Refinement in the Characteristics of Microstrip Patch Antenna Using Newly Composed Ferrite Material

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***Abstract*—A new M-Type Hexagonal ferrite material has been composed by adopting a conventional ceramic method and then being observed for microwave absorption behavior using impedance matching mechanism in the frequency range of 8.2GHz to 12-4GHz. Microwave absorption was being found to be optimum with -33.36dB reflection coefficient at doping concentration of 0.4 in the X-band range. Further, this ferrite material has been used as a substrate for microstrip patch antenna and being simulated using HFSS simulator with version 13.0 in 8.2GHz-12.4GHz frequency range. There is massive enhancement of 4.2GHz being observed in the bandwidth of antenna while comparing the results with FR4 epoxy substrate. Thus, this investigation makes it valuable for X-band communication applications.**

Keywords: Composite Material, Refection Coefficient, Doping, Bandwidth.

I. Introduction

Suppression of Electromagnetic Interference has drawn a very much attention in today's modern wireless communication system. A lot of research has been going on for developing an absorbing material in microwave region. M-type hexagonal ferrite is found to be good microwave absorbent. Further, research has been going on varying the dopant and their concentration to vary the properties of hexagonal ferrite like permittivity, permeability, hysteresis, coercivity, tensile strength and absorption properties. Mosleh et al.[10] composed a M-type $Ba1_{-x}Ce_xFe_{12}O_{19}$ hexagonal ferrite and observed a dip of -16.43dB in reflection loss in X-Band. Jasbir Singh et al.[14] had composed the Ba-Sr hexagonal ferrite using Co^{2+} and Al^{3+} dopants and found 96.94% microwave power got absorbed with reflection loss -16.4dB at 11.2Ghz frequency .In another investigation by him, he [15] achieved 96.2% absorption of microwave power with the doping of Co^{2+} and Y^{3+} at 11.2GHz frequency range in the same hexagonal ferrite. Guo et al.[4] doped the Ba-Sr hexagonal ferrite using Co^{2+} material and observed an optimum value of reflection loss i.e. -43.6dB at 4.3mm of thickness and -45.8dB at 2.8mm of thickness. Harsimrat Kaur et al.[8] synthesized a Ba-Sr hexagonal ferrite by doping it with Co-Ga and found a dip in reflection loss i.e. -29.74dB at 8.28 GHz.. Continuing in the same research, she [7]doped the ferrite with Co-La and found a good microwave absorbent with -43.33 dB Rl at 10.75GHz. Khandani et al [9] observed a dip of -8.7dB in reflection loss by doping the Sr hexagonal ferrite using Ce-Nd.

While considering the literature survey, we have composed a M-Type Ba-Sr hexagonal ferrite by adding Ga^{3+} and Co^{2+} dopant materials. Synthesization of M-type $Ba_{0.5}Sr_{0.5}Fe_{12}O_{19}$ hexagonal ferrite with doping materials is being carried out in the frequency range 8.2GHz - 12.4GHz.Furher, we have observed from the literature survey that this newly composed material can be used as a substrate material in the designing of antenna for microwave frequency range. Naveen Kumar Sexena et al.[13] has done such type of research. He designed a microstrip triangular patch antenna on LiTiZn ferrite substrate. He observed that radiation performance got very much improved while having reduced patch size as compared with dielectric substrate. Kunal Borah et al.[3] has used magneto dielectric composite with ferrite inclusion as substrate for microstrip patch antenna. He has noticed a tremendous improvement in return loss, radiation characteristics of antenna as compared

