A Low Wind Load Lightweight Dual Cylindrical Reflector Antenna with a Novel Feed for Direct Broadcast Satellite TV Reception

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***Abstract*— A low-coast, lightweight, low wind load, transparent antenna for DBS TV reception has been developed using dual parabolic cylindrical reflectors with a novel broadband small size feed. The feed is mounted on the main reflector or close to it. It is mechanically rigid and it does not cause any considerable blockage. The reflectors of the new antenna are easy to manufacture with a very high surface accuracy. They can be shipped and stored in a form of flat sheets. The new DBS TV reception antenna is easy to assemble and disassemble and has a simple lightweight mounting system that is easy to install. To reduce the weight of the new reflectors, several holes are punched in their surfaces. These holes also make the metallic sheets transparent. Punched reflectors are stable and not significantly affected by strong winds. The overall weight of the new Ku-band DBS TV reception antenna including its mounting system is less than 1 kg.**

I. INTRODUCTION

Conventional parabolic reflector antennas (dishes) have been used with DBS (direct broadcast satellite) TV reception. These dishes suffer from many problems. They have curvatures in more than one direction and therefore they are not easy to manufacture. Hence, they have a low surface accuracy and low efficiency. They are expensive and heavy in weight. They also suffer from high wind loads and they need a complicated heavy mounting system. The feed and the LNB (low noise block down-converter) are located away from the reflector and supported by long struts. Therefore, the feed is not rigid and its location is affected by the surrounding temperatures and winds. Furthermore, the feed and the struts may cause a blockage, which further reduces the efficiency.

To overcome some of the above problems, flat panel antennas (phased arrays) have been used as DBS reception antennas. However, they are more expensive than conventional dishes. Furthermore, they are still heavy in weight and they also need a complicated mounting system. Moreover, they suffer from high wind loads and they are not easy to assemble and disassemble [1]-[3]. In this research, a low-coast, lightweight, low wind load, DBS TV reception antenna that overcomes all the above problems has been developed using dual parabolic cylindrical reflectors [4] with a novel small size broadband feed.

II. TRANSPARENT DUAL REFLECTORS

Fig.1 shows the geometry of a dual parabolic cylindrical reflector antenna. It consists of two cylindrical reflectors S_1 and S_2 with curvatures in two orthogonal planes and a feed point F positioned on the focal line of the sub-reflector S_2 [4]. The focal lengths of S_1 and S_2 are F_1 and F_2, respectively. The apertures of the main reflector and the sub-reflector are rectangular in shape. The aperture area of the main reflector S_1 is X_1Y_1 and the aperture area of the sub-reflector S_2 is X_2Y_2. When a point source is located on the focal line of the sub-reflector, it becomes functionally equivalent to an equiphase line source along its directrix. Thus, adding another parabola such that its focal line coincides with the directrix of the sub-reflector, generates parallel beams that focus F to a point at infinity. Since the reflecting surfaces are curved only in one direction, their fabrication is relatively simple, and high tolerance levels can be achieved to improve their performance. Two flat metallic (aluminum) sheets can be bent to form the reflectors. This is particularly advantageous at high frequencies, where surface tolerances limit the reflector performance. The new DBS TV reception antenna system is easy to disassemble, reassemble and install. Therefore, it can be shipped and stored in a form of flat sheets.

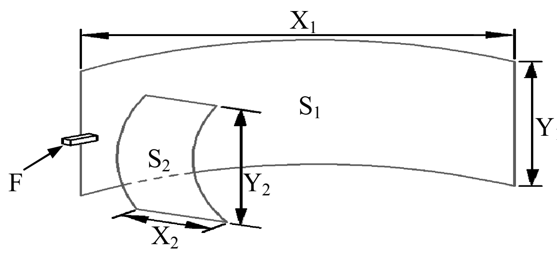
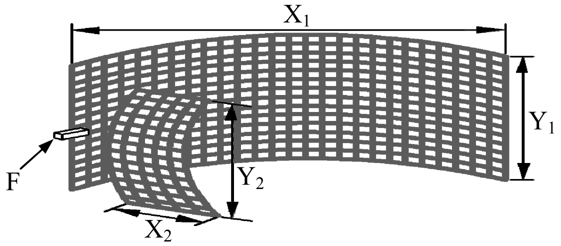


