ISSN 2347 - 3983
Volume 9. No. 3, March 2021
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter12932021.pdf
https://doi.org/10.30534/ijeter/2021/12932021

A Comprehensive Review of Different Feeding Techniques for Quasi Yagi Antenna

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ABSTRACT

Yagi Uda antenna is a directional antenna but has limited bandwidth. To improve the bandwidth, various Quasi Yagi antennas can be designed by using different feeding techniques and different element shapes. In this paper, three different types of feeding techniques are reviewed i.e. microstrip-to-coplanar stripline transition (MS-to-CPS), coplanar waveguide feed (CPW) and Tapereded balun, which convert unbalance input to balance output. From the study it is found that MS- to- CPS transition provides higher bandwidth at the cost of low gain and lower front-to-back ratio. CPW is simple feed structure having compact size but lower gain. Tapered balun provides higher bandwidth but requires larger size.

Key words: Quasi Yagi antenna, Microstrip-to-coplanar stripline transition, coplanar waveguide feed and Tapered balun

1. Introduction

Antenna is an indispensable part of any wireless communication system. It plays key role in any wireless communication system. The wireless communication applications have a huge demand of wideband, compact size, low profile, light weight, having simple fabrication and easy integration with other RF components of antenna, especially in mobile communication, satellite communication, radar, radio communication and RFID tags etc [1, 2]. Recently, Quasi Yagi antenna has received huge interest for research because it fulfils aforementioned all requirements. In this paper we have reviewed three feeding techniques for Quasi Yagi antenna and also discussed brief history of Yagi Uda antenna.

Yagi-Uda antenna was invented by Prof. Shintaro Uda of the Tohoku Imperial University in Japan and his colleague Prof. Hidetsugu Yagi in 1926. It consists three elements i.e. reflector, driven and one or more director [1]. Initially, antenna was designed by simple cylindrical wire/rod which is arranged in parallel in line that is shown in figure 1. It was most popular for the home TV antenna in early days but was bulky and heavier. Nowadays, printed Yagi-Uda antennas are also used in the fields of RADARs, satellites, Amateur Radio, power combining, phased arrays, microwave imaging systems and RFID applications [1, 27].

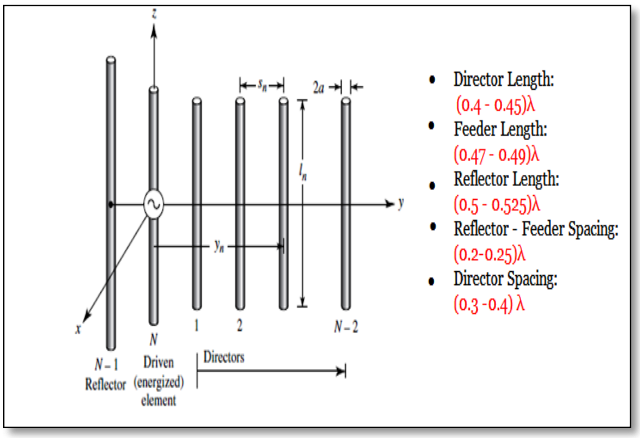

Figure 1: Yagi Uda antenna [1]

Generally, A gain of Yagi-Uda antenna is about 5-8 dB, some of literatures have reported up to 14 - 17 dB by using more number of directors [1, 27, 38]. The main drawback of Yagi-Uda antenna is its limited bandwidth. In recent time Quasi Yagi antenna is designed by using new feeding techniques to achieve the broad bandwidth. To improve bandwidth, various Quasi Yagi antennas can be designed on the basis of different feed structure and different element shapes. Quasi Yagi antenna can be fed by various feeding techniques like; Microstrip to Coplanar stripline transition (MS-to-CPS) [3 - 13], coplanar waveguide feed (CPW) [16-18], Tapered balun [19 - 26], simplified feed [14-15] and coplanar waveguide-coplanar stripline transition (CPW-CPS) [27]. Quasi Yagi antenna can be designed with different shape of dipole elements like; dual dipole [7, 32-34], log periodic antenna [7, 23-24], bowtie structure [9-10], curve shape dipole [18, 29], patch [7, 31], meander shape [7, 28-29] and multi directors [7, 32-37].

