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Tilting at wave beams: a new perspective on the St. Andrew’s Cross

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The generation of internal gravity waves by a vertically oscillating cylinder that is tilted to the horizontal in a uniformly stratified fluid of constant buoyancy frequency, is investigated. This variant of the widely-studied horizontal configuration–where a cylinder aligned horizontally with a plane of constant gravitational potential induces four wave beams forming a cross pattern known as St. Andrew’s Cross–brings out certain unique features of radiated internal waves from a line source tilted to the horizontal. Specifically, for a given tilt of the cylinder, there is a cut-off frequency below which there is no longer a radiated wave field. Furthermore, three-dimensional effects due to the finite length of the cylinder, which are minor in the horizontal configuration, become a significant factor and eventually dominate the wave field as the cut-off frequency is approached. These results follow from simple kinematic analysis and are confirmed by supporting laboratory experiments. The kinematic analysis, moreover, suggests a resonance phenomenon near the cut-off frequency, where nonlinear and viscous effects are likely to play a part. This scenario is examined by an asymptotic model which predicts transfer of energy to a horizontal mean flow component. Experimental evidence of such an induced mean flow near cut-off is also presented.