

SATELITE COMMUNICATION IN DEFENCE

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ACTIVE ANTENNA RADARS

Antennas composed of arrays of separate radiating elements have been widely used by radars in all wavebands since their first use prior to WW2. The capability of array antennas has been considerably increased in recent years by major advances in RF power generation and signal processing. As a result, radars based on “active antennas”, with each radiating element having its own power source and sensitive amplifier, are now being developed. This article will describe the technical and operational benefits and the technical challenges associated with this type of radar, that are being explored under the France/British/German AMSAR demonstrator programme.

A key component of a radar, and usually its most conspicuous part, is the antenna. This produces a beam to concentrate the power transmitted in the required direction and conversely to provide increased reception capability in the same direction. Two types of antenna are widely used. The first is the reflector, which uses a parabolic conducting surface in conjunction with a single source of radiation to form the beam. The second is the array antenna, which is composed of numbers of individual radiating elements generally distributed in one or two dimensions over a planar surface. The array antenna is particularly suitable for long-wave radars where the radiating elements are usually dipoles. Indeed, the first operational radar network (CH system) introduced into service in the UK prior to WW2 used tower-mounted arrays operating at 25 MHz. With increasing capability in electromagnetic design and precision manufacturing, the development of planar array antennas for use in the microwave band became possible. Consequently, airborne radars in particular now largely use this type of antenna. The latest advance has been to incorporate amplifying devices into the array antenna to form what is described as an “active antenna”.

In what follows we will briefly outline the basis of array antennas, and their

potential for electronic scanning. The main purpose is to describe recent development in active-antenna radars, the technical and operational benefits which result and the technical challenges to be faced. There will be particular reference to the Airborne Multi-role Solid-state Active-array Radar (AMSAR) technology demonstrator programme on which the governments and industries of France, the UK and Germany are collaborating.

ARRAY ANTENNAS

Fixed and Mechanically Scanned Antennas

The simplest array antenna uses the concept of dividing the signal from a single radio-frequency source between the individual members of a number of radiating elements, which are usually uniformly spaced in the same plane. The signals radiated from the array elements combine in space and, depending on the phase relationships between the radiated signals, constructive and destructive interference takes place. Suitable control of the phase relationships results in the addition of the signals from all elements in a desired direction. This is generally perpendicular to the plane of the array elements, but it is possible to form beams at directions of up to 60° from perpendicular. The same principle applies in reverse for the reception of signals arriving at the antenna from free space.

At long wavelengths fixed arrays have been used to provide radar coverage in specific directions. In the microwave bands mechanically scanned array antennas have been widely used in both surface and airborne applications.

A major advantage of an array antenna is that it allows close definitions of the amplitudes and phases of the signals at the radiating elements. As a result, the shape of the antenna beam and especially the response in the side-lobes away from the main beam can be carefully controlled. The achievement of low side-lobe

levels is often essential to the successful performance of a radar under operational conditions.

Electronic Scanning - Passive Antenna

The replacement of mechanical scanning of radar beam by electronic methods has long been seen to have advantage for system designers. Two methods of electronic scanning have been developed.

The first uses frequency scanning in which an array can be configured such that the direction of the beam is controlled by the operating frequency. This method has been applied particularly to scanning in one plane only and puts severe constraints on the use of frequency agility for other purposes.

The second method is based on the use of devices that are able to change the phase relationships between the radiating elements and, hence, the direction of the beam. The approach allows scanning in both azimuth and elevation. The development of relatively low-loss microwave devices capable of introducing accurate phase shifts into a transmission line has allowed the practical implementation of phase-scanned antennas. The high switching speeds available from phase shifters based on PIN diodes or magnetised ferrite result in the ability to change the direction of the beam in very short times. Consequently, the scanning is effectively inertialess. The pointing of the radar beam can, thus, be adapted to the current operational needs and is not restricted by the limitations of mechanical scanning.

This type of electronically scanned antenna is a direct replacement of a mechanically scanned version with the rest of the radar system (such as the high-power transmitter and two or three-channel receiver) remaining the same. Since the electronic scanning is achieved by means of passive components, a radar using

this technique is often called a “passive phased array radar”. Radars of this type are in service in the USA (Navy AEGIS, Army ATRIOT and Air France B-18) and in Russia (the Zaslon system on the MiG-31), and are under development in France (the RBE-2 system for the RAFALe).

