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Maintenance of Directional Antenna

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Except for the development of precise frequency control, it is probable that no other technical development has contributed so much to the efficient utilization of the standard broadcast band as the directional antenna. As of May 1974, there were authorized in the United States some 4,408 standard broadcast stations. Of these, about 1,800, or roughly 42 percent, use directional antennas in either daytime or nighttime or both. Because some stations use more than one pattern, a total of over 2,100 different directional-antenna patterns are involved.

Before authorization is granted for construction of a directional antenna in the United States, the Federal Communications Commission requires that a complete engineering showing be made. Before a license is granted for the regular operation of a directional antenna, a complete and thorough proof of performance must be made and submitted by the permittee and approved by the FCC.

We can thus assume that each directional antenna is operating properly at the time that it commences regular operation. But what of the problems of maintenance of the antenna in day-to-day operation of the system? Let us examine the factors affecting the maintenance of directional-antenna systems.

Factors Affecting the Maintenance of Directional Antenna Systems

To begin with, the design of the antenna system will affect the maintenance problems. In his design, the engineer must determine whether the array will operate with reasonable stability and efficiency. Generally speaking, the design must be such as to avoid low values of base operating resistance, either negative or positive. Such a condition could lead to excessive losses in the system and possibly to a "flip-flop" operating condition where a small change in tuning results in a drastic change in operating parameters.

In so far as the design engineer can do so, he must avoid deep minima in the pattern, since this results in a condition where a relatively small change in phase or current can cause a relatively large change in field intensity radiated in the directions of the minima.

Further factors affecting the stability of a directional antenna and the problem of its maintenance arise in the design of the phasing and coupling equipment. A design which incorporates a minimum of resonant circuits will, in general, exhibit greater stability than one which has a number of such circuits.

In the physical location of phasing and coupling equipment, one method frequently used is to have the power-division and phasing equipment distributed through the system and placed in tuning houses at the antenna bases. While this has the advantage of requiring a minimum length of transmission line and furnishes some protection against unauthorized tinkering by operating personnel, it has the disadvantage of making the initial tune-up and any necessary subsequent readjustment more difficult and lengthy than would be the case with a more convenient arrangement. The alternative and a better arrangement is to concentrate the phasing and power-dividing equipment in the transmitter building. Here the effect of adjustments can be observed at once with the monitoring system, and the tuning of the array can be completed more easily and quickly. Under this concentrated arrangement, the equipment is usually better housed, thus making for better and easier maintenance.

The development of the operating impedance bridge and the common-point impedance bridge makes it possible to incorporate a device in each phasor which permits determination at any time of the impedance of the common point of input. The common-point impedance bridge is designed to be permanently installed. In cases where a station desires to use an operating-impedance bridge at several points in the antenna system, a system of meter jacks and shorting bars can be incorporated at the common point of input and at other measuring points. If the design of the phasor is such that the common-point input network is a T network, the input coil can be made continuously adjustable, with a front-of-panel control labeled "INPUT REACTANCE." Likewise, the coil in series with the shunt capacitor of such network can be made continuously adjustable, with a front-of-panel control labeled INPUT IMPEDANCE." Thus, the common-point input impedance can be measured and adjusted if necessary during regular operation of the station.

Transmission Lines

Still more factors affecting maintenance of the directional-antenna system arise in the course of construction of the system. The choice of transmission and sampling lines, for instance, is important. Open-wire lines are unsuited for use with directional-antenna systems. The characteristics of such lines change with the accumulation of water, ice, or snow on the wires and insulators, and this alters the operating parameters of the array.

The solid-dielectric transmission lines having an outer conductor of copper braid, such as RG17U and RG19U, are also unsuitable for a directional-antenna system unless special precautions are taken. The somewhat lower efficiency of these lines must be taken into account in the design of the system. Because the outer conductor of such lines "leaks" RF energy and because of the difficulty of adequately grounding the lines along each run, the most satisfactory way in which to handle this type of line is to install it in well-grounded metal conduit. The expense of doing this, however, increases the cost of the installation so greatly as to nullify the advantage of the lower first cost of the line itself.

An article on "Phase Stability of Coaxial Cable," by Fred Mysliwiec, in the August 1967, issue of *Broadcast Engineering,* graphically pointed out the relatively large phase shifts that can occur with temperature changes in the RG-17U type of line. Such characteristics, and similar characteristics exhibited by smaller solid-dielectric lines used for sampling lines, serve to emphasize the unsuitability of such lines for use in directional installations.

No more satisfactory transmission line or sampline line can be found than air-dielectric line having either a smooth or a corrugated outer conductor of solid copper and grounded adequately along each run. The inne conductor of such lines is supported by beads of ceramic or other suitable insulation or by spirally wrapped strips or tubes of polyethylene. In any case, the major portion of the dielectric is air or nitrogen. Lines having a solid outer conductor, but using a foamed polyethylene dielectric, are also suitable, and although such lines exhibit a greater phase/temperature change than lines with essentially air dielectric, the performance is usually acceptable for all but critical installations.

Transmission lines and sampling lines should be adequately grounded along each run, and when the proper type of line is correctly installed and maintained, such lines provide many, many years of satisfactory service.

In any installation of pressurized lines, particular attention must be given to the arrangement for pressurizing the lines. Maintenance of pressure in the lines is an important part of the overall maintenance of the system; therefore, the arrangement for pressurizing must be convenient and readily accessible.

It goes without saying that the tuning equipment must be adequately housed, that all ground connections must be well made, and that good workmanship must be used in all details of the installation if maintenance problems are to be kept to a minimum.

Antenna Monitor

One of the most important aids in maintaining a directional-antenna system, if not the most important, is an adequate sampling system and a reliable antenna monitor. A sampling loop mounted on the tower is to be preferred to a resonant pickup circuit coupled to the antenna lead. If the resonant circuit is used, it will be found that the relative phase and current indications of the antenna monitor will change as the circuit drifts or is jarred out of resonance. If such a sampling pickup is used, the maintenance procedure at the station should provide for frequent checking of resonance of each such circuit.

The antenna monitor at the station should be maintained according to the directions of the manufacturer.

GENERAL MAINTENANCE PROCEDURES

Mention was made earlier of the desirability of avoiding deep minima in the design of the directional-antenna pattern. It follows that in the adjustment of the antenna, the field radiated in the direction of each minimum must not be reduced substantially below the theoretical value, since, if carried too far, such a reduction will result in a low value of field strength difficult to maintain in regular operation.

