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Development of a Fast Switcher/Combiner diplexer for High Power ECRH Applications

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Introduction

The demand for EC power is growing in order to heat and control plasmas of new machines, most notably ITER. An increased flexibility in the combination and control of beam routing will be essential in many applications. For this purpose a number of high-power diplexing-combining devices are now under study.

These devices are able to combine power from different sources into one single output channel or to switch the power between different output channels just changing the source frequency by a few tens of MHz with variations of the power supply voltage. These properties could be very useful for example in view of a more efficient Electron Cyclotron (EC) Heating, Current Drive (CD) and Neoclassical Tearing Mode (NTM) control.

Up to now, diplexers are based on quasi-optical interferometer/cavity [1] or on oversized square corrugated waveguides (SCW): there is a large number of configurations [2] that can be used in both cases and only a small fraction has been taken into account for in-depth analysis. The extension of a preliminary study to a larger set of configurations could be very fruitful in the near future, in order to assess their relative advantages and disadvantage as, for example, efficiency, compactness, mechanical integration in the launching system, as well as costs, thus providing a wider range of choices.

Our work deals with a version based on SCW of suitable length acting as a 3dB coupler (Talbot effect). Using three SCWs placed side by side and coupled with mirrors, it is possible to create nested resonant loops and, depending on the frequency of the input signal, the output power can be directed in one of the two side waveguides. Low power test were performed on this configuration [3], assessing the alignment requirements. A proposal for the installation of this type of diplexer on the Frascati Tokamak Upgrade (FTU) Electron Cyclotron Resonance Heating (ECRH) system, composed of four gyrotrons fed by two independent power supplies, is under study in order to perform high power tests. Also a quasi-optical configuration has been recently taken into account in order to check if this configuration could be more appropriate for the FTU ECRH system.

Square corrugated Waveguides Diplexer-Combiners

A suitable length ($L/2=2a^2/\lambda$) of SCW with section a acts as a 3dB coupler. It is then possible to use a mirror (M1) to send one half of the power into the second SCW. The same situation is repeated on the other side (M3) and, placing a third SCW with two other mirrors (M2, M4), two nested resonating loops are created.

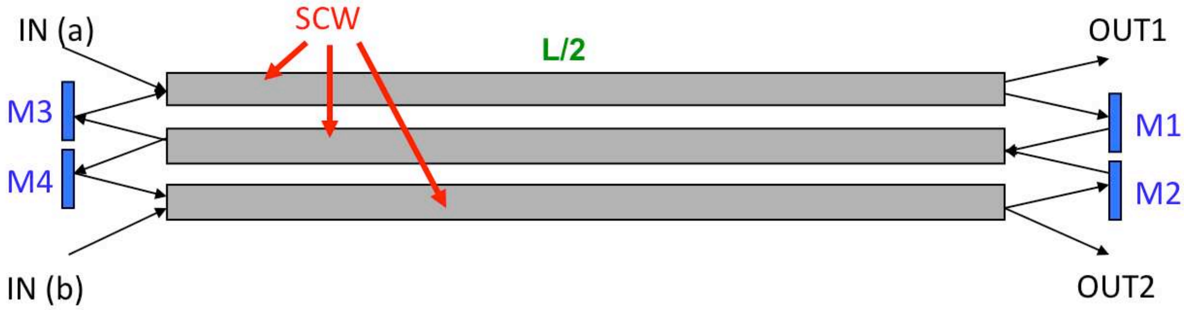

Figure 1: schematic view of the SCW diplexer-combiner

The system described gives the possibility to combine the signal coming from two different sources (IN a/b in Fig.1) into one single output (either OUT 1/2) or to switch between the two by varying the frequency of the power entering the waveguide.

Low Power Test

A SCW diplexer-combiner was assembled in the microwave laboratory of the Stuttgart University: the launcher (composed of a conical horn and a lens in the latest version) was carefully aligned in order to enter the first waveguide with an angle of 8 degrees and a beam waist of 18 mm. The system was then tested in a low power configuration in order to check that it was working properly.

