# Collinear Microstrip Patch Antenna

*Milan POLÍVKA, Alois HOLUB, Miloš MAZÁNEK*

Dept. of Electromagnetic Field, Czech Technical University, Technická 2, 166 27 Praha, Czech Republic

polívka@fel.cvut.cz, holuba@fel.cvut.cz, mazanekm@fel.cvut.cz

**Abstract.** *The paper presents a brief overview of the development of so called collinear types of antenna arrays. A new type of this structure in microstrip technology is further introduced. The principle of the antenna operation is explained via surface current distribution of excited modes. Such distribution is reached via geometrical perturbation of a radiating element by slots introduced in such a way that they eliminate radiation from even half current wavelengths. The initial design and optimization of the prototype operating in RFID band (869 MHz) has been performed in planar simulator Zeland IE3D. A prototype has been realized and measured. The reached results show that the presented antenna has directional character as it can be expected due to the proposed technology and the presence of a planar ground plane.*

## Keywords

Collinear array, microstrip patch antenna.

## 1. Introduction

Antenna arrays known as collinear arrays (CoA) are based on in-phase feeding of radiating elements that lie in the straight line and their radiation is typically broadside - perpendicular to the axis of collinear elements. The original idea comes from Franklin [1]. He first designed CoA from a long wire that had λ/4 U-shaped sections to provide phase shift to maintain in-phase feeding of straight λ/2 parts of the wire, see Fig. 1a). Instead of U-shaped sections small inductors can be used to ensure phase shift. The principle has been then applied to a coaxial collinear antenna (known also as COCO antenna for coaxial collinear) [2], see Fig. 1b). Several researches further implemented this principle in either coaxial or microstrip antenna technology [3], [4], [5], see Fig. 1 c-d). All mentioned collinear antenna arrays have nearly omnidirectional radiation pattern due the more or less longitudinal axis symmetry.

In this paper, a new type of collinear microstrip patch antenna (CoMPA) [6] that can operate with $TM_{0X}$ mode is introduced. The patch motif with ground plane is illustrated in Fig. 3a). An experimental prototype operating with $TM_{05}$ mode (see Fig. 3b) has been designed for the central frequency 869.5 MHz (European RFID sub-band 869.4 MHz to 869.65 MHz). Its radiation pattern is semidirectional due to the presence of the ground plane as a necessary part of a microstrip patch type antenna.

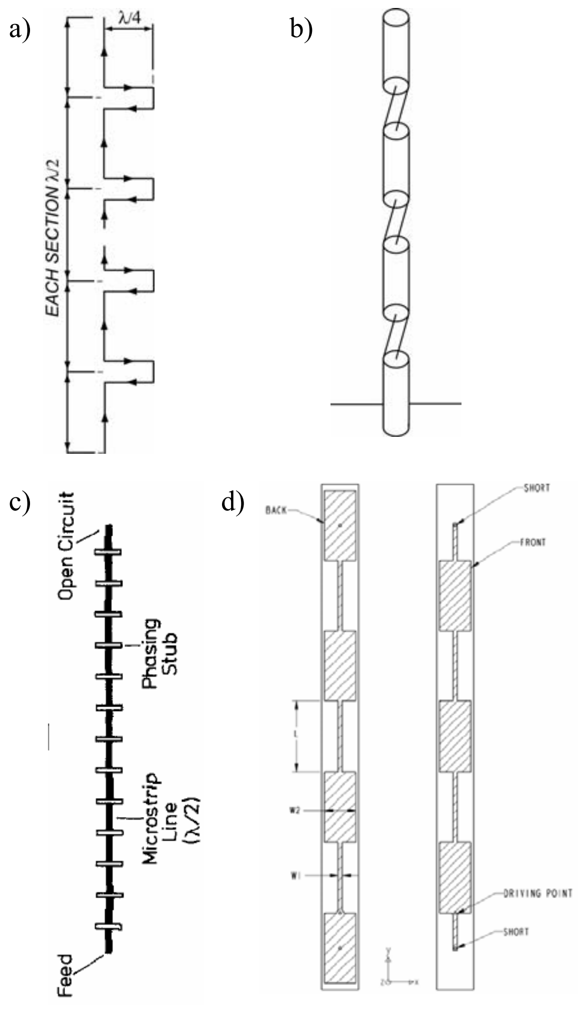


**Fig. 1.** Geometry of several collinear arrays: a) original Franklin dipole, b) coaxial collinear, c) microstrip line with a flat O shaped sections d) thin/thick section microstrip line.