In this paper various Quasi Yagi antennas are reviewed on the basis of feeding techniques. Here comparative analysis is done by considering various antenna parameters i.e. Reflection coefficient S11 < -10dB, bandwidth, VSWR< 2, gain and front-to -back ratio that is mentioned in Table 1. The further topics are divided as follows: Section 2 deals with feeding technique and it is divided into three sections; Section 2.1: MS-to-CPS transition, section 2.2: CPW feed and section 2.3: Tapered balun. Finally the conclusion is given in section 3.

2. FEEDING TECHNIQUE

The feeding technique plays an important role for antenna by impedance matching which will lead to maximum power transmission. A driven element of Quasi Yagi antenna is dipole, having balance structure with generally 73Ω impedance. While input source is coaxial feed having unbalance structure with 50Ω impedance so that balun must be designed. A balun is a passive device which acts a transformer, matching an unbalanced transmission line to a balanced line and vice versa. [1, 2, 36-37] The review of three feeding techniques is as follows

2.1 Microstrip-to-coplanar stripline transition

In 1997, Yongxi Qian reported the concept of microstrip-to-coplanar stripline transition [3]. After that, in 1998, Yongxi Qian introduced first Quasi Yagi antenna for X band prototype by using MS-to-CPS transition feeding method [4]. It is shown in figure. 2.

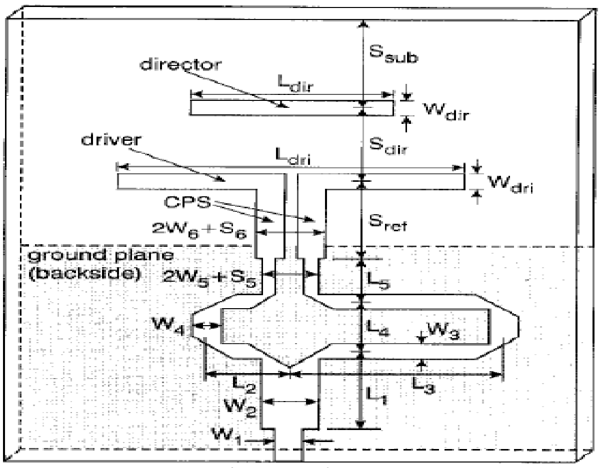

Figure 2: Quasi Yagi antenna fed by MS-to-CPS transition [4]

Figure 2 shows, driver element is fed by MS-to-CPS transition. Driver and director are fabricated at the top of the substrate while ground plane fabricated at the bottom side of the substrate which works as a reflector. The antenna is fabricated on high permittivity thick Duroid substrate with dielectric constant ε_r = 10.2, substrate thickness = 0.635 mm. The feeding structure includes microstrip line, T junction and phase delay structure. The Microstrip line provides impedance matching between input port and T junction. T junction works as power divider/combiner between two branches. Phase delay structure provides 180 degree phase shift to dipole by adjusting length of microstrip line ($L_3 - L_2 = \frac{\lambda g}{4}$). This antenna provides following results: A gain about 6.5dB, bandwidth of 17%, l8dB front-to-back ratio, and less than -15dB cross polarization level at 10 GHz.

In [5], a Quasi Yagi antenna is designed using MS-to-CPS transition feeding method for an X-band prototype. The antenna is fabricated on thick Duroid substrate with dielectric constant ε_r = 10.2, substrate thickness = 0.635 mm. This antenna provides following results: bandwidth of 48% for VSWR < 2, 3-5 dB gain, front-to-back ratio more than 12 dB, cross-polarization lower than -15 dB and 93% efficiency over the operating bandwidth. In this paper a Gain enhanced design of the Quasi Yagi antenna is also presented. In that case, a gain varies between 5–7 dB, front-to-back ratio 15 dB, cross polarization level of -15 dB across the operating bandwidth but 11% bandwidth for VSWR< 2. The increased gain has been achieved at the cost of reduced bandwidth.

