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FULL ACTIVE PHASED ARRAY MST (53 MHz) RADAR DETERMINATION OF CHARACTERISTICS OF ATMOSPHERIC TURBULENCE

[1]Ramesh Nandha Kumar, [2]T Prasad
[1]PG Student, [2]Assistant Professor, HOD
[1]VLSI Design,
[1]Shree Institute of Technical Education, Tirupati, India

Abstract: The present semi-active phased array MST radar (32 by 32 Yagi-Uda antennae, total 1024 antennae) operating at the frequency of 53 MHz, has been augmented recently as fully-active phased array (FAPA) radar to study the atmospheric dynamics and turbulence in detail. During the last 25 years of operation as semi-active phased array (SAPA), the radar beam, with 3 beam width, could be tilted only in the north-south and east-west planes and hence the three dimensional spatial properties of turbulence and its evolution in time could not be studied. In the SAPA mode, each row/column of 32 antennae was powered by a single transmitter (9 – 180 kW of peak power) through electronic power dividers and couplers and the received echoes collected by a single (sometimes 2 receivers) receiver were processed to determine the characteristics of atmospheric turbulence.

In the present case of FAPA, each and every antenna is powered individually with peak power of 1kW and a receiver module is attached. With this facility, it can be controlled the transmit beam pattern as well as its pointing direction so that a full four dimensional characteristics (space and time) of atmospheric turbulence can be studied. The main aim of the present project work is to study the generation, evolution and dissipation mechanisms of atmospheric turbulence and its imaging using multi power-patterns of the FAPA system and many digital receivers.

Index Terms **– Antenna, Radar, MST Radar, Atmospheric turbulance**

I. INTRODUCTION

Over the past century we have become increasingly aware of the complexity and diversity of dynamical processes occurring within the earth's atmosphere. In recent times issues such as the 'greenhouse effect' and drops in Ozone abundance over the Polar Regions have received extensive press coverage, bringing some of these to the attention of the general public. Even though our scientific understanding of the atmosphere, its makeup and processes have progressed dramatically over the last fifty years, it seems that there is still much more which we do not know or do not fully understand.

Strictly speaking, the atmosphere extends many hundreds of kilometers out from the earth's surface. As we studied before the Earth's atmosphere is relatively transparent to incoming solar radiation and opaque to outgoing radiation that is emitted by the Earth's surface. The blocking of outgoing radiation by the atmosphere popularly referred to as the greenhouse effect, keeps the surface of the Earth warmer than it would be in the absence of an atmosphere. The gases which block the outgoing long wave radiations are called greenhouse gases. Earth is surrounded by a thin gaseous envelope that is called atmosphere which extends up to 600km. Thus, a variety of reactions involving atmospheric constituents occur at different heights throughout the atmosphere.

Composition of the earth's atmosphere is dominated by the diatomic gases like Nitrogen (N2) and Oxygen (O2) which is about 78% and 21% in total gas concentration. Apart from these two gases, there are some other gases such as argon (Ar), Carbon dioxide (CO2), ozone (O3) and water vapor etc. In small amount, which are known as trace gases. Density and pressure of the atmosphere is decreasing exponentially with height.

The average composition of the earth's atmosphere is given in **table 1.1.**

Table 1.1 The average composition of the earth's atmosphere

Consituents	Chemical formula	Percentage in volume(%)
Nitrogen	N_2	78.08
Oxygen	O_2	20.95
Water vapour	H_{2O}	0 - 4
Argon	Ar	0.93
Carbon dioxide	CO_2	0.036
Neon	Ne	0.0018
Helium	He	0.0005
Methane	CH_4	0.00017
Hydrogen	H_2	0.00005
Nitrous Oxide	N_2O	0.00003
Ozone	O_3	0.00004

Antenna was developed in order to full fill the problem occurs and upgraded the antenna for the advanced technologies. A conventional antenna is very hard to design compared to micro strip antenna. A conventional antenna is very costly and quite heavy but the micro strip patch antenna has a simple structure and quite easy to fabricate. There are many shape of micro strip patch antenna such as rectangular, circular, triangular and other types of geometries. The most popular configuration is rectangular micro strip patch antenna. The main purpose of this project is to design a rectangular micro strip patch antenna using the Flame retardant 4 (FR4) and Roger4350 as a dielectric substrate in fabrication of the antenna.

II. IMPLEMENTATION

Fully Active phased array MST radar is advanced technology of MST radar. In this radar, by using optical cables, data loss can be reduced and also it requires very low power to operate it. As we use Transmitter modules near the antenna which results in the less number of cables are used. Due to Fully Active phased array concept, beam steering is possible to receive echo signals in all directions. Due to individual power supply is used, the controlling of each element is easier when compared to MST RADAR.

