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Performance of Ag thick film rejection filter due to ferrite thick film loading

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ABSTRACT

λ/2 rejection filters are band stop devices usually useful for one frequency only. In this paper the multi frequency aspects of the filter using overlay of $Ni._{0.7-X}Co_XZn_{0.3}Fe_2O_4$ thick film is reported. Composition dependent shifts in the resonance notch is obtained. In the Ku band double resonances are obtained with an increase in the rejection. Due to increase in cobalt content the Q of the filter and the effective dielectric constant increases. Tuning of the filter due to composition of the $Ni._{0.7-X}Co_XZn_{0.3}Fe_2O_4$ thick film overlay has been obtained in the X and Ku band. From the perturbations the complex permittivity and permeability of the ferrite thick films have been evaluated.

Key words: Overlay; Ferrite thick films; λ/2 Rejection filter; Tuning; Complex permittivity; Permeability.

INTRODUCTION

With the recent progress of microwave applications including mobile and satellite communication systems, there is a growing need to improve the performance of filter circuits to be compatible to the monolithic integrated circuits (MMIC's). The λ/2 microstrip rejection filter circuit is a standard microstrip resonant circuit with band reject characteristics. The signal while propagating through the microstripline resonator suffers various losses and affects the Q value of the circuit [1]. The overlay technique in which a material of high dielectric constant is placed over the microstripline circuit may be one of the cost effective solutions to improve the performance of the coupled circuits. Our lab has been investigating the effect of various overlays on a number of microstrip components [2- 6].

Ferrites are very useful materials in the high frequency for various devices. There is a dearth of information in the literature regarding ferrite thick film. If true planarization of ferrite based devices is to be achieved it is essential to investigate the effects of these ferrites on the device. This paper reports the studies on the modification in the filter properties due to $Ni._{0.7-X}Co_XZn_{0.3}Fe_2O_4$ thick film overlay on Ag thick film λ/2 microstrip rejection filter in the X and Ku bands of microwave frequencies. The effect of change in the composition of the ferrite on the rejection properties is also reported. Using the perturbation the material properties like complex permittivity and permeability has been evaluated.

MATERIALS AND METHODS

The ferrites with the stoichiometric formulae $Ni._{0.7-x}Co_xZn_{0.3}Fe_2O_4$ (x= 0,0.04,0.08 and 0.12) were synthesized by sucrose precursor technique using the constituent metal nitrates and sucrose precursor and sintered at 1000°C [7]. The ferrite powder was used to prepare the thick film paste and screen printed on to alumina substrate (Kyocera Japan) of dimensions 1cm X 2.5 cm X 0.06cm and fired at 950°C in a zonal furnace. The film thickness was about 35 μm as measured by weight difference method.

The poly crystalline nature of the films was confirmed by X-ray diffraction technique. Figure 1 shows the XRD for composition with X=0.08. The films show a dominant peak (311) along with the other peaks (220), (222), (400), (422), (511), (440) indicating the formation of spinel ferrite.

