

Information and Communication Technologies

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Energy-Efficient Scheduling Method for Non-Deterministic Traffic in IEEE 802.15.4e TSCH

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Long Battery-Life Network Device for Industrial IoT Systems

The invention is based on a scheduling method that minimises the device's energy consumption, and thus extends battery life, for low-density, irregular and delay-sensitive traffic.

Advantages

Compatibility: Compliant with industrial IoT standards and works alongside other standard-compliant solutions.
Low complexity: Predictions rely on an empirical model and need little processing power.
Energy efficiency: Finds the most efficient solution to maximise battery life.
Self-adaptation: The model is updated taking environmental factors into account.
Scalability: The distributed algorithm maintains performance in networks with many devices.

A network device with user-adjustable performance

The network device developed in the invention operates in IEEE 802.15.4e TSCH mode. Its scheduling method is based on an empirical model that the device uses to make performance predictions, and the model is updated according to current measurements.

Using predictions based on this model, the algorithm finds the network configuration with the lowest energy consumption that meets the delay and reliability constraints set by the user.

A Semiconductor Photodiode Functioning In A Wide Band Range And Obtaining Method Thereof

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Low-cost Broadband Silicon Infrared Detector

Our invention is about the design and production of a low cost and effective photodetector that can operate in a wide band range from the visible to wide infrared wavelengths, that is, at a wavelength range of 0.4 μm to 9 μm.

Advantages

Useful: surveillance, military, and energy device applications. It can be used in a variety of fields, including telecommunication, environmental sensing, bio-medicine, monitoring equipment's. ect.

Efficient: Large worldwide sales market.: regional analysis for the Photoelectric Sensors (highest) Market:
-North America (USA, Canada and Mexico)
-Europe (Germany, France, England, Russia and Italy)
-Asia Pacific2 (China, Japan, Korea, India, and Southeast Asia)
-South America (Brazil, Argentina, Colombia etc.)

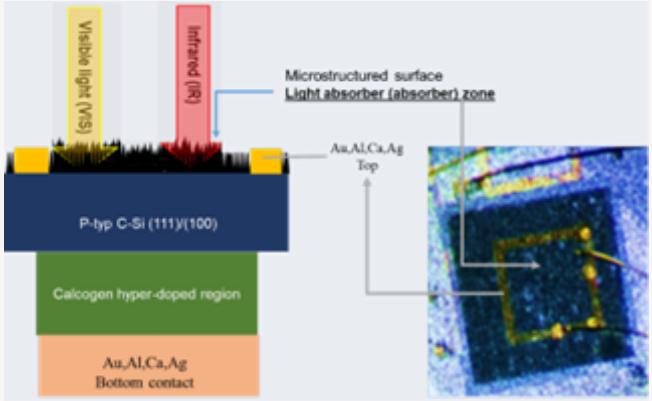
Cost performance: The proposed method offers an approach to fabricate low-cost broadband silicon-based photodetectors

High performance: High IR photoresponse of Si hyperdoped photodiodes at room -and cryogenic temperature. In other words, the invention covers a wide range of bands from visible to longwave infrared.

Sensitive: Higher sensitivity

The highly doped black Si allows the production of a new generation of photo-detectors that can operate in the near and mid-infrared region as well as in the visible region

Our invention enables the silicon to be active in the IR region by forming a new band in the forbidden band gap by doping the Si crystal with a high concentration of Se, Te, S atoms by ion implantation method. In addition, due to its compatibility with micronelectronic technology, its integration into complex CMOS circuits constitutes an important advantage.
The simple idea of our invention is that we dope semiconductors and their microstructures beyond the solubility limit of chalcogen dopants (sulfur, selenium, tellurium atoms) by processing the laser-assisted -doping and microstructuring separately on both sides of the Si; i.e., doping one side by ion implantation and microstructuring the other side



ODTÜ-24

Two-Stage Detection in One-Bit Massive MIMO Systems with Pseudo-Random Quantization

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One-Bit Newton-Hamming Detector (OBNHD)

A new quantization method and a new detection algorithm for massive MIMO systems equipped with one-bit ADCs

Advantages

The invention proposes a new quantization scheme for systems that are equipped with low-resolution ADCs, that can help overcome the negative effects of the stochastic resonance phenomenon on detection performance.

