A Novel Compact Frequency Reconfigurable Antenna for VHF/UHF/L-Band Airborne Applications

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Abstract— In this letter, we propose a novel frequency reconfigurable antenna design for aircraft and drone telecommunication that covers the applied VHF/UHF/L- bands. The proposed structure is a Reduced-Size Edge-Shorted dipole/monopole antenna and consists of metallic line, notch, and metal reflector, making it easy to combine directional, high-gain, low cross-polarization and wide bandwidth. The antenna is frequency-reconfigurable using a PIN diode switch. In the ON state, the antenna operates as a dipole-traveling antenna and covers 30–400 MHz. In the OFF state, the antenna operates as an Edge-Folded monopole antenna and covers 500–1220 MHz. This work proposes a technique for size reduction using side slot and for gain equalization using switchable folded wing based on Smart Geometry Reconfiguration. The proposed antenna has VSWR< 2 for all bands. Antenna gain is less than 1.56 dBi at 30–400 MHz and 4.56 dBi at 500–1220 MHz.

Index Terms— reconfigurable antenna; UHF/VHF Bands; PIN diode; Airborne application; Edge-Shorte; side slot.

I. INTRODUCTION

FOr VHF/UHF and L band airborne frequency ranges, the antenna size might be a major limitation for some applications, such as weight, volume and vehicle aerodynamic. Some packages may use two or three antennas on small devices, but usually only one of the antennas is used. Antenna reconfigurability could provide numerous advantages for solving these problems. In addition, reconfigurable antennas can adapt with changing system requirements or environmental and provide additional levels of functionality for any communication systems [1].

Particularly communication systems (military and commercial) need large numbers of antennas in various frequencies. In addition, these systems have parameters such as different bandwidths, polarizations, and radiation characteristics. Generally military airplanes, needs antennas for transmission and reception in the VHF/UHF and L- bands [2, 3]. It is difficult to design antennas that operate in the VHF/UHF and L- bands. One method to design antenna that operate in these bands with a high quality factor (Q) is a reconfigurable antenna. In this type antenna, the electrical length changed by using one or more RF switches. Advantages of this type antenna are that the antenna's frequency band can achieve better performance without increasing size of antenna and antenna is able to cover multi-bands without isolation problems. In addition, many researches goal are to minimize the number of switches and lumped ports in broadband antennas [4]. Therefore, we used one lumped element in this work.

The other of major challenges of designing an airborne antenna are space available in airborne for antenna integration

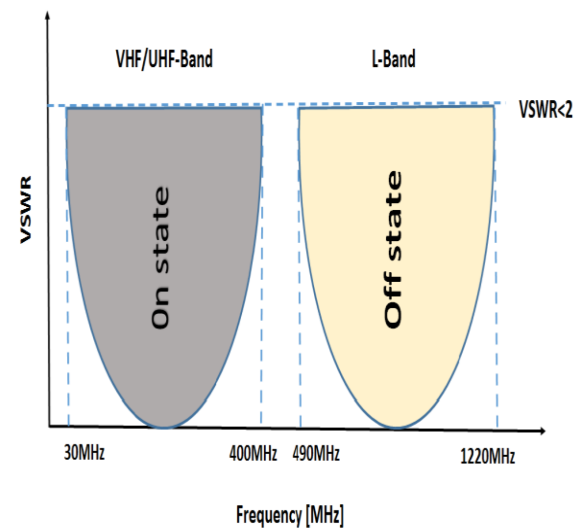

Fig. 1. Frequency operations for the proposed antenna.

In face of this limitation caused by the difficulty in large antennas construction, Edge-Shorted techniques might represent a potential solution for reducing the antenna size [5,6].

