THE IMPEDANCE CHARACTERISTICS OF A 35' ~~SHIP~~ WHIP ANTENNA IN RELATION TO THE TUNING CAPABILITIES OF THE AN/SRA-22 ANTENNA TUNER

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The efficiency of shipboard high-frequency transmitting antennas, as a radiating source, is directly affected by their location, their length (impedance characteristics) and the impedance characteristic of the associated antenna coupler as well as how intelligently the coupler is tuned by operating personnel.

This article is to explain the system impedance aspects of a standard 35' shipboard whip antenna in relation to the impedance matching characteristics of the AN/SRA-22 antenna coupler. An understanding of the fundamentals of the antenna coupler impedance characteristics associated with the manual operation of the AN/SRA-22 will assist operating personnel to achieve maximum antenna system efficiency. Further, it will permit an understanding of the capabilities of the AN/SRA-22 when used with antennas other than the 35' whip.

Figure 1 is the type of impedance characteristics measured on an isolated 35' whip antenna. It should be recognized that this impedance can change materially when installed in various locations on a ship so that even on the same ship two 35' whips will not present the same impedance to the AN/SRA-22 coupler.

In order to have an antenna tuner capable of compensating for the complex impedance of the 35' whip, a variable tapped coil is placed in series with the antenna being tuned. Also, a variable capacitor is placed either in series or shunt with the antenna.

The manual control of the variable coil and capacitor (SERIES or SHUNT position) must be a sequence operation. If an operator attempts to vary the variable coil and capacitor at the same time, the effect of the tuning capacity can be masked by the movement of the variable coil.

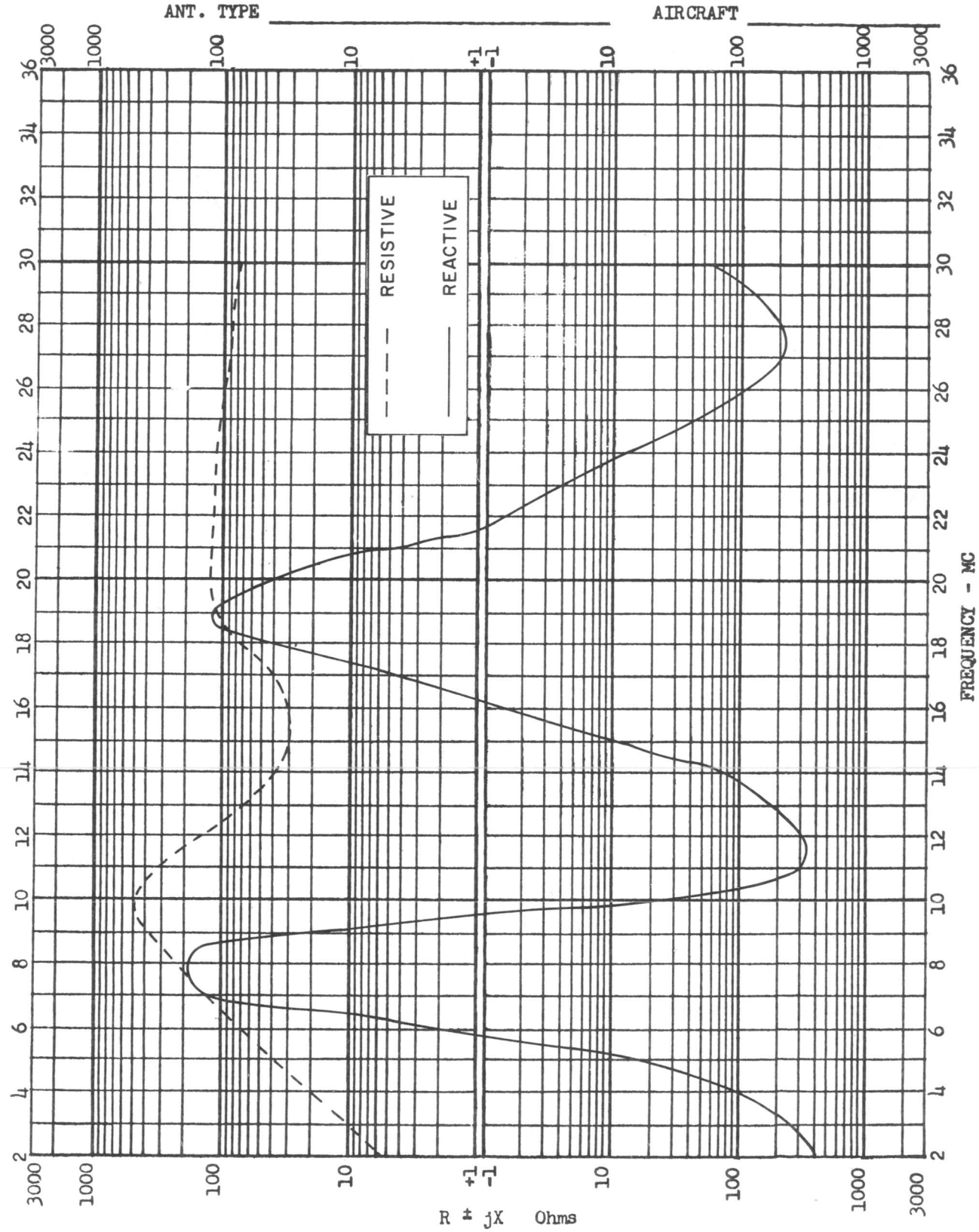
Figure 2 shows schematic of the AN/SRA-22 and illustrates the functions of the variable coil tap and capacitor.

The variable tap in the AN/SRA-22 is used to find the point on the coupler nearest 50 ohms. Adjustment of this variable tap position is always the last operation performed by the operator in the tuning process.

The operator's sequence of tuning the AN/SRA-22 into any antenna, whether it be a 35' whip or long wire antenna, is always to start from the "home" position (with the coil dial on 100, tap dial on 100, both coil and tap meters zero, series - shunt switch on shunt and the 12 position capacitor switch on position one). See figure 3.

This operation puts all variables near their minimum effective tuning position.