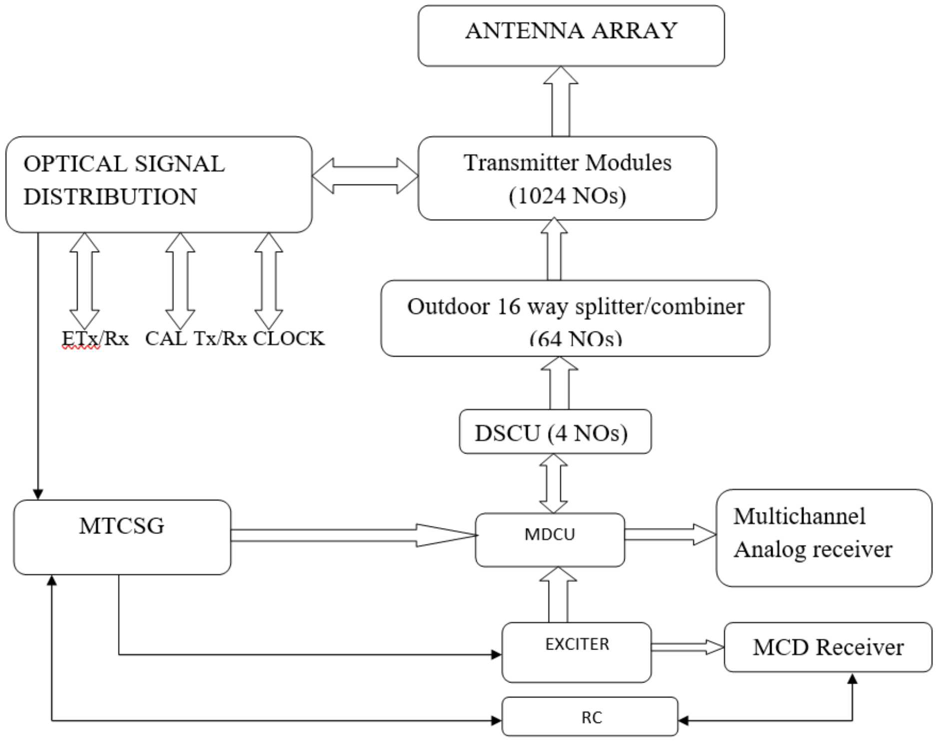


Figure 2.1: Block Diagram of Fully Active Phased Array MST radar

Antenna array:

Active phased array is used in this radar. The array will be segmented into sub-arrays. Initially at first level, the array configures into four quarters, each quarter consists of a 4×4 sub-array that means 16 groups and each group contain 16 modules. Each quarter consists of 256 elements.

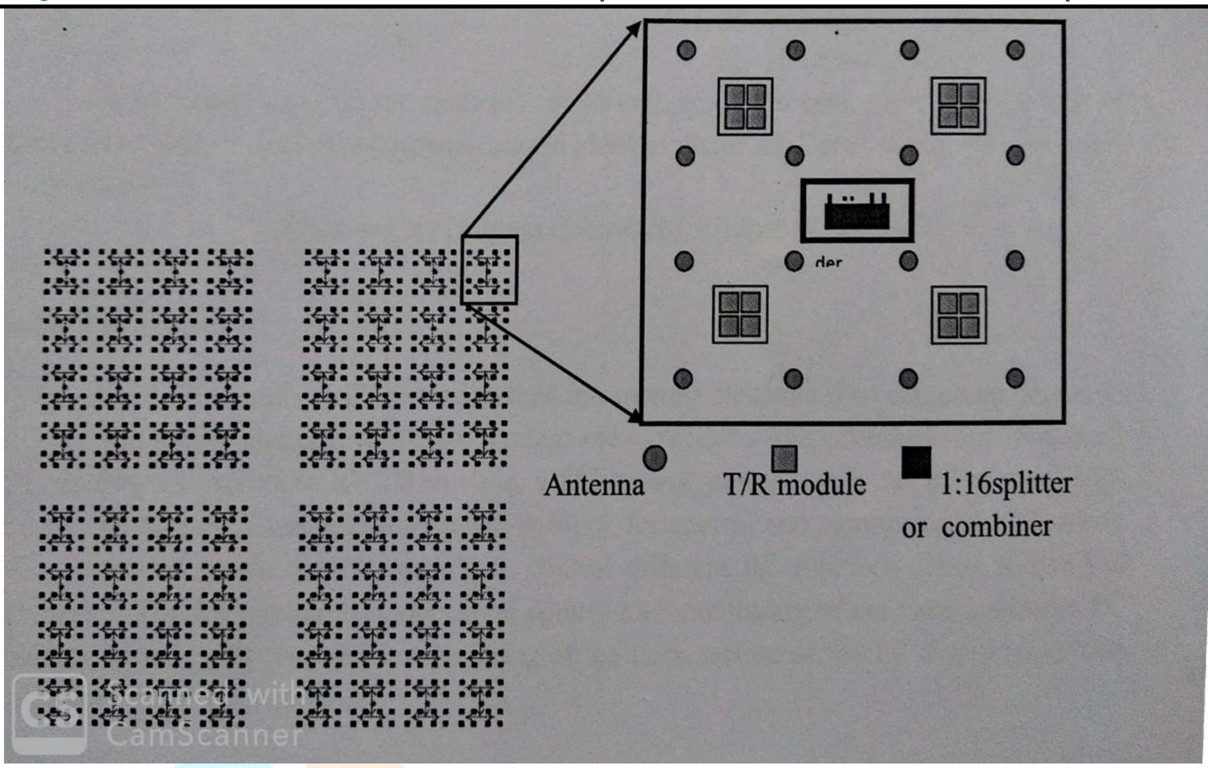


Figure 2.2: Array Setting of MST RADAR

Fully Active Phased Array:

In antenna theory, a phased array is an array of antennae in which relative phases of the respective signals that feed the antennae are a set. The effective radiation pattern of the array is strengthen in a desired direction and stopped in undesired directions. The phase relationships among the antenna may be adjustable or fixed for beam steering.

