60 GHz Range High Gain Millimeter Wave Antenna Array With Cylindrical-Parabolic Reflector

Aleksandar Nešić[1], Ivana Radnović and Milan Šunjevarić[1]

Abstract - **The paper presents concept, simulation, design and realization of the printed antenna array with a subreflector and a cylindrical-parabolic reflector. This antenna is intended for higher millimeter wave ranges and is characterized by many advantages such as efficacy, compactness, broad bandwidth and possibility of integration with other passive and active microwave circuits. Antenna gain is nearly 34 dBi and aperture efficiency is almost 50%. The antenna operates in the frequency range around 60 GHz. Measured results are in good accordance with those obtained by a simulation.**

Keywords – **Printed antenna arrays, Millimeter wave antennas, Cylindrical-parabolic reflector, Printed subreflector**

I. Introduction

Conventional high gain antennas that are used in microwave and millimeter-wave telecommunication, radar and navigation systems usually are: (1) parabolic antennas with central symmetry, (2) antennas with off-set parabolic reflector and (3) two-dimensional antenna arrays.

Due to relatively high losses in feed lines, conventional high gain printed antenna arrays are rarely used. In the suggested solution we use a cylindrical-parabolic reflector which is mainly applied in VHF and UHF ranges [1]. In millimeter wave ranges this type of antenna, to the author's knowledge, has not been used, except "pillbox" (or "cheese") antennas which have very wide E-plane beamwidth [2,3].

We will consider a suitable solution for high gain (around 34 dBi) antenna operating in millimetre wave range about 60 GHz according to ECC Recommendation (09)01 concerning the use of (57-64)GHz frequency band for point-to-point fixed wireless systems [4]. As a primary feed, in the focal line of the cylindrical-parabolic reflector, there is a printed antenna array consisting of 16 axial dipoles integrated with a subreflector, feed network and a transition from symmetrical microstrip to a waveguide. Obtained measured results of this antenna array are completely in accordance with ECC Recommendation [4] and show many advantages such as low cost, reproducibility and simple realization.

Although the simulation was carried out in the range (57-64) GHz, only the radiation patterns at 60 GHz are presented while the measurements at other frequencies are in progress at the moment (measuring procedure is rather slow due to lack of adequate equipment).

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II. Concept

The antenna consists of a cylindrical-parabolic reflector and a linear tapered axial array of printed pentagonal dipoles with printed subreflector. One half of each dipole is placed on one side and another half on the opposite side of the dielectric substrate. The dipoles operate on the second resonance (antiresonance) and their impedances are about 100Ω. The strip printed ahead of the array plays a role of a subreflector. Dipoles are fed through the printed feed network realized with symmetrical microstrip lines, like in [4]. Transition from symmetrical microstrip structure to a waveguide is inserted between the antenna and the feed line. All the elements of this antenna system, except the cylindrical-parabolic reflector, are placed on the same dielectric substrate (Fig. 1).

III. Design and Realization

Linear Array: Radiating elements in the linear array are pentagonal dipoles axially placed in the focal line of the cylindrical-parabolic reflector and operating on the second resonance. The dipoles, feed network, and the subreflector (printed on both sides of the dielectric), are realized on the dielectric substrate of h=0.127mm, ε_r=2.1 and tgδ=$4x10^{-4}$. Distance between the subreflector's axis and dipole's axis is λ/4 at the central frequency, while width of the subreflector is optimized so to obtain as high as possible gain. Dimensions of the pentagonal dipoles are optimized so to obtain impedance of about (100+j0) Ω at the central frequency of 60 GHz.

In the next step, an array of 16 dipoles has been modeled. The distance between the dipoles is chosen in such a way as to obtain high array gain with relatively high suppression of grating lobs. In our case, the distance between axial dipoles is L=1.1λ. Feed network realized in symmetrical (balanced) microstip is like in [5]. Feeding lines for dipoles penetrate the junction of two reflector halves. In the place of this junction there are holes with diameter d=1mm through which symmetrical microstrip lines of the feed network pass. Software package WIPL-D [6] has been used in these analyses.

Cylindrical-parabolic reflector: Cylindrical-parabolic reflector is assembled of its two halves. Dielectric substrate with printed radiating elements, subreflector, feed network and transition to waveguide is positioned between the reflector's halves, Fig.2. Length of the cylindrical-parabolic reflector (D=100mm) is practically defined by the linear array's length. Reflector's aperture is obtained from the condition that H-plane beamwidth is close to the E-plane beamwidth.

