Asymmetrical-fed RHCP Wide-Band Slot Element for X-Band applications

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Abstract- **An outstanding square slot element, for X-band wireless applications with asymmetric coplanar waveguide fed (CPW) is proposed. Various shapes of metallic strips are utilized as grounded stubs for providing Right Hand Circular Polarization (RHCP) functionality and wide-band properties. By adjusting the proposed stubs and hook-shaped radiator, length and positions, wider impedance band width is obtained in X-band. In addition, asymmetric feeding technique is employed with semi-hook shaped radiating patch for efficient impedance matching and generating new resonances. By using rectangular slot and semi-hook shaped radiator good impedance matching is achieved in frequency band. Besides that, by introducing strips in ground plane, RHCP is achieved in X-band. The antenna size is only about 25 × 25 × 1 mm^3, which covers the band from 6.5-12.9 GHz for S11 < -10dB. In addition, by variation of stubs' size and hook shaped patch parameters, the axial ratio (AR) and impedance bandwidths and resonances are controlled. The AR bandwidth of element covers from 9.5 to 11.8GHz. Both simulated and measured results are evaluated and compared to certify element's efficient characteristic.**

Index Terms-, Element circularly polarized, Left Hand, Right hand, Wide-band

I. INTRODUCTION

Recently, Circularly polarized (CP) wide-band element has been utilized in microwave subsystems and handheld devices in wireless systems, because of high isolation and desirable radiation performances [1-4]. CP attribute is significant because of resistance in weather degradation and the independence of signals orientation between transmitter and receiver [3-5]. Besides that, multi-pass fading that causes to degrade right handed CP (RHCP), is not a subject if receiver and transmitter antennas are CP [5-9]. In addition, wireless communication technology needs small elements for wireless subsystems. Miniaturized elements have intrinsic features, such as, narrow bandwidth and bad radiation characterestics. Square slot and asymmetric feeding method are one of the outstanding techniques in this issue in order to have efficient performance, good impedance matching and steering

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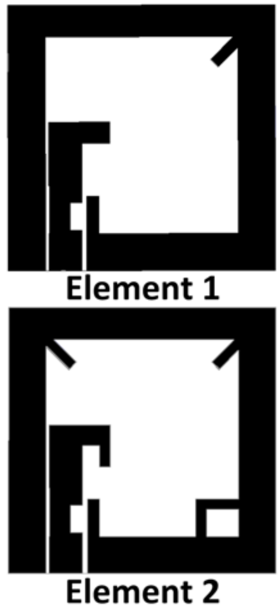

Fig. 1. Design process of ultimate RHCP X-band Elements.

RHCP [3]. The basic design of symmetric CP square slot antenna element are introduced in several scholars that they are studied as follow: 1) etching spiral form slot in ground surface [3]. 2) Inserting Arc-Shaped grounded strip [4-5]. All of the methods suffer from poor impedance tuning and polarization purity due to the generation of cross-polarization. Asymmetric feeding is the distinctive characteristics of CPW fed method which leads to have excellent impedance matching and RHCP control. A square slot RHCP element is capable to get more spatial dimension that leads to efficient power transition to far field space. Multi-bands element based on asymmetric structures and square slot have been introduced for obtaining broader bandwidth but none of them have obtained efficient impedance tuning and RHCP features [6-12]. Although these conventional elements are bulky and have poor impedance matching in bandwidth without RHCP attributes.

This paper propose a unique square slot RHCP element to repress the cross-polarization level (CPL), but here unlike the conventional element, asymmetric fed instead of symmetric fed is utilized. The feed-line is cut in rectangular form to improve impedance matching. The asymmetric method is employed on square slot element for generating strong resonances to have element with wide-band functionality. In corners of square slot different grounded stubs are implemented in order to balance the current distribution and enhance CPL. The proposed element obtain, wider impedance matching and axial ratio bandwidths (ARBW), it also maintain a high CPL over the band. It is interesting to note that, RHCP is obtained more than 50% of X-band. The element radiation performance is enhanced very well, compared with previously published papers [1-6], i.e., the ARBW & impedance BWs are broader than previous works [1-8]. The proposed element is smaller than previously

