WIDEBAND MICROSTRIP-FED PRINTED BOW-TIE ANTENNA FOR PHASED ARRAY SYSTEMS

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ABSTRACT: A micro strip-fed printed bow-tie antenna is presented inorder to achieve wide bandwidth, high gain, and size reduction. A comparison between the bow-tie and the quasi-Yagi (dipole and director) antennas shows that the bow-tie antenna has a wider bandwidth, higher gain, lower front-to-back ratio, lower cross-polarization level, and smaller size. Two-element arrays are designed and their characteristics are compared. The bow-tie antenna yields lower coupling for the same distance between elements.

Key words: wideband antennas; printed bow-tie antenna; printed quasi-Yagi antenna

1. INTRODUCTION

Printed microstrip antennas are widely used in phased-array applications because they exhibit a very low profile, small size, lightweight, low cost, high efficiency and easy methods of fabrication and installation. Among the most widely used printed antennas in phased-array systems are printed dipoles and quasi-Yagi antennas fed by coplanar strip line (CPS), which are usually used to yield end-fire radiation patterns. In order to feed this antenna, some researchers suggest microstrip-to-CPS transition that includes a 180° phase shifter [1]. Other researchers feed the dipole with two microstrip lines where the upper is an extension of the microstrip feed line and lower is connected to the ground plane through a tapered microstrip [2, 3]. However, the latter methods suffer from low radiation efficiency (88% in [2]) and low bandwidth (37% in [2] and 19% in [3]). Moreover, unbalanced radiation patterns are noticed in [2] and omnidirectional patterns are obtained in [3]. Other researchers use coplanar waveguide (CPW) -to-CPS transitions to feed printed dipole and bow-tie antennas [4]. However, these two antennas are designed for 100 ohm, not 50 ohm, characteristic impedance, in addition to having an omnidirectional pattern. An attractive design that uses the transition in [1] is presented in [5, 6] and exhibits wide bandwidth and good radiation characteristics.

![Figure 1 Geometry and dimensions of the printed bow-tie antenna](image-url)

The antenna consists of a half-wavelength dipole and an approximately quarter-wavelength rectangular director in order to increase the gain and improve the front-to-back ratio. In this paper, the printed dipole and the director of [5, 6] are replaced by a printed bow-tie, which results in an improvement in bandwidth and gain. That is because printed bow-tie antennas are planar-type variations of the biconical antenna that has wideband characteristics. Moreover, the radiating area of the bow-tie is larger than that of the dipole; therefore, gain
improvement is expected. The simulation and analysis for this new antenna are performed using the commercial software package an soft HFSS, which is based on the finite-element method. The measurements of the return loss and radiation pattern are also conducted.

2. SINGLE ELEMENT

The proposed antenna element is printed on a Rogers RT/Duroid6010/6010 LM substrate with a dielectric constant of 10.2, a thickness of 25 mil, and a conductor loss (tan _) of 0.0023. The microstrip-to-CPS transition is almost the same as that in [1]. The bow-tie geometry and dimensions are shown in Figure 1. The quasi-Yagi antenna [5, 6] is simulated in order to compare it with the new bow-tie design on the same material-type substrate and ground-plane dimensions. The simulated and measured return losses of the bow-tie antenna, compared to those of the quasi-Yagi, are shown in Figures 2 and 3, respectively. According to the HFSS simulation results, the bow-tie shows about 13% improvements in the bandwidth, where it operates from 6.8 to 11.9 GHz with a bandwidth of 54.5%, while the quasi-Yagi operates from 7.9 to 12.1 GHz, with bandwidth of 41.6%. In the measurements, the bow-tie shows about 19.6% improvements in the bandwidth, where it operates from 6.7 to 12.45 GHz with a bandwidth of 60.1%, while the quasi-Yagi operates from 8.2 to 12.5 GHz, with a bandwidth of 41.5%. The copolarized (E) and cross-polarized (E) far-field radiation patterns for the two antennas are computed at 10 GHz. Figure 4 shows the radiation patterns of the bow-tie antennas, while Figure 5 shows the radiation pattern of the quasi-Yagi antenna.

