

mm-Wave DRW Antenna Phase Centre Determination

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Abstract— This document presents an approach to the phase centre determination of a dielectric rod waveguide (DRW) antenna by means of measurements obtained with a planar measuring system at millimeter wave lengths. Phase centre determination by the least squares fit technique is described in this document for different DRW antennas (silicon and sapphire). Results at different operating frequencies are offered.

I. INTRODUCTION

Dielectric rod waveguide (DRW) antennas at millimetre-wave frequencies are of increasing interest [1]-[3]. For their proper application to mm-wave systems for instance, as reflector or lens feeders, it is essential to properly determine the phase centre position of the antenna together with the variation of its position when the operating frequency is changed.

The measured antennas are based on DRWs made of high-permittivity low-loss materials. Relatively high dielectric constant of the DRW makes the transition to a metal waveguide easier, e.g., no horn structure is required. DRW is inserted in a metal waveguide with a tapered transition section in the interface. These DRW antennas have been previously found to present, e.g., fairly constant beamwidth vs. frequency and a low return loss [2]. This is promising for their application as feed antennas of different systems at millimetre-wave lengths. Fig. 1 shows the DRW antenna model.

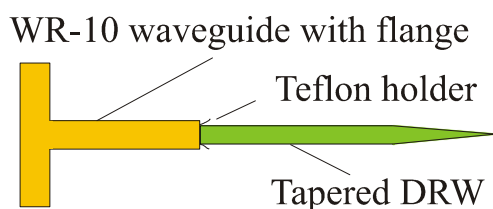


Fig. 1 DRW antenna model.

II. MEASUREMENT CONFIGURATION

There are different experimental techniques for the determination of the phase centre of the antenna under test (AUT), depending on the measuring system used for the pattern acquisition (both, amplitude and phase). In this case a planar measuring system is selected, at millimeter wavelengths [4], [5]. The measurement setup is presented in Fig. 2.

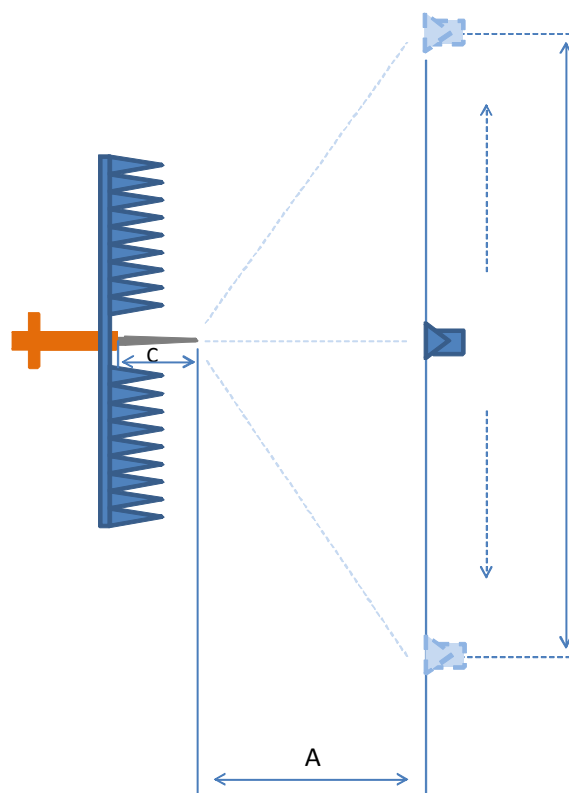


Fig. 2 Measurement setup for horizontal (x) and vertical (y) axis, distances and measuring grid.

The following distances in the measurement setup (Fig. 2) are fixed:

- A: 204 mm and 224 mm (two distances for each antenna and frequency), in order to validate the results obtained for phase centre location.
- B: 210 mm (this distance, in addition to A value offers $\sim 60^\circ$ of the antenna pattern in each axis).
- C: 11.5 mm for sapphire antenna, 19 mm for silicon antenna.