After an array has been properly adjusted in the initial operation, useful and valuable information can and should be obtained by measuring the reactance of the component branches of all tuning networks. Then if it should be necessary to replace a defective component at a later date, the value of reactance originally established can be quickly achieved. Also, the data obtained from such measurements can be used in later checking the condition of a suspected component.

After a directional antenna has been properly adjusted, a record should be made of all dial settings of variable tuning elements and the position of any clips on tapped inductors should be marked. Such marking can be done quickly and effectively by painting a strip of fingernail polish across the clip and the turn of the coil on which it is located. Where a coil has two or more clips, a different color should be used for each clip. Then, if a clip should accidentally be dislodged, it is a simple matter to replace it in the proper location.

In the maintenance of a directional-antenna system, as in the maintenance of other equipment, one rule is important: Keep it clean! Components should be wiped and blown clean each week. The tuning houses should be kept rodent and reptileproof. It adds nothing to the operation of the system to have a scorched mouse, a dead snake, or a large dirt-dauber's nest scattered among the tuning components.

Vegetation should be kept down in the vicinity of each tower base. Cut vegetation should be raked away from the tower base and burned under supervision to minimize reseeding and to prevent a fire hazard. Chemicals can be used to inhibit growth of vegetation.

Pressure in the transmission and sampling lines should be maintained at 6 to 10 pounds per square inch, using dry air or dry oil-pumped nitrogen, to prevent the entry of moisture. If a leak develops, it should be located and repaired promptly. Periodic checks should be made of the pressure gauges so as to be certain that no gauge has become stuck and is giving false indications.

It is helpful to apply a very light coating of silicone compound to exposed insulators and end seals to prevent formation of a moisture film during wet weather. It goes without saying that all insulators should be kept free of paint.

Inspection of Components

An important part of the maintenance procedure is to make a weekly visual inspection of all elements of the antenna system. Broken insulators or other damaged elements should be replaced at once. Where necessary, lightning gaps should be respaced, using a piece of flat insulation of the proper thickness as a feeler gauge.

The tightness of all connections in the antenna tuning equipment should be checked at quarterly intervals. At yearly intervals and also after every violent windstorm, a transit should be used to determine whether each tower remains plumb. It is advisable at the same time to check all tower bolts and nuts for tightness and to check for bent members. During these checks, a visual inspection should be made of the guy wires and insulators for any signs of damage or deterioration. If a tower is found to be out of plumb or other difficulties are found, a competent tower erector should be employed to correct the situation.

A prosaic, but necessary, procedure is to check each monitoring point at monthly intervals (or weekly, if required by the license) not only for the measured field intensity, but also to observe whether the directions for reaching the monitoring point are still correct, whether the marking of the monitoring point is still legible, and whether the point is free of new construction which could affect the field intensity.

Meter Readings

Meter readings having to do with the antenna system should be made carefully and logged accurately so that if difficulty arises, a complete and accurate record of what has transpired is available for reference. If an electrical storm occurs in the vicinity of the antenna, that fact should be entered in the log. Readings of the antenna base meters and the sampling loop meters must be made under conditions of no modulation. Usually, the cooperation of studio operating personnel can be obtained and a pause allowed between announcements or musical selections so that each reading can be obtained accurately. In the alternative, it is possible to rig up an "audio kill" circuit with a relay to short the audio input to the limiter, said relay being actuated by a push button located at each RF ammeter position. Needless to say, care must be used not to interrupt important announcements with this circuit. Experience will show what length of interruption of the broadcast material is necessary to permit the RF meters to "cool down" for an accurate reading, but it will usually be not over 3 or 4 seconds. When reading antenna base meters, the operator should carry with him a monitor permitting him to discern when no modulation is present. A crystal diode rectifier wired across a telephone jack and equipped with a probe or pickup coil can be used with a pair of headphones to provide such a monitor.

A device which has proved useful in antenna work is shown in Fig. 1. With the switch open, this device is a useful monitor. Adequate pickup is obtained by holding the sleeve of the plug in one's hand while touching the tip to a metal panel, messenger cable, or the like. With the switch closed, the device becomes an effective noise limiter for use with a receiver in RF bridge work.

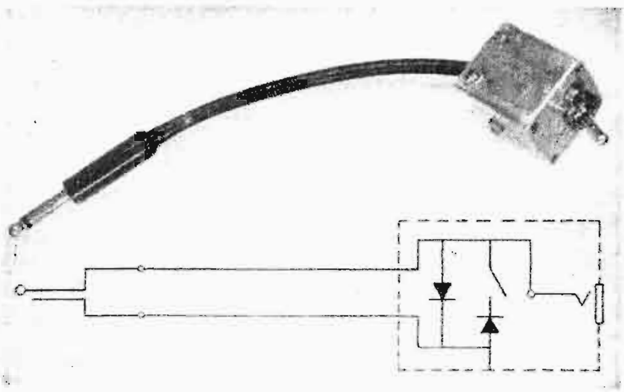

Fig. 1. Detector-noise limiter for use in antenna work.

Maintenance Report

Components

A report or maintenance book can be set up as follows. The first section shown in Fig. 2 will consist essentially of a complete description of the individual component parts arranged in four subdivisions consisting of inductance coils, capacitors, resistors, and relays. The listing in each of the subdivisions should carry a description of the unit, its location or function in the circuit, its type number, replacement-ordering information, and circuit designation. The listing should also cover the number of turns in use of each inductance coil, the value of each of the capacitors, and the dial settings of the capacitors if variable.

Meters

The second subdivision (Fig. 3) should furnish complete information concerning all meters used in the operation of the array and should consist of a listing of these units showing the circuit designations, the location and function of the unit, its range, type and serial number, and the current reading for the required output. The required antenna-monitor reading for normal operation should be listed in this subdivision.

Monitoring Points

The third subdivision (Fig. 4) should contain a listing of the monitoring points as designated by the Federal Communications Commission's license and should show the number of the monitoring points, a complete description for reaching these points, the bearing and distance, the specified unattenuated field value of one mile, the obtained unattenuated field value at one mile, together with the actual received field.

Diagrams and Measurements

The fourth and last subdivision (Fig. 5) should contain a schematic diagram and, if available, a wiring diagram of the complete antenna array equipment together with the series of curves from the Proof of Performance Report showing the dividing network or driving-point impedance of the array (Fig. 6) equipment and operating tower impedance (Fig. 7) if a single tower is used for nondirectional daytime operation. Additional pertinent information that would be of assistance to the maintenance engineer, such as transmission-line and capacitor gas pressures, should be included. While it may appear that some of this information will be a duplicate of the Proof of Performance Report, it is believed that by rearranging the data in this form and making them part of the maintenance routine, the constant reference to this information by the station engineering personnel will acquaint them with the equipment and its functions far better than a casual reference to the Proof of Performance Report.

