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DUAL-BAND CIRCULARLY POLARIZED STUB LOADED MICROSTRIP ANTENNA

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Introduction

The purpose of this study is to obtain a dual-band circularly polarized microstrip antenna with microstrip line loads. Some work has been done by others on the effects of loading an element with short circuits [1], with a coaxial stub [2] and with a microstrip line stub [3]. In this paper, the transmission line model [4], [5] is applied to a microstrip antenna with microstrip line loads to produce a dual-band circularly polarized radiator. A simple design formula has been derived and experimental results agree well with this theory.

Configuration

The configuration of the dual-band circularly polarized stub loaded microstrip antenna in Fig.1, without a pair of stubs, is a conventional rectangular patch radiator. The dimension of the patch is designed based on the transmission line model of Munson [4] and Derneryd [5], that is, the patch length ℓ_{x1} and ℓ_{y1} are approximately one-half wavelength in the dielectric at a common fundamental frequency fo. The frequency fo is a center of dual-band operating frequency f_1 and f_2. The stubs are microstrip lines located at the midpoint of each edge; $x=\ell_{x1}$, $y=\ell_{y1}/2$ and $x=\ell_{x1}/2$, $y=\ell_{y1}$. The length of both stubs are approximately a quarter wavelength in the dielectric at fo. The stub width w_x is unequal to w_y, therefore the x and y modes have different characteristic admittance of stubs, Ysx and Ysy. This antenna is fed with an SMA coaxial feed located at the diagonal line on the patch (x_f, y_f) to excite the two orthogonal modes.

Theoretical Analysis

For simplicity, suppose that the antenna in Fig.1 radiates from open ends while the radiation from the stub ends are negligible for the patch ends; $\ell_o=\ell_{x1}=\ell_{y1}\gg w_y, w_x$, and $w_x < w_y$. Since the two orthogonal modes, x and y, are independent of each other, they are treated separately. The equivalent circuit of the antenna is then obtained for both x and y modes. If Ex and Ey are the electric far fields of the x and y modes, the radiation field may be calculated by a standard method [5]. A potential function generated by the source distribution is found by integrating over the source points. Hence, the condition of generation of the circular polarization on the z axis can be found by the relation between the feeding current and the voltage across the slots. Considering $Go/Yo \ll 1$ and $Bo/Yo \ll 1$, for the ratio of the radiation admittances Go+jBo and the characteristic admittance Yo of the patch Yo is usually very small, the condition can be approximated to give

$$\frac{Ey}{Ex} \simeq \frac{Yinx}{Yiny} = \pm j \qquad (1)$$

where Yinx and Yiny are the input admittances of the x and y modes, and the upper and lower signs of $\pm j$ indicate left and right hand circular polarization, respectively.

This expression can be further simplified for both the real and imaginary parts of eq. (1). The following conditions are satisfied:

$$\tan \beta_o \ell_o \simeq -\frac{Ysx+Ysy}{2\,Yo} \tan \frac{\beta_o \ell_o}{2} \tag{2}$$

$$4\,Go \simeq \mp (Ysy-Ysx) \tan \frac{\beta_o \ell_o}{2} \tag{3}$$

where β_o is the propagation constant.

Defining $\Delta = (f_2-f_1)/fo$, $(f_2>f_1)$ as the band separation and after arranging eq. (2), the band separation Δ becomes

$$\Delta \simeq \frac{4}{\pi} \tan^{-1} \sqrt{\frac{Ysx+Ysy}{4\,Yo+Ysx+Ysy}} \simeq \frac{4}{\pi} \tan^{-1} \sqrt{\frac{Ysx+Ysy}{4\,Yo}} \tag{4}$$

As can been seen, the Δ can be controlled by changing the ratio of Ysx+Ysy to Yo.

In referring to the polarization, it is necessary to estimate eq. (3). When Ysy is rather larger than Ysx ($w_x < w_y$), because $\beta_o \ell_o = \pi(1-\Delta/2)$ at f_1 whereas $\beta_o \ell_o = \pi(1+\Delta/2)$ at f_2, f_1 is to produce the right hand circular polarization while f_2 is to produce the left hand circular polarization. Using the band separation Δ, simple solutions which can easily be derived so that the constraints of eqs. (2) and (3) are satisfied are:

$$Ysx + Ysy \simeq -2\,Yo \frac{\tan(1-\Delta/2)(\pi+\delta)}{\tan(1-\Delta/2)(\pi-\delta)/2} \tag{5}$$

