An Evaluation Method of Anti-jamming Capability to Communication System Based on Cloud-Evidence Theory

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Abstract — **With the development and application of new anti-jamming technology, the anti-jamming capability evaluation of communication system has been an important issue for electronic warfare. Aiming at the uncertainty caused by the fuzziness and randomness of evaluation indexes and the subjectivity of experts during evaluation process, an information fusion method based on cloud model and D-S evidence theory is proposed to evaluate anti-jamming capability more scientifically and objectively. This method designs cloud model of comment grades to construct the basic possibility assignment function of every index which is called cloud-evidence in this paper. And the evaluation results are determined by linearly weighting of quantization values of the comment and the basic possibility assignment which is synthesized by the improved evidence infusion rules based on evidence distance. Taken the direct sequence spread spectrum communication system as an example, the simulation results show that the rationality and effectiveness of the method. It further enhances the credibility of the evaluation process by the effective integration of the fuzziness and randomness. This study provides a beneficial reference value for the development and demonstration of communication system.**

Keywords — cloud model*; *D-S evidence theory*; *communication anti-jamming*; *capability evaluation*; *information fusion

I. INTRODUCTION

With the wide application of wireless communication technology, it faces increasingly complex electromagnetic environment such as the interference caused by natural or artificial factors which lead increasingly high demands for anti-jamming (AJ) capability of communication system [1]. AJ capability means the ability to maintain the normality of communication under the interception and disturbance by the enemy. The scientific evaluation for the AJ capability of communication system not only helps enhance the understanding and analysis about its AJ performance, but also is beneficial for the effective utility and improvement of the communication system. Whether the evaluation methods are reasonable directly affect the timeliness and the practical value of the evaluation results, which directly affect the strategic decisions of the communication campaign command. Therefore, it is necessary to constantly explore new evaluation algorithm or method in order to obtain more realistic evaluation results.

So far, lots of scholars have done many researches and made some achievements in the field. For example, some subjective or objective evaluation methods are proposed such as analytic hierarchy process (AHP), grey relational analysis (GRA), fuzzy comprehensive evaluation (FCE) [2]. But these methods cannot objectively and accurately evaluate the comprehensive system where quantitative and qualitative indexes coexist. Furthermore, the uncertainty caused by the fuzziness and randomness of the qualitative index and the subjectivity of the experts during evaluation process is still a difficult problem to be solved. In recent years, the uncertain information has been well processed with the development of cloud theory and D-S evidence theory [3]. In [4], it proposed the method based on cloud model and D-S evidence theory to solve uncertainties caused by the expert, but the cloud parameters or basic possibility assignment are constructed by subjective opinions. In [5], it proposed an evaluation method which combined cloud model with fuzzy comprehensive evaluation theory but only considering the qualitative indexes.

Focusing on the issues above, based on considering the D-S evidence theory is a popular reasoning method and cloud model blends fuzziness and randomness well, a new information fusion method is put forward based on cloud model and D-S evidence theory to evaluate AJ capability of communication system effectively in this paper. In Section II, the relevant theories and evaluation models are given, including the methods of indexes pretreatment, the cloud generator of comment grades, the algorithm for constructing basic possibility assignment function and the modified evidence fusion rule based on evidence distance. Section III describes the new algorithms and evaluation process for AJ capability in detail. In Section IV, the algorithm is applied to an illustrative example about the direct sequence spread spectrum communication system (DSSS), and the conclusions are presented in Section VI.

II. THEORY AND MODELS FOR ANTI-JAMMING CAPABILITY EVALUATION

A. Constrution of Evaluation Indexs System

In this paper, we take the direct sequence spread spectrum communication system (DSSS) as an example. According to the prior knowledge based on reference [6] and analytical hierarchical process (AHP) methods [7], we construct an index system of AJ capability for DSSS communication system from the following two parts which are general indexes and special indexes. General indexes mean the index such as transmission power and antenna gain which are the inherent parameters of communication system. Special indexes mean the anti-jamming measures of different communication equipment or system takes, such as the technology of automatic power control or adaptive narrowband filter and so on. For example, the evaluation indexes system is shown in the table below according to the analysis above.

