Command Set Receivers for All Frequencies— The Easy Way

BY GORDON E. WHITE*

The most widely-used piece of surplus equipment ever to hit the amateur market is the famous Type-K Command Set receiver. Probably thousands have been mauled by the experimenting ham in an effort to change the frequency coverage of an available unit to something more suitable. Below is a wealth of practical, no-nonsense information direct from the manufacturer's files, bound to make the job an easy one.

THE command sets, based on the Type K design, were made in fabulous numbers during WW II. Korean War and civilian versions pushed the production record to about a million receivers alone during the 20 years they were manufactured.

Such a vast outpouring, plus the high inherent quality of the command design has made the sets the most popular items in the long postwar history of amateur use of former military gear.

Unfortunately, despite the larger numbers of command sets made, there was a wide disparity in the production rate of the receivers in the different bands. Although there were eight l.f.-m.f.-h.f. receivers designed, only five are still common, and only three saw really massive production. (The tuneable v.h.f. sets are a story to themselves, and the author hopes to deal with their excellent qualities and detailed specs in a subsequent article.)

While more than 450,000 "beacon" band command receivers were made, covering 190-550 kc, only 46 sets were built for the 9-13.5 mc band. Well over 200,000 sets were built in both the 3-6 mc and 6-9.1 mc bands, but fewer than 150 were manufactured for the 13.5-20 mc and 20-27 mc segments.

The Army bought the BC-946 broadcast band (520-1,500 kc) set chiefly to be used with the ZB homing adapter, and only 11,000 were made. The Navy procured another 18-20,000, making these sets relatively scarce and costly today. There was no Army production, and fewer than 50,000 Navy sets in the 1.5-3 mc marine frequency band, also a rare unit now.

The above figures show the prudence of conversion of the more plentiful sets to cover the rare frequencies for amateurs who covet the simplicity, stability, and tuning accuracy of command receivers in other than 190-550 kc, 3-6 and 6-9.1 mc bands.

Conversion Data

The author has uncovered original design data on the entire line of command receivers, from the 1939 prototypes through the 1961 civilian production. The tables in this article cover the r.f. the i.f. and b.f.o. transformers.

These specifications will provide all the parameters necessary to build receivers in any of nine bands, including the 3.5-7 mc prototype of the original SCR-274, which was never built in quantity. Performance of these conversions should match the original recievers, with a great saving in trial and error labor.

In the past, conversion data has been published which attempted to achieve similar ends, but in most of these the writer has not had the time or test equipment to optimize the conversion. This set of tables comes directly from the meticulous designs of Dr. Frederick H. Drake, Paul O. Farnham, and Norman J. Anderson in the Boonton, N.J. laboratories of the Aircraft Radio Corporation.

*516 North King's Highway, Alexandria, Virginia.

TABLE I - Similarities & Differences									
Range		190-550	520-1,500	1.5-3.0	3-6	6-9.1	9-13.5	13.5-20	20-27
Navy No.		46102	46103	46104	46105	46106	46107	46108	46109
C_1 (mmf)		11	11	11	11	8.5	6.5	6.5	6.5
Loop Input		Yes, except ARA, SCR-274-N	Yes, except ARA; SCR-274-N	No	No	No	No	No	No
C_4 No.		3936	3936	4601	4601	6558	6558	6558	4609
C_4 Max. (mmf)		346	346	147	147	62	62	62	41
$C_{4F/G}$ Cap.		min./½	min./½	½/½	½/max.	½/max.	½/max.	½/max.	½/½
C_{10}(mmf)		690	670	365	365	240	240	340	300
R_6 (Meg.)		.51	.30	.20	.20	.15	.10	.10	.10
C_{39} across L_2		120mmf	None	None	None	None	None	None	None
I.F. (kc)		85	239	705	1415	2830	4200	4200	4200
Tuned I.F. Ckts.	274-N	2 (var.)	2 (var.)	2 fixed	2 fixed	1	1	1	1
	ARC-5	2	2	2 fixed	2 fixed	2 fixed	2 fixed	2 fixed	2 fixed
Tapped I.F. Coils		L_8-L_{11}	L_8-L_{11}	L_{10},L_{11}	L_{10}	None	None	None	None
Iron Core I.F.	274-N	No	No	Yes	Yes	No	No	No	No
	ARC-5	No	No	Yes	Yes	Yes	Yes	Yes	Yes
R_{12}		510	510	510	510	510	390	390	390

Table I—Similarities and differences in the RAV series of command receivers covering 190 kc to 27 mc.

