A comparison of fitting methods for modeling the front door coupling of two nearby parabolic antennas

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***Abstract*— In this article, we present the modeling of the front door coupling of two nearby antennas through different fitting methods. The antennas were considered as a two port network and its coupling was represented by the S21 parameter, which was obtained for diverse configurations by simulation means. The results of different fitting methods were analyzed and compared for different antennas configurations in order to determine the best fitting algorithm.**

***Keywords*— coupling, fitting methods, modeling.**

I. Introduction

The increment of electromagnetic interference due to installing a new point to point microwave link in a communication tower is one of the most common problems that regulatory bodies must face. The problem stems from the large amount of requests made by providers of telecommunication services to the regulatory body, where the regulatory body must guarantee that a new microwave link does not impact negatively the other links previously installed. For example, the national agency of the spectrum (ANE in Spanish) of Colombia receives 3000 requests every four months.

The negative impact of a new microwave link on an already established link can be quantified by using the received power due to the new link operation and the front door coupling between the parabolic antennas of the links. With the previous frame, we present the results of different rational fitting methods for modelling the front door coupling between nearby parabolic antennas. This is a step towards obtaining a parametric model that allows to compute the coupling between antennas without performing a full wave simulation.

Common approaches for estimating the front door coupling are: I) Integral form of the coupling equation, estimates the mutual coupling between two antennas by employing the integral of the scalar product between two antenna far-field patterns [1]. The mutual coupling is obtained through the transmission integral, involving simple far-field patterns of two antennas and a separation distance between them. II) The Friis power transmission formula [2]. Nonetheless, there are limitations on estimating power transmission in near-field region with respect to applicability and simplicity of the formula. The simple far-field Friis formula has often been used in the near-field region, which results in a remarkable deviation. III) Numerical evaluation using a full-wave simulation in Time domain and Frequency domain. It is important to notice that these methods are not suitable to be applied by a regulatory body due to their long execution time.

We propose to consider the antennas as a two port system where the front door coupling is given by |s21|^2, which can be modelled as a rational transfer function.

The paper is organized as follows: section II describes the considered antenna configurations; section III describes the fitting methods considered in this work; the results of the comparison between simulations and models are presented and discussed in section IV, whereas the conclusions of the work are highlighted in section V.

II. Antenna configurations

We considered the antenna configuration shown in figure 1 as a good representation of the situation found in communication towers. Different scenarios were considered by varying the parameters shown in figure 1, such as distance, reflectors diameter, rotation angles, relative height and polarization.

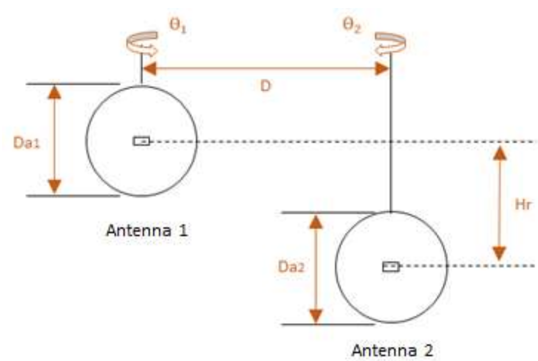

Fig. 1. Canonical antenna configuration

We chose the Integral Equation Solver since it is the most suitable method to simulate large structures in terms of wavelength because it discretizes the surfaces by the method of moments (MoM) generating fewer mesh cells than volume methods such as Time Domain Solver [3].

III. Fitting methods

We considered methods that were able to provide rational fittings with a short amount of samples since frequency domain simulations of these problem are highly time consuming, especially for large antennas. For example, a simulation of antennas whose diameter is 2.4 meters took 18 hours in a server with 12 vCPUs, 45 GB of memory RAM, 2 x NVIDIA Tesla K80.

Another requirements for the methods was the possibility of using non-uniform samples for obtaining the fitting. In the following subsections, we explain briefly the methods that fulfilled the previous conditions.

A. *Cauchy Method:* It is a technique for interpolation of data using a ratio of two polynomials. It is based on singular value decomposition and it gives an estimate for the required order of the numerator polynomial and the order of the denominator polynomial. [4]

B. *MBPE, Model-Based Parameter Estimation:* MBPE makes use of low-order analytical formulas as fitting models, while the unknown coefficients for the fitting model are obtained by matching it to multi-point sampled values or fitting it to frequency derivatives of the function at one or two frequency points. The strong point of this method is its simplicity, however it is calculation usually requires a matrix inversión that tends to be ill conditioned, specially in high frequencies. [5]

C. *Orthogonal polynomials:* It takes advantage of a special property of the frequency response function (FRF), it exhibits Hermitian symmetry about the origin of the frequency axis. So, instead of representing the FRF in terms of ordinary polynomials, it can be represented it in terms of linear combinations of orthogonal polynomials. [6]

D. *Vector fitting:* Vector Fitting is a robust numerical method for rational approximation in the frequency domain using poles and residues. The resulting approximation can be forced to have stable poles that are real or come in complex conjugate pairs. It is a pole relocation technique where the poles are improved on in an iterative manner. [7]

IV. Results and Discussion

Results of Cauchy method are not shown, because at low frequencies it overestimates the coupling up to 100 dB, it could be due to the validation of this approximation requires that the smallest singular value should be less than or equal to the number of accurate significant decimal digits of the data.

Similarly, MBPE tends to yield rational functions with polynomials whose coefficients are complex numbers. It is important to mention that real world systems have real polynomial coefficients, and hence, the basic implementation of MBPE was dismissed. We tried an optimization problem implementation with the restriction of real polynomials but the results had low accuracy. Thus, MBPE was considered not suitable for this problem.

Orthogonal Polynomials create invalid or "parasitical" poles if the samples are not soft, which implies abrupt variations in the model, and hence wrong predictions. Also, if the number of samples or the degree of the model increases, the matrix equation becomes ill-conditioned. Thus, this method is only suitable for system without many steep resonances since it only has good accuracy for low degree functions.

Thus, we applied the methods vector fitting and Orthogonal poles to the simulations obtained by varying distance between 15 m and 100 m, reflectors diameter between 0.9 m and 2.4 m, and angle between 0° and 324°. The simulations were performed for the operating frequency range of the antennas from 5.8 to 7.2 GHz.

The results showed that vector fitting yielded the best fittings in terms of agreement with the original samples. For example, the results shown in figure 2 for a configuration with the following parameters: distance 15 m, reflector's 1 diameter: 1.8 m, reflector's 2 diameter: 0.9 m, and angle 0°.

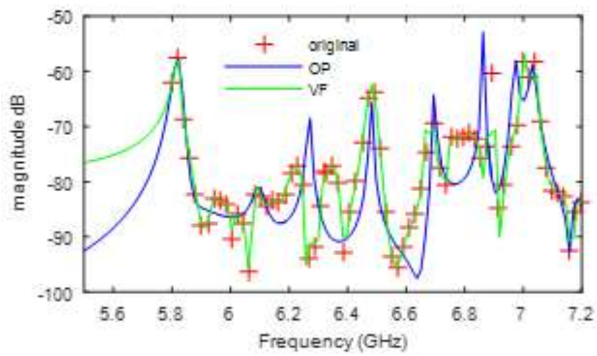

Fig. 2. Coupling between two parabolic antennas, simulated and reconstructed using Orthogonal Polynomials and Vector fitting with degree 10 and 64, respectively.

V. Conclusions

The results show that vector fitting provides the best performance in terms of accuracy when modelling the front door coupling of two nearby parabolic antennas for a diverse set of configurations.

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