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GPS 방해신호 회피용 5-패치 배열 안테나 설계

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Design of a 5-patch GPS array antenna for anti-jamming

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요 약 본 논문에서는 GPS용 패치 안테나를 이용하여 안테나 빔의 방사패턴을 조정하는 방법에 대해 기술되었다. 안테나는 5개의 세라믹 기판에 구현된 전형적인 원형편파 패치 안테나를 사용 하였으며 PCB기판위에 배열 안테나로 제작 되었다. 안테나 배열은 가운데 하나의 요소가 배치되고 4개의 요소는 각 코너에 배치되는 구조이다. 특정한 방향으로 GPS방해 신호가 도래 한다고 가정하고 그 방향의 안테나 방사 전력을 최소화 하는 방법을 제시하였다. CST MWS를 이용하여 시뮬레이션 하였으며 이를 기초로 안테나가 제작 되었고 기본적인 특성들이 측정되었고 그 결과가 제시되었다. 본 연구의 결과들을 살펴보면 방해전파 송신기로부터 방사되는 특정 방향의 방해신호를 본 연구에서 제안하는 안테나를 사용하여 충분히 제거 할 수 있는 것을 알 수 있다.

주제어 : GPS, 패치 안테나, 항재밍, 배열 안테나, 방해신호

Abstract In this paper, the implementation of a null-steering antenna array using GPS patch antennas is suggested. The antenna array consists of five patch antenna elements fabricated on the ceramic substrate. The antenna element proposed here is a typical circular polarization patch and a prototype patch array antenna is manufactured on the PCB. The antenna has one reference element located at the center and other four elements are placed at the corners. A null in the direction of the jamming signal can be produced by changing the phases of 4-elements. Simulation results of the array antenna by CST MWS are presented and discussed. The basic performances are measured and the results are shown. The results show that the antenna presented here can be used to remove the signals from the directions of any jammers.

Key Words : GPS, Patch antenna, anti-jamming, array antenna, interference

1. Introduction

The GPS services have been receiving a great deal of attention during the recent years. It has become a vital worldwide utility which is indispensable to the commercial navigation system and military applications. However, a GPS receiver is relatively susceptible to interference due to its spread spectrum characteristics. In spread spectrum communication, the information signal is deliberately spread over a wide range of frequencies. It provides increased resistance to interference and the ability to avoid hostile detection.

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Generally, the power received GPS receiver is about -160dBW. The low receiving power of the GPS systems makes these signals susceptible to jamming. In many GPS applications, especially military systems, a stable operation is concerned as a crucially important issue. It is required for receivers to operate even in serious interference environments. Interference from radar systems and other devices affects civilian use and intentionally used jammers affect military use.

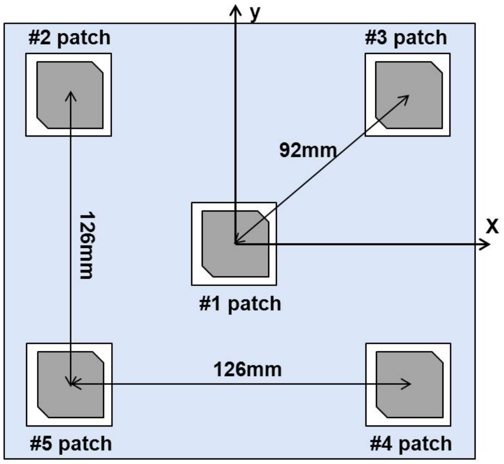
Many different anti-jamming techniques have been investigated [1-6]. However, null steering has been a commonly applied technique used for effective interference rejection[7-12]. It suppressed interference by forming a null in the direction of the jamming signal. It has a disadvantage of reducing the received GPS signal power level near the direction of a jamming signal. The adaptive antenna is suitable to cancel these types of jammers. It utilizes some cancellation techniques for determining the jammer direction based on its power. A number of antennas and signal processing techniques have been introduced to overcome this deficiency. The most effective performance improvements against interference are provided through the use of controlled radiation pattern antennas. It is also desirable to use cost effective antenna systems for small low-value military platforms[7]. Adaptive nulling is required when the directions of jamming signals are varying. Antennas using phase-only nulling can search the adequate angles for the phase shifters to form nulls in the directions where interference signal are coming [9]. It is well known that the number of antenna elements is a key factor in the array antenna performance. The more elements available, the more nulls can be generated in the direction of a jammer. The number of interference signals which can be rejected by a GPS array is equal to one less than the number of antenna elements. In general, this allows the GPS receiver to place broadband antenna-pattern nulls in the directions of any interferers, while simultaneously preserving the gain in the directions of the desired GPS satellites. In this paper, a basic simulation study of a simple null steering antenna array is introduced. And we fabricate an array antenna and measure the performances.