The dithering effect is obtained by changing the quantization thresholds of the ADC units and does not require additional oscillators.

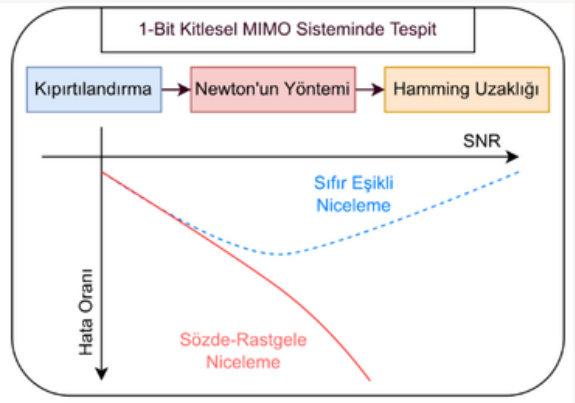
The proposed method in the invention outperforms the existing detection algorithms from the literature.

By utilizing one-bit ADCs, the proposed scheme provides exponential decrease in the power consumption compared to the systems that are equipped with high-resolution ADCs.

Due to the simple circuitry of the one-bit ADC units, important reductions in the base station construction costs can be obtained.

The invention can support higher order modulation schemes in a multi-user massive MIMO system that is equipped with one-bit ADCs and offers superior detection performance compared to that of the existing detectors from the literature.

The invention compensates for the negative effects of the stochastic resonance phenomenon on detection performance by creating a dithering effect with the help of the pseudo-random quantization scheme. The proposed detection algorithm utilizes Newton's method with an appropriate cost function created for detection purposes in the first stage and applies ML detection on a reduced candidate set formed by taking the one-bit quantized observations as binary codewords in space with a criterion based on the Hamming distance.



ODTÜ-116

Quasi-Newton Detection in One-Bit Massive MIMO-OFDM Systems with Pseudo-Random Quantization

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One-Bit Quasi-Newton Detector (OBQND)

A new quantization method and a new detection algorithm for massive MIMO-OFDM systems equipped with one-bit ADCs

Advantages

The invention proposes a new quantization scheme for systems that are equipped with low-resolution ADCs and can help overcome the negative effects of the stochastic resonance phenomenon on detection performance.

The dithering effect is obtained by changing the quantization thresholds of the ADC units and does not require additional oscillators.

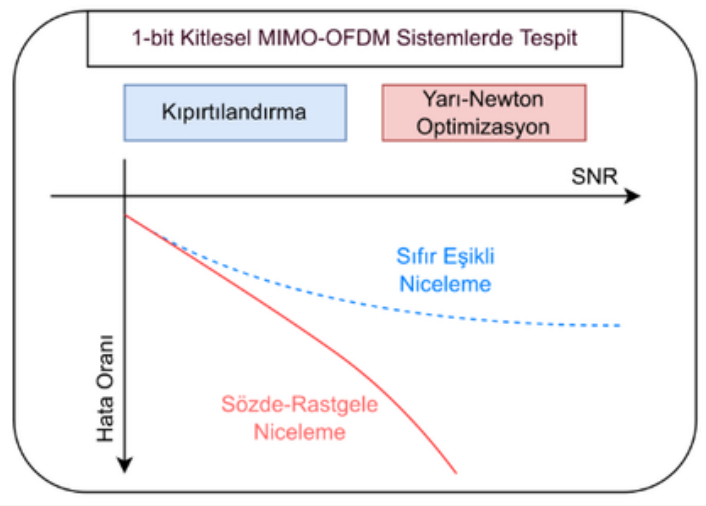
The proposed method in the invention outperforms the existing detection algorithms from the literature and offers low computational complexity as a frequency domain equalizer for wideband systems.

