Dual-frequency microstrip antenna with orthogonal polarization

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Abstract: A dual-frequency microstrip antenna with orthogonal polarizations is proposed and the measured results from a sample implemented in the 12 GHz/18 GHz bands is reported. In the lower band reflections lower than -10 dB and gains between 4.81 dB and 5.44 dB from 11.86 GHz to 12.02 GHz while in the higher band reflections lower than -15 dB and gains between 6.72 dB and 6.89 dB from 17.77 GHz to 18.03 GHz were measured. The isolations between the two feeds were better than 39.30 dB from 11 GHz to 19 GHz. The measured radiation patterns in both bands are also presented. The antenna unit is ready to be incorporated into arrays, offering the possibility of a compact, light-weight and cost-effective antenna array for various applications in television broadcasting, wireless communications, and radar systems.

Résumé: On propose une antenne microruban à bande double et polarisation orthogonale et on rapporte les caractéristiques mesurées pour un prototype opérant dans les bandes 12 GHz/18 GHz. Dans la bande inférieure, on a mesuré des reflexions plus faibles que -10 dB avec des gains entre 4.81 dB et 5.44 dB de 11.86 GHz à 12.02 GHz, et des reflexions en dessous de -15 dB avec des gains entre 6.72 dB et 6.89 dB de 17.77 GHz à 18.03 GHz. L'isolation entre les deux alimentations était supérieure a 39.30 dB de 11 GHz à 19 GHz. Les diagrammes de rayonnement mesurés dans les deux bandes sont aussi présentés. L'unité peut être incorporée dans des reseaux d'antennes, offrant la possibilité d'une antenne compacte, légère et économique pour diverses applications en télédiffusion, communications sans fil et radar.

1. Introduction

An antenna array with orthogonal polarizations can find its applications in Direct Broadcasting Systems (DBS), Personal Communication Services (PCS) and Indoor Communication Systems (ICS). Replacing parabolic dish antennas with compact, cost-effective flat printed circuit antennas is attractive to both antenna manufacturers and users[1]. The current DBS technology uses both horizontal and vertical polarizations to double the number of channels available in the limited bandwidth, and therefore, microstrip arrays with orthogonal polarizations are needed; In PCS and ICS, waves are scattered by the environmental and the signal takes several paths from a transmitter to a receiver, with resulting fluctuations in amplitude because of multi-path fading effect. One effective way to combat this effect is to implement a polarization diversity technique[2,3] for which antenna arrays with orthogonal polarizations and very low cross couplings (-30 dB) are needed; In SAR, a dual-frequency antenna[3] can be used to avoid the use of a separate array for each band for reduced weight and surface.

For the above applications, considerable effort has been devoted to the development of dual-frequency patch antennas[4] and antennas with orthogonal polarizations[5,6]. In this paper we propose a dual-frequency microstrip antenna with orthogonal polarizations and give the tested results of a unit antenna in the 12GHz/18GHz bands. The paper is composed of 5 sections and the remainder of the paper is managed as follow. In Section 2, we give the detailed configuration of the antenna. In Sections 3 and 4, we present the simulated and measured reflection coefficients and gain in both bands as well as the measured radiation patterns. In the last section, some conclusions are reached.

2. Physical configurations of the patch antenna

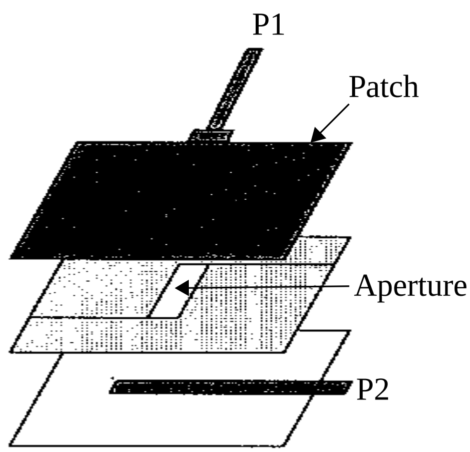

Fig.1 The physical structure of the patch antenna

The idea of the patch antenna is to make use of both sides. Because of different lengths, the patch oscillates at two frequencies, with orthogonal linear polarizations. The antenna is a two-substrate structure and its configuration is shown in Fig.1. For simplicity, the dielectric layers are not shown. In the implemented sample antenna, a rectangular patch is on the upper side of the first substrate, with a feed circuit P1 for the higher band. On the lower side of the second substrate and in a direction orthogonal to that of P1, another feed circuit P2 feeds the patch antenna at its lower band through an aperture in the conductive layer common to both substrates . All the microstrips and aperture are center-aligned with respect to the corresponding side of the rectangular patch.

