Comparison of Foiled and Non-Foiled Twisted-Wire Pairs Characteristics due to Coiling Stresses using the Feature Selective Validation Method

Olusegun Ogundapo[1], Alistair Duffy[2], and Gang Zhang[3]

[1]School of Engineering, American University of Nigeria, PMB 2250, Yola-Nigeria
[2]School of Engineering and Sustainable Development, De Montfort University, LE1 9BH, United Kingdom
[3]School of Electrical Engineering and Automation, Harbin Institute of Technology, 15000, Chin

Corresponding author: Olusegun Ogundapo (e-mail: segundapo@gmail.com, olusegun.ogundapo@aun.edu.ng).

ABSTRACT This paper compares the performance characteristics of foiled and non-foiled twisted-wire pairs due to coiling stresses using the Feature Selective Validation Method (FSV) method. The use of twisted pair cables for Internet of Things (IOT) continues to grow due increasing demand for such applications. One of the ways devised by cable designers to minimize electromagnetic interference is the use of foils which comes with additional costs. However, in typical installations, cables could be subjected to repeated coiling and uncoiling stresses which can affect performance. There is limited knowledge in literature on the effects of foils on the performance of unshielded twisted pair (UTP) cables when subjected to coiling stresses anticipated during installation, hence the need to conduct this research. In this research, four UTP cables each of 30 meters' length, with two of them foiled were tested according to the International Standard ISO/IEC 11801 Class E which allows a maximum frequency of 250MHz for category 6 cables. The four UTP cables were subjected to three rounds of coiling and uncoiling tests to mimic handling stress expected in typical installations. The FSV method was used to assess the coiling stress effects on major performance parameters like return loss, near-end crosstalk (NEXT) and impedance of the four UTP cables allowed by the cable tester. The summary of the result of the assessment is that the two foiled cables gave the lowest variations between the first and fourth NEXT measurements for all the four pairs, while for return loss and impedance it is in two pairs. The approach presented can be used by cable installers and engineers to undertake an assessment of cables measurements selected for deployment.

INDEX TERMS Foiled cable, Non-Foiled cable, Feature Selective Validation, coiling stress, return loss, NEXT, impedance

I. INTRODUCTION

The demand for Internet of Things (IOT) services using Ethernet over twisted pair cables continues to grow [1], [2]. This is due to Ethernet over twisted pair cables applications been found to be cost effective, scalable and reliable [3], [4]. The other advantage of Ethernet over twisted pair cable is the ability to transmit both power and data making them suitable for use in Power over Ethernet (POE) Systems [5], [6]. However, the aforementioned applications of Ethernet over twisted pair cables could only be effective and widely accepted if there is a reliable cabling infrastructure at a lower cost [1]. This situation has made cable designers to provide a foil around the UTP cable with the aim of minimizing electromagnetic interference which could led to signal degradation [7]. It has been stated that the bending radius of twisted pair cables during installation has practical impacts on their performance [8]. This paper therefore assesses and compares the impact of coiling stresses on the performance measurements of foiled and non-foiled twisted pair cables. FSV removes the human nature of subjectivity and ambiguity especially comparing data sets [11].

This paper therefore compares the performance of foiled and non-foiled Ethernet cables using the FSV in order to study their resilience or otherwise to handling stress that they could be subjected to during installations.

II. MATERIALS AND METHODS

A. CABLE MATERIALS

The cable materials used in this paper are as follows:

Cable 1: Non-foiled unshielded twisted pair cable, insulating material is polyethylene and conductor material is copper.
Cable 2: Non-foiled unshielded twisted pair cable, insulating material is polyethylene, and conductor material is copper.
Cable 3: Foiled - unshielded twisted pair cable, insulating material is polyethylene and conductor material is copper.
Cable 4: Foiled - unshielded twisted pair cable, insulating material is polyethylene and conductor material is copper.
All the four cables are category 6 (UTP) from different manufacturers.

