Normal Mode Helical Antenna at 1.8 GHz with Small Circular Ground Plane

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Abstract—**This paper describes the effect of wire with small circular ground plane size (radius < λ/20) for normal mode helical antenna at which resonance condition is achieved without using any external impedance matching network. A comparative study of variation in performance of helical antenna with respect to variation in thickness of wire and ground plane size at 1.8 GHz is carried out using simulation. By comparing various results, appropriate values of the parameters are selected and the proposed antenna has been fabricated and results are experimentally validated.**

Keywords-Bandwidth, Ground Plane, Helical Antenna, Normal Mode

I. INTRODUCTION

The design of helical antenna was introduced in 1946 [1]. Helical antenna is a 3-D structure, which can be considered as combination of linear and loop antennas. Normal mode helical antennas (NMHA) are used in VHF and UHF band communication, wireless equipment, telemetry, RFID, aircraft and guided missile fields, where small size is an important criteria.

NMHA has advantages of reduced height, ease of installation and good efficiency. The disadvantages are smaller bandwidth [1-2]. Helical antenna is a resonating structure and many techniques have been reported in literature for construction of NMHA [2-3]. A helix has greater field concentration than the corresponding monopole due to its physically shorter structure [4]. In [5], a pseudo-normal helical antenna has been designed for use with deeply implanted wireless sensors. The biggest drawback of the NMHA is the low impedance, which necessitates the use of impedance matching network. Several methods for impedance matching have been reported. In [2], the length of NMHA has been mentioned as λ/4 with infinite ground plane and tap feed is used to achieve impedance matching. In [6], a small profile NMHA is developed for wireless communication system using tap structure for better impedance matching but gain is about -3.9 dB. NMHA arrays have advantage of deeper nulls in comparison to their equivalent monopole antenna array [7]. In [8], a quarter wave transmission line has been used for impedance matching. A helical antenna with small ground plane and without any external impedance matching network has not yet been reported to the best of author's knowledge.

In this paper, it has been shown that impedance matching for NMHA is possible with small ground plane (radius< λ/20) without using any external impedance matching network. The appropriate dimensions of thickness of wire, ground plane size, length of wire and height of NMHA for resonance condition have also been proposed.

II. DESIGN SPECIFICATIONS

The geometry of the helical antenna is shown in Fig. 1. It consist of parameters viz., diameter of the helix (D), the pitch angle (α), spacing (S) and the number of turns (N).

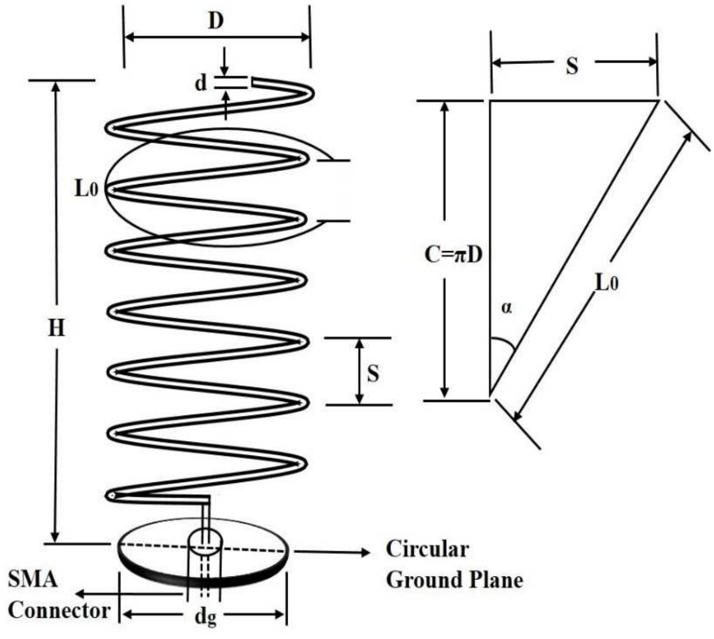


Fig. 1. a) Geometry of helical antenna and b) Representation of one turns

The total length of the wire, pitch angle (α) and height of helical antenna is calculated as

$$L = N\sqrt{(S)^2 + (\pi D)^2} \tag{1}$$

$$\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right) \quad (2)$$

$$H = N * S \quad (3)$$

For NMHA the circumference (C) is very much less than wavelength.

