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Inkjet-Printed Filtennas with Triple Bandnotch

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***Abstract*—This paper presents the layout and results of a compact inkjet-printed filtenna operating at the S-band, ISM and UWB frequencies. The filtenna has a wide passband and, alongside, rejects WiMAX 3.5 GHz, WLAN 5.8 GHz and ITU service 8.2 GHz bands. The filtenna is simulated, printed using silver nanoparticle ink on flexible Kapton substrate and measured. Obtained simulation and measurement results agree well with each other. Measured return loss of the filtenna is more than 10 dB for 1.6–10.85 GHz and triple bandnotch, measuring at an average of 1.87 dB, are present at the unwanted bands. Radiation patterns, as well as the gain and efficiency of the filtenna have also been presented; with the average values being 3.4 dBi and 90 % respectively for the passband and averaging at -1.0 dBi and 22 % respectively for the three rejected bands.**

Keywords—inkjet printing; filtennas; uwb, bandnotch.

I. INTRODUCTION

UWB technology has constantly been a hot research area due to its advantages. As the commercial UWB covers a wide frequency range of 3.1–10.6 GHz [1], it is overlapped with various other services; such as WiMAX 3.5 GHz, WLAN 5.8 GHz and ITU service 8.2 GHz bands. Since the power level of these bands is higher than the maximum limited within the UWB [1], they interfere with UWB signals; causing signal distortion and loss of sensitivity. Hence, filtering is vital for the best usage of the UWB. A possible and effective solution is to realize bandnotch at the unwanted frequencies.

Inkjet printing offers several advantages such as quicker fabrication, waste decrease and low costs. Hence, numerous inkjet printed antennas being reported in literature. Most have been targeted towards RFID integration, such as RFID tag readers; others have been meant for sensor integration, such as paper-mounted gas and temperature sensors. Yet little has been achieved in integrating UWB technology with inkjet printing; except in [2]–[6]. But these works still do not satisfy all specifications, such as compact size and rejecting undesired bands. Moreover, wireless systems' efficiency relies on the integrated filtenna which should be robust and conformal. Yet, [2]–[4] have been printed on paper substrates. While cheap and flexible, paper's high loss factor degrades the efficiency [5] and the low tensile strength introduces discontinuities when high levels of bending are needed.

In this paper, the design, printing and testing of an inkjet printed filtenna on flexible 50 µm Kapton (ε_r = 3.4) substrate is presented. Kapton is chosen because it fulfils the required properties and has a low loss factor of 0.0021. The filtenna is fed by a coplanar waveguide; thus decreasing printing costs and complexity. It covers the whole UWB spectrum as well as the S-band 2 GHz and ISM 2.45 GHz bands and is more compact than the inkjet UWB structures given in [2] by 90.6%, [3] by 55%, [4] by 66.5% and from [5] by 11.7%.

II. DESIGN AND PRINTING OF PROPOSED FILTENNAS

The filtenna is based on the work in [6], with the final layout illustrated in Fig. 1. The filtenna has a total compact size of 33 mm x 47.2 mm which is equivalent to 0.35λ_g x 0.51λ_g; where λ_g is the guided wavelength at 3.1 GHz. It is designed with a mid-band frequency of 6.85 GHz and is symmetrical with respect to the longitudinal direction (x-axis). Due to the steady change in the long oval shape of the radiating element, a broadband impedance bandwidth is easily achieved. This shape also provides a smooth shift from one resonant mode to another. To reject unwanted signals, slits and slots that produce bandnotch are cut out in the radiating element. The two slits near both edges of the radiating element are λ_g/4 long at 3.5 GHz. Two slots each are cut out for rejecting 5.8 GHz and 8.2 GHz. The two 5.8 GHz slots lie on either side of the symmetry plane (x-axis) at a distance of 2.2 mm. While the two 8.2 GHz slots lie within the symmetry plane. All four slots are λ_g/2 long at their respective bandnotch frequency.

Printing is done using Novacentrix JS-B25HV silver nanoparticle ink and Dimatix Materials Printer DMP-3000. A 25 µm drop spacing, corresponding to a printing resolution of 1016 dpi, is selected to let ink droplets sufficiently overlap each other. Amplitude of the driving waveform is set to 25 V and the printing frequency is 2 kHz. 10 pL nozzle volume cartridges are used in a horizontal configuration. Once printed, the structure is sintered in a furnace at a curing temperature of 240°C for 0.75 hours to form continuous electrically conductive lines, providing a good channel for current flow.

III. RESULTS

The proposed filtenna and the antenna from [6] were simulated using CST Microwave Studio. The printed filtenna was measured using a high frequency measurement system, comprising of Cascade Microtech PM5 RF and coplanar APC50-GSG-250 probe stations and Agilent N5230A PNA-L and E8361A PNA network analyzers. The system was calibrated on compatible impedance characterization substrate implementing standard Short Open Load calibration method.

