Array 안테나를 이용한 위성전화신호의 검출 방법

A Novel Detection Method of the Satellite Phone Signal based on Array Antennas

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요 약

위성통신시스템은 넓은 커버리지를 바탕으로 광범위한 지역에 통신을 가능하게 하는 장점을 가지고 있다. 그러나 위성통신 시스템에 할당된 주파수 대역의 사용률은 셀룰러 시스템과 같은 다른 무선통신시스템과 비교할 때 상당히 낮은 효율을 보인다. 그러므로 할당된 주파수를 이용하여 부가적인 서비스를 제공하고, 주파수 효율을 높이기 위한 방법들이 연구되고 있다. 본 논문에서는 허가 대역에서 새로운 서비스를 적용할 수 있는지에 관하여 분석해보고, 새로운 서비스를 적용하기 위하여 가장 중요한 부분인 위성 터미널의 신호를 정확하게 검출하는 방법을 제안한다. 제안하는 방법은 간섭을 회피하기 위하여 Spectrum Sensing과 Eigenvalue 검출하고, 결론을 통하여 터미널의 신호를 검출하고 성능을 분석한다.

Key Words : Satellite Mobile Phone, Spectrum Sensing, Cognitive Radio

ABSTRACT

The Satellite Mobile Communication System holds several advantages, such as wide coverage that guarantees the communication in a huge area. It is suitable in the ocean and forest and especially in emergency situation. However, the licensed frequency is not always occupied within all coverage and all the time. The actual utilization rate is relatively low compared to other wireless communications such as cellular systems. There are a large amount of white spaces in its coverage. Therefore, it is necessary to consider introducing additional services such as data communication, in order to increase the spectrum utilization as well as the revenue of the Satellite service provider. In this paper, we first analyze the possibility to implement new services in the licensed band of satellite mobile phone by its provider. Then we address the most significant issue for the implementation of current service, which is how to accurately detect the satellite mobile terminals. Finally, we suggest two new possible solutions namely, eigenvalue detection based methods to find out the existence of transmitted signal from the satellite mobile terminals.

I. Introduction

Satellite communication system has been launched when U.S MARISAT of COMSAT begin to support communication to ships on the ocean in 1976. After that, INMARSAT (International Maritime Satellite Organization) was established in 1979. Worldwide satellite communication has been served since 1982 and second generation INMARSAT provides airway and ground mobile communication service in late 1990s.[1] It can bring communication to any place where we can place on the earth station without any need for terrestrial cable or radio links, which is particularly useful for sparsely populated area.[2] Using characteristic of satellite system – broad service range, small fringe area, tolerance to disaster and etc – to provide personal mobile communication service, many kinds of system has been launched in 1990’s.

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One of the systems which employ a satellite service system of LEO (Low Earth Orbit) satellites based on proven technologies. The satellites circle the globe, routing calls and data through service provider’s owned and operated gateway in conjunction with existing PSTN (public switched telephone network) / PLMN (Public land mobile network) terrestrial networks[3]. Another one is Iridium, which was launched on November 1, 1998. It requires 66 active satellites in orbit to complete its constellation, with sparse satellite in orbit to fill in case of failure. Satellites are in low Earth orbit at a height of approximately 485 miles (780Km). It is unique that it covers the whole earth, including poles, oceans and airways.

Table 1. Number of Subscribers

	2003	2004	2005	2006
Iridium	90,890	112,700	137,500	169,000
Globalstar	109,503	141,450	195,968	262,802

Table 1.[4] indicates number of subscribers of two satellite systems. In 2006, sum of two satellite subscribers in these are almost 430,000. Satellite communication system covers whole earth around 148,940,000 Km^2. It means 0.2 person locates per 100 Km^2. To guarantee a small number of satellite communication subscribers, spectrum resource is allocated, which causes low spectrum efficiency. In this paper, we propose the detection and avoidance method using array antenna.

This remain of this paper consists of four parts. Part 2 describes system model, part 3 shows the proposed model and the proposed scheme for interference avoidance. Part 4 is simulation result and its analysis. Finally, we make a conclusion in part 5..

