Weather observation using pulse compression technique in space-borne weather radar

M Anusha, G Kaveri, A Priyanka, B Pushpalatha, N Roopavathi.
[1]B.Tech student,[2]B.Tech student,[3]B.Tech student, [4]B.Tech student, [5]Assistant professor
[1]Electronics and communication engineering
Gayatri vidya parishad college of Engineering for Women, Visakhapatnam, India

Abstract - In this project, we use pulse compression in space-borne weather radar, which is a radar operating in outer space and can be used to survey regions that cannot be observed from an aircraft. This radar details statistical methods, estimation algorithms, and design techniques for the measurement of rainfall and cloud cover over the region of oceans, and mountain ranges that remain unreachable with normal weather radar. This radar gives the weather condition of a particular area by Trans receiving a pulse compressed signal from radar. We use the linear frequency modulation(LFM) technique of pulse compression which increases the duration of a transmitted pulse, increases its energy, and improves target detection capability. On reception, the echo is passed through a pulse compression filter and the output is the autocorrelation of the modulated pulse. The peak power of the correlated output is increased by the pulse compression ratio. And the pulse will be converted into images using a technique called Synthetic Aperture Radar (SAR) imaging. SAR imaging is a type of radar imaging that uses the motion of the radar platform to create a high-resolution image of the target area. In this, we process those images using some image-processing techniques such as filtering, resizing, compression, and decompression. We use the Gabor filter for feature extraction to forecast the weather. Based on the accuracy, sensitivity, and specificity it will determine whether it will be good or bad.

Index Terms - RainCube, pulse compression, image processing techniques, Gabor filter, accuracy, sensitivity, specificity

I. INTRODUCTION

Pulse compression is an essential technique used in radars that involves transmitting a wide pulse to achieve large radiated energy and processing it to a narrow pulse to obtain fine-range resolution. Analog and digital compressions are the two main categories of pulse compression. The transmitted waveform for analog compression is a linear FM pulse. The transmitted waveform for digital compression is a phase-coded pulse. The transmitted waveform in the linear FM pulse compression is a rectangular pulse with a fixed amplitude. In LFM compression the frequency rises linearly with the pulse's duration. A matching filter or a pulse compression filter is applied to the echo after receipt. The modulated pulse's autocorrelation is the output. A lengthy pulse of time Tp is split into N sub-pulses, or "chirps", each having a width of Tc in the phase-coded pulse compression method. *a) LFM pulse compression*

In this research, we use LFM compression due to its high resolution and target identification capabilities. The range resolution can be obtained by the equation.

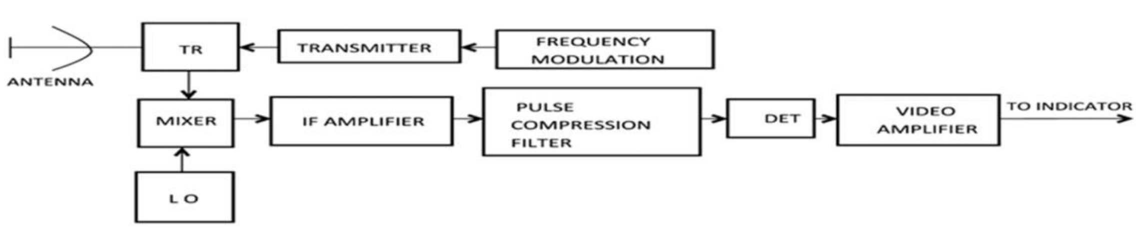
$$\delta_r = \frac{C}{2B}$$

Where C= speed of light
B = bandwidth of the signal

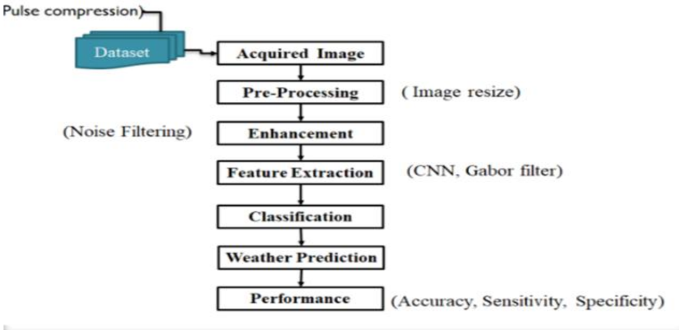
A long pulse is being transmitted and is compressed in time using a matched filter, the transmitted signal is a waveform whose frequency varies linearly with time. A frequency-modulated signal is transmitted from the radar (Antenna) and is amplified.

