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A.S.W.E.
TECHNICAL REPORT No. 3

NOVEMBER 1962

SURVEY OF DATA LINKS FOR NAVAL TACTICAL OPERATIONS (C)

(Title - Classified)

by

N. A. GODEL

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A.S.W.E. TECHNICAL REPORT NO. 3

DATE: NOVEMBER, 1962

A SURVEY OF DATA LINKS FOR NAVAL TACTICAL OPERATIONS

by

N. A. GODEL

Approved by F. A. Kitchen
Head of Division

SUMMARY:

The increasing tempo of modern warfare has demanded the dissemination of larger quantities of tactical information at higher speeds than ever before. The requirement for adequate means to meet such a demand has led to the development of digital data links.

This report is intended to present an overall picture of past, present and, so far as can be envisaged, future digital data links which are of concern to the Royal Navy. The compatibility problems brought about by the advent of such data links and the ways in which these are being dealt with are also discussed. However, the picture is far from being a stable one as operational requirements tend to be changed or modified rapidly, dependent as they are upon current concepts of waging effective naval warfare. The facts mentioned are therefore those which pertain at the time of writing the report, some of which may be completely out of date twelve months from now.

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A SURVEY OF DATA LINKS FOR NAVAL TACTICAL OPERATIONS1. INTRODUCTION

The increased tempo of modern warfare has led to the need to disseminate larger quantities of tactical information and, at the same time, has reduced the margin of time in which to take action on such information, this necessitates the dissemination being effected in much less time than hitherto. Because the amount of data involved could neither be handled by means of slow and cumbersome voice circuits, nor even by RATT facilities, the requirement was met by the introduction of high-speed data transmission systems, using digital techniques. The first system employing these techniques was the Digital Plot Transmission System, (D.P.T.); this was developed for use with Type 984 Radar and the Comprehensive Display System (C.D.S.). It was introduced into the Royal Navy in 1957, H.M.S. VICTORIOUS being the first ship to be fitted. Its function was to permit the whole of the stored air defence information in the C.D.S. stores in one ship to be made continuously available for display in other ships fitted with suitable reception and display equipments. The system was therefore essentially a broadcast system, the information being passed in a suitable form via a radio circuit.

With the threat of nuclear warfare and the consequent need for greater dispersion of ships within a task force, it became desirable that the capability of ships on the outer fringes of the task force to provide early detection of enemy targets, particularly of low flying aircraft, should be exploited by means of a data exchange system. At the same time simultaneous reports of enemy jammers could be used for triangulation purposes much more effectively. Such a data exchange system was being developed by the U.S.N. for use with the Naval Tactical Data System, (N.T.D.S.), and has been designated within the U.S.N. as the 'A' Link. In view of the requirement for co-operation between the U.S.N., R.C.N. and R.N., a CANUKUS organisation was set up to evolve design criteria for an international data exchange system. This became known as the Tactical International Data Exchange System, or T.I.D.E. Link, the characteristics of which were based very largely on those of the U.S.N. 'A' Link. Later, requirements were recognised for a low-speed data link providing summary information and a high-speed UHF data link. In order to distinguish between these three T.I.D.E. Links, they were designated T.I.D.E. Links 'P', 'Q', and 'R', to avoid confusion with the three corresponding U.S.N. Links 'A', 'B' and 'C'. These titles were short-lived as it became necessary to release information to NATO on the 'P' Link, that is the original "T.I.D.E. Link", to meet a ship/land data link requirement, to be compatible with this link. NATO link numbering was consequently adopted, giving T.I.D.E. Links 11, 12, 13 and 14, where '11' was equivalent to the 'P' Link, and '12' to Link 'R', whilst '13' and '14' evolved from what was seen to be a dual requirement in the new and recently designated Link 'Q', these requirements were a slow-speed automatic link between computer-fitted ships and a slow-speed semi-automatic link between non-computer-fitted ships and computer-fitted ships, making use of RATT.

At this point the great expense of fitting T.I.D.E. Link 11 equipment, together with the need for fitting expensive improved communication equipment for operating the link, became generally appreciated. The majority of NATO countries stated that they could not afford such an expensive system and in the R.N. the previously expected scale of fitting was drastically modified. A requirement arose therefore amongst NATO navies, other than the U.S.N., for a "poor man's Link 11", and the characteristics of Link 13 became adjusted to meet this need, with a data rate comparable with that of Link 11, but with a much less expensive modulation system, giving a reduced, although acceptable range. All NATO navies had already expressed an interest in Link 13, with the exception of the U.S.N., and following successful trials to demonstrate the suitability of the proposed modulation techniques, intended

to fit it on a wide scale. This would have introduced a compatibility problem, but for the fact that the U.S.N. have more recently stated that they now have a requirement for an A.S.W. link, for which Link 13 would appear to be suitable. To overcome the problem of having to fit yet another data link equipment a proposal was made to combine Link 12 and Link 13 equipments; this is discussed later.

As mentioned earlier, a NATO ship/land data link requirement has been stated and the NATO numbers Link 5A and Link 8A have been given to the two ship/land compatible equivalents of Links 11 and 13, respectively. Because the characteristics of these links differ from those of the NATO land links a compatibility problem exists and "buffer" terminals will be required on shore to translate from the "language" used on the ship links to that used on the NATO land links. A further data link requirement arose in which it was required to control high-speed intercept aircraft from a ground, or shipborne, control point. As this was a system in which each aircraft was to be controlled by discrete messages addressed in sequential fashion the system became known as Discrete Address, the characteristics of which have been internationally agreed. This link has been designated NATO Link 4. The other "missing" link numbers in the sequence 1 to 14 are either NATO land links, or else have not yet been allocated.

2. DIGITAL PLOT TRANSMISSION SYSTEM

The information to be transmitted via D.P.T. consists of the plan position cartesian co-ordinates of up to 48 airborne targets together with ancillary items, involving Track Reference ("tens" and "units"), Height in thousands of feet ("tens" and "units"), Category and Size. Additionally, the plan position co-ordinates of two Marker Pointers were also required to be transmitted. The co-ordinates for targets and Pointers were required to be transmitted with an accuracy of 0.1%. It was a requirement that the modulation should be such that a conventional voice channel on radio equipments, existing or under development, could be used. In other words it was a requirement that the adopted data system should not require special radio equipments to be developed.

The system chosen was therefore a serial binary digital system using Phase-Reversal Keying of an audio tone. The factors which determined the data rate were the amount of information appearing at the outputs of the C.D.S. Marker Switches, which scan the C.D.S. stores, the rate of rotation of these switches and the accuracy required in the transmitted data. These combined to give a data rate of 1562.5 bits per second so that the audio tone required was 1562.5 c/s which is derived by dividing 100 k/cs by 2°. A complete Information Cycle, containing all the information resulting from a single complete rotation of the C.D.S. Marker Switches, consists of 3600 bits and is divided into 50 Target Cycles. The 25th and 50th Target Cycles contain no C.D.S. track information, but instead contain the coded forms for known input signals. Additionally, the 50th Target Cycle contains a special Synchronising Signal sequence, consisting of 2 binary ones followed by 25 binary zeros and terminated by a binary one. This is used to indicate the beginning of each Information Cycle to the receiving equipment, successive cycles being contiguous; the last binary one of the Synchronising Signal defines the last digit in the Information Cycle.

Each Target Cycle contains 72 digits which are allocated as follows:-

Target 'X' Co-ordinate	10 bits
Target 'Y' Co-ordinate	10 bits
Track Reference "Tens" (1 decimal digit)	4 bits

Track Reference "Units" (1 decimal digit)	4 bits
Height "Tens" (1 decimal digit)	4 bits
Height "Units" (1 decimal digit)	4 bits
Category (1 decimal digit)	4 bits
Size (1 decimal digit)	4 bits
Pointer 'X' Co-ordinate	10 bits
Pointer 'Y' Co-ordinate	10 bits
Spare bits	<u>8 bits</u>
	<u>72 bits</u>

By adding two groups of 4 "Spare" bits and splitting the groups of 10 co-ordinate bits into groups of 5 bits, a symmetrical Target Cycle becomes possible by interlacing groups of 4 bits with groups of 5. This makes the design of the logical circuitry simpler by virtue of the symmetry of the required logical operations in the encoding and decoding processes. As only one Pointer is accommodated in a single Target Cycle the two Pointers are transmitted in alternate Target Cycles.

The information at the outputs of the C.D.S. Marker Switches is in voltage analogue form; analogue to digital conversion is carried out in the D.P.T. Transmitter or Encoder, (Outfit RJT(1)). Similarly, at the receiving end the information is required to be converted back to voltage analogue form for display purposes, so that digital to analogue conversion is carried out in the D.P.T. Receiver or Decoder, (Outfit RJR (1)). The construction adopted consisted of plug-in units, employing sub-miniature valves and germanium diodes, of dimensions 6 in by 3 in by 2 in, screwed onto water-cooled aluminium panels, each containing 12 by 4 plug-in units. The transmitter and receiver required 127 and 295 units, respectively, whilst their respective power consumptions were 2.5 kW and 4 kW.

Since H.M.S. VICTORIOUS was fitted, H.M.S. HERMES has been fitted for both transmission and reception, whilst H.M.S. ARK ROYAL and DLGs. 01 to 04 have been provided with reception facilities only. H.M.S. COLLINGWOOD has also been provided with a transmitter and receiver.

