# Characterization of the Channel Behavior Between Two Nearby Parabolic Antennas in the Frequency Domain

A. Rangel, A. Gallego, F. Vega, R. Campos
EMC-UN, dept. of Electrical and Electronic Engineering
Universidad Nacional de Colombia
Bogotá, Colombia
jarangelr@unal.edu.co, ajgallegog@unal.edu.co,
jfvegas@unal.edu.co, fjromanc@unal.edu.co

J. Becerra
Polytechnique Montreal
Montreal, Canadá
Juan.becerra-tobar@polymtl.ca

***Abstract*— In an effort to characterize the behavior of the channel between two nearby parabolic antennas as a function of different system parameters (distance and azimuth angle) is presented. The antennas were considered as a Linear Time Invariant (LTI) System and its coupling was represented by the transmission S-parameter, which was obtained for several scenarios by simulation mean. The Cauchy Method is applied to extract the Singularity Expansion Method (SEM) poles in frequency domain. A rational model is obtained for each parameter configuration. The resonances extracted of the S-parameter data was validated comparing the system response and its reconstruction.**

***Keywords—Cauchy Method, parabolic antenna, Linear Time Invariant (LTI) System, Singularity Expansion Method (SEM)***

## I. Introduction

Usual methods for estimating the channel behavior between two antennas are: Integral from of the coupling equation [1], the Friis power transmission formula [2] and numerical evaluation using a full-wave simulation in time domain or frequency domain. However, it is important to notice that these methods require long execution time or present limitations for the near-field region in terms of applicability and simplicity.

In the context of radar, SEM makes it possible to obtain a unique set of poles and residues for each objective. In addition, the poles contain specific objective information. Applied in the same way on antennas, SEM allows to characterize them in a unique way [3]. Therefore, we generate a set of poles and residues of the system response (transmission S-parameter) in the frequency domain through the Cauchy Method.

In this paper, we proposed a method for characterize the channel behavior between two parabolic antennas as a function of some antennas' parameters [4]. Different scenarios were considered and simulated by varying parameters such as distance and azimuth angle.

## II. LTI System and Cauchy Method

### A. Antennas as LTI System

The LTI system of the transmitting and receiving antenna can be utilized to describe the communication link between antennas as show figure 1.

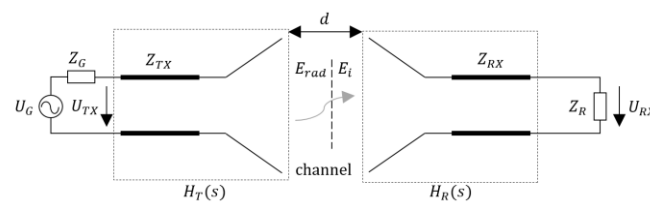


Fig. 1. Communication system of two antennas.

The general equation of the communication link is given as

$$\frac{U_{RX}(s)}{\sqrt{Z_{RX}}} = \boldsymbol{H_T}(s,\theta,\psi)\boldsymbol{H_C}(s,\theta,\psi)\boldsymbol{H_R}(s,\theta,\psi)j\omega\frac{U_{TX}(s)}{\sqrt{Z_{TX}}} \quad (1)$$

Where $\boldsymbol{H_T}$ , $\boldsymbol{H_R}$ , $\boldsymbol{H_C}$ represents the transfer function of the transmitting antenna, receiving antenna and the channel respectively.

The antenna transfer function can be extracted from the S-parameter transmission $\boldsymbol{S_{21}}$ of the two antennas. It can be derived by modeling the communication system as a two port network. Hence, the $\boldsymbol{S_{21}}$ parameter of two antennas at a distance $d$ is formulated.

$$\boldsymbol{S}_{21}(s,\theta,\psi) = \boldsymbol{H_T}(s,\theta,\psi)\frac{e^{-j2\pi fd/c}}{2\pi dc}\boldsymbol{H_R}(s,\theta,\psi)j\omega\frac{\sqrt{Z_{RX}}}{\sqrt{Z_{TX}}} \quad (2)$$

### B. Overview of the Cauchy Method

The transfer function for an LTI system, as a rational function of frequency, can be characterized by

$$H(s) = \frac{\sum_{n=0}^{P} a_n\, s^n}{\sum_{n=0}^{Q} b_n\, s^n} = \sum_{m=1}^{M}\frac{R_m}{s-s_m} \quad (3)$$

Where $a_n$ and $b_n$ are the unknown coefficients, $R_m$ is the residue and $s_m$ is the *m*th pole. We can extract the poles using the Singular Value Decomposition (SVD) and Total Least Square (TLS) method.

## III. Antenna Configurations

Different scenarios were considered by varying the parameters show in figure 2, such distance and theta angle.

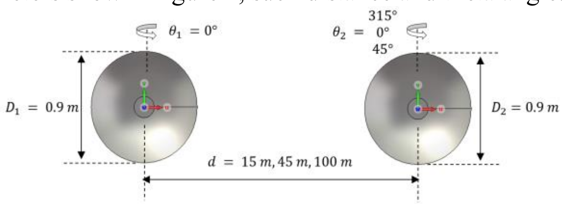


Fig. 2. Antenna Configuration

## IV. Numerical Results

Several simulations were performed, S-parameter transmission was obtained for the frequency range from 5.8 to 7.2 GHz, by varying distance between 15 m and 100 m, and azimuth angle between 315° and 45°.

