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# A comparative study on gain enhancement techniques of leaky wave antenna

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## Abstract

Over the years, Leaky wave antennas (LWA) has provided various advantages such as wide beam scanning, higher gain capabilities and easy integration with other planar components. With the advancement of metamaterial (MTM) technology, various LWA structures based on composite right/left handed (CRLH)/ substrate integrated waveguide (SIW) are investigated for obtaining narrow beam patterns at broadside. In this paper, comparative analysis & overview of various techniques for improving the gain is presented. The gain achieved from various techniques lies in the range of 10 to 18 dBi is reported.

**Key words:** Composite right/left handed (CRLH), Half mode substrate integrated waveguide (HMSIW), Gain enhancement, substrate integrated waveguide (SIW), leaky wave antenna (LWA).

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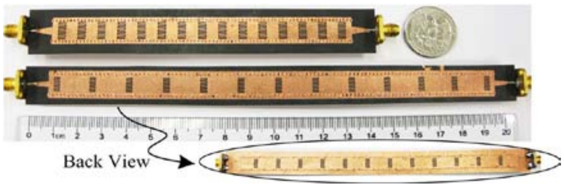
## Introduction

MTM are effectively artificial structure that exhibits electromagnetic properties not commonly found in nature such as negative values of effective permittivity, permeability and/or refractive index. Metamaterial have been found to enhance specific performance parameters of low & high profile antennas. In 1968, Veselago first investigated the electrodynamics of hypothetical materials with simultaneously negative permittivity and permeability which he called the left handed materials (LHM). On the basis of Veselago’s theoretical analysis of LH MTM, JB Pendry introduced metallic structures with negative permittivity and a periodic non magnetic structure of a split ring resonator with a negative permeability. Recently, Caloz, Iyer and Efeltheriads proposed a transmission line (TL) approach for LH MTM.

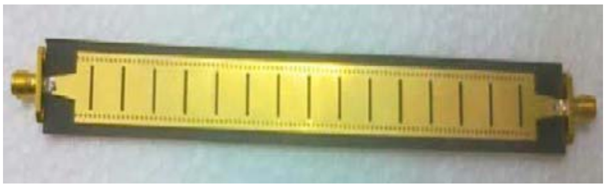
A LWA is a class of travelling wave antenna which uses a guiding structure that supports wave propagation along the length of the structure, with the wave radiating or ‘’leaking’’ along the structure. Particularly, planar LWAs configurations with their advantages of wide beam scanning, higher gain capabilities, low profile, simple fabrication and easy integration with electronic components have found applications in various radar and communication systems at microwave frequencies.

This paper focuses specifically on comparison of the gain of different leaky wave antennas based on CRLH structures. The CRLH transmission-line based LWAs can improve boresight gain over a narrow frequency band when a balanced condition (when series resonance equal to shunt resonance) is satisfied. If a CRLH structure is unbalanced, a stop-band gap region is generated between the left-handed region and the right-handed region. The stop-band gap region is undesirable for the antenna applications because it prevents the boresight radiation and thus degrades the boresight gain at the transition frequency.

Substrate integrated waveguide (SIW) and half mode substrate integrated waveguide (HMSIW) have been very popular types of planar guided wave structures over the past decade which provides minimum gain of 10dBi. It uses metamaterial radiating structures by etching interdigital slots on waveguide surface and ground. In four types of antennas are analyzed which exhibit various features such as balanced or unbalanced operating schemes, quasi-omni-directional radiation patterns and miniaturized size while keeping a high gain. A leaky wave antenna implemented on a SIW with inverted v shaped slot which contributes to the series capacitance and also act as the radiator, it radiates efficiently with high gain at the operating frequency based on CRLH. It gives a gain of 6to 8 dBi in left hand region and 13dBi in right hand region**.** The half mode SIW is a more compact guided wave structure which preserves nearly all the advantages of SIW whereas its size is nearly reduced to half. In this the SIW is cut into two parts along the symmetry plane, each of the half SIW is called the HMSIW. A novel LWA based on the Half mode SIW technique possessing features such as wide bandwidth and a conical or quasi omni-directional radiation pattern is presented in which provides a gain of 11.1 dBi in H-plane and 11.4 dBi in E-plane at 26.5 GHz frequency. A LWA based on CRLH SIW consisting of two leaky wave radiator elements featuring boresight gain of 12 dBi with a variation of 1.0 dBi over the frequency range of 8.775 to 9.15 GHz is presented.