By utilizing one-bit ADCs, the proposed scheme provides exponential decrease in the power consumption compared to the systems that are equipped with high-resolution ADCs.

Due to the simple circuitry of the one-bit ADC units, important reductions in the base station construction costs can be obtained.

The invention can support higher order modulation schemes in a wideband multi-user massive MIMO-OFDM system that is equipped with one-bit ADCs and offers superior detection performance compared to that of the existing detectors from the literature.

The invention compensates for the negative effects of the stochastic resonance phenomenon on detection performance by creating a dithering effect with the help of the pseudo-random quantization scheme. The proposed detection algorithm utilizes a Quasi-Newton optimization technique constructed for detection purposes.



ODTÜ-120

MEMS Neuristor

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The invention focuses on an alternative approach by replacing the memristor-capacitor pairs in state-of-art memristor-based neuristors with an electromechanical device, CMUT.

Advantages

Energy-efficiency: Capacitive mode provides a minimal energy dissipation and maximized energy efficiency during operation with charge conservation during collapse-snapback.

Adjustable delay behavior: MEMS neuristor provides optimizable delay feature by applying a proper combination of AC signals and DC bias, resulting in a versatility in applications.

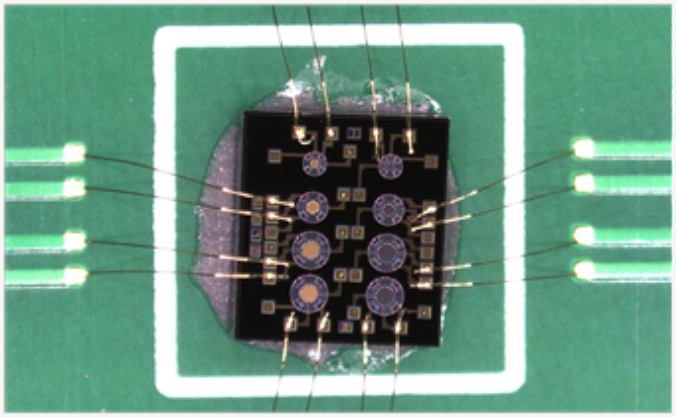
Reliability: MEMS neuristor provides a consistent and predictable behavior, free from such variability seen in memristor-based devices, ensuring greater reliability.

Compatibility with industrial microfabrication: Neuristor functionality is achieved with a single compact CMUT element, MEMS-based devices, eliminating the need for additional memristive components or specialized materials and bringing about inherent compatibility with existing CMOS processes, simplifying industrial fabrication and integration.

Frequency-dependent operation: Frequency-dependent spike generation provides adjustable sub- and super-threshold reponses in MEMS neuristor according to frequency of applied signal benefiting from spring softening effect of CMUTs.

A newly developed MEMS neuristor designed to meet the industrial demand for a reliable, high-performance, CMOS-compatible neuristor prototype to power next-generation neuromorphic electronics.

A paradigm shift from traditional analog/digital electronics to brain-inspired neuromorphic hardware has the potential to address the massive waste of energy, time, and materials. This transition can be realized by replacing transistor-based systems with neuristor-based hardware.
Memory and processing functions of a neuristor are achieved without relying on any memristive element thanks to the hierarchically layered mechanical and electrical features of the CMUT.
CMUTs, as units of MEMS neuristor, featuring collapse-snapback events present hysteresis characteristics in their capacitance and membrane deflection between their collapse-snapback voltages, offering memory feature.
Utilizing Fowler-Nordheim tunneling mechanism in CMUTs instead of insulation layer provides capacitive and resistive operation modes of CMUTs offering threshold-based spike generation.



