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RESEARCH PAPER

Dielectric material selection of microstrip patch antenna for wireless communication applications using Ashby's approach

PRIYANKA CHOUDHARY, RAJNEESH KUMAR AND NAVNEET GUPTA

In this paper, material selection has been done for dielectric substrate material in microstrip patch antenna (MPA) for three distinct classes of wireless communication applications using Ashby's approach. This material selection procedure is based on the creation and evaluation of Ashby's chart of different material indices. These material indices in turn affect the device performance indices, which decide the best possible dielectric material to be used as substrate for MPAs. In this work, quality factor, relative permittivity, and temperature coefficient of resonant frequency are chosen as material indices of MPA's dielectric substrate to get relevant performances. Ashby's selection chart shows that $0.75MgAl_2O_4$–$0.25TiO_2$ *material for millimeter waves applications,* $Ca[(L_{1/3}Nb_{2/3})0.85Ti_{0.15}]O_{3-\delta}$ *for mobile base station applications, and* $(Ba_{0.95}Ca_{0.05})O$–Sm_2O_3–$4.5TiO_2$ *ceramic for mobile phone miniaturization applications are the promising materials that allows best overall performance in MPAs for wireless communication.*

Keywords: Material selection, Ashby's approach, Microstrip patch antenna, Wireless communication, Dielectric materials

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I. INTRODUCTION

Currently, microwave and millimeter wave dielectric ceramics are being developed for various wireless applications such as mobile phones, wireless local area network (WLAN), and intelligent systems [1–4]. A recent pull for microwave components has drawn attention especially in newer types of dielectric material and composites for antennas. Materials with low-dielectric losses have been preferred more for efficient microwave devices. The characteristic parameters which are associated with dielectric material and their characterization have the important role. The new type of dielectric substrate materials have also been developed, characterized, and implemented into the working antenna model [5, 6].

The key properties required for dielectric substrate material of microstrip patch antenna (MPA) are relative permittivity (ε_r), quality factor ($Q \times f$), and temperature coefficient of resonant frequency (τ_f). These properties and their characterization ranges define the three different classes of dielectric constant composites. The first class of composites works for millimeter wave application for ultra-high-speed wireless LAN and intelligent transmission signal (ITS). This range includes very high $Q \times f$ ($\geq$100 000) and low ε_r ($\leq$20) along with near zero τ_f ($\approx$0). For high gain and directive antenna, appropriate dielectric substrate of suitable thickness, ε_r and loss tangent has to be chosen [7]. Use of thinner dielectric substrate layer reduces weight and surface wave losses of antenna. Along with thickness, ε_r of dielectric ceramic material also plays an important role. Low ε_r increases the radiated power due to increased fringing field but this reduces the delay time (T_{PD}) of electronic signal transmission of antenna which is related as [2]

$$T_{PD} = \sqrt{\frac{\varepsilon_r}{c}}, \quad (1)$$

where c represents the velocity of signal. Less losses of antenna increases the $Q \times f$ thus increases the antenna efficiency, radiation efficiency, and also used to select a narrow frequency range in communication systems. Grain size of dielectric substrate ceramic also affects the $Q \times f$. The increase in average grain size of substrate material considerably enhances the $Q \times f$ of antenna. Very high value of $Q \times f$ increases the frequency selectivity and also ensures low insertion loss for high-power applications.

Recently miniaturization with wide bandwidth (BW) is the major issue in radio frequency industry for the latest compact and smart phones. The appropriate solution to such an issue is to have high ε_r (20–80) and high $Q \times f$ (10 000–100 000 GHz), which defines the second range of dielectric materials [8]. The second range of dielectric materials is for high-performance mobile base station transmitters and receivers. This class of dielectric materials works for the relationship of antenna physical dimensions and frequencies, which

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can be transmitted for high-power antennas. Currently, ε_r with the range of 20–40 have become the industry targets. The third class of composites has higher ε_r ($\geq$80) with appropriate low $Q \times f$ ($\leq$10 000) and is well suited for the application of miniaturization of mobile phone. More recently, increase in ε_r range (100–125) has been proved with drastic reduction in $Q \times f$ [8].

