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Evangelatos, R. V.; Dunn, J. G.; Grunwald, A.; Wong, J. Y.

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AN HF ANTENNA SYSTEM  
FOR THE OPERATIONAL SUPPORT SHIP OSS - 509

T. V. EVANGELATOS, J. G. DUNN, A. GRUNWALD AND J. Y. WONG

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S. A. MAYMAN

Authority:

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RADIATION PATTERNS

- i) Port forward 35-foot whip
- ii) Goal-post 35-foot whip
- iii) Forward receiving fans
- iv) After receiving fans

ABSTRACT

An HF antenna system has been developed for the new Operational Support Ship. The transmitting system consists of two forward mounted 35-foot whips and one 35-foot whip located on top of the forward block-support. The receiving system consists of two side-mounted fans, one forward below the bridge deck and the other on the side of the funnels.



FIGURES

1. HF antenna arrangement on OSS
2. Smith-chart impedance of forward 35-foot whip
3. Smith-chart impedance of goal-post 35-foot whip
4. Mismatch loss of receiving fans
5. Isolation between tuned goal-post whip and receiving fans
6. Isolation between tuned starboard forward whip and receiving fans
7. Isolation between forward whips
8. Isolation between tuned starboard forward whip and goal-post whip
9. Figure of merit of port forward whip
10. Figure of merit of goal-post whip
11. Figure of merit of forward receiving fans
12. Figure of merit of after receiving fans

PLATES

- I. 1/48 scale model of OSS509 used in radiation pattern measurements

AN HF ANTENNA SYSTEM FOR THE OPERATIONAL SUPPORT SHIP OSS-509

- T.V. Evangelatos, J.G. Dunn, A. Grunwald and J.Y. Wong -

INTRODUCTION

As part of a continuing program of development of HF shipboard antennas for the Royal Canadian Navy, a model study was carried out to determine a suitable antenna system for the two new Operational Support Ships (OSS) now under construction. Communication requirements do not call for common antenna working, consequently no broadband transmitting antennas were required. The problem remained therefore largely in determining the optimum locations of the 35-foot whips with special attention being given to the isolation between antennas and the radiation patterns. The proposed antenna system consists of three 35-foot whips, two of which are located on the bridge deck and the third on top of the forward block-support. This antenna has been termed the goal-post whip. Each whip is operated in conjunction with an SRA-22 tuner and is intended to cover the entire 2 to 30 MHz band. The receiving system consists of two fans, one located forward below the bridge deck and the after fan located on the side of the funnel. The HF antenna arrangement is shown in Fig. 1.

IMPEDANCE MEASUREMENTS

Transmitting Whips

A 1/20 scale mock-up of the mid-section of the OSS was constructed for impedance measurements. A Smith-chart plot of the impedance of the starboard forward whip is given in Fig. 2 and for the goal-post whip in Fig. 3. In both cases the impedance is plotted from 2 to 24 MHz. Owing to symmetry, results similar to those given in Fig. 2 were measured for the port forward whip.

Receiving Antennas

One of the prime considerations in determining the location of the receiving antennas is the degree of isolation from the transmitting whips. The aim is to site the antennas for maximum isolation while at the same time to obtain a satisfactory radiation pattern. The system proposed consists of two antennas and is basically the same as that developed for the DDH 205 and DDE 257 classes. Each antenna consists of two fan-type radiators. One radiator is located on the port and the other on the starboard side of the superstructure. The two are co-phased to provide the required omnidirectional coverage. Figure 4 gives the mismatch loss of the receiving fans.

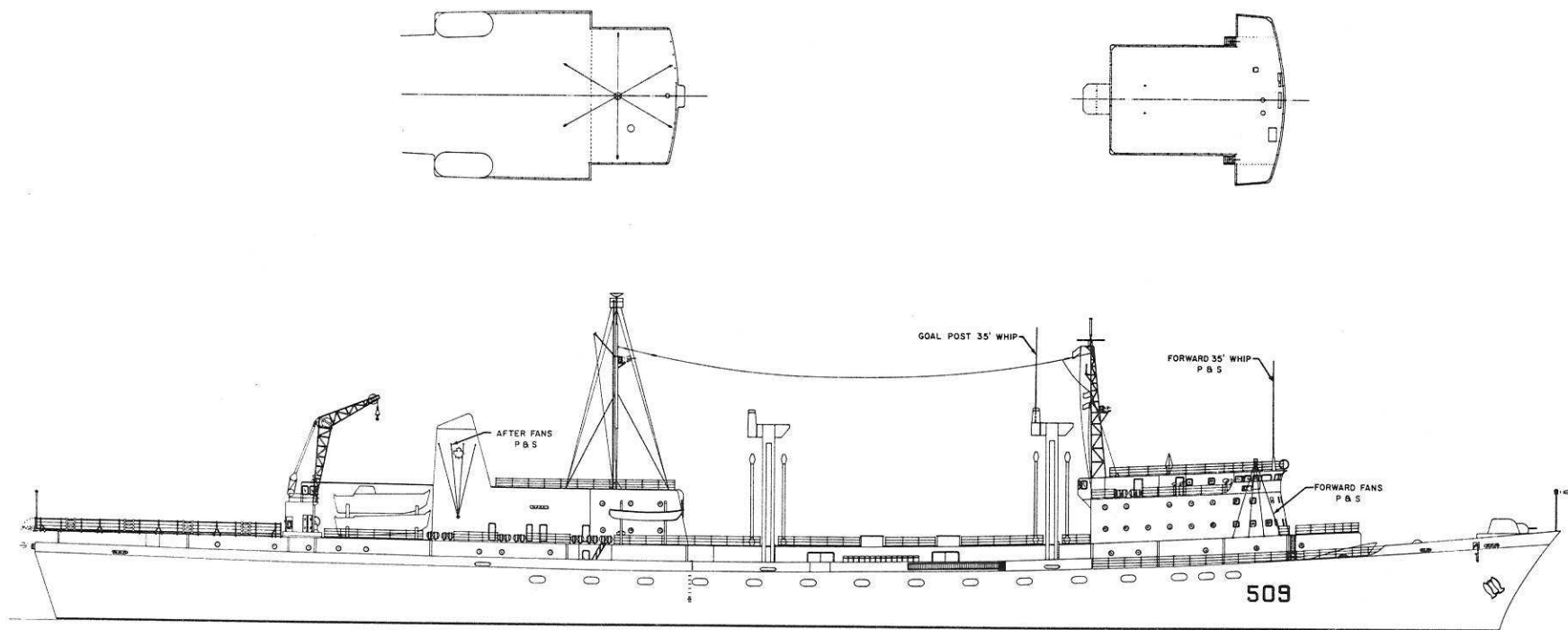


Fig. 1 HF antenna arrangement on OSS

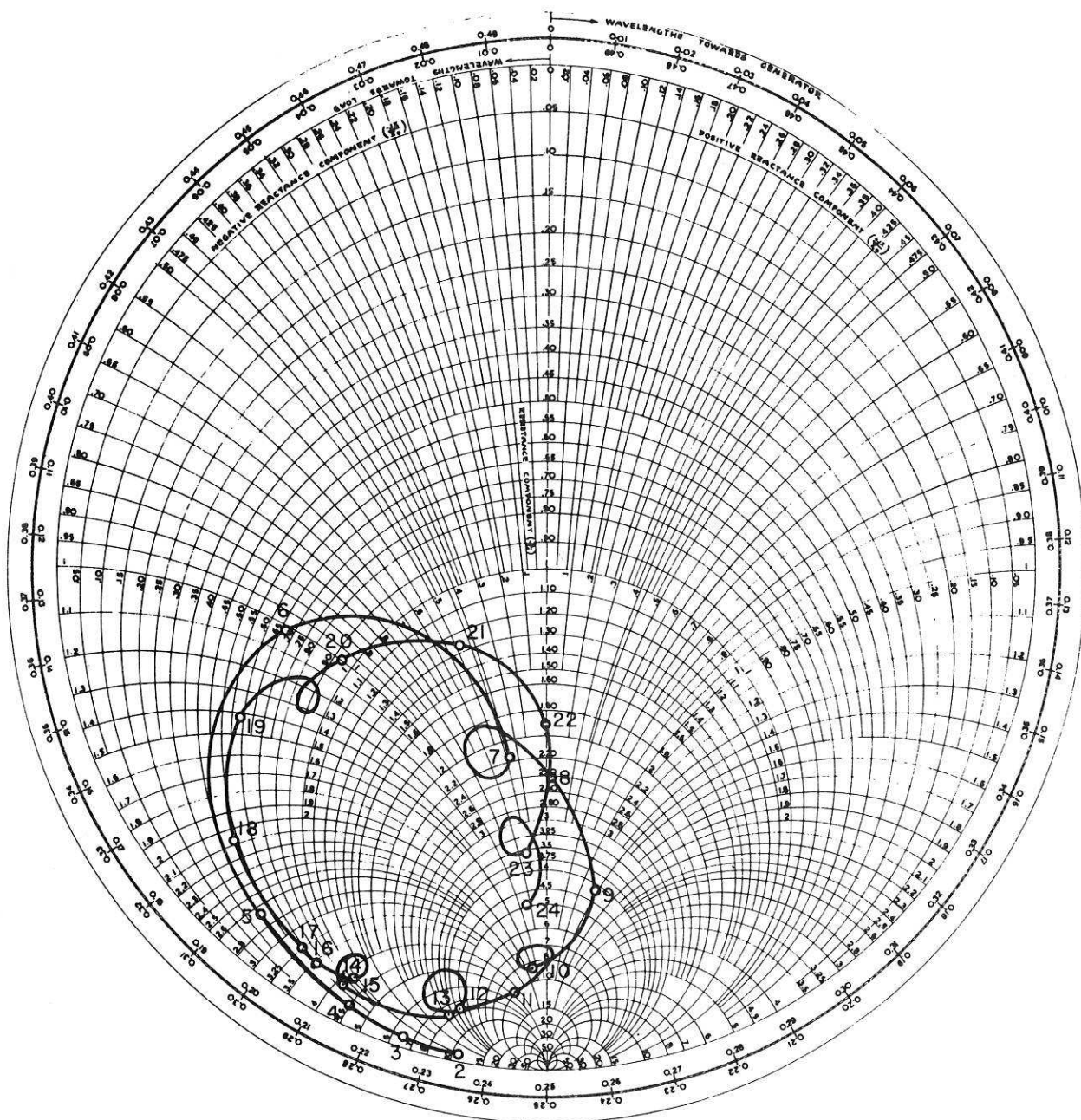


Fig. 2 Smith-chart impedance of forward 35-foot whip

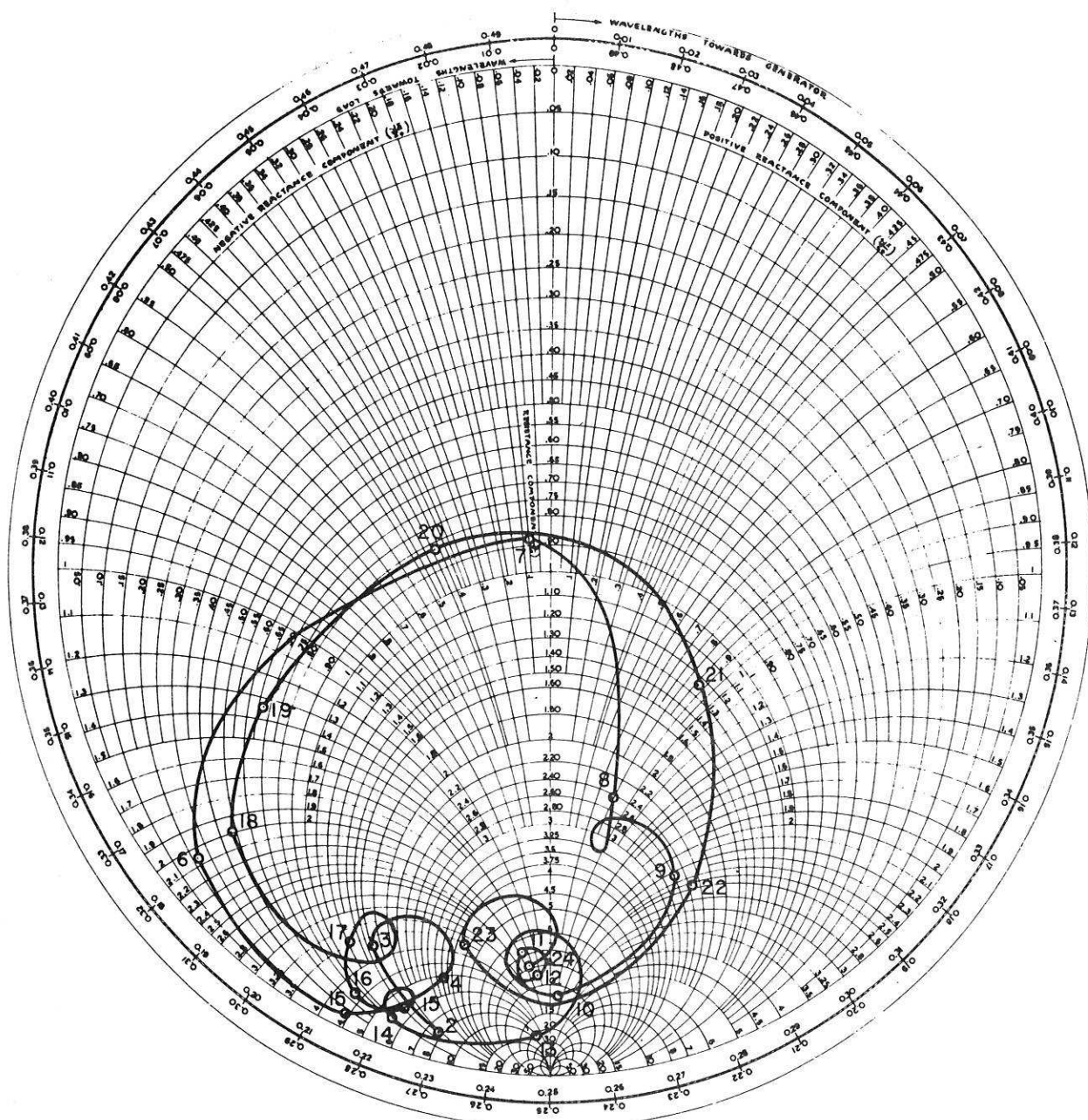


Fig. 3 Smith-chart impedance of goal-post 35-foot whip

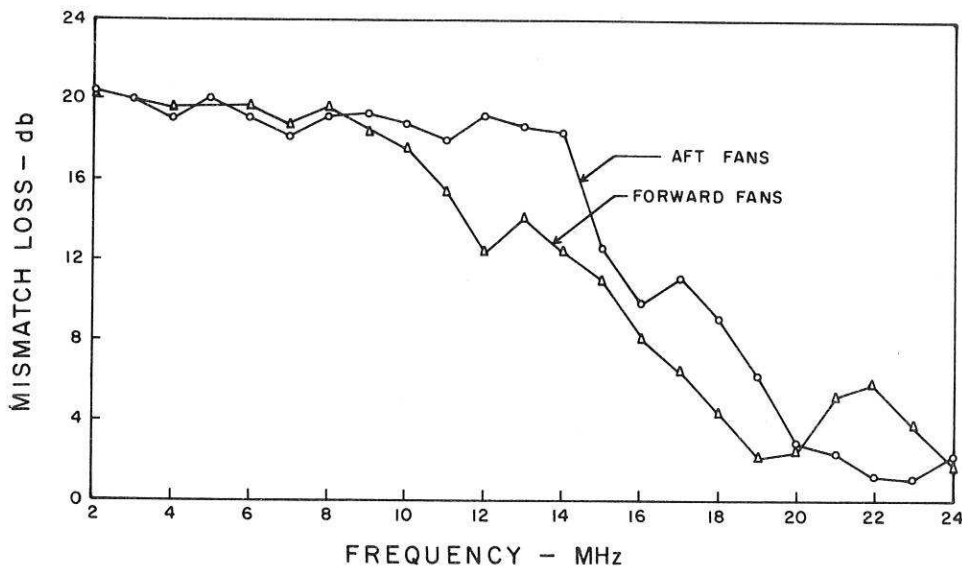


Fig. 4 Mismatch loss of receiving fans

### ISOLATION MEASUREMENTS

The same impedance mock-up was used for the isolation measurements. The measurements were carried out using an RF substitution method.

Figure 5 gives the isolation for the case of a tuned goal-post whip and the receiving fans. The isolation was first measured for an untuned whip and then corrected for mismatch loss to obtain the tuned case. Similar measurements were carried out for the starboard forward whip and the results are given in Fig. 6. The isolation between the whip and the after fans is greater than 45 db between 2 and 16 MHz.

Inadequate isolation between the transmitting antennas can result in serious detuning problems and in the generation of intermodulation products. Results of measurements between the two forward whips are shown in Fig. 7. Minimum isolation is about 10 db which occurs at 8 MHz, the resonant frequency of the whips. From Fig. 8 the minimum isolation between the forward and goal-post whips is seen to be about 18 db.

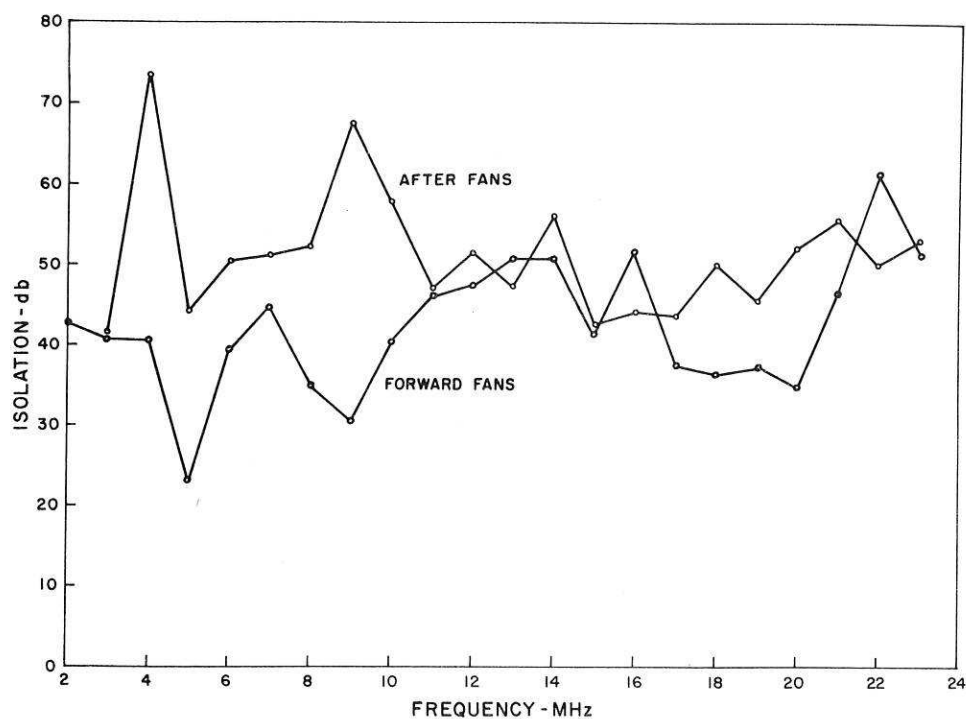


Fig. 5 Isolation between tuned goal-post whip and receiving fans

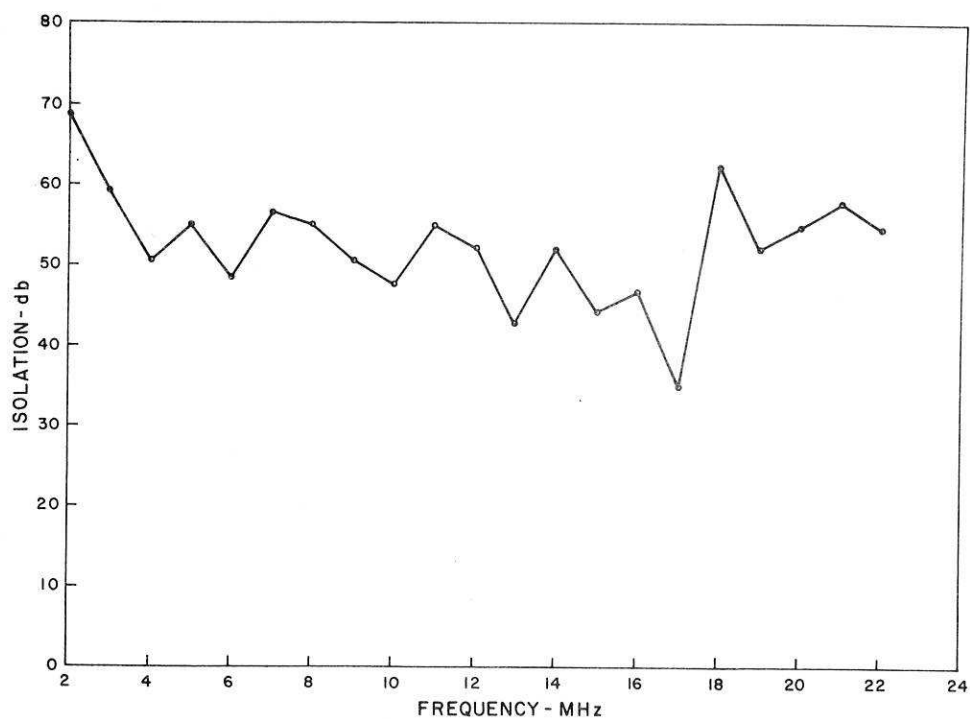


Fig. 6 Isolation between tuned starboard forward whip and receiving fans



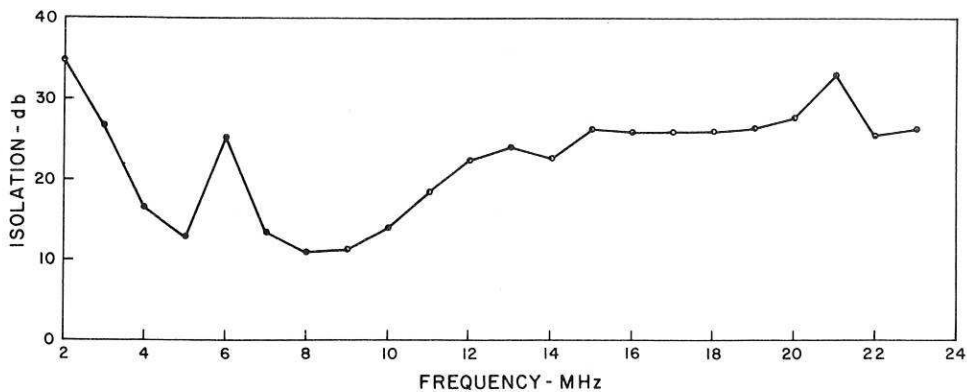


Fig. 7 Isolation between forward whips

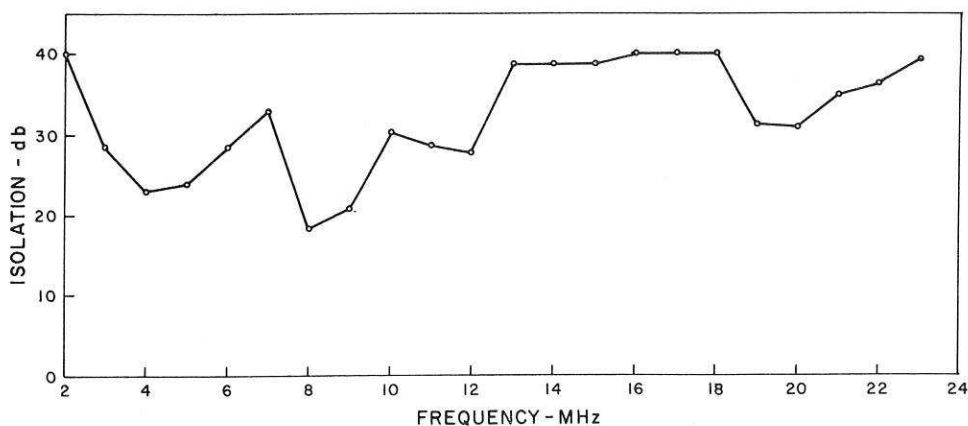


Fig. 8 Isolation between tuned starboard forward whip and goal-post whip

## RADIATION PATTERN MEASUREMENTS

Three-dimensional patterns were obtained for the whips and fan antennas. For each frequency, both  $E_\theta$  and  $E_\phi$  components were measured for a 5-degree increment in  $\theta$  but only the principal-plane patterns are included in this report. A photograph of the 1/48 scale model of the OSS used in the pattern measurements is shown in Plate I.

To facilitate the pattern analysis, the patterns were recorded both digitally on paper tape and graphically on polar chart paper. A program was written for the IBM 360 computer to calculate the figure of merit based on the method given in NRC Report ERB-647 [1]. For all cases the antenna figure of merit  $\zeta$  is compared with that of a  $\frac{\lambda}{4}$  ground based monopole, which is our standard of reference. The figure of merit of the port forward whip is plotted in Fig. 9. Between 2.25 MHz and about 4.5 MHz,  $\zeta$  is greater than it is for a  $\frac{\lambda}{4}$  monopole because of increased vertical directivity. Above 4.5 MHz,  $\zeta$  is less than for a  $\frac{\lambda}{4}$  monopole because of pattern degradation in the azimuthal plane. On the same figure is a curve labeled  $\eta$ . This curve was determined in a manner similar to that for the figure of merit by neglecting the deviation factors. The difference between the two curves is a measure of the amount of azimuth pattern degradation.

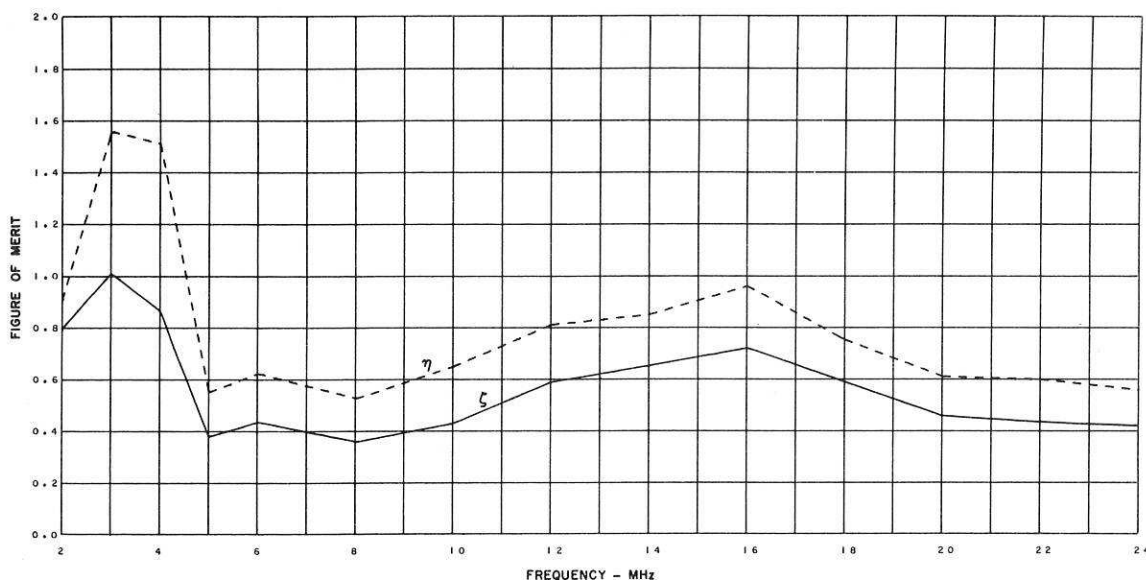


Fig. 9 Figure of merit of port forward whip

The figure of merit of the goal-post whip is given in Fig. 10. Its performance is considerably better than that of the forward whips between 2 and 5 MHz and is comparable over the rest of the band.