B. METHODOLOGY

In this research, four category 6 UTP cables were selected for assessment. Two of the UTP cables are foiled, while the other two are non-foiled. The DSX-5000 cable analyzer that can perform the certification and testing of category 6 cables was used [12], [13]. The four UTP cables were tested according to the International Standard ISO/IEC 11801 Class E which allows a maximum frequency of 250MHz for the testing of category 6 cables channels [13]. The cable analyzer has two modes: the “main” and the “remote” which have hollows to connect them to patch cord adapters [13]. The two ends of the cable under examination are connected to these patch cords with the aid of the Registered Jack-45 (RJ45) standard interface and T568 pin connection. The four pairs of each cable are labelled as orange, green, blue and brown. The cable analyzer was used to measure return loss and (NEXT). The cable analyzer also has an inbuilt HDTDR (High-Definition Time Domain Reflectometry) that measures the impedance profiles of the cables across their lengths. The cable analyzer provides test results at a frequency range from 1 MHz to 250 MHz. The analyzer does not measure Far-end crosstalk (FEXT). The photo of the cable analyzer test system is shown in Figure 1. A USB cord is connected from the main mode to a laptop to extract the test results. A software called the “LinkWare” test management provided by the cable analyzer company is installed on the laptop and used to convert the test results to a readable form.

FIGURE 1. Photo of the cable analyzer test system

Note: the yellow/blue boxes in Figure 1 are the main and remote modes of the cable analyzer. The coiled blue colored cable is the UTP to be tested. The laptop has an installed software called the “LinkWare” used to extract the test measurements from the main mode through a USB cord.

The four tests carried out on each of the cable are as follows:
Test A: Return loss, NEXT and impedance of new cable of 30 m length measured
Test B: cable in test A used to form coils of 30cm diameter and stretched out before test
Test C: cable in test B used to form coils of 30cm diameter and stretched out before test
Test D: cable in test C used to form coils of 30cm diameter and stretched out before test

C. THE FEATURE SELECTIVE VALIDATION METHOD

The FSV is a standardized tool that has been used to measure the degree of agreement between two data sets [14], [15]. The FSV can automatically compare data of any nature and put the results in a comprehensible form [16], [17]. It removes the human subjective judgment and enables objective comparison of data [11]. The aforementioned characteristics of FSV has made it applications in various fields of human endeavors possible, such as in electromagnetics, models, measurements and simulation results etc. [15], [18], [19], [20].

The FSV method uses three indicators to represent results. The first is the Amplitude Difference Measure (ADM) which measures the difference in amplitude between the data sets [16], [21]. The second is the Feature Difference Measure (FDM) which measures the difference between the features of the data sets [16], [21]. The third is the Global Difference Measure (GDM) which is a combination of the ADM and FDM is a measure of the overall difference between the data sets [16], [21]. The average values of the point-by-point comparison of the data sets gives the indicators for evaluating the quality of results as $\mathrm{ADM_{tot}}$, $\mathrm{FDM_{tot}}$ and $\mathrm{GDM_{tot}}$. The FSV interpretation scale is shown in Table 1 [21].

TABLE I. The FSV interpretation scale

FSV value (quantitative)	FSV Interpretation (qualitative)
Less than 0.1	Excellent
Between 0.1 and 0.2	Very good
Between 0.2 and 0.4	Good
Between 0.4 and 0.8	Fair
Between 0.8 and 1.6	Poor
Greater than 1.6	Very poor

III. MEASUREMENTS RESULTS

The measured return loss from the tests A, B, C and D of the four cables using the orange pair are shown in Figures 2 to 5. The return loss plots in Figures 2 to 5 shows that none of the four cable pairs crossed the standard category 6 cable limits. Similarly, the NEXT measurement of the tests A, B, C and D for the four cables are shown in Figure 6 to Figure 9 using the orange/green pairs combination. The NEXT plots in Figure 6 to Figure 9 also shows that none of the four cable pairs crossed the standard limits. Finally, the impedance measurements of the tests A, B, C and D for the four cables are shown in Figures 10 to 13 using the orange pair.

The plots in Figure 2 to Figure 13 shows that it will be difficult to draw an objective comparison by visual observation of the return loss, NEXT and impedance measurements of the four cables. This is where the use of the FSV for an objective comparison of the measurements is needed to enable the study of the resilience or otherwise of the cables to the coiling and uncoiling tests.