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to conventional substrate in the microwave frequency range. Borah et al.[2] has further investigated magneto dielectric substrate made up of Cobalt Ferrite and Nickel Ferrite in LDPE can be used as substrate material for antenna fabrication and performance of microstrip antenna got improved for X-band applications i.e. RL of -18.85dB with Nickel ferrite has been achieved which was optimum as compared with results got with FR$ substrate. M. Habib Ullah et al.[16] has designed a multiband rectangular shape microstrip patch antenna on Al_2O_3 ceramic material substrate. He achieved three resonance frequencies 4.7GHz, 9.05GHz & 13.2GHzwith impedance bandwidth below -10dB and VSWR≤ 2. Debashis Sarmah et al.[11] has investigated the performance of microstrip patch antenna designed on the substrate made up of LDPE/Tio2 material in X-band. Enhancement in the bandwidth and directivity of antenna has been achieved. Naveen Kumar Sexena et al.[12] has fabricated the MSPA on LiTiMg ferrite substrate. They observed the improvement in return loss, radiation power, gain and VSWR as compared to RT duroid substrate. Further, they concluded that antenna size also get reduced comparatively. Sanjay R.Bhongale et al.[1] has fabricated Mg-Cd ferrite substrate for microstrip patch antenna in X-band. They found the improved results of return loss, 10dB % bandwidth and VSWR. Intan Helina Hasan et al.[6] has fabricated microstrip patch antenna on thick film yttrium iron garnet (YIG) and observed enhancement in bandwidth of antenna with lesser size of antenna.

So, by going through all the above mentioned and many more literature survey, we have also fabricated microstrip patch antenna on this newly composed M-type Ba-Sr hexagonal ferrite and found the improved results as compared with FR4 substrate.

II. Experimental Procedure

We have composed a m-type $Ba_{0.5}Sr_{0.5}Co_xGa_x Fe_{12-2x}O_{19}$(x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) hexagonal ferrite with the addition of following materials: BaCo3 (Sigma-Aldrich 99.98% pure), $SrCo_3$ (Sigma-Aldrich 99.98% pure), $CoCo_3$ (Sigma-Aldrich 99.98% pure), $Ga2O_3$ (Sigma-Aldrich 99.98% pure), Fe_2O_3 (Sigma-Aldrich 99.98% pure). All these materials are processed using standard Ceramic method with the following steps:

1. Mixing and grinding of materials in distilled water.
2. Drying of mixture at room temperature.
3. Presintering of dried powder at 1000oC.
4. Regrinding of powder after cooling down.
5. Granulation of powder.
6. Conversion into pallets.

After the preparation of pallets, it is being tested for microwave absorption using Vector Network Analyzer (VNA) for different thickness of material. The rectangular shaped hexagonal ferrite material is placed in rectangular waveguide with waveguides at input and output ports also .This set up is connected to VNA. Microwave absorption characteristics are judged from scattering parameters. These parameters have correlation with permittivity and permeability of material.

G. Impedance Matching Mechanism:

The microwave signal get fully absorbed if input impedance is equal to characteristic impedance i.e. Z_{in} = Z_o. Where Z_o =377Ω for free space and inut impedance is given as

$$z_{in} = z_o\sqrt{\frac{\mu_r}{\varepsilon_r}}\tanh\left[j\left(\frac{2\pi f t}{c}\right)\sqrt{\mu_r\varepsilon_r}\right] \quad (1)$$

Where εr is complex permittivity, μr is complex permeability, t is thickness of material, f is operating frequency and c is speed of light. Input impedance is calculated from two parts i.e. real and imaginary impedance and given as

$$Z_{in} = Z_{real} + Z_{img} \quad (2)$$

III. Results and Discussions:

During the testing of microwave absorption characteristics, it is being observed that at some particular doping concentrations i.e. at x= 0.2, 0.4 and 0.8 in the composed material, Z_{real} and Z_{img} are closer to 377 Ω & 0 respectively making Z_{in} ≅ Zo . Thatswhy RL peaks are good at these doping concentrations showing maximum absorption at x=0.4 i.e. -33dB at 9.62GHz frequency. These results are shown in figure 1 below. Whereas at x=0.0, 0.6 and 1.0, the difference between Z_{in} and Z_o is very large resulting in less microwave absorption as given in table drawn below.

