The Potential of using UltraWideBand Microwave technologies in the Breast Cancer Detection

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Abstract:

Earlier detection of Breast cancer helps in increasing the chances of patients recovery and survival. In this thesis project, the possibilities of using Ultra Wideband (UWB) Microwave technologies for breast cancer detection are investigated. Based on Singularity Expansion Method, resonance-based target recognition technique, that utilizes the Complex Natural Resonance (CNR) of the breast volumes as a feature set, is considered. These CNRs can be directly extracted from the UWB time domain response using Matrix pencil method (MPM). In this project, three different strategies for CNR extraction from a single and multiple time domain response(s) are studied. The UWB time domain electromagnetic responses of simple breast volumes with different tumor sizes are computed numerically using commercial solver. The extracted CNRs from different breast volumes using different CNR extraction strategies are analysed in details.

Keywords:

SEM, Matrix Pencil Method, Complex Natural Resonance, UltraWideBand Microwave, polarization, breast cancer detection.

List of Abbreviations:

SEM Singularity Expansion Method

MPM Matrix Pencil Method

CNR Comple Natural Resonance

UWB Ultra Wideband

MRI Magnetic Resonance Imaging

MOM Method Of Moment

V Vertical

H Horizontal

R Right

L Left

ER Energy Ratio

TF Time Frequency

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1.Introduction

Early detection of breast cancer can significantly improve the survival rate of the patients. In the past couple of decades, several methods of detection and recovery tectiniques for the breast cancer were continously studied. Most predominontly, imaging approach like X-Ray mammography and Magnetic Resonant Imaging technique are in use. These two methods have some consequences and limitation, in which X-Ray is an ionizing radiation and which is not preferred for repeated exposure in short period of time since it may cause other consequences to the patient [1]. Magnetic Resonant Imaging method [8] is an expensive method that limits the patient for frequent examination of the cancer condition. In order to overcome these constraints, my project is to investigate the chances of using resonance based microwave technologies for the breast cancer detection. Resonance based target recognition is a method based on Singularity Expansion Method, where the late-time time domain transient response is considered as it contains most of the information about the target [9]. Microwave detection techniques are advantageous since they are non ionized and detects the change in dielectric properties of the tissue, which leads to periodic checkup for the patient without any risk and also it provides good contrast between malignant tumors.

For the detection of nature of breast cancer, the breast volume is considered as the “target. Electromagnetic signal is impringed on the target. The response signal from the target is computed using a Moment of Method solver called FEKO in frequency domain and Inverse fourier tranform is made to obtain in a time domain [10]. Late time response signal is usually preferred since it holds all the information about the target. Among various detection techniques we choose Matrix pencil method in our project study. Matrix pencil method is linear detection technique, which handles single response and multiple response signals. When the response signal from the target passes through the MPM algorithm, signal parameters such as Complex Natural Resonance (CNR) and residues are extracted which gives information about the desired target. CNR is the key parameter as it is aspect independent, extraction of single set of CNR is possible when considering multiple response signals. Whereas, residues are aspect dependent. Multiple response signals may be of multiple aspect and polarimetric data, multiple aspect response signal can be obtained from the target in many look directions with particular polarization. Polarimetric aspect are the response data from the target in particular look direction with all possible polarizations (4 circular or 4 linear polarization). Here, we considered two set of test cases , damped exponential signal and signal from one meter wire. The parameters are extracted for these targets in an efficient manner with MPM algorithm which handles single transient response and multiple signals. Breast tumor detection is done for three different cases of “No tumor”, “10mm tumor”, “15mm tumor”. The CNR for all three cases are extracted and CNR corresponds to the tumor are obtained.

1.1. Problem Statement

To investigate the possibility of using Ultra Wideband Microwave technologies such as Matrix pencil method for the detection of nature of breast cancer, by the developement of MPM algorithm.

Numerical study for the extraction of signal parameters such as CNR of test case, breast cancer and discusses the efficiency of MPM towards breast cancer detection.

1.2. Research Question

How efficient that the UltraWideband Microwave technology, Matrix Pencil Method is suitable for the extraction of signal parameters for breast cancer detection?

The question will be addressed in chapter – of the report where the author discussed with numerical results and explains the efficiency of Matrix Pencil Method.

1.3.Purpose

The main goal of the thesis is to analyze the advantages and pitfalls of working with an Matrix pencil method for the detection of nature of breast cancer.

Thus this thesis provides a detailed exposure to working of Matrix Pencil method with clear numerical study of simple damped exponential and signal from the wire.

1.4.Disposition

The rest of the report describes the following main topics: Project Methodology, Algorithm, Numerical Study, Results, Discussion, Conclusion.

Chapter 2. Project MEthodology

This chapter describes the methodology used to proceed with the project. The planning of two main parts of the project which are Research methodology and Sample cases are explained well here. A brief overview of the two methodologies that will be performed during the thesis to investigate processes is also provided in this section of report. It includes an overview of two different signals cases, Damped exponential signal and response signal from 1m wire. The breast tumor detection is done for 3 different cases of breast cancer, No tumor, 10mm and 15mm tumor.

Chaper 3 Algorithm

The third chapters of the report explains about flow of the matrix Pencil Method algorithm for single look direction and also the flow of algorithm which uses Matrix pencil method for Multiple signals in parameter extraction. From this chapter, reader gets good understanding about the working of Matrix pencil method. Furthermore, the chapter explains more about how MPM algorithm of single and multiple signals treats three signal cases and helps in extracting the signal parameters.

4. Numerical Study and Results

This chapter includes the signal parameters like CNR and residues which are extracted from the signal utilising MPM algorithm. These CNR are clearly explained with tables and clear comparison is made between the reference and obtained parameters for test cases. Extracted CNR for breast cancer detection are clearly tabulated.

5. Discussion

This section discusses the CNR extraction with single transient response, multiple aspect and polarimetric data. The advantages of using multiple signal over single transient response at a time and also better extraction with polarimetric data instead of multiple aspect are summarized. For breast canser detection, CNR corresponds to the tumor, difference in CNR od 3 cases od breast tumor are detailed.

6. Conclusion

This chapter summarizes the thesis by describing the learning outcome and main experience in the project. The thesis is wrapped up by providing some suggestions for the future work and summarizing the whole research and project.

2.Project Methodology

In this thesis following two strategies will be considered to address the prementioned problems of research and study of suitable solutions.

''Research can be termed as a logical and systematic search for new and useful infoemation on a particular topic. The outcome of a research is to verify and test important facts, to discover new facts and to overcome and solve problems occuring in our everyday life'' [1].

In order to get more information, the study was done with following two methodologies

a). Literature Study

b). Test Cases and Breast Cancer detection

2.1Literature Study

Research on possibility of using UWB microwave technologies for breast cancer detection is accomplished by extensive literature review on available various UWB technologies and understanding the nature of each of them. In the recent decades there were several target detection techniques were discussed and studied. Some of most familiar methods are Prony method, E-Pulse technique and Matrix Pencil Method.

To study the nature of target, an electromagnetic wave must passed through desired target and the late time response must be considered to get all information about the target. That signal have to be studied under UWB techniques so that parameters which has information about the target can be obtained. Prony's method is most popular and earliest linear method for parameter extraction from the response signal. But, the main difficulties with the Prony's method are computational complexity (i.e) it is a two step process in finding the poles and notorious for its extreme sensitivity to noise [2].

E-Pulse is an interesting technique for extraction of natural freqency of a radar target from a measured response. This is a technique which is insensitive to random noise and to estimates of model content [3]. E-pulse is an technique that helps in extraction of natural frequency of desired target and which is also a target recognition technique. An E-pulse is defined as a waveform of finite duration e(t) and which extinguishes E(t) in the late time [4]. The convolution of e(t) and E(t) yiels the null result. So, if the natural frequency of a target are known, an E-pulse for that target can be obtained by demanding E(s) = 0 and the convolution of natural frequency and its E-pulse will yield zero [3].

Matrix Pencil Method is a relatively new and popular linear technique for extraction of the parameters. It is derived from a method called pencil of funcion approach which was in use for some time [2]. Matrix pencil method is computationally more efficient and simple. When it is compared with another linear method called Prony, it has better advantages than that (i.e) it is two step process for finding the poles but Matrix Pencil Method is an one step process in extracting the value of poles. Apart from that, Matrix pencil Method has a lower variance of the estimates of parameter of interest in the presence of noise than the Prony's method. In our project Matrix Pencil Method is technique which is chosen and study of possibility of using UltraWideband Microwave in breast cancer detection is made with this technique. We also considered Matrix Pencil Method with multiple look direction, where responses are recorded along multiple look direction. An importance of multiple look direction is that the single estimate of all the poles are done utilizing multiple transient waveforms from target along multiple look direction [5]. The major difference between the waveforms are that the residues at the various poles are of different magnitudes. A single estimate for the poles will be more accurate and robust to effects of noise. An algorithm of MPM and Application of MPM with different look direction are explained clearly in the algorithm part of report.

From the Ultrawideband microwave backscatter ranging from 1-11GHz, characterization of targets features such as shape, size can also be investigated numerically. Generally, Smooth, microbulated and spiculated are the three general category in shape and four size categories which are from 0.5 to 2 cm in diameter were considered [7]. There are basically two different methods for classification in characterization, local discriminant bases and principal component analysis. By using these methods shape and size classification can be done with signal to noise ratio ranging 10dB, target size discrimation was 97% accurate and shape was accurate with 70% for about 360 targets. Figure 1 belows shows the 3 major steps for target recongtiion based on Ultra wideband transient electromagnetic responses.

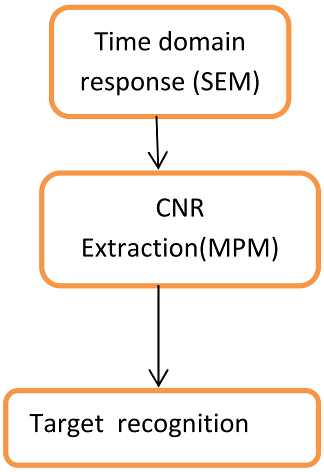

Figure 1: Three major steps for extraction and detection.

2.2 Test Cases and Breast Cancer Detection

In our project, an algorithm which is chosen for study of possibility of using Ultrawideband Microwave technology is Matrix Pencil Method. In order to deal with working of algorithm more clearly, algorithm must be executed and tested with some sample cases. For detailed and convinient study two different cases are selected, first sample case is a simple damped exponential signal and second sample case is numerical data from wire scatterer. These two cases are considered for numerical study of MPM and for MPM algorithm with multiple look direction. Damped exponential signals are developed with specific requirement for both single and multiple look direction. Single damped exponential signal is developed for MPM algorithm and Multiple look direction algorithm has two different damped exponential signal for two different looks, which has same poles and different residues magnitude. From the strength of residues the signal can be discriminated. Second sample case was the data from wire scatterer. The specification of this sample is from the reference [6]. The parameters extracted from algorithm with these sample signals helps to know efficiency and accuracy of the MPM algorithm. With the help of numerical study with sample signals we can come to the conclusion for the chances of using UWB technologies for breast cancer detection.