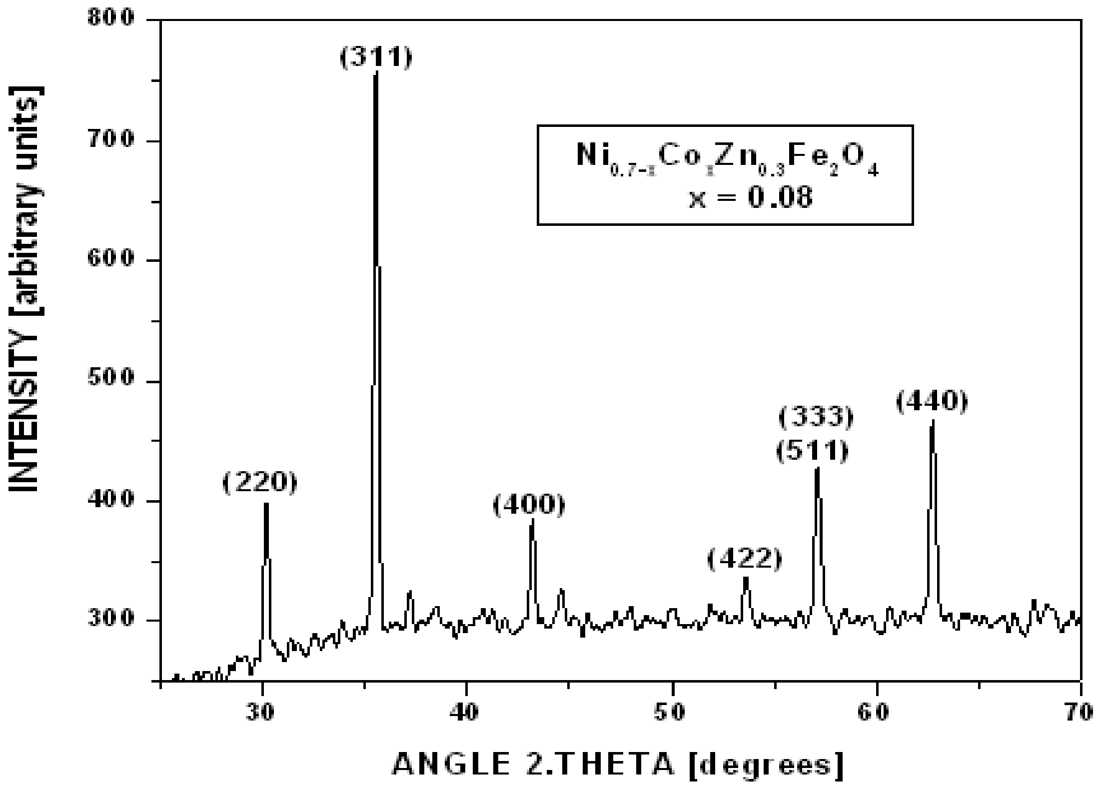

Fig.1. XRD pattern of $Ni_{0.7-X}Co_X Zn_{0.3}Fe_2O_4$ for X=0.08.

Figure 2 shows the schematic of the L section λ/2 microstrip rejection filter.

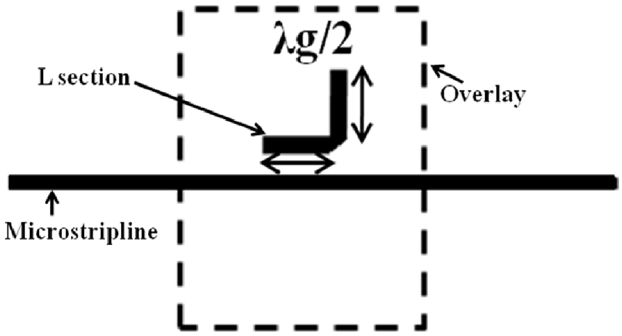

Fig. 2. The schematic of the Ag thick film L section λ/2 microstrip rejection filter with overlay

Two separate Ag thick film L section λ/2 microstrip rejection filters, one with the resonance frequency of 9.55 GHz for X-band and the other with 16.45 GHz for the Ku-band, were delineated by thick film-screen printing technique with silver paste as the metallization on to alumina substrate (Kyocera Japan) having dimensions 1 inch X 1 inch X 0.025 inch and fired at 700^{o}C with a conventional thick-film firing cycle [8].

The total length of the L section were 4.8mm in the X band and 2.8mm in the Ku band. Three identical filters each in X and Ku band respectively were studied and the average of the three results have been plotted. The error in the measurement in rejection from sample to sample was ~ ± 1db in the X band and ~ ± 1.6 db in the Ku band. Since the Ku band dimensions are smaller than the X band dimensions the errors due to thick film delineation is more.

For performance evaluation, the λ/2 microstrip rejection filter was mounted in a resilient microwave integrated circuit test fixture and transmittance (S21) measurements were made point by point in the frequency range of 8–12 GHz with the help of a microwave bench consisting of source, isolator, attenuator, directional coupler, detector and the appropriate SMA connectors and launchers. All the ferrite thick films were kept as in touch overlay covering the L section of the microstrip rejection filter.

RESULTS AND DISCUSSION

Figure 3 depicts the frequency response characteristics of the X-band Ag thick film λ/2 microstrip rejection filter without and with thick film overlay of $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ of various compositions.

The filter without overlay (indicated as W/O overlay in graph) showed a rejection of –25 dB at 9.55 GHz. The off resonance regions of the curve are almost uniform with an average insertion loss of -7 dB. Due to the overlay of the ferrite thick films, the resonance frequency shifts towards lower frequency end. As the cobalt content increases the shift also increases.