Electronic Scanning - Active Antenna

The property that defines as active antenna is the incorporation of amplifying devices as constituent components of the antenna. In this type of antenna, each separate radiating element is directly associated with a power source for radiated transmission and a sensitive amplifier for reception of signals incident on the antenna. Thus, the individual radiating elements are linked directly to Transmit/Receive Modules (TRMs). Each TRM contains a power amplifier for transmission, a low-noise amplifier for reception, and phase and amplitude control devices. A TRM in effect contains the main radio-frequency components of a low-power radar, and an active antenna may be considered to be composed of a large number of miniature radars. By suitably arranging the signals from each of the large number of TRMs, the power is combined in space to form a high-power beam in the required direction. This approach replaces the need for a single high-power transmitting device such as a travelling wave tube. Similarly, on reception high-gain beams may be formed by combining the signals from the large number of low noise amplifiers. Electronic scanning is achieved by controlling the phases of the signals within the TRMs.

The practical implementation of active antennas has depended very largely on advances in the fields of solid-state processing. In particular, the developments of devices based on gallium arsenide and silicon have resulted in compact sources of significant levels of power at useful efficiency.

So far, the major application of this approach has been to the very long-

role, there are increasing demands on the radar to be able to carry out new

MOBILE CELLULAR COMMUNICATIONS SYSTEMS

In recent years, cellular communications technologies have made quite significant advances in the civil field with the establishment of the GSM standard for global mobile communications. GSM-based Public Land-Mobile Networks (PLMNs) are currently operational in more than 56 countries. This leads to the question as to whether or not GSM-PLMNs system could be used for military applications as well.

When military and commercial (GSM) cellular communications systems are compared against the background of severe military requirements, it becomes evident that the latter are not able to fulfil these requirements. The basic shortcomings of commercial systems involve the lack of information security (TRANSEC), reduced mobility, and lack of interoperability to EUROCOM Standard.

“Command and control without suitable utilisation of available technology for information production, information transmission and information processing is nowadays not imaginable”. said Col. Konrad Menny. this task is only soluble with co-operative systems.

The communication system of the German Army (FmSysH) provides terminals and the necessary transmission paths like cables, radios, directional radios and satellite systems. The FmSysH is currently being modernised to fulfil the future requirements, which more and more involve the transmission of digital data. One part of the FmSysH is the Single Channel Radio Access (SCRA, or DWT in Germany) that the Federal Republic of Germany and the Netherlands are currently jointly developing. The SCRA shall provide mobile users as well as command and control systems for connection to the AUTOKO '90 Corps-level tactical digital nodal network.

The SCRA in Brief

Topology

The SCRA is a digital, tactical cellular communication system, in order to guarantee interoperability with existing battlefield communication systems, the SCRA is being developed in accordance to the EUROCOM Standard.

The SCRA will provide mobile users with the same performance characteristics as available to wire subscribers. Every user is attainable in the SCRA without knowledge of the location and independent of the command and control hierarchy. Users have only to derive the number with the EUROCOM scheme and dial it. Therewith an information network is built for speech- and data transmission over the whole battlefield with gateways to other EUROCOM communication networks. Noise resistance and the protected transmission of sensitive information are provided through ECCMs and encryption.

The mobile subscribers are equipped with a terminal set (Mobile Subscriber Terminal, MST) and affiliate to a base station (Radio Access Point, RAP), which is connected to the nodal network by radio relay or cable. The RAPs are developed in such a way as to cover the operational area of the MSTs without shadow-fading, if possible. A maximum of 36 MSTs can affiliate to any one RAP area. The probability of blocking will increase considerably if the subscriber density is higher.

Mobile subscribers in proximity, belonging to the same RAP area, can contact each other directly (direct traffic). The feature reduces the RAP loading, as its radio channels are not used. If no direct contact is made within a certain time, the RAP will make the connection (relay traffic). Both types of traffic (direct and relay) constitute connections within the RAP area. The RAP makes these connections independently of the nodal network. If thus operates autonomously its

internal area.

Connections to and through the nodal networks constitute external traffic. The subscribers are not restricted to a fixed location; contact while on the move are also guaranteed.

MSTs will usually affiliate to the RAP to which the most favourable radio condition exists, but specific selection is also possible by using the Control Terminal.

