Active target location system using cross-dipole based circular array FMCW radar

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Introduction

- Circular antenna arrays are used when in the arrays azimuth plane, full 360º coverage is required. In this case it is to scan the scene from a seaborne vessel and registering when an active target has been located, either on a harbour wall or out to sea structures such as oil rigs. Combining a 2.4 - 2.4835 GHz FMCW radar with a circular array eliminates the inherent multipath issues associated with circular arrays, as multipath targets will appear in different range bins.
- In the plane of a crossed-dipole the far field radiation pattern is almost omnidirectional as one dipole has an approximate cosine pattern and the other a sine pattern, the summations of the two results in the aforementioned pattern.
- The four phase feed network together with the antenna makes the processing the same as a circular antenna array, operating at with +1 and -1 phase modes, with 90º offset.
- The active target comprises of two antenna and amplifiers, one antenna receives and amplifies the signal with the other transmitting the amplified signal at a different polarisation, which acts as a radar transponder.
- The ADC is a computer's soundcard utilising the line input port, a sampling rate of 44.1 KHz with a 16-bit resolution is more than adequate for this system, real time acquisition and processing is implemented in MATLAB.

MATLAB Processing

- Using 32-bit MATLAB, which has legacy support for the PC's integrated sound card or PCI sound card, allows the acquisition of the baseband signal directly into MATLAB for processing.
- Looping the code allows real time acquisition of the baseband signal, the length of the sample for processing can be controlled hence allows for near real time acquisition and processing.
- The sampling rate is 44.1 KHz with a 16-bit resolution. The sampling rate and resolution is totally dependant on the sound card being used, 192 KHz at 24-bit resolution is available at mid range.
- Sampling the scene without the active target on allows for a calibration phase which can be saved and removed from the data when the target is on, to reduce the clutter that is in the same range as the target, by removing the low frequency components.
- Zero meaning removes the DC offset from the data.
- The frequency determines the range, the mean phase is calculated using the weighted phase average of the three closest values, according to the maximum absolute amplitude value of the FFT. This is repeated for all chirps in the time domain signal that meet the threshold criteria, with the final result the mean of all chirps, with the mean phase value determining the bearing of the target.

