Millimeter Wave High Gain Antenna with Wide Radiation Angle in Azimuth Plane

Aleksandar Nesic[1], Zoran Micic[1], Ivana Radnovic[1], Sinisa Jovanovic[1], Dusan Nesic[2]

[1]*IMTEL Institute, Belgrade*
[2]*IHTM - CMTM Institute, Belgrade*

Abstract – ***In this paper we introduce a millimeter wave printed array with eight axial dipoles and a "corner" reflector fed by a symphase network. Three different typical beamwidths are investigated by a variation of the "corner" angle. The antenna is simulated and realized in the frequency range (25.5–26.5) GHz, which is actual in microwave communication networks. Antennas with three different H-plane beamwidths: 55°, 110° and 180° and with gains of 19.3dBi, 16.5dBi and 14dBi respectively are presented. Losses are less than 1 dB.***

Index Terms – ***Antenna arrays, Printed circuit antennas, Multireflector antennas, Millimeter wave antennas***

I. INTRODUCTION

Modern microwave telecommunication systems such as indoor and outdoor wireless LAN-s, point to multipoint and multipoint to multipoint microwave systems are very prospective [1]. These systems need antennas with relatively wide radiation pattern in azimuth plane. In this paper we introduce printed antenna in millimeter range (around 26 GHz) with "corner" reflectors. Similar kind of antenna we used for a lower microwave range (2.4 GHz) [2].

In [3] and [4] discuss antennas with corner reflector with angle between 45^o and 180^o, having only one radiating element and operating at VHF and UHF frequency ranges. The reference [5] presents corrugated corner antenna with one radiating elements and central frequency around 9GHz.

This paper investigates three corner antennas having 8-dipole array as a radiating elements that operate on millimeter frequency range. One of the investigated antennas has a corner angle of 255^o in order to introduce a beamwidth of 180^o in H-plane. The presented concept is suitable for higher millimeter frequencies (up to 75 GHz) and insensitive to tolerances in fabrication.

II. CONCEPT

The proposed antenna array consists of three parts: (1) array of 8 printed radiating elements - pentagonal dipoles placed along axis; (2) two reflector planes ("corner" reflector); (3) feeding network printed on the same dielectric plate with radiating elements.

Dimensions of the radiating elements in pentagonal form are designed to obtain its second resonance at 26GHz with a input impedance of 100Ohm. These pentagonal printed dipoles have the first resonance at 22GHz and the third resonance at 52GHz. One half of the dipoles is on one side and another half of them on the opposite side of the dielectric substrate.

The distance between dipoles is $0.9\lambda_0$ (at center frequency) as a compromise between maximizing the array gain and keeping side lobes sufficiently suppressed [6].

We used symmetric (balanced) microstrip line as a feeding structure because the dipoles are symmetrical elements. The binary symphase feeding network has three stages. After the coaxial connector there is a BAL-UN for transition from a conventional microstrip to a symmetrical microstrip structure. In the first stage of the feeding network there is one T-junction, in the second stage – two T-junctions and in the third stage there are four T-junctions. Between the first and the second as well as the second and the third stage, there is a linear tapering in order to transform characteristic impedance from 100Ohm to 50Ohm. Layout of the antenna array is presented in Fig. 1.

The axial array is placed between two metallic plates which form the so-called "corner". The distance between dipole axis and the corner reflector edge is $?_0/4$ (at a center frequency). The beamwidth in the H-plane (azimuth) depends on the angle between the metallic plates. Three typical cases are investigated:

- for the corner angle of 127.5^o, the beamwidth in H-plane is around 55^o,
- for the corner angle of 180^o, the beamwidth in H-plane is around 110^o and
- for the corner angle of 255^o, the beamwidth in H-plane is around 180^o.

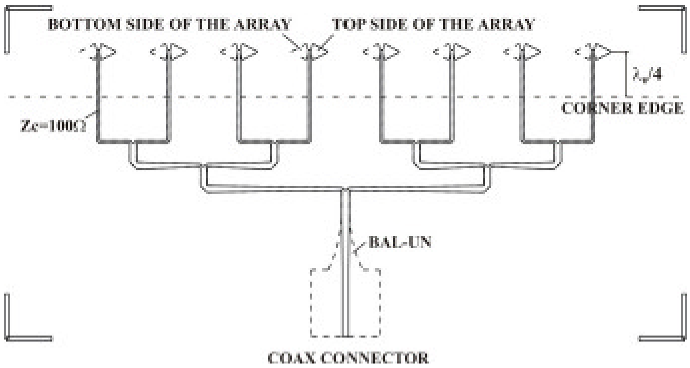

Fig. 1. Layout of the printed antenna array.

