MULTIVARIATE TECHNIQUES IN ELECTROMAGNETIC TESTING OF COMPLEX SYSTEMS

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ABSTRACT

In this paper, we describe some techniques to improve the efficiency of taking and interpreting electromagnetic susceptibility data. Such data consists of a number of parameters such as failure condition, peak field amplitude, frequency, repetition rate and many others. Empirical techniques can require many experiments to cover such a multi-dimensional space. The techniques presented here will suggest efficient experiment designs at the expense of treating the interaction between parameters.

INTRODUCTION

Electronic equipment can be upset or damaged by electromagnetic fields. In most situations of electromagnetic compatibility testing or for problems due to intentional electromagnetic interference a test designer must look for a weak point or particular vulnerability. Just such vulnerability can occur with the proper juxtaposition of a number of variables like frequency, polarization, modulation, direction, etc. Because of the many parameter values required to describe a particular situation, it is often difficult to locate possible weak points in a complex system. To efficiently find particular vulnerabilities, one must carefully combine analytical and empirical results and effectively design tests to minimize the number of tests and therefore the overall cost.

SUSCEPTIBILITY EXPERIMENT DESIGN

We begin the overall test design by considering the conditions of the test as a linear vector space whose coordinates are functions of the parameters describing the test conditions. Using that model the possible weak points would appear as regions, or hyper volumes in that vector space that we must search for. Visualization of this region and the test matrix is difficult because of the large number of dimensions in the problem but the mathematics is perfectly general for any number of dimensions. As a practical matter, we are limited to about 20 dimensions, before we encounter numerical difficulties. We now efficiently search the test space for weak points and therefore must design an efficient search algorithm for the vector space.

Suppose we are trying to find the maximum of the contour plot in Fig. 1 where the contours represent the unknown behavior of the electronic system. We start the search with a survey of the parameter space at a likely location as indicated by the cross in the lower left hand corner of Fig. 1. Data in that chosen location should give us the failure probability at that location and the direction (in the multidimensional vector space) of a local maximum as indicated by the arrow. Calculation of that generalized gradient requires at least a high and low value for each variable. For, say, five dimensions, that is a minimum of 32 tests. Efficient ways of constructing the test matrix for larger numbers of parameters that allow elimination of some of the interaction (cross) terms will also be presented. The example in Fig. 1 is only for two dimensions but shows the search strategy.

Use of a two-level test design implies that the probability of failure (upset or burnout) varies smoothly with the parameter of interest. This is true for some cases (range, for example) and not true for others (frequency). In any case, the test design must resolve large variations in the dependent variable (statement of failure). Usually, the dependent variable is not a continuous variable in these problems. We might use a 0 or 1 to describe, "not upset" or upset, respectively. We might use a number of categories for the level of failure like "normal", "interference", "upset", or "burnout" for the whole complex system or for subsystems that make up the whole system. Multivariate logistic regression is the method of choice for finding the probability of failure in such cases and the application of this technique to susceptibility testing will be presented.

In the end, we will have an empirical description of the conditions for failure of the victim system and the sensitivity of the system to variations in various parameters. We will accomplish this by efficient test design and execution techniques. The results are applicable to very complex systems since the methods relate the end state of the test to the independent variables of the test and do not require the detailed information that is required for a brute force coupling calculation. That process is the allocation of the variance of the test results to the various parameters in the test.

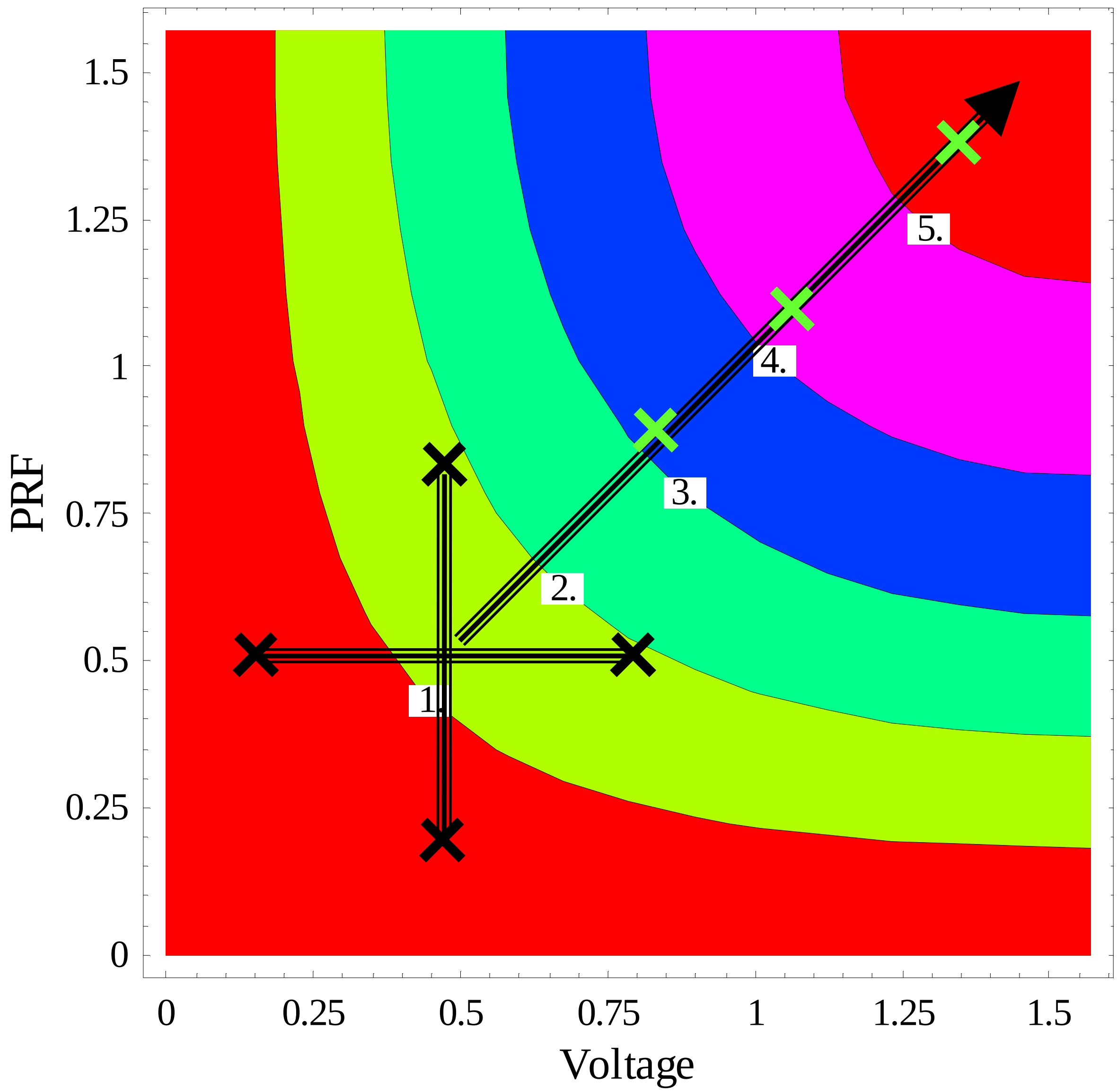

Figure 1: Example Search Strategy