Analysis of DVB-T Reception Results Using a Slight Steering Technique of the Antenna Radiation Diagram

V.S.G. Tsiafakis, Y.J. Petropoulos, C.D. Lampiris and C.N. Capsalis

Abstract – **The aim of the present study is to present a new technique in order to improve the receiving Terrestrial Digital Video Broadcasting (DVB-T) signal in portable reception, using a slight steering of the antenna radiation diagram. It seems that the proposed technique moderates the reception quality differences at different points of the coverage area, increasing the total number of the DVB-T users.**

Keywords – **DVB-T, portable reception, transmitter, steering radiation diagram.**

I. Introduction

After the completion of the Geneva '06 agreement [1] an enormous growth of the DVB-T market followed in all the involved countries. In order to achieve the switch off deadlines of the agreement, the countries redesigned their television networks by using the advantages of the digital television [2]. In most of the cases the records in Geneva '06 plan concern allotment networks. Taking into account that allotment is the entry of a designated frequency channel in an agreed plan under specified conditions [3], the allotment designed networks should now be transformed into assignment networks with real transmitter characteristics and be in conformity with the Geneva '06 provisions.

In order to achieve this consistency, the assignments stemming from allotments have to use low transmitter power. The complexity and the long duration of the coordination procedures, that are included in GE06 Agreement, make the use of low power transmitter necessary [4]. Especially in the Balkan area, where terrestrial television market is evolving and the television networks of the neighbouring countries are not coordinated on a common basis, network operators should come to solutions in the next few years. The terrain abnormalities such as the mountainous ground, the warm sea, the highly scattered towns and villages and the fulfilled spectrum will make their efforts much more difficult. Network operators are searching for technical solutions that will provide better signal quality for larger coverage areas and improved Quality of Service (QoS) so that customers will benefit from the DVB-T protocol; especially in portable reception.

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Designing a television network by using low power transmitters may overtake a lot of the aforementioned difficulties.

The aim of this study is to improve the reception signal in areas, where the minimum wanted field strength is not achieved, using a slight steer of the transmitter's antenna diagram. This new technique was applied to a DVB-T transmitter network for the coverage of a hypothetical population of users placed at a region simulated with high resolution cartographic data. The minimum required E field and the signal to noise ratio (C/I) were calculated at the position of each user for three steering angles of the transmitter. Computer simulations and result analysis show that there was an increase of the E field and the C/I in areas with poor reception signal, whereas a slight decrease of these magnitudes was calculated at the areas with good reception signals. The proposed method can obtain indoor or outdoor portable reception of DVB-T signal in areas where this is difficult to achieve, due to demanding propagation conditions, using the same technical characteristics with the fixed reception.

The structure of the present study is the following. The methodology of the study which is divided into three subsections (a, b and c) is presented in Section II. The cartographic data, the propagation model and the measured population are described in subsection a. Transmitter network and antenna characteristics are presented in subsection b and the calculation method is analysed in subsection c. The results of the study are presented in Section III. Finally concluding remarks and discussion on the efficiency of the method are given in Section IV.

II. Methodology

The application of the Slight Steering Technique, which is described in this study, concerned the coverage of a hypothetical city, using high resolution cartographic data, specific propagation models and a DVB-T transmitter network with certain antenna characteristics. The features of the simulation methodology are analysed in the next paragraphs.

a. Cartographic data, Propagation model and Population

In the present study, high resolution cartography was used in order to simulate portable reception in urban environment. Modern radio frequency planning tools require the use of analytic cartographic environment for the simulation of DVB-T technology because these data contain information about both the altitude above sea level and the ground accuracy above the terrain, which is called clutter[5]. All objects, which could cause an alteration to the propagation environment, such as buildings and trees, are modelled (Fig. 1).

Another critical issue for the use of high resolution cartographic data concerning the network plan and the simulation of the electromagnetic field is the propagation model. Empirical models simulate, using mathematical formulas, topographical characteristics such as the heights of the buildings or widths of the streets, which are not available on the cartographic dataset. High resolution cartographic data, which include these characteristics, permit the use of deterministic propagation models, improving the accuracy of the calculations (Fig. 2) [6].