$$C = \pi * D, C << \lambda \quad (4)$$

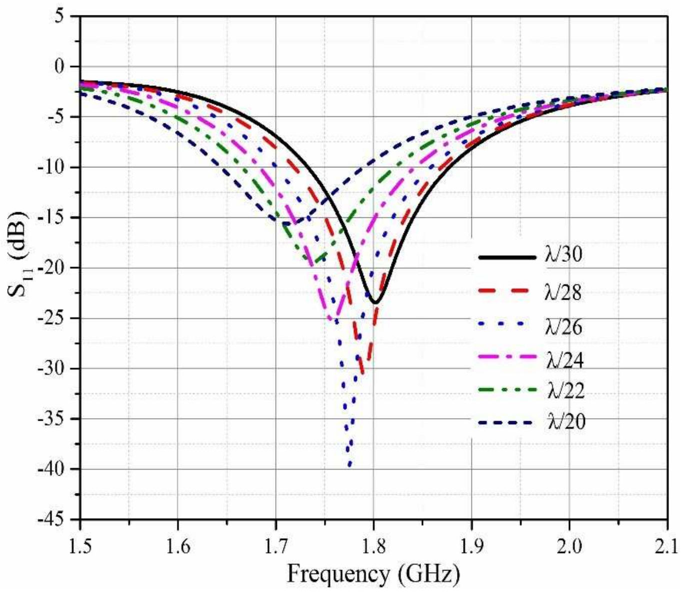
The resonance condition of NMHA can be achieved by adjusting the spacing (S) between the turns, the diameter of the helix (D), the thickness of wire (d), number of turns (N), length of wire (L) and ground plane radius (r_g). Simulations have been performed using different values of this parameters. The values of spacing (S), the diameter of the helix (D) and the number of turns are then fixed to 0.027λ, 0.033λ and 7 respectively. The length of one turn (L_0) is 0.1λ. The ground plane acts as a wave launching device and its shape and size are important parameters on which the performance of a helical antenna, like gain, impedance, beam width, radiation pattern, etc., depends. The conductor also affects the performance of helical antenna.

III. Parametric Study

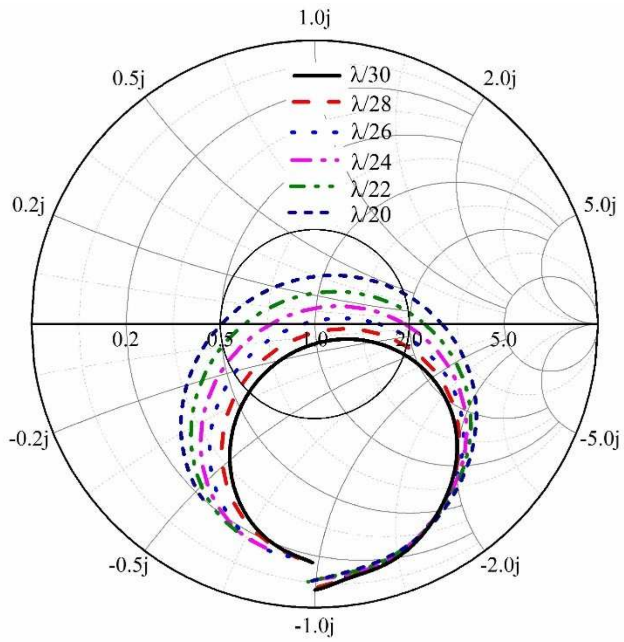
In this section, the design of the proposed NMHA at 1.8 GHz is presented. The simulated return loss and input impedance plots are compared for different values of ground plane radius (r_g) and radius of wire (r_{wire}).