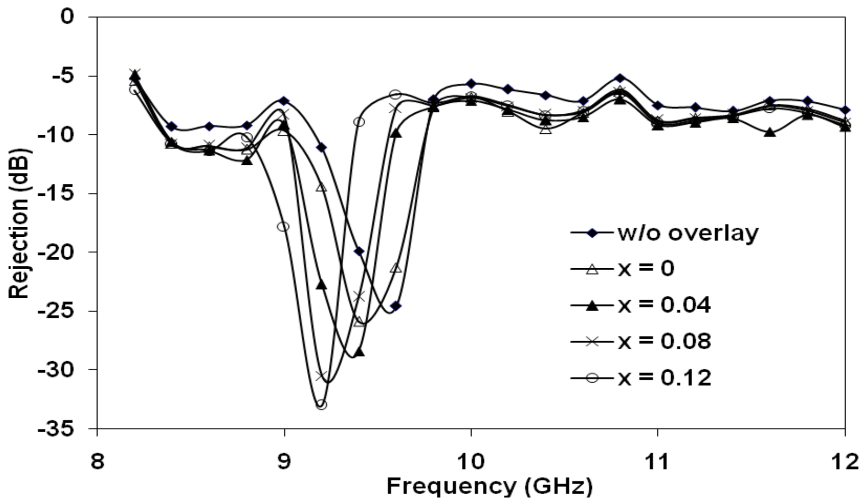

Fig.3. Frequency response characteristics of the X-band filter without and with thick film overlay of $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$

The frequency response of the rejection filter in the Ku band with $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick film overlay is given in figure 4.

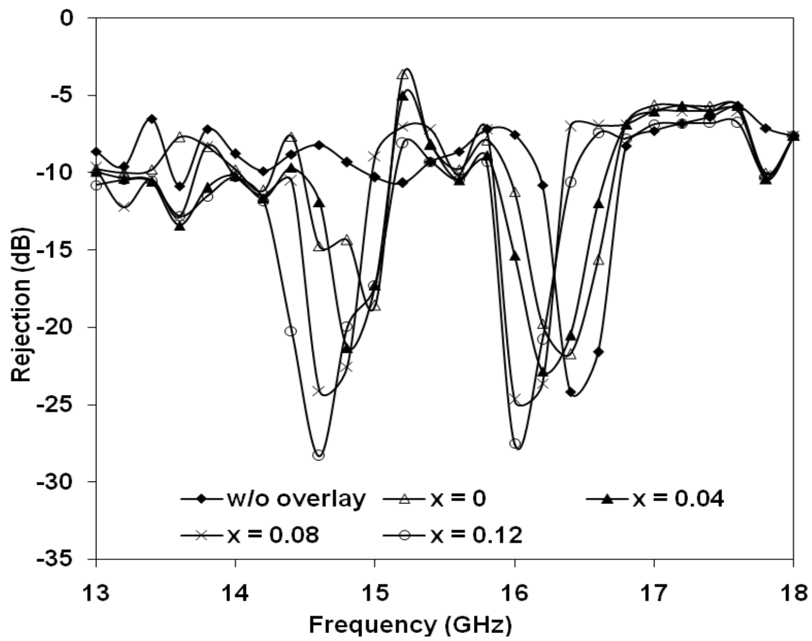

Fig.4. Frequency response characteristics of the Ku-band filter without and with thick film overlay of $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$

The filter without overlay has a rejection of –24.2 dB with resonance at 16.45 GHz. The off resonance regions of the filter without overlay are almost uniform with an average insertion loss of about –9 dB. Due to overlay of $Ni_{0.7-}$

$_xCo_xZn_{0.3}Fe_2O_4$ thick films, a split in the resonance notch is obtained. Similar to effects in the X band in the Ku band also due to increase in cobalt content the resonance shift increases. The peak rejection has also increased due to the overlay.

The off resonance insertion loss is not disturbed due to the $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick film overlay both in the X and Ku band.

The data of resonance frequency and value of maximum rejection is tabulated in table 1.

Table 1. Resonant frequency f_r and rejection Rej_{max} in the X-band and Ku-band of the rejection filters with the overlay of $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick films.

Composition x	X-band		Ku-band			
	f_r (GHz)	Rej_{max} (dB)	f_{r1} (GHz)	Rej_{max1} (dB)	f_{r2} (GHz)	Rej_{max2} (dB)
Without Overlay	9.55	-25	16.45	-24.2	-	-
0	9.42	-26.1	16.36	-21.7	15.0	- 17.26
0.04	9.37	-28.6	16.23	-23.3	14.8	-19.94
0.08	9.24	-30.5	16.10	-25.6	14.65	-24.1
0.12	9.20	-33.0	16.03	-27.7	14.60	-28.3

In the Ku band the composition dependent resonance frequency shifts are more near the original frequency whereas the rejection changes are more at the second resonance.

