

# Assessment of the Impedance Bandwidth of a Proximity-Coupled Microstrip Patch Antenna

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**Abstract**—This article proposes a new strategy to design and estimate the impedance bandwidth of a two-layer and single-material PC-MSPA through a math close form. The simulated and experimental results present good agreement with the bandwidth model presented. The proposed analytical enable the evaluation of a proximity-coupled microstrip patch antenna (PC-MSPA) bandwidth that allows developing a framework for more effective designs.

## I. INTRODUCTION

Proximity-coupled patch antennas have been introduced in the early 1970s [1]. One of the most outstanding features of the PC-MSPA is the wider bandwidth that it can provide compared to other fed MSPAs ([3], [4]) such as the aperture, inset and prob feds. This is due to the capacitive nature of the feeding structure and its intermediate location between the patch and the ground planes, as shown in Fig. 1. Even so, the percentage bandwidth of a MSPA is typically very narrow, less than 5 %, being necessary and common to develop geometrical modifications and several computational optimizations [5] enhance this parameter. It is then observed that a panoramic assessment picture of the bandwidth as a behavioral parameter of the PC-MSPA would help to develop more strategical designs of high-performance PC-MSPA.

Diverse models for different-fed MSPAs, from analytical approaches ([1],[6],[7]) such as the transmission line model and the cavity model, to the full-wave ones such as the use of the Green's functions [8], or the Method of Moments (MoM) [2], are available in the literature, although analytical models are usually limited to thin substrates and full-wave models normally require long time for implementation and computation. Moreover, despite the very few and mostly full-wave models for PC-MSPA, [9] proposed a design procedure for square and circular PC-MSPA using MoM-derived curves, but it seems not to have a complete bandwidth assessment that relates to the antenna substrate thicknesses.

This work contributes with a new strategy to estimate the bandwidth of a dual-layer and single-material PC-MSPA through a close form based on curve-fitting technique [10]. Then, the article is organized as follows: after this introductory section, the antenna design procedure and the bandwidth assessment model are proposed in Section II; then, the bandwidth model is compared with full-wave simulated and experimental results, including a discussion in Section III.

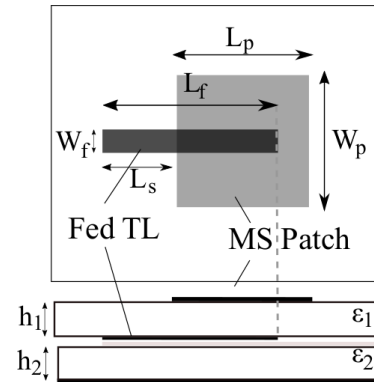


Fig. 1. Proximity Coupled Microstrip Patch Antenna (PC-MSPA): antenna geometry

## II. ANTENNA DESIGN AND BANDWIDTH ASSESSMENT

The percentage bandwidth  $\%BW$  of an antenna is the ratio between the range of frequencies from  $f_l$  to  $f_h$  where  $|S_{11}| < -10$  dB and the central frequency  $f_c = (f_l + f_h)/2$ . Also, for a design frequency  $f_o$ , the guided wavelength is  $\lambda_r = c/(f_o\sqrt{\epsilon_r})$ .

Considering the geometry of Fig. 1, and assuming  $\epsilon_1 = \epsilon_2 = \epsilon_r$ , the dimensions  $h_2$ ,  $L_f$ ,  $W_f$ ,  $L_p$  and  $W_p$  can be obtained from an initial value of the feed substrate thickness  $h_1$ , and then  $\%BW$  can be estimated. To begin with, the patch substrate thickness  $h_2 = R_h h_1$  can be set using  $R_h$  from Fig. 2(c), and  $\%BW$  is estimated from Fig. 2(d). If  $h_2 \neq R_h h_1$ , then  $\%BW$  decreases and can be calculated as follows:

$$\%BW \approx A_{BW} \sqrt{1 - \left(\frac{H_{BW}}{K_{BW}}\right)^2}, \quad (1)$$

where  $A_{BW}$  represents the bandwidth when  $h_2 = R_h h_1$ ;  $H_{BW} = \log_2 [(h_2/h_1)/R_h]$  constitutes the normalized  $h_2$  value in the logarithmic scale; and  $K_{BW}$  is the range of values of  $h_2$  in order to get bandwidth, which trend is pictured in Fig.2(f). Thus, (1) follows an elliptical pattern for each  $h_1$  value, where  $\%BW$  is maximum at  $h_2 = R_h h_1$  and zero at  $h_2 = 2^{\pm K_{BW}} R_h h_1$ , as shown in Fig. 2(e).

