'53-1

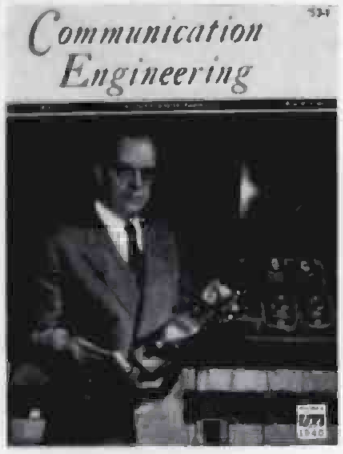
TV & RADIO ENGINEERING

Feb.-Mar. 1953 MILTON B. SLEEPER, *Publisher* Price 65 Cents

Established as RADIO Engineering 1921

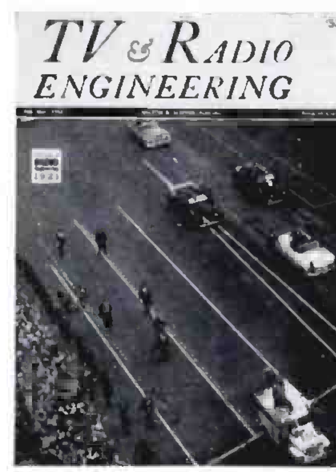
Three Specialized Magazines

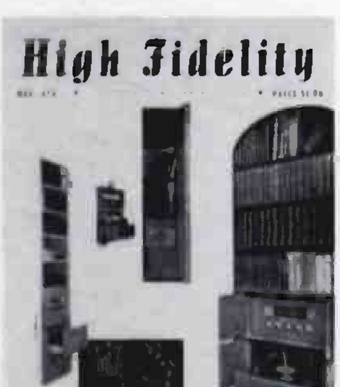
Each One Is The Leading Publication in Its Own Field:



COMMUNICATION ENGINEERING is the only magazine concerned exclusively with the development and design of components and equipment for civilian and military communications, and the planning, installation, operation, and maintenance of fixed, mobile, and microwave relay systems. Edited by Roy F. Allison, it is the principal source of information on new techniques, equipment, and system engineering for the public safety, public utility, petroleum and pipeline, special industrial, transportation, air-ground, and common carrier services. COMMUNICATION ENGINEERING also carries the basic system statistics, and reports on FCC actions concerning the entire field of safety and special services communication systems. It is published on the 20th of January, March, May, July, September, and November. $3.00 per year, or $6.00 for 3 years.

TV & RADIO ENGINEERING is the only magazine concerned exclusively with the development and design of TV, AM, and FM receivers, and broadcast studio and transmitting equipment. Edited by Roy F. Allison, this magazine, from issue to issue, is a complete what's-new record of video and audio progress from receiver components to transmitting antennas. You will find this magazine of special value as a source of ideas that can be adapted to solving your particular problems, whether they concern apparatus design or manufacturing techniques, the installation of studios and transmitters, or improved performance of present facilities. In short, if it concerns TV, AM, or FM, you find what you want to know in TV & RADIO ENGINEERING. It is published on the 20th of February, April, June, August, October, and December. $3.00 per year, or $6.00 for 3 years.





HIGH FIDELITY is the only magazine edited for people who enjoy music from FM, records, and tape. It is planned both for those whose primary interest is in music itself, and for those to whom high-fidelity reproduction is of paramount importance. With Charles Fowler as editor, and John Conly as associate editor, HIGH FIDELITY has really become the bible of these fast-growing groups. LP record reviews, contained in a special 32-page section, are written by nationally-known critics. These are supplemented by feature articles and news of artists and studio activities. For hi-fi enthusiasts, this magazine is the principal source of information on new equipment and its proper use, methods of improving reproduction from FM, records, and tape, and ideas for simple as well as elaborate custom installations. All articles are written in non-technical language, handsomely illustrated, and printed on fine paper. HIGH FIDELITY is also of great value to music teachers, educators, architects, and decorators. Published on the 1st of January, March, May, July, September, and November. $5.00 per year, or $10.00 for 3 years.

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New accessibility puts every component at your finger-tips. One latch opens both hinged sides and top. Dual bar handles provide better grip and easier carrying.

New!

RCA TV CAMERA

Here is the all-new TV camera the industry is talking about. The camera the leading networks are planning to use in their new Hollywood studios! The camera which will be used in most of the new stations this year—and next!

Leading network engineers (after careful tests) have proclaimed the TK-11A the finest camera ever produced, easiest in the world to handle, and the simplest one to get at.

The TK-11A has all the proven performance of the world-renowned RCA TK-10—plus these new features:

NEW *7-inch* viewfinder picture tube produces larger, brighter, and sharper pictures to help the cameraman.

NEW plug-in, high-stability video amplifier—with frequency response uniform to 8.5 Mc.!

NEW fixed-position alignment, coil for the Image Orthicon. Electrical control of coil eliminates all mechanical adjustments!

NEW plug-in blower for cooling the deflection coil and the Image Orthicon!

NEW electronic-protection system guards your Image Orthicon against deflection failure, or loss of driving signals.

NEW "overscan" control takes burden off Image Orthicon during warm-ups and rehearsals; new vertical reverse switch for film pick-ups.

For complete information on the TK-11A, call your RCA Broadcast Sales Representative.

RADIO CORPORATION of AMERICA
ENGINEERING PRODUCTS DEPARTMENT **CAMDEN, N.J.**

TV & RADIO ENGINEERING

VOL. 23 **FEBRUARY - MARCH, 1953** **NO. 1**

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ROY F. ALLISON, *Editor* MILTON B. SLEEPER, *Publisher*

FRED C. MICHALOVE, *Eastern Manager* — CHARLES KLINE, *Western Manager* — EDWARD BRAND, *West Coast Manager*

MIRIAM D. MANNING, *Production Manager* — LILLIAN BENDROSS, *Accounting* — WARREN SYER, *Director of Circulation* — ELEANOR GILCHRIST, *Art Director*

Publication Office: The Publishing House, Great Barrington, Mass. Tel. 1300.
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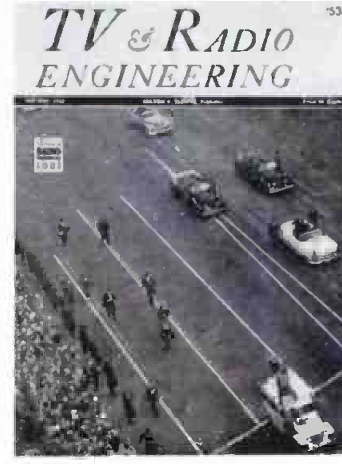
CPA AUDIT



THIS MONTH'S COVER

One of the most useful pieces of equipment a television station can own is a mobile remote-pickup unit, with which on-the-spot coverage of civic, sports, and news events of local or national interest can be obtained. Such equipment is discussed in the current and concluding installment of "Pattern for TV Profit," beginning on page 24.

