HADMÉRNÖK
VÉDELEMINFORMATIKA
15. évfolyam (2020) 2. szám 103–126.
DOI: 10.32567/hm.2020.2.8

István Balajti[1]

Advanced Issues of the Radar Conference in Boston, 2019

A 2019-es bostoni radar konferencia legkorszerűbb témakörei

The modernisation of the Hungarian Army and the success of the Zrínyi 2026 Programme basically depend on the understanding and professional lifecycle-support of the latest technologies. Consequently, it is a priority to collect, evaluate and transfer advanced research findings and collected expertise on the concepts related to sensors, including Radars. The software modules define the quality, while the flexibility of the interfaces determine the efficiency of the signal and data processing of the information of different sensor types. The software-based solutions play a key role in the artificial intelligence supported cognitive data processing and the effectiveness of the soldiers or decision-making commanders. This article summarises the most recent results of the radar-related research, taking into account domestic and Eastern European expectations.

Keywords: radar, electronic attack, electronic protection, passive radar systems, bi- and multistatic radar systems, cognitive radar, spectrum sharing technique, weather radar

A Magyar Honvédség modernizálása, a Zrínyi 2026 sikere alapvetően az új technológiák megértésén és az élettartamra szóló professzionális szintű kiszolgálásán múlik. Ezért kiemelten fontos feladat az érzékelőkkel, ezen belül, a rádiólokátorokkal kapcsolatos legújabb kutatási eredmények, illetve elképzelések szakmakritikus összegyűjtése, értékelése és az összegyűjtött tapasztalatok átadása. A szoftvermodulok határozzák meg a különböző típusú érzékelők jel- és adatfeldolgozásának hatékonyságát, míg az interfészek sokszínűsége a kidolgozás minőségét. Kulcsfontosságú a katonák, illetve döntést hozó parancsnokok szerepe a mesterséges intelligencia által támogatott kognitív adatértékelés megvalósításában. A cikk a rádiólokációval kapcsolatos legutóbbi eredményeket foglalja össze a hazai és kelet-európai elvárások figyelembevételével.

---

[1] University of Public Service, Faculty of Military Sciences and Officer Training, e-mail: balajti.istvan@uni–nke.hu, ORCID: https://orcid.org/0000-0003-3566-2904

Kulcsszavak: **rádiólokátor, aktív zavarás és zavarvédelem, passzívradar-rendszerek, bi- és multistatikus radarrendszerek, kognitív rádiólokátor, spektrumfelosztási technológiák, időjárásradar**

The article focuses on advanced papers of the Radar Conference held in Boston and it extends the conclusions and findings that have been summarised in the article "István Balajti: General Overview on the Radar Conference in Boston 2019" published in Hadmérnök, Vol. 15, no. 1 (2020). All information on the conference is available at the link: http://ieee-aess.org/conference/2019-ieee-radar-conference. [1]

Findings on weather radar

Elizabeth Kowalski, David Conway, Alex Morris, Christine Parry: Multifunction Phased Array Radar Advanced Technology Demonstrator (MPAR ATD) Nearfield Testing and Fielding. [2]

Lincoln Laboratory (MIT LL) have been working in support of the Multifunction Phased Array Radar (MPAR) program to develop low-cost phased array radar. The 76-panel fully polarimetric AESA radar has EIRP of 85 dBW, 40 dB boresite directivity, and less than 0.04° beam steering error.

The paper is remarkable for us from the point of view of radar antenna performance testing and the rising importance of the solid weather dual polarized phased array systems. The presenters are open for cooperation and technical discussions. Figure 1 shows the conceptual design of MPAR AESA radar with four faces that can perform both aircraft and weather surveillance.

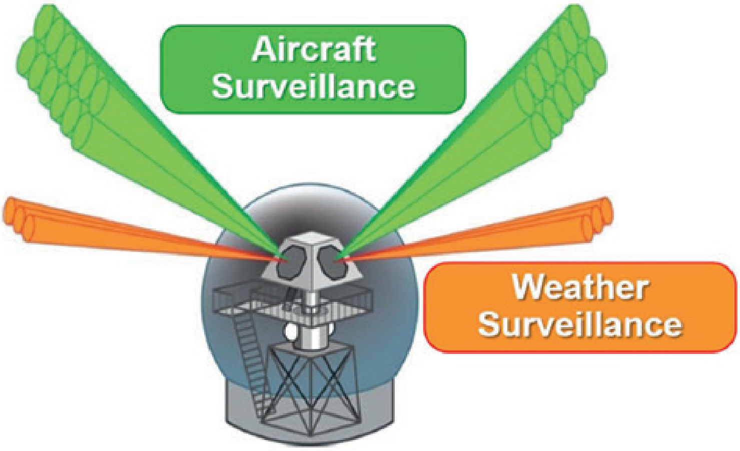


Figure 1

Concept showing the four faces of the MPAR AESA radar for aircraft and weather surveillance [2]

Figure 2 shows a picture of MPAR ATD 76-panel array at MIT LL RF Test Facility undergoing nearfield testing and calibration.

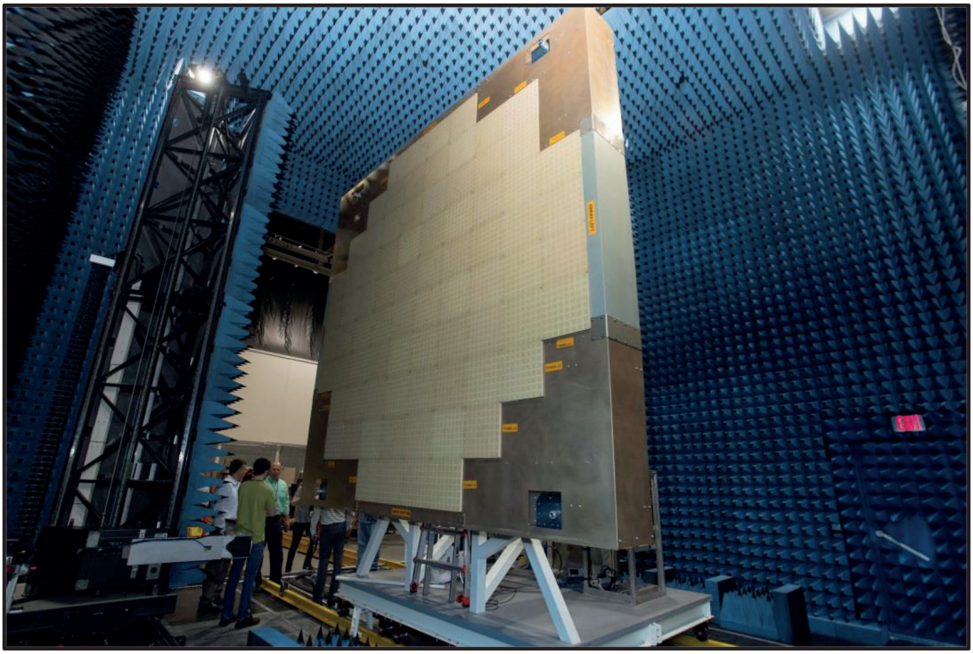


Figure 2
MPAR ATD 76-panel array in the anechoic chamber [2]

Figure 3 depicts the nearfield calibration of the MPAR ATD for the receive channel: part (a) displays the uncalibrated measured amplitude of each element; part (b) displays the amplitude after calibration; part (c) displays the uncalibrated phase for each element and part (d) shows the phase after calibration. Figure 4 shows the installation of the new radar under RADOME, while Table 1 summarises the MPAR ATD nearfield test results.

