Faisal Aldhubaib.Int. Journal of Engineering Research and Applications www.ijera.com
ISSN: 2248-9622, Vol. 6, Issue 5, (Part - 1) May 2016, pp.39-42

RESEARCH ARTICLE OPEN ACCESS

Stability of Target Resonance Modes: Ina Quadrature Polarization Context

Faisal Aldhubaib
Electronics Department, College of Technological Studies, Public Authority of Applied Education PAAET, Kuwait

ABSTRACT

The paper present a studyon the noise effect whenextracting the resonance residue in a quadrature polarization setup. The accuracy and stability of the mode quadrature residues is necessary to construct the polarization matrix, and subsequently, derive a robust polarization states of the receiver antenna. However, with lower signal-to-noise ratios the extraction performance will degrade; in this regards, the in-phase and quadrature components of the baseband signal demonstrated improvedextraction performancewhen used. Here, a case of two disjoint wires is used to verify this approach**.**

Keywords-*Resonance Theory, Method of Pencil, Singularity Expansion, Radar target, Polarization.*

I. INTRODUCTION

According to the model-based signature, namely Singularity Expansion Method (SEM) model, the late time of the target impulse response can be expressed as a sum of resonance modes with terms, namelyresonant frequency and residue, relating to the dimensions and composition of the target.Alongsideresonance based signatures when identifying radar targets, researchers have incorporatedpolarization descriptions, i.e. vector or matrix, to form enhanced feature set [1-4]. Particularly of interest is the characteristic polarizationstateswhich represent the power critical conditions at the antenna's terminal. Once based on the target resonance modes, the polarization set can reveal the target shape attributes like elongation, symmetry and tilt degrees [5, 6].

To fully obtain the target resonance modes (related in turn to itsindividual substructures), radar illumination usesa widebandcarrier-free (Baseband) radio wave.Then either extracted temporally,for example, by Method Pencil-of-Function (MPOF)[7]or estimated spectrally from peaks in magnitude spectrum for high-Q targets[8].The resonance modescan be incorporate in a setup of quadrature polarization channels to derivetheir respective polarizationset.However, to attain robust extraction, the quadrature polarized residue terms, i.e. residues matrix, of a mode should be stably extractable; else a residue term will be missed or misaligned in the polarization matrix and thus leading to ill estimatedpolarization set.

Therefore, proper extraction is necessary so not to omit or misalign a resonance along any polarization direction in this matrix. Unfortunately, omitting or misaligning a resonance can occur if the residue-to-noise ratio (*SNR*) is low. To overcome the low *SNR*drawback, the oscillatory behaviors of the resonance should be enhanced by extending the late time portion. Therefore, theauthor proposes to implement the extraction using real (in-phase) and imaginary (quadrature) versionsof the baseband signal. The real and imaginary parts have extended late time because of their more prominent oscillatory behavior compared to the original baseband signal.

This paper is outlined as follows: Section IIpresents a formulation to derive the polarization angles. Section III present the results which include descriptionof the simulation procedures and the extraction performance of the proposed technique. Section IVreaches conclusions and indicates directions for further work.

II. FORMULATION

In phasor form, the complex frequency spectrumF(ω) is expressed in term of the signal magnitude |A| response and phase φ response, at angular frequency ω, as follows

$$Y(\omega)= |A(\omega)| \,.\, \exp\,(\,\varphi(\omega)\,) \qquad (1)$$

Or in complex form as

$$Y(\omega)=\mathrm{Re}[F(\omega)]+j.\mathrm{Im}[F(\omega)] \qquad (2)$$

Where

$\mathrm{Re}[F(\omega)]=|A(\omega)|.\cos(\varphi(\omega))$, i.e. in-phase
$\mathrm{Im}[F(\omega)]=|A(\omega)|.\sin(\varphi(\omega))$, i.e. quadrature

If the Re[F(ω)] or Im[F(ω)] is substituted instead of the absolute magnitude |A| in (1), then the new magnitude spectrum will have the shape of |A(ω).cos(φ)| or |A(ω)sin(φ)| spectrums.

Then by applying a Fourier Transformer operator $F^{-1}(.)$ to Y(), $Y_{re}()$ and $Y_{im}()$, the temporal baseband responses$y(t)$, $y_{re}(t)$ and $y_{im}(t)$are obtained. For a quadrature polarization directionsin orthogonal linear basis, e.g. (h,v), the temporal baseband responsesin a quadrature set $\mathbf{y}(t_o)$, forms a R^{2x2} matrix, and according to SEM model will be expressed as follows

$$\mathbf{y}(t_o)=\sum_{n=1}^{M}\mathbf{C}_n.e^{-(\sigma_n+j\omega_n)t_o} \qquad (3)$$

Such that

$$\mathbf{C}_n=\begin{bmatrix} c_n^{hh} & c_n^{hv} \\ c_n^{vh} & c_n^{vv} \end{bmatrix} \qquad (4)$$

Here $t_o>T_L$, and T_L denotes the late time onset after which the incident wave has totally passed the target. The mode terms σ, *ω*and *c* denote the: damping factor, resonant frequency and complex residue. The modal order *M* gives the number of modes presumably excited. The subscripts denote the transmitter and receiver polarization directions, where *hh* and *vv* denote the co-polarized scattering directions or channels, while *vh* and *hv* denote the cross-polarized scattering channels (reciprocal for monostatic case).

