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HOME OFFICE

Directorate of Telecommunications

(MR4) Mobile Radio Systems Planning Group

AERIALS AND ANCILLARY INFORMATION

WARC Aerial Guidance Notes

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AERIALS

AND

ANCILLARY INFORMATION

WARC Aerial Guidance Notes.

Issue 1

Radio Mast Design Team
MR 4 Group
HQ Directorate of Telecommunications
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APPENDICES

Introduction.

Area coverage Broadcast Patterns from radio sites fall into two basic categories; Omni-directional and Directional. The purpose of this document is to illustrate the various options available to systems engineers to achieve both omni-directional and special coverage patterns by use of transmitter combining and aerial sharing techniques.

Details of "GO" path equipment parameters required for post-Warc services are defined in Sect GN4 of the Guidance Notes for Radio Planning Engineers issued June 1983. (App 6).

Single channel per site services will easily attain the target estimated radiated power (e.r.p.) of 63 Watts using a single well placed aerial, i.e. prime position at the top of the mast. However, the great majority of Home Office sites have more than one sponsored user; most utilising more than one channel per site.

To attain the required area coverage for each of the users on one site now becomes a trade-off between the actual aerial accommodation available and the power of the transmitters, in this case 100 Watts (mean). Lack of tower space compels aerial sharing with its associated power losses.

Other factors must also be considered such as the actual radiation patterns of aerials not at prime positions, physical constraints of the tower structure and the electrical effects of the tower at the frequency being broadcast.

Similar constraints must of course be equally considered for the "RETURN" path. (Sect GN4 defines.)

Omni-directional Patterns.

It is generally understood that all aerials with reflector elements or panel assemblies are directional. However, the normal Home Office single broadcast folded dipole on the side of a steel tower can also exhibit marked directional properties dependant on its position in relation to that structure.

Omni-directional patterns in their true sense can usually only be realised using prime position (top of tower) aerial(s) or combinations of aerials in circular arrays. Such arrays may be used for providing a launching base for single or multi-channel signals depending on radio equipment combining techniques and array feed networks. Application of these arrays remain constrained by overall system parameters and deciding factors include available vertical accommodation and dimensioning on towers, wind loading characteristics and electrical requirements. For example, on the higher frequency bands the physical size of the tower has a significant effect on the horizontal radiation patterns, this being due to the overall geometry of arrays in relation to the wavelength in use.

Pattern Parameters.

The basic planning parameters to achieve a designated area coverage pattern are described in GN4 which is reproduced in Appendix 6. In transmitter aerial systems the e.r.p. required in any pattern minima in the coverage area is defined as 63 Watts. Because of system losses e.g. feeder, filter and hybrid transformer losses, gain is usually required from the aerial system to achieve this minimum e.r.p.

Depending on the tower in use it is not always possible to provide the necessary aerial gain. In these cases the absolute minimum e.r.p. can be as low as 25 Watts. An example power budget is as follows:

Multi-channel site where Omni-directional patterns are required:

Transmitter Power	100 Watts 20dBW (all channels)
Trans filter loss	1dB
Aerial feeder loss	2dB
Aerial tail loss	0.25dB
Hybrid matrix loss	0.25dB
Connector/term loss	0.5dB
Total	4dB net loss

Single Turnstile:

Max gain 0dB ref 1/2 wave dipole
Min gain -2dB ref 1/2 wave dipole

hence

Max erp = 16 dBW (40 Watts)
Min erp = 14 dBW (25 Watts)

In cases where this e.r.p. is insufficient the use of High Power Linear Amplifiers (HPA) is recommended to boost the transmitter output. These figures are increased by approximately 3dB when a double Turnstile is in use.

Generally speaking the maximum ripple thought acceptable over the main lobe of the designated coverage pattern is 2dB.

Tower Structures Under Consideration.

Classifications thought suitable for standard and WARC aerial fits are derived from the physical features of the tower under consideration.

Example classifications are:

A1/4/45/1.5 Standard 4 leg tower; 45 mtrs high; 1.5m face dim for upper 10 mtrs.
A1/3/45/1.5 Standard 3 leg tower; 45 mtrs high; 1.5m face dim for upper 10 mtrs.

The standard aerial arrays for use on A1/4 and A1/3 towers are classified to suit face sizes in the following ranges:

- less than 1.5m
- 1.5m to 2m
- greater than 2m

Other structures suitable for standard aerial fits are to be considered individually.

Aerials Available.

The aerials available are listed in section GN8 of the Planning Guidance Notes (App 6). Additionally to these lists a Dipole Panel aerial is available.

Brief Description of Omni-directional Arrays.

a) Turnstile.

Single tier of four dipoles on central post. Double turnstile has two tiers of dipoles on common post. Tiers can be electrically stacked as required or used independently. Fitted in prime position only. Up to four transmitters (three omni-directional) without the usual aerial combining losses, by use of a four port reciprocal hybrid matrix. 2dB overall ripple in pattern:

0 to -2 dB for single tier

3 to 1 dB for double tier

b) Dipole and Yagi circular Arrays.

Up to eight aerials in one tier, suitable polar diagram depends significantly upon overall array diameter and therefore upon tower dimensions. Unscreened dipole arrays not generally preferred due to the risk of exciting tower (rusty bolt) intermodulation products.Some installations may make use of the hybrid matrix unit described above.

c) Slot Panel.

Four units per tier on square towers, Three or possibly four on triangular towers, depending on tower dimensions. Maximum of two tiers on any one tower. A single unit panel has a gain of 8 dB relative to a 1/2 wave dipole.

d) Dipole Panels.

Up to four aerials per tier. Similar characteristics to slot panel but each aerial unit has a forward gain of 6dB.

e) Groundplane.

A groundplane array may be used as a simple alternative to the Turnstile although it has inferior electrical performance.

f) Simple Aerials.

In all cases the final default option on 'problem towers' is to use folded dipoles, one per channel. This places the site in the category of "Directional" and opens the way to high levels of Intermodulation Products. Before exercising such an option the planning objectives should be re-assessed. The following questions are posed:

1. Is an omni directional pattern mandatory? If so, is it for all channels?

2. Is a lower e.r.p. acceptable in any particular case?

3. Can a higher powered transmitter, linear amplifier or Multi-channel transmitter (on limited channels) be made available to drive simplified arrays?

4. If the band plan allows, can duplexers or an additional aerial tier be used?

Directional Patterns.

Directional patterns can be achieved from all of the above arrays by judicious use of combining techniques or separate feeders. In some cases directional patterns can be inherent in the array by virtue of power division, and RF field phasing and addition.

Combining Systems.

The general items in use for combining/splitting systems are outlined in GN8. All of these items may be incorporated into WARC aerial solutions, the hybrid matrix combiner having several useful applications. These may be summarised as follows:

1) Using four aerials in a defined array allows up to three transmitters to be combined to give good omni-directional patterns without the normal losses associated

with hybrid transmitter combining. The losses are overcome by the elimination of load resistors and vector addition in the RF field. A fourth transmitter may be incorporated but the pattern produced is directional and has limited practical use as a broadcast channel.

2) Combines up to four transmitters into one aerial.

3) Some combinations of 1) and 2) give good directional patterns suitable for special applications.

It is important to note that in the above configurations the unused matrix port must be loaded. 25 Watt load(s) will normally be fitted inside buildings fed from RG213/U feeder connected to the hybrid combiner, the inherent losses of this feeder forming part of the total load required.

System Design Examples.

Options for WARC aerial arrays are illustrated in App 1. Certain examples are suitable for both intended frequency bands. In general, due to tower size, multiple dipole and yagi tiers are restricted in use at 150Mhz and are normally only to be considered on small towers or as special alternatives. However, use of dipoles and dipole panels at 70Mhz provide viable solutions. The option title is designated by the type of aerial followed by the number of broadcast channels, number of tiers and a suffix indicating a Multi-Channel Transmitter.

Arrays can be initially allocated to structures by the table of App2 but the final fit is controlled by a combination of pertinent circumstances as outlined in the Aerial Planning Check List of 15/7/83 (App3), in particular sect 1.1 and sect 3. Careful consideration must be given to sect 3.3.1 as this will highlight the physical suitability of the feeders for any particular case.

Included in the Appendices is a ladder table of options rating the number of channels against the highest e.r.p. achievable.

Special Patterns.

These patterns are basically directional type patterns. The term 'special' when used colloquially tends to indicate a more precisely defined service area than normal i.e. a combination of remotely linked sites from a single source, or a 'sensitive' broadcast area.

RF Feeder Installations.

The increasing use of modern foam dielectric feeders eg. 'Heliax' etc., has emphasised that aerial and feeder installation has to be carefully adjusted within fine limits for each site, both in the matter of physical aerial placement and the supply of radio signals to aerials. Again, the type of tower structure has a decisive effect in the choice of feeder for that particular installation. Some constraints governing the installation of co-axial cable are as follows:

1) To reduce the risk of fracture, foam type cable is not to be rigged on tower legs. The more flexible cables URM67 and URM74 are better suited to this application.

2) It is apparent that there are problems associated with measuring and installing 'co-phased' feeder runs using the smaller diameter feeders. This is mainly due to the ability of the feeder to retain some curvature from the drum thus making it difficult to physically match long runs. Without physical matching, electrical phase matching becomes much more difficult especially under field conditions. The larger diameter feeders are better to manage in this respect being easier to straighten. Hence all co-phased runs exceeding 20 metres should be 7/8" heliax type or URM74. Co-phased runs of greater than 20 Metres should not be considered at 150Mhz due to the difficulties of phase matching at the higher frequency. For short lengths the approved technique is to make up the feeders complete before installation. Phase differences between equal length feeders of less than 20 metres are considered not significant enough to affect aerial patterns even after any installation 'stretch' has taken place. However, accuracy in matching lengths is essential and electrical phase/delay checks at the working frequency would be desirable using a T.D.R., Vector Voltmeter or Network Analyser if available.

3) On towers up to 45 metres at normal sites it is thought permissable to run 1/2" foam feeder clamped at a MAXIMUM distance of 1 metre. Above 45 metres cable fixing points must be reduced to a distance of 0.5 metre MAXIMUM. The fitting of a cable tray to allow this reduction between the standard fixing bars is acceptable if wind loading permits.

Alternatively the feeder runs must be made in 7/8" heliax or URM74 throughout. Consideration is being given to reducing clamping intervals to 0.5 mtr spacing on all Local Authority structures over their whole length.

4) Where link path losses are low the use of URM67/RG213U or RG214U is preferred. Alternative feeder types may be used where justified (see 7 below). Some relief from induced intermodulation products may be effected using RG214U double screened silver plated co-axial feeder. This has the physical properties of URM67/RG213U but achieves a level of screening similar to 1/2" foam feeder.

5) App 4 shows the items associated with 'foam' type installations. Note that Remclamp type R2 (5/8"-3/4") will accommodate LDF4-50 but does not grip effectively. The correct size is R1 (1/2"-5/8"). Remclamp R3 (3/4"-7/8") MHC 201 is suitable for use with URM74. Remclamp R5 MHC 203 is used for 7/8" foam cable. Where aerials are not earthed, all feeders to be earthed in accordance with current practice proposed by HQ FSPG section.

6) Improved connectors are being introduced to suit the multichannel WARC requirement and should facilitate easier installation. The DIN standard 7/16mm solderless type is being considered and although it is specifically intended for use with foam cables, options are available to suit other types such as URM74.

7) In accordance with current practice (DT 50/74/1 Issue 2) all aerial feeders should be earthed both at the upper end and at the building entry point. Earthing kits are available but careful consideration must be given to the integrity of the weatherproof seal required. In some cases LDF4-50 may be specified in preference to URM67 as the solid outer conductor allows ease of earthing whilst denying moisture access to the feeder core. This is not the case for URM67 and RG214U, both these feeders having braided outer conductors.

Aerial Installations.

There will be a new generation of coated aerials using welded construction. Elements of such aerials are susceptable to bending at the joints and care must be taken in the installation phase.

Experiments on a typical tower section of 1.5 metres section have shown that the positioning of aerials is critical when trying to achieve particular patterns. Such positioning must be related to the angle and distance from the structure (face or leg as specified) and also to any other aerials in an array.

TER information for installations will require to contain details of preferred fixing points, bearings or relative angles (if required), and distance off from structure eg. 'balun to tower' distance which may be different for individual aerials in an array. Additionally, information will be provided on the earthing and coating of 'Alachrome' finished aerials. A more detailed note on installation practices and preferences will be found at App 5.

Conclusion.

It is to be hoped that the foregoing paragraphs have highlighted some of the complexities of selecting the correct aerial option for a site as well as considering the items of hardware available. Many balancing factors must be considered and the 'fail to dipole' solution resisted as much as possible in the interest of providing the optimum solution to any particular problem.

The importance of the aerial engineering at this stage cannot be over-emphasised and it is essential that a suitable information feedback network is maintained so as to solve practical problems which will occur in the field.

AERIAL OPTIONS AVAILABLE

SUMMARY OF DESIGN EXAMPLES

AERIAL OPTIONS AVAILABLE

Area coverage may be directional or omni-directional as suited to the users operational needs. For reasons explained elsewhere some of the most difficult aerial systems to engineer are those designed to provide good omni-directional pattern from aerials mounted on the side of towers. The following examples therefore concentrate on omni-directional array's or hybrid configurations where different channels are given specific patterns from specific aerial array.

The following diagrams give typical performance figures for transmitter driven array's. Most array's are designed to be reciprocal and when used as receiving aerials performance is similar. In all cases the aerials and their ancilleries should be tuned to operate over the frequency band in use. In duplexed systems a compromise is necessary and preference is usually given to the VSWR over the transmit band. Receive losses incurred are generally less tham -1dB relative the transmit path, which is acceptable.

The maximum number of transmit channels associated with any omni-directional aerial system is usually limited to two due to the hybrid combiners that will be in use. An exception to this rule is the turnstile aerial and butler matrix combination which allows 3 transmitters to be combined without resistive losses. Two turnstile aerials are available, the double tier with an inherent gain of approx 3dB and the single tier with unity gain. The pattern ripple is within 2dB and depending on circumstances the turnstile may be used with maximums of 3 or 6 channels. In addition the multichannel transmitter may be used with any suitable aerial system.

Arrays of 4 slot panels symetrically mounted on a typical 1.5m width tower develop deep nulls in the pattern when driven with a 0,90,180,270 degree phase sequence. Therefore this array is generally unsuited for use with the butler matrix.

Horizontal radiation patterns for the arrays to be described have been measured on the sections test range located at Cheveley depot. Here a typical 10 metre length of 1.5 metre parallel tower section top section has been installed to rotate between bearings such that pattern measuremants may easily be made. The patterns may be found in appendix 7.

The following examples are given :

1) SLOT PANEL ARRAYS

a) Single tier of 3 panels on triangular tower. (fig 1)

b) Single tier of 4 panels on square tower. (fig 2)

c) Single tier of 4 panels on square tower with duplexer.(fig 3)

d) Single tier of 4 panels on square tower operating with two duplexed channels. (fig 4)

e) Single tier of 4 panels on square tower with two channels using alternative method based on tower hybrid unit. (fig 5)

f) Two tiers of 4 panels operating as independent transmit and receive aerial arrays. (2 channels) see (fig 6)

g) Single tier of panels operating with two channels and providing different radiation patterns for each. System may be used in either transmit, receive or duplexed service. The array may be extended in multichannel service by adding the appropriate combiners etc. at each input.

In this example the coverage is almost omni-directional for one input and confined to a 90 degree sector for the other. All panels are driven in phase, however nulls may be introduced by introducing phase shifts between the panels as a method of "fine tuning" the array. (fig 7)

h) Single tier of 4 slots similar to (g) above but for providing North & South coverage. (fig 8)

i) Single tier for providing broad beam to N.W. for one input and omni-directional but reduced to N.W. for other input. (fig 9)

(Figure 14 shows a comprehensive POST WARC system planned for Ilkley Moor.)

2) Turnstile systems.

a) Single turnstile with 3 channels. (fig 10)

b) Double turnstile with 3 channels. (fig 11)

c) Double turnstile with 6 channels. (fig 12)

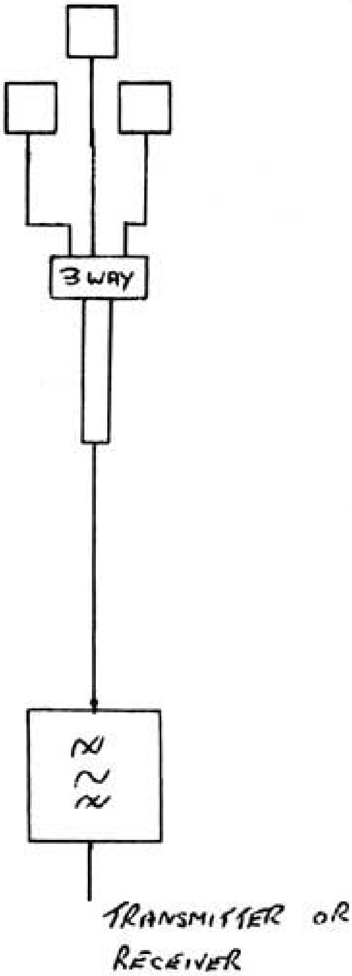
3) Multichannel transmitter with six channels operating in duplexed mode.Shown with two tiers of 4 slot panels.(fig 13)

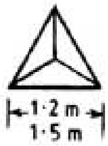
A.1.4

A1/3 SLOT PANELS

SINGLE TIER SP-/1

FIG 1





SYSTEM LOSS BUDGET

ITEM	dB
AE TAILS	-0.25
HARNESS/ MATRIX	-0.25
FEEDER	-2
FILTER	-1.5
HYBRID	-
TOTAL	-4
TX P_{out}	+20 dBW
TOTAL	+16 dBW

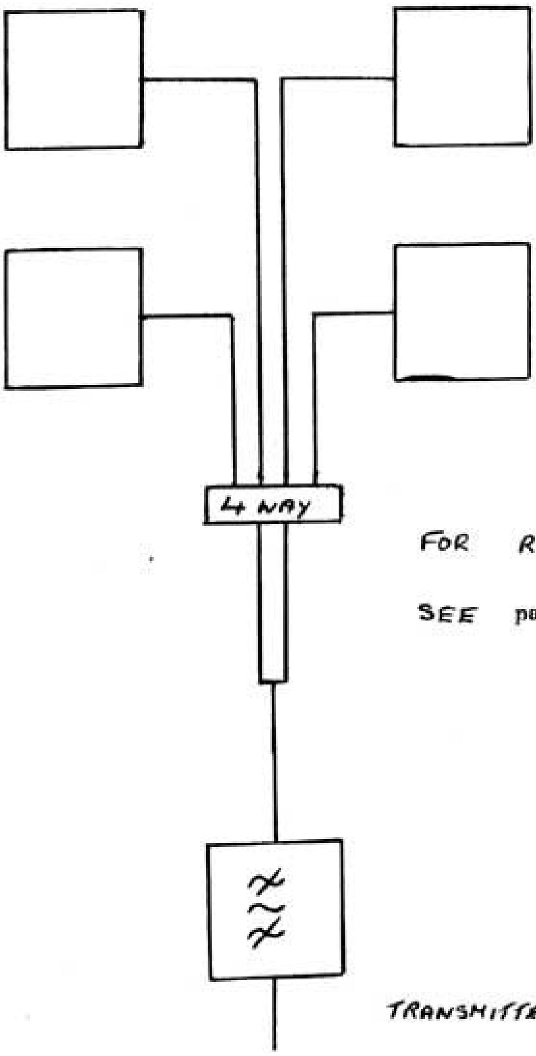
	MAX	MIN
AERIAL dB	+2	+1
SYSTEM dB	+16	-
ESTIM. ERP	+18dBW	+15 dBW
	63 W	32 W

over the main lobes

A.1.5

SINGLE TIER OF 4 SLOT PANELS

FIG 2



FOR RADIATION PATTERNS SEE page 77.

TRANSMITTER OR RECEIVER

SYSTEM LOSS BUDGET in dBs.

