Automatic Modulation Recognition of both Digital and Analog Communication Signals

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***Abstract*—Six feature parameters P1-P6 based on the first statistical moments of the received signals were proposed for automatically classify the modulation of digital and analog communication signal, which were calculated by signal processing methods. The calculation process is simpler than witch traditional algorithm, but also this process is suitable for real time online. The automatic modulation recognition algorithm was also given based on the decision-theoretic approach, which was presented in this work. With 6 Thresholds T1-T6, the 7 kinds of digital and analog communication signal were recognized with an average success rate≥98%, including 2ASK, 4ASK, 2FSK, 4FSK, AM, DSO and 16QAM, by the MATLAB simulation.**

Keywords-automatic modulation recognition; digital and analog signals; the first statistical moment; feature parameters

I. INTRODUCTION

The automatic detection and recognition of digital and analog communication signals modulation method is a relatively new research direction in the field of signal analysis. Modulation method is an important parameter of signal feature. With the rising of electronic countermeasure technology, the urgent need for the automatic identification technology research of digital communication signals modulation way, it is widely used in: signal confirmation, interference identification, radio detection, electronic countermeasures, signal monitoring and threat analysis, etc [1-5].

Through the method of judgment, this paper puts forward an algorithm whose way of modulation can be recognized automatically 2ASK, 4ASK, 2FSK、4FSK, 16QAM, AM, DSB and so on [6-12]. The process of implementing recognition algorithm is given to distinguish the commonly used digital modulation style. In addition, a relatively few parameters are selected, it's easy to extract with small amount of calculation and strong robustness.

II. THE CHARACTERISTIC PARAMETERS OF THE MODULATION SIGNALS

We assume that does not require the synchronous cold-elements in the signal receiver. When receiving the 6 kinds of digital and analog communication signals in the introduction, extracting the feature parameters are shown in TABLE I.

The first characteristic parameter P1 is defined as the unimodal number of the received signal spectrum. When we receive the signal, carries on the Fourier transform. Within a narrow spectrum, if the difference value between a component and other components is greater than a certain threshold, argues that appear a single-peak; if there are difference values between two components and other components greater than the threshold, and there is a certain distance between the two components, argues that there are two peaks within the spectrum, and so on. Characteristic parameters distinguish between the 2ASK, 4ASK and other signals, because 2ASK, 4ASK signals are single-peak.

TABLE I. THE FEATURE PARAMETERS OF DIGITAL AND ANALOG COMMUNICATION SIGNALS

Signals	Feature Parameters
P1	$P_1 = n$
P2	$P_2 = \sqrt{\frac{1}{N}\left[\sum_{i=1}^{N} A_{cn}^2(i)\right] - \left[\frac{1}{N}\sum_{i=1}^{N}\left\|A_{cn}(i)\right\|\right]^2}$
P3	$P_3 = \frac{1}{N}\max\left\|\mathrm{FFT}\left[A_{cn}(i)\right]^2\right\|$
P4	$P_4 = \frac{1}{M}\sum_{i=1}^{M}\left\|\left\|F(i)\right\| - \frac{1}{M}\sum_{k=1}^{M}\left\|F(k)\right\|\right\|$
P5	$P_5 = \frac{\sigma^2}{\mu^2}$
P6	$P_6 = \frac{1}{M}\sum_{i=1}^{M}\left\|\left\|\phi_c(i)\right\| - \frac{1}{M}\sum_{k=1}^{M}\left\|\phi_c(k)\right\|\right\|$

Among them: N is the total number of sampling, Acn(i) normalized instantaneous amplitude zero center, there is

$$\begin{cases} A_{cn}(i) = A_n(i) - 1 \\ A_n(i) = \dfrac{A(i)}{m_a} \end{cases} \quad (1)$$

where $A(i)$ is the receiving signal amplitude of the moment i, when N is the total number of sampling, may be achieved through the general signal processing technology, m_a is the average of $A(i)$, and defined as:

$$m_a = \frac{1}{N}\sum_{i=1}^{N} A(i) \quad (2)$$

Characteristic parameters P3 is mainly used to distinguish between A 2FSK, 4FSK and other signals, because the envelope of 2FSK and 4FSK signal are

constant, there is $P_3 = 0$, and the rest class of signal are not zero.

$$F(i) = \frac{1}{F_s}\left[f(i) - \frac{1}{M}\sum_{k=1}^{M} f(k) \right] \quad (3)$$

where *f(i)* is the received signal frequency at the moment *i*, when sampling a total of N.

For 2ASK signal, the absolute value of its extent is constant, so the characteristic parameters of $P_2 = 0$. But it's not a constant for 4ASK signal, there is $P_2 \neq 0$, so the feature parameters are used to distinguish the signal 2ASK and 4ASK can obtain an ideal result.

