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Directional characteristics of an ultrawideband offset reflector antenna in the scanning mode with a pattern in the 0.5–2.5 GHz frequency range

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Abstract. The possibility of scanning the radiation pattern of an ultrawideband offset reflector antenna in the frequency range 0.5–2.5 GHz has been studied. A combined antenna optimized for excitation by a bipolar pulse with a duration of 1 ns was used as a reflector antenna feed. Scanning is carried out by moving the feed antenna from the reflector focus horizontally and vertically. Based on the results of numerical modeling, the scanning angles and deviations of the feed antenna in the studied frequency range were determined.
Keywords: offset reflector antenna, combined antenna, scanning.

1. Introduction

Ultrawideband (UWB) radiation sources based on reflector antennas are being developed for radar with high spatial resolution and for studying the susceptibility of objects to the effects of strong electromagnetic fields. To ensure high peak field strength at a given distance, powerful UWB radiation sources are being developed [1, 2]. It is preferable to use a combined antenna as a feed for an offset reflector antenna [3]. Previously, a powerful source of ultrawideband radiation was developed using the reflector antenna under study [4]. The combined antenna KA was located near the focal point of the offset reflector. When the combined antenna was excited by a bipolar voltage pulse with an amplitude of 100 kV and a duration of 1 ns at a repetition rate of 200 Hz, pulses of linearly polarized radiation with a peak electric field strength of 10^5 kV/m were obtained at a distance of 5 m. The product of peak electric field strength and distance exceeded 500 kV.

To control the directional characteristics of an offset reflector antenna, an antenna array [5] or a single antenna moved near the focus of the reflector can be used as a feed. In this work, it is proposed to use a single combined antenna, optimized for excitation by a bipolar pulse with a duration of 1 ns, as a feed source. Based on the matching band of such an antenna, it is proposed to numerically study, using the CST Microwave Studio code, the possibility of scanning a reflector antenna at frequencies in the range 0.5–2.5 GHz.

2. Offset reflector antenna model

The appearance of the reflector antenna model and options for moving the feed antenna are shown in Fig. 1. A cutout from a paraboloid with a diameter of 1400 mm was used as an offset reflector. The focal length is 700 mm. Near the focal point of the reflector antenna there is a feed – a combined antenna designed for excitation by a bipolar pulse with a duration of 1 ns. The transverse dimensions of the combined antenna are 150×150 mm with a length of 190 mm. Scanning with a radiation pattern in the *H*-plane is carried out by moving the feed from the focal point along the *y*-axis, in the *E*-plane — along the *x*-axis. The optimal tilt angle of 45° was selected for the axis of the combined antenna to the reflector antenna when excited at a frequency of 1 GHz. The frequency of 1 GHz corresponds to the maximum in the spectrum of a bipolar pulse with a duration of 1 ns. At this tilt angle, the maximum intensity of the radiated field in the far zone is achieved in the variant of placing the partial phase center of the combined antenna in the focal point of the reflector. During scanning, the tilt angle of the feed does not change.

