Determination of environmental VOR errors using aerial Doppler cross-bearing measurements

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BIOGRAPHIES

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- Diploma degree in Electrical engineering from the Technical University of Braunschweig, Germany
- Dr.-Ing. degree in Electrical engineering from the Technical University of Braunschweig, Germany
- Principal Engineer, EMC Test Systems L.P., Austin, Texas, USA
- Senior Member IEEE
- 60+ scientific papers, 40+ project leader
- 15 years head of department High Frequency and Electromagnetic Fields
- Since 2020 head of division Mechanics and Acoustics at PTB

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- M. Sc. degree in Communications from Virginia Polytechnic Institute and State University, Blacksburg, USA
- Diploma degree in Electrical engineering from the Technical University of Braunschweig, Germany
- Dr.-Ing. degree in Electrical engineering from the Technical University of Braunschweig, Germany
- 40+ scientific papers in refereed journals and 80+ conference contributions
- Member of the VDE and the URSI, DAkkS auditor
- Since 2014 Privatdozent at Technical University of Braunschweig, Germany
- Since 2020 head of department High Frequency and Electromagnetic Fields at PTB

Jens Werner
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- Diploma degree in Electrical engineering from the Technical University of Braunschweig, Germany
- Dr.-Ing. degree in Electrical engineering from the Technical University of Braunschweig, Germany
- 30+ scientific papers in refereed journals and conference contributions
- Principal Engineer and RF Simulation Expert, NXP Semiconductors Germany
- Senior Member IEEE, Secretary of German IEEE EMC-S chapter
- Since 2014 Professor at Jade University of Applied Sciences, Wilhelmshaven, Germany

Jochen Bredemeyer
Head of research at Flight Calibration Service

- Diploma degree (Dipl.-Ing.) in electrical engineering, from Technische Universität Braunschweig
- Ph. D. (Dr.-Ing.) in 2001 in electrical engineering, from Technische Universität Braunschweig.

- Present position at FCS is head of research with focus on RF measurement engineering, signal processing and multipath wave propagation.
- Honorary Professor at Leibniz Universität Hannover, Faculty of Electrical Engineering and Computer Science, with lectures on radio navigation and radar.

Ralf Eichhorn
CNS-Expert for Electromagnetic Simulation

- Diploma degree in physics from the technical university of Darmstadt, Germany
- PhD in natural science from the technical university of Darmstadt, Germany
- Master degree in business administration from the university of Hagen, Germany
- Research assistant, teaching assistant, senior researcher and finally Professor in Physics at various locations (Technical University, Helmholtzzentrum Juelich, Helmholtzzentrum Darmstadt and Cornell University).
- A total of 200+ scientific papers in various journals, more than 25 talks at international conferences
- Since 2016 CNS-Expert at Deutsche Flugsicherung DFS, developing assessment methods for EM field propagation disturbances for all CNS systems
- Holder of private pilot licenses (FAA and EASA) with an instrument rating

ABSTRACT

Future airspace usage and procedure design will be based on area navigation and PBN operation. While the primary sensor for this is GNSS, several fall-back systems have to be provided which rely on terrestrial facilities, some of them being VORs. Accordingly, ANSPs have to decide whether a certain VOR supports RNAV-5 or not. Within conventional procedures, the performance is ensured by means of flight inspection but there is no good solution how to guarantee signal integrity virtually everywhere.

Our approach could contribute to improve this situation and to gain insight into signal in space on signal level. For this purpose, a new bandpass receiver technology and digital board is used to obtain measurement data of signal in space and to store that data synchronized with GPS time stamp and location on SSD. The electronics is either carried using PTB's octocopter or the touring motor glider JadeOne. Applying the doppler cross bearing we are able to locate each scatterer around the DVOR and, furthermore, to determine its associated reflectivity. This cluttermap can be used as a preload Az-Error in the VOR protection area, but, furthermore, we can calculate the scatterers' impact on the DVOR signal integrity as well as the impact of wind turbines up to the VOR range limit.

Our measurements and analysis confirmed that simple orbital data from flight inspections are not adequate to judge on the preloading Az-Error that exists due to the multipath environment. We have identified physical and metrological reasons that support existing regulations (for example by the FAA) which preclude facility restrictions solely based on orbit inspection data.

Originally aiming at refining the assessment of wind farm projects and their impact on area navigation, we were able to expand the scope of our findings. Based on the cluttermaps derived from measured data, we have developed a method that allows predicting VOR azimuth errors at almost every point in space. By that means one is able to document RNAV compliance. Furthermore, our method can also be used to predict, whether a newly constructed conventional procedure will comply with DOC 8071 requirements even bevor flight validation has taken place.