Fig.1 A dual parabolic cylindrical reflector antenna

In order to significantly reduce the weight of the reflectors and also reduce their wind loads, several holes are punched in their surfaces as shown in Fig.2. These holes can have circular, square, rectangular or any arbitrary cross-section shape. To minimize the antenna weight and wind loads, the size and the total number of the punched holes should be increased as much as possible, provided that they do not have a significant effect on the performance or the mechanical rigidity of the antenna. The overall weight of the punched (grid) reflectors can be less than half the weight of the solid surface reflectors. On the other hand, since the punched reflectors are transparent, the new DBS TV reception antennas might be allowed to be used in some communities where it is prohibited to install conventional DBS TV reception dishes. Furthermore, punched reflectors are stable and not significantly affected by strong winds.



Fi.2 Grid parabolic cylindrical reflectors

III. A NOVEL FEED ANTENNA

A novel small size broadband resonant feed is developed for the Ku-band DBS TV reception dual reflector antenna. Fig.3 shows the geometry of the new feed antenna. It consists of two narrow printed metallic arms connected together by a short metallic strip. The length of the short arm is L_1 and its width is W_1 while the length of the long arm is L_2 and its width is W_2. The thickness of the antenna is T_a and the antenna is fed at a distance F_a from the shorted edge. Each arm has a set of slots having different shapes and locations which are optimized in order to maximize the performance of the antenna. The new antenna is completely self-contained resonant antenna. It does not need a matching circuit or any other component. Furthermore, the new feed antenna has a very small size. It is made of a flexible material and it can be bent and/or folded in different forms.

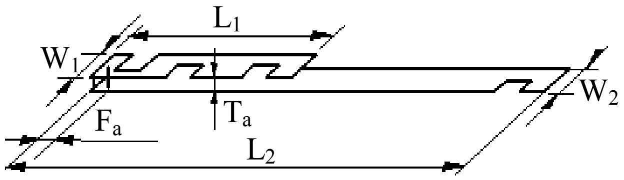


Fig.3 Geometry of the new feed antenna

A prototype of the new Ku-band feed antenna is designed and manufactured as shown in Fig.4. The dimensions of the antenna are: L_1 = 6 mm, L_2 = 9.5 mm, W_1 = 1 mm, W_2 = 2 mm and T_a = 1 mm. Thus, the overall size of the new feed antenna is 9.5 x 2 x 1 = 19 mm^3. The whole weight of the new feed antenna is less than 1 gm. The performance of the new antenna is numerically calculated by a software packages that uses the moment method and it was verified at IMST antenna labs in Germany [5]. Fig.5 shows the return loss of the new feed antenna. The return loss is around -15 dB over the whole DBS TV band which ranges from 10.75 GHz to 12.75 GHz with about 17% bandwidth. The overall efficiency of the new feed antenna is shown in Fig.6. The average efficiency is more than 95% over the whole band. Fig.7 shows the peak gain of the new feed antenna which is about 3 dBi over the whole DBS TV band. Fig.8 shows the radiation patterns of the new feed antenna alone at 11.75 GHz before integrating it to the parabolic cylindrical reflectors. The radiation patterns of the antenna alone are omni-directional with about 3 dBi peak gain. This gain will be significantly increased when the new feed antenna is integrated to the dual parabolic cylindrical reflectors with the main reflector located behind it.

