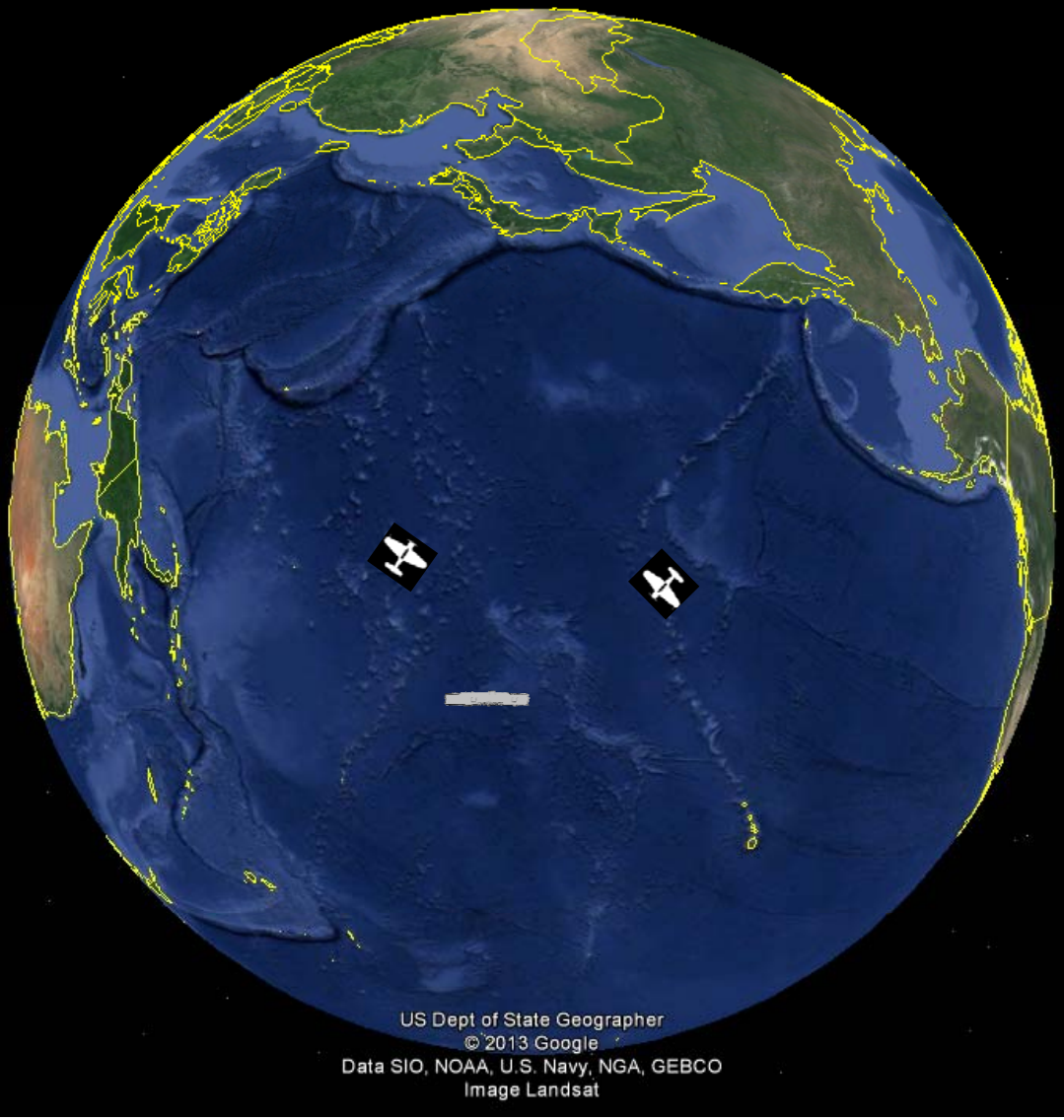
A Secret Weapon of WWII

Aircraft-to-Carrier Homing

Aircraft Carrier Warfare

- USS Langley (CV-1) 1922
- USS Lexington (CV-2) and USS Saratoga (CV-3) 1928
- USS Ranger (CV-4) 1934
- USS Yorktown (CV-5) 1938
- USS Enterprise (CV-6) 1938
- USS Wasp (CV-7) 1938
- USS Hornet (CV-8) 1941