ANTENNA CHARACTERISTICS



FREQUENCY - MC

FIGURE 1

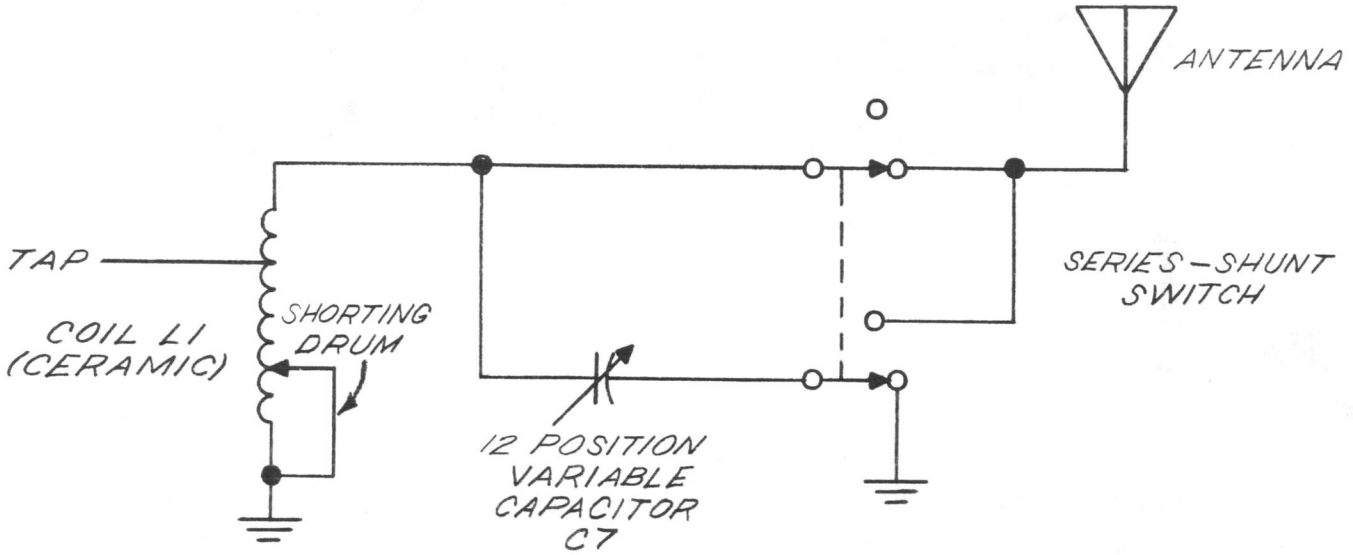

ANTENNA
TAP
COIL L1
(CERAMIC)
SHORTING
DRUM
SERIES-SHUNT
SWITCH
12 POSITION
VARIABLE
CAPACITOR
C7

FIGURE 2

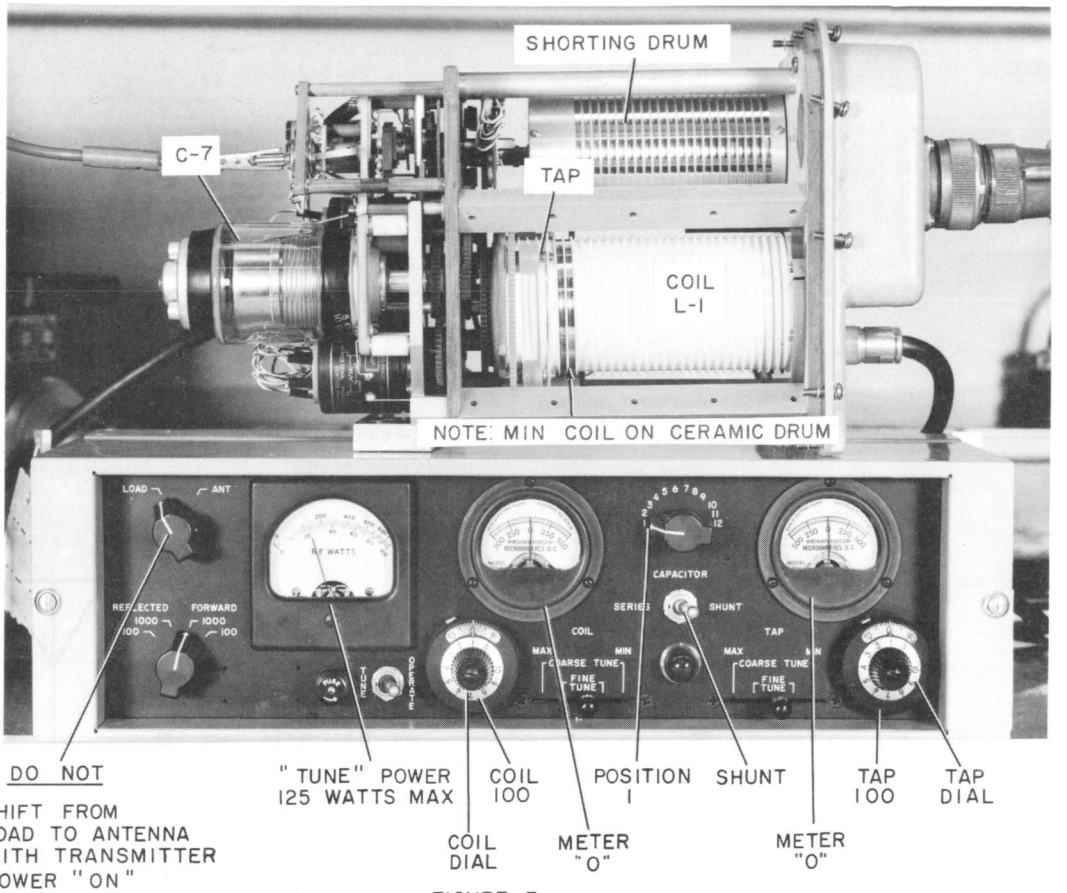


FIGURE 3

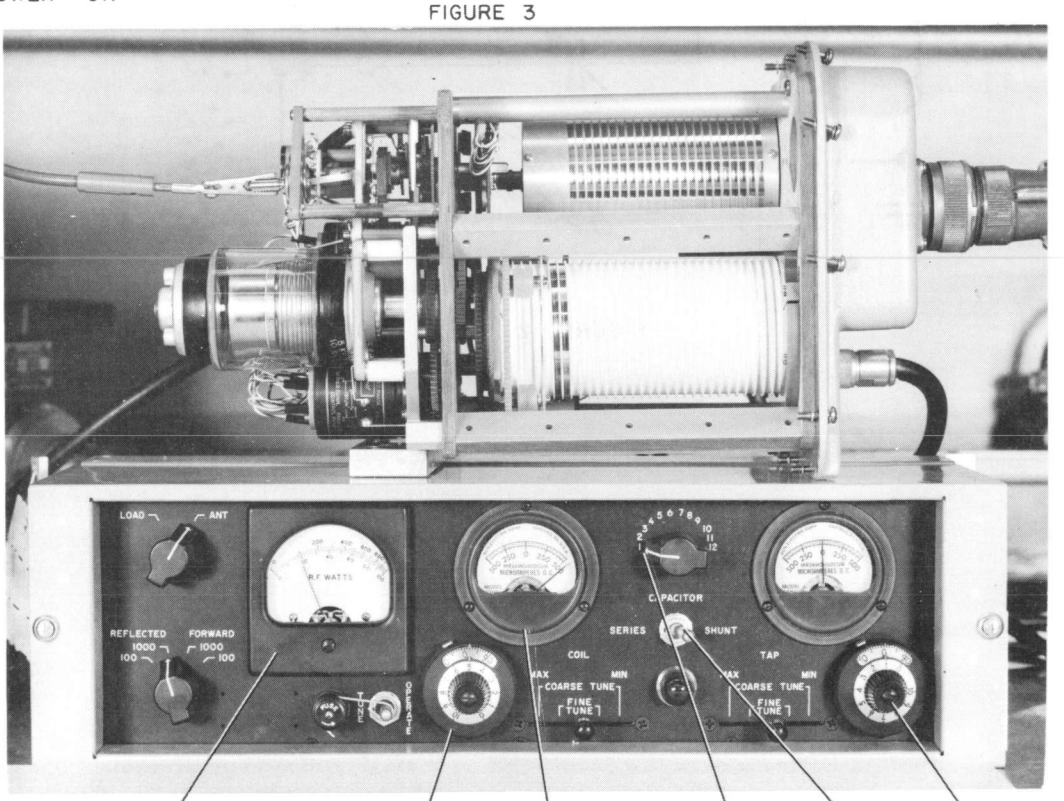


FIGURE 4

The transmitter must be set to "tune power" with a power output of not over 125 watts before tuning the AN/SRA-22 into an antenna of unknown characteristics. The power output of SSB transmitters such as the AN/URC-32 and WRT-2 can be reduced to a few watts by varying the excitation. Use only the power necessary (below 125 watts) when tuning the AN/SRA-22 into an antenna until the tuning positions of the antenna coupler have been verified as good and efficient.

As previously stated, the tuning of the AN/SRA-22 must be started from the "home" position. Figure 3 shows this position on the antenna control C-2698/SRA-22 and also the position of the coil, tap and capacitor on the CU-714/SRA-22. Note that the coil on the ceramic drum is about 2 complete turns of ribbon. The rest of the coil is on the shorting storage drum. It should be remembered that each 20 divisions on the coil dial represents one additional turn of ribbon on the ceramic drum. Since the drum is connected in series with the antenna, the addition of coil ribbon on the ceramic drum is the equivalent of adding inductance (coil) in series with the antenna, or in effect making the antenna electrically longer.