III. SIMULATION& RESULTS

For this purpose, a set of two disjoint and parallel wiresis used to validate this. The longer one is 100 units of length and rotated 10° from a reference axis, whereas the shorter one is 50 units of length, separated from the longer wire by 20 units of length and rotated 40°.In general, the plane wave direction is set normal to the wires, where the simulated backscattered data were generated in frequency-domain by method of moments algorithm (MoM) using FEKO [9].

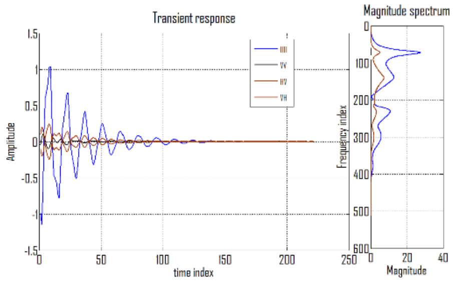
3.1 Temporal and spectral domains

Firstly, signals are corrupted by additive white gaussian noise assuming the signal power in each channel is 0dBW, i.e. this is not a case of background noise.Secondly, the signals are filtered by a Gaussian window to create the effect of a Gaussian shaped impulse,and then the frequency spectrum is transformed to the time-domain by Fourier Transform operator $F^{-1}(.)$. As depicted in Fig.1 and Fig.2for two cases of high and low *SNR*, the signals y and y_{re} withrespective Y andY_{re}as insets are shown. Comparing both signalsin time domain, it is noted that y_{re}demonstrats better oscillatory bevaviour as the late time portion extends beyond 150 units timewithlesser damping effect. While in the frequency domain, Y_{re} has more localized spectrum,i.e. high Q-peaks.

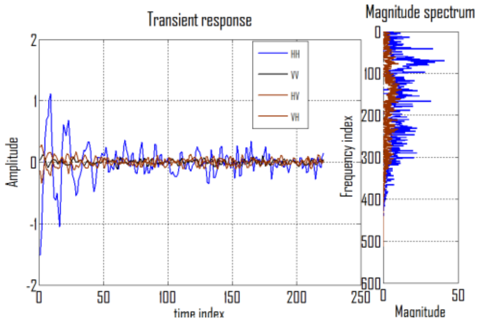
3.2 Residue extraction vs. noise: accuracy and stability

Initially, the residue terms of the resonance modes are extracted by applying the MPOF to the FFT time signal$F^{-1}(.)$ as depicted in Fig.3and Fig.4for the three set of signals. In Fig.3 with *SNR=60dB*,the residues terms of the quadrature channels are well aligned at each resonant frequency. In comparison, the y_{re} and y_{im} signals have stronger residues, i.e. more stability, as they are more extended in time, moreover, the residuesstrength and location patternsare similar for all signal as resides in the HH are the strongest while in VV are the weakest, subsequently, reflecting the polarization state of the mode. In Fig.4 with *SNR*=0dB, the residues strength pattern is less affected compared by the effect on their location pattern.

Table I, Table IIand Table IIIpresent the accuracy results of extraction for the temporal baseband responses$y(t)$, $y_{re}(t)$ and $y_{im}(t)$ with *SNR*levelfrom-5dB to 30dB. The accuracy is quantified by how much (in a percentage) the reconstructed signal (from the estimated modes) resemble the original signal. The results show that the modes terms in $y_{re}$and y_{im} signals are overall more accurate compared to the baseband signal.

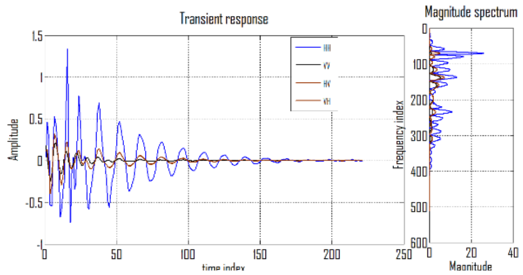


a. 30dB

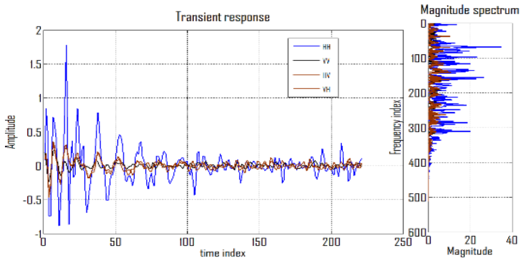


b. 0dB

Fig.1. The temporal and spectral responsesofsignal $y(t)$ vs. *SNR*level.