The quality factor of the microstrip rejection filter in the X and Ku band due to $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick film overlay is shown in figure 5. From the figure it is seen that the Q of the filter in Ku band is higher than that in the X band and as the cobalt content increases the Q factor also increases. In the Ku band the Q factor has been calculated at first resonance.

The effective dielectric constant ε_{eff1} without overlay was calculated using the formula of Owens [9]

$$\varepsilon_{eff1} = [(\varepsilon_r+1)/2]\,[1+(29.98/Z_O)\,(2/\varepsilon_r+1)^{1/2}\,(\varepsilon_r-1/\varepsilon_r+1)(\ln\pi/2 + 1/\varepsilon_r \ln 4/\pi)]^2$$

Where ε_r=9.6; the dielectric constant of substrate (alumina), Z_O=50 Ω, The ε_{eff2} with overlay was calculated by using the formula given in the literature [10]

$$f_2^2/f_1^2 = \varepsilon_{eff1}/\varepsilon_{eff2}$$

Where f_1 and f_2 are the resonance frequency without overlay and with overlay respectively.

The effect of composition of the thick film ferrite on the effective dielectric constant of the filter is also depicted in figure 5.

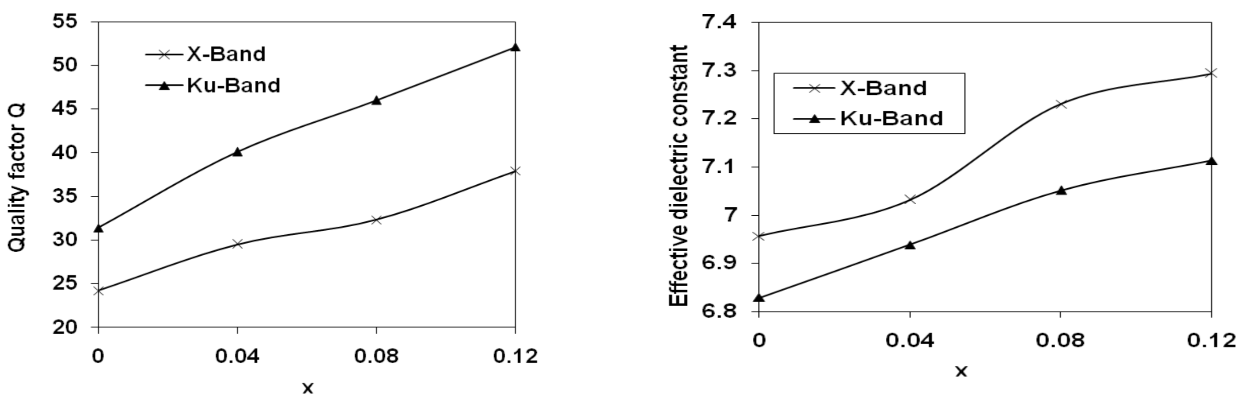

Fig. 5. Composition of overlay dependent quality factor and effective dielectric constant of the λ/2 microstrip rejection filter

From the figure it is seen that the effective dielectric constant obtained in the X band are higher than those obtained in Ku band. As cobalt content increases ε_{eff} increases, the increase being larger in the X band.

The perturbation in the resonance peaks can be translated into the material characteristics of the overlaid material. The complex permittivity and permeability of the $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick film overlay has been calculated according to the formula published in our earlier work [11]. The data of the composition dependent complex permittivity and permeability are tabulated in table 2. The values have been calculated at the resonance frequency.

From the table it is seen that the dielectric constant ε' and permeability μ' in the 8-12 GHz and 13-18 GHz frequency range increases due to increase in cobalt content in the ferrite. The dielectric loss is not affected by change in the cobalt content, where as the magnetic loss μ" decreases as cobalt content increases.

