Compact Ultra Wide Band Antenna with Filtering Structure using Metamaterial (MTM) and Substrate Integrated circuit (SIC) Technologies

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ABSTRACT: In this paper we present an ultra compact monopole UWB antenna integrated with a filtering structure based on SIC technology and metamaterial transmission line. Preliminary simulation results of the filtering structure and experimental results of the antenna are presented along with design procedure.

INTRODUCTION

Since the release of an UWB frequency spectrum from 3.1 to 10.6 GHz by the FCC [1], much attention is focused to design the devices (filters and antennas) for these systems. However due to the overlap of the currently allocated UWB frequency band with the existing wireless local area network(WLAN), an UWB filtering structure is desirable for reducing the interference between the two communication systems. The filtering structure is designed using the recently emerging metamaterial (MTM) and the SIC technologies. UWB filters of wider bandwidth can be designed using metamaterial technology [2]. This can be done by the composite right/left hand balanced transmission line. The SIC technology [3] can greatly facilitate interconnects and integrations between planar and non-planar circuits, which can be made within a planar fabrication process. A novel SICx technology [4] developed recently is compatible with the UWB systems. Miniaturization of UWB antennas plays an important role in communication systems with broad band and spread-spectrum features in radar communication systems. Various types of monopole antennas have been developed to cover the entire UWB bandwidth [5-7] defined by FCC.

In this paper, a novel UWB filtering structure with suppression of WiLAN is designed using metamaterial and SICX technology and also a new compact design of the monopole antenna is proposed to operate in the UWB band (3.1- 10.6 GHz).

DESIGN OF UWB FILTER AND ANTENNA

A novel UWB filtering structure which consists of suppression of WiLAN frequency range (5 – 5.8 GHz) is proposed based on SICX technology using LH zeroth order resonator. SICX UWB filter is a three layer structure as shown in Fig.1. In the middle layer the circuit lines are patterned. The via holes that unite the top and bottom layers facilitate the interconnection of the shunt inductor to ground without parasitic through hole interconnect effects since the whole plane acts as a virtual shielded metal wall. Two substrates (Rogers 6010, dielectric constant of 10.8 and thickness of 1.27mm) were placed on top of each other to form the three layer structure. The diameter of the holes was 0.5mm and the distance between them was 0.35mm, complying with the $\lambda/10$ high- isolation rule required by SICX [4].

SICX filter is implemented using a balanced CRLH transmission line to obtain the UWB range (3.1 -10.6 GHz). Then, for improved selectivity at 3.1GHz, a zeroth order resonator is coupled. Moreover, another resonator is also coupled for the suppression of WiLAN frequency range (5 – 5.8 GHz). These two resonators are implemented as a unit cell LH to eliminate any harmonic at the band of interest. Finally, to get better rejection at 10.6 GHz a conventional resonator of length $\lambda/2$ was used. In this latter case, further harmonics are not of interest since they are out of band. Fig.1. shows the layout of the final structure. The UWB filtering structure is designed and optimized using ADS [9]. The optimized elemental values of a CRLH Balanced TL are C_L=0.6pF, C_R=0.65pF, L_L=1.5nH and L_R=1.5nH. For higher selectivity a unit cell LH resonator is coupled to achieve high selectivity at 3.1 GHz. The elemental values of this resonator are C_L=0.65pF and L_L=4nH. A conventional ($\lambda/2$) resonator of length 4.09mm is coupled to CRLH to obtain higher selectivity at 10.6 GHz.

The geometry of the proposed compact UWB printed circuit antenna is shown in Fig.2. The total volume of the antenna is $50\times32\times1.27$ mm^3. L and W denote the length and width of the dielectric substrate, respectively. The width of the microstrip feed line is fixed at W_1=1mm to achieve 50 Ω impedance. On the otherside of the substrate, the conducting ground plane with a length of L_1=22.5mm only covers the section of the microstrip feed line. 'h' is the height of the feed gap between the feed point and the ground plane. The overall dimensions of the antenna are much smaller than the

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previously proposed monopoles[7-8]. A prototype of the proposed antenna with optimal design i.e., r=11mm, h=0.5mm, W=50mm, L=32mm, L_1=22.5mm, W1=1mm and d=4mm is shown in Fig.2.

