A new metal-rod-supported hat antenna for potentially combining with the eleven antenna as a dual-band feed for reflectors

A New Metal-rod-supported Hat Antenna for Potentially Combining With The Eleven Antenna as a Dual-Band Feed for Reflectors

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***Abstract*—A new hat feed entirely made of metal without using dielectric material has been developed. Compared to the previous hat feeds, it has lower manufacture cost, higher reliability, and wider bandwidth of reflection coefficient. The feed has been optimized using Genetic Algorithm. A prototype has been manufactured, and measured results are presented to verify the numerical simulations. In addition, the new design opens up the possibility to combine the new hat antenna with the Eleven antenna for a dual-band feed.**

I. Introduction

Hat feeds [1]- [7] are self-supported, rear-radiating feeds which consist of a waveguide (referred to as neck), a piece of dielectric material (head) and a corrugated brim (hat), as shown in Fig. 1. This geometry avoids the blockage of support struts and meanwhile make it possible to locate the transmitter and receiver at the rear side of the reflector. Therefore, hat feed reflector antennas have found many applications, such as in mini-link, satellite-communication terminals [8] and gauge radars.

The paper presents a new solution to hat feed geometry in order to reduce manufacture cost, increase reliability and make it possible to combine the hat antenna with the Eleven antenna [9]- [11] for a dual-band feed. The new hat feed is entirely made of metal without using dielectric material, with a new technique - slits on the waveguide wall.

A prototype of the new hat feed has been manufactured. Simulated and measured performances of the new hat feed are presented in the paper for verifying the new design.

II. Geometry of the new hat feed

The corrugated brims of all previous hat feeds were supported by a piece of dielectric material (head) through gluing the three parts (hat, head and neck) together. The gluing procedure requires high temperature treatment for strengthening the stability, which is time consuming and often causes unqualified products due to the difficult tolerance control for the head position.

Therefore, it will be cheaper to use thin metal rods as support structure instead of dielectric head. Thus, minimizing

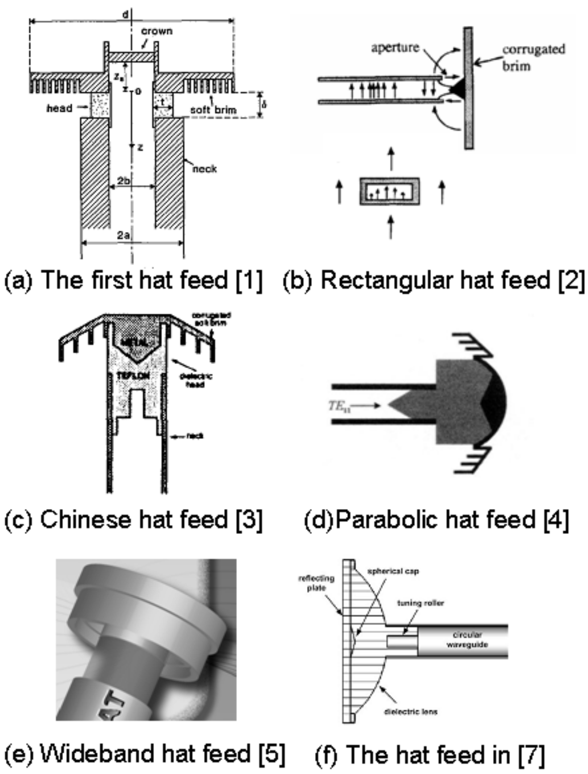

Fig. 1. Previous versions of hat feeds

the effect of the metal rods on the aperture field distribution is a critical issue in the design.

The aperture distribution between the hat brim and the neck waveguide for a hat antenna can be decomposed into two modes [1], φ-mode with only φ-directed E-field, and z-mode with z- and ρ-directed E-fields, see Fig. 3.

