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PROCEDURE FOR ADJUSTING PERCENTAGE MODULATION OF TEST EQUIPMENT USED TO CALIBRATE ILS RECEIVERS

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PROCEDURE FOR ADJUSTING PERCENTAGE MODULATION OF TEST EQUIPMENT USED TO CALIBRATE ILS RECEIVERS

SUMMARY

A procedure is here described for calibrating the percentage modulation and for adjusting to equal amplitude 90- and 150-cycle per second localizer test signals when using the Boonton Type 211-A radio-frequency signal generator together with the Collins 479S or with the Wedd Laboratories, Incorporated, CA-1374 audio-signal generators The procedure is used at the present time at the Technical Development and Evaluation Center of the Civil Aeronautics Administration, Indianapolis, Indiana, to calibrate the test equipment used to standardize localizer and glide-slope receivers

INTRODUCTION

Those who are experienced in operating or maintaining the airborne radio receivers used with the Instrument Landing System (ILS) are well aware of the advantages that result from accurately calibrating the test equipment prior to adjusting the receivers to their required standards It is a well-known fact that the test equipment must be calibrated to a greater degree of accuracy than is required for the receivers, so that more precise adjustments can be made on the receivers

During the past few years several systems for measuring and adjusting the percentage modulation of the localizer and glide-slope test signals have been evolved, namely, the oscillator-mixer-amplifier-oscillograph method, the two-meter method, and the trapezoidal-pattern method All of these have been used and evaluated at TDEC, and it was found that they were usable but that a higher degree of accuracy was desirable The method now used at this Center to adjust the percentage modulation is described in this report

TEST EQUIPMENT

The following is a list of the test equipment used to calibrate the localizer and glide-slope receivers

Boonton Radio Corporation
- Model 211-A radio-frequency (rf) generator
- Model 212-A glide-slope test set (Univerter)

Collins Radio Corporation
- Model 479S audio-signal generator

Measurements Corporation
- Model 202 high-frequency (HF) Barretter

Sorenson & Company, Incorporated
- Nobotron direct-current (dc) voltage regulator
- Model 1000S alternating current (ac) voltage regulator

The Superior Electric Company
- Type SVR 4106 automatic ac voltage regulator

Allen B Du Mont Laboratories, Incorporated
- Model 304H oscillograph

Ballantine Laboratories, Incorporated
- Model 300 ac voltmeter

Weston Electrical Instrument Corporation
- Model 430 dc voltmeter

Miscellaneous test meters, such as cathode and flag-current meters

Crystal-controlled oscillator built at TDEC

A quarter-wave shorting stub for 109 9 megacycles (Mc)

