Compact quasi-Yagi antenna with folded dipole fed by tapered integrated balun

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Planar quasi-Yagi antennas including a printed balun are designed and experimentally characterised. The parasitic array driver is a folded dipole connected to a parallel stripline. The unbalanced to balanced transition between the input microstrip and the folded dipole terminals is obtained by linearly tapering both the microstrip and the ground plane widths. These printed antennas are more compact and directive than their counterparts based on resonant half-wavelength dipole drivers: indeed, in the presence of one director, the size of the board is about 0.4 $\lambda_0 \times 0.5\ \lambda_0$ and the measured gain is 7 dB.

Introduction: Directive antennas printed on low-cost substrates can be a breakthrough for point-to-point wireless fidelity (WiFi) links on condition of being compact and readily integrable on a circuit board. Printed versions of the Yagi–Uda parasitic array, where the driver is a half-wavelength resonant strip, are widely described in the scientific literature [1–3]. The impedance matching between the input microstrip and the differentially fed radiator can be obtained by means of a microstrip-to-coplanar strip balun [1, 2], but also a less complicated transition between the input microstrip and a parallel stripline (consisting of two broadside-coupled strips) has been proposed [3]. The first solution requires an accurate tuning of the *T*-junction and of the delay line, whereas the second one is simpler but utilises a larger area on the board (roughly $\lambda_0 \times 2\lambda_0$).

Design and simulations: The proposed quasi-Yagi antenna is fabricated around a printed folded dipole: with respect to a standard dipole, this radiator offers the key advantage of a considerably larger input impedance (up to 300 Ω at resonance) and this makes easier the design of the balun for the quasi-Yagi antenna. As an additional benefit, the bandwidth of a folded dipole is wider than that of a standard dipole. The antenna was designed by using CST Microwave Studio and by considering a 1.58 mm thick FR4 substrate ($\varepsilon_r = 4.3$, $\tan\delta = 0.025$). A sketch of the planar folded dipole can be seen in Fig. 1; one arm is on the board top layer and the other is on the bottom layer, whereas the electric contact between the two arms is guaranteed by a metallic via. This antipodal configuration is different from the single side folded dipoles already present in literature [4, 5] and it was chosen because it is compatible with the parallel stripline. The two long sides of the folded dipole have a length of 41.6 mm and two different widths that were tuned to put the resonance at 2.44 GHz.

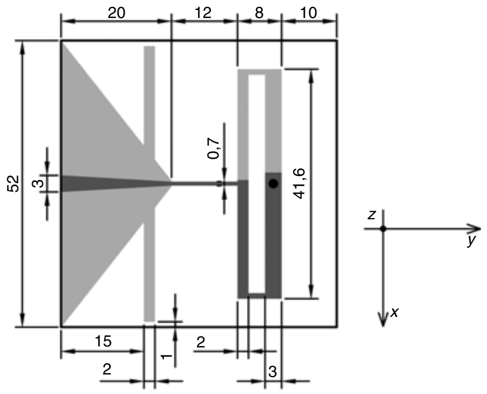


Fig. 1 *Drawing of driver and reflector of quasi-Yagi antenna; dark area indicates top copper layer (half-folded dipole and microstrip), whereas light grey is bottom copper layer (half-folded dipole, reflector and ground plane). Black circle is metallic via. Board total area is about 0.42 $\lambda_0 \times 0.41\ \lambda_0$. Unit of measurement is millimetre*

