Use of High Frequency Radio Systems During And After World War 2 With Special Reference To Redland City: Capalaba Brisbane City: Hemmant Queensland Australia

2017

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PREFACE

This publication stems from my long-time interest in Amateur Radio, spanning over 50 years. The use of High Frequency Radio Systems during and after World War 2 is a particular interest as it was a catalyst in the use of these frequency bands for commercial world-wide communications after the war.

Sources of inspiration for this publication included two members of the Australian Defence Forces during World War 2 in the Pacific 1941-45, both Licensed Radio Amateurs, the late Peter Brown, and the late Albert (Al) Carter. For many years I was involved in daily conversations via Amateur Radio with both of them. These High Frequency "skeds" as they were called covered many aspects of Amateur Radio including signal propagation. They also kept these two friends in contact with each other despite advancing years.

Australian Radio Amateurs' licensing was controlled in earlier times by the Radio Branch of the Commonwealth Government and it was its task to monitor radio transmissions and measure frequencies, including those of Radio Amateurs, using a "Frequency Standard" at Capalaba. On moving from the City of Brisbane to Redland City in 1983 I became more aware of the existence of the sites and heard comments about their past use in World War 2. Unfortunately there was little technical information available as to how the sites were designed, what radios and other equipment were installed, and the level of technology at that time. Difficulties in obtaining factual information eventually led to both Australian and United States of America Radio Amateurs assisting with source document identification and retrieval, and culminated in the preparation of this material. Their generosity in both time and effort was unmatched.

Information for this publication came from a number of sources. In addition to the two World War 2 Diggers and radio "buffs" mentioned above, other amateur radio enthusiasts are acknowledged as are other personal contacts who provided valuable information.

As this is an electronic publication, URL sources for information are given in the text to allow the reader to access these directly. Bear in mind though, that they are relevant as at the date of publication. The author/date system is used to acknowledge other primary sources which are cited in this document.

The author would be pleased to hear from anyone who can add information and/or sources relevant to the topics discussed.

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Note(1): All URLs are current as at the time of publication.

LIST OF ABBREVIATIONS

4QG	Brisbane ABC Radio station
4QR	Brisbane ABC Radio station

A

AAF	American Air Force
ABC	Australian Broadcasting Commission
AC	Alternating Current
ACAN	Army Command and Administrative Network (USA)
ACMA	Australian Communication and Media Authority
AF	Amplifier
AFC	Automatic Frequency Control
AGC	Automatic Gain Control
AIEE	American Institute of Electrical Engineers
AIF	Australian Imperial force
AM	Amplitude Modulation (radio). Also a-m.
AMP	Australian Mutual Provident Society
AMR200	Eclipse HF radio receiver
AMR300	STC HF radio receiver
AMT	American Transmitter
AMT150	Low powered transmitter made in Australia during WW2 for use on High Frequencies
AO	Order of Australia (Honours System)
AR7	Kingsley Radio Receiver Type.
AR88	WW2 USA HF superheterodyne communications receiver
ARRL	American Radio Relay League
ASF	US Army Service Forces
AT	Australian Transmitter
AT14A	Tasma High Frequency transmitter
AT&T	American Telephone and Telegraph Corporation
AVC	Automatic Volume Control
AWA	Amalgamated Wireless (Australasia) Ltd (later AWA Ltd)

B

BC	Basic component- part nomenclature system developed for the US Signals Corps equipment.
BC200	WW2 USA 200 watt HF radio transmitter
BC339K	WW2 USA 1kw HF radio transmitter
BC340	WW2 USA 10kW HF radio transmitter
BC348	USA WW2 28 VDC powered HF communications receiver
BC610	WW2 USA 400 watt HF radio transmitter
BC779-A	WW2 USA Hammarlund HF radio receiver
BFO (bfo)	Beat Frequency Oscillator
BRT400	GEC HF Radio receiver

C

CBI	China-Burma-India (Theater)
Class C	Non linear radio frequency amplifying method used for FM, CW, or RTTY transmissions.
CMF	Citizen Military Forces
CW	Morse Code
CW3	Wilcox Radio Receiver Type
CW3-D	Wilcox Diversity Radio Receiver Type

D

dB	Decibel
DC	Direct Current

E

ETOUSA	European Theater of Operations, US Army.

F

Fax	Facsimile
FDM	Frequency Division Multiplexing
FM	Frequency Modulation (radio)
FRC	Fixed Ground Radio Communication
FS	Full Scale
FSK	Frequency Shift Keying
F3	Wilcox HF Radio Receiver Type

G

GBP	Great Britain Pounds
GEC	General Electric Corporation
GHQ	General Headquarters. Also referred to as GHQ SWPA
GHz	Gigahertz
Group	As in CW, 5 characters including letters or numbers or both.

H

Ha	Hectare
HF (h-f)	High Frequency 3 to 30 MHz (Shortwave)
HRO	National Type HF Radio receiver
Hz	Hertz (one cycle per second)

I

IARU	International Amateur Radio Union
IBM	International Business Machines Corporation,USA
IF	Intermediate Frequency
ISB	Independent Sideband
ITU	International Telecommunications Union

J

JORN	Jindalee Operational Radar Network

K

kc	Kilocycle
KCMG	Knight Commander, St. Michael and St. George (Honours System)
kHz	Kilohertz (1000 Hertz)
kVA	1000 Volt Amps
kW	Kilowatt (1000 Watts)

L

Lb	Pound Weight
LO	Local Oscillator
Lq	Tube (Valve) Standing Current or Tube Quiescent Current

M

MC (Mc)	Megacycles. Later renamed Megahertz (MHz) by international agreement
MCW	Modulated Continuous Wave (CW)
MHz	Megahertz (one million Hertz)

MUF	Maximum Usable Frequency being the highest radio frequency that can be used for transmission between two points via reflection from the ionosphere at a specified time independent of transmitter power.
MUX	Multiplexing - A method by which multiple analog or digital signals are combined into one signal over a shared medium.
N	
NAA	National Archives of Australia
NARA	National Archives and Records Administration (USA)
O	
Ohm	Measurement of resistance
OTC	Overseas Telephone Commission and from 1 February 1992 the Australian and Overseas Telecommunications Corporation Limited (AOTC)
OZATWAR	Peter Dunn's on-line Australian Wartime History Collection
P	
PCM	Pulse Code Modulation
PEP (pep)	Peak Envelope Power
PMG	Post Master General's Department (Australia); now known as Australia Post.
Press	Press Wireless Corporation USA
Q	
QLD	Queensland, Australia
QRM	Indicating channel interference when using morse code.
R	
RA	Right Ascension
RA17	Racal HF radio receiver
RAAF	Royal Australian Air Force
RAN	Royal Australian Navy
RCA	Radio Corporation of America
REL	Radio Electronics Laboratory
Revs	Continuous teletype transmission of the letters RY. Also called Reversals.
RF	Radio Frequency
RTTY	Radio teletype
RX	Radio receiver
S	
SCR	Set Complete Radio
SDR	Software Defined Radio
SIGSALY	Secure speech system used in World War 2 for the highest-level Allied communications
SK	Silent Key – a deceased licensed radio amateur
SSB	Single Sideband
STC	Standard Telephones and Cables Pty. Ltd. Sydney
SWPA	Southwest Pacific Area. Also referred to as GHQ SWPA
T	
TA175	UK Racal 1kW HF radio transmitter
TEC	Naval version of Press PW-40 transmitter
Tp	Teleprinter
TTY	Teleprinter (UK) Teletype (USA)
TUBE	A vacuum tube used in radios. Also called a Valve
TV	Television
TX	Radio Transmitter

U

UHF	Upper or Ultra High Frequency 300MHz to 3 GHz
UK	United Kingdom
URL	Uniform Resource Locator
US	United States
USA	United States of America
USAFIA	U.S. Army Forces in Australia
USASOS	United States Army Services of Supply
USNO	United States Naval Observatory

V

Vac	Volts, Alternating Current
VALVE	A vacuum tube used in radios. Also called a Tube
Vdc	Volts, Direct Current
VE DAY	Victory in Europe
VFT	Voice Frequency Telegraph
VHF	Very high frequency 30MHz to 300MHz
VLF	Very Low Frequency

W

WAC	Womens Army Corps (US Army)
WAAAF	Women's Australian Auxiliary Air Force
WAR	ACAN Net Control Wireless Station, Washington, USA
W.E. Co.	Western Electric Corporation, USA
WIA	Wireless Institute of Australia
WTA	US Army's Manila Wireless Station
WTJ	Fort Shafter, Hawaii Radio Station
WTJJ	US Army's Melbourne Wireless Station
WTO	US Army's Brisbane Wireless Station
WVJJ	US Army's Brisbane Wireless Station prior to establishing the Brisbane WTO
WVLH	US Army's Hollandia Wireless Station (from May 1944)
WW2	World War 2,1938 to 1945
WWII	World War 2,1938 to 1945
WWV	USA High Frequency time signal transmission station

Z

Z Ohm	Impedance

ACKNOWLEDGEMENTS

- Bob Bolin, Business Librarian, University of Nebraska-Lincoln Libraries, USA, (http://libraries.unl.edu/) helped early in the search for details of the radio receiver used at Capalaba during WW2 through his online bibliography and personal communications.

- Mr. Peter Dunn assisted this project with encouragement and comments. Approval to use extracts from his material is appreciated. Through a lot of hard work he has put together a mountain of information on the impact of World War 2 on Queensland and elsewhere. This material is publicly available on his website http://www.ozatwar.com . The late US Major Bill Bentson was a large contributor to the Ozatwar history. In April 1942 Bill was posted to General Douglas MacArthur's General Headquarters (GHQ) in Melbourne, Australia. In July of that year, GHQ moved to Brisbane where he was involved in the setting up of and supply to U.S. Army camps around Queensland. He then served in Papua New Guinea, Borneo and the Philippines. Bill met and married Joan Staines while stationed in Brisbane. His War Bride joined him in Salem, USA, in 1946 and they settled in the Multnomah area of Portland in 1950. Upon his retirement, in 1964, the family moved to Brisbane. He held Australian Radio Amateur Callsign VK4QF and was well known in Radio Amateur circles in Brisbane and was known to the author and many other licensed radio amateurs.

- Cullen Langford, a USA Licensed Radio Amateur, early in this study kindly emailed a copy of his own Instruction Book for the Wilcox Electric Co. CW3 Radio Receiver and Receiver Bay 113A in the absence of any information known about the Wilcox Electric Co. CW3-D receiver. Later in 2016 he was able to source and email a copy of US War Department November 1945 Technical Manual TM 11-853, Radio Receivers (Wilcox Electric Co. Types CW3 and F3) and Receiver Bay (Wilcox Electric Co. Type 113A) which expanded on his earlier material. In addition late in 2016 he sourced US Army Service Forces Catalog SIG-10-325, Fixed Plant Maintenance List, Receiving Equipment, Technical Reference TM 11-2204, Wilcox Electric Co., Manufacturers Model No. 4CW3-D, Dual Receiver. This was the only material that had been found regarding the Wilcox Electric Co. CW3-D until Technical Manual TM 11-2204 dated 28 December 1944, totalling some 31 pages, giving full operational and technical details was sourced, at his suggestion, from the Library of Congress in the USA. This was done through the State Library of Queensland early in 2017.

- Christopher Story, a USA Licensed Radio Amateur, also assisted in the search for radio receiver documentation.

- The late Peter Oliveri, a Licensed Radio Amateur, who worked at the Capalaba Radio Receiving site as a Senior Communications Technician for the Post Master General’s Department (PMG) from 1952 to 1959 was interviewed by the author in 2015 accompanied by Peter’s friend, Licensed Radio Amateur, Victor Stallan.

- Lionel Sharp, a Licensed Radio Amateur, also worked at the Capalaba Radio Receiver Site, late 1954 to early 1955, and was then transferred to the Hemmant Transmitter site until promotion to Senior -Technician in the City of Brisbane. Lionel kindly provided historical comments and assistance in relation to the Radio Receivers and other equipment used at Capalaba during the war and Transmitters at Hemmant post-war.

- Paul Hayden, a Licensed Radio Amateur, also visited both the Capalaba and Hemmant sites 1958-1961 and 1964-1970 as part of his role with the PMG. Paul also provided much vital factual and technical advice plus encouragement over a long period.

- Mr. Ken Buckley, of Cleveland, advised on matters concerning the Willard and Cotton families who, in turn, had ownership of the Capalaba site. The property is now officially defined as part of the suburb of Birkdale in Redland City.

- Members of the Bayside District Amateur Radio Society were also consulted on technical aspects. Details of this study are available on the Society's website. (http://www.bdars.org.au/) The Society is affiliated with the Wireless Institute of Australia, the national body representing Australian licensed Radio Amateurs. (http://www.wia.org.au/).

- Michael O'Leary recorded his work as a young technician at the Hemmant Transmitter site post-war and the disposition of the buildings and antennas at that time.

- A.L. (Lloyd) Butler, a Licensed Radio Amateur, through his website provided a glimpse into how the Australian built Kingsley High Frequency Receiver Type AR7 was used during and after the war. (http://www.qsl.net/vk5br/AR7.htm).

- Ray Robinson, a Licensed Radio Amateur, provides much needed advice to those refurbishing a Kingsley High Frequency Receiver Type AR7 through his online museum. These were used extensively in World War 2 and beyond. (http://www.tuberadio.com/robinson/museum/AR7/)

- John Berry through his contribution about the early days at Capalaba and Hemmant published on Peter Dunn's website.

- Engineer John Andrews advised on rhombic antennas used in New Guinea post-war.

- Barry Johns whose recollections published on the Queensland WWII Historic Places Website (http://www.ww2places.qld.gov.au/places/?id=1231) included comments made by American Ex-servicemen visiting the sites about 1987/1988 provided some eyewitness testimony.

- Graham Crosier, one time head of the Radio Branch, Brisbane, who made a number of suggestions concerning past documentation relating to the sites that may still be available in Melbourne.

- Thanks also to my wife Christine who assisted with words of encouragement plus special thanks to my daughter, Jennifer, who helped with the many software issues that emerged. Also thanks to the volunteer editor whose dedication helped the completion of this document, and who wishes to remain nameless.

For an acknowledgment of the contribution of Licensed Radio Amateurs to World War 2, and/or to this publication, see Section 8 (Pages 38,39) which also lists their Amateur Radio callsigns.

1 INTRODUCTION

The outbreak of hostilities in the Pacific on 7th December 1941 saw Australia ill prepared for a war that emerged without warning. The entry of the USA into the war then brought support and new technology of all kinds to our shores, including the Redlands.

The Redlands and the Brisbane suburb of Hemmant are extremely important places in the history of Australia as they were intertwined hosting the main international radio links during World War 2 and provided communication between General Douglas MacArthur and American and Australian forces fighting the territorial ambitions of the Nation of Japan in South East Asia.

Much has been written about the contribution generally of the Redlands to Australia's success during the Second World War but only a small amount is known about the role of High Frequency Radio Communications, the equipment and technologies used during the war and the subsequent advantages that this new radio technology delivered to Queensland.

The document clearly defines the role which these suburbs played in providing sites for the main USA military communications hub during the War in the Pacific until October 1944. General MacArthur then moved his headquarters to Hollandia, now Jayapura, in West New Guinea following successes in the war.

This study also shines a light on the role of the WW2 facilities at the Capalaba and Hemmant Radio Sites constructed by the Americans at the outset the war not only because of their technical importance but because it has been recorded by American Ex-servicemen that the Capalaba Radio Site was where General MacArthur slept at a time of great threat not only to Queensland but to the rest of Australia. Its importance as one of the main links left of World War 2 in the Redlands is undoubted, and is a symbol of our enduring friendship with the USA.

The radio systems used by General Douglas MacArthur of the United States of America were critical to his strategy for victory. Some may remember his slogan was "I shall Return". He used the radio installations to talk to the President of the USA, US Chiefs of Staff located in that country and other "theatre" Commanders, such as Admiral Kinkaid, to determine the best strategies to defeat the Japanese. This communication system was also important for the wellbeing of our own troops in the Pacific. Secure communications were provided by Bell Laboratories through its "Sigsaly" equipment assembled in the basement of the AMP Building in Brisbane. The system was an incredible feat of engineering and was used by the USA world- wide during the Second World War. It was never compromised. The MacArthur Museum in Brisbane at https://www.mmb.org.au/ covers these aspects in detail. Military historian Peter Dunn's on-line collection is also suggested for this and other information on World War 2 sites and activities in the Redlands and other centres in Queensland. His website is at http://www.ozatwar.com/. The MacArthur Memorial Museum in Norfolk, Virginia, is another source of information on his life and achievements. http://www.macarthurmemorial.org/. Another museum is at Little Rock, Arkansas. https://www.littlerock.gov/for-residents/parks-and-recreation/macarthur-museum-of-arkansas-military-history/.

The Capalaba land has been the home of radio ever since the War but the property will shortly be sold by the Commonwealth Government. Hemmant has long gone as a radio site but according to at least one person contacted it may still hold buried equipment.

A number of applications were made by the Bayside District Amateur Radio Society in 2015 to the Commonwealth Government authorities so as to enable a physical assessment of the Capalaba site for club purposes, particularly the World War 2 brick building built by the Americans and the operational radio towers, but no visits by club members eventuated. This has added to the difficulty in assessing the site for historical purposes.

No interviews were possible with World War 2 engineers or radio technicians who worked at Capalaba during these times, but some comments and analysis by various persons, mainly members of the Amateur Radio fraternity, who knew the sites through providing technical support post-war, helped confirm the types of communications equipment, systems and technologies used during the war. It must be recorded that many Licensed Radio Amateurs enlisted in the armed forces in World War 2 and quite a few were killed in action. Most of these servicemen have passed on now but their legacy and bravery must not be forgotten.

It has been said that history repeats itself. Despite the advances in digital communication via the internet it could come about that if the current communication systems were physically compromised during a time of international difficulty then High Frequency Radio might have to be called upon again.

This document does not cover the history of the adjoining Department of Civil Aviation's Capalaba Remote Receiving Station and Powerhouse Building dating from July 1959.

The Capalaba location is now in the suburb of Birkdale through a gazetted boundary change, but the reference throughout this document to Capalaba is to prevent confusion when accessing and reviewing the historical records held in Australia and overseas.

2 FAST MOVING DEVELOPMENTS 1941-1942

Australia feared the threat of invasion during 1942 following the bombing of Pearl Harbor in Hawaii on 7 December 1941. The Japanese invaded Malaya and the Philippines with hostilities commencing 8 December 1941 in both places. The invasion of New Guinea followed on 23 January 1942. The bombing of Darwin by 242 planes commenced on 19 February 1942 with a total of 63 raids. The main force involved in the raid was the 1st Carrier Air Fleet which was commanded by Vice-Admiral Chuichi Nagumo. This force comprised the aircraft carriers Akagi, Kaga, Hiryu and Soryu and a powerful force of escorting surface ships. All four carriers had participated in the six carrier attack on America's naval base at Pearl Harbor, Hawaii, which precipitated the start of the World War 2 in the Pacific.

USA official military history document by Thompson et. al., (1957) records that " The Navy transport *Republic,* flagship of a convoy which had formed just west of Honolulu on 29 November and which was diverted, after Pearl Harbor, from Manila to Brisbane, had aboard the 36th Signal Platoon and its organizational equipment. This convoy, carrying the first American forces to Australia, reached Brisbane on 22 December 1941", (Page 29). The USA 52nd Signal Service Battalion arrived in Australia during February 1942. The Army Command and Administrative Network (ACAN) set-up group, comprising an Officer and 19 enlisted men, arrived mid March 1942. On March 10, 1942, Fort Shafter, WTJ, Hawaii, established a manual Morse Code (CW) radio circuit to the Royal Australian Air Force station in Melbourne, which was then serving as U.S. Army Headquarters in Australia. These facilities were used till early May 1942. (Thompson et.al., 1957, p.112).

Peter Dunn's records show that on Saturday 24 January 1942, military authorities visited Somerville House, an independent boarding and day school for girls located at 17 Graham St, South Brisbane QLD, with a view to taking it over. The school was officially commandeered by the Australian Military Forces on 1 February 1942, and was later used as "Base Section Three Headquarters of the United States Army, East Asian Command" for the duration of the Second World War. Three different radio rooms were established.

Fig. 1: Somerville House circa 1943.
Source: (https://en.wikipedia.org/wiki/Somerville_House)

Later students at the school, Beth and Lea Brown, confirmed that this history was well known at the school. They were the daughters of the late Captain Peter Brown AIF who was captured in New Britain by the Japanese invaders at the start of the war. Peter, who was an engineer, became a Licensed Radio Amateur post-war.

Lionel Sharp remembers being told a story about Somerville House. "A couple of (Australian) PMG (Commonwealth Government Post Master General) technicians were sent to Somerville House to fix a telephone fault and the guards wanted to inspect their tool bags. The techs refused to hand over their bags for inspection and a stand-off developed. The chief PMG engineer at the time was a Charlie Anderson who happened to be a Colonel in the CMF or equivalent. So Charlie turns up in his Colonel's uniform and the matter was resolved and the techs did not have to turn over their bags for inspection. Seems that the Americans were impressed with Charlie and his uniform".

The American Commander in the Philippines, General Douglas MacArthur, was ordered to move from the Philippines to Australia In March 1942. He arrived in Melbourne on 21 March of that year. The Philippines surrendered to the Japanese on 8 May 1942.

Fig: 2: USA General Douglas MacArthur (1880-1964) with Major-General Richard Sutherland (1893-1966) in Brisbane during World War 2 (MacArthur Museum Brisbane). Source: **(**https://www.mmb.org.au/site-page/macarthur-brisbane).

On 18 April 1942, Macarthur was appointed Commander-In-Chief of the Allied Forces, and his Headquarters became known as General Headquarters, Southwest Pacific Area, (GHQ, and SWPA) and it moved to Brisbane on 21 July 1942 setting up its offices in the nine storey AMP Building in Queen Street, Brisbane. The building is now known as MacArthur Chambers, an exclusive apartment building.
A communications centre was established in the basement of the building.

General Douglas MacArthur and his senior staff were located on the 8th floor of the AMP Building. Initially MacArthur and his deputy, General Richard Sutherland shared Room 809. General MacArthur then occupied Room 806 and Sutherland occupied the adjacent Room 807. Both these rooms have been restored as part of the MacArthur Museum, Brisbane. (http://www.mmb.org.au).

The Battle of the Coral Sea was a series of naval engagements off the north-east coast of Australia between 4 and 8 May 1942. It was fought by Allied aircraft (United States and Australian) and Japanese aircraft against four different major groups of warships. (See Battle of the Coral Sea (http://www.anzacday.org.au/).

Although the Coral Sea battle was a tactical victory for the Japanese in terms of ships sunk, it would prove to be a strategic victory for the Allies. More importantly, the Japanese fleet carriers Shokaku and Zuikaku – one damaged and the other with a depleted aircraft complement – were unable to participate in the Battle of Midway which took place the following month, 4 to 7 June 1942. There the outnumbered U.S. Pacific Fleet succeeded in destroying the four Japanese aircraft carriers that had attacked Darwin earlier with the loss of only one of its own, the Yorktown, thus reversing the tide against the previously invincible Japanese navy. Better intelligence through code breaking helped the Allied forces.

The Battle of the Coral Sea was fought before sufficient radio communication facilities (ACAN) had been built up to accommodate a large volume of traffic which resulted in delay of messages calling for air support. (Thompson, et. al., 1957 p.113).

The severe losses in carriers at the Battle of Midway prevented the Japanese from again attempting to invade Port Moresby from the sea. Two months later the Allies took advantage of Japan's resulting strategic vulnerability in the South Pacific and launched the Guadalcanal Campaign. This action, along with the New Guinea Campaign, eventually broke Japanese defences in the South Pacific and was a significant contributing factor to Japan's ultimate defeat in World War 2. The changed naval situation allowed a move away from the unsubstantiated "Brisbane Line" strategy that had prevailed previously, based on the fact that the Australian War Cabinet had put in place strategies prioritising defence for vital industrial areas in time of war. (Australian War Memorial, https://www.awm.gov.au/encyclopedia/homefront/brisbane_line/).

The History of the 832nd Signal Service Company, records that "On May 20, 1942, by Headquarters USAFIA declared the area north of a line Rockhampton, Queensland, Alice Springs, Northern Territory, Geraldton, Western Australia inclusive to be the combat zone". (Thompson et.al.,1957, p.24).

3 WARTIME INTERNATIONAL COMMUNICATIONS ESTABLISHED

Before World War 2 international communication methods from Australia were by cable the first connection being 70 years before the war. Cables are still used today supplemented by satellite services. Capacity and security limitations of cable were a problem at the outset of hostilities so there was a need for an alternative system - secure radio communication. The same might be said of the situation today where all terrestrial /satellite long haul services could be at risk during a war.

Darwin had been bombed and communication facilities there had been demolished. Critically, Brisbane was the northern-most city on the east coast of Australia with the necessary communication facilities that determined the establishment of high powered radio facilities in the Redlands. The area became the lynch pin of MacArthur's secure communications to America and outlying bases. Brisbane's new role was to be Australia's northern communication hub for the duration of the war. The overall Brisbane region infrastructure, including major port facilities, was another contributing factor to the decision.

Communications were central to the prosecution of the war for the obtaining of intelligence on enemy movements and deployment of Allied troops and equipment. The supply chain also used radio communications. Radio networks were indeed the heart of the American and Australian command systems.

Prior to the war, newspaper proprietors, mainly in the USA, were developing long haul radio transmission and receiving systems to handle the dissemination of news on a large scale. This activity was progressed mainly by "Press", a consortium of newspaper companies in the USA which had established radio manufacturing facilities on Long Island, New York. This technology was vital during the war. (http://www.tmchistory.org/PressWireless/Prewi_company_history.htm).

At the onset of the war a number of radio sites were established in and around Brisbane but very quickly a purpose built High Frequency Radio Receiving Site, initially utilizing Wilcox Electric Co. CW3-D Receivers, was established by the American military at Capalaba in Redland City. Its sister transmitting station was set up at Redland Bay in the Redlands initially but later the high powered transmitter at Hemmant in the City of Brisbane became dominant. These were designed to enable communication mainly with the USA so used very large rhombic antennas set out in large areas of land at a height of some 100 feet. The transmitters and receivers had to be separated by a large distance to stop mutual interference. High Frequency Radio installations are best located on wet or damp ground to provide a good earth mat for the antennas and maximize efficiency. Distance from man-made interference would have been another factor. This would have been some of the criteria for the establishment of this type of facility and which were met at that time at Redland Bay, Capalaba and Hemmant.

In Australia the US military initially used hand encrypted and hand keyed Morse Code type transmission, but subsequently ACAN turned to high speed and high powered automatic encrypting and decrypting systems. Once General MacArthur shifted his headquarters to the AMP Building in Queen Street Brisbane on 24 July 1942 high powered radio circuits to the USA and elsewhere were established. General MacArthur's radio station WVJJ in Brisbane became the centre point of the Southwest Pacific ACAN System until much later in the war. (Thompson and Harris, 1991, Ch. 18 http://tothosewhoserved.org/usa/ts/usatss03/chapter18.html).

This situation is also highlighted in The official history of the US Army Signal Corps, (Thompson et al.,1957) which records that " in mid 1942 station WVJJ Brisbane replaced Melbourne, WTJJ, as the hub of ACAN nets in Australia and the Southwest Pacific. Brisbane also became the terminus of the direct circuit from WAR, by way of San Francisco. It would remain a key station until late in 1944 when the focus of military activity shifted farther north. Before the Papua Campaign late in 1942, Brisbane traffic had averaged only between 80,000 and 100,000 groups a day. Even so, the circuits had been overloaded" (p.112). "Then, in February 1943, the pressure was somewhat relieved when the Army's single sideband multichannel sets became available on the Brisbane-San Francisco link. Traffic volume rose to 250,000 groups a day, 80 to 85 percent of its administrative business." (Thompson et. al., 1957, pp 113, 298).

Again "After the loss of WTA Manila upon the fall of the Philippines early in 1942, Melbourne, Australia, first became the anchor of the ACAN system serving the South and Southwest Pacific areas. As the campaigns against the Japanese progressed, Brisbane (WVJJ, later WTO) replaced Melbourne as the ACAN station site. Equipped with powerful transmitters, the Brisbane station by mid-1943 was able to reach San Francisco directly and dependably, as well as stations in the CBI, thereby establishing a reliable round-the-world belt line of signals. Brisbane traffic reached a million words a day as the campaigns advanced up through the islands of the South and Southwest Pacific." (Thompson and Harris, 1991, p.60).

This was no mean feat at the time but required top notch receivers and new technology in high powered Single Sideband Transmitters. More words than bullets were produced during the war. USA Major General Frank Stoner, Chief of ACAN, towards the end of the war "estimated that eight words were sent overseas for every bullet fired by Allied troops". (US Army TS Signals 3 in Thompson and Harris, 1991, Ch. 18, http://tothosewhoserved.org/usa/ts/usatss03/chapter18.html).

"In March (1943) ACAN established an emergency link, Brisbane to Karachi, and replaced it a month later by a Brisbane-New Delhi channel. Soon 40 kilowatt equipment at Brisbane strengthened the links with the United States and with India. Belt line traffic from the West and the East passed through this main Australian terminal and on to other subordinate networks in Australia, New Guinea, and islands to the north. By the early summer of 1943 eight command and administrative circuits radiated from Brisbane: 10-kilowatt circuits to Honolulu and San Francisco, a 1-kilowattcircuit to Noumea, 800-watt circuits to Adelaide River and Port Moresby, a 400-watt general headquarters circuit to Townsville, and 300-watt circuits to Townsville and Sydney". (Thompson et.al., 1957, p.467).

The statement above about the 40 kilowatt equipment for the Brisbane India link did not differentiate between the various locations of the facilities involved. Antenna pointing angles in wartime plans sighted confirm that the Capalaba rhombic antennas identified did not provide a circuit to New Delhi. This was done through the lower powered installation at Redland Bay, October 1943. (Sullivan n.d., p.9). Pointing angles are discussed further in Appendix 3.

As noted previously General MacArthur moved his General Headquarters for the Southwest Pacific Area (GHQ SWPA) to the AMP building in Queen Street, Brisbane on 21 July 1942. MacArthur kept in contact with the United States and Washington DC via the High Frequency (HF) radio system. Radio circuits from Sydney, Townsville, Darwin, Noumea and Honolulu were now relocated to terminate in Brisbane. (Thompson et. al., 1957, p.298).

Following its installation on 1 November 1943 in the AMP Building USA General Douglas MacArthur used new secure radio telephone technology developed by Bell Laboratories of the USA, titled Sigsaly, with communication via the Capalaba and Hemmant radio installations. Later the Brisbane based Sigsaly equipment was moved to a 250-ton ship, OL-31. This floating version accompanied General MacArthur on his island hopping campaign in the Pacific, and would have been a key facility if an invasion of Japan had been necessary. After the war the Sigsaly machines were broken up. (MacArthur Museum, Brisbane). (https://www.mmb.org.au/site-page/macarthur-brisbane).

This equipment was the most advanced speech encryption device of the times, permitting MacArthur to confer by telephone with Washington DC in complete security. Others were in London, Algiers, Hawaii, California, Guam and later in Paris (after its liberation) and in Frankfurt and Berlin (after VE Day).

The American Signal Corps appears to have been excellently and very quickly supported by that country's communications industry in the provision of modern and capable radio equipment as well as communication engineering expertise once the need was known. Materials, equipment and trained personnel were however in short supply in the early days. The speed of manufacturing and distribution became breathtaking.

Very quickly rhombic antennas were recognized by the US Army as the best technical and flexible solution for long haul High Frequency (HF) US Army radio communication. They were known to work well, could be erected quickly, at low cost, and transmission frequencies could be easily altered. The USA had vast experience in this field through a large number of commercial installations. Radio bases using rhombic antennas were established at a number of points in the Redlands. This was the first time that Queenslanders had seen such equipment and organizational expertise. Rhombic antennas were also used extensively at other sites both in Australia and overseas during the war. Technical details of rhombic antennas are discussed in Appendix 3.

4 CAPALABA OPERATING AS THE MAJOR WARTIME RADIO RECEIVING SITE SERVICING THE SOUTHWEST PACIFIC AREA

To improve radio reception the US Army Signal Corps established a Radio Receiving (Telecommunications) site in 1942 at Cotton's Farm, Capalaba, 18 Kilometres south east of the centre of Brisbane. It was bounded by Tingalpa Creek on the west, the now Old Cleveland Road East on the eastern side and Uhlman Road to the north. See site map below.

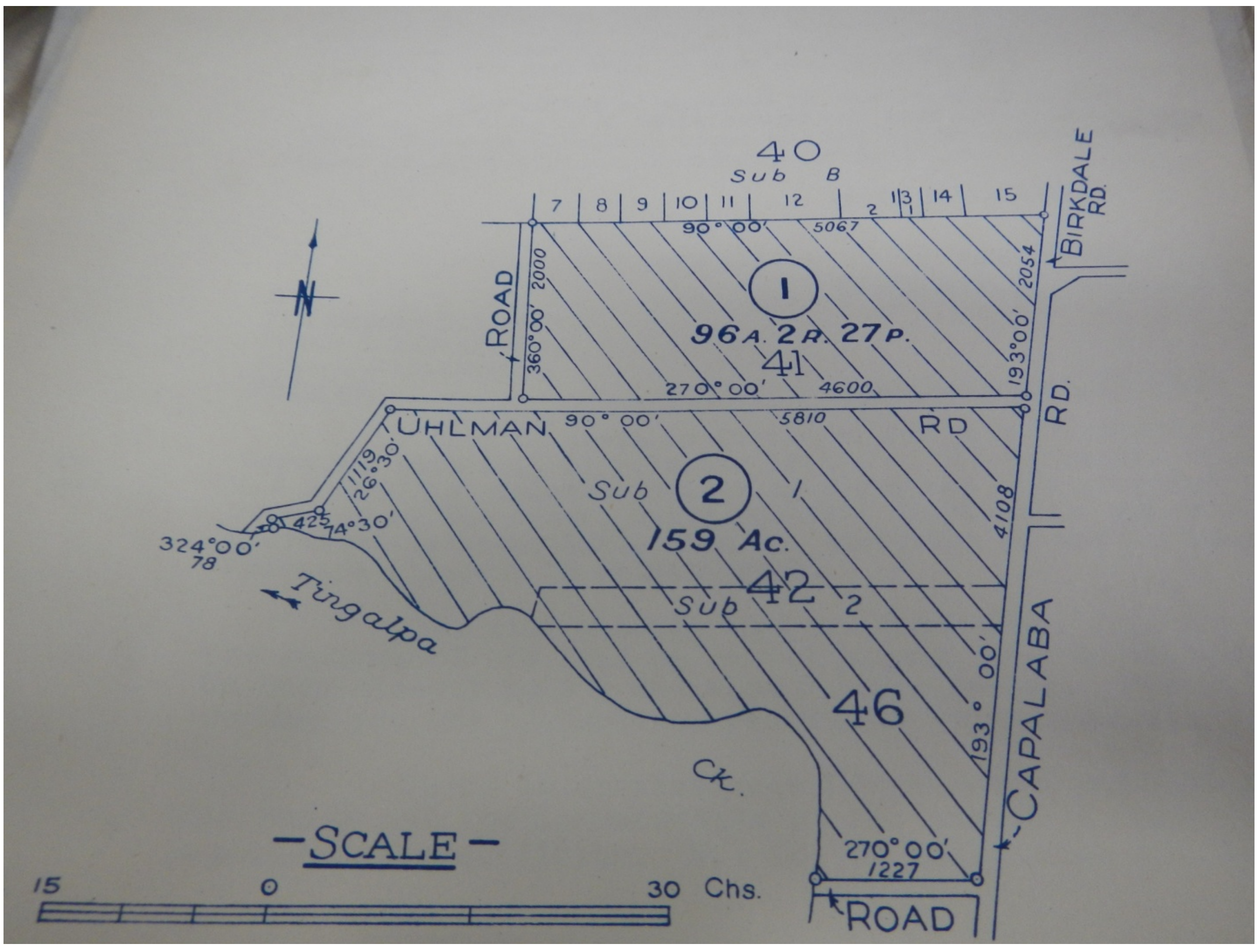


Fig.3: Site of Cotton's Farm.
<u>Source</u>: National Archives of Australia, (1951). (http://www.naa.gov.au/).

Following a number of changes in ownership the farm was sold to Rosemary Innes Cotton in June 1941. (Queensland Department of Environment and Heritage Protection, Heritage Recommendation, p.7, 26 August 2015). The land was owned by Doug and Rosemary Cotton at the time it was acquired by the Americans.

The Capalaba Radio Site was also known previously as "Willard's Old Property". James Willard was a well known landowner in the area settling there in the 1860's. Mary Howells in her 2001 thesis titled " Living on the Edge: Tingalpa Creek a History of Upper Tingalpa, Capalaba and Thorneside" records that James and Margaret Willard married in Brisbane in 1861, and settled to the north of the Daveson's land located on Birkdale Road. The site of their home “The Pines” was registered to James Willard and Mark Blundell in December 1965. She also records that James Willard senior’s farm was in Capalaba and James Willard junior’s farm was in Thorneside. (Howells, 2001).

A road with the Willard name runs off north from Finucane Road parallel to and east of Old Cleveland Road East. It then meets Daveson Road which finishes nearly opposite and slightly south of the Cotton’s cottage on Old Cleveland Road East.

The American soldiers who looked after the radio stations were accommodated at Capalaba on the flats behind the Capalaba Hotel which was also commandeered by the Americans. (Dunn. Ozatwar, http://www.ozatwar.com/).

Shortly after the war, the Commonwealth Government’s Postmaster General’s Department acquired most of the 159 acres of the former communications centre, being most of Portions 46 and 41, and subdivisions 1 and 2 of Portion 42 for “postal purposes”.

Commonwealth government archival records and page 7 of an Assessment of the Willard’s Farm by the Queensland Department of Environment and Heritage Protection does show that some 2000 pounds, the then legal tender, was paid to the Cottons but they were clearly dissatisfied by the amount evidenced by the fact that a relative, Senator Bob Cotton KCMG AO 1915-2006, Senator 1965-1978, was constantly fighting their case with the Government in Canberra. (Buckley, Ken, interview).

Mr. Ken Buckley of Cleveland also recorded in June 2015 that from 1969 to 1973 he and his wife Patricia lived on three quarters of an acre, about 3000 square metres, opposite the Capalaba Wartime Radio Station site on Old Cleveland Road, a narrow bitumen strip with wide gravel shoulders in those days! . This section of the road was renamed Old Cleveland Road East in later years. At that time it ran all the way to Ormiston.

Living across the road in a cottage called “The Pines” were Doug and Rosemary Cotton. The Cottons mentioned to him once that their children used to ride on horse-back up Finucane Road when it was just a dirt track. They told Ken and his wife Patricia that the majority of their land had been requisitioned by the Government for the World War 2 Radio Station and that they had never been properly recompensed**.** They clearly considered themselves badly done by. At that time there were two squatters on a fenced off section of the land a little further down the road towards the radio site – an old lady and her daughter who had a herd of goats. They eked out a living selling the goats milk and lived in a small building near the main road.

Howells, (2001), noted that “Rosemary Cotton acquired the property in 1941 and lived there with her husband Doug until her death in 1979”. The recommendation by the Queensland Department of Environment and Heritage Protection dated 26 August 2015 that the farmhouse and surrounds on RP 211270 be listed on the Queensland Heritage Register was rejected by the Heritage Council.
(Queensland Department of Environment and Heritage Protection 2015).

The land excluded from the acquisition by the Australian Post Master General’s Department which included the old farmhouse and surrounds, was purchased by The Redland City Council in 2016 to retain the heritage status of the area. (Redland City Council News 12 February 2016, https://news.redland.qld.gov.au/2016/02/willards-farm-to-remain/).

Answer to Senate Estimates Questions on Notice, Additional Hearings February 2016, Australian Communications and Media Authority Question No. 178(e) had references therein to the Capalaba Radio site. The area was given as 62.38 Hectares (154.144 acres), Land Value $5 million, current assets $118 000, Building 250 square metres valued at $37 000. Also stated was that the site is designed to operate unmanned and the building houses specialised equipment. (Senate Standing Committee on Environment and Communications, 2016). Fig 3 shows Sub 2 as 159 acres but this figure includes the 5 acres of land retained by the Willard's, correctly leaving ACMA with 154 acres as stated.

Heritage Recommendation **650011**

Queensland Heritage Act 1992

Under delegation from the Chief Executive, Department of Environment and Heritage Protection, and under the provisions of s.44 of the *Queensland Heritage Act 1992*, I, Delegated Authority, Fiona Gardiner:

Recommend to Enter this place in the Queensland Heritage Register as a State Heritage Place

[redacted]

Recommendation Date: 26-Aug-2015

Delegate Name/Position: Delegated Authority, Fiona Gardiner

Figure 1: Willard's Farm from northeast (EHP, 2015)

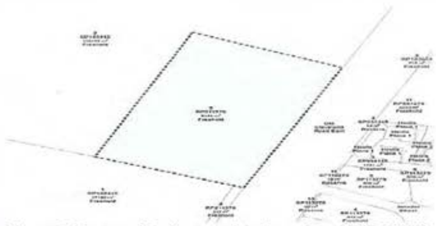


Figure 2: Proposed heritage register boundary (EHP, 2015) (see attached map) (see attached map)

Place name	Willard's Farm
Address	302 Old Cleveland Road East, BIRKDALE, 4159
LGA	REDLAND CITY COUNCIL
RPD	2 RP211270

Prepared by Heritage, Department of Environment and Heritage Protection_26-Aug-2015 1

Fig. 4: Recommendation of 26 August 2015 for Willard's Farmhouse (Doc. 650011).
Source: Queensland Department of Environment and Heritage Protection (2015).

This document records- "World War 2 brought dramatic change to Willard's Farm. Most of its land was requisitioned by the US army for a communications centre in 1943. Primarily on Portion 42, they erected a receiving station, comprising a brick communications block and several tall radio masts; an important link in the global communications system operated by the US Army during World War 2. The Cotton family retained five acres (2.03 ha) on which the house and outbuildings were located." It also referred to a 1951 "Detailed Survey Radio Receiving Station, Capalaba, LS2634", held at the National Archives of Australia (NAA) but this was not sighted. Comments by technicians working at the radio site post-war suggest that it may be that the bricks used in the construction of the building were sourced from the USA due to their specific size. Barry Johns has recorded that the US Army sent a letter to the Australian officials asking whether bricks were made in Australia. This matter remains unresolved.

Maps of the area obtained from the Commonwealth Government Archives, (now NAA) were Commonwealth Department of the Interior Drawing No. L&S 740 dated 22 May 1943 “Position of Transmitter Building” Job No U.S.M 386 and QL 583 (see Fig. 41, pg. 146), L&S 1731 “Capalaba Radio Station” showing it located in Sub 2 (see Fig. 40, pg. 145). The latter also showed two underground pipes from Tingalpa Creek north to the radio station, and the farmhouse windmill and buildings including a dairy and cow bails. L&S 740 shows a building marked as being 102 foot 2 inches long by 26 foot 7 inches wide, viz. 2715.9306 square feet or 252.318 square metres. This agrees with ACMA’s answer to a Senate question No 178(e), Hansard Reference: Written, 19 February 2016. The current fenced area is approximately 7225 square metres.