A quarter-wave shorting stub for 333 8 Mc

TEST SETUP

A block diagram of the test setup used at TDEC is shown in Fig 1

1 The automatic voltage regulator Type SVR 4106 provides regulated input power of

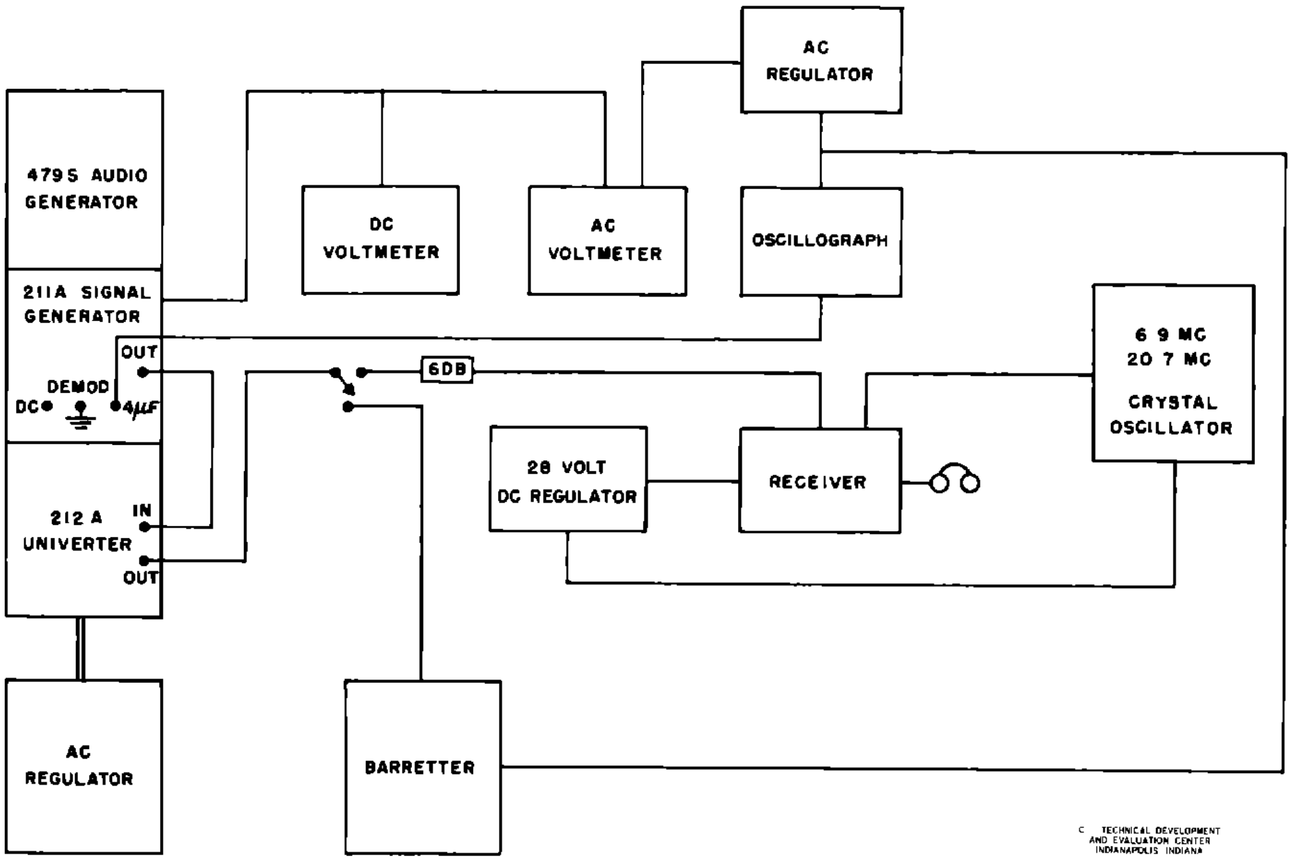

Fig 1 Block Schematic Diagram of Test Setup at TDEC

115 volts ± 1 5 volts to the navigation test rack consisting of the 211-A rf signal generator, the 212-A glide-slope test set, and the 479S audio-signal generator

2 The Sorensen Model 1000S ac voltage regulator provides regulated voltage of 115 volts ± 0 5 volt to the Barretter, the Ballantine ac voltmeter, and the Du Mont 304H oscillograph

3 The dc voltmeter and the Ballantine ac voltmeter are permanently connected in parallel from Pin 5 of Plug PL-201 to ground Pin 5 connects to the screen grid of the 6AK5 output tube in the 211-A signal generator These voltmeters are calibrated every three months by the use of a standard cell, a high-precision potentiometer, a volt box, and a galvanometer The dc voltmeter is calibrated in the 60- to 160-volt range, and the Ballantine ac voltmeter in the 30- to 60-volt range These are the normal operating ranges, and by calibrating at these points the meters can be set more accurately

4 The instruments used to calibrate the 211-A meters are calibrated in the same manner already mentioned The test equipment is checked and calibrated approximately every three months

5 The Y-axis input of the Du Mont 304H oscillograph is connected to the four-microfarad demodulated-output (DEMOD) terminal of the 211-A generator The line-frequency test signal, which is a 60-cycle per second (cps) sine wave, on the 304H oscillograph is interconnected to the X-axis The ground terminals of the oscillograph are connected to the ground terminal of the 211-A signal generator

6 The harmonic distortions of the 90- and 150-cps modulating signals from the 211-A signal generator and from the 212-A Univerter are closely checked with a General Radio Company wave analyzer during the normal three-month calibration checks Measurement of the distortion is made at the DEMOD terminals of the 211-A and 212-A signal generators The total harmonic distortion should not exceed two per cent for the 211-A generator or five per cent for the 212-A Univerter when the output signal is

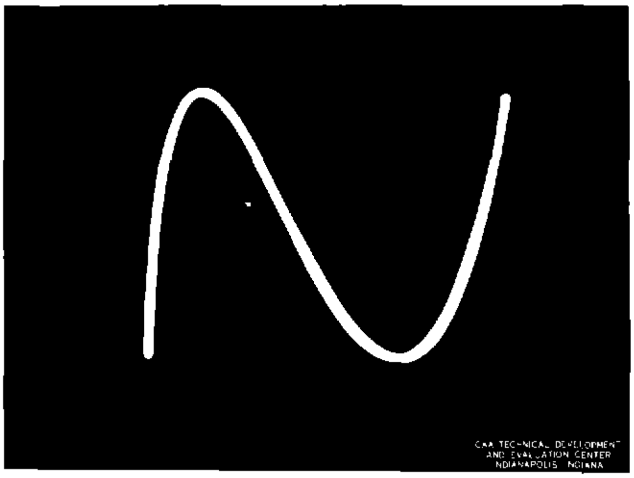

Fig 2 Oscillograph Pattern of 90-cps Modulating Signal Swept at 30-cps Rate (Closed for Condition A)

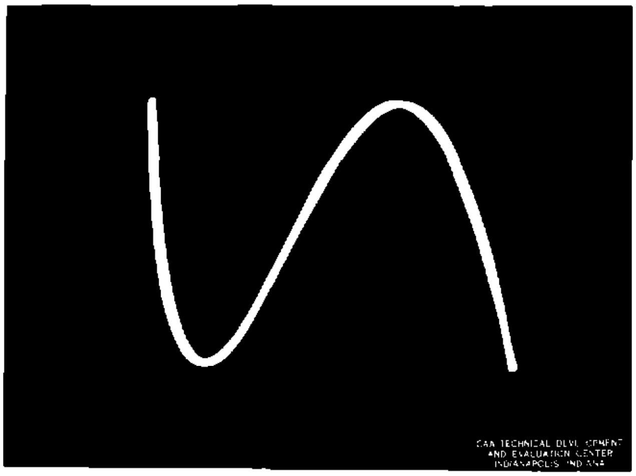

Fig 3 Oscillograph Pattern of 90-cps Modulating Signal Swept at 30-cps Rate (Closed for Condition B)