In this paper, we will address the above issues and present an antenna design that is suitable for drone covering the VHF/UHF/L-bands. The antenna is a frequency-reconfigurable antenna using a PIN diode. Fig. 1 shows the frequency operations for our proposed reconfigurable antennas in on and off state. It has a relatively simple structure. The antenna is dipole traveling antenna in the ON state covers 30–400 MHz and Edge-Folded monopole antenna in the OFF state to cover the L-bands. In Section II, the base antenna design and the performance will be described. Smart Geometry Reconfiguration and parametric design will be described in Section III. In Section IV, measurement results of the structure will be presented and compared to simulation results.

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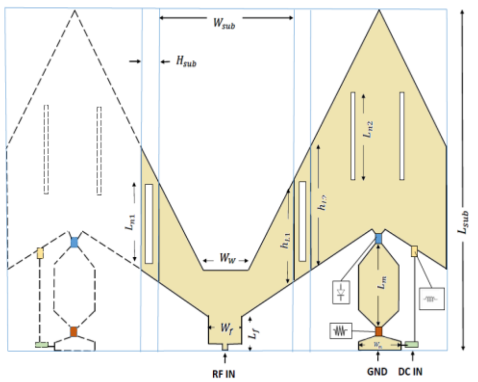

Fig. 2. Antenna geometry with embedded wing on the left

II. ANTENNA STRUCTURE AND DESIGN

As illustrated in Fig. 2, the reconfigurable antenna is designed on FR4 substrate (ε_r = 4.4, tanδ = 0.022) with thickness of 8 mm. The width of the 50 Ω microstrip feedline is calculated at 14.6 mm with length of 11.2 mm, but due to the feedline width and wing shape structure, and base on parametric analysis, is fixed at 11.0 mm that is designed on a single-layered substrate circuit board. The size of antenna is 100*151.5 mm. The semi-wing element and microstrip 50Ω feeding line are on the top of the substrate as shown in Fig. 3(a). The antenna side view with notch is depicted in Fig. 3(b). The bottom face, Fig. 3(c), contains the tuning notch, DC bias, metallic line and truncated ground plane with a plate. A photograph of the fabricated antenna with a gasket (ground plane) is shown in Fig. 4. To enable electronical reconfiguration, one commercial Metal Electrode Leadless Face (MELF) MACOM ™ RF p–i–n diodes, model M/A-COM's MA4P with a maximum power dissipation of 18 W, is embedded on the prototypes in order to connect the reflector to the metallic line stubs. Thus the maximum power dissipation of the proposed antenna is 18 W. Moreover, a current regulating SMD 51 Ω resistor, commercial choke inductors as AC block, are embedded in the proposed antenna geometry. In Fig. 2, L_f, taking into account feed length plus SMA attach.

In the proposed model, the RF p–i–n diodes are used to behave as 'ON/OFF' RF switch. By reverse biasing the p–i–n diode, the RF switches are in OFF-state. Otherwise, by forward-biasing the p–i–n diodes, the switches are in ON-state. The resulting solid-state switch has a switching time much faster than any mechanical switch or relay. This model can be extended to other RF structures such as frequency selective surfaces (FSSs) or RF filters. In this letter, simulated results are rendered on an equivalent circuit model in the ON/OFF state of a PIN diode. In ON-state, the RF p–i–n diode has an equivalent circuit corresponding to an inductor in series with a resistor, while in OFF-state, the equivalent circuit consists of an inductor in series with a parallel capacitor and a resistor. The RF p–i–n diodes are modelled for numerical simulation as series resistance under forward bias RS = 0.5 Ω; reverse parallel resistance RP = 5 kΩ; diode total capacitance at zero or reverse bias CT= 0.8 pF; and lead inductance L = 0.2 nH (the same value for ON-state and OFF-state) [4, 5].

