Design of a Meander-on-Slab Dielectric Resonator Antenna for UHF Hand-Held Radio Application

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1.0 Introduction

Handheld radios technologies compose one of the most rapidly growing industrial markets today. Moreover, the handheld radio, which is also called as a 'walkie-talkie' has been vastly used across sectors such as business, military, public safety etc. Naturally, these applications require antennas, and typically the types of the antenna that are more popularly used are such as helical antennas or dipoles. Due to the possible large miniaturization factor provided by the Meander Line Antenna (MLA), this work is an effort to investigate and determine the suitability of this design and miniaturization technique as an alternatives to dipoles and helical antennas. Moreover, it is also known that even though a higher dielectric constant (ε_r) may be inefficient in its radiation properties, implementing the antenna on a thin slab with high ε_r will most certainly produce a miniaturized antenna. In this project, the meander line technique has been applied to design a Meander-on-Slab (MoS) antenna to significantly reduce the physical size of a two-way radio antenna [1 – 4]. The design of the MoS, which has small dimension, is implemented on several ceramic materials with different er, such as a Barium Strontium Titanate (BST), Rogers RO4003C and FR-4. Finally, results comparison between simulated MoS will be presented in order to determine its suitability for potential fabrication and commercialization.

2.0 MoS Design and Calculation

The design of the MoS antenna is shown in Fig. 1. As mentioned, since the MoS antenna design will be implemented using different materials, three potential materials are chosen as contenders. The materials chosen are (BST), FR-4 Board and Rogers RO 4003C, since all of them has significant difference in terms of material properties, especially their dielectric constant (ε_r). Since different ε_r will produce a different calculated slab thickness, a formula in [1] is used to determine its real value. The resonant frequency, f_0, (in GHz) which is a function of the resonator diameter, D_r, and length, L_r, both in inches, are determined based on calculation from equation (1) below:

$$f_0 = \frac{8.553}{\sqrt{\varepsilon_r}\left(\frac{\pi}{4}\left(D_r^2\right)\left(L_r\right)\right)^{\frac{1}{3}}} \qquad (1)$$

This formula which originated from a cylindrical shaped resonator was altered to suit the rectangular-shaped dielectric used as the basis of the MoS. The fix in the value of D_r in order to define L_r where $L_r = l$. Surface area of the cylinder, A will be compared with surface area of the rectangular slab, B, which is given in formulas as follow:

$$A = 2\pi r^2 + 2\pi rl \qquad (2)$$

$$B = W_S \times t_s \qquad (3)$$

Where W_s is the width of the dielectric slab, *l* the height of the cylinder, *r*, the radius of the cylinder, and t_s is the thickness of the dielectric slab.

