A Low Wind Load Lightweight Foldable / Deployable Base Station Antenna for Mobile TV, CDMA and GSM

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***Abstract*— A low-coast, lightweight, low wind load, broadband, foldable / deployable base station antenna has been developed using dual parabolic cylindrical reflectors with a novel small size broadband feed. The new base station antenna is easy to assemble and disassemble. The parabolic cylindrical reflector surfaces are replaced by a group of narrow rectangular plane panels. The new feed antenna is linearly polarized. It can be easily modified in order to make it sensitive to two perpendicular polarizations. This can be achieved by combining two orthogonal antennas with a common feed point. Dual polarization can also be accomplished by using two orthogonal antennas with two different feeds for MIMO configurations. The new base station antenna covers a frequency band from 450 to 960 MHz with 72% bandwidth. It can cover the frequency bands of 450 and 700 MHz WiMax, UHF DVB-H, CDMA and GSM.**

I. INTRODUCTION

There are some recent expansions in mobile wireless applications. Mobile TV and mobile WiMax are examples of such new applications. As the number of mobile applications increases, the need for broadband base station antennas increases. Arrays of crossed dipoles are commonly used as base station antennas for mobile communications [1]. This is because base station antennas of mobile communications are demanded to achieve two orthogonal polarizations. They are also required to generate narrow elevation beamwidths and wide azimuth beamwidths. However, such arrays have limited frequency bandwidths which are not sufficient for recent expansions in mobile applications. Furthermore, they are heavy in weight, high in coast and they suffer from high wind loads. Moreover, they are not easy to assemble and disassemble. Therefore, they are shipped and stored in their large-size assembled forms.

In this research, a low-coast, lightweight, low wind load, foldable / deployable, broadband base station antenna that overcomes all the above problems has been developed using dual parabolic cylindrical reflectors [2] with a novel small size broadband dual-polarized resonant feed. The new base station antenna covers a wide frequency band, which ranges from 450 to 960 MHz with 72% bandwidth. Thus, it can cover all bands of 450 MHz WiMax (450 MHz-470 MHz), 700 MHz WiMax (698-806 MHz), UHF mobile digital TV "DVB-H" (470-862 MHz), CDMA / GSM800 (824-894 MHz) and E-GSM900 (880-960 MHz).

II. FOLDABLE / DEPLOYABLE REFLECTORS

Fig.1 shows the geometry of a dual parabolic cylindrical reflector antenna. It consists of two parabolic cylindrical reflectors S_1 and S_2 with focal lengths F_1 and F_2 and a feed F positioned on the focal line of S_2 [2]. 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. Dual parabolic cylindrical reflector antennas can generate arbitrary azimuth and elevation beam widths with an arbitrary ratio between them. However, they have some challenging problems when they are used as base stations in UHF band. The first problem in conventional UHF dual parabolic cylindrical reflectors is their heavy weight and high wind loads.

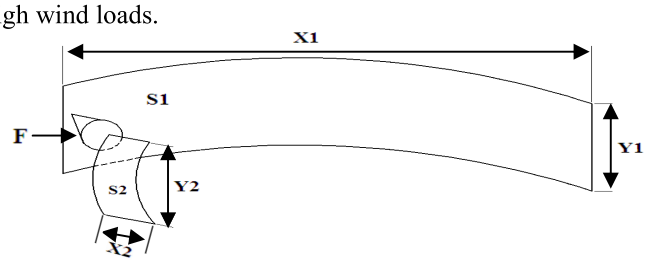

Fig.1 A dual parabolic cylindrical reflector antenna

In order to significantly reduce the weight of the reflectors and also reduce their wind loads, the solid parabolic cylindrical reflector surfaces are replaced by a group of narrow rectangular plane panels as shown in Fig. 2. A plurality of narrow plane panels are assembled edge to edge to form an approximation to parabolic cylindrical surfaces. With large size antennas, it is important to make the antenna deployable and foldable in a compact form. Of course, simulating parabolic cylindrical reflectors by a group of plane panels will cause some reduction in the antenna efficiency. However, the accuracy of simulating parabolic cylindrical reflectors can be significantly increased by reducing the widths of the plane panels. Reducing the panel widths will also reduce their wind loads. The antenna wind load can be further reduced by increasing the separating distance between the panels as much as possible provided that they do not have a significant effect on the performance of the antenna.