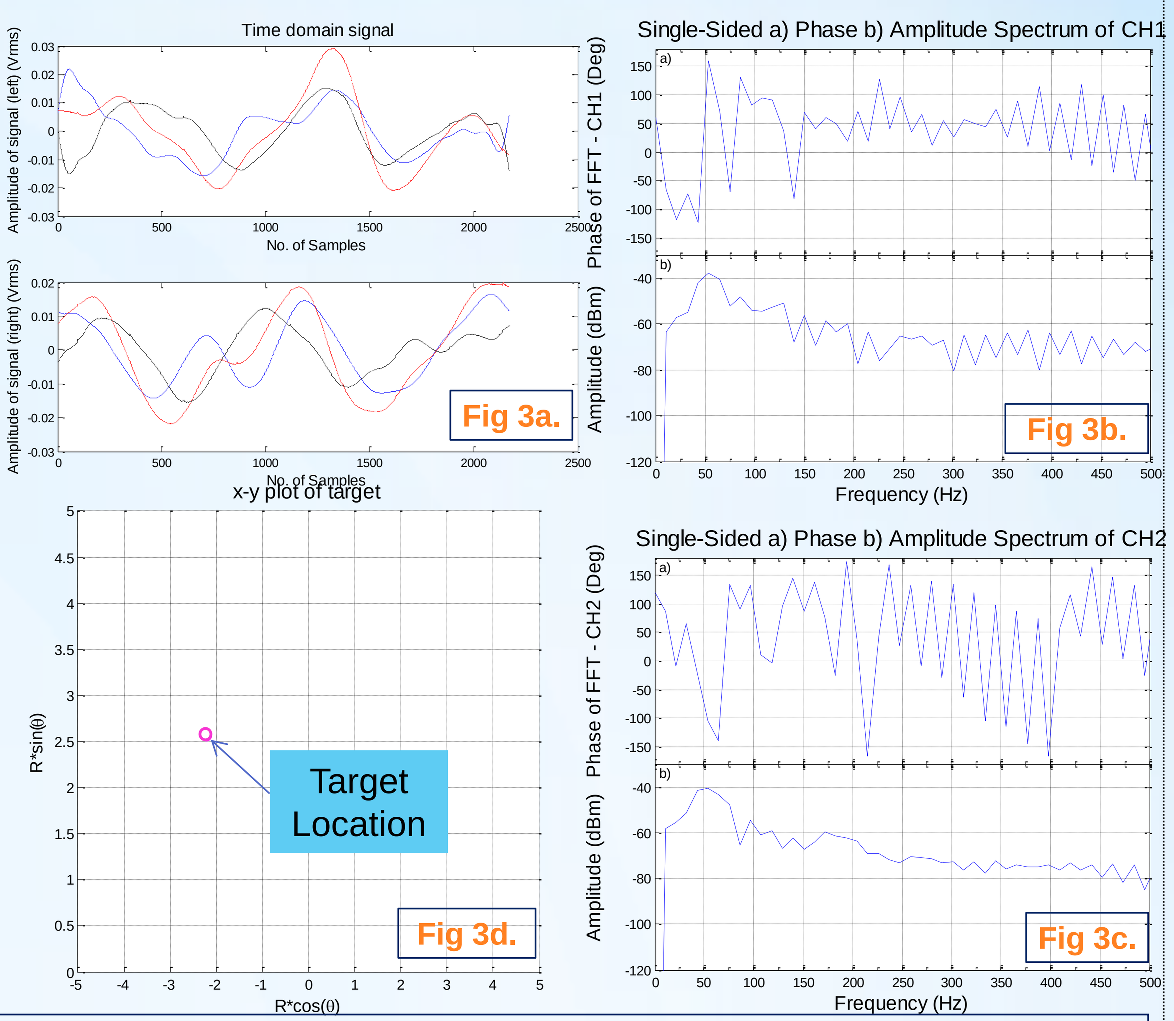


Figure 3a. Time domain single sample calibrated, uncalibrated and resultant signal **b.** CH1 **c.** CH2 target ON (1m) **d.** Target at 130º, 3.38m