## 2. Collinear Microstrip Patch Antenna

First, let’s sharpen the meaning of the following three expressions in microstrip patch antenna (MPA) technology: radiator, patch, motif. A radiator is a complete MPA element. A patch is a conductive part of a radiator placed in the height *h* over the ground plane. Finally, a motif is understood as particular geometrical shape of the patch. Further, we describe exciting in-phase currents on the planar structure of CoMPA. The idea is based on the application of so called perturbation elements (PE) – geometrical perturbations of a patch operating with higher order modes.

As it is well-known MPA can be designed to operate with higher order modes. Here $TM_{0X}$ mode (where x determines the number of half current wavelengths in the resonant longitudinal dimension of the patch) is used. PEs in the shape of slots are then applied to the structure of the patch in such a way that they eliminate radiation from even out-phase half current wavelengths. Specific motif(s) of the perturbed patch thus arise. The simplest example of the usage of the described principle is MPA operating with $TM_{03}$ mode with one central narrow slot placed in the middle of the patch. The slot of the length approx. $\lambda_g/2$ and the width of a fragment of $\lambda_g$ causes that second/even currents flow around the slot (see Fig. 2a). The currents in the vicinity of the slot circumference thus cancel their contributions to the radiated fields due to the out-phase orientation on opposite sides. Vector current distribution of MPA operating with $TM_{05}$ mode with two slots is illustrated in Fig. 2b. The same effect around both slots as in case of a motif with $TM_{03}$ mode can be seen in Fig. 2b.

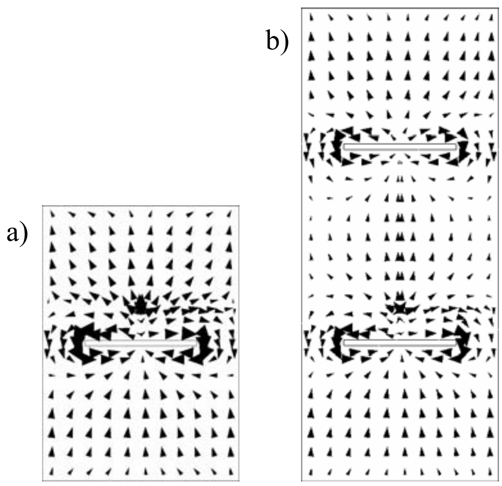


**Fig. 2.** Vector surface current distribution on the patch with a) $TM_{03}$ and b) $TM_{05}$ modes as modeled in Zeland IE3D with infinite ground plane.

An approximate dimension of the initial model coming from the above mentioned idea can be seen in Fig. 3. Such initial design has been optimized by means of IE3D build-in procedures with the criteria of impedance matching and maximum gain. The dimensions of the optimized antenna are: the patch 268 x 643 mm and the ground plane 298 x 680 mm. The height of the patch over the ground plane is 10 mm. The patch was excited by a coaxial feeding placed on y-axis symmetry in the distance of approx. 0.05 $\lambda_g$ above the lower slot (see Fig. 3). In IE3D feeding was modeled by vertical localized port.

The measured reflection coefficient of the realized prototype with and without 3 mm thick HPS (hardened polystyren) radom placed in the height of 40 mm over the patch is illustrated in Fig. 4.

