

# HIGH-GAIN MILLIMETER-WAVE LENS HORN ANTENNAS WITH SUPPRESSED SIDE-LOBE RADIATION

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**Abstract:** The paper introduces high-gain conical lens horn antennas with suppressed side lobes for the frequency band 71-76/81-86 GHz (E-band) which is dedicated for point-to-point communication. Two concepts of dielectric lenses are proposed. The first lens is of hyperbolic shape and the other one is flat with perforation based on a transmitarray. Both of the proposed antennas were simulated in CST MWS. The gain is above 38 dBi and the side-lobes exceed -15 dB level.

**Keywords:** Horn antenna, E-band, mmWave, side-lobe suppression, dielectric lens, transmitarray

## 1 INTRODUCTION

At the present time, backhaul systems of modern internet providers and mobile operators must provide very high data throughput of 1-10 Gbps. One of the possible solutions is to use point-to-point links in the 71-76/81-76 GHz frequency band known as E-band. The European regulation prescribes that antennas for that frequency band have to comply the gain higher than 38 dBi (half-power beam width below 2°) which means that those links can provide large distance, up to several kilometers [1]. The requirement of sufficient side-lobe suppression is for the antenna interference minimization and meeting the ETSI radiation pattern masks. Low level of the first side-lobe has also practical utilization in facilitation of radio link pointing during mounting radios on the masts and roofs. These requirements can be satisfied using lens-based antennas which are presented below.

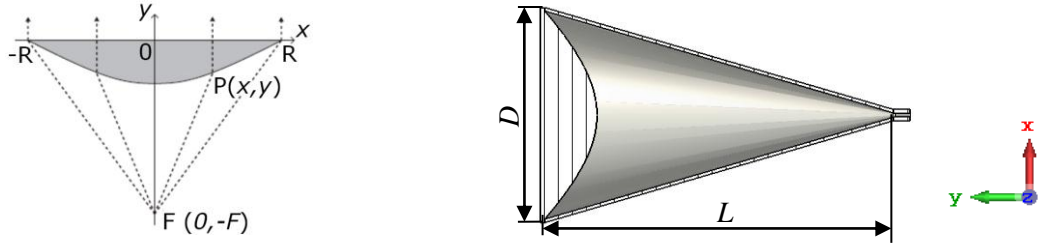
## 2 DESIGN OF ANTENNA LOADED WITH HYPERBOLIC DIELECTRIC LENS

The hyperbolic shape conical lens antenna was designed according to [2] utilizing dielectric material Teflon with relative permittivity  $\epsilon_r$  of 2.1 and tangent loss of 0.0002. The hyperbolic shape is given by equations (1)-(3) where  $R$  and  $F$  are the radius and the focus distance of the lens, respectively. The XY-coordinate system of the lens and the antenna structure are shown in Fig. 1. The simulated realized gain ( $G_r$ ), side-lobe suppression (SLS(E), SLS(H)) and radiation pattern with ETSI mask restriction, are shown in Fig. 2. Lens has diameter  $D$  of 180 mm and length of the antenna horn  $L$  is 234 mm. The maximum thickness of 40 mm of the lens corresponds to the designed length to diameter ratio  $L/D$  of 1.3.

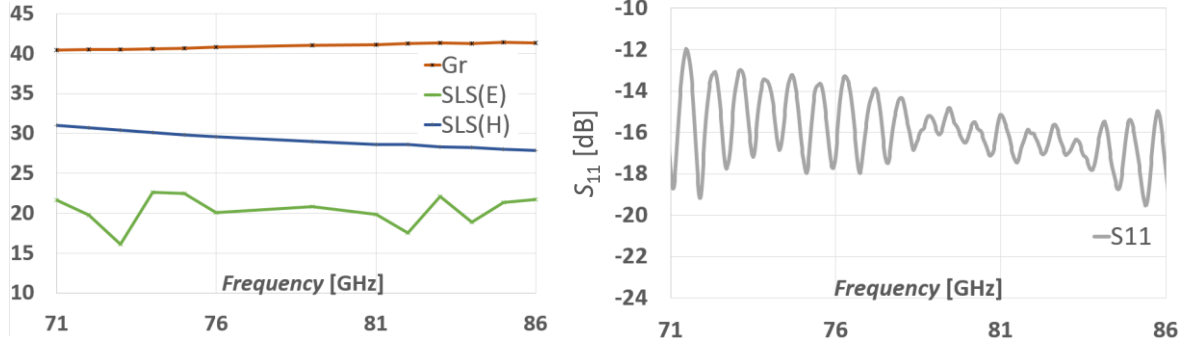
$$A = \epsilon_r - 1 \quad (1)$$

$$B = \sqrt{\epsilon_r \cdot (R^2 + F^2)} - F \quad (2)$$

$$y = \frac{-B + \sqrt{B^2 - A \cdot (R^2 - x^2)}}{A} \quad (3)$$



**Fig. 1.** XY coordinate system of the lens (left) and the cross-section of the antenna structure (right).



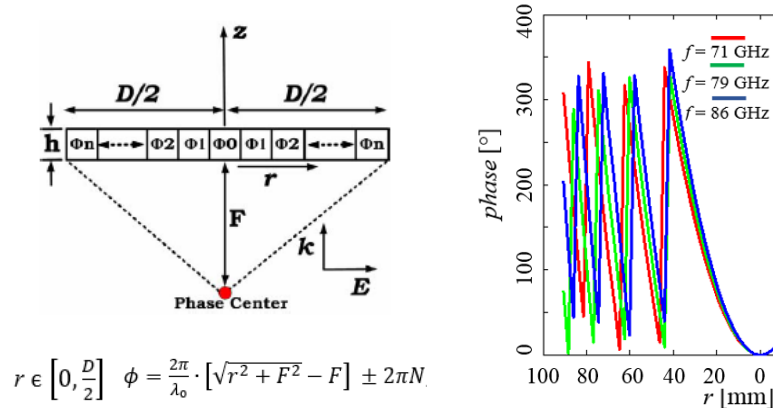
**Fig. 2.** Simulated parameters of antenna with hyperbolic shape conical lens.

