Passive Radar: Defender of National Security or Threat to Personal Privacy?

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In today's society almost everyone has a cell phone attached at the hip, and somewhere a television or radio is blaring. These everyday items may sometime soon aid in national defense. They will do so because a large component of defense comes from radar systems which depend on the same electromagnetic radiation that cell phones, televisions, and radios do. As a result of the growing prevalence of these household items a new form of radar has begun to emerge: Passive Radar.

Passive Radar and the Technology

Radar, an acronym for Radio Detection and Ranging, was first used by Sir Robert Watson-Watt in a British radar experiment to detect a Heyford bomber in February 1935 [8]. All radar systems operate on the concept of emitting electromagnetic radiation in radio or microwave frequencies and receiving the reflected signal, or echo, to locate an object. The reflected signal can reveal the object's distance, speed, direction of motion, or shape depending on the purpose of the system. Radar systems are used by both the civilian and military sectors in space, land, and sea for navigation, detecting objects, traffic control, and providing scientific data such as weather [10].

Radar systems can be classified in two configurations: monostatic or bistatic. Both configurations rely on the same principle of gathering information; by detecting a signal reflected from an object in space. The first radar system used by Watson-Watt was a bistatic system, meaning the transmitter and the receiver was not collocated. Passive radar is a special type of bistatic radar that uses a transmitter of opportunity emitting radio and microwave signals instead of a transmitter controlled by the system [11]. The more conventional monostatic systems use a duplexer which allows the same antenna to be used for transmission and reception.

Bistatic radar systems achieve radar functionality by analyzing a signal transmitted from a known location and the same signal after it has collided with a target [11]. More specifically, the receiver has a reference signal directly from the transmitter and a reflected signal that is attenuated and delayed upon colliding with a moving or static object. Using sophisticated algorithms and specialized hardware similar to those for monostatic radar, various data about the signal can be measured and an accurate depiction of an object's location and movement can be obtained.

One such measurement of the received signal is its Doppler shift - the frequency difference between a direct signal received and the reflected signal [9]. The difference is caused by the movement of the target that the signal bounced off of. The movement of the target towards the receiver causes the signal's wave to contract on itself, resulting in an apparent increase in frequency. Movement away will cause an apparent decrease in the signal's frequency [4]. The measured frequency difference enables the program to determine the object's speed and direction.

Another measurement that can be made is the time difference of arrival between the direct signal and the reflected signal. Measuring the time difference of arrival between the two signals can help determine how far away the target is. The farther away it is from the transmitter and receiver, the longer the difference in time of arrival between the reflected signal and the direct one.

Yet another measurement that will sometimes be made is direction of arrival of the received signal [4]. When using one transmitter and one receiver, there is a continuum of possible locations for the target. To see this, consider the triangle made by the transmitter, the receiver, and the target. The reflected signal travels along the side of the triangle connecting the transmitter to the target, and then from the target to the receiver. Considering the speed of propagation of the signal to be fairly constant, the most important parameter is the distance that the signal travels. This is the sum of the distances that the reflected signal travels along the two aforementioned sides of the triangle. Using the time difference of arrival measurement, an approximation for this total distance can be calculated, but this measurement can imply any one of many locations in three dimensional space (the two legs of the triangle can differ in their lengths as long as the sum adds up to the calculated total, and they can be oriented anywhere along an arc in the dimension perpendicular to the plane of the transmitter, receiver, and target). However, if the direction from which the reflected signal came is known, the accuracy of the position measurement can be greatly improved (pinpointing to the accuracy of the measurement if the direction is three dimensional, or eliminating a dimension of inaccuracy if a direction measurement if only one dimension is made).

All of the measurements that are made can be compounded into a fairly accurate description of the location and movement of a target such as a plane. If the direction of the reflected signal cannot be determined at the receiver, or if this measurement is not very accurate, the system can use multiple transmitters to improve the accuracy of the position measurement. Increasing the number of transmitters used for this calculation can allow for a two- or three-dimensional location of the target to be calculated as well as improving the accuracy of the overall calculations [1, 4].

