Shorting pin loaded microstrip antenna for dual-band operation

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The series and shunt inductivity introduced by the probe and shorting pin respectively, in a single-feed shorted rectangular microstrip antenna has been evaluated theoretically using transmission line method. The proposed structure provides compact dual band operation using single feed mechanism. The input impedance, VSWR, is calculated theoretically. It is found that the ratio of the resonant frequencies highly depends on the position of shorting pin.

Keywords: Microstrip antenna, Shorting pins, Dual band antenna, Transmission line
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1 Introduction

Microstrip antenna is now established as a separate entity in the broad field of microwave antenna, because of their numerous advantages such as light weight, low volume, low cost, planar configuration and compatibility with integrated circuits. The dual band antenna is very useful for satellite communication, to cover both transmit and receive operation simultaneously. Its applications are in radar, satellite communication, wireless network, mobile communication and microwave sensors. One of their principal disadvantages is narrow bandwidth. Recently several papers have been reported using shorting pins as a dual band microstrip antenna. The dual band operation using different techniques has been discussed in the paper. The input impedance become very sensitive to the feed position and strongly depends on the distance between the shorting pin and feed position. By incorporating a shorting pin in the centre line (Fig. 1) of rectangular microstrip patch and exciting the patch through a suitable feed position from the centre line, we find that a good matching condition for both the resonant frequencies of the microstrip patch can be obtained. Here, the theoretical study of single-feed, dual-frequency rectangular microstrip antenna is presented.

2 Theoretical considerations

In this paper, the dual band rectangular microstrip antenna is discussed using shorting pin technique with a single feed. By loading shorting pins in proper positions the rectangular microstrip antenna can be tuned for various dual bands. The placement of shorting posts offers shunt inductance reactance, which is given as:

\[ X_s = \frac{\eta_0 h}{2\pi c} \ln \left( \frac{4c}{\xi \omega d \sqrt{\varepsilon_r}} \right) \]  

Here \( \xi = 1.781072... \) and is derived from Euler's constant. Also \( c \) is velocity of light, \( d \) the diameter of feed probe, the intrinsic impedance of vacuum \( \eta = 377 \) and \( h \) the thickness of dielectric substrate.

2.1 Input impedance

The analysis of the input impedance of shorting pin loaded rectangular microstrip antenna has been divided in two cases:

Case I—When shorting pin is on the left of the probe feed of the patch, we use the equivalent transmission line model of shorting post rectangular microstrip antenna shown in Fig. 2. Here we take a transmission line with load impedance \( Z_l \). We take the impedance from shorting pin position, so that
Fig. 2—Equivalent transmission line model with shorting pin in the left of probe feed (typically probe inductance reactance is taken equal to shunt inductance reactance \( X_p = X_s \))

\[
Z_{m3} = Z_0 \left( Z_l + jZ_0 \tan \beta d_s \right)
\]

\[
Z_{m4} = \frac{jX_p Z_{m3}}{jX_s + Z_{m3}}
\]

\[
Z_{m5} = Z_0 \left( Z_l + jZ_0 \tan \beta (L - d_s) \right)
\]

\[
Z_{m6} = Z_0 \left( Z_l + jZ_0 \tan \beta (L - d_s) \right)
\]

The total impedance of the shorting pin with probe can be given as

\[
Z_{m\text{pin} \text{left}} = jX_p + \frac{Z_{m3} Z_{m6}}{Z_{m5} + Z_{m6}}
\]

Case 2—When shorting pin is on the right of the probe feed of the patch, then we use equivalent transmission line model of shorting post loaded rectangular microstrip antenna shown in Fig. 3. Here we take input impedance from shorting pin position as

\[
Z_{m3} = Z_0 \left( Z_l + jZ_0 \tan \beta (L - d_s) \right)
\]

\[
Z_{m4} = \frac{jX_p Z_{m5}}{jX_s + Z_{m5}}
\]

\[
Z_{m1} = Z_0 \left( Z_l + jZ_0 \tan \beta (d_s - y_0) \right)
\]

\[
Z_{m2} = Z_0 \left( Z_l + jZ_0 \tan \beta (y_0 - d_s) \right)
\]

The total impedance of the shorting pin with probe can be given as

\[
Z_{m\text{pin} \text{right}} = jX_p + \frac{Z_{m1} Z_{m2}}{Z_{m1} + Z_{m2}}
\]

The real and imaginary parts of the impedance for left and right pin loaded antenna were calculated, which are shown plotted in Fig. 4 for various spacing of pins. The value of \( f_1 \) and \( f_2 \) along with \( f_3/f_1 \) we calculated for different values of spacing of the pins.

3 Design specifications

The various design parameters of the antenna are given below.
Substrate material used | Glass Epoxy
---|---
Thickness of the dielectric substrate | \( h = 1.59 \text{ mm} \)
Relative permittivity of the substrate | \( \varepsilon_r = 4.5 \)
Design frequency | \( f = 2.5 \text{ GHz} \)
Thickness of the patch | \( t = 0.0018 \text{ cm} \)
Intrinsic impedance of vacuum | \( \eta = 377 \)
Permeability constant | \( \mu_0 = 4.\pi \times 10^{-7} \text{ H/m} \)
Permittivity constant | \( \varepsilon_0 = 8.854 \times 10^{-12} \text{ F/m} \)

Designed values were calculated using the standard equation and are given as follows:

The width of the rectangular patch | \( w = 36.20 \text{ mm} \)
The length of the rectangular patch | \( L = 27.80 \text{ mm} \)
Effective relative permittivity | \( \varepsilon_e = 4.20 \)
Feeding point at rectangular patch | \( y_0 = 4.6 \text{ mm} \)

4 Discussion of results

(a) The variations of real and imaginary parts of impedance with frequency for different shorting positions are shown in Fig. 4. It is observed that the lower resonance frequency increases and the upper one decreases with increasing pin positions. This further indicates that the separation between the resonance decreases with increasing value of the shorting pin positions.

(b) A variation of VSWR with frequency for different positions of shorting pin is shown in Fig. 5. It is observed that VSWR at lower and upper resonance frequency decreases with increasing value of shorting pin position. It is minimum for \( d = 7 \text{ mm} \). The increase of value beyond 7 mm decreases the VSWR at both resonance frequencies.

(c) The variation of resonance frequency \( f_1 \) and \( f_2 \) with shorting pin position is shown in Fig. 6. It is observed that the lower resonance frequency increases and the upper one decreases with increasing value of shorting pin position. It is observed from Fig. 7 that the ratio \( f_2/f_1 \) decreases with increasing value of the shorting pin positions. This observation agrees well with the reported results of Wong and Chen\(^2\).

References