Feeding network penetrates the junction of two reflector plates. In the place of this junction there are holes through which symmetrical microstrip lines of the feeding network pass. Influence of the metallic plate on the microstrip lines is minimized by selecting the sufficient holes' diameter (2 mm), Fig. 2.

III. DESIGN AND REALIZATION

The radiating elements and the feeding network are realized on the same dielectric substrate with a relative dielectric constant of ε_r=2.1, thickness h=0.254mm and tgδ=4x10^{-4}. Dimensions of the pentagonally shaped dipole are optimized together with a symmetrical microstrip feeding line with characteristic impedance of 100Ohm and length of $\lambda_g/2$ to obtain impedance of 100Ohm at center frequency of 26 GHz by using program package WIPL-D [7].

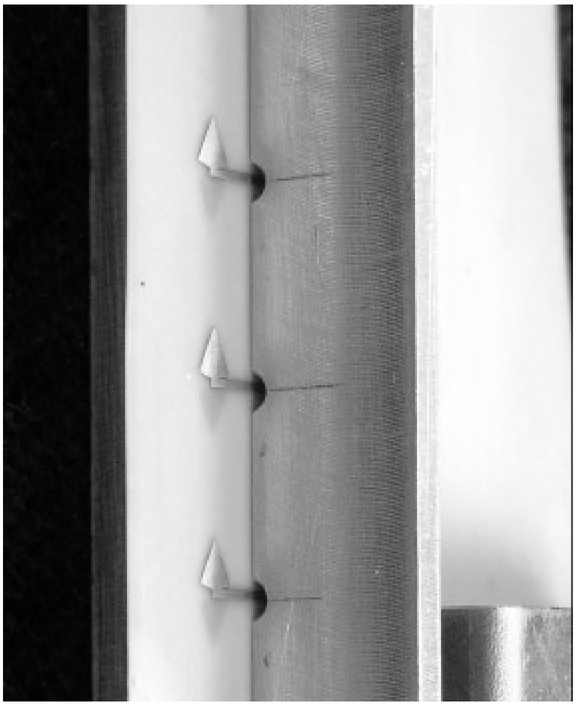

Fig. 2. Detail of the antenna array with the corner reflector.

The optimization is performed using a four dipole array to take into account the dipoles mutual coupling. All dipoles are coupled with two adjacent dipoles except the first and the last dipole in the array having only one adjacent dipole. The maximum coupling of about -30dB occurs between the adjacent dipoles, while coupling between non-adjacent dipoles is so low that could be ignored. The dipoles were optimized with separate generators connected at the end of the $\lambda_g/2$ long symmetrical microstrip lines that provide 1:1 transformation of the generators to the dipoles input. As a result of small coupling, the impedance variation between the dipoles in the array is insignificant. Thanks to the very low coupling between the dipoles

For the optimization purposes the symphase feeding network is designed using linear taper transformer from 50Ohm to 100Ohm symmetrical microstrip line [8]. BAL-UN is designed using ref. [9].

The simulation of the complete printed structure was not performed since the corner reflector decupled the feeding network from the dipoles.

We analyzed “corner” reflectors with three different angles: 127.5°, 180° and 255° in order to obtain different beamwidths in azimuth (H-plane): 55°, 110° and 180°, respectively. Due to the “corner” plate influence on dipoles’ impedance we had to make some corrections of dipole dimensions in each case, but these corrections were practically negligible. The radiation diagram in H-plane (azimuth) and E-plane (elevation) in all three cases obtained by simulation are shown in Fig. 3 and Fig. 4. Simulated VSWR is less than 1.2 in the whole frequency range (25.5-26.5) GHz.

IV. Obtained Results

We performed the simulation for three cases mentioned above and realized two of them: with corner angles of 127.5° and 180°. Photographs of two realized antenna arrays are shown in Fig. 5 and Fig. 6. Experimental results for all radiation diagrams are to a great extent in accordance with those obtained by a simulation, except the side lobe attenuation which is about 1 dB lower than the simulated one. VSWR is less than 2 in the whole frequency range. The difference between simulated and measured results is probably due to the discontinuity between the microstrip and the coaxial connector as well as due to fabrication tolerances.

