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Assessing the Susceptibility for installing Radars in Indian Scenario

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Abstract

This paperwork is indented to the research findings with respect to factors that affect directly and indirectly the efficiency of a radar operation in perspective of Indian geographical and meteorological scenario. Visual search habits are discussed and the integrations of such habits for the analysis of radar characteristics have been pointed out. Reference is needed to some of the design factors with respect to weather and atmospheric conditions; which determines the geographical accuracy with which target range and bearing are presented. A brief account of radar performance has been analyzed with respect to the Indian atmospheric and geographical conditions with respect to atmospheric ducts.

Key Words: *Radar, Meteorology, Atmospheric Condition, Geographical Location, Atmospheric Ducts*

Introduction

According to study, it is known that the Doppler has been developed during the Second World War. The RADAR is an acronym for Radio detection and ranging (radar). The radar was extensively used to detect the presence of ships and aircrafts. Since then there have been many advances in radar technology for example; Doppler techniques and it's used on land, sea, and in space for both research and operational needs. The basic elements of radar are transmitter, antenna, feed horn, receiver and radome. The transmitter generates the microwave signal of the correct phase and amplitude for the radar. Next, we have the antenna; the main purpose of the antenna (also called the "dish") is to focus the transmitted power into a small beam and also to listen and collect the returned signal. The feed horn directs the signal from the transmitter onto the antenna and directs the return signal from the antenna to the receiver. The receiver detects the signal returned from a target and the radome protects the antenna from high winds. For radar to find a target of interest, one needs to have three pieces of information. These are azimuth angle or direction relative to north, elevation angle or angle above the ground and distance to the target of interest. Generally, radars usually employ one of two scanning techniques. The first one is Plan Position Indicator (PPI). The radar holds its elevation angle constant but varies its azimuth angle. If the radar rotates through 360 degrees, the scan is named a "surveillance scan". If the radar rotates through but 360 degrees, the scan is named a "sector scan". Next is Range Height Indicator (RHI). The radar holds its azimuth angle constant but varies its elevation angle. The elevation angle normally is rotated from near the horizon to close the zenith (the point within the sky directly overhead). Radar is a crucial component within the arsenal of forecaster tools to know both the present state of the atmosphere also as what might happen within the near future. While satellite data gives a forecaster a way of the "big picture", radar provides more detail on at smaller scales of weather. [1]

Brief history on Radar

Radar stands for radio detection and ranging. Early radar equipment was adapted from the radio communications field, using HF, VHF, and UHF tubes and antenna techniques. First working model of Radar was not ready until 1935. It was during the early stages of Second World War, when the English claimed that they had established a chain of radar stations along its south and east coasts to detect aggressors in the air or on the sea. Experiments with radar began within the late 1800's, when Hertz saw that metallic objects reflected radio waves. In 1915, Robert Watson-Watt used radio technology to supply advance warning to airmen and through the 1920s went on to steer the U.K. research establishment to form many advances using radio techniques, including the probing of the ionosphere and therefore the detection of lightning at long distances. Progress of the radar technology during the war was rapid, probably one of the decisive factors for the victory of the Allies. In 1922 United States Navy researchers A. Hoyt Taylor and Leo C. Young placed a transmitter and a receiver on opposite sides of the Potomac and observed that ships passing through the beam path caused the received signal to fade in and out. United Kingdom, France, Germany, Italy, Japan, the Netherlands, the Soviet Union, and the United States independently developed technologies that led to the modern version of radar. In India, Electronics and Radar Development Establishment (LRDE) is the pioneer in development of radar. The laboratory is operated under the Defence Research and Development Organisation (DRDO).Several Radar systems that are today used by the Indian Armed Forces are developed by LRDE and installs them. It began its journey by developing short-range 2D systems, which was known as (Indra-1). Now there are many advanced projects, which DRDO develops. Some of the projects, which are known in public domain, are as follows. Rajendra preparation radar for the Akash SAM: The Rajendra may be a high power, Passive electronically scanned array radar (PESA). The system rotates 360 degrees on a rotating platform and has a detection range of 80 km with 18 km height coverage against small fighter sized targets and is able to track 64 targets, engaging four simultaneously, with up to 3 missiles per target. Next comes Primary Radar for AEW&C It is a major sensor of the AEW&C system, is long range multimode radar. The major role of PR is to supply surveillance for air defence and early warning alongside capability of aiding in tactical missions or in offensive strikes. It is a solid-state fully active electronically steered active array (ESA) radar mounted on the dorsal unit of EMB-145 executive jet aircraft. The radar has monopulse processing capability in azimuth and elevation. Up next is the Synthetic Aperture Radar (SAR). Synthetic Aperture Radar (SAR) is one of the important airborne imaging sensors for surveillance, reconnaissance and precision targeting. Being a day/night, all weather imaging system unlike its electro optical and thermal counterparts, SAR forms an indispensable system for the Defence applications. The imagery and the ground moving target information from the SAR can also be used to guide weapons. Key features of SAR include strip map mode imaging, spotlight mode imaging, and GMTI mode for detecting moving vehicles on ground.[2]