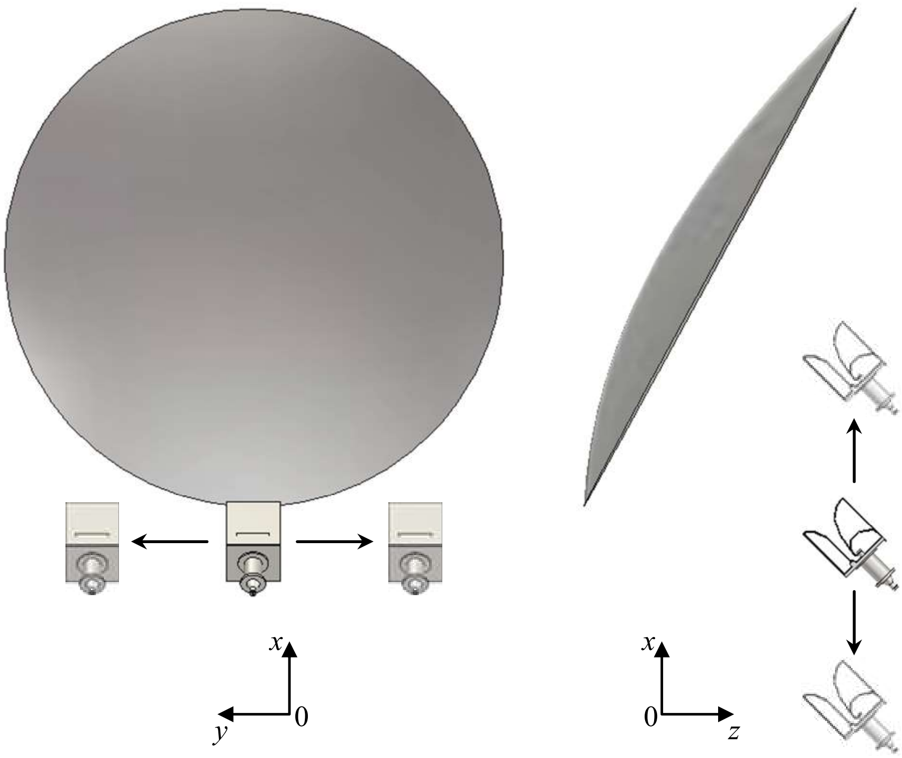

Fig. 1. Offset reflector antenna model.

The dependences of the voltage standing wave ratio (VSWR) on the frequency of an isolated combined antenna and a combined antenna with a reflector are shown in Fig. 2. The matching band of an isolated combined antenna for VSWR ≤ 2 level occupies the frequency range 0.4–2.45 GHz. When the feed antenna is located at the focus of the reflector antenna, the matching band shifts towards higher frequencies and occupies the range 0.46–2.5 GHz. Based on the matching band, we will consider the directional characteristics of the reflector antenna in the frequency range 0.5–2.5 GHz.

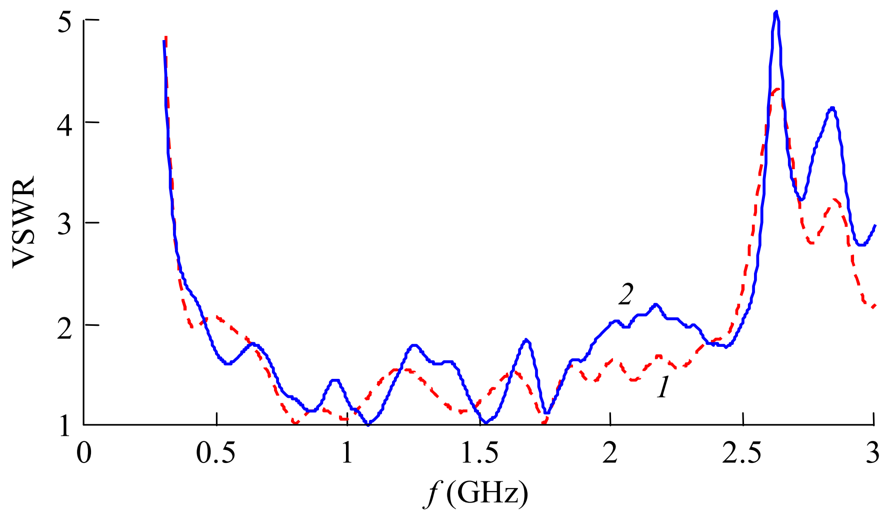

Fig. 2. Dependences of VSWR on frequency. *1* — isolated combined antenna; *2* — combined antenna with reflector.