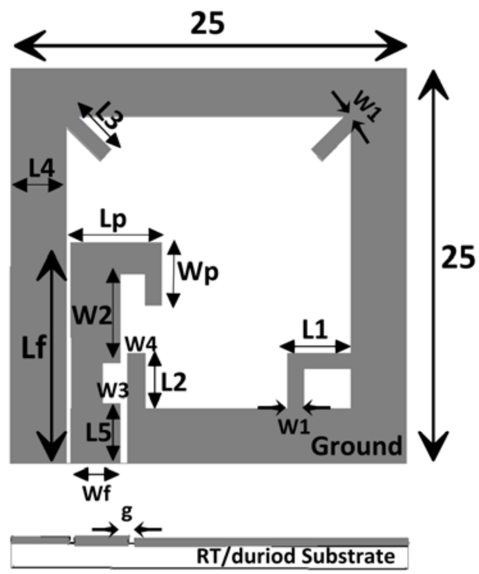

Fig. 2. Geometry of the proposed Asymmetrical-fed RHCP element.

published elements [1-5]. The prototype of element is fabricated and measured in Microwave & Antenna Research Center of Islamic Azad University Urmia Branch to certify simulation results. The average gain of element is relatively good about 5dBi in X-band.

II. ELEMENT DESIGN

The design process of ultimate element is depicted in Fig. 1. As exhibited in Fig. 1 there are steps for achieving final scheme:

Step 1) Asymmetric square slot with modified rectangular CPW-fed is introduced

Step 2) Rectangular patch and two grounded stubs are inserted to previous step

Step 3) another grounded stub, L-shaped strips and rectangular radiator are attached to previous step

The geometry of miniaturized RHCP square slot wide-band element is illustrated in Fig. 2. The element consists of a ground conductor square loop with side length of 25 mm. the grounded L-shaped and different rectangular optimized stubs are attached to excite two orthogonal modes with same amplitudes. The grounded stubs' size and positions have important role for obtaining broader ARBW. In addition, rectangular slot is cut from feed-line in order to enhance impedance tuning. The 50 Ω characteristic impedance is tuned for asymmetric method with length (L_f = 15 mm) and width (w_f = 2.2 mm). The gap between asymmetric feed-line and ground is g = 0.4 mm. The hook-shaped radiator with different size is employed to generated two separate resonance mode to achieve dual band functionality (See Fig. 3). It is understood from Fig. 3 that hook-shaped radiator causes to generate direct current path to produce the resonance stronger. Also, The L-shaped and diagonal stubs

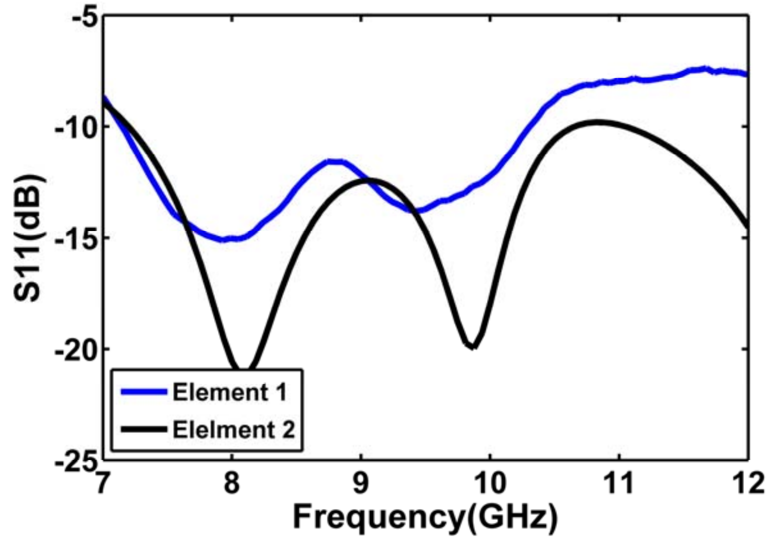

Fig. 3. S_{11} for different schemes of element 1 & element 2.