### 3 DESIGN OF ANTENNA LOADED WITH PERFORATED LENS (TRANSMITARRAY)

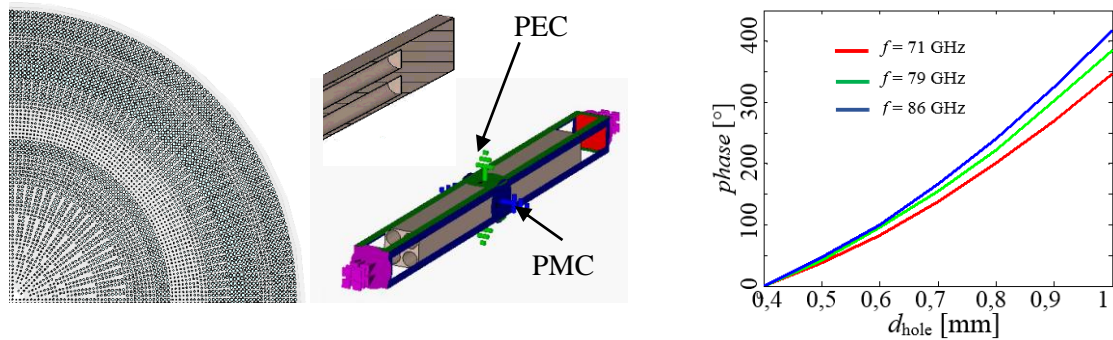
The design of flat perforated lens was based on the smaller version of transmitarray presented in [3]. The same dielectric material for the lens has been chosen as in the previous case.

In the first design step, the required phase correction of each unit cell within the lens was performed using MATLAB code based on Fermat's principle as shown in Fig. 3 where  $\lambda_0$  is the free space wavelength at the designed frequency,  $F$  is the focus distance from the phase center point of the feed source to the center point of the lens,  $r$  is the distance between the central elements and any other element on the lens. The term  $\pm 2\pi N$  is added to the calculated required phase in order to keep the required phase value within the range of 0-360°.

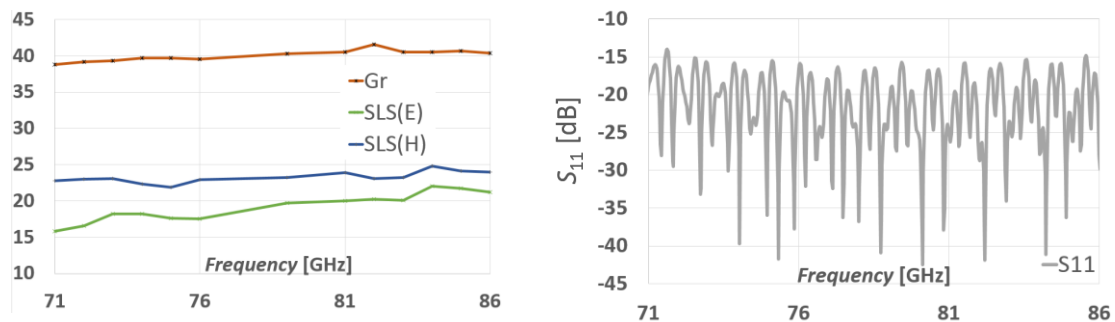
In the second design step, the phase response of the unit cell for various hole diameters was determined using TEM-waveguide numerical model with PEC and PMC boundary conditions for the unit size of about  $0.6 \lambda_0$ . The lens is composed of approximately 4600 waterproof unit cell elements which are composed of phase change segments terminated by filled layer of dielectric material which is suitable for operation in the outdoor. The phase responses and the fraction of the whole structure are shown in Fig. 4. The simulated antenna parameters are shown in Fig. 5. The maximum thickness of 22 mm of the lens corresponds to the designed length to diameter ratio  $L/D$  of 1.3.



**Fig. 3.** Calculated required phase correction of each unit cell within the lens.



**Fig. 4.** Fraction of the lens, numerical model of unit cell and unit cell phase response.



**Fig. 5.** Simulated parameters of antenna with perforated flat lens.

#### 4 CONCLUSION

In this paper, the design of hyperbolic shaped lens and perforated flat lens antennas have been presented. The antenna with hyperbolic lens features higher realized gain (40.4 dBi at 71 GHz and 41.4 dBi at 86 GHz) and higher side-lobe suppression (ETSI class 3 compliance). In addition, it is more suitable for faster fabrication process. The antenna with flat transmit-array perforated lens is cheaper thanks to a half dielectric material consumption; however, it has worse performance of all parameters (lower gain, no ETSI class compliance). The impedance matching of both designed antennas is under the condition  $S_{11} < -10$  dB over the desired band.

#### ACKNOWLEDGEMENT

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