Conductor Backed Coplanar Waveguide Feed Network For A Beam Steerable Star Patch Antenna

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Abstract
A conductor backed coplanar waveguide feed network for a star patch antenna is presented. The feed network matches the input impedance of the antenna to a standard 50Ω line and can switch the location of the antenna feed in order to achieve beam steering.

Keywords: Star Patch Antenna, Beam Steering, Feed Network

1. Introduction

In many modern wireless communication systems, beam steering is achieved with the use of phased array antennas. For applications with space limitation, these antennas are not suitable. As an alternative, a single element spiral antenna with switches was proposed originally [1]-[3]. In that antenna, the current distribution along the spiral arm is modified with the use of switches. The switch connects or disconnects sections of the spiral, or short circuit certain points of the spiral to the ground, leading to different radiation patterns with their main beams in different directions. Unfortunately, this current switching action in the spiral antenna causes polarization randomness. In addition, the antenna gain and VSWR change with the switch configuration. These problems have been overcome with the recent introduction of square loop [4], circular loop [5], and four feed star [6] antennas. In particular, depending on the location of the feed point, the printed star patch antenna is capable of generating a doughnut shape pattern and four different patterns with beams tilted in four different directions [7]-[8]. These tilted beams are the only directional patterns with a dominant E_θ polarization. Thus, a beam steerability is achieved when the antenna generates each of these four tilted beams individually. The star patch antenna is constructed over a stratified dielectric substrate with a ground plane on the opposite side. It was proposed that this ground plane can be used to fabricate a coplanar waveguide (CPW) feed network, embedding the switches, to feed the antenna [9]-[10]. In this paper, the feasibility of this proposal is investigated. To this end, a CPW feed network constructed on the star patch antenna ground plane is presented and it is shown this feed network adversely affects the operation of the antenna. An alternative solution based on a conductor backed CPW network is introduced eliminating the interaction between the antenna and the feed network. In the example treated, the antenna operates within the S band (2.9-3.5GHz) at the centre frequency of 3.2GHz. The performance of the antenna including the feed networks is predicted using Agilent Advanced Design System (ADS, 2009) [11]. The experimental verification of the results was performed using SATIMO starlab antenna test facility [12].

2. Antenna configuration

The star patch antenna is constructed over a stratified dielectric substrate composed of a 1.5mm thick dielectric layer with ε_r = 3.48, and a 10.5mm dielectric layer with ε_r = 3.45 [7]. To maintain the homogeneity of the substrate, the materials are selected to have almost the same dielectric constants. The opposite side of the substrate has a conducting plane. The substrate surface area is 78mm x 78mm.

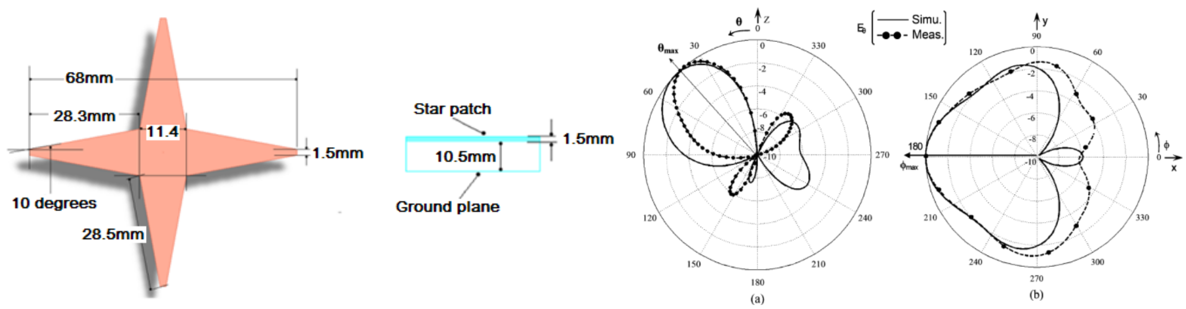

Figure 1: (left) Printed star patch antenna and its dimensions and (right) (a) Elevation cut of E_θ, (b) Azimuth cut of E_θ at Φ_{max} = 180 deg.

Figure 1 (left) shows the configuration of the antenna. In order for the antenna to generate a tilted beam in a particular direction, the feed location must be at the end of a star branch along that direction. The antenna input impedance when fed at this location is about 60-j95Ω [7]. This value was measured at the ground plane of the antenna with a via connecting the patch to an SMA connector. Figure 1 (right) shows the elevation and azimuth cuts of the tilted beam, generated by the antenna under these conditions.

3. Feed network on open CPW

The first feed network uses a CPW circuit [13] fabricated on the ground plane of the antenna. This CPW circuit is not enclosed. Figure 2 shows the shape of the feed network and its corresponding.

