Analysis of injection locked magnetron with various reflections: correction of the injection ratio in the Adler's Equation

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The source of injection signals cannot be distinguished by magnetron. The reflected injection signal is different from the external injection signal, which is similar to the self-injection signal in the self-injection locking system. Because of imperfect impedance matching, the reflected signals of magnetron's output enters the magnetron again. Thus, the injection locking system can be regarded as including external injection and self-injection. The output power of magnetron is much greater than that of external injection signal, even a small reflection coefficient may make the reflected signal larger. Adler wrote his equation for small injection signals, In the case of reflected signal ,the injection ratio of the Adler's Equation should be reconsidered.

Assuming that the impedance at the output of magnetron is adjustable, injection lock bandwidth should be analyzed theoretically based on the effect of impedance changing. Fig.1 is schematic diagram of the magnetron injection locked system with an impedance regulation device. A three stubs tuner is used as an impedance regulator connected to the output port of magnetron. Between the three-port circulator. The S-parameter matrix of the microwave device is used to analyze this cascaded microwave network.

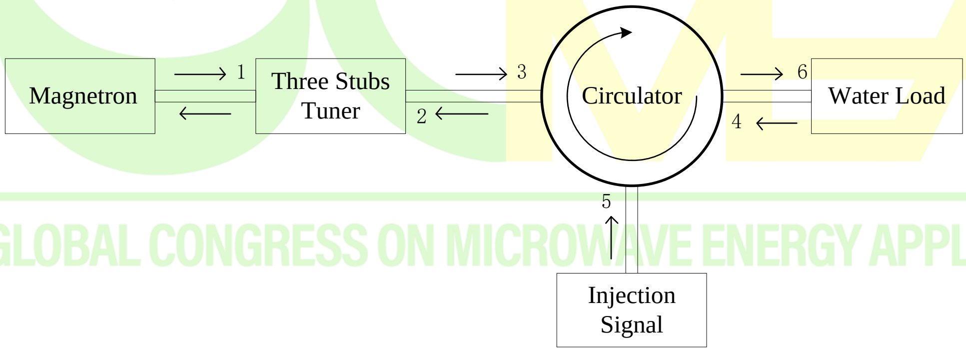

Fig.1 The injection locked magnetron impedance adjustment system.

Assuming that **a, b** is the incident voltage wave and the reflected voltage wave of each port, respectively. According to the system block diagram, the injection signal actually injected into the magnetron $\mathbf{b_1}$ should be as following,

$$\mathbf{b}_1 = \left(\frac{-S_{12}^{A}\left(S_L S_{11}^{B} S_{22}^{B} - S_L S_{12}^{B} S_{21}^{B} - S_{11}^{B}\right) S_{21}^{A}}{\Delta} + S_{11}^{A} \right) \mathbf{a}_1 + \left(\frac{-S_{12}^{A}\left(S_L S_{22}^{B} - 1\right) S_{13}^{B} + S_{12}^{A} S_{12}^{B} S_L S_{23}^{B}}{\Delta} \right) \mathbf{a}_5$$

here $\Delta = S_L S_{22}^{A} S_{11}^{B} S_{22}^{B} - S_L S_{22}^{A} S_{12}^{B} S_{21}^{B} - S_L S_{22}^{B} - S_{22}^{A} S_{11}^{B} + 1$.

For the magnetron, it is not possible to distinguish the source of the injected signal. The Reflected injection signal is distinguished from external injection signals, similarly to the self-injecting signals in self-injection locking systems. The original external injection signal enters through the three stubs tuner into the magnetron, and the reflected signal also enters the magnetron. The injection locking system at this point can be seen as encompassing both external injection and self-injection. In the case of a small injection ratio, because the magnetron output power is much greater than the power of the external injected signal, even a small reflection coefficient may make the reflected signal larger.

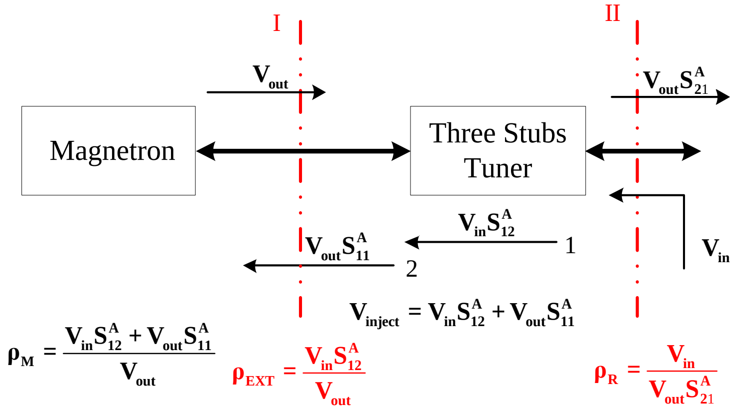

Fig. 2 Schematic diagram of the actual injection signal of magnetron

In the case of impedance matching, according to the derivation process of Adler et al., the injection-locked magnetron system does not has impedance adjustment device[4, 9], the injection ratio expression is defined as $\rho = V_{in} / V_{out}$. When the impedance adjustment is added, as shown in Fig.2, assumed that the reference plane I is the output end of the magnetron. and the reference plane II is between the adjuster and the circulator. Considering the impedance adjustment, the injected signal and the magnetron output signal is different on the reference planes I and II, so the equivalent injection ratio and locking bandwidth analysis are performed at the different reference planes.

For the magnetron, on the reference plane I, the "modified injection ratio" ρ_M is obtained based on the signal actually injected into the magnetron according to the formula

$$\rho_M = \frac{|V_{in}||S^A_{12}|e^{-j\theta}e^{j\omega_{in}t} + |V_{out}||S^A_{11}|e^{j0}e^{j\omega_{out}t}}{|V_{out}|e^{j\omega_{out}t}}$$

Conclusion

The injection-locked magnetron system, with the influence of the reflected signal in the actual system is analyzed by the microwave network analysis method. According to the Alder equation, optimal phase difference will be existed between the external injection and the self-injection signal. The injection locking system can be regarded as including external injection and self-injection. In the case of reflected signal, the correction of the injection ratio is derived based on Adler's Equation. It can be predicted that by designing the relationship between the reflected signal and the injected signal, a weak external injection signal can be used to obtain a better injection locking bandwidth.