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Investigation of Microwave Characteristics of M-type $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ Ferrite at X-band

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Abstract— The microwave current voltage characteristics of $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ (x=0.0,0.2,0.4,0.8 and 1.0) ferrite have been investigated. The microwave characteristics reflected power (%) and voltage standing wave ratio (VSWR) have been investigated as a function of frequency and substitution in the microwave frequency range of 8-12.4 GHz, while current voltage (I-V) characteristics have been reported as function of voltage and substitution. The results indicate lower reflected power at in x=0.2, which makes it suitable for use in microwave absorber applications. The electrical current is small in the composition with x=0.2 and 0.4.

Index Terms—ATD method, Ferrite, Current -voltage characteristics (I-V), Microwave absorber, Microwave frequency band, Microwave reflected power, Voltage standing wave ratio (VSWR).

1 Introduction

IN the modern science and technology electromagnetic interference (EMI) is an undesirable aspect and is necessary to develop and investigate absorbers with high performance and operating at GHz range of frequencies. Microwave absorbing materials are use for lowering the effect of electromagnetic interference due to widespread of information technology in mobile, commercial and millitary applications [1]-[3]. The use of electromagnetic wave absorber is an efficient way to lower the effect of electromagnetic interference (EMI)/electromagnetic compatibility (EMC) problems. M-type hexagonal ferrites are special type of absorbing materials due to having magnetic losses at microwave (or GHz) frequency range and are used as absorbers in providing solution to EMI/EMC problem at microwave and higher frequencies.

2 Experimental Detail

Microwave characteristics of M-type $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ hexagonal ferrite with different substitutions x=(0.0, 0.2, 0.4, 0.8 and 1.0) has been investigated by Absorber Testing Device (ATD) method [4], [5]. This method incorporates frequency generator, isolator, slotted waveguide, directional coupler and voltage standing wave ratio (VSWR) meter. The samples are coated on both sides with silver paste to make it conductive for the I-V measurements of all the compositions.The samples are placed inside copper plates.The dc voltage was applied from 0 to 3V and dc current was measured accordingly.

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3 Results and Discussion

3.1 Voltage Standing Wave Ratio (VSWR)

Voltage standing wave ratio is measured as a function of frequency and substitution. Following observations have made from the graph shown in figure 1.

(i) In the composition x=0.0 ($Ba_{0.5}Sr_{0.5}Co_{0.0}Ru_{0.0}Fe_{12}O_{19}$) in fig. 1(a), the least value of VSWR is 1.7 at a frequency of 9.0 GHz and highest of 3.9 at 8.0 GHz from 8.0–9.0 GHz. In the range of 9.2-11.0 GHz, maximum value of VSWR, 5.8, is seen at 9.2 GHz. The lowest value of VSWR is 2.3 at 10.8 GHz. From 11.2-12.4 GHz, VSWR starts increasing and peaks to 5.8 at 11.4 GHz. The minimum value of VSWR is 2.3 at 11.8 GHz.

(ii) In the composition x=0.2 ($Ba_{0.5}Sr_{0.5}Co_{0.2}Ru_{0.2}Fe_{11.6}O_{19}$) in fig. 1(b), the maximum value of VSWR is 3.1 at 8.0 GHz, then it starts decreasing and reaches to 1.7 at 9.0 GHz in the range of 8.0–9.0 GHz. The maxima of 4.7 is observed at 10.6 GHz and then it starts decreasing by attaining value of 2.2 at 10.8 GHz, which is the minimum value seen in the frequency region of 9.2– 11.0 GHz. From 11.2-12.4 GHz, the maximum of 4.3 at 12.4 GHz and minimum of 2.2 at 11.8 GHz is observed.

(iii) In the composition x=0.4 ($Ba_{0.5}Sr_{0.5}Co_{0.4}Ru_{0.4}Fe_{11.2}O_{19}$) in fig. 1(c), the maximum VSWR of 4.6 at 8.0 GHz and minimum of 1.8 at 9 GHz is observed from 8.0-9.0 GHz. It peaks to 7.6 at 10.6 GHz, which is the maximum value of VSWR among all the compositions in the range of 9.2-11.0 GHz. The minimum VSWR of 2.8 at 10.8 GHz is observed. It shows an increase in VSWR with maxima of 6.3 at 11.4 GHz and minima of 2.6 at 11.8 GHz from 11.2–12.4 GHz.

