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COLLECTION OF RECENT TELEVISION PAPERS

"Color Television" by Dr. P. C. Coldmark

"Projection Television" by Dr. I. G. Maloff

"Inductive Tunning System for FM-Television Receivers" by Mr. Paul Ware

THE RADIO CLUB OF AMERICA

11 West 42nd Street ★ ★ ★ New York City

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PROCEEDINGS
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Volume 23 MAY, 1946 No. 5

COLOR TELEVISION

by

Dr. P. C. Goldmark*

EDITOR'S NOTES

Since Dr. Goldmark's paper was presented without written copy a summary of his paper has been prepared from notes taken by Mr. Lewis Winner.

Recently, the Columbia Broadcasting System demonstrated operation of their new color transmitter utilizing a special directive antenna system providing what is said to be an effective signal strength of 20 kilowatts, although the power input to the antenna is only approximately 1 Kilowatt.

Both direct view and projection type color television receivers have been built by the Columbia Broadcasting System for operation at 490 megacycles. The operation of these receivers has been demonstrated on several occasions to the press and public.

With color television interest growing daily and the Columbia Broadcasting System playing an important role in fostering this interest, Dr. Goldmark has offered several color television papers during the past few years analyzing progress of the art. In this paper he continued these analyses, offering data on the current television developments of the Columbia Broadcasting System Engineering Research Department.

BAIRD SYSTEMS

Recalling the color television demonstration of J. L. Baird in England in July 1928, he said that the famous Nipkow mechanical scanning disc used had three sets of spirally-disposed holes about its circumference, one set of holes being provided with red filters, the second with blue and the third with green filters. The system produced approximately 15-line pictures and required a transmission bandwidth of 10 Kc.

It was not until 1938 that color demonstrations were given again. And again Baird did the demonstration, showing this time a 120-line system which employed a 20 facet mirror drum revolving at 6000 rpm, plus a 2-color filter disc (orange and blue-green) revolving at 500 rpm, all in conjunction with an optical lens system and a photocell arrangement.

In 1941 Baird demonstrated a 600-line color television system using a cathode-ray tube scanning arrangement plus a rotating 2-color filter disc. The two sets of images were made to register on a common screen through an optical system. This was an extremely difficult problem because registration of the images had to be exact to within 1/2000 of the picture height if a good resultant image was to be obtained.

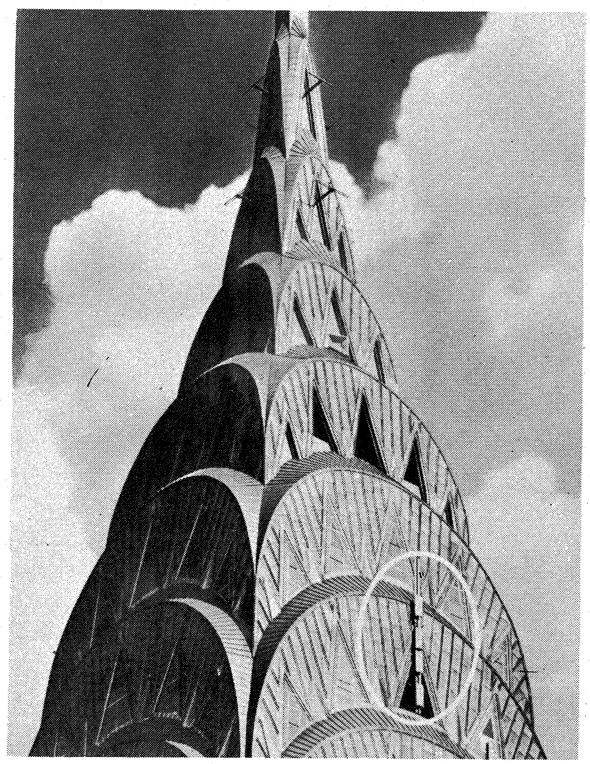
In 1944 Baird announced a different 2-color television system. It made use of a special cathode-ray tube having two electron gun structures and a special translucent target which was scanned on one side with one electric gun, and has red fluorescent material on the target. It was scanned on the other side with the other electron gun with a blue-green target material.

COLOR PHOTOGRAPHY AND TELEVISION

Dr. Goldmark explained that in color photography always additive color primaries are used on the taking end and mostly subtractive methods are used on the reproducing end. A three-layer film composed of magenta (which is a mixture of red and blue, or minus green), cyan (which is a mixture of blue and green, or minus red) and yellow (which is a mixture of red and green, or minus blue) is used to achieve the subtractive process.

Dr. Goldmark was of the opinion that a subtractive process was out of the question for color television because of the technical difficulties in providing registration of the three color control surfaces and proper storage characteristics.

*Engineering Research Department, Columbia Broadcasting System, New York City. Paper presented to The Radio Club of America, New York City, in December, 1945.



CBS Ultra-High Frequency, Full-Color Television Transmitting Antenna (In Circle)

As a consequence, additive methods must be considered, and these are of two basic types--

1 - A 3-channel simultaneous method, which imposes virtually impossible registration requirements.

2 - The sequential scanning method, which is quite feasible and is used in the present Columbia Broadcasting System color television system.

Dr. Goldmark discussed the Maxwellian color triangle, and showed how closely the present-day color photography art had succeeded in approaching perfection by synthetic means. He then compared this optimum synthetically produced triangle with the one which represents the Columbia Broadcasting System's color television system, and pointed out that the television system came close to duplicating the color values which are possible with the optimum photographic process.

PRESENT COLUMBIA BROADCASTING SYSTEM'S SYSTEM

The present Columbia Broadcasting System color television standards call for a 525-line system utilizing a 10 Mc wide transmission band. Equal horizontal and vertical resolution were said to be obtainable with this arrangement. According to Dr. Goldmark, the present Columbia Broadcasting System's television system is transmitted on a carrier frequency channel from 480 to 496 Mc. Their experimental receivers use 115 Mc i-fs, 10 Mc wide, with either color drums or color discs to effect sequential scanning. Each color field interval is 1/144 second, whereas the frame interval (normal plus interlaced) is 1/72 second. A complete color frame (3 color) is thus scanned in 1/48 second, whereas a complete color picture is obtained on 1/24 second.

Direct View CBS Color Receiver

Color phasing of the receiver disc is automatically insured by transmission of synchronizing pulses every 1/48 second.

Sound is transmitted in the form of bursts of frequency modulation on the picture carrier, these bursts of modulation being introduced only during the flyback time of the horizontal traces. This effectively gives a time-division multiplexing action, which therefore permits the use of the same transmitter and wideband antenna for both the picture and the sound. The picture or video modulation is of the single sideband, amplitude type.

Full-Color Television Receiving Antenna

PROJECTION TLEVISION

by

Dr. I. G. Maloff*

It has been known for a long time that aspherical surfaces in combination with either sperical or aspherical mirrors may be arranged into optical systems of high aperture and high definition. Astronomers made use of this principle in an arrangement consisting of a spherical mirror and an aspherical lens; however, high costs and difficulties in constructing such systems prevented their general utilization.

