Investigation of an electrode system for a new calculable capacitor is being carried out at NIST through 3-D field simulation. From the results, we have determined the most critical factors to the design of the system. The scope of the study would not have been possible through any empirical study.

Introduction

Although the value of the calculable cross capacitor at NIST has being maintained with uncertainties of less than 0.02 \( \mu \)F/F, a new calculable cross capacitor design with an operating range of 0.1 pF is being investigated. Information on the most sensitive and critical design parameters for the electrode system could be evaluated through a 3-D electric field simulation program.

Main Electrodes

Considering that a Fabry-Perot interferometer with relative uncertainty below \( 4 \times 10^{-10} \) over a range of 50 mm from an initial length of 180 mm between mirrors is being developed at NIST to apply to a new calculable capacitor, the diameter and length of the main bars are 40 mm and 400 mm respectively for the field simulation (Fig. 1). Through the simulation for the items listed below, we could determine the most critical design factors such as adjustable range and directional sensitivity to obtain symmetrical location of the main bars, optimum gap size between main bars and outer shielding cylinder, guard structure on the top and bottom covers, and the requirement to keep the main bars fixed to avoid errors arising from twist and tilt, etc.

![Fig. 1. Basic arrangement of main bars and guards to achieve an operating range 0.1 pF.](image1)

1. Asymmetry of main bar positions (Fig. 2),
2. Leakage capacitance between gaps of bars,
3. Leakage capacitance between bars and outer shield,
4. Leakage capacitance between bar's end and top and bottom covers,
5. Tilt effects of the main bars,
6. Twist effects of the main bars,
7. Effects of stepped diameter of a main bar (Fig. 3),
8. Effects of a spike on the main bar (Fig. 4).

Guard Electrodes

During a study of the coefficient of friction between a PTFE ring and the polished main bar surfaces, it was discovered that PTFE debris adhered to the bar surfaces. To avoid potential influences of the dielectric deposits in the active field, an upper guard structure with four PTFE bars that slide internally between the upper guard and the neighboring main electrodes was utilized [1]. But some unexpected problems such as misalignment between guard's axis and the central axis of main electrodes were encountered. To solve this shortcoming of the earlier design, a new guard structure in which four PTFE bars are located outside the main electrode as shown in Fig. 5 is investigated by field simulation. By installing two capacitive sensors on the upper guard, not only displacement and tilt of the upper guard (Fig.

![Fig. 2. Effect of bar horizontal displacement.](image2)

![Fig. 3. Effect of a step bar diameter increase.](image3)
6) but also displacement of the main bar (Fig. 7) can be precisely detected.

![Fig. 4. Effect of a spike on the main bar.](image1)

![Fig. 5. Structure of new upper guard electrode.](image2)

![Fig. 6. Effect of diagonal tilt of the upper guard.](image3)

In addition, we examined through the simulation the optimum configuration and detailed dimensions of the guard electrodes to obtain a capacitance of 0.2 pF for the initial guard separation of 180 mm measured between two mirrors. With these conditions, it is possible to get results on the effect of proximity of the guard electrodes as shown in Fig. 8.

![Fig. 7. Effect of displacement of a main bar.](image4)

![Fig. 8. Effect of proximity of the guard electrodes.](image5)

**Conclusion**

An investigation of the design of a new calculable capacitor has been carried out through 3-D field simulation to find the critical design factors. Further details and results will be presented at the conference.

**Acknowledgements**

The authors would like to express appreciation to KRISS for the collaborative arrangement that allows Dr. Rae Duk Lee to perform work at NIST; and to thank Mr. Lai Lee of NIST for helpful discussions of the mechanical structure; thanks to Dr. Yu Semenov of VNIIM for suggestion of the novel concept of the upper guard.

**References**