Russian Physics Journal, Vol. 55, No. 8, January, 2013 (Russian Original No. 8, August, 2012)

NAVIGATION CHARACTERISTICS OF THE SLOT STRIP LEAKY-WAVE ANTENNA

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UDC 621.396.6

Dependences of the technical characteristics of the slot strip leaky-wave antenna on the elevation and azimuth angles of the received navigation signal are investigated. It is demonstrated that the application of additional slots with small electric length located between the main slot transmitters and shaped as concentric arcs around the antenna phase center improves the axial ratio and suppresses the cross-polarization in the range of working angles of the antenna. The antenna is intended for receiving navigation signals from GLONASS/GPS global navigation satellite systems in three frequency ranges L1/L2/L3.

Keywords: slot strip antenna, GLONASS/GPS, frequency ranges $L1/L2/L3$.

INTRODUCTION

For metrological applications of GLONASS/GPS global navigation satellite systems (GNSS), more rigid requirements are imposed on the main technical characteristics of the receiving antenna, including angle of receiving navigation signal with right-handed polarization, gain, stability of the phase center, axial ratio, level of cross polarization, and suppression of the back lobe.

The GNSS receiving antenna that meets most completely the above-enumerated requirements is well known [1]. To suppress the multibeam radiation pattern, a choked ring antenna is used. However, such an antenna is bulky, heavy-weight, and expensive.

Microstrip spiral antennas [2] have wide bandwidths and wide radiation patterns. However, the phase characteristic of such antennas in the azimuth plane is nonuniform. This introduces phase distortions depending on the direction of the navigation signal received.

Microstrip antennas based on two transmitters (square, round, ring, etc.) [3] have the stable phase center and wide radiation pattern. However, such antennas have narrow radiation bandwidth.

To receive GLONASS/GPS GNSS navigation signals in $L1/L2/L3$ frequency ranges, slot strip leaky-wave antennas are widely used [4]. Among their apparent advantages are wide bandwidth, wide radiation pattern, common phase center for frequency ranges $L1/L2/L3$, small overall dimensions and weight, and print circuit technology.

In [5] it was suggested to use additional slots with the electric length several times smaller than the half wavelength at the highest operating frequency of the antenna to improve the technical characteristics of the slot strip leaky-wave antenna. Frequency dependences of the antenna technical characteristics were studied. It was demonstrated that the application of additional slots shaped as arcs around the geometrical antenna center and located between the main slot transmitters smoothes the frequency dependence of the antenna gain, improves the axial ratio, and increases the suppression of cross-polarization in the entire working frequency range of the antenna.

In the present work, the influence of additional slots on the technical characteristics of the slot strip leaky-wave antenna is investigated depending on the elevation angle Θ and azimuth angle φ of the received navigation signal.

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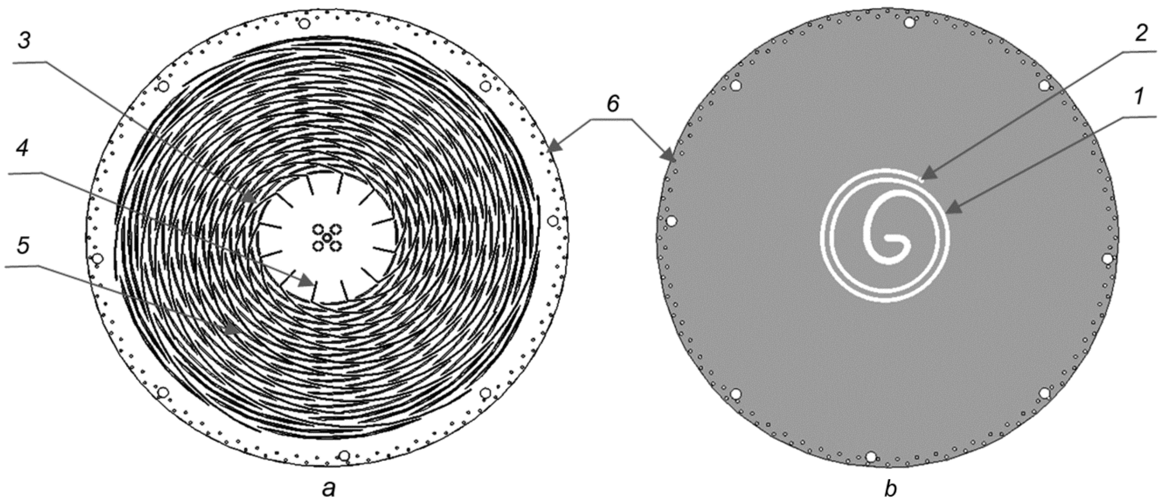

Fig. 1. Upper (*a*) and lower (*b*) sides of the antenna transmitter.