In searching for efficient optical systems for projecting television images originating on screens of cathode-ray tubes, the principle of reflective optical systems has been made a subject of concentrated study and experimentation. This has resulted in the development of a number of reflective optical systems suitable for projecting television images with diagonals ranging from 25 inches to 25 feet. RCA Systems consist of a spherical front surface mirror and an aspherical lens, positive in the central portion and gradually changing into negative near its periphery. The gain in illumination on the viewing screen with the new systems is about six or seven to one when compared with a conventional f/2 lens. The quality of the images obtained is comparable with images produced by conventional projection lenses.

The main handicap of the new system, the high cost of the aspherical lens, has been overcome by the development of machines for making aspherical molds and by development of a process for molding aspherical lenses from plastics. RCA reflective optical systems are designed for a fixed image distance and require cathode-ray tubes having face-curvatures fixed in relation to the curvature of the mirrors in the system. The last two factors, while limiting the versatility of a given system, appear to be a small price to pay for the manifold gain in light. The design, manufacturing, installation and servicing of the RCA reflective optical systems have been improved and simplified to such a point that these systems can be considered as proven tools in television and oscillographic techniques.

The problem of projecting images originating on the screens of cathode-ray tubes has received a great deal of attention from investigators here and abroad over a period of years. It has been shown that the space distribution of light emitted by the screen of a cathode-ray tube follows very closely the cosine or Lambert law of perfectly diffusing surfaces. When a lens such as the conventional motion-picture projection lens is used to project a cathode-ray tube image onto a viewing screen, the overall efficiency of such a system is extremely low.

In motion-picture projection most of the light striking the film is delivered to the viewing screen, except of course for the light absorbed by the darkened portions of the film, thus creating the picture itself. However, when projecting light from a perfectly diffusing surface onto a viewing screen by means of the same lens, much of the light is lost. Good, commercially available, treated projection lenses having a relative aperture of f/2 and a transmission coefficient of nearly 100 per cent, collect from the tube and deliver at large magnification to the viewing screen only 6.25 per cent of the light generated.

The image on the face of the cathode-ray tube is obtained at a relatively high cost in equipment, effort and power. Any increase in the brightness of this image may be obtained only at great cost from the standpoint of design and operation. For this reason, the problem of providing a more efficient optical projection system has received a great deal of attention. Improvement of a few per cent was of no interest. A manifold increase in the percentage of light delivered to the screen was sought. The answer was finally found in modifying a principle of reflective optical system known to astronomers and adapting it to the problem on hand.

SYSTEMS FOR TELEVISION PROJECTION

When a reflective optical system is used for projecting images originating on luminescent screens of cathode-ray tubes, the requirements which the optical system must fulfill are considerably different from those of the astronomical camera. The most important difference is that the light from a point on the luminescent screen does not emerge from the optical system as a bundle of parallel light. On the contrary, it emerges as a bundle converging to a point of focus at a definite distance. This finite throw system is radically

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*RCA Victor Division of the Radio Corporation of America, Camden, N.J. Paper presented to The Radio Club of America, New York City, in February, 1946.

different from that of the infinite throw. The other difference is that the thickness of the glass face plate of the cathode-ray tube introduces a certain amount of spherical aberration, which has to be taken into account when balancing the spherical aberration of the correcting lens against that of the mirror.

The outstanding advantage of an optical system such as that shown in Figure 1 over a more conventional optical system is its ability to focus a large field (large tube diameter) with a large relative aperture. Such a system possesses this property primarily because a spherical mirror with an aperture located at the center of curvature of the mirror suffers from only two aberrations, spherical aberration which is uniform all over the field, and curvature of the field.

The object of the correcting lens is to correct for the spherical aberration of the mirror without introducing any serious aberrations of itself. This is accomplished by making the correcting lens as weak as possible and locating it in the plane of the aperture at the center of curvature. In this way, the symmetry property of the spherical mirror is least disturbed. The curvature of the field is not corrected as it is actually used to good advantage in cathode-ray tube projection.

The spherical aberration of the mirror may be interpreted as focusing by means of zones, each zone having a different focal length. The correcting lens has to be such that each zone of the lens has a different focal length, compensating for the various focal lengths of the mirror and resulting in a focusing system with all zones of the same focal length.

ALIGNMENT REQUIREMENTS

The center of the correcting lens must be located at the center of curvature of the mirror and,

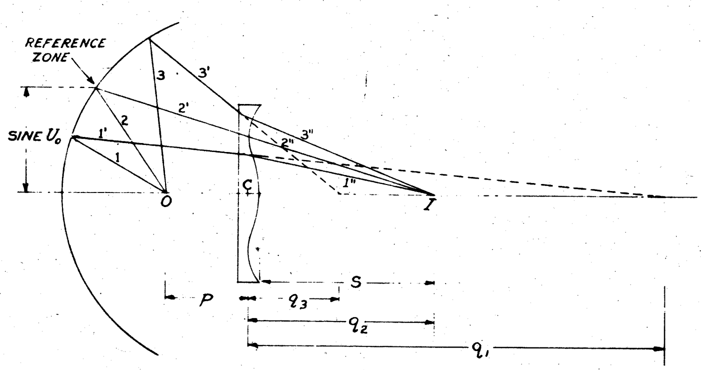


Figure 1

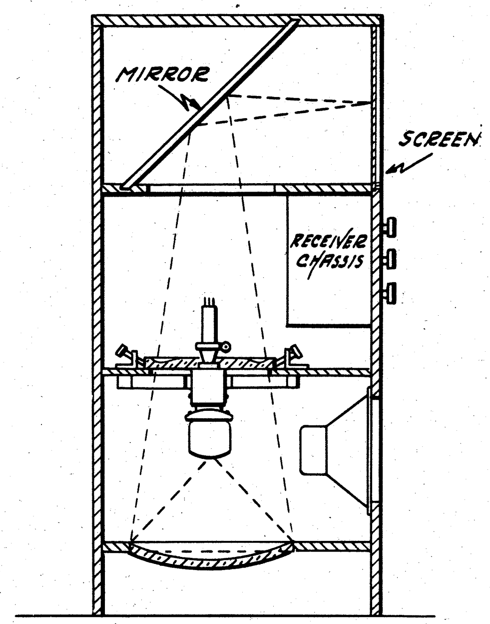


Figure 2

for uniform illumination over the field, the axis of symmetry of the correcting lens should preferably coincide with the axis of symmetry of the periphery (circle) of the mirror. The tube face must be located so that the center of curvature of the tube face lies on the axis of symmetry of the correcting lens. For uniform illumination over the field, the axes of symmetry of periphery of tube face and correcting lens should preferably coincide. The tube face should, of course, be located at the correct axial distance from mirror or correcting lens for focusing. The viewing screen should be normal to the axis and at the correct throw.

The most critical alignment items are: (1) Lateral displacement of the center of the correcting lens from an axis of symmetry of the mirror, i.e., a line passing through the center of curvature of the mirror; (2) Lateral displacement of the center of curvature of the tube from the axis of symmetry of the system. For good resolution these displacements should be kept within 0.001 R, where R is the radius of curvature of the mirror. The permissible tolerances on other alignments are about 10 times greater.

