COMPACT DUAL-LAYER SIW STRUCTURE FOR WIRELESS SYSTEM SOLUTION

by

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LIST OF ABBREVIATIONS

3D	Three Dimension
ADS	Advance Design System
AUT	Antenna Under Test
CPW	Coplanar Waveguide
CST	Computer Simulation Technology
EM	Electromagnetic
HPBW	Half Power Beamwidth
LCT	Inductance-Capacitor-Transformer
TE	Transverse Electric
TM	Transverse Magnetic
LTTC	Low-Temperature Co-Fired Ceramic
PCB	Printed Circuit Board
RF	Radio Frequency
RWG	Rectangular Waveguide
SIW	Substrate Integrated Waveguide
SMA	Sub-Miniature version A
VSWR	Voltage Standing Wave Ratio

STRUKTUR PADAT DWI-LAPISAN SIW UNTUK PENYELESAIAN SISTEM TANPA WAYAR

ABSTRAK

Cabaran untuk memperoleh cara baru dan realistik bagi menunjukkan jalan penyelesaian inovatif sistem RF telah membawa pereka-pereka untuk meneruskan dan mengoptimumkan reka bentuk peralihan pelbagai lapisan yang sedia ada. Dalam kajian ini, ciri-ciri reka bentuk dan serba boleh yang terdapat dalam teknologi SIW telah diterokai, direalisasi, dan seterusnya dicirikan dalam dwi-lapisan SIW struktur yang dicadangkan untuk kemungkinan penyelesaian sistem RF di 10 GHz. Dwi-lapisan struktur SIW yang dicadangkan terdiri daripada dua SMA-mikrostrip kerugian yang rendah dengan tirus-via peralihan sebagai input dan output di antara muka, dan dua struktur SIW yang disusun secara manual disambungkan secara elektrik melalui slot gandingan kecil. Slot gandingan direka dan dimodelkan berdasarkan kepada dua bentuk yang berbeza; slot gandingan segi empat tepat dan slot gandingan bersilang untuk peningkatan jalur lebar. Setiap satu daripada reka bentuk slot gandingan dioptimumkan dengan menggunakan kajian parametrik. Semua struktur yang dicadangkan masing-masing direka dan dimodelkan menggunakan perisian CST dan ADS. Kemudian, mereka direalisasikan menggunakan teknologi konvensional Papan Litar Bercetak (PCB) pada Rogers 4003C dengan ε_r = 3.38 dan ketebalan 0.813 mm. Struktur yang dicadangkan dipasang secara manual menggunakan bahan pelekat, dan diukur untuk pengesahan rekabentuk. Keputusan diukur bagi dwi-lapisan SIW struktur yang dipasang secara manual dengan slot gandingan segi empat tepat dan slot gandingan silang menunjukkan keputusan hampir menjanjikan berbanding dengan hasil keputusan simulasi dan dimodelkan. Kedua-dua struktur yang dipasang secara manual memperoleh kehilangan pulangan kurang daripada 10 dB, kehilangan sisipan lebih daripada 3 dB, dan lebar jalur yang lebih baik daripada 10 %. Selepas itu, dwi-lapisan struktur SIW yang dicadangkan dilaksanakan sebagai sistem pelbagai lapisan SIW dengan menggabungkan SIW slot antenna di atasnya. Untuk pengesahan reka bentuk, sistem pelbagai lapisan SIW yang dicadangkan difabrikasi dan dipasang secara manual. Perjanjian yang baik antara keputusan simulasi dan diukur untuk sistem pelbagai lapisan SIW ditunjukkan pada frekuensi salunan yang sama iaitu pada 10 GHz. Sistem pelbagai lapisan SIW yang dipasang dengan slot gandingan segi empat tepat diukur untuk mempunyai kehilangan pulangan sebanyak 21.5 dB, lebar jalur sebanyak 200 MHz, dan keuntungan sebanyak 6.05 dBi. Kemudian, sistem pelbagai lapisan SIW yang dipasang dengan slot gandingan silang diukur untuk mempunyai kehilangan pulangan sebnyak 24.0 dB, lebar jalur sebanyak 280 MHz, dan keuntungan sebanyak 5.93 dBi. Jalur lebar bagi sistem pelbagai lapisan SIW yang dipasang dengan slot gandingan silang menunjukkan peningkatan sebanyak 0.8 % berbanding dengan sistem pelbagai lapisan SIW yang dipasang dengan slot gandingan segi empat tepat. Prestasi elektrik di atas menunjukkan bahawa reka bentuk peralihan pelbagai lapisan yang dipasang mempunyai potensi untuk penyelesaian sistem RF pada 10 GHz, yang biasanya digunakan untuk aplikasi radar dan satelit.