Some known stipulated factors varying the radar performance

Factors on which maximum range of radar depends are as follows. The first factor is frequency of the radio wave. Increase in Frequencies of a radio wave results in greater loss in power (attenuation). Lower frequencies have longer wavelength, therefore are preferred for longer detection ranges. The second factor is peak power. It is the useful power of radar. With the increase in peak power, range capabilities also increases. There is an increase in 25 percent in range capabilities when the peak power is doubled. The third factor is pulse length. The longer the pulse length, greater amount of energy is transmitted which results in increase in the range capability of the radar. The fourth factor is pulse repetition rate (PRR). The maximum measurable range of the radar can be determined by pulse repetition rate (PRR). There should be a significant amount of time between the pulses for an echo to return from a target that is located within the maximum operating range of the system. Or else continuous transmitted pulses block the echoes returning from the distant targets. This necessary time interval determines the highest pulse repetition rate that can be used. The fifth factor is beam width. The detection range of the radar increases with the increase in the concentration of the beam. The sixth factor is target characteristics. At greater distances, large target can be seen on scope provided; line of sight exists between the radar antenna and the target. Any conducting materials like steel hull of a ship returns comparatively strong echoes while non-conducting materials like a wooden hull of a boat return much weaker echoes. The seventh factor is receiver sensitivity. Increase in sensitivity of the receiver helps in greater detection ranges. Then it becomes more vulnerable to jamming. The eighth factor is antenna rotation rate. The detection range of the radar increases as the antenna rotation rate decreases.

The performances of a radar system are often judged by the following:

(1) The utmost range at which it can see a target of a specified size,

(2) The accuracy of its measurement of target location in range and angle,

(3) Its ability to differentiate one target from another,

(4) Its ability to detect the specified target echo when masked by large clutter echoes, unintentional interfering signals from other "friendly" transmitters, or intentional radiation from hostile jamming (if a military radar),

(5) Its ability to acknowledge the sort of target, and

(6) Its availability (ability to work when needed), reliability, and maintainability.

Some of the major factors that affect performance are discussed in this section. Transmitter power and antenna size .The maximum range of a radar system depends in large part on the typical power of its transmitter and therefore the physical size of its antenna. (In technical terms, this is called the power-aperture product.) There are practical limits to each. As noted before, some radar systems have a mean power of roughly one megawatt. Phased array radars about 100 feet (30 metres) in diameter are not uncommon; some are much larger. There are specialized radars with (fixed) antennas, like some HF over-the-horizon radars and therefore the U.S. Space Surveillance System that extend more than one mile (1.6 km). **Receiver noise** -The sensitivity of a radar receiver is decided by the unavoidable noise that appears at its input. At radar frequencies, the noise that limits detectability is typically generated by the receiver itself (i.e., by the random motion of electrons at the input of the receiver) rather than by external noise that enters the receiver via the antenna. A radar engineer often employs a transistor amplifier because the first stage of the receiver albeit lower noise are often obtained with more sophisticated (and more complex) devices. This is an example of the appliance of the essential engineering principle that the "best" performance which will be obtained won't necessarily be the answer that best meets the needs of the user. The receiver is meant to reinforce the specified signals and to scale back the noise and other undesired signals that interfere with detection. A designer attempts to maximize the detectability of weak signals by using what radar engineers call a "matched filter," which is a filter that maximizes the signal-to-noise ratio at the receiver output. The matched filter features a precise mathematical formulation that depends on the form of the input and therefore the character of the receiver noise. A suitable approximation to the matched filter for the standard pulse radar, however, is one whose bandwidth in hertz is that the reciprocal of the heart beat width in seconds. [3]

