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DATE 21 February 1934

SUBJECT

Test of Models RAA and RAB Receiving Equipments

(R.F. and I.F. Amplifier and Detector Circuits of the Model RAA)

BUREAU OF ENGINEERING
MAR 5 1934

BY

NAVAL RESEARCH LABORATORY

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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

TEST OF MODELS RAA AND RAB RECEIVING EQUIPMENTS

(This report is submitted in three sections, this section dealing with the test of the

R.F. and I.F. Amplifier and Detector Circuits of the Model RAA.)

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D.C.

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Reported by:

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APPENDICES

I AUTHORIZATION

1.1 The tests as reported upon herein were authorized by Bureau of Engineering letter S67/46/L5(12-22-W8) of 26 December 1933.

II OBJECT

2.1 This problem requires that exhaustive tests and examination of the Model RAA and Model RAB receiving equipments be made to provide the required data necessary for the preparation of revised specifications covering such equipments.

III DESCRIPTION OF EQUIPMENT

3.1 The receivers tested were manufactured by the RCA Victor Company of Camden, New Jersey, on Contract 22837. The Model RAA consists of the following:

1 - CRV 4550 Radio Frequency Tuner Serial #115
1 - CRV 4551 Intermediate and Audio Amplifier Serial #115
1 - CRV 4554 Power Unit Serial #157

The Model RAB consists of the following:

1 - CRV 4552 Radio Frequency Tuner Serial #74
1 - CRV 4553 Intermediate and Audio Frequency Amplifier Serial #74
1 - CRV 4554 Power Unit Serial #203

3.2 The audio system as reported upon and covered by the data, shown on Plates 200 to 217 inclusive, was not the one included in either of the receiver models, but was made up of the following parts purchased from the same company and under the same specifications as apply in the receiver contract, on Naval Research Laboratory Contract N-173 S-1893.

1 Type CRV 30019 input transformer, 35.7-1 ratio
1 Type CRV 53001 low pass filter
1 Band pass filter either (Type CRV 53002 for the RAA or (Type CRV 53010 for the RAB.
1 Type CRV 4555 audio chassis

3.3 The voltage supply to the assembled audio system was as indicated in the instruction books supplied with the RAA and RAB equipments. The standard power unit was used for voltage supply in all cases where wave form and harmonic analysis data was taken. A Laboratory power pack was employed in other tests due to there being but one complete standard model of each type of equipment available, these being required almost continuously for other tests which were made simultaneously with the audio tests.

3.4 Both receivers are of the superheterodyne type. The RAA covers the range of 10 to 1000 and the RAB 1000 to 30000 kcs. These equipments are AC operated from a 60 cycle 110 volt power supply and have an output impedance suitable for use with from one to four pairs of 600 ohm telephone receivers connected in parallel.

3.5 The Model RAA employs an antenna coupling capacitor to the first of two loosely coupled tuned circuits which are followed by a single type 38035 R.F. amplifier tube. The R.F. amplifier tube has a tuned plate circuit which is inductively coupled to the tuned grid of the first detector. The first detector as well as the second function as plate detectors for weak signals while for stronger signals they function with both grid and plate rectification due to the presence of grid leak and stopping condensers as well as cathode bias resistors. Both the first and the second oscillators are type 38027 tubes. Their oscillator circuits are inductively coupled to the detector cathode bias lead. The coupling transformers from the first detector to first I.F., from first to second I.F., and from second I.F. to second detector have tuned primary and tuned secondaries which are slightly less than critically coupled, inductively. The second detector feeds into a low pass filter cutting off at around 4,000 cycles and a band pass filter may be cut in at will giving appreciable attenuation below 750 and above 1250 cycles. The audio amplifier consists of a resistance coupled stage employing a type 38024 tube followed by 38027 output stage feeding into a 600 ohm output transformer. An automatic volume control is provided which may be cut in at will. This consists of a high ratio step up transformer the primary of which, for AVC action, is cut in parallel with the output transformer. The secondary is center tapped and feeds to two 38027 vacuum tubes connected as biased rectifiers. As the receiver audio output voltage is applied to the rectifier anodes (plate-grid), this anode resistance decreases. This resistance is reflected through the high ratio transformer resulting in a lowering of the effective impedance load in the receiver output stage plate circuit, thus limiting the output voltage. The degree of limitation is controlled by a variable cathode bias on the rectifier tubes, thus providing an audio output level that can be controlled by the bias voltage.

3.6 The Model RAB receiver input couples to the antenna through a variable coupling capacitor which is used to compensate for various antenna constants, thus providing the ability to obtain resonance in the first tuned input circuit. There are two capacitively coupled tuned circuits preceding the first R.F. tube, which is a type 38058 pentode. This tube's grid is connected through a 1.0 megohm leak to a fixed 1.5 volt negative bias and is coupled to its grid circuit through a 250 uufd capacitor. The plate of the first R.F. tube connects to a mid tap of the inductance forming a part of the tuned grid circuit of the second R.F. stage. The tuned grid circuit of this stage, as well as that of the first and that of the first detector also, employs a fixed series capacitor in addition to the customary variable. The capacitance of this fixed capacitor varies from about double to triple that for the maximum of the variable depending upon the frequency band. The grid coupling capacitor for both of the R.F. amplifier grids is connected between the fixed and the variable capacitors. The grid of the second R.F.

tube obtains its bias voltage through a 1.0 megohm leak which is connected to a potentiometer volume control. The bias voltage variation obtainable from this volume control is from -1.5 to -75 volts. The plate of the second R.F. tube connects to the detector tuned grid at a mid point on the inductance similar to the preceding stage. The grid of the detector, however, is connected directly to the plate of the second R.F. tube through a coupling capacitor and to ground or -B through a 1.0 megohm leak. The detector functions as a plate rectifier for weak signals due to a cathode bias resistor but for sufficiently strong signals to draw grid current, both grid and plate rectification occur. Both the first and the second oscillators are type 38064 tubes. These oscillators couple to their respective detectors inductively through couplings provided in their cathode circuits. The oscillator filaments are heated by direct current supplied from the rectified B supply potential divider. The plate circuit of the first detector is tuned to the I.F. and coupled through a low impednace line to the tuned grid circuit of the first I.F. tube (type 38035). The coupling transformers between the first I.F., second I.F., (type 38035) and the detector (type 38024) are similar and consist of separately tuned grid and tuned plate circuits, capacitively coupled. Both of the I.F. grids obtain their bias voltages from the same volume control voltage regulating potentiometer as does the second R.F. tube mentioned previously. The second detector differs from the first in that it is a straight cathode biased plate rectifier. The plate circuit of this detector is provided with an R.F. filter in addition to the transformer primary which feeds the low pass filter as mentioned in connection with the Model RAA audio system previously described. The audio system is similar to that described for the Model RAA except for the characteristics of the band pass filter system which passes from 700 to 1300 cycles with slight attenuation and with appreciable attenuation below 600 and above 1600 cycles.

3.7 The type CRV-4554 power supply unit which is adaptable to either the Model RAA or the RAB has been designed to operate from a 60 cycle 110 volt line drawing approximately 235 watts. The power supply circuit consists essentially of an R.F. filter in the 110 volt supply line to the electrostatically shielded power transformer, two type 38180 rectifier tubes, a two stage filter, a voltage regulator tube and the voltage divider system. The two type 38180 rectifier tubes are operated in parallel and the type 38274 regulator tube is employed to stabilize the 90 volt B supply which feeds the oscillator plates and improves frequency regulation.

3.8 In view of the detailed description given in the instruction books supplied with each type of equipment, only a brief description has been given herein. If further detail is desired, the reader is referred to RCA-Victor Company's instruction books as issued with Contract NOs 22837 dated 30 June 1931, #IB-23206 applying to the Model RAA and #IB-23207 to the Model RAB.

IV TESTS

4.a OUTLINE OF TESTS. The following tests were completed in the time allotted:

4.a.1 Sensitivity. The amplitude of the CW input signal required to produce an audio output of 5 milliwatts (signal-plus-receiver noise), the receiver volume control being set for an output of 0.42 milliwatts of receiver noise with no input signal and with the receiver tuned so as to produce a 1,000 cycle output signal. Tests made for five frequency settings (each of which is the geometric mean of the adjacent two) in each of the five frequency bands.

4.a.2 Selectivity. Ratio of the amplitude of a CW input signal (the frequency of which differs from resonant frequency by a given percent) to the amplitude of a resonant frequency input signal, which produces the same signal voltage on the grid of the second detector as was produced by the former signal, resonant frequency being defined as that frequency which produces a 1,000 cycle output note. Tests made for three frequency settings in each of the five frequency bands.

4.a.3 Gain of individual circuits. Ratio of the signal voltage on the grid of any tube to the signal voltage on the grid of the preceding tube which produced the former. Tests made for three frequency settings in each of the five frequency bands and for various percentages each side of each resonant frequency.

4.a.4 Image frequency sensitivity. Amplitude of the image frequency CW input signal required to produce an audio output of 5 milliwatts under conditions identical with those of par. 4.a.1. Image frequency being defined as a frequency equal to the resonant frequency plus twice the intermediate frequency.

4.a.5 Overload curves. Resonant CW input microvolts plotted against milliwatts output and against second detector plate current. Test made at resonant frequency of 1,000 kcs. Receiver tuned for 1,000 cycle audio output note.

4.a.6 Beat frequency stability. Percent deviation from 500 cycles of the audio output frequency plotted against AC supply line voltage. (See par.4.b.6 for reason for use of 500 cycles.)

4.a.7 Duplex selectivity data by the two signal generator method. The number of CW input microvolts required at 2%, 5%, and 10% off resonance to vary, by 3 decibels, the standard output obtained from a resonant frequency input signal. The receiver being adjusted as in par. 4.a.1. (Test not completed for reason given in par.4.b.7.)

4.a.8 Signal voltage per tube. Amplitude of the CW signal appearing on any grid at resonance and at various percentages off resonance, per microvolt applied to the receiver input terminals.

4.b METHOD OF CONDUCTING TESTS

4.b.1 Sensitivity. A standard signal generator was connected to the receiver input terminals through a 300 ohm non-inductive resistor in series with the antenna input terminal. With the signal generator delivering a CW signal of predetermined frequency, the receiver was resonated so that the beat note (audio output frequency) between the second oscillator and the intermediate frequency was 1,000 cycles (on the side of zero beat giving the loudest signal) and the antenna compensator was adjusted for maximum audio output under these conditions, with the antenna coupling switch in the "tight coupling" position. All tests were made with the automatic volume control and the band pass filter turned off.

With the signal generator attenuator set at zero output, the receiver volume control was adjusted to produce 0.42 milliwatts of receiver noise output. (At some frequencies, full gain setting did not produce this noise output.) There was then applied an input signal of sufficient amplitude to produce an audio output (noise-plus-signal) of 5 milliwatts. The amplitude of the required input signal is the sensitivity of the receiver at the test frequency.

It should be noted that tests of sensitivity for modulated signals using 1,000 cycle modulation would be impractical because the resulting side bands would differ from the intermediate frequencies by the following percentages: Band 5, 0.412%; Band 4, 1.05%; Band 3, 2.65%; Band 2, 5.0%; and Band 1, 2.65%. Reference to curve sheets nos.6-20 shows that these side bands are amplified, by the intermediate frequency stages, to a far less degree than the carrier frequency which they accompany. For this reason, such measurements would mean little or nothing. The side bands of 100 cycle modulation would differ from the intermediate frequency by 0.5% in Band 1 and although the discrimination against these side bands in the other bands of the receiver would be negligible, the use of 100 cycle (or lower frequency) modulation would be impractical because of the discrimination of the audio system for such low frequencies. As a consequence, all sensitivity measurements were made using a CW input, the audio output being obtained by combining the intermediate frequency with the output of the second oscillator in the grid of the second detector.

4.b.2 Selectivity. Inasmuch as selectivity is a ratio as defined in 4.a.2, it would seem that the use of 100 cycle modulated test signals might be satisfactory except perhaps in Band 1, because the discrimination of the intermediate frequency circuits is not great for side bands differing by such small percentages and also because the low efficiency of the audio system at 100 cycles would be cancelled out by the fraction representing the ratio of input signals. There is, however, an important discrepancy which arises in the measurement of selectivity by the use of modulated signals which are adjusted to maintain a "constant" audio output while the test signal is detuned by various percentages. This discrepancy arises in the following manner: As outlined in par.A.a.2, the receiver sensitivity is adjusted so that the noise output is 0.42 milliwatts. This noise is produced as follows: In the tuned input circuit preceding the first RF tube, there are generated, by thermal agitation, minute voltages of all frequencies from the lowest audio frequency to the highest radio frequency. Because this input circuit is tuned, those thermal agitation voltages having frequencies near the natural frequency of the tuned input circuit appear across the parallel tuned input circuit (that is, on the grid of the first RF tube) as far larger voltages; their amplitudes being in the range of 0.2 to 1 microvolt. The thermal agitation voltages having frequencies differing from the natural frequency of the tuned input circuit appear as lesser voltages, so that the voltages on the grid of the first tube may be represented by a resonance curve of the tuned input circuit, the area of which is completely filled with voltage ordinates of every frequency represented by the width of the base of the curve.

Each of these thermal agitation frequencies is amplified by the first R.F. tube, detected by the first detector, amplified by the intermediate frequency stages and delivered to the grid of the second detector. Of course, in passing through each tuned amplifier stage, each individual agitation frequency is amplified in proportion to its position on the resonance curve of that particular stage so that the agitation voltages appearing on the grid of the second detector may be represented by an overall receiver resonance curve, the area of which is completely filled with voltage ordinates of every frequency represented by the width of the base of the curve.

Assuming the second detector to be an essentially square law device, these many voltages on the grid will produce the following currents in the plate circuit:

Group A. Frequencies identical with those impressed. The amplitude of the plate current of each frequency in this group is proportional to the amplitude of the voltage of the same frequency appearing on the grid. These are radio frequencies and can not be amplified by the audio system.

Group B. Frequencies which are twice the frequency of each voltage appearing on the grid. The amplitude of the plate current of each frequency in this group is proportional to the square of the amplitude of the input voltage which produced it. These are radio frequencies and can not be amplified by the audio system.

Group C. Frequencies which are equal to the sum of each frequency, on the grid, added to each of the other frequencies, on the grid, respectively. The amplitude of the plate current of each frequency in this group is proportional to the product of the amplitudes of each frequency which produced it. These are radio frequencies and can not be amplified by the audio system.

Group D. Frequencies which are equal to the difference of each frequency, on the grid, subtracted from each of the other frequencies, on the grid, respectively. The amplitude of the plate current of each frequency in this group is proportional to the product of the amplitudes of each frequency which produced it. THESE ARE AUDIO FREQUENCIES and CAN be amplified by the audio system, but the degree of amplification of each is dependent on the frequency characteristic of the audio system. All audio frequencies are present and their combined output is a "noise" by definition.

Group E. This group is represented by plate currents of zero frequency; that is, by increments of DC plate current. Each input voltage produces an increment of plate current proportional to the square of its amplitude. The total increment of plate current is proportional to the sum of the squares of the amplitudes of the individual grid voltages and is independent of their respective frequencies.

Now consider an unmodulated carrier frequency at the center of the overall receiver resonance curve and having an amplitude several times larger than the agitation voltage of the same frequency. The audio noise output of the second detector (Group D) is now greater than before because each of the other agitation voltages while beating with each other are producing the same audio output as before, yet each of them, while beating with the large carrier, is producing a larger audio output than before. The DC plate current of the detector has also been increased by an amount proportional to the square of the carrier amplitude.

Suppose this carrier to be 30% modulated at 100 cycles. The carrier amplitude is unchanged, but there are added two side bands spaced in frequency 100 cycles above and below the carrier. These side bands will correspond in frequency to two of the agitation frequencies already present whose difference frequency was already producing the 100 cycle component of the noise output. The addition of these side bands not only increases the amplitude of the 100 cycle component (desired audio output in this case) but also increases the amplitude of all the other audio noise frequencies in the same manner as did the introduction of the unmodulated carrier. The addition of these side bands also increases the DC plate current by an amount equal to $K\frac{M^2E^2}{2} = 0.045\ KE^2$ (where $M = 0.3$ for 30% modulation, E is the amplitude of the carrier, and K is a proportionality factor. The increment caused by the carrier alone was KE^2; therefore, the increment caused by the 30% modulated carrier is $KE^2(1 + 0.045)$ and thus the increment caused by the side bands is only 4.5% of that caused by the carrier.

It can now be seen that, although the receiver may be originally set to produce 0.42 milliwatts of noise, when there is applied a modulated input signal of sufficient amplitude to produce a signal-plus-noise output of 5 milliwatts, the noise component of this output is far greater than 0.42 milliwatts. This is easily proved by removing the modulation from the carrier and noting that the output usually drops from 5 milliwatts to about 4 milliwatts and not to 0.42 milliwatts. The second detector plate current changes hardly at all when this is done. Consequently, the amplitude of the input signal, required to produced a signal-plus-noise output of 5 milliwatts, is far less than would be required had the noise level not increased.

Consider now, a modulated carrier on the grid of the second detector of the same amplitude as before, but located several percent away from its former position in the center of the overall receiver resonance curve. (To produce this carrier, the receiver input amplitude must, of course, be far greater.) Suppose the frequency of this new signal to be such that the difference between its frequency and that of the agitation voltage, at the center of the overall resonance curve, to be a higher frequency than the audio system will amplify. Then, those agitation frequencies which are nearer the carrier frequency may or may not produce an audible output, depending on the location of the carrier, but in any event, this increased noise output, if produced, will be less than with the carrier at the center of the resonance curve, because the amplitudes of the agitation voltages which do produce an audible output, are far less than the agitation voltages near the center of the overall resonance curve. Consequently, if the amplitude of this off resonance modulated carrier is now adjusted to produce a signal-plus-noise output of 5 milliwatts, the audio output will contain less noise than is the case at resonance and may well contain only the original 0.42 milliwatts of noise provided that the carrier is far enough removed from resonance.

From the foregoing, it will be observed that for a constant signal-plus-noise audio output of 5 milliwatts, less modulated carrier is required on the grid of the second detector at resonance than at a few percent off resonance. This condition is **untenable** because the method of test predicates that constant modulated carrier voltages on the grid of the second detector shall produce constant audio output over a large frequency range.

To alleviate this condition, the audio system was not used as a measure of the radio (IF) frequency on the grid of the second detector, but instead the increment of average plate current of the second detector was used for this purpose. From the foregoing discussion, it is evident that the value of the increment of the average (DC) plate current of this tube is proportional to the sum of the squares of the amplitudes of all the individual voltages impinging on its grid, regardless of frequency, so that the agitation voltages are represented by a constant increment of plate current and the addition of an unmodulated carrier causes an additional increment of plate current regardless of the frequency of the carrier (within the limits in which we are interested).

Therefore, this method makes possible the accurate measurement of the modulated or unmodulated (results are the same in either case) signal input required, at any percent off frequency, to produce the same carrier voltage on the grid of the second detector as is produced by a given input signal at resonance.

For reference to the foregoing theory see "Communication Engineering" by W.L. Everitt, 1st edition, Chapter XVI in general and equation (9) in particular.

4.b.3 Gain of individual circuits. The measurement of gain of each stage was made concurrently with the measurement of overall selectivity as follows:

Using a CW input signal of predetermined frequency, the receiver was tuned so that the audio output frequency (difference in frequency between I.F. carrier and second oscillator) was 1,000 cycles and the antenna compensator adjusted for maximum output with the "antenna coupling" switch in the tight position. The second oscillator was then turned off and with no input signal the receiver volume control was set for an audio output of 0.42 milliwatts of noise. Following these adjustments, no further use was made of the audio system.

The normal plate current of the second detector is approximately 35 microamperes. The increments of this plate current were measured by means of a 0-6 scale microammeter shunted by a 1.5 volt battery in series with 43,000 ± 1,000 ohms to act as a "bucking" circuit. The instrument resistance was only 3,500 ohms, thus insuring good sensitivity.

With the receiver adjusted as described above, there was applied sufficient CW input signal to cause a 0.4 microampere increment in second detector plate current (a purely arbitrary value). Next the same frequency input signal was applied direct to the grid of the RF tube (the lead from the grid cap of the tube to the normal input circuit being disconnected) and the ground return circuit from the signal generator connected to the main bias lead as shown at "B" on Plate 24. The input signal was then increased until there was obtained a 0.4 microampere increment in second detector plate current. The ratio of the signal on the grid of the RF tube to the input signal (300 ohms in series with antenna terminal in all tests) then being the gain of the input stage at resonance.

Similarly, the signal on the grid of the first detector required to increase the second detector plate current 0.4 microamperes was measured; the ground return from the signal generator being connected to ground. The ratio of this signal to that on the grid of the RF tube being the gain of the RF circuit.

Next, the signal was again applied to the receiver input to make beneficial use of the usually detrimental first circuit noise. With sufficient signal applied to produce approximately 0.4 microamperes increment of second detector plate current, the signal from a second signal generator was very loosely coupled in parallel with the normal input circuit of the first I.F. tube through a 25,000 ohm resistor. The second signal generator was set approximately to the known intermediate frequency and then tuned to the exact intermediate frequency (produced by the carrier from the first signal generator passing through the first detector in combination with the first oscillator signal) by listening for the audio output note produced by beating the second signal generator with the I.F. carrier. Identical frequencies may be obtained by first tuning for "zero beat" which may be sixty or more cycles on either side of true synchronism, and then by more careful tuning the noise level originating in the first tuned circuit may be caused to slowly rise and fall as the two signals fall into exact synchronism.

Having thus set the second signal generator to a frequency identical with the intermediate frequency, it was now directly connected to the grid of the first I.F. tube, its ground return being connected to the normal bias lead at "B" as in the case of the R.F. tube. The amplitude of this intermediate frequency was then determined as before and the gain of the first detector was taken as the ratio of the I.F. signal on the grid of the first I.F. tube to the R.F. signal on the grid of the first detector.

In a similar manner, the gain of the first I.F. stage was determined and finally there was found the signal on the grid of the second detector required to produce the 0.4 microampere increment of plate current. The value of this signal determined the gain of the second I.F. stage and the overall gain of the system.

From similar measurements made at radio frequencies differing from resonant frequency by given percentages, the gain curves of individual circuits were plotted against "percent off frequency".

Data for the gain of the second detector were taken as follows: At each intermediate frequency the gain of the second I.F. stage was carefully determined, as outlined in par.4.b.3, and maintained at this level. The proper intermediate frequency was applied to the grid of the second I.F. tube so that in combination with the second oscillator signal, a 1,000 cycle beat note was produced in the plate circuit of the second detector. The intermediate frequency was applied to the second I.F. tube rather than direct to the second detector so that the grid circuit of the latter would be normal in every way. Sufficient input signal was applied to produce a given number of audio output milliwatts. By substituting a measured 1,000 cycle signal across the primary of the first audio transformer, the audio voltage required to produce the given output was determined. The input signal at the grid of the second detector was determined from the input to the second I.F. tube and the known gain of that stage. The ratio of the audio output voltage to the intermediate radio frequency input voltage is the gain of the second detector.

4.b.4 Image frequency sensitivity. The frequency of the input signal was approximately set to the image frequency and then accurately adjusted to produce a 1,000 cycle audio beat note (intermediate frequency beating second oscillator frequency). The amplitude of input signal necessary to produce a noise-plus-signal output of 5 milliwatts was then the required "sensitivity"; the receiver gain having been set for 0.42 milliwatts of noise output with no input signal.

In some instances, the image frequency sensitivity was 0.5 volts or less in which case very accurate measurements could be made using input signals direct from the signal generator. In other cases, it was necessary to amplify the signal generator output, measuring the receiver input signal by means of a vacuum tube voltmeter. In such cases, the increased noise level arising from the tubes and circuits of the signal amplifier made measurement difficult but despite this, fairly reliable results were obtained by means of measuring the receiver total noise output (including noise from signal amplifier) without input signal and then by introducing an image signal sufficient to increase to audio output by 4.58 milliwatts. This latter figure was taken because the signal content of the 5 milliwatts output, when no additional noise was being introduced by the signal amplifier, was 4.58 milliwatts; the remaining 0.42 milliwatts being receiver noise.

