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Radar and Satellite Communication

B. J. Vishnu Vardhan[1], Mrudu Lahari[2]
[1,2]B.Tech. Student, Department of Electronics and Communication Engineering, VIT University, Vellore, India

***Abstract*: In this paper we present RADAR, a radio-frequency (RF) based system for locating and tracking users inside buildings. RADAR operates by recording and processing signal strength information at multiple base stations positioned to provide overlapping coverage in the area of interest. It combines empirical measurements with signal propagation modeling to determine user location and thereby enable location aware services and applications. In case you've been wondering who to thank (or strangle) for today's monster broadband, look no further than the satellite industry. Okay, fiber gets some credit, too. But it's a relative newcomer to the broadband market when compared to satellite.**

***Keywords*: Satellite Communication**

1. Introduction to satellite communication

Satellites were the original, curiously strong broadband. satellite communication, in telecommunications, the use of artificial satellites to provide communication links between various points on Earth. Satellite communications play a vital role in the global telecommunications system. Approximately 2,000 artificial satellites orbiting Earth relay analog and digital signals carrying voice, video, and data to and from one or many locations worldwide. Satellite communication has two main components: the ground segment, which consists of fixed or mobile transmission, reception, and ancillary equipment, and the space segment, which primarily is the satellite itself. A typical satellite link involves the transmission or up linking of a signal from an Earth station to a satellite. The satellite then receives and amplifies the signal and retransmits it back to Earth, where it is received and reamplified by Earth stations and terminals. Satellite receivers on the ground include direct-to-home (DTH) satellite equipment, mobile reception equipment in aircraft, satellite telephones, and handheld devices

2. Introduction to radars

Radar is an object-detection system which uses radio waves to determine the range, altitude, direction, or speed of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. The radar dish or antenna transmits pulses of radio waves or microwaves which bounce off any object in their path. The object returns a tiny part of the wave's energy to a dish or antenna which is usually located at the same site as the transmitter. The term RADAR was coined in 1940 by the United States Navy as an acronym for radio detection and ranging.

3. History

As early as 1886, Heinrich Hertz showed that radio waves could be reflected from solid objects. The German Christian Huelsmeyer was the first to use radio waves to detect "the presence of distant metallic objects". In 1904 he demonstrated the feasibility of detecting a ship in dense fog but not its distance receiver for the signal when the antenna is used in both situations.

- A receiver. Knowing the shape of the desired received signal (a pulse), an optimal receiver can be designed using a matched filter.
- An electronic section that controls all those devices and the antenna to perform the radar scan ordered by software.
- A link to end users.

4. Radar equation

The power P_r returning to the receiving antenna is given by the equation:

$$P_r = \frac{P_t G_t A_r \sigma F^4}{(4\pi)^2 R_t^2 R_r^2}$$

Where

- P_t = transmitter power
- G_t = gain of the transmitting antenna
- A_r = effective aperture (area) of the receiving antenna
- σ = radar cross section, or scattering coefficient, of the target
- F = pattern propagation factor
- R_t = distance from the transmitter to the target
- R_r = distance from the target to the receiver.

5. Radar components

A radar's components are:
A transmitter that generates the radio signal with an oscillator such as a klystron or a magnetron and controls its duration by a modulator. A waveguide that links the transmitter and the antenna.
A duplexer that serves as a switch between the antenna and the transmitter or the receiver for the signal when the antenna is used in both situations.

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and the antenna to perform the radar scan ordered by software.

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6. Configurations

Radar come in a variety of configuration in the emitter, the receiver, the antenna, wavelength, scan strategies, etc.

- Bistatic radar
- Continuous-wave radar
- Doppler radar
- Fm-cw radar
- Monopulse radar
- Passive radar
- Planar array radar
- Pulse-doppler
- Synthetic aperture radar
- Synthetically thinned aperture radar

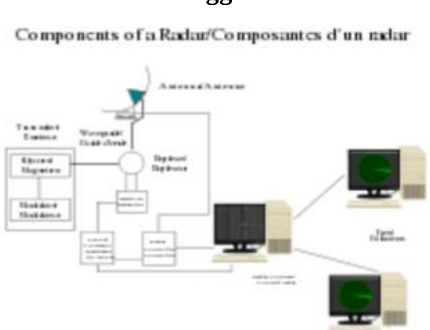
7. Detection and search radars

Search radars scan a wide area with pulses of short radio waves. They usually scan the area two to four times a minute. The waves are usually less than a meter long. Ships and planes are metal, and reflect radio waves. The radar measures the distance to the reflector by measuring the time from emission of a pulse to reception, and dividing by the speed of light. To be accepted, the received pulse has to lie within a period of time called the range gate. The radar determines the direction because the short radio waves behave like a search light when emitted from the reflector of the radar set's antenna.