3. NEW DIGITAL PLOT TRANSMISSION EQUIPMENT

The decision to fit an ADA (Action Data Automation) system in H.M.S. EAGLE during her present modernisation programme, with the capability of operating on T.I.D.E. Link 11, raised the problem of providing a measure of compatibility with C.D.S./D.P.T. fitted ships. The solution to this problem was to provide an equipment capable of taking selected air defence plot information, such as is passed from C.D.S. ships, from the ADA digital stores in H.M.S. EAGLE and translating it into the D.P.T. serial format, so that when received in a C.D.S. ship it would appear in the same form as if it had originated in another C.D.S. ship. Conversely, the new equipment was required to be capable of receiving a C.D.S./D.P.T. transmission and translating it into a form suitable for passing into the ADA computers. Because the scales used for the C.D.S./D.P.T. co-ordinates and ancillary information differ from those programmed into the computer for the T.I.D.E. system, the computer has to perform scale conversions on the D.P.T. data, in both transmit and receive operations. Since ADA is a digital system, whereas C.D.S. is an analogue one, the C.D.S. type D.P.T. cannot be used with ADA, necessitating therefore the development of the new D.P.T. equipment. The construction of the new equipment is identical with that of the ADA computers and makes use of the same types of transistorised logic circuit cards.

Unlike the C.D.S. type D.P.T., the new equipment will be capable of simultaneous transmission and reception. This means that H.M.S. EAGLE could operate a continuous two-way exchange with another ADA/D.P.T. ship using two radio frequencies, whilst C.D.S./D.P.T. ships could receive from either of the two ADA/D.P.T. ships. Alternatively, a C.D.S./D.P.T. ship with transmission capability could transmit to H.M.S. EAGLE, whilst the latter transmitted to everyone else, the C.D.S./D.P.T. ship transmitting to H.M.S. EAGLE being, of course, unable to receive. Such a mode of operation is shown in Figure 1. The logical equipment required occupies 3 shelves of cards in Outfit RJA(1), which consists of a standard ADA computer cabinet, containing 8 shelves of transistor card units. The remainder of the cabinet is required for two other equipments used in connection with Link 11 and Link 14. The module for D.P.T. is called the ADA/D.P.T. Translation Module.

4. TIDE LINK 11

In order to meet the requirement for providing gapless cover over a range of 300 miles, a system of multi-channel modulation employing phase-quadrature techniques was proposed. The system was developed by Collins Radio Company of America, and the trade name "Kineplex" was given to it. Alternatively, the technique involved was called "Predioted Wave Signalling". The multi-channelling is provided by 15 audio tones consisting of 935 c/s, thence in 110 c/s steps to 2365 c/s and 2915 c/s. Each of these is phase-quadrature modulated to give 2 channels per tone, resulting therefore in 30 channels in all. Additionally, since it is the intention of the U.S.N. to include AEW aircraft in the link, a 605 c/s tone is included, which is unmodulated and provides a reference tone to facilitate compensating for the shift in frequency of each tone arising from the Doppler effect. In order to achieve the required accuracy of $\pm \frac{1}{2}$ c/s in the received tones when SSB transmission is employed, and at the same time to permit synchronising using the 2915 c/s tone, to be effected no more frequently than once every 24 hours, a frequency stability of better than ± 1 part in 10^8 is required. This is provided by the Central Frequency Standard in R.N. ships. Each of the channels is keyed at either 45.45 or 75 bauds, the former being the normal keying rate, giving a total bit rate for the 30 channels of 1363.5 bits per second and 2275 bits per second, respectively.

There are two normal modes of operation of a tactical net with this link, known as Roll Call and Round Robin. In the Roll Call mode, one ship selected as the TIDE Communications/Control Unit (TCCU) interrogates each of the others, termed Pickets, according to a prearranged order of call. All ships are capable of receiving the transmissions of all the others and in the case of the Pickets, are normally in the Receive condition. When a Picket is called-up by the TCCU transmitting an Address allocated to that Picket, the latter switches to the Transmit condition and broadcasts information of tactical importance to the Force. In the Round Robin Mode each ship, at the end of its own Report, transmits the Address of the next ship in a prearranged order. This has the advantage of reducing the amount of "dead" time in completing one cycle of the net, the "dead" time being the total time required, apart from that when actual data is being transmitted, to transmit special signals, described later, and addresses.

The Net Cycle Time is broadly defined as the time taken for the Net Control Ship to interrogate all Pickets in the Roll Call Mode once around the net, or the time to complete one cycle in the Round Robin Mode. This will naturally depend upon the time required by each ship to transmit its Report, but a maximum limit of 10 seconds has been imposed to ensure that the transmitted information is always reasonably up-to-date. In order to improve the efficiency of operation of the net in either mode the concept of Track Quality has been introduced, which is a measure of the accuracy with which a given track is known. It is then required that no ship

reports a contact on the link unless the Track Quality figure it has allocated to it, according to agreed rules, is higher than that included in another ship's report. By this means the amount of data transmitted by each ship is kept to a minimum. Because the range of any ship may vary considerably over the 300 miles required, as each of the others takes its turn to transmit, it is necessary to allow time at the beginning of each ship's transmission for the correct AGC setting to be achieved in the radio receivers. At the same time it is also necessary to allow sufficient time for relays to operate, in the change-over process from receive to transmit and conversely, and to allow for Doppler correction when ATDS aircraft are operating in the net. For these operations a total time equivalent to six Frame Intervals is allowed, a Frame Interval being the time occupied by 30 bits simultaneously transmitted on the 15 audio tones.

During the 5 AGC Frames only two of the tones are transmitted, these being the 605 c/s Doppler Correction tone and 2915 c/s Synchronising tone. When these tones are transmitted, the whole of the transmitted power is applied to these two only, so that the best possible signal is provided at the radio receiver for the AGC and Doppler Correction processes. Following the 5 AGC Frames, it is necessary to transmit the 15 keyed tones for a period of one Frame Interval in order to provide a Reference Phase on each channel. This is because the system is a phase comparison one, in which the "reference" phase is obtained from the immediately preceding bit. The power in each tone is at a correspondingly lower level as there are now 16 tones to transmit instead of 2.

The format of the Frames following the Reference Frame will depend upon the mode of operation and the ship making the transmission. There are three basic formats, two of which are essentially required in the Roll Call Mode and the third normally required in the Round Robin Mode, although under special circumstances which are mentioned later one of the Roll Call Mode formats is also used in the Round Robin Mode. The three basic formats are:-

- (a) Roll Call Call-up Used by the TCCU when interrogating a Picket and consisting of:-

/5 AGC Frames/Ref./ADD₁/ADD₂//

where Ref. is the Reference Frame and ADD₁ and ADD₂ are 2 Frames of a special "Control Code" combination of bits representing the Address of the called ship.

- (b) Roll Call Reply Used by the Picket ship when replying to an interrogation by the Net Control Ship and consisting of:-

/5 AGC Frames/Ref./ST₁/ST₂/Data Frames/SP₁/SP₂//

where ST₁ and ST₂ are 2 Frames of a Control Code combination of bits representing the "Start" signal, required by the computer; Data Frames are the frames containing the data bits; SP₁ and SP₂ are 2 Frames of a Control Code combination of bits representing the "Picket Stop" signal signifying the end of the Picket's report.

When the TCCU has to make its own report it uses the Round Robin Reply format.

- (c) Round Robin Reply Used by each ship in a Round Robin net on recognising a call-to-transmit from the previous ship to transmit in the net, consisting of:-

/5 AGC Frames/Ref./ST₁/ST₂/Data Frames/SP₁/SP₂/ADD₁/ADD₂//

where SP₁ and SP₂ are 2 Frames of a Control Code combination of bits representing

the "Round Robin Stop" signal followed by the Address Frames constituting the call-to-transmit to the next ship in the rota.

If for any reason no reply is received to the first "call to transmit" to the next ship, the call is repeated. In both Roll Call and Round Robin Modes the format used for the repeated call is the same as the "Roll-Call Call-up". In the Roll Call Mode, if the second call is unanswered, then the TCCU simply calls the next ship. In the Round Robin Mode the operation is a little more complicated. If the calling ship happens to be the TCCU it goes on calling ships around the net, with 2 calls to each, until one of them answers or, in the extreme event of no answers at all, until the TIDE Net Controller takes action as appropriate depending on the cause of the trouble. In the case of the Picket in the Round Robin Mode, it calls up the three ships which are next in succession in the rota. If it is unsuccessful after repeated calls to each of the next three ships it reverts to and remains in the Receive condition. In the meantime, the TCCU, which is continuously monitoring the net, after a specified period to ensure the net is cleared of any possible spurious transmissions, switches to the Transmit condition and attempts to re-initiate the Net transmission, but this time automatically.

When an A.E.W. aircraft (U.S.N. only) is operating in a Round Robin net, because its equipment (A.T.D.S.) has been designed for the Roll Call Mode only, it is necessary for the ship which calls the aircraft to revert to the Roll Call Mode. This means that when the aircraft has replied, because it cannot take control of the net, and cannot therefore interrogate the next ship, this must be done by the ship which called the aircraft. This constitutes the special circumstance referred to earlier, in which the Roll Call Call-up format is used during a Round Robin cycle. In order to effect an improvement in the efficiency of operation of the Net in the presence of errors due to noise, a means for Error Detection with an option of Error Correction is built into the system. Of a Frame of 30 bits only 24 actually contain data; the remaining 6 bits are added to provide what is known as a Systematic Error Detection and Correction Code, based on a method proposed by Hamming. (Ref. 1). In such a code, redundancy is introduced into the system in such a way as to produce a number of combinations which is greater than the number actually required to carry the data, that is, 2^{30} combinations instead of 2^{24} . The original 2^{24} combinations are transformed into a new set, selected from the 2^{30} in such a way that it requires more than one error to change one member of the new set into another. The addition of the 6 bits enables 3 errors to be detected, or alternatively, if so desired, enables 1 error to be corrected and 2 errors to be detected. In the event of up to 3 errors in the first case, or 2 errors in the alternative, the whole of the data Frame would be discarded. The relative merits of the two systems will depend upon the application. The former system would allow less erroneous information to be passed into the computer but would also reject more information which could otherwise have been corrected.