This ability to analyze multiple signals simultaneously gives bistatic radar, and thus passive radar, one of its greatest advantages over monostatic radar. Compared to the analysis made by one reference signal, or a monostatic radar, bistatic radar has a much higher resolution. It can also sense objects that would be invisible to a uni-directional signal, such as a stealth plane. One of the main ways a stealth plane remains undetectable is that it fools monostatic radar by not directly reflecting the signal. This is possible because monostatic radars rely on only one transmitter. However, when there are multiple transmitters at different locations from the receiver, it becomes nearly impossible to design a surface that will not reflect something in the direction of the receiver. As a result, such a system, if fully established, could have far reaching effects within the military [21].

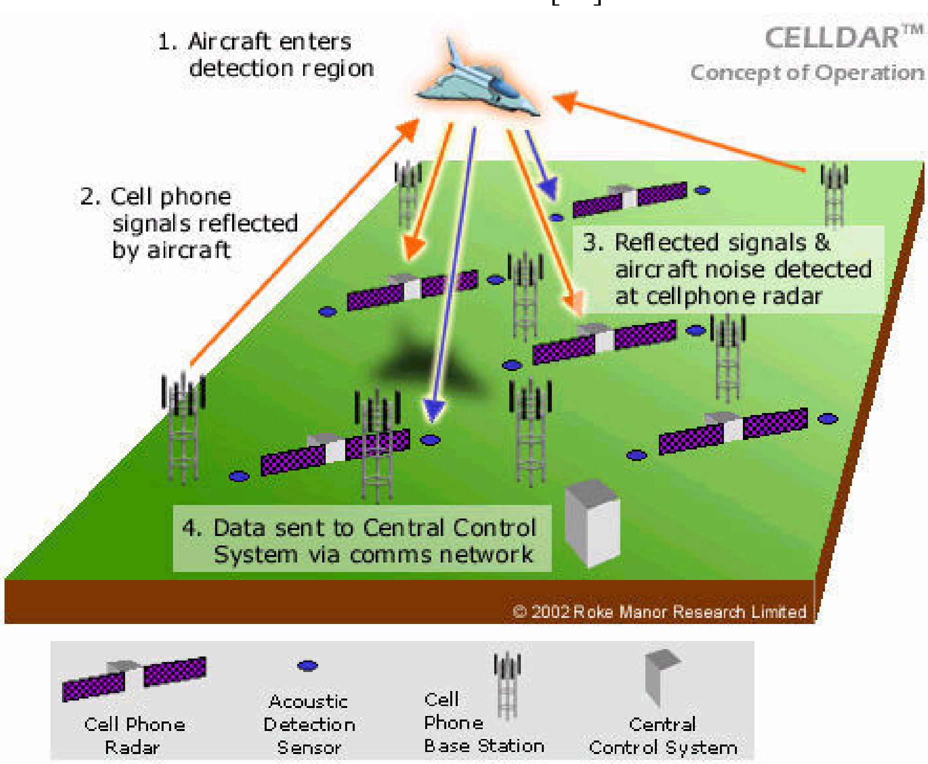
The recent developments in this technology have focused on the availability of low cost components, fast computer systems, and the choice of signals and how the system is implemented. According to the editorial, "Passive Radar" in IEE Proceedings, interest in these systems has surged in the last few years due to advances in cheap and fast analogue-to-digital converter cards and fast computer systems that can efficiently implement quick signal processing algorithms [8]. It is now economical for researchers and governments to build and experiment with powerful passive radar systems that are capable of real-time signal analysis for tracking moving aircraft and other targets. Governments are also interested in this technology because of the low cost and the potential high return for national security.

The difference in cost between conventional radar and passive radar is fairly significant. In conventional radar, most of the cost goes to building and maintaining a transmitter. Transmitters use hundreds of kilowatts of energy to generate a pencil beam of electromagnetic radiation. This continual power need costs a lot, and occurs after construction costs. However, in passive radar system, existing signals are used. Therefore there is no transmitter cost, either for construction or a power bill [21]. A rough estimate of the cost difference between an average monostatic system to a passive system is twenty-five million dollars to only twenty thousand dollars [16].