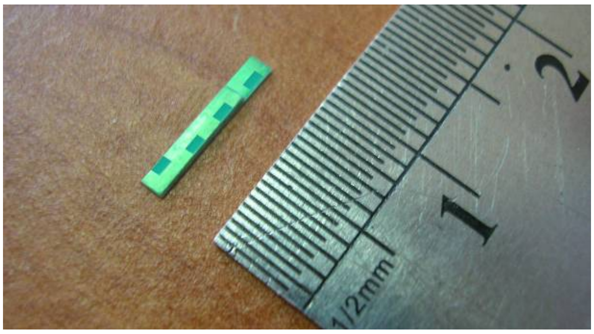


Fig.4 A prototype of the new feed antenna

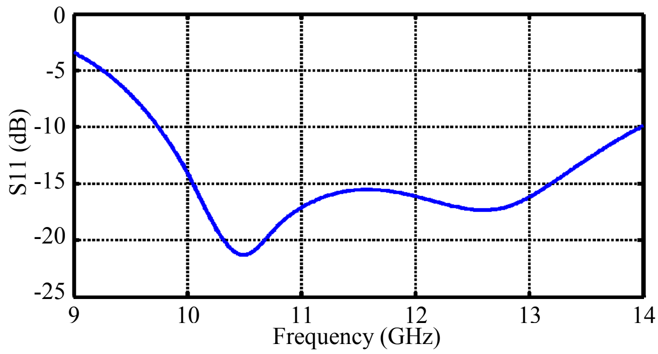


Fig.5 The return loss of the new feed antenna

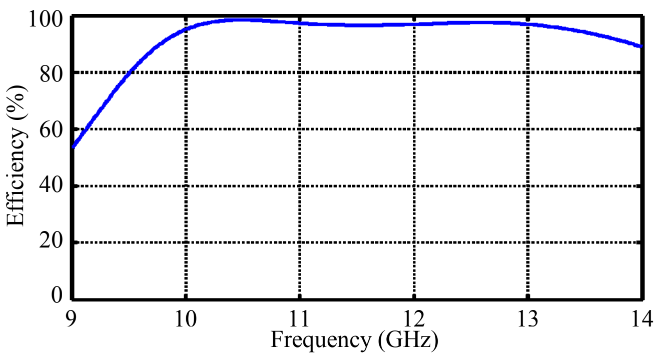


Fig.6 The efficiency of the new feed antenna

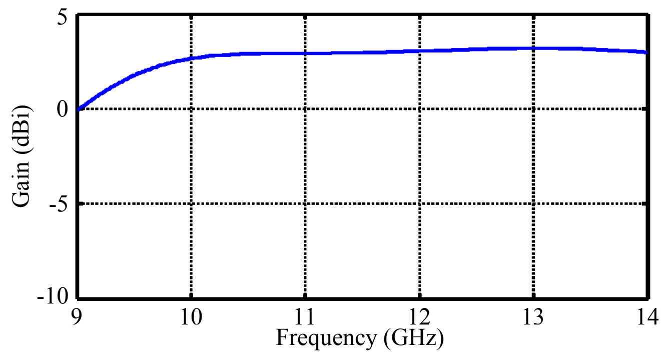


Fig.7 The peak gain of the new feed antenna

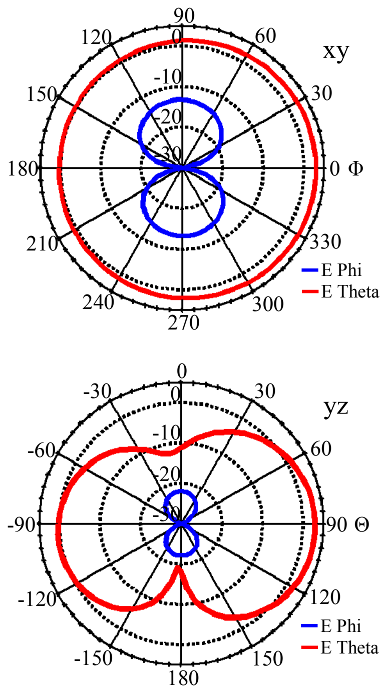


Fig.8. Radiation patterns of the new feed antenna in two principal planes at 11.75 GHz

IV. DUAL PARABOLIC CYLINDRICAL REFLECTORS WITH THE NEW FEED

A prototype of a Ku-band dual parabolic cylindrical reflector antenna is designed and manufactured as shown in Fig.9. The Dimensions of the reflectors are: F1 = 52 cm, F2 = 34 cm, X_1 = 45 cm, Y_1 = 22.5 cm, X_2 = 22.5 cm and Y_2 = 22.5 cm. The reflectors are manufactured from 1 mm thick aluminium sheets. The punched holes are square in shape. The length of each hole is 7 mm and the distance between the holes is 5 mm. The overall weight of the punched dual parabolic cylindrical reflector antenna is less than 1 Kg. The new feed is located on the focal line of the sub-reflector [4]. Since the overall size of the new feed antenna is very small, it does not cause any considerable blockage for the main reflector or the sub-reflector.