At some frequencies, the preselection was so excellent that 4.58 milliwatts of signal output could not be obtained even with the maximum input signal of 15.45 volts which was convenient to measure with the vacuum tube voltmeter. Inasmuch as the measurement of greater input signals would have been of little practical value, there is reported, in such cases, the audio signal output obtained with this maximum signal voltage.

4.b.5 Overload curves. Data for these curves was taken only at 1,000 kcs. The receiver was adjusted so that the intermediate frequency, so produced, beat with the second oscillator to produce a 1,000 cycle output note.

For Plate 21, the receiver gain was set to produce 0.42 milliwatts of noise output and data plotted showing receiver signal input versus output milliwatts (signal-plus-noise) and versus second detector plate current. Under these conditions, an input signal of 3.5 microvolts was required to produce 5 milliwatts output.

For Plate 22, the receiver gain was set so that 200 microvolts was required to produce 5 milliwatts output.

For Plate 23, the receiver gain was set so that 3,400 microvolts was required to produce 5 milliwatts output.

4.b.6 Beat frequency stability. The data for Plate 25 was obtained at 1,000 kcs (highest frequency of this receiver) by tuning the receiver to the second harmonic of a 500 kc crystal oscillator, so that character, will produce such large key clicks in the receiver that any small variation in desired signal level resulting from the steady interfering carrier, will be insignificant in comparison to the interference produced by the clicks.

4.b.8 Signal voltage per tube. The data, representing the results of this test, were taken directly from the data used in obtaining the "Gain of individual circuits" (par.4.b.3).

Obviously the signal voltage on the grid of the first R.F. tube per microvolt receiver input is numerically identical with the gain of the input stage. The signal voltage on the grid of the first detector per microvolt receiver input is numerically identical with the product of the gains of the input and first R.F. stages.

This method of portraying the same data set forth in the curves of "Individual stage gain" is valuable in permitting the direct prediction of the signal voltage appearing on any grid for any input signal up to the point of overload for any tube.

V. RESULTS OF TESTS

5.1 Sensitivity. The overall receiver sensitivity for five frequencies in each of the five bands is plotted on Plate 26.

5.2 Selectivity. The overall receiver selectivity for three frequencies in each of the five bands, is plotted on Plates 1, 2, 3, 4, and 5. On Plate 5A is plotted the overall selectivity at 10 kcs over a greater frequency range than depicted on Plate 5.

5.3 Gain of individual circuits. The gain of each circuit of the receiver is plotted for three frequencies in each of the five bands on Plates 6 to 20 inclusive. The gain of the second detector (CW conditions) for each intermediate frequency is as follows:

Band	Gain
1	10.48
2	7.85
3	10.48
4	12.59
5	8.80

The gain of the second detector is constant for any output up to overload point for the audio system beyond which the gain could not be measured.

5.4 Image frequency sensitivity. The amplitude of the image frequency input signal, required to produce standard output, appears in the following table. If standard output was not obtainable, the output obtained is given.

6.3 Gain of individual circuits. Plates 6 to 20 indicate that the alignment of individual circuits is tolerable but not compatible with good manufacturing practice.

It is noted that in Band 2, Plates 15, 16, and 17, the gain of the first intermediate frequency stage is very low although the stage is properly aligned. The coupling is evidently too small either through accident or by intention to prevent oscillation.

The gain of the second detector is satisfactory although the excitation of the second oscillator might be better adjusted so as to equalize this gain in each band. (See par.5.3 for second detector gain.)

6.4 Image frequency sensitivity. The discrimination against image frequencies is good except at the following frequencies: 400(4), 158(3), and all of Bands 2 and 1. (See par.5.4)

6.5 Overload curves. Plates 21, 22, and 23, indicate that at resonance, the audio system overloads before any preceding R.F. or I.F. tube overloads.

6.6 Beat frequency stability. Plate 25 indicates that the audio output beat frequency stability, for variations in supply line voltage, is excellent.

6.7 Duplex selectivity data by the two signal generator method. No data.

6.8 Signal voltage per tube. Plates 27 to 41, inclusive, clearly show the need for greater pre-selection in order to increase the duplexability of the Model RAA receiver.

6.9 In conclusion it may be said that, in general, the Model RAA receiver is not only excellent but far superior to any shipboard receiver previously used in the Naval Service.

At some points in some of the frequency bands of the receiver tested, the stage alignment was poor, but nevertheless the overall sensitivity and weak signal selectivity was satisfactory.

The selectivity is insufficient to permit duplexing within about 2% at any frequency or within 10% at the lowest frequencies without overloading some one or more tubes and thus producing cross modulation and key clicks originating within the receiver; the absolute value of minimum frequency separation necessary for duplex operation depending on the amplitude of the undesired signal reaching the receiver input.

Although the low frequency selectivity of the radio frequency system does not meet the specification requirements, the action of the band pass filter in the audio system provides the necessary off resonance attenuation so that the overall selectivity of the receiver is satisfactory. Duplexability is not required at these frequencies.

VII RECOMMENDATIONS

There are no recommendations for easily accomplished minor modifications of the existing equipment.

In order to improve duplexability, it is recommended that experiments be conducted leading to the design of a suitable preselector which may be connected external to receiver. It should be noted that while the receiver average sensitivity is one microvolt, the noise level aboard ship (electrical disturbances) may be 20 or 30 microvolts (exact value unknown). Under such conditions a preselector circuit which at resonance attenuates a desired signal from 30 microvolts to 2 microvolts, not only delivers sufficient desired signal to the receiver for clear reception, but also attenuates the ship noise level by a much larger ratio than 30 to 2 by reason of its selectivity and thus makes readable a 30 microvolt signal which would otherwise be buried in the ship noise level. In addition to this advantage, a properly designed preselector reduces the frequency separation necessary for duplexing.

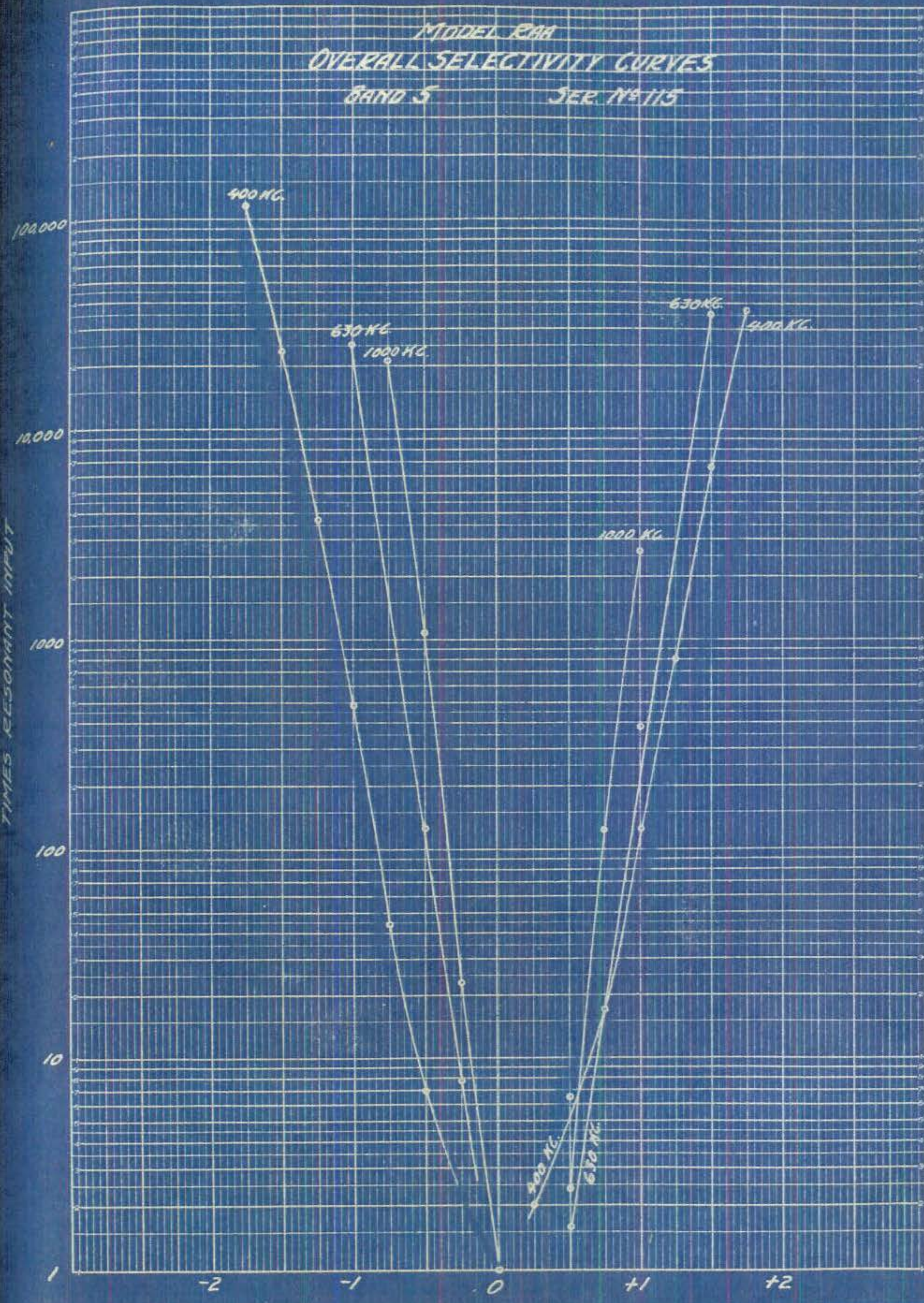

MODEL RAA
OVERALL SELECTIVITY CURVES
BAND 5
SER. Nº 115
400 KC.
630 KC.
1000 KC.
630 KC.
400 KC.
1000 KC.
400 KC.
630 KC.
100,000
10,000
1000
100
10
1
TIMES RESONANT INPUT
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 1

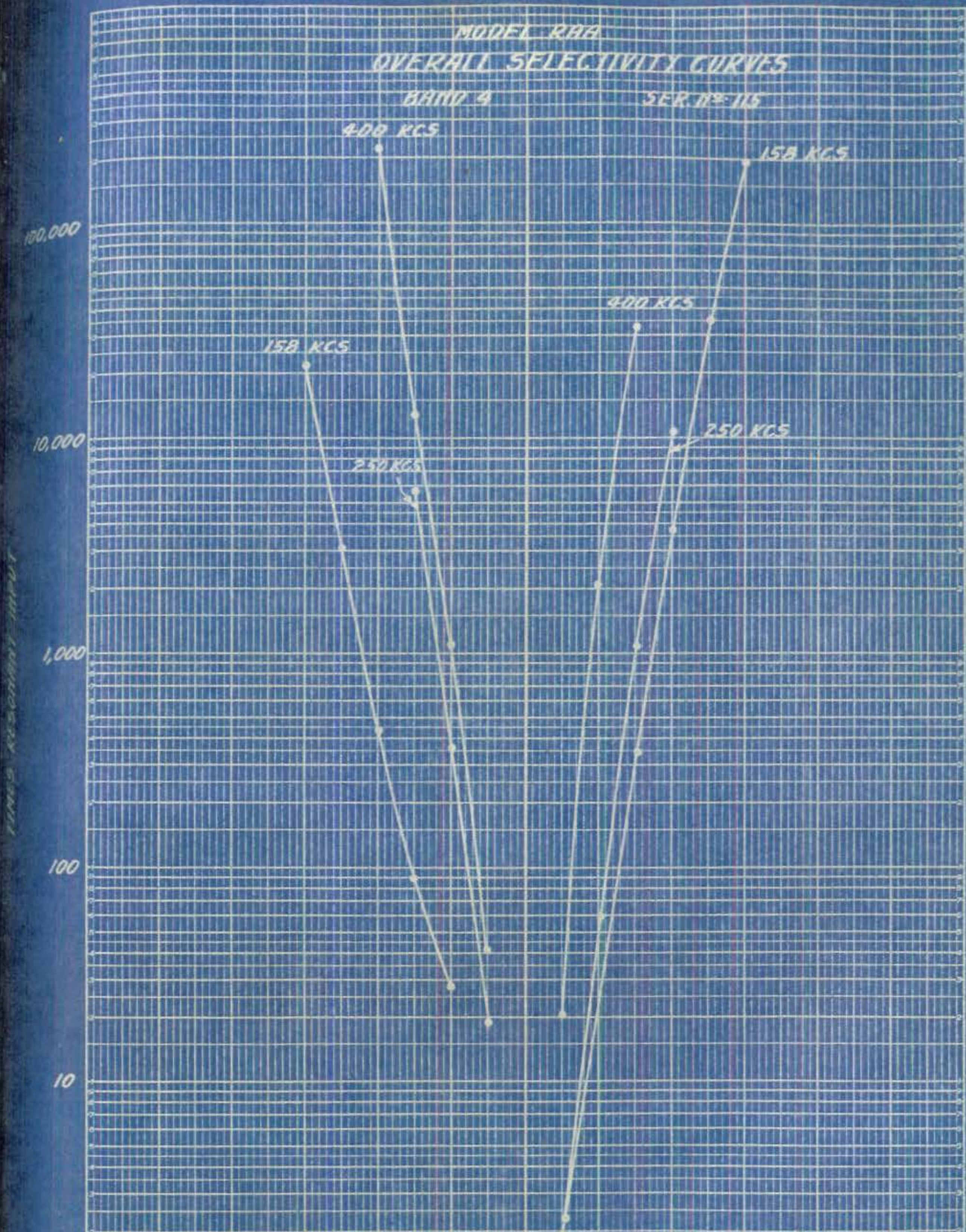

MODEL RAA
OVERALL SELECTIVITY CURVES
BAND 4
SER. No 115
400 KCS
158 KCS
400 KCS
158 KCS
250 KCS
250 KCS
100,000
10,000
1,000
100
10
1
TIMES RESONANT INPUT
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 2

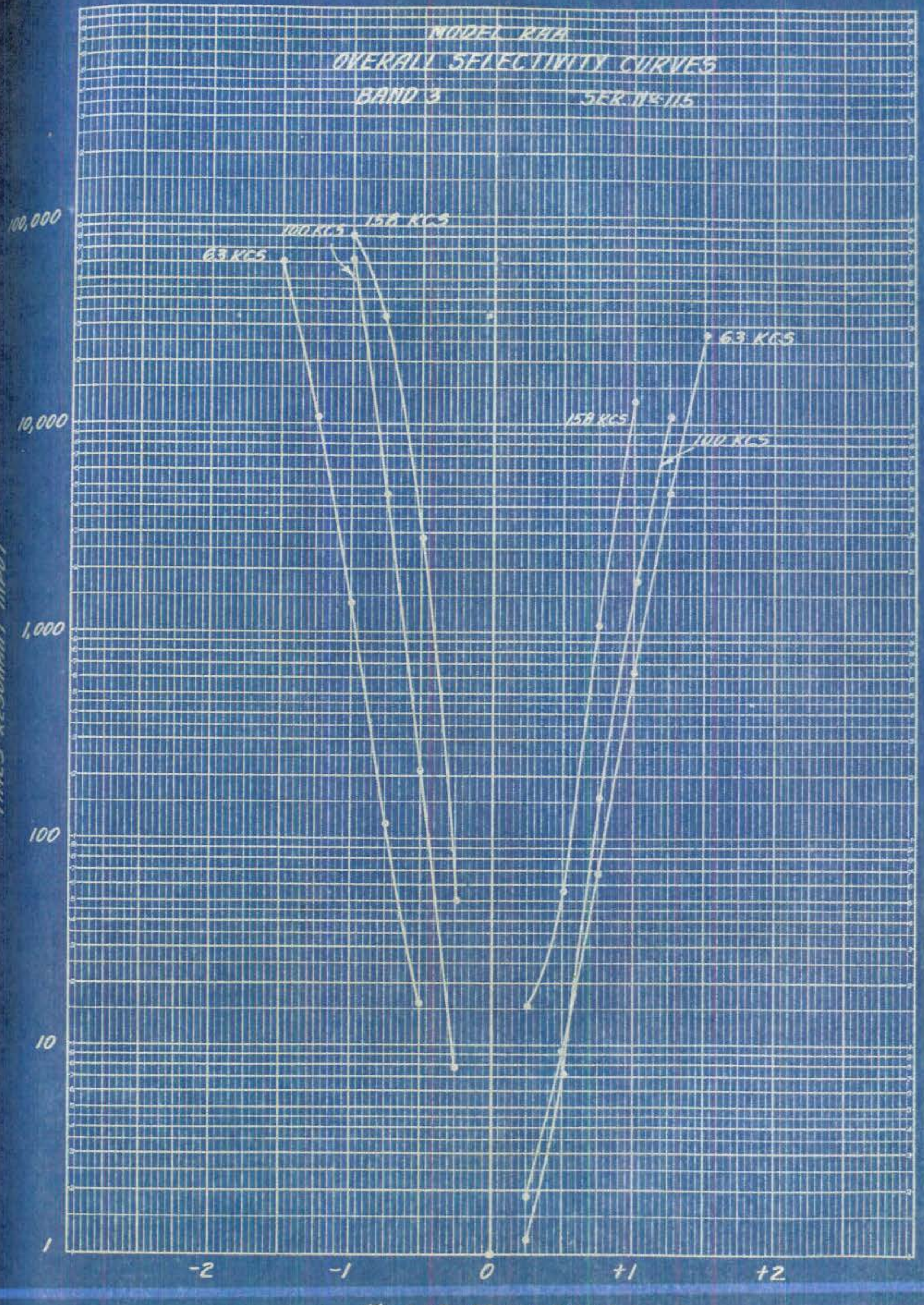

MODEL RAA
OVERALL SELECTIVITY CURVES
BAND 3
SER. No 115
100,000
10,000
1,000
100
10
1
TIMES RESONANT INPUT
63 KCS
100 KCS
158 KCS
63 KCS
158 KCS
100 KCS
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 3

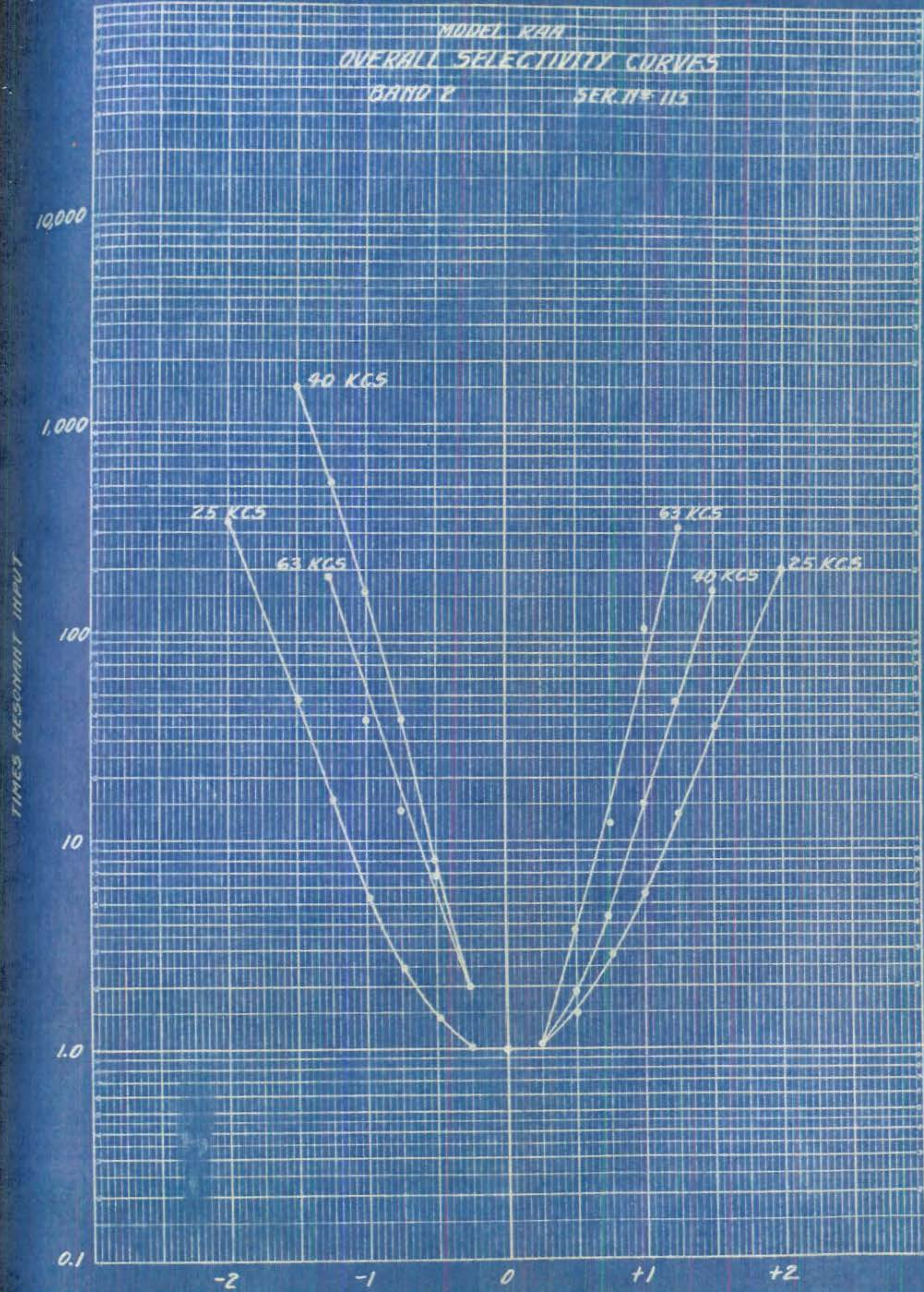
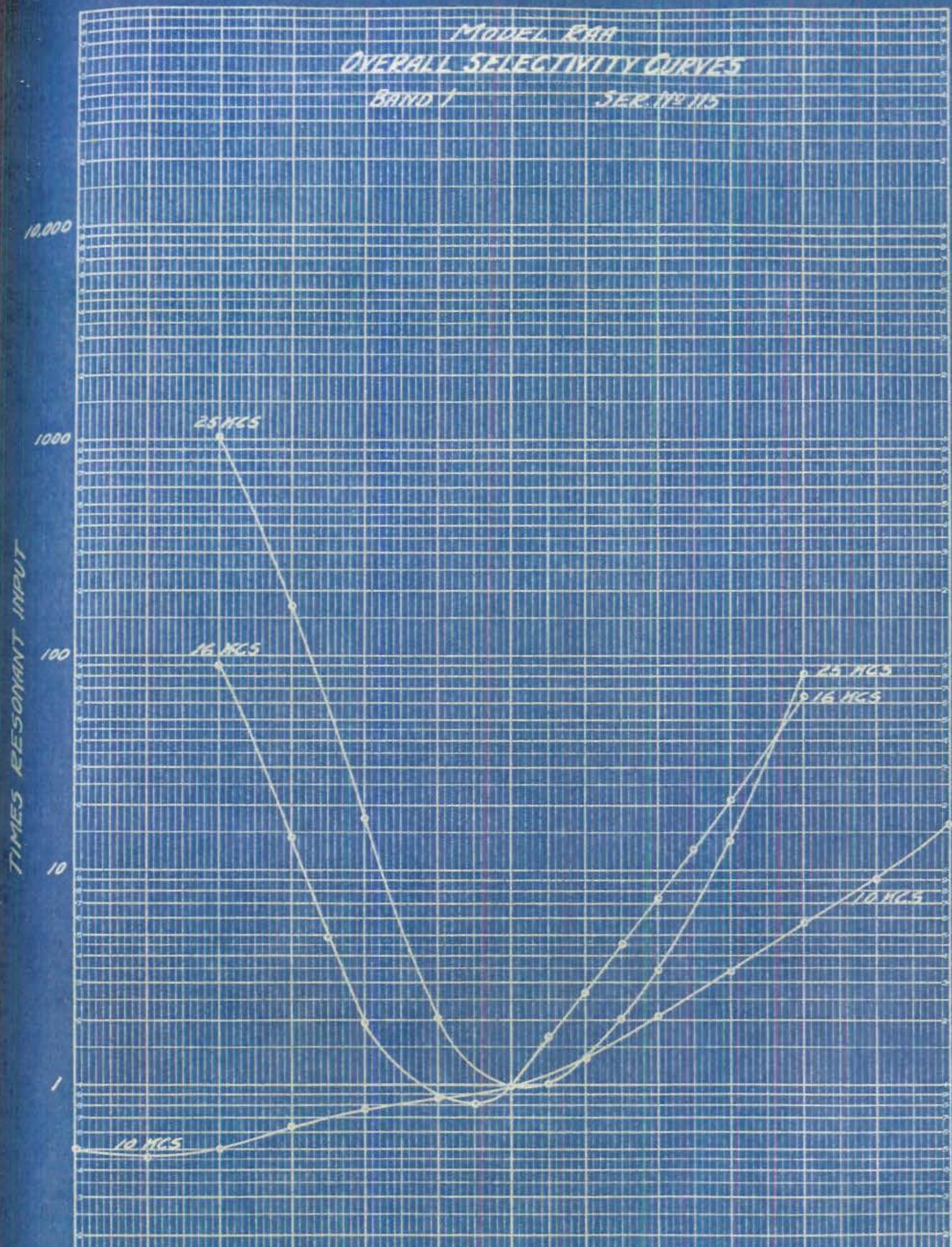

