Development of a Rapidly Re-Deployable HF Radar Concept

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Abstract

The requirement for a rapidly re-deployable HFSWR system that can be deployed by a single fast road vehicle, and made operational within 2 hours is discussed. Several scenarios in which such a system would be beneficial are presented. The barriers to achieving a rapidly re-deployable system with current HFSWR designs are identified, and new solutions to these barriers are developed. Radar performance is estimated for this rapidly re-deployable system, and the results show useful performance can be achieved in scenarios identified.

Keywords: HF Radar, Surface Wave, Re-deployable

INTRODUCTION

This paper discusses the system concept and architecture for a Rapidly Re-Deployable HF Surface Wave Radar (HFSWR). Traditionally HFSWR systems have not been available in a rapidly re-deployable form, due to the significant difficulties of implementing such a system in a format suitable for rapid deployment and recovery.

In this paper we discuss scenarios where a rapidly re-deployable HFSWR would find application. We discuss the difficulties to implementing a rapidly re-deployable system, identify solutions to those difficulties and present an architecture for a rapidly re-deployable HFSWR. We propose an architecture that could be dispatched to an operational area in a single fast road vehicle and made operational within 2hours.

HFSWR BACKGROUND

HF Surface Wave Radar has a unique capability to sense targets beyond the horizon over the sea, not rivalled by other sensors. This capability can provide a wide area surveillance facility around the clock in all weather conditions. A full range of targets can be detected including ships, small fast boats, and aircraft. Additionally HFSWR has the ability to sense environmental parameters including sea surface current, wave height, wind speed and direction.

Operated from a coastal site an HFSWR can provide an effective low cost surveillance facility. It does not suffer problems of long search times and endurance when compared to aerial surveillance, and does not suffer the broken coverage and revisit times inherent with satellite surveillance. Its potential application areas include both military and civilian roles.

The capabilities of HFSWR have been demonstrated by a number of hardware demonstrators, however these systems are large fixed site installations, and are not suited to a rapidly re-deployable role. Some organisations have demonstrated more compact systems [1] with unmanned autonomous operation, and remotely networked data and control, to further demonstrate the potential and effectiveness of HFSWR.

However in the current world political climate, a large fixed site installation does not suit many of the surveillance requirements that arise. In many Civilian or Military scenarios what is required is a surveillance system that can be rapidly deployed to be in the Right Place at the Right Time. The detection capabilities of HFSWR are suited to many of these modern day scenarios, if only the system could be in the right place at the right time.

APPLICATION AREAS

There are a number of application areas or scenarios, both military and civilian, where a rapidly re-deployable HFSWR can play a beneficial role, providing a capability that is impossible or difficult to provide using other sensor systems. Table 1 lists some of these application area's and the UK Agencies that will have a prime interest.

Scenario	Agency
Drug smuggling	Customs and Excise
Illegal entry	Customs and Excise
Ongoing incident at Sea	Coast Guard
The passage of hazardous cargo	Coast Guard
Pollution incident	DEFRA
Coastal monitoring	DEFRA
Terrorist threat	Security Services

Table 1 Application areas

The smuggling of drugs by small fast boat presents a difficult policing problem. Small fast boats such as the Rigid Inflatable Boat or RIB are difficult to detect and intercept at sea. Often prior intelligence is available regarding smuggling runs, and a re-deployable HFSWR could be tasked to the target area based upon intelligence to assist in the detection and interception of small fast boats upon landfall.

The passage of illegal immigrants can pose a significant policing problem, giving rise to political and resourcing issues. If illegal entrants can be detected at sea, and their vessel intercepted and dealt with at an earlier stage, these problems can be minimised.

Ongoing incidents at sea can pose a serious problem to the coast guard, when radar cover is incomplete or not available. For example, in December 2002 the car transporter the Tricolor sank in a busy shipping lane of the English channel. This vessel posed a serious hazard to navigation and was struck in January 2003 by the fuel oil tanker Vicky. A re-deployable HFSWR that can be tasked to a problem area to provide extended radar coverage, can assist in the management of such incidents.

Vessels carrying hazardous cargo, be it a pollutant or some other hazardous material often pass through UK waters on route to other destinations. Often as the vessel is only passing through UK waters, knowledge of the vessels intentions is minimal. The problem is further heightened as these vessels are often crewed by foreign sailors with poor English communication skills and little knowledge of local conditions.