R.F. Problems

One or two cautions are in order. First, the 20-27 mc receiver was built with the same circuit and tubes as the lower frequency sets. It was satisfactory for short, direct, plane-to-plane work, but definitely lacks the sensitivity for long range reception. In fact, it was replaced by the General Electric RAX set in liaison use for Navy patrol aircraft early in the war. A single 12SK7 tube just cannot function as well above 20 mc as it does at six or nine megacycles.

The author has at least partially solved the sensitivity and noise problem in his own RAT-1 sets by substituting a 6AB7 for the r.f. tube. The filaments have been wired for 12 volt parallel operation, with the exception of the r.f. and audio tubes. Wiring these in series allows the use of a 6V6 output tube which nicely matches the filament current of the 6AB7.

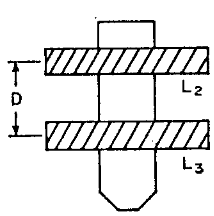
Running the heater wiring directly from the r.f. to the audio gave no trouble, but dress of wiring involved could in some causes cause feedback. This applies particularly to the plastic wiring in the later AN/ARC-5 sets.

The 6AB7 of course required a screen voltage boost to 200 volts from 85 in the original circuit. A 200 ohm cathode resistor should replace the standard 620 ohm unit.

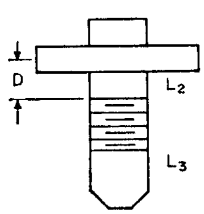
I.F. Changes

In the SCR-274-N and ARA sets, and the older

TABLE II - R.F. Coil Data									
Range (mc)	Antenna L_1	Mixer L_2	f (kc)	Mixer L_3	Oscillator L_4	Oscillator L_5	Loop L_{16}	D (Inches)	Winding Data L_1,L_3,L_5
0.19-0.55	* 285 t. ① #36 SSE	* 720 t. ③ #38 SSE	147	* 255 t. 5-41 Litz	* 50 t. #36 SSE	* 235 t. 5-41 Litz	28 t. ④ #36 SSE	0.500	U.W.
0.52-1.5	* 102 t. ② 7-41 Litz	* 743 t. #38 SSE	394	* 104 t. 7-41 Litz	* 20 t. #36 SSE	* 83 t. 7-41 Litz	15 t. ④ #36 SSE	0.469	U.W.
1.5-3	* 61 t. 5-41 Litz	* 219 t. #36 SSE	1125	* 61 t. 5-41 Litz	7½ t. #36 e.	* 48 t. 5-41 Litz	N.A.	0.219	U.W.
3-6	31½ t. #30 e.	* 110 t. #34 SSE	2250	31½ t. #30 e.	6 t. #32 e.	26 t. #30 e.	N.A.	0.219	52 t.p.i.
3.5-7	22½ t. #26 e.	* 75 t. #34 SSE		23½ t. #30 e.	6 t. #32 e.	21 t. #30 e.	N.A.	0.219	52 t.p.i.
6-9.1	20½ t. #26 e.	* 50 t. #34 SSE	4550	20½ t. #26 e.	2½ t. #32 e.	17 t. #26 e.	N.A.	0.219	36 t.p.i.
9-13.5	13½ t. #24 Tin	* 33 t. #34 SSE	6665	13½ t. #24 Tin	2½ t. #32 e.	10½ t. #24 Tin	N.A.	0.219	24 t.p.i.
13.5-20	8½ t. #24 Tin	* 20 t. #34 SSE	9450	8½ t. #24 Tin	2½ t. #32 e.	7½ t. #24 Tin	N.A.	0.219	18 t.p.i.
20-27	6½ t. #24 Tin	* 14 t. #34 SSE	14,900	6½ t. #24 Tin	2½ t. #32 e.	5½ t. #24 Tin	N.A.	0.219	17 t.p.i.
27-40	←EXPERIMENTAL→						N.A.	0.219	14 t.p.i.



