REMOTE PICKUP BROADCAST COVERAGE TESTS ON 152.93 Mc

CONDUCTED BY THE GENERAL ENGINEERING DEPARTMENT
OF THE
AMERICAN BROADCASTING COMPANY

FOREWORD

From the following data it will be evident that FM mobile relay broadcasting in the 152-162 megacycle band will be of considerable value to the broadcaster who may encounter extreme and adverse conditions with respect to terrain in the operation of a remote pickup broadcast service. It will be logical to conclude that where terrain conditions are more favorable, results exceeding those mentioned in this report may be expected.

PRESENT FREQUENCY ALLOCATIONS

Remote pickup broadcasting units have demonstrated their value to the broadcasting industry by providing the means whereby special events of general public interest are made available for broadcasting despite the lack of wire lines between the station and the spot where the event is taking place.

The assigned frequencies in the groups around 2000 kc have generally been used for all spot pick-ups close to or beyond the limits of line of sight transmission. Those frequencies in the 30 to 40 megacycle region have usually been employed where the pick-up point is within the line of sight distance. The use of the higher frequencies, where possible, is preferred to the 2000 kc channels because of the smaller units and simpler antennas available for these frequencies.

RECENT ALLOCATIONS[1]

Allocation proceedings held by the FCC in 1948-49 provided in addition to the 2000 kc blocks of frequencies 50 other channels for remote pickup broadcast services, namely: 19 exclusive 20 kc channels from 26.11 megacycles to 26.47 megacycles; 9 shared and 2 restricted 60 kc channels in the 152-162 megacycle band; and 20 exclusive 100 kc channels between 450.05 megacycles and 451.95 megacycles. Rules relating to these assignments appear in Part 4 of FCC's Rules and Regulations.

PURPOSE OF THE TEST

The accelerated wartime development of transmitters and receivers for use on frequencies between 100 and 200 megacycles resulted in production of equipment suitable for broadcast use on channels in the 152 to 162 megacycle band. The Facilities Section of the General Engineering Department of ABC, therefore, undertook to investigate the usefulness of the 152 to 162 megacycle band for mobile relay broadcasting by determining the maximum useful range of transmissions from a mobile unit to a receiving point 900 feet above sea level in midtown Manhattan. The following tests were made during the fall of 1946, the results of which showed that this band would provide excellent coverage within line of sight distance.

Comparison can also be made with the probable results to be expected on the 26 megacycle channels as these assignments will follow very closely the previous experience on the 30 to 40 megacycle channels, which have been deleted from remote pickup use.

EQUIPMENT

Transmitter

A transmitter powered from the six-volt car battery was used in the mobile unit. It is designed for communication type of service, and has the following specifications:

Assigned Frequency	152.93 mc
Output Power	15 watts
Frequency Stability	± .005%
Method of Modulation ...	Phase
Frequency Deviation for 100% Modulation	± 20 kc
Audio Response	± 1 db from 500-3000 cps
Duty	Intermittent

Receiver

A receiver powered from 115 volt 60 cps was used. It was installed on the roof at 30 Rockefeller Plaza, New York City. This unit is designed for communication type of service, and has the following specifications:

Sensitivity	1 UV for 20 db noise suppression
Selectivity	6 db down at ± 20 kc 85 db down at ± 120 kc
Audio Response	± 2.5 db from 350-5000 cps
Duty	Continuous

Signal strength readings were made at the receiver by measuring the current in the first

[1]Altered by NAB to conform with FCC actions.

TABLE I

SIGNAL STRENGTH AT RECEIVER INPUT IN MICROVOLTS					
TRANSMITTING ANTENNA		RECEIVING ANTENNA 5 ELEMENT YAGI			
		POLARIZATION			
TYPE	POLARIZATION	VERTICAL		HORIZONTAL	
		uV	Db	uV	Db
QUARTER WAVE WHIP	VERTICAL	10.8	0	6	−5.1
HALF WAVE DIPOLE	VERTICAL	14	+2.28	2.9	−11.41
	HORIZONTAL	6	−5.1	20	+5.39
HALF WAVE FOLDED DIPOLE	VERTICAL	16.5	+3.69	14	+2.28
	HORIZONTAL	9.5	−1.14	26	+7.6

limiter grid circuit. The use of this method of measurement results in a scale of values which gives a good spread from no signal level to limiter saturation level. The receiver sensitivity was calibrated by feeding measured signal in microvolts, as obtained from a signal generator, to the antenna terminals of the receiver. The current in the first limiter grid was measured as this input signal was varied from 0.2 to 60 microvolts. The curve of Figure 1 was plotted from the above test. With this curve it is a simple matter to convert all of the readings taken in this test to microvolts of signal at the input of the receiver.

Antennas

A. Transmitting--The transmitting antenna is a one-quarter wave flexible whip mounted above the top of the car. The metal roof acted as the ground screen below the antenna. Ten feet of Type RG-58/U coaxial transmission line having a nominal characteristic impedance of 53.5 ohms was used to connect the transmitter to the antenna.

B. Receiving--A five element Yagi type antenna was used for reception. It consists of a half-wave radiator and four parasitically excited elements - one reflector and three directors. A 300 ohm "ribbon" type transmission line was used, delta matched to the antenna. This line was connected to the 50 ohm input of the receiver through a one-quarter wave matching section near the receiver. The antenna was installed in the clear, approximately 900 feet above sea level, at 30 Rockefeller Plaza, New York City. Since this antenna is directional, it was arranged so that it could be rotated. Vertical polarization was used at all times except during the cross-polarization test described later.

The antenna was directed towards the mobile transmitter during all of these tests although no attempt was made to rotate it for best results on each transmission. This practice was followed as published data on multi-element antenna arrays indicated that signals at the receiver should be essentially constant as long as the mobile unit was within ± 15 degrees of the heading of the array.

C. Receiving Antenna Pattern--In order to check the actual variation in received signal for the 15 degree maximum error of antenna heading held throughout the field tests, the pattern of the receiving antenna was determined. This was done by using it at the mobile unit for the transmitting antenna. During this test the mobile unit was located in a flat open field to reduce to a practical minimum any reflections of

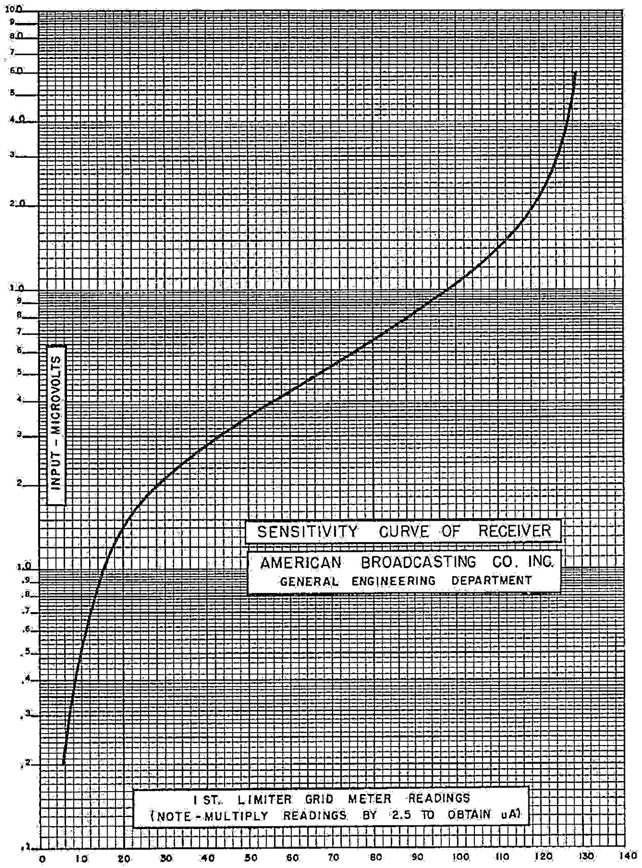

Figure 1

the signal. The receiver was located about one-half mile away with a clear line of sight path from it to the transmitter. A 4" length of wire was used for the receiving antenna in order that the received signal remain below the saturation level of the limiter at all times.

Using both horizontal and vertical polarization, the directional antenna was rotated in 10° steps and readings taken of the receiver meter for each of these points. The results converted to microvolts input to the receiver were plotted as shown in Figures 2 and 3.

From these curves we find that an antenna heading 15° off the actual transmitter location resulted in a decrease of signal strength at the receiver of approximately 10%. For purposes of these tests, this 10% variation was ignored in computing the signal levels at the receiver for the various locations of the mobile transmitter.

RESULTS

Transmission From Car to Roof

Routes for the mobile transmitter were selected to give check points out to the limits of coverage in all directions from the receiving point. Transmissions were made from the mobile unit to the fixed receiver from hundreds of points along these routes ranging from the immediate vicinity around the receiving point out as far as 42 miles from the receiver. In each case, a signal strength reading was recorded at the receiver to be used in the final tabulation of results. Unfortunately, the requirement that the transmitter be operated on an intermittent duty cycle prevented the making of continuous recordings, but enough spot readings were obtained to give a close approximation of such a recording.