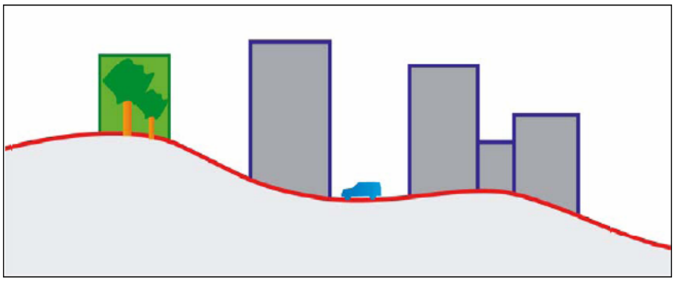

Fig. 1. High resolution cartography and simulation of the ground model with the use of clutter.

In the present study, the deterministic formula for the calculation of the free space loss, described in ITU-R P.525 [7] was used. In Line Of Sight (LOS) environments, the free space loss due to the topographic data is:

$$L_{fsd} = 20\log_{10}(d[\text{km}]) \quad (1)$$

Where: L_{fsd}= free space loss due to the topographic data
d: distance between transmitter and receiver

The LOS calculation depends also on the frequency used. The formula (1) including the parameter frequency is as follows:

$$L_{fsd} = 20\log_{10}(f[\text{GHz}]) + L_{fsd} + 92.5 \quad (2)$$

For the calculation of the diffraction effects the ITU-R P.526 recommendation with Deygout method was used [8]. In the Deygout diffraction method two obstacles are considered, the primary in the line of sight of the transmitter and the secondary in the line of sight of the receiver. This method is slightly optimistic but with the calculation of the sub-path attenuation effect – or the ground reflection attenuation L_{gr} – more deterministic predictions can be obtained. Sub-path attenuation losses were also calculated with ITU-R P.526.

The population of the city consisted of one hundred and twenty (120) separate users – subscribers, which were positioned in the buildings randomly by the software. The users were divided in three groups in proportion to their position in the city which has an effect on both the median value of the received electrical field strength and the median value of the C/I ratio. The first group, named "GROUP1", was located in the region with the best average values of C/I and $E_{med.}$ The other two groups ("GROUP2" and "GROUP3") were situated at regions with descending values of C/I and E_{med} (Fig.3). The measured population was considered to receive the electromagnetic signal with isotropic antennas with no additive receiver gain (Rx).

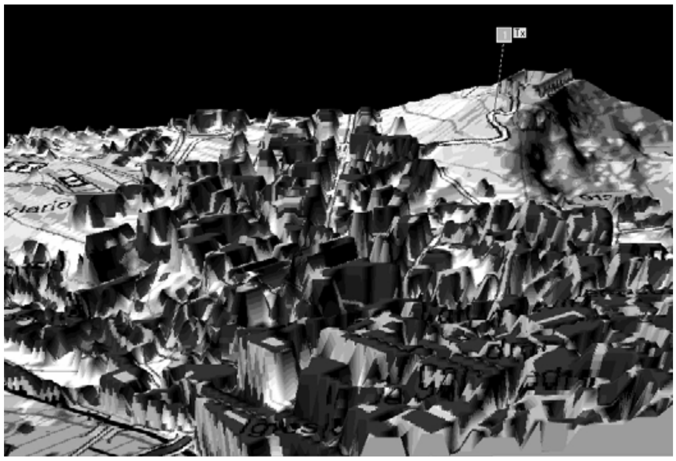

Fig. 2. 3D representation of the transmitter site and a part of the city

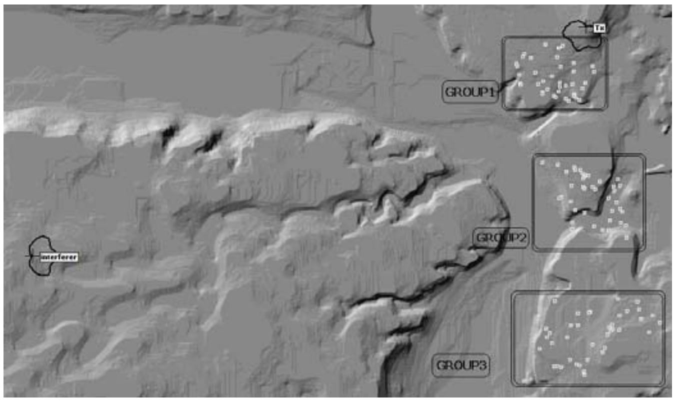

Fig. 3. A panoramic view of the elevation map, the network of the DVB-T transmitters and the population of the city divided into 3 Groups.

b. Transmitter network and Antenna Characteristics

The transmitter network included two transmitters, operating at the same frequency channel, so that the one caused harmful interference to the other [1]. The wanted transmitter (Tx) was placed near the city with small effective height [9] while the second transmitter (interferer) was placed on the top of a mountain in order to cover the suburbs and part of the city. Both transmitter sites had 30m antenna height and were operating at 474MHz frequency (21st channel – Europe zone [3]).

