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Design and Analysis of Microstrip Filtenna with Discontinuity Compensation Techniques

Munira Bano and Alok Kumar Rastogi
Department of Physics and Electronics
Institute for Excellence in Higher Education
Bhopal, India

***Abstract*—This paper presents design, simulation and measurement of a novel broadband microstrip patch antenna co-designed with a microstrip hairpin filter for wireless communication. The compact design of filter and antenna gives a pass-band from 2.03 GHz to 2.3 GHz giving minima at two different frequencies instead of one. The rectangular patch acts not only as a radiating element, but also as the last resonator of the bandpass filter. The simulated results demonstrate that the co-design can be used to improve the bandwidth and reduce the size as well as return loss of the device.**

Keywords—Microstrip Patch Antenna; Microstrip Hairpin Filter; Return Loss; Bandpass Filter; Resonator.

I. INTRODUCTION

Miniaturization and low cost are the two most fundamental demands for RF receiver front ends. One way to minitiarize is to integrate required multiple functional circuitries into one device. Wireless communication setup needs an antenna which acts as a transmitter and/or receiver. Also a bandpass filter is an important component which is able to select signals inside a specific bandwidth at a certain frequency and reject signals in another frequency region, esp. in those which have the potential to interfere the information signals. In wireless communication systems, the antenna and the filter are key components.

Due to the increasing trend towards simplicity and miniaturization, it is desirable to integrate the filter and the antenna into a single component that achieves filtering and radiating functions simultaneously, known as filtering antenna, "filtenna", referred to as co-design. The co-design method can change the structure of the circuit, improve the performance of the circuits, and simplify the connections between different components.

Filtering antennas have been implemented in different forms including rectangular patch [1], [2], circular patch [3], patch array [4], Γ-shaped antenna [5], slot dipole [6], monopole antenna [7], inverted-L antenna [8], Yagi antenna [9], waveguide slot antenna [10], and dielectric resonator antennas [11].

A novel broadband microstrip patch antenna co-designed with a microstrip hairpin filter has been simulated, fabricated and measured in this work. In the co-design approach presented here, the antenna filter is composed of a microstrip patch antenna and a hairpin filter, both of which share the same ground plane to reduce the size and the combination operates at 2.3 GHz. The simulated S11 parameter with much lower return loss and improved bandwidth capacity can be obtained by modifying antenna-filter design by chamfering the right angled bend discontinuity at the corners of the antenna. This has been shown by simulation and the measurement of the fabricated filtenna.

II. DESIGN GEOMETRY

A. Design of Antenna

The microstrip antenna have a number of useful properties such as small size, low cost fabrication, low profile, light weight, ease of installation and integration with feed networks. With the rapid growth of the wireless mobile communication technology, the future technologies need a very small antenna. Dimensions, substrate selection and feed techniques are the important parameters that affect the antenna response. The dimensions of the antenna can be calculated from simple mathematical equations [12].

In this paper the co-design of antenna and filter is modified. The basic antenna designed is a rectangular patch antenna which operates at the center frequency of 2.3 GHz. The optimized design parameters for the antenna with 50 Ω interface impedance are used accordingly to provide better bandwidth.

B. Design of Filter

The filter which is used in this co-design is a microstrip bandpass hairpin filter. The lowpass prototype parameters, given for a normalized cutoff frequency $\Omega_c=1$, can be found in the literature [13], [14] and having obtained the lowpass parameters, the bandpass design parameters can be calculated.

C. Codesign Filter Antenna

For microstrip implementation, a dielectric substrate FR4 was used. The dielectric constant of the material is 4.4 and the loss tangent is 0.02. The dielectric thickness is h=1.6 mm, the ground plane has a width W_g=75 mm, and length L_g=71 mm. Rest all the parameters are calculated keeping resonant frequency 2.3GHz.

D. Modeling the Antenna

The designing and simulation is done through Sonnet Software 13.56 [15]. This is a full wave simulator which works on the Method of Moments. It has been widely used in the design of MICs, filters, power dividers, antennas etc. It plots the S, Y, Z parameters, VSWR, Z_{in}, current density and gain of antennas.

