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An UWB Microstrip Antenna Array with Novel Corporate-Fed Structure

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Abstract—A novel feed network based on the microstrip/slotline transition is proposed in this paper. This feed network not only has ultra-wide impedance bandwidth but also can improve space utilization and make the design of antenna array easier. Then an ultra-wideband (UWB) antenna array with four elements fed by the network is designed. The antenna array is simulated, manufactured and measured. The results show that the impedance bandwidth with return loss under -10 dB is 88.76%, from 2.35 GHz to 6.1 GHz. Within the impedance bandwidth, the radiation performance is satisfactory, and the gain of the array is 2.1–7.1 dB, higher than that of the element. The cross-polarization level of the array is lower than -20 dB, just as the element. A reasonable agreement of results is achieved between simulation and measurement.

1. INTRODUCTION

With the rapid development of wireless UWB communication technology, UWB antenna has attracted much attention and shows its advantages. Recently, there have been many methods to achieve planar UWB antenna, such as the monopole, spiral antenna, tapered slot antenna, etc. However, sometimes we want to focus the power on a given direction or raise the gain according to the demands, which cannot be realized by a single antenna. Thus the study of the UWB antenna array is significant and necessary.

One of the key parts for the design of the UWB antenna array is the feed network. Now there are two kinds of microstrip antenna arrays according to the feed network, namely series-fed array and corporate-fed array [1, 2]. The series-fed array [3], formed by interconnecting the radiation elements with high-impedance microstrip line, is simple and has compact feed network, but is subject to beam squint with frequency, so it cannot be used in UWB antenna array design. As to the corporate-fed array [4–8], the elements are fed by a power divider with identical path lengths from the feed point to each element, which insures phase coherence and broadside array beam, but it experiences efficiency limitation especially in large arrays, where the feed lines are long and complicated.

In this paper, a novel corporate-fed network, which has advantages of series-fed network and corporate-fed network, is proposed firstly. Then a 2×2 microstrip antenna array is designed based on this feed network and planar monopole antenna. All the designs mentioned below are etched on a P4BM-2 substrate with relative permittivity $\varepsilon_r = 2.2$ and thickness $h = 1$ mm.

2. ANALYSIS OF THE FEED NETWORK

As verified [9], when the electrical length from the junction to the terminal of the microstrip/slotline transition is $\lambda_g/4$, and the microstrip line is perpendicular to the slot line, the transition coefficient is to the peak. The schematic diagram and equivalent circuit of this transition can be seen in Figure 1, which shows that the terminal of the microstrip and slotline is open and short respectively, so what on

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the sections from the junction to the terminal is standing wave. Thus, at the position of junction, the maximum current and minimum voltage are achieved on the microstrip section, while the opposite is true on the slotline section. Then the maximum transition coefficient is observed.

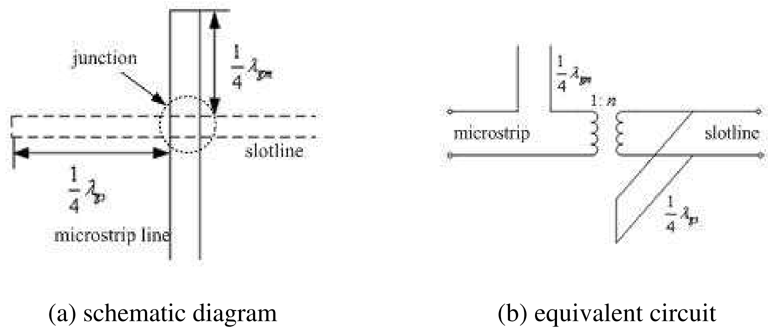


Figure 1. The microstrip/slotline transition.

Based on the theory of microstrip/slotline transition, a novel feed network is proposed. The structure of the network can be seen in Figure 2, which consists of three microstrip line sections on the signal plane and one slot line on the ground plane. The central microstrip is fed by probe. In order to insure identical length from the feed-probe to any terminal port, the structure is symmetrical. Here the fan-shaped terminals are adopted to expand the impedance bandwidth. When the four ports are matched approximately, what on the microstrip section between the port and junction 1 is propagating wave, and the same is true to the slotline section between junction 1 and junction 2, so the effects of changing L1 and L2 on the transition coefficient is negligible. The widths of the microstrip and the soltline are determined according to the input and output impedances conveniently.