A plan showing three rhombic antenna locations and dimensions is given in L&S294 (see Fig. 39, pg. 144). It is also available from the Commonwealth Government Archives (n.d.). The pointing angles of the rhombic antennas are given as (1) 49 Degrees, (2) 57 Degrees 51 minutes, and (3) 79 minutes 59 minutes respectively. Matching of the azimuth in degrees with the destination from Brisbane shows a good fit for Honolulu against latest computer generated data (49.3799 degrees), a possible for Washington (61.45003 degrees) and a possible for Samoa (74.56464 degrees). For further discussion see Appendix 3.

An Azimuthal map of the world that can be centred on your location is available at http://www.dxzone.com/dx22824/ns6t-s-azimuthal-map.html. Type in your location e.g. Brisbane.

Post war archival map sighted was Commonwealth Department of Works (1959) site plan QA59/460/C, July 1959, Capalaba Remote Receiving Station for the Department of Civil Aviation and as amended in QA60/45/D/1, 1960, relating to Portion 21. Further records are held interstate by the National Archives of Australia but were not sighted. (http://www.naa.gov.au/).

The smaller antennas erected at the start of the war are shown in the following photograph Fig. 5. Two buildings and an army tent are readily visible. The main building was still being used on the site as at the beginning of 2017. Measurements from the original plan and Commonwealth Hansard as noted previously confirm that it is the original World War 2 building.

The use of separate sites for receiving and transmitting was necessary due to the extensive amount of communications traffic requiring simultaneous reception and transmission without mutual interference. Both were connected to Brisbane by land-line.

Fig. 5: Early days – (From US Archives (NARA) RG 111 SC 310224) Tingalpa Radio Antennas – area now known as Capalaba WW2 Radio Site. Listed on R. Marks, Archive Photos of Queensland During WW2 Source: (http://www.qaww2.com/photos.html).

Boundary changes since that time now place this area in the Redland City suburb of Birkdale. The site was originally named after the creek running through the property, Tingalpa.

Paul Hayden has reported that the building now has a new roof and the equipment room door has been bricked up. The five post structure on the side of the building was probably an open wire antenna feedline termination point. Note also the windmill at the right rear in the photograph.

Lionel Sharp advised that the late George Barr, a Licensed Radio Amateur, worked at the site for the US Army. He lived in the nearby Brisbane suburb of Wynnum.

Poles 100 foot high were used at Capalaba and Hemmant and the above photo, (Fig. 5) with lesser height poles, would have been taken before then. The Redland Bay Golf Course installation had 100 foot high poles for its antennas in late 1942. Poles 90 foot high from Point Reynes in California replaced 50 foot poles at Rocklea Radio Transmitting and Receiving Site by 31 January 1943, so Capalaba may have had very high poles by then. Rocklea radio site was also used in conjunction with the Hemmant transmitting site which had the high power transmitter. (Peter Dunn, http://www.ozatwar.com).

Fig. 6: A more recent photo of the World War 2 Radio Receiving Site at Old Cleveland Road East, Source: Peter Dunn. Annotations by Paul Hayden 2015.

This picture shows on the left the then PMG Regulatory Branch (radio inspectors), common facilities e.g. lunch room in the centre and on the right the PMG Radio Receiving Station plus the Radio Communications and Broadcasting Section. A smaller backup generator building is on the near right. Paul Hayden advised that the building near the main road arrived on the site much later after the war. It was not sighted on the Capalaba radio station plan.

Lionel Sharp records that in his time the position was similar with Radio Branch equipment and sleeping room at the northern end of the building, kitchen, showers and toilets plus lunch room in the centre and the PMG flood emergency network and radio teletype to Townsville at the other end.

Barry Johns has recorded that he worked at the Capalaba Radio site from 1983 to 1988 as a Technical Officer, and that in 1987/1988 two former American soldiers, a Communications Technician and Operator, visited the site. General MacArthur is recorded as sleeping at the station at times to maintain communication with the US Fleet. He slept in the switching room from near where the cables from the antenna entered the room through a panel. This room was across from the room with the monitoring equipment. The Americans pointed to where General MacArthur's bed was placed. (http://www.ww2places.qld.gov.au/places/?id=1231). The walls of the building were stated as being made of brick, 18 inches thick, and reinforced to take a bomb blast. Beams were made of Douglas Fir (an evergreen conifer species native to Western North America). All cables were under the floor. These recollections clearly indicate the critical importance of the Capalaba Radio site during the World War 2 in the Pacific.

Fig.7: Capalaba Radio Site.
Source: Google Earth 2015. Annotations by Paul Hayden 2015.

A Building- (purpose unknown) – On right next to Old Cleveland Road East
B Building- Receiving Station – Large white building in the centre
C Building - Auxiliary Power Plant – Smaller white building to right of main building
R Rhombic Support Masts – throughout the open area, 4 to the right, 2 to the left
Comments by Paul Hayden 2015

See Appendices 14 & 15 for details of equipment used at Capalaba and Hemmant post-war.

5 FIRST RADIO RECEIVER AT CAPALABA – A USA WILCOX ELECTRIC COMPANY DUAL DIVERSITY CW3-D RADIO

At the outset of this study the use of a Wilcox radio receiver at Capalaba was first noted as being recorded by Peter Dunn, but nothing else including the type of receiver was known. The search for information on the Wilcox receivers was very difficult. Bob Bolin, Business Librarian, University of Nebraska-Lincoln Libraries assisted early in the search for details of this receiver type through his online bibliography and personal communications which are much appreciated. (http://libraries.unl.edu/).
He forwarded the following bibliographic information:-
PB 85507 - BSIR 8(4):315; 01/23/48, Technical Manual, TM 11-853, p.45, relating to Radio Receivers, Wilcox Electric Co. Types CW3 and F3 and Receiver Bay Wilcox Electric Co. Type 113A (US War Department, 1945) and PB 48154 - BSIR 4(3):189; 01/17/47, Technical Manual, TM 11-2204, 44. (US War Department, 1944a).

Specific details of Technical Manual TM 11-2204 were now sought. Initial searches were fruitless but early in these investigations engineer Cullen Langford, Licensed Radio Amateur K5HAL, of 102 Fox Brook Drive, Landenberg, PA 19350-1152 USA kindly emailed a copy of his own Wilcox Electric Co. CW3 Receiver War Department Technical Manual TM 11-853, November 1945. Receiver specifications though were not of the type needed to allow teletype reception so the search continued. Searches for the instruction manual suggested by Bob Bolin were still not successful. Following Cullen's suggestion a copy of Technical Manual TM 11-2204 for the CW3-D (US War Department, 1944a.31p.) was eventually sourced early in 2017 from the USA Library of Congress through the State Library of Queensland. At 31 pages it is smaller than the reference by Bob Bolin. A copy is attached in Appendix 10. Cullen Langford's unwavering assistance over a considerable period of time in searching for and sourcing information on the Wilcox Electric Co. CW3-D Receiver in the USA is gratefully acknowledged. (Wilcox Electric Company, 1943).

It has been established that the CW3-D Radio Receiver Assembly OA-59/FRC was a crystal –controlled, dual diversity, fixed frequency, AM (CW) receiving equipment used for radio teletype and radio telegraph long-range communication in fixed installations, using two rhombic or two other matched – type antenna systems. Ordinarily 2 Radio Receiver Assemblies OA-59 FRC (4 Wilcox Electric Co. CW3-D receivers) were mounted in the one cabinet, 6 foot high and 2 foot wide and 17 inches deep. Two duplicate receivers, A and B, were identical electrically but different slightly in tube arrangements, each diversity receiver being constructed by the conversion of two non-diversity receivers. Four pre-set channels were used with the Type AN/FGC-1 teletype. As each CW3-D receiver had only had one pre-set frequency four receivers had to be used to accommodate the teletype characteristics. A Frequency Shift Keyer (FSK) provided two identical fixed-frequency diversity receivers with common h-f (high frequency oscillator) and bfo (beat frequency oscillator). Army Service Forces Catalog (1945) SIG 10-325, Fixed Plant Maintenance List, gives a full list of parts used in the CW3-D and is attached at Appendix 11.

The Wilcox Electric Company (USA) was a major designer and manufacturer of radio equipment during World War 2 and was founded by Mr. Jay Wilcox in 1931. (http://ireport.cnn.com/docs/DOC-1114191)
The company manufactured both receivers and transmitters. The CW3-D Dual Diversity radio receiver was one of a number of similar radio receiver types made by the Wilcox Electric Company, earlier ones being the F3 and the CW3. The D in the name is to denote its role as a "Diversity" radio receiver. (US War Department, 1944a).

“For fixed radio stations, providing long channels (continuous wave only) for military purposes, the Signal Corps employed commercial transmitters and receivers, either unaltered or slightly modified to meet military characteristics. A common receiver, for example, was the Hammarlund Super Pro, used in its commercial form or adapted as the SCR-244 which served Army’s intercept and fixed receiving stations all over the world” (Thompson et.al., 1957 pp.76,77). No mention of Wilcox Electric Company receivers or radio receivers manufactured by other firms was found in this report. Details of US Civilian and Navy equipment used during WW2 do however show that all three types of the Wilcox Electric Company Receiver, the F3, CW3 and CW3-D, were used by the US military at that time. (http://www.signal.army.mil/index.php/signal-school/directorates/office-of-the-chief-of-signal/67-signal-museum/signal-museum-pages/257-civilian-and-navy-equipment-used-during-wwii)

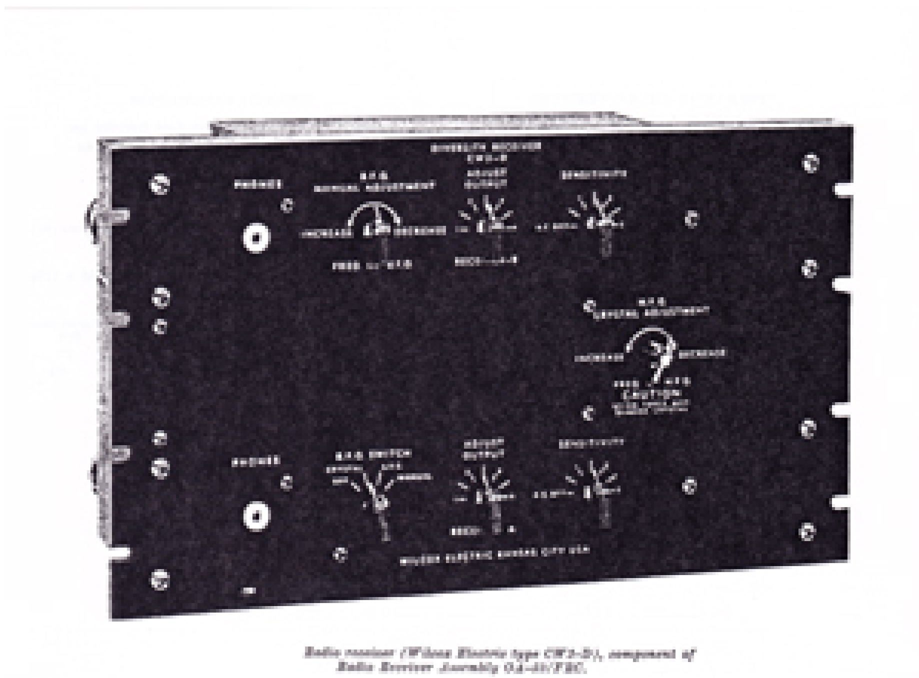


Fig. 8: World War 2 Wilcox Electric Co. Dual Diversity HF Receiver Type CW3-D, Front Panel.
Source: US Army Service Forces Catalogue (1945) p.3.

The top of the front panel had (Head) Phones, BFO Manual Adjustment, Output, Sensitivity.
Middle right has manual Crystal adjustment of the High Frequency Oscillator by changing crystal pressure.
Bottom row has (Head) Phones, BFO Switch –Off- Crystal-AFC-Manual, Adjust Output and Sensitivity
To assist understanding, and in the absence of a clear picture, a front panel sketch of the CW3-D was developed by Cullen Langford, (See Fig.9), and is based on the above picture.

The circuit shows that the radio receiver used Space Diversity, that is a Dual Diversity receiver meaning two receivers with common circuitry, two antennas spaced well apart, common local oscillator and BFO frequency, AFC on received tone, and separate AGC to try to obtain constant audio levels. The two audio streams are fed to the AN/FGC-1 terminal equipment which does the decision making processes, based on the demodulated signal quality. It measures the Bias and the Distortion of the signals, and determines which signal will be used to drive the teletype circuit. Bias is a term used to indicate when the telegraph signal changes its mark to space ratio from normal and is caused by the signal being distorted during transmission.

The operator could disable each receiver output in turn, to check that the diversity switch was producing equal quality signals on each signal path. In the event of interference to either the Mark or Space Frequency, the decision making circuit can be set to use one or the other, instead of both tone frequencies. Poor Signal/Noise Ratio on both indicates the need to change the RF channel frequency, up or down to try and obtain a path.

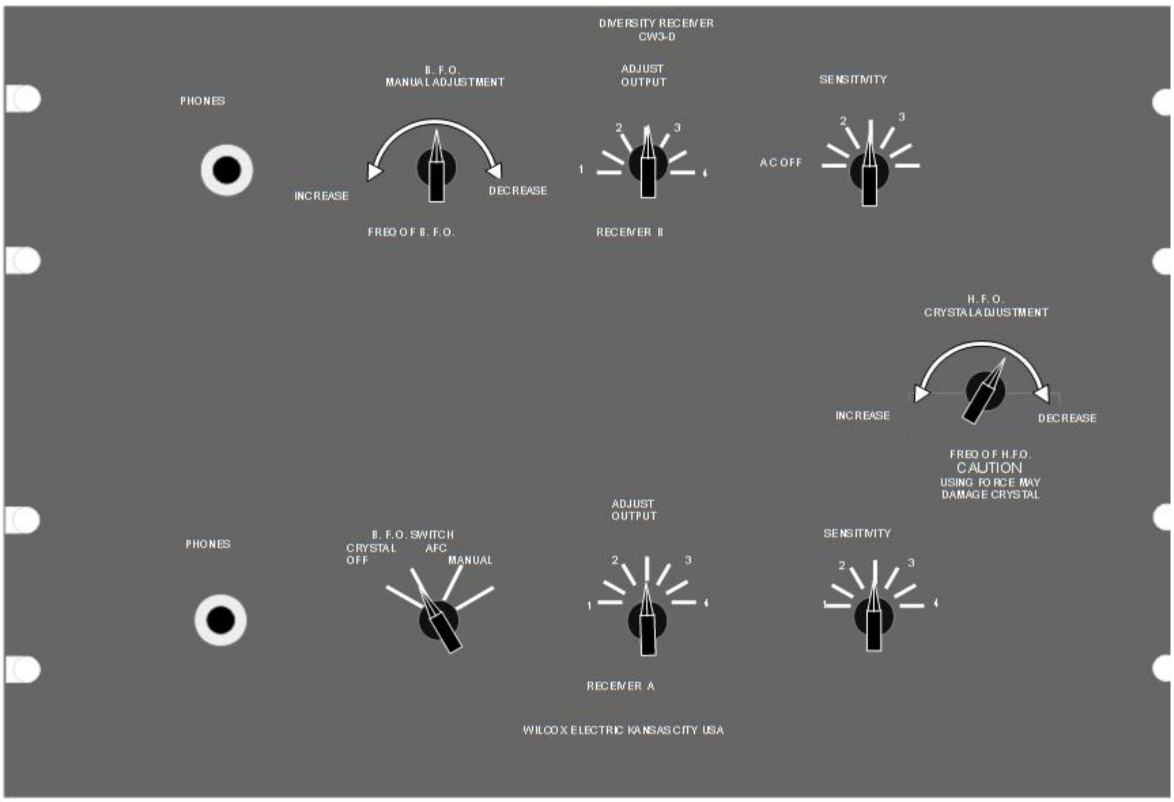


Fig. 9: World War 2 Wilcox Electric Co. Dual Diversity Radio Receiver, Type CW3-D, Front Panel Sketch. Source: Cullen Langford 2017

The use of Wilcox Co. CW3-D Radio Receivers at Capalaba during World War 2 has been confirmed by Lionel Sharp. He has recorded that these receivers were still at Capalaba after the war during his time there. They were "reconditioned" by the PMG (unserviceable capacitators were replaced) in the late 1950's before being used on the RTTY circuit to Townsville. Messages received at Capalaba were forwarded by landline to the Central Telegraph Office in Brisbane. Hemmant was the transmit site for messages sent by landline from there. This is an example of Australia being assisted by the use of war surplus equipment.

The Wilcox Electric Company crystal controlled Dual Diversity Radio Receiver, CW3-D, was eventually superceded by more modern Single Sideband (SSB) receivers. The performance of this receiver though was critical in the early phase of the war and its great contribution cannot be challenged. The Wilcox Electric Company CW3-D Dual Diversity Receiver was top notch technology at the outbreak of the war and the F3 AM version was still being used post-war in the USA.

SSB technology is still used today throughout the world and by radio amateurs. It was first used for two way Trans-Atlantic telephone traffic in 1927. Single Sideband equipment gave both better transmission and reception with lower band width allowing more transmitters to operate on the crowded frequencies Three teletype (RTTY) machines on diversity reception were employed to help correct "fade" or "message dropout." The teletypes could be on the lower side band with the upper side band being used for voice control. Messages could also be mechanically encoded and decoded.

Pulse Code Digital Technology was developed by Bell Laboratories of the USA and used at Brisbane. This technology, which had taken ten years to develop, was also used in the UK and many other places in the world during the war but its use in Australia was in the earliest times.

Lionel Sharp remembers the WW2 era AN/FGC-1 Radio Teletype equipment (RTTY) which would have been fed the Mark and Space tones from Wilcox Electric Co. Diversity Radio Receivers. Full details of the system are given by Singer (1948) a Member of the AIEE. References show that twin channel SSB system development was well in hand in 1938 through Bell Telephone System engineers. See especially page 1405 of the document above re the FGC-1 equipment.
(Singer 1948, https://www.nonstopsystems.com/radio/pdf-hell/article-AIEE-1948.pdf).

Singer (1948) records that each teletypewriter channel usually operated at a rate of only 60 words per minute, later 100 words per minute. Some automatic (paper tape) Morse channels operated at much higher speeds, but experience demonstrated that much more traffic could be handled each day over a single teletypewriter channel compared with a single high-speed Morse channel. This was because of minimal disruptions and automatic and instantaneous enciphering and deciphering. Teletypewriter tape relay methods were also used to control transmitters on other circuits. The Teletype tape was initially some 8 inches wide. (http://ibiblio.org/hyperwar/USA/ref/LL-Ship/LL-Ship-5.html).

Details of the radio frequencies used by the Americans at Hemmant are unknown but interference by other transmitters was always a problem when using the high frequency bands. Lionel Sharp records that it was common knowledge that the US in Brisbane during the war had chosen a frequency for their teletype circuit that was being used by many other transmitters so they ran what was called “Revs On The Frequency” using the powerful Hemmant transmitter for a week and by then the frequency was very quiet, no QRM (channel interference), so they used it. REVS are a continuous stream of RYRYRYRY sent at normal speed by tape.

Paul Hayden records that “The first and most common diversity setup is to sample the two RXs AVC (AGC) line voltages with a comparator and use the strongest RF signal to drive the output switch to select the strongest (best) audio signal.

In the second method, the audio outputs feed the comparator and the strongest audio output signal drives the switch to select the largest audio (best) output.

A third method (least satisfactory) is to simply parallel the audio outputs and tie the AVC (AGC) lines together. Again the strongest RF signal will produce the largest audio output but because the two audio signals are present, they produce distortion as they change in amplitude and phase.

Today digital radio systems use incredibly complex adaptive equalization based on bit error rates".

A top view of the Wilcox Electric Co. CW3-D Dual Diversity Receiver is given in Fig. 10. This photograph clearly shows the integration of two modified Wilcox Electric Co. CW3 receivers into one Wilcox Electric Co. CW3-D Dual Diversity receiver. Some details and a basic comparison of the Type F3, Type CW and Type CW3-D Receivers are given in Appendix 1.

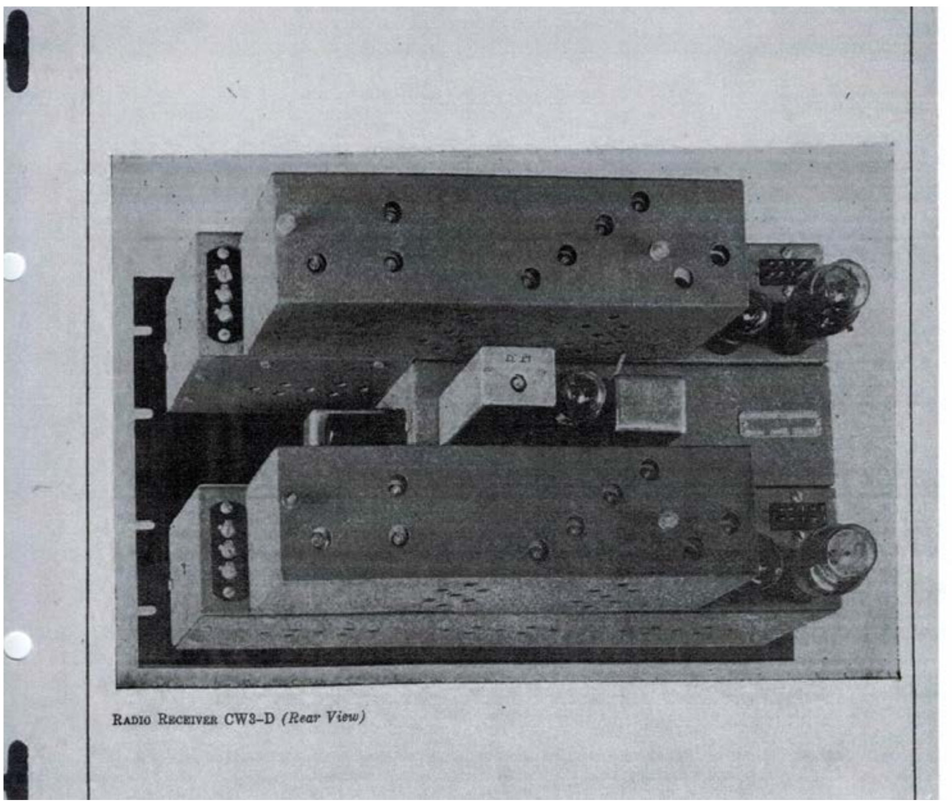


Fig. 10: Top view of the Wilcox Electric Co.Type CW3-D Dual Diversity Receiver
Source: (US Army Service Forces Catalog (1945), p 5. Supercedes Catalog SIG 10-325, 7 November 1944)

6 HEMMANT WARTIME RADIO TRANSMITTER SITE

Fig. 11: Hemmant Radio Transmitter Site Building, Post-War.
Source: (Peter Dunn website showing photo provided by Leo Maloney). Annotations by Paul Hayden (2015). Also refer to (Appendix 14) Fig. 30 for another annotated view of the building.

No photo of the Hemmant site taken during the war was located.
Left: Open wire transmitter feeder frame and transmitter hall
Centre: Equipment room access
Right: Facilities area

Peter Dunn records on his website that “The aerials have long gone but the old transmitter building and diesel (250kilowatt Buckeye) building still remain to this day.”

Thompson et.al. (1957) confirms the role of the 832d Signal Service Company stating “At General Headquarters and Base Section 3 in Brisbane, the Company was responsible for the large radio installations, including the construction and maintenance of the intercept station under General Headquarters and the radio stations working the United States, New Caledonia, and Hawaii, and for the telephone and teletype facilities required by headquarters and base as well. “ (p.468).

The 180 Youngs Road Hemmant site boasted 100 ft high Rhombic antennas. It was stated by Sullivan in "The Things We Save" 1945 that for a time the transmitter was a "Federal" 1kW Type BC339K driving a 10kW "Colonial" Amplifier Type BC340. A "Press" brand Wireless Shifter Unit was installed, which converted teletype signals into radio signals. Clarence Irvin recorded that February 1943 saw the installation of a 40 Kilowatt transmitter at Hemmant manufactured by the Press Company of New York. Research shows that It was possibly using Type 233 or Type 880 tubes. The receiving station was some 9km to the southeast, near Capalaba. All equipment was disposed of many years ago and the property sold. (Peter Dunn Website). The Brisbane ACAN station utilizing double modulation diversity equipment was placed into operation and able to reach San Francisco directly on 10 March 1943. (Major M.K. Wilkins in Sullivan n.d. p.16).

Also recorded by Lt. Col. D.W.Eddy in 'An Article on Communications in the Pacific" p8, was that when General MacArthur moved to Hollandia, "the only Army radio circuit from the Southwest Pacific to the United States was one from Brisbane to San Francisco using Western Electric single sideband equipment in conjunction with a Press 40kW amplifier". Fig. 20 (p.55) shows a Press Wireless 40-kW transmitter in the foreground, which is driven by the Western Electric 15D-6000 Single Sideband exciter on the right. This arrangement of equipment could have been the same at Hemmant.

The reference consulted for this high power transmitter does not agree with later observations of the facilities at Hemmant as recalled by Paul Hayden and the known large physical size of such a unit at that time. However, it was reported in the official USA military history of ACAN that the new WTA Manila in mid 1945 used the 40-kilowatt transmitter that had gone in at Brisbane nearly two years earlier. (Thompson and Harris, 1991 p. 600). ACAN had used many such 40 kW Press amplifiers around the world during the war. The unit weighed in at 11,000 pounds. It has been suggested by Paul Hayden that it must have been housed independently at Hemmant.

Paul Hayden records that to get a feel for the power of this radio network, in those days a 1 kW transmitter was considered fairly large for example at the time Brisbane AM radio stations 4QR and 4QG operated 2 kilowatt STC transmitters that were half the size of a low set suburban house. So a High Frequency 10kW transmitter installation was massive. Federal brand transmitters though were fairly compact by comparison to STC transmitters.

Supplies to a large army require great logistics. The USA Signal Corps history (Thompson et.al., 1957,) records that "The Services of Supply maintained base section headquarters at Brisbane and at Townsville. It maintained an advanced base section in Port Moresby. A large 10-kilowatt radio served the Brisbane base section. Beginning operation in mid-July (1942), it provided channels to Melbourne, Sydney, Townsville, Darwin, Noumea, Honolulu, and San Francisco. Another channel opened in mid-September bringing in Port Moresby". (p.300). On approximately 1 November 1943, the 805th Signal Service Company set up a telephone voice scrambling circuit at Gen. MacArthur's GHQ. It was known as Sigsaly and used the upper side band of the ACAN SSB radio link. (Peter Dunn Website).

By July 1943 photographs could also be sent over the SSB radios and this was done from 'Cintra' in Brisbane. Cintra was the headquarters of a photo unit from the US Army's 832nd Signal Service Battallion. (http://www.ww2places.qld.gov.au/places/?id=124). This location was a bungalow adjoining well known Cintra House.

Poor propagation conditions may also have been a factor in going to higher power in Brisbane. ACAN did many tests and found that locations away from the equator had degraded signal strengths. By trial and error the most reliable routes were found to be Asmara, Karachi, New Delhi, Manila, Honolulu. On 22 May 1944, the centenary of the first telegraph message that Samuel Morse had telegraphed in 1844, a test by ACAN was relayed through four relay stations, San Francisco, Brisbane, New Delhi and Asmara. The message took three and one half minutes. On 28 April 1945 another message was sent through San Francisco, Manila (presumably it was using the high powered transmitter that had been removed from Hemmant), New Delhi and Asmara and took nine and one half seconds. (Thompson and Harris, 1991, Chapter 18). See Appendix 13 for extracts.

December 1943 saw the erection of a new antenna at Hemmant for the transmission of standard frequencies and time signals on five, ten and fifteen megahertz. Frequency multiplier and time signal keying equipment was installed at Hemmant and Capalaba for use in conjunction with the A.W.A. 10kW and Federal BC-339 frequency and time signal transmitters and commenced operation January 1944. Time signals broadcast were at seven and eleven a.m. and seven and eleven p.m. (Sullivan, n.d. p16).

The reason for this installation is unknown. It has been recorded however that radio station WWV in the USA became a standard of time interval as well as frequency in 1937, when it began transmitting pulses at one second intervals. Ironically, the pulses were not held in phase with any time reference because the United States Navy still served as the nation's official radio time broadcaster. This changed in June 1944, when the Superintendent of the United States Naval Observatory (USNO) authorized the synchronization of the WWV time signals to those of the USNO, largely because the Navy had ordered the USNO to cut back time transmissions during World War II. As a result, WWV began sending time messages in telegraphic code every five minutes in October 1945. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4487279/)

High frequency time signal transmissions are still maintained by the USA through station WWV. (https://en.wikipedia.org/wiki/WWV_(radio_station)).

Australian Time and Frequency Standards HF broadcasts by Radio VNG were inaugurated by the Australian Post Office on 21 September 1964. All transmissions ceased on 31 December 2002. (https://en.wikipedia.org/wiki/Radio_VNG). See also (Time Measurement http://www.measurement.gov.au/Services/Pages/RadioClocksinAustralia.aspx).

The Press Company was established in the USA by some 13 newspaper interests in 1929. As the company grew it assembled expert engineering and production staff and began building equipment itself to ensure that they had their own communications system. This led to it manufacturing high powered transmitters in a factory on Long Island, New York. Many of the new engineers were radio amateurs, including Ray de Pasquale, who became the company's Director of Manufacturing in the late 30's. It was often the first to develop, and put into service, improved communications technology, and this included FSK for both RTTY and Facsimile (Fax). It also pioneered frequency multiplexing for RTTY with its "Duo-Plex" system. (See Press Wireless at http://www.tmchistory.org/PressWireless/Prewi_company_history.htm).

The importance of the private sector in developing high powered transmitters pre-war must not be underestimated. A technical explanation of SSB transmission by Paul Hayden is given in Appendix 5.

7 DECODING OF ENEMY SIGNALS

The Capalaba and Hemmant radio sites were never involved in any decoding of enemy signals. Encrypted messages were received by radio at Capalaba. Outward messages were sent by radio through the facility at Hemmant.

The story of World War 2 in the Pacific and the use and usefulness of decoding enemy signals through a system called "Ultra" has been canvassed by many authors. Edward J. Drea recorded that Ultra enabled General MacArthur to select the weakest point in the enemy's defences and then strike with overwhelming superiority. (Drea, Edward J., 1992 p.233).

MacArthur formed his own signals intelligence organization, known as the Central Bureau, from Australian intelligence units and American cryptanalysts who had escaped from the Philippines. This code breaking unit utilized IBM tabulators to assist. Much of the decryption of enemy signals was done at 21 Henry Street, Ascot, Brisbane, and fed into Ultra. Our good relationship with the USA was forged during this time and endures today. The MacArthur Museum in the centre of the city of Brisbane should be consulted for information on this aspect of the war, Website http://www.mmb.org.au/.
See also Peter Dunn's online military history site at http://www.ozatwar.com/.

8 CONTRIBUTIONS BY LICENSED AMATEUR RADIO OPERATORS

Amateur Radio is a truly international hobby open to licence holders to use designated frequencies for purposes of private recreation, non-commercial exchange of messages, wireless experimentation and self training. It also contributes to the community by being available to provide help with communications in the event of an emergency.

The Wireless Institute of Australia (WIA) has described the Amateur Service as existing to meet the needs of the community for public access to the radio frequency spectrum for self-training, technical experimentation and self-development, as defined in the International Telecommunications Union (ITU) Radio Regulations Article 1: 1.56 Amateur Service: A radio communication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorised persons interested in radio technique solely with a personal aim and without pecuniary interest. (http://life.itu.int/radioclub/rr/art1.pdf)

The WIA is the national organisation of Australian radio amateurs (http://www.wia.org.au/).It is the peak body representing the interests of the Australian radio amateur community nationally and internationally. Founded in 1910, the WIA is acknowledged as being one of the first radio societies in the world, and is the world's oldest national amateur radio society. The WIA represents the interests of the Australian radio amateur community through formal liaison with the ACMA, other government institutions and other organisations. A key role of the WIA is providing training and licence assessment services for people interested in obtaining their amateur licence, particularly young people. WIA appointees participate in the work of spectrum management, and consultative and standards bodies.

The WIA is a member of the International Amateur Radio Union (IARU), (http://www.iaru.org/), which represents the interests of the amateur and amateur satellite services internationally and is recognised by the International Telecommunications Union. Membership of the IARU is comprised of the national societies of each separate country or territory. The WIA was one of the first 14 national societies to become a member of the IARU when it was formed in 1925.

Radio Amateurs in both Australia and America provided a lot of their own equipment and expertise to governments at a crucial time during World War 2 and quite a few paid the final sacrifice. Human resource and technical assistance today is provided through such bodies as State Emergency Services.

Radio Amateurs continue to be at the sharp end of technology by way of improvements in messaging through software development and signal propagation research. Individual Radio Clubs also establish and maintain their own licensed independent HF, VHF and UHF analogue and digital radio based networks in Australia. A national monthly magazine is also produced and is devoted entirely to amateur radio. National and local weekly amateur radio news broadcasts are also a feature. In addition technical training and accreditation for licensing purposes is carried out by local radio clubs through the Wireless Institute of Australia. Despite all this activity and investment the hobby in Australia is self funded through subscriptions and donations. It is hoped that it continues to be recognized by governments as a national and internationally active human, technological and physical resource as well as a body that promotes technical improvement and capacity.

The following provides the callsigns of all the radio amateurs or organisations whose names have been listed either directly or indirectly in this study. They are:-

United States of America

- K5HAL Cullen Langford
- KE6RWJ Christopher Story

Australia

- VK4GB George Barr (SK)
- VK4LT Albert (Al) Carter (SK)
- VK4NS Lionel L. Sharp
- VK4PJ Peter Brown (SK)
- VK4PO Peter Oliveri (SK)
- VK4QF Bill Bentson (SK) (EX USA WW2)
- VK4RF Fred Lubach (SK)
- VK4BAY Bayside District Amateur Radio Society Inc.
- VK4WST Victor Stallan
- VK4ZBV J.P. (Paul) Hayden

Websites of Radio Amateurs:-

- VK2BV Waverley Amateur Radio Society
- VK2NO Ray Robinson
- VK4KDP D.G. Prince
- VK5BR A.L. (Lloyd) Butler

Special thanks must go to Peter Oliveri who was interviewed by the author during the course of the study and, despite illness and incapacity, provided much valuable information on the post-war days at the two radio sites.

9 CONCLUSIONS

A major conclusion from this study of the use of the High Frequency radio system during and after World War 2 is that its success during the war in the Pacific, 1941-1945, was achieved in part by the high level of technological competence of the United States of America in a number of fields, but particularly its engineering expertise in message security and speed of delivery. The use of High Frequency Radio as the communications backbone was its first use on this massive world wide scale and without it the war's conclusion would have been delayed considerably.

Communications expertise in the USA was initially developed by private business interests backed up by highly capable and dedicated engineers and scientists working in industry and academia. These features allowed the USA to quickly move to mass production of great communications technology once war was declared. Australia benefited from this technology and research, both during the war and post-war. An important lesson here is that the methodology used by the USA in utilising their local industry expertise to manufacture and develop new and better technology is a blueprint. This should not be forgotten in Australia.

Another lesson learned relates to the method of communication. It is evident that cable, and more lately, satellite services are vulnerable to denial of service as they can be easily destroyed physically. High Frequency Radio facilities utilizing the ionosphere must always be available for international messaging in view of such a concern.

What has been realised, particularly in hindsight, is that the role of licensed Radio Amateur operators was vital during World War 2 by providing a large number of highly trained and dedicated individuals at a time of great urgency in all theatres of war. The hobby, underpinned by licensed volunteers from all walks of life, continues to develop the technical and human resource capabilities of new and older members to ensure that it remains available to assist the community in times of any emergency.

Appendix 1 - WILCOX ELECTRIC COMPANY CW3-D DUAL DIVERSITY RADIO RECEIVER SPECIFICATIONS

Frequency range was 1.9 to 24 MHz with 6 sets of plug in coils.
Bands were :(1) 1.9 to 3.6 MHz, (2) 3.4 to 5.9 MHz, (3) 5.8 to 9.4 MHz, (4) 9.4 to 16.5 MHz, (5) 16.5 to 20 MHz, (6) 20 to 24 MHz.
Number of crystals : 2 per receiver (one each for the two connected receivers)
Preset frequencies : 1
Antennas: 2 rhombics or two matched antennas
Power: 110 volt, 60 cycle, single phase ac, 1.3 amps.
Range: long, dependent on antenna used, frequency and ionospheric conditions.
Number of tubes: 16
Use: Radio teletypewriter or other dual diversity use.
Type of signal: AM or CW
Principal components: Radio assembly OA-59/FRC, consisting of 2 Wilcox Electric Co. Type CW3-D receivers, each 10.5x19X11.5 inches. Total weight: 528 lbs

US War Department (1944b, p.472) Technical Manual TM 11-487 records that four pre-set channels were used with Type AN/FGC-1 Teletype equipment developed in 1942. Four Wilcox Electric Co. CW3-D crystal controlled receivers (each unit comprising two interconnected modified radios) were assembled in a single 155 A-D Type Cabinet and were used for teletype reception. The specification meant that there was one redundant system available in the cabinet at all times. The photo of the front panel of a Wilcox Electric Co. CW3-D Receiver, Fig. 8, is the same as that given in Appendix 11, page 103.

A common h-f oscillator and three arrangements of bfo were provided and were common to both receivers. Two power supplies were used due to the manner of the receivers' conversion. The keyer caused the radio transmitter to emit radio power at a particular frequency for teletypewriter open pulses and a slightly different frequency but the same power for the closed pulses - FSK. Fading of signals was reduced by using two separate antennas and two radio receivers – "space diversity "as it is known. The system also overcame a lot of the noise on the frequency and the equipment continued to operate without errors even when the tones were indistinguishable to the human ear. Some Wilcox Electric Co. CW3-D details are given in Section 5 of this document, and US War Department (1944a) Technical Manual TM 11-2204, Dual Diversity Receiving Equipment Wilcox Electric Co.Type CW3-D , is attached at Appendix 10.

The US War Department Technical Manual (1945) TM-11-853 for the Wilcox Electric Co.Type CW3 and Type F3 receivers plus the Receiver Bay Type 113A provides an insight into the technical aspects of this receiver and the way it was used. The CW3 did not however have the higher frequency capacity of the CW3-D. Comparison of the three known types of Wilcox Electric Co. Radio Receivers used in World War 2 viz. the Wilcox Electric Co. Receiver Type F3, Wilcox Electric Co. Receiver Type CW3, and the Wilcox Electric Co. Receiver Type CW3-D using two Type CW3 receivers and modified systems is as follows:- Wilcox Electric Co.Type F3 was voice, (a-m) and covered 1.950 to 16.5 and later to 18 MHz. Types CW3 (CW) and CW3-D (CW) covered – 1.9 to 24.0 and later to 25MHz All types were crystal controlled superheterodyne fixed frequency receivers with band coverage by means of four or more groups of plug-in coils.

Wilcox Electric Company Radio Receivers

Stage	**Valve**	**F3**	**CW3**	**CW3-D**	**Type of Valve**
R-F Amplifier	V1	6K7	6K7(GT)	6K7	Pentode
	V10			6K7	“
Mixer-Oscillator	V2	6K8	6K8	6K8	Triode Hexode converter
	V11			6K8	“
I-F amplifier	V3	6K7	6K7 (GT)	6K7	Pentode
	V12			6K7	“
Detector	V4	6F7	6C8G	6C8	6F7- Triode & Remote cut-off Pentode
	V13			6C8	6C8 – Double (Twin) Triode
Audio Amplifier	V5	6C8G	6C8G	6C8	Double (Twin)Triode
	V14			6C8	“
Rectifier	V6	80	80	80	Rectifier
	V15			80	“
Common BFO Control	V7	-	6SN7(GT)	6SN7GT	Dual (Twin)Triode
Common Control	V8	-	-	6AC7/1853	Metal pentode high gain amplifier
	V9	-	-	6SA7	Pentagrid, stable mixer/ oscillator
	V16	-	-	VR-105-30	Cold cathode voltage stabiliser

Note: Valves V10 to Valve 15 relate to the second receiver. GT valve classification was for later designs.

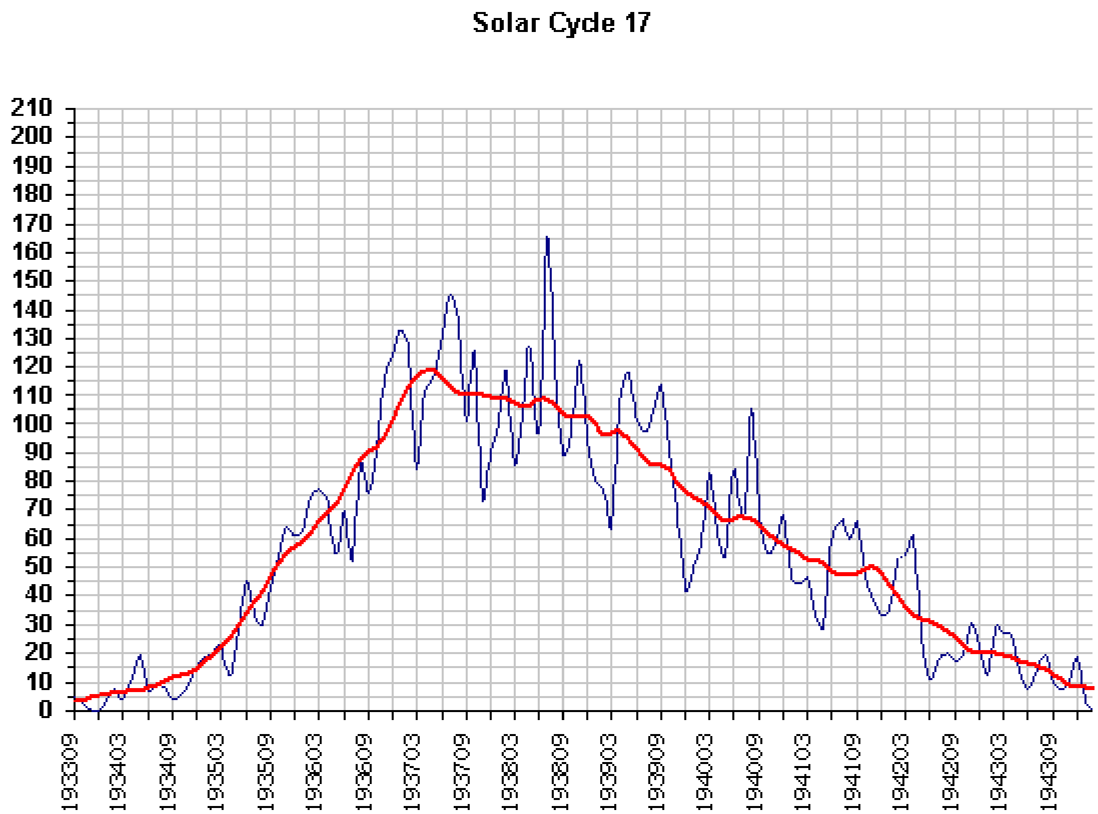
V6 and V7 are located together and not shielded on the receiver chassis. To the right of V6 and V7 on top from the left are V5,V4,V3,V2 and V1 in that order with no room for any more valves etc. Therefore V8,V9 and V16 would be situated between the receivers in the photograph of the Type CW3-D in page 5 of US Army Forces Catalog SIG 10-325 (1945), (Ref. TM 11-2204). The Wilcox Electric Co. Type CW3-D had an additional three valves to provide the common oscillator, voltage regulation and amplification.

