Narrow beamwidth antenna for DTH satellite television

Peter Z. Petkov, Boncho G. Bonev

The exponential growth of channel number and services transmitted lead to exhaustion of existing satellite orbital positions, and traced the path for new regulations in an industry last regulated in the mid of 20-th century. Recent developments in DTH satellite television, particularly HDTV and SHDTV put a high requirements to the whole receive subsystem. One of the most problematic issues is the adjacent satellite interference in DTH receive systems. Due to fact that user terminals are relatively small in size, the antenna receives signals along with the primary satellite, at least from one or two neighbors in addition, which leads to decreased Eb/No and may totally disrupt the service in adverse weather conditions. In this paper a new, shaped, narrow beamwidth offset antenna for DTH satellite television is developed and proposed. Radiation pattern and antenna gain for three different frequencies are simulated, experimentally estimated, and compared with these of conventional offset antenna with the approximately same size.

Антена със стеснена диаграма на насочено действие за спътникова телевизия (Петър Ж. Петков, Бончо Г. Бонев). *Експоненциалният ръст на каналите и услугите предлагани от сателит (спътник) доведе до изчерпване на наличните орбитални позиции и стана причина за началото на нови регулации в индустрия, в която не бяха правени промени през последните 40 години. Последните нововъведения в сателитната телевизия за домашно ползване - висока и свръхвисока разрешаваща способност поставят високи изисквания към цялата приемна подсистема. Един от най-големите проблеми са смущенията по съседен сателит в приемната част. Заради относително малкият размер на приемната антена, едновременно се приемат сигналите от основния и съседни сателити, което води до понижаване на отношението Eb/No и може напълно да преустанови услугата в случаи на влошаване на времето. За потискане на тези смущения, в настоящата статия е предложена модифицирана антена с елиптична апертура. Симулирани и измерени са ДНД и сравнени с такива на обикновена, серийно произвеждана антена с идентичен геометричен размер.*

Introduction

The rapid development of information technologies and in particular satellite communications requires the transmission of increasing amounts of information. This poses a number of challenges for satellite communications technologies, using geostationary orbit. Decision may be sought on the one hand with the use of higher frequency bands and on the other by reducing the distance between satellites in geostationary orbit and increasing their number. The latter approach, however, is also connected to another problem - interference from adjacent satellites. The downlink protection criteria in the Plan for GSO BSS systems with national coverage based on a completely digital technology for television programs transmissions for Regions 1 and 3 countries (Europe, Africa, Asia and Australia) adopted by the World Radiocommunication Conference 2000 (WRC-2000) are based on the 60 cm reference antenna radiation pattern for the BSS receiving earth stations. It is taken from ITU-R Recommendation BO.1213 with a half power beamwidth of 2.86° and included in Annex 5 of RR Appendix 30 [1]. One of possible ways to avoid this interference is to use antennas with a narrow main beam in the azimuthal plane, while maintaining their size in the same range, and retention of their relatively low cost.

In this article are proposed such an antenna with elliptical aperture equivalent to about 60 cm circular aperture. The experimental researches of its gain and co-polar and cross-polar radiation patterns in the open range are presented. The results are analyzed and compared with these of the standard 60 cm offset antenna for DTH television. It is of highest importance the fact that both antennas has identical area (therefore identical windload and mass), which highlights the efficiency of the proposed model.