TABLE I

MEASUREMENT OF PHASE RELATIONSHIP OF 90- TO 150-CPS SIGNAL

479S Audio-Generator Variable Phase Setting

Condition A		Condition B	
90-cps (degrees)	150-cps (degrees)	90-cps (degrees)	150-cps (degrees)
7 2	67 7	67 1	31 9
127 2	139 7	187 1	103 9
247 2	211 7	307 1	175 9
	283 7		247 9
	355 7		319 9

modulated 40 per cent by either the 90- or the 150-cps voltage

7 Measurement made at the DEMOD terminal of the 211-A signal generator of all such spurious signals as the ac hum and its harmonics should not exceed a total of one per cent of the DEMOD output The total percentage is computed as the square root of the sum of the squares of each individual signal

PHASING OF THE 90- AND 150-CPS SIGNALS

The following section describes a method used at TDEC for determining the phase relationship of the 90- and the 150-cps signals

The output of the 90-cps filter is connected to the input terminal of the vertical amplifier of the oscillograph A 30-cps signal from the jack, labeled VAR ϕ GEN, in the 479S audio generator is connected to the input terminal of the horizontal amplifier of the oscillograph The 30-cps variable-phase control, labeled OMNI RANGE, in the 479S audio generator is rotated until the pattern on the oscillograph is closed See Fig 2 The variable-phase dial reading is recorded under the column headed "Condition A, 90-cps " See Table I The variable-phase control is rotated approximately 60° until the pattern is again closed See Fig 3 This is the pattern for Condition B at 90 cps The difference in the patterns between Conditions A and B is a 180° phase shift of the 90-cps signal The variable-phase dial reading is recorded under the column headed "Condition B, 90-cps " See Table I The variable-phase control is rotated through 360°, and the dial readings are recorded under the appropriate columns for each time the pattern is closed There will be a total of six points where the pattern is closed

The leads are then disconnected from the output of the 90-cps filter and are connected to the output of the 150-cps filter All other connections remain the same

The variable-phase dial is rotated until the pattern on the oscillograph is closed See Fig 4 The dial reading is recorded under the column headed "Condition A, 150-cps " See Table I The variable-phase control is again rotated approximately 36° until the pattern is closed See Fig 5 This

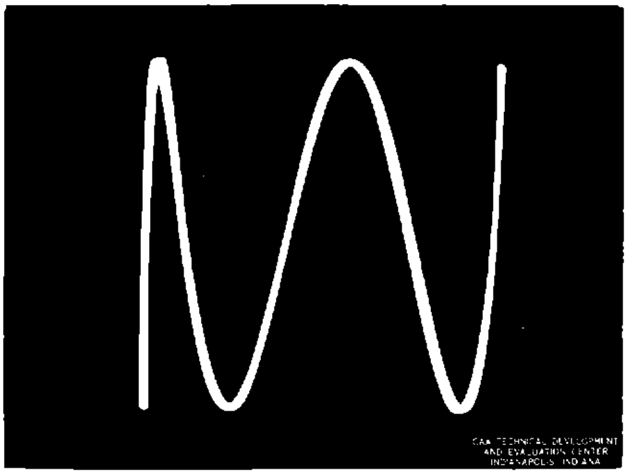

Fig 4 Oscillograph Pattern of 150-cps Modulating Signal Swept at 30-cps Rate (Closed for Condition A)

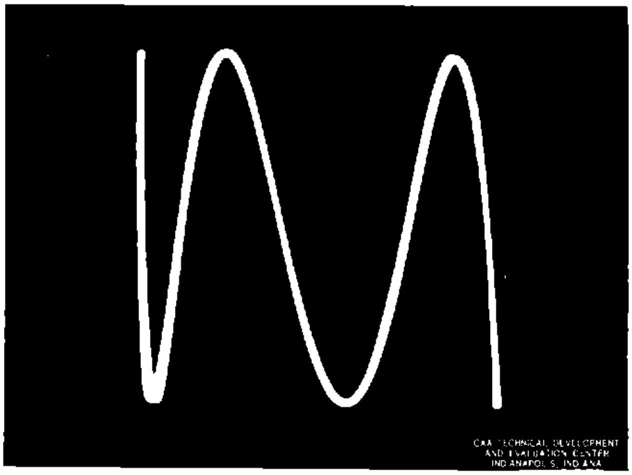

Fig 5 Oscillograph Pattern of 150-cps Modulating Signal Swept at 30-cps Rate (Closed for Condition B)

is the pattern for Condition B at 150 cps, and the dial reading is recorded under the column headed "Condition B, 150-cps " See Table I The variable-phase dial is rotated through 360°, and the dial readings are recorded under the appropriate columns each time the pattern is closed There will be a total of 10 points where the pattern is closed in 360° rotation of the variable-phase dial

