A Dual-Band Retrodirective Reflector Array on Paper Utilizing Substrate Integrated Waveguide (SIW) and Inkjet Printing Technologies for Chipless RFID Tag and Sensor Applications

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***Abstract*—In this paper, the dual-band retrodirective reflector array using Substrate Integrated Waveguide (SIW) and inkjet-printed technologies on paper, for operability around 3.6 GHz and 5.8 GHz is proposed. It offers the versatility of multi-band retrodirective designs potentially covering numerous RFID interrogation, sensing and communication bands.**

I. INTRODUCTION

Retrodirective array technology has found many applications in military and communications systems, including collision avoidance sensors, RFID and solar power satellite systems [1]. In contrast to conventional smart antenna systems, retrodirective systems are capable of self-steering, transmitting an incoming wave back towards the direction of the transmitter, without requiring complicated signal processing in order to compute the angle of arrival of the incoming wave.

Recently, chipless RFID and sensors are receiving significant scientific and commercial interest due to the use of passive circuitry, and consequently their low cost [2]. Retrodirective technology has already been considered for RFID applications [3] and, in its simplest form, the Van Atta architecture presents itself as a candidate for chipless RFID and sensing systems. Furthermore, substrate integrated waveguide (SIW) technology is an attractive technology for low cost, compact and high performance circuits due to ease of fabrication, low loss, and increased isolation compared to microstrip technology [4].

In this paper, a dual-band passive retrodirective array on paper substrate combining SIW and inkjet printing technologies is presented. Furthermore, the design can be easily scaled up to millimeter wave frequencies offering additional advantages for compact circuit topologies and larger array size.

II. RETRO-DIRECTIVE VAN ATTA ARRAY

In this section, a dual-band retrodirective Van Atta array prototype for chipless RFID tag and sensor applications is proposed using inkjet printing technology. The SIW antennas operating at 3.6 GHz and 5.8 GHz are interwoven in order to achieve retrodirective property as shown in Fig. 1. The simulated and measured reflection coefficients (S_{11}) and radiation patterns of each antenna element are shown in Fig. 2 and Fig. 3. The antenna array which is operating at the higher frequency range is placed in the middle of the antenna array operating at the lower frequency band in order to minimize the loss from the U-shaped interconnects of the antenna array for the higher frequency band. Due to the fact that the length of the outer U-interconnect is longer than the inner one, the antennas which are operating at high band frequency should be embedded between the antennas which are operating at low frequency. The simulated normalized RCS patterns are shown in Fig. 4 verifying the retrodirectivity for incidence angles of 0 and 30 degrees. These RCS pattern verifies the retrodirectivity of the proposed design since the retrodirected power is detected. The low power level detection is due to the low gain of the antennas resulting from the high-loss of the paper.

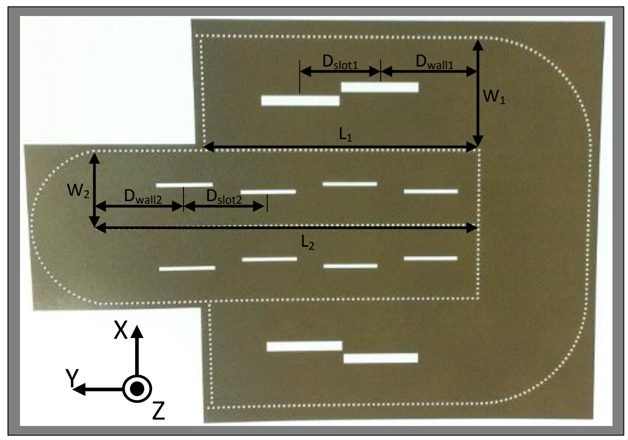
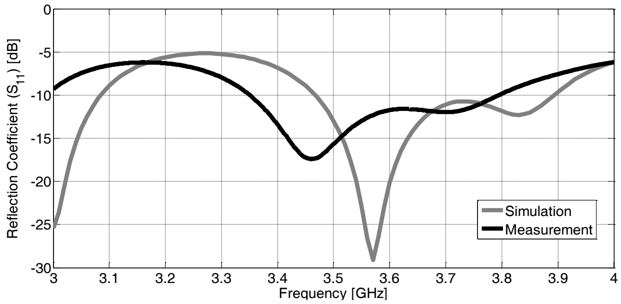
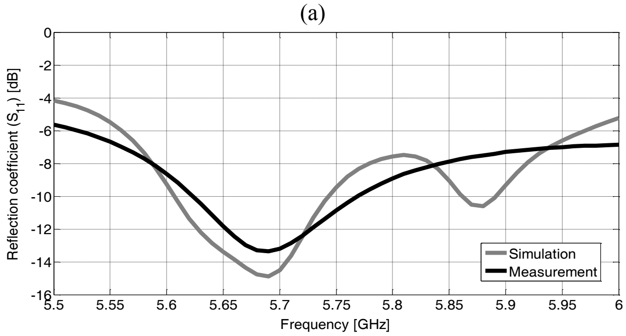