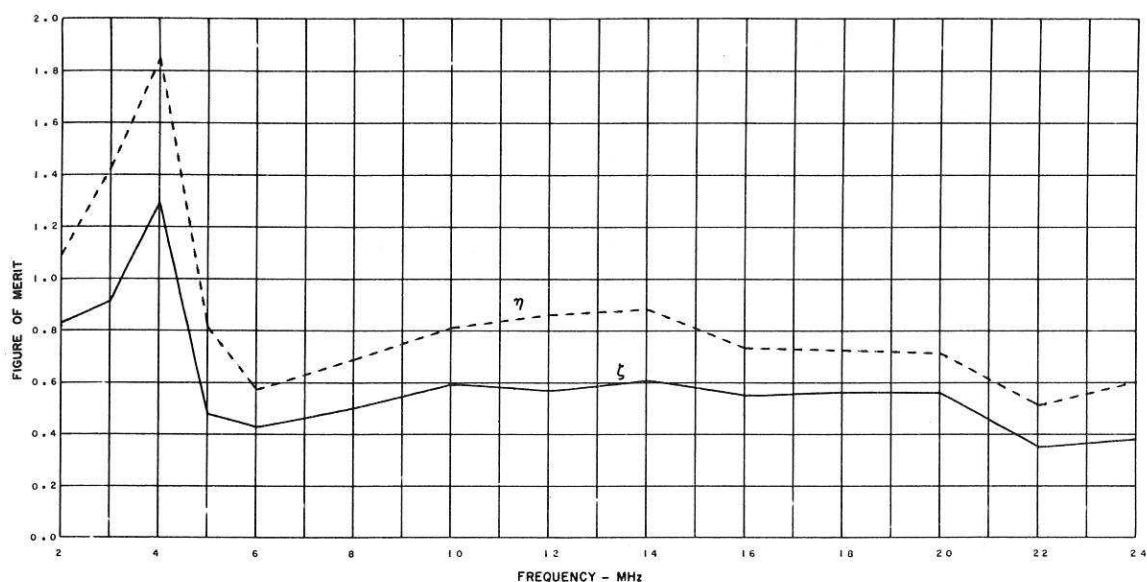


Fig. 10 Figure of merit of goal-post whip

Figure 11 gives the figure of merit of the forward fans and Fig. 12 of the after fans. In general the performance of the after fans is superior over the entire 2 to 24 MHz band.

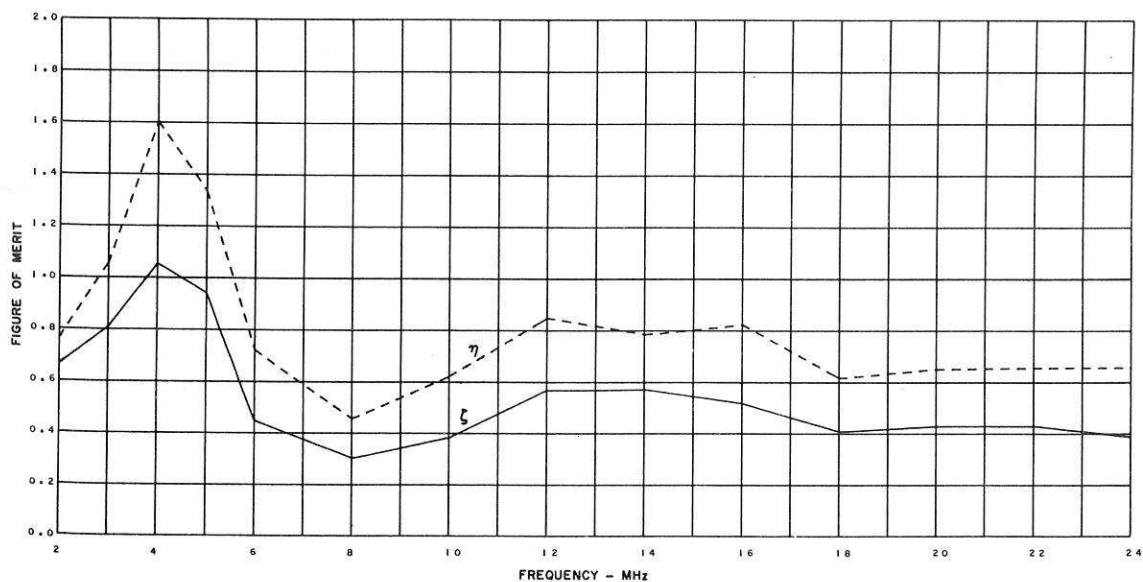


Fig. 11 Figure of merit of forward receiving fans

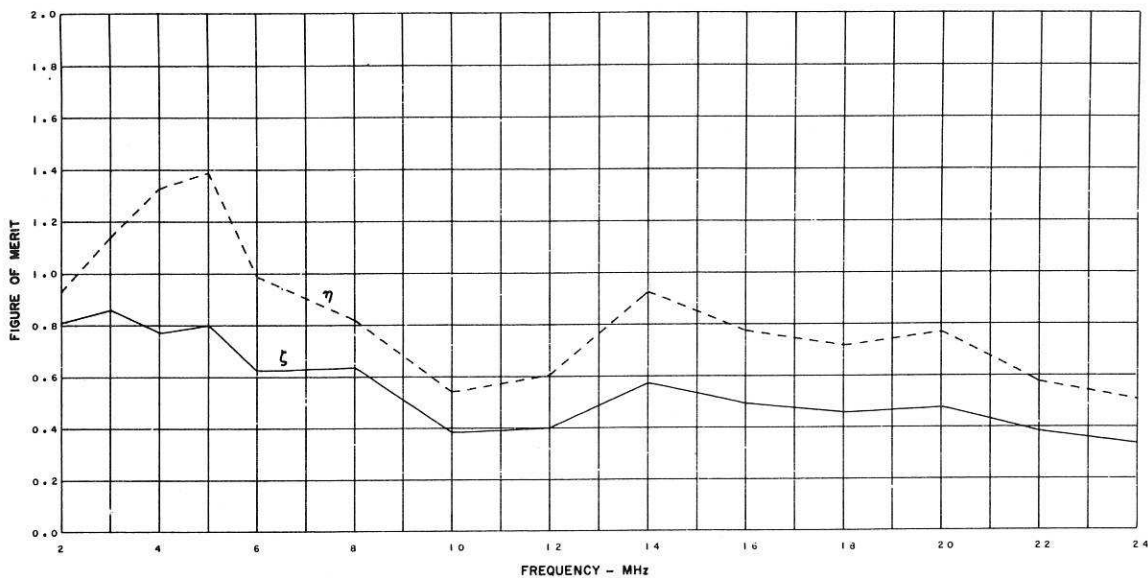


Fig. 12 Figure of merit of after receiving fans

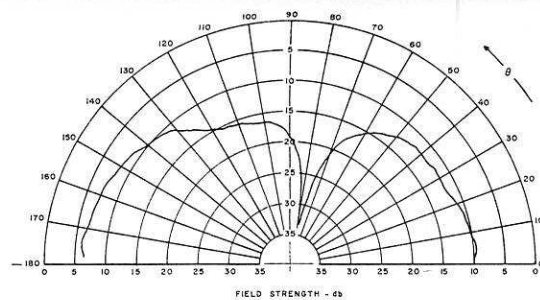
## CONCLUSIONS

Using scaled model techniques an HF antenna system has been developed for the new Operational Supply Ship. Results of measured impedance, isolation, and radiation pattern performance are given for the antennas.

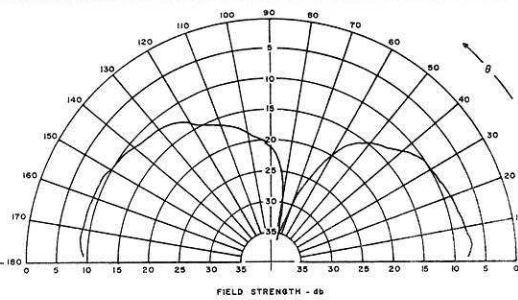
## REFERENCE

1. J.Y. Wong. A proposed method for evaluating the performance of an HF shipborne transmitting antenna. NRC Report ERB-647, September, 1963

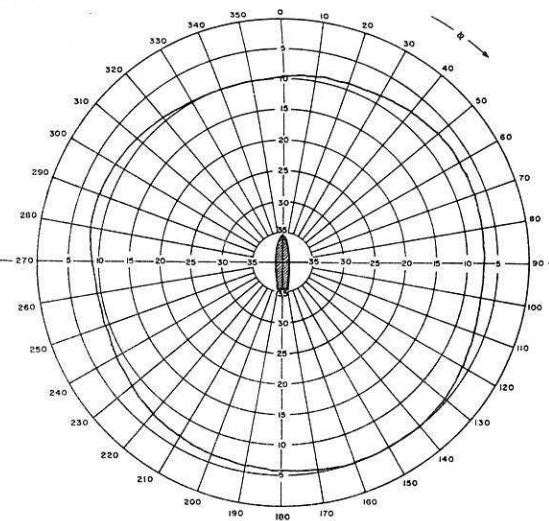
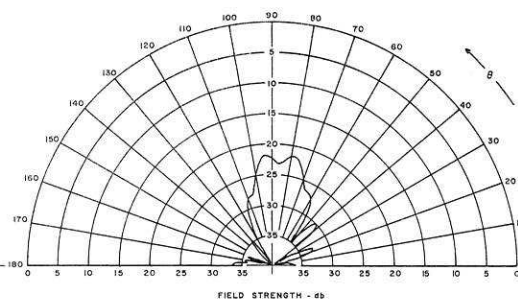
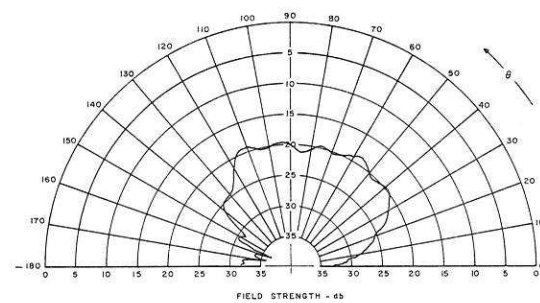
i) Port forward 35-foot whip

$E_{\theta}$ 

FWD-AFT



PORT-STBD

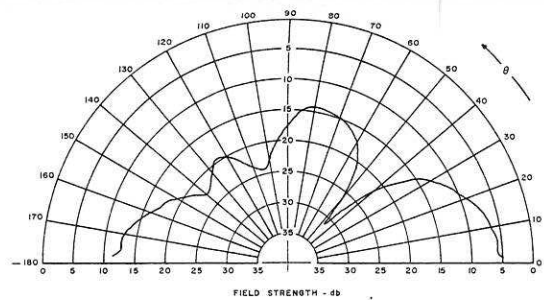
 $\theta = 0^\circ$  $E_{\phi}$ 

ANTENNA : PORT FWD WHIP

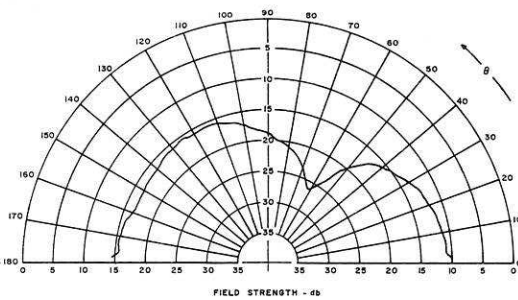
FREQ. : 2 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

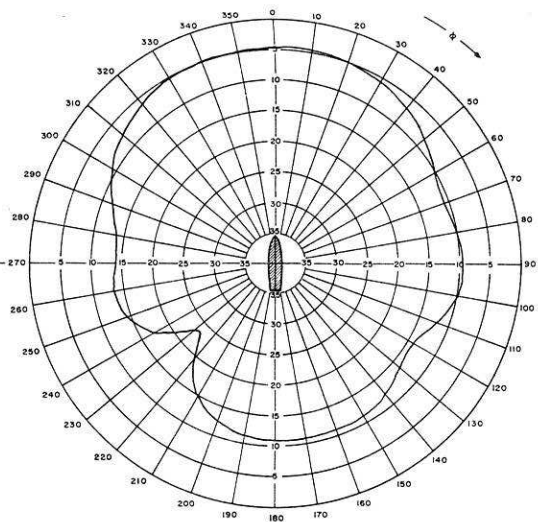
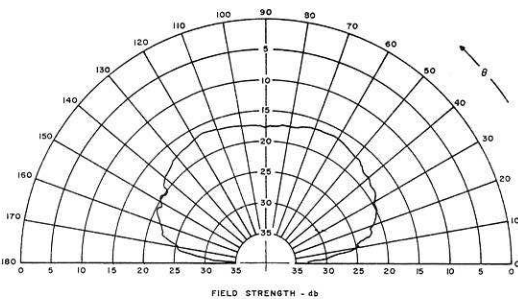
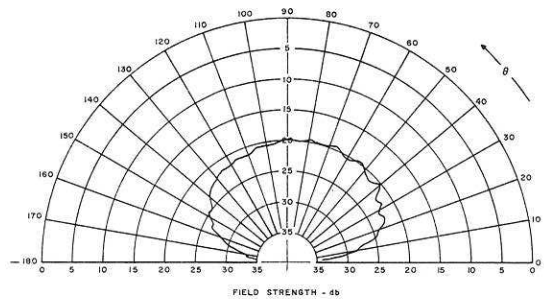


$E_\theta$ 

FWD-AFT



PORT-STBD

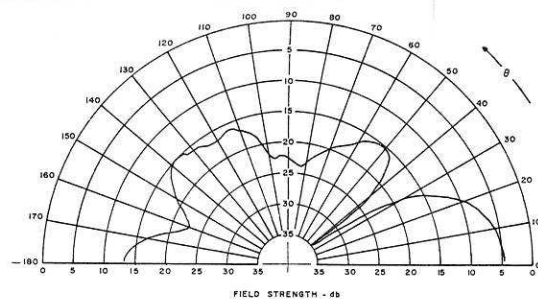
 $\theta = 0^\circ$  $E_\phi$ 

ANTENNA : PORT FWD WHIP

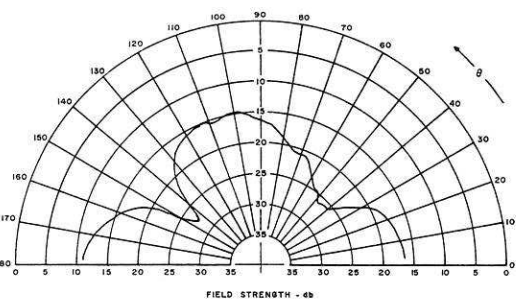
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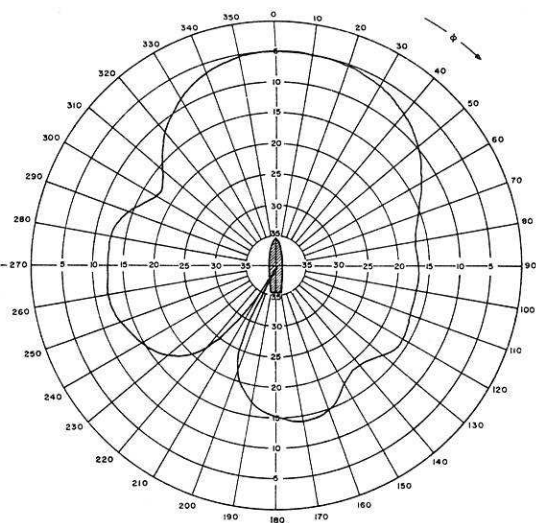
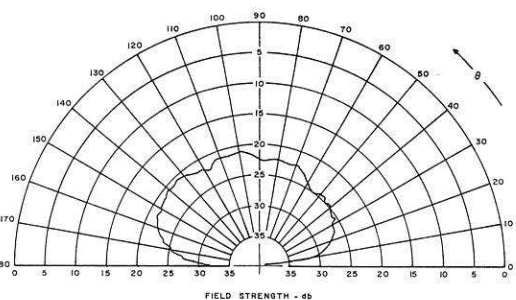
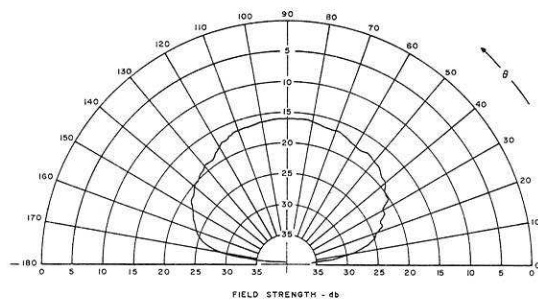


$E_\theta$ 

FWD-AFT



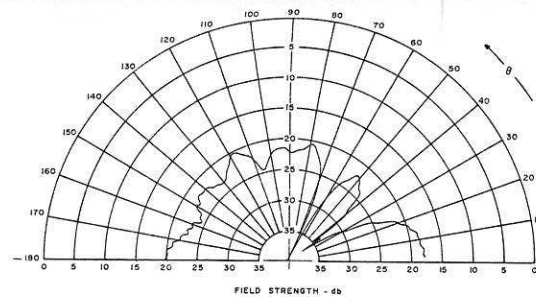
PORT-STBD

 $\theta = 0^\circ$  $E_\phi$ 

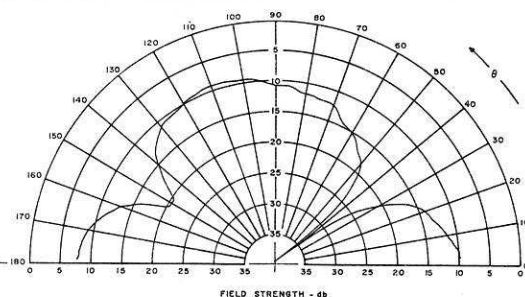
ANTENNA : PORT FWD WHIP

FREQ. : 4 MHz

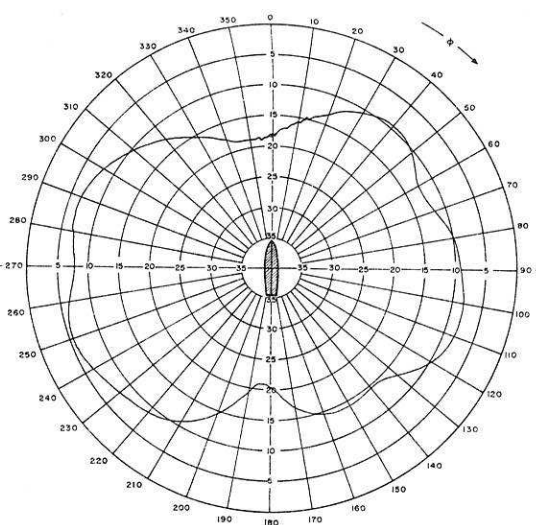
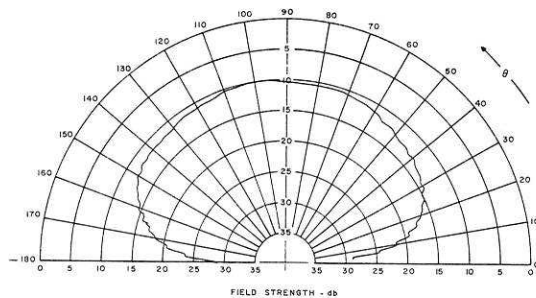
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TERMINATED IN  $50\Omega$

$E_{\theta}$ 

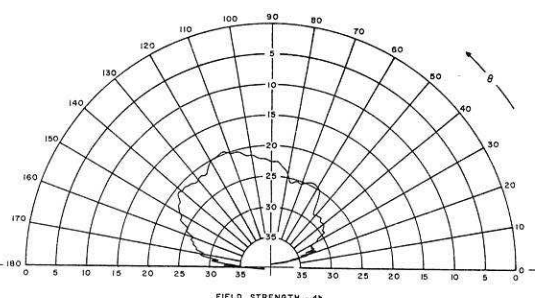
FWD-AFT



PORT-STBD

 $\theta = 0^\circ$  $E_{\phi}$ 

FIELD STRENGTH - dB

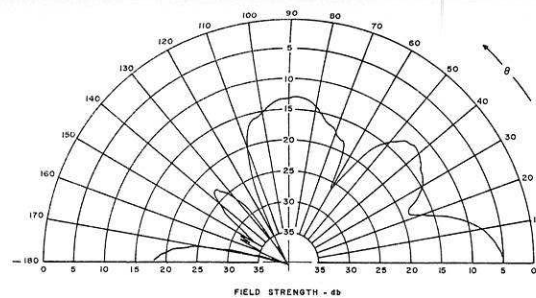


FIELD STRENGTH - dB

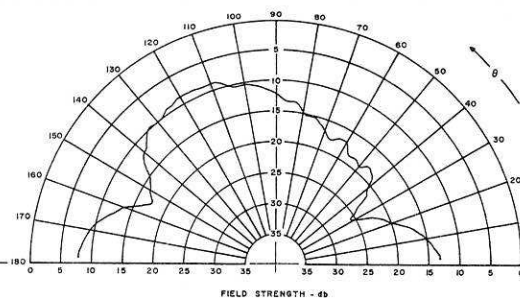
ANTENNA : PORT FWD WHIP

FREQ. : 5 MHz

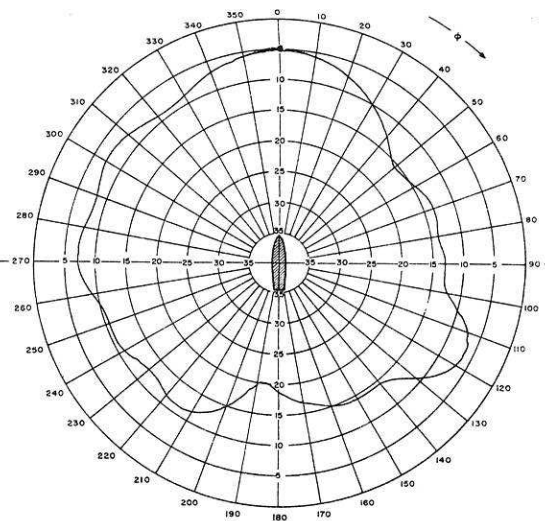
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TERMINATED IN 50 $\Omega$

$E_{\theta}$ 

FWD-AFT

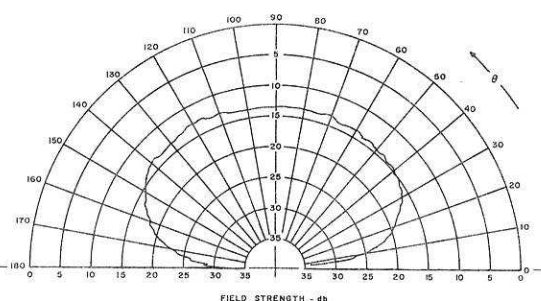
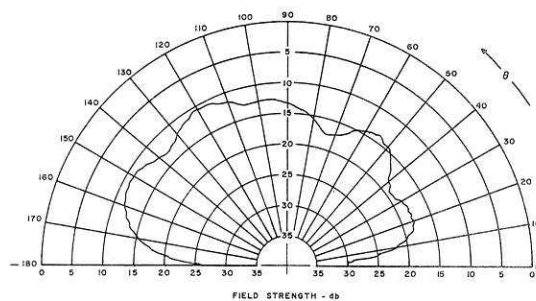


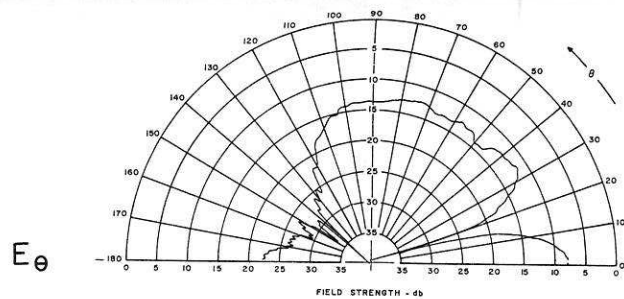
PORT-STBD

 $\theta = 0^\circ$ 

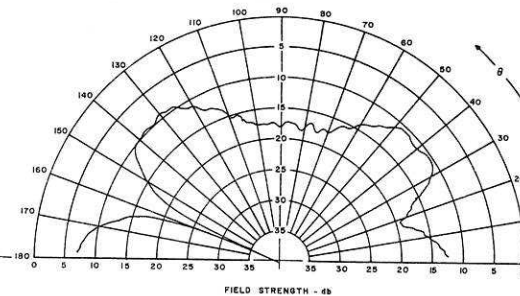
ANTENNA : PORT FWD WHIP

FREQ. : 6 MHz

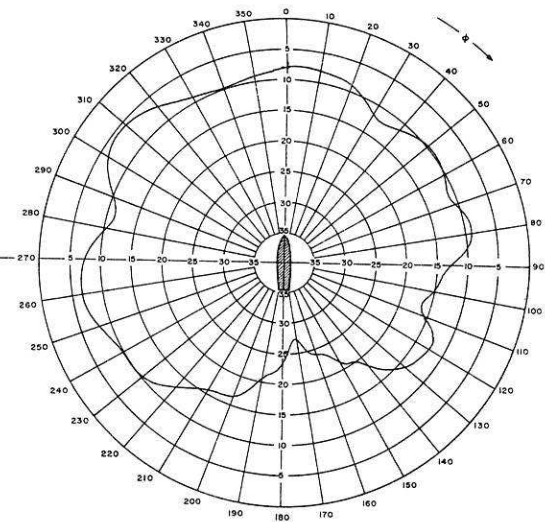
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TERMINATED IN 50 $\Omega$  $E_{\phi}$ 



FWD-AFT



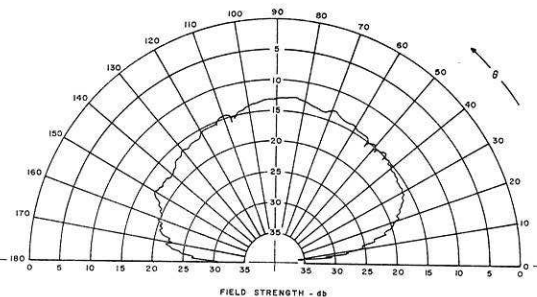
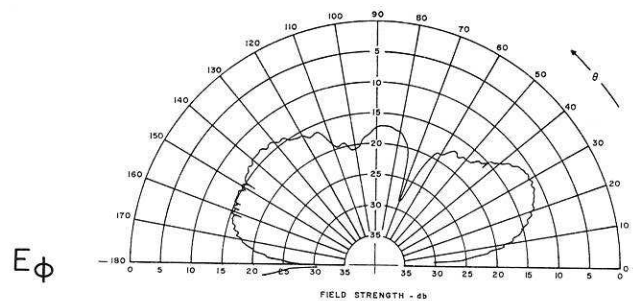
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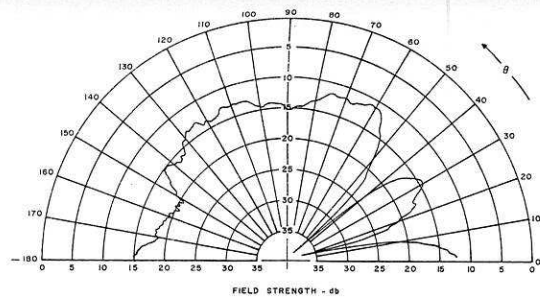


