The BRUIN Communications System

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Abstract

The BRUIN communication system was an an essential element in the operational structure of the British Army of the Rhine between 1967 and 1985. It represented a major change from conventional combat net radio communication policy and paved the way for secure area trunk systems such as PTARMIGAN, its successor. This article explains the history and role of the BRUIN communication system and describes its facilities, its configuration and the equipment used.

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The BRUIN Communications System

Introduction

From the inception of army wireless communications early in the twentieth century, stations were arranged in "nets" controlled by a single station and organised to mirror the chain of command. Towards the end of the second World War, radio relay systems such as the British WS10 and the American AN/TRC series were introduced in order to replace line trunk circuits during mobile operations and these also generally linked headquarters.

Thus, each headquarters was a focus for considerable communications activity and something of the order of one third of all the vehicles at a headquarters had a communications role. This concentration of personnel and equipment at headquarters had a number of serious disadvantages:

- The headquarters were large and difficult to hide.
- They were complex and time consuming to set up and break down.
- Moving the headquarters was very disruptive to communications.
- Tactical and engineering siting considerations were often in conflict.
- Siting the radio systems close to the headquarters was a gift to enemy direction finders.

A potential answer was, of course, to make the communication system's location independent of the headquarters it served. This was obviously easier said than done because the army and its communications system had to be mobile, so could not rely on a network of static installations. Today we are all familiar with the mobile telephone network, which is a static form of the sort of system the army required. In these networks, the nodes (cell stations) are linked by wideband multi-channel trunk links and provide access to the mobile phones using complex automatic call routing. Unfortunately, in the 1950s such a system could not be designed because wireless and routing technologies were not sufficiently advanced.

It became clear after the war that operational requirements in North Western Europe would call for quicker reactions, greater resilience and enhanced facilities, along with reduced manpower, than had been available up to that point. At the same time, new technologies, notably digital computing (then known as "automatic data processing") and digital frequency synthesis, were emerging and would clearly play a part. Following numerous studies during the 1950s, a team from the Planning Wing of the Army Operational Research Establishment began work on "Study No. 27" which, in 1961, received the codename HOBART. This document was the first to include proposals for a secure area trunk communications system, the use of computer controlled switching and a new family of combat net radios. In about 1963 the HOBART plan was split into three in order to make it easier to let contracts for industry studies:

- ALLERTON: Secure switched trunk[1] system, which evolved into PTARMIGAN via international co-operation projects TEAL and MALLARD[2].
- BOXFORD: Radio trunk extension which later became known as the "Single Channel Radio Access" system (SCRA), a part of PTARMIGAN.
- CLANSMAN: Combat net radios.

Various agencies had been studying the application of computers in the military arena since the mid 1950s, and it became clear that the control of the ALLERTON system would be a prime candidate.

Originally, it was thought that the trunk switching system would be an international project in cooperation with America, Canada and Australia, the so-called "ABCA" consortium. The international efforts, projects TEAL and MALLARD, were eventually abandoned when the USA withdrew in 1970, but long before the departure of the Americans it had become clear to all the allies that the area concept represented the future for land force communications.

[1] "Trunk" is the name conventionally given to a main circuit connecting telephone exchanges. Trunks are normally capable of carrying a number of conversations.

[2] These codenames may be causing confusion and this is, in fact, the general idea. Official codenames are obtained from a cross-service MoD list which should be random, to confuse a potential enemy. The fact that TEAL, MALLARD and PTARMIGAN are all birds was, it is said, a coincidence.

Development of the British Army switched trunk system reverted to being a UK effort in 1970, under the code name PTARMIGAN, which was finally fielded in 1985. However, the need for some sort of area system was pressing and in the mid-60s it was decided that a project, codename BRUIN, should be initiated to provide a stop-gap system. The system went into service in 1968 with an expected life of some eight to ten years but in the event, had to remain in service for seventeen.

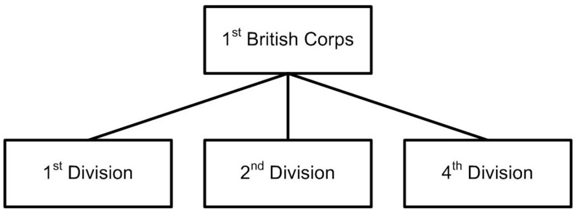
BRUIN was in the main constructed from off the shelf commercial equipment (nowadays known as COTS[3]) and has been called a "semi-area" communications system. Because of the limits of the available technology, it was not possible to separate the trunk system completely from the headquarters. Some vehicles, collectively known as the Communications Head, were retained at the headquarters to be served, while the majority of the vehicles were sited remotely, forming Communications Centres, the whole system interconnected via multi-channel radio relay links. Thus BRUIN was more accurately described as a "detached communication centre system following the chain of command".

BAOR

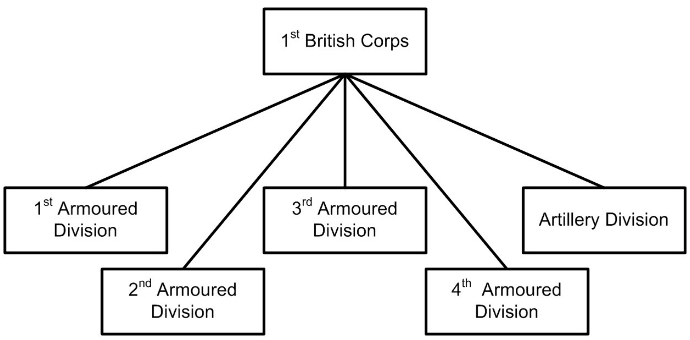
When the Second World War in Europe ended, Field Marshall Sir Bernard Montgomery's 21st Army Group was occupying the North West of Germany, with the US forces to the South, facing the Russians in the East. The Yalta and, later, Potsdam conferences defined four zones of occupation, including a relatively small French zone in the South East and the city of Berlin, embedded well within the Russian zone, was likewise spilt into four zones. In August 1945, 21st Army Group was re-designated the "British Army Of the Rhine" and at that time, its strength was approximately 80,000.

In 1949, with the formation of NATO, BAOR became the British contribution to NATO's Northern Army Group (NORTHAG or NAG). Its composition varied considerably during the 47 years of its existence but its remit remained relatively unchanged, to defend the British Zone in the event of a Russian invasion. When the Soviet Union collapsed, this threat was perceived to have reduced and BAOR ceased to exist in 1992, becoming part of the NATO Allied Command Europe Rapid Reaction Corps (ARRC). BAOR's strength had been reduced over the years and by 1992 was some 25,000 men.

For ten years, the high level organisation of BAOR remained roughly stable:



The three divisions contained a mixture of armoured, mechanised and infantry brigades, as well as an artillery brigade (within 4th Division). In 1973, an Artillery Division was formed to contain the artillery elements, including heavy, missile, air defence, locating and transport regiments, as well as 1st Battalion, Royal Scots. Finally, 1978 brought a major reorganisation, producing the structure below, which represented the situation for the last seven years of BRUIN's life:

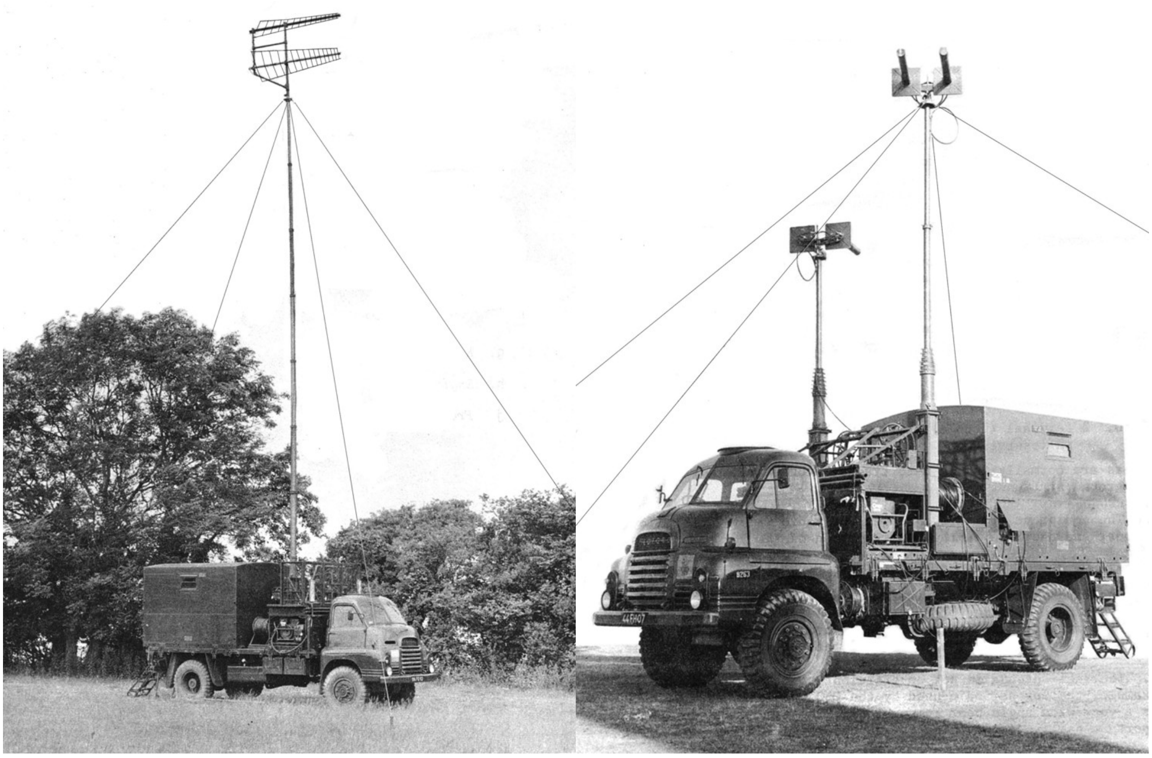


Obviously, the structure of the BRUIN system had to change to support the operational structure as it developed, but for the purpose of this article, in order that a logical description of the system

[3]Commercial Off The Shelf.

can be given, the structures of 1972–1973, before the creation of the Artillery Division, will be used. Also, because this is a descriptive article aimed at giving the reader an understanding of what the system was used for and how it worked, the level of detail will be limited. It is convenient that much of the available surviving documentation dates from the early 1970s, in particular the training manual *Signal Engineering Instruction : The BRUIN System* [1], which provided the initial information upon which this article is based.

Throughout the seventeen years of BRUIN's life, the task of supplying its facilities fell to 7th Signal Regiment based at Maresfield Barracks, Herford and 22nd Signal Regiment based at Churchill Barracks, Lippstadt. 7 Sig Regt provided communications from Corps Main HQ forward to Brigades and 22 Sig Regt to the rear. Although the main communication requirement followed the chain of command, Corps – Division – Brigade, there were numerous supporting arms and elements which also had to be served by BRUIN.



(a) C50 Radio Link Terminal Station (b) C70 Radio Link Relay Station

Figure 1: Radio Link Stations

The System

BRUIN provided mobile communications for the operational units of BAOR, that is to say 1(BR) Corps[4], composed of three or four Divisions, each of two or three Brigades. It did not extend forward of Brigade headquarters, communications in this zone being traditional combat net radio based on the Larkspur series of equipment. Supporting arms, particularly air, were comprehensively covered and in the rear communications zone, BRUIN was well provided with links to the static command systems.

Two main areas of functionality were delivered by BRUIN to its users:

Telephony	A secure, automatic, subscriber dialled telephone system.
Telegraphy	A complex teleprinter network, originally manual but automatic message routing was added later.

The design principle was that each headquarters should be provided with a local Communications Head (COMM HD) consisting of a small number of vehicles, and a Communications Centre (COMCEN[5]) located at a distance from the HQ and containing the majority of the communications

[4]The official abbreviation, 1(BR) Corps, was used to to differentiate it from the 1st Corps of other allied armies.

[5]Although the official literature of the time shows "COMMCEN" as the official abbreviation, BRUIN COMCENs were conventionally spelt with one 'M', thus differentiating them from the traditional R Signals COMMCEN, which is a message centre - static or field.

vehicles. In fact, for resilience, *two* COMCENs were provided for Corps and Divisional HQs and were known as the Executive and Non-executive COMCENs. it was originally intended that only one would be in use at a time, the other held in reserve. However the facilities provided by BRUIN proved so popular that both COMCENs had to be open to service the traffic levels required. In consequence, closing a COMCEN, as happened when it had to move, became much more difficult than had been envisaged by the designers of the original system.