The radio frequency currents passing through the coil cause heat to be generated in the coil and coupler. The less number of coil ribbon turns on the ceramic drum the less heat will be generated. Tuning chart NavShips 93286.21A, has placed limits, which should not be exceeded, for coil settings when tuning to various frequencies such as 500 for tuning frequencies 2-6 mc, 6-12 mc - 350, 12-16 mc - 250, and 16-30 mc - 200.

Visualize the AN/SRA-22 tuned into an antenna, for example at 2.5 mc. The coil dial reading should be 500 or less. There would be approximately 500/20 (25 turns) of coil ribbon on the ceramic drum. This is a considerable amount of inductance added to the antenna in order to increase its electrical length. This unfortunately causes reduced efficiency of the coupler due to the inherent loss in any conductor, but this cannot be avoided when using an antenna requiring this high coil setting as would a 35' whip antenna in the 2 to 6 mc frequency range.

Under no circumstances should the coil dial reading exceed 500 for frequencies 2-6 mc. This, as stated before, represents 25 turns of coil ribbon on the ceramic drum and is a large potential heat source for the coupler to dissipate.

Figure 4 shows the initial position of the controls for tuning an antenna in the 2-6 mc range. Note that this operation also starts with the same number of turns on the ceramic drum. The coil "coarse fine tune" switch is moved full left (see figure 5) to bring the coil dial meter back to zero. This operation increases the coil ribbon on the ceramic drum (see figure 5).

As the number of turns of the coil ribbon on the ceramic drum is increased (see figure 6), a reduction in reflected power is obtained. This reduction in reflected power continues (see figure 7) until the reflected dip is obtained. Note that a dip in reflected power was obtained by coil alone and that since the coil meter is still to the right of zero, this indicates the coil setting is less than 500 as it should be.

After "fine" tuning to eliminate the reflected power, figure 8 shows the position of all indicators in full operate position for a frequency of 2.5 mc, that is, forward power 500 watts, coil reading 459, capacitor in shunt position 1 and tap indicator on 93.

When tuning the AN/SRA-22 to the next band of frequencies, 6-12 mc range, the maximum coil reading is reduced to 350. In this range of frequencies the coil limits are imposed for an additional reason. If more coil than 350/20 or 17.5 coil ribbon turns are used on the ceramic drum, any extra turns will cause the coil to go through parallel resonance. This makes the