Operational characteristics

From the point of view of the user, the major performance characteristics of SCRA are:

- Duplex switched connections
- Digital speech or data transmission
- Link-encryption of all information (COMSEC)
- Resistance to interference (TRANSEC)
- User facilities in accordance with EUROCOM
- Connection to other networks via specific interfaces.

Organisation of the SCRA Net

SCRA provides mobile subscribers with 16 kbit/s duplex traffic channels. Specific, additional data exchange is also required for network organisation, for which dedicated administrative channels must be provided. Time Division Duplex (TDD) is used for radio transmission of information. This is done by compression of

the data on the time place, the transmission rate being increased to supply the capacity required for traffic and administrative channels available.

Regular changes in the direction of transmission and reception, plus a transmission speed of 48 kbit/s on the radio link, then permit its use as a duplex channel as far as the user is concerned although only a single frequency is used.

When a traffic channel is used for data transmission and reception, plus a transmission speed of 48 kbit/s is required, the available redundancy is used for SCRA-specific FEC (Forward Error Correction).

All information, on both the traffic and administrative channels, is encrypted.

A major feature of the system is its resistance to interference, this being achieved by a series of measures. The basis is medium-fast frequency hopping, whereby the LRC calculates the frequency to be used from a cryptoalgorithm. Further measures are incorporated in the frequency management and network administration methods.

GSM - Description

In 1982, the CEPT decided to set up a working group to establish the specifications for a pan-European cellular communications system for the 900 MHz band that had recently been allocated to land mobile use. The results of the activities of the GSM have been available since 1984 in the form of technical specifications for the first phase of the system.

Topology

The GSM (the acronym now stands for Global System for Mobile communications), known in some countries under different names (for instance, in Germany it is the D-Netz) is a mobile telephone network, i.e., its design is optimized to transmit speech. Because of the digital radio transmission there are many possibilities of transmitting data. In comparison to existing analog systems, like the C-Netz in Germany, the GSM offers many advantages:

- The mobile stations can be used in every country that has a GSM-compatible cellular system (the list included 56 countries by late 1994);
- Better exploitation of scarce frequency resources;
- Better exploitation of scarce frequency resources;
- Improved signal quality;
- reduced production costs.

The main elements are as follows:

- Mobile Stations (vehicle-mounted, man-portable or hand-held);
- Base Stations, including the base transceiver station and the base station controller;
- Mobile Switching Centre;
- Operation and Maintenance Centre.

The information is sent from the mobile station (MS) to the base station (BS) in the 900 MHz band on a 16 kbit/s channel. Between the BS and the MSC there are switched transmission paths (cable or directional radio) with 64 kbit/s

Mobile Switching Centre

the Mobile services Switching Centre (MSC) controls the traffic- and common channel and works together with the switching centres of the PSTN. The MSC consists of a modern SDN switching centre with additional functions and interfaces to manage the mobile communications. The MSC makes use of a signalling support network following the CCITT Signalling System No. 7 protocols; this signalling network enables co-operative interworking between MSC machines within one or several GSM networks.

The MSC also includes data bases. Subscriber information relevant to the provision of telecommunications services is held on the infrastructure side in the HLR (Home Location Register), independently of the actual location of the subscriber. The HLR also includes some information related to the current location of the subscriber. A functional subdivision of the HLR identifies the Authentication Centre (AC), the role of which is limited to the management of security data for the authentication of subscribers. The second database function identified in GSM is the VLR (Visitors Location Register), linked to one or more MSCs, and in charge of temporarily storing subscription data for those subscribers currently situated in the service area of the corresponding MSC, as well as holding data on their location at a more precise level than the HLR.

To set up a call towards a GSM user, the call is first routed to a gateway switch without any knowledge of the whereabouts of the subscriber. The gateway switches are in charge of fetching the location information and of routing the call towards the MSC through which the subscriber can obtain service in that specific moment. To do this, they must first find the right HLR, knowing only the directory number of the GSM subscriber, and interrogate it. This procedure is called "off air call set-up".

into test operation. The DCS 1800 has been developed according to the GSM 900, and the frequency lay in area of 1800 MHz. The advantage is that smaller cells with higher capacity can be installed.