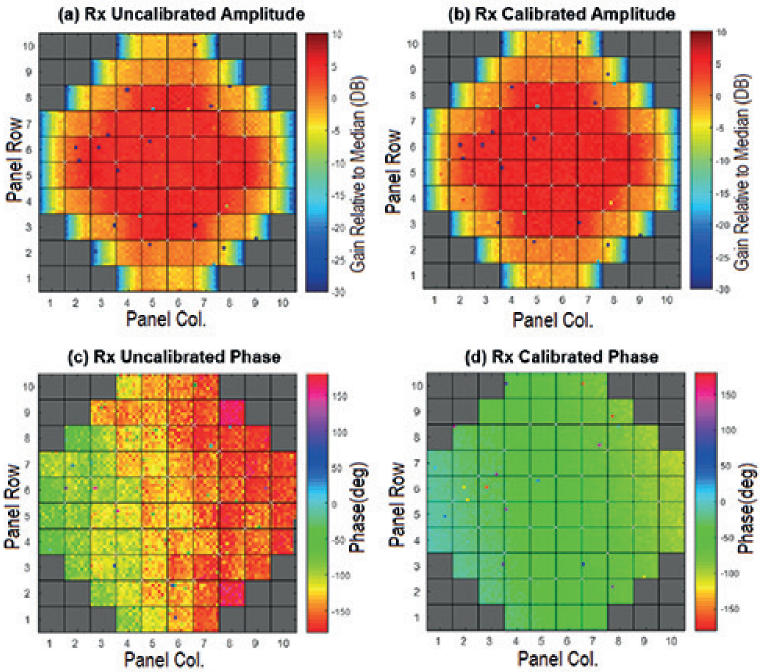


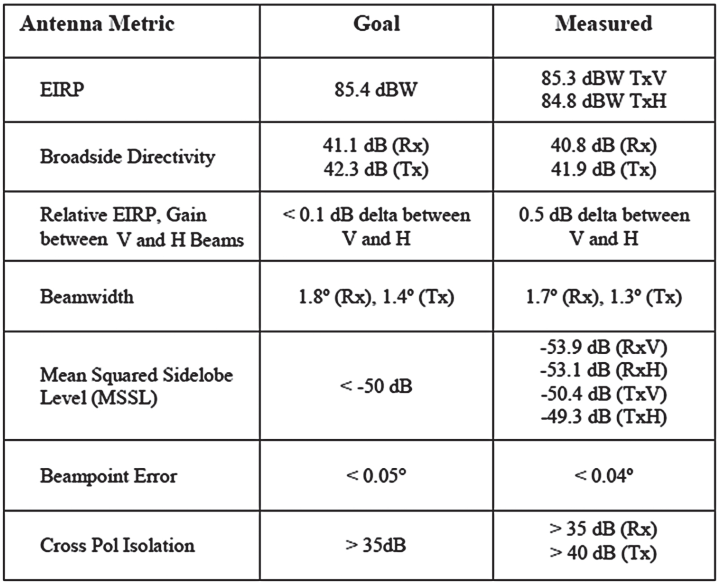
Figure 3

Power of the MPAR Antenna near Field Calibration [2]

Figure 4

Installation of the NWRT RADOME in July 2018 [2]

Table 1
MPAR ATD nearfield test results [2]



Antenna Metric	Goal	Measured
EIRP	85.4 dBW	85.3 dBW TxV 84.8 dBW TxH
Broadside Directivity	41.1 dB (Rx) 42.3 dB (Tx)	40.8 dB (Rx) 41.9 dB (Tx)
Relative EIRP, Gain between V and H Beams	< 0.1 dB delta between V and H	0.5 dB delta between V and H
Beamwidth	1.8° (Rx), 1.4° (Tx)	1.7° (Rx), 1.3° (Tx)
Mean Squared Sidelobe Level (MSSL)	< -50 dB	-53.9 dB (RxV) -53.1 dB (RxH) -50.4 dB (TxV) -49.3 dB (TxH)
Beampoint Error	< 0.05°	< 0.04°
Cross Pol Isolation	> 35dB	> 35 dB (Rx) > 40 dB (Tx)

Andrew Byrd, Robert Palmer, Caleb Fulton: Implementation of a Low-Cost Passive Weather Radar and First Weather Observations, University of Oklahoma, USA. [3]

A passive weather radar system has been implemented that can operate in conjunction with any in-band transmitter using only the direct path signals from that system and the knowledge of time-stamped pointing angles. The radar is capable of high-quality pulse detection, frequency synchronisation and handling data produced by several specialised WSR-88D weather radar transmit schemes.

Figure 5 plots data from a WSR-88D scans at an elevation of 5:01 . The top row of plots contains observations of range corrected power and bistatic velocity collected by the passive receiver (censored at 3 dB SNR). The bottom row shows reflectivity and radial velocity data collected by KTLX (radar site name, which is censored below 10 dBZ). Isotropic-range ellipses are plotted in black, while KTLX and the passive receiver are indicated in blue.

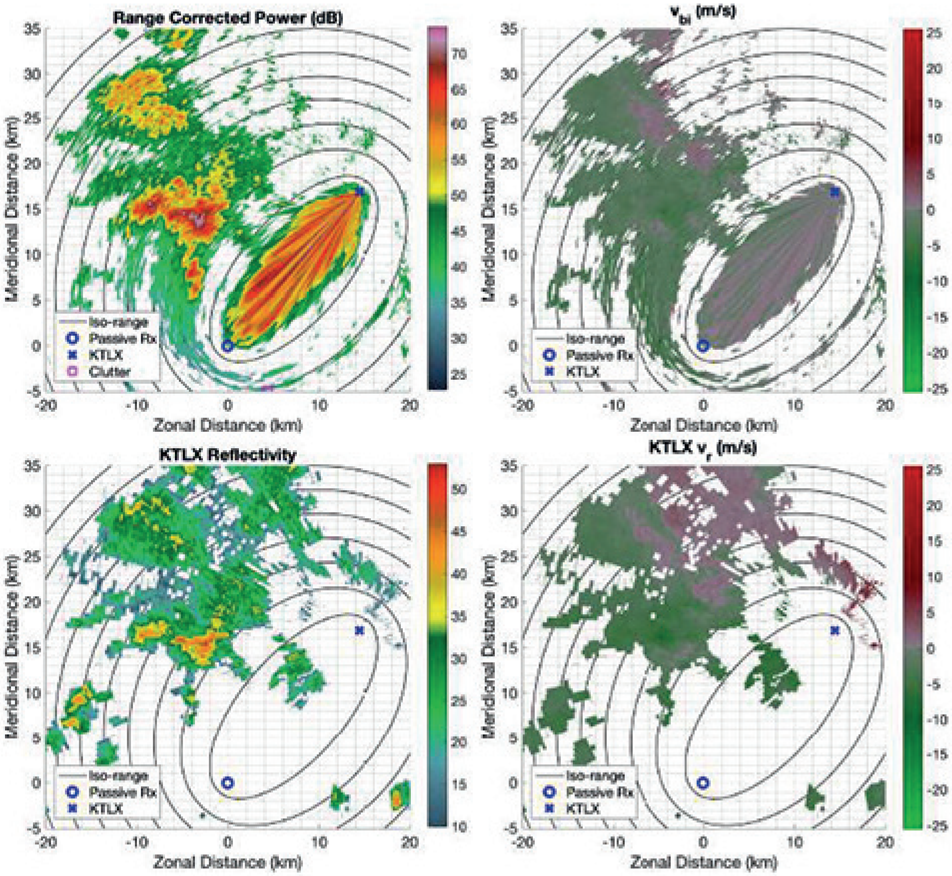


Figure 5

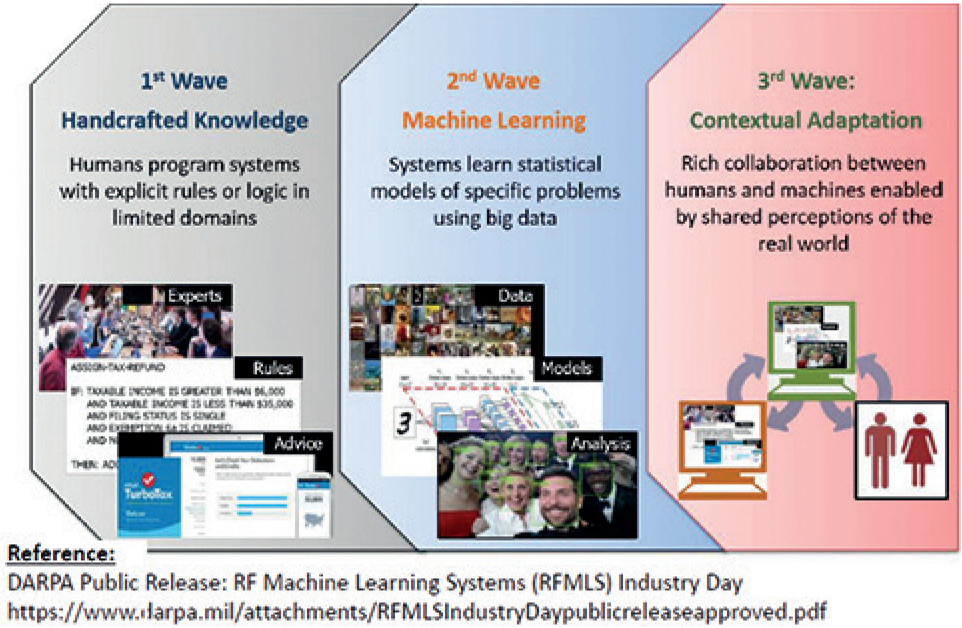
Plots from WSR-88D, KTLX and passive radar [3]