8. Targeting radars

Targeting radars use the same principle but scan a much smaller area far more often, usually several times a second or more, where a search radar might scan a few times per minute. Some targeting radars have a range gate that can track a target, to eliminate clutter and electronic counter-measures.

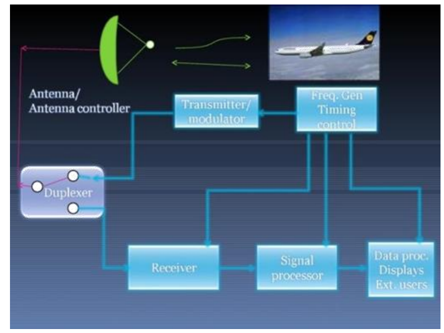
9. Triggers



Components of radar

Radar proximity fuses are attached to anti-aircraft artillery shells or other explosive devices, and detonate the device when it approaches a large object. They use a small rapidly pulsing omnidirectional radar, usually with a powerful battery that has a long storage life, and a very short operational life. The fuses used in anti-aircraft artillery have to be mechanically designed to accept fifty thousand, yet still be cheap enough to throw away.

Principle of radar:



It works on the principle of "radio echoes"

10. Applications of radar

The modern uses of radar are highly diverse, including air traffic control, radar astronomy, air-defense systems, antimissile systems; marine radars to locate landmarks and other ships; aircraft anti-collision systems; ocean surveillance systems, outer space surveillance and rendezvous systems; meteorological precipitation monitoring; altimetry and flight control systems; guided missile target locating systems; and ground-penetrating radar for geological observations. High tech radar systems are associated with digital signal processing and are capable of extracting objects from very high noise levels

In aviation, aircraft are equipped with radar devices that warn of obstacles in or approaching their path and give accurate altitude readings. The first commercial device fitted to aircraft was a 1938 Bell Lab unit on some United Air Lines aircraft [24]. They can land in fog at airports equipped with radar-assisted ground-controlled approach systems, in which the plane's flight is observed on radar screens while operators radio landing directions to the pilot.

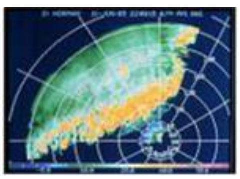
Marine radars are used to measure the bearing and distance of ships to prevent collision with other ships, to navigate and to fix their position at sea when within range of shore or other fixed references such as islands, buoys, and lightships. In port or in harbour, vessel traffic service radar systems are used to monitor and regulate ship movements in busy waters. Police forces use radar guns to monitor vehicle speeds on the roads.

Meteorologists use radar to monitor precipitation. It has become the primary tool for short-term weather forecasting and to watch for severe weather such as thunderstorms, tornadoes, winter storms, precipitation types, etc. Geologists use specialized ground-penetrating radars to map the composition of the Earth's crust.

11. Weather-sensing radar systems

Weather radars can resemble search radars. This radar uses radio waves along with horizontal, dual (horizontal and vertical), or circular polarization. The frequency selection of weather radar is a performance compromise between precipitation reflectivity and attenuation due to atmospheric water vapor. Some weather radars uses doppler shift to measure wind speeds and dual-polarization for identification of types of precipitations.

- Weather radar
- Wind profilers
- Millimetre cloud radar



Storm front reflectivities on a Weather radar screen (NOAA)

Wind profiling radar

Navigational radars

Surface search radar display commonly found on ships

Navigational radars resemble search radar, but use very short waves that reflect from earth and stone. They are common on commercial ships and long-distance commercial aircraft. Marine radars are used by ships for collision avoidance and navigation purposes. The frequency band of radar used on most ships is x-band

(9 GHz/3 cm), but s-band (3 GHz/10 cm) radar is also installed on most ocean going ships to provide better detection of ships in rough sea and heavy rain condition. Vessel traffic services also use marine radars (x or s band) for tracking ARPA and provides collision avoidance or traffic regulation of ships in the surveillance area.

General purpose radars are increasingly being substituted for pure navigational radars. These generally use navigational radar frequencies, but modulate the pulse so the receiver can determine the type of surface of the reflector. The best general-purpose radars distinguish the rain of heavy storms, as well as land and vehicles. Some can superimpose sonar and map data from GPS position.

A. Air Traffic Control and navigation

Air traffic control uses Primary and Secondary Radars. Primary radars are a "classical" radar which reflects all kind of echoes, including aircraft and clouds. Secondary radar emits pulses and listens for special answer of digital data emitted by an Aircraft Transponder as an answer. Transponders emit different kind of data like a 4 octal ID (mode A), the onboard calculated altitude (mode C) or the Callsign (not the flight number) (mode S). Military use transponders to establish the nationality and intention of an aircraft, so that air defenses can identify possibly hostile radar returns. This military system is called IFF (Identification Friend or Foe).