III. Results and Discussion

Full wave electromagnetic simulations were performed on EM Simulator (Sonnet 13.56 Software). Due to better coupling between the antenna and the filter, two resonant frequencies appear that show the co-designed version has a better bandwidth. Fig. 1 shows the Sonnet geometry of this filtenna while Fig. 2 shows the fabricated co-designed filtenna. The measurements are taken using Spectrum Analyser FS315 shown in the Fig. 3.

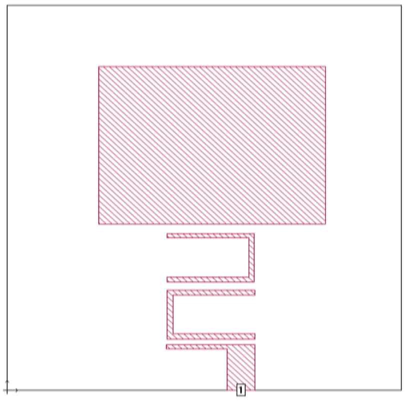

Fig. 1 Filtenna Geometry in Sonnet

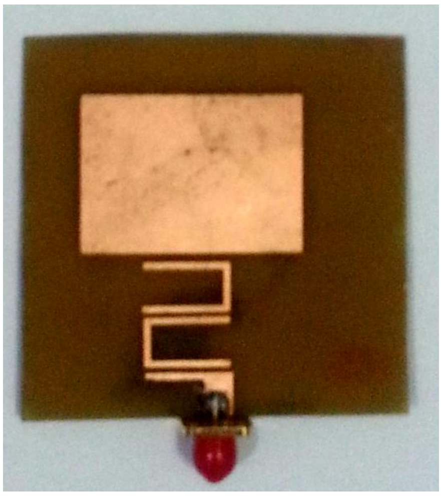

Fig. 2 Fabricated Microstrip Filtenna on FR4

Fig. 3 Return Loss (-15.4 dB) at 2.064 GHz

Fig. 4 compares the simulated and measured curves of the filtenna. It shows a very good resemblance between them. Here practically the minimum return loss is obtained to be -15.4 dB at 2.06 GHz and at 2.31 GHz it becomes equal to -13.9 dB. The former value is slightly less than the simulated one which may be because of losses present in the practical scenario. During simulation we assume microstrip circuit to be inside a box with minimum losses while in practical it is open to air due to which the box walls are actually placed at infinity which were present at a finite distance in simulations. This results in some differences in practical and simulated readings. This is clear from Fig. 4.

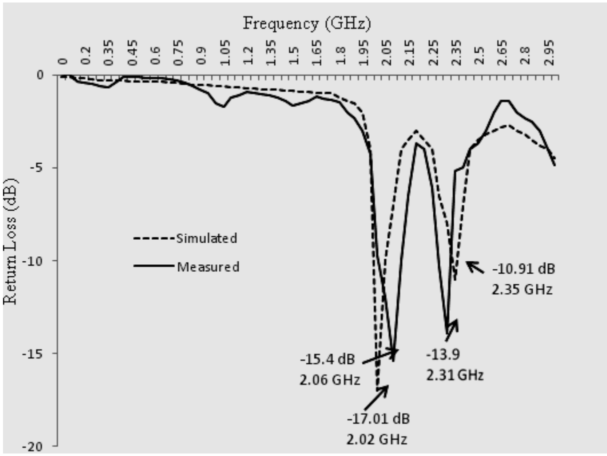

Fig. 4 Comparison of Simulated and Measured Return Loss

In order to reduce the reflections through microstrip line, the microstrip right angled bends are compensated. The corners of microstrip antenna have been chamfered to compensate the right angled bends. This results in lesser return loss as compared to the previous one. The simulated return loss curves for noncompensated and compensated filtennas have been shown in Fig. 5.