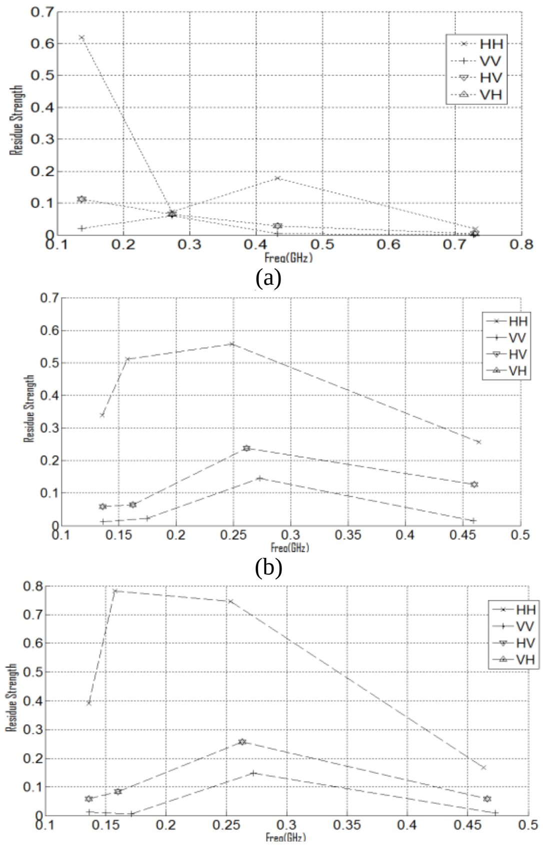


a. 30dB



b.0dB

Fig.2. The temporal and spectral responses of signal $y_{re}(t)$ vs.*SNR*level.

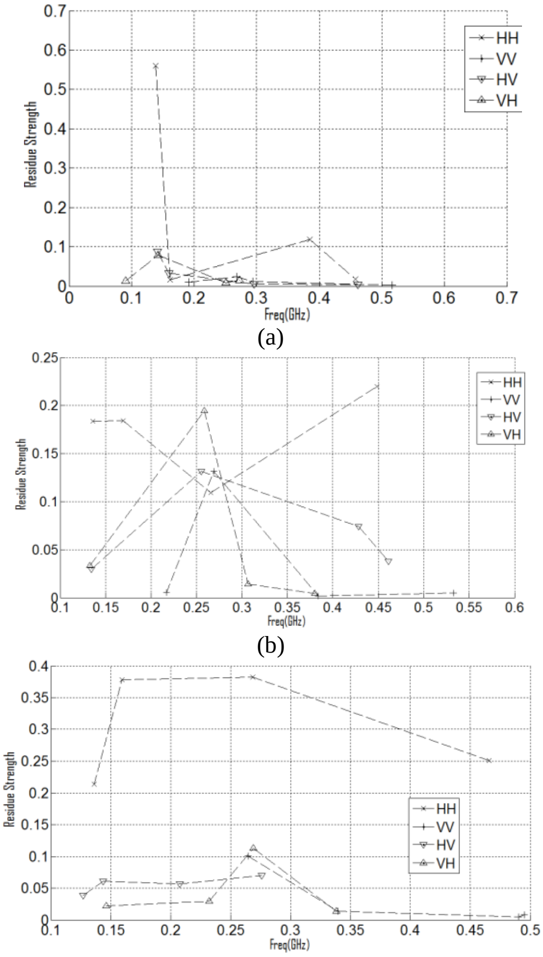


(a)

(b)

(c)

Fig.3. The residue distribution with 60dB *SNR*for (a)f^{1}(Y(f))), (b) f^{1}(Re[Y(f)]) and (c) f^{1}(Im[Y(f)]) .



(a)

(b)

(c)

Fig.4. The residue distribution with 0dB *SNR*for (a) f^{1}(Y(f))), (b) f^{1}(Re[Y(f)]) and (c) f^{1}(Im[Y(f)])

TABLE I.THE ACCURACY OF THE SEM MODEL TERMS FORCOHERENT SPECTRUM Y(F)

dB	HH	VV	HV	VH	Mean per SNR
30	99.8	97.6	99.5	99.4	99.1
25	99.4	94.2	98.1	98.3	97.5
20	97.4	82.2	94.2	94.1	92.0
15	94.2	56.5	81.5	83.1	78.8
10	87.6	26.9	53.0	60.9	57.1
5	63.7	12.8	37.0	46.5	40.0
0	49.4	15.5	10.1	27.6	25.6
-5	31.8	14.5	16.7	16.7	19.9
Mean per channel	77.9	50.0	61.3	65.8	63.8 overall accuracy

