Novel Prototypes of Single and Dual Elements of CRLH SIW LWA for Continuous Beam-scanning

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Abstract— Three proposed structures of CRLH SIW leaky wave antennas are designed and fabricated in this paper. The first prototype consists of a conventional CRLH SIW leaky wave antenna operating in the frequency band [6.9–11 GHz] and supporting a continuous beam scanning from −39° to 68°. The second structure is also composed by 25 cascade CRLH unit cells and allows a backward to forward beam steering from −32° to 72° in its operating frequency band [8.9–10.2]. At the final stage, an array composed by the parallel combination of these two antennas was designed to support a wider beam scanning range covering the entire operating bands of the two single elements. Beside of these properties, this structure features a dual beam scanning behavior in some particular operating bands which meet the needs of many wireless systems such as the tracking systems. Both simulations and measurements verify the intended beam scanning operations.

Introduction: In recent years, many works have been focused on the design of planar leaky wave antennas based on microstrip or coplanar waveguide [1, 2]. Nevertheless, those designs have suffered from high losses and surface wave mode excitation that is not required for many millimeter wave band applications. Substrate integrated waveguide has been widely developed as one of the most suitable structures implemented in the design of slotted planar leaky wave antennas [3, 4].

Antenna Design, Radiation Patters: This communication presents three structures where the two first antennas consists of a conventional CRLH SIW LWA and the third one is an array structure composed by the two previous antennas. Results revealed from the two first structures exhibit a continuous single beam scanning over frequency with good radiation performances. The array structure shows a complex steering behavior over the frequency supporting single and dual beam radiation.

The radiation of the antenna array can be expressed as the superposition of the two particular antennas:

$$E_{\theta 1} = I_1 \frac{j\omega\mu_0}{4\pi r} e^{-jk_0 r} \sin\theta \left[\frac{e^{(jL(k_0\cos\theta)e^{-(jL(\beta_1 - j\alpha_1))})} - 1}{j(k_0\cos\theta - (\beta_1 - j\alpha_1))} \right],$$
$$E_{\theta 2} = I_2 \frac{j\omega\mu_0}{4\pi r} e^{-jk_0 r} \sin\theta \left[\frac{e^{(jL(k_0\cos\theta)e^{-(jL(\beta_2 - j\alpha_2))})} - 1}{j(k_0\cos\theta - (\beta_2 - j\alpha_2))} \right]$$

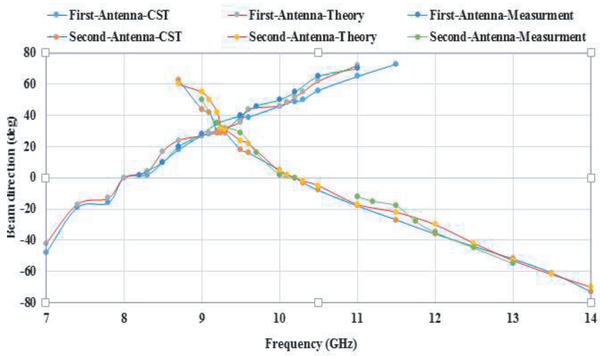

Figure 1: Measured, simulated, and theoretical analysis of main beam directions of the two different CRLH leaky wave antennas composing the array.

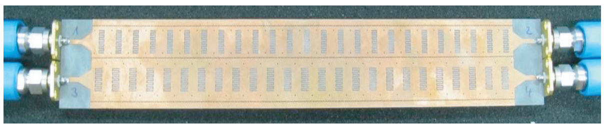

Figure 2: The fabricated antenna array.

Figure 1 shows the agreement between main lobes of radiation patterns calculated by above equations, simulated by the CST Mw Studio, and measured. The measured radiation pattern of the array copies arrays shown in Fig. 1. Fig. 2 shows the fabricated antenna array.

The antenna was designed and fabricated on the Rogers RT/duroid 5880 substrate with a permittivity of 2.2 and 0.508 mm in thickness. Excitation of the antenna array is through two opposite input ports with phase shift $\varphi = 180^\circ$. The array shows a good performance in the entire frequency band of operation. Simulated gain reaches values between $11 \sim 15$ dBi whereas measured values are between $10 \sim 15.5$ dBi.

Conclusions: The radiation behavior of the proposed system — antenna array is more flexible compared to conventional dual-beam antennas. The proposed antenna array is designed to steer a single beam and two asymmetrical beams as a function of frequency from -72° to 73°.

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