Diagnosis of Delusion and Hallucination from Schizophrenia Patient Using RADWT

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Abstract

In this paper, early detection of schizophrenia types such as hallucination and delusion propose through the high Q-factor of RADWT in EEG signal acquired during the cognitive task of the patient. The earlier diagnose obtains from the energy distribution of the EEG signal in the high resolution via optimum tuning in dilation factor, which influences the Q-factor, redundancy and ringing in the EEG signal. The early detection of type of schizophrenia prevents the illness progression and lifelong disease. In existing clinical trial, the psych clinician diagnose only the schizophrenia disease through the standard DSM screening question and Prodromal signs checklist according to the standard of American Psychiatric Association. Furthermore, clinician tries to diagnose the disease through brain imaging and EEG signal. However, procedure in the diagnosis of Schizophrenia possible only in the acute stage, minimum after 2 years of illness progression and still sub classification of the type of schizophrenia is a challenging task. In the proposed system, we acquire EEG signal during the three conditions such as reverse counting of the number, screening questions (DSM), and eye rest state with a distance of 1-m part of the clinician and patient to analyse cognitive behaviour. From the result of 25 patients EEG, signal during cognitive task show the different sub band energy pattern in RADWT to distinguish hallucination and delusion patient exactly for 21 patients and provide 84% of accuracy in sub-classification of type schizophrenia.

Keywords ECG · RADWT · Hallucination · Schizophrenia

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Introduction

A mental disease arises due to illness in the brain, which causes the problem in thinking, emotion, behaviour and make hard to cope with the life for ordinary demands. The mental health affect due to the genetic, brain structure, chemistry, and trauma. The mental disorder, broadly classifies as Anxiety disorders and mood disorders. Anxiety disorder classifies as Obsessive-compulsive, traumatic stress, panic, post-traumatic stress disorder. The mood disorder classifies as depression and bipolar depression. In this world, 10% of adults affect with mood disorder and 18% of adults with anxiety disorder. Furthermore, the mental illness among the people in this world tends to the higher rate, when compare to other diseases such as cancer, diabetes and heart problems. In addition, schizophrenia mental disorder disease never diagnose from blood test or medical imaging. The schizophrenia diagnose through the physical exam, psychiatric evaluation and Diagnostic and statistical manual of Mental Disorders

(DSM-5). The schizophrenia classify as Paranoid, disorganized, catatonic, residual, schizoaffective disorder and undifferentiated. The Paranoid schizophrenia persons suspect others; pose more delusion, and Hallucination. The Disorganized Schizophrenia persons show the mood and emotions, which are not appropriate to the situation with absent of Hallucinations. The catatonic schizophrenia persons are always negative and isolated. The residual schizophrenia persons never suffer from delusions, hallucinations, or disorganized speech, still lack in interest and motivation in day-to-day activities. The schizoaffective disorder persons endure to the mood disorder such as a major depression, mixed or bipolar mania. The undifferentiated schizophrenia never meets the above types and shows the features of more than one of the above types with unclear predominance of a particular type of character. Schizophrenia persons show two types of symptoms for diagnosis such as the characteristic and cognitive symptoms. In the characteristic symptoms, persons suffer from delusions which involves belief in false strongly without any valid evidence. The symptoms of Hallucination are classified as the visual, auditory, Olfactory Gustatory. The symptoms are disorganized speech, grossly disorganized behaviour, and negative symptoms. In addition, the cognitive symptoms are slow, disorganised thinking, difficulty understanding, poor concentration and memory, difficulty expression and integrating thoughts.

In the low and middle-income countries, the percentage of mental disorder without any treatment is about 76% to 85% and 55% in the high-income countries. However, the clinician finds difficulty in diagnosing the mental disorder especially Schizophrenia due to non-availability of physical tests. Schizophrenia often shows many symptoms with other disorders, which lead the erroneous diagnoses by the clinician. The Nation depression and bipolar support alliance survey shows an average delay of 10 years form the first onset of symptoms to the correct diagnosis of schizophrenia disorder.

A recent screening test detect acute Schizophrenia person but never in the earlier stages. The recent screening test includes of Brain imaging, smell test and EEG schizophrenia test moves closer. The earlier detection of the Schizophrenia disease helps low incidence and prevalence of the florid episode in Schizophrenia patients. The delay in Schizophrenia detection leads longer time for the patients to remit and less measure completion of their remission. The earlier detection of the exact type of Schizophrenia leads to lower symptomatic and rapid response to treatment. In this paper, the author proposes RADWT algorithm for the diagnosis of various types of Schizophrenia disease such as Hallucination and delusional memory, a type of delusion. The hallucination and delusional memory disease are diagnosed through EEG acquired during the screening question, resting state and reverse counting of numbers. The acquired EEG signal is processed through the

RADWT algorithm for energy distribution and classification of the disease from the signal pattern.

Contributions

i.   The EEG signal is acquired from the frontal lobe with two electrodes. EEG for cognitive change in brain is developed via screening question, reverse counting of the number from 100 and the brain being in rest state.
ii. The optimum Q-factor is analysed via changing the p,q and s parameter for high resolution in RWDT. In addition, EEG signal energy subband is extracted to keep earlier diagnoses of Hallucination and delusion.
iii. The results with the clinical traits are compared and validated energy distribution is classified.

Related work

Recently clinicians in the medical field never use the physical or lab test for the correct diagnosis of schizophrenia, but the clinicians diagnose only through clinical symptoms. However, Researchers evaluate the possible physical test such as eye-tracking, brain imaging, smell test and IQ test for identifying Schizophrenia. Still all the above tests are in the trial stages only. A few clinicians adopt such tests. They detect schizophrenia in a person through the screening questions that shown in Table 1. In addition to screening, clinicians train to make identification through the eight warning sign of schizophrenia as shown in Table 2.

Table 1   Schizophrenia Clinician's questions for screening patients

A 10-question screening (10-QS)

1. How have you been sleeping in the past week? Any difficulties in getting sleep? Waking up early?
2. Have you lost your appetite recently? Weight loss of 2 or more kilograms?
3. Have you experienced loss of energy or interests recently?
4. Have you been worrying a lot about everyday problems?
5. Have you had any difficulty in concentrating on reading or watching television? Have you been more forgetful than usual?
6. How do you see the future? Do you ever feel that life is not worth living? Have you ever felt you would like to end it all?
7. Have you any odd habits, like checking or cleaning more than other people?
8. Have you ever had attacks of palpitations, sweating, shaking, or dizziness accompanied by feelings of intense fear?
9. Has anybody commented that your speech has become odd or difficult to understand?
10. Have you ever had the experience of hearing any voices speaking when nobody seems to be around?