In a self-contained projection television receiver shown in Figure 2, the optical system can be mounted near the floor with its axis vertical, projecting the image straight up and onto a flat mirror inclined at 45 degrees to the incoming beam of light, and throwing the image on a translucent screen. Such an arrangement presents the advantages of compactness, relatively small depth of the cabinet and can be styled along the familiar lines of a radio console.

A number of such reflective projection systems suitable for home receivers of the type described have been designed, built and operated in actual receivers. The smallest of these was built for use with a cathode-ray tube having face diameter of 3 inches, and consists of a spherical mirror 9 inches in diameter and a correcting lens 6 inches in diameter. The largest has tube, mirror and lens diameters of 5, 14 and 9.5 inches respectively. A number of systems in sizes intermediate between the two just described have been built. The throw or distance between the correcting lens and the viewing screen varies between 36 and 54 inches and the optical efficiencies are between 18 and 35 per cent. In resolution and contrast these systems compare favorably with well-corrected conventional projection lenses, and do not limit the performance of present television systems.

COST FACTORS IN REFLECTIVE OPTICS

The major objection to the use of reflective optics in television receivers has been the high cost of the aspherical correcting lens. The spherical mirror, while quite large, is an old and familiar item to the well-established optical industry, as most of the conventional optical surfaces are spherical and are easily made. The aspherical correcting lens, similar to a figure of revolution developed by rotating a shallow letter S around one of its ends, presents an altogether different problem. Unlike the spherical mirror, such a figure is not a naturally-generated surface and there are no machines on the market for straightforward production of such surfaces.

In the early stages of the development, RCA used methods and machines based upon astronomical technique. Exceedingly high cost of experimental reflective optics resulted. The gain in light over the conventional projection lens was very attractive, but the cost of such individually produced lenses was prohibitive. The apparent solution to the cost problem was that of molding the aspherical lenses from a suitable transparent material, such as methyl-methacrylate sold under the registered trade names of Lucite and Plexiglas.

A new set of difficult problems came to the foreground. The most formidable of these was that of making molding surfaces of metal in shapes of the negative replicas of aspherical lenses. Almost as serious was the problem of obtaining optical finishes on metals. Both of these problems have been successfully solved.

The molding process is essentially that of applying very high pressure to heated plastic material confined in a heated mold and cooling it under pressure until it reaches room temperature. The mold is then opened and the lens extracted. The only operation which remains is that of boring a hole in the center of the lens for accommodating the protruding neck of the cathode-ray tube. The lens is then ready for use, with no polishing or finishing of any sort required.

Molded correcting lenses for reflective optical systems possess very good optical properties, including slightly better transmission and slightly lesser scattering of light than glass. They do not possess the surface hardness and scratch resistance of glass, but even without any special care or protection they have stood up under laboratory operation for more than three years. The cold flow under operating conditions of four years was found to be negligible.

MOUNTING PROBLEMS

From a practical standpoint, the use of reflective optics in television receivers calls for careful consideration in the mechanical construction of the mounting which supports the optical

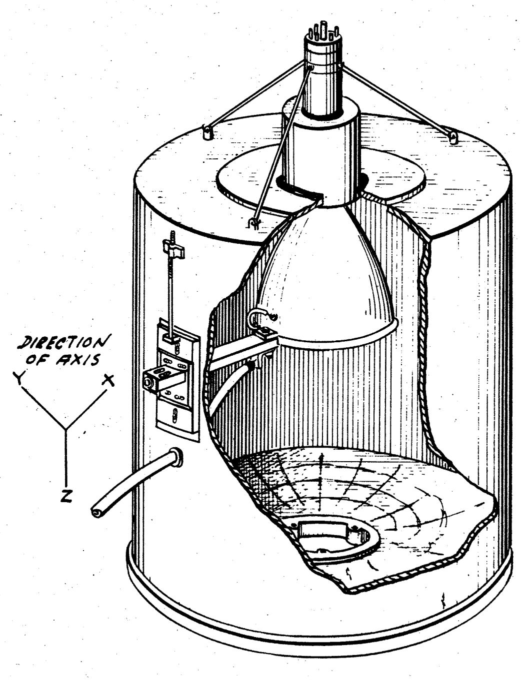


Figure 3

system and the cathode-ray tube. This mounting, combining "the barrel" and "tube support", has to fulfill a number of requirements.

TYPICAL MOUNTING

A layout of a mounting satisfying the requirements discussed is shown in Figure 3. Here the correcting lens fits into a recess on the top of a metal barrel, this recess being counterbored for a snug fit with the correcting lens. The spherical mirror is mounted on the bottom cover of the barrel by means of a collar and nut through the center hole in the mirror.

The tube support consists of an arm of insulating material anchored on the side of the barrel and a metal ring supporting the face edges of the cathode-ray tube. The tube face is held tight against this ring by suitable springs. The high voltage is brought to the second anode of the tube through a dust-tight hole in the wall of the barrel. The metal ring holding the tube is at high potential, and several inches of Micalex insulate it from ground. The high-voltage cable has a grounded shield on the outside and the barrel itself is grounded.

The tube support arm is arranged to slide back and forth, providing for tube adjustment in a direction perpendicular to the optical axis of the system, say, along a rectangular coordinate x. The support of the arm is arranged to slide along an intermediate supporting plate in a direction y, perpendicular to both the x coordinate and the axis of the optical system. The intermediate supporting plate is made to slide up and down the barrel by means of a screw, providing a focusing means along the axis of the optical system or coordinate z.

The deflecting yoke is supported by the neck of the cathode-ray tube and is equipped with dust-proof gaskets. The top of the barrel may be equipped with a cardboard shield reaching to the upper part of the television cabinet and preventing dust from settling on the upper side of the correcting lens.

The arrangement described satisfies the requirements enumerated more or less completely and allows for variations governed by the individual preference of the designer.

APPARENT DETAIL

If one wants to place an enlargement of a given photograph on the wall of a room of a given size, he can find by experiment a size of enlargement that will give an "optimum effect". This size will give a picture that is not unduly blurred and does not require squinting to see the detail. In television with its intrinsic or absolute detail governed by the bandwidth of the channel of the transmitter or the wire channel, the subject of optimum size for a given application is of major importance.

The amount of apparent detail needed for a pleasing television picture will determine how much magnification the picture will stand in any particular application. For a given amount of absolute detail the picture size will be larger for hotel lobby applications than it will be for home use, still larger for auditorium use and much larger for theater use. The exact sizes may vary somewhat, but it is believed that the buying public will soon find out what value of apparent detail is the most acceptable for a given use. Consequently, the apparent detail will determine the size of the projected television picture to be preferred for each application.

INDUCTIVE TUNING SYSTEM FOR FM-TELEVISION RECEIVERS

by

Paul Ware*

PART I - HISTORY AND DESCRIPTION

Just 8 years ago this system‡ was demonstrated to be acceptable for broadcast and short wave coverage. Wide tuning ratios were covered and with excellent electrical performance. For contact reliability however the structures were found to be too large and expensive and the undertaking was dropped for the time being, but with the very firm conviction that much smaller coils would be practical in every way and that the tuner development was ahead of its time and would have to wait for higher frequency bands to become active.

