DRGH Antenna with Improved Gain and Beamwidth Performance

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***Abstract*— Double Ridge Guide Horn (DRGH) antennas are widely used in antenna and EMC testing facilities as feed antennas and gain transfer standards. Increasing the low frequency gain to obtain a more constant 3 dB and 10 dB beamwidth, over the operating frequency band of 1-18 GHz, will result in a more uniform illumination of the devices under test. In this communication the ridge profiles of a conventional DRGH antenna with dimensions complying with the requirements of MIL-STD-461F, are modified to produce a more constant beamwidth, especially from 3 GHz upwards. The width of the ridges is tapered along the axial length of the DRGH to increase the effective radiating aperture and reduce the beamwidth, at the lower frequencies. An accurate numerical model was developed of the conventional 1-18 GHz DRGH antenna and modified ridges were implemented. The radiation properties of a prototype antenna were measured in a compact antenna range. Simulated and measured results are presented for the modified DRGH antenna.**

***Index Terms*— Broadband ridged horn antennas, electromagnetic compatibility (EMC) measurements.**

I. INTRODUCTION

Ridges were added to the conventional pyramidal horn in the 1970s to decrease the cut-off frequency and thereby improving the bandwidth of the Horn antenna [1]. It is well know that Double Ridge Guide Horn (DRGH) antennas have evolved to become the preferred source antenna in EMC/EMI testing facilities with its 18:1 operation bandwidth, developed from the short axial length, broadband 1-12 GHz DRGH antenna presented by Kerr [2]. MIL-STD-461F specify the dimensions of the 1-18 GHz DRGH antenna to be used for EMI and EMC testing purposes [3].

A number of studies aimed to optimize and improve on the performance of wide band DRGH antennas. The majority of these studies focused mainly on the VSWR performance of the DRGH antenna and the suppression of higher order modes to eliminate pattern deterioration (breakup) at frequencies above 12 GHz. The coaxial-to-ridged waveguide transition was redesigned and mode suppression fins added to suppress higher order modes, and the curvature of the ridges was modified to improve aperture match and VSWR performance [4, 5, 6, 7]. The dielectric sidewalls were removed to improve the radiation characteristics of the DRGH antenna above 12 GHz, at the expense of gain performance below 4 GHz.

In [8] an improved DRGH antenna with conducting strip sidewalls was proposed. The coaxial to ridged waveguide transition was redesigned and optimized. Cubic Bezier ridge profiles over the axial length of the DRGH antenna were used to improve aperture match and VSWR performance in the lower frequency range. The design obtained a VSWR performance below 2:1 and gain variation from 8 to 16 dBi over the frequency band 1-18 GHz. Adjustable conducting grid sidewalls and a cross-shaped back cavity [9] were proposed to improve gain performance at low frequencies, while maintaining high frequency performance. In [10] a new coaxial feedline structure, modified waveguide dimensions and ridge curvatures were proposed, to achieve a uniform field distribution for radiated susceptibility testing. All these studies considered only a constant ridge width over the axial length of the DRGH antenna and focused mainly on the VSWR performance and suppression of higher order modes.

Various TEM [11, 12] and quad ridge horn antenna [13, 14] designs pursue constant beamwidth performance versus frequency. A DRGH antenna with near-constant beamwidth performance over a 4:1 frequency range is presented in [15]. The beamwidth performance was improved by increasing the length and the aperture size of the horn by 1.65 and 5.65 times, respectively. In this communication the ridge profiles of a conventional DRGH antenna with dimensions complying with the requirements of MIL-STD-461F, are modified to produce a more constant beamwidth, especially from 3 GHz upwards. The width of the ridges is tapered along the axial length of the DRGH to increase the effective radiating aperture and reduce the beamwidth at the lower frequencies. An accurate numerical model was developed of the conventional 1-18 GHz DRGH antenna and modified ridges were implemented. The radiation properties of a prototype antenna were measured in a compact antenna range. Simulated and measured results (impedance bandwidth, gain, and radiation patterns) are presented for the modified DRGH antenna.