Radiation patterns of the combined antenna in the *H*- and *E*-planes at frequencies 0.5, 1, 1.5 and 2.5 GHz are shown in Fig. 3. In the *H*-plane, the patterns are symmetrical. With increasing frequency, the width of the pattern decreases to 58° at a frequency of 2.5 GHz. At a frequency of 1 GHz, the beamwidth is 92°. Cross-polarization is observed in the *H*-plane. At a frequency of 1 GHz, the amplitude of the cross-polarized field component is 0.14 relative to the amplitude. In the *E*-plane, the radiation patterns are asymmetrical. With increasing frequency, the width of the pattern decreases from 152° to 66° for frequencies 0.5–2.5 GHz. At a frequency of 1 GHz, the width of the radiation pattern is 84° and the maximum of the pattern directed at an angle of 9°. The level of cross-polarization in the *E*-plane is negligible.

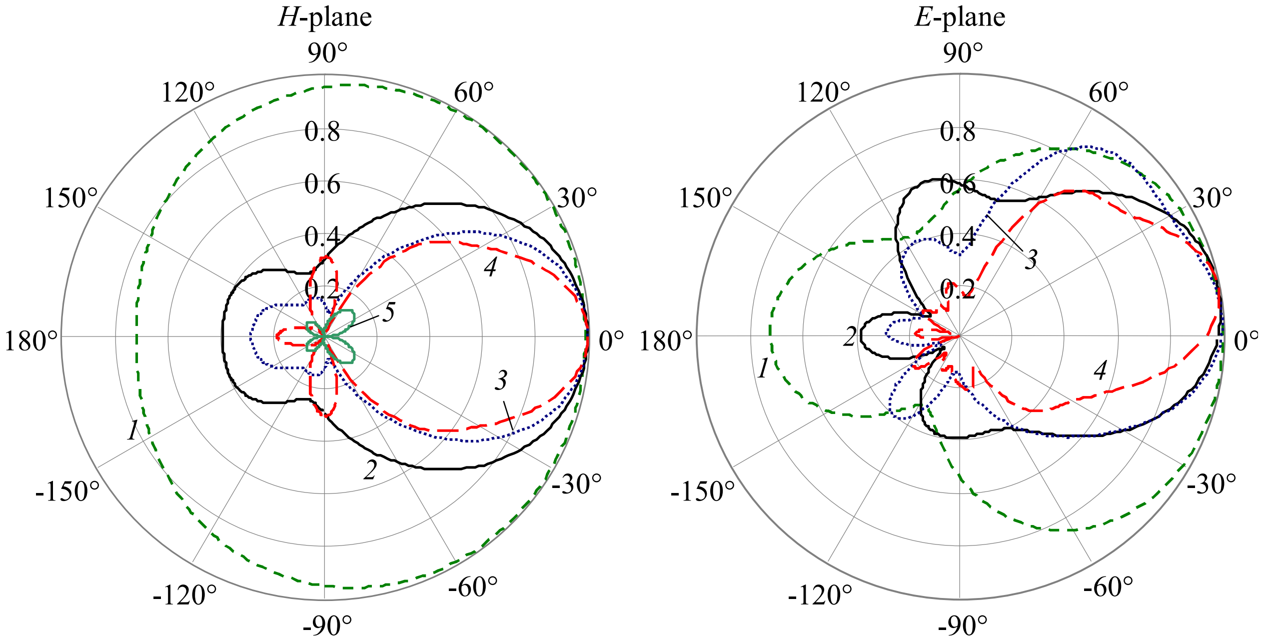

Fig. 3. Radiation patterns of the combined antenna in the *H*- and *E*-planes. *1* — 0.5 GHz; *2* — 1 GHz; *3* — 1.5 GHz; *4* — 2.5 GHz; *5* — cross-polarization in the *H*-plane at a frequency of 1 GHz.