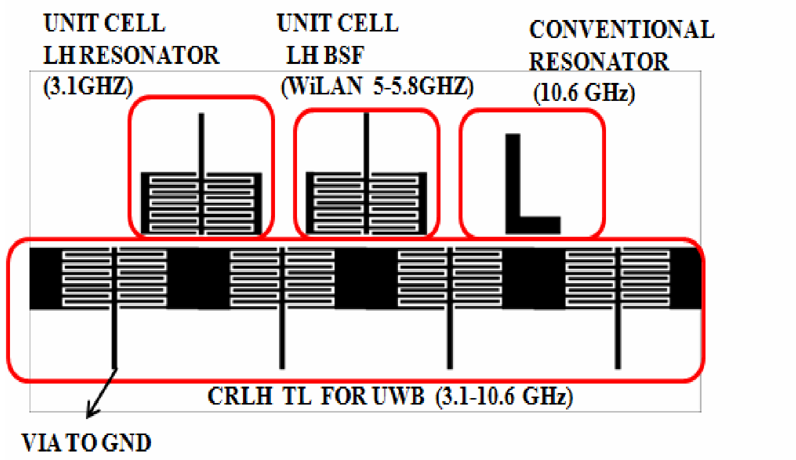


Fig.1 UWB filtering structure using MTM and SICX technologies.

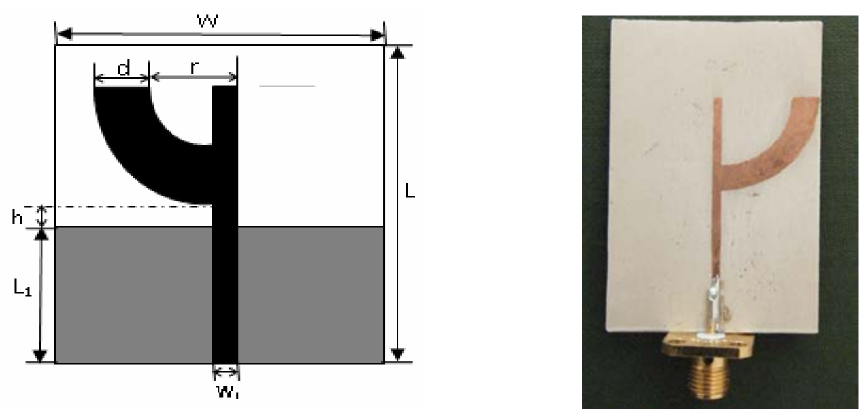
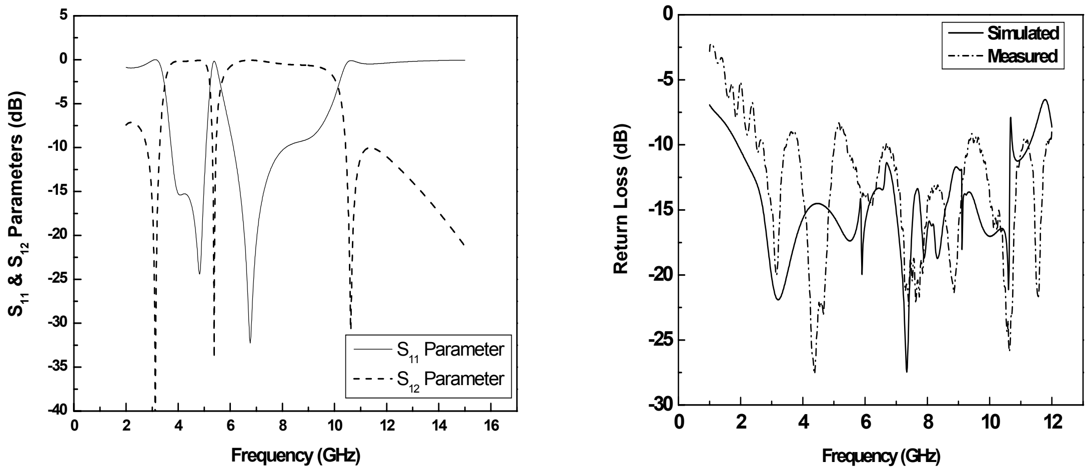