II. NUMERICAL MODEL

The numerical model in Fig. 1, was developed in FEKO [16] based on the improved DRGH antenna presented in [8]. This antenna complies with the dimensional requirements specified in the standard, MIL-STD-461F [3], for EMI and EMC testing; viz. an aperture size of 242 (A) × 136 (B) mm and axial length of 175.5 mm (C).

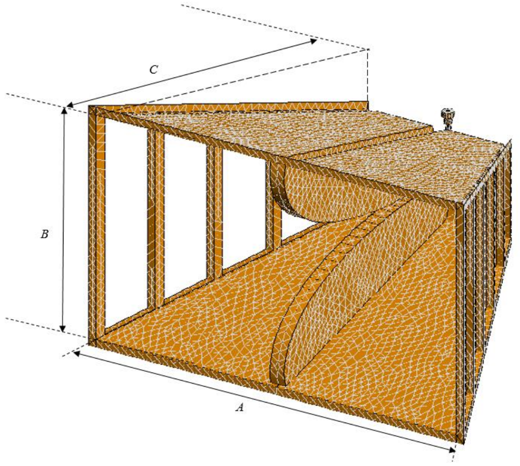

Fig. 1. Numerical DRGH antenna model developed in FEKO.

Previous studies aiming to optimize and improve on the performance of wide band DRGH antennas mainly focused on the coaxial to ridged waveguide transition, the back cavity and a few papers investigate the effect of the ridge profile (over the axial length of the DRGH antenna) on the antenna performance. All these studies considered only a constant ridge width over the axial length of the DRGH antenna, as shown in Fig. 2(a).

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The purpose of tapering the ridge width along the axial length of the DRGH antenna is to increase the effective radiating aperture and thus reducing the beamwidth, especially in the lower frequency part of the operating band. Comparing the gain performance of DRGH antennas for different ridge profiles along the axial length of the antenna, the elliptical profile yields the most promising results [17]. The ridge width taper along the axial length of the antenna was obtained, firstly using a wave impedance (for the TE_{10} mode) transformation from the cavity to the aperture. Secondly, a linear taper from the cavity to the aperture was considered for the ridge width.

The wave impedance taper along the axial length (flared section) of the DRGH antenna is divided into 52 discrete sections of ridged waveguide with constant cross sections. The wave impedance, $Z_{0\infty}$, for the TE_{10} mode in double ridged waveguide [18] at the start of the flare is determined from the dimensions of the cavity and coax to ridged waveguide transition in [8] as $Z_{0\infty} = 32.125\Omega$. The wave impedance at the end of the flared section is determined from the ridged waveguide dimensions close to the aperture of the DRGH antenna as $Z_{0\infty} = 434.481\Omega$. The ridge width for each discrete section of waveguide was obtained by fitting a Klopfenstein taper [19] along the axial length of the flared section to determine the wave impedance, and corresponding ridged width, for each section as shown in Fig. 2(b). The second ridge width taper considered, employed a linear taper in terms of ridge width from the cavity to the aperture as shown in Fig. 2(c). The dimensions of the DRGH antenna and modified ridges are summarized in Table I.


(a) (b) (c)

Fig. 2. Different ridge width profiles implemented in FEKO, (a) constant width, (b) Klopfenstein impedance taper and (c) linear ridge width taper.

TABLE I

DRGH HORN ANTENNA DIMENSIONS

Description	Dimension (mm)
Aperture width (*A*)	242
Aperture height (*B*)	136
Axial length of flared section (*C*)	175.5
Ridge width at feed	9.6
Ridge width at aperture for Klopfenstein taper	20.86
Ridge width at aperture for Linear taper	70.43

Figs. 3 and 4 show the FEKO results for VSWR and boresight gain of a DRGH with the three ridges, respectively. The VSWR with the three ridges are nominally the same. The boresight gain of the DRGH antennas with both of the two modified ridges showed an improved performance over most of the operating band if compared to the conventional ridge with constant width. It is clear that the ridge with the linear ridge width taper has the best performance overall. The rapid variation of the Klopfenstein taper close to the feeding point is probably exciting higher order modes, causing a decrease in boresight gain at the higher frequencies.

