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# Wide-Beam Microstrip Antenna for Application in 24 GHz Short-Range Doppler Sensors

Krzysztof Wincza, Artur Rydosz, Jakub Sorocki, Ilona Piekarz, Izabela Slomian and Slawomir Gruszczynski
AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Krakow, Poland

***Abstract* – A wide-beam microstrip antenna for applications in short-range Doppler sensors has been developed. Beam widening has been achieved with the use of appropriately fed three radiating patches. To ensure a proper signal distribution along the array, a center radiating element has been designed as an aperture coupled patch fed at its center thorough the slot. Moreover, the center patch serves as a two-way power divider allowing for feeding two outer patches with appropriate amplitudes and phases ensuring simultaneously central symmetry of the antenna which improves radiation pattern.**

***Index Terms* — microstrip antennas, series-fed antennas, aperture coupled antennas, Doppler sensors.**

## I. Introduction

Microstrp antennas are often used in contemporary wireless communication and radar systems due to their advantages such as low-profile, low manufacturing cost and attractive properties that can be achieved when a proper design technique is applied. A classic microstrip square patch features beamwidth equal 80°, which is not sufficient when sector antennas for base-station applications or wide beam antennas for short range radar sensors, such as ceiling mount sensors, are desirable. To broaden the beam many different solutions have been proposed in literature often involving non-planar printed strip dipoles above shaped reflectors [1], [2]. Planar wide beam antenna concepts have been presented in [3]-[5], where a sector antenna element is constituted by a linear array consisting of three microstrip patches appropriately excited. In [3] such an array has been fed by a three-way power divider, in [4] a direct electromagnetic coupling between the patches has been used for beam broadening, whereas in [5] the planar antenna element combining both techniques shows the capability of beam broadening in a wide frequency range.

In this paper we present a wide beam microstrip antenna operating in 24 GHz frequency range and designated for short-range Doppler sensor. The beam widening has been achieved with the use of three microstrip patches appropriately feed similarly to the concepts presented in [3] and [5]. However, in the presented solution a center radiating element has been fed at its center with the use of aperture coupling and simultaneously serves as a two-way power divider. Such an approach allows for feeding two outer radiating elements in series with appropriate amplitudes and phases ensuring at the same time a central symmetry of the antenna, which in turn improves the achieved radiation pattern. Both electromagnetic calculations and measurements of the manufactured model are presented.

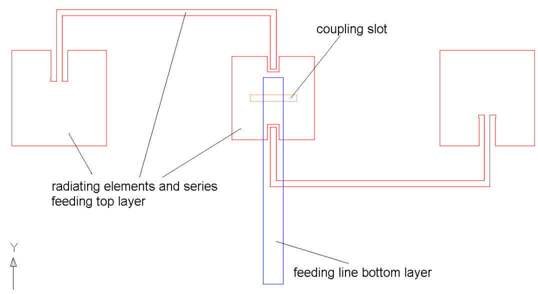


Fig. 1. Concept of a wide beam antenna array consisting of appropriately fed three radiating elements.

## II. Wide Beam Antenna Concept

The proposed concept of a wide-beam antenna is presented in Fig. 1. As it is seen the antenna consists of three radiating elements, and such a linear array allows for achieving beam widening when it is excited as follows: center element – amplitude $A_2 = 1$, phase $\phi_2 = 100°$ and two outer elements – amplitude $A_{1,3} = 0.5$, phase $\phi_{1,3} = 0°$ [3]. To achieve such signals, the center patch has been aperture coupled to the feeding line placed beneath through the slot located at its center. Moreover, two microstrip lines have been electromagnetically coupled to the center patch along vertical line which allows for series-feeding of two outer patches with appropriate amplitudes [6]. Therefore, the center radiating element is simultaneously used as a two-way power divider required in the presented concept. The needed signal phases exciting two outer patches have been adjusted by a proper selection of electrical lengths of the series-feeding transmission lines as it is seen in Fig. 1. It has to be underlined that the output signals achieved at the two microstrip lines coupled to the center patch have equal amplitudes due to the symmetry along horizontal line and are out-of-phase due to the applied aperture coupling [7]. Hence, to ensure an appropriate radiation pattern of the antenna array the two outer patches have to be mirrored with respect to each other along vertical line, as it is seen in Fig. 1. Such a solution ensures simultaneously a central symmetry of the entire antenna array, which improves achievable radiation pattern. The major advantage of the proposed concept in comparison to the solution presented in [3], is that the presented antenna requires only one slot in the common ground plane which saves space on the bottom layer for microwave electronics which is desirable when compact Doppler sensors are to be developed.