Antenna design

The proposed antenna design is based on paraboloid shape main reflector, cut out with an oval rim. The rim shape is selected in a manner to introduce reduction in the main lobe of the antenna, with edge illumination kept in control for low sidelobes, while the antenna gain still see a minimal reduction, predicted by PO technique [6]. To achieve a proper edge illumination level for oval (not circularly symmetric rim) a special dual mode feed horn (Fig. 2) was developed. In general, a single mode horn combined with elliptical aperture will be sufficient to provide edge illumination good enough for the low first side lobes (Fig. 6), however the induced currents on the reflector will have a component, degrading the cross-polar pattern of the antenna. In order to suppress the cross-polar component and improve the cross-polar pattern and antenna performance over the frequency band of operation (10.7-12.75 GHz), a second order circular mode (TM_{11}) is excited in the horn [3]. The phase relation between the modes is controlled with the proper selection of the horn length after the mode launcher and aperture flaring. The flaring causes excitation of additional high-order modes, however it was determined that their amplitudes are low enough to impair the horn pattern and particularly cross-polarization component level. This problem is addressed by application of MMT technique [2]. Since the proposed antenna has an offset geometry it still has a rise of the cross-polar component levels in the Azimuth plane, the proposed technique helps these levels to be kept within predefined maximum limits. For further reduction of the spillovers and improvement of the horn (primary) pattern a quarter-wave choke is introduced around the horn aperture. The experimental antenna horn was precisely machined out of aluminum block on a CNC machine. All these measures led to bore-sight cross-polar levels of -40 dB across the band for the secondary pattern. Additional measurements were conducted on casted aluminum samples, and they show a slight degradation of the cross-polar performance to -35dB, which is still a satisfactory result for receive-only antenna, and will completely exclude the chance of cross-polar interference on the received channel. The prototype of the main reflector is milled out of large single piece aluminum block which lead to surface deviation of 0.05mm (~2thou) RMS against the ideal shape. Such deviation will introduce 0.02dB gain reduction [4], [5] - an insignificant value, comparable with the error of the measurement instrument.

Fig. 1. Common view of Narrow-beam antenna.

Additional loss may occur due to imperfect surface roughness, however estimations are for another 0.02-0.05dB (antenna surface was brushed).

The experimental antenna will not count for the large surface deviations which occur in stamped regular production antennas, due to material spring-back and tooling imperfections and will lead to pattern and side-lobe deviations. Such analysis should be performed on regularly produced samples only.

Experimental results

The measurements of the radiation patterns of the standard and proposed antennas were implemented in open range on the setup given in Fig. 3. For the source was used standard 60 cm parabolic antenna powered by the tracking generator -synthesizer (TG) with max power -10 dBm, and amplifier with gain of 20 dB. In distance of approximately 90 m the antenna under test was situated on a turn table with angle resolver. The received power level was measured with spectrum analyzer (SA) connected to a PC, where the data was automatically collected.

The optical encoder FRP-6C (ZGPU, Gabrovo, Bulgaria) provides 2500 counts per turn, therefore the angular resolution achieved (0.1 deg after internal interpolation) is sufficient enough to provide reasonable number of points in order to recreate antenna pattern for the frequency bands and geometrical dimensions specified before. The distance is selected (Fig. 3) for far field for the source and antenna under test [7]. There is a minimal phase discrepancy of 0.15 deg and amplitude distortion of 0.2dB over the AUT aperture, which will lead to no pattern distortion during pattern measurement and accurate interpretation of measurement results.

Fig. 2. Antenna feedhorn

The measured results are depicted on Fig. 4 – Fig. 6, for low, mid and high end of the TV Receive band. It is clearly evident that the main beam of the AUT is narrower than the beam width of a standard antenna in the region 2 to 3 deg, where usually interferers are located. This provides additional 5-10 dB adjacent satellite interference protection in favor of the proposed design.

The side lobes of the optimized antenna are also on par or lower compared to the standard antenna. For the source was used standard 60 cm parabolic antenna powered by the tracking generator (TG) with max power -10 dBm, and amplifier with gain of 20 dB.

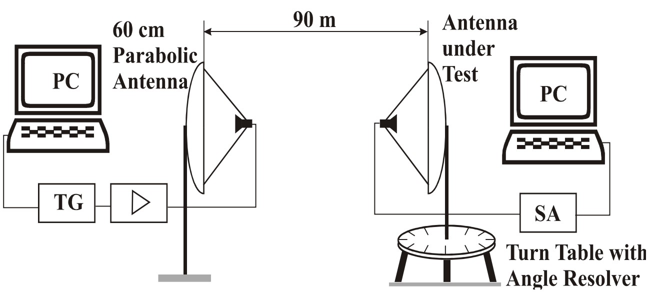

Fig. 3. Experimental setup for radiation pattern measurement.