$$l \propto \lambda = \frac{c}{f\sqrt{\varepsilon_r \mu_r}}. \quad (2)$$

Therefore apart from the vast availability option in selection of antenna geometries, the size of antenna can be reduced by increasing the relative permittivity or relative permeability of the material. But incorporation of magnetic material in antenna is very complex and most impractical. So the size of the antenna can be practically reduced by taking high range of relative permeability. However excessive miniaturization may lead to degrade the efficiency and BW of antenna [9].

$$Gain = \left(\frac{\pi l}{\lambda}\right)^2 \frac{73}{R_r}, \quad (3)$$

$$Efficiency = \frac{Gain}{Directivity}, \quad (4)$$

where l is length of antenna and R_r is the resistance of antenna. As with very high-relative permeability, the losses increase with indirect reduction in radiating power of antenna. Thus gain of antenna was improved through the increase in l and decrease in R_r and λ, which were decided from electromagnetic (EM) properties of base frame material of antennas. Therefore, their properties should be optimized for the gain of the antenna as [9]

$$\lambda = \frac{\lambda_o}{\sqrt{\varepsilon_r \mu_r}}, \quad (5)$$

$$BW \approx \frac{96\sqrt{\frac{\varepsilon_r}{\mu_r}\frac{1}{\lambda_o}}}{\sqrt{2\left|4 + 17\sqrt{\varepsilon_r \mu_r}\right|}}, \quad (6)$$

$$BW \propto Gain \propto Efficiency. \quad (7)$$

An antenna with high gain must be larger in size which have low Q-factor and therefore will have a higher BW. As the size of the antenna decreases, the effective aperture size is reduced, lowering directivity. There have been some efforts to use high ε_r substrates of microstrip antennas to recover some of the gain lost by the reduction in size. For true miniaturization, the substrate size must also be reduced. Another set of drawbacks for high ε_r materials involve their mechanical properties and material tolerances. This weakens the robustness of the antenna, which traditionally is one of the advantages in using a microstrip antenna. Also, loss in the dielectric material tends to be higher for the ceramic dielectrics [10].

Equation (5) shows the BW of second class of ceramics is wider than that of third class of ceramics substrates and is more useful for miniaturization and broad BW of antenna. So, to make the optimum choice for overcoming this trade-off, the Ashby's approach is chosen.

Besides the factors mentioned earlier, one more factor affects the performance of antenna which is temperature coefficient of resonant frequency (τ_f). The frequency drift of an antenna is a consequence of the overall thermal expansion of its unique combination of construction materials and each design requires different τ_f for temperature compensation [11]. Here, higher thermal conductivity with smaller thermal expansion is required. So, to obtain such requirements, near zero τ_f is needed. τ_f can be calculated using the change in resonant frequency of antenna and is given by [5]

$$\tau_f = \frac{f_2 - f_1}{f_1(T_2 - T_1)}, \quad (8)$$

where f_1 and f_2 show the resonant frequency at temperature T_1 and T_2, respectively.

Depending on the antenna application, selection of an appropriate material is the challenging part of engineering design. Here the selection of the substrate material is done using the Ashby's approach material selection chart. This methodology is based on material indices by creation and evaluation of Ashby's chart for different material indices, which affects the performance indices. The methodology is well established and is useful in the design of various electronic components where various trade-off exists [12, 13]

This paper is organized as follows: Section II presents a brief introduction of the Ashby's approach for material selection. Section III discusses the materials and their properties for MPAs. Then Section IV explains the results and discussion for the appropriate selection through this approach. Finally, Section V provides the conclusion of the study.

II. ASHBY'S APPROACH

Ashby's approach is a material selection procedure based on material indices by creation and evaluation of Ashby's selection chart between different material indices. These material selection charts are used for initial screening of materials and provide quick visual implication of the relative position for all the material being considered. For the best suitable material selection, the main steps are sample materials collection, translation, screening, ranking, followed by documenting the top-ranked material elements [12–14]. By following these steps with the design demands in material specification and application-dependent design constraints, vast available materials are reduced to a single significant material element with the respective eliminations. Top most ranked material is the best possible material for the application to give relative performance. Performance is measured by performance metric which depends on control variables that represent property of a material called material indices Here material attributes or material properties include ε_r, $Q \times f$ and τ_f, which has been optimized to get the best performance. Trade-off exists between these properties to get the improved performance of antenna for various wireless communication applications. Selection of the best possible material is used to make optimal trade-offs between conflicting objectives. These desired material attributes are identified and compared with the real engineering material.