In addition to the Error Detection and Correction feature described in the foregoing, the audio tones are used to modulate a radio frequency carrier as a Double Sideband Amplitude Modulation with suppressed carrier. This has the advantages of Independent Sideband operation in which the same information is modulated on both sidebands. The sidebands are then demodulated separately, following which one of two procedures may be adopted. In the first, the two sidebands are separately checked for errors and at the same time analogue-diversity-added and the result again checked for errors. The analogue-diversity adding consists of a simple voltage-adding operation of corresponding tones obtained from the separate demodulation of both sidebands. In the second method, adopted by the R.N., the two demodulated sideband outputs are accepted by the computer, in which a bit-for-bit check is carried out on the corresponding bits obtained from the 30 channels in each sideband. A check on each sideband output is then made as before and the results are compared with the bit-for-bit check. By this means

up to 4 errors can, in most cases, be corrected.

So far only two modes of operation have been mentioned, namely Roll Call and Round Robin; however, there are others. Firstly, if the stability of the Central Frequency Standard is to be exploited in the Synchronising operation such that synchronising need not be effected more frequently than once per 24 hours, it is essential to ensure that all ships in the Net are properly synchronised at the start of a Net Transmission. To effect this, the TCCU is switched to the "Net Sync." Mode, in which it initiates a transmission in the normal manner. At the end of the 5 AGC Frames involving two tones it does not switch in the remaining tones, but continues to transmit two tones only as in the 5 previous AGC Frames. This is continued for a period long enough to allow all ships to be synchronised on the transitions which occur on the 2915 c/s and which define the Frame Intervals. At the 45.45 baud rate, these will be 22 ms long. The required period is normally expected to be of the order of two minutes, after which time the mode of operation will be changed, the timing systems in all ships retaining a common reference of time for a period of not less than the following 24 hours. The synchronising circuits are manually switched off when synchronisation has been achieved. There will of course be occasions such as when a ship returns to the net following an equipment break-down, or when a ship newly joins the net and was unable to be present when the Net Sync. Mode was in operation. To enable such ships to join in the net some means must be provided to enable them to achieve synchronisation. This may be achieved by either of two methods, one of which is known as the Slow mode and the other the Fast mode. The first of these is actually the method employed when synchronising during the Net Sync. mode, except that, whereas in the latter case synchronising is achieved with respect to the transitions in the 2915 c/s tone received from the TCCU, synchronising can only be achieved by "averaging" the timing of transitions obtained from different ships involving different propagation delays. Once achieved the synchronising circuits are made inactive as in the Net Sync. mode. In the alternative Fast mode synchronising is achieved by using only the transitions during the 5 AGC Frames at the beginning of each ship's transmission, which makes the synchronising operation equivalent to a "start-stop" type. This mode enables greater ranges than 300 miles to be achieved when propagation conditions are good because the effect of propagation delays is eliminated, but the principle of operation depends upon receiving a good signal for the first 5 Frames of each transmission. Both of the above methods are compromise operations, the price paid being an effective reduction in signal-noise ratio. Under reasonable propagation conditions this is acceptable.

A further mode of operation is that known as "Radio Silence". Under this condition, which is self explanatory, all ships must remain in the Receive condition. However, a "Single Report" capability is provided which, under emergency conditions, allows any ship to make a Single Report. This is a Report in the Tide sense, which may contain information on several target contacts, but in which each target is reported only once. It then reverts to the receive condition and it is for the TIDE Net Controller then to decide whether the report warrants starting a Roll Call or Round Robin transmission.

Of lesser importance are facilities to provide a Broadcast Mode, which enables any ship to transmit indefinitely to all others in a continuous fashion, a "Net Test" mode in which known signals are transmitted and the error rates observed as a means for checking the propagation conditions, and a "Self Check" Mode which is merely a fault locating facility, in which the output of the Kineplex Transmitter is fed into the input of the Kineplex Receiver and the connections to the radio equipment broken. To achieve the required range of 300 miles with gapless cover, frequencies in the HF band must be used. These will generally be chosen in the range 2-5 Mc/s to give adequate ground wave.

The equipment developed by the U.S.N. for use on Link 11 is designated AN/SSQ-29. This consists of two units. Unit 1 is a 6 ft cabinet containing 3 pull-out racks in each of which are mounted shelves of transistor card units. Unit 2, known as the Remote Control Unit, provides the facilities for such operations as selecting the station mode and net mode required, synchronising and setting up, by means of binary octal switches, the addresses of all the ships which have to be called. Unit 1 contains all the circuitry of the Kineplex transmitter and receiver, as well as all the logic required to effect error detection and correction and to control the net. The last operation includes generating the special signal format for AGC purposes at the start of each transmission, generation of control codes and recognition thereof, controlling the transfer of data to and from the computer and controlling the switching on and off of the radio transmitter. These two units are shown in Figure 2. In H.M.S. EAGLE, and any other R.N. ships which may be fitted, many of the operations required for net control and address selection will be carried out by the Poseidon Computer. This means that the Remote Control Unit, as designed, and one of the 3 racks in Unit 1 will not be required. However, it is still required to match the remaining cabinet equipment, which is essentially the Kineplex part, to the External Highway of the ADA system, ("Proctor"). To meet this requirement the Kineplex/ADA Translation Module has been developed, which is part of Outfit RJA(1). The remainder of the Link 11 equipment is referred to as Outfit RJB.

When transmitting, the 30 bits constituting each Frame are transferred from the computer via Proctor to the Kineplex/ADA Translation Module in two groups of 15 bits in parallel and in rapid succession, the transfer being effected in less than 200 μ s. The 30 bits are then stored until the next Frame is required, during which time they are presented in parallel to the Kineplex Transmitter in the AN/SSQ-29 equipment where the tones are modulated appropriately. When receiving both sidebands are demodulated separately, thus giving 2 groups of 30 bits, which are transferred to ADA in 4 groups of 15 bits, again in rapid succession.

The stringent requirements affecting frequency stability and linearity demanded by this link have largely dictated the characteristics of the new HF radio transmitters and receivers designed for the shipborne Integrated Communication System (ICS). A ship-to-shore version of this link is required by NATO and has been given the number NATO Link 5A. The information passed from ships via Link 5A will require to be translated, in a shore-based Buffer Terminal, into a form which will permit it to be passed via telephone circuits to a Sector Operations Centre (SOC). This landline part of the link is called Link 5B which will have the same characteristics as those of NATO Link 1 between SOCs.

5. TIDE LINK 12

TIDE Link 12 is defined as a high-speed link for use on frequencies in the V/UHF band 225 Mc/s to 400 Mc/s. Its use will be mainly confined to ASW operations within a range of 20 miles. The essential difference between this link and Link 11 lies in the form of modulation and data rate. The information is transmitted in single channel form, unlike that on Link 11 where it is multi-channelled. For this reason the system cannot exploit the stability of the Central Frequency Standard for bit synchronisation purposes over a 24 hour period, because the propagation delay differences between various ships taking part in the net are of the same order as the bit length itself. The method of synchronising used is therefore of the "Start-Stop" type, as used, for example, in the 7 $\frac{1}{2}$ unit teleprinter code. The serialised binary digits are used to frequency-modulate a radio-frequency carrier in the V/UHF band 225 Mc/s to 400 Mc/s, such that a deviation of +20 kc/s corresponds to a binary "1" and a deviation of -20 kc/s corresponds to a binary "0". The radio-frequency carrier itself is never radiated unmodulated.

The data rate proposed by the U.S.N. is 9600 bits per second, which is used on their "C" link, but this data rate is not yet agreed internationally. It is considered to be higher than necessary by the R.N. If it is changed, it will either become 4800 or 2400 bits per second in order to conform to the requirement that data rates should obey the preferred formula $2^n \times 75$ bits per second, where n is any integer, or zero, for systems whose data rates are not less than 75 bits per second. Features which have been agreed, apart from the type of modulation, are the message standards, which will be the same as are used on Link 11. This reduces the load on computers. On Link 12 each message frame of 30 bits is repeated once, which has the effect of halving the data rate. Although a control code system has yet to be agreed for use on this link, it has been proposed that advantage be taken of the repetition of frames by inverting the second frame whenever a control code is transmitted. This would give an improved capability for segregating message frames and control code frames when errors occur due to interference.

The modes of operating a net on Link 12 have also yet to be agreed. The U.S.N. have proposed that a method called "Time Slot" should be adopted. In this system time is divided into 400 ms "slots" and each ship is allocated a particular slot in N slots, where N is the number of ships participating. Thus each ship knows exactly when it has to transmit without needing to be called and, consequently, the cycling of the net cannot stop fortuitously, for if one ship is unable to transmit during its allocated time-slot the next ship will automatically take its turn during the next time-slot. This system has the advantage that the control code problem is reduced and there is no need for the complicated re-call facilities required in the Roll Call and Round Robin Modes used on Link 11. The disadvantage of the system is that in general the time-slots will not be completely filled with data. This implies that the net cycle time is not used as efficiently as in the case of Link 11. On the other hand this is partly compensated for by the higher digit rate possible on UHF.

