# APPLICATION OF DIELECTRIC AND TEM HORNS IN PHASED ANTENNA ARRAYS

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**The effect of the dielectric layer and metal horns on the characteristics of waveguide phased antenna arrays was studied using the finite element method. The geometric dimensions of the horns were optimized for better matching of the antenna array when scanning at an angle θ. Graphs illustrating the dependence of beam width and directivity on the number of elements in one side of the square array are plotted. Radiation patterns of the antenna array are plotted for different numbers of elements on one side of it.**

**Keywords:** antenna array, dielectric covering layer, horn, reflection coefficient, directivity.

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## 1. Introduction

In [1], the possibility of matching a waveguide antenna array using a dielectric layer, a metal diaphragm and the dielectric layer and the diaphragm together was considered. The integral equation method was employed. It was shown that using a dielectric layer or a metal diaphragm, it was possible to reduce the absolute value of the complex reflection coefficient $|R|$, but only in a small sector of scanning angles.

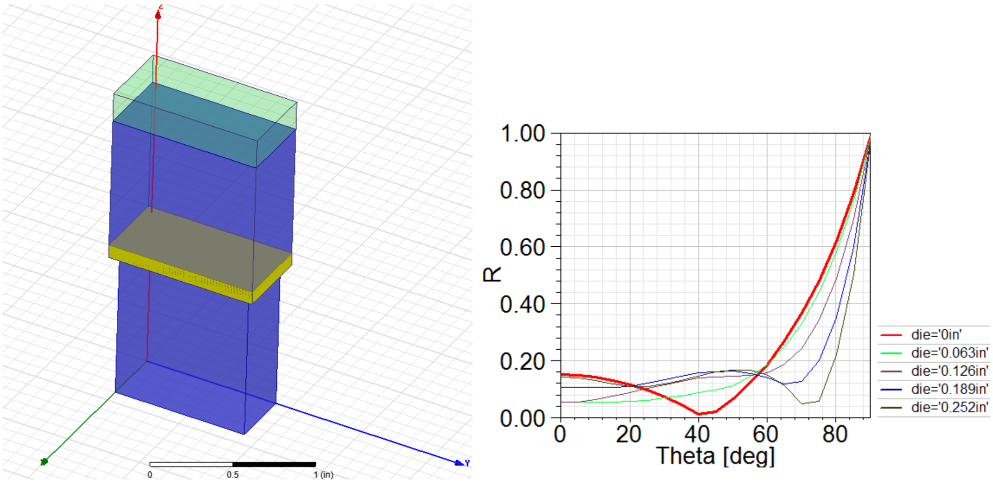
Antenna arrays from TEM horns (transverse electromagnetic modes) are widely applied as ultra-broadband antennas. In works [2-3], the characteristics of radiation and matching of linear arrays with TEM horns, located both in the E- and H-planes, were investigated. Using horns, it is possible to reduce the value of $|R|$, as well as to expand the frequency band of the antenna array. For example, the frequency band of linear array with TEM horns, starting with 6-element arrays, exceeds the value of 1:20. In the scanning mode for such a grating, the frequency band is narrowed to 1:5. The research was conducted using horns with straight walls (regular) and with walls with an exponential or quadratic generating line (irregular).

Ultra-wideband antenna arrays have a bandwidth of more than 10:1, that is, they cover more than one waveband. Such (overband) antenna arrays can be used in multi-functional multi-band radio technical systems.

Cylindrical antenna arrays with TEM horns are also used. For example, it is shown that an array with 16 TEM horns, with metallization of the interhorn space and a screen, is matched in the frequency band by more than 40:1. Ring arrays with new types of TEM horns were investigated: an asymmetric loop TEM horn and horns in the form of a cutout from a polyconical antenna, as well as arrays of bicones and cutouts from bicones.

