Inkjet Printed Bandpass Filters and Filtennas using Silver Nanoparticle Ink on Flexible Substrate

Ahmad, W., Budimir, D., Maric, A. and Ivanisevic, N.

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Waqas Ahmad and Djuradj Budimir
Wireless Communications Research Group
University of Westminster
London, W1W 6UW. United Kingdom
d.budimir@westminster.ac.uk

Andrea Maric and Nikola Ivanisevic
Faculty of Technical Sciences
University of Novi Sad
Novi Sad, 21000. Serbia

Abstract—**This paper presents an inkjet printed CPW filtenna designed at 5.8 GHz. The proposed structure consists of a CPW pseudo-interdigital bandpass filter and a CPW inset-fed antenna. The bandpass filter is fabricated using inkjet printing technology. The structure is printed on flexible Kapton substrate with polyimide film using silver nanoparticle ink. The filter is then used to suppress the spurious harmonics of the antenna. Measurements from the fabrication confirm the accuracy of the design method and the simulation results.**

I. INTRODUCTION

Inkjet printing is fast becoming an emerging technology to manufacture printed electronics due to its direct-write technique. As compared to conventional etching techniques, it is able to reduce the material usage and the waste generated. Inkjet printing is simpler, generally faster and has low fabrication costs than other additive manufacturing techniques. Over the last few years, inkjet printed technology has been implemented in a wide range of applications, from displays and lighting to RF and microwave applications. In recent years a number of inkjet printed electronics have been reported in published work [1]-[6]. These electronics have been usually printed on specific substrates in order to decrease losses. For example, antennas on Liquid Crystal Polymer (LCP) substrates [1], coplanar waveguides (CPW) and filters on LCP substrate [2]–[4], inkjet printed antennas on paper substrates [5], inkjet printed CPW inductors on Kapton substrate [6]. However, there has been no reported work on employing Kapton substrate with flexible polyimide film for inkjet printed filters using silver nanoparticle ink. In this paper, the design and modelling of an inkjet printed filtenna is presented. The filtenna consists of a pseudo-interdigital bandpass filter integrated with an inset-fed antenna using inkjet printing technology. The structures are single-layer CPWs without any background metallization. In Section II, the design of the structures is detailed. Section IV presents the results. Conclusions of the results follow in Section V.

II. DESIGN OF FILTERS, ANTENNAS AND FILTENNAS

The two pole pseudo-interdigital filter has a center frequency of 5.8 GHz with transmission zeros to improve rejection. As shown in Fig. 1, it has rectangular CPW lines around it which serve as ground planes and act as a replacement for background metallization. It consists of two folded resonators in the middle, where the lengths of resonators define the center frequency. In this case, the length of the inner fingers is $\lambda_g/4$; where λ_g is the guided wavelength at center frequency of 5.8 GHz. The gap between all the fingers of the resonators is the same. Decreasing the gap between the resonators broadens the bandwidth; whereas increasing causes higher insertion loss. A standard CPW antenna with fundamental resonant frequency 5.8 GHz is designed. As shown in Fig. 2, inset transmission line feeding was chosen to reduce the total area. Increasing of inset feed length reduces the input impedance at resonant frequency but causes slight effect on the frequency itself. The filtenna is formed by replacing the inset-feedline by the designed filter; as presented in Fig. 3.

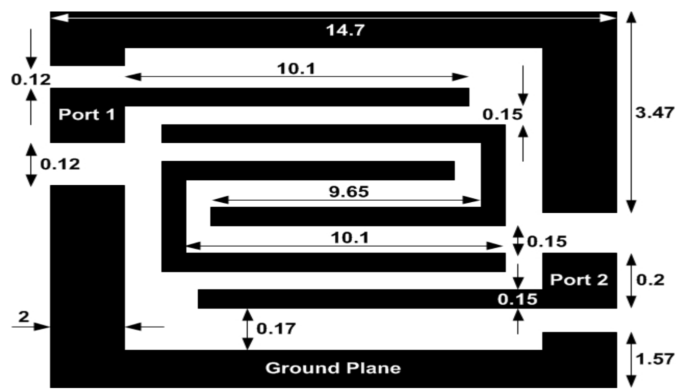

Fig 1. Geometry of bandpass filter.

