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REPORT ON THE ELECTRICAL SENSITIVITY, SELECTIVITY AND FIDELITY OF FORTY 1929 RADIO BROADCAST RECEIVERS

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MEASUREMENTS of the overall electrical performance of radio broadcast receivers by means of a standard modulated signal have been carried on since 1925 by the Radio Frequency Laboratories in connection with the receiver design work regularly undertaken on behalf of its manufacturing licensees. These measurements of the electrical fidelity, sensitivity and selectivity were at first confined to RFL models, that is to the prototype models furnished by RFL to the licensees and the production models as finally marketed. In the spring of 1927 the standards and test procedure were revised and the standard signal generator and attenuator were entirely redesigned and rebuilt. The standards and the test procedure which were adopted at that time are set forth below, and differ in minor details from those which have lately been adopted by the Standardization Committee (Receiving Set Sub-Committee) of the Institute of Radio Engineers.[1] These differences are enumerated elsewhere.

After the new apparatus had been completed it was decided to elaborate the test program into an extensive survey of the important receivers on the market. This program is consistent with the policy of and function of the RFL in keeping its licensees informed as to the contemporary art and the standing of their products in relation to it.

The first measurements in this program were published in June, 1928 in a confidential report to the RFL licensees designated as *Contribution from the Radio Frequency Laboratories No. 5*, Report of Measurements of the Sensitivity, Selectivity and Fidelity of Modern Broadcast Receivers, by Malcolm Ferris and W. D.

[1] The report and recommendations of this committee will be found in the *Yearbook of the Institute of Radio Engineers, 1929*, page 106.

Loughlin. The report covered twenty-one receivers of interest at that time (1927–1928) as follows:

Atwater Kent 36	**Kellogg 1927** (RFL)
Atwater Kent 38	Kolster 6D
Bosch 66 (RFL)	Kolster 6J
Bosch 57 (RFL)	**Majestic 70** (RFL)
Erla S62 (RFL)	Radiola 17
Erla S72 (RFL)	Radiola 18
Eveready DC (RFL)	Sparton AC 62
Eveready AC (RFL)	Splitdorf "Abbey"
Fada "Special"	Stewart Warner 700
Fada 10	Stromberg-Carlson DC
Grebe Sync. 7	

The present supplementary report contains the results of the measurements of forty important broadcast receivers of the current year (1929). These include the electrical sensitivity, selectivity and fidelity. Other electrical characteristics, such as overload analysis, harmonic distortion, regulation, hum, automatic volume control characteristic, etc., have been investigated and will be covered in a separate report.

A detailed description of the measurement technique has been given in Contribution No. 5. For present convenience of reference a brief outline of the procedure and standards is included here. The general test scheme is shown in the functional diagram, Fig. 1.

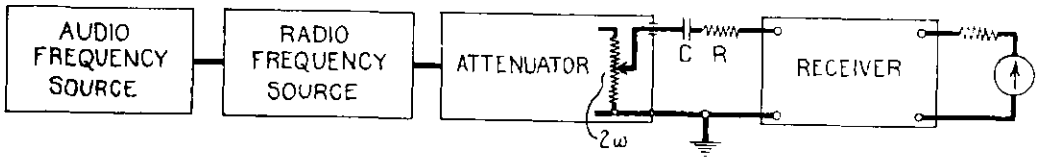

Fig. 1.

Standard Audio Output.—The standard audio output adopted is 100 milliwatts (0.1 watt) in a non-inductive resistance load which replaces the loud-speaker winding. The value of this resistance is adjusted with each receiver for maximum power output at 400 cycles. Arrangements are made to filter out the direct-current component whenever necessary.

It will be noted that the RFL standard output is twice that adopted by the Standardization Committee of the Institute of Radio Engineers (0.05 watt, see page 107 reference 1), which is

considered inadequate on account difficulties with noise disturbances in testing very sensitive receivers.