Mathematically Fourier transform is being done to the transmitted signal and after that inverse Fourier transform is being done for future analysis. After amplification, the signal is filtered and the output is the autocorrelation of the transmitted and the received signal. Overall Pulse compression radar systems are useful instruments for military, aviation, weather monitoring, and scientific research applications because they provide excellent range resolution, sensitivity, and target identification capabilities.

BLOCK DIAGRAM



II. IMPLEMENTATION METHODOLOGY



The radar signal is compressed to increase the range resolution as well as the signal-to-noise ratio and a relatively long pulse of high energy is transmitted. LFM signal is transmitted from precipitation radar (Rain cube) and depending on the received signal weather condition of a particular area is determined. In this, we have acquired an image from the radar and some preprocessing techniques are performed. To the acquired image resizing operation is being done in which the size of the image is changed to 256*256. After noise filtering is done for enhancement. In this Gaussian filter is being used to eliminate noise, which is a sort of linear filter frequently used in image processing to minimize image noise and blurring. The standard deviation (σ) and kernel amount of blurring are determined by the size of the kernel. The size of the kernel affects how blurry a picture is; a lower kernel size results in less blur. CNN and Gabor's filters are used to extract features from the picture. An artificial neural network called a CNN is used to analyze images. It consists of convolutional, pooling layers through which an image is transmitted. A Gabor filter is a type of linear filter used in image processing and computer vision to recognize edges and texture components in an image. The Gabor filter is extensively used in applications including texture segmentation, image analysis, and feature extraction. Finally, performance is calculated and the weather is projected as excellent or terrible based on the features that were retrieved. An LFM compressed signal is being transmitted with a frequency of 10 Hz and a samplingrate1KHz.The received signal is plotted with and without noise. An image is being acquired from radar. A Signal can be converted into an image using the SAR method. SAR imaging is a type of radar imaging that uses the motion of the radar platform to create a high-resolution image of the target area The LFM signal from the radar is reflected off the target area and returned to the radar receiver in SAR imaging. The phase and amplitude information from the signal is then extracted and used to build an image of the target area. In this, we have taken a data set that consists of images of good and bad weather. The resized image is obtained by changing the size of rows and columns using the resize function in Matlab. After resizing the image, it is filtered to remove noise. In this, we have used a Gaussian filter to blur, and remove noise. In Matlab, we used a special function which is an inbuilt function that produces a two-dimensional filter of a specified type. After filtering the image is compressed for efficient storage of the image. Compressing the image refers to changing the size of the image. Initially, the size of the image is 6Kb, and after compression, the size is reduced to 3.03Kb. After compression, the image is decompressed for analysis and to extract features from the image to observe the weather. Gabor filters are frequently employed in conjunction with other image-processing methods in weather radar to distinguish and categorize various types of precipitation, such as rain, snow, and hail. Meteorologists can better comprehend the size, form, and intensity of precipitation structures in the atmosphere by examining the characteristics of the radar echoes at various spatial frequencies and scales. We have extracted some features for the acquired image after passing through the Gabor filter. A CNN processes its input data through several layers, each of which conducts convolution, pooling, and activation operations. When a collection of filters are applied to the input, feature maps capture various aspects of the input. Gabor filter evaluates the gray threshold value and converts the input image into binary by thresholding. After extracting features from the CNN algorithm, the Gabor filter concatenates two features, and by gray thresholding, we predict the weather as good or bad. It is being displayed as good or bad. The performance of the system is estimated in terms of accuracy, sensitivity, and specificity. Accuracy Refers to the degree to which a determined value is accurate concerning a reference or known value, Specificity refers to correct classification and Sensitivity refers to the rejection of wrong classification in results. A graph is plotted in comparison of proposed and existing weather radars.