The results obtained were plotted on a map of the New York metropolitan area, (Figure 4) making the following information readily available:

1. Location of Transmission Point.
2. Distance from Transmission Point to Receiver Location.

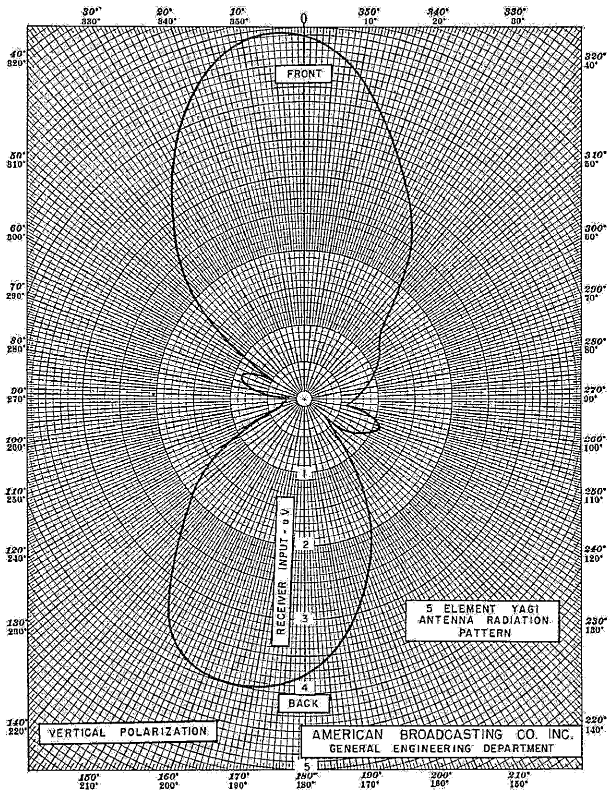

Figure 2

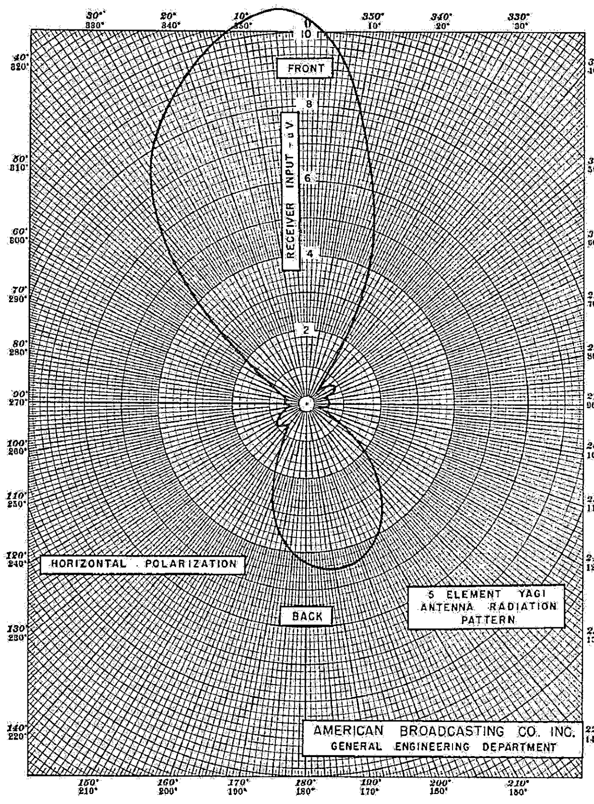

Figure 3

3. Signal strength in microvolts input to the receiver from each transmission point.
4. Relative usability of received signal.

The received signals obtained from various points throughout the borough of Manhattan were of great interest in view of the difficulty experienced with numerous dead-spots when operating on the 30 to 40 megacycle channel. A very thorough coverage was, therefore, made of this area and included many transmissions from both avenues and cross streets from the Battery to the Henry Hudson Bridge. It was found that good signals were obtained from every point tried in this entire area with the exception of a short section of Front Street in the vicinity of Whitehall Street at the Battery. Here the signal level dropped to a non-usable value, but moving the car a short distance brought the signal level back to a usable value. The Wall Street region has in the past been particularly "dead" for 30-40 mc transmission. Accordingly, a large number of tests were made from this district. These were made on Wall, Pine, Cedar and other streets close by, along their entire traverse from the Hudson to the East Rivers. Again good usable signal levels were obtained with some instances of very quick signal dips. These, however, were of such short durations that it was found impossible to stop the car at any point which would produce a non-usable signal. Spot checks were made from many points in upper Manhattan all of which gave good usable signals. It can, therefore, be assumed that, with the exception previously noted, complete coverage of the borough of Manhattan can be counted on.

It will be noted that practically all of the transmission points in Manhattan fall within a five mile circle. Following the completion of runs in other directions, a general pattern of results based on distance became apparent. For example, inside a five mile circle, all transmissions except those previously noted and those from a small area near North Bergen, New Jersey, were received with good signal strength. The few points of non-usable signal within the ten mile circle were caused by shielding from large buildings or hills close to the transmitter and directly in the transmission path. Beyond the ten mile circle, results became somewhat erratic and were completely dependent on the terrain. Figure 4 shows the results obtained on all transmissions from the mobile unit to the fixed receiver.

Comparison of Antennas and Polarization

A. Changes in Transmitting Antennas--All of the tests described so far were made using a quarter wave whip antenna above the car and a five element Yagi antenna on the building roof. Both of these antennas were vertically polarized. In order to determine the effects of some changes in antenna types and polarization, the following tests were made: The mobile unit was parked on top of Bear Mountain. This point is 42 miles from our receiving point and there is a clear line of sight path between them. The receiving antenna was set for vertical polarization and carefully lined up for maximum signal from the transmitter. Transmissions were then made from the mobile unit using:

(a) Quarter wave vertical whip.
(b) Half wave dipole.
(c) Half wave folded dipole.

The latter two were operated both vertically and horizontally polarized at a height of nine feet above ground. Signal strength readings at the receiver were made for each of these transmissions. The receiving antenna was then changed to horizontal polarization and the same series of tests repeated. Table 1 shows the signal strength expressed in microvolts at the receiver input for each of these combinations. This table also shows the signal change in decibels for these antenna tests using the combination of

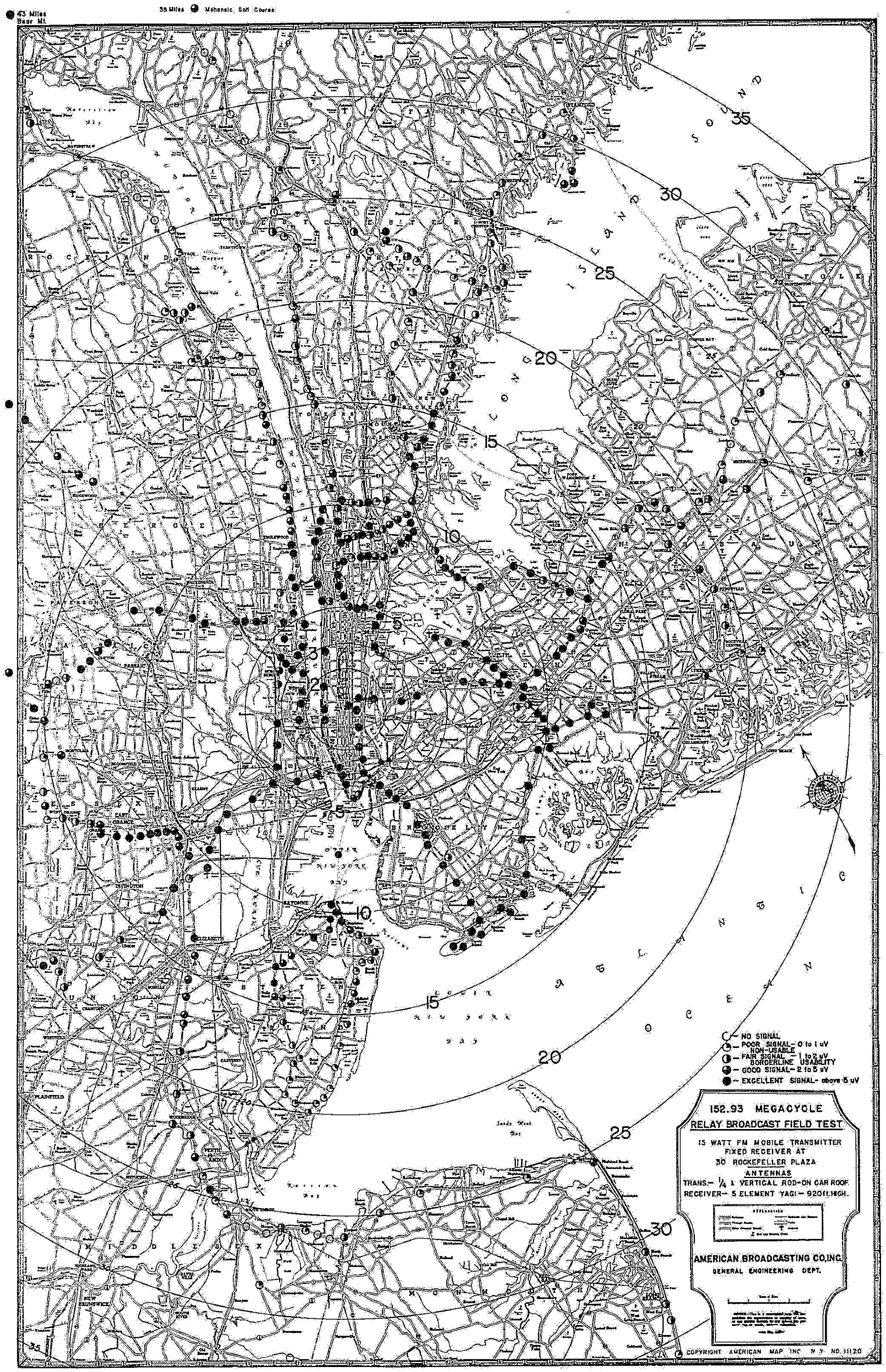
43 Miles
Bear Mt.
38 Miles Mohansic Golf Course
NO SIGNAL
POOR SIGNAL – 0 to 1 uV NON-USABLE
FAIR SIGNAL – 1 to 2 uV BORDERLINE USABILITY
GOOD SIGNAL – 2 to 5 uV
EXCELLENT SIGNAL – above 5 uV
152.93 MEGACYCLE
RELAY BROADCAST FIELD TEST
15 WATT FM MOBILE TRANSMITTER
FIXED RECEIVER AT
30 ROCKEFELLER PLAZA
ANTENNAS
TRANS. – 1/4 λ VERTICAL ROD-ON CAR ROOF
RECEIVER – 5 ELEMENT YAGI – 920 ft. HIGH.
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Figure 4

the vertical quarter wave whip antenna at the mobile transmitter and the vertically polarized Yagi antenna at the receiver as the zero db reference level.

An additional mobile antenna test was made from Staten Island. At a point on Hylan Boulevard twenty-one miles from the receiving point the received signal in New York was too far down in the noise to be useful. Two parasitic elements, a director and a reflector, were mounted around the quarter wave vertical whip on the car top. Spacing between elements was one quarter of a wavelength. An increase of 3.06 db was recorded at the receiver as a result of this change.

B. Change In Receiving Antenna--The five element Yagi antenna was used for reception in all of the tests so far. To check the gain of this antenna against a standard half wave dipole, a series of transmissions were made from the mobile unit to the fixed receiver over a route extending from the Queensboro Bridge to the vicinity of Hicksville, Long Island, and return. The Yagi antenna was used at the receiving point for the run out and the half wave dipole for the return trip. While it is true that a single comparison would give a gain figure, it is of interest to check the actual results over varying terrain conditions and distance between the transmitter and receiver.