Movement was, of course, key to the successful operation of BRUIN and it is necessary at this point to note the way the British Army was organised for mobility. More information may be found in the various staff training publications of the time, but in summary, each headquarters could be made up of three elements; Rear HQ, Main (or Forward) HQ and Step-up HQ. Corps Rear HQ was mainly concerned with the logistic aspects of the operation, including re-supply, and in the case of BAOR, was linked to the static communications infrastructure.

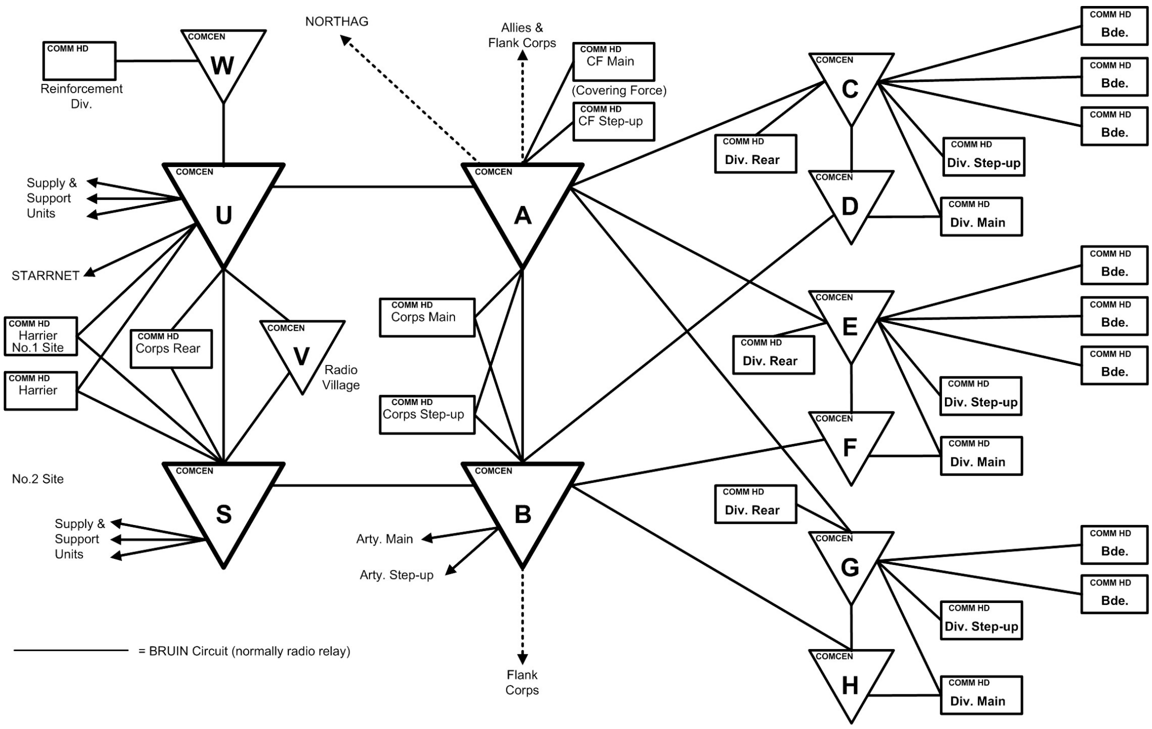


Figure 2: BRUIN System Layout, 1973 (Simplified)

The main Corps command and control functions were normally exercised from the Main HQ, but when the HQ needed to move, the Step-up element made the move and it then became the Main, while the original Main reverted to being Step-up. Whether any individual HQ was so divided was presumably dependant upon operational conditions – BRUIN normally served the Corps and Divisional Rear, Main and Step-up HQs but only the Brigade Main HQs. COMCENs were allocated to Corps and Divisions as shown in Table 1 (Brigade HQs were connected to their Division's COMCEN).

HQ	**COMCENs**
Corps Main & Step-up	A and B
Corps Rear	U and S
1 Div Main & Step-up	C and D
1 Div Rear	C
2 Div Main & Step-up	E and F
2 Div Rear	E
4 Div Main & Step-up	G and H
4 Div Rear	G

Note: *A, U, C, E & G were originally Executive, the others Non-executive.*

Table 1: COMCEN Utilisation, 1973.

It has been reported that during operations, moves were commonly made *every night* although it seems that later in the system's life and probably due to the complexity of the logistics as much as any perceived change in threat, the frequency of movement was reduced. It has been reported that everyone in R Signals with a BRUIN role learned to snatch some sleep whenever they could!

COMCEN U was equipped to connect to the COMCEN of a reinforcement division (designated COMCEN W) and COMCENs U and S (via COMCEN V) to the "Radio Village", a site separated from the COMCEN which contained a number of wireless systems, mainly high powered HF stations.

Each of the headquarters shown in Table 1 was equipped with a COMM HD, as were Brigade HQs, the reinforcement division HQ, the Radio Village and two Harrier air support sites, as shown in Figure 2. This is a simplified diagram which, of course, represents the situation before the formation of the Artillery Division and the later reorganisation of 1978 and only shows the overall system layout in terms of COMCENs, COMM HDs and (without detail) connections to other units and arms. Dotted line connections were not necessarily BRUIN-style radio relays and connections shown without a COMM HD normally used a C41/R222 VHF radio link[2][3] to a Terminal Equipment Vehicle (Liaison). More information on the systems used in the COMCENs, COMM HDs and Terminal Equipment Vehicles (Liaison) will be given later.

Telephony

At each headquarters, subscribers with access to the system were provided with a dial telephone extension (mainly the British Post Office type 706[4] – see Figure 3) through which they were able to connect to other local subscribers and, over the telephone network, those at other headquarters. The subscribers' appointments were allocated predefined three digit numbers, which were the same for the corresponding appointment at every headquarters. For example, the Commanding Officer's number was 601, whether he commanded a Brigade, a Division or the whole Corps.

Figure 3: BPO 706

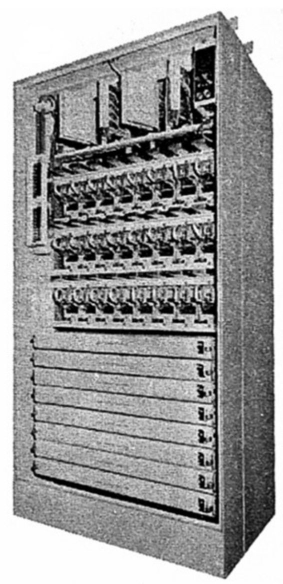


Figure 4: Tandem Exchange

To achieve this, each COMM HD was equipped with an automatic telephone exchange, known as a Terminal Exchange, which served all the extensions at its associated headquarters. However, if the subscriber dialled '9', a connection was set up to an auto exchange at the nearest COMCEN, known as a Tandem Exchange, which handled onward connections. So if a Brigade commander wished to speak to his Divisional commander, he would dial '9' to connect to the divisional tandem exchange, then '4' to connect to the Division Main COMM HD and finally '601' for the commander. If he had wanted the Corps commander, he would have dialled '9' (Div tandem exchange), '7' (Corps tandem exchange), '4' (Corps Main COMM HD) and finally '601'. These examples used extensions at Main HQs but Rear HQs were available in the same way. For example, the Div Rear HQ was reached from the Div tandem exchange by the digit '6', rather than '4'.

Transfer of command to a Step-up HQ was achieved in BRUIN in a particularly clever way. Main HQs were on level 4[6] of their COMCEN's tandem exchange and Step-up HQs on level 5. When command was passed to the Step-up, a single switch was operated at the tandem exchange swapping the level 4 and 5 circuits, allowing '4' to continue as the (new) Main HQ's access digit. On the next transfer of command, the switch was thrown back.

The terminal exchanges offered a number of advanced features:

Hunt Groups A number of extensions could be associated so that if the first extension was engaged when called, the next would be rung, and so on. Operationally, hunt groups were limited to two extensions.

Trunk Access Barring Extensions could be barred from dialling '9', thus limiting them to making local calls.

Break-in Any extension could be given the ability to break into a call in progress by dialling '1' when the called extension was found to be engaged. This facility was available for calls at the local and/or distant exchange.

First Junction Override *Junction* is the conventional term used to describe a single connection between exchanges, capable of carrying one call. The junctions between two tandem exchanges

[6] i.e. Reached by dialling the digit '4' at that exchange.

were normally used in numerical order, which could block connections if the first junction went out of service. The First Junction Override facility allowed the exchange to bypass the faulty junction by using the second or a subsequent junction.

Short Circuit Detection After a loop was detected by a terminal exchange (the signal that the extension handset had been lifted), if no dial pulses were detected within 50 seconds, the connection was rejected. This prevented a short circuit fault from seizing and holding an access relay set.

Temporary Out of Service Keys were provided at the terminal exchanges which allowed individual extensions to be taken out of service, resulting in calls to those extensions receiving the Number Unobtainable (NU) tone. This facility was particularly useful during moves, before all personnel had arrived at the new site.

Resilience under battle conditions was obviously an important consideration for the system designers and every auto exchange in the system had an associated manual exchange performing a number of functions:

- Back-up in case of auto exchange failure. A single switch could be used to route important extensions to the manual exchange and thus maintain essential service. It is worth noting that due to the reliability of the auto exchanges, this facility was seldom, if ever, used in anger.
- Operator assistance. If the caller needed to speak to an operator, he could dial a specific extension on the local terminal exchange or '0' on a tandem exchange.
- Manual intervention. If a trunk route failed, callers attempting to use it were routed to an operator.
- Conference calls, which were controlled by operators at the COMCEN.
- External connections. Any connection which did not enter the system via a COMM HD used a manual exchange. Two examples:
  1. Support and logistic units.
  2. Civil telephone lines.

  Note that many of these connections used signalling systems unlike that of the BRUIN system and "signal conditioning" arrangements were required.

Figure 5: 40/160 Exchange

Figure 5 shows a single position 40/160 Field Exchange[5]. This was the standard portable manual exchange for use at headquarters above battalion level and in the configuration shown could handle up to 40 lines. However, by linking up to four positions, 160 line could be connected. In BRUIN, this exchange was used at Corps COMM HDs and COMCENs.

The standby manual exchanges at Divisional and Corps COMM HDs were Ericsson Cordless CB[7] exchanges. At Division, a 12-line unit[6] was used, equipped with seven extensions; two magneto extensions and three CB or auto exchange lines. At Corps, the 25-line version[7] was used; sixteen CB extensions, four magneto extensions and five exchange lines. These units are shown in Figure 6.

From	At Div COMCEN	At Corps Main COMCEN	At Corps Rear COMCEN
Level 1	1st Bde COMM HD	1st Div COMCEN	Harrier Site 1
Level 2	2nd Bde COMM HD	2nd Div COMCEN	Harrier Site 2
Level 3	3rd Bde COMM HD	3rd Div COMCEN	Rft Div COMM HD
Level 4	Div Main COMM HD	Corps Main COMM HD	Corps Main COMCEN
Level 5	Div Step-up COMM HD	Corps Step-up COMM HD	Corps n/e Main COMCEN
Level 6	Div Rear COMM HD	Corps Rear COMCEN	Corps Rear COMM HD
Level 7	Corps Main COMCEN	Covering Force COMM HD	Corps Rear COMM HD
Level 8	Div n/e COMCEN	Corps n/e Main COMCEN	Corps n/e Rear COMCEN
Level 9	Engineering	Engineering	Engineering
Level 0	Manual Exchange	Manual Exchange	Manual Exchange
	Note: n/e=Non-Executive	*Rft=Reinforcement*	

Table 2: COMCEN Tandem Exchange Levels

[7] Common (or Central) Battery signalling, as opposed to Magneto.

Figure 6: Standby Manual Exchanges – 16-Line (left) and 25-Line (right)

Table 2 shows the connections which could be obtained from the tandem exchanges at the executive COMCENs. Note that Harrier Site 1 also housed the Wing Operations Centre and that Level 7 at the executive Corps Main COMCEN connected to the covering force COMM HD as shown in the table, while the same level at the non-executive Corps Main COMCEN) connected to the Artillery Brigade headquarters. Finally in Table 2, notice that Level 9 at all tandem exchanges is labelled 'Engineering'. These are connections to the R Signals engineering control and monitoring telephone system, which is discussed below.