III. SIMULATION RESULTS AND ANALYSIS:

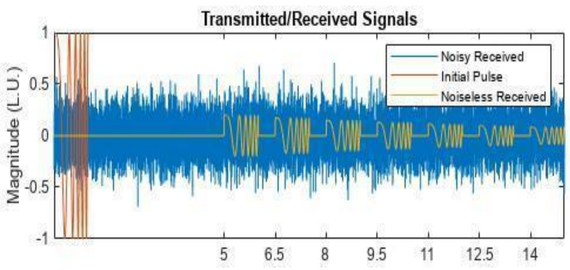


Fig: Transmitted signal without compression

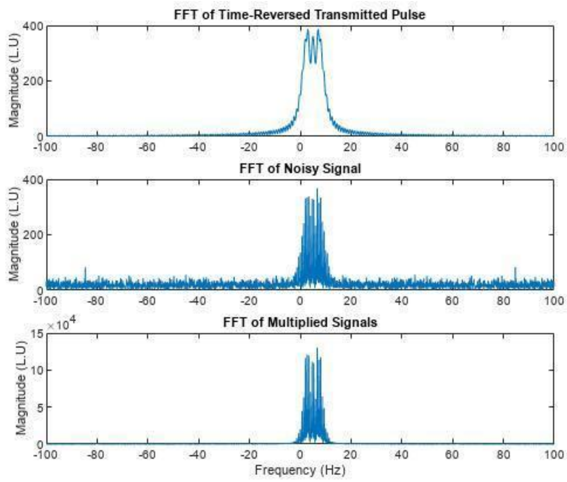


Fig: FFT of the transmitted signal

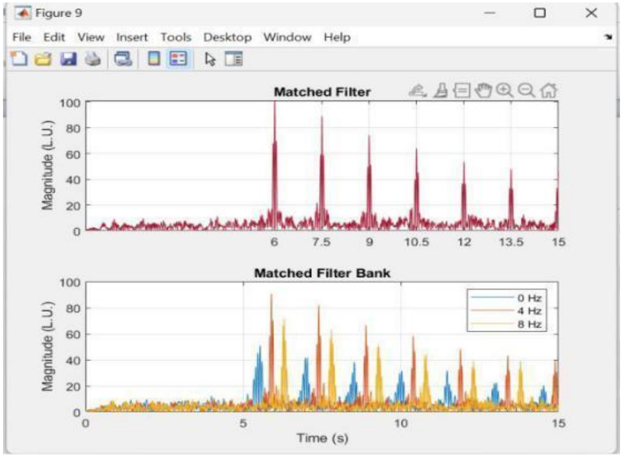


Fig: Matched Filter output

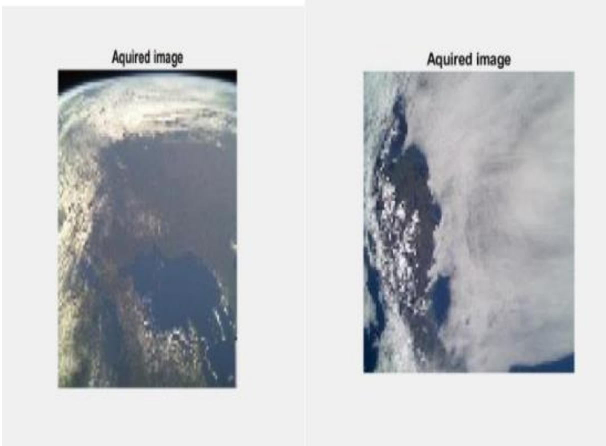