Item	
Filter	-1.5
Ae Tails	-0.25
Harness	-0.25
Matrix	-
Feeder	-2
Hybrid	-
Duplexer	-
TOTAL	-4

Estimated	Max	Min
Aerial gain (dBd)	+2	0
SYSTEM NET LOSS	-2	-4
erp with 100W transmitter is :	63	40

in watts over the main lobes

A.1.6

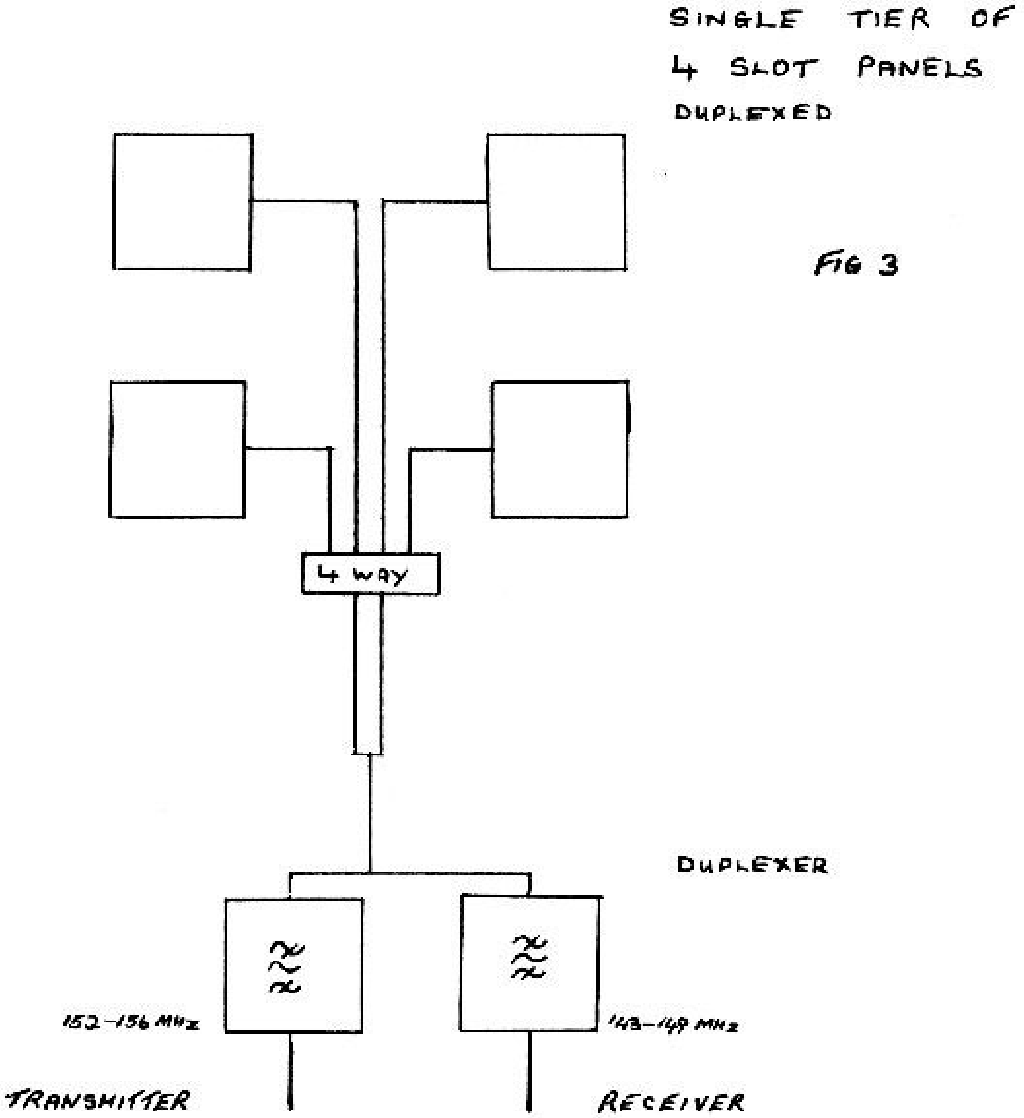


FIG 3

SYSTEM LOSS BUDGET in dBs.

Item	
Filter	-
Ae Tails	-0.25
Harness	-0.25
Matrix	-
Feeder	-2
Hybrid	-
Duplexer	-1.5
TOTAL	-4

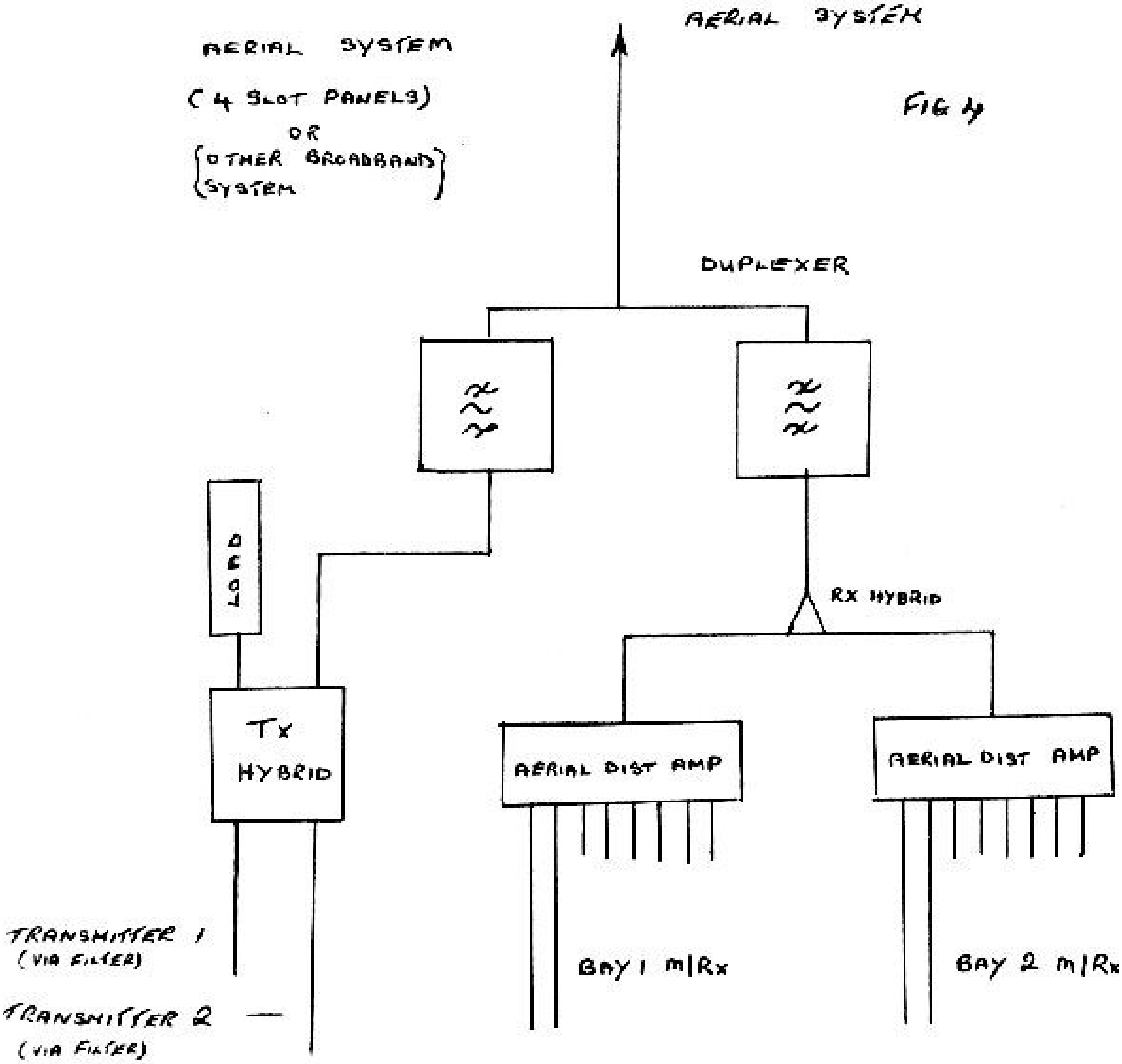
Estimated Aerial gain (dBd)	Max +2	Min 0
SYSTEM NET LOSS	-2	-4
erp with 100W transmitter is :	63	40

in watts over the main lobes.

A.1.7

TWO CHANNEL SYSTEM FOR SINGLE AERIAL SYSTEM

FIG 4



SYSTEM LOSS BUDGET in dBs.

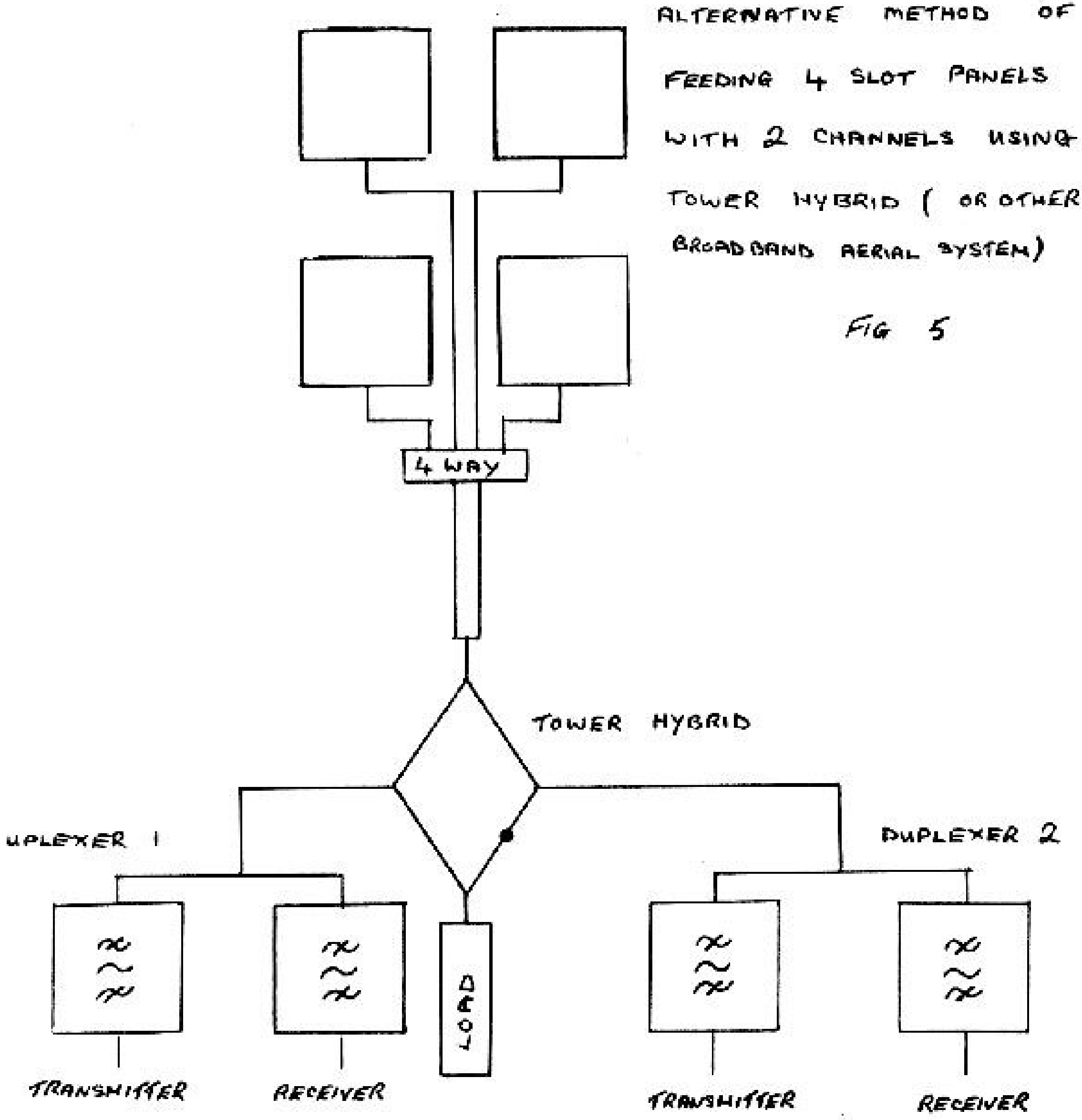
Item	
Filter	-1.5
Ae Tails	-0.25
Harness	-0.25
Matrix	-
Feeder	-2
Hybrid	-3
Duplexer	-
TOTAL	-7

Estimated	Max	Mi
Aerial gain (dBd)	+2	
SYSTEM NET LOSS	-5	
erp with 100W transmitter is : in watts over the main lobes.	32	2

A.1.8

ALTERNATIVE METHOD OF FEEDING 4 SLOT PANELS WITH 2 CHANNELS USING TOWER HYBRID (OR OTHER BROADBAND AERIAL SYSTEM)

FIG 5



SYSTEM LOSS BUDGET in dBs.

Item	
Filter	-
Ae Tails	-0.25
Harness	-0.25
Matrix	-
Feeder	-2
Hybrid	-3
Duplexer	-1.5
TOTAL	-7

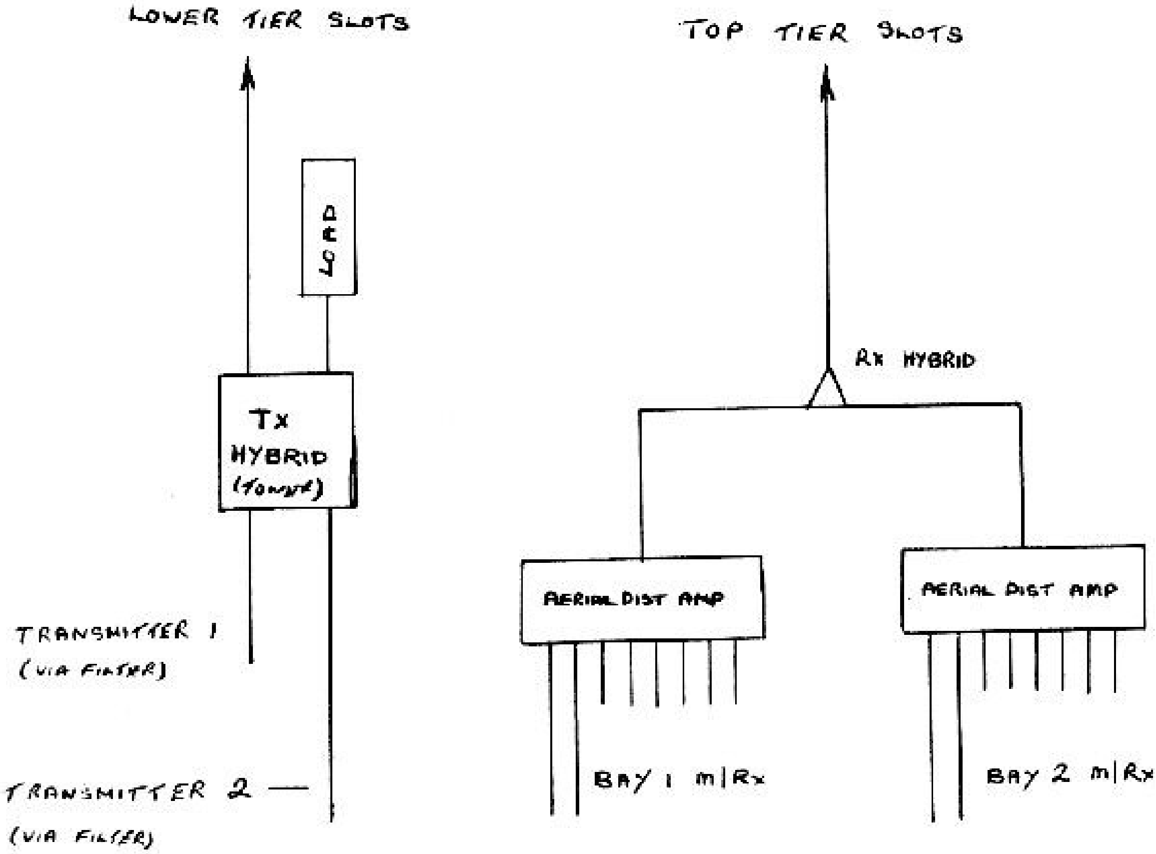
Estimated Aerial gain (dBd)	Max	Min
	+2	0
SYSTEM NET LOSS	-5	-7
erp with 100W transmitter is :	32	20

in watts over the main lobes.

TWO CHANNEL SYSTEM FOR

TWO TIERS OF 4 SLOT PANELS

FIG 6



SYSTEM LOSS BUDGET in dBs.

Item	
Filter	-1.5
Ae Tails	-0.25
Harness	-0.25
Matrix	-
Feeder	-2
Hybrid	-3
Duplexer	-
<u>TOTAL</u>	-7

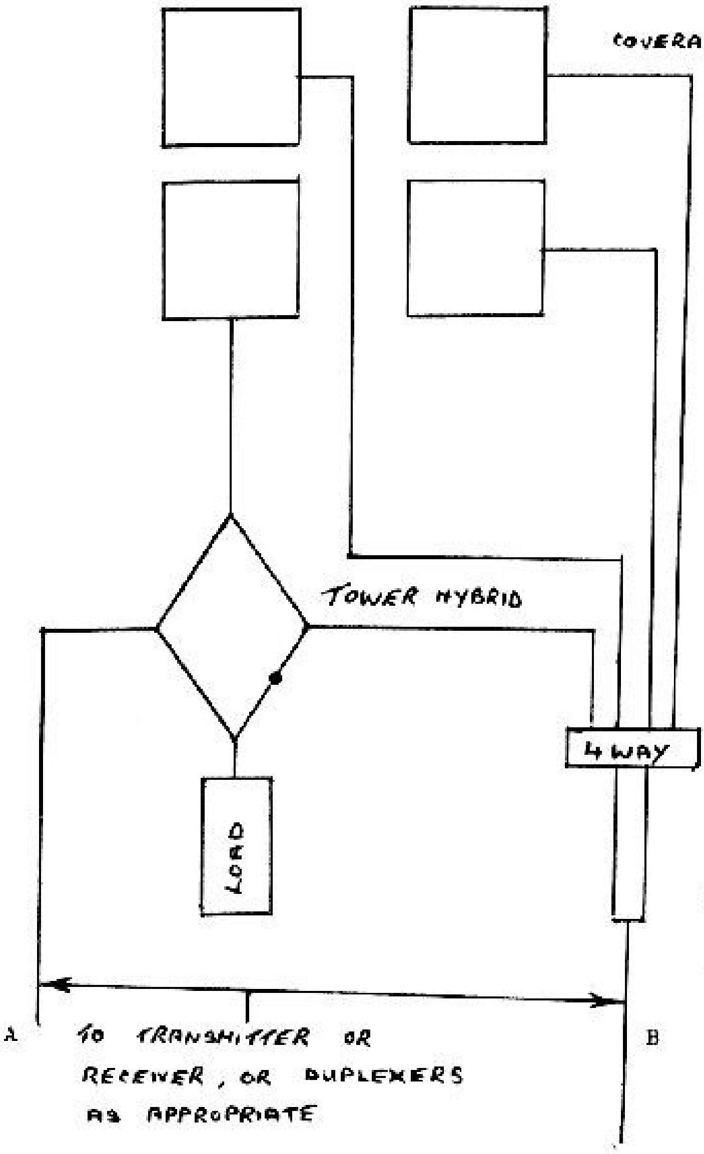
Estimated	Max	Min
Aerial gain (dBd)	+2	0
SYSTEM NET LOSS	-5	-7
erp with 100W transmitter is :	32	20

in watts over the main lobes.

A.1.10

METHOD OF PROVIDING OMNI-DIRECTIONAL COVERAGE & 90° COVERAGE FOR TWO INDEPENDANT CHANNELS

FIG 4



FOR RADIATION PATTERNS SEE Page 78

SYSTEM LOSS BUDGET in dBs.

Item	A path	B path
Filter	-1.5	-1.5
Ae Tails	-0.25	-0.25
Harness	-0.25	-0.25
Matrix	N/A	N/A
Feeder	-2	-2
Hybrid	-3	-3 or 0
Duplexer	-	-
TOTAL	-7	Max -7 Min -4

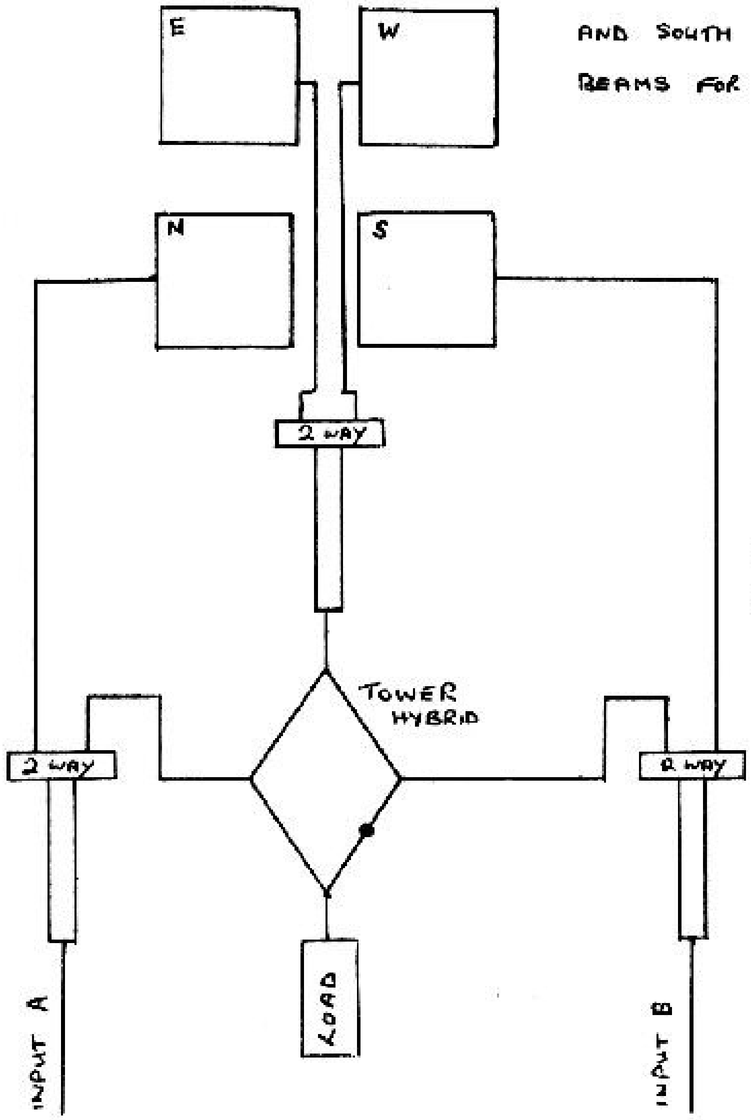
Estimated	A	B
Aerial gain	+8	+3
SYSTEM NET LOSS	+1	-1 to -4
erp with 100W transmitter is :	125	80 to 40

in watts over the main lobes

A.1.11

METHOD OF PROVIDING NORTH AND SOUTH COVERAGE WITH WI BEAMS FOR INDEPENDANT INPUTS

FIG 8



For Radiation pattern see page 79

SYSTEM LOSS BUDGET in dBs.

