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A 8×1 Sprout-Shaped Antenna Array with Low Sidelobe Level of -25 dB

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Abstract

This paper proposes a 8 × 1 sprout-shaped antenna array with low sidelobe level (SLL) for outdoor point to point applications. The array has the dimensions of 165 mm × 195 mm × 1.575 mm and is designed on Rogers RT/Duroid 5870tm with the thickness of 1.575 mm and permittivity of 2.33. In order to achieve low SLL, Chebyshev distribution weights corresponding to SLL preset at -30 dB has been applied to design the feed of the array. Unequal T-junction dividers have been used to ensure that the output powers are proportional to the Chebyshev amplitude distribution. A reflector has been added to the back of the antenna to improve the directivity. The simulated results show that the proposed array can work at 4.95 GHz with the bandwidth of 185 MHz. Moreover, it can provide the gain up to 12.9 dBi and SLL suppressed to -25 dB. A prototype has also been fabricated and measured. A good agreement between simulation and measurement has been obtained. It is proved that the array can be a good candidate for point to point communications.

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Keywords: Linear microstrip antenna array, Chebyshev distribution, Low sidelobe.

1. Introduction

Outdoor point to point access points often require high gain antenna to enhance the coverage and signal quality [1]. Moreover, modern wireless systems, nowadays, are often equipped with microstrip antennas which have benefits of low profile, light weight and easy integration. In order to get high gain, microstrip arrays have been employed, but conventional ones will generate high SLL which wastes energy in undesired directions and gets interferences to the systems. Therefore, due to the abilities of minimization of interferences and saving the energy radiated in undesired direction, low SLL arrays has captured great attention from designers and researchers worldwide. Nevertheless, microstrip antenna arrays have faced the difficulty of gaining low SLL as being affected by the spurious radiation form the feeding network. Thus, in order to achieve relative SLL of 20 dB or below, the feeding network should not be on the same substrate face with the radiation patch [2]. It means that the low SLL microstrip antenna arrays must have at least two layers to distinguish the radiation element and the feeding network. This makes the antennas more complicated to manufacture, and larger in size.

To gain low SLL in microstrip antenna arrays, the feeding network can be designed to get the output signals in accordance with the amplitude distribution. There are some common amplitude weighting methods, for example Binomial, Chebyshev, and Taylor [3]. Of three

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methods, Chebyshev arrays are preferable due to having optimum beamwidth for a specified SLL [3, 4]. Among three methods, Chebyshev arrays can provide better directivity with lower SLL [5].

In the literature, a number of low SLL linear microstrip arrays that applied Chebyshev amplitude distribution have been studied and introduced. In 1989, J. Wang and J. Litva introduced a new design for low sidelobe microstrip antenna array [6]. The antenna, which consists of 10 rectangular patches, can achieve -25 dB SLL. However, to minimize the effects of the feed on the radiation of the arrays, the feed is quite large. In [7], a microstrip linear antenna array with 5 elements, fed by Chebyshev amplitude weights and has been proposed. The array has a smaller size but can only get -17 dB of SLL. Another 5×1 linear array antenna with side lobe suppression has been proposed by Y. P. Saputra [8]. The antenna can only provide SLL around -20 dB at the frequency of 9.3 GHz. Several corporate feed arrays with low SLL has been designed and presented in [9, 10]. A. Nesic has introduced the design of printed antenna arrays with high side lobe suppression [9, 11]. The array with 8 double side printed dipoles can achieve a high gain of 20 dB with SLL of -34 dB. However, to increase the gain, corner reflector consisting of two metal plates has been added, and this makes the antenna bigger and more complicated to fabricate. The authors in [10] presented the design of a low sidelobe collinear antenna array with 8 printed dipole elements. This array can achieve -25 dB SLL and gain of around 15 dB. However, the array has 3D structure so that it is also difficult to fabricate. Another 8×1 aperture coupled patch linear array has been proposed in [12]. Although having 3 layers to distinguish the radiation patch and the feed, the array can only acquire about -18 dB SLL.