TABLE II.THE ACCURACY OF THE SEM MODEL TERMS FORRE [(Y(F)]

dB	HH	VV	HV	VH	Mean per SNR
30	80.3	99.3	93.9	94.1	91.9
25	79.9	98.4	94.0	93.8	78.2
20	79.1	97.5	92.5	92.5	76.3
15	75.7	94.4	91.1	91.2	73.5
10	74.2	80.7	79.4	77.9	64.4
5	59.1	62.9	46.2	55.9	45.8
0	38.3	40.4	42.7	20.0	28.3
-5	31.2	11.1	25.8	27.5	18.1
Mean per channel	64.7	73.1	70.7	69.1	69.4 overall accuracy

TABLE III.THE ACCURACY OF THE SEM MODEL TERMS FORIM [(Y(F)]

dB	HH	VV	HV	VH	Mean per SNR
30	82.5	99.4	94.3	94.6	92.7
25	82.0	98.8	94.3	94.4	92.4
20	81.5	97.8	92.6	93.1	91.2
15	78.6	93.7	90.2	91.0	88.4
10	74.2	89.0	80.3	76.3	79.9
5	57.8	69.6	67.1	54.7	62.3
0	47.9	36.1	31.9	43.6	39.9
-5	21.3	16.9	21.1	26.5	21.4
Mean per channel	65.7	75.2	71.5	71.8	71.0 overall accuracy

IV. CONCLUSIONS

The in-phase or quadrature filtered signal of a wideband baseband signal has better oscillatory behaviors which makes them relatively more immune to noise when extracting the resonance modes. This is an essential requirement when mode residuesare used to construct the polarization matrix, as missing or misaligninga residue in the matrix will lead to inaccurate polarization states. The residue strength pattern is less affected by noise relatively to their location pattern.Finally, investigating the performance of the characteristic polarization states based on the in-phase or quadrature components of the signal can be a subject of further studies.

ACKNOWLEDGEMENT

This work was supported and funded by The Public Authority of Education and Training, Research project No (TS-11-14).

REFERENCES

[1] D. A. Garren, A. C. Odom, M. K. Osborn, J. S. Goldstein, S. U. Pillai, and J. R. Guerci, "Full-polarization matched-illumination for target detection and identification," Aerospace and Electronic Systems, IEEE Transactions on, vol. 38, pp. 824-837, 2002.

[2] W. M. Steedly and R. L. Moses, "High resolution exponential modeling of fully polarized radar returns," Aerospace and Electronic Systems, IEEE Transactions on, vol. 27, pp. 459-469, 1991.

[3] P. B. Silverstein, O. S. Sands, and F. D. Garber, "Radar target classification and interpretation by means of structural descriptions of backscatter signals," Aerospace and Electronic Systems Magazine, IEEE, vol. 6, pp. 3-7, 1991.

[4] F. Aldhubaib, N. V. Shuley, and H. S. Lui, "Characteristic Polarization States in an Ultrawideband Context Based on the Singularity Expansion Method," IEEE Geoscience and Remote Sensing Letters, vol. 6, pp. 792-796, 2009.

[5] F. Aldhubaib, "Polarization Angles As A Radar Feature Set " International Journal of Enhanced Research in Science Technology & Engineering (IJERSTE), vol. 5, April - 2016 2016.

[6] F. Aldhubaib and N. V. Shuley, "Radar Target Recognition Based on Modified Characteristic Polarization States," IEEE Transactions on Aerospace and Electronic Systems, vol. 46, pp. 1921-1933, 2010.

[7] T. K. Sarkar and O. Pereira, "Using the matrix pencil method to estimate the parameters of a sum of complex exponentials," Antennas and Propagation Magazine, IEEE, vol. 37, pp. 48-55, 1995.

[8] F. F. H. Aldhubaib and N. V. Z. Shuley, "Characteristic Polarization States Estimation in an Ultrawideband Context: A Frequency Approach," IEEE Transactions on Geoscience and Remote Sensing, vol. 47, pp. 2808-2817, 2009.

[9] E. s. a. systems, "Feko Suit 5," 9.3.24 ed. S.A (Pty) Ltd, 2003-2005.

Faisal F. H. Aldhubaib received his B.E. degree in electrical and computer engineering and thenM.Sc. degreein radio and microwave engineering from the University of Leeds, UK, in 1995 and 1997, respectively. Then in 2010, he received his PhD in Electromagnetic and Imaging research at the School of Information Technology and Electrical Engineering (ITEE) from the University of Queensland, Australia. Currently, he is an assistant professor working in the college of technological studies, PAAET, Kuwait.