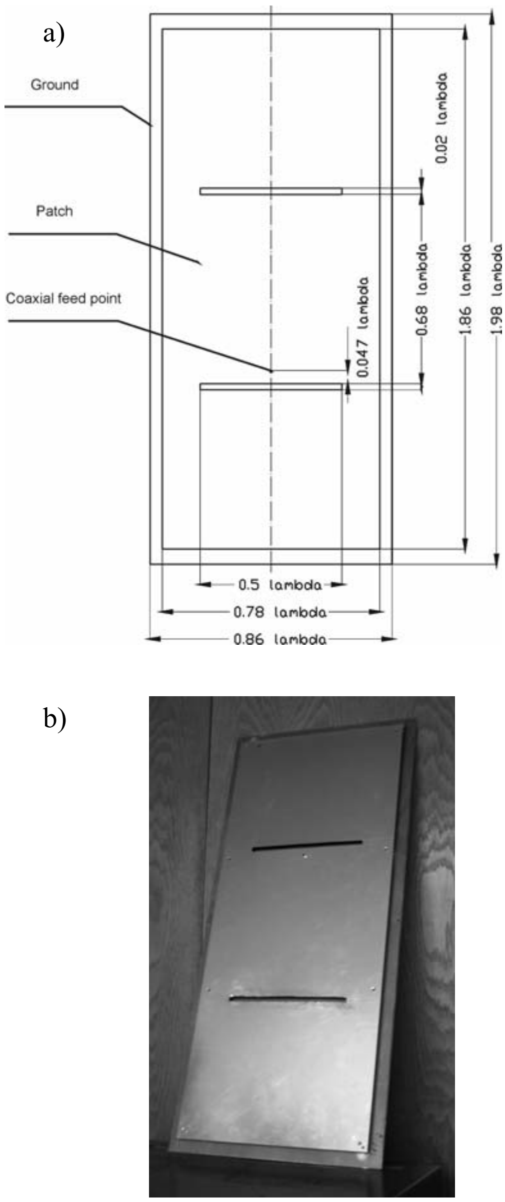


**Fig. 3.** CoMPA operating with $TM_{05}$ mode: a) top view of the layout with optimized dimensions related to wavelength, b) photograph of the prototype

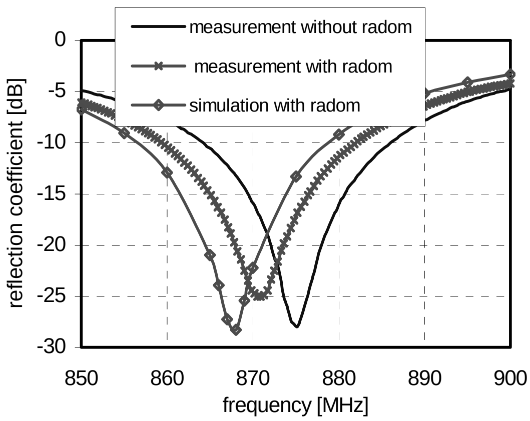


**Fig. 4.** Measured and simulated reflection coefficient of the realized prototype CoMPA with $TM_{05}$ mode without and with a dielectric cover.

Measured radiation patterns are illustrated in Fig. 5. The distance between the middle part of rectangular in-phase source current areas is approx. 0.68 $\lambda_0$, that's why the side-lobe level is about –13 dB as in case of 0.5 $\lambda_0$ spaced uniform array. The front-back ratio is about 19 dB in E plane and 14 dB in H plane although ground plane dimensions are just only about 0.1 $\lambda_0$ larger than the patch itself.