Ⅱ. System Model

As we mentioned in previous part, spectrum sensing for detection and avoidance will be touched in this part. Furthermore, we will consider terminal to satellite (uplink) link. Considering the satellite phones in the satellite system, when some phones are not active or far from, there is an area where other communication services can be provided on the same frequency bands without causing the interference to the satellite phones, which is denoted as the dark area in the Figure. 1. When the satellite terminals want to provide other communication services, the first thing is to perform the spectrum sensing of the observed frequency band. For the case that access points exist in the satellite system in Figure. 1, we consider they can utilize the multi-antenna structure to perform the spectrum sensing. Due to the good performance of the sensing technology using array antenna, the sensing result is should be accurate and reliable, which ensure a large dark area in the figure. If the sensing result shows the absence of active satellite phones in the neighborhood, they will adapt into the point-to-multipoint communication links to provide other communication services without making the interference to the existing satellite phones in the system, which can improve the spectrum efficiency largely under this reliable sensing.

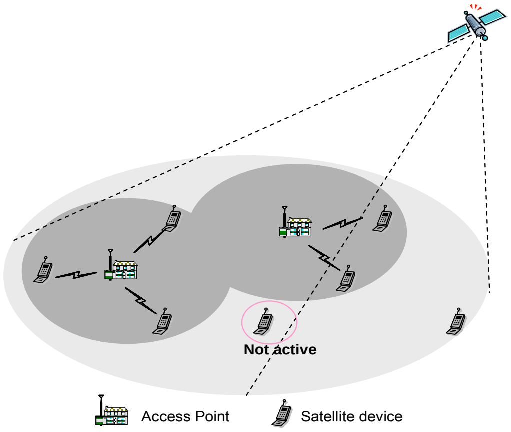

Figure 1. Point-multipoint communication in multi-antenna Access Point networks

Ⅲ. Spectrum Sensing for Interference Avoidance

Spectrum sensing has been studied as one of the most important functions in Cognitive Radio[5]. In this paper, we introduce an advanced eigen-value sensing method to detect the existence of satellite mobile phone signal.

Due to the complexity limitation in the terminals, we select the 4-element linear array antenna in each terminal. The received signal $x_i(n)$ at each terminal transmitted by D transmitters is modeled as where the element $a_m(\theta i)$, called the array manifold contains the phase information of the i th (i=1,2,..,D)

$$X=\begin{bmatrix} x_1(n) \\ x_2(n) \\ x_3(n) \\ x_4(n) \end{bmatrix}_{4\times1} = \begin{bmatrix} a_1(\theta_1) & a_1(\theta_2) & \cdots & a_1(\theta_D) \\ a_2(\theta_1) & a_2(\theta_2) & \cdots & a_2(\theta_D) \\ a_3(\theta_1) & a_3(\theta_2) & \cdots & a_3(\theta_D) \\ a_4(\theta_1) & a_4(\theta_2) & \cdots & a_4(\theta_D) \end{bmatrix}_{4\times D} \begin{bmatrix} s_1(n) \\ s_2(n) \\ \vdots \\ s_D(n) \end{bmatrix}_{D\times1} + \begin{bmatrix} w(n) \\ w(n) \\ w(n) \\ w(n) \end{bmatrix}_{4\times1} \quad (1)$$

signal arrived at the m th (m=1,2,3,4) antenna element. It can be expressed as:

$$a_m(\theta_i) = e^{-j2\pi\frac{d}{\lambda}m\sin(\theta_i)} \qquad (2)$$

Where d is the distance between two adjacent array elements; λ indicates the wavelength; sm(n) is the mth signal received at a CR terminal. w(n) represents the AWGN.

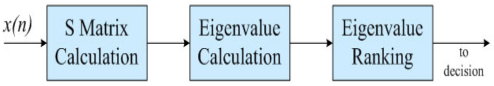

Figure 2. Block diagram of Spatial Information Extraction

The eigenvalues in which the spatial information is embedded are calculated and ranked following the procedure as shown in Figure.2.

