A Symmetrically Fed Aperture-Coupled Stacked-Patch Antenna

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Introduction

UWB radio is a recent field of research which gains more and more popularity, especially for medical applications. Antennas are the backbone of every wireless communication and radar system. However, in the UWB case antennas have to perform over an extremely large bandwidth and thus need to be designed in non-common ways. The aperture-coupled stacked-patch antenna (ASPA) is one well-known approach to achieve the desired wide bandwidth [1] and has already been applied to an UWB breast cancer imaging system [2,3]. Symmetrical feeding is preferred in order to integrate balanced monolithic circuits without the need of a lossy balun, resulting in a compact overall system. In [4,5] patch antennas are fed symmetrically connecting differential lines vertically with the patch. This method is not realizable in standard PCB technique and requires a difficult manual assembly. A similar approach is used in [6], where the patch is fed with two microstrip lines. However, only a narrowband antenna could be realized in such a manner. Another possible method is described in [7], where a single patch is fed with two sideways placed aperture-couplings. In this publication a different symmetrical feeding is presented. Instead of feeding the patch differentially, the slot itself is fed by a pair of microstrip lines with each line ending in an open stub. Furthermore, a passive balun needed for characterization is shown.

Design of the Antenna

Layer	ε_r	h / mm	Substrate
Feed	2.2	1.57	RT/Duroid 5880
Foam 1	1.07	2.6	Rohacell HF 31
Patch 1	2.2	3.18	RT/Duroid 5880
Foam 2	1.07	1.56	Rohacell HF 31
Patch 2	2.2	1.57	RT/Duroid 5880

Table 1: Substrate layers of the ASPA.

The antenna itself consists of a stack of different substrate layers (Table 1), fed by a rectangular slot based on [1]. The height of foam substrate as well as the dimensions of the two patches are optimized on the basis of iterative simulations with Microwave Studio [8], targeting at the European UWB norm (ECC) with a bandwidth from 6 GHz - 8.5 GHz [9]. In Table 2 the resulting dimensions of the patches and the slot aperture are displayed.

The electromagnetic behavior of the ASPA can be explained by three resonating elements, i.e. the two patches and the slot. The coupling between slot and the

w_1	l_1	w_2	l_2	w_s	l_s
12.35	20.8	11.05	20.8	1.51	17.68

Table 2: Patch and slot dimensions in mm.

lower patch and the interaction between the lower and the upper patch leads to the broadband behavior of the antenna. When the antenna's reflection coefficient is plotted in the Smith chart, two impedance loci represent these resonances. Variation of the parameters of one patch results in a complex change of the corresponding impedance locus. This mutual coupling between the resonating structures can be controlled changing the height of the foam layers.

The novel differential feeding is achieved via a pair of closely spaced microstrip lines terminated by two open stubs (see Fig. 1). Therewith, the excitation of the rectangular slot is achieved with a strong coupling. The impedance of the coupled microstrip lines in the odd mode is 100 Ω. The dimensions of the complete feeding structure can be found in Table 3.

Balun Transformer

Albeit the benefit of the differential feed is the avoidance of a balun, a balun is required for characterization purposes due to single-ended measurement equipment. Therefore, a balun based on a transition from microstrip to slot line is developed (see Fig. 1). The wide bandwidth is achieved using circular stubs for both the microstrip and the slot line. A coplanar strip line is obtained from the slot line with an exponential taper. A back-to-back version of this balun including the addition of a ground plane was built and measured. This measurement showed a matching performance better than 10 dB in the frequency range from 3 GHz to 11 GHz and an insertion loss of less than 4 dB in this frequency band and less than 2.5 dB from 2 GHz to 9 GHz. The insertion loss increases with frequency due to a parasitic radiation of the structure. A shielding is necessary for the antenna characterization in order to suppress this radiation. The group delay variation of the balun is lower than 60 ps, making it suitable for impulse based UWB systems. In Fig. 1, the balun and the feeding structure are shown, and Table 3 lists all dimensions according to Fig. 1.

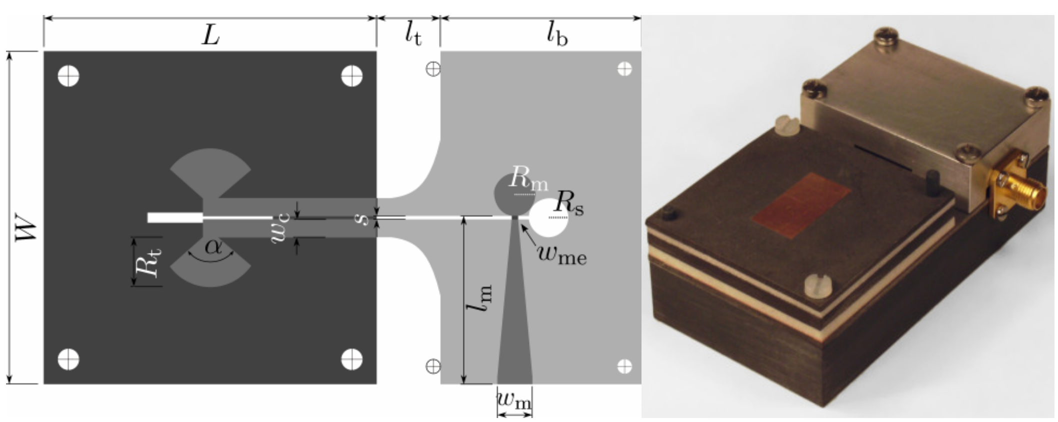

Fig. 1: Sketch of the differential feed including balun (left), and photograph of the manufactured antenna (right).