Signal strength recordings were therefore made at the receiver for a representative group of transmitter locations using the same points on each run so that the difference in results could be attributed to the change in receiving antennas. The following readings were taken:

TABLE II

DISTANCE (MILES) FROM RECEIVER	uV INPUT TO RECEIVER HALF WAVE DIPOLE	YAGI
13	3.6	7.5
13.5	10	6
16	1	2.1
19	1	2.5
21	1.8	3.6
22	.7	1.8

From this table we can calculate that the average gain for the Yagi antenna over the standard half wave dipole is approximately 6 db. In one case the half wave dipole showed a higher signal level than the Yagi antenna, which can probably be attributed to effects of signal reflection due to the terrain.

SUMMARY AND CONCLUSIONS

The principle purpose in making the survey described above was to establish the utility of the 152 to 162 mc band for short-range relay broadcasting. In addition, it was important to learn the maximum usable range of the specific equipment on hand. The test shows that with a 15 watt FM transmitter feeding a quarter wave vertical whip mounted 6 feet above ground atop the mobile unit, and with a directional receiving antenna having gain of at least 6 db mounted 900 feet above sea level in Manhattan, the following coverage around the receiving point can be expected:

1. Complete coverage within a radius of 5 miles.
2. 95% coverage within a radius of 10 miles.
3. 85% coverage within a radius of 15 miles.
4. Some coverage within a radius of 30 miles, depending on the location of the mobile unit with respect to surrounding terrain.

Previous experience with mobile operations using 30 to 40 mc AM equipment has shown that coverage was very unreliable within the New York metropolitan area. Dead spots were numerous and any attempt to follow a parade resulted in noisy reception at the pick-up point from many spots throughout the parade route. Similar results would be expected in the proposed 25 to 28 mc band.

The General Engineering Department, therefore, recommends the use of 152 to 162 mc FM equipment for mobile relay broadcasting. The mobile units should be equipped with a transmitter having a power output of from 15 to 30 watts, and facilities should be provided to use antennas with higher gain than the conventional quarter wave vertical whip. A directive array with a gain of at least 6 db should be used at the receiving point.

A PRACTICAL 26 MC REMOTE PICKUP BROADCAST SYSTEM

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This article describes in detail the conversion of war surplus transmitting and receiving equipment for remote pick-up short wave broadcast relay use.

PART I

The FCC has recently assigned exclusively to the remote pickup broadcast service the following 19 channels between 26.11 mc and 26.47 mc.

26.11 mc	26.19 mc	26.27 mc	26.35 mc	26.43 mc
26.13 mc	26.21 mc	26.29 mc	26.37 mc	26.45 mc
26.15 mc	26.23 mc	26.31 mc	26.39 mc	26.47 mc
26.17 mc	26.25 mc	26.33 mc	26.41 mc	

Under Part 4, Subpart D,[1] of the FCC rules and Regulations the above and other frequencies are authorized for remote pickup broadcast stations. The use of these frequencies is permissible regardless as to the availability of telephone lines. A license will be issued by FCC to an established broadcasting station and renewals may be made concurrently with the application for renewal of the regular station license. Application for construction permit is made using FCC Form 313 which is a short form and requires only a minimum of information similar to the following:

1. Type of station (remote pickup).
   Station with which proposed station is to be used (your call letters).

2. Frequency (one of those listed above)
   Power (40 watts)
   Type of emission (FM).
   Communication bandwidth, kc. 2(8.5 + .005% of carrier frequency in kc)
   Example: 2(8.5 + .00005 x 26,410)
   = 2(8.5 + 1.3205)
   = 2(9.8205)
   = 19.641 kc

3. Location of transmitter (vicinity of city in which standard station is located)

4. Antenna system (vehicle mounted whip 114 inches high)

7. Transmitter manufacturer (various)
   Type No. (BC -604 modified)
   Maximum rated power output (40 watts)
   Oscillator, type of circuit (crystal)
   Oscillator frequency (carrier frequency divided by 54)
   Oscillator tube type (6V6 GT), make (various), number (one)
   Last radio stage:
   Tubes, make (various), type (807), number (one)
   Normal plate current (120 ma), plate voltage (500), modulation (not modulated)

8. Percentage of modulation or swing (8.5 kc)
   Frequency tolerance per cent (.005%)
   Means for maintaining frequency tolerance (temperature controlled CT cut crystal)
   External means employed to insure maintenance of assigned frequency within tolerance specified by FCC rules (BC-221 frequency meter or crystal controlled multivibrator, checked against WWV)

Rule 4.481 requires that a simple log be kept of each transmission. An operator holding a commercial license or permit is necessary at the remote pickup transmitter.

The equipment described has been in use for about two years, and a hundred or more transmissions have been successfully relayed over KFBC. About a score of other stations located in nine states have used identical equipment, also successfully, for several months. The range of reasonably quiet transmission is determined largely by the height and efficiency of the receiving antenna. Several stations report ranges of from ten to twenty-five miles. A good average figure is about four or five miles. In large metropolitan cities when working from locations surrounded by extremely tall steel buildings, particularly when the receiver is at some distance from the transmitter, deep fading effects may be experienced and it is likely that in these locations somewhat better results might be experienced with equipment operating on the 152-162 mc band. Little difficulty has been experienced in towns of less than 100,000 population from these effects.

Noise, measured through both transmitter and receiver, exclusive of atmospheric interference, will be better than 50 db below maximum modulation. Distortion will be less than 3% at maximum modulation, overall. Frequency modulation is used, and though the frequency response, may not be termed High Fidelity it will be better than that designated for Class C lines.

This article, the drawings and the circuits refer to the materials listed in Part 2. In

[1] See Section 1, Article 7, for FCC Rules and Regulations.

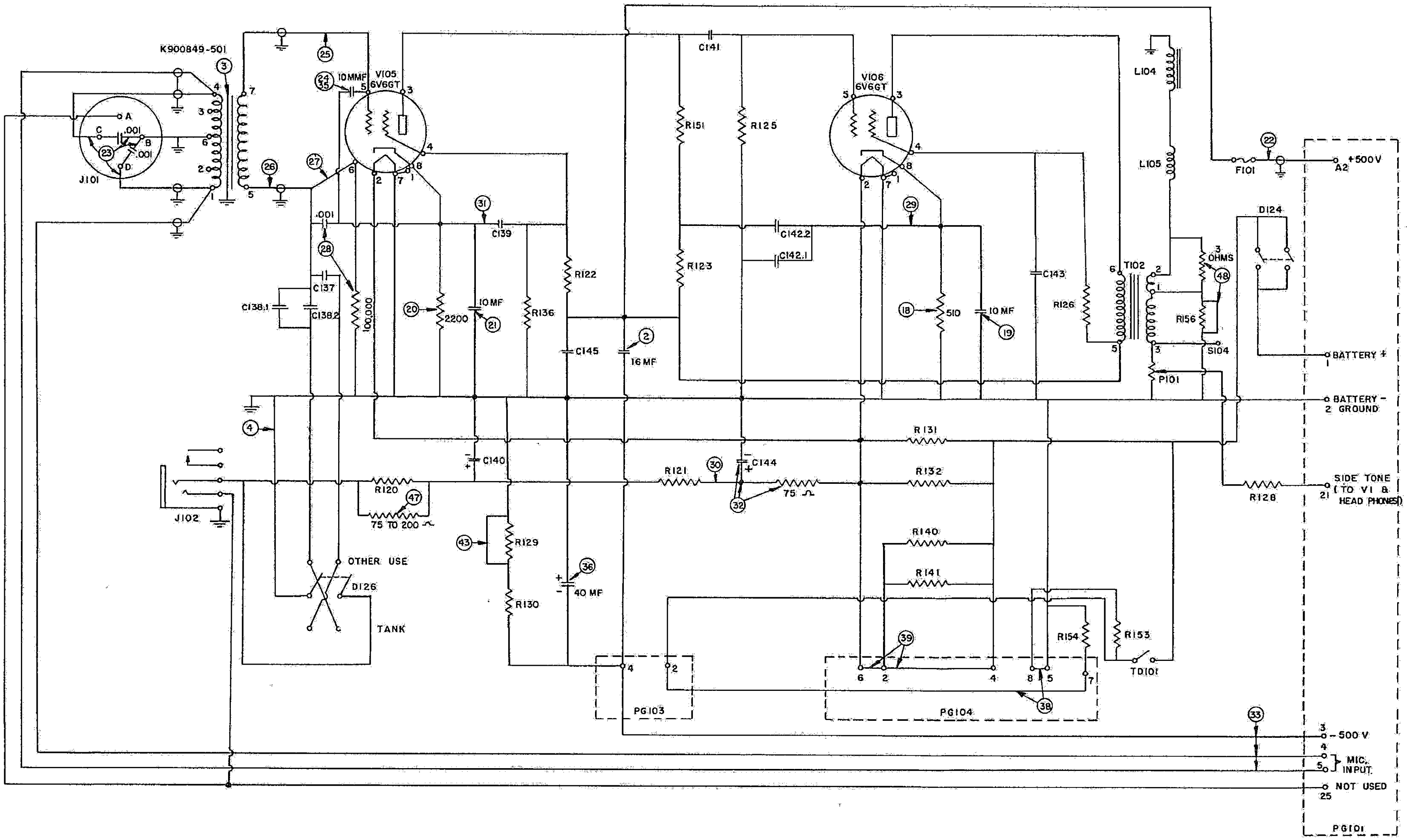


Fig. 1.--BC 604 Transmitter, audio circuits, converted. 31 indicates reference to paragraph 31, Part 6.