Item	A path		B path	
Filter	-1.5		-1.5	
Ae Tails	-0.25		-0.25	
Harness	-0.25		-0.25	
Matrix	-		-	
Feeder	2		2	
Hybrid	0 or -3		0 or -3	
Duplexer	-		-	
	Max	Min	Max	Min
TOTAL	-4	-7	-4	-7

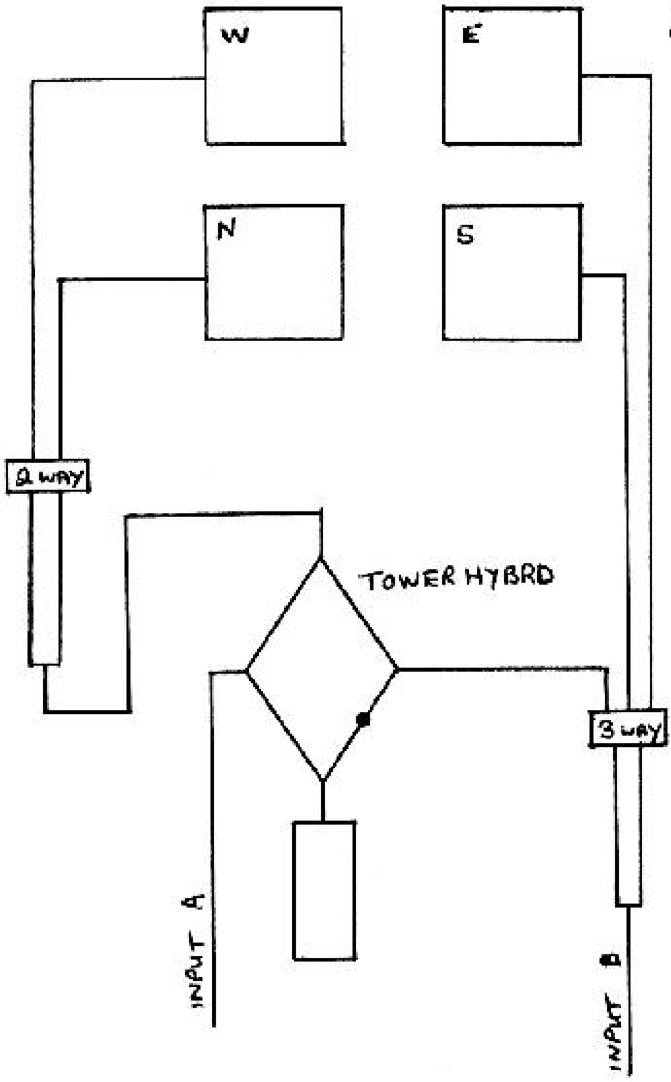
	A	B
Estimated Aerial gain	+5 to+2	+5 to+.
SYSTEM NET LOSS	+1to-5	-1to-

erp with 100W transmitter is : 125 to 32
125 to
in watts over the main lobes

A.1.12

METHOD OF PROVIDING OMNI-DIRECTIONAL COVERAGE FOR INPUT 2 AND WIDE BEAM TO N.W FOR INPUT 1

FIG 9



For Radiation patterns see page 80

SYSTEM LOSS BUDGET in dBs.

Item	A path	B path	
Filter	-1.5	-1.5	
Ae Tails	-0.25	-0.25	
Harness	-0.25	-0.25	
Matrix	N/A	N/A	
Feeder	-2	-2	
Hybrid	-3	0 or -3	
Duplexer	-	-	
TOTAL		Max	Min
	-7	-4	-7

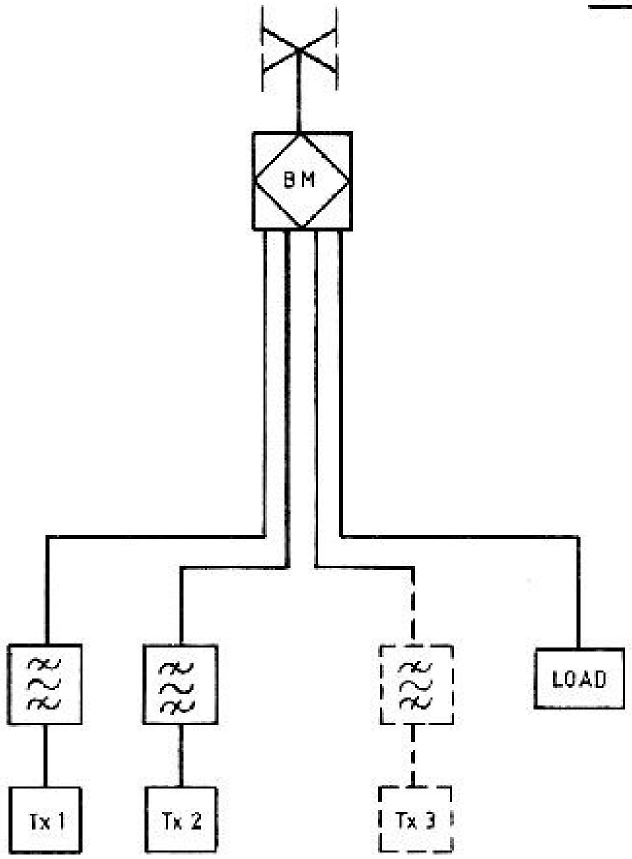
	A	B
Estimated Aerial gain	5	5
SYSTEM NET LOSS	-2	+1 or -2
erp with 100W transmitter is :	63	125 to 63

in watts over the main lobes.

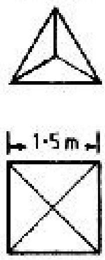
TURNSTILE 2/3 CH.

SINGLE TIER (TS 3/1)

FIG 10



TOWER



SYSTEM LOSS BUDGET

ITEM	dB
AE TAILS	−0·25
HARNESS/ MATRIX	−0·5
FEEDER	−2
FILTER	−2
HYBRID	—
TOTAL	−4·75
TX	20 dBW
TOTAL	15·25

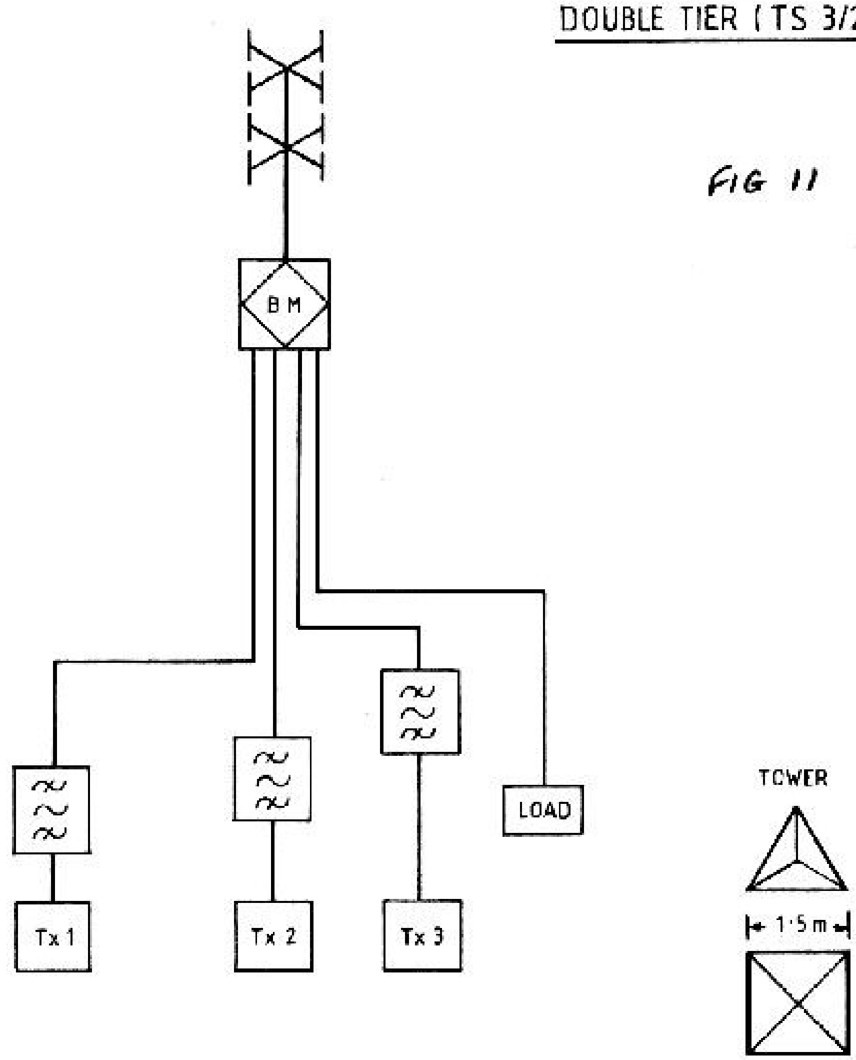
	MAX	MIN
AERIAL dB	0	−3
SYSTEM dB	15·25	15·25
ESTIM. ERP	15·25 dBW	15·25 dBW
	32 W	16 W

A.1.14

TURNSTILE 2/3 CH.

DOUBLE TIER (TS 3/2)

FIG 11



SYSTEM LOSS BUDGET

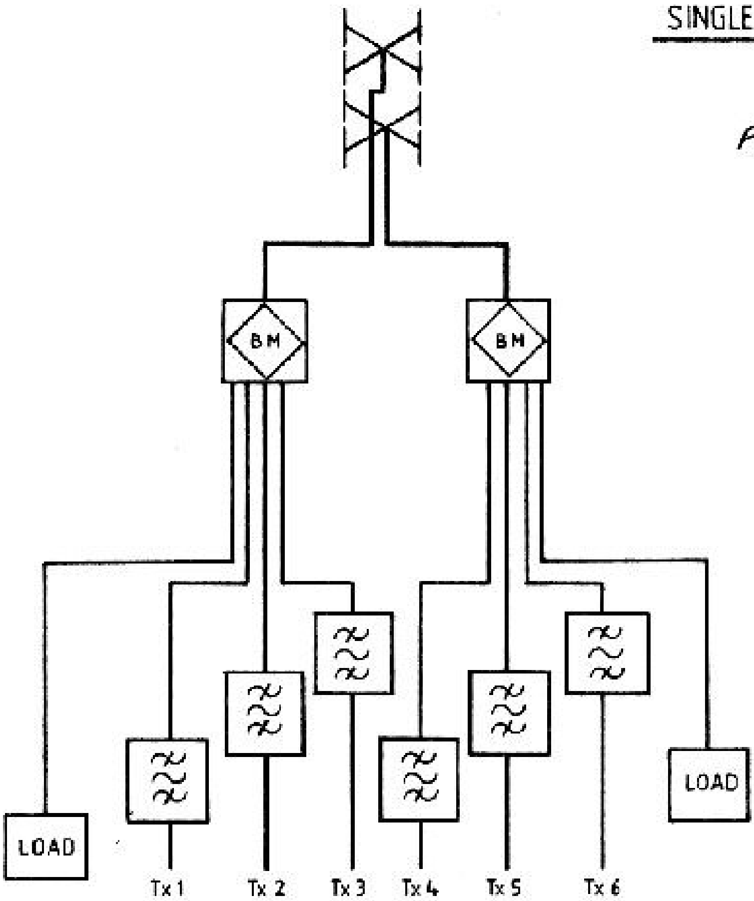
ITEM	dB
AE TAILS	−0·25
HARNESS/ MATRIX	−0·5
FEEDER	−2
FILTER	−2
HYBRID	—
TOTAL	−4·75
TX	20 dBW
TOTAL	15·25

	MAX	MIN
AERIAL dB	3	0
SYSTEM dB	15·25	15·25
ESTIM. ERP	18·25 dBW	15·25 dBW
	63 W	32 W

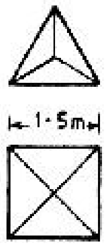
TURNSTILE 6 CHANNEL

SINGLE TIER (TS 6/1)

FIG 12



TOWERS



SYSTEM LOSS BUDGET

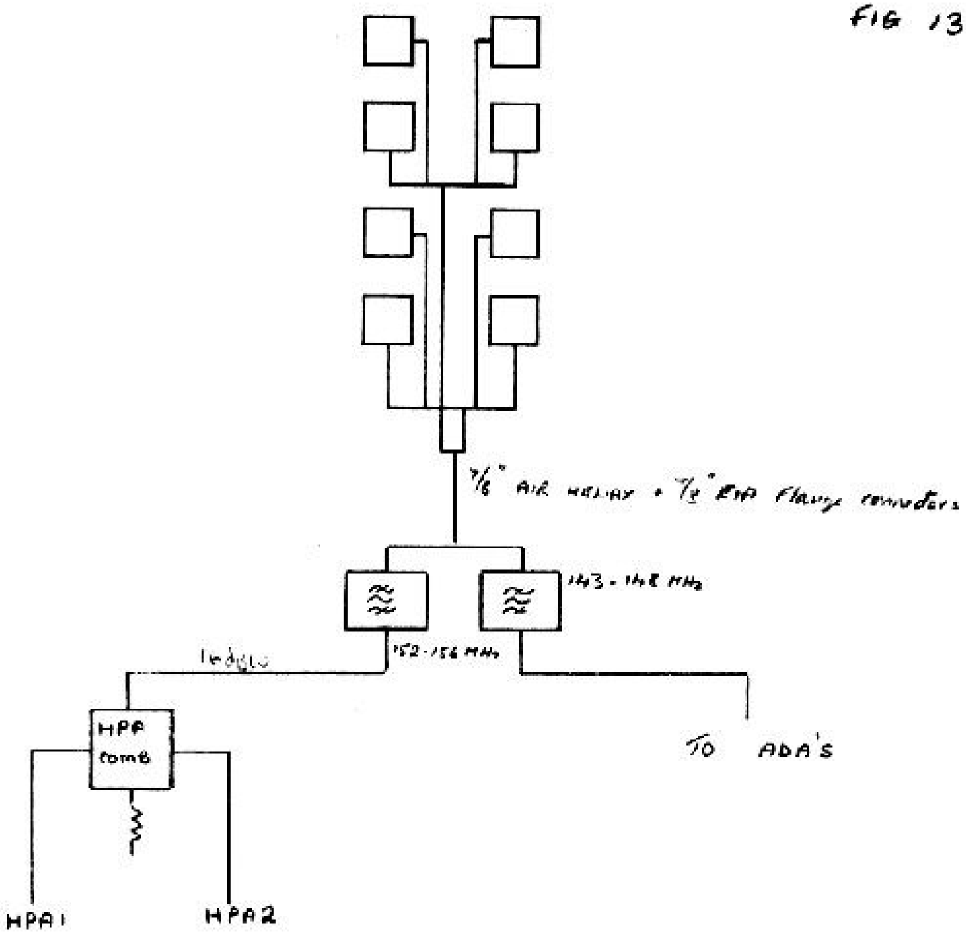
ITEM	dB
AE TAILS	−0·25
HARNESS / MATRIX	−0·5
FEEDER	−2
FILTER	−2
HYBRID	—
TOTAL	−4·75
TX	20
TOTAL	15·25

	MAX	MIN
AERIAL dB	0	−3
SYSTEM dB	15·25	15·25
ESTIM. ERP	15·25 dBW	12·25 dBW
	32 W	16 W

A 1/4 SLOT PANELS

DOUBLE TIER SP-12

FIG 13



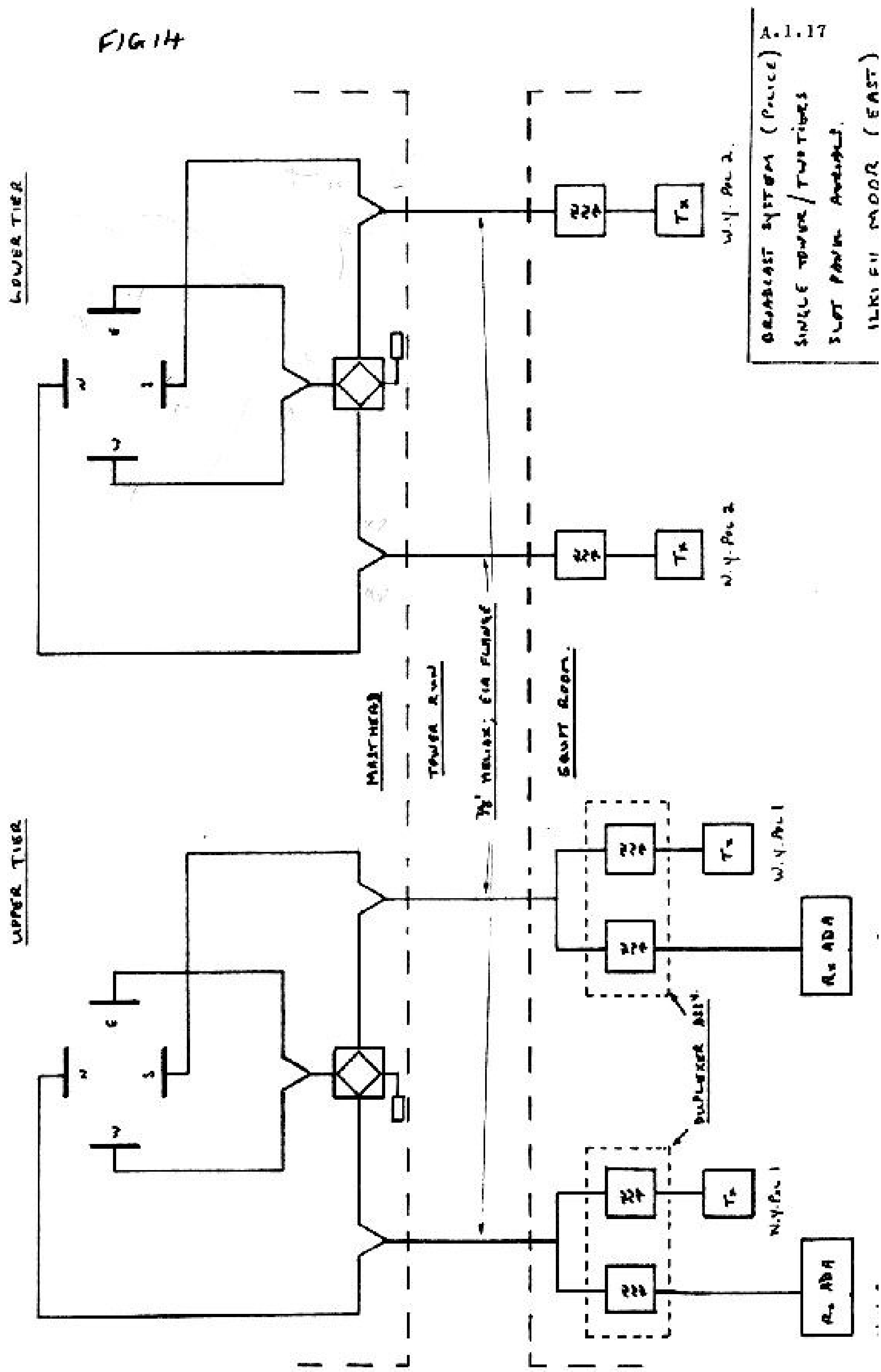
SYSTEM LOSS BUDGET

ITEM	dB
AE TAILS	-0.25
HARNESS/ MATRIX	-0.25
FEEDER	-1
FILTER	-1.5
HYBRID	-
TOTAL	-3
TX P_{out}	+16 dBW
TOTAL	+13 dBW.

	MAX	MIN
AERIAL dB	+ 5·8	+ 2·3
SYSTEM dB	+13	-
ESTIM. ERP	+19 dBW	+15 dBW
	80 W	32 W

over the main lobes.

FIG 14


A.1.17
BROADCAST SYSTEM (POLICE)
SINGLE TOWER/TWO TIERS
SLOT PANEL AERIALS
ILKLEY MOOR (EAST)
LOWER TIER
UPPER TIER
MASTHEAD
TOWER RUN
7/8" HELIAX; EIA FLANGE
EQUIPT ROOM
Tx
Rx ADA
DUPLEXER ASSY.

