A New Class of Electromagnetically Coupled Printed Antenna Arrays

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Abstract- **We report a new class of electromagnetically coupled microwave printed antenna arrays using three coplanar strip-TCS (CPW with finite narrow ground strips). Two versions of this antenna array are introduced. (1) Antenna array with practically pure omnidirectional radiation pattern in horizontal plane, vertical polarization and gain of 8 dBi. (2) Directional antenna with gain of 14 dBi. Both versions are designed for frequency of 10.5 GHz.**

Keywords - **Printed antenna, Omnidirectional antenna, Directional antenna, TCS-three coplanar strip**

I. Introduction

Modern microwave telecommunication systems like: Earth-satellite, indoor and outdoor wireless LANs, point to multipoint microwave systems and others are very perspective. These systems need antennas with omnidirectional radiation pattern in the horizontal plane, most frequently with the vertical polarization. Omnidirectional radiation pattern was, most often, obtained with using two solutions. The first solution is four panel antennas. The second solution is axial dipoles, which are realized like coaxial structures. However, in the case of using panel antennas one of problems is loss in the linking cable in connection between panel units and power divider. Fabrication of the axial dipoles for higher microwave frequencies is very delicate and complex due to small dimensions. Certainly, planar printed antenna structures with omnidirectional radiation pattern and the vertical polarization would be a valid solution due to simplicity, reproducibility and low price.

Till now, printed antenna and printed antenna arrays was consist of different printed structures for feeding printed radiation elements: microstrip, coplanar waveguide (CPW) and coplanar strips (CPS). In this paper we introduce complete new printed antenna with radiation elements fed by three coplanar strips – TCS (CPW with finite narrow ground strips). Basic antenna structure consist of radiation tapes which is electromagnetically coupled with TCS. Using this structure we introduce very simple and uniplanar omnidirectional printed antenna array, and, also, directional printed array. In this paper we present design, simulation, realization and experimental results of one collinear printed electromagnetically coupled antenna array with omnidirectional radiation pattern, and, also, an example of a directional antenna array using described new concept.

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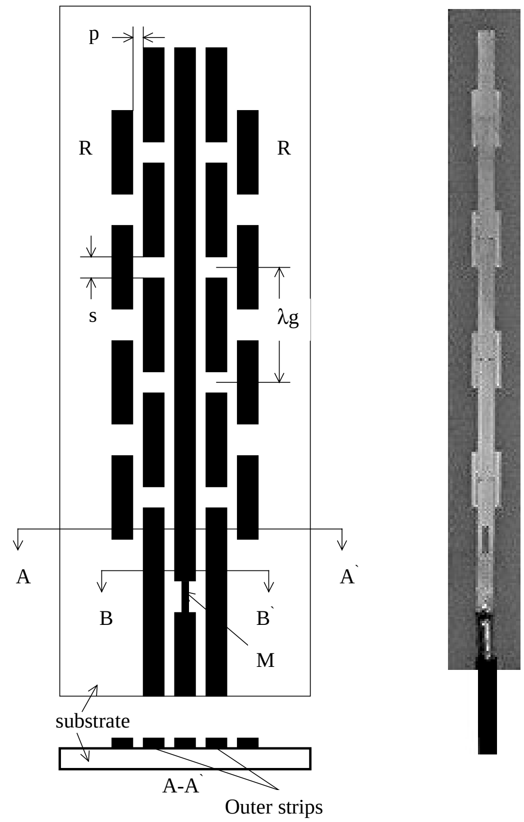

a b

Fig. 1a) Sketch and 1b) photograph of electromagnetically coupled omnidirectional printed antenna array with 4 pairs of radiating elements

II. Concept

Main basic idea for this completely new class of printed antenna is certain analogy between three coplanar strips TCS (CPW with finite narrow ground strips) and coaxial structure. In the ref. [1] a new type of collinear antenna, called electromagnetically coupled coaxial dipole array (CDA) antenna, is proposed. The radiation dipoles of CDA is fed by an annular ring slot which extend radially from the outer conductor of the feeding coaxial cable.

In our case feeding structure of antenna array are TCS instead of a coaxial. Instead of the circular annular ring slot on the outer conductor of the feeding coaxial cable for the electromagnetic coupling with radiating element (circular pipes [1]), we use interruption (slot) of outer strips of TCS (s in Fig.1a). Instead of the circular pipes which act like radiating elements in [1], we use pairs of two symmetrical strips (R in Fig. 1a).

In this way, electromagnetic coupling between feeding line (TCS) and radiating elements (pairs of the symmetrical strips R-R) is realized. The spacing between the radiating elements are all identical and correspond to λg on TCS. If we use dielectric substrate with relative dielectric constant of ε_r between 2 and 4, we have electrical length of TCS, λg, between 0.9 and 0.7 of λ_0. With this distance between radiating elements along TCS line we obtain radiation pattern in the elevation (E-plane) with side lobe suppression of minimum 10 dB [2]. The feeding TCS line, Fig. 1, is open ended.

