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The usage of Monopole antenna in Airborne activity

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Abstract: *AcompactprintedwidebandantennaoperatinginVHFbandwithsimplegeometry and nearly omni directional radiation characteristics is presented for airborne applications. The monopole antennas used in VHF airborne communications have height constraints as well as ground plane size constraints. This Letter proposes a printed monopole antenna with very compact size for airborne application which overcomes the ground plane size constraints of monopole antennas. The size of the proposed antennais $0.063\lambda_0$ X$0.118\lambda_0$, and the groundplanesizeis$0.025\lambda_0$X$0.132\lambda_0$ where λ_0 is the free space wavelength at lowest frequency of operation. The antenna achievesaheightreductionof75%comparedtoaconventionalquarterwavemonopole antenna. It also exhibits a 3:1 VSWR bandwidth of 32% in VHFband.*
Key words: *Airborne, Compact, Reduced Ground Plane, VHF, Wideband Antenna*

I. Introduction

Airbornesystemrequiresbroadbandomnidirectionalantennaswithsmallsize,lightweightand aerodynamic shape for applications like direction finding, communication etc. Monopole antennas, owing to its simple structure and omnidirectional radiation characteristics, are more preferred for airborne applications [1]. Monopole antennas for airborne applications have both height constraints as well as ground plane size constraints. It is well known that the radiation characteristics of monopole antennas are dependent both on the radiator geometry as well as on the ground plane. The resonant frequencyofmonopoleantenna doublesasthegroundplanesize diminishes from infinity to zero; resulting in a very large mismatch loss at the original frequency of intended operation [2]. This results in deterioration in the antenna impedance bandwidth and the monopole gain at the desired frequency band. Although considerable research efforts have been made to decrease the radiator size of monopole antennas, only limited number of research papers has been published discussing ways to mitigate theproblem ofground planesize constraints of the seantennas. Adipoleantenna combined with an RF choke canprovideaground-plane-independentantennasystemwithomnidirectionalradiation pattern [3]. But, the size of dipole antenna at VHF band is often very large and hence not suitable as a solution for ground plane size constraintsinair borne applications.Areducedgroundplanesize is achieved for monopole antennas in [3-5] by modifying the ground plane structure but they are also not suitable for this application as the skin of the airborne platform serves as ground plane for airborne monopoles. Printed monopoles require no backing ground plane as the ground plane of these antennas are printed either on same side or opposite side of substrate. Hence, they can provide a height and ground plane size reduced antenna with omnidirectional radiation characteristics suitable for airborneplatforms.

Various configurations of printed monopole antennas have been evolved for UWB radio systems in the frequency band 3.1-10.6 GHz. But, as the airborne communication system is operating in VHF/UHF band, it is required to design a low profile wideband printed monopole antenna. Therefore, size reduction and bandwidth enhancement are the major constraints for designing printed monopole antenna in VHF/UHF band for airborne applications.

In this Letter, a compact, wideband, printed monopole antenna, which requires a reduced ground plane to mount on, is presented for airborne applications. The proposed antenna uses folding technique for achieving height reduction [6] and loading technique for achieving bandwidth enhancement [7]. The antenna offers 32% bandwidth in VHF band. A preliminary study on this antenna has been reported in [8]. The new structure has a simple geometry and it achieves a height reduction of 75% compared to conventional quarter wave monopole antenna at lowest frequency of operation.

1. Proposed Antenna Design

Theproposedantennaisdesignedonglassepoxysubstrateofpermittivity4.4andsize145mm X 270mm. The antenna has two layers of 1.6mm thick substrates, the top layer contains the radiating element and bottom layer contains the ground patch, placed back to back. A double folded monopole design is used for designing radiator for achieving compactness. The ground plane consists of L shaped patch. Resistance loading method is used to achieve wideband characteristics.Sincetheresistorabsorbsapartofenergy,thegainoftheantennawilldecrease. Therefore, by considering the tradeoff between impedance bandwidth of the antenna and gain, theresistancevalueischosenas23.5Ω.Lumpedresistanceof23.5Ωisconnectedinserieswith the radiating patch. The antenna is fabricated and mounted vertically on an aluminium base plate of rectangular shape of dimensions 0.025 λ_0 X 0.132 λ_0 where λ_0 is the free space wavelength at lowest frequency of operation. The aluminium base plate was used to hold the connector and provide inter face to platform. The holding base also actsasareflector,increasing the gain of the antenna. A 50Ω TNC connector is used to excite the antenna. The centre conductor is connected to the printed radiating element of the antenna and outer to the bottom portion of the patch and to the aluminium base plate. Fig 1 depicts the antenna geometry. The dark black geometry in Fig 1 shows the radiating patch and the grey colored geometry shows the ground patch at the bottom of the substrate.Thedimensionaldetailsoftheproposedantenna are shown in Table1.