Equation 4 assumes that distances and azimuth angle influence resonance frequencies.

$$\boldsymbol{S}_{21}(s) = \sum_{m=1}^{M} \frac{R_m(d, \theta_{1,2})}{s - s_m(d, \theta_{1,2})} \tag{4}$$

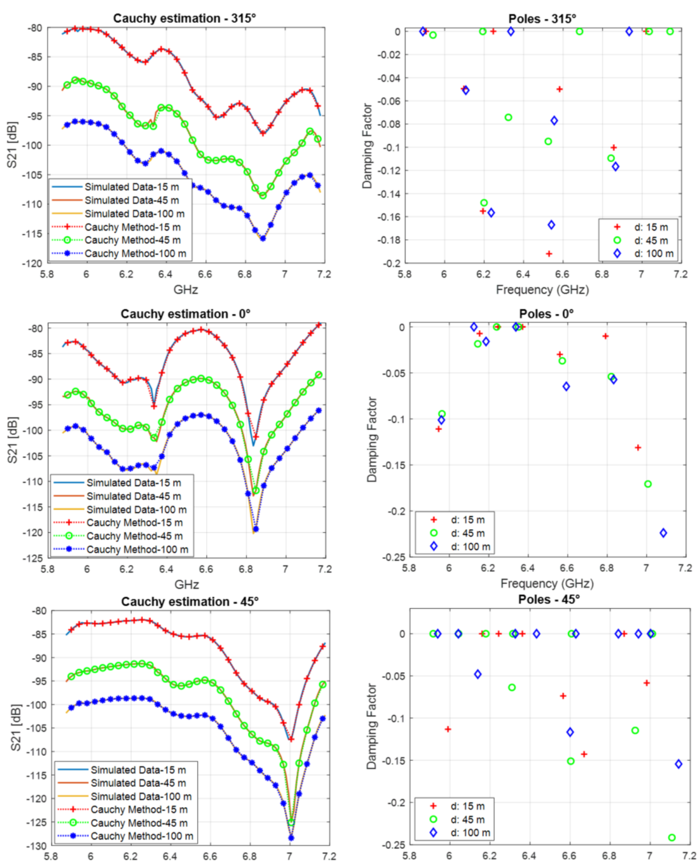


Fig. 3. Transmission S-parameter of the two parabolic antennas (*left*), Poles extracted from the transmission S-parameter (*right*).

In left side of figure 3 show the magnitude of $\boldsymbol{S}_{21}$ parameter for several configurations. While, right side show the behavior of poles extracted through the Cauchy Method from the transmission S-parameter. These resonances are used to reconstruct of the system response with a similarity of 98 % in average as show in left side.

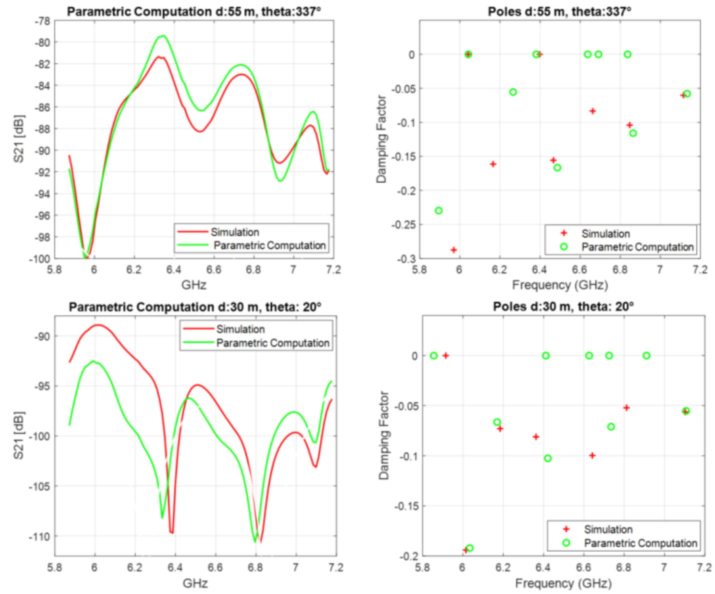


Fig. 4. Channel behavior between two parabolic antennas, simulation and parametric computation (*left*), poles extracted form the transmission S-parameter (*red: simulation*), poles used to reconstruct the signal (*green: parametric computation*) (*right*).

Figure 4 (*left*) illustrate a comparison between the simulation and parametric computation of the channel behavior between two parabolic antennas with the following parameters: antennas diameter: 0.9 m, distance: 30 m and 55 m, and theta angle: 20° and 337°. While, right side show the behavior of poles used to reconstruct of the system response (*green: parametric computation*) through equation 4 and poles extracted form $\boldsymbol{S}_{21}$ parameter (*red: simulation*).

## V. Conclusions

The results show that Cauchy method provides a great performance in terms of accuracy when modelling the channel behavior of two nearby parabolic antennas for a diverse set of configurations.

## References


[1] Yaghjian, A.D, "Efficient computation of antenna coupling and fields within the near-field region," IEEE Trans. Antennas Porpag., 1982, AP-30, pp. 113-128.

[2] Friss, G.H.T, "A note a simple transmission formula," Proc. IRE, 1946, 34, pp. 254-256.

[3] F. Tesche, "On the analysis of scattering and antenna problems using the singularity expansion technique," IEEE Transactions on Antennas and Propagation, 1973, vol. 21, no. 1, pp. 53 – 62.

[4] J. Becerra, Z. Lopez, J. A. Rangel, and F. Vega, "A comparison of fitting methods for modeling the fornt dor coupling of two nearby parabolic antennas," USNC-URSI Radio Science Meeting, 2018, pp. 27-28.