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Low sidelobe wideband series fed double dipole microstrip antenna array

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Abstract: A linear endfire wideband series fed double-dipole antenna array with low sidelobe level, SLL, and high front to back ratio, F/B, is proposed. The array can provide −27 dB SLL at centre frequency of 16.26 GHz, 20 dB SLL bandwidth of 9.2%, 22 dB F/B and 14.6% impedance bandwidth. By extending, in between the array elements, comb like linear tapered narrow strips from the finite ground plane of the structure, SLL of the basic array improves to −32 dB, the 20 dB SLL bandwidth become 12.1% while the F/B and impedance bandwidth remains the same as before. To verify the accuracy of the simulation results, both of the arrays are fabricated and tested.

Keywords: endfire, series fed, low sidelobe, wideband, microstrip array

Classification: Microwave and millimeter wave devices, circuits, and systems

References

[1] D. M. Pozar and B. Kaufman, "Design considerations for low sidelobe microstrip arrays," *IEEE Trans. Antennas Propag.*, vol. 38, no. 8, pp. 1176–1185, Aug. 1990.

[2] D. M. Pozar and D. H. Schaubert, "Comparison of three series fed microstrip array geometries," *Proc. IEEE AP-S Int. Symp.*, vol. 2, pp. 728–731, 1993.

[3] G. Gronau, H. Moschuring, and I. Wolf, "Microstrip antenna arrays fed from the backside of the substrate," *Proc. Int. Symp., Antennas Propag.*, Kyoto, Japan, 1985.

[4] D. M. Pozar, "A microstrip antenna aperture coupled to a microstrip line," *Electron. Lett.*, vol. 21, pp. 49–50, June 1985.

[5] Y. Kimura, *et al.*, "76 GHz alternating-phase fed single-Layer slotted waveguide arrays with suppressed sidelobes in the *E*-plane," *IEEE Trans. AP-S Dig.*, vol. 41, pp. 1042–1045, June 2003.

[6] S. D. Targonski, R. B. Waterhouse, and D. M. Pozar, "A wideband aperture coupled stacked patch antenna using thick substrates," *Electron. Lett.*, vol. 32, pp. 1941–1942, Oct. 1996.

[7] S. Oh, S. Seo, M. Yoon, C. Oh, E. Kim, and Y. Kim, "A broadband microstrip antenna array for LMDS applications," *Microw. Opt. Lett.*, vol. 32, no. 1, pp. 35–37, Jan. 2002.

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Published October 25, 2009

[8] T.-H. Chio and D. H. Schaubert, "Parameter study and design of wideband widescan dual-polarized tapered slot antenna arrays," *IEEE Trans. Antennas Propag.*, vol. 48, no. 6, pp. 879–886, June 2000.
[9] N. Kaneda, W. Deal, Y. Qian, R. Waterhouse, and T. Itoh, "A broad-band planar quasi-Yagi antenna," *IEEE Trans. Antennas Propag.*, vol. 50, no. 8, pp. 1158–1160, Aug. 2002.
[10] J. R. James and P. S. Hall, *Handbook of microstrip antennas*, Peter Peregrinus Ltd., London, United Kingdom, pp. 645–665, 1989.

1 Introduction

Light weight, small size, low cost, high efficiency, ease of fabrication and installation make printed antenna arrays ideal solution for use in radar microwave and millimeter systems [1].

In radar systems parameters such as sidelobe level, SLL, front to back ratio, F/B, [1] and bandwidth are of high importance. Depending on the radar system SLL in between −20 to −50 dB is usually required. With conventional printed antennas, realization of arrays with lower SLL than −25 dB becomes increasingly difficult mainly due to: mutual coupling between radiating elements; surface wave effect; parasitic radiation from a feeding network; and tolerances in fabrication [1].

There are usually two types of arrays in microstrip structures, the corporate fed and the series fed both of which are inherently narrow in bandwidth. The discontinuities, bends, power dividers, and other components in the corporate fed array cause spurious radiation that limits the minimum SLL achievable [1]. The structure of a series fed array is such that it uses shorter line length in comparison with corporate fed arrays and this leads to an antenna with less space on substrate, lower attenuation loss and spurious radiation from feed lines [2].

In order to reduce the SLL in broadside printed antenna arrays several approaches have been proposed. Among which are use of: coaxial probes along with phase shifters to reduce SLL to almost −35 dB [1]; feed network behind the ground and connected to the antenna via pins [3]; aperture coupled patch antennas [4]; and a waveguide fed microstrip patch array at 76 GHz [5].

Bandwidth enhancement in patch antenna array is mostly based on stacking patches on top of each other [6], or placing parasitic elements beside the patch antenna [7]. There is, however, no mention of the SLL performance of such array structures in these papers.