Since that time, and with the impetus of the war, higher and higher frequencies have been put in service and today we have the commercial FM and television assignments within the VHF band. The Inductive Tuner equipped with a new and much smaller coil has, by the inventive combination of chemistry, mechanics and metallurgy, evolved to be a 'natural' for wide range tuning in the VHF region.

There is no detectable contact noise even after life test runs of several hundred thousand turns. With a special oscillator-amplifier arrangement constructed for the purpose of studying relative contact noise, indications are that residual noise decreases rather than increases during the life tests; this being the reverse of observations made with the earlier large structures. It can now be announced that the device is entirely reliable and free of contact noise so far as any known receiving set applications are concerned.

*Allen B. DuMont Laboratories, Inc., Passaic, N.J. Paper presented at a joint meeting of The Radio Club of America, and Institute of Radio Engineers, New York City, in March, 1946.

‡Paul Ware, "A New Inductive Tuning System", Proc. Radio Club of America, Vol. 15, No. 1, Feb. 1938; and Paul Ware, "A New System of Inductive Tuning", Proc. IRE, Vol. 26, pp 308-320, March, 1938.

The new contact technique was perfected during the war when thousands of these devices were used successfully in airborne equipment.

Tuning systems using these coils have the advantage of having <u>all</u> contacts contained in one box of specialized design and not deployed in the open on the chassis and subject to dust and mechanical displacements.

Figure 1 pictures the new 3-section Inductive Tuner, or Inductuner‡‡, housed in its new square section die casting. Figure 2 is the unit with cover removed and shows the general layout of the coils on the ceramic shaft, with nibs, and at the end an accumulation stop to prevent damaging the device if turned too far in either direction. Each coil is tunable continuously for 10 turns which varies the inductance over approximately 0.02 to 1.0 microhenry.

The trolley contact nib divides each coil into a used and unused part. The low frequency end of the coil is "shorted" to the nib, thus raising the natural frequency of the unused part which becomes a minimum when the nis is nearest the high frequency end of its travel. The upper limit of a tuning range therefore must be somewhat lower than this natural frequency of the unused part. In this 10 turn design the minimum frequency of the unused part is somewhat lower than 300 Mc.

Figure 3 might be described as the basic Inductive Tuner circuit, comprising a variable coil, a fixed coil and a fixed capacitance in series. Instead of using a small part of the variable coil to reach the desired highest frequency, the variable coil is run out to the limit and the separate end inductance L_e is used.

‡‡Mfg. by P.R. Mallory & Co., Inc. under U.S. Pats. 2163644, 2163645, 2163646, 2163647, 2260877. Inductuner is reg. U.S. Pat. Off.

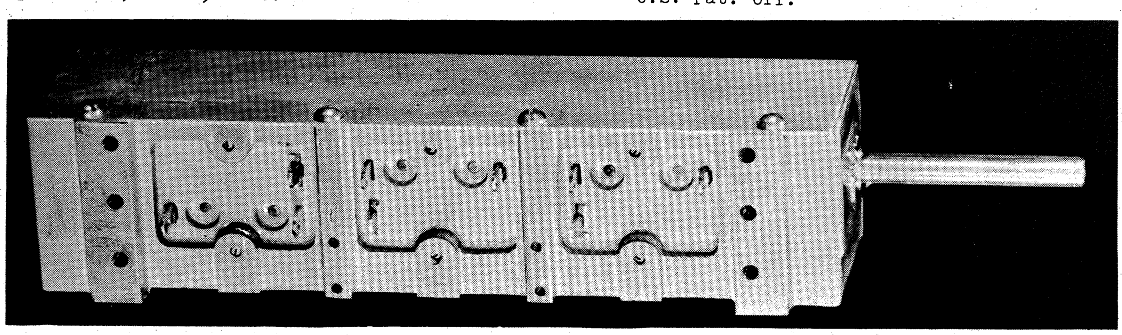


Figure 1
Ball bearing 3-section Inductuner in new die cast housing, showing connections for each coil structure. The coils are ungrounded.

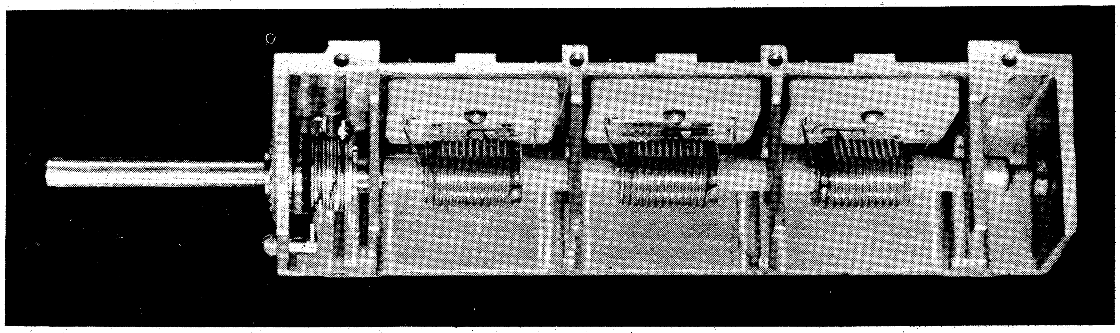


Figure 2
Inductuner with cover removed so as to show internal details. Note that sections 2 and 3 are wound in opposite directions to permit close positioning of their end inductances.

It has always been possible to make an end inductance of better performance, or Q, than an equivalent stopped-off portion of the variable coil. The general curve under the diagram shows the effect of the end inductance. Over any range being tuned as between f_1 and f_2, the advantage becomes evident as the Q is seen to rise desirably toward the higher frequencies, as in the solid line. If no end inductance were used and the same frequency range tuned, the Q of the circuit would drop off toward the higher frequencies as indicated by the dotted portion of the curve.

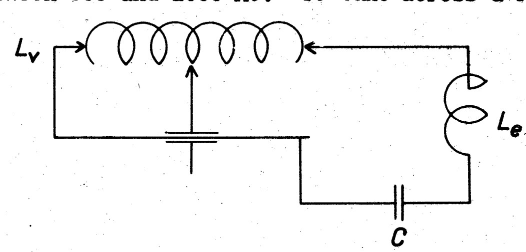
The tendency here is toward constant impedance*, which would be realized if the Q varied directly with frequency.

The use of these variable coils inherently affords wider tuning ratios than the variable air condenser. This is because the length of a wire and hence its inductance can be reduced to a smaller relative degree than the minimum capacitance of a variable condenser structure. Also, the losses reduce with the reduction in inductance, as shown by the ascending Q with frequency characteristic.

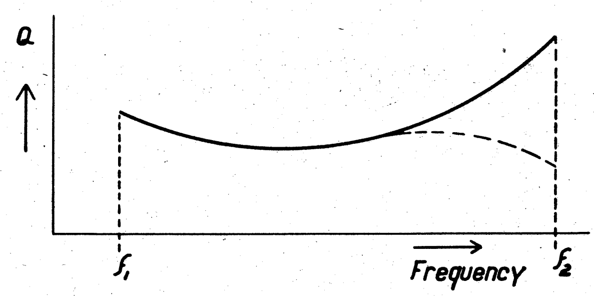
For superheterodyne tracking technique I should like to refer you to my March 1938 I.R.E. paper where the description is complete and not repeat it here. It should be noted however that while 3-point tracking deviation errors increase with increase in the tuning ratio, in television applications this is of minor importance because of the wide bandwidths required.

