COUPLING EFFECTS FOR COMPLEX WAVES IN MULTILAYER CYLINDRICAL STRIP AND SLOT LINES

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ABSTRACT

Using the mathematical model, based on finding the isolated critical points (ICP) of dispersion equation for the multilayer cylindrical strip and slot lines, 'coupling' effects of two different modes were discribed.

INTRODUCTION

The spectral problem for the waves in the multilayer circular cylindrical strip and slot lines (CCSTL and CCSLL) may be reduced to finding a number of decisions γ_h of the following dispersion equation:

$$F(h, \xi_n) = \det\left[I - A(h, \xi_n)\right] = 0, \qquad (1)$$

where $A(h, \xi_n)$ -the kernel operator-function, ξ_n ($n=1, \ldots, m$)- the nonspectral parameters. The traditional approach to solving the equation (1) is investigating of the arrangement γ_h for different values ξ_n. In [1-4] the evolution of γ_h as function of frequency, angular slot width, dielectric layers parameters was studied. A special interest has been excited by the physical situations, in which the curves of the dependences of the spectral parameter from nonspectral ones are discribed by well known Vien's diagram. The mutual change of dependences of the spectral curves and filds structure for two modes takes place in this case. This effect may be named as 'coupling', or 'interaction', or mutual transformation of the natural modes.

FORMULATION OF THE PROBLEM

In [5] it was shown, that 'interaction' effects in the resonators and waveguides exist when the function $F(h,w)$ (w- one of the ξ_n parameters) has an isolated Morce critical point (IMCP), having the coordinate (h_0, w_0), in which the following equations are performed:

$$F'_h = F'_w = 0; \qquad F''_{hh} \cdot F''_{ww} - F''_{hw} \cdot F''_{wh} \neq 0 \qquad (2)$$

Here $F(h,w)$ is considered to be a mapping $F : C^2 \to C$ - whith the region D, in which $F(h,w)$ is an analytical function of two complex variables. Near (h_0, w_0) the equation $F(h,w)=0$ may be represented as Taylor's series:

$$F(h,w) \approx F(h_0, w_0) + \Delta(h, w, h_0, w_0) = 0, \qquad (3)$$

where

$$\Delta = \frac{1}{2}\left[F''_{hh}(h-h_0)^2 + 2 \cdot F''_{hw}(h-h_0)(w-w_0) + F''_{ww}(w-w_0)^2\right]$$

Here it will be shown, that there are the points $(\hat{h}_0, \hat{w}_0)$

too, in which the function $F(h,w)$ have the complex double root.

$$F(\hat{h}_o, \hat{w}_o) = F_h' = 0; \qquad F_{hh}'' \cdot F_w' \neq 0 \qquad (4)$$

Let us call these points the degeneration points (DP). Near $(\hat{h}_o, \hat{w}_o)$ the equation $F(h,w) = 0$ is:

$$F(h,w) \simeq F_w'(w - \hat{w}_o) + \Delta(h, w, \hat{h}_o, \hat{w}_o) = 0. \qquad (5)$$

The aim of this report is to find special points, that answer conditions (2), (4) and to discuss physical effects, connected with these points.

NUMERICAL RESULTS

Originally the effects of the modes 'coupling' in the CCSLL and CCSTL were found under investigation of the dispersional characteristics in the narrow slot and strip cases, accordingly. The modes 'interaction' in CCSLL take place under $\theta \to 0$ between slot wave $H_{oo}^+(\theta)$ and $H_{mn}^+(\theta)$, $E_{mn}^-(\theta)$ waves of the inner waveguide, which are perturbed by the narrow slot. Similarly, in CCSTL the strip $T_{oo}^-(\theta)$ wave enters into an 'interaction' with the modes of the open circular dielectric rod. It is important, that in these cases the 'coupled' waves are slow ones, and they have the real values of the spectral parameter. These results were published in [1-3]. Now it may be noted, that under $\theta \to 0$ or $\delta \to 0$ (δ = 180 - θ) the isolated Morce critical points (h_o, ka_{oi}) exist, where $h_o \to k\sqrt{(\varepsilon+1)/2}$ ($k = 2\pi/\lambda$, λ - free space wavelength, ka_{oi} - the values of the parameter ka under which the asymptotic dispersional curves cross line $h = h_o$. If the coefficients (3) are defined, the dispersional curves will be restored. When the slot width was changed, the ICP for the complex waves can not be calculated in this case, as the function $F(h,\theta)$ isn't an analitical one of the parameter θ. However, this problem does not arise for slow waves and IMCP were found.
ICP for the complex waves may be calculated under considering the function dependence from the complex parameter ka. The dispersional curves of the CCSTL waves are shown in fig. 1, where isolated points: IMCP and DP are marked. Calculations showed, that DP describe the cases, when the function $F(h, \xi_n)$ has the complex double root under some real values ka and δ. One of these examples is represented in fig. 1, where the dispersional curves of the two modes are given for two near values δ. These curvers may be restored by means of (5) in the vicinity of these points.