The information obtained in Table I is inspected to determine which two variable-phase settings from the 90-cps column will match any two phase settings from the 150-cps column under the Condition A heading These phase settings are matched when they are within approximately 23° of each other See Table II The sum of the differences between each pair of matched phase settings (90- and 150-cps settings) will equal 24° ± 0 1° The measured phase difference between two matched phase settings is the phase relationship between the 90- and 150-cps signals when compared with a 30-cps signal See Table II

If the phase relationship between the 90- and 150-cps signals does not equal the 12° ± 1°, a correction should be made This is done by connecting a capacitor across the output terminals of either the 90- or the 150-cps alternators, whichever one requires the less capacity to produce the proper phase relationship The actual value of the capacitor will have to be determined by measuring the resultant phase shift It is desirable to adjust the phase difference to 12°, since this is the phase relationship of these two signals in the glide-slope transmitters See Fig 6

TABLE II

RESULTANT PHASE RELATIONSHIP DETERMINED FROM TABLE I

Matched Patterns	Matched Phase Settings		Difference Between Matched Phase Settings (degrees)	Sum of Differences Between Matched Phase Settings (degrees)
	90-cps (degrees)	150-cps (degrees)		
Condition A	7 2	355 7	11 5	24 0
	127 2	139 7	12 5	
Condition B	187 1	175 9	11 2	24 0
	307 1	319 9	12 8	

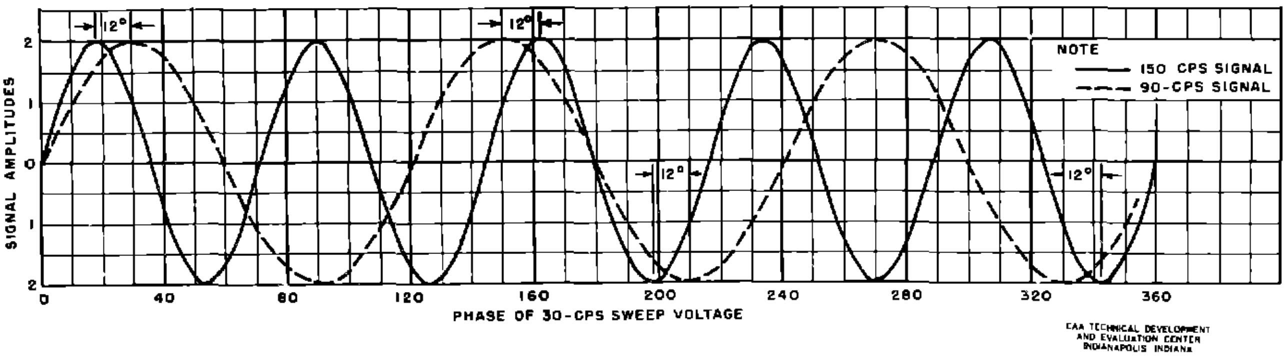

Fig 6 90- and 150-cps Signal Phase Relationship in the Glide-Slope Transmitters (Referenced to 30 cps)

OPERATING PRINCIPLE AND CALIBRATION OF THE BARRETTER

This instrument operates by unbalancing a Wheatstone bridge as a result of passage of rf current through a fine platinum filament known as a bolometer The amount of adjustment of a calibrated potentiometer required to restore the bridge balance is an accurate measure of rf power in the bolometer element The potentiometer is calibrated in terms of microvolts, since the rf power is always dissipated in a fixed impedance of 53 ohms

The bolometer consists of a 0 0001-inch diameter platinum filament in a small, highly evacuated glass envelope The resistance of this element is a direct function of its temperature, which in turn will be affected by the passage of electric current through the filament To eliminate other sources of temperature variation, the bolometer is contained in a thermostatically controlled oven

The entire bridge, in which the bolometer forms a part of one arm, is termed a Barretter and is driven by a regulated source of voltage at 60 cps An ac bridge amplifier with an indicating circuit increases the sensitivity of the system in its response to unbalanced potentials across the Barretter bridge This permits the use of a simple, rugged type of galvanometer

Prior to conducting the test, the Barretter should be calibrated in the following manner

1 It should be warmed up for at least one hour prior to making any tests

2 Using a coaxial T-connector, connect the shorting stub for the desired frequency across the signal input terminals The purpose of this stub is to prevent any dc or 60-cps ac from entering the bridge input circuit and damaging the bolometer This stub also acts as a high-pass filter at the desired frequency

3 Throw the check-zero test switch to CHECK ZERO position Adjust the galvanometer pointer to the red center mark

4 Throw the check-zero test switch to the TEST position and depress the CHECK button Rotate the microvolt dial until the galvanometer pointer is over the red line The dial should read 50,000 (50K) ± 2 per cent. The purpose of this check is to determine whether circuit constant or bolometer characteristics have changed, if so, the equipment is in need of maintenance