Table 2   Warning sign for Schizophrenia symptoms

Prodromal signs checklist

Onset of one of the following without explanation:

1. Marked peculiar behaviour

2. Inappropriate, or loss, of expression of feelings

3. Speech that is difficult to follow

4. Marked lack of speech and thoughts

5. Marked preoccupation with odd ideas

6. Ideas of reference -- things have special meanings

7. Persistent feelings of unreality

8. Changes in the way things appear, sound, or smell

Most of the clinicians label the psychotic disorder patients possess either to schizophrenia or bipolar disorder. The correct diagnosis of schizophrenia is still a challenging task and earlier detection of schizophrenia helps the people in getting short term recovery. However, the average waiting time for the diagnoses of schizophrenia is about 18 months and then the treatment starts. The treatment taken after long time leads to lifelong disease for the patients. The earlier diagnosis plays a vital role in mental order disease provides a American Psychiatric Association in obviating lifelong disease and getting a cure within a short period. The eight warning sign outline from the DSM-III (American Psychiatric Association 1980) and shown in Table 2.

Cognitive and EEG

The cognitive brain behaviour analysis through EEG signal is an efficient and inexpensive method. The EEG signal provides details relating to the relationship between the brain activity and memory performance. The EEG signal pattern changes due to a fast shift in brain functions, postsynaptic and cognitive processing. EEG signal of the cognitive process to diagnose schizophrenia depends on the appropriate task, the number of electrodes, identification of artefacts and data analyses. The Table 3 shows the existing procedure in the diagnose of the schizophrenia disease.

EEG acquisition for hallucination and delusion

The EEG signal with frequency and transform algorithms helps diagnosis of the high prevalence or high-risk schizophrenia. The hallucination and delusion in schizophrenia classification is a challenging task for clinicians. Hallucination such as auditory, visual, olfactory, gustatory, and tactile occurs

Table 3   Existing procedure in the diagnose of the schizophrenia disease

S.No	Authors	Schizophrenia diagnose procedure	Sensor/clinical trials	Type of Schizophrenia identified
1	Haichun Liu et.al (2018) [1]	EEG data-driven supervised learning method identifies the mental status of schizophrenia patient	EEG power and coherence	Only schizophrenia diagnosed
2	Lara N et al. (2016) [2]	Investigates mismatch negativity (MMN) as a potential biomarker	EEG located in Fz, Cz, Pz.	High Risk Schizophrenia
3	Élisabeth Thibaudeau et al. (2017) [3]	Patients are asked to read short stories aloud and to answer one or two questions that require taking into account the characters' mental state (i.e., their intentions, beliefs, or emotions	Questions and rating the answer	Schizophrenia (associated with deficits in Theory of mind (ToM))
4	Michael Rehse et.al (2016) [4]	Data from 458 psychiatric out patients (2004–2010) neuropsychological Testing in two-hour morning sessions as part of clinical routine.	Principle component analysis/Verbal Learning and Memory Test	schizophrenia (cognitive impairment)
5	Stéphane Potvin et.al (2018) [5]	Scanned for fMRI during performing the Balloon Analogue Risk Task	fMRI images during task	High prevalence of suicidal ideas/attempts in schizophrenia
6	Thilakvathi B et.al (2017) [6]	The 23 channel Brain Clarity-Brain Tech+40 equipment is used for recording EEG at FP2, F4, C4, P4, F8, T4, T6, O2, FP1, F3, C3,P3, F7, T3, T5 and O1 positions of International standard 10–20 system using mono polar montage with linked ear as reference.	EEG-during rest and mental activity i.e. EEG recording during conventional and stimulus presentation (pictures display in windows media player)	No Sub classification
7	*Proposed system*	*EEG to Study Cognitive Development and psychology*	*2-Electrode EEG-fp1 and fp2*	*Earlier diagnosis of Schizo affective-Hallucination and Delusional memory*

in the sensory modality. A patient with auditory hallucination (AH) hears two or many voices in running commentary of about 60%–90% cases. AH voice includes human voice, animal noises, music and environmental sounds. Delusion occurs due to a false belief and leads to misinterpretation experiences. Delusions are classified as persecutory somatic religious, referential and grandiose. Electrodes and the state of the patient play a vital role in distinguishing between delusion and hallucination. The EEG electrode cap provides different signals for various locations. For AH, EEG electrode in all the location of the brain never provides efficient result. The EEG signal acquired for FP2 and F4 lobe is shown in Figs. 1 and 2 respectively.

Electrodes are placed in the frontal lobe for helping classification the AH EEG signal. In the frontal lobe, the inferior frontal gyrus area plays a vital role in the motor syllable. The frontal gyrus area acts mostly when the vocal tract opens and closes during the syllable production in the vocal tract. The front vocal tract has an indirectly interaction with the motor cortex. In addition, phonological and arithmetic processing is involved in the interior frontal gyrus and angulargyrus for cortical activation such as subtraction, multiplication and phonology [8]. EEG signal from the inferior frontal region provide better AH classification than from the other regions namelyparietal, limbic, and striatal regions. The frontal lobe has an influence on the delusion in Schizophrenia patients [7]. The delusion damages the structure in the frontal region due to organic delusion syndromes. The frontal region plays a vital role in the schizophrenic symptomatology and appears as a significant component for the pathophysiology of schizophrenia [9]. This paper encourages the use of the signals from the two electrodes in the frontal region of the brain for the purpose of classification of delusion and hallucination. The EEG electrode is placed in the region of fp1 and fp2 for acquisition of signal to distinguish the delusion and hallucination signal patterns. However, the method of acquisition of signal varies between the hallucination and delusion. For hallucination, the EEG signal obtained in the resting state of the patients is eye closed in awakened state and not fallacy in sleep for a period of 15 s. Normally, the delusion patient avoids consultation with psychiatrists or general practitioners and loses faith
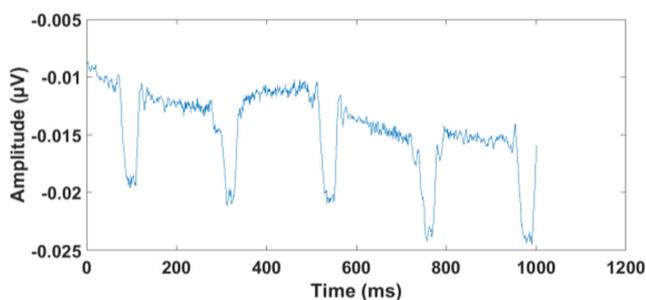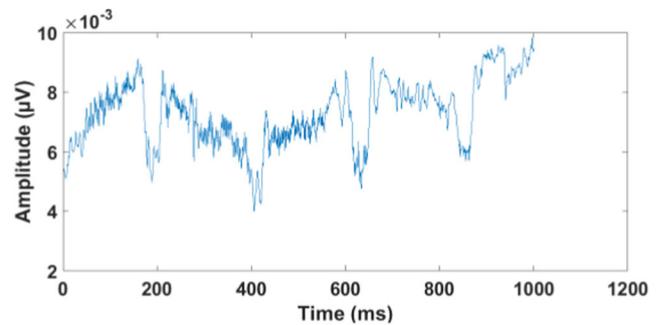

Fig. 1 EEG signal at FP2

Fig. 2 EEG signal at F4

in professional medicine. The Delusion patient shows the symptoms related to mood such as anger, paranoid ideas, and aggression [delusion infestation]. The EEG signal for delusion is obtained during the question screening. Both delusion and hallucination patients are asked to say the number from 100 to one in the reverse order with the Eye closed condition. The Fig. 3 shows the EEG signal acquisition via Digital Class-B Power amplifier. The class-B amplifier filters the wave harmonics and the artefacts in the EEG signal which does the processing via Rational Dilation Wavelet Transform (RADWT), for high-frequency resolution [10].