S matrix is defined as a 4×4 covariance matrix of the received signal under the basic assumption that the incident signals and the noise are uncorrelated, as expressed in (4)

$$S = \overline{XX^*} \qquad (4)$$

Since the number of incident waveforms D is 0 or 1 depending on the existence of satellite mobile phone signal, there should be 4 eigenvalues of S matrix as proved in [6]. The minimum value will occur repeated N = 4 - D times. Thus, it is convenient to arrange the calculated eigenvalues in an increasing way. They finally form the sequence λ_i, where i=1,2,3,4, in the eigenvalue Ranking step. The expressions of the complete set of eigenvalue for both hypotheses are as follows,

$$H_0 : \lambda_i = P_n \qquad (5)$$

$$H_1 : \lambda_i = \begin{bmatrix} \lambda_1 = P_n \\ \lambda_2 = P_n \\ \lambda_3 = P_n \\ \lambda_4 = 4P_{Sat} + P_n \end{bmatrix} \qquad (6)$$

where P_n and P_{Sat} represent the power of noise and the received satellite mobile phone signal during the observation time, respectively. The number 4 in (6) indicates the number of array element.

The complete set of eigenvalues for both hypotheses is shown in Figure. 3. The left figure indicates the hypothesis H_0, in which all the eigenvalues represent the noise power in the receiver as expressed in (5).

The figure in the right illustrates the complete set of eigenvalues under hypotheses H_1, in which the largest eigenvalue represents the summation of noise power and satellite mobile phone signal power in the receiver as expressed in (6).

Since we know that λ1 through λ3 represent the power of local noise aggregated during the observation period under both hypotheses, it is able to use one of them to represent the noise power (here we select λ1).

We are interested in the difference between each eigenvalue and the smallest one, which is expressed by Ri,

$$R_i = \lambda_{i+1} - \lambda_1, \quad i = 1,2,3 \qquad (7)$$

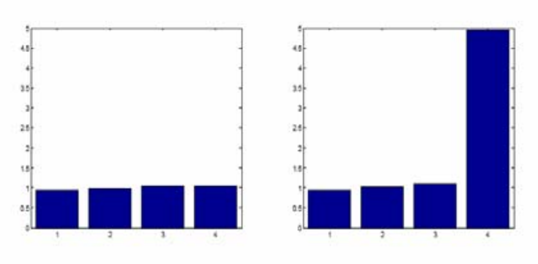

Figure 3. Complete set of eigenvalues for both hypotheses

The test statistic is based on R3. If T is larger than the threshold, the receiver declares satellite mobile phone exists. Otherwise, the receiver declares satellite mobile phone absent.

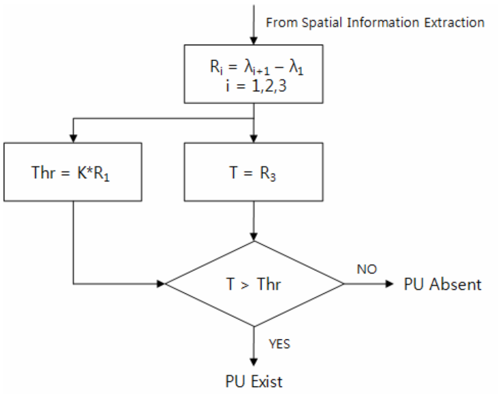

Figure 4. Proposed decision procedure for detection

The threshold Thr is selected based on K* R1. K is a pre-defined factor that is used to adjust the false alarm probability. Large K value will result a lower probability of detection, however, the probability of false alarm is also lower. On the other hand, small K value will lead to higher probability of detection; meanwhile, the probability of false alarm is also increased.

Ⅳ. Analysis of Simulation Result

Simulations are carried out to evaluate the performance of the proposed method. First of all, it is valuable to evaluate the effect of K factor, which is directly related to the probability of false alarm. Figure.5 illustrates the change of detection probability according to different K values when the observation time is 1.6ms. It is clear that smaller K factor leads to better detection performance; however, the false alarm probability is also increased accordingly. The optimum K factor is determined based on the requirement of false alarm probability.

