Passive FM Radar

L. S. Bharadwaj(E-Mail:lsbharadwaj@gmail.com), Manu Gaurav, O. C. Vishnu , Kishan Sharma,
P. Radhakrishnana
Affiliated to:Electronics and Radar Development Establishment, DRDO

***Abstract*—This paper explains the work that has been done on FM Passive Radar. A commercial FM transmitter was used as the source of illuminator. The RF spectrum was digitized using a digitizer which was used for analysis. The analysis was offline and was carried out using MATLAB.**

***Index Terms*—Passive Radar, FM based Passive Radar.**

I. Introduction

PASSIVE RADAR is gaining importance in the recent years again. These radars are capable of detecting and tracking targets using only the illuminators of opportunity. Illuminators of Oppurtuity like TV, FM, GSM transmissions etc. are normally not meant for use as Radars but they can be very well exploited for Radar purpose. These sources have lot of potential as they are transmitted with very high powers. They are also often many in number.

These radars are a variant of bistatic radar where the commercial transmitter acting as the transmitter and the receiver form a bistatic pair. Each pair of transmitter and receiver makes measurements of the range and doppler as observed by the pair. These measurements are not the actual location of the target rather they are known as bistatic range and the bistatic doppler. These measurements from the individual pairs need to be finally fused inorder to get the final picture with the actual locations of the target.

Here the experimentation was done using FM signals as they are of adequate power as needed and also there are plenty of FM stations in the vicinity. The FM stations transmit a power of 10kW with a bandwidth of approx. 150kHz. All the measurements made here are bistatic ranges and bistatic doppler only.

II. Setup

The setup consisted of a digital recorder which was a digitizer. The digitizer wrote data to a high speed semiconductor hard disk. This digitizer was used to record the FM band of 88Mhz to 108 MHz. The ADC in the digitizer worked till 500 MHz so a decision was made to go for direct digitization of the FM band. For this purpose an analog front end consisting of a LNA and a band pass filter tuned to pass only 88-108 MHz was used. A sampling frequency of 19.63 MHz was chosen. This frequency was the lowest frequency that could be chosen without causing an overlap between the frequencies where the transmissions where going on. The recorder was capable of digitizing two such channels simultaneously.

Two antennas were used to feed data to the digitizer. One antenna was an array of Yagi antenna and was made to point to one of the FM station. This is called the *Reference Channel*. The other antenna was a single Yagi antenna which was positioned so that the FM station was towards the null of its beam pattern and the main beam pointed towards the airport. This second channel is called the *Echo Channel*. Fig.1 shows the setup configuration and Fig.2 shows the real setup as it was made.

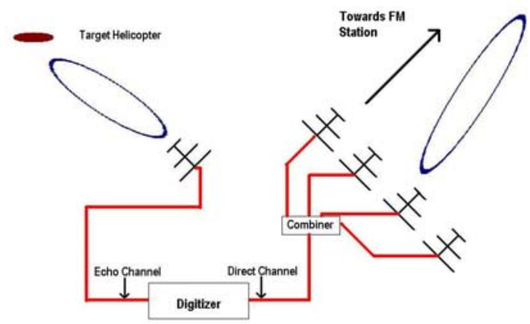

Fig. 1. Test Setup

Fig. 2. Real Setup

The whole setup was kept at a convenient distance of around 10 km from both the FM transmitter and the airport. This separation was conveniently selected to satisfy two needs. Firstly the received power from the transmitter shouldn't be so strong as to saturate the Reference Channel or the Echo Channel. Secondly the signal received by the Echo Channel from the reflections from the target should be strong enough for easy detection.

III. Processing

The data was recorded using the setup described in the previous section. This data was later used for offline processing. MATLAB was used for doing all the processing. Using the processing preliminary detections where obtained.