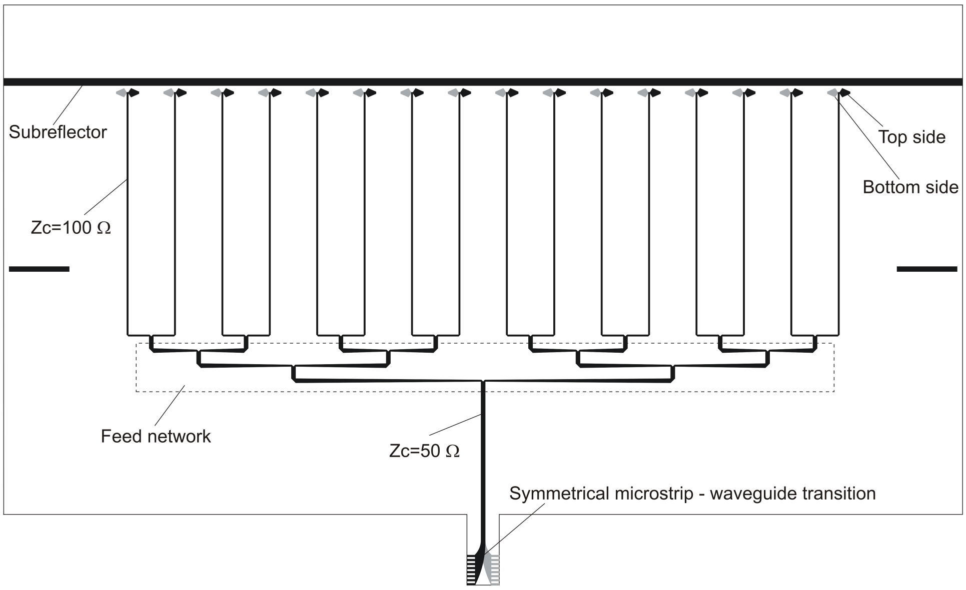


Fig. 1. Printed antenna array with feed network and symmetrical microstrip – waveguide transition integrated on the same dielectric substrate.