The pattern is acquired for a rectangular grid ($\Delta x = \Delta y = 1.05$ mm), as seen in Fig. 3.

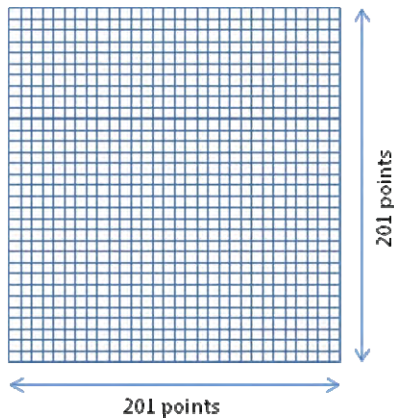


Fig. 3 Measurement grid for the planar acquisition.

Images of the acquisition process are offered in Fig. 4.

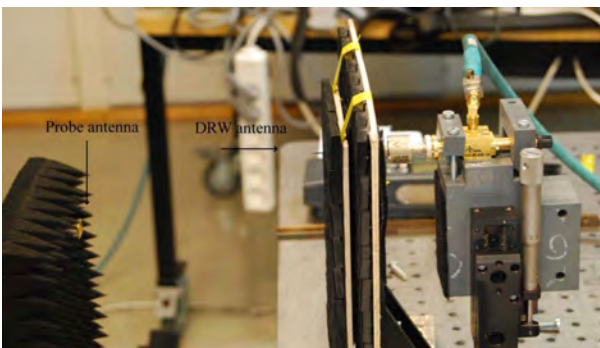


Fig. 4 Details of the acquisition setup for measurements.

Due to the planar measurement system used, it is necessary to introduce source compensation in the acquired data, as the distance and angle of incidence of the source probe is varying, as seen in Fig. 5. The effect of the probe can be eliminated by subtracting the amplitude and phase pattern of the source from the obtained measurements.

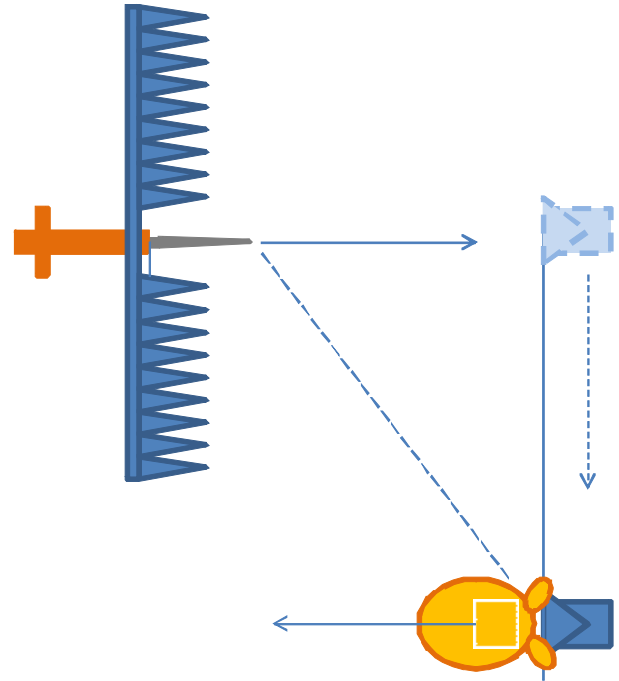


Fig. 5 Effect of the measuring probe pattern and source compensation necessity.

In order to have the highest accuracy in terms of the radiation pattern after source compensation (the lower influence of the feeding probe) an open-ended WR-10 waveguide (Fig. 6) is selected as a measuring probe. For comparison the measurements were done also with a horn antenna as a probe.



Fig. 6 WR-10 waveguide as a measuring probe.

III. LEAST SQUARES FIT

There are different techniques for phase centre determination. The calculation of the phase centre with the least squares fit technique comes from the comparison between the measured phase and the theoretical one for different distances (DRW antenna to probe distances). The distance that provokes the smallest deviation of theoretical results regarding measured ones is the one that establishes the phase centre position. As mentioned, to minimize the deviation between theory and measurements, the least squares fit procedure is applied with the theoretical phase value as given in Fig. 7 and in (1). Equation (2) offers the minimum phase deviation calculation for the least squares fit, for different distances from the measuring probe. Parameter n is the number of measurement points in an x - y measurement grid.

