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Influence of the frequency of satellite signals on the depth of spoofing suppression in Global Navigation Satellite Systems

An influence of GNSS frequency on the depth of spoofing suppression was studied. The method of suppressing spoofing from four directions while using different frequencies is illustrated.

Spoofing suppression algorithm

The signals of navigation satellites are easily affected by spoofing interference, causing the wrong position, speed or time of the receiver calculation. An adaptive spoofing suppression method was investigated in [1]. It was shown that the use of small-sized antenna arrays in navigation systems consisting of satellite constellations or their combinations makes it possible to detect and suppress interfering signals by forming zeros of the antenna array directional pattern in the directions of their arrival [2]. The GNSS satellites continuously transmit navigation signals in two or more frequencies in L band. These signals contain ranging codes and navigation data which allow the users to compute the travelling time from satellite to receiver and the satellite coordinates. Let`s consider how the frequency of the satellite signal is related to the depth of suppression of radio interference. The directions of arrival of radio interference are chosen in the four quadrants of the upper hemisphere. The fixed value of weighting coefficients was chosen:

$$x0 = 1.137890924686325 - 0.000000000000000i;$$
$$x1= -0.579859913779087 + 0.051103290780182i;$$
$$x2=-0.270227485764871 + 0.042442469283546i;$$
$$x3= -0.579859913779087 - 0.051103290780182i;$$
$$x4= -0.270227485764871 - 0.042442469283546i;$$

We set the wavelength at the average frequency for the lowest GPS frequency L5 = 1176.45 MHz, lambda = 25.5. We get the following results:

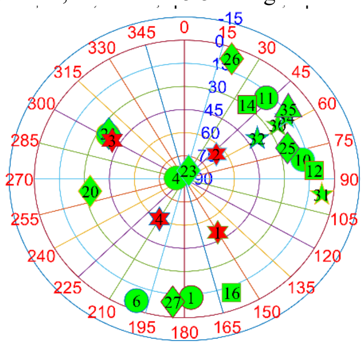

Fig. 1. Visible satellites in the coordinates of the navigation receiver (frequency = 1176.45 MHz)

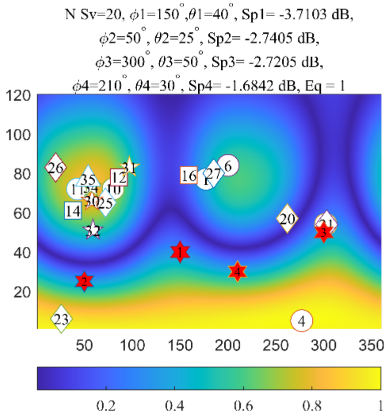

Fig. 2. Radiation pattern is in Cartesian coordinate system (frequency = 1176.45 MHz)

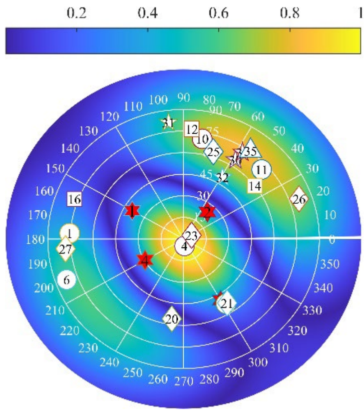

Fig. 3. Radiation pattern in polar coordinate system (frequency = 1176.45 MHz)

In figures above N_Sv – the number of satellites remaining after applying the spoofing suppression procedure; φ and θ are azimuth and elevation angles of the spoofers respectively; Sp1,..,Sp4 – calculated values of the spoofing suppression depth. Concentric circles in polar coordinates correspond to an angle of arrival of spoofing. The positions of the interference sources are indicated by octagonal stars.

The results show us that the suppression is breaking. The depth of interference suppression Sp1, Sp2, Sp3, Sp4 is approximately 3 dB. Which is insufficient.