Fig: Acquired images with good and bad weather

Fig: Resized image to 256*256 pixels

Fig: Filtered image using Gaussian filter

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Fig: Compressed image

Fig: Decompressed image

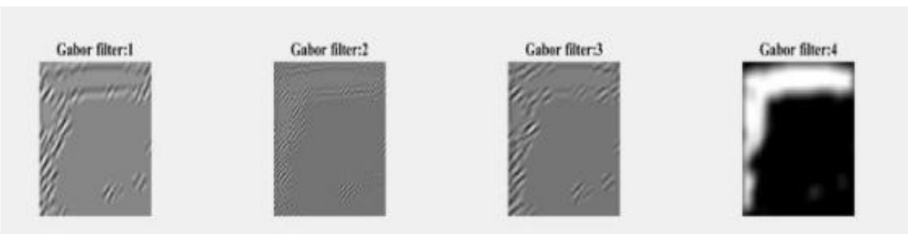
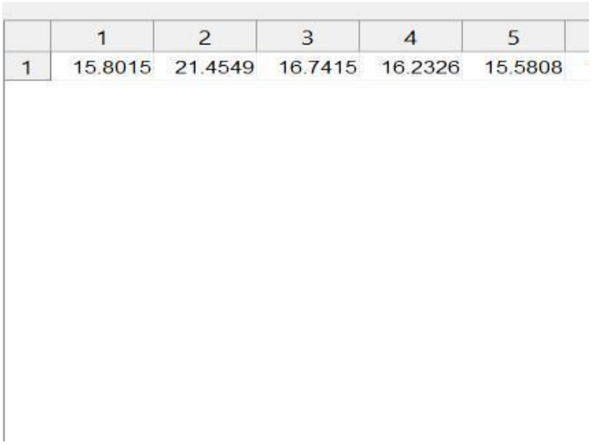
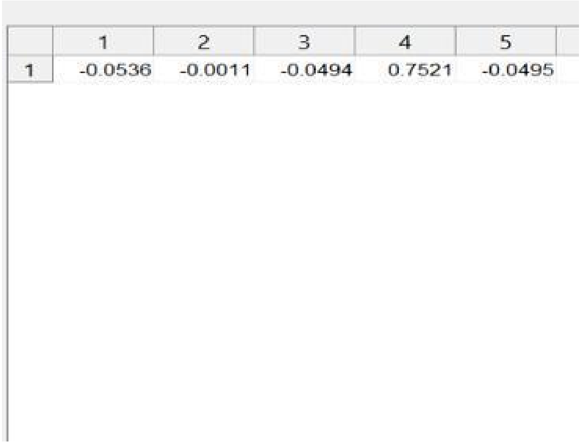