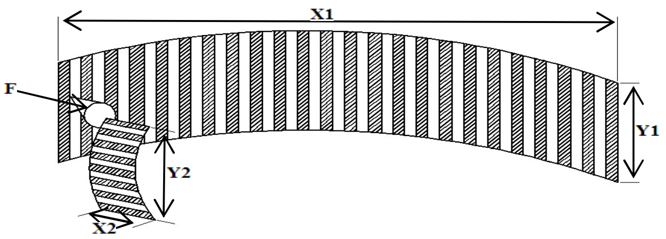

Fig.2 Simulating parabolic cylindrical reflectors by a group of narrow rectangular plane panels

III. A NOVEL BROADBAND FEED

The most challenging problem in conventional UHF dual parabolic cylindrical reflector base station antennas is finding a small size UHF feed with a broad bandwidth that is sufficient for the above applications. UHF feed antennas are large in size and, therefore, they cause severe blockage for the main reflector and/or the sub-reflector [3]. In this research, a novel small size broadband dual-polarized resonant feed is developed with the required bandwidth. 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 bandwidth of the antenna. The new antenna is completely self-contained and it does not need an additional ground plane, a matching circuit or any other component. Furthermore, the new feed antenna is made of a flexible material and it can be bent and/or folded in different forms.

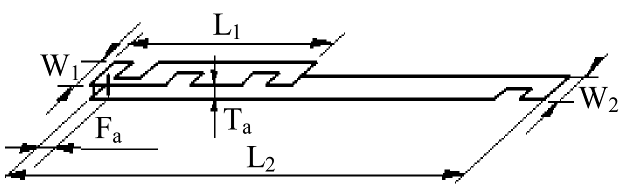

Fig.3 Geometry of the new feed antenna

A UHF prototype of the new broadband feed antenna is designed and manufactured as shown in Fig.4. The dimensions of the feed antenna are: L_1 =11.5 cm, L_2 = 25 cm, W_1 = 2.6 mm, W_2 =3.5 mm and T_a = 2 mm. Thus, the overall size of the new UHF feed antenna is 25 x 0.35 x 0.2 = 1.75 cm^3. The whole weight of the new feed antenna is about 1 gm. The performance of the new antenna is numerically calculated by a software packages that uses the moment method. It is also measured at IMST antenna labs in Germany [4]. Fig.5 shows the radiation patterns of the new antenna alone (without parabolic cylindrical reflectors). The radiation patterns are omni-directional with about 0 dBi peak gain and they are sensitive to only one polarization.

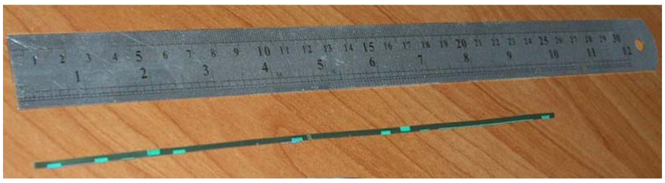

Fig.4 A prototype of the new broadband feed antenna

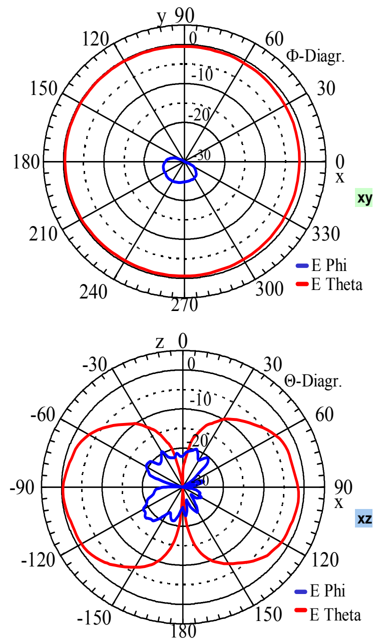

Fig.5. Measured radiation patterns of the new feed antenna at 800 MHz

IV. DUAL POLARIZED FEEDS

The new feed antenna can be modified in order to make it equally sensitive to two perpendicular polarizations. Dual polarization can be accomplished by combining two orthogonal antennas with a common feed point as shown in Fig. 6. The thickness of the feed antenna is increased to 4 mm and its width is increased to 12 mm in order to increase the efficiency and the peak gain. The return loss of the new dual polarized antenna is shown in Fig.7 from 470 to 960 MHz. The efficiency is shown in Fig.8. The efficiency is higher than 80% over most of the band. The peak gain of the new dual polarized antenna is shown in Fig.9 and it is higher than 2 dBi over most of the band. Fig.10 shows the radiation patterns of the new dual polarized antenna. It is clear that the new feed antenna is equally sensitive to two orthogonal polarizations.