(iv) In the composition x=0.8 ($Ba_{0.5}Sr_{0.5}Co_{0.8}Ru_{0.8}Fe_{10.4}O_{19}$) in fig. 1(d),the maximum value of VSWR is 3.9 at 8.0 GHz and minimum value of 1.8 at 9 GHz from 8.0-9.0 GHz. It attains maximum value of 5.5 at 10.6 GHz and minimum value of 2.4 at 10.8 GHz in the range of 9.2-11.0 GHz. Above this frequency the value of VSWR starts increasing and reaches to 4.5 at 11.4 GHz. The minima of 2.3 are observed at 11.8 GHz.

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(v) In the composition x=1.0 ($Ba_{0.5}Sr_{0.5}Co_{1.0}Ru_{1.0}Fe_{10}O_{19}$) in fig. 1(e), the minimum and maximum VSWR of 1.9 and 3.9 at 9.0 GHz and 8.0 GHz is seen in the frequency range of 8.0-9.0 GHz. In the range of 9.2-11.0 GHz, VSWR varies from 2.5 to 6.9. The composition attains maximum value of VSWR 4.8 at 11.4 GHz and minimum of 2.4 at 11.8 GHz in the range of 11.2-12.4 GHz.

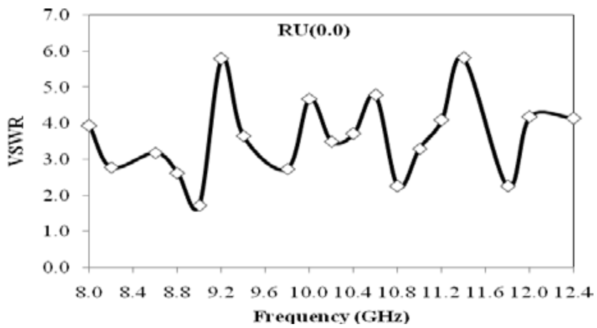

Fig. 1(a). Voltage standing wave ratio as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.0.

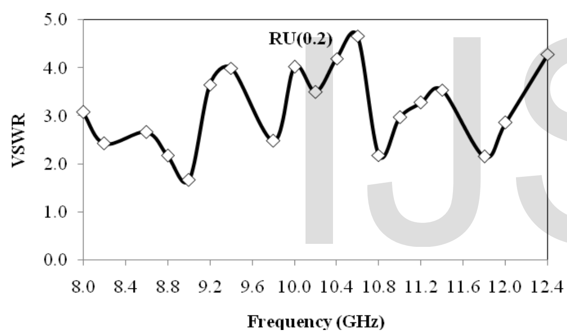

Fig. 1(b). Voltage standing wave ratio as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.2.

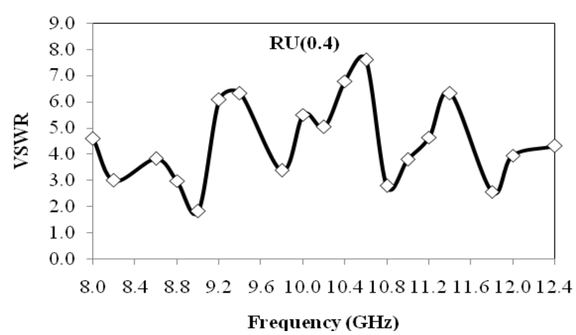

Fig. 1(c). Voltage standing wave ratio as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.4.

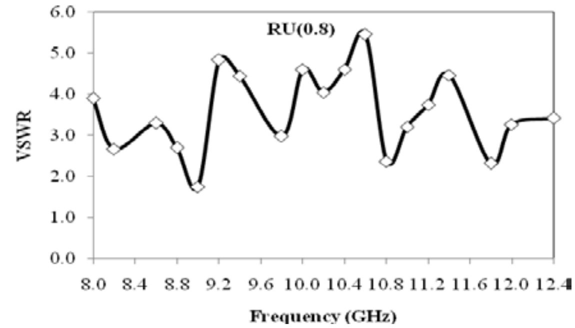

Fig. 1(d). Voltage standing wave ratio as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.8.