Target size the dimensions of a target as "seen" by radar isn't always associated with the physical size of the thing. The measure of the target size as observed by radar is named the radar cross section and is given in units of area (square metres). It is possible for 2 targets with an equivalent physical cross-sectional area to differ considerably in radar size, or radar cross section. For example, a flat plate 1 square meter in area will produce a radar cross section of about 1,000 square metres at a frequency of three GHz when viewed perpendicular to the surface. A cone-sphere (an object resembling an ice-cream cone) when viewed in the direction of the cone rather than the sphere could have a radar cross section of about 0.001 square metre even though its projected area is also 1 square metre. In theory, the radar cross section has little to try to to with the dimensions of the cone or the cone angle. Thus, the flat plate and therefore the cone sphere can have radar cross sections that differ by 1,000,000 to at least one albeit their physical projected areas are an equivalent. The sphere is an unusual target therein its radar cross section is that the same as its physical cross-sectional area (when its circumference is large compared with the radar wavelength). That is to mention, a sphere with a projected area of 1 square meter features a radar cross section of 1 square meter.

Commercial aircraft might have radar cross sections from about 10 to 100 square metres, except when viewed broadside, where the cross sections are much larger. Most air-traffic-control radars are required to detect aircraft with a radar cross section as low as 2 square metres, since some small general-aviation aircraft can be of this value. For comparison, the radar cross section of a man has been measured at microwave frequencies to be about 1 square metre. A bird can have a cross section of 0.01 to 0.001 square metre. Although this is a small value, a bird can be readily detected at ranges of several tens of kilometres by long-range radar. In general, many birds can be detected by radar, so special measures must usually be taken to ensure that their echoes do not interfere with the detection of desired targets. The radar cross section of an aircraft and that of most other targets of practical interest fluctuate rapidly as the aspect of the target changes with respect to the radar unit. It would not be unusual for a slight change in aspect to cause the radar cross section to change by a factor of 10 to 1,000. Clutter Echoes from land, sea, rain, snow, hail, birds, insects, auroras, and meteors are of interest to those who observe and study the environment, but they are a nuisance to those who want to detect aircraft, ships, missiles, or other similar targets. Clutter echoes can seriously limit the capability of a radar system; thus, a significant part of radar design is devoted to minimizing the effects of clutter without reducing the echoes from desired targets. The Doppler frequency shift is the usual means by which moving targets are distinguished from the clutter of stationary objects. Detection of targets in rain is less of a problem at the lower frequencies, since the radar echo from rain decreases rapidly with decreasing frequency and the average cross section of aircraft is relatively independent of frequency in the microwave region. Because raindrops are more or less spherical (symmetrical) and aircraft are asymmetrical, the use of circular polarization can enhance the detection of aircraft in rain. With circular polarization, the electric field rotates at the radar frequency. Because of this, the electromagnetic energy reflected by the rain and the aircraft will be affected differently, which thereby makes it easier to distinguish between the two. (In fair weather most radars use linear polarization; i.e., the direction of the electric field is fixed.) Atmospheric effects .As was mentioned, rain and other forms of precipitation could cause echo signals that mask the desired target echoes. Other atmospheric phenomena can affect radar performance as well. The decrease in density of the Earth’s atmosphere with increasing altitude causes radar waves to bend as they propagate through the atmosphere. This usually increases the detection range at low angles to a slight extent. The atmosphere can form “ducts” that trap and guide radar energy around the curvature of the Earth and allow detection at ranges beyond the normal horizon. Ducting over water is more likely to occur in tropical climates than in colder regions. Ducts can sometimes extend the range of an airborne radar, but on other occasions, they may cause the radar energy to be diverted and not illuminate regions below the ducts. This results in the formation of what are called radar holes in the coverage. Since it is not predictable or reliable, ducting can in some instances be more of a nuisance than a help. Loss of radar energy due to atmospheric absorption, when propagation is through the clear atmosphere or rain, is usually small for most systems operating at microwave frequencies. Interference Signals from nearby radars and other transmitters can be strong enough to enter a radar receiver and produce spurious responses. Well-trained operators are not often deceived by interference, though they may find it a nuisance. Interference is not as easily ignored by automatic detection and tracking systems, however, and so some method is usually needed to recognize and remove interference pulses before they enter the automatic detector and tracker of radar. Electronic countermeasures (electronic warfare) .The purpose of hostile electronic countermeasures (ECM) is to degrade the effectiveness of military radar deliberately. ECM can consist of

