CIRCULARLY POLARIZED TRIANGULAR MICROSTRIP LINE ANTENNA WITH A GAP FOR MOBILE SATELLITE COMMUNICATIONS

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1. Introduction

The interest in the mobile satellite communications system technologies is expected to increase with the launch of the Japan Aerospace Exploration Agency's (JAXA) Engineering Test Satellite VIII (ETS-VIII). Among its applications, ETS-VIII will conduct orbital experiments on mobile satellite communications in S-band [1]. One of the experimental aims is the development of a technology enabling the transmission and reception of multimedia information such as voice and images by use of the geostationary satellite for land mobile systems. Although the specifications depend on the services and systems available, a small and light antenna having a high gain on a wide angular range is desired.

Up to now, several antennas able to meet these requirements have been extensively investigated, are widely available in the literature, and include the conical beam antennas and the satellite-tracking antennas. The advantage of the latter is that the beam generated by satellite-tracking systems is always directed towards the satellite direction even when the azimuth of the mobile changes. Therefore, such antennas have the possibility to reach a higher gain as compared to the conical beam antennas.

Hence, the authors have widely investigated and presented simple on-board satellite-tracking circularly polarized array antennas for single [2] and dual frequency [3], aiming at ETS-VIII applications. However, although the aforementioned antennas can satisfactorily be used in outdoor experiments [4], their size is relatively large. Consequently, in this paper, the authors present a more compact satellite-tracking antenna based on the microstrip line (wire antenna) model [5].

Here, a microstrip line antenna which has a very simple structure is introduced to radiate a circularly polarized wave. This antenna consists of a triangular conducting wire above a ground plane with a gap on one of its side to produce a circular polarization [6]. After analysis of the radiation characteristics of a single pattern, the proposed element is made in an array configuration and the possibility of beam-switching in the azimuth space is confirmed by numerical simulations.

2. Specifications and targets

In this research, a thin miniaturized antenna aiming at ETS-VIII applications and designed for a hundred kbps data rate is analyzed. In this case, the necessary minimum gain on the azimuth space is set to 5 dBic with a maximum axial ratio over the investigated angular range set to 3 dB [2], [3]. In addition, in this study, the measurements are assumed to take place in the center of Tokyo (elevation angle *El* of the geostationary satellite 48°). Furthermore, the operating frequency is fixed to 2.5025 GHz.

3. Structure of the antenna

Fig. 1 shows the configuration of the triangular wire antenna with a gap above a ground plane. Although various shapes can be considered [7], the triangular one is chosen so that it can be easily made and the current distribution on the wire can be controlled by changing the gap position, the gap width and the wire perimeter. The feeding source (line feeding) is located at one of the corner to reduce the number of parameters to be changed. Moreover, theoretically the top feeding configuration allows the generation of a traveling wave and it ensures broad impedance characteristics [7]-[8].

The antenna is made of a thin conducting wire of width w etched on a substrate whose thickness is t. It has a side l (hence a perimeter $L=3*l$) and a gap of width Δs placed at the distance s from the corner where the feeding source is located.

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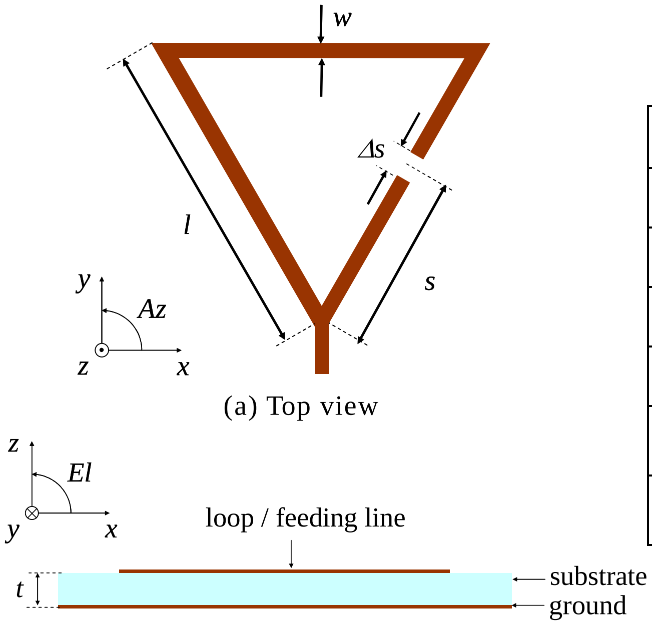


(b) Side view

Fig. 1 Analyzed model

Table 1. Antenna parameters

Designation	Parameter	Value
Wire length	l	40.78 mm
Wire width	w	5.00 mm
Gap location	s	30.00 mm
Gap width	Δs	3.00 mm
Substrate thickness	t	1.60 mm
Relative permittivity	ε_r	2.17

4. Calculated results

The Method of Moments (MoM) has been chosen for the analysis for its asset of fast calculation. Owing to the software characteristics, the dielectric substrate and the ground plane are considered to be infinite for both single element and array. As the microstrip line antenna is backed by a perfectly conducting ground plane of an infinite extent acting as reflector, this antenna can be handled by the method of image in the following discussion.

