PLANAR FIVE-ELEMENT YAGI-UDA ANTENNA

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Abstract

The paper describes a design of planar five-element Yagi-Uda antenna for 2,4 GHz band. The structure has been optimized for a maximum directivity and maximum front-to-back ratio by planar simulator IE3D. Special feature of the antenna are reflector formed by ground plane edge and solution of impedance symmetrization and matching. Antenna has been realized and measured. Comparison of simulated and measured data are also presented.

Introduction

The planar five-element Yagi-Uda antenna (see fig. 1) has been designed for an ISM (Industrial, Science, Medical) band with a frequency range 2.40 – 2.483 GHz. Similar three-element antenna array has been realized in [1]. The structure of the planar antenna consists of three main parts. The first part is an antenna array itself. The second one is a planar microstrip-coplanar balun that provides symmetrization and matching of unbalanced feeding microstrip (MS) line to balanced coplanar strip (CPS) line. The third part is the symmetrical CPS line that transforms array impedance Z_{arr} to the impedance Z_{CPS} at the MS-CPS balun output (see reference planes in Fig. 1 a).

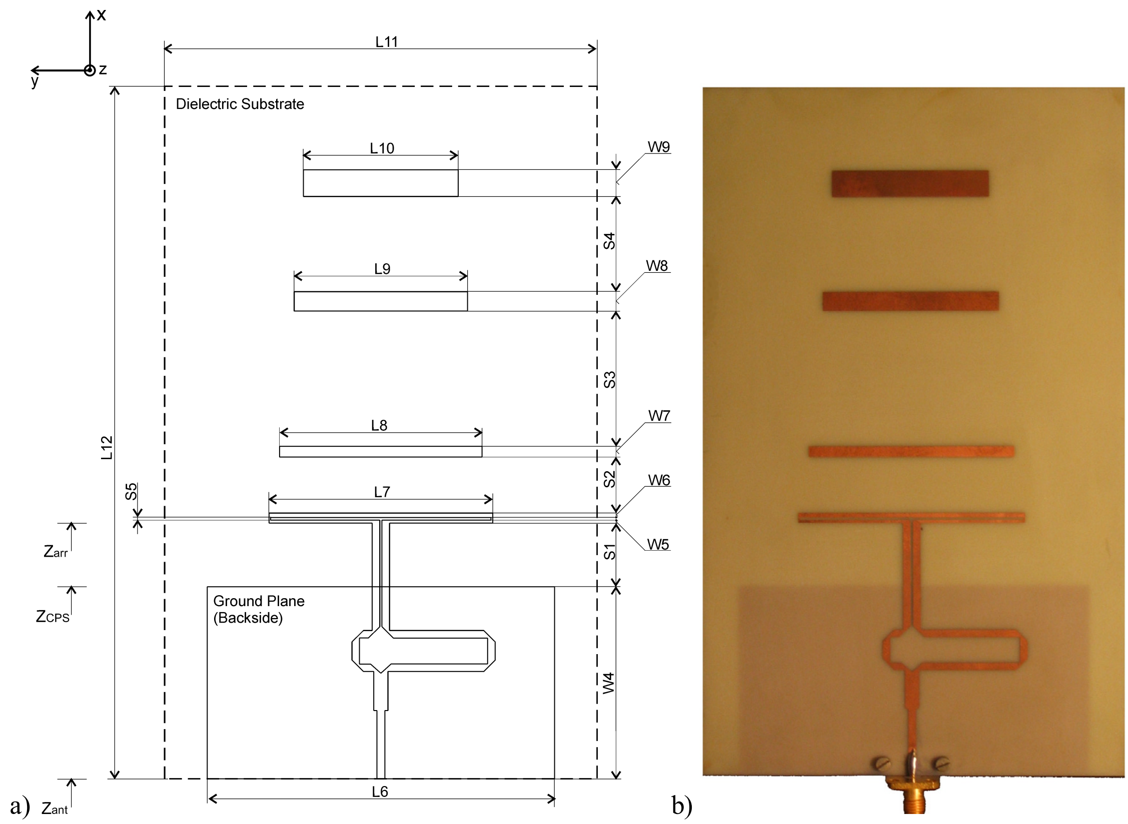


Fig. 1 The structure of the planar Yagi-Uda antenna a) layout, b) photograph of the antenna (parameters: L6=82mm, L7=52.84mm, L8=47.8mm, L9=40.95mm, L10=36.54mm, L11=100mm, L12=165mm, W5=0.74mm, W6=1mm, W7=2.52mm, W8=4.6mm, W9=6.35mm, S1=15.1mm, S2=13.32mm, S3=32.13mm, S4=22.6mm, S5=0.61mm)