Fig 1. Geometry of proposed SIW Van Atta array: W_1=39mm, L_1=89mm, D_{slot1}=24.5mm, D_{wall1}=24.5mm, W_2=28mm, L_2=116mm, D_{slot2}=25.5mm, D_{wall2}=23.25

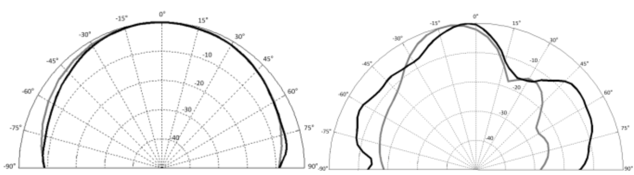


(a)



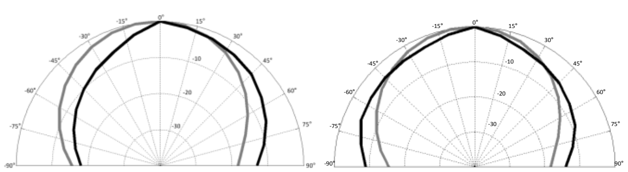
(b)

Fig 2. Reflection coefficients of antennas at (a) 3.6 GHz, (b) 5.8 GHz



E-plane H-plane

(a)



E-plane H-plane

(b)

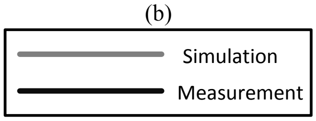
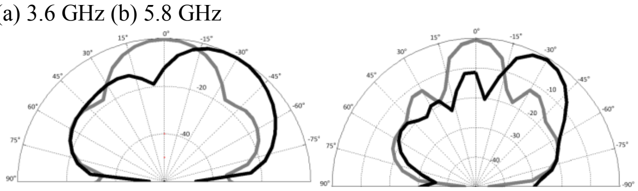


Fig. 3. Simulated and measured radiation patterns of the antennas for (a) 3.6 GHz (b) 5.8 GHz



(a) (b)

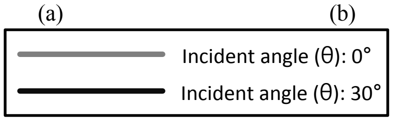


Fig. 4. Simulated bi-static scattered power pattern at (a) 3.6 GHz (b) 5.8 GHz

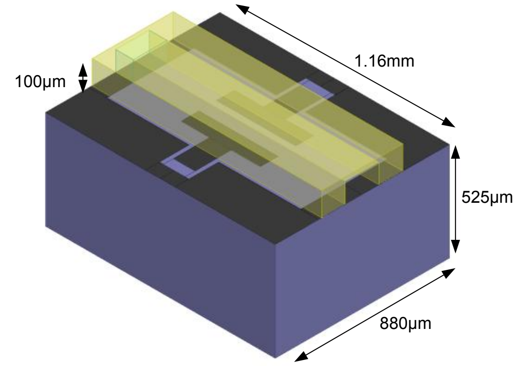


Fig. 5. 3D schematic of the proposed micro-fluidic temperature sensor.

III. SENSOR INTERROGATION BENCHMARKING

As a proof-of-concept demonstration of the sensor interrogation capabilities of the proposed dual-band retrodirective antenna, RCS variability of the micro-fluidic temperature sensor shown in Fig. 5 can be integrated with the proposed retrodirective array. Previous results with horn antenna interrogation have demonstrated a RCS variability of 4 dBm for the temperature range of 24~33 ˚C, but the sensitivity is depending on the angle of illumination. It is expected that the use of the proposed retrodirective structure enhances the readability for the majority of illumination angles and offer a two-frequency temperature-dependent RCS variability verification.

IV. CONCLUSION

In this paper, an inkjet-printed passive SIW dual-band retro-directive array on paper substrate for chipless RFID tag and sensor applications is presented. The proposed topology features numerous advantages such as compactness, versatility for multiband implementations, completely passive operation and significantly reduced electromagnetic interference due to feeding structures.

ACKNOWLEDGEMENT

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REFERENCES

[1] R.Y. Miyamoto, T. Itoh, "Retrodirective arrays for wireless communications," *IEEE Microwave Magazine*, vol.3, no.1, pp.71-79, Mar 2002.

[2] N.C. Karmakar, Handbook of Smart Antennas for RFID Systems, Wiley 2010.

[3] R.Y. Miyamoto, Q. Yongxi, T. Itoh, "An active integrated retrodirective transponder for remote information retrieval-on-demand," *IEEE Transactions on Microwave Theory and Techniques,* vol.49, no.9, pp.1658-1662, Sep 2001.

[4] A.A.M.Ali, H.B. El-Shaarawy, H. Aubert, "Millimeter-Wave Substrate Integrated Waveguide Passive Van Atta Reflector Array," *IEEE trans. Ant. Prop.*, Vol. 61 No. 3.