Other investigations are planned, in the frameworks of a more rigorous study, on the quality of the frequency calibration and mitigation of sidelobe contamination that are using the concept of sidelobe whitening on transmit among networked sensor units.

Findings on machine learning technology and cognitive radar

Uttam Kumar Majumder, Eric Blasch, and David Garren: Machine Learning Techniques for Radar ATR, USA.

This tutorial focused on recent research results, technical challenges, and directions of Deep Learning (DL) based on object classification using radar data such as Synthetic Aperture Radar (SAR) data [4]. The presentation highlighted implementations of DL-based Convolution Neural Networks (CNN) SAR objects, recognition algorithms in Graphical Processing Units (GPUs) and energy efficient computing systems. Figure 6 shows the three waves of Artificial Intelligence applied.



Humans program systems with explicit rules or logic in limited domains

Systems learn statistical models of specific problems using big data

Rich collaboration between humans and machines enabled by shared perceptions of the real world

Reference:
DARPA Public Release: RF Machine Learning Systems (RFMLS) Industry Day
https://www.darpa.mil/attachments/RFMLSIndustryDaypublicreleaseapproved.pdf

Figure 6
The three waves of Artificial Intelligence [4]

L. M. Hoang, M. J. Kim, S. H. Kong: Deep Learning Approach to LPI Radar Recognition, Institute of Science and Technology, South Korea [5]

The paper introduces an advanced automatic Low Probability of Intercept (LPI) radar recognition technique (LWRT – LPI Waveform Recognition Technique) that includes both LPI radar signal classification and parameter extraction. Figure 7 depicts the block diagram of the proposed LWRT concept. Figure 8 and Figure 9 show, together with Monte Carlo simulation, It demonstrates that even the unrealistic assumptions used in the previous studies, the proposed LWRT achieves classification performance like the state-of-the-art LWRT for pulse wave (PW) LPI radar waveforms.

The paper highlights findings by the combination of the "single shot multi-box detector" (SSD) or "you only look once version 3" (YOLOv3) and a supplementary classifier: in this way the proposed LWRT achieves an extraordinary classification performance. This conclusion is proven for continuous (CW) LPI radar waveforms for all the twelve modulation schemes considered in the literature (i.e., BPSK, Costas, LFM, Frank, P1, P2, P3, P4, T1, T2, T3, and T4). Finally, the proposed LWRT summarises the existing and proposed new parameter extraction functions, which can help to design the countermeasure in electronic warfare.

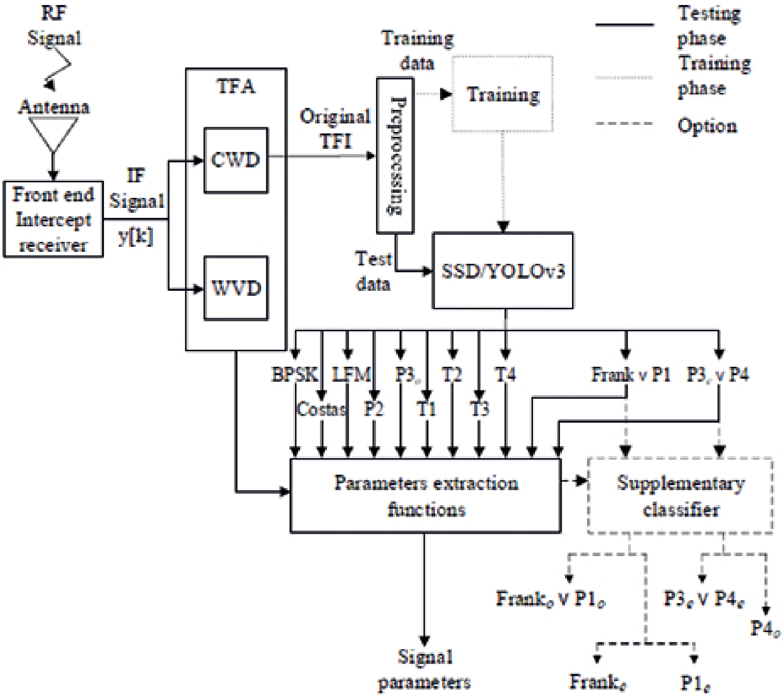


Figure 7

Block diagram of the proposed LWRT concept [5]

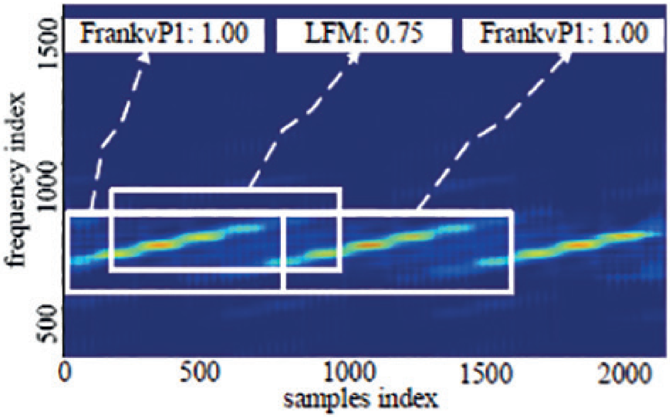


Figure 8

Single Shot Multibox Detector classification hypotheses of a CW Frank signal [5]

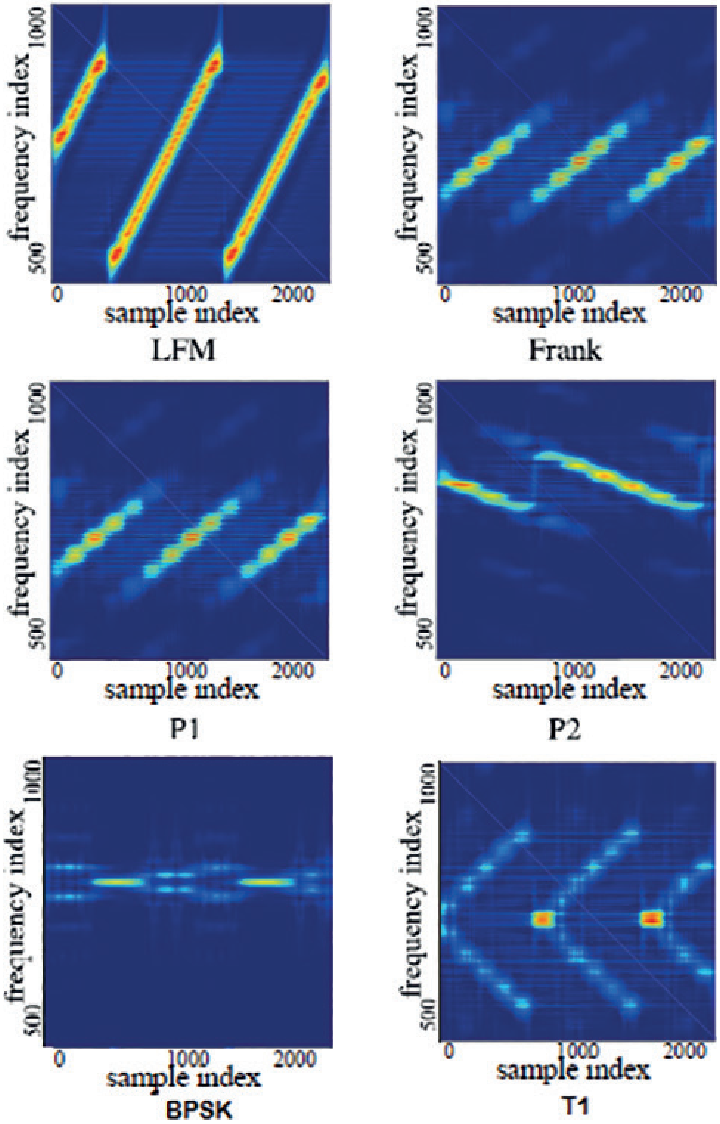


Figure 9

LPI radar signals over multiple periods

(Author's modification based on [5])

