The American Journal of Engineering and Technology
(ISSN – 2689-0984)
Published: September 25, 2020 | **Pages:** 64-66
Doi: https://doi.org/10.37547/tajet/Volume02Issue09-11

IMPACT FACTOR
2020: 5. 32

Journal Website: http://usajournalshub.com/index,php/tajet

The Use Of Fractal Theory In Digital Signal Processing In Radio Communication Systems

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ABSTRACT

When digital signal processing in a radio communication system, it is advisable to calculate the fractal dimension D and the Hausdorff dimension based on the topological mathematical expression D_0, analyze the methods of digital signal processing by the electro-optical method, i.e. perform experimental calculations of fractal points.

KEYWORDS

Fractal dimension, analyze the methods, dimension calculated.

INTRODUCTION

We assume that there exists a positive number C for which the inequality $N(\varepsilon) \geq c/\varepsilon^{2}$ is valid for any $\varepsilon > 0$, where r is some integer. Then:

$$D = \lim_{\varepsilon \to 0} \inf \left[-\frac{\log N(\varepsilon)}{\log \varepsilon} \right]. \qquad (1)$$

The Hausdorff dimension calculated using formula (1) for some deterministic fractal models is shown in Table 1. [1].

Table 1

Fractal D and topological D_0 dimensions of some deterministic fractal models

Deterministic fractal models	D	D_0
Cantor set	$\ln 2 / \ln 3 \approx 0{,}63$	0
Koch curve model	$\ln 4 / \ln 3 \approx 1{,}26$	1
Mandelbrot-Tiven model	$\ln 8 / \ln 3 \approx 1{,}89$	1
Sierpinski's napkin model	$\ln 3 / \ln 2 \approx 1{,}58$	1
Sierpinski carpet model	$\ln 8 / \ln 3 \approx 1{,}89$	1
Tosper Curve Model	$\ln 3 / \ln \sqrt{7} \approx 1{,}13$	1
Liecher universal curve model	$\ln 20 / \ln 3 \approx 2{,}73$	1

MATERIALS AND METHODS

The fractal dimension, called the correlation dimension, is widely used by experimenters [2,3,4] and is determined by the correlation integral:

$$C(r) = \lim_{N\to\infty} \frac{1}{N^2} \sum_{i,j=1}^{N} \theta(\vec{r} - |\vec{x_i} - \vec{x_j}|), \qquad (2).$$

which is evaluated directly for a sequence of points.

In this |(x_i)⃗-(x_j)⃗| - distance between pedals of points (x_i)⃗ and (x_j)⃗;

θ – unit function..

For many fractals, the correlation integral depends on r as r ⟶ 0 according to a power law, i.e.

$$C(r) = r^{D_3}. \qquad (3)$$

Therefore, the fractal correlation dimension D_3 (or the correlation indicator $〖v = D〗_3$) is determined by the slope of the straight graph ln $〖C(r) = f(\ln r)〗$.

Currently, there are no devices that generate a signal at the output that is proportional to the fractal dimension. Electro-optical methods, however, make it possible to determine an approach to solving this problem [7]. In practice, in numerical and physical experiments, fractal dimensions D are found by sampling signals with subsequent data processing on a computer. In digital algorithms, 103 - 106 points are used to calculate D, which requires enormous computational costs, although there are more rational programs containing about 500 samples [5].

The analysis showed that in digital processing, as a rule, one of three main methods is used: time discretization of variables in phase space, calculation of Poincaré mappings, or one-time measurements of a time series (space embedding method).

Determination of fractal dimension using Poincaré mappings is used to find, mainly, D strange attractors [4]. If the fractal dimension of the Poincaré map ($0 < D < 2$) does not depend on the phase of the Poincaré map ($0 \le \omega t \le 2\pi$), then the dimension of the full attractor is $D_A = 1 + D$. This measurement method is used for non-linear circuits [6].

Thus, several methods of digital processing were analyzed, in which the theory of fractals was used in the process of experimental research. Fractal D and topological dimension D_0 were determined by some deterministic fractal models.

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