The remarkable cover photograph, showing an ABC mobile unit covering the recent Presidential inaugural parade, was taken by Joe Lewis of—right the first time—the American Broadcasting Company.

AUTHORS & ARTICLES

The lead article in this issue is, we think, a good one for many reasons. First, it does a thumping good job in its primary purpose—to evaluate the performance of the NTSC color system in the presence of noise. Second, it serves to give those unfamiliar with color TV techniques some idea of the nature of the general problems involved. Third, it clarifies basic color theory and the specific philosophy of the NTSC signal for those who have only general knowledge of its workings. Mr. Jones is to be congratulated on a well-written and informative work.

"Pattern for TV Profit" is concluded with this, the eleventh installment. We hope that it has been of real value to those who subscribed to RADIO COMMUNICATION primarily for this series, and we hasten to assure that other articles on station planning, operation, and maintenance will comprise an important part of the coverage of TV & RADIO ENGINEERING.

WHAT'S COMING NEXT

The article in this issue on FM head-ends, by Henry Cross, is the first of a series on FM tuner design. Next will come a superlative treatise on IF, limiter, and detector sections by Roy Paananen. Messrs. Cross and Paananen did the research work described while at Massachusetts Institute of Technology and, in fact, these articles are developed from their theses. Mr. Cross is now with Pickard and Burns, Needham, Mass.; Mr. Paananen is at Lincoln Laboratory, MIT.

This is the oldest magazine in the radio field published by its founder. It was established as RADIO ENGINEERING in 1921 by Milton B. Sleeper. Subsequently it was sold and published under the title of COMMUNICATIONS until 1950, when it became TELEVISION ENGINEERING. It was purchased by Radiocom, Inc. in 1952, combined temporarily with RADIO COMMUNICATION, and then published separately again under the present title.

TELEVISION ENGINEERING

CIRCULATION AUDITED BY
HENRY R. SYKES
CERTIFIED PUBLIC ACCOUNTANT
SYKES, GIDDINGS & JOHNSON
PITTSFIELD, MASSACHUSETTS

TV-AM-FM SET PRODUCTION

IN 1952, RTMA statistics reveal that TV set production increased 10% over 1951, while AM sets dropped 22%. Dollar-wise this change resulted in a substantial net increase for the industry.

During the first half of '52, however, average monthly TV production lagged behind the '51 average, but the last four months, with an all-time high in December, finally put 1952 slightly ahead of 1950, when the previous record was set, as shown by the Monthly Averages in the accompanying Production Barometer chart.

Surprisingly, AM production in December, topping 1¼ million, was the highest since May, 1951, although average monthly figure for '52 was down ¼ million sets.

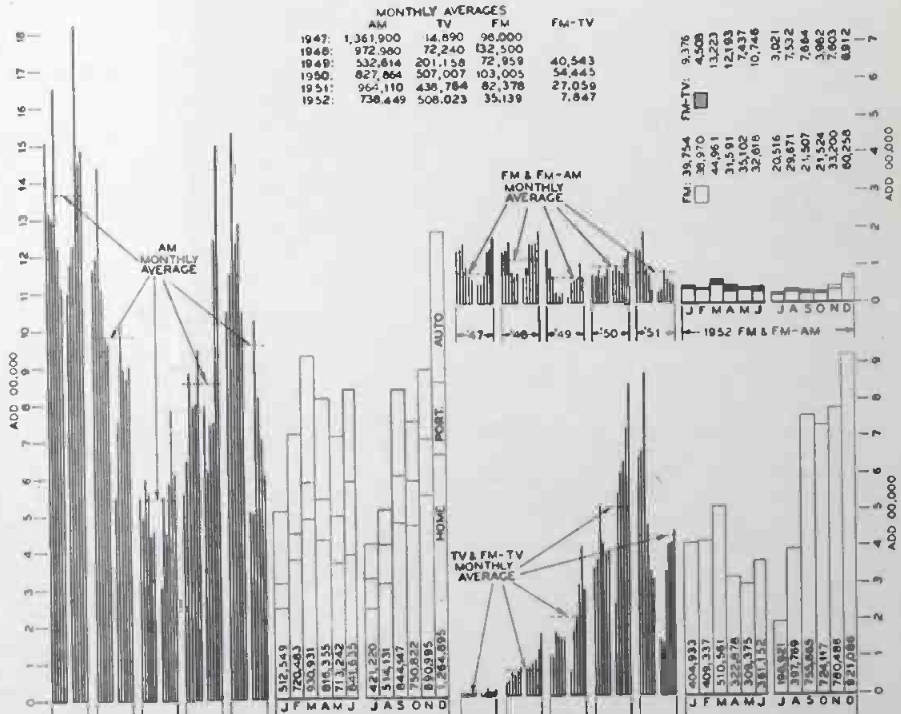
It appears entirely possible that TV production may run ahead of AM sets in 1953. During the last four months of '52, the TV figure was only 15% below AM. Now, with new television stations scheduled to come on the air each month, it would hardly be unexpected if TV sets take the lead.

Currently, a considerable part of TV sales is accounted for by replacements of old types with small picture tubes, up to 12 ins. Big tubes have so changed viewing habits that few people are content to watch images on small screens.

TV interference was reduced to some extent in the past year, but that caused by receiver radiation is still a serious problem, and it will continue to plague viewers for as long as the great number of offending sets are in use.

Considering that manufacturers have concentrated their advertising and promotion on TV to the virtual exclusion of audio receivers, it is surprising that the sales of the latter held up so well. Some effort has been put behind clock radios, but there is a question as to whether they were bought as clocks with radio as an extra feature, or radios with clocks as a plus value! Zenith was the only company to promote FM sets consistently through the year. That accounts for the relatively small number of FM cabinet models produced. RTMA figures do not include FM and FM-AM tuners, since they are not classified as factory-built types.

Nevertheless, the number of FM tuners built in '52 was several times that in '51, and it will be much higher in '53. The older companies are steadily increasing their output, and others are planning to enter the market this spring. Sales, it should be noted, are being handled by mail order houses, dealers specializing in high-fidelity equipment, and the parts jobbers, rather than the conventional outlets for factory-built radio and TV sets.