Then the model of the network is designed and simulated with the software HFSS. Through simulating and optimizing, it is concluded that when the input and output ports are matched with the impedance of $50\,\Omega$, only if the width of the slotline is 0.4 mm, the maximum transition coefficient is achieved. The simulated results of the design are shown in Figure 3. For the paths from port 0 to the other four ports are identical, the magnitudes of the signal from the four output ports are the same. Here we just give the reflection coefficient S_{00} and transmission coefficient S_{10}. As shown in Figure 3, the impedance bandwidth with the reflection coefficient under -10 dB is 40%, from 3.6 GHz to 5.4 GHz, within which the minimum S_{10} is -7.4 dB. At the central frequency, 4.2 GHz, S_{10} is -6.9 dB, 0.9 dB smaller than the theoretical value -6 dB.

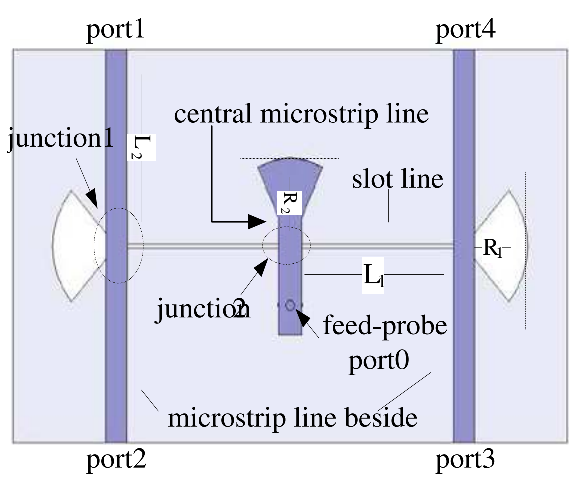


Figure 2. Structure of the feed network.

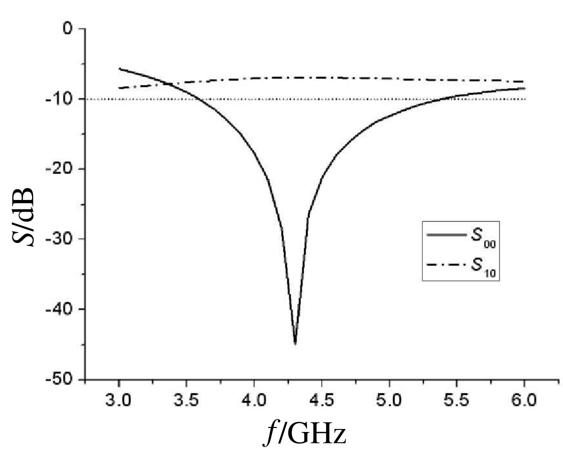


Figure 3. The reflection and transmission coefficient of the network.

Moreover, for the symmetrical structure of the network, the signal phases of port 1 and port 4 are consistent; the same is true to the signal phases of port 2 and port 3. The signal phases of port 1 and port 2 are opposite to each other, and the same is true to the phases of port 3 and port 4. These can be explained with the schematic diagram of electromagnetic field distribution in the sections of junction1 and junction 2 in Figure 4, which indicate that the output signal phases in the two sides of slotline-to-microstrip transition junction 1 are opposite, while in the two sides of microstrip-to-slotline transition junction 2, the output signal phases are identical. The simulated results of the model verify the theory, and the maximum phase imbalance is only 0.9°.

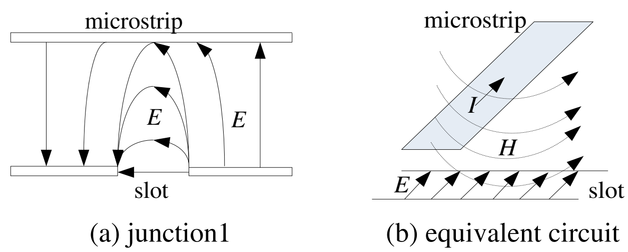


Figure 4. The electromagnetic field distribution in the sections of junctions.