It's a Big Ocean



Dead Rekoning

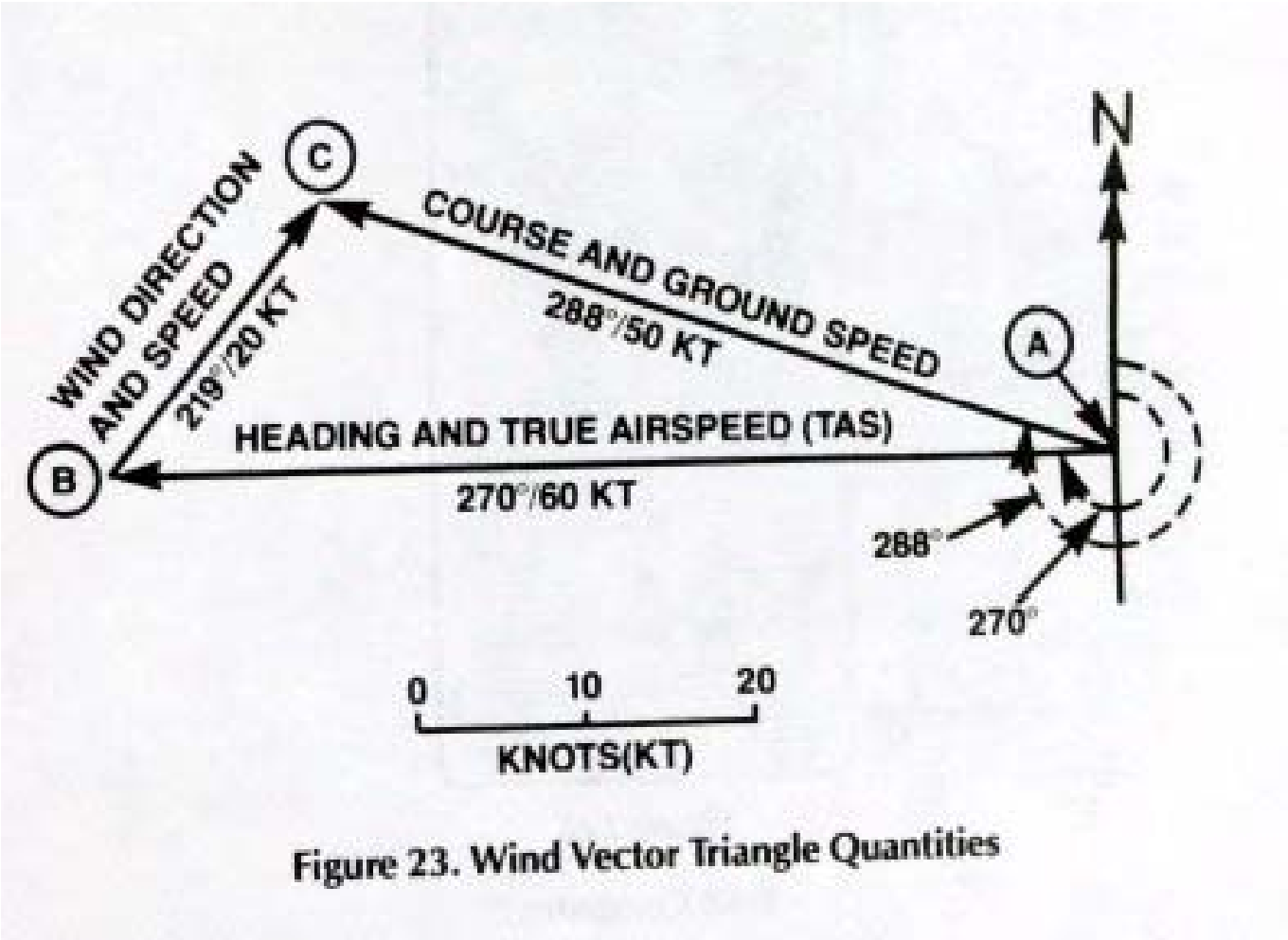
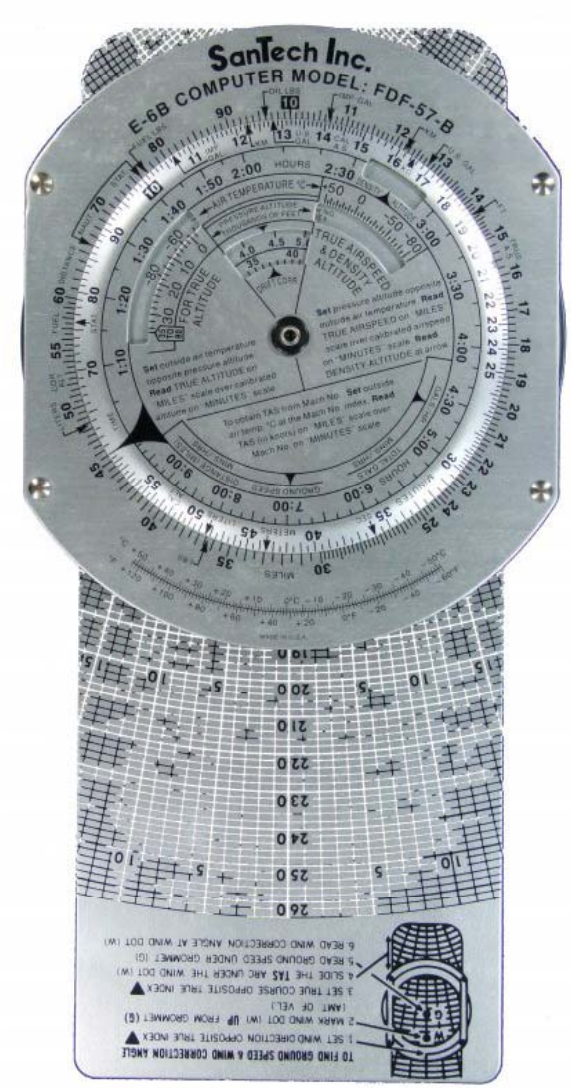
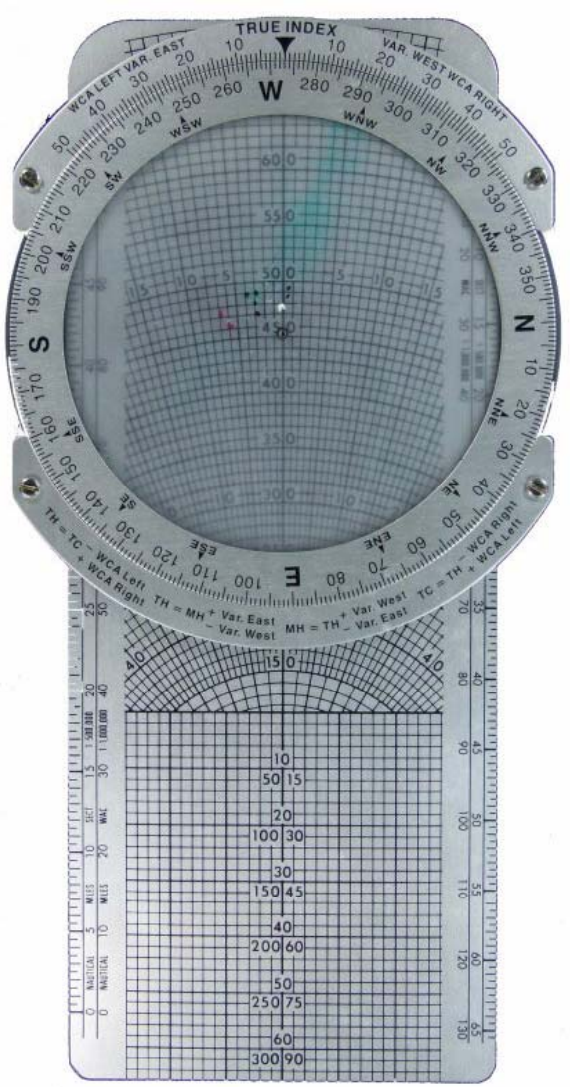