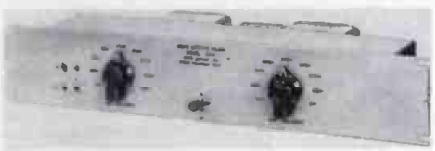
MONTHLY AVERAGES

	AM	TV	FM	FM-TV
1947:	1,361,900	14,890	98,000	
1948:	972,980	72,240	132,500	
1949:	532,614	201,158	72,959	40,543
1950:	827,864	507,007	103,005	54,445
1951:	964,110	438,784	82,378	27,059
1952:	738,449	508,023	35,139	7,847

TV, FM, and AM set Production Barometer, prepared from RTMA figures

PRODUCT INFORMATION

Sound Effects Filter: Built on a standard slotted rack panel 3½ ins. high, this versatile sound-effects filter has 8 high and low cut-off frequencies from 100 to 5,000 cycles, and flat positions at both ends. Cutoff rates are 16 db per octave on all positions. Toroid coils are used for hum-pickup immunity. All



inductors and capacitors are hermetically sealed, so that aging effects are negligible. Input and output impedances, 500/600 ohms. Hycor Company, Inc., 11423 Vanowen Street, North Hollywood, Calif.

Miniature Electrolytics: Claimed to be the smallest ever made, a new line of metal-encased electrolytic capacitors has been developed for hearing-aids and similar applications. These Microlytic series 999 units are .175 in O.D. and 11/32 to 1 1/32 ins. long, rated at .05 to 3 mfd., 3 to 50 WVDC. Other types can be supplied to specifications. Micamold Radio Corp., 1087 Flushing Avenue, Brooklyn 37, N. Y.

High-Output Tape: Greater dynamic range than ever before obtained on magnetic recording tape is provided by a new line of tape introduced recently. Designated Scotch No. 120 High-Output tape, it will accept recording levels of 8 db over conventional red-oxide tape at a given distortion level, thus bettering the signal-to-noise ratio by 8 db. Same bias methods are used. Minnesota Mining and Manufacturing Company, 900 Fauquier Street, St. Paul, Minn.

VHF Trimmer Capacitor: Measuring only 3/4 by 5/8 in. and with a range of 1.4 to 19.6 mmf., type MAC variable capacitor is intended for miniaturized VHF equipments.

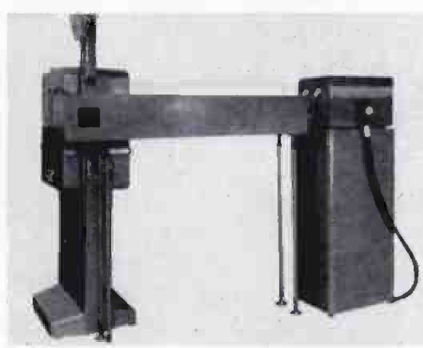
Rotor and stator are of silver-plated brass. The wiper rotor contact is of silver-plated beryllium-copper. Hammarlund Manufacturing Company, Inc., 460 West 34th Street, New York 1, N. Y.

CRO Table: A movable table for mounting oscilloscopes has just been made available. Table top is adjustable in height and can be tilted 0 to 20° backward. Lower shelf and large drawer are provided for storing auxiliary equipment. The table is mounted on large swivel-type rubber-tired casters. A. B DuMont Laboratories, Inc., Instrument Division, 1500 Main Avenue, Clifton, N. J.

Capacitor Catalogue: Dimensions, prices, and specifications are given for virtually all types and sizes of transmitting and receiving capacitors in Catalog C-10, available from Wells Sales, Inc., 833 West Chicago Avenue, Chicago 22, Ill.

Reverberation Unit: A multiple-head magnetic tape loop recorder-reproducer, occupying only 8 3/4 ins. of standard rack space, has been developed to replace the space-wasting and expensive echo chamber. Amazingly flexible and effective, the unit contains equalizer controls and incorporates a zero-loss straight-through channel. Model 40 contains 5 heads with reverberation time adjustable to 6 seconds; model 42, 7 heads and 10 seconds. Audio Instrument Company, Inc., 133 West 14th Street, New York 11, N. Y.

TV Film Shadow Box: This new film multiplexer and shadow box permits film pickup by standard image orthicon TV cameras. Assembly consists of light-tight wooden shadow box with apertures for two 16-mm. film pro-



jectors and the TV camera. Inside the box are a mirror multiplexer and a high-resolution screen upon which the camera is focussed. Unit is mounted on four adjustable legs to provide easy leveling. Federal Telecommunication Laboratories, Inc., Nutley, N. J.

Miniaturized Potentiometers: Designed for use in TV receivers and small radios, a line of dime-sized composition variable resistors is rated at .3 watt below 10,000 ohms and .2 watt above. These type 70 units are available in various tapers and shaft styles. Chicago Telephone Supply Corp., Elkhart, Indiana.

New Slide Projector: Standard 2 by 2 in., or 35-mm. transparent slides in unlimited number can be projected automatically by remote or local control with the Telojector. This unit provides lapped, superimposed, or divided images through the use of two turrets. Additional pre-loaded turrets can be exchanged with used turrets in seconds. Gray Research and Development Company, Inc., 16 Arbor Street, Hartford 1, Conn.

Parabolic Reflectors: Complete mechanical dimensions and specifications for over 100 types of stock parabolic reflectors are given in a catalog just prepared and available on request from Workshop Associates Division, The Gabriel Company, Endicott Street, Norwood, Mass.

Continued on page 8

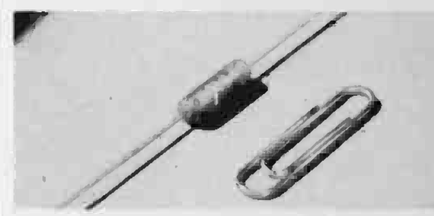
NEW PRODUCTS

(Continued from page 7)

Hybrid Junctions: A new type of broad-band matched hybrid junction for X band wave-guide is available in aluminum or brass, with choke or flange connections. VSWR ranges from 1.08 to 1.20, depending on frequency, for the series arm; 1.05 to 1.175 for other arms. General Precision Laboratory, Inc., Pleasantville, N. Y.