In [7], Quasi Yagi is presented and it is fed by MS-to-CPS transition. Antenna is designed in five shapes of driven element: dipole driver (QY), patch driver (PY), meander driver (MEY), log-periodic director array (LGY), and multi-director array (MY). Antennas achieved broad bandwidth for 1.85 to 2.7 GHz, front-to-back ratio about 15 dB for dipole driver, log-periodic configuration and multiple configuration while 10 dB for patch driver and 22 dB for meander shape. Meander shape antenna has achieved 18.18% bandwidth while remaining shape of antennas has more than 42% bandwidth.

In [8], A Quasi-Yagi antenna is designed using a MS-to-CPS transition for 7.5 GHz. It is shown in figure 3. The antenna is fabricated on substrate RT6010 with dielectric constant ε_r = 10.2 and 0.635 mm thickness.

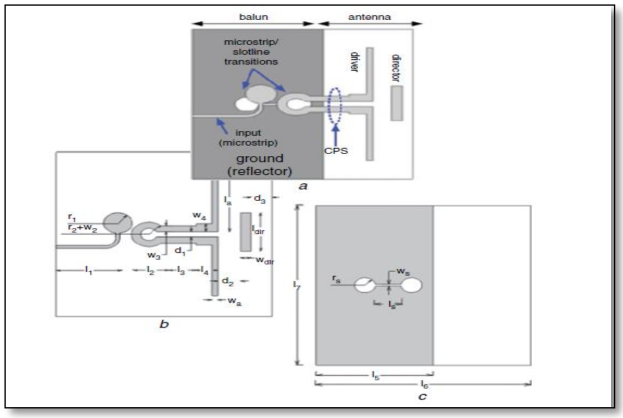

Figure 3: Quasi Yagi antenna fed by MS-to-CPS balun [8]

The feeding structure of the antenna includes microstrip-to-slotline transition, circular microtrip patch, CPS transition and ground plane works as a reflector. The circular microstrip patch at top layer provides impedance matching at input port and also couples signal with circular slots at bottom layer of the substrate. The circular slot at the bottom layer provides signal couple with a CPS at the top layer of the substrate. CPS transition gives equal magnitude and 180 degree phase output to driver element. This antenna provides following results: 70% bandwidth with return loss S_{11} < -10 dB, front-to-back ratio more than 18 dB and around 4 dBi Gain over the operating frequency.

In [9], a Quasi Yagi antenna is presented using bow-tie shape driver element. It is shows in figure 4. It consists three elements; bow-tie shape driver, balun and director. MS-to-CPS transition balun is used. It provides impedance matching at input side and also provides balance output to bow-tie shape driver element. The antenna is designed on Rogers RT 6010 substrate with dielectric constant ε_r = 10.2, substrate thickness = 0.635 mm. The overall size of antenna is 30 mm × 24.24 mm. It achieves the following results: bandwidth of more than 75% (4.70–10.44 GHz) for $S_{11} < -15$ dB and a gain varies between 5.0–9.1 dB over the operating frequency.

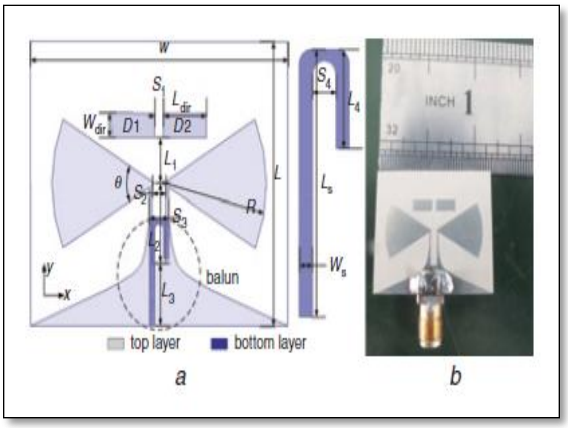

Figure 4: Quasi Yagi antenna using bowtie driven [9]

2.2 Coplanar waveguide feed

MS-to-CPS Transition feeding method has complicated balun structure that is major drawback of the method. This drawback can be overcome by simplified feed method. In [14-15], antenna is designed using a simplified feed structure. Two parallel strips fabricated on top and bottom of the dielectric substrate makes the transmission line, which is used to feed the driven element. It is required to be etched two side of the substrate and also required a large ground plane which works as a reflector. The result is increased size of the antenna which hindrance its use in applications where compact size antenna is needed.