TRANSMITTER OF THE SLOT STRIP ANTENNA

Figure 1 shows the topology of the transmitter developed for the slot strip leaky-wave antenna. The transmitter is manufactured using the circuit board 1.524 mm thick with dielectric permittivity $\varepsilon = 3.3$ and dual-sided metallization. The transmitter diameter is 145 mm. At one transmitter side, the feeding microstrip line (MSL) *1* is located. To establish the leaky-wave regime, the MSL is loaded with active resistance *2* equal to the wave impedance of the line. Main slot transmitters *3* are located on the other metallized side of the transmitter. To receive signals with right-handed polarization, the main slot transmitters are performed as spiral sections twisted around the geometrical center of the antenna. Resonant frequencies of the main slot transmitters were tuned alternately for frequency ranges *L*1 and *L*2 + *L*3. For better adjustment to the feeding line, the slot transmitters in the area of connection with MSL *4* are linear. Additional slots with electric length several times smaller than the half wavelength at the highest operating frequency of antenna *5* are fabricated. Additional slots are performed as concentric arcs around the phase centre of the antenna coinciding with its geometrical centre.

To suppress the surface waves, two series of metallized apertures *6* are made along the antenna edge. The distance between the apertures is smaller than one tenth of the wavelength at the highest operating frequency of the antenna.

RESULTS AND DISCUSSION

Figure 2 shows the measured standing-wave voltage ratio (SWVR) of the antenna without (small squares) and with additional slots with smaller electric length (circles). From the figure it can be seen that the character of SWVR frequency dependences for both antennas in *L*1/*L*2/*L*3 frequency ranges is identical. The measured SWVR values do not exceed 1.5. Hence, introducing additional slots with smaller electric length into the antenna transmitter does not influence the adjustment of the main slot transmitters of the antenna to the feeding MSL in frequency ranges *L*1/*L*2/*L*3.

Figure 3 shows the angular dependences of the gain *G* of the antenna calculated without (the dashed curve) and with additional slots (the solid curve) in the vertical plane at the main carrier frequency of the GLONASS navigation signal in the *L*2 range (1246 MHz). It can be seen that the character of their angular dependences and the absolute gain values of the radiation patterns almost coincide.

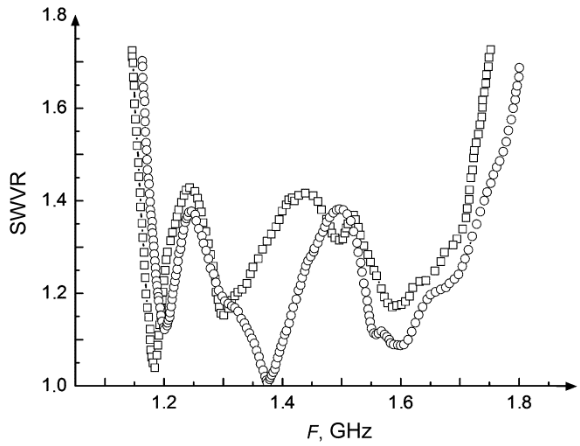

Fig. 2. SWVR of the antennas.

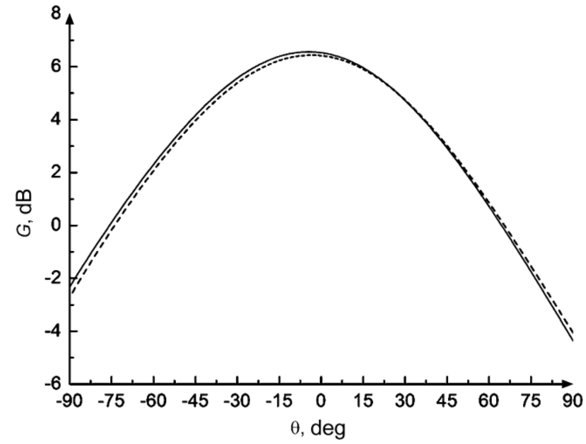

Fig. 3. Antenna radiation patterns in the vertical plane.