Daily Work Schedules

The second section of the maintenance report book should contain a complete list and schedules of the daily work to be done and, where necessary, complete instruction covering the methods and equipment to be used. A suggested list is shown in Table 1. In the case of the example used, the antenna maintenance work is divided into two main classifications. The first classification is designed to cover the daily routine inspection and work that is to be handled by the "late trick" station engineer after sign-off. This work has been arranged in such a manner that all parts and circuits will be cleaned and inspected at least once each week. The second classification already mentioned has been designed to cover a series of

CIRCUIT INFORMATION

Circuit Designation	*Circuit Function*	*Adjustment Information*	*Replacement Information*
L1	Shunt input coil	20½ turns	Continuously variable coil—type 4224 MS4—26 μh
L2	Series input coil	9½ turns	Variable tap coil—type 322-4N4—26 μh
L3	No. 1 tank coil	8 turns	Variable tap coil—type 3208NT10—38 μh
L4	No. 2 tank coil	7 turns	Variable tap coil—type 3208NT10—38 μh
L5	No. 1 line feed coil	½ turn	Continuously variable coil—type 4103—HMS5—7 μh
L6	No. 2 line feed coil	7¾ turns	Continuously variable coil—type 4103—HMS5—7 μh
L7	No. 3 line feed coil	7 turns	Continuously variable coil—type 4103—HMS5—7 μh
L8	No. 4 line feed coil	5½ turns	Continuously variable coil—type 4103—HMS5—7 μh
L9	No. 1 line series phase coil	13¼ turns	Continuously variable coil—type 4224 MS4—26 μh
L12) L13)	No. 2 line series phase coil	8¼ turns	Continuously variable coil—type 4224 MS4—26 μh
L14	No. 2 line shunt phase coil	8½ turns	Variable tap coil—type 4164-N5—16 μh
L15) L16)	No. 3 line series phase coil	11⅓ turns	Continuously variable coil—type 4224 MS4—26 μh
L17	No. 3 line shunt phase coil	5¾ turns	Variable tap coil—type 4164-N5—16 μh
L18) L19)	No. 4 line series phase coil	8¼ turns	Continuously variable coil—type 4224 MS4—26 μh
L20	No. 4 line shunt phase coil	6 turns	Variable t p coil—type 4164-N5—16 μh
L21	No. 1 tower series input coil	11 turns	Variable tap coil—type 3164-N5—16 μh
L22	No. 1 tower series output coil (D)	7 turns	Variable tap coil—type 4165-N5—22 μh
L23	No. 1 tower shunt coil	D10 turns ND 3½ turns	Variable tap coil—type 3106-NT12—10 μh
L25	No. 2 tower series input coil	9 turns	Variable tap coil—type 4165-N5—22 μh
L26	No. 2 tower series output coil	4½ turns	Variable tap coil—type 4105-N5—12 μh
L27	No. 2 tower shunt coil	10 turns	Variable tap coil—type 4164-N5—16 μh
L29	No. 3 tower series input coil	1 turn	Variable tap coil—type 4143-N5—8 μh
L30	No. 3 tower series output coil	4 turns	Variable tap coil—type 4165-N5—22 μh
L31	No. 3 tower shunt coil	11 turns	Variable tap coil—type 4164-N5—16 μh
L33	No. 1 tower series output coil (ND)	10¾ turns	Variable tap coil—type 4165-N5—22 μh
L34	No. 4 tower series input coil	11¼ turns	Variable tap coil—type 3164-N5—16 μh
L35	No. 4 tower series output coil	5½ turns	Variable tap coil—type 3165-N5—22 μh
L36	No. 4 tower shunt coil	12 turns	Variable tap coil—type 3164-N5—16 μh
L24	No. 1 TC choke coil		RF choke
L28	No. 2 TC choke coil		RF choke
L32	No. 3 TC choke coil		RF choke
L37	No. 4 TC choke coil		RF choke
L38	No. 1 tower static drain		
L39	No. 2 tower static drain		
L40	No. 3 tower static drain		
L41	No. 4 tower static drain		
	Condensers	*Setting*	
C1	Shunt input capacity		Type 750FBA90—750 μμf
CA	Series input capacity		Type 1000 FBA90—1,000 μμf
C2	No. 1 tank tuning capacity	45	Type 750FVSP250—750 μμf
C3	No. 2 tank tuning capacity	85	Type 750FVSP250—750 μμf
C4	No. 1 line series phase capacity		Type 1500 FBA90—1,500 μμf
C5	No. 2 line shunt phase capacity		Type 1000 FBA90—1,000 μμf
C6	No. 3 line shunt phase capacity		Type 1000 FBA90—1,000 μμf
C7	No. 4 line shunt phase capacity		Type 1000 FBA90—1,000 μμf
C8	No. 1 tower series output capacity		Type 1000 FBA90—1,000 μμf
C9	No. 1 tower shunt capacity		Type 1250FD150—1,200 μμf
C11	No. 2 tower series output capacity		Type 1000 FBA90—1,000 μμf
C12	No. 2 tower shunt capacity		Type 1000 FBA90—1,000 μμf
C14	No. 3 tower shunt output capacity		Type 1000 FBA90—1,000 μμf
C16	No. 4 tower shunt capacity		Type 1000 FBA90—1,000 μμf
C17	No. 3 tower series output capacity		Type 1000 FBA90—1,000 μμf
C19	No. 4 tower series output capacity		Type 1000 FBA90—1,000 μμf
C20	No. 1 tower series output capacity (D)		Type 1000 FBA90—1,000 μμf
C10	No. 1 TC shunt capacity		Type CD 2-MFD
C13	No. 2 TC shunt capacity		Type CD 2-MFD
C15	No. 3 TC shunt capacity		Type CD 2-MFD
C17	No. 4 TC shunt capacity		Type CD 2-MFD
	Relays		
S1	Antenna array transfer relay		RF contactor
S4	No. 1 tower antenna ammeter switch		MBB switch
S5	No. 1 tower antenna transfer relay		RF contactor
S6	No. 2 tower antenna ammeter switch		MBB switch
S7	No. 2 tower antenna transfer relay		RF contactor
S8	No. 3 tower antenna ammeter switch		MBB switch
S9	No. 3 tower antenna transfer relay		RF contactor
S12	No. 4 tower antenna ammeter switch		MBB switch
S13	No. 4 tower antenna transfer relay		RF contactor

Fig. 2. Maintenance book showing complete description of the individual component parts.

