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Integration of noise modelling into RF receiver design

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2017

https://hdl.handle.net/10539/24241

Klein, Benjamin (2017) Integration of noise modelling into RF receiver design, University of the Witwatersrand, <https://hdl.handle.net/10539/24241>

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Abstract

The scientific requirements for Radio Frequency (RF) receivers especially for Radio Astronomy have become more demanding, requiring: compact, low-profile, multi and wideband antennas and more sensitive receivers. Integration of the antenna into the receiver system is often critical to meet these demands.

Noise theory to model these more complex systems is well developed but is not implemented in commercial solvers, given the niche market of the receivers it is only available using specialised software. If the system is closely coupled, it becomes necessary for design to incorporate Electromagnetic (EM) and Microwave (MW) modelling into the multi port noise modelling. `CAESAR`, a combined noise and EM/MW modelling code is available, but to use it requires the exclusive use of the `CAESAR` software, which is impractical given the utility and wide use of commercial solvers.

Mathematical methods are developed to incorporate commercial solvers into the more specialised `CAESAR`, validated using a folded dipole and applied to a wideband Eleven antenna system, a compact form of a log periodic dipole array. The Eleven antenna consist of eight single ended or four differential ports, with a closely coupled feeding arrangement. Cryogenic measurements are done to verify the modelling, the measured sensitivity matches with the model closely in amplitude and shape, giving confidence to the approach, and allowing modelling but not system optimisation.

Optimising the antenna based on receiver design and still being able to use commercial code requires the external scripting of a commercial solver. The `EDITFEKO` (card based) module of `FEKO` (a powerful and versatile solver) is used along with the meshing software `GMSH` and `GNU Octave`. Optimisation of system sensitivity is demonstrated on a choke horn fed reflector system at $1420\,\mathrm{MHz}$.

This optimisation method is applied to a practical application, an octave band system ($4.5\,\mathrm{GHz}$ to $9\,\mathrm{GHz}$) for the Hartebeesthoek Radio Observatory. The design is split into smaller simulations using waveguide modes and the associated S–parameters, the techniques are presented and checked on a truncated system. Initial design and optimisation are given.

The combining of specialised multiport noise modelling design and optimisation within commercial EM/MW solvers allows more sensitive and specialised receivers to be built.

Index terms— noise modelling, wideband, multiport, corrugated horn, octave band receiver, EM/MW optimisation