**Ms. No. Sensors-86249-2025** **Authors’ Reply to Reviewers’ Comments**

Analysis and Experimental Validation of SSTDR for Simultaneous Distributed Diagnosis of Wire Networks Sensor Journal.

Change the corresponding author to Mouad Addad

Dear Editor and Reviewers,

We would like to thank you very much for your valuable comments and the care and time you took in reviewing this manuscript. We have made substantial revisions to the manuscript, guided by your comments, and we believe this has made it a much better paper. Thank you very much. Please find the red-lined manuscript indicating the changes made. Also, we have highlighted the changes in response to your comments below.

Thank you again. We appreciate your expertise and comments.

Mouad Addad, Ali Djebbari, Evan Benoit and Cynthia Furse

**Editor’s Comments:**

Based on the enclosed set of reviews this manuscript is not acceptable for publication in its current form, but may be acceptable after being thoroughly reworked. If you choose to resubmit, please send the reworked manuscript as soon as possible. The sooner we receive the resubmission, the better the likelihood that we can utilize the same editor and reviewers.

Thank you for your review. We believe the comments have been extremely helpful in greatly improving the paper. Details are given below in blue, and our changes to the manuscript are highlighted in blue.

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**Reviewer #1:**

**Reviewer #1 Comment #1:**

Dear Author,

Complex branched cable networks such as the ones found in aircrafts can indeed be installed in harsh environment, which may result in cable defects subsequently leading to critical failure. Reflectometry is therefore a good way to monitor them, and improving old techniques like TDR /distributed TDR is thus always welcome and this makes your motivation really clear.

When I read your paper, it gave me an impression of "déjà vu" and I quickly found out why: you submitted a very similar manuscript (An Enhanced Method for the Distributed Diagnosis of WireNetworks, M. Addad & al..) in 2022.

But your work is now far more complete than it was 2 years ago because you added a whole new experimental validation section, which is greatly appreciated.

**Response to Reviewer #1, Comment #1:** Indeed, this work was initially submitted for review in 2022. Since then, we have taken the time to thoroughly validate our results thoroughly, both experimentally and through simulation. We believe these additions significantly strengthen the contribution of our study.

Thank you very much for taking the time to review our work and for your valuable feedback.

**Reviewer #1 Comment #2:**

I found answers to most of questions I had at the time, except these 3 points which still remain:

- eq. (3): P is missing (upper bound of the sum)

- eq. (7): it should be s'\_{i,m} instead of s\_{i,m}

- eq. (14): it should be \delta\_{l-l\_p} instead of \delta\_{l-p}

**Response to Reviewer #1 Comment #2:** Thank you for bringing this to our attention. We have corrected these errors in the revised version of the paper.

**Reviewer #1 Comment #3:**

On the downside, I still think you should have cited [1] (I would like to point out I am not one ofthe authors), because it has been available for more than 15 years and already provides answers to most of the issues your method was designed to address.Your main contribution was to replace M/Gold Sequence by ZCZ, but the rest is quite similar.

[1] Distributed Reflectometry-based Diagnosis for Complex Wired Networks, N. Ravot & al.(2007)

Best regards,

**Response to Reviewer #1 Comment #3:** Thank you for pointing this out. The recommended work has been added to the reference list. We appreciate your insightful comments, which have contributed to improving the paper.

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**Reviewer #2:**

Time Domain Reflectometry (SSTDR). By evaluating the pseudo-noise zero correlation zone, it enables simultaneous distributed testing. The work is particularly interesting in the context of simultaneous distributed testing. However, I recommend the following revisions before the paper can be considered for publication:

**Reviewer #2 Comment #1:**

In the abstract, please include performance metrics (e.g., maximum length) to help readers evaluate the work more easily.

**Response to Reviewer #2 Comment #1:** Adding quantitative performance metrics is a very good suggestion. Because of the detail of explaining what the metrics are, we have added them within the text rather than the abstract. Details are included below:

A quantitative performance metric for selecting suitable sequences was discussed in our previous work [Simultaneous…Addad et al.] (Section C, Subsection 2). In that work, we proposed a modified metric based on the merit factor, defined as the ratio between the autocorrelation peak at zero (representing the desired signal) and the autocorrelation sidelobes.

To better quantify the impact of interference in simultaneous distributed testing, the modified metric uses the power peak of the autocorrelation divided by the power in the cross-correlation function. The following statement has been added to the revised manuscript:

A performance metric based on the merit factor was proposed in [Simultaneous…Addad et al.] to evaluate the effectiveness of different sequences. This metric is a ratio of the autocorrelation peak (representing the desired signal) and the cross-correlation sidelobes (representing the interference). It was shown in [ref] that ZCZ sequences are promising candidates for simultaneous and distributed diagnosis due to their favorable correlation properties.