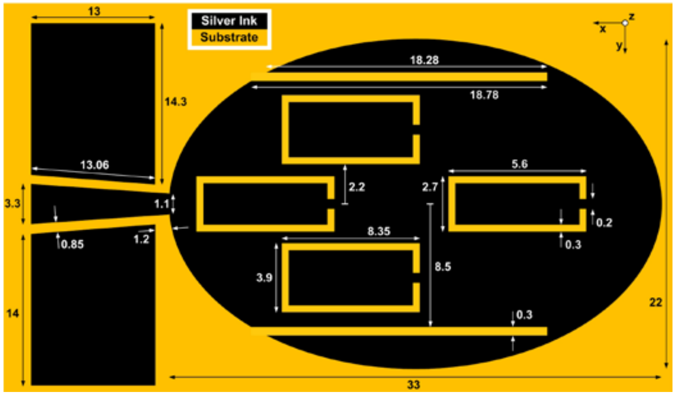

Fig. 1. Geometry of filtenna (dimensions in mm).

The return losses of both structures are shown in Fig. 2. Filtenna simulation shows a full bandpass response at a return loss of more than 10 dB from 1.45–10.32 GHz. Within this passband, triple bandnotch are present at 3.5 GHz, 5.78 GHz and 7.95 GHz at a return loss of 0.82 dB, 0.87 dB and 2.11 dB respectively. Measurements agree with the simulation and show the passband to be from 1.6–10.85 GHz. The triple bandnotch are present at 3.55 GHz (1.8 dB), 5.65 GHz (1.5 dB) and 8.16 GHz (2.3 dB). The slight frequency shift of ±43.33 MHz in the triple bandnotch is due to the fabrication tolerances and the decreased return loss is due to the low conductivity of the silver ink. Hence, these minor differences may be ignored.

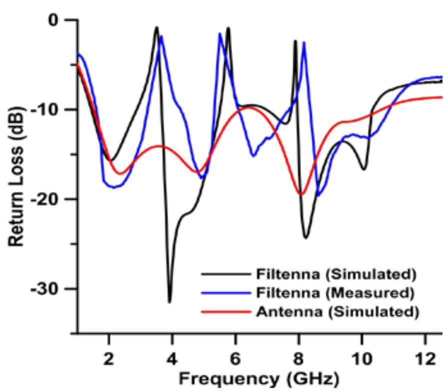

Fig. 2. Return loss of filtenna and antenna.

The radiation patterns at 3.5 GHz bandnotch and 4 GHz passband frequency in E-plane (normalised to a minimum of -40 dB) and H-plane are shown in Fig. 3. At 4 GHz, stable bidirectional pattern in the E-plane and omnidirectional pattern in the H-plane are observed. But at 3.5 GHz, due to bandnotch suppression, rough bidirectional pattern in the E-plane is seen. Also, the magnitude is significantly reduced in both planes.

The simulated gain and efficiency of the filtenna are given in Fig. 4. The average gain and average efficiency is 3.4 dBi and 90 % respectively. However, at the triple bandnotch, the gain falls to an average of -1.0 dBi. The efficiency, too, drops to an average of less than 22 %. As seen, variance of the filtenna gain across the UWB is within 5 dBi. The drops in the gain and efficiency shows the filtenna is capable of rejection.

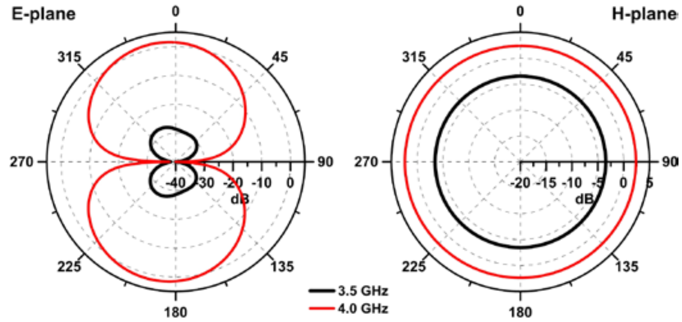

Fig. 3. Radiation patterns of filtenna.

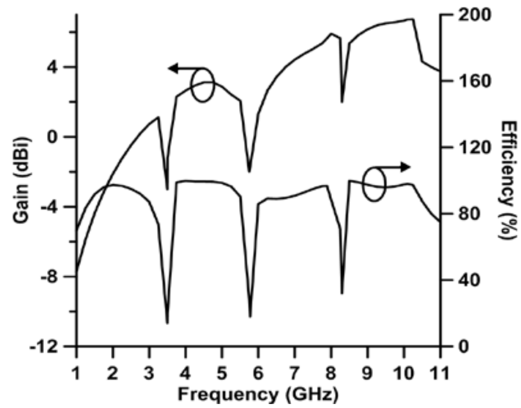

Fig. 4. Gain and efficiency of filtenna.

IV. Conclusion

A filtenna for UWB systems has been fabricated by inkjet printing technology using silver nanoparticle ink on flexible Kapton substrate. Simulation and measurement results of the filtenna have been provided. Results show that a full UWB has been attained, except at the unwanted WiMAX 3.5 GHz, WLAN 5.8 GHz and ITU 8.2 GHz bands, where sharp triple bandnotch are present. These results are also echoed in the gain and efficiency: where drops in the values have been obtained.

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