Impedance Characteristics for Microstrip-fed Wide Slot Antenna using Volume Integral Equation Approach

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Abstract: - In this paper, the impedance characteristics of a microstrip-fed wide slot antenna are investigated using volume integral equations. The effects of different microstrip end offset and microstrip position from the centerline of the wide slot on the impedance characteristics are investigated. Technique based on the method of moments (MoM) using volume integral equation (VIE) approach is used. The results suggest that the impedance characteristics and bandwidth highly depend on the microstrip end offset.

Key-Words: - **V**olume integral equation, Method of moment, Microstrip, Slot antenna, Bandwidth, Return loss

1 Introduction

Recent technological trend in communication systems has focused much effort into the design of planar antennas. With a simple geometry, these antennas offer many advantages not commonly exhibited in other antenna configurations. For example, they are extremely low profile, lightweight, simple and inexpensive to fabricate using modern day printed circuit board technology, compatible with microwave and millimeter-wave integrated circuits (MMIC), and have the ability to conform to planar and non-planar surfaces. Among them slot antennas have played an important role for a variety of applications. The main advantages of radiating slots are less interaction via surface waves, better isolation and negligible radiation from feed network.

Microstrip-fed planar antennas such as microstrip patches, dipoles or slots have been investigated due to its attractive features, such as low profile, lightweight, low cost, and ease of integration with other circuits. Among them slot antennas have played an important role for a variety of applications. The main advantages of radiating slots are less interaction via surface waves, better isolation and negligible radiation from feed network. Depending upon the electrical dimension of the width, the slot antennas are usually of two types; narrow and wide slot antennas. Narrow slots have been analyzed by various methods [1]-[2]. Most of the work is based upon the assumption that the electric field in the slot has a single component varying sinusoidally along the slot, which is no longer valid for wide slot.

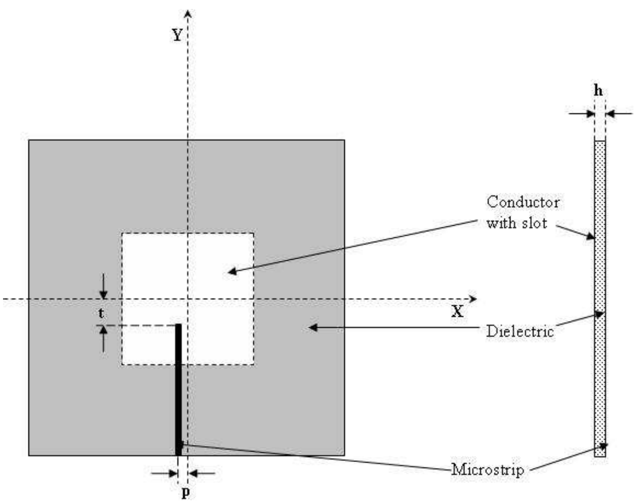
From the recent research results [3]-[7], it is shown that the impedance bandwidth of the slot antennas depend on layout of the etched slot. Although various microstrip-fed wide slot antennas have been proposed, studies on the effect of the microstrip-fed offset and microstrip position are rare. In this paper, it is shown how the impedance characteristics of a microstrip-fed wide slot antenna structure depend on microstrip offset and microstrip position.

However, there are many commercial software packages available for the analysis and design of microstrip structures and microwave components, not all packages have the same capabilities or performance. Since both software and hardware capabilities places a premium on practical applications [8], an analytical scheme that can facilitate analysis while maintaining acceptable degree of accuracy and validate the application of MoM approach for VIE was used. The validation was also carried out with experimental results for similar printed patch/slot antennas reported in [9] and is not presented here for brevity. For simulation the antenna configurations are done separately for input to the main solver. The impedance characteristics for microstrip-fed wide slot antenna were observed to provide a 1:1.75 VSWR bandwidth.

2 Analysis and Geometrical Layout

The analysis of scattering, radiation, and propagation in planar-layered structures with printed conductors is often carried out using the field integral equation (FIE) written in the mixed potential form. It includes two coupled equations—one for the dielectric volume and another for a metal surface. In the method of moments (MoM) approach for simulating the performance of metal-dielectric antennas, use of a surface integral equation (SIE) currently dominates for pure dielectric and metal antenna structures [9]. The method of a volume integral equation (VIE), has a number of advantages, including applicability to various inhomogeneous materials. For the purpose of analysis all the current distributions and basis functions were considered in solving the integral equations. The solution obtained in terms of vector and scalar-potential Green's functions was implemented in the codes used for the investigations.