In low side lobe antenna array any extra components, phase shifters, etc., which are placed on the same substrate as the radiating elements cause spurious radiation that deteriorate the SLL dramatically. This problem becomes even more conspicuous in broad side arrays where the main radiation pattern and spurious radiation from other components are all at broadside direction. However, in an end-fire array, the broadside spurious radiations would have less effect on the end-fire SLL. Among the most widely used end-fire printed

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antennas are tapered slot antennas, TSA [8] and quasi-Yagi antennas [9].

Based on the literature review done by the present authors, most of the works published on printed end fire antennas are on increasing the bandwidth of the single element, and if placed in an array, no mention of SLL are provided.

Motivated by the aforementioned issues, in this paper a linear series fed double-dipole antenna array, SDD, is introduced leading to an end-fire fan beam with low SLL, high F/B and wide impedance bandwidth. Further improvement in SLL is achieved by introducing linear tapered narrow strips, comb like, connected to the finite ground plane of the structure, between each double-dipole antenna elements, referred to as the series-fed double-dipole antenna array with combed ground plane, SDDC. These antenna arrays are optimized through the commercial package, HFSS. Both SDD and SDDC arrays are fabricated and tested and compared with the simulated results.

2 Antenna design

It is well known that printed dual sided double-dipole antennas produce an end-fire radiation along with a large impedance bandwidth. Also it is known that a series fed printed antenna array can provide a lower SLL. These two ideas are the base of this work to design a low SLL and wide bandwidth end fire antenna array.

The proposed low side lobe antenna array design follows the following steps: (1) design of a double-dipole antenna element according to some given specifications, (2) design of the microstrip series-fed feeding network to provide a tapered amplitude distribution to achieve low SLL, (3) modification to the structure to further improve the SLL and (4) optimization of the proposed antenna array for high F/B, low SLL and reasonable bandwidth.

The schematic and parameters of the proposed antenna are shown in details in Fig. 1. The end fire antenna consists of two dipoles of different lengths and a finite ground plane which also acts as a reflector. The dipoles are center-fed by a short pair of parallel strips, and as can be seen from Fig. 1 (a) there is no complicated balun for matching the driven elements to the antenna feed line. The width of the parallel strips is set narrow enough to provide high input impedance, making it well suited for series-fed antenna array design. The lengths of the long and the short dipoles control the lower and upper operating frequencies, respectively. The distance between the two dipoles and the distance between the first dipole and the finite ground plane control the return loss level between the two main resonances. It should be noticed that the total impedance bandwidth of the antenna array is limited by the series-fed feeding network, The Ansoft's HFSS is used to optimize the antenna element to achieve high F/B and high input impedance which results in the following values of the antenna parameters assuming the substrate to be Rogers RT/duroid 5880 (0.508 mm, $\varepsilon_r = 2.2$): $L = 310$ mm; $W = 20$ mm; $W_f = 1.5$ mm; $L_{d1} = 6.96$ mm, $W_{d1} = 0.35$ mm; $L_{d2} = 5.6$ mm; $W_{d2} = 0.45$ mm; $L_1 = 1.5$ mm; $t = 1$ mm.

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The microstrip series-fed double-dipole antenna array contains 22 similar elements. The design center frequency is 16.26 GHz. The antenna array is split in to two linear sub arrays and fed in the middle. This symmetric arrangement further improves the cross-polarization level of the array and prevents the beam-pointing direction from varying with frequency. As such, the cross polar component generated in one side of array is cancelled by the cross polar component generated in opposite side of array at boresight direction. In order to get a boresight pattern, the spacing between the feed points of the array elements must be set at one guided wavelength λ_g, to ensure an equal phase between the elements.

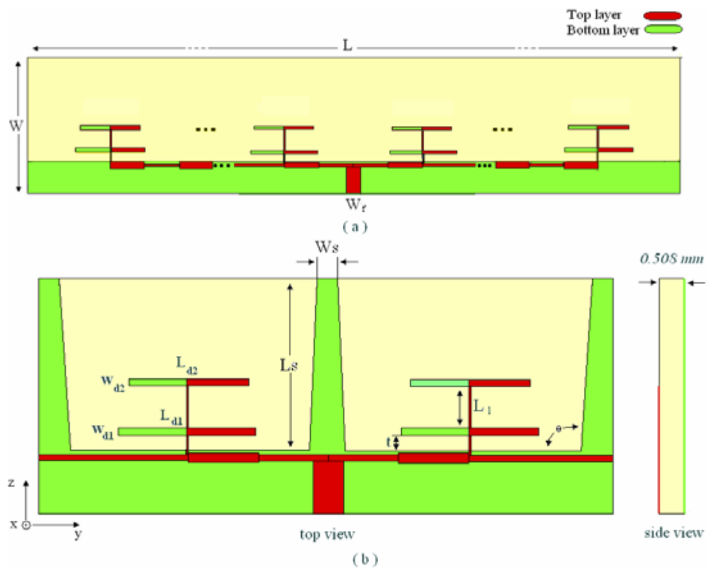

Fig. 1. The structure of the proposed series fed (a) double-dipole antenna array, (b) double-dipole antenna array with combed ground plane.