2.2.aTest Case1-Damping Exponential Signals

For better understanding of working of MPM algorithm it is always good to deal with simple case first. A simple damped exponential signal is generated with matlab. The damped exponential signal with known signal parameters is given to developed MPM algorithm. The main property of MPM algorithm is to derive signal parameters such as poles and residues of given known input signal. The verification and testing of matrix pencil method algorithm is made with the simple example cases as shown below.

In this case, the synthetic data (damped exponential signal) is taken,

$$s(t) = \sum_{i=0}^{M} Ai * \exp(\beta)t \qquad (1)$$

s (t) = damped exponential signal
Ai = Residue
β = -α + jωi
α = damping factor
ω = angular frequencies.

2.2.bTest Case2-Wire Data of 1m

In the second case, numerical data of a wire scatterer is considered. This sample is a bit complicated when compared to case 1, but which provides more detailed study and understands the working and efficiency of MPM algorithm. Here, response from the wire (wired data) with wire length, L = 1m and two different look angles, θ = 15^{o} and 75^{o} are provided. The data set of wire has frequency range from 4.39MHz to 9GHz with equally spaced 2048 number of samples. The response signal of wire scatterer with above specification is given to MPM algorithm for parameter estimation. In [6] for better understanding of results, parameter extracted using another method called Method of Moments, which is solely depends on the target geometry and dielectric properties are also considered and is included in and explained in numerical study part of the report. Extracted parameters using MPM algorithm for sample case 2 is compared with results of Method of Moments and Matrix Pencil Method for two different angles.

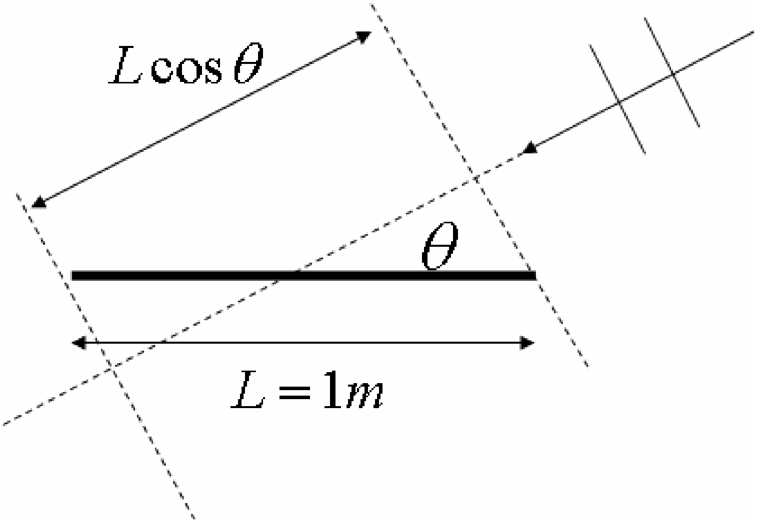

Figure 2: Test Case- 1m wire

2.2.cBreast Cancer Detection

The breast tumor in the breast volume is studied. Three different cases are considered, breast volume with no tumor, 10mm tumor and 15mm tumor. The breast volume of 6cm hemisphere with tumor is considered with 18 plane wave sources around with seperation of 20° each. The breast volume is illuminated with the frequency of 23MHz to 3GHz with 128 samples in frequency domain (256 samples in time domain). Each time, one plane wave source is considered and the corresponding scattered far-field in the 18 directions are computed. [10]. The electromagnetic response is computed in the frequency domain and the time domain response are obtained via an inverse Fourier Transofrm of the frequency data. Both circular and linear polarization are considered. These datas are processed with matrix pencil method by considering multiple aspect and polarimetric data. Multiple aspect datas are considered in a way that the transient responses from all the 18 look direction with certain polarization state. Polarimetric datas are transient response from a particular look direction and by considering the datas from circular or linear polarization state [10]. From this case study, it can be said whether the better parameter extraction can done with multiple aspect data or polarimetric data.

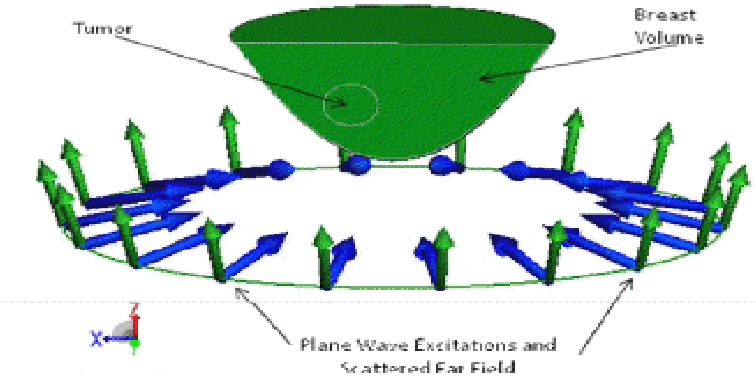

Figure 3: Simulation setup for Breast Cancer Detection in FEKO

3. Algorithm

This chapter describes the flow of Matrix Pencil method with regards to the case of single and various input signals. The procedure of Matrix pencil method varies according to noise level in an input signal and reacts better even in noisy situation. In absence of noise, parameter of estimation can get through in a simple way and the procedure of algorithm flows an another way for a noisy situation. In our project we include Matrix pencil method which treats single set of data and also use an algorithm multiple look direction for noisy condition which are as follows.

3.1 Matrix Pencil Method For Single transient response

The term pencil originated with Gantmacher [2], similar to Gantmacher's definition for matrix pencil, with another entity wehn combining two functions defined on a common interval, with a scalar parameter, λ [2].

$$f(t, \lambda) = g(t) + \lambda h(t) \qquad (2)$$

f(t, λ) is called as a pencil of functions g(t) and h(t), parameterized by λ. In the case of parameter extraction, pencil of function contains most important information about poles of given input signal. Total least matrix pencil method is found to be more superior, simple and more robust to noisy signal [2]. The main objective of this method is to findout the poles Z, residues R and model order M of noise contaminated data y(t).

In this implemetation of total least square matrix pencil method, initially the noise contaminated response signal collected which is specified as x(k). For the reason of developement of algorithm, data x(k) is replaced by y(k) for the formation of matrix [Y1] and [Y2].

Next, the formation of data matrix [Y] is done from noisy data matrix [Y1] and [Y2] and is obtained as mentioned below.

$$[Y] = \begin{bmatrix} y(0) & y(1) & \cdots & y(L) \\ y(1) & y(2) & \cdots & y(L+1) \\ \vdots & \vdots & & \vdots \\ y(N-L-1) & y(N-L) & \cdots & y(N-1) \end{bmatrix}_{(N-L)\times(L+1)} \qquad (3)$$

Note that, formation of matrix [Y1] and [Y2] is obtained from [Y] by deleting the last column and first column from [Y] matrix respectively. The dimension of data matrix [Y] is given as (N-L)x(L+1), where N is number of samples taken from the response signal and the parameter L must be choosen between N/3 and N/2 for efficient noise filtering and for these values of L, the variance in the parameter poles because of noise has been found to be minimum [2].

Once after the formation data matrix [Y], singular value decomposition of matrix [Y] must be done. Singular value decompostion is a process of factorizing a matrix in the form

$$[Y]=[U][\Sigma][V]^* \qquad (4)$$

Here, [U] and [V] are said to be unitary matrices, where [U] comprised of eigen vectors of [Y][Y]* and [V] matrix has eigen vectors of [Y]*[Y] and [∑] is a diagonal matrix which has singular value of [Y].

In this stage, estimation of parameter model order M is done. The procedure of finding M varies according to input m value, when input m value is set greater than zero the model order M that is the number of estimated parameters are same as input model order. The way of finding model order M is different when input m is negative. In case of m less than zero, one consider the ratio of various singular values to the largest one. The singular values are represented as σc and largest singular value which is the first singular value is given as σmax. The model order M can be estimated with the following equation.

$$\frac{\sigma c}{\sigma \max} \approx 10^{-p} \qquad (5)$$

Where p is the number of significant decimal digits in the data. The ratio of singular value to its maximum must be approximately equal to 10^{-p} and those singular values are considered for the reconstution of the data. For example, if the data is accurate up to 4 significant decimal digits, then the singular values for which the ratio less than 10 to the power of -4 are considered to be noisy data and these datas must not be used for the reconstution of the data. So the selection of singular values which is approximated with the above equations helps in parameter estimation effectively.

The next process is to find out the matrix [Y1] and [Y2], for this we consider the filtered matrix [V'] which is constructed in a way it comprises only M dominant right singular vectors of matrix [V]. The remaining right singular vectors of matrix (i.e) from M+1 to L are neglected as they are smaller. Inorder to form [Y1] and [Y2] matrix, [V1'] and [V2'] filtered matrix must be derived from [V'] by deleting its last row and first row respectively. So,

$$[Y1] = [U][\Sigma'][V1']^* \qquad (6)$$

$$[y2] = [U][\Sigma'][V2']^* \qquad (7)$$

In the above equation, [∑'] is obtained from M columns of [∑] that is by considering only M dominant singular values [2].

Once after finding the matrices [Y1] and [Y2], Matrix pencil equation must be solved to accomplish its eigen values which is described below [2],

$$\{[Y2] - \lambda[Y1]\}LxM \Rightarrow \{[Y1]=[Y2] - \lambda[I]\}MxM'$$

The eigen values which we attained with above equation will be equivalent to the eigen velues of the following matrix,

$$\{[V2']^* - \lambda[V1']^*\}LxM \Rightarrow \{[V1]\}\{[V2]\} - \lambda[I]$$

An above approach of construe the Matrix pencil equation is more transparent in obtaining poles with minimum variance in the presence of noise, typically up to 20-25 dB of signal to noise ratio can be handled effectively and simpler than prony method [2]. Once after retrieving the model order M and poles Z, the residues are solved from the following least square problem,

$$\begin{bmatrix} y(0) \\ y(1) \\ \vdots \\ y(N-1) \end{bmatrix} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ z_1 & z_2 & \cdots & z_M \\ \vdots & \vdots & & \vdots \\ z_1^{N-1} & z_2^{N-1} & \cdots & z_M^{N-1} \end{bmatrix} \begin{bmatrix} R_1 \\ R_1 \\ \vdots \\ R_M \end{bmatrix} \quad (8)$$

Therefore, Matrix Pencil Method algorithm for estimating the signal parameters such as poles, residues of the desired target is clearly expained.

3.2 Matrix pencil Method for multiple signals

This method is an attempt to study more about the target from many aspects like many look directions and different polarization. In this method, target is surrounded by many antennas placed in certain interval. One antenna acts as transmitter and rest of the antennas take the position of receiver. All the antennas takes a turn as tansmitter and receiver. The data from the target are collected by all the receiver and processed in time domain. The poles recorded are independent of look directions and polarization, so here common single set of poles are obtained with different amplitudes. It is believed that parameter extraction by multiple aspect helps in easy parameter extraction. The following is an MPM algorithm that process these multiple aspect data.