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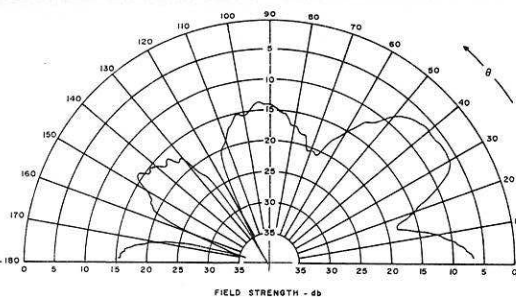
FREQ. : 8 MHz

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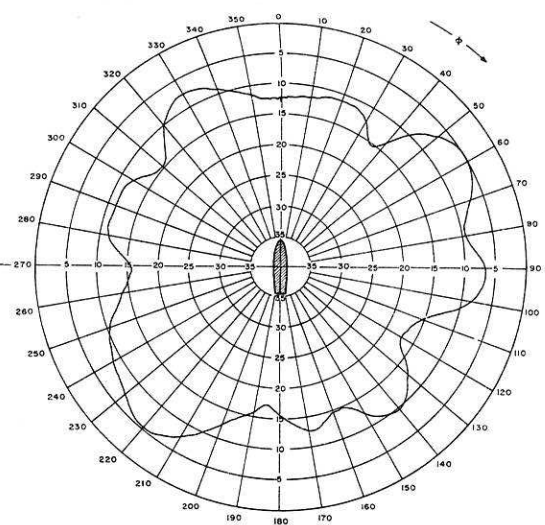
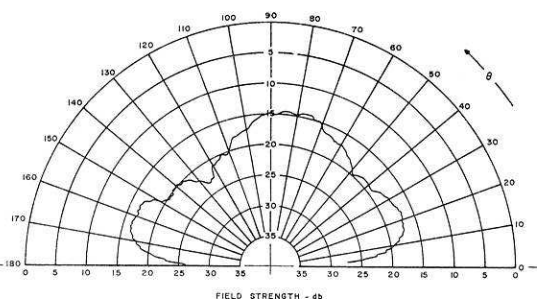
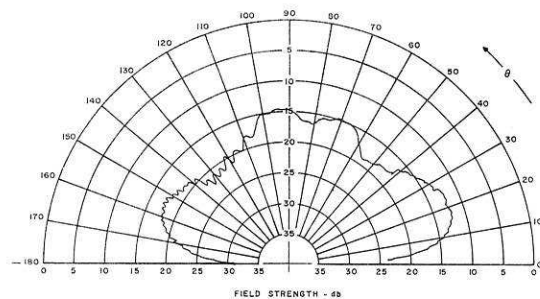


$E_{\theta}$ 

FWD-AFT



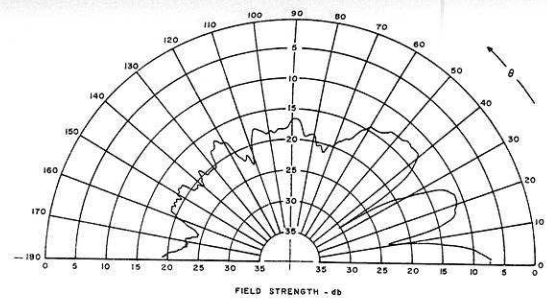
PORT-STBD

 $E_{\phi}$ 

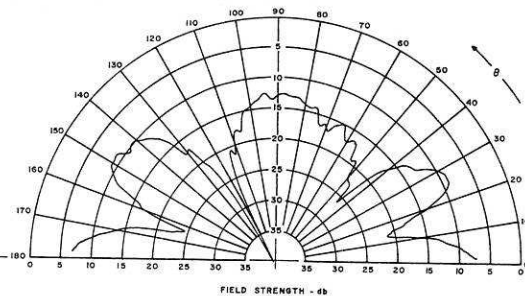
ANTENNA : PORT FWD WHIP

FREQ. : 10 MHz

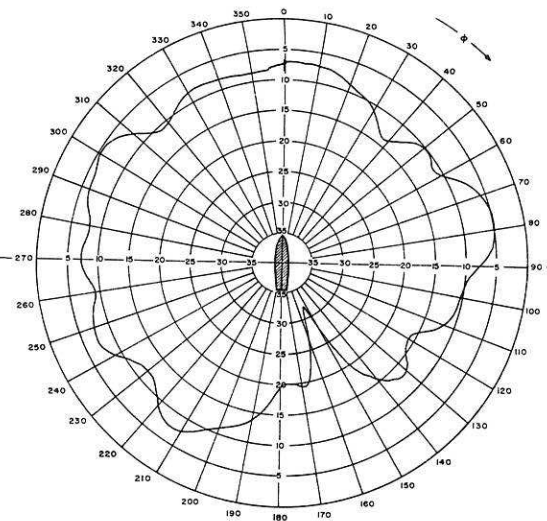
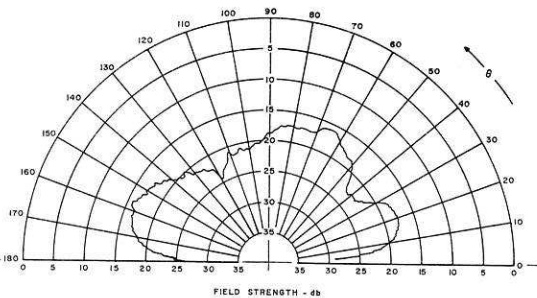
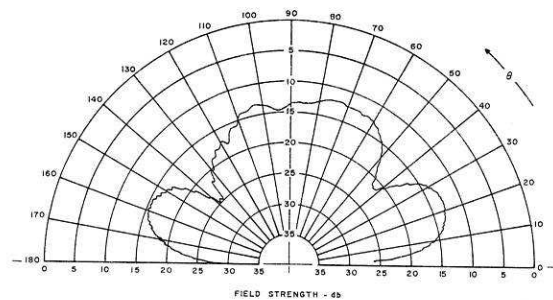
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω

$E_{\theta}$ 

FWD-AFT



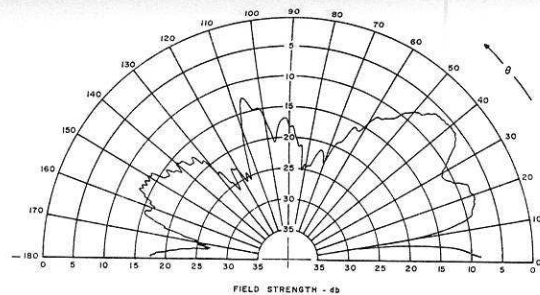
PORT-STBD

 $\theta = 0^\circ$  $E_{\phi}$ 

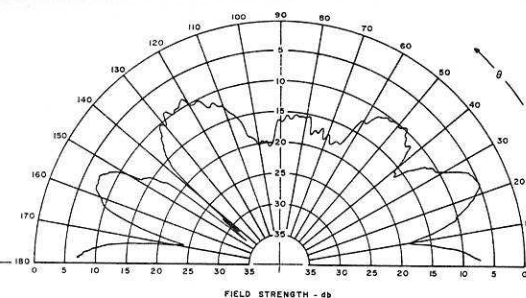
ANTENNA : PORT FWD WHIP

FREQ. : 12 MHz

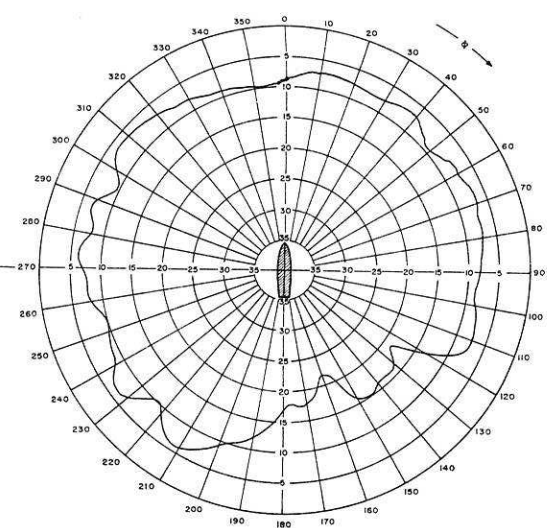
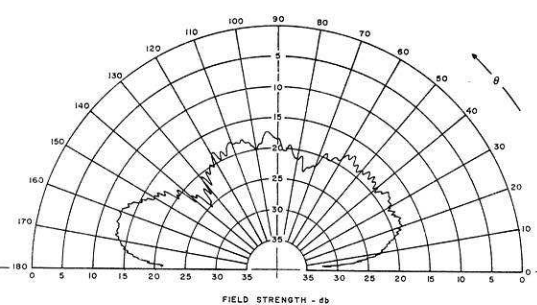
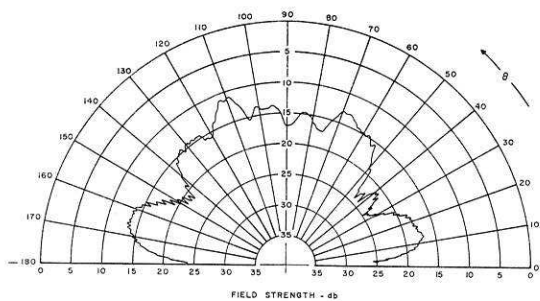
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω

$E_\theta$ 

FWD-AFT



PORT-STBD

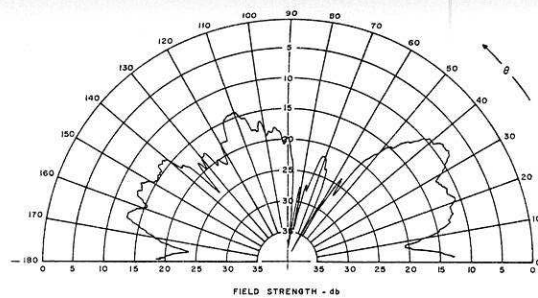
 $E_\phi$ 

ANTENNA : PORT FWD WHIP

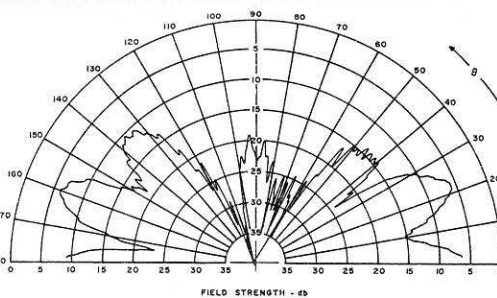
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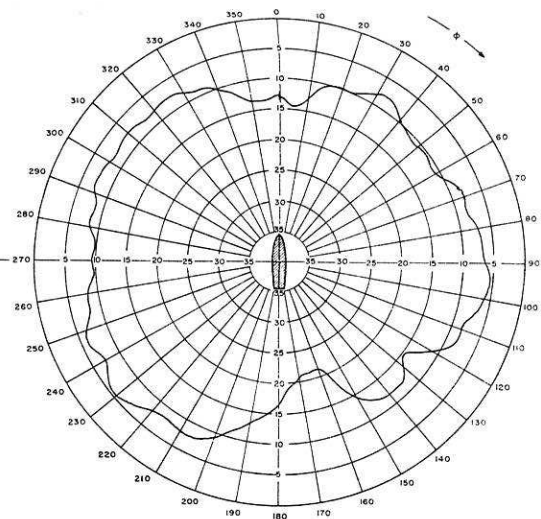
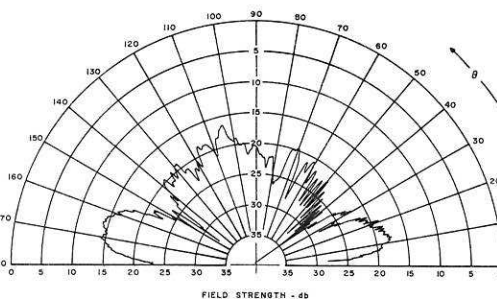
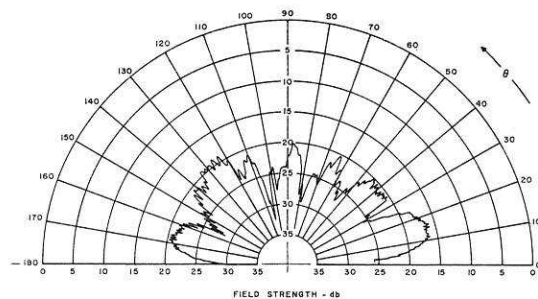


$E_\theta$ 

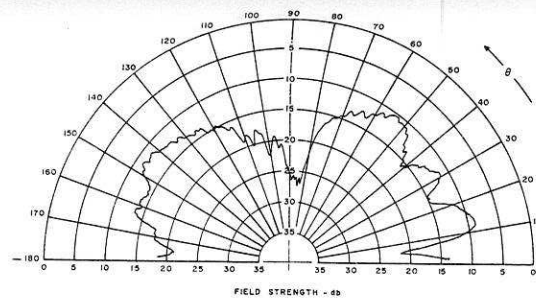
FWD-AFT



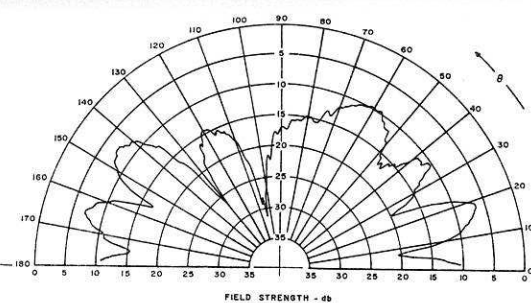
PORT-STBD

 $E_\phi$ 

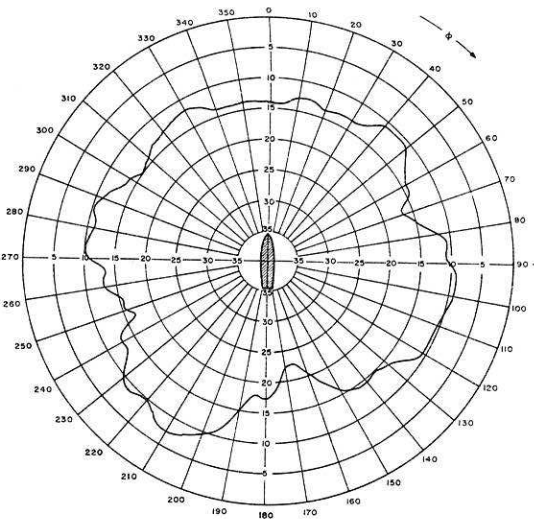
ANTENNA : PORT FWD WHIP  
 FREQ. : 16 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω

$E_{\theta}$ 

FWD-AFT

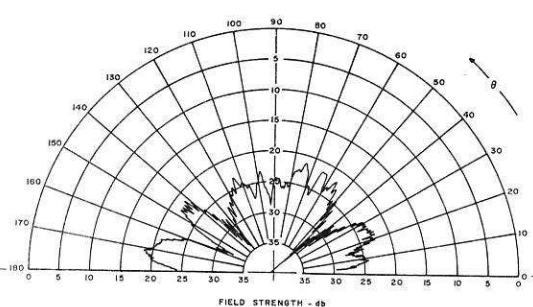
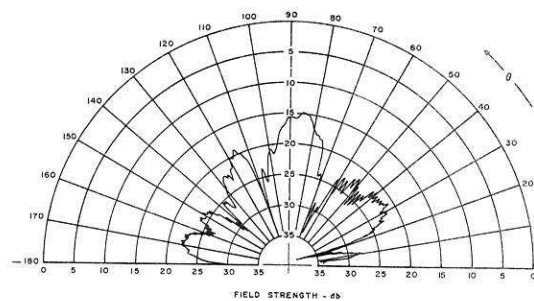


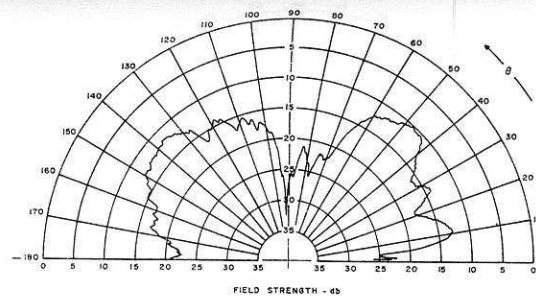
PORT-STBD



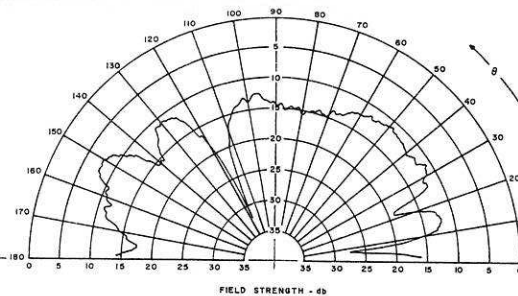
ANTENNA : PORT FWD WHIP

FREQ. : 18 MHz

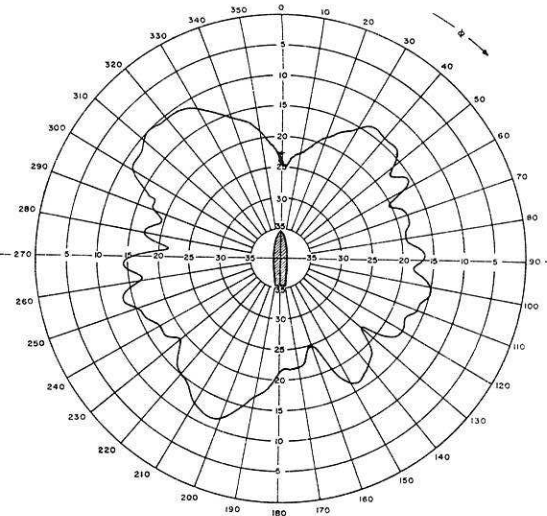
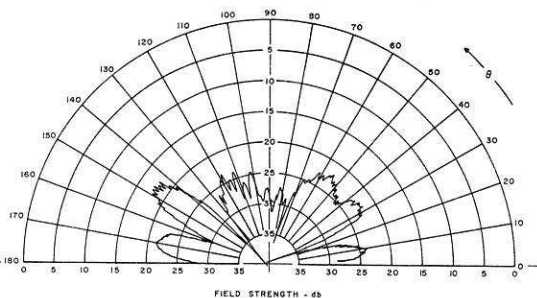
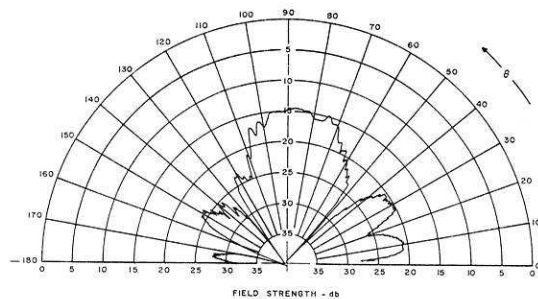
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω $E_{\phi}$ 

$E_\theta$ 

FWD-AFT



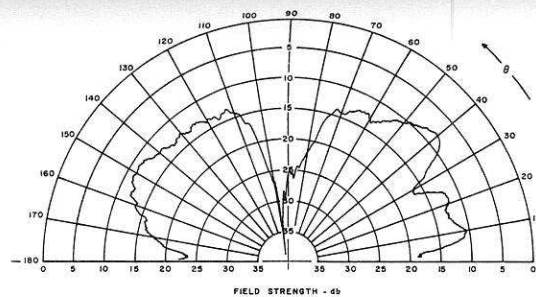
PORT-STBD

 $\theta = 0^\circ$  $E_\phi$ 

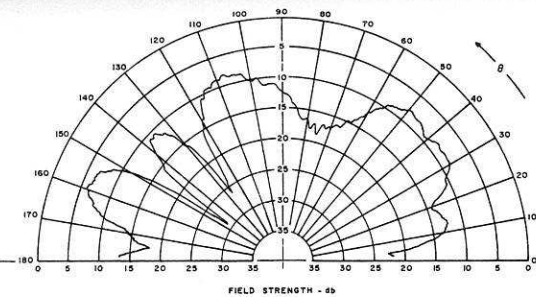
ANTENNA : PORT FWD WHIP

FREQ. : 20 MHz

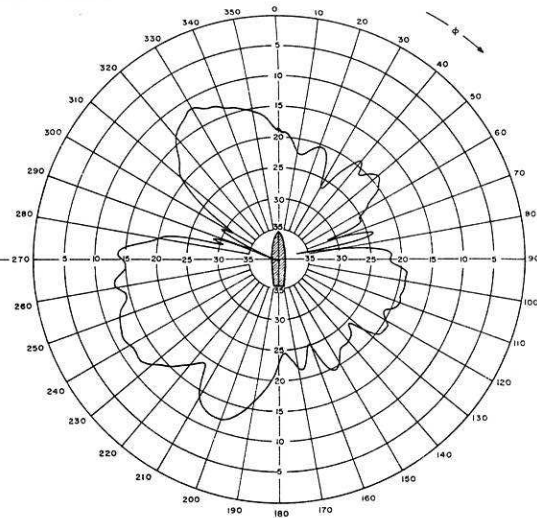
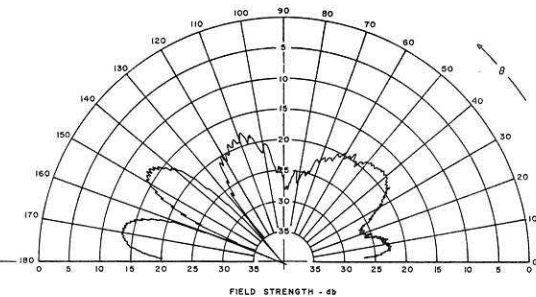
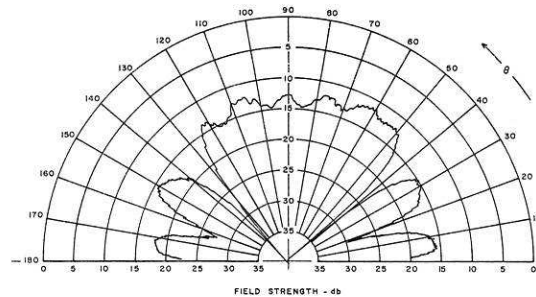
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

$E_\theta$ 

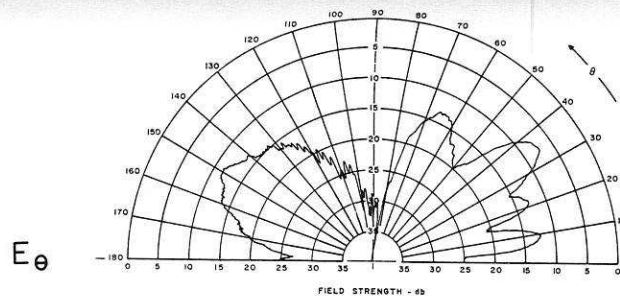
FWD-AFT



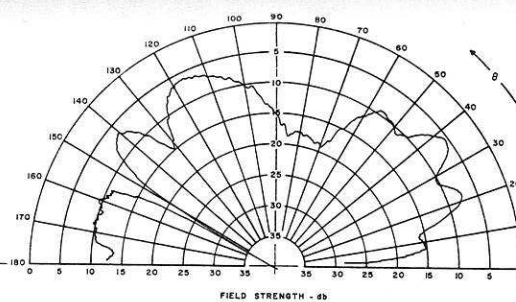
PORT-STBD

 $\theta = 0^\circ$  $E_\phi$ 

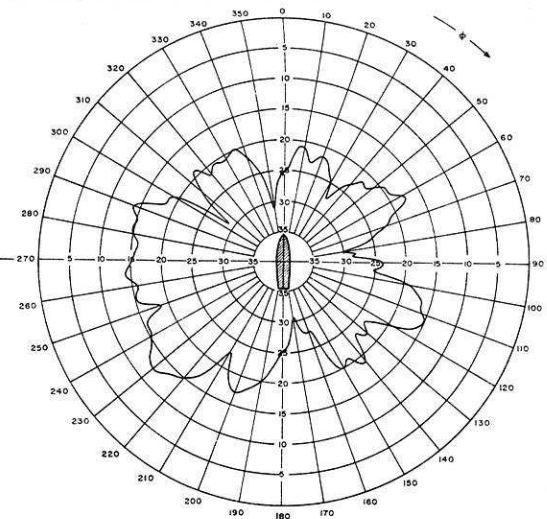
ANTENNA : PORT FWD WHIP  
 FREQ. : 22 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω



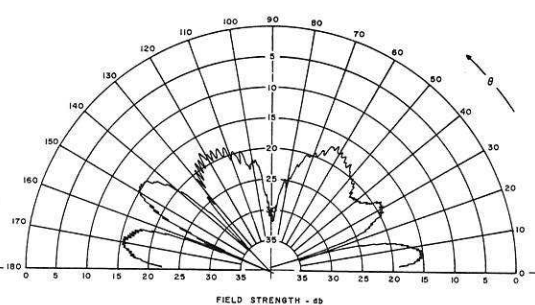
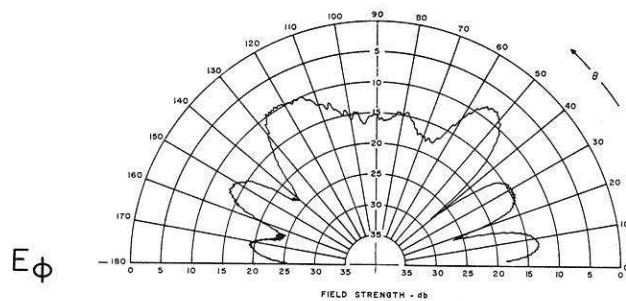
FWD-AFT



PORT-STBD

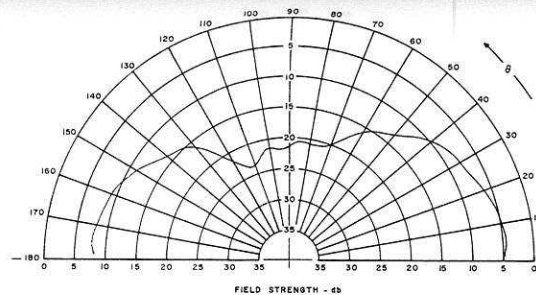


ANTENNA : PORT FWD WHIP  
 FREQ. : 24 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$