Second type of antenna designed, using the same concept, is a directional antenna array, Fig. 2. Behind antenna on distance of $\lambda g/4$ there is a reflector plate wider than 5 λ_0. In this case beamwidth in H-plane is about 90^0 and gain are 6 dB more then in case of antenna with omnidirectional radiation pattern.

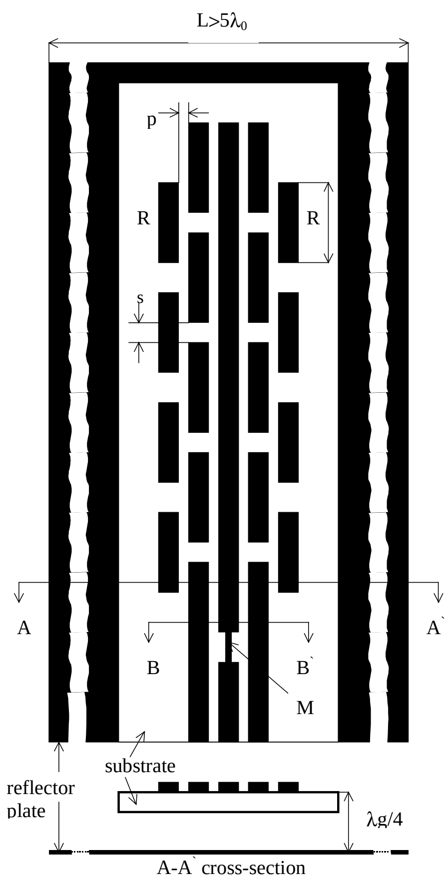

Fig. 2. Sketch of directional printed antenna array with 4 pairs of radiating elements with a reflecting plate

III. Design and realization

Simulation and optimization of the described antenna with omnidirectional radiation pattern shown in Fig.1 has been performed using software package for electromagnetic simulation IE3D [3]. Antenna with omnidirectional radiation pattern are realized on ROGERS 4003 dielectric substrate with relative dielectric constant ε_r=3.38, thickness h=0.2 mm and tan(δ)=$20\cdot10^{-4}$. The width of each three TCS lines is 1 mm with gaps 0.07 mm between them that corresponds to the characteristics impedance of 50 Ω. Initial distance between interruption of outer strips of TCS (i.e. slots) are λg because of the sin-faze excitation of radiating elements. The pairs of the radiating elements, R in Fig.1 are parallel with TCS line and symmetrical in relation to the interruption slots. Width of the radiating elements is 1 mm each.

We obtain final dimensions after simulation and optimization of: the distance between outer line of TCS and radiating elements p=0.2 mm (in Fig.1), the width of the coupling slots s=0.25 mm and the length of the radiating elements R=10.6 mm. In the cross-section B-B', Fig.1, we obtain real impedance of the antenna array of 389 Ω. With $\lambda g/4$ impedance transformer (M in Fig.1), realized also on TCS line (Zc = 137 Ω), we obtain impedance of the antenna array near 50 Ω on frequency 10.5 GHz. A thin coaxial cable (shown in Fig. 1b) is connected to the TCS line and has a SMA connector at the other end.

Simulated radiation pattern in azimuth (H-plane) is shown in Fig.3. Measured radiation pattern is practically same with deviation lower than 1 dB.

Fig. 4 shows simulated and measured radiation pattern in elevation (E-plane). There is some difference between the simulated and the measured results, especially outside the main lobe. The reason is some coupling between the feeding line and the radiating elements. Measured VSWR are shown in Fig.5.

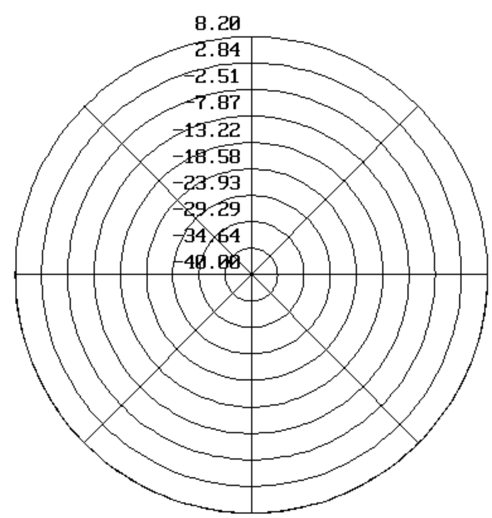

Fig. 3. Simulated radiation pattern of omnidirectional antenna array (H-plane)