There were occasions where it was desirable to group extensions in twos and threes. An example requirement for a two-telephone arrangement was the need to filter calls made to a commander, while allowing the commander to place outgoing calls directly. This used a system used by the British Post Office known as "Plan 8"[8], one of a large number of special arrangements used by the BPO. The only other plan used in BRUIN was Plan 3XH[9], an arrangement of three extensions and three lines. Plan 8 and Plan 3XH systems are illustrated in Figure 7.

(a) Plan 8 (b) Plan 3XH

Figure 7: Special Telephone Extension Plans

The Trunk Network.

Having gained some insight into the complexity of the BRUIN telephone network, we must now consider what connected its elements together to produce the system shown, in simplified form, in Figure 2.

BRUIN COMCENs, COMM HDs and liaison TEVs were generally connected by radio links carrying six duplex audio connections (with signalling), although not all channels were used for telephone junctions as we shall see. If the distance to be covered was less than 1600m (1 mile), "Carrier Quad" cable in lengths of 30m and 400m could be used – carrier quad was a heavy duty sealed, flexible cable containing two low loss balanced pairs, capable of carrying the six channel multiplexed signals.

Telephone connections from terminal exchanges, etc. in groups, were combined into a Pulse Code Modulated (PCM), Time Division Multiplexed (TDM) digital stream which could be handled by the two main radio link stations, the C70[11][12] and the C50/R236[13][14]. This operation was carried out by a six channel multiplexer which included secure encryption of the signals and was known as the BID-200[8]. In the case of the C70 station, two 6-channel streams could be combined for transmission over the link.

COMM HDs, COMCENs and one type of liaison TEV (Type A) were equipped with a number of multiplexers and thus provided full, secure access to the BRUIN telephone system, but there

[8]A 'British Inter-Departmental' number is given to each type of official UK encryption system.

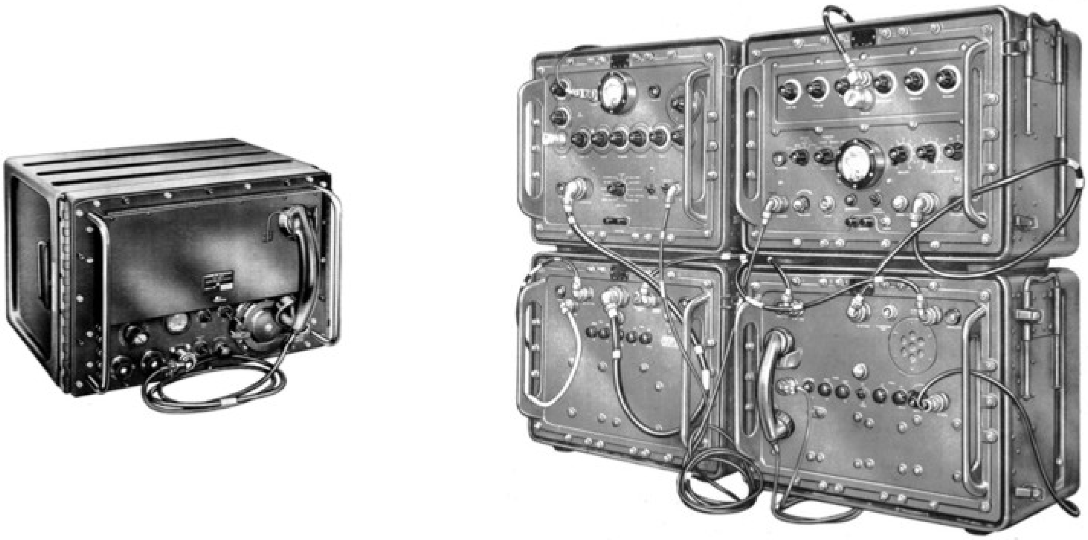


Figure 8: CST1+4 No 3 (left) and C41/R222 (right)

were also a number of telephone connections which were not required to be secure. These were connected via a standard Army Frequency Division Multiplexer (FDM), the CST1+4 No 3[15], and the C41/R222 VHF radio link station. These systems could be carried in the Type B TEV (Liaison), in air portable form in Sankey trailers (known as 'fish fryers') or separately rigged.

As mentioned above, not all the radio link audio channels were connected to the telephone systems and frequently a 6-channel trunk would be employed for four telephone junctions, an omnibus audio intercom for R Signals engineering use and one channel dedicated to telegraphy. The next section deals with the BRUIN telegraphy system in more detail.

Figure 9: The MuFAX D900/901-AM/DJ (left is the receiver, centre the transmitter)

Finally, although no special connections were involved, each COMM HD was equipped with a FAX set, the MuFAX D900/901-D[16], replaced in 1972 by the D900/901-AM/DJ[17] (see Figure 9). Extension 807 appears to have been used for FAX.

Telegraphy

In the context of BRUIN, telegraphy meant teleprinters – duplex, single current, negative mark, 75 baud systems – connected either point to point or in nets. The standard teleprinter was the Seimens T100[18] in various configurations, with and without paper tape capability. Telegraph circuits were derived from the same type of audio circuit used for telephony by means of a Telegraph Terminal, Voice Frequency, the TTVF 4/12[19]. This device was made up of two parts, the Channel Box which converted the telegraph signals to and from audio tones and the Group Box which could combine the signals from three channel boxes. Each channel box on its own could provide up to four teleprinter channels and using the group box, up to 12 were available.

Unlike the telephone system, no automatic exchanges were originally used, messages being routed semi-automatically, in vehicles known as "Telegraph Relay Station, Torn Tape, Semi-Automatic, 22(15) Lines"[20]. These 3 ton Telegraph Relay Vehicles (TRVs) were located at all the COMCENs and could handle either 15 circuits for Divisional COMCENs or 22 circuits for Corps COMCENs. Incoming messages were perforated and printed on paper tape using semi-electronic EPR/1 printing

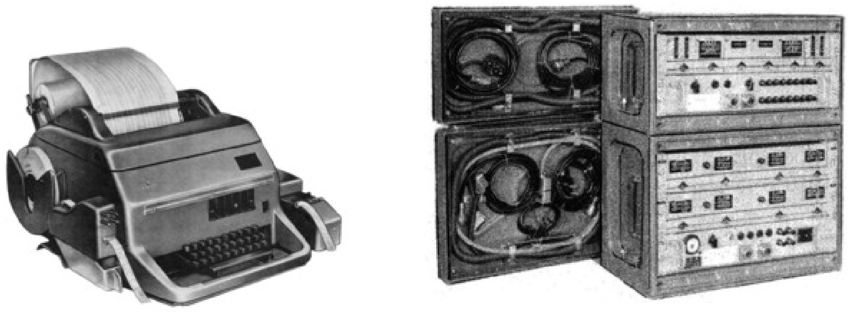


Figure 10: T100/R Teleprinter and TTVF 4/12

reperforators. The operators could each use a number of tape readers type TR92, with electronic parallel to serial convertors ETP/TM, to retransmit the messages to the required destinations. Circuit selection and automatic message numbering was achieved by means of uniselectors and relay sets, controlled by the operators. This switching system was again a commercial product, by Standard Telephones & Cables.

The TRVs were not entirely satisfactory, for a number of reasons:

- The equipment was unreliable.
- Space was too limited for normal operation, supervision or training.
- There were too many relay stations in the system.
- Handling of the paper tape in poor environments led to problems.
- Central control of the system was difficult.

So in the 1970s, the TRVs were replaced by TARIF, Telegraph Automatic Routing In the Field[21], a project completed in late 1973, by which time one TARIF system was in place at each Corps COMCEN, incidentally reducing the manning requirement by around 50.

Figure 11: Bedford 4 ton Flat Platform Truck with Container Body

TARIF was mounted in a CB305 container body mounted on a 4 ton flat platform vehicle and contained an entirely automatic teleprinter switching system which routed messages on the basis of standard headers[9]. When originally introduced, each TARIF system could handle 27 channels but by 1976, this had been increased to 45 external channels plus three internal teleprinters. An example of the standard vehicle with container body is shown in Figure 11, a view from the rear door of the TARIF container is shown in Figure 12 and the internal layout in Figure 14.

[9]Standard teleprinter message formats were specified in the document *Tape Relay Procedure ACP127(D)*. This unclassified document is still used in its current version, ACP127(G)[22].

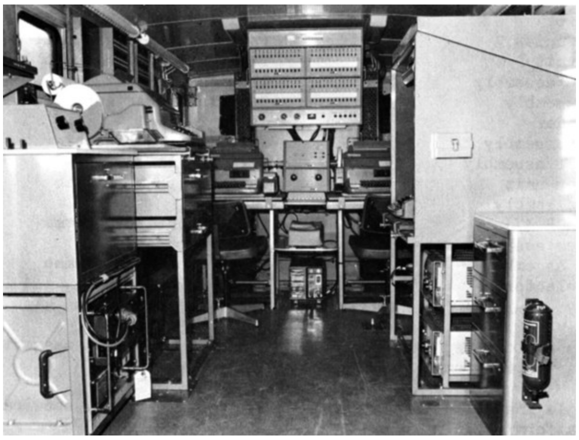


Figure 12: The TARIF vehicle.

TARIF was based on an Elliot 920B computer which was equipped with magnetic drum storage capable of holding two thousand messages of four hundred characters. The system operated on the store and forward principle, received messages being stored, then analysed to determine the destinations and finally forwarded to the destinations when circuits became available. In practice, unless there was a queue of messages waiting to go to a particular destination, routing was almost instantaneous.

Every formation HQ message centre was equipped with a teleprinter connected to one of the four TARIF systems in the Corps COMCENs. Note that since TARIF operated on an international standard teleprinter message format, message routing was not limited to terminals within the 1(BR) Corps area but could extend to other NATO units, including NORTHAG. However, in some cases, special measures were required to provide encryption and these were included in the Type B liaison TEV. The circuits controlled by TARIF were known as *common user* circuits to differentiate them from the teleprinter *nets* provided within BRUIN.

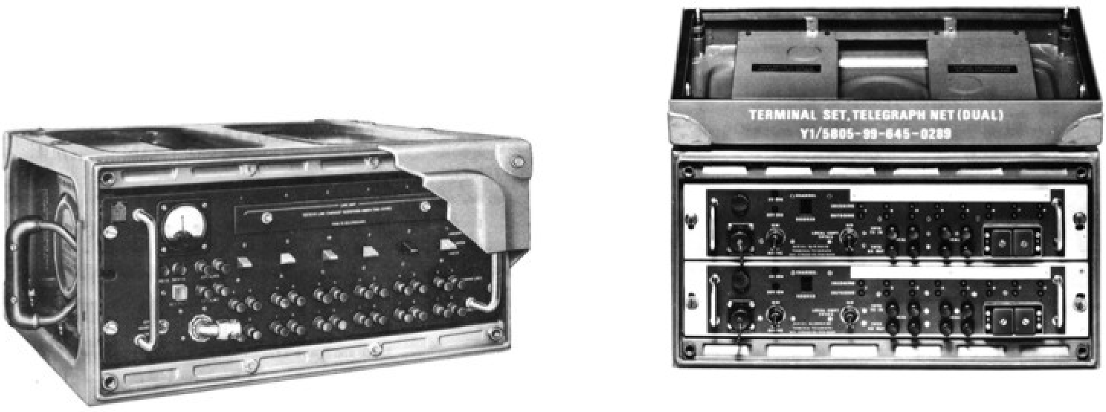


Figure 13: Telegraph Conference Unit (left) and Terminal Set, Telegraph Net, Dual (right).

There were three main teleprinter nets, provided by means of six channel Telegraph Conference Units[23] installed at Corps COMCENs:

Artillery Request Net Linked the Artillery Brigade to the Artillery Operations centres at Corps Main and Step-up HQs and the Division Main HQs.

Air Request Net Linked the Air Support Signals units at the Corps Main and Step-up HQs to the Ops/Intelligence staffs at the Division Main HQs and the Reinforcement Division HQ.

Harrier Net Linked the Wing Operations Centre (at the Harrier No 1 site) with the Air Support Signals units at 1(BR) Corps HQ, 1st Belgian Corps HQ and 1st German Corps HQ.

In addition, there were teleprinter nets used by the R Signals engineering control staffs at Corps and Division.