Insulating Resin: A remarkable new electrical insulating resin, Silicone Varnish 994, retains 65% of initial dielectric strength after 2,000 hours at 250°C. According to manufacturer, craze life is longer by 4 times than that of best previous materials. For coating glass cloth and sleeving, and for bonding mica and glass. Dow Corning Corp., Midland, Michigan.

Molded Paper Capacitors: Type 85-P molded paper capacitors, said to be the smallest available, are rated for continuous operation at 125°C. They are now available for

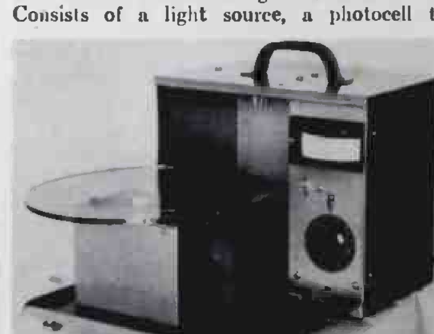


general use in two mould sizes, .175 by 5/8 in. and .200 by 5/8 in., and in 20, 10, and 5% tolerances. Bulletin 205E sent on letterhead request to Sprague Electric Company, 243 Marshall Street, North Adams, Mass.

90° Deflection Yoke: With horizontal inductance of 45 millihenries, a new cosine deflection yoke produces 90° deflection for 27-in. picture tubes. Sharp focus across entire screen is maintained, according to maker. DX Radio Products Company, 2300 West Armitage Avenue, Chicago 47, Ill.

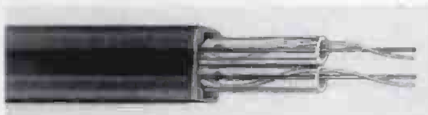
Decade Amplifier: Type 140-A miniaturized laboratory voltage amplifier has frequency response flat within .1 db from 2 cycles to 1 mc., and stabilized voltage gains of 10 or 100. Straight RC coupling is used without peaking coils or compensators, hence transient and phase responses are excellent. Undistorted output, 40 volts max. Self-contained power supply. H. H. Scott, Inc., 385 Putnam Avenue, Cambridge 39, Mass.

CRT Glossmeter: Developed for the CRT committee of RTMA, this instrument measures reflectance from any type of tube face with radius of curvature greater than 12 ins. Consists of a light source, a photocell to



pick up light reflected as glare, a power supply, a calibrating variac, and a direct-reading microammeter indicator. Gardner Laboratory, Inc., Bethesda, Md.

UHF Transmission Line: New weatherproof 270-ohm UHF transmission line, type ATV-270, consists of two conductors surrounded by polyethylene spiral threads which act as centering mediums, permitting the conductors to float within individual polyethylene tubes. Outer jacket is constructed so that these tubes also are virtually suspended in air but are held to rigid spacing from one another. Efficiency at UHF is



claimed to be 55 times that of standard flat ribbon line. Attenuation at 500 mc., 3.6 db/100 ft.; at 900 mc. 5.1 db/100 ft. Dimensions, ½ by ⅝ in. Developed by RCA Service Company and Anaconda Wire & Cable Company, New York 4, N. Y.

UHF-VHF Field Strength Meter: Covering 52 to 218 mc. and 470 to 890 mc. in 2 continuous ranges, a new field strength meter has a minimum sensitivity of 100 mv. for 50% meter deflection. Unit is portable, measuring 10¾ by 11¼ by 14¼ ins. Erwood, Inc., 1770 Berteau Street, Chicago 13, Ill.

Closed-Circuit TV: Designed particularly for industrial applications, the TV camera shown is stated to be no more difficult or complicated to operate than the standard TV receivers which can be used with it. The camera is completely self-contained,

with all adjustments on the viewing panel. Over-all size is 14 by 9⅝ by 4⅝ ins. Dage Electronics Corp., 69 North 2nd Street, Beech Grove, Indiana.

Tantalum Foil Electrolytics: Polarized and non-polarized electrolytic capacitors of wound tantalum foil construction are described in a new bulletin, No. 523. Compactness, ruggedness, non-corrosive electrolyte, extremely low leakage current, long shelf life, low power factor, high operating temperature, and good frequency characteristics are claimed for these units. Cornell Dublier Electric Corp., Industrial Division, South Plainfield, N. J.

UHF Signal Generator: Model 612A generator, covering 450 to 1,200 mc. continuously, provides up to .5 volts output into 50 ohms. Broadband internal modulation up to 5-mc. can be obtained, or the instrument can be AM or pulse-modulated externally by pulses of .2 miroseconds or more. Frequency and output are set directly and read on large dials. Hewlett-Packard Company, 395 Page Mill Road, Palo Alto, Calif.

Transistor Batteries: A line of miniature low-voltage mercury batteries has been designed for junction transitor power supplies. Single cells of various sizes, called Energy Capsules, and cell combinations called Power-Pak batteries, are available in a wide range of voltages and ampere-hour capacities. P. R. Mallory & Company, Inc., Battery Division, North Tarrytown, N. Y.

Tubes and Sockets: Literature and technical data is available on the following tubes, germanium diodes, transistors, and sockets:

Amperex Electronic Corp., 230 Duffy Avenue, Hicksville, L. I., N. Y. — Type 5894-A UHF-VHF twin tetrode, 45 watts at 500 mc., wide-band RF amplifier, modulator, frequency multiplier.

Beam Instruments Corp., 350 Fifth Avenue, N. Y., N. Y. — Miniature CRT type 1CP1, for monitoring and similar purposes. Automatic focussing, only 1 anode potential required, cathode bias.

Hugh H. Eby, Inc., 4712 Stenton Avenue, Philadelphia 44, Pa. — New line of subminiature tube sockets meeting recognized industry standards and dimensions. Rectangular and round sockets.

International Rectifier Corp., 1521 East Grand Avenue, El Segundo, Calif. — Novel germanium diode assemblies, in double housings of phenolic material and glass. Excellent shock and vibration resistance claimed.

Lewis and Kaufman, Ltd., 62 El Rancho Avenue, Los Gatos, Calif. — Technical data sheet available on 4D21 power tetrode as Class AB1 or AB2 AF amplifier and modulator, Class C RF oscillator and unmodulated or high-level modulated amplifier.

Mycalex Tube Socket Corporation, 60 Clifton Boulevard, Clifton, N. J. — Transistor sockets molded of Mycalex 410 glass-bonded mica insulation, available in quantity. Contacts are of brass or beryllium copper. Also 7 and 9-pin miniature tube sockets for UHF applications.