Instruction books for the Wilcox Electric Co.Type CW3 Receiver and associated Receiver Bay 113A in 1943 are readily available from booksellers in the USA and are suggested as further reading. Circuit diagram and component details are listed in the books and photographs are excellent. An Instruction Book sighted titled “Wilcox Electric” recorded that “Equipment covered by this instruction book was manufactured by Communications Equipment Corporation, 134 West Colorado Street Pasadena, California”. This possibly gives an indication of the wartime pressures on production of radio equipment. (Wilcox Electric Company Inc. (1943) Instruction Book for Receiver CW3).

The Wilcox Electric Company also manufactured transmitters. JANAP 161, Instruction literature TM 11-2204, records that a Wilcox Electric Co. Type CW3-D Receiver could communicate with a wide range of equipment including the Wilcox Electric Co. Type 96D and Type 99A transmitters. (http://jptronics.org/Military/JANAP161/an.fifrr/an.frr-type.oa-59.frc.pdf).

Appendix 2—HF RADIO PROPAGATION DIFFICULTIES 1942-1945

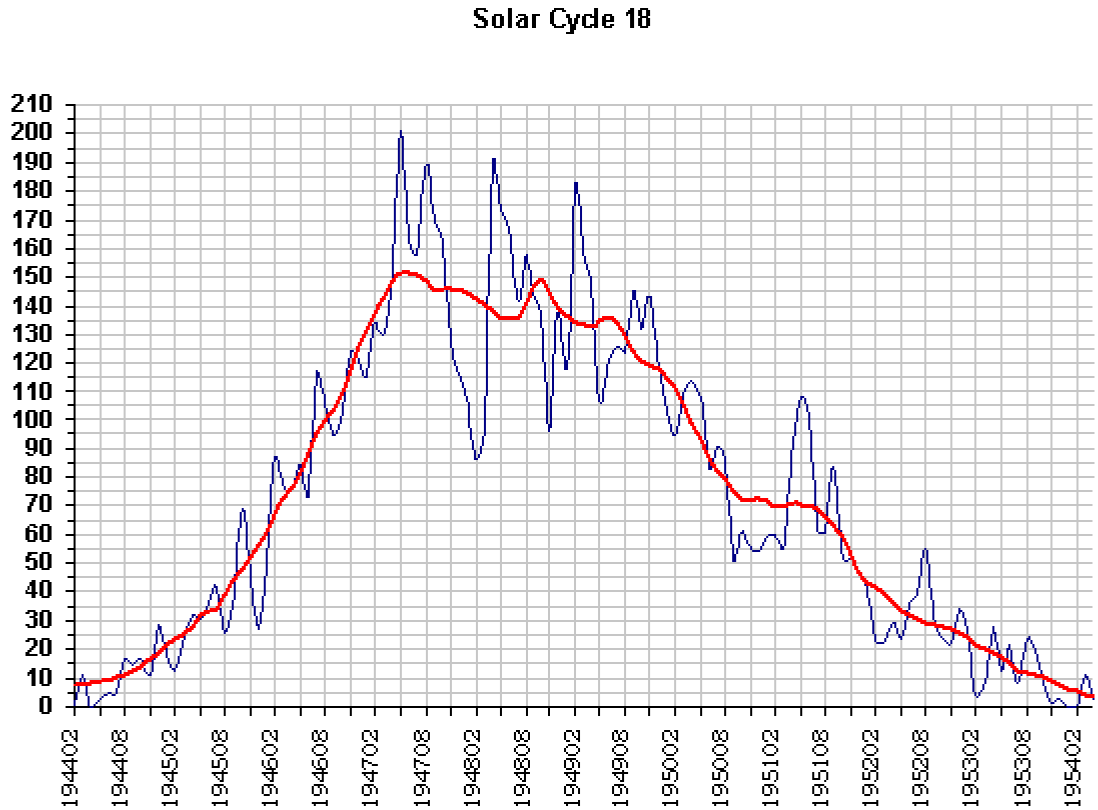
Radio signals in the High Frequency Bands up to 30 Megahertz are propagated by the ionosphere. The height of the ionosphere is determined by many factors but when sunspot numbers are high the result is generally very good received signal strengths but with solar flares at times cutting communication temporarily. Likewise when sunspots numbers are low signal strength is degraded and the maximum usable frequency (MUF) declines. World War 2 in the Pacific, which commenced on 7 December 1941, was within both Solar Cycle No. 17 (Fig. 12) which commenced in September 1933 and ended in February 1944 and Solar Cycle No. 18 (Fig. 13) beginning in February 1944 and ending in April 1954.



Asterisks to the right show the Wartime Period

Fig. 12: Graph Solar Cycle 17. (http://www.solen.info/solar/cycl17.html).

Solar Cycle 17 covered the early part of World War 2 in the Pacific. It was the seventeenth solar cycle since 1755, when extensive recording of solar sunspot activity began and lasted 10.4 years. The maximum smoothed sunspot number (monthly number of sunspots averaged over a twelve-month period) observed during the solar cycle was 119.2 (April 1937), and the minimum was 7.7.There were a total of 269 days with no sunspots during this cycle. A great aurora display was seen all over Europe on 25 January 1938. (https://en.wikipedia.org/wiki/Solar_cycle_17).



******* Asterisks to the left show the Wartime Period

Fig. 13: Graph Solar Cycle 18. (http://www.solen.info/solar/cycl18.html).

Solar cycle 18 covered the latter part of World War 2 in the Pacific which ended on 2 September 1945. It was the eighteenth solar cycle since 1755, when extensive recording of solar sunspot activity began. The solar cycle lasted 10.2 years, beginning in February 1944 and ending in April 1954. The maximum smoothed sunspot number (monthly number of sunspots averaged over a twelve-month period) observed during the solar cycle was 151.8 (May 1947), and the minimum was 3.4. There were a total of 446 days with no sunspots during this cycle. (https://en.wikipedia.org/wiki/Solar_cycle_18). This data shows that this solar cycle had a higher maximum and a lower minimum that its predecessor as well as having more days without any sunspots.

As can be seen, these cycles are not the same in amplitude or length or shape and are confirmation that the sun is a variable star. Solar Cycle 17 maximum was April 1937 and it ended February 1944. Solar Cycle 18 maximum was May 1947 and it ended April 1954, very similar lengths of time.

The main point here is that High Frequency (HF) communications from Australia to the northern hemisphere and return are long haul, requiring good antennas, powerful transmitters and good receivers. In addition, the effectiveness of transmissions depends on what point of the solar cycle one is in. World War 2 in the Pacific started during the down part of Solar Cycle 17 at which stage the sunspot numbers were in the low 40's and declining to a minimum that did not change much until the end of 1944. This must have been a period of low HF communications reliability, partly the reason for the need for massive rhombic antennas and the high powered multichannel single sideband (SSB) transmitter at Hemmant and the search for good reliable radio communication sites by ACAN throughout the world.

Military history of the USA Signal Corps (Thompson et.al. 1957 p. 433) records “An initial obstacle encountered in providing satisfactory world-wide radio service was magnetic absorption in the polar regions, which reduced the reliability of direct channels between WAR and some of the more strategic ACAN stations overseas. There then was no known means of overcoming this effect. But the polar regions could be bypassed. Therefore, the Signal Corps designed a belt line of communications circuits which circled the world in the vicinity of the equator. The eastward equatorial route from WAR sped by way of Asmara in Eritrea, Africa, New Delhi in India, Brisbane in Australia (later Manila was substituted when the Philippines were retaken), and San Francisco, thence back to WAR by landline. Terminals at strategic points to the north and south tapped into the equatorial belt line with secondary circuits. Thus from any point served by Army circuits, messages could be sent to any other point around the world. If ionospheric conditions in one direction were bad, traffic could readily be routed in the opposite direction to reach its destination. This around the-world belt line was a happy solution which not only evaded the difficulty of communicating by radio over the polar regions but also facilitated communication in the event of failures or interference anywhere.

Radio circuits were unpredictable at best. The British in Libya had found that at times units forty to sixty miles apart could not communicate with each other by (HF) radio, regardless of the power output they used, yet each could communicate with London. Therefore, while the condition lasted, traffic between the nearby points had been relayed through London facilities. Similarly, in the continental United States, there were times when an antenna built and beamed for communication with Chicago, for example, transmitted a stronger signal to San Francisco. The operators confessed they did not know why it was so, but they found by experimenting that when signals were bad over authorized channels they could often be bettered by an unorthodox hook up. The improvement might last from minutes to weeks and months”.

Interestingly, cyclones appeared every year from 1937 to 1940 but were minimal during World War 2 with one cyclone crossing the coast of Queensland north of Rockhampton on 8th February 1942 and then none until March 1946. This could be a reflection of the lowered sunspot numbers.(See Cyclones http://www.windworker.com.au/qldcyclones.htm.).

Sunspot cycles themselves have their own larger cycle, that is a cycle encompassing smaller cycles, with the highest recorded sunspot numbers being from Solar Cycle Number 19 in March 1958. Solar Cycles since then have been dropping in intensity of sunspot numbers. The Maunder Minimum, also known as the "prolonged sunspot minimum", is the name used for the period starting in about 1645 and continuing to about 1715 when sunspots became exceedingly rare, as noted by solar observers of the time. (https://en.wikipedia.org/wiki/Maunder_Minimum and see Solar Cycles, Maunder Minimum https://en.wikipedia.org/wiki/Maunder_Minimum#/media/File:Sunspot_Numbers.png).

Wikipedia records that “During the Great Frost of 1683-84, the worst frost recorded in England, the Thames was completely frozen for two months, with the ice reaching a thickness of 11 inches (28 cm) in London. Solid ice was reported extending for miles off the coasts of the southern North Sea (England, France and the Low countries), causing severe problems for shipping and preventing the use of many harbours. Near Manchester, the ground was frozen to 27 inches; in Somerset to more than four feet” (https://en.wikipedia.org/wiki/River_Thames_frost_fairsts)

Four hundred years of sunspot observations from 1600 to December 2016 are given as follows:-

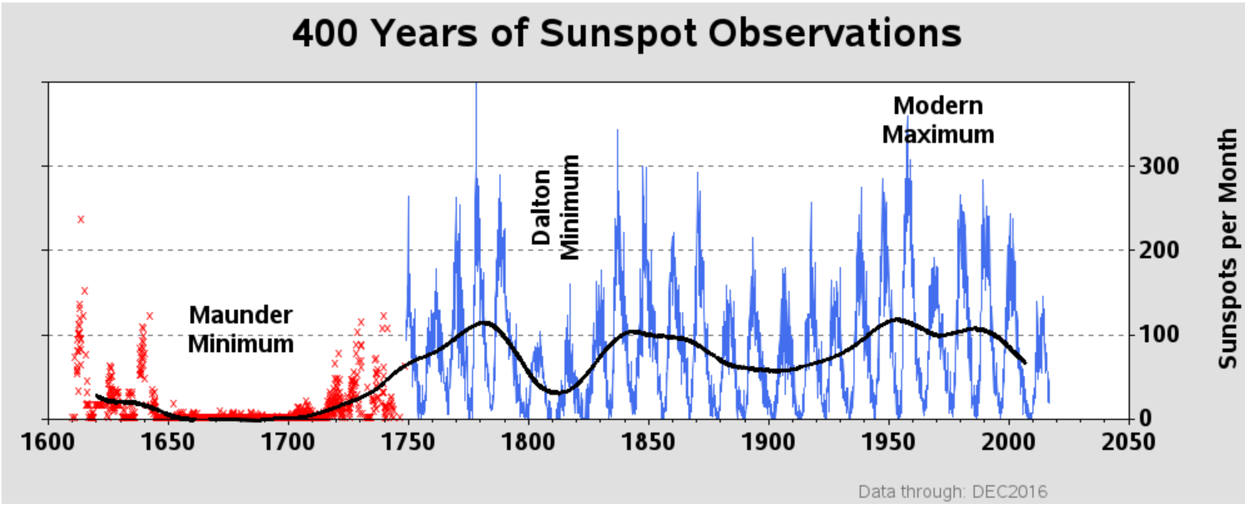


Fig. 14: Graph of Four Hundred Years of Sunspot Observations.
Source: Sunspots https://en.wikipedia.org/wiki/Sunspot

More modern investigatory techniques based mainly on tree ring histories suggest that some sunspots did occur during the period. Nevertheless the sun did go through a relatively quiet period. This situation is likely to occur again sometime in the future. The inference here is that use of the ionosphere for radio communication will be difficult at such a time. High Frequency long haul radio transmissions in the future may well require large antennas to be successful, but new computer based receiver technology and better understanding of the ionosphere's characteristics will assist greatly. Already there are software defined radios (SDR) operated around the world very successfully, by governments, private business and radio amateurs.

The use of the High Frequency Bands for national broadcasting around the world is in decline but the bands are now being used by military forces of many nations for Over The Horizon Radar purposes. This involves wide bandwidth and high power transmission often causing interference to other users. The Australian system is called JORN. Source: (http://www.airforce.gov.au/docs/JORN_Fact_Sheet.pdf)

Appendix 3 - RHOMBIC ANTENNAS EXPLAINED

Radio reception has always relied on good antennas, even in modern mobile phones. At High Frequencies (HF), up to 30 Megahertz, it is a case of using large antennas to ensure good communications.

Wikipedia records " The rhombic antenna, like other horizontal antennas, can radiate at elevation angles close to the horizon or at higher angles depending on its height above ground relative to the operating frequency and its physical construction. Likewise, its beamwidth can be narrow or broad, depending primarily on its length. The shallow radiation angle makes it useful for skywave ("skip") propagation, the dominant mode at shortwave frequencies, in which radio waves directed at an angle into the sky reflect from layers in the ionosphere and return to Earth beyond the horizon". Shortwave here refers to the High Frequency Band or its abbreviation HF.

Most military in World War 2 used Rhombic antennas for "long haul' radio communications. A Rhombic is a huge diamond shaped wire antenna that covers acres (hectares) of land, hopefully very damp. Each of the four poles on which the wires sit can be 80 to 100 feet (25-30 metres) or more high depending on the frequency and angle required for the radio signal to head off to the ionosphere which extends from 50 to 1000 kilometres above the earth.

Rhombic antennas are non-resonant simple travelling wave band antennas. Frequencies can be easily changed as ionospheric conditions change, as against resonant antennas, for example a dipole, which will only work well around a specific frequency. For many years after the war they were the workhorse of long distance communication by the PMG, ABC and OTC. These days a complex Log Periodic antenna might seem a reasonable compromise.

The radiation pattern of rhombic antennas is dependent on its length in wavelengths. The radiation pattern changes with frequency as it becomes higher in gain as the frequency increases. The important thing is that it retains its maximum gain in the direction it points and the side-lobes become smaller.
(See Rhombic Antennas http://www.mapability.com/ei8ic/rhombic/rhombic.php for details). (Figs.15 to 18 refer).
In summary the rhombic antenna is a diamond-shaped antenna, suspended between 4 masts.
The 3 parameters of a rhombic antenna are:
- l: antenna leg length
- γ: one half of the large interior angle
- h: antenna height

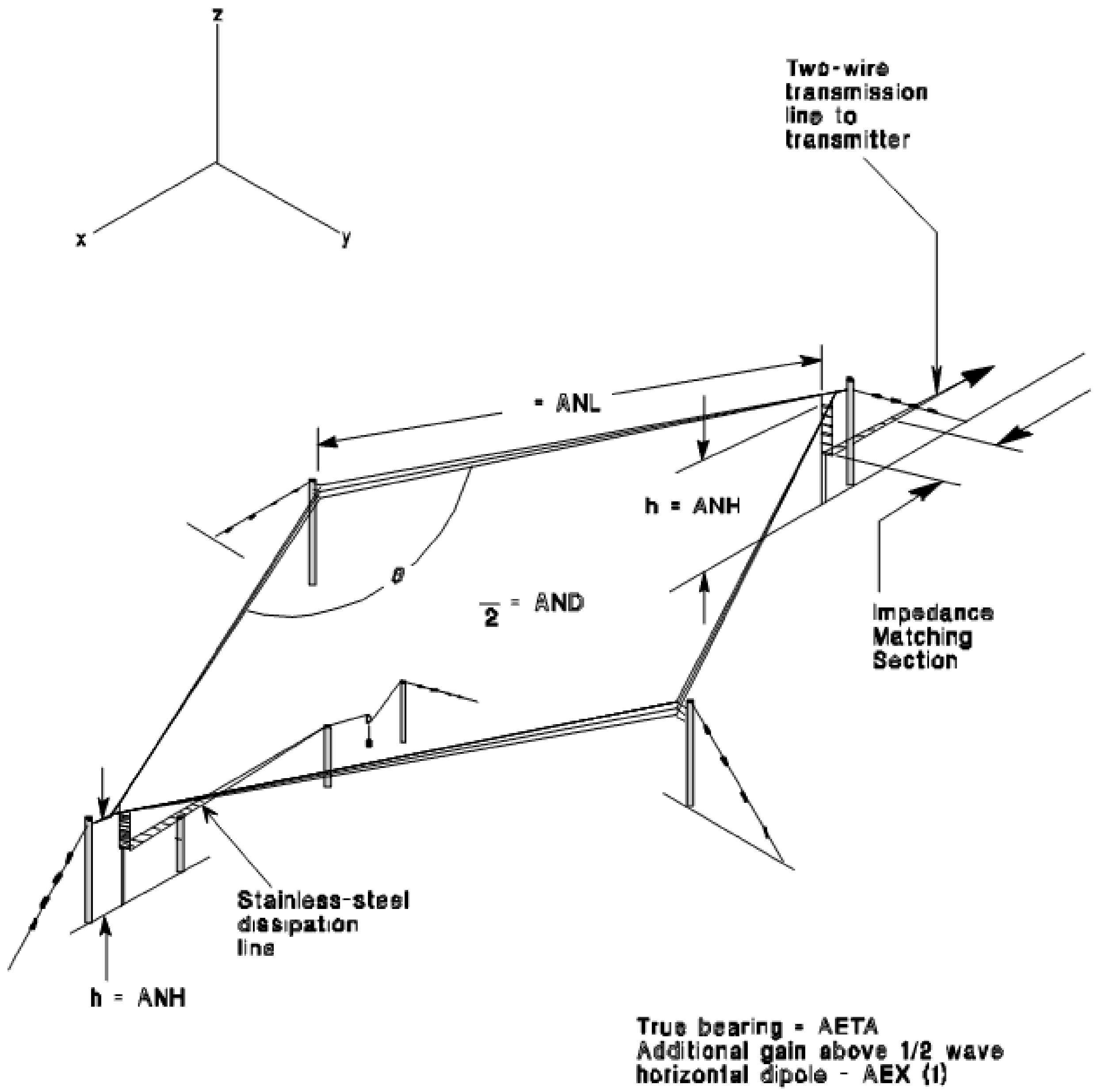


Fig.15: Sketch of Three Wire Rhombic Antenna. (http://www.antenna.be/rh.html)

Lionel Sharp records this type of antenna was used at Hemmant, the three wire design broad-banding the antenna to some extent.

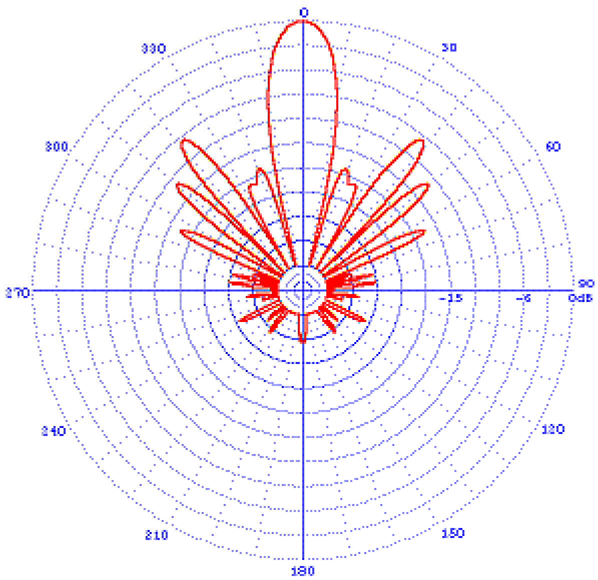


Fig. 16: Graph of Rhombic Antenna Azimuth Pattern. (http://www.antenna.be/rh.html).

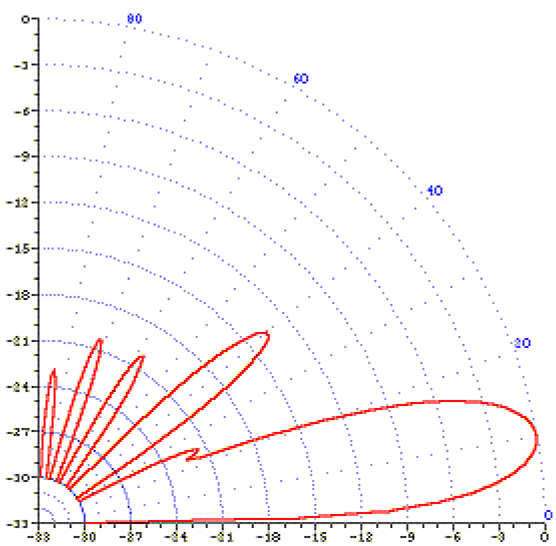


Fig. 17: Graph of Rhombic Antenna Elevation Pattern. (http://www.antenna.be/rh.html).

Figure 16 shows the type of radiation pattern of a rhombic antenna in terms of horizontal angle or azimuth whilst Figure 17 shows its elevation pattern. These patterns can be modified through changes to the design of the antenna.

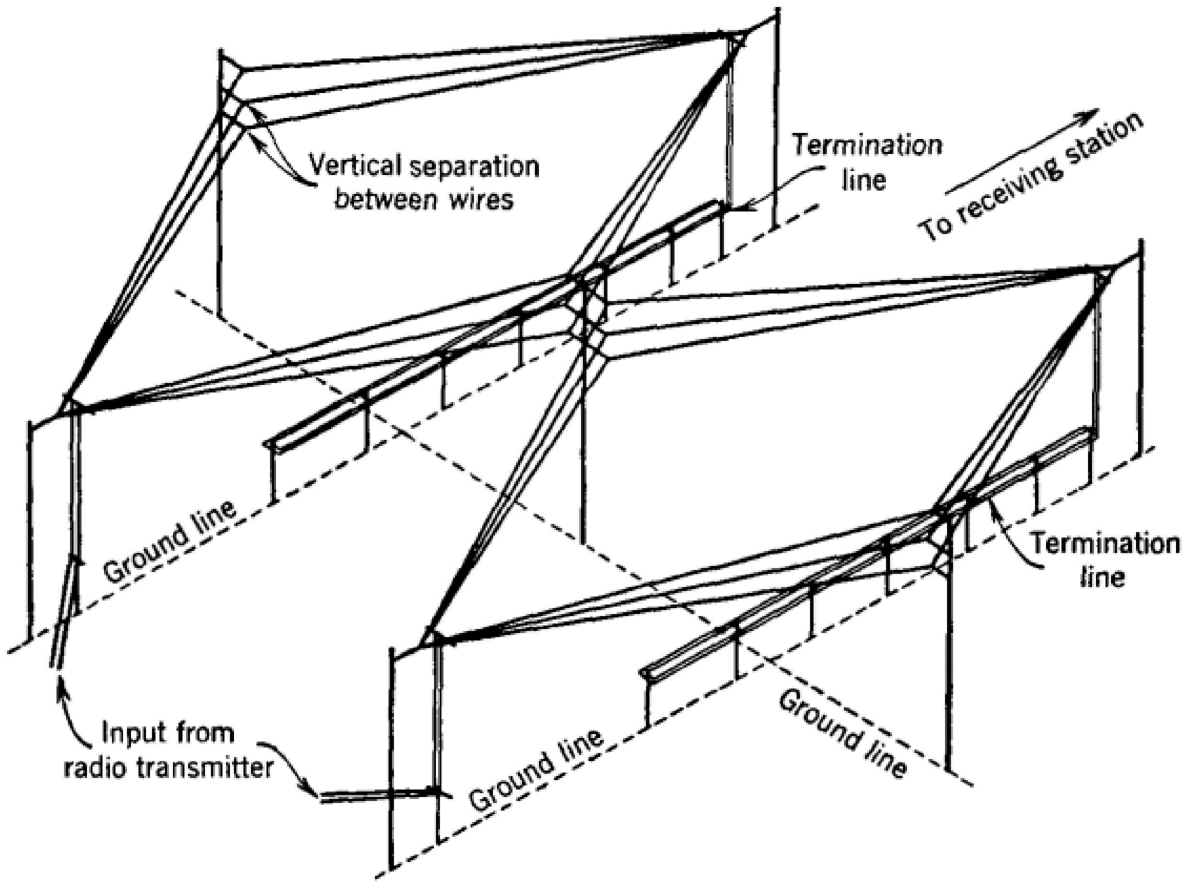


Fig.18: Sketch of Twin 3 Wire Rhombic Antenna. (http://www.antenna.be/rh.html).

The " Twin 3 Wire" design gives characteristics better than a single large rhombic. The "termination line" of iron (steel) wire serves the same purpose as a terminating resistor and is used with large transmitting antennas.

As mentioned in Section 4, a plan showing three rhombic antenna locations and dimensions is given in L&S294 (see Fig. 39, pg. 144) also available from the Commonwealth Government Archives (n.d.). The pointing angles of the rhombic antennas are given as (1) 49 Degrees, (2) 57 Degrees 51 minutes, and (3) 79 minutes 59 minutes respectively. Matching of the azimuth in degrees with the destination from Brisbane shows a good fit for Honolulu against latest computer generated data (49.3799 degrees), a possible for Washington (61.45003 degrees) and a possible for Samoa (74.56464 degrees).
The following table shows some computer generated azimuth pointing angles:-

Rhombic Antenna Pointing Angles.
Azimuth in Degrees - Brisbane to –

Honolulu	49.39799	Washington	61.45003
San Francisco	53.70462	Noumea	69.70148
Philadelphia	59.72361	Samoa	74.56464
San Diego	60.26648	Miami	79.27666
Baltimore	60.73569	New Delhi	301.6853

Source: (http://earthdirections.org/locate. Use a Search Engine.

The matter of allowing for magnetic declination when calculating the required rhombic antenna pointing angle is not covered in this document, however the pointing angles confirm that Capalaba did not provide a circuit to New Delhi. This was done through the installation at Redland Bay, October 1943. (Sullivan, n.d., p.9).

Paul Hayden in 2017 provided some thoughts on the technical aspects of this situation as follows:-

"I have always looked at Rhombics as being a wide RF bandwidth antenna. You must also look at them as having a wide beam width measured at the -3db point.

If you take a fairly large rhombic at the middle of its design bandwidth it will have a beam-width of typically 20 to 25 degrees. At lower frequencies that will increase to 30 degrees, and at higher frequencies it will fall to something less like 15 degrees. This is countered by a decrease in gain as the frequency goes down and an increase in gain as the frequency goes up. So it is hard to come up with any sort of precise figure for beam width as it depends on the frequencies in use.

Having said that beam-width is not one of the design parameters used in rhombic design, the standard starting point is path length. Once you know that, you then need to know what vertical angle of radiation is required to provide the path mathematics for that distance. This is where the optimum frequency of transmission (typically the critical frequency minus 10%) that will be reflected at the required vertical height comes into play. This is of course determined by the point in the sunspot cycle.

So it all comes back to path length, vertical angle required, sunspot cycle, frequency to be used, and the daily change to follow the MUF. One can see that they are designed for point to point communications, but with a little luck one might get more or less than you expected in terms of off bore-sight coverage.
I would tend not to even try to pinpoint exact directions, there are too many variables involved without even thinking of things like ground conductivity and water tables.

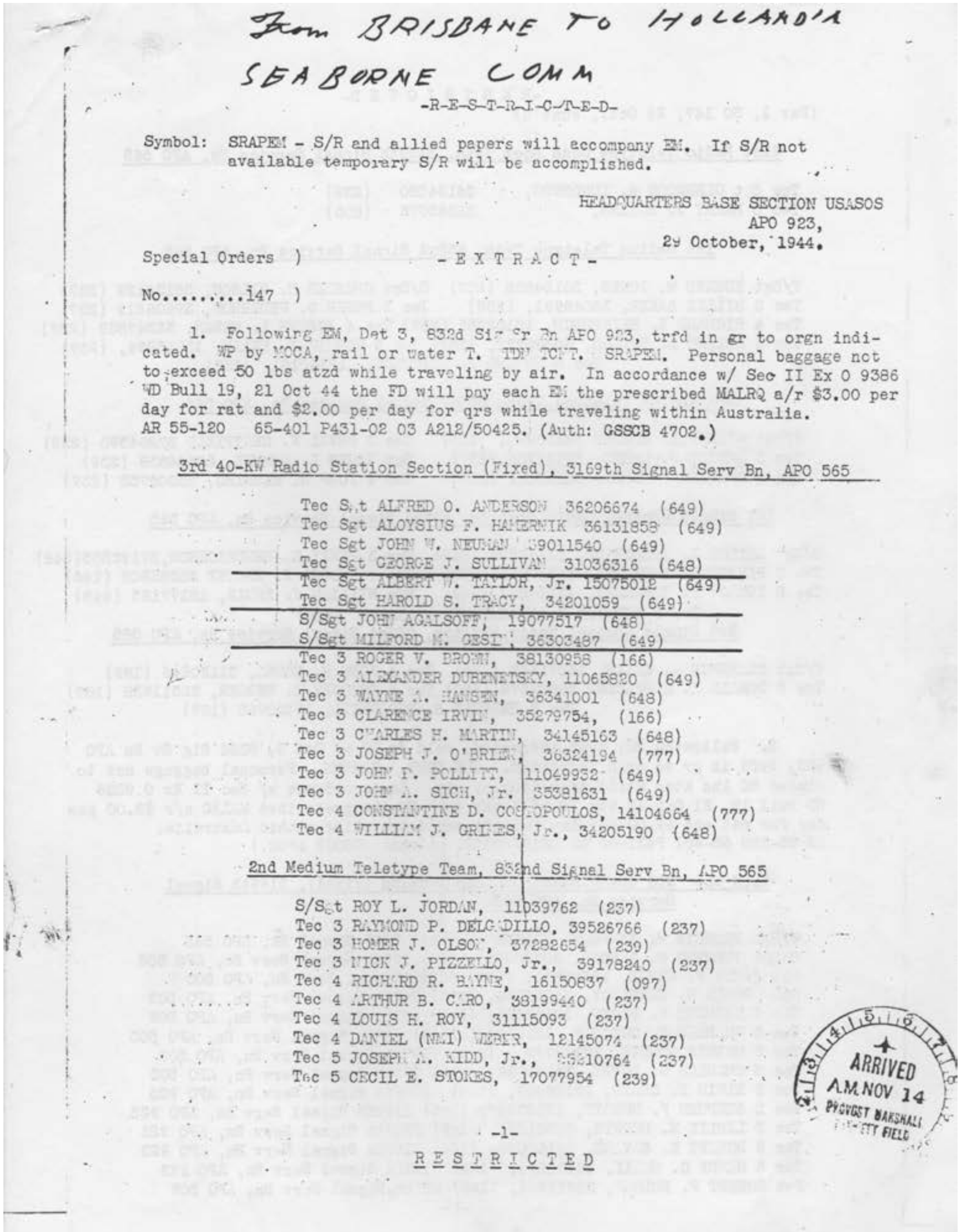
Based on simple rule of thumb measurements, the maximum single hop path length with a fairly good ionosphere is about 3,000 miles (approx 4800 kilometres) and about 5 degree angle of radiation of main lobe. The distance Brisbane to San Francisco is about 7,100 miles so with two hops you get 6,000miles, too short, and with three hops you get 9,000 miles, too long.

To get to San Francisco from Brisbane you need three smaller hops of about 2,370miles. To reduce the hop distance, you lower the antenna, to raise the angle of radiation. The antenna beam width in the vertical plane helps, depending on the size of the antenna it may well be 10 degrees to 20 degrees wide

You must use frequencies that the ionospheric propagation supports on your chosen Path, then set the antenna height to provide the required angle of radiation, to give the required hop length necessary to reach the target with one or more hops. The ionospheric height changes from day to night, as does the critical frequency, so the calculations of antenna height (that determines the necessary angle of radiation) at both day and night frequencies must fit the antennas vertical beam width, it will likely be a compromise at both day and night frequencies but variations in the ionosphere are even more of a compromise

Over the years as the sunspot cycle varies the antenna height may be re -adjusted to suit the changing ionospheric conditions. So you adjust the antenna height to concentrate the radiation angle to hit that critical vertical height at the mid-point of the hop, to deliver maximum signal on the ground (water) 2,370 miles away. It's lucky that things are not too precise, because you have huge variables forced upon you by the ionosphere."

Appendix 4 - POSSIBLE EVIDENCE OF THE MOVEMENT OF PRESS 40kW USA SSB AMPLIFIER FROM BRISBANE 1944



From BRISBANE TO HOLLANDIA

SEABORNE COMM

-R-E-S-T-R-I-C-T-E-D-

Symbol: SRAPEM - S/R and allied papers will accompany EM. If S/R not available temporary S/R will be accomplished.

HEADQUARTERS BASE SECTION USASOS
APO 923,
29 October, 1944.

Special Orders)
No.........147)

- E X T R A C T -

1. Following EM, Det 3, 832d Sig Sr Bn APO 923, trfd in gr to orgn indicated. WP by MOCA, rail or water T. TDN TCNT. SRAPEM. Personal baggage not to exceed 50 lbs atzd while traveling by air. In accordance w/ Sec II Ex 0 9386 WD Bull 19, 21 Oct 44 the FD will pay each EM the prescribed MALRQ a/r $3.00 per day for rat and $2.00 per day for qrs while traveling within Australia. AR 55-120 65-401 P431-02 03 A212/50425. (Auth: GSSCB 4702.)

3rd 40-KW Radio Station Section (Fixed), 3169th Signal Serv Bn, APO 565

Tec Sgt ALFRED O. ANDERSON 36206674 (649)
Tec Sgt ALOYSIUS F. HAMERNIK 36131858 (649)
Tec Sgt JOHN W. NEUMAN 39011540 (649)
Tec Sgt GEORGE J. SULLIVAN 31036316 (648)
Tec Sgt ALBERT W. TAYLOR, Jr. 15075012 (649)
Tec Sgt HAROLD S. TRACY, 34201059 (649)
S/Sgt JOHN AGALSOFF, 19077517 (648)
S/Sgt MILFORD M. GESIN, 36303487 (649)
Tec 3 ROGER V. BROWN, 38130958 (166)
Tec 3 ALEXANDER DUBENETSKY, 11065820 (649)
Tec 3 WAYNE A. HANSEN, 36341001 (648)
Tec 3 CLARENCE IRVIN, 35279754, (166)
Tec 3 CHARLES H. MARTIN, 34145163 (648)
Tec 3 JOSEPH J. O'BRIEN, 36324194 (777)
Tec 3 JOHN P. POLLITT, 11049932 (649)
Tec 3 JOHN A. SICH, Jr. 35381631 (649)
Tec 4 CONSTANTINE D. COSTOPOULOS, 14104664 (777)
Tec 4 WILLIAM J. GRIMES, Jr., 34205190 (648)

2nd Medium Teletype Team, 832nd Signal Serv Bn, APO 565

S/Sgt ROY L. JORDAN, 11039762 (237)
Tec 3 RAYMOND P. DELGADILLO, 39526766 (237)
Tec 3 HOMER J. OLSON, 37282654 (239)
Tec 3 NICK J. PIZZELLO, Jr., 39178240 (237)
Tec 4 RICHARD R. BAYNE, 16150837 (097)
Tec 4 ARTHUR B. CARO, 38199440 (237)
Tec 4 LOUIS H. ROY, 31115093 (237)
Tec 4 DANIEL (NMI) WEBER, 12145074 (237)
Tec 5 JOSEPH A. KIDD, Jr., 35210764 (237)
Tec 5 CECIL E. STOKES, 17077954 (239)

-1-

R E S T R I C T E D

ARRIVED
A.M. NOV 14
PROVOST MARSHAL
FIELD

Fig. 19: From Brisbane to Hollandia Seaborne Comm. Special Order 147. Source: Peter Dunn.

USA Technical Sergeant George Sullivan is clearly defined in the above as being attached to the fixed 40kW (Press) ACAN radio station in Australia. The above notation and the date of 2 October 1944 suggests that this could relate to the transfer of the high powered amplifier to Hollandia or just the movement of the members of the Signal Corps to that area. The transmitter was installed in Manila in mid 1945.

Sergeant Sullivan (Fig. 19) collected a great deal of information about fellow service-men's experiences during the course of World War 2 in the Pacific War 1941-45 after being posted 'Down Under'. He kept in touch with his comrades through reunions after the war and encouraged them to record their stories as a contribution to US military history. This resulted in two type-written books – book 1 and book 2 entitled ' The Things We Save' (Sullivan, n.d.). A number of the contributors covered the installation of radio equipment in Brisbane by the US 832nd Signal Service Company and the installation of equipment and antennas at Hemmant and Redland Bay. Book 2 especially details the US operations in Brisbane City and South Brisbane. (This reference appears on Peter Dunn's website and a full copy is available at https://www.scribd.com/document/337215466/Things-We-Save-by-George-Sullivan).

Appendix 5 – EXPLANATION OF HIGH POWERED SSB TRANSMISSIONS by Paul Hayden 2016

For the technically minded Paul Hayden advised in 2016 that " a transmitter used for AM, FSK or high speed CW rated at 10 Kilowatts (10kW) is also likely to be rated at 40 Kilowatts (40kW) Peak Envelope Power (PEP) Single Sideband (SSB). In Amplitude Modulation (AM) a transmitter is rated at unmodulated carrier power e.g. 10kW. When 100% modulated the carrier envelope doubles in amplitude (100% + peak mod). At twice the voltage you get twice the current or four times the power (40kW pep) and then it drops to zero (100% -peak mod) 0kW.The average power measured through one cycle of AM modulation will be 15 kW. So the 10kW Power amplifier may have had a 40kW PEP SSB Rating. Evidence that the amplifier was classified as 40kW by the Americans is given in Appendix 4.

SSB and Mux (Multiplexing) signals like VFT (Voice Frequency Telegraph) require Linear Class B or Class AB1 amplifiers, so a 40kW class C would run a lot less power in Linear mode. There is no mention of a high level AM Modulator but you would require 20kW of audio to run AM with a Class C plate modulated final. The specifications are a bit light on detail but a single high speed morse channel 400wpm at 40kW could be run. In telecommunications Muxing allows you to share an expensive resource (Bandwidth) between a number of less expensive devices (Users)".

Paul Hayden also stated that "a change to SSB Linear mode is only a change in Bias Voltage. SSB is low level modulation so the SSB and any VFT Mux modulation is done in the driving stage.

A clue to the SSB mode is in the Tube (Valve) List at the end of the Specification page 7 (4 tubes type 2X2/ 879) listed as SSB Input monitor and SSB Plate Monitor. So Power Output would be adjusted by means of linearity monitors on the input and output of the amplifier. The tube 879 is a high vacuum rectifier. (http://www.wikiwand.com/en/List_of_vacuum_tubes).

A Linear amplifier should faithfully amplify the input so if you rectify a sample of the input signal RF Drive as a reference and rectify a small sample of the Amplifier output signal they can be compared on a DC meter, to easily find the overload point. The meter would indicate when the two samples are no longer identical showing the onset of Non Linearity and Distortion.

So the high powered amplifier at Hemmant was designed to run as a SSB Linear Amplifier even if the document says Class C. It only takes a simple adjustment of bias to linearize the output stage. The challenge is finding the right balance, power output versus the Tube Standing Current (lq). The higher the quiescent or standing current (Iq) the more linear the amp, the cleaner the signal, but the lower the efficiency, higher tube temperatures and the shorter the final tube life".

The following photograph shows how large and complex a US Army Signal Corps 40kW transmitter was in World War 2. It was water cooled to maintain the life of components. It was manufactured by Press Wireless (USA) and the exciter driving the amplifier was made by Western Electric (USA). This is the arrangement of equipment that is referred to in Section 6 of this document.

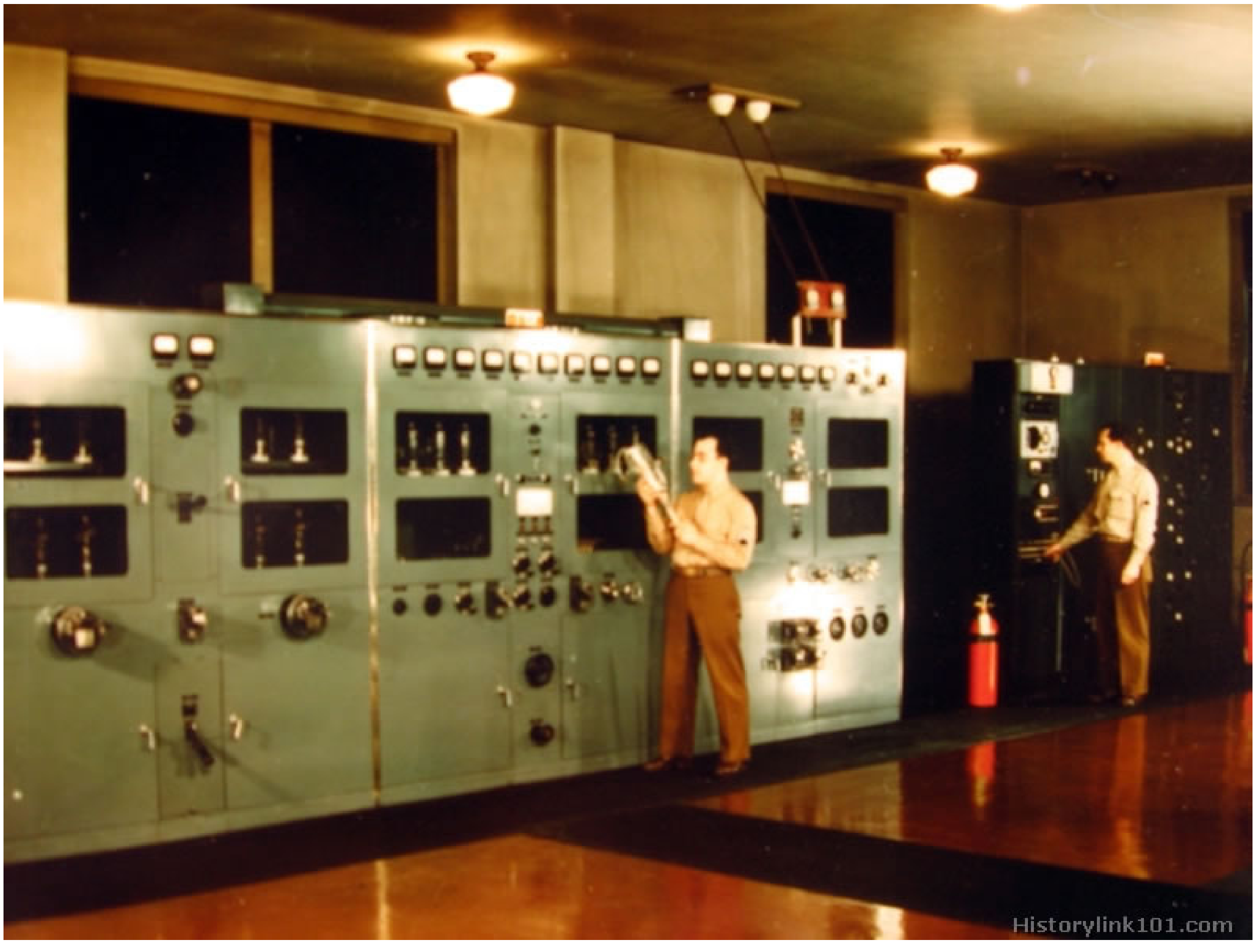


Fig. 20: Example of a USA Press SSB 40 Kilowatt Transmitter and Western Electric SSB Exciter (http://historylink101.com/ww2_color/WorldWarIICommunication/IMG_3107.html)

This example of Signal Sideband transmission from the Signal Center, Pentagon Building, Washington DC. Transmitter Room shows a Press Wireless 40kW transmitter in the foreground, which is driven by the Western Electric 15D-6000 Single Sideband exciter on the right. In this way, more than one teletype circuit can be handled simultaneously on just one transmitter. Here the S/Sgt. holds a water-cooled type 233 transmitter tube which is the same as used in the 40kW amplifier, while the M/Sgt. makes a distortion test on the Western Electric transmitter. (August 1946).