From the figure, it can be seen that it will affect the aperture

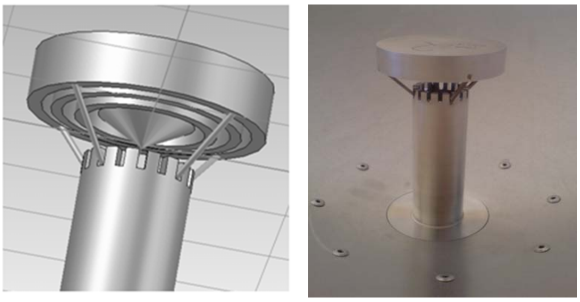

Fig. 2. The new hat feed. Left: Modeling in CST MS; Right: Manufactured prototype.

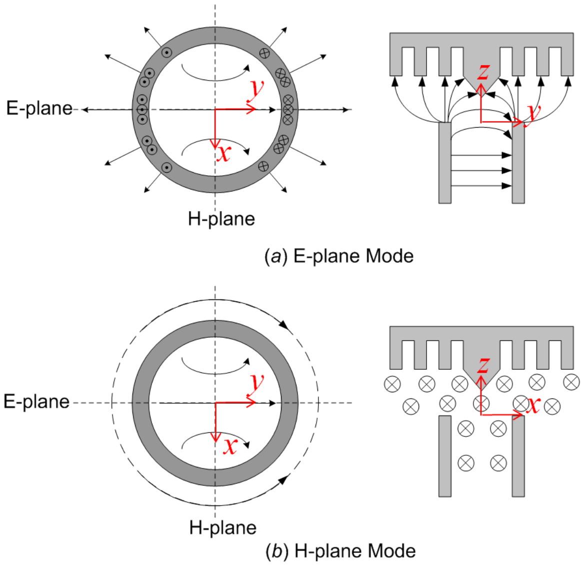

Fig. 3. E-field Distributions of (a) z-mode (the E-plane mode) and (b) φ-mode (the H-plane mode) in the aperture between the hat and the waveguide.

distribution minimally and maximally if metal rods are located in the H-plane and E-plane, respectively. Therefore, for dual-polarized hat feeds, an optimal trade-off between the two polarizations for the support structure is four thin straight tilted metal rods in $\varphi = 45°$, $135°$, $225°$ and $315°$ planes; see Fig. 2. By this geometry arrangement, it also eliminates the radiation along the waveguide while the radiation in other directions remains because the spacing between rods at the waveguide end is less than half wavelength of operating frequencies while the distance between rods at the hat brim is much larger than the half wavelength. In other words, the z-mode fields cannot propagate between the support rods near the waveguide end, which leads the radiation along the waveguide will be reduced and therefore no vertex plate is needed. At the same time, the z-mode fields propagate easily between the support rods close to the hat brim and are reflected by the corrugations towards the reflector. It should be noted that thin tilted rods do not affect the φ-mode field and that the φ-mode field does not radiate along the outer surface of the metal waveguide.

The new hat feed is not pure BOR antenna [12] due to the new support structure, whereas all previous hat feeds were perfect BOR type. Therefore, the BOR_1 efficiency [12] [13] of the new hat feed will not be 100%. Consequently, optimization of the new hat feed configuration is applied to obtain an optimal BOR_1 efficiency.

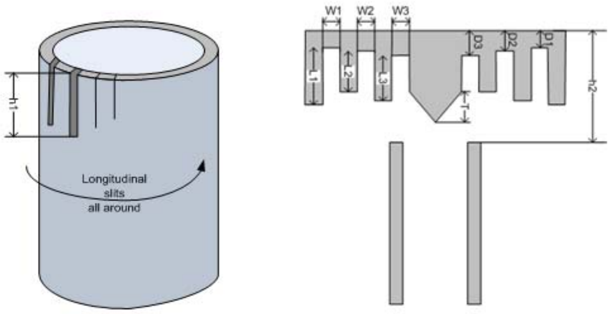

Fig. 4. Slits around the waveguide wall and corrugations of different depths on the head brim.