Figure 23. Wind Vector Triangle Quantities

The Whiz Wheel

E-6B dead reckoning computer

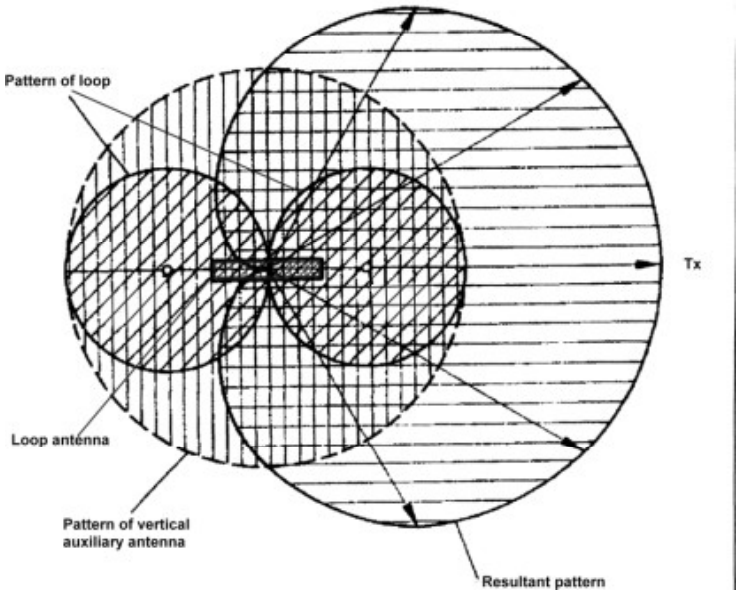




Early Electronic Solutions

- Fixed DF loops in single-seat fighters
  - In pilots headrest or wound around fuselage.
  - Required change of direction to find the null.
- External rotatable loops
  - Impair aircraft performance

DZ-1 Loop Antenna



Medium-Wave DF Shortcomings

- Needs a radio operator.
- Impaired aircraft performance.
- The enemy can easily home to your ship.

How to Navigate Home?

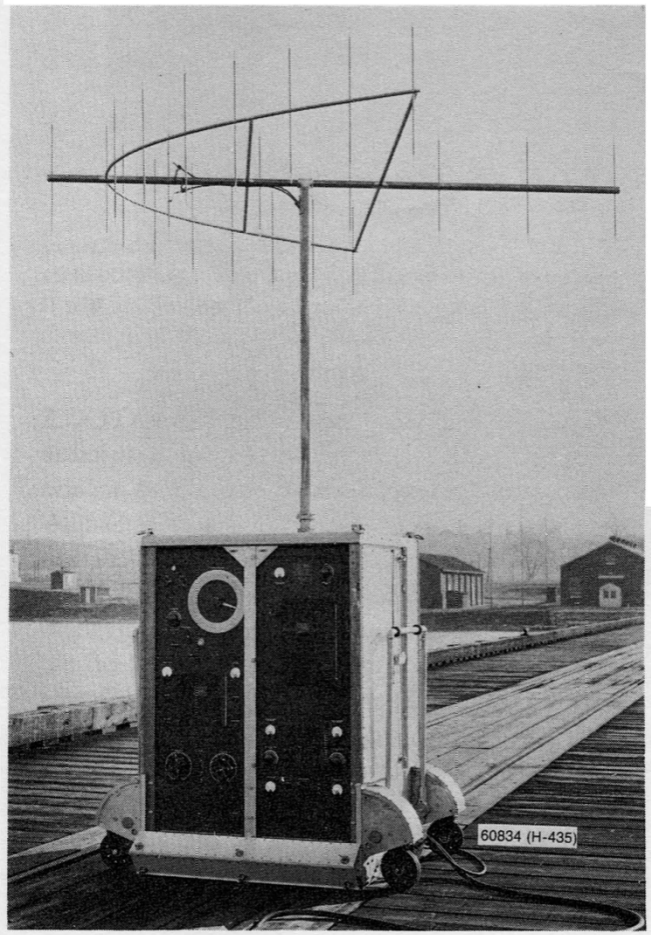
- Naval Research Lab (NRL) assigned the problem.
- Use conventional low-frequency homing beacons?
- Create a new VHF line-of-sight beacon?
- Problem – 1928-1930 era vacuum tubes not effective at VHF frequencies.
- Mid 1930's, TV research began to develop tubes that were usable at VHF frequencies.

Enabling Technology

- UHF Vacuum tubes
  - TX - RCA 8025 triode

  - RX - RCA 954 Pentode

NRL to the Rescue



THE PRIMARY AIRCRAFT-TO-CARRIER RADIO HOMING SYSTEM USED BY ALL CARRIERS AND THEIR AIRCRAFT DURING WORLD WAR II
THE MODELS YE-ZB

The experimental model shown here, developed by NRL (1937), comprised the shipboard equipment, the Model YE (lower) and the airborne equipment (upper). For installation aboard ship, the antenna was mounted as high in the superstructure as possible, and the transmitter was placed below decks. The airborne equipment, shown mounted in a type TBF-1 aircraft, comprised the Model ZB UHF adapter and the Model RU high-frequency receiver, which was also used for communication.

Acceptance

- NRL's experimental model was installed on the carrier USS Saratoga, flagship of the Commander Aircraft Battle Force, then Adm. E.J. King (May 1938).

- After witnessing its performance, Adm. King, in a letter to the Navy Department dated 29 Aug. 1938, stated "The acceptability of the principle of a rotating superfrequency beacon for homing to aircraft carriers at sea or landing fields ashore has been fully demonstrated. Adopt the (Model YE) system for primary means of homing carrier aircraft."

The System Was Designated YE/ZB

- YE = The Carrier Beacon Transmitter
- ZB = The Aircraft Homing Receiver
- The Army Air Corps later adopted it as the AN/ARR-1 receiver.
- The YE beacon transmitter was also used at some Army, Navy & Marine Corps airfields.

How Did It Work

- Carrier used a rotating directional antenna that made two 360 degree sweeps per minute.
- Morse code letters were transmitted in 30 degree segments during each sweep.
- Each aircraft had a ZB receiver that allowed the pilot to copy the letters.
- The Morse code letters indicated which directional heading would get the pilot back to the carrier.