Standard Antenna.—The standard constants of the artificial antenna are:

$$C = 100 \text{ mmfds}$$

$$R = 20 \text{ ohms}$$

$$L = 0$$

These differ from those adopted by the Institute of Radio Engineers, which are as follows: (page 108, reference 1)

$$C = 200 \text{ mmfds}$$

$$R = 25 \text{ ohms}$$

$$L = 20 \text{ microhenries}$$

The Institute of Radio Engineers recommendations are believed to be just and will be adopted for the next report.

Standard Signal.—The standard modulated signal is of the symmetrical side-band type with 30% modulation. It may be represented mathematically by:

$$e = E_0 (1 + m \sin at) \sin \omega t$$

where E_0 is the carrier voltage (max.), m is the degree of modulation ($= 0.3$), $a = 2\pi \times$ modulation frequency, $\omega = 2\pi$ × carrier frequency.

Standard Tubes.—A set of standard tubes is maintained for these tests. These are selected for average characteristics and are checked from time to time in order to detect secular changes in these characteristics.

Electrical Sensitivity.—This is defined as the r.m.s. value of carrier voltage in the standard signal, as applied in series with the artificial antenna, required to produce standard (0.1 watt) output, the receiver having been carefully tuned. The modulation frequency is 400 cycles.

In addition to the *overall sensitivity*, which is the sensitivity for a signal introduced in the antenna, the operation of the several r.f. amplifier stages of the receiver has been studied in each case. These measurements are made by impressing the signal voltage successively on the grids of the several r. f. amplifier tubes through a 0.5 mfd condenser. The curve marked "1st Grid" therefore represents the sensitivity for a voltage directly applied to the grid

of the first amplifier tube; that marked "2nd Grid," to the second amplifier tube, and so forth. The difference between the "Antenna" and "1st Grid" curves represents the transmission of the antenna input circuit. Similarly, the difference between the curves for the mth and $m+1$th stages represents the gain in the mth stage.

The audio voltages at various points in the detector-audio-amplifier system are also of interest. These are shown by the dotted lines in the upper parts of the *Sensitivity Curves*. They represent the voltages corresponding to standard output.

Selectivity.—This is ordinarily measured at two frequencies, 600 kc (500 m) and 1000 kc (300 m) and is represented graphically. The receiver is first tuned to the standard signal (400-cycle modulation) and standard output obtained. The carrier frequency is then changed by a few kilocycles from the resonant value and the signal input is increased to regain standard output. The ratio of the two signal inputs is plotted against the departure in kilocycles from resonance. Readings are normally taken at steps of 5 kc.

Electrical Fidelity.—This is ordinarily measured at two carrier frequencies, 600 kc (500 m) and 1000 kc (300 m). The receiver is carefully tuned to the signal, which is first modulated at 400-cycles. The signal strength is adjusted for standard output. Then with the signal strength at this value, the modulation frequency is varied and the variation of audio frequency output current is noted. In representing this variation graphically the current output at 400 cycles is arbitrarily regarded as 100%.

Precautions.—All receivers are carefully aligned, and when necessary, balanced, prior to test in order to obtain optimum performance.

Tabular Description of the Receivers.—The important data of the 40 receivers have been assembled in compact form in Tables I and II. The receivers manufactured by RFL licensees are shown in bold face. In table II the selectivity is represented as the ratio taken from the selectivity curves at a departure from resonance equal to 20,000 kc. In many cases the selectivity curves are not symmetrical and in these cases the average values have been given.