The risks presented by such vessels can be high, and examples of incidents arising from the passage of such vessels through UK waters are a mater of record. For example the Oil tanker MV Braer taking a shorter but dangerous route past the Shetlands founded and caused a major pollution incident.

In many cases it would be beneficial to monitor the passage of such vessels as they pass through particular difficult areas. By monitoring such vessels early warning of navigational errors or ill decisions can be provided, and an early dialogue initiated to avert a potential incident. A rapidly re-deployable HFSWR has the potential to be tasked, as an when high risk situations arise, to provide extended radar coverage over a particular area of concern, for the duration of passage of a hazardous cargo.

Pollution incidents have generally two phases, the initial incident phase when the pollutant is released into the sea and is mobile on the sea surface, and the contamination phase when the pollutant is washed up onto the coastline. Combating the incident in the first phase may last several days, whilst combating the incident in the second phase may last several weeks. In general an early and more effective response in the first phase will reduce the severity of the second phase and the length of the resulting clear up operation.

The management of pollution incidents is often hampered by the lack of good information upon which to make decisions on where best to deploy limited resources to tackle the incident. The environmental information available from a rapidly re-deployable HFSWR can significantly aid this process. The sea surface data available from the radar, in conjunction with general flow models can predict the spread of pollutants, allowing the better targeting of resources to combat the incident in the initial phase, thus minimising the severity of the contamination phase.

Coastal monitoring involves the measurement of sea conditions, to support applications such as the study of coastal erosion, mapping of the sea coastal environment, and to investigate changes to the marine habitat. This type of measurement is generally conducted as a short campaign lasting a few days or weeks. A re-deployable HFSWR is ideally suited to this type of application providing wide area sea surface measurement from a land based sensor.

RAPIDLY RE-DEPLOYABLE REQUIREMENT

Clearly for a HFSWR system to be truly rapidly re-deployable it must be possible to dispatch it from a depot or holding location to a coastal site, deploy it and set it to work in the shortest possible time. The system must also be self contained, so that it can be dispatched to a green field or unprepared site and set to work At the end of a deployment it should be possible to recover the system in a short time scale and return it back to its depot or onto the next deployment. Furthermore the system should be efficient, that is it should not require a large manpower and should have a low running or operational cost.

These are the basic requirements for rapidly re-deployable system, and we require a system concept to meet this requirement. The concept developed here is for a complete HFSWR system packaged in a single fast road vehicle, that can be deployed by two people and made operational within 2 hours of arrival at a deployment site. Such a package could be employed operationally to assist in the management of the scenarios listed in Table 1.

Our target system will be a complete HFSWR packaged into a single fast road vehicle, that can be dispatched to an operational area by road. The radar will provide floodlight transmit illumination over a 90 degree arc, and a linear receive array of up to 32 elements providing finger beams in the coverage area. Such a system will suit many scenarios where a rapidly re-deployable system is required.

THE BARRIERS TO RAPID RE-DEPLOYMENT

There are four major tasks to be undertaken when deploying a HFSWR. These are, deployment of the receive antenna array, the receive array cabling or distribution, the operations centre, and the transmit antenna. These tasks are significant and the deployment of an HFSWR is usually measured in days or weeks, and involves significant man power.

The deployment of the receive antenna array involves the assembly and erection of each antenna element, deployment of a ground screen and guying for each element. Typically these elements will be several metres in length and difficult to handle by two people alone. In addition to assembling and erecting the antenna elements, we must also accurately position the antenna elements (generally using surveying methods) so that receive beams can be accurately formed. If we consider a linear receive array of up to 32 elements, it becomes clear that deployment of the receive antenna array will be a very labour intensive and time consuming task and hence a major barrier to rapid deployment.

The deployment of the receive array cabling involves running a cable from each receive antenna element to a receiver. Typically this will be arranged by running cables from each receive antenna element to receivers housed in a central shelter. These cables will be long (perhaps 300metres) large diameter low loss coaxial cables. They are heavy, have a minimum bend radius, and are difficult to handle. This type of cable is expensive, is not intended for repeated deployment and recovery, and will hence require frequent replacement. Deploying 32 such cables will be a very labour intensive and time consuming task.