Finally, the feed transmission line length can be set to  $L_f = L_s + R_p L_p$ , where  $R_p$  follows the pattern of Fig. 2(a) to get

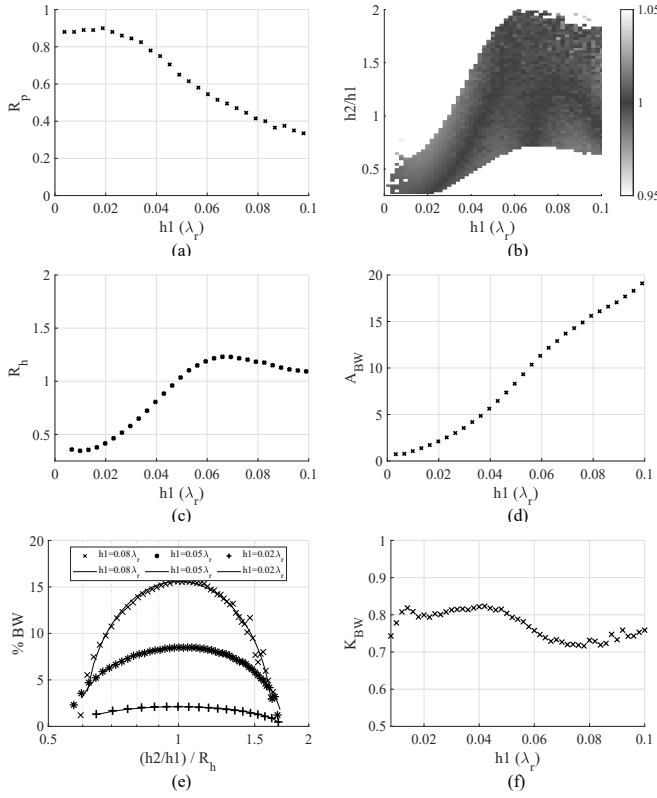


Fig. 2. PC-MSPA design curves ( $\epsilon_r=2.2$ ) and bandwidth estimation: (a)  $R_p$ , (b)  $f_c/f_o$ , (c)  $R_h$ , (d)  $A_{BW}$ , (e)  $\%BW$ , (f)  $K_{BW}$

$f_c \approx f_o$  as shown in Fig. 2(b);  $W_f$  is set for matching; and the patch size ( $L_p = W_p$ ) can be set from the width of a rectangular patch ([4]).

### III. RESULTS AND DISCUSSION

The proposed model of the impedance bandwidth expressed in (1) is evaluated and shown as a bandwidth picture in Fig. 3(a), where  $h_1$  varies from 0 to  $0.1\lambda_r$ ; and  $h_2$ , from  $0.25h_1$  to  $2h_1$  from each  $h_1$  value. Besides, a PC-MSPA was implemented ( $f_o=3$  GHz,  $\epsilon_r=2.2$ ,  $h_1=h_2=125$  mil= $3.175$  mm  $\equiv 0.047\lambda_r$ ,  $L_p=W_p=29.4$  mm) and measured, being the magnitude of  $S_{11}$  displayed in Fig. 3(c).

Fig. 3(a) and 3(b) reveal a pretty good agreement between the impedance bandwidth simulation and estimation, with an estimation error between 0.02 and 1 in the impedance bandwidth, as observed numerically in Fig. 3(d). On the other hand, the experimental results also show a good agreement with the simulation, although the measured frequency response looks slightly wider, being the bandwidth in these cases 9.2 % measured, 7.7 % estimated and 7.3 % simulated.

### IV. CONCLUSION

In conclusion, the impedance bandwidth of a PC-MSPA can be estimated from a design that has an operative central frequency around the designed value. To achieve these results:

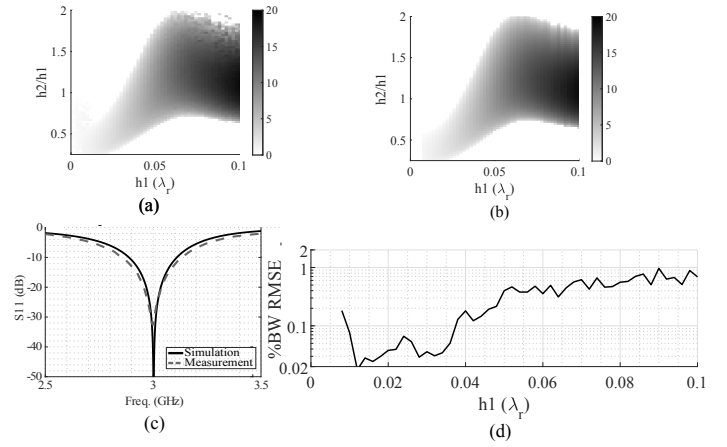


Fig. 3. Impedance bandwidth assessment: (a) simulation, (b) estimation, (c) measurement, (d) RMSE

- 1) Set the patch dimensions and the feed substrate thickness  $h_1$  as an initial start point.
- 2) Follow the curve from Fig. 2a to get  $R_p$  and then the feed transmission line width  $L_f$ .
- 3) Follow the curve in Fig. 2c to get  $R_h$  and then the patch substrate thickness  $h_2 = h_1 R_h$  to maximize bandwidth.
- 4) The estimated bandwidth will just be  $A_{BW}$  from (1) which is pictured in Fig. 2d. If the patch substrate thickness out of the optimum value, then follow (1), where  $K_{BW}$  is pictured in Fig. 2f.

### ACKNOWLEDGMENT

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