3. Simulation results

Ensemble 4.1 was used to simulate the sample antenna and the reflections and gains are shown in Fig. 2 and Fig. 3, respectively. The lower band has a center frequency of 11.99 GHz and at which the reflection is -39 dB and the gain 4.75 dB. The reflection is lower than -10 dB from 11.86 GHz to 12.11 GHz, giving a bandwidth of 250 MHz. The higher frequency band has a center frequency of 17.87 GHz, at which the reflection is -24 dB and the gain 7.52 dB. In a bandwidth of 250 MHz around the center frequency the reflections are lower than -16.83 dB. The isolations between the two feeds in both bands are all higher than 70 dB.

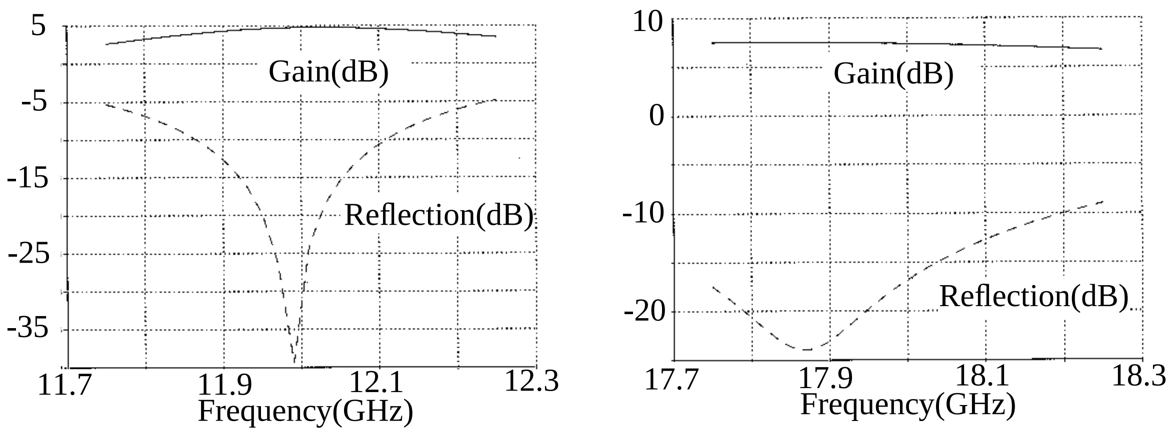

Fig. 2 The simulated reflections and gains in both bands

4. Measured results

Fig. 3 shows photographs of the patch antenna fabricated according to the simulated structure. Its gains and reflections in both bands were measured using the 3-Antenna Method. For the measurements in the lower band, we used two X-band horns, Horn 1 and Horn 2 (aperture 46.6 mm and 48.5 mm) in addition to the patch antenna fed at its lower frequency port. The return losses and gains of the antennas in both bands are shown in Fig. 4 and Fig. 5. For the lower band, the reflections were lower than -10 dB from 11.86 GHz to 12.02 GHz and the center frequency was 11.94 GHz with a reflection of -18.16 dB. The gain of the patch was 4.81 dB at 11.86 GHz, 5.44 dB at 11.94 GHz, and 4.58 dB at 12.02 GHz. The highest gain was measured to be 5.58 dB at 11.93 GHz.

For the higher band, we used two K-band horns, Horn A and Horn B (aperture 19.5mm and 12.5 mm) and the patch antenna fed at its higher frequency port. The return loss of the three antennas vs. frequency is shown in Fig. 5. The reflections of the patch were lower than -15 dB from 17.77 GHz to 18.03 GHz and the center frequency was 17.90 GHz with a reflection of –25.53 dB. The gain of the patch was 6.72 dB at 17.77 GHz, 6.73 dB at 17.90 GHz, and

6.89 dB at 18.03 GHz. The highest gain was measured to be 7.10 dB at 18.06 GHz. The isolations were also measured and they were better than -39.30 dB from 11.00 GHz to 19.00 GHz.