Radio Receptor Company, Inc., 251 West 19th Street, New York 11, N. Y. — New and complete line of germanium diodes, including preferred JAN types. Tapered hexagonal bodies facilitate handling and indicate polarity at a glance.

Rauland Corporation, 4245 North Knox, Chicago, Ill. — Two new 21-in. rectangular TV picture tubes with spherical faceplates, 21YP4 and 21ZP4A, now in production. Former has electrostatic focus, latter magnetic focus.

Raytheon Mfg. Company, Receiving Tube Division, Newton 58, Mass. — Junction transistors CK721 and CK722, now available. CK721 has power gain of 38 db; CK722, 30 db.

Sylvania Electric Products, Inc., Radio Tube Division, Emporium, Penn. — Two new damping diodes for TV, 6AX4GT and 12AX4GT. Miniature high-perveance double triode for TV vertical deflection circuits, 12BH7. Sharp-cutoff high-transconductance video pentode, 12BY7, with miniature T-6½ construction, separate suppressor grid connection. Rectangular 17-in. TV picture tube, magnetic focus, cylindrical faceplate, 17QP4. Miniature 9-pin triode-pentode type 6U8, designed for oscillator-mixer service in FM and TV receivers.

Texas Instruments, Inc., 6000 Lemmon Avenue, Dallas 9, Texas — Point-contact transistor types 100 and 101. Former is for switching-circuit applications. Type 101 is high-efficiency amplifier for use below 1 mc. capable of handling large signals.

COMPANIES and PEOPLE

$8.5 Million for WPTZ:

Philco's TV station, started as an experimental transmitter in 1932, has been purchased by Westinghouse Radio Stations, Inc. It is understood that there will be no changes in the WPTV staff.

William P. Maginnis:

Elected vice president and chief engineer of Federal Telephone & Radio Corporation, Clifton, N. J. Prior to joining Federal in 1951, he was with RCA for 21 years. Mr. Maginnis will direct the telephone, radio, and vacuum tube engineering activities.

UHF Survey at Portland:

RCA has issued a very complete report on the coverage furnished by KPTV, now operating on 548 to 554 mc., with 16 kw. effective radiation. The report, of 24 pages, is profusely illustrated with photographs and charts. Copies can be obtained from the Engineering Products Division at Camden, N. J.

Relay Plant:

A new factory of 50,000 square feet, designed specifically for the manufacture of telephone relays, has been completed by C. P. Clare & Company, at 3101 W. Pratt Avenue, Chicago. Of windowless construction, it is provided with air conditioning, electrostatic air cleaning, humidity control, and shadowless lighting.

See You at the IRE Show:

TV & Radio Engineering, together with Communication Engineering and High Fidelity, will be represented at booth 3-310. We shall be glad to greet all our friends, and to discuss editorial material with those who are interested in preparing articles for any of our three magazines.

Speaker Magnet Requirements:

The RTMA Speaker Section, of which Russell Fenton is chairman, has submitted an estimate of Alnico 5 magnets which will be required for 1953 speaker production. The figure is 2,110,000 lbs., allowing 1½ oz. for each of 22,500,000 speakers. Last year, 18.807,515 speakers were manufactured in this Country.

Radio Industry Statistics:

Data on the radio industry by the Bureau of the Census has lacked certain significant information in the past, because it has been handled as a subclassification of electrical machinery. RTMA is now seeking to obtain more adequate recognition of the radio industry in the Bureau's industrial classifications.

L. W. Teegarden:

RCA vice president in charge of technical products has been elected executive vice president, a post made vacant when Joseph H. McConnell resigned to become president of Colgate-Palmolive-Peet.

West Coast Components Plant:

Construction has been started by Aerovox Corporation on a new plant at Monrovia, Calif. Manufacturing operations are scheduled to start early this summer.

North Adams, Massachusetts:

Robert C. Sprague, founder of Sprague Electric Company, has resigned as president. He has been succeeded by Julian K. Sprague. Also elected to the board of directors are Ernest L. Ward, William J. Nolan, George B. Flood, and Robert C. Sprague, Jr. Neal W. Welch has been appointed director of sales.

Radio Club of America:

Officers elected for 1953 are: John H. Bose president, Ralph R. Batcher vice president, Joseph Stantley treasurer, Frank H. Shepard, Jr. secretary, Frank A. Gunther recording secretary. Also elected to the board of directors are Ernest V. Amy, Edwin H. Armstrong, George E. Burghard, Alan Hazeltine, Harry W. Houck, Jerry Minter, and Harry Sadenwater.

Cleveland, Ohio:

Construction has been completed on Hickok Electrical Instrument Company's new assembly plant at 10626 Leuer Avenue. New techniques and facilities have been worked out for continuous workflow in such a manner as to permit quick changeover in response to demands for the 60 instruments which now comprise the line. Engineering and meter manufacturing will continue at 10514 Dupont Avenue.

Dr. Gordon K. Teal:

Has joined Texas Instruments, Inc. as assistant vice president in charge of materials and components research. Before he assumed this post, he had been with Bell Laboratories since 1930 where, in recent years, he had a part in the development of transistors and resistors.

An Interesting Opportunity:

There's a very interesting position open at The Publishing House for an engineer who is interested in technical writing. It is an opportunity for diversified experience on COMMUNICATION ENGINEERING, TV & RADIO ENGINEERING, and HIGH FIDELITY Magazines. For a man who wants to work and live in the country, and yet keep up with city activities by making trips to various places where interesting things are going on, this is an ideal situation. If you are interested, write to Milton Sleeper, The Publishing House, Great Barrington, Mass.

NARTB Los Angeles Conference:

Program for the annual Broadcast Engineering Conference is being planned by a guidance committee comprised of Raymond Guy NBC, chairman, Frank Marx ABC, William B. Lodge CBS, Rodney D. Chipp, Dumont, Earl M. Johnson MBS, A. James Ebel WMBD, and Carl Nopper WMAR-TV. This group is working with Neal McNaughton, NARTB.

Color TV Research:

Admiral Corporation is operating a color research laboratory at Palo Alto, Calif., staffed under Robert M. Jones.

1952 Tube Production:

RTMA reports production of 7.6 million cathode ray tubes valued at $170.6 million in 1952, and 368.5 million receiving type tubes valued at $259.1 million.

MEETINGS and EVENTS

MARCH 23 - 26,
IRE NATIONAL CONVENTION & SHOW
Grand Central Palace, New York City

APRIL 11,
NEW ENGLAND RADIO ENGINEERING MEETING
Univ. of Connecticut, Storrs, Conn.