The control codes which are required on this link are those associated with the start of a message sequence and the end of a message. Although each transmission nominally commences at the start of each 400 ms time-slot, because the propagation delays may be anything up to about 120 μ s for up to 20 miles range, bit synchronisation is necessary at the start of each transmission. Additionally, as the maximum delay is of the order of a bit length at 9600 bits per second, 104 μ s, it is necessary to re-establish the position of the first message bit in each new transmission. Frame synchronism is established by sending a fixed number of bits at the start, arranged in some special code, which can be recognised without ambiguity even when errors are present. Bit synchronism is achieved by preceding the special start by a similar number of bits and observing the positions of the transitions between bits, making the required timing adjustment accordingly.

The present series of V/UHF transmitters and receivers in use in the R.N. are quite incapable of meeting the requirements for this link, in the first place because they cannot provide a ± 20 kc/s FSK type of modulation. The U.S.N. has had the AN/SRC-17 developed for this purpose and also for Discrete Address, which will be discussed later. If these two data link systems are to be fitted in the R.N. either the AN/SRC 17 equipment will have to be fitted, or an entirely new V/UHF equipment will need to be developed. As other uses are envisaged for a new V/UHF radio equipment, the latter course is preferable and is likely to be adopted.

6. TIDE LINK 13

The present requirement for Link 13 has arisen from the need for a less expensive equipment than that required for Link 11, using a less sophisticated modulation technique. The range performance is inevitably reduced compared with that obtained by the Kineplex system in Link 11. This has been accepted and the range requirement for this alternative link is 100 miles at a data rate of about 1000 bits per second, or 250 miles at about 250 data bits per second. To meet the range requirements a serial FSK system has been proposed in which binary 1 and 0 are represented by two audio tones. At the present time these are respectively 2100 c/s and 900 c/s. It is considered however that these may not be optimum and the use of 2400 c/s and 1200 c/s has been suggested. Whilst these would have some advantages compared with the present tones, tests have yet to be carried out to determine the optimum tones to use.

In order to comply with the requirement that the digit rates should conform with the recommended formula $2^n \times 75$, digit rates of 300, 600 and 1200 bits per second have been agreed. At the highest data rate, with the present tone frequencies, only $\frac{3}{4}$ cycle at 900 c/s is obtained for a binary 0 and only $1\frac{3}{4}$ cycle at 2100 c/s. In order to simplify detection at the receiving end, therefore, the audio signals are heterodyned by mixing with 8 kc/s, thus giving a minimum of 6 cycles per bit in which to recognise the corresponding tone frequency. It has been agreed that the same message structure as that agreed for Links 11 and 12 will be used on Link 13. Because the maximum data rate which can be employed on conventional HF circuits cannot be as high as that which is possible on Link 12, the loss of information rate due to the duplication of 30-bit Frames employed on Link 12 cannot be tolerated on Link 13. Transmissions in the HF band must be made on Link 13, as in the case of Link 11, in order to achieve the desired ranges.

It has been proposed by the R.N. that the same net modes should be possible on Link 13 as on Link 11, with the exception of the Net Sync. Mode, which is not required. The reason for not requiring this mode of operation is the same as that for Link 12, or any other high-speed serial system, namely, the different propagation delays between ships at different ranges. A Start-Stop system of synchronising similar to that adopted for Link 12 has, therefore, to be employed. Because greater ranges are required than in the case of Link 12, it becomes necessary, as for Link 11, to allow for receiver AGC levels to be reset with each transmission. A period corresponding to two 30-bit Frames is allocated for AGC purposes, during which alternating binary ones and zeros are transmitted. These are followed by two 30-bit Frames constituting a special Start code, whose combination has yet to be agreed.

Because Links 12 and 13 are similar in many respects, it has been proposed that the requirements for either might be met conveniently by one common equipment. One of the requirements to be met by the proposed Link 13 equipment is that it should be possible to use it on radio equipments which are generally fitted in 1966, without necessarily fitting expensive radio equipments, such as are used in ICS. However, in order not to prejudice the design of the data link equipment, it is intended that it should be capable of exploiting the improved capabilities of later radio equipments, as they become more widely fitted. For example, until SSB/ISB radio equipments have been widely fitted it is desirable that the link should be capable of being operated using DSB amplitude-modulation. This prevents the exploitation of the two sidebands for error detection and correction purposes as is done for Link 11; but it is highly desirable that this should be possible for Link 13 when ISB transmission can be used in operating a Link 13 net. Because of the requirement to be able to use less sophisticated radio equipment, the system will require a frequency stability of not greater than about

1 part in 10^7 where SSB or ISB equipments are used. It is inevitable, of course, that the ranges to be expected will be less for the less sophisticated equipments, having the minimum frequency stability and using DSB or SSB modulation modes, than those which will be obtained with ISB on ICS type radio equipments.

It is intended that the equipment for the R.N. will be produced in collaboration with the Royal Netherlands Navy who are carrying out the development work. Although it has been proposed that the same net modes as are used on Link 11 should also be used on this link, the R. Neth. N. have expressed the viewpoint that, in order to keep the equipment simple and hence the cost as low as possible, the time-slot Round Robin system as proposed for Link 12 should be used. The objection against this proposal is the amount of dead time within partially filled slots; this is of greater significance on HF, where the bandwidth available is less than on V/UHF, and cannot, therefore, be exploited by a higher bit rate. As in the case of Link 11, there is to be a ship-to-shore version of Link 13, which has been given the number NATO Link 8A, with an associated land-line link called Link 8B, which will probably be equivalent to Link 1, as is Link 5B. Here again a Buffer Terminal will be required ashore.

7. TIDE LINK 14

The introduction of data transmission systems and computers has given rise to the problem of incompatibility between those ships which are so fitted and those which are not. Link 14 has been proposed in order to reduce this problem by affording a measure of compatibility, the means of achieving which does not necessitate the fitting of special equipment in the non-computer-fitted ships. It is assumed of course that these are not fitted with CDS and DPT. By the time the first computer-fitted ships go to sea, most other ships likely to take part in operations with such ships will be fitted with RATT equipment; Link 14 is designed to make use of this equipment. It is expected that the data rate which will be used on this link will be 75 bauds, but the additional translation equipment being designed for the computer-fitted ship will also be capable of operating at 50 bauds, to cover the interim period during which the change-over to the higher RATT data rate takes place. A special message format has been designed which enables data to be transmitted via a RATT circuit from a non-computer-fitted ship and injected directly into ADA without the need for human interpretation in the computer-fitted ship. As the data is in the conventional serial 5-unit RATT form, the translation equipment in the computer-fitted ship has to recognise and remove the start and stop elements of each $7\frac{1}{2}$ -element RATT character and convert the serial form of the 5 Murray code elements into the required parallel form for passing into ADA via the external highway system. In the equipment designed for the R.N. a means is also provided for taking data from ADA and translating it into the RATT format for transmitting out to non-computer-fitted ships.

Agreement has yet to be reached internationally on the philosophy of operating this link and on the message structure. In the meantime the R.N. proposal has been adopted in the programming of the first computers. In this proposal each message consists of 17 RATT characters, preceded by 2 carriage-return 1 line-feed and 1 figure-shift characters, which ensures that when printed out on a teleprinter each message is printed out on a new line. Each new report from a non-computer-fitted ship is preceded by 2 letter-shift and 3 figure-shift characters, which are required to activate the radio transmitter in the sending ship and the radio receivers in the receiving ships. Each report ends with 2 carriage-returns and 6 line-feeds to give a definite indication of the end of a report which serves as the instruction to the next ship to transmit. No control codes are proposed for this link since the transmission is monitored by a human operator in each ship taking part in the net.

Up to twenty seconds is allowed following each report for the operator in the next ship to initiate his own transmission when his turn arrives. The net cycle time is expected to be of the order of 3-5 minutes, depending on the amount of data to be transmitted and the number of ships in the net. Each operator is expected to prepare a new perforated tape during the reception periods, up-dating the information passed on the previous tape, transmission via the link being effected by means of an auto-sender and not by manual operation, in order to reduce transmission time. The manual preparation of tapes however is very prone to introduce errors. To reduce the errors from this cause a special "black box" has been devised which permits the required characters in each message to be set up by means of rotary, edge-reading, switches. As the required symbols are selected by means of these a completed message sequence can be read off very readily from the row of 17 side-by-side switches. When the messages have been set up and the time comes to transmit, the pressing of a "Start Transmit" switch will result in the messages selected by the rotary switches being transmitted automatically. A typical edge-reading switch and assembly are shown in Figure 3. The equipment has been named "Message Indicating and Digital Generating Equipment" (MIDGE). Each row of switches will have associated with it an "inhibit" switch, which, when in the "inhibit" position, will prevent that particular message from being transmitted, the resulting message slot being closed up so that there is no break in the transmitted sequence. This means that if the particular message being up-dated has not been completed the message is not transmitted when the call-to-transmit arrives. The switches for setting up messages will be capable of being remotely situated with respect to the controlling logic circuitry, which will be close to the monitoring teleprinter. Because the messages are composed from the conventional 5-unit Murray code used in RATT the message structure differs from the structure adopted on the other TIDE links. The necessary translation from one to the other is carried out by the computer.