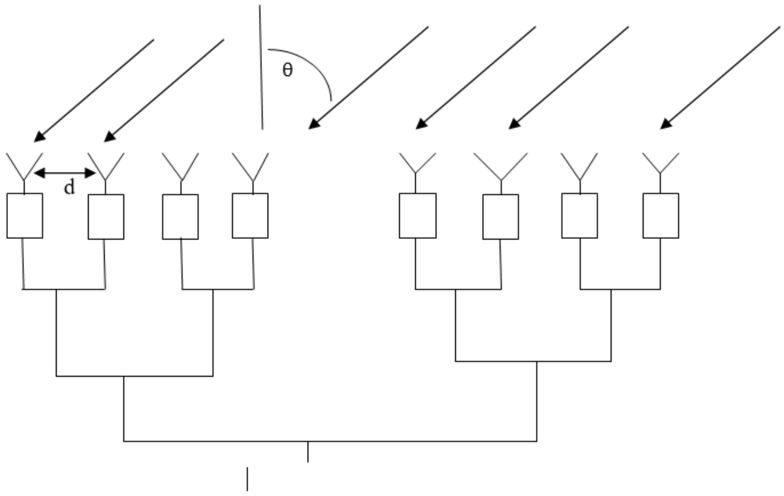


Figure 2.3: phased array

Transmitter Modules

1 kW transmit-receive (TR) modules will be used to feed power to the elements in antenna. The ratio of maximum duty is 10 %. The minimum pulse width is 0.5 ms and a range of resolution is 75m. Each transmit-receive(TR) module consists of an radio frequency (RF), transmit-receive(TR) module, UPS supply for TSG card, DC normal power supply for RF section and optical transceiver block for control and monitoring .

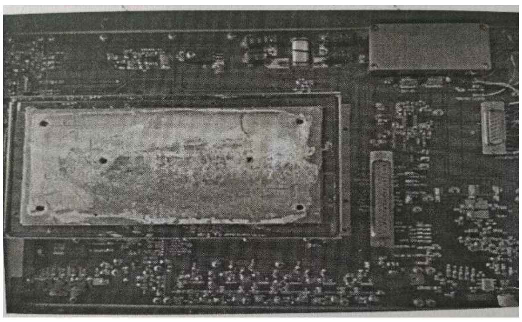


Figure 2.4: TR Module

III. RESULTS

The Digital receiver is programmed to perform radar operations independently, as well as receive only function in synchronous to the existing radar systems. Clock synchronization with stable reference oscillators is implemented by dedicated sinusoidal to TTL converter and associated clock generator integrated circuits. The time resolution of synchronization signals for TX pulse, Rx blanking pulse and duplexer synchronization pulses are verified for synchronization and precise timing relationship that can be tuned with a resolution of 10 ns.

The Digital receiver is attached to MST Radar simultaneously with analog by synchronizing the Digital receiver with radar operations. The real time echoes from atmosphere are fed to both receivers. Radar is operated with its highest resolution with operating parameters 16µs coded pulse with 1µs baud length, 1000µs inter pulse period, 64numbers of coherent integrations, 256 FFT points, and 150 range bins starting from 3.6 km(24thµs). Digital receiver successfully detected the weak atmospheric signals. Figure 10 presents the stacked power spectrum plot from 3.6 to 20 km, shows good performance of digital receiver signal detect ability capability.

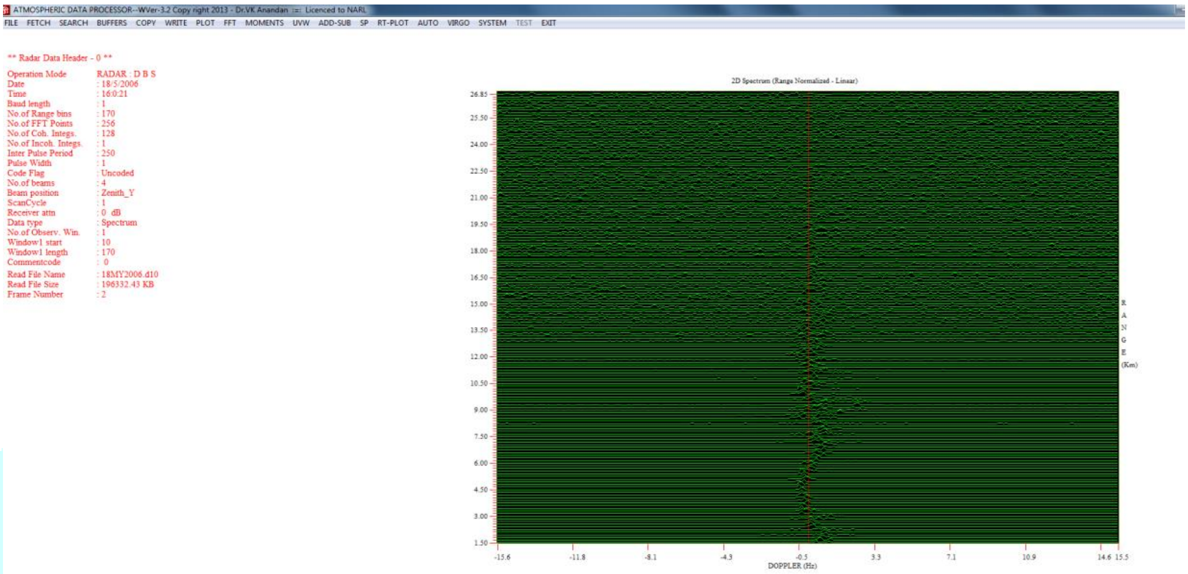


Figure 3.1: MST Radar power spectrum plot with Digital receiver-showing stacked power spectral plots of atmosphere at height ranging from 1.50 km to 26 km with 150 m height intervals at Zenith_Y.