(1) Noise jamming that enters the receiver via the antenna and increases the noise level at the input of the receiver,

(2) False target generation, or repeater jamming, by which hostile jammers introduce additional signals into the radar receiver in an attempt to confuse the receiver into thinking that they are real target echoes,

(3) Chaff, which is an artificial cloud consisting of a large number of tiny metallic reflecting strips that create strong echoes over a large area to mask the presence of real target echoes or to create confusion,

(4) Decoys, which are small, inexpensive air vehicles or other objects designed to appear to the radar as if they are real targets. Military radars are also subject to direct attack by conventional weapons or by antiradiation missiles (ARMs) that use radar transmissions to find the target and home in on it. A measure of the effectiveness of military radar is the large sums of money spent on electronic warfare measures, ARMs, and low-cross-section (stealth) aircraft. Military radar engineers have developed various ways of countering hostile ECM and maintaining the ability of a radar system to perform its mission. It might be noted that a military radar system can often accomplish its mission satisfactorily even though its performance in the presence of ECM is not what it would be if such.[4]

A close look on the Atmospheric effects on Radar Performance

As was mentioned, rain and different sorts of precipitation will cause echo signals that mask the specified target echoes. There are different region phenomena which will have an effect on radiolocation performance further. The decrease in density of the Earth’s atmosphere with increasing altitude causes radiolocation waves to bend as they propagate through the atmosphere. This sometimes will increase the detection vary at low angles to a small extent. The atmosphere will kind "ducts" that lure and guide radiolocation energy round the curvature of the planet and permit detection at ranges on the far side the conventional horizon. Ducting over water is additional seemingly to occur in tropical climates than in colder regions. Ducts will generally extend the vary of mobile radiolocation, however on different occasions they'll cause the radiolocation energy to be amused and not illuminate regions below the ducts. This ends up in the formation of what ar known as radiolocation holes within the coverage. Since it's not inevitable or reliable, ducting will in some instances be additional of a nuisance than a facilitate. Loss of radiolocation energy thanks to region absorption, once propagation is thru the clear atmosphere or rain, is typically tiny for many systems in operation at microwave frequencies.[5]

The Atmospheric Duct

In telecommunications, an atmospheric duct could even be a horizontal layer within the lower atmosphere during which the vertical index of refraction gradients are such radio signals (and light rays) are guided or ducted, tend to follow the curvature of the earth, and knowledge less attenuation within the ducts than they might if the ducts weren't present. The duct acts as an atmospheric dielectric waveguide and limits the spread of the wave front to only the horizontal dimension. Atmospheric ducting could even be a mode of propagation of electromagnetic wave, usually within the lower layers of Earth's atmosphere, where the waves are bent by atmospheric refraction. In over-the-horizon radar, ducting causes an area of the radiated and target-reflection energy of a radar system to be guided over distances far greater than the traditional radar range.[6] It also causes long distance propagation of radio signals in bands which can normally be limited to line of sight. Normally radio "ground waves" propagate along the surface as creeping waves. That is, they're only diffracted round the curvature of the earth. This is often often often one reason that early long distance radio communication used long wavelengths. The sole known exception is that HF (3–30 MHz) waves are reflected by the ionosphere. The reduced index of refraction due to lower densities at the upper altitudes within the Earth's atmosphere bends the signals back toward the earth. Signals during a far better index of refraction layer, i.e., duct, tend to stay therein layer because of the reflection and refraction encountered at the boundary with a lower index of refraction material. In some weather, like inversion layers, density changes so rapidly that waves are guided round the curvature of the earth at constant altitude. [7][8].

Research Methodology and Findings

Four locations namely Sriharikota, Mumbai, Kolkata and New Delhi have been chosen. These regions have a largely varying geographical and climatic condition. A comparative study has been exercised in order to establish the atmospheric refractivity (N) among these locations.