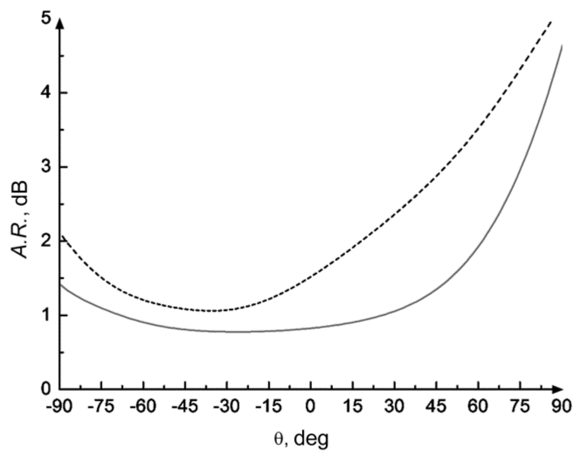

Fig. 4. Axial ratio of the antennas.

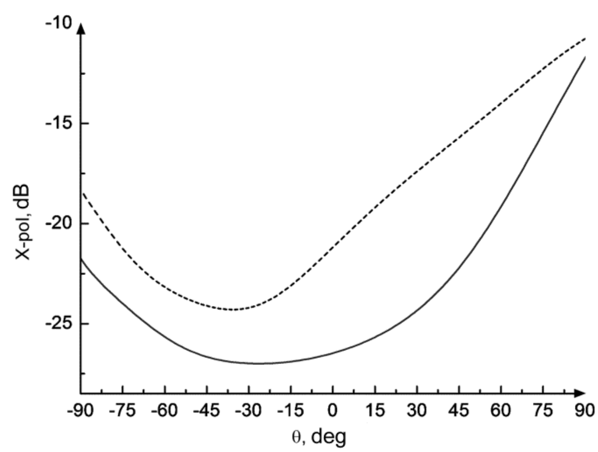

Fig. 5. Antenna cross-polarization.

Figures 4 and 5 show the calculated angular dependences of the axial ratio (*A.R.*) and cross-polarization (X-pol) levels of the antennas at a frequency of 1246 MHz. The dashed curve here is for the antenna without additional slots, and the solid curve is for the antenna with additional slots. From the figures it can be seen that introducing additional slots improves the axial ratio (Fig. 4) and increases the suppression of cross-polarization (Fig. 5). In addition, the angular dependences of the axial ratio factor and cross-polarization become more uniform near the zenith direction of the antenna radiation pattern.

Figure 6 shows the calculated phase patterns of the antennas, where Fig. 6*a* shows the dependence of the signal phase (ψ) on the elevation angle Θ and azimuth angle φ at a frequency of 1246 MHz for the antenna with additional slots, and Fig. 6*b*, *c*, and *d* compares the phase patterns of the antennas without (crosses) and with additional slots (closed circles) at the central frequencies in *L*1, *L*2, and *L*3 ranges for angles $\Theta = \pm 85°$ and $\varphi = \pm 180°$, where $\Theta = 0$ is the zenith angle of the antenna radiation pattern. From Fig. 6 it can be seen that the nonuniformity of the phase pattern of the antennas with additional slots is similar to that of the phase pattern of the antenna without additional slots in *L*1 and is smaller in *L*2 and *L*3.

To elucidate reasons for improving technical characteristics of the slot strip leaky-wave antenna, we now consider the influence of additional slots on the distribution of ultrahigh frequency current over the main slot transmitters.