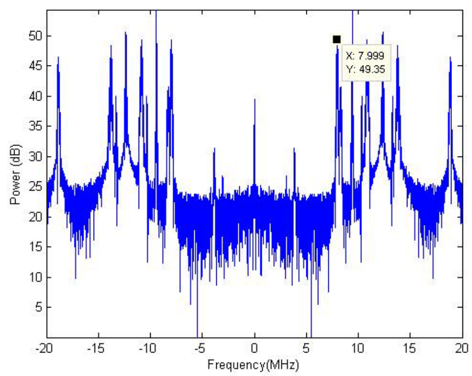

Fig. 3. Spectrum of Recorded Data

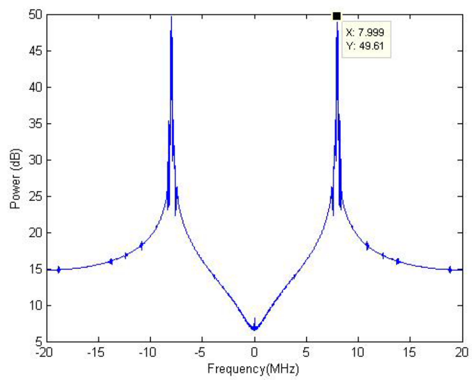

Fig. 4. Channel of Interest

The processing chain consisted of digital filtering, direct signal cancellation, Matched filtering and CFAR.

A. Filtering

Both the Reference channel and the Echo channel initially allowed a 20 MHz of bandwidth from 88Mhz to 108Mhz to pass through for digitization. This was guaranteed by the use of the front end filters. As the whole band of 88 MHz to 108 MHz does not contain transmission in it a frequency below the necessary frequency was chosen. Care was taken so that frequencies which we were interested in did not alias.

The bandwidth of interest is only 200 kHz. This is the bandwidth which is allocated to the commercial FM transmitters. As the occupancy is only so much the higher sampling rate of 19.63 only packs in redundant information and thus had to be downsampled. Before it could be down sampled the data was filtered at the interested frequency.

The frequency spectrum of the recorded data can be seen as given in Fig.3. Out of these channels the channel which is our frequency of interest is the one which is at 7.999 MHz as shown in the figure. We use a filter to filter out only the desired channel of interest and the filtered data then looks as shown in Fig.4.

B. Direct Signal Cancellation

Now that the channels are filtered we were left with basically two channels recording the same frequency. *Reference channel* which is the channel we obtained from the antennas looking at the transmitter in the setup will be used as the true copy of the signal. There will be some amount of interference and multipath in this channel which will result in the deterioration of the performance of the radar. This deterioration can be reduced by wisely placing the receive station. Nothing can be done to improve it once the data is digitize.

The second channel, *Reference Channel* was obtained using antennas which where pointing away from the transmitter. Careful efforts were made to place a null of the antenna to point towards the transmitter. On analysis it turned out that the channel still had a strong influence of the direct signal. This happened because it is not possible to practically have a very deep null. This direct signal had to be removed inorder to detect any target as it the direct signal from the transmitter always masked the target echo. For this sequential cancellation algorithm [1] was used. This algorithm takes into account the correlation between the signal from the *Reference channel* and the direct signal leak into the *Echo channel*.

Sequential cancellation works by initially replicating the reference channel signal with various amounts of delays an doppler shift. These are the delays and the dopplers for which the methods expects unwanted signal. It then correlates to find the strength of the returns at these values. These strengths are then used to weight the signal and subtract from the main signal. This theoretically eliminates those interferences.

In our trial we basically removed the first 20 range bins at 0 Hz,-1 Hz and 1 Hz of doppler. These corresponds to the clutter that was being received. These values where obtained by trial and error. The success of this method depends on how clean the reference channel is. If the reference channel contains echoes from the target also then the algorithm will remove the target as well.