Antenna array

The analysis and optimization of antenna array has been done by planar simulator IE3D that uses integral equation/method of moment (IE/MoM) analysis in frequency domain. Simulator IE3D ver. 10.23 includes the ability of the analyses with finite substrate dimensions that also has been used in simulation of antenna structure. The genetic algorithm optimization scheme has been chosen to reach maximum directivity ($D \geq 10\,\text{dBi}$) and maximum front-to-back ratio ($FBR \geq 25\,\text{dB}$). Optimization requirement for the directivity has been selected with respect to theoretically reachable value presented in [2].

The principle of the planar Yagi-Uda antenna is the same as the wire Yagi-Uda antenna [3]. The reflector of the array is formed by the ground plane edge. Folded dipole as active fed element and three directors with various element width as a result of optimization process are used to provide array input impedance $Z_{arr} = 81.3 - j114.4\ \Omega$.

Microstrip-coplanar balun

Symmetrical microstrip T-junction with different arm lengths has been used to divide input power and ensuring phase shift 180˚. The output of the balun is linked up microstrip coupled line (MCL) with impedance of TEM odd mode $Z_{odd} = Z_{CPS} = 41\ \Omega$. CPS line has impedance $Z_{CPS} = 130\ \Omega$ and transforms symmetrical antenna array impedance Z_{arr} to the balun output impedance $Z_{out} = Z_{CPS}$ (see ref. planes in Fig. 1 a).