The solution to match the radiating element to an input 50 Ω microstrip is based on tapering of both the ground plane and the microstrip. The triangular tapering of the ground plane has already been proposed as a simple method to obtain balun for printed dipoles [6] and tapered corporate feed networks [7] have been implemented in arrays of strip dipoles. Our balun is very compact (shorter than $\lambda_0/4$) because of the relatively narrow 3.4% fractional bandwidth required by WiFi: the triangular ground plane has a width of 52 mm, a length of 20 mm and the 3 mm wide microstrip is narrowed down to 0.7 mm, which corresponds to a parallel stripline having a characteristic impedance of 150 Ω. The geometrical parameters of the balun were obtained by simulating a back-to-back transition [8] and tuning the parameters in order to maximise the transmission: the reflection coefficient is smaller than −15 dB in 2.1–2.8 GHz band and the insertion loss is smaller than 0.5 dB. Owing to its triangular shape, the ground plane is not an efficient reflector [1, 2] and therefore it is necessary to add a reflecting element to increase the directivity, i.e. a 2 mm wide metallic strip at a distance of 15 mm from the folded dipole. The full sketch of the quasi-Yagi antenna with the balun and the reflector is shown in Fig. 1: the area occupied on the board is 0.42 $\lambda_0 \times 0.41\ \lambda_0$. The calculated reflection coefficient is depicted in Fig. 2 and the predicted −10 dB bandwidth is about 190 MHz. The computed *E* and *H* plane radiation patterns are plotted in Figs. 3*a* and *b*, respectively: the calculated gain is 6.1 dB (efficiency = 92%).

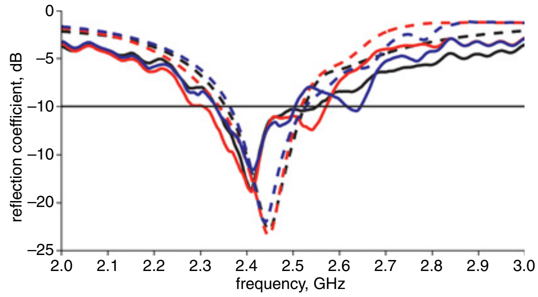
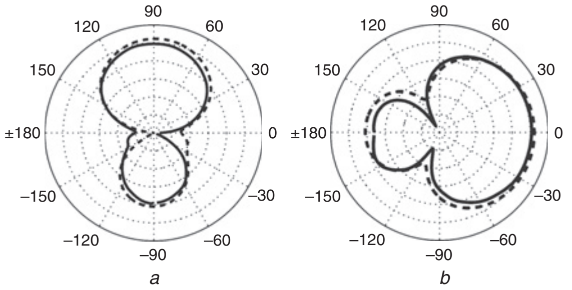


Fig. 2 *Dashed (solid) lines are calculated (measured) reflection coefficients of folded dipole fed quasi-Yagi antenna with no director (black), one director (red) and six directors (blue)*



a

b

Fig. 3 *Dashed (solid) lines are calculated (measured) radiation patterns of folded dipole quasi-Yagi antenna with no director; scale is from −20 to 10 dB (5 dB per division)*

a E-plane: angles are counted from *x* to *y* axis
b H-plane: angles are counted from *y* to *z* axis

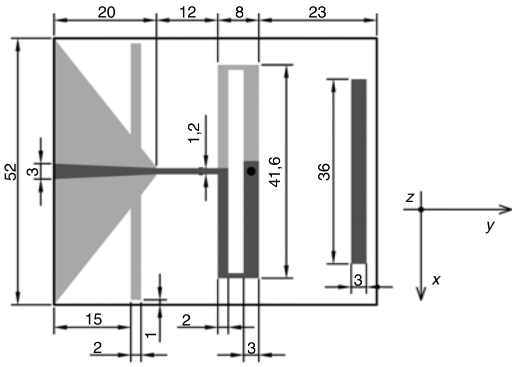


Fig. 4 *Drawing of printed folded dipole fed quasi-Yagi antenna with one director; dark area indicates top copper layer (half-folded dipole, director and microstrip), whereas light grey is bottom copper layer (half-folded dipole, reflector and ground plane). Board total area is about 0.42 $\lambda_0 \times 0.51\ \lambda_0$. Unit of measurement is millimetre*

It is known that the directivity can be enhanced by adding metallic strips acting as directors: the layout for the quasi-Yagi antenna with one (six) director(s) is reported in Figs. 4 and 5. The distance between the driver and the nearest director is only 18 mm and, since the electromagnetic coupling between the driver and the nearest director affects the driver input impedance, it is necessary to tune the balun parameters: the resulting optimal width of the parallel strips is 1.2 mm. Thanks to the addition of one (six) director(s), the calculated gain is increased up to the remarkable value of 7.5 (10.6) dB, as shown in Figs. 6 and 7, and the corresponding efficiency is 90% (88%). One of the advantages of the folded dipole driver is that the bandwidth is not significantly influenced by the number of directors [4].