C. Matched Filtering

After the echo channel was cleaned of any reference signal that must have entered from its sidelobe matched filtering was carried out between the two channels. An approach very close to the Cross Ambiguity Function was utilized. The signal from the *Reference channel* acts as one of the input and the *Echo channel* acts as the other. The ambiguity function matches the first signal with the second. This process is then repeated for all the different dopplers. The ambiguity function is written as given in Eqn.1.

$$\left|\psi(R_R, f_d)^2\right| = \left|\int_{-\infty}^{\infty} S_1(t).S_2(t+R_R).exp[j2\pi f_d t]\right|^2 \quad (1)$$

Fig.5 shows how the CAF looks when the direct signal is not cancelled. As a matter of fact it closely resembles its self ambiguity function. Once the direct signal is removed from the *Echo channel* the major peak at (0,0) ie. 0 range and 0 doppler vanishes and other targets starts appearing at different locations as shown in Fig.6.

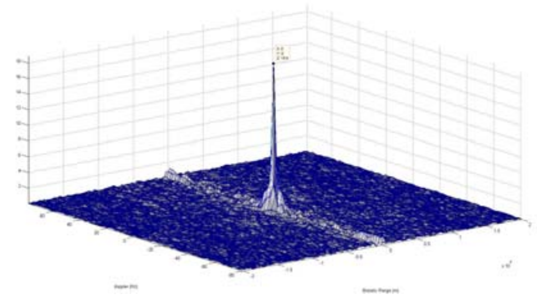

Fig. 5. CAF without cancellation

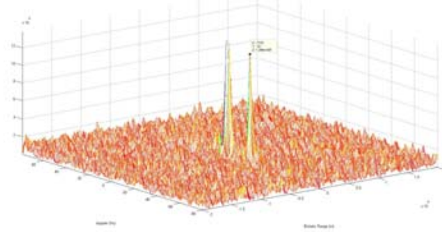

Fig. 6. CAF after cancellation

D. CFAR

One dimensional Cell Averaging CFAR was used for target detections. This method works by choosing a cell to be tested as and calling it as the Cell under test. Then a few cells on either side of the Cell under test is taken as an estimate of the background. These cells are averaged. Note that in this modification of CA-CFAR we do not leave any guard cell. This was done because of the size of the range bins. The bandwidth of the channel is only 200kHz. This results in a range resolution far greater than the targets of influence. Hence there is no need of leaving few cells as guard cells which is done inorder to remove the influence of the presence of target in the Cell under test.

This process is repeated for every doppler bin. It resulted in a cluster of detections and the peak of the cluster was taken as the target location. The accumulated detections for a duration of 10 mins is shown in the Fig.7. Targets at ranges greater than 60km of bistatic range can be seen in the tracks. There is also a stationary clutter visible at around 85kms of bistatic range.

IV. Conclusion

Passive Radar is a very promising technology which is still in its initial stage. Preliminary detections using one transmitter and one receiver has been achieved and this verified algorithms like the sequential cancellation and extensive cancellation. It also shows that one dimensional CFAR is capable of providing preliminary detections.

V. Future Work

There are several other challenges which needs to be tackled before the radar could be completed. Challenges like the target localization using multiple such transmit receive pairs which is required before the true location of the target can be known has to be done. A further challenge will be to develop an efficient target association algorithm which has to be implemented before the multilateration can be done. These challenges are not addressed by this paper.