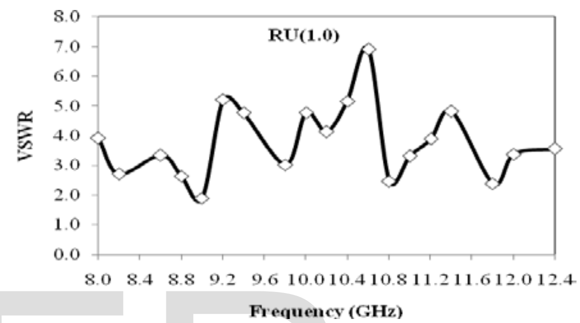

Fig. 1(e). Voltage standing wave ratio as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=1.0.

3.2 Reflected Power (%)

The reflected power at corresponding frequency of $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ has been measured and shown in figure 2. Following observations for all composition have been drawn:

(i) In the composition x=0.0 ($Ba_{0.5}Sr_{0.5}Co_{0.0}Ru_{0.0}Fe_{12}O_{19}$) in fig. 2(a), the reflected power is of maximum value, 75.68 %, at 8.4 GHz and minimum value 6.87 % at 9GHz. In the frequency range of 9.2 to 11.0 GHz, it exhibits maximum reflected power of 49.77 % at 9.2 GHz and minimum of 14.86 % at 10.8 GHz. In the frequency range of 11.2-12.4 GHz, the maximum value of 89.95 % is observed at12.2 GHz, which is the highest reflected power along the entire investigated region. The minimum value of 14.86 % is exhibited by the composition at 11.80 GHz.

(ii) In the composition x=0.2 ($Ba_{0.5}Sr_{0.5}Co_{0.2}Ru_{0.2}Fe_{11.6}O_{19}$) in fig. 2(b), the reflected power shows maximum value of 51.52 % at 8.4 GHz, minimum of 6.28 % at 9 GHz in the frequency region of 8.0-9.0 GHz. This is the minimum reflected power exhibited by the composition along the whole investigated region. From the frequency range of 9.2 to 11.0 GHz, minimum reflected power is 13.87 % at 10.8 GHz and of 41.88 % at 10.6 GHz. The highest reflected power is shown by the composition with 82.04 % at 11.6 GHz and the minimum, 13.43 %, is observed at 11.8 GHz in the investigated range of 11.2-12.4 GHz.

(iii) In the composition x=0.4 ($Ba_{0.5}Sr_{0.5}Co_{0.4}Ru_{0.4}Fe_{11.2}O_{19}$) in fig. 2(c), the maximum and minimum reflected power of 94.41

% and 8.32 % is observed at 8.4 GHz and 9.0 GHz in the frequency range of 8.0 to 9.0 GHz. The value of reflected power varies from 22.13 % to 58.88 % in the frequency range of 9.2 to 11.0 GHz. In the range of 11.2 to 12.4 GHz, the composition shows maximum value of 99.54 % at 12.2 GHz, which is the highest value of reflected power seen among all the samples along the entire investigated frequency range. The minimum value of 19.14 % at 11.8 GHz is observed.

(iv) In the composition x=0.8 ($Ba_{0.5}Sr_{0.5}Co_{0.8}Ru_{0.8}Fe_{10.4}O_{19}$) in fig. 2(d), the reflected power peaks to 87.50 % at 8.4 GHz in the low frequency region. Above this, it shows a decrease in reflected power with increase in frequency and reaches to 7.45 % at 9 GHz. From 9.2 to 11.0 GHz, highest value of 47.64 % at 10.6 GHz and lowest value of 16.60 % at 10.8 GHz is observed. The maximum value of reflected power with 94.41 % at 11.6 GHz and least with 15.89 % are observed at 11.8 GHz from 11.2-12.4 GHz.

(v) In the composition x=1.0 ($Ba_{0.5}Sr_{0.5}Co_{1.0}Ru_{1.0}Fe_{10}O_{19}$) in fig. 2(e), the reflected power reaches to maxima of 90.16 % at 8.4 GHz and minima, 9.59 %, at 9 GHz from 8.0-9.0 GHz. The highest and lowest reflected power of 55.85 % and 17.99 % at 10.6 GHz and 10.8 GHz is seen from 9.2-11.0 GHz. The composition shows peak reflected power of 99.08 % at 11.6 GHz and lowest dip of 16.75 % at a frequency of 11.8 GHz in the range of 11.2-12.4 GHz.