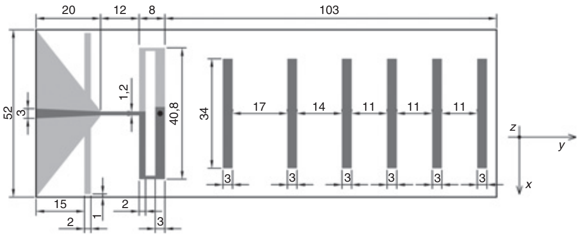


Fig. 5 *Drawing of printed folded dipole fed quasi-Yagi antenna with six directors; dark area indicates top copper layer (half-folded dipole, directors and microstrip), whereas light grey is bottom copper layer (half-folded dipole, reflector and ground plane). Board total area is about 0.42 λ_0 × 1.16 λ_0. Unit of measurement is millimetre*

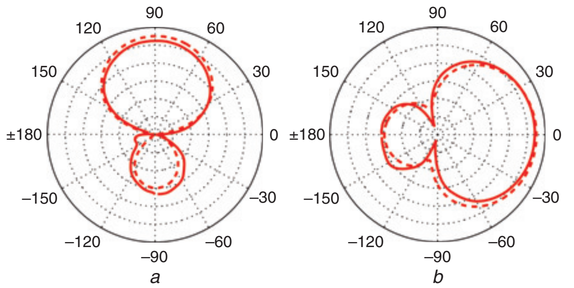


Fig. 6 *Dashed (solid) lines are calculated (measured) radiation patterns of folded dipole fed quasi-Yagi antenna with one director; scale is from −20 to 10 dB (5 dB per division)*

a E-plane: angles are counted from *x* to *y* axis
b H-plane: angles are counted from *y* to *z* axis

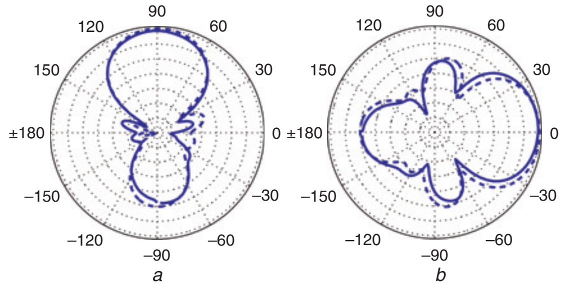


Fig. 7 *Dashed (solid) lines are calculated (measured) radiation patterns of folded dipole fed quasi-Yagi with six directors; scale is from −25 to 11 dB (5 dB per division)*

a E-plane: angles are counted from *x* to *y* axis
b H-plane: angles are counted from *y* to *z* axis

Measurement results: The prototypes were etched on FR4 substrates by using standard photolithography. The reflection coefficients were measured by means of a vector network analyser (Agilent N5230 PNA-L) and the results are reported as solid lines in Fig. 2.

The experiments reveal a slight detuning of the reflection coefficient minimum with respect to the simulations (which is due to the uncertainty in estimating the value of the FR4 dielectric constant) and a bandwidth even larger than the calculated one. The measured radiation patterns (Figs. 3, 6 and 7) show a remarkable good agreement with the numerical predictions; the measured gains are 5.5 dB for the antenna with no director, whereas in presence of one (six) director(s) the gain is 7 (9.8) dB; the measured gains of the fabricated prototypes differ from the numerical values of only about 0.5 dB and we ascribe this discrepancy to dielectric losses higher than expected.

We underline that those gains are larger than the measured values already reported for quasi-Yagi antennas working in the X [1] or WiFi bands [2]. Moreover, these antennas exhibit a high polarisation purity: in fact, the cross-polarisation component is always at least 20 dB less than the co-polarisation component (which is the only one plotted in Figs. 3, 6 and 7).

Conclusion: This Letter presented quasi-Yagi antennas based on folded dipole drivers: gains larger than 5.5 dB (up to 9.8 dB) make these antennas suitable for point-to-point links. The measured 250 MHz bandwidth is large enough for WiFi applications. Moreover, thanks to the good radiation properties and the presence of an integrated balun, these antennas can be used as elementary radiators in planar arrays.

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One or more of the Figures in this Letter are available in colour online.

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