2. Directional characteristics of offset reflector antenna

2.1. H-plane

The possibility of scanning the radiation pattern of a reflector antenna in the *H*-plane has been studied. Figure 4 shows the radiation patterns in scanning mode at a frequency of 1.25 GHz. When scanning, the radiation patterns are symmetrical relative to the vertical axis of the reflector antenna. The maximum scanning angle is determined by the level of 0.707 relative to the amplitude. At a frequency of 1.25 GHz, the maximum scanning angle is ±21° with the feed antenna shifted by ±410 mm. Patterns of the cross-polarized field component of the reflector antenna at a frequency of 1.25 GHz are shown in Fig. 5. When the feed antenna is displaced from the focus of the reflector antenna, the amplitude of the cross-polarized field component changes slightly and reaches a level of 0.24 relative to the amplitude within the scanning angles.

The dependences of the feed antenna deviation and scanning angle on frequency are shown in Fig. 6. The maximum scanning angle of ±23° is achieved at a frequency of 1 GHz with a feed antenna deviation of ±450 mm. As the frequency increases, the scanning angle decreases and at a frequency of 2.5 GHz is ±14° with a feed antenna deviation of ±260 mm. Figure 7 shows the dependences of the amplitude of the cross-polarized field component on frequency when the feed antenna is placed at the focus of the reflector antenna (curve *1*) and when the feed antenna is shifted corresponding to scanning angles along the main polarization (curve *2*). The curves differ slightly. The maximum value of the cross-polarization amplitude is 0.31 relative to the amplitude along the main polarization and is achieved at a frequency of 2 GHz.

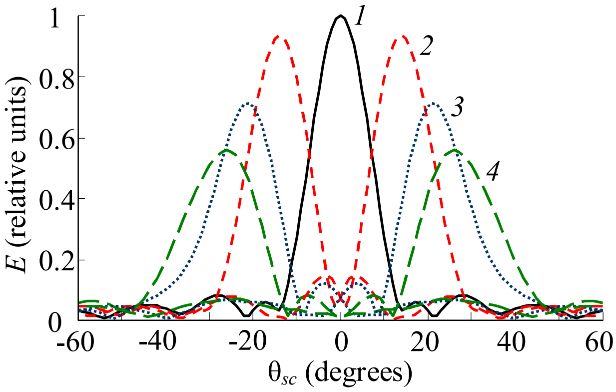

Fig. 4. Patterns of the reflector antenna in the *H*-plane at a frequency of 1.25 GHz with feed antenna deviations: *1* — 0 mm; *2* — ±250 mm; *3* — ±410 mm; *4* — ±500 mm.

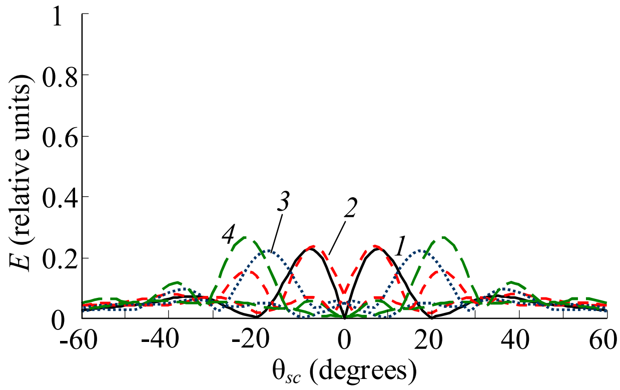

Fig. 5. Patterns of the cross-polarized field component of the reflector antenna in the *H*-plane at a frequency of 1.25 GHz with feed antenna deviations: *1* — 0 mm; *2* — ±250 mm; *3* — ±410 mm; *4* — ±500 mm.

