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Printed Wide-slot Antenna Structures for Wideband Wireless Applications: Progress in Last Decade

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Abstract:- This paper mainly focuses on the advancements in the printed wide-slot microstrip antenna structures designed for wideband operation. Initially, the discussion starts with the introduction of the microstrip patch antenna structures having single printed wide-slot for wideband wireless applications. Since the size of the wide-slot is decided by the lower cutoff frequency, hence several techniques to minimize the overall size of the antenna have been discussed. Following to this, the discussion about the wide-slot antenna structures supporting circular polarization operation is performed. The comparison of all the wide-slot antennas on the basis of several parameters including return loss bandwidth (RLBW), physical and electrical dimensions and complexity is also performed. This exercise will prove helpful to the antenna researchers which are working on wideband behaviour as such kind of work is not openly available in the literature as far as author's knowledge is concerned.

Keywords: Printed wide-slot, wideband, return loss bandwidth, circular polarization.

1. Introduction

In last few decades, the improvement in the wireless technology has changed our lives drastically. The advancements in other fields apart from the field of wireless or electromagnetics, including very large scale integrated circuits (VLSI), mobile communications has shrunk the size of the wireless devices. With the compactness in the wireless devices, the space availability for antenna gets also shrunk. This poses a challenge to the antenna researchers to devise such antenna structure that not only take less size but at the same time also supports the high data rates and multiple frequency bands (multi-configurability). Microstrip patch antennas (MSPAs) being low-profile in nature, are generally preferred over conventional antenna structures. MSPAs can be easily integrated with other microwave devices and easy to fabricate in bulk. But their operation is inherently affected by their narrow bandwidth operation. Also, they have low gain and have high cross-polarization levels.

In this paper, a review of printed wide-slot antennas of different shapes and configurations has been carried out based on the data available in the previously published articles. The organization of the paper is as follows: Section 2 discusses about the basic definition of the wide-slot antenna. Followed by this, the wideband nature of the MSPAs with single wide-slot has been discussed. To minimize the overall dimensions and supporting of lower resonating frequencies, different wide-slot structures are etched from the ground plane. In the next subsection, wide-slot antenna structures supporting circular polarization are discussed. Finally, Section 3 gives the conclusion of this review article. A comparison table in each subsection is also included for comparing the wide-slot antenna structures.

2. LITERATURE REVIEW

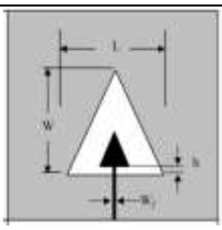
2.1 Definition

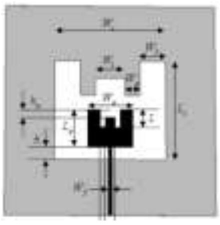
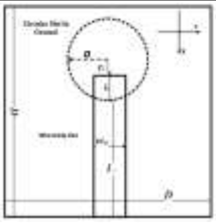
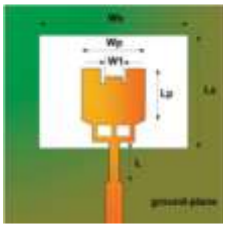
Wide-slot antennas are the antennas where the size of the slot is comparable to the operating wavelength. Nowadays, several printed wide-slot antennas are widely used in wireless applications because they generate two orthogonal modes that are eventually merge and produce wide bandwidth (technically termed as return loss bandwidth, RLBW measured for 10-dB return loss). They are superior to their co-planar waveguide and narrow slot counterparts in the sense that they produce exceptionally wide RLBW along with low cross-polarization [1].

2.2 Single wide-slot based antenna configurations

Wide-slots of different shapes such as triangular [2], E-shaped [3], circular [4, 5], rectangular [6] have been proposed in the literature. In [2], two wide-slot antennas, one having semi-circular and other having triangular shaped have been proposed. An E-shaped wide-slot having a similar radiating structure is proposed in [3] produces a RLBW of about 120% ranging from 2.8-11.4 GHz. A simple circular wide-slot antenna with arc-shaped slot and parasitic strip fed by using calabash-shaped feeding patch is discussed in [4]. Another circular wide-slot antenna fed by using microstrip-line is proposed in [5] shows RLBW of 56.67% (or 9.8-17.55 GHz). A rectangular wide-slot antenna integrated with slotted microstrip patch antenna for obtaining high polarization purity is discussed in [6]. The proposed antenna shows bandwidth of 163% over the frequency range 2-19.95 GHz with extremely low cross-polarization level of below -50 dB.

