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# DIELECTRIC PERMITTIVITY OF FERRITE SAMPLES IN THE FREQUENCY RANGE FROM 0.3 TO 20 MHZ

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## I. Introduction

In this note, results of measurements of the dielectric permittivity of C2010, CMD10, and G4 ferrite samples are presented. Four samples of each material were measured (for G4, one sample was measured twice) to get statistically sound results.

A method of the measurement and the first result of sample measurement (G10 and Teflon) were described in the previous note [1], so only results of the ferrite sample testing will be presented in this note. More over, following the results obtained in [1], only a 10:1 probe will be used for the measurements; nevertheless, the results of simplified sample capacitance calculation will be kept for comparison. The samples of the ferrite were 76.2 mm in lengths, 25.4 mm in width and 5.08 mm thick. The electrodes were identical to used in [1]. Fig. 1 shows expected capacitance of the sample setup as a function of the material permittivity

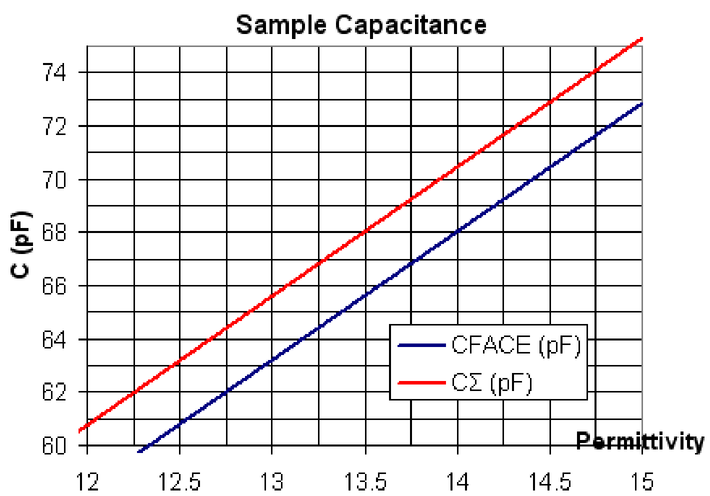


Fig. 1: Calculated capacitance as a function of frequency

## II. Ferrite C-2010

Table 1 shows data table for the first measured sample in the frequency range from 300 kHz to 20 MHz. In this and in all similar tables below, C11 is the capacitance calculated by using a simple algorithm while C1 takes into the account power loss.

Table 1

| f (MHz) | C1 (pF) | C11 (pF) | tg(delta) | ϕ (deg) |
|---|---|---|---|---|
| 0.3 | 72.3 | 72.4 | 0.028 | 83.3 |
| 0.50 | 71.3 | 71.2 | 0.022 | 85.5 |
| 1.00 | 66.4 | 66.3 | 0.013 | 85.0 |
| 3.00 | 65.3 | 64.4 | 0.028 | 74.0 |
| 10.00 | 67.2 | 61.1 | 0.024 | 47.6 |
| 20.00 | 48.6 | 32 | 0.048 | 26.2 |

If to take into account only surfaces of the electrodes facing the ferrite, according to the table, we should have the permittivity of the ferrite in the range from 14.2 (65.4 pF) to 15.7 (72.3 pF).

Results of the capacitance measurement for all the four samples are summarized in Fig. 2. The blue curve (here and below) represents simplified method of capacitance calculation while the red curve takes into the account power loss in the sample.

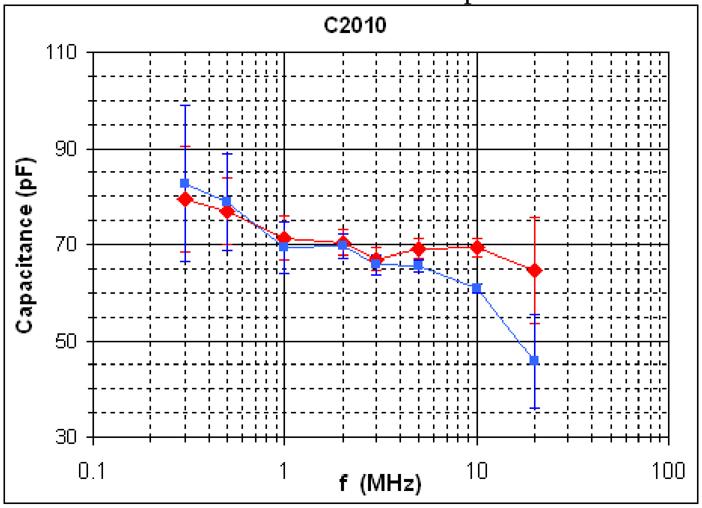


Fig. 2: Capacitance with C2010 ferrite as a dielectric.