The answer to the question what special points, namely IMCP or DP, describe the concrete physical situation of waves coupling in better way, depends both on values $Im\, ka_o$ in special points and on how far the special points (h_o, ka_o) is situated from the region of the spectral curves closing in.

It is evident, that the mutual transformation effects will be observed in the multilayer CCSLL and CCSTL, which have more nonspectral parameters, than homogeneous lines, namely, the dielectric layer permeabilities and wave sizes of the layers, for example.

Let us consider a structure, that has one inner and one outer dielectric layer, placed in a perfectly conducting screen (fig. 2). The dispersional curves of the waves of such a structure are shown in fig. 2, where the case $\theta = 0$ is noted by dashed lines. When $\theta = 0$, the waves of the coacsi-

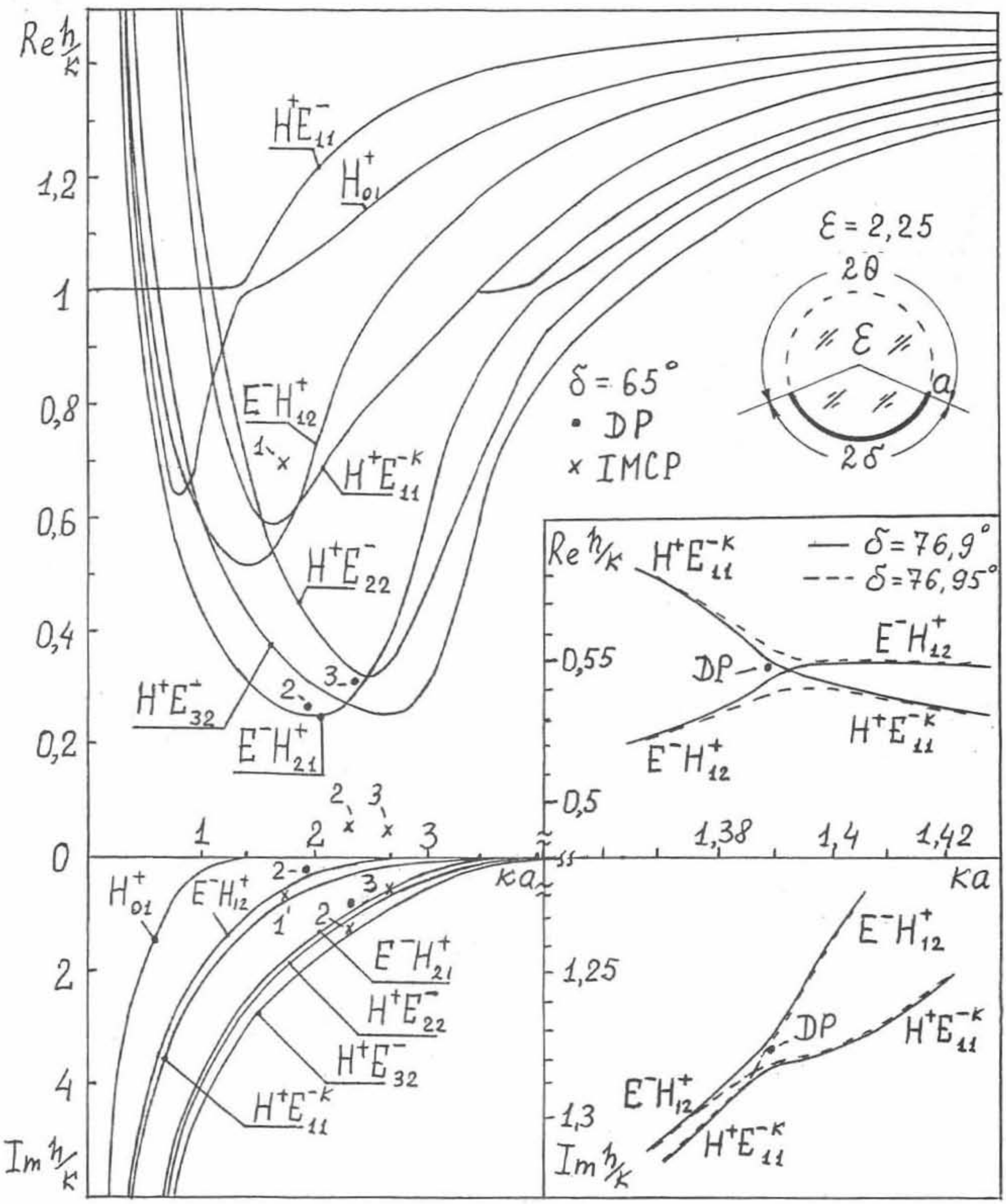

Fig. 1. $\delta = 65^\circ$: 1(×) – Im $ka_0 = 0,1$; 2(×) – Im $ka_0 = -0,178$;
2(•) – Im $ka_0 = -0,282$; 3(×) – Im $ka_0 = -0,223$;
3(•) – Im $ka_0 = 0,0083$. $\delta = 76,9^\circ$: (•) – Im $ka_0 = 5 \cdot 10^{-4}$.