The Ashby's material selection chart provide graphical domain to apply and analyze quantitative selection criteria in terms of performance indices using material attributes. The material indices are derived from the performance function (P) as

$$P = f(F, G, M), \tag{9}$$

where, P is the performance of material selected as the function of functional requirement (F), geometric parameter (G), and material property (M). As separate function, these can be represented as

$$P = f_1(F)f_2(G)f_3(M). \tag{10}$$

Above equation shows that material properties (M) are independent of functional requirement (F), geometric parameter (G). The performance indices are derived through mathematical analysis, which finds a material with high value of indices that maximizes the performance of the antenna.

III. MATERIAL AND PROPERTIES FOR MPA

The schematic view of MPA is shown in Fig. 1. This consists of a conducting patch on one side of dielectric substrate material with a ground plane on the other side. For developing dielectric materials for substrate, various methods have been proposed which include solid state method, aqueous gel-casting, and wet chemical method [5]. Such prepared dielectric substrate material has successfully been fabricated in microstrip antennas for global positioning system (GPS) application.

A) Material indices

The design and optimization of these properties are performed to obtain maximum performance of antenna. Relationship between material indices, performance indices,

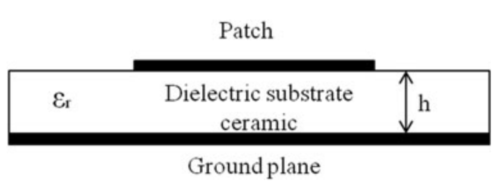

Fig. 1. Structure of microstrip patch antenna.

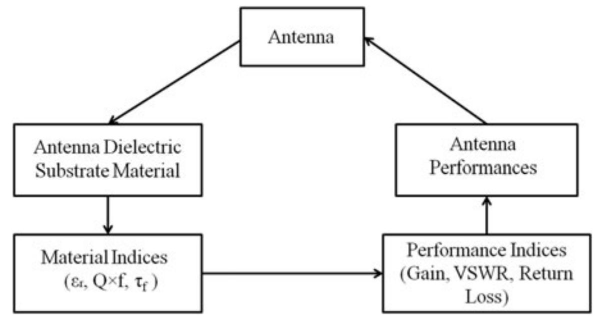

Fig. 2. Relationship of material indices, performance indices, and antenna.

and antenna is shown in Fig. 2. For particular application, material selection objective includes proper range of material properties. So, the strategy of selecting material properties range for three distinct classes of applications is given in Table 1.

B) Performance indices

Ashby's method utilizes the performance indices function to describe the performance of MPAs. Here, the aspect of performance in terms of voltage standing wave ratio (VSWR), return loss (R.L.), and gain of antenna are described as

$$P = f(gain, R.L., VSWR). \tag{11}$$

These performance indices depend upon material indices. Various mathematical equations relate performance indices to material indices. As the increase in ε_r, frequency of device decreases along with the length of antenna. But, the $Q \times f$ has inverse relation with the loss. In MPAs, gain is expressed in terms of radiated power. Radiated power of antenna depends on losses. Less loss produces more radiation power and better $Q \times f$.

Return loss of antenna represents the acceptable antenna parameters in the range of BW impedance matching of the device. So, we need high R.L. for good antenna performance. Another performance index is VSWR and we have to minimize (typically <2.0 or 1.5) the VSWR in order to have maximum signal transmission. As the R.L. increases with the increase in ε_r, hence very less amount of power is forwarded to radiating element [15, 16]. The relationship of R.L. and VSWR shows the dependency on frequency, $Q \times f$, ε_r. And relation of $Q \times f$ with VSWR is represented as

$$BW = \frac{VSWR - 1}{Q \times f\sqrt{VSWR}}, \tag{12}$$

Table 1. Recommended technical targets of material indices.

Application no.	Application	Range of properties		
		Relative permittivity (ε_r)	Quality factor, $Q\times f$ (GHz)	Temperature coefficient of resonant frequency, τ_f (ppm/°C)
I	Millimeter wave application	$\leq$20	$\geq$100 000	$\approx$0
II	High performance mobile base station transmitter and receivers	20–80	10 000–100 000	$\approx$0
III	Mobile phone miniaturization	$\geq$80	$\leq$10 000	$\approx$0

$$Q \times f \propto \frac{1}{VSWR}. \quad (13)$$

This leads to the relation of τ_f with frequency. Thermal stability and material strength have been provided by near zero τ_f. These performance indices depend upon material indices.