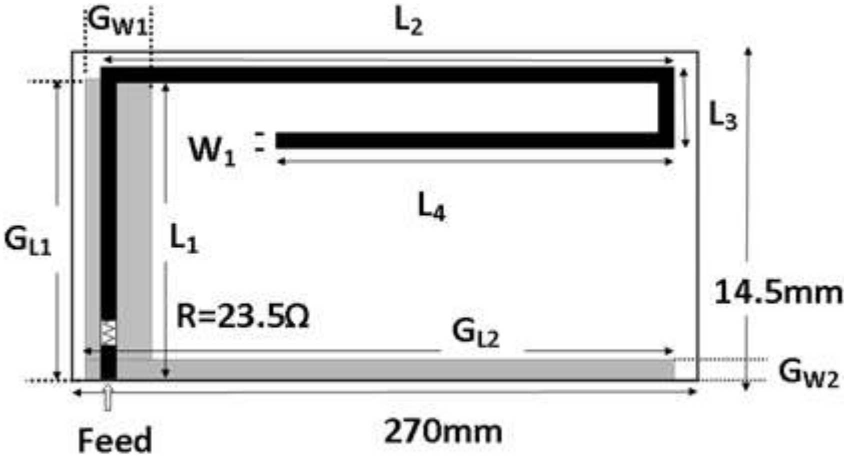


Figure 1 Geometry Layout of the proposed antenna

Table 1 Dimensions of the proposed antenna

Parameters	L_1	L_2	L_3	L_4	W_1	G_{L1}	G_{L2}	G_{W1}	G_{W2}
Value (mm)	140	235	36	180	12	130	255	30	10

2. Simulation Results And Parametricstudy

A parametric study on the proposed monopole antenna design was carried out using HFSS software to investigate the influence of each antenna dimension on the antenna performance. One parameter is varied and the other parameters are kept constant, as they are in Table 1.

2.1. Effect of radiating patchdimensions

The length of the radiating element determines the resonating frequency. It was found that,the dimensions $L_1$and $L_2$are found to contribute more on size reduction of the antenna than the dimensions $L_3$and L_4. The proposed antenna was simulated for various patch widths and the effect of this parameter on the return loss characteristics is shown in Fig 2. The radiatingpatch width (W_1) is varied from 2mm to 8mm instep of 2mm. AsseenfromFig2,thebandwidthfor return loss less than -6dB of the antenna increases as the radiating patch width increases from 2mm to 8mm, where, the lower edge of the bandwidth remains almost constant and the upper edge of the bandwidthincreases.

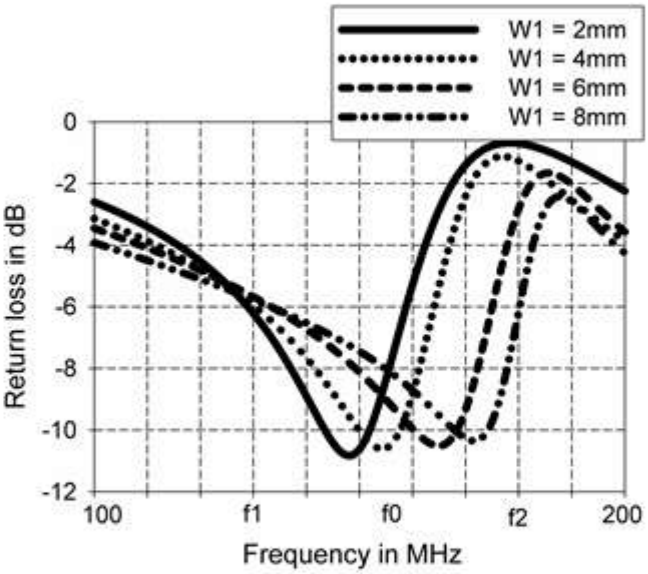


Figure 2 Effect of W_1 on the impedance bandwidth of proposed antenna

2.2. Effect of ground planedimensions

The proposed antenna was simulated for various ground plane dimensions. The ground plane lengthG_{L1}wasvariedfrom5cmto13cminstepof4cmandtheeffectofG_{L1}onthereturnloss of the proposed antenna is shown in Fig 3. It can be seen from Fig 3 that increase in G_{L1} improves the impedance matching of the antenna at lower frequency. The effect of G_{W1} on the return loss of antenna was studied by varying G_{W1}from1cmto3cminstepof1cmandisplotted in Fig 4. The bandwidth of the antenna for S11 < -6dB, increases with increase in G_{W1} as seen from Fig4.