APRIL 16 - 17,
JOINT RTMA CONFERENCE, U. S. & CANADA
Ambassador Hotel, Los Angeles

APRIL 18,
CINCINNATI SECTION IRE CONFERENCE
Cincinnati, Ohio

APRIL 26 - 30,
73RD CONVENTION SMPTE
Hotel Statler, Los Angeles

APRIL 28 - MAY 1,
NARTB BCST. ENGINEERING CONFERENCE
Philharmonic Auditorium, Los Angeles

APRIL 29 - 30, MAY 1,
ELECTRONIC COMPONENTS SYMPOSIUM
Shakespeare Club, Pasadena, Calif.

MAY 11 - 13,
IRE AIRBORNE ELECTRONICS CONFERENCE
Dayton, Ohio

MAY 18 - 21,
1953 ELECTRONICS PARTS SHOW
Conrad Hilton Hotel, Chicago

JULY 13 - 16,
MUSIC INDUSTRY TRADE SHOW
Palmer House, Chicago

AUGUST 19 - 21,
WESTERN ELECTRONIC SHOW
San Francisco Auditorium, San Francisco

SEPTEMBER 1 - 3,
INT'L SIGHT AND SOUND EXPOSITION
Palmer House, Chicago

SEPTEMBER 28 - 30,
9TH NATIONAL ELECTRONICS CONFERENCE
Hotel Sherman, Chicago

OCTOBER 26 - 28,
RTMA-IRE RADIO FALL MEETING
Toronto, Ontario, Canada

TV & Radio Review

PERHAPS this first Review should, like Janus, look back toward the past, and forward toward the future. But can it be said that radio broadcasting, and particularly television, has had time to acquire a past? And how, with the short focus of a few years, can we expect to get a sharp picture of the future?

These questions were brought to mind by the address which Dr. Lloyd V. Berkner, president of Associated Universities, Inc., delivered before the Radio Club of America last December. By way of introducing his discussion of the world's sources of energy, Dr. Berkner said: "Aside from the energy needed for food and minimum of warmth that is common to all biology, it is energy under man's control that forms the very basis of his civilization. In his quest for better living, and for time to follow intellectual pursuits, which are the bases of civilization, man first used slaves, both human and animal, as his principal energy-source. Then man learned to use the wind to sail his ships, and a little waterpower to grind his flour. But until two centuries ago, this was about the limit. The man without slaves, or without the favor of a court that had slaves, was poor indeed.

"The industrial revolution and, with it, the revolution in our civilized habits was started by James Watt [in 1769], who with his steam engine contrived to make controlled energy abundant. With the coming of simple electrical transmission of energy over great distances by fixed conductors, the first stage of the industrial revolution was complete. Each man, woman, and child in the United States now has the equivalent of 200 slaves at his disposal. Energy has made each of us king in contrast to the miserable situation of our forebears.

"This change has not been a slow evolution. It has been, rather, a sudden revolution. Man's written history is but 300 generations old. [For statistical purposes, a generation is considered to be 30 years.] So close are we to the beginning of civilization that about 7% of all men born throughout history are still living. Power in substantial quantities under man's control goes back only 6 or at the most 7 generations. Yet we routinely accept the mechanical slaves that power gives us as though they had always been present."

It seems impossible to believe now, in a land where there is available the work output of 200 slaves for each man, and woman, and child, that human slavery could have been an issue in a civil war less than three generations ago! And as we make plans today for the progress of tomorrow, we can see by looking at the past how short-sighted must be our view of things to come.

FOR example, there is the current philosophy that regards some 125 stations as the limit of TV network expansion, a figure indicated by operational economics. That figure may stand, of course, but its acceptance presumes that people who are now satisfied with the present picture quality of fringe-area reception from metropolitan stations will not prefer to tune in local stations, as they go on the air, in order to get the sharper pictures provided by stronger signals. Listeners, as we know, become conditioned to inter-station interference, static, and fading. But those viewers who have been putting up with the visual uncertainties of poor TV reception will quickly reject images that are less than clear and steady once they become available from new, nearby stations.

While broadcasters may be right in assuming that audio signals must be good enough because people listen to them, whatever the quality of reception may be, television signals from one station are good enough *only* if they are better than those from other stations picked up in a given area. The hand may be quicker than the eye, but the eye is more critical than the ear. Moreover, high-power TV, like FM, does not have the secondary coverage that AM broadcasting provides. Also, as time goes on, if TV stations spring up in a considerable percentage of the areas where frequencies have been allocated, present fringe-area coverage may be reduced by interference. The final answer as to the number of stations which should comprise a TV network depends in part, at least, on factors not yet finalized, such as receiving conditions when another 500 transmitters are on the air, audience viewing habits, and the possible reduction of networking rates.

PROGRESS in color television highlights the antagonism which has always existed between those whose interests lie in regulation, and those who insist that they be free to conquer limitations. The extent to which government agencies can be legally right and factually wrong was never demonstrated as clearly and quickly as when our Federal Communications Commission attempted to dictate the course of advancement that color television should take. An interesting aspect of this case was that the public, the industry, and the scientists all rejected the Commission's purely legalistic stand.

There is no timetable yet for the introduction of color. Even if it were completely ready now, it would be too early to start transmission, and to offer receivers to the public. That will be the logical next step after the basic black-and-white method of broadcasting has been established on a national basis. It is only sound procedure to solve problems first in their simpler forms, with the least number of undetermined variables. The time to undertake color will come when the industry has completed its job of furnishing satisfactory monochrome service on a national basis for, until then, we shall not have encountered and solved all the basic problems of TV transmission and reception. At that point a compatible color system will be required, not only because it will facilitate the introduction of color but because, certainly at the beginning, programming will be switched back and forth between monochrome and color.

One important point about color was not established in the FCC tests, nor has it been subsequently: what will be the difference in the service areas of black-and-white and color transmission? Many viewers are now satisfied with substantially deteriorated picture quality. What will they see when their same stations switch to color? Will the images be more or less acceptable? To put it another way: How will people choose between sharp monochrome pictures from a local station, and less-than-perfect images in color provided by weaker signals from distant, high-power stations? Color will undoubtedly be an important factor in the competition for audiences, but only time will assign values to these presently-unknown quantities.