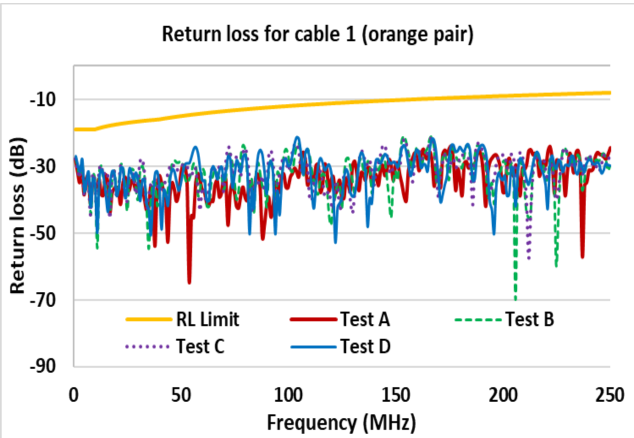

FIGURE 2. Return loss measurement for cable 1

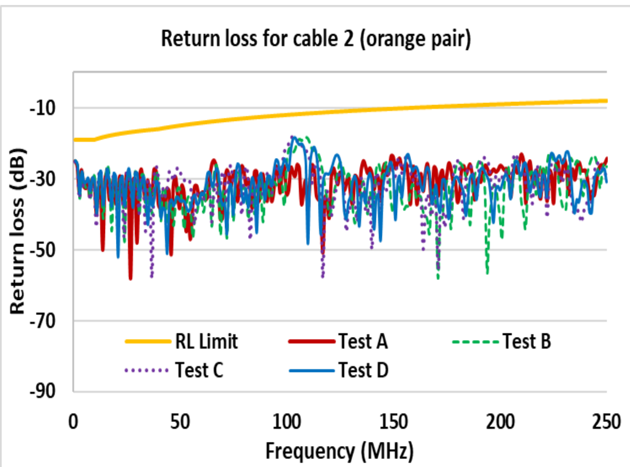

FIGURE 3. Return loss measurement for cable 2

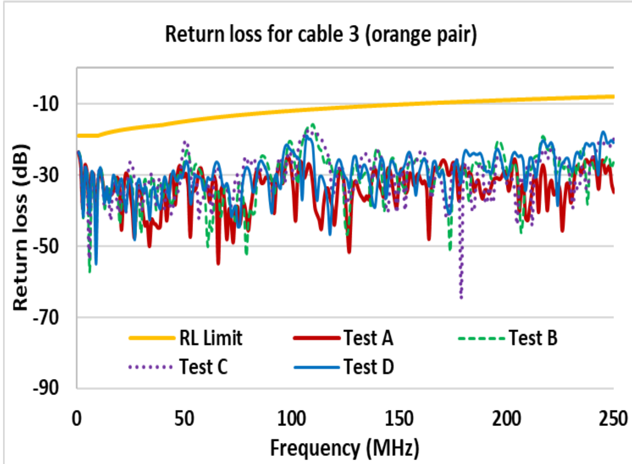

FIGURE 4. Return loss measurement for cable 3

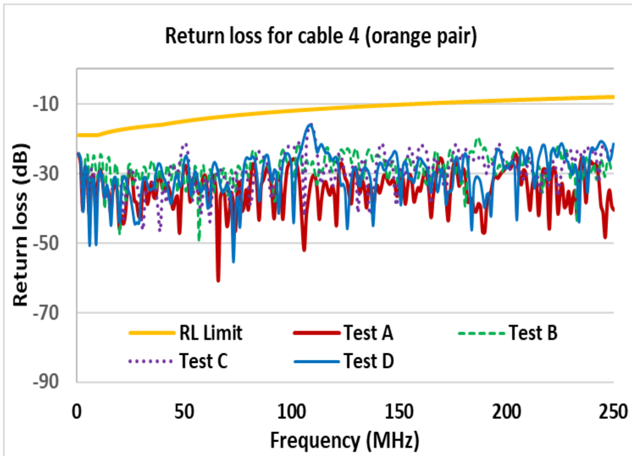

FIGURE 5. Return loss measurement for cable 4

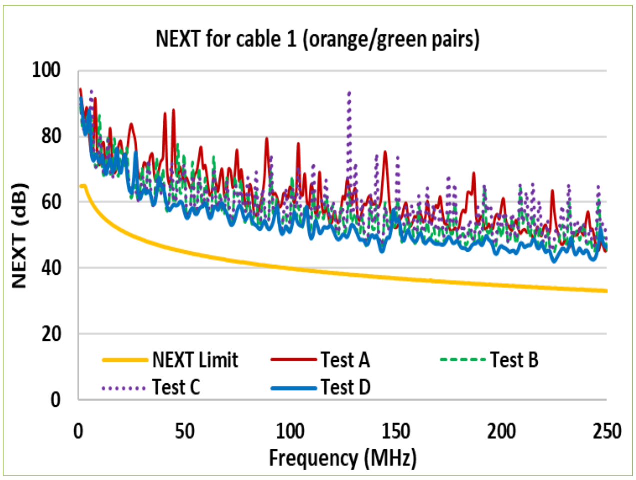

FIGURE 6. NEXT measurement for cable 1

