THEORETICAL CONSIDERATIONS ON PARALLEL-PLATE MODE SUPPRESSION IN A SLOT-COUPLED MICROSTRIP ANTENNA WITH A STRIPLINE FEED

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1. INTRODUCTION

In the slot-coupled microstrip antenna with a microstripline feed, the backlobe radiation is caused by the slot and the feedline. This radiation can be suppressed by using a stripline instead of a microstripline. But in the stripline configuration, a parallel-plate mode[1] is excited by the slot, and propagates between two conducting plates which constitute the stripline. The parallel-plate mode causes harmful influence to the characteristics of the antenna, such as the degradation of the radiation efficiency. One way to reduce the excitation of the parallel-plate mode is to use shorting posts. However, this method may complicate fabrication of the antenna. In this paper, we perform theoretical considerations on parallel-plate mode reduction of the slot-coupled microstrip antenna with a stlipline feed using moment method in the spectral domain. The reduction method proposed in this paper is to use the resonance of a radiating patch, and no shorting posts are used.

2. ANALYTICAL MODEL

The geometry of the slot-coupled microstrip antenna with a stripline feed is shown in Fig. 1. The radiating patch is of length L_p and width W_p, and is printed on the dielectric substrate with relative permittivity ε_{ra} and thickness d_a. Two conductive ground planes separated in space d_b and feedline of width W_f constitute a stripline. Dielectric of relative permittivity ε_{rb} is filled between two conductive ground planes. The feedline is truncated at distance L_{f1} from the center of the slot in order to form an open-circuited stub. In the analysis, the dielectric substrates and the ground planes are assumed to be infinitely wide.

In this paper, the moment method in the spectral domain[2] is used to analyze this geometry. The exact Green's functions for the grounded dielectric substrate are enforced in this approach, consequently, the analysis accounts rigorously for the guided waves as well as the radiated waves. Making use of this feature, we can evaluate the effects of these waves on the characteristics of the antenna.

3. NUMERICAL RESULTS

An impedance matching of the slot-coupled microstrip antenna is generally achieved at a parallel resonant frequency due to the coupling between the radiating patch and the slot[3]. The relation of the power of the parallel-plate mode and the return loss versus frequency when the matching is obtained at the parallel resonant frequency are shown in Fig. 2, where the resonant frequency of the patch itself is 2.800GHz, and the power is normalized by the input power into the antenna. This result leads that the power is reduced to the minimum not at parallel resonant frequency but at resonant frequency of the patch.

Next, we discuss about the cause of the phenomenon mentioned above. The equivalent circuit of the slot-coupled microstrip antenna can be expressed as shown in Fig. 3, where jX is a reactance due to the open circuit stub, and Z_s represents the series antenna impedance seen from the feedline at the slot[2]. The series antenna impedance can be expressed as a parallel circuit in terms of admittances $Y_p = G_p + jB_p$, $Y_{s+} = G_{s+} + jB_{s+}$ and $Y_{s-} = G_{s-} + jB_{s-}$. Y_p is admittance due to the contribution of the patch, Y_{s+} and Y_{s-} are admittances due to the contribution of the slot on the side of the patch and the feedline respectively[3]. As seen from Fig. 3, the power ratio of the sum of the radiated and surface wave to the parallel-plate mode is equal to the ratio of $G_p + G_{s+}$ to G_{s-}[4]. The frequency response of the conductance $G_p + G_{s+}$ and G_{s-} are shown in Fig. 4. The maximum conductance $G_p + G_{s+}$ occurs at 2.800GHz, which indicates the resonance of the patch, while G_{s-} is almost constant to the frequency. As a result, the power of the parallel-plate mode is reduced to the minimum at the resonant frequency of the patch. From this fact, the impedance matching can be achieved at the resonant frequency of the patch to minimize the excitation of the parallel-plate mode.

The input admittance at 2.450GHz, which is the resonant frequency of the patch, versus the distance, L_r, from the center of the slot to the reference position is shown in Fig. 5. In this figure the admittance is normalized by the characteristic admittance of the line. The normalized conductance is 1 at a distance from the slot, consequently, the matching may be achieved using an additional open-circuited stub connected in shunt with the feedline to cancel the susceptance as shown in Fig. 6[5].