Where such wide bandwidths of the order of 5 to 6 Mc are desired as in television, 2 adjacent sections of the Inductive Tuner may be overcoupled and caused to track throughout the entire tuning range. The desire is for a constant bandwidth in megacycles to be achieved throughout the range rather than a constant percentage bandwidth. This constant numerical bandwidth is obtained by a combination of capacitive and inductive coupling, with due consideration as to sign. Such a circuit arrangement is shown in Figure 4. The tabulation gives the approximate bandwidth variation with frequency that can be obtained by this method.

At present writing it is estimated that the upper practical limit for this system is somewhere between 500 and 1000 Mc. To tune across a range



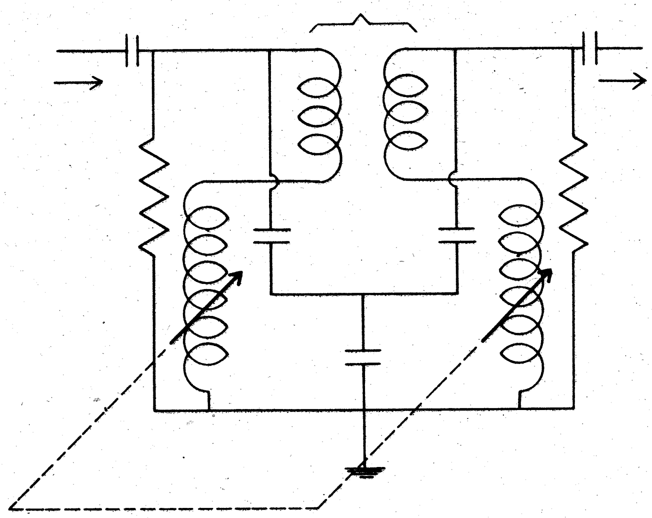
Tuning ratio $\frac{f_2}{f_1} = \sqrt{\frac{L_v(max)+L_e}{L_e}}$



Basic Inductuner Circuit showing connection of End Inductance and its affect in h.f. region of a tuning range.

Figure 3

*Parallel impedance is roughly $Z=Q/2\pi fC$. In the fixed capacitance-inductively tuned circuit case, therefore, Q would vary as f where C and Z remain constant.

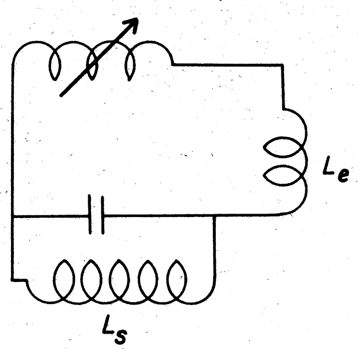


Frequency in Megacycles.	Bandwidth
50	5
100	6
150	7
200	6

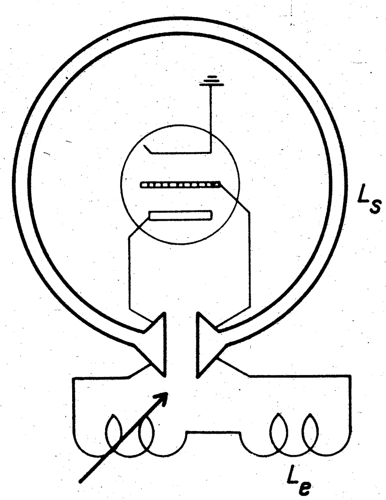
A pair of continuously variable Inductive Tuning circuits suitable for passing the wide television band at any point between the limits of 44-216 MC/s. The band-pass is obtained by overcoupling both capacitively and inductively.

Figure 4

having such an upper limit would require a drastic reduction in the number of total turns as well as in the diameter of the variable coil to assure that the natural frequency of the unused part would be out of the way. Also a shunt coil across the circuit would be needed to improve bandspread. Figure 5 shows the schematic and to the right an arrangement which has worked out satisfactorily to about 400 Mc with a 3-turn variable coil. In such a circuit the shunt coil and capacitance carry most of the resonant current, with the series connected variable and end coils acting as a vernier. Coverages of 2:1 are readily obtainable with good performance.



(a)



(b)

at (a) is circuit for approximate 2:1 coverage in UHF band. (b) is more physically proportioned view of (a). Max. inductance of variable coil is about 0.1 μh and the tuner operates like a shunt vernier.

Figure 5

Working with Inductive Tuners requires a reverse approach to that of variable air condenser technique. The proper proportions of a circuit for a given tuning range are about met when there is attained the optimum selection of L, C and R near, but not at, the high frequency extreme. This is because adding inductive reactance to a circuit to enable tuning to a lower frequency seldom causes complications or hurts the performance. The end inductance invariably takes care of the performance toward the high frequency end. It is also observed that the length of leads becomes much more important than stray capacitances which add to the fixed intended capacitance. This does not apply to by-passing, of course, which must be correct in any circuit.

Inductuner makes an excellent oscillator. Resettability is better than 0.02% throughout the VHF band. Some work has been done on temperature compensation. From tests at 100 Mc indications are that the frequency after a brief warm-up can be held within 500 cycles per degree centigrade over the temperatures likely to be encountered in home television equipment. Tuning ratios as high as 7 are obtainable, and in superheterodyne circuits there is no difficulty holding the injection voltage amplitude into the mixer within a variation of 2:1 over an entire wide range. Except for the vacuum tube itself, these oscillators have the advantage of being completely free of microphonism.

PART II - APPLICATIONS

The development of an input system for 44-216 Mc employs 3 tubes, an antenna coupling tube, a mixer and an oscillator. The cathode input tube is a convenient and efficient way to couple a fixed line impedance to a wide tuning ratio, wide bandpass circuit. Figure 6 is a view of the complete assembly showing the 3 tubes, Inductuner on the far side and simple 'clock dial' with tuning handle at the left. Figure 7 is a bottom view of the assembly with cover removed. The 3-section Inductuner is across the bottom of this picture with dial to the left. I believe the small quantity of electrical components shown here will interest you when I say that these are the entire circuit components required for amplifier, mixer and oscillator to cover all of the commercial FM-Television channels or, better, to cover continuously and quite acceptably all of the frequencies between 44 and 216 Mc.