Francesco Fioranelli (University of Glasgow, UK), Sevgi Zubeyde Gürbüz (University of Alabama, Tuscaloosa, USA), Matthew Ritchie and Hugh Griffith (University College, London, UK): Multistatic human micro-Doppler classification with degraded/jammed radar data. [6]

This paper investigates the classification performance for using multistatic human micro-Doppler radar data that have been degraded by some form of jamming. Experimental data collected with multistatic radar are used in this study, which aims at classifying seven similar human activities, when individual subjects are walking and carrying different objects, as Figure 10 shows.

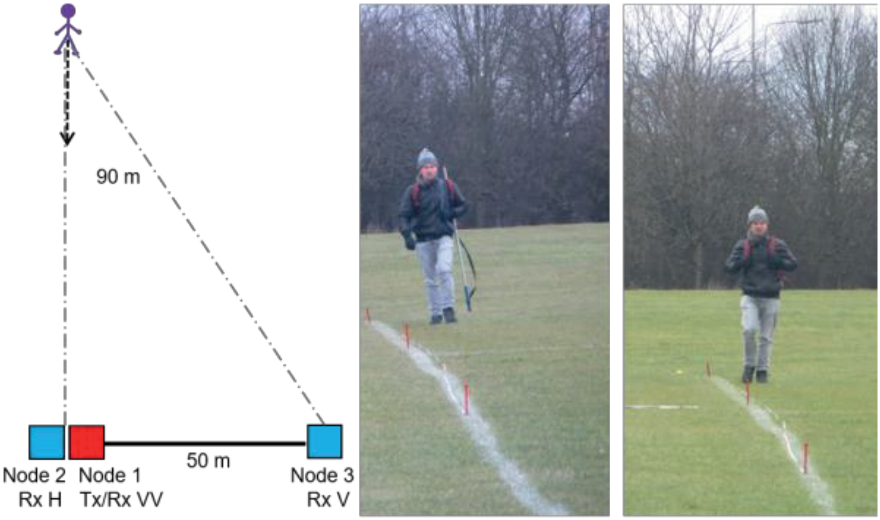


Figure 10

Sketch of experimental setup and example pictures of subjects performing the activities
(Author's modification based on [6])

Figure 11 plots examples of spectrograms for four activities: (a) walking, (b) walking while carrying a rucksack on the back with both straps on, (c) walking while carrying a metal post with both hands, and (d) walking while carrying both rucksack and metal post.

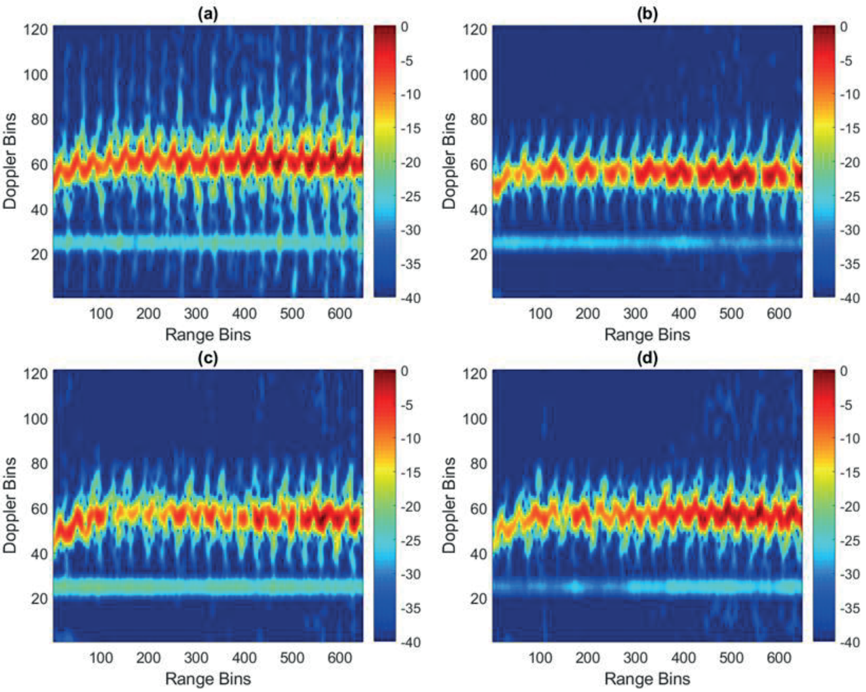
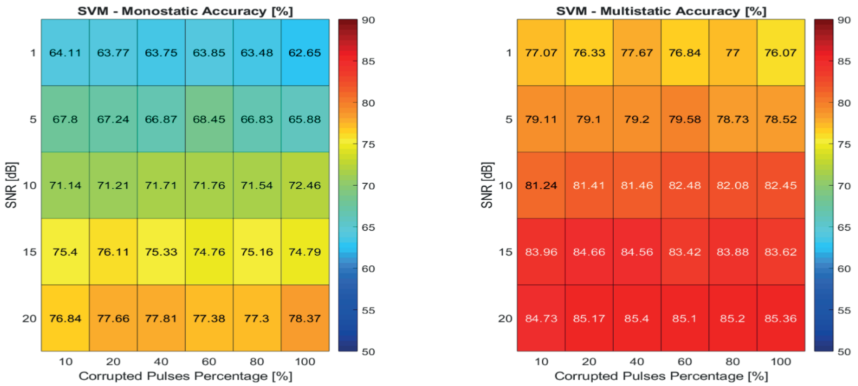


Figure 11

Examples of spectrograms for four activities [6]

Figure 12 depicts "heat maps" of classification accuracy with SVM classifier comparing monostatic (left) and multistatic (right) data as a function of SNR, and shows the percentage of pulses of those SNR that has been altered.



SVM - Monostatic Accuracy [%]

SNR [dB]	10	20	40	60	80	100
1	64.11	63.77	63.75	63.85	63.48	62.65
5	67.8	67.24	66.87	68.45	66.83	65.88
10	71.14	71.21	71.71	71.76	71.54	72.46
15	75.4	76.11	75.33	74.76	75.16	74.79
20	76.84	77.66	77.81	77.38	77.3	78.37

SVM - Multistatic Accuracy [%]

SNR [dB]	10	20	40	60	80	100
1	77.07	76.33	77.67	76.84	77	76.07
5	79.11	79.1	79.2	79.58	78.73	78.52
10	81.24	81.41	81.46	82.48	82.08	82.45
15	83.96	84.66	84.56	83.42	83.88	83.62
20	84.73	85.17	85.4	85.1	85.2	85.36

Corrupted Pulses Percentage [%]

Figure 12

"Heat maps" of classification accuracy, monostatic (left) and multistatic (right) data as a function of SNR [6]

Figure 13 shows the categorisation accuracy for different classifiers and different percentages of received radar pulses that have been forced to zero.