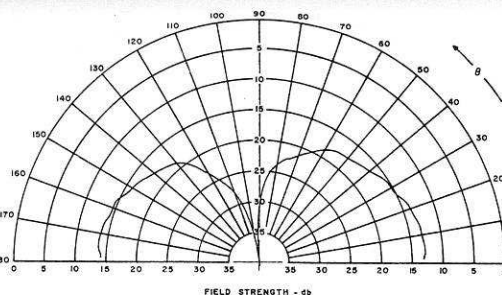




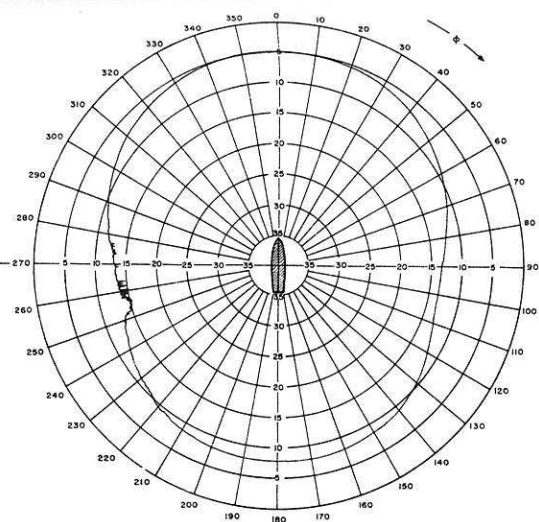
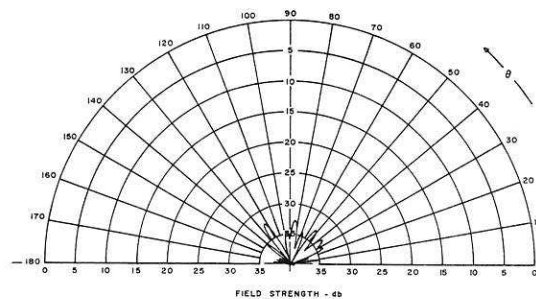
ii) Goal-post 35-foot whip

$E_\theta$ 

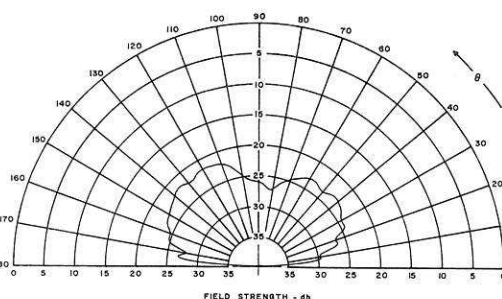
FWD-AFT



PORT-STBD

 $\theta = 0^\circ$  $E_\phi$ 

FIELD STRENGTH - dB



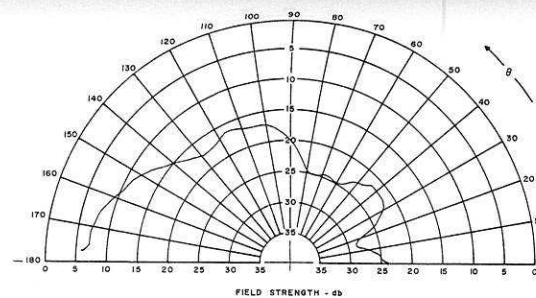
FIELD STRENGTH - dB

ANTENNA : GOAL POST WHIP

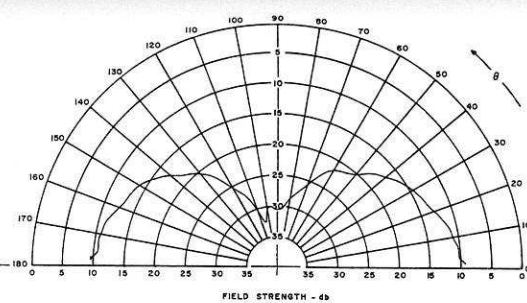
FREQ. : 2 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

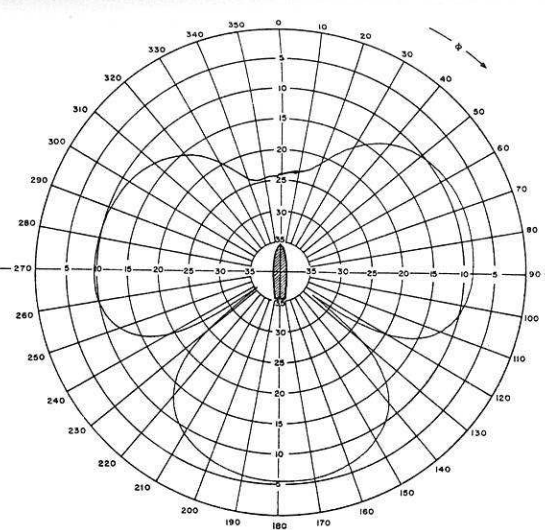
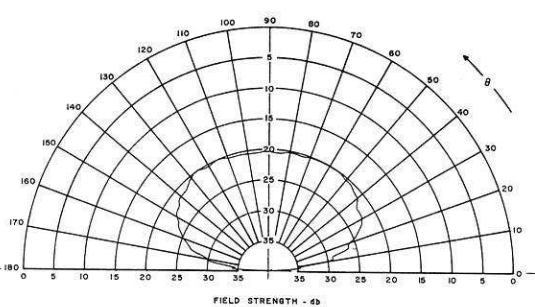
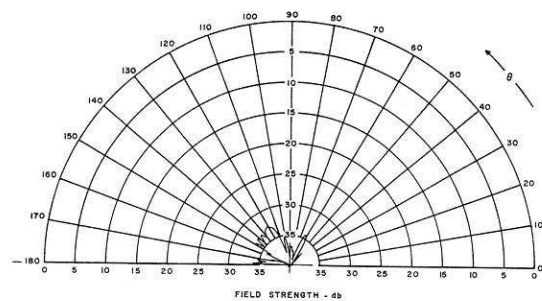


$E_{\theta}$ 

FWD-AFT



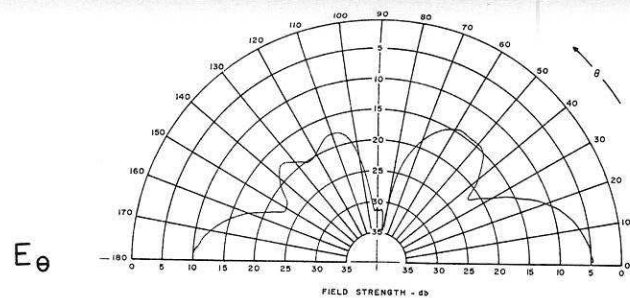
PORT-STBD

 $\theta = 0^\circ$  $E_{\phi}$ 

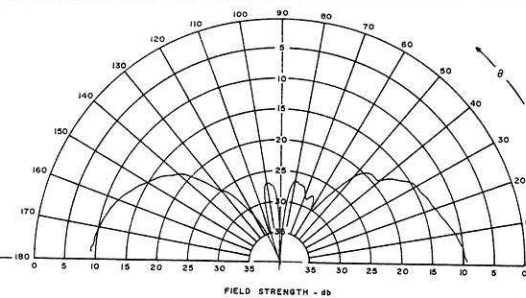
ANTENNA : GOAL POST WHIP

FREQ. : 3 MHz

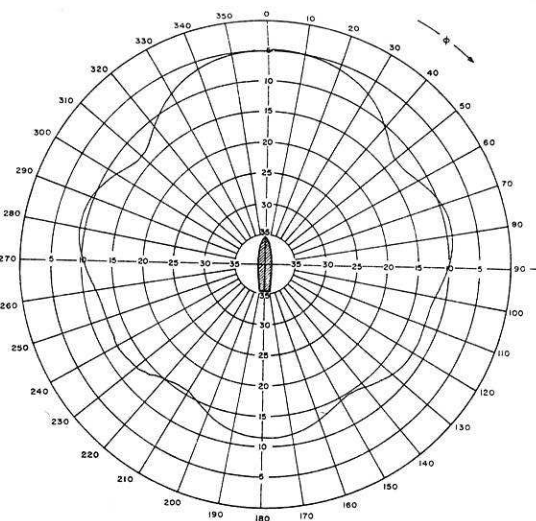
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$



FWD-AFT



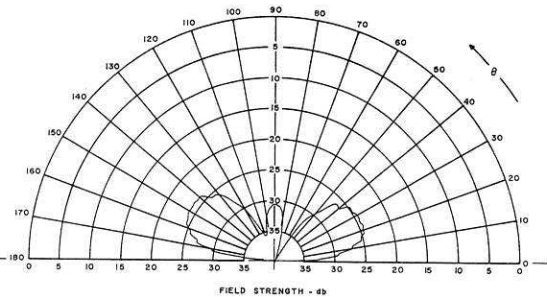
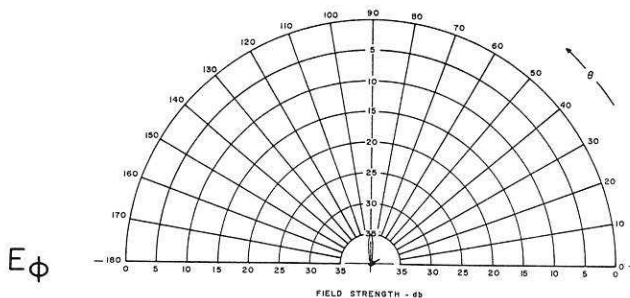
PORT-STBD

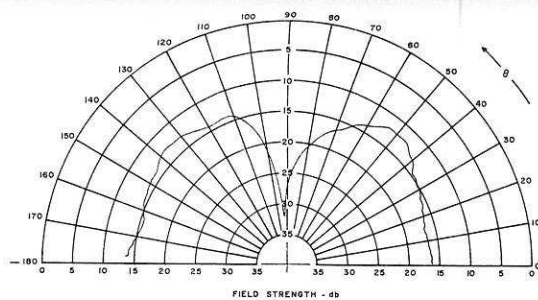


ANTENNA : GOAL POST WHIP

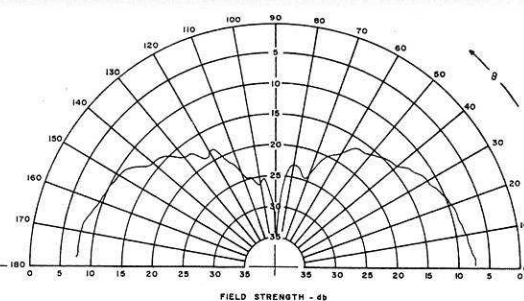
FREQ. : 4 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

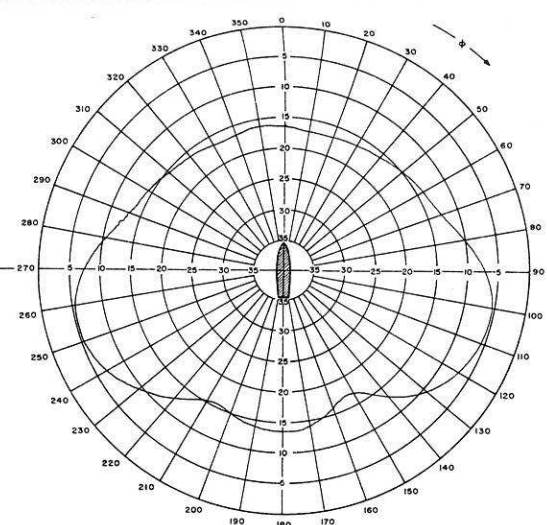
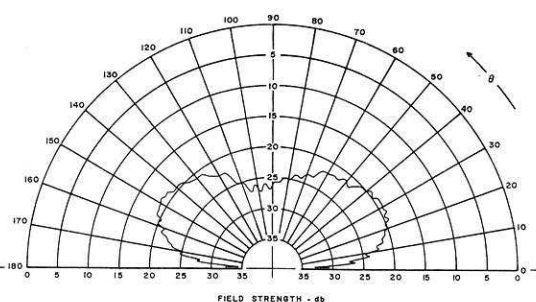
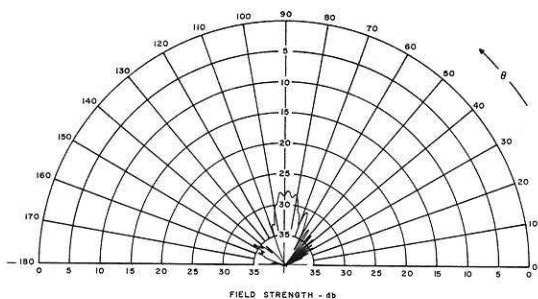


$E_\theta$ 

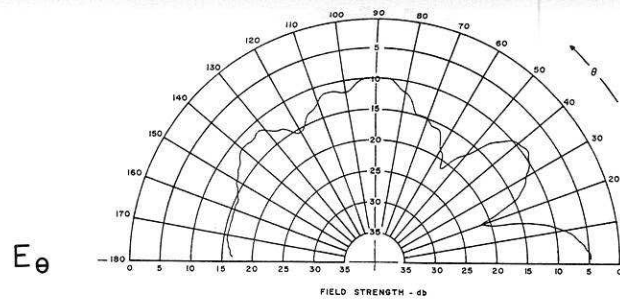
FWD-AFT



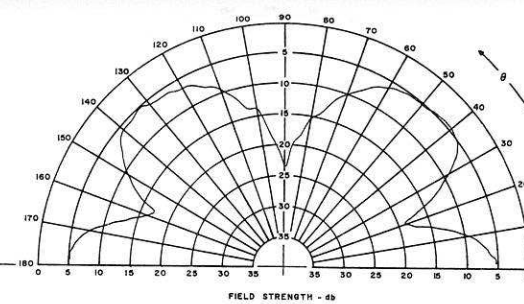
PORT-STBD

 $\theta = 0^\circ$  $E_\phi$ 

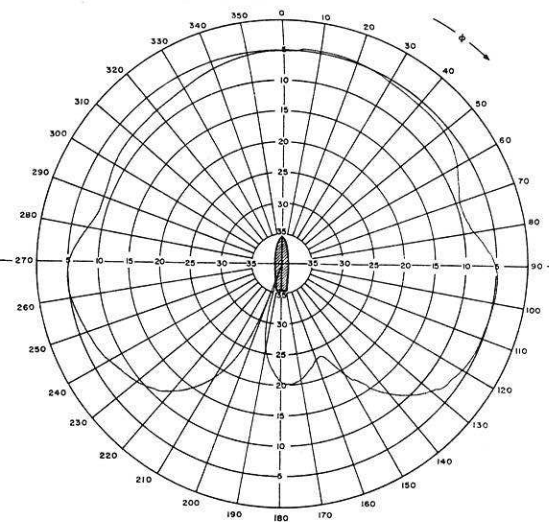
ANTENNA : GOAL POST WHIP  
 FREQ. : 5 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω



FWD-AFT



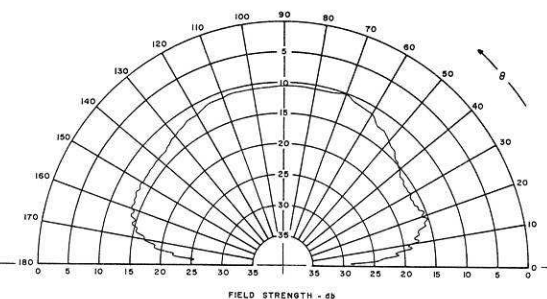
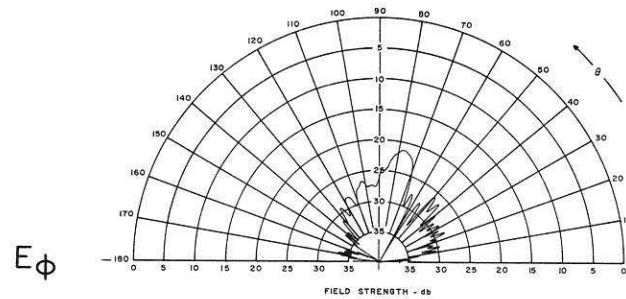
PORT-STBD

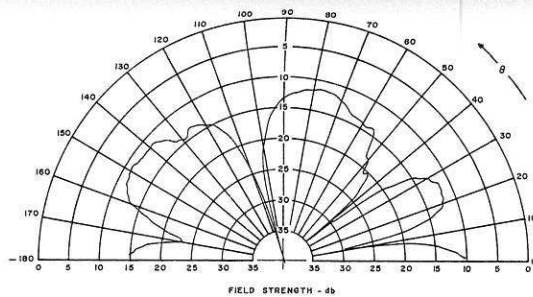


ANTENNA : GOAL POST WHIP

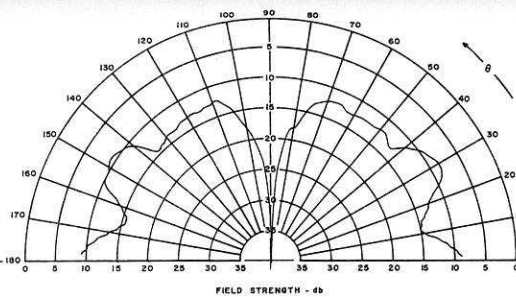
FREQ. : 6 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

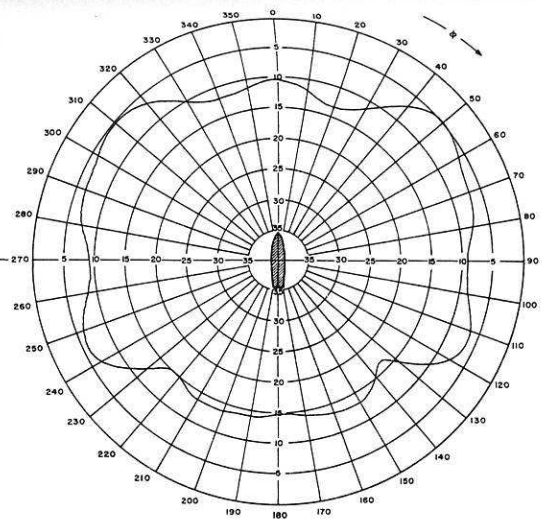
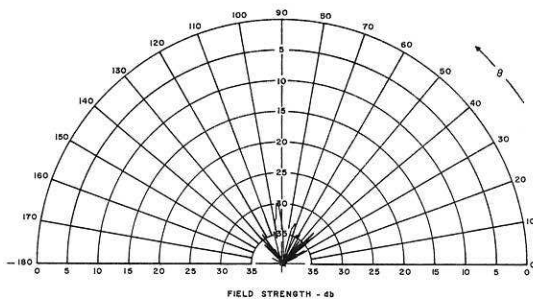


$E_{\theta}$ 

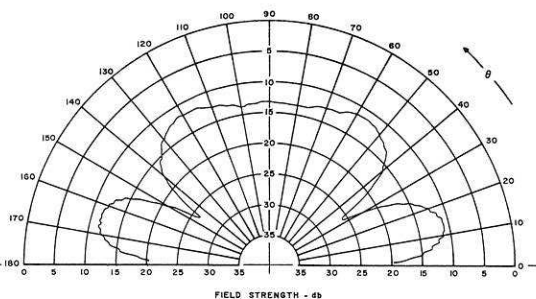
FWD-AFT



PORT-STBD

 $\theta = 0^\circ$  $E_{\phi}$ 

FIELD STRENGTH - dB

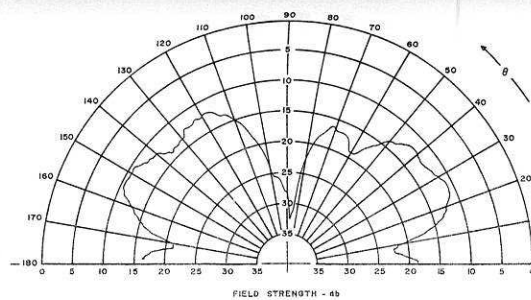


FIELD STRENGTH - dB

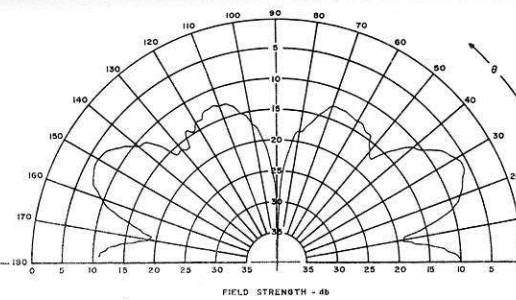
ANTENNA : GOAL POST WHIP

FREQ. : 8 MHz

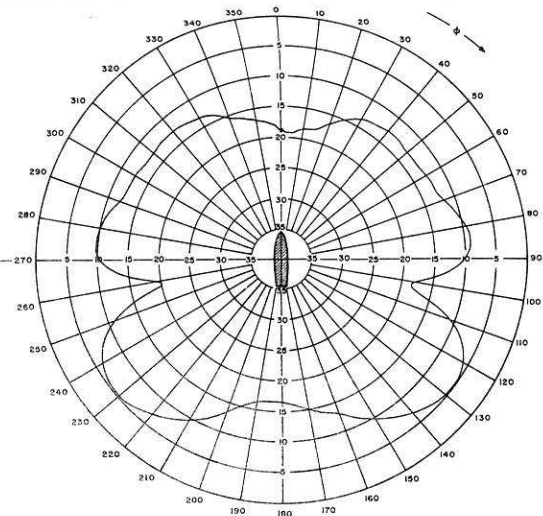
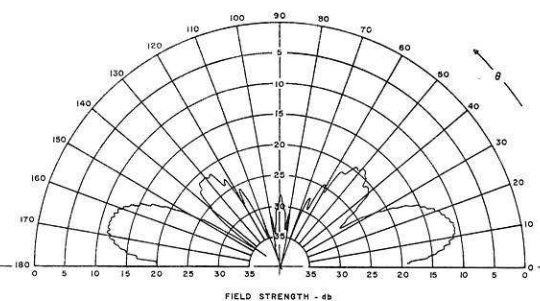
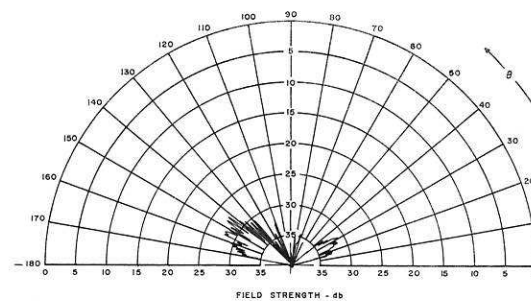
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

$E_\theta$ 

FWD-AFT



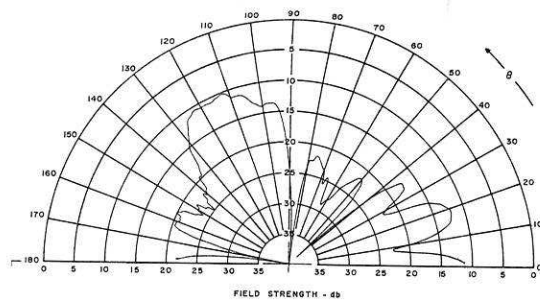
PORT-STBD

 $\theta = 0^\circ$  $E_\phi$ 

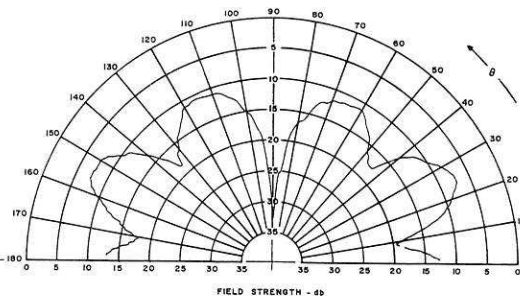
ANTENNA : GOAL POST WHIP

FREQ. : 10 MHz

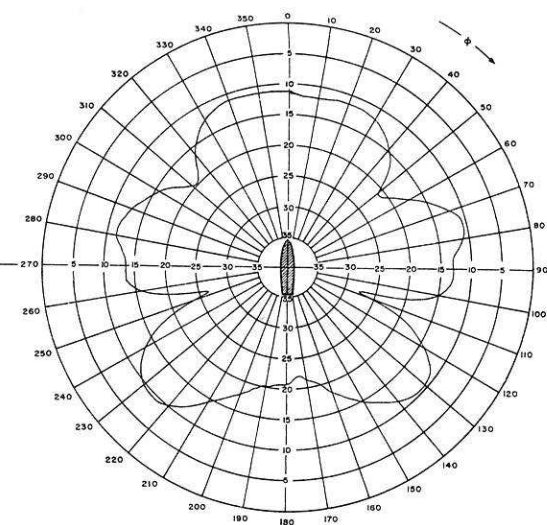
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω

$E_{\theta}$ 

FWD-AFT

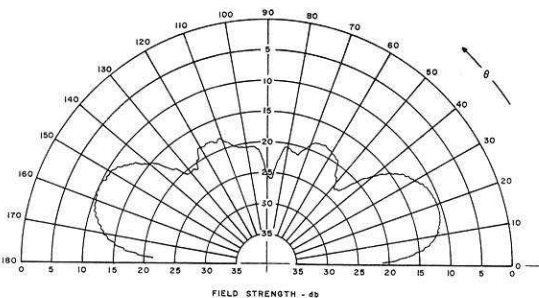
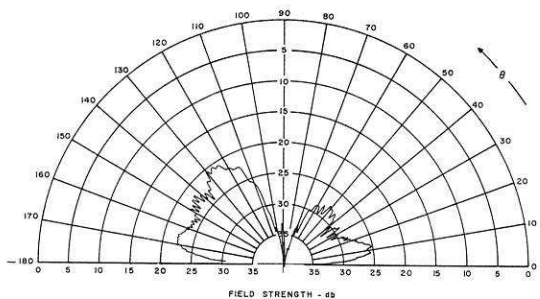


PORT-STBD

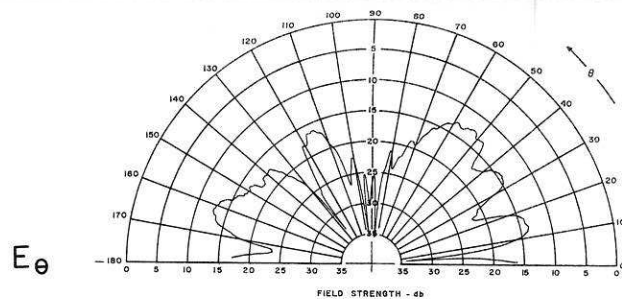
 $\theta = 0^\circ$ 

ANTENNA : GOAL POST WHIP

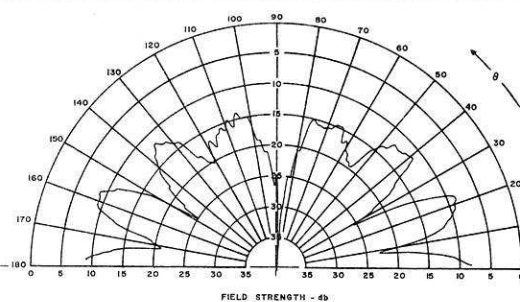
FREQ. : 12 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$  $E_{\phi}$ 