The plot shows the Doppler shift corresponding to each height. The signal detectability can be observed up to about 21-22 km. Panel on the right presents the experiment parameters. The radar output plot stacked power spectral density plot represent target Doppler shift at each height (Doppler shift in x-axis, Range/Height in y-axis). Digital receiver is successfully integrated with MST radar with 128 coherent integrations, 256 FFT points, and complementary coding technique to get 150 m resolution. The pulse modulated simulated signal is placed at 10km, 4 Hz along with actual radar trace. In the Atmospheric Data Processor, we can see power spectrum from this now, we consider single beam, and we are going to calculate the characteristics of turbulence at different heights.

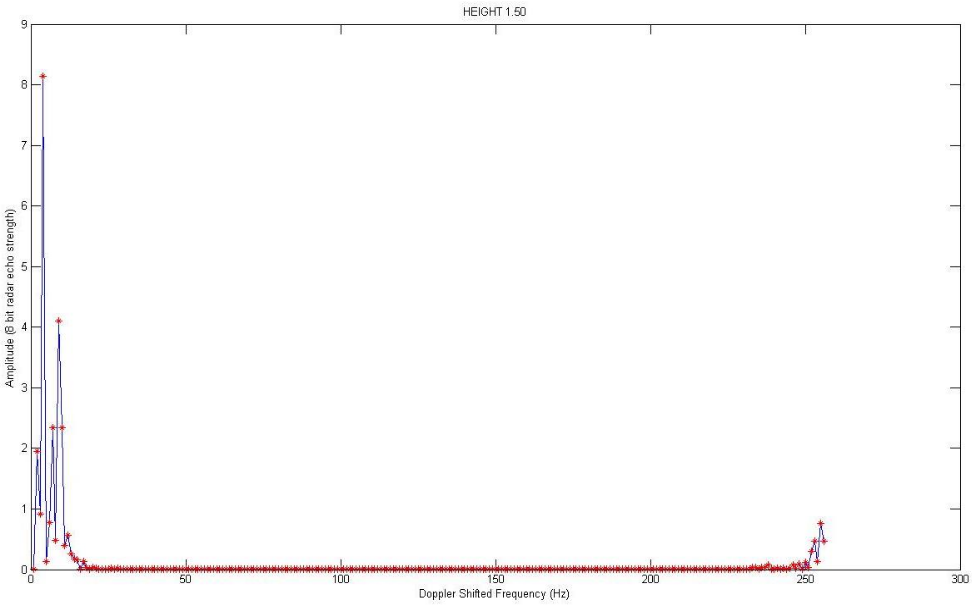
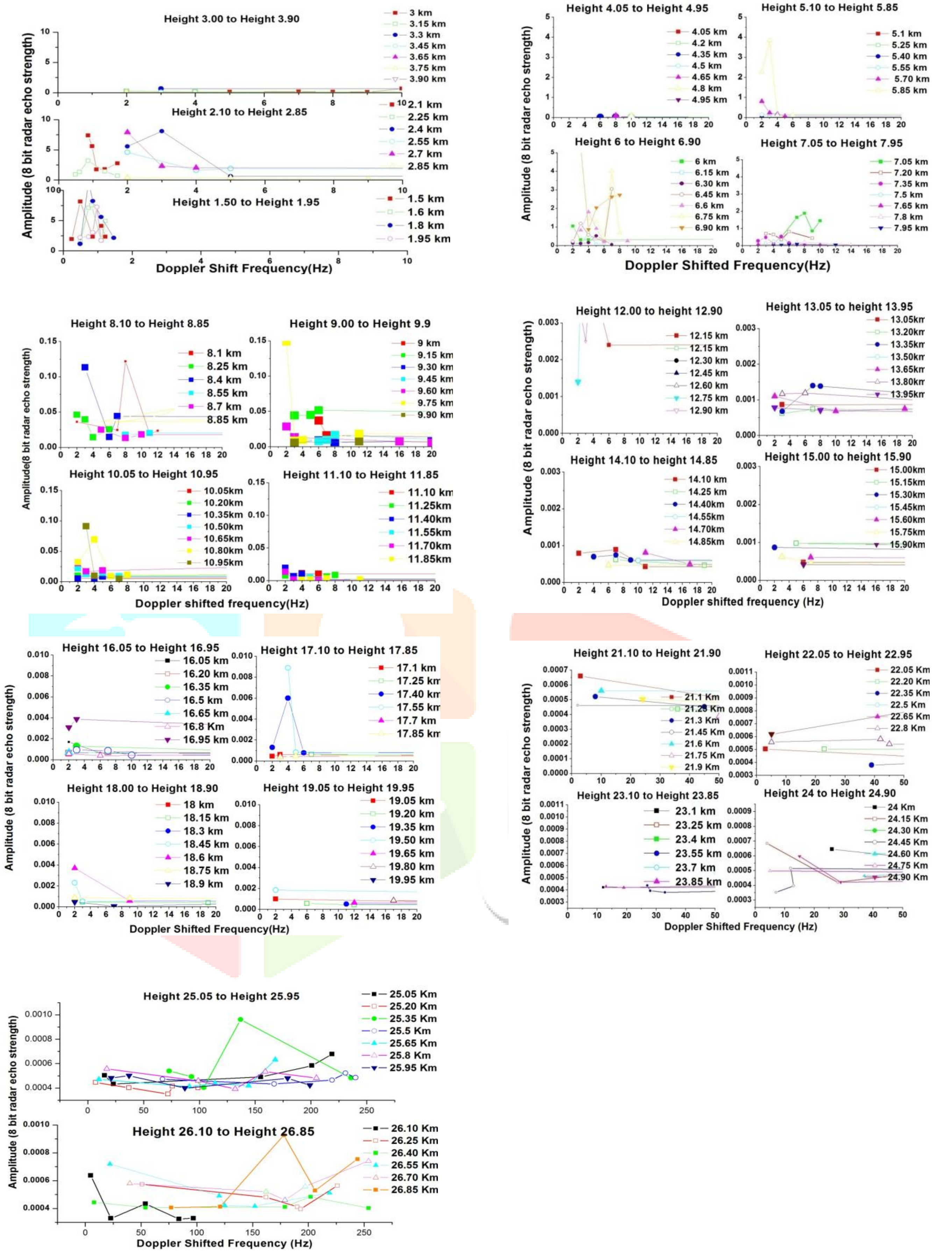


Figure 3.2: Power spectral plot of atmosphere at height at 1.50 km with 150 m height intervals at Zenith_Y.