2. Antenna Design

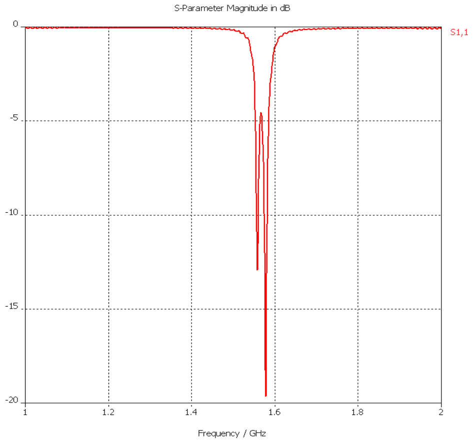
In general, the array antenna performance is determined by the number of antenna elements. The number of interference signals which can be rejected by a GPS array is equal to one less than the number of antenna elements. The proposed array is a set of 5-elements conventional GPS array antenna which is introduced in the previous study[3]. A theoretical approach and simulation study are well performed but implementation is omitted. The configuration of the suggested 5-patch GPS array antenna is shown in Figure 1. The proposed antenna has five elements placed on the PCB substrate (εr=4.6, t=1.0mm). Each GPS patch antenna is built on the ceramic substrate with thickness of 5.5mm, width of 21mm and a relative permittivity of 10.0. The first element is placed right at the center of the antenna array. Other 4 patches are placed at the corner with spacing 90mm apart from the center patch. The distance(r=92mm) between each element is chosen to be half wavelength at the center frequency, 1.575GHz. The antenna itself has a dimension of 16.5x16.5mm. The array factor is given by taking the center element as the reference[3].

$$E_o(\theta,\ \phi)= E_o\left(1+\sum_{i=1}^{4} e^{j(\Phi_i - \Theta_i)}\right)$$

We assume all the 5-elements have equal amplitudes. E_o is the electric field intensity for the center element, Φ_i is the required phase for the i^{th} element and Θ_i is the phase delays of the 4-element with reference to the center element.



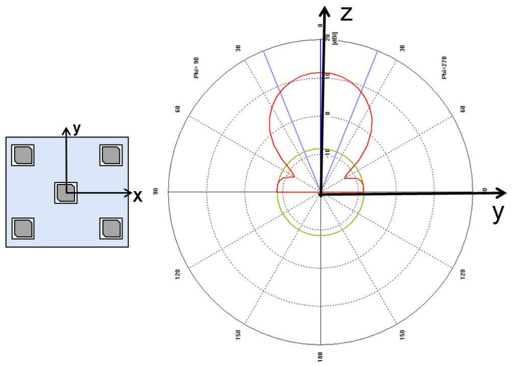
[Fig. 1] Antenna configuration



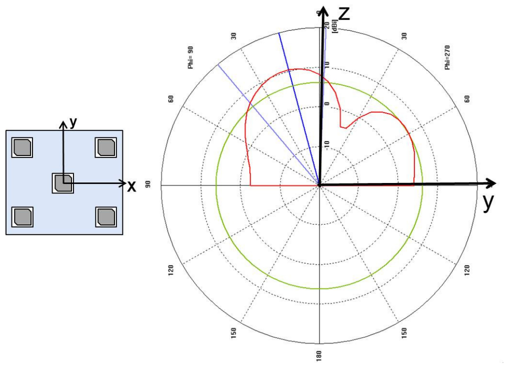
[Fig. 2] Simulated return loss

3. Antenna simulation and measurement

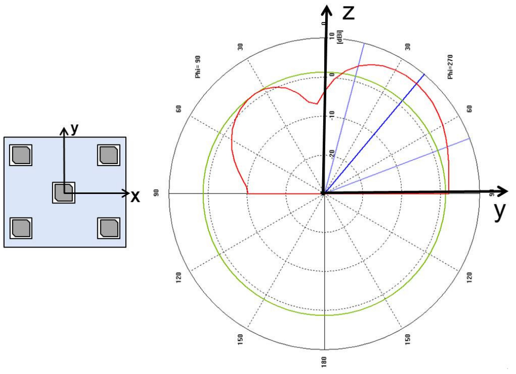
The 5-element array antenna is designed and simulated using CST MWS. In order to get a nulling at the specific angle, the phase for each element is determined based on the simulation result. The simulated return loss for proposed array antenna is presented in figure 2. The radiation pattern of the proposed array is shown in figure 3, where all the five elements are equally excited. The peak gain at 1.575GHz is 11.0dBic in Y-Z plane. In figure 4, the radiation pattern of the array antenna with phase of 0°(#1), 45°(#2), 45°(#3), 90°(#4), 90°(#5). In figure 5, the radiation pattern of the array antenna with phase of 0°(#1), 45°(#2), 135°(#3), -45°(#4), -135°(#5). This results show that the interference can be removed by steering a null in its direction. In figure 6, a 3-dimensional pattern that has nulls generated to the direction of jamming signals is presented. We assume the jamming signals are coming to the two directions as described in the figure. In this case, we use only three elements(#1, #3, #5) with the phase of 0°, 45°, 135°, respectively.