Transmitter Scan Pattern

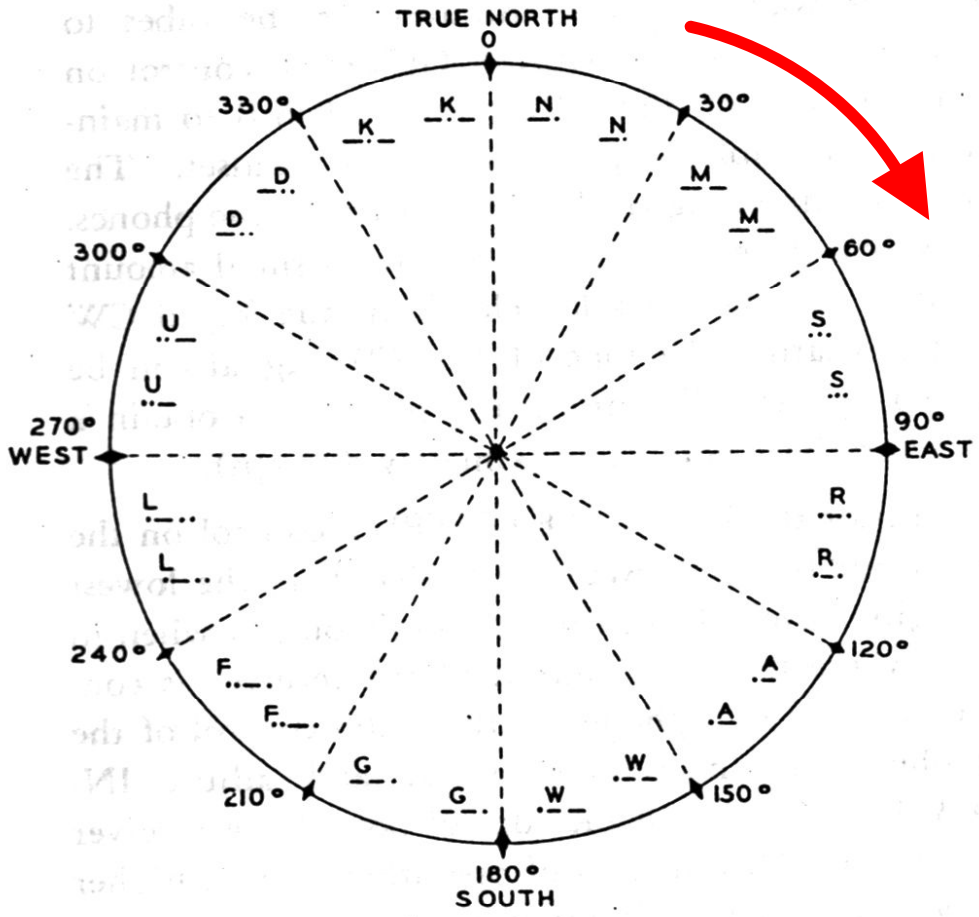
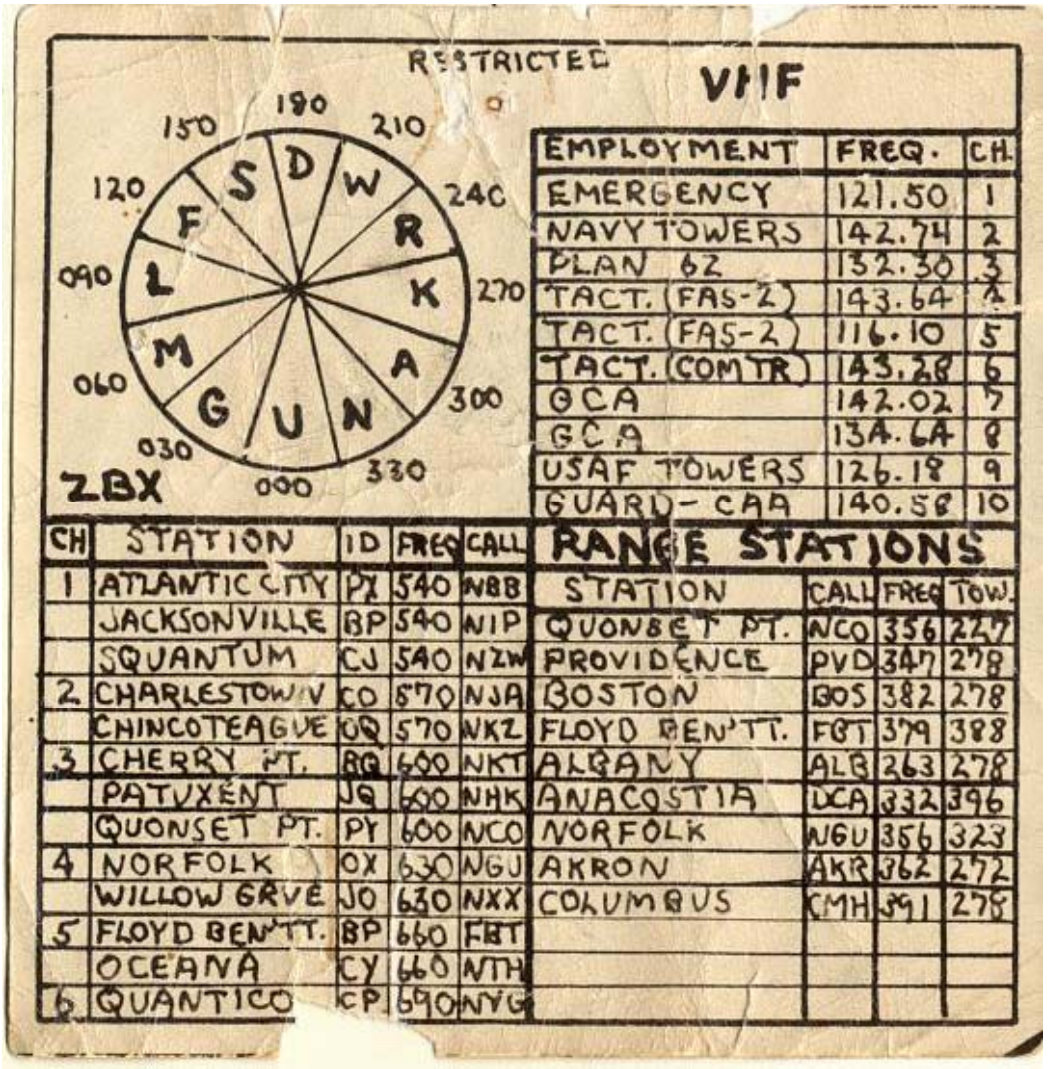