MODEL RAA
OVERALL SELECTIVITY CURVES
BAND 2
SER. Nº 115
40 KCS
25 KCS
63 KCS
63 KCS
40 KCS
25 KCS
10,000
1,000
100
10
1.0
0.1
TIMES RESONANT INPUT
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 4



MODEL RAA
OVERALL SELECTIVITY CURVES
BAND 1
SER. Nº 115
10,000
1000
100
10
1
0.1
TIMES RESONANT INPUT
25 MCS
16 MCS
25 MCS
16 MCS
10 MCS
10 MCS
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 5

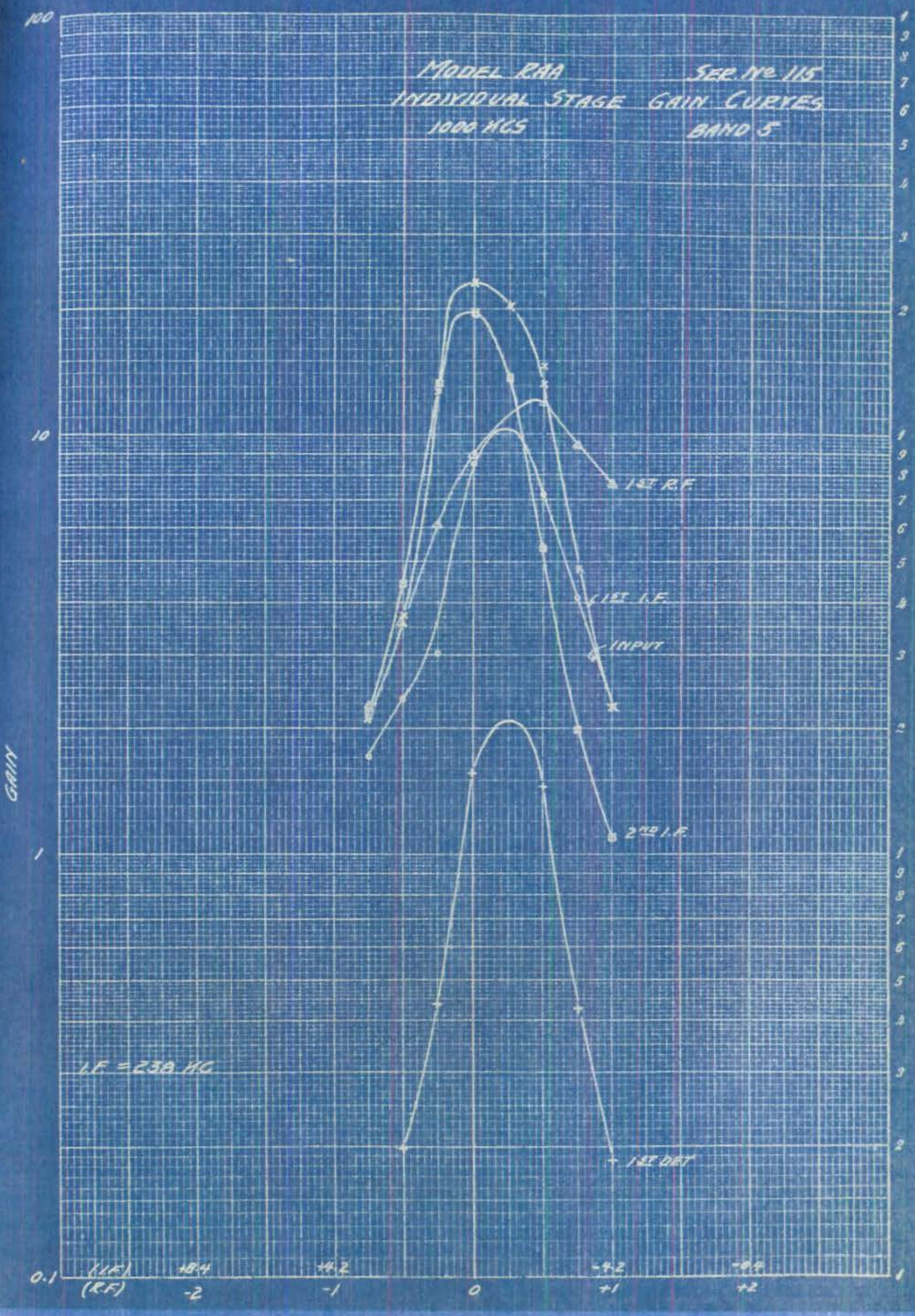
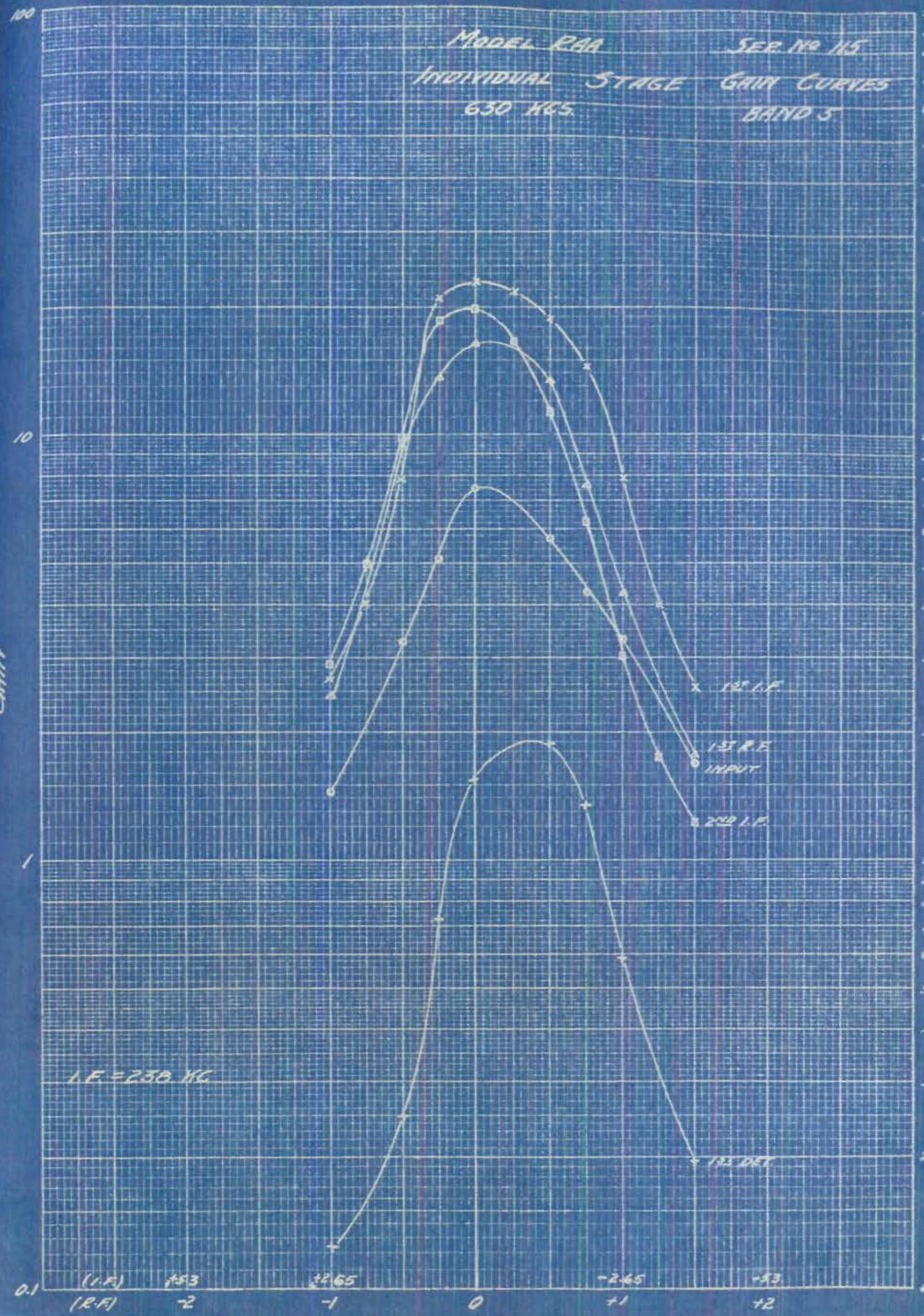

MODEL RAA
SER. Nº 115
INDIVIDUAL STAGE GAIN CURVES
1000 MCS
BAND 5
100
10
1
0.1
GAIN
1ST R.F.
1ST I.F.
INPUT
2ND I.F.
1ST DET
I.F. = 238 MC
(I.F.)
(R.F.)
+8.4
+4.2
-4.2
-8.4
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 6


MODEL RAA
SER. No 115
INDIVIDUAL STAGE GAIN CURVES
630 KCS.
BAND 5
GAIN
1ST I.F.
1ST R.F.
INPUT
2ND I.F.
1ST DET.
I.F. = 238 KC.
(I.F.)
(R.F.)
% OFF FREQUENCY

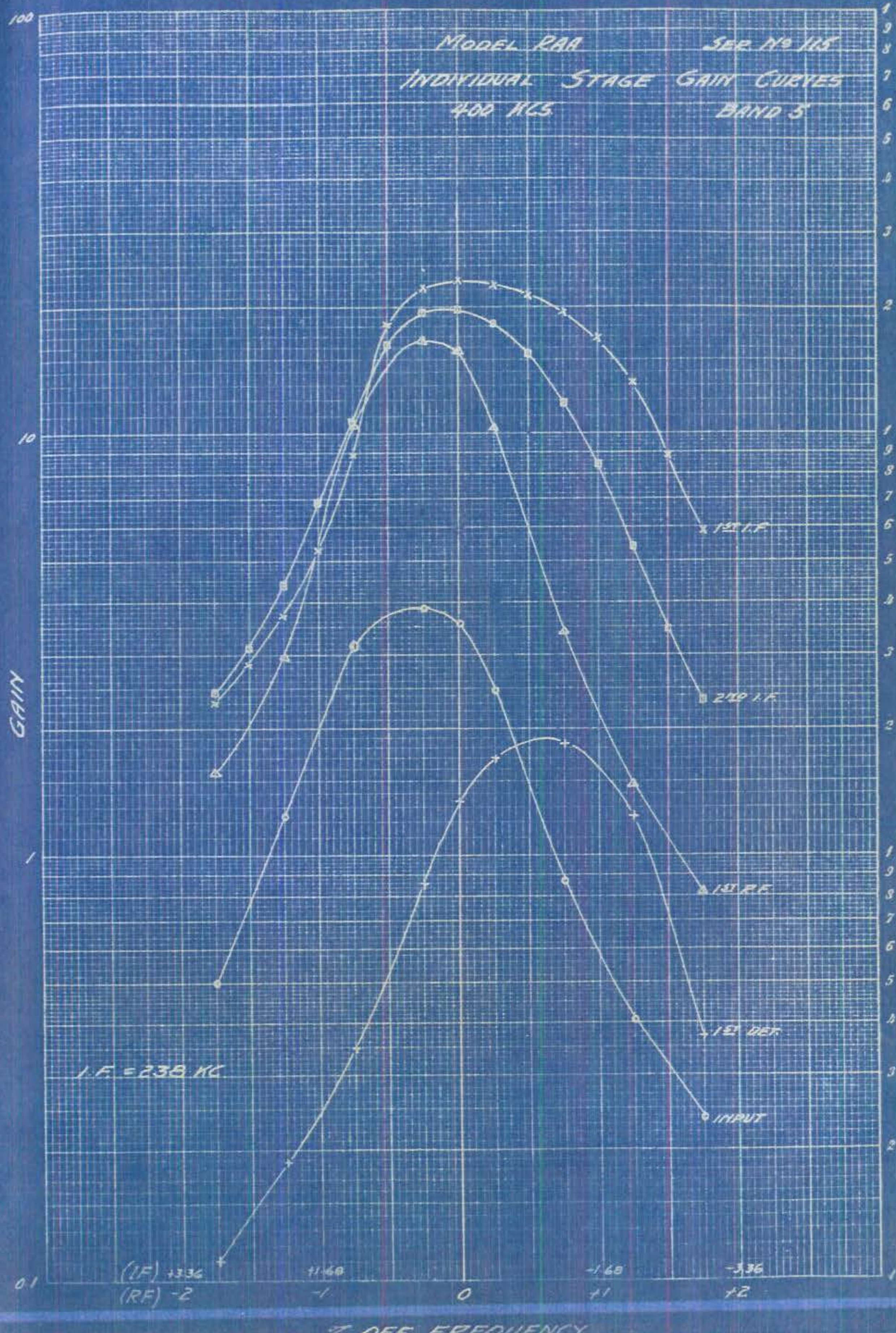
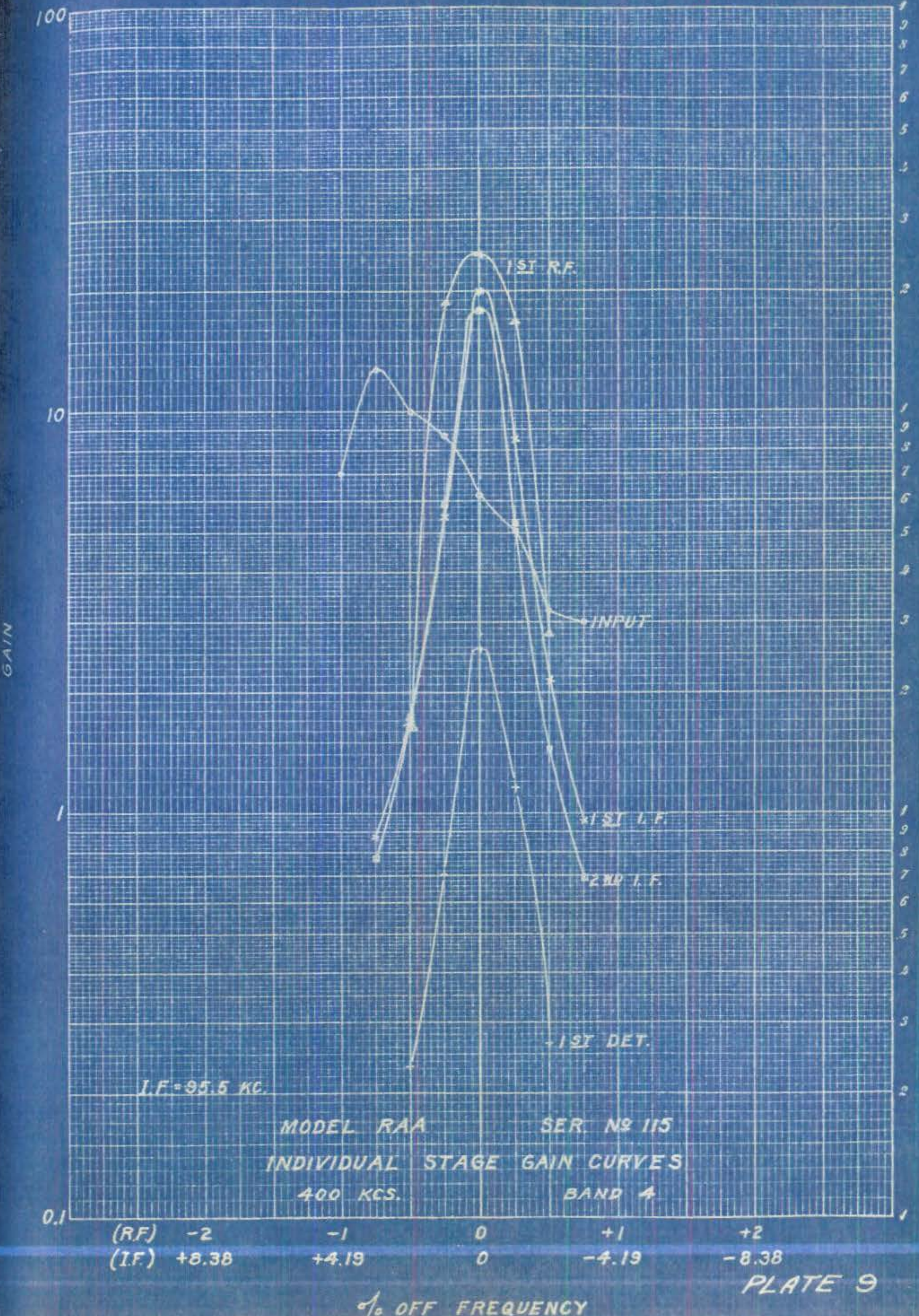
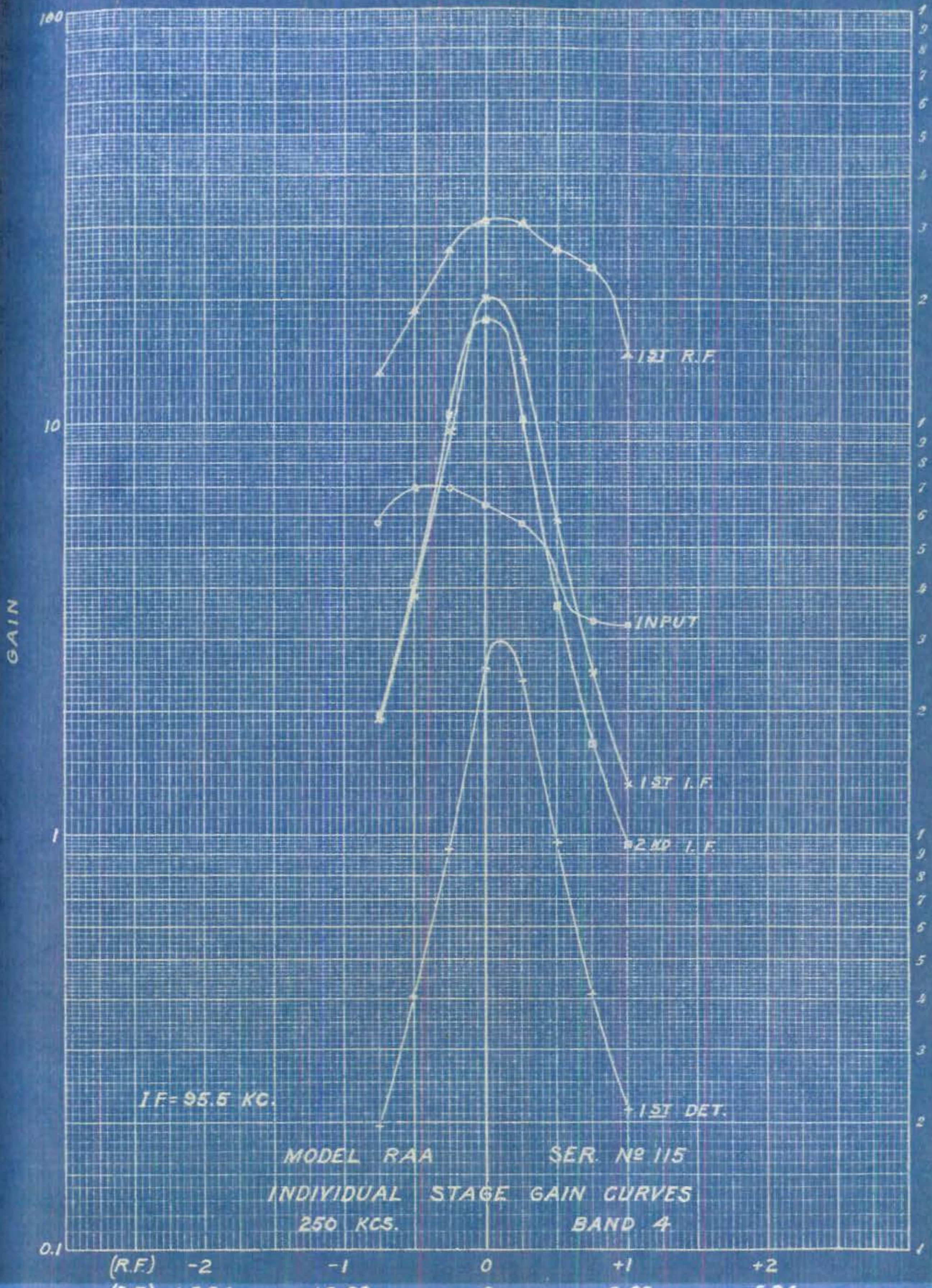

MODEL RAA
SER. No 115
INDIVIDUAL STAGE GAIN CURVES
400 KCS.
BAND 5
GAIN
1st I.F.
2nd I.F.
1st R.F.
1st DET.
INPUT
I.F. = 238 KC
(IF) +3.36 +1.68 -1.68 -3.36
(RF) -2 -1 0 +1 +2
% OFF FREQUENCY