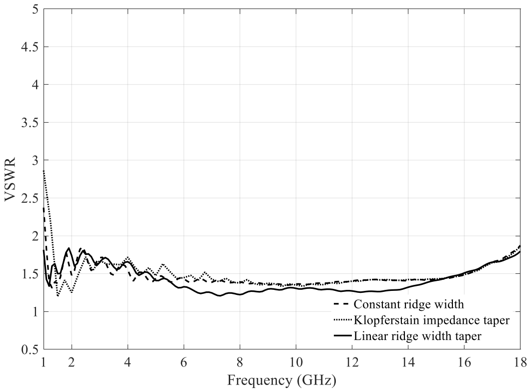


Fig. 3. VSWR comparison of the DRGH antenna.

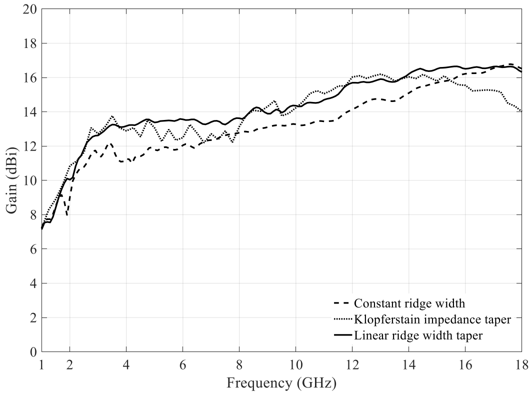


Fig. 4. Boresight gain comparison of the DRGH antenna.

III. SIMULATION RESULTS

The width of the ridges is tapered along the axial length of the DRGH to increase the effective radiating aperture and the boresight gain (Fig. 5) at the lower frequencies, while reducing the beamwidth. In this section, simulated results are presented to illustrate the increased effective radiating apertures at the lower frequencies, obtained with the modified ridges. Radiation properties of the DRGH antenna with modified ridges are also compared to that of a conventional DRGH antenna. Fig. 5 shows the FEKO models for the two DRGH antennas.

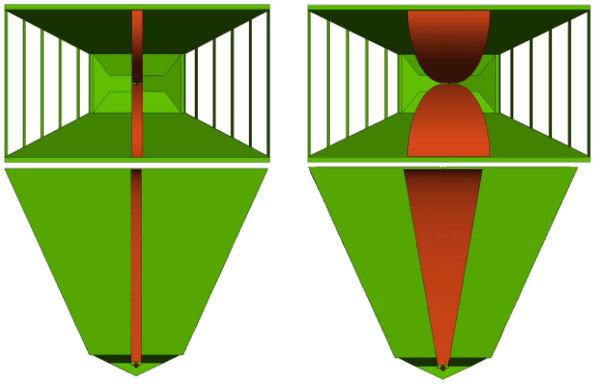

(a) (b)

Fig. 5. DRGH antenna numerical model simulated in FEKO with (a) conventional ridges and (b) modified ridges.

The field distributions for the two DRGH antenna were obtained at three positions along the axial length of the flare section as shown in Fig. 6. Figs. 7 to 9 show the results of the near field monitors; (i) at 3 GHz, close to the aperture; (ii) at 9 GHz, in the center of the flared section; and (iii) close to the cavity at 18 GHz. It is clear that the modified ridges significantly increased the effective radiating aperture, especially at the lower frequencies.

The 3 dB beamwidths shown in Fig. 10 for the two DRGH antennas were obtained from simulated H-plane radiation patterns. The main improvement occurs above 3 GHz where the 3 dB beamwidth of the modified DRGH antenna varies from 18.3° to 39.4° compared to the conventional ridges with a variation from 17.5° to 56.8°. In Fig. 11, the 10 dB beamwidth varies from 38.6° to 134.21° for the modified DRGH compared to variations from 28.5° to 136.1° for the conventional ridges.