Fig: Image Filtering using the Gabor filter for edge detection



	1	2	3	4	5
1	15.8015	21.4549	16.7415	16.2326	15.5808

Fig: Features extracted using the CNN algorithm



	1	2	3	4	5
1	-0.0536	-0.0011	-0.0494	0.7521	-0.0495

Fig: Features extracted with Gabor filter

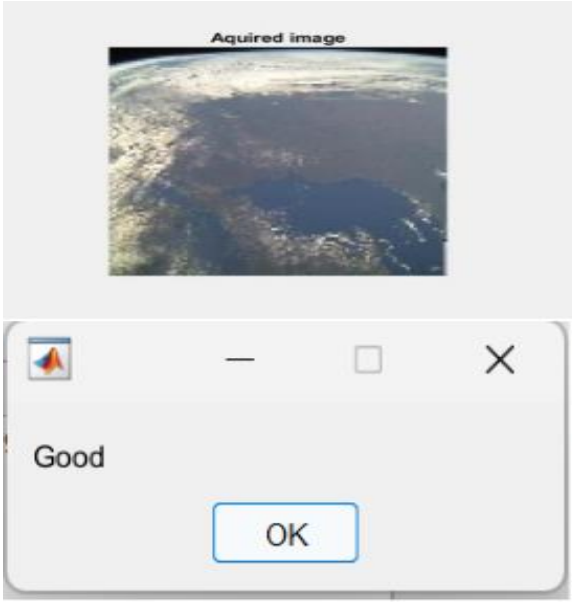


Fig: The weather predicted as good

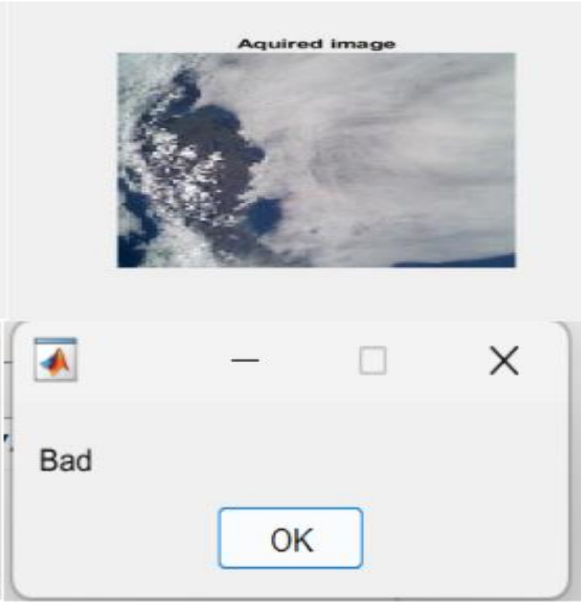
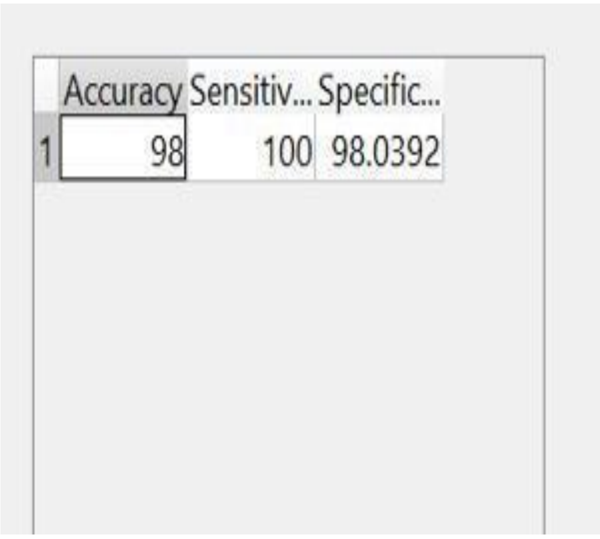


Fig: Weather predicted as bad



	Accuracy	Sensitiv...	Specific...
1	98	100	98.0392

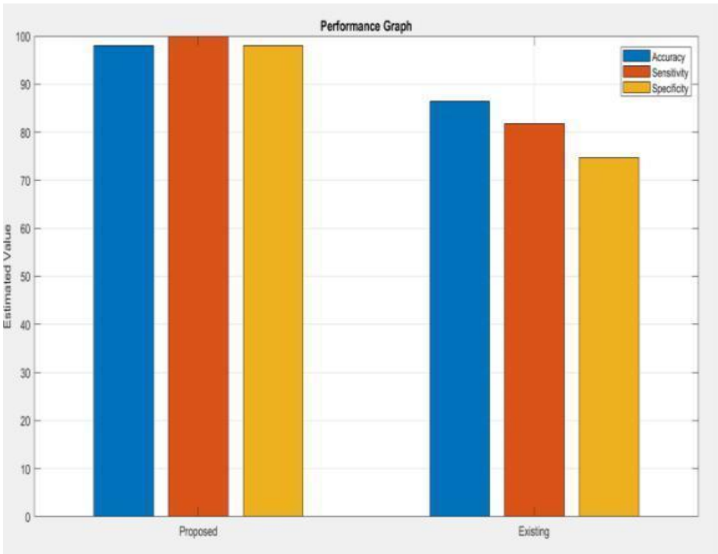


Fig: Performance estimation

IV. CONCLUSIONS

Weather is observed using pulse compression and image pre-processing techniques. Accuracy is being increased for weather prediction, enhancing the precision, sensitivity, and range resolution of radar observations, the pulse compression approach has completely changed the way that weather is observed. It has made it possible for meteorologists to more accurately comprehend and anticipate weather occurrences, resulting in weather forecasting and warning systems that are more effective. After applying some image filtering, compression, and decompression as well as some feature extraction to the dataset image we obtained, we predicted whether as good or bad. The accuracy, sensitivity, and specificity of the existing model were compared to those of our proposed model, and we were able to determine that the accuracy was 98%, the sensitivity was close to 100%, and the specificity was 98.0392%.

V. REFERENCES

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