For antenna to work efficiently there should be proper impedance matching between an antenna and its feed. The impedance matching in an antenna is measured in terms of R.L. which represents the power reflected back into the feed in transmitting mode. We can infer that R.L. is inversely proportional to VSWR or directly proportional to $Q \times f$, which are frequency and ε_r dependent. ε_r is directly proportional to R.L. and inversely proportional to VSWR, whereas $Q \times f$ is inversely proportional to loss which in turn affects the radiated power. So, with increase in radiated power, gain also increases. Hence, proper choice is required for these conflicting parameters as per applications I, II, and III.

For application I, appropriate dielectric substrate of suitable thickness, ε_r and loss tangent has to be chosen to attain high-gain directivity and antenna. Low ε_r increases the radiated power due to increased fringing field. Whereas low value of ε_r also reduces the delay time (TPD) of electronic signal transmission of antenna. For application II, high value of $Q \times f$ increases the frequency selectivity and also ensures low insertion loss for high-power applications. For application, we should have low or moderate $Q \times f$ in order to have wide BW and very high ε_r in order to have reduced size of antenna. Hence, we must also look for trade-off in performance metric conflicting demands.

IV. RESULT AND DISCUSSION

A) For application I

The recommended targets for this application are mentioned in Table 1. the Ashby's selection charts between different material indices are represented in Figs 3–5. Figure 3 shows the Ashby's selection chart variation of relative permittivity (ε_r) and quality factor ($Q \times f$). Considering the requirement of millimeter wave applications, materials B, D, and H satisfy the criteria for ε_r and $Q \times f$ as shown in Fig. 3. The variation of τ_f versus $Q \times f$ is represented in Fig. 4. According to the selection chart in Fig. 4, materials B and F satisfy the criteria of τ_f and $Q \times f$ for this application. The Ashby's selection charts for ε_r versus τ_f variations are given in Fig. 5. Materials B, C, G, and I satisfy the requirements of ε_r and τ_f for application I. Using Ashby's selection chart, screening have been done and best three materials for all three applications are selected. For application I, low ε_r with very high $Q \times f$ is necessary which are nearby satisfied by materials B, D, and H, as a result of all Ashby's material selection chart. In order to further select the best possible material out of these three materials in every class of application, an antenna is designed and simulation is done using Ansoft HFSS implementing these three classes of materials as the substrate of the antenna (Table 2).

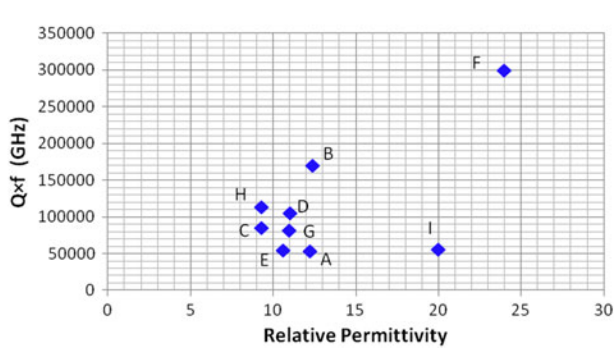

Fig. 3. Ashby's selection chart for quality factor versus relative permittivity for application I.

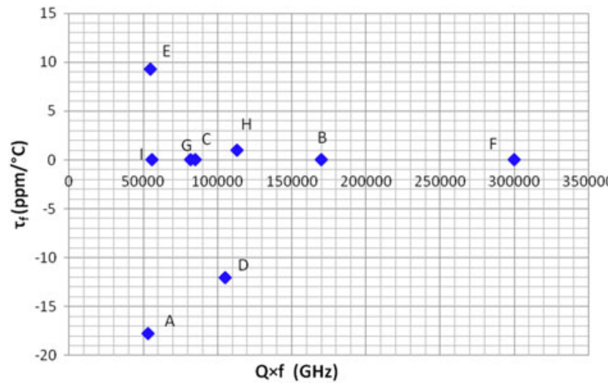

Fig. 4. Ashby's selection chart for temperature coefficient of resonant frequency versus quality factor for application I.