The configurations of the proposed antenna are shown in Fig. 1. The slot has dimensions of 53.7 mm x 53.7 mm on a substrate of 110 mm x 110 mm. The thickness of the substrate is 0.8 mm and relative permittivity is 4.4. The slot is considered to be etched in the ground plane and is fed by a 50-Ω microstrip line of width 1.5 mm, which is placed on the opposite side of the substrate. Different microstrip end offset (t) along x-axis and microstrip position (p) along y-axis from the centerline of the slot were considered.



(a) (b)

Figure 1: Configurations of microstrip-fed square slot antenna (a) top view (b) side view

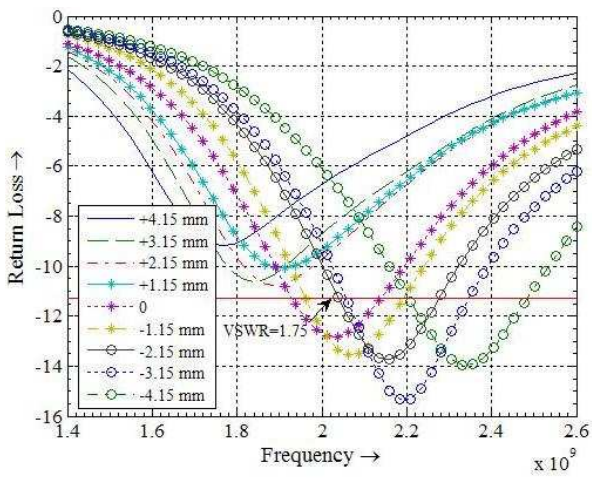
Since the large tangential fields of the slot will be coplanar with the vanishing tangential fields of the metal, the mesh is also important for the accurate results. So a suitable volume/surface meshing is done to the antenna configuration. The feed is a voltage gap connector between the ground plane and the microstrip. The constant voltage V is given in the finite gap. The input impedance of the antenna is then given by the ratio of gap voltage to total current through the feeding edges

$$Z = \frac{V}{\sum l_n I_n}$$

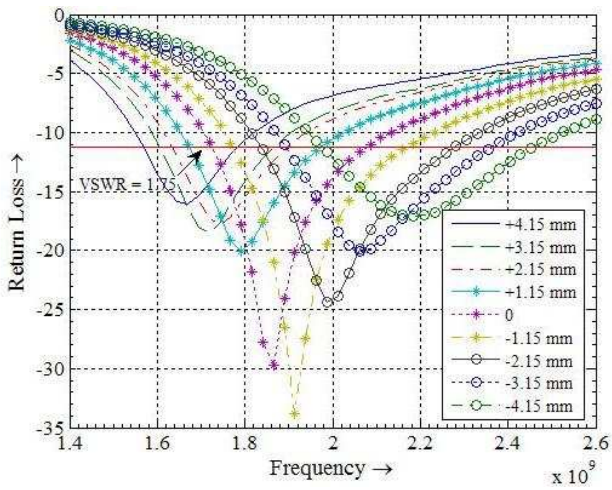
where I_n are the solutions to MoM equations with the basis functions.

3 Result and Discussion

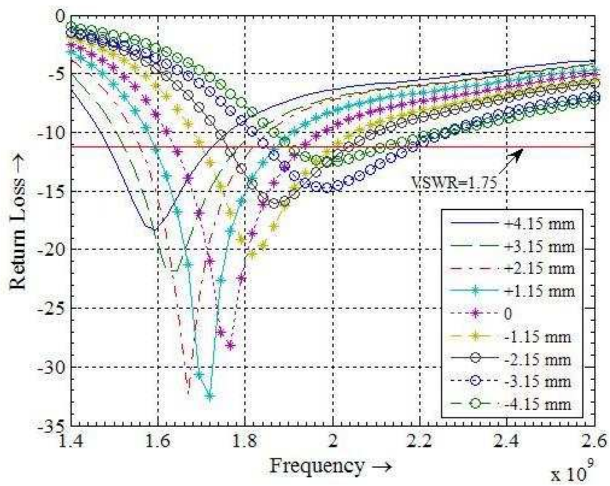
Based on the scheme of analysis described above, the return loss of the antenna configurations with different microstrip end offset (t) and microstrip positions (p) with respect to the centerline of the slot are obtained. Fig. 2(a)-2(h) depicts the simulated return loss of the slot antennas as a function of frequency for different values of t and p. The return loss of less than -20 dB is observed for some values of t and p out of different t and p values considered for the investigation, which show good impedance matching characteristics.