The adjustment of this circuit is very simple once the constants are worked out and the dial calibration is determined. The bandpass circuit, except for one final adjustment, can itself be adjusted before it is mounted on the input subchassis. The oscillator is tracked to the dial calibration by means of 2 adjustments. Then the whole system is observed on a combination "wobbulator" and signal generator for shapes and gain checks. Contrast this with the multiple adjustments

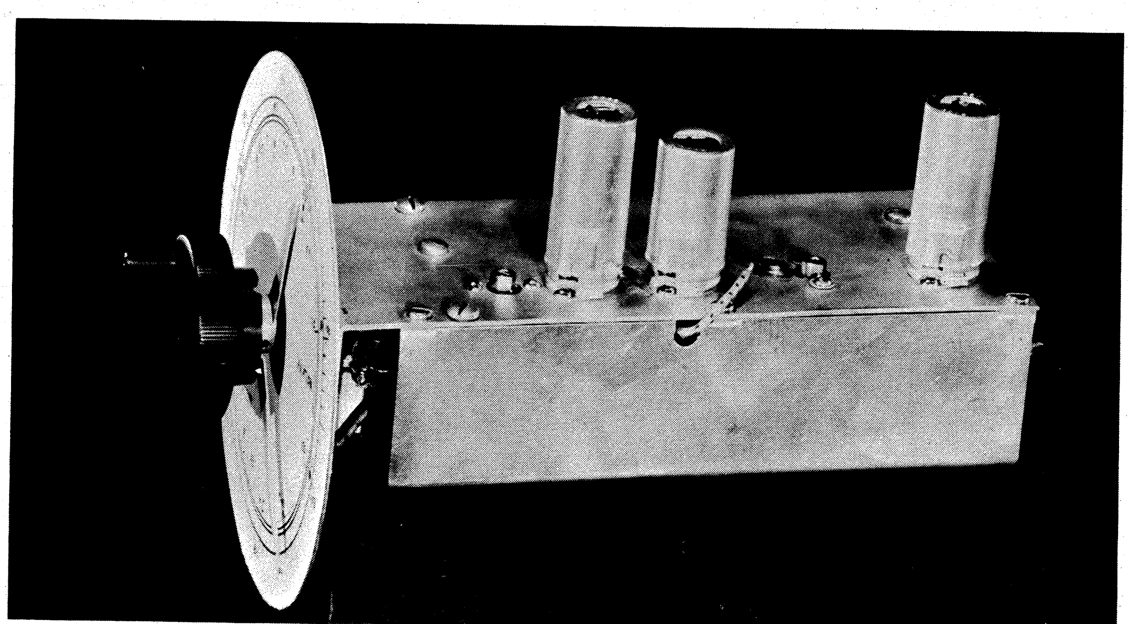


Figure 6
Complete Inductuner input assembly for continuous 44-216 Mc coverage. Assembly is preadjusted and precalibrated and requires no further adjustment after installation.

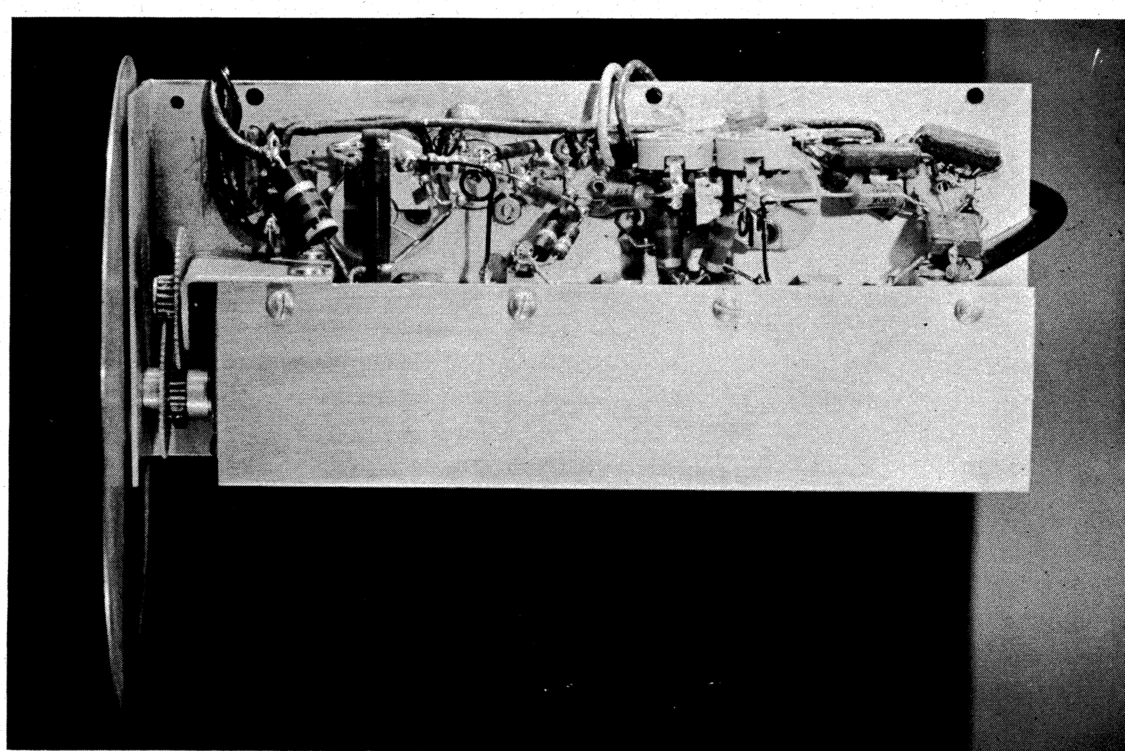


Figure 7
Due to elimination of band switching this view shows total components required for complete continuous 44-216 Mc coverage with performance as described.

required with variable condenser band switching arrangements of comparable overall performance. The nature and rugged construction of this assembly make it feasible to deliver to the production line a complete and calibrated system which requires no further adjustment whatever after assembling on the main chassis.

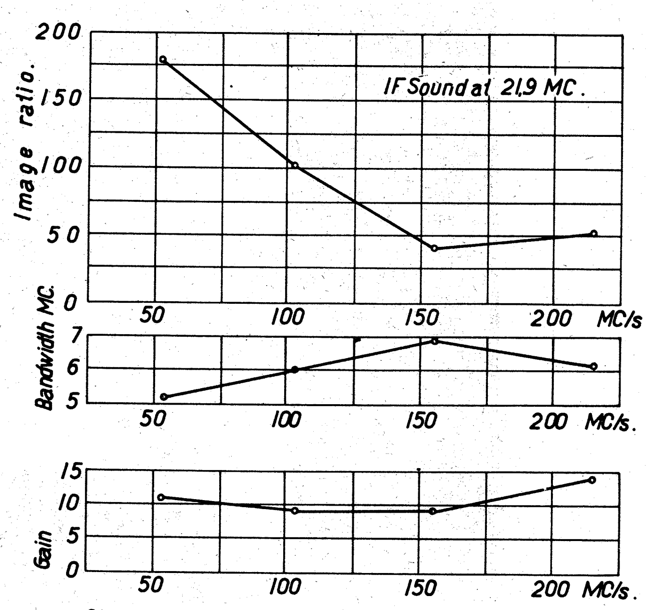
The electrical performance of this input system is shown in Figure 8. The top curve is image suppression ratio. Note that across the FM band this is better than 100, or 40 db, and that at 200 Mc it is better than many pre-war television receivers gave at 50 Mc.

The center curve is that of bandwidth as obtained by the circuit already shown. This can probably be improved in the 150 Mc region with consequent bettering of the image ratio there.