For the algorithm development, the transient response of length N+1 and k look directions are considered. the response is the noise contaminated data so Total least square Matrix pencil method is preferrable. The first step is to form a matrix [D] from the noise contaminated data, where [D1] matrix can be obtained from [D] by eliminating the last row and matrix [D2] is by deleting the first row of [D] matrix respectively.

The data matrix [D] looks as follows [5],

$$[D]_{(L+2)\times[K\cdot(N-L)]} = [U]_{(L+2)\times(L+2)}[\Sigma]_{(L+2)\times[K\cdot(N-L)]} \cdot [V]^H_{K\cdot(N-1)\times[K\cdot(N-L)]}. \quad (9)$$

Next step deals with factorization of matrix [D] by singular value decomposition, it is done according to [5]

$$[U_1][\Sigma][V_1]^H$$

Where [U]&[V]* are two orthogonal matrix, whereas [Σ] has the singular values of [D] matrix. In order to combat the noise effect, model order M must be obtained for matrix filtering. M can be obtained in the same way as it was discussed in the above algorithm. Singular value filtering is done by retaining the M dominant value in the matrix [Σ]. With the filtered matrix, new matrix [D1], [D2] are formed and processed in the matrix pencil equation,

$$[D2] - \lambda[D1]$$

The poles are obtained from the above equation. Once the poles and model order is known it is easy to find out the amplitude value from the following equation [5],

$$[Y] = [Z]\cdot[A] \quad (10)$$

4. Numerical Study and Results:

4.1. Test Case1- Damping Exponential Signals:

In this case, the synthetic data (damped exponential signal) is taken,

$$?(t) = \sum_{i=0}^{M} Ai * \exp(\beta)t \qquad (11)$$

? (t) = damped exponential signal
Ai = Residue
β = -α + jωi
α = damping factor
ω = angular frequencies.

The above damped exponential signal is taken as a sample with order M = 6, amplitude, A = {1, 2, 3}, α = {2, 3, 4} and the frequency, f = {4, 5, 6} with ω=2*pi*f for the better understanding. Input is given to MPM algorithm and the parameters like poles and residues are obtained. The estimation of the parameter is done for the different modes. The number of poles and residues are decided with the factor called Model order with the condition say,

$$\frac{\sigma c}{\sigma \max} \approx 10^{-p} \qquad (12)$$

Where, σc = sigular values of the data matrix

σmax = maximum (i.e) the first sigular value

p = number of significant decimal digits.

The model order is selected, when the fraction of the singular value with its maximum one is less than or equal to the 10^{-p}. For example, consider m= 2 , σmax = 58 and the number of singular values must be, σc ≤ 0.58. In the case of M < 0, the fraction of singular value σc and maximum singular value σmax must be greater than M.

$$\frac{\sigma c}{\sigma \max} > M \qquad (13)$$

Here the extraction of poles and residues were attained in an efficient manner with MPM. For the verification purpose, reconstruction of the signal is also done and shown with factor called VAF.

In the table below, poles and residues are obtained for the various M and the parameter extraction is done more effectively for the M = -5, -3 -1, 4, 6, 8, 10. When we consider the case of M = -5, by implementing the value of M in the above condition (3) which leads to the number of poles and residues. For M = 2, the poles and residues are extracted with the condition (2). The extracted poles and residues can be clearly seen in the table 1(a)&1(b).

Table 1 : parameters for the damped exponential signal

M=-5	M=-3	M=-1	M=2
VAF = 100 pole = -2.0000 25.1327 -2.0000 -25.1327 -3.0000 31.4159 -3.0000 -31.4159 -4.0000 37.6991 -4.0000 -37.6991 residue = 1.0000 0.0000 1.0000 -0.0000 2.0000 -0.0000 2.0000 0.0000 3.0000 0.0000 3.0000 -0.0000	VAF = 100 pole = -2.0000 25.1327 -2.0000 -25.1327 -3.0000 31.4159 -3.0000 -31.4159 -4.0000 37.6991 -4.0000 -37.6991 residue = 1.0000 0.0000 1.0000 -0.0000 2.0000 -0.0000 2.0000 0.0000 3.0000 0.0000 3.0000 -0.0000	VAF = 100 pole = -2.0000 25.1327 -2.0000 -25.1327 -3.0000 31.4159 -3.0000 -31.4159 -4.0000 37.6991 -4.0000 -37.6991 residue = 1.0000 0.0000 1.0000 -0.0000 2.0000 -0.0000 2.0000 0.0000 3.0000 0.0000 3.0000 -0.0000	VAF = 95.8660 pole = -6.3272 33.1170 -6.3272 -33.1170 residue = 6.4034 0.1868 6.4034 -0.1868

Table 2 : parameters for the damped exponential signal

M=4	M=6	M=8	M=10
VAF = 98.7306 pole = -2.4068 24.1538 -2.4068 -24.1538 -5.7587 35.6636 -5.7587 -35.6636 residue = 0.8223 0.6629 0.8223 -0.6629 5.1870 -0.8183 5.1870 0.8183	VAF = 100 pole = -2.0000 25.1327 -2.0000 -25.1327 -3.0000 31.4159 -3.0000 -31.4159 -4.0000 37.6991 -4.0000 -37.6991 residue = 1.0000 0.0000 1.0000 -0.0000 2.0000 -0.0000 2.0000 0.0000 3.0000 0.0000 3.0000 -0.0000	VAF = 100 pole = -2.0000 25.100 -2.0000 -25.100 -3.0000 31.400 -3.0000 -31.400 -4.0000 37.700 -4.0000 -37.700 residue = 1.0000 0.0000 1.0000 -0.0000 2.0000 -0.0000 2.0000 0.0000 3.0000 0.0000 3.0000 -0.0000	VAF=100 Pole = -2.0000 25.100 -2.0000 -25.100 -3.0000 31.400 -3.0000 -31.400 -4.0000 37.700 -4.0000 -37.700 residue = 1.0000 0.0000 1.0000 -0.0000 2.0000 -0.0000 2.0000 0.0000 3.0000 -0.0000 3.0000 0.0000

4.2. Test Case2-Wire Data:

In case of second example of resonance based target recognition method is taken which also considers late time response from the target scattering based on singularity expansion method(SEM), the target tesonance are purely depends on the target composition and geometry not on the incident aspect angle.

In the example, response from the wire (wired data) with L = 1m and the angle θ = 15^{o} and 75^{o} and frequency range from 4.39MHz to 9GHz with equally spaced 2048 samples in frequency domain. The data set for this wired response is given to MPM algorithm for parameter estimation. Here, the parameter extracted using Method of Moments and MPM, which is solely depends on the target geometry and dielectric properties are taken as the reference from [6] and added in the table.

Mode	MOM reference	MPM reference	MPM I/p m = 20 O/p M = 20		MPM I/p m = -3 O/p M = 43		MPM I/p m = -4 O/p M = 178	
			VAF = 100%		VAF = 99.99%		VAF = 100%	
			Poles	Residues	Poles	Residues	Poles	Residues
1	-0.260±j2.91	-0.252±j2.87	-0.2533±j2.8733	49.64	-0.2533±j2.8733	49.64	-0.2533±j2.8733	49.69
2	-0.381±j6.01	-0.373±j5.93	-0.3733±j5.9333	13.37	-0.3733±j5.9333	13.28	-0.3700±j5.9333	13.21
3	-0.468±j9.06	-0.444±j9.05	-0.4400±j9.0267	2.044	-0.4267±j9.0300	2.155	-0.4567±j9.0067	2.197
4	-0.538±j12.2	-0.545±j12.1	-0.5433±j12.110	11.63	-0.5567±j12.123	11.18	-0.5267±j12.103	11.14
5	-0.600±j15.3	-	-0.6200±j15.953	1.278	-0.5728±j15.217	1.385	-0.5733±j15.216	1.395
6	-0.654±j18.4	-0.881±j17.6	-0.6400±j18.330	2.804	-0.6320±j18.327	2.993	-0.6333±j18.326	2.844
7	-0.704±j21.5	-0.850±j21.6	-0.6900±j21.526	4.647	-0.6900±j21.433	4.587	-0.6900±j21.433	4.635
8	-0.749±j24.6	-	-	-	-	-	-	-
9	-0.792±j27.7	-1.005±j28.6	-0.7933±j28.510	3.253	-0.781±j27.688	2.624	-0.7817±j27.688	2.792
10	-0.832±j30.8	-	-	-	-0.818±j30.838	2.131	-0.8167±j30.840	1.771

Table 3: θ = 15° CNR for Different M.

The extraction of useful parameters are completely based on the strength of the residues and is difficult when the residue value is less or 0. The residue values are also provided in the table below in order to show the strength of the poles. The model order considered here are, M = 20, -3, -4. Most of the useful poles are aquired better in the case of M = -4 and reconstuction of the signal is 100% as shown below in the table(2). Residues here shows the strength of the poles. In the case of M = -4, number of resonant poles are approximarely 178. Resonance values are obtained and compared with the verified with reference poles. The reconstruction of the signal and pole extraction is more appropriate when it is compared with the proved one.

For the data at the angle 15° and 75° is provided to MPM algorithm with different M values are considered. The number of obtained poles with respect to the input order is also shown clearly. The poles for the different model order is compared and the poles obtained are mentioned.

For θ = 15°, different M values are considered and the poles obtained are mentioned in Table 3.

For θ = 75°, different M values are considered and the poles obtained are mentioned in Table 4.

Mode	MOM reference	MPM reference	MPM I/p m = 55 O/p M = 55		MPM I/p m = -2 O/p M = 86		MPM I/P m = -3 O/p M = 579	
			VAF = 99.59%		VAF = 100%		VAF = 99.99%	
			Poles	Residues	Poles	Residues	Poles	Residues
1	-0.260±j2.91	-0.252±j2.87	-0.2486±j2.8788	2.394	-0.2525±j2.8732	2.450	-0.2517±j2.8739	2.441
2	-0.381±j6.01	-0.372±j5.93	-0.3849±j5.9277	4.434	-0.3703±j5.9312	4.254	-0.3711±j5.9342	4.236
3	-0.468±j9.06	-0.455±j9.01	-0.4460±j9.0118	5.467	-0.4569±j9.0120	5.675	-0.4558±j9.0123	5.655
4	-0.538±j12.2	-0.525±j12.1	-0.5439±j12.112	7.053	-0.5228±j12.105	6.719	-0.5247±j12.105	6.732
5	-0.600±j15.3	-0.585±j15.2	-0.5769±j15.195	7.395	-0.5871±j15.207	7.639	-0.5856±j15.207	7.633
6	-0.654±j18.4	-0.637±j18.3	-0.6557±j18.340	8.509	-0.6362±j18.317	8.193	-0.6352±j18.315	8.164
7	-0.704±j21.5	-0.692±j21.4	-0.6953±j21.410	8.739	-0.6919±j21.436	8.758	-0.6963±j21.438	8.846
8	-0.749±j24.6	-0.733±j24.6	-0.7405±j24.597	8.984	-0.7345±j24.559	8.978	-0.7258±j24.562	8.779
9	-0.792±j27.7	-0.785±j27.7	-0.8161±j27.664	9.792	-0.7818±j27.692	9.225	-0.7873±j27.698	9.324
10	-0.832±j30.8	-0.817±j30.8	-0.8031±j30.869	8.679	-0.8211±j30.832	9.234	-0.8158±j30.833	9.123

Table 4: θ = 75° CNR for Different M.