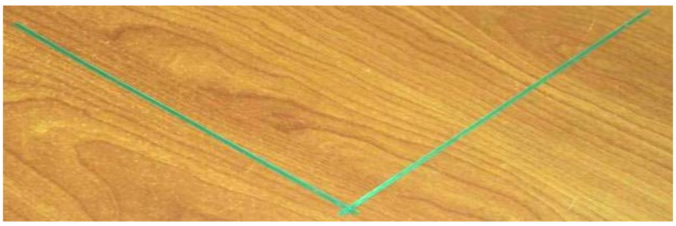

Fig.6 Two orthogonal antennas with a common feed point

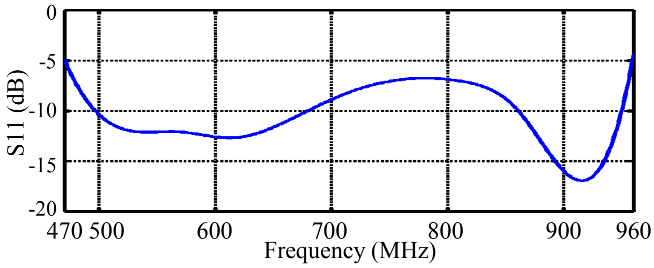

Fig.7 Return loss of the new dual polarized feed

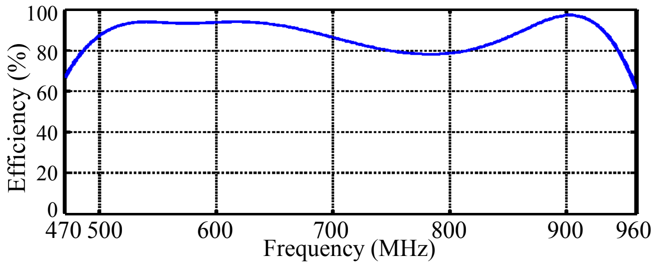

Fig.8 Efficiency of the new dual polarized feed

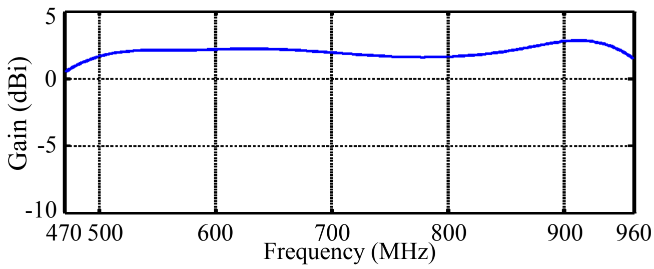

Fig.9 Peak gain of the new dual polarized feed

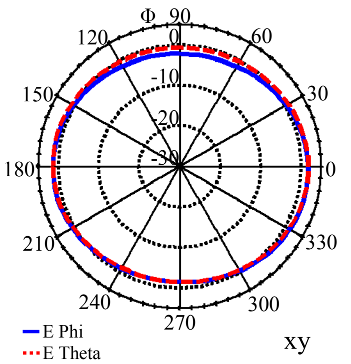

Fig.10 Co-polar and cross-polar radiation patterns of the dual polarized feed

Dual polarization can also be achieved by using two orthogonal antennas with two different feed points as shown in Fig. 11. This is important for multi-input multi-output (MIMO) techniques. Since the interference between the orthogonal MIMO antennas is negligible, the return loss and the efficiency of the orthogonal antennas are not affected by the MIMO configuration and they are almost the same as the above presented results of single antennas. However, the radiation patterns of the orthogonal antennas are significantly affected by MIMO configurations. The overall radiation patterns of MIMO antennas are the summations of the radiation patterns of the orthogonal antennas. Fig.12 shows the co-polar and cross-polar components of the radiation patterns of two orthogonal antennas in the plane of the antennas. The orthogonal antennas are 1 cm apart from each other. The co-polar and cross-polar components are exactly the same.

Fig.11 Two orthogonal antennas with two different feed points for MIMO configurations

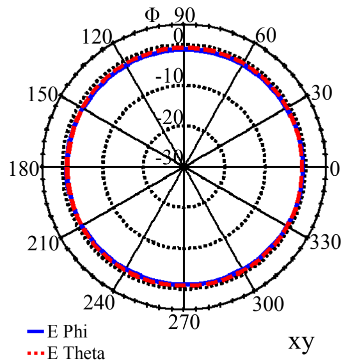

Fig.12 Radiation patterns of two orthogonal antennas

V. FOLDABLE / DEPLOYABLE DUAL PARABOLIC CYLINDRICAL REFLECTORS WITH THE NEW FEED

A UHF prototype of foldable / deployable dual parabolic cylindrical reflector antennas is manufactured as shown in Fig.13. The Dimensions of the antenna are: F1=80 cm, F2 = 19 cm, X_1 = 210 cm, Y_1 = 30 cm, X_2 =32 cm and Y_2 = 30 cm. The parabolic cylindrical reflectors are replaced by a group of rectangular narrow plane panels. The width of each panel is 2 cm and the separation between them is also 2 cm. The rectangular narrow plane panels are manufactured from 1 mm thick aluminium sheets. The overall weight of the foldable / deployable dual parabolic cylindrical reflector antenna is less than 6 kg. The new feed is located on the focal line of the sub-reflector [2]. 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.13 A prototype of the deployable / foldable antenna with the new feed