The bottom chart is particularly interesting because it runs counter to our usual expectation. Here the gain stays fairly constant across the chart until the higher frequencies are reached and then is actually better than at 50 Mc. This is the gain of the complete input system and is the ratio of the voltage measured at the grid of the first IF tube to that between cathode and ground of the antenna coupling tube. The probable explanation for this gain characteristic is twofold:

1 - That the approximately constant bandwidth in cycles, assuming constant Q, rides higher on the bandpass resonance characteristic at the higher frequency end, and

2 - That the circuit Q is rising as tuning proceeds toward the high frequency end of the range.



Characteristics of 3-Tube Input System employing 3-section Inductive Tuner.

Figure 8

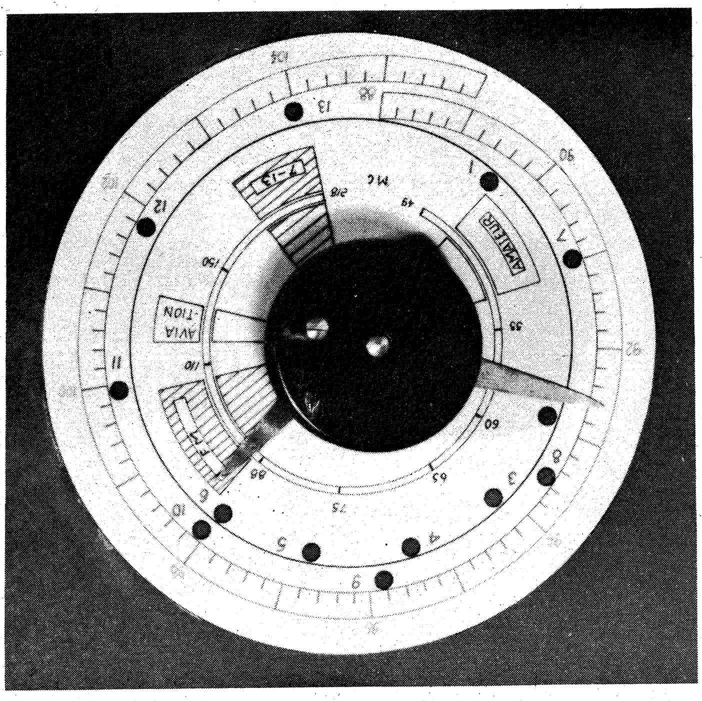


Figure 9
Dial and direct connected tuning knob used with 3-section Inductuner input assembly. The 'hour hand' traverses the arc 49 to 218 Mc while the 'minute hand' turns the complete 10 turns with the tuner. The FM segment as well as the outer peripheral scale is colored green, while the 7-13 segment as well as the large dot peripheral scale is colored red. Wide range bandspread discrepancy is thus overcome.

This is an approximation however as the coefficient of coupling is also changing along with the tuning frequency.

It should be pointed out that the FM band of 88-106 Mc occupies a little more than one complete turn of the Inductuner compared with one-half turn in the case of the variable air condenser.

Any wide range tuning system, whether employing band switching or not, is plagued with too much bandspread in the lower frequency region and too little at the higher end. This is inherent of course and can be minimized by special geometrical shaping of the tuning elements or by special dial arrangements. In our simplified assembly we have overcome this difficulty satisfactorily by the expedient of a 'clock dial'.

The 'minute hand' is connected directly to the Inductuner shaft and to the knob handle, and acts as the vernier, while the 'hour hand' is geared to this and is rotatable through less than one turn, for complete 10-turn coverage of the Inductuner. A front view of the dial, with its centrally positioned knob-tuning handle, is given in Figure 9. The 'minute-hand' is used to indicate tuning on the 2 peripheral scales outside the heavy line, while the 'hour hand' is used in

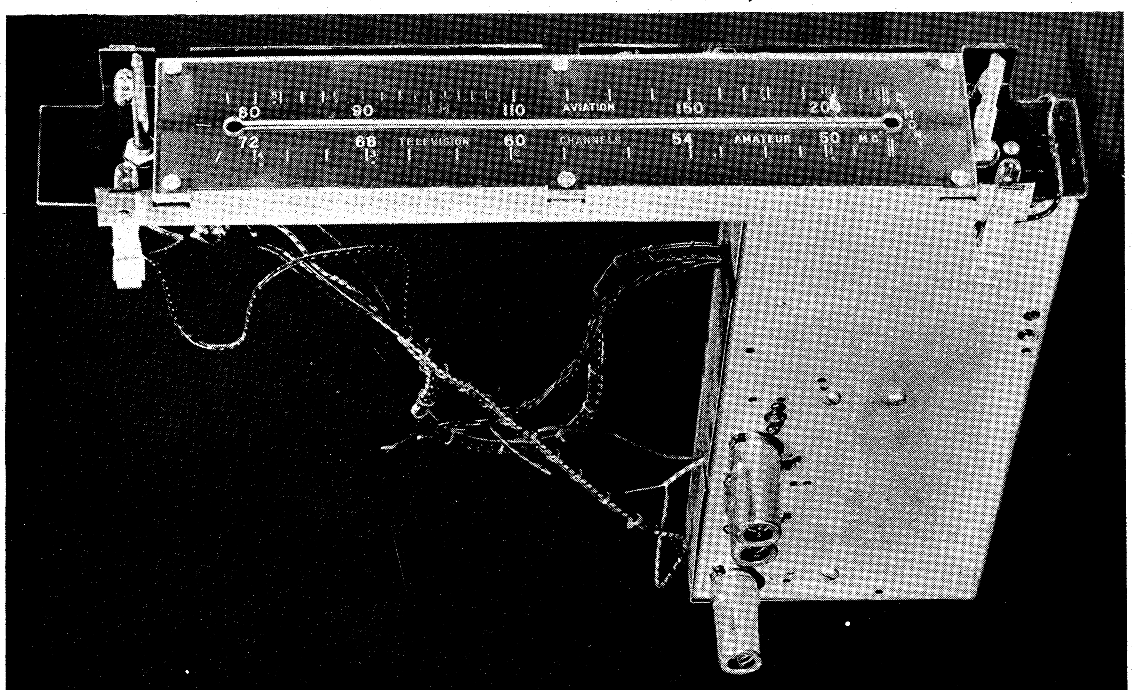


Figure 10
This assembly contains the same electrical circuits as described in Figures 6, 7 and 8 but in place of the tuning-handle knob is fitted with a right-left motor drive, magnetic clutch and chain-drive reversing slide rule scale. The shaft to the left actuates the motor switch and the one to the right actuates the magnetically coupled vennier which is deenergized when the motor is running. The scale is edge lighted and colored green for FM and red for each television channel.

