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A Wideband Series Fed Patch Array with Side Lobe Level Control

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Abstract

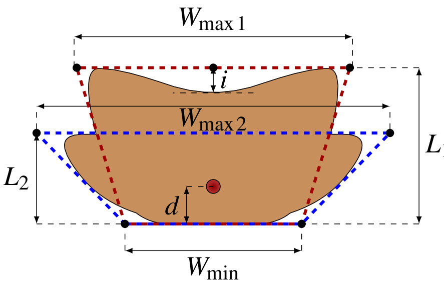
In this paper a novel series fed patch array for healthcare radar monitoring applications has been proposed. The antenna is composed of six patches and works in the 5.8 GHz Industrial, Scientific and Medical (ISM) band. The shape of the single patch has been designed to overcome two important limitations of this antenna topology: narrow bandwidth and high Side Lobe Level (SLL). To enhance the bandwidth, a dual band structure, obtained by the superposition of two tapered patches with different lengths has been used. For the SLL an innovative technique has been proposed. The amount of power radiated by each patch of the array and one transferred to the following radiating elements are controlled by the curvature degree of the upper hedge of the patch. The designed antenna has a fractional bandwidth of 5.92% (more than twice the available one at 5.8 GHz) and a SLL of −21.6 dB at the central frequency. Both the reflection coefficient and the radiation pattern at 5.8 GHz have been measured showing a really good agreement with simulation results.

1 Introduction

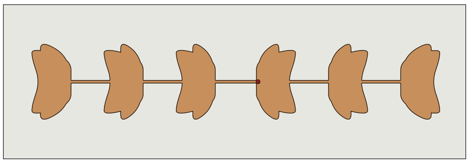
Given the steady increase in the average age of the world population, novel health monitoring technologies have been investigated in the last decades. Radar sensors represent a promising solution for long-term home care monitoring, being able to estimate the patient position and measure its respiratory rate and heartbeat completely contactless [1, 2]. For this kind of applications, Frequency Modulated Continuous Wave (FMCW) radars have shown several advantages compared to other radar technologies, such as Continuous Wave (CW) and Ultra Wideband (UWB), in terms of complexity reduction of the system. With FMCW radars, the vital signs information can be extracted with an algorithm based on the phase of the received and preprocessed signal [3]. For this reason it makes sense to develop radar systems working at frequencies with a wavelength comparable to the breast excursion during the respiration activity (of around 1.5 cm [4]). The Industrial, Scientific and Medical (ISM) band centred at 5.8 GHz then represents a good candidate for this kind of systems. Regarding instead the position estimation, given that the radar resolution is inversely proportional to the bandwidth [5], it is fundamental to design antennas that have a band equal or larger than the available one. However, the fractional bandwidth available at 5.8 GHz is of about 2.6%, a value hard to cover with conventional series fed arrays. Possible solutions are stacked structures or hybrid configuration involving series-corporate feed techniques [6, 7]. Nevertheless, these approaches increase the system complexity and the area occupation. In this paper, instead, a study based on the patch shape only to increase the bandwidth has been carried out. As another fundamental parameter for antenna design the Side Lobe Level (SLL) has been taken into account and an alternative method to the patch amplitude tapering has been proposed. In section 2 the patch shape is described. In section 3 and in section 4 the bandwidth enhancement and the technique for SLL control are presented, respectively. In section 5 measurements results are shown and in section 6 conclusions are drawn.

2 Geometry

The proposed patch geometry and the complete antenna are reported in Figure 1a. The single antenna element is given by the superposition of two tapered patches. The



(a)



(b)

Figure 1. Geometry of (a) the proposed patch geometry and (b) the designed antenna.

Table 1. Geometry parameters.

Parameter	Dimension (mm)
W_{min}	16.7
W_{max1}	25
W_{max2}	30.7
L_1	14.6
L_2	7.15
i	3.6
w_{line}	1
l_{line}	14.34

shape of the two patches is obtained by spline interpolation respectively within the red and the blue polygons of Figure 1a. A resonant frequency is associated to each patch, according to its lengths (L_1 or L_2). To widen the bandwidth of the single resonance, the width of the two patches is tapered and variates from $W_{\min}$ to $W_{\max 1}$ or to $W_{\max 2}$. The parameter i controls instead the amount of energy transferred by each radiating element to the following one. The array has been designed to be fed with a coaxial cable, with the central pin directly connected with one of the two central patches (red point in Figure 1b). The input impedance of the antenna depends on the number of patches and is more finely controlled by the distance of the feeding point from the patch edge along its symmetry axis. The antenna has been designed on a substrate of Rogers RO4003C [8] 1.542 mm thick. The parameters of the designed antenna are listed in table 1. The values w_{line} and l_{line} refer to the interconnecting microstrip lines width and length, respectively.