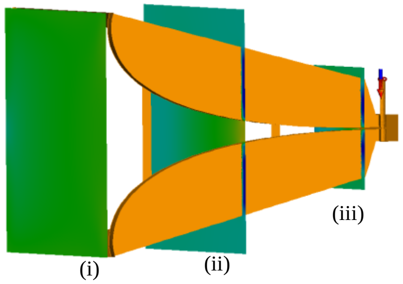
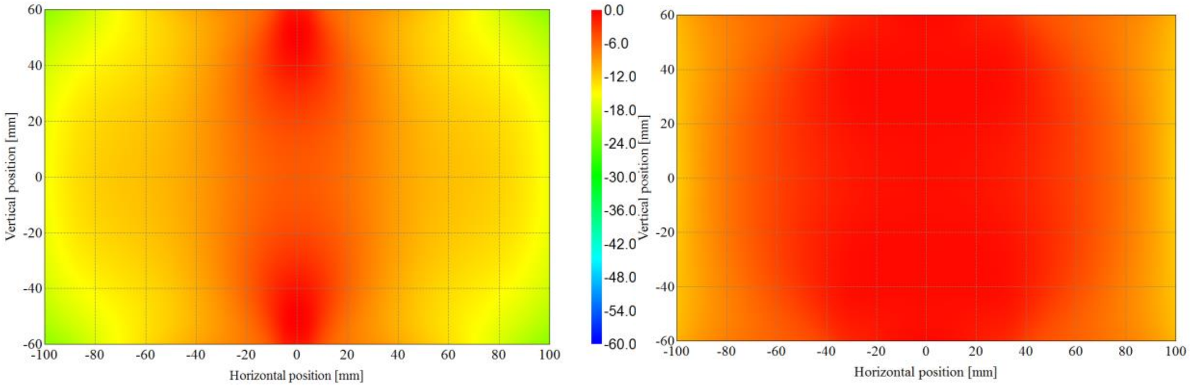
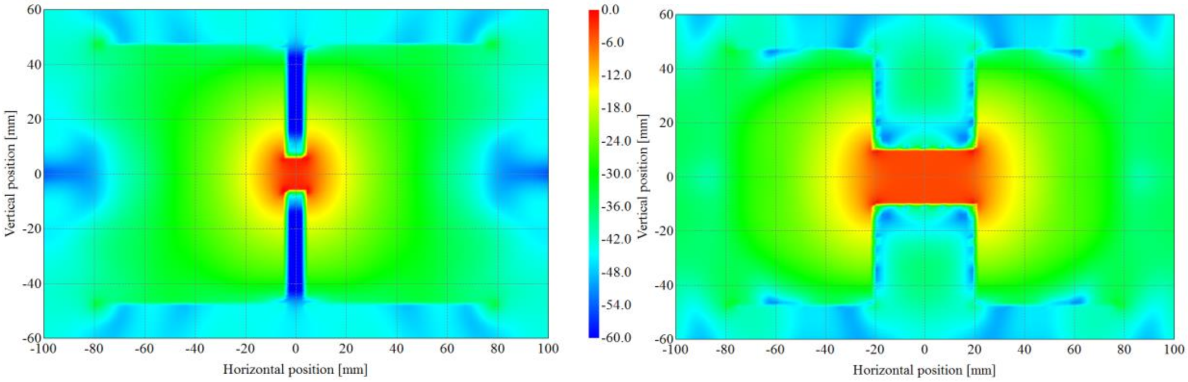


Fig. 6. Cut through DRGH indicating the positions of field monitors (i), (ii) and (iii).



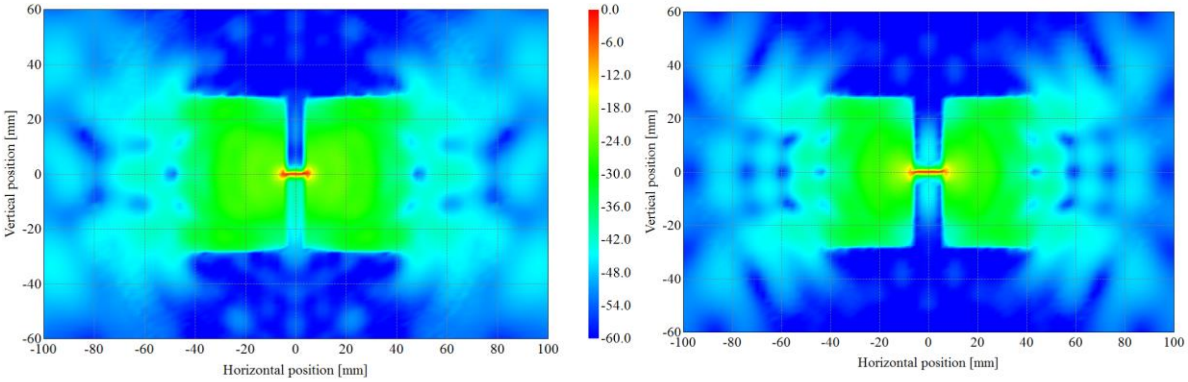
(a) (b)

Fig. 7. Comparison of field monitor (i) result for 3 GHz; (a) conventional ridges (b) modified ridges.