Table 2. Complex permittivity and permeability of $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick films calculated from perturbations in the filter

X	ε_{eff}	ε'	ε"	μ'	μ"	ε_{eff}	ε'	ε"	μ'	μ"
In X-band						In Ku-band				
0	6.956	10.332	0.8333	2.2783	1.1492	6.829	5.0368	0.8191	1.4061	0.1091
0.04	7.031	14.12	0.8256	2.7809	0.6913	6.938	8.0535	0.8175	1.7061	0.0821
0.08	7.23	17.568	0.8211	3.2305	0.6539	7.051	12.001	0.8142	2.0945	0.0791
0.12	7.293	23.233	0.8161	3.9534	0.0571	7.113	13.872	0.811	2.2769	0.0501

The geometry of the λ/2 microstrip rejection filter has the associated fringing fields in the air-substrate interface. These fields interact with the overlay material and lead to changes in the frequency response characteristics of the filter circuit. In the Ku band the size of the region between the L section and the line is comparatively smaller than in the X band. This might result in a more concentrated fringing fields present here which might result in over coupling with the overlay material resulting in the appearance of double resonance notch. Basically these filters are reciprocal components containing two degenerate orthogonal modes. Under symmetry conditions these have the same resonance frequency. If the symmetry is disturbed or perturbed the two degenerate modes lead to splitting of the resonance curve. The overlay acts as the perturbation factor. In the Ku band the effect of the perturbation seems to be more.

The increase in effective dielectric constant with cobalt content indicates an increase in dielectric constant of the overlay material. The higher dielectric constant of the overlay material makes the fringing field lines get concentrated more, as a result the fringe field capacitance increases and leads to larger decrease in the resonant frequency. The increase in Q value and the rejection $R_{max}$of the both the filters with the increase in cobalt composition x is attributed to absorbing nature of the overlaid material. The overlay also changes the electrical length by varying the phase velocity via the dielectric overlay.

Since no external magnetic field was applied, these ferrites are magnetically non saturated and as such multi domains are nucleated in the ferrite materials. Another cause for the perturbations of the microstrip filters due to overlaid materials might be the electromagnetic interference effects. The interfering electric and magnetic fields on the surface of the circuit could trigger or excite the microstrip circuit to cause malfunctions or other interference effects. The magnetic field intensity causes more interference than the electric field intensity [12]. Loading of the superstate on the surface of the circuits increases the magnetic field intensity by ~ 4.4 times. This interference is bound to cause unavoidable difference in the characteristics of the microstripline components. The fact that the overlay used in this work is magnetic in nature results in the interference problems.

CONCLUSION

A split in the resonance frequency due to $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick film overlay is obtained in the Ku band (12-18 GHz). The split frequency does not differ much in their rejection indicating possible applications as multi frequency filter. The resonance frequency of both the filters has shifted towards shorter frequency end due to the increase in effective dielectric constant, which has been caused by the increase in cobalt concentration in the overlay ferrite material. The complex permittivity and permeability of the $Ni_{0.7-x}Co_xZn_{0.3}Fe_2O_4$ thick film has been successfully determined using the perturbation of the filter. Thick film ferrite overlay on thick film components might provide non reciprocal effects also if a magnetic material is delineated along with the ferrite. Further investigations are in progress for this.

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REFERENCE

[1] Belohoubek, E, Denlinger, E, *IEEE Trans.Microw. Theo. Tech.*, 23, 522-526 **(1975).**
[2] Kamble, P, Puri, V, *Int. J. Electr., 97*, 7, 857-865 **(2010).**
[3] Puri, V, Sathe, M, *J. of Active and Passive Electronic Devices.*, 5, 79–91 **(2010).**
[4] Mane, VV, Puri, V, *Advances in Applied Science Research.*,1, 92-101 (**2010).**
[5] Surve, V, Puri, V, *Microelect Int*., 24,35-39 **(2007).**
[6] Kanade, SA, Puri, V, *J. of Active and Passive Electronic Devices*, 5, 229–238 **(2010).**
[7] Rendale, MK, Kulkarni, SD, Puri, V, AIP Conference proceedings-1003, 76-78 **(2008).**
[8] Rane, SB, Amalnekar, D, Puri, V, *J of Mater. Sci.,Mater. Electron.*, 11, 667-674 **(2001).**
[9] Owens, R P, *Radio. Electron. Engg.*, 46**,** 360-364 **(1976).**
[10] Joshi, KK, Pollard, RD, Postoyalko, V, *IEE Proc. Microw Ant. Prop.*, 141, 138-140 **(1994).**
[11] Kulkarni, DC, Patil, SP, Puri, V, *Microelec. Journal.*, 39, 248-252 **(2008).**
[12] Wong, KL, Chen, WS, Huang, WL, *IEEE. Trans.Electromag. Comp.*,34, 17-23 **(1992).**