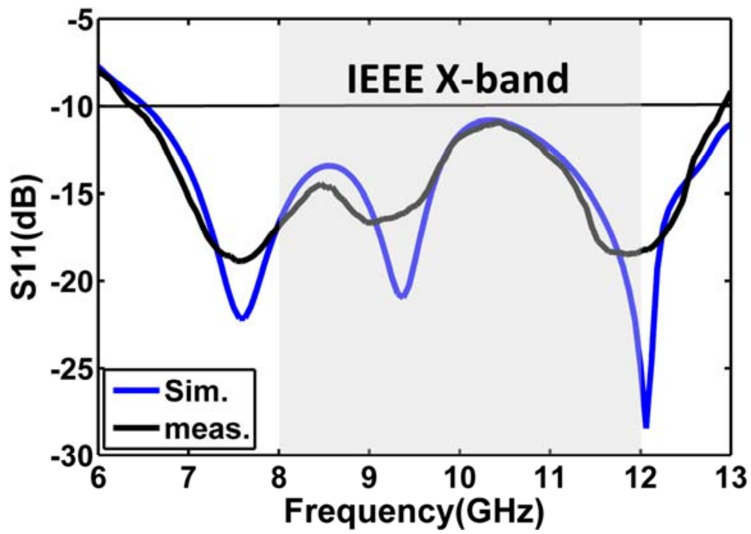

Fig. 4. S11 for RHCP wide-Band Element with parametric optimization.

have great role for resonance of X-band. The polarization purity and RHCP can be steered by changing length and size of the attached stubs on sides of ground loop conductors. The Ansys high frequency structure simulator was used for simulation of elements performance and the realized prototype of element was measured by using Agilent 8722ES network analyzer. The volume of compact element is only about 25 × 25 × 1 mm^3 which is printed on RT/duroid 5880 substrate, with Permittivity of 2.2. It is optimized by parametric study procedure. The optimized dimensions values are as follows: L_1 = 4.1 mm, L_2 = 3.9 mm, L_3 = 3.7 mm, L_4 = 3.4 mm, L_5 = 3.9 mm, W_1 = 1.1 mm, W_2 = 5.4 mm, W_3 = 1.4 mm, W_4 = 1.5 mm, L_p = 5.8 mm, W_p = 4.3 mm.

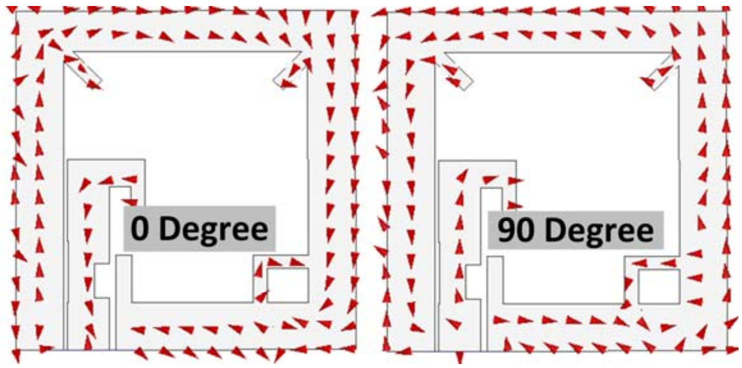

Fig. 5. Distribution of the surface current on the feed and ground of the structure at 10.5 GHz in 0^o & 90^o phases.