Single response extraction is done with matrix Pencil Method algorithm for the data from the wire scartter. The poles obtained are corresponds to the wire target at different look direction of 15° and 75°. The response signals are processed one after one since we could use MPM which can perform single extraction. So for the simplification of this process, the trasient responses from two different look directions are being processed in MPM algorithm which handles multiple signals. The CNR extraction is more straight forward, single set CNR is obained as it is aspect independent and 2 set of residues are obtained which corresponsds to two different look directions (15° and 75°). The ectracted CNR with multiple aspect are explanined in multiple aspect extraction.

4.3 Breast Cancer Detection:

The data from the breast volume with No tumor, 10 mm tumor and 15 mm tumor are considered. The poles are extracted for no tumor case. Response signal comprises of datas releted to 18 different aspects. Each aspect has its own 8 polarization (4 in Linear and 4 in Circular). All the response signal from 18 aspect with 8 different polarizations are processed and poles are extracted. so, 18*8=144 number of extractions are done. Dominant poles are judged by Energy Ratio (ER) and verified by using Time Frequency analysis plot. Energy ratio of each resonant mode is obtained by dividing energy level of each resonant mode by sum of energy level of all the resonant modes. Dominant poles for no tumor extraction with the energy ratio for all 18 aspects (time_transmit_receiver: time_1_1 to time_1_18) with different polarization (VV, HH, VH, HV, LL, RR, LR, RL) are tabulated below.

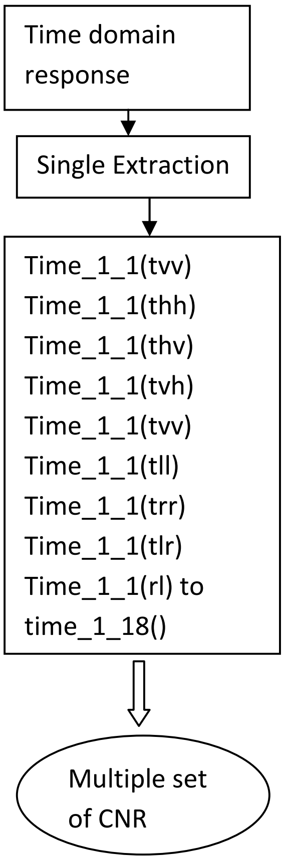

Figure 4: Strategies for Single response extraction

At the end of extraction, set of CNR are obtained and It is most important to find out the most dominant poles. In our project there are two strategies are implemented to get the most domonant poles corresponds to the required target. Energy Ratio (ER) gives the information about the most dominant poles, it is defined as the enery level of each mode to the sum of energy level of all resonant modes. Mode with higher energy is the most dominant pole of the specific target and represented in percentage.

TF analysis is a technique that consist of both time and frequency domain simultaneously. TF plot shows the most intensive frequency component among all the modes which helps in finding the dominant CNR of the target. TF plot looks as follows,

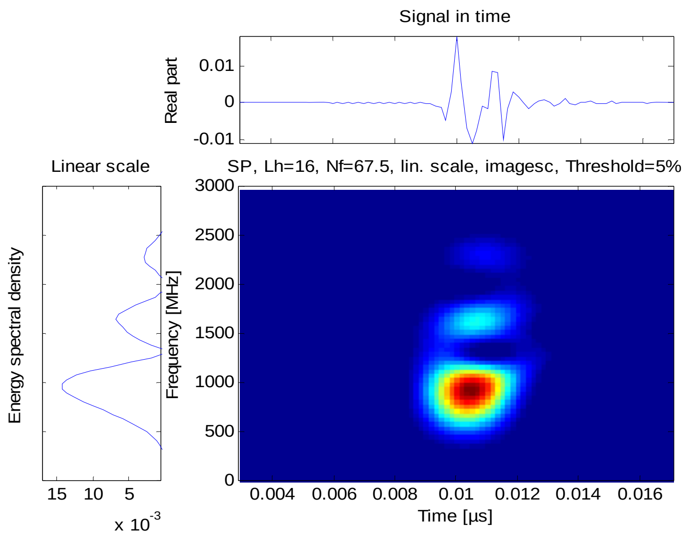

Figure 4: TF Plot Model

From the above plot, it is very clear that the frequency of 1GHz is more intensive and also it posses higher energy among all the component. So by looking at TF plot the most dominant poles can be identified.

The most dominant CNR for No tumor case for all the look directions are tabulated below with its Energy ratio.

Time_1_1

Poles	ER(VV) (%)
-3.272±44.306	5.89
-4.545±33.489	89.21
-4.603±54.715	3.36
-8.526±23.571	1.53

Poles	ER(HH)
-3.425±22.435	64.17
-3.085±29.99	1.23
-3.666±53.072	0.07
-4.611±42.22	33.62

Poles	ER(VH)
-2.591±54.291	0.03
-4.501±43.719	0.22
-5.523±25.358	0.003
-4.182±35.213	99.76

Poles	ER(HV)
-3.272±44.306	5.89
-4.545±33.489	89.21
-4.603±54.715	3.36
-8.526±23.571	1.53

Poles	ER(LL)
-3.647±27.892	2.339
-3.868±43.381	96.9
-4.200±53.506	0.736

Poles	ER(RR)
-3.652±27.88	2.179
-3.865±43.386	97.29
-4.194±53.499	0.49

Poles	ER(LR)
-3.635±52.054	0.03
-3.979±32.221	3.7
-4.057±25.021	96.2

Poles	ER(RL)
-3.642±53.061	0.028
-3.953±32.160	4.044
-4.057±25.021	95.916

Table 5: time_1_1 dominant CNR for 8 polarizations

Time_1_2

Poles	ER(VV)
-3.361±44.293	4.39
-4.607±33.607	90.82
-5.620±54.090	2.26
-8.593±23.813	2.45

Poles	ER(HH)
-3.512±28.423	11.45
-4.412±42.146	9.06
-3.646±51.527	0.006
-3.337±25.725	79.484

Poles	ER(VH)
-2.581±53.895	0.03
-5.923±23.967	0.85
-4.499±43.725	0.003
-5.519±34.430	98.76

Poles	ER(HV)
-3.361±44.293	4.39
-4.607±33.607	90.82
-5.620±54.090	2.26
-8.593±23.813	2.45

Poles	ER(LL)
-3.561±28.02	1.88
-4.397±52.917	0.79
-3.815±43.230	97.2

Poles	ER(RR)
-3.572±27.978	2.44
-4.410±52.827	0.78
-3.821±43.241	96.75

Poles	ER(LR)
-3.220±51.183	0.028
-3.914±23.191	91.16
-3.627±46.936	3.22
-4.757±32.352	5.584

Poles	ER(RL)
-2.632±53.706	0.411
-4.058±24.187	93.31
-4.306±31.803	6.26

Table 6: time_1_2 dominant CNR for 8 polarizations

Time_1_3

Poles	ER(VV)
-2.032±53.513	0.003
-4.740±33.373	5.21
-3.640±42.983	0.154
-9.365±25.605	94.56

Poles	ER(HH)
-2.181±53.209	0.823
-3.580±28.456	95.625
-4.445±41.442	0.982
-9.50±22.892	2.36

Poles	ER(VH)
-2.716±54.199	0.05
-4.768±43.629	2.36
-5.820±33.706	97.32

Poles	ER(HV)
-2.032±53.513	0.003
-4.740±33.373	5.21
-3.640±42.983	0.154
-9.365±25.605	94.56

Poles	ER(LL)
-3.725±42.42	99.68
-3.562±28.231	0.034

Poles	ER(RR)
-3.740±42.411	99.70
-3.565±28.236	0.031

Poles	ER(LR)
-3.304±25.460	0.026
-3.540±54.728	0.63
-4.571±36.835	74.4
-4.955±43.524	25.48

Poles	ER(RL)
-2.939±54.35	0.69
-3.535±35.259	1.213
-3.683±43.296	0.002
-3.872±25.52	97.94

Table 7: time_1_3 dominant CNR for 8 polarizations

Time_1_4

Poles	ER(VV)
-2.136±53.663	0.0004
-3.228±44.242	0.0001
-4.8143±33.458	2.56
-9.4299±25.223	97.43

Poles	ER(HH)
-7.802±22.961	0.03
-3.648±28.371	98.88
-3.291±52.143	1.01
-5.419±40.762	0.06

Poles	ER(VH)
-4.854±43.155	0.03
-5.685±33.905	99.87
-6.102±26.803	0.124
-5.112±53.555	0.001

Poles	ER(HV)
-2.136±53.663	0.0004
-3.228±44.242	0.0001
-4.8143±33.458	2.56
-9.4299±27.223	97.43

Poles	ER(LL)
-2.740±53.172	1.36
-4.721±40.886	0.06
-4.346±27.495	98.57

Poles	ER(RR)
-2.748±53.150	1.29
-4.696±40.482	0.08
-4.377±27.465	98.33

Poles	ER(LR)
-3.212±27.751	0.21
-4.586±41.931	0.004
-2.632±54.11	1.217
-4.881±33.001	98.54

Poles	ER(RL)
-2.550±53.83	0.82
-3.887±28.294	96.53
-4.062±43.054	0.02
-4.986±32.992	2.34

Table 8: time_1_4 dominant CNR for 8 polarizations

Time_1_5

Poles	ER(VV)
-2.330±53.379	0.003
-3.298±44.045	0.0013
-4.841±33.134	0.198
-8.256±24.162	99.79

Poles	ER(HH)
-3.591±28.415	99.86
-4.337±51.917	0.13
-7.1593±40.368	0.013

Poles	ER(VH)
-4.268±24.402	96.23
-2.576±54.125	0.001
-4.842±42.017	2.03
-5.328±33.055	1.20

Poles	ER(HV)
-2.330±53.379	0.003
-3.298±44.045	0.0013
-4.841±33.134	0.198
-8.256±24.162	99.79

Poles	ER(LL)
-2.590±52.291	0.002
-3.822±28.500	3.736
-5.065±43.428	96.26

Poles	ER(RR)
-2.594±52.31	0.003
-3.819±28.501	3.600
-5.069±43.423	96.27

Poles	ER(LR)
-3.852±26.211	1.43
-4.685±34.158	98.54

Poles	ER(RL)
-2.550±53.83	0.08
-3.887±28.294	2.10
-4.062±43.054	0.09
-4.986±32.992	97.41

Table 9: time_1_5 dominant CNR for 8 polarizations

Time_1_6

Poles	ER(VV)
-2.699±43.194 -4.751±53.67 -9.2822±34.201	0.025 0.06 99.91

Poles	ER(HH)
-2.918±28.488 -7.085±42.564	99.23 0.74

Poles	ER(VH)
-2.430±54.331 -2.829±41.186 -4.382±34.844 -5.112±22.312	0.0001 0.01 92.52 7.477