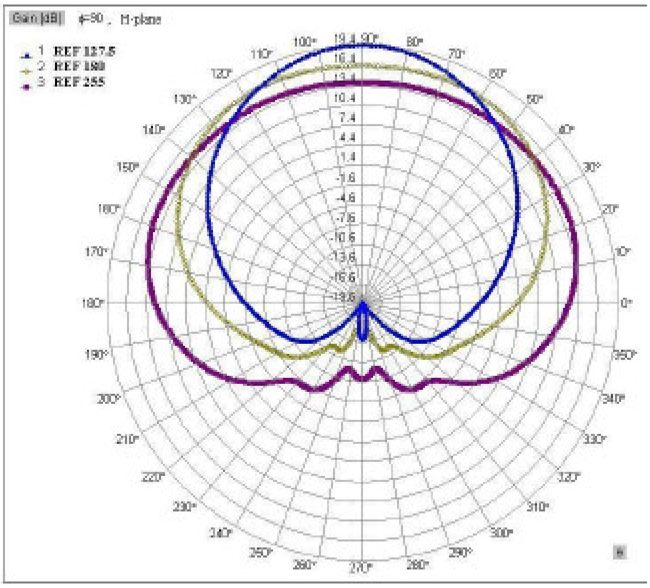

Fig. 3. Simulated radiation patterns of the antenna array in H-plane for three different corner angles (127.5°, 180° and 255°).

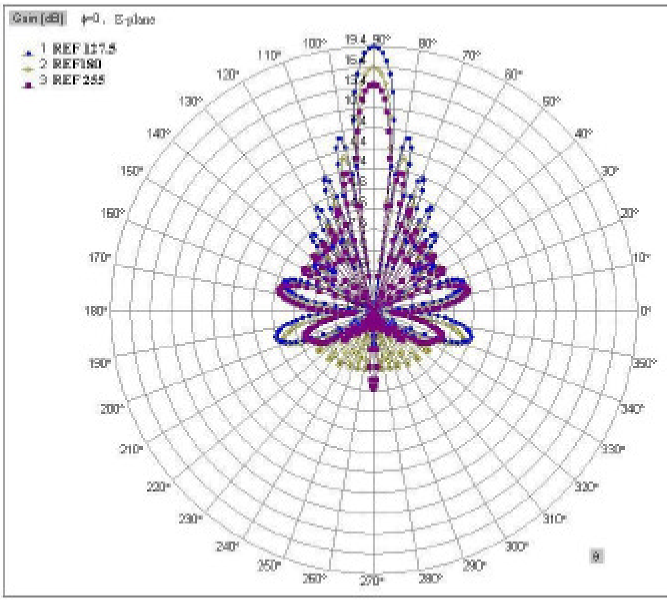

Fig. 4. Simulated radiation patterns of the antenna array in E-plane for three different corner angles (127.5°, 180° and 255°).

TABLE 1: Simulated results at f=26 GHz

Reflector angle	G [dBi]	FSLA [dB]	F/B [dB]	$HPBW^E$ [?]	$HPBW^H$ [?]
127.5°	19.4	13	33	6.9	54.6
180°	16.6	13	31	6.9	109.5
255°	14	12.9	22	6.9	182

TABLE 2: Measured results at f=26GHz

Reflector angle	G [dBi]	FSLA [dB]	F/B [dB]	$HPBW^E$ [?]	$HPBW^H$ [?]
127.5°	19.3	12	30	7.4	57
180°	16.5	12	28	7.4	112

G- Gain
FSLA- first side lobe attenuation
F/B- front-to-back ratio
$HPBW^E$- half-power beamwidth in E-plane
$HPBW^H$- half-power beamwidth in H-plane

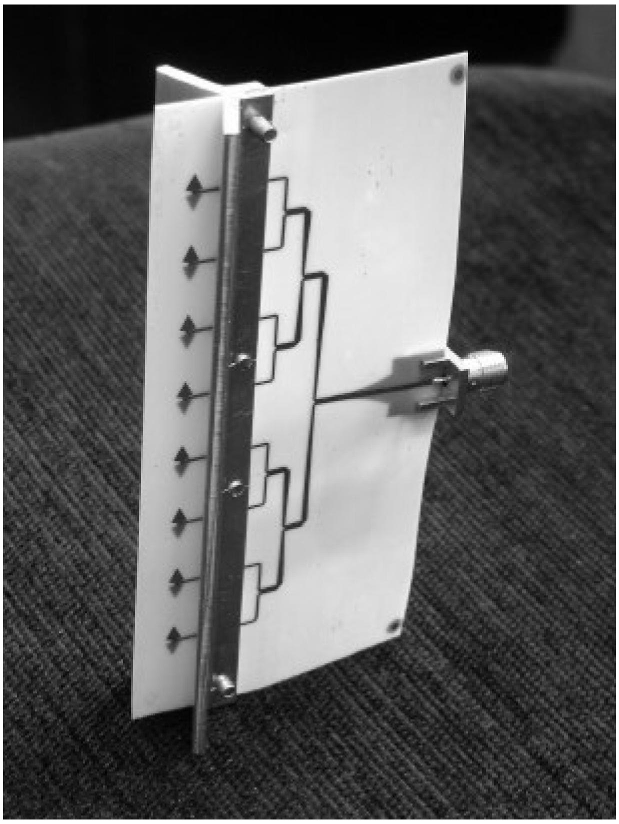

Fig. 5. Photograpf of the antenna array with 127.5° corner reflector.