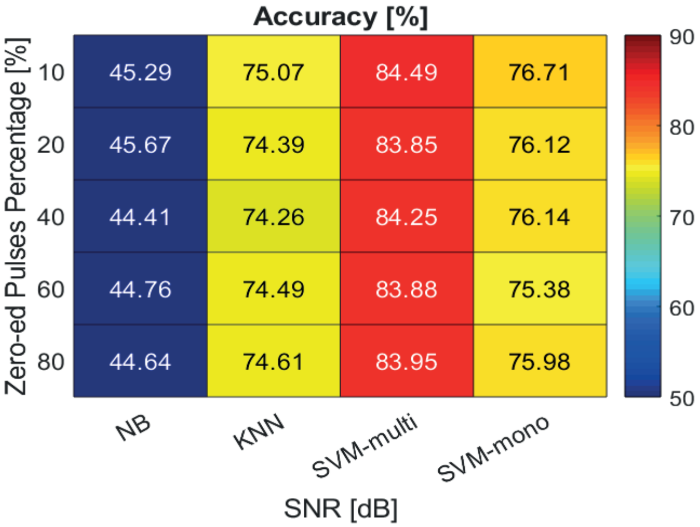


Figure 13

Classification accuracy for different classifiers [6]

The majority of the works in the open literature for classification appears to assume that the quality of the radar data is good, i.e. pulses are not missing, or they all have a given SNR because of the experimental and scenario conditions. This paper evaluates the effect of degrading subsets of radar pulses by either changing their SNR (for example, mimicking the effect of an involuntary competing transmitter near the radar), or completely replacing them with zeroes (for example: mimicking malfunctioning events that make batches of pulses unusable). The results show that the classification accuracy of the overall system can be reduced, especially if many radar pulses have degraded SNR. The possibility to restore and/or improve micro-Doppler classification performances by using multistatic data has also been briefly explored with a simple decision-level fusion scheme.

Jacob A. Kovarskiy, Ram M. Narayanan (The Pennsylvania State University, USA), Anthony F. Martone, Kelly D. Sherbondy (Army Research Laboratory, Sensors and Electronic Devices Directorate, USA): A Stochastic Model for Prediction and Avoidance of RF Interference to Cognitive Radar. [7]

This work focuses on next-generation radar/radio systems which have to sense, predict, and avoid interference as the spectrum grows to be more crowded. It presents a real-time implementation of a cognitive radar system that predicts and avoids interference using a stochastic model of Radio Frequency (RF) activity. These interference probabilities determine a radar transmit bandwidth and centre frequency to avoid colliding with other emitters in the environment. The tested cognitive radar monitors are to estimate the stochastic model parameters of the RF environment, which is followed by a prediction and avoidance stage.

The proposed solution outlines the effects and complexity of utilising different distributions, parameters, and modes of operation for the implemented radar system. Such a cognitive system adaptively utilises sub-bands of opportunity using a three-stage perception action-cycle (PAC), as Figure 14 shows. This cycle consists of sense (detect interference), learn/decide (tune parameters), and adapt (select centre frequency and bandwidth) stages. First, the sensing stage measures RF activity in the spectral, temporal, and spatial domains in order to detect the presence of RF interference (RFI). Then, the learn/decide step tunes a model or parameters, which describe the behaviour of the RFI in the desired domains. Finally, the adapt stage uses the learned model to determine the optimal sub-bands to occupy in the spectrum.

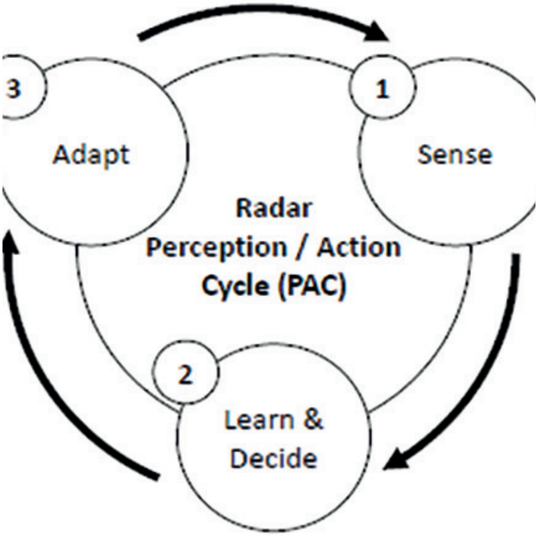


Figure 14
Visual representation of the PAC for cognitive radar [8]

The performance evaluation proves that the suggested predictive RFI avoidance scheme can mitigate collisions in a real-time system. Figure 15 shows random activity in Local Time Emission (LTE) uplink band around 1750 MHz as users access cellular internet data.

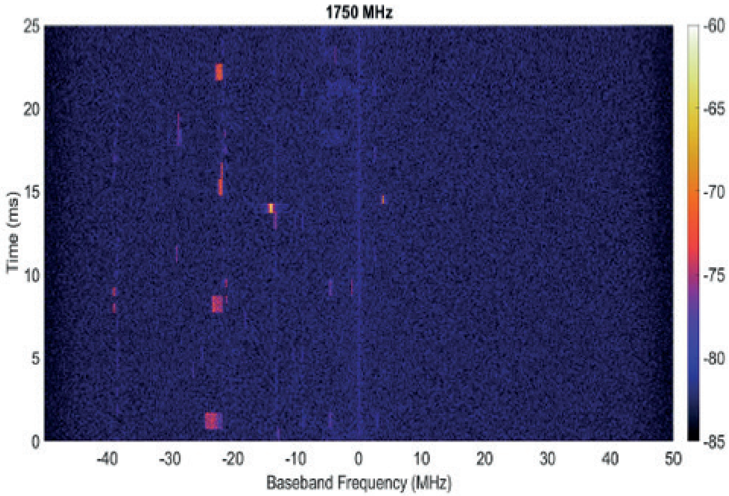


Figure 15

LTE uplink activities at 1750 MHz [7]

Depending on the desired collision and missed opportunity trade-off, the appropriate parameter and function choice could achieve attributes as examples present in Figures 16 and 17 show. In deterministic zero variance scenarios, the reactive mode cognitive radar collides during state transitions, while this predictive scheme can perfectly avoid RFI.

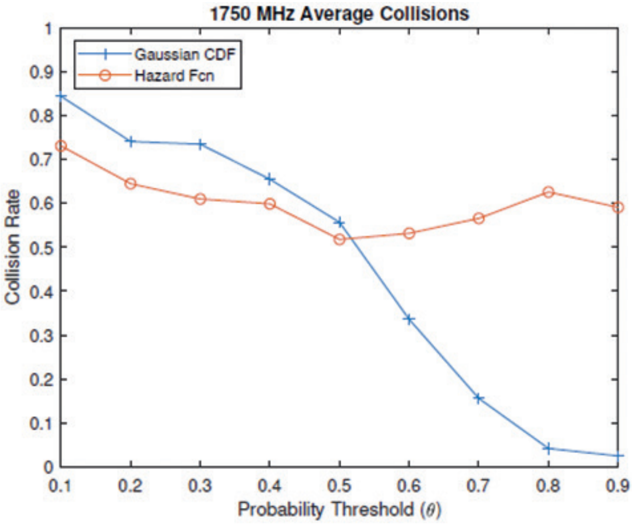


Figure 16

Average collision rate for the 1750 MHz band [7]

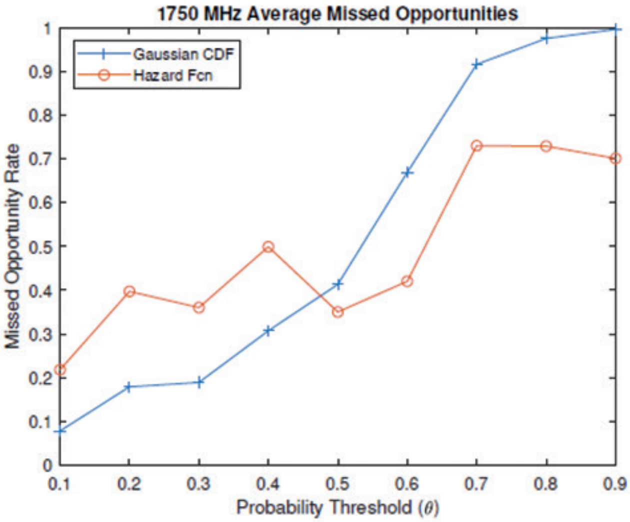


Figure 17

Average missed opportunity rate for the 1750 MHz band [7]