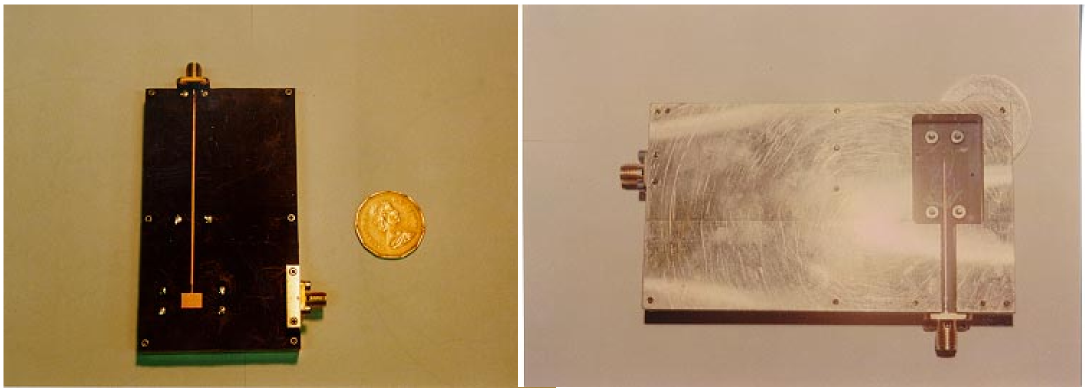

Fig.3 Upper side view and down side view of the patch antenna

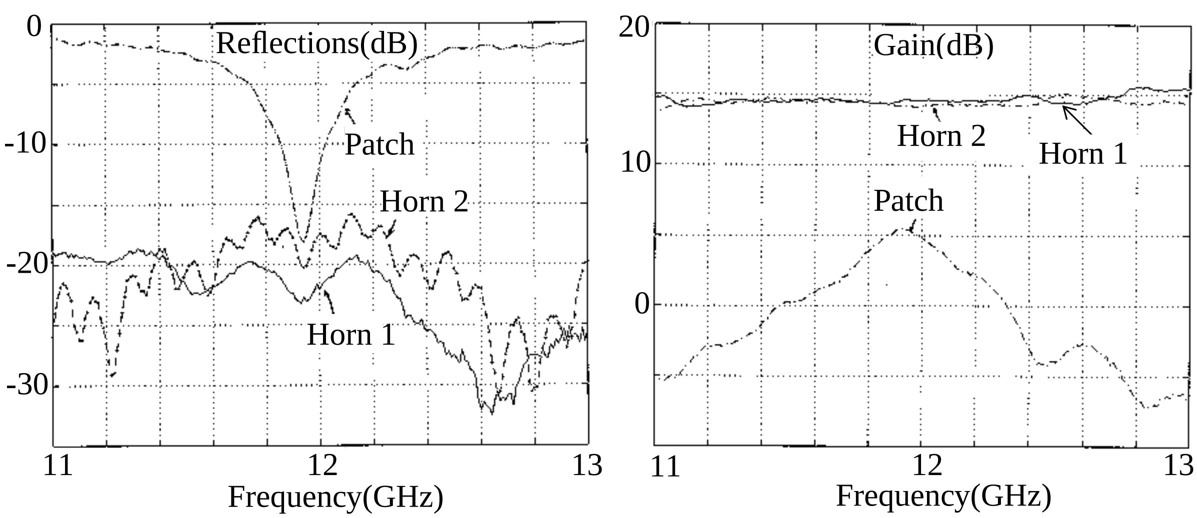

Fig.4 Measured reflections and gains of the patch antenna at lower band and two X-band horn antennas

The radiation patterns of the antenna at its lower and higher bands were measured and Fig. 6 shows the H-plane radiation pattern at 11.94 GHz and the E-plane radiation pattern at 17.77 GHz. Similar radiation patterns were measured at other frequencies in each band. From Fig. 6, the 3-dB beamwidths were about $95°$ and $73°$, respectively. The two dips in the radiation patterns in the lower band were typical and we believe them to be caused by the receptacle at the lower frequency feed port which stuck out by 6mm and was 29.8 mm away from the closest edge of the patch.

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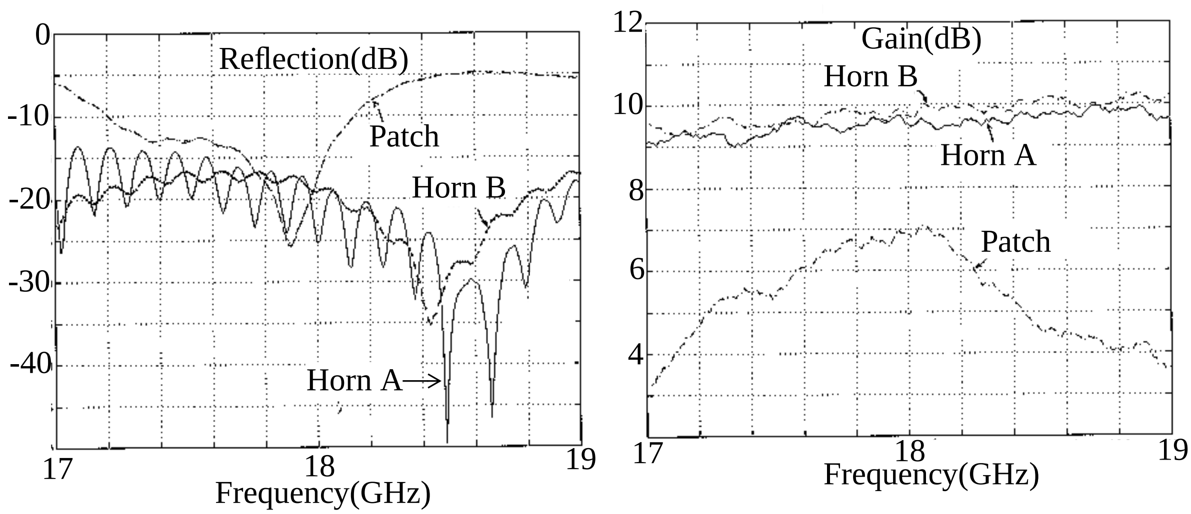