PLATE 8



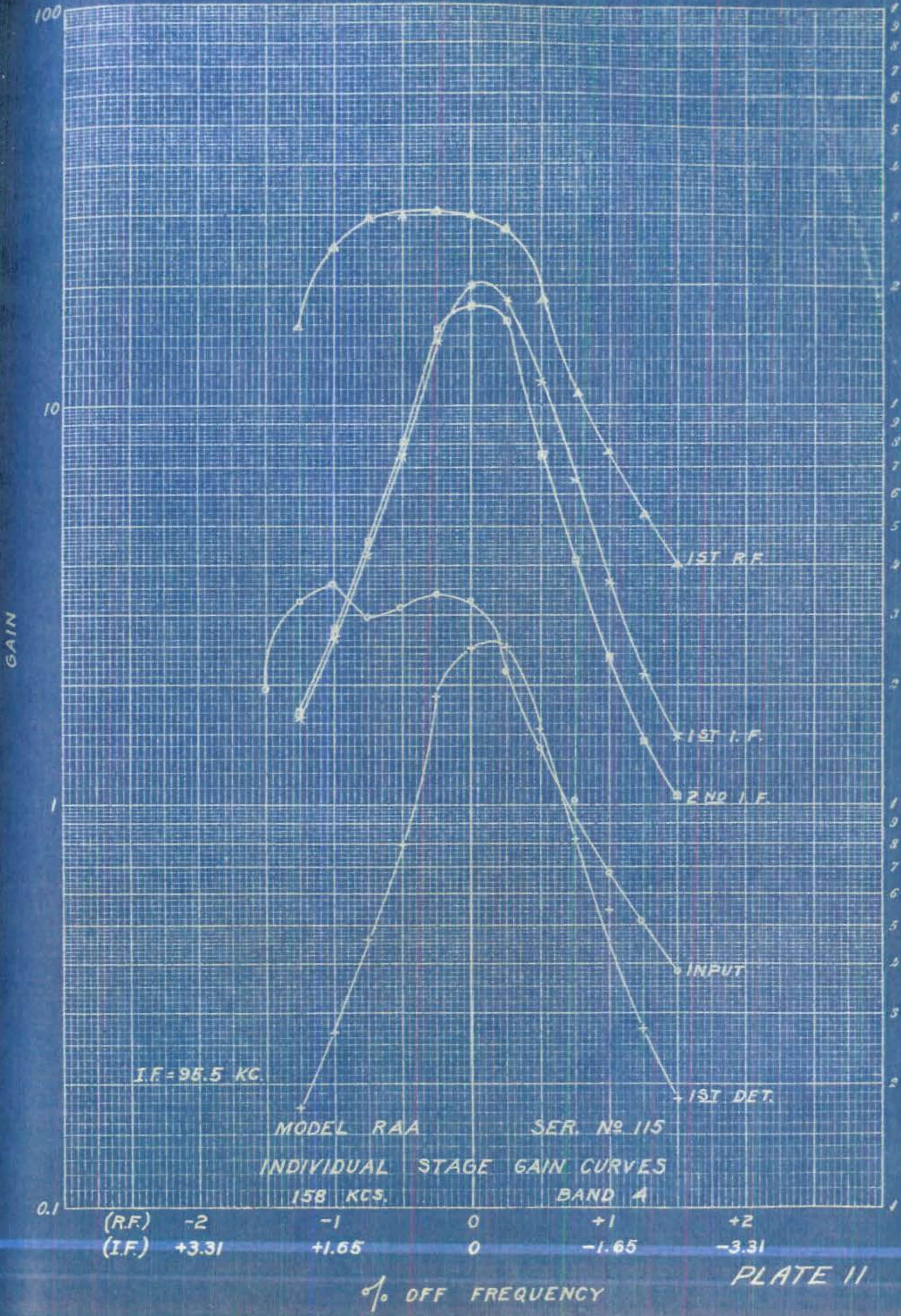
100
10
1
0.1
GAIN
1ST R.F.
INPUT
1ST I.F.
2ND I.F.
1ST DET.
I.F. = 95.5 KC.
MODEL RAA
SER. № 115
INDIVIDUAL STAGE GAIN CURVES
400 KCS.
BAND 4
(RF) -2 -1 0 +1 +2
(I.F.) +8.38 +4.19 0 -4.19 -8.38
% OFF FREQUENCY

PLATE 9



GAIN
100
10
1
0.1
1ST R.F.
INPUT
1ST I.F.
2ND I.F.
1ST DET.
I.F.=95.5 KC.
MODEL RAA
SER. № 115
INDIVIDUAL STAGE GAIN CURVES
250 KCS.
BAND 4
(R.F.) -2 -1 0 +1 +2
(I.F.) +5.24 +2.62 0 -2.62 -5.24
% OFF FREQUENCY

PLATE 10



100
10
1
0.1
GAIN
1ST R.F.
1ST I.F.
2ND I.F.
INPUT
1ST DET.
I.F. = 96.5 KC.
MODEL RAA
SER. № 115
INDIVIDUAL STAGE GAIN CURVES
158 KCS.
BAND 4
(R.F.) -2 -1 0 +1 +2
(I.F.) +3.31 +1.65 0 -1.65 -3.31
% OFF FREQUENCY

PLATE 11

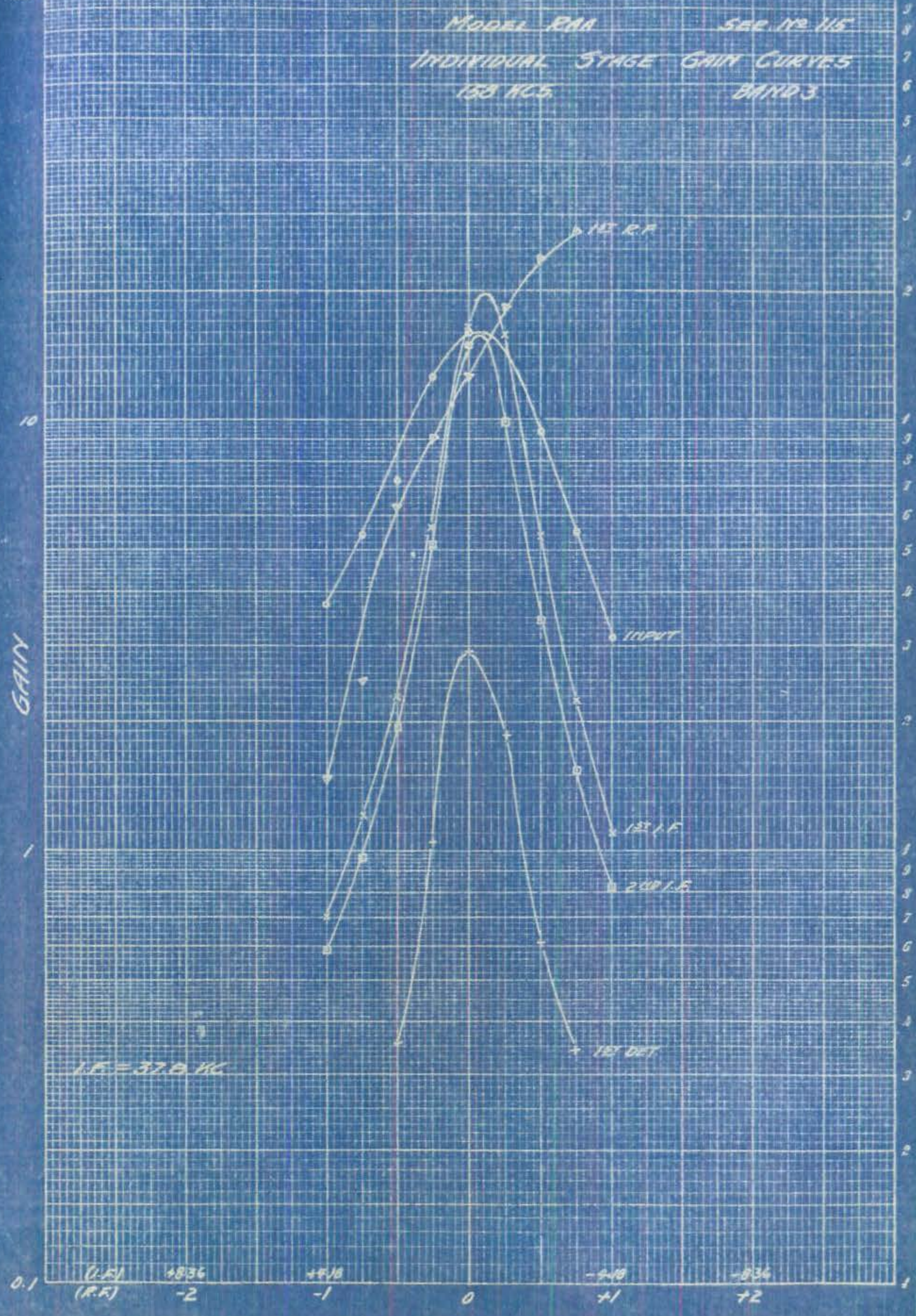
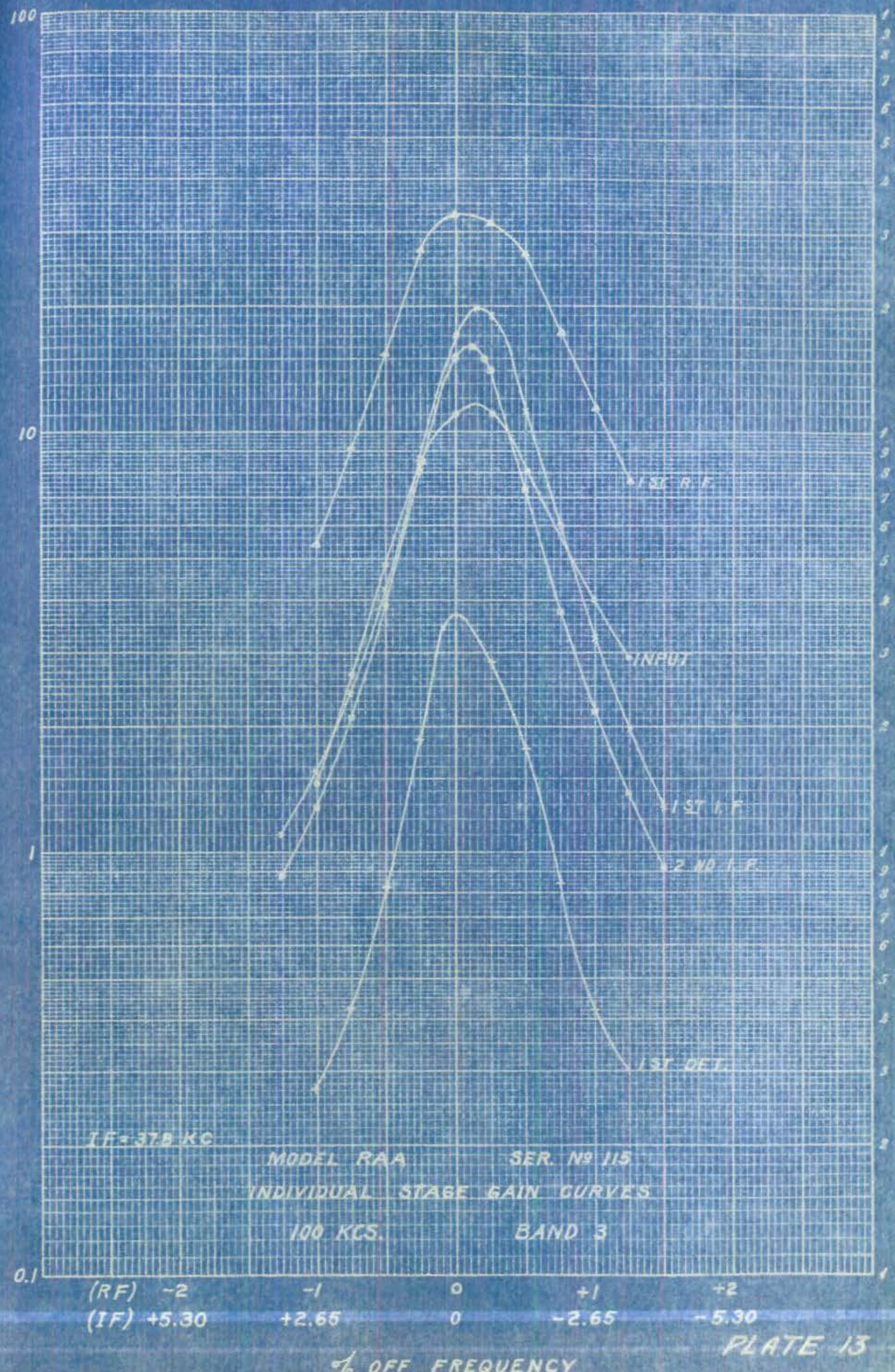

MODEL RAA
SER. Nº 115
INDIVIDUAL STAGE GAIN CURVES
158 KCS.
BAND 3
1ST R.F.
INPUT
1ST I.F.
2ND I.F.
1ST DET
I.F. = 37.8 KC
GAIN
(I.F.)
(R.F.)
+836
-2
+418
-1
0
-418
+1
-836
+2
% OFF FREQUENCY

PLATE 12



100
10
1
0.1
GAIN
1 ST. R.F.
INPUT
1 ST. I.F.
2 ND. I.F.
1 ST. DET.
I.F. = 378 KC
MODEL RAA SER. Nº 115
INDIVIDUAL STAGE GAIN CURVES
100 KCS. BAND 3
(RF) -2 -1 0 +1 +2
(IF) +5.30 +2.65 0 -2.65 -5.30
% OFF FREQUENCY

PLATE 13

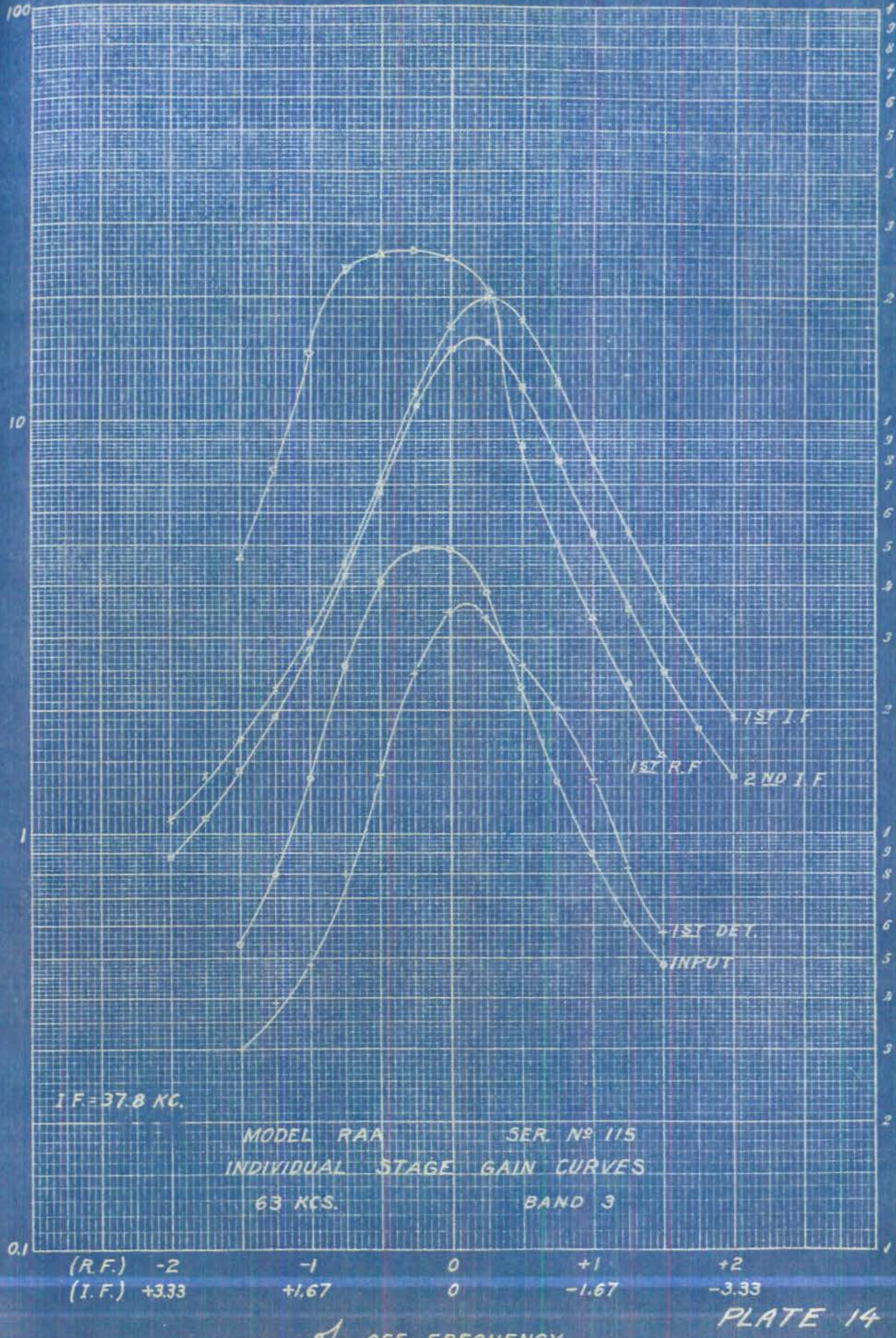
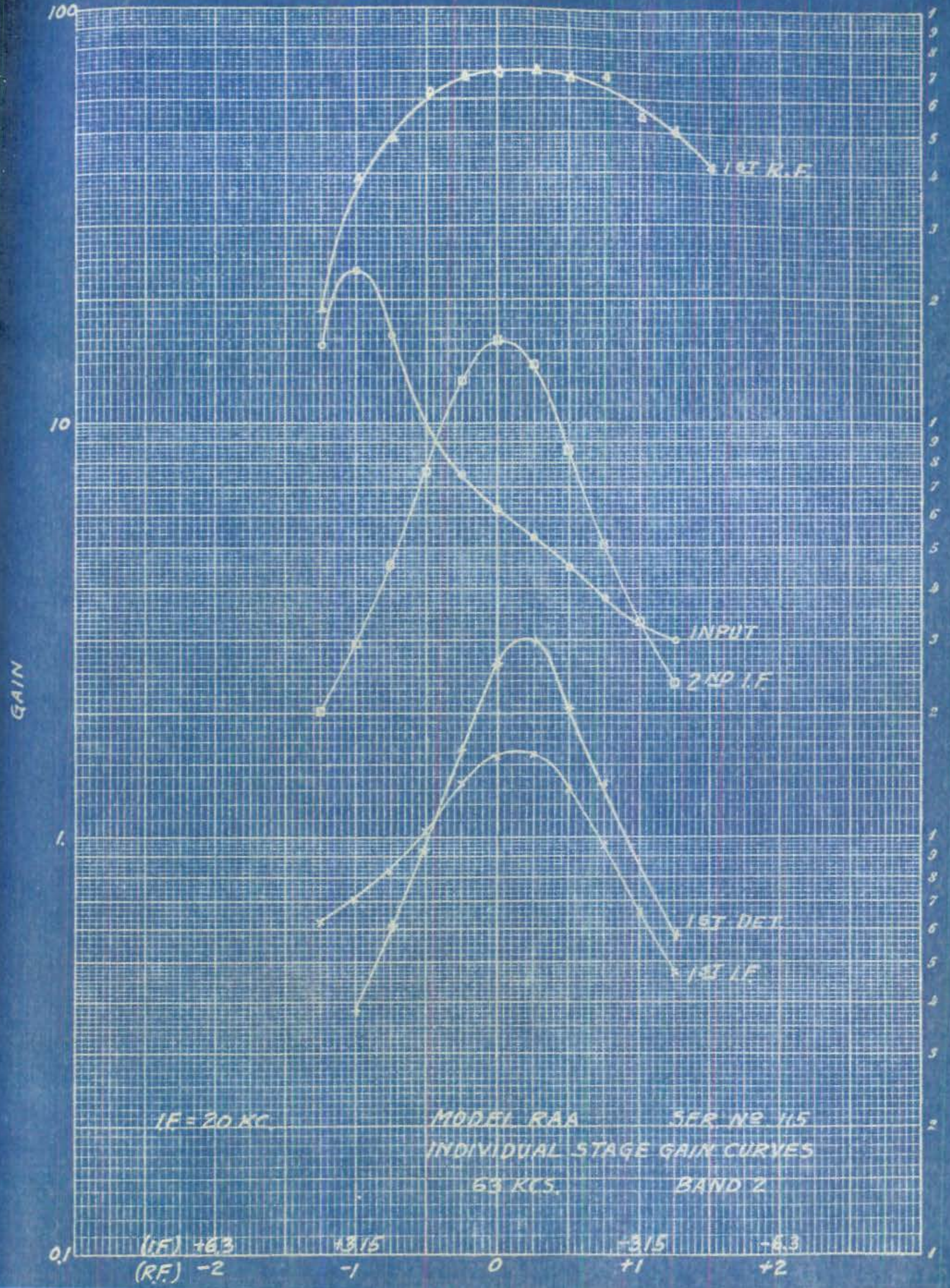

100
10
1
0.1
GAIN
1ST I.F
1ST R.F
2ND I.F
1ST DET.
INPUT
I.F.=37.8 KC.
MODEL RAA SER. Nº 115
INDIVIDUAL STAGE GAIN CURVES
63 KCS. BAND 3
(R.F.) -2 -1 0 +1 +2
(I.F.) +3.33 +1.67 0 -1.67 -3.33
% OFF FREQUENCY

PLATE 14



100
10
1.
0.1
GAIN
1ST R.F.
INPUT
2ND I.F.
1ST DET.
1ST I.F.
IF = 20 KC.
MODEL RAA
SER. No 115
INDIVIDUAL STAGE GAIN CURVES
63 KCS.
BAND 2
(I.F.) +6.3
+3.15
-3.15
-6.3
(R.F.) -2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 15

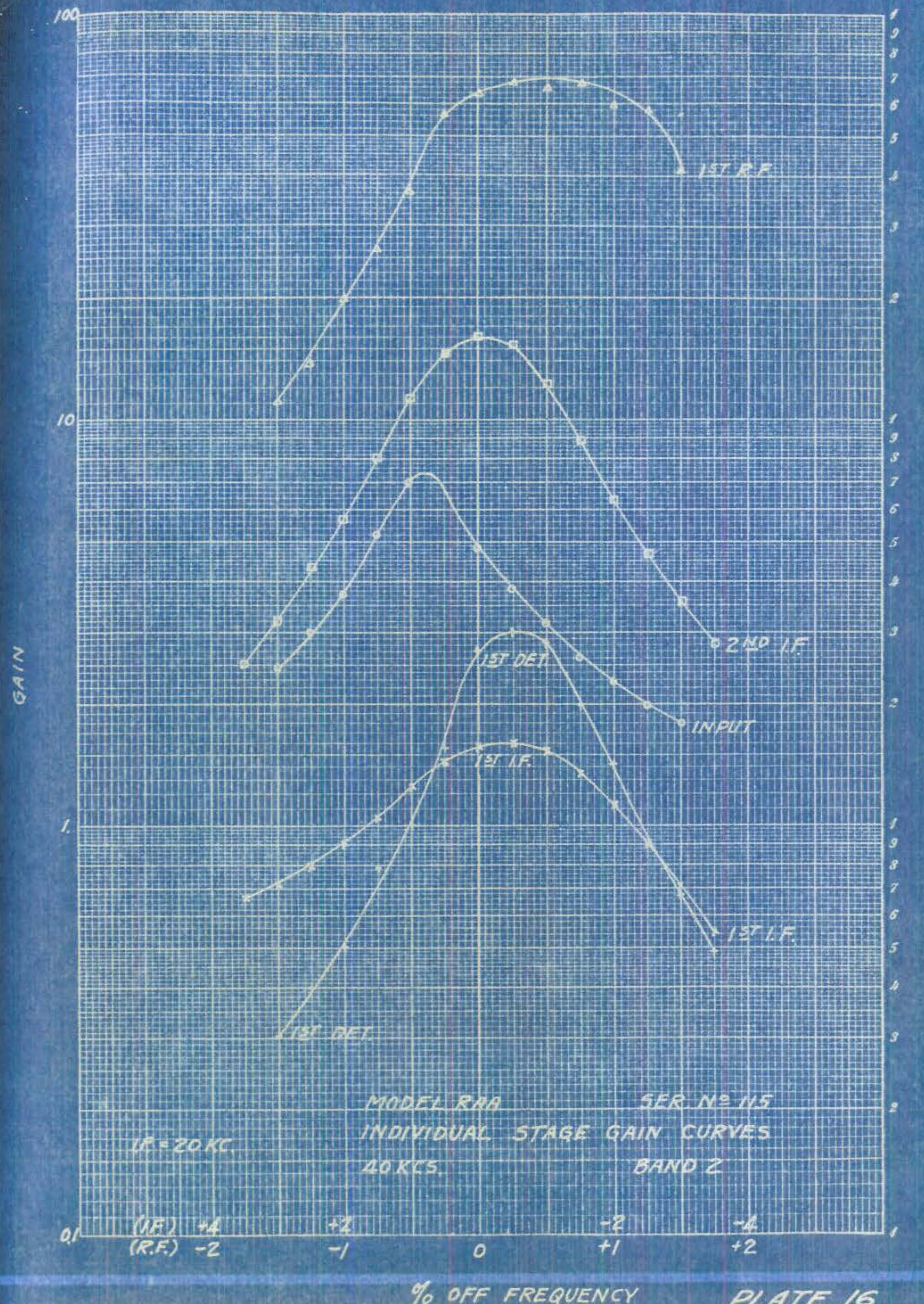

GAIN
100
10
1.
0.1
1ST R.F.
2ND I.F.
INPUT
1ST DET.
1ST I.F.
1ST I.F.
1ST DET.
MODEL RAA
SER. No 115
INDIVIDUAL STAGE GAIN CURVES
I.F. = 20 KC
40 KCS.
BAND 2
(I.F.) +4 +2 -2 -4
(R.F.) -2 -1 0 +1 +2
% OFF FREQUENCY