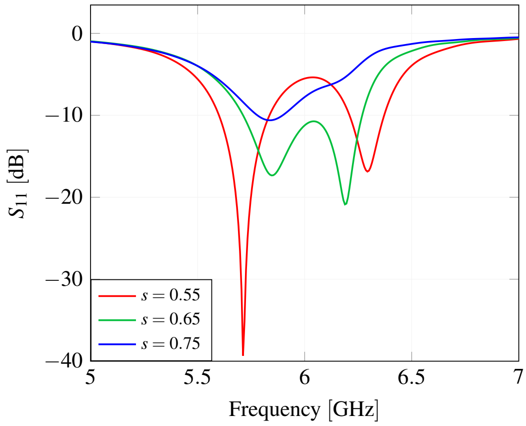


Figure 2. Effect of the superposition degree s on the bandwidth enhancement.

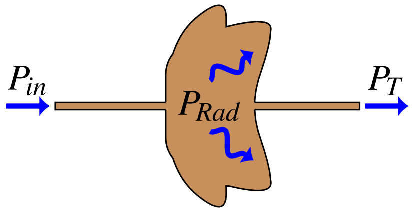


Figure 3. Power distribution along the array.

3 Bandwidth Enhancement

The bandwidth enhancement can be obtained thanks to the dual band nature of the antenna. The two resonances are determined by the values of the lengths L_1 and L_2, characterising each patch. Varying the ratio $s = L_2/L_1$ the two resonances can be separated or approached (see Figure 2). An opportune value of s (0.65 in Figure 2) assures a partial fusion of the resonances and then an increase of the antenna bandwidth. Furthermore, the width tapering of both the patches constituting the elementary array element, further widen the bandwidth of each resonance.

4 SLL Control

For the SLL, a method alternative to the amplitude tapering of the patches has been applied. In series fed arrays, neglecting the losses, a fraction of the input power P_{in}, received directly from the feed or from a previous patch, is radiated (P_{Rad}), while the remaining one P_{T} is transmitted to the following elements (see Figure 3). In the proposed antenna the fraction of transmitted power

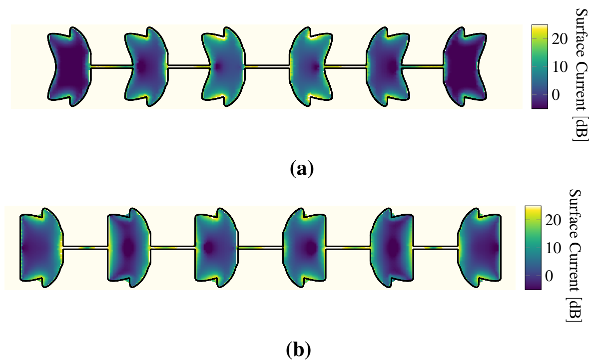


Figure 4. Surface current distribution of (a) the designed antenna and (b) of the same antenna with $i = 0\,\mathrm{mm}$.

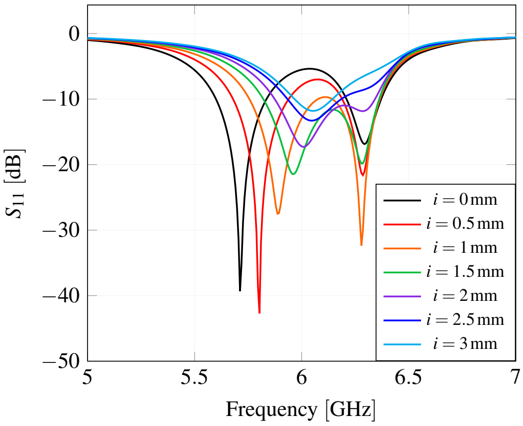


Figure 5. Effect of the indent degree on the resonant frequency.

