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The window increasing technique to discriminate mathematical and physical resonant poles extracted from antenna response

F. Sarrazin, P. Pouliguen, A. Sharaiha, P. Potier and J. Chauveau

This letter presents a new approach called window increasing technique (WIT) to discriminate mathematical and physical poles extracted from a noisy antenna response. The principle of the WIT is to apply a pole extraction method on several windows of the response and then to observe the stability of the extracted poles. In order to compare the WIT to the classical window moving technique (WMT), we apply these two techniques on the electric far field backscattered by a dipole antenna. We show that, in presence of noise, the WIT allows finding more physical poles with a good accuracy than the WMT.

Introduction: Since its introduction by Baum [1], the singularity expansion method (SEM) has been widely used for antenna characterisation [2-3]. This method allows modelling the late time response of an antenna with only a few sets of parameters: poles and residues. The main advantage of the SEM is that resonant poles, also called complex natural resonance (CNR), depend only on antenna characteristics and are independent of the direction of the incoming wave, the excitation waveform and its polarization [1]. Therefore, poles allow representing an antenna in a compact unique way. There are several extraction methods to obtain CNR from antenna response but the most commonly used is the matrix pencil method (MPM) [4]. In practice, the number of poles contained in a response is unknown; that is why the number of poles to be extracted is usually overestimated by the MPM. Due to this overestimation, some mathematical poles are extracted in addition to the physical ones. In order to use the CNR to characterize an antenna, one needs to discriminate the mathematical poles from the physical ones. A classical way to discriminate poles is the window moving technique (WMT). However, the WMT is limited when applied on noisy response [5]. In this letter, we suggest a new approach called the window increasing technique (WIT). In order to compare the WMT and the WIT, these two techniques are applied on the noisy electric far field backscattered by a dipole antenna.

The window moving technique: We consider a dipole antenna of length $L = 34$ mm and diameter $D = 0.05$ mm, so its ratio L/D is equal to 680. The impedance of its lumped port is a matched load of 73 Ω. This antenna, simulated using CST Microwave Studio, is excited by a plane wave in the boresight direction and the backscattered electric far field is measured using a probe at a distance of 2 meters. The late time response backscattered by the dipole antenna is shown in Fig. 1. For the noisy case, a white Gaussian noise (WGN) is added to the noiseless response to obtain a signal to noise ratio (SNR) of 10 dB.

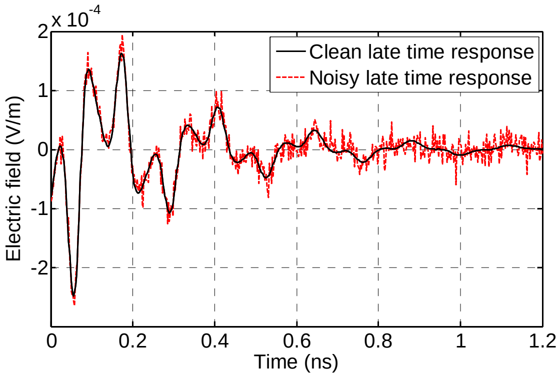


Fig. 1 *Late time electric far field backscattered by a dipole antenna.*

The MPM is applied to the noiseless response and the resonant poles are shown in the complex plane in Fig. 2 with a $|R|/|\alpha|$ weighting where α is the damping coefficient of the pole, i.e. its real part and R is its residue. It means that the more the marker is big, the more the pole's contribution is important. Resonant frequencies of poles correspond to natural frequencies of the dipole antenna at $\lambda/2$, $3\lambda/2$, $5\lambda/2$ et $7\lambda/2$ where λ is the free space wavelength.

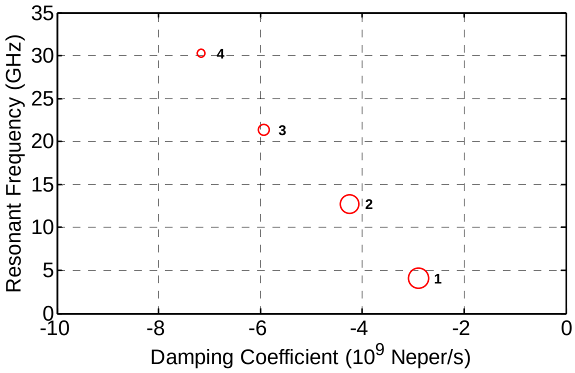


Fig. 2 *Resonant poles in the complex plane, extracted from the field backscattered by a dipole antenna with* $|R|/|\alpha|$ *weighting.*

The principle of the WMT is to apply the MPM on a windowed response. Then, the window is shifted of a small time step and the MPM is applied again. The assumption is that, depending on the window, the position of the mathematical poles will change from window to window whereas the physical poles will remain essentially unchanged. The WMT is applied on the noisy late time dipole response shown in Fig. 1. The window length is 140 samples (0.29 ns) and the window shift is 10 samples (0.019 ns). Results are presented in terms of resonant frequencies and damping coefficients in Fig. 3.

