Evaluation of Interaction Effect between LEO Ground Station Antennas

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Abstract

The purpose of this paper is evaluation of radiation pattern interaction and input impedance coupling between two adjacent ground station antennas in different frequency bands. Thus the antennas were simulated in different distances. Then a reliable relative distance for proper radiation performance, with acceptable characteristics degradation (in communication link), was defined. NEC-pro Software was used as the solution code for the antenna structure modeling.

1. INTRODUCTION

In general the interaction between antennas, in spatial, angular and polarization correlation [1], was discussed strictly in assessment of the array antenna functionality, including excitation, distances and configuration of elements. The very first analysis of the performance of an array of antennas (zeroth order solution) may simply ignore the effect of coupling between the elements of array [2]. A necessary condition for complete decoupling and descattering is power orthogonality between the patterns of the individual antennas [3].

Mutual coupling between identical array elements was calculated from far-field radiation [4]. One method for modification of classical approach by multiplication of a decoupling matrix was presented to compensate the mutual coupling effect in phased array antennas [5]. Also the possibilities of connecting a lossless network between input ports and antenna ports, so that there is no coupling and scattering between the antennas, are discussed [3].

In this work, the antennas of a ground station for a LEO satellite were evaluated, which consists of two antennas for two narrow frequency bands in VHF and UHF. To create a directional pattern with over than 10 dB gain with circular polarization in original direction, a cross yagi and a quadrifilar helical antenna (QHA), according to fig. 1, was recommended for two bands respectively. Also a dual-band turnstile antenna with quasi-hemispherical coverage patterns was proposed to be installed on the satellite.

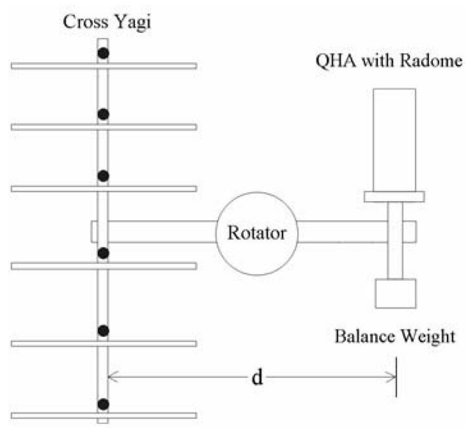

Fig. 1. Installation of ground station antennas on tracking system rotator

In a similar work, mutual coupling between two loop antennas mounted on the helicopter at the HF band was analyzed with NEC software [6]. In another work, a multitude of collocated VHF and UHF antennas, (in different configurations) were installed on a common mast, with the need for minimal coupling and the consequent interference between them [7]. Also, in satellite application, the coupling between elements of array and mounting platform of satellite has been evaluated [8]

In the literature, the use of cross polarization in different frequency elements for minimizing the mutual coupling has been recommended [9], but in this work, both of the antennas possess right hand circular polarization for matching with the satellite antenna.

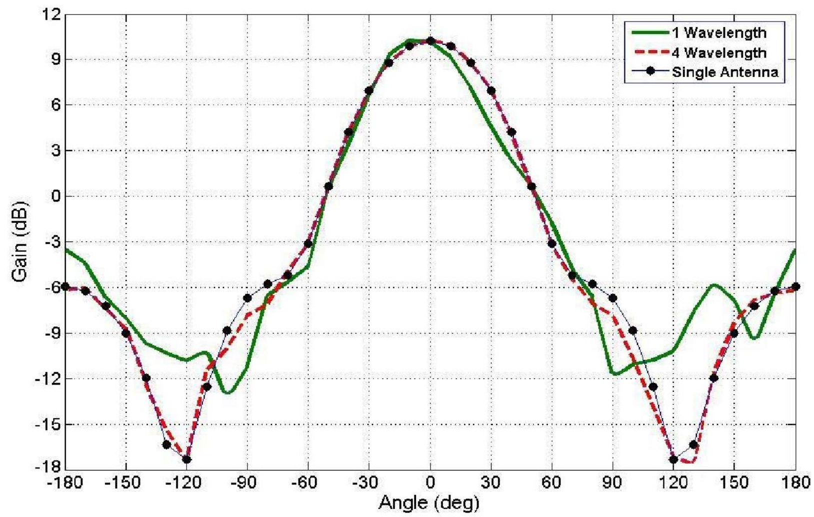

Fig. 2. Comparison of θ plane pattern for single QHA and with 1 and 4 wavelength distances

2. SIMULATIONS AND RESULTS

At the first step, as usual, each one of the antennas was designed and tested separately and then installed on the tracking system. Thus both of the antennas were designed and then the effect of each one was assessed as a main parasitic element in the near-field of the other one.

Therefore (For this reason), a 6+6 element cross yagi in 137 MHz and a 4.5 turn QHA in 400 MHz are designed as small as possible and with proper impedance characteristics which shall be matched with the 50Ω transmission line.

The considerable effect of this vicinity was observed on degradation of pattern symmetry of φ plane and axial ratio (AR) of polarization, which increase with distance reduction. Since the UHF antenna is smaller than the other antenna, the interaction effect in cross yagi is less and negligible. Thus in the following section, only degradation effects on QHA antenna are considered.

2.1. Pattern degradation

The θ plane patterns of QHA for 1 and 4λ distances between antennas (d) and also single antenna are shown in fig. 2.

The main lobe of pattern is tilted to the other parasitic antenna structure, but with increase in distance, the pattern converges to the single antenna pattern shape, as is shown in fig. 2 (for the 4λ curvature). In addition, the radiation pattern in φ plane (for θ=30deg) is shown in fig. 3, for the 75 cm distance between antennas which is the minimum possible physical distance.