III. MEASUREMENT AND SIMULATION RESULTS

The measured results of fabricated element (Element 2) are illustrated in this section. The return-loss of element design procedure is shown in Fig. 4. It is understood, by employing different grounded stubs, the matching of element at both bands are enhanced. By inserting stubs and the L-shaped stub, the X-band is achieved. The element covers from 6.5-12.9 GHz in X-band (industrial band application) for VSWR<2. The size of hook-shaped radiator, the positions of stubs, increases impedance BW. By changing the position of stubs in optimization process, the lower edge and higher edge of the band are tuned to have complete frequency coverage. The Agilent Network analyzer is used to measured returnloss for element 2 which it is shown in Fig. 4. It is deduced that the X-band bandwidths is obtained completely. The small differences in the results are ascribed to non-ideal SMA connection. The ultimate element (element 2) has relatively good impedance and axial ratio bandwidths while no reduction in gain functionality. Fig. 5 depicts Distribution of the surface current on the feed and ground of the structure at 10.5 GHz in 0^o & 90^o phases. Fig. 6 depicts simulated and measured ARBW. The ARBW extends 9.5-11.8 GHz, which is larger than ARBW element reported researches. The minimum point of measured AR is taken place at 10.9 GHz with corresponding amplitude of approximately 1.5dB. It is observed from Fig. 7 illustrates that by increasing the frequency, the gain of element stays relatively linear in X-band. The average value of gain is about 5dBi in band. The measured and simulated normalized radiation patterns at 8.5 GHz & 11 GHz are shown in Fig. 7. Note that the final layout of the element, gives RHCP in half-upper space. The final realized element has compact size in comparison with previously published works [1-5]. The realized prototype element is the best candidate for wireless industrial communication.

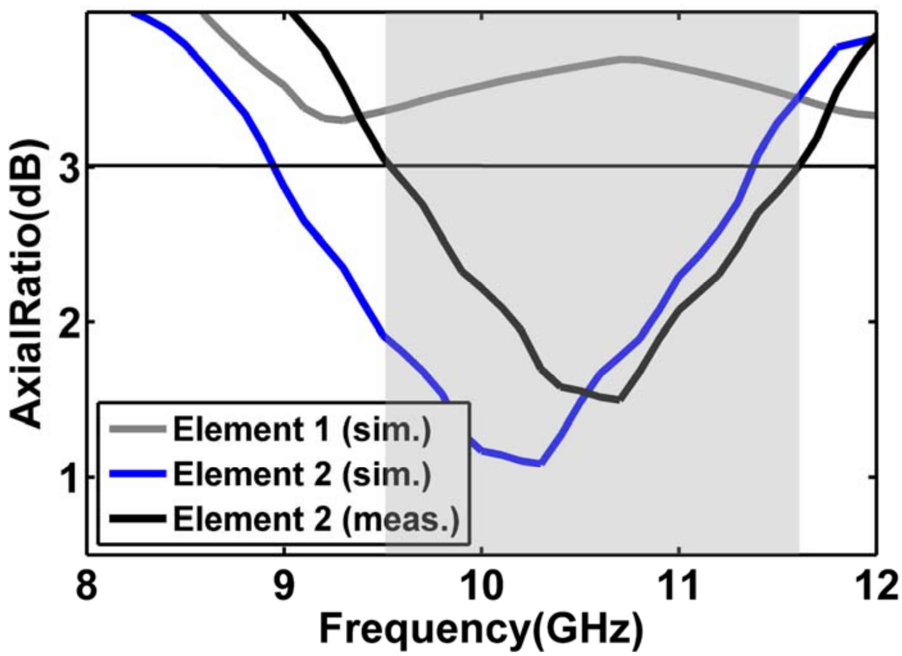

Fig. 6. Measured and simulated AR for RHCP X-Band Element1 and element 2.