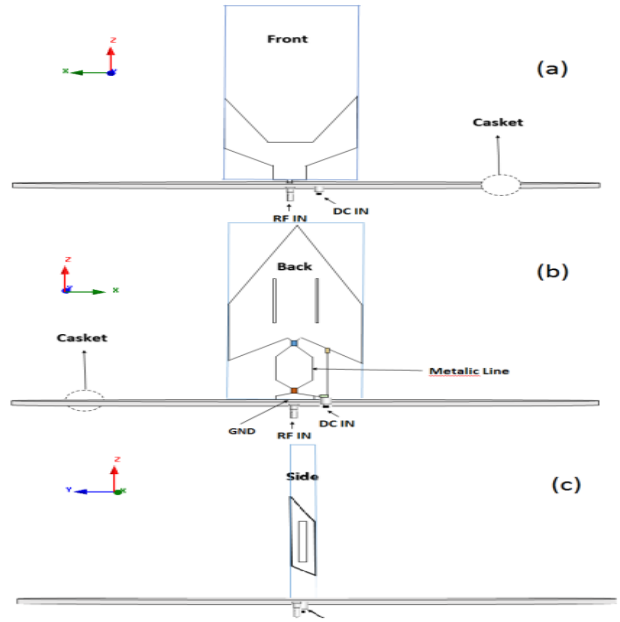

Fig. 3. Proposed antenna geometry

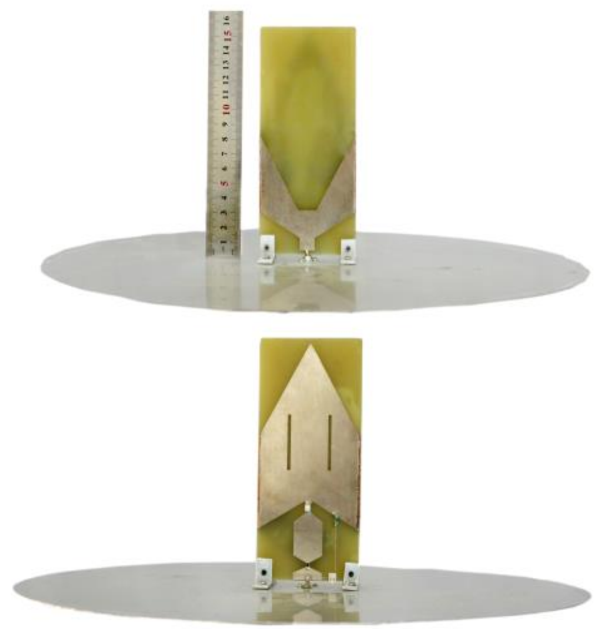

Fig. 4. The Picture of realized reconfigurable antenna

In certain reconfigurable antennas, a shorter path may mean a shorter current flow and thus a certain resonance associated with it. A longer path may denote a lower resonance frequency than the shorter path. In reconfigurable antennas resorting to physical and angular alterations, a shorter path means a faster response and a swifter reconfiguration [3].

In the ON state, the antenna operates as a dipole antenna with neither reflected current in the metallic line, and it operates in the VHF/UHF band. Then the most current is flowing to ground from the radiator and metallic line. When in the OFF state, the antenna operates as a monopole in the L-band. Thus, the most current is distributed over a radiator. In addition, the current is not distributed in the radiator [4].

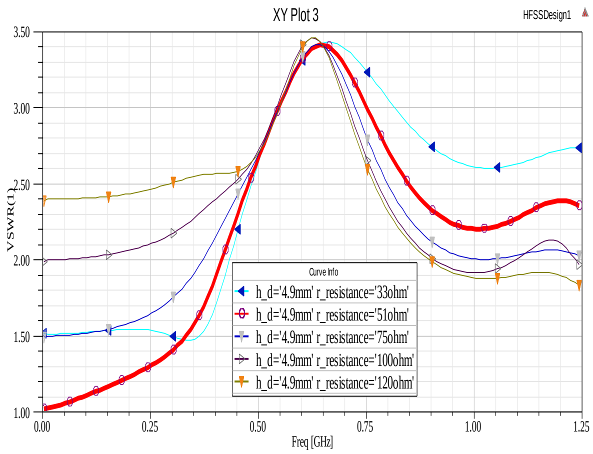

FIG. 5. SIMULATED VSWR WITH VARYING TERMINATION RESISTORS IN THE ON STATE.