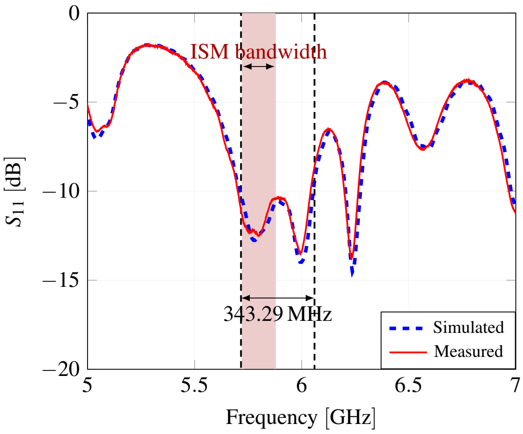


Figure 6. Simulated and measured reflection coefficient of the designed array.

is controlled by the indent degree i: with higher values of i P_{Rad} is increased and P_{T} reduced. Feeding the array from the center and choosing an opportune value of i, a current distribution giving rise to a stronger radiation from the central patches and a lower one from the most external elements can be established. Figure 4 shows the absolute value of the surface current for the designed antenna with $i = 3.6\,\mathrm{mm}$ (a) and for the same array with $i = 0\,\mathrm{mm}$ (b). In Figure 4a the surface current is higher in the two central patches and degrades towards the extremity, while in Figure 4b the current distribution is almost invariant along the whole antenna. Looking at Figure 4, it is also possible to notice that, with the proposed technique, increasing performance incidentally decreases the overall length of the antenna. The entity of the antenna length reduction is directly related with the number of patches. In addition, with this method, an array of identical radiating elements, with an appropriate indent degree i, can achieve a complete SLL control. This is in stark contrast with amplitude tapering techniques that require each patch of the array to have different geometrical parameters. It is worth noting that the parameter i does not only act on the power distribution, but modifies also the length L_1. Figure 5 shows that, if i increases L_1 decreases, determining then an increase of the corresponding resonant frequency. For the antenna design both the effects of s and i must be taken into account contextually to obtain the desired bandwidth and SLL.

5 Realisation and Measurement Results

A prototype of the antenna has been realised with a computer numerical control Milling Machine. Figure 6 shows the simulated and measured reflection coefficient of the designed array. The S_{11} is less than $-10\,\mathrm{dB}$ for about 343 MHz, more than the double of the ISM available bandwidth. A really good agreement can be noticed between measurements and simulations. Figure 7 reports the radiation pattern at the central frequency (5.8 GHz) for both the E and H planes. With the chosen value of i, the resulting gain is of about 14 dB and the SLL is −21.6 dB. Also for the radiation pattern in both planes measurements and simulations are in good

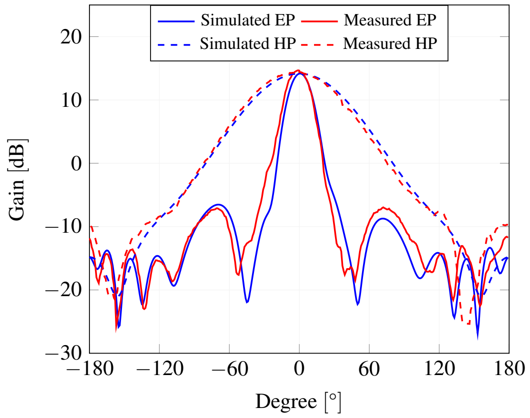


Figure 7. Simulated and measured farfield at 5.8 GHz in the E plane (EP) and H plane (HP).

agreement.

6 Conclusions

In this paper a novel series fed patch array working in the 5.8 GHz ISM band for healthcare monitoring applications has been proposed. The patch shape has been studied to widen the bandwidth, typically narrow for standard rectangular patch arrays. The enhancement of the bandwidth has been achieved with a dual band structure, obtained by the superposition of two tapered patches with different lengths. A new technique for the SLL control has been presented. With the only variation of the curvature degree of the upper hedge of the patch, associated to the indent degree i, the power radiated and the one transferred by a patch to the following one can be modulated. With the proposed solution an array with identical patches, with the feed connected to one of the central elements, will give raise to a stronger radiation from the central patches and a lower one from the most external ones. A six patch array has been designed and realised with a computer numerical control Milling Machine. The antenna has a fractional bandwidth of 5.92% and a SLL of −21.6 dB at 5.8 GHz. The reflection coefficient and the radiation pattern at the central frequency (5.8 GHz) have been measured showing a really good agreement between simulation results and measurements.

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