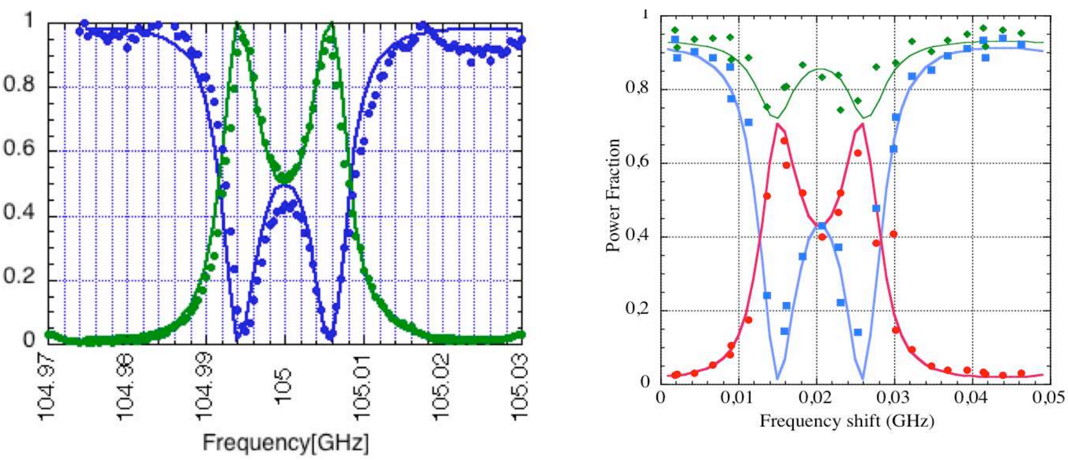

Figure 2: Power distribution in OUT 1 (blue) and OUT 2 (green/red) when power was launched in channel 1: test performed with the VNA (left) and with a quasi-optical bolometer (right).

Single point measurements, performed with Vector Network Analyzer, confirm the good behaviour of the resonant system as function of frequency even if integrated power measurements performed with a quasi-optical bolometer still evidence significant losses and incomplete channel separation that are possibly due to mode conversion at the waveguide apertures and the low tolerance to misalignment (offset and tilt).

Proposal for FTU High Power Test

A proposal for installing the diplexer-combiner on FTU is in preparation; the ECRH system of FTU consists of four 140 Ghz GYCOM gyrotrons feeding 4 different lines. Two high-voltage power supplies feed two gyrotrons each. The frequency vs beam voltage curves of the four gyrotrons permits a controlled change in the input frequency with the required precision.

The principal goals of the diplexer-combiner will be high frequency switch injection for NTM control, fast control of power between launchers and steady combination of beams in single line. Once again, when dealing with this kind of device, the possibilities are multiple: for example a switch can be set up with one or even two gyrotrons. In the first case, the gyrotron must be tuned near its optimum performance, varying the voltage provided by the power supply in order to change the frequency entering the first waveguide. When using two gyrotrons instead, it can be done in independent combination, i.e. they are fed by different power supplies and it is necessary to change them simultaneously to double the power switched between the outputs. Given the periodicity of the diplexer-combiner response, it will be possible to select different frequencies for the two gyrotrons, and this will allow selecting optimal working points for both of them. In all these cases, the frequency change must be synchronous with magnetic island rotation. In case of beam combination with a single power supply, one of the gyrotrons will be mantained at a frequency far from its resonance and the other one will be tuned to send all the power in the resonant output.

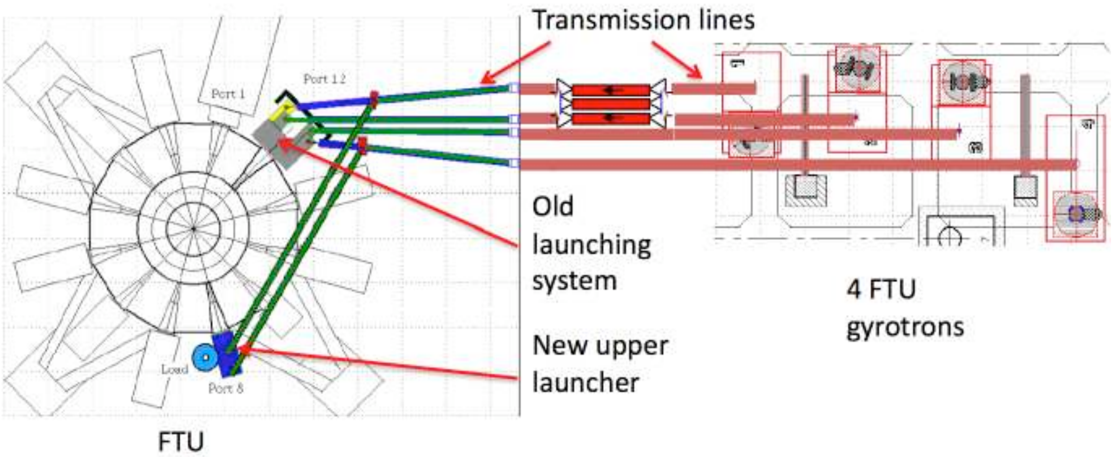

Figure 3: Overview of the old/new launching system of FTU.

If tests are positive, the application of such a device on the FTU transmission line could have multiple benefits in view of the foreseen installation of a new upper launcher [4]; a diplexer combiner would be a very flexible instrument to exploit the full potential of the integrated launching system.

A further possibility will be the injection of the full power in the new upper launcher, but this will require the insertion of two combiners in parallel.

Conclusion

Different versions of Diplexer-Combiner are under study: these components, whose potential still need to be fully exploited, represent a promising and extremely flexible instruments for increasing the plasma heating and stabilization efficiencies.

A version based on SCW have been realized and tested in a low power configuration. Further work is needed to obtain a more precise characterization of the system’s losses.

Also a quasi-optical version is under study: it has been recently integrated in the IFP microwave laboratory and low power test will be performed to check this completely different geometry.

Since a proposal for testing the device in high power configuration using the ECRH system of FTU is under consideration, after the low power tests of this quasi-optical version, the one that offers better performances and integration capabilities in the FTU launching system will be selected.

References

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