TABLE I—TABULAR DESCRIPTION OF RECEIVERS

Trade name of receiver	Number of RF Stages	Number of Tuned Ckt	Type of RF Amplifiers	Type of Detector	Type of 1st AF Amplifier	Type of Power Output System	Method of stabilizing RF Amplifier	Type of Speaker	Type of Cabinet	List Price
Amrad—70	3	4	226	227	226	250	Balanced	Dynamic	Console	$295.00
Atwater Kent—53	3	3	226	227	226	PP–171	Losser	Dynamic	Console (M)	117.00
Atwater Kent—55	2	3	224	227	227	PP–245	SG Tubes	"	Table (M)	122.00
Balkite—A	3	3	227	227	227	PP–112	Balanced	"	Console (W)	175.00
Bosch—48	3	4	224	227	None	PP–245	SG Tubes	"	"	168.50
Crosley—"Show Box"	3	3	226	227	226	PP–171	Balanced	Dynacone	Table (M)	105.00
Crosley—41-S	3	3	224	227	227	PP–245	SG Tubes	Dynacoil	" (M)	113.00
Earl—32	3	4	227	227	227	PP–245	Balanced	Dynamic	Console	191.50
Edison—R2	3	4	226	227	226	250	Losser	"	"	225.00
Eveready—32	3	4	227	227	227	PP–171	RFL	"	"	175.00
Fada	4	4	227	227	227	PP–210	Balanced	Cone	Table (W)	160.00
Freed Eisemann—NR80	4	4	227	227	227	PP–171	"	Dynamic	Console	———
Freshman—N	3	3	226	227	226	250	Losser	Dynamic	Console	215.00
Kellogg—515	2	3	K E	L L	O G	G	RFL	"	" (W)	99.50
Kellogg—516	4	5	K E	L L	O G	G	RFL	"	Console	375.00
King	3	4	226	227	226	PP–171	Balanced	Cone	Table (M)	160.00
Kolster—K-21	4	4	226	227	226	171	Losser	"	Table (W)	160.00
Majestic—90	4	5	227	227	None	PP–245	RFL	Dynamic	Console	137.50
Mohawk	4	4	226	227	227	PP–171	Losser	Cone	Drawer Type	147.00
Philco—65	2	3	224	227	None	PP–245	SG Tubes	Dynamic	Console	119.50
Philco—512	3	4	226	227	226	171	Balanced	"	Console	———
Radiola—44	2	3	224	224	None	245	SG Tubes	Cone	Table (W)	110.00
Radiola—60	2*	3	227	227	"	171	Balanced	Cone	" (W)	147.00
Radiola—64	2*	3	227	227	"	250	"	Dynamic	Console	625.00
RFL—3	3	4	224	227	"	PP–245	SG Tubes	"	———	———
RFL—4	3	4	222	201A	"	112A	"	Cone	———	———
RFL—Exp. 3	3	4	227	227	227	PP–171	RFL	Dynamic	———	———
RFL—Exp. 4	4	5	227	227	227	PP–245	"	"	———	———
Silver—95	3	4	224	224	227	PP–245	SG Tubes	"	Console	160.00
Sonora—A30	3	4	A R	C T	U R	U S	Low gain	"	"	225.00
Sparton	5	4	227	227	227	PP–245	"	"	Table (W)	189.50†
Splitdorf—M5	3	4	226	227	226	250	Losser	"	Console	225.00
Standard—227	3	4	R O	G E	R S-32	PP R-15's	RFL	"	———	———
Standard—AVC	3	4	224	R-32	R-32	PP R-15's	SG Tubes	"	———	———
Steinite—40	3	4	227	227	227	PP-171	RFL	"	Console	135.00
Steinite—10	3	4	224	227	None	PP–245	SG Tubes	"	"	
Stewart Warner—900	3	4	227	227	227	PP–245	Balanced	"	"	142.50
Stromberg Carlson—635	3	4	227	227	227	171	"	Cone	Table (W)	185.00
Stromberg Carlson—641	3	4	224	227	None	245	SG Tubes	"	" (M)	155.00
Victor—R32	5	4	226	227	226	PP-245	Balanced	Dynamic	Console	155.00

NOTE: PP—Push-pull. SG—Screen grid. CG—Control grid. * I.f. Amplifier. † With tubes.