Meter Information

Current

Meter	*Range*	*Model*	*No.*	D	ND	*Unit*
M1	0–8	640	2845	4.58	—	Transmitter input to divider network
M2	0–15	640	2843	1.0	9.9	Transmission-line current—tower 1
M3	0–8	640	2835	3.9	—	Transmission-line current—tower 2
M4	0–8	640	2820	3.8	—	Transmission-line current—tower 3
M5	0–8	640	2830	2.5	—	Transmission-line current—tower 4
M6	0–15	640	2810	1.0	9.45	Transmission-line coupling unit—tower 1
M9	0–8	640	2815	2.6	—	Transmission-line coupling unit—tower 2
M12	0–8	640	2816	3.85	—	Transmission-line coupling unit—tower 3
M15	0–5	640	2819	2.5	—	Transmission-line coupling unit—tower 4
M8	0–15	640	2821	3.0	10.39	Antenna current—tower 1
M11	0–8	640	2822	5.4	—	Antenna current—tower 2
M14	0–8	640	2823	5.35	—	Antenna current—tower 3
M17	0–5	640	2924	3.11	—	Antenna current—tower 4
*M7	0–15	425	3130	3.0	10.39	Remote antenna current—tower 1
*M10	0–8	425	3131	5.4	—	Remote antenna current—tower 2
*M13	0–8	425	3133	5.35	—	Remote antenna current—tower 3
*M16	0–8	425	3134	3.11	—	Remote antenna current—tower 4
MP1	0–150%	743	3638	100%	100%	Antenna monitor—tower 1
MP2	0–150%	743	3624	100%		Antenna monitor—tower 2
MP3	0–150%	743	3636	100%		Antenna monitor—tower 3
MP4	0–150%	743	3621	100%		Antenna monitor—tower 4

Note: All meters Weston Electric Company.
* External heater type—see Fig. 4-5 for location in circuits.

Antenna Monitor Readings for Directional Operation

Tower 1 Leads tower 2 by 230°
Tower 1 Leads tower 3 by 84°
Tower 1 Leads tower 4 by 302°

Fig. 3. Maintenance book showing complete information concerning all meters.

Monitor Points and Field-strength Information

Point 4

Azimuth angle	Distance, miles	Mv/m 1 mile Specified	Mv/m 1 mile Obtained	Mv/m Measured
12°	1.89	30	20	3.95

Insert location of measuring point as described in proof of performance

Point 14

Azimuth angle	Distance, miles	Mv/m 1 mile Specified	Mv/m 1 mile Obtained	Mv/m Measured
40°	2.75	90	76	6.5

Insert location of measuring point as described in proof of performance

Point 25

Azimuth angle	Distance, miles	Mv/m mile Specified	Mv/m mile Obtained	Mv/m Measured
63°	1.33	70	25	8.55

Insert location of measuring point as described in proof of performance

Fig. 4 ***(Continued)***

Point 62

Azimuth angle	Distance, miles	Mv/m 1 mile Specified	Mv/m 1 mile Obtained	Mv/m Measured
181°	1.36	72	40	10.75

Insert location of measuring point as described in proof of performance

Point 82

Azimuth angle	Distance, miles	Mv/m 1 mile Specified	Mv/m 1 mile Obtained	Mv/m Measured
219°	2.18	52	40	5.6

Insert location of measuring point as described in proof of performance

Point 104

Azimuth angle	Distance, miles	Mv/m 1 mile Specified	Mv/m 1 mile Obtained	Mv/m Measured
302°	0.86	40	17	7.6

Insert location of measuring point as described in proof of performance

Point 118

Azimuth angle	Distance, miles	Mv/m 1 mile Specified	Mv/m 1 mile Obtained	Mv/m Measured
337°	1.15	61	40	13.4

Insert location of measuring point as described in proof of performance

Fig. 4. Maintenance book showing a listing of the monitoring points as designated by the FCC's license.

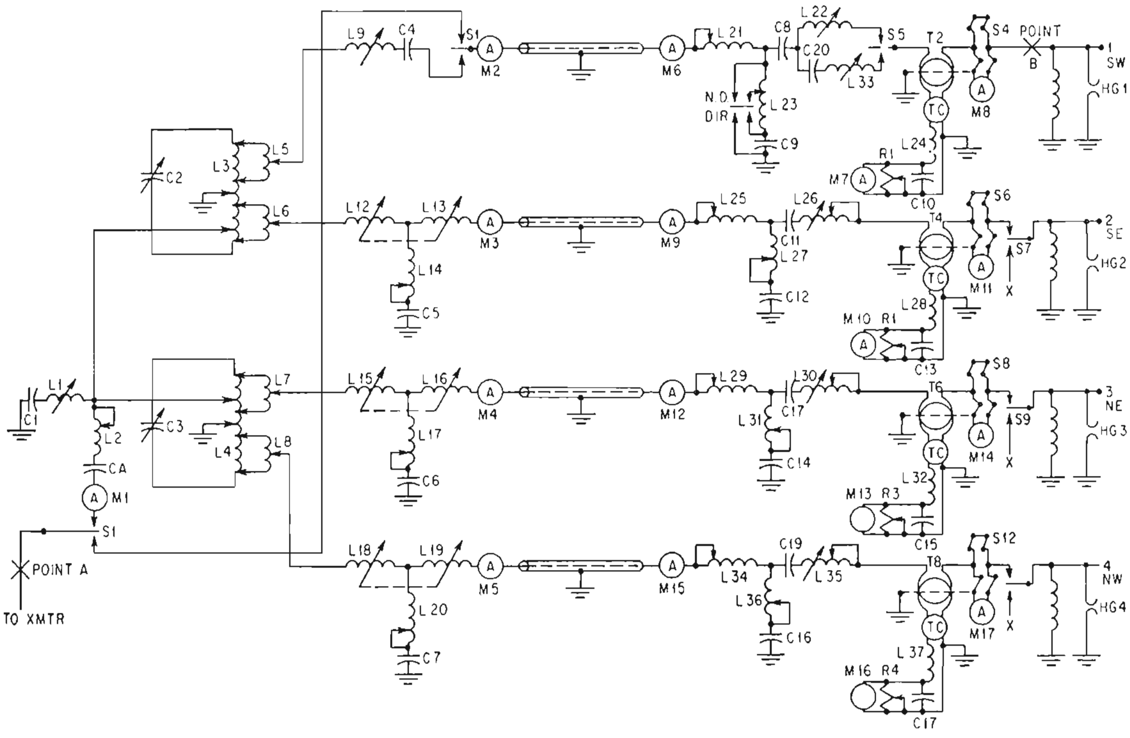

Fig. 5. Schematic diagram showing coupling and phasing networks.

