

INVESTIGATION OF USING FERROELECTRIC MATERIALS IN  
HIGH POWER FAST RF PHASE SHIFTERS FOR CHARGED PAR-  
TICLE ACCELERATORS

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A fast ferroelectric phase shifter is being investigated for high-power RF vector modulation. Such a device could be used in charged particle accelerators, allowing vector control of the RF power delivered to accelerating RF cavities. This will save construction and installation cost by reducing number of klystrons; allowing many cavities to be powered by a single high-power klystron, while maintaining control over the input to each cavity. A vector modulator is constructed using two of these phase shifters connected to a quadrature hybrid junction. By varying the phases of these shifters independently, one can control amplitude and phase of the output signal. Ferromagnetic materials have previously been developed for high-power phase shifters in accelerators, but the response of these devices tends to be slow since it is difficult to change the bias magnetic field quickly.

Bulk ferroelectric materials, particularly those based on barium-strontium titanate compounds, have shown promise in high-power applications because of their low loss tangent and high dielectric strength. Phase shifting is affected by changing the permittivity through application of a bias electric field. Such materials have already been investigated for use in fast phase shifters at X-Band frequencies [1]. Several different compositions of barium-strontium titanate compounds are tested at frequencies from 100 MHz to 2 GHz that could be used for future large-scale accelerator projects employing superconducting RF cavities. The ratio of barium versus strontium in the composition is varied from sample to sample. This allows an investigation of the tradeoffs involved between dielectric strength, loss tangent, tunability, and relative permittivity. Since ferromagnetic materials have also been investigated for this application, a comparison is made between phase shifters employing ferromagnetic materials and those employing ferroelectric materials. Both qualitative and quantitative comparisons are presented.

Since ferroelectrics are by nature nonlinear dielectric compounds, the effects of nonlinearity on the propagation of the high-power RF signal are of concern. Harmonic generation and shock waves could be produced if care is not taken. Preliminary research on the effect of these nonlinearities is conducted through computer simulation. The simulations give rough estimates of the amount of distortion, aiding the evaluation of the feasibility of this phase shifter concept.

[1] V.P. Yakovlev, O.A. Nezhevenko, and J.L. Hirshfield, Fast X-Band Phase Shifter, Advanced Accelerator Concepts: Eleventh Workshop, 2004

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