APPENDIX 2

TOWER/ARRAY COMPATIBILITY

ARRAY / TOWER COMPATIBILITY TABLE

				TOWER STRUCTURE											
				Al/4 FACE SIZE				Al/3 FACE SIZE				4 LEGS		3 LEGS	
AERIAL ARRAY	FREQ. MHz 70	80	150	> 2 m	2–1·5	1·5–1	< 1 m	> 2 m	2–1·5	1·5–1	< 1 m	MATRIX	HARN.	MATRIX	HARN.
SLOT PANEL	X	X	√	X	√	O	X	X	O	O	X	X	√	X	√
TURNSTILE*	X	X	√	√	√	√	√	√	√	√	√	√	√	√	X
3 EL YAGIS	X	O	√	X	X	O	√	X	X	O	√	X	√	X	√
DIPOLE / DIPOLE PANELS	√	√	√	X	X	O	√	X	O	X	X	X	√	X	√
GROUNDPLANE*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	X

N.B. Ae marked * are fitted to top of mast

KEY ➤ √ = ACCEPTABLE
O = POSSIBLE
X = NOT ACCEPTABLE

APPENDIX 3

PLANNING PROCEDURE CHECKLIST

WARC AERIAL PLANNING - SITE RECORD

WARC AERIAL PLANNING

PROCEDURE CHECKLIST (GENERAL

1. Check tower, site and occupancy arrangements

2. Customer Requirement

3. Plan aerial array and ancillaries

4. Load Tower

5. Record

PROCEDURE CHECK LIST (DETAIL)

1. Check tower, site and occupancy

    1.1 Search records and files

        1.1.1 Establish tower type and owner

        1.1.2 Check if tower replacement is planned

        1.1.3 If shared, ascertain limiting agreements if any.

        1.1.4 Obtain original design loading if available

        1.1.5 Frequency plan in use (Broadcast and Linking)

2. Customer requirement

    2.1 Services in use

        2.1.1 Present commitment) Note origin of information
        2.1.2 Future commitment)

    2.2 Operational requirement

        2.2.1 Type of cover required

        2.2.2 Special patterns?

    2.3 Other users

        2.3.1 New positions required?

        2.3.2 New agreements?

3. WARC Aerial Array

    3.1 Consider WARC options

        3.1.1 Types of aerial available

        3.1.2 Types of combining available

        3.1.3 Aerial Polarity Commitment

    3.2 Space available

        3.2.1 in tower

        3.2.2 in building

    3.3 Practical Solutions

        3.3.1 Physical constraints of tower and accessories (brackets, feeder supports, trays, loading etc)

3.4 Produce design

4. Load Tower

4.1 Produce load schedules

4.1.1 Aerial layout schedules

4.1.2 Aerial listing (p.6b)

4.1.3 Aerial loading (p.8b)

4.2 Submit to structural engineer
(with original loading data if available)

5. Record

5.1 Retain copies of design under alphabetic site name list

5.2 Cross reference user with appropriate parts of alphabetical list

5.3 Update current records.

WARC AERIAL PLANNING-SITE RECORD DATE

SITE NAME COUNTY/AREA

USER(S) OWNER

TWR TYPE TUBE/ANGLE TWR DATE

HEIGHT(M) DIFFICULT FACE SIZE

FEEDER ACCESS GOOD/REASONABLE/DIFFICULT REPEATER SITE

TOTAL B/C CHANNELS ERP PLANNED EXPANSION

POLICE DATE

FIRE USER

OTHERS

BROADCAST REQ

TOTAL LINK CHANNELS RPTR CH CHANNEL DIR

POLICE

FIRE

GCN

UKMO

OTHERS

WARC TEMP FACILITES SUITABLE POST-WARC FIT

BROADCAST POL

FIRE

EST ERP POL EST ERP POL

FIRE FIRE

REVERSE FREQ SITUATION YES/NO

APPENDIX 4

DESIGN OPTION HARDWARE

1. EQUIPMENT AVAILABLE
2. FOAM FEEDER INSTALLATION KITS

HIGH VHF BANDS   SITE: TYPE:

description	frequency band	quantity	HO part no.
slot panel	140-160 Mhz		
dipole panel	143-156 Mhz		
dipole folded HD	143-156 Mhz		
dipole folded LD	143-156 Mhz		
dipole end fed	143-156 Mhz		
groundplane	152-156 Mhz		
	143-148 Mhz		
2 element yagi	152-156 Mhz		
	143-148 Mhz		
3 element yagi	152-156 Mhz		
	143-148 Mhz		
6 element yagi (B/C)	152-156 Mhz		
6 element yagi (B/C)	143-148 Mhz		
Double Turnstile	143-156 Mhz		
Single Turnstile	143-156 Mhz		
4 way hyb matrix dble	152-156 Mhz		
	143-148 Mhz		
sgle	152-156 Mhz		
	143-148 Mhz		
TX hybrid (building)	152-156 Mhz		
Tx hybrid (tower)	152-156 Mhz		
isolator 150 watt	152-156 Mhz		
isolator 500 watt	152-156 Mhz		

Machined AE splitters

4 way	152-156 Mhz		
	143-148 Mhz		
3 way	152-156 Mhz		
	143-148 Mhz		
2 way	152-156 Mhz		
	143-148 Mhz		

Machined transformers

4 : 1 ratio	152-156 Mhz		
	143-148 Mhz		
3 : 1 ratio	152-156 Mhz		
	143-148 Mhz		
2 : 1 ratio	152-156 Mhz		
	143-148 Mhz		

TX filters (main)	152-156 Mhz		
RX filters (main)	143-148 Mhz		
RX Distribution amp	143-148 Mhz		
Duplexer (bandpass)	143-156 Mhz		

LOW AND WIDE VHF BANDS SITE: TYPE:

description	frequency band	quantity	HO part no.
dipole panel	70 - 84 Mhz		
dipole folded HDA	70 - 84 Mhz		
dipole folded LDA	70 - 84 Mhz		
dipole folded HDA(FCP)	80 - 102.1		
dipole endfed	70 - 84 Mhz		
groundplane	70.5-71.5 Mhz		
	80 - 84 Mhz		
2 element yagi	70.5-71.5 Mhz		
	80 - 84 Mhz		
3 element yagi	70.5-71.5 Mhz		
	80-84 Mhz		
4 way hybrid matrix	70.5-71.5 Mhz		
	80 - 84 Mhz		
TX hybrid (building)	70 - 72 Mhz		
TX hybrid (tower)	70 - 72 Mhz		
isolator 200 watt	70 - 72 Mhz		
isolator 500 watt	70 - 72 Mhz		
Machined AE splitters			
4 way	70.5-71.5 Mhz		
	80 - 84 Mhz		
3 way	70.5-71.5 Mhz		
	80 - 84 Mhz		
2 way	70.5-71.5 Mhz		
Machined transformers			
4 : 1 ratio	70.5-71.5 Mhz		
	80 - 84 Mhz		
3 : 1 ratio	70.5-71.5 Mhz		
	80 - 84 Mhz		
2 : 1 ratio	70.5-71.5 Mhz		
	80 - 84 Mhz		
TX filters	70.5-71.5 Mhz		
RX filters @	80 - 84 Mhz		
RX AE distribution amp	80 - 84 Mhz		
Duplexer (bandpass)	70.5-84.0 MhZ		
2 way hybrid RX	wideband		
4 way hybrid RX	wideband		

@ existing at most sites as a PYE filter

RADIO LINK EQUIPMENT AND HQ INTERFORCE/INTERBRIGADE

	SITE:		TYPE:
description	frequency band	quantity	HQ part No
isolator 25 watt	152-156 Mhz		
isolator 150 watt	152-156 Mhz		
isolator 25 watt	143-148 Mhz		
isolator 150 watt	143-148 Mhz		
link TX or RX filter	154-156 Mhz		
link TX or RX filter	146-148 Mhz		
RX distribution amp	154-156 Mhz		
RX distribution amp	146-148 Mhz		
TX hybrid (tower)	154-156 Mhz		
TX hybrid (tower)	146-148 Mhz		
TX hybrid (building)	154-156 Mhz		
TX hybrid (building)	146-148 Mhz		

Machined harnesses etc. included in main equipment descriptions.

4 way machined
3 way machined
2 way machined

4 way coaxial
3 way coaxial
2 way coaxial

4 : 1 transformer
3 : 1 transformer
2 : 1 transformer

Thru-line wattmeter panels

RF LOAD RESISTORS 25 watt
RF LOAD RESISTORS 100 watt
RF DIRECTIONAL COUPLER PANELS

1/2 INCH FOAM CABLE
7/8 INCH FOAM CABLE
URM74 COAXIAL CABLE
URM67 COAXIAL CABLE
RG214 COAXIAL CABLE
URM76 COAXIAL CABLE

CONNECTORS   SITE: TYPE:

description	quantity	HO part No
a)To suit RG214/RG213 & URM67		
N TYPE MALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY (PANEL MOUNTED)		
DIN 7/16 MALE CABLE ENTRY		
DIN 7/16 FEMALE CABLE ENTRY		
DIN 7/16 FEMALE CABLE ENTRY		
b)To suit Andrew 1/2 inch heliax		
N TYPE MALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY (PANEL MOUNTED)		
DIN 7/16 MALE CABLE ENTRY		
DIN 7/16 FEMALE CABLE ENTRY		
DIN 7/16 FEMALE CABLE ENTRY (PANEL MOUNTED)		
c)To suit Andrew/Kabelmetel 7/8 inch heliax.		
N TYPE MALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY (PANEL MOUNTED)		
DIN 7/16 MALE CABLE ENTRY		
DIN 7/16 FEMALE CABLE ENTRY		
DIN 7/16 FEMALE CABLE ENTRY (PANEL MOUNTED)		
d)To suit URM74		
N TYPE MALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY (PANEL MOUNTED)		
e)To suit URM76		
BNC MALE - CABLE ENTRY		
BNC FEMALE CABLE ENTRY		
BNC FEMALE CABLE ENTRY (PANEL MOUNTED)		

CONNECTORS (cont)   SITE: TYPE:

	quantity	HO part no.
N TYPE MALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY		
N TYPE FEMALE CABLE ENTRY (PANEL MOUNTED)		

f) INTERSERIES ADAPTERS

DIN 7/16 TO N MALE		
DIN 7/16 TO N FEMALE		
N MALE TO BNC FEMALE		

ITEMS REQUIRED FOR INSTALLATION OF ½" FOAM DIELECTRIC CABLE

ANDREWS ½ INCH FOAM HELIAX LDF 4-50 .... WRF27

N TYPE CONNECTOR MALE ANDREWS NO. L44W CMC9B

N TYPE CONNECTOR FEMALE ANDREWS NO.L44N CFC15C

PANEL MOUNTING ADAPTOR FLANGE CA15/10

OR ALTERNATIVELY

KABELMETAL ½ INCH FOAM CELLFLEX CF½" CU2Y 50 OHM WRF26

N TYPE CONNECTOR MALE 155 210 01 .... CMC10A

N TYPE CONNECTOR FEMALE 155 211 01 .... CFC17

N TYPE CONNECTOR FEMALE BULKHEAD MOUNTING HN 74 75 03 .... CFC17C

20CC TUBE PLAST 2000 158 004 01 .... M12214B

(1 TUBE PER 4 CONNECTORS REQUIRED)

HARDWARE FOR ½" CABLES

EARTHING KIT TYPE 154 095 01 .... M12214A

REMCLAMPS SIZE R1 .... MHC200

STAINLESS STEEL STUDDING 8½ INCH X ⅜ WHIT M11751/

STAINLESS STEEL NUTS ⅜ WHIT M11751/

STAINLESS STEEL WASHERS ⅜ M11751/

ISS.4.

ITEMS REQUIRED FOR INSTALLATION OF $\frac{7}{8}$" FOAM DIELECTRIC CABLE

HO SPEC A30

ANDREWS $\frac{7}{8}$ INCH FOAM HELIAX LDF 5-50 .... WRF23

N TYPE CONNECTOR MALE ANDREWS NO. L45W CMC9D

N TYPE CONNECTOR FEMALE NO. L45N CFC15A

OR ALTERNATIVELY

KABELMETAL $\frac{7}{8}$ INCH FOAM CELLFLEX OF $\frac{7}{8}$" CU2Y 50 OHM WRF28

N TYPE CONNECTOR MALE 155 410 01 .... CMC10B

N TYPE CONNECTOR FEMALE 155 411 01 .... CFC17A

N TYOE CONNECTOR FEMALE BULKHEAD MOUNTING BN 73 31 04 .... CFC17B

20CC TUBE PLAST 2000 158 004 01 .... M12214B

(1 TUBE PER 2 CONNECTORS REQUIRED)

HARDWARE FOR $\frac{7}{8}$ INCH CABLES

EARTHING KIT TYPE 154 296 01 .... M12214

HEMCLAMPS SIZE R5 .... MHC203

STAINLESS STEEL STUDDING $8\frac{1}{2}$ INCH X $\frac{3}{8}$ WHIT M11751/5

STAINLESS STEEL NUTS $\frac{3}{8}$ WHIT M11751/7

STAINLESS STEEL WASHERS $\frac{3}{8}$ M11751/8

ISS.3.

Table GN4/4 Blocking Values for R6HO Receiver

Amount of Degradation	Blocking Signal at 1MHz From Wanted Signal
12dB to 6dB SINAD	-40dBW
12dB to 11dB SINAD	-50dBW
20dB to 14dB SINAD	-40dBW

Note: For 12dB SINAD in R6HO, rf input level $< 2\mu V$ emf.

3.3 Intermodulation

Intermodulation occurs when two or more carriers mix in a non-linear junction to produce a number of other frequencies. If these intermodulation frequencies fall on either the main or mobile receiver input frequencies, then interference to the wanted signal occurs. The relative signal levels will dictate whether this interference is at an acceptable level.

The sum of the integers of the frequencies generating the intermodulation product frequencies defines the 'order' of the product eg if the IM frequency C = 3A - 2B, the sum of the integers is five and the IM product is fifth order.

Intermodulation can occur in three main areas:

(a) Transmitter output stages
(b) Receiver input stages
(c) Non-linear metallic elements of the aerials, masts, metal fences etc. (known as the 'rusty bolt' effect)

3.3.1 Transmitter Output Stages

To reduce the level of IMs generated due to the unwanted coupling between transmitter output stages, filters, isolators and increased aerial isolation may be employed as appropriate. (See Diagram GN4/5 for performance characteristics of items to be purchased for the FCP)

Note that any additional item connected in series with the transmitter output could also be a source of IM generation and hence must have a low IM performance level to be effective.

3.3.2 Receiver Input Stages

To prevent intermodulation occurring in the receiver input stages, filters tuned to reject unwanted transmitter frequencies may be incorporated in series with the receiver aerial input. (CEPT specification requires receivers to have an IM rejection ratio of 70dB.)

INSTALLATION PRACTICES AND PREFERENCES

1. Tower and Aerial Orientation

Tower and aerial orientation should be based on Magnetic North. From an observer positioned at the centre of the structure base area, legs should be consecutively numbered with leg 1 being the first leg encountered when moving in a clockwise direction from Magnetic North. In an attempt to avoid confusion and provide standardisation several examples are illustrated at Note 1.

Aerial locations on a structure should be referred to as a height in metres followed by a leg/face identification. ie 36/1 for a leg mounted aerial; 36/1-2 for a face mounted aerial between legs 1 and 2. All heights should be taken to the centre of the balun, usually the centre line of the supporting boom.

2. References and Records

Future Technical Engineering Requirements or Instructions will contain as much information as possible to provide a data base for recording purposes as well as the technical information needed to produce optimum results. The "As fitted" record should reflect the original document and must not be amended to suit local preference such as height in feet or differing leg numbers.

All proposed changes or alterations should be notified as soon as possible to the Frequency and Site Planning Group (FSPG) for authorisation or incorporation in Headquarter records as may be necessary.

Local records should be accurate and contain most of the information noted below for ease of fault identification and rectification:

a. Physical information for the site record is to include aerial type and make, feeder tail length with connector type and gender, together with harness arrangements if applicable. Mechanical fittings and fixture types and sizes may need recording to cover differing tower leg sections and imperial or metric thread sizes. Reference to boom sleeve sizes may also be required.

b. Electrical information will need to be initiated on installation in order to afford a comparison at a later date. Basic requirements would include VSWR checks, resistance and insulation measurements and Time Domain Reflectometer signatures. RF phase measurements may be required in the case of power division or asymmetric splits and co-phased arrays.

3. Feeder Identification, Termination, Earthing and Sealing

Feeder cables should be identified at each end and at the foot of the tower. Associated aerial tails should be identically coded. Identification should take the form of a number code. This will prevent any ambiguity currently caused by numerous colour code rings fading due to the elements. In most cases number codes will not exceed two digits.

A list should be displayed within the building detailing aerial, feeder number and function.

As current HO aerial specifications dictate that a plug will be fitted to the aerial tail it is expected that all feeders will require a socket at the tower end. This situation may require a double check and subsequent reversal if a harness system is to be used. It is seen by some manufacturers to be a more simple construction exercise to use all sockets on machined harnesses.

Cable harnesses can be specified similarily to aerials, calling for a plug on the harness tail which subsequently allows the standard use of a socket on the aerial feeder cable.

All connectors and earthing kits should be made up in accordance with manufacturers instructions. Attention should be given to detail at every step as the standard of these joints is paramount to the overall system efficiency. Connectors and joints should be made up under dry and warm surroundings whereve possible. Mating and sealing should also take place in similar conditions if moisture is to be excluded.

Earthing kits should be fitted close (preferably within 1 metre) to the tower connector and bonded to the nearest feeder anchor point.

In order to carry out adequate sealing for external connectors and earthing connections it will be necessary to withdraw the covering boot away from the aerial tail connector. In the past this has proved to be a source of water retention. Next, wind on a 'weather board' overlap coating of black self amalgamating (Rotunda) tape, once in each direction if unsatisfied with the first wrap. This should be followed up with a top coating of 'Denso' tape in a thorough attempt to exclude the ingress of driven water under the most arduou site conditions. To date these are the most effective methods known to the departments.

4. Fittings and Fixtures

A variety of aerial fittings and fixtures are available and are usually added to over a period of time. Following United Kingdom manufacturers excursions into metrication and recent amalgamations of past well-known companies, it is necessary to keep a watchful eye on thread sizes as these are prone to change without notice. This is, unfortunately, outside Home Offic control.

In order to provide a locking function all nuts should be tightened down onto spring washers placed on top of flat washers, all of the appropriate size for the thread concerned.

All bolts, nuts washers, threaded parts, pins, hinges, wire, eyes, corner plates and grips associated with ancillary equipment and fittings and fixtures should be given a light coating of grease, or be similarly protected, before us

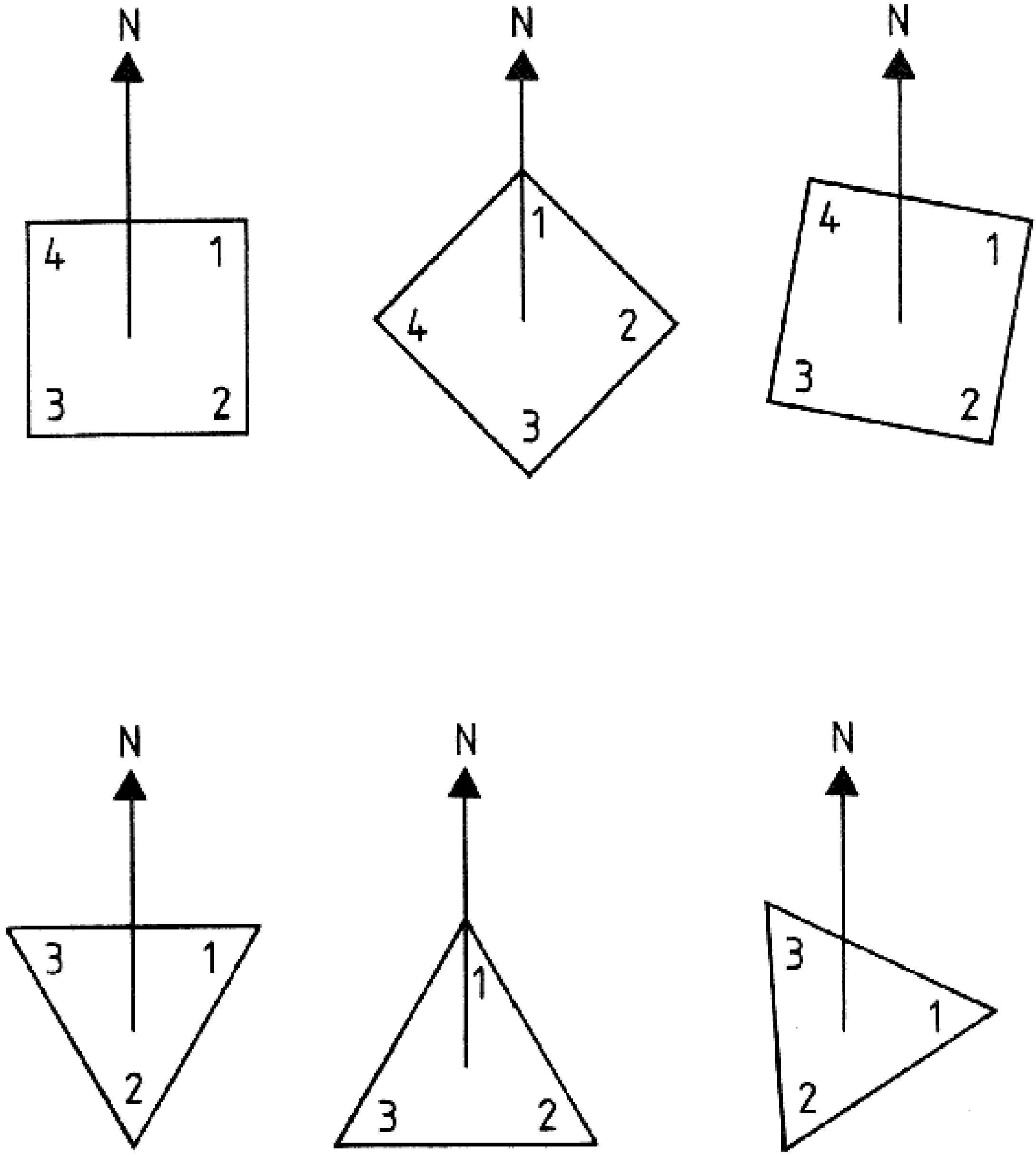
A comprehensive list of ancillary equipment is provided for reference at note 2

5. Standards

A higher level of accuracy will need to be achieved if aerial systems are to be installed to the standards required of operational aerial patterns for the post WARC commitment. This will require renewed effort and concentration on th part of the aerial teams, with particular attention to QA by the Charge Hand Aerial Rigger.