FREQ (kHz)	R (OHMS)	X (OHMS)
1350	47	8.7
1355	58	4
1360	65	0
1365	68.5	-2.5
1370	68	-3
1375	62	-2
1380	51.5	0
1385	48	8.5
1390	54	25.4
1395	64	28
1400	80	23.2
1405	108	14
1410	153	0

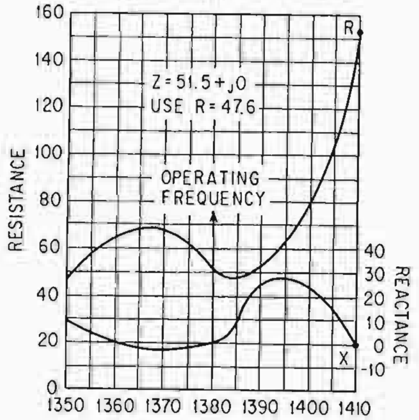

Fig. 6. Dividing network impedance.

FREQ (kHz)	R (OHMS)	X (OHMS)
1350	41.5	36
1355	42	37.5
1360	43	39.2
1365	44	41.3
1370	45	43.5
1375	45.5	44.5
1380	46.5	46.4
1385	47.5	47.5
1390	48.25	47.8
1395	49	50
1400	50	51.1
1405	51	52.7
1410	52.1	54.1

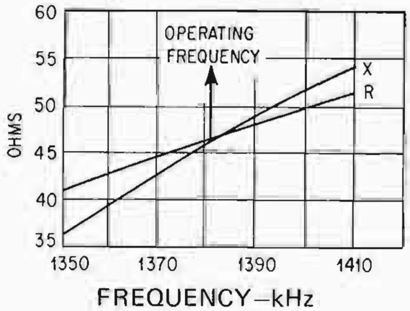

Fig. 7. Nondirectional Tower 1 impedance.

special maintenance routines for checking the array operation at regular specified intervals.

Weekly Log

The third section of the maintenance report book contains the weekly station maintenance log. This portion of the routine is of extreme importance, as it will provide the station supervisor or chief engineer with a method of checking the work done as well as the data necessary to determine the operating conditions of the array and its equipment at all times. The log shown in Fig. 8 as set up for the example station is arranged to cover one week's complete maintenance information divided into daily sections.

Each daily section provides space for recording the temperature, weather, array meter readings, antenna-monitor readings, transmission-line pressures, routine maintenance performed, routine tests results, other pertinent data, and the signature of the duty engineer.

The recorded data obtained from the daily and special maintenance tests after a period of six months can be plotted to show the actual operating conditions of the array. Variations from the normal conditions will undoubtedly appear in the graphs. By a careful analysis of the records, it will be possible to identify any variations due to seasonal or weather conditions. This accumulated information properly evaluated should provide the station engineer with a complete and thorough understanding of his directional-antenna-array operating and maintenance problems.

It is, of course, realized that the suggestions and recommendations described above are not the total and complete answers to all directional antennas. However, it is believed that the need for establishing schedules similar to the suggested program is well demonstrated and can be fitted to the individual station requirements, and the results of this program will be of mutual benefit to both the engineering staff and management.

Usually, the station license requires that field-strength measurements be made periodically at each of the monitoring points. In the event that the license does not require such measurements, it is a good practice to make them at monthly intervals.[1] Such measurements should, of course, be made carefully, and an accurate record maintained, indicating the date and time of each measurement and the field strength observed at each monitoring point. If any unusual conditions are encountered, a record should be made of them. If a monitoring point becomes unusable, an informal application should be made to the FCC to change to a new monitoring point along that radial.

In dealing with tuning equipment for directional antennas, we must deal with the component

[1] This is particularly important if the station contemplates applying to the FCC for remote control authorization.

Month			Sun.		Mon.		Tues.		Wed.		Thur.		Fri.		Sat.		Remarks				Eng.			
Date																								
Weather																								
Temperature																								
M1-Dir.																								
M2-N on-Dir.																								
M7-Dir.																								
M7-Non-Dir.																								
M10																								
M13																								
M16																								
#1-#2 Phase																								
#1-#3 Phase																								
#1-#4 Phase																								
TX Line #1 Press.																								
TX Line #2 Press.																								
TX Line #3 Press.																								
TX Line #4 Press.																								
Phase Monitor																								
Prot. Circuits																								
EMC TX Lines																								
Main Phase Unit																								
Non-Dir. Imp.																								
Dir. Imp.																								
FS Mon. Pt. #4																								
FS Mon. Pt. #14																								
FS Mon. Pt. #25																								
FS Mon. Pt. #62																								
FS Mon. Pt. #82																								
FS Mon. Pt. #104																								
FS Mon. Pt. #118																								
Overall Dir. Test																								
#1 Coupling Unit																								
#2 Coupling Unit																								
#3 Coupling Unit																								
#4 Coupling Unit																								

Fig. 8. Weekly maintenance report.