The frequency response of the return loss and the power of the parallel-plate mode with some slot lengths are shown in Figs. 7 and 8, where the matching is achieved at the resonant frequency of the patch using the matching circuit mentioned above. The bandwidth of the antenna is sensitive to the slot length, while smaller power is obtained at the matched frequency independent of the slot length in comparison with the case where the matching is achieved at the parallel resonant frequency. In consequence, it is desirable that slot length is chosen so that the maximum bandwidth is obtained.

4. CONCLUSION

The power of the parallel-plate mode exited in the slot-coupled microstrip antenna with a stripline feed is reduced to the minimum when the antenna is operated at the resonant frequency of the radiating patch itself. We have clarified this mechanism theoretically using the moment method in the spectral domain. We proposed the use of matching circuit for the parallel-plate mode reduction instead of the shorting posts used to suppress this parasitic mode.

Acknowledgement

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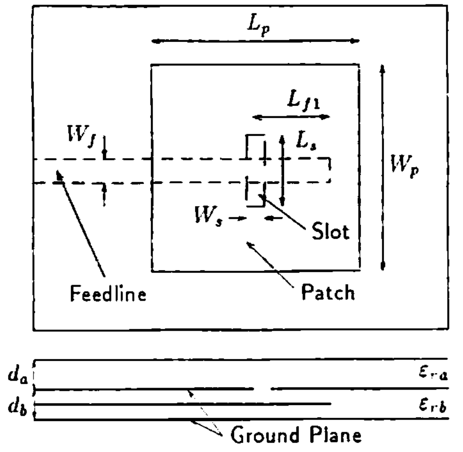
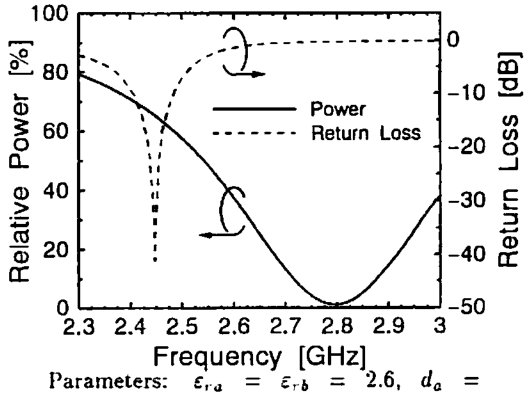


Fig. 1 : Geometry of a slot-coupled microstrip antenna with a stripline feed.



Parameters: $\varepsilon_{ra} = \varepsilon_{rb} = 2.6$, $d_a = d_b = 1.56\text{mm}$, $L_p = W_p = 32\text{mm}$, $L_s = 18\text{mm}$, $W_s = 1\text{mm}$, $W_f = 2.27\text{mm}$, $L_{f1} = 19\text{mm}$

Fig. 2 : Power of the parallel-plate mode and return loss versus frequency.

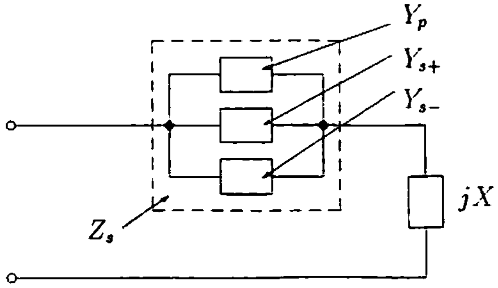


Fig. 3 : Equivalent circuit of the slot-coupled microstrip antenna.

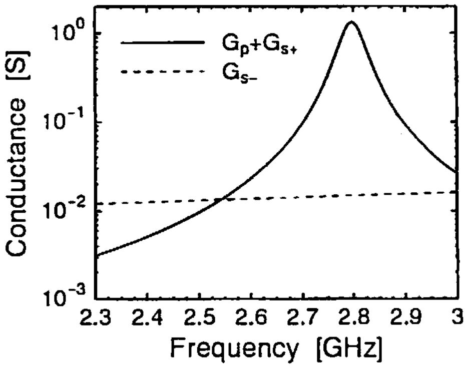


Fig. 4 : Various kinds of conductance versus frequency. (Parameters are same as of Fig. 2.)