III. CONFIGURATION AND DISCUSSION

When 0 V was applied to the DC-IN port, the diode was in the OFF state, and at 1.0 V, the diode is in the ON state, Thus resistor pass is available. Fig. 5 suggests that the value of adding resistance, connecting with the shorting structure between the reflector element and the electric plane, should be properly set in order to get lower VSWR. Comparing the five kinds of resistance, we find that 51 Ω is the best choice for the shorted antenna, supporting the better VSWR less than 2 and Lower VSWR is obtained with an optimum termination resistor of 51Ω. The proposed antenna was evaluated for its performance using metallic circular ground plane with diameter of 40 cm [4].

These dimensions consist a solution space for HFSS parametric analyses and to obtain the final design values, parametric studies have been done and the final values are listed in TABLE I.

TABLE I

OPTIMIZED PARAMETERS OF THE RECONFIGURABLE ANTENNA

Param	mm	Param	Mm	Param	mm	Param	mm
W_f	11	W_m	13.40	h_{L2}	58.86	W_{sub}	151.2
L_f	11.2	h_{L1}	51.23	L_{n1}	36	L_{sub}	70
W_W	20	L_m	35.7	L_{n2}	35	h_{sub}	8

IV. SIMULATED AND EXPERIMENTAL RESULTS

The parametric analysis of the main structure and simulation results with HFSS show that the antenna at ON state meets the conditions of VSWR less than 2, vertical polarization, and horizontal omni-directional radiation, on the work frequency band ranging from 30 MHz to 400 MHz. The antenna has a wide application in the VHF/UHF communication system.

The simulated and measured VSWR and The frequency responses of the final proposed antenna is shown in Fig. 6, Fig. 6(a) and (c) shows the VSWR and S11 in the switched ON state of the antenna. When in the ON state, the antenna has a VSWR and covers the VHF/UHF band (30–400 MHz). Fig. 6(b) and (d) shows the VSWR and S11 in the OFF state of the antenna. It has a VSWR of and covers the L-band (500–1216 MHz). The measured results of the bandwidth and gains related to fabricated antenna and case study in [4] are compared in TABLE II. When in the ON state, the measured peak gain of the antenna is less than 1.56 dBi at 30–400 MHz. When in the OFF state, the measured peak gain of the antenna is less than 4.56 dBi at 500–1216 MHz. Fig. 8 shows the measured result of the normalized radiation pattern. Fig. 7(a), (c), (e), (g) is radiation patterns of the antenna in the ON states respectively for 30 MHz, 200 MHz, 350 MHz, 1100 MHz . Fig. 7(b), (d), (f), (h) is in the OFF states and previously mentioned frequency.

Although small differences between simulation results and the construction of 1) feed impact and wiring related to the manufacturing process. 2) Using four compact substrate with a width of 2mm rather than a substrate with a width of 8mm. However, acceptable results as measured in HF band due to the lack of access to equipment and lack of compliance with the measurement results, regardless of its presentation was.

Positive point in this work by using of side slot was achieved, antenna size using this new technique compared to about 49 percent in the [4] removed. This success owes patch utilizes the maximum space that has imposed the manufacturing process more difficult; However, it seems that a compromise has been well-off and good trade-off.

Work done on the side slot that enables the use of radiation maximum levels patch was partly stripping revived. This method is applied for the first time in this article. Availability reflect the radiator surface notches to fine-tune the frequency is expected.