EDUCATIONAL television is a subject about which differences of opinion are drawn sharply. In theory, it has almost unlimited possibilities as an effective means of mass education. Practical-minded educators, on the other hand, recognizing that television is not a substitute for classroom instruction, view with alarm the possible diversion to television of funds which, if and when available, are so sadly needed for additions to already inadequate school facilities. In some instances, it is held that support to educational television is being given by those whose real purpose is to confuse the issue of increased appropriations for new schools and more capable teachers, in order to postpone action on increasing funds for *any* educational purpose.

In any case, it is obvious that neither the FCC nor the educators who are actively supporting educational television have a realistic attitude toward the problems of producing effective program material, and the cost of programming and operating such stations.

And behind all that is being said about the potential values of educational television on a national basis, as envisioned by the FCC's plan of frequency allocations, there is the question in many minds as to the possibility that, somewhere in the background, lurks the undisclosed purpose of using such stations for government-controlled education, to be directed at children and adults alike.

Perhaps the wisest decision that can be made about educational television at this time is to make no decision at all and to let the right answer make itself evident, as it certainly will if it is allowed time to do so.

IN the field of scientific progress, one of the most interesting developments is that of recording TV shows on tape. If the work now being done was started from the point of basic research into the nature of the electrical impulses to be recorded, there is every reason to expect that tape can produce the visual equivalent of a live show, just as it is doing now in audio programs.

The use of TV tapes will probably be as an adjunct to film, however, because the latter has a practical advantage in editing. That is because film provides a record that can be seen, while tape does not. Interestingly enough, tape may eventually bear the same relation to film that disc records now bear to tape!

Television tapes may offer an important advantage to small stations, since the cost of equipment should be lower than that required for programming from movie film. Thus it may come about that TV shows will be taped from master films, just as phonograph records are made from master tapes.

EQUIPMENT is now available for theatre television, but this project is confronted with problems of frequency allocation and frequency utilization. There is keen competition for the channels being sought by the National Theatre TV Committee and the Motion Picture Association of America. The need for radio operation, according to representatives of these groups, is due to the fact that common carrier service is not available for network connections. On the other hand, while the theatres are asking for exclusive frequency allocations, their ultimate expectancy for using the channels they want is limited to 5 hours per day.

Considering the aspects of public interest, convenience, and necessity, the FCC is also concerned with the possibility of direct competition between the present TV broadcasting service and theatre television, since the movie producers might favor the latter at the expense of the former.

From the point of view of frequency utilization, it is argued that theatre television is a point-to-point service to be operated only a few hours a day, and should, therefore, be handled over a common carrier relay system, with wire-line connections to the theatres. Certainly the economics favor that plan, for part-time use of a microwave system might well run into such expense as to preclude any boxoffice profit. That seems particularly so if, as some experts contend, present TV standards are not high enough to give the degree of definition needed for satisfactory theatre projection.

RELAXATION of FCC operator requirements and the authorization of remote controls promise a measure of relief to the smaller audio broadcasting stations. Under the Report and Order issued on January 27, "holders of commercial radio operator licenses of any class except aircraft radiotelephone operator authorizations or temporary limited radiotelegraph second-class licenses may be employed to stand regular watches and perform limited duties at all AM broadcasting stations with operating power of 10 kw. or less when employing non-directional antennas, and at all FM and non-commercial educational FM stations with operating power of 10 kw. or less. However, at least one person holding a radiotelephone first-class operator license is required to be employed as a regular full-time operator at all AM and FM stations affected, to supervise and insure the proper functioning of the station equipment.

Further: "At non-commercial educational FM stations of 1 kw. or less, but above 10 watts, the operator may be a person holding a radiotelephone second-class license. At non-commercial educational FM stations of 10 watts or less, the operator may be a person holding a radiotelephone or radiotelegraph second-class operator license, but he is not required to be a regular full-time employee of the station, although he must be available on call."

Use of remote controls for transmitters is another means of reducing the expense of operating small stations. The Report and Order referred to above provides that: "A station which is authorized for non-directional operation with power of 10 kw. or less may, upon prior authorization from the Commission, be operated by remote control at the point(s) which shall be specified in the station license. . . . Operation by remote control shall be subject to the following conditions:

"(1) The equipment at the operating and transmitting positions shall be so installed and protected that it is not accessible to or capable of operation by persons other than those duly authorized by the licensee.

"(2) The control circuits from the operating position to the transmitter shall provide positive on and off control, and shall be such that open circuits, short circuits, or other line faults will not actuate the transmitter, and any fault causing loss of such control will automatically place the transmitter in an inoperative condition.

"(3) Control and monitoring equipment shall be installed so as to allow the licensed operator, either at the remote control point or at the transmitter, to perform all the functions in a manner required by the Commission's Rules and Standards."

A remote control installation has already been made at KEAR San Mateo, Calif., and another is under way at KSON San Diego, using equipment furnished by The Rust Industrial Company of Manchester, N. H. Of relatively inexpensive design, the Rust system provides for as many as nine meter readings and nine transmitter adjustments over two telephone pairs. Thus, as a transmitter function is adjusted from the remote point, the corresponding meter-reading can be observed.

Principal argument advanced against the relaxation of the Rules was that some engineers will lose their jobs. While it is true that stations will be able to reduce their payrolls, the change may be a blessing in disguise for the operators. There is a large unfilled demand for licensed operators to take charge of radio communication systems, and at wages substantially higher than those paid by the smaller broadcast stations. Quickest way to locate those positions is to inquire of the companies manufacturing communication equipment, for they get the information from their field engineers.

Noise and NTSC Color Standards

PRACTICAL EFFECTS OF NOISE ON TENTATIVE NTSC COLOR SIGNAL UNDER VARIOUS CONDITIONS OF CHROMATICITY AND LUMINANCE — *By* C. H. JONES*

Abstract

The purpose of this paper is to evaluate the efficiency with which the NTSC color television system transmits color information in the presence of noise.

For such an analysis, it is convenient to use the concept of a three-dimensional color solid. One dimension is determined by the amplitude of the black-and-white modulation envelope. The other two dimensions, in polar form, are determined by the magnitude and phase of the 3.9-mc. color subcarrier signal. The Munsell Color Solid specifies in an ideal way the visual relationship that exists among colors, because equal distances have equal visual meanings. In order to compare the NTSC solid with the ideal, contours of Munsell hue, value (related to luminosity), and chroma (saturation) have been plotted. An examination of these contours shows quantitatively what colors are most influenced by noise. The effects of placing the Z-Y and X-Y axes 119° apart are discussed. The proposed gamma of 2.75 is examined to determine whether or not it gives the best luminosity signal-to-noise ratio. The effect of applying gamma correction to each of the colors is analyzed.