III. New Technique - Slits on the Waveguide End

In hat feed design, the z- and φ-modes should be excited with correct amplitudes and phases so that the E- and H-plane radiation functions are similar and therefore the cross polar radiation level is low[11]. This was achieved by adjusting the aperture size (distance between the hat and the waveguide end) and the shape of the dielectric support material inside the waveguide for the previous had feeds.

In the present design, we introduce a new technique - longitudinal slits at the end of the waveguide, shown in Fig. 4, so that the z- and φ-modes excitations can be adjusted separately. The longitudinal slits can be modeled as wire grids that allow the φ-mode field to penetrate through but not the z-mode field. Therefore, the wire grids function as a open area for the φ-mode field and a normal waveguide for the z-mode field. Hence, the aperture size for the φ-mode field is $h1$ longer than that for the z-mode field where $h1$ is the length of the slits; see Fig. 4. By changing the depth of the slits, we can adjust the φ-mode field without changing the z-mode field in the aperture.

It should be noted that the reflection coefficient at the waveguide input port is also affected by these slits so optimization procedure includes the dimensions of the slits. In this design, sixteen slits are used.

IV. Simulated and Measured Results

A prototype of the new hat feed was manufactured for verifying the design; see Fig. 2.

Fig. 5 shows that the decrease of the simulated BOR_1 efficiency caused by the 4 metal rods is smaller than 0.3 dB. Meanwhile the polarization efficiencies remains higher than -0.5 dB. Consequently, the deterioration caused by the 4 rods is acceptable.

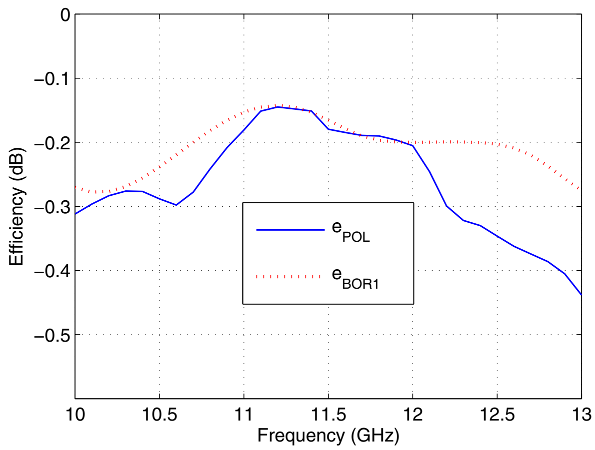

Fig. 5. Simulated BOR_1 and polarization efficiencies of the new hat feed.

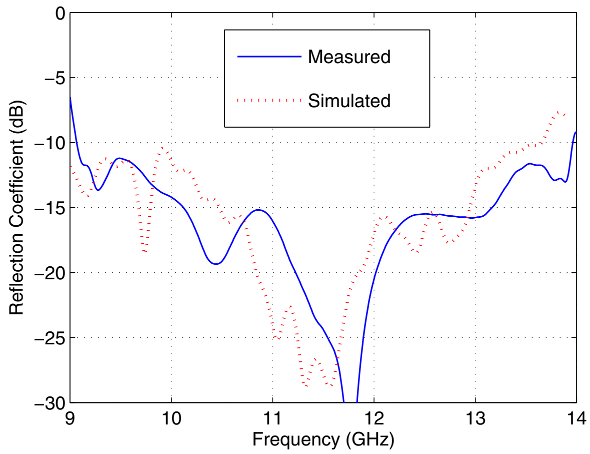

Fig. 6. Simulated and measured reflection coefficient of the new hat feed mounted in the reflector.

Fig. 6 shows the simulated and measured reflection coefficient of the hat feed reflector antenna with the new hat feed mounted in a reflector with a diameter of 654 mm and a subtended angle of 105°, shown in Fig. 7. Notice the following facts: first, there is no vertex plate in the new hat feed reflector antenna [14]; second, the reflector is a ring-focus paraboloids [15]; finally, the screws on the reflector surface used for mounting the hat feed has no significant effect on the performance [16]. The measured result shows that a 26% bandwidth with reflection coefficient below -15 dB is achieved.