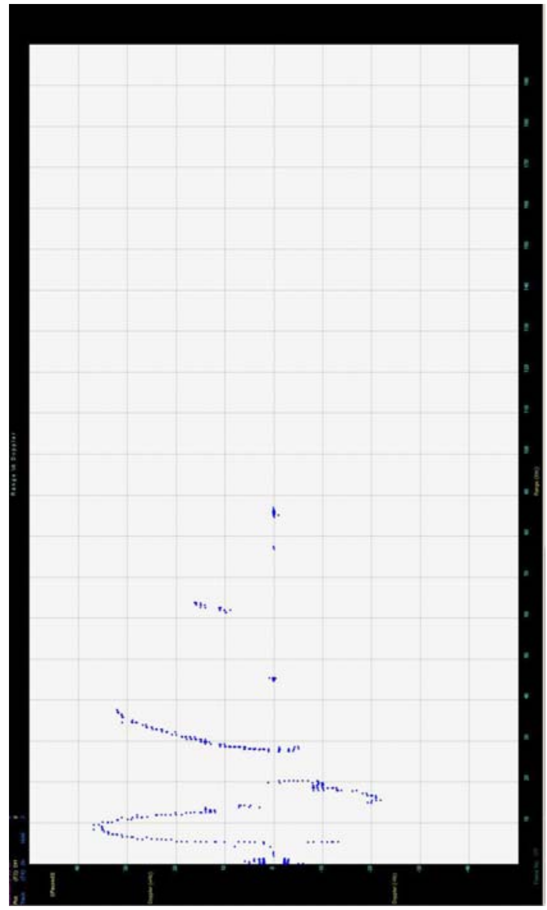

Fig. 7. Accumulated target track

Acknowledgment

The authors would like to thank Mr. Jagdeesha, Mr. J.Manigandan and Mr. S.Sreenivas for their valuable support.

References

[1] F. Colone, R. Cardinali, and P. Lombardo, “Cancellation of clutter and multipath in passive radar using a sequential approach,” *IEEE*, 2006.

[2] M. I. SKOLNIK, “An analysis of bistatic radar,” *IRE Transactions on Aerospace and Navigatonal Electronics*, 1961.

[3] A. Lauri, F. Colone, R. Cardinali, C. Bongioanni, and P. Lombardo, “Analysis and emulation of fm radio signals for passive radar,” *IEEEAC*, 2006.

[4] P. E. Howland, D. Maksimiuk, and G. Reitsma, “Fm radio based bistatic radar,” *IEE*, 2005.

[5] M. Malanowski, K. Kulpa, and J. Misiurewicz, “Parade – passive radar demonstrator family development at war-

saw university of technology," *MRRS-2008 Symposium Proceedings*, 2008.

[6] K. Kulpa and M. Malanowski, "Simple cots pcl demonstrator," *Multi-National Passive Covert Radar Conference*, 13 - 15 November 2007.

[7] M. Malanowski, K. Kulpa, J. Misiurewicz, and M. Purchla, "Silent police radar," *3-rd International Workshop on Inteligent Transportation*, March 2006.

[8] K. Kulpa, "Adaptive clutter rejection in bi-static cw radar," *International Radar Symposium,Warsaw*, 2004.

[9] H.D.Giffiths, C.J.Baker, J.Baubert, N.Kitchen., and M.Treagust, "Bistatic radar using spaceborne illuminator of opportunity," *IEE*, October 2002.

[10] S.Herman and P.M.Moulin, "A particle filtering approach to passive radar tracking and automatic target recognition," *IEEE Aerospace Conference Proceedings*, 2002.

[11] T.Tsao, P.Varshent, D.Weiner, and H.Schwarzlander, "Ambiguity function for a bistatic radar," *IEEE Trans Aerospace and Electronic Systems*, 1997.

VI. Biography

L.S. Bharadwaj is currently working as scientist 'B' at Electronics Radar and Development Establishment, DRDO, Bangalore. He is working in this establishment since Dec 2010. He has completed his B.Tech (ECE) from NIT Durgapur. His area of work is Radar Signal Processing.

Manu Gaurav is currently working as scientist 'D' at Electronics Radar and Development Establishment, DRDO, Bangalore. He has been with the Establishment for 10 years. His areas of interest includes radar receiver design and antenna Design.

O.C. Vishnu is currently working as scientist 'D' at Electronics Radar and Development Establishment, DRDO, Bangalore. He is working in this establishment since 2005. His area of interest includes Radar Signal Processing.

Kishan Sharma was born on 1985 at Sheopur, India. He graduated in Electronics from Jiwaji University Gwalior. Joined DRDO as Scientist in 2009. He is currently working in the field of RF & microwave circuits and Receivers.

P.RadhaKrishnan is a fellow of IETE and a member of IEEE. He was born on 1963. He received his degree BE (ECE) from College of Engineering Andhra University in 1985. He completed his M.Tech (E&ECE with Computer engineering) in 1996. He has been working in LRDE from 1988. He is currently working in Multi Static Radars and Naval Radar systems. His area of interest includes Radar signal processing. processor architecture for signal processor and radar systems.