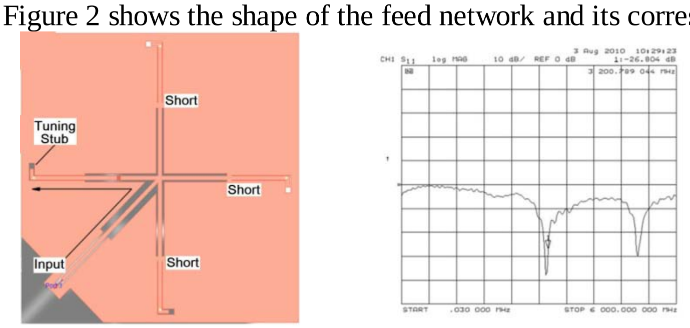

Figure 2. (Left) First proposed feed network, (Right) The measured S_{11} of the antenna fed by this network

measured S_{11}. The input is an SMA connector that connects to the diagonal branch leading to the centre of the feed network, Figure 2. Impedance matching is achieved with the use of quarter wavelength transformers between the 50 Ω line at input and a 60Ω impedance at the start of a feed branch. Matching the 60 Ω branch to the 60-j95Ω antenna input impedance is achieved by using an open circuit shunt stub located at the end of the feed branch, and connected to the antenna through the via. As seen in Figure 2, the signal is directed to one of the branches by shorting the centre conductor of the other three branches to the ground plane at a branch length of approximately $\lambda_g/4$. The -10 dB bandwidth is 400 MHz covering 3 GHz to 3.4 GHz. Figure 3 shows the measured E_θ radiation pattern of the antenna when fed by this feed network. As seen in Figure 3, the antenna radiation pattern does not match the intended pattern in Figure 1 (right) obtained by feeding the antenna directly at one of the feed points (by using a coaxial line) when there is no CPW network on the ground plane.

4. Feed network on conductor-backed CPW

From the investigation presented in Section 3, it is clear that the open CPW feed network has an effect on the operation of the antenna. In other words, the correct operation of the star patch antenna is highly dependant on the current distribution on its ground plane.

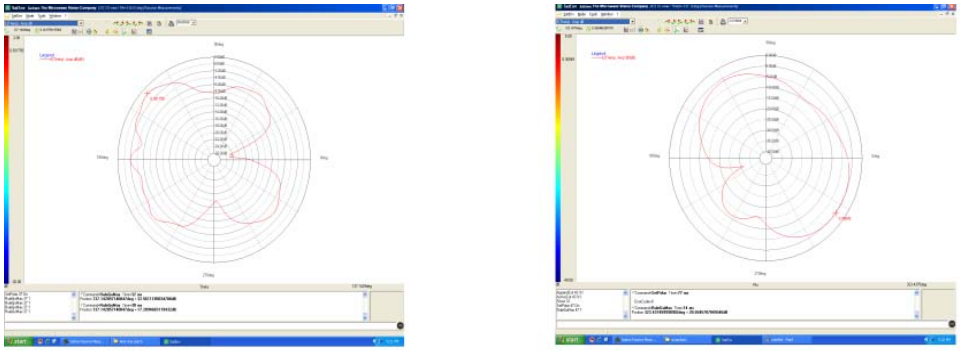

Figure 3: Measurement of E_θ, (Left) Elevation cut, (Right) Azimuth cut

In order to overcome this problem, a new feed network is proposed which uses the concept of conductor backed CPW. This feed network no longer shares the antenna ground plane and is fabricated on a 1.5mm substrate with ε_r = 3.48. A 1.5mm air gap separates the antenna ground plane from the feed network ground plane. The diagonal feed branch is removed to improve the symmetry of the structure and the SMA for the input is connected to the centre of the feed network. In order to minimize the induced current flow on the feed network, each feed branch is only connected (switched) to the input SMA when the respective antenna branch needs to be fed. An additional switch was added to the end of each feed branch (in open circuit position) to prevent the current flow from the antenna returning back into the feed network. Figure 4 shows this feed network and its corresponding measured S_{11}. The radiation pattern of the antenna fed by this new feed network is measured. Figure 5 presents the results. These measurements confirm the feed network no longer interferes with the antenna operation. In addition, by comparing Figures 1 (right) and 5, it is seen that the side lobes in the antenna pattern connected to the new feed network are 7dB lower than the main lobe whereas in the case of the antenna without the feed network, this difference is 5dB. Thus the conductor backed coplanar waveguide feed network improves the radiation pattern generated by the antenna.

5. Conclusions

The correct operation of the printed star patch antenna is adversely affected by the presence of currents due to asymmetry of the open CPW feed network. A conductor backed CPW feed network was proposed having no interaction with the radiation pattern of the antenna. This network satisfies the impedance matching and beam switching requirements of the system. It also improves the ratio of main lobe to sidelobe by 2 dB.