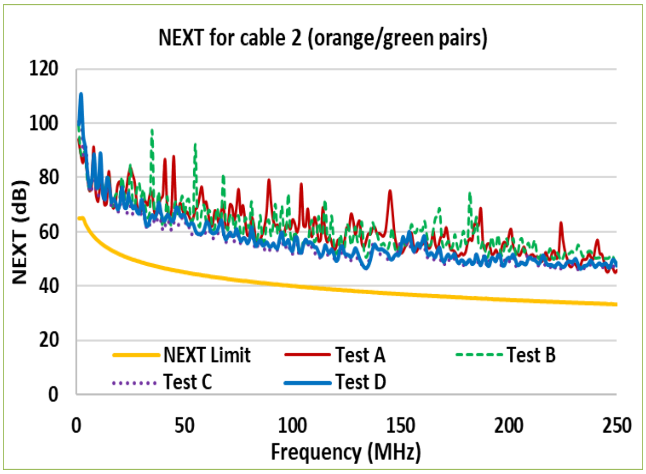

FIGURE 7. NEXT measurement for cable 2

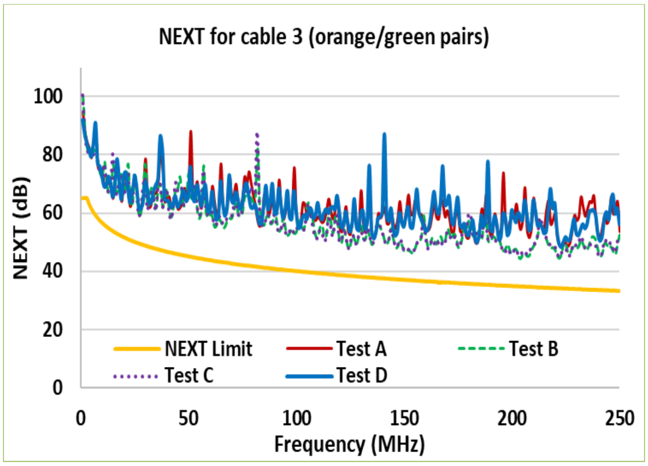

FIGURE 8. NEXT measurement for cable 3

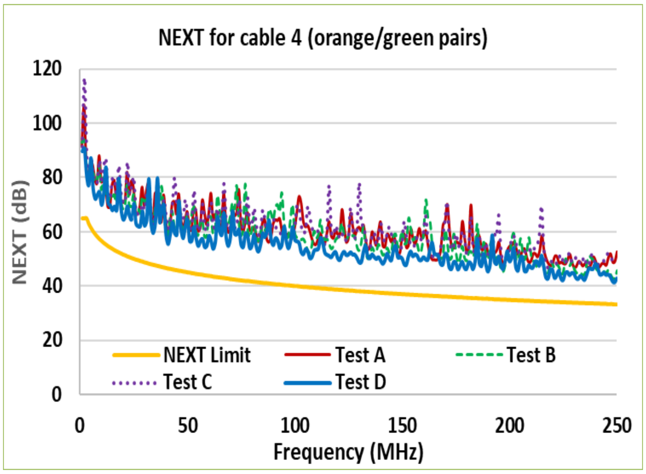

FIGURE 9. NEXT measurement for cable 4

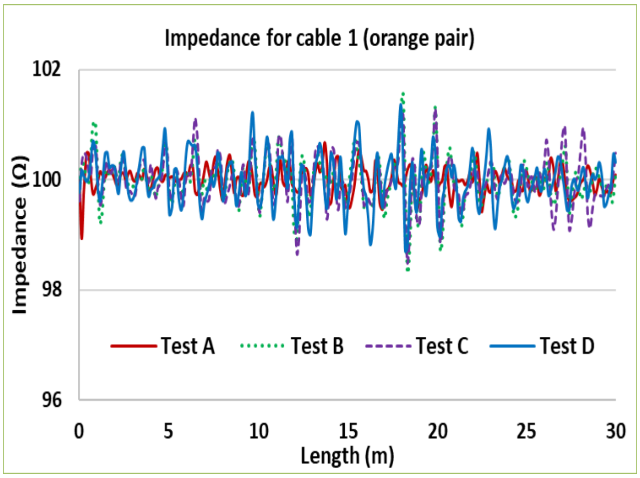

FIGURE 10. Impedance measurement for cable 1

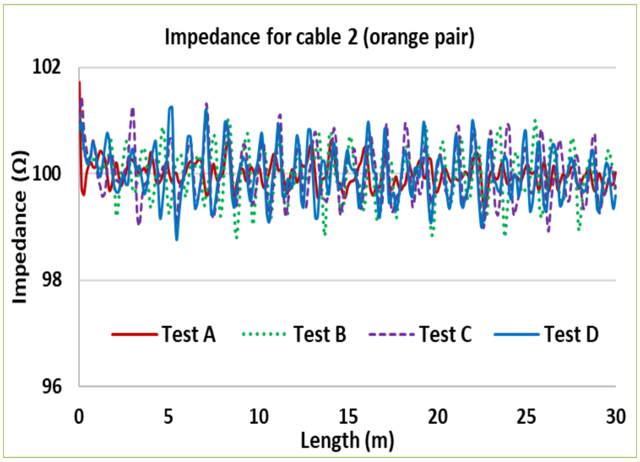

FIGURE 11. Impedance measurement for cable 2