Implications and Possible Uses

Aside from cost, there are other unique attributes of passive radar. They are invisible to anti-radar weapons since there are no transmitters [16]. The use of less hardware enables systems to potentially be portable [19]. Finally, because of their passivity, these systems are more environmentally friendly and less afflicted by bad weather [20].

As mentioned above passive radar has some serious implications for stealth technology. Passive radar will not replace existing radar systems; instead they will fill in several gaps in the current technology. The radar defense system will be augmented economically with the association of pre-established television and cell phone signals. The challenge with setting up a nationwide passive radar system for defense would be to ensure that the data could be looked at in real time. Researchers have pointed out that if the point is to defend against stealth or non-stealth airplanes, "it wouldn't be useful if you couldn't shoot the aircraft down" [23].



Outside of the military, passive radar is still popular for defense and security. It has been proposed in place of expensive cameras due to its effectiveness in foul weather. Also, if "the radar picked up movement then a single camera could be focused on a specific area" [4]. This could be installed at airports, (since less than six percent of public U.S. airports have radar systems [16]), at harbors, nuclear plants, and other sensitive installations. Private security companies or detectives could also make use of this technology, though this begins to lead to public concern.

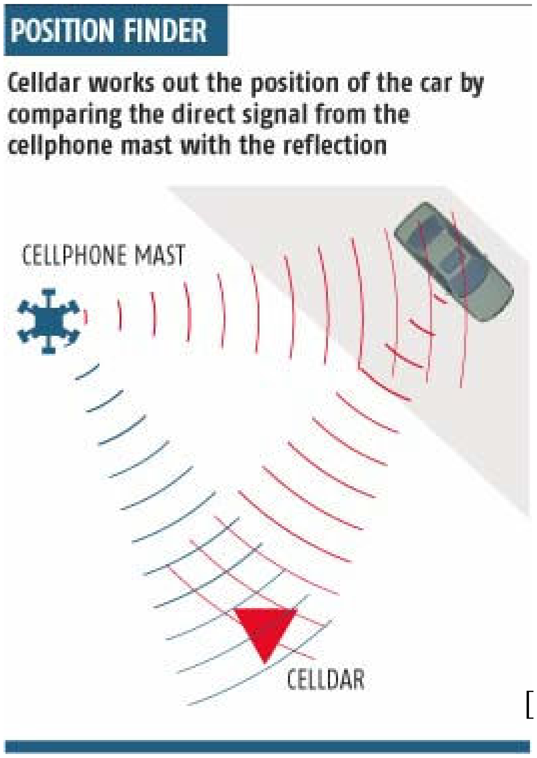
Even within the public sector there are a variety of uses. The most popular suggestion would be for monitoring traffic. Peter Lloyd, head of Roke Manor's Celldar program, has suggested this idea, which would be cheaper than putting the sensors in the roads or overhead TV's. This would help transportation officials, as well as be crucial during traffic accidents. Police could follow suspect cars at a safe distance without being detected [17]. Furthermore, companies could use this in place of GPS for tracking their trucks while on the road [16]. Lastly, there has been a suggestion that passive radar would help in the detection of tornado touchdowns [5].

While passive radar has many strengths and benefits, it is not flawless. Since the systems are cheaper than conventional radar, being more dependent on software than hardware, it is possible for hard core hobbyists to build their own small systems [16]. There may be concerns with the common citizen following national defense so closely, but regulating these systems would be difficult. Also, the technology's cheapness and availability make it easier for hostile forces to acquire it. As mentioned in a 2001 article in the Wall Street Journal, Mr. Brownstone of Intergon believes that China, Japan, and Russia are developing passive radar and may sell it to smaller nations that have poor relations with the United States [18]. Therefore what is advantageous for the U.S. will be equally or more so for other countries.

Celldar and Silent Sentry

There are a number of companies and programs that make use of passive radar technology. Some of the leading companies include Roke Manor Research, Lockheed Martin Corporation, Avtec Systems, Dynetics, and ONERA [16]. Roke Manor and Lockheed Martin are clearly leaders in the field as the former is working on a Celldar program in the UK and latter on Silent Sentry in the U.S. These two programs both depend on passive radar technology, but employ different approaches.