The same process continues for another cycle i.e, Zenith_X in semi active radar and Zenith_Y in fully active radar.



The above figures shows MST Radar power spectrum turbulence at different heights at zenith X.

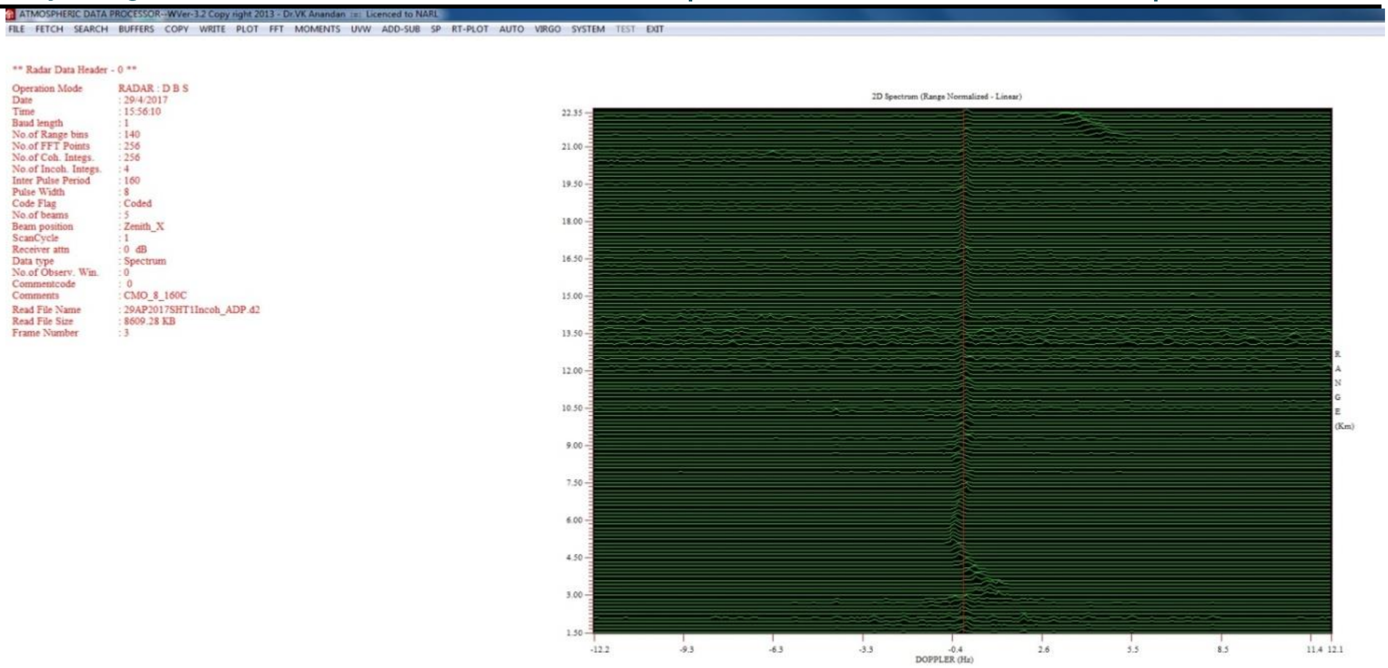
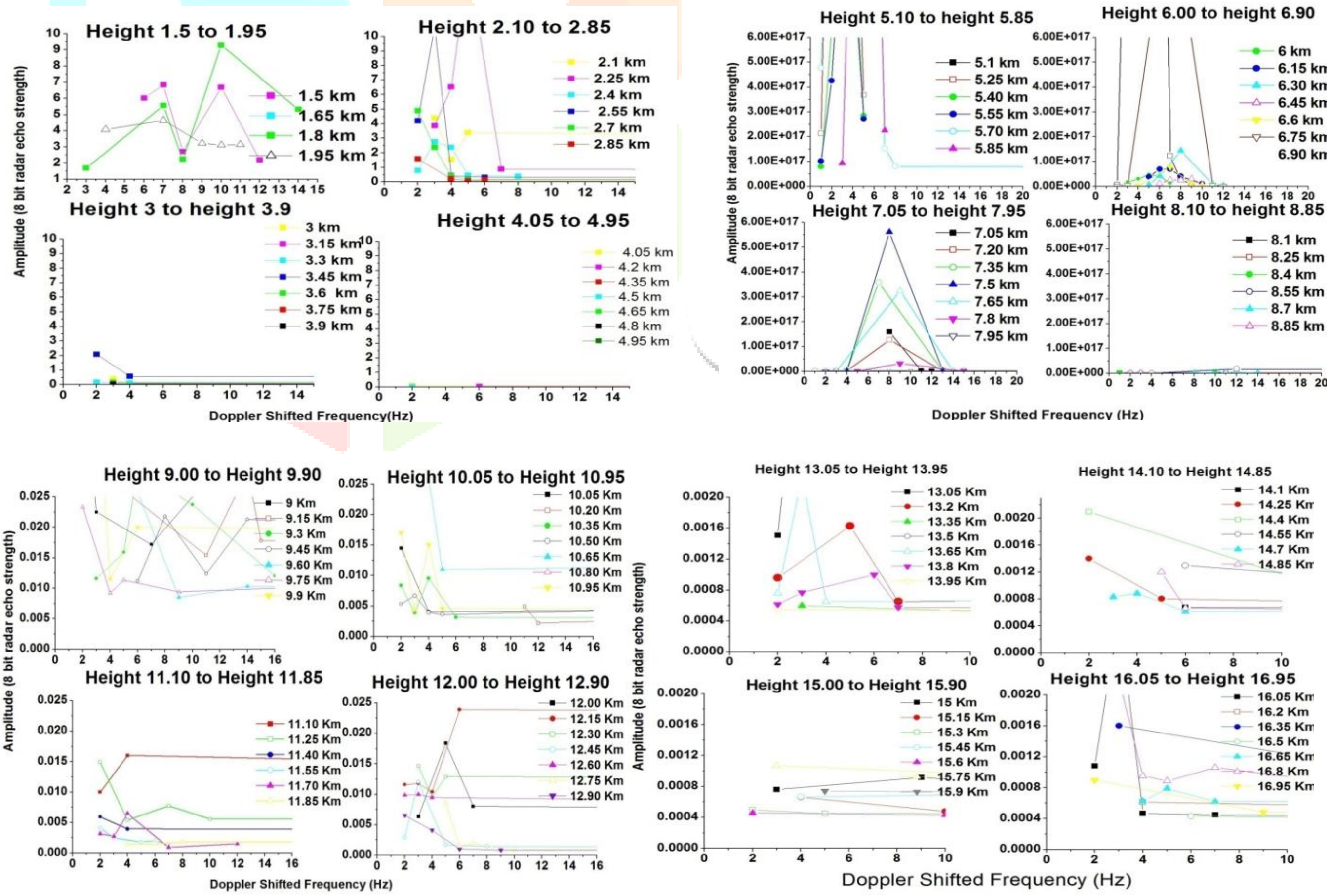
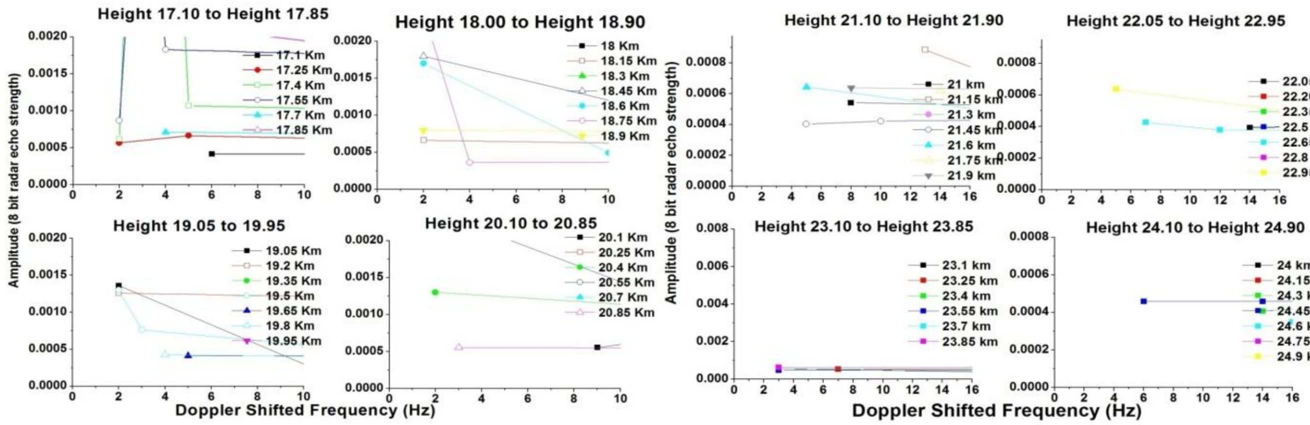