The simulated and measured radiation patterns in $\varphi = 45°$ plane of the new hat feed reflector antenna are shown in Fig. 8. The measurements were done in the anechoic chamber at Chalmers. The radiation patterns almost meet the requirement of class 2 of ETSI EN 302 217-4-2 [17] (ETSI RIC2).

Fig. 9 shows the calculated and measured aperture efficiency of the new hat feed reflector antenna. We used two methods to calculate the aperture efficiency based on the simulations by CST: 1) $e_{ap} = D_{0sim} - D_{max}$, where D_{0sim} is the directivity

Fig. 7. The new hat feed mounted in a reflector with a diameter of 654 mm and a subtended angle of 105°.

of the antenna simulated by CST, and D_{max} the theoretical maximum directivity; 2) calculating aperture efficiency based on the simulated radiation patterns. The measured aperture efficiency is obtained by $G_{0mea} - D_{max}$, where G_{0mea} is the measured gain of the antenna. From the figure, the two calculated results are very close to each other. The measured values agree with the calculated ones quite well, within the measurement error. The results of aperture efficiency also show the property of a wide bandwidth.

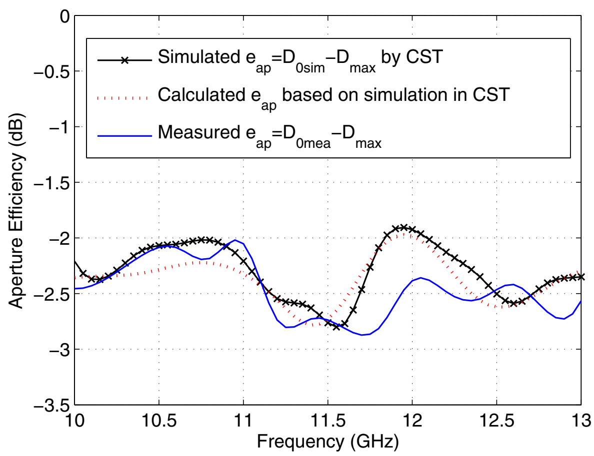

Fig. 9. Calculated and measured aperture efficiencies of the new hat feed reflector antenna.

V. Vision of Combining the New Hat Feed with the Eleven Feed

The metal-rod-supported hat feed opens up the possibility for designing a dual-band feed by combining it with the Eleven feed [9] - [11]. Fig. 10 shows a version of dual band feed combining the new hat feed and the Eleven feed, where the metal rods are replaced by coaxial cables for feeding the Eleven feed. More detailed design and analysis for the dual band feed will be carried out and reported.