Figure 6 shows the design of MPA used for simulation [45]. The MPA is designed at 6 GHz frequency, having ε_r of 2.2 with thickness of substrate of 1.6 mm [22]. The MPA feeds from microstrip line and for proper impedance matching QWT is designed. For the best material selection, the dielectric substrate material is replaced by materials B, D, and H for analyzing the maximum performance of the antenna. The frequency at which the R.L. of the antenna becomes minimum is called resonant frequency of the structure. MPA with material B shows the resonant frequency of 5.28 GHz which represents the frequency is shifted by 0.78 GHz. For dielectric materials D and H, the antenna resonates at 5.61 and 6.09 GHz, respectively and showing the frequency shift of 0.4 and 0.9 GHz, respectively. The comparison of these R.L. is represented in Table 3. Another parameter of performance of antenna is gain and is defines graphically in terms of two-dimensional (2D) gain. For this 2D form, E- and H-plane patterns are considered. The E- or H-plane is defined as the plane containing the electric or magnetic field vector, respectively,

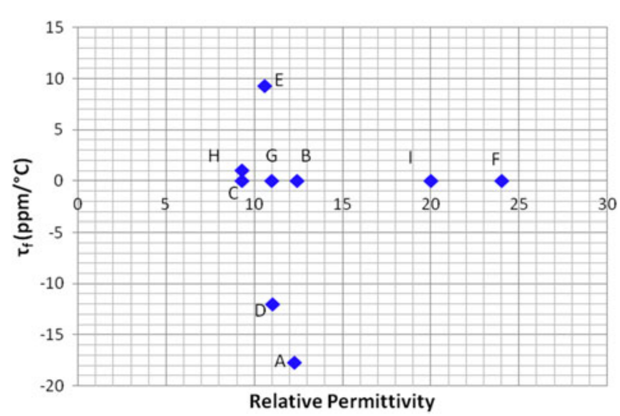

Fig. 5. Ashby's selection chart for relative permittivity versus temperature coefficient of resonant frequency for application I.

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Table 2. Characteristic parameters of selected materials.

Material code	Substrate material	ε_r	$Q \times f$ (GHz)	τ_f (ppm/°C)	Reference
Application-I: dielectrics for millimeter waves applications					
A	$0.9(0.75ZnAl_2O_4–0.25TiO_2)–0.1MgTiO_3$	12.25	53 334	−17.76	[5]
B	Rutile added to alumina	12.4	170 000	0	[1]
C	Rutile added to forsterite	9.3	85 000	0	[1]
D	$0.75MgAl_2O_4–0.25TiO_2$	11.03	105 400	−12	[17]
E	$0.95(0.79ZnAl_2O_4–0.21MgTiO_4)–0.05SrTiO_3$	10.6	55 000	9.3	[18]
F	$Ba(Mg_{1/3}Ta_{2/3})O_3$	24	300 000	0	[19]
G	Mg_2SiO_4+24 wt%TiO_2	11	82 000	0	[20]
H	$ZnSiO_4$+11 wt%TiO_2	9.3	113 000	1	[21]
I	$0.95MgTiO_3–0.05CaTiO_3$	20	56 000	0	[22]
Application-II: dielectric selection for mobile base stations applications					
J	$0.7CaTiO_3–0.3SmAlO_3$	45	42 000	1	[11]
K	$0.65CaTiO_3–0.35NdGaO_3$	45	32 000	1	[11]
L	$0.65CaTiO_3–0.35SmGaO_3$	45	34 000	1	[11]
M	$(Zr_{0.8}Sn_{0.2})TiO_4$	38.9	51 500	0.7	[23]
N	$0.9(Zr_{0.8}Sn_{0.2})TiO_4+0.1BaCO_3$	39.5	47 500	0.3	[23]
O	$0.93(Zr_{0.8}Sn_{0.2})TiO_4+0.05ZnO + 0.02NiO$	38	58 800	−0.1	[24]
P	$0.9(Zr_{0.8}Sn_{0.2})TiO_4+0.1CaCO_3$	39.2	46 500	0.1	[23]
Q	$CaTi_{0.54}(Al_{0.5}T_{0.5})0.46O_3$	47	27 300	0	[25]
R	$Ca_{0.7}Nd_{0.3}Ti_{0.7}Al_{0.3}O_3$	44	33 000	0	[26]
S	$0.65CaTiO_3–0.35LaGaO_3$	47	40 000	0	[27]
T	$Ca[(L_{1/3}Nb_{2/3})0.85Ti_{0.15}]O_{3-\delta}$	39	26 100	0	[28]
U	$Ba(Zn_{1/3}Ta_{2/3})O_3$+1 mol%$CaTiO_3$	30	100 000	0	[29]
V	$Ba(Mg_{1/3}Ta_{2/3})O_3$+1 mol%ZrO_2	26	112 500	0	[30]
W	$Ba_2La_3Ti_3TaO_{15}$	45.4	26 800	−1	[31]
X	$CeO_2+0.06CaTiO_3$	29	25 000	0	[32]
Y	$0.76ZrTi_2O_6O–0.2ZnNb_2O_6$	47	34 000	0	[33]
Z	$MgTa_{1.5}Nb_{0.5}O_6$	27.9	33 100	−0.7	[34]
Application-III: dielectric selection for mobile phone miniaturization applications					
A1	$0.9(Zr_{0.8}Sn_{0.2})TiO_4+0.1MgCO_3$	38.9	4000	−2.3	[23]
B1	$La_{0.4}Ba_{0.6}Ti_{0.6}Yb_{0.4}O_3$	65	4500	1	[35]
C1	$0.58ZnNb_2O_6–0.42TiO_2$	45	6000	0	[36]
D1	$Ca_{0.4}(L_{1/2}Nd_{1/2})_{0.6}TiO_3$	113	5000	8	[37]
E1	$Pb_{0.6}Ca_{0.4}ZrO_3$	94	3600	−10	[38]
F1	$BaO–PbO–Nd_2O_5–TiO_2$	88	5000	0	[39]
G1	$Pb_{0.45}Ca_{0.55}(Fe_{1/2}Nb_{1/2})O_3$	93	6000	2	[40]
H1	$Ba_{4.2}(Sm_{0.8}Nd_{0.2})_{9.2}Ti_{18}O_{54}$	84	9000	0	[41]
I1	$(Ba_{0.8}Sr_{0.2})_{4.2}Sm_{9.2}Ti_{18}O_{54}$	82.3	2860	0.4	[42]
J1	$(Ba_{0.95}Ca_{0.05})O–Sm_2O_3–4.5TiO_2$	81	9500	2	[43, 44]