3. DESIGN OF THE UWB ANTENNA ARRAY

The conventional planar monopole was chosen as the radiation element, for it has low profile and can be integrated with the feed network mentioned above. The dimensions of the monopole are computed based on the central frequency 4.2 GHz, which can be seen in Figure 5. Through optimizing with HFSS, we get that the impedance bandwidth of the monopole is 72.1% (2.75–5.85 GHz).

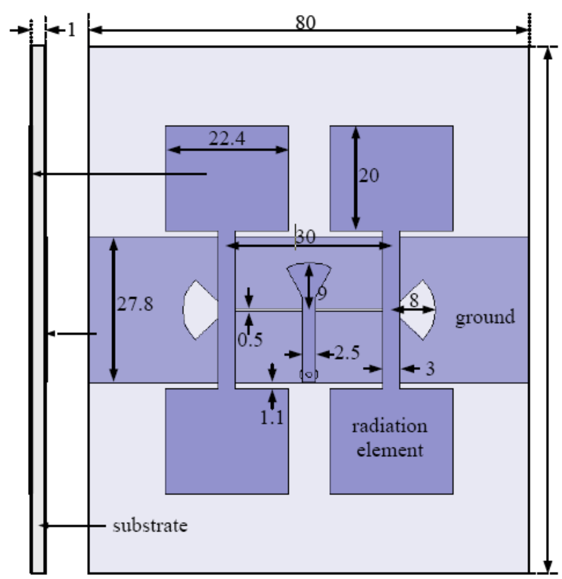
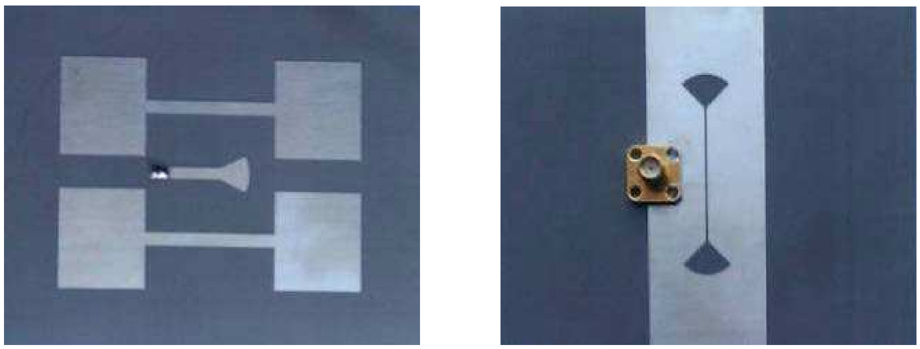


Figure 5. Structure of the antenna array (Units: mm).

Then a 2×2 antenna array is designed. Its structure and optimized dimensions can be seen in Figure 5. The widths of the microstrip and slotline of the network are determined according to the input impedance of the monopole and the probe. The spacing between elements is determined according to both of the radiation performance and electromagnetic coupling among elements. For the network's character of the terminals' signal phases, the four radiation elements are fed with the coincident signal phases.