ODTÜ-152

High-Sensitivity MEMS and Fiber-Optic Microphone Immune to Electromagnetic Waves

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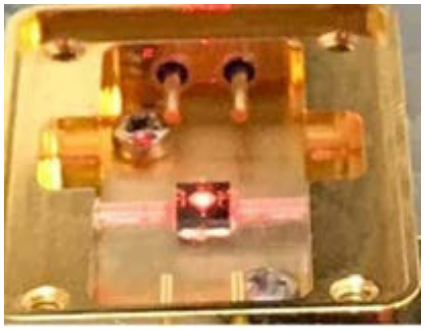
Fiber-Optic MEMS Microphone

Thanks to its optically tunable flexible membrane design, the invention offers superior microphone performance compared with other fiber-optic MEMS microphones.

Advantages

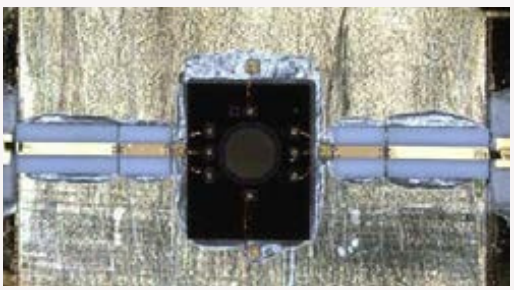
Reliable: Delivers stable, dependable microphone performance.
Long-lasting: Robust structure provides a long service life.
High sensitivity: Tunable MEMS membrane enables precise sound detection.
EM immunity: Unaffected by electromagnetic waves.
Harsh-environment resistance: Operates outdoors and in harsh conditions.



A reliable, sensitive, outdoor-resistant microphone

Fiber-optic MEMS microphones combine a passive MEMS diaphragm with optical fibers. This invention replaces the passive diaphragm with an electrically tunable MEMS membrane.

A photodiode chip generates electrical energy from the laser light passing through the membrane; the energy of the light carried in the optical cable is converted into a voltage on the membrane via a photodetector. This removes the need for electrical transmission along the fiber and significantly reduces the cost of large-scale use.



A Method For Direct Resonance Computation Of Nonlinear Structures By Using Response Dependent Nonlinear Normal Modes (RDNMS)

RDNM DRC

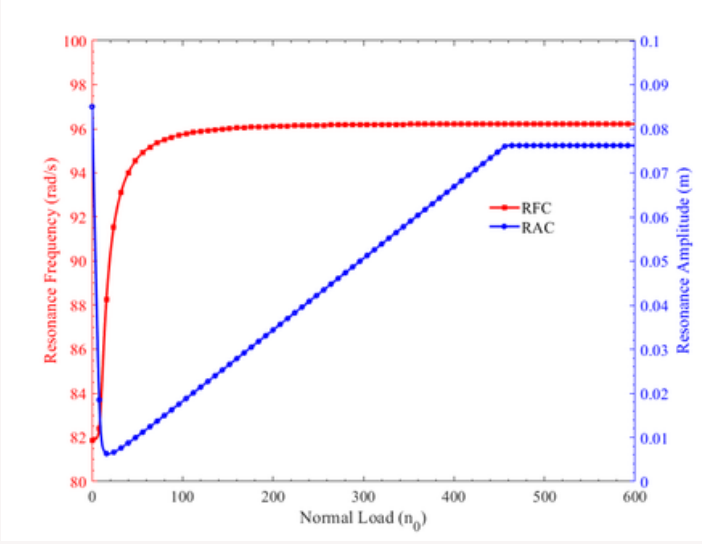
The present invention enables the direct computation of the resonance response of nonlinear systems by employing Response-Dependent Nonlinear Modes (RDNMs). The RDNM-DRC approach calculates the resonance response as a function of variations in both the excitation amplitude and the nonlinear parameter. Furthermore, the method is applicable to systems exhibiting complex nonlinear behaviors, such as internal resonance or modal coupling.

Advantages

- **Computational Efficiency:** Direct calculation of the resonance response and a significantly reduced number of required mode shapes substantially decrease the overall computational time.
- **Direct Resonance Characterization:** Resonance amplitudes and nonlinear natural frequencies can be directly determined with minimal computational effort using analytical or numerical methods.
- **Wide Parametric Capability:** Resonance amplitude and frequency can be evaluated as functions of both the excitation amplitude and various nonlinear parameters.
- **Low Computational Cost:** The total time required to generate resonance characteristics is merely on the order of computing a single frequency response curve (FRC).
- **High-Fidelity Applicability:** The method's efficiency makes it highly suitable for use with high-fidelity finite element models while maintaining strict accuracy.