RADWT for EEG signal

The RADWT extracts the energy features of sub band EEG signal for the classification delusion and hallucination of the disease. However, the existing discrete wavelet transform provides better results in low frequency resolution in an oscillatory signal. The DWT is limited to redundancy and application for the de-noising of the EEG signal. DWT shows redundancy and poor resolution in high frequency signal due to the scaling and shifting factors. The problem of redundancy and poor resolution is solved through RADWT in EEG signal.

The synthesis and analysis of filter bank of the proposed RADWT is as in Fig. 3.

The dilation factor is a rational Number of q/p. However, RADWT's basic functionality is Filter Bank. The p, q and s represent the positive integers to satisfy $1 \leq p \leq q$ and $p/q + 1/s \geq 1$.

The coprime is p and q. Furthermore, the Fig. 4 show the one channel of rational filter.
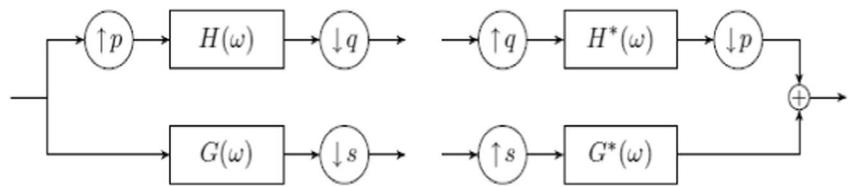
The Perfect Reconstruction (PR) of RADWT attains with the FFT, so the PR condition in frequency domain. Furthermore, for the system in Fig. 4 has

$$U(\omega) = X(a\omega) \tag{1}$$

Where,

$X(a\omega)$ represents input to the single channel rational filter bank.

Figure 3 synthesis and analysis of filter bank

$$V(\omega) = \frac{1}{b}\left[F(\omega)U(\omega) + F\left(\omega+\frac{2\pi}{b}\right)U\left(\omega+\frac{2\pi}{b}\right) + \cdots + F\left(\omega+(b-1)\frac{2\pi}{b}\right)U\left(\omega+(b-1)\frac{2\pi}{b}\right)\right]F^*(\omega) \quad (2)$$

Subtitling the eq. 2 in the eq. 3

$$Y(\omega) = \frac{1}{a}\left[V\left(\frac{\omega}{a}\right) + V\left(\frac{\omega}{a}+\frac{2\pi}{a}\right) + \cdots + V\left(\frac{\omega}{a}+(a-1)+\frac{2\pi}{a}\right)\right] \quad (3)$$

Where,

$Y(\omega)$ represents output of single channel rational filter bank.

$$U\left(\frac{\omega}{a}+k\frac{2\pi}{b}+n\frac{2\pi}{a}\right) = X\left(\omega+ak\frac{2\pi}{b}\right) \quad (4)$$

After substituting eq. 4, yields eq. 5

$$Y(\omega) = \sum_{k=0}^{b-1}C_k(\omega)X\left(\omega+ak\frac{2\pi}{b}\right) \quad (5)$$

When

$$C_k(\omega) = \frac{1}{ab}\left[F\left(\frac{\omega}{a}+k\frac{2\pi}{b}\right)F^*\left(\frac{\omega}{a}\right) + F\left(\frac{\omega}{a}+k\frac{2\pi}{b}+\frac{2\pi}{a}\right)F^*\left(\frac{\omega}{a}+\frac{2\pi}{a}\right) + \cdots F\left(\frac{\omega}{a}+k\frac{2\pi}{b}+(a-1)\frac{2\pi}{a}\right)F^*\left(\frac{\omega}{a}+(a-1)\frac{2\pi}{a}\right)\right] \quad (6)$$

The eq. 3 now provide the filter bank output as in eq. (7)

$$Y(\omega) = \sum_{k=0}^{q-1}L_k(\omega)X\left(\omega+pk\frac{2\pi}{q}\right)$$
$$+ \sum_{k=0}^{s-1}M_k(\omega)X\left(\omega+k\frac{2\pi}{s}\right) \quad (7)$$

Where in the Lk and Mk as in eq. 8 and 9

$$L_k(\omega) = \frac{1}{pq}\sum_{n=0}^{p-1}H\left(\frac{\omega}{p}+k\frac{2\pi}{q}+n\frac{2\pi}{p}\right)H^*\left(\frac{\omega}{p}+n\frac{2\pi}{p}\right) \quad (8)$$

$$M_k(\omega) = \frac{1}{s}\left[G\left(\omega+k\frac{2\pi}{s}\right)G^*(\omega)\right] \quad (9)$$

The RADWT in the frequency domain is as below in the eq. (1)

$$\psi(\omega) = \lim_{j\to\infty}\left(\frac{p}{q}\right)^{\frac{j}{2}}G_j\left(\left(\frac{p}{q}\right)^j\omega\right) \quad (10)$$

The RADWT redundancy of the transform define as the iterated FB with stages of j and eq. (2) show the no of analysis of filter bank coefficients per input sample

$$Red_{j(p,q,s)} = \frac{1}{s}\frac{1-(p/q)^{j+1}}{1-p/q} + \left(\frac{p}{q}\right)^{j+1} \quad (11)$$