Characteristic parameters P_3 is mainly used to distinguish between A 2FSK, 4FSK and other signals, because the envelope of 2FSK and 4FSK signal are constant, there is P3= 0, and the rest class of signal are not zero. The characteristic parameter P_4 is mainly used to distinguish between the 2FSK and 4FSK signal. The 2FSK signal *f(i)* contains two discrete values, so $P_4 = 0$. The 4FSK signal *f(i)* contains four discrete values, so $P_4 \neq 0$.

The fifth characteristic parameter P5 mainly reflects the changeable extent of signal envelope.

No noise in the ideal, the 2PSK signal due to its instantaneous phase *Φ(i)* with two discrete values 0、π. Therefore, after taking the absolute value in the center of zero, the two discrete values become π/2, are constant, and $P_6 = 0$; But the instantaneous phase of 4PSK signal contains four discrete values. Therefore, after taking the absolute value in the center of zero, the *Φ(i)* will have two discrete values, namely, $P_6 = 0$. Therefore, we can distinguish between 2PSK and 4PSK signals through the characteristic parameters P_6.

III. RECOGNITION ALGORITHM

The method of modulation in time domain and frequency domain have different characteristics: in the time domain has permanently envelope signals and constant envelope; look on the spectrum, there are residual carrier signal and no residual carrier signal. Based on decision theory, the modulation signal in section 2 of the characteristics of all kinds of characteristic parameters are shown in the modulation mode automatic identification algorithm flow chart including threshold T1-T6 as shown in Table II.

TABLE II. THRESHOLD VALUE AND SIGNAL TO NOISE RATIO OF CHARACTERISTIC PARAMETERS

Signals	Threshold	Threshold value	Noise ratio
P1	T1	1	≥-1dB
P2	T2	0.25	≥-1dB
P3	T3	0.87	≥3dB
P4	T4	0.82	≥-5dB
P5	T5	0.88	≥5dB
P6	T6	0.82	≥-15dB

IV. IDENTIFY VALIDATION

To evaluate the effectiveness of automatic identification and test method of digital and analog signals mentioned in this article, the threshold value of each characteristic parameters can be determined by MATLAB simulation. In this method of modulation, the 0,1 randomly generated sequence use the zero-mean Gaussian white noise. Digital baseband signal waveform use rectangular pulse, the number of samples taken 4000, the carrier frequency taken 100 KHz, SNR taken from -5 ~ 20dB. As shown in Figure I , there are fifth characteristic parameter P_5 and the simulation graphics of SNR. From the above conclusions: no matter in the type, quantity, minimum signal-to-noise ratio, and the average recognition rate of the pending identification signal, the performance of the proposed recognition algorithm is superior to the general algorithm.

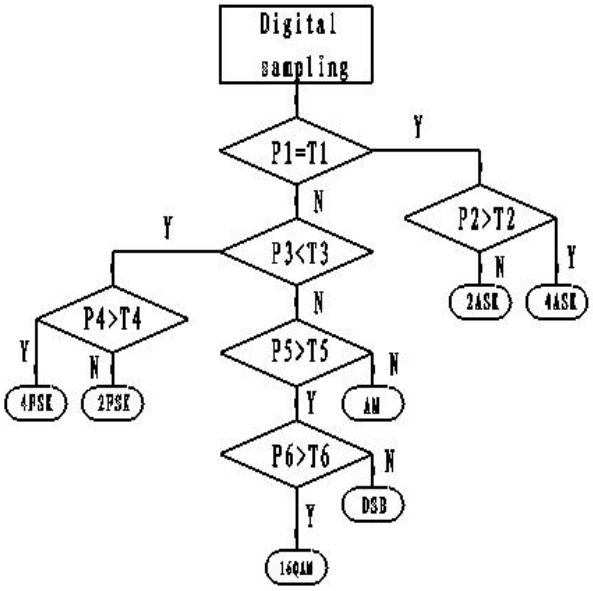

FIGURE I. AUTOMATIC MODULATION RECOGNITION ALGORITHM FLOW CHART

V. CONCLUSIONS

Based on the Decision Laws, the signal instantaneous amplitude, instantaneous phase and instantaneous rate on the basis of six characteristic parameters *P1-6*. The simulation results show that when the SNR≥15 db,the average recognition rate of 7 kinds of signal can reach 99.25%. When SNR≥9db, except 16QAM is 77.5%, other signals' recognition rate remains 100%; When SNR≥6db, except 16QAM is 77.5%, other signals' recognition rate remains more than 96%. When SNR≥5db, except 16QAM, other signals' recognition rate keep more than 87%. When SNR≥0db, the recognition rate of 2FSK signal can reach 90%.

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