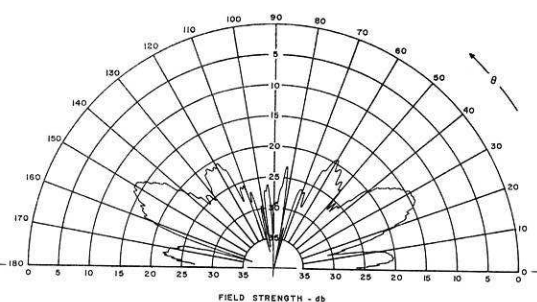
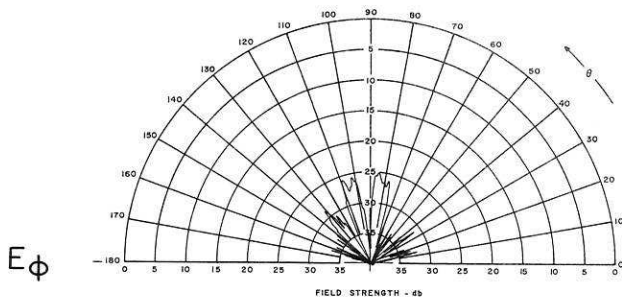
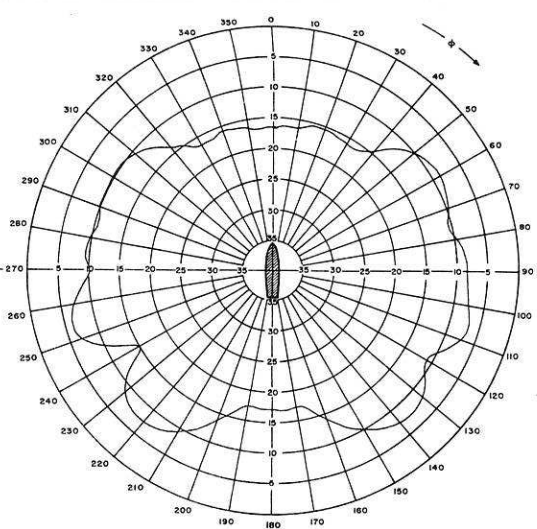




FWD-AFT



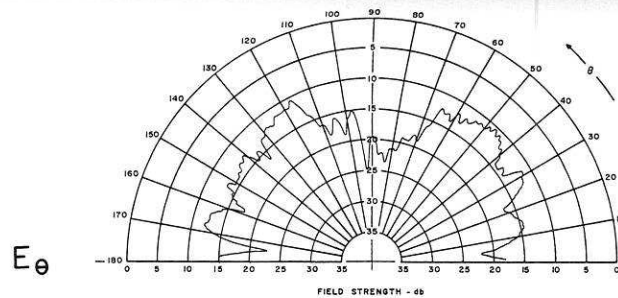
PORT-STBD



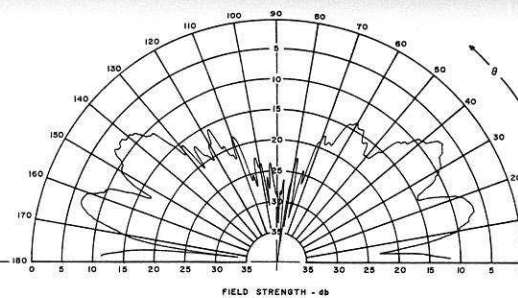
ANTENNA : GOAL POST WHIP

FREQ. : 14 MHz

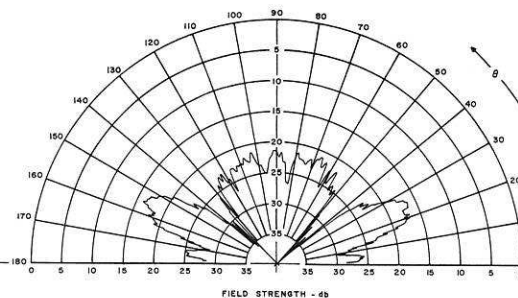
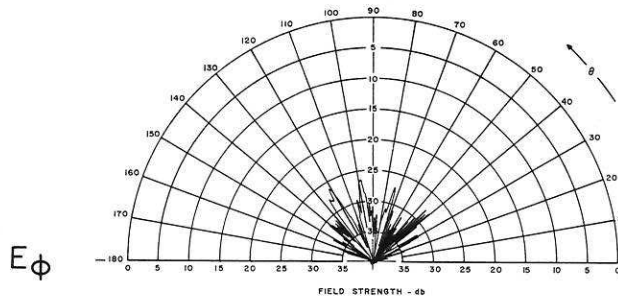
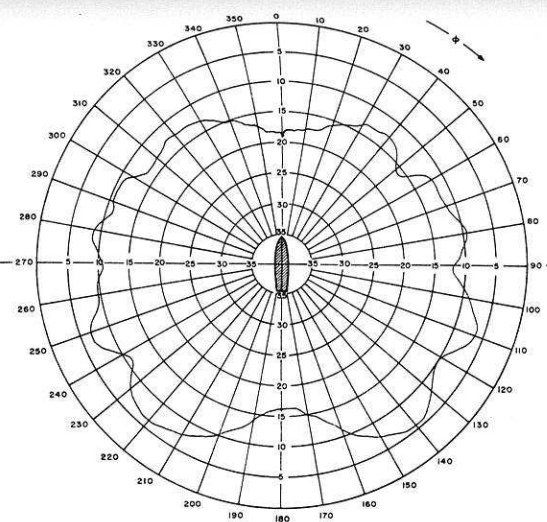
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω



FWD-AFT



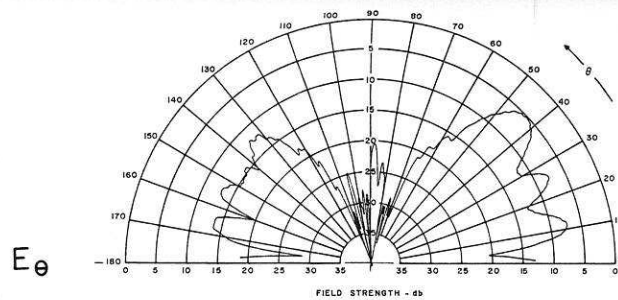
PORT-STBD



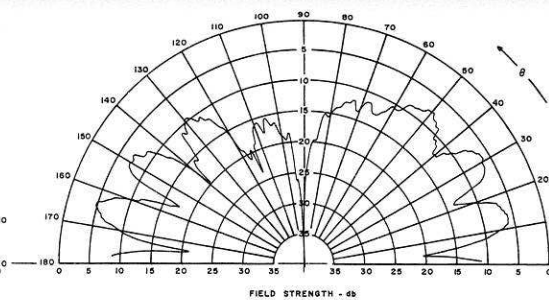
ANTENNA : GOAL POST WHIP

FREQ. : 16 MHz

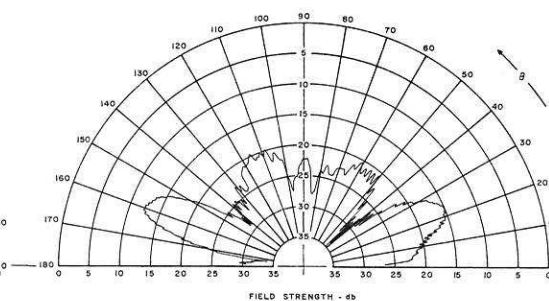
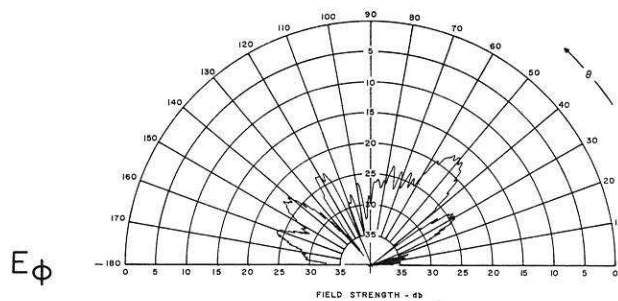
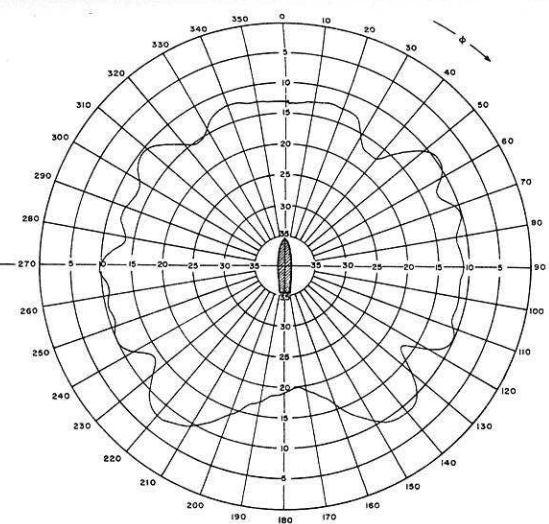
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω



FWD-AFT



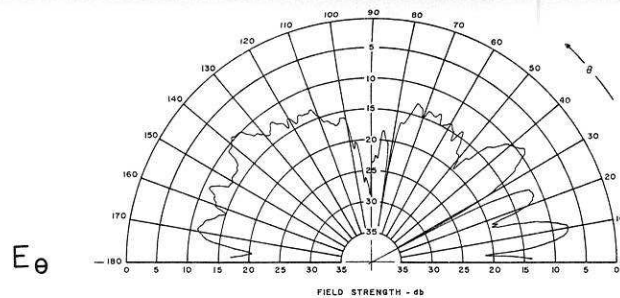
PORT-STBD



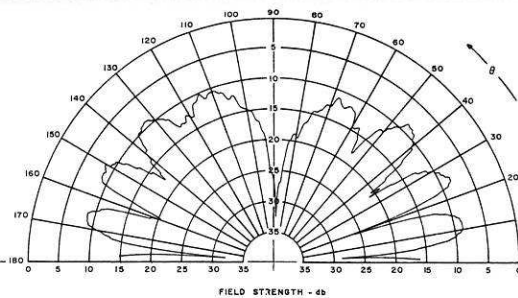
ANTENNA : GOAL POST WHIP

FREQ. : 18 MHz

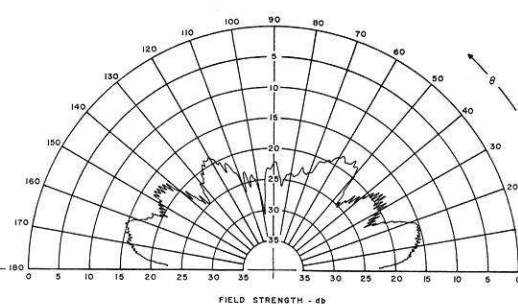
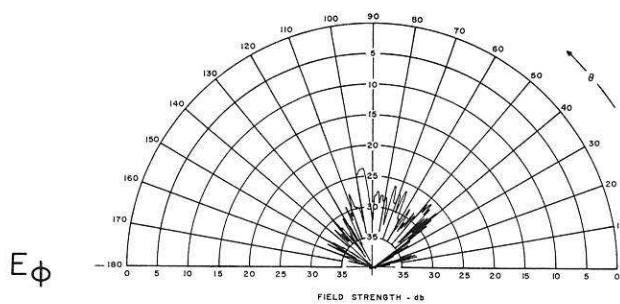
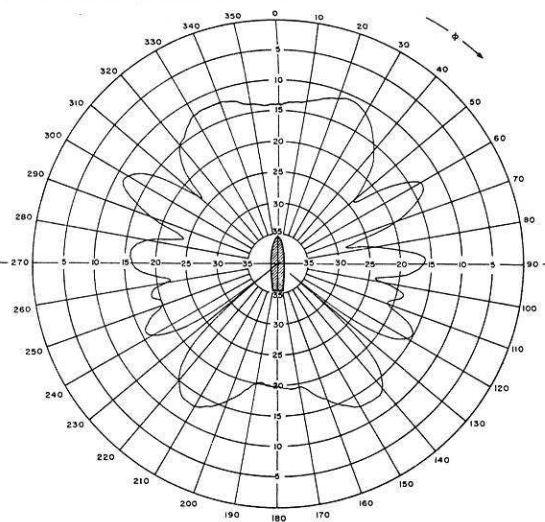
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$



FWD-AFT



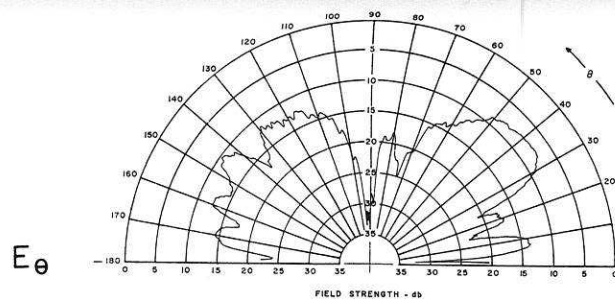
PORT-STBD



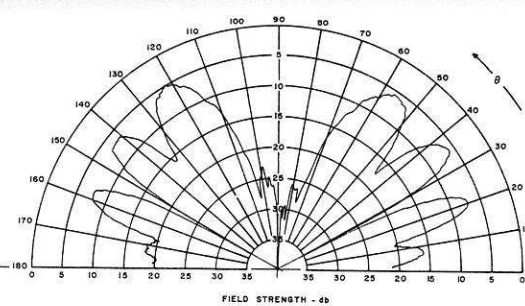
ANTENNA : GOAL POST WHIP

FREQ. : 20 MHz

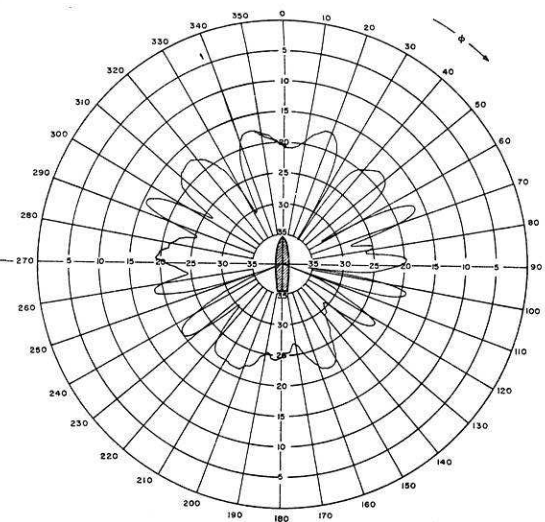
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω



FWD-AFT



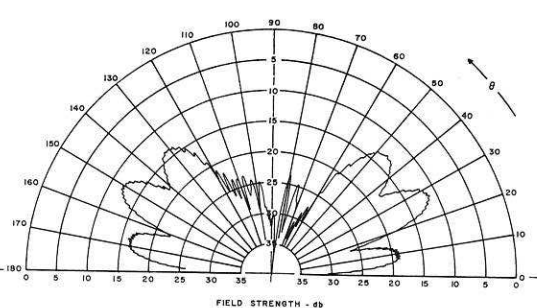
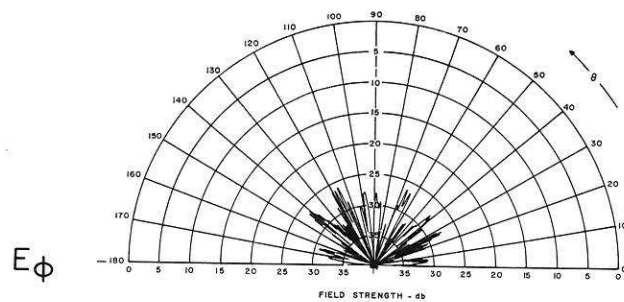
PORT-STBD

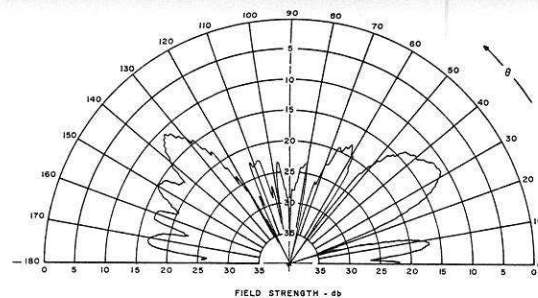


ANTENNA : GOAL POST WHIP

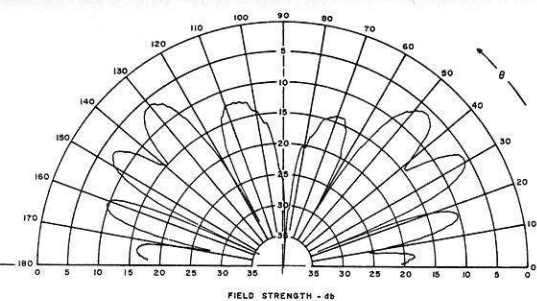
FREQ. : 22 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω

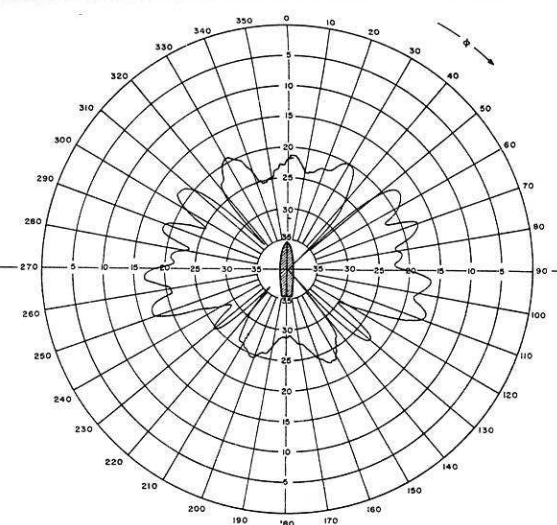
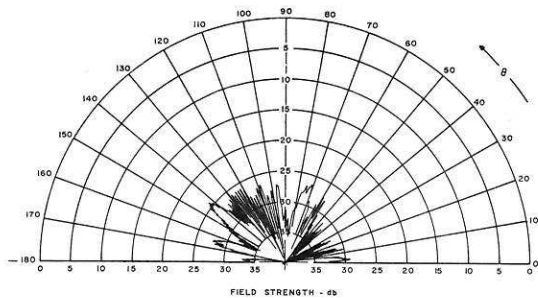


$E_{\theta}$ 

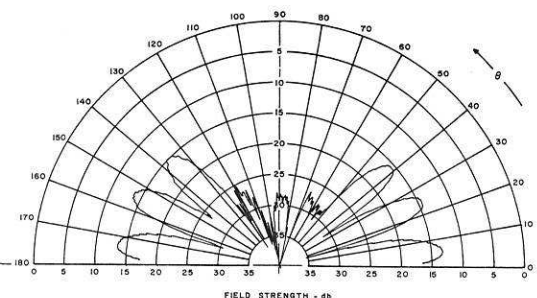
FWD-AFT



PORT-STBD

 $\theta = 0^\circ$  $E_{\phi}$ 

FIELD STRENGTH - dB



FIELD STRENGTH - dB

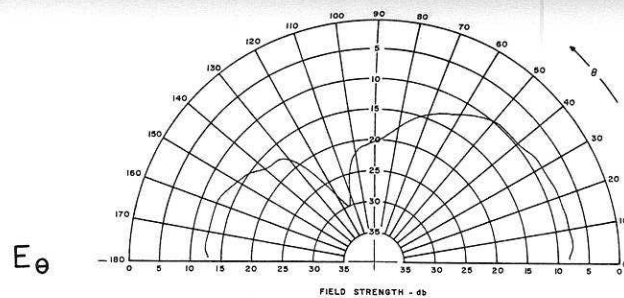
ANTENNA : GOAL POST WHIP

FREQ. : 24 MHz

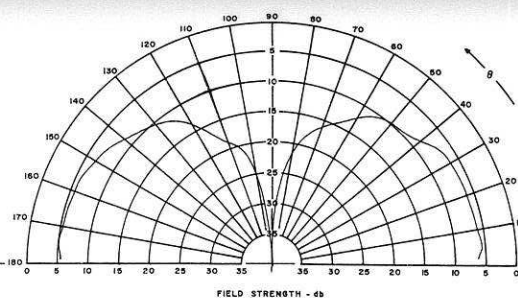
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω



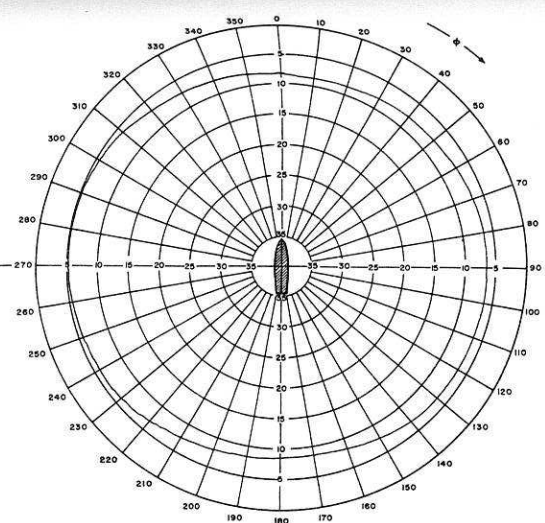
iii) Forward receiving fans



FWD-AFT



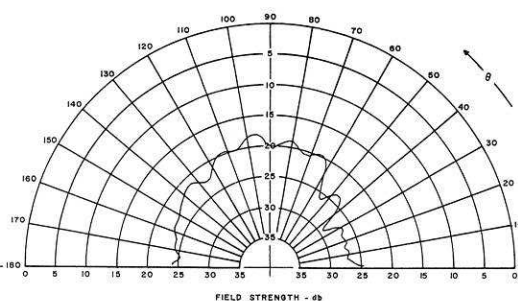
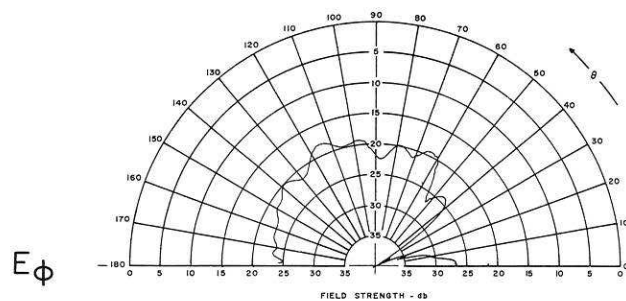
PORT-STBD

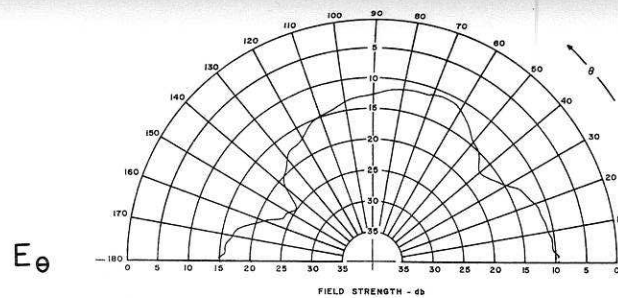


ANTENNA : FWD RECEIVING FANS

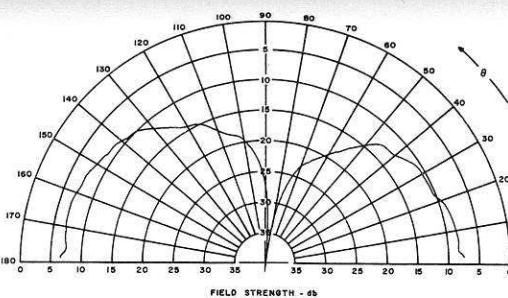
FREQ. : 2 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω

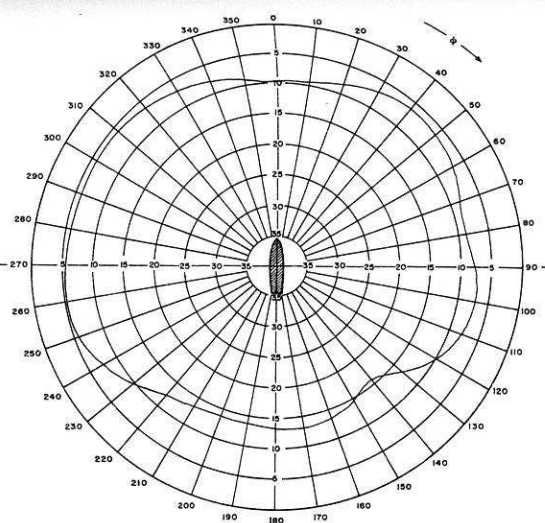




FWD-AFT



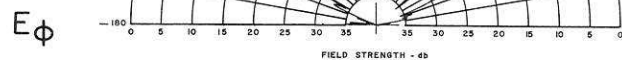
PORT-STBD

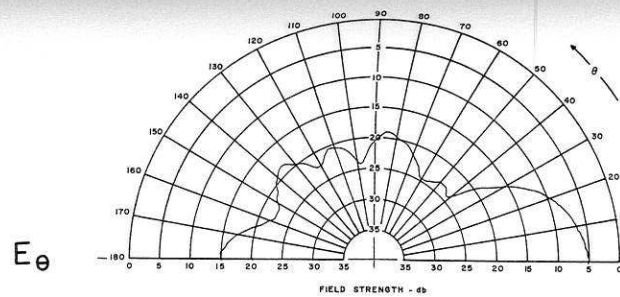


ANTENNA : FWD RECEIVING FANS

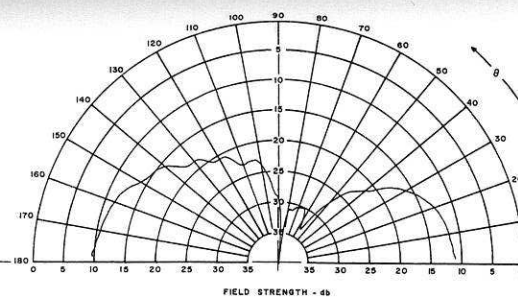
FREQ. : 3 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

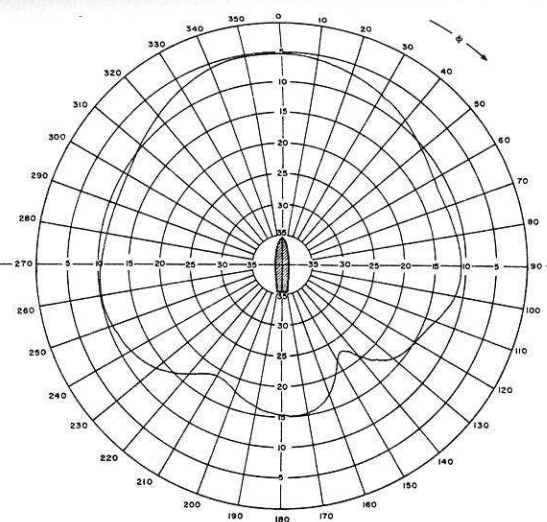




FWD-AFT



PORT-STBD

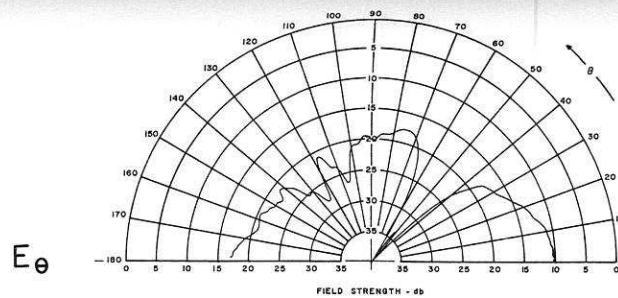


ANTENNA : FWD RECEIVING FANS

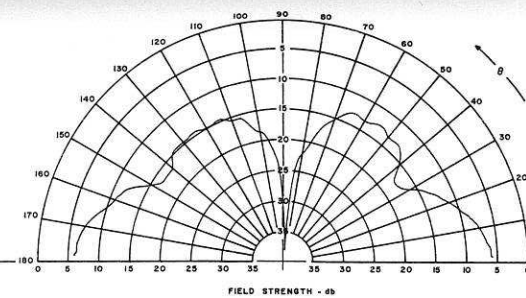
FREQ. : 4 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