Moreover, the reductant of the wavelet transform of iterated filter banks

$$Red_{(p,q,s)} = \lim_{j\to\infty}Red_{j(p,q,s)} = \frac{1}{s}\frac{1}{1-p/q}$$
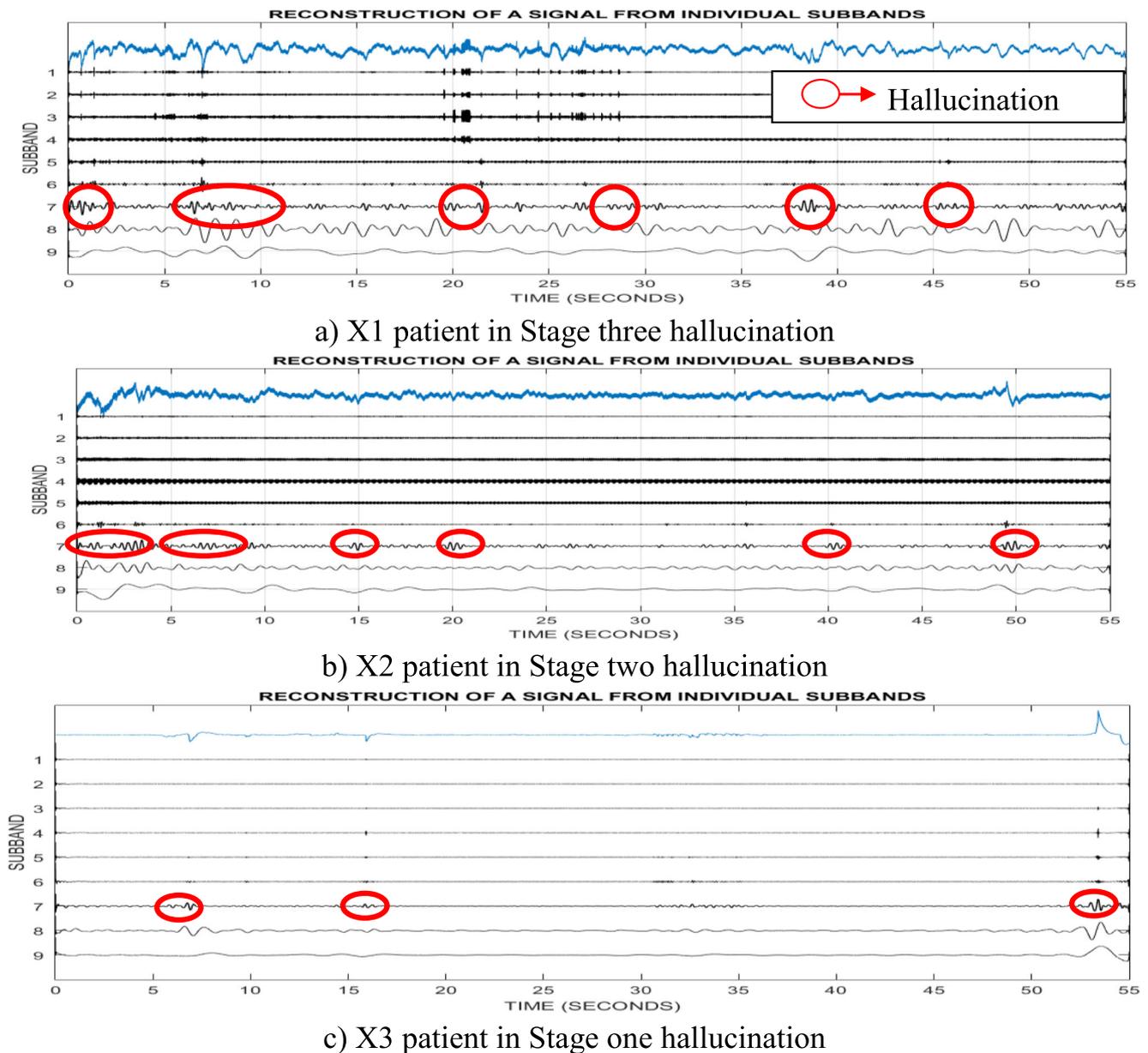
For the filter bank of single channel rational as in Fig. 4, in which the filters achieve PR with non-zero rational transferring function and with $p + 1 = q = s$ condition. The condition shows the filter bank in orthonormal. Furthermore, to attain perfect reconstruction filter in the over complete condition, the filter never possess the rational transfer functions.

Figure 4 single channel rational filter bank
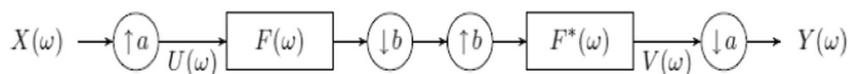
Table 4 Patient characteristics

Patient ID	Gender (M/F)	Age (Years)	Age at onset (years)	Height (cm)	Year since first symptom	No. of hospitalizations
1	M	40	35	162.56	5.7	2
2	M	45	33	155.4	14	1
3	F	36	34	158.94	3.2	1
4	M	28	22	164	7.2	3
5	M	42	38	175	5.6	2
6	F	36	30	160	8	1
7	F	44	40	150	4.5	2
8	M	50	46	171	4.9	1
9	M	32	28	168	5.3	2
10	F	57	52	155	6.5	2

a) X1 patient in Stage three hallucination

b) X2 patient in Stage two hallucination

c) X3 patient in Stage one hallucination

Figure 5 EEG Signal classification of hallucination patients in the resting state (Eye closed) through RADWT

Energy extraction in EEG signal of schizophrenia patients

EEG signal consists of rhythmic and transient signals in superposition. The rhythmic signal consists of alpha, theta etc., range frequency and with other several frequency bands. The transient consist of signal of non-rhythmic activity such as spikes, spindles and vertex waves vary in different amplitude and duration. The rhythmic component consists of both low and high frequencies and the transient component never has single frequency. Furthermore, the rhythmic and transient component always overlap in frequency and time. Moreover,

the RADWT decomposed signal tacks the power of specific frequency band at time and diagnose the synchrony changes in the frontal lobe due to the different mental task for delusion and hallucination. The EEG signal acquired from patient and their characteristics is given in Table 4.