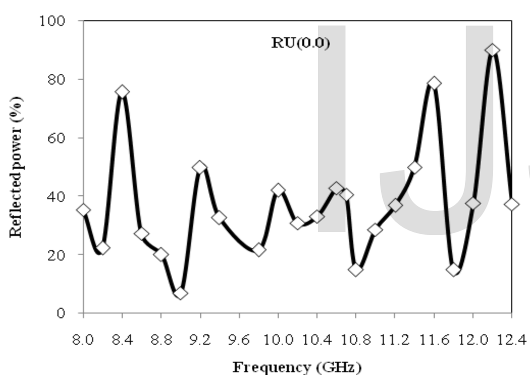

Fig. 2(a). Reflected power (%) as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.0.

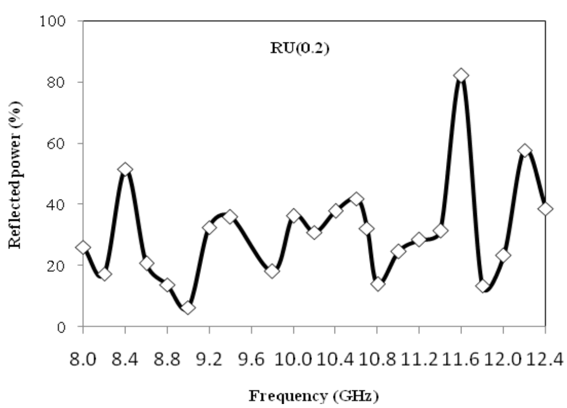

Fig. 2(b). Reflected power (%) as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.2.

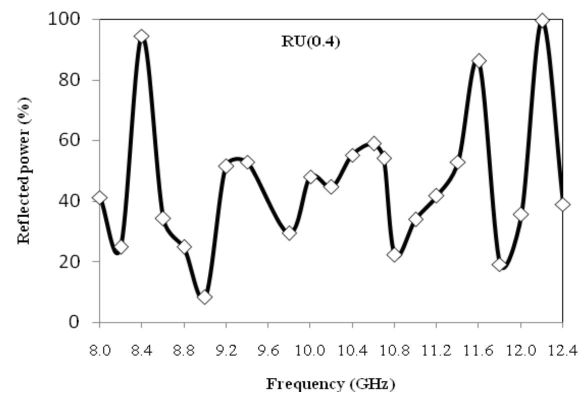

Fig. 2(c). Reflected power (%) as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.4.

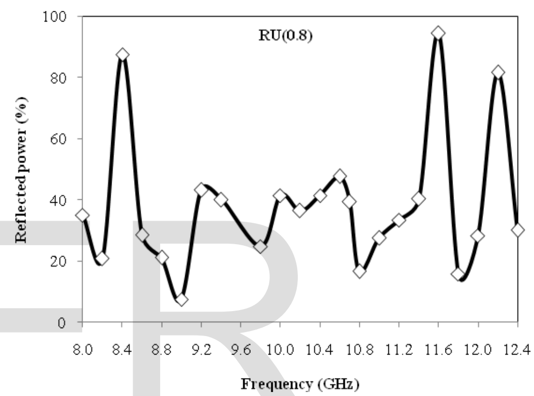

Fig. 2(d). Reflected power (%) as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=0.8.

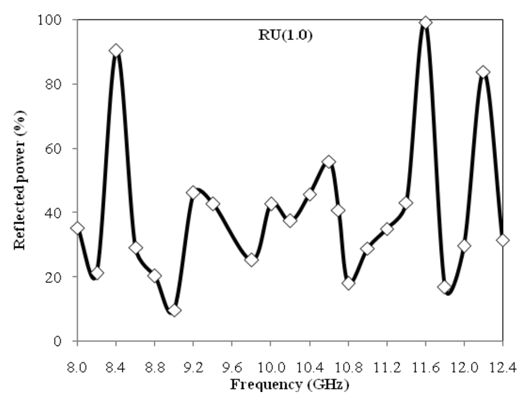

Fig. 2(e). Reflected power (%) as a function of frequency for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=1.0.