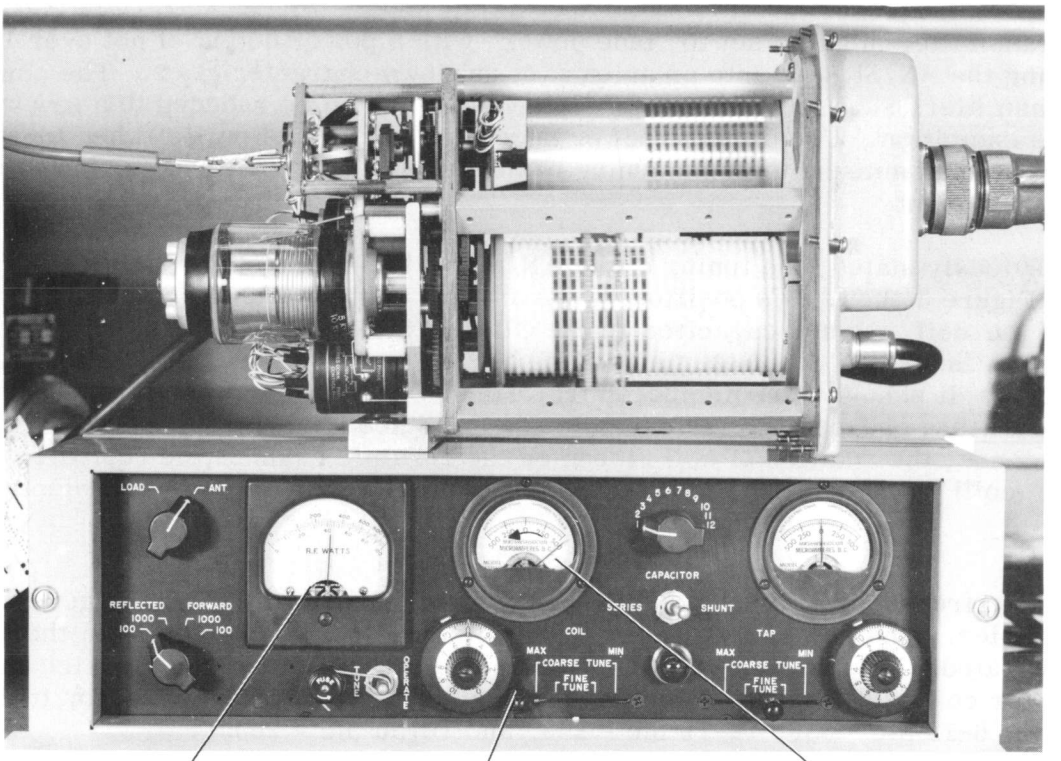


FIGURE 5

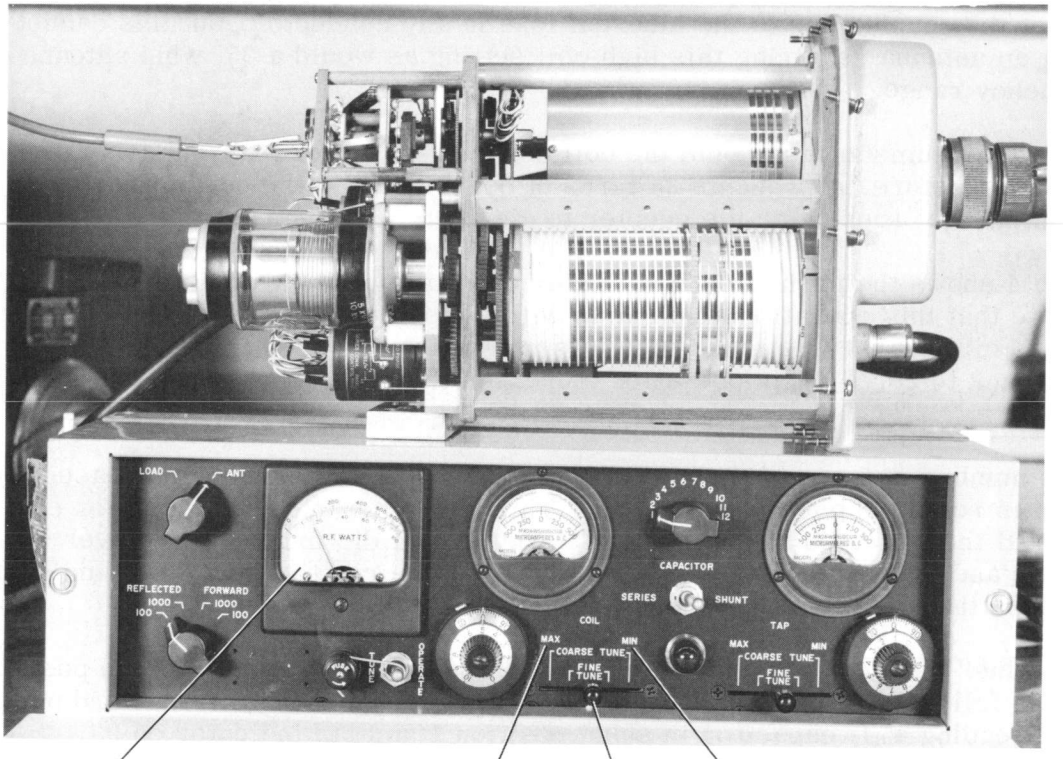
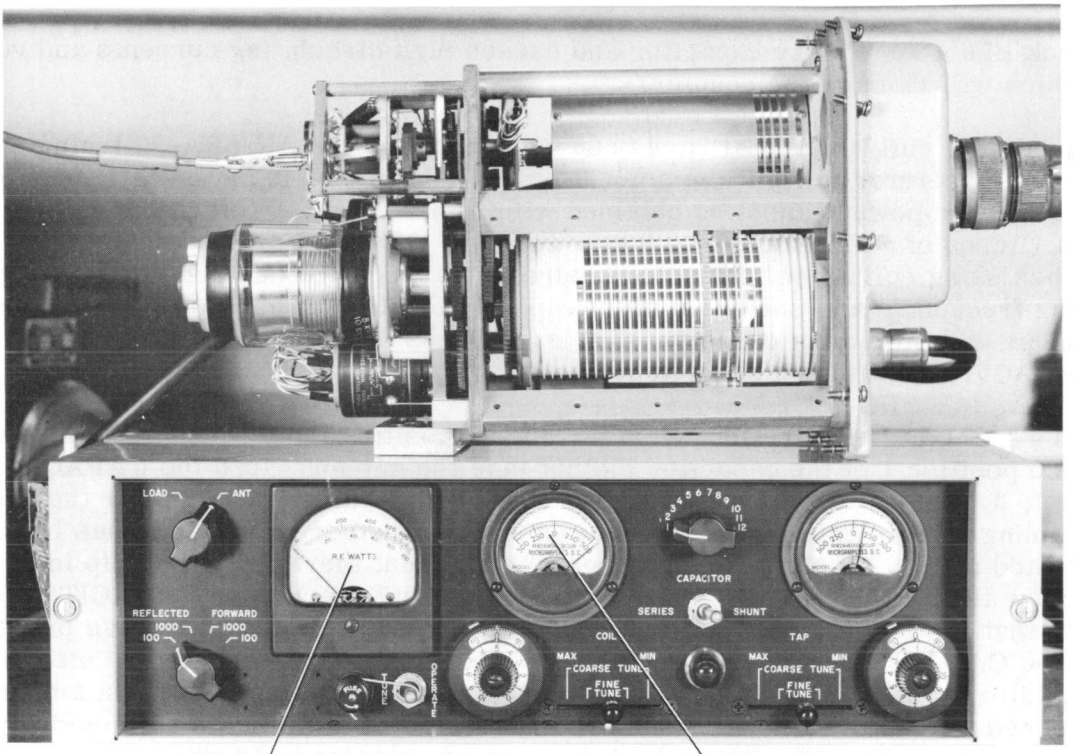


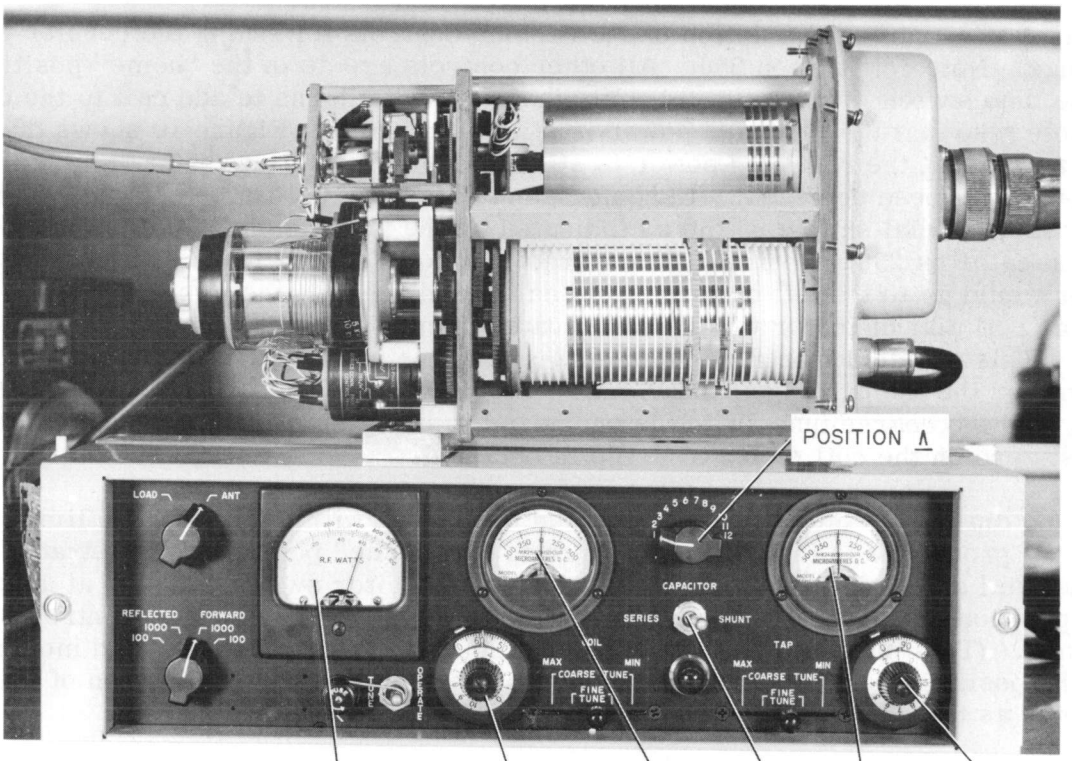
FIGURE 6



REFLECTED POWER "ZERO"

COIL METER STILL TO RIGHT OF ZERO INDICATES THAT ANTENNA WAS <u>TUNED</u> WITH LESS THAN COIL SETTING OF 500

FIGURE 7



COUPLER IN FULL OPERATE POSITION FOR 2.5 MCS

FORWARD POWER 500 WATTS

COIL READING 459

METER "0"

SHUNT

METER "0"

TAP-93

FIGURE 8

coil now look like a very lossy capacitor and causes high circulating currents and very high voltages which will damage the coupler.

The maximum coil limits that have been established in the AN/SRA-22 tuning procedure are to force the operator to limit the amount of coil ribbon that is put on the ceramic drum. If a dip in reflected power cannot be obtained within these limits, return the coil dial setting to 130 or 3 + turns of coil ribbon (coil meter zeroed). If a dip in reflected power cannot be obtained when using coil alone, the antenna already is inductive (antenna too long electrically at the tuning frequency) and series or shunt capacity must be used. Start this phase of the tuning process with minimum capacity, that is, with the SERIES - SHUNT switch on SHUNT and the CAPACITOR switch on position 1.

Position 1 of the CAPACITOR switch is "home" position from which all tuning procedures start. Since position 1 of the capacitor did not tune the antenna, turn the CAPACITOR switch to position 2, 3, 4 -- to 12 in discrete single steps. Wait after each step for the red capacitor tuning light to extinguish. Note at each step whether or not a dip has been obtained in the reflected power. If after reaching position 12 shunt there is still no dip in the reflected power, change the SERIES - SHUNT switch to SERIES and operate the CAPACITOR switch in reverse, that is, 12, 11, 10, etc. to 1. One position at a time. The above procedures in moving the CAPACITOR switch and SERIES - SHUNT switch in the step by step manner described, is to enable the operator to positively find the very first or lowest amount of capacity needed to tune the antenna. This is indicated by the dip in the reflected power using the least capacitor setting (closest to 1 while in shunt, closest to 12 while in series).