Hallucination and delusion signal pattern analysis

The Fig. 6 shows the RADWT processed EEG signal, which classify hallucination patients in three different stages such as stage one, stage two, and stage three. The Fig. 5(a) shows the stage three, 5(b) stage two and 5(c) stage one. In the stage three
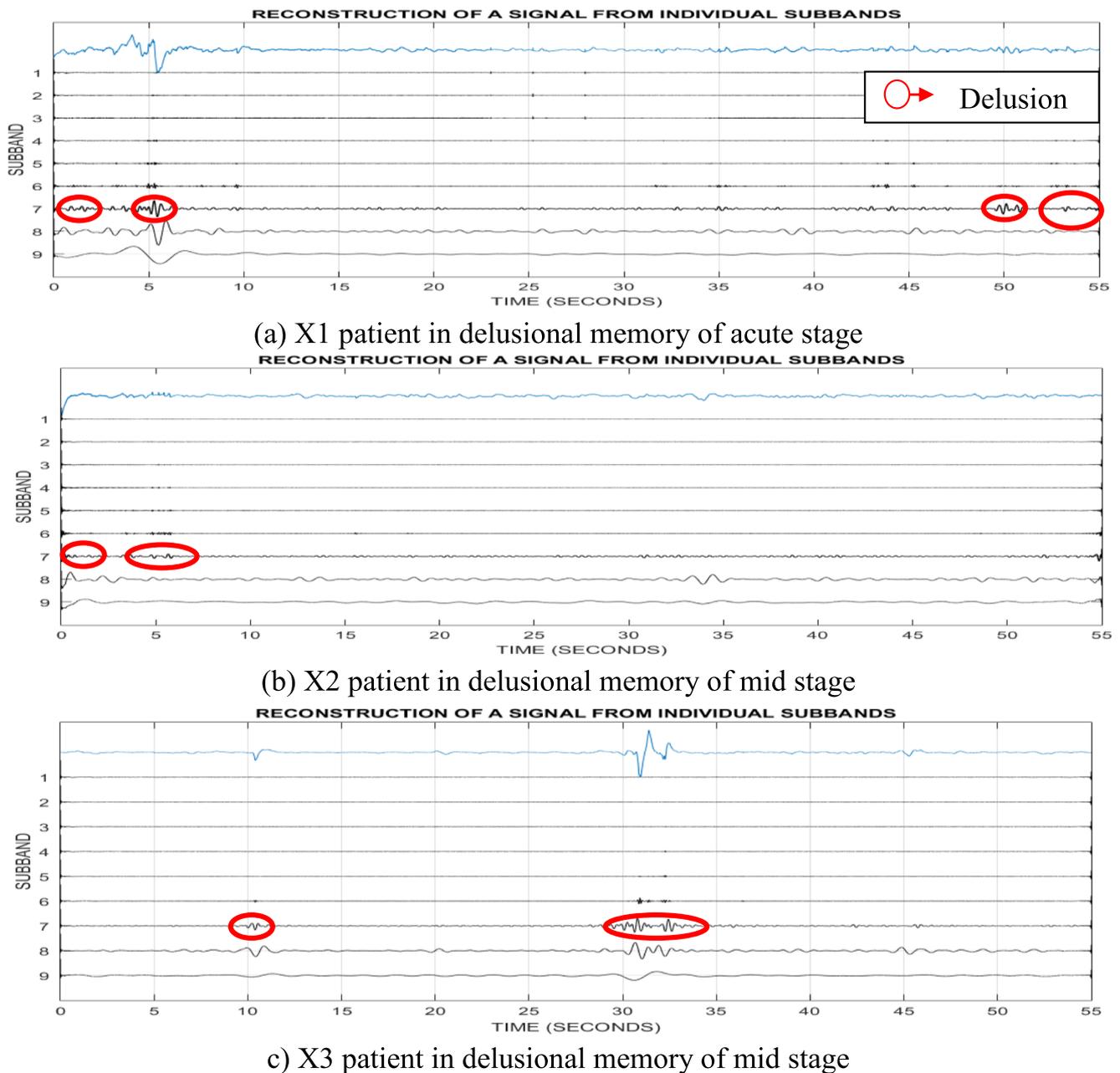

(a) X1 patient in delusional memory of acute stage

(b) X2 patient in delusional memory of mid stage

c) X3 patient in delusional memory of mid stage

Figure 6 Delusional memory patients EEG Signal classification of in counting through RADWT

of X1 hallucination patient show continuous eyeball movement in the eye closed condition due to anxiety, which arise due to panic. The X1 patient hear voice and threatened due to command from illusion voice and Fig. 5(a) with the change in pattern at band seven due to controlling phase in resting stage. The X2 patient EEG signal shows the stage two, where the slight change in signal due to the condemning stage. The signal Patten amplitude varies the reduced attention span and increase in the distress. Furthermore, the X3 patient in the stage one show the beginning stage of hallucination and where patient in the comforting stage of guilt and focus on the thought and control.

Delusion classify as primary and secondary. The primary is un-understandable and secondary is understandable after psychiatric examination. The both type of delusion patient hold the belief, where the belief itself false and incorrigible. The primary delusion classify as delusional mood, delusional perception, delusional memory, delusional ideas and delusional awareness. In this paper, we delineate the signal of EEG for delusional memory. The delusional memory symptom identify during remember of idea or event. For delusional memory

diagnose from the EEG signal acquired during the screen questions and spell the numbers in reverse order from 100 to 1.During the EEG acquisition the patient allowed to sit 1 m meter apart from the clinician. The distance of 1 m for the acquisition of EEG signal evaluates the patient concentration power and memory test. The memory test of EEG during counting reverse of number shown in Fig. 6(a), (b) and (c) after processing with RADWT algorithm. In fig. 6 the red color marked region shows the illusion thought, which arise in the seventh sub band of the graph.

Delusion patient diagnose through the reverse counting from 100, for concentration evaluation. The reverse counting focus concentration and intervention of bothering thought which influence in the brain signal and the same shown in the Fig. 6. The counting from 100 challenge the patient concentration without overwhelming thoughts in the EEG signal. The reverse counting provide an opportunity to reset the brain of its own and make the patient to think in different perspective to avoid the unwanted illusion thoughts. Furthermore, the disorder in the thought of delusion patient analysis through the screening
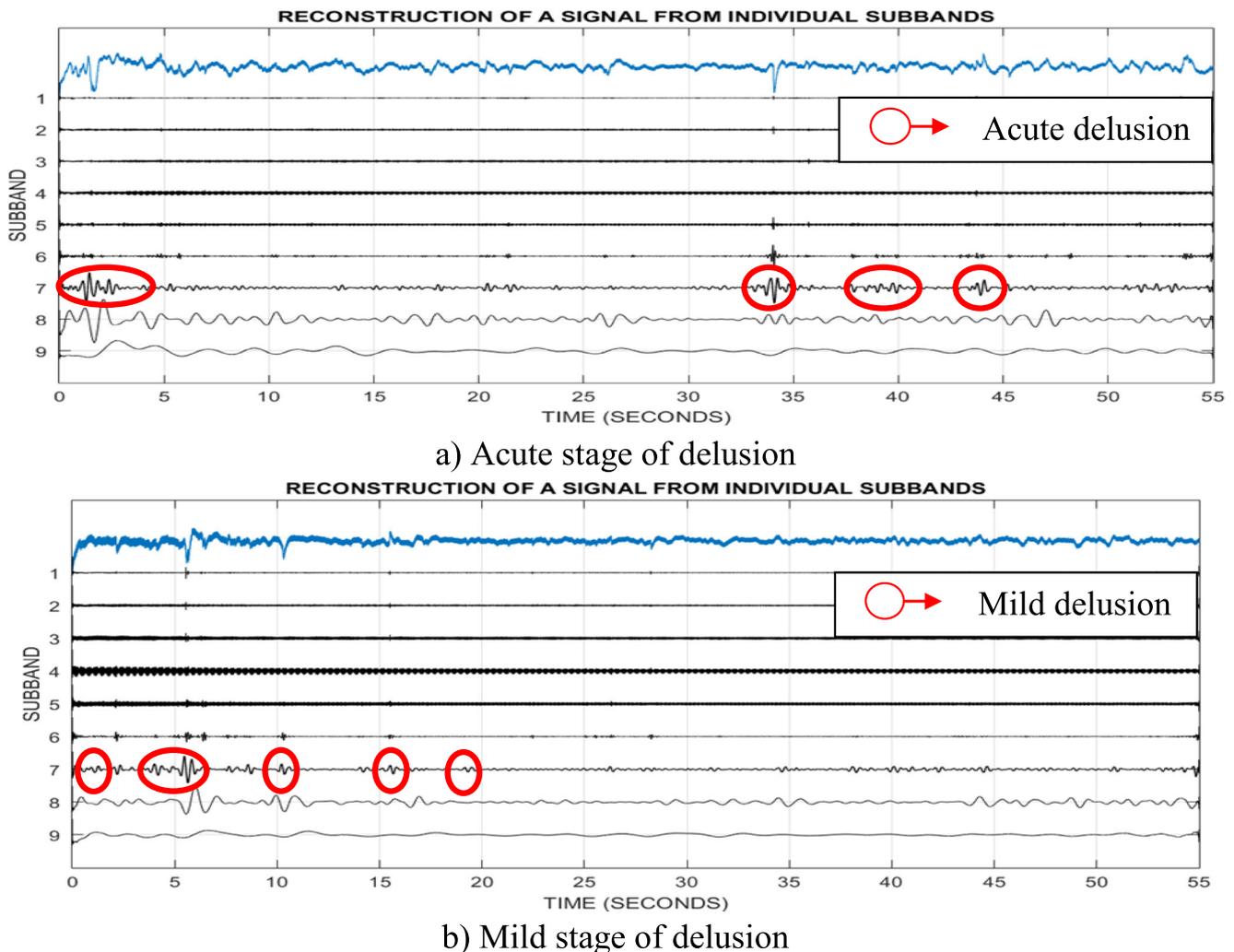