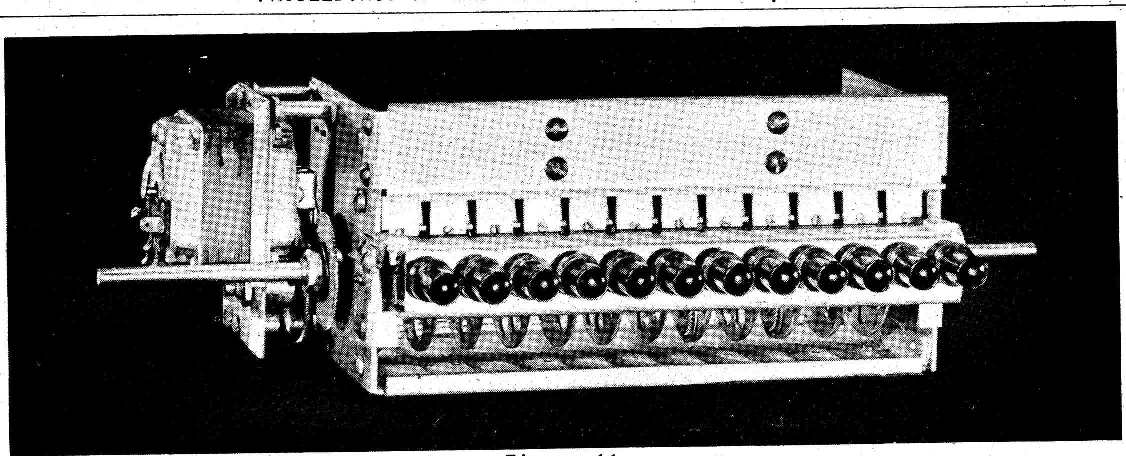


Figure 11
This 12-button selector contains the driving motor and will operate the assembly of Figure 6 when 'clock dial' is removed. Accuracy of approximately ±0.001 part of one complete turn is attained and is found to satisfactorily and automatically tune in desired stations with this system.

connection with the space inside the heavy line and is tunable around the arc from 49 to 218 Mc.* To facilitate tuning, the dial scale is made in 2 colors, red for television and green for FM, the balance of the scale being in some other background color or shade selection. With a little practice, handling of the 'clock dial' is simple and is as follows:

> Overall broad tuning as well as fine tuning of frequencies below the FM band is done by the 'hour hand'. Fine tuning of the FM band is by the 'minute hand' on the outer peripheral green scale <u>when</u> the 'hour hand' is within its green segment. And fine tuning of the television channels 7 through 13 is likewise by the 'minute hand' but on the peripheral red scale <u>when</u> the 'hour hand' is within its red segment.

This small dial affords approximately 15 inches of length for each of the peripheral scales, which is ample bandspread; and the direct-coupled instead of gear-coupled vernier is a decided advantage.

Figure 10 illustrates a right-left switch motor drive assembly with magnetic clutch vernier and double slide rule dial. The unique feature here is that the dial is twice its physical length. This is accomplished by a chain drive arrangement that

*All television channels are calibrated at sound carri frequency. Thus when dial is tuned for Channel 1, pointer is on 49.75 Mc. and whole 44-50 Mc band is being received.

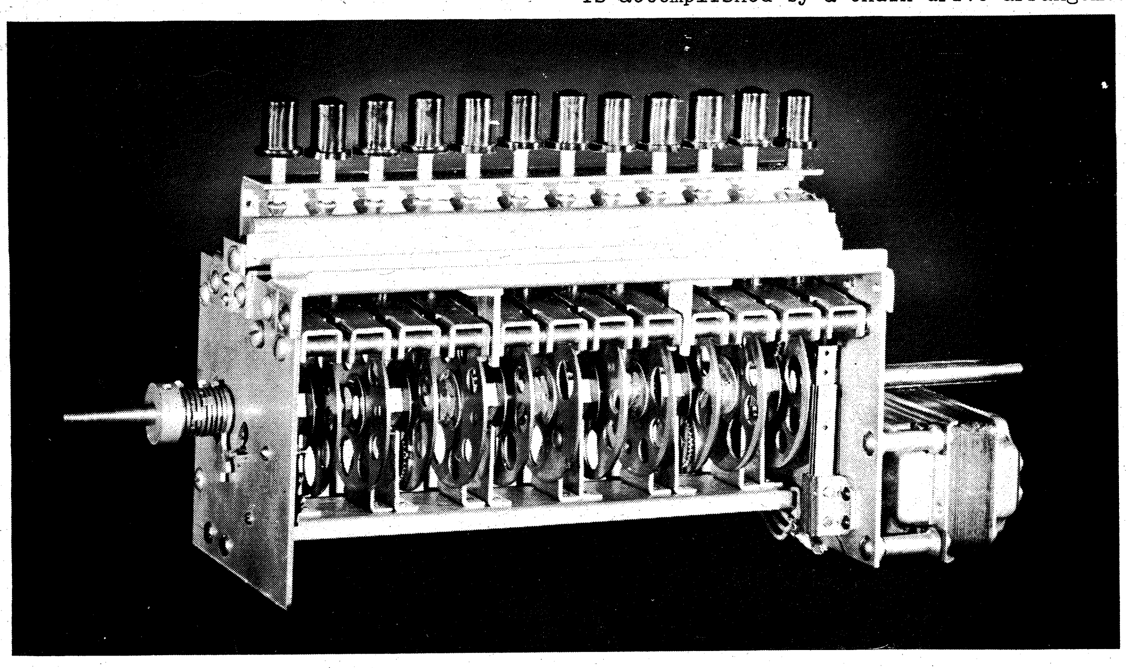


Figure 12
This is bottom view of selector shown in Figure 11. The arrangement is of the type where the slots of the slow and fast wheels for each push-button must coincide to release the current from the motor and at the same time abruptly stop the mechanism.

causes the pointer to traverse a slot completely in both directions while the tuner makes its complete 10 turns in one direction. The vernier is magnetically coupled to the motor shaft and thus operates the Inductuner through the high ratio motor gear train. The clutch current is 'off' whenever the motor is energized, so as to avoid this extra load on the motor, as well as to prevent the rapid rotation of the vernier-knob whenever the motor is running.

The oscillator, in a special housing with power supply, will make an excellent Meterodyne frequency meter covering, say 40-240 Mc. Another interesting application of the oscillator would be its use as a readily tunable oscillator part of an amateur transmitter that could continuously cover any or all of the 3 VHF bands. The equivalent of this whole input system may be especially housed with power supply to act as a continuously tunable converter for all of the VHF amateur bands.

*Developed for the Inductuner system by Croname, Inc.

Figure 11 shows the front view of an automatic 12-button station selector.* The unit will operate this system satisfactorily by stopping the tuner within the ± 0.001 of one complete turn necessary to reliably tune in an FM station with acceptable quality. The view in Figure 12 is the same selector mechanism turned over to show greater detail.

Although this paper is principally concerned with FM and television input tuning, there are many other applications for the Inductive Tuner such as input systems for amateur and communications receivers, boosters, and a variety of test equipment. Band switching may of course be applied to the Inductuner to extend its useful range if that should become desirable.

I would like to take this occasion to thank the people at Mallory's as well as my own associates in DuMont for their indispensable contributions toward the final attainment of the success of this system.

At the conclusion of the meeting, a special television program was presented by W3XWT, the DuMont outlet in Washington and transmitted over the new coaxial cable to DuMont's WABD in New York and broadcast for the occasion. A DuMont 20 inch direct viewing receiver in the auditorium picked up the program and was enjoyed by those in attendance. This receiver incorporated the Inductuner in its design.

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