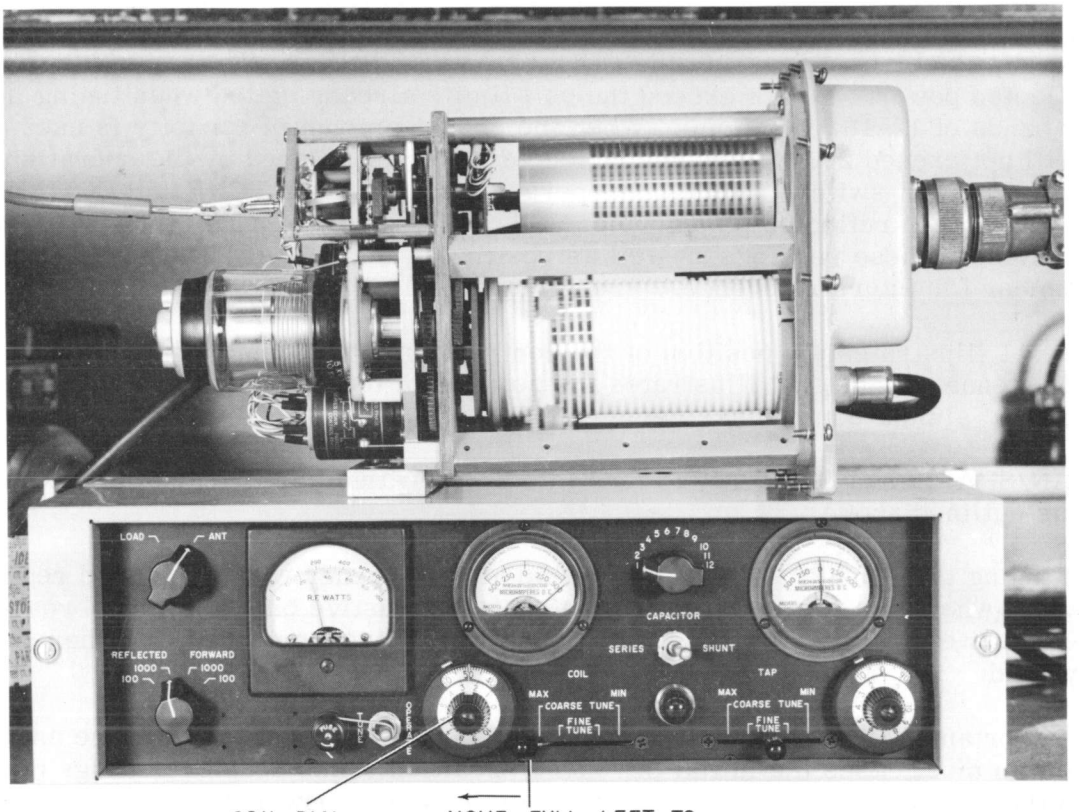
If excessive capacity is used, the operator will have to compensate this excess by more inductance or coil ribbon on the ceramic drum. This, as stated before, can result in high heat or voltage arcing with the coupler.

Figure 9 illustrates the position of the various controls for tuning the coupler in the 12-16 mc range. Note coil dial on 250. All other controls are as in the "home" position. As the coarse tune switch is moved to full left, the coil motor turns to add coil to the ceramic drum. Note also that the reflected power is still rather high. Figure 10 shows that the coil meter is zeroed but the reflected power is still too high, indicating that a dip in reflected power has not yet been achieved. It should be noted that no dip can be obtained without exceeding the coil dial setting of 250 as indicated by the fact the dial meter is zeroed with the dial indicator on 250. Continuing to operate the coil "coarse tune" switch so that the coil meter would go to the left of zero would cause additional turns to be put on the ceramic drum. The coil dial indicator would read greater than 250 when the coil meter was finally ZEROED. This should not be done for the 12-16 mc tuning range. After the setting the coil dial setting for the tuning ranges of 2-6 mc - 500, 6-12 mc - 350, 12-16 mc - 250 and 16-30 mc - 200, and the coarse tune switch is energized to bring the coil meter back to zero, do not go past zero on the coil meter if no dip is obtained.

When no dip in reflected power is obtained by staying within the coil dial limits above, the following procedure is to be used. Return to the "home" position as illustrated in figure 3. Set coil dial at 130 and zero coil meter. Move capacitor switch one step at a time starting from position one and wait each time until the red light on the antenna control panel is extinguished. (This indicates that the variable vacuum capacitor has stopped moving and has reached the position indicated by the numbers on the switch). Note the action of the reflected power meter as the capacitor is switched one position at a time.

When a dip is indicated in the reflected power, make no further movement of the capacitor switch.

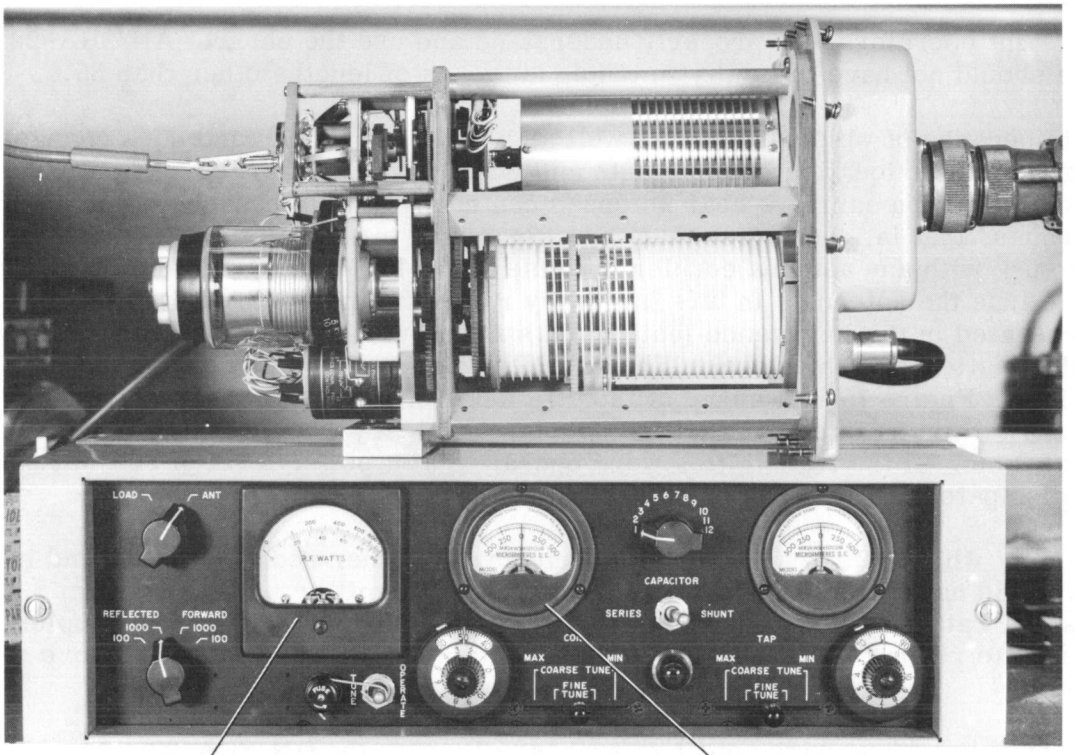
If position 12 shunt is reached and no dip is yet indicated, shift the series shunt switch to series and reverse the steps, that is, 12, 11, 10, 9, etc. until a dip is obtained.



COIL DIAL
250-(12-16MC)

MOVE FULL LEFT TO
ZERO COIL METER

FIGURE 9



ANTENNA STILL UNTUNED
AS INDICATED BY HIGH
REFLECTED POWER (100 WATTS)

COIL LIMITS OF 250 (12-16 MC)
HAVE BEEN REACHED
BEFORE DIP IS OBTAINED

FIGURE 10

Once a dip is obtained, operate the COIL COARSE TUNE switch to obtain a further reduction in reflected power. Do not exceed the coil limits already stated when tuning in the frequency bands of 12-16, 16-30 mc. When the proper amount of capacity is used, the coil settings will not exceed 200. After the reflected power is reduced by the operation of the COIL COARSE TUNE switch, alternately operate the TAP FINE TUNE and COIL FINE TUNE switch to obtain zero reflected power. Zero all meters by the operation of the COIL and TAP dial. Record these readings as well as position of the CAPACITOR (SERIES or SHUNT) and the number for future reference.