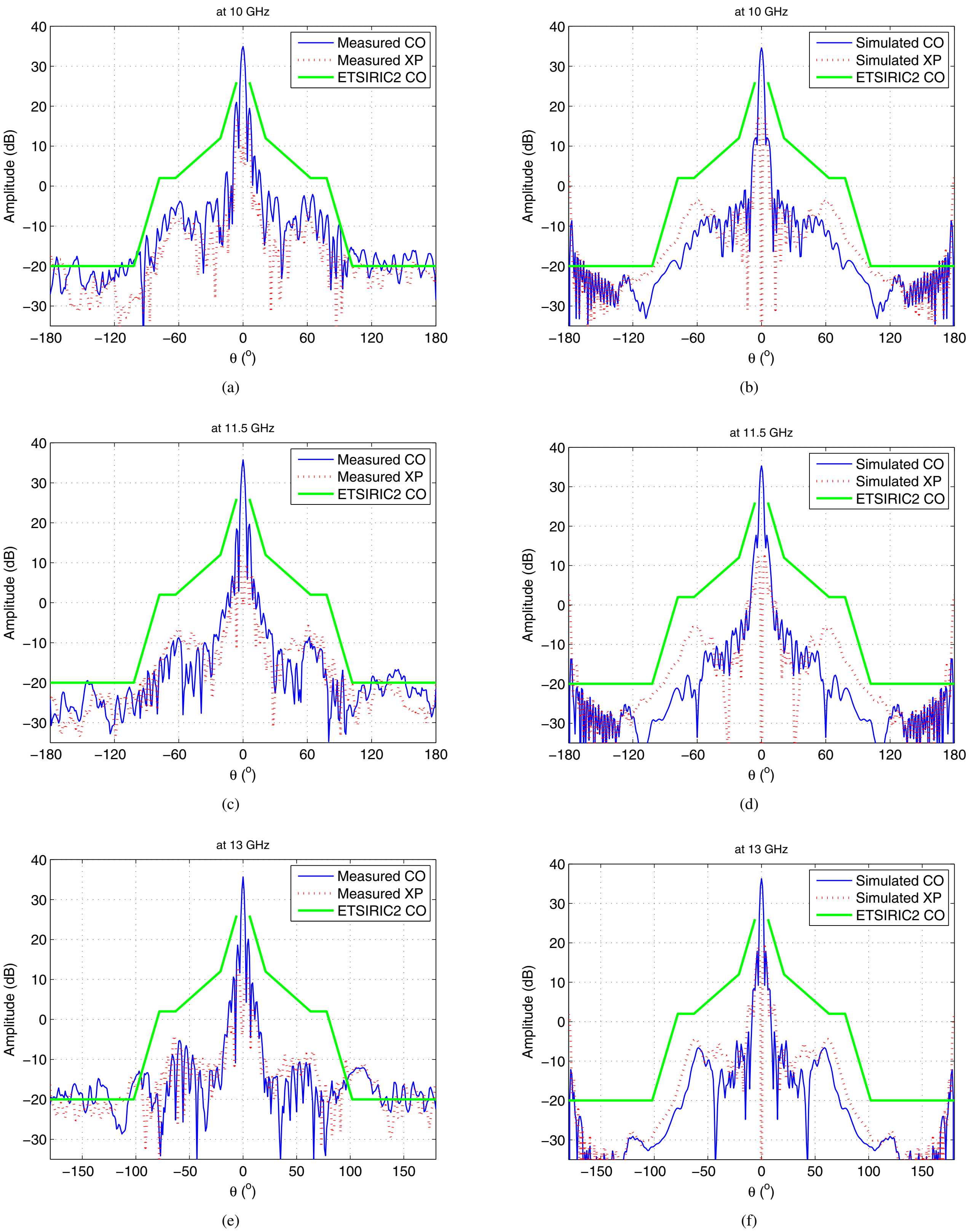

Fig. 8. Measured and simulated co- and cross-polar radiation patterns in 45° plane.

VI. Conclusions

A new hat feed that uses four metal rods as a supporting structure for the head has been successfully designed. The new hat feed not only has a lower manufacture cost than the previous ones, but also opens up the possibility of combining

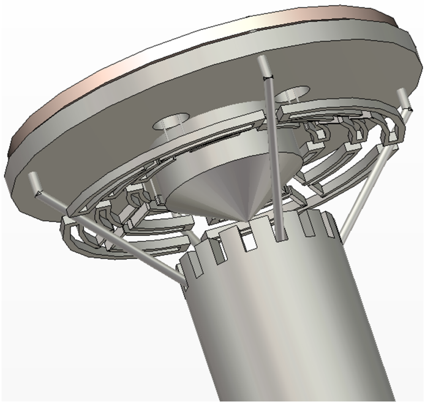

Fig. 10. One version of dual band feed combining the new hat feed and the Eleven feed.

the Eleven feed for dual band feed for reflectors.

ACKNOWLEDGMENT

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