It is possible to see that in the frequency range from 0.3 MHz to 5 MHz, the two curves are very similar. Power loss in the samples starts be noticeable at higher frequencies.

The y-axis error bars in Fig. 2 corresponds to  standard deviation from the average value. So, we have here quite a significant uncertainty, especially near the ends of the measurement frequency interval where this uncertainty can be a result of a limited amplitude and phase measurement precision.

Permittivity of the material can be obtained by combining Fig. 2 and Fig. 1, which will be made in the concluding part of this report

### III. Ferrite CMD10

Table 2 shows the measurement data of the first sample in the frequency range from 300 kHz to 20 MHz.

Table 2

| F (MHz) | C1 (pF) | C11 (pF) | tg(delta) | $\phi$ (deg) |
|---|---|---|---|---|
| 0.3 | 72.4 | 72.4 | 0.028 | 87 |
| 0.50 | 69.9 | 69.8 | 0.015 | 86.9 |
| 1.00 | 67.8 | 67.7 | 0.017 | 84.7 |
| 3.00 | 68.2 | 67.5 | 0.016 | 76.2 |
| 10.00 | 70.6 | 61.8 | 0.099 | 47.9 |
| 20.00 | 77 | 51 | 0.19 | 26.2 |

If to take into account only surface of the electrodes facing the ferrite, according to the table, we should have the permittivity of the ferrite in the range from 14.7 (67.7 pF) to 15.7 (72.3 pF). The capacitance measurement results for all the four samples are summarized in Fig. 3.

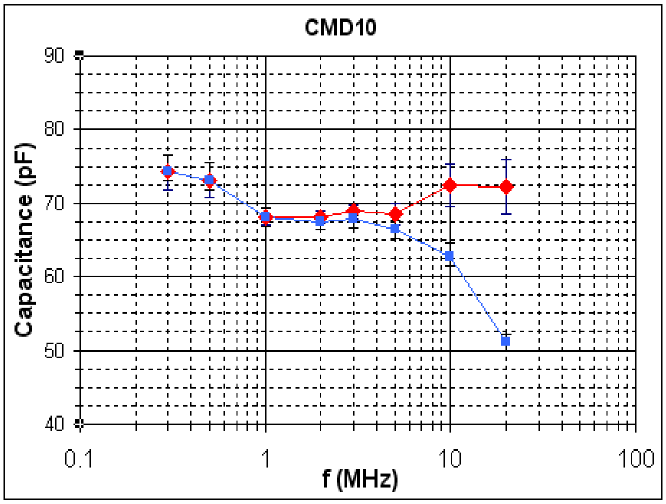


Fig. 3: Capacitance with CMD10 ferrite as a dielectric.

Again, the blue curve corresponds to the simplified method of calculation. As it is possible to see, capacitance of the sample with CMD10 ferrite tends to be more stable with frequency than that of C2010 ferrite.

### IV. Ferrite G4

Table 3 shows the measured capacitance of one sample in the frequency range from 300 kHz to 20 MHz.

Table 3

| f (MHz) | C1 (pF) | C11 (pF) | tg(delta) | $\phi$ (deg) |
|---|---|---|---|---|
| 0.30 | 71 | 71 | 0.011 | 88 |
| 0.50 | 69.7 | 69.8 | 0.010 | 82.3 |
| 1.00 | 67.9 | 67.8 | 0.002 | 84.3 |
| 3.00 | 68.3 | 67.5 | 0.025 | 75.7 |
| 10.00 | 73.8 | 63.9 | 0.11 | 46.4 |
| 20.00 | 75 | 53 | 0.09 | 29 |

A graph corresponding to the averaged data taken using all four samples is shown in Fig. 4.