## 2. Calculation results

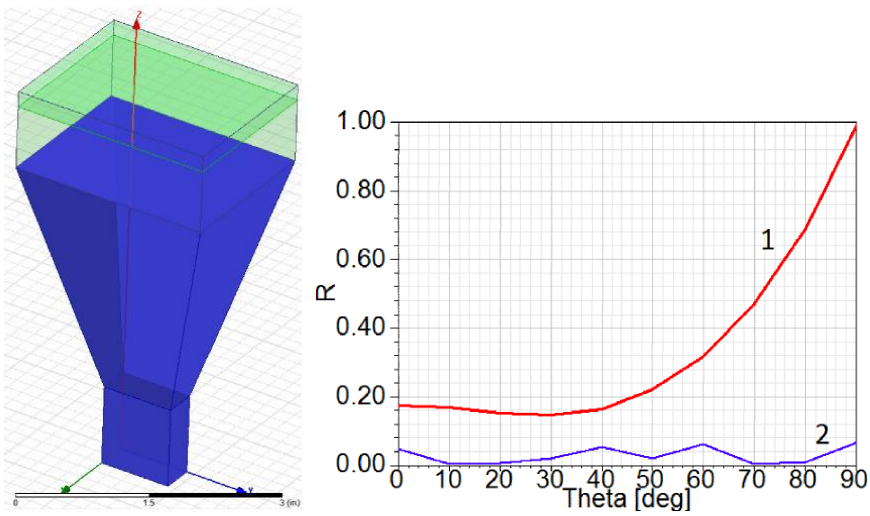
An antenna array (radiation frequency 9.25 GHz) made of rectangular waveguides (dimensions 22.86×10.16 mm), inside which there is a dielectric layer (dielectric constant 1.6), was considered and compared with an array without a dielectric layer. Adding a dielectric allows to reduce the value of $|R|$ in the scanning angle sectors 58°–90° and from 0° to 20° or 30°, but due to its increase in the intervals of 20°–55°. It is possible to slightly reduce the average value of $|R|$, which is equal to: 0.24 without the use of a dielectric; 0.20 with dielectric layer thickness $3\lambda_\varepsilon/16$; 0.18 with dielectric layer thickness $\lambda_\varepsilon/4$ ($\lambda_\varepsilon$ – wavelength in the waveguide), for all scanning angles θ (Fig. 1).




(a) (b)

**Fig. 1. a) Unit cell model of an antenna array with a dielectric layer; b) dependence |R| on the scanning angle θ at different thicknesses of the dielectric layer.**

The phased antenna array, which consists of rectangular waveguides (dimensions 22.86×10.16 mm) with metal horn emitters, with radiation frequency 9.25 GHz was considered. Its numerical simulation was carried out using the finite element method. It was shown that using horns it was possible to significantly reduce the value of |*R*|. Thus, the use of horns is a better option than the use of a dielectric layer. The optimal geometric dimensions of the horn were found for the best matching of the antenna array when scanning at the angle θ: the dimensions of the end of the horn were 63.5×50.8 mm; its height was 76.2 mm (Fig. 2). At any value of the scanning angles θ and φ, the value of |*R*| was small (less than 0.1).




(a) (b)

**Fig. 2. a) cell model of a phased antenna array made of rectangular waveguides with metal TEM horns; b) |*R*| dependences on the scanning angle θ for such antenna array: 1 – without using horns (average value |*R*|=0.324); 2 – with horns (average value |*R*|=0.027).**

If we take other dimensions of the horn to reduce its size – 43.18×30.48 mm and the height of 43.18 mm, then the average value of |*R*|=0.054.

Horns of various configurations were considered. It was established that the H-plane horn, which expands only in the H-plane, allows to reduce the value of |*R*| only for small scanning angles ($\theta < 40°$). The E-plane horn, which expands only in the E-plane, matches better than the H-plane, with the average value of |*R*|=0.112, but it is still several times larger than in the case of a pyramidal horn, for which the average value of |*R*| = 0.027.

A planar antenna array consists of elements that are arranged in a square with the number of elements on one side *n*. Fig. 3 shows a graph of the dependence of the beam width on *n* (radiation along the normal: θ=0°; φ=0°). The more elements in the array, the narrower the beam. With an array of 5×5=25 elements, the beam width is less than 1 degree.

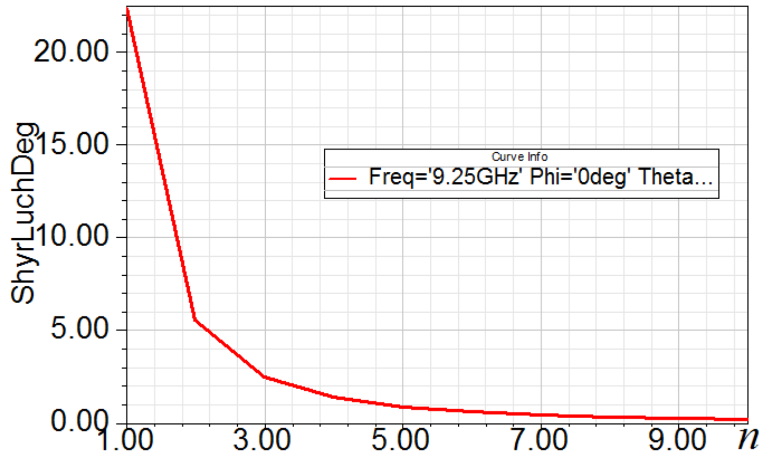



**Fig. 3. Dependence of the beam width in degrees on the number of elements in one side of the array *n* (θ=0°; φ=0°).**

A graph of the dependence of the directivity (by power) on *n* when radiating along the normal is also plotted (Fig. 4). It can be seen that the more elements in the array, the greater the directivity.