Table 1: Comparison of single wide-slot antenna structures

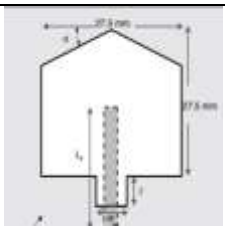
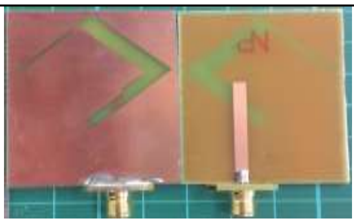
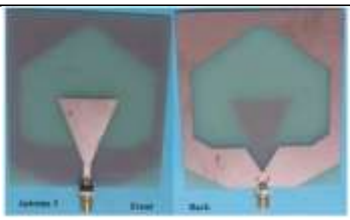
Ref./Year	Proposed wide-slot structure	Size (mm×mm)	Shape of the wide-slot	Shape of the radiating	RLBW	
					Range (GHz)	%
[2]/2004		110×110	Triangular	Triangular	2.42-8.48	110

[3]/2008		85×85	E-shape	E-shape	2.8-11.4	120
[4]/2011		32×35	Circular	Calabash-shaped	2.91-11.45	118.94
[5]/2014		36×36		Open ended microstrip-line	9.8-17.55	56.67
[6]/2010		80×70	Rectangular	Slotted rectangular	2-19.95	163

2.3 Hybrid wide-slot based antenna configurations

The main drawback of using a wide-slot structure for obtaining wide RLBW is their size. At lower resonating frequencies, the size of the wide-slot is large, i.e., unfit for modern wireless applications where high degree of compactness is required. To overcome this issue, either several wide-slots of different shapes and sizes (or hybrid wide-slot antennas) are merged together or a parasitic of similar or different shape is placed inside the wide-slot. In [7], a combination of an irregular pentagon and a short square produce the RLBW of 7.5 GHz, ranging from 3.1 GHz to 10.6 GHz. A similar wide-slot antenna with modified radiating patch is proposed in [8]. In [9], a heptagonal wide-slot having similar smaller slots at its corners is proposed. This technique minimizes the overall dimensions of the antenna hence, leading to miniaturization. The proposed antenna shows the operating frequency range from 1.87 GHz to 5.90 GHz. A rhombus shaped wide-slot antenna with offset microstrip-line feed with truncated corners is presented in [10] shows RLBW of 108.2% (2.21-7.42 GHz). A miniaturization of 52% is reported in [10]. An irregular polygonal shaped wide-slot with triangular notch is shown in [11] gives the RLBW of 127.55% ranging from 1.15 GHz to 5.2 GHz. A wide-slot with a combination of trapezium and rectangle discussed in [12] with reconfigurable feature for excluding WLAN/WiMAX applications provides the RLBW of 2.7-8.8 GHz. A microstrip antenna with a Y-shaped radiator proposed in [13] gives the 10-dB return loss from 2.8-12.4 GHz with trapezoidal wide-slot with two smaller rectangular slots. Another Y-shaped radiator with tapered edges integrated with a rounded square wide-slot discussed in [14] shows a wideband behaviour where the RLBW reaches from 148.60% (0.9-6.1 GHz).