Poles	ER(HV)
-2.699±43.194 -4.751±53.67 -9.2822±34.201	0.025 0.06 99.91

Poles	ER(LL)
-4.361±27.949 -5.266±43.284 -7.745±52.144	99.664 0.3356 0.0001

Poles	ER(RR)
-4.360±27.956 -5.28±43.272 -7.669±52.163	99.791 0.27 0.0001

Poles	ER(LR)
-2.610±34.207 -3.632±28.26	99.97 0.02

Poles	ER(RL)
-1.549±42.77	98.396
-3.88±28.66	0.33
-2.715±35.07	1.09

Table 10: time_1_6 dominant CNR for 8 polarizations

Time_1_7

Poles	ER(VV)
-2.935±51.326	0.0001
-3.251±40.471	0.298
-6.281±34.171	99.57

Poles	ER(HH)
-2.067±52.837	0.0001
-4.104±28.553	98.56
-5.571±41.890	1.32

Poles	ER(VH)
-2.698±42.801	1.23
-5.687±52.830	0.009
-5.815±30.132	98.23

Poles	ER(HV)
-2.935±51.326	0.0001
-3.251±40.471	0.298
-6.281±34.171	99.57

Poles	ER(LL)
-4.525±53.587	0.0002
-3.310±29.296	99.90
-4.627±42.511	0.01

Poles	ER(RR)
-4.389±52.981	0.0001
-3.299±29.593	99.88
-4.587±43.256	0.02

Poles	ER(LR)
-2.317±43.067	0.12
-3.656±32.828	99.879

Poles	ER(RL)
-1.135±52.317	0.41
-3.366±42.401	7.99
-2.994±37.492	91.52
-3.936±28.634	0.01

Table 11: time_1_7 dominant CNR for 8 polarizations

Time_1_8

Poles	ER(VV)
-5.341±33.557	93.43
-5.576±42.889	6.56
-5.477±58.581	0.0002

Poles	ER(HH)
-4.321±28.575	98.19
-5.373±40.783	1.726
-4.554±52.259	0.077

Poles	ER(VH)
-2.568±54.304	0.001
-2.430±43.250	0.29
-5.053±35.158	56.02
-5.143±22.453	43.66

Poles	ER(HV)
-5.341±33.557	93.43
-5.576±42.889	6.56
-5.477±58.581	0.0002

Poles	ER(LL)
-2.994±29.184	99.02
-5.1062±41.95	0.91
-5.956±53.994	0.0002

Poles	ER(RR)
-3.045±29.296	99.04
-5.141±41.932	0.87
-5.821±54.121	0.0002

Poles	ER(LR)
-3.799±29.434	99.498
-4.298±42.200	0.5

Poles	ER(RL)
-2.205±32.257	97.96
-2.803±53.219	1.34
-3.035±42.966	0.52

Table 12: time_1_8 dominant CNR for 8 polarizations

Time_1_9

Poles	ER(VV)
-3.272±56.127	0.012
-4.026±43.915	9.60
-5.392±33.064	90.25

Poles	ER(HH)
-4.434±28.441	99.78
-5.396±40.562	0.21
-5.614±55.101	0.005

Poles	ER(VH)
-2.530±43.874	0.03
-3.080±54.513	0.001
-4.672±22.957	59.39
-4.821±35.894	40.59

Poles	ER(HV)
-3.272±56.127	0.012
-4.026±43.915	9.60
-5.392±33.064	90.25

Poles	ER(LL)
--4.789±55.562	0.01
-4.526±43.714	19.99
-4.992±29.282	79.99

Poles	ER(RR)
-4.882±55.591	0.009
-4.426±43.158	20.32
-4.725±29.782	79.54

Poles	ER(LR)
-3.811±29.294	99.87
-3.940±42.755	0.098

Poles	ER(RL)
-2.871±53.752	0.09
-3.120±43.478	2.02
-3.949±29.350	97.85

Table 13: time_1_9 dominant CNR for 8 polarizations

Time_1_10

Poles	ER(VV)
-2.796±54.666	0.23
-3.999±43.954	16.78
-5.280±33.088	82.99

Poles	ER(HH)
-3.161±54.577	0.0038
-4.437±28.531	95.61
-5.705±43.497	4.38

Poles	ER(VH)
-2.530±43.874	0.32
-3.080±54.513	0.002
-4.672±23.994	2.63
-5.213±34.213	97.53

Poles	ER(HV)
-2.796±54.666	0.23
-3.999±43.954	16.78
-5.280±33.088	82.99

Poles	ER(LL)
-4.105±54.694	0.39
-4.268±44.086	18.09
-4.953±29.051	81.45

Poles	ER(RR)
-4.113±54.698	0.4
-4.589±44.254	18.52
-5.012±29.531	81.01

Poles	ER(LR)
-3.349±43.137	1.194
-3.896±29.308	98.532

Poles	ER(RL)
-3.040±43.135	2.89
-3.896±29.306	97.02

Table 14: time_1_10 dominant CNR for 8 polarizations

Time_1_11

Poles	ER(VV)
-3.275±56.134	0.26
-4.026±43.915	16.71
-5.329±33.064	83.02

Poles	ER(HH)
-4.434±28.44	97.78
-5.396±40.563	2.213
-5.611±55.099	0.005

Poles	ER(VH)
-2.531±43.878	1.23
-3.095±52.521	0.01
-4.622±21.121	60.78
-4.832±35.912	38.02

Poles	ER(HV)
-3.275±56.134	0.26
-4.026±43.915	16.71
-5.329±33.064	83.02

Poles	ER(LL)
-2.542±52.030	0.41
-4.958±43.704	18.98
-3.089±29.297	80.45

Poles	ER(RR)
-2.567±30.084	0.48
-4.789±55.49	19.49
-4.723±43.753	79.99

Poles	ER(LR)
-2.874±53.760	1.001
-3.122±43.482	0.89
-3.950±29.359	97.76

Poles	ER(RL)
-3.937±42.758	1.12
-3.812±29.290	98.86

Table 15: time_1_11 dominant CNR for 8 polarizations

Time_1_12

Poles	ER(VV)
-5.343±33.556	88.89
-5.572±42.881	9.98
-5.461±51.571	1.15

Poles	ER(HH)
-4.322±28.573 -5.371±40.785 -4.553±55.250	98.38 1.58 0.0001

Poles	ER(VH)
-2.567±54.309 -2.4316±43.241 -5.048±35.150	0.002 56.46 43.53

Poles	ER(HV)
-5.343±33.556 -5.572±42.881 -5.461±51.571	88.89 9.98 1.15

Poles	ER(LL)
-3.018±29.27 -5.143±41.92 -5.569±53.994	98.67 1.22 0.001

Poles	ER(RR)
-2.997±29.210 -5.124±41.961 -5.463±53.874	99.02 0.92 0.001

Poles	ER(LR)
-2.801±53.21 -3.038±42.96 -4.844±35.488	1.99 3.02 94.968

Poles	ER(RL)
-3.806±30.431	99.51
-4.268±42.180	0.49

Table 16: time_1_12 dominant CNR for 8 polarizations

Time_1_13

Poles	ER(VV)
-3.247±40.474	0.35
-6.278±34.166	99.56

Poles	ER(HH)
-2.076±52.827	0.0002
-4.102±28.551	99.65
-5.574±41.888	0.24

Poles	ER(VH)
-2.698±42.798	9.3
-5.699±52.806	0.03
-5.983±35.977	90.23

Poles	ER(HV)
-3.247±40.474	0.35
-6.278±34.166	99.56

Poles	ER(LL)
-4.531±53.586	0.0001
-3.321±29.288	99.64
-4.615±42.522	0.29

Poles	ER(RR)
-3.329±29.292	99.82
-4.721±42.991	0.17
-4.951±52.785	0.0001

Poles	ER(LR)
-1.152±52.334	0.42
-5.988±25.492	0.29
-3.374±42.397	89.12
-3.934±32.641	9.06

Poles	ER(RL)
-3.408±33.135	93.25
-2.311±43.073	6.67

Table 17: time_1_13 dominant CNR for 8 polarizations

Time_1_14

Poles	ER(VV)
-2.701±43.194	1.005
-4.749±55.679	0.05
-5.296±34.192	98.75

Poles	ER(HH)
-3.917±28.488	97.89
-5.080±42.565	2.10

Poles	ER(VH)
-2.430±54.340	0.05
-2.837±41.182	92.76
-4.387±34.829	7.23

Poles	ER(HV)
-2.701±43.194	1.005
-4.749±55.679	0.05
-5.296±34.192	98.75

Poles	ER(LL)
-4.362±27.952	99.69
-5.288±43.288	0.21
-5.689±52.100	0.0002

Poles	ER(RR)
-4.372±27.949	99.71
-5.381±43.279	0.17
-5.221±52.186	0.0001

Poles	ER(LR)
-2.531±42.689	0.097
-3.895±28.64	1.90
-4.212±36.285	97.99

Poles	ER(RL)
-3.577±33.574	99.89
-2.61±44.187	0.0001
-3.627±28.26	0.002

Table 18: time_1_14 dominant CNR for 8 polarizations

Time_1_15

Poles	ER(VV)
-2.288±53.368	0.36
-3.273±44.10	0.002
-4.839±33.065	3.99
-7.238±23.920	95.65

Poles	ER(HH)
-3.591±28.418	99.85
-4.332±51.92	0.003
-5.079±40.371	0.14

Poles	ER(VH)
-2.576±54.126	0.02
-4.845±42.016	1.03
-5.333±33.043	98.99
-5.053±23.125	0.001

Poles	ER(HV)
-2.288±53.368	0.36
-3.273±44.10	0.002
-4.839±33.065	3.99
-7.238±23.920	95.65

Poles	ER(LL)
-2.596±52.328	0.01
-3.818±28.501	97.06
-3.915±43.421	2.93

Poles	ER(RR)
-2.583±52.307	0.04
-3.820±28.499	96.35
-3.992±43.582	3.61

Poles	ER(LR)
-2.551±53.828	0.02
-3.891±28.291	1.01
-4.048±46.050	0.25
-4.893±37.523	98.53

Poles	ER(RL)
-2.125±35.603	99.72
-3.206±27.151	0.04

Table 19: time_1_15 dominant CNR for 8 polarizations

Time_1_16

Poles	ER(VV)
-2.145±53.684	0.64
-3.294±44.226	0.0002
-4.820±33.460	2.89
-7.289±27.531	96.26

Poles	ER(HH)
-3.799±45.946	0.85
-3.648±28.367	96.89
-3.288±52.143	1.96
-5.422±23.562	0.14

Poles	ER(VH)
-4.859±43.158	0.001
-5.704±33.897	99.98
-5.986±52.846	0.002
-5.987±24.856	0.001

Poles	ER(HV)
-2.145±53.684	0.64
-3.294±44.226	0.0002
-4.820±33.460	2.89
-7.289±27.531	96.26