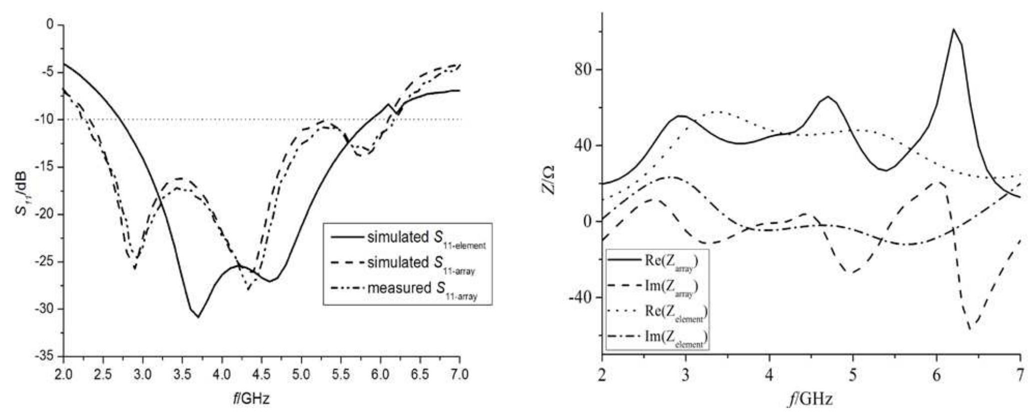
4. SIMULATED AND MEASURED RESULTS

The UWB antenna array is fabricated and measured with reflection coefficients through a N5230C vector network analyzer. A photograph of the fabricated prototypes is shown in Figure 6. The reflection coefficients and input impedance of the monopole and the array are shown in Figure 7. A desirable agreement of results between simulation and measurement is observed. The impedance bandwidth with the return loss under −10 dB is 88.76%, from 2.35 GHz to 6.1 GHz, which is wider than that of the network and the monopole element due to the electromagnetic coupling between elements.



(a) Radiation plane (b) Ground plane

Figure 6. Photograph of fabricated antenna.



(a) The reflection coefficients (b) The input impedance

Figure 7. The reflection coefficients and input impedance of the antenna array and element.

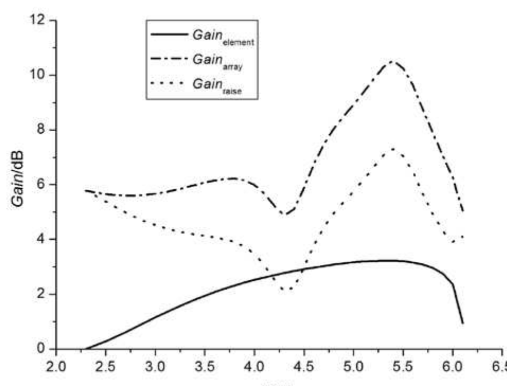


Figure 8. The gain of the UWB array and the element.

The radiation performances of the array and element (for comparison) can be seen in Figure 8 and Figure 9. In Figure 8, the gain curves with frequency are shown. The gain of the array is more than 4 dB higher than that of the element except at the frequencies around the center, for they are more sensitive to the electromagnetic coupling among elements. The loss is attributed to the mismatch loss, radiation of the slotline and calibration errors.

The radiation pattern and directivity of the array and element at different frequencies can be seen in Figure 9. They verify that the directivity will be improved and that the gain will be raised obviously after the antenna array is made with the monopole. Following Figure 9, we can see that the beams are quite consistent in substance whereas the beams of series-fed array can be subject to squint with frequency. This novel corporate-fed network makes the array obtain higher efficiency than the conventional corporate-fed array whose power divider will increase loss.

Because of the spacing between elements is too wide for high frequencies, the side-lobes appear at high frequencies as shown in Figure 9(d). For a reasonable agreement of results between measurement and simulation in Figure 8, the measured results are omitted for brevity in Figure 9. The cross polarization of the array is very low and maintains below −20 dB, just as the element.

