A COMPUTER PROGRAM FOR THE CALCULATION OF WAVES ON CYLINDRICAL STRUCTURES

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ABSTRACT

A computer program based on the multiple multipole (MMP) method[1] is presented. This allows the calculation of different waveguides (hollow waveguides, dielectric waveguides, optical fibers, microstrips, cables) as well as scattering of waves on cylindrical structures.

INTRODUCTION

A lot of technical problems consist of a certain number of domains with linear, homogeneous, isotropic material. Dealing with time-harmonic fields on cylindrical structures, one has to solve two-dimensional Helmholtz equations in each domain with different boundary conditions.
In the sixties and early seventies the simple point-matching (PM) technique[2] was used to solve such problems. This method consists of an analytic part, where the so called Rayleigh hypothesis[3] was applied to get an expansion of the fields inside the domains and a numerical part, where the boundary conditions are matched in certain matching points. This technique was found to be useful only for quite simple geometries. If both, the analytic and the numerical part are improved, we get the MMP method, which shows up to be very poverful.

PROGRAM STRUCTURE AND SPECIAL FEATURES

At first, the matching points on the boundaries are chosen. If the usual PM technique is applied, this is not really a choice, because the results depend very much on the distribution of the matching points. To avoid poor results, "almost optimal" distributions must be found. The MMP method on the other hand, allows any distribution of matching points, as long as the distances between neighbouring points are small enough. (The maximum distance depends on the needed accuracy of the solutions.) For example, if a part of a given structure is of special interest, one can use a high density of matching points there and a low density everywhere else. This feature is important in the first example of the following section.
In a second step the MMP-expansion must be chosen in an appropriate way. The accuracy of the results depends much on this. Fortunately there are some simple rules which are very helpful. An automatic choice of the MMP-expansion seems to be possible but has not been implemented yet.
Now, the parameters of the expansions and (in the case of waveguides) the

propagation constant are calculated. If this is done, one has analytic expressions (i.e. the MMP-expansions) for the approximations of the solutions everywhere. For this reason, it is usually quite easy to get other quantities like currents, power densities, poynting vectors and so on.

If no severe cancellations occur, maximum errors are found on the boundaries. This may be advantageous if one is interested in the behaviour of the farfield rather than the nearfield.

EXAMPLES

The geometrical data of the following examples might be not too realistic because they are calculated above all to show the possibilities of the MMP method even if not very much memory is available. (For these examples it is necessary to store a triangular matrix with less than 140 columns.) Figure 1 shows some field lines in the right half space of a microstrip with very thin ideal conductors. It would be absolutely imossible to solve such a problem with the simple PM technique. Near the edge of the strip, errors seem to occur. But the strange field lines are only due to the routine which generates the plots. (The field vectors are calculated on a grid with 15*15 nodes to save computation time. The lines are ploted on a small computer by interpolation. It should be mentioned that the field density in these plots is not correlated with the strength of the field.) Figure 2 shows that the calculation is in fact very accurate even near the edge.

