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Parametric Study of Series-fed Microstrip Antenna Arrays for mmWave Medical Radar Applications

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Abstract. In this paper, single row series feed antennas are presented with narrow beamwidth in one direction at a resonance frequency of 61.25 GHz. The proposed edge fed antennas consist of 8, 10 and 12 single patches. The antennas are based on Megtron6 with $\varepsilon_r = 3.62$ and a $\tan(\delta) = 0.004$. We modelled and simulated these antennas with the full wave simulation tool AnsysEM HFSS. The designed antennas are in good agreement with well-known theoretical approximations. We also validated the results with fabricated antenna arrays with a connector and a radiation measurement setup from NSI. Finally, we show that the simulation and measurement results are in good agreement. The achieved characteristic values of the radiation are for the 8x1 array a gain of 15.4 dBi and a HPBW 11.0°, for the 10x1 array a gain of 15.6 dBi and a HPBW 8.5° and for the 12x1 array a gain of 15.9 dBi and a HPBW 8.5°.

1. Introduction

Medical radar is one of the most promising applications in modern medicine today. A developed system with this radar can support by recording the vital signs of patients contact less. Especially for patients that need intensive medical care, such a system brings better living conditions. One of the most important aspects is the detection of the heart rate, blood circulation or breathing. All of the parameters can be detected with medical radar.

2. Analysis, Simulation and Comparison of Series Feed Antennas

In this section, linear series feed antenna arrays are designed at a resonance frequency of 61.25 GHz on the substrate Megtron6. This substrate has a $\varepsilon_r = 3.62$, $\tan(\delta) = 0.004$ and a thickness of 250 µm. The metal thickness of the planar patches and the ground plane is 35 µm.

The conventional series feed microstrip patch antenna array is presented in Figure 1. The array consists of 8 patch elements, which have the same spatial extent. The edge fed patches are connected with a microstrip line. To connect the entire array with a current feeding microstrip line a quarter-wave transformer is used. It is assumed that we obtain a gain of approximately 15 dBi with an 8x1 series feed array. It is also theoretically well known that the doubling of the elements causes a max. increase of the gain of 3dB.

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The geometrical dimensions of the modelled series feed arrays are shown in Table 1. Based on the geometric dimensions, we theoretically achieve a Θ_{HPBW}= 11, 4° for 8x1, Θ_{HPBW} = 9, 1° for 10x1 and Θ_{HPBW}= 7, 6° for 12x1 series feed array.
In addition to the designed antennas, test structures are developed. A coaxial 1mm edge-launch connector from the company South West was selected. For comparison purposes with the measurements, the test structures are simulated with the connector. An exemplary antenna array with the connector is shown in Figure 2.

The developed arrays differ essentially in the addition of individual patch elements. This means that all elements of the three arrays have the same size. Therefore, only an adaptation of the connections between the elements and the connection between the microstrip line and the total array is required. However, this only results in an absolute change in length. In relation to the 8x1 array, the 10x1 array is 5000 µm or 20% longer and the 12x1 array is 11000 µm or 44%

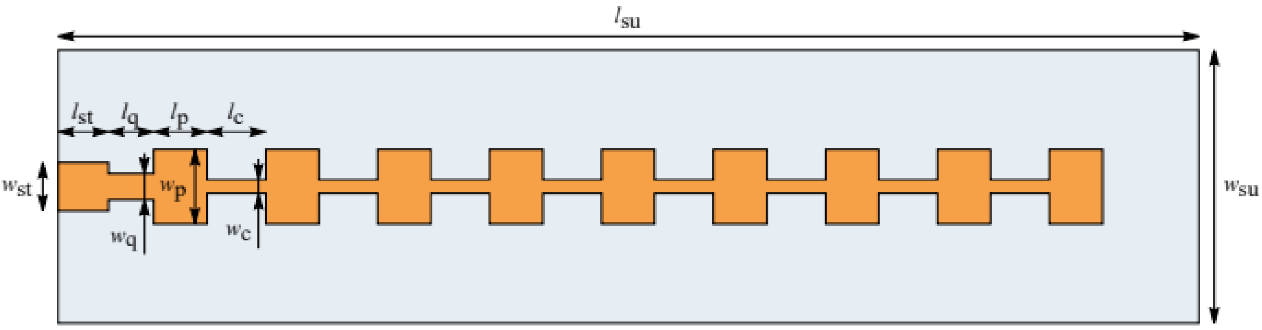

Figure 1 Top view on a conventional designed 8x1 series feed antenna, which is based a Megtron6 substrate.

Figure 2 Manufactured 8x1 linear series feed array with coaxial connector

Antenna	Antenna 8x1	Antenna 10x1	Antenna 12x1
patch length l_p [µm]	1270	1270	1272
length λ/4 section l_q [µm]	680	680	680
strip line length l_{st} [µm]	1200	1200	1200
substrate length l_{su} [mm]	25	30	36
line length l_c [µm]	1530	1530	1530
patch width w_p [µm]	800	800	800
width λ/4 section w_q [µm]	180	200	280
strip line width w_{st} [µm]	520	520	520
substrate width w_{su} [6m]	6	6	6
line width w_c [µm]	80	80	80

Table 1 Geometric dimensions of the designed series feed antennas

3. Measurement

The measurement of the radiation pattern from the antennas with the connectors are performed with the measurement system from the company NSI. This system essentially consists of a robot, which can position an arm with a horn antenna along a sphere.