PLATE 16

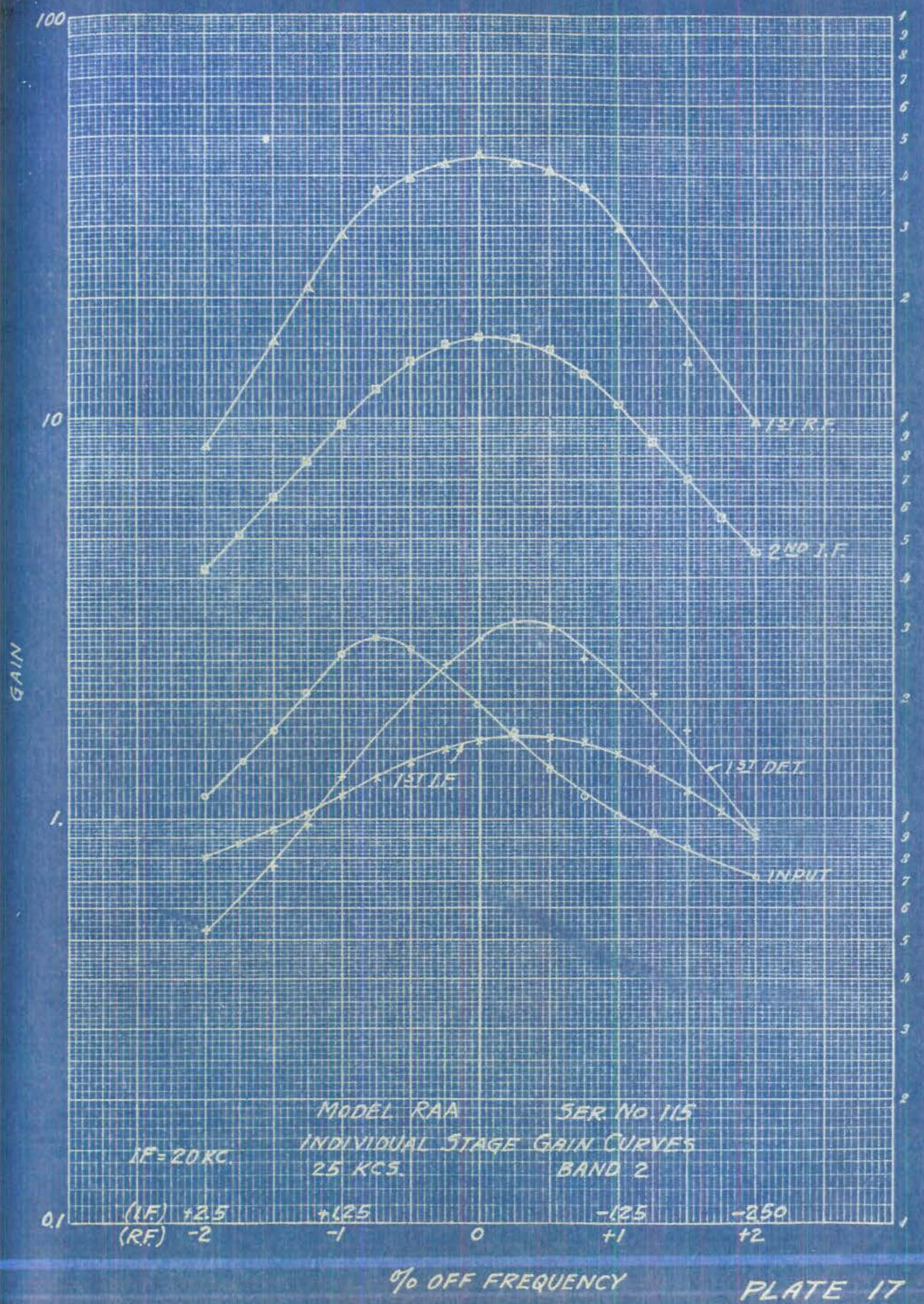

100
10
1.
0.1
GAIN
1ST R.F.
2ND I.F.
1ST DET.
1ST I.F.
INPUT
MODEL RAA
SER. NO. 115
INDIVIDUAL STAGE GAIN CURVES
I.F. = 20 KC.
25 KCS.
BAND 2
(I.F.) +2.5 +1.25 -1.25 -2.50
(R.F.) -2 -1 0 +1 +2
% OFF FREQUENCY

PLATE 17

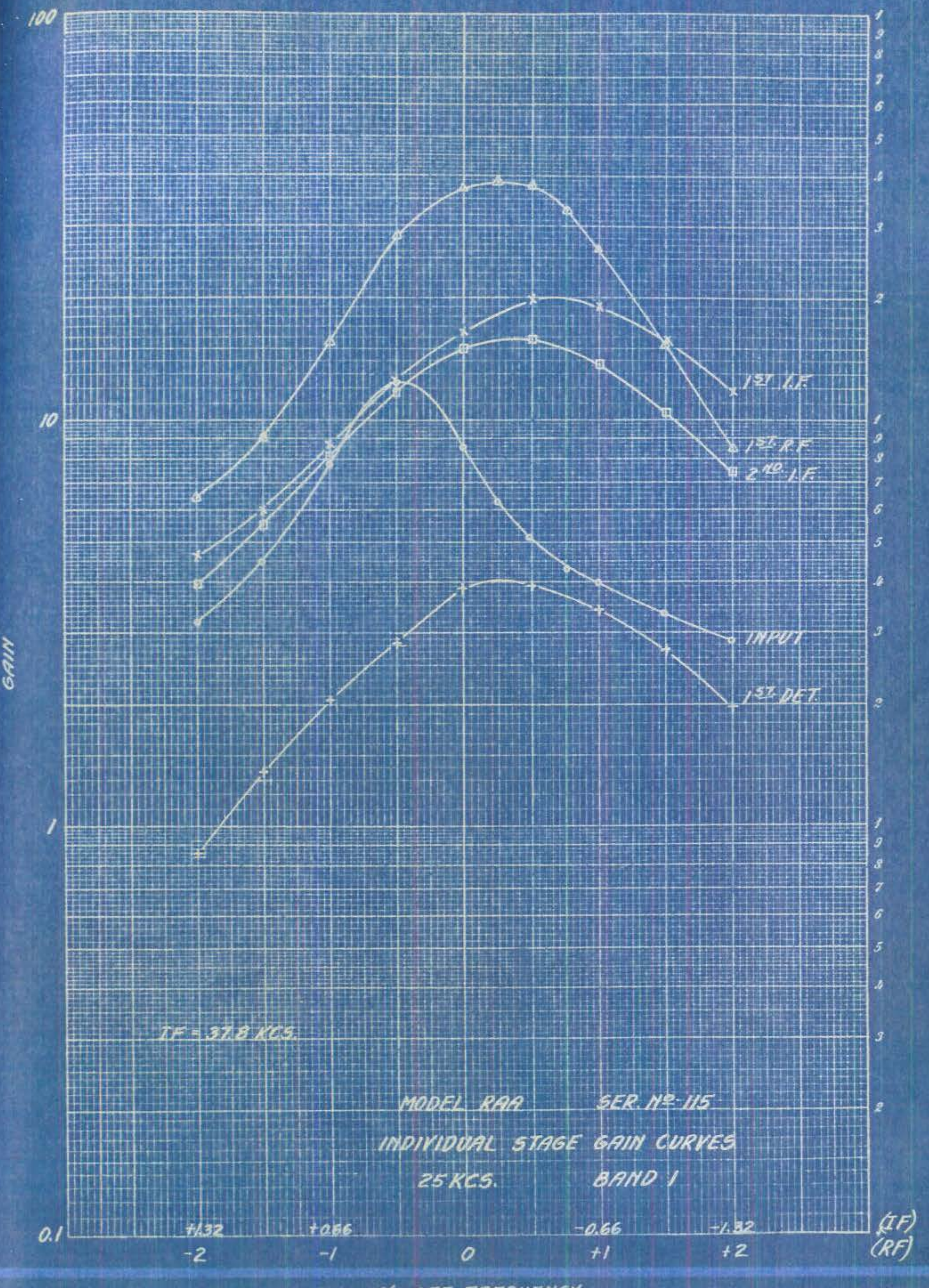

100
10
1
0.1
GAIN
1ST I.F.
1ST R.F.
2ND I.F.
INPUT
1ST DET.
IF = 37.8 KCS.
MODEL RAA SER. Nº 115
INDIVIDUAL STAGE GAIN CURVES
25 KCS. BAND I
+1.32 +0.66 -0.66 -1.32 (IF)
-2 -1 0 +1 +2 (RF)
% OFF FREQUENCY

PLATE 18

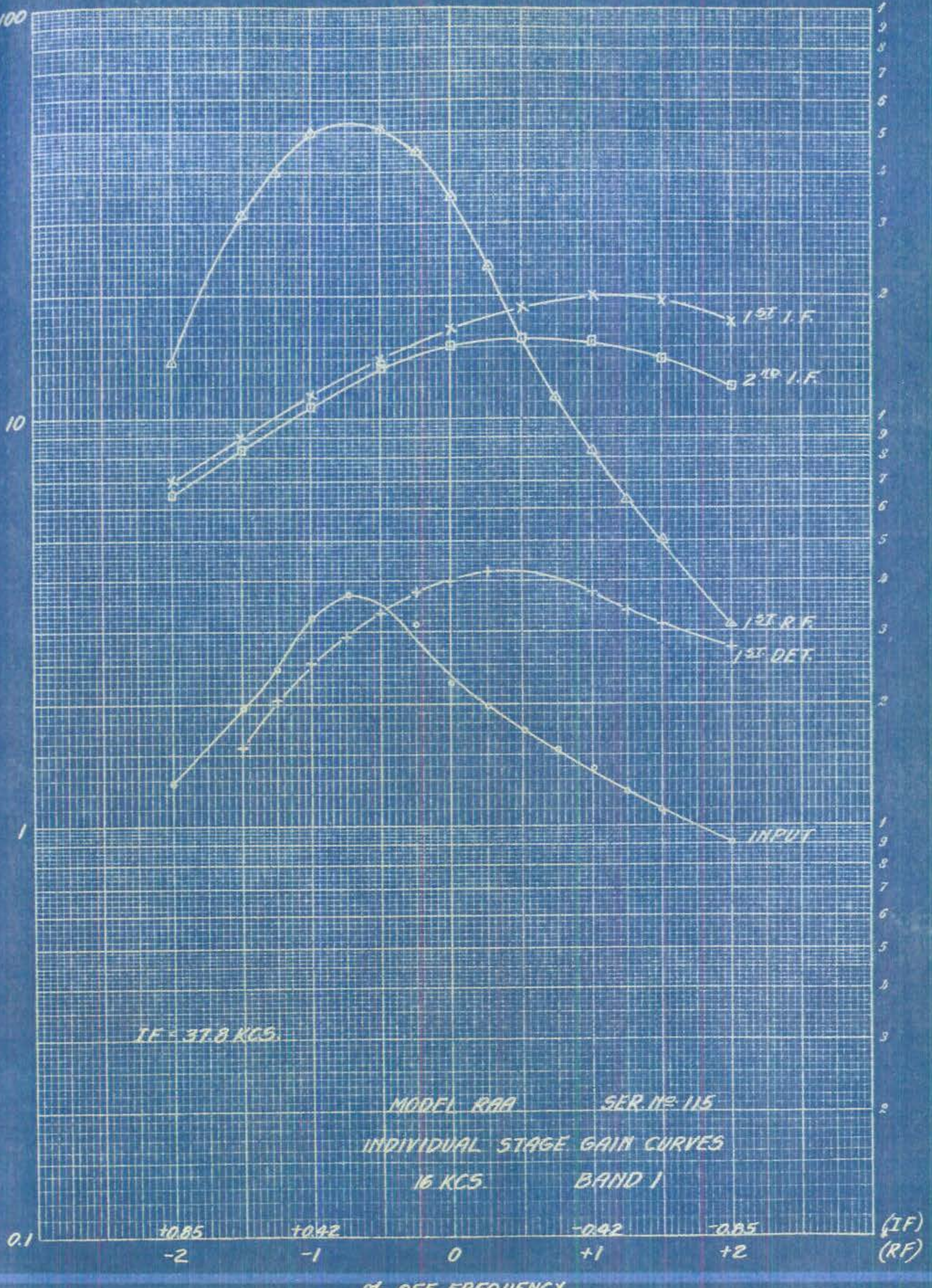
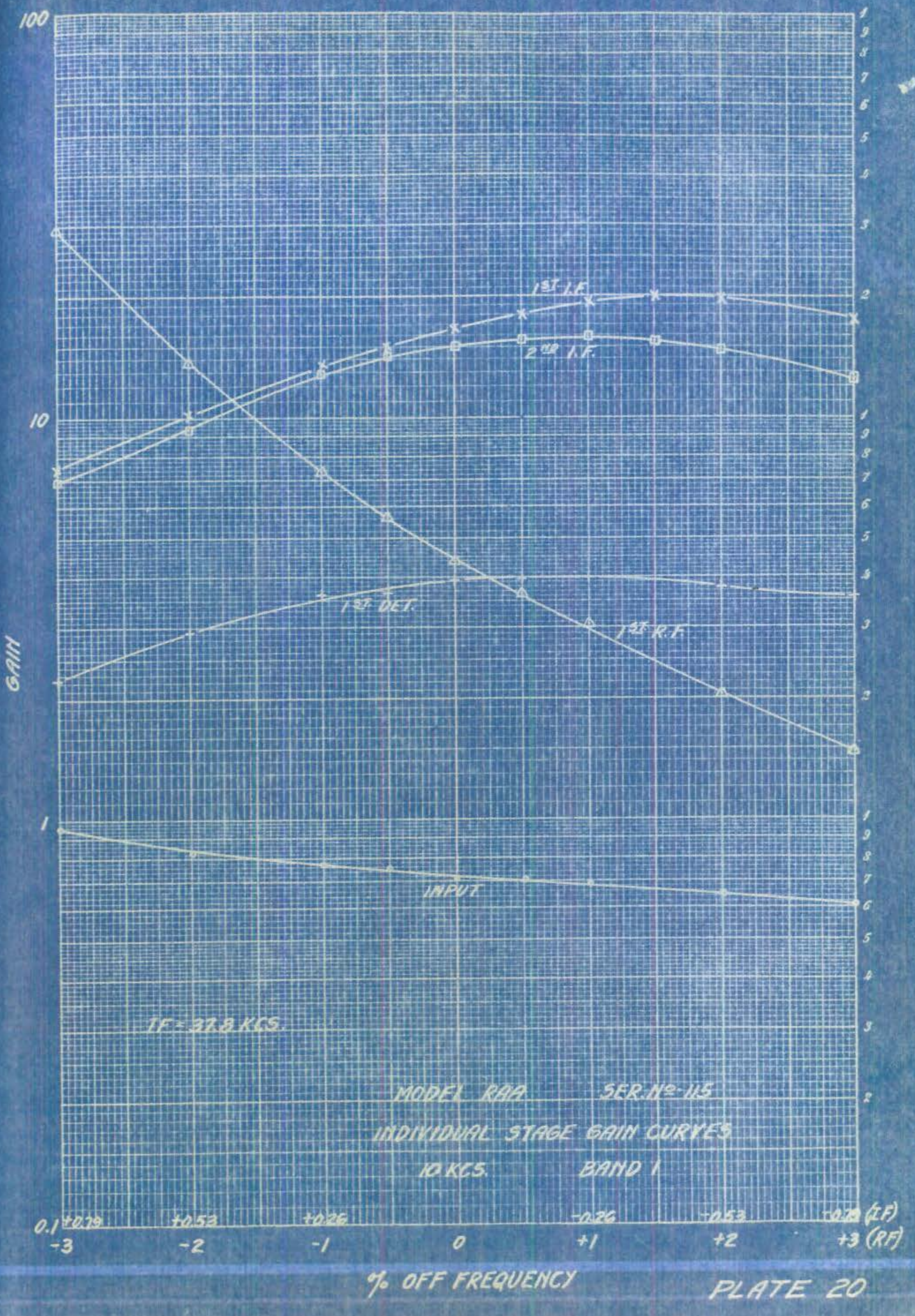

100
10
1
0.1
GAIN
1ST I.F.
2ND I.F.
1ST R.F.
1ST DET.
INPUT
IF = 37.8 KCS.
MODEL RAA SER. No 115
INDIVIDUAL STAGE GAIN CURVES
16 KCS. BAND 1
+0.85
+0.42
-0.42
-0.85
(IF)
-2
-1
0
+1
+2
(RF)
% OFF FREQUENCY

PLATE 19



GAIN
100
10
1
0.1
1ST I.F.
2ND I.F.
1ST DET.
1ST R.F.
INPUT
IF = 37.8 KCS.
MODEL RAA SER. Nº 115
INDIVIDUAL STAGE GAIN CURVES
10 KCS. BAND 1
+0.79 +0.53 +0.26 -0.26 -0.53 -0.79 (IF)
-3 -2 -1 0 +1 +2 +3 (RF)
% OFF FREQUENCY

PLATE 20

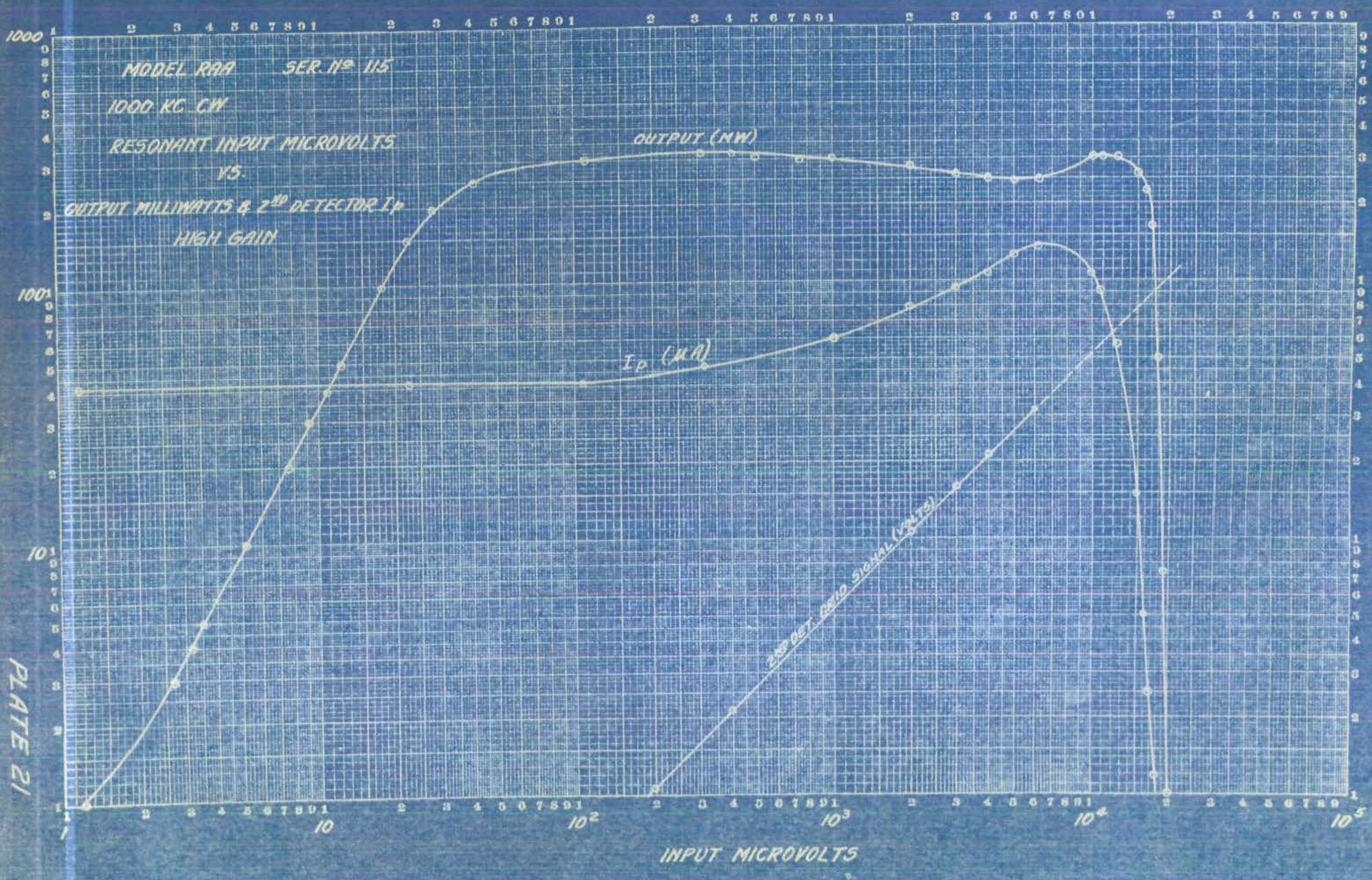

MODEL RAA SER. Nº 115
1000 KC CW
RESONANT INPUT MICROVOLTS
VS.
OUTPUT MILLIWATTS & 2ND DETECTOR Ip
HIGH GAIN
OUTPUT (MW)
Ip (μA)
2ND DET. GRID SIGNAL (VOLTS)
INPUT MICROVOLTS
1000
100
10
1
10
10²
10³
10⁴
10⁵

