Contributions of Yoshio Yamaguchi’s top 10 Selected Papers with Google Scholar Citations: GSC, 2016 December 02

His major contributions are model-based scattering power decompositions, short-range FM-CW radar sensing, and wave propagation in lossy media including tunnel environs. Among them, top 8 papers are related to the model-based scattering power decomposition.


**Abstract:** A four-component scattering model is proposed to decompose polarimetric synthetic aperture radar (SAR) images. The covariance matrix approach is used to deal with the non-reflection symmetric scattering case. This scheme includes and extends the three-component decomposition method introduced by Freeman and Durden dealing with the reflection symmetry condition that the co-pol and the cross-pol correlations are close to zero. Helix scattering power is added as the fourth component to the three-component scattering model which describes surface, double bounce, and volume scattering. This helix scattering term is added to take account of the co-pol and the cross-pol correlations which generally appear in complex urban area scattering and disappear for a natural distributed scatterer. This term is relevant for describing man-made targets in urban area scattering. In addition, asymmetric volume scattering covariance matrices are introduced in dependence of the relative backscattering magnitude between HH and VV. A modification of the probability density function for a cloud of dipole scatterers yields asymmetric covariance matrices. An appropriate choice among the symmetric or asymmetric volume scattering covariance matrices allows us to make a best fit to the measured data. A four-component decomposition algorithm is developed to deal with a general scattering case. The result of this decomposition is demonstrated with L-band Pi-SAR images taken over the city of Niigata, Japan.

This paper is the original “Four-component scattering power decomposition” in which the helix scattering is added, and is known as **Y40 decomposition.**


**Abstract:** This paper presents an improvement to a decomposition scheme for the accurate classification of polarimetric synthetic aperture radar (POLSAR) images. Using a rotation of the coherency matrix to minimize the cross-polarized component, the four-component scattering power decomposition is applied to fully polarimetric SAR images. It is recognized that oriented urban area and vegetation signatures are decomposed into the same volume scattering mechanism in the previous decompositions and that it is difficult to distinguish vegetation from oblique urban areas with respect to the radar direction of illumination within the volume scattering mechanism. It is desirable to distinguish these two scattering mechanisms for accurate classification although they exhibit similar polarimetric responses. The new decomposition scheme by implementing a rotation of the coherency matrix first and, subsequently, the four-component decomposition yields considerably improved accurate results that oriented urban areas are recognized as double bounce objects distinguishable from volume scattering.

This paper contributed significantly to the polarimetric scattering power decomposition and its accuracy improvement using rotation of coherency matrix, based on the minimization of HV component. This improvement of decomposition scheme resulted in **Y4R method.**


**Abstract:** A four-component decomposition scheme of the coherency matrix is presented here for the analysis of polarimetric synthetic aperture radar (SAR) images. The coherency matrix is used to deal with non-reflection symmetric scattering case, which is an extension of covariance matrix approach. The same decomposition results have been obtained based the coherency matrix as for the Y40 model. The advantage of this approach is explicit expressions of four scattering powers in terms of scattering matrix elements, which serve for the interpretation of polarimetric SAR data quantitatively.
This letter showed the equivalence of the covariance matrix decomposition approach and the coherency matrix approach and some advantages of coherency matrix formulations, providing an easy and straightforward implementation of the Y4O, which is further transferred to the Y4R model.


Abstract: It is important to monitor environmental changes of the Earth's cover by remotely sensed data. This paper analyzes seasonal changes of a wetland by a modified polarimetric four-component scattering power decomposition method. The data sets analyzed here are L- and X-band fully polarimetric synthetic aperture radar (POLSAR) data, which have been acquired by the NICT/JAXA airborne polarimetric and interferometric synthetic aperture radar system in 2004. Since there existed a deficiency in the currently adopted decomposition schemes in that negative powers appear in a few pixels in the image analysis, we modified the approach taking into account physical conditions. It is shown with the modified scheme that the seasonal changes and features of the vegetation near Sakata Lagoon in Niigata, Japan, are observed clearly, demonstrating the utility of POLSAR image analysis for wetland assessments in general.

This paper modified the Y40 decomposition scheme, especially the negative power problem, and showed the agreement of decomposition images with actual ground truth data acquired with Pi-SAR system; and it represents an improved version of the Y40 Model.