System Overview

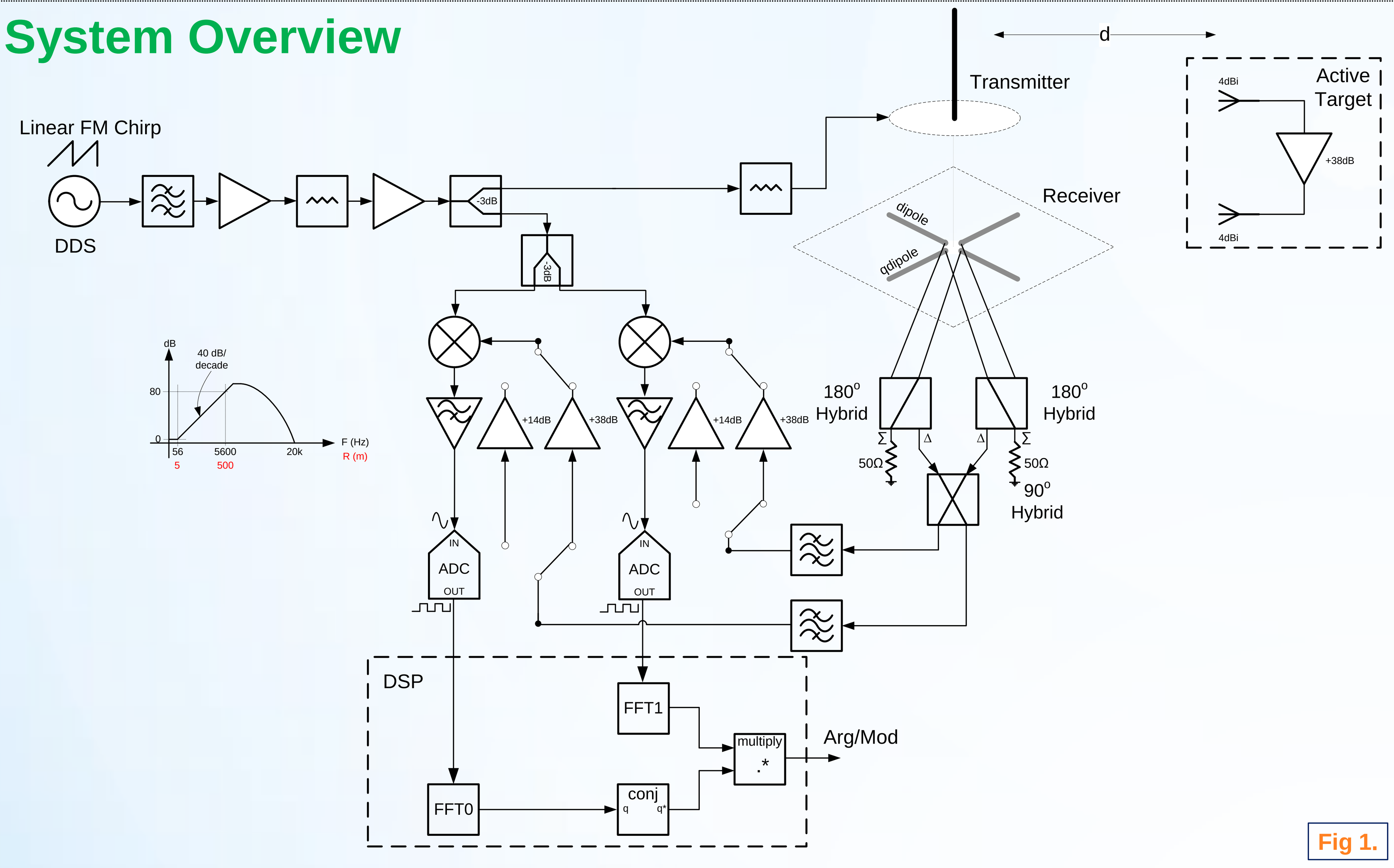


Figure 1. Shows the system diagram

Radar Development

- The radar is construction has been completed, there may be additional modifications at a later date if other parts of the system are upgraded, i.e. the baseband active filter would have to be reconstructed if the active target is upgraded.
- The radar antennas are mounted above the main radar unit, with the transmitter vertically above the receiver, a separation of 4λ, hence an isolation of 34 dB, additional isolation achieved by the ground plane facing the receiver and the difference in polarisations between the transmitter and receiver.