Poles	ER(LL)
-2.749±53.149	1.125
-4.365±27.467	97.34
-2.292±43.153	0.24

Poles	ER(RR)
-2.755±53.165	1.90
-4.335±27.506	98.008
-4.745±43.903	0.17

Poles	ER(LR)
-3.3524±54.795	0.06
-3.7135±24.915	98.88
-4.325±34.523	1.01
-3.953±42.625	0.03

Poles	ER(RL)
-3.375±25.703	0.03
-4.858±37.267	98.696
-4.306±42.324	0.12
-5.134±52.79	0.98

Table 20: time_1_16 dominant CNR for 8 polarizations

Time_1_17

Poles	ER(VV)
-2.021±53.501	1.652
-3.662±42.984	0.192
-4.74±33.37	8.98
-6.846±25.359	89.17

Poles	ER(HH)
-4.928±21.325	8.03
-2.175±53.206	0.124
-4.445±41.442	0.208
-3.580±28.454	91.619
Poles	ER(VH)
-2.715±54.21	0.02
-4.751±43.632	1.23
-5.820±33.757	97.01
-5.923±26.262	1.03

Poles	ER(HV)
-2.021±53.501	1.652
-3.662±42.984	0.192
-4.74±33.37	8.98
-6.846±25.359	89.17

Poles	ER(LL)
-3.743±42.422	3.22
-4.183±33.107	96.69

Poles	ER(RR)
-3.745±42.433	2.31
-3.559±32.230	97.68

Poles	ER(LR)
-2.926±54.371	0.12
-3.582±43.278	0.03
-3.555±28.252	97.85
-3.981±37.125	1.894

Poles	ER(RL)
-3.3026±27.471	1.81
-4.551±36.793	86.93
-4.953±43.501	5.98
-3.544±54.728	5.19

Table 21: time_1_17 dominant CNR for 8 polarizations

Time_1_18

Poles	ER(VV)
-3.356±44.289	6.89
-4.609±33.605	88.21
-5.638±54.086	3.36
-9.254±26.317	1.53

Poles	ER(HH)
-3.513±28.428	11.43
-4.413±42.148	9.24
-3.638±51.230	0.006
-4.328±25.716	79.254

Poles	ER(VH)
-2.583±53.886	0.006
-4.487±43.713	2.03
-5.542±25.702	0.03
-5.543±34.373	97.21

Poles	ER(HV)
-3.356±44.289	6.89
-4.609±33.605	88.21
-5.638±54.086	3.36
-9.254±26.317	1.53

Poles	ER(LL)
-2.855±55.469	0.339
-3.822±43.241	96.9
-3.372±28.002	2.36

Poles	ER(RR)
-3.819±43.233	96.61
-3.569±27.999	2.55
-2.998±54.891	0.394

Poles	ER(LR)
-2.633±53.708	94.00
-4.295±31.732	0.027
-3.171±43.621	5.62
-4.077±28.206	0.365

Poles	ER(RL)
-3.216±55.189	91.31
-3.609±46.905	3.47
-4.668±32.381	0.041
-3.922±28.156	5.167

Table 22: time_1_18 dominant CNR for 8 polarizations

From the above tables, the most dominant poles obtained but it is time consuming process. So it is preferrable to do multiple extraction with MPM algorithm which handles multiple signals.

4.4 Multiple aspect extraction:

The CNR extracted with single transient are time consuming process. So the extraction can be done by utilizing multiple signals at once through MPM algorithm. For test case of 1m wire, the response from the two aspect 15° and 75° are processed through the Matrix pencil method and poles extraction is made. The major advantage with this method is time consumption. The extracted single set of CNRand residues for 15° and 75° are tabulated below,

MOM reference	MPM reference	MPM (m = -2 & M = 55) Poles (VAF=100%)	MPM (15°) Residues (A1)	MPM(75°) Residues(A2)
-0.260±j2.91	-0.252±j2.87	-0.2486±j2.8788	49.64	2.394
-0.381±j6.01	-0.373±j5.93	-0.3849±j5.9277	13.28	4.434
-0.468±j9.06	-0.444±j9.05	-0.4460±j9.0118	2.155	5.467
-0.538±j12.2	-0.545±j12.1	-0.5439±j12.112	11.18	7.053
-0.600±j15.3	-	-0.5769±j15.195	1.385	7.395
-0.654±j18.4	-0.881±j17.6	-0.6557±j18.340	2.993	8.509
-0.704±j21.5	-0.850±j21.6	-0.6953±j21.410	4.587	8.739
-0.749±j24.6	-	-0.7405±j24.597	3.629	8.984
-0.792±j27.7	-1.005±j28.6	-0.8161±j27.664	2.624	9.792
-0.832±j30.8	-	-0.8031±j30.869	2.131	8.679

Table 23: CNR WITH Multiple aspect (wire)

Multiple aspect extraction leads to better extraction of CNR when compared with single response extraction. When 15° aspect was under extraction, some poles are not excited and missed. But when utilising two aspect, the chances of getting poles related to target increases. Multiple extraction helps in better pole extraction and target identification.

4.5 Multiple extraction for breast volume:

The response data from the breast volume has 18 aspects with 8 different polarization. The possibilities of poles extraction can be done in two ways, Multiple aspect (18 look direction with 8 polarizations each) and polarimetric data (4 linear and 4 circular polarization for all the 18 aspects). Poles extraction with multiple aspect and polarimetric datas are tabulated below,

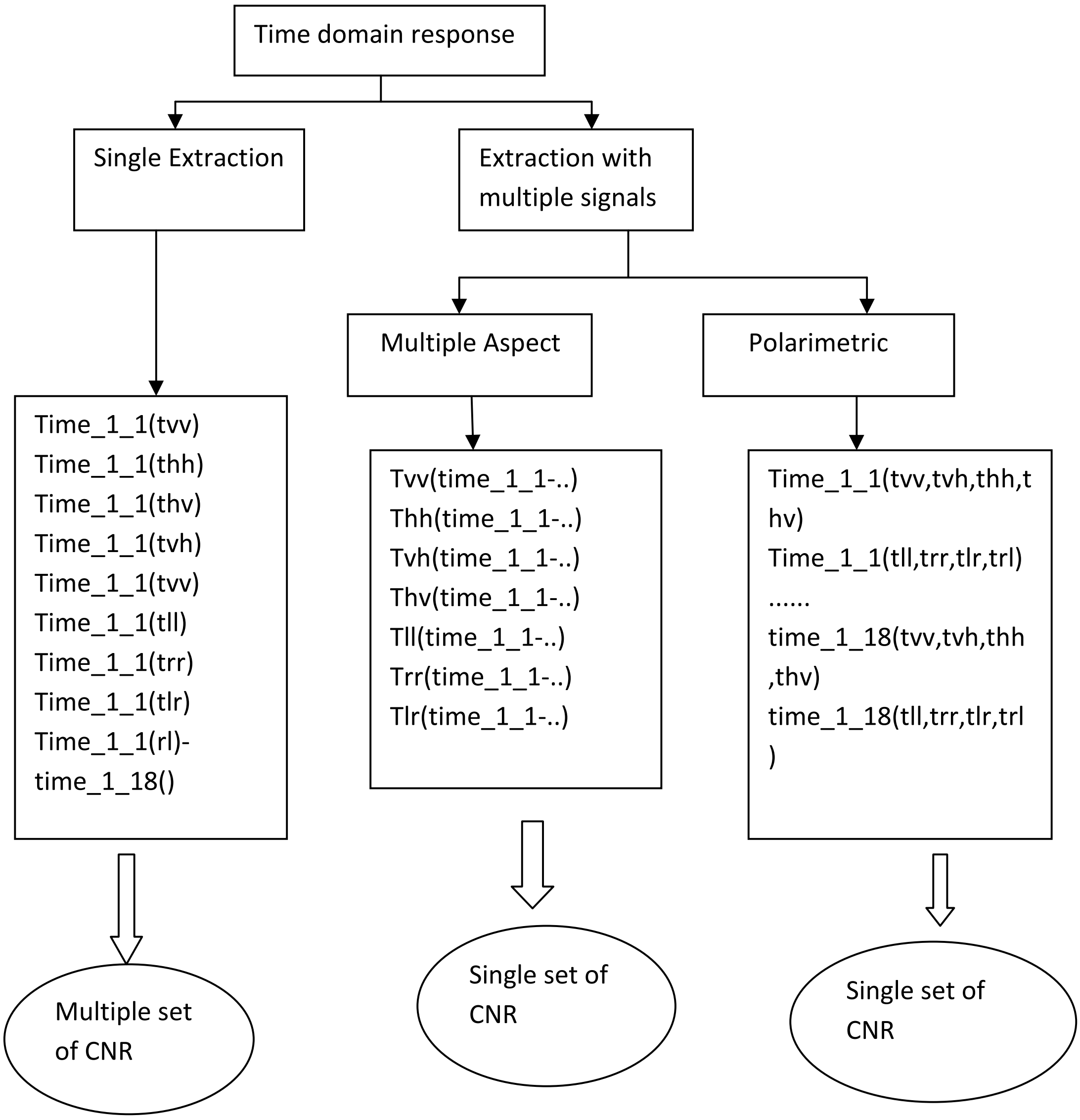

Fig5: Various ways of CNR extraction [11]

4.6 Multiple Aspect Extraction for breast tumor detection:

Poles are extracted using Multiple aspect for data time_1_1 of No tumor case are tabulated below, Time_1, TLR

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-2.764±54.105	0.04	0.0001	0.05	1.36	0.0001	0.0001	0.0001	0.0001	0.0001
-3.825±24.533	97.99	94.36	0.034	0.29	1.39	0.03	0.0000	99.48	99.87
-4.414±45.427	0.0001	2.045	22.23	0.001	0.0001	0.0001	0.15	0.49	0.089
-5.104±33.746	1.88	3.574	77.85	98.36	98.57	99.98	99.86	0.0001	0.0001

ER	ER	ER	ER	ER	ER	ER	ER	ER
0.0001	1.003	1.89	0.39	0.0001	0.02	0.059	0.12	0.32
98.54	97.85	0.0001	0.3	1.99	1.0	98.78	97.82	94.06
1.18	0.88	2.99	89.35	0.08	0.3	0.03	0.03	5.33
0.0001	0.0001	94.968	8.99	97.53	98.51	1.00	1.89	0.03

Table 24: CNR of 18 aspect with Polarization LR

Time_1,TRL

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-2.75±54.096	0.03	0.39	0.7	0.79	0.08	0.0001	0.39	1.29	0.09
-3.872±24.52	95.62	94.00	97.53	96.52	2.1	0.32	0.01	0.0001	97.86
-4.4023±45.43	0.0001	0.0001	0.002	0.02	0.07	98.39	7.89	0.53	2.00
-5.128±33.76	3.99	6.25	1.24	2.33	97.39	1.09	91.56	97.93	0.0001

ER	ER	ER	ER	ER	ER	ER	ER	ER
0.0001	0.00012	0.0001	0.0001	0.0001	0.0001	1.78	3.25	93.31
98.22	97.66	0.0001	0.0001	0.003	0.03	0.04	1.83	3.16
1.69	2.35	0.5	5.37	0.0001	0.0001	0.16	4.98	2.47
0.0001	0.0001	99.38	94.55	99.89	99.75	97.896	89.73	0.04