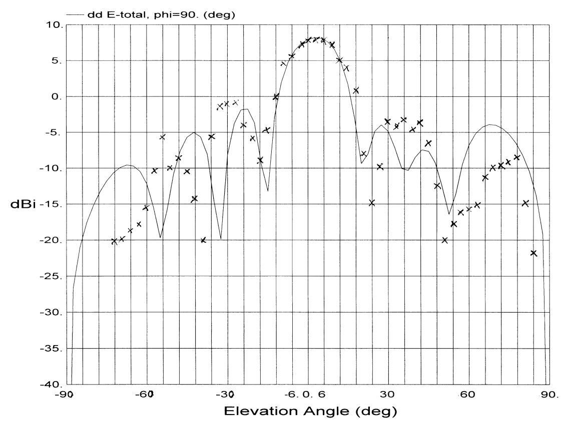

Fig. 4.Simulated (solid line) and measured (X) radiation pattern of omnidirectional antenna array in elevation (E-plane)

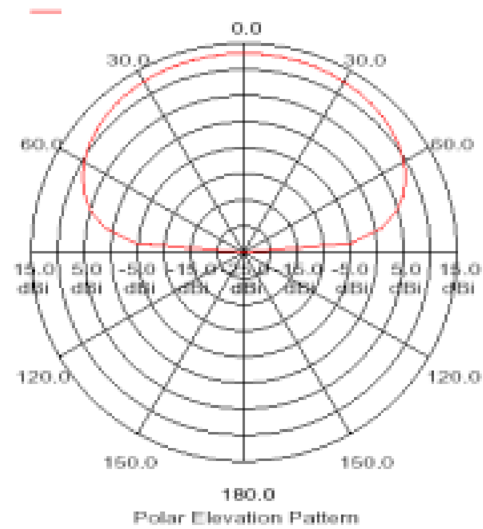

Fig. 6. Simulated radiation pattern of directional antenna array (H-plane)

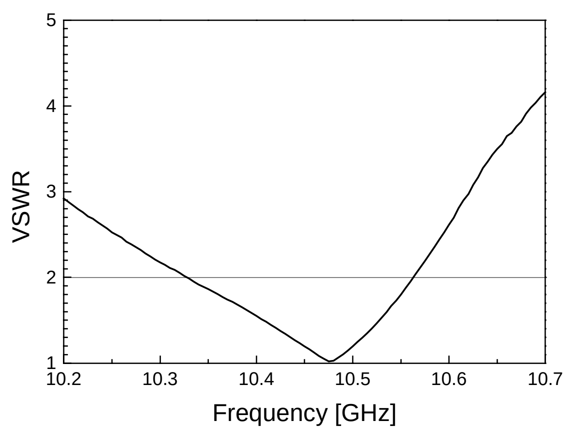

Fig. 5. Measured VSWR of omnidirectional antenna array

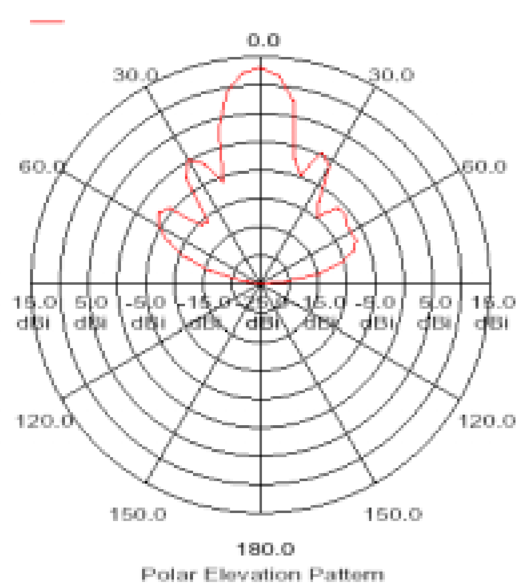

Fig. 7. Simulated radiation pattern of directional antenna array (E-plane)

Directional antenna array, in this moment, is only simulated. Due to influence of reflecting plate on antenna which is primary designed as omidirectional (without reflecting plane), we must make same correction of dimension radiating elements. Simulated radiation pattern in H-plane and E-plane are shown on Fig.6 and Fig.7 respectively.

IV. Conclusion

A new class of very simple and cheap printed antenna arrays with omnidirectional and also directional radiation pattern is introduced. Omnidirectional antenna array with four pair of radiating elements on X band (around 10.5 GHz) is simulated, realized and measured. Obtained omnidirectional characteristic is practically without variation. Obtained gain is 8 dBi and VSWR less than 2 on 220 MHz frequency range.

Directional antenna array designed with same concept (but with a reflecting plate) is simulated and optimized. Obtained gain is 14 dBi. Realization of this antenna is in progress. Concept of presented antenna arrays may be used for frequency from several hundred MHz to about 30 GHz.

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REFERENCES

[1] Miyashita, H., Ohmine, H., Nishizawa, K., Makino, S. and Urasaki, S.: ``Electromagnetically coupled coaxial dipole array antenna``, *IEEE Trans. Antenna Propagation*, vol.47, 1999, pp.1716-1725

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

[3] IE3D, *Zeland Software*, Inc., Fremont, CA 4538, version 4.0