US War Department Technical Manual (1944b) TM 11-487 (p. 443), records that the" PW40 40kw amplifier consisted of five units- rectifier, exciter, power amplifier, water cooling unit and expansion tank. Telegraph, teletype or single sideband operation; local start-stop remote keying; manual selection of master oscillator, one of six crystals or external exciter; external exciter for teletype operation required. May also be arranged to operate as a linear amplifier for single sideband operation requiring a W.E.Co. D-156000 transmitter as an exciter and Rhombic antennas. Frequency coverage is 4.0 Mc to 21 Mc.. Power required was 94kVA at 220 volts 60 cycles. Shipping weight 41.6 tons. Extracts from USA War Department Technical Manual TM 11-487, Electrical Communication Systems Equipment, 2 October 1944, are given in Appendix 12.

A similar amplifier produced by TEC was also used extensively by the US Navy during the war and used two water cooled GL880, possibly RCA brand, power amplifier tubes. (Bureau of Ships, April 1946, page T-124). (https://maritime.org/doc/ecat/cat-1214.htm).

A data sheet of the Press amplifier Tube 233 was not found but the following 233B is similar :-

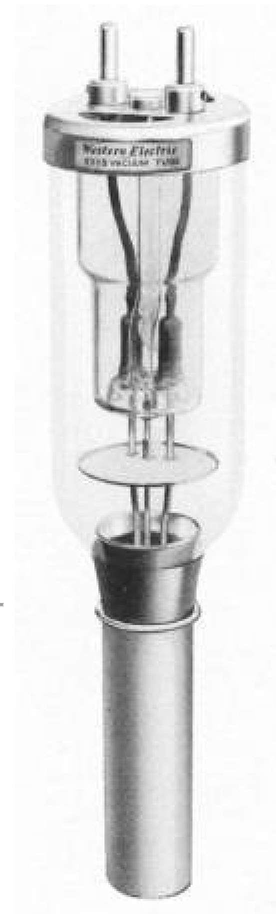
---

Country: United States of America (USA)	Brand: Common type USA tube/semicond. Tube type: Half-Wave Vacuum Rectifier Power-supply	
Identical to	**233B**	
Similar Tubes	Other shape (e.g. bulb type): 233A	
Predecessor Tubes	232B	

Filament Vf 21.5 Volts / If 41 Ampere / Direct/

Description Half-wave power rectifier; gridless 232B, thoriated tungsten filament with reduced current drain. 20KV, 2A. Enlarged glass section.
Machlett and WE.

Literature Tube Lore, Sibley, USA 1996 (restricted use)



233B: Manufacturer's Literature
Emilio Ciardiello

Fig. 21: Tube Type 233B.
(http://www.westernelectric.com/spec_sheets/233B.pdf).

This site gives details of the Western Electric 233B Vacuum Tube August 1941.
It is a replacement for the 233A

Appendix 6 - A BUCKEYE DIESEL GENERATOR, USA

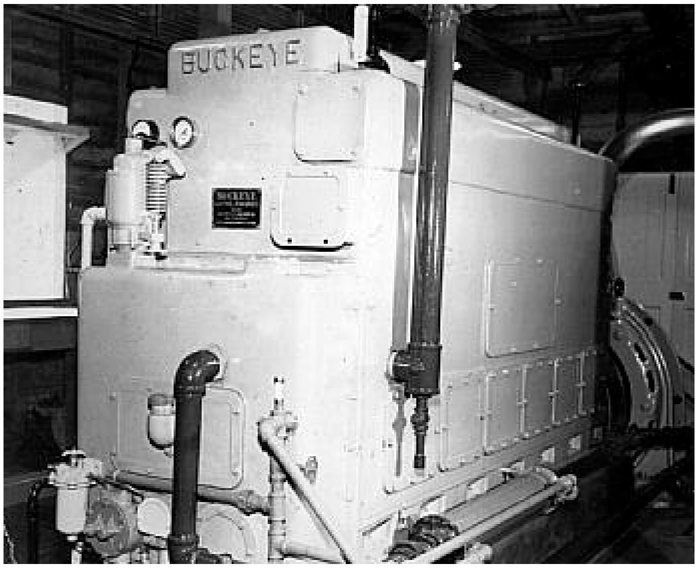


Fig. 22: Buckeye Diesel Generator, USA. (http://aboutww2.com/images/).

Lionel Sharp advised that a Buckeye 250 kVA diesel standby generator made in Lima, Ohio, USA, was installed some time before the end of the war at Hemmant. The generator he knew was water cooled and had a large radiator. It was manually started by discharging compressed air from a large compressed air bottle about six feet tall. The bottle was charged up by a small compressor powered by a small petrol four stroke engine. An external fuel tank was mounted on the ground at the southern end of the engine room. The generator was run for about an hour each month for maintenance purposes and had exposed rocker arms on the top of the engine that had to be oiled by hand with an oil can. This is a very large engine by any means and would have run the 40kW SSB transmitter and associated equipment. The transmitter required 94kVA at 220 volts, 60 cycles. (US War Department, (1944b, p.443).

Paul Hayden also advised that the standby plant he saw after the war was a Blackstone diesel, about 60kVA and 60Hz used by the USA. It was tried running at 50Hz and it was useless, outside its power band, hopeless regulation and blew lots of black smoke! It would never have run a 40 Kilowatt water cooled transmitter of World War 2 vintage as the unit had a typical efficiency overall of about 20% if you were lucky. This 60Hz generator was clearly of USA origin and from the war.

Appendix 7 - NOTES ON DESIGN OF A WW2 RADIO COMMUNICATIONS SYSTEM by Paul Hayden 2016

"You start off with a single channel teletype running 60 words per minute and producing a pulsing Direct Current (DC) to line. (A mechanical morse code like system). You need a cable to send it to its destination. You can't send DC over a radio circuit designed for voice.

To make it compatible you have to convert the Marks and Spaces into Audio tones (FSK) and an 850Hz shift between the Mark and the Space frequency is a good starting point.

You feed the FSK audio into a radio transmitter receiver system designed to carry one voice circuit 200Hz to 3kHz. (simple, stable, not very efficient, but very reliable)

To keep everyone happy you set standard frequencies for Mark and Space and ensure that the European standard is different to the USA standard. This will ensure that they can't talk to each other, Standards are a wonderful thing.

A single teletype signal 850Hz wide is a poor use of the available spectrum, using less than one third of the available audio circuit bandwidth, so we resort to a wonderful new (1870) invention called Multiplexing, (or how to put three teletypes on one circuit all at once). In telecommunications Muxing allows you to share an expensive process (Bandwidth) between a number of less expensive devices (Users).

A simple version of Muxing is Frequency Division Multiplexing. With FDM you divide the Voice circuit into three bands, and allocate each teletype machine one third of the voice circuit bandwidth to use independently of the other users. (Tp1, 200Hz up to 1200Hz, Tp2, 1200Hz up to say 2 kHz and Tp3, 2kHz up to 3kHz). You can simplify the design of the required filters by reducing the frequency shift to say 170Hz which allows lots of space between each channel (reduced interference) and reduced bandwidth (allowing more channels). This system is known as Voice Frequency Telegraph or VFT. (they leave out the big word multiplexing, its too technical).

With better filters (more expensive) you can run up to six or even eight 170Hz shift circuits in a single voice circuit bandwidth. (Remember you must have a guard band between each teletype channel so they don't interfere with each other).

You can transmit VFT signals with an AM radio circuit, and with identical information in both upper and lower sidebands you have the possibility of dual diversity. (If one sideband has interference you can use the other).

There is another problem. As you increase the number of data channels it increases the number of sidebands in the voice bandwidth. Unlike Voice with its low average and high peak power ratio, the VFT signals are in effect six constant amplitude sidebands each side of the RF Carrier. Even though they are each FSK signals on their own frequency the fact they are Alternating Voltages means that at some time they will all add together so if each one was 1 volt peak the RF power amplifier must be able to handle the sum or +12 volts or -12 volts without distorting, so you have to de-rate your PA to handle this much higher than average, high peak power requirement. (This is why the same power amplifier can have different ratings say 25kW for six channel VFT service or 20kW for eight channel VFT or a 40kW PEP for Voice).

Unlike a voice transmitter where the average modulation % might be 45% with peaks to 100% a VFT signal is 100% modulation all of the time, so it must be designed for high continuous power. With teletypes idling with no traffic you run reversals, RYRYRYRYRYRYRYRY, to keep the channel active and monitor it in case a frequency change is needed due to propagation changes.

You can go one step further in the process and improve the Data throughput of the RF circuit by using independent sideband (ISB) transmission techniques. As the upper and lower sidebands are normally identical in what they carry, one is redundant, so the next step is independent sidebands with say VFTs on one sideband and a Voice circuit on the other sideband.

The RF carrier is reduced to say -20dB, (1% but not suppressed). This is to provide a pilot tone, a reference signal to lock to, so you can regenerate the exact carrier frequency to demodulate the two sidebands without any frequency errors.

This is the sort of system which fits with the type of equipment I suspect was at Hemmant with the Type AN/FGC-1 teletype and the description of a two channel SSB radio transmitter with independent sideband (ISB), giving possibly 5 VFT teletype circuits on one and Voice or Fax on the other. Many channel (16) VFTs are restricted to wire line circuits or VHF Radio, where wide bandwidths are available.

To ensure equally good performance in VFTs it is important that all circuits have equal performance. This is obtained by the use of band equalisation filters and pads to ensure that all VFT signals are of equal amplitude over the bandwidth of the audio circuit.

Basically multiplexing allows you to share the available RF circuit audio bandwidth over a number of services as suits your requirements. Filters with a fast cut-off introduce Phase Distortions unless they are corrected for group delay so the narrow band filters come at increased cost.

Digital Computer techniques have reached the stage where for example a Digital TV signal has 8,000 individual carriers and each one carries its own multiplexed data stream”.

Appendix 8 - NOTES ON DIVERSITY RECEPTION AND TRANSMISSION

One of the chief antenna designers for RCA, Edmund A. Laport, first published "Radio Antenna Engineering" in 1952. This book is an excellent source of information and is now freely available for perusal on the internet (http://snulbug.mtview.ca.us/books/RadioAntennaEngineering/) and other sites. Also the USA ARRL Antenna Book (23rd Softcover Edition) is recommended. Visit the shop for full details (http://www.arrl.org/home).

In general, High Frequency reception and transmission relies on the ionosphere to propagate signals. It consists of layers of electrons at varying heights and thickness. The virtual heights of the layers vary with latitude, hours of the day, the seasons and sunspot activity. A signal may make a number of reflections, "hops", before it reaches its destination. Total attenuation over a path is the total of solar absorption, ionospheric reflections, earth reflections, and attenuation due to the expansion of the wave front as distance increases.

According to Fette (2008), there are a variety of diversity technologies. Three of these are:-

Space Diversity reception requires more than one receiver and more than one antenna several wavelengths apart. The aim is to reduce errors due to propagation, multiple hop paths and conditions. When using space diversity broader antenna horizontal patterns can be achieved by turning one antenna slightly with respect to the other. The antennas should also utilize the optimum vertical angles. Stable operation requires the use of a frequency below the maximum usable frequency eg 10%.

Frequency Diversity involves transmitting on separate frequencies. The longer the path the smaller the frequency difference needed. **Polarization Diversity** is when the antennas are differently polarized. (Fette, 2008, pp. 87-88). It is used on HF and VHF non line of sight paths, but only rarely.

The meaning of the various diversity systems noted in this document can be summarised as follows:-

- Dual Diversity and Parallel diversity mean the same thing with two signal sources being used.
- Space Diversity indicates a single transmit or receive frequency using a number of antennas at the same time.
- Frequency Diversity means that two transmitters are used at the same time but on different frequencies.
- Double Modulation means using multiplexed signals on the one transmitter, like independent sidebands.
- Polarization Diversity is when the antennas are differently polarized in the vertical or horizontal planes.

A description of the method as regards teletype reception is given on page 222 and 223 of Thompson et.al. (1957). George Sullivan (n.d., pp 1-14) included a history of the 832nd Signal service Company from 1 May, 1942 to 31 December 1942. Major M.K.Wilkins (in Sullivan n.d.) recorded that " In July 1943, double modulation diversity equipment was provided for the Brisbane-San Francisco system that permitted six radio-teletype channels to be operated on a frequency diversity basis, as compared to the original three channels which operated on a different diversity principle (parallel diversity)". (Sullivan n.d.p.16) also at https://www.scribd.com/document/337215466/Things-We-Save-by-George-Sullivan)

Appendix 9 - TIMELINE

7 December 1941	Japanese bomb US base at "Pearl Harbor" in Hawaii. WW2 in the Pacific commences.
22 December 1941	First USA convoy reaches Brisbane - 36th Signal Platoon.
January 1942	US Navy issues formal decrypts of Japanese coded messages.
24 January 1942	Somerville House boarding school for girls in South Brisbane visited by military authorities with a view to taking it over.
1 February 1942	Somerville House School commandeered by Australian military.
19 February 1942	First bombing of Darwin by 242 planes with 292 killed then. Total of 63 raids.
February 1942	The 52nd Signal Service Battalion of the US Army arrives in Melbourne, Australia.
3 March 1942	Bombing of Broome. 88 killed. Wyndham also bombed.
10 March 1942	Manual Morse Code (CW) radio circuit established by US Army Signals Corps to Fort Shafter, WTJ, Hawaii from Melbourne RAAF Station. Used till May 1942 in this role.
15 March 1942	Somerville House becomes USA Base Section 3.
21 March 1942	General Douglas MacArthur arrives in Melbourne from the Philippines where his forces had been defeated by the Japanese, via Darwin and Adelaide.
Mid March 1942	A group comprising an Officer and 19 enlisted men from the USA 52nd Signal Service Battalion start to set up the Army Command and Administrative Network (ACAN)
April 1942	Signal Office at Somerville House opened circuit between Brisbane and Melbourne, then Darwin.
18 April 1942	General MacArthur appointed Commander-in-Chief of the Allied Forces in the Southwest Pacific.
2 May 1942	Last entry in visitors book at Redland Bay Golf Course, then taken over by the military.
4 to 8 May 1942	Battle of the Coral Sea. Japanese on way to Port Moresby by sea turned back.
8 May 1942	The Philippines surrenders to the Japanese.
4 to 7 June 1942	Battle of Midway, four Japanese aircraft carriers sunk preventing any further attempt to invade Port Moresby from the ocean.

18 June 1942	Arrival of USA Fixed Station Communication Company, 125 Officers and men. Some stayed in Brisbane.
July 1942	Training on the installation, operation and maintenance of SSB systems commenced in New York, USA.
July 1942	Signal Office at Somerville House opened circuit between Brisbane and Darwin.
21 July 1942	General MacArthur moves headquarters to Brisbane's AMP Building.
Latter part of 1942	Signal Corps SSB specialists arrive to install the Brisbane Terminal of the Brisbane - San Francisco system.
February 1943	High powered multi-channel Single Sideband (SSB) radio transmitting station established at Hemmant using a "Press" 40 Kilowatt amplifier with Western Electric Co. Exciter module.
10 March 1943	Brisbane SSB ACAN station placed in operation able to reach San Francisco directly. Major M.K. Wilkins, 21 June 1945
July 1943	In July 1943, double modulation diversity equipment was provided for the Brisbane-San Francisco system that permitted six radio-teletype channels to be operated on a frequency diversity basis, as compared to the original three channels which operated on a different diversity principle (parallel diversity).
1 November 1943	Highly classified "Sigsaly" or "Green Hornet" telephone voice scrambling circuit built by Bell Laboratories in the USA set up in MacArthur's headquarters in the AMP building, Brisbane.
December 1944	Somerville House evacuated by US Army forces.
Mid-1945	High powered 40kW High Frequency amplifier at Hemmant arrives in Manila along with "Sigsaly". Some radio equipment remained in Brisbane.
15 August 1945	End of World War 2 in the Pacific
20 August 1948	Land at Capalaba (Birkdale) Radio Receiving Station taken over by the Commonwealth Government.
2015	Call for submissions by Redland City Council on future uses of the land. Original freehold cottage "The Pines" established on a small area of land later purchased by the Council for heritage purposes.
2017	Planned disposal by the Commonwealth Government's Australian Communication and Media Authority (ACMA) of the WW2 Capalaba, now Birkdale, Radio Receiving site. The Hemmant Radio Site was sold quite some years ago. (Date unknown).

Appendix 10 -USA WAR DEPARTMENT TECHNICAL MANUAL TM 11-2204 DUAL DIVERSITY RECEIVING EQUIPMENT (WLCOX TYPE CW3-D) 28 DECEMBER 1944

Photocopy Source: USA Library of Congress.

See pages 64-99

U.S. WAR DEPARTMENT TECHNICAL MANUAL

TM 11-2204

DUAL DIVERSITY RECEIVING EQUIPMENT (WILCOX TYPE CW3-D)

WAR DEPARTMENT 28 DECEMBER 1944

RESTRICTED. *DISSEMINATION OF RESTRICTED MATTER.* The information contained in restricted documents and the essential characteristics of restricted material may be given to any person known to be in the service of the United States and to persons of undoubted loyalty and discretion who are cooperating in Government work, but will not be communicated to the public or to the press except by authorized military public relations agencies. (See also Par. 23b, AR 380-5, 15 Mar 1944.)

I.

WAR DEPARTMENT,
WASHINGTON 25, D. C., 28 DECEMBER 1944.

TM 11-2204, War Department Technical Manual, Dual Diversity Receiving Equipment (Wilcox Type CW3-D), is published for the information and guidance of all concerned.

[A.G. 300.7 (28 Feb 44.)]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
J. A. ULIO,
Major General,
The Adjutant General.

DISTRIBUTION: "X"
(For explanation of symbols see FM 21-6.)

TABLE OF CONTENTS

Section I. Dual Diversity Receiving Equipment (Wilcox Type CW3-D). *Page*

[redacted]

LIST OF ILLUSTRATIONS

DESTRUCTION NOTICE

WHY —To prevent the enemy from using or salvaging this equipment for his benefit.

WHEN—When ordered by your commander.

HOW —1. Smash—Use sledges, axes, handaxes, pickaxes, hammers, crowbars, heavy tools.

2. Cut—Use axes, handaxes, machetes.

3. Burn—Use gasoline, kerosene, oil, flame throwers, incendiary grenades.

4. Explosives—Use firearms, grenades, TNT.

5. Disposal—Bury in slit trenches, fox holes, other holes. Throw in streams. Scatter.

USE ANYTHING IMMEDIATELY AVAILABLE FOR DESTRUCTION OF THIS EQUIPMENT

WHAT—1. Smash—All tubes, switches, coils, transformers, resistors, crystals, capacitors, terminal strips, jacks, and every other electrical or mechanical part.

2. Cut—All wiring, cables, etc.

3. Burn—All charts, diagrams, and technical manuals.

4. Bend—All panels, cabinets, covers, and other metal parts.

5. Bury or scatter—All that remains of the equipment.

DESTROY EVERYTHING

RESTRICTED

SECTION I
CW3-D RADIO RECEIVER

The Wilcox Electric Type CW3-D Radio Receiver is designed for use with Radio Teletype Terminal Equipment AN/FGC-1 (TM 11-356), to provide two identical fixed frequency diversity receivers with common high frequency and beat frequency oscillators.

GENERAL DESCRIPTION.

1. The CW3-D Receiver is a highly selective crystal controlled superheterodyne unit operative at any fixed frequency in the band 1900 KC to 24000 KC. The total band is covered by means of six groups of plug-in coils. Plug connections are provided for 110 volt, 60 cycle AC power. Each CW3-D Receiver requires about 1.3 amperes.

1.1. The receiver unit consists of three U shaped chassis attached to a standard 10½"x 19" relay rack panel. Ventilated removable side plates are placed on U shaped chassis. A dust cover is provided for covering all radio frequency coils and vacuum tubes. The overall depth of the unit is 11½".

1.2. Four CW3-D Receivers are mounted in a 115 A-D Type Cabinet which is a metal cabinet 72" high, 24" wide, and 17" deep. Access to units mounted in the cabinet is possible by means of a rear access door. An air filter box and blower unit is attached to the door. The antenna terminals are located at the top of the cabinet. The cabinet is wired to accept four CW3-D Radio Receivers and outputs of both halves of each receiver may be selected by a switch located on bottom panel of cabinet. The wiring of the cabinet is shown in Figure 7.

DESCRIPTION OF CIRCUITS.

2. The CW3-D Receiver is a diversity receiver consisting of two duplicate receivers A and B which are identical electrically but differ slightly in tube arrangement in that the diversity receiver has been constructed by the conversion of two non-diversity receivers. A HF oscillator and three choices of BFO are furnished and are common to both receivers. Two power supplies are also required due to method of conversion. In the following description corresponding references are given for receivers B and A. The lower receiver is designated A and the upper B.

2.11. The input plug-in Antenna Coil L1 (L10) provides coupling from transmission line to grid of V1 (V10) (fig. 10). The primary of L1 (L10) is a low impedance center tap winding electrostatically shielded from the secondary. The secondary is resonated by the capacitor C1 (C58), which covers the specified frequency range of the coil.

2.12. The radio frequency amplifier, V1 (V10), type 6K7 vacuum tube, operates between the antenna coil L1 (L10) and plate coil L2 (L11). The cathode of V1 (V10) is returned to a sensitivity control R1 (R37) which is also common to tube V3 (V12). The top of the sensitivity control also appears on terminal 1 of plugs P1 and P2 but this now serves no purpose during operation of receiver.

2.13. The plate circuit of V1 (V10) operates into the plate coil L2 (L11) which consists of a primary winding L2 (L11), resonated by capacitor C5 (C62), and a small secondary winding serves as a means of coupling to the grid coil L3 (L12). Link coupling between plate coil of the R. F. amplifier and the grid coil of mixer tube, results in a low impedance circuit which considerably improves image rejection.

2.14. The grid coil L3 (L12) operates into the mixer tube V2 (V11), type 6K8. The 6K8 is a triode-hexode type vacuum tube. The triode portion was previously used for an oscillator but since a separate oscillator is now provided this part of tube has no function and the plate of the triode has been connected to ground. The hexode portion of the tube is used as the mixer resulting in a difference frequency of 455 KC which is the frequency of the I-F stage.

2.15. The mixer tube V2 (V11), operates into the intermediate frequency amplifier which consists of one stage of selective amplification operating at a frequency of 455 kc. Two double tuned circuits coupled to form a band-pass filter are used as a coupling means between the mixer, the intermediate frequency amplifier and the detector. The intermediate frequency amplifier vacuum tube V3, (V12) type 6K7, operates between the band-pass filter or intermediate frequency transformer L4 (L13) and L5 (L14). The cathode of V3 (V12) is connected to the sensitivity control R1 (R37) in parallel with the cathode of V1 (V10). Each sensitivity control also has a switch associated with it which turns on and off the AC power for half of the receiver.

2.16. The detector is a modified plate detector using one triode section of the twin triode vacuum tube V4 (V14), type 6C8G. The second tuned circuit of the intermediate frequency amplifier L5 (L14) feeds directly into the detector. The resistor R12 (R54) in the cathode circuit produces bias to cause the tube to operate as a plate circuit detector. Capacitor C22 (C89) bypasses the radio frequency from the plate circuit. A resistor R10 (R47) in the grid return acts as a limiter when excessively high voltages appear at the detector circuit. The beat frequency oscillator is injected into the detector at the top of resistance R10 (R47). The magnitude of the injection voltage is about one volt. The output of the detector is resistor-capacity coupled to the audio amplifier.

2.17. The audio amplifier consists of one section of the twin triode vacuum tube V5 (V14). It will be noted that different tube locations are used in the top and bottom receivers. The reason for this is that it was desirable on the lower receiver to have the BFO as far away as possible from the I-F stages to reduce spurious pick up of BFO input of receiver.

The audio triode section operates between the resistance capacity network R15 (R53), C34 (C94) and output transformer T1 (T3). A small amount of voltage feedback R17 (R57) and C35 (C93) is connected to the audio tube to reduce the output impedance, as seen looking into the output, to about 600 ohms. Capacitor C38 (C92) is connected across the output transformer to prevent oscillation at high audio frequencies and to attenuate harmonics. Due to fact that outputs of both receivers are connected to the frequency indicator in AN/FGC-I equipment it is necessary to have outputs of two receivers poled alike. This may be checked by connecting one antenna to both receivers and noting which poling gives greater output when outputs are connected in parallel.

2.18. Automatic volume control is accomplished by coupling the audio tone through capacitor C37 (C95) to one section of vacuum tube V7. This tube, a twin triode type 6SN7, is located in the upper receiver. Half of the tube is used to provide AVC for the upper and half for the lower receiver. Referring to the upper receiver the audio tone is impressed on grid 1 (4) of the tube which is at a negative potential with respect to its cathode due to the voltage drop through the volume control R22 (R61) which is connected in series with the negative side of the plate rectifier. The plate of the tube is at ground potential but since the cathode is —100 volts, the tube acts as a plate detector and generates a negative voltage at its plate with respect to ground. This negative voltage is fed through the network consisting of C45 (C46), R24 (R28), and C44 (C47) which has a large enough time constant to provide suitable AVC action. It is desirable to have C44 (C47) fairly large which will act as a tank circuit so that a single large static hit will not depress the gain unduly. The negative voltage is applied to the grid of the 6K7 tubes V1 (V10) and V3 (V12) through suitable filtering networks R2 (R38), C2 (C59), and R7 (R43), C11 (C70).

The AVC action is such that the output is held within 4 db over a large range of input voltages. Variations in output larger than this will be experienced in operation due to the period of fading of the receiver signals and will vary from many db below normal to about 8 or 10 db above normal. These variations are corrected by the limiter associated with the telegraph equipment and the function of the AVC circuit is to prevent excessive levels which would overload the receiver and produce harmonics.

2.19. The volume adjustment controls the bias on the AVC tube V7 by changing the grid bias. The greater the bias the greater the output signal required to give a given amount of negative AVC voltage.

2.2. Features Which Are Common to Both Receivers

High Frequency Oscillator

2.21. The high frequency crystal oscillator consists of vacuum tube V8, type 6HC7. The high frequency crystal is connected between screen (anode) and control grid which is connected to ground through resistance R29. The oscillator so formed is electron-coupled to the plate circuit which has a main load impedance consisting of plug-in coil L8. The coil L8 is the same type coil as used for L2 (L11) and is tuned for the harmonic frequency desired. The output of the high frequency oscillator is coupled through capacitor C51 (C48) to the mixer tube V2 (V11).

2.22. The frequency of the high frequency oscillator can be varied plus or minus .01% by an adjustment on front of the panel which changes the air gap of the crystal.

Beat Frequency Oscillators.

2.23. Three arrangements of BFO are furnished as follows:

1. Crystal-controlled Oscillator.
2. Self-excited Oscillator.
   a. Automatic frequency control.
   b. Manual control.

2.24. The crystal controlled BFO is situated in the top receiver and uses half of the twin-triode V4. The plate resonant circuit consists of L6 and associated capacitors. R14 and C33 serve no useful function, being provided initially as a grid leak capacitor and resistance for the use of a triode oscillator. The crystal frequency used is 452.45 kc, which results in a nominal average audio frequency of 2550 cycles which is desired when the receiver is used with Radio Teletype Terminal Equipment AN/FGC-1.

2.25. Automatic frequency control is obtained by the combination of triode oscillator V13 and reactance tube V9.

2.26. The self-excited oscillator consists of one-half of the twin- triode V13, type 6C8 and inductance L15 with its associated capacitors. Capacitors C86 and C87 perform no useful function, having been disconnected when the oscillator was modified for AFC. The output of the triode oscillator is connected to the other half of the same tube which is used as a buffer amplifier. This is desirable so that any voltages from strong signals fed back from injection point will not affect frequency of the oscillator. In particular a condition might arise where a strong signal would change the frequency enough to give a zero audio beat which would disable the AVC circuit and hence cause lock-up.

2.27. The reactance tube V9 type 6SA7 presents an adjustable impedance which may be lowered by either increasing the feed-back by increasing R32, or by making grid 3 (terminal 8) more positive. Similarly decreasing R32 or making grid 3 more negative will increase the impedance from plate to ground. This impedance is connected across the tuned circuit of the triode oscillator and is such that when the impedance is lowered the frequency of the oscillator is decreased. For automatic tuning the AFC lead grid 3 (terminal 8) is connected to a discrimator and detector associated with the AN/FGC-1 equipment which generates positive voltage when the audio frequency is less than 2125 cycles and negative voltage when the frequency is greater than 2125 cycles. The sensitivity of the AFC tube is in the order of 2000 cycles per volt and the sensitivity of the discrimator and detector about 1 volt per 40 cycles, hence fairly accurate automatic tuning is effected.

For manual tuning the AFC grid of the reactance tube is connected to a fixed voltage and manual adjustment effected by changing the feed-back voltage by adjustment of R32. The plate and screen supply for the oscillator and reactance tube is obtained from both power supplies through resistors R63 and R64 and is regulated by the voltage regulator tube V16. For ARC or manual BFO, V16 should be a VR 105-30 tube. However, if difficulty is experienced in starting the crystal BFO, use a VR-150-30 tube.

PERFORMANCE.

3.11. The sensitivity of the receiver varies with frequency and with the groups of plug-in coils. Over the complete range the receiver varies at the lowest frequency from a sensitivity of less than 1 microvolt to a sensitivity of less than 10 microvolts for plus 8 dbm output 30%, 400 cycle modulation.

3.12. The selectivity of the receiver is determined, primarily, by the intermediate frequency amplifier. The average selectivity is as follows:

Times Down	db	Total Band Widths
2	6	4 kc
3.16	10	4.6 kc
10	20	6 kc
100	40	12 kc
1000	60	20 kc
10000	80	33 kc

3.13. The image response of the receiver as well as all other undesired responses is at least 75 db down from desired signal for all but the upper bands. On the upper bands it is expected that the image response will be at about 70 db.

3.14. The signal to noise ratio of the receiver, referred to a 400 cycle, 30% modulated carrier (BFO off), is at least three to one. Since additional selectivity is furnished by the filters in the AN/FGC-1 equipment and since an unamplitude — modulated carrier and BFO are used the amount of noise affecting telegraph signals will be correspondingly less than indicated above.

3.15. The measured AFC characteristics for a sample receiver are listed in table A.

TABLE A

Volts	Frequency Deviation From Zero Volts VR-105-30 R32=2000	R32=0
+22	—4600	—2850
+10	—4350	—2600
+ 4	—3850	—2350
+ 3	—3700	—2200
+ 2	—3500	—2100
+ 1	—2350	—1200
0	0	0
— 1	2500	1300
— 2	3950	2150
— 3	4400	2450
— 4	4650	2650
—10	5400	2900
—22	5650	3150

Manual Range, Zero Volts 2500.

3.16. The measured stability of the manual oscillator alone is not more than a few cycles change for a 20 volt change in AC supply voltage.

3.17. However the reactance tube is somewhat more sensitive to voltage changes as shown in table B.

TABLE B

Stability of Manual Oscillator........R-32=1000

V-16	AFC Voltage	Frequency Change for 20 Volt Change in AC	Cycles Per Volt
VR-105	0	80	4
VR-105	— 3	40	2
VR105	—22	2 or 3	....

For AFC operation these characteristics are satisfactory; also it is believed that they are satisfactory for manual operation where the power supply is stable or the period of manual operation is short.

3.18. For continuous manual operation it will be desirable to bias the AFC grid by about —3 volts which can easily be done by connecting a battery across terminals in 115 A-D type cabinet. This will result in suitable stability and still give manual adjustment from front of panel.

INSTALLATION.

4. Installation and operating procedure when the CW3-D Radio Receiver is associated with AN/FGC-1 telegraph equipment are covered in Section II.

CONTROLS ON FRONT PANEL.

5. The following controls are available on front panel:

Common to Receivers A & B	Receiver A	Receiver B
HFO Crystal Adjustment	Sensitivity*	Sensitivity*
BFO Switch (OFF-CO-AFC-MAN)	Adjust Output	Adjust Output

Frequency of Man. BFO | Phone Jack | Phone Jack

*AC OFF switch also associated with these controls.

TUNING PROCEDURE.

6.1. The CW3-D Radio Receiver as received from the manufacturer has been completely tested and tuned. The only normal adjustment which should have to be made is to tune the antenna coil, the plate and the grid coil.

6.2. The proper coils and crystals should be plugged into the receiver. A signal generator capable of producing the desired frequency is used to adjust the receiver. Adjustments may be most easily made with a signal generator that contains internal 30%, 400 cycle modulator. With a generator of this type, the BFO control is turned off. The generator is coupled to the grid of V1 (V10) after first removing the grid lead from L1 (L10). AVC tube V7 is removed. The generator is set to the desired frequency and the output adjusted to a maximum.

6.3. The grid coil L3 (L12) is tuned by means of the slotted capacitor shaft appearing in the top of the coil, until the 400 cycle modulated frequency is noted in the output of the receiver. This circuit is tuned to produce a maximum output at the output of the receiver. In order to prevent overloading of the receiver it is recommended that an output meter or AC voltmeter be placed across the receiver output circuit. The receiver output should then be kept below 1.73 volts or plus 8 dbm output by re-adjusting the signal generator output as the various circuits are adjusted.

6.4. After peaking the grid coil, L3, the plate coil, L2 (L11), is adjusted by means of the slotted capacitor shaft appearing in the top of the coil. The capacitor is rotated until a maximum signal is noted in the output of the receiver. Care is again taken to reduce the signal generator output to prevent an overloading condition by keeping the output of the receiver below plus 8 dbm.

6.5. The signal generator is then removed from the grid of V1 (V10) and placed across the antenna transmission line circuit after removing the transmission line from the receiver input. The grid cap from L1 (L10) is replaced on V1 (V10). The antenna coil, L1 (L10) is then adjusted by means of the slotted capacitor shaft appearing at the top of the shield can, until a maximum output is noted at the receiver, again being careful to keep the signal generator input reduced so as not to produce an overloading condition.

6.6. After these adjustments are made it is necessary to recheck the tuning of L3 (L12) and L2 (L10). It is suggested that several repetitions of these adjustments be made. The signal generator is then removed from the antenna circuit and the transmission lines connected. L1 (L10) may require a slight re-adjustment because of the difference of impedance between the signal generator and the transmission line. This adjustment may be made when monitoring the distant station or by using the signal generator in the field with an antenna as a signal source. Replace AVC tube V7.

6.7. If for some reason it is necessary to completely retune the receiver the procedure should be as follows:

6.71. A modulated frequency of 455 kilocycles should be applied to the grid of the intermediate frequency amplifier tube V3 (V12). A headset or output indicator should be provided to give aural or visual indication. The output of the signal generator should be adjusted to give maximum output but observing the conditions concerning overloading. The BFO must be off. If a modulated signal is not available the crystal BFO may be left on and the 2550 cycle output tone may be used as an indicator or the crystal BFO may be left off and tube noise may be used as a guide to tuning. The AVC tube V7 should be removed.

6.72. Capacitor C20 (C77) is then adjusted to produce a maximum aural output or meter deflection. Capacitor C17 (C74) is then adjusted to produce a maximum aural output or meter deflection. After adjusting C17 (C74) it is necessary to recheck the adjustment of C20 (C77).

6.73. Replacing the grid lead from L4 (L13) to V3 (V12), the signal generator is placed across the grid of V2 (V11) to ground after removing the grid lead from L3 (L12). Capacitors C9 (C66) and C13 (C69) are then adjusted in the same manner as C20 (C77) and C17 (C74).

6.74. The circuits of L3 (L12), L2 (L11), and L1 (L10) are then re-adjusted according to preceding.

6.75. With the signal generator connected to the antenna the crystal beat frequency oscillator is turned on and the signal generator internal modulation is turned off. With the beat frequency oscillator on it is necessary to make a slight re-adjustment of C20 (C77) to produce maximum output. It may also be desirable to readjust C49 associated with L8 and then to re-adjust L3 (L12).

Replace AVC tube V7 and check AVC action on both sides of receiver by changing input voltage over complete range.

MAINTENANCE.

7.1. Cleanliness. Ventilated dust covers are provided to cover the radio frequency coils and tubes of the receiver and to cover the chassis components. The receiver should be inspected at regular intervals. Dust and dirt collected at any point should be removed by a soft brush or blown out with a moderate compressor air jet. Care should be taken to see that leads are not disturbed as to location.

7.2. Tube Checks. The vacuum tubes should be checked at regular intervals. A standard type tube tester that will measure mutual conductance is recommended for determining tube condition. If no tube tester is available and the output is low the tubes in the receiver may be replaced one at a time noting the output to determine which tubes are in good condition. Each tube replaced will require retuning of the circuits between which the tube operates.

TROUBLE SHOOTING.

8. Following is a table giving socket voltages on a sample receiver which may be used as a guide and compared with similar tests on other receivers. Figure 3 is a sample test report which gives representative values of sensitivity, etc.

Figures 1 and 2 give coil data which may occasionally be of assistance in unusual conditions. This table is not a complete set of specifications and is included for general information only.

Experience indicates that a large percentage of troubles are due to simple causes, such as defective vacuum tubes, loose or broken wires, high resistance soldered joints, broken down or defective capacitors, etc. Adequate tools and testing apparatus will expedite the clearing of trouble. In addition to the usual tools such as soldering iron, long nose pliers, cutters, screw drivers, socket wrenches, etc., it is almost essential to have available a suitable tube tester and a voltohmmeter. A voltohmmeter which has a high resistance in the order of 10 megohms and will also measure AC voltages is advantageous.

A signal generator, cathode ray oscillograph, and radio frequency voltmeter are also of great value when these can be justified.

	ANTENNA RF INPUT L1 & L10	PLATE RF OUTPUT L2 & L11	GRID MIXER GRID L3 & L12
BAND 1	LT 76	LT 77	LT 78
BAND 2	LT 79	LT 80	LT 81
BAND 3	LT 82	LT 83	LT 84
BAND 4	LT 85	LT 86	LT 87
BAND 5	LT 88	LT 89	LT 90
BAND 6	LT 91	LT 92	LT 93

BAND 1 = 1.9 TO 3.6 M.C. BAND 4 = 9.4 TO 16.5 M.C.
BAND 2 = 3.4 TO 5.9 M.C. BAND 5 = 16.5 TO 20 M.C.
BAND 3 = 5.8 TO 9.4 M.C. BAND 6 = 20 TO 24 M.C.

BANDS OVERLAP EACH OTHER

Figure 1. Coil Data Chart No. 1.

Coil Band	Designation L	Dia. Form	Primary Size Wire	Primary No Turns	Secondary Wire	Secondary No Turns	Inductance—MH P	Inductance—MH S	Inductance—MH M	Q	Distance Between Windings	Shield
1	1	5/8	#24DSC	9.5	15-44 Litz	100	2.1	61.5	.92	115–140	1/8	yes
1	2	5/8	15-44 Litz	100	24DSC	5	52.8	0.689	1.07	117–152	0	no
1	3	5/8	#24DSC	5	15-44 Litz	100	0.735	59.7	1.4	141–162	0	no
2	1	5/8	#24DSC	9.5	#26CEL	58	1.6	23	1.15	90–102	1/8	yes
2	2	5/8	#26CEL	48	#24DSC	2	18.52	0.219	0.57	100–115	3/32	no
2	3	5/8	#24DSC	2	#26CEL	58	0.21	23.6	0.4	104–117	3/32	no
3	1	5/8	#24DSC	9.5	#20DSC	35	1.62	7.9	0.4	138–149	1/16	yes
3	2	5/8	#20DSC	35	#24DSC	3.25	7.95	0.355	0.18	132–138	1/8	no
3	3	5/8	#24DSC	4.75	#20DSC	35	0.62	7.7	0.22	138–149	1/8	no
4	1	5/8	#24DSC	5.5	#16 En.	20	0.34	2.91	0.13	160	7/32	no
4	2	5/8	#16 En.	20	#24DSC	3.75	2.94	0.496	0.10	138–146	5/32	no
4	3	5/8	#24DSC	4	#16 En.	20	0.7	3.1	0.16	145–157	5/32	no
5	1	5/8	#24DSC	5.5	#16 En.	14	0.77	2.0	0.12	127–182	5/32	no
5	2	5/8	#24DSC	2.75	#16 En.	14	0.3	2.06	.035	100–185	11/32	no
5	3	5/8	#16 En.	14	#24DSC	2.75	2.09	0.32	.045	175–100	11/32	no

15-44 litz = 15 Strands No. 44
CEL = Celanese
DSC = Double Silk & Cotton
EN = Enameled

Figure 2. Coil Data Chart No. 2.

CW3-D RADIO RECEIVER

AC Volts—115
AC Frequency—60 cycles
All Controls maximum
V-16=VR 105

MEASURED VOLTAGES TO GROUND
TUBE SOCKET PIN NUMBER

TUBES	1	2	3	4	5	6	7	8	Cap.	Tube* Key	NOTES
V1 (V10) RF 6K7	0	0	225	135	6.3	....	6.1	6.3	AVC	S	
V2 (V11) Mixer 6K8	0	0	225	120	−20	0	6.1	0.7	0	S	
V3 (V12) IF 6K7	0	0	225	130	5.9	225	6.1	5.9	AVC	S	
V4 Det. Cry. Osc. 6C8	0	0	105	0	0	210	6.1	7.0	0	E	Switch in C. O. Position
V4 Det. Cry. Osc. 6C8	0	0	−1	0	0	210	6.1	7.0	0	E	Switch in AFC Position
V5 Audio 6C8	0	0	....	....	0	220	6.1	5.5	....	N	
V6 Rect. 80	265	265	....	....	....	....	....	....	....	....	
V7 AVC 6SN7	+115	0	095	−115	0	−80	6.1**	0	....	S	
V8 HF0 1852	0	0	0	−15	0	115	6.1**	230	....	....	
V9 React. 6SA7	0	0	0	0	0	0	6.1**	0	....	S	Switch in C. O. Position
V9 React. 6SA7	0	0	58	52	0	2.3	6.1**	0	....	S	Switch in Man. Position
V13 BFO 6C8	0	0	240	+6.0	−5.5	95	6.1**	0	0	N	Switch in Man. Position
V13 BFO 6C8	0	0	240	+6.0	0	0	6.1**	0	0	N	Switch in C. O. Position
V14 Det. Audio 6C8	0	0	240	5.6	0	215	6.1**	8.0	0	E	
V15	250	250	....	....	....	....	....	....	....	....	
V16	....	0	105	....	105	....	105	....	....	....	