Table 25: CNR of 18 aspect with Polarization RL

Time_1,TLL

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-3.827 ±30.285	1.36	0.88	0.04	97.47	1.52	99.66	99.90	99.18	78.79
-3.865 ±53.399	0.83	0.65	0.0001	2.46	0.002	0.0001	0.0002	0.0002	0.01
-4.4727±43.082	97.62	98.01	99.69	0.06	98.45	0.34	0.01	0.75	20.65

ER	ER	ER	ER	ER	ER	ER	ER	ER
83.39	82.45	97.55	99.62	98.64	98.26	97.34	97.69	2.36
0.45	0.39	0.001	0.0001	0.0002	0.01	1.125	0.0001	0.33
16.10	16.98	2.34	0.3	1.26	1.73	0.24	2.22	96.9

Table 26: CNR of 18 aspect with Polarization LL

Time_1,TRR

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-3.828 ±30.275	2.36	3.44	0.04	98.47	2.59	99.70	99.91	99.09	77.79
-3.864 ±53.399	0.73	0.86	0.0001	1.46	0.002	0.0001	0.0002	0.0002	0.01
-4.4728±43.081	98.62	95.75	99.82	0.08	97.27	0.28	0.01	0.65	21.65

ER	ER	ER	ER	ER	ER	ER	ER	ER
82.41	0.04	99.35	99.52	96.64	97.26	98.34	97.71	2.22
0.25	19.49	0.001	0.0001	0.0002	0.03	1.74	0.0001	0.19
17.10	79.77	0.45	0.39	3.26	2.73	0.19	2.39	97.12

Table 27: CNR of 18 aspect with Polarization RR

Time_1_x (x = 1 to 18),TVV

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-3.338±43.8823	4.79	5.14	0.20	0.0001	0.0013	0.035	0.502	7.36	9.32
-4.501±33.2407	91.41	91.57	6.21	1.76	1.178	99.89	99.35	92.62	90.42
-2.855±53.4440	2.81	1.51	0.029	0.0005	0.003	0.08	0.0001	0.0004	0.010
-6.521±23.1334	0.98	1.7	93.56	98.23	98.89	0.0001	0.0001	0.0001	0.0001

ER	ER	ER	ER	ER	ER	ER	ER	ER
14.69	15.71	10.02	0.44	2.12	0.002	0.0002	0.189	5.77
84.99	84.02	87.77	99.46	97.75	3.79	1.89	9.98	88.32
0.23	0.26	1.20	0.0001	0.05	0.66	0.64	1.552	3.36
0.0001	0.0001	0.0001	0.0001	0.0001	95.55	97.26	88.24	1.53

Table 28: CNR of 18 aspect with Polarization VV

Time_1,THH

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-3.683±29.992	1.23	11.56	95.05	97.75	99.34	98.90	97.48	98.86	99.339
-3.692±42.001	33.62	9.822	0.958	0.06	0.0125	1.01	2.368	1.09	0.12
-3.718±52.953	0.79	0.143	1.235	2.12	0.413	0.0001	0.008	0.07	0.002
-5.444±25.195	64.17	78.46	2.56	0.03	0.0001	0.0001	0.0001	0.0001	0.0001

ER	ER	ER	ER	ER	ER	ER	ER	ER
96.88	96.34	98.86	98.48	96.90	98.358	97.254	94.016	15.565
3.04	2.97	1.02	1.375	1.582	1.118	0.2242	0.267	5.812
0.0059	0.659	0.003	0.0660	0.0001	0.412	1.390	0.004	0.143
0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.1300	5.71	78.478

Table 29: CNR of 18 aspect with Polarization HH

Time_1,TVH

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-2.655±33.219	99.43	98.96	98.91	99.75	2.05	91.98	98.04	55.98	38.112
-4.084±44.308	0.321	0.005	2.20	0.6	3.012	0.014	1.42	0.18	0.0332
-4.705±52.647	0.006	0.02	0.04	0.004	0.001	0.0002	0.009	0.0002	0.0001
-6.245±22.442	0.0016	0.65	0.0003	0.160	94.56	7.322	0.045	43.98	62.56

ER	ER	ER	ER	ER	ER	ER	ER	ER
96.96	40.23	42.66	89.56	5.96	4.01	95.883	99.90	99.96
0.0506	0.99	56.46	10.02	93.55	0.004	3.74	0.0804	0.035
0.0002	0.0003	0.0002	0.045	0.0003	0.0001	0.205	0.0002	0.0002
3.02	58.23	0.0001	0.046	0.0001	95.65	0.163	0.0001	0.0001

Table 30: CNR of 18 aspect with Polarization VH

Time_1,THV

Poles	ER	ER	ER	ER	ER	ER	ER	ER	ER
-3.338±43.8823	4.79	5.14	0.20	0.0001	0.0013	0.035	0.502	7.36	9.32
-4.501±33.2407	91.41	91.57	6.21	1.76	1.178	99.89	99.35	92.62	90.42
-2.855±53.4440	2.81	1.51	0.029	0.0005	0.003	0.08	0.0001	0.0004	0.010
-6.521±23.1334	0.98	1.7	93.56	98.23	98.89	0.0001	0.0001	0.001	0.0001

ER	ER	ER	ER	ER	ER	ER	ER	ER
14.69	15.71	10.02	0.44	2.12	0.002	0.0002	0.189	5.77
84.99	84.02	87.77	99.46	97.75	3.79	1.89	9.98	88.32
0.23	0.26	1.20	0.0001	0.05	0.66	0.64	1.552	3.36
0.0001	0.0001	0.001	0.0001	0.0001	95.55	97.26	88.24	1.53

Table 31: CNR of 18 aspect with Polarization HV

4.7 Polarimetric data

The poles are extracted for all aspect with particular polarization, when extracting the poles with particular polarization there is possibility of missing dominant poles so it is necessary to extract for all polarization in linear or circular.

Poles extracted with polarimetric data for (time_1_1 to time_1_18 for 4 linear and 4 circular polarizations) are tabulated below,

4.7.a Linear polarization for 18 aspects.(VV,HH,VH,HV)

Time_1_1

Poles	ER	ER	ER	ER
-2.433±54.888	1.64	0.75	1.06	1.98
-4.108 ±42.51	5.16	33.92	0.231	5.01
-4.6003±33.53	90.43	1.22	98.76	89.99
-3.8475±27.96	1.02	63.17	0.001	1.67

Time_1_2

Poles	ER	ER	ER	ER
-3.889±28.021	1.7	79.07	0.01	1.7
-4.797 ±33.488	90.5	12.56	98.96	90.5
-4.242±42.618	5.63	8.96	1.03	5.14
-2.559 ±54.077	1.80	0.14	0.0001	2.51

Time_1_3

Poles	ER	ER	ER	ER
-2.278±54.19	0.02	2.23	0.05	1.02
-3.871 ±28.158	92.26	2.56	0.0001	91.56
-4.538±33.707	6.21	93.05	97.85	6.21
-4.985±42.035	1.34	0.958	1.95	1.20

Time_1_4

Poles	ER	ER	ER	ER
-4.312 ±42.38	0.0001	0.06	0.02	0.0001
-5.121±32.78	3.76	95.45	98.25	3.76
-2.323±53.25	0.0005	2.12	0.924	0.0005
-3.876 ±28.18	96.23	1.03	0.001	95.23

Time_1_5

Poles	ER	ER	ER	ER
-4.231±43.66	0.0013	0.0125	0.244	0.0013
-4.323±33.255	1.178	95.34	1.30	1.178
-2.416±54.267	1.003	1.417	0.07	2.003
-3.632±28.443	97.89	1.0001	97.56	96.89

Time_1_6

Poles	ER	ER	ER	ER
-3.156 ±42.089	0.035	2.56	0.01	0.035
-4.223±35.319	98.89	0.0001	92.62	97.89
-2.445±54.86	1.08	1.0001	0.0038	1.08
-3.722±28.332	0.001	95.90	6.88	0.001

Time_1_7

Poles	ER	ER	ER	ER
-3.831±43.431	1.502	2.36	1.03	0.502
-3.510 ±33.898	97.35	97.48	97.25	99.35
-3.306±54.61	0.0001	0.0008	0.08	0.0001
-3.767±28.686	0.0001	0.0002	1.25	0.0001

Time_1_8

Poles	ER	ER	ER	ER
-3.742 ±44.19	7.36	1.09	1.56	8.36
-3.221±33.59	92.62	97.86	64.36	91.62
-2.964±54.23	0.0004	1.07	0.05	0.0004
-3.751±28.90	0.0001	0.0001	33.88	0.0001

Time_1_9

Poles	ER	ER	ER	ER
-4.120 ±44.498	9.32	0.12	2.36	9.32
-4.902±33.050	90.42	99.33	83.64	90.42
-3.545±54.732	0.010	0.0002	0.075	0.010
-4.130±29.108	0.001	0.0001	13.96	0.0001

Time_1_10

Poles	ER	ER	ER	ER
-4.1307±45.52	10.69	3.04	1.38	14.03
-5.3651±32.55	87.99	95.88	95.66	84.12
-4.117±55.256	1.23	1.005	0.09	0.23
-4.485±29.188	0.0001	0.0001	2.89	0.0001

Time_1_1 1

Poles	ER	ER	ER	ER
-4.102±44.48	15.71	2.97	1.56	15.71
-5.105±33.08	83.02	95.34	42.56	84.02
-3.553±54.735	0.26	1.659	0.06	0.26
-4.131±29.108	0.0001	0.0001	56.05	0.0001

Time_1_12

Poles	ER	ER	ER	ER
-3.815±44.246	10.02	1.02	33.59	10.02
-5.441±33.66	87.77	98.86	65.26	86.77
-3.013±54.271	1.20	0.003	0.12	2.20
-3.749±28.902	0.0001	0.0001	0.0114	0.0001

Time_1_13

Poles	ER	ER	ER	ER
-3.817±43.42	2.44	1.37	0.3	2.44
-3.51±33.590	97.46	98.04	92.36	97.46
-3.29±54.192	0.0001	0.06	0.07	0.0001
-3.758±28.688	0.0001	0.0001	6.89	0.0001

Time_1_14

Poles	ER	ER	ER	ER
-3.155±42.101	2.12	1.58	87.76	2.12
-4.238±36.142	97.43	96.90	12.212	97.75
-2.368±54.87	0.05	0.0001	0.0238	0.05
-3.706±28.33	0.0001	0.0001	0.0001	0.0001

Time_1_15

Poles	ER	ER	ER	ER
-4.126±43.595	0.002	1.118	0.023	0.002
-5.238±35.236	3.79	98.35	4.59	3.79
-2.1961±54.194	0.66	0.412	0.177	0.66
-3.635±28.45	95.02	0.0001	94.62	95.03

