Design of Low Reflection Coefficient Printed Antennas

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***Abstract*—In this paper a design strategy is presented to achieve low reflection coefficients (< - 40 dB) for printed antennas over reasonable bandwidths (> 10 %) without the need for external matching structures. The design strategy revolves around critical coupling between multiple resonances within the radiating structure. The strategy is applied to aperture stacked patches and can be applied to other forms of antennas. The theoretical results are validated through experiment.**

I. INTRODUCTION

Low reflection coefficient antennas are necessary components for applications requiring high performance wireless transmitters/receivers. Whether for reducing the insertion loss of an integrated antenna/receiver and thereby increasing its dynamic range, or for enabling high RF power to be transmitted efficiently from the antenna, low reflection coefficient antennas are highly sought after. There are antenna structures that appear to be inherently low reflection coefficient solutions; waveguide-based antennas are well known. One simple/fundamental reason for this is that the 'characteristic' impedance (and hence the normalizing impedance) of the transmission line of these antennas is high and therefore the impact of structural imperfections or other abnormalities within the antenna are minor. On the other hand, printed antennas are typically designed around 50 Ohm transmission lines. Therefore any minor physical impairment whether associated with a connector or a finite surface discontinuity, can make the design of low reflection coefficient printed antennas very challenging.

In this paper a design methodology is presented that can enable low reflection coefficient printed antennas to be realized over reasonable bandwidths. The technique is based on the concept of achieving critical coupling in an antenna, whether it occurs between multiple resonances within an antenna or between the internal matching mechanism and the radiating element itself. The methodology is applied here to an aperture stacked patch (ASP) [1], although it can also be applied to a variety of other printed antennas such as printed quasi antennas, or printed circular slot radiators. The design is focused at operating frequencies within X-band and it is shown that reflection coefficients better than – 40 dB can be achieved. For the ASP antenna, a – 40 dB reflection coefficient over a frequency range of 1 GHz was accomplished.

II. DESIGN PHILOSOPHY

The underlying concept behind achieving a low reflection coefficient printed antenna is critical coupling. The concept can be easily illustrated for a simple probe-fed patch antenna. As the probe position is varied along one of the axes of the antenna from the center to the edge, the impedance of the antenna varies from a low impedance to a high impedance. At one point the antenna will be matched to the feed transmission line impedance (typically 50 Ohms) and at this position the antenna is said to be critically coupled. For cases when the probe position yields an impedance below this value the antenna is referred to as being undercoupled, whereas for cases that yield a higher impedance the antenna is said to be overcoupled. It is possible to achieve better than -40 dB reflection coefficients for single layer patches, however the bandwidth is typically very small since the fundamental radiator is inherently narrowband.

The concept described above can be extended to more complicated printed antennas which can provide enhanced performance. To obtain improved performance we effectively need more than one 'resonator', unlike the single patch antenna described earlier, and then we need to critically couple these 'resonances'.

III. APERTURE STACKED PATCHES

Consider an ASP shown in Fig. 1 (please refer to [1] for details of the antenna and its design methodology). Traditionally we try to optimize the mutual resonances between the three main radiators (two patches and a slot) to ensure that the -10 dB reflection coefficient is maximized. As an example, consider the antenna presented in Fig. 4(b) of [2]. As can be seen from that Smith chart, although the impedance loci is well behaved since it is relatively close to the center of the Smith chart), the 'resonators' of the antenna cannot actually be deemed critically coupled. In fact, based on the definitions in Sect. II this antenna is overcoupled.

There are many ways to reduce the coupling between the radiators of an ASP, including modifying the dimensions of the patches and slot and changing the dielectric constants of the substrates of the antenna [2]. Probably the simplest procedure is to increase the separation distance between the two patches. Fig. 2 compares the reflection coefficient performance of an

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ASP design where the thickness of the dielectric layer between the lower patch and the upper patch has been increased from 5.0 mm to 5.5 mm. The original configuration which has 5.0 mm thick substrate and is referred to as the 'reference' radiator in Fig. 2, is the wideband design presented in [1]. As can be seen from the results in Fig. 2, this simple modification has resulted in a design with a reflection coefficient better than -40 dB over a bandwidth of 1 GHz. Importantly, the modifications have minimal impact on the radiation performance of the antenna.

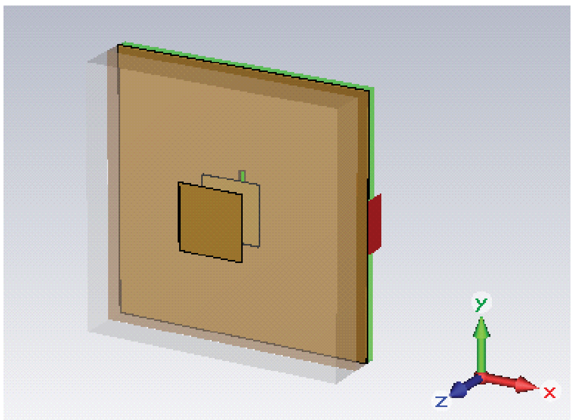

Fig. 1. Schematic of ASP.