a) Acute stage of delusion

b) Mild stage of delusion

Fig. 7 Delusional memory patients RADWT processed EEG Signal during the screening question test

questions and classifies the negative symptoms in the delusion patient in advance. The EEG signal negative symptoms show the variation in the pattern in the seventh band of the signal as in Fig. 7. The Fig. 7 shows the RADWT EEG signal of the delusion patient and the red color marked region in the Fig. 7 show the disorder in through during the screening questions.

The RADWT of EEG signal classify the Hallucination and delusion patients through the various testing method such as question screening, reverse counting and eye closed rest state. The EEG signal show the negative symptoms during the various test and plot the same with sub band of RADWT. Furthermore, EEG signal for the schizophrenia patients a patient classify with energy band of RADWT. The Fig. 8 shows the energy band plot of the schizophrenia patient. In the plot the x-axis represents the sub band and y-axis the percentage of energy.

The conventional low Q factor DWT based extraction of features as shown in the Fig. 9. The Fig. 9 never show the different time and frequency characteristics of hallucination and delusion of the EEG signal. The EEG signal during delusion the transient and frequency component various in minimum duration 24 to 36 Hz. Furthermore, the eyeball movement in rest state is oscillatory time domain character and band limit frequency behavior in the low frequency of 12 to 17 Hz. The RADWT energy distribution shows the differentiation of the EEG signal for the hallucination and delusion memory as in Fig. 8. The Fig. 10 show the EEG signal for the normal person, where the energy component widely distributed. The Fig. 8 show the energy distribution for the high Q-factor analysis for the hallucination and delusion EEG signals. The EEG signals with high Q-factor analysis show the distinctive frequency characteristics for the hallucination and delusion in the energy band. For the high Q-factor form with $p = 6$, q = 7 and s = 5 and the dilation factor of about 1.17 and 1.40 of redundancy for the eight levels. From eight levels the RADWT provides the eight group of coefficient in details and one approximation coefficients. The Energy band diagram distinguishes the hallucination and delusion, due to improved frequency resolution. The frequency resolution for the EEG signal show the variation in the energy band as the narrow spread spectrum for the hallucination and widely spread spectrum. Furthermore, the EEG signal of normal person RADWT energy band shows the more widely
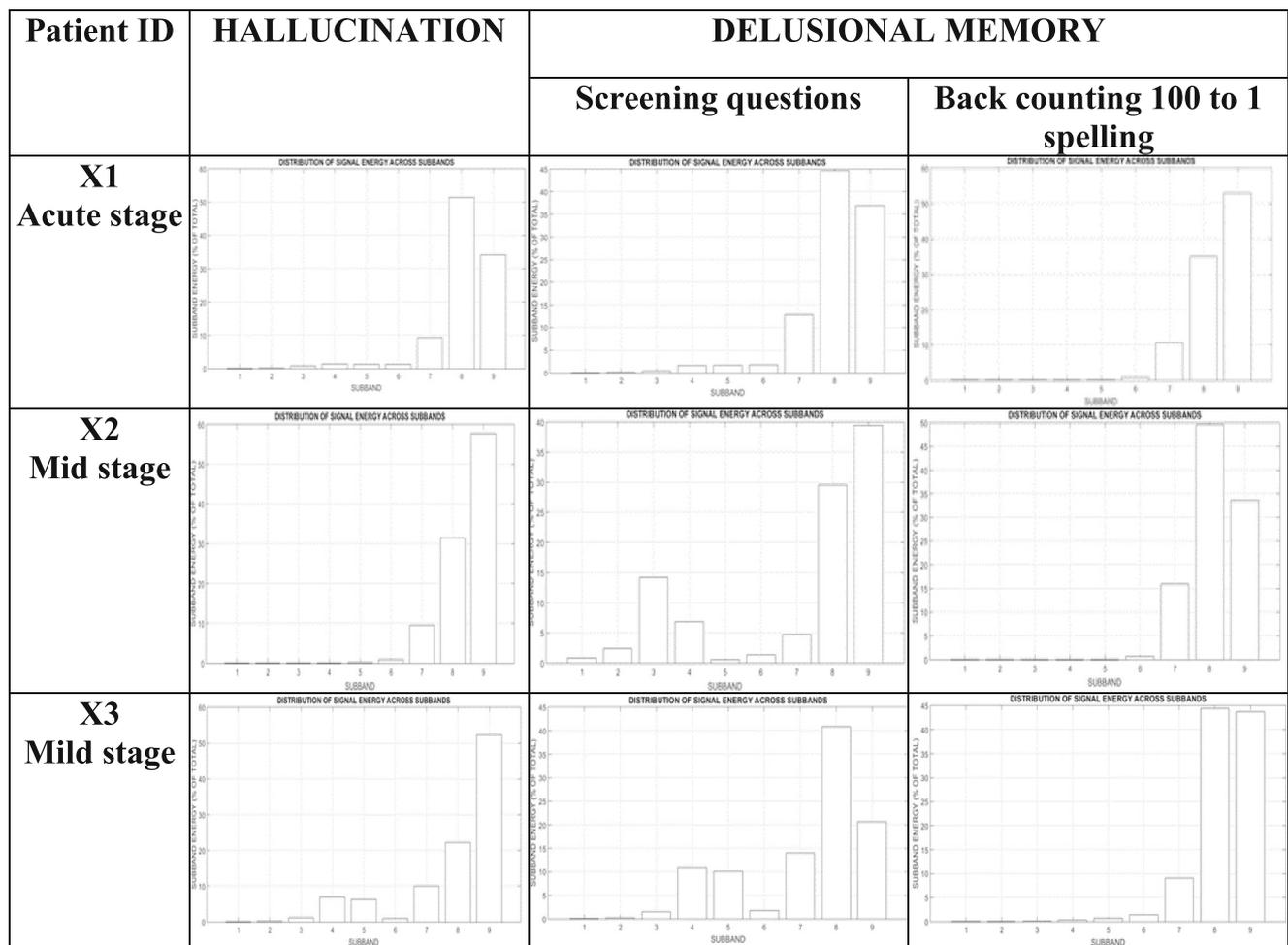