Time_1_16

Poles	ER	ER	ER	ER
-4.982±42.395	0.0002	0.22	0.02	0.0002
-5.123±32.838	2.89	97.25	99.63	1.89
-2.305±53.291	1.64	1.39	0.0004	0.64
-3.871 ±28.176	95.26	0.13	0.001	96.26

Time_1_17

Poles	ER	ER	ER	ER
-5.096±41.994	0.189	0.26	2.23	1.189
-4.478±33.881	9.98	94.06	96.98	9.98
-2.101±54.138	1.552	0.004	0.0032	1.552
-3.869±28.155	88.24	5.71	0.014	87.24

Time_1_18

Poles	ER	ER	ER	ER
-4.368±42.32	5.77	5.81	0.03	5.77
-4.568±33.66	88.01	15.565	98.89	87.32
-2.552±54.149	3.08	0.143	0.0898	4.36
-3.8908±28.008	2.53	78.47	0.0534	1.53

Table 32: CNR extraction with Linear polarizations

4.7.b **Circular polarization (LL, RR, LR, RL)**

Time_1_1

Poles	ER	ER	ER	ER
-3.7424±26.084	1.36	0.36	97.99	95.62
-2.621±53.958	1.83	1.05	0.04	0.03
-3.720±42.56	96.62	98.62	0.0001	0.0001
-4.146±35.463	0.0001	0.0001	1.88	3.99

Time_1_2

Poles	ER	ER	ER	ER
-3.749±28.244	0.88	3.44	94.36	92.00
-2.037±53.964	0.65	0.86	0.0001	0.39
-4.160±42.234	98.01	95.05	2.045	0.0001
-4.146±35.463	0.0001	0.0001	1.574	6.25

Time_1_3

Poles	ER	ER	ER	ER
-3.733±28.144	0.04	0.04	0.034	96.53
-2.793±54.573	0.0001	0.0001	0.05	1.7
-4.620±42.828	99.43	98.82	22.23	0.002
-4.146±35.463	0.0001	0.0001	77.85	1.24

Time_1_4

Poles	ER	ER	ER	ER
-3.778±28.204	96.47	98.02	0.29	96.52
-2.797±53.108	2.46	1.24	1.36	0.12
-4.586±41.931	0.32	0.08	0.001	0.02
-4.146±35.463	0.0001	0.0001	97.36	2.33

Time_1_5

Poles	ER	ER	ER	ER
-3.723±28.403	1.52	2.59	1.39	2.1
-2.894±54.55	0.002	0.002	0.0001	0.08
-4.028±43.751	97.45	96.27	0.0001	0.07
-4.146±35.463	0.0001	0.0001	98.57	96.39

Time_1_6

Poles	ER	ER	ER	ER
-3.673±28.372	99.66	99.70	0.03	0.32
-2.384±54.574	0.0001	0.0001	0.0001	0.0001
-3.697±41.644	0.34	0.28	0.0001	98.39
-4.146±35.463	0.0001	0.0001	99.98	1.09

Time_1_7

Poles	ER	ER	ER	ER
-3.767±28.636	99.90	99.91	0.0001	0.01
-4.147±53.36	0.0002	0.0002	0.0001	0.39
-4.947±43.648	0.01	0.01	0.15	7.89
-6.103±32.710	0.0001	0.0001	99.86	91.56

Time_1_8

Poles	ER	ER	ER	ER
-4.108±28.768	99.18	99.09	99.48	0.0001
-4.588±53.596	0.0002	0.0002	0.0001	1.29
-3.7138±40.948	0.75	0.65	0.49	0.53
-5.293±32.266	0.0001	0.0001	0.0001	97.93

Time_1_9

Poles	ER	ER	ER	ER
-4.652±28.637	78.79	77.79	99.87	97.86
-3.248±54.437	0.01	0.01	0.0001	0.09
-3.899±42.1729	20.65	21.65	0.089	2.00
-4.765±32.511	0.0001	0.0001	0.0001	0.0001

Time_1_10

Poles	ER	ER	ER	ER
-4.703±28.617	83.39	82.41	98.54	98.22
-4.405±54.268	0.45	0.25	0.0001	0.0001
-5.098±45.846	16.10	17.10	1.18	1.69
-4.829±32.582	0.0001	0.0001	0.0001	0.0001

Time_1_11

Poles	ER	ER	ER	ER
-4.649±28.626	82.45	0.04	97.85	97.66
-3.244±54.40	0.39	19.49	1.003	0.0001
-3.932±42.185	16.98	79.77	0.88	2.35
-4.744±32.498	0.0001	0.0001	0.0001	0.0001

Time_1_12

Poles	ER	ER	ER	ER
-4.065±28.88	97.55	99.35	0.0001	0.0001
-4.570±53.66	0.001	0.001	1.89	0.0001
-3.813±42.93	2.34	0.45	2.99	0.5
-5.329±32.25	0.0001	0.0001	94.968	99.38

Time_1_13

Poles	ER	ER	ER	ER
-3.764±28.641	99.62	99.52	0.3	0.0001
-4.0093±53.555	0.0001	0.0001	0.39	0.0001
-5.162±43.604	0.3	0.39	89.35	5.37
-4.523±32.814	0.0001	0.0001	8.99	94.55

Time_1_14

Poles	ER	ER	ER	ER
-3.644±28.358	98.64	96.64	1.99	0.003
-2.388±54.57	0.0002	0.0002	0.0001	0.0001
-3.697±41.641	1.26	3.26	0.08	0.0001
-4.130±33.435	0.0001	0.0001	97.53	99.89

Time_1_15

Poles	ER	ER	ER	ER
-3.731±28.416	98.26	97.26	1.0	0.03
-2.507±54.31	0.01	0.03	0.02	0.0001
-4.037±43.731	1.73	2.73	0.3	0.0001
-4.523±35.629	0.0001	0.0001	98.51	99.75

Time_1_16

Poles	ER	ER	ER	ER
-3.778±28.194	97.34	98.34	98.78	0.04
-2.798±53.10	1.125	1.74	0.059	1.78
-4.306±42.324	0.24	0.19	0.03	0.16
-4.879±33.099	0.0001	0.001	1.00	97.896

Time_1_17

Poles	ER	ER	ER	ER
-3.892±28.05	97.69	97.71	97.82	1.83
-2.738±54.57	0.0001	0.0001	0.12	3.25
-4.310±33.76	2.22	2.39	0.03	4.98
-4.752±44.256	0.0001	0.0001	1.89	89.73

Time_1_18

Poles	ER	ER	ER	ER
-4.091±28.070	2.36	2.22	94.06	3.16
-3.679±55.543	0.33	0.19	0.32	93.31
-4.127±42.525	96.9	97.12	5.33	2.47
-4.030±33.925	0.0001	0.000	0.03	0.04

Table 33: CNR extraction with circular polarizations

When the extraction is done with multiple aspect, the response signal corresponds to the target are from many look directions (here 18 look directions) and with particular polarization state. Some poles are excited at the particular polarization and some poles are excited with other. So in order to get the most dominant poles of a certain taget, the poles must be extracted for all the polarizations (Linear or circular). For instance, the poles extracted for multiple aspect (time_1_1 to time_1_18) with polarization LL, the pole 23 is missing but when it is with the polarization LR it appears and it is possible to extract the most dominant poles when we perform extraction with all polarization cases. When the polarimetric data is utilized for a specific look direction, the poles which are excited with all the polarization aspect can be extracted. So, usage of polarimetric data helps in dominant pole extraction better and time consuming.

4.8 Poles extraction for NO tumor, 10mm and 15mm tumor:

The response data from No tumor, 10mm and 15mm tumor are processed through Matrix Pencil Method. The poles are extracted for all the three cases, the poles which are extracted from no tumor data corresponds only to the breast volume, while the poles from 10mm and 15mm tumor related to both breast volume and breast tumor. The polarimetric data for all the three cases are utilsed in poles extraction are tabulated below,

Poles (No tumor, M = 16)	Poles (10mm tumor, M = 23)	Poles (15mm tumor, M = 36)
-3.742±j26.084 -2.621±j53.958 -3.720±j42.561 -4.146±j35.463	-3.357±j28,114 -2.896±j53.824 -3.353±j41.774 -4.473±j32.229 -3.473±j40.782 -2.094±j45.452	-2.6905±j27.18 -2.645±j54.387 -4.114±j42.885 -4.921±j33.954 -1.981±j40.958 -2.108±j30.193 -1.924±j51.037 -2.186±j37.381

Poles obtained in the first column corresponds to no tumor target and poles corresponds only to breast volume. In the case of 10mm and 15mm, poles are related to both breast volume and tumor. It is noticeable that there are common poles in all three cases which are related to breast volume and new poles represent the tumor.

5.Discussion:

The transient response signal from the target are processed through the MPM algorithm, the extracted CNR corresponds to the target. In order to simplify the process of CNR extraction, multiple signal from the target are processed at once through MPM algorithm which can handles more than one signal. Multiple signal may be of Multiple aspect or polarimetric, when analysing the parameter extraction with response signal from multiple look directions at particular polarization, there are some missing dominant poles since all the modes are not excited at particular polarization. So all the polarization aspects are considered for all the look directions and again it is a time consuming process. But the extracted CNR with the polarimetric data comprises of all dominant poles related to the target since all modes are excited. From the analysis, it is very clear that the polarimetric data possess the good chances of CNR etraction of breast tumor.

When the response signal from the No tumor, 10mm tumor and 15mm tumor are processed through the MPM algorithm, CNR extracted for all the 3 cases. The extracted parameter for No tumor corresponds only to the breast volume, whereas the CNR from the 10mm and 15mm tumor corresponds to the breast tumor and breast volume. Better discriminations are seen for 3 different cases of breast tumor.

6. Conclusion

Based on Singularity Expansion Method, resonance based target recognition using Complex Natural Resonance was implemented. Matrix pencil Method is the microwave technique for extraction of parameter CNR has been selected. Algorithm of Matrix Pencil Method which processes the transient response signal was developed and CNR extracted. To make the CNR extraction easy and reduce the extraction time, MPM algorithm which handles multiple signal was developed. Two different cases of multiple signals, multiple aspect and polarimetric data were utilized. CNR extraction was obtained for both the cases and the best method was analysed. Form the numerical analysis, it was shown that the polarimetric datas helps in better target recognition.

The test case of 1m wire was considered and poles are extracted using single response and multiple aspect. the breast cancer detection was made by parameter extraction of 3 different cases of breast tumor. No tumor, 10mm and 15mm tumor are considerd for parameter extraction. The extracted CNR are tabulated for all the 3 cases and dominant CNR corresponds to the breast cancer and breast volume are shown. As we could able to see the CNR corresponds to the breast tumor, it gives us a good confidence about the chances of using Ultra Wideband microwave technologies in breast tumor detection.

From the project, the clear idea of using microwave technologies for breast cancer detection and uniqueness of microwave technology were shown. As Ultra Wideband microwave technologies has consist of good positive points of non ionizing radiations, good sensitivity and find out the changes in the dielectric properties of tissues it creates the revolution in breast tumor detection. The numerical parameter CNR of the breast tumor are clearly idenified so it makes the bright chances of using this technique in breast cancer detection.

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