PLATE 21

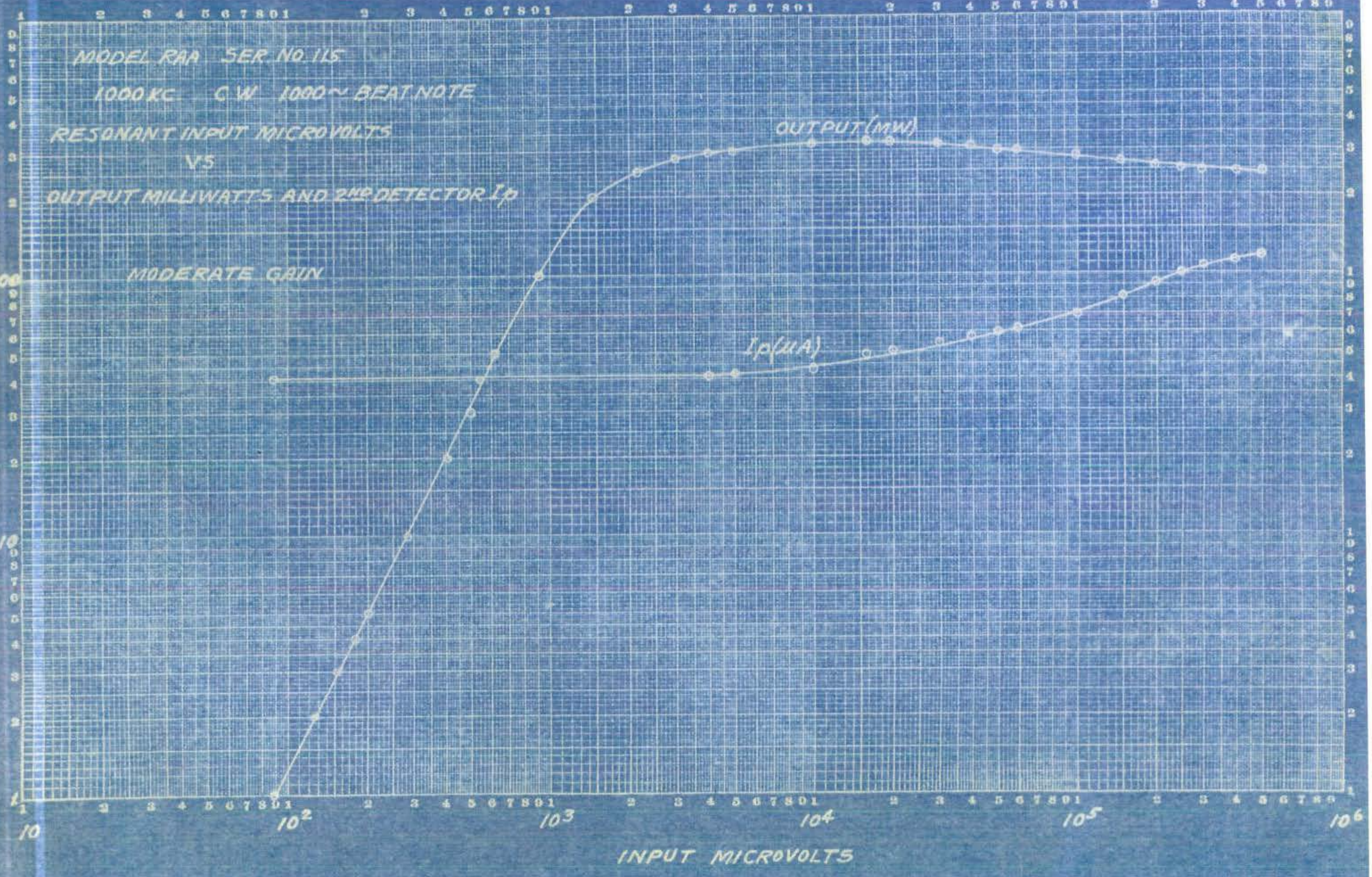

MODEL RAA SER. NO. 115
1000 KC C.W. 1000~ BEAT NOTE
RESONANT INPUT MICROVOLTS
VS
OUTPUT MILLIWATTS AND 2ND DETECTOR Ip
MODERATE GAIN
OUTPUT (MW)
Ip(μA)
100
10
1
10
10²
10³
10⁴
10⁵
10⁶
INPUT MICROVOLTS

PLATE 22

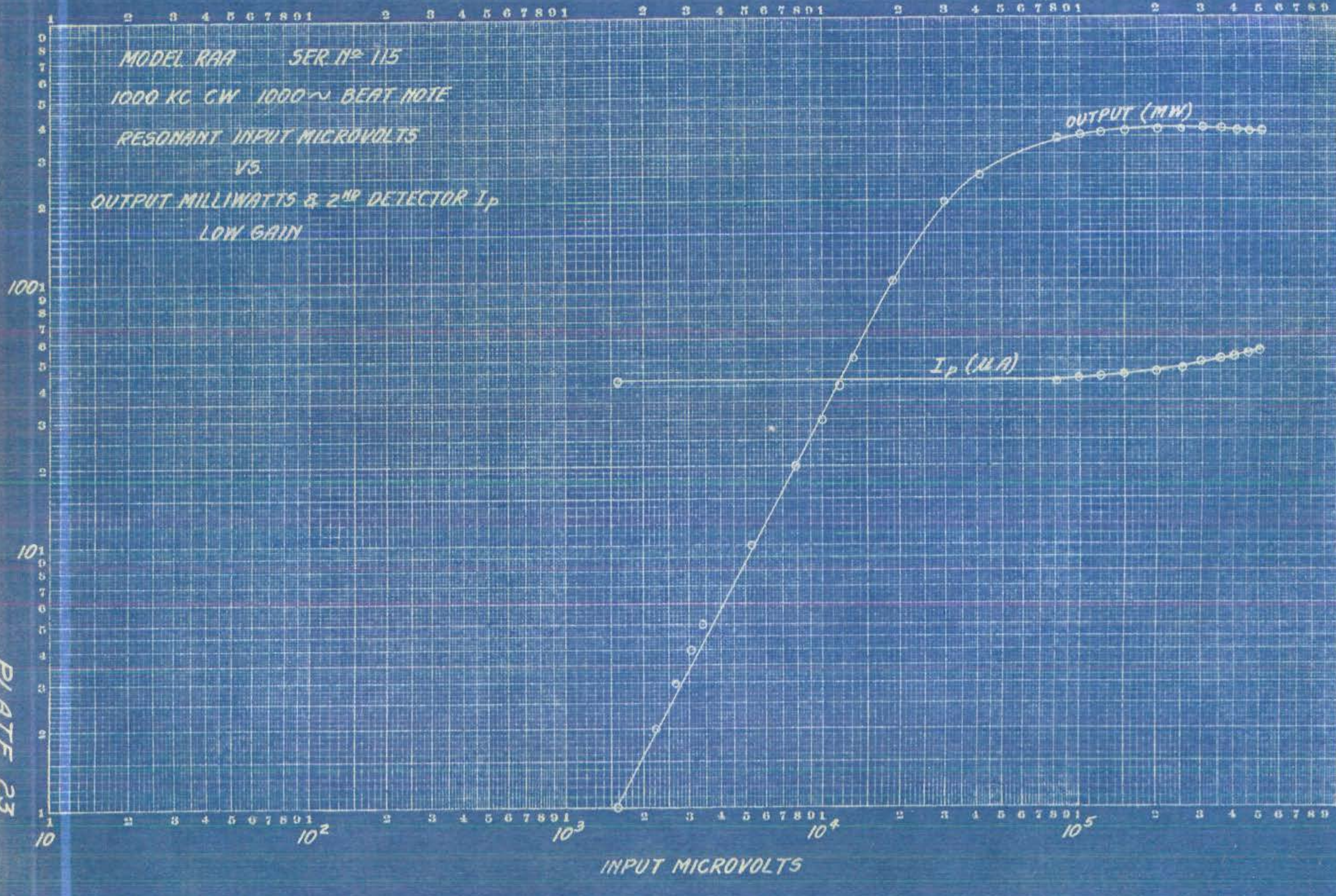
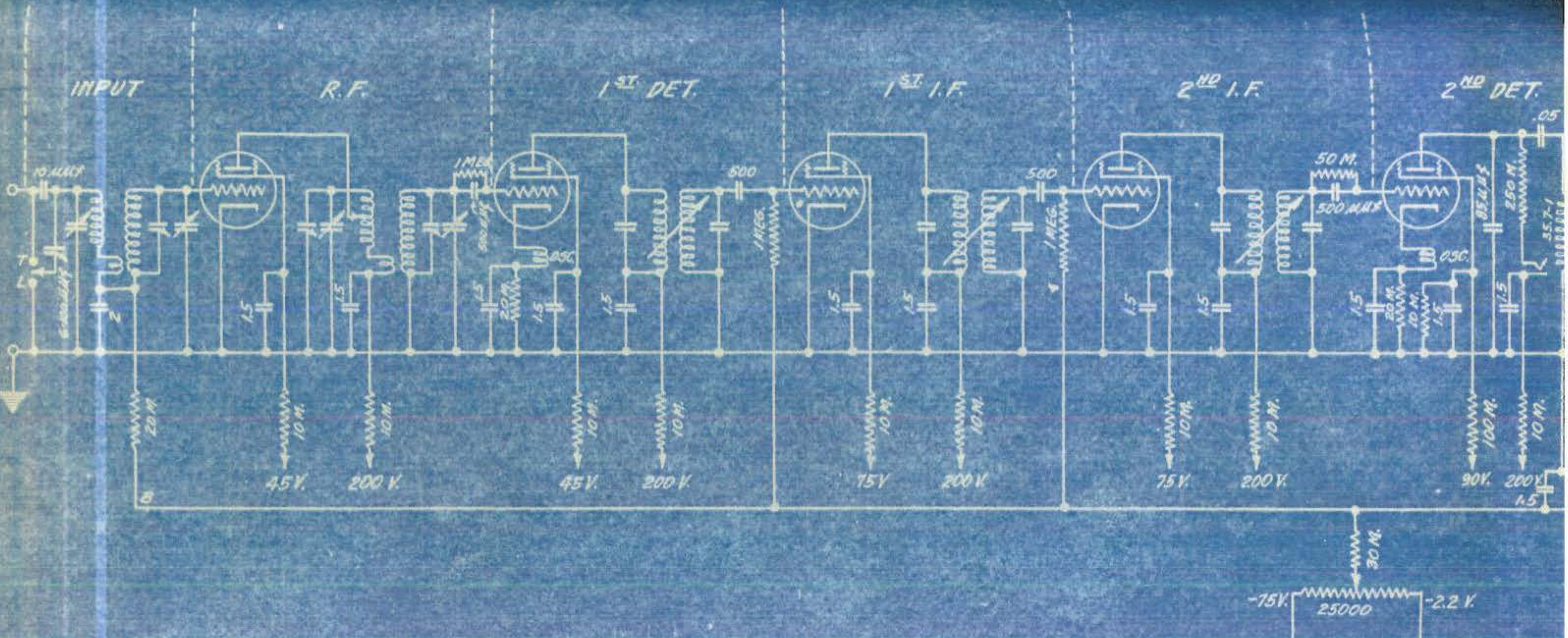

MODEL RAA SER. No 115
1000 KC CW 1000~ BEAT NOTE
RESONANT INPUT MICROVOLTS
VS.
OUTPUT MILLIWATTS & 2ND DETECTOR Ip
LOW GAIN
OUTPUT (MW)
Ip (μA)
100
10
10
10²
10³
10⁴
10⁵
INPUT MICROVOLTS

PLATE 23



MODEL RAA RECEIVER
SCHEMATIC WIRING DIAGRAM
OF R.F. & I.F. CIRCUITS

PLATE 24

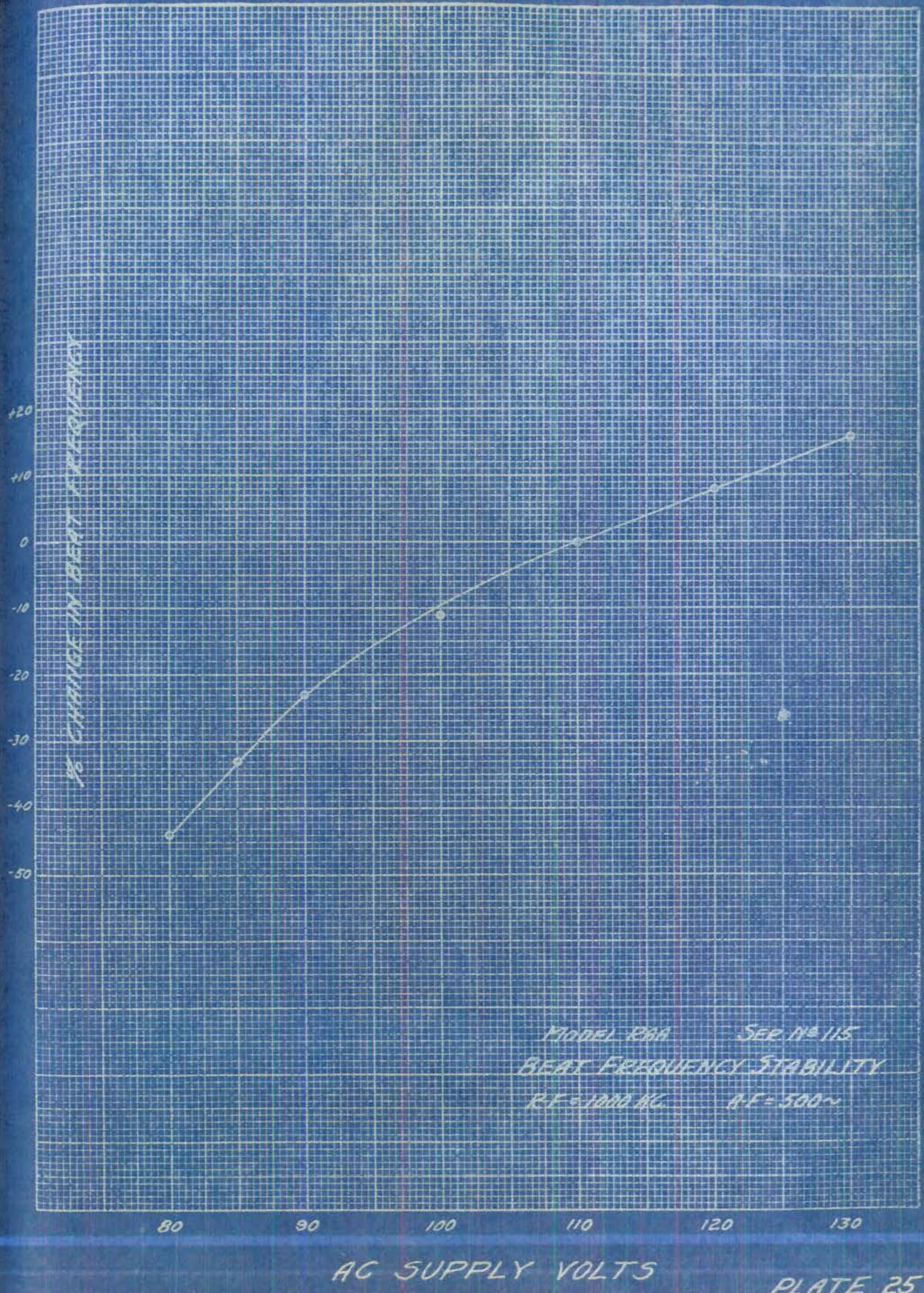

% CHANGE IN BEAT FREQUENCY
+20
+10
0
-10
-20
-30
-40
-50
MODEL RAA SER Nº 115
BEAT FREQUENCY STABILITY
R.F = 1000 KC. A.F = 500~
80
90
100
110
120
130
AC SUPPLY VOLTS

PLATE 25


MODEL RAA SER NO 115
CW SENSITIVITY 10-1000 KC
STANDARD OUTPUT - 5 MW
BAND 1
BAND 2
BAND 3
BAND 4
BAND 5
10
20
40
100
200
400
1000
KILOCYCLES
10
1
0.1
MICROVOLTS

PLATE 26

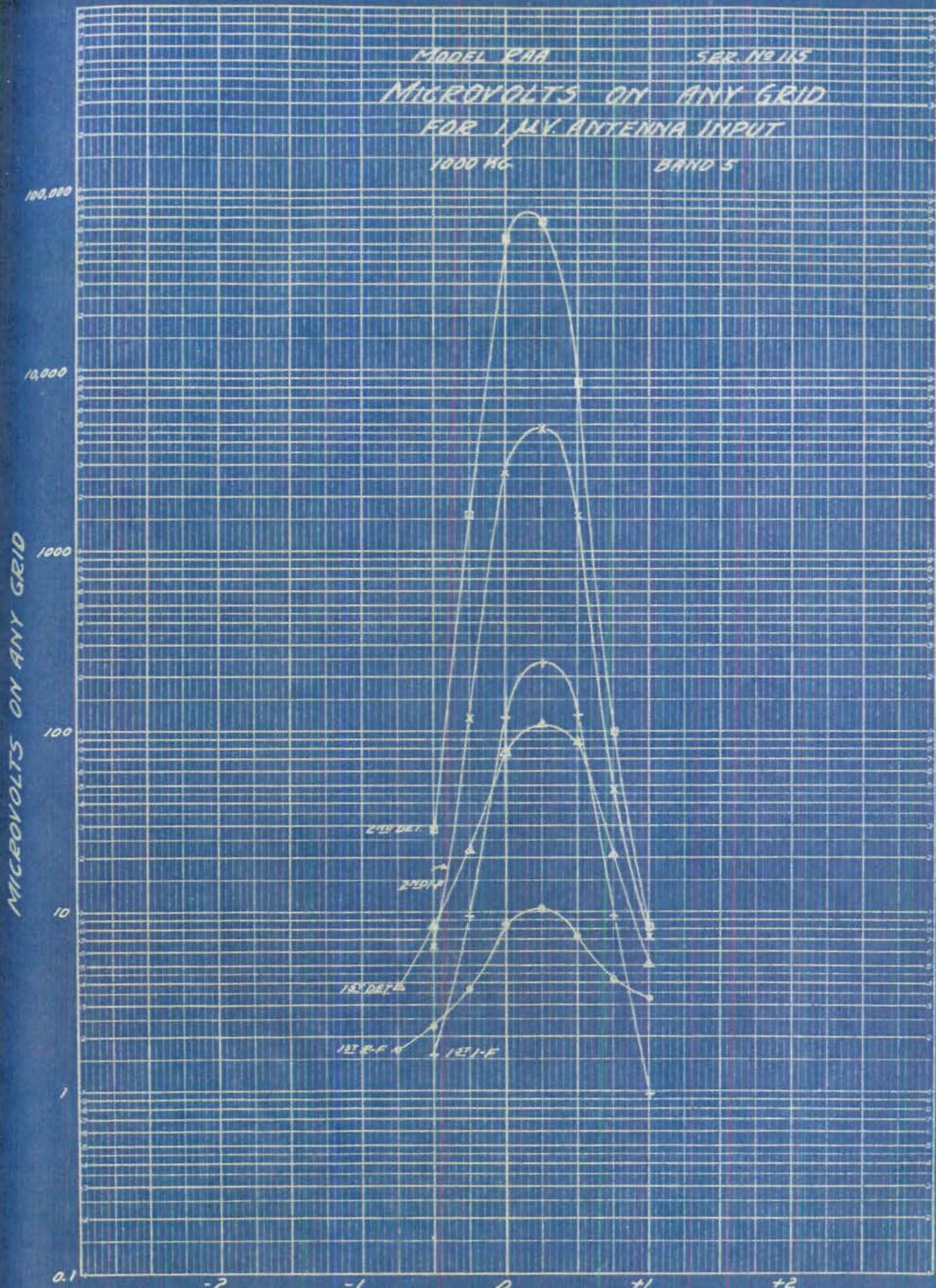

MODEL RAA
SER. No 115
MICROVOLTS ON ANY GRID
FOR 1 µV. ANTENNA INPUT
1000 KC
BAND 5
100,000
10,000
1000
100
10
1
0.1
2ND DET.
2ND I-F
1ST DET.
1ST R-F
1ST I-F
-2
-1
0
+1
+2
MICROVOLTS ON ANY GRID
% OFF FREQUENCY

PLATE 27

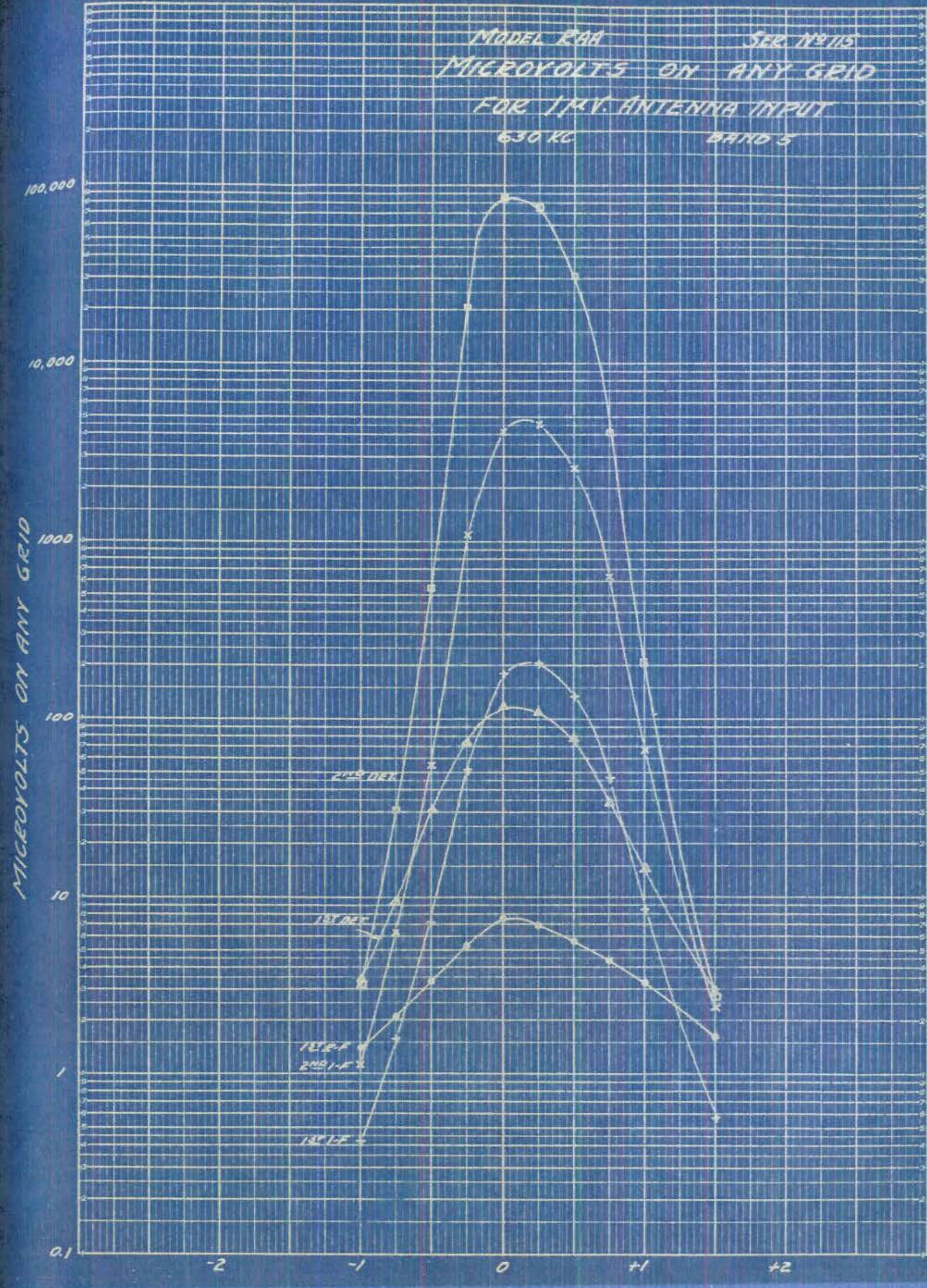

MODEL RAA
SER. No 115
MICROVOLTS ON ANY GRID
FOR 1 MV. ANTENNA INPUT
630 KC
BAND 5
100,000
10,000
1000
100
10
1
0.1
MICROVOLTS ON ANY GRID
2ND DET.
1ST DET.
1ST R-F
2ND I-F
1ST I-F
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 28