0.19-1.5mc



1.5-27mc

NOTES:

① RAV, ARA and AN/ARC-5 series, tapped at 198 t.

② RAV, ARA and AN/ARC-5 series, tapped at 71 t.

③ Paralleled with a 100mmf capacitor.

④ Wound on L_1 for low impedance loop antenna input.

f—Resonant frequency of L_2, cold, with tubes in place.
D—Coil spacing between L_2 and L_3.
SSE—Single silk wound enameled wire.
U/W—Universal wound.
N/A—Not applicable.
e—enamel.

Table II—R.f. coil data necessary to convert the more available command sets to cover any desired frequency range. All windings marked with an asterisk are universal wound; the others are single layer windings. Chart term definitions are listed above.

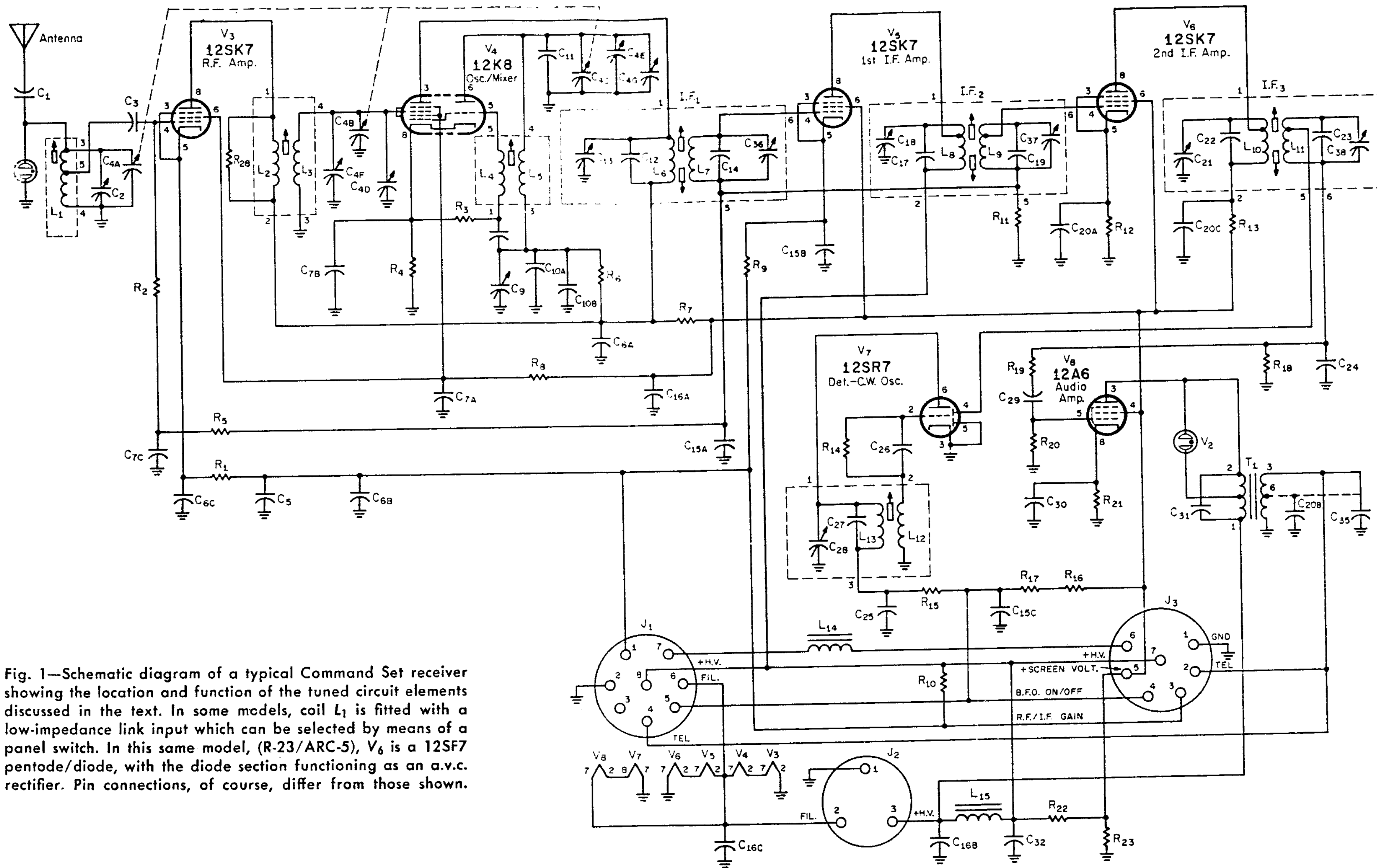


Fig. 1—Schematic diagram of a typical Command Set receiver showing the location and function of the tuned circuit elements discussed in the text. In some models, coil L_1 is fitted with a low-impedance link input which can be selected by means of a panel switch. In