(a) (b)

Fig. 8. Comparison of field monitor (ii) result for 9 GHz; (a) conventional ridges (b) modified ridges.



(a) (b)

Fig. 9. Comparison of field monitor (iii) result for 18 GHz; (a) conventional ridges (b) modified ridges.

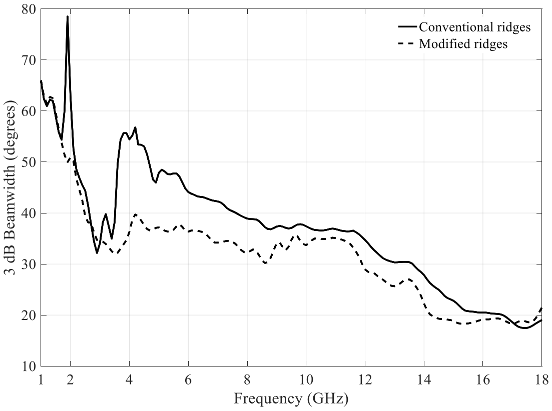


Fig. 10. Simulated 3 dB beamwidth for the two DRGH antennas.

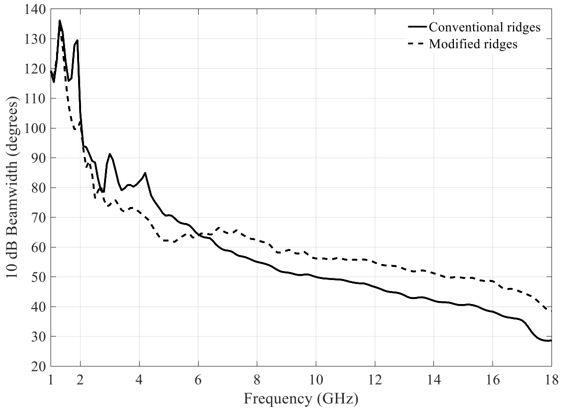


Fig. 11. Simulated 10 dB beamwidth for the two DRGH antennas.

IV. MEASURED RESULTS FOR THE MODIFIED DRGH

The measured results for a prototype of the modified DRGH antenna are compared to the simulated results obtained with FEKO. The DRGH antenna was measured in the compact antenna test range at the University of Pretoria, Fig. 12. The measured VSWR in Fig. 13 have a maximum value of 2.1:1 at 1 and 18 GHz and remains below 2:1 over the rest of the frequency range. The measured and simulated boresight gain are compared in Fig. 14. The measured and simulated results are within 1.15 dB from 1 to 7 GHz and 0.92 dB from 7 to 18 GHz. There are no sharp dips due to the excitation of higher order modes over the entire frequency range, indicating the absence of pattern deterioration at higher frequencies.

H-plane and *E*-plane patterns for the prototype of the modified DRGH antenna are shown in Figs. 15 and 16, respectively. There is no pattern breakup present in the measured or simulated radiation patterns and good agreement exists between the measured and simulated results. The 3 dB beamwidth and 10 dB beamwidth results obtained from the measured and simulated *H*-plane radiation patterns are compared in Figs. 17 and 18, respectively. The measured and simulated co-polarization radiation pattern in the 45° plane of the DRGH antenna are shown for 18 GHz in Fig. 19. It is clear that the radiation patterns for the modified DRGH antenna do not exhibit any pattern deterioration due to the excitation of higher order modes.