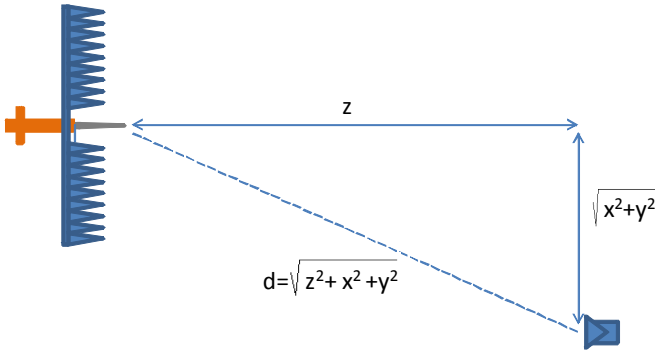


Fig. 7 Distance for theoretical phase calculation.

$$\varphi_{theoretical} = \frac{2\pi}{\lambda} \sqrt{z^2 + x^2 + y^2} \quad (1)$$

$$\min \sum_n (\varphi_{n,measured} - \varphi_{n,theoretical})^2 \quad (2)$$

Both DRW antennas are measured at four different frequencies (83.5, 93.5, 103.5, and 113.5 GHz). Fig. 8 exhibits the measurement setup for sapphire and silicon antennas.

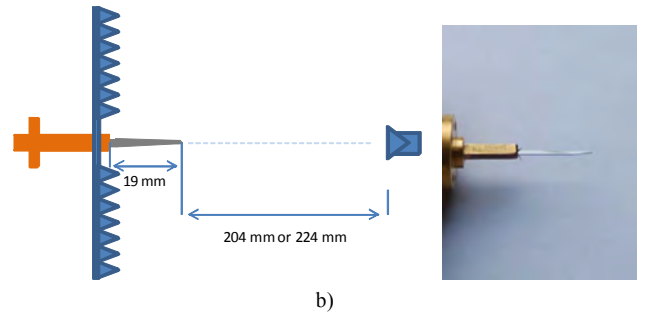
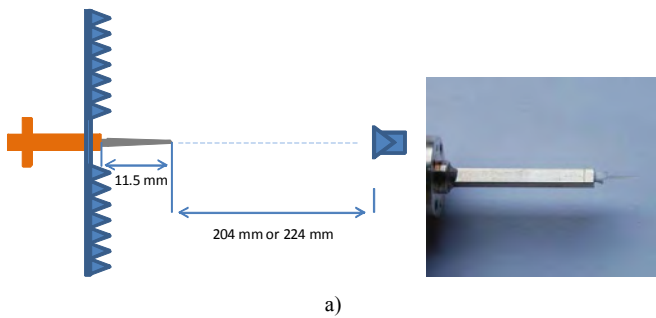


Fig. 8 Measurement setup for a) sapphire, b) silicon antennas.

IV. RESULTS

Results obtained in the planar scanner acquisition system are processed in order to derive the phase centre position of the different DRW antennas. As the phase centre position of the probe horn is known the difference between the results obtained with different probes is negligible. Figs. 9 and 10 offer the results for sapphire and silicon antennas, for different distances of the feeding probe. Results are summarized in table I.