The reflected power (%) graph for all compositions is shown in figure 3. It is observed that maximum value of reflected power (%) is present at lower frequency region from 8.0 to 9.0 GHz and high frequency region from 11.2 to 12.4 GHz, in comparison to middle frequency region from 9.2 to 11.0 GHz.

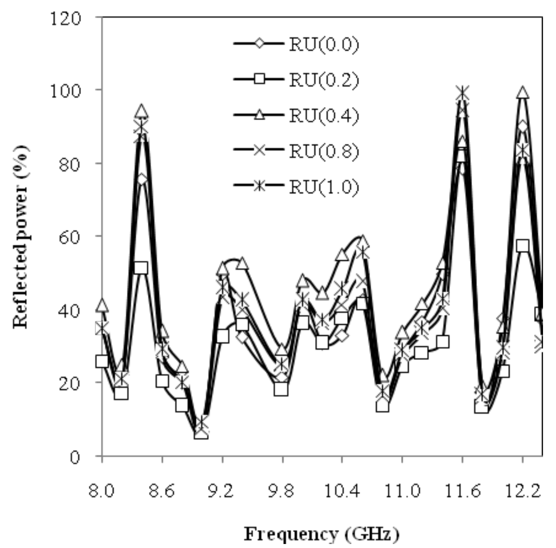

Fig. 3. Reflected power (%) as a function of frequency and substitution for $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x=(0.0, 0.2, 0.4, 0.8 and 1.0)

3.3 Current-Voltage (I-V) Characteristics

The dc current voltage relationship for all the compositions is shown in figure 4. Following observations are made from for all the compositions from graph shown in figure:

(i) In the composition x=0.0 ($Ba_{0.5}Sr_{0.5}Co_{0.0}Ru_{0.0}Fe_{12}O_{19}$), it varies linearly with voltage and has maximum and minimum value of 13.60 µA and 2.80 µA.

(ii) In the composition x=0.2 (Ba0.5Sr0.5Co0.2Ru0.2Fe11.6O19), the current follows small increment with the applied voltage. The maximum and minimum value of current is 1.10 µA and 0.04 µA.

(iii) In the composition x=0.4 ($Ba_{0.5}Sr_{0.5}Co_{0.4}Ru_{0.4}Fe_{11.2}O_{19}$), the constant value of current, approximate 0.02 µA, is observed along the entire applied voltage. This observed current is small among all the compositions.

(iv) In the composition x=0.8 ($Ba_{0.5}Sr_{0.5}Co_{0.8}Ru_{0.8}Fe_{10.4}O_{19}$), also has linear current characteristics with minimum value of 3.50 µA at 0.2 V and reaches to 14.50 µA at 3 V.

(v) In the composition x=1.0 ($Ba_{0.5}Sr_{0.5}Co_{1.0}Ru_{1.0}Fe_{10}O_{19}$), minimum value of current is 3.81 µA and maxima of 15.10 µA is observed. It is the maximum current exhibited by this composition among all the compositions along the entire range of applied voltage.

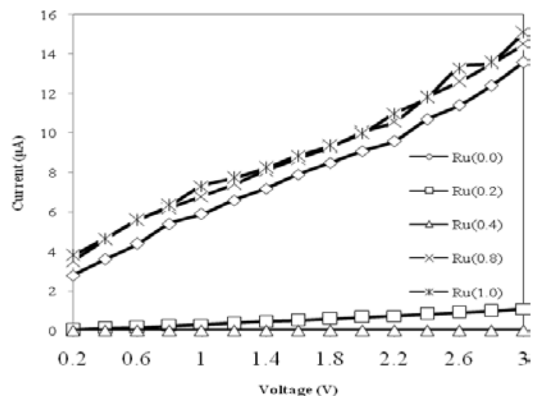

Fig. 4. Variation of current as a function of applied voltage and substitution in $Ba_{0.5}Sr_{0.5}Co_xRu_xFe_{(12-2x)}O_{19}$ ferrite with x =(0.0, 0.2, 0.4, 0.8 and 1.0)

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