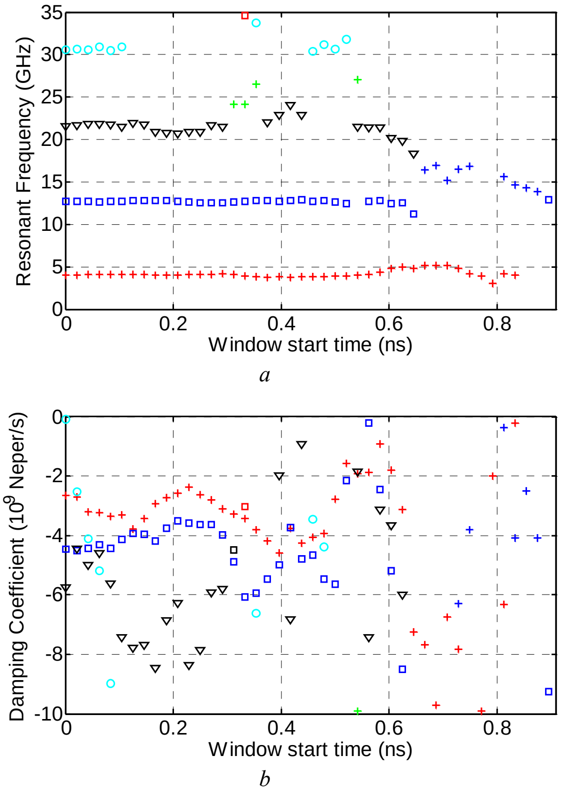


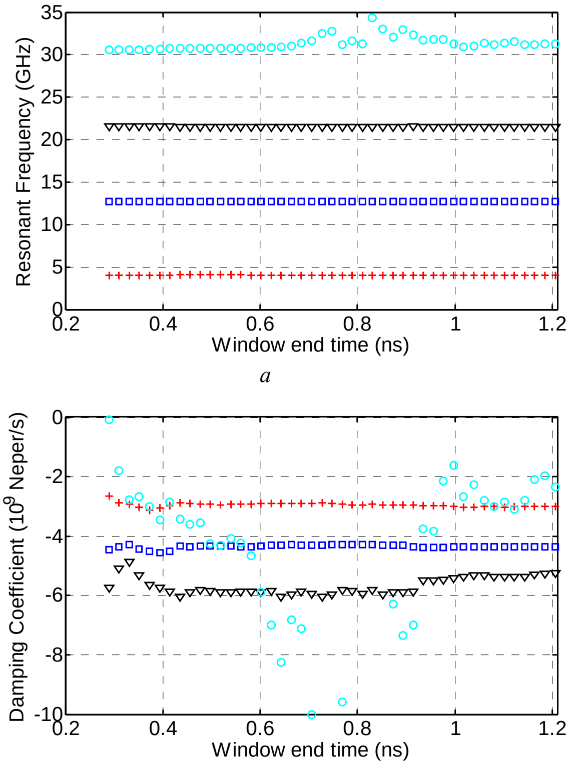
Fig. 3 *WMT applied on the electric far field backscattered by a dipole antenna*

a Resonant frequencies

b Damping coefficients

We can see that three resonant frequencies are stable around 4, 13 and 21 GHz. These frequencies are in good agreement with frequencies of the three first poles extracted from the noiseless response. Moreover, the WMT confirms the poles' weighting. Indeed, the more a pole's weight is important, the more this pole is accurately extracted late from the response. However, damping coefficients are not as stable as resonant frequencies. The two first damping coefficients can be evaluated around -3.10^9 and -4.10^9 Neper/s but the third one cannot be defined. Indeed, its variation is too important according to the window. Using this approach, only two physical poles of the dipole antenna can be determined with a good accuracy.

The window increasing technique: Since results of the WMT seem to be stable for the first windows, we suggest keeping the beginning of the antenna response in all windows considered. Indeed, these first samples contain data with the highest SNR. This novel approach, that we call the WIT, consists of applying the MPM to a windowed response beginning from its first samples, and then to increase the window's length and to apply the MPM again. It means that the beginning time of the window is unchanged whereas the end time is increased until including the final sample. Results of the WIT applied on the noisy dipole antenna response are presented in terms of resonant frequencies and damping coefficients in Fig. 4.



a

b

Fig. 4 *WIT applied on the electric far field backscattered by a dipole antenna*
a Resonant frequencies
b Damping coefficients

Three resonant frequencies around 4, 13 and 21 GHz are perfectly stable for all windows and the fourth one is stable around 31 GHz except for some windows. All these frequencies are in good agreement with ones extracted from noiseless response. Moreover, damping coefficients of the three first poles are also very stable according to the window and correspond to those extracted in the noiseless case.

Conclusion: In this letter, the novel WIT is proposed in order to discriminate the physical poles of an antenna response. This technique is compared to the classical WMT. Although the WMT could be of interest, the WIT appears to be a more powerful technique that allows extracting stable damping coefficient, especially in presence of noise.

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