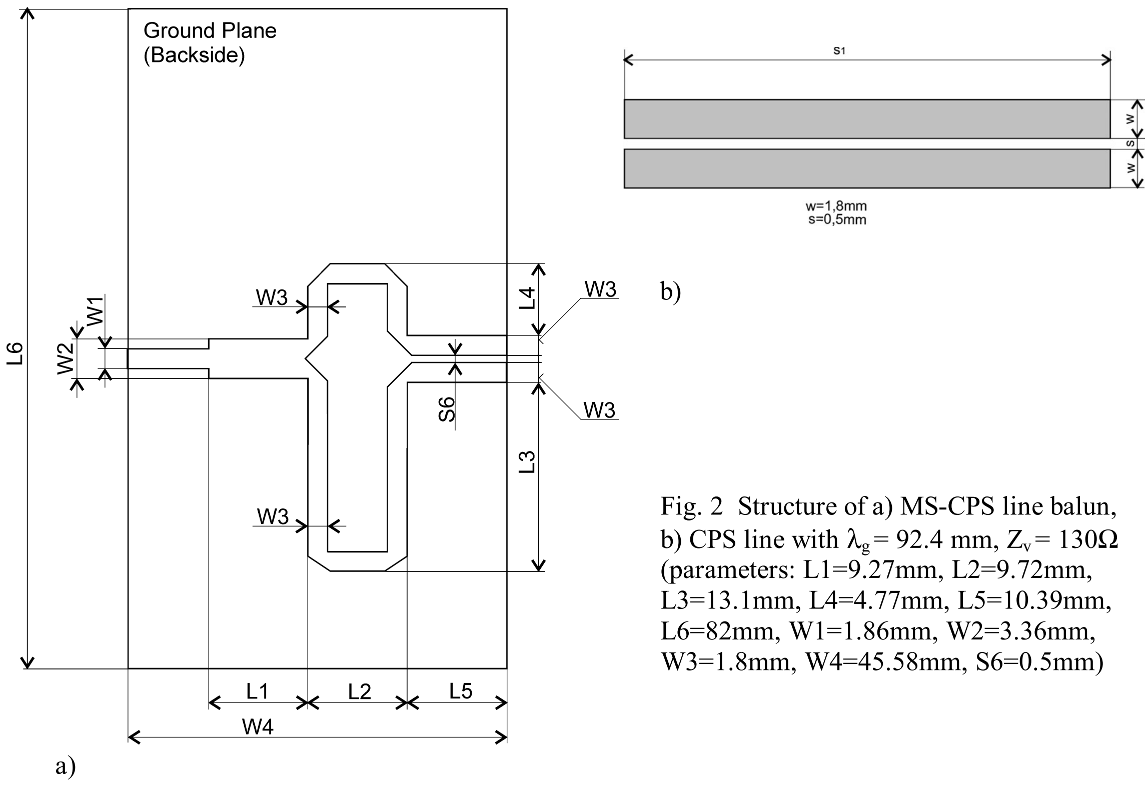


Fig. 2 Structure of a) MS-CPS line balun, b) CPS line with $\lambda_g = 92.4$ mm, $Z_v = 130\Omega$ (parameters: L1=9.27mm, L2=9.72mm, L3=13.1mm, L4=4.77mm, L5=10.39mm, L6=82mm, W1=1.86mm, W2=3.36mm, W3=1.8mm, W4=45.58mm, S6=0.5mm)

Results

The structure has been realized on a dielectric substrate Gil GML 1000 with dimensions 165 x 100 mm (height of substrate h = 0.76mm, relative permitivity $\varepsilon_r = 3.2$, dissipation factor $tg\delta = 0.004/2.5$ GHz). Measured resonant frequency has been shifted to f = 2.317 GHz. It is about 5.0 % difference compared to simulated results (see Fig.3).

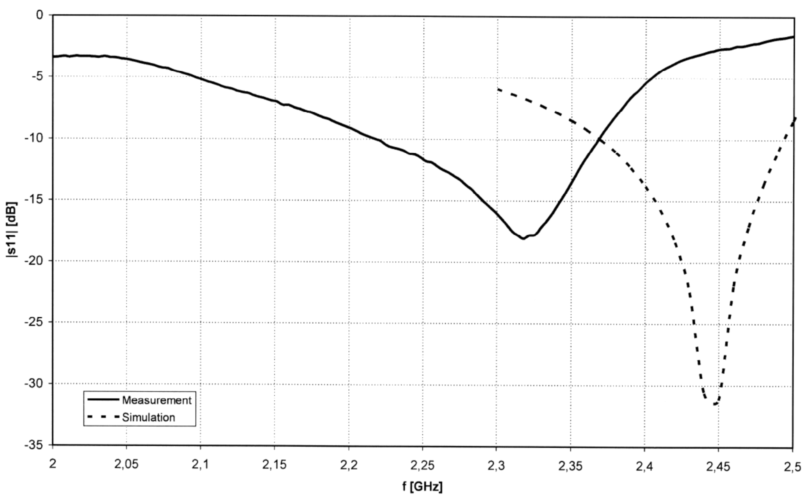
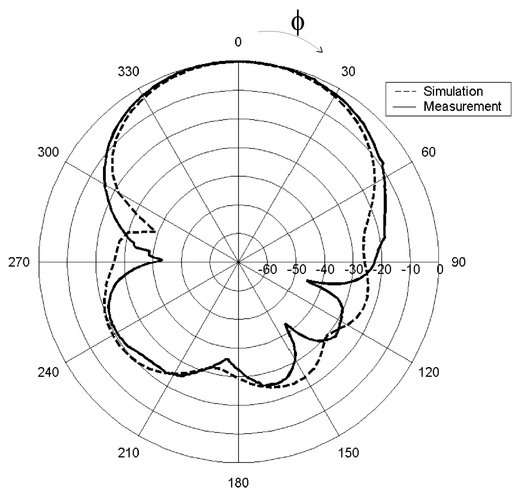


