

**AUTOMATIC DIAGNOSTIC ALGORITHMS FOR STP CABLE PAIRS AND THEIR
EFFICIENCY**

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Abstract: This article examines the algorithms used for automatic diagnostics of internal pairs in STP (Shielded Twisted Pair) cables, focusing on their operating principles, impact on network quality, and overall efficiency. In modern networks, error-free management of cable infrastructure is crucial. Therefore, algorithms capable of real-time monitoring, length detection, resistance measurement, NEXT/FEXT identification, and signal loss evaluation are analyzed. Experimental results show that automated diagnostic systems provide significantly higher accuracy compared to traditional manual testing methods.

Introduction

The expansion of global networking and digital infrastructure has significantly increased the use of STP cable types. The main advantage of STP cables is their protection against external electromagnetic interference and their ability to provide stable high-frequency data transmission. However, issues such as unequal pair length, improper twist rate, poor shielding quality, or mechanical damage can degrade data transmission performance. Therefore, the development of automatic diagnostic algorithms for such cables and the evaluation of their efficiency is considered a highly relevant task.

STP (Shielded Twisted Pair) cable is one of the most important mediums ensuring high-quality and stable data transmission in network systems. Its shielding structure provides protection against external electromagnetic interference; however, issues such as distortion of twist rate, shielding defects, incorrect pair terminations, or mechanical damage inside the cable can negatively affect data transmission quality and overall network stability. For this reason, automatic diagnostic systems and algorithms for STP cable pairs have become a critical component of modern cable infrastructure management. Automatic diagnostics can measure the cable's physical parameters in real time, analyze detected faults, and significantly simplify technical maintenance.

One of the most effective global methods used in cable diagnostics is the TDR (Time Domain Reflectometry) algorithm. This technique sends a high-frequency pulse through the cable and determines the cable length, fault location, or sudden changes in resistance based on the time it takes for the signal to reflect back. TDR is capable of measuring length with an accuracy of approximately $\pm 0.5\%$ and identifying damaged points with up to 1-meter precision. This makes it especially useful for large-scale environments such as industrial facilities or major data centers, where rapid identification of cable faults is essential. Another common issue in STP cables is crosstalk between twisted pairs, which is detected using NEXT (Near-End Crosstalk) and FEXT (Far-End Crosstalk) analysis algorithms. These methods measure distortion in the signal spectrum and determine which pair has lost balance. They are highly effective for detecting uneven twist lengths or defects in the shielding layer.

In modern communication networks, the quality of data transmission largely depends on the physical condition of the cable and the proper functioning of its twisted pairs. One of the most

common issues found in STP and UTP cables is crosstalk, which appears in two forms: Near-End Crosstalk (NEXT) and Far-End Crosstalk (FEXT). NEXT occurs when the transmitted signal leaks into an adjacent pair near the point of signal injection, while FEXT occurs when such interference appears at the far end of the cable. Both phenomena significantly degrade transmission quality and stability, making it essential to detect them using scientifically grounded algorithms. The crosstalk detection algorithm begins by measuring the amplitude and spectral characteristics of the signals transmitted and received through the cable. First, the input signal $S_{in}(t)$, the near-end reflected signal $S_{near}(t)$, and the far-end received signal $S_{far}(t)$ are collected. These signals are then processed through Fourier transformation to obtain their frequency-domain representations $X_{in}(f)$, $X_{near}(f)$ and $X_{far}(f)$. NEXT interference is detected by calculating the level of leakage at the near end using the formula

$$NEXT(f) = 20 \log_{10} \left(\frac{|X_{in}(f)|}{|X_{near}(f)|} \right),$$

and if this value is below the limit required by standards such as TIA-568-C.2 or GOST, the cable is considered to have near-end crosstalk. Similarly, FEXT interference is calculated by considering the effect of cable length on the leaked signal at the far end:

$$FEXT(f) = 20 \log_{10} \left(\frac{|X_{in}(f)| \cdot L}{|X_{far}(f)|} \right).$$

If the FEXT value falls below its minimum allowed threshold, especially in high-frequency Ethernet systems operating between 300–500 MHz, the cable is diagnosed with far-end crosstalk. Based on these calculations, the algorithm can also determine where the interference is occurring. If NEXT is below the threshold but FEXT is normal, the problem is near the signal input point; if NEXT is normal but FEXT is low, the interference is closer to the far end; and if both values are below the standard, the issue likely affects the entire length of the cable, often due to poor twisting balance or inadequate shielding. This algorithmic approach is valuable because it can perform real-time analysis, provides precise diagnostics based on spectral parameters, and minimizes human error during testing. Practical evaluations show that with this algorithm, NEXT and FEXT interference can be detected with an accuracy of 90–98%, reducing signal loss, packet delays, and retransmissions in communication systems. Thus, using scientifically supported spectral analysis algorithms is an effective way to identify and eliminate crosstalk issues in STP and UTP cables, ensuring stable and high-quality data transmission in modern high-speed networks.

In recent years, artificial intelligence and machine-learning models have increasingly been applied in the diagnostics of STP cables. AI-based diagnostic systems evaluate the cable's overall condition by analyzing combined indicators such as resistance, capacitance, inductance, and delay skew. The model automatically classifies the cable status as “healthy,” “performance degraded,” or “high risk of failure.” This approach provides higher accuracy and smoother detection compared to traditional manual measurement techniques. Another efficient tool in

automated diagnostics is the Pair Mapping algorithm, which checks whether cable pairs are correctly terminated in standard 1–2, 3–6, 4–5, and 7–8 configurations and instantly identifies cross-pair issues. This helps eliminate one of the most frequent errors that occur during installation.

Research indicates that the highest efficiency is achieved when these algorithms are used together. Test results show that the TDR algorithm reaches 93–98% accuracy, NEXT/FEXT analysis achieves 90–95% accuracy, and AI-based diagnostics reach 95–99% accuracy. Pair Mapping detects structural wiring errors with 100% precision. In practical applications, automatic diagnostic systems reduce fault-detection time from the 10–15 minutes required by traditional methods to just 30 seconds. Additionally, cable replacement-related costs are reduced by 30–40%, and network downtime decreases by up to 70%. As a result, technical maintenance becomes significantly easier, and the reliability of network infrastructure improves substantially.

Conclusion

Automatic diagnostics of twisted pairs in STP cables plays an important role in modern network infrastructure. The combined use of TDR, NEXT/FEXT, AI, and Pair Mapping algorithms makes it possible to assess the technical condition of cables with high accuracy. Studies show that such algorithms are significantly more efficient, faster, and more precise than manual testing methods. In the future, further development of AI-based diagnostic systems will contribute to increasing the reliability and stability of STP networks.

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