*Top of receiver considered north.

**AC

SAMPLE

CW3-D TEST REPORT

A. C. VOLTAGE	115		RECEIVER FREQUENCY 12000 KC		
R. F. PLATE	225	VOLTS	SENS. FULL ON		
R. F. SCREEN	135	VOLTS	OUTPUT FULL ON		
I. F. PLATE	225	VOLTS	A.V.C. TUBE OUT		
I. F. SCREEN	130	VOLTS	A.F.C., 455 KC AT I. F. INPUT		
H. F. O. PLATE	230	VOLTS	1 VOLT	2100	
H. F. O. SCREEN	115	VOLTS	—1 VOLT	2300	

	"A"	"B"			
(1) SENS. I. F.	210	190	A.V.C. SET AT "O" (+ 8 dbm) LEVEL AT 50 M.V.		
(1) SENS. CONV.	250	230	5 MV	0	0
(2) SENS. R. F.	38	42	500 MV	0	0
(3) SENS.	1.8	2.2	5000 MV	2	2
NOISE RATIO	4:1	8:1	50000 MV	6	3
IMAGE RATIO	4000	4500	SHOULD HOLD WITHIN 5 db TO 5000 MV		

	CLEAR	CHECK TONE AT "O" LEVEL.
(4)	40 CYCLES	STABILITY
	V	CHECK BFO TRIMMERS FOR CENTER.
	2500	CHECK RANGE OF MANUAL BFO.
(5)	8db	CHECK LEAKAGE OF BFO CIRCUIT.

(1) SIGNAL GENERATOR CONNECTED TO MIXER TUBE GRID.

(2) SIGNAL GENERATOR CONNECTED TO R. F. GRID.

(3) SIGNAL GENERATOR CONNECTED TO ANTENNA TERMINAL.

(4) —3 VOLTS AFC LEAD, 20 VOLTS CHANGE IN AC VOLTS.

(5) GRID LEAD OF BUFFER REMOVED AND TUBE GRID GROUNDED.

NOTE: FIGURES ARE REPRESENTATIVE BUT SHOULD NOT BE USED AS LIMITS.

Figure 3. Sample CW3-D Test Report.

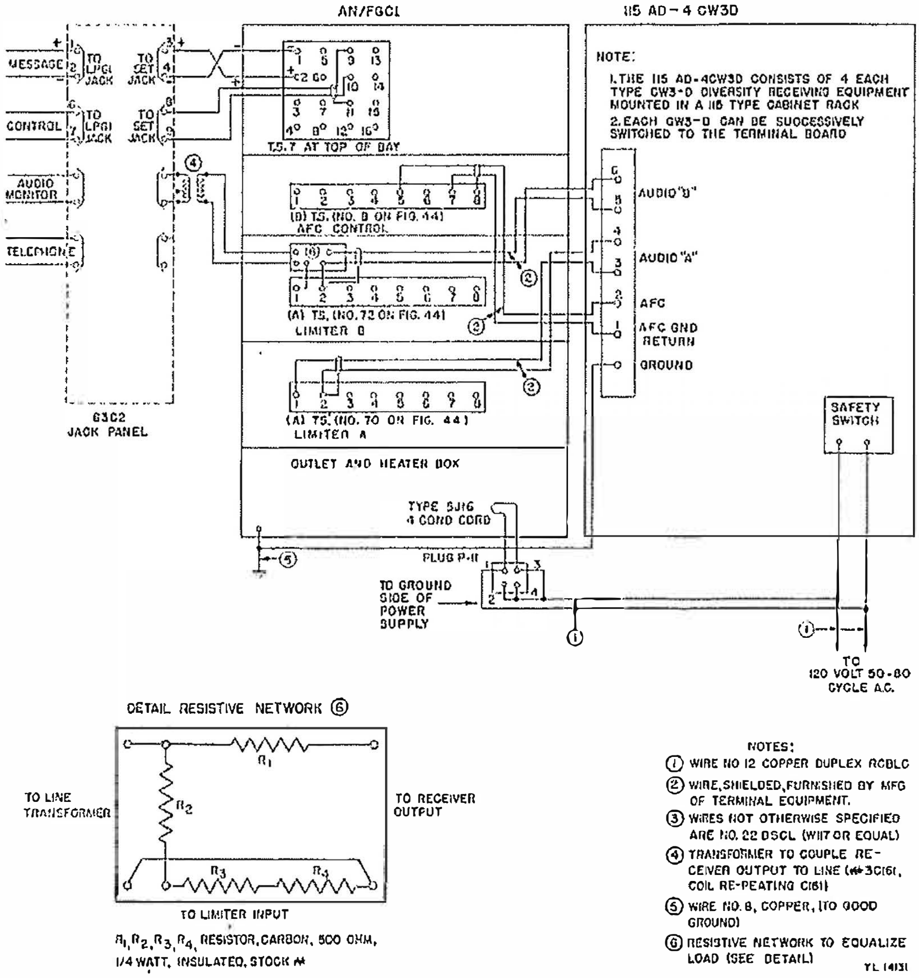
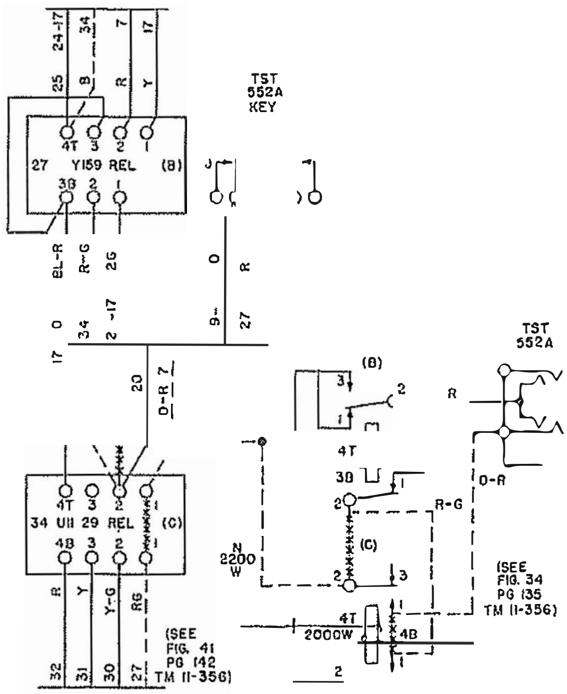


Figure 4. Block Diagram of Interconnected AN/FGC-1 and 115 AD-4 CW3-D.



MODIFICATION OF AN/FGC-1 TO PROVIDE FOR MONITOR LOCK UP CIRCUIT WHICH IS RELEASED UPON RECEIPT OF "MARK" SIGNAL FROM DISTANT TRANSMITTER. (REQUIRED ON SERIAL NUMBERS UP TO 400)

NOTES:

———— EXISTING WIRING – NO CHANGE

-XXXXXXX- EXISTING WIRING REMOVED OR RELOCATED

– – – – ADDITIONAL WIRING

1 REMOVE STRAPS BETWEEN #1 CONTACTS OF (C) RELAY

2 MOVE RG WIRE FROM TOP CONTACT #2 OF (C) RELAY TO BOTTOM CONTACT #1 OF (C) RELAY

RUN NEW LEAD FROM TOP CONTACT #1 OF (C) RELAY TO SPRING OF (TST) KEY

4 RUN NEW LEAD FROM TOP CONTACT #2 OF (C) RELAY TO TOP CONTACT #4 OF (B) RELAY IF SLATE WIRE IS NOT IN PLACE

TL 18333

Figure 5. Modification of AN/FGC-1 to Provide Monitor Lock-up Circuit.

SECTION II
USE OF CW3-D DIVERSITY RECEIVER WITH AN/FGC-1 RADIO TELETYPE TERMINAL EQUIPMENT

GENERAL.

This section covers the use of the Wilcox CW3-D Diversity Radio Receiver when used with the AN/FGC-1 Radio Teletype Terminal Equipment (TM 11-356) to make a complete Radio Teletype receiving terminal.

The Wilcox CW3-D receiver consists of two modified CW3 Radio Receivers both mounted on a 10½x19 inch panel, together with a suitable common high frequency oscillator, and beat-frequency oscillator. The resultant equipment is a dual channel receiver. Each channel is separately fed by a rhombic antenna. The antennas are spaced several wave-lengths apart, the recommended distance for optimum operation being about 1,000 feet. The two separate audio-frequency outputs are fed to a common source through the teletype terminal channel. Where conditions will not permit the use of a rhombic antenna, a double doublet can be used. For construction of the antennas, see TM 11-2611, Antenna Kit for Rhombic Receiving Antenna, Drawing ES-E-386-E, or Drawing ES-D-378-A, Antenna Equipment 2A299-GP-10, Horizontal Rhombic Receiving, and Drawing ES-D-276-C, Antenna Equipment 2A299-GP-9, Double Doublet Receiving.

The CW3-D receiver is a diversity receiver consisting of two duplicate receivers which are identical electrically, but differ slightly in tube arrangement. Two power supplies are also required, due to the method of conversion.

The CW3-D receiver is an adjustable crystal-controlled superheterodyne unit operative at any fixed frequency in the range of 1900 kc to 24,000 kc. The total range is covered by means of six groups of plug-in coils with overlapping bands as shown in figure 1. Plug connections are provided for 110-volt, 60-cycle a-c power. Each CW3-D receiver requires about 1.3 amperes.

The CW3-D receiver is designed for single-frequency operation, and to use several carrier frequencies, it is convenient to mount four CW3-D receivers in a metal cabinet, Type 115 A-D, 72″ high, 24″ wide, and 17″ deep. Access to units mounted in the cabinet is possible by means of a rear access door. An air filter box and blower unit is attached to the door. The antenna terminals are located at the top of the cabinet. The cabinet is wired to accept four CW3-D radio receivers, and outputs of both halves of each receiver may be selected by a switch located on the bottom front panel of the cabinet.

For the purpose of this section the following definitions are used:

CW3—Modified Wilcox CW3 Radio Receiver.

CW3-D—Two modified CW3 Receivers, plus conversion equipment, mounted on 10½″x19″ panel.

Radio Set—Four CW3-D Receivers mounted in 115 Type Cabinet.

Coil Set—Set of plug-in coils for one CW3 Receiver. For one CW3-D Receiver two sets of three coils, consisting of antenna (RF Input), plate (RF Output), and grid (mixer), are required, plus a high frequency oscillator harmonic selector coil which should be same type as RF Output coils.

Frequency Indicator—A device associated with the AN/FGC-1 equipment which measures the difference between the input audio frequency in the band from 1600-3600 cycles and the frequency of a local oscillator having a frequency of 2550 cycles. It is connected to channel A at the output of the limiter. A zero indication on the meter indicates a difference of 425 cycles.

Negative readings indicate a smaller difference and positive readings indicate a larger difference. Figure 6 shows the general characteristics of the Frequency Indicator. An alarm bell is also associated with the frequency indicator circuit.

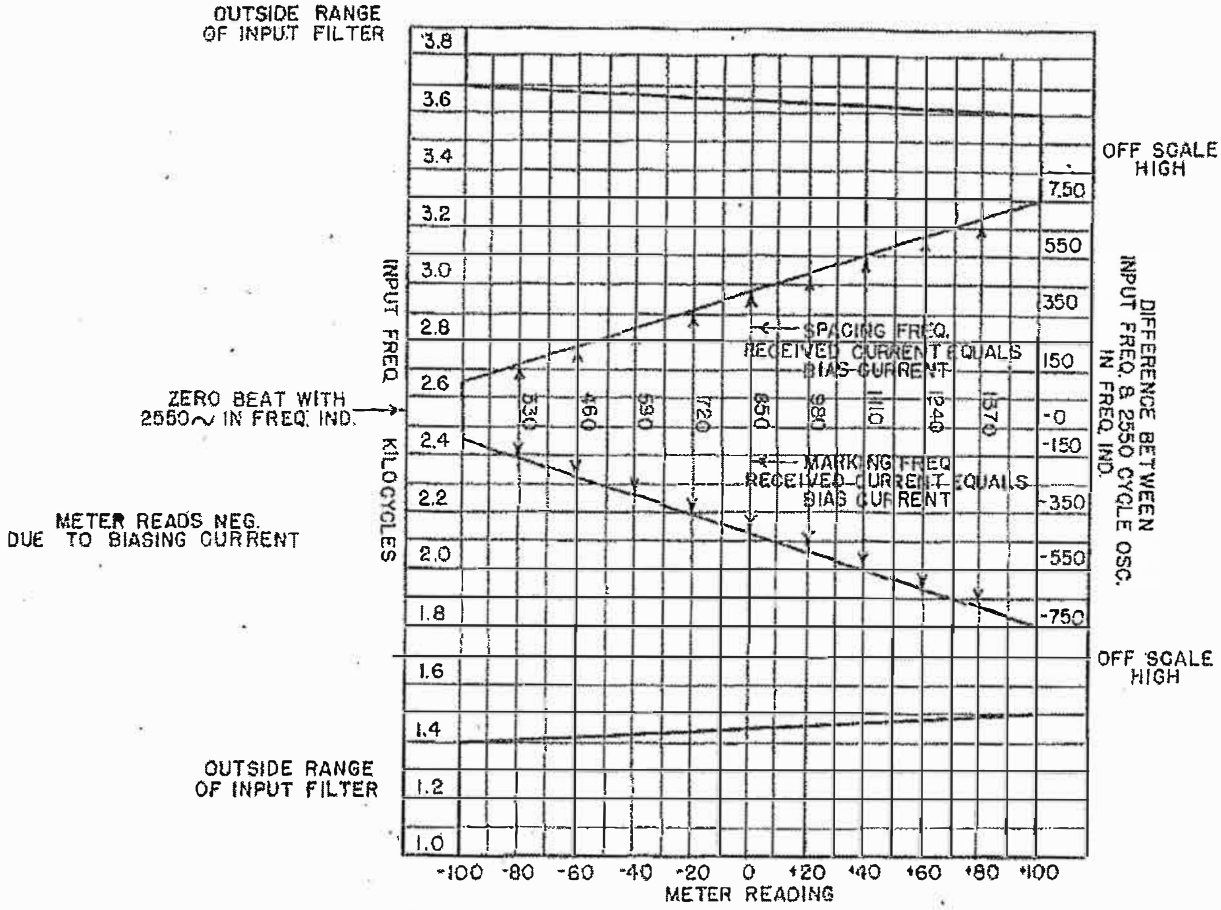


Figure 6. General Characteristics of Frequency Indicator.

AFC (Automatic Frequency Control)—A circuit associated with the AN/FGC-1 equipment which measures the difference in frequency between 2125 and the input frequency and puts out a DC voltage proportional to the difference frequency. This voltage appears on an ungrounded pair of terminals and is zero for a 2125 cycle input. It is important, therefore, that output of AFC circuit be poled correctly when connected to reactance tube V9 in the CW3-D receiver. The AFC equipment is connected to the output of the diversity receiver, preferably at the point of connection of the input filters of the AN/FGC-1 equipment.

The conversion equipment supplies a crystal-controlled, high-frequency oscillator, a choice of three BFO (crystal control, AFC, or manual control), and suitable switching arrangements. The HFO and BFO supply the same frequencies to both receivers so that the audio tone is the same from either receiver. The frequency of the HFO can be changed plus or minus .01 percent by a manual adjustment which changes the pressure on the crystal used. An adjustable type crystal holder is used. A suitable harmonic of this crystal frequency is specified as 455 kc higher than the assigned signal frequency, which is the average of the marking and spacing frequencies employed by the transmitter when in proper adjustment.

The high-frequency oscillator crystal is to provide a frequency 455 kc higher than the mean carrier frequency. The crystal frequency may be calculated as follows:

$$F_x = \frac{F + 455}{N} \text{ kc}$$

Where: F_x =Crystal Frequency in kilocycles
F =Mean carrier frequency (assigned by CLB).
N =Harmonic (such that F_x is greater than 1.8, but less than 5 mc).

Three choices of common BFO are provided in the CW3-D receiver as follows:

1—452.45 kc ±0.02 percent, crystal-controlled oscillator.
2—452.45 kc self-excited oscillator with automatic frequency-control, by means of a reactance tube coupled to the AFC circuit in the AN/FGC-1 teletype terminal equipment.
3—Self-excited oscillator with manual control.

If, for example, the assigned carrier frequency were 12,000 kc the transmitter would be adjusted as closely as possible so that the marking and spacing conditions would transmit the following frequencies:

Marking frequency —12,000 kc + 0.425 kc = 12,000.425 kc.
Spacing frequency —12,000 kc —0.425 kc = 11,999.575 kc
Average (carrier) frequency—12,000 kc.

Since the harmonic of the high frequency oscillator in the receiver is 455 kc greater than the average incoming signal frequency, the marking and spacing frequencies in the IF stages will be centered and the marking frequency will be lower. The IF and audio output frequencies desired are, therefore:

IF
Mark 455 —0.425=454.575
Space 455 +0.425=455.425
Average 455

Audio Output
454.575 —452.450 = 2.125
455.425 —452.450 = 2.975
= 2.550

NOTE: In problems of this type considerable computations will be saved if average frequencies are used throughout. Thus, the high frequency oscillator is 455 kc above the assigned frequency. The IF average is 455 kc and the average audio output is 2.550 kc.

It will be noted that the correct adjustment of the transmitting oscillator and two receiving oscillators must be precise in order to obtain the correct audio frequency outputs which are required for satisfactory service. In order to take care of moderate variations, an AFC circuit is provided which automatically keeps the marking audio frequency near its correct value. However, the AFC circuit changes only the BFO and it is necessary to operate so that the desired signal remains in the IF pass band which may be considered to be from one to two kc in width.

Occasionally it may be impossible to use the crystal BFO and the AFC circuit may be affected by unwanted interference or it may not be available for other reasons and, therefore, a third method of the beat-frequency oscillator control is available which provides for manual tuning of the BFO. This is the least desirable arrangement, but can be used to provide service when temporary conditions make the use of crystal and AFC BFO impracticable. In general, AFC should be used when practicable. If not practicable, crystal or manual oscillator should be used in that order.

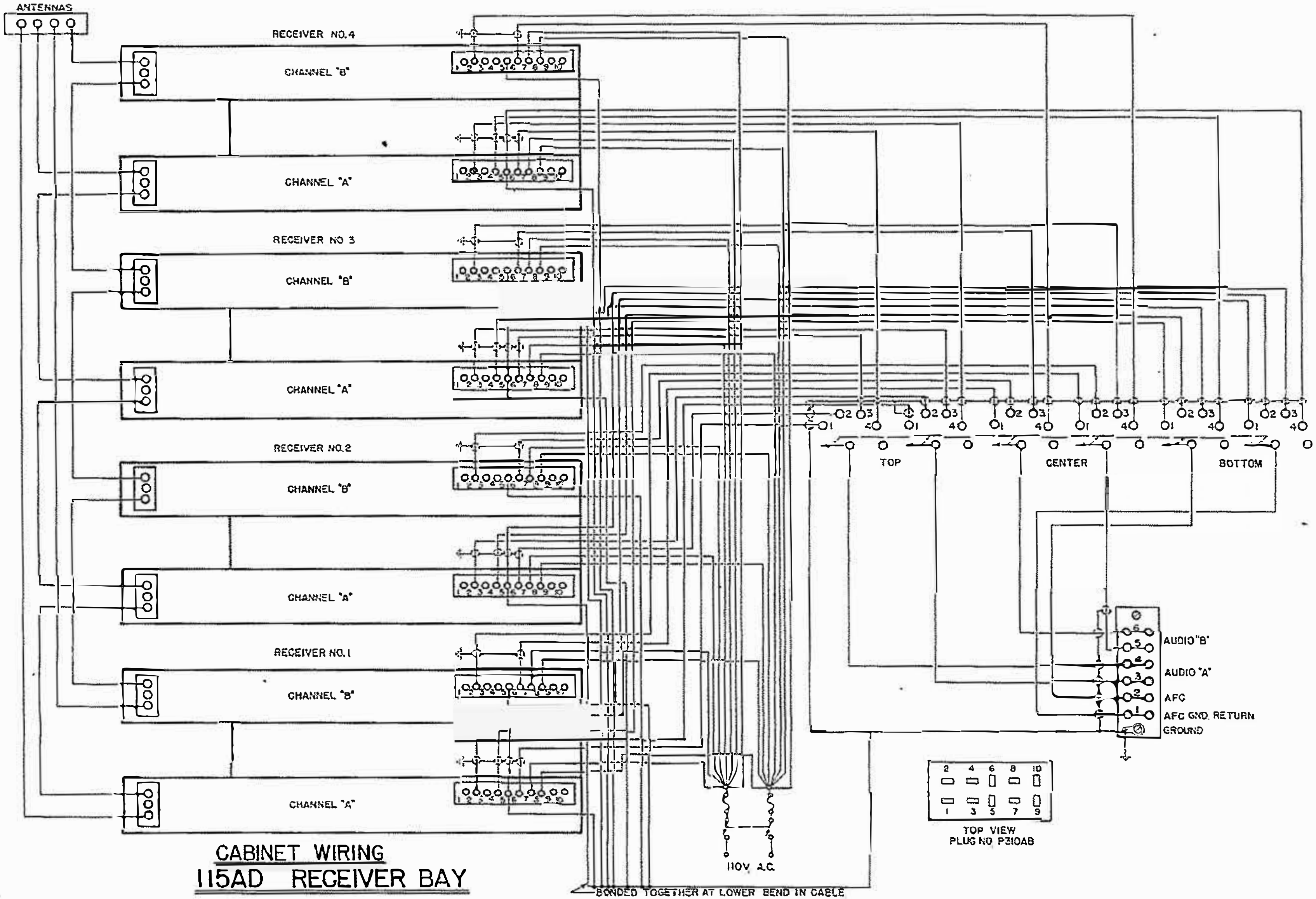


Figure 7. 115 AD Cabinet Wiring Diagram.

INSTALLATION (fig. 4).

Remove the 115 Type Cabinet from its box and remove "knock-out plate" covering entrance below power switch at rear of cabinet. Place cabinet beside the AN/FGC-1 Cabinet to the left as you face the fronts of the two cabinets. The holes near the bottom of the two cabinets should line up so that inter-cabinet wiring is possible. Fasten the cabinet to the floor using suitable fastenings such as expansion bolts through the four bolt holes provided.

Remove the blower from the rear door and re-install on the outside of the door and install dust filter.

Connect 110 volt, 50 or 60 cycle single phase power to safety switch in accordance with diagram in cover of switch. Operate power switch and note that blower operates satisfactorily. Terminal 7 of Jones plug shall be the grounded side of AC, otherwise, fuse would not protect receiver in all cases. If power is wired directly to 115 Type Cabinet and one side is grounded, it may be desirable to strap out fuse in grounded lead. If receiver is terminated on power plug, a polarized plug is desirable and it may be desirable to strap out fuse on grounded side. A non-polarized plug is undesirable, but if necessary to use, both sides of line should be fused.

Connect water pipe or other low resistance ground connection to ground terminal in 115 Type Cabinet, which is below terminal block having six terminals on bottom panel.

In the first models of CW3-D Radio Sets no arrangement has been provided to furnish power for the AN/FGC-1 Equipment from the radio cabinet. In particular, no AC relay is provided to transfer power from rectifier to dehumidifying lamps.

If practicable the electric circuit shown in figure 36 of TM 11-356 (replacing X63642 [AN/FGC-1 Instruction Book]) should be wired as shown on drawing. To assist in this, a three wire AC switch can be used so that lamps will be lit when power is turned off rectifier.

If a three wire switch is not available, Terminals 1 and 2 of the Jones plug associated with AN/FGC-1 Equipment may be connected permanently to AC supply, Terminal 1 grounded side of AC. The live side of AC may be connected through two switches to Terminals 3 and 4 of the Jones plug. One switch will then turn on the rectifier and the other will turn on the lamps. For a simplified wiring diagram see drawing ES-E-32614-A.

The 115AD-4CW3-D equipment is packed for shipment in six boxes. The total weight is 628 pounds, and the volume is 37.1 cu. ft. The largest dimension is 76x36x26 inches.

Unpack the four CW3-D Receivers and place on suitable work bench or improvised table. Remove can covers and dust shields and make a mechanical inspection.

If tubes are shipped in separate boxes, unpack the boxes and test all tubes. It will probably assist operation if each tube is given an identification mark and a record kept of its history giving receiver and socket location.

If tubes should be shipped in place, remove tubes and record position so that they may be replaced in same sockets and test the tubes.

Tubes should preferably be tested in a suitable tube tester, if one is available. If not, each tube may be tested for internal shorts with an ohmmeter and for continuity of heater circuit.

Place tubes in designated sockets in each CW3-D Receiver and install tube shields on glass tubes. Each Radio Set has a diagram on inside of rear door showing tube locations.

If shipped separately, unpack and install "plug-in" antenna, grid, plate, and oscillator coils. Location of coils is shown in figure 1. It will probably assist operation if each coil is given a designation and a record kept of its history showing receiver and socket location.

Wire a spare Jones plug to 50 or 60 cycle AC power and to ground; power to terminals 7-8; ground to terminal 5. Connect power to one receiver at a time and observe for possible trouble. The 80 tube may be inspected for signs of excessive current by noting if the plates are red, or if a blue color exists in the tube. Other signs of excessive current may be excessive humming in the power transformer, or, if troubles due to internal shorts have developed due to shipping or broken-down bypass capacitors, the characteristic odor of hot insulation may be detected.

In case 50 cycle power is employed, the power transformer will run somewhat warmer than when 60 cycle power is used.

Measure the DC and AC voltages and compare them with similar receivers. It will probably assist future operation if the initial value of these voltages is recorded.

After the above tests indicate that the receivers are satisfactory, install the high- and low-frequency crystals. The crystal shield must be used on all frequencies in order to insure proper performance.

A vacuum-tube shield has been provided for use on the 6K7, V3 and V12, i-f amplifier tubes, when glass tubes are used. In order to plug in the crystals and the antenna grid and plate coils, the dust cover of the receiver must be removed by means of the two top screws on the dust cover. This cover must be replaced when the receiver is in operation. Tuning adjustments may be made through holes provided in the dust cover.

To install the high frequency crystal remove knob from shaft associated with "HFO—Crystal Adjustment". Pull out shaft with attached Johnson coupling and remove coupling by turning small screw at end of shaft in counterclockwise direction. Plug high frequency crystal into its socket and fasten Johnson coupling to short shaft. Insert long shaft from front of panel into other end of coupling and turn small screw in center of shaft in a clockwise direction. Install knob allowing sufficient clearance from front of panel. Install crystal shield. The crystal or coupling may be damaged if excessive force is used.

Install the four CW3-D Radio Receivers in the cabinet starting at the top as follows:

Small Blank Panel
CW3-D Receiver No. 4.... (4A & 4B) CW3—4

Small Blank Panel
CW3-D Receiver No. 3.... (3A & 3B) CW3—3

Small Blank Panel
CW3-D Receiver No. 2.... (2A & 2B) CW3—2

Small Blank Panel
CW3-D Receiver No. 1.... (1A & 1B) CW3—1

Large Panel with switch for switching receivers and AFC leads to telegraph equipment.

NOTE: Receivers are numbered from bottom to top in order to be consistent with arrangement used in AN/FGC-1 Cabinet. It is believed this will avoid confusion which would occur otherwise.

Install antenna connections in accordance with figure 7. The four receivers are connected in series to avoid antenna switching problems. A limited number of tests indicate that about half the available voltage delivered by the rhombic antenna may be expected to appear across the antenna input that is tuned to the desired signal. Each input has a capacity in the order of 35 mmf. to the electrostatic shield which is provided and grounded in each receiver. This acts as a shunt to the desired voltage. It is believed that it would be undesirable to use form wiring or shielded wiring with shield grounded to the receivers since this would increase the shunt capacities to ground. Open wiring is, therefore, employed. This, however, presents another problem since the inside of the cabinet must remain electrically quiet. If, due to low received fields, noise is picked up in the cabinet, it may be necessary to shield the power wires by wrapping screening, or to use tape foil around it in the cabinet or to provide a radio frequency filter in the power supply.

For any given set of three or four carrier frequencies it may be found that certain arrangements of receivers are better than others. This may be found experimentally by using the audio output with no AVC action or by using the AVC voltage as a guide to signal strength.

CONNECTIONS TO AN/FGC-1 EQUIPMENT

1—Bond ground connection in 115 Type Cabinet to ground connection on cabinet upright in AN/FGC-1 Cabinet.

2—Bond cabinets at at least one location.

3—Using shielded pair with shield connected to ground at both ends, make following connections:

AN/FGC-1 EQUIP.			115 TYPE CABINET
Panel	Terminal Block	Terminal Number	Terminal Number
Limiter A	A	1	3
Limiter A	A	2	4
Limiter A	A	2 Shield	Shield—Ground
Limiter B	A	1—Net.	Net.—5
Limiter B	A	2—Net.	Net.—6
Limiter B	A	2 Shield	Shield—Ground
AFC	B	5	2
AFC	B	7	1
AFC	B	8 Shield	Shield—Ground

Make local tests which apply on AN/FGC-1 Equipment as specified in TM 11-356.

RECEPTION FROM DISTANT STATION.

General. In first establishing radio teletype communication there is usually no easy way to communicate directly with the distant station. It is desirable, therefore, to make as many local tests as possible before attempting overall communication. These tests include careful checks of both the transmitting and receiving facilities. The poling of the transmitting side is checked by sending a steady marking signal from the teletype equipment, observing the condition of the sending relay at the transmitter, and zero beating the output of the frequency shifter with an SCR-211 frequency meter. Then a steady spacing signal is sent from the teletype equipment, the position of the sending relay is again observed, and the SCR-211 is again adjusted to zero beat. If the marking frequency is higher than the spacing frequency, as it should be, it will be necessary to turn the SCR-211 dial very slightly in a counter-clockwise direction (toward the lower end of the scale) to get zero beat on the spacing frequency. If the reverse condition occurs, there is a turnover which must be corrected. Care must be taken to correct this turnover at the right point. That is, all teletype equipment must be poled the same way at the signal center so that patches may be made at the loop switchboard without causing turnovers.

The steady spacing signal referred to above may be transmitted by stopping the TD motor, operating the armature of the starting magnet by hand, and then slowly turning the flywheel of the motor toward the right, as viewed from the front, until the brushes rest on the "Start" segment.

Similar tests should be made on the receiving equipment to insure proper poling. When the armature of the 255A Relay in the AN/FGC-1 terminal is held on the right side, the teletype set or reperforator should be "closed." When the armature is held on the left side, the reperforator should run "open".

In the case of a simplex circuit, or a duplex circuit when a monitoring receiver is available, it is usually desirable to send teletype signals out on the air, pick them up at the local receiver, and copy them with the receiving teletype equipment. If this cannot readily be done, local loop tests should be made at the Signal Center by patching the output of the sending teletype equipment to the input of the receiving equipment.

Another useful test may be made by sending a signal of the proper frequency from an SCR 211 into the receiver, and checking the tuning, alignment and output.

Finally, it is usually necessary to arrange by radio for overall tests. A good plan is to have the distant station send steady carrier (marking) for a specified period long enough to tune the receiver. During the period the station call letters should be sent occasionally, since there is sometimes a steady carrier on a nearby frequency which may be confused with the desired frequency. The radiogram should also specify that slow marks and spaces be sent for a short period following the steady marking signal, so that the filter outputs, received relay current, and relay position in the AN/FGC-1 Equipment can be checked, and, finally, RY or a test sentence should be transmitted. When transmission is satisfactory in one direction on one frequency, similar action should be taken in the other direction, after which two-way communication may be established and the remaining frequencies lined up. It is undesirable and results in confusion to line up in both directions at once, or to shift to a different frequency in both directions at once. Try to maintain communication in one direction of transmission while tests or changes are being made in the other direction. If necessary, then instructions may be sent "blind."

It is well to supplement the frequency indicator readings with listening tests on the outputs of the marking and spacing filters and to observe Rec. Relay Current to avoid tuning into the spacing filter instead of the marking (either one can be made to give a mid-space indication) or to avoid picking up the second harmonic of the audio frequency output of the receiver. The 2550-cycle tone on the normal level test jack in the AN/FGC-1 Equipment may be listened to if desired in order to judge by comparison whether output of the receiver is at approximately the proper frequency.

NORMAL OPERATION.

Assuming that there are not any temporary inexactitudes in the transmitting or receiving crystal frequencies, and that the manufacturer's adjustments have not changed due to shipment, the transmitting station may be tuned in as follows:

1.—**Crystal BFO.** v—Set Receiver Selector Switch at bottom of 115 Type Cabinet to receiver number having correct high frequency crystal and coils to receive desired frequency.

2—Operate all sensitivity knobs on other receivers to minimum position, thus reducing noise in output cable but do not turn power off unless necessary. It will probably simplify operation if power can be left on all receivers since frequency drift due to warming up will be eliminated.

3—On receiver panel being used insert phone plug into either phone jack.

4—Put BFO Switch to CO (crystal oscillator).

5—Turn Sensitivity Controls fully clockwise.

6—Turn Output Potentiometers to their maximum clockwise position, thus giving maximum output. A beat note should be heard in the head phone the frequency of which can be adjusted by turning the Crystal Adjustment knob. Adjust the frequency as determined by ear until it is between 2000 and 3000 cycles and adjust Output Potentiometers on both Receiver A and Receiver B until a pleasing tone, that is, one free from harmonics, is heard in the corresponding outputs. CW communication may now be maintained with transmitting station if circuit in opposite direction of transmission is available.

7—Ask the transmitting station to slowly alternate between mark and space and to name each condition. The received audio marking frequency should be lower than the spacing frequency. (It is the highest frequency on the air.)

8—Ask the transmitting station for a steady mark.

9—In the AN/FGC-1 Equipment patch METER DC to REC. REL. CUR. and, while listening to tone in phone jacks, adjust crystal until marking rectified current is obtained. That is, meter indicates positive current.

10—Patch METER DC to FREQ. IND. OUT. jacks and readjust crystal until meter reads zero. When crystal oscillator is raised in frequency, audio tone will also be raised, which will bring it nearer the 2550 cycle oscillator in the frequency indicator and, hence, the meter reading should decrease. If a steady space were being received raising the crystal oscillator should result in a higher meter reading. Figure 6 shows the general characteristics of the frequency indicator.

11—Check the calibration of Frequency Indicator and repeat 10.

12—Obtain signals from distant transmitter and adjust crystal tuning until a steady deflection is obtained showing that marking and spacing signals are equally distant from 2550 cycles. If the indications of the meter are outside of limits of ±15, it indicates that the frequency swing is incorrect. A reading to right indicates too great a swing, and one to left too small a swing. An inspection of figure 6 will indicate the actual swing.

A-2—Operation With AFC. 13—If AFC is desired, adjust crystal oscillator until a steady mark results in marking current and frequency indicator indicates zero, showing that correct marking frequency is being obtained. Use crystal BFO.

14—Operate BFO Switch to Manual and adjust BFO Manual Adjustment until audio tone gives zero beat with NOR. TEST LEVEL (2550 cycles) and raising frequency of BFO results in marking rectified current showing that BFO is below IF frequency. Increase BFO frequency until marking rectified current is obtained and frequency indicator indicates zero. If necessary, trimmer capacitors on triode oscillator L-15 may be changed slightly to center manual adjustment of BFO.

15—Turn AFC knob in AN/FGC-1 Cabinet to ON and, if necessary, adjust FREQ. ADJ. on AFC circuit in AN/FGC-1 Cabinet until a sensitive meter connected across Terminals 5 and 7 of B Terminal Strip of AFC circuit indicates zero voltage at same time frequency indicator indicates zero on mark.

16—Operate BFO Switch in 115 Type Cabinet to AFC and observe indication of frequency indicator. (If operating properly indicator will indicate correct frequency even when HFO is changed from its correct position. If poled incorrectly frequency will deviate greatly from desired value.)

NOTE: Step 16 may be only required initially and when trouble is experienced.

17—When signals are obtained from distant end, frequency indicator will be unsteady since spacing frequency will not necessarily be correct.

A-3—Operation With Manual BFO. 18—Operate BFO Switch to manual and adjust BFO Manual Adjustment until audio tone gives zero beat with NOR. TEST LEVEL (2550 cycles), raise frequency of BFO until marking rectified current is obtained and frequency indicator indicates zero. (If the above or some similar procedure is not followed, the BFO may be adjusted to be above the IF frequency, this giving an unworkable arrangement, or the audio frequency may be half the marking frequency and tuning may be done on second harmonic.)

19—Obtain signals from distant terminal and change BFO Manual Adjustment slightly until steady meter reading is obtained on frequency indicator.

A-4—Adjustment of Receiver Output. 1—With a steady mark and receiver tuned for condition of BFO to be used, patch AC meter first into Normal Test Level jack and then into Radio Rec. Out. Channel A jack.

2—Adjust the Output Potentiometers associated with Receiver A to obtain an average reading corresponding to that obtained on Normal Test and not to exceed full scale peaks.

3—Similarly, adjust output of Receiver B. These adjustments should remain undisturbed unless meter indicates that excessive or low output is being obtained. Operating at too high a setting will result in distorted waves having harmonics which will affect the action of the AFC circuit. Operating at too low a level is also undesirable.

METHOD OF ALIGNING I-F CIRCUITS IF SIGNAL GENERATOR IS NOT AVAILABLE.

The triode BFO of another receiver can be adjusted to 455 kc and this oscillator may be used as a signal generator.

1—Using a convenient spare receiver, remove the 6SA7 reactance tube and plug a bare wire about two inches long into the control grid terminal of the socket (Terminal 5). Wrap a few turns of insulated wire around the bare wire and connect other end of wire to the grid of the intermediate amplifier tube V3 or receiver to be tested.

2—Connect receiver to be tested to AN/FGC-1 Equipment and set its BFO Switch to CO. The receiver being used as a signal generator should be on Manual BFO and its frequency should be changed until raising its frequency slightly results in spacing current, and lowering its frequency results in marking current. The receiver being used as a signal generator will then be 2550 cycles higher than the crystal, or 455 kc. Another way of testing is to pick up Normal Test Level, which is 2550 cycles and to zero beat this with the audio output of the receiver being tested.

3—Proceed to tune IF in accordance with instructions in Section I.

MARK AND SPACE TURN-OVERS.

One of the features of the Radio Teletype System is its symmetry. Except for the arbitrary designations "Mark" and "Space," there is no difference between the two conditions used for signaling.

If, however, a turn-over occurs at some point in the circuit, marks and spaces will be reversed and unintelligible copy will be received. This could be corrected at any other point in the circuit as far as transmission results are concerned and occasionally it may be necessary to operate temporarily in this manner. Such operation will in the long run cause excessive confusion and make extra work for those in charge.

In a circuit where a turn-over can occur at any one of five points, there are 32 possibilities, one of which is the correct one. It is quite improbable, therefore, that the correct arrangement will be found by random experiment and when difficulty is experienced, it is generally desirable to check each point.

In case of doubt ask the transmitting station for a mark. Operate on manual BFO and adjust until marking detector current is received and frequency indicator meter indicates zero.

Increase the frequency of the BFO oscillator and note whether the audio frequency is lowered or raised and corresponding action of frequency indicator meter. Consult Table A below to determine if BFO is below or above IF.

If BFO is above IF, retune BFO until signal is tuned in, but BFO is below IF.

Increase frequency of HFO and from table below determine whether HFO is above or below signal frequency. Except for an error in crystal frequency, it is very improbable that HFO will be below the signal frequency. If this should occur, however, it would be necessary to operate with the BFO above the IF frequency or to turn over outputs of detectors.

If the above tests indicate that the HFO is above the signal frequency, and that the BFO is below the IF frequency, ask the transmitting station to send a space signal and note the Rec. Relay Current.

If the marking and spacing currents correspond to those transmitted, the turn-over, if any, must exist in the DC portion of the receiving circuit. If they do not correspond, the turnover is at the transmitting end, and may be due to such things as keying equipment, turn-over in loop to transmitting polar relay, etc.

TABLE A

Condition—Receiving Marking Frequency.

HFO	BFO	HFO	BFO	IF	Audio Freq.	Ind.
Above Carrier	Below IF	Fixed	Increase	Fixed	←	→
Above Carrier	Above IF	Fixed	Increase	Fixed	→	←
Above Carrier	Below IF	Increase	Fixed	→	→	←
Above Carrier	Above IF	Increase	Fixed	→	←	→
Below Carrier	Below IF	Fixed	Increase	Fixed	←	→
Below Carrier	Above IF	Fixed	Increase	Fixed	→	←
Below Carrier	Below IF	Increase	Fixed	←	←	→
Below Carrier	Above IF	Increase	Fixed	←	→	←

→ Indicates increase in frequency or reading of frequency indicator.

← Indicates decrease in frequency or reading of frequency indicator.

Fixed indicates steady frequency.

Increase—Turn adjustment in direction to increase frequency.

EMERGENCY OPERATION.

Occasionally some part of the complete system will not function as desired. However, in the two cabinets there exists considerable equipment which may be used quite flexibly for emergency operation. In fact, as long as the transmitting station can swing the frequency at least a few hundred cycles and even if only one-half of one of the four CW3-D Radio Receivers were in operating condition, emergency operation could be maintained.

Figure 8 is a chart showing recommended action which may be used as a guide in this work.

BIAS.

The bias tolerance of the overall system with ideal radio conditions is 35%. If the cumulative bias in the circuit is not kept within close limits for example ±5%, inferior operation will be obtained during periods which occur each day when radio conditions are not ideal. The desirability of removing bias cannot be overemphasized.

