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A Review on "Weather Surveillance Radar"

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Abstract— *This paper strives to make an impact on Weather radar, also called weather surveillance radar (WSR) and Doppler weather radar, is a type of radar which locates precipitation and estimates its type (rain, snow, hail etc.). Soon after the World War II, surplus radars were used and since then, weather radar has evolved and is now used by national weather services and research departments. Modern weather radars i.e. Doppler radars are capable of detecting the motion of rain droplets in addition to the intensity of the precipitation to determine the structure of storms and their potential to cause severe weather. Hence, it is a key forecasting tool. Weather radars send directional pulses of microwave radiation, on the order of a microsecond long, using a cavity magnetron or klystron tube connected by a waveguide to a parabolic antenna and receives the return signals from particles in the air on the order of a millisecond, which is a thousand times longer than the pulse duration.*

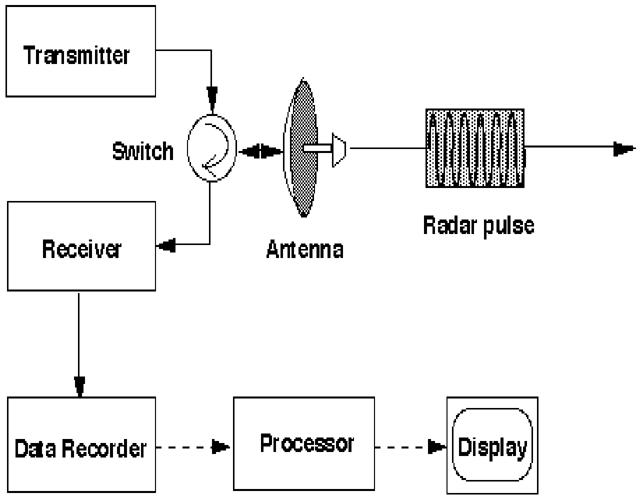
Keywords- ***Cavity Magnetron, Cavity Resonators, Control Head, Klystron, Radar.***

I. INTRODUCTION

Mostly, people plan their leisure time ahead according to the weather and so for the sake of weather forecasting, radar is a significant concept. It's a classic example of an electronic engineering system that utilizes many of the specialized elements including propagation, electromagnetic scattering, detection, information extraction and data processing. The name reflects the importance placed by the early workers in this field on the need for a device to detect the presence of a target and to measure its range. Invented just before World War II for military purpose, it has since been applied to many areas, an important one being weather monitoring. A weather radar detects rain in the atmosphere by emitting pulses of microwave and measuring the reflected signals from the raindrops. Through detecting raindrops in the atmosphere, the weather radar is a very effective tool for monitoring severe weather such as tropical cyclones, thunderstorms and heavy rain. Doppler radar has become increasingly popular in recent years. The Doppler principle can be explained by noting the change in pitch of an ambulance siren. The pitch heightens as the ambulance approaches and lowers as it departs. In other words, the faster the ambulance approaches, the higher will be the pitch. The Doppler radar has also been applied in healthcare, such as fall detection and fall risk assessment, for nursing or clinic purpose.

1. Basic Radar

Before proceeding to the working of weather radar, let us first understand the meaning of RADAR which stands for Radio Detecting And Ranging as indicated by the name. Radar is an electromagnetic (EM) system for the detection and location of reflecting objects like aircrafts, people, ships and natural environment. It operates by radiating energy into space and detecting the echo signal reflected from a target. By detecting these signals target location and related information can be determined. It can operate in snow, haze, fog, rain and darkness.



Block Diagram of Fundamental Radar System

A transmitter (in the upper left portion of the figure) generates EM signal (such as a short pulse of sine wave) to provide sufficient energy to detect a target, be easily modulated to faithfully produce the desired waveforms, generate a stable signal of tunable bandwidth, high efficiency and high reliability. The generated signal is radiated into space by an antenna. The radar antenna is a distinctive and important part of any radar, it has parabolic shape for great directivity of transmitted signals in the direction of target. A portion of the transmitted energy is intercepted by the target and reradiated in many directions. The re-radiation directed back towards the radar is collected by the radar antenna, which delivers it to a receiver. There it is recorded by data recorder and then processed to detect the presence of the target and determine its location using processor and radar display.

II. WEATHER RADAR / DOPPLER RADAR

The most powerful method for detecting moving targets in the midst of large clutter (unwanted echoes from the natural environment) is by using Doppler effect. Weather radar is a specialized radar that makes use of this Doppler effect to produce velocity data about objects at a distance. It does this by beaming a microwave signal towards a desired target and listening for its reflection, it tracks the phase shift between the transmitted radio wave and the received echo. This phase shift shows whether the target is moving directly toward or away from the radar, called its radial velocity. A positive phase shift implies motion toward the radar and a negative shift suggests motion away from the radar. The phase shift effect is similar to the "Doppler shift" observed with sound waves. If an object emits sound waves as it approaches a location, the waves are compressed leading to a higher frequency. As the object moves away from a location, the sound waves are stretched leading to a lower frequency. This is often experienced when an emergency vehicle drives past with its siren blaring. Hence, by analyzing how the frequency of the returned signal has been altered by the object's motion, the variation gives direct and highly accurate measurements of the radial component of a target's velocity relative to the radar.

Components of Weather Radar

Weather radar comprises of cavity magnetron, klystron, radar dish and indicator/control head as its basic components. They are defined as follows:-

2.1 Cavity Magnetron**-** The cavity magnetron is a high-powered vacuum tube that generates microwaves using the interaction of a stream of electrons with a magnetic field while moving past a series of open metal cavities (cavity resonators).