Patient ID	HALLUCINATION	DELUSIONAL MEMORY	
		Screening questions	Back counting 100 to 1 spelling
X1 Acute stage			
X2 Mid stage			
X3 Mild stage			

Fig. 8 Energy distribution in sub bands for EEG signal for hallucination and delusion
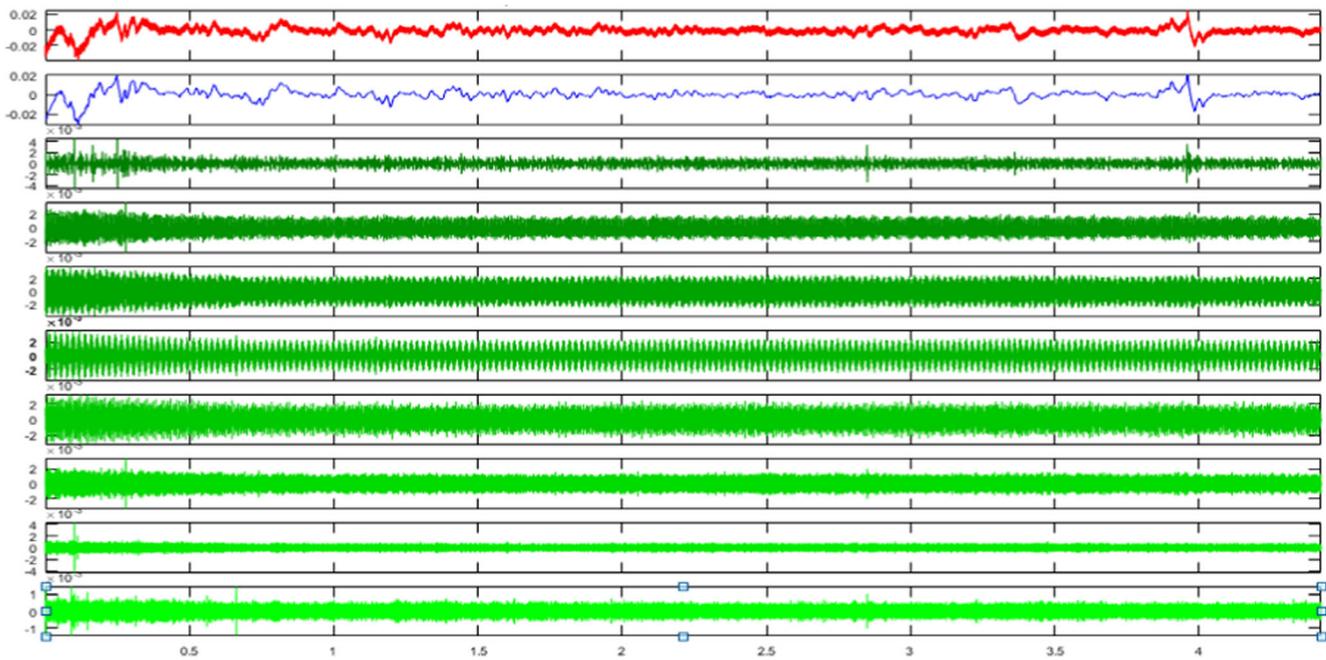
Fig. 9 DWT analysis of X2 patient in Stage two hallucinations

spread spectrum with more sub band energy percentage as shown in Fig. 10.

The extracted sub band signal further classify with various statistical values such as entropy, mean, standard deviation (STD) and kurtosis of RADWT coefficients to validate the result for identification of type of Hallucination and Delusion schipoherina. From the result the seventh sub band signal consider for the statistical evaluation and compare with the other best level of the coefficient in wavelet transform for analysis. Entropy describes information-related property for an accurate representation of a signal. Entropy concept apply in different Engineering fields, mostly in signal processing. In the following equation

explain the entropy, s is the signal and (si) is the coefficients of s in an orthonormal basis. The entropy E must be an additive cost function such that E (0) = 0 and

$$E(s) = \sum_i E(s_i)$$

The (no normalized) Shannon entropy.