In [16], a broadband Quasi Yagi antenna is designed using coplanar waveguide feed (CPW). It is shown in figure 5. It includes four elements i.e. a driven element, two director elements and a ground plane acting as a reflector. The antenna is designed on a single layer with simple CPW feeding technique which is very compact. The antenna is printed on Rogers RT=6010LM with dielectric substrate with $\varepsilon_r = 10.2$, and a thickness of 0.64 mm. This antenna provides following results: 40% bandwidth for $S_{11} < -10$ dB return loss, Gain varies between 2 dB to 8.8 dB, 13 dB front-to-back ratio measured at 10 GHz.

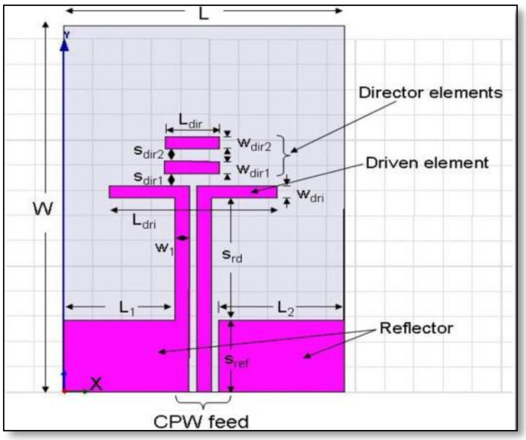

Figure 5: Quasi Yagi antenna fed by CPW feed [16]

In [18], a Quasi Yagi antenna is designed using simple CPW feeding technique for X band prototype. It is shown in figure 6. The antenna is designed in elliptical shape instead of straight shape. This antenna design gives wide bandwidth and compact size but has low gain. This antenna achieves the following results: a bandwidth of 40% for S_{11} <-10 dB, a gain varies between 2.25 - 3.2 dB and 11 dB front-to-back ratio measured at 10 GHz.

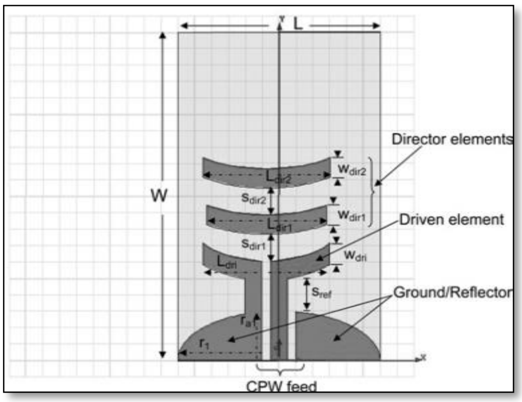

Figure 6: Elliptical Quasi Yagi antenna fed by CPW feed [18]

2.3 Tapered balun

CPW feed structure provides broad bandwidth with compact size of antenna but it is achieved at the cost of reduced gain and low front-to-back ratio [18]. In 1956, R. W. Klopfenstein has given concept of the tapered impedance matching [19]. A tapered balun is formed like a slowly peeled coaxial cable and reshaped until it is a balanced transmission line [20]. There are two type of tapered balun; 1) inline tapered balun 2) Marchand balun. Gradual tapering is required at top and bottom of the conductor in inline tapered balun method. The potential is developed between the conductor ends. Tapering of only bottom conductor is required in Marchand balun. The signal potential is developed across the gap in what is normally the ground plane of a MS circuit [21].

