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Scattering Characteristics of Mirror Antennas with Discrete Reflectors

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Introduction

Analysis of mirror antennas characteristics with semi-flat reflector deals with investigation of directional and focusing properties of discretely-flat reflectors (Frenel mirror)[1,2,3,4,5] and discretely- parabolic reflectors (sectioning mirror)[6]. At the same time, investigations deal with the problem of scattering characteristics of mirror antennas particularly antennas with large electrical sizes especially as antennas with discrete reflectors(ADR).This problem appears by analyzing of scattering systems which consist of conductive spheres characterized by multistage calculation[7]. Under these circumstances it is necessary to take into consideration the diffraction phenomena, especially multiple-reflection in these systems.

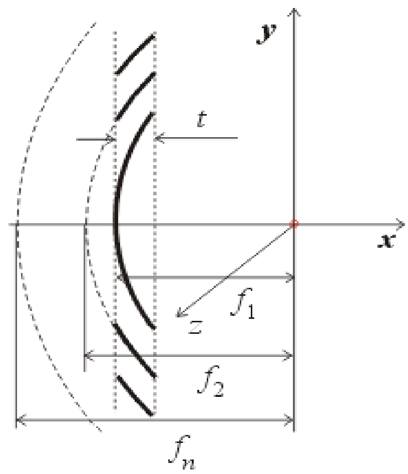
Evaluation of numerical methods depends on computer's performance which will give an opportunity to search antennas by difficult methods as the method of integral equation[8,9]. these methods can be performed by the investigation of directional and focusing properties of reflectors with discrete surfaces with size of aperture equal to 50 λ [10,11].

The purpose of this paper is to analyze the influence of geometric parameters and frequency factors on scattering characteristics of mirror antennas with discrete reflectors by comparing scattering characteristics of standard mirror antennas with parabolic antennas.

Geometry of discrete surfaces

For investigation we will use the following reflector models which having symmetrical discrete working surface, such as discretely-flat and discretely-parabolic.

In two dimensional case, the discretely parabolic surface consists of element collection conducting fine surfaces, focused as parabolic cylinder. These elements are limited by two sides by imaginary parallel planes figure1.a . Profile height such as surface *t* can be selected equally half-length of the waveform λ_0 ,or multiple of λ_0 ,so the focus of adjacent parabolic elements can be defined from the relationship $f_{n+1} = f_n + t$,which is necessary for supporting the uniform phase distribution of the field by using the surface as a reflector.



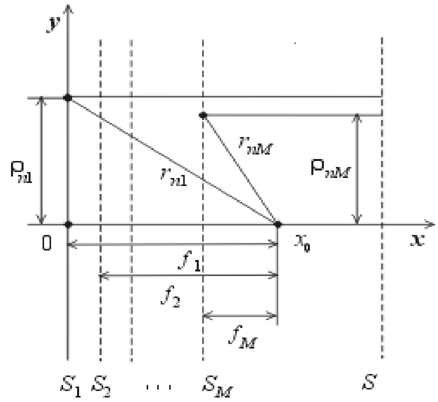


Fig. 1. geometrical constructions with digitization – surfaces

Discretely-plane surface formed by means of symmetrical discretization of some plane layers. For example, consider M parallel-planes $S_1, S_2, ..., S_m, ...S_M$, (calling them as layers) located, as seen in Fig. 1.

If we take, for instance, a point x_0 at the axis x, given by focus f_m for every layer in respect with:

$$f_{m+1} = f_m - \lambda_0 / 2M \quad . \tag{1}$$

So, the number M≥2 is a digitization parameter and $m = 1,2,3...M$ indicates the layer's number. Dividing every plane S_m by zones and number of these zones, so the distances from x_0 to the extreme points of n-zone (radios r_{nm}) belong to m-plane :

$$r_{nm} = f_m + \frac{n\lambda_0}{M} . \tag{2}$$

Radius of zones ρ_{nm} can be defined:

$$\rho_{nm} = \sqrt{\frac{2 f_m \lambda_0}{M} + \left(\frac{n\lambda_0}{M}\right)^2} , \tag{3}$$

where, n -zone number, $n = 1,2...$

If monochromatic field source is located in point x_0, condition (1) will make plane S in phase as the scattering –discrete field.

Meanwhile the difference phase of fields found in the outer points caused by this source in every zone which equal: $2\pi / M$.

Let's consider digitization parameter $M = 1$, so field phase difference at outer points of every zone will be 2π . In this case:

$$r_{(n+1)m} - r_{nm} = \lambda_0 , \tag{4}$$

so it makes a sense to call these zones as unit wave. if $M = 2$, it corresponds half-wave zones (Fresenal Zones), $M = 4$ - quarter wave and so on. We can call the zones formed by discretization parameter $M > 2$, generalized Fresenal Zones. Numbering unit wave zone by $k_m = 1,2,...$ starting with axis x . If $M > 2$, in the range of every m-layer then we can extract in phase sub ranges of generalized Fresenal Zones, q_m which is defined by :

$$q_m = (k_m - 1)M + m . \tag{5}$$

The in phase zones are fabricated as fine conductive layer which means finally to get symmetrical multi layer discrete surface[10] .