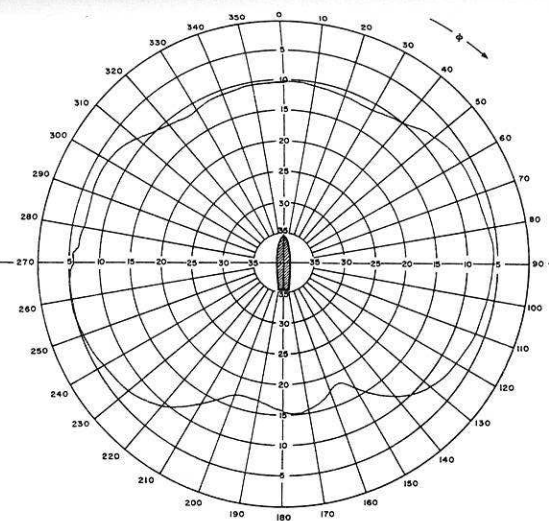




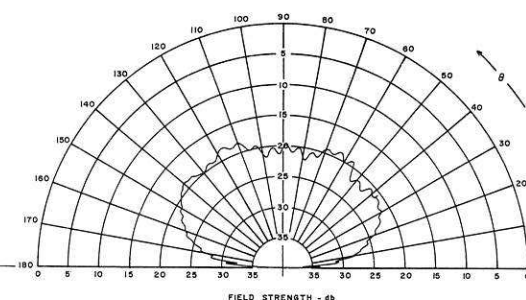
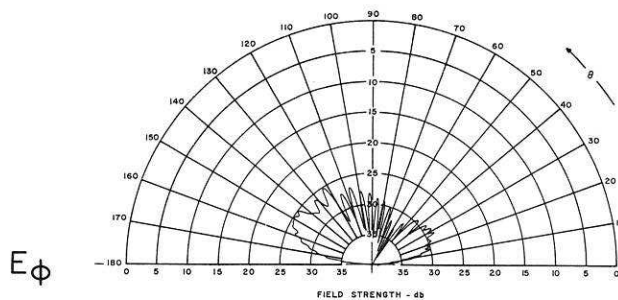
FWD-AFT



PORT-STBD

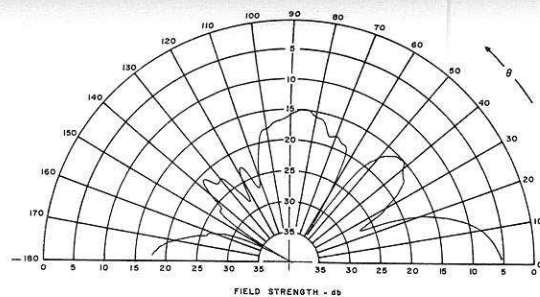


$\theta = 0^\circ$

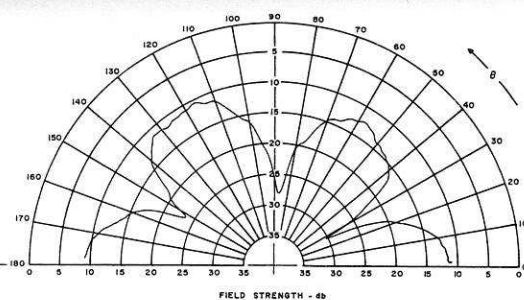


ANTENNA : FWD RECEIVING FANS  
 FREQ. : 5 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω

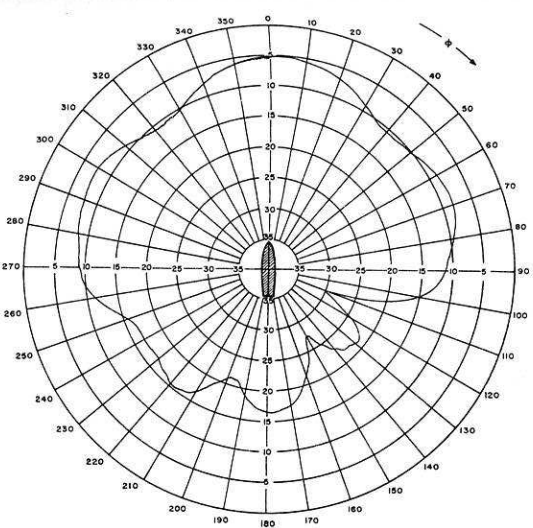
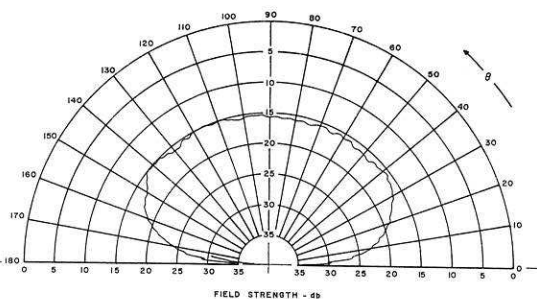
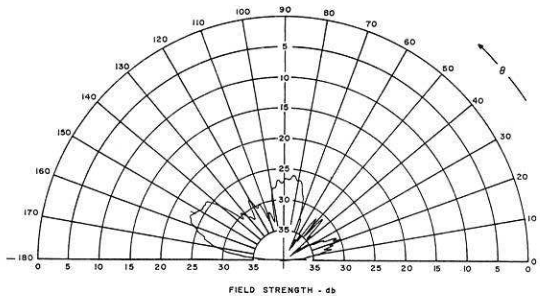


$E_\theta$ 

FWD-AFT



PORT-STBD

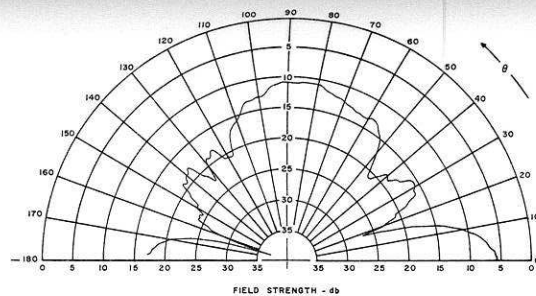
 $E_\phi$ 

ANTENNA : FWD RECEIVING FANS

FREQ. : 6 MHz

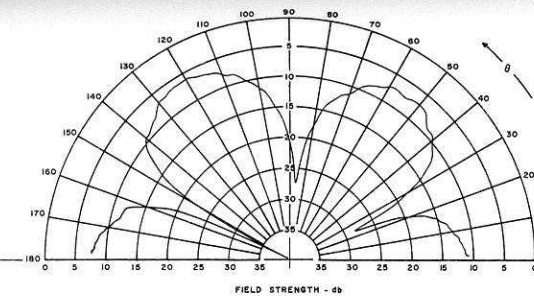
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50Ω



$E_{\theta}$ 

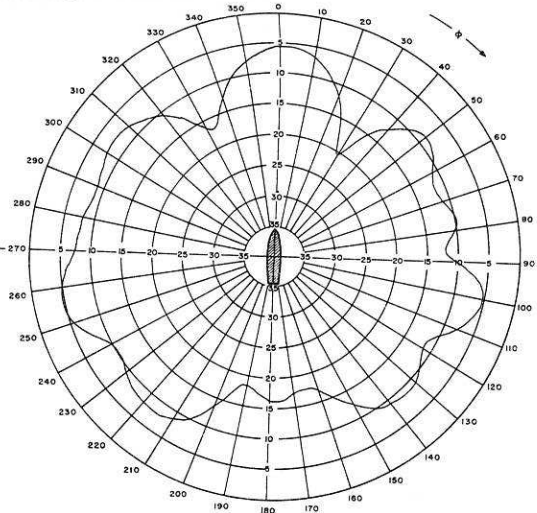
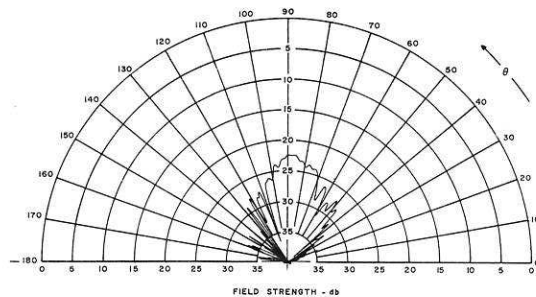
FIELD STRENGTH - dB

FWD-AFT

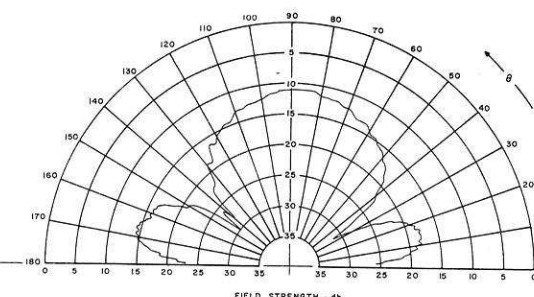


FIELD STRENGTH - dB

PORT-STBD

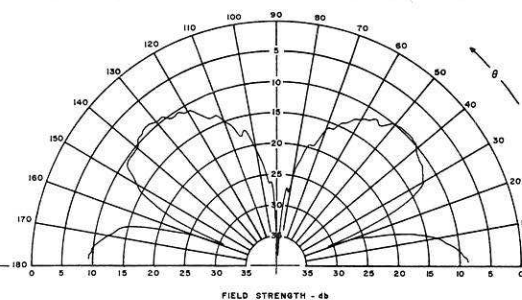
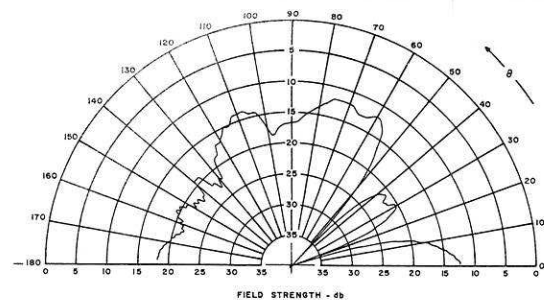
 $\theta = 0^\circ$  $E_{\phi}$ 

FIELD STRENGTH - dB



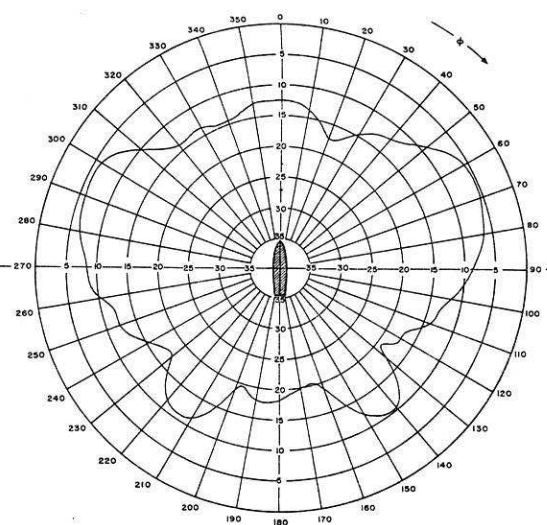
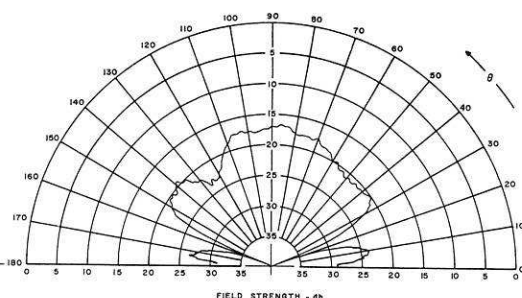
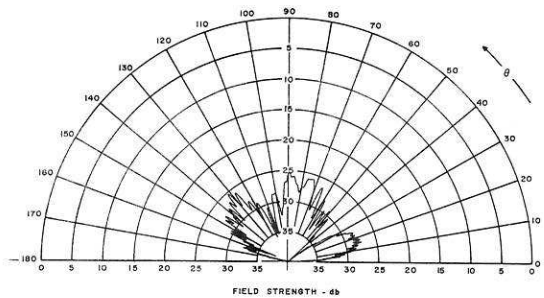
FIELD STRENGTH - dB

ANTENNA : FWD RECEIVING FANS  
FREQ. : 8 MHz  
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

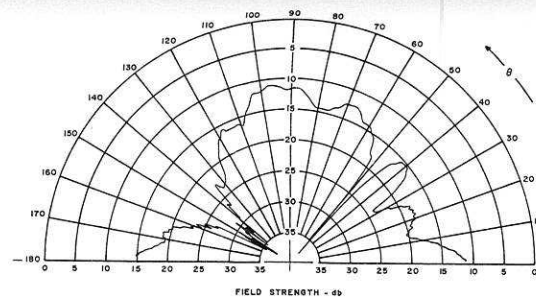
$E_{\theta}$ 

FWD-AFT

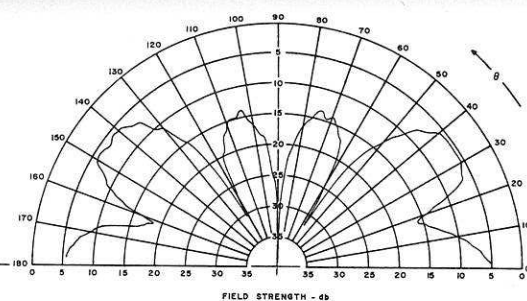
PORT-STBD

 $\theta = 0^\circ$  $E_{\phi}$ 

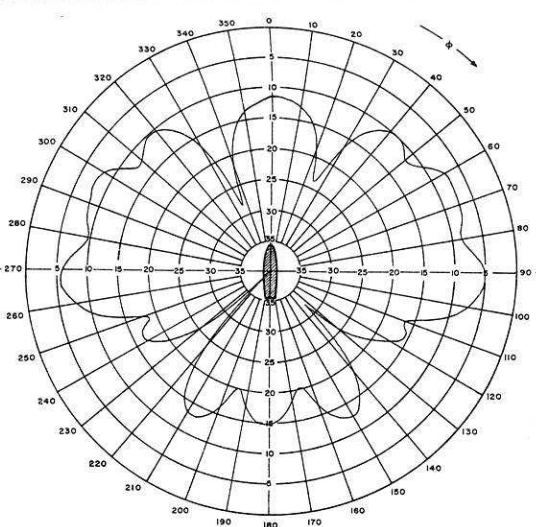
ANTENNA : FWD RECEIVING FANS  
FREQ. : 10 MHz  
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

$E_{\theta}$ 

FWD-AFT

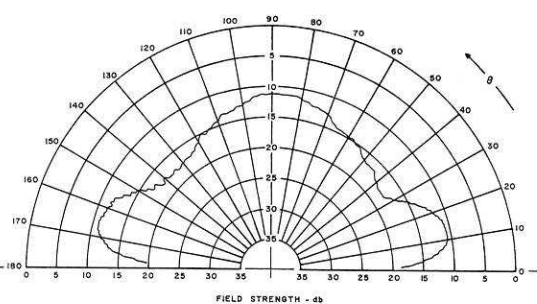
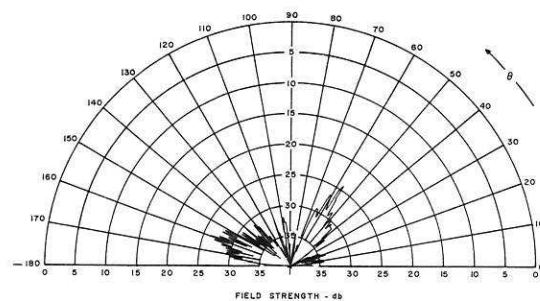


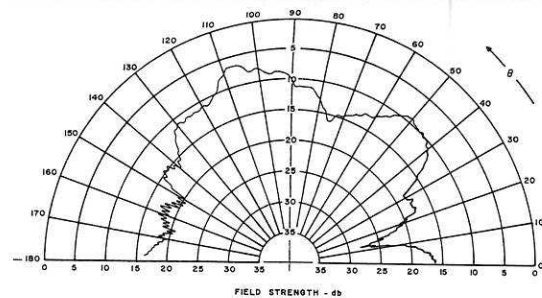
PORT-STBD

 $\theta = 0^\circ$ 

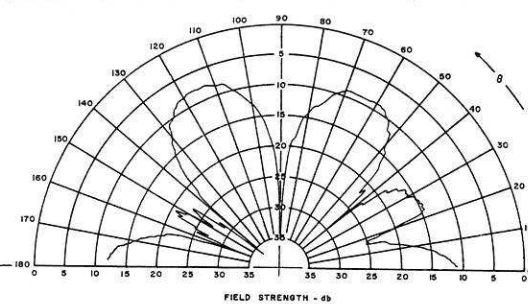
ANTENNA : FWD RECEIVING FANS

FREQ. : 12 MHz

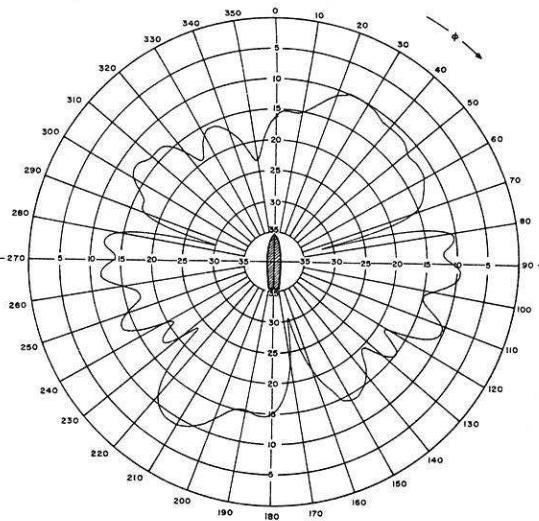
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$  $E_{\phi}$ 

$E_{\theta}$ 

FWD-AFT

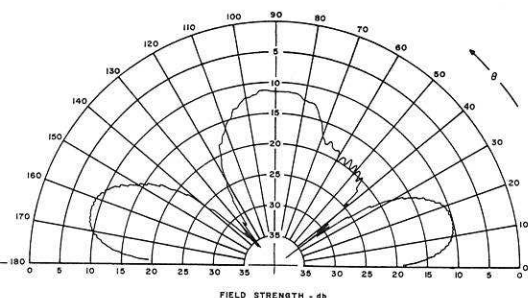
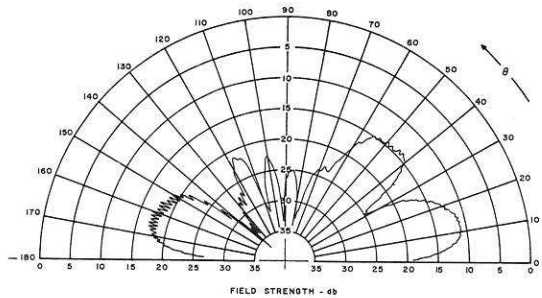


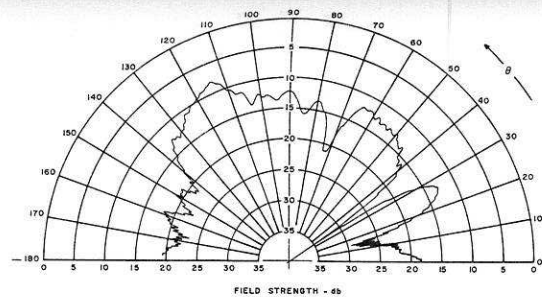
PORT-STBD



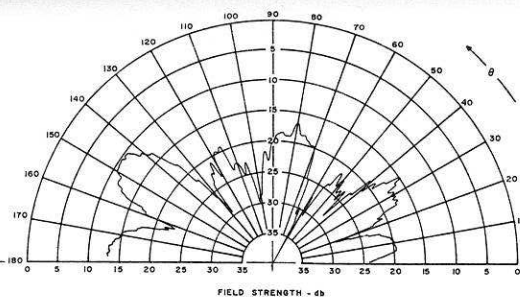
ANTENNA : FWD RECEIVING FANS

FREQ. : 14 MHz

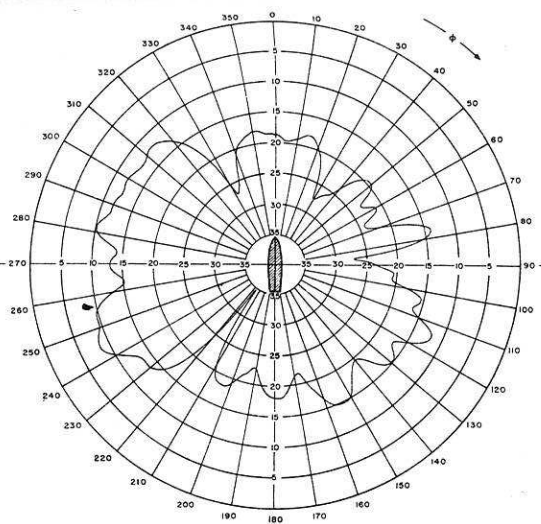
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$  $E_{\phi}$ 

$E_\theta$ 

FWD-AFT

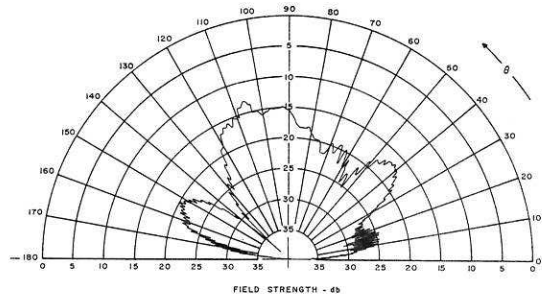


PORT-STBD

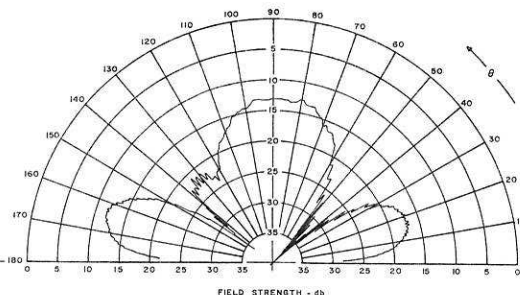
 $\theta = 0^\circ$ 

ANTENNA : FWD RECEIVING FANS

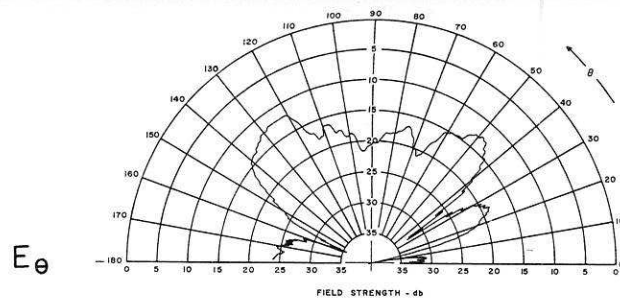
FREQ. : 16 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$  $E_\phi$ 

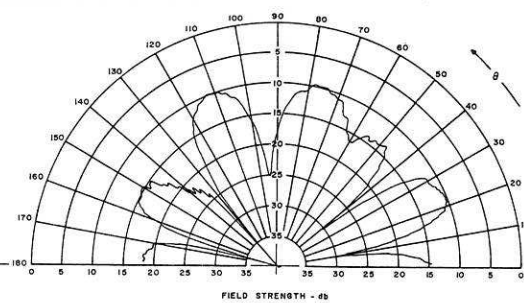
FIELD STRENGTH - dB



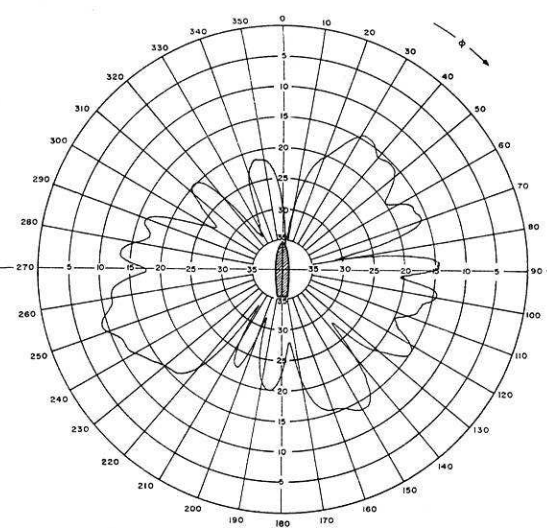
FIELD STRENGTH - dB



FWD-AFT



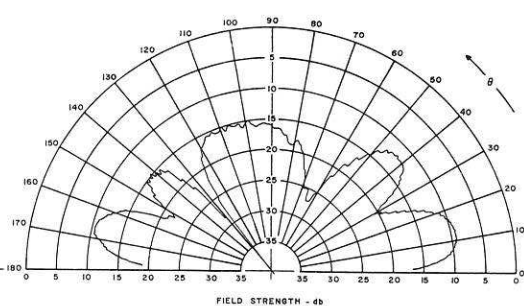
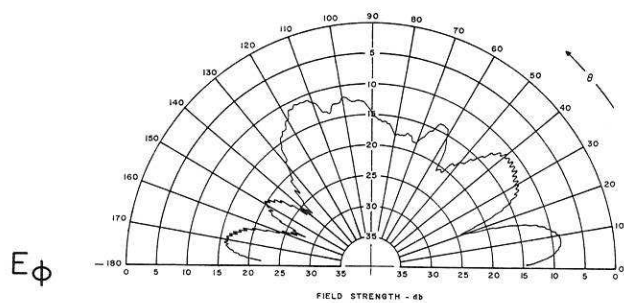
PORT-STBD



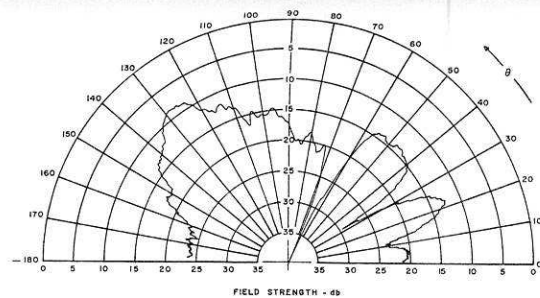
ANTENNA : FWD RECEIVING FANS

FREQ. : 18 MHz

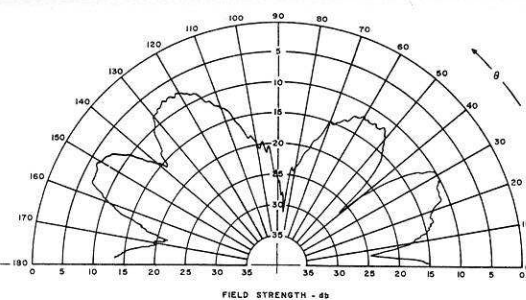
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$



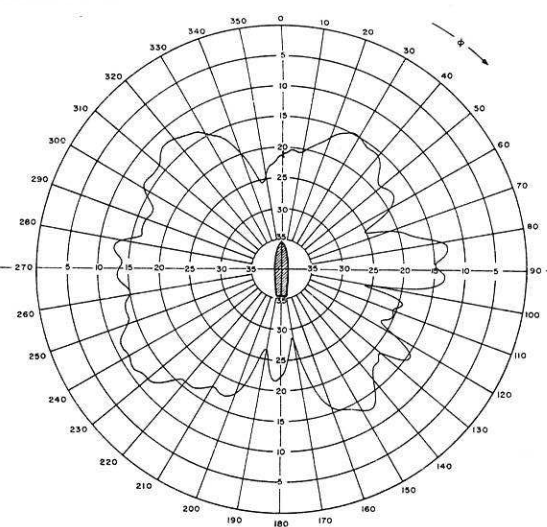
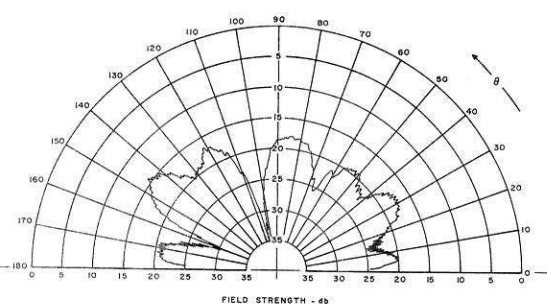
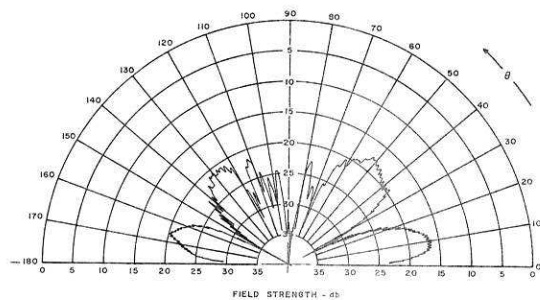