Fig.9 A prototype of the grid antenna with the new feed

Fig.10 shows the measured return loss of the new feed antenna with the grid main reflector behind it. The return loss is still lower than -15dB over the whole band. On the other hand, the existence of the grid main reflector behind the feed antenna significantly modifies its radiation patterns. The Co-polar and cross-polar patterns of the feed antenna at 11.75 GHz with the main reflector behind it are shown in Fig.11 and Fig.12, respectively. Although the radiation patterns of the feed alone were omni-directional with 3 dBi peak-gain, the existence of the main reflector behind it significantly increases its directivity. The gain of the feed antenna in front of the grid main reflector is about 9 dBi.

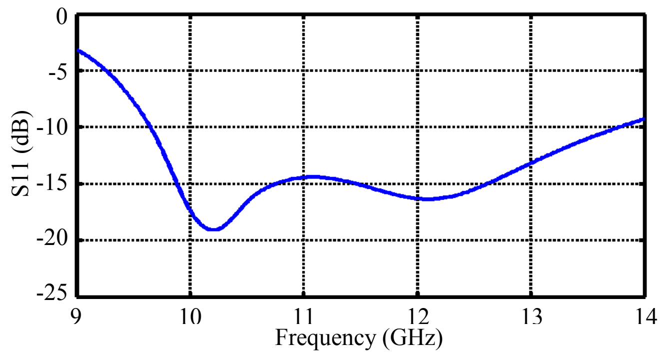


Fig.10 The return loss of the new feed antenna with the grid main reflector behind it

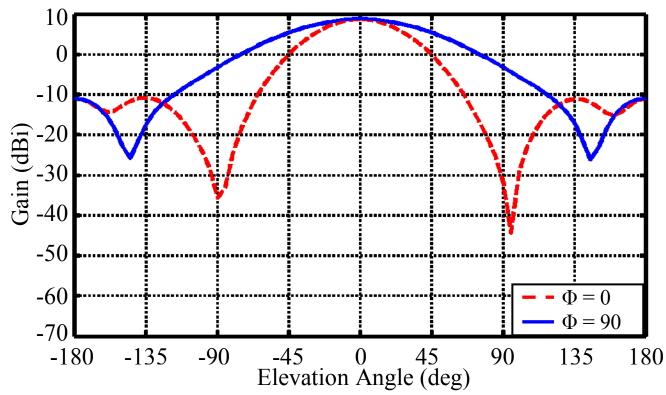


Fig.11 Co-polar radiation patterns of the feed antenna at 11.75 GHz with the grid main reflector behind it

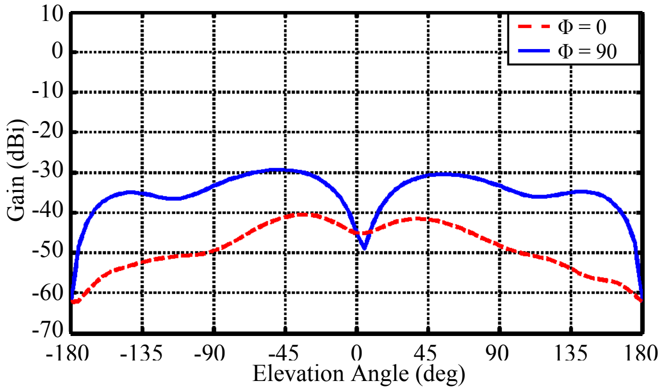


Fig.12 Cross-polar radiation patterns of the feed antenna at 11.75 GHz with the grid main reflector behind it

The radiation patterns of the grid dual parabolic cylindrical reflector antenna with the new feed are calculated using GTD (geometrical theory of diffraction) [4]. A GTD software code was written for dual parabolic cylindrical reflectors with arbitrary feed patterns and its accuracy was verified experimentally [6]. Fig.13 shows the calculated co-polar radiation patterns of the new developed grid DBS TV reception antenna with the new feed at 11.75 GHz. The cross-polar patterns are shown in Fig.14. The gain of the antenna is more than 31 dBi.

