Stability Analysis Methods for Microwave Power Amplifiers: A Modern Perspective

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ABSTRACT

There is a long established history of feedback theory and stability analysis methods for audio, RF, and microwave circuits, emanating from the first vacuum tube amplifiers and the realization by Nyquist[1], Barkhausen[2], and numerous others that an amplifier could oscillate when exposed to feedback. Many stability analysis techniques have been proposed through the years, based on loop gain methods[3][4], two-port networks[5], network determinant/NDF[6][7], stability index, circulators, unilateral loop gain[8][9], nodal transfer functions[10][11], and in-situ CAD probes[12]. Kurokawa, the father of modern oscillator theory, derived the conditions for startup and steady state oscillations[13], by analysing the impedance loading of a negative resistance. Some of these historical methods are rigorously defined and global in scope such as Ohtomo's method[9] and NDF[7], and the rest are local in scope and limited in their deep ability to detect potential instabilities in amplifying circuits. In their totality, these methods appear to be highly fragmented and range from being uselessly simplistic for expert designers, to prohibitively complicated for junior designers. Yet, despite the appearance of fragmentation, there is an underlying framework for all these methods. They can all be derived or generated from nodal transfer functions. This work walks through a brief history of stability methods for amplifying circuits, and discusses how the concept of nodal transfer functions can be completely generalized and used as a mathematical framework for constructing these historical stability analysis methods. A demonstration of this capability is found with the WSProbe in Keysight's PathWave Advanced Design System[14]. The WSProbe is used to identify a subset of circuit nodes from which generalized transfer function matrices are derived. From the availability of these transfer function matrices, not only can advanced stability analysis be demonstrated, but many other in-situ and powerful design techniques be unleashed with minimal effort and easy access for designers at all levels of expertise.

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