The antenna array has been designed for a −35 dB SLL through appropriate Chebychev taper distribution. A tapered distribution is readily obtained using quarter-wavelength transformers along the line.

Two quarter-wave transformers, $\lambda_g/4$, along with a half wave transformer, $\lambda_g/2$, are used throughout the first 7 elements on each side of the main feed source (one $\lambda_g/4$ has the same characteristic impedance as the $\lambda_g/2$, which results in less spurious radiation from such discontinuities). Between elements 7 to 11 four $\lambda_g/4$ are used (in this way for the last array elements the size of the feed lines would be physically large enough to be constructed). The characteristic impedance of the half wave lines are set at 115 ohm while those of the quarter wave transformers are between 80-125 ohms. The detailed design considerations for series-fed antenna array are discussed in [10].

Following the design of the single element and the array of such elements, to further improve the SLL of the array, the finite ground plane can be modified to include comb like strips in between the array elements, Fig. 1 (b). Through optimization, it is found that linear tapered narrow strips extended

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from the finite ground plane provide a better SLL than simple narrow strips. Addition of the comb like strips, affect the surface wave coupling between the neighboring elements, resulting in a lower SLL. Through optimization for the lowest SLL, the size of the extended strips are $Ls = 11.64\,\text{mm}$, $Ws = 0.4\,\text{mm}$ and $\theta = 99°$.

3 Results and discussions

In this section, detailed simulation and experimental results of the proposed antenna array are presented. Fig. 2 (a) shows the simulated as well as the measured reflection coefficient of the microstrip series-fed double-dipole antenna array, SDD of Fig. 1 (a). The results show that this antenna has a wide impedance bandwidth of approximately 14.6%, ranging from 15.1 to 17.4 GHz for $S11 < -10\,\text{dB}$. In comparison to the rectangular patch antennas investigated in [1], the impedance bandwidth of the proposed antenna array is increased more than 5 times. The printed double-dipole antenna can provide wide impedance bandwidth individually. However, when placed in the array the total achievable impedance bandwidth would be limited by the feeding network. The longitudinal feed line along with each dipole may act as two quarter-wavelength monopole antennas. The finite substrate and the ground plane also may interfere with the antenna resonances and change their locations, and may produce extra resonances. By tuning the antenna parameters the reflection coefficient between the resonances is reduced and as a result wider bandwidth is obtained.

Fig. 2 (b) shows the simulated as well as the measured reflection coefficient of the microstrip series-fed double-dipole antenna array with combed ground plane, SDDC of Fig. 1 (b). The results show that the addition of the linear tapered narrow strips connected to the ground plane does not affect the bandwidth of the array much. However, the comb has improved the impedance matching of the proposed antenna array, as stated earlier.

Fig. 3 (a) shows the simulated and measured (z-y) and (z-x) plane co polar and cross polar radiation pattern of the SDD antenna array. The patterns show that the proposed endfire antenna has $-27\,\text{dB}$ SLL at the centre

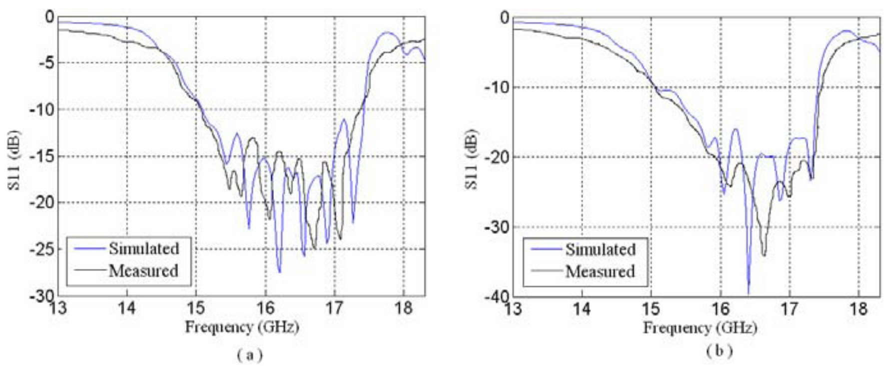

Fig. 2. The reflection coefficient of the (a) series fed double-dipole antenna array, (b) series fed double-dipole antenna array with combed ground plane.