5 The Barretter is thus calibrated and ready for use

CALIBRATING THE TEST EQUIPMENT

1 Turn on all power All test equipment must be warmed up for at least one hour prior to making any measurements

2 Set the meters at zero in the 211-A signal generator in accordance with the procedure set forth in Technical Development Report No 122 [1]

3 Interconnect the 211-A signal generator and the 212-A glide-slope test set

4 Turn the 211-A oscillator selector switch (marked OSC SEL) to the master oscillator (MO) and adjust the megacycle dial to 133 8 Mc Then the 212-A output frequency will be 333 8 Mc

[1] Francis J Gross and Max Kincaid, "Procedure for Calibrating Collins 51R-1 Navigation and BC733D Localizer Receivers," CAA Technical Development Report No 122, September 1950

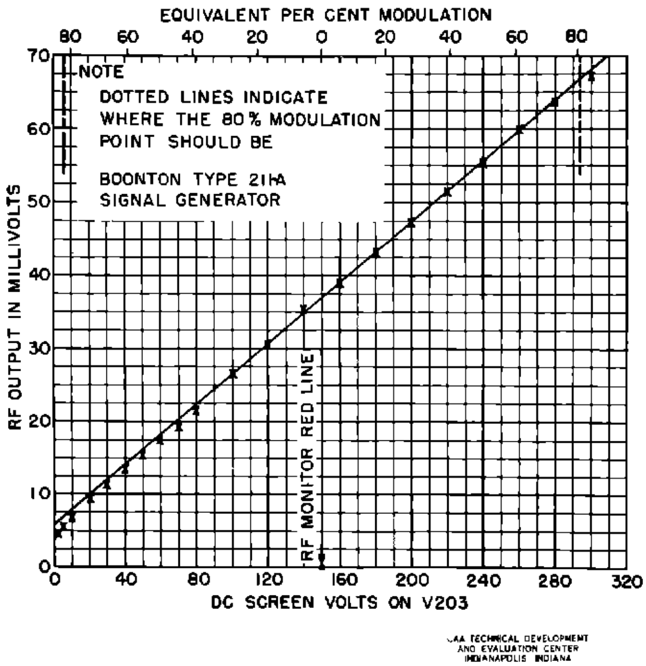

Fig 7 Radio-Frequency Output (in Microvolts) Versus dc Screen Volts on V203 of the 211-A Signal Generator

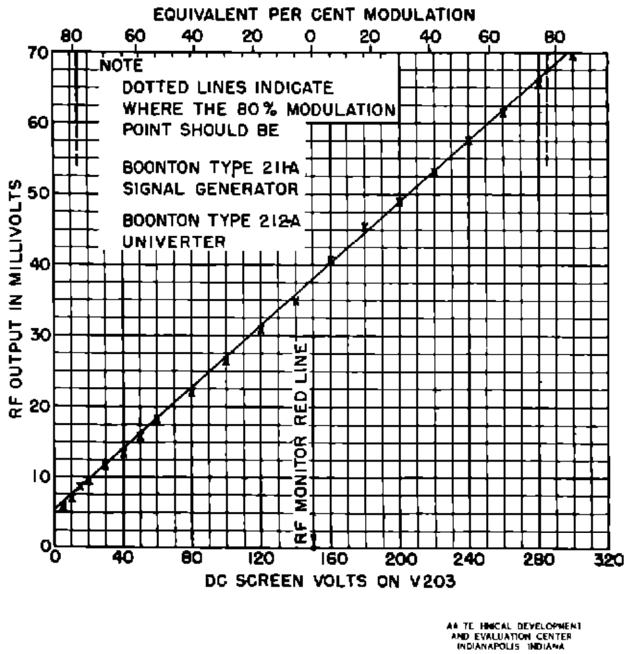

Fig 8 Radio-Frequency Output of Univerter (in Microvolts) Versus dc Screen Volts on V203 of 211-A Signal Generator

5 Set the microvolt dial of the 211-A generator to 0 1 volt The needle of the output monitor meter in the 212-A test set should be on the red line of the meter face when the function selector switch S-302 is set to the Univerter level position, labeled UNIV LEVEL, and when the output cable is terminated with a 53-ohm load Adjust the Univerter gain control to compensate for any deviation from the proper reading which indicates the Univerter level

6 Calibrate the Barretter

NOTE FOR STEPS 7 THROUGH 18

A standard glide-slope signal is modulated 40 per cent by each of the 90- and 150-cps signals When the carrier is modulated by either the 90- or 150-cps signal voltage, the carrier will vary ± 40 per cent from its normal stable amplitude As indicated in Figs 7 and 8, the rf outputs of the 211-A signal generator and of the 212-A Univerter are directly proportional to the dc screen voltage on the 211-A output tube, therefore, any change in the screen voltage on this tube means a proportional change in the rf outputs of both units This will be indicated in Steps 7 through 18

7. Interconnect the output of the 212-A test set with the Barretter input Set the microvolt dial of the 211-A signal generator at approximately 37K, and adjust the needle of the rf monitor meter to coincide with the red line with no modulation See Fig 7

8 Set the Barretter microvolt dial at 37K Increase or decrease the microvolt output of the 211-A signal generator until the Barretter galvanometer needle is on the red line

