Microstrip Antenna Bandwidth Estimation using Bhatnagar's Postulate

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Abstract: **Large variety of substrate materials are available for manufacturing microstrip antennas. These differ in thickness (h) and dielectric constant (ε) apart from loss tangent and other microwave properties. This paper presents a new approach for selecting the h and ε of the MSA substrate. Bhatnagar's postulate has been used to investigate dependence of bandwidth on h and ε. This has resulted in a new formula for estimating the bandwidth of the MSA. For the required bandwidth, desired values of h and ε can be obtained. These can then be used in selecting the substrate material.**

Key Words: **Microstrip Antenna, Dielectric constant, Bandwidth, Bhatnagar's Postulate, Resonant Frequency.**

1. INTRODUCTION

Microstrip Antennas (MSA) find wide applications in modern communication gadgets. Small size, weight, volume and good characteristics of MSA are responsible for this. Design and manufacturing of MSA has, therefore, attracted big attention. Properties of materials play an important role in selection of materials for manufacturing. This in turn depends upon the desired characteristics of the product to be manufactured. Impedance Bandwidth (BW) is one such characteristics of MSA. This paper presents estimation of MSA Bandwidth by a new method which is based on Bhatnagar's postulate. The method relates BW with material parameters such as dielectric constant (ε) and thickness (h) of the antenna substrate. Therefore, the investigations presented in this paper are useful for selection of material for MSA substrate. Knowledge of Bhatnagar's Postulate and its implications are required for following the investigations presented in this paper. Therefore, these are given below.

A. Bhatnagar's Postulate

Basic structure of a rectangular microstrip antenna is shown in Fig 1. Bhatnagar's Postulate states that "For a rectangular microstrip antenna, extension (d) in the physical length of the patch is directly proportional to the thickness (h) of the antenna substrate and the electrical length (L_e) of the patch and is inversely proportional to its width (W_p). The constant of proportionality (β) is independent of the dielectric constant (ε) of the substrate, thickness (h) and resonant frequency (f_o)" [1, 2].

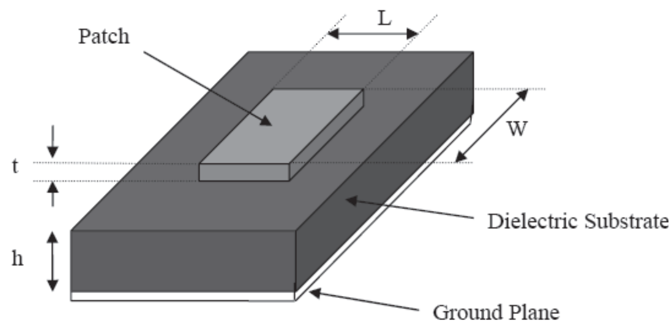


Fig 1: Basic structure of microstrip patch antenna

Mathematically

$$d \propto \frac{h \times L_e}{W_p} \quad (1)$$

or

$$d = \beta \frac{h \times L_e}{W_p} \quad (2)$$

where β is the constant of proportionality. It has been termed as Bhatnagar's constant. For a rectangular patch its value is unity.

Classically, $d = 2 \vartriangle L$ and $Wp = \frac{\lambda g}{2}$. Therefore

$$\vartriangle L = \beta \times H \times Le \quad (3)$$

where,

$$H = \frac{h}{\lambda g}$$

Therefore, for a rectangular patch,

$$\vartriangle L = H \times L_e \quad (4)$$

The extension in length (due to fringing fields) of the radiating edge is directly proportional to the electrical length of the radiating patch.

Physical length (L_p) of the patch is then given by

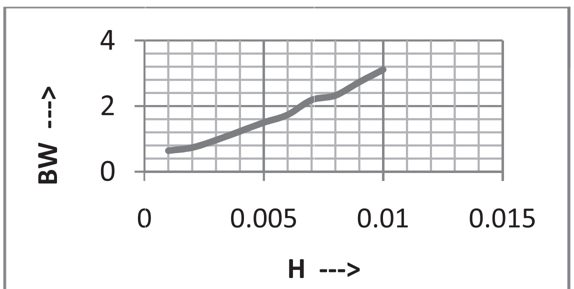
$$L_p = L_e - 2 \vartriangle L$$

$$= (1 - 2H)\ L_e \quad (5)$$

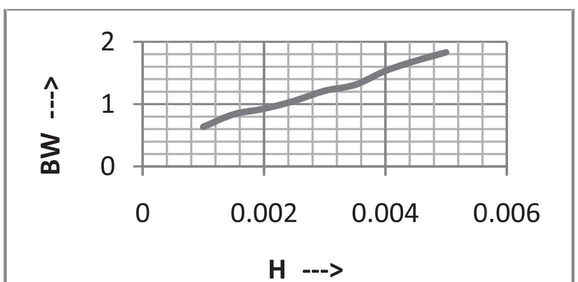
This is the new, simple and straight forward formula for finding the physical length of the patch.