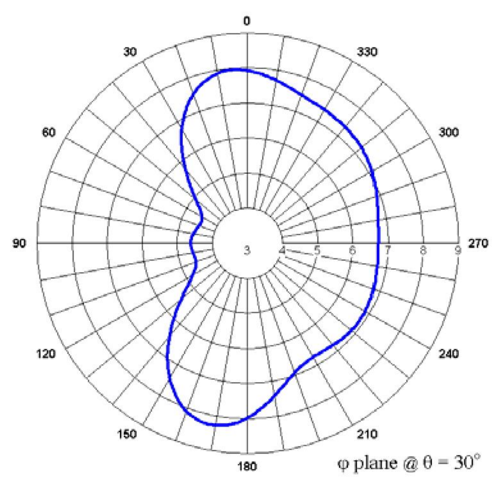

Fig. 3. QHA pattern in φ plane (θ = 30°)

The single antenna pattern shape is symmetrical and pattern declination arises from the effect of the other antenna.

2.2. Polarization degradation

As mentioned before, the polarization quality is one of the interaction effect's sensitive points. The AR curvatures for QHA, single and with parasitic in 75 cm distance are shown in fig. 4.

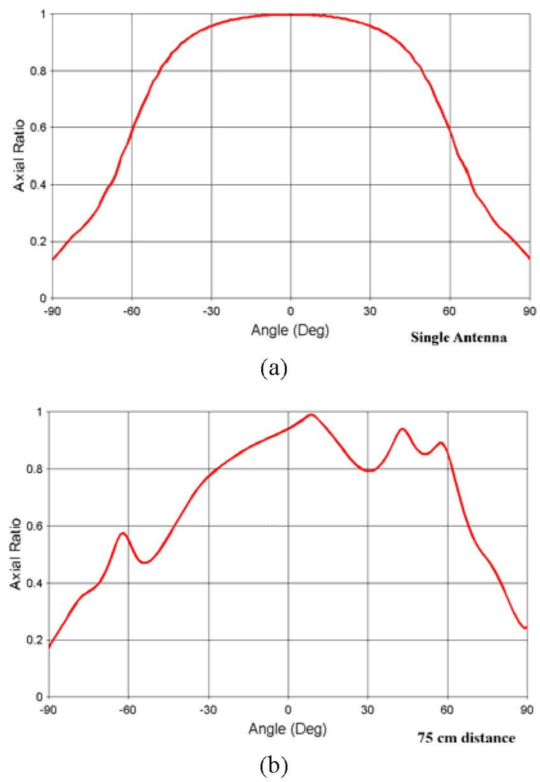

Fig. 4. AR of QHA: (a) single and (b) with parasitic in 75cm distance

The polarization loss (PL) due to the polarization degradation effect calculated from (1) in dB, by considering a pure circular polarization in transmitter antenna.

$$PL \cong 3 - 20\log\frac{1+AR}{\sqrt{1+AR^2}} \tag{1}$$

Where AR, the ratio of small diameter to large diameter of polarization ellipse, is between 0 and 1. Based on relation (1), variations of RL with respect to AR are shown in fig. 5.

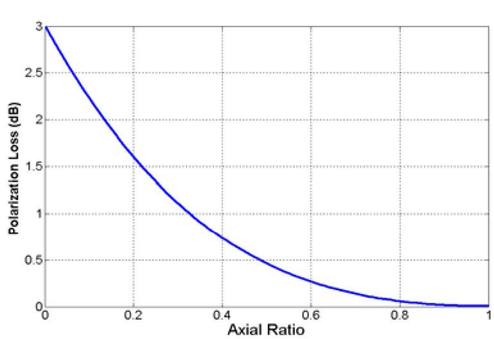

Fig. 5. Variations of RL with respect to AR

As is shown in fig. 5, variation of PL in two AR curvature in θ=30deg (in fig. 4), from .96 to .77, is less than 0.1 dB.

2.3. Proper distance for acceptable degradation

By numerous common simulations of antennas and by considering a threshold for acceptable degradation, minimum authorized distance between antenna structures is achievable. This threshold was defined based on the tolerance to variations in total performance. In this case, for asymmetry lower than 1 dB (in φ plane & θ=30deg), minimum distance is 1.70 meter (equal to 2.27λ in UHF). For this distance, the maximum asymmetry of cross yagi pattern is about 0.07 dB. Also, the PL variation of QHA is less than 0.004dB in this distance.

The vicinity effect for all possible distance variations range on input impedance is limited and as a result the VSWR variations become lower than 1.1. Consequently, the transmit power percentage is over 99.8% [10].

A recent study reported that it is possible in some cases to maximize the radiation and minimize the scattering properties with a suitable choice of impedance loads [11]. In this paper only the effect of interaction between the antennas was evaluated and the effect of rotator, arms, balance weight, pedestal, and variations of antennas position relative to ground plane, during the complete tracking of satellite, were not simulated.

3. CONCLUSION

Results illustrate that the main effect of interaction is on radiation pattern and in lower terms on polarization; and this effect on input impedance and consequently on VSWR is not significant and negligible. Also comparison of simulation result show that the effect of the low frequency antenna is dominating, because of the larger size and consequently stronger scattering effect. In this application, for distances over 2.3λ (in higher frequency) the interaction effect on communication link degradation is negligible with acceptable accuracy.

4. ACKNOWLEDGMENT

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