Circular Polarization Antennas with High Permittivity Substrates and Self-biased NiCo-Ferrite Films Loading

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Abstract

Circular polarization antennas with self-biased magnetic films loading are designed and analyzed in this paper. The designed circular polarization antenna is realized by a cross slot with unequal length of slots on a circular patch and fed by a coupling microstrip. The self-biased magnetic films are used as a practical means to tune the working frequency of the antenna. Three different cases of antennas with films loading are designed and analyzed. Antennas with self-biased magnetic films loading working at 1.575 GHz exhibit a tuning range of 10% ~30% of the antenna bandwidth and the axial ratio is improved by 0.62dB at the maximum.

1. Introduction

Recently, widespread use of handheld and wireless communications systems has increased the great demand for smaller, inexpensive antennas. While these requirements can easily be achieved at high frequency bands by using microstrip patch antennas, it may be a design challenge at frequencies in L-band or even lower, due to the relatively large resonant length of the patch. One of the effective methods to reduce the geometry dimension is by utilizing high permittivity material as the substrate, i.e. using a substrate with a permittivity of 20 or even higher. However, probe-fed antennas with high-K materials exhibit poor efficiency and very narrow bandwidth, especially for the circular polarization antennas, which require an excitation of two near-degenerate orthogonal modes with equal amplitude and 90 degree phase difference. Antenna with a cross slot of unequal slot lengths coupled to the microstrip feed line shows great potential in those designs with high-K material as they have relative wide bandwidth\cite{[1]-[3]}. In order to be practically feasible in miniature antenna applications, such as handheld wireless communication devices, it is important for antenna substrates to be comprised of self-biased magnetic materials, in which no external bias magnetic field is needed. Magnetic thin films provide a unique opportunity for achieving self-biased magnetic patch antenna substrates with $\mu_r > 1$ at $> 1$ GHz frequencies\cite{[4]-[7]}.

In this paper, we present a circular polarization antenna with self-biased magnetic films loaded on the top of the patch, under the high-K substrate and both on the top of the patch and under the high-K substrate. The designed antennas with self-biased magnetic films showed a large radiation frequency tunability of about 10% ~ 30% of the -10dB bandwidth, and an improvement of axial ratio. And these magnetic antennas can be made conformably at a low cost near room temperature.

2. Antenna Configuration

The top view and side view of the circular polarization antenna is depicted in Fig. 1 (a) and (b), respectively. The antenna for the GPS application utilizes one side feed only to avoid the disadvantages of external polarizer of hybrid coupler. This designed antenna consists of a circular patch with a cross slot embedded in the patch. The radius of the patch is 9.75mm and is printed on the substrate of high-K material, which has a relative permittivity of 91.7 and a thickness of 1.0mm. The lengths of coupling slot of unequal slots are 10.15mm and 10.75mm, and the width is 0.55mm. The feed line is printed on the Rogers R3010 with a relative permittivity of 10.2 and thickness of 1.28mm. The proposed antenna is designed and simulated with the help of High Frequency Structure Simulator (HFSS 10.0).
3. Experimental and Numerical Results

Three circular polarization antennas with NiCo-ferrite films are designed as follows. First, a ferrite thin film of thickness 2 μm is introduced just above the circular patch, as indicated in Fig. 2 (a). Second, a 2 μm thick ferrite film is added just under the high-K material, as shown in the schematic in Fig. 2 (b). In this case, the ferrite film has the same size as the substrate. Combining the above two cases, we also design an antenna with two layers of ferrite film, in which one layer is just above the patch, and the other under the high-K material substrate as shown in Fig. 2 (c).

From Fig. 3 (a)-(c) we can see that the central resonant frequency of the non-magnetic antenna is about 1.578 GHz, the -10dB bandwidth is 29 MHz, the axial ratio is 1.56dB and the gain of RHCP is 21dB higher than that of LHCP. When a ferrite film is added above the circular patch the central resonant frequency shifts down to 1.570 GHz. This indicates a tuning range of 28% of the bandwidth, and the axial ratio is 1.37dB. When a ferrite film is added just under the high-K material, we observe that the resonant frequency is 1.575 GHz, a shift about 10% of the antenna bandwidth relative to the non-magnetic circular loop antenna, and the axial ratio is 0.94dB combined with an improvement of the gain of RHCP 26dB higher than the LHCP. When two ferrite films are added above the circular patch and under the high-K material at the same time, which moves the resonant frequency further down to 1.569 GHz, a shift about 30% of the antenna bandwidth relative to the non-magnetic antenna. The axial ratio is 1.24dB and the RHCP is 22.5dB higher than the LHCP.
Fig. 3. (a) Simulated return loss against frequency for four different cases. (b) Simulated axial ratio of four antennas. (c) The radiation pattern in the broadside direction ($\theta = 0$) versus frequency.

4. Conclusions

Four circular polarization antennas with/without ferrite films are designed and analyzed in this paper. The designed antennas with self-biased magnetic films can realize a tuning range of 10 to 30% of the antenna bandwidth, which shifts from 1.57GHz to 1.575GHz and 1.569GHz, respectively. And the axial ratio is improved from 1.56dB to 1.37dB, 0.94dB and 1.24dB in these three cases.

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6. References