Figure 2 Computed return losses of the bow-tie and the quasi-Yagi Antennas.

The simulation results show that at least 1.3-dB improvement in the gain has been obtained when using the bow-tie. The maximum gain for the bow-tie is around 5.7 dB, while it is around 4.4 dB for the quasi-Yagi. The 3-dB beam width in the E-plane (x-y) is almost the same for both antennas: 106° and 108° for the bow-tie and the quasi-Yagi antennas, respectively. However, in the H-plane (y-z), the quasi-Yagi shows much wider beam width: 108° for the bow-tie and 153° for the quasi-Yagi antenna. The H-plane pattern becomes more focused for the bow-tie, which results in enhanced gain and reduced beam width. As shown in Figures 4 and 5, the computed front-to-back ratio is improved by 1.5 dB, where it is around 14.1 dB for the bow-tie and 12.6 dB for the quasi-Yagi. The cross-polarization level in the E-plane is -22.5 dB for the bow-tie, while it is -20 dB for the quasi-Yagi, and for the H-plane it equals to -23 dB for the bow-tie and -24 dB for the quasi-Yagi, considering only the angles defining by the 3-dB beam width.

3. TWO-ELEMENT ARRAY

Two elements of the bow-tie and quasi-Yagi antennas are simulated and fabricated in order to compare the coupling (S21 in dB) between the array elements. The distance between elements is fixed to 15 mm, which is the free-space half-wavelength at 10
Figure 3 Measured return losses of the bow-tie and the quasi-Yagi antennas.

Figure 4 Computed far-field radiation pattern for the bow-tie antenna at 10 GHz. Photographs of the two-element arrays are shown in Figure 6. Figure 7 shows a comparison of the measured coupling between the bow-tie and quasi-Yagi elements. The coupling is less between the bow-tie elements, as shown in Figure 7, where the coupling improves by an average value of around 4 dB. It is worth mentioning...
That this improved coupling is also associated with antenna-size reduction, as the bow-tie edge-to-edge dimension is 7 mm while that of the quasi-Yagi is 8.7 mm, which gives a 24% reduction. The co- and cross-polarized far-field radiation patterns for two-element arrays of the bow-tie and quasi-Yagi antennas are computed at 10 GHz. Figure 8 shows the radiation patterns of the two-element array of the bow-tie antenna, while Figure 9 shows the radiation pattern of the two-element array of the quasi-Yagi antenna. According to these results, approximately 2-dB improvement in the gain has been obtained with the bow-tie array. The maximum gain for the bow-tie array is around 9.3 dB, while it is around 7.3 dB for the quasi-Yagi array. The 3-dB beam width of the co-polarized pattern in the E-plane is 46° and 48° for the bow-tie and the quasi-Yagi, respectively. The beam width in the H-plane for the quasi-Yagi is 120°, while that for the bow-tie is 90°; these are different from that of the one-element configuration due to the coupling between the elements. The front-to-back ratios also found to be improved, as it is 20.7 dB for the bow-tie antenna array and 11.7 dB for the quasi-Yagi antenna array. The cross-polarization level is also enhanced using bow-tie elements. In the E-plane, the cross polarization level is -29 dB for the bow-tie while it is -26 dB for the quasi-Yagi, and for the H-plane it equals to -26 dB for the bow-tie and -24 dB for the quasi-Yagi.

4. CONCLUSION

In this paper, a printed bow-tie antenna has been designed to replace the dipole and the director in the printed quasi-Yagi antenna configuration. This new bow-tie design provides wider bandwidth, smaller size, higher gain, and smaller cross polarization than the quasi-Yagi, and shows an improvement in the front-to-back ratios for one- and two-element arrays. The design of larger arrays based on this type of antenna is therefore more appropriate for phased-array systems.
Figure 7 Comparison of the measured coupling for two-element arrays of the bow-tie and quasi-Yagi antennas.

![Diagram of coupling comparison]

Figure 8 Computed far-field radiation pattern for the two-element array of the bow-tie antenna at 10 GHz.

![Diagram of radiation pattern]

REFERENCES