At some point, probably in the late 1970s, the Telegraph Conference Unit was replaced by the Terminal Set, Telegraph Net[24]. This unit performed a similar function, in that it allowed up to six teleprinters to be conferenced – any message incoming from one of the conferenced teleprinters was transmitted to all the others. However, it was half the size and included two additional circuits,

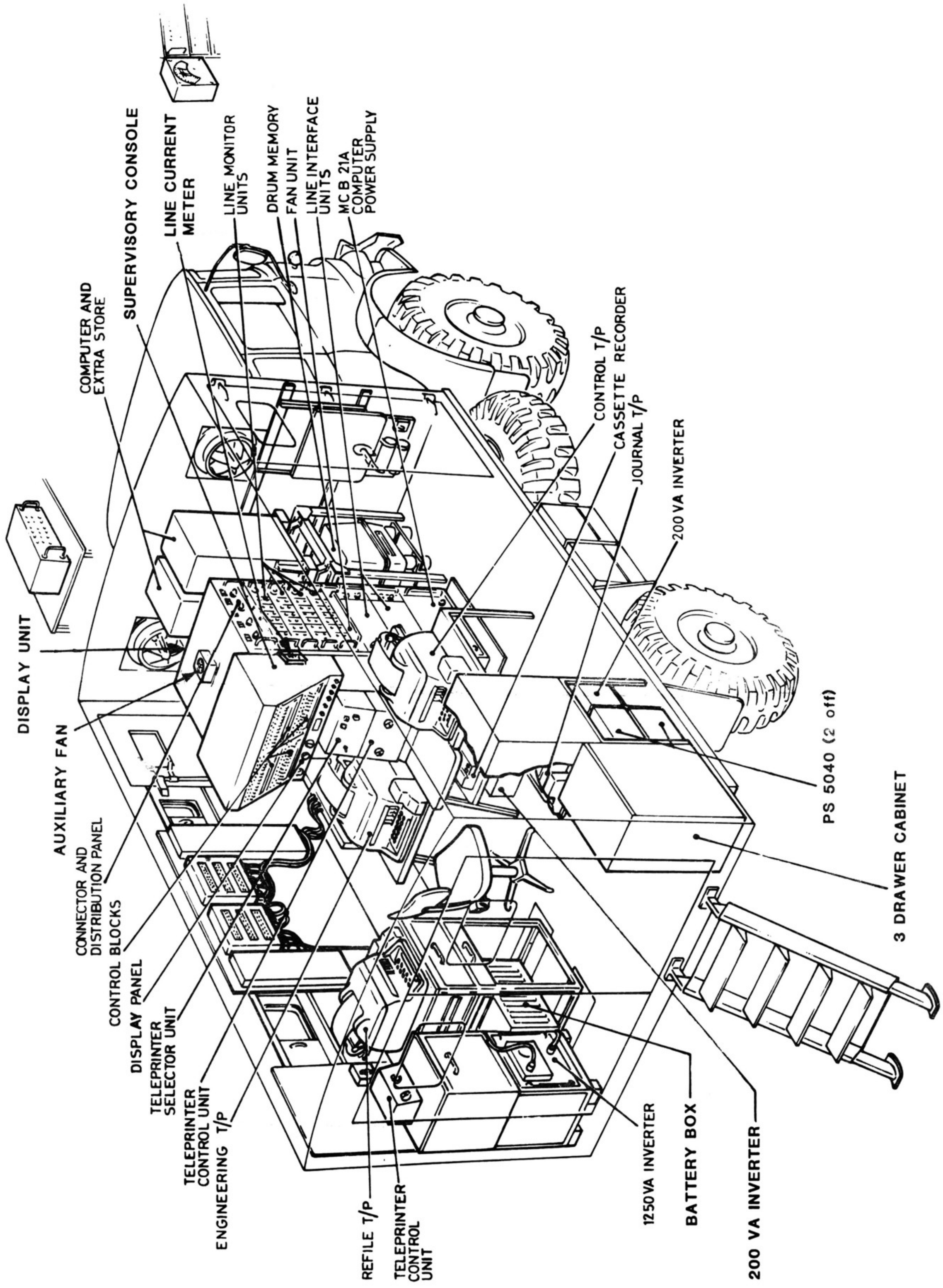


Figure 14: TARIF vehicle layout.

one for a local teleprinter and one for a TARIF connection. Thus the nets could be linked into the common user system. Both types of conference unit are shown in Figure 13

Finally, it appears that the signalling conventions used for telephony and telegraphy varied amongst the armed forces of the allies. Around 1980, an interface unit, the BRUIN – NATO Interface[25], was put into service to simplify interconnection, capable of connecting up to eight telephone and four telegraph channels.

Radio Link Equipment

Two main types of radio link and relay equipment were used in BRUIN, the C50/R236 and the C70, both capable of carrying the 6-channel TDM streams which made up the trunk circuits, but the C70 was additionally capable of carrying two streams, using a combiner. Both were configured as dual and triple stations, the former for use as terminals and the latter for relay sites.

C50/R236

Figure 15: Components of the C50/R236 Station

This system may have been designed specifically for the BRUIN role, but is more likely to have been modified from a commercial relay set. A BRUIN C50 terminal station is shown in Figure 1a and the components of the system are illustrated in Figure 15.

The set was used in the more forward links as it was felt that its lower frequency range (225 and 400MHz) would be more suitable than the higher range of the C70 because of the difficulty of finding suitable sites with line of sight access to the distant station. The armoured terminal stations used at the Brigade COMM HDs were typically unable to choose their locations and simply had to go where the Bde HQ went.

Two steps were taken to maximise the effectiveness of the system, the use of the lower frequencies and the provision of a high power amplifier. The C50 operated at a power of 10 watts on its own, 50 watts with the RF Amplifier No 13 on medium power or 250 watts with the RFA 13 on high power. It had a nominal range of 40 miles using a pair of 16-element log-periodic arrays[28] set at 90° to each other and 45° to the vertical, mounted on a Clark 40ft pneumatic mast[30].

The frequency sources for the set (which had to be operated at a minimum transmitter/receiver separation of 5MHz) could be internal crystals or, more often, supplied from a PG342 frequency synthesiser[32][33]. This consisted of two identical phase locked synthesisers (PG341), each of which could deliver 2v into 75Ω in steps of 125KHz from 225 to 399.95MHz. The PG342 is shown in Figure 16. It is worth noting that the PG342 could also provide the source for the C41/R222 station, in the range 50 to 100MHz.

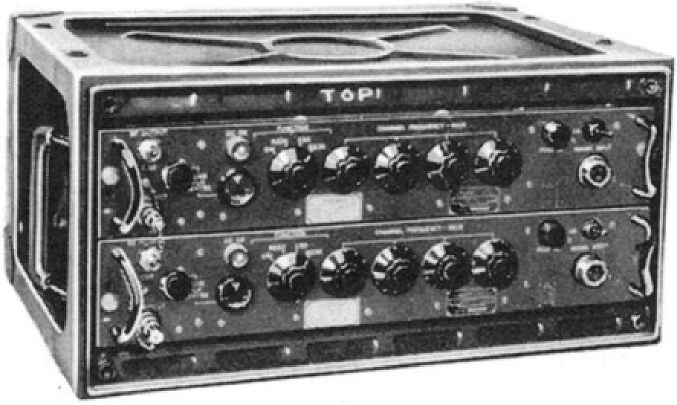


Figure 16: The PG342 Synthesiser

C70

The C70 was another COTS system (the Siemens FM 12/800 relay station), modified for use with BRUIN, but unlike the C50, its role was to the rear of Divisions where it was more likely that sites could be chosen with engineering considerations in mind. The C70 was a UHF system covering the range 610 to 960MHz and used helical aerials normally mounted side by side in parallel with two feeders, on a Clark 40ft pneumatic tower and can be seen in Figure 1b. With this configuration, the half power beam width varied from 26° at 610MHz to 16° at 960MHz and the separation between transmitter and receiver frequencies had to be at least 8Mhz. Other aerial configurations were possible, altering the beam width and the frequency separation requirement. The output power of the C70 was 10 watts and the nominal range 15 to 20 miles (24 – 32Km).

The C70 itself is shown in Figure 17, along with a view of a dual installation. This picture is of the installation in a Trucks, 1-ton, Signals (Austin K9), but is contemporary with BRUIN and may be assumed to be similar to the dual installation in a container body. Note the units on top of each of the C70 sets; these are reconsituters which regenerated clean pulse waveforms from the received TDM stream. Note also that the two units are different – the left is a 6-channel unit and on the right is the later 6 or 12-channel unit. The reconstituters were designated BID-200/10 and BID-200/11 respectively.

The C70 did not require an internal synthesiser because the transmitter and receiver were controlled by continuously tuned internal oscillators with AFC using a highly stable coaxial line frequency standard and motor-operated adjustment. The transmitter could be set and would hold frequency within $\pm 2 \times 10^{-4}$ of the operating frequency.

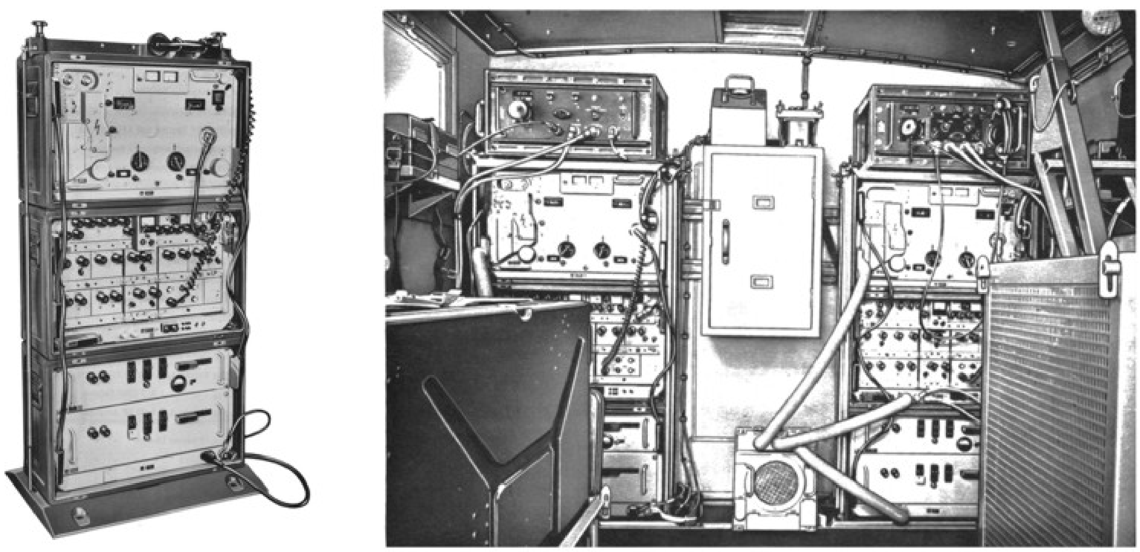


Figure 17: The C70 (left) and a Dual Installation (right)

C41/R222

The C41/R222 was a much earlier system than the other BRUIN radio link sets, having been first tested in prototype form in 1949 under the designation Wireless Set No 86, although it was not put into service until 1959, then using the "new" set designation C41/R222. It is normally described as being "non-BRUIN" because it was FDM only and therefore could not be used to carry the BRUIN trunk streams. It was however, ideally suited to the transmission of the FDM signal produced by the CST 1+4 VF telephony multiplexer which carried four telephony junctions (which could also be used for telegraphy, with the TTVF 4/12), and one engineering circuit. The signals could not be connected directly to the BRUIN trunk network, but could be used for the connection of support units, etc. in the Corps rear area.

The station operated on frequencies between 50 and 100MHz, originally crystal controlled but used with the PG342 synthesiser in its BRUIN role. The transmitter produced 4 watts on low power and 18 to 38 watts on high power, depending on frequency, and had nominal ranges of 20 miles on low power and 30 miles on high power. The four units making up the station may be seen on the right of Figure 8.

The Installations

In this section, the major features of the three main types of COMM HD and two main types of COMCEN installation are described. Variations, for example between Main, Step-up and Rear COMM HDs, are noted in the text.

Figure 18: C50 terminal station installed in FV439

Brigade COMM HDs

The most forward of the COMM HDs consisted of three armoured command post vehicles, type FV439, containing the following systems:

Auto Exchange One BID-200 6-channel multiplexer and an ATE 20.5.5[10] automatic telephone exchange (see Figure 19).