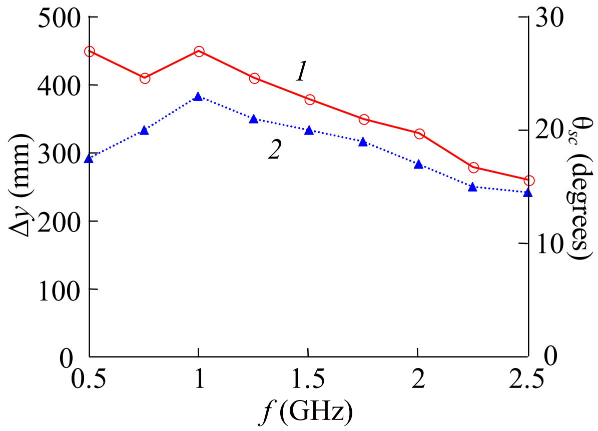

Fig. 6. Dependences of the deviation of the feed antenna (*1*) and the scanning angle (*2*) on the frequency in the *H*-plane.

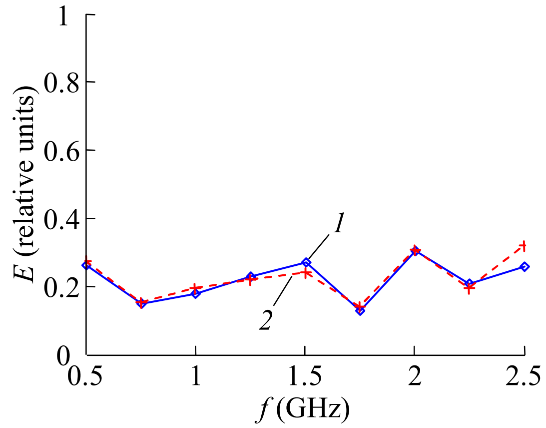

Fig. 7. Dependences of the amplitude of the cross-polarized field component on frequency when the feed antenna is placed at the focus of the reflector antenna (*1*) and at the maximum scanning angles (*2*).

2.2. E-plane

The possibility of scanning the radiation pattern of a reflector antenna in the *E*-plane has been studied. Patterns in the *E*-plane are asymmetrical in the *x*0*z* plane, since the geometries of the reflector and combined antennas are asymmetrical in this plane. The level of cross-polarization in the *E*-plane is negligible. The radiation patterns of the reflector antenna in the *E*-plane at frequencies of 0.5 GHz, 0.75 GHz and 1.25 GHz are shown in Fig. 8. When the feed antenna is deviated upward along the *x*-axis, the maximum of the radiation pattern shifts to the region of negative angles. When deviated downward, it shifts to positive angles. At frequencies of 0.5 and 0.75 GHz, when the feed antenna is deviated upward from the initial position at the focus of the reflector antenna (curve *2*), the amplitude first increases (curve *3*), then decreases (curve *4*). With further deviation of the feed antenna, the field amplitude increases again (curve *5*), then decreases (curve *6*). Thus, the possibility of double scanning appears, since when the feed antenna is deviated, two radiation patterns with maximum field amplitudes are observed. When the feed antenna is deviated downward from its initial position at the focus of the reflector antenna (curve *2*), a decrease in the field amplitude is observed (curve *1*). At frequencies from 1 GHz and higher, when the feed antenna is deviated upward, an increase in amplitude is first observed. With further deviation, the amplitude decreases until the radiation pattern falls apart. When the feed antenna is deviated downward, the field amplitude decreases over the entire frequency range. The width of the radiation pattern has a minimum value when the feed antenna is placed at the focus of the reflector antenna. At a frequency of 1.25 GHz, the width is 10°. When the feed antenna is deviated downwards, the width of the radiation pattern increases and at a frequency of 1.25 GHz at the scanning angle it is 14.7°. When the feed antenna is deviated upward, the width of the radiation pattern also increases and at a frequency of 1.25 GHz the scanning angle is 26°. This changes in the radiation pattern width is valid throughout the entire frequency range 0.5–2.5 GHz.