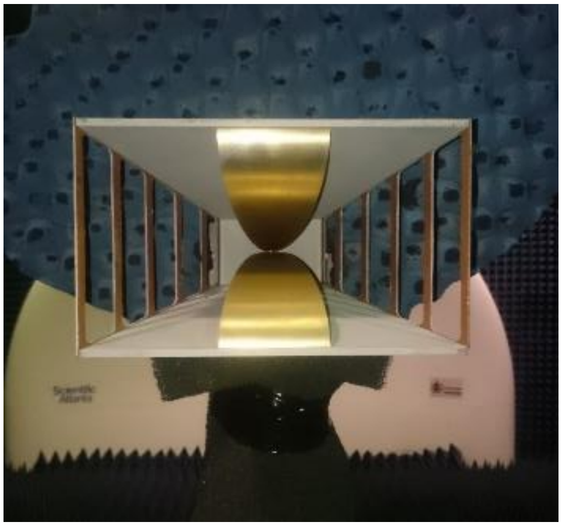


Fig. 12. Modified 1 – 18 GHz DRGH antenna in the compact range.

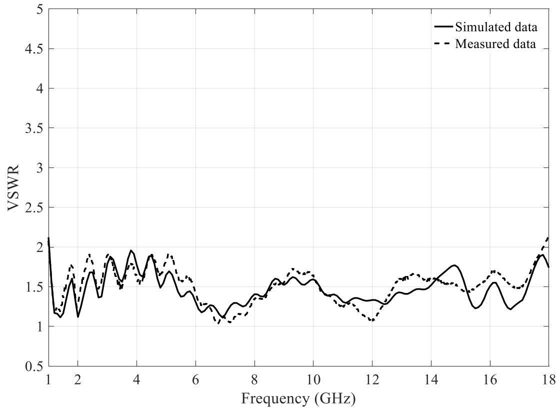


Fig. 13. Measured and simulated VSWR for the modified DRGH.

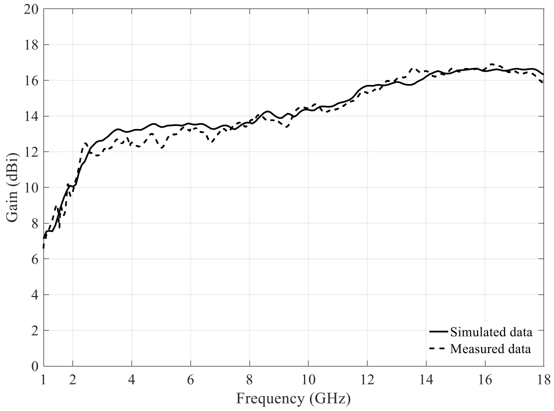


Fig. 14. Measured and simulated boresight gain for the modified DRGH.