$E_\theta$ 

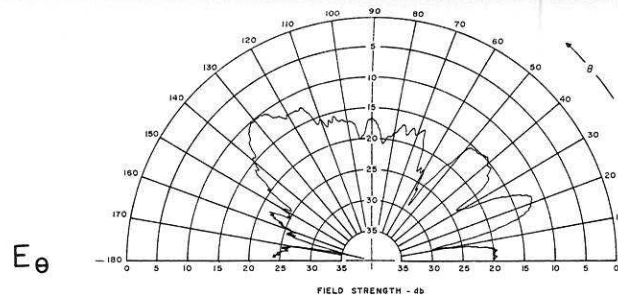
FWD-AFT



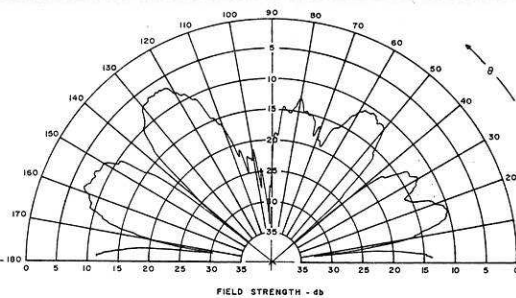
PORT-STBD

 $E_\phi$ 

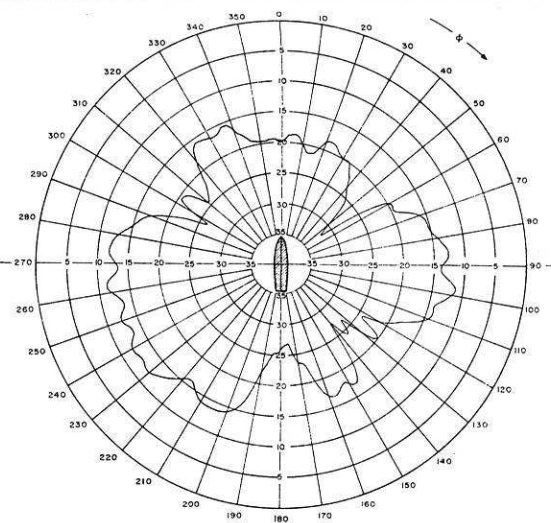
ANTENNA : FWD RECEIVING FANS  
 FREQ. : 20 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω



FWD-AFT



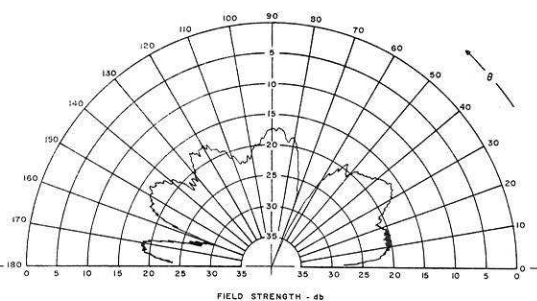
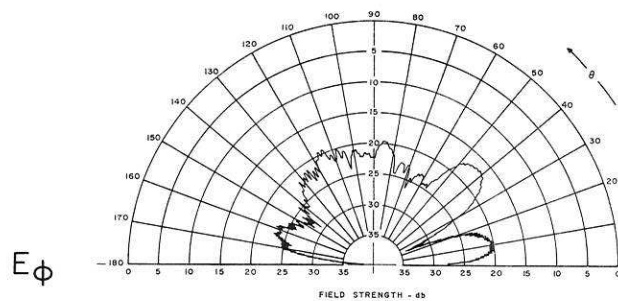
PORT-STBD

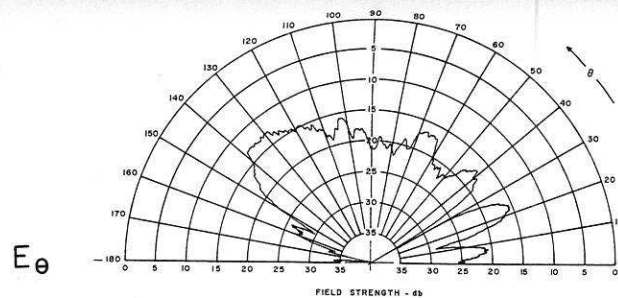


ANTENNA : FWD RECEIVING FANS

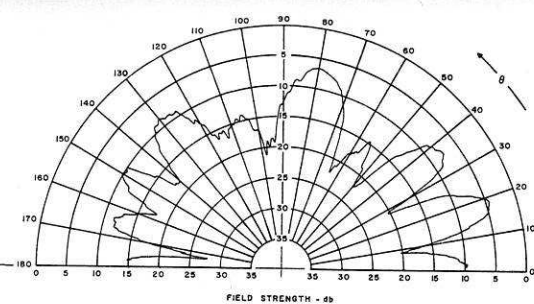
FREQ. : 22 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$

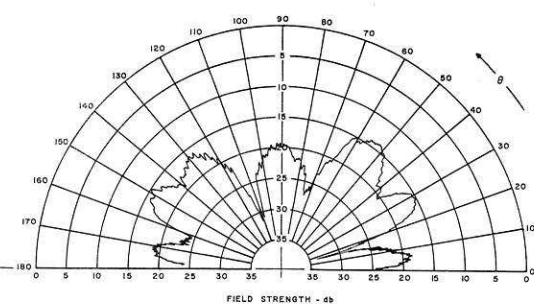
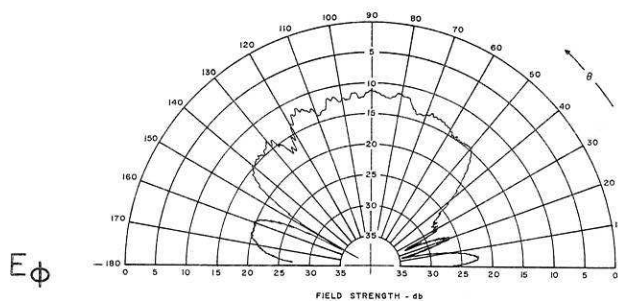
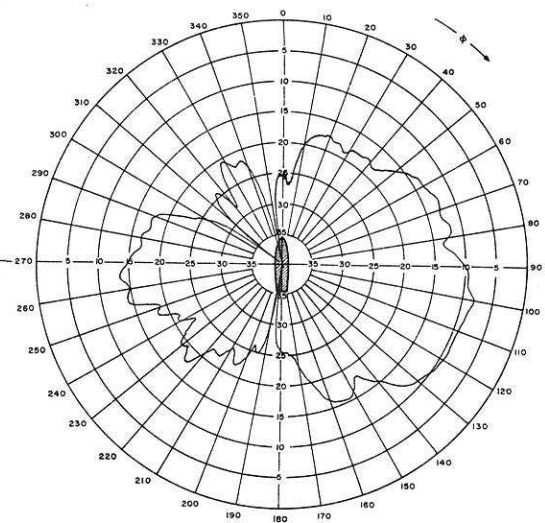




FWD-AFT

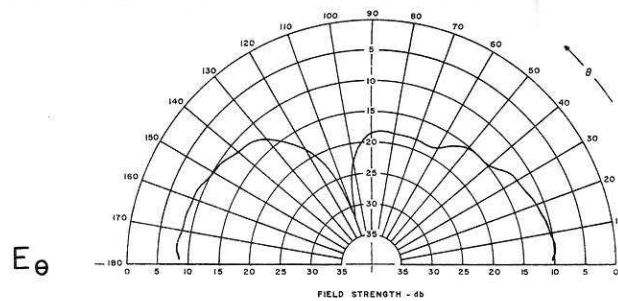


PORT-STBD

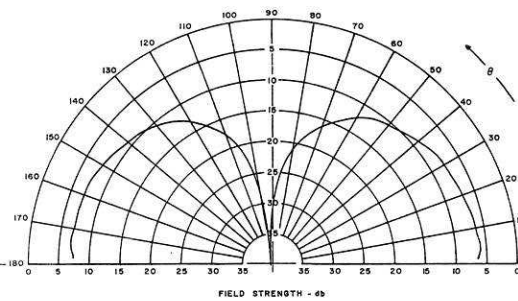


ANTENNA : FWD RECEIVING FANS  
 FREQ. : 24 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$

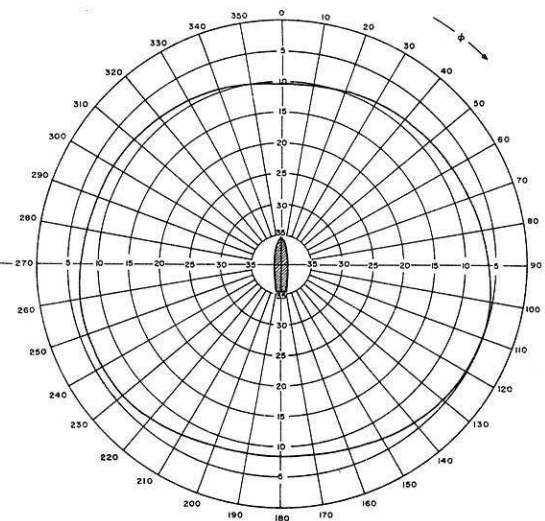
iv) After receiving fans



FWD-AFT



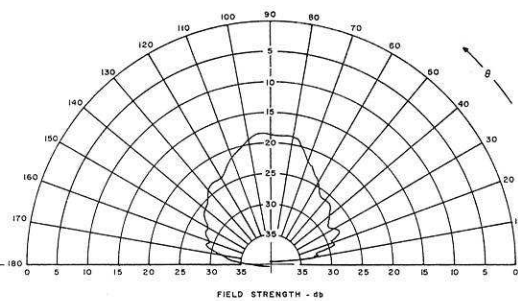
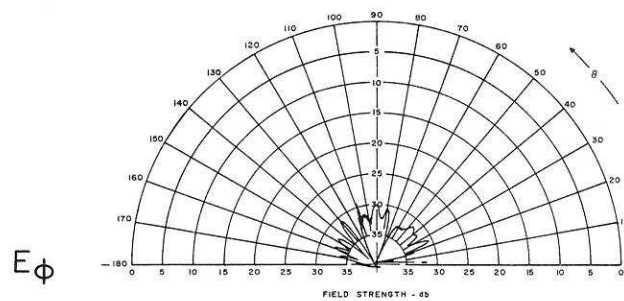
PORT-STBD



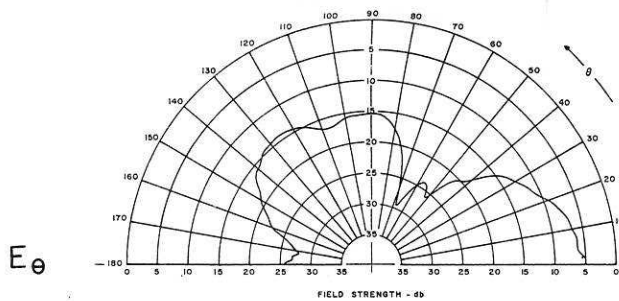
ANTENNA : AFT RECEIVING FANS

FREQ. : 2 MHz

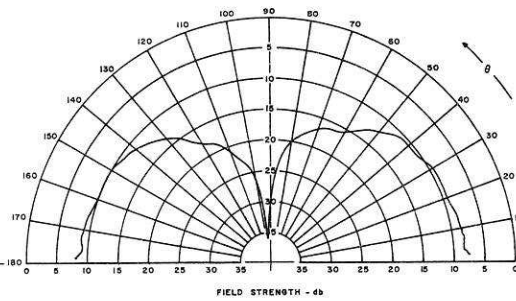
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$



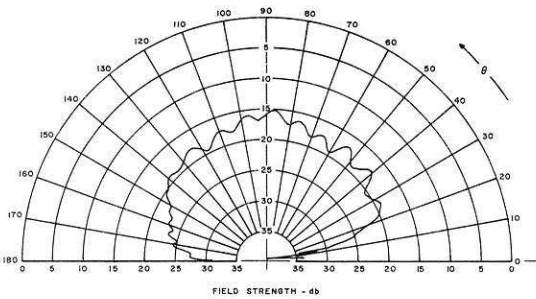
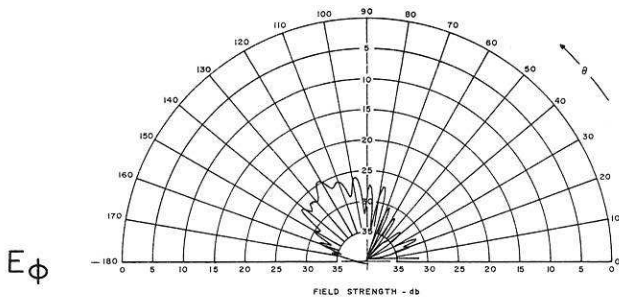
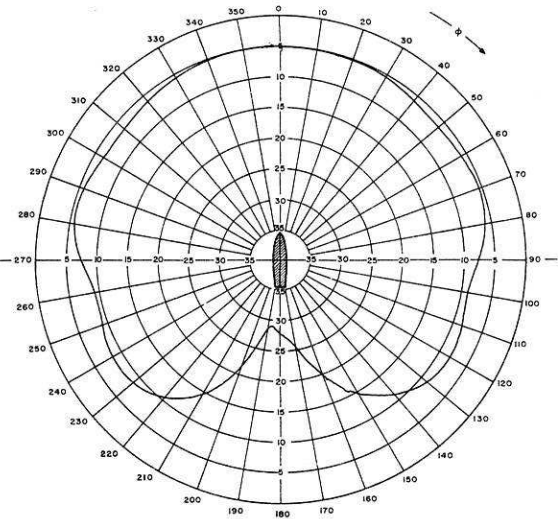




FWD-AFT

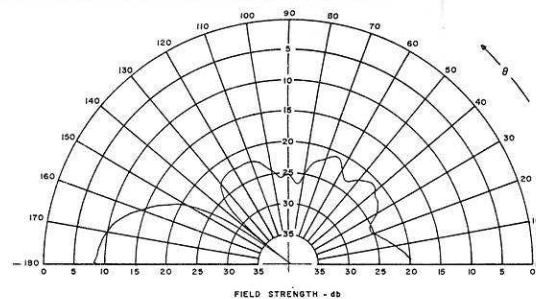


PORT-STBD

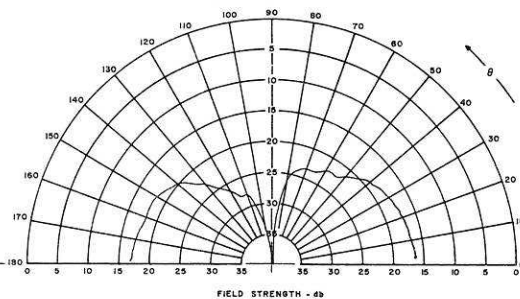


ANTENNA : AFT RECEIVING FANS  
 FREQ. : 3 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$

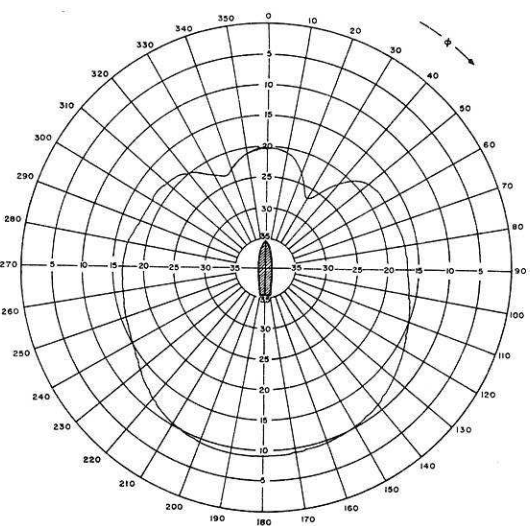


$E_{\theta}$ 

FWD-AFT

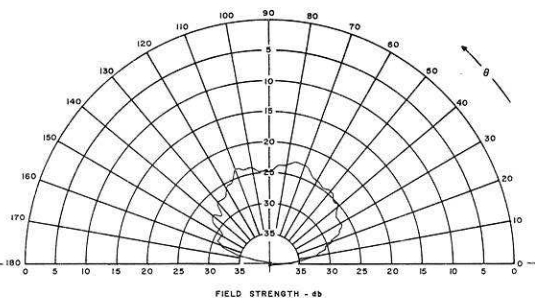
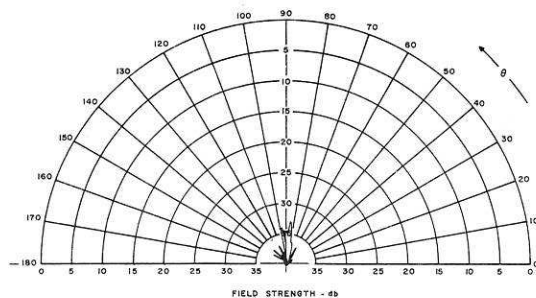


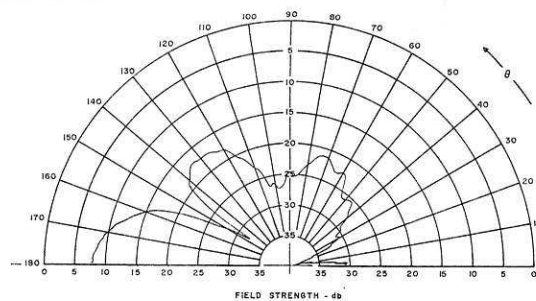
PORT-STBD

 $\theta = 0^\circ$ 

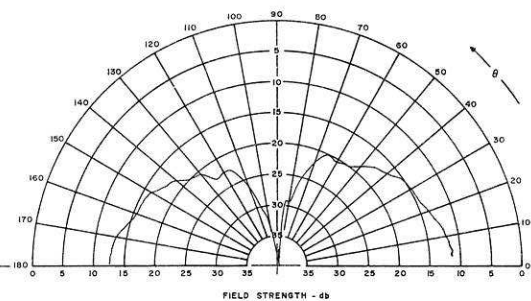
ANTENNA : AFT RECEIVING FANS

FREQ. : 4 MHz

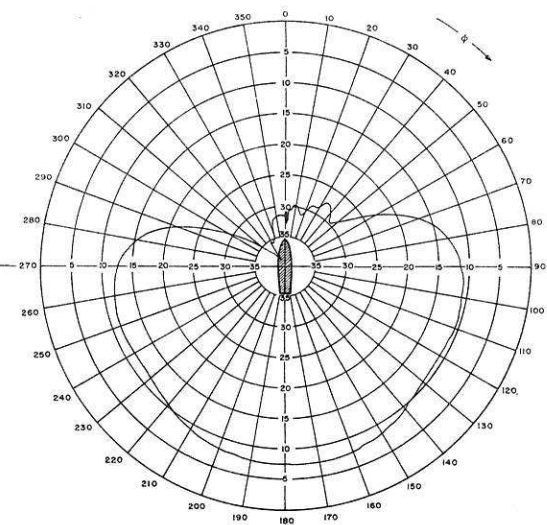
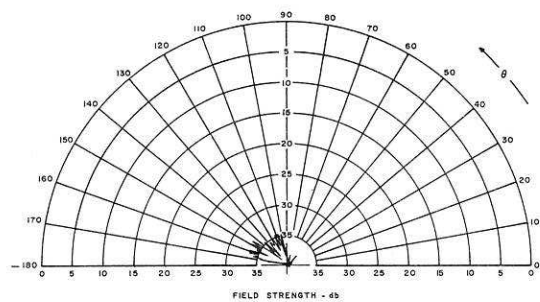
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$  $E_{\phi}$ 

$E_{\theta}$ 

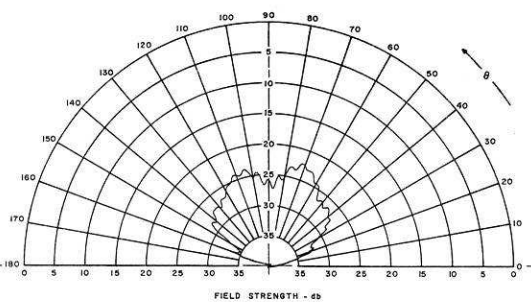
FWD-AFT



PORT-STBD

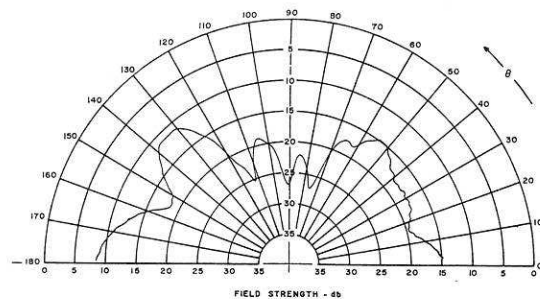
 $\theta = 0^\circ$  $E_{\phi}$ 

FIELD STRENGTH - dB

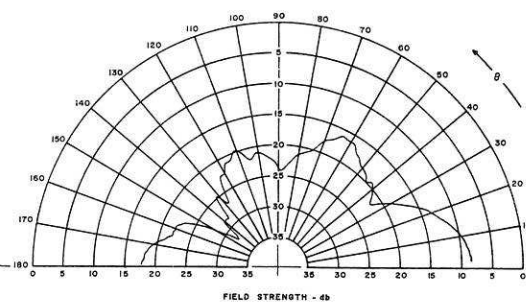


FIELD STRENGTH - dB

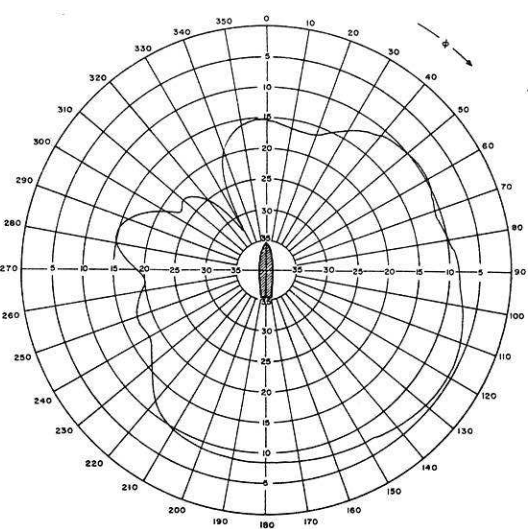
ANTENNA : AFT RECEIVING FANS  
 FREQ. : 5 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$

$E_{\theta}$ 

FWD-AFT

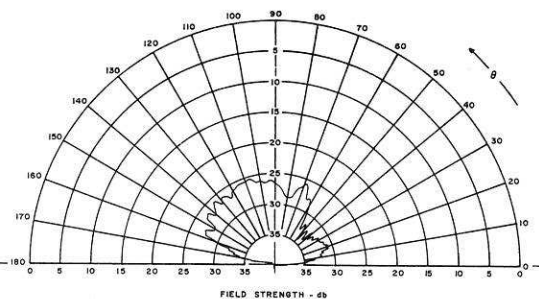
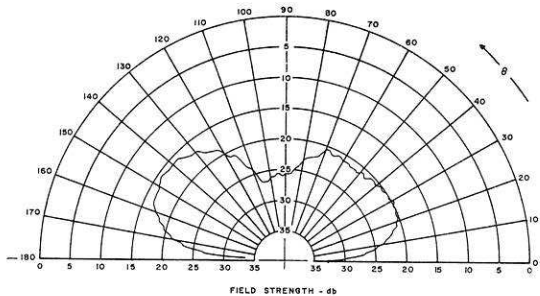


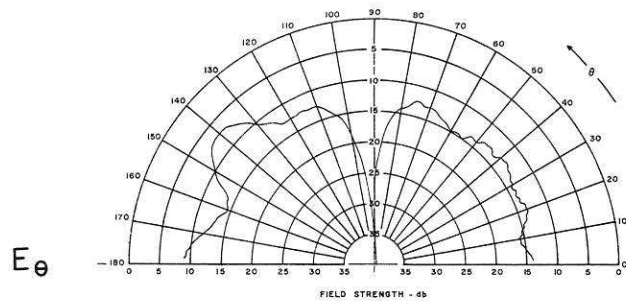
PORT-STBD

 $\theta = 0^\circ$ 

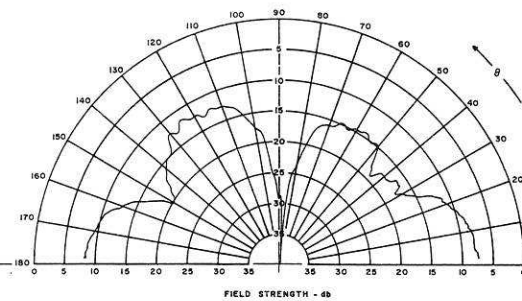
ANTENNA : AFT RECEIVING FANS

FREQ. : 6 MHz

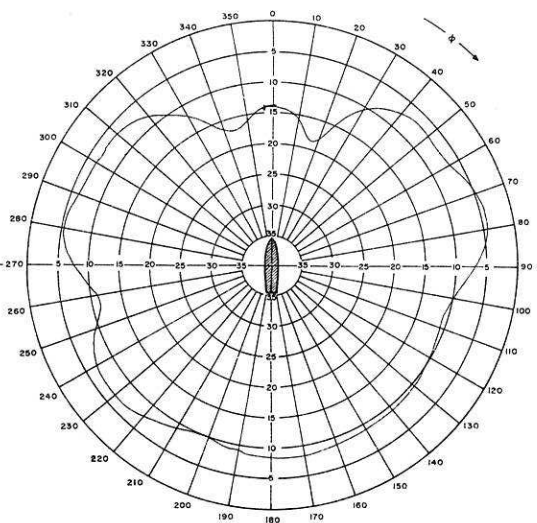
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$  $E_{\phi}$ 



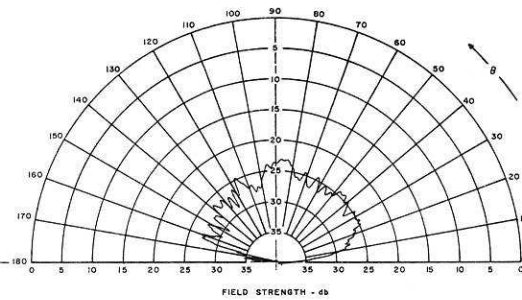
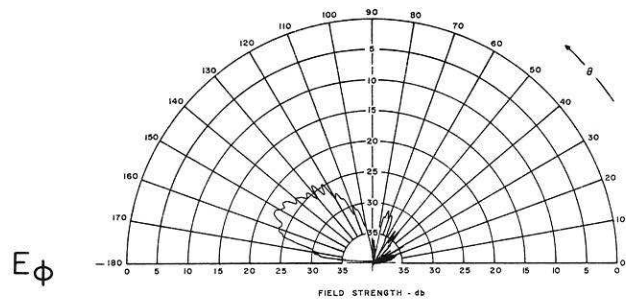
FWD-AFT