In [22], a quasi yagi antenna using folded dipole antenna as a driven element is presented as shows in figure 7. To feed the driven element tapered balun is used with gradually tapering at top and bottom of the conductor. The antenna is fabricated on low cost FR 4 with dielectric substrate with εr = 4.3, and a thickness of 1.58 mm. For $S_{11} < -10$ dB, the achieved bandwidth and gain are 190 MHz and 6.1 dB respectively. The gain is further enhanced by using six directors which is more than7 dB over the entire bandwidth.

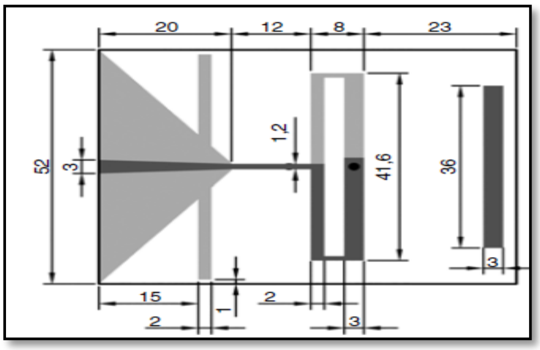

Figure 7: Quasi Yagi antenna fed by Tapered balun [22]

In [23], a Quasi Yagi antenna is designed using tapered balun. This antenna includes reflector, driven element as two-element log-periodic antenna and director. It is shown in figure 8. To feed the driven elements, a tapered balun is designed which provides impedance matching between unbalanced coaxial feed and driven element. This antenna achieves following results: bandwidth of 41.4% for VSWR ⩽ 2, a gain of 6.5dBi ± 0.5 dB and 20 dB front-to-back ratio over the bandwidth.

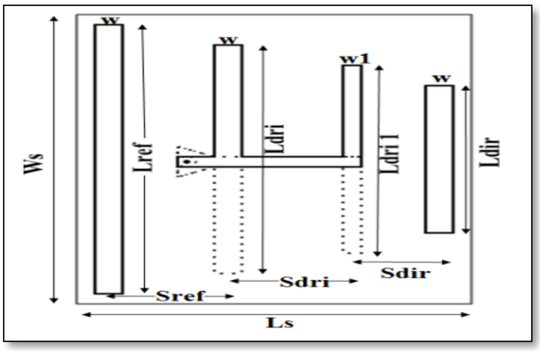

Figure 8: Quasi Yagi antenna using log periodic antenna [23]

In [25], a Yagi-Uda antenna is designed using tapered balun. In this paper two different designs are presented on bases of the shape of driven and reflector elements. It is shown in figure 9 and figure 10.

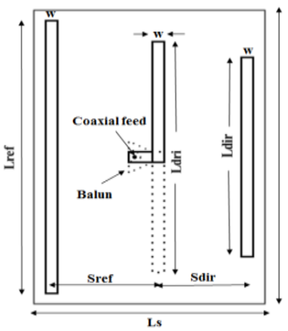

Figure 9: Rectangular shape Yagi antenna [25]

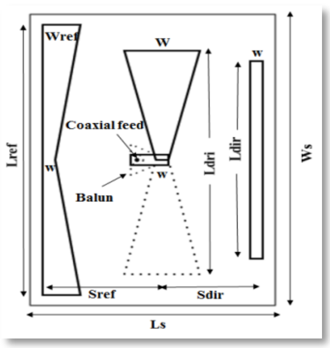

Figure 10: Tapered shape Yagi antenna [25]

In both designs, the driven element is fed by a tapered balun. Design 1 antenna achieved following results: 15.4% bandwidth for VSWR ⩽ 2, gain varies 6.3 dB and front-to-back ratio 18 dB over the bandwidth. Design 2 achieved following results: 18.6 % bandwidth for VSWR ⩽ 2, gain varies 6.4 dB and front-to-back ratio 30 dB over the bandwidth. On comparing both antenna designs, it is found that a tapered shape Yagi-Uda antenna is more compact and has better performance with respect to bandwidth, gain and front-to-back ratio than rectangular shaped Yagi antenna.