Figure 11 illustrates the position of the controls for a frequency of 9 mc tuned into a 35' simulated antenna. Figure 12 illustrates the position of the controls for a frequency of 15 mc tuned into a 35' simulated antenna.

The AN/SRA-22 has the ability to tune into a wide variety of antennas if used and operated as outlined above.

When tuning the AN/SRA-22 into a 35' whip at a frequency where the whip represents a quarter wave (where the impedance of the antenna is resistive only), a much broader dip in the reflected power will be experienced than that normally experienced elsewhere in the frequency band.

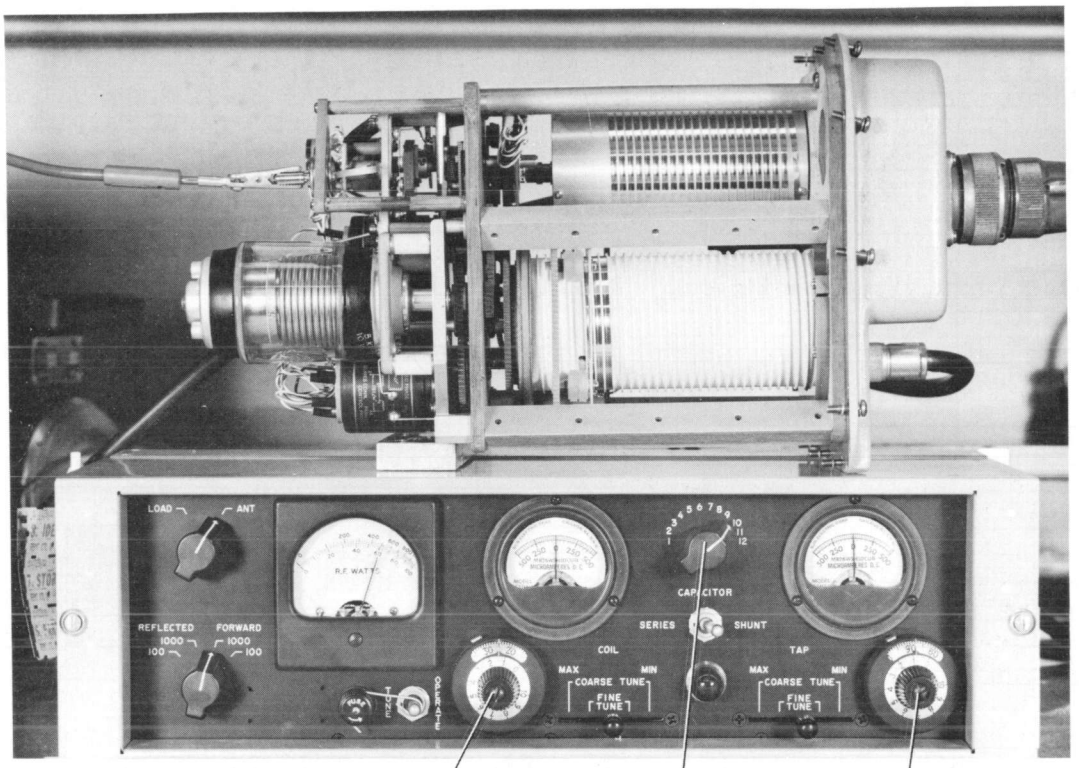
It is important that minimum (125 watts) transmitter power be used in the antenna tuning procedure. In most cases the initial or "home" position of the coupler settings places the coupler in the detune position which results in the reflected power being high. High reflected power at transmitter power levels of 125 watts will not damage the coupler. The reason for the use of minimum power on tune-up is that high reflected power reacts on the transmitter and causes the plate current of the transmitter tubes to exceed their current rating with probable resultant damage to the power amplifier tubes or high voltage supply fuses.

Competent operators who properly understand and use the correct AN/SRA-22 tuning procedure should not have difficulty in tuning antennas of lengths other than 35 ft.

The impedance of whip antennas as well as wire antennas can and does change radically depending upon their location, their length and other physical characteristics. The roll of a ship and aircraft on carriers near antennas can change the impedance of an antenna. Short antennas, that is, those less than 35', when used in the 2-6 mc range are the most difficult to use with any antenna coupler because of the high inductance (coil) values that are required to tune the antenna. In this frequency range the major difficulty is the dissipation of heat generated in the inductance (coil). This is why it is wise to use reduced power to keep the heat dissipation at a safe level. The AN/SRA-22 is capable of dissipating 300 watts at 65°C ambient. Figure 15 is a curve of the efficiency of the AN/SRA-22 when used with a 35' whip antenna. Note on figure 15 that the coupler efficiency when working into a 25' whip is only 50% at 2 mc. If the transmitter were operating at a power level of 500 watts, 250 watts would be dissipated within the coupler as heat.

With a 15' whip at 2 mc the coupler efficiency is further reduced to 20% and in this case 400 watts would have to be dissipated as heat if the transmitter was operated at 500 watts. Since this 400 watts of heat will exceed the heat dissipation capacity of the coupler, it would be necessary to reduce the transmitter output to about 250 to 300 watts to insure safe operation.

Ships have used long wire antennas successfully with the AN/SRA-22. The USS Northampton is using the AN/SRA-22 on a voice only circuit on a 2.5 kw power amplifier on frequencies of 4 to 30 mc using a 35' ship antenna. Antennas shorter than 35' should be tuned with care and in no case should the coil setting ever exceed 500 in the 2 to 6 mc range.