The invention enables the direct, fast, and highly accurate computation of the resonance responses of nonlinear systems over a wide parameter range.

In the current state of the art, Frequency Response Curves (FRCs) are commonly used to analyze nonlinear systems. However, such approaches require the computation of a large number of FRCs, which leads to high computational cost and does not allow accurate determination of the resonance response. In contrast, the present invention first determines the nonlinear natural frequency of the system and subsequently computes the vibration amplitudes directly at this frequency. As a result, the need for conventional frequency-sweeping-based methods is eliminated.



ODTÜ-172

A New Computationally Efficient Method for Direct Determination of Flutter Speed for Linear and Nonlinear Structures

DNFSD: Direct Nonlinear Flutter Speed Determination

This invention presents a novel frequency-domain computational method that directly and efficiently determines the flutter speed of both linear and nonlinear structures. Unlike existing methods (p-k, k-method), this approach computes flutter speed in a single step without requiring a flow speed sweep, and is directly applicable to nonlinear aeroelastic systems.

Advantages

Direct Solution Without Speed Sweep: Flutter speed is computed directly without iterating over flow speed values, reducing both computation time and risk of missing the flutter point.

Applicability to Nonlinear Systems: The method determines flutter speed and post-flutter characteristics for nonlinear structures in the frequency domain a capability absent in all current commercial aeroelastic tools.

No Time Integration Required: The high computational cost of transient time-domain solutions is eliminated; the method reaches the steady-state solution directly.

Suitability for Design Optimization: Its computational efficiency makes the method compatible with optimization algorithms that require repeated evaluations of the same problem for varying design parameters.

High Accuracy: Since flutter speed is obtained by directly solving for the condition of zero net damping rather than detecting a sign change during a speed sweep superior accuracy is achieved.

The invention enables the direct, fast, and highly accurate determination of flutter speed and post-flutter characteristics for linear and nonlinear aeroelastic structures without time integration using a frequency-domain formulation.

Existing methods (p-k, k-method) require repeated eigenvalue computations across a range of flow speeds to detect a sign change in equivalent damping; nonlinear systems additionally require costly time-domain integration. The proposed method reformulates the equations of motion in harmonic form using the Harmonic Balance Method (HBM), integrates flow speed, vibration frequency, and amplitude as unknowns into a single nonlinear algebraic system, and directly solves for the flutter condition (net damping = zero) as a constraint. This eliminates the flow speed sweep entirely and naturally accounts for amplitude-dependent nonlinear effects.

Design and Manufacturing Method for Surface-Deformed Passive Reflectors for mmWave Mobile Communication

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Passive Reflector for mmWave Coverage

A design and manufacturing method for single-piece, energy-free reflectors with shaped conductive surfaces that reflect signals from a source to predefined areas with low loss in millimetre-wave mobile communication.

Advantages

Steerable reflection: The surface shape reflects the signal in the desired directions at the desired power.
Easy design: Only the problem requirements are needed for a design.
Requirement-driven: The method generates a structure that meets the requirements.
Time saving: Saves time in the design phase.
Low cost: 3D printing and coating reduce infrastructure and production costs.

Single-piece passive reflector for 5G mmWave

The reflector is designed in a computer environment. Unlike existing passive reflectors for 5G millimetre-wave mobile communication systems, the invention realises single-piece conductive structures.

Manufacturing involves two simple steps: 3D printing and conductive coating. Independent reflector surfaces can be produced without infrastructure upgrades, and coating a printed structure instead of machining metal blocks reduces cost.

Age-of-Information Threshold Mini-Slotted Random Access

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MuMiSTA Random Access Protocol

A random access protocol that adds Age of Information (AoI) control thresholds to slotted ALOHA, which has long been used in computer networks.