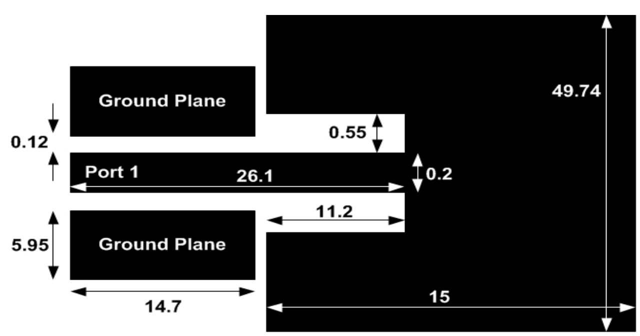

Fig 2. Geometry of inset-fed antenna.

Fig 3. Geometry of filtenna.

III. RESULTS

All structures are designed on 50 µm thick Kapton substrate of a dielectric permittivity ε_r = 3.4 and a loss tangent tanδ=0.0021. Simulations are done using the commercial software *emSonnet*. The fabricated filter was characterized using high frequency measurement system. The system comprises of Süss MicroTech PM5 RF probe station, Agilent PNA-L vector network analyzer N5230A, high frequency interconnecting cables and coplanar ground-signal-ground Cascade Microtech APC50-GSG-250 probe station. The measuring system was calibrated on compatible impedance characterization substrate implementing standard SOL (Short Open Load) calibration method. The simulated and measured S-parameters of the bandpass filter presented in Fig. 4 show that the filter is centered at 5.8 GHz and has a 14% fractional bandwidth. The simulation result shows the insertion loss to be about 2.1 dB in the passband. However, the measured result shows the insertion loss to be at 5 dB. This difference in loss arises from the printed metallic layers, dielectric losses and low conductivity of ink. The loss is also attributed to the positional accuracy of the inkjet printer. Two transmission zeros appear at frequencies below and above the passband. The transmission zeroes improve near-bandwidth rejection. The return loss is more than 15 dB for most of the passband bandwidth.

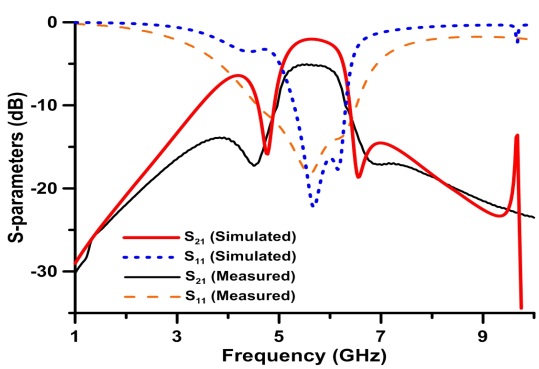

Fig. 4. S-parameters of bandpass filter.

The simulated S-parameters of the antenna and the filtenna are shown in Fig. 8. The antenna has a fundamental resonant frequency at 5.8 GHz with a return loss of about 27 dB. However as seen, it also has spurious harmonics at various other frequencies. After integration of the filter, a slight shift in the fundamental frequency is observed. The resulting return loss of the filtenna at the new resonant frequency of 5.75 GHz is 18.5 dB. As desired, the spurious harmonics of the antenna have been fully suppressed because of the integration of the filter.

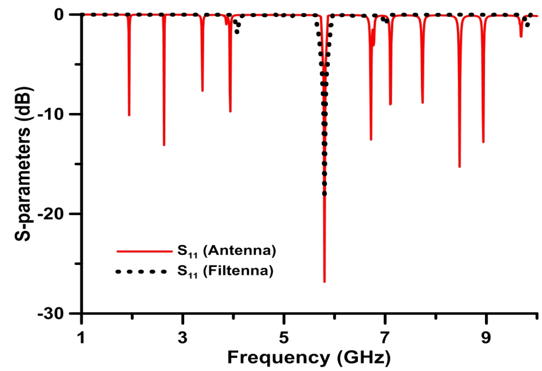

Fig. 5. S-parameters of antenna and filtenna.

IV. CONCLUSION

Inkjet printing presents a very encouraging future for low-cost fabrication process of passive RF and microwave circuits. In this paper, inkjet printing is utilized to design and fabricate a bandpass filter centered at 5.8 GHz. The simulated and measured results have been presented. The filter is integrated with a CPW antenna having spurious harmonics to form a filtenna. The filtenna has resonant frequency at 5.8 GHz and the spurious harmonics are fully suppressed because of the integrated filter. The results of the antenna and filtenna are given. Although the losses are substantial, these can be reduced by increasing the printed layers' thickness and/or by increasing the concentration of silver in the ink or the curing temperature and time resulting in an increase in the electrical conductivity of the metallization.

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