Table 1: Variation In RL w.r.t Doping Concentration in X-Band

Doping Concentration(x)	Frequency(GHz)	RL(dB)
0	9.62	-25.68
0.2	9.37	-20.08
0.4	9.62	-33.36
0.6	8.95	-25.22
0.8	12.4	-14.41
1	9.29	-18.12

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Further, by using this magneto dielectric material as a substrate of microstrip patch antenna , we can enhance the bandwidth of antenna according to the given equation:

$$BW = 96 \frac{\sqrt{\frac{\mu}{\varepsilon}}}{\sqrt{2(4+17\sqrt{\mu\varepsilon})}} \frac{t}{\lambda_o} \quad (3)$$

This equation is according to zero order analysis suggested by Hansen & Burkey [5]. Here μ is permeability of material, ε is permittivity of material and t is thickness of material. Means bandwidth enhancement is possible by varying these parameters of material. An antenna is designed using this material as substrate and found better results as compared with FR4 substrate. The design of antenna comprises of a number of MTM cells loaded subsequently in the patch. The performance of antenna is calculated with two types of substrates i.e. with FR4 epoxy and composed ferrite material. We have simulated the design using HFSS 13.0 simulator. The comparison of results is shown in table below.

From the results, it is very much clear that there is a noticeable enhancement in antenna bandwidth when we are using ferrite material as a substrate for MSPA in comparison with FR4 substrate. Further, it is to be noted that improvement in absorption coefficient is more with FR4 as a substrate given in figure 2.

IV. Conclusion

We have composed a M-type $Ba_{0.5}Sr_{0.5}Co_xGa_xFe_{12-2x}O_{19}$(x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) hexagonal ferrite and analyzed microwave absorption parameter using VNA method. Wit increase in doaping concentration, RL is improving and is maximum with x=0.4 i.e. -33.36dB at 9.62GHz. Means it is very much suitable for x-band application and this has been further confirmed using ferrite material as a substrate for microstrip patch antenna design. We got the enhanced bandwidth of 4.2 GHz with ferrite material as compared with FR4 substrate. So, this newly composed material is very much suitable for communication applications in X-band rage.

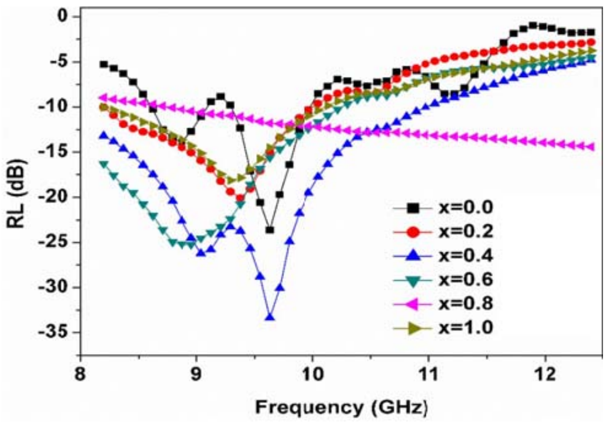

Fig. 1: Graph Showing Variations in Reflection Loss w.r.t Doping Concentration in X-band

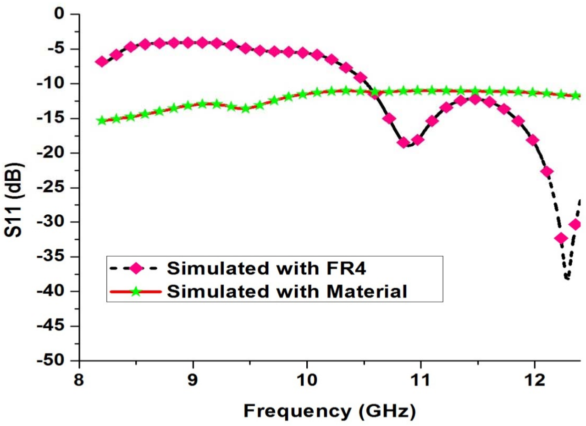

Fig. 2: Graph Showing Comparison of Absorption Coefficient eith Both FR4 snd Ferrite Material Used ss Substrate.

Table 2: Comparison of Results with FR4 Substrate and Ferrite Material

Results Eith FR4 Rpoxy Dubstrate			Results with Gallium Substituted Ba-Sr Hexagonal Ferrite Substrate		
Resonant Frequency (GHz)	Return Loss	Bandwidth	Resonant Frequency (GHz)	Return Loss	Bandwidth
10.888	-18.9089	(12.4-10.531)GHz =1.869GHz	8.2	-15.3319	(12.4-8.2)GHz= 4.2GHz
12.316	-35.5072				

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