The calculation of the atmospheric refractivity is performed utilising the following equations-

M = N+ Z/R *10^6........................... (1)

&

N= 77.6/T (P+ 4810 e/T).................. (2)

Here M is the modified refractivity of the atmosphere; N is the refractivity of the atmosphere; Z is the height above sea level (in meters); R is the mean radius of the earth and is assumed to be 6371 Kms; T is the air temperature (in Kelvin) ; P is the air pressure (in Hpa) and e is the vapour pressure (in Hpa)

- Here the vapour pressure is referred as saturated vapour pressure of the location

The ray at small angle emitted to the ground will bent downwards if M (modified refractivity) decreases and will bent upwards if M(modified refractivity) increases with respect to the height or elevation. In this way the ray may get trapped in the Atmospheric Duct and there by increases the range of the radar.[1]

Data Analysis

LOCATION	ELEVATION	HIGH TEMP	LOW TEMP	MEAN TEMP	DEW POINT	AIR PRESSURE
	(in meter)	(in Kelvin)	(in Kelvin)	(in Kelvin)	(in Kelvin)	(in hPa)
Sriharikota	1	312	294	302	296	1009
Mumbai	4	307	291	301	294	1009
Kolkata	14	309	286	300	294	1007
New Delhi	216	313	281	299	290	1008

Table 1

The table has been prepared on the basis of the daily averages of Highest and Lowest temperatures, dew points and average air pressure recorded at the above mentioned locations from 2009-2019.Source(s)- IARI(The Indian Agricultural Research Institute),IMD(Indian Meteorological Department)

The Vapor Pressures (in hPa) of the following locations at varied Climatic Scenarios

AT	HIGH TEMP	LOW TEMP	MEAN TEMP
Sriharikota	69.33	24.63	39.7
Mumbai	52.73	20.44	37.46
Kolkata	58.9	14.83	35.33
New Delhi	73.15	10.61	33.31

Table 2

The Vapor Pressure have been calculated with an open source software developed by the National Oceanic and Atmospheric Administration from the Data as per Table 1

THE MODIFIED REFRACTIVITY INDICES

Location	(M) at High Temperature	(M) at Low Temperature	(M) at Mean Temperature
Sriharikota	516.914	372.772	420.3319
Mumbai	464.3728	358.8899	413.7845
Kolkata	485.227	343.062	409.0931
New Delhi	528.6037	362.356	433.703

Table 3

The chart showing the modified refractivity values of the following locations at the varied climatic conditions