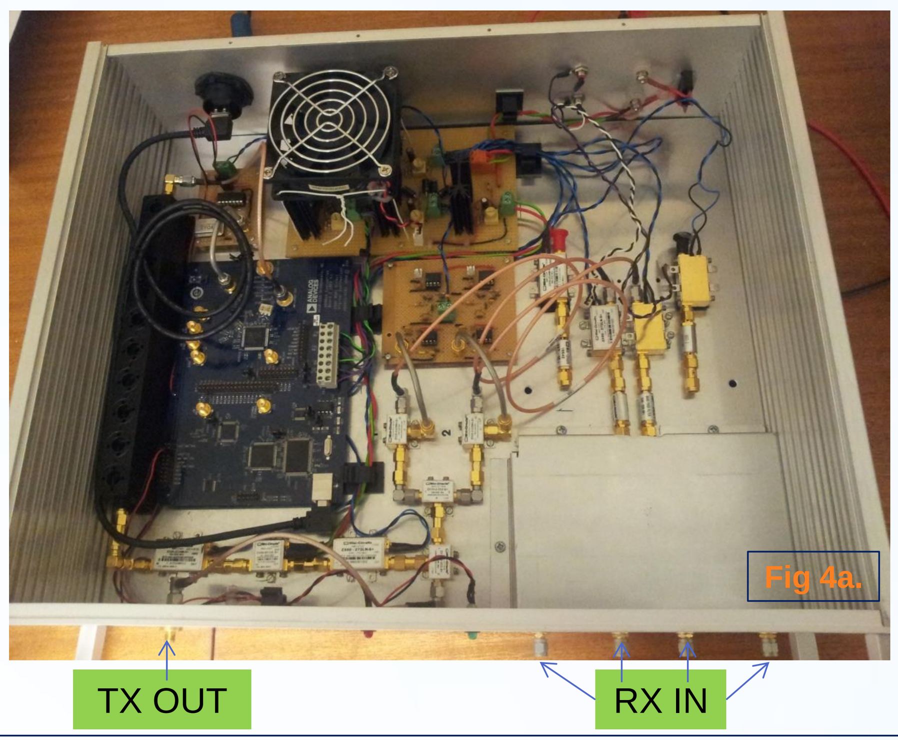
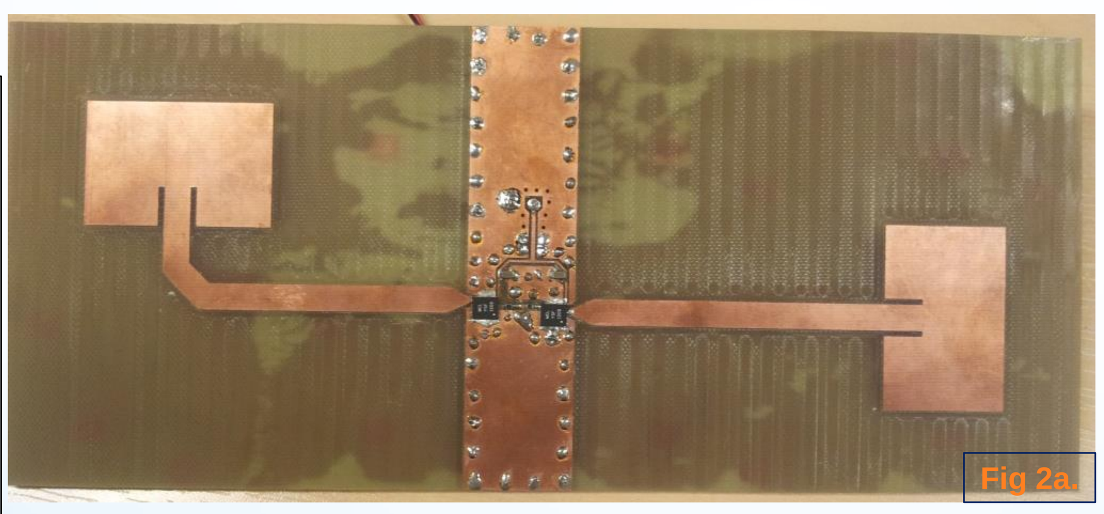
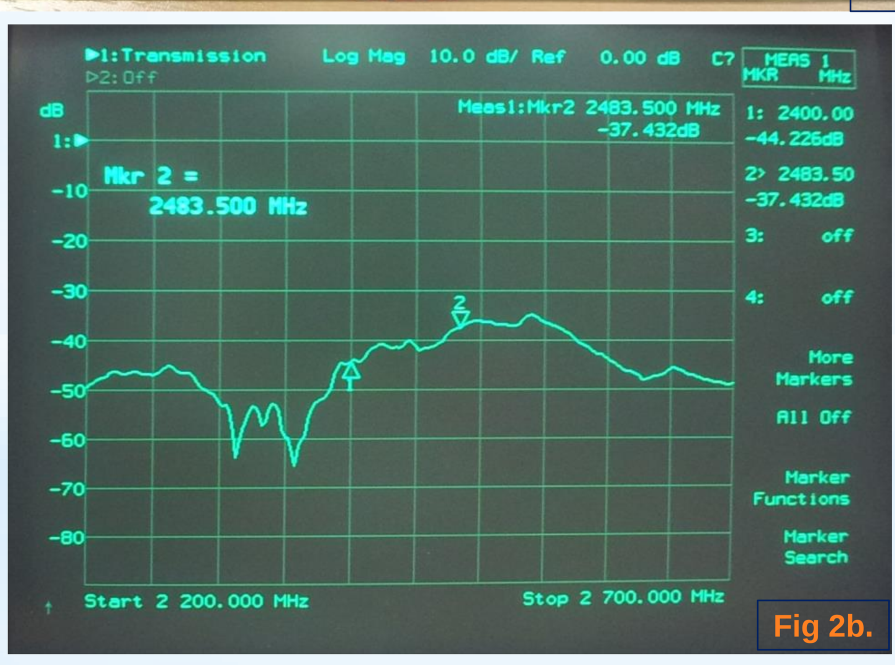


Figure 4a. Photo of Radar **b.** Radar with antenna mount

Active Target Design and Testing

- The active targets' role in this system is of a transponder in a usual air traffic control secondary surveillance radar (beacon radar) system here used for maritime purposes.
- The radar systems' transmitter is a vertically polarised antenna, hence the receiving antenna for the active target is also vertically polarised.
- The active target has a horizontal transmitter as the radar has a horizontally polarised printed crossed dipole antenna.
- For the target to be visible amongst the clutter is has two 19 dB amplifiers, which amplify the received signal and retransmit it at a higher power.
- The changes in polarisation has the additional advantage of increasing the isolation between the two antenna on the target, a separation between the antenna is 2λ, which has an isolation of 28 dB, (this value is based on the antennas with the same polarisation), with the antenna having orthogonal polarisations the isolation would increase by approximately 10 dB.
- A possibility of self oscillation remains, this is where the isolation is not enough to stop the transmitted signal coupling into the targets receive antenna, this would degrade the performance of the target by saturating the amplifiers, this can be detected and negated by attenuating the gain of the amplifiers (using a 'T' attenuator network) such that the gain is lower than the isolation.
- The target is designed on 3.2 mm FR-4 PCB, the thickness is twice that of usual 1.6 mm FR-4, this is in order to increase the bandwidth of the antennas to approximately 75 MHz (3%).
- The active target was constructed and tested using 2 patch antenna in the vertical and horizontal (TX, RX respectively) using a VNA.
- The expected increase in the received power gave assurance that the target was working correctly.