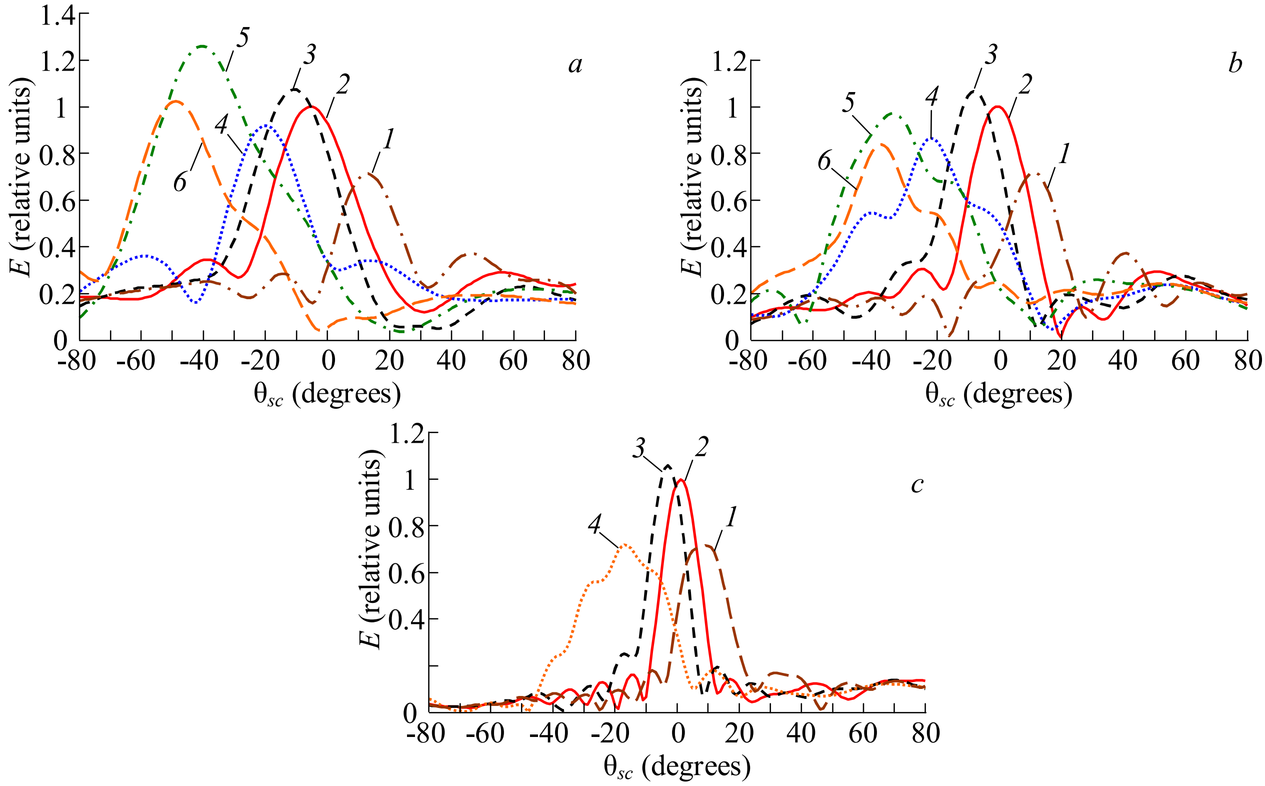

Fig. 8. Radiation patterns of the reflector antenna in the E-plane at frequencies 0.5 GHz (*a*), 0.75 GHz (*b*) and 1.25 GHz (*c*) with feed antenna deviations at a frequency of 0.5 GHz: *1* — −430 mm; *2* — 0 mm; *3* — 150 mm; *4* — 400 mm; *5* — 750 mm; *6* — 900 mm; 0.75 GHz: *1* — −300 mm; *2* — 0 mm; *3* — 150 mm; *4* — 450 mm; *5* — 600 mm; *6* — 700 mm; 1.25 GHz: *1* — −230 mm; *2* — 0 mm; *3* — 100 mm; *4* — 400 mm.