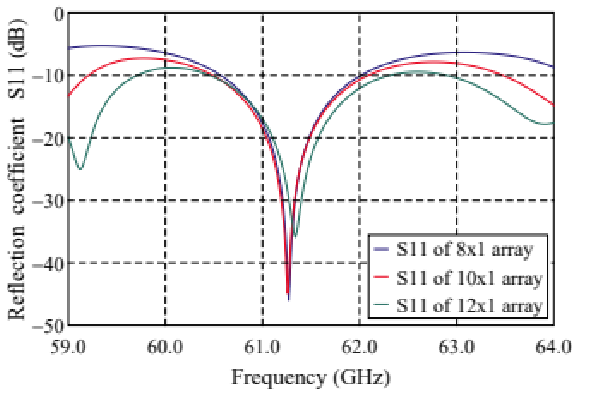

Figure 3 Manufactured 8x1 linear series feed array on the substrate Megtron6, which is mounted on a 1 mm connector from SouthWest (Model number 2492-04A-14).

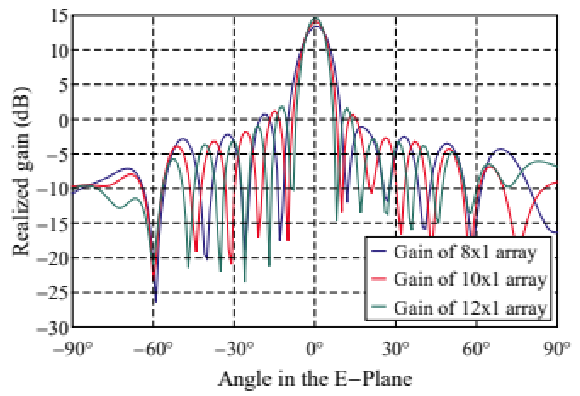

Figure 4 Manufactured 8x1 linear series feed array on the substrate Megtron6, which is mounted on a 1 mm connector from SouthWest (Model number 2492-04A-14)

The transmitting side is located in the center of the sphere. Here, the series feed antennas are subsequently mounted. Both the transmitter and the receiver are connected to an Agilent N5227A network analyzer. Before the measurement of the fabricated series feed antennas begin, a calibration with a second horn antenna is performed.

Table 2 Simulated and measured results of the series feed antenna arrays

	Simulation			Measurement		
Antenna	8x1	10x1	12x1	8x1	10x1	12x1
Bandwidth [GHz]	1.1	1.2	1.4	1.1	2.1	2.9
Gain [dBi]	14.4	15.3	16.0	15.4	15.6	15.9
Beamwidth E-plane [°]	10.9	8.7	7.3	11.0	8.5	8.5
Beamwidth H-plane [°]	71.6	71.1	71.2	64.5	62.0	72.0

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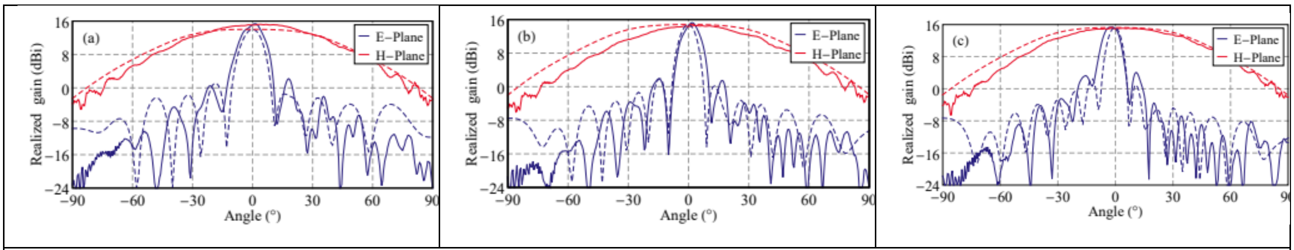

Figure 5 Simulated (dashed lines) and measured (solid lines) far field of the 8x1 (a), 10x1 (b) and 12x1 (c) series feed array with the connector from South West.

4. Results and Discussion

The Finite Element Method in HFSS is used and thus a 3D full wave simulation is available. A resonance frequency of 61 GHz is achieved for all simulation models. The band width (BW) varies slightly around 1.2 GHz (cf. Table 2). It can be seen that the theoretical values of both, the gain and the half-power beamwidth, are almost the same as those of the simulation. The differences are due to the fact that no connector is taken into account in the theoretical analysis. A direct comparison between the measurement and the simulation shows a good agreement (Figure 4). From these directional diagrams it is also evident that the radiation is essentially more directional in the E-plane i.e., along the individual antenna elements. It is also clear that as the number of elements increases from 8x1 (Figure 4 (a)) to 10x1 (Figure 4 (b)) or 12x1 (Figure 4 (c)), the half-power beamwidth in the E-plane becomes narrower. Furthermore, there are also more side lobes and as well the side lobe level is higher.

When looking at the characteristic values from the table, there is also a good agreement between the values for the reflection coefficient. All measured test structures show a resonance frequency at 61.25 GHz, as expected. Conclusion

Our results show that the measured beam profiles are as expected. Likewise, the radiation patterns in the E-plane are very narrow and thus well suited for very focused applications. However, it has been shown here that increasing the antenna elements no longer has a strong effect with an already high number of elements. Therefore, it is recommended to consider whether the main direction should become even narrower with the associated higher space requirement. Another effect is the increasing side lobe level with a larger number of antenna elements. To reduce this we plan to develop series feed antennas with tapered antenna elements.

Acknowledgemet

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