Table 2: Comparison of hybrid wide-slot antenna structures

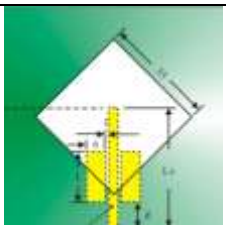
Ref./Year	Proposed wide-slot structure	Size (mm×mm)	Shape of the wide-slot	Shape of the radiating	RLBW	
					Range (GHz)	%
[7]/2008		40×50	Irregular pentagon with a small square slot	Open ended microstrip-line	3.1-10.6	109.45
[8]/2013		28×28	Trapezium + rectangle	U-shaped slotted rectangular patch with T-shaped strip	2.4-2.85, 3.1-10.6	17.14, 109.45
[9]/2009		-	Heptagonal with similar slots at the corners	Open ended microstrip-line	1.87-5.90	103.73
[10]/2014		37.4×54	Rhombus shaped	Open ended microstrip-line	2.21-7.42	108.20
[11]/2017		70×70	Irregular polygonal shaped	Microstrip-line with Y-shaped tuning element	1.15-5.2	127.55
[12]/2017		20×20	Tapered rectangular shaped	Fork-shaped	2.7-8.8	106.09

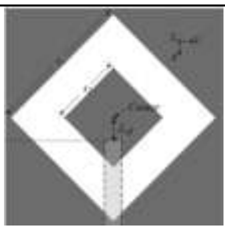
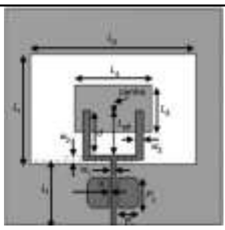
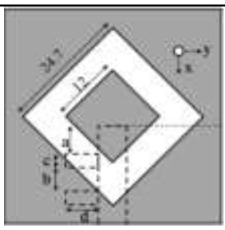
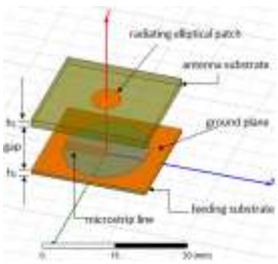
[13]/2017		25×25	Trapezoidal	Y-shape	2.8-12.4	126
[14]/2019		220×220	Tapered rectangle	Fork shaped	0.9-6.1	148.60

2.4 Wide-slot antenna structures with parasitic elements

To further enhance the RLBW for supporting lower frequencies of operation, a parasitic element of similar shape as that of the wide-slot or of different shape are used. Not only with the wide-slot, parasitic elements along with the radiating geometry can also be used. In [15], two rectangular parasitic elements are placed along the open ended microstrip-line hence, supporting both WLAN and WiMAX applications ranging from 2.13 GHz to 6.17 GHz. Another rectangular slotted wide-slot antenna discussed in [16], fed excited by using a microstrip-line integrated with a hexagonal feeding stub and rectangular parasitic element for better impedance matching, shows a wideband operation from 3.1 to 11.5 GHz. In [17], a rotated square wide-slot with similar parasitic patch placed inside it produces the RLBW of about 80% (2.23-5.35 GHz). In [18], two types of parasitic elements are used for obtaining wideband frequency response. One rectangular parasitic element is placed inside the similar wide-slot while the other one is placed along the Y-shaped microstrip-line. Antenna structure similar to [17], when integrated with the matching stubs (added in the microstrip-line) shows exceptionally large bandwidth of 7.26 GHz (2.38-9.64 GHz) [19]. An elliptical wide-slot with similar rotated parasitic patch is proposed in [20] where RLBW of 91.63% (from 3.84 to 7.78 GHz) is reported just rotating the parasitic elliptical patch by 45°.

Table 3: Comparison of wide-slot antenna structures with parasitic elements

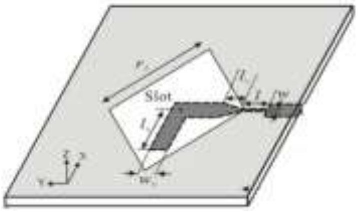
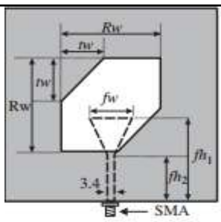
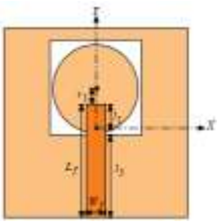
Ref./Year	Proposed wide-slot structure	Size (mm×mm)	Shape of the wide-slot	Shape of the radiating	RLBW	
					Range (GHz)	%
[15]/2008		70×70	Rotated square	Open ended microstrip-line	2.13-6.17	97.35