A. *Effect of variation of ground plane radius on normal mode helical antenna*

The simulated return loss and input impedance plots are shown in Figs. 2 for different values of ground plane radius (r_g).



(a)



(b)

Fig. 2. Effect of variation of ground plane radius on (a) Return loss and (b) Input impedance plots of 1.8 GHz NMHA for r_{wire}=1.6 mm (λ/100).

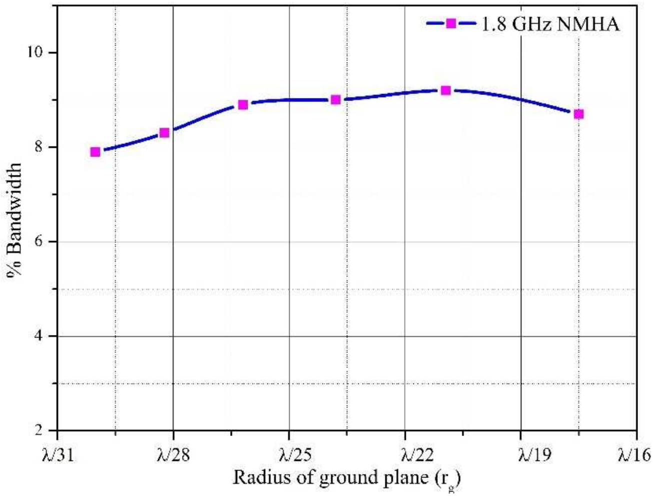
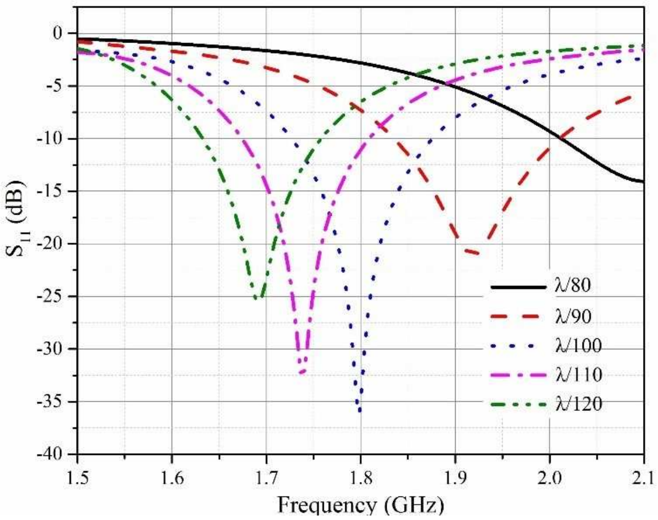