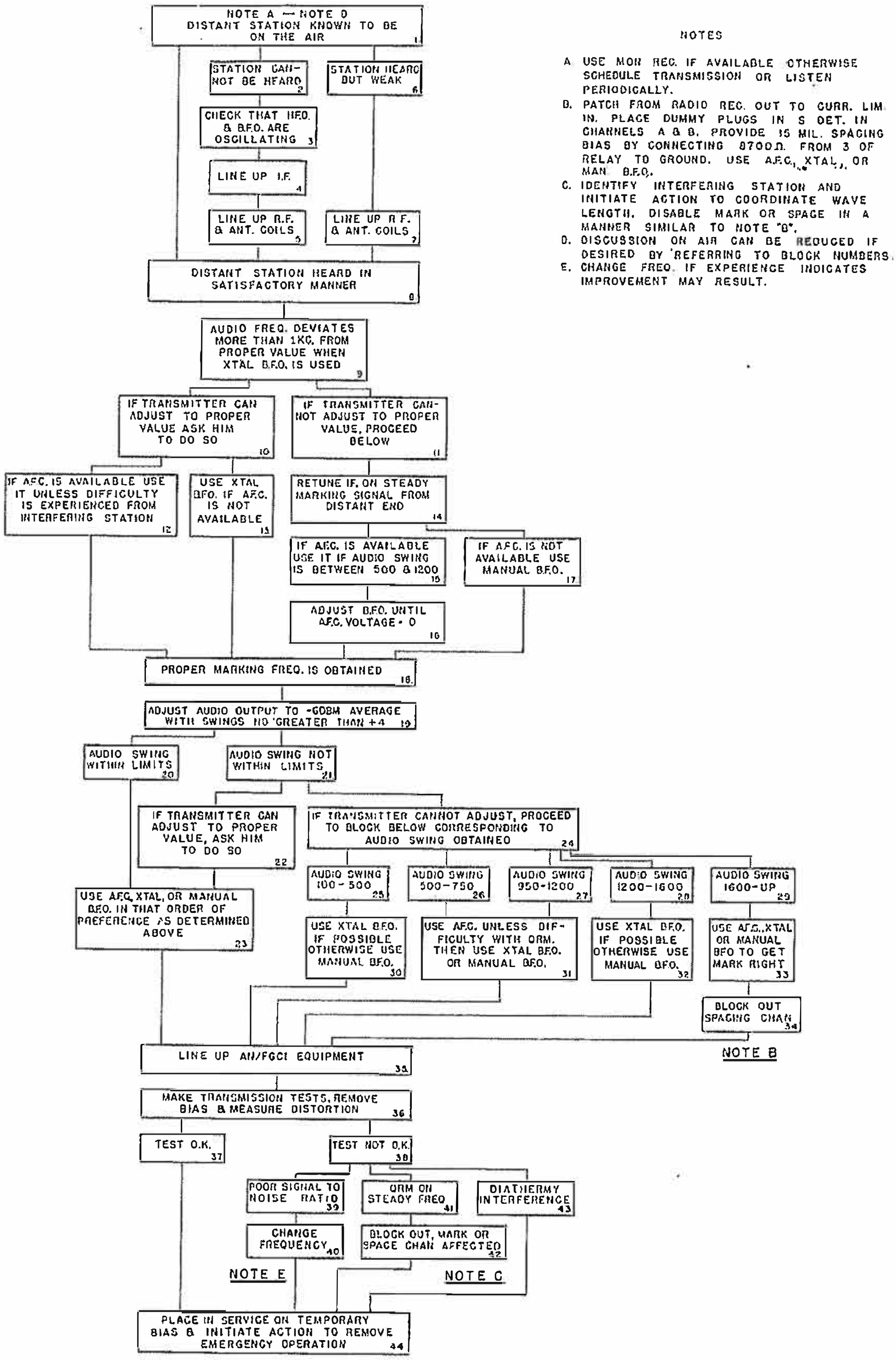


Figure 8. Recommended Action for Emergency Operation.

NOTES.

I. Note on Diversity Operation. With space diversity operation two duplicate channels are used at the receiving end. The system will work, although in an inferior manner, if for some reason one channel becomes disabled. For example, one power supply might become weak or ineffective or by mistake the sensitivity control of one receiver might be left at a low setting. It is desirable, therefore, to listen to the outputs of the two receivers occasionally to find out if they are similar. Another test which may be useful is to watch the received copy while disabling first receiver A and then receiver B and note that copy is similar in each case.

II. Note on Function of Reactance Tube. In a vacuum tube circuit with voltage feedback the impedance from plate to ground is:

$$ZA = \frac{Zp}{1 - MuB}$$

where ZA = Active Impedance
Zp = Passive Impedance when Mu = 0
Mu = Mu of tube
MuB = Round Trip Feedback

Therefore, by the proper choice of Zp and MuB it is possible to obtain for example, an adjustment capacity. The adjustment may be madè by changing Mu or B.

The reactance tube used in connection with AFC is of the pentagrid converter type. The five grids are used as follows:

G-1—Feedback voltage
G-2—Screen voltage
G-4
G-3—AFC voltage
G-5—Suppressor voltage

Increasing the feedback voltage to Grid 1 lowers the active impedance by changing B. Making G-3 positive also lowers the active impedance by increasing Mu. Making G-3 negative raises the impedance by lowering Mu.

Therefore, if the impedance ZA is bridged across the tuned circuit of the oscillator, the frequency will be lowered when ZA is lowered and raised when ZA is raised.

ERRATA.

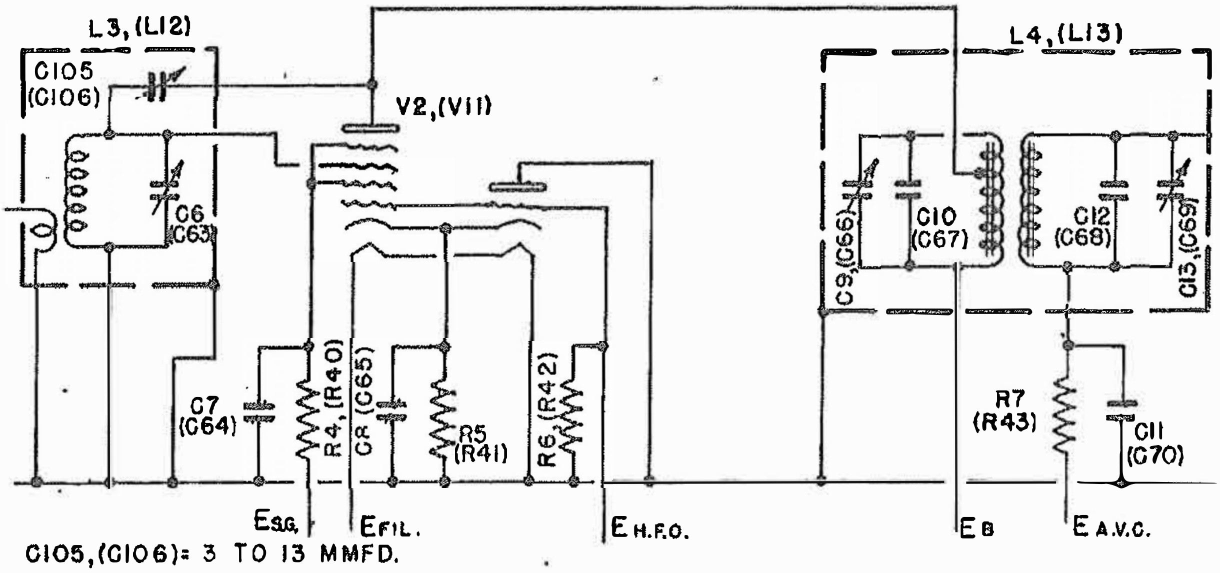


Figure 9. Partial Schematic, Showing Change in Mixer Circuit.

The capacitors C105 and C106 have been added to the Band 4 and Band 5, 6K8 Mixer Grid Coils, as shown above, for the purpose of effecting neutralization of the 6K8 Mixer Tube. These capacitors will ordinarily be pre-set at the factory to effect complete neutralization at the highest frequency in the Band, and should require no further adjustment. However, in the event that oscillation should take place in the 6K8 mixer stage due to the replacement of the tube or to changing the frequency, the Receiver can be brought back to a stable state by adjusting the capacitors C105 and C106. Caution should be exercised in making this adjustment, so as not to over-neutralize, thereby reducing the sensitivity of the Receiver unduly. Increasing the neutralizing capacitance will decrease the gain of the 6K8, while decreasing the neutralizing capacitance will increase the gain of the 6K8. The neutralizing capacitance should not be reduced to the point where the Receiver becomes unstable. The capacitors C105 and C106 can best be adjusted by removing the Coils from the Receiver, and removing the Coil Shields.

In Receivers, which have not been modified for use of these neutralizing capacitors, such modification can easily be made by connecting a short bus bar between pin No. 3 of V2 and pin No. 7 of L3 in Channel B, and between pin No. 3 of V11 and pin No. 7 of L12 in Channel A. A Centralab NC300, 3 to 13 mmfd. variable capacitor is then placed in both L3 and L12, connecting one lead to pin No. 7 and the other to the end of the Coil, which is connected to the stator of the tuning capacitor.

Figure 5 shows the modifications required in certain models of AN/FGC-1 to provide monitor lock up.

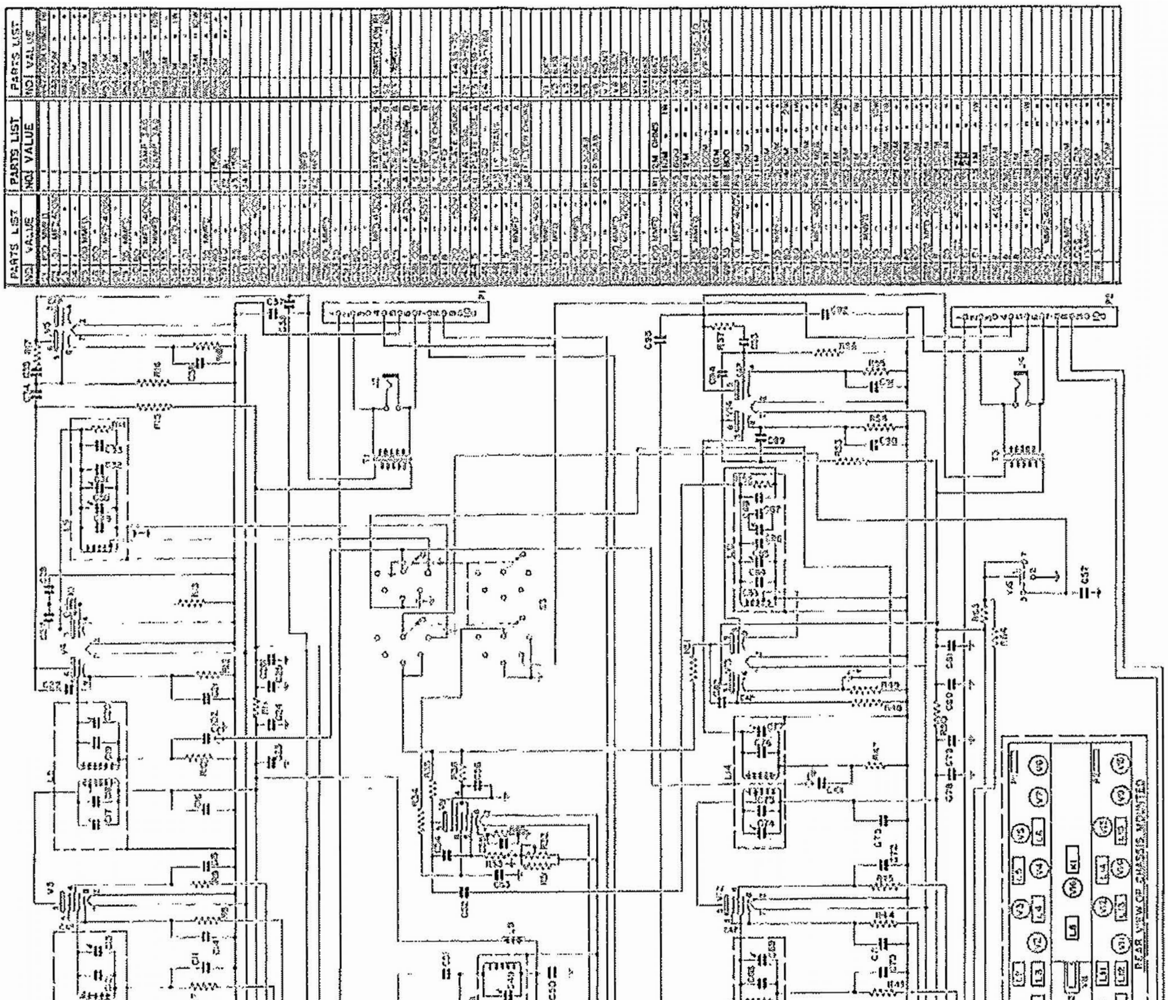


Figure 10. CW3-D Receiver, Schematic Diagram.

LIST OF MANUFACTURERS

Code	Manufacturer's Name
A5	Allen-Bradley Co.
A13	American Phenolic Corp.
A14	American Radio Hardware Co., Inc.
C4	Centralab
C10	Clarostat Mfg. Co., Inc.
C15	Cornell-Dubilier Electric Corp.
I2	International Resistance Co.
I8	Industrial Condenser Corp.
J1	Jefferson Electric Co.
J5	Jones, Howard B.
L3	Littelfuse Lab.
M1	Mallory, P. R. & Co.
M2	Micamold Radio Corp.
M4	Millen, James Mfg. Co., Inc.
R2	RCA Mfg. Co.
S3	Sickles, F. W. Co.
S5	Solar Mfg. Corp.
T4	Thordarson Electric Mfg. Co.
W9	Wilcox Electric Co.

MAINTENANCE PARTS LIST FOR DUAL DIVERSITY RECEIVING EQUIPMENT, TYPE CW3-D

Ref symbol	Signal Corps stock No.	Name of part and description	Quan. per unit	Mfrs part and code No.	†Station stock	†Region stock
C2, C7, C11, C15, C23, C26, C34, C35, C52, C55, C56, C59, C64, C70, C72, C78, C81, C93, C94	3DA10-140.2	CAPACITOR: paper; 0.01-mf; 400 v dc (working).	19	340-21 (M2)	*	*
C3, C4, C8, C14, C16, C37, C45, C46, C50, C57, C60, C61, C65, C71, C73, C95	3DA100-112.1	CAPACITOR: paper; 0.1-mf; 400 v dc (working).	16	345-21 (M2)	*	*
C5		CAPACITOR: part of L2.				
C6, C105		CAPACITOR: part of L3.				
C9, C10, C12, C13,		CAPACITOR: part of L4.				
C17, C18, C19, C20		CAPACITOR: part of L5.				
C21, C90	3DB8-59	CAPACITOR: electrolytic; 8-mf; 150 v dc (working).	2	MM (18)	*	*
C22, C27, C38, C82, C89, C92	3DA2-61.2	CAPACITOR: mica; 0.002-mf; 500 v dc (working).	6	1W-5D2 (C15)	*	*

† Parts not stocked in station or region stock are carried in depot stock.

* Indicates stock available.

MAINTENANCE PARTS LIST FOR DUAL DIVERSITY RECEIVING EQUIPMENT, TYPE CW3-D (contd).

Ref. symbol	Signal Corps stock No.	Name of part and description	Quan per unit	Mfrs part and code No.	†Station stock	†Region stock
C24, C25, C44, C47, C53, C79, C80	3DA500-57.1	CAPACITOR: paper; 0.5-mf; 400 v dc (working).	7	50263 (S5)	*	*
C28	3K2010114	CAPACITOR: mica; 0.0001-mf; 500 v dc (working).	1	MO (S5)	*	*
C29, C30, C31, C32, C33		CAPACITOR: part of L6.				
C36, C91	3DB25-11	CAPACITOR: electrolytic; 25-mf; 25 v dc (working).	2	MM (18)	*	*
C39, C40, C41, C96, C97, C98	3DB8-31	CAPACITOR: electrolytic; 8-mf; 450 v dc (working).	6	M408 (S5)	*	*
C42, C43, C99, C100	3DB20-13.1	CAPACITOR: electrolytic; 20-mf; 150 v dc (working).	4	M220 (S5)	*	*
C48, C51	3D9050-59.2	CAPACITOR: mica; 0.00005-mf; 500 v dc (working).	2	5W (C15)	*	*
C49		CAPACITOR: part of L8.				
C54, C101, C102	3K2005014	CAPACITOR: mica; 0.000005-mf; 500 v dc (working).	3	5W (C15)	*	*
C58		CAPACITOR: part of L10.				
C62		CAPACITOR: part of L11.				
C63, C106		CAPACITOR: part of L12.				
C66, C67, C68, C69		CAPACITOR: part of L13.				
C74, C75, C76, C77		CAPACITOR: part of L14.				
C83, C84, C85, C86, C87, C88		CAPACITOR: part of L15.				
C103, C104	3DA6-33.1	CAPACITOR: mica; 0.006-mf; 500 v dc (working).	2	MW (S5)	*	*
L7, L16	3C316-28	COIL: filter choke; 10 h at 100 ma.	2	T45692 (T4)		*

L1, L2, L3, L10, L11, L12	2C4547-2/C	COIL SET: r-f; 3 coils per set, includes C1, C5, C6, C59, C62, C63, C105, C106; (order by frequency range).	2	(W9)		
L8		COIL ASSEMBLY; h-f osc; includes C49; (order by frequency range)	1	LT-77 (W9)		
L9	3C341-3	COIL: filter; HFO plate choke; 2.5-mh.	1	34102 (M4)		*
K1, K2		CRYSTAL HOLDER: with crystal; (frequency as specified).	2	80D (W9)		
F1, F2	3Z1927	FUSE: 2-amp; 250-v; type 3AG.	2	1042 (L3)	*	*
J2, J4	2Z5581-3	JACK: phone; single-open circuit.	2	A1 (M1)		*
P1, P2	2Z7228.40	PLUG: 10-prong.	2	P-310-AB (J5)		*
R1, R22, R32, R37, R61	2Z7279-24	RESISTOR: wire-wound; variable; 2,000 ohms with SPST switch.	5	22011000 (C4)	*	*
R5, R41	3RC35CE101K	RESISTOR: 100-ohm; 1-w.	2	G1012 (A5)	*	*
R4, R21, R31, R40, R60	3Z6200-82	RESISTOR: carbon; 2,000-ohm; 1-w.	5	GB (A5)	*	*
R2, R7, R38, R43	3RC30BE103M	RESISTOR: carbon; 10,000-ohm; 1-w.	4	GB (A5)	*	*
R3, R8, R39, R44	3Z6080-30	RESISTOR: 800-ohm; 1-w.	4	GB1 (A5)	*	*
R6, R26, R29, R30, R34, R42, R46	3RC30BE104M	RESISTOR: carbon; 100,000-ohm; 1-w.	7	GB (A5)	*	*
R9, R18, R45, R49, R51, R55	3Z6500-129	RESISTOR: carbon; 5,000-ohm; 1-w.	6	GB (A5)	*	*
R10, R13, R47	3Z6700-99	RESISTOR: 100,000-ohm; 1-w.	3	G1042 (A5)	*	*
R11, R33, R50	3RC30BE102M	RESISTOR: carbon; 1,000-ohm; 1-w.	3	GB (A5)	*	*

† Parts not stocked in station or region stock are carried in depot stock.
* Indicates stock available.

MAINTENANCE PARTS LIST FOR DUAL DIVERSITY RECEIVING EQUIPMENT, TYPE CW3-D (contd).

Ref symbol	Signal Corps stock No.	Name of part and description	Quan per unit	Mfrs part and code No.	†Station stock	†Region stock
R12, R54	3Z6620-41	RESISTOR: 20,000-ohm; 1-w.	2	G2232 (A5)	*	*
R14		RESISTOR: part of L6.				
R15, R35, R53	3Z6650-33	RESISTOR: carbon; 50,000-ohm; 1-w.	3	GB (A5)	*	*
R16, R56	3Z6750-24	RESISTOR: carbon; 500,000-ohm, 1-w.	2	BT-1 (I2)	*	*
R17, R57	3Z6802-25	RESISTOR: carbon; 2-megohm; 1-w.	2	GB (A5)	*	*
R19, R58	3Z6580-11	RESISTOR: wire-wound; 8,000-ohm; 10-w.	2	10C (C10)	*	*
R20, R59	3Z6625-57	RESISTOR: wire-wound; 25,000-ohm; 10-w.	2	10C (C10)	*	*
R23, R62	3Z6250-66	RESISTOR: wire-wound; 2,500-ohm; 10-w.	2	A10C (C10)	*	*
R24, R28	3Z6750-46	RESISTOR: carbon; 500,000-ohm; 1-w.	2	GB (A5)	*	*
R25, R27, R48	3Z6725-32	RESISTOR: carbon; 250,000-ohm; 1-w.	3	GB (A5)	*	*
R36	3RC30BE153K	RESISTOR: carbon; 15,000-ohm; 1w.	1	GB (A5)	*	*
R52		RESISTOR: part of L15.				
R63, R64	3RC35CE103K	RESISTOR: 10,000-ohm; 1-w.	2	G1032 (A5)	*	*
R65	3Z6050-104	RESISTOR: carbon; 500-ohm; 1-w.	1	GB (A5)	*	*
	2Z8674.8	SOCKET: tube; bakelite; 4-contact.	2	S4 (A13)		
	2Z8795.9	SOCKET: tube octal; bakelite; 8-contact.	12	S8 (A13)		
	2Z8650.5	SOCKET: octal bakelite.	2	25909 (W9)		
S3	3Z9827.7-3	SWITCH: rotary; 2-gang; each gang 2-pole, 5 position nonshorting.	1	1325-L (M1)		
	6D13374	TECHNICAL MANUAL: CW3-D receivers.	1	TM 11-2204		
J-1, J-3	2Z9403.31	TERMINAL STRIP: 3-contact.	2	1506 (A14)		*
T1, T3	2Z9632.58	TRANSFORMER: output; 6C8C plate to 500-ohm ct line.	2	T43970 (T4)		*

7875—Phila—44;—4000—31 January 1945

T2, T4	2Z9632.60	TRANSFORMER: power; pri, 115-v, 60-cyc; sec No. 1, 6.3 v at 2.5 amp; No. 2, 5 v at 2 amp; No. 3, 720 v ct at 50 ma.	2	463-001-167 (J1)		*
L4, L5, L13, L14	2Z9641.34	TRANSFORMER ASSEMBLY: i-f; 455 kc; L4 includes C9, C10, C12, C13; L5 includes C17, C18, C19, C20; L13 includes C66, C67, C68, C69; L14 includes C74, C75, C76, C77.	4	54659 (S3)		*
L6, L15	2Z9644.4	TRANSFORMER ASSEMBLY: BFO; 455 kc; L6 includes C29, C30, C31, C32, C33, R14; L15 includes C83, C84, C85, C86, C87, R52.	2	55251 (S3)		*
V1, V3, V10, V12	2J6K7	TUBE JAN-6K7.	4	6K7 (R2)	*	*
V2, V11	2J6K8	TUBE JAN-6K8.	2	6K8 (R2)	*	*
V4, V5, V13, V14	2J6C8	TUBE JAN-6C8.	4	6C8 (R2)	*	*
V6, V15	2J80	TUBE JAN-80.	2	80 (R2)	*	*
V7	2J6SN7	TUBE JAN-6SN7.	1	68N7 (R2)	*	*
V8	2J6AC7	TUBE JAN-6AC7/1852.	1	1852/ 6AC7 (R2)	*	*
V9	2J6SA7	TUBE JAN-6SA7.	1	6SA7 (R2)	*	*
V16	2JOC3/VR105	TUBE JAN-OC3/VR105.	1	VR-105-30 (R2)	*	*

† Parts not stocked in station or region stock are carried in depot stock.
* Indicates stock available.

Appendix 11- US ARMY FORCES CATALOG SIG 10-325 FIXED PLANT MAINTENANCE LIST, RECEIVING EQUIPMENT, TECHNICAL REFERENCE TM 11-2204 WILCOX ELECTRIC CO. 115AD RACK, 4CW3-D DUAL RECEIVER

See pages 101-108

Rescinded per DA Cir 310-77, 23 July 57

ARMY SERVICE FORCES CATALOG **SIG 10-325**

SIGNAL SUPPLY CATALOG

Fixed Plant Maintenance List

RECEIVING EQUIPMENT

TECHNICAL REFERENCE: TM 11-2204

Manufacturer: WILCOX ELECTRIC CO. *Mfr's Model No.* 115AD RACK 4CW3-D DUAL RECEIVER

Headquarters Army Service Forces—July 1945

★

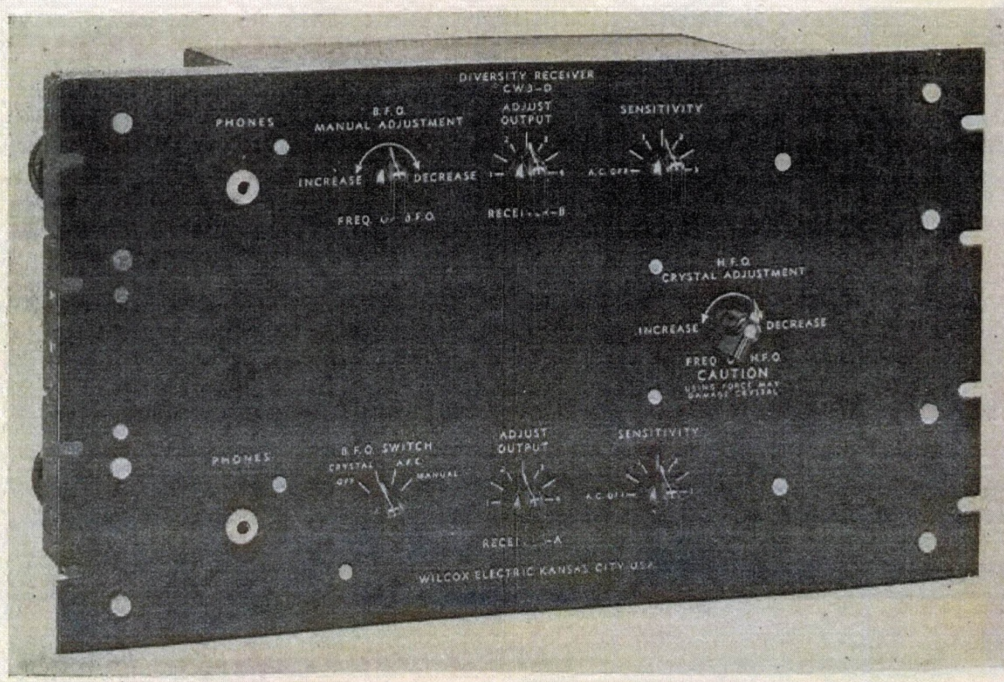
Supersedes SIG 10-325, 7 November 1944

Refer to "SIG 10-1" and "SIG 10-2" for general instructions regarding use of this list

Mfr's Part No. & Mfr's Code No. (Ref SIG 10-2)	Reference (See below)	SIG C Stock No.	Nomenclature	Unit of Measure	Quantity per Equipment	Allowance: Station Stock 1-3 Equip Ref SIG 10-2	Initial Stock Guide: Regional or Field Stock 1-3 Equip Ref SIG 10-2	Initial Stock Guide: Base Depot Stock Per 100 Equip
115AD-4CW3-D	TM 11-2204		RECEIVING EQUIPMENT 115 AD-4CW3-D, DIVERSITY, DUAL, RADIO, AM, 2-24 mc, CONSISTING OF:					
		NSNR	RELAY RACK ASSEMBLY 115AD	ea.	1			
		NSNR	RADIO RECEIVER CW3-D, DUAL, DIVERSITY	ea.	4			
		(Order through AGO channels)	TECHNICAL MANUAL TM 11-2204	ea.	2			
	Dwg. D294		Relay Rack Assembly 115AD					
148 (E5)		3G1250-13.3	BUSHING, insulating, porcelain, 13/16" lg x 1-1/8" OD, 1/2" hole	ea.	1	1		2
27764 (W9) 8341 (A17)		6Z7783-1	CONNECTOR, male, 2 flat parallel blades	ea.	1			2
Dwg. E144 (W9)		3E7205	CORD, 12 ft lg, 33 cond, w/plug and tp type term at other end	ea.	1			2

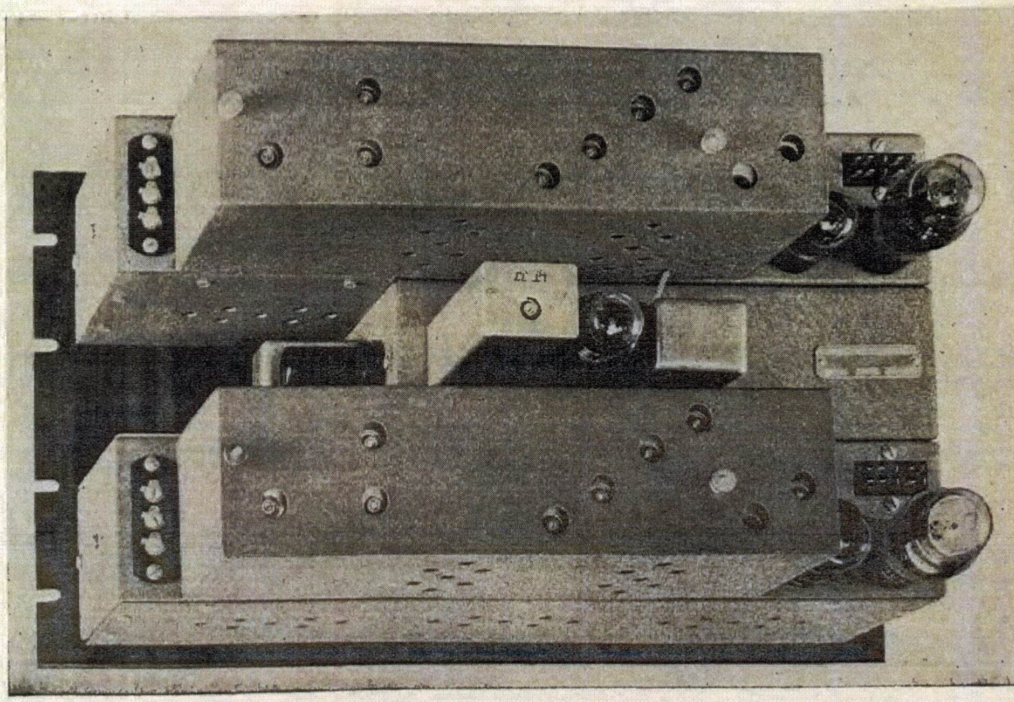
Copy 1

Mfr's Part No. & Mfr's Code No. (Ref. SIG 10–2)	Reference (See below)	SIG C Stock No.	Nomenclature	Unit of Measure	Quantity per Equipment	Allowance: Station Stock 1–3 Equip Ref SIG 10–2	Initial Stock Guide: Regional or Field Stock 1–3 Equip Ref SIG 10–2	Initial Stock Guide: Base Depot Stock Per 100 Equip
	TM 11–2204		Relay Rack Assembly 115AD (Continued)					
10102KL (A23)		6Z3854–4	FILTER, air, Air Maze, 10" x 10" x 2"	ea.	1	1	1	25
810 (B9)		3Z2610.15	FUSE, plug, 10 amp, 125 v	ea.	2	8	8	800
JS3–73 Dwg. BA16 (S4) 45502 (W9)		3H3000–105	MOTOR, blower, AC, induction, 1/500 hp, 120 v, 60 cps, single ph	ea.	1	----	1	7
256 (S4) 73002 (W9)		3H370.2–1	BLADE ASSEMBLY, fan, 4 blade	ea.	1	----	----	2
P–333–FHT (J5)		2Z3045–21	PLUG, male, 33 prong	ea.	2	----	----	4
8339 (A17)		6Z7783–3	RECEPTACLE, 2 cont, female, 10 amp, 125/250 v	ea.	1	----	----	2
1913G (A17)		6Z7786–1	RECEPTACLE, duplex, 125/250 v, bakelite	ea.	1	----	----	2
S–310–FHT (J5)		2Z8680–2	SOCKET, female, 10 cont	ea.	8	----	----	16
S–333–AB (J5)		2Z8699–4	SOCKET, receptacle, female, 33 cont	ea.	2	----	----	4
1335L (M1)		3Z9825–55.79	SWITCH, rotary, 3 sect, 6 ckt, 5 position	ea.	1	----	1	8
93211 (S9)		3Z9503–20	SWITCH, safety, tumbler type, 2 pole, 30 amp, 125/250 v, w/fuse block	ea.	1	----	----	2
6–21 (J5)		2Z9406.207	TERMINAL STRIP, 6 term, 7/8" wd, bakelite insulated	ea.	2	----	----	4
4–136A (J5)		2Z9404.200	TERMINAL STRIP, ant, 16 term	ea.	1	----	----	2
	Dwg. E151–3		Radio Receiver CW3–D					
	C1	NSNR	CAPACITOR, p/o Coil Assem L1	----	----	----	----	----
340–21 (M2)	C2,7,11,15,23, 26,35,52,55, 56,59,64,70, 72,78,81,82, 93,94	3DA10–140.2	CAPACITOR, paper, 0.01 mf, 400 vdcw	ea.	76	4	4	752
	C5	NSNR	CAPACITOR, p/o Coil Assem L2	----	----	----	----	----
	C6,105	NSNR	CAPACITOR, p/o Coil Assem L3	----	----	----	----	----
	C9,10,12,13	NSNR	CAPACITOR, p/o Transf Assem L4	----	----	----	----	----
	C17,18,19,20	NSNR	CAPACITOR, p/o Transf Assem L5	----	----	----	----	----
BR–815 (C15)	C21,90	3DB8–59	CAPACITOR, electrolytic, 8 mf, 150 vdcw	ea.	8	2	2	280
1W–5D2 (C15)	C22,27,38,89, 92	3DA2–61.2	CAPACITOR, mica, 0.002 mf, 500 vdcw	ea.	20	----	1	100
XTIM4–.5 (S5)	C24,79	3DA500–121.3	CAPACITOR, paper, oil, 0.5 mf, 400 vdcw	ea.	8	1	1	48
S–0263 (S5)	C25,44,47,53, 80	3DA500–23	CAPACITOR, paper, 0.05 mf, 400 vdcw	ea.	20	2	2	200
CM20A101M	C28	3K2010114	CAPACITOR, mica, 0.0001 mf, 500 vdcw	ea.	4	----	1	20
	C29,30,31,32, 33	NSNR	CAPACITOR, p/o Transf Assem L6	----	----	----	----	----
XBS.5–11–10 (S5)	C34	3DA10–299	CAPACITOR, mica, 0.01 mf, 500 vdcw	ea.	4	----	1	20



RADIO RECEIVER CW3–D *(Front View)*

Mfr's Part No. & Mfr's Code No. (Ref. SIG 10–2)	Reference (See below)	SIG C Stock No.	Nomenclature	Unit of Measure	Quantity per Equipment	Allowance: Station Stock (1–3 Equip Ref SIG 10–2)	Initial Stock Guide: Regional or Field Stock (1–3 Equip Ref SIG 10–2)	Initial Stock Guide: Base Depot Stock (Per 100 Equip)
	TM 11–2204		Radio Receiver CW3–D (Continued)					
BR–252–A (C15)	C36,91	3DB25–23	CAPACITOR, electrolytic, 25 mf, 25 vdcw	ea.	8	2	2	200
M–408 (S5)	C39,40,41,96, 97,98	3DB8–31	CAPACITOR, electrolytic, 8 mf, 450 vdcw	ea.	24	6	6	840
BR2015 (C15)	C42,43,99,100	3DB20–13	CAPACITOR, electrolytic, 20 mf, 150 vdcw	ea.	16	4	4	560
5W (C15)	C48,51	3D9050–59.2	CAPACITOR, mica, 0.00005 mf, 500 vdcw	ea.	8	-----	1	40
	C49	NSNR	CAPACITOR, p/o Coil Assem L8	---	---	-----	-----	---
CM20A050M	C54,101,102	3K2005014	CAPACITOR, mica, 0.000005 mf, 400 vdcw	ea.	12	-----	1	60
	C58	NSNR	CAPACITOR, p/o Coil Assem L10	---	---	-----	-----	---
	C62	NSNR	CAPACITOR, p/o Coil Assem L11	---	---	-----	-----	---
	C63,106	NSNR	CAPACITOR, p/o Coil Assem L12	---	---	-----	-----	---
	C66,67,68,69	NSNR	CAPACITOR, p/o Transf Assem L13	---	---	-----	-----	---
	C74,75,76,77	NSNR	CAPACITOR, p/o Transf Assem L14	---	---	-----	-----	---
	C83,84,85,86, 87,88	NSNR	CAPACITOR, p/o Transf Assem L15	---	---	-----	-----	---
MW (S5)	C103,104	3DA6–33.1	CAPACITOR, mica, 0.006 mf, 300 vdcw	ea.	8	-----	1	40
345–21 (M2)	C3,4,8,14,16, 37,45,46,50, 57,60,61,65, 71,73,95,107	3DA100–112.1	CAPACITOR, paper, 0.1 mf, 400 vdcw	ea.	68	4	4	340
41518 (W9)	L1,10	3C4005	COIL ASSEMBLY, ant, RF input, Band #1, 1.9 to 3.6 mc, plug-in, includes C1,58	ea.	8	-----	1	24
41521 (W9)	L1,10	2C4547–2/C22	COIL ASSEMBLY, ant, RF input, Band #2, 3.4 to 5.9 mc, plug-in, includes C1,58	ea.	8	-----	1	24
41522 (W9)	L1,10	2C4547–2/C21	COIL ASSEMBLY, ant, RF input, Band #3, 5.8 to 9.4 mc, plug-in, includes C1,58	ea.	8	-----	1	24
41523 (W9)	L1,10	2C4547–2/C23	COIL ASSEMBLY, ant, RF input, Band #4, 9.4 to 16.5 mc, plug-in, includes C1,58	ea.	8	-----	1	24
41544 (W9)	L1,10	2C4547–2/C25	COIL ASSEMBLY, ant, RF input, Band #5, 16.5 to 20 mc, plug-in, includes C1,58	ea.	8	-----	1	24
41547 (W9)	L1,10	2C4547–2/C24	COIL ASSEMBLY, ant, RF input, Band #6, 20 to 24 mc, plug-in, includes C1,58	ea.	8	-----	1	24
41524 (W9)	L2,8,11	2C4547–2/C10	COIL ASSEMBLY, plate, RF output and HF osc (L8), Band #1, 1.9 to 3.6 mc, plug-in, includes C5, 49,62	ea.	12	-----	1	36
41525 (W9)	L2,8,11	2C4547–2/C15	COIL ASSEMBLY, plate, RF output and HF osc (L8), Band #2, 3.4	ea.	12	-----	1	36



Radio Receiver CW3–D *(Rear View)*

Mfr's Part No. & Mfr's Code No. (Ref. SIG 10–2)	Reference (See below)	SIG C Stock No.	Nomenclature	Unit of Measure	Quantity per Equipment	Allowance: Station Stock, 1–3 Equip Ref SIG 10–2	Initial Stock Guide: Regional or Field Stock, 1–3 Equip Ref SIG 10–2	Initial Stock Guide: Base Depot Stock, Per 100 Equip
	TM 11–2204		Radio Receiver CW3–D (Continued)					
			to 5.9 mc, plug-in, includes C5, 49,62					
41583 (W9)	L2,8,11	3C1084R–18	Coil Assembly, plate, RF output and HF osc (L8), Band #3, 5.8 to 9.4 mc, plug-in, includes C5, 49,62	ea.	12	-----	1	36
41570 (W9)	L2,8,11	3C1084R–17	Coil Assembly, plate, RF output and HF osc (L8), Band #4, 9.4 to 16.5 mc, plug in, includes C5, 49,62	ea.	12	-----	1	36
48545 (W9)	L2,8,11	3C1084R–20	Coil Assembly, plate, RF output and HF osc (L8), Band #5, 16.5 to 20 mc, plug-in, includes C5, 49,62	ea.	12	-----	1	36
41548 (W9)	L2,8,11	2C4547–2/C19	Coil Assembly, plate, RF output and HF osc (L8), Band #6, 20 to 24 mc, plug-in, includes C5, 49,62	ea.	12	-----	1	36
41528 (W9)	L3,12	2C4547–2/C14	Coil Assembly, grid, Band #1, 1.9 to 3.6 mc, plug-in, includes C6,63,105,106	ea.	8	-----	1	24
41529 (W9)	L3,12	2C4547–2/C11	Coil Assembly, grid, Band #2, 3.4 to 5.9 mc, plug-in, includes C6,63,105,106	ea.	8	-----	1	24
41530 (W9)	L3,12	3C4005–1	Coil Assembly, grid, Band #3, 5.8 to 9.4 mc, plug-in, includes C6,63,105,106	ea.	8	-----	1	24
41569 (W9)	L3,12	3C1084R–19	Coil Assembly, grid, Band #4, 9.4 to 16.5 mc, plug-in, includes C6,63,105,106	ea.	8	-----	1	24
41546 (W9)	L3,12	2C4547–2/C8	Coil Assembly, grid, Band #5, 16.5 to 20 mc, plug-in, includes C6,63,105,106	ea.	8	-----	1	24
41549 (W9)	L3,12	2C4547–2/C20	Coil Assembly, grid, Band #6, 20 to 24 mc, plug-in, includes C6,63,105,106	ea.	8	-----	1	24
T45692 (T4)	L7,16	3C316–28	Coil, filter choke, 10 hy @ 100 ma	ea.	8	-----	1	24
34102 (M4)	L9	3C341–3	Coil, filter, keyer grid, 2.5 mh	ea.	4	-----	1	12
1042 (L3)	F1,2	3Z1927	Fuse, 2 amp, 250 v, type 3AG	ea.	8	40	40	4000
1075 (L3)		3Z3275	Fuse Post, extractor	ea.	8	-----	1	24
A1 (M1)	J2,4	2Z5581–3	Jack, phone, single, open ckt.	ea.	8	-----	-----	16
2300 (D26)		2Z5821–7	Knob, bakelite	ea.	6	-----	1	18
P–310–AB (J5)	P1,2	2Z7120.12	Plug, connector, 10 prong	ea.	8	-----	-----	8
22–011–006 (C4)	R1,32,37	2Z7279–24	Resistor, pot, WW, 2000 ohm, R1 includes S1; R37 includes S2	ea.	12	1	1	300
RC30BF103M	R2,7,38,43	3RC30BF103M	Resistor, carbon, 10,000 ohm, 1 w	ea.	16	1	1	80
GB1 (A5)	R3,8,39,44	3Z6080–30	Resistor, carbon, 800 ohm, 1 w	ea.	16	1	1	80
GB1 (A5)	R4,21,31,40,60	3Z6200–82	Resistor, carbon, 2000 ohm, 1 w	ea.	20	1	1	100
RC35CE101K	R5,41	3RC35CE101K	Resistor, carbon, 100 ohm, 1 w	ea.	8	1	1	40

Mfr's Part No. & Mfr's Code No. (Ref. SIG 10–2)	Reference (See below)	SIG C Stock No.	Nomenclature	Unit of Measure	Quantity per Equipment	Allowance: Station Stock (1–3 Equip Ref SIG 10–2)	Initial Stock Guide: Regional or Field Stock (1–3 Equip Ref SIG 10–2)	Initial Stock Guide: Base Depot Stock (Per 100 Equip)
	TM 11–2204		Radio Receiver CW3–D (Continued)					
RC30BF104M	R6,10,13,26, 29,30,34,42, 46,47	3RC30BF104M	RESISTOR, carbon, 100,000 ohm, 1 w	ea.	40	2	2	211
RC41BF472K	R9,18,45,49, 51,55	3RC41BF472K	RESISTOR, carbon, 5000 ohm, 2 w	ea.	24	2	2	156
RC30BF102M	R11,33,50	3RC30BF102M	RESISTOR, carbon, 1000 ohm, 1 w	ea.	12	1	1	60
RC30BF223M	R12,54	3RC30BF223M	RESISTOR, carbon, 22,000 ohm, 1 w	ea.	8	1	1	40
	R14	NSNR	RESISTOR, p/o Transf Assem L6	----	----	----	----	----
RC30BF473M	R15,35,53	3RC30BF473M	RESISTOR, carbon, 50,000 ohm, 1 w	ea.	12	1	1	96
RC31BF474K	R16,56	3RC31BF474K	RESISTOR, carbon, 500,000 ohm, 1 w	ea.	8	----	1	40
RC30BF185K	R17,57	3RC30BF185K	RESISTOR, carbon, 2 meg, 1 w	ea.	8	1	1	40
A10–C	R19,58	3Z6580–11	RESISTOR, WW, 8000 ohm, 10 w	ea.	8	1	1	40
10C (C10)	R20,59	3Z6625–57	RESISTOR, WW, 25,000 ohm, 10 w	ea.	8	1	1	40
P–20–2000 (C10)	R22,61	2Z7279–102	RESISTOR, pot, WW, 2000 ohm, w/SPST sw	ea.	8	----	1	200
A10C (C10)	R23,62	3Z5425.6	RESISTOR, WW, 2500 ohm, 10 w	ea.	8	1	1	40
GB (A5)	R24,28	3Z6750–46	RESISTOR, carbon, 500,000 ohm, 1 w	ea.	8	1	1	64
GB (A5)	R25,27,48	3Z6725–27	RESISTOR, carbon, 250,000 ohm, 1w	ea.	12	1	1	84
RC30BF153K	R36	3RC30BF153K	RESISTOR, carbon, 15,000 ohm, 1 w	ea.	4	1	1	32
	R52	NSNR	RESISTOR, p/o Transf Assem L15	----	----	----	----	----
RC35CE103K	R63,64	3RC35CE103K	RESISTOR, carbon, 10,000 ohm, 1 w	ea.	8	1	1	64
RC30BF471K	R65	3RC30BF471K	RESISTOR, carbon, 500 ohm, 1 w	ea.	4	1	1	20
9950 (C6)		2Z8650.5	SOCKET, tube, octal, bakelite	ea.	12	----	----	36
S8M (A13)		2Z8795.9	SOCKET, tube, octal	ea.	44	----	----	88
S4 (A13)		2Z8674.8	SOCKET, tube, bakelite, 4 cont	ea.	8	----	----	24
29525 (W9)		2Z8673.24	SOCKET, xtal, 3 cont	ea.	4	----	----	8
	S1	NSNR	SWITCH, p/o Resistor R1	----	----	----	----	----
	S2	NSNR	SWITCH, p/o Resistor R37	----	----	----	----	----
1325L (M1)	S3	3Z9827.7–3	SWITCH, rotary, 2 sect, 4 pole, 5 position	ea.	4	----	1	12
1506 (A14)	J1,3	2Z9403.31	TERMINAL STRIP, 3 term	ea.	8	----	----	16
T439–70 (T4)	T1,3	2Z9632.58	TRANSFORMER, AF, output, 6C8G plate to 500 ohm CT line	ea.	8	----	1	56
463–001–167 (J1)	T2,4	2Z9613.60	TRANSFORMER, power, pri 115 v, 60 cps, secd #1 6.3 v @ 2.5 amp, secd #2 5 v @ 2 amp, secd #3 720 v CT @ 50 ma	ea.	8	----	1	56
54659 (S3)	L4,5,13,14	2Z9641.34	TRANSFORMER ASSEMBLY, IF, 455 kc, L4 includes C9,10,12,13; L5 includes C17,18,19,20; L13 includes C66,67,68,69; L14 includes C74,75,76,77	ea.	16	----	1	128
55251 (S3)	L6	2Z9644.4	TRANSFORMER ASSEMBLY, BFO, 455 kc, includes C29,30,31,32,33, R14	ea.	4	----	1	32
55251 Mod. (W9)	L15	2Z9641.226	TRANSFORMER ASSEMBLY, BFO, 455 kc, includes C83,84,85,86,87,88, R52	ea.	4	----	1	32
JAN6K7	V1,3,10,12	2J6K7	TUBE, type 6K7	ea.	16	32	32	3200
JAN6C8	V4,5,13,14	2J6C8	TUBE, type 6C8	ea.	16	32	32	3200

Mfr's Part No. & Mfr's Code No. (Ref. SIG 10-2)	Reference (See below)	SIG C Stock No.	Nomenclature	Unit of Measure	Quantity per Equipment	Allowance: Station Stock 1-3 Equip Ref SIG 10-2	Initial Stock Guide: Regional or Field Stock 1-3 Equip Ref SIG 10-2	Initial Stock Guide: Base Depot Stock Per 100 Equip
	TM 11-2204		Radio Receiver CW3-D (Continued)					
JAN6K8	V2,11	2J6K8	TUBE, type 6K8	ea.	8	16	16	1600
JAN80	V6,15	2J80	TUBE, type 80	ea.	8	16	16	1600
JAN6SN7GT	V7	2J6SN7GT	TUBE, type 6SN7GT	ea.	4	8	8	800
JAN6AC7/1852	V8	2J6AC7	TUBE, type 6AC7/1853	ea.	4	8	8	800
JAN6SA7	V9	2J6SA7	TUBE, type 6SA7	ea.	4	8	8	800
JANVR-105-30	V16	2JVR105-30	TUBE, type VR-105-30	ea.	4	8	8	800

Expendability of individual items will be in accordance with the latest edition of Signal Supply Catalog SIG 5, which shows expendability of all items stored and issued by the Signal Corps.