Numerical Analysis Technique

The following analysis is realized by two-dimensional model (ADR) consisting of reflector with discrete-surface and irradiator as planer waveguide, which has aperture matches with geometric focus of the reflector. The model of under study antenna has aperture size $D = 50\ \lambda_0$, focus distance $f_1 = 0{,}5D$ height profile $t = 0{,}5\ \lambda_0$, length and width irradiator waveguide $a = 1{,}5\ \lambda_0$, $b = 0{,}71\ \lambda_0$.

The geometry of discrete reflectors is calculated for mid-band frequency f_0 and for corresponding wavelength in free space λ_0. So in the analysis process, irradiator and reflector was considered as unified two-dimensional infinite fine and ideal conducting discrete surface (screen).

The orientation of this screen in Cartesian system (x, y, z), plane $z = 0$ matches with section plane and makes in this section screen profile L. Antenna model profiles with discrete parabolic and discrete plane reflectors are shown in Fig 2,a and Fig. 2,b correspondingly.

Antenna irradiates plane and monochromatic wave (E-polarization) with a direction defined by angle θ_i, while scattering field is observed at the distance zone of antenna with a direction defined by angle θ_s .

If the back scatter diagram was found, then after finding scattering field in reverse- direction, the direction of plane wave incidence will be changed and so the diffraction problem will be solved again. For the studied case, the finding of surface current-density J_z on the screen will solve first-order integral equation[8,9]:

$$\frac{\omega\mu}{4} \int_L J_z(t) K(\tau, t) dt = E_z^0(\tau) , \tag{6}$$

where $K(\tau,t) = H_0^{(2)}(kR_0(\tau,t))\sqrt{(\partial\xi(t)/\partial t)^2 + (\partial\eta(t)/\partial t)^2}$; H_0^2 – Hankel function; $E_z^0(\tau)$ – Incidence field; R_0 – distance between integration point and observation; ξ, η – local coordinates point at loop L .

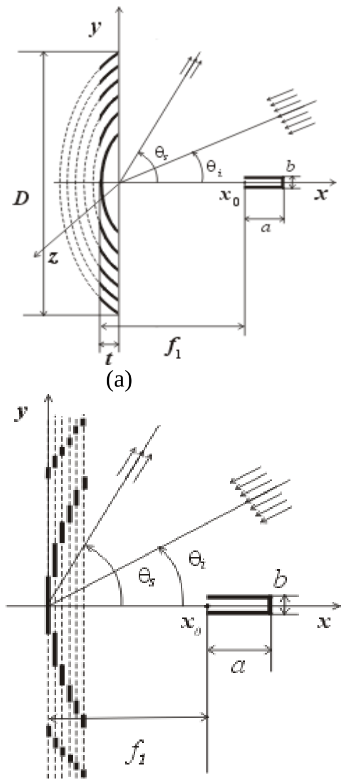


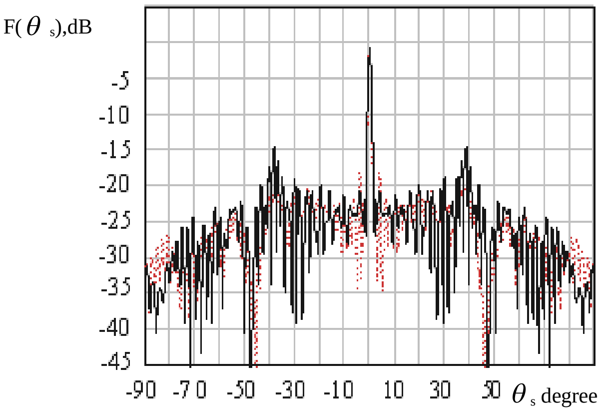
Fig.2. Geometry of antenna model with discrete- reflector

The numerical solution of equation (6) achieved by using linear algebraic equations using collocation method. by solving process the number of optimal collocation points was found, taking into consideration the permissible error of calculation on the screen with one wavelength size, which will offer relative error less than 0.1 %.the control of solution convergence and performance of boundary condition and Micsenar conditions performed within the calculation process, guarantees the precision and assurance of the solution [8,9].