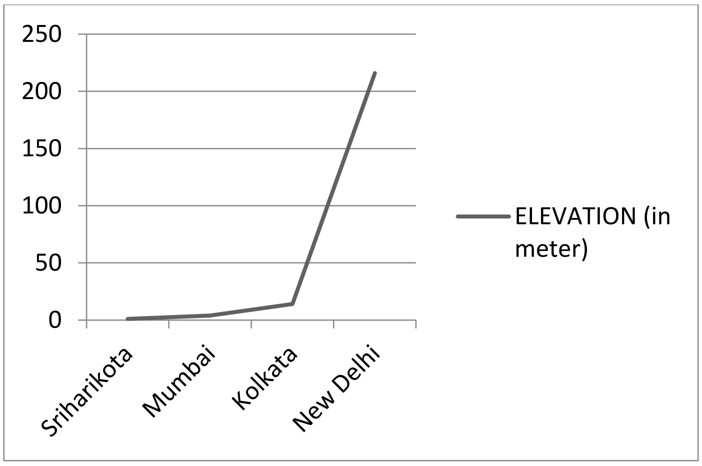

Fig 1. Elevation of the four chosen locations above sea level

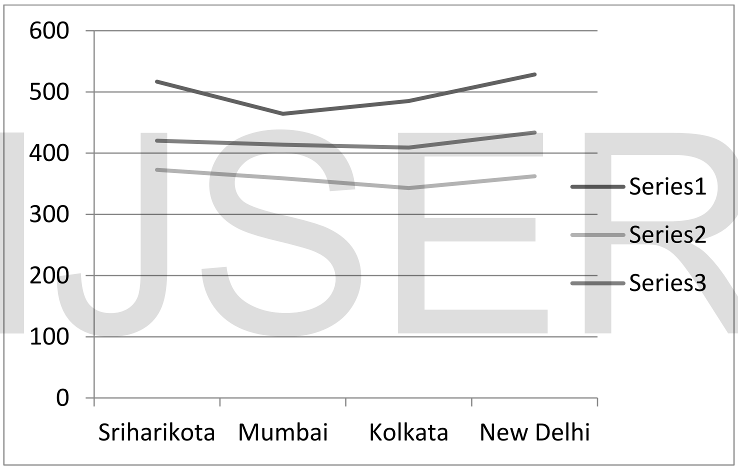

Fig.2 The variation of the Modified Atmospheric refractivity at the four chosen locations at High Temperature, Mean Temperature and Low Temperatures

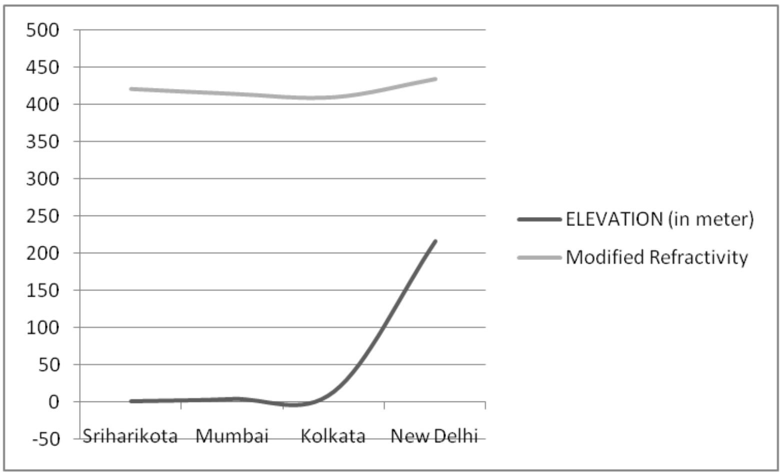

Fig.3. The Correlation between Elevation and Modified Refractivity (M) at mean temperatures =0.880045435

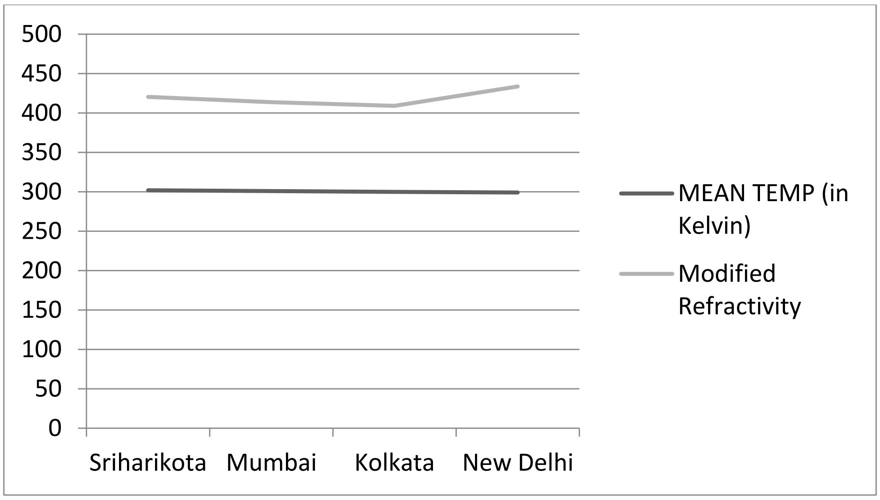

Fig.4. The Correlation between Dew Point and Modified Refractivity (M) at mean temperatures = -0.68978