(a) Prototype of two fabricated CRLH SIW leaky-wave antennas



(b) Prototype of Multilayered CRLH LWA with consistent gain

**Fig.1: Prototype of Antenna**


(a) Prototype of dual elements based LWA

(b) Photograph of the fabricated antennas using grating cover.

**Fig.2: Prototypes of Antenna**

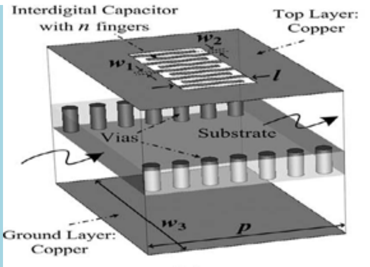
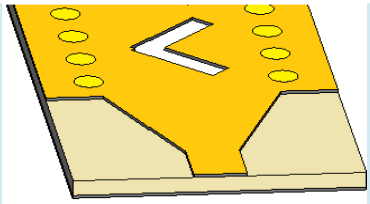
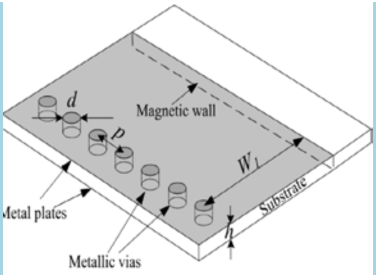
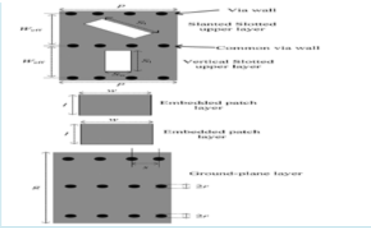
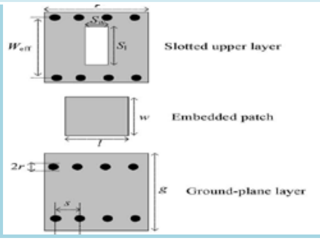
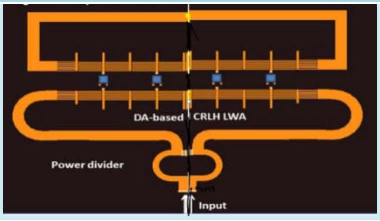
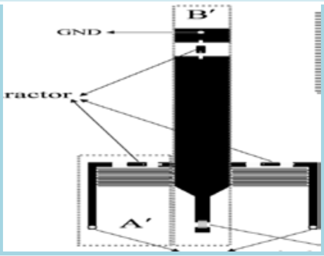
It Uses LWA based on CRLH SIW which consists of two leaky wave radiator elements with different unit cells. The dual element configuration is proposed to improve the boresight radiation. Each CRLH based element is designed using the multilayered SIW structures consisting of an embedded patch array and slot array. A LWA for boresight radiation have also been proposed based on the different aperture-shaped structures. A multilayered CRLH based LWA composed of 15 unit cells with consistent gain is presented. A multilayered CRLH based LWA is proposed which comprises of a SIW with an array of CRLH unit cells. The CRLH unit cell is formed by a slot cut on the upper ground of SIW, and a parasitic patch beneath the slot. The antenna achieves continuous beam scanning against frequency and the optimal boresight gain at the balanced condition frequency. Generally, a LWA with more unit cells features higher gain but this paper shows that, there is a limitation for gain enhancement with the increasing of the unit cells. This multilayered structure offers desired measured performance with the 3-dBi gain bandwidth of 47% with the maximum gain of 12.8 dBi. A novel high gain active antenna array using dual fed distributed amplifier(DA) based on CRLH LWA with a maximum gain of 16dBi is presented, it offers around 7 dBi increase in gain in comparison to the single-fed DA-based active antenna. A CRLH microstrip structure incorporating varactor diodes for fixed frequency voltage controlled operation. A 30-cell LWA structure is designed incorporating both series and shunt varactors for optimal impedance matching and a maximum gain of 18dBi at broadside is also achieved. A planar beam scanning SIW slot LWAs are proposed for gain enhancement using a metallic phase correction grating cover. Two types of grating (type A & type B) are introduced as the upper layer of the antenna with an unchanging feeding structure.