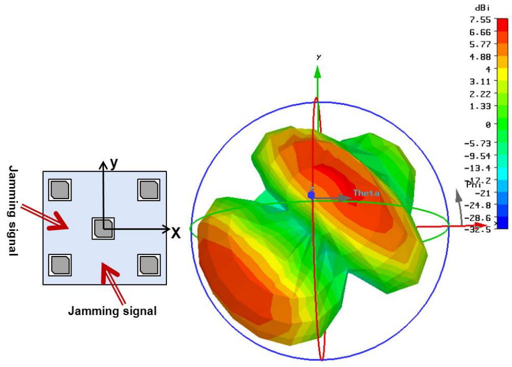
[Fig. 3] Radiation pattern of the 5-patch array antenna with equal phase



[Fig. 4] Radiation pattern of the 5-patches with phase of 0°, 45°, 45°, 90°, 90°



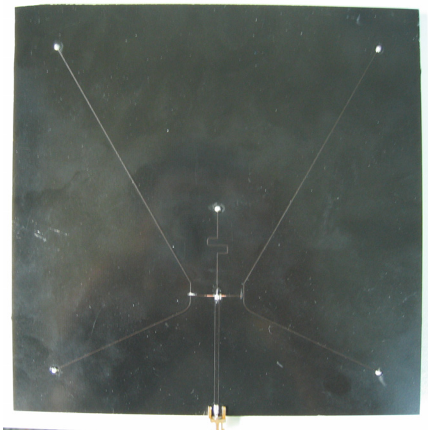
[Fig. 5] Radiation pattern of the 5-patches with phase of 0°, 45°, 135°, -45°, -135°



[Fig. 6] Simulated radiation pattern with 0°(#1), 45°(#3),135°(#5).

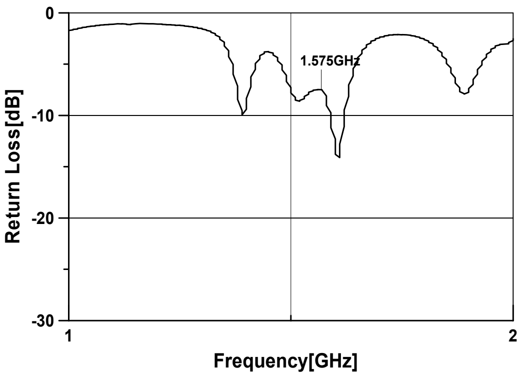
Figure 7 presents the fabricated antenna and feeding structure. In figure 7(b), the actual feeding configuration is shown. We consider the case that the phase delays of the 4-element with reference to the center element are 45°(#2), 45°(#3), 90°(#4), 90°(#5), respectively. The phase differences are controlled by the length of feeding line as shown in figure 7(b). The measured return loss is shown in figure 8. The resonant frequency is 1.575GHz, at which a -8 dB return loss is achieved. Figure 9 shows the measured radiation pattern in X-Y plane, Y-Z plane. The peak gain at 1.575GHz is 0.6dBic in X-Y plane and 4.73dBic in Y-Z plane, respectively.

(a)

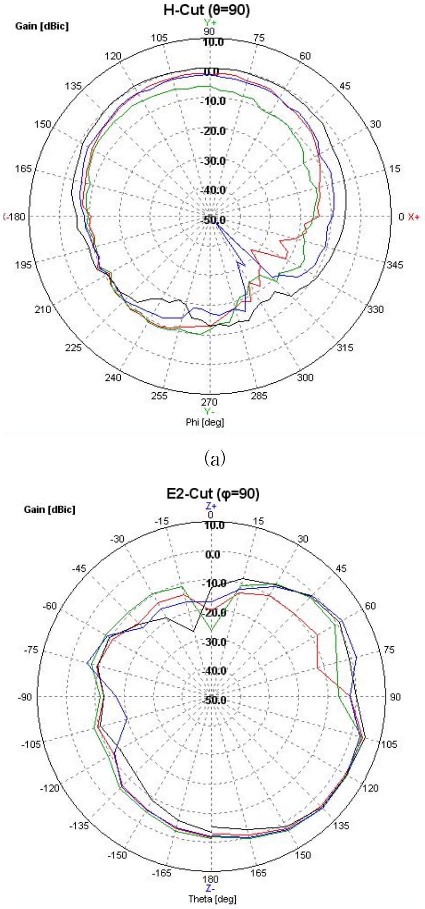


(b)

[Fig. 7] Picture of the fabricated antenna
(a) Front side(Array elements)
(b) Back side (Feeding network)



[Fig. 8] Measured return loss for 5-elements array



(a)

(b)

[Fig. 9] Measured radiation pattern with phase of 0°, 45°, 45°, 90°, 90° (a)Azimuth (H-plane) (b)Elevation (E_2-plane)

4. Conclusions

The purpose of this study was to design and fabricate an antenna array for GPS applications that can be used to remove GPS interference signal. We present the null-steering GPS patch array antenna. The antenna has five patches built on a ceramic substrate. The antenna proposed here is a typical circular polarization patch and a prototype is manufactured using the simulation results. We show a null in the direction of the jamming signal can be generated by changing the phases of 4-elements with reference to the center element. The results show that the array is providing the maximum null-depth with -15dB. It can provide quite effective protection against jamming signals. The radiation pattern is measured and all the results are quite similar with our prediction. The proposed array antenna can be used for a cost effective platform in the military applications.

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