Figure 6B—Example of Radiated Signals in Sectors of YG Transmitter

Pilot's Decode Card



RESTRICTED

VHF

EMPLOYMENT	FREQ.	CH.
EMERGENCY	121.50	1
NAVY TOWERS	142.74	2
PLAN 62	132.30	3
TACT. (FAS-2)	143.64	4
TACT. (FAS-2)	116.10	5
TACT. (COMTR)	143.28	6
GCA	142.02	7
GCA	134.64	8
USAF TOWERS	126.18	9
GUARD - CAA	140.58	10

CH	STATION	ID	FREQ	CALL
1	ATLANTIC CITY	PX	540	NBB
	JACKSONVILLE	BP	540	NIP
	SQUANTUM	CJ	540	NZW
2	CHARLESTOWN	CO	570	NJA
	CHINCOTEAGUE	OQ	570	NKZ
3	CHERRY PT.	BQ	600	NKT
	PATUXENT	JQ	600	NHK
	QUONSET PT.	PY	600	NCO
4	NORFOLK	OX	630	NGJ
	WILLOW GRVE	JO	630	NXX
5	FLOYD BEN'TT.	BP	660	FBT
	OCEANA	CY	660	NTH
6	QUANTICO	CP	690	NYG

RANGE STATIONS

STATION	CALL	FREQ	TOW.
QUONSET PT.	NCO	356	227
PROVIDENCE	PVD	347	278
BOSTON	BOS	382	278
FLOYD BEN'TT.	FBT	379	388
ALBANY	ALB	263	278
ANACOSTIA	DCA	332	396
NORFOLK	NGU	356	323
AKRON	AKR	362	272
COLUMBUS	CMH	391	278

Pilot's Decode Card

DECODE CARD

BLACK SECTOR (TRUE)	RED MAGN.	STN. IDENT. YG DATE ____			STN. IDENT. YZ DATE ____			STN. IDENT. ZQ DATE ____		
		SECTOR DESIGNATING LETTERS								
		SET-UP A	SET-UP B	SET-UP C	SET-UP A	SET-UP B	SET-UP C	SET-UP A	SET-UP B	SET-UP C
0°-30°	180-210	N	S	R						
30°-60°	210-240	M	R	S						
60°-90°	240-270	S	A	N						
90°-120°	270-300	R	W	G						
120°-150°	300-330	A	N	M						
150°-180°	330-360	W	L	F						
180°-210°	0-30	G	U	D						
210°-240°	30-60	F	M	A						
240°-270°	60-90	L	D	U						
270°-300°	90-120	U	K	W						
300°-330°	120-150	D	F	K						
330°-360°	150-180	K	G	L						

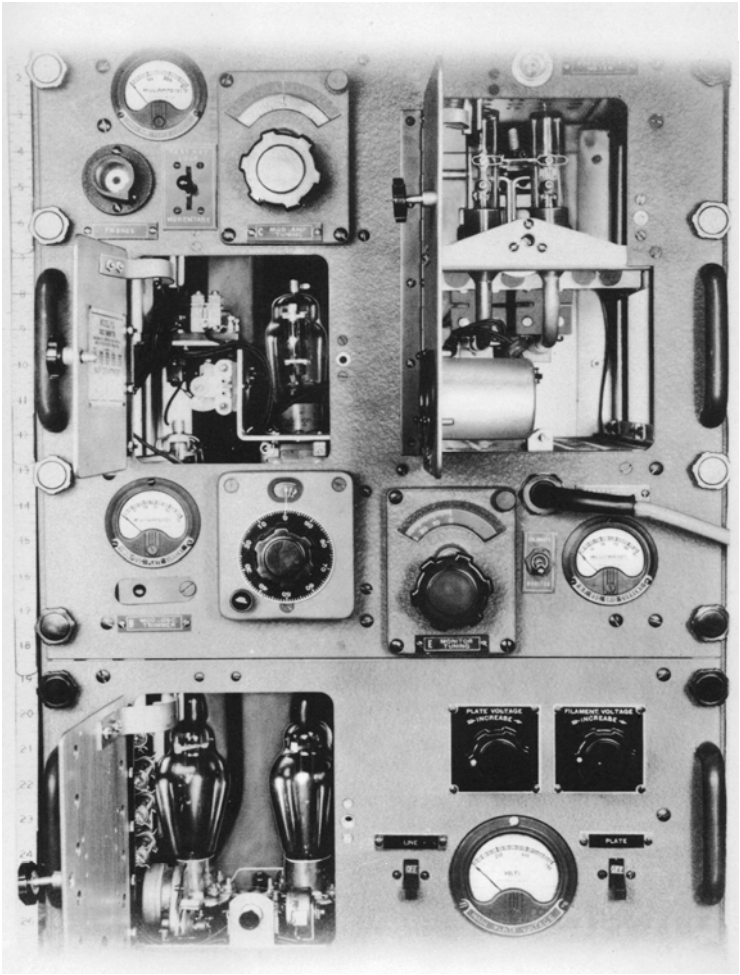
Characteristics

- Frequency – 234 - 258 MC
- Modulation Frequency 540 – 830 KC
  - Continuous-Wave Morse Code
  - Letter repeated twice in each 30° sector.
- Antenna Rotation
  - 2 RPM
  - ID sent every 10th rotation.
- Range 275 miles at 15,000 feet.