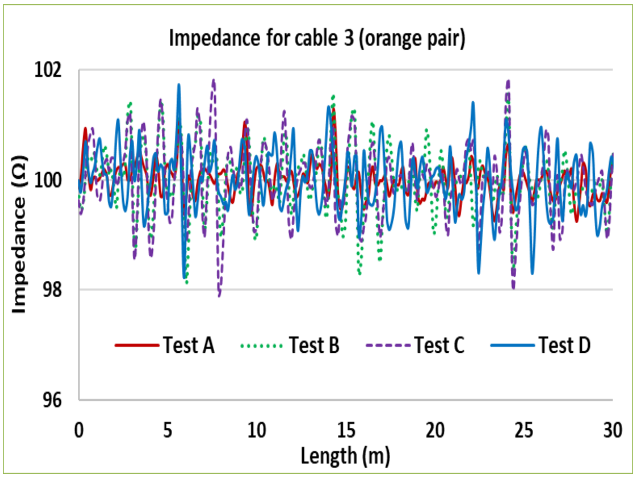

FIGURE 12. Impedance measurement for cable 3

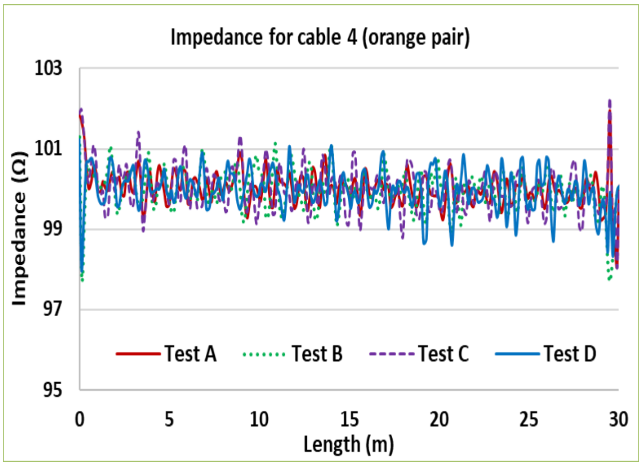

FIGURE 13. Impedance measurement for cable 4

IV. DISCUSSION OF FSV COMPARISON RESULTS

This section discusses the FSV GDM results of the comparison between measurements A (baseline) and B (second test), C (third test), D (fourth test) for return loss, NEXT and impedance of the twisted wire-pairs from the four UTP cables.