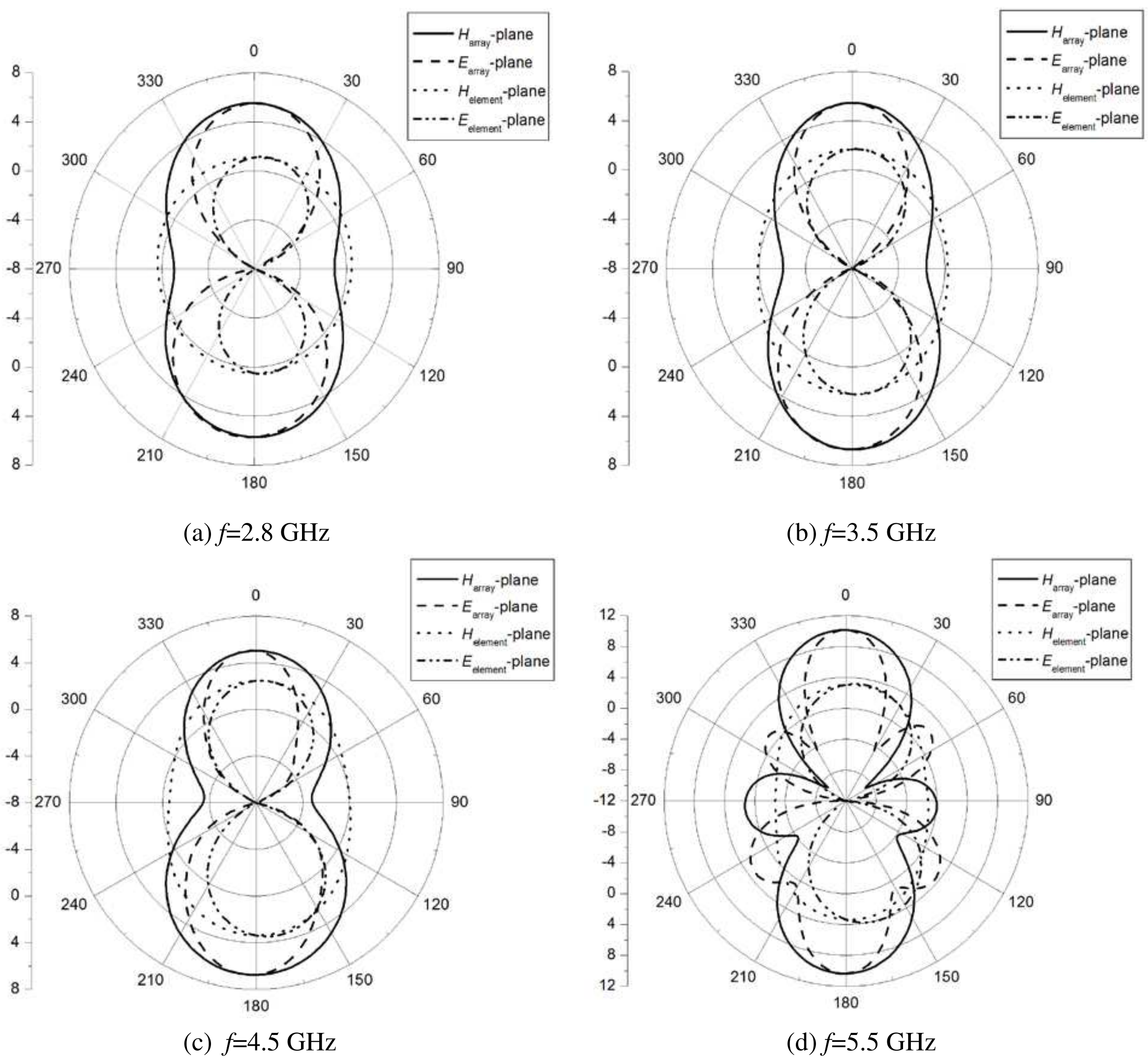


Figure 9. The radiation pattern of the array and the element.

5. CONCLUSION

In this paper, a novel corporate-fed network based on microstrip/slotline transition is investigated in the design of UWB planar antenna array. This novel feed network has advantages of low profile, high efficiency, and ultra-wideband. For comprehensive study, the UWB antenna array is designed, fabricated and measured. Numerical and experimental results both confirm that the impedance bandwidth with a return loss under -10 dB is 88.76%, from 2.35 GHz to 6.1 GHz. Within the bandwidth, the radiation performance is satisfactory. According to ultra-wideband and low cross-polarization of this array, it can be concluded that this array can be used as the subarray to extend into a much larger array with the same feed network conveniently. It is known that when the main beam is scanned the S_{11} is affected considerably. The antenna array has ultra-wideband, so the performance may not been deteriorated seriously for scanning purposes. With the rapid development of UWB radar technology, the time-domain antenna has attracted much more attention. So the time-domain antenna array has a wide application prospect for it can improve the performance of antenna in UWB impulse radar system. The time-domain antenna array will be investigated in our future works.

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