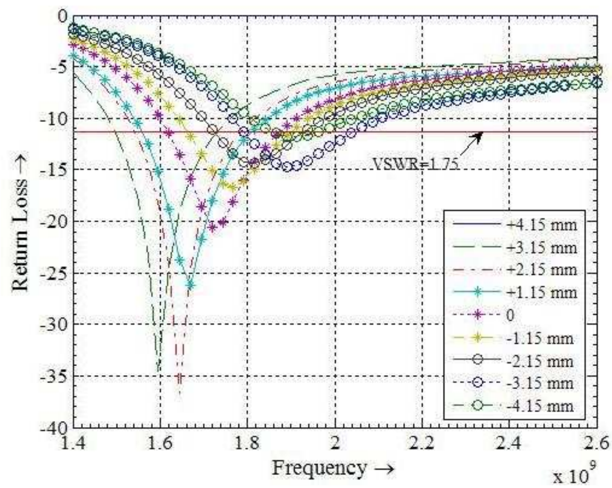
(a)


Return Loss →
Frequency →
x 10^9
VSWR = 1.75
+4.15 mm
+3.15 mm
+2.15 mm
+1.15 mm
0
-1.15 mm
-2.15 mm
-3.15 mm
-4.15 mm

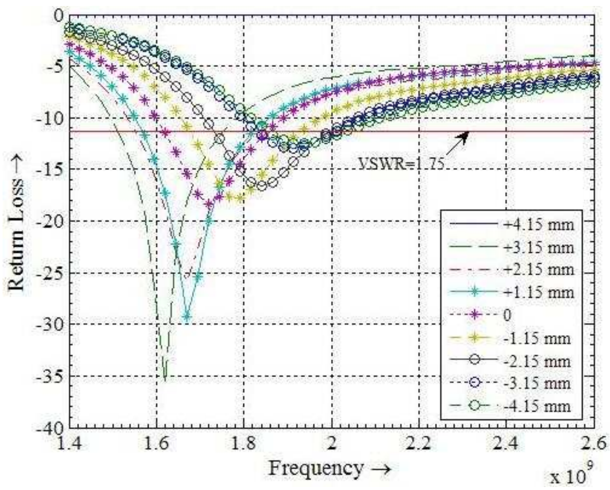
(b)


Return Loss →
Frequency →
x 10^9
VSWR=1.75
+4.15 mm
+3.15 mm
+2.15 mm
+1.15 mm
0
-1.15 mm
-2.15 mm
-3.15 mm
-4.15 mm

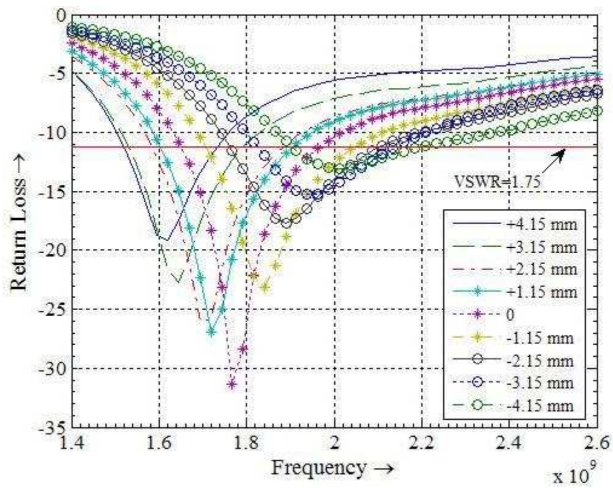
(c)


Return Loss →
Frequency →
x 10^9
VSWR=1.75
+4.15 mm
+3.15 mm
+2.15 mm
+1.15 mm
0
-1.15 mm
-2.15 mm
-3.15 mm
-4.15 mm