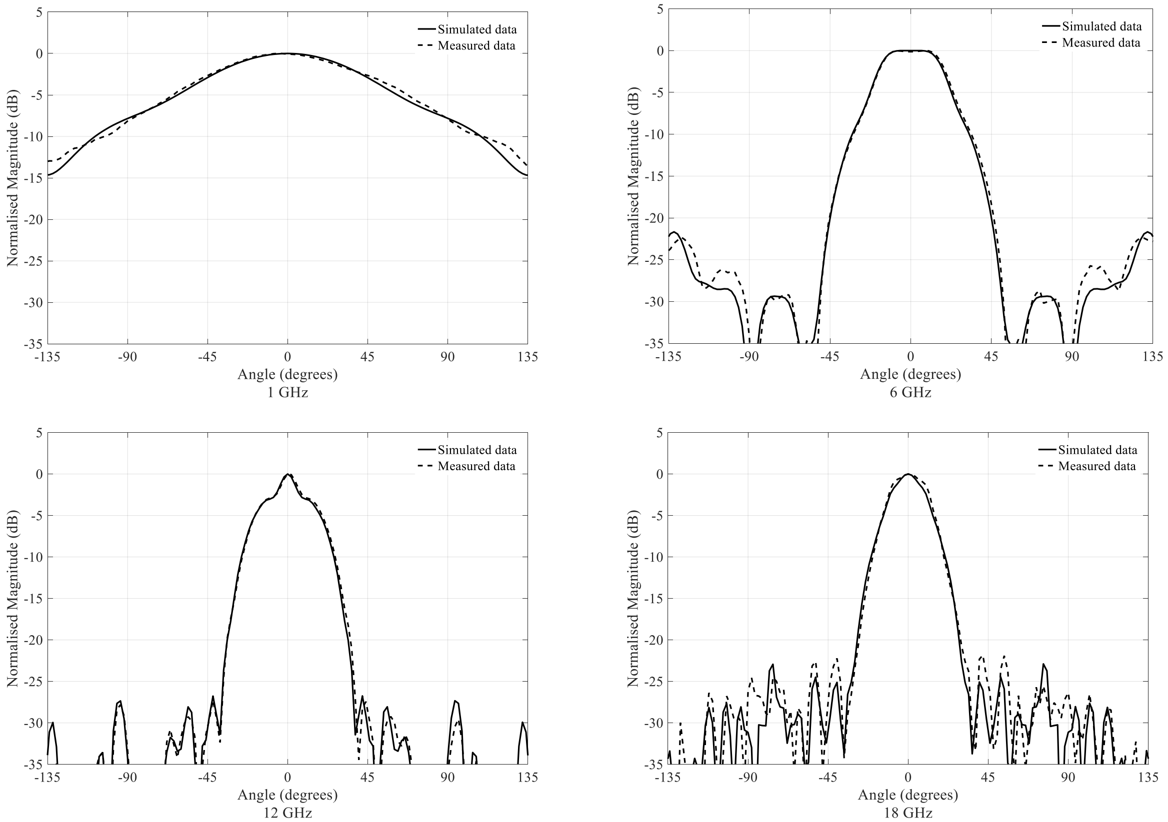


Fig. 15. Measured and simulated *H*-plane radiation patterns of the modified DRGH antenna.