A.5.4

NOTE 1



TOWER ORIENTATION WITH RESPECT TO MAGNETIC NORTH

APPENDIX 5 NOTE 2

ANCILLARY EQUIPMENT

H.O. PART NO.	DESCRIPTION	QUANTITY
MHC 205	Remclamp R00 (For use with URM 67 cables).	
MHC 200	Remclamp R1 (For use with 1/2" foam cables).	
MHC 201	Remclamp R3 (For use with URM 74 cables).	
MHC 203	Remclamp R5 (For use with 7/8" foam cables).	
M 5939	Lindapter clamp	
M 5939 A	Lindapter nut & stud 3.1/2" * 3/8" Whit.	
M 5939 B	Lindapter nut & stud 2" * 3/8" Whit.	
M 5937	Lindapter packing piece	
MHC 120	6" Plasticlip	
MHC 121	9" Plasticlip	
MHC 122	12" Plasticlip	
MHC 123	9mm Identification tab	
SA 32	Lanolin grease	
SA 33	Denso tape	
SA 39 C	Rotunda tape	
M12138	Stainless steel bolt 6" * 3/8" Whit	
M 11751/5	Stainless steel stud 8.1/2"*3/8" Whit	
M11751/6	Stainless steel set screw 4.1/2"*3/8" Whit	
M11751/7	Stainless steel full nut 3/8" Whit	
M11751/8	Stainless steel flat washer 1/2"*3/8" Whit	
M12572	Stainless steel Carriage bolt M6 * 150mm (With first 75mm threaded)	
M12572 A	Stainless steel nut-M6 size	
M12572 B	Stainless steel flat washer, M6 clearance	
	(M6 Items above are all for use on standard, Admiralty pattern cable tray).	
AEA 20/1	2.1/2" Galvanised Plate and Saddle Clamp	
AEA 20/2	3". Galvanised Plate and Saddle Clamp	
AEA 20/3	3.1/2" Galvanised Plate and Saddle Clamp	
AEA 20/4	4". Galvanised Plate and Saddle Clamp	
AEA 20/5	4.1/2" Galvanised Plate and Saddle Clamp	
AEA 20/6	4.3/4 Galvanised Plate and Saddle Clamp	
AEA 20/7	5"..Galvanised Plate and Saddle Clamp	
AEA 20/8	5.1/2" Galvanised Plate and Saddle Clamp	
AEA 20/9	6" Galvanised Plate and Saddle Clamp	
	(HO Drawing number 01/262/1/1 refers to all imperial plate and saddle clamps).	

H.O. PART NO	DESCRIPTION	QUANTITY
AEA 21/1	60mm Galvanised Plate and Saddle Clamp	
AEA 21/2	75mm Galvanised Plate and Saddle Clamp	
AEA 21/3	85mm Galvanised Plate and Saddle Clamp	
AEA 21/4	90mm Galvanised Plate and Saddle Clamp	
AEA 21/9	170mm Galvanised Plate and Saddle Clamp	
AEA 21/10	195mm Galvanised Plate and Saddle Clamp	
	(HO Drawing number 01/263/1/1 refers to all metric plate and saddle clamps).	
AEA 23/1	Aerial earthing distribution panel, type A (For use in equipment rooms).	
AEA 23/2	Aerial earthing distribution panel, type B (For use in equipment rooms)	
AEA 23/3	Aerial earthing distribution panel, type C (For use in equipment rooms)	
AEA 23/4	Aerial earthing distribution panel, type D (Blank). (For use in equipment rooms)	
AEA 23/5	Aerial earthing distribution panel, 4 panel mounting frame (For use in equipment rooms)	
AEA 23/6	Aerial earthing distribution panel 2 Panel mounting frame (For use in equipment rooms)	
AEA 23/7	Aerial earthing distribution panel 2 * frame mounting brackets. (for use in equipment rooms)	
	For detailed information on the above building earthing system see HO drawing numbers:- 01/268/1/1 01/268/1/2 01/269/1/1 01/270/1/1 01/271/1/1 01/275/1/1 and 01/3155/1/1 in respect of associated connectors suited to individual panels.	
AEA 24	Galvanised Plate 45 degree Tower cleat c/w 2*6"*1/2" Whit. J bolts and U bolt c/w galvanised 1/2" Flat and Spring washers	
AEA 24/1	Galvanised Plate, 45 degree tower cleat	
AEA 24/2	U bolt 2"*1/2" Whit for 45 degree tower cleat c/w galvanised 1/2" Flat and Spring washers	
AEA 24/3	J bolt 6"*1/2" Whit for 45 degree tower cleat c/w galvanised 1/2" Flat and Spring washers	
AEA 24/4	J bolt 8"*1/2" Whit for 45 degree tower cleat c/w galvanised 1/2" Flat and Spring washers	
AEA 24/5	J bolt 10"*1/2"Whit for 45 degree tower cleat c/w galvanised 1/2" Flat and Spring washers	

AEA 24/6	J bolt 15"*1/2" Whit for 45 degree tower cleat c/w galvanised 1/2" Flat and Spring washers (HO Drawing number 01/3151/1/1 refers to the 45 degree tower cleat assembly)
WW 6 E	1/2" Whit clearance, plated spring washer
M1366 A	12Ft.* 1.29/32" Aluminium scaffold pole
M1366 B	20Ft.* 1.29/32". Aluminium scaffold pole
M12379	20Ft.* 1.29/32". Galvanised steel pole
M9496	Base plate for 1.29/32" poles
M6951	Norstel joint pin
M2798 F	Single Norstel clamp
M2798 B	Double Norstel clamp
M6740	Swivel Norstel clamp
M2798 J	1.1/4" Norstel sleeve (converts 1.1/4" boom to 1.3/4" O.D.)
M2798 U	1.1/2" Norstel sleeve (converts 1.1/2" boom to 1.3/4" O.D.)
AEA 36	1.1/4" boom sleeve, (31.5mm) (converts 1.1/4" boom to 1.29/32" O.D.)
AEA 37	1.1/2" boom sleeve (38mm) (converts 1.1/2" boom to 1.29/32" O.D)
AEA 38	1.3/4" boom sleeve (44.5mm)(converts 1.3/4" boom OR booms fitted with M2798 J OR booms fitted with M2798 U, to 1.29/32" O.D.)
M 6212	Galvanised Wall brackets (12" stand off) Comprising 1 three leg and 1 two leg bracket, c/w 2 * 2" * 3/8" Whit. U bolts, nuts and washers.
M 6212 A	Galvanised wall brackets (18" stand off) Comprising 1 three leg and 1 two leg bracket, c/w 2 * 2" * 3/8" Whit. U bolts, nuts and washers.
M 12337	4" Channel bracket, c/w 3/8" (10mm) Rawl bolt (For use in narrow or restricted locations)
M 2798	Chimney lashing kit (Heavy duty)
M 4563	Catenary wire (Galvanised steel) in 100Ft lengths
MHC 190	Bulldog grips (for use with catenary wire)
M 12453	5mm heart shaped thimble (for use with catenary wire)
M 8563	Wire strainer (for use with catenary wire)
M 12214	Earthing kit for 7/8" foam cable
M 12214 A	Earthing kit for 1/2" foam cable

APPENDIX 6

EXTRACT FROM RADIO SYSTEMS PLANNING NOTES

GN 4
GN 8

SYSTEM PARAMETERS & DESIGN FEATURES GN4

1. General

As the 'national' frequency assignment plan has not yet been completed by (MR5) Group, it is not possible to be definitive about the engineering solutions that may be required to guarantee the best and most cost-effective frequency conversion programmes for the Police and Fire emergency services. Questions needing to be answered to eliminate some uncertainties include:

(a) What is the 'national' frequency plan?
(b) What provisions are there in the plan for radio schemes expansions and what are the Users' aspirations?
(c) What intermodulation product frequency free assignments can be guaranteed?
(d) What protection level standard is to be adopted in terms of foreign and local interference?

For the sake of this GN, it will be necessary to plan using the 'best quality' engineering available - in the absence of answers to the above questions. Should a frequency plan be produced which will allow IMP frequency free assignments, then it should be possible to adopt simpler engineering solutions in a cost-effective manner, by removal of some of the sophisticated engineering.

The following parameters and features are a compilation of some results of experimentation and published papers from within the Directorate. They are to be adopted as bases for post-WARC FCP planning.

2. Parameters

2.1 Main Transmitter:

Output power (mean)	+20dBW (100W)
Target erp	+18dBW (63W)

2.2 Main Receiver:

Minimum subjectively-acceptable signal level	-134dBW (3µV emf)
Mute setting level	-137dBW (2µV emf)
Protection ratio (on minimum signal level)	20dB

2.3 Link Receiver:

Minimum signal level	-114dBW (30µV emf
Mute setting level	-123dBW (10µV emf
Protection ratio (on minimum or mute setting level)	20dB
Fade margin (on minimum signal level)	10dB

2.4 Path Loss

Main transmitter to mobile receiver typically 141dB.

This equates to a range of 26km at 150MHz (see Table GN4/1)

Table GN4/1 (Ref FCP(83)21) Range-vs-Path Loss at 150MHz

Range (km)	Path Loss (dB)
15.0	131
17.5	134
20.0	136
22.5	138
25.0	140
27.5	142
30.0	143
32.5	145
35.0	146

Note: Local terrain may cause significant changes in path loss.

2.5 IMP Frequencies

Assume 5th order free assignments for Police and Fire frequency bands until the actual frequency plan is known and the power levels established.

2.6 Mobile Receiver

Target minimum received signal (QSAM operation) -123dBW (10µV e
(This level may be reduced to -133dBW (3µV emf) for single stat
working)
Mute setting level -137dBW (2µV em
Protection ratio (on mute level) 20dB

3. Design Features

The relatively close frequency spacing between transmitters and receivers on the post-WARC bands will require filters and isolatc to reduce the effects of transmitter wideband noise, interaction between transmitters and receiver blocking.

3.1 Transmitter Noise

As well as producing the required on-frequency carrier, noise voltages are produced at frequencies on either side of the carrier. The levels of these voltages after a few MHz spread, although at a low level, may be high enough to contribute significantly to the receiver noise and thereby degrade receiver performance. See Table GN4/2 for examples of measured levels.

Table GN4/2 Measured Transmitter Noise Levels

Transmitter Type	Noise Level (dBW)
Park Air (Main Tx) Marconi RC782 (Main Tx) Pye T150 (Link Tx) Pye U450L (Link Tx)	-107 -127 -163 -153
All the above measured in 50Hz bandwidth. For conversion to other bandwidths: 50Hz to 1Hz 17dB 50Hz to 1kHz 13dB 50Hz to 7.5kHz 22dB 50Hz to 10kHz 23dB 50Hz to 15kHz 25dB	

Note: The levels measured in the WARC evaluation samples will be substituted as they become available.

3.2 Blocking

This is defined as a change, generally a reduction of the output power (or SINAD ratio) in a receiver adjusted to a wanted signal, due to an unwanted signal on another frequency over the bands +1 to +10 and -1 to -10kHz from the wanted signal frequency. The blocking level at any frequency within the range specified should not be less than 100dBµV emf (-45dBW) * at the input to the receiver (except for spurious responses) at which point a wanted signal SINAD of 12dB is reduced to 6dB.

The audio quality of the 6dB SINAD level is subjectively unacceptable so it is suggested that a 20dB margin is used ie the maximum level of an interfering (blocking) signal should not exceed 80dBµV emf (-65dBW), at the input to the receiver - see the loop equations attached to this GN.

Tables GN4/3 and GN4/4 list measured blocking performance levels for current main and link receivers.

Table GN4/3 Blocking Values for T150 and U450L Receivers

Wanted Signal Level	Blocking Signal Level For Slight Degradation
-113dBW (30µV emf)	-13dBW
-123dBW (10µV emf)	-20dBW
-133dBW (3µV emf)	-25dBW

* Home Office Specification

Table GN4/4 Blocking Values for R8HO Receiver

Amount of Degradation	Blocking Signal at 1MHz From Wanted Signal
12dB to 6dB SINAD	-40dBW
12dB to 11dB SINAD	-50dBW
20dB to 14dB SINAD	-40dBW

Note: For 12dB SINAD in R8HO, rf input level < 2μV emf.

3.3 Intermodulation

Intermodulation occurs when two or more carriers mix in a non-linear junction to produce a number of other frequencies. If these intermodulation frequencies fall on either the main or mobile receiver input frequencies, then interference to the wanted signal occurs. The relative signal levels will dictate whether this interference is at an acceptable level.

The sum of the integers of the frequencies generating the intermodulation product frequencies defines the 'order' of the product eg if the IM frequency C = 3A - 2B, the sum of the integers is five and the IM product is fifth order.

Intermodulation can occur in three main areas:

(a) Transmitter output stages
(b) Receiver input stages
(c) Non-linear metallic elements of the aerials, masts, metal fences etc. (known as the 'rusty bolt' effect)

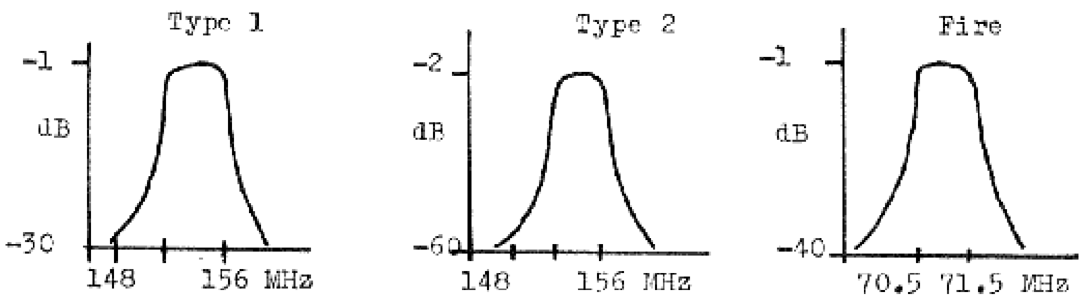
3.3.1 Transmitter Output Stages

To reduce the level of IMs generated due to the unwanted coupling between transmitter output stages, filters, isolators and increased aerial isolation may be employed as appropriate. (See Diagram GN4/5 for performance characteristics of items to be purchased for the FCP)

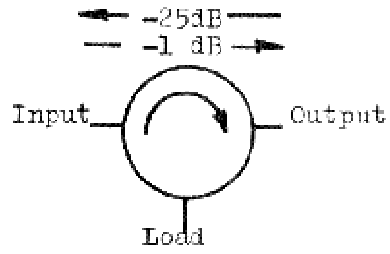
Note that any additional item connected in series with the transmitter output could also be a source of IM generation and hence must have a low IM performance level to be effective.

3.3.2 Receiver Input Stages

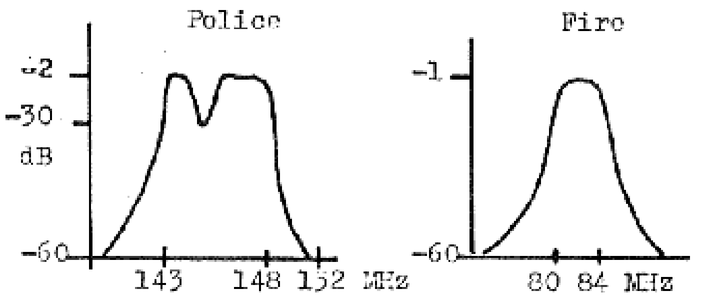
To prevent intermodulation occurring in the receiver input stages, filters tuned to reject unwanted transmitter frequencies may be incorporated in series with the receiver aerial input. (CEPT specification requires receivers to have an IM rejection ratio of 70dB.)



TRANSMITTER FILTERS



CIRCULATOR



RECEIVER FILTERS

Transmitter IMP Conversion Loss

1. 2nd Order (T55 on 70MHz)

   At 100kHz with 30dB coupling = 6dB
   At 1MHz with 30dB coupling = 30dB

2. 5th Order (Dark Air on 150MHz)

   At 0.5-2MHz with 30dB coupling = 50dB.

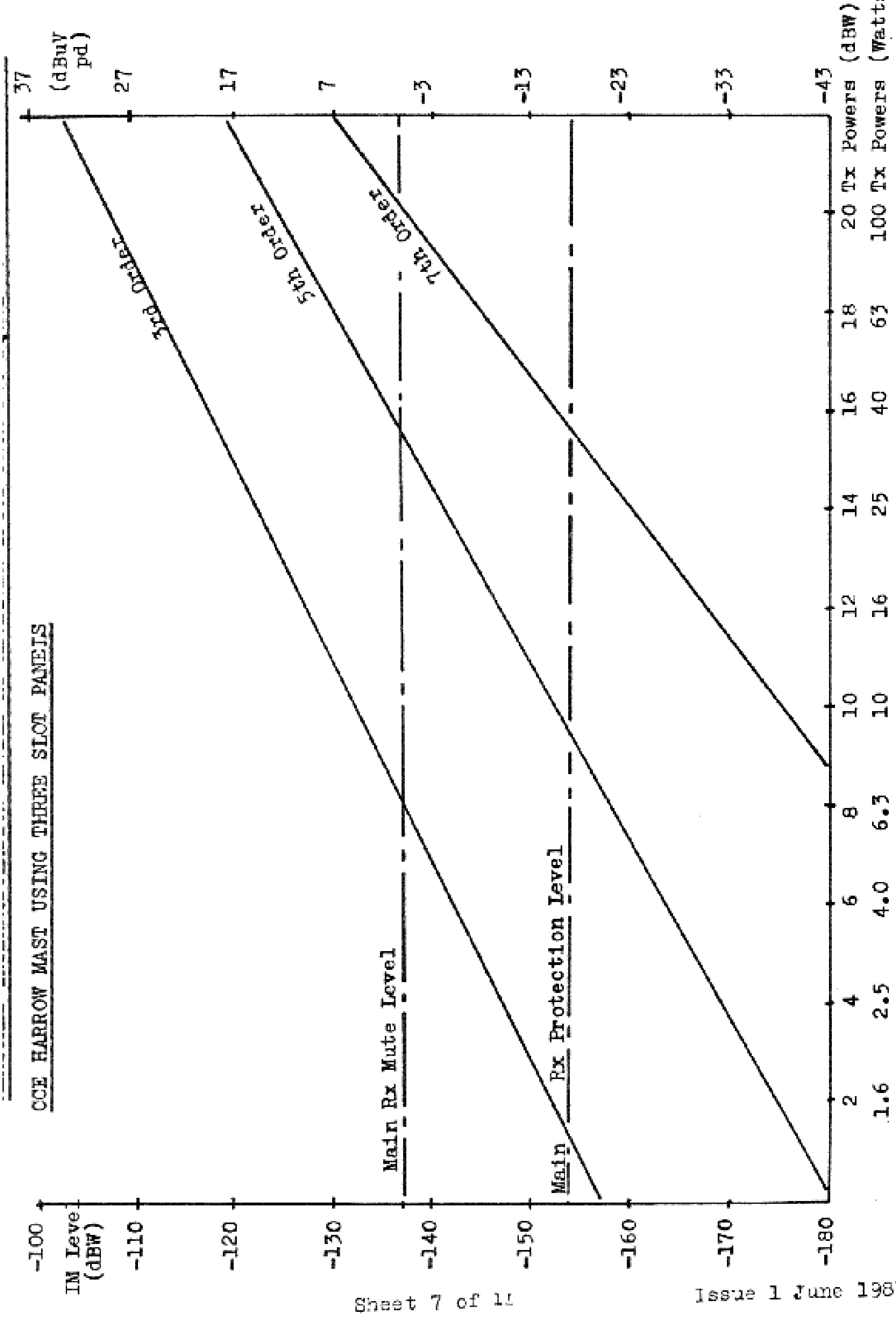
3.3.3 Rusty Bolt Effect

To reduce the effect due to the aerials and mast, screened and low IM source aerials will be required. A reduction in transmitte powers may also have a marked effect for those schemes that can toler a reduction in erp (from the target of 63W as previously stated). See Diagram GN4/6 attached to this GN which is based on the results of measurements taken over a period of time at CCD by Mr R S Keeble.

4. Loop Equations

Please see attached loop equation sheets. These are some possible methods of ensuring that the link and main receivers are protected to the specified levels of intermodulation and blocking effects. By using this general method, any configuration may be calculated. It is a requirement that these calculations be recorded on the system planning file and to this end a standard format is to be devised.

GN4/6 IM LEVEL-vs-TX POWERS



Issue 1 June 1983

Loop Equations - Police Main Receiver Protection

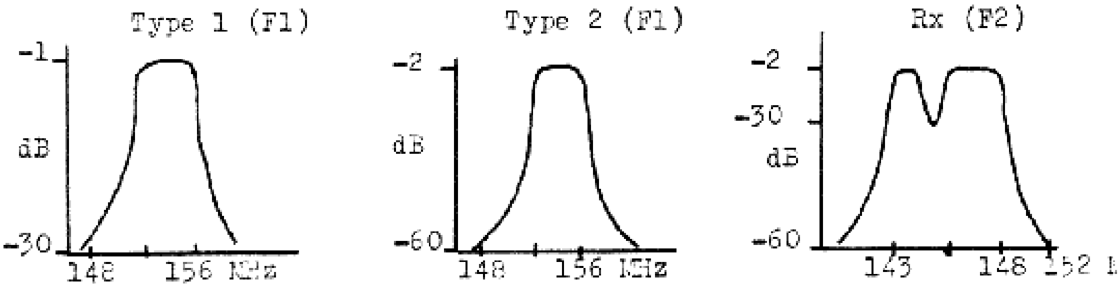
IMP Protection Level

Mute level = -137dBW
Minimum acceptable subjective signal level = -134dBW
Protection margin = 20dB
Thus IMP protection level required = -154dBW

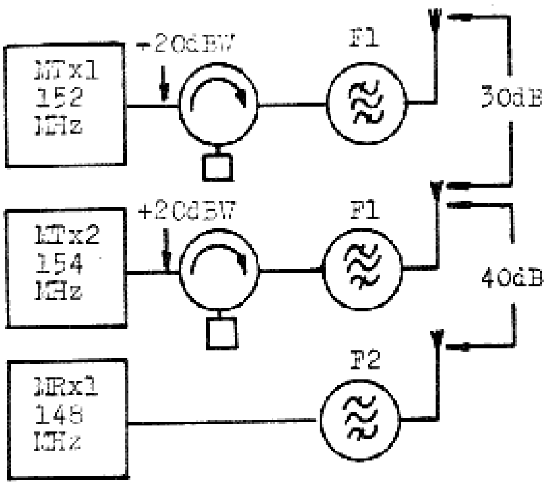
Blocking Protection Level

Specification requirement (to 6dB SINAD) = -43dBW
Protection margin desirable = 20dB
Thus blocking protection level = -63dBW

WARC Filter Specifications



Loop Network



MTx

5th order IM conversion is 50dB.

