HIGH PERFORMANCE BROADBAND PLANAR ANTENNAS THE SSFIP CONCEPT

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ABSTRACT

The **SSFIP** (**S**trip - **S**lot - **F**oam - **I**nverted **P**atch) antenna concept provides a very broad frequency bandwidth, with high efficiency, a very low crosspolarisation level and an integrated radome. It is lightweight, rigid and inexpensive. Single patch and stacked antennas yielded respectively 13.2% and 33% bandwidths, both for a VSWR lower than 2:1. These results open new possibilities and applications to planar antennas.

1. INTRODUCTION

Microstrip patch antennas present significant advantages in terms of size, ease of fabrication and compatibility with printed circuits, but are also plagued by several drawbacks, the most notorious being their narrow frequency bandwidth capability. While hailed as an inherently low-cost technology, current designs often remain rather expensive because materials actually developed for microstrip circuits are generally used. The use of the same (single) substrate for both the radiating elements and the feed network is a poor compromise: the patch must radiate, while the connecting.lines should not. The coaxial excitations that always appear in theoretical developments are not suited for cheap mass production. These problems were recently discussed by Hall and Hall [1]. Last but not least, patch antennas should be protected against environmental effects by a suitable cover.

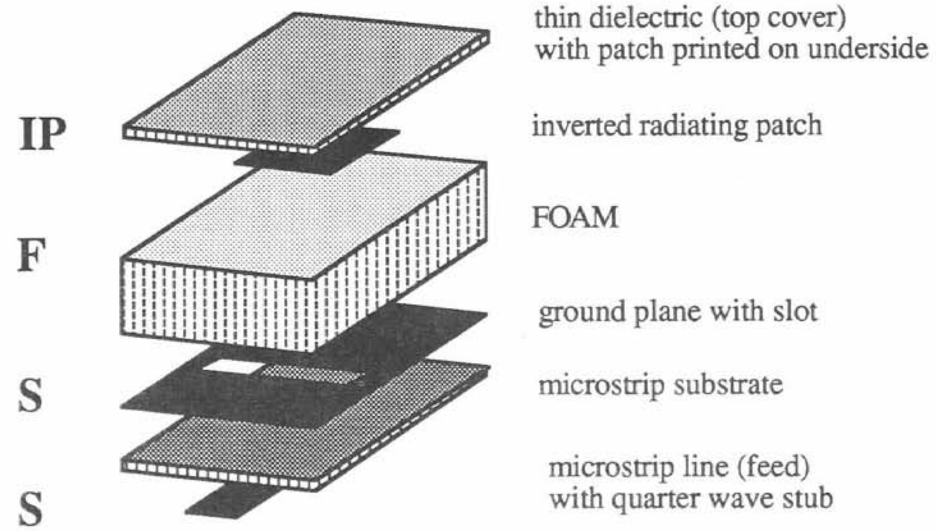

Fig. 1 exploded view of SSFIP antenna structure

To improve the overall performance, the functions of radiator and of feed must be clearly separated : the antenna is placed above, the feeding line below a common ground plane, and both are coupled through a rectangular slot (Fig. 1) [2]. The slot must not be at resonance over the operating frequency band of the antenna, as that would produce an important back radiation. To avoid surface waves and to increase the bandwidth, a very low-permittivity foam substrate was used for the radiating element. Available low cost materials provide a relative permittivity as low as $\varepsilon_r = 1.07$, together with a small loss factor $\tan \delta = 8 \cdot 10^{-4}$. The radiating metal patches cannot be deposited directly on the foam, hence they are placed **on the underside** of a thin plastic sheet that also serves as protective cover . The microstrip line is deposited on a high quality microstrip dielectric substrate . This sandwich structure is called: **S**trip - **S**lot - **F**oam - **I**nverted **P**atch antenna (SSFIP), indicating the sequence of features seen by the radiated signal. The foam itself is quite rigid and the resulting structure is extremely lightweight, making it a suitable candidate for aerospace applications. In addition, all the materials used are rather inexpensive, so that this approach could be used to realize consumer antennas for direct reception of satellite TV. Antenna arrays form flat panels, that are easily mounted over the walls of buildings.

2. SINGLE PATCH ELEMENT

A single element antenna was first designed experimentally for 9 GHz.operation, using RT/Duroïd 5870 for the microstrip substrate, a polymethacrylamid hard foam for the radiator substrate and a thin epoxy fiberglass as cover. The patch size was first determined with the software package MICPATCH [3], assuming that the coupling slot would not modify the resonant frequency. However, when using a thick foam to increase the bandwidth, the slot dimensions must also increase to provide sufficient coupling, and then the resonant frequency of the patch decreases. The slot providing the optimum coupling reduced the resonant frequency by about 20 %. Preliminary results were reported in the technical literature [4].