3. CONCLUSION

In this paper, three feeding techniques are reviewed for the Quasi Yagi antenna. Following conclusion remarks are for each feeding technique.

- The MS-to-CPS Transition provides broad bandwidth at the cost of the limited gain and low front-to-back ratio. This technique requires complicated balun structure which may degrade the performance of the designed antenna.
- The CPW feed technique is simple feeding structure, not requiring complex balun structure like MS-to-CPS transition. It provides compact antenna structure with broad bandwidth but has limited gain and low front-to- back ratio.
- The Tapered balun provides broad bandwidth, moderate gain and good front-to-back ratio. In this method impedance matching is achieved by gradually tapering of bottom or both side of conductor and that is the difficultly of this technique.

The general observation is: Trade-off must be done among these parameters; bandwidth, gain and front-to-back ratio. If one of the parameter is improved, the performance of the antenna degrades in with respect to other two parameters.

Table 1. Comparison of Quasi Yagi Antenna

Reference paper		**Center frequency (GHZ)**	**% Bandwidth**	**Gain dB**	**F/B dB**	**Substrate, dielectric constant**	**Substrate thickness (mm)**	**No. of element**	**Feeding technique**	**Driven element shape**
[4]		X-band (10)	17	6.5	18	Duroid, ε_r =10.2	0.635	3	MS-to-CPS	Dipole
[5]		X-band (10)	48	3-5	12	Duroid, ε_r =10.2	0.635	3	MS-to-CPS	Dipole
[5]		X-band (10)	11	5-7	15	Duroid, ε_r =10.2	0.635	3	MS-to-CPS	Dipole
[6]		2	35	5.4	13	Substrate, ε_r= 4.12	1.56	3	MS-to-CPS	Dipole
[7]	QY	2.27	43.17	---	15	FR-4, ε_r = 4.8	1.6	3	MS-to-CPS	Dipole
	PY	2.19	41.20	---	10	FR-4, ε_r = 4.8	1.6	3	MS-to-CPS	Patch
	MEY	2.53	18.18	---	22	FR-4, ε_r = 4.8	1.6	3	MS-to-CPS	Meander
	LGY	2.33	42.06	---	15	FR-4, ε_r = 4.8	1.6	5	MS-to-CPS	Log-Periodic
	MY	2.33	42.06	---	15	FR-4, ε_r = 4.8	1.6	5	MS-to-CPS	Multi-Director
[8]		7.5	70	4	18	RT6010, ε_r = 10.2	0.635	3	MS-to-CPS	Dipole
[9]		7.6	75	5.0–9.1	------	RT6010, ε_r = 10.2	0.635	3	MS-to-CPS	Bowtie
[16]		X-band (10)	40	8.8	13	RT6010, εr = 10.2	0.64	4	CPW feed	Dipole
[17]		X-band (10)	44	7.4	15	RT6010, εr = 10.2	0.64	4	CPW feed	Dipole
[18]		X-band (10)	40	3.2	11	RT6010, εr = 10.2	0.64	4	CPW feed	Dipole
[22]		2.44	7	6.1	----	FR-4, ε_r = 4.3	1.58	3	Tapered balun	Folded

[23]	1.45	41.4	6.5 ± 0.5	20	FR-4, $\varepsilon_r = 4.4$	1.6	3	Tapered balun	Log-Periodic
[25]	1.3	15.4	6.3	18	FR-4, $\varepsilon_r = 4.4$	1.6	3	Tapered balun	Dipole
[25]	1.29	18.6	6.4	30	FR-4, $\varepsilon_r = 4.4$	1.6	3	Tapered balun	Tapered
[15]	10	40	---	15	RT6010LM, $\varepsilon_r = 10.2$	0.64	3	Simplified	Dipole
[30]	4.9	40.81	6.5 – 8.0	------	RTDuroid 6010, $\varepsilon_r = 10.2$	0.635	4	CPS feed	Dipole
[31]	3.22	85.5	4.5 - 9.3	10	FR-4, $\varepsilon_r = 4.4$	1.6	8	Microstrip-Fed	Patch

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