Fig. 3. Effect of ground plane radius on % bandwidth

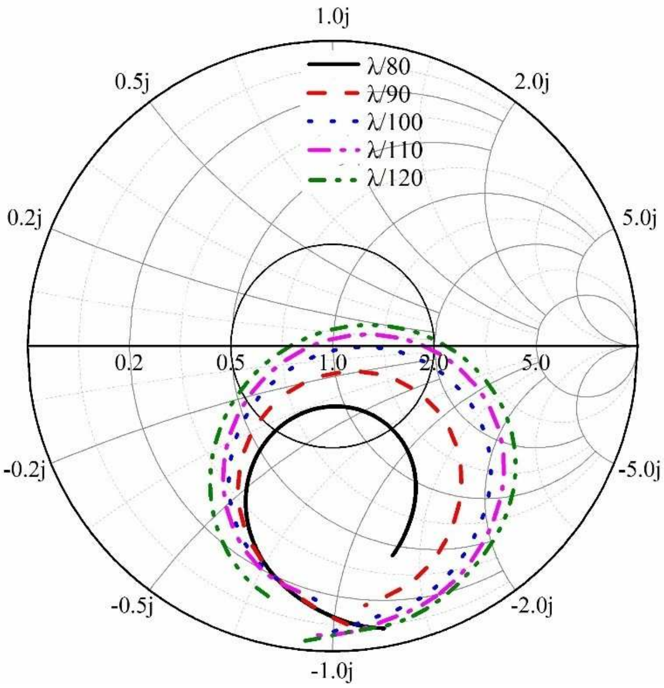
It has been observed that as the ground plane size increases from 5.53 mm (λ/30) to 8.3 mm (λ/20), the resonance frequency decreases from 1.802 GHz to 1.712 GHz and the impedance curve shifts upwards as the impedance decreases. The better impedance matching has been obtained for ground plane radius (r_g) value of 5.5 mm (λ/30). It shows inductive nature when ground plane radius (r_g) increases and capacitive nature when ground plane radius (r_g) decreases as observed from Fig. 2(b). A bandwidth of 8.0 % is obtained at a resonance frequency of 1.8 GHz NMHA which is shown in Fig. 3. It is observed from Fig. 3 that with increase in ground plane radius from λ/30 to λ/20, bandwidth increases but decreases after that.

B. *Effect of variation of thickness of wire on normal mode helical antenna*

The simulated return loss and input impedance plots for different values of wire radius (r_{wire}) are shown in Fig 4. As the thickness of wire increases, its inductance decreases and hence the resonance frequency increases.



(a)



(b)

Fig. 4.Effect of variation of thickness of wire on (a) Return loss and (b) Input impedance plots at 1.8 GHz NMHA for r_g=5.5 mm (λ/30).

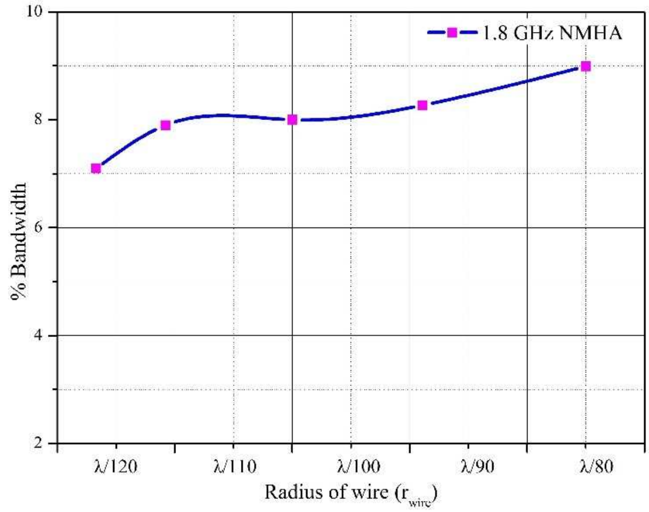


Fig. 5. Effect of thickness of wire on percentage bandwidth

It has been observed that for ground plane radius of 5.5 mm (λ/30), as r_{wire} increases from 1.38 mm (λ/120) to 2 mm (λ/80), the resonance frequency increases from 1.676 GHz to 2.053 GHz and impedance plot shifts downwards as inductive reactance decreases due to increase in thickness of wire. The value of r_{wire} for which the impedance plot passes through the centre of smith chart is found to be, λ/100 for resonance frequency of 1.8 GHz NMHA. Bandwidth of 8.0 % is obtained at resonance frequency 1.8 GHz NMHA which is shown in Fig. 5. It is also observed from Fig. 4 (b) that the bandwidth of helical antenna with thicker wire (λ/80) can be increased further by increasing the size of ground plane.