2.2 Klystron**-** A klystron is a specialized linear- beam vacuum tube, invented in 1937 by American electrical engineers Russel and Sigurd Varian, which is used as an amplifier for high radio frequencies, from UHF up into the microwave range. In the Klystron, an electron beam first passes through a cavity to which the input signal is applied. The energy of the electron beam amplifies the signal, and the amplified signal is taken from a cavity at the other end of the tube.

2.3 Radar Dish-A radar dish is a device used to send and receive microwave signals. It is a parabolic shaped antenna used for data transmission and broadcasting. The primary function of a satellite dish is to convert microwave signals into electric signals that can be used by a computer, television and other devices. By using radar dish, the signals can be sent anywhere without having miles of cables.

2.4 Indicator/Control Head- The third component of any weather radar system is the Indicator/Control Head. The job of the Indicator unit is to present the information being received by the Antenna/Radar dish as a top-down view of the approaching storm. This format is color coded in order to indicate the intensity of a particular region in a storm.

III. WORKING OF WEATHER RADAR

Before proceeding to the working of weather radar, let us first understand the meaning of RADAR which stands for Radio Detecting And Ranging and as indicated by the name. Weather radars send directional pulses of microwave radiation, on the order of a microsecond long, using a cavity magnetron and finally signals get amplified using klystron. When an electromagnetic wave is transmitted, some of the energy will eventually strike an object and will be reflected back towards the transmitter. By detecting the reflected energy, the object’s position in relation to the transmitter can determined.

The frequencies that make this detection possible are in C-band or X-band. The C-band range of frequencies is 4 to 8 GHz, while the X-band ranges in frequency between 8 to 12 GHz. These band frequencies have a better penetration ability and resolution. When the transmitted microwave energy strikes the rain droplets, some of it gets refracted and some gets absorbed. Some of it, however, does also get reflected, the fact that not all energy is reflected by the water droplets is important to note, as it allows the weather radar system to show if there is actually a storm accompanying the initial rainfall, or if there are just clear skies.

When the reflected energy gets back to the antenna, it picks up the signal and sends it to the control head. The circuitry in the control head system analyzes these returning signals in order to calculate the intensity and position of the rain. The unit knows the precise moments the microwave energy was transmitted and received. Therefore, the position of the storm can be determined by converting the time into a distance. Determining the intensity of the water droplets is a little more complicated than just analyzing the amplitude of the reflected signal. Consider, for a moment, the analogy of throwing a ball against a wall. It is obvious that if you stand close to the wall, the ball will return at relatively the same strength at which you threw it. However, if you move further away from the wall, the ball will return at a fraction of the strength that you threw it.

This analogy relates to weather radar if you think of the wall as the water droplets and the ball as microwave energy. When the energy hits water droplet that are close to the transmitter, a great deal more energy will be returned than for water droplets than for those that are far away. Comparing amplitudes of these signals would suggest that a storm that is a vast distance away is less intense than a storm which is closer. After processing the signals, the indicator creates a graphical visual representation of the sky directly on the screen.

IV. APPLICATIONS

Weather radar has been employed to detect targets on the ground, on the sea, in the air and in the space. The major areas of its application are described below:-

1. In sounding satellites
2. In meteorology
3. In police speed guns
4. In aviation
5. In radiology
6. Bistatic radar (surface to air missile)
7. In fall detection
8. In fall risk assessment
9. For nursing or clinic purpose.

V. BENEFITS AND CHALLENGES

Weather radar is the only way to map spatial distribution of precipitation and determine its type over large areas. It is beneficial in forecasting flash flooding and severe thunderstorms. In addition to this, it has the added capability to measure the frequency shift that is introduced in reflected signals by the motion of precipitation particles, which is then used in calculating wind speeds. It's a tool to determine the structure of storms and their potential to cause severe weather. Despite of this, the problem is compounded when small changes in the wind speed and direction result in significant changes in weather because winds near the equator are generally quite light and variable, and thus more difficult to predict. The most common type of weather systems that bring heavy rain are thunderstorms induced by strong solar heating of land areas in the afternoon and convergence of sea breezes, these thunderstorms can occur at practically any time of the year but are most frequent during the Inter-Monsoon months of April-May and October-November. The onset time and location of heavy rain caused by such systems are often difficult to forecast as the thunderstorms develop randomly and very quickly. An added challenge when tracking the movements of such system comes from the light and variable wind conditions, which are conducive for the development of intense thunderstorms. Though advances in Numerical Weather Prediction models have helped improve our weather forecasts over the years. Yet, there are still limitations in predicting the exact location and intensity of individual thunderstorms (single thunderstorms cells are usually less than 10 km in radius). Furthermore, the exact physics behind the convective processes which lead to the formation of such thunderstorms is not yet fully understood. As such, these numerical models require the application of empirical correlations to simulate the formation of thunderstorms.

VI. CONCLUSION

RADAR is an important component in the arsenal of forecaster tools to understand both the current state of atmosphere as well as what might happen in the near future. Forecasting using weather radar is the application of science and technology to predict the state of the atmosphere for a given location. It is made by collecting quantitative data about the current state of the atmosphere on a given place and using scientific understanding of atmospheric processes to project how the atmosphere will evolve on that place. Many improvements have been made over older weather radar system like ability to see motion of air (precipitation) using Doppler effect, increase in sensitivity and resolution for the clear observation of rainfall, moisture, storms and other severe climate conditions. Its great significance in determining the movement and trend of thunderstorms is used to protect life and property and also detecting the variability and concentration of precipitation is important to agriculture. Hence, since outdoor activities are severely curtailed by heavy rain, snow and the wind chill, weather radar plays a vital role in planning the activities around these events, and to plan ahead and survive them.

VII. ACKNOWLEDGEMENT

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