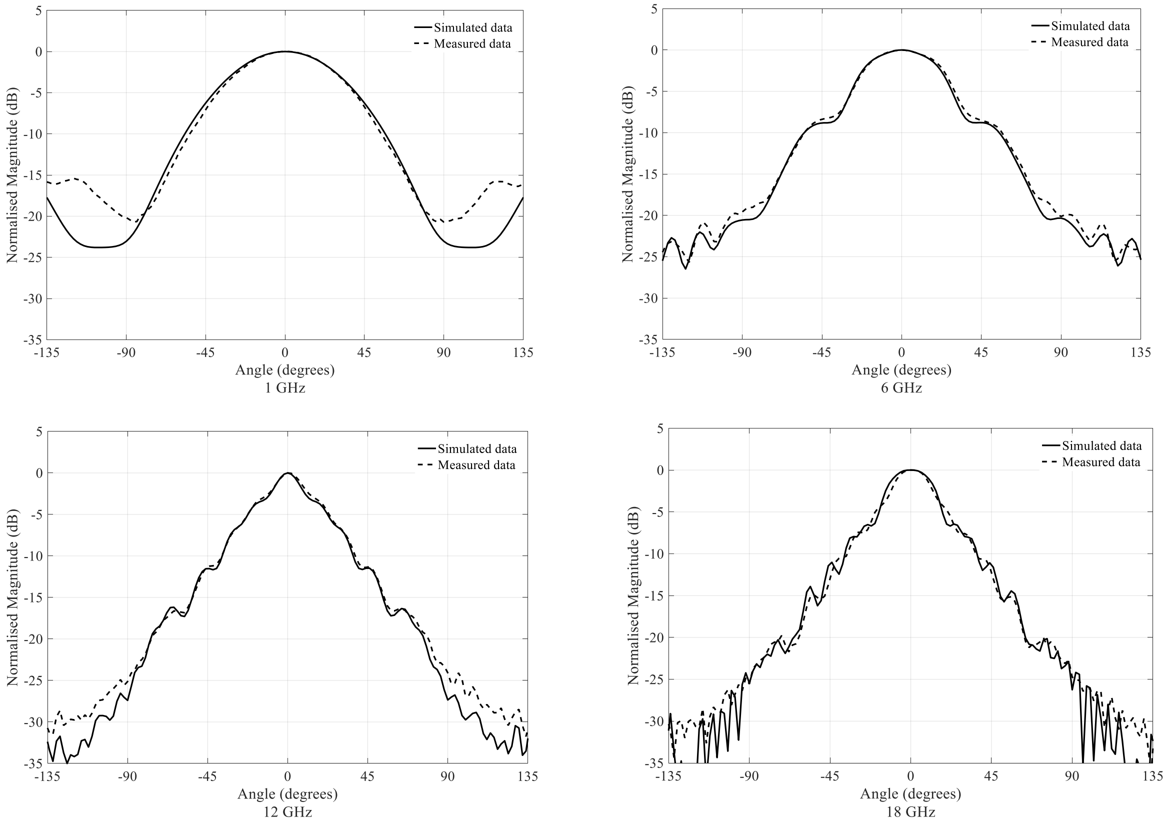


Fig. 16. Measured and simulated E-plane radiation patterns of the modified DRGH antenna.

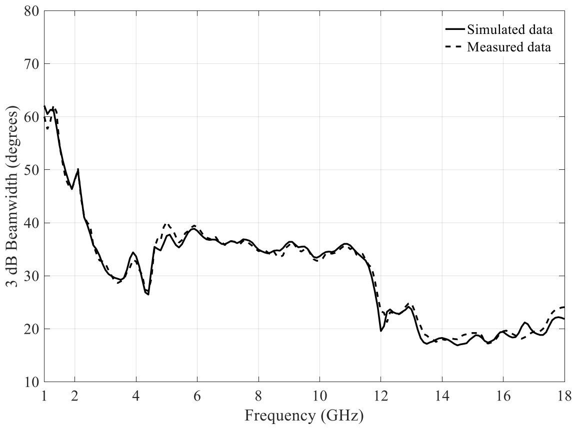


Fig. 17. Measured and simulated 3 dB beamwidth for the modified DRGH.

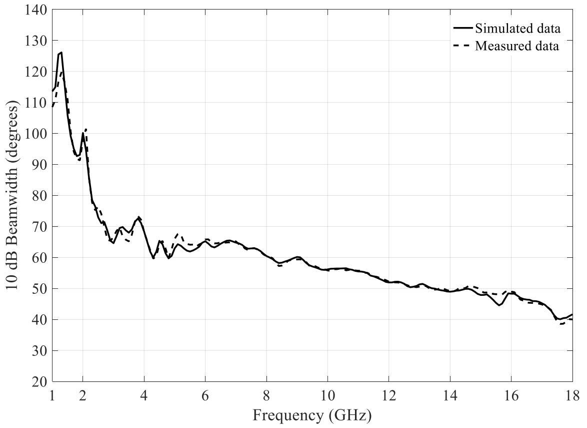


Fig. 18. Measured and simulated 10 dB beamwidth for the modified DRGH.

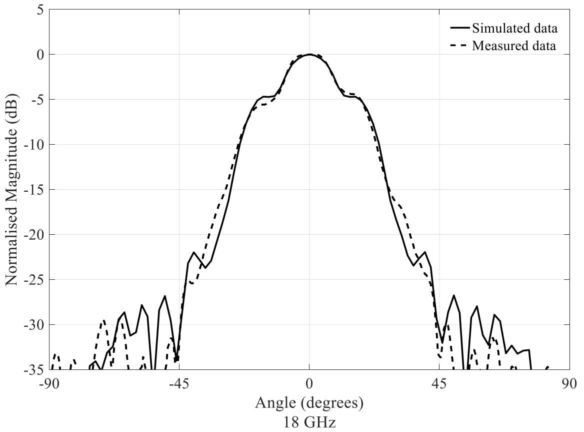


Fig. 19. Measured and simulated co-polarized radiation pattern in the 45°-plane of the DRGH antenna.

V. Conclusion

The ridge profiles of a conventional 1-18 GHz DRGH antenna with dimensions complying with the requirements of MIL-STD-461F, were modified to produce a more constant beamwidth, especially from 3 GHz upwards. The width of the ridges was tapered along the axial length of the DRGH to increase the effective radiating aperture, boresight gain and reduce the beamwidth, especially at the lower frequencies. The radiation properties of a prototype antenna were measured in a compact antenna range. The gain of the modified DRGH antenna is almost 2 dB higher than the corresponding DRGH with conventional ridges. The modified antenna also has a smaller variation in 3 dB and 10 dB beamwidth over the operating frequency band.

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