9 Record the screen voltage of the 6AK5 output tube of the 211-A signal generator, which voltage is indicated by the Weston dc voltmeter This will be approximately 150 volts

10 Reduce the reading of the Barretter microvolt dial to 22 2K This value is obtained by the following equation

37K - (37K x 0 4) = 22 2K

Reduce the rf level control in the 211-A signal generator until the Barretter galvanometer needle is on the red line

11 Record the screen voltage of the output tube of the 211-A signal generator which voltage is indicated by the Weston dc voltmeter This will be approximately 78 volts dc

12 Compute the change in the screen voltage from the normal value when the

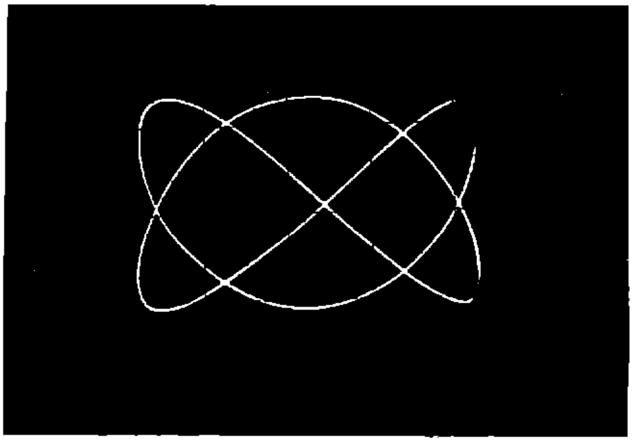

Fig. 9 Oscillograph Pattern of 90-cps Modulating Signal Swept at 60-cps Rate

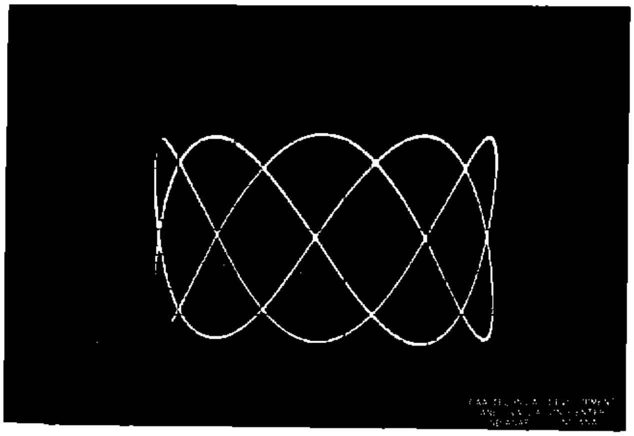

Fig. 10 Oscillograph Pattern of 150-cps Modulating Signal Swept at 60-cps Rate

carrier is reduced by 40 per cent, that is

$$\text{dc volts}_1 - \text{dc volts}_2 = \text{dc volts}_3$$

The value of dc volts_1 is 150 volts dc, as obtained from Step 9, and that of dc volts_2 is 78 volts dc from Step 11, or

$$150 \text{ volts dc} - 78 \text{ volts dc} = 72 \text{ volts dc}$$

13 The ac modulation voltage equivalent to the dc voltage computed in Step 12 is

$$\text{volts dc}_3 \times 0\ 707 = \text{ac voltmeter reading,}$$

or

$$72 \times 0\ 707 = 51\ 0 \text{ volts}$$

This is the voltage necessary for 40 per cent modulation

14 Reset the rf monitor meter of the 211-A signal generator to the red line Check the dc screen voltage, which should be the same as in Step 9

15 Disconnect the output cable of the 212-A test set from the Barretter input Connect the output cable through a six-decibel (db) pad to the input of the receiver being tested

16 Switches on the 479S generator must be set to coincide with the following position The switch marked FUNCTION SELECTOR is set at the TONE LOCALIZER position, and the switch marked LOCALIZER is set at the position labeled CAL 90 The pattern appearing on the oscillograph will be similar to that shown in Fig 9

17 Adjust the MOD LEVEL control of the 211-A signal generator until the ac voltage, as read on the Ballantine voltmeter, is equal to the same level of voltage obtained in Step 13 (51 0 volts ac)

18 Set the LOCALIZER switch at the CAL 150 position The pattern appearing on the oscillograph will be similar to that shown in Fig 10 Adjust the 150-cps potentiometer in the 479S generator until the ac voltage, as indicated by the Ballantine voltmeter, is the same as obtained in Step 17

19 Recheck Steps 17 and 18 to make sure that the voltage amplitudes for the 90-cps and 150-cps signals are equal

20 Change the 479S generator switch marked LOCALIZER to 0 db, and note the pattern on the oscillograph This pattern should be a typical Lissajous figure showing the peaks of the 90- and 150-cps signals when swept at a 60-cps rate See Figs 11 and 12 The two peaks should just meet when the amplitudes of both modulating voltages are equal and when the phase relationship between the 90- and the 150-cps signals is within 12° ± 1 0° Figs 13 and 14 indicate that the amplitudes of the 90- and the 150-cps modulating signals are unequal