B. Mapping radars

Mapping radars are used to scan a large region for remote sensing and geography applications. They generally use synthetic aperture radar, which limits them to relatively static targets, normally terrain.

Specific radar systems can sense a human behind walls. This is possible since the reflective characteristics of humans are generally more diverse than those of the materials typically used in construction. However, since humans reflect far less radar energy than metal does, these systems require sophisticated technology to isolate human targets and moreover to process any sort of detailed image. Through-the-wall radars can be made with Ultra Wideband impulse radar, micro-Doppler radar, and synthetic aperture radar (SAR)

Road radar Radar gun, for traffic policing and as used in some sports. Radars for biological research Radar range and wavelength can be adapted for different surveys of bird and insect migration and daily habits. They can have other uses too in the biological field.

- Bird radar
- Insect radar
- Surveillance radar (mostly X and S band, i.e. primary ATC Radars)

- Tracking radar (mostly X band, i.e. Fire Control Systems)
- Wearable radar and miniature radar systems are used as electric seeing aids for the visually impaired, as well as early warning collision detection and situational awareness.

12. GPS

Civilian GPS receiver ("GPS navigation device") in a marine application.

U.S. Air Force Senior Airman Nayibe Ramos runs through a checklist during Global Positioning System satellite operations. The operations center here controls a constellation of 29 orbiting satellites that provides navigation data to military and civilian users worldwide.

Artist's conception of GPS Block II-F satellite in Earth orbit. GPS receivers are now integrated in many mobile phones.

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible by anyone with a GPS receiver with some technical limitations which are only removed for authorized users.

Automotive navigation system in a taxicab. The GPS program provides critical capabilities to military, civil and commercial users around the world. In addition, GPS is the backbone for modernizing the global air traffic system.

- *Military:* Attaching a GPS guidance kit to a 'dumb' bomb, March 2003. As of 2009, military applications of GPS include:
- *Navigation:* GPS allows soldiers to find objectives, even in the dark or in unfamiliar territory, and to coordinate troop and supply movement. In the United States armed forces, commanders use the Commanders Digital Assistant and lower ranks use the Soldier Digital Assistant.
- *Target tracking:* Various military weapons systems use GPS to track potential ground and air targets before flagging them as hostile. These weapon systems pass target coordinates to precision-guided munitions to allow them to engage targets accurately. Military aircraft, particularly in air-to-ground roles, use GPS to find targets (for example, gun camera video from AH-1 Cobras in Iraq show GPS co-ordinates that can be viewed with specialized software).
- *Missile and projectile guidance:* GPS allows accurate targeting of various military weapons including ICBMs, cruise missiles and precision-guided munitions. Artillery projectiles. Embedded GPS receivers able to withstand accelerations of 12,000 g or about 118 km/s^2 have been developed for use in 155 millimeters (6.1 in) howitzers.
- *Search and Rescue:* Downed pilots can be located faster if their position is known.
- *Reconnaissance:* Patrol movement can be managed more closely. GPS satellites carry a set of nuclear detonation detectors consisting of an optical sensor (Y-sensor), an X-ray sensor, a dosimeter, and an electromagnetic pulse (EMP) sensor (W-sensor), that form a major portion of the United States Nuclear Detonation Detection System.

13. Current information in military using radar

- Mission to keep the secrets: U.S. military pursues anti-tamper technologies to ensure the critical technologies that give the U.S. and its allies a military advantage stay out of the hands of terrorists and potential adversaries

- Nine years ago, a U.S. Navy EP-3 reconnaissance aircraft made an unauthorized emergency landing at a Chinese air base on Hainan Island in the People's Republic of China. The stricken electronic intelligence aircraft landed in China after a mid-air collision with a Chinese J-8II jet fighter caused severe damage to the EP-3. While reasons for the incident are in dispute, the so-called "Hainan Island Incident" was perhaps the defining event that brought electronic anti-tamper technology to the forefront of military electronics planning and development.
- The EP-3 is an electronics intelligence (ELINT) aircraft designed to monitor electronic signals from radio communications, cell phones, radar, and other electronic emissions. Like all the rest in the nation's EP-3 fleet, the one involved in the Hainan Island Incident had sensitive information and technology aboard. Despite the crew's at tempts to destroy computers, hard disk drives, and other important equipment before landing on Hainan Island, it is believed that at least some sensitive and/or secret military information fell into the hands of the Chinese government as a result of the emergency landing.
- Since that time nearly a decade ago, U.S. military officials have vowed to make it as difficult as possible for foreign nations to obtain sensitive U.S. information and technology resulting from a similar incident ever again. They are doing this with so-called "anti-tamper" technology, which seeks to slow or prevent the unauthorized reverse engineering of U.S. electronic equipment, computers, software, and other critical technologies that give the U.S. and its allies a military advantage.