Abstract: In the three- or simplified four-component decompositions, polarimetric scattering properties and corresponding physical scattering models play essential roles for power decomposition. This letter proposes an improved four-component scattering power decomposition method that employs a suitable volume scattering model for single- or double-bounce scattering in the polarimetric synthetic aperture radar image analysis. The cross-polarized HV component is created by both single-bounce object (such as vegetation) and double-bounce structures (such as oriented building blocks). It has been difficult to discriminate these two objects (vegetation against oriented buildings) in the decomposed images since the HV component is assigned to the volume scattering due to vegetation only. It is proposed to extend the volume scattering model suited for two physical scattering models. It is shown that a vegetation area and an oriented urban building area are well discriminated compared to those resulting from the implementation of the existing four-component scattering power decompositions Y40 and Y4R.

A decomposition improvement was applied to Y4R and resulted in S4R, which enabled to distinguish the HV component of buildings from that of vegetation. This method is referred as the S4R model.


Abstract: This paper presents a new general four-component scattering power decomposition method by implementing a set of unitary transformations for the polarimetric coherency matrix. There exist 9 real independent observation parameters in the 3 x 3 coherency matrix with respect to the second order statistics of polarimetric information. The proposed method accounts for all observation parameters in the new scheme. It is known that the existing four-component decomposition method reduces the number of observation parameters from 9 to 8 by rotation of the coherency matrix, and that it accounts for 6 parameters out of 8, leaving 2 parameters (i.e., real and imaginary part of $T_{13}$ component) un-accounted for. By additional special unitary transformation to this rotated coherency matrix, it became possible to reduce the number of independent parameters from 8 to 7. After the unitary transformation, the new four-component decomposition is carried out that accounts for all parameters in the coherency matrix including the remaining $T_{13}$ component. Therefore, the proposed method makes use of full utilization of polarimetric information in the decomposition. The decomposition also employs an extended volume scattering model, which discriminates the volume scattering between dipole and dihedral scattering structures caused by the cross-polarized HV component. It is found that the new method enhances the double bounce scattering contributions over the urban areas compared to those of the existing four-component decomposition, resulting from the full utilization of polarimetric information.
By using double unitary transformations, this G4U method accounts for all relative polarimetric information into scattering power decomposition. This method is named as the **G4U model**.


**Abstract:** This paper presents scattering power decomposition images of fully polarimetric synthetic aperture radar (SAR) data for disaster monitoring. Utilization of fully polarimetric data can derive full color images with red–green–blue color coding, red for the double-bounce power, green for the volume scattering power, and blue for the surface scattering power, for which each color brightness corresponds to the magnitude. Since disaster events cause the changes of each scattering power, it becomes straightforward to recognize the changes of the color in the polarimetric decomposed images provided time series data sets are made available.

After applying the four-component scattering power decomposition (Y4R/S4R) to fully polarimetric image data sets acquired with the Advanced Land Observing Satellite (ALOS) Phased-Array-type L-band SAR (PALSAR), several images are presented for natural disaster monitoring of volcanic activity, snow accumulation, landslides, and tsunami effects caused by great earthquakes. It is seen in the polarimetric decomposition images that the surface scattering power becomes predominant in most disaster areas compared to those in normal situations.

The changes caused by the 2011 East Japan Great Earthquake were observed by ALOS-PALSAR. This paper deals with the decomposition results obtained with the Y4R models in utilizing the available ground truth records, in addition to other monitoring results using full color decomposition images.


**Abstract:** In this paper, a general scheme for complete model-based decomposition of the polarimetric synthetic aperture radar (POLSAR) coherency matrix data is presented. We show that the POLSAR coherency matrix can be completely decomposed into three components contributed by volume scattering and two single scatterers (characterized by rank-1 matrices). Under this scheme, solving for the volume scattering power amounts to a generalized eigen-decomposition problem, and the nonnegative power constraint uniquely determines the minimum eigenvalue as the volume scattering power. Furthermore, in order to discriminate the remaining components, we propose two approaches. One is based on eigen-decomposition, and the other is based on model fitting, both of which are shown to properly resolve the surface and double-bounce scattering ambiguity. As a result, this paper in particular contributes to two pending unresolved needs for model-based POLSAR decomposition. First, it overcomes the negative power problems, i.e., all the decomposed powers are strictly guaranteed to be nonnegative; and second, the three-component decomposition exactly accounts for every element of the observed coherency matrix, leading to a complete utilization of the fully polarimetric information.