along the direction of propagation. Table 3 also shows the 2D gain of MPA for materials B, D, and H, respectively. It is observed that in case of materials D and H, the gain is 5 and 3.4 dB, respectively. Material D as a dielectric substrate in MPA gives the smaller R.L. with better gain of antenna as compared to materials B and H. Therefore, material D ($0.75MgAl_2O_4–0.25TiO_2$) is the best substrate material for MPA for millimeter wave applications.

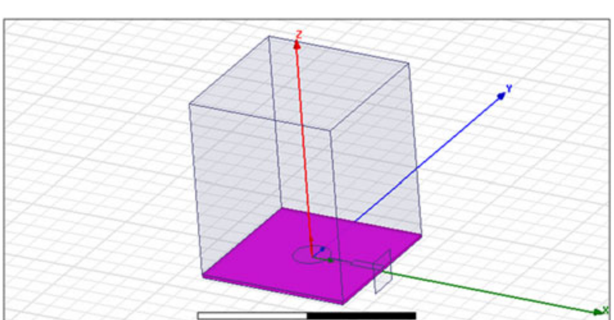

Fig. 6. Circular microstrip patch antenna using Ansoft HFSS.

B) For application II

The Ashby's selection chart variation of ε_r and $Q \times f$ for all set of available materials is similar to that for application I charts. For mobile base stations applications requirement, only material V does not fulfill the requirement and rest all other satisfies the recommended targets. The variation of τ_f versus $Q \times f$ represents that materials Q, R, S, T, U, X, and Y are satisfying the requirements for this application. The Ashby's selection charts for ε_r versus τ_f variations concludes, materials Q, R, S, T, U, V, and X satisfy the requirements of ε_r and τ_f. Using Ashby's selection chart, screening has been done and best three materials are selected. Out of these possible materials, we have chosen the best possibility to narrow down our selection and for carrying the simulation for checking the radiation properties of the antenna using these three materials as the substrate material. Materials J, N, and T have been selected for this application.