Message Centre One TTVF 4/12 telegraph multiplexer (up to 4 channels), two Siemens T100/R teleprinters, a 12 line CB cordless exchange and a MuFax FAX system.

Radio Relay Twin C50/R236 installation with two Clark 40ft pneumatic masts, two twin log-periodic Yagi arrays and a pair of 3.5KVA generators. One 6-channel link to the Brigade's Divisional COMCEN was provided, the second C50 being a spare. Figure 18 shows an example of this vehicle and one of the masts may be seen on the roof in its carrier. The box seen behind the mast contained the generators.

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[10]The automatic terminal exchanges were given a three number designation:

extensions . link relay sets . junction relay sets

The link relay sets could each handle one connection within the exchange and the junction relay sets each allowed a connection to the trunk system. Thus a 20.5.5 exchange had 20 extensions and could handle up to 5 simultaneous local calls plus up to 5 trunk calls.

Divisional COMM HDs

The COMM HD systems at Div Main, Step-up and Rear HQs were each mounted in three container bodies mounted on 4 ton flat platform trucks, equipped as below:

Auto Exchange Two BID-200 6-channel multiplexers and an ATE 40.10.10 automatic telephone exchange[36].

Message Centre One TTVF 4/12 telegraph multiplexer (up to 4 channels), three Siemens T100/R teleprinters, a 25 line CB cordless exchange and a MuFax FAX system.

Radio Relay (Main and Step-up) Triple C70 installation providing 6-channel links to the executive and non-executive COMCENs. (Rear) Dual C70 installation providing one 6-channel link to the executive COMCEN.

Figure 20 shows a view of the front compartment of the Message Centre vehicle. On the left is the TTVF 4/12 unit underneath a piece of monitoring and testing equipment, the TDMS No 2, and on the right is the 25 line manual exchange. The rear compartment can be seen in Figure 21 and the FAX machine can be seen on the right. The unit to the upper left of the picture is a spirit duplicator.

Divisional COMCENs

The two Divisional COMCENs were identical and each consisted of eleven 4 ton flat platform trucks with container bodies, plus some ancillary vehicles. The container installations were:

Manual Exchange A single position 40/160 manual exchange. This vehicle was also used by the COMCEN command and technical control staff, containing an Ericsson RURAX[11] 7.1.2 auto exchange and 6-way intercom.

Auto Exchange A 48-junction Ericsson RURAX tandem automatic exchange, two BID-200 6-channel multiplexers.

Terminal Equipment Vehicle (TEV) Six BID-200 6-channel multiplexers.

VF Telegraph Eleven TTVF 4/12 telegraph multiplexers and teleprinter technical control.

Radio Relay (Three vehicles) Two triple and one dual C50/R236 installations providing circuits to the three Brigades, the Covering Force and the other divisional COMCEN.

Radio Relay (Three vehicles) Three triple C70 installations which provided circuits to the Corps COMCEN and the Main, Step-up and Rear Divisional HQs.

Radio Relay One triple C70 installation for use as a relay station.

Power for the COMCEN (excluding the radio relay detachments which carried their own generators) was derived from four 10kVA trailer mounted generators. In addition the COMCEN carried a number of support vehicles:

- Two $^{1}/_{4}$ ton trucks for the lines detachment. This detachment was responsible for cabling within the COMCEN and any external line laying requirements.

[11] RURal Automatic eXchange.

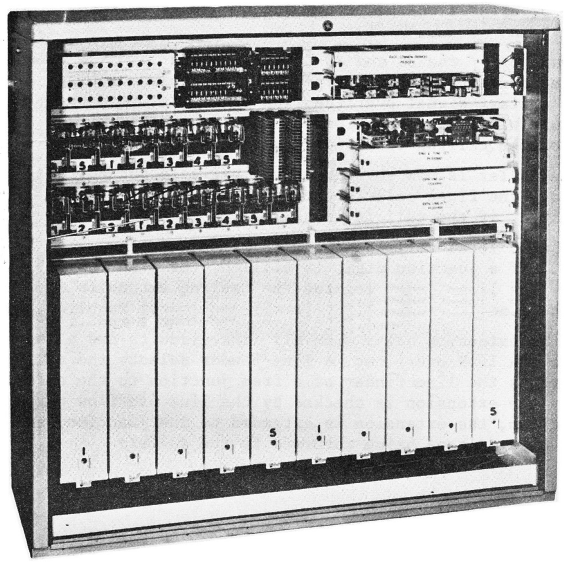


Figure 19: ATE 20.5.5 Auto Exchange (the 40.10.10 was similar)

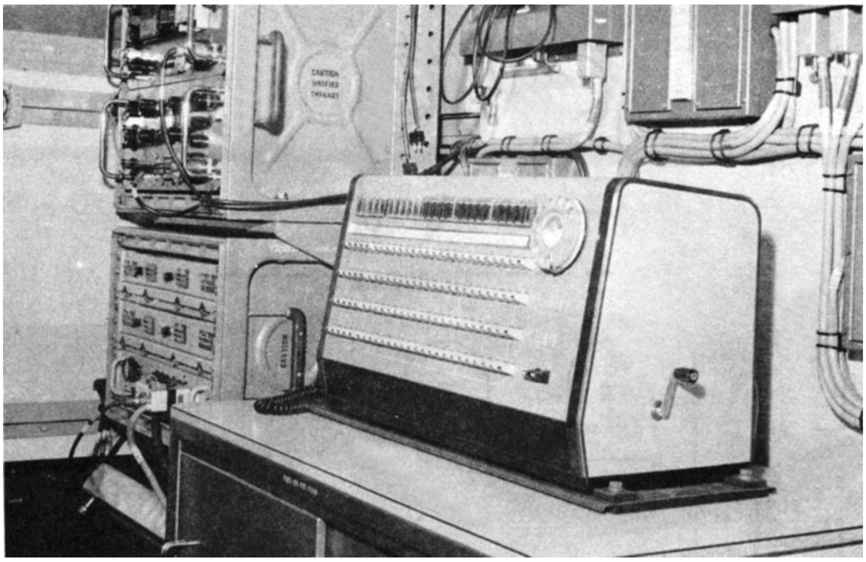


Figure 20: Div COMM HD Message Centre – Front Compartment

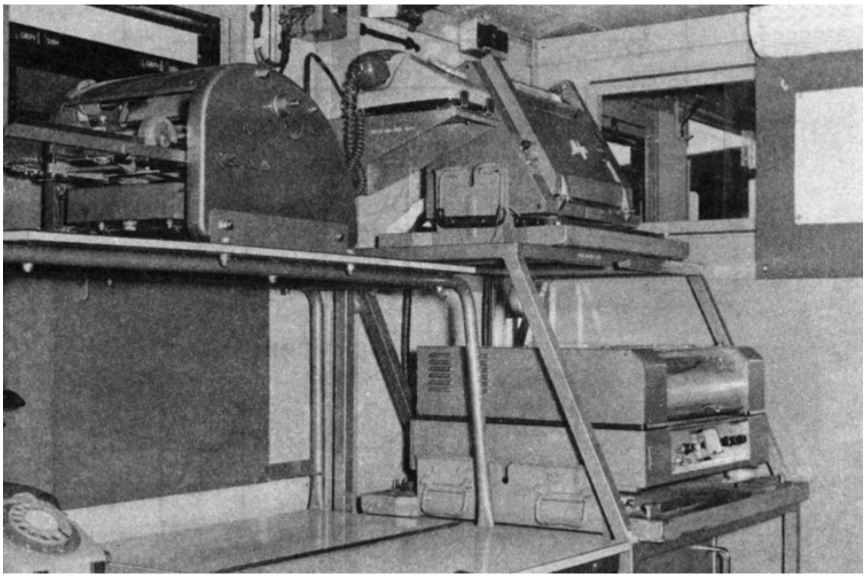


Figure 21: Div COMM HD Message Centre – Rear Compartment

- $^3/_4$ ton truck fitted with a C11 HF radio, for use by the COMCEN commander.
- $^3/_4$ ton truck fitted with a C11 HF radio, for use by the COMCEN 2 i/c.
- Light Aid Detachment vehicle.
- Technical Workshop.
- Stores vehicle.
- POL carrier.

Corps COMM HDs

The Corps Main and Step-up HQ COMM HDs were composed of seven 4 ton flat platform trucks with container bodies containing the following installations:

Manual Exchange A two-position 40/160 manual exchange. This vehicle is also used by the COMM HD command and technical control staff.

Auto Exchange An Ericsson RURAX 100.24.24 automatic telephone exchange[37].

Terminal Equipment Vehicle Four BID-200 6-channel multiplexers with combiners and four TTVF 4/12 telegraph multiplexers with a Group Box.

Message Centre Four Siemens T100/R teleprinters and a FAX machine.

ASSC Air support communications equipment (assumed to have been supplied by the RAF).

Radio Relay One triple C70 station providing two links to the Corps COMCEN.

Radio Relay One dual C70 station providing one link to the Corps COMCEN.

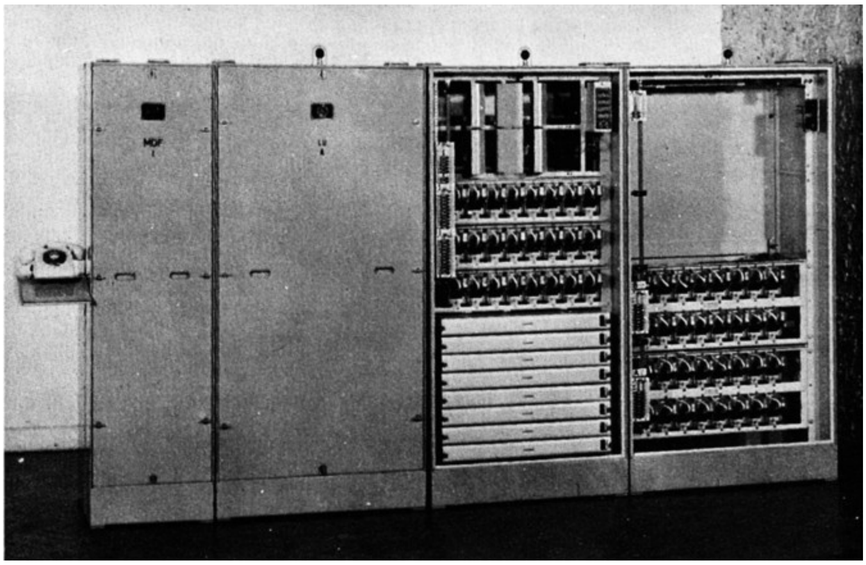


Figure 22: Ericsson RURAX 100.24.24 Auto Exchange

The Corps Rear HQ COMM HD was identical to the above except that in place of the ASSC vehicle there was a TEV(L) Type A (see below) which provided limited step-up facilities.

It is also worth mentioning that there is some evidence that at one time there may have been, as part of the Main and Step-up Corps COMM HDs, a dual C41/R222 station in a 4 ton truck providing a link to COMCEN V, the Radio Village. However, by 1973, this appears to have been moved to the Corps Rear COMCENs.

Corps COMCENs

The two identical Corps Main COMCENs consisted of twenty 4 ton flat platform trucks with container bodies plus seventeen support vehicles. The twenty main vehicles were configured as follows:

COMCEN Command Local communications facilities including Ericsson RURAX 7.1.2 auto exchange and 6 way intercom.

Manual Exchange Two position 40/160 manual exchange and Technical Control.

Auto Exchange A 64-junction Ericsson "RURAX" tandem automatic exchange

TEVs Three vehicles each containing six 6-channel BID-200 multiplexers and one combiner.

VF Telegraph Thirteen TTVF 4/12 telegraph multiplexers with two Group Boxes and a telegraph conference unit.

TARIF Telegraph Automatic Routing In the Field (described above).

Traffic Office Seven TTVF 4/12 units and the office for traffic supervision.

TEV Telegraph It is not currently clear exactly what equipment was installed in this vehicle but its purpose was to terminate any rearward non-BRUIN telegraph circuits.

Radio Relay (Five vehicles) Five triple C70 stations

Radio Relay (Five vehicles) Five triple C50 stations.