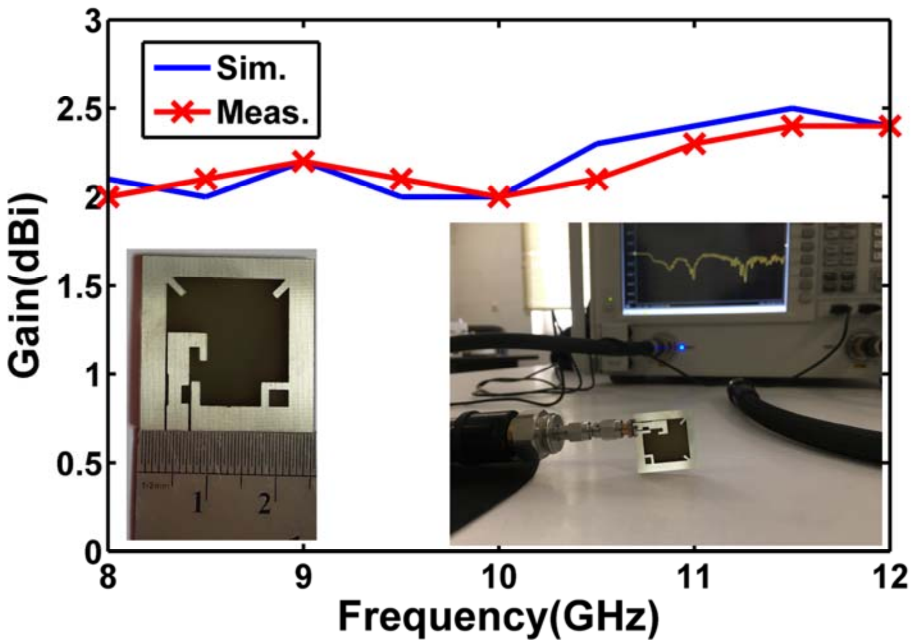

Fig. 7. Simulated and measured gain of RHCP X-band element 2.

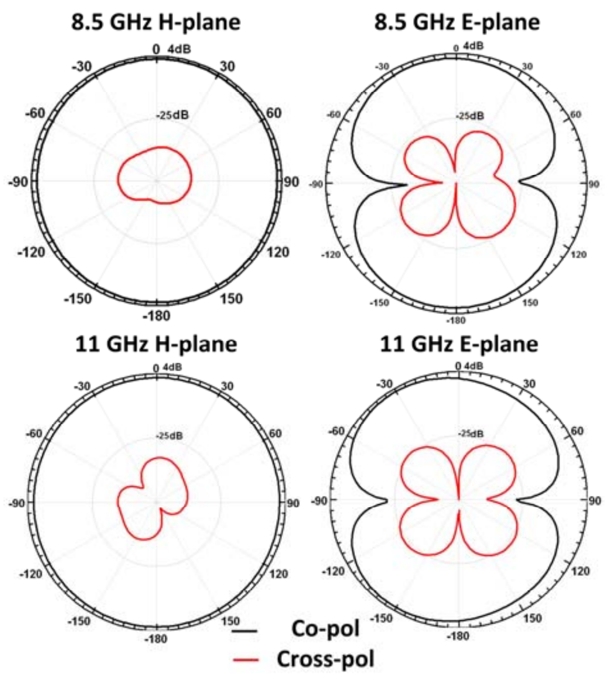

Fig. 8. Measured patterns of wide-band Element.

Table 1. Performance Comparison of The Proposed Antenna With Other Refrences.

	Substrate	IEEE X-band	Circular polarization property	Impedance Band width (BW) [GHz]	3dB Axial Ratio BW [GHz]	Size [mm^3]
Ref. [5]	FR4	×	×	7.8–8.5	N/A	40 × 40 × 1
Ref. [6]	FR4	✓	×	7.5-12.4	N/A	15 × 15 × 1
Ref. [8]	FR4	✓	×	7.6-12.4	N/A	15 × 15 × 1
Proposed Antenna	RT/duroid 5880	✓	✓	6.5-12.9	9.5-11.8	25 × 25 × 1

IV. CONCLUSION

In this paper, a unique asymmetric fed square slot element is presented. A semi-hook shaped patch with rectangular feed utilized as radiator and asymmetric CPW-feed technique used for much better impedance tuning. An outstanding X-band square slot element element with circular polarization is proposed that exhibits remarkable radiation performance and far field features which is so small and compact for X-band communications. The extracted measured results illustrate that generated bands and circular polarization by the proposed element is a function of the various shape of stubs. Different shapes of stubs like L-shaped and a pair of diagonal stubs are employed for producing two applicational bands and non-linear polarization. The position and size of stubs has major role on the element's impedance tuning features. The both measured and simulated results of fabricated element were studied in detailes. Ultimate element is the best candidate to be utilized in X-band systems at wireless communication. Moreover, The circularly polarized X-band element is the proper choice for hand-held devises in wireless industrial communications.

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