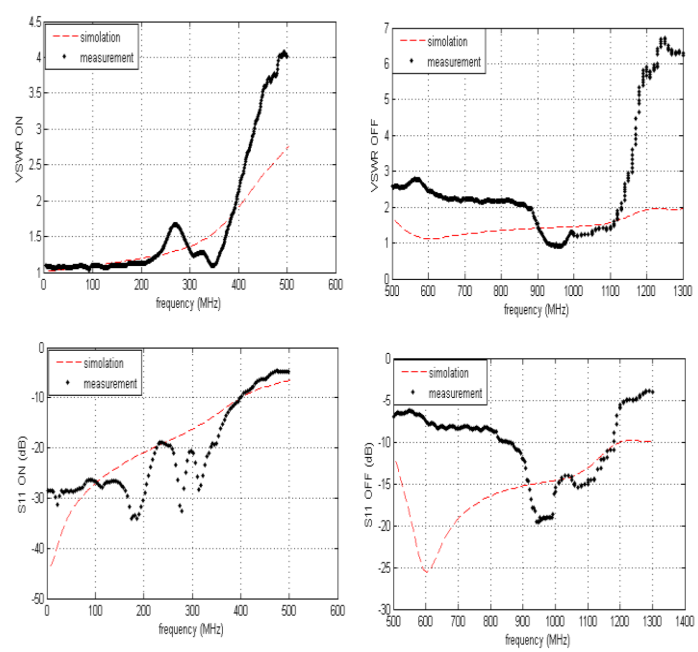

Fig 6. Comparison between simulated and measured reflection coefficient of the presented reconfigurable antenna.

TABLE II
Comparison with previously published works

Character	Switch/band	(Rhee et al., 2014)	This work
Bandwidth	ON	30~300 & 960~1220 MHz	30~400
	OFF	300~400 & 1150~1220 MHz	500~1216
Gain	VHF	0.75	1.45
	UHF	1.1	1.56
	L-band	2.6	4.56
Size (mm)	Patch	216*100*8	151.5*70*8
	Gasket diameter	1000	400

V. CONCLUSIONS

A triple band airborne blade antenna covering 30–400/ 500–1220 MHz has been designed and measured. The fabricated antenna has a VSWR<2 of for all bandwidths. The measured antenna gain is less than 1.56 dBi at 30–400 MHz and 4.56 dBi at 500–1220 MHz. Frequency bands of the antenna are reconfigured using a PIN diode switch and do not cover the entire operating band at the same time.

The proposed antenna has a simple structure since it minimizes the number of switches and lumped elements. It can also be used as a high-power antenna designed to withstand up to 18 W for aircraft applications. This antenna is enclosed in an aerodynamic radome and can be mounted in airborne platforms. Reduction in patch size with respect to a traditional rectangular patch and of up to 50% respect to [6] operating at the same frequency is obtained. Thereafter, antenna prototypes were fabricated and measured for validation purposes. Simulation and measurement results were obtained showing good agreement. As a result, the proposed antenna is attractive and can be practical for various multi-frequency airborne systems.

VI. ACKNOWLEDGMENT

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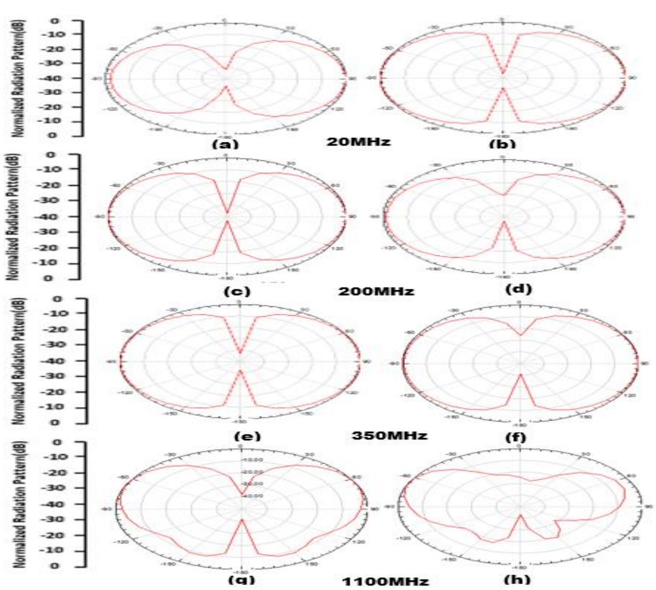

Fig. 7. Normalized measured radiation patterns

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