To study these material performances in antenna application and for attaining the best dielectric ceramic material, the antenna design is loaded with dielectric materials J, N, and T for simulation using Ansoft HFSS. The simulation is

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Table 3. Comparison of return loss (R.L.) and two-dimensional (2D) gain for applications I, II, and III.

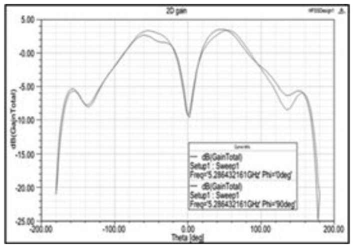
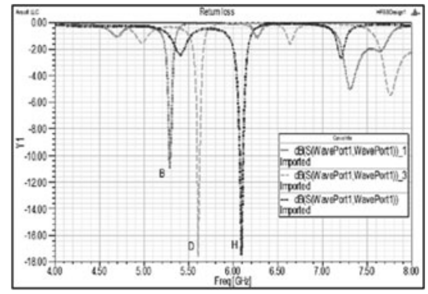
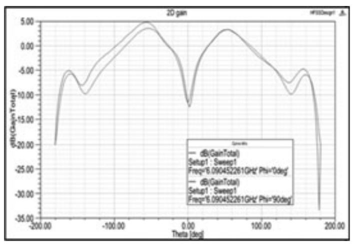
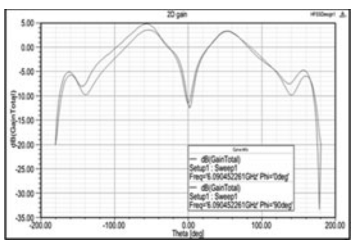
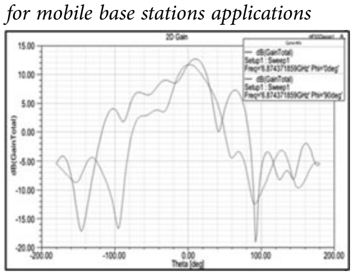
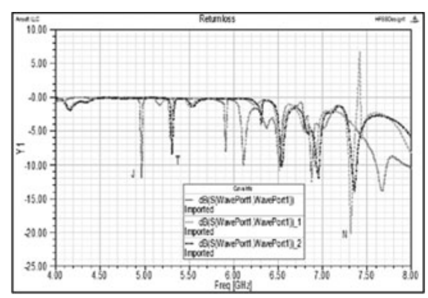
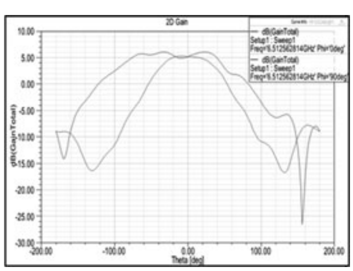
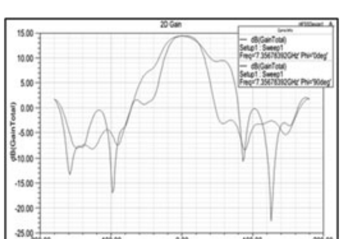
Material	**2D gain**	**R.L.**
Application-I: dielectrics for millimeter waves applications		
B		
D		
H		
Application-II: dielectric selection for mobile base stations applications		
J		
N		
T		

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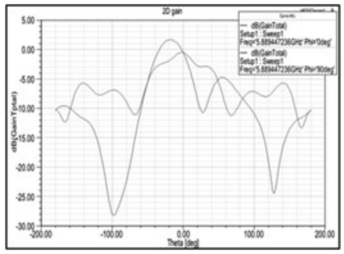
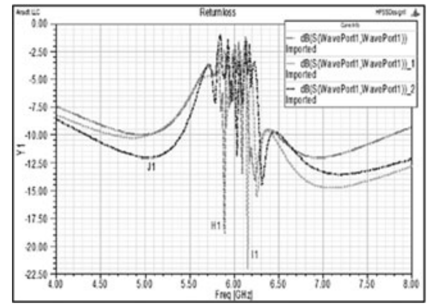
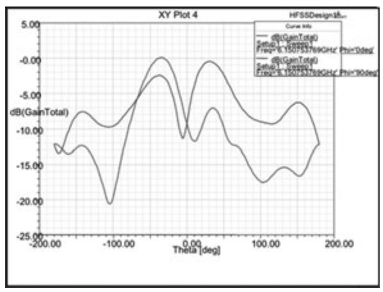
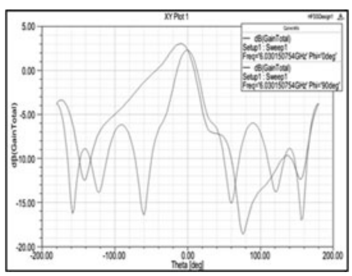
Table 3. Continued