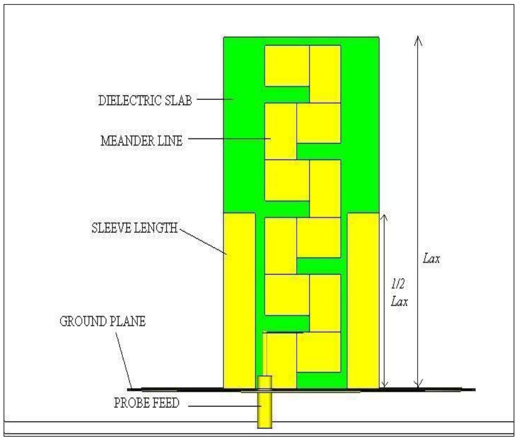

Figure 1: Overview of the MoS

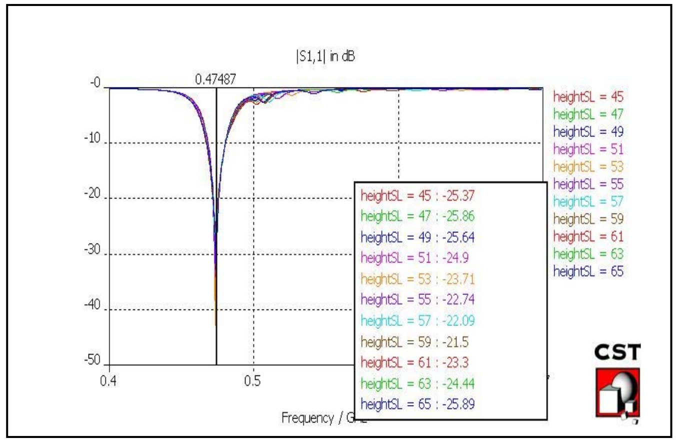

Figure 2: Parameter sweep for sleeve length

3.0 Results, Analysis and Discussion

The width of dielectric slab fixed 49 mm. The height of a dielectric slab depends on number of turns, *N*. The increase in *N* will have direct effect on the height of dielectric slab, *Ls*. Sleeve length depends on height of the meander line antenna, which is ½ *Lax*. From the investigation through simulation using different materials, only BST as its substrate could produce a MoS with a satisfactory performance in terms of reflection coefficient. Another significant discovery from this work is that the MoS which is backed with Rogers RO4003C substrate could increase the resonance bandwidth. This fulfill theoretical literatures in [4] in antenna broadbanding using either a dielectric cover, or in [5], in using an increased thickness for the same purpose.

The parametric sweep for different slab height, *Lax*, is also investigated and shown in Fig. 2. Increasing the slab height, *Lax*, from 45 mm to 65 mm in 2 mm steps has not produced much of difference in terms of the reflection coefficient. Although it shown a slight decrease in this parameter between 49 mm to 59 mm, all values are still acceptable and maintained an acceptable antenna performance of S11 < -10 dB [6]. However, to maintain a compact size, and conformity to a mould with less than 50 mm length [7], the least value is chosen, which is 49 mm.

Table 2: The effect number of turn (N)

Number of turns (*N*)	Directivity (dBi)	Frequency response (MHz)	Reflection Coefficient S_{11} (dB)	Bandwidth, *BW* (MHz)
1	5.086	483.09	-8.48	0
2	5.664	474.29	-11.54	4.41
3	5.651	473.80	-37.54	12.83
4	5.593	474.55	-16.12	8.63

Table 2 is a summary of the investigation in determining the best number of turns for the MoS, *N*. It clearly shows that *N=3* will produce an optimal reflection coefficient of -37.54 dB at the desired frequency, which is 473.80 MHz. This *N* produced a bandwidth of 12.83 MHz. Figure 2 and Table 3 is an examination of the effect of the matching section's height, which is also known as the sleeve. The parametric study shows that with the increase of sleeve height, the reflection coefficient will increase, and so will the resonant frequency. The optimal height of sleeve should be half the total length of the meander line (*1/2 Lax*).

As previously mentioned, the best MoS design, achieving the widest bandwidth and best reonance will be obtained using the R4003C-backed, BST design. The reflection coefficient value, Γ, for MoS antenna is $\Gamma = 0.0133$, the standing wave ratio, $VSWR = 1.027$, and return loss, $RL = 37.523$ dB. The bandwidth was about 13 MHz. Summary of the optimal MoS design is tabled out in Table 4.

In this work, four number of N is tested out to study the parametric performance of the MoS. Between $N = 1$ and $N = 2$, the directivity increases steadily between 5.086 dBi and 5.664 dBi, and start decreasing to 5.593 dBi after $N = 3$. More number of turns will provide lower resonant frequency to the MoS, with the lowest at 473.80 MHz at $N = 3$. Reflection coefficient and its bandwidth, which are -37.54 dB and 12.83 MHz, respectively, at that specific number of turns are also at its optimal performance.

The length of matching sections between 7 mm to 10 mm in Table 3 showed a slight positive effect on the frequency response, and a drastic increment when it is increased to 11. On the other hand, using between 7 mm and 10 mm matching section's length will also steadily increase the bandwidth from 4.24 MHz to 8.00 MHz. A decreasing trend is observed when an 11 mm matching section is used. However, the 11 mm matching section produced the best reflection coefficient (S_{11}) with the value of -41.83 dB. In stark contrast, matching sections of lengths 7 mm to 10 mm produced S_{11} of -11.82 dB to a maximum of -18.22 dB only.