Therefore, we will try to determine, slowly retreating from the central frequency, in what range of wavelengths the suppression will be maintained. For example, up to -60 dB. We change lambda = 18.987 cm, which corresponds to a frequency of 1580 MHz:

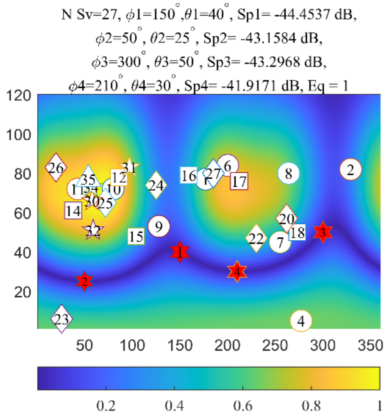

Fig. 4. Radiation pattern is in Cartesian coordinate system (frequency = 1580 MHz)

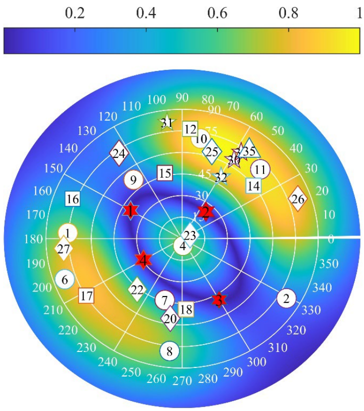

Fig. 5. Radiation pattern in polar coordinate system (frequency = 1580 MHz)

Results show that at a frequency of 1580 MHz, the spoofing suppression depth is approximately 43 dB

Also, this method was used for a frequency of 1570 MHz, which corresponds to a wavelength of lambda = 19.108 cm:

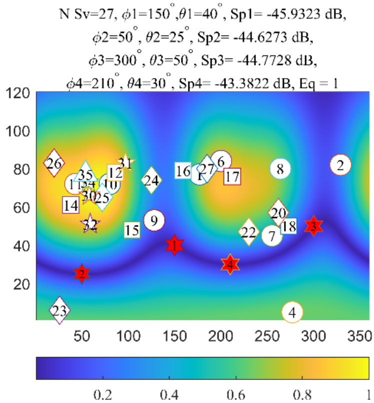

Fig. 6. Radiation pattern is in Cartesian coordinate system (frequency = 1570 MHz)

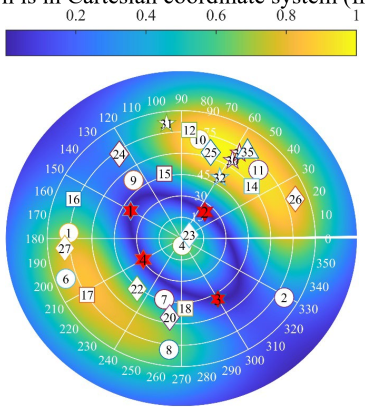

Fig. 7. Radiation pattern in polar coordinate system (frequency = 1570 MHz)

Figures above show that at a frequency of 1570 MHz the spoofing suppression depth is 45 dB. The findings from the research suggest, that suppression of more than -40 dB can be obtained in the 1570 – 1580 MHz band. For a more detailed study of the depth of suppression of spoofing in further studies, it is also possible to consider frequency for different directions of spoofing arrival and the weighting coefficient.

References

1. Konin, V., Averyanova, Y. & Ishchenko, O. Antenna Array Application to Support Operation of GNSS Receivers under Interfering Signals. *Radioelectron. Commun. Syst.* **66**, 305–314 (2023). https://doi.org/10.3103/S0735272723100023

2. *V. Konin, Y. Averyanova and O. Ishchenko*, "Virtual Radiation Pattern of a Digital Antenna Array for Satellite Navigation", Proc. 2023 IEEE Sixth International Conference on Information and Telecommunication Technologies and Radio Electronics (UkrMiCo), Ukraine, 2023, doi:10.1109/UkrMiCo61577.2023.10380401