The dependences of the deviation of the feed antenna and the scanning angle on frequency in the E-plane when the feed antenna is shifted down along the x-axis are shown in Fig. 9. The maximum scanning angle of 13° is achieved at frequencies of 0.5, 0.75 and 1 GHz with feed antenna deviations of −430, −320, −320 mm, respectively. With increasing frequency, the scanning angle decreases and, starting from a frequency of 1.5 GHz, practically does not change and amounts to 8–9 degrees. Figure 10 shows the dependences of the deviation of the feed antenna and the scanning angle on frequency in the E-plane when the feed antenna is shifted upward along the x-axis. The graph does not show frequencies below 1 GHz, since at frequencies of 0.5 and 0.75 GHz the scanning criterion is not applicable in the generally known formulation. The maximum scanning angle of −21° is achieved at a frequency of 1 GHz with a deviation of the feed antenna of 525 mm. With increasing frequency, the scanning angle decreases and, starting from a frequency of 1.5 GHz, practically does not change and ranges from −10° to −8°.

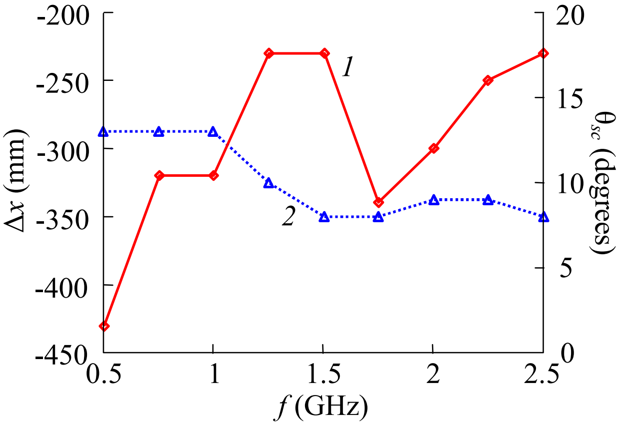

Fig. 9. Dependences of the deviation of the feed antenna (*1*) and the scanning angle (*2*) on frequency in the *E*-plane when the feed antenna is shifted down along the *x*-axis.

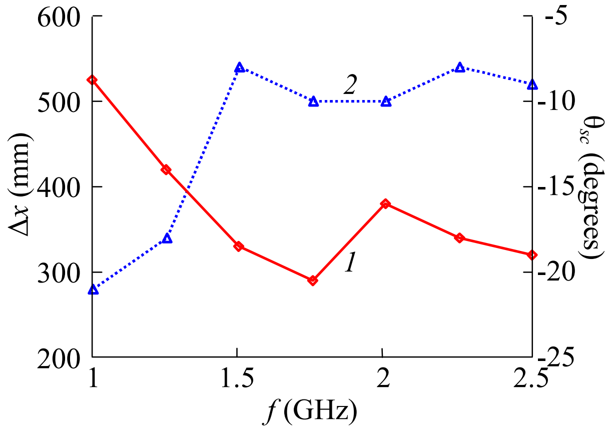

Fig. 10. Dependences of the deviation of the feed antenna (*1*) and the scanning angle (*2*) on frequency in the *E*-plane when the feed antenna is shifted upward along the *x*-axis.

3. Conclusion

A numerical model of an offset reflector antenna with a feed of a combined antenna has been created. The possibilities of scanning with the radiation pattern of a reflector antenna in the frequency range 0.5–2.5 GHz have been studied. The scanning angles and the corresponding deviations of the feed antenna in the *H*- and *E*-planes were found. In the *H*-plane, the maximum scanning angle of ±23° is achieved at a frequency of 1 GHz with a deviation of the feed antenna of ±450 mm. In the *E*-plane, a scanning angle of 13° is achieved at frequencies of 0.5, 0.75 and 1 GHz with feed antenna deviations of −430, −320, −320 mm, respectively, and a scanning angle of −21° is achieved at a frequency of 1 GHz with a feed antenna deviation of 525 mm.

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4. References

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