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Input Impedance Modeling of Patch and Semi-Rectangular Substrate Integrated Waveguide Cavity Hybrid Antenna

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***Abstract*— A complete equivalent-circuit model of input impedance is developed for a hybrid antenna, which consists of a Half Mode Substrate Integrated Waveguide (HMSIW) resonator and a microstrip patch. An accurate circuit model is derived using Transmission Line (TL) model and lumped-element. The results based on the circuit modeling are presented and compared with those obtained using full-wave simulation. The proposed model, for the first time, clarifies fundamental characteristics of the input impedance of the hybrid antenna, which are verified by the results of a full-wave simulation and those obtained by measurement.**

Index Terms **– Hybrid Antenna, Circuit Modeling, Transmission Line, Substrate Integrated Waveguide (SIW), Input Impedance.**

I. INTRODUCTION

In recent years, demand for low weight, low cost and low power consumption microwave wireless communication systems is increased, leading to emerging research and development on low profile and compact antennas. Substrate Integrated Waveguides (SIW) technology have been proposed to implement microwave circuits and antennas due to their useful alternate to bulky metallic waveguides. Therefore, realization of antennas is feasible using low cost Printed Circuit Board (PCB) processes [1]. Low profile SIW cavity backed slot antennas with a patterned slot in metallic ground plane, provide efficient radiation. However, impedance bandwidth of these antennas is limited up to 3% due to the resonant characteristics and thin substrate of the structure [2-5].

By using a wide radiating slot backed by a SIW cavity in [6], impedance bandwidth is increased from 3% up to 11.6%. Also, a wideband SIW cavity backed patch antenna has been proposed in [7-9]. Recently, a broadband hybrid antenna and its array structure consisting a patch and semi circle SIW cavity has been developed in [10-12] by authors. The proposed hybrid antenna provides dual resonate from the semicircular cavity and the microstrip patch. It demonstrates 10% fractional impedance bandwidth with suitable radiation characteristics including radiation gain of 7.5 dB.

This study discusses the circuit modeling of the patch and semi-rectangular SIW cavity hybrid antenna based on Transmission Line (TL) modeling of SIW cavity and microstrip patch resonators. In addition to, the equivalent circuit models for different sections of the hybrid antenna are developed and an analytical formula for input impedance of the hybrid antenna is developed. The theoretical results are verified by numerical results, which are obtained by High Frequency Structure Simulator (HFSS) and those obtained by measurement.

II. Antenna Structure

Fig. 1 shows the geometry and parameters of the patch and semi-rectangular SIW cavity hybrid antenna. A rectangular patch of length L_p and width W_p is printed on the top surface of a substrate layer by distance g from the semi-rectangular cavity. The cavity is formed with dimension W_c and L_{cc} by metallic via arrays and a dielectric aperture. The via holes have a diameter of d and are separated by distance S. An inset 50 Ω microstrip line with width of W_m is used to excite TE_{110} mode of the SIW cavity, which is printed on the backside of the substrate and to simplify applying input signal using an SMA connector. Electromagnetic fields are radiated through the dielectric aperture of the semi-rectangular cavity, which are coupled to the patch. The amount of coupling between the semi-rectangular cavity and patch is controlled by adjusting the distance g. By proper selection of resonator's dimensions, resonant frequencies of the cavity and patch are merged and in turn, a wide bandwidth is achieved [10].

The hybrid antenna is designed to work at 8 GHz using a single layer of TLY031 substrate with ε_r of 2.2, tangent loss of 0.002, and thickness of h=0.787 mm. The whole size of the proposed antenna is 22×27.45 mm^2. The geometrical parameters of the hybrid antenna are summarized in Table I.

III. Hybrid Antenna Modeling

The hybrid antenna consists of two resonators, the cavity and the radiating patch. Fig. 2(a) shows the equivalent circuit of the proposed hybrid antenna including two parallel *RLC* resonators. These are established two corresponding resonant frequencies. The parallel $R_cL_cC_c$ and $R_pL_pC_p$ circuits represent the semi-rectangular cavity and the microstrip patch respectively. Also, the capacitor C_g is designated as the capacitance of the coupling gap between the cavity and