3rd European Conference on Antennas and Propagation
Berlin, Germany, March 23–27, 2009

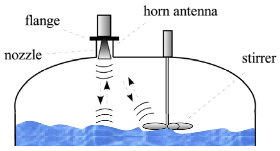
Dielectric Travelling Wave Antennas Incorporating Cylindrical Inserts with Tapered Cavities

Gunnar Armbrecht*, Eckhard Denicke*, Nils Pohl#, Thomas Musch##, Ilona Rolfes*

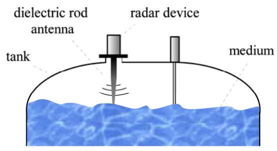
I. Introduction

Dielectric travelling wave antenna solutions for **industrial radar level measurements** are presented to provide monostatic radar operation from **8.5** to **10.5 GHz**, particularly featured by:

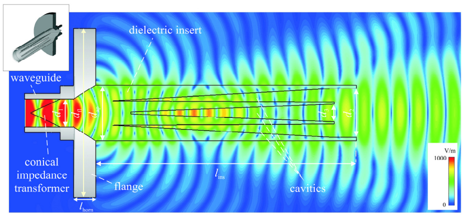
- **High directivity** at limited aperture size as well as **low side lobe levels**
- **Marginal** time-domain reflections ("**ringing**")
- **Compact outer dimension** (larger effective aperture size than metal horn antennas & shorter axial length than common dielectric rods)
- **Fully encapsulated** by chemically inert materials, e.g. **PTFE** (Teflon)



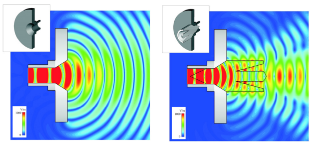
Small radiating apertures raise signal distortion by parasitic reflections



Dielectric rod antenna dipping into the medium



E-plane electric field distribution of a conical metallic excitation horn equipped with a dual cavity insert at 9.5 GHz



Two other E-field distributions (E-plane, 9.5 GHz)

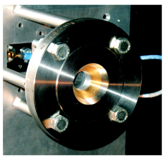
II. Conical Horn Excited Dielectric Inserts

In order to exploit the maximal standardized **tank nozzle diameters** of d_{ap} = 50 mm for inserting an improved endfire radiating antenna, that exceeds the directivity values of state-of-the-art tapered dielectric rod antennas, **tapered cavities** inside a solid rod are utilized. This yields more **directive endfire radiation** than conventional rod structures with tapered outer dimension at the same axial length. By a short **flange-integrated metallic horn**, a field distribution on the rod is excited consisting of a variety of different **hybrid dielectric eigenmodes**. At each axial position l_{ins}, where the modes constructively interfere, the total field distribution is maximally widened in the outer rod region. Additionally, to obtain an even stronger aperture size augmentation, tapered cavities are incorporated inside the rod increasing the outer field extension.

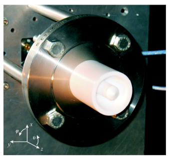
- First position l_{ins}: **Single cavity**
- Second position l_{ins}: **Dual cavity**

One important **figure of merit** is defined by regarding an equivalent **TE_{11}-distributed aperture diameter d_{eq}**, indicating the minimal required equivalent metallic horn diameter to achieve similar **peak directivity properties D_0** as the proposed antenna designs.

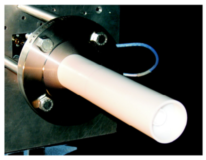
$$d_{eq} = \sqrt{\frac{d_{eff}^2}{\eta_{TE_{11}}}} = \frac{\lambda}{\pi} \cdot \sqrt{\frac{D_0}{\eta_{TE_{11}}}}$$



Horn w/o dielectric insert



Single cavity insert



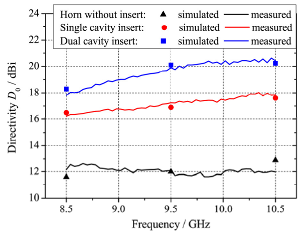
Dual cavity insert

III. Antenna Characteristics

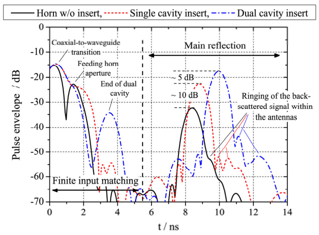
The **dielectric insert equipped antenna** versions with constant geometrical aperture size but significantly enlarged directivity are **compared to** the **solely radiating short metallic horn** as well as are classified concerning the introduced figures of merit like **equivalent horn diameter** d_{eq} and **equivalent rod length** l_{eq}. The anticipated performance gain is proved by measurement results in **frequency** and **time domain**. The radiation pattern, obtained from antenna measurements conducted inside an anechoic chamber by utilizing a **3D spherical near-field measurement** transformed into the antenna's far-field, are presented and compared to those derived from **FIT simulations** (CST MIRCOWAVE STUDIO, Vers. 2008). The simulated and measured results for normalized co-polar **radiation patterns** are separately plotted for the **H-** and **E-plane** at 9.5 GHz. As well the **characteristic antenna parameters** are provided as a tabular overview at the corner frequencies of 8.5 and 10.5 GHz and the center frequency of 9.5 GHz for **the peak directivity** value D_0 and also for the **half power beam width** (HPBW), the **side lobe level** (SLL) and the magnitude of the **input reflection** S_{11}. Since radar signal processing is often evaluating the time domain, the transient antenna properties also have to be considered by investigating the system's **impulse response envelopes** to identify sources of signal distortion caused by the antennas. The measurements are conducted for a single trihedral corner reflector scenario in main beam direction.