The method proposed in the foregoing paragraphs for operating Link 14 and the message format for use on it have, at the present time, the status of an R.N. proposal only, since agreement has yet to be achieved internationally on both aspects. The U.S.N. considers that a link of this type should be used as a broadcast link from computer ship to non-computer ships. The R.N. on the other hand considers that the link can also be usefully employed as an "In-link" to the computer ship. The R.C.N. supports the R.N. viewpoint, but considers that the information as received by the computer ship should be manually processed before injection into the computer. It has been agreed between these three navies that the "In-link" should be called Link 14A and the broadcast link should be called Link 14B; NATO ratification of this proposal has, however, still to be obtained. The Link 14B format would be similar to that used by the U.S.N. in its N.T.D.S. 'B' link broadcast, whilst the format for Link 14A has yet to be decided. In order to meet H.M.S. EAGLE's completion date a decision has been taken to programme her computers according to the U.S.N. format for the broadcast, and according to the R.N. proposal for Link 14A. To overcome the R.C.N. objection to the direct injection of Link 14A information into the computer, it was agreed that this could be a matter for national resolution.

A very recent R.N. proposal, involving a slight modification to the original, involves the provision of a means for enabling a degree of error detection and correction to be achieved. It is required that it should be possible to monitor the transmitted information at both ends of the link by means of a teleprinter. This means that the redundancy necessary for error detection, which is normally provided by adding one or more bits to each 5-unit character, has to be provided in some other manner if the need for conversion equipment, which would permit print-out to be obtained, is to be avoided. This is achieved by adding two check teletype characters at the end of each 2-character message. The check characters are derived from the addition of the 5-bit binary numbers formed by all twenty-one 5-unit characters in the message. The addition is performed in a 10 stage register which retains the digits of

the 10-bit binary number which results from the addition. The teletype "start" and "stop" elements are added to these 10 bits in two 5-bit groups to form the two check characters. In the computer the summation is repeated and checked against the check characters. If errors have occurred there will generally be a difference between summation and check characters, thus providing the means for error detection. A small degree of correction is possible by virtue of the fact that not all of the 32 character code combinations are used on this link. The use of the check characters enables all single errors to be detected. Of double errors, 91% can be detected; those which cannot be detected include transposition errors where a "1" becomes "0" and a "0" becomes "1" in the same column in the addition. Of triple errors, 99% can be detected and of quadruple errors, 95%.

Although it would have been sufficient to transmit a single check character derived from the 5 least significant bits in the addition, giving probability figures not very much different from those quoted above, the transmission of both check characters does remove a problem. This occurs when there are some ships in the net which are fitted with MIDGE and some which have not yet been fitted. Since the latter will have to resort to making up tapes if they are to take part in the net, it cannot be expected of them to determine manually the check characters. It has therefore been proposed that in such ships the two check characters be replaced by two figure sevens, so that the computer can recognise that such a transmission emanates from a non-MIDGE ship. The highest binary number which can be obtained from the summation of 21 five-bit binary numbers is 11001, 11111, most significant digit first, which assumes that all 5-bit numbers are 11111. In fact, a message will not consist of all letter-shift characters (i.e. 11111) and since, of the characters used, a figure one is represented by the highest 5-bit binary number in the teleprinter code, the highest number in the summation will not exceed 17 times 11101, plus the message preamble, i.e. 10000, 10100. Two figure sevens in 5-unit code would be 11100, 11100, which is a higher binary number than can be achieved in the summation process. As it is possible for the 5 least significant digits in the summation to simulate a letter-shift character, 11111, a figure-shift character is included in the message preamble. This ensures that the monitoring teleprinters at transmitting and receiving ends of the link revert to "Figures" in time for the next message should a letter-shift character be simulated in the summation. At the receiving end, the figure-shift character also gives the monitoring teleprinter a chance to revert to figures for the following message if a letter-shift character is produced as a result of propagation errors in any character during a message.

8. DISCRETE ADDRESS (NATO LINK 4)

"Discrete Address" is the name given to the mode of operation employed in the control of interceptor aircraft, via a digital data link designed for use on frequencies in the V/UHF band 225 Mc/s to 400 Mc/s. Each aircraft is addressed by means of a discrete "call-sign" which is allocated to that aircraft only, hence the name. Thus any message which is prefixed by the digit combination representing the address code of a particular aircraft is accepted, translated and acted upon if necessary, by that aircraft alone.

Time is divided into alternating 14 ms and 18 ms "slots". During a 14 ms time-slot the controlling station transmits a 70-bit message to an aircraft, whilst during an 18 ms time-slot the aircraft makes a 56-bit reply if required. The longer period for the reply is provided to ensure adequate clearance between messages, in order to cater for different propagation delays between various aircraft and the controlling station. The agreed bit rate for this link is 5000 bits per second, which does not conform to the preferred formula $2^n \times 75$. The form of modulation adopted is FSK as in the case of Link 12, wherein a binary 1 is represented by a carrier frequency deviation of +20 kc/s, whilst a binary 0 is represented by a deviation of -20 kc/s.

As in the case of Link 12, synchronism is achieved on a start-stop basis, so that each message must be preceded by a special synchronising sequence. For Link 4 this consists of a 13-bit sequence, the first 8-bit periods being made up of reversals between +20 kc/s and -20 kc/s, each being transmitted for half a normal bit period of 200 μ s. These are followed by a 4-bit period, consisting of a continuous -20 kc/s deviation, equivalent to 4 successive binary zeros, whilst the 13th bit period is occupied by a +20 kc/s deviation, or binary one. In order to give an aircraft time to formulate a reply, when one is required, the reply message is transmitted by the aircraft in the next 18 ms slot but one following the 14 ms message from the controlling station.

The construction of the 70-bit, "Ground-to-Air" message is as follows:-

<u>Bit No.</u>	
1 - 13	Synchronising sequence
14 - 26	Address
27	Message Origin
28 - 32	Control Message Number and Label
33	First Parity
34 - 49	Information
50	Second Parity
51 - 66	Information
67	Third Parity
68 - 69	Information
70	Guard Space(Transmitter Off)

The construction of the 56-bit "Air-to-Ground" reply message is as follows:-

<u>Bit No.</u>	
1 - 13	Synchronising sequence
14 - 16	Reply Message Number and Label
17 - 26	Information
27	Message Origin
28 - 40	Information
41	Programme
42 - 55	Information
56	Guard Space

In R.N. computer-fitted ships which are required to be capable of aircraft control via this link, the information contained in bits 14 to 69 inclusive will be formulated in ADA. These will be passed to a peripheral equipment whose function in the transmit direction will be to accept the data bits from ADA in parallel form and convert them into a serial sequence at the required bit rate. At the same time it will complete the message format with the addition of the synchronising sequence and bit 70, which can be either a binary "1" or "0" as convenient

in the design, since it carries no useful information. In the receive direction the data terminal equipment must accept the 56-bit reply message and correctly synchronise and extract the data bits 14 to 55. These bits are then converted to the required parallel form for passing to ADA. The serial/parallel conversion process in either direction is rather like that carried out in RJA(1) (DPT) and the amount of logical circuitry should be about the same.

9. COMPATIBILITY PROBLEMS

The compatibility problems generated by the introduction of automation and data links are manifold and complex. They can be generally sub-divided as follows:-

(a) Intra - R.N. in which, because of the time it takes to fit all ships with new equipment, there is the compatibility problem between ships fitted and those not fitted.

(b) Inter-Service, in which compatibility problems arise in Joint-Service operations, because there has been a tendency in the past to develop data links along quite different paths by each Service.

(c) International, into which both (a) and (b) problems can be translated.

In the first category, the ships not fitted with a new Data Link equipment will be those which have only Voice or RATT as their means of communication - apart from morse, which is tending to be relegated to emergency use only - or else in a few instances those which have been fitted with a data link equipment which is rendered obsolescent by the advent of the new equipment, e.g. DPT Links 14A/14B have been evolved in an attempt to solve this problem, they exploit the existence of RATT equipment and basically do not require additional new equipment to be fitted in order to participate on such a link. The MIDGE proposal was made in order to improve the situation at the transmitting end, at much lower cost and with fewer installation problems than would be the case with the provision of more sophisticated automatic equipments. In the case of the relatively few ships fitted with a form of C.D.S. and DPT Transmission and reception, or just the latter, a somewhat more sophisticated means of data transmission is available. The compatibility problem here, which is now being dealt with, arose from the decision to install ADA and the TIDE Link 11 equipment; it has been solved, without the need for modifying or introducing new equipment in the CDS/DPT ships, by developing a new equipment, RJA(1), for ADA fitted ships.

In category (b), Joint-Service discussions are presently being held, in order to resolve the problems incurred by the considerable divergences in the independent development of different data links. The problems are many because of the differently fitted ships which will remain in service with the R.N. for several years to come, any of which may be directed to take part in Joint-Service operations, such as those in Kuwait. It is probable that Link 13 will provide the main R.N. and NATO ship-to-shore data link facility, with Link 4 Discrete Address being used for the Joint control of aircraft, when it becomes available. There will however, still be the problem of compatibility with CDS/DPT fitted ships.

In category (c), compatibility with other NATO countries will be achieved mainly via Link 13, assuming the successful outcome of the present Link 13 trials, except in the case of the U.S.N. perhaps, who intend to make Link 11 their most widely-fitted data link. However, they have recently stated an interest in Link 13 should the trials be successful in showing that the proposal for the characteristics

of this link will meet the operational requirement. In the absence of either Link 11 or Link 13, Links 14A/14B will have to be resorted to, or else conventional voice and RATT communications will have to be used.

