are located on a high relative permittivity substrate, \epsilon_r = 10.8. The antenna design is fully planar allowing integration with monolithic integrated circuits.

II. SINGLE ELLIPTICAL RING ANTENNA

The geometry is shown in Fig. 1 (a). The antenna is fed by two dumbbell shaped apertures in the common ground plane, which are each excited by a 50 \Omega open circuited microstrip feedline located on the second substrate. The antenna substrate thickness is 50 mils with a dielectric constant of 2.2. The microstrip feed substrate thickness is 25 mils with a dielectric constant of 10.8. The circular ring is designed for a center frequency of 12.0 GHz for the TM_{11} mode. The ring inner radius is 1.575 mm and the outer radius is 3.9375 mm. The ring geometry allows for a smaller physical size, 2R_{\text{a}}/\lambda_0 = 0.315 than the corresponding square and circular patch geometries. Derivation and extensive discussion of

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1636
the theory and numerical methodology for microstrip elements used in this communication is presented in [7].

A. Analysis of Antenna Geometry

For a circular ring fed by two orthogonal feeds, the resonance frequency is the same at each port due to the symmetry of the antenna geometry. Each port excites a linear polarized field with the E-plane parallel to the excitation feedline. A dual resonance is achieved by modifying the circular ring to an elliptical ring. We define the major axis of the ellipse, $a$, as the mean radius of the original circular ring, $a = (3.9375 + 1.575)/2 = 2.756$ mm. This length is kept constant in the analysis. The minor axis, $b$, is reduced creating the elliptical geometry. The eccentricity is defined as the ratio of the foci length to the major axis length, $e = c/a$, where $c = \sqrt{a^2 - b^2}$. An eccentricity of 0 denotes a circle while an eccentricity of 1 denotes a line.

Fig. 1 (b) and Fig. 2 (a) show the scattering parameter frequency characteristics for different eccentricities. The resonance frequency of the major axis, $S_{11}$, remains near the original frequency of 12.0 GHz. As the eccentricity increases the resonance frequency shifts upward with a maximum shift of nearly 7% at eccentricity of 0.8. The resonance frequency of the minor axis, $S_2$, increases more rapidly with an increase in eccentricity. For $e = 0.45$, the second resonance is at 12.9 GHz, while for $e = 0.8$ the resonance is shifted to 16.25 GHz. This corresponds to frequency shifts of 6% and 26%, respectively. The VSWR < 2 bandwidths are of the same order of the circular ring, about 6%. Fig. 2 (b) shows the isolation between the ports for the same eccentricities. The magnitude is about 25 dB for the circular ring and increases substantially to 14 dB for the case of $e = 0.8$. This is due to the increased electrical size of the apertures and the thicknesses of the substrates.

The radiation patterns at the two resonant frequencies for the case of $e = 0.6$ are shown in Fig. 3. We observe symmetric patterns with 3 dB beamwidths of nearly 90° and cross polarization components greater than 30 dB below the co-polarization components.

III. Conclusion

In conclusion, an elliptical ring antenna can be designed for dual frequency bandwidth capabilities. The eccentricity of the ring controls the separation between the two antenna resonances. The antenna is proximity coupled by two orthogonal apertures in the ground plane which are fed by microstrip feedlines on a second substrate. This orthogonality provides for dual orthogonal linear polarization. The antenna system has the advantage of small size and non-contact feeding. The elliptical ring antenna element promises to be a viable candidate for communications systems.

References


Fig. 1. (a) Dual microstrip feed proximity coupled elliptical ring antenna geometry, (b) $S_{11}$ for different eccentricities. $e = c/a$ where, $c = \sqrt{a^2 - b^2}$. $e = 0$ is a circle while $e = 1$ is a line.

Fig. 2. Scattering parameters for different eccentricities, (a) $S_{22}$, (b) $S_{33}$. $e = c/a$ where, $c = \sqrt{a^2 - b^2}$. $e = 0$ is a circle while $e = 1$ is a line.
Fig. 3. Radiation patterns at the two resonant frequencies for elliptical ring with eccentricity $e = 0.6$, (a) Port 1, $f = 12.25$ GHz, (b) Port 2, $f = 14.0$ GHz.