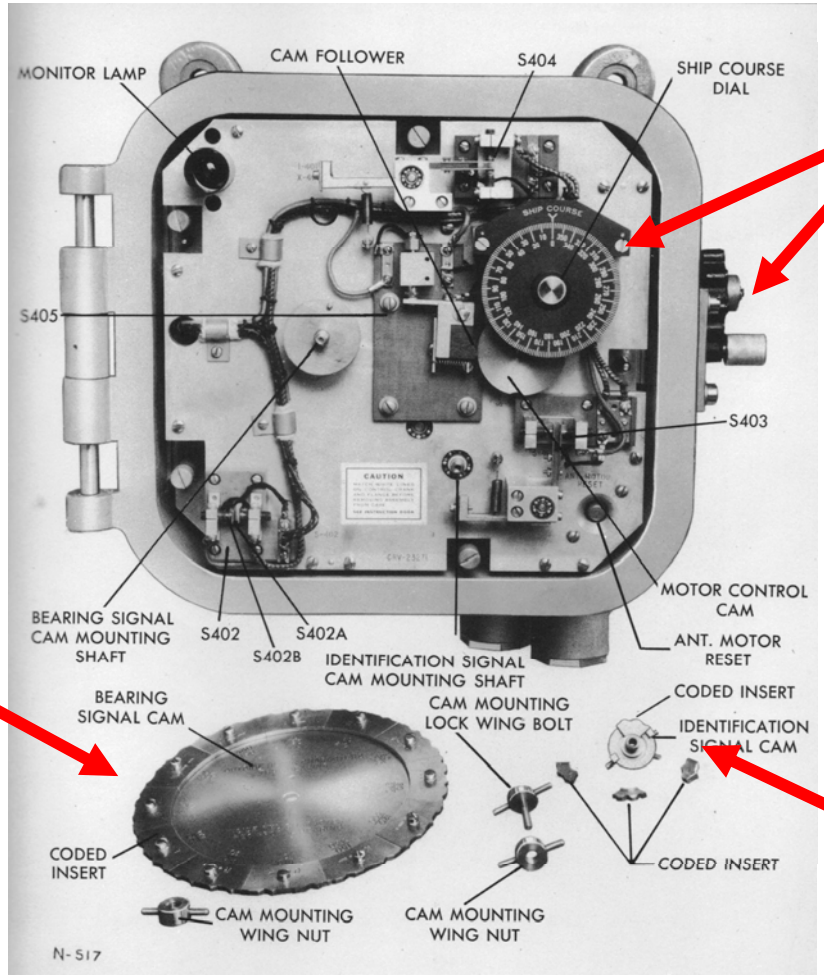
Charteristics

- Only a small simple antenna was required on the aircraft
- The homing receiver and communications receiver that it fed could be set at pre-flight