Roland Oechslin and Peter Wellis (Science and Technology, Switzerland), Uwe Aulenbacher, Sebastian Wieland and Sebastian Hinrichse (Ingenieurbüro für Sensorik und Signalverarbeitung, Germany): Cognitive Radar Performance Analysis with Different Types of Targets. [9]

This paper presents a research in which detection and tracking experiments with the cognitive adaptation of waveform and processing parameters have been performed. See Figure 18. Novel radio frequency (RF) technologies and concepts such as Software Defined Radio (SDR), arbitrary waveform generation (AWG) and digital signal processing (DSP) trigger new possibilities of real-time optimising and tuning a radar system to the current operational goal and environment. The CODIR ("COgnitive Detection, Identification and Ranging") testbed consists of an X-band radar sensor and a controller segment which tracks the target and selects the optimal radar parameters based on the past sensor perception (measured position, SNR, measurement accuracy). By feeding the sensor perception back to the optimiser, a perception-action cycle is defined.

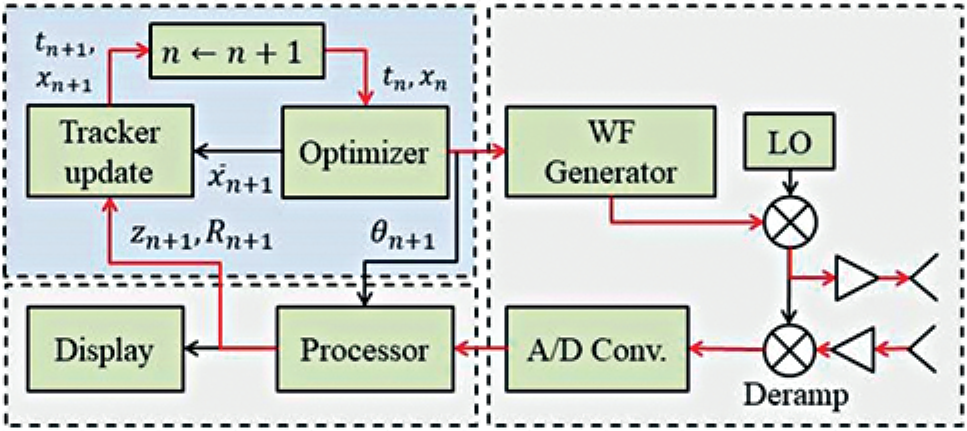


Figure 18

CODIR block diagram. The controller is highlighted in blue. Red arrows mark the implemented perception action cycle [9]

Figure 19 shows optimised radar performance and radar-setting choice for bicycle target with the T3 set of weights. Panels from top to bottom: a) Range and velocity evolution (red: measurements, blue: track, green: range limits); b) Track uncertainty defined by the *a posteriori* covariance matrix P; c) SNR – Signal Interference Noise Ratio (red: measurement from RD map, blue: track); d) Radar parameter evolution (T=1/PRF; e) Measurement time effort (red), tracker update time (blue); f) single objective costs. Only the single objective costs with non-zero weights are shown.

Four target-types with different backscatter and dynamic behaviour have been used and the radar system has been optimised to different combinations of the three top-level objectives, "track accuracy," "bandwidth minimisation" and "time effort minimisation."

The system can be fine-tuned to one or to a combination of top-level objectives with a given prioritisation. For example, a simultaneous minimisation of bandwidth usage (main objective, 1st prioritisation) and track error (2nd prioritisation) can be performed.

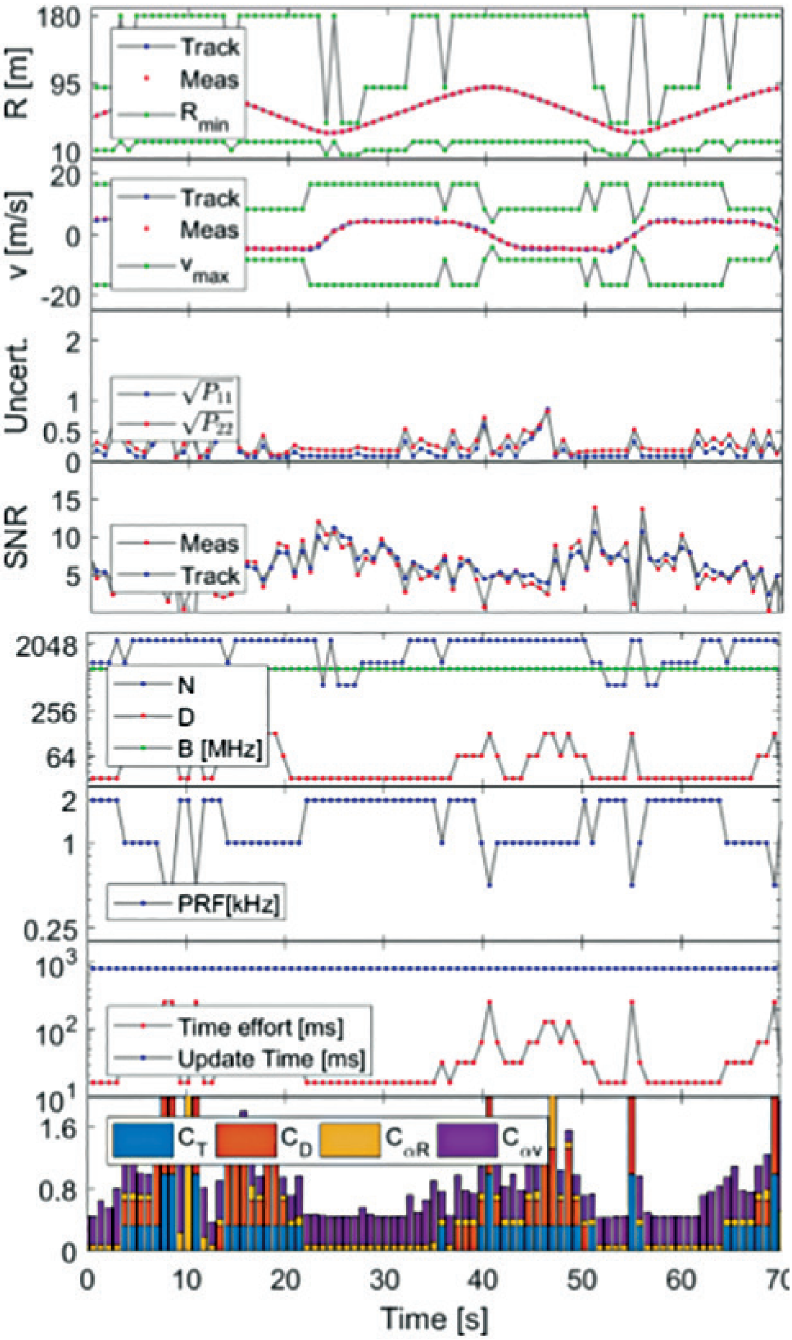


Figure 19

Optimised radar performance and radar setting choice for bicycle target with the T3 set of weights [9]

Findings on emerging technologies

Hitoshi Nohmi: The Development of Vibration Imaging Radar (VirA).

By combining microwave FMCW radar with DBF processing, a VirA was developed that can measure surface vibrations in two dimensions. [10] Figure 20 shows the Principle of vibration measurement.

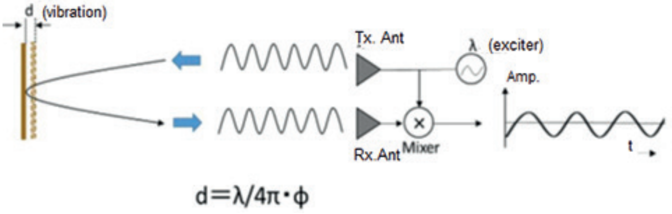


Figure 20
Principle of Vibration Imaging Radar (Author's modification based on [10])

Figure 21 depicts results of the measurement of building vibration. It acquires 1,000 radar images every second and can detect vibrations as small as 20 μm from the phase changes in the captured images. Using VirA, it is possible to monitor the health of infrastructure such as bridges in a short timeframe. Moreover, this innovative approach costs less compared to conventional methods.

