Application of Electromagnetic (EM): Radar

Salah M. Al-Ofi
EE-340 Project
Department of Electrical Engineering
King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia.

***Abstract*- This report gives a brief information about radar and discuss its background, principles and some types to emphasize the importance of Electromagnetics in modern technologies.**

I. INTRODUCTION

Radar stands for Radio Detecting and Ranging and it is a system that depends on electromagnetic waves to detect some physical properties such as direction, speed, distance or altitude of stationary or moving object e.g. plane, cars, iceberg or missile. Since the evolution of radar in the second World War, it has been considered as an essential technology in many applications like weather forecasting, speedometers, air traffic controlling and by the military as a defense and offence weapon [1].

II. BACKGROUND

Radar technology was firstly named in the United Kingdom as RDF (Radio Direction Finder) where the developments started. However, the invention of radar was not declared to a specific inventor, but many engineers in several countries contributed to the development of radar. The first attempt to use radio waves in radar was to detect the presence of a ship in the middle of the fog by Christian Hulsmeyer in 1904. In 1917, Nikola Tesla was the first one who established the basic principles regarding frequency and power level of radar units which many inventions later based on [1].

Before the Second World War, many countries performed many experiments to find a way to predict the enemy aircraft movements and targeting or tracking lunched bombs. The British government was the first to gather a team of scientists and engineers to research the possibility of building a system that can send a "death ray" to hit an aircraft in the air and cause damage to the pilot and his plane. But in 1935, Waston-Watt reported to the government that although it's possible theoretically but no such high energy ray can be produced to harm an aircraft or its crew.

Despite the failure of "death ray" development, The British developers carried on their tests until in 1935 when they succeeded in detecting radar echoes from a flying boat at a range of 17 miles and they were able to increase the range afterward. In 1936, The British Air Ministry was able to build the first radar system called "Cain Home" which consists of an array of towers of 300 feet high to guide the pilots towards incoming German bombers.

Later, Alan Blumlein succeeded to program a radar circuitry called H2S which is able to allocate a target with a precision never seen before for the bombers. The H2S radar was a main radar development and the main role of ending the second World War by targeting the atomic bomb [2].

III. PRINCIPLE OF WORK

The main concept of radar relays on ECHO PRINCIPLE, that is a radio wave of the speed of light is transmitted, reflected off a target and then returned as echo which is being measured and calculated. The reflected wave is detected by the receiver which is usually very weak, so the receiver is connected to an amplifier to enlarge the signal. This gives a chance to the radar to lose detection of the too weak emissions like sound or visible light.

A. Radar Components

The basic radar system consists of a transmitter, a receiver, one or two antennae and lots of signal-processing circuitry.

The transmitter produces electromagnetic signals, which is able to propagate through space, are radiated through the antenna. If any object blocks the way of those propagations the signal is reflected to the radar where the receiver picks up the echo, using the same antenna or a dedicated one. The signal processor detect the echo, separates them out of noise and other interferences and take the measurements out of this signal which differs from the original one regarding the wave characteristics. From these measurements they can calculate speed, distance or other aspects [3]. (See Fig. 1)

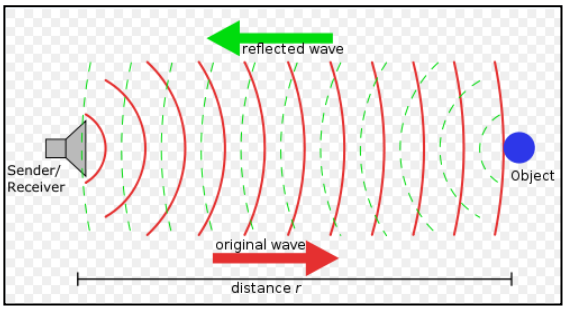

Fig. 1: Radar Basic Principle

B. Radar Types

Based on the radar mode of operation, it's divided into two groups:

1) Active systems:

Their sensor provide their own illumination and therefore contain a transmitter and receiver. Those radars are usually used in imaging radar, scatterometers and altimeters. Moreover, most radars use imaging systems where so often the antenna used for both transmission and reception

2) Passive systems:

They consist of receivers that measure the radiation emanating from an object such as microwave radiometers [4].