In distance of approximately 90 m was situated the tested antenna on the turn table with angle resolver.

The received power level was measured with spectrum analyzer (SA) connected to the PC, where the data were automatically collected.The optical encoder FRP-6C (ZGPU, Gabrovo, Bulgaria) provides 10 000 counts per turn, therefore the angular resolution achieved (0.1 deg after internal interpolation) is sufficient enough to provide reasonable number of points in order to recreate antenna pattern for the frequency bands and geometrical dimensions specified before.

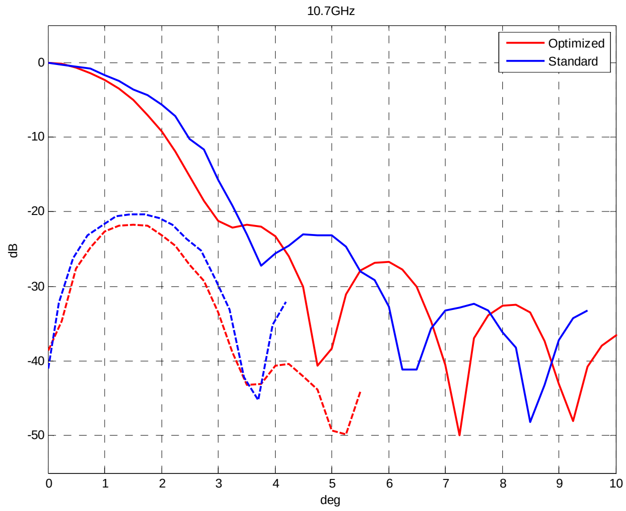

Fig. 4. Measured Antenna Radiation Patterns at 10.7GHz.

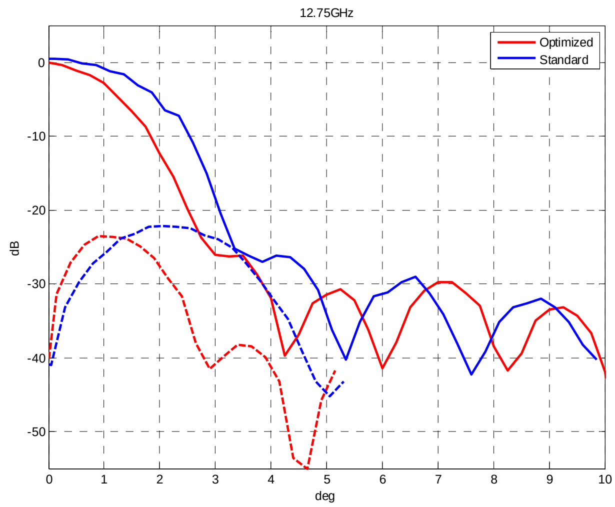

Fig. 5. Measured Antenna Radiation Patterns at 11.725GHz.

The distance is selected (Fig. 3) for far field for the source and antenna under test [7]. There is a minimal phase discrepancy of 0.15 deg and amplitude distortion of 0.2dB over the AUT aperture, which will lead to no pattern distortion during pattern measurement and accurate interpretation of measurement results.

The measured results are depicted on Fig. 4 – Fig. 6, for low, mid and high end of the TV Receive band. It is clearly evident that the main beam of the AUT is narrower than the beam width of a standard antenna in the region 2 to 3 deg, where usually interferers are located. This provides additional 5-10 dB adjacent

satellite interference protection in favor of the proposed design. The side lobes of the optimized antenna are also on par or lower compared to the standard antenna designs.

