NONLINEARITIES IN MICROWAVE DEVICES AND SYSTEMS

Summary

With microwave devices and systems utilized ever closer to their limits, linear measurement techniques are no longer sufficient to describe their performance. Consequently, a number of techniques have evolved to characterize nonlinear behavior. This panel has been organized as a forum to discuss the merits of various methods and to attempt a translation of the resulting inter- and cross-modulation parameters into customer requirements.

After an introductory presentation of how the CATV industry is treating this problem, panel members will discuss four of the more commonly used techniques. The selected topics are ordered by the number of tones used to probe the nonlinearities: Single-tone testing for gain compression and AM-PM conversion coefficient; two-tone testing of the second- and third-order nonlinearities to find the intercept point; three-tone testing to find the third order intermodulation coefficient; noise loading to find the noise power ratio. Relationships between these coefficients for pure third-order systems will be shown. Other techniques will, hopefully, be considered in the ensuing discussions.

The Relationship Between Non-Linearity Measurements and Performance in CATV Systems

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The signals carried by a CATV system generally consist of a great many (20 or more) amplitude-modulated picture carriers, each accompanied by its frequency-modulated sound carrier. In a large system, these signals pass through as many as 50 amplifiers in tandem. To avoid appreciable degradation of the received picture, distortion products must be kept 50 to 60 dB below the picture signal for the entire system, which implies distortion levels 90 to 100 dB down in the individual amplifiers.

In attempting to relate amplifier measurements to system performance, it has been customary to assume that the amplifier distortion can be characterized by assuming a Taylor series transfer characteristic:

$$e_{out} = a_1 e_{in} + a_2 e_{in}^2 + a_3 e_{in}^3 + \ldots\ldots$$

where a_1, a_2, etc. are constants, and the use of the first three terms is taken to be sufficient. If this were true, CATV amplifiers could be characterized by relatively simple measurements involving, at the most, three signal sources.

In actual practice, it is found that to obtain a mathematical model which provides a reasonable approximation to the performance of these amplifiers requires a series in which the coefficients are functions of frequency, and the use of terms of higher order than the third. As a result, distortion testing which relates reliably to real-life performance requires approximately as many signal sources as there are picture carriers in the operating system.

TWO-TONE NONLINEARITY TESTING - THE INTERCEPT POINT P_i

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When a nonlinearity is modeled as memoryless with a three-term power series, a convenient way of expressing the characteristics is by the use of intercept points. An intercept point is the output power level at which the fundamental tone and the distortion tone have equal amplitudes. For many practical system problems, specification of an intercept point permits very quick calculation of distortion tone levels; in particular, given two equal amplitude fundamental tones at similar frequencies, the adjacent third order distortion product is down from a fundamental by twice the number of decibels that the fundamental is down from the third order intercept point. Even more simply, the second order distortion is down from a fundamental by an amount equal to the number of decibels that the fundamental is down from the appropriate intercept point.

In addition to being easy to use, the intercept point is also easy to measure indirectly. Direct measurement is usually out of the question, because the three-term model is inadequate at power levels near that of the intercept point. However, measurement of distortion product due to fundamental tones about twenty to thirty decibels below the intercept point provides data for immediate calculation of the intercept point in most cases. The exceptions occur when special techniques are used to enhance linearity without correspondingly increasing the power output capability of the circuit; measurements then have to be made at such low distortion levels that precautions against distortion within the test equipment become important.

The inadequacies of the intercept point characterization are primarily due to the assumption in modeling that the circuit has no memory. In actual circuits, the measurements of distortion products do depend upon the frequencies used for the measurement. However, in narrow band systems where third-order intermodulation products are the primary concern, the intercept point concept has been quite convenient.