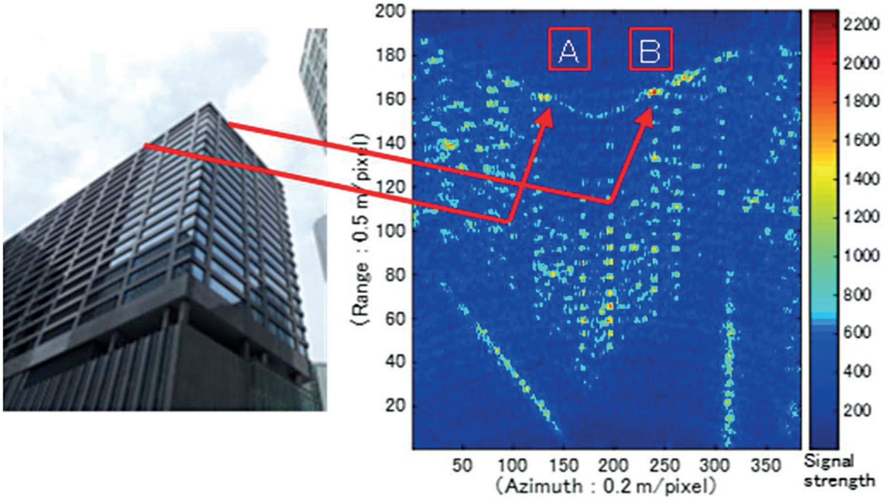


Figure 21
Measurement results of building vibration
(Author's modification based on [10])

The system could also be used as a monitoring tool for various civil engineering projects.

David Luong, Anthony Damini, and Bhashyam Balaji (Defence Research and Development, Canada), C. W. Sandbo Chang, A. M. Vadiraj, and Christopher Wilso (Institute for Quantum Computing University of Waterloo, Canada): A Quantum-Enhanced Radar Prototype. [11]

Any type of radar that exploits the laws of quantum mechanics to enhance detection ability can be termed as quantum radar. Several theoretical proposals for various types of quantum radars exist, such as interferometric quantum radar and quantum illumination radar. The latter one is one of the most promising approaches. It uses a phenomenon called entanglement to distinguish between signal and noise. The system of the subject paper is a variation on the quantum illumination concept. The transmitter generates a pair of entangled microwave signals and transmits one of them through free space, where the one-way signal is measured using a simple and rudimentary receiver. The type of entanglement used is called two-mode squeezed vacuum (TMSV), so it may be called as a quantum two-mode squeezing radar (QTMS radar). Figure 22 shows the simplified block diagram of the tested quantum radar setup. The Josephson parametric amplifier (JPA) generates the entangled signal, which undergoes amplification and it is transmitted through a horn antenna.

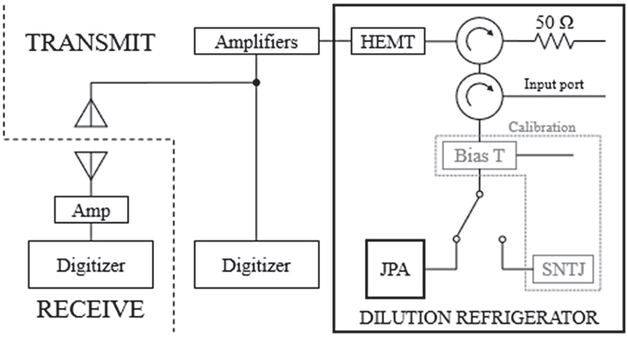


Figure 22

Simplified block diagram of the quantum radar setup
(Author's modification based on [11])

Figure 23 shows the interior of the dilution refrigerator. From top to bottom, each round plate is colder than the previous one. The JPA is inside the car at the bottom. The JPA is connected through a microwave switch to a bias tee, two circulators, and a chain of amplifiers beginning with a high-electron-mobility transistor (HEMT), which is a low-noise amplifier. The HEMT is inside the fridge, and the remainder of the amplifiers are at room temperature. After the signal is amplified, it is split between a Narda 640 horn antenna and a digitiser in the same way as in the classical setup.

Figure 24 depicts the Receiver Operator Characteristic (ROC) curves for classical and quantum-enhanced radars at a power level of roughly -82 dBm, calculated from experimental data for an integration time of 50 ms. The result rules out the contention that is beneficial for a quantum radar, which demonstrates a significant gain over a similar classical radar system.

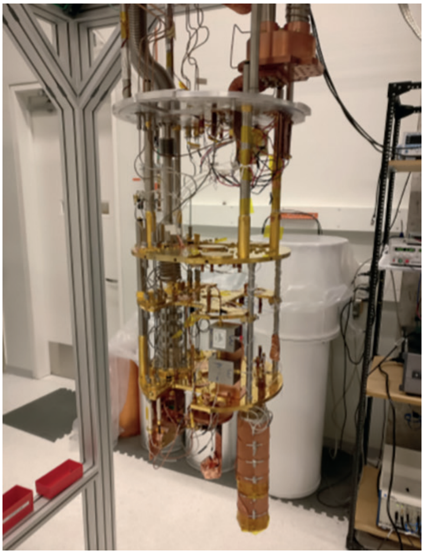


Figure 23

Interior of the dilution refrigerator of the QTMS radar [11]

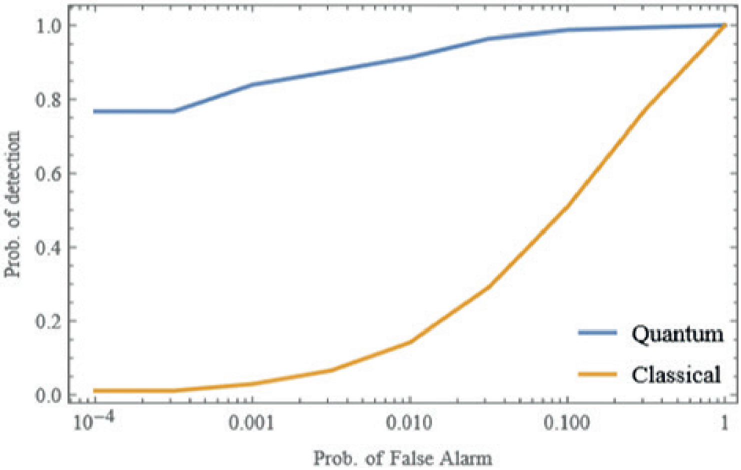


Figure 24

Receiver operator characteristic curves for classical and quantum-enhanced radars [11]

The experiment described in this paper makes it possible to say from now on that microwave quantum radar is possible and practical.

Zhenwei Mo, Ruoming Li, Jiyao Yang, Jingwen Dong, Jiming Cao, Wangzhe Li (Institute of Electronics, Chinese Academy of Sciences, China): A Photonics Radar with Remoting Antenna based on Photonic Assisted Signal Generation and Stretch Processing. [12]

Photonics-based broadband radar with remoting antennas is proposed and experimentally demonstrated in this paper. A linearly-frequency-modulated (LFM) signal is generated by microwave photonic frequency quadrupling in central office and transmitted to a remote antenna unit by employing the radio-over-fibre (ROF) technology. In antenna unit, the photonic LFM signal is split into two branches. Light signal in one branch is converted to RF and emitted out. Light signal in the other branch is fed into a dual polarisation in parallel the topological photonic mixers to perform the operation of de-chirp on receive. Ku-band photonics-based radar with a bandwidth of 2 GHz is demonstrated. Inverse synthetic aperture radar (ISAR) imaging experiment is carried out to verify the performance of the system. Figure 25 shows (a) Schematic diagram of the proposed photonics-based radar with remoting antenna. (b) The structure of a DP-QPSK modulator. (c) The structure of a Pol-demux coherent receiver. AWG: arbitrary waveform generator; LNA: low-noise amplifier; BPF: band-pass filter; CW-Laser: continuous wave laser; MZM: Mach-Zehnder modulator; PM-Fiber: polarisation maintaining fiber; OC: optical coupler; PD: photodetector; DP-QPSK: dual-polarisation quadrature phase shift keying modulator; DP-OBPF: dual-polarisation optical bandpass filter; DP-EDFA: dual-polarisation erbium doped fiber amplifier; ADC: analogue-to-digital converter; PR: polarisation rotator; PBC: polarisation beam combiner; PBS: polarisation beam splitter.