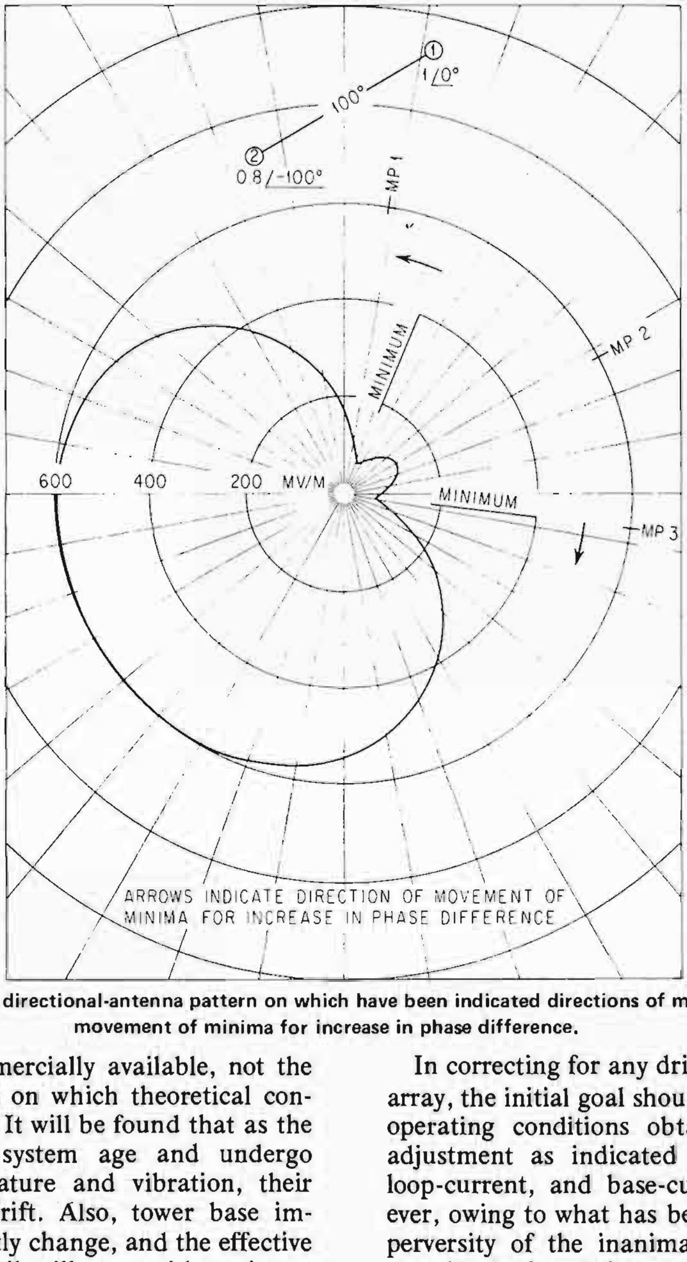

Fig. 9. Two-element directional-antenna pattern on which have been indicated directions of minima and directions of movement of minima for increase in phase difference.

parts which are commercially available, not the idealized components on which theoretical considerations are based. It will be found that as the components of the system age and undergo variations in temperature and vibration, their values will usually drift. Also, tower base impedances will frequently change, and the effective conductivity of the soil will vary with moisture content and temperature. In time, these changes may result in change of the operating parameters of the array to the extent that the field strengths at the monitoring points are no longer within the allowable values and it becomes necessary to readjust the array.

READJUSTMENT OF ARRAY

Any readjustment should be attempted only by personnel familiar with directional antenna theory. Since any adjustments of the tuning elements probably will alter the common-point impedance, it follows that the person making the adjustments must have either an operating impedance or common-point bridge or a usual RF bridge and associated equipment and must be familiar with their operation.

In correcting for any drift in adjustment of the array, the initial goal should be to reestablish the operating conditions obtained in the original adjustment as indicated by antenna monitor, loop-current, and base-current readings. However, owing to what has been politely termed the perversity of the inanimate objects, it will on occasion be found that reestablishing the original current ratios and phase indications does not result in producing the desired field strengths at the monitoring points. Assuming that the monitoring system is in good working order and that no reradiation is occurring from nearby metallic objects, it then becomes necessary to readjust the array.

Readjustment Aids

In undertaking readjustment of the array, certain aids may be found useful in guiding the adjustments to be made. For a two-element directional-antenna system, it is helpful to have a copy of the theoretical pattern on which the directions of the minima are indicated, as well as the direction of each monitoring point. Fig. 9

illustrates such a pattern. It is also helpful to indicate on this pattern the direction in which the minima will move for an increase in phase difference between the towers. It will be recognized, of course, that the depth of the minima will depend upon the current ratio. Theoretically the minima will become complete nulls if the fields radiated by the two towers are equal. This overlooks the effects of reradiation from nearby objects, but this concept does provide a point of departure for adjustment of the array.

A similar device may be found useful in readjusting an array with four towers arranged in the shape of a parallelogram. In this case, it is desirable to portray the basic patterns which go to make up the final pattern, preferably in contrasting colors. Fig. 10 shows a pattern produced by such a four-tower array. In Fig. 11, one of the basic patterns is shown as a solid line and the other as a dashed line. Here, too, arrows have been placed on the basic patterns to indicate the direction of movement of each minimum for an increase in phase difference between the sets of towers making up each basic pattern. The direction to each monitoring point is also given. Since the final pattern is the result of multiplying together the values of the basic patterns in any given direction, the effect of a change of parameters of a basic pattern on the final pattern can be readily visualized.

Vector Calculator

Of possible use for a two-tower system is a calculator in the form of a circular slide rule, based on an article appearing in the December 1944, issue of *Proceedings of the IRE.* Fig. 12 illustrates such a calculator, which was quickly constructed from two sheets of graph paper and a piece of cardboard. In the operation of this calculator, the towers are numbered 1 and 2, and the phase of Tower 2, read on the scale on the periphery of the rotary element, is set to the vertical zero degree line. The outer fixed-scalė on the base represents the bearing from the line of towers, measured from the Tower 2 end. A

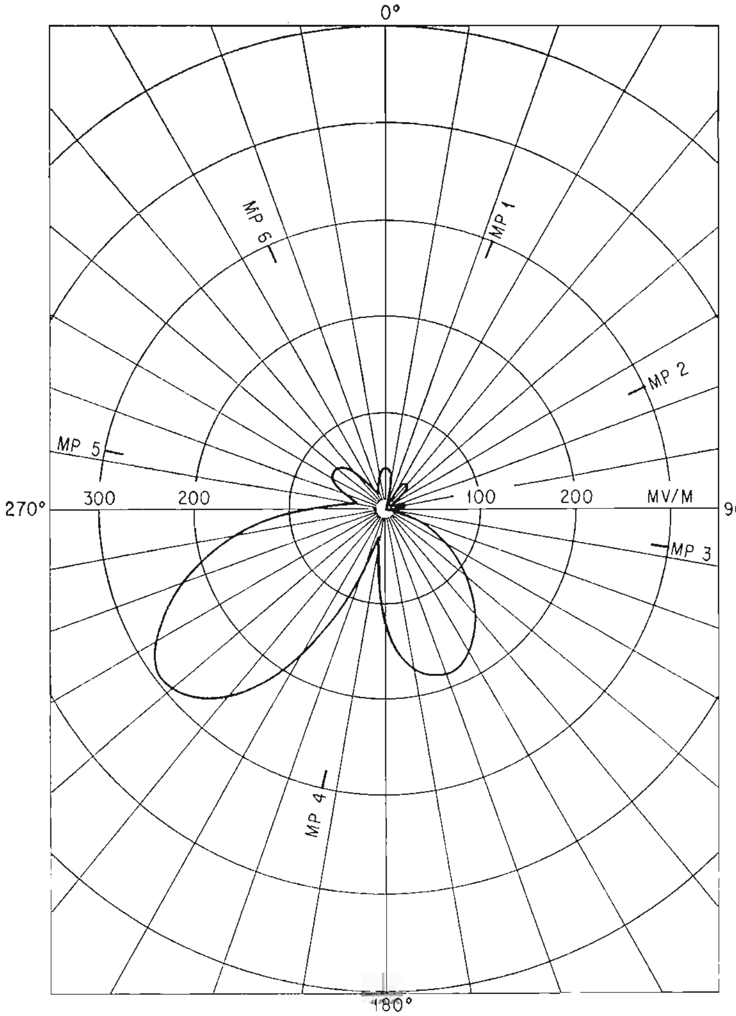

Fig. 10. Pattern produced by a directional antenna consisting of four elements arranged in a parallelogram.