The proposed slight steering antenna technique concerns commercial antennas for the transmission of the television signal. Almost all UHF transmission antennas use panels as basic elements which have the same characteristics, concerning the horizontal and vertical pattern, regardless the manufacturer. Usually the transmitter antenna consists of antenna panels pointing to one up to four different directions. The transmitter radiation diagram depends on the diagrams of each panel. The realization of a specific horizontal diagram, using panels, has many limitations due to their single horizontal diagrams (Fig.4).

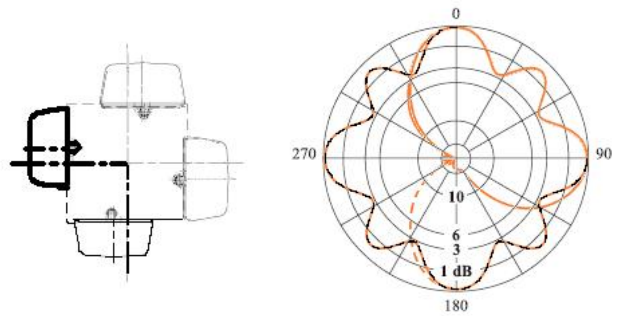

Fig. 4. Ground plan of antenna structure consisted of panels and their horizontal antenna diagrams respectively.

In the present study the slight steering antenna technique was applied to a typical television transmitter, with a radiation angle of the main lobe set at 90°. The transmitter consisted of two panels positioned in a 90° angle with respect to each other and the horizontal diagram is as shown in Fig. 5. The disadvantages of this diagram can be summarized to the almost 3 dB attenuation of the antenna gain at specific azimuths and the difficulty to increase the radiation angle

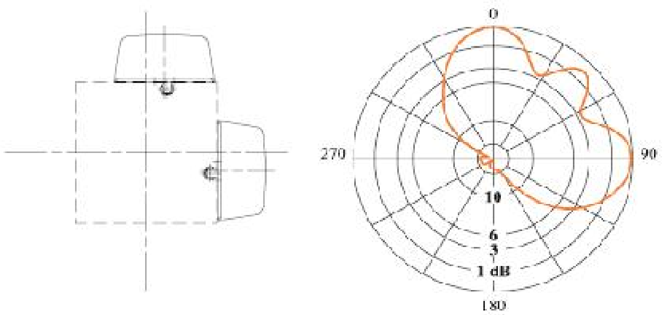

Fig. 5. Ground plan of antenna structure consisted of two panels positioned in a 90° angle with respect to each other and the produced horizontal antenna diagram.

C. CALCULATIONS

The calculations were made [10], at a height of 1.5m over the ground level for portable type of reception. All users (subscribers) were placed at the same height (1.5m) above ground level, inside the simulated buildings. The advanced technique "Rx over ground spot" was used in order to calculate the wanted E_{med} for each subscriber inside the buildings. This technique calculates both the field strength that derives from the clutter and the building attenuation and also the field strength as a result of the diffraction on the edges of the building (Fig. 6).

The magnitudes of E field (dBμV/m) and the C/I ratio (dB) were calculated for each user, for three steering angles (φ=±5°, ±15° and ±25°) and also for the stable transmitter (φ=0°). The average of these values for each group and for the total of the users was also calculated.

Each user's data were normalized according to the following procedure. The differences (D_{perf}) between the values for the stable transmitter and the steering condition were calculated for each steering angle, for each user. These differences depend on the attenuation of the antenna gain at specific azimuths due to the steering.

In order to take into account this relation, the maximum differences (D_{ant}) of the antenna attenuation, between the stable and each steering condition were calculated. The ratio between D_{perf} and D_{ant} represent the performance of the proposed technique independently of the characteristics of the shape of the antenna diagram.