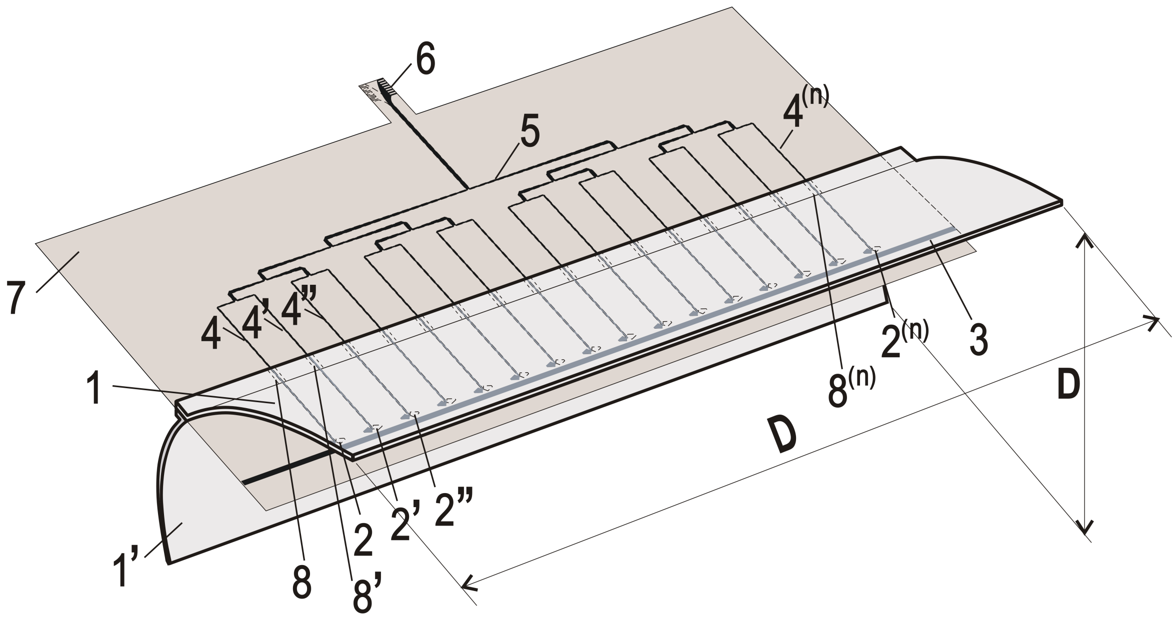


Fig. 2. Layout of the printed antenna array with subreflector placed in cylindrical-parabolic reflector: 1 and 1': two halves of the parabolic reflector; $2\text{-}2^{(n)*}$: printed pentagonal dipoles; 3: subreflector; $4\text{-}4^{(n)*}$: 100Ω-lines of the feed network; 5: feed network; 6: transition from symmetrical microstrip to a waveguide ; 7: dielectric substrate; $8\text{-}8^{(n)*}$: holes in the cylindrical-parabolic reflector (* n= number of dipoles in the array).

Focal length (L_f) is 16λ/4 (20mm at f=60 GHz). Thus, L_f/D is around 0.2 that makes the overall size and depth of the antenna smaller. Owing to the subreflector, more suitable illumination distribution, i.e. higher gain and better side lobe suppression in H-plane has been achieved.

IV. Obtained results

E- and H-plane radiation patterns of the antenna with and without a subreflector, obtained by a simulation are shown in Fig. 3a and Fig 3b, respectively. Simulated gain of the antenna without a subreflector is nearly 34 dBi. There is an improvement in the antenna gain of about 2 dB in the case with subreflector. Figures 4a and 4b show simulated and measured E- and H-plane radiation patterns of the array. Measured gain is approximately 2 dB lesser than simulated due to losses in the feeding lines and the transition from balanced microstrip to waveguide, which were not taken into account. VSWR against frequency measured in the range from 57.5 GHz to 75 GHz is given in Fig. 5, while photograpf of the realized printed antenna array in the parabolic reflector is presented in Fig. 6.

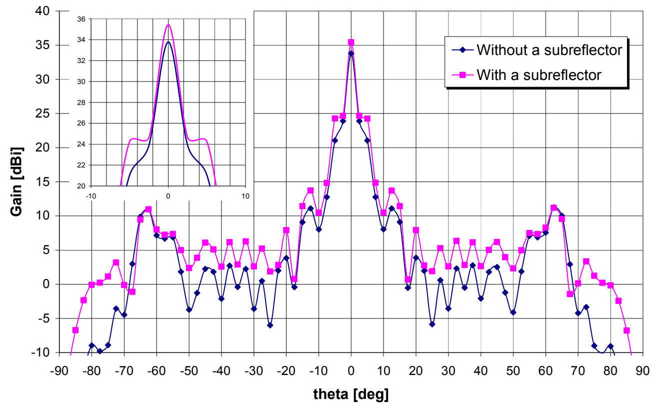


Fig. 3a. Simulated E-plane radiation patterns of the antenna with and without printed subreflector