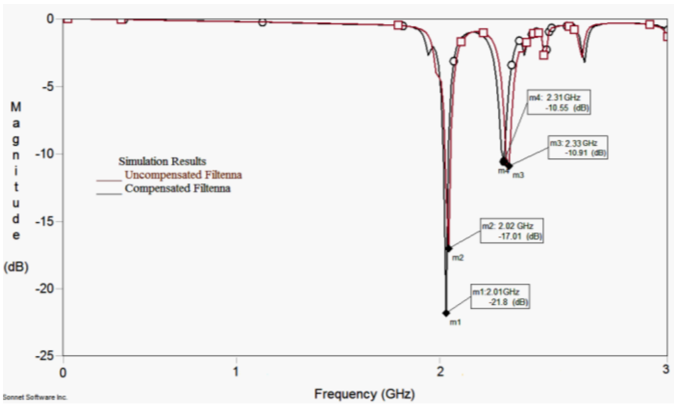

Fig. 5 Simulated Return Loss of Uncompensated Filtenna and Compensated Filtenna

The simulation results show that the return loss is reduced after compensation of microstrip discontinuities. At 2.3 GHz, the return loss decreases from -13.9 dB to -15.2 dB.

The fabricated compensated filtenna is shown in the Fig. 6 while Fig. 7 shows the practical results obtained on Spectrum Analyser.

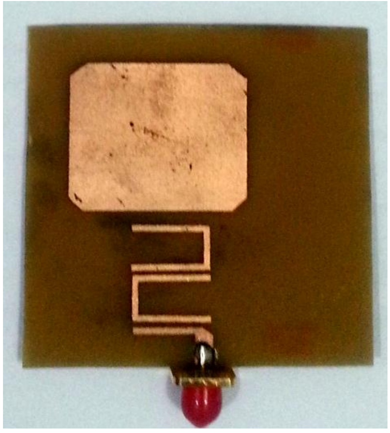

Fig. 6 Fabricated compensated Filtenna

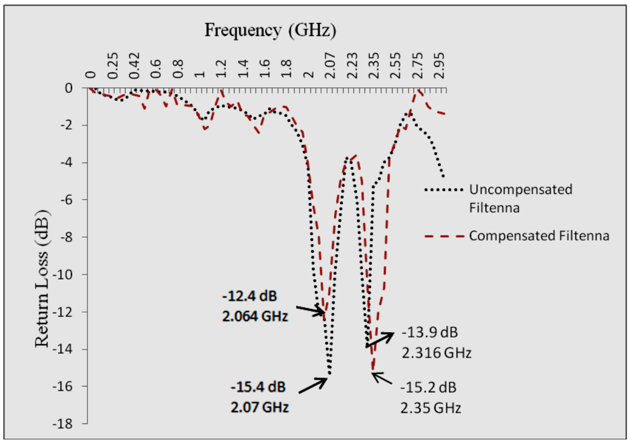

Fig. 7 Measured Return Loss of the uncompensated and compensated filtenna

At 2.3 GHz the return loss is reduced from -13.9 to -15.2 dB. Thus compensation of discontinuities helps in reducing losses in microstrip circuits.

IV. Conclusion

In the past decade, because of its low profile, small size and low manufacturing cost, the microstrip filters and antennas have found to be in significant demand for commercial applications. Especially in the area of satellite communications, the demand for microstrip antennas is more evident. It is believed that this small size antenna will continue to benefit the human race for many future years.

A microstrip filter is developed into an antenna by replacing the last resonator with a radiating patch in this work. Thus, the structure combines filtering and radiating functions simultaneously. The proposed system can reduce the size and cost of the communication system by combining two systems components into one. Thus we see that the co design approach is helpful in reducing the size of microwave circuits: combining two important devices into a single. Obviously, due to better coupling between the antenna and the filter, two resonant frequencies appear that show the co-designed version has a better bandwidth and the structure combines filtering and radiating functions simultaneously. The suggestions on compensation of discontinuities can be applied to get better results in terms of reflection and radiation.

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