A more thorough experimental investigation was then carried out, considering separately the effects of the substrate permittivity and of the thickness of the feed line, of the foam thickness, of the size of the coupling slot and of the cover material. A number of interchangeable antenna elements were designed and fabricated, using the CAD/CAM program MICROS 6 [5]. Since the various parameters interact, the determination of the best choice is a long and tedious process (it is hoped that a computer program for the simulation of the structure will soon become available, so that the optimization process can be sped up). The "best" antenna designed so far (fig. 2) has a 13.2% frequency bandwidth for a 2:1 VSWR, i.e. slightly larger than the one described previously in [4].

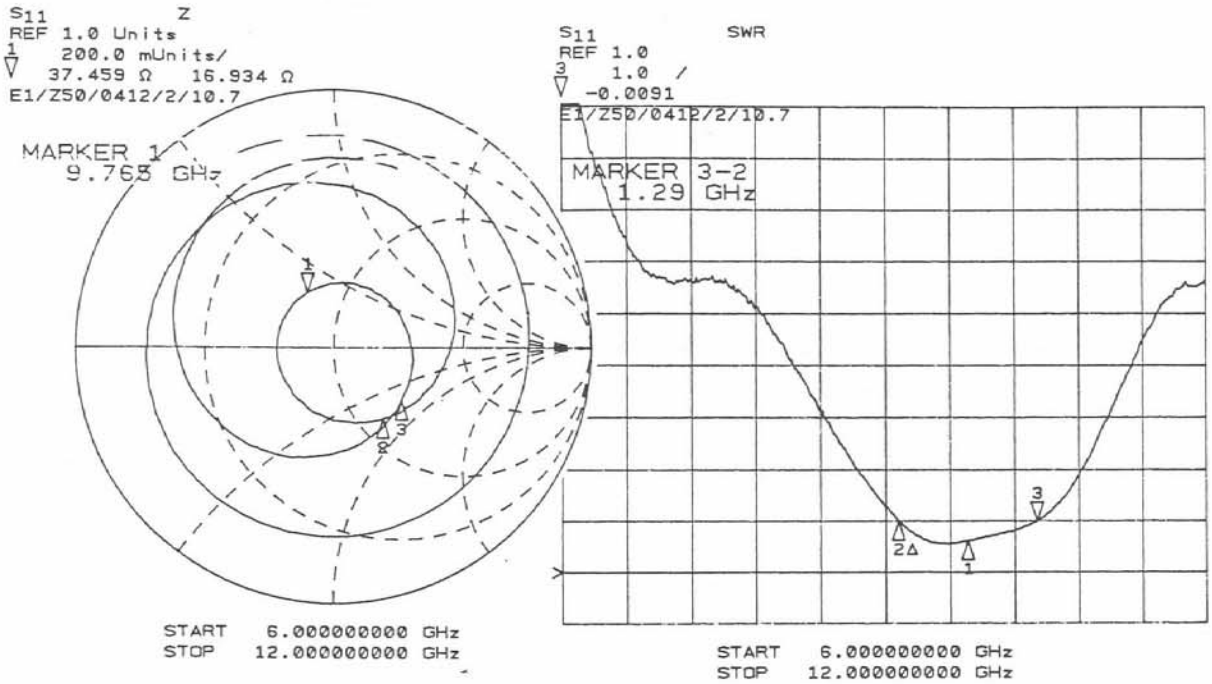

Fig. 2 Input impedance (Smith chart) and VSWR of a single element SSFIP antenna

The microstrip feed line is deposited on a substrate of relative permittivity of $\varepsilon_r = 2.33$ and thickness 0.51 mm, the slot dimensions are 12 x 0.4 mm, the foam is 2 mm thick and the radiating patch is 10.7x10.7 mm, on a 0.1 mm epoxy sheet.

3. ANTENNA WITH TWO STACKED PATCHES

The changes in parameters observed in the previous section were rather small, i.e. at this point it does not appear that the bandwidth of a single element SSFIP could be significantly increased, for instance above 15%. Further increases would require the addition of elements. Other authors have shown that the bandwidth of a standard patch antenna could be significantly increased by placing a second radiating element over the first one [6]. This approach was investigated with the SSFIP, making use of the interchangeable antenna elements developed for the experimental investigation.

As compared to the structure depicted in Fig. 1, the stacked SSFIP antenna comprises an additional layer of foam, above the cover of the first patch, and a second patch with its cover, placed on top of the second foam layer. The effects of the upper and lower patch sizes were found to be predominant, the largest bandwidth increase corresponding to a lower patch larger than the upper one. In all cases considered, the microstrip feed line was deposited on a substrate of relative permittivity $\varepsilon_r = 2.33$ and thickness 0.51 mm, the slot size is 10 x 0.4 mm , the foam is 1 mm thick and square patches are on a 0.1 mm epoxy sheet. The largest frequency bandwidth obtained was 33% for a 2:1 VSWR, for the case shown in fig. 3. It is apparent, from the the Smith chart, that the presence of a second loop, produced by the presence of two coupled resonators, is the cause of the large increase in bandwidth observed.