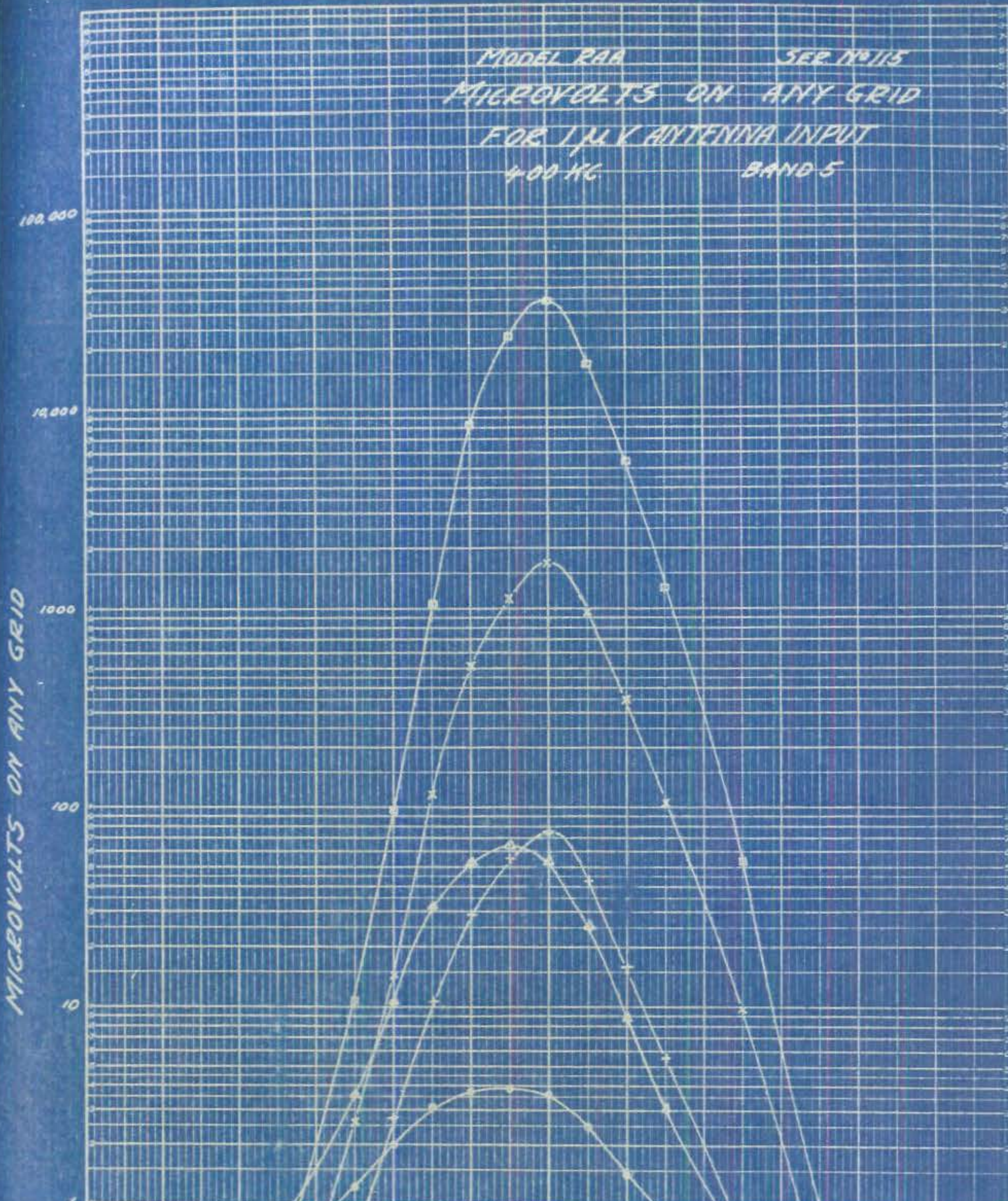

MODEL RAA
SER Nº 115
MICROVOLTS ON ANY GRID
FOR 1 μV ANTENNA INPUT
400 KC
BAND 5
MICROVOLTS ON ANY GRID
100,000
10,000
1000
100
10
1
0.1
-2
-1
0
+1
+2
2ND DET.
2ND I-F
1ST R-F
1ST DET.
1ST I-F
% OFF FREQUENCY

PLATE 29

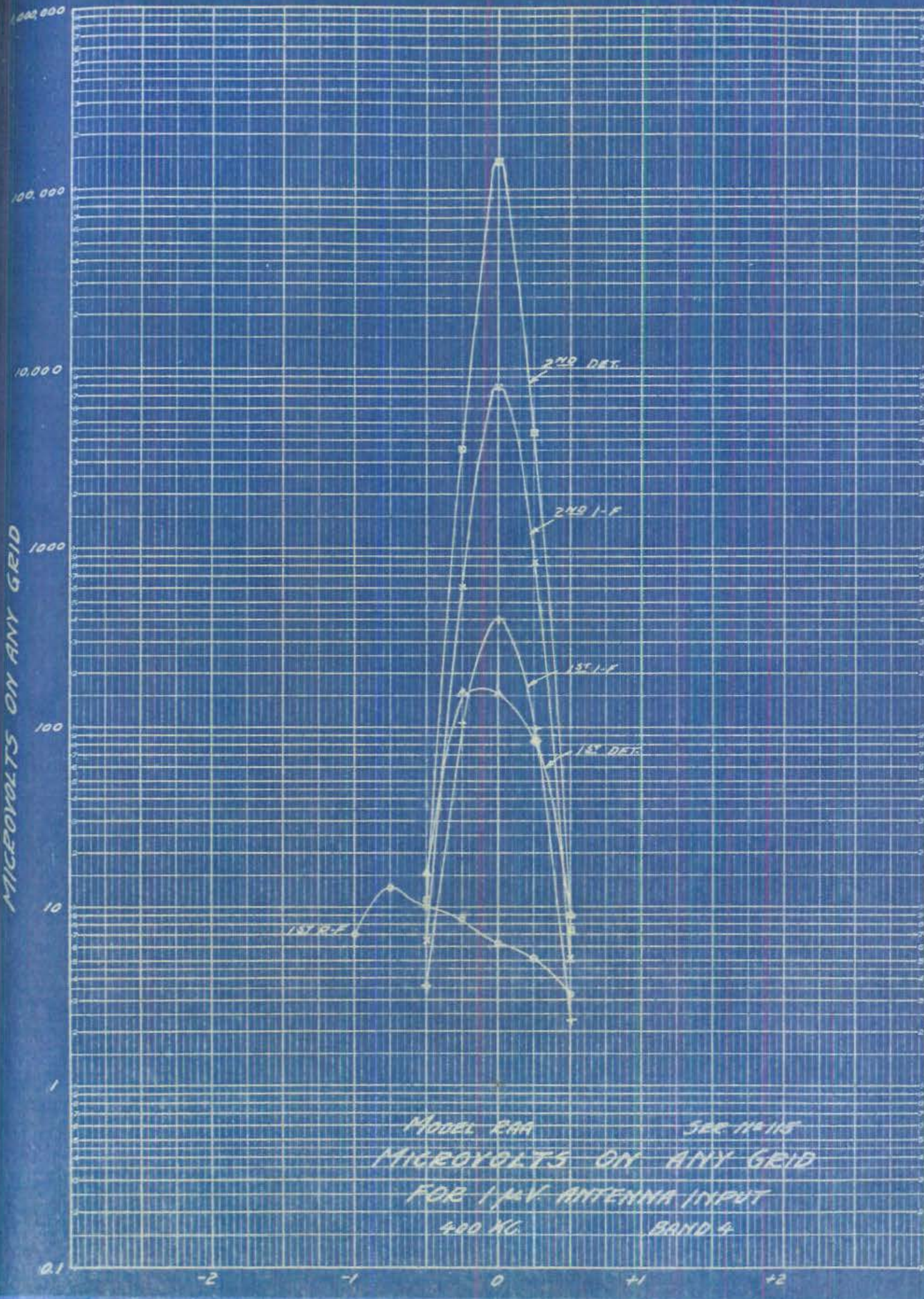
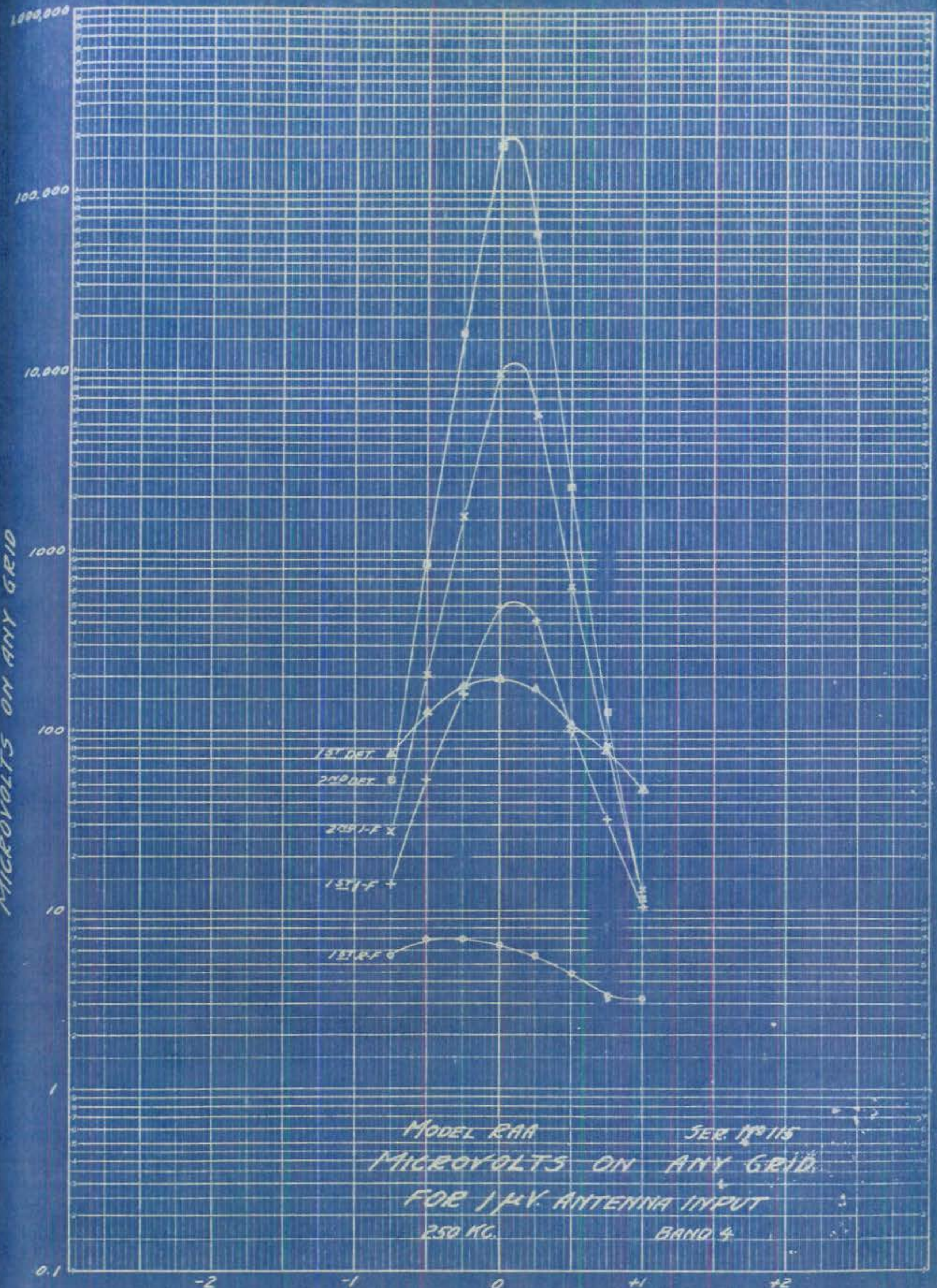
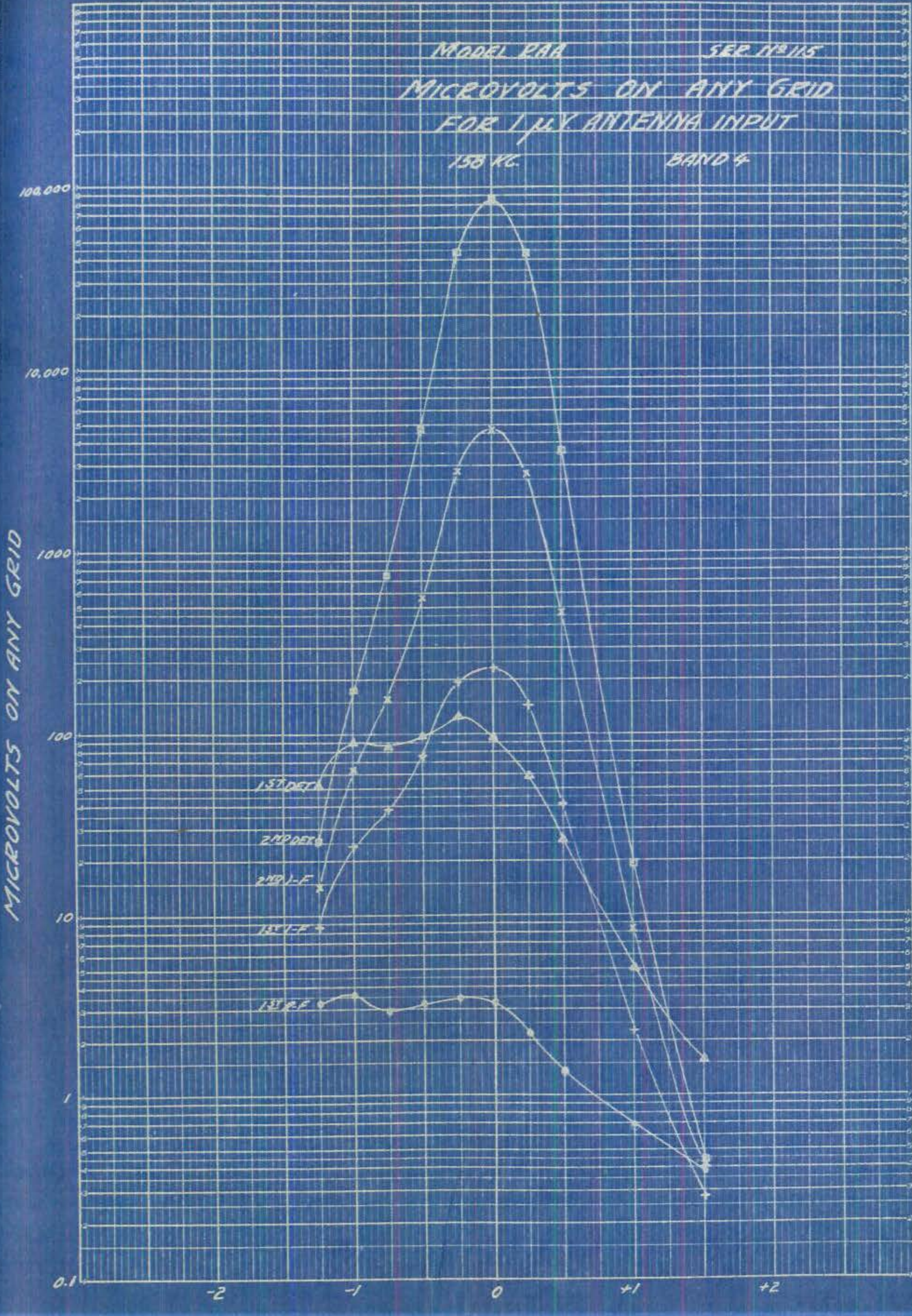

1,000,000
100,000
10,000
1000
100
10
1
0.1
MICROVOLTS ON ANY GRID
2ND DET.
2ND I-F
1ST I-F
1ST DET.
1ST R-F
-2
-1
0
+1
+2
MODEL RAA
SER. Nº 115
MICROVOLTS ON ANY GRID
FOR 1 μV. ANTENNA INPUT
400 KC.
BAND 4
% OFF FREQUENCY

PLATE 30



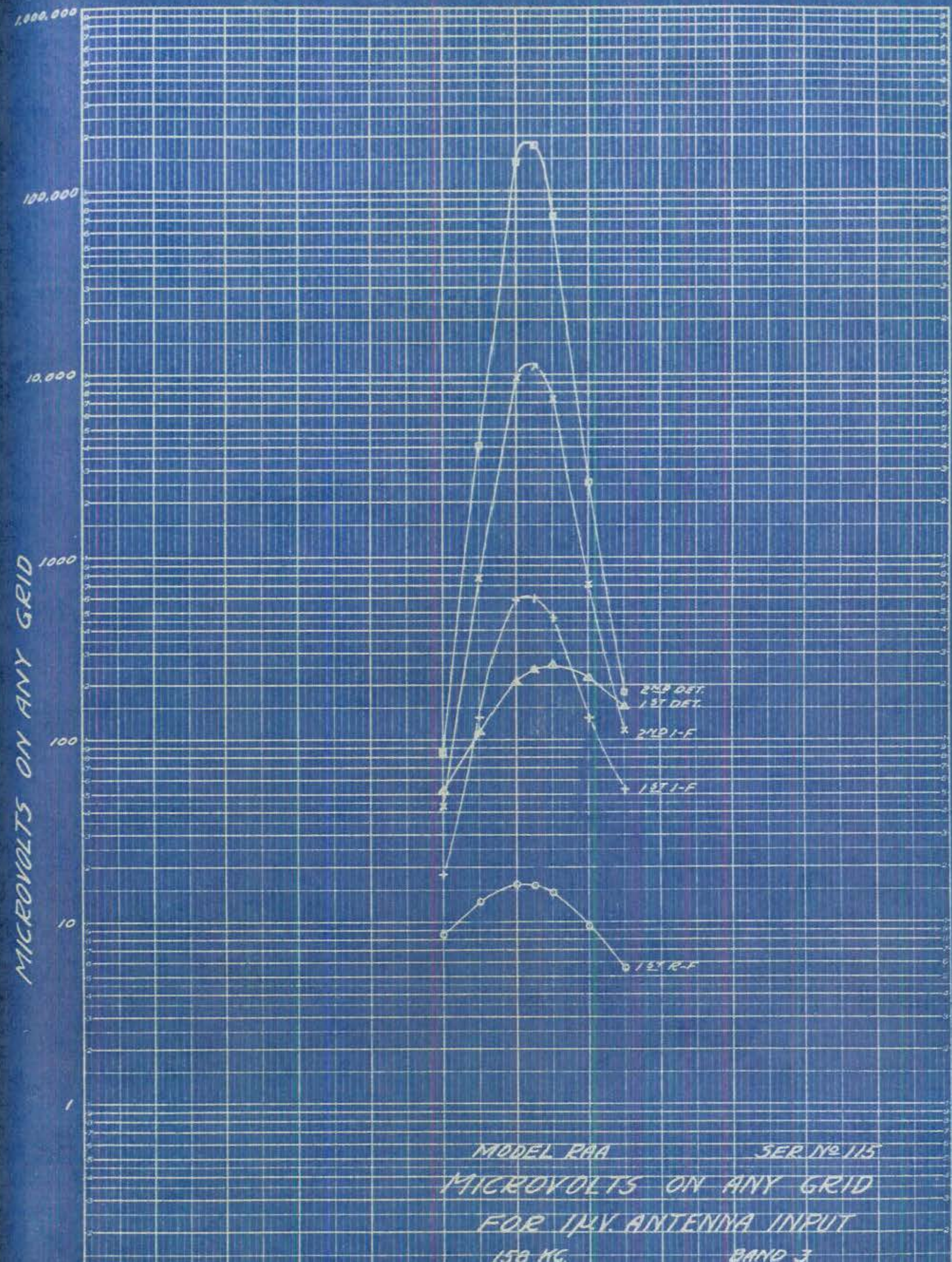
% OFF FREQUENCY

PLATE 31



MODEL RAA
SER. Nº 115
MICROVOLTS ON ANY GRID
FOR 1 µV ANTENNA INPUT
158 KC.
BAND 4
100,000
10,000
1000
100
10
1
0.1
1ST DET
2ND DET
2ND I-F
1ST I-F
1ST R-F
-2
-1
0
+1
+2
MICROVOLTS ON ANY GRID
% OFF FREQUENCY

PLATE 32



% OFF FREQUENCY PLATE 33

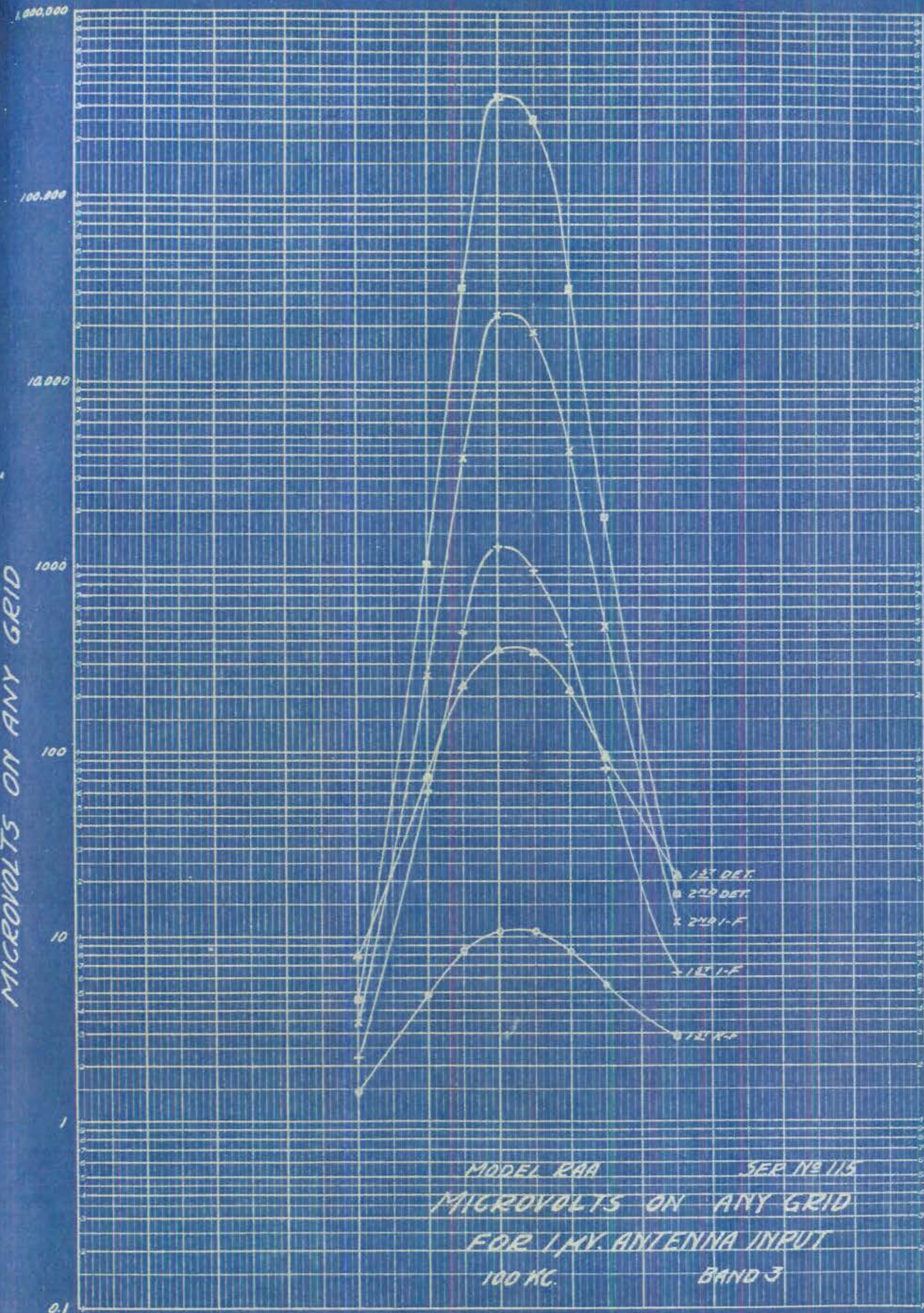

MICROVOLTS ON ANY GRID
1,000,000
100,000
10,000
1000
100
10
1
0.1
-2
-1
0
+1
+2
% OFF FREQUENCY
1ST DET.
2ND DET.
2ND I-F
1ST I-F
1ST R-F
MODEL RAA
SER. No 115
MICROVOLTS ON ANY GRID
FOR 1 MV. ANTENNA INPUT
100 KC.
BAND 3