Power arrangements for the Corps COMCENs included eight 10kVA trailer mounted generators and a truck. The other support vehicles were:

- **Line Detachment** – Three $^{3}/_{4}$ ton trucks and a stores vehicle.
- **Maintenance** – Four vehicles.
- **Command and Recce** – Four $^{3}/_{4}$ ton trucks, two fitted with C11 HF radios.
- **Admin** – Four vehicles; Personnel, POL and two Stores vehicles.

The two Corps Rear COMCENS were very similar in makeup to the Main COMCENS but their requirement to connect to a number of non-BRUIN equipped units will have led to variations, particularly in the use of C41/CST1+4 links and appropriate terminal equipment. See also the description of liaison TEVs below.

Harrier Force COMM HDs

The Harrier Force deployed two sites, No 1 and No 2 Primary Sites, which in turn were divided into sub-sites. Communication between the primary and sub-sites was by secure VHF net radio and was not part of BRUIN. Connection to the BRUIN system was by two types of COMM HD, containing four vehicles at the No 1 Primary Site (which also contained the Wing Operations Centre) and three at the No 2.

Harrier No 1 Site COMM HD:
Manual Exchange A single position 40/160 exchange.
Auto Exchange A BID-200 6-channel multiplexer and an ATE 20.5.5 automatic exchange[35].
Message Centre A Siemens T100/R teleprinter and a FAX machine.

Harrier No 2 Site COMM HD:
Auto Exchange A BID-200 6-channel multiplexer and an ATE 20.5.5 automatic exchange.
Message Centre A Siemens T100/R teleprinter, a FAX machine and a 12 line manual CB exchange.
In each case the remaining vehicle was a triple C70 station providing links to Corps Rear COMCENs U and S.

Terminal Equipment Vehicles (Liaison)

The liaison TEVs were again 4 ton flat platform trucks with container bodies and were designed to provide access to BRUIN from sites and units not equipped with COMM HDs or which required reduced access. It is thought that many of these vehicles used redeployed pre-BRUIN equipment, convenient because units not equipped with BRUIN could continue to use their existing systems.

TEV (Liaison) Type A The TEV A appears to have been used at HQs which did not have a COMM HD and contained equipment to permit limited access to BRUIN via the trunk network. It had a BID-200 6-channel multiplexer, a TTVF 4/12 telegraph multiplexer, two teleprinters, a small automatic exchange (the Ericsson RURAX 7.1.2[34]), a 25 line cordless manual exchange and a FAX machine.

TEV (Liaison) Type B The purpose of the Type B vehicle is less clear but it seems to have been able to provide secure telegraph circuits and possibly a limited non-secure telephone service. It contained a CST1+4 No 3 VF telephone multiplexer, a TTVF 4/12 telegraph multiplexer, two teleprinters with BID-610 encryptions systems and a 25 line cordless manual exchange. The secure telegraph system appears to have pre-dated BRUIN.

System Management

Although the information presented above has been simplified, it is clear that BRUIN was a complex, geographically extended system and it is well known that such systems require very careful management in order to operate effectively. A great deal of thought appears to have been given to the control of BRUIN when the system was being planned and this is likely to account for the system's success.

There was a clear chain of command and control from command posts located at the COMCENs through to the COMM HDs and the relay detachments, all of which were, of course, manned by R Signals personnel. The objectives were:

- Executive control.
- Quality control.
- Trouble shooting.
- Provision of communications advice.

All four were, of course, normal functions of R Signals personnel.

It was intended that engineering staff should use magneto telephones and teleprinter nets for communication. The engineering teleprinter nets have already been mentioned and magneto telephone facilities were provided at all sites. Brigade COMM HDs were equipped with an engineering manual exchange, a cordless magneto 12-line system manufactured by ATE, and Divisional COMM HDs used the 25-line version of this exchange. At Divisional COMCENs and Corps COMM HDs, the engineering circuits shared the 40/160 manual exchange at the site and Corps COMCENs were equipped with a small auto exchange for engineering purposes, the Ericsson RURAX 7.1.2. These exchanges are shown in Figure 23.

By 1972, the concept of Executive and Non-executive COMCENs had been abandoned and all COMCENs were in continuous use when BRUIN was fielded. This, and the enthusiasm of staff to use the system, appears to have put a great deal of pressure on the system management personnel. In 1972 the Signal Officer-in-Chief requested the Defence Operational Research Establishment to carry out a study to determine how the management of BRUIN might be improved, with three constraints:

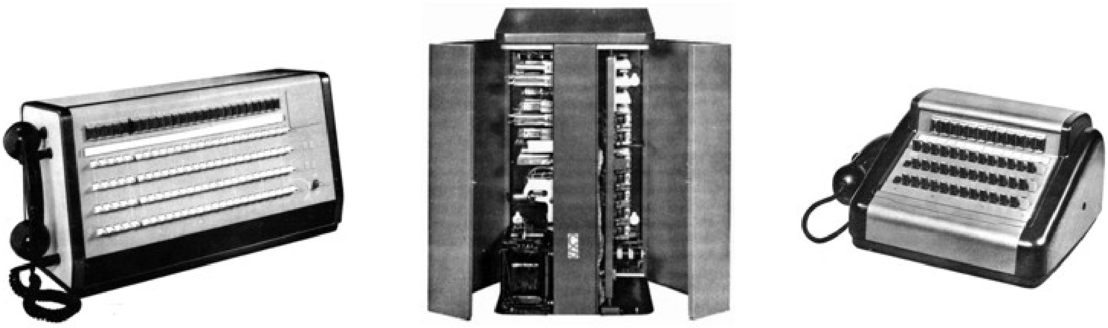


Figure 23: Engineering Exchanges – (l to r) 25-Line Magneto, 7.1.2 Auto, 12-Line Magneto

- Recommended improvements were to be in place as soon as possible and in any case no later that 1st June 1973.
- No major expenditure (subsequently defined as an upper limit of £250,000 to £300,000).
- No major reorganisation of signal units.

The resulting report[40] highlighted a number of management issues and presented recommendations in three main areas:

1. An information bank available to all management levels to enable them to make effective decisions.
2. A system for the dissemination of command instructions.
3. Communications to enable engineers to set up and control circuits.

The lack of (1) was felt to be so important that DOAE set up a contract with Standard Telecommunications Laboratories to investigate appropriate data handling systems to fulfil this need.

A total of 38 recommendations were made in the DOAE report, the most important of which are discussed below. However, the primary finding was the need for a suitable system for the timely transmission, storage and retrieval/display of management data.

Management Roles

The R Signals management organisation for BRUIN was quite complex, formed from elements of two signal regiments (7th and 22nd), with system, traffic and engineering roles widely distributed around the system. In theory, the chain of command within the structure would result in decision taking at each level, only referred upwards when necessary. Unfortunately, in practice this was often not the case and higher management became involved in matters which should have been left to their subordinates. For example, a COMCEN commander would frequently become involved in the rectification of a technical fault which should have been dealt with by engineering personnel.

This sort of problem could easily be put down to the enthusiasm of the COMCEN commanders but the DOAE study suggests two more subtle issues, firstly the siting of engineering telephones in the COMCEN command vehicle, inviting intervention by the commander, although the siting had been done in order to increase efficiency during COMCEN moves. Also, the rank of the users of the system naturally led to a considerable degree of pressure being exerted on the system management staff when circuits failed, provoking a more senior response from the R Signals side than should have logically been warranted. In any case, the additional pressure on those, normally junior, personnel working to fix the fault was not helpful.

The report recommended the following:

- A restructuring of the management functions into clearly defined engineering, traffic and system roles.
- Senior management should give subordinate levels reasonable time (15 minutes was suggested) to determine the cause of faults and initiate repairs.

System State Information

There was found to be a general lack of up to date information on which circuits were working and which were out of service. This information was, of course, essential because users of the automatic telephone system who wished to connect outside their sites had to know which route to dial. Also, the manual exchange operators needed the information in order to make their inter-site routes.

Less obvious was the fact that, in the absence of appropriate circuit status information, management personnel tended to dial around the system to discover which circuits were working, thus

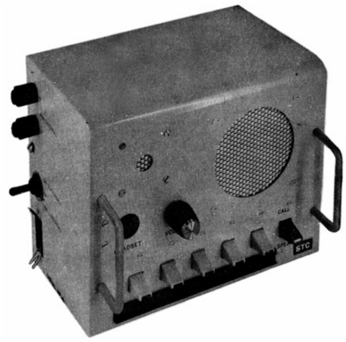


Figure 24: 6-channel Intercom Unit

engaging circuits which should have been available to users. In one exercise, the CCR Signals[12] noted that he had found all the trunk junctions between certain nodes occupied by system management personnel.

The recommendations covering these issues can be summarised as follows:

1. Remove management communications from the automatic telephone system by:
   - Introducing a management information system serving all levels of management, based on the use of dedicated telegraph channels.
   - Introducing a separate trunk engineering intercom forward of the COMCENs A and B.
   - Reducing the scale of trunk access telephones for R Signals personnel.
   - At all sites, prohibiting the use of of automatic telephones at levels below Engineering Control.
2. Reorganise Corps and Division COMCENs to provide an improved Engineering Control area[13], provided with comprehensive local circuit sensors and quality control instrumentation.
3. Provide Engineering Control cells at COMM HDs with improved local circuit sensors and quality control equipment, to a lesser degree than at COMCENs.
4. Standardise intercom systems to minimise maintenance problems. Figure 24 shows the 6-channel intercom[41] provided as a result for inter-site communications within BRUIN.

Diagnostic Routines

The study found that fault diagnosis was often intuitive and procedures varied between different parts of the system. Also, it seems that the engineering personnel were not always aware of the purpose and effectiveness of standard tests. Because the majority of the equipment used across the BRUIN system was standard, there was no reason why standard fault finding processes should not be used and DOAE tasked AWST[14] Royal Signals with the production of these processes.

Call Routing

The means of routing telephone calls between sites has been described above in some detail. Although not difficult, it did require that all users were aware of the routing logic and the system configuration. At the time of the study, the users were informed of the numbers to be dialled for each route but this information had to be updated for every change of configuration and connectivity, as they took place. Subscribers who were not informed of the current situation had to call the local manual switchboard operator for assistance, overloading them and detracting from their task of providing a subscriber assistance service.

The report proposed the provision of Directory Translators at all COMCENs, allowing a two-digit route number to be allocated to each unit and headquarters served by the BRUIN automatic telephone system. These devices would permit users to dial the same number for each distant site, irrespective of configuration or circuit status, the translator being able to attempt call completion over a preferred and an alternative route. Obviously, it would be necessary to keep the translators supplied with up to date circuit and configuration information, but this was thought to be easier than keeping all users informed of changes.

[12] Corps Commander Royal Signals.
[13] Known, for some reason, as Engineering Control "Cells".
[14] The derivation of this acronym is currently unknown.

A data summary EMER[15] (Tels U540)[43] dated May 1976 described the "Automatic Trunk Dialling Directory Translator" intended specifically for BRUIN. Enquiries have been made of ex-BRUIN personnel and as far as is currently known, this system may never have entered service.

Central Control

There is an interesting note in the report on the subject of overall control of the system:

> *At the present time, the divisional trunk nodes of BRUIN may be strongly influenced by Division Commanders and this could be to the detriment of the overall effectiveness of the BRUIN network.*

Quite what this refers to is unclear, but in any case the writers were of the opinion that in order to tackle this issue, a reorganisation of R Signals in BAOR would be required, which was outside the study's remit. However, it was felt that this would be an important consideration in planning the PTARMIGAN system.

Frequency Management

The allocation of radio relay frequencies was a serious problem and was raised by CCR Signals at the time of the study. The report proposed a simplification of the method of allocation and this will be considered in the section on Radio Link Frequency Allocation below.

The BRUIN MIS

The recommendations of the 1972 DOAE report regarding provision of a Management Information System (MIS) were taken up and a trial was organised during the 1973 Flying Falcon exercise. The report on the trial[42] gave a very detailed description of the system used – essentially a tape storage system at each site, with a VDU for notifying changes in status and configuration to the other terminals. This was preferred to an "intelligent" terminal because it was thought using a software controlled system on a trial might be too risky.