Figure 3.3: MST Radar power spectrum plot with Digital receiver -showing stacked power spectral plots of atmosphere at height ranging from 1.50 km to 22 km with 150 m height intervals at Zenith_X.

The plot shows the Doppler shift corresponding to each height. The signal detect ability can be observed up to about 21-22 km. Panel on the right presents the experiment parameters. The radar output plot, stacked power spectral density plot represent target Doppler shift at each height (Doppler shift in x-axis, Range/Height in y-axis). Digital receiver is successfully integrated with MST radar with 128 coherent integrations, 256 FFT points and complementary coding technique to get 150 m resolution. The pulse modulated simulated signal is placed at 10km, 4 Hz along with actual radar trace.





The above figures shows **:** MST Radar power spectrum turbulence at different heights at Zenith_X.

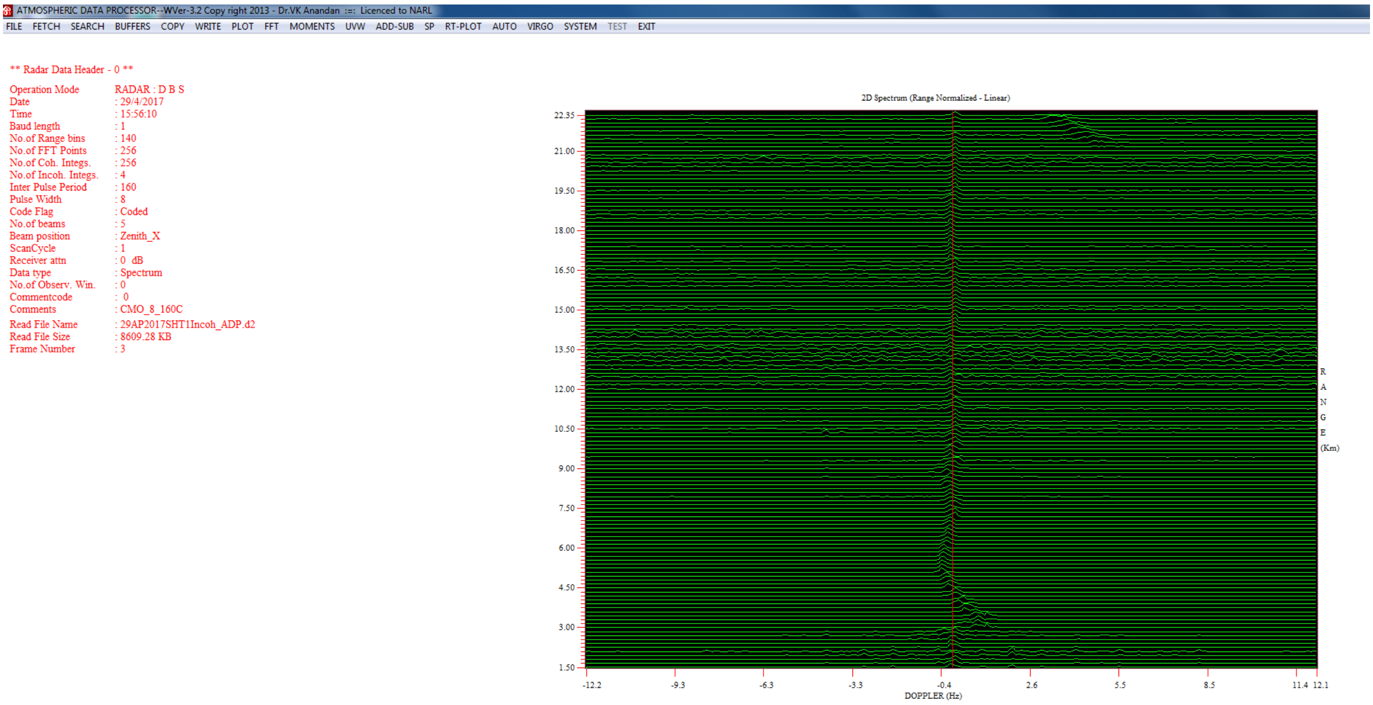
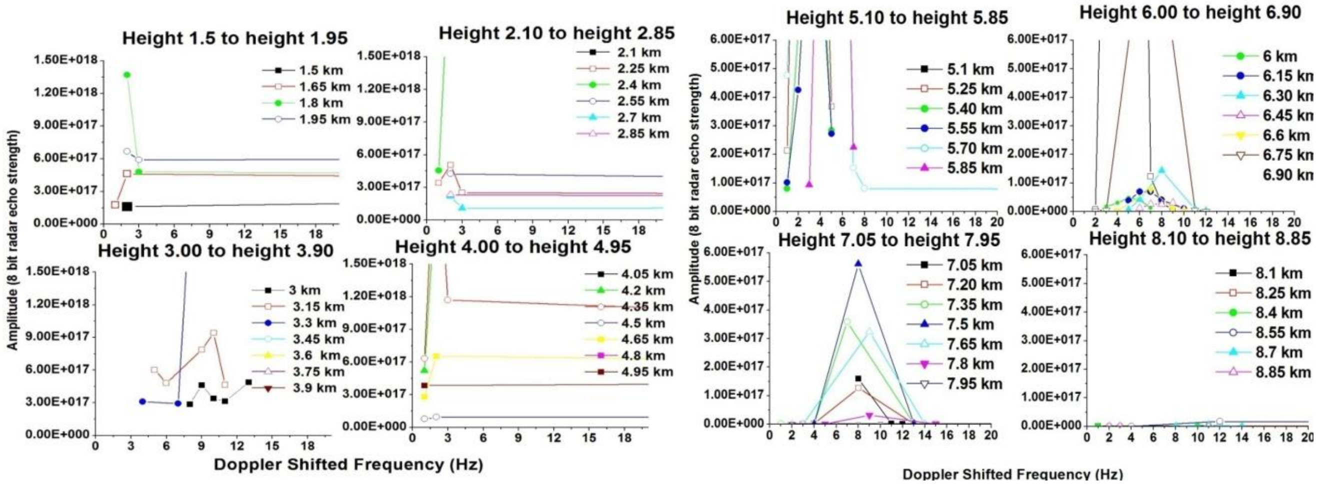
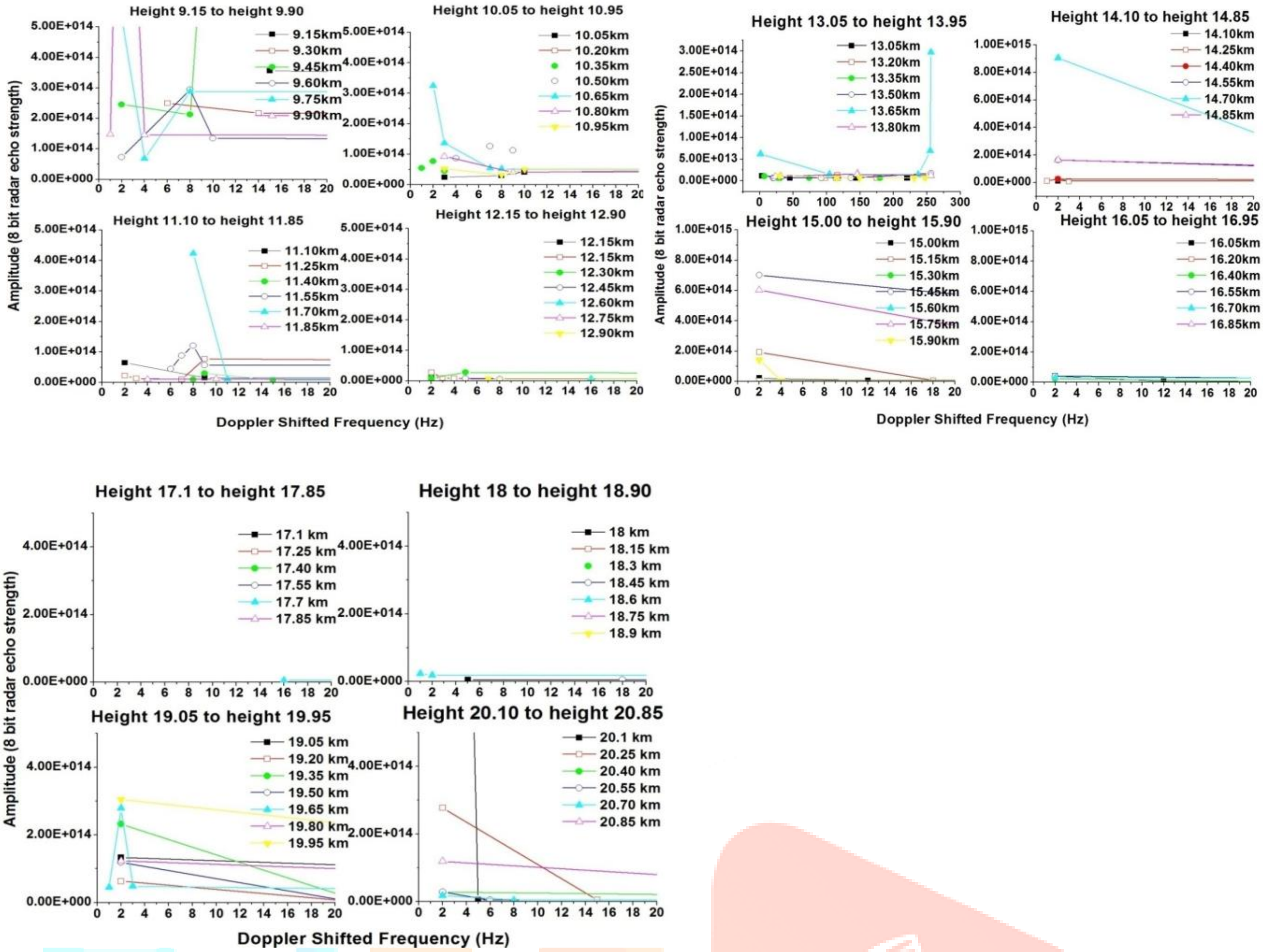