4.1. Conditions for circular polarization

A loop antenna needs to have a traveling wave current distribution which has constant amplitude and a linearly changing phase to radiate a circularly polarized wave. The circular loop can radiate a circularly polarized wave by means of loading a reactance of an appropriate value [9]. Instead of loading an appropriate reactance, to have a gap is a very simple method [6] and it is clarified here that suitable parameters for the perimeter of the wire, the gap position and the gap width exist to radiate a circularly polarized wave. Moreover, to have a gap is considered to load very large impedance.

An interesting point should be noted here when using the proposed model. The direction of circular polarization can easily be changed from the left to the right and vice-versa by simply changing the position of the gap to its symmetric with respect to the location of the feeding point.

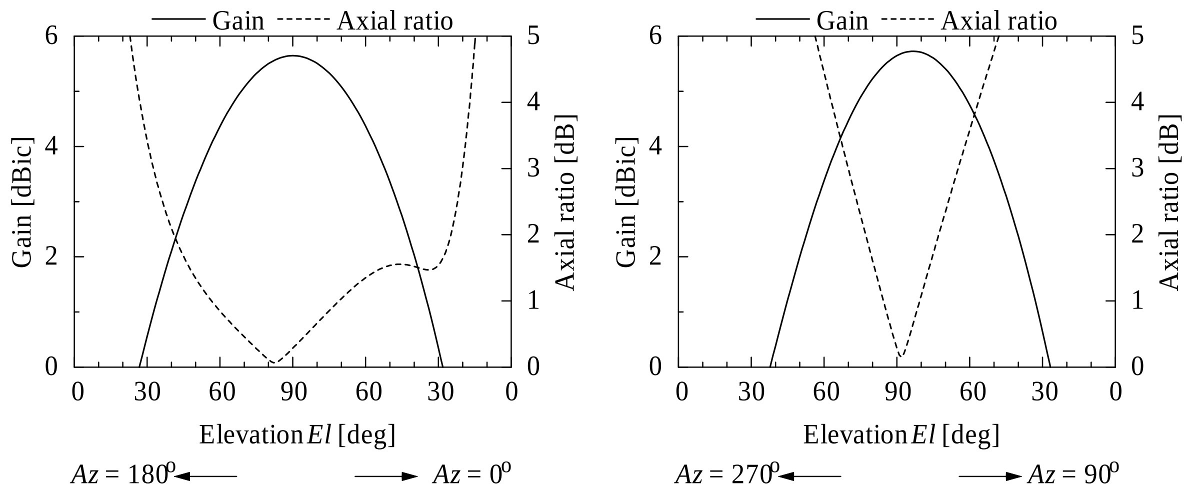
4.2. Wire parameters

The parameters of the wire considered this time, deduced from the variations of the perimeter, the gap location and the gap width not shown here for the sake of brevity and that would be described during the presentation, are as summarized in Table 1. It should be noticed here that the feeding line is not optimized.

4.3. Gain and axial ratio in the constant *Az* plane

Fig. 2 shows the gain and axial ratio with respect to the elevation *El* in the *xz* and *yz* planes, respectively. From Fig. 2(a) and (b), the gain in the upward direction is 5.65 dBic in both planes while the minimum axial ratio is 0.29 dB along the *z*-axis in both planes.

The discrepancy in the symmetry of the axial ratio in the right part of Fig. 2(a) is explained by the presence of the gap and the effect of the edges on the current distribution. Although it is difficult to explain the mechanism of the axial ratio qualitatively because of the complicated mutual coupling between the triangular microstrip line antenna and its image, the change in the axial ratio is closely related to the behavior of the current distribution. At the edge of the triangular wire as well as on both sides of the gap, a retrogressive current, causing the total current distribution to be a standing wave form together with a progressive current, deteriorates the axial ratio, because the rotational sense of a circularly polarized wave radiated from the retrogressive current traveling towards the input of the wire (feeding source) is opposite to that of a circularly polarized wave radiated from the progressive current traveling from the feeding source towards the gap.



(a) *xz* plane (b) *yz* plane

Fig. 2 Antenna performances in the azimuth plane

4.4. Verification of beam-switching in the azimuth space

In order to check the possibility of beam-switching with the model proposed above, an array of three elements shown in Fig. 3 is considered. This array consists of the previously discussed single element duplicated three times and sequentially rotated of 120°. The gap is located outwards compared to the center of the array so that it does not have any adverse influence on the adjacent elements hence decreasing the performances.