21 The output of the crystal oscillator is used to set accurately the frequency of the master oscillator in the 211-A signal generator to the desired test frequency

22 After the foregoing procedure, the test equipment is calibrated and ready for the standardization tests and for operational adjustments on the glide-slope receiver

Calibration of localizer receivers requires the same procedure as described previously for the glide-slope receiver, with the following exceptions

Step 3

Omit in its entirety

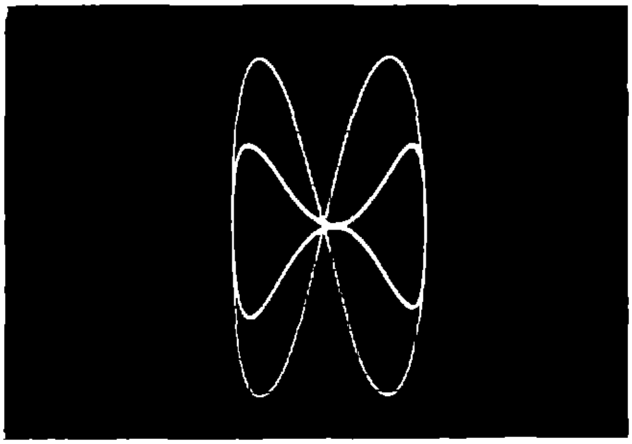

Fig. 11 Oscillograph Pattern of Composite Wave for 90- to 150-cps Modulating Signal Swept at 60-cps Rate (Condensed View)

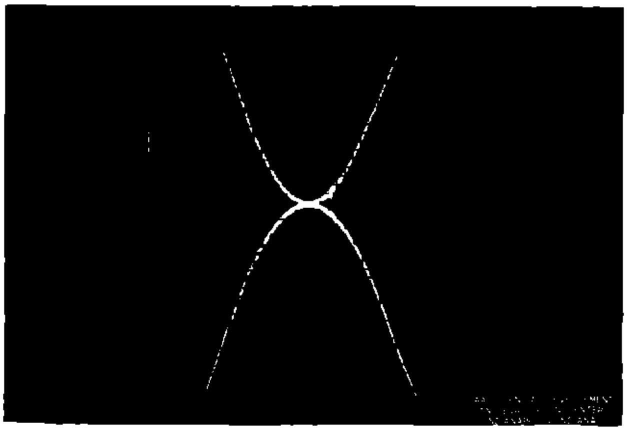

Fig. 12 Oscillograph Pattern of Composite Wave for 90- to 150-cps Modulating Signal Swept at 60-cps Rate (Expanded View)

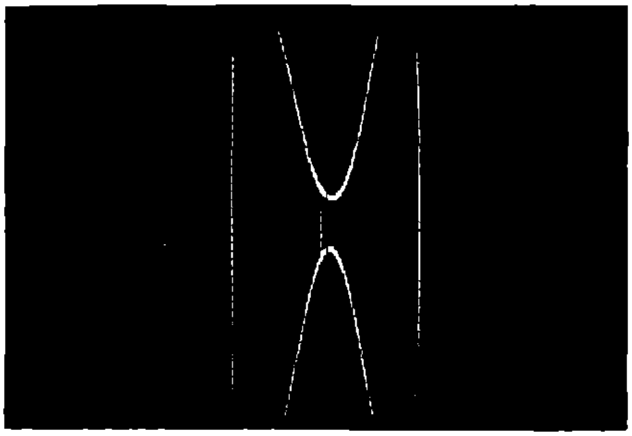

Fig 13 Oscillograph Pattern for 90- to 150-cps Modulating Signal Swept at 60-cps Rate When the Amplitude of the 90-cps Signal is + 0 5 db Above the 150-cps Level (Expanded View)

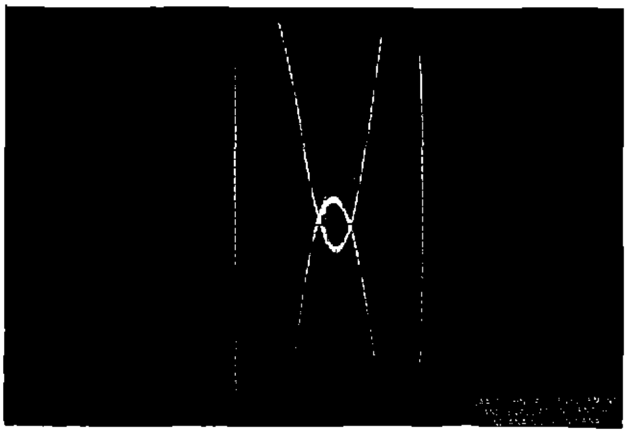

Fig 14 Oscillograph Pattern for 90- to 150-cps Modulating Signal Swept at 60-cps Rate When the Amplitude of the 150-cps Signal is + 0 5 db Above the 90-cps Level (Expanded View)

Step 4

Frequency is 109 9 Mc Omit last sentence

Step 5

Omit in its entirety

Step 7

Interconnect the 211-A signal generator and the Barretter

Steps 1 to 22

Change all references from 40 per cent modulation to 20 per cent modulation, and from 2 db to 4 db ratio