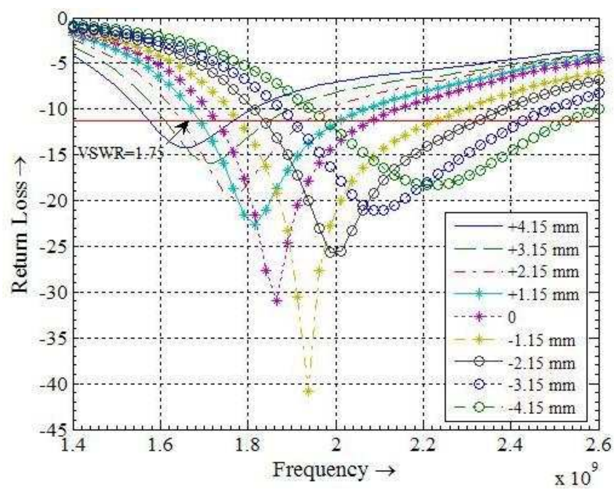
(d)


Return Loss →
Frequency →
x 10^9
VSWR=1.75
+4.15 mm
+3.15 mm
+2.15 mm
+1.15 mm
0
-1.15 mm
-2.15 mm
-3.15 mm
-4.15 mm

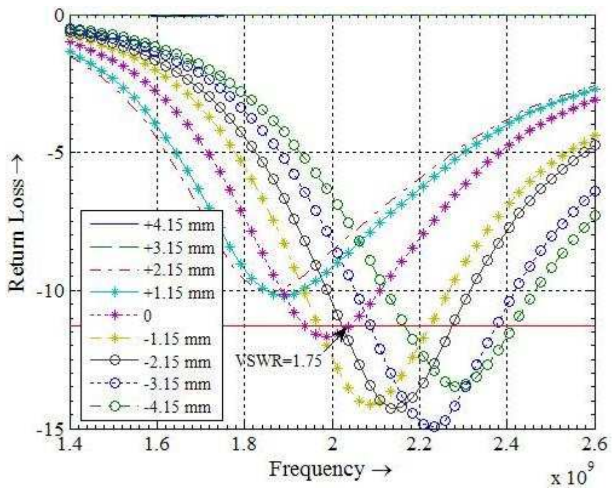
(e)


Return Loss →
Frequency →
x 10^9
VSWR=1.75
+4.15 mm
+3.15 mm
+2.15 mm
+1.15 mm
0
-1.15 mm
-2.15 mm
-3.15 mm
-4.15 mm

(f)


Return Loss →
Frequency →
x 10^9
VSWR=1.75
+4.15 mm
+3.15 mm
+2.15 mm
+1.15 mm
0
-1.15 mm
-2.15 mm
-3.15 mm
-4.15 mm

(g)



(h)

Figure 2: Plot of return loss as a function of frequency for different microstrip end offset (t) ; (a) p=+20 mm, (b) p=+15 mm, (c) p=+10 mm, (d) p=+5 mm, (e) p=-5 mm, (f) p=-10 mm, (g) p=-15 mm, (h) p=-20 mm

Fig. 3 illustrate the 1:1.75 VSWR bandwidth for different values of t and p, which indicate that by adjusting the microstrip end offset and microstrip position a better bandwidth can be achieved. For the configurations under consideration, the best bandwidth of 550 MHz is achieved for t = -4.15 mm and p = -15 mm.

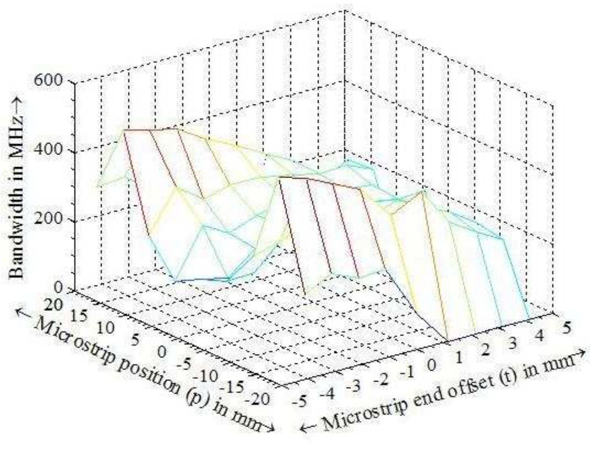


Figure 3: Plot of bandwidth dependence on the microstrip end offset (t) and microstrip position (p)

4 Conclusions

Impedance characteristics of a microstrip-fed wide slot antenna were investigated. An extensive numerical simulation was carried out. Investigated results indicated that 1:1.75 VSWR bandwidth of 550 MHz was achieved at operating frequencies around 2.2 GHz, which is nearly five times that of a similar microstrip-fed slot antenna reported in [9].

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