In order to diminish the spurious radiation from the feeding network, some researches about series feed arrays have been done [13, 14]. In [13], an aperture coupled microstrip antenna array with low cross-polarization, low SLL and backlobe has been given. The array was designed with a good matched feeding network and can offer low SLL of -20.9 dB. The array consisting of 6 microstrip patches has been designed to suppress the sidelobes [15]. Though applying Chebyshev weights, this antenna can only get -16 dB sidelobe suppression. [16] presented a low SLL series fed dielectric resonator antenna (DRA) array with 22 elements. This antenna can achieve SLL of -30 dB, but it is impractical as it is really lengthy. W. Shen, J. Lin, and K. Yang have introduced two low SLL and wideband series feed linear DRA array in [17, 14]. The two antennas have the SLL of -23 dB and -27 dB, respectively. However, those proposals are difficult to fabricate due to the complex structure of the feeding network (2-3 layers) that may cause high fabrication tolerance.

In the authors' previous work, the analysis and procedure to design the feeding network using Chebyshev weighting method has been presented in [18]. This procedure has been used to build the feeding network of the array in this work.

In this work, we proposed a low SLL linear microstrip antenna array that has simple structure to fabricate using printed circuit board (PCB) technology. The array consists of 8 double-sided printed dipoles (DSDP). The Chebyshev amplitude weights (corresponding to SLL of -30 dB) has been used in designing the feeding network of the array to gain low SLL. The simulation results indicate that the antenna can operate at 4.95 GHz with bandwidth of 185 MHz. Moreover, the simulated gain and SLL are 12.9 dBi and -25 dB, respectively. A prototype has been fabricated and measured. Good agreement between simulation and measurement has been obtained. The detailed of the design will be presented in the next section.

2. Antennaarraydesign and construction

2.1. Single element

Possessing the advantages of small size and wide bandwidth outweigh other printed antennas, DSDP has been used as the single element to construct the array. The analysis and formulas to design this kind of element have been specifically demonstrated in authors' previous work [19]. The antenna has been designed on Rogers RT/Duroid 5870 tm using the formulas mentioned in [19]. The final single element has been optimized and shown in the Figure 1.

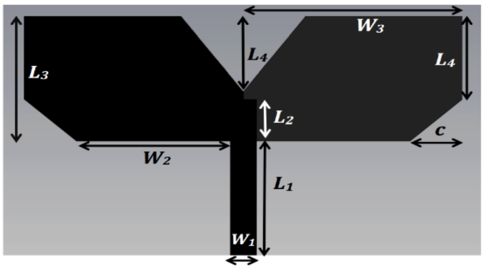


Figure 1. Proposed single element.

Table 1. Parameters of the single element (unit: mm)

Parameters	Value	Parameters	Value
w_1	*1.25*	L_1	*7*
w_2	*7.375*	L_2	*2.5*
w_3	*10.5*	L_3	*7.5*
c	*2.5*	L_4	*5*

2.2. Feeding network design

After having the single element, a feeding network has been designed. Chebyshev weights for SLL preset at -30 dB (as given Table 2) is used to gain low SLL. To design the feeding network with output signals being proportional to the Chebyshev weights, the unequal T-junction dividers has been used.

Table 2. Chebyshev amplitude weights for 8×1 linear array with the inter-element spacing = 0.5λ (SLL = -30 dB)

Element No. (n)	1	2	3	4	5	6	7	8
Normalized amplitude (u_n)	0.2622	0.5187	0.812	1	1	0.812	0.5187	0.2622
Amplitude distribution (dB)	-19.9	-13.98	-10.08	- 8.27	-8.27	-10.08	-13.98	-19.9

Figure 2 shows the final feeding network in this work.