This hybrid (model-based and eigenvalue) method overcomes negative power problems and accounts for every element of the observed coherency matrix, leading to a complete utilization of the fully polarimetric information. This method is named as the **C3D model**.


**Abstract:** A real aperture FM-CW radar system was developed for the detection of objects buried in and under heavily wet snow pack. This radar uses the L band microwave frequency with a maximum output power of 100 mW, and utilizes digital signal processing techniques. A laboratory simulation and two field experiments were carried out to detect and map various objects embedded in the snowpack. It was possible to map a metallic pipe 3 cm in diameter at a depth of 70 cm and a 10x60 cm metallic plate at depth of 90 cm in the natural wet snowpack. Fundamental detection results are demonstrated in this paper taking into account a wide range of verified wet snow conditions.

A Hand-held FMCW radar system was developed and applied to actual detection of objects buried in snowpack. The effectiveness was confirmed.

**Abstract:** This paper presents the principle of the synthetic aperture frequency modulated continuous wave (FMCW) radar and demonstrates the detection results of several objects buried in natural snowpack using the radar system. First, the synthetic aperture radar system is explained with emphasis placed on showing that the Fourier-transformed beat signal obtained by the FMCW radar system is equivalent to one kind of Fresnel hologram, which enticed us to make use of SAR techniques. Then a radar system operative in the microwave L-band is designed and explored for detecting objects buried in natural snowpack. Several detection results are presented demonstrating the potential capability of high resolution imaging in the azimuthal direction, comparing it with real aperture images.

This paper showed and realized a synthetic aperture FMCW radar system. Since FMCW radar systems are suitable for near range sensing and are cost-effective, those serve various applications such as detection of buried objects. This principle was further extended to realize fully polarimetric FMCW radar systems, known as the YY-POL-FMCW sensors.

For the reference, Google Scholar summary page is:
http://scholar.google.com/citations?hl=en&user=J7G1ys4AAAAJ&view_op=list_works

***********

It should be noted here that various important contributions of Professor Yoshio Yamaguchi’s Laboratory have been cited in Japanese, and here one outstanding paper is added as an example:


**Abstract:** The Sinclair scattering matrix is defined in a fixed radar range. If a radar target extends in the range direction, the reflected signal or the compound scattering matrix will undergo interaction of multiple reflections. Since scattering matrix is subject to target parameters such as shape, size, orientation, material, and radar parameters as frequency, polarization, and incidence angle, it is difficult to specify a representative scattering matrix of a general target. Therefore we choose the simplest target, wire, and its scattering matrix to examine the effect of targets aligned in the range direction with respect to the compound scattering matrix. First, we present a simple formula for the compound scattering matrix of wires with the phase difference due to spacing. Then, we employed the FDTD method to examine the scattering phenomena, changing the spacing in the range direction. The FDTD result reveals that two wires can become sphere (plate) and dihedral corner reflector (diplane) component generators; and that four wires can become a good helix component generator. These phenomena are verified with a laboratory measurement. From the result, the target decomposition should be carefully carried out in terms of range. If a range resolution of a radar is not high enough, the scattering matrix of the desired target may be affected by the targets behind.

This paper has been published in IEICE Transactions of Japan and is not cited in Google Scholar. However, it is a basic and important contribution to polarimetry and therefore needs to be included here. It treats a basic scattering mechanism aligned in the range direction and proves that any compounded scattering matrix can be realized by combination of several targets along range as is being applied currently to a most recent extension 6SD {submitted to IEEE-TGRS} of the Y4R, G4U [6] and S4R [5] schemes. The coherent sum of scattering matrices yields some compounded scattering matrices of relevance in remote sensing of natural and manmade scattering scenarios, which has been confirmed by FDTD simulations and laboratory experiments, for example, the Helix target was realized by a combination of oriented dipoles clarifying many queries about the existence of the helix scattering model in polarization radar theory and applications.

**VERIFICATION OF DECOMPOSITION MODELS**

In order for verifying the efficiency of the developed Decomposition Models, San Francisco images by ALOS are attached for reference.