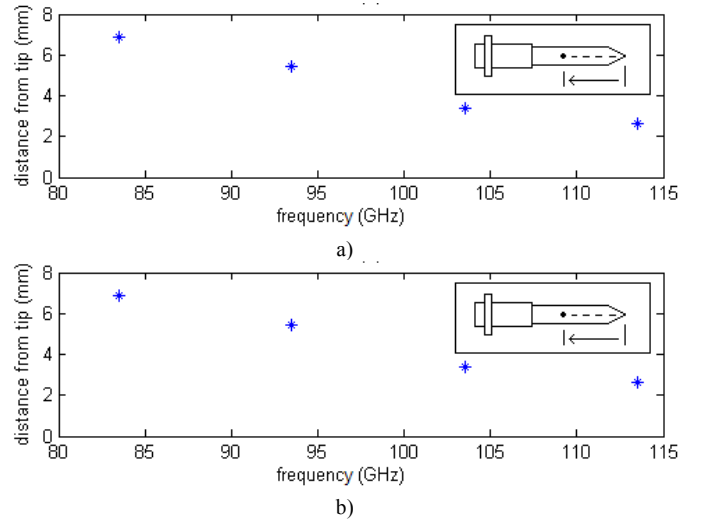
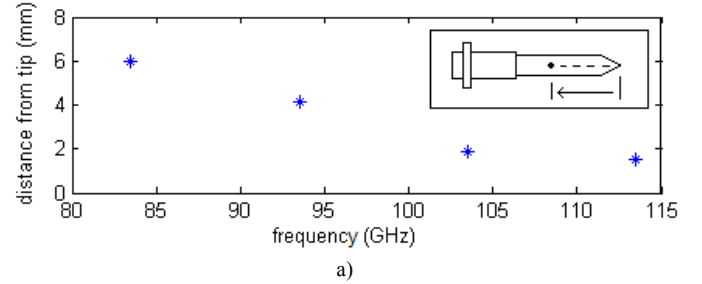


Fig. 9 Phase centre position for different frequencies, for sapphire DRW antenna, a) distance (A) = 204 mm, b) distance (A) = 224 mm.



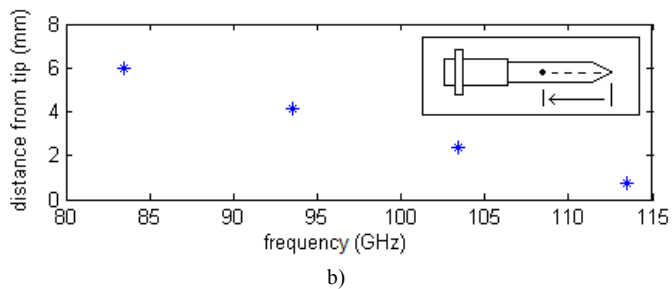


Fig. 10 Phase centre position for different frequencies, for silicon antenna, a) distance (A) = 204 mm, b) distance (A) = 224 mm.

TABLE I
PHASE CENTRE POSITION RESULTS

Planar system feeder to DRW antenna distance (A) = 204 mm		
Freq. (GHz)	Phase centre Position (mm), for sapphire rod	Phase centre Position (mm), for silicon rod
83.5	6.9	6.1
93.5	5.4	4.2
103.5	3.4	1.9
113.5	2.6	1.7
Planar system feeder to DRW antenna distance (A) = 224 mm		
Freq. (GHz)	Phase centre Position (mm), for sapphire rod	Phase centre Position (mm), for silicon rod
83.5	6.8	5.9
93.5	5.4	4.2
103.5	3.4	2.4
113.5	2.6	0.8

When the tendency of the results obtained for the phase centre position is analyzed, it can be seen that the phase centre position is moving towards the tip of the antenna when the frequency is increased. Notice that the position of the phase centre of the antenna is related to the antenna itself, as the phase centre of the probe for each frequency and the distances

of the measurement scheme are known. The measured movement of the phase centre towards the tip of the DRW antenna is potentially linked to the constant beamwidth that has been observed for these antennas. The analysis of this is a subject of further study, also considering the implications for DRW antenna use as a feeder or as an element in an antenna array.

V. CONCLUSION

In this work, an experimental least squares fit method for the phase centre determination of a DRW antenna is applied. Experimental results are obtained at different mm-wave frequencies for silicon and sapphire antennas. The behaviour of the phase centre position with the frequency has been studied. The phase centre position is moving towards the DRW antenna tip as the frequency is increased.

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