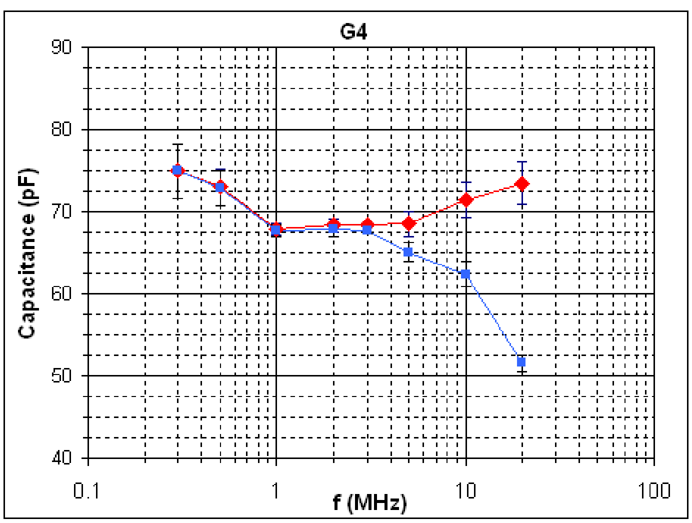


Fig. 4: Capacitance with G4 ferrite as a dielectric.

Comparing Fig. 3 and Fig. 4, we can see a great deal of similarity. We are dealing with a very similar (if not identical) material here.

### V. Conclusion

Taking into the account Fig. 1, we can find material permittivity for each sample. The data in the figure can be well extrapolated by the expression:

$$\varepsilon = (C - 3.2) / 4.8,$$

where C is capacitance in pF. Using this expression, we can recalculate the measurement results to extract permittivity of the three materials in the range of frequencies. The results are summarized in the Table 4 below and illustrated by Fig. 5 where only the data is used that take into account power loss.

Table 4

| f (MHz) | 0.3 | 0.5 | 1 | 3 | 10 | 20 |
|---|---|---|---|---|---|---|
| ε_C2010_ϕ | 15.9 | 15.4 | 14.2 | 13.3 | 13.8 | 12.8 |
| ε_C2010_0 | 16.6 | 15.8 | 13.8 | 13.0 | 12.0 | 8.9 |
| ε_CMD10_ϕ | 14.8 | 14.6 | 13.5 | 13.7 | 14.4 | 14.4 |
| ε_CMD10_0 | 14.8 | 14.6 | 13.5 | 13.5 | 12.4 | 10.0 |
| ε_G4_ϕ | 14.9 | 14.5 | 13.5 | 13.6 | 14.2 | 14.6 |
| ε_G4_0 | 14.9 | 14.5 | 13.4 | 13.4 | 12.3 | 10.1 |

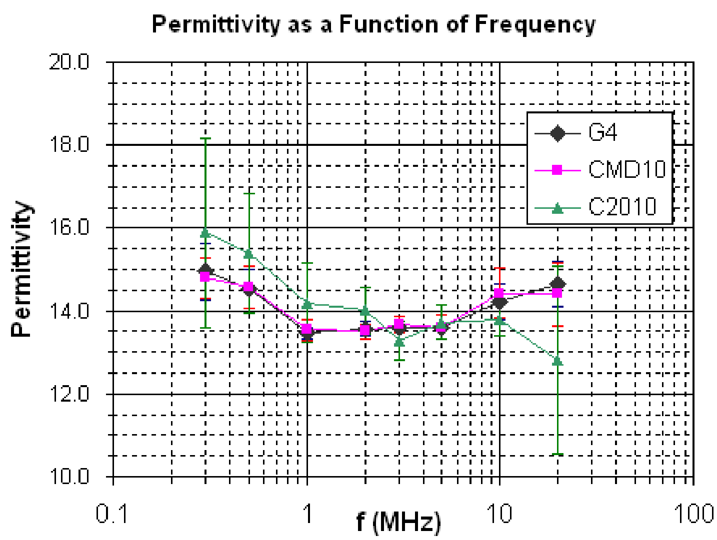


Fig. 5: Permittivity of the ferrite samples vs frequency

Although there is noticeable drift of permittivity with frequency for each tested material, this drift is lower for CMD and G4 samples. The difference between the last two materials is statistically undetectable. Permittivity of the samples is close to what was used while modeling the transition line-type kicker (ε = 13), but using a value of permittivity ε = 14 could be a better approximation.