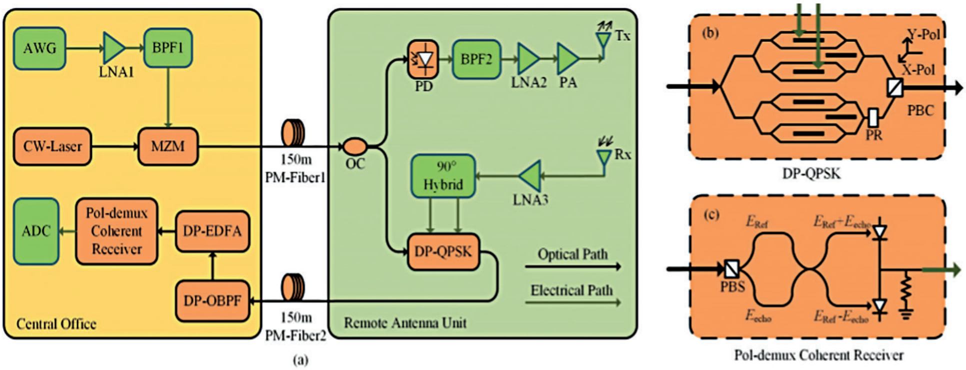


Figure 25

Schematic diagram of the proposed photonics-based radar with remoting antenna
(Author's modification based on [12])

For the performance evaluation of the system, two targets were used in the experiment, which were separated by distances of 38 cm in the range direction and 54 cm in the cross-range direction. The imaging result of the two targets is shown in Figure 26.

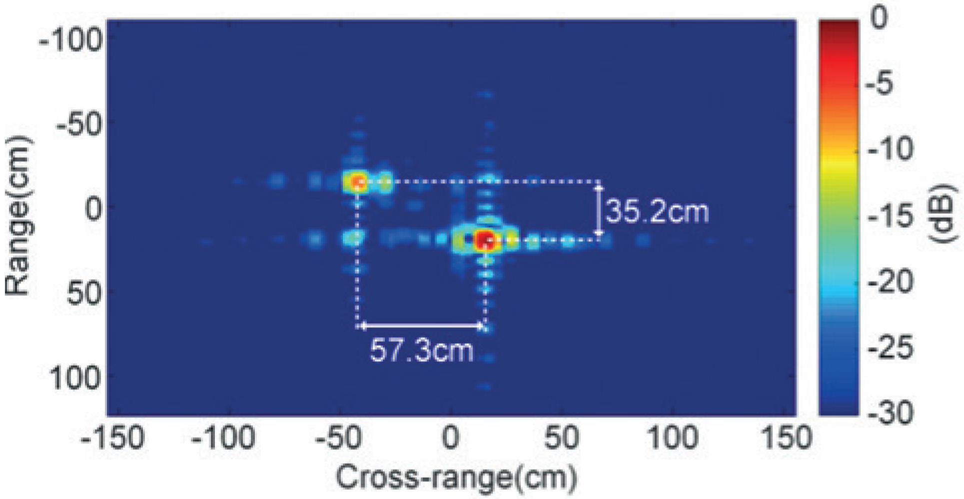


Figure 26

The ISAR image of the two targets [12]

Conclusion

The paper presents a selective review of the most-advanced radar topics of the conference and it would like to kindly draw the reader's attention to the fact that the radar technology is growing fast. The radar measurement's degree of freedom has to be extended in space, frequency and polarisation, due to the new customer needs such as automobile radar, civilian air traffic control, the growth of safety requirements and advanced military requirements.

The fast-growing computer and IT technology, the Spectrum Sharing Techniques between radars and communication systems, the Machine Learning Technology and Cognitive Radar are essential parts of the modern bi-static and multi-static radar, passive radar systems, weather radar with emerging quantum and photonics-based radar solutions. The radar system related electronic warfare techniques and tactics are advancing from the achievements of the current, above-mentioned state of the art technologies, while the radar performance measures could be supported and maintained for life-time cycle of the sensors, and they shall be part of the modern radar networks.

Proposals for domestic consideration:

- The interests in modern weather radar performance support activities are increasing and it makes sense to follow its grow.
- The University of Luxembourg has shown remarkable progress in the field of radar technologies in the last five years. This proves for the Hungarian users that radars shall be considered seriously and educational skills of radar technologies should be increased, such as developing radar prototyping and radar performance measurement know-hows. It is important, because the

related engineering skills are disappearing in Europe and USA, while fast-growing advance automobile radar technologies and other customers show a growing interest for this area.
- Follow the events of the Military Radar and other Radar Conference activities, such as IRS 2019, MIKON etc. and send radar experts to the upcoming conferences.

References

[1] 2019 IEEE Radar Conference Program, Boston, 22-26 April 2019. [Online]. Available: http://ieee-aess.org/conference/2019-ieee-radar-conference. [Accessed July 1, 2020]

[2] E. Kowalski, D. Conway, A. Morris, and C. Parry, "Multifunction Phased Array Radar Advanced Technology Demonstrator (MPAR ATD) Nearfield Testing and Fielding," USA, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835837

[3] A. Byrd, R. Palmer, and C. Fulton, "Implementation of a Low-Cost Passive Weather Radar and First Weather Observations," University of Oklahoma, USA, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835555

[4] U. K. Majumder, E. Blasch, and D. Garren, "Machine Learning Techniques for Radar ATR," Tutorial, USA, Proceedings of Revolution in Radar and Tutorial Material.

[5] L. M. Hoang, M. J. Kim, and S. H. Kong, "Deep Learning Approach to LPI Radar Recognition," Institute of Science and Technology, South-Korea, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835772

[6] F. Fioranelli, S. Z. Gürbüz, M. Ritchie, and H. Griffith, "Multistatic human micro-Doppler classification with degraded/jammed radar data," University of Alabama Tuscaloos, USA, University College London, UK, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835618

[7] J. A. Kovarskiy, R. M. Narayanan, A. F. Martone, and K. D. Sherbondy, "A Stochastic Model for Prediction and Avoidance of RF Interference to Cognitive Radar," The Pennsylvania State University, Army Research Laboratory, USA, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835523

[8] M. Lopez-Benitez, "Sensing-based spectrum awareness in cognitive radio: Challenges and open research problems," In *Proc. 9th International Symposium on Communication Systems Networks and Digital Sign* (CSNDSP), Manchester, UK, July 2014, pp. 459–464. DOI: https://doi.org/10.1109/CSNDSP.2014.6923873

[9] R. Oechslin, P. Wellis, U. Aulenbacher, S. Wieland, and S. Hinrichse, "Cognitive Radar Performance Analysis with different Types of Targets," Science and Technology, Switzerland, Ingenieurbüro für Sensorik und Signalverarbeitung, Germany, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835493

[10] H. Nohmi, “The Development of Vibration Imaging Radar,” Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835776

[11] D. Luong, A. Damini, B. Balaji, C. W. Sandbo Chang, A. M. Vadiraj, and C. Wilso, “A Quantum-Enhanced Radar Prototype,” Defence Research and Development Institute for Quantum Computing University of Waterloo, Canada, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835632

[12] Z. Mo, R. Li, J. Yang, J. Dong, J. Cao, and W. Li, “A Photonics Radar with Remoting Antenna based on Photonic Assisted Signal Generation and Stretch Processing,” Institute of Electronics, Chinese Academy of Sciences, China, Proceedings of Revolution in Radar and Tutorial Material. DOI: https://doi.org/10.1109/RADAR.2019.8835512