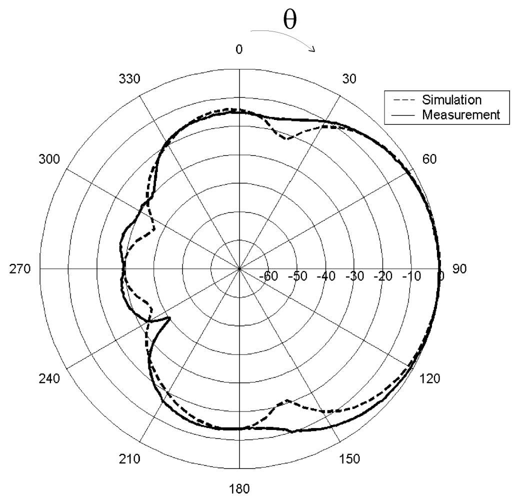
Fig. 3 Comparison of measured and simulated reflection coefficients of the complete antenna

Radiation patterns of the antenna has been measured at resonant frequency f = 2.317 GHz. Measured and calculated co-polar radiation patterns are almost the same (see Fig.4).



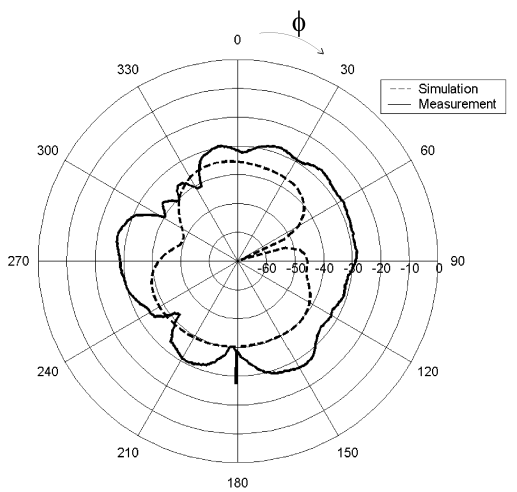
a)

E plane – co-polar, xy plane



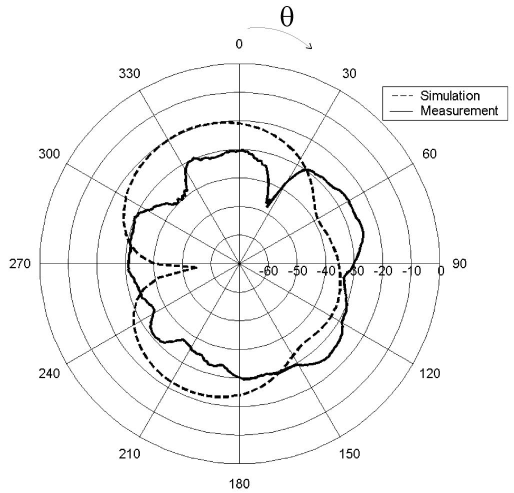
b)

H plane – co-polar, xz plane



c)

E plane – cross-polar, xy plane



d)

H plane – cross-polar, xz plane

Fig. 4 Measured and simulated radiation patterns of the array a), b) co-polar, c), d) cross-polar components in principal planes

Comparison of measured and simulated antenna parameters can be seen in Tab.1. Directivity of the array has been evaluated from measured data as average value of directivities in E a H plane.

Parameter		Simulation	Measurement
f_o	[GHz]	2.44	2.317
directivity	[dBi]	9.94	10 (evaluated)
gain	[dBi]	9.68	9.33
efficiency	[%]	94.25	84.75
front to back ratio	[dB]	29.11	30
$\|s_{11}\|$	[dB]	-31.18	-18
BW_{rel} ($\|s_{11}\|$<-10dB)	[%]	5.1	5.2
co/cross polar ratio	[dB]	35	30
3dB width of main lobe E-plane	[°]	56.14	64.62
3dB width of main lobe H-plane	[°]	71.95	80.51

Tab. 1 Measured a simulated parameters of the planar five element Yagi-Uda array

Conclusion

Planar five element Yagi-Uda array has been designed with the help of planar simulator IE3D. MS-CPS balun and transformation CPS line has been used to provide symmetrization and impedance matching between input SMA connector and active folded dipole of the array. Antenna has been realized and measured. Agreement of the simulated and measured co-polar radiation patterns is quite good. Minimum of the measured reflection coefficient is shifted about 5.0 % compared to simulated one. However it is not too much different from the results of other similar antenna structures published in literature.

Acknowledgement

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