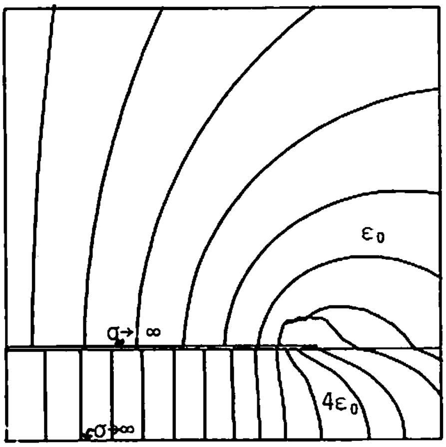

fig.1 electric field lines in the right half-plane of a microstrip

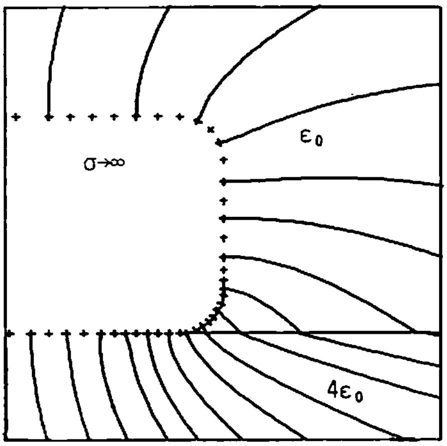

fig.2 electric field lines near the edge of the microstrip in fig.1

To calculate a single material optical fiber (fig.3) one domain was separated fictionally into three domains along the dotted lines. This is in fact a step in the direction of finite elements. Figure 4 shows the electric field lines in the first quadrant of a transverse plane. In fig.5 the lines of constant power flux density of the first mode of this fiber are ploted. From this one can see that the light is not concentrated in the core as one would wish. If the same calculation is done at a higher frequency, one finds that the power density outside the core is now less than 10% of the maximum density. (fig.6)

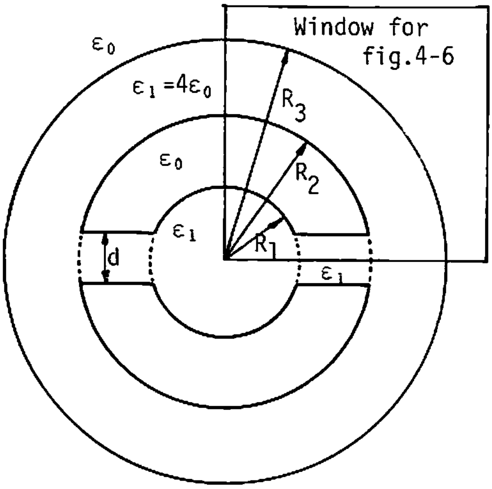

fig.3 cross-section of a single material optical fiber

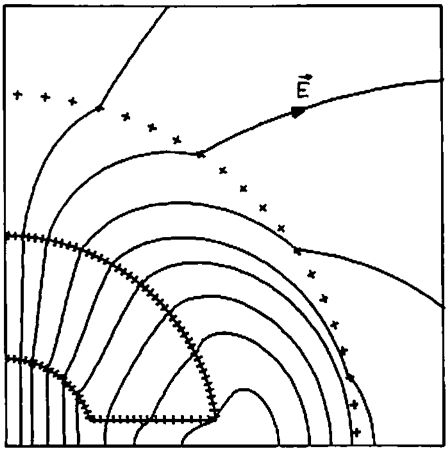

fig.4 electrical field lines of the vertically polarised HE_{11}-mode in a single material optical fiber

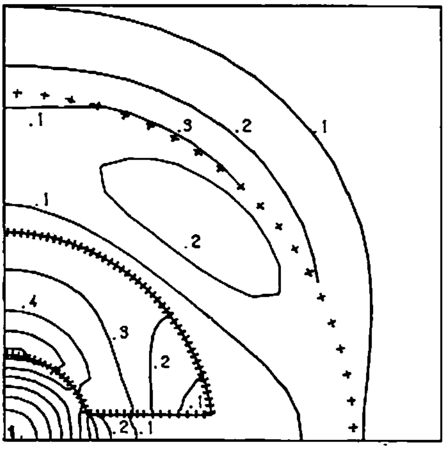

fig.5 lines of constant power flux density for the same mode as in fig.4 .

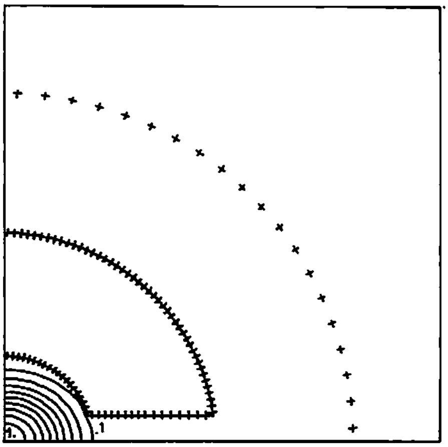

fig.6 like fig.5. Calculation at a higher frequency. (f(fig.6)=8/3 f(fig.5))

REFERENCES

1. Hafner C and Klaus G, will be published in COMPEL(1985).
2. James JR and Gallett INL, The Radio and Electronic Engineer 42(1972),103.
3. Bates RHT, Electronics letters 5(1969),654.