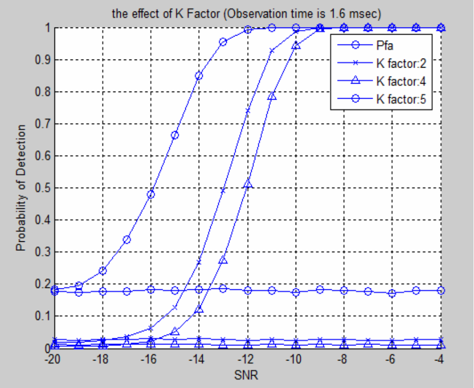

Figure 5. The probability of detection VS. SNR under the different K factor

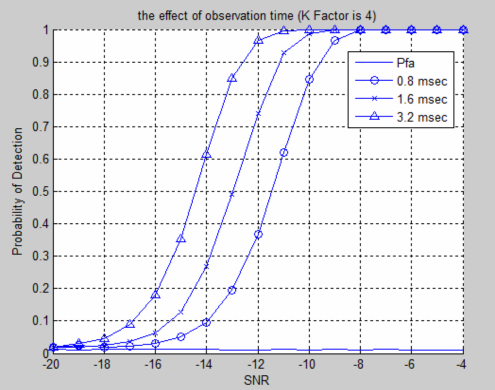

Figure 6. The probability of detection VS. SNR under the different observation time

We are also interested in the effect of observation time. Longer observation time could increase the detection performance; however, it will increase the processing time as well.

As shown in Figure. 6, when the observation time is doubled, almost 2dB SNR gain could be achieved while the target detection probability is 90%. It is valuable for the tradeoff between processing time and detection performance.

In order to evaluate the interference that may be caused by the transmission of additional services, as shown in Figure.7, we find that with the increase of distance, the INR (Interference-to-Noise Ratio) decreases as expected. Furthermore, as the EIRP decreases and exponent factor increases, the INR suffered by satellite phones decreases.

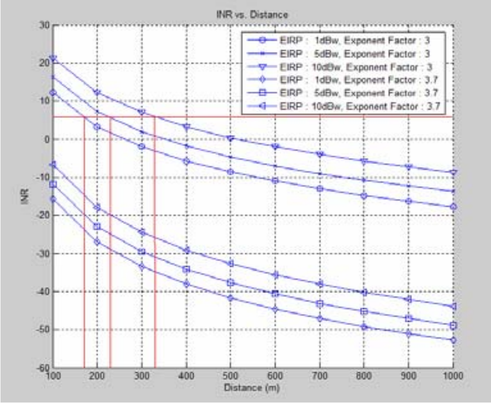

Figure 7. INR VS. Distance under different EIRP and Exponent Factor

Considering the largest interference level 6dB which can be endured by satellite phone, the smallest distance allowed is about 180 meters under the condition of EIRP 1dBw and exponent factor 3. If less than 180 meters, the INR exceeds to the allowable range of satellite phones.

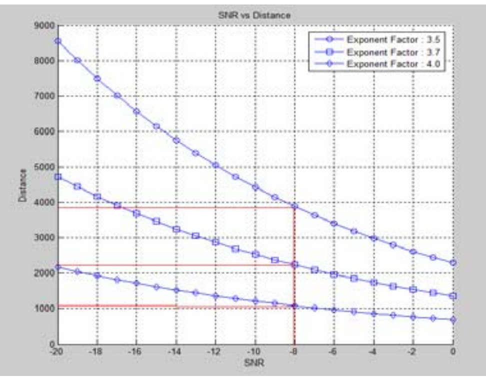

Figure 8. Distance VS. SNR under different Exponent Factor

From the Figure.6, we know that for the case of observation time 0.6msec, SNR should be as large as -8dB to achieve the 100% detection probability, which can ensure the protection of satellite phone communications. Therefore, as shown in Figure.8, we can get the distance value about 1000 meters under the case of exponent factor 4.0, which is larger than the smallest allowable distance, as indicated 180 meter in Figure.7.

V Conclusions

In this paper, we explore the existing problem of low spectrum utilization efficiency in the Satellite Mobile Communication System, where there are large mount of temporal and geographical white holes in its coverage. In order to improve the spectrum efficiency, in this paper, we first analyze the possibility to implement new services in the licensed band of satellite mobile phone by its provider. Then we explore the most significant issue for implementing the new service, which is how to accurately detect the satellite mobile terminals. We suggest two new possible solutions, namely energy detection and eigenvalue detection based methods to find out the existence of transmitted signal from the satellite mobile terminals. The simulation results show our proposed system performs well.

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