Leaky-Wave Focusing Antenna With Tapered Dielectric Constant Distribution

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1. Introduction

To address the challenge of portability in contemporary millimeter wave imaging systems, an active millimeter wave imaging system small enough to be operated by hand was proposed [1]. Despite the good results obtained, a problem with the structure was that it is inherently complex to manufacture owing to the tapering of the broadwall height of the waveguide. To address this challenge, a leaky-wave focusing antenna (LWFA) with a relatively easier to fabricate tapered dielectric constant distribution is proposed in this work where the dielectric constant distribution will be fabricated using the process discussed in [2].

2. Design of the proposed leaky wave lens

As shown in [1] and [4], the required β distribution to focus at a position S(x_s, z_s) in the near field is

$$\beta(z') = k_0 \frac{z_s - z'}{\sqrt{(z_s - z')^2 + x_s^2}}. \quad (1)$$

The β in the case of a leaky-wave antenna (LWA) is approximated using a closed rectangular waveguide and the required dielectric constant profile is then derived as

$$\epsilon_r(z') = \frac{(z_s - z')^2}{(z_s - z')^2 + x_s^2} + \left(\frac{\pi}{k_0 a}\right)^2. \quad (2)$$

3. Simulation results and discussion

To verify the proposed concept, a LWFA model with the $\varepsilon_r(z')$ from (2) at the design frequency of 15 GHz was fabricated in full-wave simulation software and the electric field distribution along the z-direction was extracted at x=x_s. From the results shown in Fig. 2, the required focusing effect was achieved though only at 17 GHz as at 15 GHz the travelling wave is cutoff owing to the difference between the closed waveguide and LWA β.

4. Conclusion

In this work, a LWFA is proposed where the phase constant of the travelling wave inside the waveguide is tapered by varying the dielectric constant distribution

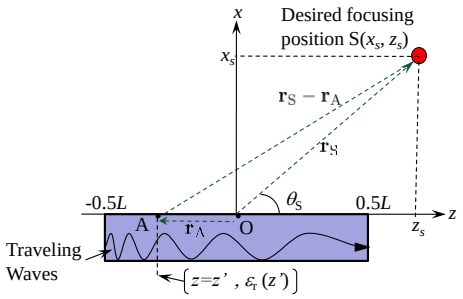

Fig. 1. Concept of leaky-wave lens antenna with tapered dielectric constant distribution.

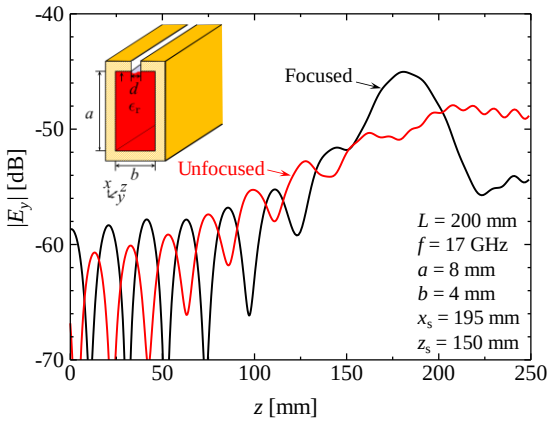

Fig. 2. Electric field distribution extracted along the z-direction at x = x_s = 195 mm.

along the length of the LWA. Focusing effect was achieved though owing to the difference between the actual LWA and closed waveguide phase constant approximation used, the travelling wave is cutoff at the design frequency. Should the actual phase constant of the LWA be used in the design process, it is anticipated that this problem will be cleared which therefore informs the next step in this study.

References

[1] K. K. Mutai, H. Sato and Q. Chen, "Active Millimeter Wave Imaging Using Leaky-Wave Focusing Antenna," *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 5, pp. 3789-3798, May 2022.

[2] T. Hayat, M. U. Afzal, A. Lalbakhsh and K. P. Esselle, "Additively Manufactured Perforated Superstrate to Improve Directive Radiation Characteristics of Electromagnetic Source," *IEEE Access*, vol. 7, pp. 153445-153452, 2019.