In addition to the previously mentioned metric based on the merit factor, we have also introduced a second performance metric in Section IV.3.A to further quantify the impact of interference on distributed measurements. We added a normalized interference error metric, which measures how the merit factor (theoretical) affects experimental performance in the presence of multiple interfering sequences:

The normalized interference error, illustrated in Fig. 8, is defined as the average difference between measurements with 0 and 15 interferers across the 0–70 m range, normalized by the magnitude of the peak response at point A. For m-sequences, Gold codes, and ZCZ sequences, the normalized interference error values are [insert values], [insert values], and [insert values], respectively. Similar trends are observed for SSTDR measurements in Fig. 9, where m- and Gold sequences exhibit normalized interference errors of [insert values] and [insert values], respectively, while ZCZ sequences show significantly lower error at [insert value].

These additions provide a more comprehensive quantitative evaluation of the system's performance under simultaneous testing conditions.

**Reviewer #2 Comment #2:**

In Section 2, Equation (6) introduces a cross-correlation function that is used to derive Equation (3) and eliminate noise signals. Please provide a detailed explanation of the reasoning behind this process.

**Response to Reviewer #2 Comment #2:** We suggest two responses: add a correlation term for the noise in equations (6) and (12). And add detail on other ways noise is reduced in SSTDR … baselining & averaging , and how well this does with live signals (eg mil 1553) (Cindy find references).

**Reviewer #2 Comment #3:**

Ensure that all figures include units on the y-axis.

**Response to Reviewer #2 Comment #3:** This is a good point. There are several different ways we could define the magnitudes on the y-axes of these figures. Correlation itself does not have a unit, and neither does the reflection coefficient (because it is a ratio of reflected and incident signals). As you have noted, this is important to clarify, however.

We have added the following after (4) when the correlation is first defined:

The magnitude of the correlation in (4) depends on the length of the signals and how well correlated they are and is called the correlation amplitude we will show in Fig. 2. We will use this correlation to evaluate more complicated systems as well.

We have also renormalized Figs. 4-10 to represent reflection rather than correlation. This will allow the user to evaluate the standard reflection coefficient equations when looking at the reflection diagrams. We added this new normalization below Fig. 4 during the discussion of the magnitudes of the peaks:

The magnitude of a reflection at a T-junction between cables of equal impedance is 1/3, so we have used this value to normalize the correlation magnitude, giving the reflection magnitudes (|Reflection|) shown in Fig. 4 and all remaining figures in this paper.

**Reviewer #2 Comment #4:**

The paper employs a test signal amplitude of 62.5 mV. Please discuss whether using different amplitudes would affect the testing results. Additionally, determine whether the test signal is a pulse signal and provide the relevant signal details. If it is a pulse signal, specify its pulse width and explain whether the pulse width impacts the test.

**Response to Reviewer #2 Comment #4:**We have added the following to the manuscript:

Increasing the amplitude of the test signal will raise the correlation peak amplitudes, however, the overall shape of the response remains unchanged. The test signal is a square wave modulated by a sequence, with each chip having a duration of , which corresponds to sampling distance of . The sequence is up-sampled by a factor of resulting in a sample width of corresponding to a sampling distance of .

**Reviewer #2 Comment #5:**

In Figure 3 (experimental setup), please provide additional details regarding the signal source, sensing component, and demodulation process.

**Response to Reviewer #2 Comment #5:**

This is definitely important, thank you for your comment. We have added additional details about the signal source, and how it is measured with the scope. The highlighted sections have been added, and we also added a figure to better show the ideal and measured signals. The scope is the sensing component, and there is no demodulation done in this work. Details are expanded in Section IV.1 (blue highlighted sections have been added):

We use a Rohde & Schwarz MXO5 oscilloscope with two waveform generators, as shown in Fig. 3. The function generators in this scope output predefined waveforms at 625 Msample/s, while its arbitrary waveform generators output user-defined waveforms with rates up to 312.5 Msample/s. We generated a signal sequence using MATLAB and uploaded it to the arbitrary waveform generator. The signal was captured by using one of the input channels (8 channels) with input impedance that can be set to either 50 Ω or 1 MΩ. An example of 30 chips of a 25 MHz m-sequence signal are shown in Fig. 3. The theoretical and measured values (using a direct connection between generator and scope) are compared.



Fig 3. First 30 chips of the 25 MHz m-sequence comparing the ideal (theoretical) and measured (generated) time domain values.