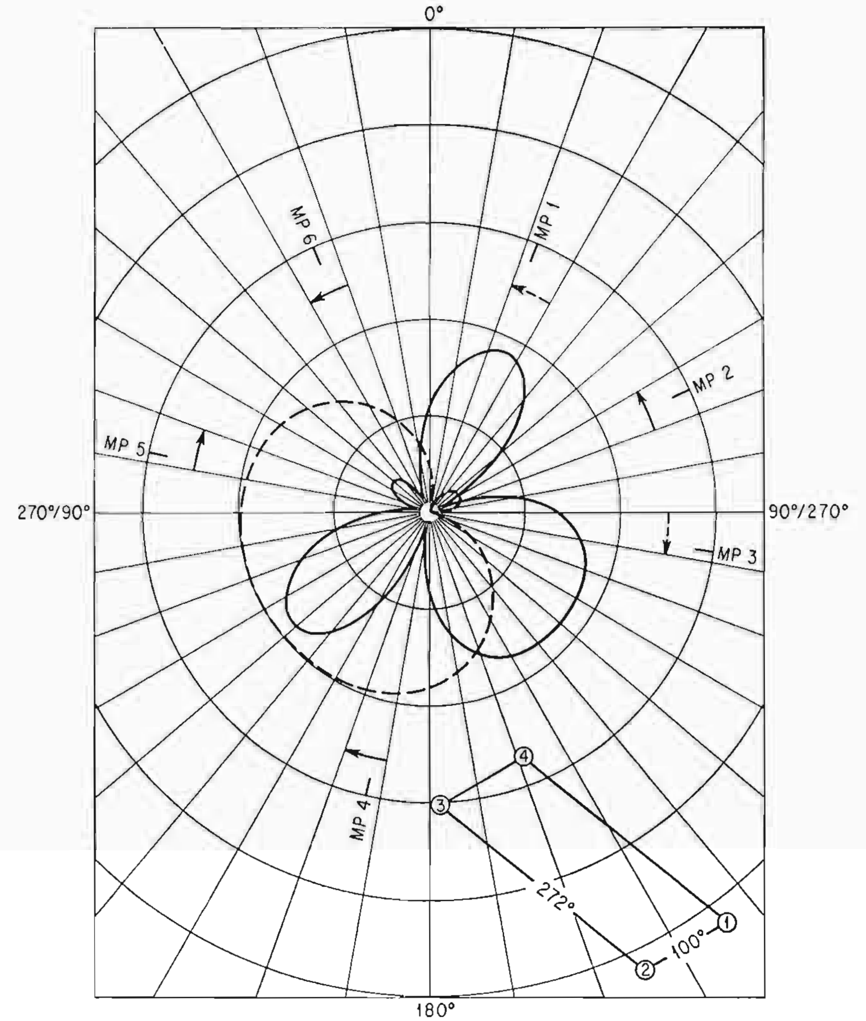

Fig. 11. Basic vector patterns which make up the pattern of Fig. 10. Arrows indicate the directions of movement of minima for increase in phase difference between pairs of elements.

separate outer scale is needed for each tower spacing. The group of figures on the runner represents field ratios. The resultant vector field is read from the inner scale opposite the figure for the field ratio. It can be seen that the effect of a change in phase or field ratio on the field radiated in any given direction can be quickly determined.

A modified form of the calculator can be used with a three-element in-line array. The vector representation of the resultant field of such an array in a given direction is as shown in Fig. 13, where vector 2 represents the field from the center tower and vectors 1 and 3 represent the fields from the end towers. Considering the position of vector 2 as fixed, vectors 1 and 3 revolve in opposite directions as one's vantage point is moved around the array.

When redrawn, the vector relationship is as shown in the lower half of Fig. 13. Here R is the resultant vector, drawn from the origin of vector 1 to the terminal point of vector 3. If we construct a mechanical device having scales depicting the position of vectors 1 and 3 for various bearings from the line of towers, we can then determine the effect of changes in operating parameters on the resultant field in any desired direction.

Such a device is illustrated in Fig. 14. Here the distance between pivot points for the rotary elements has been scaled to represent the magnitude of vector 2. The radius of each of the rotary elements has been chosen to represent the magnitude of vectors 1 and 3. If desired, a scale could be marked on each of the rotary elements along the line from the center to the 0° mark on the periphery.

When this device is used, a pencil mark or a small tab of drafting tape is placed on the periphery of each rotary element at a point corresponding to the phase of the tower there represented.

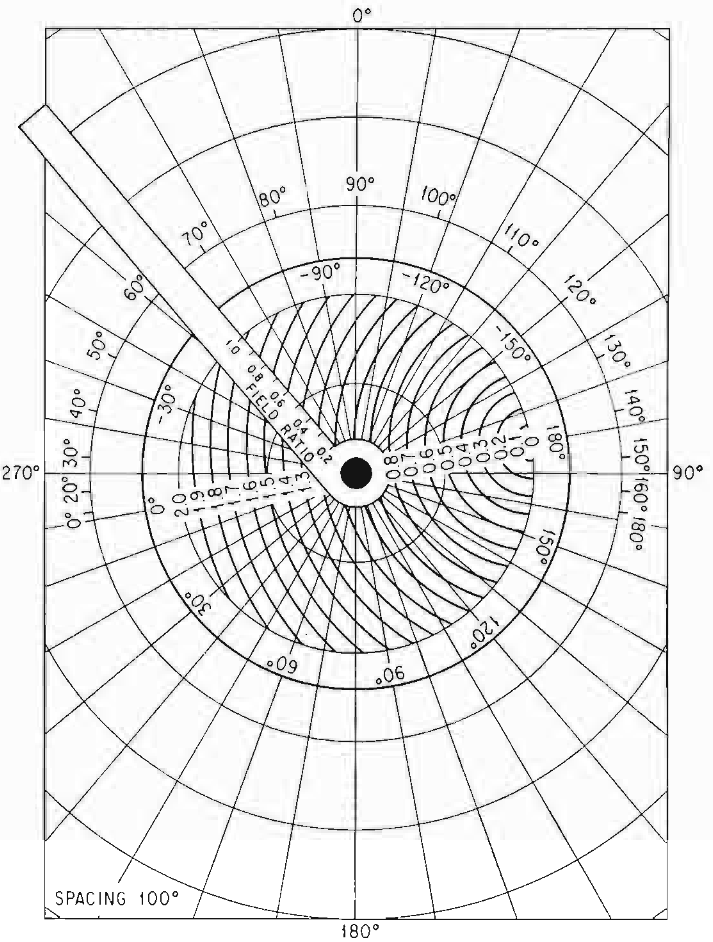

Fig. 12. Calculators for two-element directional antenna having spacing of 100° between elements.