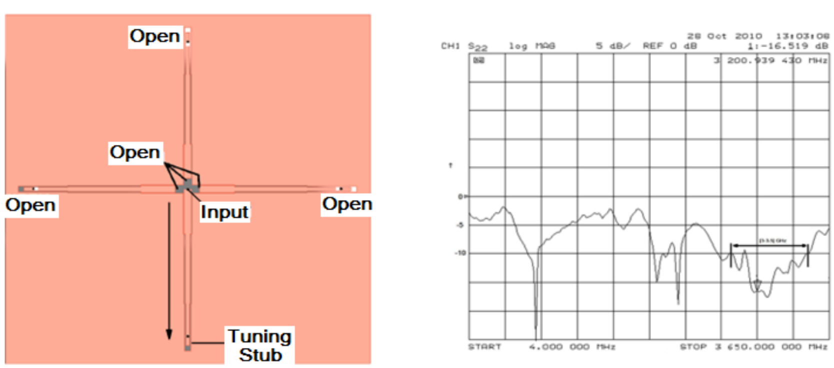

Figure 4. Feed network constructed on conductor backed CPW (left) and the measured antenna S_{11}(right).

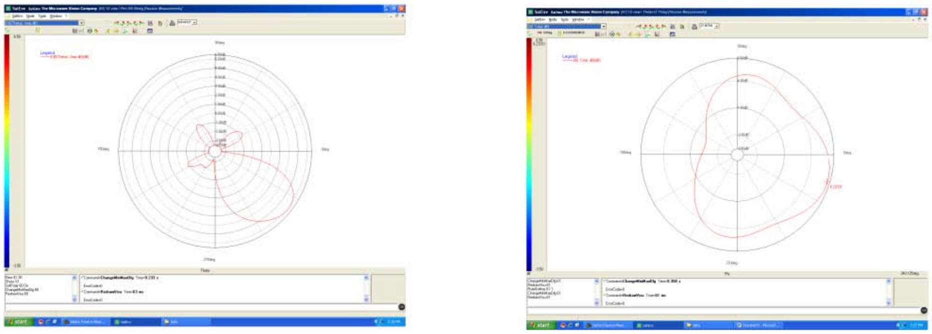

Figure 5 Measurement of E_θ, (a) Elevation cut, (b) Azimuth cut

References

[1] A. Mehta, D. Mirshekar Syahkal, and H. Nakano, "Beam adaptive single arm rectangular spiral antenna with switches," Proc. IEE Microw. Antennas Propag., vol. 153, pp. 13-18, Feb. 2006.

[2] C. Won, M. J. Lee, G. P. Li, and F. De Falviis, "Reconfigurable beam-scan single-arm spiral antenna with integrated MEMS switches," IEEE Trans. Antennas Propag., vol. 54, no. 2, pp. 455-463, Feb. 2006

[3] G. H. Huff and J. T. Bernhard, "Integration of packaged RF MEMS switches with radiation pattern reconfigurable square spiral microstrip antennas," IEEE Trans. Antennas Propag., vol. 54, no. 2, pp. 464-469, Feb 2006.

[4] A. Mehta and D. Mirshekar-Syahkal, "Pattern steerable square loop antenna," IEE Electron. Lett. (IET), vol. 43, no. 9, pp. 491-493, April 2007.

[5] P. Deo, A. Mehta, D. Mirshekar-Syahkal, P. J. Massey, H. Nakano, "Circular loop antenna for pattern steerable applications," IEEE Antennas and Propagation Society Int. Symp. Digest, Charleston, South Carolina, USA, 4 pages, June 2009.

[6] A. Mehta, D. Mirshekar-Syahkal, H. Nakano, "A novel star patch antenna for beam steering applications," IEEE Antennas and Propagation Society Int. Symp. Digest, pp. 5857-5860, Honolulu, Hawaii, USA, June 2007.

[7] A. Mehta, D. Mirshekar-Syahkal, and H. Nakano, " A Star patch antenna for generating multiple radiation patterns," Microwave and Optical Tech. Letters, vol. 50, no. 7, pp. 1908-1910, July 2008.

[8] A. Pal, A. Mehta, D. Mirshekar-Syahkal, and P. J. Massey, "Doughnut and Tilted Beam Generation using a Single Printed Star Antenna," IEEE Trans. Antennas and Propag., vol. 57, no. 10, pp. 3413-3418, Oct. 2009.

[9] M. R. Kamarudin, P. S. Hall, Colombel and M. Himdi, "Switchable disk-loaded monopole antenna array with CPW feeding system," IEEE Antennas and Propagation Society Int. Symp. Digest, pp. 2313-2316, July 2006

[10] X. Liang, S. Zhong, and W. Wang, "Tapered CPW-fed printed monopole antenna," Microwave and Optical Tech. Letters, vol. 48, no. 7, pp. 1411-1413, July 2006.

[11] Advanced Aesign System. Version 2009, Agilent, Palo Alto, California, USA.

[12] SATIMO Starlab Antenna Measurement Facility, Villebon-sur-Yvette, France

[13] C. P. Wen, "Coplanar Waveguide", A surface strip transmission line suitable for nonreciprocal device applications," IEEE Trans. Microwave Theory and Tech., vol. 17, no. 12, pp. 110-115, May 1969.