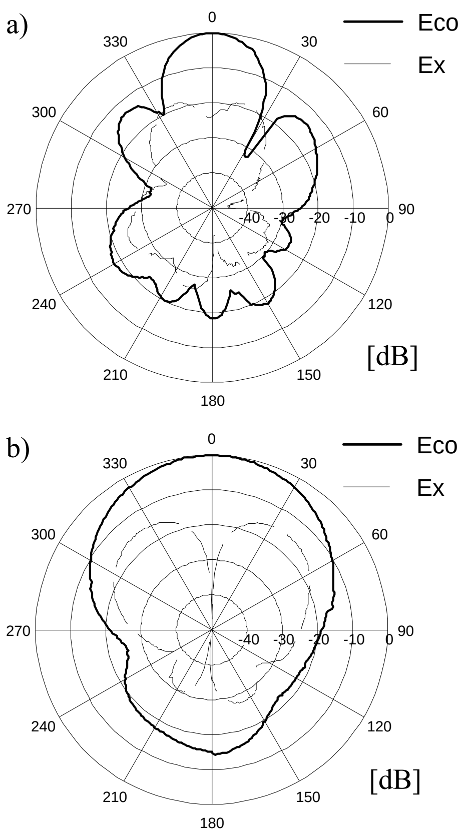


**Fig. 5.** Measured radiation patterns of CoMPA operating with $TM_{05}$ mode in a) E-plane, b) H-plane.

The antenna gain (Tab. 1.) was measured by substitution method at 869 MHz in the antenna anechoic chamber [7] with the help of standard horn antennas. Simulated values of directivity 12.6 dBi and gain 12.4 are a little bit higher than the measured value 11.7 dBi of gain. Of course precise gain error estimation could be made but anyway a gain error at least of about +/- 0.5 dBi can be supposed.

| Simulated directivity [dBi] | Simulated gain [dBi] | Simulated efficiency [%] | Measured gain [dBi] |
|---|---|---|---|
| 12.6 | 12.4 | 95 | 11.7 |

**Tab. 1.** Measured and simulated values of gain, directivity and efficiency.

Measured narrower 3 dB beamwidth in E plane (25°) confirms measurement results (Tab. 2.) that exhibit gain enhancement compared to gain of standard rectangular microstrip patch operating with $TM_{01}$ mode (approx. 6-9 dBi, see for example [8]). Impedance bandwidth is related to the common value of VSWR = 2. The value of BW = 2.8 % is relatively small as in case of microstrip patch antennas generally. In the particular RFID application the bandwidth is sufficient as just 250 kHz band is required.

| BW [MHz] | BW [%] | $\theta_{3dB}$ [°] in E plane | $\theta_{3dB}$ [°] in H plane |
|---|---|---|---|
| 24 | 2.8 | 25 | 62 |

**Tab. 2.** Measured values of CoMPA with $TM_{05}$ mode bandwidth and 3dB beamwidths.

## 3. Conclusion

The novel type of collinear antenna array was proposed, designed and realized in microstrip patch antenna technology. The principle of the operation has been explained via surface current distribution on the structure of the antenna and can be described as the slot loaded microstrip patch operating with $TM_{0x}$ modes. Due to the collinear arrangement of in-phase source current areas, the beamwidth in E plane together with directivity can be enhanced by increasing the order of operational mode together with enlargement of patch resonant dimension. Realization in microstrip patch antenna technology thus causes that the proposed antenna belongs to directive kinds of antennas compared to omnidirectional coaxial types of collinear arrays.

## Acknowledgement

This work has been conducted at the Dept. of Electromagnetic Field of the Czech Technical University in Prague and supported by the grant of the Czech Grant Agency no. 102/04/P131 *Multiband planar antennas with compact-shaped radiators* and by the Czech Ministry of Education project *Research in the area of the prospective information and navigation technologies* MSM 6840770014.

## References

[1] FRANKLIN, C. S. Brit. Patent 242342-1924, 1924.

[2] JUDAZS, T. J., BALSLEY, B. B. Improved theoretical and experimental models for the coaxial collinear antenna. *IEEE Trans. Antennas and Propagat*. 1989, vol. 37, p.289-296.

[3] SOLBACH, K. Microstrip-Franklin Antenna. *IEEE Trans. Antennas and Propagat*. 1982, vol. 30, no. 4, p. 773-775.

[4] ČERNOHORSKÝ, D., NOVÁČEK, Z., Dipole array excited by slots in its coaxial feeder. *Radioengineering.* 2001, vol. 10, no. 4, p. 9-16.

[5] BANCROFT, R., BATEMAN, B.. An omnidirectional planar microstrip antenna. *IEEE Trans. Antennas and Propagat*. 2004, vol. 52, no. 11, p. 3151-3153.

[6] POLÍVKA, M., HOLUB, A. CZ Patent Application PUV 2005-396, 2005.

[7] MAZÁNEK, M., KLEPAL, M., PECHAČ, P., POLÍVKA, M., BARTÍK, H. Anechoic and EMC chambers - modelling, design, testing. In *Proc. of the Millennium Conference on Antennas and Propagation.* Noordwijk, European Space Agency, 2000, vol. 2, p. 156-160.

[8] GARG. R., BHARTIA, P. *Microstrip Antenna Design Handbook.*, Artech House, 2000.