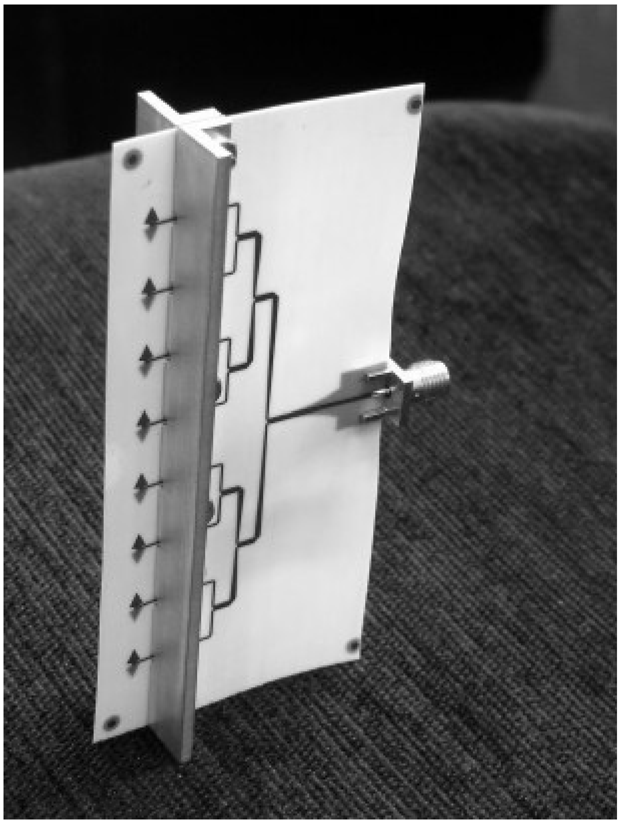

Fig. 6. Photograpf of the antenna array with 180° corner reflector

TABLE 3: Measured gain at center and edge frequencies

f [GHz]	25.5	26.0	26.5
$G_{REF\ 127.5}$	19.15	19.30	19.45
$G_{REF\ 180}$	16.4	16.5	16.6

V. CONCLUSION

The millimeter wave printed antenna array in the frequency range around 26 GHz with the “corner” reflector with three different angles is simulated, realized and measured. The antenna has a wide angle radiation pattern in H-plane (55°, 110° and 180°) and relatively high gain. The insertion loss is extremely low (less than 1dB). The proposed concept of the antennas is very suitable for applications in higher millimeter frequencies (up to 75 GHz) and insensitive on fabrication tolerances. The agreement between the simulation and the experimental result is excellent.

ACKNOWLEDGMENT

The authors would like to thank Ms. M. Marjanovic and Mr. N. Tasic for their help in the realization of the experimantal model. This work has been supported by the Serbian Science Ministry.

REFERENCES

[1] A. Nesic, V. Brankovic, D. Kuprezevic, M. Ratni, D. Nesic: “Broadband Printed High Gain Antenna with Wide Angle Radiation in Azimuth”, IEEE AP-S, June 2001, pp.468-471.

[2] V. Brankovic, A. Nesic, S. Zimmerman: “Antenna Solution for High Data Rate In-Door Communication Systems in mm-wave Range”, Mobile Communication Summit, June 1998, pp. 411-415.

[3] A. C. Wilson, H.V. Cottony: “Radiation Pattern of Finite-Size Corner-Reflector Antennas”, IRE Transaction Antennas Propagation, Vol. 8, pp. 144-157, March 1960.

[4] H. M. Elkamchovchi: “Cylindrical and Three-Dimensional Corner Reflector Antennas”, IEEE Transaction on Antennas and Propagation, Vol. AP-31, No.3, May 1983.

[5] K. Vasudevan, K. G. Nair: “A Corugated Corner Reflector System”, IEEE Trans. On Antennas and Propagation, Vol. AP-30, No.3, May 1982.

[6] M. Mikavica, A. Nesic: “CAD for linear and planar antenna array of various radiating elements”, Artech House, Norwood, MA, 1992.

[7] WIPL-D Pro v5.1, Branko Kolundzija, Jovan Ognjanovic, Tapan K. Sarkar

[8] A. Nesic, I. Radnovic, V. Brankovic: “Ultrawideband 60GHz Printed Antenna”, IEEE AP-S, June 1997, pp.2111-2115

[9] A. Nesic, S. Dragas: “Frequency Scanning Printed Array Antenna”, IEEE AP-S, June 1995, pp.950-953, Newport Beach, California, USA.