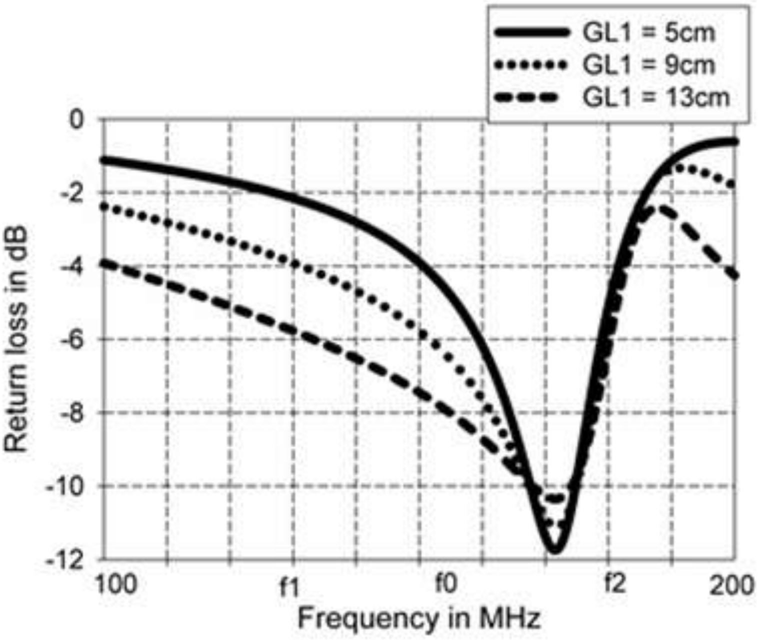


Figure 3 Effect of GL1 on return loss of proposed antenna

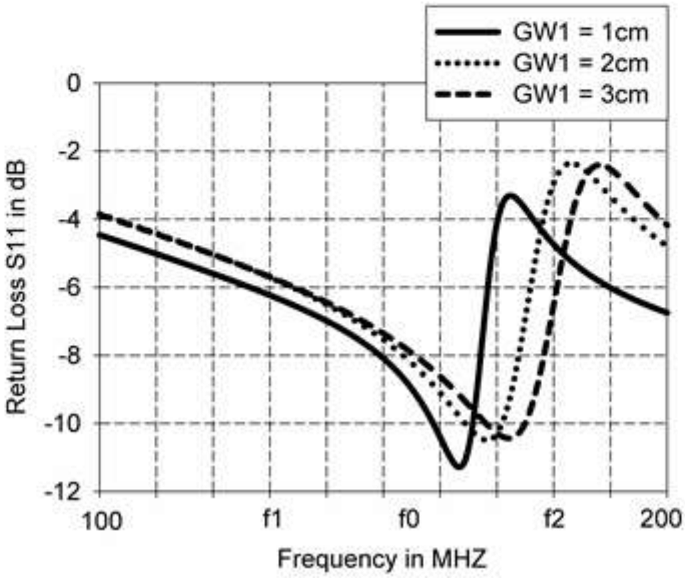


Figure 4 Effect of G_{W1} on the impedance bandwidth of proposed antenna

The dimension G_{L2} is polarization determining factor. In the absence of G_{L2}, the antenna is horizontally polarized when mounted vertically. G_{W2} does not have any significant influence on the antenna characteristics.

2.3. Effect of the substrate thickness on the proposed antennaperformance

Theeffectofthethicknessofthesubstrateontheimpedancebandwidthandgainoftheantenna is studied by varying the thickness from 1.6mm to 6.4mm in step of 1.6mm. Unlike microstrip patch antennas, increase in the thickness of the substrate decreases the antenna impedance bandwidth. However, the gain of the antenna increases with increase in the thickness of the substrate. The variation of gain of the antenna at frequencies f_1, $f_0$and f_2 MHz for various substrate thickness is tabulated in Table 2. The gain of the antenna for substrate thickness 3.2mmisgreaterthanthatforthickness1.6mmasseenfromTable2.So,asacompromise,the thickness of the antenna was fixed to 3.2mm as it could give improved gain in the entire frequencyband.

Table 2 Variation in the gain of the proposed monopole antenna with substrate thickness

Frequency (MHz)	Peak gain in dB for various substrate thickness			
	1.6mm	3.2mm	4.8mm	6.4mm
f_1	-29.89	-18.90	-16.69	-15.48
f_0	-24.25	-14.73	-12.57	-11.38
f_2	-14.96	-8.14	-7.03	-7.01

II. Experimental Results

The performance of the proposed monopole antenna was evaluated using E5061A Vector Network Analyzer [Agilent]. The measured return loss of the antenna is found to be less than- 6dB over the referred frequency band. The antenna exhibits a 3:1 VSWR bandwidth of 32%at the centre frequency f_0 MHz as shown in Fig 5. Measured result shows a good agreement with the simulated result. The slight discrepancy is due to the fabricationtolerance.