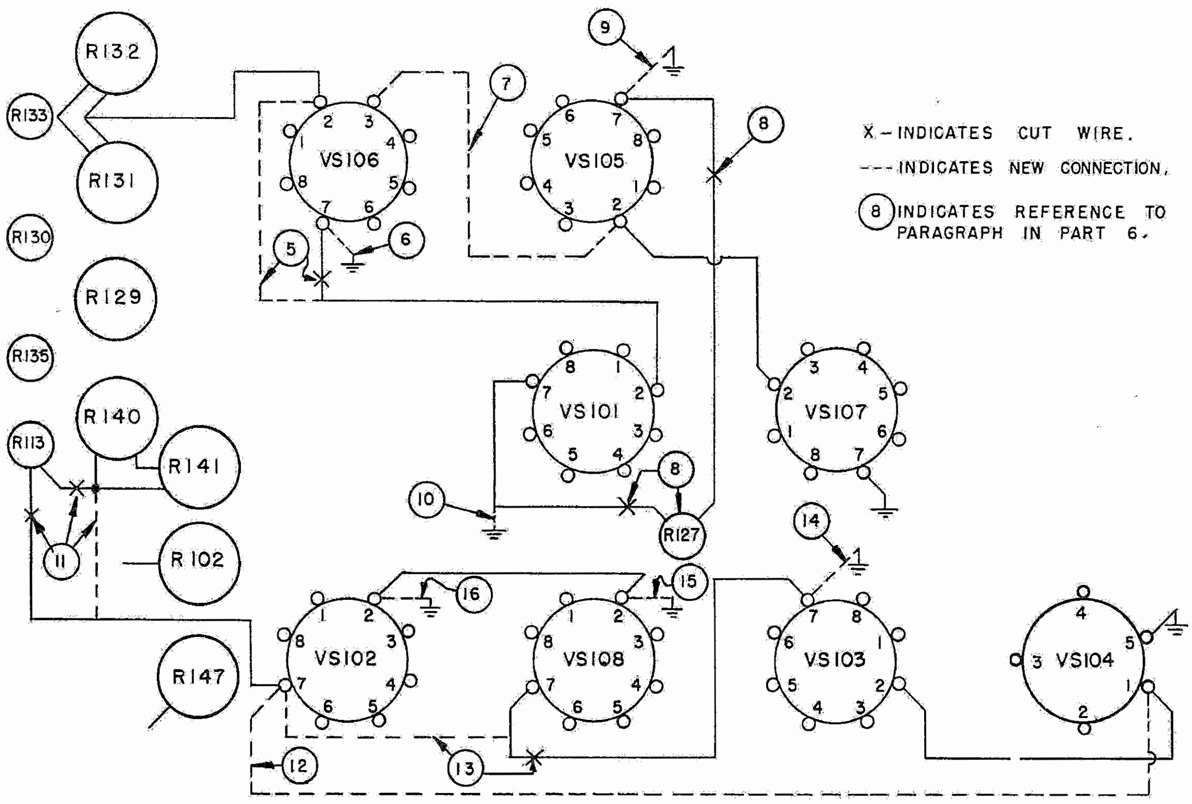


Fig. 2.--BC 604 Transmitter, filament circuit wiring diagram, showing changes made in Part 6.

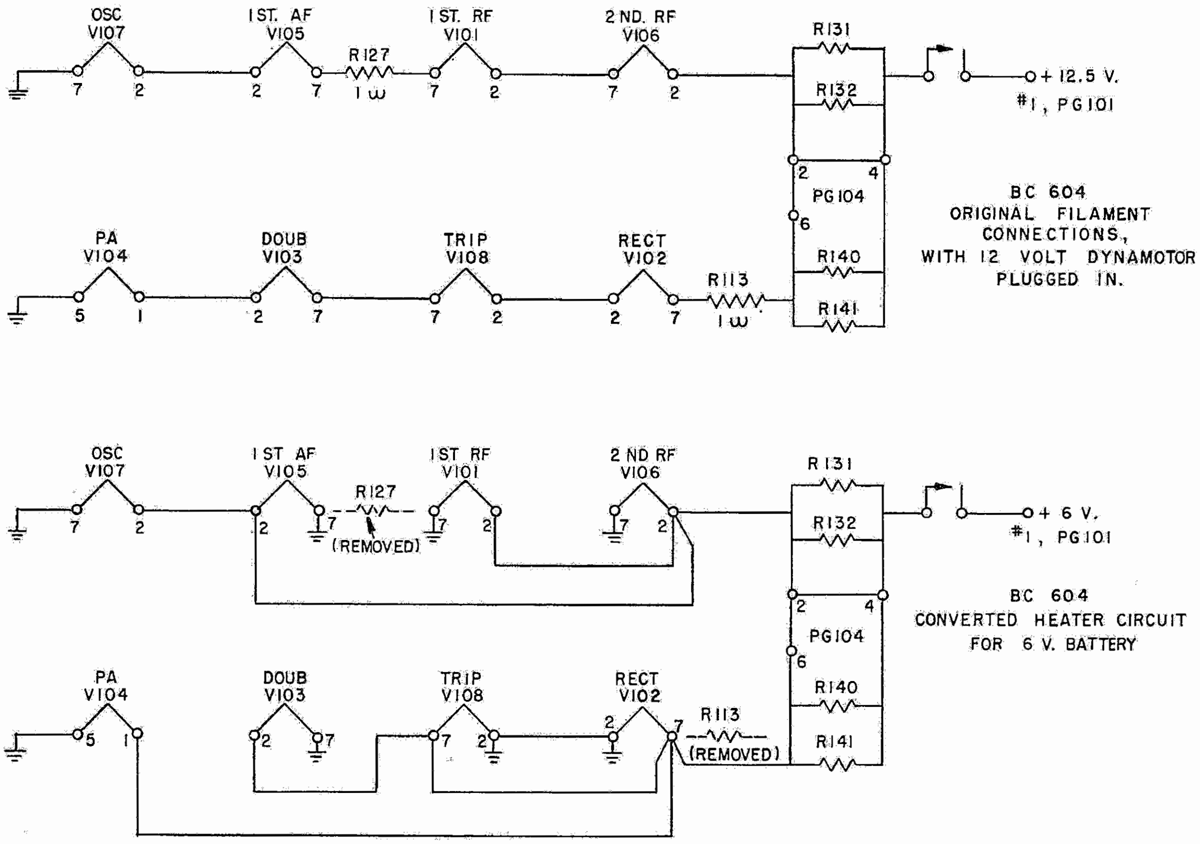


Fig. 3.--BC 604 Transmitter, original filament schematic and converted heater schematic.

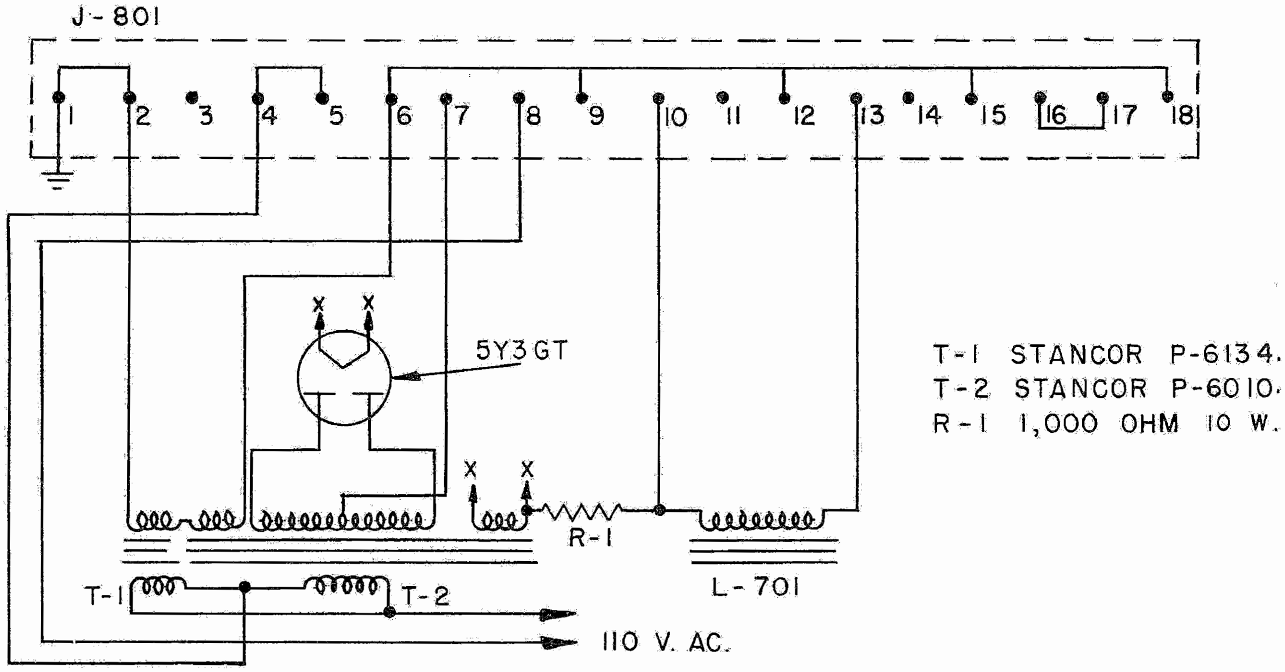


Fig. 4.--BC 603 Receiver, 110 V AC power supply.

many cases, such as the plugs, sockets and cables, substitute materials will serve equally as well. Circuit drawings and diagrams are furnished only for the changes made and additions, it being assumed the user will procure a copy of War Department Technical Manual TM 11-600 which contains complete circuit and adjustment information of the equipment as originally furnished for the armed services. TM 11-600 does not cover Dynamotor PE 103. However, the circuit diagram of this unit, as well as changes, is included as Figure 6.

The major units, except the dynamotor are component parts of SCR 508 (SCR 528 and SCR 538 also contain the same components). The incidental components such as plugs and receptacles are also mostly available as war surplus. Such items as the transformers for the receiver power supply, microphone sockets, VI meter, will likely be new materials. The total cost of all materials, war surplus and new, will likely be less than $200. Spray painting of the components is recommended. Masking of the front panel and name plates will be found quite simple. Duco Feather Grey #246-54909 or equivalent is recommended.

Crystals, in mounting FT 241 are readily available on the surplus market and carry the channel number and carrier frequency. The crystal frequency is multiplied 54 times to generate the carrier frequency. Crystals are readily available to produce carrier frequencies just under several of those specified by the FCC for remote pickup service. They are as follows:

Channel No.	Crystal Freq.	Carrier Freq.	FCC Channel
61	483.333 kc	26.1 mc	26.11 mc
62	485.185 kc	26.2 mc	26.21 mc
63	487.037 kc	26.3 mc	26.31 mc
64	488.889 kc	26.4 mc	26.41 mc

These crystals are wire mounted, and silver plated. They vibrate in such a mode that the frequency is determined, for a given crystal, and within limits, by the large dimensions. Grinding one edge a very small amount will raise the frequency of the crystals listed above to exactly fit the corresponding FCC channel. It is also entirely feasible to grind somewhat more from the edge of the crystal, raising the frequency to one of the higher channels. The crystal mounting base is clamped in a vise and the crystal itself held by its edges by means of a pair of long nose pliers the prongs of which have been covered with either thin rubber tubing, rubber tape, or masking tape. A few light strokes of very very fine sandpaper will take off sufficient material to raise the frequency measureably. Results are better if the sandpaper is wet. It is necessary in this case to wash and dry the crystal each time it is tested as to frequency.