To determine the relative field radiated in a given direction, the rotary elements are rotated so that the tab or mark lies at the desired bearing shown on each fixed scale. The distance between the 0° marks on the periphery of the rotary elements then corresponds to the resultant vector field. The effect of a change in phase of any of the towers or a change in field ratios can be readily visualized.

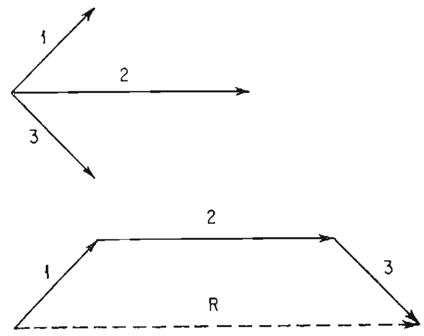

Fig. 13. Typical relationship of field vectors for three-element directional-antenna systems.

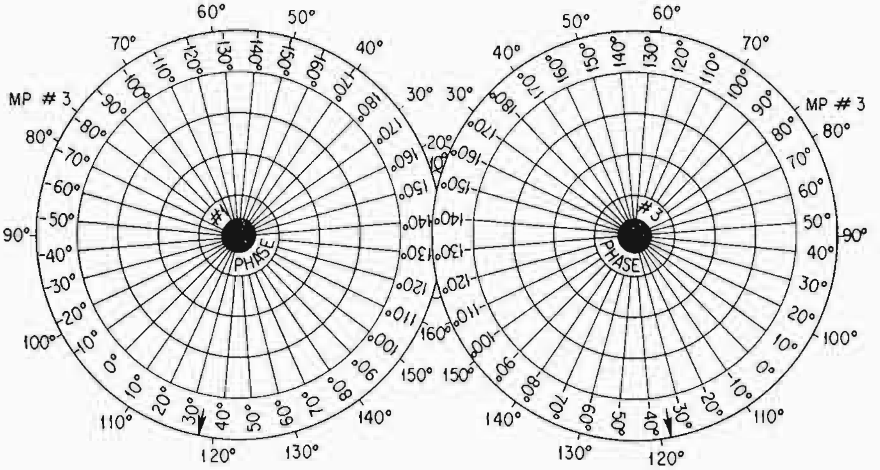

Fig. 14. Calculator for three-element in-line directional antenna.

Unfortunately, these relatively simple procedures cannot be so easily applied to arrays with more elements; however, if the basic patterns that go to make up the over-all pattern are known, these procedures can be applied to the basic patterns.

TABLE 1

Maintenance Schedules

Sunday

1. Transfer all towers and antenna phasing units to emergency transmission lines and operate at full power for 5 min.
2. Restore all equipment to regular transmission lines. Check operation under full power.
3. Clean and check all connections, remote meter, antenna monitor, and meter panels.
4. Check all antenna monitor tubes with tube checker. Check all transmission-line protective circuits.
5. Check and record all transmission-line gas pressures.

Monday

1. Check all condensers and other equipment in antenna phasing unit immediately after sign-off for overheating.
2. Clean and check all transmission-line end seals.
3. Clean interior of all sections of antenna phasing units.
4. Clean contacts and check alignment of antenna transfer relay.
5. Check and tighten all connections in antenna phasing unit.
6. Check gas-filled condensed pressures.

Tuesday

1. With array set for directional operation check drive-point impedance at X with radio-frequency bridge at operating frequency (first and third Tuesdays).
2. With array set for nondirectional operation check drive-point impedance at X with radio-frequency bridge at operating frequency (first and third Tuesdays).
3. Set up array for normal full-power directional operation. Compare readings of all antenna and remote antenna meters. Make any necessary adjustments.
4. Make complete set of field-strength readings at indicated monitor points (second and fourth Tuesdays).
5. Check and record all transmission-line gas pressures.

Wednesday

Antenna coupling unit 1:

1. Check all condensers and equipment in coupling house for overheating immediately after sign-off.
2. Check spacing and clean antenna and transmission-line horn gaps.
3. Check and clean all antenna lead-in insulators.
4. Check and clean all transmission-line end seals.
5. Clean contacts and check alignment of antenna relay.
6. Clean contacts and check alignment of antenna ammeter switch.
7. Check and tighten all connections of inductance coils and condensers.
8. Clean all meters.

Transmitter building:
Read and record all transmission-line gas pressures.

Thursday

Antenna coupling unit 2:

1. Check all condensers and equipment in coupling house for overheating immediately after sign-off.
2. Check spacing and clean antenna and transmission-line horn gaps.
3. Check and clean all antenna lead-in insulators.
4. Check and clean all transmission-line end seals.
5. Clean contacts and check alignment of antenna relay.
6. Clean contacts and check alignment of antenna ammeter switch.
7. Check and tighten all connections of inductance coils and condensers.
8. Clean all meters.

Transmitter building:
Read and record all transmission-line gas pressures.

TABLE 1

Maintenance Schedules *(Continued)*

Friday
Antenna coupling unit 3: 1. Check all condensers and equipment in coupling house for overheating immediately after sign-off. 2. Check spacing and clean antenna and transmission-line horn gaps. 3. Check and clean all antenna lead-in insulators. 4. Check and clean all transmission-line end seals. 5. Clean contacts and check alignment of antenna relay. 6. Clean contacts and check alignment of antenna ammeter switch. 7. Check and tighten all connections of inductance coils and condensers. 8. Clean all meters. Transmitter building: Read and record all transmission-line gas pressures.

Saturday
Antenna coupling unit 4: 1. Check all condensers and equipment in coupling house for overheating immediately after sign-off. 2. Check spacing and clean antenna and transmission-line horn gaps. 3. Check and clean all antenna lead-in insulators. 4. Check and clean all transmission-line end seals. 5. Clean contacts and check alignment of antenna relay. 6. Clean contacts and check alignment of antenna ammeter switch. 7. Check and tighten all connections of inductance coils and condensers. 8. Clean all meters. Transmitter building: Read and record all transmission-line gas pressures.