Table 3: The effect of matching section

Matching Section length (mm)	Reflection coefficient (S_{11}) dB	Frequency response (MHz)	Bandwidth (MHz)
7	-11.82	465.20	4.24
8	-14.06	465.19	5.96
9	-16.40	465.60	7.09
10	-18.22	466.51	8.00
11	-41.83	496.60	7.48

Table 4: Summary of the MoS parameters

Parameters	MoS Antenna
Reflection Coefficient (Γ)	0.0133
VSWR	1.027
Return Loss (*RL*) dB	37.523
Bandwidth (*BW*) MHz	12.84
Gain dB	1.236
Directivity	5.651
Efficiency	0.2187

4.0 Conclusion

A design and parametric investigation of a Meander-on-Slab (MoS) antenna is successfully conducted and analyzed. The results show that a good antenna of this kind could be designed even when the high dielectric constant (ε_r) is used. Despite the design of an antenna which is lower in radiation efficiency and smaller resonant bandwidth, increasing the layer thickness [8] could be a solution in undertaking the bandwidth constraint, in the mission to produce a compact antenna for the UHF domain.

Acknowledgement

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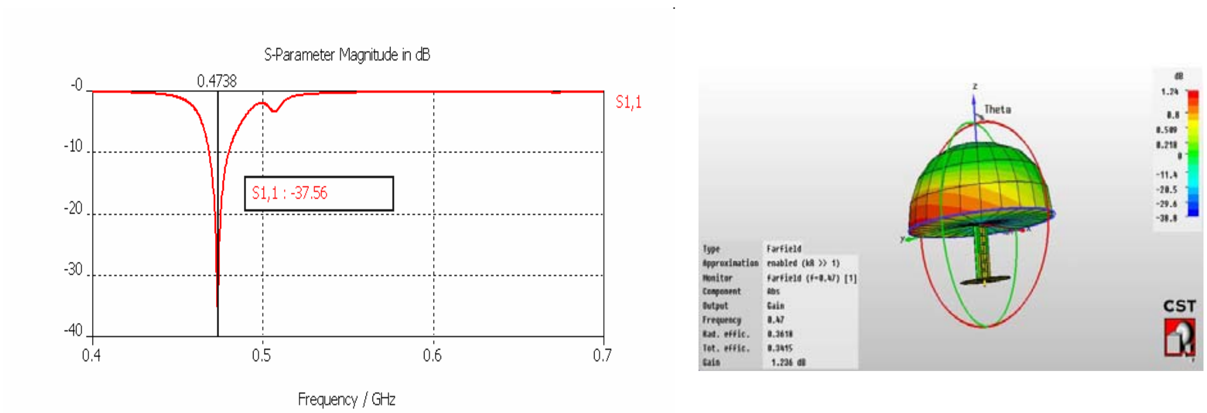
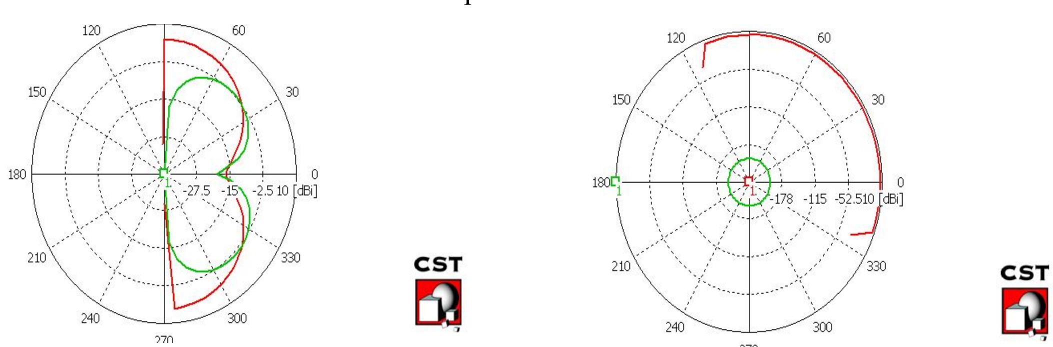


(a) (b)

Figure 3: (a) S11 for the MoS (BST as dielectric slab backed by RO4003C and (b) 3-D Far-field radiation pattern



(a) (b)

Figure 4: Far field radiation pattern for the designed MoS (a) H-Plane and (b) E-Plane