Circulator

Insertion loss = 1dB
Isolation = 25dB

Type 1 Case

5th order IM level to MRx1 input = -161dBW, following round loop.
Blocking level to MRx1 input = -82dBW, following round loop.
Thus, both IMP protection and blocking protection levels are achieved.
(Note: Feeder loss not included in the calculations)

Loop Equations - Fire Main Receiver Protection

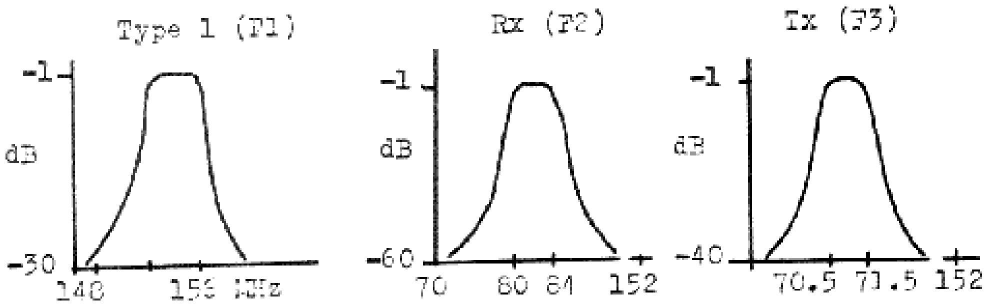
IMP Protection Level

Mute level = -137dBW
Minimum acceptable subjective signal level = -134dBW
Protection margin = 20dB
Thus IMP protection level required = **-154dBW**

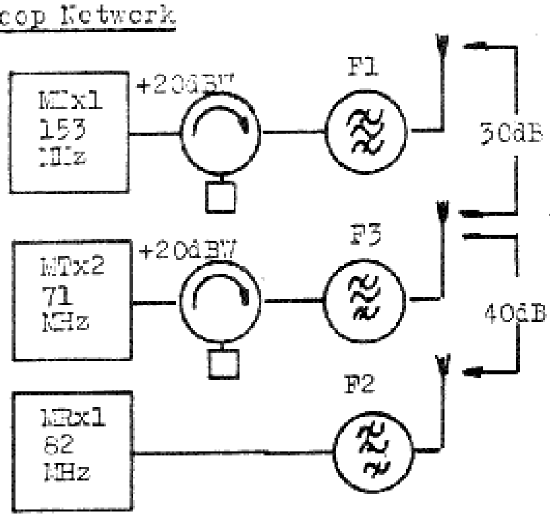
Blocking Protection Level

Specification requirement (to 6dB SINAD) = -43dBW
Protection margin desirable = 20dB
Thus blocking protection level = **-63dBW**

WARC Filter Specifications



Loop Network



MTx2

2nd order IM conversion is 30dB

Circulator

Insertion loss = 1dB
Isolation = 25dB

Calculation

2nd order IM level to MRx1 input = -189dBW, following round loop.
Blocking level to MRx1 input = -82dBW, following round loop
Thus, both IMP protection and blocking protection levels are achieved.
(Note: Feeder loss not included in the calculations)

Loop Equations - Link Receiver Protection - Case 1

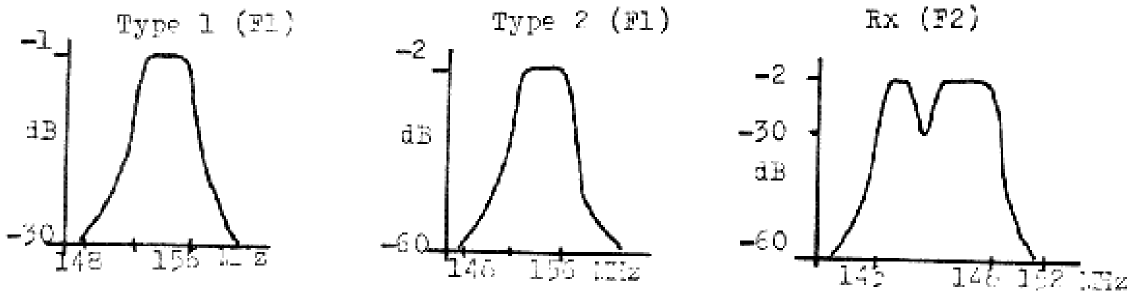
IMP Protection Level

Mute level = -123dBW (10μV e.m.f.) Note that normal minimum link signal level should be -114dBW (30μV e.m.f.)
Protection margin = 20dB
Thus IMP protection level assuming worst case = -143dBW

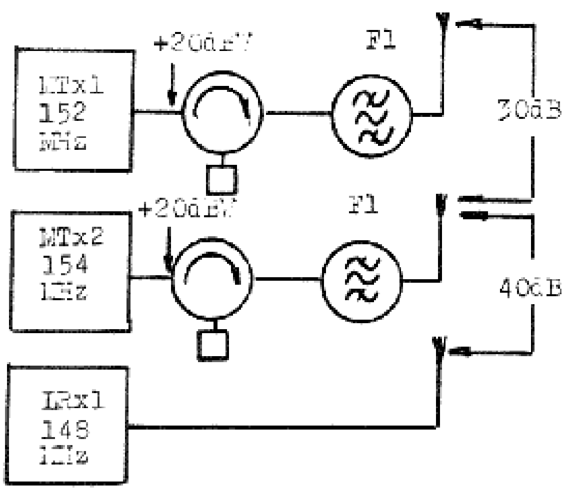
Blocking Protection Level

Practical tests show that a signal of -20dBW just degrades a wanted signal of -123dBW.
Thus blocking protection level = -20dBW

WARC Filter Specifications



Loop Network



MTx

5th order IM conversion loss is 50dB.

Circulator

Insertion loss = 1dB
Isolation = 25dB

Type 1 Case

5th order IM level to LRx1 input = -159dBW, following round loop.
Blocking level to LRx1 input = -22dBW, following round loop.
Thus, both IM protection and blocking protection levels are achieved.
(Note: Feeder loss not included in the calculations)

Loop Equations - Link Receiver Protection - Case 2

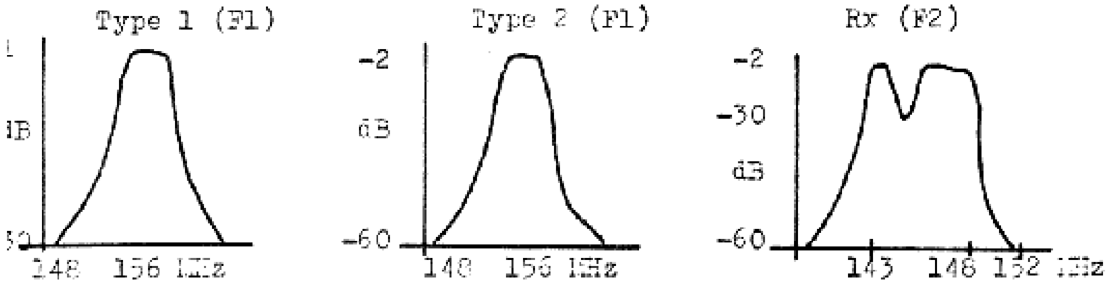
IMP Protection Level

Mute level = -123dBW (10µV e.m.f.) Note that normal minimum link signal level should be -114dBW (30µV e.m.f.)
Protection margin = 20dB
Thus IMP protection level assuming worst case = -143dBW

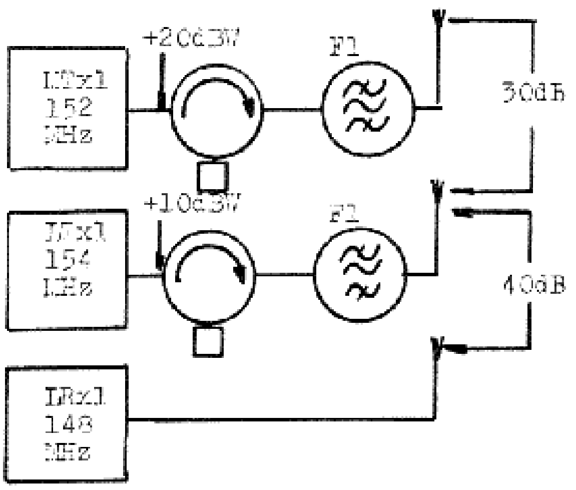
Blocking Protection Level

Practical tests show that a signal of -20dBW just degrades a wanted signal of -123dBW.
Thus blocking protection level = -20dBW

WARC Filter Specifications



Loop Network



LTx1

5th order IM conversion is 50dB.

Circulator

Insertion loss = 1dB
Isolation = 25dB

Type 1 Case

5th order IM level to LRx1 input = -159dBW following round loop. To this should be added 10dB for the difference in power levels ie -159dBW.
Blocking level to LRx1 input = -32dBW, following round the loop.
Thus, both IM protection and blocking protection levels are achieved.

(Note: Feeder loss not included in the calculations)

AERIAL SYSTEMS GN8

1. General

It will be the task of the Aerial Planning Group to produce standard aerial plans, with reference codes, for hill-top site mast dressing - for both the temporary facilities and WARC FCP phases. A list of hill-top sites, with the specific aerial fits to be adopted will be produced.

2. Liaison Areas

Liaison between the Aerial Planning Group and the WARC teams will be as follows:

(1) Mr Hill will work with Mr Fielding's team

(2) Mr Armstrong will work with Mr Smith's team

(3) Mr Bridgeman will work with Mr Martin's team

3. Aerial Arrays

The use of single aerials on the side of the mast gives rise to directional aerial patterns and tower-excited intermodulation product frequencies (IMPs). In general, aerial arrays will be used for post-WARC schemes. Exceptions may be for single-channel sites or where site owners refuse permission to fit additional aerials.

4. Aerial Types & Usage

Note that the aerial gains shown are referred to a dipole in free space (which in turn has a power gain 1.76 dB above an isotropic radiator).

Both E- and H-plane beamwidths are shown although only H-plane beamwidths are considered for general planning purposes.

4.1 Folded Dipole: Gain = 0 dB
Unscreened dipoles may be used for single channel sites or where no other aerial or system is possible.
Dipoles with reflecting screens may be used - normally in an array (single ring or two rings stacked and co-phased).

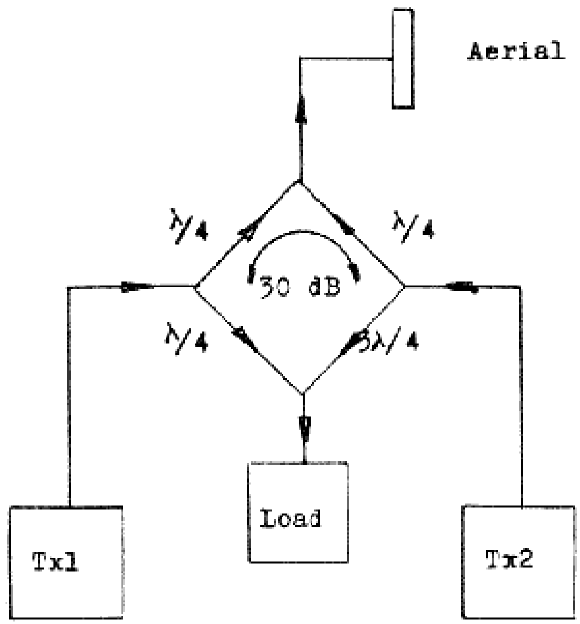
4.2 Turnstile: Gain = 0 db (nominal)
Comprises four dipoles with booms welded to a single pole in a symmetrical ring. Also contains a ground-plane and a screening sleeve.
Can only be used on the top of the mast.

4.3	Double Turnstile:	Gain = 3 dB (nominal) As for single turnstile but comprises two rings of dipoles co-phased. This system has an increased wind loaded area which may restrict its use.
4.4	End-Fed Dipole:	Gain = 0 dB Can be used for single-channel sites but only where the top of the mast is free.
4.5	Ground-Plane:	Gain = 0 dB Can be fitted if the top of the mast is free. May be used in an array (normally four) with a Butler Matrix combiner to provide good horizontal radiation patterns for up to three channels.
4.6	Slot Panel:	Gain = 8 dB Consists of a skeleton slot in front of a screen. For a single ring of four panels, the gain may be 0 dB to -2 dB. The cross-sectional size of the mast will affect the h.r.p. Using two rings and co-phasing will provide 3 dB gain.
4.7	2-Element Yagi:	Gain = 3 dB Beamwidth to 3 dB points = 62° (E), 95° (H) Bandwidth w.r.t. centre-frequency = ± 6% Front-to-back ratio = 12dB Used with main transmitters and receivers where h.r.p. shaping, or some improved mast isolation is required.
4.8	3-Element Yagi:	Gain = 6 dB Beamwidth to 3 dB points = 58° (E), 74° (H) Bandwidth w.r.t. centre-frequency = ±5% Front-to-back ratio = 16dB Use as for 4.7
4.9	4-Element Yagi:	Gain = 7.5 dB Beamwidth to 3 dB points = 58° (E), 74° (H) Bandwidth w.r.t. centre-frequency = ± 5% Front-to-back ratio = 15dB Use as for 4.7
4.10	6-Element Yagi:	Gain = 8.5 dB Beamwidth to 3 dB points = 56° (E), 64° (H) Bandwidth w.r.t. centre-frequency = ± 5% Front-to-back ratio = 16dB Used mainly for radio linking but, in welded form may be used for main transmitters and receivers if required.

5. Combining/Splitting Methods

The following methods are used for equipment combining, or splitting, from a common aerial (or array). Many of the devices used are reciprocal in that they may be used either for combining or splitting purposes.

5.1 Hybrids - Transmitter Combining



Each hybrid has two input ports, an output port and a load port. Power loss, per transmit leg, is 3.5dB. The isolation between the input ports is typically 30 dB. The load is usually rated to that of the highest power transmitter connected to the hybrid.

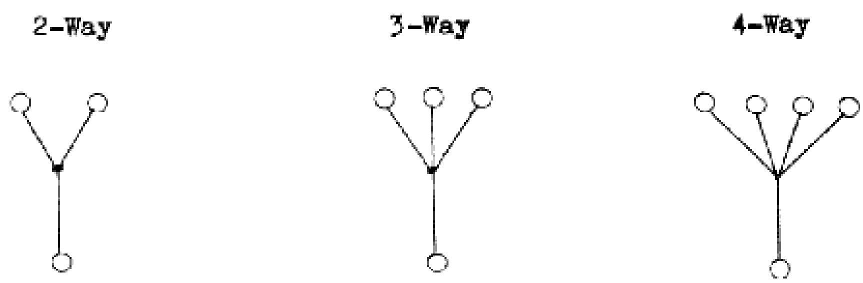
Hybrids may be cascaded but each addition further splits the available power by half. Thus, only a maximum of four transmitters would be considered to be combined by this method (ie 7dB loss per transmit leg.

In the 180° hybrids used, on arm is $3\lambda/4$ with all the other arms $\lambda/4$. Use is made of this factor in providing the isolation between transmitter input ports. The path length from each port to the opposite port differs by 180° when comparing the top and bottom routes.

5.2 Hybrids - Receiver Signal Splitters

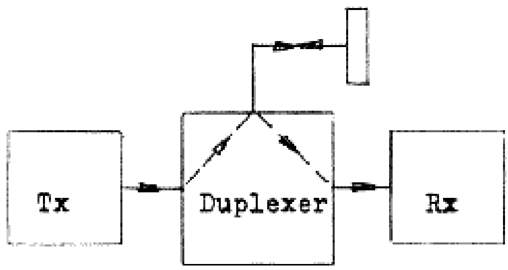
Small 3-port (one aerial input and two output ports) signal splitting hybrids may be used for receiver circuits to provide aerial sharing on two-channel sites. For three or more channel operation and where signal losses can be tolerated eg on high signal level link paths, receiver hybrids having three or more output ports may be acceptable. Where such losses cannot be tolerated then aerial distribution amplifiers will be required - see 5.5.

5.3 Power Splitting Harnesses



These are generally formed from co-axial cable sections and may be used for signal combining or splitting - the power division being 3dB per split. In addition, an insertion loss, over and above the power split, will be about 0.5dB

5.4 Duplexers



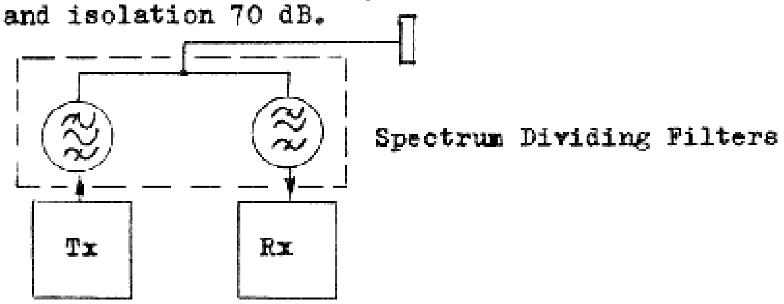
Duplexers permit simultaneous transmission and reception, using a common aerial, with little or no mutual interaction. Three types are in common usage:

(1) Co-axial cable. Formed from critical lengths of cable.

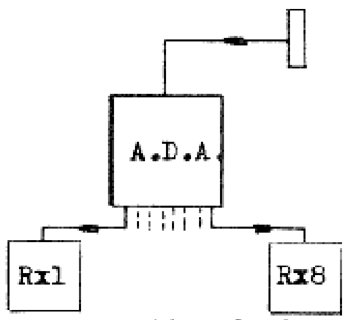
(2) Cavity resonators. Bandpass or reject-mode cavities are coupled via critical co-axial harnesses.

(3) Spectrum dividing filters. These are bandpass types and coupled via critical co-axial harnesses.

The spectrum dividing bandpass filters are the preferred type and will be used. They are physically smaller than cavity types for the same power rating. Typical minimum frequency spacing between transmit and receive sections is 4 MHz, with insertion loss per section of 1 dB and isolation 70 dB.

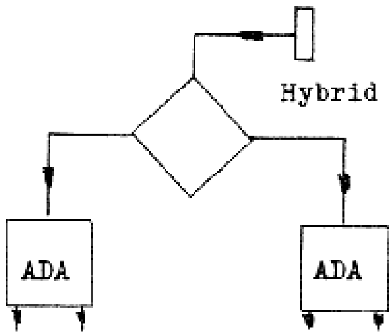


5.5 Aerial Distribution Amplifiers

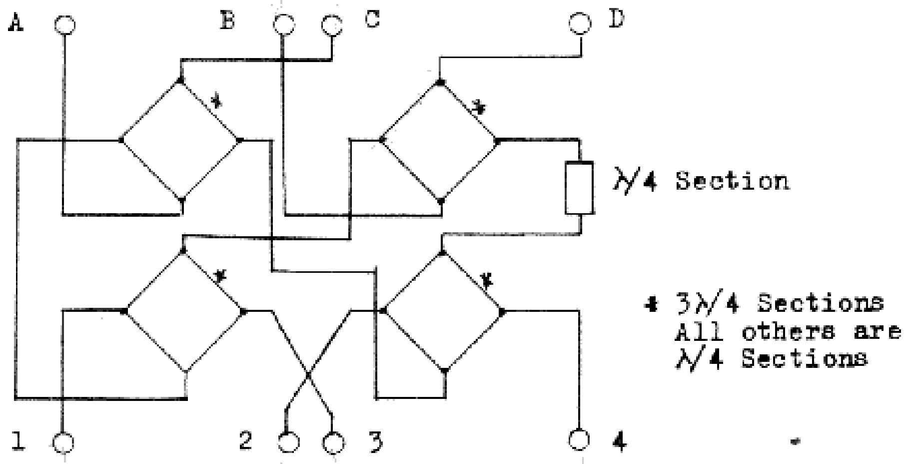


The amplifiers are active devices and are used to feed up to eight receivers from a common aerial. Gain is generally 0 dB to 6 dB and isolation between output ports is 20 dB. Bandwidths will depend on the design and particularly which filter is fitted. For WARC FCP use, the Aerial Facilities unit contains a spectrum dividing filter providing bandpass at 143 to 144 MHz and 146 to 148 MHz whilst also providing a reject notch centred on 145 MHz.

To provide the required 'redundancy' stipulated for active devices, two aerial distribution amplifier units should be used in conjunction with a passive receiver splitting hybrid.



5.6 Butler Matrix

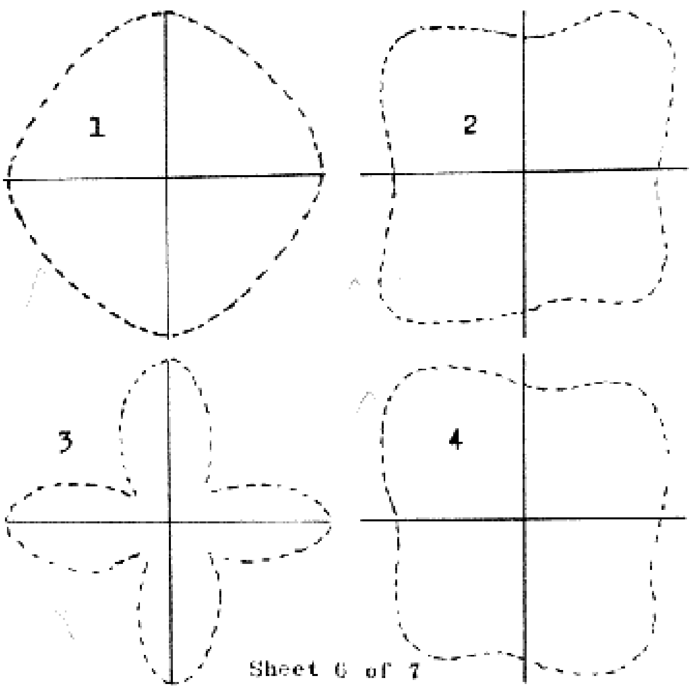


Phase relationships between input and output ports

Port	A	B	C	D	
1	180	180	180	180	Degrees
2	180	270	360	450	
3	180	360	180	360	
4	180	450	360	630	

Note: λ/4 = 90°
3λ/4 = 270°

HRPs using single turnstile array



The Butler Matrix enables up to four transmitters to be connected to four aerials. Power at any input port is split equally between the output ports. Losses using this configuration are low (typical insertion loss = 0.5 dB) and the isolation between ports is 20 dB. The phase relationships between input and output ports are shown in the table with the corresponding horizontal radiation patterns achievable when using a turnstile aerial array.