Figure 4 illustrates, in block-schematic form, the data links which are being provided in H.M.S. EAGLE's current modernisation. Figure 5 is an artist's impression of the proposed new carrier, which is imagined fitted with all the data links discussed in previous sections, in company with other ships between which the links are operated.

10. FUTURE POSSIBLE DATA LINKS

In Joint-Service operations it is desirable, from the R.N. point of view, that in the working of a ship-shore data link the shore station should take part in a data transmission as a "ship" in the net. This means that in the case of Link 11 (5A), or Link 13 (8A), if the latter eventually uses the same net modes as Link 11, the computers in the shore terminal would need to be programmed so as to cope with the complicated netting procedure used in the Net Modes concerned. Economic and other factors may, however, limit the permissible complexities allowed in the shore-based terminal equipments, so that a simpler two-way point-point data link without such complicated netting procedures may be required.

Consideration has recently been given to the fitting of ADA in nuclear submarines and to the provision of suitable data links to exploit the capabilities of the submarines to the full. The problem of providing such links is rendered more difficult by the fact that, ideally, communication is required whilst the submarine is submerged; at long ranges, requiring the use of HF transmissions, it is further aggravated by the severe restrictions on the number of HF transmissions which can be made from a submarine, because of the aerial bandwidth and siting problems. The design of a suitable broadband aerial for submarines is still not within sight of being solved.

Considerable efforts have been made to solve the submarine communication problem. Investigations have been made into the use of acoustic links for submerged operations, but the ranges obtainable are not reliable because they depend upon sea conditions, which vary considerably. The use of acoustic links is likely, therefore, to be restricted to use over short ranges of the order of a few miles or so, such as will be involved in the close escort role. Under exceptionally good conditions ranges of up to about 30 miles may be achieved and exploited. For longer ranges of up to 100 miles or more HF communication must be used, pending a break-through using more sophisticated techniques, such as underwater electromagnetic transmission using ultra-low frequencies, which can however only be used with very low keying rates, e.g. 1 cycle in 10 seconds.

The use of HF means that the submarine must either raise an aerial above sea-level or tow a communications buoy, in either case the risk of visual detection is greatly increased. The use of HF itself increases the risk of detection by direction-finding equipment. It appears therefore that, in order to minimise the amount of time a submarine needs to spend at or near the surface, a high-speed data link is essential. Until the broadband aerial problem is solved, it has been proposed that I.S.B. (Independent Side-Band) transmission be exploited, in order to provide two HF channels simultaneously, one of which could be used for a data link. However, if the other channel is to be used quite independently of the data link, it follows that the radio transmitter would have to be left in the switched-on condition all the time that transmissions were required to be made on either channel.

Consequently, the data channel could not be used in a Net mode, as with Link 11 or Link 13, because these nets normally use a common frequency for transmission and reception by all participants. In a submarine reception cannot take place on the same virtual carrier frequency as the I.S.B. transmission, because of the separation problem in the receiver. Reception of the two channels must be on a different frequency from that used for transmission, or on two different frequencies, if the reply channels are from different sources. In addition, the level of cross-talk in the data channel, due to the other channel, when the data transmission from the submarine was required to be in the "off" condition could, in one of the receiving ships in the net, exceed the level of the signal from a ship transmitting from a greater range. For example, a cross-talk figure of 60 dB, which is exceedingly good, could be inadequate by 15 to 20 dB for range differences of 100 miles or more, if the well-known inadequacies of radiation patterns of shipborne aeriels are also taken into account. This is particularly the case if the submarine were less than about 40 miles from any of the ships in the net. Until the broad-band aerial problem is solved, therefore, the submarine data link will have to be a two-way point-to-point one between the submarine and a suitable surface vessel, unless the HF transmission can be allowed to be used solely for the data link. Whilst this may be possible in some limited circumstances, in general it will be desirable to use the other channel for other HF communication needs, if only as a voice support link to the data link.

No concrete proposals have yet been made for a two-way point-point data link, but it has been suggested that since the new ADA/DPT equipment is capable of operating as a simultaneous two-way point-point link, it could be exploited for this purpose. TIDE-type messages could be passed via the ADA/DPT equipment without any modifications to the equipment. It would be necessary to programme the computer so that it could present information to the RJA(1) equipment in one of two modes of operation. One of these would be the normal DPT mode which requires 18-bit words to be passed from the computer, 4 such words constituting a DPT Target Cycle. Every 50th Target Cycle contains a special 28-bit Synchronising Signal. In the second mode each 18-bit word would include a 15-bit TIDE word, as in the case of the Link 11 equipment, 2 such words forming a TIDE Frame of 30-bits, and 2 Frames, or 4 words, forming a TIDE message. The remaining 3 bits of the 18-bit word in the second mode would need to be any combination of 1's and 0's except 000 and 111 to prevent the false simulation of the special synchronising signal in ordinary messages. The synchronising signal would also be required in the second mode. The advantage of using the DPT equipment for passing TIDE type messages is that the same error detection and correction method would be applicable as for TIDE Links 11, 12 and 13, whereas the normal DPT signals do not include error detection and correction bits.

Another possible data link requirement is for the control of blind landing of aircraft, for which the Discrete Address link could be adapted. Looking further into the future, considerable activity is going on at present concerning the introduction of a standardised teletype character, which will have 7 or 8 bits, as opposed to the present 5 bits. One serious contender is a modified form of the so-called A.S.I.I. code (American Standard for Information Interchange). There is much pressure in the U.S.A. to adopt such a standard for a ground-air-ground data link for the control of all aircraft, both civil and military. This proposal is strongly supported by the U.S.A.F., but the U.S.N. position has yet to be formally resolved. Whilst the U.S.N. would have to conform to the agreed code for aircraft applications, the current view appears to favour Fieldata code for general usage, should an 8-unit code be adopted. Whilst the R.N. concur in principle with the need for a code of this kind for general purposes, there are considered to be very strong objections to its use for high-speed data links transmitting real-time data. The main objection is excessive redundancy and consequent loss of data rate; this is regarded as a serious limitation in the case of HF circuits, where the available

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bandwidth is used in some instances to the maximum practical capacity. The time-scale for the proposed ground-air-ground data link is 1970. Its introduction would probably render the presently planned Discrete Address link (NATO Link 4) obsolete.

11. ACKNOWLEDGEMENTS

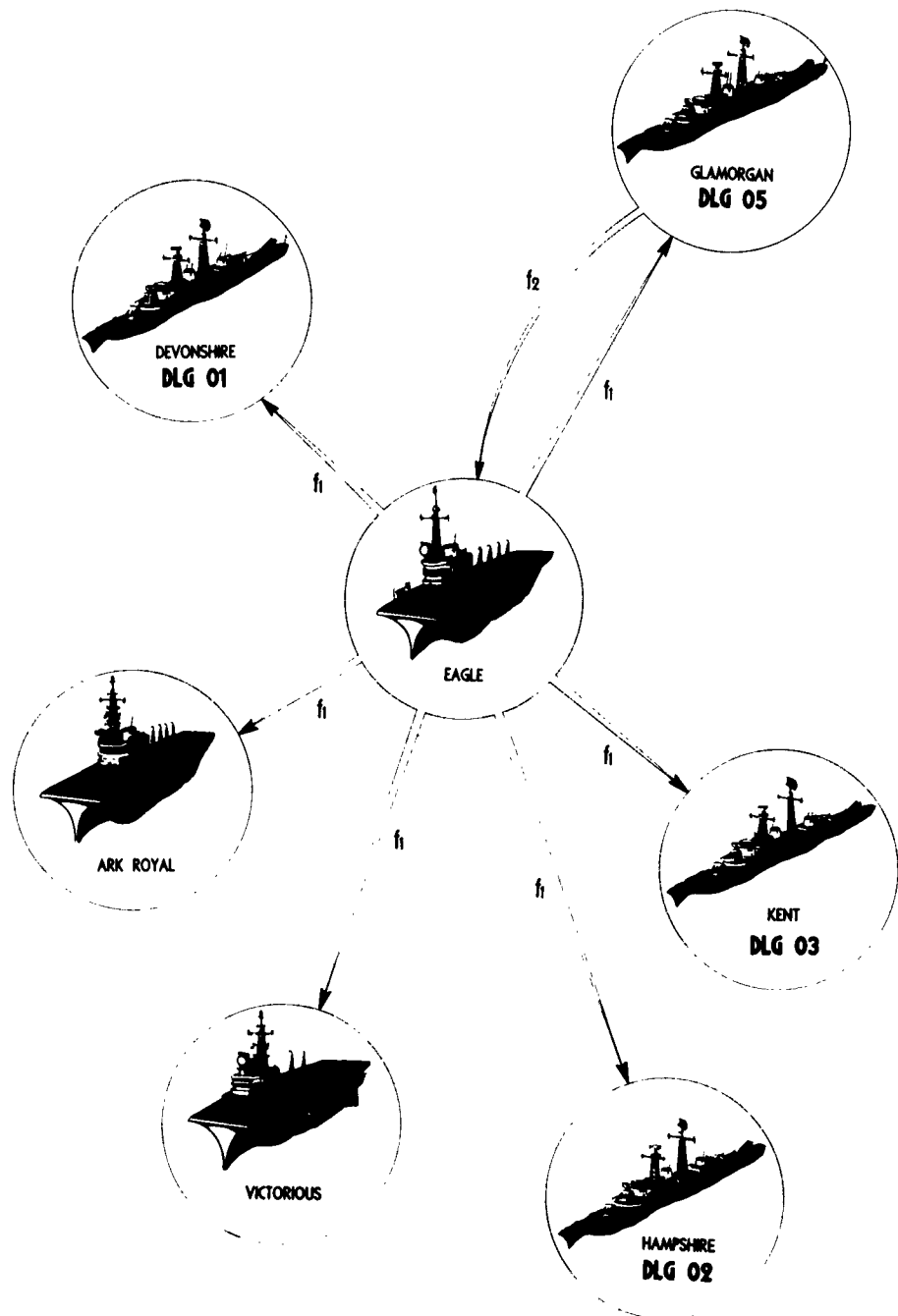
The assistance of Mr. P. E. Yeo in preparing the drawings and the helpful comments of Mr. F. A. Kitchen who criticised the draft are gratefully acknowledged.