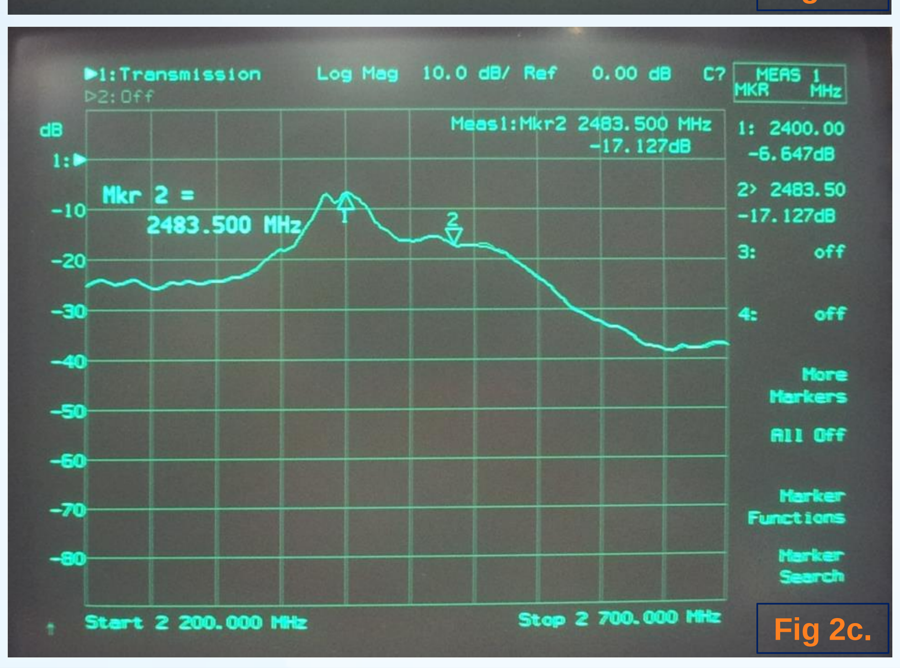


Figure 2a. Photo of active target **b.** Target present not powered **c.** Target powered

Repeatable Measurements

- Using a stepper motor, Arduino mega 2560 and an Arduino motor shield a mount for the receive antenna has been constructed.
- It will allow the repeatable measurements with an accuracy of 0.9º.
- Serial communication between the Arduino and a computer allows the number of steps taken in either direction to be monitored.
- Both clockwise and anti-clockwise rotations controllable, any re-measurements can be carried out manually.

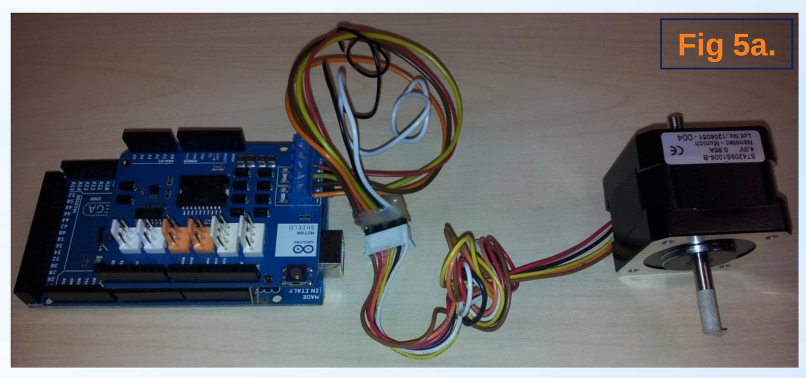


Figure 5. Arduino with motor shield and stepper motor **b.** Receiver stand

Conclusion and Future Work

- The system as a whole has been tested with quite good results.
- The system has been tested in the lab, the limitations of the room have limited the range of testing to approximately 1 - 2 m.
- Clutter in the same range as the target integrate over the circumference at that range, the clutter power can be as high as the gain of active target, masking the target, calibrating noise and direct signal allows for the target to be detected at close range.
- The signal acquisition and data processing have been implemented in MATLAB with real time updates.
- The active target will be modified to include modulation, this will allow the target to detected at close range to the radar system.
- The modifications to the target means that the active baseband filter will have to be redesigned.
- Field tests need to be carried out once the modifications are completed.

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