$$Ysx - Ysy \simeq -\frac{4\,Go(1-\Delta/2)^2}{\tan(1-\Delta/2)(\pi-\delta)/2} \tag{6}$$

where

$$\delta \simeq \frac{G_2-G_1}{G_2+G_1} \pi \Delta/2 \tag{7}$$

The function δ compensates for the effect of a difference in radiation conductances G_1 and G_2 at f_1 and f_2, respectively. For the radiation conductance a simplified formula for small values of the width has been used [5]. The dependence of the band separation Δ on the difference between the characteristic admittance of stubs Ysx and Ysy is visible in Fig.2. If Yo is constant, the band separation Δ is seen to be wider for larger values of Ysx and Ysy, and for the case of large differences between Ysx and Ysy.

Experimental Results

This antenna was etched on a 3.175 mm thick PTFE printed circuit board with a relative dielectric constant of 2.50. The center frequency fo is designed to be 1500 MHz. The radiators were mounted on a 200 × 200 mm square ground plane. The microstrip line stubs could be varied in width for obtaining the optimum circular polarization to be investigated. One example for the case of Δ=0.3, the following parameter values were used: $\ell_{x1} = \ell_{y1}$=61.3 mm, $\ell_{x2} = \ell_{y2}$=30.0 mm, w_x=2.7 mm, w_y=4.0 mm and $x_f = y_f$=41.3 mm. The band separation Δ predicted by the theory is shown in Fig.2 with quite good agreement. On-axis axial ratios in Fig.3 and radiation patterns in Fig.4 were also measured for the antenna at f_1 and f_2. The agreement between theoretical and experimental results are very good.

Conclusions

The transmission line model is applied to a microstrip antenna with microstrip line loads to produce a dual-band circularly polarized radiator. A simple analytical model has been developed and used to generate useful design data for the stub loaded microstrip antennas.

References

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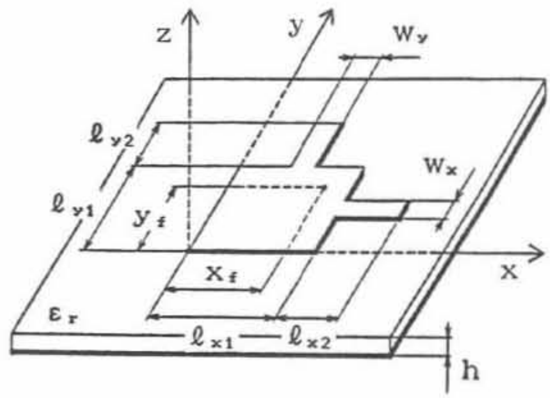

Fig.1. Geometry of dual-band circularly polarized stub loaded microstrip antenna.

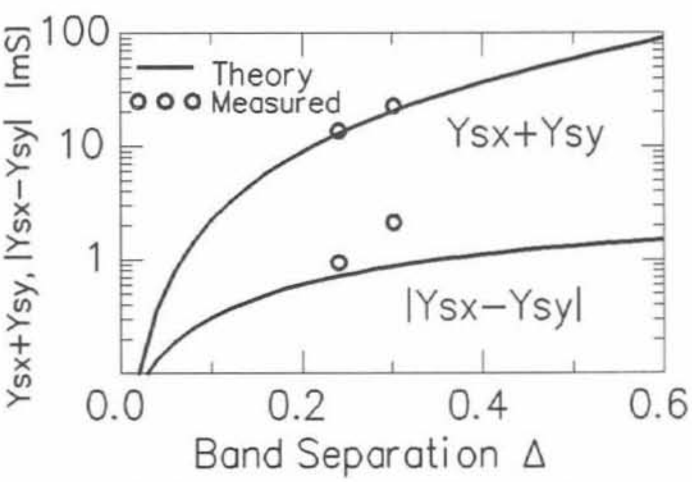

Fig.2. Characteristic admittance of stub versus band separation Δ.