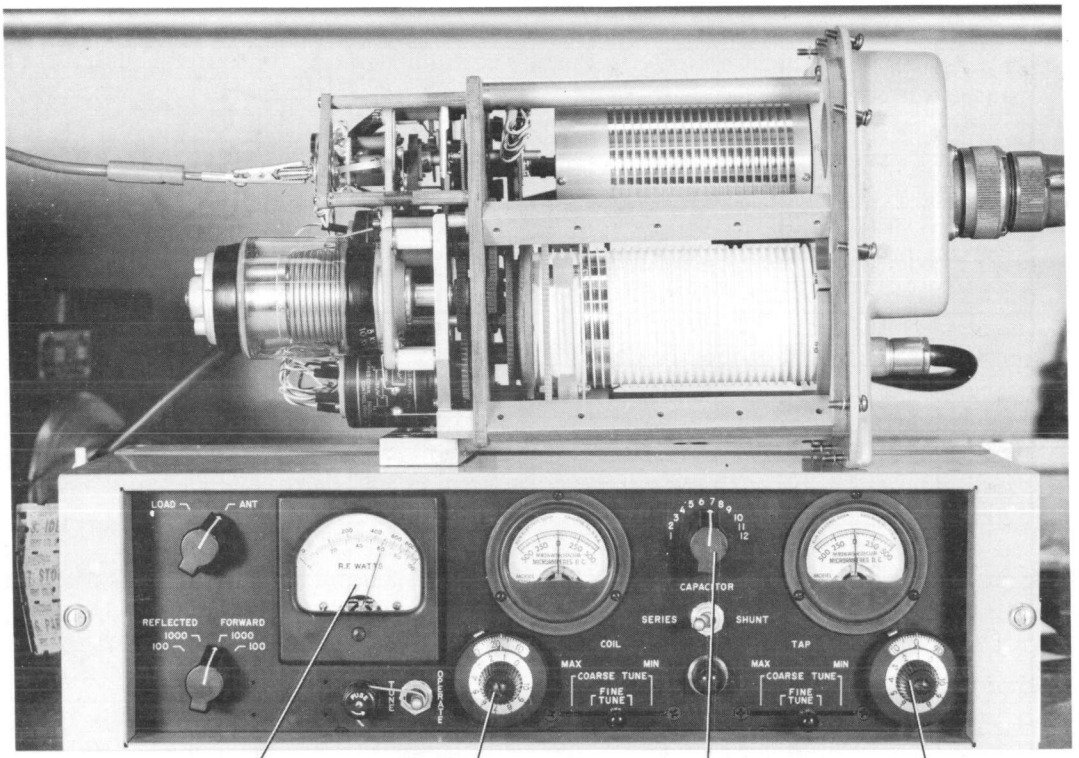


COIL SETTING 125

CAPACITOR SHUNT 10

TAP SETTING 88

FIGURE 11
ILLUSTRATES COUPLER SETTING FOR 9MC INTO 35' SIMULATED WHIP



500 WATTS

COIL SETTING 118

CAPACITOR SERIES 7

TAP SETTING 100

FIGURE 12
ILLUSTRATES COUPLER SETTING FOR 15 MC INTO 35' SIMULATED WHIP

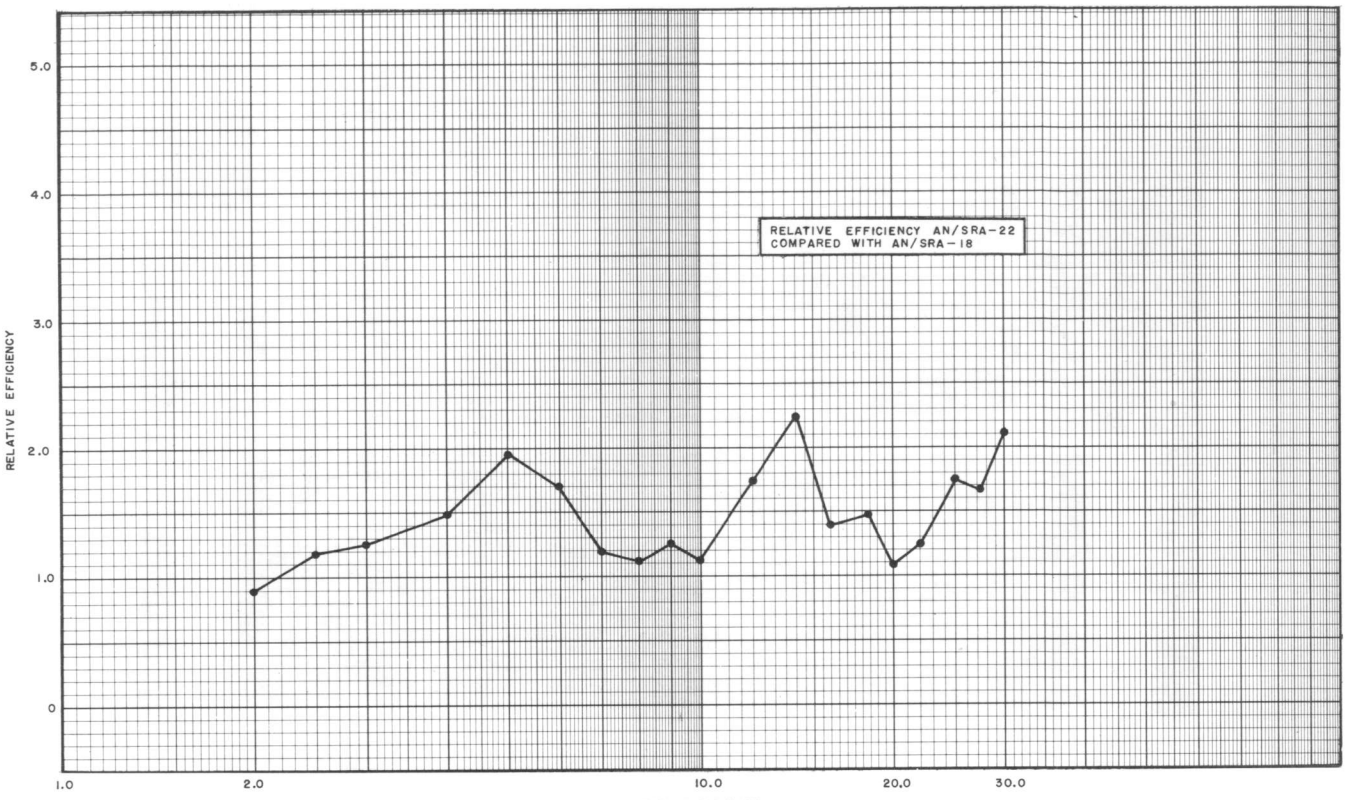


FIGURE 13

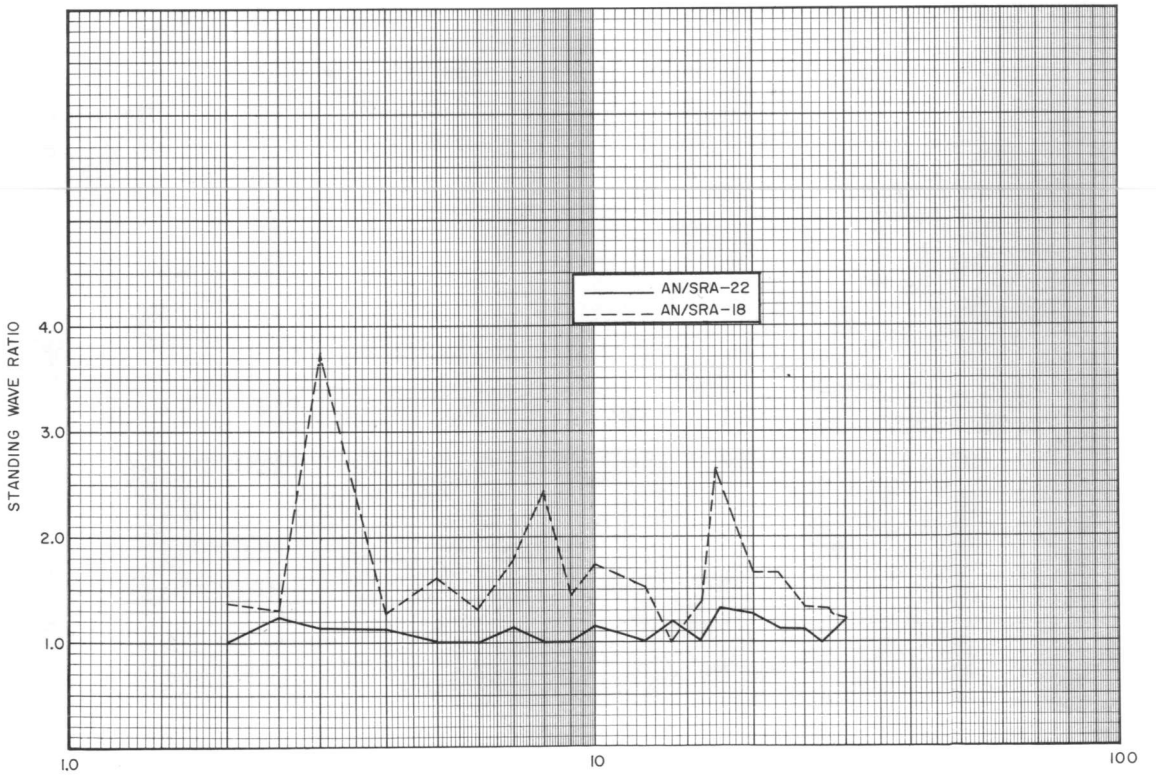


FIGURE 14

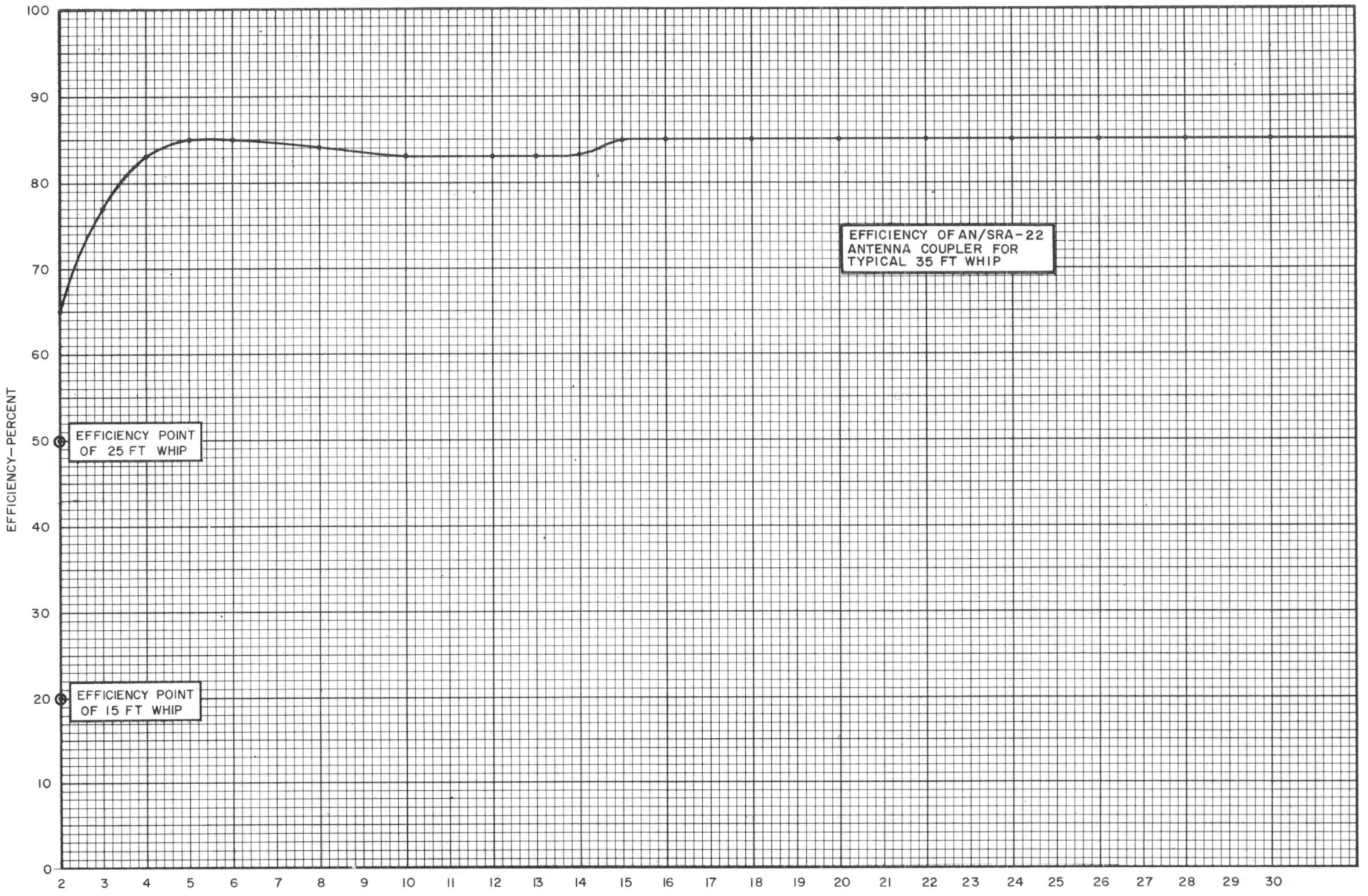

EFFICIENCY OF AN/SRA-22
ANTENNA COUPLER FOR
TYPICAL 35 FT WHIP
EFFICIENCY POINT
OF 25 FT WHIP
EFFICIENCY POINT
OF 15 FT WHIP
EFFICIENCY—PERCENT
100
90
80
70
60
50
40
30
20
10
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
FREQUENCY—MC

FIGURE 15

If short antennas must be used in an emergency on 2 to 6 mc, power must be reduced so as to reduce the internal heating of the coupler.

As a matter of interest, figures 13 and 14 show curves which appeared in a Naval Electronics Laboratory report showing the efficiency of the AN/SRA-22 vs the AN/SRA-18, as well as its ability to tune to a very small VSWR.

In summary, the following is important regarding antenna impedance vs the tuning characteristics of the AN/SRA-22:

1. Antenna impedances should be known in order to operate any antenna coupler intelligently. The shorter the antenna, the more severe are the operating conditions placed on the antenna coupler. If the antenna is shorter than 30', reduce transmitter power to stay within safe coupler operating limits.

2. Always use minimum transmitter power in tuning the AN/SRA-22 (125 watts maximum).

3. Always start the AN/SRA-22 tuning procedure from the "home" position.

   a. CAPACITOR SERIES/SHUNT switch on SHUNT.

   b. CAPACITOR switch on position 1.

   c. COIL and TAP dial on "100."

   d. COIL and TAP meters on 0.

   e. Capacitor indicator light (red) out.

4. Never exceed coil indicator limits established in NavShips 93286.21(A), 500 for 2-6 mc, 350 for 6-12 mc, 250 for 12-16 mc, 200 for 16-30 mc. Excessive coil causes heat and lower efficiency.

5. Always use minimum coil necessary to obtain a dip in reflected power.