TABLE I. INDEX SYSTEM

Anti-jamming Capability(*I*)	***General Indexes* (I_1)**	DSSS Bandwith (I_{11})
		Maximun Launch Power (I_{12})
		Processing Gain(I_{13})
		Minimun Information Rate (I_{14})
		AJ margin (I_{15})
	***Special Indexes* (I_2)**	Transcoding DSSS (I_{21})
		Automatic Power Control(I_{22})
		Adaptive Narrowband Filter(I_{23})

B. Normalization Processing of Indexs

Normalization processing algorithm can make all the indexes on the same comparable level and obtain the comments value. Here we use the methods below to transfer all indexes into the interval [0, 1].

1) If I is a quantitative indexes, we design two kinds of normalization processing functions which can be called linear and logarithmic type based the relationship between indexes value and anti-jamming capability As shown in the formula below are the expression of the specific function. Supposing the value of I is x_i, x_{min} and x_{max} represent the minimum and maximum value of this kind of index. C_{lin} and C_{log} are the comment value after linear and logarithmic normalization processing, thus:

a) if I belongs to efficiency type,

$$C_{lin}=\frac{x_i-x_{min}}{x_{max}-x_{min}},\quad C_{log}=\frac{log_\alpha(x_i)-log_\alpha(x_{min})}{log_\alpha(x_{max})-log_\alpha(x_{min})} \tag{1}$$

b) if I belongs to cost type,

$$C_{lin}=\frac{x_{max}-x_i}{x_{max}-x_{min}},\quad C_{log}=\frac{log_\alpha(x_{max})-log_\alpha(x_i)}{log_\alpha(x_{max})-log_\alpha(x_{min})} \tag{2}$$

2) If I is a qualitative index, this kind of index can only be denoted in the form of natural language. Supposing $s_1 \sim s_n$ is the comment grades, where s_1 means the worst comment of the index, and s_N represents the best comment. $s=\{s_1, s_2, \ldots, s_N\}$ is a set of comment grades and its corresponding quantization value is $\{c_1, c_2, \ldots, c_N\}$. Through the comments from K experts, we count the times of the comment result that the indexes belong to each comment grade and calculate the probability. Then the normalization processing result of I can be expressed as：

$$C_I=\sum_{j=1}^{M} c_j \times \frac{k_j}{K}, k_j=1,2,\ldots,K \tag{3}$$

Where k_j is the times that I belongs to comment grade s_j, c_j is the corresponding quantization value of s_j.

C. Cloud Model generator for Comment Grades

Cloud model uses expected value (Ex), entropy (En) and hyper entropy (He) to characterize a concept through the fuzziness of fuzzy set merged with the randomness of probability theory [8]. The whole feature of concepts expressed by cloud model can be characterized by the numerical characteristics of cloud. Assuming that U is a quantitative numerical universe of discourse and A is a qualitative concept in U. If $x \in U$ is a random realization of concept A, and $u(x) \in [0,1]$, standing for certainty grade which x belongs to A, is a random variable with stable tendency: $u: U \to [0,1], \forall x \in U, x \to u(x)$, the distribution of x in universe of discourse U is called Cloud(Ex, En, He). Supposing $U \in [0,1]$, A is a comment grade such as s_i and its corresponding quantization value is c_j. The entropic and hyper entropic functions are

$$\begin{cases} Ex=c_i \\ En=(c_i-c_{i-1})/6 \\ He=En/\xi \end{cases} \tag{4}$$

Where ξ is a given constant which can adjust according to fuzzy condition of s_i. We called this cloud generator as comment grade cloud.

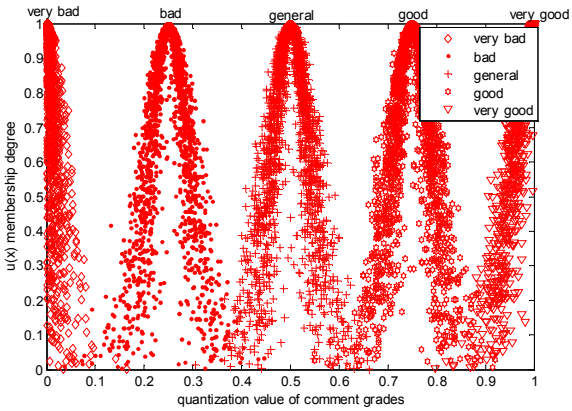

Figure.1 The Comment Grades Cloud