COMPACT DUAL-LAYER SIW STRUCTURE FOR WIRELESS SYSTEM SOLUTION

ABSTRACT

The challenge to acquire new and realistic means to demonstrate innovative RF system solution has lead designers to pursue and optimize available multilayer transition design. In this research, design properties and versatility exhibited in SIW technology has been explored, realized, and then characterized in a proposed dual-layer SIW structure for possible RF system solution at 10 GHz. The proposed dual-layer SIW structure consists of two low loss SMA-microstrip taper-via transition, and two manually stacked SIW structures electrically connected via a small slot coupling. The slot coupling is designed and modeled based on two different shapes; rectangular slot coupling and cross slot coupling for bandwidth enhancement. Each of the slot coupling design are optimized using parametric studies. All the proposed structures are designed and modeled using CST and ADS software, respectively. Then, they are realized using conventional Printed Circuit Board (PCB) technology on Rogers 4003C with ε_r = 3.38 and thickness of 0.813 mm. These proposed structure are manually assembled using adhesive material, and measured for design verifications. Measured results of the manually assembled dual-layer SIW structure with rectangular slot coupling and cross slot coupling shows almost promising results compared within the simulated and modeled results. Both manually assembled structures were obtained return loss less than 10 dB, insertion loss more than 3 dB, and bandwidth better than 10 %. After that, the proposed dual-layer SIW structure is implemented as a multilayer SIW system by incorporating a SIW slot array antenna on it. For design verifications, the proposed multilayer SIW system is fabricated and manually assembled. Good agreement between simulated and measured results for the multilayer SIW systems is demonstrated at the same resonance frequency of 10 GHz. The assembled multilayer SIW system with rectangular slot coupling was measured to have return loss of 21.5 dB, bandwidth of 200 MHz, and gain of 6.05 dBi. Then, the assembled multilayer SIW system with cross slot coupling was measured to have return loss of 24.0 dB, bandwidth of 280 MHz, and gain of 5.93 dBi. Bandwidth of the assembled multilayer SIW system with cross slot coupling shows enhancement by 0.8 % compared to the assembled multilayer SIW system with rectangular slot coupling. The above electrical performance indicated that the assembled multilayer transition design have potential for 10 GHz RF system solution, which commonly used for radar and satellite applications.

CHAPTER ONE

INTRODUCTION

1.1 Overview

Growing demand in the field of micrometer-wave and millimeter-wave frequency design requires a development of novel structures, with the aim to reduce cost, design complexity, and weight. These requirements can be archived by combining two or more types of transmission line in one single substrate as a multilayer transition design and fabricated using low-cost fabrication methods. In this recent years, Substrate Integrated Waveguide (SIW) technology has been introduced in several papers and journals as a laminated waveguide, which are easily demonstrated using conventional Printed Circuit Board (PCB) fabrication method. Since the introduction of SIW, various SIW-based component, interconnection, and circuits have been developed which offer advantages over other transmission lines.

Basically, SIW technology is a 3-Dimensional (3D) structure essentially dielectric filled rectangular waveguide but in planar form. The SIW technology is formed by arranging two rows of metallic via holes to replace metallic walls in the conventional dielectric filled rectangular waveguide. Therefore, SIW technology still maintains the advantages of the rectangular waveguide such as low loss, good power handling, and good shielding although in planar form. Thus, SIW technology becomes one of the best choices for signal transmission and integration with planar circuits. Subsequently, SIW technology has been rapidly used in many circuit components such as power dividers (Kordiboroujeni & Bornemann, 2013), resonator cavities (Sirci et al., 2011), filter (Zhang et al., 2007), and antenna (Wang et al., 2010).

As interconnection, SIW technology usually provides bandpass characteristics with a good isolation from electromagnetic interference. Meanwhile, planar conventional transmission lines are known as crowding in ultra-wideband systems due to their limited bandwidth and high-frequency losses. In SIW technology, the electric field distribution fills the volume inside the waveguide, while surface currents are maximum propagate at the waveguide walls, which contribute to the lower conductor loss. As the design frequency and circuit density are increased, the use of conventional transmission lines interconnects such as microstrip line and strip line are become diminished. Their open structure have increases the radiation loss. Therefore, the demands for wideband interconnects and compact structure brings SIW technology as a solution to implement in several RF applications at high-frequency design.

Recently, the development of multilayer transition design involving SIW technology has become a subject undergoing intense study in order to fulfill current RF demands (Bozzi et al., 2009). Hence, various multilayer transition design between rectangular waveguide to SIW structure have been explored for microwave and millimeter wave frequency band (Li et al., 2009; Glogowski et al., 2013; Li & Luk, 2014). The multilayer transition design between SIW structure and rectangular waveguide offers improved performance in term of low transmission loss, high power capacity, and solve interconnection problems. However, the use of the rectangular waveguide especially dielectric-filled rectangular waveguide in the multilayer transition design still does not promise a compact structure and reduce design