Fig.2 Schematic and photograph of the UWB compact antenna

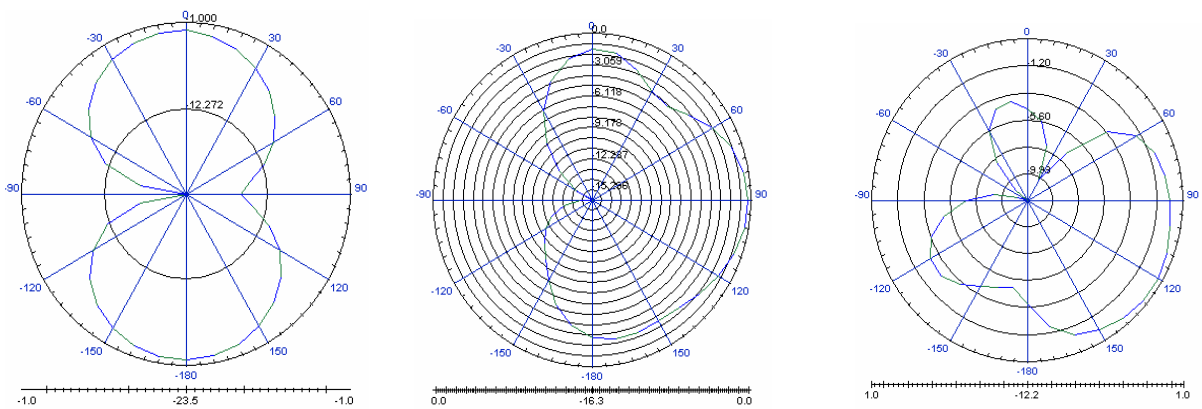
RESULTS AND DISCUSSION

The reflection coefficient and the transmission coefficient of the simulated structure are given in Fig.3(a). The obtained insertion losses are -1dB and return losses are below –10dB throughout the band. The proposed antenna shown in Fig.2 is designed and optimized using the commercial simulation software Ansoft HFSS [10]. The antenna was fabricated according to the dimensions and tested for reflection coefficient measurements using PNA series network analyzer (E8361A). Fig.3(b) shows the simulated and measured reflection coefficient (S_{11}) against frequency. The measured 10dB return loss bandwidth is from 3.1 – 10.6 GHz. The measurement confirms the UWB characteristic of the proposed antenna structure, as predicted in the simulation. The simulated antenna radiation patterns at 3, 6.5 and 10 GHz are plotted in Fig.4. It is observed that the E-plane radiation pattern at lower frequency (3 GHz) is similar to that of the conventional monopole, while at the higher frequency (10 GHz) it is slightly distorted [11]. The patterns have big back lobes at lower frequencies. With the increase of frequency, the back lobes become smaller, splitting into many minor ones, while the front lobes start to form notches.



(a) (b)

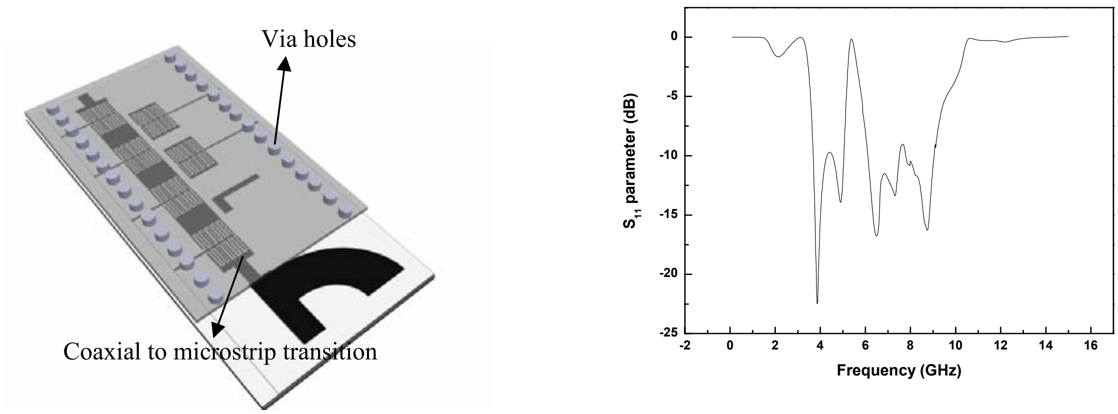
Fig.3(a) Reflection coefficient and transmission coefficient of the UWB filtering structure. (b) Simulated and measured return loss of the compact UWB antenna.



f= 3.0 GHz f=6.5GHz f=10.0GHz

Fig.4 Radiation patterns of the compact UWB antenna (E-plane)

The integration of the UWB antenna with the suppression of WiLAN band and a new miniaturized UWB monopole on the same substrate is done on the same substrate as shown in Fig.5(a). The simulated reflection coefficient (S_{11}) against frequency after integration of the filter with antenna is shown in Fig 5(b).



(a) (b)

Fig.5(a) Integration of the UWB filter with the antenna on the same substrate. (b) Simulated reflection coefficient of the entire structure (UWB filter with the antenna)

CONCLUSION

A novel UWB filtering structure with suppression of the WiLAN frequency is implemented using metamaterial and SIC technologies. The simulation results show the suppression of the WiLAN frequencies. The simulated result of the structure has return loss of less than -10 dB and insertion loss of -0.1dB. A compact UWB antenna is designed and fabricated. The simulation and measured return loss of the antenna are in good agreement. Simulation results of the radiation patterns at 3 GHz, 6.5GHz and 10 GHz are presented. Integration of the UWB filter with Antenna is presented. Simulation results of the entire device is also presented.

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