## Comparative Study

On comparing various techniques, it is found that minimum gain achieved is 10dBi using CRLH/SIW, HMSIW technique while the maximum gain achieved is 18dBi using CRLH structure incorporating varactor diodes. Beam scanning is achieved either by varying the operating freq. or voltage. Minimum beam scanning achieved is (-30˚ to+30˚) using metallic phase correction grating cover technique while the maximum beam scanning achieved is (-66˚ to 78˚) using multilayered CRLH/SIW. The technique providing the maximum gain is better as it provides angle scanning at fixed frequency as well as Beamwidth tuning is obtained by making the structure non-uniform by application of a non-uniform bias voltage distribution of the varactors.

## Conclusion

In this paper a comparative analysis and overview of various techniques for improving the gain of LWA is presented. Among the different techniques discussed, CRLH/SIW, HMSIW technique provides a minimum gain of 10dBi, which emphasizes on making the structure compact, while the maximum gain achieved is 18dBi by using CRLH structure involving varactor diodes which focuses on achieving the gain at broadside as well as on optimum impedance matching. Further by implementing metallic phase correction grating cover with a planar antenna, the gain can be enhanced by 4 to 6 dBi.

| TECHNIQUES USED | FEATURES | GAIN | STRUCTURE |
|---|---|---|---|
| **1. CRLH/SIW,HMSIW** | Beam scanning=(-70˚ to 60˚)<br>Operating freq.=(8.6 to 12.8 GHz)<br>Avg. efficiency= 87% | 10dBi |  |
| **2. CRLH/SIW** | Beam scanning=(-32˚to 61˚)<br>Operating frequency=(31to 41ghz) | 6-8dBi (left hand) & 13dBi (right hand) |  |
| **3. HMSIW** | Operating freq.=(26.5 to 28GHz) | 11dBi |  |
| **4. CRLH/SIW** | Beam scanning=(-60˚ to +66˚)<br>Operating freq.=(8.775 to9.15GHz) | 12dBi |  |
| **5. Multilayered CRLH/SIW** | Beam scanning=(-66˚ to 78˚)<br>Operating freq.=(8.0 to 13.0GHz) | 12.8dBi |  |
| **6. CRLH[using dual fed DA amplifier]** | Operating freq.=(2.4GHz ISM band) | 16dBi |  |
| **7. CRLH [using varactor diodes]** | Fixed freq.=(3.33GHz)<br>Beam scanning=(50˚ to -49˚) | 18dBi |  |

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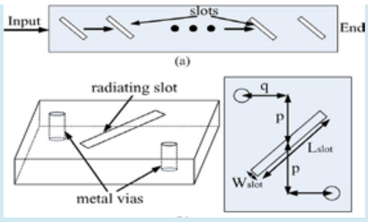
|---|---|---|---|
| **8. Metallic phase correction grating cover** | Beam scanning= (-30˚ to 30˚) Operating freq.=25.45GHz | It enhances gain by 4 to 6 dBi |  |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