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Assessment of the Impedance Bandwith 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 exoerimental results, including a discussion in Section III.

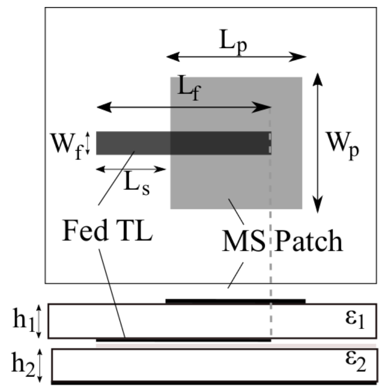

Fig. 1. Proximity Coupled Microstrip Patch Antenna (PC-MSPA): antenna geometry

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 λ_r=$c/(f_o\sqrt{\varepsilon_r})$.

Considering the geometry of Fig. 1, and assuming ε_1=ε_2=ε_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 $h2 = R_h h_1$; $H_{BW} = \log_2\left[(h_2/h_1)/R_h\right]$ 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 $h2 = R_h h1$ and zero at $h2 = 2^{\pm K_{BW}} R_h h_1$, 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

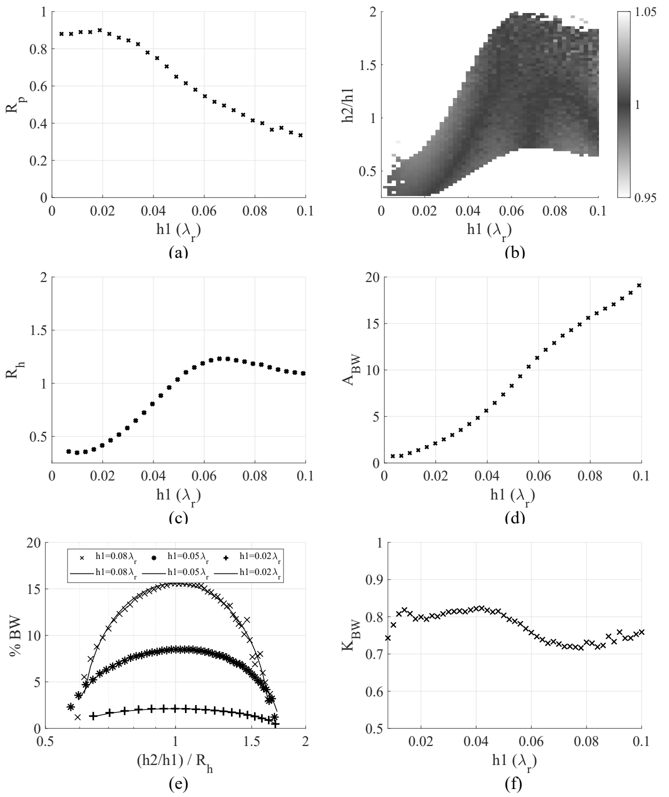

Fig. 2. PC-MSPA design curves (ε_r=2.2) and bandwidth estimation: (a) R_p, (b) f_c/f_o, (c) R_h, (d) A_{BW}, (e) $\%BW$, (f) K_{BW}

$f_c \approx f_o$ 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, ε_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:

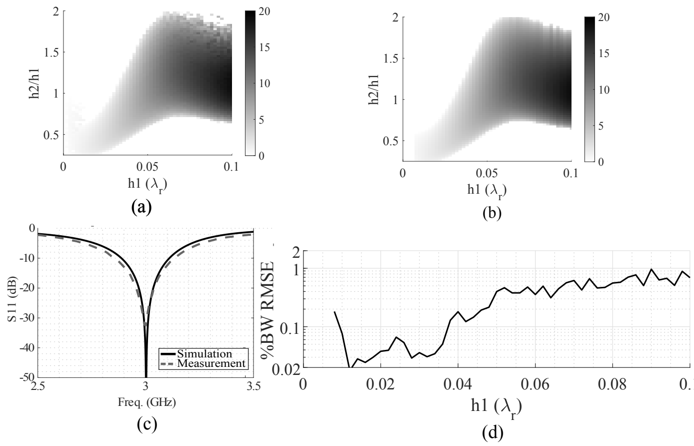

Fig. 3. Impedance bandwidth assessment: (a) simulation, (b) estimation, (c) measurement, (d) RMSE

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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