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Frequency locking in spatially extended systems: from bifurcations to resonance

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An oscillator subjected to external periodic forcing may exhibit entrained, quasi-periodic or chaotic dynamical motions. Entrainment or frequency locking phenomena can be observed in many systems, either by local coupled oscillators or by externally applied periodic forcing, examples include nonlinear optics, chemical reactions or biological rhythms. A system is frequency locked when its oscillation frequency is adjusted to an irreducible fraction of the forcing frequency. Although the frequency locking phenomena have been extensively studied for single oscillator type systems, the fundamental description of resonance phenomena for spatially extended systems is missing. Our research is concerned with frequency locking phenomena in spatially extended media and addresses the effects of pattern formation on resonance behavior. The study has been motivated by recent experiments on temporally driven Belousov-Zhabotinsky reaction-diffusion systems focusing on standing-wave patterns. We study pattern formation mechanisms and parameters ranges where resonant and non-resonant standing-wave patterns are developed. The analysis is based on the complex forced Ginzburg-Landau equation which describes universal dynamical behavior of periodically driven oscillatory media. Among our results we show that in extended systems spatial structures and instabilities may reduce or extend the boundaries of frequency locking so that the resonance ranges for a single oscillator do not always coincide with resonance ranges in extended systems. At the end, we confront our findings with experimental observations and extend the concept of frequency locking to spatially extended systems.