IV. Results and Discussions

Fig. 6 shows fabricated NMHA at 1.8 GHz and Fig.7 shows simulated and measured return loss plots for NMHA at 1.8 GHz. The antenna is fabricated using a copper wire of 3.2 mm diameter. As per antenna dimensions, the spacing between the turns is 4.5 mm (0.027λ), diameter of coil is 5.5 mm (0.033λ), ground plane radius is 5.5 mm (λ/30) and number of turns are 7. The radiation characteristics of this antenna are the same as those of the linear monopoles, i.e., maximum radiation is in the plane perpendicular to helix axis and a null along the direction of helix axis.Fig. 8 shows the simulated and measured radiation pattern in E-plane (co-polar and cross-polar components) at 1.8 GHz NMHA with ground plane radius (r_g) of λ/30 and radius of wire (r_{wire}) of λ/100. For this antenna half power beamwidth is 83.9^o and maximum cross polar component is -25dB. Maximum gain achieved at ground plane radius of 5.5 mm (λ/30) and wire radius of 1.6 mm (λ/100) is 2.08 dB.

Fig. 6. Fabricated 1.8GHz NMHA

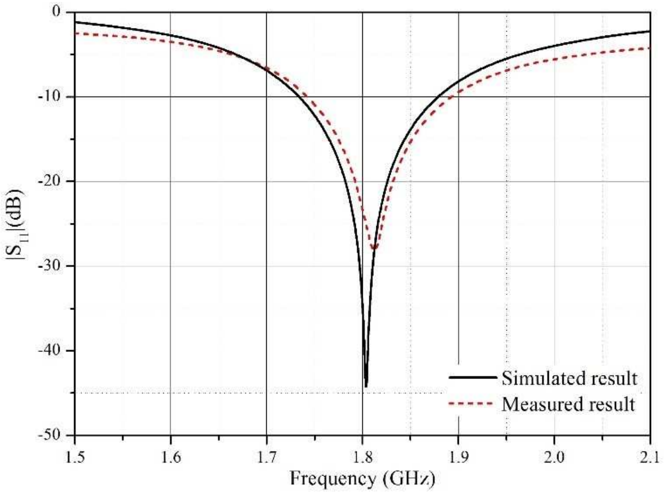


Fig. 7. Simulated and measured return loss plot at 1.8 GHz NMHA.

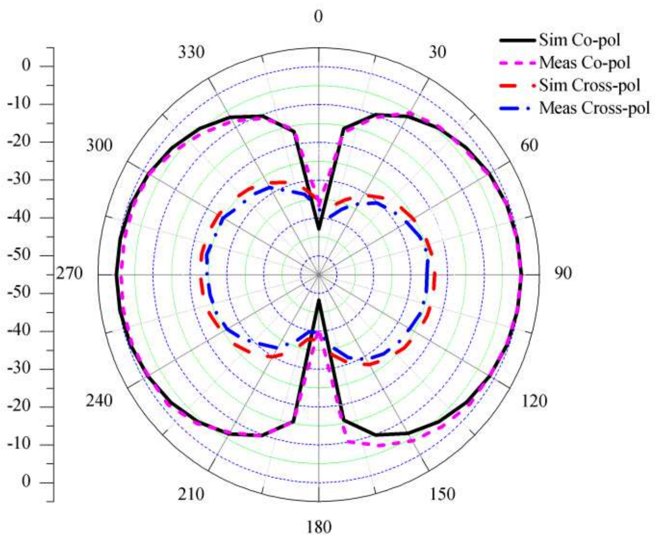


Fig.8. Simulated and measured radiation pattern at 1.8 GHz NMHA

V. Conclusions

The simulation results of NMHA at 1.8 GHz shows that a small circular ground plane (radius < λ/20) do not require any external impedance matching network. The resonance condition of NMHA is achieved for spacing as 0.027λ, diameter of the coil as 0.033λ and number of turns as 7.The value of ground plane radius and that of radius of wire at resonance frequency 1.8 GHz is λ/30 andλ/100 respectively. The simulated and measured results of 1.8 GHz NMHA are in good agreement.

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