IV. TARGET CHARACTERISTICS

There are several target characteristics which will enable one target to be detected at a greater range than another, or for one target to produce a stronger echo than another target of similar size.

A. Height

Since radar wave propagation is almost line of sight, the height of the target is of prime importance. If the target does not rise above the radar horizon, the radar beam cannot be reflected from the target. Because of the interference pattern, the target must rise somewhat above the radar horizon.

B. Size

Up to certain limits, targets having larger reflecting areas will return stronger echoes than targets having smaller reflecting areas. Should a target be wider than the horizontal beam width, the strength of the echoes will not be increased on account of the greater width of the target because the area not exposed to the radar beam at any instant cannot, of course, reflect an echo. Since the vertical dimensions of most targets are small compared to the vertical beam width of marine navigational radars, the beam width limitation is not normally applicable to the vertical dimensions. However, there is a vertical dimension limitation in the case of sloping surfaces or stepped surfaces. In this case, only the projected vertical area lying within the distance equivalent of the pulse length can return echoes at any instant.

C. Aspect

The aspect of a target is its orientation to the axis of the radar beam. With change in aspect, the effective reflecting area may change, depending upon the shape of the target. The nearer the angle between the reflecting area and the beam axis is to 90°, the greater is the strength of the echo returned to the antenna.

D. Shape

Targets of identical shape may give echoes of varying strength, depending on aspect. Thus a flat surface at right angles to the radar beam, such as the side of a steel ship or a steep cliff along the shore, will reflect very strong echoes. As the aspect changes, this flat surface will tend to reflect more of the energy of the beam away from the antenna, and may give rather weak echoes. A concave surface will tend to focus the radar beam back to the antenna while a convex surface will tend to scatter the energy. A smooth conical surface will not reflect energy back to the antenna. However, echoes may be reflected to the antenna if the conical surface is rough.

E. Texture

The texture of the target may modify the effects of shape and aspect. A smooth texture tends to increase the reflection qualities, and will increase the strength of the reflection, but unless the aspect and shape of the target are such that the reflection is focused directly back to the antenna, the smooth surface will give a poor radar echo because most of the energy is reflected in another direction. On the other hand, a rough surface will tend to break up the reflection, and will improve the strength of echoes returned from those targets whose shape and aspect normally give weak echoes.

F. Composition

The ability of various substances to reflect radar pulses depends on the intrinsic electrical properties of those substances. Thus metal and water are good reflectors. Ice is a fair reflector, depending on aspect. Land areas vary in their reflection qualities depending on the amount and type of vegetation and the rock and mineral content. Wood and fiber glass boats are poor reflectors. It must be remembered that all of the characteristics interact with each other to determine the strength of the radar echo, and no factor can be singled out without considering the effects of the others [5].

V. RADAR APPLICATIONS

Based on the mentioned target characteristics that are picked up from the returned signal can classify radar into many uses. Many characteristics of echo wave such as magnitude, phase, time interval difference, polarization and Doppler frequency they are combined to define various radars. The most popular radars are:

1) Detection and Search Radars:

As used in Early Warning and Target Acquisition Systems.

2) Missile Guidance Systems:

Air-to-Air, Air-to-Surface and Surface-to-Surface Missiles.

3) Air Traffic Control and Navigation

4) Space radar systems

5) Weather-sensing Radar Systems:

Which is the most often used nowadays. The Weather Radar allocates the precipitation's position and motion using some information using refraction between two media and Doppler effect to forecast its future position [1].

CONCLUSION

It's clear that radar technology is a major tool in many aspects of human life. Thus, Electromagnetics which plays a main role in radar is an essential science to acquire this technology.

REFERENCES

[1] http://en.wikipedia.org/wiki/Radar
[2] http://www.doramusic.com/Radar.htm
[3] http://www.bbc.co.uk/dna/h2g2/A644311
[4]http://earth.esa.int/applications/data_util/SARDOCS/spaceborne/Radar_Courses/Radar_Course_III/radar_principles.htm
[5]http://www.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/RNM/310ch1.pdf