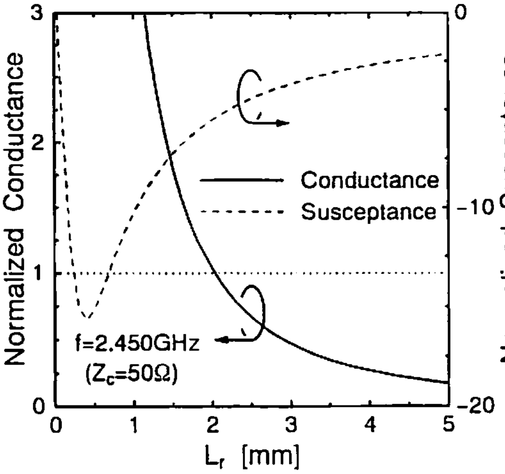


Fig. 5 : Normalized input admittance versus reference position.

Parameters: $\varepsilon_{ra} = \varepsilon_{rb} = 2.6$, $d_a = d_b = 1.56$mm, $L_p = W_p = 36.7$mm, $L_s = 7$mm, $W_s = 1$mm, $W_f = 2.27$mm, $L_{f1} = 18.1$mm.

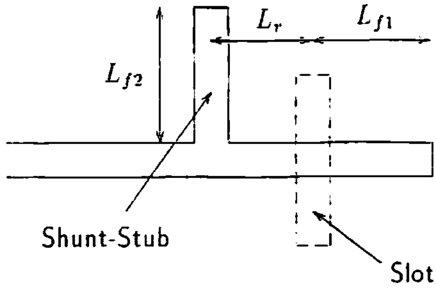


Fig. 6 : A matching circuit using a shunt-stub.

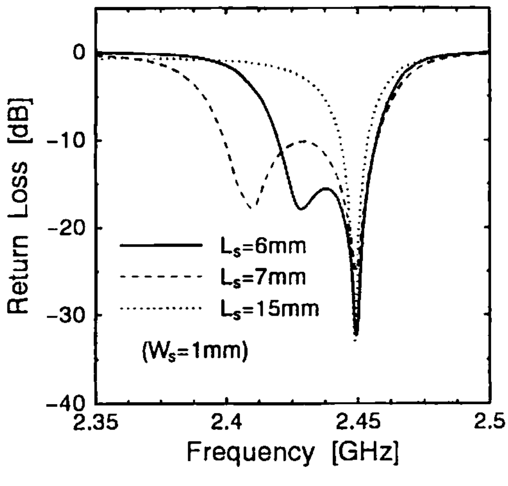


Fig. 7 : Return loss versus frequency with some slot lengths.

L_s = 6mm: L_{f1} = 18.1mm, L_{f2} = 16.3mm, L_r = 1.6mm; L_s = 7mm: L_{f1} = 18.1mm, L_{f2} = 16.0mm, L_r = 1.9mm; L_s = 15mm: L_{f1} = 18.4mm, L_{f2} = 16.4mm, L_r = 1.5mm. Other parameters are same as of Fig. 5.

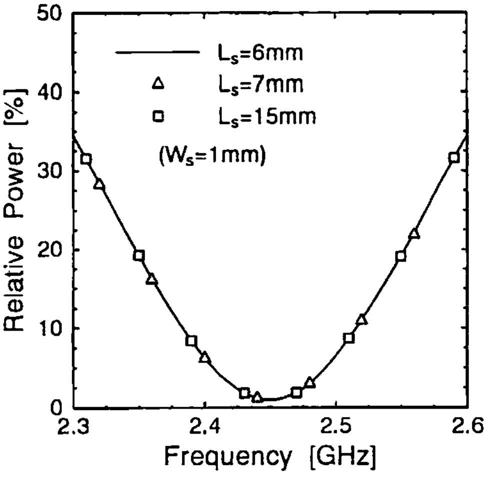


Fig. 8 : Power of the parallel-plate mode versus frequency with some slot lengths. (Parameters are same as of Fig. 7.)