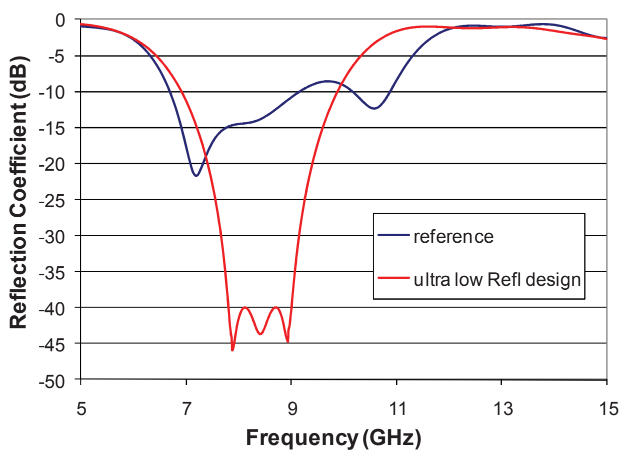

Fig. 2. Comparison of reflection coefficient of ASP antennas.

A prototype of the proposed low reflection coefficient ASP antenna was developed. Here a modified tab SMA connector (SC5370) was used to minimize the discontinuity between the connector and the microstrip feed line. The dimensions and material parameters of the antenna are provided in the caption of Fig. 3. The multilayered antenna was held together using epoxy.

Fig. 3 shows the measured reflection coefficient response of the antenna. For reference, the predicted performance is also provided. As can be seen from the plot in Fig. 3, the antenna displays better than -40 dB reflection coefficient over approximately 1 GHz of bandwidth and the experimental results are in good agreement with the simulations.

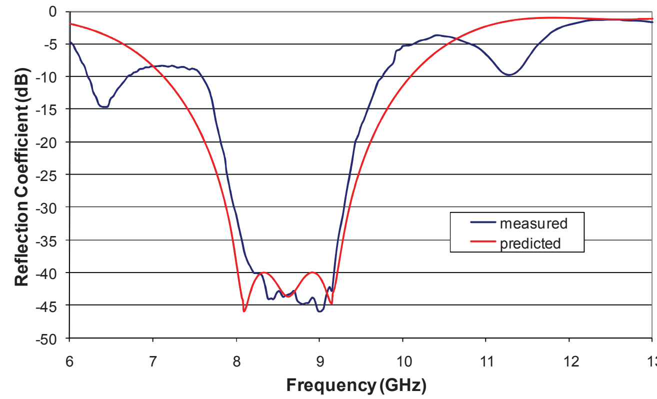

Fig. 3. Reflection coefficient performance of low reflection coefficient ASP antenna (Antenna dimensions: $L_{p1} = W_{p1} = 9.1$ mm; $L_{p2} = W_{p2} = 10$ mm; $S_l = 9.9$ mm; $S_w = 0.8$ mm; $w_f = 4.7$ mm; $L_{os} = 3.4$ mm; outer dimensions of antenna: 40 mm × 40 mm; layer parameters: $\varepsilon_{rf} = 2.33$, $d_f = 1.6$ mm; $\varepsilon_{r1} = 2.2$; $d_1 = 3.2$ mm; $\varepsilon_{r2} = 1.1$; $d_2 = 5.5$ mm; $\varepsilon_{r3} = 2.2$; $d_3 = 0.254$ mm. Refer to [1, 2] for the definition of these parameters).

The measured radiation patterns of the antenna (E-plane and H-plane co-polar) are presented in Fig. 4. Once again, these results are consistent with conventional ASP radiators. The measured gain of the antenna at 8.5 GHz was approximately 7.9 dBi.

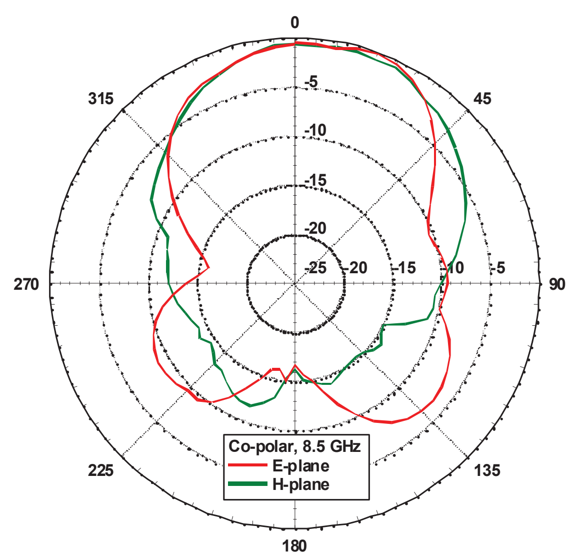

Fig. 4. Measured radiation patterns of low reflection coefficient ASP antenna at 8.5 GHz.

REFERENCES

[1] S. D. Targonski, R. B. Waterhouse and D. M. Pozar, "A wideband aperture coupled stacked patch antenna using thick substrates," *Elect. Lett.*, vol. 32, pp. 1941 – 1942, Oct. 1996..

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