Advantages

Age threshold: An AoI threshold keeps transmission focused on fresh data.
Mini slots: Multiple mini slots are used for access control.
New access scheme: Introduces a new mini-slot access structure.
Optimised parameters: Protocol parameters are optimised for AoI.
High speed: Up to 53% faster, with AoI reduced to about one third.

Faster and fresher data transmission

Existing random access protocols were not designed around AoI, so their channel control mechanisms ignore it and perform far from optimal. Efficiency remains at 18% for ALOHA and 37% for slotted ALOHA.

MuMiSTA optimises AoI while preserving the random access structure. The protocol is up to 53% faster and reduces AoI to about one third.

High-Performance Object Detection Using HDR Images from LDR Cameras in Autonomous Vehicles

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HDR-Assisted 3D Object Detection

An integrated solution that uses low-cost cameras to automatically detect people, vehicles and objects that cannot be seen by eye in dark areas or under strong glare.

Advantages

Recognition performance: Joint training of sub-blocks increases system performance.
Cost advantage: Low-cost LDR cameras replace expensive HDR cameras.
Difficult lighting: Objects can be recognised in tunnels and at sunrise or sunset.
Integrated solution: Image enhancement and object detection in one system.
Safety: Helps prevent unwanted accidents in autonomous vehicles.

HDR-quality detection with low-cost LDR cameras

Current autonomous vehicles mostly use LDR cameras, so objects cannot be separated and recognised under high-contrast lighting such as tunnels, sunrise or sunset.

The invention offers a high-performance object detection system using HDR images obtained from LDR cameras. By transferring the most informative parts of the HDR image into detail-rich images, the system improves automatic object detection and helps prevent accidents.

High-Speed Network Packet Classification on GPUs

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BVGPU

GLAS is a software technology that runs the multi-dimensional associative search used in packet classification on general-purpose GPUs, reaching about 8.98 billion classifications per second with 1K rules and 3.83 billion with 10K rules.

Advantages

Highest throughput: 8–27× faster with 1K rules and 4–8× faster with 10K rules than competitors.
Low latency: 10–20 µs lookup latency suits time-critical applications.
Fully programmable: Software-based, so rules update without hardware changes.
Cost-effective: Runs on standard GPUs; cheaper than FPGA/ASIC or TCAM.
Comprehensive matching: Prefix/ternary, range and exact matching in one framework.

Packet classification on GPUs without special hardware

GLAS performs classification, the most critical and resource-intensive stage of the packet processing pipeline, with an associative search method that exploits the massive parallelism of GPUs. Packet header fields (IP addresses, ports, protocol) are compared with the rule set simultaneously across thousands of GPU cores.

Prefix/ternary matching for IP addresses, range matching for ports and exact matching for protocols are supported. Running above 200 Gb/s with 10–20 µs latency, it offers a flexible, low-cost solution for firewalls, data centres, 5G/6G core networks and next-generation routers.

Image Alignment through Deep Feature Matching

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DFM – Deep Feature Matching

An integrated architecture that uses any pre-trained deep network to find point correspondences between two images with high precision, following coarse geometric alignment with a coarse-to-fine strategy.

Advantages

No training required: Features of any pre-trained classification network can be used without dedicated training.
High localisation accuracy: Matches are refined up to the original image resolution.
Viewpoint robustness: Coarse alignment ensures reliable matching under large viewpoint changes.
Modular design: No retraining needed when the feature-extractor backbone changes.
Speed and accuracy: High match counts and precise localisation suit real-time use.

Matches images from different viewpoints in a single framework

The invention solves the matching problem between images taken from different viewpoints in a single framework, without the classical sequential pipeline in which detection, description and matching stages constrain each other.

In the first stage, a coarse geometric transformation is estimated with Dense Nearest Neighbour Search (DNNS) on final-layer feature maps and the second image is aligned. In the second stage, the Hierarchical Refinement Algorithm (HRA) refines the matches up to the original resolution.