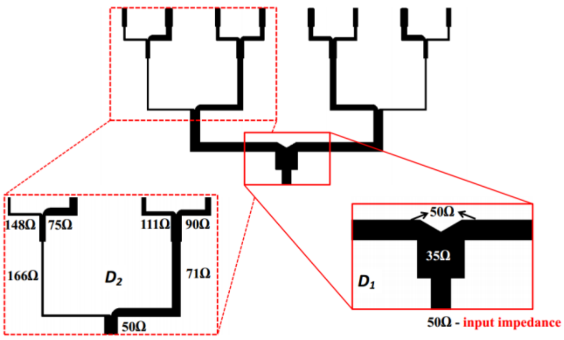


Figure 2. Proposed Chebyshev feeding network.

It is observed that the Chebyshev coefficients are symmetrical at the center. Therefore, with even number of elements, an equal T-junction power divider, D_1, has been designed to ensure that two sides are identical. The combination of dividers, D_2, is calculated and designed in order to match the first four weights of Chebyshev distribution. After that, the divider D_2 is mirrored at the center of the divider D_1 to get the full feeding network. Each port has been designed with uniform spacing to ensure that the output signals are in phase.

The array was constructed by combining the single element with the feeding network. A reflector which made of double sided copper cladding FR4 epoxy has been added at the back of the array to improve the directivity of the array. Figure 3 presents the final array with the Chebyshev distribution feeding network.

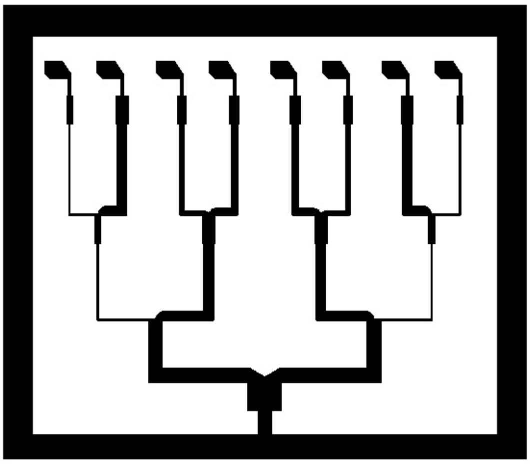


Figure 3. Proposed microstrip linear array.

3. Simulation, measurement and discussions

3.1. Simulation results

Figure 4 presents the simulation results of S-parameters of the array. It can be seen from the simulated result that the resonant frequency of the antenna is 4.95 GHz, and the bandwidth is 185 MHz.

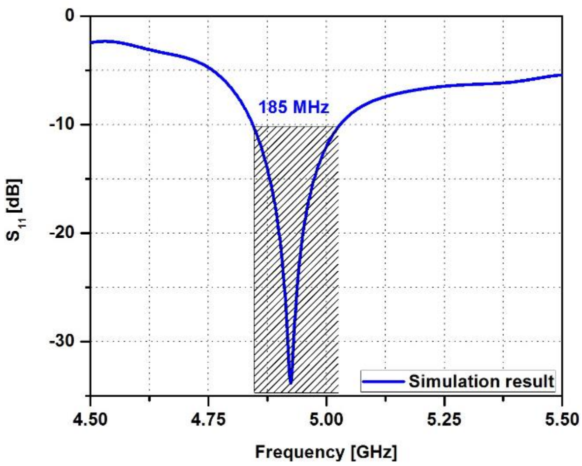


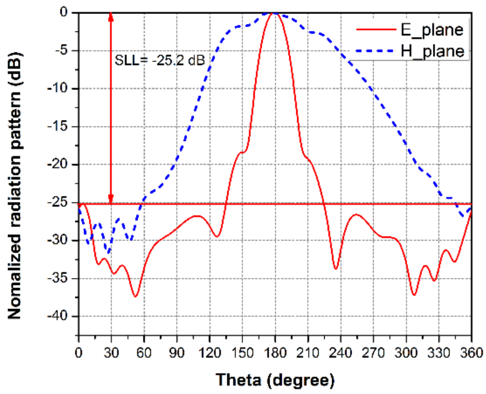
Figure 4. Simulated S_{11} of the array.

The simulation of the radiation pattern of the sprout-shaped antenna array in E and H planes and in 3D have been shown in the Figure 5. It is clear that the array can provide the gain of 12.9 dBi and the low SLL of -25.2 dB.