Fig. 5 Measured reflections and gains of the patch antenna at higher band and two K-band horn antennas.

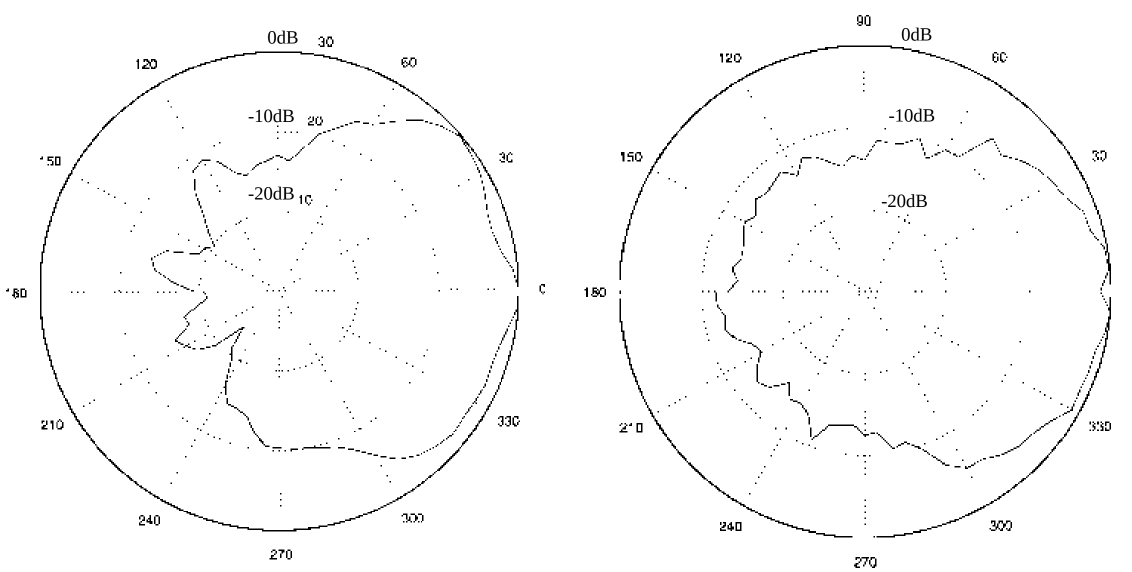

Fig. 6Measured H-plane radiation pattern at the lower band and E-plane radiation pattern at the higher band.

5. Discussions and conclusions

In conclusion, a dual-frequency patch antenna with orthogonal polarizations was proposed for possible applications in direct broadcasting systems, personal communication services, and synthesized aperture radars. A unit antenna in the 12GHz/18GHz bands was designed and tested. The antenna worked in the lower band centered at 11.94 GHz and its reflections were lower than -10 dB in a bandwidth of 250 GHz. The gains in the band were 4.81 dB to 5.44 dB. In the higher band which was centered at 17.90 GHz, the reflections were lower than -15 dB in a bandwidth of 260 GHz and the gains were 6.72 to 6.89 dB. The measured return loss center frequencies were only 5 MHz away from the simulated ones and the measured gains were in good agreement with the simulated ones within $\pm 0.8 dB$. The measured radiation patterns also agreed with the simulated ones. The isolations were better than -39.30 dB from 11.00 GHz to 19.00 GHz.

The two oscillating frequencies of such antennas can be varied independently of each other. For DBS, PCS and ICS applications, the two bands can be set to be the same while for SAR applications, different oscillating frequencies can be realized. The patch antenna is compact and the feed circuits for the higher band and lower band are on different layers, thus the cross coupling isolation can be very high and this also guarantees enough room for the distribution of feed networks when the antenna is incorporated into arrays. An antenna array using this kind of patches is under design in our laboratory.

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