$$E1(s_i) = S_i^2 \log\left(s_i^2\right)$$

so,

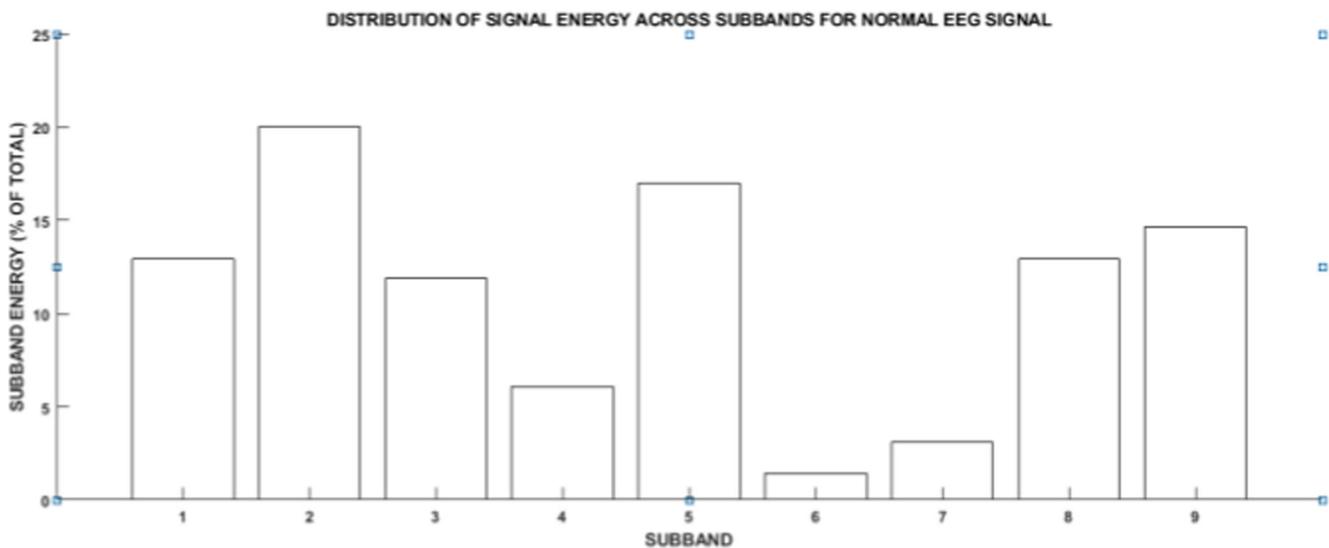$$E1(s) = -\sum_i s_i^2 \log s_i^2$$

Fig. 10 RADWT sub band Energy diagram of EEG signal of a normal person during screening question

Table 5 Classification of hallucination and delusion with RADWT & Wavelet transform

Transform	Disease	Statistical methods	Patient-ID (X1)	Patient-ID (X2)	Patient-ID (X3)	Patient-ID (X4)	Patient-ID (X5)	Patient-ID (X6)	Patient-ID (X7)	Patient-ID (X8)	Patient-ID (X9)
Haar Wavelet	Hallucination (Rest State)	Mean	1.254	1.119	1.217	1.072	1.164	1.145	1.119	1.105	1.138
		STD	3.958	3.125	3.424	3.232	3.321	3.157	3.145	3.167	3.138
		Entropy	4.273	4.124	4.182	4.054	4.038	4.169	4.163	4.097	4.087
	Delusion (reverse counting No)	Mean	1.369	1.117	1.123	1.254	1.198	1.276	1.255	1.212	1.264
		STD	3.248	3.121	3.128	3.184	3.232	3.132	3.195	3.226	3.123
		Entropy	2.958	2.762	2.745	2.821	2.791	2.816	2.712	2.891	2.847
	Delusion (screening question)	Mean	1.458	1.329	1.354	1.381	1.314	1.387	1.412	1.375	1.381
		STD	3.548	3.435	3.498	3.457	3.415	3.479	3.491	3.465	3.419
		Entropy	4.021	3.981	3.752	3.715	3.943	3.826	3.948	3.864	3.753
Demy wavelet	Hallucination (Rest State)	Mean	1.356	1.286	1.294	1.275	1.312	1.287	1.318	1.297	1.324
		STD	4.122	4.026	4.087	4.064	4.035	4.085	4.033	4.075	4.034
		Entropy	4.356	4.268	4.249	4.274	4.297	4.241	4.216	4.218	4.297
	Delusion (reverse counting No)	Mean	1.354	1.247	1.268	1.287	1.291	1.289	1.312	1.298	1.232
		STD	3.421	3.321	3.365	3.389	3.349	3.379	3.389	3.394	3.355
		Entropy	3.014	2.912	2.887	2.835	2.913	2.987	2.813	2.982	2.816
	Delusion (screening question)	Mean	1.524	1.486	1.463	1.427	1.482	1.425	1.439	1.495	1.432
		STD	3.789	3.682	3.628	3.715	3.681	3.687	3.712	3.682	3.748
		Entropy	4.230	4.135	4.224	4.182	4.194	4.187	4.143	4.127	4.182
RWDT	Hallucination (Rest State)	Mean	1.324	1.224	1.247	1.268	1.275	1.289	1.215	1.268	1.284
		STD	5.292	5.189	5.243	5.172	5.189	5.273	5.147	5.138	5.237
		Entropy	4.096	3.945	3.981	3.924	3.918	3.967	3.912	3.841	3.977
	Delusion (reverse counting No)	Mean	1.925	1.816	1.821	1.913	1.874	1.866	1.841	1.835	1.873
		STD	5.756	5.687	5.718	5.687	5.615	5.702	5.691	5.678	5.619
		Entropy	4.985	4.865	4.802	4.863	4.819	4.897	4.912	4.873	4.921
	Delusion (screening question)	Mean	1.789	1.751	1.725	1.720	1.782	1.725	1.761	1.749	1.706
		STD	4.965	4.879	4.815	4.935	4.861	4.873	4.891	4.881	4.813
		Entropy	5.014	4.968	4.982	4.923	4.978	4.938	4.981	4.973	4.913

,with the convention 0log (0) = 0., The concentration in lp norm entropy with $1 \leq p$.

$$E2(s_i) = |s_i|^p \text{so}$$

$$E2(s) = \sum_i |s_i|^p = ||S||_p^p$$

The "log energy" entropy.

$$E3(si) = \log(s_i^2)$$

so,

$$E3(s) = -\sum_i \log s_i^2$$

, with the convention log (0) = 0.

- The threshold entropy. E4(si) = 1 if |si| > p and 0 elsewhere so E4(s) = #{i such that |si | > p} is the number of time instants when the signal is greater than a threshold p. The "SURE" entropy. $E5(s) = n - \#\{i \text{ such that} |s_i| \leq p + \sum_i \min(s_i^2, p^2)\}$

The Table 5 shows the classification of the hallucination and delusion signals with RADWT and Wavelet transform. From the table hallucination in rest sate shows the earlier stage in the entropy of the signal. Whereas, the RADWT shows subband signals with the pattern in less entropy value. However, the entropy value reduced than existing HAAR and Wavelet transform shows better classification compared to wavelet transform. Moreover, the delusion in reverse counting number and screening question show better results in the mean of the signal and entropy. The entropy of hallucination patients of wavelet transform classifies the signal in the early stage. Whereas, RADWT with different Q factor with low and high-resolution frequency settings provides better classification for hallucination and delusion in early stage.

Conclusion

EEG signal diagnose the brain related disease such as epilepsy, head injury and brain tumor. However, quantitative analysis of EEG signal diagnoses the psychiatric disorders through the frequency content in the signal. Furthermore, the energy band analysis of the EEG signal with variable Q-factor classifies the Schizophrenia disease such as Hallucination and delusion. From the results, the classification of

Schizophrenia disease such as hallucination and delusion is possible when the EEG signals acquired from the three conditions such as resting state, reverse counting, and screening questions with the distance of minimum of 1-m between the clinician and Schizophrenia patient and never with the Normal EEG signal or quantitative analysis. The EEG acquired during the cognitive task show the variation in the signal for earlier diagnose and classification of Hallucination and delusion type of Schizophrenia after varying the Q-factor in RADWT. The different Q-factor of EEG signal with the different cognitive task will still enable us to classify other type of Schizophrenia disease in the earlier stage and help the patient from prolong illness and quick recovery.

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