Hainan Island Incident

U.S. military leaders have vowed never to let military secrets fall into the hands of potential adversaries, as happened in 2001 during the Hainan Island Incident and a version of the U.S. Navy P-3, shown at right.

- It was the morning of April 1, 2001, as the U.S. EP-3 Aries four-engine turboprop reconnaissance aircraft from U.S. Navy Fleet Air Reconnaissance Squadron One, which was based at Kadena Air Base on Okinawa, Japan, neared the end of a six-hour ELINT mission about 70 miles away from Hainan Island, China. Just after 9 a.m. local time, two Chinese J-8 jet fighters from Lingshui air field on Hainan approached the Navy reconnaissance plane.
- China says the Navy plane was violating Chinese air space, while U.S. officials say they were operating in international air space. At any rate, one of the Chinese fighters made two close passes beside the slower and less-maneuverable Navy EP-3, and started a third close pass when the fighter collided with the reconnaissance aircraft, causing the fighter to break apart and crash, and the Navy EP-3 to drop into a steep dive before its pilot regained control of the aircraft. Although the EP-3's pilot managed to re-establish level flight, the aircraft sustained serious damage to one of its four propellers, left aileron, and nose-mounted radome, which was ripped completely off the aircraft during the collision

A U.S. Navy EP-3 reconnaissance plane was nearing the end of an electronic intelligence mission in April 2001 when it was intercepted by, and collided with, a Chinese jet fighter.

- The EP-3 pilot had a tough choice to make: he could order the crew to bail out of the airplane, ditch the damaged aircraft in the sea far from home, or take a chance at landing at the nearest air field, which was Lingshui on Hainan. The Navy pilot, Lt. Shane Osborn, decided to make for Lingshui, but ordered his crew to destroy as much of the airplane's sensitive equipment as possible en-route.
- Crew members of the EP-3 reportedly tried to smash computer gear and hard drives with hammers, and even tried pouring coffee into disk drives and computers in attempts to destroy them to keep sensitive information out of Chinese hands. Chinese authorities never granted the Navy plane permission to land at Hainan, which also is the location of a Chinese ballistic missile submarine base. When the stricken plane touched down on the Lingshui runway, it was met by armed Chinese soldiers, who took the plane, the crew, and the onboard equipment into custody.
- The crew of the Navy plane was held in China for 10 days. Their aircraft and equipment were dismantled, stripped, closely examined, and ultimately returned to the Navy crated in pieces. Despite the best efforts of the EP-3 crew, Navy officials believe the Chinese were able to gain valuable intelligence data from their examination of the aircraft and its equipment; evidently stronger measures than hammers and hot coffee would be necessary to keep critical information out of the wrong hands.

The EP-3 Aries reconnaissance aircraft like the one shown above, was confiscated, stripped, and examined during the Hainan Island Incident to gather sensitive intelligence on U.S. systems.

14. Anti-tamper technology

Within months of the Hainan Incident, some of the first anti-tamper policy memos started circulating in the U.S. Department of Defense (DOD), and by the next year "it was really starting to pick up," says Jeff Hughes, division chief for the ATSVI Technology Office at Wright-Patterson Air Force Base in Dayton, Ohio. The ATSVI Technology Office originally stood for Anti-Tamper Software Protection Initiative, yet today its mission has expanded to encompass hardware, as well as software.

15. Conclusions

Within recent decades, because of both,

- The advent of high-speed computers, and
- The deployment of the Global Positioning System, passive, multi-static radar systems have become technologically feasible. Radar technology has developed to the extent that it is now being discussed for use not only in defense and intelligence applications, but in the civilian sector also.

In this paper, we have presented RADAR, a system for locating and tracking users. RADAR is based on empirical signal strength measurements as well as a simple yet effective signal propagation model. While the empirical method is superior in terms of accuracy, the signal propagation method makes deployment easier. We have shown the despite the hostile nature of the radio channels, we are able to locate and track users with a high degree of accuracy. The median resolution of the RADAR system is in the range of 2 to 3 meters, about the size of a typical office room. Our results indicate that it is possible to build an interesting class of location-aware services, such as printing to the nearest printer, navigating through a building, etc., on an RF wireless LAN, thereby adding value to such a network.

16. Acknowledgments

Many individuals have contributed to our understanding of the subject of radar and satellite communication, and to the preparation of this paper. I owe a large debt of gratitude to all them, as well as to others, who made minor contributions.

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