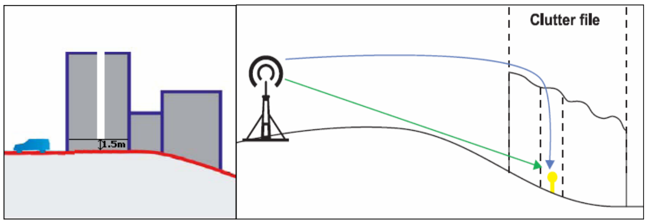

Fig. 6. Advanced method in order to calculate the E field inside buildings and clutter layer of high resolution cartographic data.

III. RESULTS

The Field Strength (E) and the C/I ratio of each user, when the transmitter is stable, are shown in Figs. 7 and 8 respectively. The values are higher for Group 1 which is closer to the transmitter.

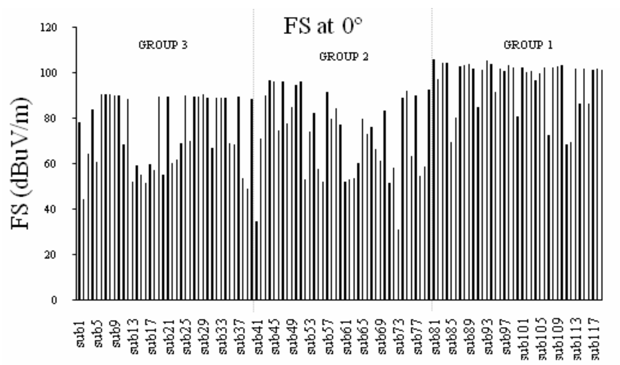

Fig. 7. The Field Strength (E) of each user, when the transmitter is stable

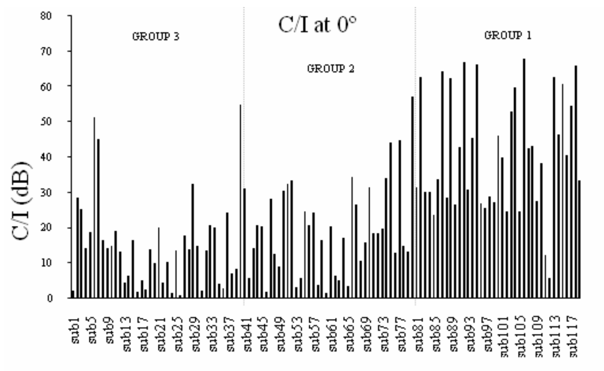

Fig. 8. The Signal to Noise ratio (C/I) of each user, when the transmitter is stable

The average values of E and C/I for the four angle values (0°, ±5°, ±15° and ±25°) are presented in Tables I and II, for each Group of users. A progressive decrease of the values is noticed for Group 1 as the steering angle increases, while the opposite is noticed for Groups 2 and 3.

TABLE I
THE AVERAGE VALUES OF E FOR THE FOUR ANGLE VALUES (0°, ±5°, ±15° AND ±25°)

E (dBuV/m)				
	MEDIAN VALUE AT 0°	MEDIAN VALUE AT 0° AND ±5°	MEDIAN VALUE AT 0° AND ±15°	MEDIAN VALUE AT 0° AND ±25°
Group 1	99.63	99.63	99.64	99.59
Group 2	84.10	84.18	84.65	84.93
Group 3	83.23	83.31	83.80	84.12
ALL	92.49	92.51	92.64	92.67

TABLE II
THE AVERAGE VALUES OF C/I FOR THE FOUR ANGLE VALUES (0°, ±5°, ±15° AND ±25°)

C/I (db)				
	MEDIAN VALUE AT 0°	MEDIAN VALUE AT 0° AND ±5°	MEDIAN VALUE AT 0° AND ±15°	MEDIAN VALUE AT 0° AND ±25°
Group 1	58.80	58.78	58.74	58.66
Group 2	41.74	41.84	42.43	42.80
Group 3	40.82	40.83	40.96	40.99
ALL	54.18	54.16	54.14	54.07

Figs. 9 to 14 show the percentage (%) of the performance of the proposed technique for both E and C/I, as described in the calculation section. The negative values represent the reduction of the measured values in comparison to the stable transmitter condition. Table III shows the best performance of E and C/I of the steering technique for the three angle values (±5°, ±15° and ±25°), for all Groups of users.