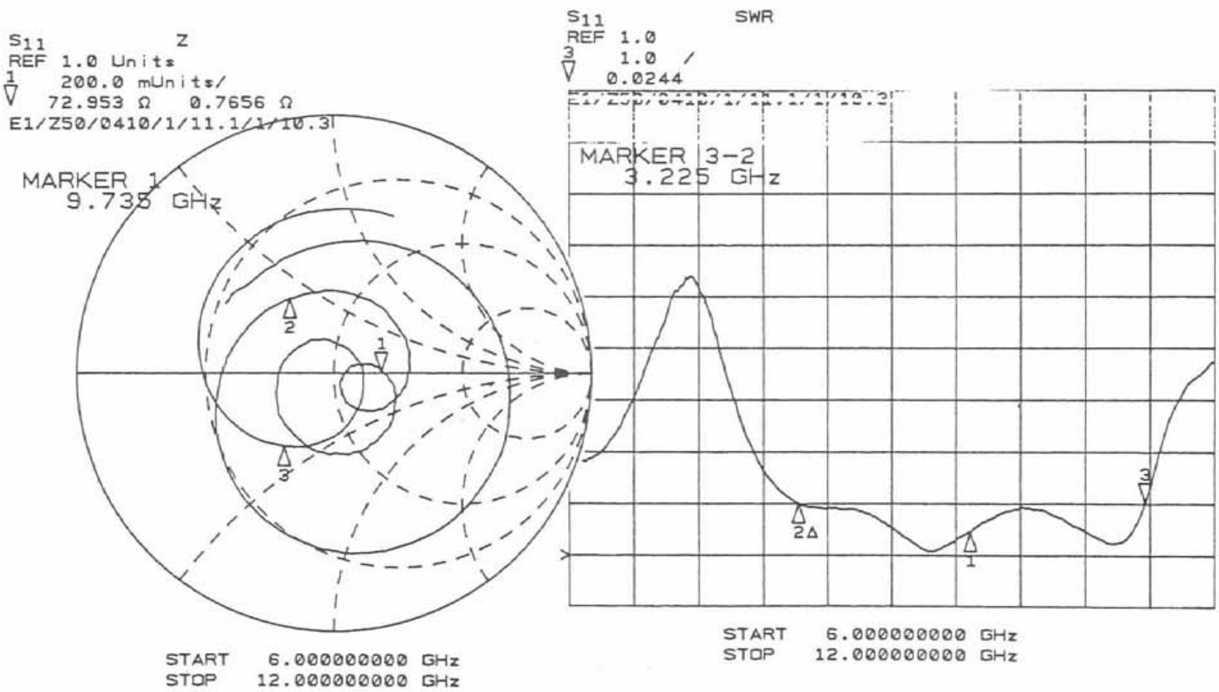

Fig. 3 Input impedance (Smith chart) and VSWR of a stacked SSFIP antenna

It must be noted that the thickness of each one of the two foam layers used for the stack antenna (fig. 3) is 1 mm, whereas the one of the single foam layer of the single antenna (fig. 2) is 2 mm. This means that the increase in bandwidth results exclusively from the addition of a second resonator. The overall thickness of the stacked antenna is practically identical to the one of the single patch one.

4. ANTENNA ARRAY

A 16 element broadside antenna array (4 x 4) with a corporate feed network was designed using broadband single element SSFIP radiators, to replace a standard X-band horn antenna. An antenna gain of 16-17 dB was obtained over the range 8-10 GHz, with a VSWR smaller than 2.5 over that range. A 1.9 GHz range was obtained (21.1%) for a VSWR under 2. A more detailed description of the array and of its performance is given elsewhere [4]. SSFIP arrays were not yet realized with stacked patches.

5. CONCLUSION

The **SSFIP** concept (**S**trip - **S**lot - **F**oam - **I**nverted **P**atch) optimizes both the electrical and the mechanical characteristics of planar antennas, and additionnally incorporates a protective radome. The performance obtained indicates that SSFIP antennas could advantageously replace other types of antennas in many applications. They exhibit high gain, a very large bandwidth (for a printed antenna), excellent mechanical characteristics, very low weight and low price. All the components are designed by the photolithographic process, i.e. there is no need to drill holes through substrates and ground planes to connect shorting pins or coaxial lines.

So far, SSFIP antennas were developed experimentally, which makes the selection of the "optimal" structure rather difficult and time consuming, because many parameters contribute to their overall performance. Accurate theoretical tools are presently being developed for their design, that will permit to simulate the behaviour of such antennas on a computer.

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