The deployment of the operations centre can be a trivial task. If our system is contained within a single fast road vehicle, its deployment becomes little more than parking the vehicle. Similarly the deployment of the transmit antenna, although not a trivial task, is less time consuming as only one unit is to be deployed.

Thus we deduce the major barriers to rapid deployment are, deployment of the receive antenna array and deployment of the receive array distribution.

RECEIVE ANTENNA ARRAY

The major difficulty with deploying the receive array is the size of the individual antenna elements. A small or short receive element that is self standing and could be placed by one man, such as that shown in Figure 1, whilst still meeting the electrical requirements would allow the receive array to be deployed much more rapidly.

A short active antenna, that is a short antenna element combined with an amplifier matching unit, as shown in Figure 2, can meet this requirement. Traditionally though active antennas are not suited to a radar application, due to the need to provide sensitive low noise performance with a high input impedance, with a good inter-modulation characteristics whilst in the presence of a local high power radar transmitter that will overload the active antenna amplifier. However the availability of a short active antenna suitable for radar applications would significantly simplify the rapid deployment of the receive antenna array.

Work under this programme has developed an active antenna design specifically for HFSWR applications, where a local high power radar transmitter is sited nearby. The design shows the ability to achieve low noise performance with good inter-modulation characteristics and survive the repetitive high signal levels due to a local high power transmitter. This work is described in references [3], [4], and [5]. The antenna design produced is a self standing active antenna comprising a base unit, a plug in 2.5 metre pole of 25 mm diameter and some ground radials.

This design is the basis of our solution to the rapid deployment of the receive antenna array. Using this antenna design makes it possible for a two people to deploy an array of 32 receive elements in under 1hour. The antennas will be deployed from the back of the deployment vehicle with one person driving the vehicle, and the other person taking the antenna base unit from the back of the vehicle, placing it on the ground, inserting the antenna pole and connecting the ground wires. The driver then moves onto the next location and the process is repeated.

ARRAY DISTRIBUTION

We have identified that the receive array cabling or distribution is also a major barrier to rapid deployment. The problems of deploying long, heavy low loss RF cables were discussed and it became clear that an array distribution system of this type is impractical

Let us consider the handling of the receive antenna signal in more detail. The signal from each antenna element is carried back to a receiver, converted to baseband and digitised for radar processing. We could alternatively place the receiver at the base of each receive element, digitise the data, and just carry the digitised data back to the operations centre for processing.

The digitised baseband signal has a relatively low bandwidth of 51 kHz. Using a realistic over sampling factor and 16bit precision leads to a data transmission rate of 2 Million bits per second. The total data transmission rate for 32 such receivers is then 64 Mbps

So in principle the digitised output from all the receivers could be accommodated on a single 100Mbps data link. In practice it is not necessary to transfer the full time bandwidth product, hence this data rate can be lower still, making this a practical proposition.

Thus if we place a receiver at the base of each receive antenna element we could carry the receiver data back to the operations centre all down one daisy chained data link. This data link would be considerably easier to deploy than the heavy low loss coaxial cables discussed earlier.

However by placing each receiver at the base of each receive element we have exchanged one array distribution problem for a rather more difficult array distribution problem. Each receiver requires several supporting signals for it to function, and these are generally centrally generated and distributed to each receiver. A typical HF radar receiver is shown in Figure 3. We can see that several local oscillator and timing waveforms are required, as well as control signals. Thus by placing the receiver at the base of receive element we have made the distribution problem far more complex, requiring us to distribute several high purity signals.

Work under this programme has developed a solution to the array distribution problem. Using this solution we need only a daisy chain cable running along the array, carrying the data link and power to each receive element, making the deployment of the array distribution a practical proposition. The data link itself carries only receiver baseband signals that have already been time stamped, or low speed control signals, hence any propagation uncertainty over the data link has no impact upon the radar performance.

The diagram of Figure 4 shows the simplicity of the proposed solution. The short active antenna, with receiver integrated into its base and the daisy chain array distribution scheme, make it considerably easier to deploy the radar system. The integration of the receiver and digitisation, with the receive element is often regarded as an expensive solution. In this case however the receiver and digitisation requirements can be met at modest cost using digital technology, due to the low signal frequencies and bandwidths required at HF. This negates the need for expensive high quality RF cables, thus making this a cost effective solution.