The equipment at each site comprised:

- A VDU, used to send and receive messages from other terminals and to make updates to the data store.
- A tape data store which contained the current information on the system. It is not clear exactly what the tape store was, but there was evidently a degree of intelligence involved, since it had to respond to commands from the VDU to store and retrieve data, etc.
- A teleprinter channel (75 or 110 baud), used to carry messages between terminals and groups of terminals. These messages generally informed the distant terminals of changes or were used to pass requests.
- A modem and telephone connected to the automatic telephone system. Under certain circumstances, for example if a terminal was disconnected for some time, a bulk download of the status data was required. This could be done through the modem at 2.4Kb/s.

Presumably the trial was judged successful, since the report made recommendations for the specification and trial of an operational MIS:

1. A minimum of 2 years was thought to be required to produce an operational terminal, ready for trials. It was recommended that these should be carried out in 1976, with a view to an in-service date of 1978.
2. A MIS based on an extension of existing teleprinter nets would not be feasible because of filing, display and control problems.
3. Although the use of a common highway telegraph circuit (the preferred option in the 1972 report) was technically feasible, this should be reconsidered in favour of a store and forward system.
4. In order to remove the need for a specialised operator, intelligent terminals should be used, providing a range of automated processes and assistance to the operator.
5. Bulk transfer of data at 2.4Kb/s was occasionally required. This, of course, was more than twenty times the speed of a BRUIN telegraph circuit.
6. The use of an MIS should reduce Royal Signals use of the automatic telephone system and increase the effectiveness of system management.
7. The provision of a BRUIN MIS would provide valuable practical experience of automatic data processing in the field and would assist in the planning for PTARMIGAN.
8. The total cost of an operational MIS, excluding spares, was estimated at £575K.

[15] Electrical and Mechanical Engineering Regulation.

Unfortunately, the results of the 1976 trial, assuming it took place, are not currently known. However, it is reasonable to assume that all went well because an EMER for the MIS first appeared in late 1978[44]. The Data Summary was issued in November 1978 and the Technical Description in August 1979, which would indicate that the system was fielded around the middle of 1979.

The operational MIS was a somewhat different system from that envisaged in 1972, probably because of advances made in the intervening years. It was fully computer controlled rather than being an intelligent terminal and, although there was still a tape drive, it was only used for the loading of system software, data backup and diagnostics. The main storage medium was a 128 Kilobyte core store which would have provided vastly increased data access speeds compared to tape.

The telegraph plus telephone and modem connectivity had disappeared, to be replaced by a ten channel telegraph connection to a TTVF 4/12 voice frequency telegraph unit. The exact configuration of the telegraph circuits is not known, except that the connections were under computer control, but it may be assumed that they were set up as omnibus networks accessible at all terminal sites.

The terminals, as before, were used to enter changes, requests and messages, but now everything was done under computer control with the result that changes were automatically propagated to all terminals and if a terminal became disconnected from the network, it continued to operate with existing data until reconnected, when it would fetch updates from the other terminals.

It would appear that the MIS continued in service until BRUIN was replaced by PTARMIGAN.

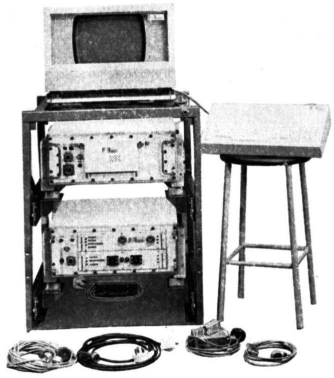


Figure 25: BRUIN MIS

Radio Link Frequency Allocation

The problems of providing a network of radio links under battlefield conditions have much in common with those affecting tactical radio communications in a congested battlefield area. In particular, the allocation of frequencies from a non-infinite available set was, and remains, a major issue. The HOBART project considered the issue and its implications for the provision of ALLERTON-type trunk systems over the whole NATO theatre which, aside from US forces, involved four army groups (Dutch, German, British and Belgian), each operating such a system and requiring more than seventy links apiece, each of two frequencies (one for each direction of transmission).

As a spin-off from Study No 27, the Defence Operational Analysis Establishment were asked to study the problems of radio link frequency allocation in a deployment across the NORTHAG operational area. The results appear in DOAE Report No 5/65 of November 1965[45] entitled "Frequency Assignment to Radio Relay Area Communication Systems in the Forward Combat Zone of an Army Group". The aim of the study was to find a method of allocation which was suitable for use by NATO in such a deployment.

The Issues

Clearly the problem would have been bordering on the insoluble without some assumptions and rules which would serve to constrain the use of frequencies. Those used were fairly complex:

- The equipment to be used would be similar in specification to the then proposed Canadian Marconi AN/GRC-103 system, with a power output of around 25 watts and a bandwidth of 0.5MHz for each direction of transmission. This set does not seem to have been used by the British Army and certainly not in BRUIN, but is apparently still in use by US forces. It was similar in concept to the TRIFFID UHF relay set (UK/TRC-471) used in the PTARMIGAN system, although it had four frequency ranges rather than three, the fourth range covering from 1.35 to 1.85GHz. It is likely however, that when the report was written, the fourth range was not in the specification and frequencies below 1GHz only were planned to be available.
- A number of frequency compatibility rules were set up, based on the expected performance of the AN/GRC-103. Each of these rules refers to the link equipment at a "nodal point" which was generally a COMCEN at or near which several links would be sited.
    1. Receiver to receiver separation. Receiver frequencies not to be less than 1MHz apart and not separated by the IF frequency of the AN/GRC-103 (30MHz).

2. Transmitter to transmitter separation. Transmitter frequencies not to be less than 0.5MHz apart at a COMCEN or 1MHz at a COMM HD. Again, no transmitter frequencies to be spaced at 30MHz.
3. Transmitter to receiver separation. The minimum spacings to be 10MHz for aerials on the same mast, 8MHz for aerials on masts separated by a vehicle length and 3MHz for aerials separated by $^1/_4$ mile. There were also a number of rules dealing with the potential of certain combinations of frequency to cause interference by the generation of spurious signals.

The relay sets actually used in BRUIN, the C50 and C70, had different separation requirements but this was obviously not relevant at the time of the report. However, the use of a set of separation rules increased the realism of the study.

- Only those frequencies which would have been available to NORTHAG in time of war would be used. There were 57 between 225 and 400MHz, 216 between 622 and 790MNhz and 96 between 790 and 960MHz. As an aside, it should be noted that in peace time, many of these frequencies were not available to NATO, being allocated to broadcasting, PMR and the like. This fact appears several times in BRUIN exercise-related reports and appears to have limited the realism of large scale exercises.
- Some re-use of frequencies was therefore permitted, but this was constrained by a measure of "repetition distance", the permissible distance between links working on the same frequency. The distance used appears to have been that quoted as the "planning range" of the AN/GRC-103 – 80Km, which in many cases could not be met in practice.
- It was recognised that there was a major requirement for the frequency allocation plan to cope with movement, expansion and re-configuration. These proved to be very difficult to accommodate.

Manual Allocation Methods

The report[45] considered four alternative methods for the manual allocation of frequencies, chosen for flexibility and simplicity of operation in the proposed radio relay environment. A full description of the methods will not be attempted and those interested in the details may study the original document at the National Archive. However, brief summaries are given below.

The Six-way Linear Lattice Method. Like all these methods, this was semi-graphical in inspiration. A lattice of interconnecting nodes was drawn with each node being connected to six neighbours, one connection to each. The nodes represented the planned radio link sites and the lattice provided for six links mounted in three vehicles, which was the default for COMCENs in the HOBART plan. The connections were drawn roughly to scale for the path lengths involved. The rules for frequency separation were then applied, to produce an allocation plan. This method was deemed unsuitable because:

- In practical use, it proved difficult to fit the lattice to sites which were unevenly distributed geographically, resulting in excessive distortion of the lattice. This seriously affected the reliability of frequency allocation, particularly in terms of the "safe" distances between set using the same frequencies.
- The method only catered for links between adjacent nodes, whereas in practice this was not always the case.
- The fixed geometry of the lattice overlay was not conducive to tactical flexibility, the moving of a single node often resulted in multiple frequency changes at nodes not otherwise involved.

The Quadrant Plan. This was a US system designed to control the separation of frequencies in both frequency and distance without the necessity for rigorous central control. In it, the ground where deployment was to be made was divided into squares, sixteen squares together in a square being known as a quadrant. each group of four squares being a quarter quadrant. The quadrants were repeated as necessary to cover the map. Generally, the squares corresponded to the map grid squares and one radio relay site could be placed in each square. Thus the squares corresponded to the nodes in the Six-Way Lattice method.

Each square was allocated four numbers from the set 1 to 24, which were marked on an overlay placed over the map. Each number in the square corresponded to a compass direction; North, South, East or West and indicated the direction of one incoming link. Each link receiver at the square's link site was designated with one of three letters; A, B or M.

The Quadrant Plan relied on a lookup table with 24 rows, corresponding to the numbers in the squares, and six columns of frequencies for links from A to B, A to M, B to M, B to A, M to A and M to B. Thus the plan required 144 frequencies and the allocation was done by referencing the designated letter of each link and the number on the overlay for the link's direction.

The results found for this method were encouraging, the time for an initial deployment plan being around four hours and for a site move, up to one and a half hours. However, it was discovered that although the method worked reasonably well for a single Corps, its use over the four European Corps of NORTHAG presented major problems. In summary, mutual interference between Corps could only be avoided if the allocation was done centrally at Army Group – but this imposed an unacceptable delay in allocation when moves were required.

The Modified Quadrant Plan. Further investigation proved that the problems inherent on the Quadrant Plan could be overcome if adjacent Corps were assigned frequencies from different lists and if formation HQ links, particularly those most subject to moves, were assigned frequencies from a third list, not used by the Quadrant plan.

Because there were four Corps, two lists (A and B) would be required and it was calculated that a total of 424 frequencies would be needed. Unfortunately, only 369 were available so the Quadrant Plan was modified to require only 96 frequencies, providing a total of 328 frequencies, with 20 spares. This resulted in the frequency groupings shown in Table 3. List A was assigned to 1(NL) and 1(BR) Corps, and List B to 1(GE) and 1(BE) Corps.

Group	**Freqs.**	**Use**	Total Freqs.
I	235.5–399.5MHz	Formation HQ Links	List A = 69
	622.5–684MHz		List B = 68
II	684.5–701MHz	Spares for HQ Links	10 each list
III	701.5–908MHz	Trunk Links (Quadrant Plan)	96 each list
IV	908.5–923MHz	Spares for Trunk Links	10 each list

Table 3: Modified Quadrant Plan Frequency Grouping

The Modified Quadrant Plan was found to be successful in use for an Army Group deployment and quicker, with times recorded of around two hours for initial deployment and fifteen minutes for a normal move (longer, of course, for major redeployments). However, it was rejected because:

- It was a very time consuming and laborious task to avoid frequency repetition. To a certain extent, this could be resolved by the the use of a central assigner, but this defeated one of the aims of the Plan, reduction of reliance on rigorous centralised control.
- Re-assignment of frequencies for a move was complex and in the case of a move of the whole system, could take more than three hours.

The Modified A-B-M Plan. This Plan retained the best features of the Modified Quadrant Plan but was much simpler to operate in that it required no overlay. It used the same number of frequencies (96) for trunk links and provided the following separations at each site:

Transmitter – Receiver	-	16 channels
Receiver – Receiver	-	1 to 5 channels
Transmitter – Transmitter	-	1 channel

These were not, however, mandatory and the assigner could vary them to suit the deployment.

In use, a roughly to scale map of the communications system deployment was made, and each site was marked with 'A', 'B' or 'M'. The six-column table referred to earlier was used as the basis for an assignment table which was constructed on the basis of the required Receiver – Receiver separation. Working from the forward edge of the operational area back, frequencies were assigned from this table, according to some simple rules.

The report notes that the Modified A-B-M Plan was satisfactory in all respects, the time taken to plan for a deployment being half an hour and for moves, from five minutes for a simple move to three quarters of an hour for a redeployment of the whole network.

The Modified A-B-M Plan was therefore recommended to NATO and the report[45] contains frequency allocation plans for the four Corps of NORTHAG.

Use of Computers

It is evident that the work of the frequency assigner was a prime candidate for computerisation, when that became practical. It seems that this was also clear at the time and an investigation was carried out. A report "Assignment of Frequencies to Radio-Relay Networks by Computer"[46] was issued in November 1968, announcing the completion of a program to allocate radio relay frequencies.