Figure 3.4: MST Radar power spectrum plot with Digital receiver-showing stacked power spectral plots of atmosphere at height ranging from 1.50 km to 26 km with 150 m height intervals at Zenith_X.

The plot shows the Doppler shift corresponding to each height. The signal delectability can be observed up to about 21-22 km. Panel on the right presents the experiment parameters. The radar output plot stacked power spectral density plot represent target Doppler shift at each height (Doppler shift in x-axis, Range/Height in y-axis). Digital receiver is successfully integrated with MST radar with 128 coherent integrations, 256 FFT points, and complementary coding technique to get 150 m resolution. The pulse modulated simulated signal is placed at 10km, 4 Hz along with actual radar trace.





The above figures shows Turbulence at height from 1.50 km to 20.85 km at Zenith_X in Fully Active Phased Radar.

IV. CONCLUSION AND FUTURE SCOPE

Fully Active phased array MST radar is advanced technology of MST radar. In this radar, by using optical cables, data loss can be reduced and also it requires very low power to operate it. As we use Transmitter modules near the antenna which results in the less number of cables are used. Due to Fully Active phased array concept, beam steering is possible to receive echo signals in all directions. The digital receiver functionality and performance are quite satisfactory as the signal detectability is up to 26 km and the excellent matching of parameters (Doppler shift etc.,) is obtained in comparison with analog receiver results during MST Radar operational test. The process gain performance of the coding, coherent integration, FFT, timing relationship and automatic execution of the experiments are satisfactory.

The advantage of digital receiver system over analog counterpart in range side lobes is exceptional due to digital IQ demodulation. The end to end functionality of IF signal to atmospheric parameters extraction is performed successfully with digital receiver and hence the analog counterpart is replaced with digital system for better functionality and latest technical advantages of digital techniques viz., easy software upgrades, digital systems stability and reduced component tolerance. The Digital receiver digital down conversion module has multi-channel capability, at least for three channels with different IF frequencies and NCO, which will be exploited in next step of development of this receiver to cater multi-receiver requirement of spaced antenna and imaging applications of active array MST Radar system.

Future Scope

Fully-active phased array (FAPA) radar to study the atmospheric dynamics and turbulence in detail. In the present case of FAPA, each and every antenna is powered individually with peak power of 1kW and a receiver module is attached. With this facility, it can be controlled the transmit beam pattern as well as its pointing direction so that a full four dimensional characteristics (space and time) of atmospheric turbulence can be studied. The future scope of the present project work is to study the generation, evolution and dissipation mechanisms of atmospheric turbulence and its imaging using multi power-patterns of the FAPA system and many digital receivers.

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