Table 3. Summary of simulation resultswidth=1tw

Parameters	Simulation data
Center frequency	4.95 GHz
Bandwidth at RL ≤ -10 dB	185 MHz
Gain	12.9 dBi
SLL	-25.2 dB

[Normalized radiation pattern of the array]



[Gain in 3D]

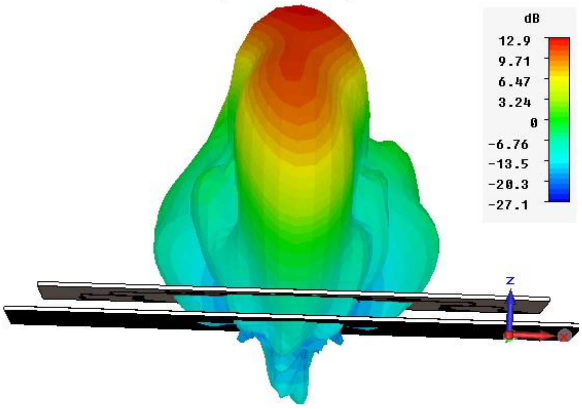


Figure 5. Radiation pattern of the sprout-shaped antenna array.

3.2. Measurement and discussion

A prototype has been fabricated to validate the simulation data. Figure 6 gives the fabricated sample. The sample has been then measured, and the measured data was compared with the simulation result as shown in Figure 7.

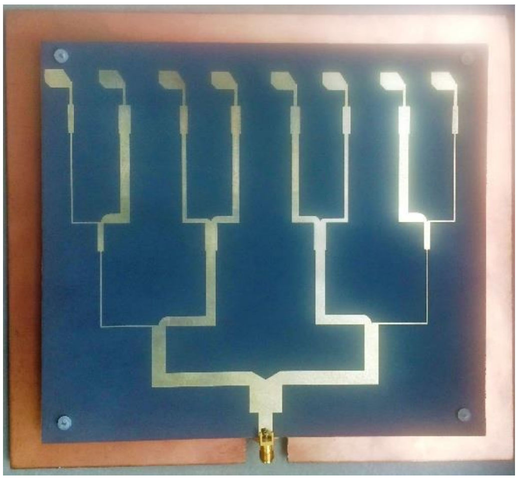


Figure 6. Array prototype.

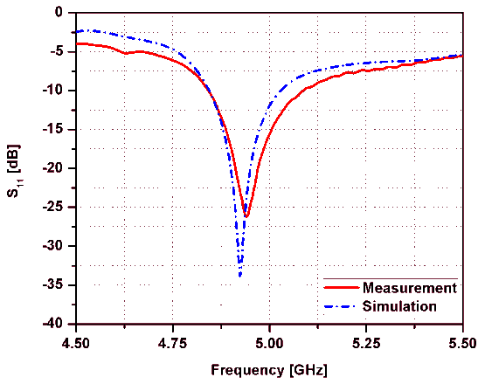


Figure 7. Comparison between simulated and measured S_{11}.

It is observed that a good agreement between measurement and simulation has been obtained. The simulated bandwidth of the array is about 185 MHz, while the counterpart in measurement is around 260 MHz. The resonant frequency is shifted a little bit due to the fabrication tolerance. However, it is still able to work well in the whole simulated bandwidth.

4. Conclusions

In this paper, a 8×1 sprout-shaped antenna array with low sidelobe level (SLL) for point to point applications has been proposed. The array has the dimensions of 165 mm × 195 mm × 1.575 mm and is designed on Rogers RT/Duroid 5870tm with the thickness of 1.575 mm and permittivity of 2.33. In order to achieve low SLL, Chebyshev distribution weights (preset sidelobe level of -30 dB) has been applied to the feed of the array. The simulated results show that the proposed array can provide the gain up to 12.9 dBi and SLL suppressed to -25 dB. A prototype has also been fabricated and measured. Good agreement between simulation and measurement has been obtained. It is proved that the array can be a good candidate for applications such as point to point communications, WLAN.

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