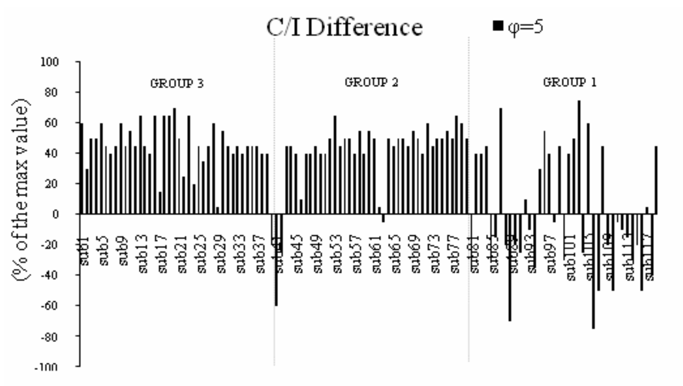

Fig. 9. The percentage (%) of the performance of the steering technique for C/I at φ=5°

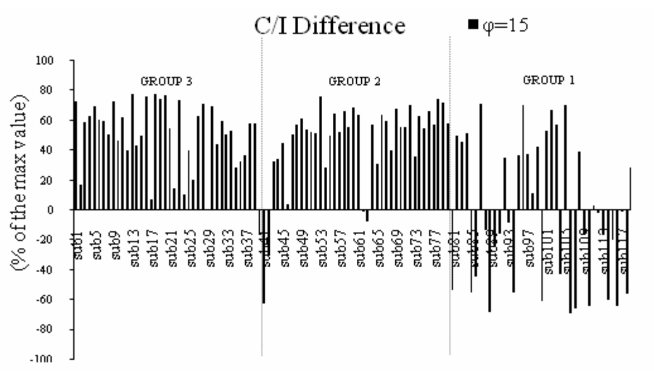

Fig. 10. The percentage (%) of the performance of the steering technique for C/I at φ=15°

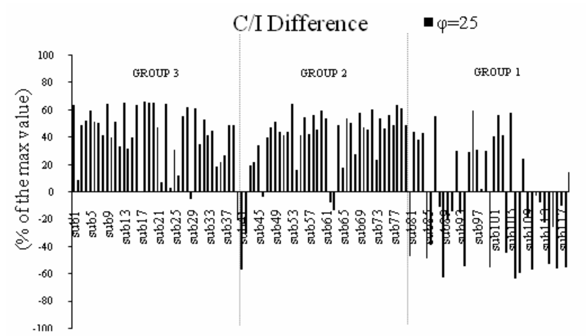

Fig. 11. The percentage (%) of the performance of the steering technique for C/I at φ=25°

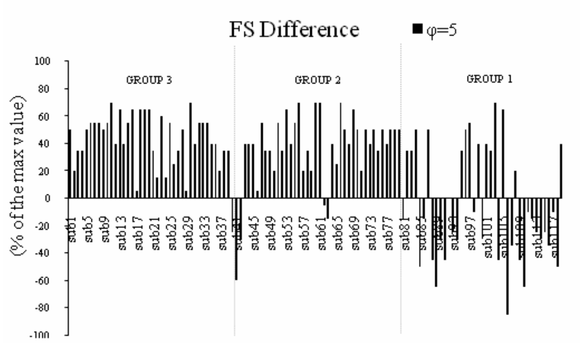

Fig. 12. The percentage (%) of the performance of the steering technique for E at φ=5°

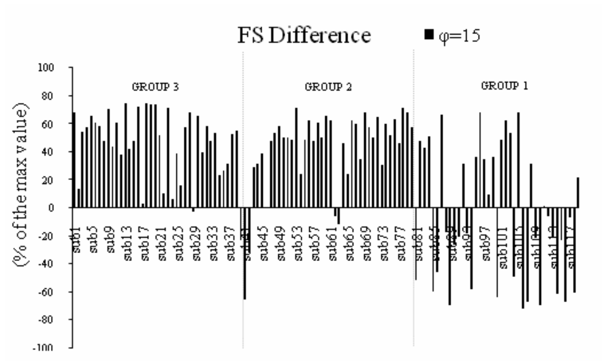

Fig. 13. The percentage (%) of the performance of the steering technique for E at φ=15º