PART 2

MATERIALS NEEDED

Transmitter

1 BC 604 transmitter
6 6v6GT tubes

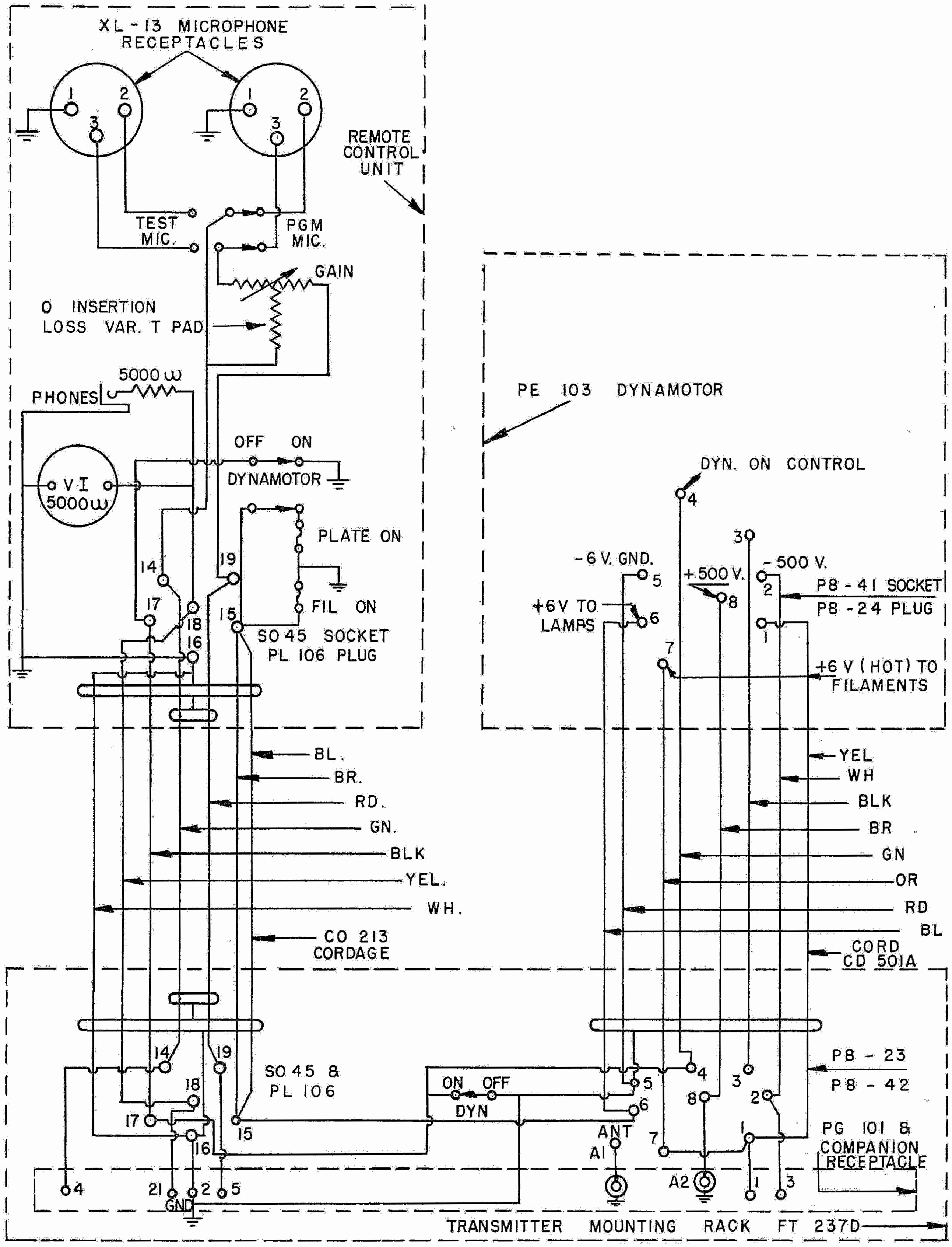


Fig. 5.--FT 237D Mounting, schematic as modified; remote control schematic; and connections for interconnecting cords, plugs, and sockets.

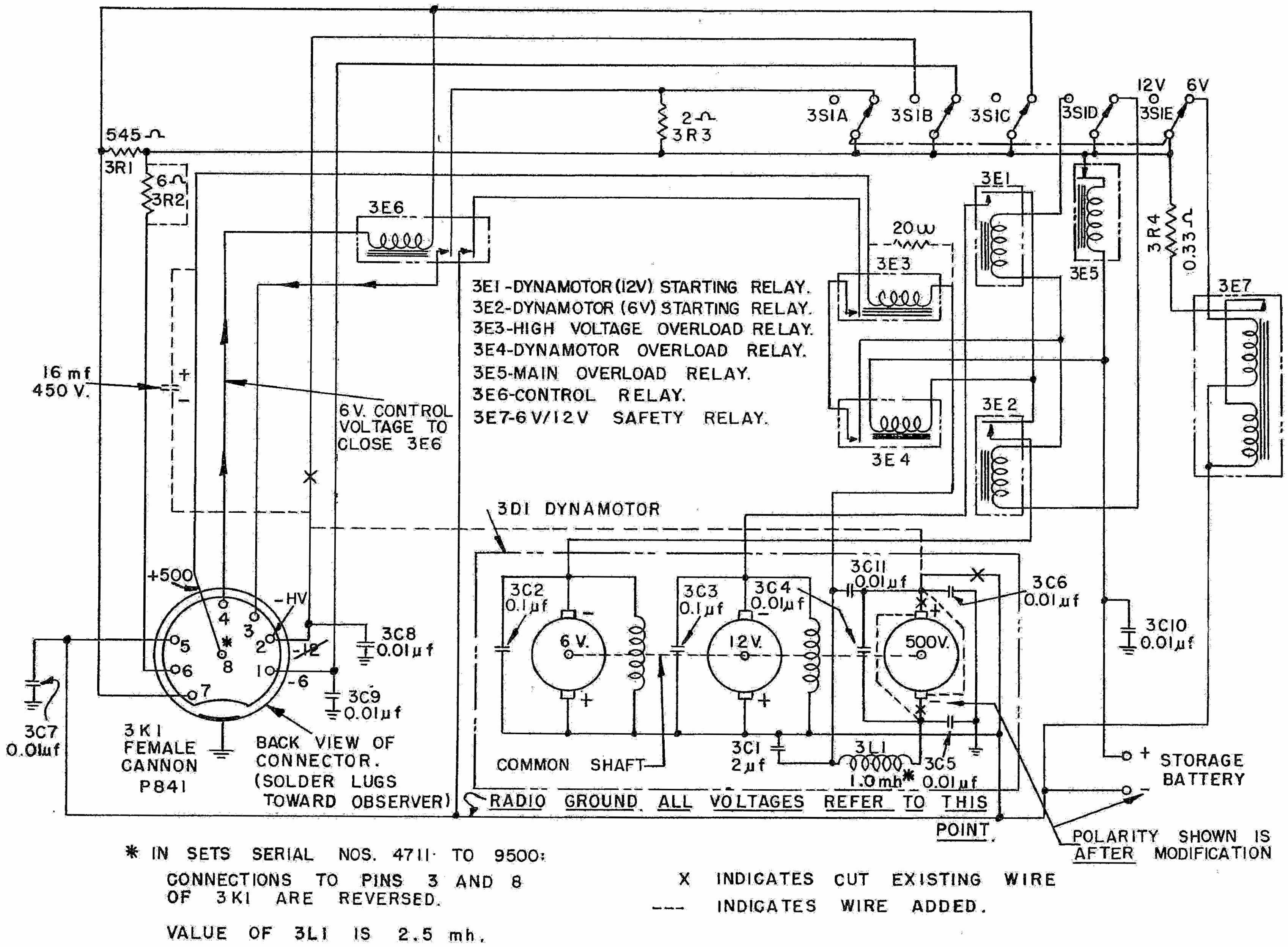


Fig. 6.--PE 103 Dynamotor schematic, showing modifications.

1 6L6 tube
1 807 tube
1 RCA K900849-501 microphone input transformer, or equivalent
3 .001 300v mica condensers
1 10 mmf 300 v mica condenser
1 2200 ohm 1/2 watt carbon resistor
1 510 ohm 1/2 watt carbon resistor
1 16 to 20 mfd 450 volt tubular electrolytic condenser
1 10-10 mfd 25 volt tubular electrolytic condenser
1 40 mfd 25 volt tubular electrolytic condenser
insulated tie points
2 75 ohm 1/2 watt wire wound or carbon resistors
7 feet of shielded insulated stranded, single conductor hook up wire
5 feet of insulated stranded single conductor hook up wire
18" Varnished cambric tubing
20 feet lacing cord
1 3 ohm 2 watt wire wound resistor
1 Crystal, in FT 241 mounting
1 100,000 ohm 1/3 watt carbon resistor

Receiver

1 BC 603 Receiver
1 1/2 watt 2500 ohm resistor
1 small banana pin and socket
1 miniature bayonet base lamp socket
2 20 mfd 250 volt tubular electrolytic condensers
1 .1 mfd 300 volt paper condenser

BC 603 Receiver Power Supply

1 base from dynamotor DM 34 or DM 36
1 Stancor plate transformer P-6134 or equivalent
1 Stancor filament transformer P-6010 or equivalent
1 1000 ohm 10 watt resistor, wire wound
1 octal tube socket
1 110 volt power cord and convenience plug
1 5Y3GT tube

Transmitter Mounting

1 Transmitter mounting FT 237D
1 Socket SO-45
1 Cannon receptacle, male, P8-42
1 SPST toggle switch

Dynamotor

1 PE 103 Dynamotor
1 20 ohm 1/2 watt wire wound resistor
1 16 mfd electrolytic tubular condenser, 450 v

Remote Control Unit

1 Box, removed from Dynamotor BD 77c or similar, or plain steel box, 9" long, by 5-1/2" wide, by 3" deep
1 No-insertion loss, T wire wound or carbon 250 ohm volume control (1800 ohm simple rheostat in shunt with mic will work quite well)
2 miniature bayonet-base pilot lamp mountings and 6v lamps
1 V I meter, Weston Model 301, type 23, 5000 ohm resistance, or equivalent
1 open circuit headphone jack (two in parallel if, desired)
1 hinged jack dust cover
1 six contact banana plug, male, receptacle, SO-45
2 microphone sockets, to match station's mike plugs
1 DPST toggle switch
1 DPDT toggle switch
1 5000 ohm 1/4 watt carbon resistor

