1. INTRODUCTION

The Dynamic Ergodic Divertor (DED) of TEXTOR is installed to control plasma edge behaviour [1]. The DED helical coils create a specific topology of magnetic field at the plasma edge, where external DED helical perturbations with poloidal number \( m \) and toroidal number \( n \) are resonant on the magnetic surfaces \( q(r_{res}) = m/n \) (\( q(r) \)- safety factor) (see, e.g., [2, 3]). However, this topology was investigated using vacuum DED field perturbations without the plasma response. Remind, that the \( m = 12, n = 4 \) perturbation field structure is chosen as a standard DED operation regime.

The interaction of an external helical field with a plasma was investigated also in the CSTN-IV tokamak [4].

In the present paper the influence of plasma response to DED helical perturbation penetration is considered in cylindrical geometry. Analytical solutions of perturbations are found and their numerical investigation is carried out.

2.

\[
\frac{d}{dr} \frac{d}{dr} V_{r_{res}}^{+} - \left( \frac{m^2 + i \delta^2}{4 \pi \rho \omega^2} \right) F(r) V_{r_{res}}^{+} = \left( \frac{r}{\delta^2} \frac{F(r)}{4 \pi \rho \omega^2} + \frac{r^2}{\delta^2} \frac{F(r)}{4 \pi \rho \omega^2} + \frac{3 r}{\delta^2} \frac{F(r)}{4 \pi \rho \omega^2} \right) B(r) \tag{3}
\]

The perturbations \( V_{r_{res}}^{+} \) and \( B_{\rho}^{+} \) are small and for simplicity we put \( V_{r_{res}}^{+} = B_{\rho}^{+} = 0 \). We use approximation of an incompressible plasma motion \( \frac{d}{dt} V = 0 \), neglect the \( \nabla p \) term, variations of the plasma density \( \rho \) and conductivity \( \sigma \) (compare with [5]).

The value \( F(r) \) is equal to zero inside the plasma, \( F(r_{res}) = 0 \) when \( q(r_{res}) = m/n \) (\( q(r) = rB_{\rho}/RB_{\rho} \)). The region near \( r = r_{res} \) is the resonant (interaction) zone.

Inside and near the interaction zone Eq. (3) have the next general solution normalized to the value \( V_{r_{res}} = B_{\rho_{res}}^{+}/\sqrt{4\pi \rho} = C I_{\omega}(kr)/\sqrt{4\pi \rho} \) \( (I_{\omega}(kr)) \) - modified Bessel and \( H_{\omega}^{(2)}(z) \) - Hankel functions:

\[
V_{r_{res}}^{+}(r) = \frac{\pi}{4\sqrt{2I_{\omega}(kr)}} \left[ H_{\omega}^{(2)}(z_{e}(r)) \exp \left( i \frac{3\pi}{4} \right) \right] 0.5 \left[ \int_{z_{e}(r)}^{z_{e}(0)} du u H_{\omega}^{(1)}(u) \exp \left( i \frac{3\pi}{4} \right) R(u) \right] - 0.5 \left[ \int_{z_{e}(0)}^{z_{e}(r)} du u H_{\omega}^{(1)}(u) \exp \left( i \frac{3\pi}{4} \right) R(u) \right] - \left[ \int_{0}^{z_{e}(r)} du u H_{\omega}^{(1)}(u) \exp \left( i \frac{3\pi}{4} \right) R(u) \right] + H_{\omega}^{(2)}(z_{e}(0)) \exp \left( i \frac{3\pi}{4} \right) \frac{\delta}{r} \left[ \int_{z_{e}(0)}^{z_{e}(r)} du u H_{\omega}^{(1)}(u) \exp \left( i \frac{3\pi}{4} \right) R(u) \right] \tag{5}
\]
\[ V_+^r (r) = \frac{\pi}{4 \sqrt{2}} L_n (kr) \left| H_0^0 \right| \left( z^2 \exp \left( \frac{3z}{4} \right) \right)^{1/2} 0.5(1 + i) \int_0^\infty \left( u \exp \left( \frac{3z}{4} \right) \right) R^+(u) - 0.5(1 - i) \int_0^\infty \left( u \exp \left( \frac{3z}{4} \right) \right) R^-(u) - \right. \\
- \left. \int_0^\infty \left( u \exp \left( \frac{3z}{4} \right) \right) R^+(u) + H_0^0 \left( z^2 \exp \left( \frac{3z}{4} \right) \right) \int_0^\infty \left( u \exp \left( \frac{3z}{4} \right) \right) R^-(u) \right) \bigg|_{r=0}^{r=r_{\text{res}}} \right) \]
A very wide interaction region width $\Delta r$ is observed. In Ref. [4] the theoretical estimate $\Delta r \sim 4$ mm was declared. In the figures the vertical dashed line shows the resonant radius position.

### 3.2 TEXTOR-DED

Here the calculations for the TEXTOR-DED tokamak are presented ($R = 1.75$ m, $a = 0.47$ m, $r_{res} = 43$ cm, $m=12$, $n=4$, $B_{0b} = 2.25$ T, $n_{pl} = 10^{19}$ m$^{-3}$).

### CONCLUSIONS

It is shown that for the high frequency ($\gtrsim 10$ kHz) the radial component of the perturbation field $B_r$ is amplified inward of plasma from the interaction zone. This theoretical result confirms the CSTN-IV tokamak measurements.

For a lower frequency ($\lesssim 1$ kHz) $B_r$ is only attenuated in the plasma between the resonant zone and antenna.

Note, that for TEXTOR-DED the poloidal magnetic field component of the vacuum perturbation is practically...
completely compensated by the plasma perturbation response at \( r = r_{ce} \).

The width of the resonant zone \( \Delta r \) for TEXTOR-DED is of the order of 0.5 cm (or larger). It is much larger than the ion gyroradius. For the CSTN-IV experiment the width of the interaction region is very wide.

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REFERENCES