## III. Experimental Results

To verify the presented concept an antenna array operating in 24 GHz frequency range has been designed, manufactured and measured. For the design the dielectric structure shown in Fig. 2 has been used consisting of two Arlon 25N laminate layers having thickness $h$ = 0.305 mm and the relative dielectric constant $\varepsilon_r$ = 3.38. Fig. 3 presents the results of both EM calculations and measurements of the reflection coefficient. As it is seen the center frequency of the measured antenna is slightly higher than the calculated one, which is most likely caused by an infinite ground plane assumed during calculations. Fig. 4 shows the comparison of the calculated and measured radiation pattern. As it is seen the developed antenna features wide beam and the calculated and measured radiation patterns are in good agreement. Fig. 5 presents an assembled model of the developed wide-beam planar antenna array.

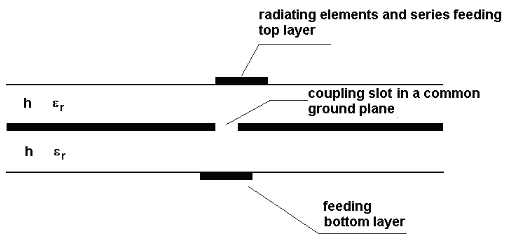


Fig. 2. Cross-sectional view of the dielectric structure used for the design of a wide beam antenna.

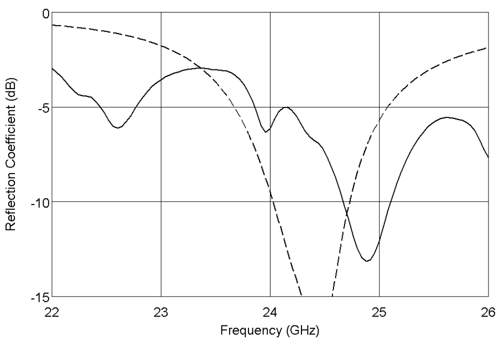


Fig. 3. Calculated (dashed line) and measured (solid line) reflection coefficient of the developed wide beam antenna.

## IV. Conclusion

A wide-beam planar antenna array operating in 24 GHz frequency range has been developed. The developed antenna consists of three appropriately fed microstrip patches. The center antenna element has been fed with the use of aperture coupling and used simultaneously as a two-way power divider allowing for series feeding of the two outer radiating elements. The major advantage of the proposed solution in comparison to the known concepts is that it requires only one slot in the ground plane which saves the space for other microwave electronics that has to be placed on a bottom layer. Therefore, the developed antenna is suitable for application in low-cost short-range Doppler sensors.

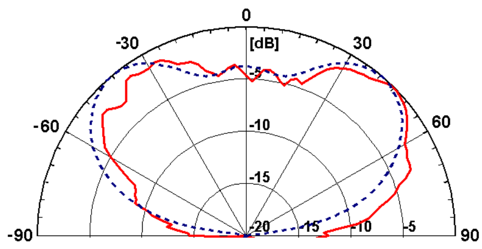


Fig. 4. Calculated (dashed line) and measured (solid line) radiation patterns of the developed wide beam antenna.

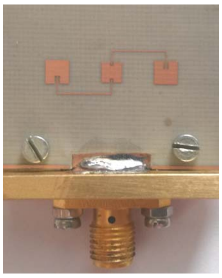

Fig. 5. Picture of the assembled model of the developed wide beam antenna.

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