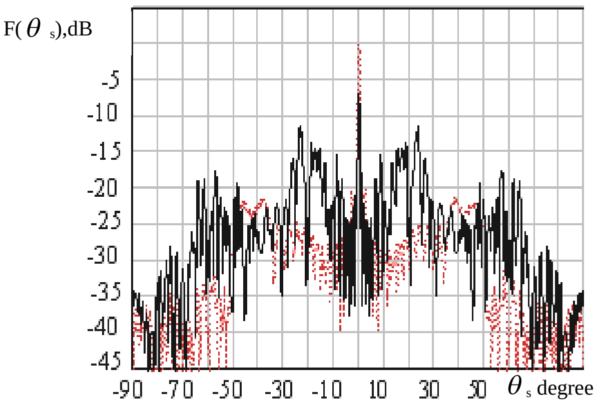
Results and Discussions

Calculated scattering diagrams results are shown in Fig. 3–6 for the frequencies f_0 and $1{,}5 f_0$. In these figures the dotted line is shown the scattering diagram of reference antenna and the parabolic reflector of the same size and the same aperture angle is shown by solid lines.

In Fig. 3,a solid lines demonstrate biostatic scatter diagram ($\theta_i = 0, -90^\circ \le \theta_s \le 90^\circ$), calculated at frequency f_0 for antenna with discrete-parabolic reflector. and a similar diagram ,which was calculated at frequency equal to $1{,}5 f_0$ is demonstrated in Fig. 3,b .



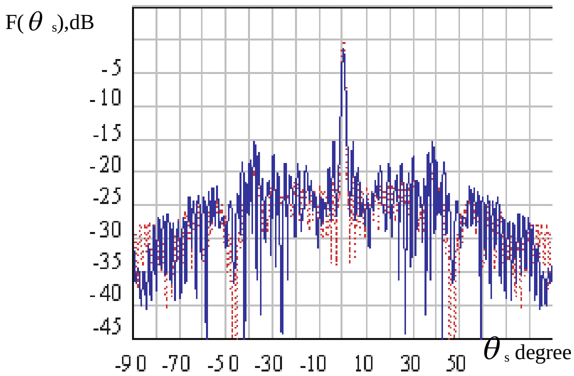
(a)



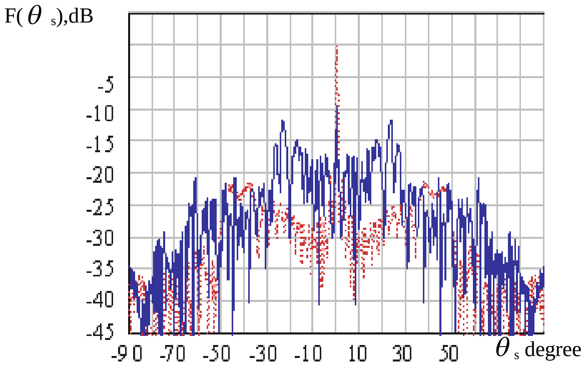
(b)

Fig. 3. Scattering diagram of discretely-parabolic antenna

The level of ADR is in the range $30^\circ \le |\theta_s| \le 70^\circ$ is little more than in the range of $75^\circ \le |\theta_s| \le 90^\circ$, and this result is characteristically for all semi–plane reflectors .and at the same time (Fig. 3,b). by the frequency $1{,}5 f_0$, the main lobe is in 7 dB less , and the coma lobs are increasing in the range $|\theta| \approx 20^\circ$ and $|\theta| \approx 60^\circ$. The same situation is observed in Fig. 4,a and Fig. 4,b [10,11] .



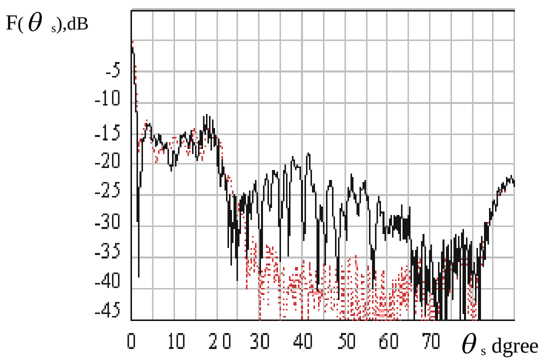
(a)



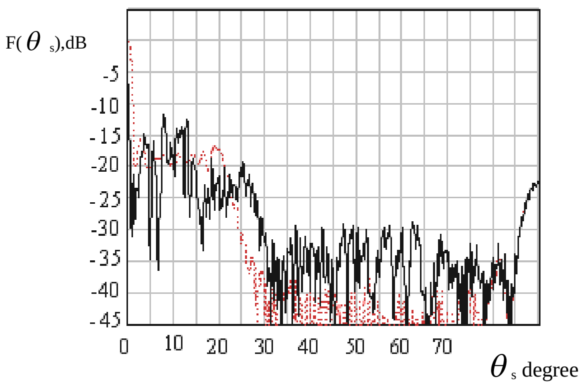
(b)

Fig. 4. Scattering diagram of discretely- plane antenna

Case for $\theta_s = \theta_i, 0^\circ \le \theta_s \le 90^\circ$ is shown in Fig. 5 and Fig. 6.