YG-1 Transmitter



YG-1 Antenna Control

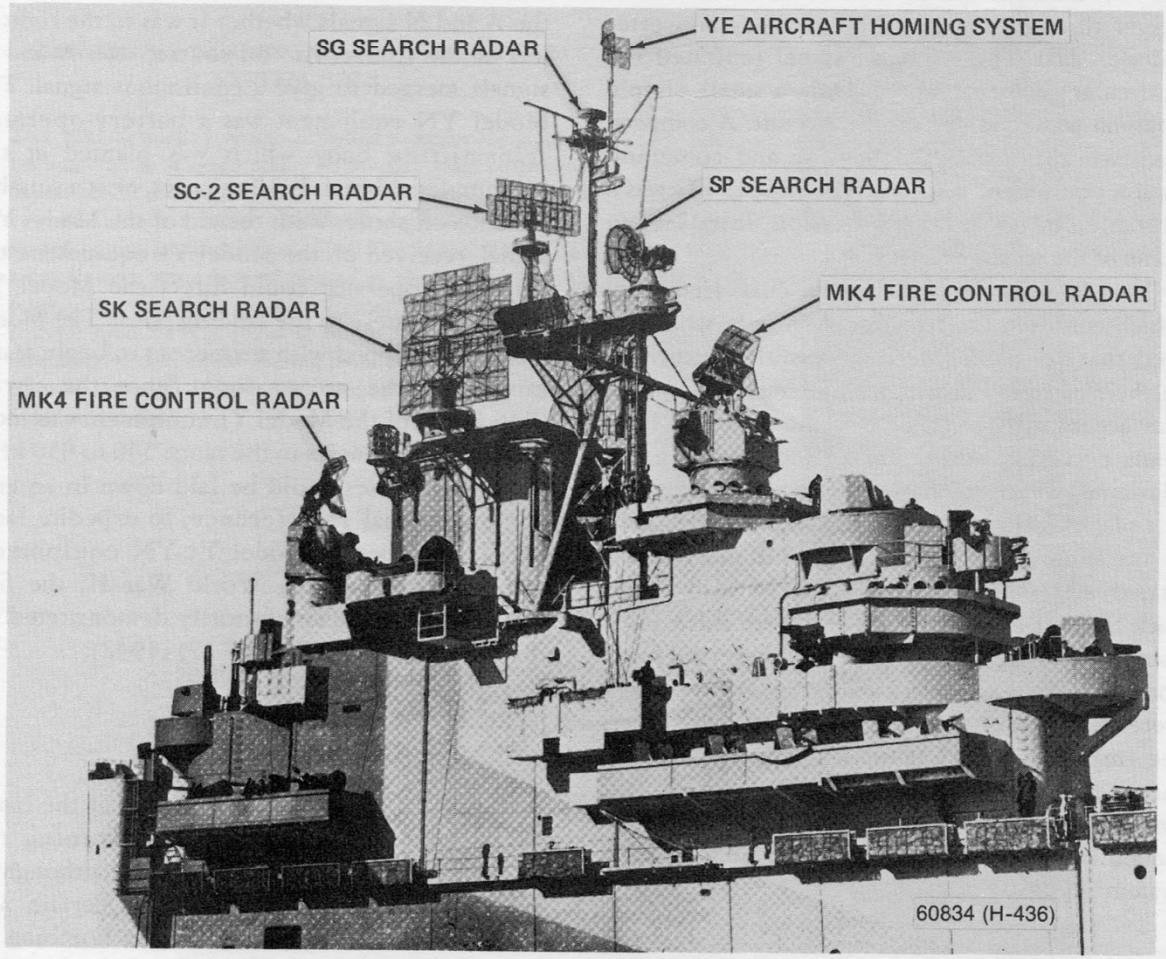


Ships heading indicator and adjustment crank

Cam with sector letters

Cam with station ID

Actual Installation



CARRIER INSTALLATION OF MODEL YE AIRCRAFT HOMING EQUIPMENT

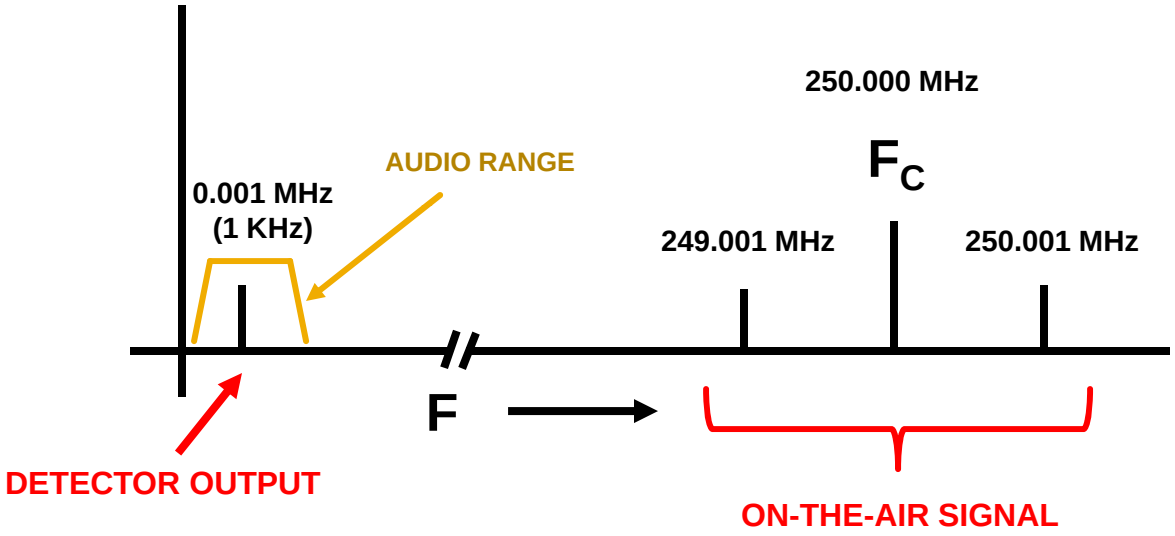
How Did It Avoid Enemy Homing

- Operated in the range of 250 Mhz. With “line-of sight” transmission limits.
- Used dual modulation requiring double-detection receivers.
- Enemy VHF direction finding technology was extremely limited.
- Sector-code signals, modulation frequency, and transmitted VHF frequency could be changed regularly.

In Modern EW Terms

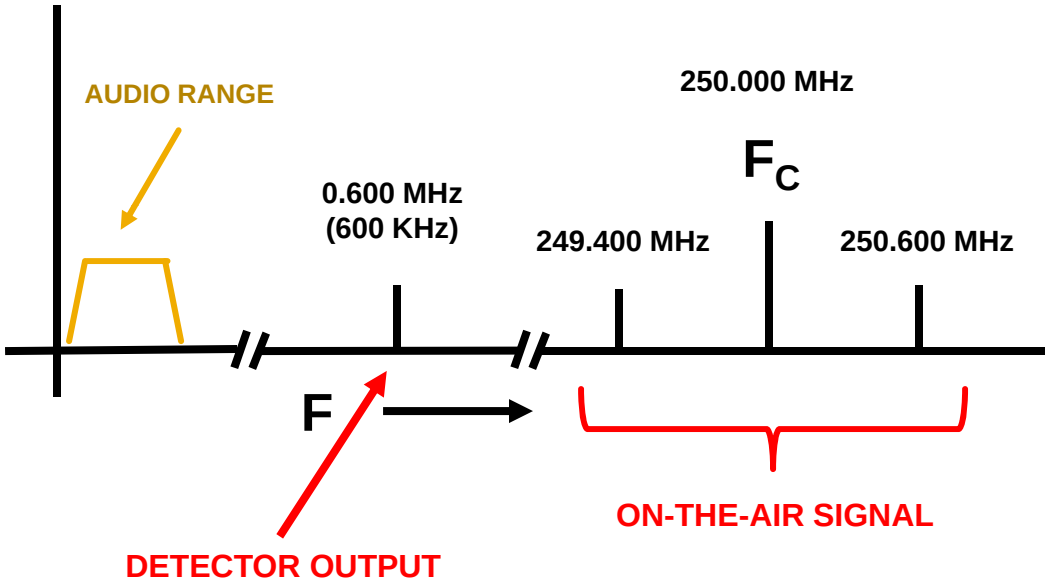
- Low Probability of Detection
  - 250MC was considered Ultra-High Frequency.
  - Range limited to line-of-sight.
  - Japan had no appropriate equipment for detection.
- Low Probability of Intercept
  - “Double modulation”
  - Random sequence of sector ID’s

Standard AM Detection



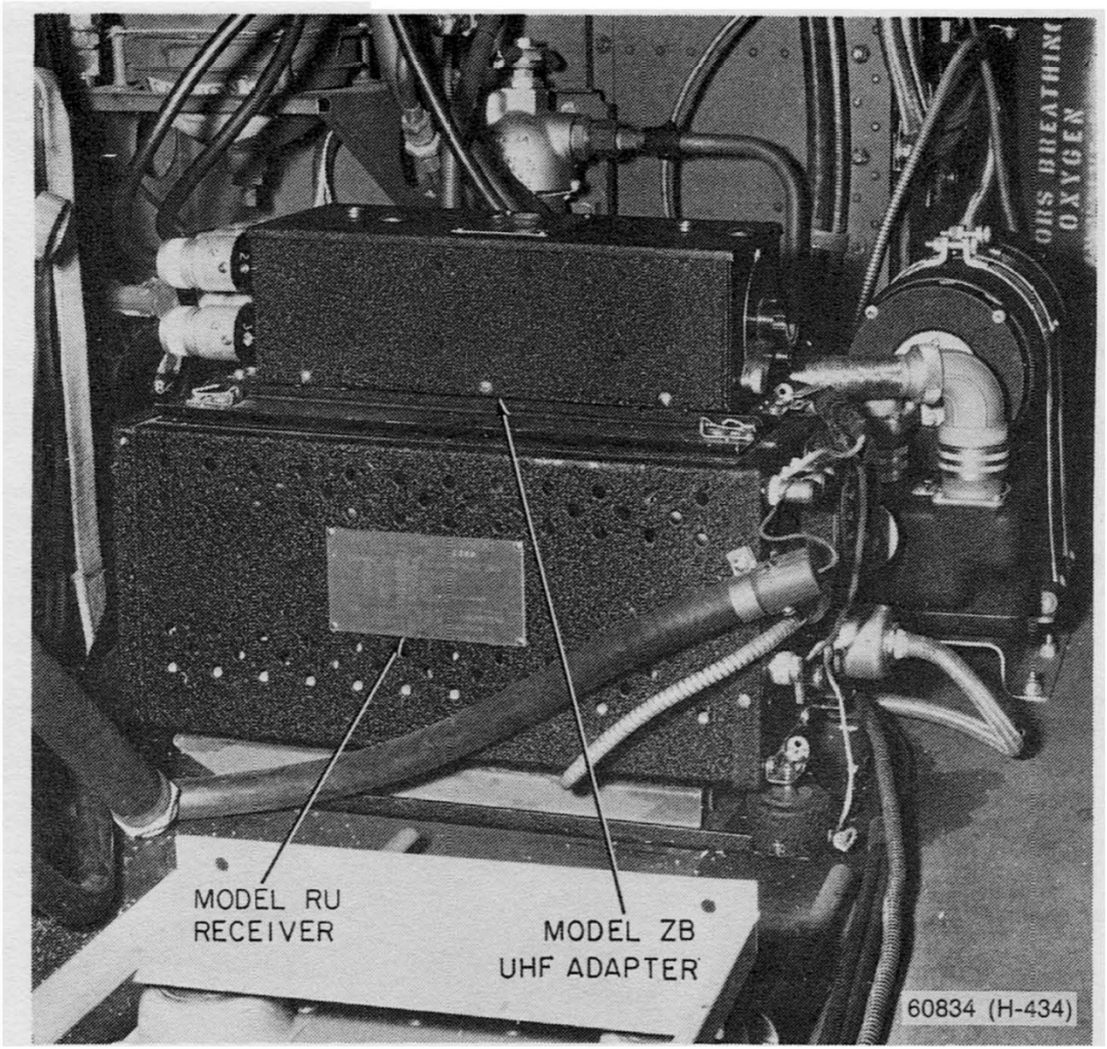
In the receiver detector, the sideband signals beat against the carrier resulting in a signal in the audio range.