It should be noted that in-phase, or 90° relative phases between the aerials will produce reasonably omni-directional coverage patterns but 180° relationships (as in 3) will not. Hence, omni-directional cover may be obtained for three transmitters with a fourth one showing directional properties and may be of limited practical use.

APPENDIX 7

SELECTED ARRAY PATTERNS

Selected Array Patterns

A 10 metre section of standard aerial tower recently erected at Cheveley Depot has enabled aerial patterns to be measured with a high degree of accuracy and repeatability.

Pages 1 to 4 of the attached polar plots illustrate the patterns obtained with some frequently used single aerial positions. Figure 5 shows the effect of two aerials used with a combining harness; this pattern is eminently suitable for temporary FCP facilities use.

Similar aerial fits to fig 5 using post-WARC frequencies will not have the same omni-directional properties due to the shorter wavelength in use, see fig 6.

Fig 7 shows the pattern achieved using four 150Mhz slot panel aerials combined with a four way harness. Figs 8, 9 and 10 are slot panel array patterns using various splitting and hybrid combinations to electrically steer the coverage for any particular channel. The limiting factor is the total loss tolerable in channel combining and steering hybrids when considered against the minimum ERP required.

Patterns may also be adjusted by means of lateral (sideways) offset and polar (angular) shift of individual panels on the mast structure.

Fig 11 shows the pattern achieved by three slot panels on a triangular tower section.

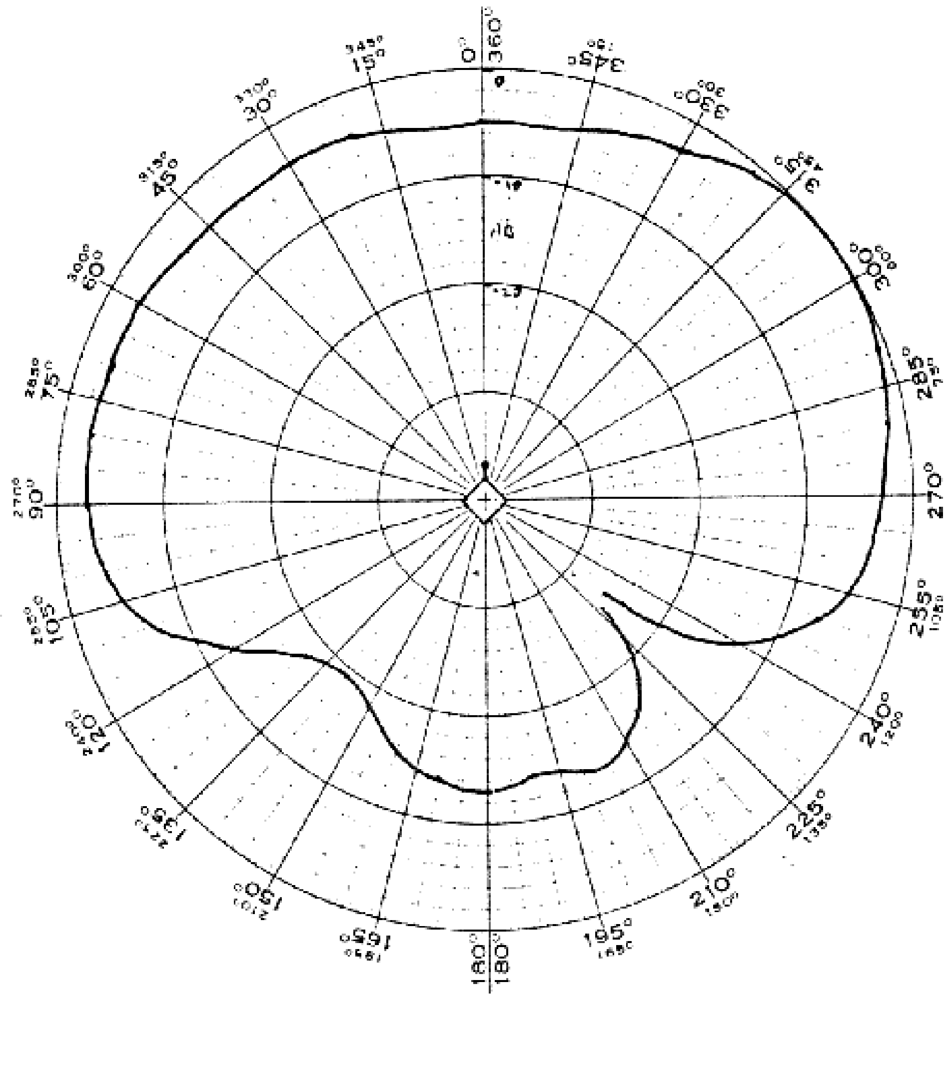
A.7.3

Folded dipole 0.25λ stand-off (6
from corner of square tower

100Mhz

Cheveley Jan 84

Fig. (1)



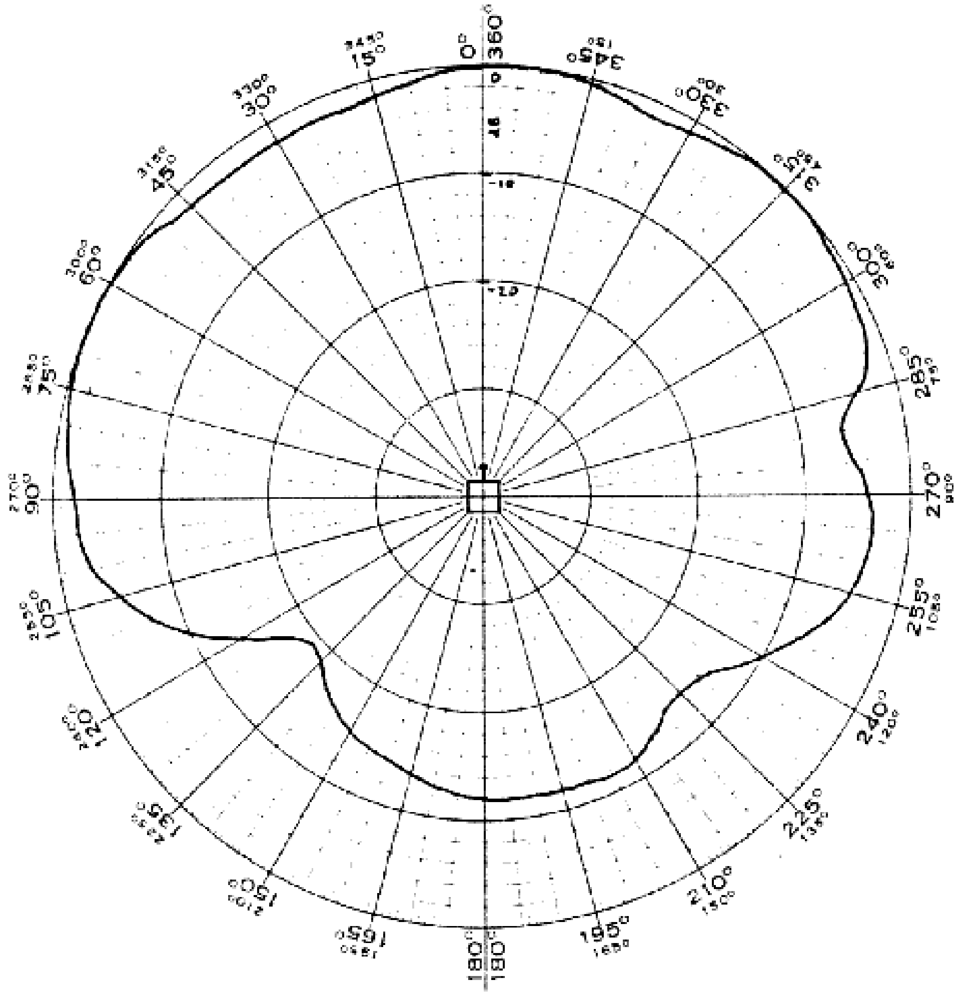
A.7.4

Folded dipole 0.25λ stand-off (65cm) from face of square tower

100Mhz

Cheveley Jan 84

Fig. (2)



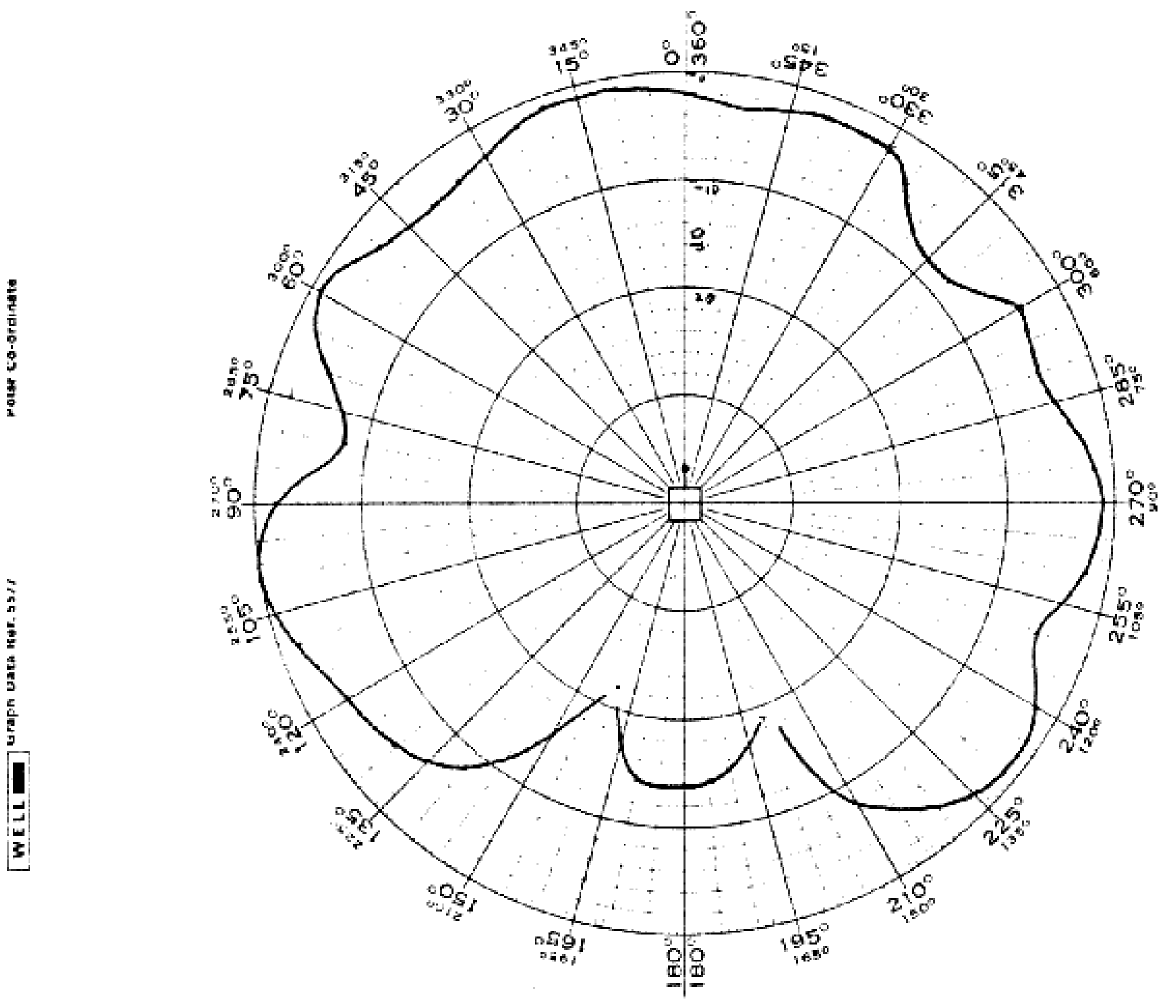
A.7.5

Folded dipole 0.67λ stand-off
from face of square tower

100Mhz

Cheveley Jan 84

Fig. (3)



A.7.6

Folded dipole 0.16λ stand-off (48cm) from face of square tower

100Mhz

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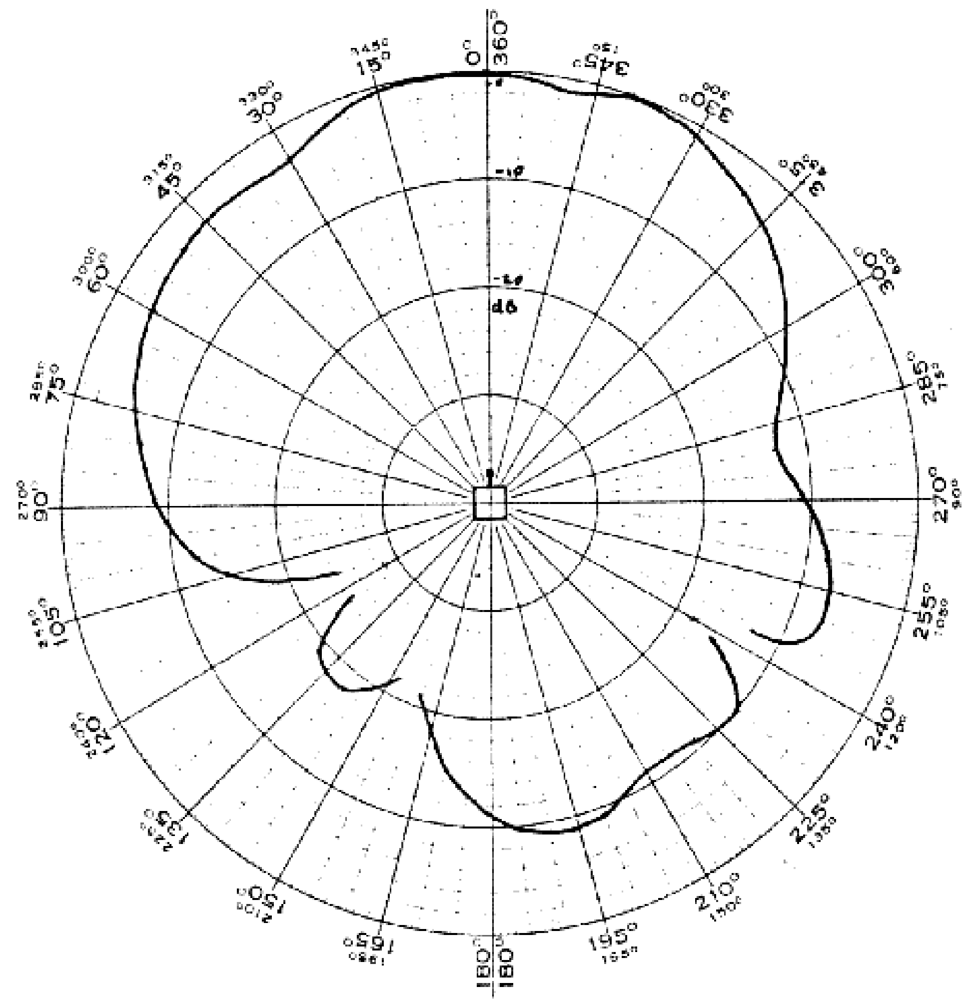
Fig. (4)



A.7.7

Two Folded Dipoles.
Stand-off .16λ (48cm)
from face of square
tower (1.5m)

100Mhz

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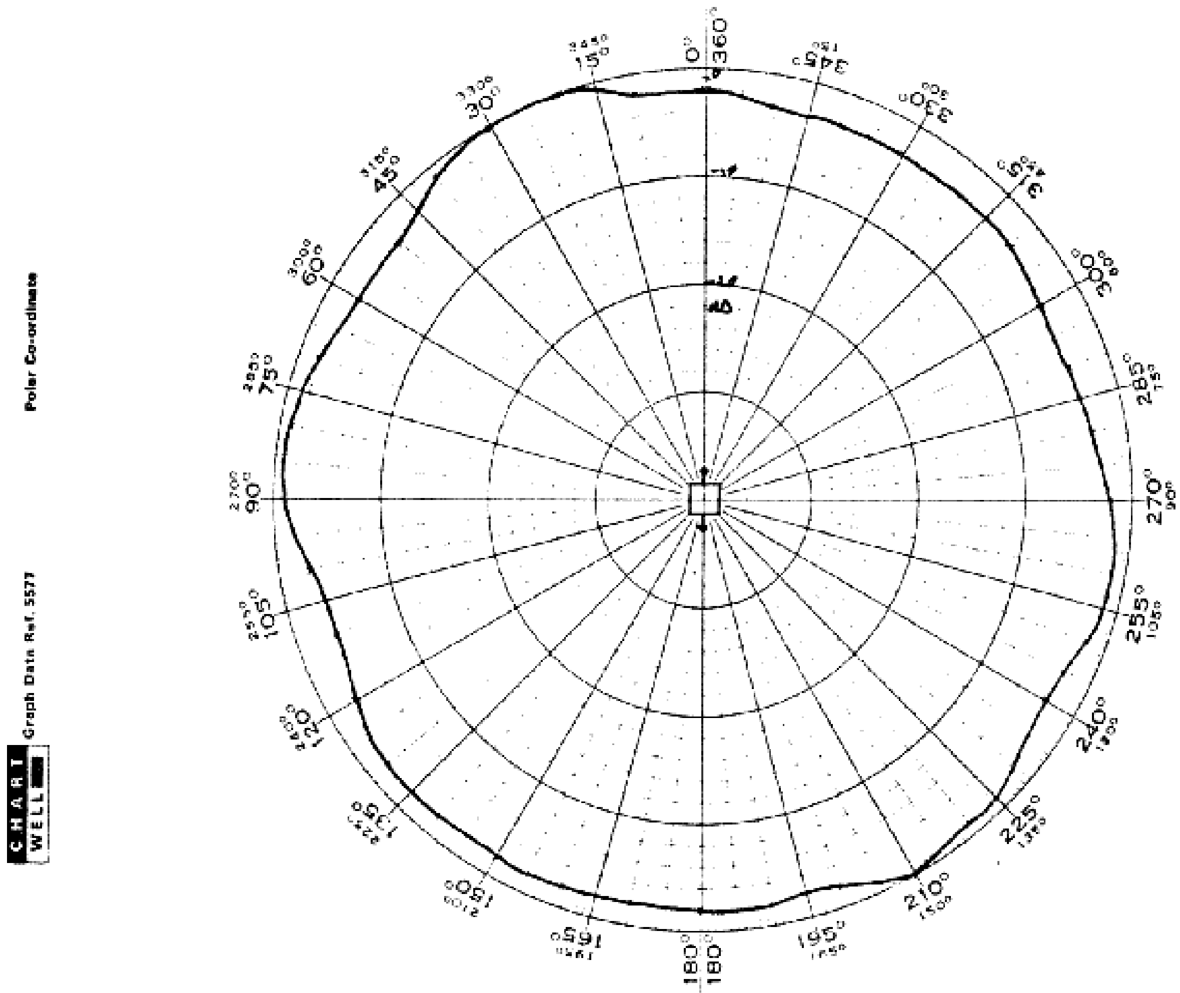
Fig. (5)



Two Folded Dipoles.
Stand-off .16λ (30cm)
from face of square
tower (1.5m)

144Mhz

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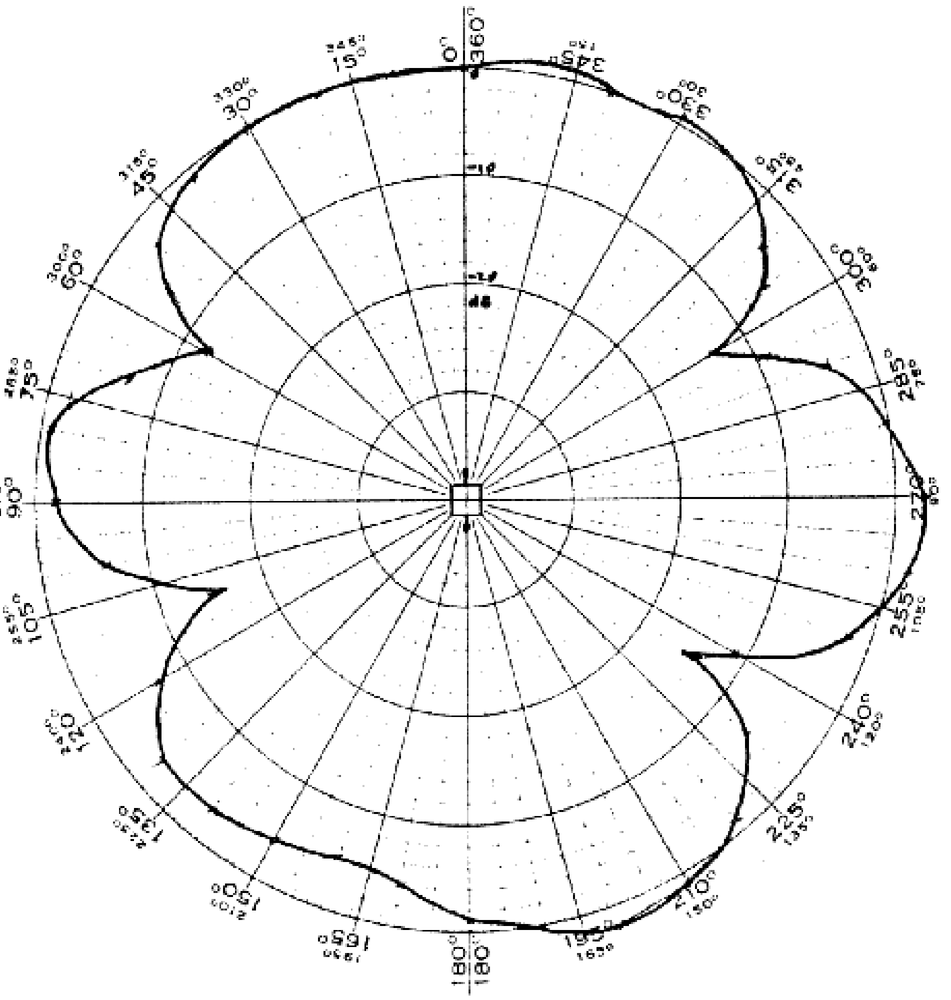
Fig. (6)