A. FSV RETURN LOSS COMPARISON

The result of the FSV GDM comparison between return loss measurements A (baseline) and B, C, D for the four cables using the orange, green, blue and brown pairs is shown in Figures 14, 15 and 16 respectively. The FSV return loss result in Figures 14, 15 and 16 indicates that the variations between test A (first) and subsequent tests B (second), C (third) and D (fourth) increases as the coiling test is repeated.

The summary of the FSV comparison after the fourth test in Figure 14, 15 and 16 indicates that cables 3 and 4 both foiled gave the lowest variations between measurements A and D in the blue and green pairs respectively. Similarly, cable 1 (non-foiled) gave the lowest variations between return loss measurements A and D in the orange and brown pairs.

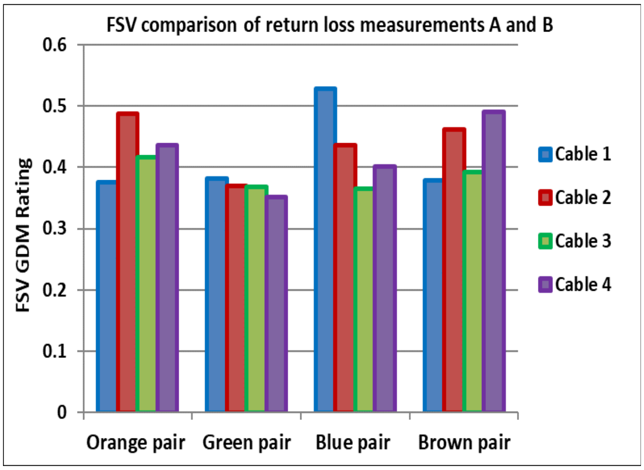

FIGURE 14. FSV comparison between return loss measurements A and B for the four cables

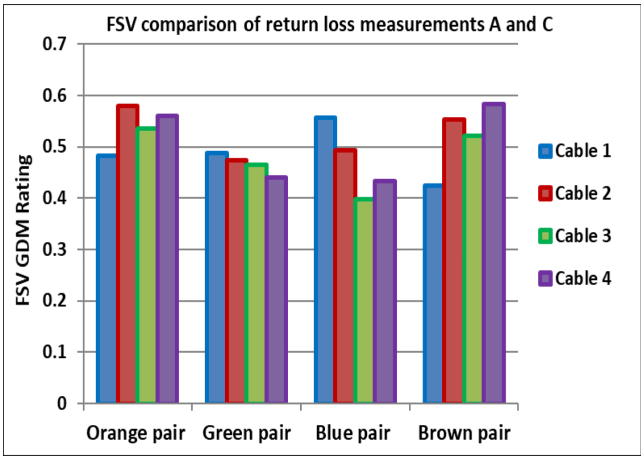

FIGURE 15. FSV comparison between return loss measurements A and C for the four cables

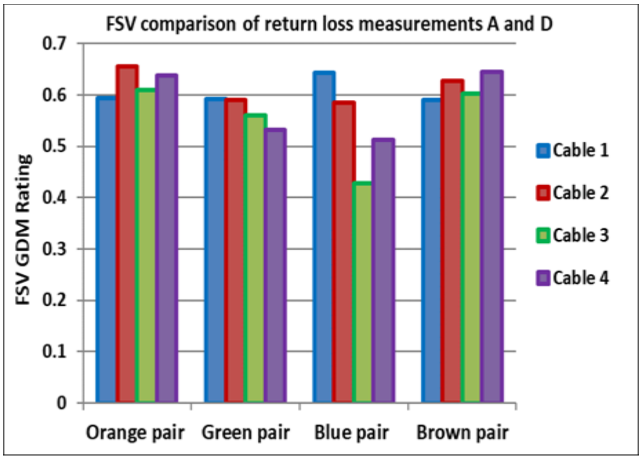

FIGURE 16. FSV comparison between return loss measurements A and D for the four cables