MODELING

So we have outlined a radar architecture that can meet our rapidly re-deployable requirement. Radar equation modelling of this system has been carried out using representative radar parameters to establish the performance that our rapidly re-deployable system could achieve. Four operational uses have been considered in the modelling, the detection of small fast boats or RIB, the detection of general shipping, the remote sensing of the sea surface environment and the detection of air targets.

The detection ranges estimated by this modelling are listed in Table 2. Note that there are essentially two different radar modes listed, one at 19MHz and the other at 9MHz.

Role	Frequency	Bandwidth	Range
RIB detection	19MHz	37kHz	44km
General ship detection	19	37	81
Sea state sensing	19	37	60
General ship detection	9	51	90
Sea state sensing	9	51	100
Air target detection	9	51	76

Table 2 Modelled detection performance

The results suggest that useful performance could be attained, for the scenarios listed in Table 1, in a rapidly re-deployable format.

SUMMARY

We have outlined some of the application areas for a rapidly re-deployable HFSWR, and identified that a system capable of detecting small fast boats, general shipping and sensing the sea surface environment could play a beneficial role in many applications. We have discussed current approaches to HFSWR system design, and identified those features that are barriers to a rapidly re-deployable system.

We have considered the deployment of the receive antenna array, and the array distribution, which are the major barriers to a rapidly re-deployable system.. We have developed solutions to the rapid deployment of the receive array and array distribution. This work has been described in the reports [3], [4], [5] and [6].

We have considered the practical constraints on a HFSWR system packaged in a rapidly re-deployable format. Radar modelling of expected performance, has established that a useful capability can be achieved.

The solution we have developed requires only a simple daisy chain cable running the length of the receive array, carrying a data link and power. The deployment concept is shown in Figure 4.

The major steps forward here are the development of a compact active receive antenna that is suitable for radar operation with a co-sited transmitter, and the development of an array distribution scheme, using only a daisy chain data cable. These developments remove the barriers to a rapidly re-deployable system, and enable existing capabilities in HFSWR to be pressed into use for new applications. The solutions developed can easily be incorporated into an existing HFSWR radar system such as that described in references [1] and [2].

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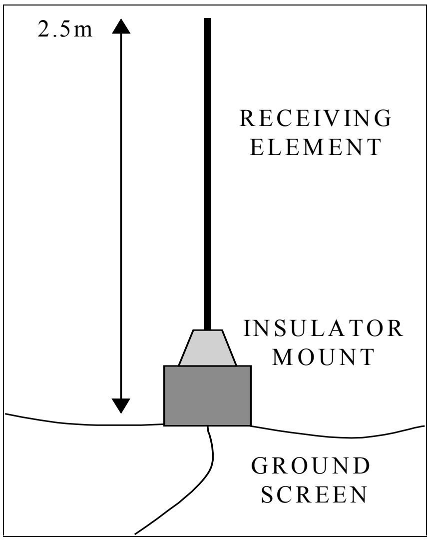