The program was written in Algol for an Elliott 503 computer, and had the following characteristics:

Set	Constraints
C50	a. T/R separation on one link of 23 and 46Mc/s not permitted. b. T/R separation on one link not less than 6Mc/s. c. T/R separation for two links from the same vehicle not less than 3Mc/s. d. T/R, T/T, R/R separations at one site not less than 1Mc/s.
C70	a. T/R separation on one link of 50 and 100Mc/s not permitted. b. T/R separation on one link not less than 40Mc/s. c. T/R separation for two links from the same vehicle not less than 3Mc/s.

Table 4: BRUIN Radio Relay Frequency Allocation Constraints

1. The 1(BR) Corps network was assumed to consist of 28 nodes with 45 inter-connecting links, not including Div and Bde COMM HDs as these were assumed (as noted above) to be covered by a separate allocation list.
2. The AN/GRC-103 was again used as the radio link equipment, thus setting a number of electromagnetic compatibility conditions and hence frequency restrictions at sites.
3. No propagation model was included and therefore no attempt was made to compute frequency re-use on the basis of topography – a simple minimum re-use distance was assumed.

A list of available frequencies, nodes, connections and path lengths (plus the specific allocation rules, such as the minimum re-use distance) were entered, and the frequency allocation matrix was printed out after about thirty minutes. There was also a provision for the deleting and re-entry of nodes, to cope with site moves. The report unfortunately does not mention how long this process took to complete.

There is no evidence that computers were ever used in practice for the allocation of BRUIN link frequencies. In 1986, a data summary EMER was issued describing the Computer Assisted Radio Relay Frequency Assignment system (CARRFA)[47], but this is thought only to have been used with BRUIN's successor, PTARMIGAN.

Practical Allocation

The DOAE report on the BRUIN Management Information System[40] mentioned above gives us evidence of the manual method actually used for BRUIN frequency allocation. Up to the date of implementation of the report's recommendations, a staff officer at HQ R Signals allocated blocks of frequencies to 7 Sig Regt and 22 Sig Regt, sufficient for the circuits to be provided plus a number of spare frequencies. It was noted that when this staff officer was not immediately available, frequency problems could not be dealt with effectively.

The constraints observed during allocation of frequencies to C50 and C70 links are shown in Table 4. Frequencies were assigned in pairs, taking into account these constraints, because that allowed constraints (a) and (b) in Table 4 to be easily satisfied and the use of pair numbers was a helpful shorthand when dealing with four figure frequencies, the manipulation of which was tedious.

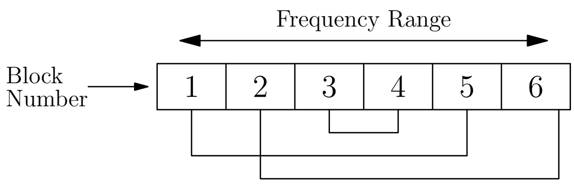


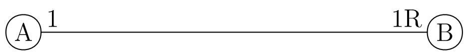
Figure 26: Division of Frequencies into Discrete Blacks

The available frequencies for a relay set type were arranged in numerical order and divided into six blocks (see Figure 26). Frequencies in block 1 were paired with those in block 5, those in block 2 with those in block 6, in either case to produce a receive and a transmit frequency. The frequencies in block 3 were paired with those in block 4 and used only at relay sites for pairs of transmit frequencies (the constraints for T/T separation being much looser than those for T/R separation).

In practice, there were problems. It seems that the pair numbers did not match the frequency order and that in the C70 procedure, some frequencies had to be used in more than one pair. Thus the potential advantages of using pair numbers as a form of shorthand were lost. Therefore, a new method of assignment was recommended and, as far as is currently known, adopted around the end of 1972.

Under the new procedure, the available frequencies for a relay set were arranged in order of frequency, from low to high, and the list was split in the middle into two equal sized sub lists. The lowest frequency in the first (lower) sub list was paired with the lowest frequency in the second (higher) sub list, and so on through the sub lists. Thus T/R separations at a site were satisfied.

The lower sub list (known as the 'Plain' list) was used to pick the transmit frequency for one end of a link and, obviously, the receive frequency for the other end. The upper sub list (known as the 'Reverse' list) was used for the opposite direction of transmission on the link. On network diagrams each end of the link was labelled with the pair number followed, in the case of the frequency from the Reverse list, by the letter 'R'. The following example shows a link from site A to site B using the first pair of frequencies:



If the allocation used all the frequencies in the lists (as was inevitable when the full system was fielded), allocation returned to the beginning of the lists. Clearly, there were also a number of rules and guidelines which varied slightly between relay set types, designed to ensure that the constraints in Table 4 were applied.

This allocation method was simple compared with those considered in the 1965 report[45] and outlined earlier. Bear in mind that those methods were for application across the whole of the NATO Northern Army Group and sought to devolve control to the armies while also obeying the rules and constraints imposed by the proposed HOBART plan. The practical BRUIN procedure just described was not required to be applied across the army group and was for use with BRUIN, a different and more limited system than in the HOBART plan.

Link Planning

The BRUIN staff did not rely on chance to provide working radio relay link paths. Quite apart from the complexities of frequency planning, the uncertainties of topographical features, which could render paths unusable, had to be eliminated or at the very least minimised. Signal Engineering Instructions (for example[48]) were issued describing in detail the methodology of planning link paths (using nomograms) so that paths would work, based on proper radio site selection. This enabled the Royal Signals planners to determine which paths would work and which would not, and thus be able to have some influence over where the various HQ elements could go, with a degree of certainty that the required communication routes would actually work. Although initially this involved a lot of work, as time passed sufficient knowledge of the areas in which BRUIN was likely to be required was built up and recorded, and eventually BRUIN deployments could take place without the necessity of much, if any, prior analysis of radio routes.

Siting Considerations

It was mentioned earlier that one of the considerations which lead to the concept of the area trunk communications system was that under the combat net point to point system, around one third of all the vehicles at a major headquarters were communications related and thus the communications systems were very difficult to hide from the enemy. It is therefore not surprising that once BRUIN was in service, steps were taken to discover how effective its use was in this regard.

Survivability of Army Field Formation Headquarters post 1980" which included at least one trial of the detectability of communications targets. The report on the March 1972 trial[49] may be seen in the National Archive and sheds interesting light on the problems of camouflaging communication systems and conversely the detection of similar systems in use by an enemy.

The trial took place during the annual Flying Falcon Exercise held by CCR Signals which involved mainly the COMCENs, COMM HDs and R Signals personnel providing a full BRUIN system, plus skeleton headquarters represented by staff vehicles. On this occasion, the COMCEN of 3 Div was also available, having been deployed to Germany for the exercise.

	COMCENs	**HQs**	**Overall**
a. Photographic	68%	100%	77%
b. Visual (confirming a.)	50%	22%	42%
c. IRLS (confirming a.)	18%	11%	16%

Table 5: Detectablity Trial Results – Percentage Targets Detected

The plan for the trial was for No 2 Squadron, RAF to fly three Phantom reconnaisance sorties per day from RAF Laarbruch for the four days 20th to 23rd March, at 500 feet and a speed of 360 knots. Each aircraft was fitted with Infra-Red Line Scanning (IRLS) equipment, four optical cameras taking a fan of oblique photographs and one optical camera for vertical shots. The aircrew were given target locations which they were told were either communication centres or headquarters and had been discovered by radio intercept and DF techniques. The targets were given as points, strips (start and end points specified) or areas (four points supplied). In the event, only eight sorties were flown and the reasons given for this are interesting:

- Two (early morning) flights were cancelled due to adverse weather conditions either at RAF Laarbruch or over the exercise area.
- One sortie was not tasked, prior information having been received that the aircraft was not available.
- One sortie was cancelled due to an unserviceable aircraft.

The eight remaining sorties were tasked to overfly 31 targets and the report considered that the reduced number of sorties did not materially affect the usefulness of of the trial.

The information collected on the sorties was returned to the Photographic Interpretation flight at RAF Laarbruch, who produced an "Immediate Photographic Interpretation Report" around 40 minutes after touchdown. The report presents the results in terms of "Detection" (signs of miltary activity noticed and reported) and "Location" (a six figure grid reference assigned, not more than 100 metres in error). In every case where a target was detected, it was also located to within 100 metres. The overall results are shown in Table 5.

The trial was primarily directed at the detection of COMCENs and with this in mind, the report also presents the following results:

- COMCENs detected — 68%.
- COMCENs showing masts/aerials — 53% of detections.
- COMCENs showing sufficient aerials for indentification as COMCENs — 40% of detections.

The writers of the report considered that the trial was limited to a certain extent by the conditions of the exercise, notably:

- Only COMCENs, COMM HDs and skeleton HQs were deployed, limiting the amount of activity and personnel on the ground.
- Aircrew suffered no wartime stress.
- The weather conditions were not as expected (the exercise had been planned to use the normal snowy conditions of that time of year but the mild weather let them down and there was no snow).
- The aircraft were tasked to overfly actual targets, not targets detected by intercept and DF.
- Because this was an exercise, the targets were not always fully deployed and camouflaged. It was noted that this was inevitable in peace time to retain the goodwill of the German civilian population.

Nevertheless, some interesting conclusions were drawn regarding the camouflage of masts and aerials, which were generally visible to such an extent that the particular types used by the C41, C50 and C70 could be identified. The report recommended that means of disguising the antennae should be investigated, perhaps by the use of matt paint to cover the silver metallic colour of the equipment or breaking up the typical outlines of the aerials (the extent to which this latter suggestion would have been possible in practice may be doubted). There is a note that in the case of the 1(BR) Corps Rear HQ COMM HD on 22nd March, the aerials were much less obvious than usual and there was a suspicion that they might have been specially painted.

Major Development Timeline

In summary, BRUIN was a ground breaking communications system which ably exploited contemporary technology. It should not be thought however, that the system stood still over its eighteen year life and some of the developments have been mentioned above. In particular, former R Signals personnel involved with BRUIN point to four major periods of change:

1. Early in the system's life, the concept of executive and non-executive COMCENs was dropped due to the popularity of the system with its users.
2. In 1972 and 1973, the Tape Relay vehicles at all the COMCENs were replaced by four TARIF vehicles at the Corps COMCENs. TARIF itself was at some point upgraded from 28 to 45 channels.
3. The 1978 order of battle changes led to a major reconfiguration of BRUIN.
4. In the early 1980s, a battlefield information system with codenamed WAVELL was introduced, with the role of disseminating all sources of intelligence to commanders in the field. This system continued into the PTARMIGAN era at which time it provided VDUs and hard copy terminals at headquarters down to Brigade level. It is assumed that modems were used over BRUIN trunk telephony circuits.

Afterword

It is hoped that this article has shed some light on the BRUIN system, the Army's answer to the communications needs of a European field force in the aftermath of the Second World War. The period of roughly the second half of the 20th Century, the "Cold War", was one of great political uncertainty and the threat posed by the massive Soviet armoured forces in the East was very real to the NATO allies. Add to that the availability of tactical nuclear weapons to both sides for much of the period and you have a potentially explosive situation which lasted for decades. So when the troops went out on exercise and set up the BRUIN network, they were not playing war games, they were practising their response to the threat of invasion from the East.

So would BRUIN have worked in time of war? We can take the view of Von Moltke:

No battle plan survives contact with the enemy.

BRUIN was an extremely complex system which required a great deal of expertise to operate, so there was probably much scope for things to go seriously wrong. In addition, the NATO forces were outnumbered in terms of quantities of military hardware, so it was thought likely that defensive action would be common in face of a Soviet invasion. And as the Duke of Wellington remarked:

The hardest thing of all for a soldier is to retreat.

However, the technology represented the best available at the time, every aspect of the system was meticulously planned, the technical and operational aspects were revisited frequently in order to make improvements and the personnel operating it were the finest signallers in the world. Therefore the author's view is that the chances are that BRUIN would have performed its role of providing communications to the staff with efficiency.

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If the reader can correct any statements or assumptions made, or can amplify any of the areas covered, contact with the author may be made via the Group's website:

http://www.royalsignals.org.uk.

This document will be available online at that web site.

The following bibliography is by no means exhaustive, but does include those documents which may be downloaded from the Group website.

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Colophon

The article was prepared using the TexNicCentre editing system and typeset as an 'article' using the Memoir document class for Leslie Lamport's LaTeX typesetter. The font is Computer Modern by Donald Knuth.