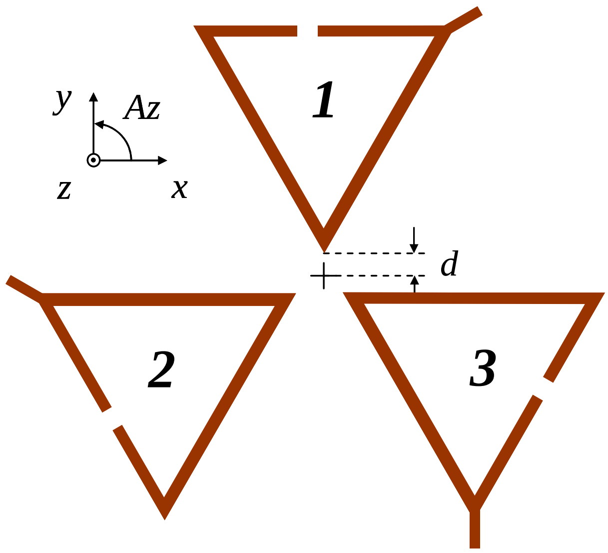
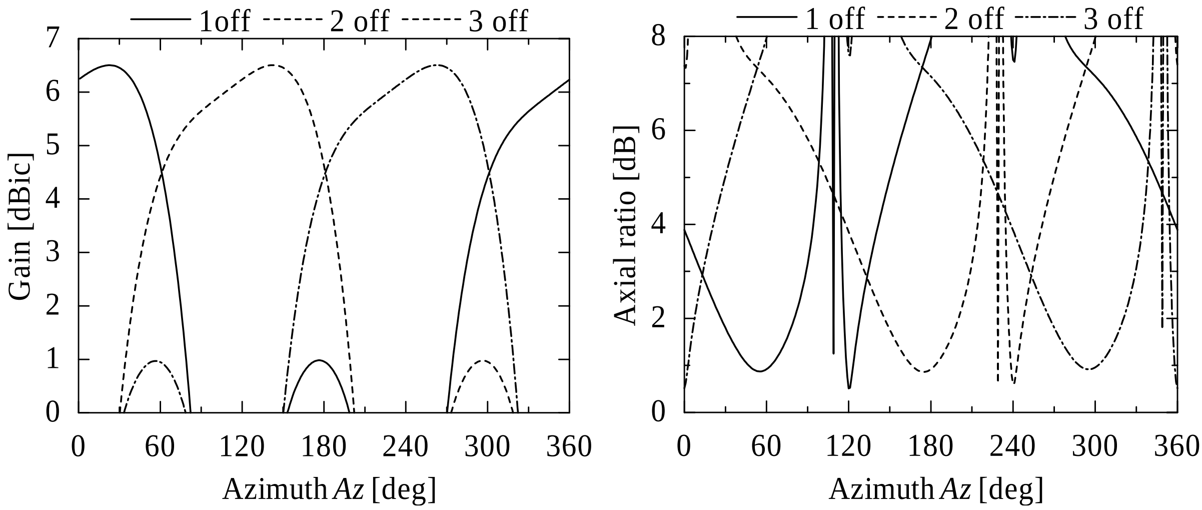


Fig. 3 3 elements array antenna

Fig. 4 shows the gain and axial ratio performances in the azimuth space when each element from 1 to 3 is successively turned off for *El*=48°. The distance *d* between the center of the array and the tip of each triangle is set to 12 mm.

From Fig. 4(a), the peak gain is 6.23 dBic and the proposed antenna can scan the azimuth space with a minimum gain of 4.63 dBic which is close to the target value of 5 dBic. From Fig. 4(b), the minimum axial ratio is 0.87 dB. However, the generated beam has a maximum axial ratio of 7.12 dB over the whole azimuth space thus it does not meet the target of 3 dB yet. This fact is considered to be due to the influence of the mutual coupling between feeding lines which are not optimized. Hence it can reasonably be thought that when the feeding lines are optimized, the mutual interaction between lines and elements is decreased thus improving the axial ratio and the minimum gain as well.



(a) Gain (b) Axial ratio

Fig. 4 Beam-switching in the azimuth plane

5. Conclusion

In this paper, a simple triangular microstrip line antenna with a gap, able to generate a circular polarization, has been proposed and analyzed by numerical simulations. The circular polarization can be simply obtained by properly adjusting the wire parameters as proved by the radiation characteristics of a single element that has a minimum axial ratio of 0.29 dB in the upper direction. Then an array of three elements has been realized and the possibility of beam-switching in the azimuth space with a minimum gain of 4.63 dBic has been confirmed still by use of numerical simulations.

In the next step, the effect of the edge of the triangle on the current flow will be accounted for to optimize the gain and axial ratio performances. In addition, the feeding line will be optimized to diminish its adverse effect on the array hence improving the gain and axial ratio performances.

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