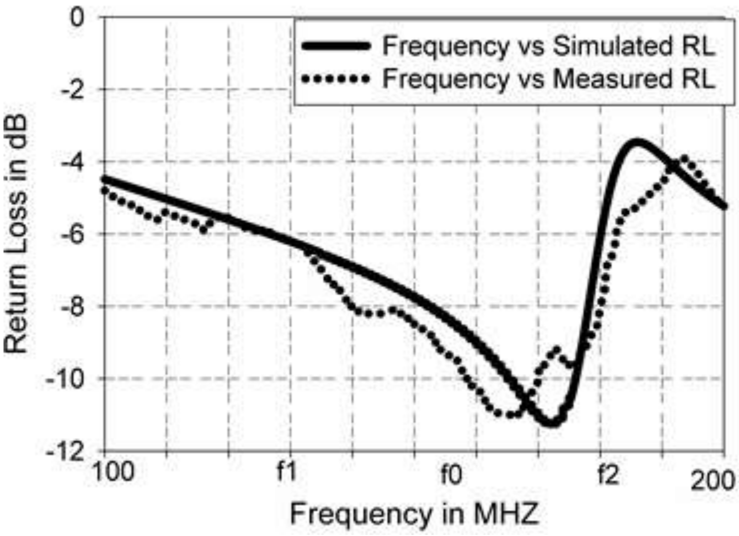
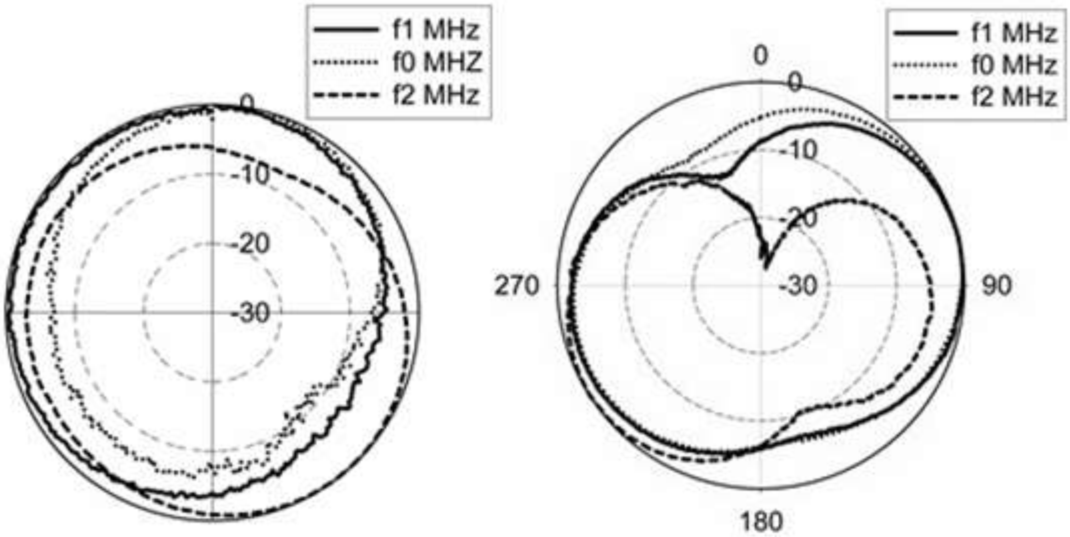


Figure 5 Measured and simulated return loss of the proposed antenna

The antenna was tested for its far field radiation characteristics in an open field. The measured H plane and E plane radiation patterns of the antenna at f_1, f_0 and f_2 MHz are shown in Fig 6(a) and Fig 6(b) respectively. It can be seen that the H plane radiation pattern of the proposed antenna is nearly omnidirectional at all frequencies. The measured gain of the proposed antenna at three discrete frequencies f_1, f_0 and f_2 MHz is shown in Table 3. This is expected as the loaded resistance absorbs a part of the energy.



(a) (b)

Figure 6 Measured radiation pattern of proposed antenna (a) H plane (b) E plane

Table 3 Measured gain of the proposed monopole antenna

Frequency (MHz)	Measured gain (dB)
f_1	-16.9
f_0	-15.4
f_2	-9.2

III. Conclusion

A compact, wideband printed monopole antenna, with a reduced ground plane, operating in VHF band has been developed and the results are presented. A parametric study was carried out to study the effect of the dimensions of the radiator as well as the ground plane on the antenna performance. The proposed antenna has a simple geometry and is easy to fabricate.

Theantennaexhibitsa3:1VSWRbandwidthof32%anditachievesaheightreductionof75% compared to conventional quarter wave monopole antenna. The antenna, due to its very compact size and reduced ground plane, finds application for VHF airbornecommunications.

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