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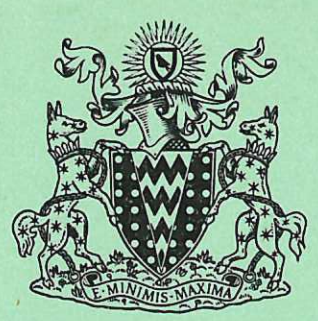

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Report

THE MICROWAVE EMISSIVITY OF A TURBULENT PLASMA WITH NON-PARALLEL ORIENTATION OF THE TURBULENCE ELEMENTS

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THE MICROWAVE EMISSIVITY OF A TURBULENT PLASMA WITH NON-PARALLEL ORIENTATION OF THE TURBULENCE ELEMENTS

by

D.J.H. WORT

A B S T R A C T

This report extends previously published work on the microwave emissivity of a turbulent plasma by considering the effect of non-parallel alignment of the turbulence elements. It is found that for random orientation the emissivity may be increased or decreased by a few times, but that for a more realistic helical representation of a turbulent diffuse pinch plasma the effect is rather less, and that the emissivity then only differs from that of the corresponding plasma with parallel turbulence by a few tens per cent.

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1. INTRODUCTION

1. A previous paper[1] has considered the emissivity of a turbulent plasma in which the turbulence elements were parallel, with the direction in which the emitted radiation was observed normal to the axis of the elements. It was pointed out that the degree of symmetry assumed in this model would not apply to plasma devices in which the magnetic field possessed shear, e.g. a pinch device, as the turbulence elements would be aligned with the magnetic field and would thus no longer be parallel. In a pinch device the elements would have some fundamentally helical arrangement, and it would in theory be possible to compute the emissivity of such a system provided that the emissivity of the individual cylindrical turbulence elements in an oblique direction, no longer normal to the cylinder axis, was known. The geometry of such a system, however, is exceedingly complicated, and from the analytical point of view it is much more straightforward to proceed to the situation in which the turbulence elements are orientated in random directions. It will be shown that this random orientation does not change the emissivity very greatly from the parallel case, and it is reasonable to suppose that any quasi-regular array of elements will yield emissivities lying somewhere between the extremes of parallel or random orientation. This supposition will be found to be justified for a helical system by a semi-empirical approach, although the rigorous solution has not been attempted.

2. GEOMETRY

2. The turbulence elements are assumed to be cylinders with a parabolic density profile. We define the centre-centre spacing S of the cylinders by considering the points of intersection of the cylinder axes with a plane drawn through the system normal to the axis of the containing cylinder. If there are M such intersections in a container of radius R, then we can define

$$S^2 = \frac{2\pi R^2}{M\sqrt{3}} ,$$

so that S would be the lattice spacing if the same number of intersections were arranged in a regular close-packed lattice. This gives S a very similar meaning to the S used in (1).

3. We now consider a ray random-walking its way from wall to wall by bouncing around amongst these cylinders and we assume that there is no correlation between the orientations of the two cylinders at the ends of any one step in the random walk. The problem is simplified by considering the projection of the ray path on to a plane normal to the

7. CONCLUSIONS

17. This report has shown how to correct the previously obtained emissivity of a turbulent plasma in which the turbulence elements lie parallel to one another, to allow for random or quasi-random orientation of the elements. In particular it has been shown that a helical array, of the type which would occur in a diffuse pinch device such as ZETA, will yield an emissivity which is not greatly different from a parallel array.

18. As a complementary result, recent work by Heald has shown that the arbitrary adoption of a parabolic profile for the turbulence elements is unlikely to lead to gross error in the quantitative conclusions, which are comparatively insensitive to the profile shape.

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