3. INVESTIGATION OF BANDWIDTH AS A FUNCTION OF 'H' PARAMETER

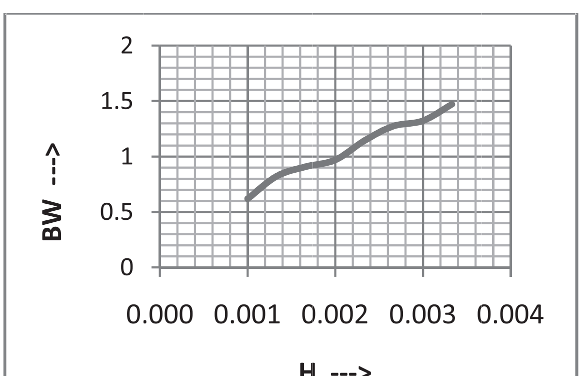
In the past, classical formulae were used to calculate length and width of the antenna patch. In this paper, Bhatnagar's postulate is used to calculate parameters of proposed designs. Values of 'H' used in these simulations cover the range from 0.002 to 0.02. Large number of rectangular MSA were designed. Every design was simulated using HFSS. Percentage band width (% BW) was extracted and plotted against H for various values of ε. Resonant frequency (f_o) was randomly selected to be 2 GHz. Figure 2 shows the dependence of the % bandwidth on the normalized thickness of the antenna substrate. Study of these graphs indicates that this dependence is a function of ε also. % BW increases as 'H' is increased but decreases as ε is increased.



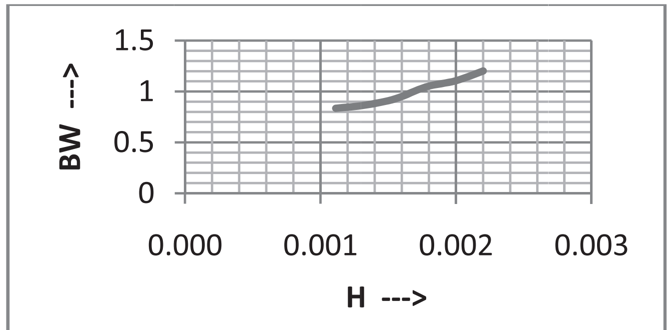
(a) % BW v/s H for ε = 2



(b) % BW v/s H for ε =4



(c) % BW v/s H for ε = 6



(d) % BW v/s H for ε = 9

Fig 2: Variation of % Bandwidth with normalized thickness of the antenna substrate for various values of the dielectric constant

Therefore bandwidth was investigated as a function of H/√ε. However, the results still varied with ε. Finally, H/ε was selected as the key parameter. Fig 3. Shows the dependence of % BW on H/ε for f_o = 2 GHz. A linear relationship was obtained.

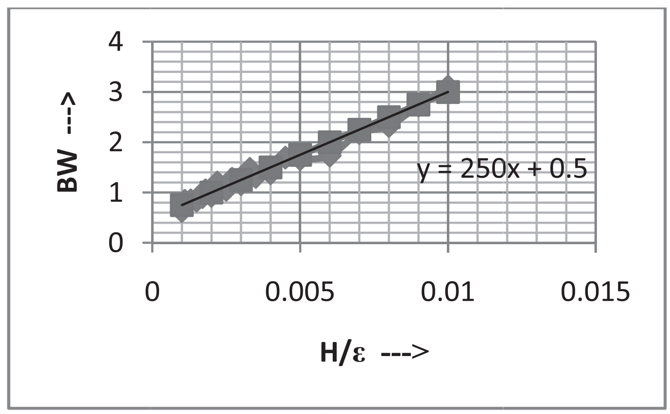


Fig 3: Variation of % Bandwidth with H/ ε

This gives the empirical formula (6) for estimating % BW for the material parameters.

$$\% BW = 250 * \left({}^{H}/_{\varepsilon} \right) + 0.5 \qquad (6)$$

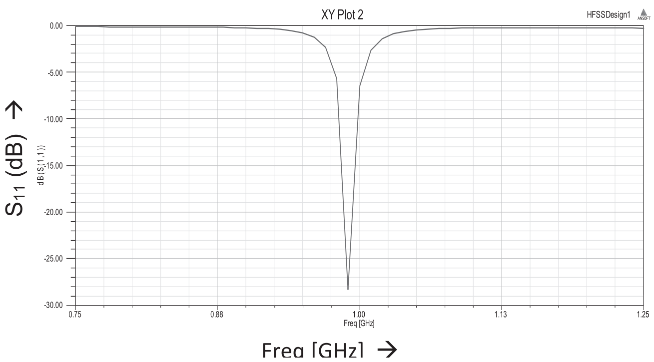
This formula can be used in selecting the material of the antenna substrate. For the desired % BW, H/ε can be derived. Since H = h/λ_g , H/ε = $f_o h/(c\sqrt{\varepsilon})$. Physical thickness (h) of the antenna substrate can therefore be selected for the desired f_o and ε. The result is in-line with earlier results [3, 4].