Steps 10 through 13

Change computations from 40 per cent to 20 per cent modulation

The VOR receivers are calibrated in accordance with the procedure described in Technical Development Report No 122 [2]

TEST DATA AND COMMENTS

The following illustrations show data obtained during the calibration of the test equipment at TDEC

[2] Ibid

Fig 6

The curves indicate the phase relationship between the 90- and 150-cps signals when the oscillograph sweep voltage is a 30-cps sine wave, and when the phasing is adjusted to produce a minimum peak amplitude of the 90- and 150-cps composite signal When the 90- and 150-cps signals are phased so that their peaks are separated by 12° and when the amplitude of each signal is adjusted to produce 40 per cent modulation of the carrier, the amplitude of the composite signal will produce approximately 74 per cent modulation of the carrier level

Fig 7

As shown by the data, the rf output of the Type 211-A signal generator is almost directly proportional to the screen voltage applied to the Type 6AK5 output tube V203 This figure also indicates the change in screen voltage necessary to increase or decrease the rf output level by a desired percentage value It will be noted that due to the slight nonlinearity of the curve at the extreme ends, there is a small error at the two 80 per cent modulation points The solid lines indicate the measured values, and the broken lines indicate the correct percentage values. To determine the root mean square (rms) value of the ac voltage needed to modulate the rf carrier, the following formula is used Multiply the change of the screen voltage from 0 per cent modulation to the desired per cent modulation by 0 707 This is obtained by the following equation

ac modulating volts = change in screen volts multiplied by 0 707.

The results shown in Fig 7 were obtained under the following test conditions

a The dc screen voltage was supplied from an external variable power supply At those levels above the normal screen-operating voltage (180 to 300 volts), the screen power was applied intermittently only long enough to obtain a reading and then allowed to cool before the next reading was taken This was done to prevent any change in the tube characteristics during the tests

b The Barretter, in conjunction with the output attenuator of the 211-A signal generator, was used to indicate the rf-output level in millivolts at each value of the screen grid voltage

Fig 8

These results are the same as those shown in Fig 7, except that they show the output of the 212-A Univerter The rf output of the 211-A signal generator is fed to the input of the Univerter, which increases the signal frequency by 200 Mc The test conditions are the same as those used during the test on Fig 7

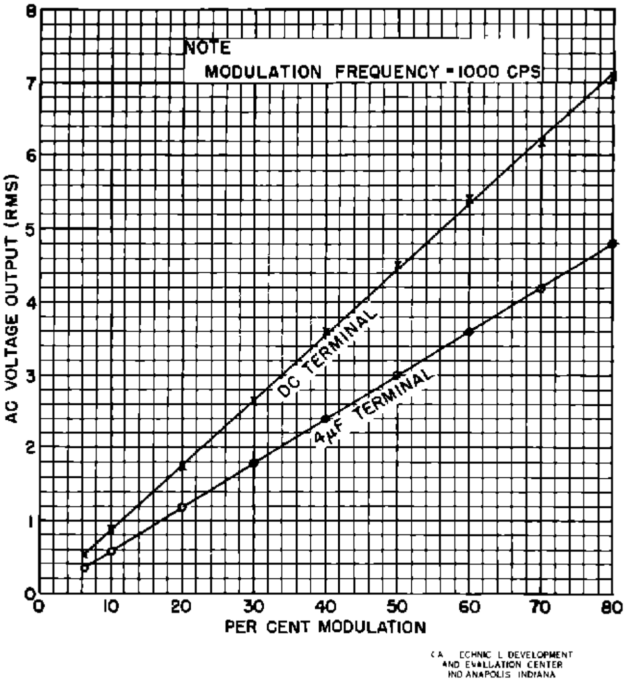

Fig 15 DEMOD Output Versus Per Cent Modulation

Figs 11 and 12

These are photographic reproductions of the composite wave when both the 90- and 150-cps modulating signals are swept at a rate of 60 cps Fig 12 is a greatly expanded view of Fig 11 These two figures show that the 90- and 150-cps signals are of equal amplitude (0 db) This is indicated when the maximum peak of one of the signals just touches the minimum peak of the other

Figs 13 and 14

These are similar to the pattern in Fig 12, except that the 90- and 150-cps signals are of different amplitudes Fig 13 indicates that the amplitude of the 90-cps voltage is higher by + 0 5 db than that of the 150-cps voltage Fig 14 indicates that the amplitude of the 150-cps voltage is higher by + 0 5 db than that of the 90-cps voltage

Fig 15

This indicates the linearity of the DEMOD output The 1,000-cps modulation was used to obtain the data, and the percentage modulation was adjusted as indicated on the meter showing the per cent of modulation in the 211-A signal generator The ac output was measured with the Ballantine voltmeter

CONCLUSIONS

The method of calibrating percentage modulation described in this report is desirable for the following reasons

1 Greater ease and accuracy are obtained in setting the 90- and 150-cps voltage amplitude

2 A check of the relative amplitudes of the 90- and 150-cps modulating voltages is provided by the oscillograph pattern

3 The percentage modulation of the output from the Type 212-A Univerter is measured directly

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