al cable and the ones of the inner guide can not 'interact'. But under Θ = 1°, the mutual transformation effects take place first, between slot $H^{+}_{00}(\theta)$ - wave and the waves of the inner guide, second, the coupling regions are formed for the waves of the coacsial cable and those of the inner guide. The IMCP were calculated in the noted cases. They have the coordinates, conciding under $\Theta \to 0$ with points, in which the asimptotical curves (dashed lines) are crossed. Thus, the interaction effects may be described by means of the mathematical model, based on the isolated critical points: IMCP and DP. It is evident, that investigating of the ICP evolution gives a possibility to prognosticate and study the regions on mutual transformation of the waves.

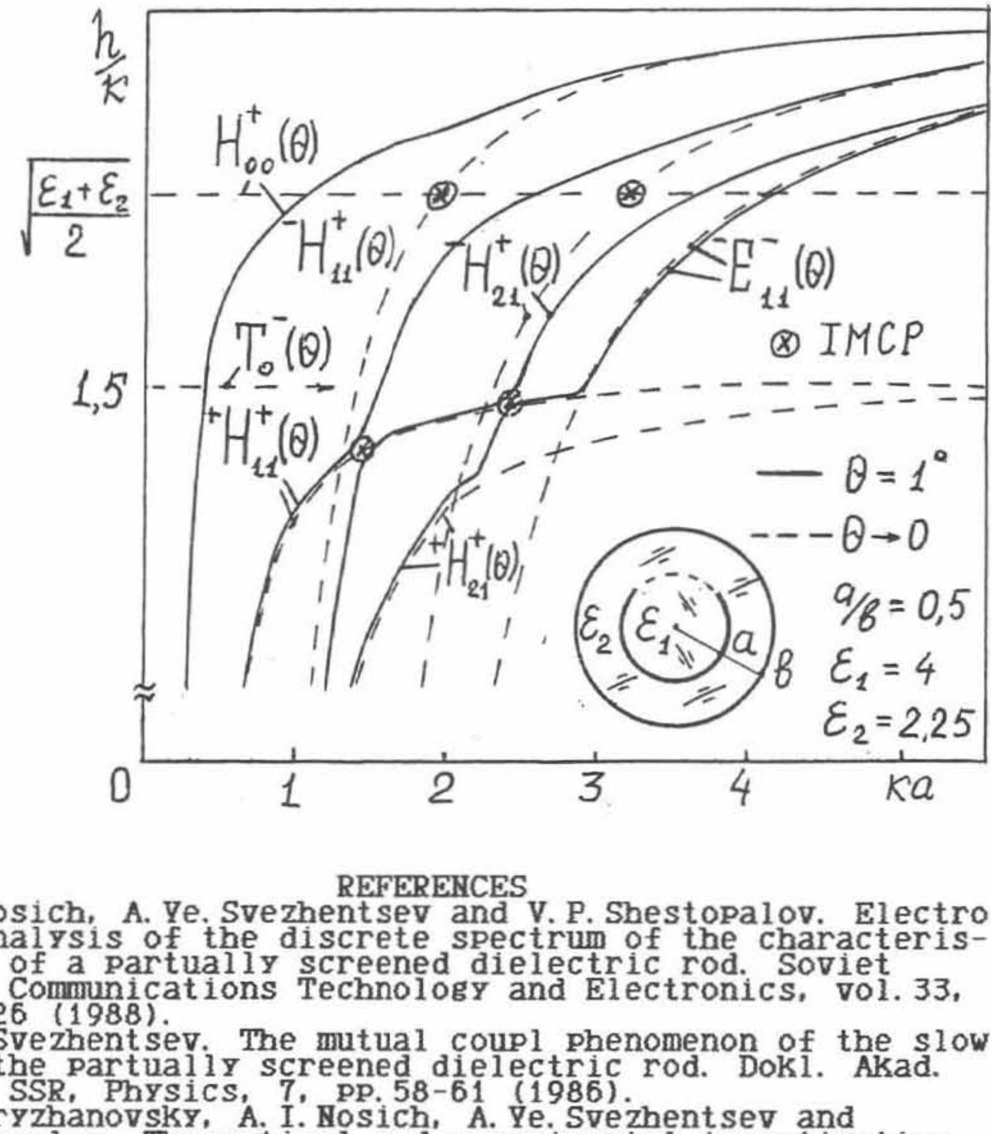

Fig. 2

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