4. VALIDATION

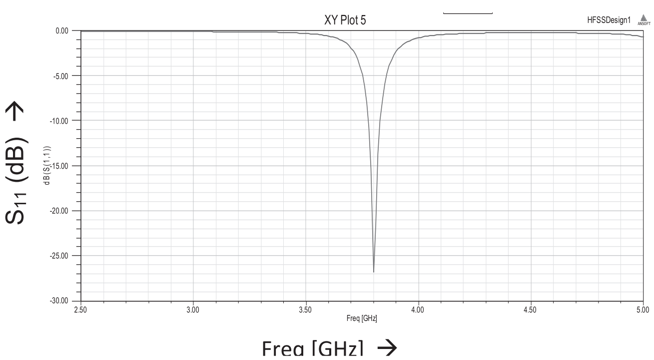
It is important to validate the results of any investigation. The study presented above used a fixed frequency of 2 GHz. For validating the formula f_o was varied from 1 GHz to 6 GHz and the whole exercise was repeated. Simulation results are shown in Fig 4 and tabulated in table 1.

Table 1: Comparison of % BW – estimated by new formula and obtained by simulation

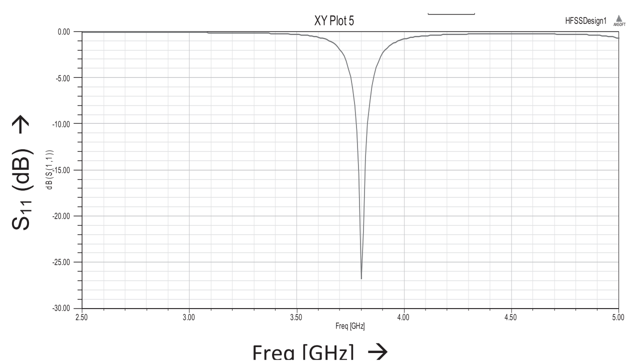
fo (GHz)	H	ε	BW from new formula	BW by simulation	% Difference
1	0.018	9	1.1001	1	10
2	0.008	6	0.8233	0.833	1
3	0.016	4	1.4441	1.5	5.5
4	0.01	2	1.6925	1.75	5.7
5	0.02	6	1.3767	1.33	4.6
6	0.018	4	1.5979	1.625	2.7



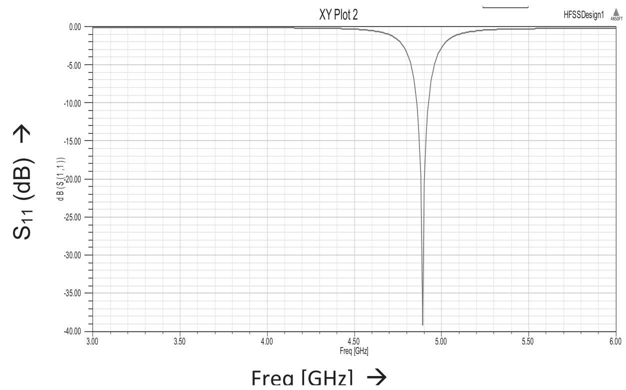
(a) Designed for 1 GHz, simulated value 0.99 GHz, ε = 9



(b) Designed for 4 GHz, simulated value 3.8 GHz, ε =2



(c) Designed for 5 GHz, simulated value 4.9 GHz, ε = 6



(d) Designed for 6 GHz, simulated value 5.8 GHz, ε = 4

Fig 4: Simulated results for antennas designed with new formula for various resonant frequencies

5. CONCLUSION

Large variety of substrate materials are available for manufacturing microstrip antennas. These differ in thickness (h) and dielectric constant (ε) apart from loss tangent and other microwave properties. This paper presents a new approach for selecting the h and ε of the MSA substrate. Bhatnagar's postulate has been used to investigate dependence of bandwidth on h and ε. This has resulted in a new formula for estimating the bandwidth of the MSA. For the required bandwidth, desired values of h and ε can be obtained. These can then be used in selecting the substrate material.

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