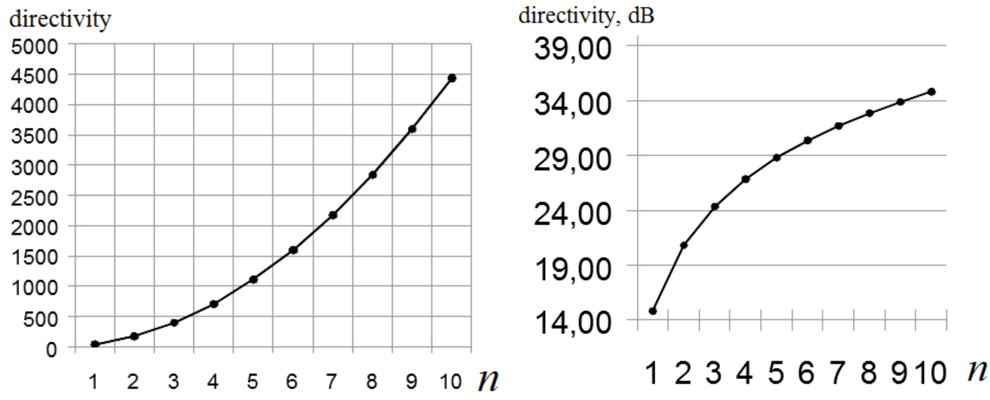



**Fig. 4. Dependence of directivity (a – in conventional units; b – in dB) on the number of elements in one side of the array *n* (θ=0°; φ=0°).**

Fig. 5 shows the radiation patterns of the antenna array depending on *n* (*n*=1; 5; 10). The cases θ=0° and θ=30° (at φ=0°) were calculated. It can be seen from the graphs that when the number of elements of the antenna array changes, the shape of the radiation patterns changes significantly.

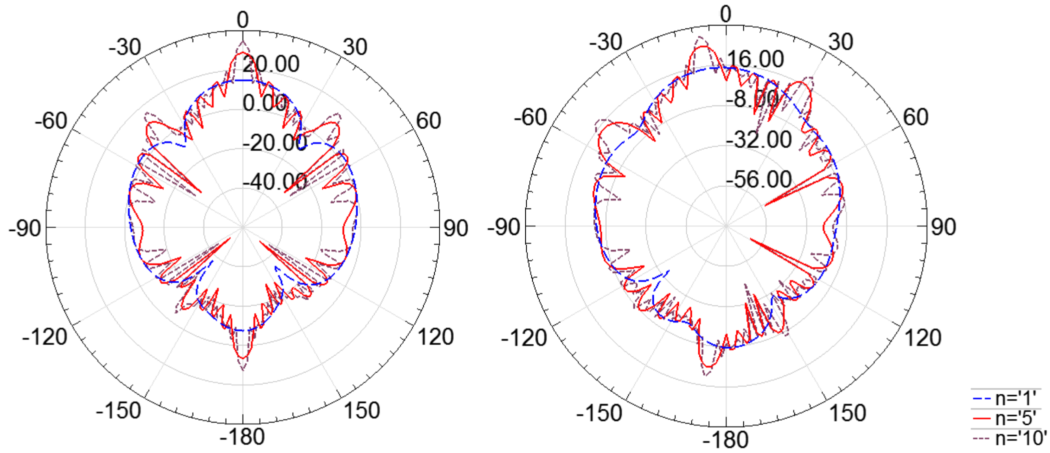



**Fig. 5. Radiation pattern of the antenna array (dB) when radiating along the normal (a): θ=0°; φ=0°; and at an angle (b): θ=30°; φ=0°depending on the number of elements in one side of the array n.**

## 3. Conclusions

Using a dielectric layer, it is possible to reduce the absolute value of the reflection coefficient |R| only in a certain sector of scanning angles.

Using metal horns, it is possible to significantly reduce $|R|$, as well as to expand the frequency band of antenna arrays of various types.

A waveguide phased antenna array with horns was investigated using the finite element method. The geometric dimensions of the horns have been optimized to minimize $|R|$.

The more elements on one side of a planar square array, the narrower the beam and the greater the directivity.

When changing the number of elements in the array, its radiation pattern changes significantly at different values of the scanning angle θ.

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