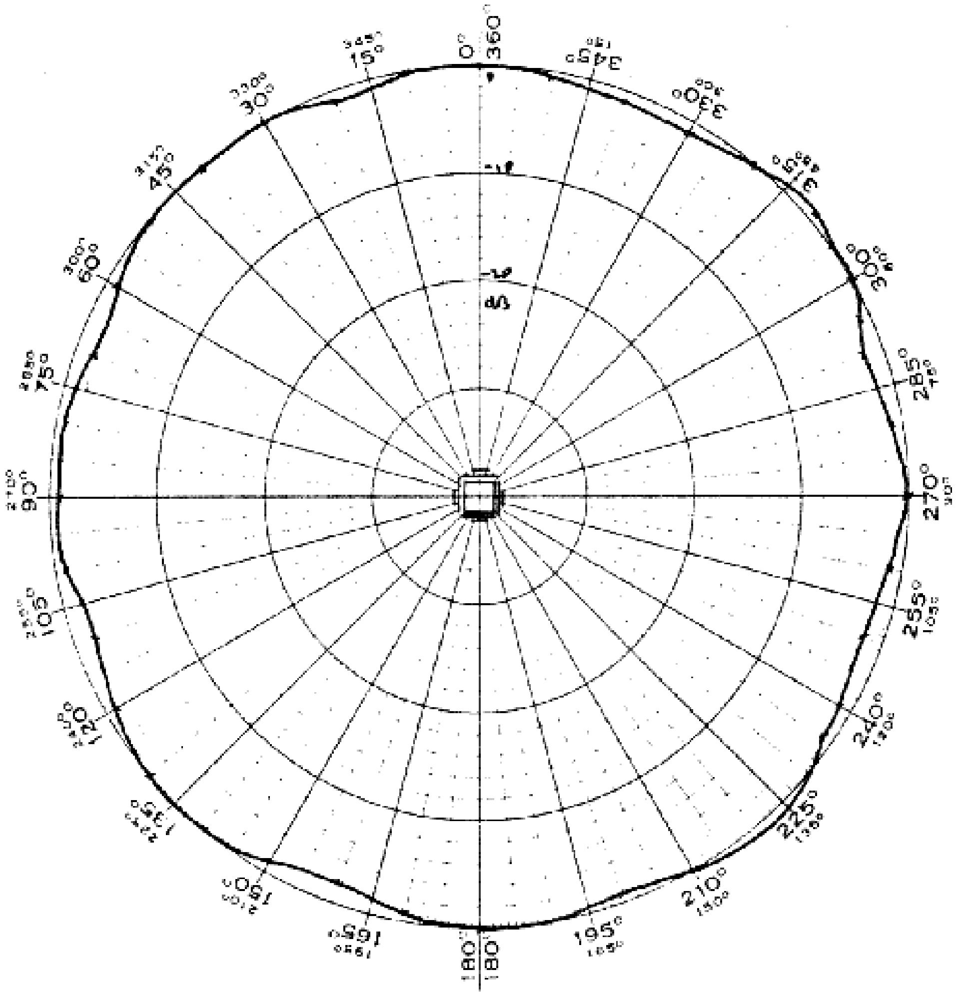
A.7.10

Slot Panel Array 2.3m between pa
Square tower (1.5m)

144Mhz

Cheveley Apr 84

Fig. (7)



A.7.11

Slot Panel Array 2.3m between panels
Square tower (1.5m)

Ch1 N,E,S,W ————
Ch2 N — · —

144Mhz

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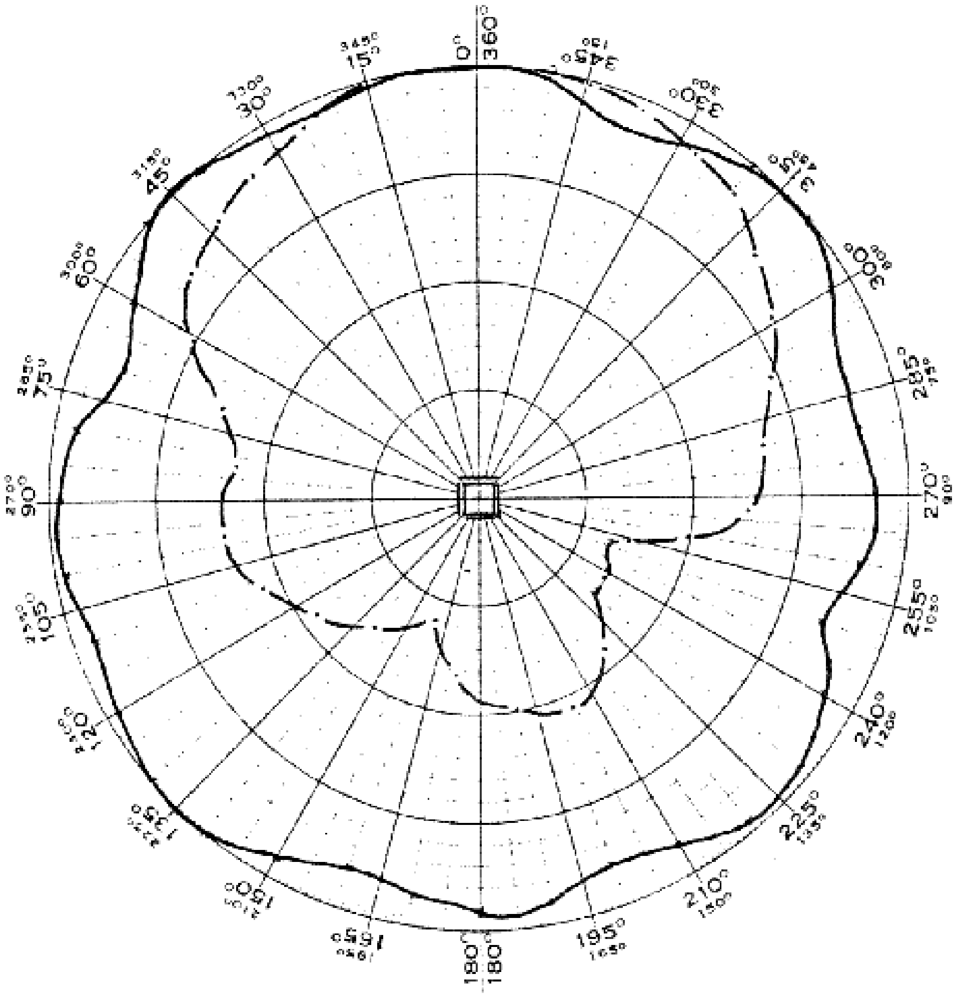
Fig. (8)



A.7.12

Slot Panel Array 2.3m between pa

Square tower (1.5m)

Ch1 N,E,W ———

Ch2 S,E,W —·—

156Mhz

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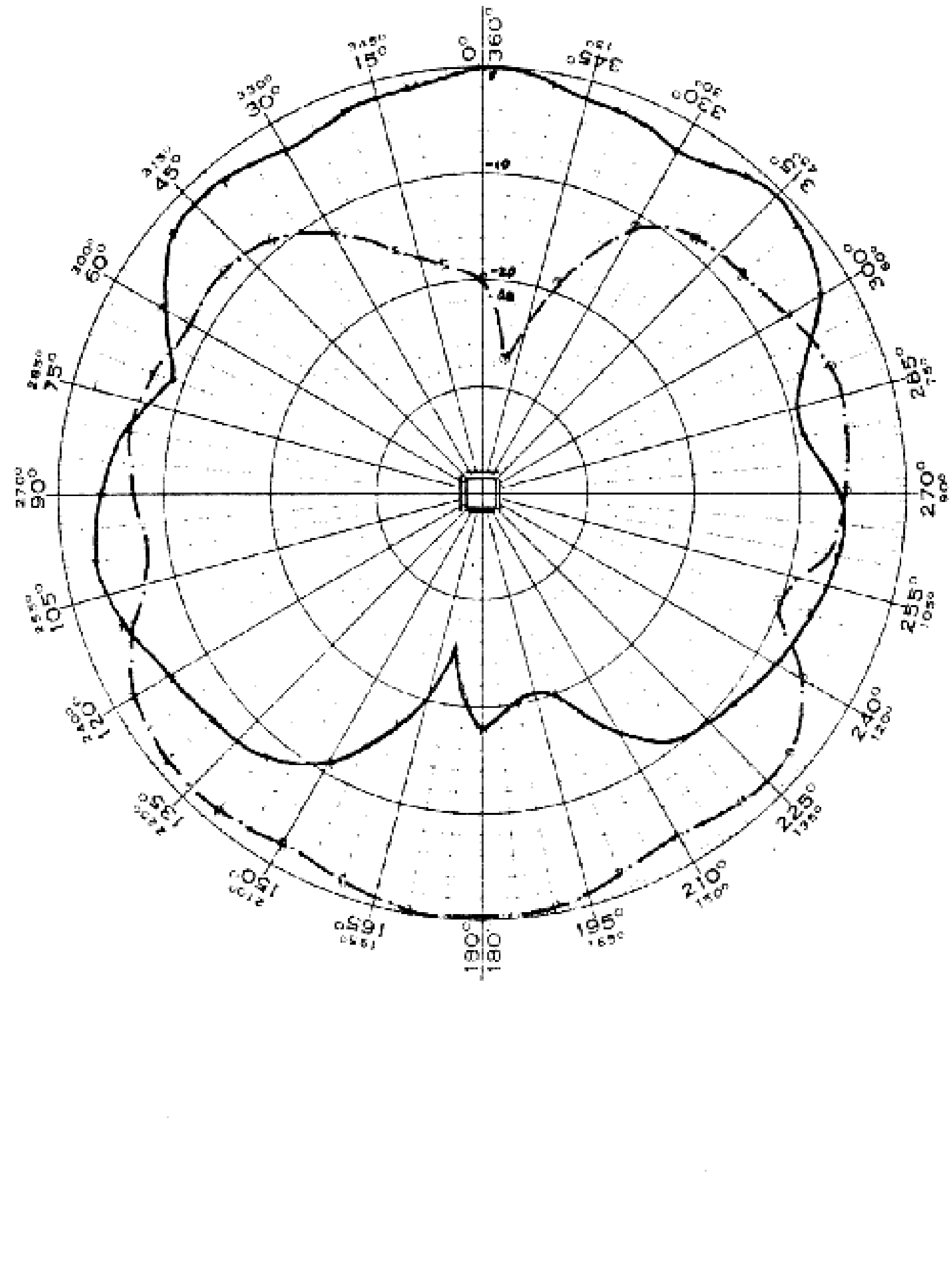
Fig. (9)



A.7.13

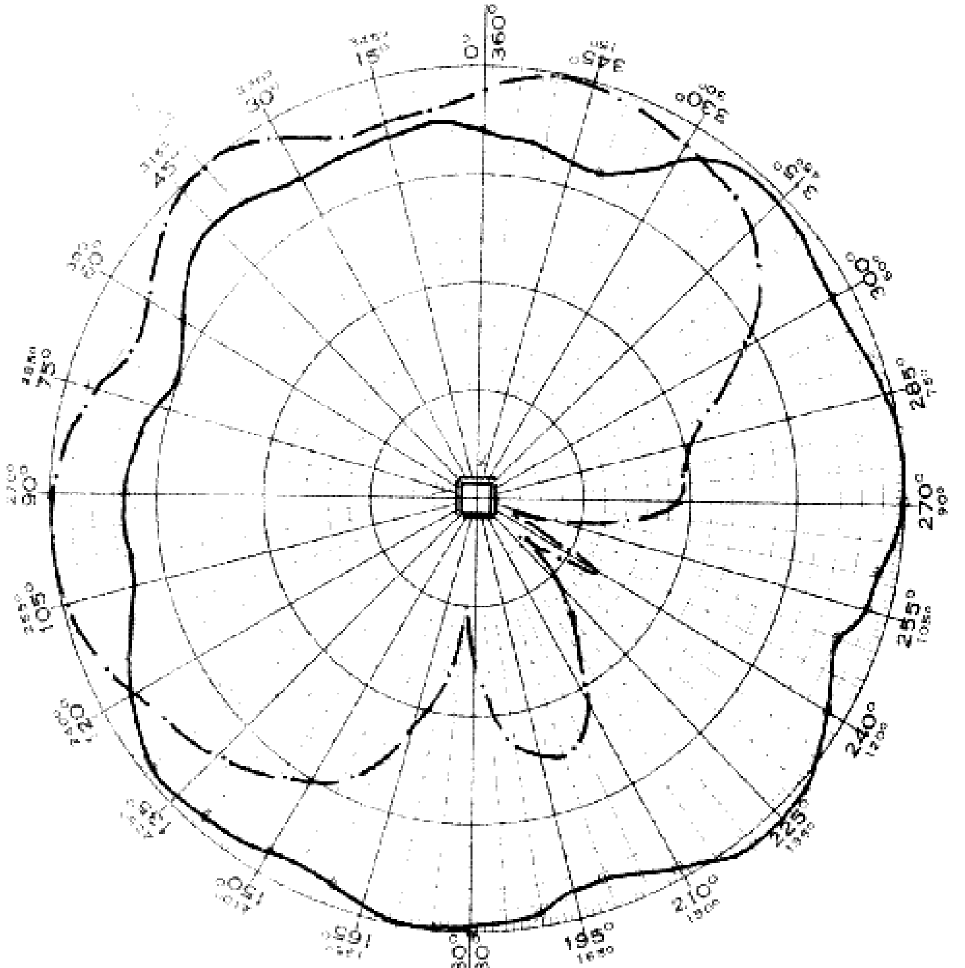
Slot Panel Array 2.3m between pan
Square tower (1.5m)

Ch1 N,E,S,W ————
Ch2 N,W —— - ——

144Mhz

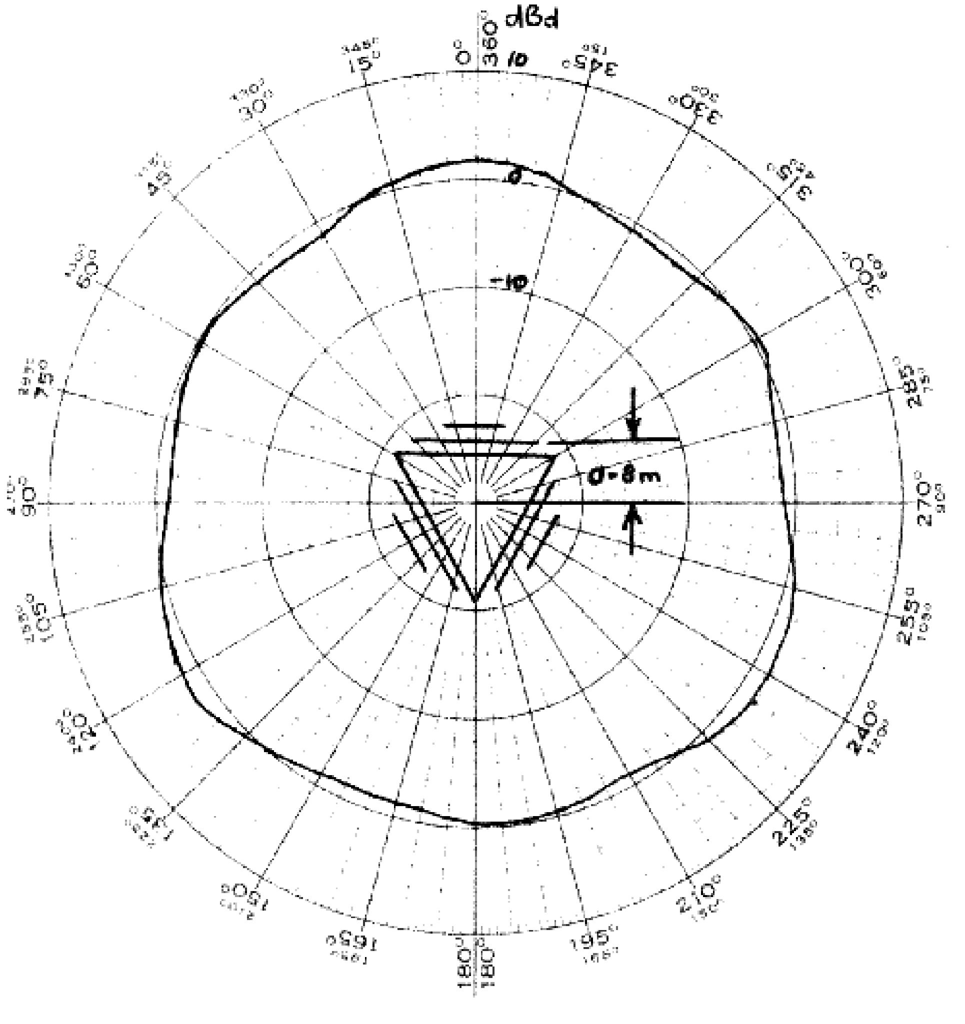
Cheveley Apr 84

Fig. (10)



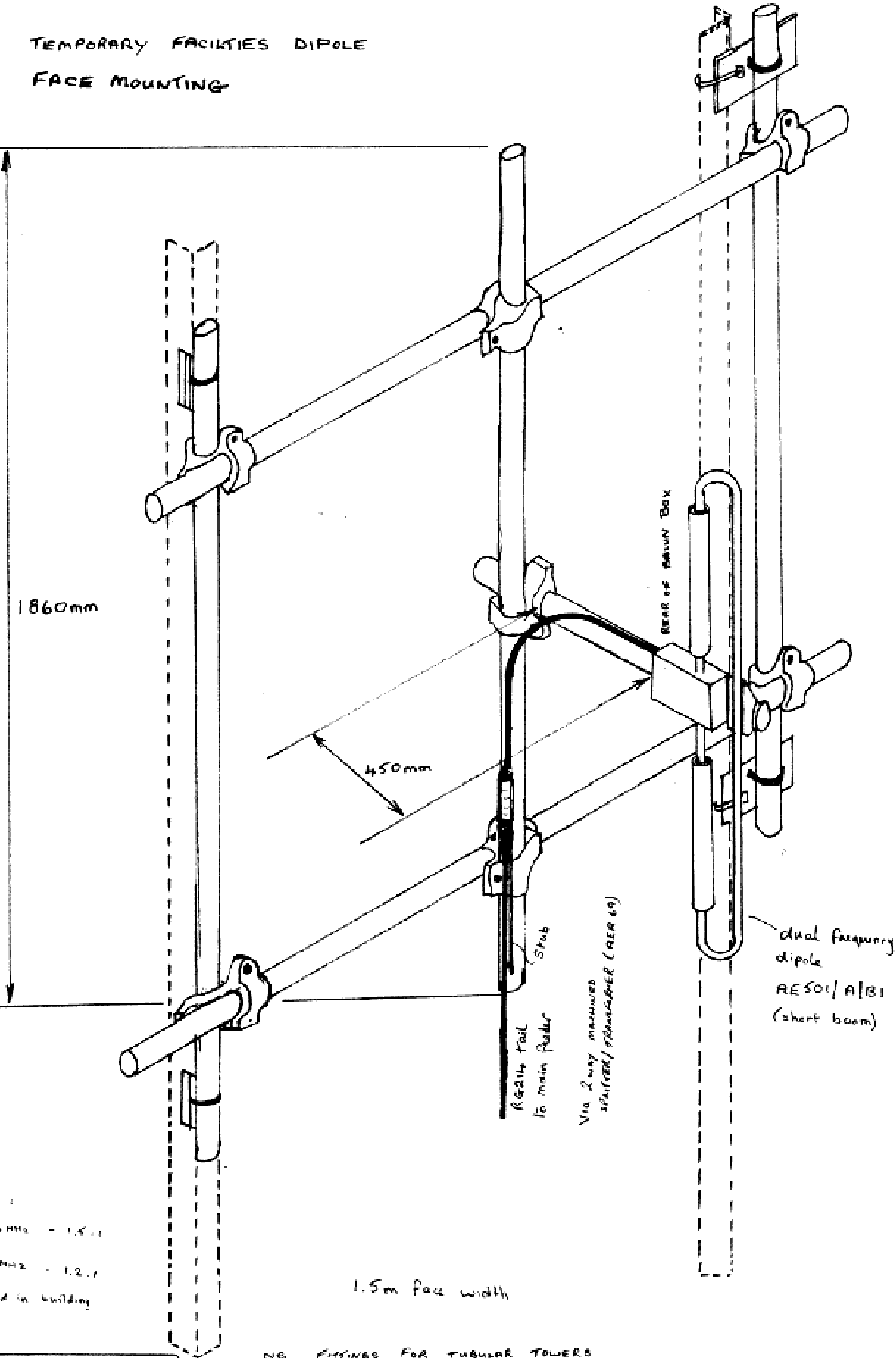
THREE SLOT PANELS ON TRIANGULAR TOWER SECTIO

Fig. (11)



TEMPORARY FACILITIES DIPOLE

FACE MOUNTING



...R :

...84 MHz - 1.5:1

...03MHz - 1.2:1

...red in building

NB. FITTINGS FOR TUBULAR TOWERS WILL VARY

BRIDGEMAN 14 Nov 84