Detection of YE/YG Signal

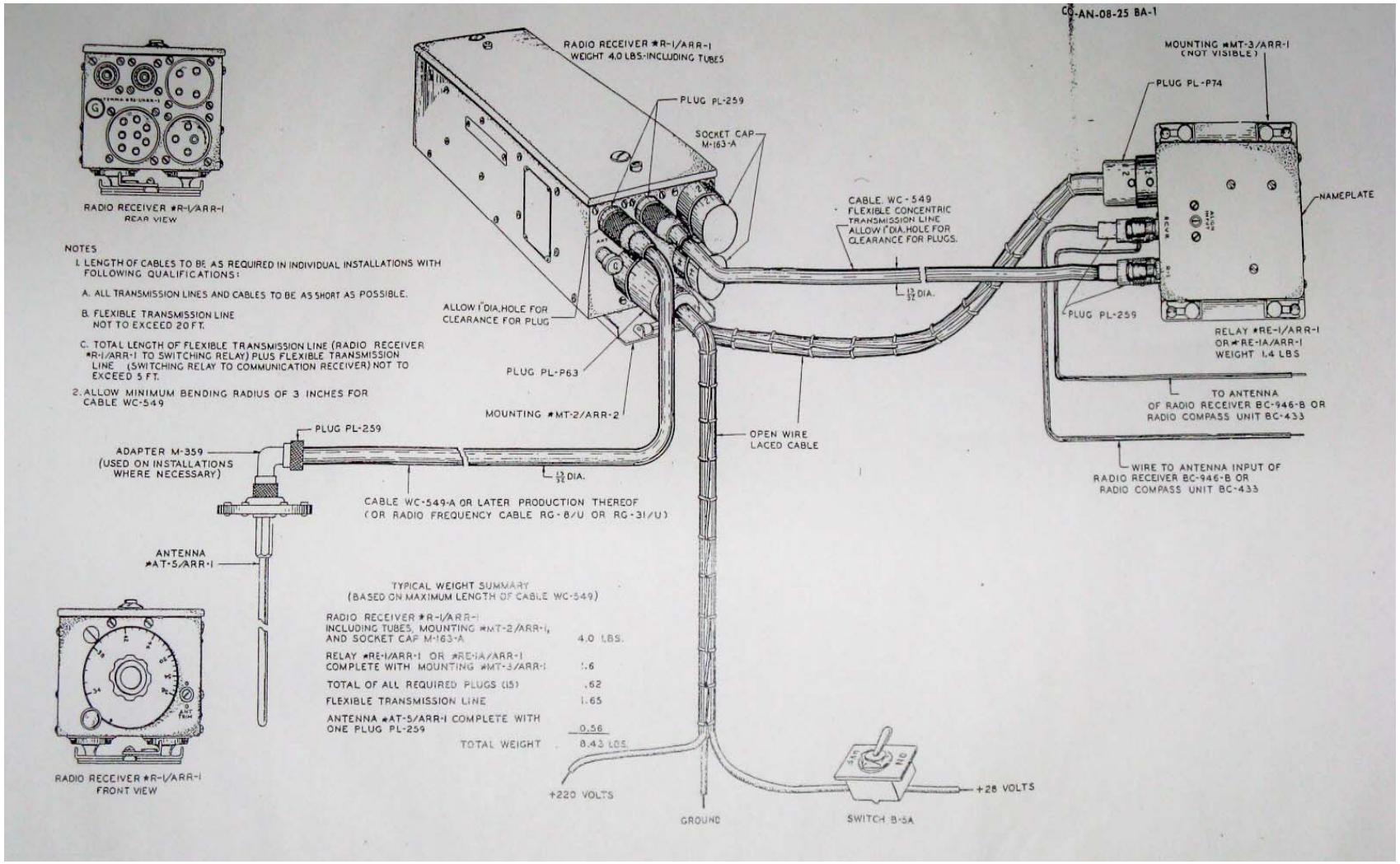


- Standard AM receiver hears nothing.
- Detector output of ZB receiver is sent to a medium-wave CW receiver for a second detection.

Aircraft Equipment



ZB Connection Diagram



Performance

- Stories are legion of the systems ability to lead pilots home, sometimes in the dark and with dwindling fuel reserves.
- The enemy Admirals never could understand how our pilots were so adept at returning to their carriers.
- There are incidents where Japanese pilots landed on our carriers because they were lost.

Second Generation Receiver

The ZB and ARR-1 receivers were upgraded to ARR-2 receivers that combined the VHF and MF receivers in a single unit that fit a standard rack mount thereby simplifying the system.

Lifetime

- This system remain in use as the primary carrier-homing method until 1960.
- Replaced by the TACAN UHF VOR/DME transponder system.

In Conclusion

Suffice to Say that Many of Our Pilots in the Pacific Theatre (and other areas as well) Were Saved by This Unique System