this same model, (R-23/ARC-5), V_6 is a 12SF7 pentode/diode, with the diode section functioning as an a.v.c. rectifier. Pin connections, of course, differ from those shown.

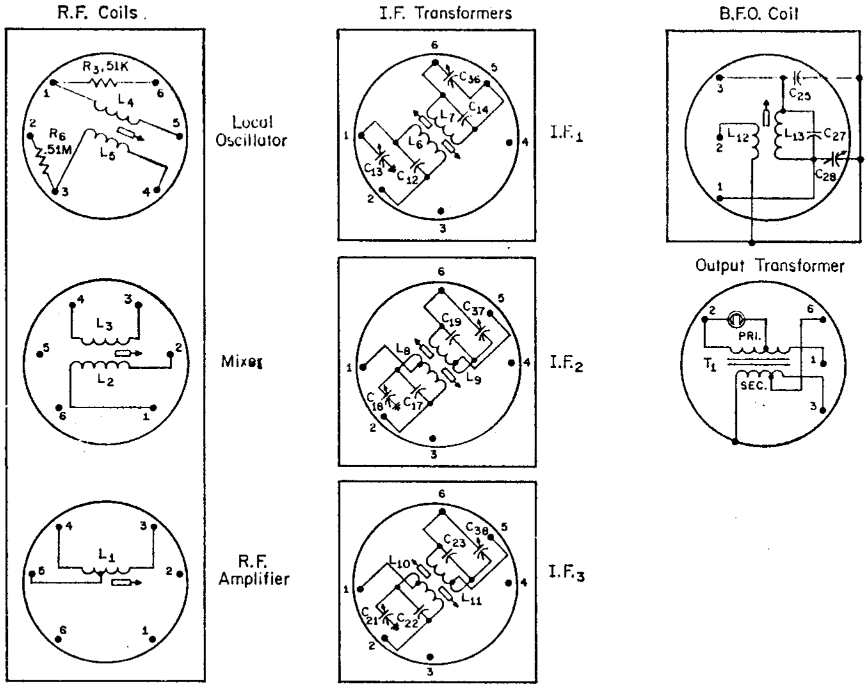


Fig. 2—Circuit data for the r.f. coils of the ARC-5.

RAT and RAV versions, 6AC7 tubes can be used in the i.f. versions, with appropriate filament changes and set realignment. The sharp cutoff characteristics of the 6AC7 does not harm the pseudo a.v.c. action in these receivers. It would *not* operate properly in the a.v.c.-equipped ARC-5 on postwar units.

The original bands will "track" accurately across the entire tuning range when properly aligned, when the correct i.f. is used and the correct part values installed.

The 3.5-7 mc receiver used an i.f. of 1660 kc, and the units covering the 9-27 mc bands used a 4,200 kc i.f. These are of course broad, but they eliminate most image response and most important, allow good tracking.