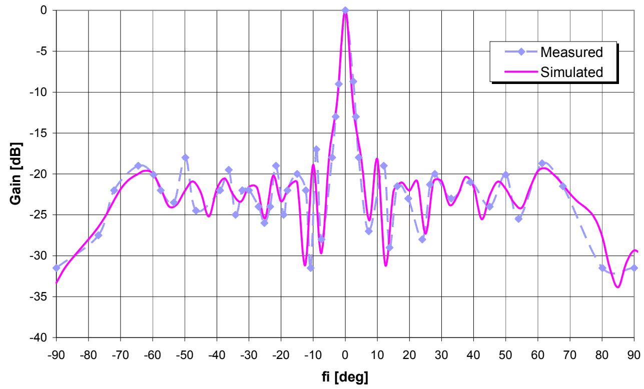


Fig. 4b. Simulated and measured H-plane radiation patterns of the antenna

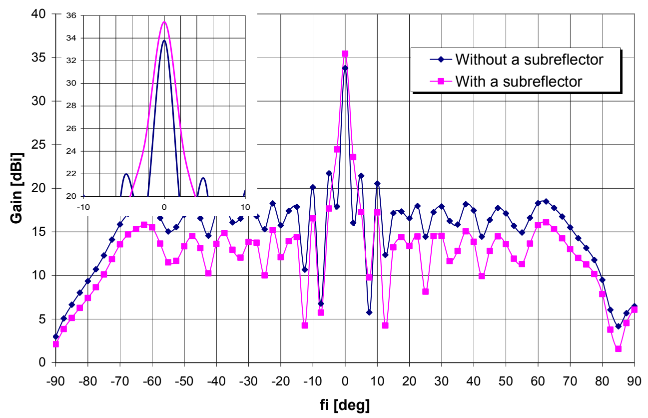
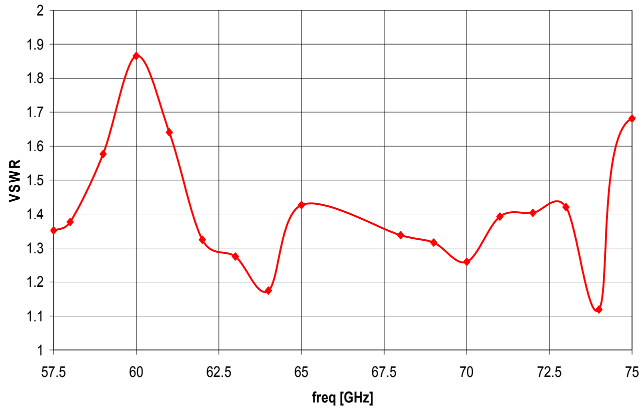


Fig. 3b. Simulated H-plane radiation patterns of the antenna with and without printed subreflector



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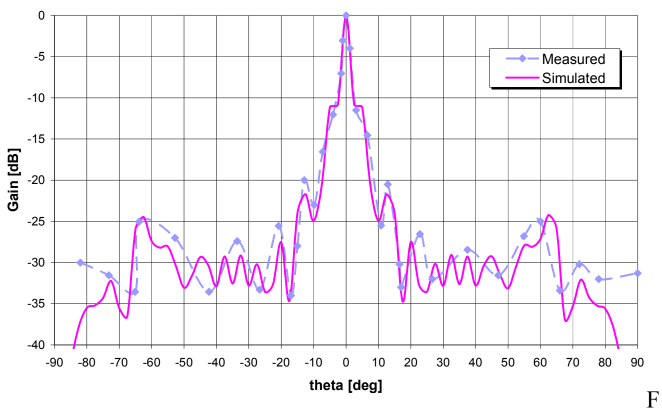

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ig. 4a. Simulated and measured E-plane radiation patterns of the antenna

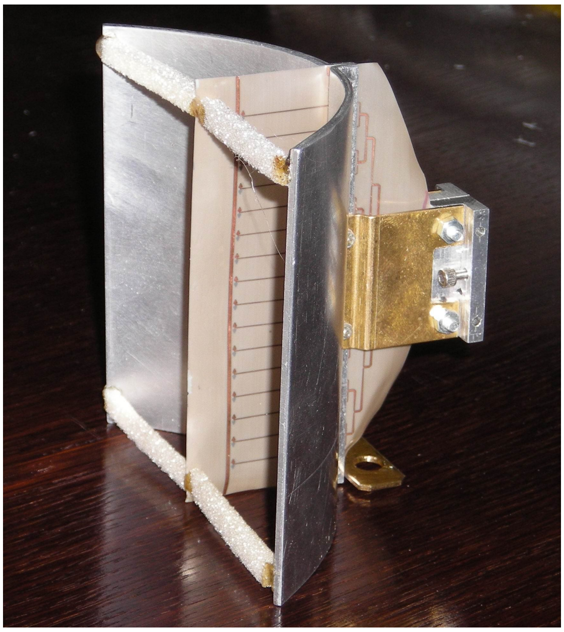

Fig. 6. Photograph of the realized antenna

V. Conclusion

The paper presents a new type of printed antenna array with a subreflector, placed in a cylindrical-parabolic reflector. Axial array of 16 pentagonal dipoles operating on the second resonance plays a role of a primary feed. In front of the array, there is a printed strip that acts as a subreflector. Symmetrical microstrip – waveguide transition, feed network, printed dipoles array and subreflector are all on the same dielectric substrate. Measured gain at 60 GHz is about 34dBi which is about 2 dB lesser than the gain obtained by a simulation where losses in the dielectric substrate and microstrip lines were neglected. There is a very good accordance between measured and simulated results. VSWR of the array is lesser than 2 in the range from 57.5 GHz to 75 GHz. Proposed concept of the cylindrical-parabolic antenna with a printed primary feed can be used in millimeter ranges up to 110 GHz.

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