12. REFERENCES

1. Hamming, R. W. "Error detecting and error correcting codes".
B.S.T.J., Vol. 29, No. 2, April, 1950, p.147.

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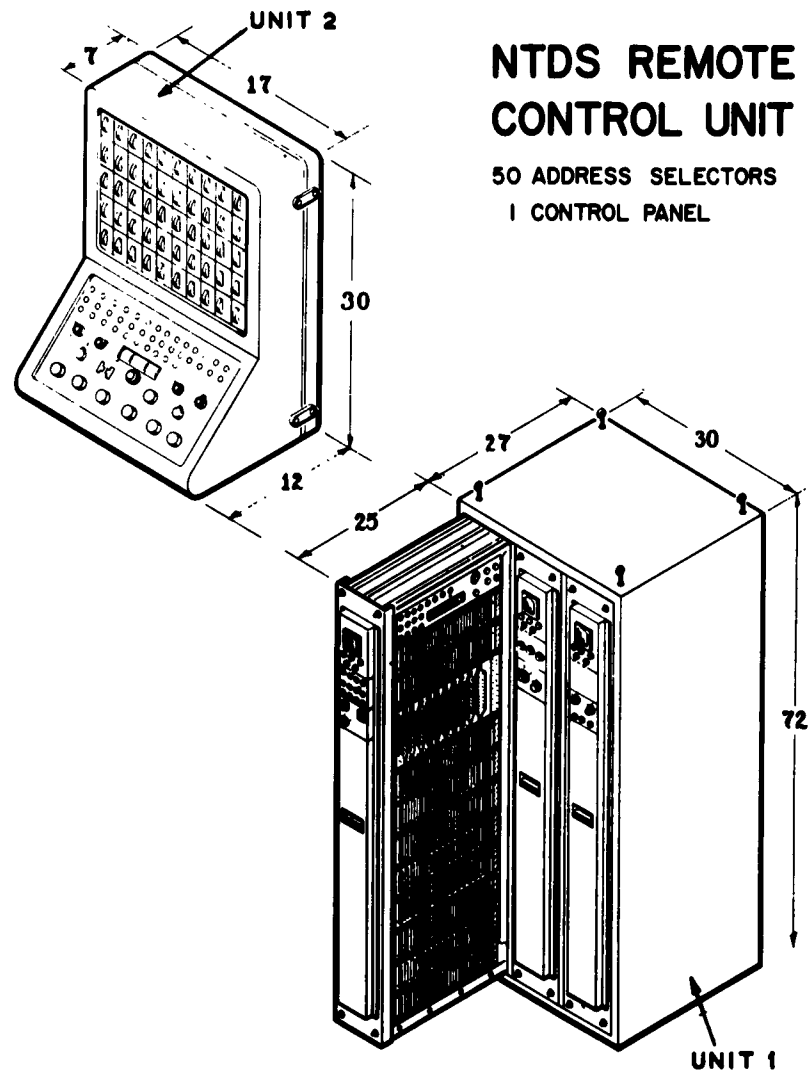
DLG — GM SHIPS

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FIG. 1—DPT NET

L62/772

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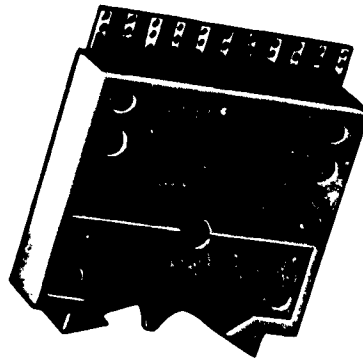
AN/SSQ-29 NTDS CABINET ASSEMBLY

3 SLIDE MOUNTED EQUIPMENT RACKS PER CABINET
39 CARD CHASSIS OR EQUIVALENT PER CABINET
24 PRINTED CIRCUIT CARDS OR EQUIVALENT PER CARD CHASSIS
936 PRINTED CIRCUIT CARDS OR EQUIVALENT PER CABINET
900 POUNDS TOTAL PER CABINET

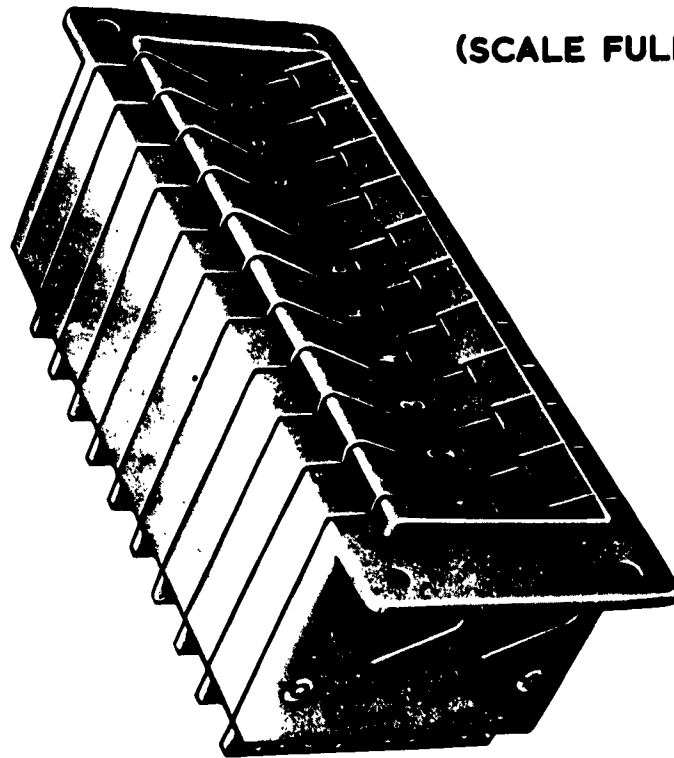
FIG.2

SR1,516

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(SCALE FULL SIZE)