Celldar made its first appearance with Roke Manor Research in 1997. The first prototype was built in 1999, for $3,000 [16]. According to Roke Manor "Celldar uses extended multi-static radar detection and data processing for the tracking, identification and cueing of objects moving in cell phone fields" [1]. In other words, cell phone towers can record the waves that reach them, and the Celldar program can then interpret the signals to form an image of what was between the towers it 'heard' and itself [2]. It can even filter out immobile objects so that it essentially tracks moving objects such as cars, aircraft, or possible sea craft. A different program called 'alongside technology' can be used with Celldar so that individual phones (and their owners) are identified [2]. The ability for Celldar to track people without this technology is a future possibility as the current resolution is insufficient for identifying individuals [16].



[19]

In the U.S., Lockheed Martin has spent twenty years working on Passive Coherent Location technology, and has found success in its Silent Sentry Program [14]. Lockheed Martin first demonstrated Silent Sentry in December 1999 at the STS-103 Launch at the Kennedy Space Station. The passive radar system was being considered as a tracking and surveillance system for space launch vehicles. In 2002, it was permanently installed at the station [20]. That same year, Silent Sentry was demonstrated for the U.S. Air Force by using TV and FM echoes to pick up all traffic traveling over Washington D.C. [16]. This Program differs from Celldar in that is uses FM radio and VHF television waves [23]. These waves are able to travel ten times farther than cell phone waves [16], and are much stronger than the ten watts that cell phones emit [21]. However, there are more cell phone towers than FM radio or television stations, which compensates for the difference [19]. Silent Sentry is designed to fill in the gaps in surveillance radar by operating autonomously and continuously. It can track both high altitude fast moving aircrafts, as well as low altitude slower moving ones. Receivers can be mounted on buildings and other fixed structures or aboard moving platforms. They can also operate individually or as a network [13].

Social Implications of Passive Radar

This technology can be a double-edge sword. On the one hand, advances are made for national defense systems. Also public defense and traffic monitoring improve. On the other hand, the potential invasiveness and unclear regulations leave many people concerned. Simon Davis, director of Privacy International, said "The Government is just capitalizing on current public fears over security to introduce new systems that are neither desirable nor necessary" [2].

One of the biggest issues is whether this system can detect and track a person individually. Roke's website does mention that one of Celldar's advantages is the ability to locate illegal immigrants that are stowed away in commercial vehicles, suggesting it can track people [17]. Understandably, people perceive this as an invasion of their privacy. Thus, primarily protestors of passive radar claim that Big-Brother is trying to take too much control. In addition, ordinary people could obtain a cheap passive radar system to detect their neighbor's comings and goings [16].

On the other hand, some proponents argue that radar does not have enough resolution to identify individuals [19]. Also, the power of the existing signals, cell phone, radio or TV signals is very weak. Thus, with existing signals, it would be impossible to track people moving around. In another aspect, for a radar system to track something, the signal must reflect off the objects. "But there'd be a lot of technical challenges," because the human body is a poor reflector of radio signals, says Shawn

M. Herman [19]. Therefore, radar will not get the accurate information to measure the distance and speed of the people.

To minimize these social concerns, there would be regulations governing the passive radar system, similar to search warrants that are necessary to enter a suspect's home. As Roger Bingham of Liberty said, "Like all intrusive surveillance, we need to be sure that it is properly regulated, preferably by the judiciary." The regulation for the use of this new system should be strictly defined and enforced [2].

Passive Radar is a promising technology in several sectors of society. It is a special type of bistatic radar that is more software oriented and economically sound since it relies on signal towers that already exist, such as those from TV and cellular phones. However, its software dominance enables hacking and its cheapness does not prevent hostile forces on obtaining such a system. Furthermore, several privacy questions in regard to civilians are present. The assessment of passive radar cannot be complete since the technology is currently under development and many of the current concerns may be addressed in the future.

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