POST-TUNED SINGLE-FEED CIRCULARLY POLARIZED PATCH ANTENNAS

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SUMMARY

It is generally known [1] that circular polarization can be obtained from an ordinary patch antenna by using two orthogonally phased feeds located geometrically 90 degrees apart. In situations where space is at a premium both on the antenna circuit board and at the rear of the board, the incorporation of an extra feeding network may be disadvantageous. A number of approaches have therefore been proposed to achieve circular polarization using a single feed [2-4]. Although they are different from each other, they all operate on the principle of slightly detuning the degenerate modes of the symmetrical structure, i.e., they rely on certain asymmetry in the radiator. The present paper describes the design conditions for obtaining circular polarization from a single-feed circular patch antenna tuned by passive metallic or shorting post(s) appropriately placed in the input region of the antenna. A similarly tuned rectangular patch antenna has been experimentally developed in [5].

Consider a post located along the ϕ = 45 degree line close to the center of a circular patch antenna fed from the back by a coaxial probe as shown in Fig. 1. It can be shown [6-7] that in the presence of the post, the two degenerate orthogonal modes, named a and b, respectively, will produce approximately equal input impedance while their resonant frequencies split with two distinct angular frequencies, say ω_a and ω_b, respectively. The resonant frequency ω_a of mode a remains the same as that of the untuned antenna (i.e., ω_0) and that of mode b (i.e., ω_b) shifts upward from ω_0 by an amount depending on the radius and location of the tuning post.

Near resonance the impedance variation due to each mode can be obtained from an equivalent parallel R-L-C circuit and is given by

$$Z_{in}^{a,b} = \frac{R_{in}}{1 + jQ \frac{\delta\omega}{\omega_{a,b}}} , \qquad (1)$$

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where R_{in} is the resonant input impedance due to each mode, Q is the quality factor, and $\delta\omega$ is the frequency deviation from resonance. Figure 2 shows the input impedance and corresponding phase variation vs normalized frequency for these two modes. If the antenna is operated at a frequency intermediate between ω_a and ω_b, it can be seen from Fig. 2 that the impedance due to the a and b modes will be capacitive and inductive, respectively. When the operating frequency ω_p is chosen properly, the total impedance of the antenna will be real at ω_p, i.e., the resonance condition will be obtained. If the degree of mode splitting is chosen such that the phase angles of the modal impedances are ±45 degrees apart at the operating frequency, then the conditions for circular polarization are achieved. Under these conditions as shown in Fig. 2, the frequency shift satisfies the following condition

$$\frac{\omega_b - \omega_a}{\omega_a} = \frac{1}{Q} \quad . \tag{2}$$

Thus, from a knowledge ω_0 (= ω_a) and Q of the untuned antenna, ω_b is obtained from (2). The dimension and location of the post can be obtained [6,7] from a knowledge of ω_b. Left and right circular polarizations are obtained for a post located at ϕ = 45 degree, and ϕ = 135 degree radials, respectively.

Circular polarization is obtained only over a very narrow bandwidth centered at ω_p. For an axial ratio within 3.0 dB which would produce a polarization mismatch loss less than 0.25 dB, the bandwidth will be limited to a fraction of the impedance bandwidth. The useful circular polarization bandwidth can also be obtained from Fig. 2. If the frequency deviates from ω_p by $\delta\omega$, the axial ratio is approximately given by

$$\left| \frac{1 + j2Q \frac{\Delta\omega - \delta\omega}{\omega_0}}{1 + j2Q \frac{\Delta\omega + \delta\omega}{\omega_0}} \right| = \frac{1 + \left(1 - \frac{\delta\omega}{\Delta\omega}\right)^2}{1 + \left(1 + \frac{\delta\omega}{\Delta\omega}\right)^2} \quad , \tag{3}$$

where $\Delta\omega = \omega_p - \omega_a = \omega_b - \omega_p$. For a 3.0 dB axial ratio, eq. (3) yields $\delta\omega/\Delta\omega$ = 0.35 which indicates that the useful circular polarization bandwidth is only 35 percent of the bandwidth of the original linearly polarized antenna. A plot of axial ratio vs normalized frequency for a typical antenna is shown in Fig. 3 where some available experimental [3] results are given for comparison.

References

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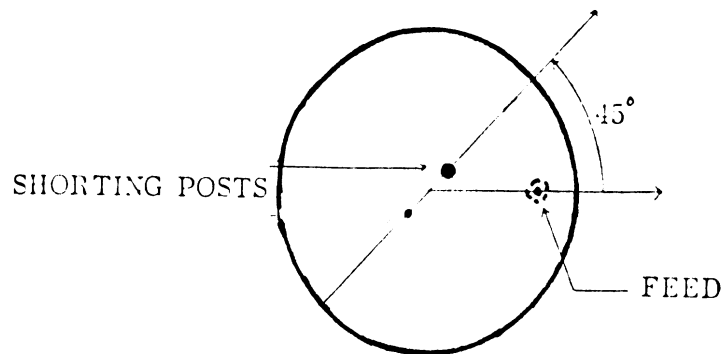
Fig. 1: Single feed circularly polarized patch antenna using shorting post.

Fig. 2: Condition for generating circular polarization.

Fig. 3: Axial ratio vs normalized frequency.