Figure 1 Short Antenna

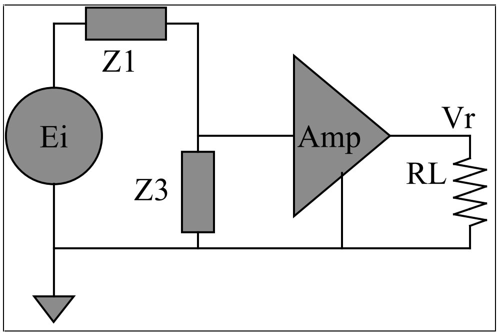

Figure 2 Active Antenna

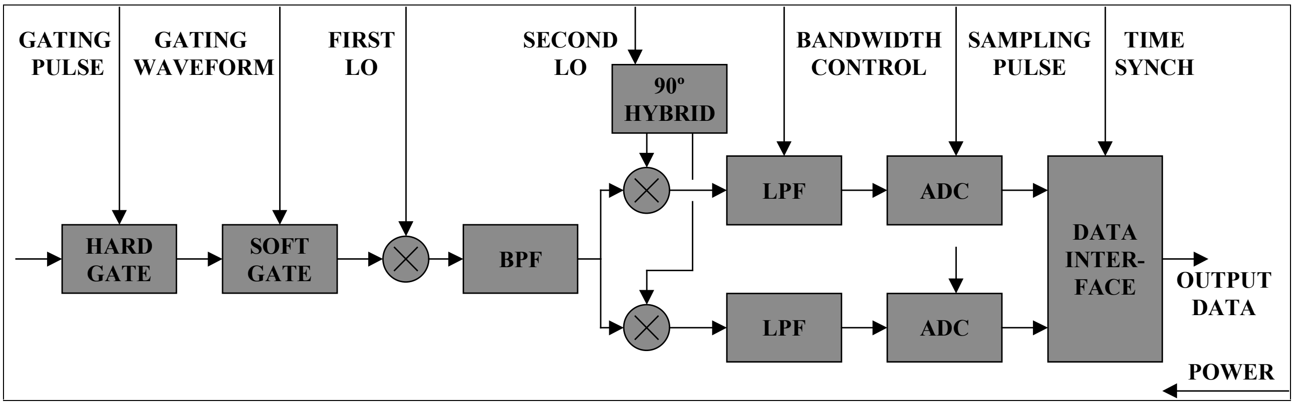

Figure 3 Typical Receiver

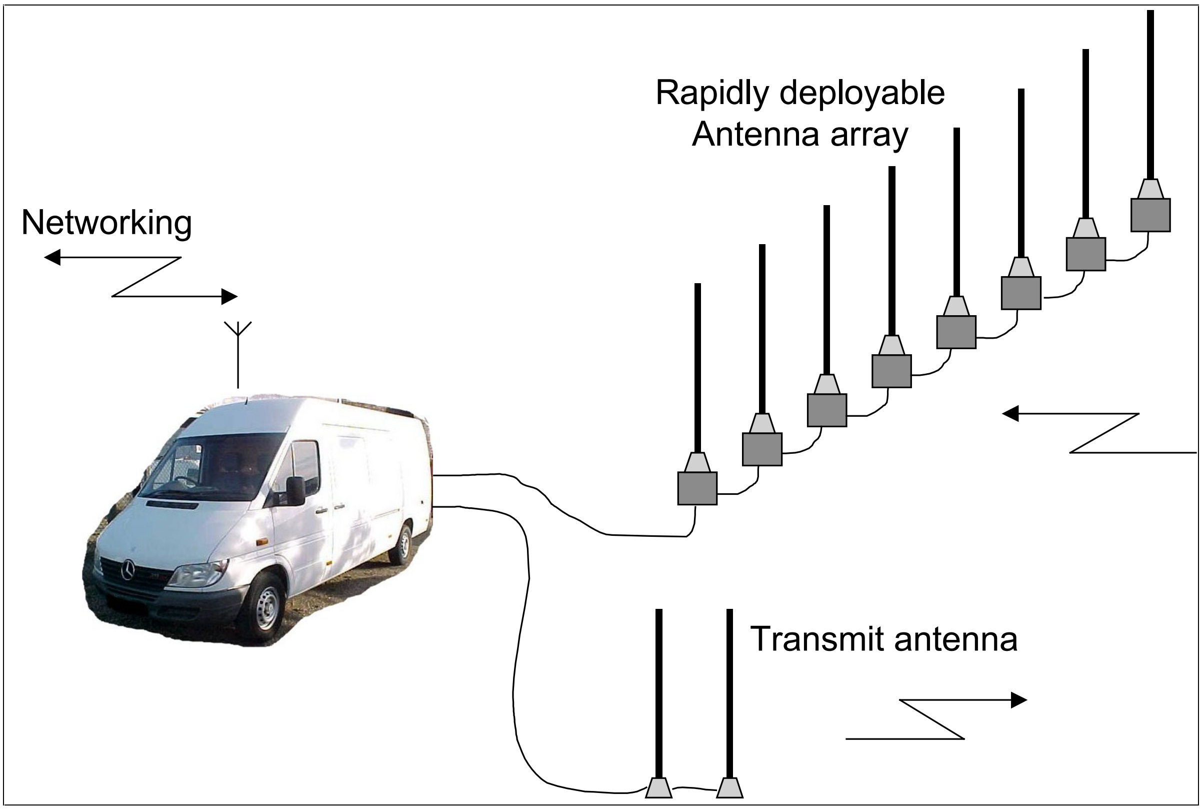

Figure 4 Deployed HFSWR