Fig.14 shows the measured return loss of the new feed antenna with the multi-panel main reflector behind it. Locating the main reflector behind the feed significantly changes its performance. With the main reflector behind the feed, it naturally resonates from 450 MHz to 960 MHz with a return loss lower than -7dB and without using matching circuits or any tuning components. On the other hand, the existence of the multi-panel main reflector behind the feed antenna significantly modifies its radiation patterns. The radiation patterns of the feed alone without the main reflector and without increasing its width or thickness were omni-directional with a peak gain of about 0 dBi. The calculated radiation patterns of the feed antenna with the main reflector behind it at 800 MHz are shown in Fig.15. The gain of the feed in front of the main reflector is about 9 dBi.

The radiation patterns of the foldable / deployable dual parabolic cylindrical reflector antenna with the new feed are calculated using GTD (geometrical theory of diffraction) [2]. A GTD software code was written for dual parabolic cylindrical reflectors with arbitrary feed patterns and its accuracy was verified experimentally [5]. Fig.16 shows the calculated radiation patterns of the new developed foldable / deployable base station antenna with the new feed in two principal planes at 800 MHz. The gain of the antenna is about 15 dBi.

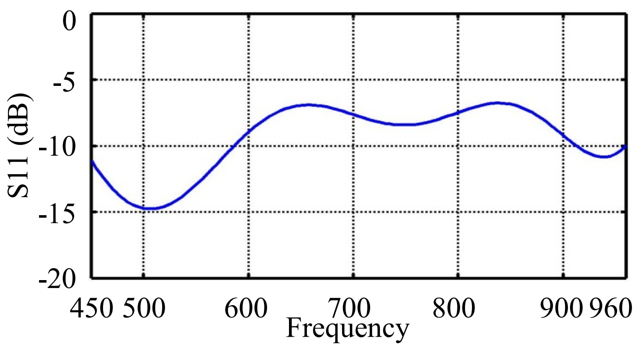

Fig14 Measured returns loss of the new feed while it is in front of the multi-panel main reflector

VI. Conclusions

A low-coast, low wind load, lightweight foldable / deployable dual parabolic cylindrical reflector antenna was developed with a novel dual polarized broadband resonant feed. The new base station antenna covered a frequency band from 450 MHz to 960 MHz with 72% bandwidth. It could cover all the bands of 450 MHz WiMax (450 MHz-470 MHz), 700 MHz WiMax (698-806 MHz), UHF DVB-H mobile digital TV (470-862 MHz), CDMA / GSM800 (824-894 MHz) and E-GSM900 (880-960 MHz). The new feed antenna was linearly polarized. It could be easily modified in order to make it dual polarized with one feed point or two feed points in order to be used in MIMO configurations.

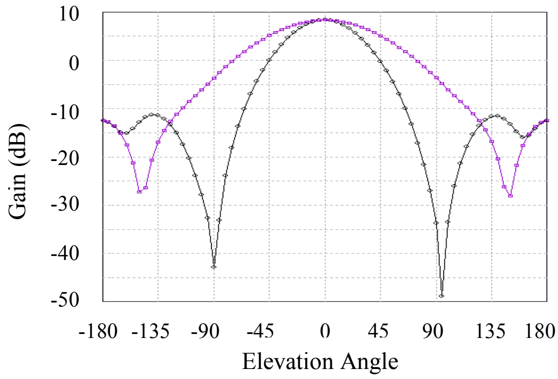

Fig.15 Radiation patterns of the new feed at 800 MHz with the multi-panel main reflector behind it

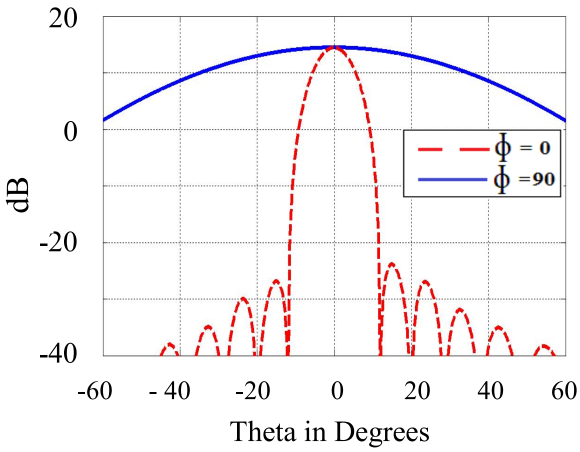

Fig.16 Radiation patterns of the new foldable / deployable base station antenna at 800 MHz

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