B. FSV NEXT COMPARISON

The result of the FSV GDM comparison between NEXT measurements A (baseline) and B, C, D for the four cables using the orange/green, green/blue, blue/brown and brown/orange pairs combination is shown in Figures 17, 18 and 19 respectively. The FSV NEXT result in Figures 17, 18 and 19 indicates that the variations between test A (first) and subsequent tests B (second), C (third) and D (fourth) increases as the coiling test is repeated. However, the impact of the coiling stress on NEXT is less for most pairs of the cables for tests A and B as most of them fall below 0.4 and not more than 0.5.

The summary of the FSV NEXT comparison after the fourth test in Figures 17, 18 and 19 indicates that cable 3 and cable 4 both foiled gave the lowest changes between NEXT measurements A and D in all the pairs considered. This indicates that the foiled cables provided the highest resilience to the coiling and uncoiling stress when it comes to NEXT.

Note: In Figures 17, 18 and 19, OR is orange, GR is green, BL is blue and BR is brown.

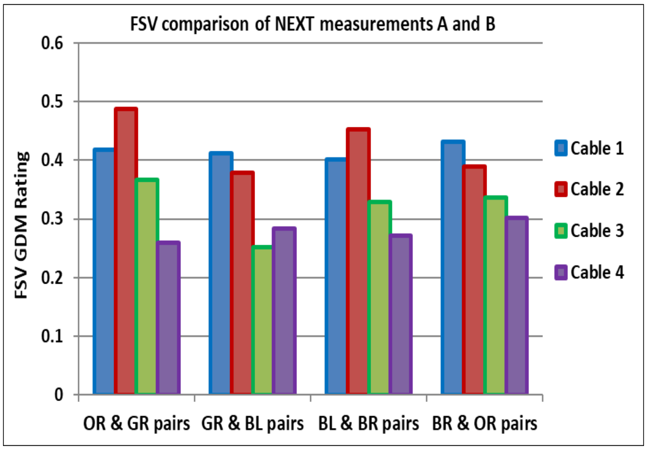

FIGURE 17. FSV comparison between NEXT measurements A and B for the four cables

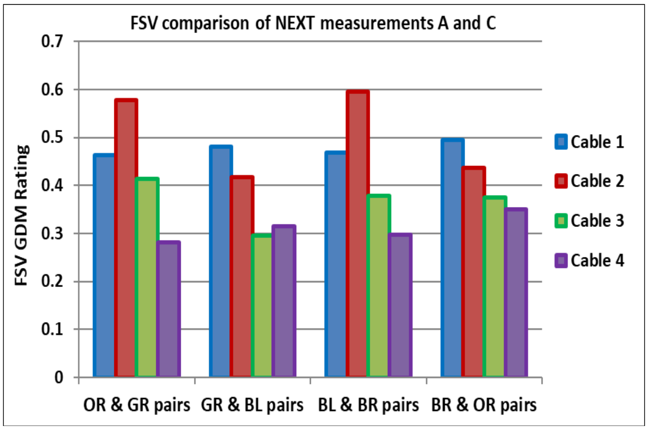

FIGURE 18. FSV comparison between NEXT measurements A and C for the four cables

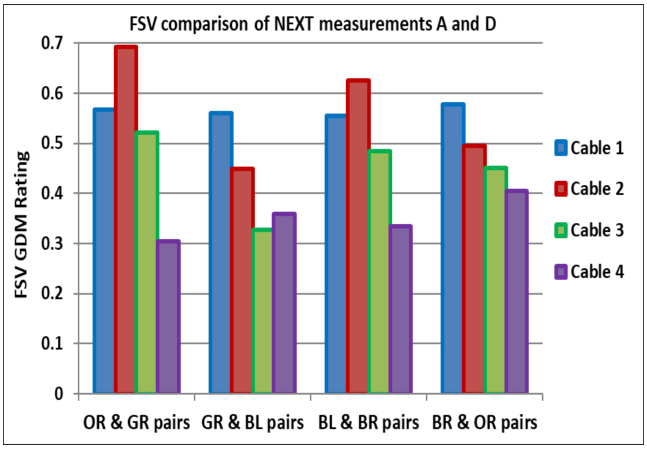

FIGURE 19. FSV comparison between NEXT measurements A and D for the four cables

C. FSV IMPEDANCE COMPARISON

The result of the FSV GDM comparison between impedance measurements A (baseline) and B, C, D for the four cables using the orange, green, blue and brown pairs is shown in Figures 20, 21 and 22 respectively. The FSV impedance result in Figures 20, 21 and 22 indicates that the variations between test A (first) and subsequent tests B (second), C (third) and D (fourth) increases as the coiling test is repeated.