TABLE II—TABULAR DESCRIPTION OF RECEIVERS AND ELECTRICAL PERFORMANCE

Trade name of receiver	Type of Antenna Coupling System	Type of Volume Control	Type of Detection	Sensitivity in microvolts		Selectivity ratio (average for 2nd channel)		Fidelity (1000kc) in per cent	
				600 KC	1000 KC	600 KC	1000 KC	100 cycles	3000 cycles
Amrad—70	Tuned	Ant. Res.	G	300	40	300	75	60°	5°
Atwater Kent—53	Impedance	Ant. Res.	G	1500	400	150	10	50	50
Atwater Kent—55	Tuned	SG Bias	P	300	50	300	15	70	35
Balkite—A	Tuned	Plate Voltage	G	150	200	200	25	60	40
Bosch—48	**Tuned**	**CG Bias**	**P**	**50**	**20**	**1700**	**60**	**85**	**35**
Crosley—"Show Box"	Impedance	Ant. Pot.	G	300–120†	120–70†	150	30	75	45
Crosley—41-S	Tuned	SG Bias	P	35	15	250	85	50	30
Earl—32	Tuned	———	G	250	55	150	20	45	35
Edison—R2	Tuned	RF Amplf. Res.	G	2000	700	500	90	80	30
Eveready—32	**Tuned**	**CG Bias**	G	45	25	450	65	55	35
Fada	Tuned-(loop)	———	G	40	15	800	40	60	60
Freed Eisemann—NR80	Tuned	CG Bias	G	100	100	150	15	70	40
Freshman—N	Impedance	Ant. Res.	G	2000	150	70	25	25	25
Kellogg—515	**Tuned**	**CG Bias**	**G**	**200†**	**250†**	**30**	**8**	**35**	**35**
Kellogg—516	**Tuned**	**CG Bias**	**G**	**10†**	**10†**	**1000**	**100**	**50**	**30**
King	Tuned	Ant. Res.	G	500	150	200	30	50	55
Kolster—K-21	Impedance	Ant. Rheo.	G	100	100	325	35	60	50
Majestic—90	**Tuned**	**CG Bias**	**P**	**100**	**60**	**3200**	**300**	**75**	**35**
Mohawk	Tuned	RF Ampl. Pot.	G	300	700	400	6	45	60
Philco—65	Tuned	SG Bias	P	700	200	200	35	30	20
Philco—512	Tuned	Ant. Pot.	G	200	15	1500	80	30	20
Radiola—44	Tuned	SG Bias	P	600	700	80	30	140	60
Radiola—60	Impedance	CG Bias	P	50	30	1000	600	55	45
Radiola—64	Impedance	AVC	P	60	Osc.	2000	——	90°	10°
RFL—3-Tetrode	**Tuned**	**CG Bias**	P	85	30	1200	700	95	30
RFL—4-Tetrode	**Tuned**	**Fil.**	**P**	**8**	**2**	**1000**	**160**	**80**	**35**
RFL—3-227	**Tuned**	**CG Bias**	**G**	**12**	**6**	**400**	——	**50**	**20**
RFL—4-227	**Tuned**	**CG Bias**	**G**	**1.5**	**1.2**	**6000**	——	——	——
Silver—95	Impedance	SG Bias	P	40	25	600	25	70	40
Sonora—A30	Tuned	Plate Rheo.	G	100	100	900	65	85	20
Sparton	Tuned	CG Bias	P	100	100	1600	40	50	30
Splitdorf—M5	Tuned	RF Amplf. Res.	G	2000	1500	400	——	90	55
Standard—227	**Tuned**	**CG Bias**	**G**	**20**	**10**	**1000**	**35**	——	——
Standard—AVC	Tuned	**AVC**	**P**	**15**	**10**	1300	**150**	**80**	55
Steinite—40	**Tuned**	**Ant. Pot.**	**G**	**40**	**15**	**450**	**25**	——	——
Steinite—10	**Tuned**	**CG Bias**	**P**	**55**	**25**	**900**	**85**	70°	35°
Stewart Warner—900	Tuned	CG Bias	G	300	70	250	25	30	40
Stromberg Carlson—635	Tuned	Ant. Pot.	G	70†	25†	400	25	85	40
Stromberg Carlson—641	**Tuned**	**CG Bias**	**P**	**70–25†**	**20–15†**	**1500†**	70	85	**45**
Victor—R32	Impedance	Ant. & RF Amp. Pot.	G	55	30	400	50	70	70

Note: G—Grid rectification. P—Plate rectification. °At 600 KC only. †Artificial antenna capacity equals 200 mmfds.