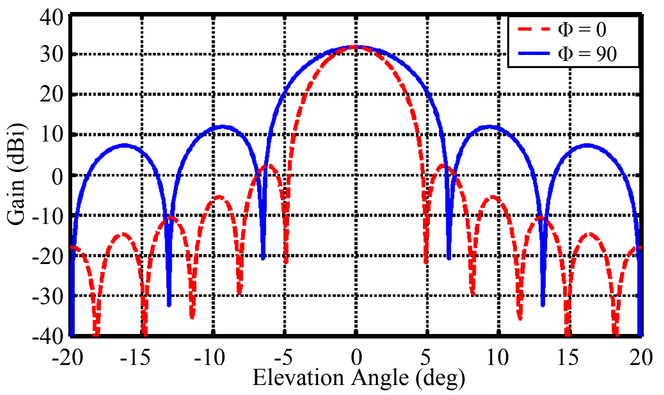


Fig.13 Co-polar radiation pattern of the new grid satellite TV antenna at 11.75 GHz with the new feed

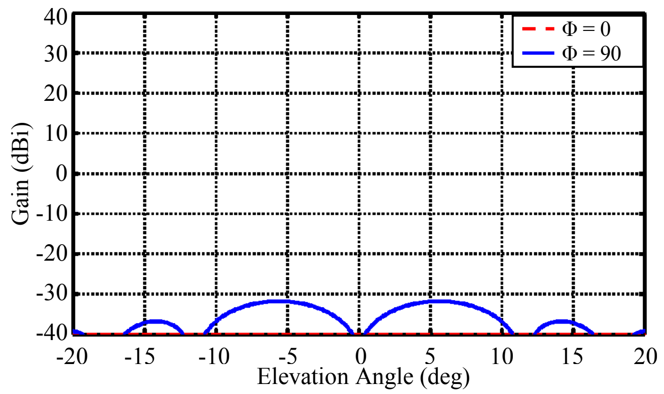


Fig.14 Cross-polar radiation pattern of the new grid satellite TV antenna at 11.75 GHz with the new feed

A very simple lightweight mounting system was designed. The total weight of the whole antenna including the mounting system and the LNB was still less than 1 Kg. This low-cost lightweight transparent prototype was tested in the field trial to replace conventional DBS TV reception dishes. The new antenna prototype successfully received all satellite TV channels that were received by all the 45 cm (18 inches) diameter conventional DBS TV reception dishes.

V. CONCLUSIONS

A low-coast, low wind load, lightweight DBS TV reception antenna was developed using dual parabolic cylindrical reflectors with a novel resonant feed. The reflectors of the new antenna were easy to manufacture with a very high surface accuracy. They could be shipped and stored in a form of flat sheets. To reduce the weight of the cylindrical reflectors, several holes were punched in their surfaces. These holes also made the reflectors transparent with low wind load. A novel small size broadband resonant feed was developed for the dual reflector antenna. The new feed was completely self-contained resonant antenna that did not need a matching circuit. The whole weight of the new feed antenna was less than 1 gm and its average efficiency was more than 95% over the whole frequency band.

A prototype of the DBS TV reception dual reflector antenna was manufactured with the new feed. The dimensions of the rectangular aperture of the main reflector were 45 cm x 22.5 cm. The gain of the antenna was more than 31 dBi. A very simple lightweight mounting system was designed and manufactured. The total weight of the whole antenna including the new feed, the LNB and the mounting system was less than 1 Kg. This prototype was tested in the field trial to replace conventional DBS TV reception dishes. The new antenna prototype successfully received all the satellite TV channels that were received by all the 45 cm (18 inches) diameter conventional dishes.

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