Transmitting Antenna

1 Commercial police type mobile antenna mounting swivel, spring, and insulator
1 Mast Section MS 49
1 Mast Section MS 50
1 Mast Section MS 51

Cables

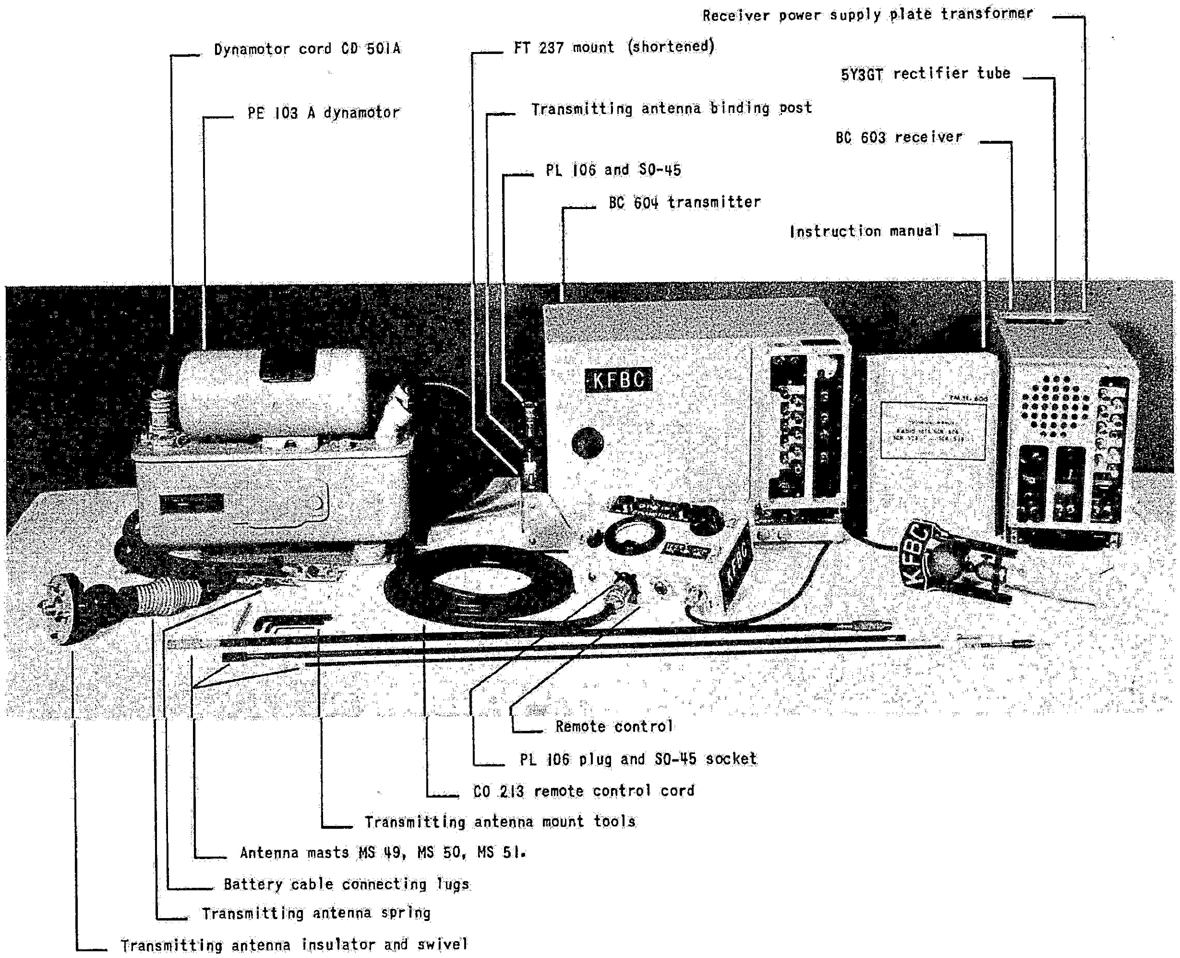
1 Dynamotor cable shielded, CD 501A, with male plug, P8-24 on one end, and female connector P8-23 on the other end, 8 contact. (7 contacts only used). This fits the socket P8-41 on the PE 103 dynamotor, and connects the dynamotor to the transmitter mounting.
1 15 ft. length Cordage CO 213. This is a seven conductor rubber covered, shielded cable, with two of the conductors separately shielded within the overall shield. CO 213 is a component part of SCR 508.
2 Plugs PL 106. These are six contact female cord connectors and are attached to the ends of CO 213 and the cord thus constructed is used to connect the remote control box with the transmitter mounting, plugging into socket SO 45 on each end.

PART 3

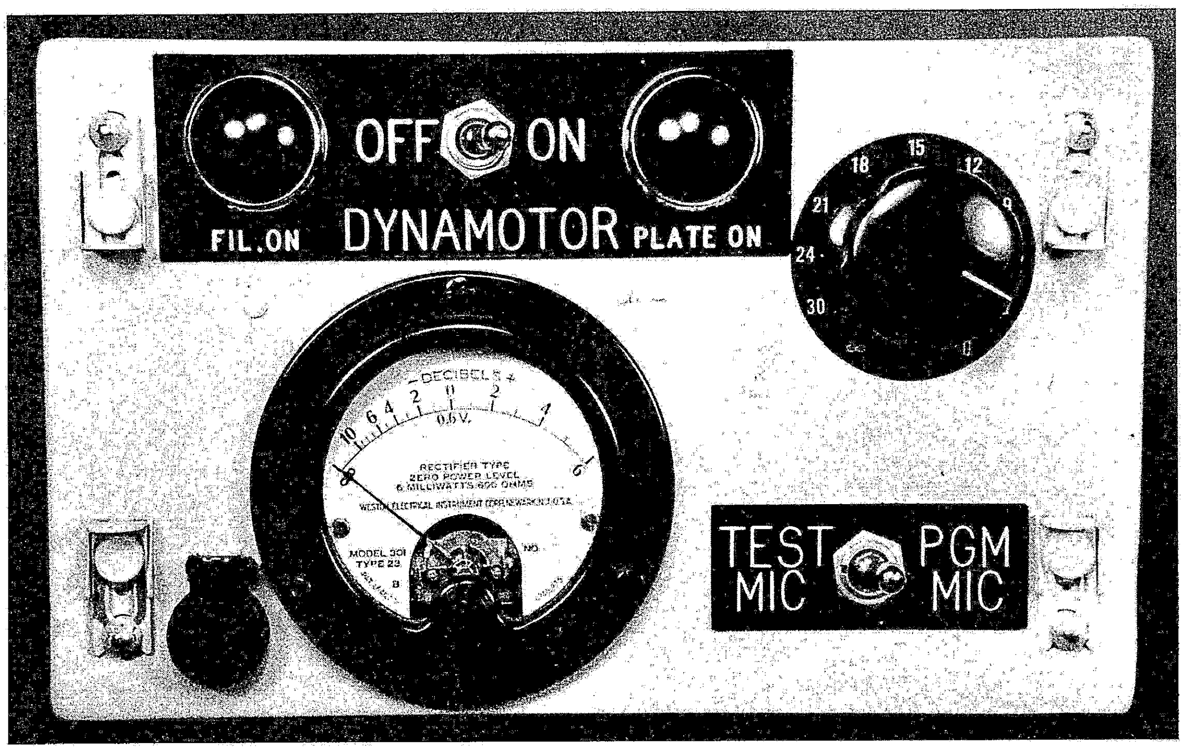
Installation

Receiver

Results as regards distance covered without objectionable noise will depend largely upon the height and efficiency of the receiving antenna. A ground plane quarter wave antenna or co-axial half wave antenna located on top of the main transmitting tower will probably be the best, provided, the main transmitter is not too far removed from the area in which most of the relayed programs will originate. Next best is a similar antenna on top of a tall building in the center of the area in which programs will originate. Good results can be had over shorter distances with an antenna located in an open and



View of the Various Components of the System



Remote Control Unit

quiet location on a 40 foot telephone pole. The receiving antenna is matched to a concentric transmission line such as RG 12U and the line connected to the receiver. The Squelch control of the receiver should be OFF during program reception. The audio output is taken from the receiver at the phone jack. VOLUME is adjusted for + 4 VU into 500 ohms. One side of output is grounded. The receiver should be peaked at carrier frequency by means of the RF trimmers. It is vital that the Antenna trimmer be so peaked.

Transmitter

If a pleasure car is used, the transmitter is installed in the luggage compartment, on the left side. The mounting is screwed to the floor by means of heavy sheet metal screws or bolted down. It must be carefully grounded to the chassis of the car.

Transmitting Antenna

Transmitting antenna is mounted on the left side of the body of the car at the rear, keeping the antenna lead as short as possible. Use three mast sections, a total of 114 inches. A commercial police type antenna mounting and insulator, which includes a spring to protect in case of driving under an obstacle, should be selected.

Dynamotor

Mount the dynamotor permanently in the rear luggage compartment, next to the transmitter, on the right side of the car. Clamp the low voltage lead to the frame of the car. Cut a hole 1-1/4 inches diameter thru the floor. Pass the + low voltage lead thru the hole, and forward to the car battery. Clamp the lead directly to the hot terminal of the battery, splicing with similar cable if necessary. Clamp by means of pipe straps and tie snugly to the under side of the floor of the car to prevent chafing and shorting. By means of cable CD 501A connect dynamotor to transmitter mounting.

Remote Control

Pass remote control cable around the back of the rear seat, forward to the driver's seat. Lay the remote control on the seat. Make the cord sufficiently long so that the operator may stand on the street with the remote control in hand, beside the car.

PART 4

Operation

Leave the Filament switch of the transmitter on. Leave the high voltage and main overload switches of the dynamotor on. Turn the filaments on by means of turning on the filament overload of the dynamotor (the switch nearest to the hinge of the door covering the overload controls). If left on continuously, this switch causes a small drain of about 15 milliamperes on the battery. Allowing the normal time for the filaments to warm, turn the DYNAMOTOR switch of the remote control to ON position. This applies high voltage to the transmitter, and places the carrier on the air. Microphones of an output level as great as that of the RCA 88 type must be used. Those of a low output level such as the RCA 44 type will not fully modulate the transmitter. Such microphones can be used, however, by using a regular remote amplifier, the output of which is fed through the microphone terminal of the remote control, or directly into the transmitter through the MAGNETIC MIC socket. Once properly tuned up, the transmitter and transmitting antenna circuits will need little re-adjustment. These circuits will keep their adjustment even though the car is driven over hundreds of miles of rough roads. The equipment has been used for many months without any re-adjustment of any kind. Since the equipment draws approximately 32 amperes from the 6 volt battery, it is well to run the car engine if transmissions are longer than 15 minutes.