Original proposals for a wide band system with code multiplex transmissions were rejected because of their cost. However, this approach is currently being examined by the European Union in the framework of the RACE programme for the follow-on system UMTS (Universal Mobile Telecommunication System). The standard for this Future Public Land Mobile Telecommunication Systems (FPLMTS) are expected to be formulated by the CCIR in 1998.

The UMYS is visualised as a 3rd generation cellular communications system, using frequencies from 1884 to 2025 MHz and from 2110 to 2200 MHz (the higher frequency range can only be used after the year 2000). The UMTS will be compatible with the ISDN, and will offer a data transmission rate of 2 Mbit/s.

overall architecture envisaged for the next-generation system will, therefore, incorporate a number of significant changes which are summarised graphically.

Technology Migration for Next-Generation Architecture

The features required from the next-generation milsatcom system can be mapped to technologies and developments needed within the space segment and ground segment to achieve the overall system objectives.

Migration to the next-generation milsatcom architecture will require advanced technologies in both space segment and ground segment. Many of the required advances in the ground segment will be provided through the introduction of advanced modern systems, such as the Universal Modem. In addition to enhancement of AJ capability through the use of ECCM modems, the Universal Modem system also allows autonomous management for individual user groups, and a high degree of flexibility in satellite access and call management. The adoption of common modern system standards with allies is critical to achieving a high level of direct terminal-to-terminal interoperability.

Further ground segment technology improvements are required to support provision of “seamless end-to-end connectivity” for user communications. A specific feature for the UK system will be the incorporation of a Baseband Interface Function (BBIF) within the central ground segment to provide signalling translation and routing functions to allow extension of UK terrestrial network services over the satcom system.

Space segment technologies are discussed further in the following section. However, it is clear that space and ground segment technologies for the next generation need to be considered together in a system context to ensure an effective

simultaneous coverage of more than one theatre or simultaneous theatre/metro-politan area coverage. Multi-headed beams provide excellent flexibility and offer additional benefits in terms of reduced channelisation complexity.

A multi-matrix solution provides a good match to the transmit antenna requirements. The concept incorporates a 55-element feed assembly radiating onto a reflector of approximately 1.5m aperture. The feed assembly is supplied by a series of matrix amplifiers within each of which, power is distributed evenly amongst eight Solid State Power Amplifiers (SSPSs). The transmit antenna provides a similar degree of flexibility to the receive antenna including the facility to provide double headed beams. The incorporation of matrix amplifiers results in an even distribution of power and, therefore, a relatively stable thermal environment. Reliance on a group of amplifiers rather than a single transponder chain also leads to more graceful degradation of performance under failure conditions.

SHF Nulling System

The next-generation milsatcom system design needs to take into account an environment in which the capability for electronic warfare is more sophisticated and mobile. A high performance, flexible on-board nulling system will be required to allow continued support for communications service under a jamming attack.

The concept envisaged for the next generation uses the flexible phased array receive antenna to place multiple nulls within any, or all, of the communications post beams. The antenna can be used in combination with an on-board spectrum analyser which provides jammer location and characterisation data. The on-board system is capable of operating largely autonomously, although ground controlled initiation of nulling operation is anticipated. Once initiated, null positions can be trimmed, using a closed loop adaptive algorithm to compensate for any

tions do not generally require extremely flexible routing, since most links are usually within a single operational theatre or between a theatre and metropolitan area. It is, therefore, the survivability benefits which provide the strongest arguments for on-board processing. Regenerative processing at EHF provides an attractive solution for survivable naval communications since it offers good AJ protection and maximum possible protection against geolocation. For maximum survivability, attention is focussed on Low Data Rate (LDR) processing which allows recognisable voice links to be maintained, under high stress conditions. Protection is obtained by complex coding and interleaving of signals and hopping over a wide (2GHz) bandwidth.

Two further features of on-board processing are potentially of interest to naval users; Support for dispersed users, and decentralised and devolved management. On-board processing can be used in conjunction with digital beamforming techniques to provide a set of agile spot beams to support users outside the main spot beam coverage areas. This allows optimisation of performance for individual users and improves overall system flexibility, although at some cost in terms of space segment design complexity.

The architecture of on-board processing systems decreases the reliance on a central communications management function, since network management and operations are carried out by the on-board systems. This offers remote users a high degree of autonomy and flexibility in the management of their own communications resource within limits of precedence and priority established by the central management function.