HEADQUARTERS ARMY SERVICE FORCES
WASHINGTON 25, D. C., 11 July 1945

Army Service Forces Signal Supply Catalog, SIG 10-325, Fixed Plant Maintenance List for Receiving Equipment, has been prepared under the supervision of the Chief Signal Officer, and is published for the information and guidance of all concerned.

[SPX 461 (5 Jul 45)]

BY COMMAND OF GENERAL SOMERVELL:

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Refer to FM 21-6 for explanation of distribution formula.

Appendix 12 - EXTRACTS FROM US WAR DEPARTMENT TECHNICAL MANUAL TM 11-487 ELECTRICAL COMMUNICATION SYSTEMS EQUIPMENT 2 OCTOBER 1944

Western Electric Co. D-156000 2kW Transmitter Weight 2428 lbs.
Source US War Department (1944b) (Page 443, Figure 1491, Paragraph 1422.

One unit-transmitter, mounted in 3 bays. Local start-stop, remote signaling, fixed frequency operation. May also be used as exciter for PW-40 arranged for operation as a linear amplifier. Part of entire terminal for single sideband, reduced carrier, radio telephone system for twin channel operation, giving 6 two-way telegraph circuits over one two-way radio telephone circuit. Entire terminal consists of radio transmitter; distortion measuring set; single sideband receiver (Western Electric D-99945 Fig. 1492, par 1423) including its associated testing and measuring equipment; and V.F. Carrier Telegraph Equipment (par 1025). A picture of the unit is available on page 468 of US War Department (1944b), Technical Manual TM 11-487, but is of poor quality.

AN/FRR-3 Press Wireless Diversity Receiver. Weight 650 lbs.. Page 450, Figure 1492, Paragraph 1423, Technical Manual TM 11-487. Used as Radioteletype Receiving Station.

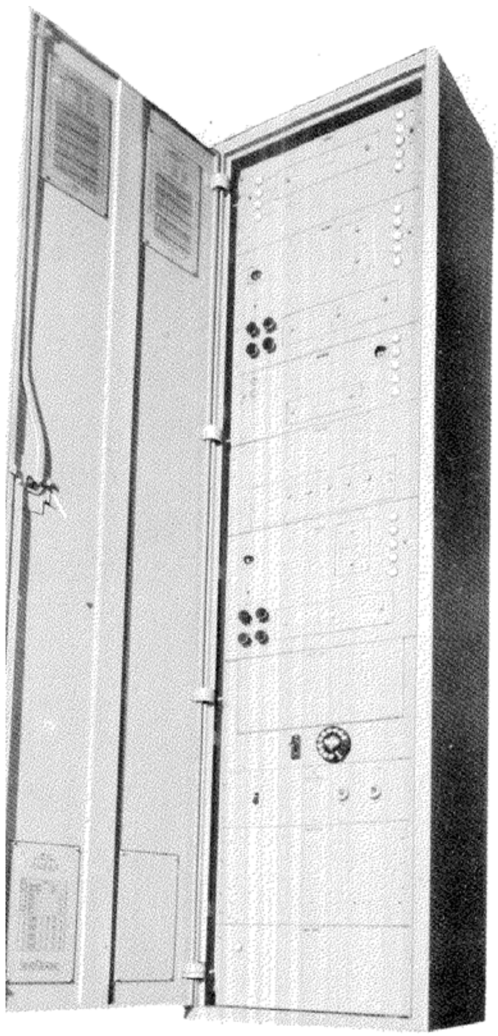

Fig. 23: Press Wireless Diversity Receiver Type AN/ FRR-3.
Source: US War Department (1944b) Page 451, Figure 1492, Paragraph 1423.

Emission – Special Range 2.4 to23 Megahertz,
Control by Crystal - Holder FT-249,
Normal antenna 2 Rhombics Fig. 1539, Output Balanced 600 Ohm,
One unit; local or remote control; requires one terminal unit AN/FGC-l.

Oscillator Exciter 0-5 /FR Press Wireless FS12A Keyer Weight 81 lbs. Page 242, Figure 1025, Paragraph 1027, US War Department Technical Manual TM 11-487.

Provides a means for keying an HF radio transmitter by the frequencyshift method to obtain "Mark" and "'Space" conditions for transmitting signals over radio circuit. The "Space" frequency i.e. 425 cycles lower than the carrier frequency and the "Mark" frequency is 425 cycles higher than the carrier frequency. Thus the frequency shift is 850 cycles and is suitable for reception by Radioteletype Terminal AN/FGC-l. Exciter receives d-c telegraph signals from teletypewriter or other sending source and its output side is connected to the radio transmitter using a coaxial line. Exciter replaces the regular radio frequency Oscillator of the radio transmitter to which it is connected. Equipment is panel mounted and arranged for use on 19-inch relay Rack. Running spares are provided.

Press PW-40 (kW) Amplifier Weight 21715 lbs. Shipping tons 41.6. Figure 1489, Page 448, Paragraph 1422, US War Department Technical Manual TM 11-487.

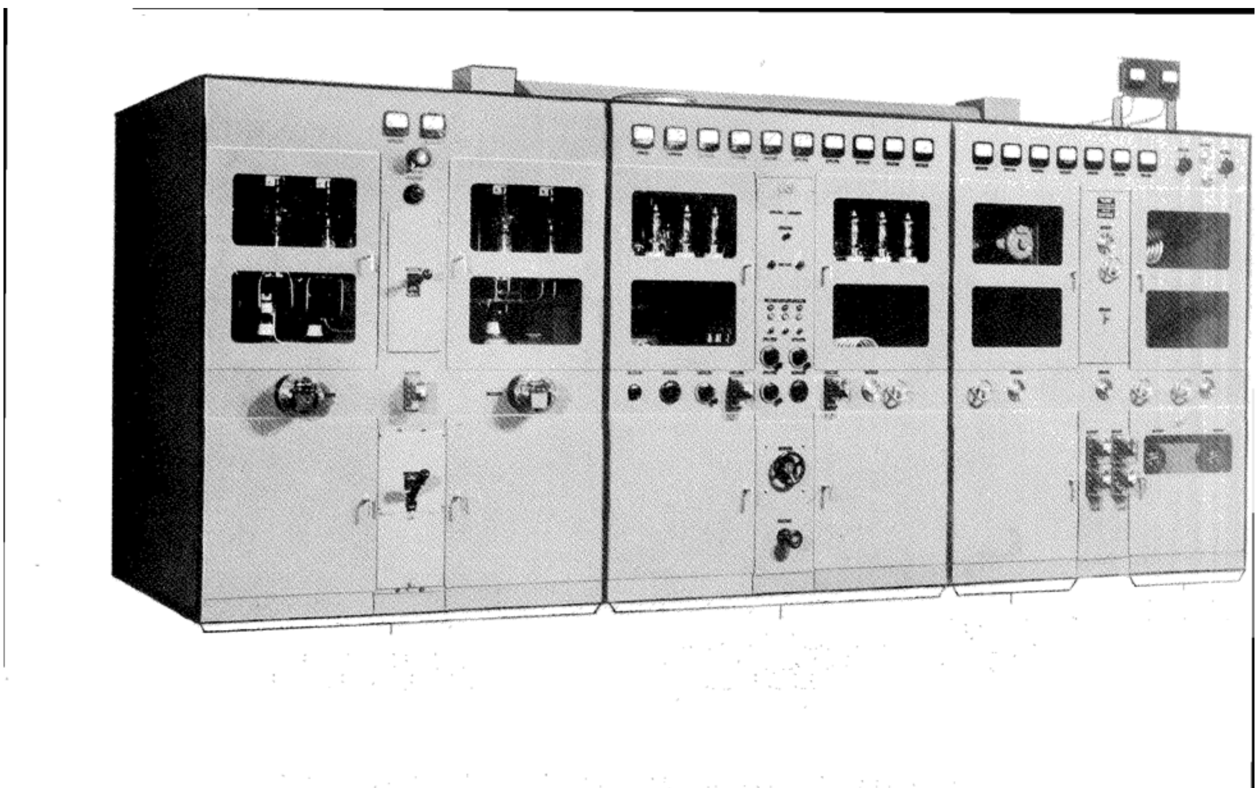

Fig. 24: Press Wireless Type PW-40: Radio Transmitter
Source: US War Department (1944b) Page 448, Figure 1489, Para. 1422.

Includes from the left - rectifier, exciter, power amplifier. Water cooling unit and expansion tank are not shown. Telegraph, teletype or single sideband operation; local start-stop remote keying; manual selection of master oscillator, one of 6 crystals or external exciter; external exciter, for teletype operation required. May also be arranged as a linear amplifier for single sideband operation requiring Western Electric Co. D-156000 transmitter as exciter.

Teletype Terminal Equipment AN/FGC-1 Weight 425lbs. Page 242, Figure 1022, Paragraph 1027, War Department Technical Manual TM 11-487.

Voice frequency carrier telegraph equipment for use as single channel two-tone space diversity radioteletype receiving terminal is shown below. Associated radio receivers invert the incoming signals to a frequency of 2125 cycles for the "closed" condition and 2975 cycles for the “open" condition of the sending contacts. The AN/FGC-1 equipment rectifies these signals to d-c telegraph signals for operation of teletypewriter equipment at a signal center.

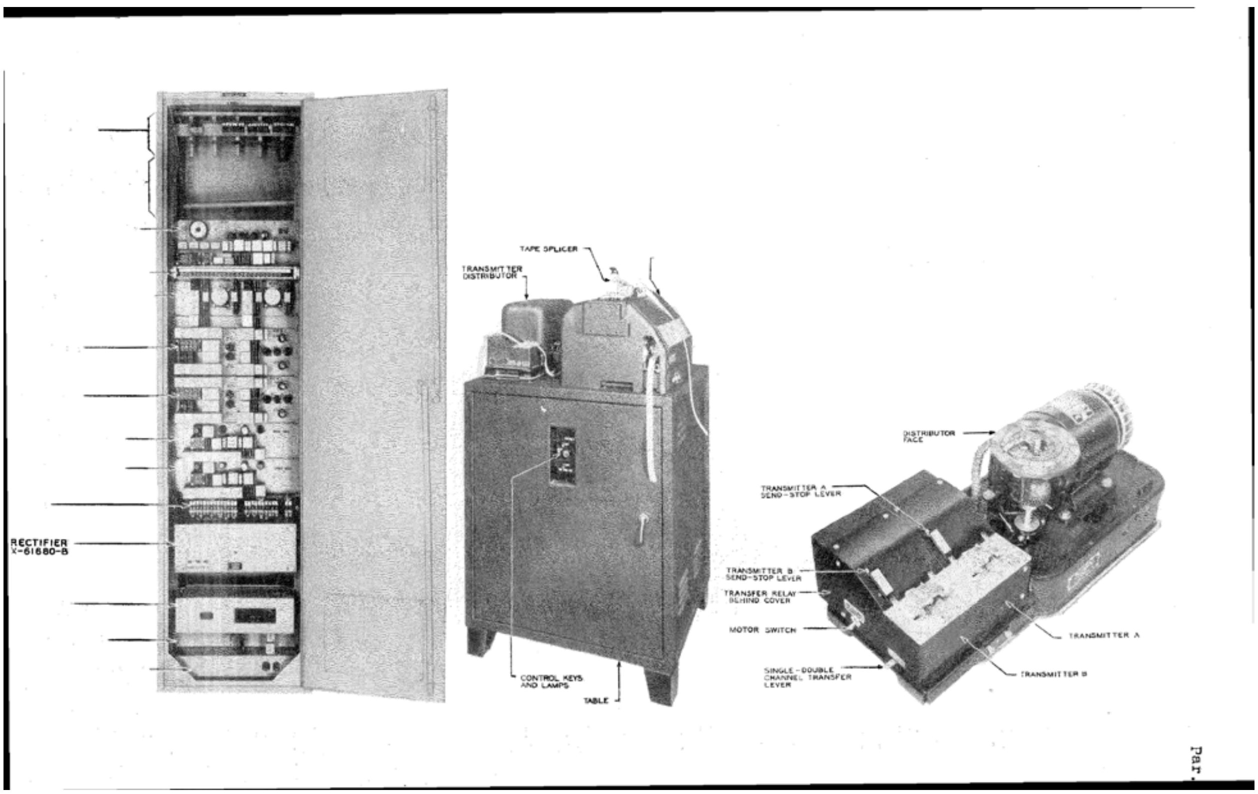

Figure 1022 Figure 1023 Figure 1024

Fig. 25: Radioteletype Equipment
<u>Source</u>**:** US War Department (1944b) Page 242, Figure 1022, Paragraph 1027.

Figure 1022: Radioteletype Terminal AN/FGC-1.
Figure 1023 : Teletypewriter Subscriber Set 132A2
Figure 1024: Transmitter- Distributor XD 91.

Appendix 13 EXTRACTS FROM CHAPTER 18: SIGNALING THE WORLD IN "THE SIGNAL CORPS: THE OUTCOME (MID-1943 THROUGH 1945)" BY GEORGE RAYNOR THOMPSON AND DIXIE R. HARRIS (1991). (http://tothosewhoserved.org/usa/ts/usatss03/chapter18.html)

The commodity dispatched overseas in greatest quantity during World War 2, and at greatest speed, was neither munitions, nor rations, neither clothing nor supply items. It was words, billions of words, messages of strategy and command, plans of campaigns and reports of action, requests for troops and schedules of their movements, lists of supplies requisitioned and of supplies in shipment, administrative messages, casualty lists. All of this and much more, such as services for the press (news dispatches, telephotos) and services for the soldiers (expeditionary force messages), poured over far-flung wire, cable, and radio circuits and channels—routine and urgent, plain text and enciphered, on a scale unimagined before the war by any communications agency, military or commercial. All this was the work of the Signal Corps Army Communications Service. ACAN was actually moving some fifty million words a day (with a capacity of a hundred million daily) toward the end of World War 2. Maj. Gen. Frank E. Stoner, chief of the Army Communications Service throughout the war, estimated that eight words were sent overseas for every bullet fired by Allied troops. "The pen is still mightier than the sword," he quipped.

In mid-1943 the major ACAN stations outside the United States were in London, Algiers, Accra, Cairo, Asmara, Karachi, New Delhi, Brisbane, and Hawaii. Many lesser stations tied into the net wherever a local Army radio served local troops or commands, as at Reykjavik, Tehran, Noumea, and on numerous Pacific isles and atolls. From the major stations, which often served as relay points to outlying posts, lesser radio nets and wire lines radiated out to meet the needs of local Army installations. Control over this world-wide military communications system—ACAN—was vested in the Chief Signal Officer in the Washington headquarters, the location of the net control station WAR.

Army communications before Pearl Harbor scarcely extended beyond the boundaries of the continental United States. "Our facilities," General Stoner recalled, "consisted primarily of radio communications, some wire and some cable to each one of the Corps Area Headquarters, and to some of the overseas commands, such as Puerto Rico, Panama, Hawaii, and the Philippines." Then suddenly the exigencies of the first year of war took the United States Army around the world, and with it went the Army's communications system. At the mid-point of the war, General Stoner could already say with pride, "We have got our net in, and it is the finest network in the world."

Fiscal year 1944 saw the vigorous emergence of the Army Command and Administrative Network as a communications system unrivaled either in peacetime or in time of war. Its myriad circuits enmeshed the nation and reached out to bring into its web every overseas headquarters and every command, however remote. It transmitted securely, thanks to cipher machines. And it transmitted fast, as signalized by the round-the-world passage on 24 May 1944 of a test message, completing the trip in three and a half minutes (a similar test in 1945 cut the time to nine and a half seconds). The ACAN system therefore met two of the most exacting requirements in military communications—security and speed. A third requirement was that traffic capacity be increased. The number of radio channels that the frequency spectrum permitted could not be multiplied. Laws of physics and the immutable spectrum itself forbade. Ways had to be found to provide greater traffic capacity over the same channels, using the same limited number of frequencies.

Thus, while the need for speed forced the abandonment of slow hand-keyed transmission and while the need for both speed and security urged the development of machine cipher devices, the necessity for greater traffic capacity compelled the Signal Corps to develop mechanical sending and receiving apparatus employing semiautomatic radio and carrier techniques, permitting the transmission of several communications simultaneously over circuits that handled only one channel before.

Fig. 26: WACs operate teletypewriters at ETOUSA Communications Center, Paris
Source: Thompson and Harris (1991) p. 583

The basic techniques that enabled these achievements were radio teletypewriter applications, coupled with carrier multichannel and single sideband radio developments. The SSB technique was in itself a major innovation that provided several shortwave (HF) circuits using only one-half, or one sideband (suppressing the other sideband) of the usual spread of transmitter frequencies that extend out for several thousand cycles on each side of the center frequency. The technique, valuable for the conservation of frequencies in the severely congested short-wave portion of the spectrum, had been partly developed by AT&T. Early in 1942, W. G. Thompson of AT&T discussed with Stoner the possibility of further development and perfection of the technique for military use. SSB was needed at once (coupled with teletypewriter equipment and automatic ciphering) to speed and secure Army's growing traffic loads. SSB proved out well and quickly, and the first system, leased from commercial companies, opened successfully between Washington and London on 20 July 1942. Other big multichannel SSB systems followed, to Algiers, Brisbane**,** and elsewhere, until the technique became standard on all major radio circuits between the War Department and overseas ACAN stations.

The conversion of numbers of Army circuits to RTTY (radioteletype) the world over constituted "perhaps the most important single Army Communications Service development during the year." This was the cautious estimate of an ASF report of fiscal year 1944. The author ventured to add that the development was "revolutionary." For not only did radioteletype eliminate the slow transmission of Morse code by hand-keyed radio telegraph (accompanied by the still slower procedures of hand enciphering and deciphering) but it also enabled semi-automatic methods of transfer of traffic from wire to radio circuits, and vice-versa. In addition, it created a standard world-wide message transmission system, comparable to a single-gauge railroad system, over which any train can move to all points.

The standard "gauge" of the ACAN "track" was the 5-unit perforated tape, employing the five units of the standard teletypewriter code, which had been in general use for some years. This tape, with its 5-unit code perforations, was interchangeable between landline, radio, and overseas cable circuits. The resultant message in tape form could be routed by both types of circuits or a combination of circuits (wire and/or radio). After the creation of the tape at the point of origin, all the rest of its handling along the way, the relays and the transfers till the destination was reached, was automatic (except for reading or routing the tapes at relay points). The typing of the delivered text at the destination was automatic.

The typing of whatever copies might be needed for information addressees along the way was likewise automatic. "A message could go from Keokuk, Iowa, around the world with drop-off copies at intermediate points, with manual typing necessary only at the point of origin," General Stoner told an Army Industrial College audience after the war and, very important in military communications, the encipherment of the plain language text at the point of origin and its decipherment at every point of delivery were also automatic, accomplished by cipher machines working in conjunction with the teletypewriters.

During 1944 and 1945 increasing numbers of ACAN signal centers completed conversion to semiautomatic operation, relieving the troubles engendered by greater traffic loads requiring smaller personnel forces to move them. For example, before conversion, the growing load at the Atlanta station (having increased by more than 15,000 words a day) compelled the rerouting of some of that traffic by way of Washington and Dallas. After the semiautomatic equipment went to work at Atlanta, the station handled the full load readily. Another alleviating technique was the conversion of some circuits from operation at 60 words per minute to 100. This speed-up relieved congestion on 16 transcontinental wire circuits, on 2 radioteletypewriter circuits extending overseas from Washington, the one to Caserta, Italy, the other to Honolulu, and on a third circuit, one between Manila and New Delhi.

Extensive use of "packaged" sets of the new equipment helped in the conversion. The semiautomatic packaged unit**,** teletypewriter set AN/TGC-1**,** was a streamlined militarized version of the first bulky product. It was compact, rugged, and easy to install, operate, and maintain. It was also tropicalized. The War Department Signal Center, where new ACAN equipment regularly met its first trials and tests, had designed and developed the packaged sets under the officer in charge in 1943, Maj. William S. Sparks, and his assistant, Capt. Ralph A. Scofield. On 15 January 1944 the radio semiautomatic section went to work in the signal center, encountering "little trouble." Its operations showed "immediate improvement," Stoner reported. The equipment enabled the center to handle its World War 2 peak

Fig. 27: Teletype conference, as viewed in telecom room of the Pentagon. Flashlight glare has obliterated the messages. Source: Thompson and Harris (1991) p. 585.

Meanwhile much was done to streamline and improve ACAN operating efficiency, not all of it involving equipment, but rather procedures and methods traffic engineering such as the juggling of circuits and traffic loads in various ways in order to secure maximum effectiveness and economy. One innovation toward a uniform intra-Army relay procedure took effect on 1 February 1945. It was a revised teletypewriter procedure, intended to simplify and reduce transmission time. It did eliminate the confusion that had previously hampered the relay of messages to combat zone stations.

Telecommunication Group Conference (Telecon) Facilities

Radioteletype and automatic on-line encipher and decipher machines made conferences possible between various headquarters and men thousands of miles apart. The conferring parties needed but to assemble at the ends of an ACAN RTTY circuit and put questions that a teletype operator tapped out. The receiving party could answer and question in turn with only such delay as the typing time required, since both the transmission time and the encipher/decipher time were so nearly instantaneous as to be negligible. This was Sigtot.

Thus, the instantaneous operation of the teletypewriters at the sending and receiving stations, however many thousands of miles apart, whether the connecting links were wire, radio, submarine cable, or all three, enabled men to confer with each other almost as over a telephone line. The use of a projection screen, which would display to a room full of persons the outgoing and incoming sentences, made possible teletypewriter conferences between groups of men at the ends of the circuit. In addition the system provided a written record of the discussions. All this came to be called a telecon system and came to be used extensively and importantly, sometimes between more than two parties, by the use of several circuits, each with its own viewing screen. Just before the Normandy invasion, for example, General Marshall in effect brought together in conference General Eisenhower in the European theater and General MacArthur in the Southwest Pacific. He also brought in by means of a third circuit and screen Maj. Gen. John R. Deane, head of the U.S. military mission in Moscow. The remarkable, almost world-wide, conference lasted over an hour, and produced, Stoner stated, “an understanding between commands equal to one where all would be present in person.” He exulted, “We carried three messages to Garcia today.” This tremendous communications facility, he added, was “really one of the secret weapons of the war.”

Time and tireless effort remedied the initial difficulties of the teletype conference system. Before the end of 1944, scheduled conferences over ACAN circuits were averaging three a day, some of them running to as many as 20,000 words.

By V-J Day Sigtot facilities were available at 19 overseas stations:

Algiers	Honolulu	Paris
Asmara	Kharagpur	Recife
Brisbane	Leyte	Tehran
Caserta	London	Valognes
Chungking	Manila	Versailles
Guam	Moscow	
Hollandia	New Delhi	

Communications for VIP Conferences - Extracts

The second Quebec conference (OCTAGON, September 1944) made good use of the latest radioteletypewriter conference facilities. These tied in with the Sigtot facilities in the ACAN system extending to Washington and San Francisco and to such overseas points as New Delhi, Kharagpur, Brisbane, and Hollandia.

The connection to General MacArthur's headquarters through Hollandia was importantly used, for it was at this conference that the Combined Chiefs of Staff sought to determine whether General MacArthur could attack Leyte earlier than 20 December, as then planned. In the course of the debate in the Chateau Frontenac, General Marshall requested General Handy to go to the signal control room adjacent and ask MacArthur in Hollandia, New Guinea, by radioteletypewriter if he could advance the attack date. Within five minutes Handy rejoined the conferees with the answer that MacArthur's headquarters had said he could invade on 20 October.

Expansion Through V-J Day

Physical improvements in the Washington area outside the War Department Signal Center installations included by 1945 a UHF control system that linked station WAR with the receiver station in La Plata in nearby Maryland and with the transmitter stations at Fort Myer and Battery Cove, Virginia. This system provided a dependable line-of-sight radio service that was unhampered by wire line troubles or weather vagaries. As of June 1944 the Fort Myer and Battery Cove transmitter stations and the La Plata receiving station served as terminals for more than a score of major overseas ACAN circuits and stand-by continental circuits, accomplishing the task with an appropriate quantity of radios, up to 40 kilowatts in power.

ACAN installations overseas expanded rapidly in 1944 following the Normandy invasion and accelerated successes in the Pacific. Major stations developed in France, principally in Paris and Reims, at Hollandia in New Guinea, in Manila, and finally at the war's end, in Frankfurt, Germany, and in Tokyo.

Throughout the last two years of World War 2, the New Delhi station served as a major link in the ACAN world-wide system. Station JGTA occupied an air-conditioned building, which also housed the theater signal section**.** By late 1944 the station equipment included a Federal BC-340 (10 kilowatts) working on the Asmara 2-tone duplex A and B circuits, a Federal BC-399 (one-kilowatt) used as a utility transmitter, a Federal BC-270 (300 watts) on the Ledo circuit, a Hallicrafter BC-610 (300 watts) on the Bombay circuit, a Federal BC-447 (300 watts) on the Ramgarh manual circuit, a Federal BC-325 (400 watts) on the Karachi 2-tone circuit, and a Federal BC-399 (one-kilowatt) working 2-tone on the Chabua circuit. There were 3 large Press Wireless sets. One of 15 kilowatts worked the circuit to Brisbane**;** a second, of 40 kilowatts, served the Asmara C circuit at reduced power; and a third, of 2.5 kilowatts, operated a Boehme circuit with Chungking. A Wilcox Type 96-C transmitter, 3 kilowatts, worked 2-tone on the Calcutta circuit, a Federal BC-399 1 kilowatt performed on the circuit with Myitkyina in Burma, and a Federal BC-399 was employed as a utility transmitter. Radio traffic over these New Delhi circuits exceeded 13,000,000 words during the month of March 1945. Power for the equipment came from seven 50-kilowatt and two 100-kilowatt diesel-engined generators. The New Delhi antenna system included 11 rhombics —2 directed on Asmara, one each **to** Washington, Brisbane, Kunming, Chungking, Calcutta, Chabua, Myitkyina, Kandy, and Hollandia. Three long wire antennas were directed on Ledo, Bombay, and Ramgarh.

ACAN in the Pacific

After the loss of WTA Manila upon the fall of the Philippines early in 1942,Melbourne, Australia, first became the anchor of the ACAN system serving the South and Southwest Pacific areas. As the campaigns against the Japanese progressed, Brisbane (WVJJ, later WTO) replaced Melbourne as the ACAN station site. Equipped with powerful transmitters, the Brisbane station by mid-1943 was able to reach San Francisco directly and dependably, as well as stations in the CBI, thereby establishing a reliable round-the-world belt line of signals.

Brisbane traffic reached a million words a day as the campaigns advanced up through the islands of the south and southwest Pacific.

Captured in April 1944, Hollandia by May became a major station, WVLH. In October, MacArthur's headquarters arrived and Hollandia became a communications center. The ACAN transmitters at Hollandia maintained connections with New Delhi and San Francisco, depending on radioteletypewriter supplemented by manual circuits to the many lesser stations among the islands. Traffic grew to a million words a day by mid-November 1944 and remained high even after GHQ moved to Leyte because supply headquarters USASOS remained for a time at the New Guinea base. Messages coming into the theater from outside continued to flow through Hollandia, where they were decoded, screened, and sent on to Leyte by courier or radio. The Hollandia ACAN station moved to Manila early in 1945**,** and the old station WTA, which had fallen to the Japanese on the capture of Corregidor in May 1942, arose from its ashes.

The new WTA Manila used the 40-kilowatt transmitter that had gone in at Brisbane nearly two years earlier. It was set up at the Manila Country Club. The receiver installation went in the receiver station the Japanese had built. Code room, message center, and teleprinters were installed first at the Trade and Commerce Building, but later moved to the Municipal Waterworks Building. The USASOS at first used these ACAN facilities but later acquired parallel circuits of its own and removed to the Far Eastern University. A second multichannel

SSB system was set up, beginning operations between Manila and San Francisco in June 1945. Manila ACAN thus became one of the largest overseas stations, with radioteletype circuits to Okinawa, San Francisco, Honolulu, Guam, Noumea, Finschhafen, Brisbane, Hollandia, Leyte, Calcutta, New Delhi, and Chungking.

Telephoto—Pictures by Wire and Radio

Late in 1941, the Signal Corps, together with an engineer from Acme Newspictures, undertook to adapt equipment for wire telephoto work, and in June 1942 ACAN set up its first telephoto net, in consequence of the submarine warfare off the east coast of the United States. Daily submarine situation maps were distributed over the net, which extended from the first installations at New Orleans and New York City to each of the four defense commands and to the headquarters of the Alaska Communication System. Semiweekly weather charts were also transmitted, over a wire line network for the AAF. The technique, when applied to radio channels, became facsimile. It was first used on the Algiers multichannel single sideband transmitter when a special team flew there in February 1943 to ready the equipment, including a developing laboratory. The corresponding equipment at the Washington end, in the Munitions Building, was at first crammed into a converted broom closet presided over by Sgt. Joseph E. Dunn of the 17th Signal Service Company. Dunn operated the net control station of the entire telephoto system.

Over the Algiers facility news pictures from the North African theater traveled direct to station WAR. Similar radiophoto provisions followed in ACAN stations in London, Paris, Caserta, Honolulu, Brisbane, Manila, and, finally, Berlin. From processing a few dozen prints weekly beginning in June 1942, the operators of the radio telephoto facilities in station WAR reached a peak of 600 prints processed in the first week of the Normandy invasion. The pictures were all black and white, and each required about seven minutes to transmit and receive.

The picture or print to be sent was clamped to a drum at the transmitting station, and at the receiving end a similar drum was covered with sensitized paper. While both drums revolved at the same speed, one hundred revolutions a minute, synchronized, a beam of light scanned the transmitting drum laterally, covering a band about an inch wide a minute. The intensity of the beam, varying with the black, white, and gray tones of the picture, modulated the radio wave, which traveled to the receiver where the varying light was recreated, varying exactly in step with the pick-up beam at the transmitter end. As the beam at the receiver traveled over the sensitized paper on the drum, it reproduced the scene.

The methods and quality of this process improved steadily through the war. Then in August 1945, the first news color picture ever transmitted by radio (Sergeant Dunn receiving) arrived from Berlin on 3 August, picturing President Truman, Prime Minister Atlee, and Marshal Stalin at the Potsdam conference. By the end of 1945 there were six outlying stations of the facsimile net in operation: Manila, Honolulu, San Francisco, Paris, Tokyo, and Frankfurt. There had been at one time or another during the war 25 such stations. The peak year of facsimile traffic was 1944 when 11,533 transmissions passed over the ACAN system.

The conditions of World War 2 made it imperative that the U.S. Army create and use a world-wide communications net, and Signal Corps ACAN became that net. Station locations around the world were obtained by conquest or by emergency agreement. Signal Corps operated and controlled the stations. Not all station sites were equally good and reliable since the vagaries of the ionosphere, by which long-distance high frequency radiations were directed over the earth, favored some sites and hampered others. By trial and error the better sites were discovered. The best routes, over which high frequency sky waves were most reliably transmitted with least disturbance, were found to lie around the equatorial regions. Stations in these areas—Asmara, Karachi, New Delhi, Manila, Honolulu—with their high capacity, multichannel radioteletypewriter equipment provided Signal Corps and the U.S. Army with dependable channels for any number of messages**,** which could be relayed to other stations over the world efficiently, inexpensively, and rapidly, under a single integrated system. Private communications companies some years before the war had demonstrated that a message could be sent around the world in about nine minutes—but with some awkwardness of relaying and retransmitting through different facilities and companies.

On 24 May 1944 (the centennial of the first telegraph message that Samuel Morse sent from Washington to Baltimore) Signal Corps transmitted the same words that Morse had telegraphed in 1844: "What hath God wrought?" Station WAR transmitted the words both east and west around the world belt line. The two messages passed through four relay stations, San Francisco, Brisbane, New Delhi, and Asmara. The eastbound message made it first, returning to Station WAR in three and one-half minutes. The westbound message arrived a minute and a half later. Again on 28 April 1945, after the Signal Corps had installed faster radioteletypewriter equipment (semiautomatic tape relay), another message circled the world during a Sunday afternoon Army Hour radio program. "This is What God Hath Wrought, Army Communications Service," sped out of WAR, was automatically relayed by radioteletypewriter from Washington through San Francisco, Manila, New Delhi, and Asmara. Having covered 23,200 miles in five skywave hops by high frequency radio, it returned and was printed on a WAR receiving teletypewriter in nine and one-half seconds, those seconds representing the mechanical transmission time. The flight through the sky of course occurred at the speed of light—in one-eighth of a second.

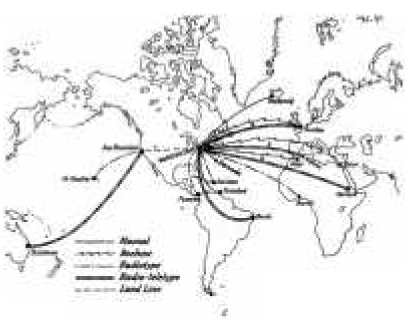

Fig. 28: Army Command and Administrative Network Overseas, December 1943
Source: Thompson and Harris (1991) p. 608

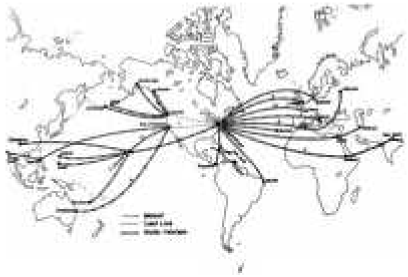

Fig. 29: Army Command and Administrative Network Overseas, June 1945
Source: Thompson and Harris p. 609

Footnotes: Extracts from Chapter 18. (Included for reference to text above)

11. Annual Rpt, ASF, FY 44, p. 188. A single large SSB radio could provide six RTTY channels simultaneously, each operating at 60 words per minute, together with a two-way telephone or radio-photo channel, all within a single radio frequency band. Stoner, Speech to the Federal Com Bar Assn, 11 Jan 46, p. 4, Com

30. CSigO, Annual Rpt, FY 44, pp. 543f. By 1944 the Signal Corps was acquiring the entire output of Press Wireless production of 40- kilowatt SSB transmitters. The SSB systems the Army had employed earlier, as on the Washington- London circuit, had been leased from AT&T. By V-J Day the Signal Corps was operating a total of 12 SSB systems, (1) Oakes, The Army Comd and Admin Com System, pt. II, p. 39. (2) Melia, SigC Fixed Com in World War 2: Sp Assignments and Techniques, p. 16. (3) CSigO, Annual Rpt, FY 45, p. 704. (4) Stoner, Draft MS Comment, Jul 59.

Appendix 14 - TYPES OF EQUIPMENT POST-WAR, CAPALABA AND HEMMANT

Capalaba Equipment – Receivers

The late Peter Oliveri in an interview during June 2015 recorded that from 1952 onwards, after the takeover by the PMG, equipment at the Capalaba Radio Receiving site on hand included RCA Type AR-88 receivers, three Hammarlund Super Pro receivers and one or two Australian built Kingsley Type AR7 receivers. Two RCA Type AR-88's receivers were used as back-up to landlines for the Australian Broadcasting Commission (ABC) on the Sydney to Melbourne link and for the public broadcasting stations 4QG and 4QR in Brisbane. During the war Peter was in New Guinea & New Britain from 1943 to 1945 so had no knowledge of the war period at Capalaba. Peter also stated that any later documents or photos relating to the site would have been held at the PMG regional head Office in Creek Street the City (Brisbane). He "did not remember seeing anything associated with war time activity (at Capalaba) except antenna drawings and that's about all. I did not take photos of the racks or gear. Didn't seem important at the time. Al Smith worked at Capalaba and I was at Birkdale. Only CW or MCW was used, no SSB".

Lionel Sharp also worked at Capalaba after the war and recorded that he sighted three wartime Radio Corporation of America (RCA) Type AR-88 receivers and three wartime Hammarlund Super Pro Receivers. He also recorded that he saw an STC Type AMR 300 receiver. The latter was produced by the Standard Telephones and Cables Pty. Ltd. Sydney, Australia around 1945. It was tuned to a southern ABC shortwave transmitter with the program being fed to the ABC studios to cover for landline failure. Later there was also a couple of GEC Type BRT 400 receivers which were used for the same purpose. Only one Racal Type RA17 receiver that came along in about 1956 was sighted. He also confirmed that he did not sight any Kingsley Type AR7 receivers.

The use of Wilcox CW3-D Radio Receivers at Capalaba during World War 2 has been confirmed by Lionel Sharp. He has recorded that these receivers were still at Capalaba after the war. They were "reconditioned" by the PMG (unserviceable capacitators were replaced) before being used on the RTTY circuit to Townsville.

Paul Hayden records that equipment at Capalaba that he sighted included Racal Receivers Type RA17's, first produced in the UK in 1954, and Racal Transmitters. The Racal receivers used the Wadley Loop principle and Capalaba was the only place where they could be viewed. They were the pride and joy of the late Fred Lubach VK4RF. The Radio Branch's Radio Inspectors had their own Racal receiver with a Racal Transmitter driven by the local oscillators from the desk top receiver making the system into a transceiver. Other equipment at the Radio Branch was German frequency measuring equipment and a Nems Clarke VHF receiver with spectrum display. World War 2 Wilcox Electric Co. receivers and Standard or Federal transmitters were not seen but were spoken about. He also knew the GEC Type BRT400 which came with an external crystal oscillator for about six frequencies. One was used every day. It was first manufactured in 1947.