Dual cavity insert, l_{ins} = 235.5 mm	8.5 GHz	9.5 GHz	10.5 GHz
Peak directivity D_0/ dBi	18.3	20.1	20.2
HPBW /° (H-/E-plane)	25.4/23.5	19.8/17.9	18.0/17.9
Side lobe level / dB (H-/E-plane)	−21.0/ − 15.3	−25.1/ − 15.6	−18.1/ − 19.4
Equivalent TE_{11} horn diameter d_{eq}/ mm	100.9	111.2	101.7
Equivalent rod length (MG, $m = 10$) l_{eq}/ mm	238.5	322.9	298.9
$\lvert S_{11}\rvert$ / dB	−22.1	−22.6	−19.2
Single cavity insert, l_{ins} = 60 mm			
Peak directivity D_0/ dBi	16.5	16.9	17.6
HPBW /° (H-/E-plane)	27.9/25.2	27.7/23.3	22.9/23.2
Side lobe level / dB (H-/E-plane)	−20.2/ − 14.6	−17.6/ − 13.5	−14.5/ − 23.3
Equivalent TE_{11} horn diameter d_{eq}/ mm	82.1	76.9	75.4
Equivalent rod length (MG, $m = 10$) l_{eq}/ mm	157.5	154.5	164.3
$\lvert S_{11}\rvert$ / dB	−21.5	−21.4	−20.6

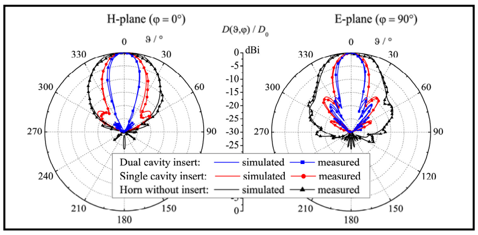
Broadband simulated characteristic antenna parameters



Simulated and measured antenna directivities



Measured pulse envelope of a one reflector scenario w/o parasitic reflections (Hanning windowed)

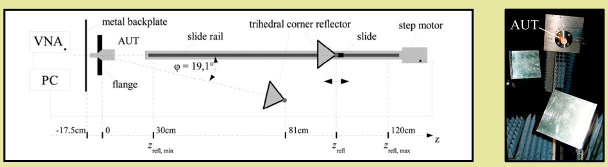


Normalized co-polar radiation pattern in the H- and E-plane at 9.5 GHz

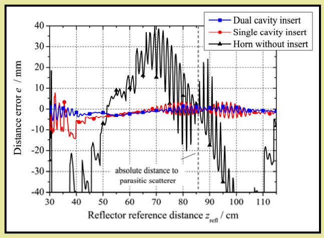
IV. Radar Distance Measurement Accuracy

For radar distance measurements two equally sized **trihedral corner reflectors** are placed at different positions in front of the antennas under test (AUT), as sketched. One reflector is mounted as a **main target** on a **movable slide** positioned by a step motor that serves as a distance reference in an interval ranging within z_{refl} = [30 ... 120 cm].

A **commercial VNA** is incorporated for the emulation of a **radar device** and common pulse-based signal detection by **barycentric processing algorithms** is used. The **parasitic reflector** is arranged offset to the main reflector axis by an angle of approx. **19.1°** being located still within the main beam direction in the E-plane for both AUT. The measured **distance errors e** caused by the parasitic reflector correlate directly with the improved directivity properties of the two proposed horn excited antennas with dielectric inserts. This yields an about **8x** improved accuracy when applying the **single cavity** version and an improvement of up to **16x** in case of the **dual cavity** version respectively.



Sketch and photograph of an experimental setup for radar distance measurements to evaluate the impact of various antennas in the presence of parasitic reflections



Measured distance error e in an experimental scattering scenario with one parasitic reflector

Leibniz Universität Hannover
*Institut für Hochfrequenztechnik und Funksysteme
Appelstraße 9A
30167 Hannover (Germany)

Ruhr-Universität Bochum
#Lehrstuhl für Integrierte Systeme
##Lehrstuhl für Elektronische Schaltungstechnik
Universitätsstraße 150
44801 Bochum (Germany)

Contact:
Dipl.-Ing. Gunnar Armbrecht
Phone: +49 (0)511 762-19552
E-Mail: armbrecht@hft.uni-hannover.de