Material	**2D gain**	**R.L.**
Application-III: dielectric selection for mobile phone miniaturization applications		
J1		
H1		
I1		

repeatedly performed for these three different dielectric substrate materials of antenna. As observed, the R.L. of antenna using these materials is −15.2 dB at 6.8 GHz, −10.9 dB at 6.51 GHz, and −14 dB at 7.36 GHz. The antenna loaded with dielectric materials J, N, and T gives the gain of 12.9, 6.4, and 14.5 dB, respectively. These are shown in Table 3, respectively. It is clear from these observations that material T ($Ca[(L_{1/3}Nb_{2/3})0.85Ti_{0.15}]O_{3-\delta}$) is giving large gain with small R.L. and is the best possible material for mobile base station applications.

C) For application III

Similarly by plotting the Ashby's selection chart between similar material indices for all set of material, materials F1, H1, and I1 satisfy the criteria based on the requirements. The characteristics of the three-screened dielectric material have been determined through antenna design simulation using Ansoft HFSS.

Table 3 shows the comparison for simulation of R.L. of circular microstrip antenna using three different selected dielectric materials H1, I1, and J1 for application III. The simulation gives three resonances modes centered at 5.89, 6.25, and 6.03 GHz frequencies and R.L. of −17.79, −24, and −14 dB, respectively. The center frequency is selected as the one at which the R.L. is minimum. As seen from the results, gain of the proposed dielectric materials antenna is 1.9, 0.2, and 3 dB. These 2D gains are shown in Table 3. For high ε_r materials, the R.L. is good which shows maximum energy given to antenna but with poor gain. Gain of very high dielectric materials is more degraded due to negative permeability which affects the maximum energy transmission to antenna and antenna still does not radiate effectively. Literature also shows that very high permeability degrades the gain for ferrite material along with very good BW and R.L.. So, optimization and methods to attain positive permeability have to be performed to improve the gain of the antenna with very ε_r dielectric substrates. Although the high dielectric constant microwave ceramic substrate material J1 ($(Ba_{0.95}Ca_{0.05})O–Sm_2O_3–4.5TiO_2$) is adopted in our study as optimum material for application III.

The outcome of this study is justified with the methods in literature [5, 6, 18, 45–47]. It is observed that the best performance of the antenna can be obtained using these selected materials. This validates our study of the dielectric substrate ceramic material for MPA.

V. CONCLUSION

In this paper, we report the dielectric substrate material selection in MPA for three distinct classes of wireless communication applications using Ashby's approach is done. The criteria of Asbhy's selection chart in terms of relative permittivity

(ε_r), quality factor ($Q \times f$), and temperature coefficient of resonant frequency (τ_f) for three different classes of applications (millimeter waves applications (application I), mobile base station applications (application II), and mobile phone miniaturization applications (application III)) have been satisfied. For application I materials B, D, and H; materials J, N, and T for application II; and materials H1, I1, and J1 has been screened for application III dielectric substrate material. In order to further select a best appropriate material for maximum performance of antenna based on R.L., gain, and VSWR, software simulation has been performed using Ansoft HFSS. Simulations confirm the potential use of material D ($0.75MgAl_2O_4$–$0.25TiO_2$, $\varepsilon_r = 11.03$, $Q \times f = 105\,400$, $\tau_f = -12$) for application I, material T ($Ca[(L_{1/3}Nb_{2/3})0.85Ti_{0.15}]O_{3-\delta}$, $\varepsilon_r = 39$, $Q \times f = 26\,100$, $\tau_f = 0$) for application II, and material J1 ($(Ba_{0.95}Ca_{0.05})O$–Sm_2O_3–$4.5TiO_2$, $\varepsilon_r = 81$, $Q \times f = 9500$, $\tau_f = 2$) for application III, have the larger gain with minimum R.L. that allows the best overall performance in MPAs. These samples of materials are found to possess microwave dielectric parameters suitable for designing an antenna for their respective mentioned applications.

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