PORT-STBD

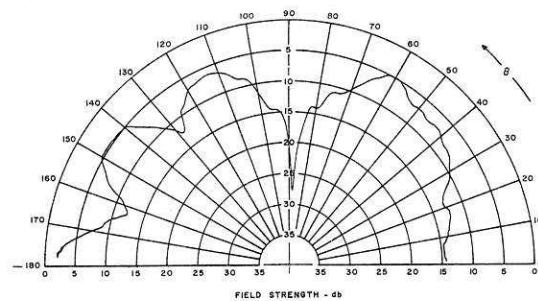


$\theta = 0^\circ$

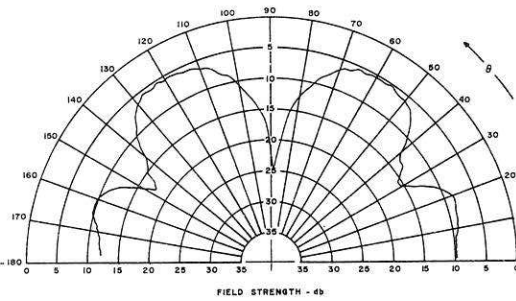


ANTENNA : AFT RECEIVING FANS  
 FREQ. : 8 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$

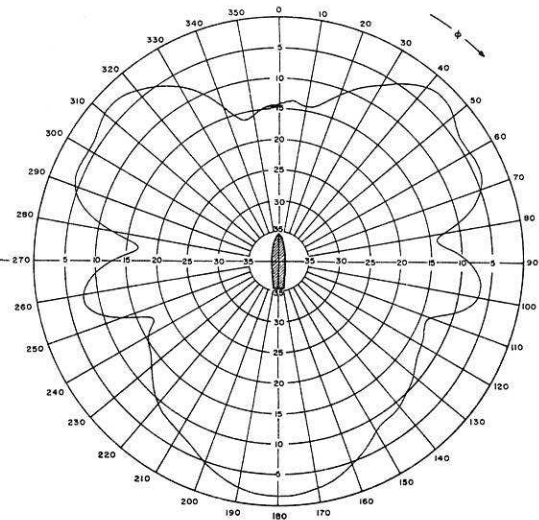
$E_\theta$



FWD-AFT

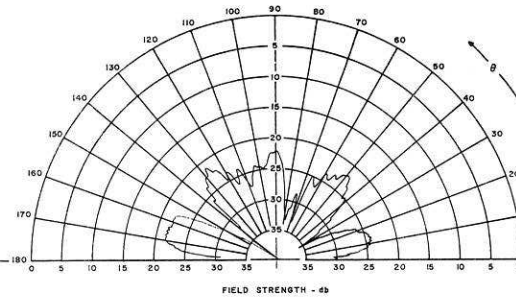
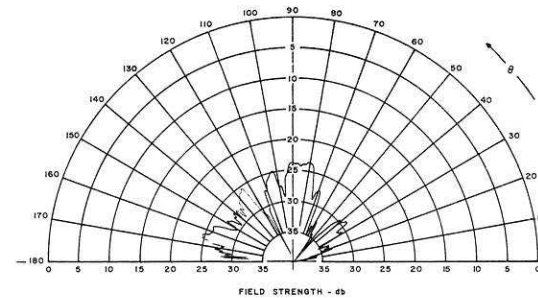


PORT-STBD

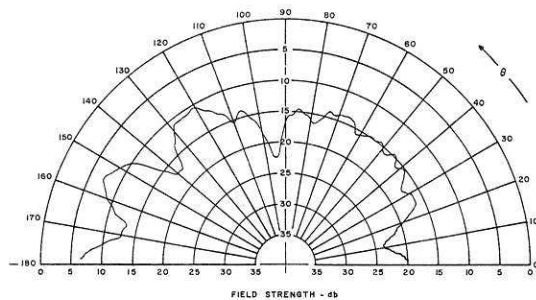


$\theta = 0^\circ$

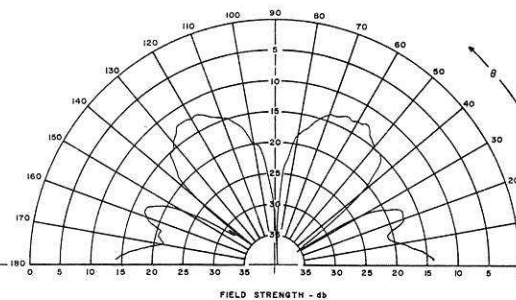
$E_\phi$



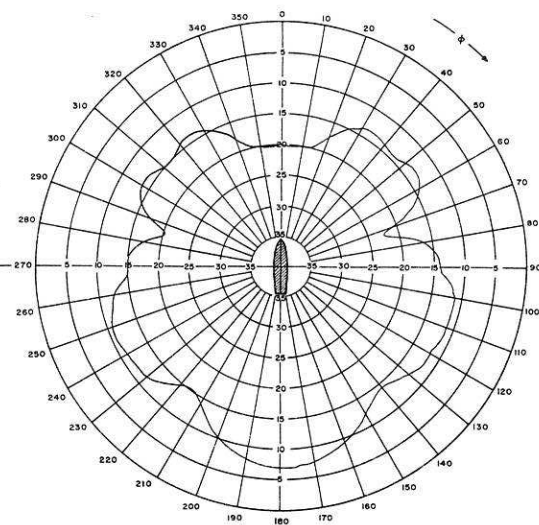
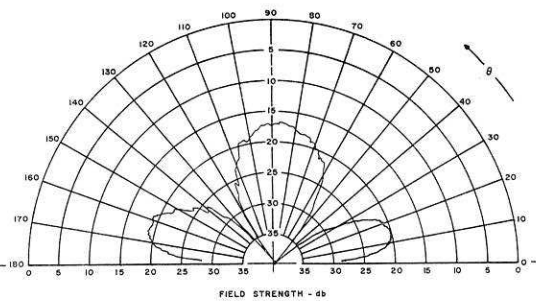
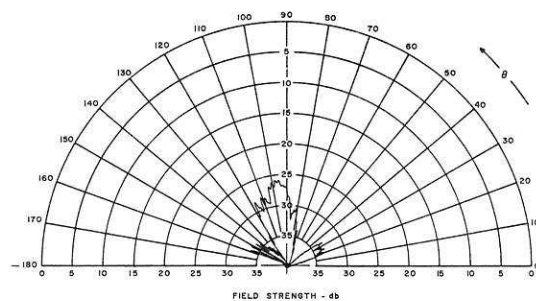
ANTENNA : AFT RECEIVING FANS  
 FREQ. : 10 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω

$E_\theta$ 

FWD-AFT

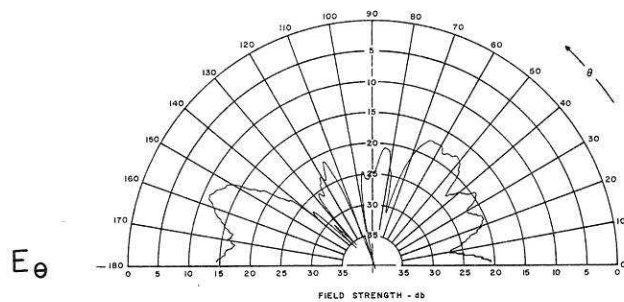


PORT-STBD

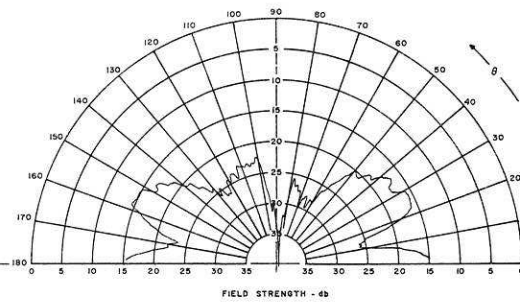
 $\theta = 0^\circ$  $E_\phi$ 

ANTENNA : AFT RECEIVING FANS  
 FREQ. : 12 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$

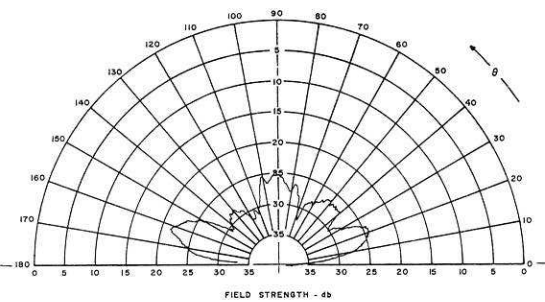
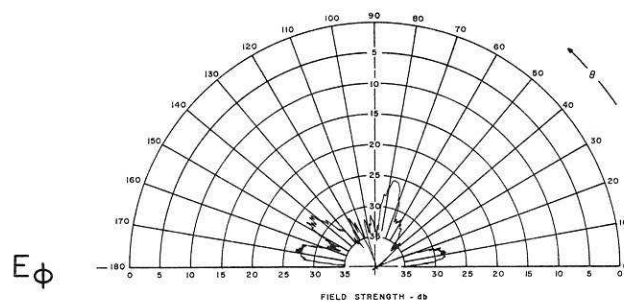
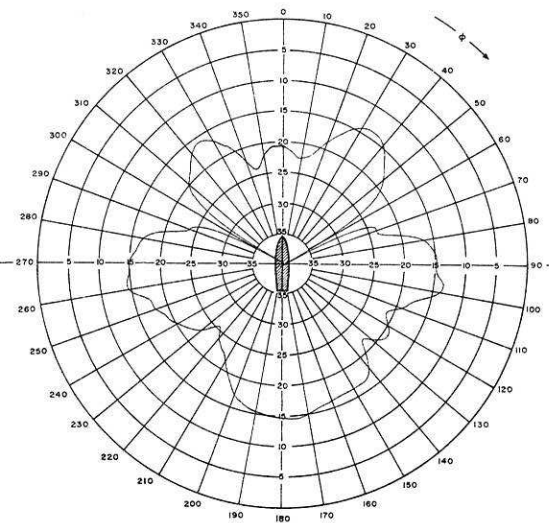




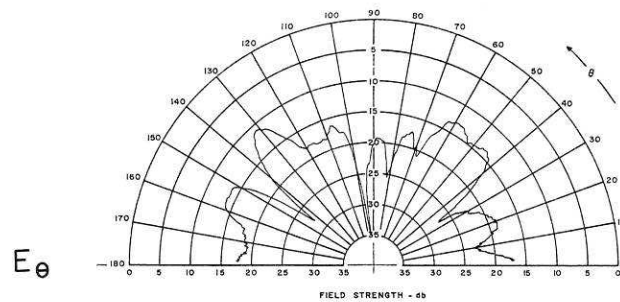
FWD-AFT



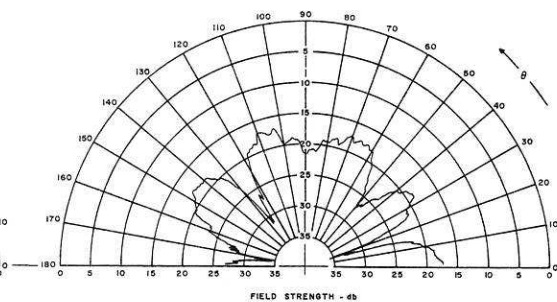
PORT-STBD



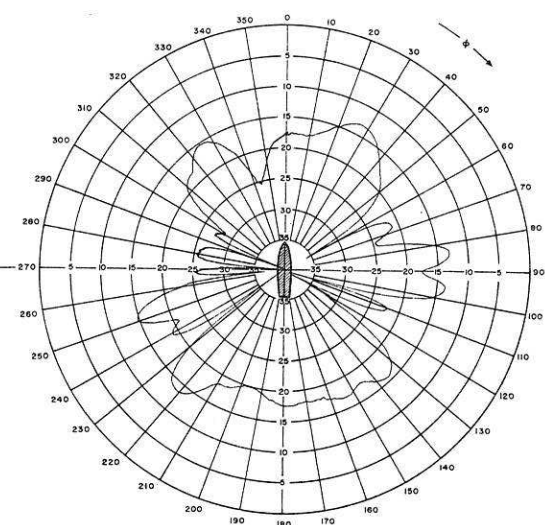
ANTENNA : AFT RECEIVING FANS  
 FREQ. : 14 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$



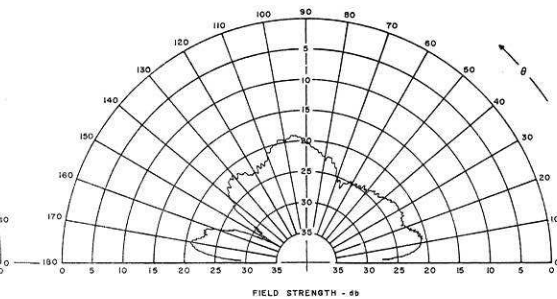
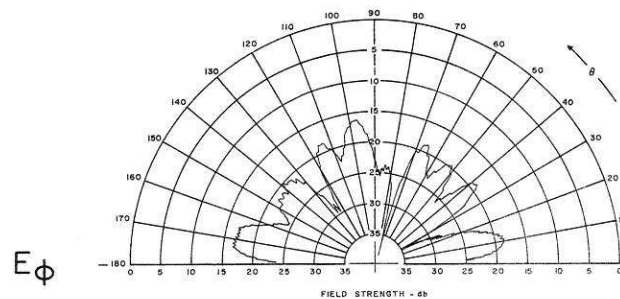
FWD-AFT



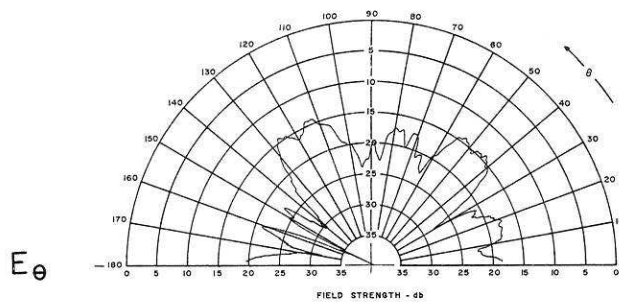
PORT-STBD



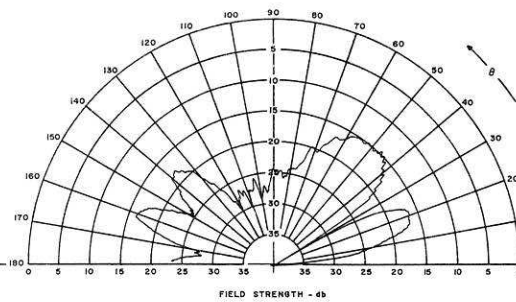
$\theta = 0^\circ$



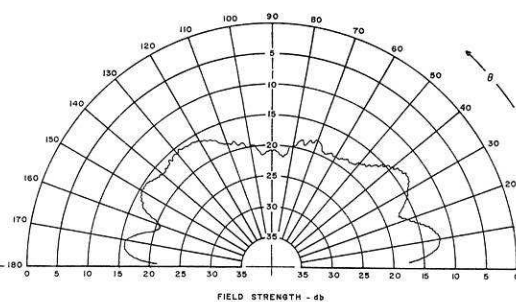
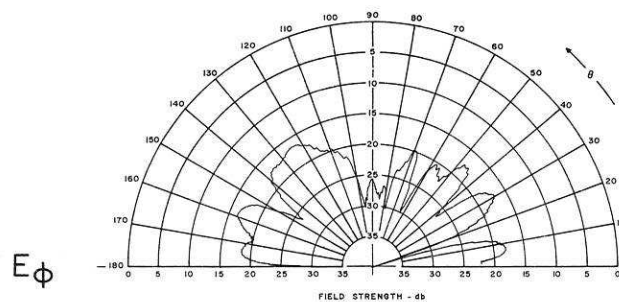
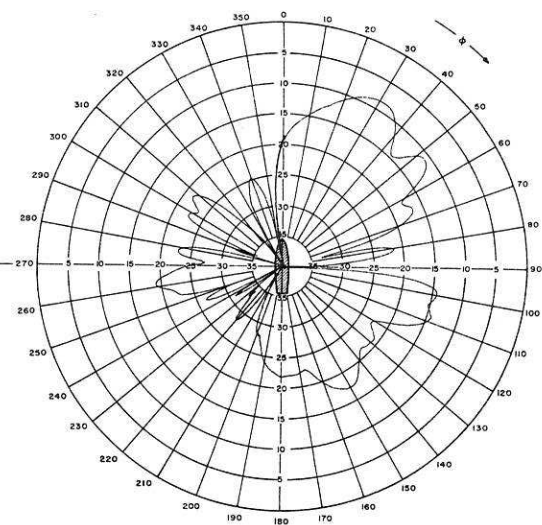
ANTENNA : AFT RECEIVING FANS  
 FREQ. : 16 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω



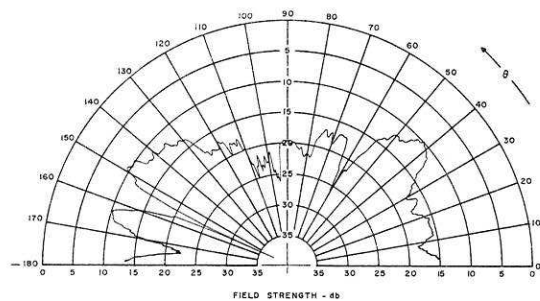
FWD-AFT



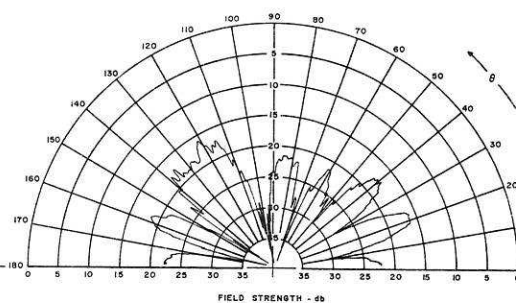
PORT-STBD



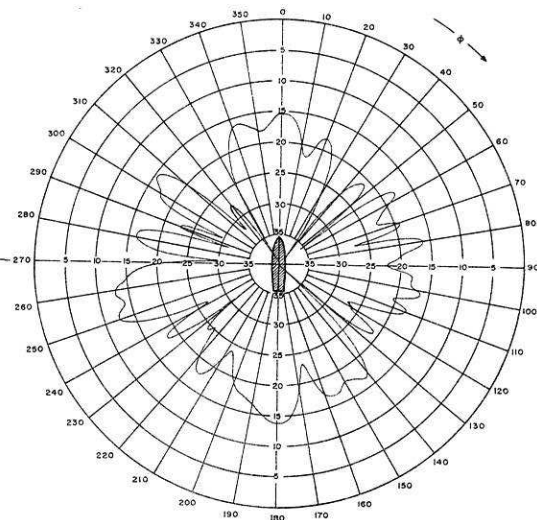
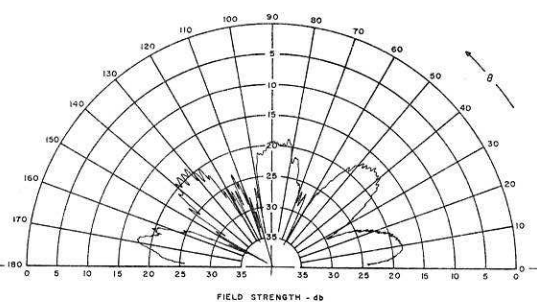
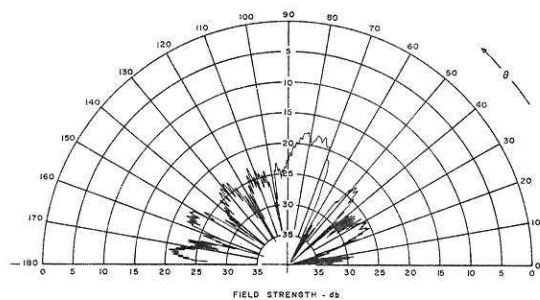
ANTENNA : AFT RECEIVING FANS  
 FREQ. : 18 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50Ω

$E_{\theta}$ 

FWD-AFT



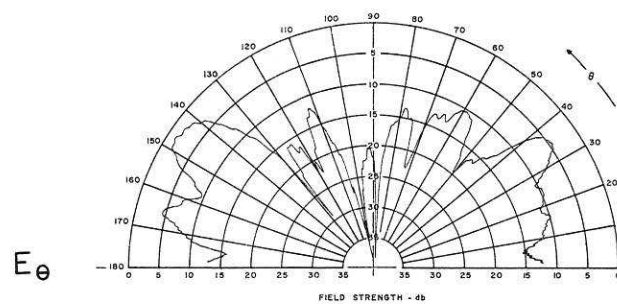
PORT-STBD

 $\theta = 0^\circ$  $E_{\phi}$ 

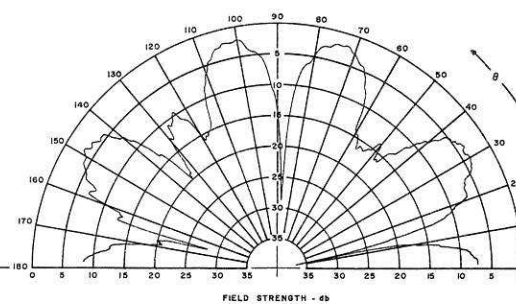
ANTENNA : AFT RECEIVING FANS

FREQ. : 20 MHz

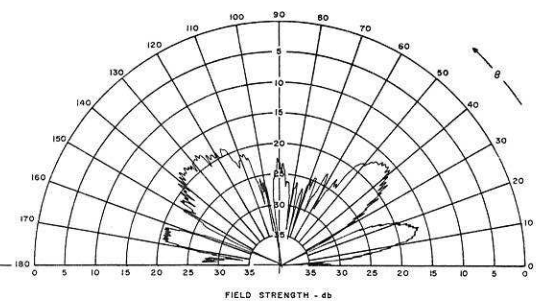
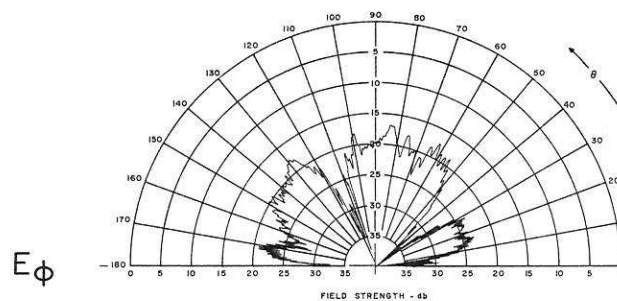
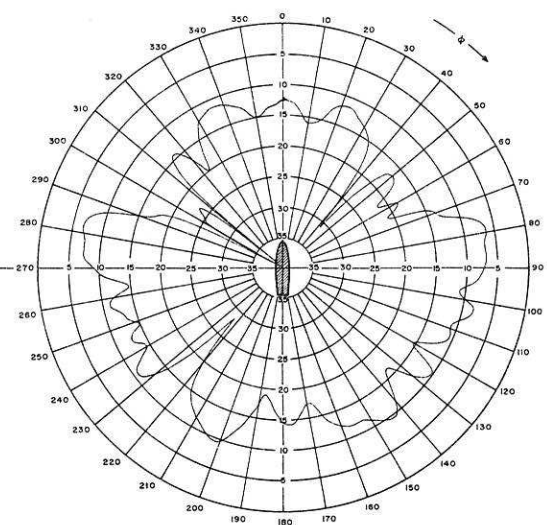
REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$



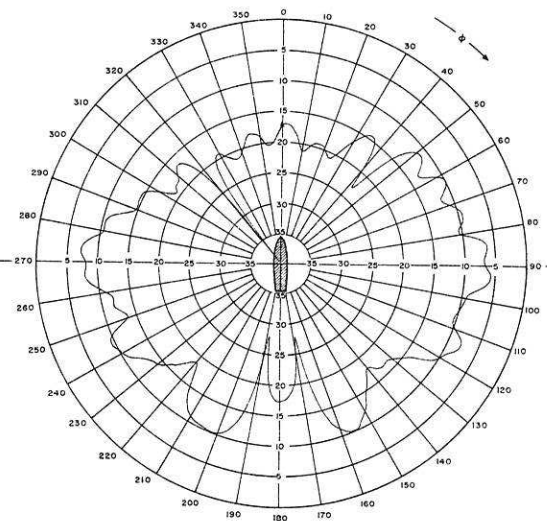
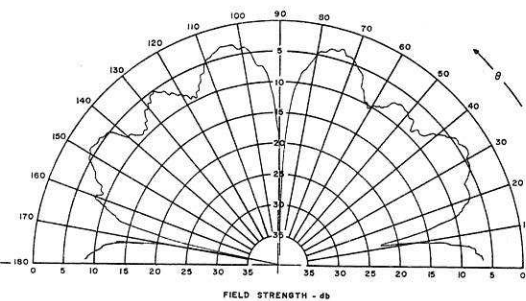
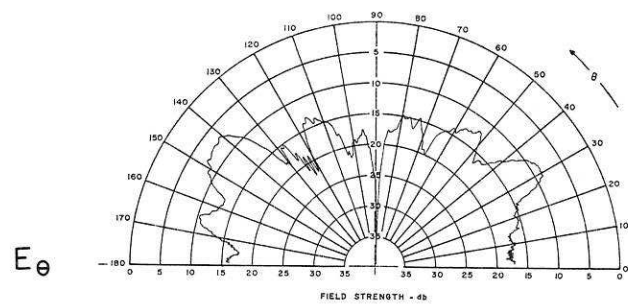
FWD-AFT



PORT-STBD

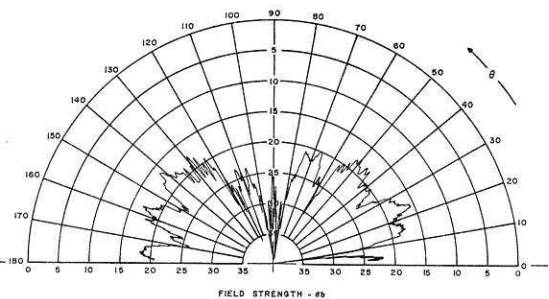
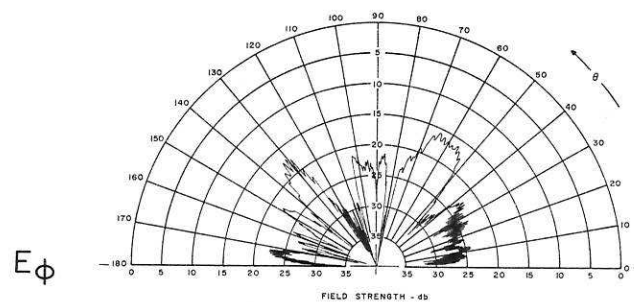


ANTENNA : AFT RECEIVING FANS  
 FREQ. : 22 MHz  
 REMARKS : ALL OTHER ANTENNAS  
 TERMINATED IN 50 $\Omega$



FWD-AFT

PORT-STBD



ANTENNA : AFT RECEIVING FANS

FREQ. : 24 MHz

REMARKS : ALL OTHER ANTENNAS  
TERMINATED IN 50 $\Omega$





Plate I 1/48 scale model of OSS509 used for radiation pattern measurements