For transmission from airplanes where the acoustic noise level is high, provision in the modification instructions is made for use of a carbon microphone. In such conditions, the carbon mic will give better over-all results than a high quality broadcast type mic. The close-talking variety such as T-17 is most suited. The carbon mic is plugged into the "CARB MIC" jack. The volume control on the remote control is turned off during use of the carbon mic. No variable volume control for carbon mic is provided. However, the "TANK-OTHER USE" switch is a high-low carbon mic volume control. The gain for a given carbon mic can be adjusted by shunting resistor R120 within the transmitter. The volume will be indicated on the VI meter. It should be anticipated that the announcer will use a high voice level under high noise conditions.

PART 5

Transmitter Notes

Since the Type 1619 tubes have been replaced in the RF lineup with Type 6V6GT, and since the 6V6GT has a different internal capacitance between the elements than the 1619, the trimmer condensers across the tuning coils will have to be changed to compensate. While this effect is very substantial, nevertheless, the condensers do not need to be rotated more than about 15 degrees, in order to bring the circuits into resonance. Some will be increased, some decreased. The tuneup procedure is to set the meter switch at position #3, Rectifier Grid

Current, and rotate the main tuning shaft until a reading of 20 or 21, or maximum on the meter is had. Then set the meter switch to position #4, Doubler Grid Current, and adjust C153 and C157 for maximum meter indication. Next, set the meter switch to #1, Tripler Grid Current, and adjust C114 and C116 for maximum meter deflection. Next, set the meter switch to #5, Power Amplifier Grid Current, and adjust C120 for maximum deflection on the meter. Great care must be used to see that the 9th harmonic of the crystal frequency is selected in the plate circuit of the rectifier tube and not some other harmonic. One method, before modifying, is to connect the transmitter by means of using dynamotor DM-35 and a 12 volt source and a dummy antenna A162, and rotate the main tuning shaft with the tuning lock loosened until maximum output into the dummy antenna is had, all in accordance with instructions contained in the technical manual.

By using an absorption type wave meter, the proper harmonic can easily be selected and with such an instrument at hand, it should not be necessary to tune up the transmitter initially before making the modifications. There is the advantage, however, since surplus and not new equipment is being used, that if there may be any defect in the transmitter it can more easily be located and remedied if the transmitter is tested before modifications are undertaken.

Typical meter indications, after conversions outlined herein, are:

Meter Position	Circuit Metered	Meter Reading
2	RF Amp. grid	19
3	Rectifier grid	21
4	Doubler grid	20
1	Tripler grid	23
5	Power Amp. grid	20
6	Total B supply current	60

The only value that is critical is the Rectifier Grid Current, meter Position #3. The only requirement in the other grids is that sufficient grid excitation be had in each stage to drive the stage following and to secure stability of operation.

The SIDETONE control adjusts the voltage fed to the VI meter. With a meter as specified, the proper setting of this control will be about 15 degrees less than maximum clockwise position. Apply 1000 cycles of audio frequency to the microphone input, at such level as to cause 11.5 volts to appear at terminal 21 of PG 101 of the BC 604 transmitter, with VI meter and headphones of the remote control disconnected, measured with a vacuum tube voltmeter, with SIDETONE at maximum clockwise. This will produce a frequency swing of about 5 kc. Modulation peaks will achieve the legal limit of 8.5 kc swing. Connect the VI meter, insert high impedance headphones, and adjust SIDETONE control to indicate + 4 on the VI Meter.

If the transmitter is adjusted so that a reading of other than 20 or 21 with meter selector on position 3 is obtained, the carrier swing, (modulation percentage) and distortion will not be optimum. This reading can be controlled by changing the screen grid voltage of the first RF amplifier, V101, by changing the value of R103.

The antenna current meter reads not only the antenna current, but the capacitance current of the small section of concentric line in the antenna circuit.

Frequently, large scale readings of antenna current can be had with the antenna entirely disconnected. Two antenna mast sections will produce a higher antenna current reading than three, but three will give considerably more radiation than two.

There is provision for operation on ten different frequencies, changed by means of pressing a single push button. For this application, the trimmers should be peaked at the single frequency, disregarding tracking over the whole band. Follow the tuning instructions of Technical Manual TM 11-600 in every other respect.

The modifications make inoperative the RECEIVER-TUNE and RADIO-INTERPHONE switches. Tune the output stage and antenna coupling circuits for maximum antenna current, with three masts connected.

PART 6

BC 604 Transmitter

Following is a step by step procedure for modifying the BC 604 transmitter. The essential modifications are: Change microphone input transformer to improve frequency response and reduce noise; Change direct heated filament tubes to cathode type, to adapt filament supply to 6 volts and to reduce noise; Change certain circuit elements to retain proper voltages on tube elements when plate supply is reduced to 500 volts; Secure bias of audio stages from cathode resistors instead of filament drop. Figures 1, 2, & 3 pertain to these notes, and the numbers circled in Figures 1 and 2 refer to the same paragraph of these notes.

1. Unsolder heavy wires and smaller wire from contacts of dynamotor relay S102. Clip leads to coil of S102, at S102. Remove 4 screws holding relay S102, and remove relay. Remove 2 screws holding condenser C162.

Clip strap connecting + end of C162 to tie point. Cut wire connecting - end of C162 to R133, at R133. Remove C162. Unsolder heavy wire that connected relay S102 at #1 and #3, PG104, and discard. Splice heavy wire that formerly connected #1, PG101 to contact of S102 to smaller wire that formerly connected to same contact of S102, and slip piece of spaghetti over splice. This wire feeds battery to filaments. This operation removes the dynamotor relay and associated condenser since they are no longer needed, but preserves the filament feed.

2. Mount 16 mfd 450V electrolytic lengthwise of transmitter in space formerly used, in part, by dynamotor relay S102. Connect positive end of this condenser to hot terminal of C145 (or R147) with a wire about 6" long and negative end to that end of R130 that is connected to #4, PG103 (-B) or using a longer wire run direct to #4, PG103, if preferred.

3. Install RCA mike transformer #K900849-501 in space formerly occupied by relay S101 and condenser C162.

4. Disconnect WH lead that connects D126 (Tank-other use) switch to #2 VS107, at #2 VS107, and ground D126 using same WH wire, shortened, connecting at solder lug close to D126. (This is necessitated by other changes in filament circuit.) Clip wire at #2, VS107. Don't try to unsolder it here.

5. Change lead connected to #2, VS101 from #7, VS106 to #2, VS 106. Filament.

6. Ground #7, VS106 to ground lug, not to #8, VS106, because #8, VS106 will be lifted from ground later. Filament.

7. Disconnect lead connecting #2, VS106 from C139 at C139 end. Connect #2, VS106 to #2, VS105, using this wire that formerly connected to C139. Filament.

8. Disconnect lead from #7, VS105, which runs to R127, and pull from cable and discard. Also discard R127, unsoldering other lead to R127 at R127. Filament.

9. Ground #7, VS105.

10. Ground #7, VS101, using wire that formerly connected #7, VS101, to R127.

11. Cut strap connecting R113 to R140 and R141 at R140 and R141. Remove screw holding R113 and disconnect R113 from #7, VS102 at R113, and use wire formerly connected to R113 to connect #7, VS102 to R140 and R141 at former junction with R113. Cut yel wire that connects to lamp ES101 from R113 and reconnect to R140 and R141 at former junction of R140 and R141 with R113. (Cut wire from R113. Don't try to unsolder.) This connection is made to the accessible end of R141. Discard R113. Filament.

12. Connect #7, VS102 to #1, VS104, with a wire 13" long. Filament.

13. Change #7, VS108 from #7, VS103, to #7, VS102. Filament.

14. Ground #7, VS103. Filament.

15. Ground #2, VS108. Filament.

16. Ground #2, VS102. Filament.

17. Disconnect C110 from #2, VS102 and discard. There is no C110 in later units.

18. Install 510 ohm, 1/2 watt, resistor between #8, VS106 and ground, removing ground from #8, VS106. Cathode bias resistor.

19. Install 10 mfd 25 or 50V electrolytic condenser between #8 and ground, VS106, + to #8 (cath). Cathode by-pass.

20. Install 2200 ohm, 1/2 watt, resistor between #8 and ground, VS105, removing ground from #8, VS105. Cathode bias resistor.

21. Install 10 mfd 25V or 50V electrolytic condenser between #8 and ground, VS106, + to #8. Cathode by-pass.

22. Disconnect BL-YL wire connecting #8 on PG103 (+HV) to F101 at F101, and tape end and tuck under cable, and use concentric line that connects C161 to #A2, Pg101, for this + HV lead, making +B come through A2 on PG101 for using external dynamotor. Disconnect C161 from end of co-ax transmission line. Cut BL and GR wires from center contact of S101. Unsolder bus wire connecting L111 to S101 at L111 and discard bus. Unsolder short co-ax that connects "ANT" terminal to S101, at S101. Remove the four mounting screws of S101. Clip the BLK wire and the BL-OR wire connecting to the coil of S101. Cut the BLK-RD and RD wires from S101. Remove relay S101. Mount an insulated tie point in relay mounting screw hole near end of co-ax cable connecting to A2, PG101. Solder end of co-ax to tie point. Connect tie point to F101 by means of an insulated stranded wire 19" long, taking this wire through hole A. Tie this wire to cable at top of transmitter, also at end removing plate at right end of transmitter to make cable accessible. See paragraphs 43, 44, and 45 for disposition of the rest of the wires that formerly connected to S101.

23. Disconnect transformer T101 primary from terminals C and D of J101 at J101, and install condensers from C and D to ground (.001) and connect shielded wires from C and D to #4 and #1 of RCA mike transformer K900849-501. Ground shields at jack J102 (to solder lug installed under mounting screw) and ground shields at transformer. Prepare and connect to transformer K900849-501 an additional shielded wire to each #1 and #4 and to #5 and #7 to be used later. Ground lug #6 of transformer K900849-501 to 6-32 screw adjacent, using soldering lug and small 6-32 nut. Run wire from this soldering lug to ground at C143. Slip spaghetti over ends of wires removed from C and D, J101.