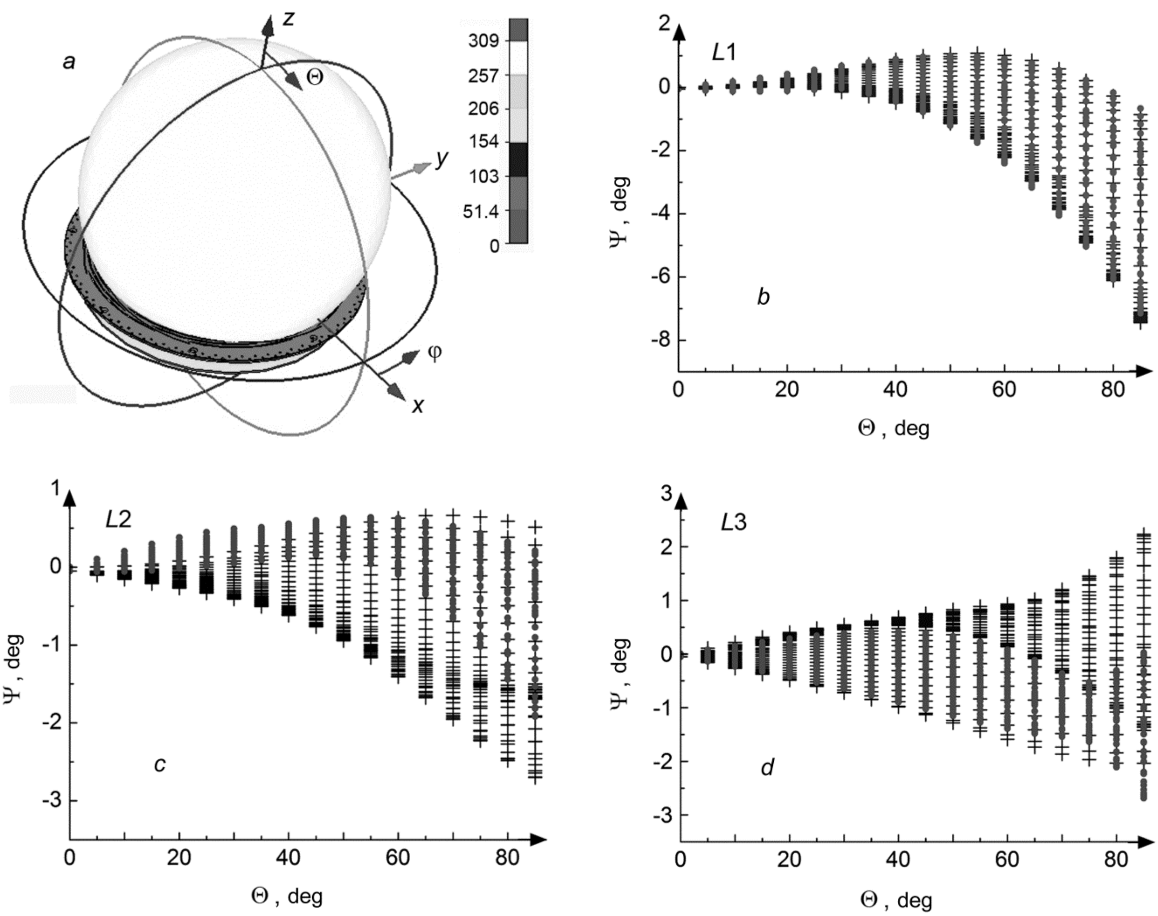

Fig. 6. Phase patterns of the antennas.

Figure 7 shows a part of the antenna with the current distribution over its surface. The antenna without additional slots is shown in Fig. 7*a* and the antenna with additional slots is shown in Fig. 7*b*. From the figure it can be seen that the additional slots performed as concentric arcs around the phase center of the antenna allow the current lines to be more uniformly distributed over the main slot transmitters, improving the technical characteristics of the antenna.

CONCLUSIONS

Thus, the dependences of the technical characteristics of the slot strip leaky-wave antenna with right-handed polarization on the elevation and azimuth angles of the received navigation signal have been investigated in the present work. It has been demonstrated that introducing additional slots with small electric length between the main slot transmitters performed as concentric arcs around the phase center of the antenna improves the axial ratio and suppresses the cross-polarization in the range of working angles of the antenna. The angular dependences of the antenna technical characteristics are improved due to additional slots. The current antinodes are more uniformly distributed over the length of the main slot transmitters of the antenna.

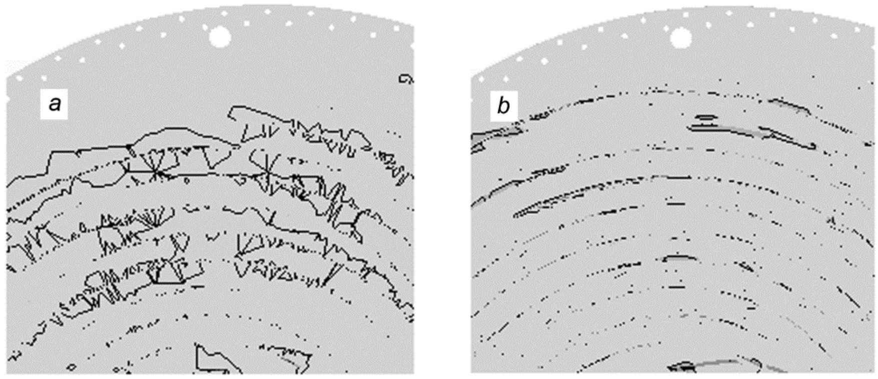

Fig. 7. A part of the antenna with distribution of the ultrahigh frequency current over the main slot transmitters.

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