The I.F. Coils and the B.F.O.'s

Since the Type K-prototype Command Sets were the first superhetrodyne receivers used as standard quipment in the majority of U.S. combat aircraft, the design of the intermediate frequency circuits necessarily required thinking and solutions to problems that were, in 1935, new. Primarily, the receivers needed to combine light weight and small size with good sensitivity, and in the lower frequency sets, selectivity. Conversely, the high frequency receivers needed to be relatively broad because of the inherent drift limitations of airborne transmitters; remember, the command sets were designed for plane-to-plane communications in the 3—20 mc frequencies.

The engineers at Aircraft Radio Corporation had a solid background in commercial broadcast receivers, and had held patents on automatic volume control and "ganged," tracked superhet circuits. In designing for civil aircraft use, cost was secondary to performance. In military aeronautical designs, cost was hardly a factor; thus A.R.C. had great freedom to use the optimum in components and basic design.

Anyone who doubts this should look at an early command set coil: wound meticulously with enameled copper wire on a ceramic form, with all other dielectrics of clear ruby mica, even the small capacitors are specially-made. Such capacitors were, in 1935, unreliable, but Dr. F. H. Drake, at A.R.C. designed a stacked silver-mica capacitor, on a stainless steel screw, which could be adjusted to extremely fine tolerances. This was later converted to the silver-mica bell-shaped "button," for manufacturing convenience.

Images

In order to avoid leak-through of "image" signals, a high intermediate frequency is often used. The Type K design criteria called for an i.f. just under half the lowest tuneable r.f. frequency, thus eliminating all but the strongest images in the final output.

At low r.f. frequencies (190-550 kc; 520-1,500 kc) this Type K criteria gives quite a low i.f. In the military design this was proper because the lower two receivers were used for navigation or homing on ground stations, which could have rigidly controlled frequency standards.

At higher frequencies, above 3 mc, broadness was indicated in order to work with other airborne equipment. This was met admirably by i.f.'s of 1415 kc in the 3-6 mc receiver; 2830 kc in the 6-9.1 set, and 4,200 kc in the remaining h.f. units.

For ground use by amateurs or SWL's today, this broadness is undesirable, but may be eliminated by a variety of methods such as double-conversion into a "*0*-5er," the lowest band command receiver. These devices however do not concern us at present.

TABLE III – I.F. and B.F.O. Coil Data						
INTERMED. FREQ. (KC)	I.F. PRI. L_6, L_8, L_{10}	I.F. SEC. L_7, L_9, L_{11}	SPACING D_1	B.F.O. L_{12}	B.F.O. L_{13}	D_a
85 (NOTE 1)	1200t. * #38SSE	1210t. * #38SSE	0.250"	180t. * #38SSE	633t. * #38SSE	0.172"
239 (NOTE 2)	420t. * 5-41 LITZ	425t. * 5-41 LITZ	0.875"	70t. * 5-41 LITZ	213t. * 5-41 LITZ	0.172"
705 (NOTE 3)	100t. * 7-41 LITZ	102t. * 7-41 LITZ	0.875"	40t. * 7-41 LITZ	98t. * 7-41 LITZ	0.172"
1415 (NOTE 3)	47t. * 7-41 LITZ	48t. * 7-41 LITZ	0.875"	25t. * 7-41 LITZ	45t. * 7-41 LITZ	0.157"
1660	39t. * 7-41 LITZ	40t. * 7-41 LITZ	0.875"	22t. * 7-41 LITZ	39t. * 7-41 LITZ	1/32"
2830	35t. * 7-41 LITZ	36t. * 7-41 LITZ	0.875"	15 7/8"t. #34 e.	26 1/8"t. #30 DSE	1/32"
4200	24t. * 7-41 LITZ	25t. * 7-41 LITZ	0.875"	12 7/8"t. #32 e.	17 1/8"t. #30 e.	1/32"
2830	41t. #28e.	300t. * #38 SSE	FOR ARA, SCR-274-N	NOTES ON L_8–L_{11}: 1. TAPPED AT 400t. FROM START. 2. TAPPED AT 180t. FROM START. 3. TAPPED AT 30t. FROM START.		
4200	28 1/2 t. #24	200t. * #36 SSE				

Table III—I.f. and b.f.o. coil data for the command set series. Those windings marked by an asterisk are single layer windings; all others are universal wound.