L	W	l_t	l_b	w_m	w_{me}	l_m	R_m	R_s	s	w_c	R_t	α
47	47	9	28.5	4.94	0.88	23.78	3.15	2.8	0.5	2.5	4.5	110

Tab. 3: Dimensions of the antenna backside, feeding structure and balun in mm/°.

Characterization of the Antenna

As shown in Fig. 3, the antenna (including balun) shows a good matching performance with a 10 dB bandwidth of 4.7 GHz, neglecting the small rises at 5 GHz and 8 GHz. This leads to a relative bandwidth of 70 %, which is a similar compared to [1], but achieved with a symmetrical feed.

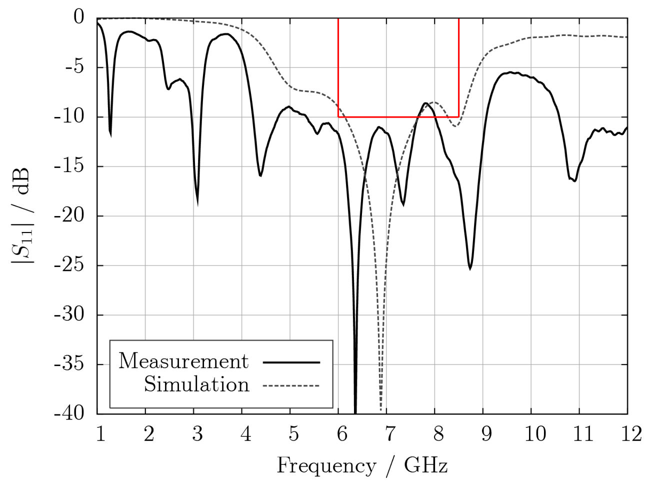

Fig. 2: Matching performance of the stacked patch antenna including balun.

The radiation patterns of the antenna are measured in an anechoic chamber. Fig. 4 and Fig. 5 show the measured results for the E-plane and the H-plane in comparison with the simulated results. As can be seen, the diagrams agree very well. The aforementioned metallic housing, shielding the balun, shadows the antenna, and thus an asymmetry can be seen in the measurement in Fig. 5. The measured maximum gain of the antenna is 9.7 dBi.

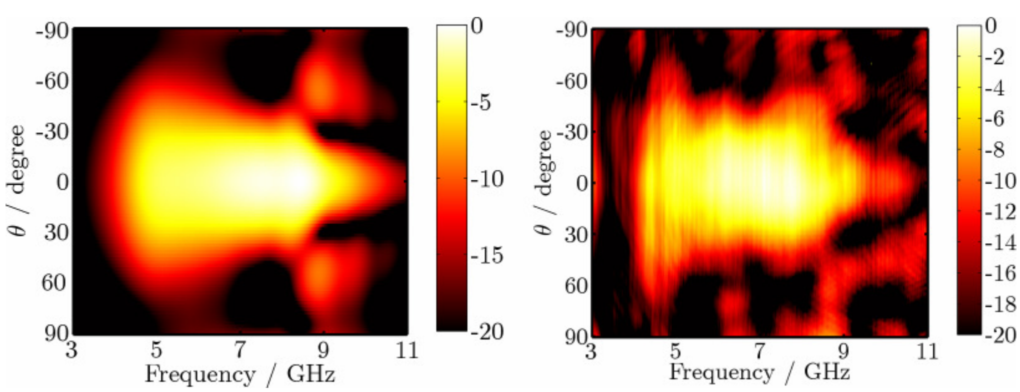

Fig. 4: Simulated (left) and measured (right) radiation pattern (E-plane).

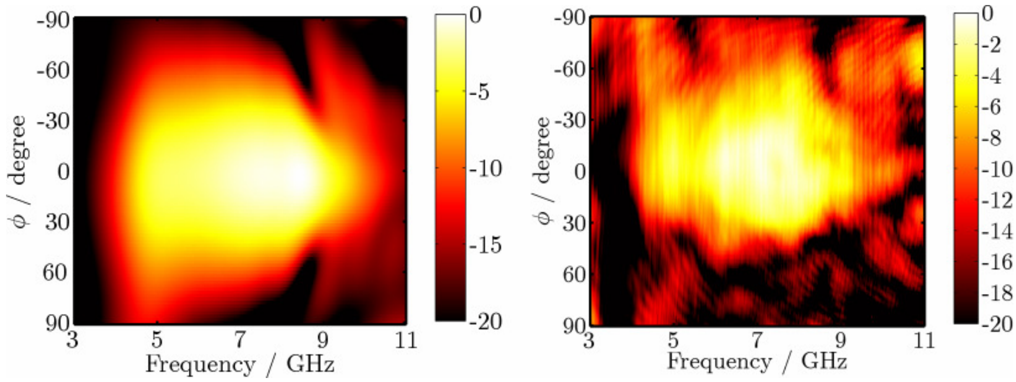

Fig. 5: Simulated (left) and measured (right) radiation pattern (H-plane).

Conclusion

Although the proposed antenna does not completely fulfill the10 dB matching requirement of the ECC UWB band entirely, it qualifies itself as a good candidate for UWB applications requiring radiation to one side only. The antenna's high gain makes it suitable for directional radio systems, e.g. in the medical field for communication with a pacemaker implant. For this purpose, further investigations have to focus on downsizing the whole antenna structure as well as on optimizations for radiating into human body tissue.

Acknowledgement

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