[16]/2012		22×22	Slotted rectangular	Microstrip-line with hexagonal feeding stub	3.1-11.5	115.07
[17]/ 2012		37×37	Rotated square	Open ended microstrip-line	2.23-5.35	82.32
[18]/2015		44.3×44.3	Rectangular	Y-shaped fork like	2-13.5	148
[19]/2016		37×37	Rotated square	Open ended microstrip-line	2.38-9.64	120.80
[20]/2017		25×24	Elliptical	Open ended microstrip-line	3.84-7.78	67.82

2.5 Circularly polarized wide-slot antenna structures

Circular polarization operation of antennas becomes a necessity when the transmitter and receiver antennas are not present in line-of-sight. Also, it helps in combating fading issues in wireless scenario. Circular polarization in wide-slot antenna structures can be introduced by modifying either the wide-slot or radiating element geometry. In [21], a rotated square-shaped wide-slot with inverted L-shaped tapered microstrip-line is proposed. The RLBW of about 48% along with the axial-ration bandwidth (ARBW) of 42% is reported. By tapering the edges of a square slot (thereby making it a hexagonal shaped), RLBW and ARBW of 48.9% and 17%, respectively have been obtained in [22]. Another circularly polarized semi-circular antenna with open C-shaped wide-slot shows 107% RLBW and 40% ARBW is proposed in [23]. By placing a circular parasitic patch inside the square shaped wide-slot, circular polarization operation can be obtained in [24]. In [25], an elliptical wide-slot is rotated by 45° to bring the circular polarization and gives the RLBW of more than 120.57% (8.59 - >20 GHz) with an ARBW of 34.39% (8.78-12.15 GHz). Several multilayered configurations are also published in the literature to introduce the circular polarization in them. In [26], a circular wide-slot with circular parasitic patch is proposed where both are fed with the help of the L-shaped tapered microstrip-line.

Table 3: Comparison of wide-slot antenna structures with parasitic elements

Ref./Year	Proposed wide-slot structure	Size (mm×mm)	Shape of the wide-slot	Shape of the radiating	Bandwidth	
					RLBW (GHz; %)	ARBW (GHz; %)
[21]/2012		100×100	Rotated square	Tapered inverted L-shaped microstrip-line	(1.68-2.76; 48)	(1.7-2.61; 43)
[22]/2013		60×60	Tapered hexagonal	Tapered non-uniform microstrip-line	(3.52-5.8; 48.9)	(4.3-5.1; 17)
[23]/2014		30×55	Open C-shaped	Semi-circular	(2.3-7.6; 107)	(4.1-6.2; 40)
[24]/2015		32×32	Square	Open ended microstrip-line	(6.48-9.5; 37.79)	(6.72-6.89; 2.79) and (8.73-9.22; 5.46)
[25]/2019		20×32	Ellipse	Open ended microstrip-line	(8.59-20; 120.57)	(8.78-12.15; 34.39)

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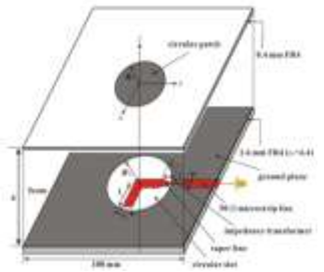
[26]/2008		100×100	Circular	Inverted L-shaped tapered slot	(2.24-2.82; 22.93)	(2.45-3.37; 31.62)

3. CONCLUSION

This review paper has addressed the performance of wide-slot antenna structures designed for wideband/ultra-wideband (UWB) applications. Almost all the configurations of the wide-slot antennas, i.e., when singly used, with two or more wide-slots (hybrid form) and intently designed for circular polarization operation. It has been observed that the wide-slot antenna structures not only provide large RLBW but also produce low cross-polarization (or high polarization purity) and high gain as compared to their MSPAs used in conventional form. The authors hope that this review article the researchers working for the betterment of their bandwidth especially using wide-slot structures.

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