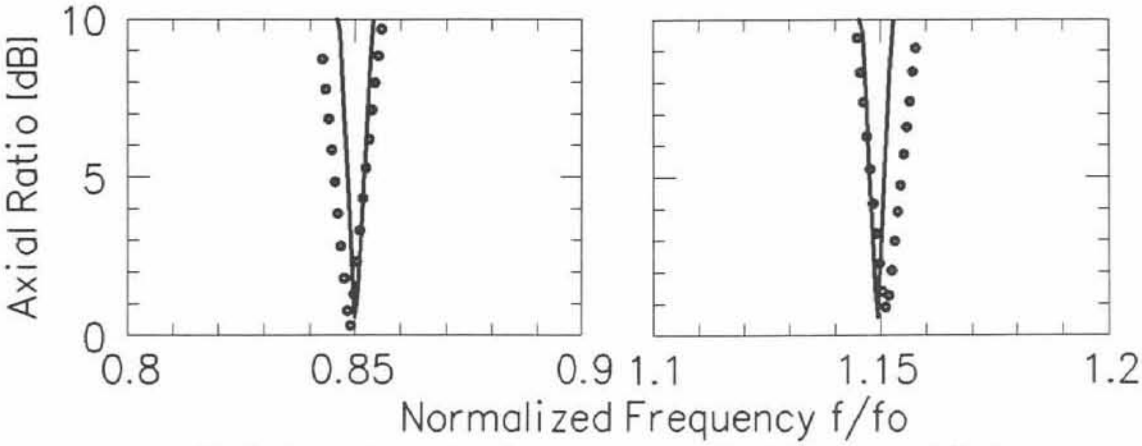

Fig.3. On-axis axial ratio versus normalized frequency f/fo for band separation Δ =0.3. Theoretical and measured center frequency fo were 1500MHz and 1477MHz respectively. Solid line is theoretical and ▫▫▫ is measured.

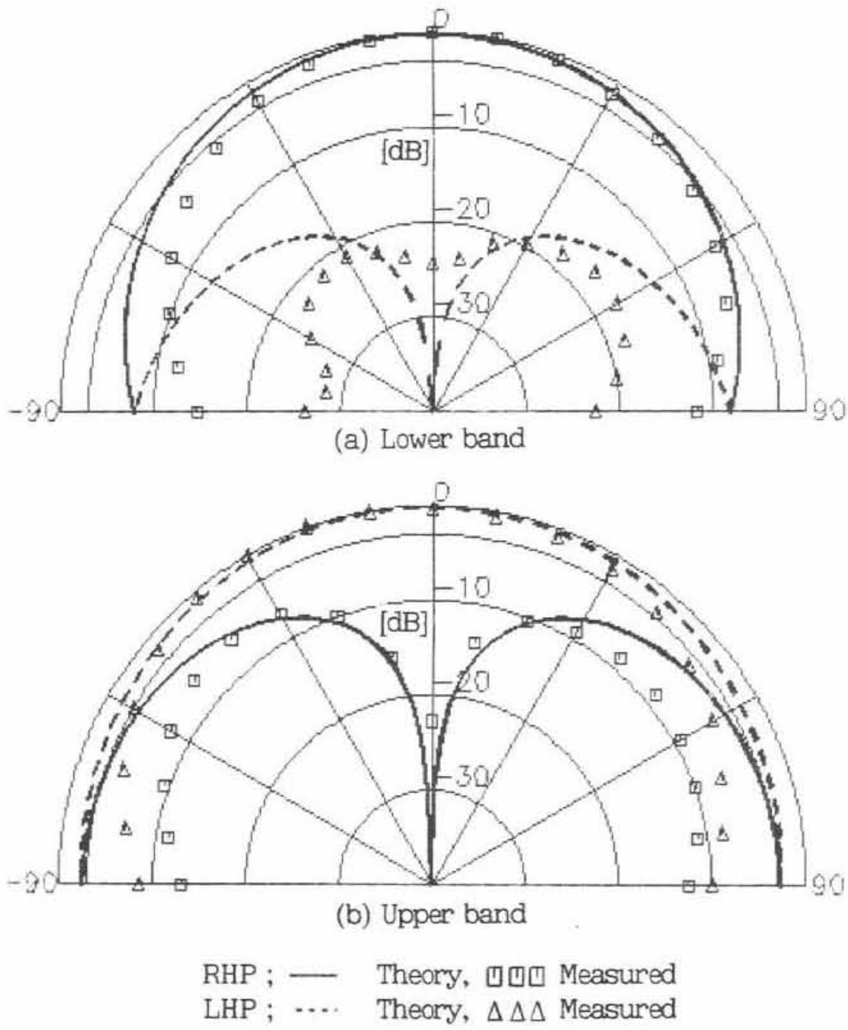

Fig.4. Radiation pattern of dual-band circularly polarized microstrip antenna for band separation Δ =0.3.