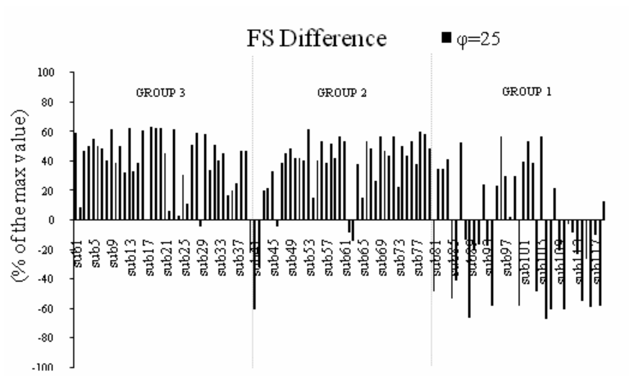

Fig. 14. The percentage (%) of the performance of the steering technique for E at φ=25º

TABLE III
THE BEST PERFORMANCE OF E AND C/I OF THE STEERING TECHNIQUE FOR THE THREE ANGLE VALUES (±5°, ±15° AND ±25°) AND FOR ALL GROUPS OF USERS

Maximum Performance (%)			
	STEERING ANGLE ±5°	STEERING ANGLE ±15°	STEERING ANGLE ±25°
E	85	75	68
C/I	75	77	65

The users of each group were divided into three categories according to the negative or positive (increase, constant and decrease) results of the steering technique. The number of users of each division is presented in Tables IV and V. Only for the 25% of the users the measured values of both C/I and E were decreased in comparison to the stable transmitter condition. None or one user stayed constant to the original values.

TABLE IV
THE NUMBER OF USERS OF EACH CATEGORY ACCORDING TO THE RESULTS OF THE E OF THE STEERING TECHNIQUE

E									
	±5°			±15°			±25°		
	Inc	Con	Dec	Inc	Con	Dec	Inc	Con	Dec
Group 1	39	0	1	38	0	2	37	1	2
Group 2	36	0	4	35	1	4	35	0	5
Group 3	14	1	25	17	0	23	16	0	24
ALL	89	1	30	90	1	29	88	1	31

TABLE V
THE NUMBER OF USERS OF EACH CATEGORY ACCORDING TO THE RESULTS OF THE C/I OF THE STEERING TECHNIQUE

C/I									
	±5°			±15°			±25°		
	Inc	Con	Dec	Inc	Con	Dec	Inc	Con	Dec
Group 1	39	0	1	38	1	1	37	1	2
Group 2	37	0	3	36	0	4	35	0	5
Group 3	16	0	24	17	0	23	16	0	24
ALL	92	0	28	91	1	28	88	1	31

IV. CONCLUSION AND DISCUSSION

In this paper, a slight steering antenna technique was presented. The free space model was replaced by a deterministic model with high resolution data for modelling a city. The fortuity of the position of the DVB-T users in combination with the accurate model of the city leads to a wide range of E_{med} and C/I values. This is the challenge that network designers face in large population regions, where “good” and “poor” reception areas coexist.

The slight steering technique does not change the technical and physical characteristics of the transmitting antenna, although there is a remarkable increase of the coverage. This is of great importance since otherwise the additional cost for the broadcasters might be unreachable. The results of this paper, point at an increase of the field strength for the users that have “bad” signal reception (group2 and group3) and also a decrease for the users that have “good” signal reception (group3). This could be an important outcome due to the fact that the reception quality differences at different points of the coverage area are moderated because the proposed technique flattens the ripple of the antenna diagram.

Another important observation is that the increase of φ doesn't entail improvement of E_{med} and C/I in all conditions, since this improvement depends on the complexity of the urban environment. This remark indicates that the exact parameters of steering technique depend on the position of the covered area and the difficulties to cover a city using low power transmitters.

New technology of interactive DVB-T in combination with the proposed technique can lead to the design of smart networks. These networks can use parameters such us FS, C/I and their standard deviation respectively from each user and dynamically change their antenna diagram in order to achieve better signal quality and QoS. The proposed technique does not require expensive changes on the hardware of the transmitter nevertheless achieves remarkable results. Even established DVB-T networks can take advantage of these results and cover new areas and suburbs of the uninterruptedly growing cities. Finally, the implementation of the proposed technique in other protocols and services that use directive antennas may lead to similar results.

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