(a)



(b)

Fig. 5. Back-scatter diagrams with discrete parabolic antenna

As expected, the frequency variation changes the character of scattering in bands 1 and 2, so with the frequency increasing to the value of $1{,}5 f_0$, will decrease main lobe level of ADR and drop of near and remote coma – lobs.

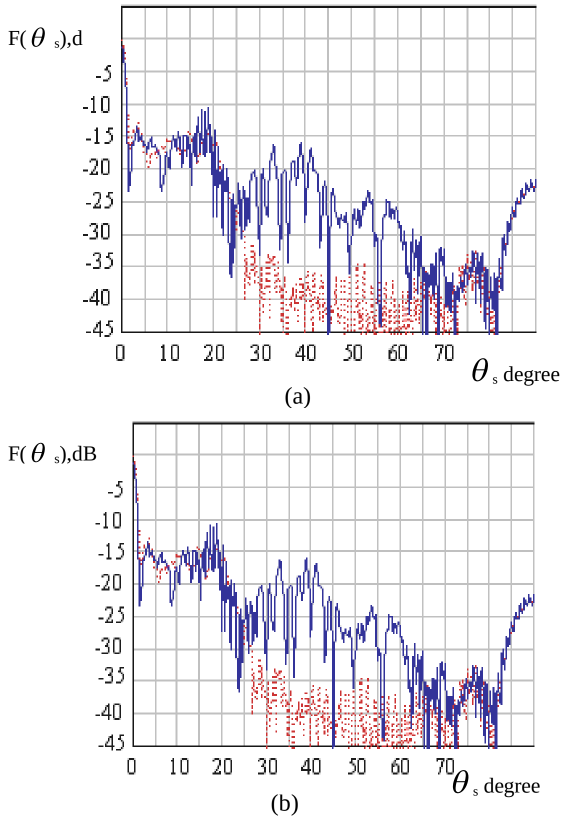


Fig. 6. Back–scatter diagram with discrete–flat antenna

Conclusions

As a result we can say that scattering characteristics of ADR, critically depend on frequency, on the other hand this relation has no place for reference antenna, therefore, out-of operating range scattering field of ADR (main lobe) is less than the same range of reference mirror antenna. But coma–lobe level scattering diagram (as directional diagram) for ADR is higher than the same level in reference antenna. It is worth taking into consideration that two-dimensional antenna model is characterized by higher level of coma-lobs for directional diagram and scattering diagram with respect to three dimensional models with circle symmetry. Also we have to take into consideration that the supply and the fastening systems of the reflector in real conditions didn't change scattering field level in the direction of the main lobe. As a conclusion, ADR has a low level reflected in the direction of the main lobe but it has an average level of coma lobs matching with reference antenna.

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Mohammed Yousef Al-Gawagzeh, Amjad Yousef Hendi. Scattering Characteristics of Mirror Antennas with Discrete Reflectors // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 7(87). – P. 89–92.

On the basis of integral equation for two dimensional models, a numerical analysis of scattering properties of mirror antennas with discrete reflectors is presented with the result of calculation of monosatatic and bistatic scatter characteristics. The influence of geometric parameters and frequency factors on scattering characteristics of mirror antennas with discrete reflectors were analyzed. Ill. 6, bibl. 11 (in English; summaries in English, Russian and Lithuanian).

Мохаммед Иоусеф. Ал-Гавагзех, Амчад Иоусеф Гхенди. Характеристики дискретных рефлекторов зеркальных антенн // Электроника и электротехника. – Каунас: Технология, 2008. – № 7(87). – С. 89–92.

Представлен дискретный анализ зеркальных антенн на основе двухмерных моделей, которые описываются интегральными уравнениями. Приводятся результаты рассчета характеристик распределения. Найдены зависимости частоты от геометрических параметров антенн. Ил. 6, библ. 11 (на английском языке, рефераты на английском, русском и литовском яз.).

Mohammed Yousef Al-Gawagzeh, Amjad Yousef Hendi. Veidrodinių antenų su diskretiniais reflektoriais sklaidos charakteristikos // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 7(87). – P. 89–92.

Remiantis dvimačių modelių integrinėmis lygtimis, atlikta veidrodinių antenų su diskretiniais reflektoriais skaitmeninė analizė ir pateikti monostatinių ir bistatinių sklaidos charakteristikų skaičiavimo rezultatai. Analizuota geometrinių parametrų ir dažnio įtaka veidrodinių antenų su diskretiniais reflektoriais sklaidos charakteristikoms. Il. 6, bibl. 11 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).