24. Remove lead connecting #5, VS105 to #5, T101 and discard lead. If a small mica condenser is connected to #5, VS105, leave it connected to #5 but move other end from #2, VS105 to #8, VS105.

25. Run shielded lead from #7 transformer K900849-501 to #5, VS105. Ground shield at both ends. Audio grid lead.

26. Connect shielded wire from #5, transformer K900849-501 to #6, VS105, (used as tie point). Ground shield at both ends.

27. Disconnect wire that runs from junction of C137 and C138 to #4, T101 at T101 end, and connect junction of C137 and C138 to #6, VS105, (actually #5, transformer K900849-501). It may be advisable to replace the existing wire which is solid with a new wire about 3" long, which is stranded. Do not solder #6, VS105, until after next step is completed.

28. Connect 1/3 watt, 100,000 ohm resistor from #6, VS105, to #1, VS105, and a .001 postage stamp condenser from #6, VS105, to #8, VS106.

29. Disconnect BL-OR wire connecting C of C142.1 and C142.2 to C139 at C139 and move to #8, VS106 (it formerly went eventually to VS106, #2). Plate and grid isolation filters.

30. Disconnect R121 from C139.

31. Connect C139 (terminal formerly connected to R121) to #8, VS105. Screen grid by-pass, V105.

32. Solder the ground lug of an insulated tie point to the terminal of C138 nearest PG101, and connect the end of R121 that formerly connected to C139 to the tie point. Connect a 75 ohm 1/2 watt resistor from #2, VS106 to the tie point. Remove dust shield from trimmer condensers and S104. Disconnect C144 from radio-interphone relay S104, at S104, also at C144, and discard the wire. Connect a new wire 8" long from C144 to the tie point to which R121 is now connected, using hole E. Carbon mike button current feed and filter.

33. It is necessary to remove four mounting screws holding PG101, also spacers. Be sure spacers and grounding straps are restored after connections have been made. PG101 must be free to move.
Connect #4, PG103 to #3, PG101, (-HV) with a wire 8" long.
Connect #1, transformer K900849-501 to #4, PG101, using shielded wire and ground shield at transformer end.
Connect #4, transformer K900849-501 to #5, PG101, using shielded wire and ground shield at transformer end.
This operation disconnects mike circuit of T101 and substitutes transformer K900849-501 for T101 and connects -HV of dynamotor to R130.
Disconnect present wires from #4, PG101 and #5, PG101 and slip spaghetti over ends and tuck under cable. Slip spaghetti over new wires to be connected to #3, #4, #5, of PG101 and slide same over terminals after soldering.

34. Disconnect at socket shielded wire from #5, VS106 which goes to #2, S104, thus removing R148 from the circuit and raising the gain of the audio amplifier. Some sets do not have R148 and have no connection to Sec. 2, S104, and Para. 34 can be disregarded in these cases. The purpose of R148 is to reduce the audio gain while transmitting and, in any event, this gain reduction circuit is not desired in this application. The easiest way may be to clip also the other shielded wire of this pair, at #6, VS106, (used as tie point), also the ground of the shield, so spaghetti can be slipped over end of entire cable and cable tucked away adjacent to relay S103. R148 may also be disconnected from #6, VS106, also at its other end, and discarded.

35. Connect A 10 mmf. condenser from #5, VS105, to #8, VS105, keeping leads not over 3/8" long. Some transmitters already have such a condenser connected from #5, VS105 to #2, VS105. If so, this condenser has been re-connected in Para. 24.

36. Lay a 40 MF, 25V or 50V, tubular electrolytic condenser in the space between the end of transmitter and PG103 and PG104, and connect the positive end of condenser to ground, using the ground lug at the corner of PG101, and the negative end to #4, PG103 (-B). Bias filter. If resistor R152 is in way, disconnect same and remove it. This

resistor serves as a load on the interphone output and is not needed. It is connected from #20, PG101, to ground. Cut wire at #20, PG101, and at ground lug. The screw can be retained to tie the condenser to.

37. Connect #4, VS104, to ground (#5, VS104), grounding cathode of V104, Type 807.

38. Connect #2, PG103 to #7, PG104 and #5, PG104 to #8, PG104. Crystal heaters.

39. Connect #2 to #4 to #6 on PG104, shorting the 24V dropping resistors R131 and R132, and R140 and R141.

40. Disconnect R115 from C138 and from T101 and discard R115.

41. Cut the BR wire at D122 that connects to R135, and cover cut end with spaghetti and tuck under cable. This makes it impossible to close the battery circuit through the coils of antenna relay S101 and receiver disabling relay S103, which are not used, thereby saving battery current.

42. Cut the RD-BR wire at the tie point (near R132 and to which tie point + C162 was formerly connected) which connects S104 to D124. This cuts the feed of the DC filament battery to the coil of S104, radio-interphone relay, which is not used and which thereby saves a drain on the filament battery if radio-interphone switch should be inadvertently thrown to "Interphone."

43. Mount a soldering lug in the hole which formerly held S101, near L110, and ground the GR and BL wires which were removed from the contact of S101 to the lug, thus maintaining a continuous short to ground of R129. R129 was used to quickly block all tubes when the press-to-talk switch is pressed. This feature is not needed since for this application the carrier is kept continuous.

44. Mount an insulated tie point with insulation suitable for RF near the end of short RF co-ax cable that connects to "ANT" post and solder free end of this co-ax to tie point. Connect the end of L111 formerly connected to S101 to the tie point by means of a piece of heavy tinned bus wire, taking care to form bus so it will not short to ground.

45. Mount a 3-point, vertical, insulated tie point strip in the remaining hole formerly used for mounting S101. To the lower tie point, connect BLK wire that formerly connected to coil S101. To the second point, connect BL-OR wire that formerly connected to coil, S101. To the top point connect the RD and BLK-RD wires that are in series with the HV to V4. The antenna relay S101 is not used.

46. Remove lamp E101, which is a 24V lamp and replace with a 6V to 8V or a 12V lamp. The 24V lamp removed, is used in the receiver.

47. Shunt R120 (200 ohms) with a 75 ohm 1/2 watt resistor. The carbon mike current feed was designed to work from 12V and having added 75 ohms in series with R121 already in Para. 32, it is now necessary to reduce the total resistance in the carbon button circuit so that the 6V source will cause sufficient button current to flow. However, if the particular carbon mike used does not give sufficient output, this 75 ohm resistor should be replaced with one of 200 ohms. If mike level is too high, substitute 25 ohm resistor, which, while increasing the current flow, will act as a voice frequency load, reducing the signal level.

48. Clip BL shielded wire from terminal #0 of L105 and clip RD-BL shielded wire from #2, T102, and clip the ground wire of this shielded twisted pair and slip spaghetti over the bared end of the cable and tuck away in space around relay S103. Unsolder bus wires from #1, L105 and temporarily remove L105. Short R156 by connecting #1, T102 to ground with a short bare tinned wire. Connect an insulated stranded wire 3" long to #2, T102, skin and tin the other end of wire. Connect a 3 ohm 2 watt wire wound resistor between #2, T102 and ground. Restore L105 to its original mounting. Connect #0, L105 to #2, T102 by means of wire already connected to #2, T102. Reconnect bare bus wires to #1, L105.

49. Rearrange screen grid dropping resistors R114 and R116, for V104, from series to parallel. Clip strap at #2, VS104 (screen grid) and solder clipped end to adjacent terminal of R114, thus connecting R114 and R116 in parallel. By means of an insulated wire 4" long, connect the original junction of R114 and R116 to #2, VS104.

50. Install tubes in transmitter as follows:

V101	6V6GT	V104	807
V102	6V6GT	V106	6L6
V103	6V6GT		
V105	6V6GT		
V107	6V6GT		
V108	6V6GT		

PART 7

Transmitter Mounting

Mounting FT 237D is a component of SCR 508, SCR 528, SCR 538. FT 237D is designed to accommodate one BC 604 transmitter and two BC resistors to the circuit, with their positions interchanged. In other words, change R10 from the original value of 250 M ohms to 1 meg ohm and change R11 from the original value of 1 meg ohm to 250 M ohms. This reduces the audio level at the grid of the 1st audio stage to prevent overloading.

17. Cut a piece of sheet metal of such size to cover the plug on the back of the receiver and drill two holes in the cover and two matching holes in the receiver at the ends of the plug and by means of self-tapping 6-32 screws, mount the cover. This is to protect the live contacts on the plug which now bear 110V AC.

PART 10

Power Supply for Receiver

Since the receiver in most cases will be located at a place such as the studios or the main transmitter location, where 110 volt 60 cycle ac power supply is available, it is modified to operate from such a power source, rather than from a dc source. The receiver requires 12 volts filament supply. If the components are carefully chosen, they can be mounted on the base of the originally furnished Dynamotor DM 34 or DM 36. The socket for the rectifier tube is mounted flush with the dynamotor base. A 1000 ohm 10 watt resistor is used as a resistance filter, and to drop the voltage from that provided by most stock transformers that will fit the base. The base suggested will plug into the receiver, thus making a convenient arrangement. The receiver requires 200 volts at about 60 ma. plate supply. Figure 4 indicates suitable wiring of such a rectifier and strapping of the multiconnector socket on the base, to connect the front panel ON-OFF switch into the primary, and to connect the separate filament strings in parallel.

PART 11

Remote Control

The function of the remote control is to provide a convenient means of controlling the audio level, and indicating when the filament is on, also to switch the plate supply dynamotor on and off. By frequent use of the DYN ON switch, much battery current is saved during test transmissions and cueing transmissions. Means is also provided for switching in a test microphone in place of the regular program mic. The remote control is usually placed on the seat beside the driver of the car. When not in use, it is removed from the connecting cord and placed in an out-of-the-way place.

If more than one mic at a time is needed, a regular 4 channel remote amplifier is connected in place of the program mic, by means of suitable level reducing pads and isolation coils. Since the volume indicator is fed from the output of the audio amplifier at about 0 level, through the same cable that the low level microphone is fed to the audio amplifier, it is absolutely necessary that the two microphone conductors be separately shielded, preferably within the overall shield of the cable. Such a cable is CORDAGE 213, a component of SCR 508. Figure 5 is a circuit diagram of the internal wiring of the remote control, also the manner in which the remote control is connected to the transmitter through the transmitter mounting and to the dynamotor. The lettering of the remote control shown in the photograph is engraved. An excellent job of lettering can be done with decals.