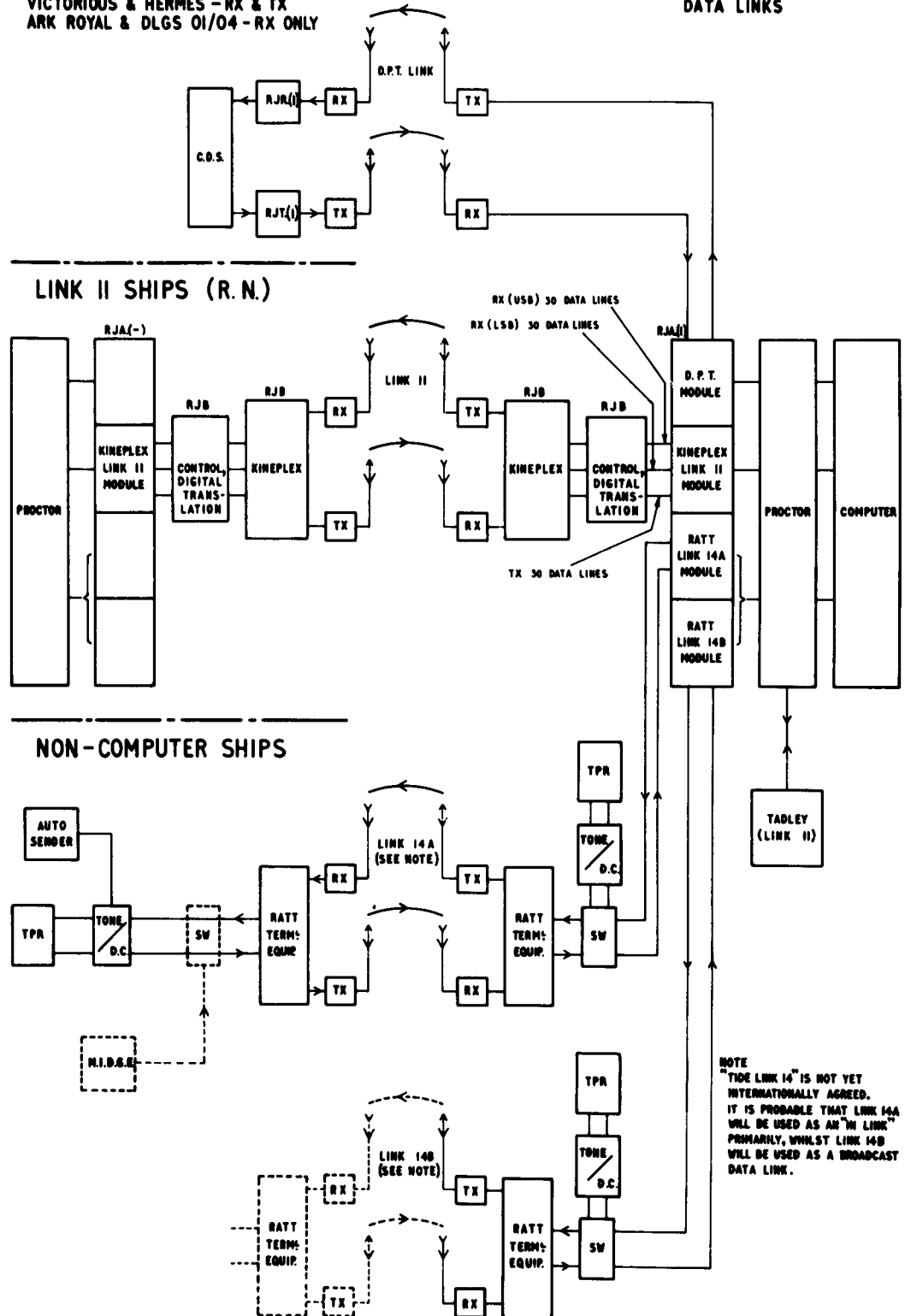
TYPICAL EDGE-READING
INDICATOR SWITCH
AND ASSEMBLY

FIG. 3

C.D.S. SHIPS
VICTORIOUS & HERMES - RX & TX
ARK ROYAL & DLGS 01/04 - RX ONLY

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H.M.S. EAGLE
DATA LINKS



DRG. No. 254619.

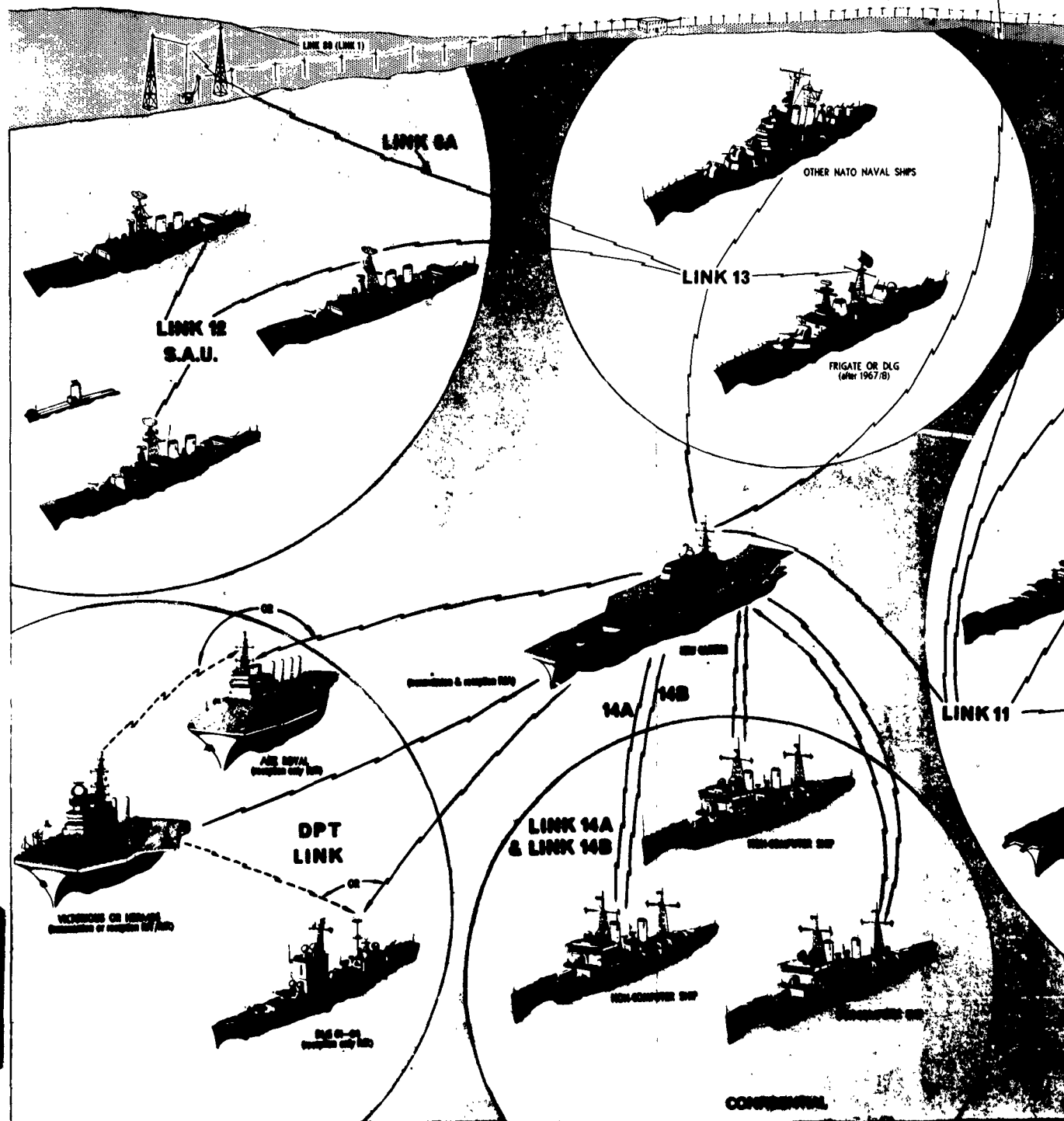
EAGLE DATA LINKS

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FIG. 4.

SECTOR OPERATIONS CENTRE

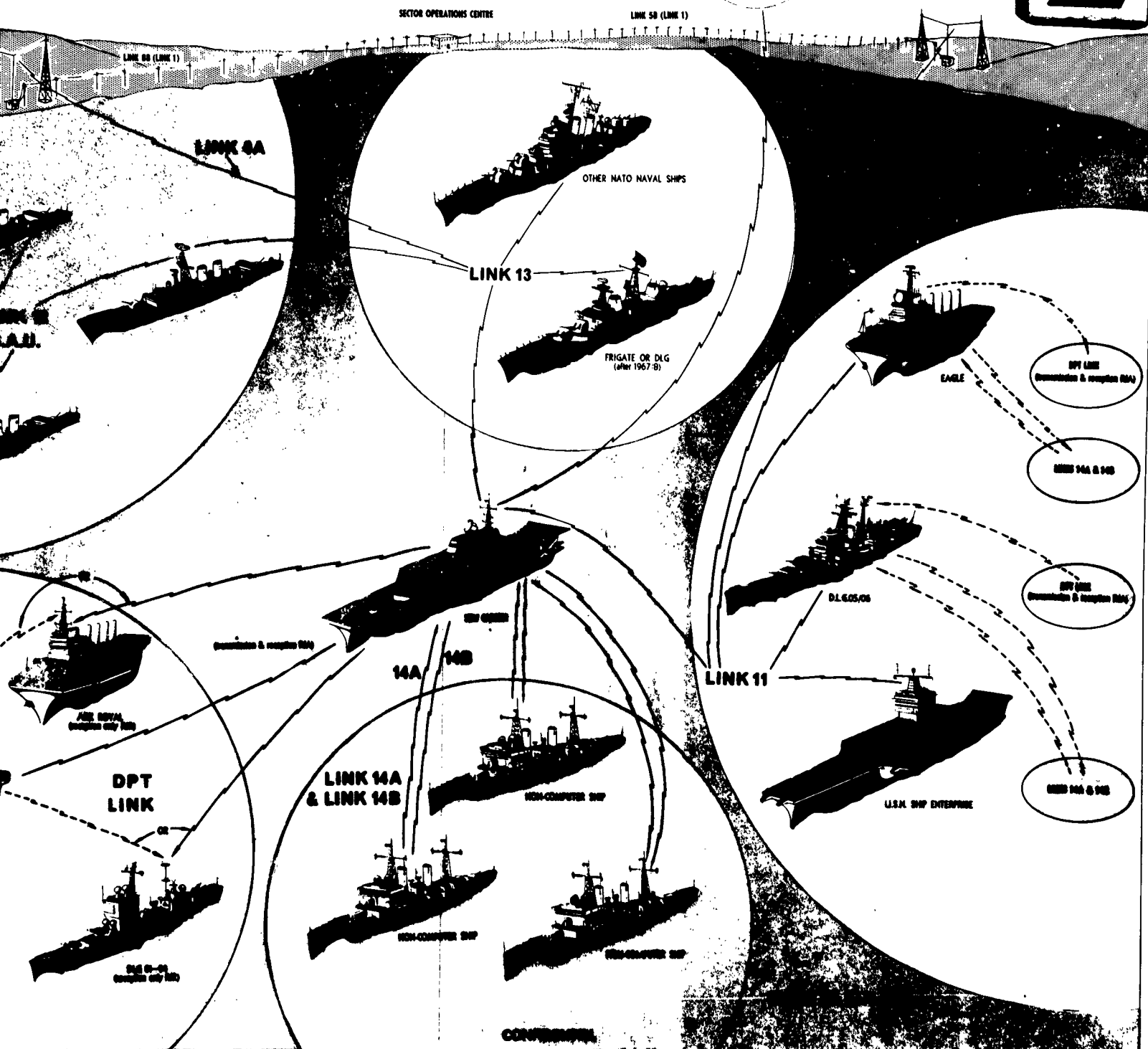
LINK 50 (LINK 1)



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1

BACCHETTI ADDRESS
(LINK 4)





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AD#: AD337254

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