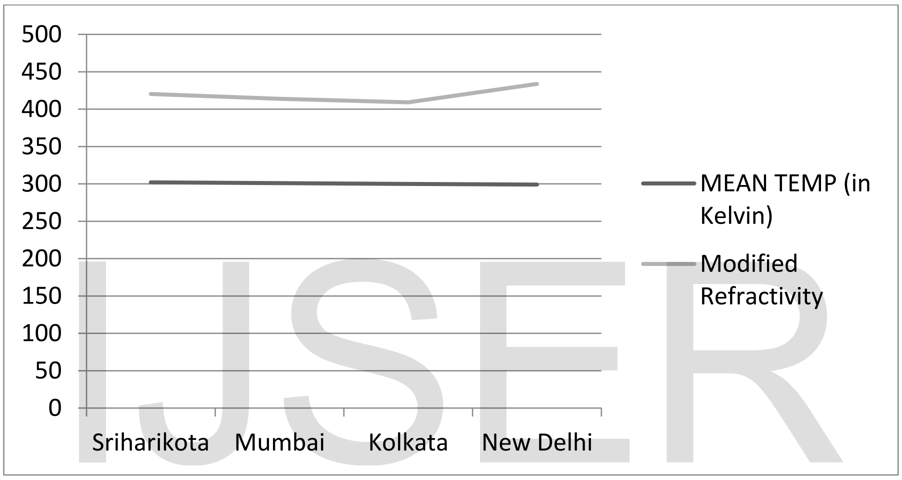

Fig.5.The Correlation between Atmospheric Pressure and Modified Refractivity (M) at mean temp. =0.188

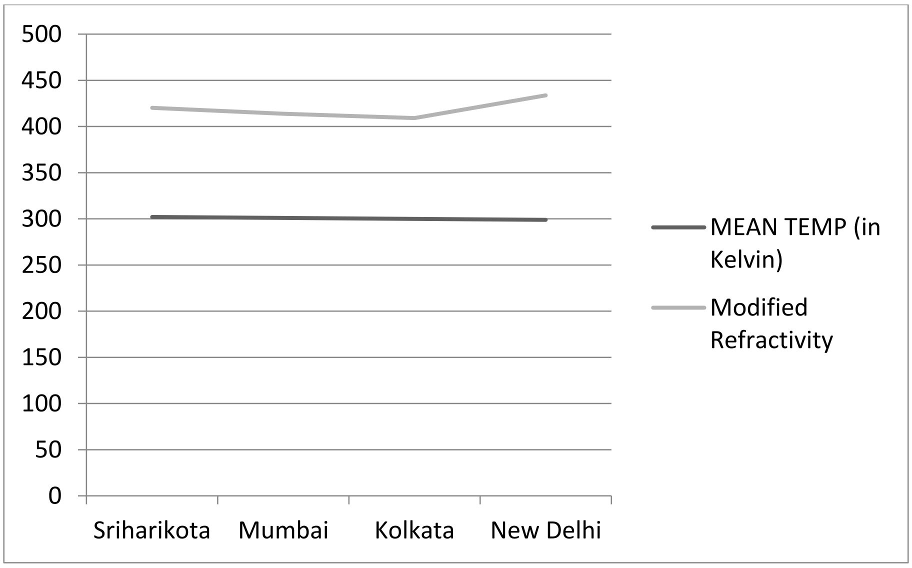

Fig.6. The Correlation between Mean Temperatures and Modified Refractivity (M) at mean temperature=-0.427

CONCLUSION

From the above analysis it is verified that all these factors are the functions for Atmospheric Modified Refractivity (M) and hence helps in the formation of Atmospheric Ducts. From the collected data we see that the elevation factor (z) plays a very important role as it holds a very strong positive correlation with M. On the other hand the dew point of various locations hold a negative correlation with M. Atmospheric Pressure and Vapor Pressure are also key player for selecting the location which can be more susceptible for the formation of atmospheric ducts which directly or indirectly will benefit in increasing the radar range and so as its performance. In this paper location of New Delhi is seen to be best capable of sending radio waves through atmospheric ducts.

FUTURE SCOPE OF RESEARCH AND DEVELOPEMENT

The paper work is a reflection for suggesting the best place in terms of geographical and climatic conditions to set up or propose the installation of RADAR. Soft Computing techniques like Genetic Algorithm etc. can be integrated into this methodology for developing simulating software that can very easily propose the installation location of RADAR. An efficient RADAR network can also be modeled with the help of this methodology that will directly or indirectly benefit in giving a much more precise or accurate data of Weather / Enemies etc.to name a few. The development of this methodical software will not only benefit the static RADARs but also moveable ones by finding through iterative techniques for its proper placements and thereby giving data of increased range by passing the radio signals through atmospheric ducts.

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