In summary the HF receivers sighted by the above were:-

Made in the USA – AR-88 (RCA), Super Pro (Hammarlund), Wilcox CW3-D (Wilcox Electric Co.)
Made in Australia- AMR300 (STC).
Made in the UK - RA17 (Racal), BRT400 (GEC).
Some receiver details can be seen at Kurrajong Radio Museum, http://vk2bv.org/archive/museum/ and also at http://www.radiomuseum.co.uk/racal.html

John Berry recorded in November 2015 that In the early 1960's he was a PMG radio trainee, and spent some time at both Hemmant and Capalaba. When he was at Capalaba, there was one man in charge of the receiving station, and his name was Fred Lubach. At the other end of the building, the Radio Inspectors had frequency monitoring equipment to check the frequency of radio and television transmitters. The two sections were separated by a door which was open most of the time.
The Radio Inspectors' 'head office' was located in one of the old wartime wooden huts at Perry Park where the PMG radio installation section was located. He did not remember a lot about Hemmant, but did remember a lot of Racal receivers being mounted on racks at Capalaba. Fred Lubach told him that he had formerly worked at the 200 Kilowatt VLF Naval Transmitting Station at Belconnen in Canberra before joining the PMG. Source: Peter Dunn.

Capalaba Equipment – Transmitters

The late Peter Oliveri advised that he was a Senior Communications Technician for the then Post Master General's Department at Capalaba from 1952 to 1959. He recorded that the Capalaba receiving site and the Hemmant transmitter site were connected by landline. Transmissions from Hemmant were sourced and controlled through the Brisbane Central Telegraph Office working duplex CW or MCW only. There was no SSB equipment post-war until the 1960's. Al Smith worked at Hemmant.

Peter also recorded that the Radio Branch was supplied with an old RCA transmitter which was of World War 2 origin. Henry Beaumont was the CW operator there. Radio Technician Herbie Gore was killed in a high voltage accident on the site in later years using other equipment. This resulted in a new transmitter being supplied. Fred Lubach was another technician on site.

Other Comments

Lionel Sharp recorded that he knew a couple of the technicians who had worked for the Americans. One was a radio amateur, the late George Barr VK4GB, who lived at Wynnum.

Paul Hayden recorded that the Commonwealth Government's Radio Inspectors had a 1 kilowatt Racal Transmitter tuned by the Racal receiver, in essence a transceiver at Capalaba. The Commonwealth Government's Radio Branch utilised the site to monitor radio frequencies to ensure that commercial and other transmitters held to the approved licensed frequency as well as complying with all regulations. Lionel Sharp recorded that the Radio Branch used Rhode and Schwarz equipment to measure transmit frequencies of radio stations during the 1950's and1960's.

Paul also recorded that all of the ABC Medium Frequency radio transmitter sites in Queensland were fitted with AWA Type AMT150 transmitters and American type BC 348 or RCA Type AR-88 receivers as part of a HF emergency network able to work back to the PMG Radio Brisbane Office via Hemmant/Capalaba. This equipment was replaced with 60W Racal SSB transceivers in the early 1960s, type unknown. None of this equipment was installed at Capalaba or Hemmant but those sites were an integral part of the emergency communications system. The equipment has since been removed from all sites.

Capalaba Equipment - Antennas

The late Peter Oliveri recorded that antennas at Capalaba, post-war, comprised six Rhombics utilizing 600 ohm open wire feeders to coaxial cable.

Lionel Sharp VK4NS recorded that the Rhombics were fed with 600 Ohm open wire lines terminating on a timber framework, then going into a 600 to 75 Ohm transformer, which was quite small, then to coaxial cable. The primary (600 Ohm side) was centre tapped. The idea he said was that the direction of the signals could be reversed by feeding a DC voltage to operate a reversing relay that controlled the termination resistor. Lightning strikes “used to knock them about”. Coaxial cable Ohmage reflects type of use.

John Andrews records that when he was employed as an engineer by the Post and Telegraph Department in New Guinea in the 1960’s there were rhombic antennas in Rabaul with one kilowatt transmitters. Rhombics were also used by OTC in Port Moresby. Paul Hayden’s recollections were that OTC in Rabaul ran telephone traffic to Doonside, Sydney. No OTC traffic ever went through Capalaba.

Capalaba Equipment – Other

Lionel Sharp recorded that a 30kVA Cummins Diesel Generator from the wartime was used as standby power at Capalaba. Post-war it was replaced due to problems with obtaining spare parts. There was no mains water supply to the site, water being obtained from a bore using a windmill. In the 1950’s the windmill was replaced by an electric pump.

Hemmant Equipment – Buildings

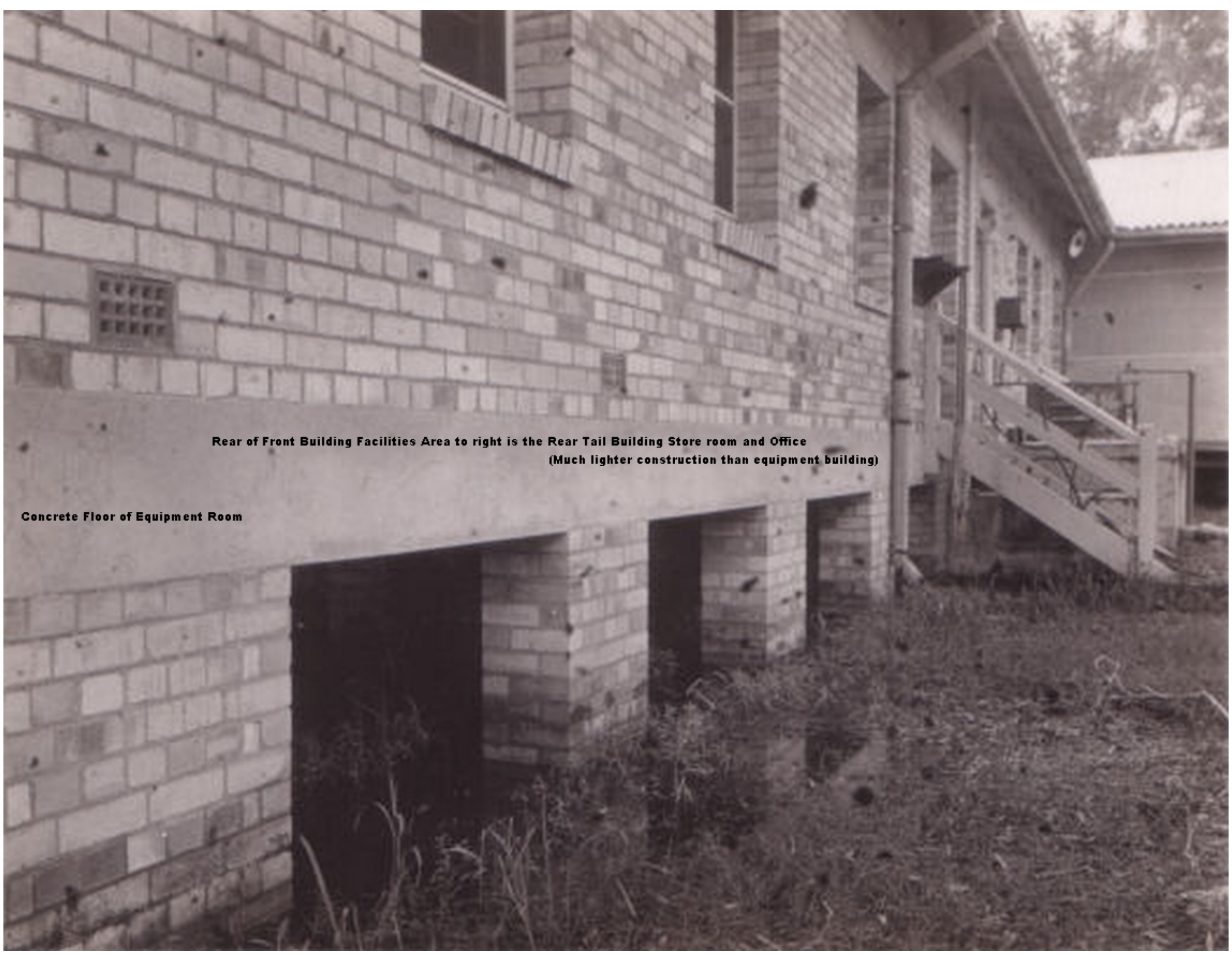

Fig. 30: Hemmant Radio Transmitter Site Building, Post-War.
(Peter Dunn website, showing photo provided by Leo Maloney. Annotations by Paul Hayden (2015))

No photo of the Hemmant site taken during the war was located.
Left: Strengthened concrete floor of equipment room, now said to be at dirt level.
Centre: Rear of Facilities Area
Right: Rear of tall building store room and office of light construction
Also refer to Section 6, Fig. 11 for another annotated view of the building. (p.34).

Paul Hayden recorded that the building he knew was a T shape with the tail offset 2/3 to one side. The transmit hall along the top of the western end of the front building contained the lunch room, bathroom, and several locked store rooms. The eastern end of the building was the transmit hall so his comment was that there was no room there big enough for the USA Press brand 40kW single sideband transmitter based on the pictures of such a transmitter and exciter detailed in this document. The conclusion is that this RF Amplifier may have been accommodated separately.

The tail of the T had two small rooms one either side of the entrance into the transmit hall behind the 10 kilowatt transmitter. One room contained shelving with compartments for transmit spares and a section reserved for the transmit crystals marked with the various radio circuit frequencies used. The second room looked like an office. The remainder of the Tail was a single long room with windows both sides. It only contained boxes of assorted stuff, uniforms and parts left behind when the Americans moved on.

Hemmant Equipment – Receivers

Lionel Sharp recorded that a Racal RA-17 was used at Hemmant.

Hemmant Equipment – Transmitters

The late Peter Oliveri VK4PO recorded that the Young's Road Hemmant transmitters utilized a World War 2 Australian Tasma 400 Watt exciter to a 10 Kilowatt final amplifier till around the 1970's to 1980's. The accuracy of this statement could not be verified.

Tasma (https://vintage-radio.com.au/default.asp?id=companies5) was the trade name of Thom and Smith Proprietary Limited founded by Fred Thom and John Smith in Woolloomooloo, New South Wales in 1929. During World War 2, the firm digressed into building receivers and transmitters for the Royal Australian Air Force.

Paul Hayden recorded that a 10kW transmitter was still there during his time and placed at about the junction of the top of the building with the tail probably a type BC340. Lionel Sharp recorded that it used two valves. By the mid 1950's it was non operational. There were several smaller transmitters either side of this transmitter possibly a BC339K one kilowatt transmitter which was used to drive the more powerful BC340. Lionel Sharp recalls that there were two BC339K transmitters there in his time. He also records that the working transmitters which were in daily use to contact stations all over Queensland were war surplus, one only TypeBC200 and an Australian made Tasma 200 watt Type AT14A. The AT14A was identical in appearance to the BC200 the difference being that the AT14A used plate modulation whilst the BC200 used cathode modulation.

Lionel Sharp also recorded that a Racal TA-175 One Kilowatt Transmitter that he sighted may well have been used for the Brisbane Thursday Island teletype circuit until the late 1960's. The only Racal transmitter he saw at Hemmant was used remotely by the Weather Bureau to talk to its Willis Island weather station in the Coral Sea. At Hemmant there was also a World War 2 Radio Electronic Laboratories (REL) transmitter built in the USA which was very heavy and ran 50 watts of power using four type 807 tubes on a frequency around four megahertz. It was used to talk to Bribie Island once a week. It was left by the Americans probably due to its weight. In the 1950's the Radio Branch, as it was called in those days, installed a 400 watt Type BC610 transmitter but it developed a high tension earthing problem in the modulation transformer which was "fixed" by raising the transformer on insulators. This unit was based on the Hallicrafters Type HT-4 transmitter design which had earlier been produced for the amateur radio market in the USA and used extensively by the Americans in World War 2.

Hemmant WW2 Transmitter Summary:-

Tasma	400 Watt exciter.- Australia.
Tasma AT14A	200 Watt transmitter- Australia
BC200	200 Watt transmitter - USA
BC340	Ten Kilowatt transmitter - USA
BC339K	One Kilowatt transmitter.- USA
BC610	400 Watt transmitter –USA (Based on the Hallicrafters Type HT-4)
Racal TA-175	One Kilowatt transmitter- UK

Radio Electronic Laboratories (REL) transmitter- 50 Watt USA

Note: Excludes the USA 40kW Press amplifier removed by the Americans in 1944.

Hemmant Equipment – Antennas

The number of Rhombic antennas at Hemmant during the war according to wartime maps are not known but Lionel Sharp recorded that two were there in his time, one was directed at Manila in the Philippines and another at San Francisco. The Rhombics were removed when their 100 foot timber poles rotted out. Lionel Sharp also stated that each leg of the Rhombics consisted of three wires to broadband the antenna.

Paul Hayden stated that his recollection was that there were 5 or more rhombic antennas pointing to the West Coast of the USA, Mid Pacific, Japan, India and London in the UK. The antenna poles were 6 inch square Oregon Pine. The open two wire Feeders (200lb hard drawn copper, one eighth inch thick) from the various rhombics came in through the wall into the front (northern) face of the building, and then through large cone shaped insulators about 8 foot up the wall. Antenna switching consisted of wires running overhead above the transmitters. There were also antenna leads running parallel North /South and other leads running East/West to form a square matrix interconnected by short vertical jumpers. (you did not switch antennas often).

Michael O'Leary recorded that he was the sole radio technician at Hemmant in the early 1970's looking after a few remaining SSB radio networks and before the facility was run remotely from the Mt Gravatt Radiocom Centre. He also recorded that the Hemmant facility was built in a tidal swamp which offered excellent ground conductivity to enhance SSB radio transmission from a number of large rhombic antennas that occupied several hectares of land on both sides of Youngs Road, Hemmant. Nestled between these paddocks stood the main building and a side building that housed the emergency diesel generator. These buildings were enclosed behind a tall, barbed wire fence with white wooden posts. Adjacent to the engine room was a basketball court. He also noted the diesel engine in the shed that he saw did not look like the Buckeye from the war days.

Michael also recorded that the site had beautiful surrounds with tall melaleucas hiding tawny frogmouths; magpies feeding from the transmission lines at the front of the building; noisy minor and butcher birds feeding from the table at the rear steps; brown and red-belly black snakes, together with feral foxes; and even a plague of rats for a time that inhabited the floor ducts. He was advised by the person who grazed cattle on the site that the Americans buried equipment that they would not be taking back to the USA in a paddock. His suspicion is that it is near the basketball court in a grassed area.

Hemmant Equipment – Other

Lionel Sharp recorded that a Buckeye 250 kVA diesel standby generator made in Lima, Ohio, USA, was installed some time before the end of the war at Hemmant. It was run for about an hour each month for maintenance purposes and was later removed to power the PMG workshops at Bulimba. It was replaced by a Southern Cross Diesel generator that came from the Australian Broadcasting Commission's Alice Street studio when it was shut down.

This was a very large engine by any means and would have run the 40kW SSB transmitter and associated equipment. The transmitter required 94kVA at 220 volts, 60 cycles. (US War Department, (1944b, p.443). See Appendix 6 (Fig. 22) for a photograph of a large Buckeye Generator and further details.

Paul Hayden stated that the standby plant he saw was a Blackstone diesel, about 60kVA and 60Hz (USA). It was tried running at 50Hz and it was useless (outside its power- band), hopeless regulation and blew lots of black smoke! It would never have run a 40Kilowatt water cooled transmitter of World War 2 vintage as the unit had a typical efficiency overall of about 20% if you were lucky. This 60Hz generator was clearly of USA origin and from the war.

Appendix 15 SPECIFICATIONS OF RADIO RECEIVER TYPES POST-WAR

A number of radio receivers were recorded by those interviewed (pages 122 to 127) as being on the sites post-war. These are in addition to the Wilcox Electric Company's CW3-D receiver. They were :-

RCA, HF Radio Receiver, Type AR-88.
Hammarlund HF Super-Pro Radio Receiver, Type BC-779-A.
Eclipse HF Radio Receiver, Type AMR-200.
Racal HF Radio Receiver, Type RA17.
STC HF General Purpose Radio Receiver, Type AMR300
GEC- HF Radio Receiver, Type BRT400
Kingsley HF Radio Receiver, Type AR7.

Specifications are as follows:-

RCA, HF Radio Receiver, Type AR-88.

Fig. 31: RCA, HF Radio Receiver, Type AR-88.
Source:(http://www.radioblvd.com/ar88.htm).

Design stages probably date from as early as 1939 and the demands of WW2 in Europe pushed RCA into having the AR-88 ready by early 1941. The finalized AR-88 was a 14 tube superheterodyne that covered 0.54 to 32MC (now MHz) in six tuning ranges, featuring incredible sensitivity (even up to 10 meters), excellent stability and high fidelity audio along with mechanical and electronic reliability that couldn't be found in any other receivers of the day. Weight 40 kilograms. Some had no signal strength meter as they were unobtainable but had a one eighth inch thick window for when they became available.

Hammarlund HF Super-Pro Radio Receiver, Type BC-779-A.

Fig. 32: Hammarlund HF Super-Pro Radio Receiver, Type BC-779-A.
Source: (http://www.radioblvd.com/hammarlund_super_pro.htm).

Wikipedia records “In March 1936, the Hammarlund Manufacturing Company initiated the first of the famous “Super-Pro” line, the SP-10 receiver, followed in January 1937 by the SP-100. Their efforts to improve the design resulted in October 1939 with the SP-200 series, an 18-tube, single conversion superhet receiver. The SP-200 series Super-Pro receivers were manufactured through 1945, with thousands delivered to the military during World War 2; they saw wide use by the U.S. Signal Corps as the BC-779. Power Supply Unit was Type RA-84-A.

During World War 2, government agencies like the FBI used the 200 Series Super-Pro at their listening posts. Many were used at ground stations in England to communicate with the Royal Air Force and U.S. Air Force armadas that flew bombing missions over Germany.

According to a November 1940 QST Magazine advertisement, "The fact that 'Super-Pro' receivers are used extensively by the U.S. Signal Corps and many other governmental departments, speaks for itself."

At the end of the war, the market was flooded with surplus Super-Pro receivers at bargain prices, which may be a reason many working examples of this model are still found today. From 1946 to 1948, Hammarlund produced the SP-400 Super Pro for the amateur radio market. In 1947 the SP-600 Super-Pro receiver, which surpassed the SP-200 in performance, was introduced. The SP-600 series were widely used throughout the world for military, laboratory and commercial application. The Super-Pro was first offered in two basic models, with and without a crystal filter.

Eclipse HF Radio Receiver, Type AMR-200.

Fig. 33: Eclipse HF Radio Receiver, Type AMR-200.
Source: Dave's Army Radio Page (http://www.qsl.net/vk4kdp/army.html)

Eclipse Radio in Melbourne made copies of the Hammarlund SP-200. It was renamed the AMR-200 Various models of the SP-200 series cover 0.1 - 40 MHz in 5 bands. The radio and cabinet weighed 73 pounds (33 kg) while the separate power supply added another 57 to 61 pounds. They were not used at Capalaba (Lionel Sharp).

Racal HF Radio Receiver, Type RA17.

Fig. 34: Racal HF Radio Receiver, Type RA17.
Source: Allan's Virtual Radio Museum (http://www.radiomuseum.co.uk/racal.html).

The Racal RA-17 and RA-117 desktop military receivers, made in the United Kingdom, were notable as the first production communications receivers to implement the Wadley Loop tuning system. The Wadley Loop was a technique to improve tuning precision and stability at higher frequencies in the days before phase-locked-loop systems were feasible economically. These were premium receivers in their day, and the choice of many military, government and commercial services from1954 the 1960s.

STC HF General Purpose Radio Receiver, Type AMR300.

Fig. 35: STC HF General Purpose Radio Receiver, Type AMR 300.
Source: Kurrajong Radio Museum (http://vk2bv.org/archive/museum/amr300.htm).

General Description
The AMR300 was one of three groups of receivers developed by STC, Sydney, Australia, for the armed services during WW2. The original receivers were identified as A679, usually A679-H, A679-J and A679-K.

These sets in the first instance were designed and manufactured for the R.A.N. and R.A.A.F. The differences in type numbers reflected changes to cater for a variety of different applications.

The general purpose receiver covered 1.5 - 24 MHz in 4 bands. These were 1.5 - 3.0, 3.0 - 6.0, 6.0 - 12.0 and 12.0 - 24.0 MHz.

The identifier AMR300 did not come into being until 1945 when the US services required a HF communications receiver - this set improved on the previous models eg AMR-100 and included temperature compensation of the local oscillator and Faraday screens to enable the set to be used successfully with direction finding systems.

Technical Data

The set had a sensitivity of 2 microvolts.
The valve line-up was as follows:

V1 6U7 1st RF Amp
V2 6U7 2nd RF Amp
V3 6K8 Frequency Converter
V4 6U7 1st IF Amp
V5 6G8 2nd IF Amp and 2nd Detector
V6 6B8 Audio Amp
V7 6V6 Audio Output
V8 6J7 BFO
V9 5V4 Rectifier

The IF frequency was 455kHz. In its original form, the audio output was 40mw into 5000 ohms connected across one phone jack and 2 watts at 600 ohms across the line terminals. The oscillator stability was, after 10 minutes warm up, less than 0.05% of the operating frequency on any range.

The sets were designed to operate from either 240 or 110v AC (62 watts), while a separate vibrator supply was available for 12 volt DC operation. The set weighed 74lbs, approx. 34 kg. The HT line at the output tube was approximately 230v dc, with 215v ac being applied to the plates of the rectifier.

The receiver was in high demand by radio amateurs and short wave listeners after the war and commanded high purchase prices from disposal outlets. Unlike other sets of similar performance produced during this period, the AMR300 series did not use plug in coil boxes, which made them easier to use and somewhat tidier!

GEC- HF Radio Receiver, Type BRT400.

Fig. 36: GEC HF Radio Receiver,Type BRT400.
Source: Radio Museum (http://www.radiomuseum.org/r/gec_brt400.html).

Year 1948

Valves / Tubes 11: **W81 W81 X81 N77 W81 W81 DH81 unknown_Tube KT81 KT81 unknown_Tube**

Main principle	Superheterodyne with RF-stage; ZF/IF 455 kHz; 2 AF stage(s)
Wave bands	Broadcast, Long Wave and more than two Short Wave bands.
Power type and voltage	Alternating Current supply (AC) / 95-130; 195-250 Volt
Loudspeaker	For headphones or amplifier.
Material	Metal case
Shape	Table model, low profile (big size).
Notes	Coverage in 6 bands; 150-350 kHz and 550kHz to 33MHz. Electrically identical to the rack-mounted BRT402. The second KT81 valve is used for dynamic smoothing.
Price in first year of sale	120.00 GBP

This radio receiver was classed as a commercial receiver in the market.

Kingsley HF Radio Receiver, Type AR7.

The workhorse of Australian Radio Communications during and after World War 2 – they are still around today in Amateur Radio circles.

Fig.37: Kingsley HF Radio Receiver, Type AR7.
Source: (http://www.radioblvd.com/WWII_Communications_%20Equipment.htm)

The following is from the Radio Boulevard WW2 site above. "During WW2, both the Allies and the Axis copied the famous National HRO Receiver. Probably the "knock-off" that got the most use was the Kingsley AR7, built during WW2 by Kingsley Radio Company of Melbourne, Australia. Kingsley submitted the design (probably around 1940) as the K/CR/11 but after the design was accepted, the receiver became the AR7. Though the AR7 uses a micrometer dial and plug-in coil sets, that is about as far as copying the National HRO went. The AR7 did use two RF amplifiers but used a Converter stage instead of a separate LO and Mixer. Eight "American-type" tubes are used in the receiver and two in the power supply. Frequency coverage is 138kc up to 25mc using five plug-in coil sets. Two IF amplifiers are also used operating at 455kc. An S-meter amplifier circuit provides the user with a front panel Calibration control. The audio output is a single 6V6 to a dual impedance output transformer that provides 600 Z and 1750 Z impedances. A Crystal Filter is provided. All AR7s are rack mounted and came with a rack mounted power supply that operated on either 240vac or 12vdc. A rack mounted speaker was also included. Some receiver housings had four coil storage cubbies, two on each side of the receiver. Normally, the receiver was lowest in the table rack with the speaker in the middle and the power supply on top. The Australian Army referred to the AR7 as "Reception Set No.1" and sometimes had the panels painted green. Normally, the AR7 panel, since it was a stainless steel overlay, was left unpainted with the nomenclature slightly polished to improve readability.

After WW2, many AR7s were installed at various airports around Australia where they served as tower and air to ground receivers. Many were modified to have crystal controlled frequency reception with the

LO coils removed from the coil set and a crystal controlled fixed frequency oscillator installed to allow specific frequency reception with no tuning. Some receivers also had the AVC modified while others had different scales installed on the S-meter. Most AR7s don't have the original audio output transformer as it seems this component was easily damaged. Banks of AR-7s could be found at various airport communications facilities and some tower installations would feature a fairly stock AR7 that could still be tuned. Today, many AR7 receivers that are available are in dismal condition due to heavy use followed by indifferent storage. Most receivers are incomplete and don't have the original power supply or speaker panel. Many suffer from corrosion and are non-functional.

Performance of a functional AR7 is impressive. They are similar to National HROs but do have their quirks. For instance, the micrometer dial tunes "backwards" when compared to the PW-D of the HRO. That is 500 on the AR-7 is the lowest frequency of the coil set installed while it's the highest frequency with an HRO. Also, the S-meter works "backwards" with FS being "0" and mechanical zero being "S-9." The ability to calibrate the S-meter for the particular coil set being used is a nice feature and not one that is found on the HRO. Coil sets are steel construction and very heavy while the HRO sets are all aluminum. With all of the use that the AR7 provided, both in WW2 (and especially post-WW2) it obviously was a great performer and very stable. Great audio, although it doesn't have the original audio output transformer but rather has the commonly installed replacement transformer made by Rola. Unfortunately, the Rola transformer only has a single 600 Z ohm winding for the audio output".

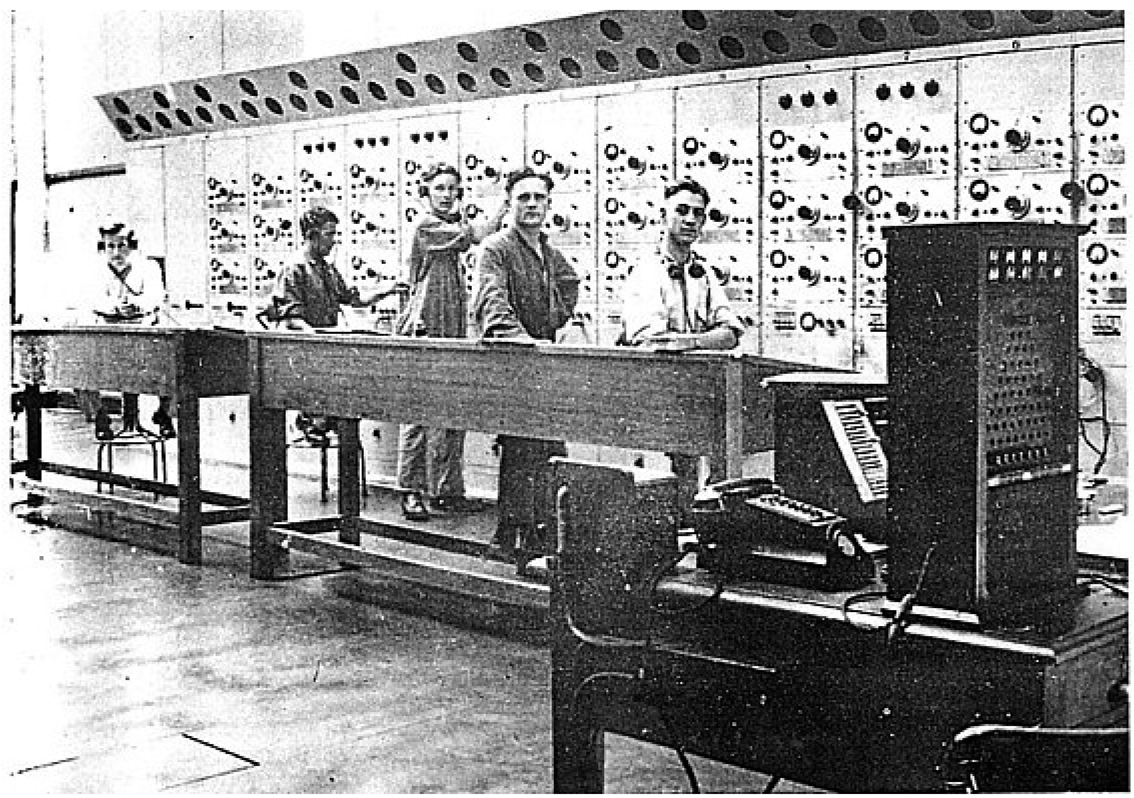

Fig. 38: Kingsley HF Radio Receivers, Type AR7 – WW2 RAAF Remote Receiver Station at Werribee. Source: Butler, Lloyd VK5BR. (http://www.qsl.net/vk5br/AR7.htm).

He records that "There are 39 AR7 receivers shown in the racks. There could possibly be more as the right hand edge of the picture cuts off the end of the array of racks. The site was the main Australian

Central Receiving Station for the RAAF and the receivers were fed from 31 Rhombic antennas. The outputs of the receivers were fed via landlines to the signals office at Frognall where the signals were copied by RAAF and WAAAF telegraphists. Frognall is a large two story residence in Canterbury, a suburb 10 km from Melbourne. Frognall was occupied by the RAAF between 1941 and 1975 as their Melbourne Wireless Telecommunications Centre ".

Ray Robinson VK2NO has written about the AR7 and its refurbishment. Details including some excellent photographs of the receiver are available on his website.
(http://www.tuberadio.com/robinson/museum/AR7/).

GLOSSARY

Azimuth	Direction, in terms of horizontal angle, measured clockwise from the north
Code	A method of communication in which predetermined symbols or terms are substituted for the words of the message text.
Cryptography	the process of putting message texts into meaningless letters or symbols by means of a code and/or cipher systems
Electromagnetic wave	A radio or radar radiation travelling in space at the speed of light ; Also heat, light, X-, gamma and cosmic rays, which are all alike except in frequency and wave length.
Frequency wave or radiation	The number of Hertz (Cycles) per second which characterizes any electromagnetic
Hand-key	In manual radiotelegraph sending, the key (operated by the hand or fingers) is a kind of switch capable of being opened or closed rapidly in order to form the dots and dashes of Morse code signals
High Frequency	3-30 Megahertz
Ionosphere	The outer layer of the earth's atmosphere which reflects the sky wave component of radio waves of the High Frequency Band, enabling long-distance signals.
Key	Hand -key
Kilohertz	1000 Hertz
Kilowatt	1000 watts
Manual radio	Transmitting Morse code dah-dits by hand key
Megahertz	One million hertz per second
Morse	Morse code: communications according to the code, employing combinations of dashes and dots (dah-dits) to spell out the letters, as in radio or wire telegraphy.
Muxing	Allows you to share an expensive process (Bandwidth) between a number of less expensive devices (Users).
Rhombic Antenna	A large transmitting antenna utilized by fixed long-range radio stations. The antenna wires, extended between four poles or towers, form a diamond shaped or rhombic pattern, capable of directing powerful electromagnetic waves in a definite direction.
Sigsaly	Secure speech system used in World War 2 for the highest-level Allied communications
Sky-wave	That portion of a radio wave transmitted from an antenna which travels upward and is reflected down to earth by the ionosphere. Used in the High Frequency Band by long-range radios, the sky wave under favourable conditions enables communication over long distances.

Superheterodyne	A radio receiver (often shortened to superhet) is a type of radio receiver that uses frequency mixing to convert a received signal to a fixed intermediate frequency (IF) which can be more conveniently processed than the original carrier frequency.
Teleprinting	Name used in the United Kingdom for Teletype
Teletype	Name used in the USA for Teleprinting or teletypewriting
Transceiver	A radio transmitter and receiver combined in one unit, portions of its circuits being used for both functions
Very high frequency	30-300 Megahertz
Ultra-high frequency	300-3000 Megahertz

SOURCE: Based partly on extracts from Thompson et. al., 1957, pp 572-579.

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NOTES:

(1) Copy to browser where necessary.
(2) Look under the history banner on the site for Battle of the Coral Sea
(3) Do a Web-Search for the site

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CAPALABA RADIO STATION, WW2 - DRAWINGS

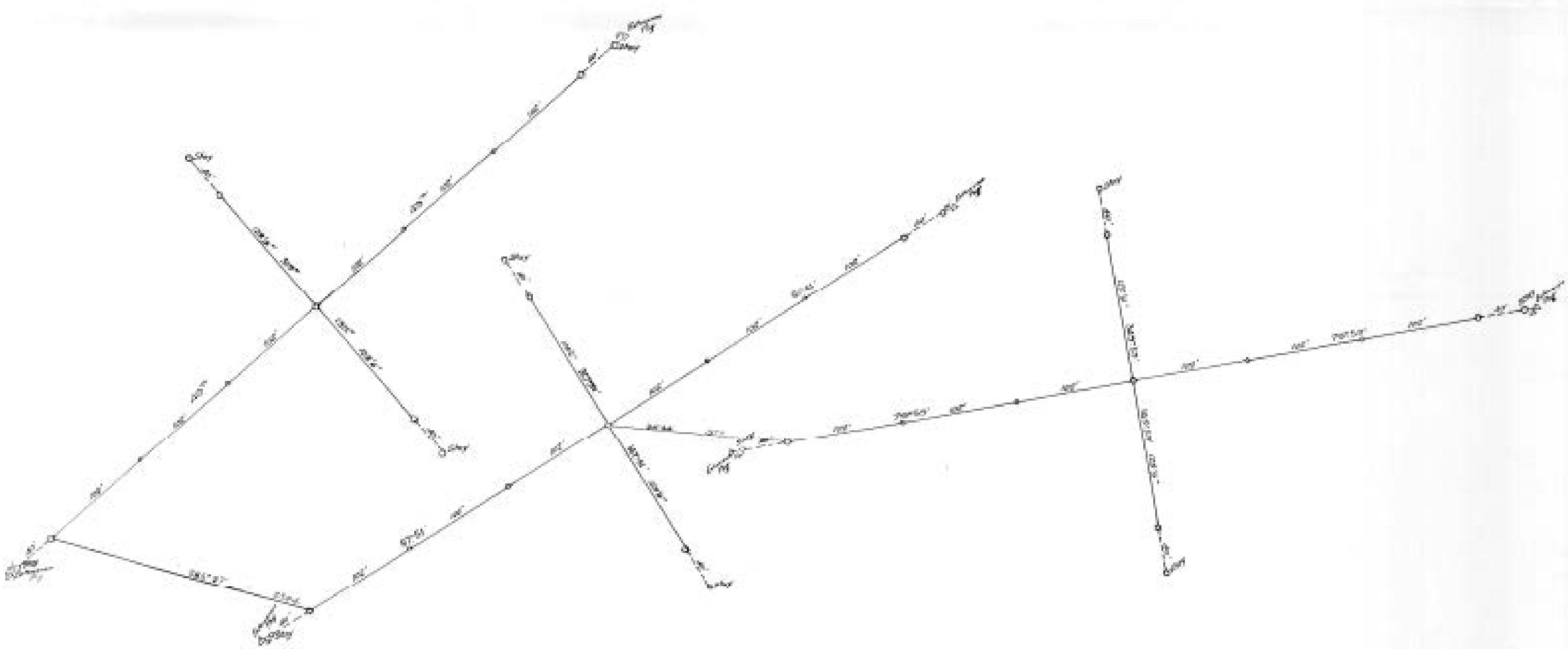

Fig. 39: Drawing No. L&S 294 – Location of Rhombic Antennas at Capalaba, WW2.

Source: Commonwealth Government Archives (n.d.)

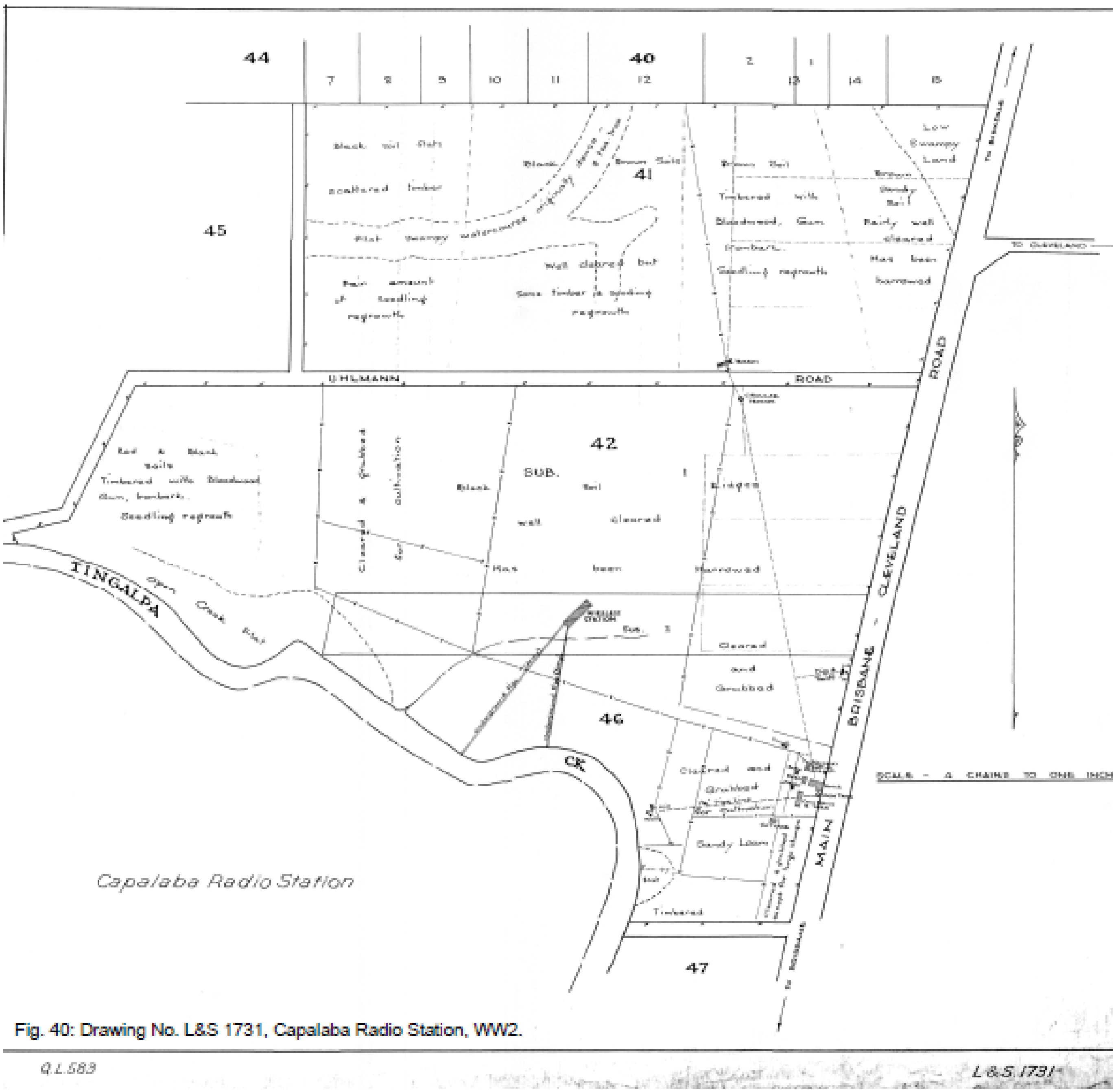

Fig. 40: Drawing No. L&S 1731, Capalaba Radio Station, WW2.

Source: Department of the Interior (1943)

CAPALABA RADIO STATION, WW2 - DRAWINGS (Cont.)

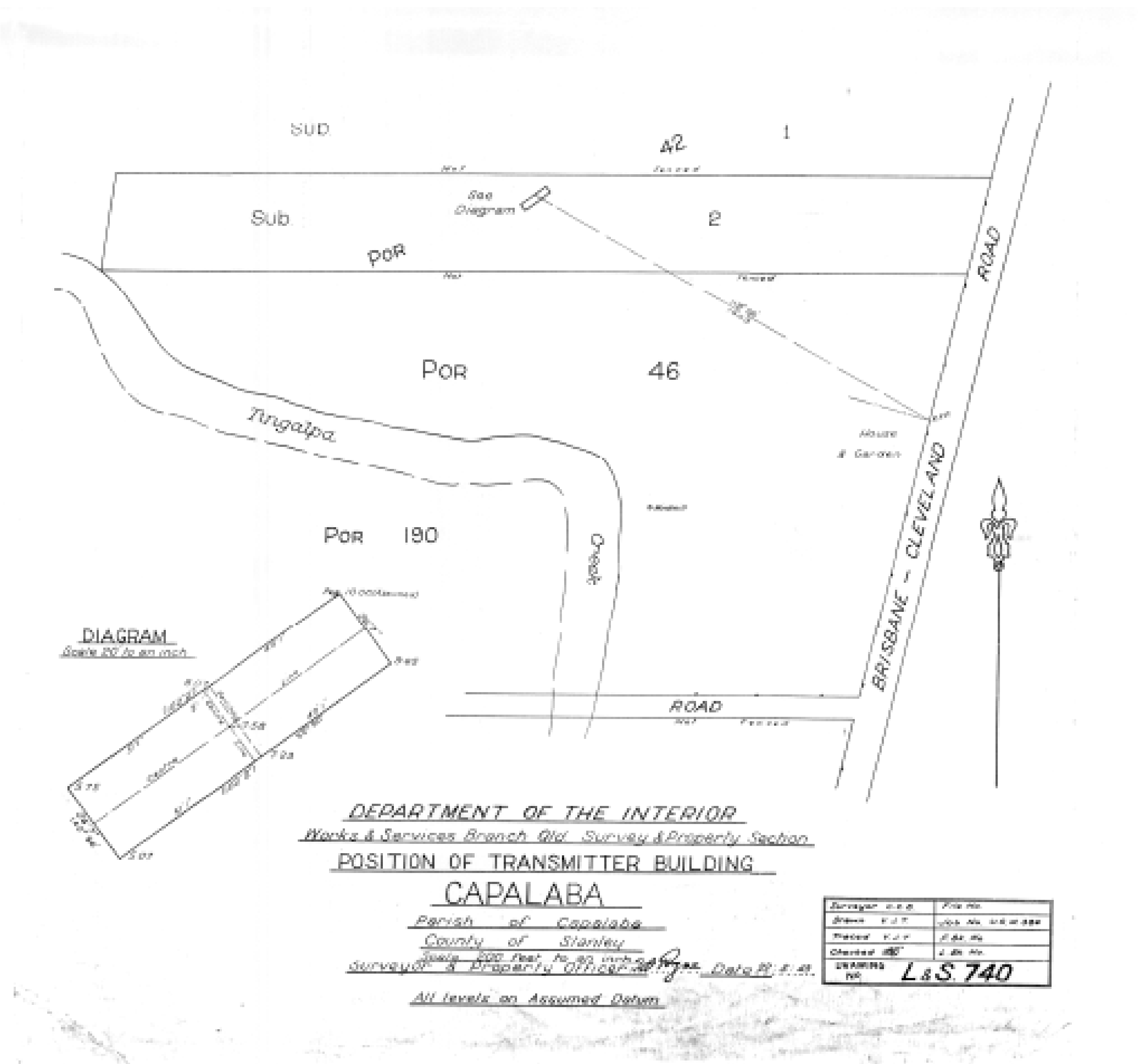

Fig. 41: Drawing No.L&S 740, Position of Transmitter Building, Capalaba, WW2

Source: Department of the Interior (1943)