PLATE 34

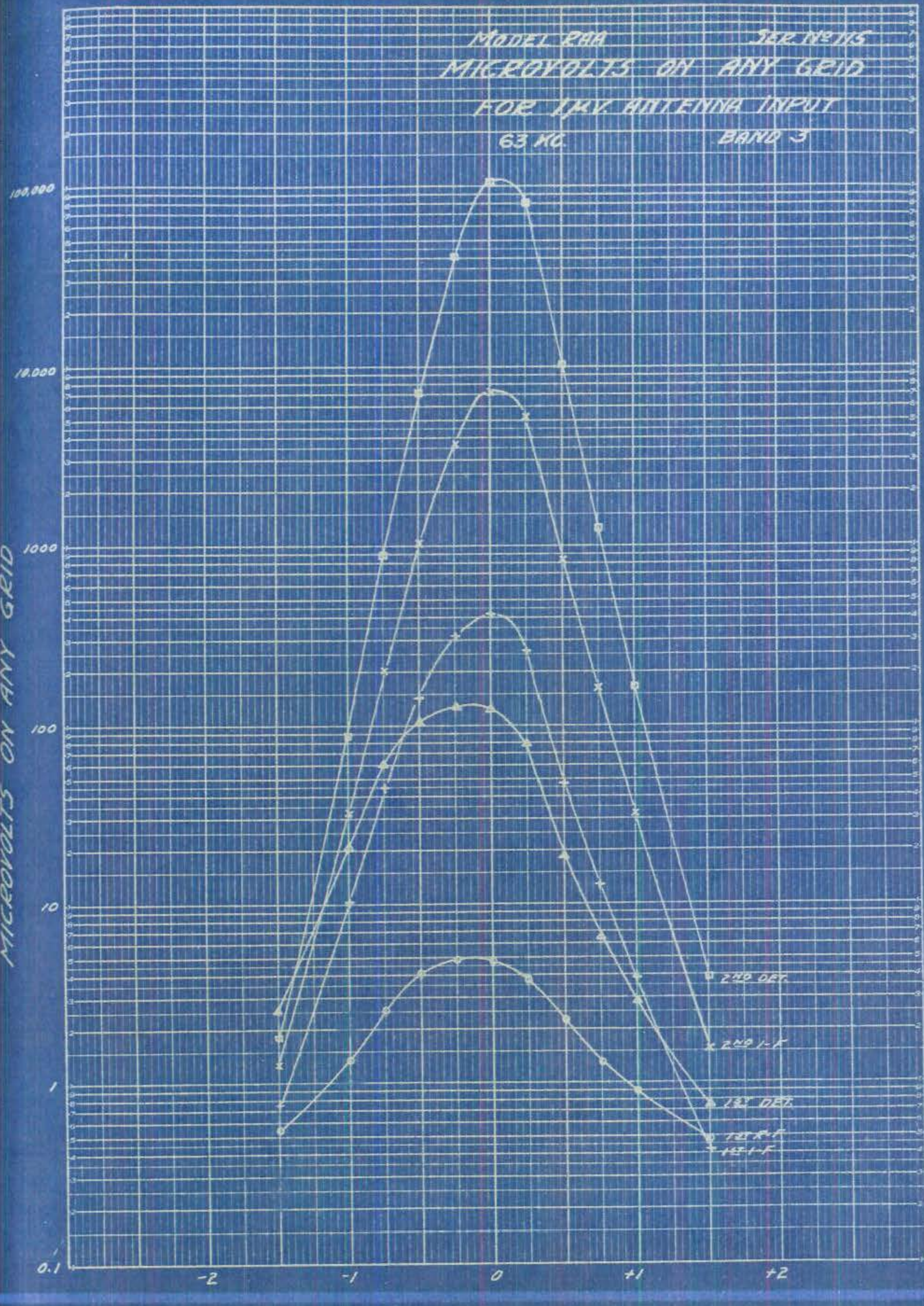
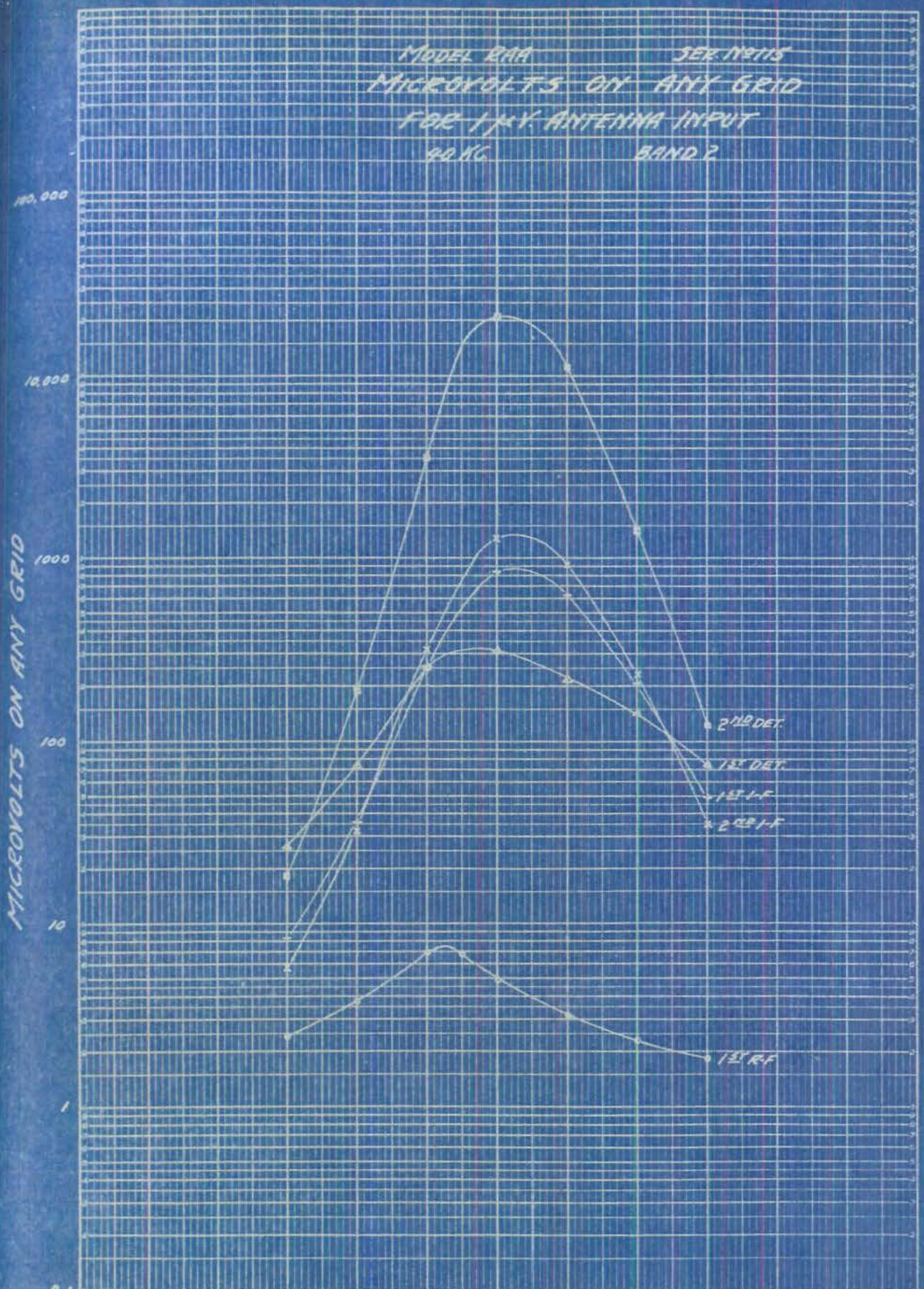

MODEL RAA
SER. Nº 115
MICROVOLTS ON ANY GRID
FOR 1 μV. ANTENNA INPUT
63 MC.
BAND 3
MICROVOLTS ON ANY GRID
100,000
10,000
1000
100
10
1
0.1
-2
-1
0
+1
+2
2ND DET.
2ND I-F
1ST DET.
1ST R-F
1ST I-F
% OFF FREQUENCY

PLATE 35



MODEL RAA
SER. No 115
MICROVOLTS ON ANY GRID
FOR 1 μV. ANTENNA INPUT
90 KC.
BAND 2
MICROVOLTS ON ANY GRID
100,000
10,000
1000
100
10
1
0.1
-2
-1
0
+1
+2
2ND DET.
1ST DET.
1ST I-F
2ND I-F
1ST R-F
% OFF FREQUENCY

PLATE 37

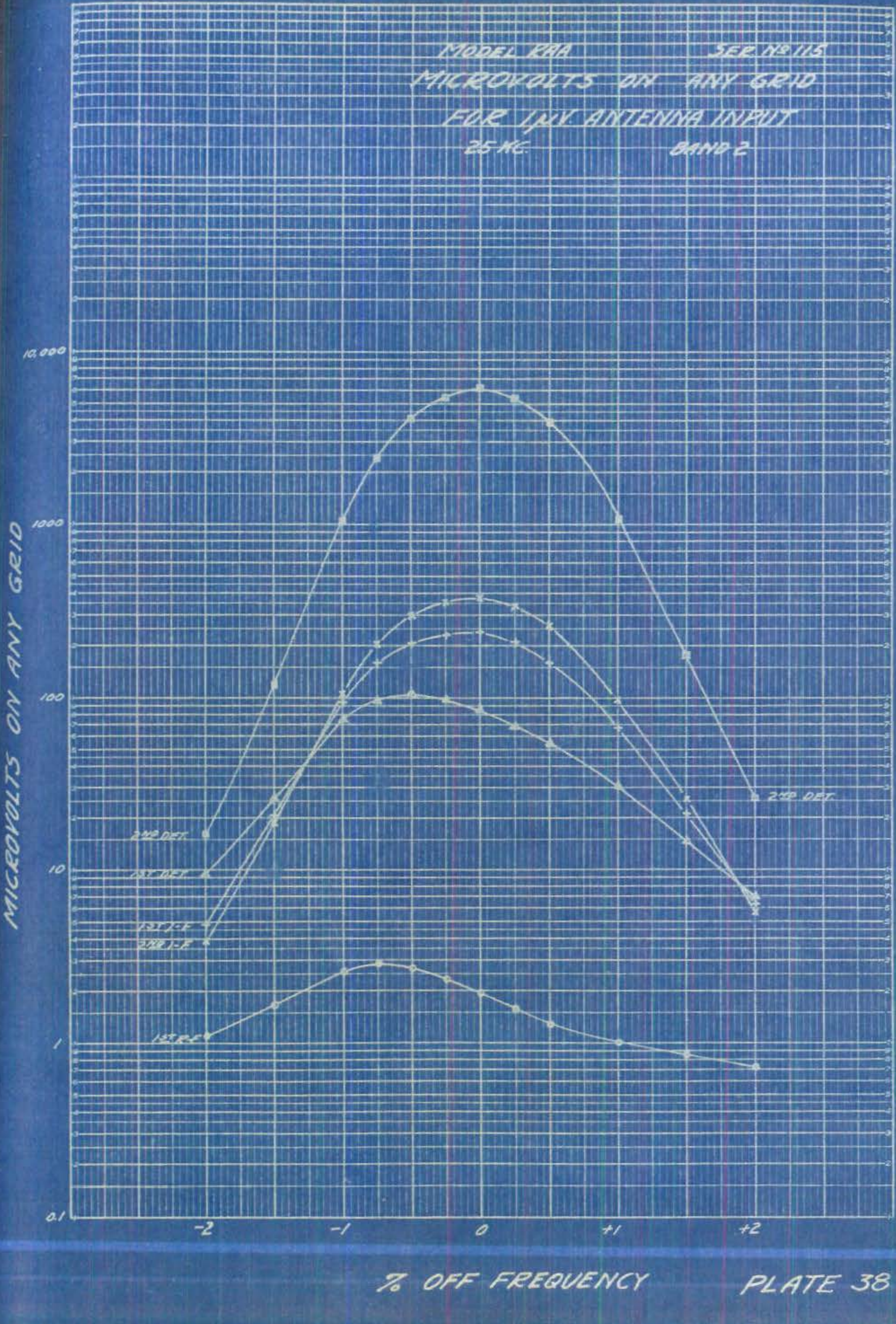
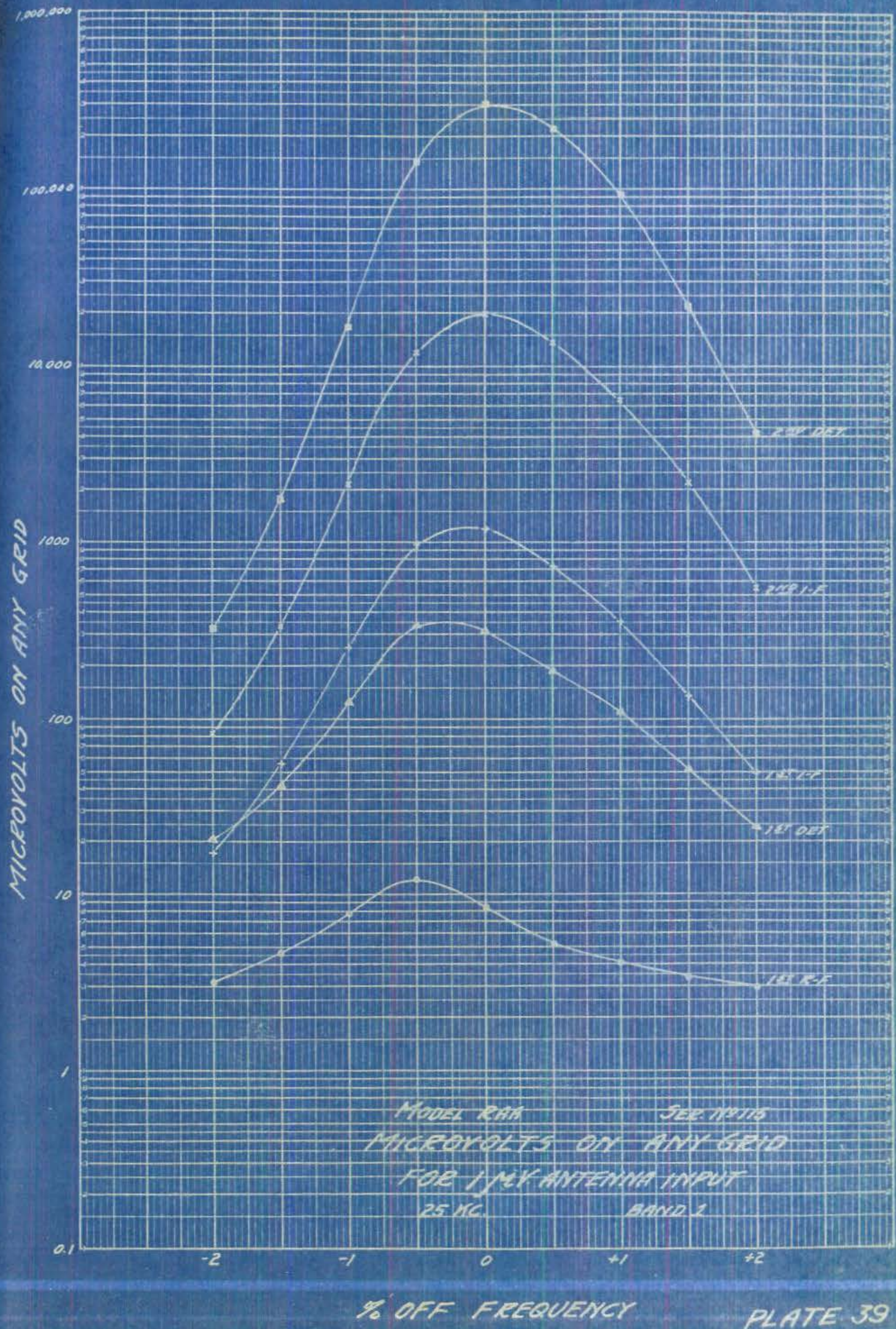

MODEL RAA
SER. Nº 115
MICROVOLTS ON ANY GRID
FOR 1μV ANTENNA INPUT
25 KC.
BAND 2
MICROVOLTS ON ANY GRID
10,000
1000
100
10
1
0.1
2ND DET.
1ST DET.
1ST I-F
2ND I-F
1ST RF
2ND DET.
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 38



MICROVOLTS ON ANY GRID
1,000,000
100,000
10,000
1000
100
10
1
0.1
-2
-1
0
+1
+2
2ND DET.
2ND I-F
1ST I-F
1ST DET
1ST R-F
MODEL RAA SER. No 115
MICROVOLTS ON ANY GRID
FOR 1 MV ANTENNA INPUT
25 MC. BAND 2
% OFF FREQUENCY

PLATE 39

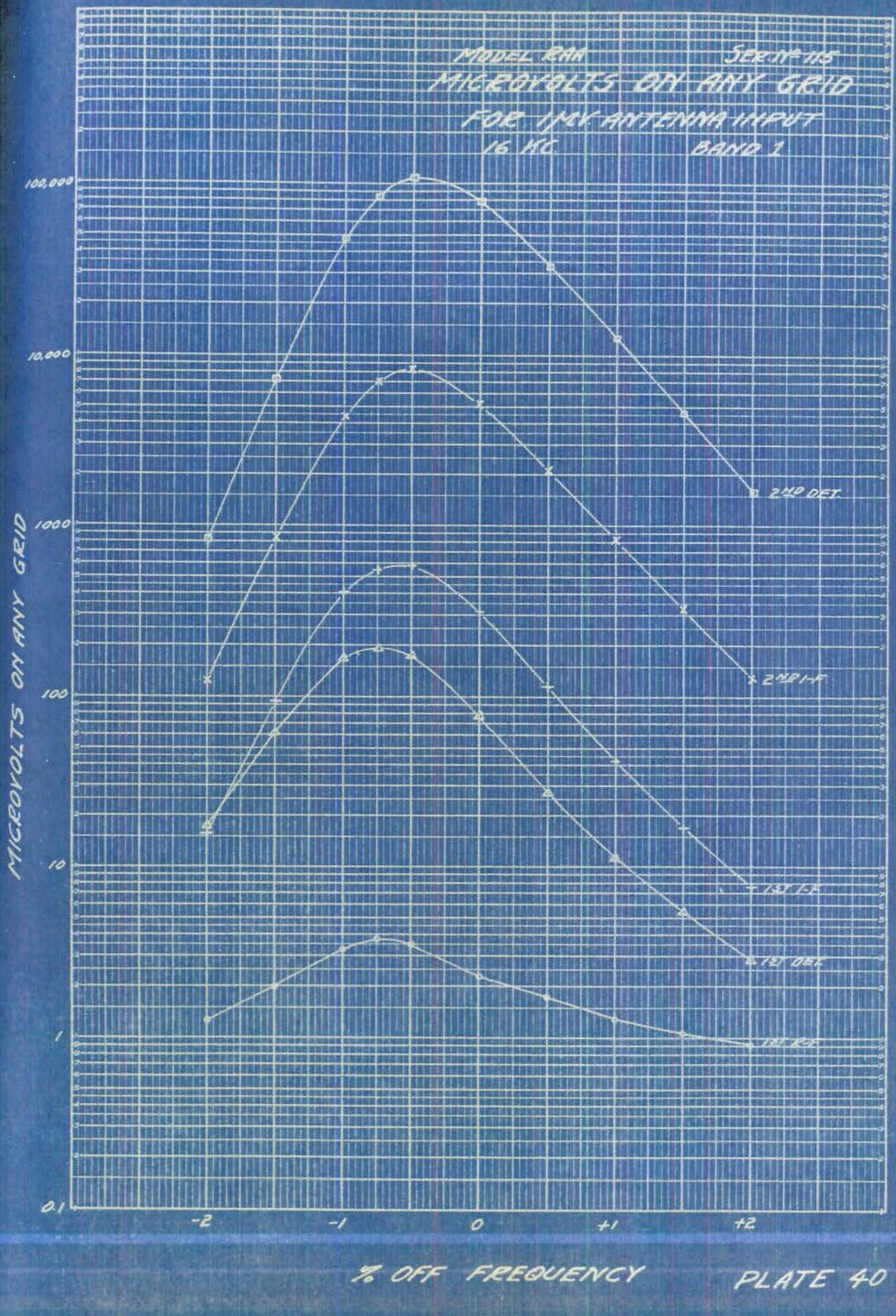
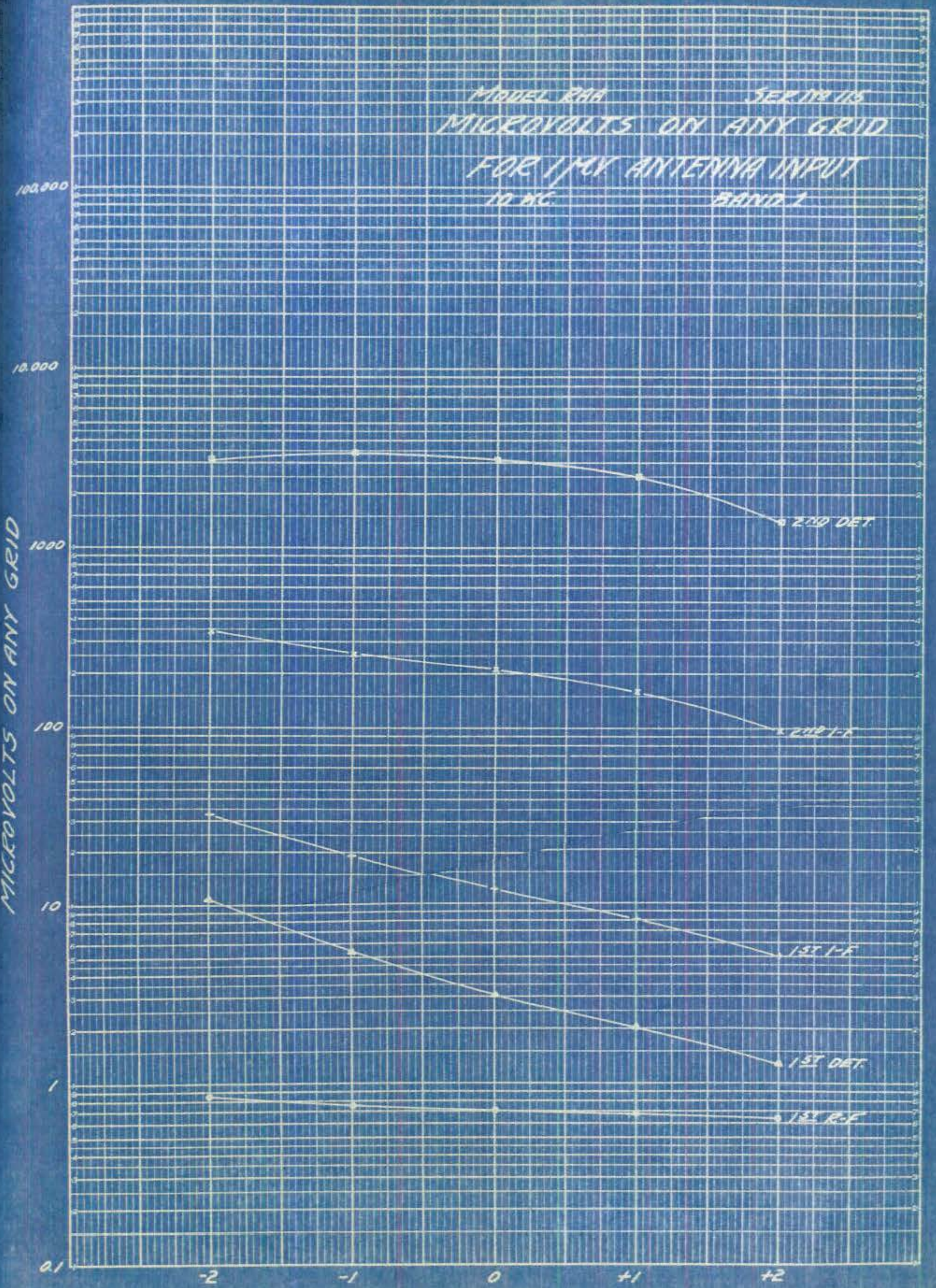

MODEL RAA
SER. Nº 115
MICROVOLTS ON ANY GRID
FOR 1 M.V. ANTENNA INPUT
16 KC
BAND 1
100,000
10,000
1000
100
10
1
0.1
2ND DET.
2ND I-F
1ST I-F
1ST DET.
1ST R-F
MICROVOLTS ON ANY GRID
-2
-1
0
+1
+2
% OFF FREQUENCY

PLATE 40



% OFF FREQUENCY

PLATE 41