Three RG-58 coaxial cables with characteristic impedance 50Ω are used to form the Y-network. Generator 1 (Gen1) is connected at A to a 30.5 m cable, which connects at B to a T-junction of 13.7 m and 31.2 m cables. The BNC T-adapter at A also connects channel 1 of the oscilloscope. The signals are generated based on sequences uploaded from MATLAB. These are either STDR or SSTDR. The STDR is a square wave modulated by a sequence (as in (1), shown in Fig. 3), and the SSTDR is a sine wave modulated by the STDR signal. The sequences are of length for *m-* and Gold sequences, and for ZCZ sequences. The chip rate is giving a chip duration of . The sequence is up-sampled by a factor of so the sample rate is *.* The highest sampling rate available for this generator is slightly above . The reflected signals come back to the scope through the T-junction at A. Then the signals are downloaded and processed (cross-correlated with the incident signal) using MATLAB.

**Reviewer #2 Comment #6:**

Include a comparative table that lists and compares the proposed method with other related work.

**Response to Reviewer #2 Comment #6:** We have added additional review of algorithms used to evaluate the reflectometry data:

Many algorithms have been developed for network evaluation with reflectometry including the Greedy algorithm [5], iterative calculations [3], [6], reverse image searching [7], removing the pulses from nodes [8], selective averaging [2], wavelet transforms [9], [10], support vector machines [11], sensor fusion [12], genetic algorithm [13], [14], residual voltage inversion [15], time reversal [16], and more.

And we added information on how different types of reflectometry can/ cannot readily be used for evaluation of networks:

Instead of a table, we have added the following: (cindy is still working on this section)

A reflectometry-based measurement technique, such as time domain reflectometry (TDR), uses a step or pulsed incident signal, whereas noise domain reflectometry (NDR) uses existing noise and signals in the system as a passive test system. These techniques are not suitable for testing multiple channels simultaneously, as they would interfere with each other. Testing multiple channels simultaneously requires multiple orthogonal signals. This can be accomplished with spectral time domain reflectometry (STDR) and spread spectrum time domain reflectometry (SSTDR)”.

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**Reviewer #3:**

Comments: This paper presents and experimental validation of SSTDR for simultaneous distributed diagnosis of wire networks. However, the serous concerns needs to improve the content of the paper?

**Reviewer #3 Comment #1:**

What is the novelty of the paper? the sate of the art mechanisms are not added and discussed and the number of references is not sufficient

**Response to Reviewer #3 Comment #1:** The paper experimentally validates the idea that selecting the right type of sequences (codes) is crucial, specifically for an application like distributed, simultaneous, and continuous diagnosis (monitoring) of wire network. Previous contributions focused mainly on theoretical and idealized models for analysis (cable effects like loss and distortion, noise in the systems, measurement device limitations, etc.).

What does state-of-the-art mechanism mean?

We need to add more references but not just any.

**Reviewer #3 Comment #2:**

Please mention the number of equations in the content of paper

**Response to Reviewer #3, Comment #2:** Thank you for this comment. We’ve gone through the paper and made sure equations are numbered and referenced throughout.

**Reviewer #3 Comment #3:**

Why do you choose PN and ZCZ codes? the motivation is not clear in paper.

**Response to Reviewer #3 Comment #3:** Reflectometry-based measurement techniques, such as time domain reflectometry (TDR), use a step or pulsed incident signal. STDR (Sequence Time Domain Reflectometry) uses pseudo noise (PN) sequences as the test signal, and Spread Spectrum Time Domain Time Reflectometry (SSTDR) uses sine or square wave modulated (by PN sequences) test signals. A detailed response to the reviewer's comment is given in Section III as follows :

‘Among the conventional sequences, maximal-length m-sequences have the smallest PACF side lobes. The disadvantage of these sequences is their PCCF peaks which increase rapidly with sequence length. Consequently, m-sequences are optimal for single-point diagnostic systems, but not for simultaneous distributed sensing. Large sets of sequences with relatively good PCCF such as Gold sequences can be generated from a pair of m-sequences called the preferred pair. Zero Correlation Zone (ZCZ) sequences have recently been introduced to the field of wire diagnostics. Their performance was evaluated in the case of simultaneous diagnosis of multiple wires in [7], distributed diagnosis of noisy wire networks in [6], and simultaneous diagnosis of shielded cable bundles in [8]. The distinctive property of ZCZ sequences is that they have a zero-correlation zone in both their PACF and PCCF, where they are ideal for testing. If the zero-correlation zone width is chosen to be large enough to encompass all of the significant reflections in the system, interference from other codes transmitting simultaneously can be eliminated.’

**Reviewer #3 Comment #4:**

The conclusion Section needs to be summarized and the equation shou

**Response to Reviewer #3 Comment #4:** Thank you for this comment. The Conclusion Section is now summarized.

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Thank you again for these very helpful comments. We think they have helped us greatly improve the paper.