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frequency and the 20 dB SLL bandwidth of 9.2%. The proposed antenna has 22 dB of F/B level. At the beam peak, the antenna has maximum co-polarization gain of 15.5 dBi at endfire direction. The cross polar level of the array is quite low, being −30 dB in the (z-y) plane and −25 dB in the (z-x) plane.

Fig. 3 (b) shows the simulated and measured (z-y) and (z-x) plane co polar and cross polar radiation pattern of the SDDC antenna array. The patterns show −32 dB SLL at the centre frequency, a 3 dB SLL bandwidth of 3.1% and a 20 dB SLL bandwidth of 12.1%. This shows that addition of the linear tapered narrow strips results in some 5 dB improvement in the SLL at the centre frequency of the antenna array. The 20 dB SLL bandwidth has also improved by some 2.9%. It is worth mentioning that if simple narrow strips were used in placed of the linear tapered narrow strips the SLL would be degraded by 2 dB. The F/B level of the SSDC antenna has not changed much compared to the SDD antenna array while its gain has reduced by 0.15 dB due to the conductor losses in the extended strips of the ground plane. The cross polar level of the SDDC in the (z-x) plane is less than −15 dB and in the (z-y) plane is less than −25 dB. The cross polar has increased due to the current along the strips which are orthogonal to the dipoles.

Fig. 3 (c) presents the radiation pattern of the SDDC antenna array at three different frequencies, showing that the pattern is almost uniform over

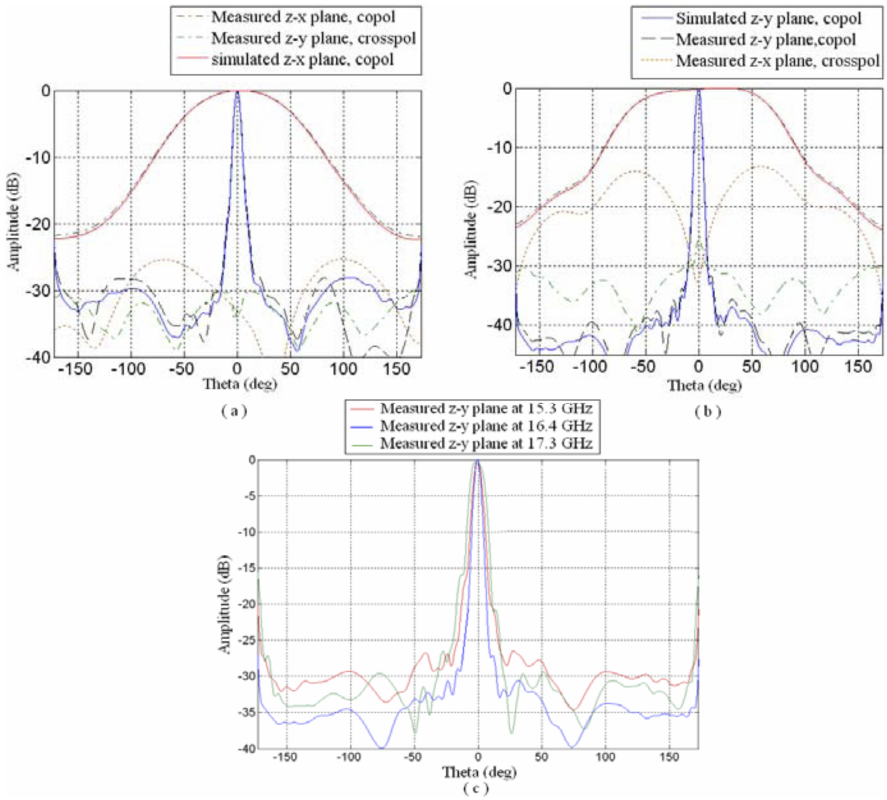

Fig. 3. The radiation pattern of (a) The SDD antenna array 16.26 GHz, (b) the SDDC antenna array at 16.26 GHz and (c) SDDC array at three different frequencies.

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the bandwidth.

4 Conclusion

The design of a linear endfire series fed double-dipole antenna array with low SLL, high F/B, and wide impedance bandwidth has been given. The array has 14.6% impedance bandwidth, 22 dB F/B and −27 dB SLL. By introducing comb like linear tapered narrow strips from the ground plane, in between the elements of the antenna array structure, −32 dB SLL which is some 5 dB improvements as compared to the basic array structure is obtained. Simulated and measured results on both of the arrays show a good agreement. The proposed array antenna is suitable for low SLL radar applications.

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