Tracking

In order to "track" a superhet receiver, the antenna, r.f., and oscillator stages must tune together very closely, with the oscillator frequency differing from the r.f. by the intermediate frequency, in a most constantly accurate fashion. The problems of attaining really good tracking require a combination of carefully taken data on the circuit with a grasp of some intricate mathematics; for most of us, tracking is a matter of luck in home brew superhets.

Since, however, the designers in Boonton worked out tracking solutions for nine bands of command receivers between 190 kc and 27 mc, we can filch their data to build excellent conversions from the more common command receivers.

It is necessary to keep in mind only that the tracking solution remains the same for a given receiving gang tuning capacitor so long as the ratio of the highest tuned i.f. frequency to the lowest tuned frequency remains constant with respect to the i.f.

For instance, using the same 21 gang in the 1.5-3 mc receiver, with its 705 kc i.f., the ratio remains quite close for the 3-6 mc set, with its 1415 kc i.f., and the 3.5-7 mc prototype, with a 1660 kc intermediate frequency. Thus all three should track approximately correctly using the same padders such as C_{10} in the command circuit. This would hold true for any band you might choose, using the same tuning gang, so long as the ratios were about the same. The formula is this:

$$R = \frac{i.f.}{\frac{L + H}{2}}$$

where R is the ratio, $i.f.$ is the intermediate frequency, L is the lowest tuned frequency, and H is the highest. Thus, for the 1.5-3 mc set:

$$R = \frac{705}{\frac{1.5 + 3}{2}} = 313$$

To obtain correct tracking for 3.5-7 mc coverage with the same gang and oscillator padders work it backwards:

$$313 = \frac{unknown\ i.f.}{\frac{3.5 + 7}{2}}$$

$$i.f. = 313 \times 5.25$$

$$= 1643\ kc$$

This gives an i.f. of 1643 kc, very close to the 1660 "round number" actually used by A.R.C. engineers.

To work out tracking for a different i.f. would require considerably more math. Do it the easy way! Copy their data shown in Table III.

Coil strips for the r.f. section of the command receivers are available in surplus channels, generally in the 6-9.1 mc band, and are easily converted to higher frequencies. The author will supply the three section r.f. coils suitable for conversion at $1.00 per set and 4,200 kc i.f. transformers at 3 for $2, as long as his small supply lasts. Other sources include Rex Radio, 84 Cortland Street, Manhattan—(4,200 kc i.f. cans), Communications Equipment Corp., 343 Canal Street, Manhattan (i.f. and r.f. cans), Aircraft Radio Industries, 85 St. John Street, New Haven, Conn., Ritco Electronics, 7275-C Little River Tpk., Annandale, Va. ■

FLASH! 11,000 Miles Spanned On 144 Mc!

Occuring almost accidentally as an unscheduled shot-in-the-dark, a solid two-way contact was established between VK3ATN in Victoria, Australia and K2MWA of Homdel, New Jersey on November 28th on 144.90 mc which *has been confirmed*. Rendering obsolete the long-standing 5250-mile record between OH1NL and W6DNG, this feat comes very close to matching the 12,000-mile all-time v.h.f. record set achieved in 1956 on 50 mc between Japan and Argentina.

Regular moon bounce efforts between "T.R." Naughton, VK3ATN and the famed WA6LET group came to a halt during the wee hours of November 28th when the Australian learned of an equipment breakdown at the California end. However, with prior knowledge of WA6LET's schedule with the Crawford Hill Radio Club of Homdel, N.J., the 150-watt VK3ATN decided to "go all the way" for a long-haul direct contact with K2MWA. At approximately 5 A.M. EST, his signals were not only heard, but acknowledged, marking the beginning of a new era in long-distance moonbounce communications.

VK3ATN's antenna system, consists of a 50-wavelength rhombic, while the Homdel group, headed by W2IMU, used a full kw into a 60-foot dish.

Formal presentation of statements, correpondence and tape recordings was made to ARRL approximately two weeks later for official documentation and endorsement. — *K2ZSQ*