6. Definitely use capacitor in discrete single steps. Do not jump steps, use minimum capacity settings.

7. When tuning an antenna different from a 35' whip, use extra care in the tuning process so as to tune the coupler at its most efficient point.

8. Be especially careful when operating into antennas shorter than 35' whips. Antennas less than 25' should not be used unless emergency conditions so require. In any event on antennas shorter than 35' whips on frequencies below 6 mc, use reduced transmitter power; otherwise you will burn up the coupler because of excess internal heat.

9. When transmitting FSK where the duty cycle is high or when the transmitter is to be operated for reasonably long continuous periods, be sure you have tuned your AN/SRA-22 at its most efficient point for the frequency used. This will greatly reduce the internal heat in the coupler.

10. Insure that you have a good ground at the coupler. Lack of a good ground will make coupling tuning erratic.

11. Keep the bowl insulator clean and all outside connections watertight. Inspect often to insure this.

12. When using a slightly reduced length of coil ribbon as a result of emergency repairs, OPERATE COIL "COARSE TUNE" SWITCH WITH CAUTION AND AVOID RUNNING TAP OR COIL TO THEIR STOPS. In this case of reduced ribbon length DEFINITELY START TUNING PROCEDURE FROM THE "HOME" POSITION AND operate coil "course tune" switch to increase or decrease coil as indicated in figure 6.

13. Since 35' whip antennas are normally used with the AN/SRA-22 and AN/URC-32 as transmitting antennas, fleet experience indicates that improved receiving capabilities can be obtained for the AN/URC-32 when used in the receive condition by using a separate receiving antenna. This can be done by patching the AN/URC-32 receiver to the ship's receiving antenna patch panel. See NAVSHIPS 93285(A) TD-496, page 3. Connect receiving antenna patch panel to J1 and connect J2 to J11 of the Frequency generator chassis (786E-1). See page 27 of SP-127 note 5.

IMPROVED AN/URC-32 RECEIVING CAPABILITIES WILL BE OBTAINED IF SEPARATE RECEIVING ANTENNA IS USED FOR THE AN/URC-32.