

Progress in Passive Intermodulation Characterisation of Printed Circuits

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Since the early 1960-s passive intermodulation (PIM) generation has presented a ubiquitous threat to the performance of the communications equipment, severely affecting the signal integrity in the mobile base stations, navigation radars and in the space-born communication and earth-observation payloads. The advent of the printed circuit components into the arena of multicarrier high-power transmission and sensitive multi-channel receive has posed a new challenge to the high-performance RF design.

The typical example of detrimental impact of PIM is the base station printed antennas used in duplex mode. The PIM distortion generated as a result of nonlinear mixing of the high power uplink carriers in printed circuits can cause dangerous interference with the weak downlink signal. There is also a more general interest to the non-linear performance of laminate materials intended for the future high-speed wide-band communications, for instance, inside the space vehicles or in sensitive instrumentation, such as nuclear magnetic resonance cameras, where large signal transmission is found side by side with sensitive noise-free detection. Since a large part of modern RF design utilizes microstrip transmission lines fabricated on various laminated substrates, their characterisation with respect to their nonlinear properties is of utmost importance.

The third-order PIM response at frequency $f=2f_1-f_2$ and 2×43 dBm excitation carriers of frequencies f_1 and f_2 measured in 1 m long microstrip lines fabricated on different commercial laminates varies between the noise limit of the test setup, typically below -120 dBm, in high-performance laminates and -70 dBm upper limit of the standard PIM analysers in low-performance laminates, depending on the laminate composition and even more on board processing. There are a number of factors contributing to PIM production and thus determining such a strong dissimilarity of the laminates, e.g., substrate content, conductor-to-substrate adhesion, quality of the etched tracks, de-lamination and contamination of the conductor track underside, material and quality of the finish coating, etc. Despite extensive research conducting both by industry and academia in order to reduce the PIM generation in printed circuits, there is still a fundamental gap to fill in order to link the microscopic mechanisms of PIM generation and their characterisation with the network electrical measurements.

This paper reports on the progress to date in the macroscopic phenomenology of PIM generation in printed circuits and experimental techniques of their characterisation. The concept of distributed PIM generation in printed lines is presented, as also an appropriate phenomenology of distributed PIM generation based on the nonlinear transmission line modelling. The experimental techniques of two-port PIM measurements and near-field probing of PIM product distributions are reviewed and their application to the characterisation of distributed and lumped PIM sources is discussed. Essential points of the low-PIM microstrip launchers and probe designs are presented. Key experiments on the geometrical dependence of PIM products in microstrip lines, cumulative effect, isotropic PIM generation by the point sources and the effects of microstrip and connector discontinuities are revisited. An approach to establishing a correlation between the microscopic mechanisms and network PIM measurements combined with the structural analysis of the samples is discussed. Comparative experiments using catalogued emulated PIM sources of known nature are proposed for identification of the primary contribution to the gross PIM response of printed lines.

This study provides the vital insight into the conceptual grounds, modelling approach and experimental techniques necessary for the accurate PIM characterisation of low-PIM commercial laminates. It revises the aims, methodology and problems of the current approaches and lays a strong foundation for the standardisation of PIM characterisation of printed circuits and electromagnetic material, in particular microwave laminates.