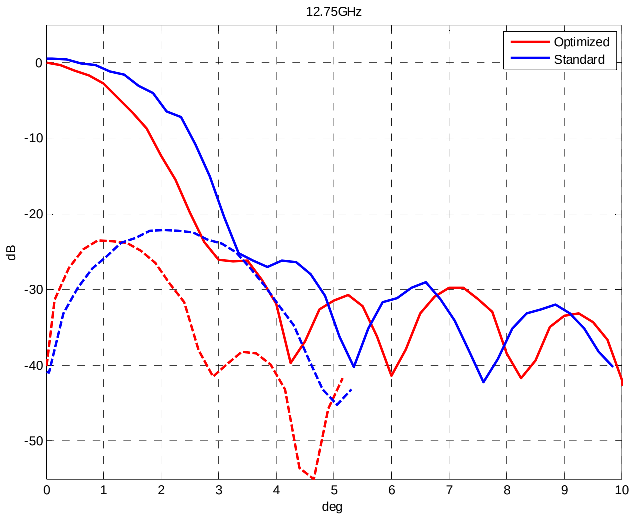

Fig. 6.Measured Antenna Radiation Patterns at 12.75GHz

The dual mode horn provides very low cross-polar component level for the center of the band and the levels are comparable in the band edges. This is a typical performance of a Potter horn, which despite its simplicity is still a narrowband solution. The newly developed horn patterns (co-polar only) are depicted on Fig. 7. Over the subtended angle (around 50 deg) the new design shows significant difference (10dB) in the levels of edge illumination.

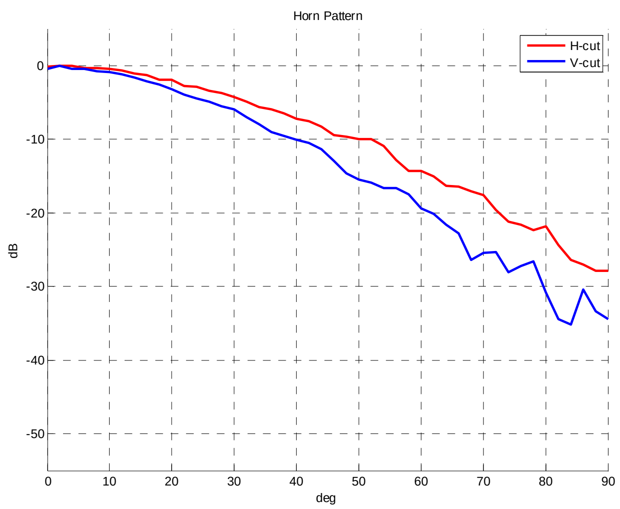

Fig. 7. Optimized feedhorn pattern.

This power flux distribution leads to lower side lobes in the H-plane and improves overall antenna efficiency to about 65%, which is almost impossible to achieve with rotationally symmetric horns and asymmetric shape of the reflector.

Table 1

Measured gain of Standard and Optimized antenna

Antenna	10.7GHz	11.725GHz	12.75GHz
Standard	36.0dB	36.2dB	36.6dB
Optimized	36.2dB	36.4dB	36.8dB

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The gain of both antennas is compared in Table 1. It is clearly seen that proposed design has certain advantage in the performance.

REFERENCES

[1] Appendix 30 of the Radio Regulations, Edition of 2008.

[2] Diamantis, S.G. et al. Horn Antennas Analysis Using a Hybrid Mode Matching-Auxiliary Sources Technique. Progress in Electromagnetic Research Symposium, Pisa, Italy, p-p 458-460, 2004

[3] Potter, P. D. A New Horn Antenna with Suppressed Sidelobes and Equal Beamwidths. Microwave Journal, pp. 71-78, June 1963. (reprinted in A.W. Love, Electromagnetic Horn Antennas, IEEE, 1976, pp. 195-202.)

[4] Ruze, J. Antenna tolerance theory - a review. Proceedings of the IEEE, vol. 54, pp. 633–640, 1966.

[5] Ruze, J. The effect of aperture errors on the antenna radiation pattern. Il Nuovo Cimento, vol. 9, no. 3, pp. 364–380, 1952.

[6] Dim, L., T. Milligan. Antenna Engineering Using Physical Optics. Practical CAD Techniques and Software, Nonvood, MA, Artech House, 1996.

[7] Evans, G. Antenna Measurement Techniques. Nonvood, Artech House, 1999

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