The summary of the FSV comparison after the fourth test in Figure 20, 21 and 22 indicates that cables 3 and 4 both foiled gave the lowest variations between measurements A and D in the green and blue pairs. Similarly, cable 1 (non-foiled) gave the lowest variations between return loss measurements A and D in the orange and brown pairs.

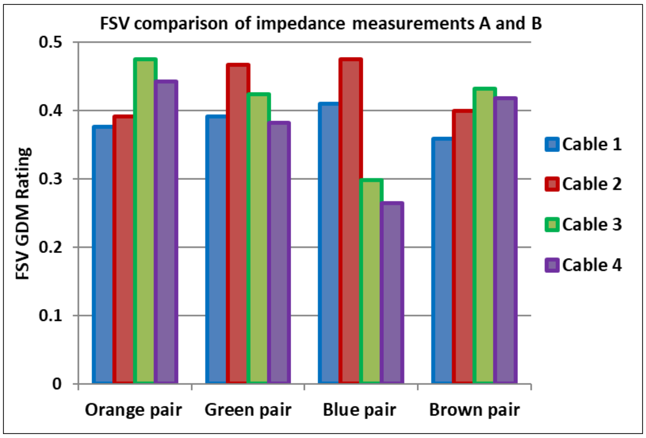

FIGURE 20. FSV comparison between impedance measurements A and B for the four cables

FIGURE 21. FSV comparison between impedance measurements A and C for the four cables

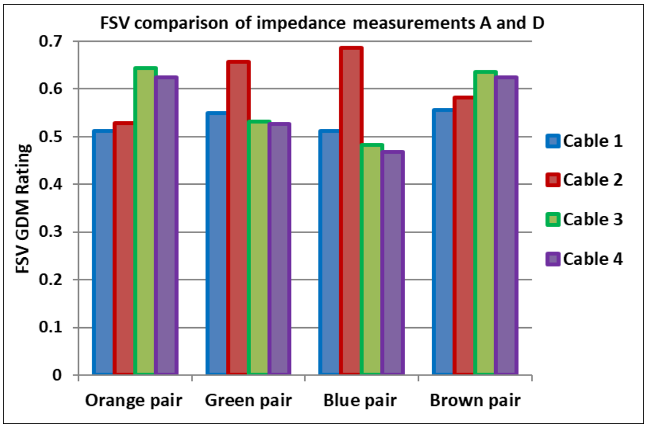

FIGURE 22. FSV comparison between impedance measurements A and D for the four cables

V. CONCLUSION

This paper provides a technique that can be used to assess the impact of coiling stresses on the performance measurements of foiled and non-foiled UTP cables. Four UTP (category 6) cables were subjected to three rounds of coiling and uncoiling tests. The FSV GDM results show that cable 3 and cable 4 both foiled gave the lowest variations between measurements A (baseline) and D (fourth test) in all pairs of the four cables for NEXT. Similarly, the foiled cables 3 and 4 gave the lowest variations between measurements A and D in two pairs for return loss and impedance. The FSV result also show that cable 1 (non-foiled) gave the lowest variations between measurements A and D in two pairs for return loss and impedance. In conclusion, the paper has presented a technique that can be used by cable engineers and installers to undertake an assessment of performance measurements obtained from twisted pair cables selected for deployment.

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