While the tentative NTSC color signal is undergoing field tests, it is advisable to examine this signal theoretically to determine how it is affected by noise. Comparison with similar systems should reveal the strong and weak points of the proposed signal. In order to make such an examination, quantitative information is needed as to just how well the normal eye is able to perceive changes in brightness, changes in hue, and changes in saturation. Fortunately, such data is available in the form of Munsell[1,2] Value, Hue, and Chroma specifications.

When dealing with different types of color specifications, the concept of a color solid is often very helpful.[3,4,5] Five different color solids are discussed in this paper, but they are all of the general form shown in Fig. 1. The vertical axis is a measure of brightness; the radial distance from this axis, saturation; and the angular position on any plane, hue. Shape of the color solid and the units used for the three dimensions vary from one solid to another. Fig. 2 shows a three-dimensional model of one color solid.

Munsell Colors: The three scales shown for the Munsell system are intended to agree as closely as possible with a normal observer's perception of the three dimensions of the color solid. Lightness differences that are equally perceptible are spaced equally along the vertical axis, and are measured as Munsell Value.** Hue differences that are equally perceptible are separated by uniform angles, and are specified as Munsell Hue. Saturation steps are measured radially in uniformly perceptible steps as Munsell Chroma. A typical color specification would be 5R 4/8, which is a Hue of 5R, a Value of 4, and a Chroma of 8. Dorothy Nickerson[6] has suggested that the Munsell Renotation Values[7] be used to study systems that are based on the CIE (ICE) system of colorimetry.

CIE Diagrams: The CIE or ICI diagram[8] is by now familiar to color television engineers.[9,10] If the spectral response of a surface is known, the tristimulus values X, Y, and Z can be obtained. By multiplying points on the sample curve by corresponding points of the standard |X| curve, Fig. 3, and integrating, X is obtained. Y and Z are obtained by using the curves |Y| and |Z| in the same way. The sum of the tristimulus values X, Y, and Z gives the color mass or color weight.

$$W = X + Y + Z \qquad (1)$$

The quantity W can be obtained directly by multiplying the spectral curve of the sample by curve |W| shown in Fig. 3. It will be noted that blue colors, or those with wavelengths near 445 millimicrons, have relatively low luminosity but high color mass. Therefore, reflected energy in this region has little effect on brightness but a great effect on chromaticity. In the field of color television, there seems to be some tendency to underestimate the importance of blue.

*Research Laboratories, Westinghouse Electric Corp., East Pittsburgh, Pa. This paper was presented at the eighth National Electronics Conference in Chicago, Ill., December 29, 1952.

[1] *Munsell Book of Color*, Munsell Color Company, 10 East Franklin St., Baltimore, Maryland; 1929.

[2] *A Color Notation*, 9th Edition, by A. H. Munsell, Munsell Color Company; 1941.

[3] "Colorimetry in Television", by F. J. Bingley, a paper presented at the 1951 Convention of the I.R.E., New York.

[4] "Color Systems and Their Inter-Relation", by Deane B. Judd for the National Bureau of Standards, a paper presented at the 1940 Annual Convention of the Illuminating Engineering Society, Spring Lake, New Jersey.

[5] *Color in Business, Science, and Industry*, by Deane B. Judd, Wiley and Sons, Inc., New York. Part II, pp. 80-296.

**In this paper, when the words Value, Hue, and Chroma are capitalized, Munsell Value, Munsell Hue, and Munsell Chroma are implied.

[6] "Munsell Renotations Used to Study Color Space of Hunter and Adams", by Dorothy Nickerson, *J. Opt. Soc. Am.*, vol. 40, No. 2, pp. 85-88; February, 1950.

[7] "Final Report of the OSA Subcommittee on the Spacing of the Munsell Colors", by S. M. Newhall, D. Nickerson, and D. B. Judd, *J. Opt. Soc. Am.*, vol. 33, p. 385; 1943.

[8] *Handbook of Colorimetry*, Massachusetts Institute of Technology.

[9] *Television Engineering*, by Donald G. Fink, McGraw-Hill Book Company, Inc., New York, Chapter 8; 1952.

[10] "Color Fundamentals for Television Engineers", by Donald G. Fink, *Electronics*, vol. 23, pp. 88-93, December 1950; vol. 24, pp. 78-83, January 1951; pp. 104-109, February 1951.

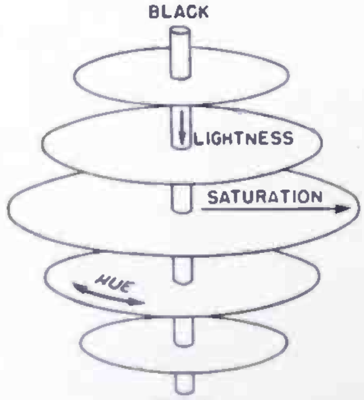


FIG. 1. DIMENSIONS OF A COLOR SOLID.

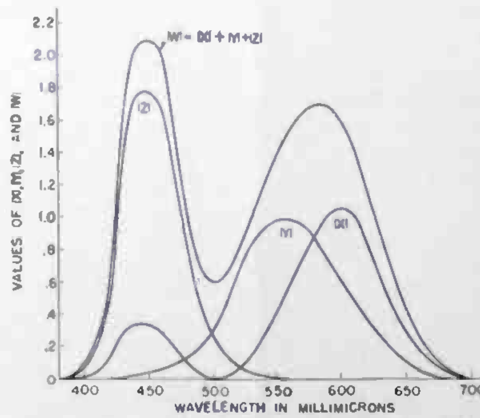


FIG. 3. STANDARD CIE CURVES FOR X, Y, Z, AND W.

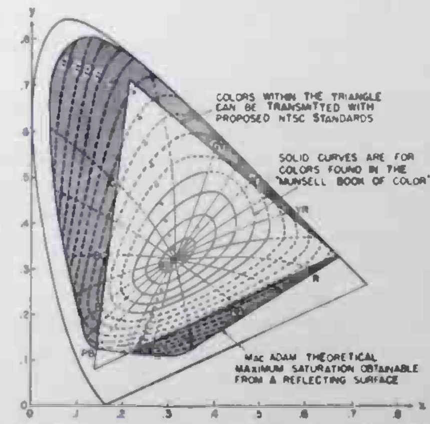


FIG. 4A. A CHROMATICITY DIAGRAM FOR MUNSELL VALUE 5

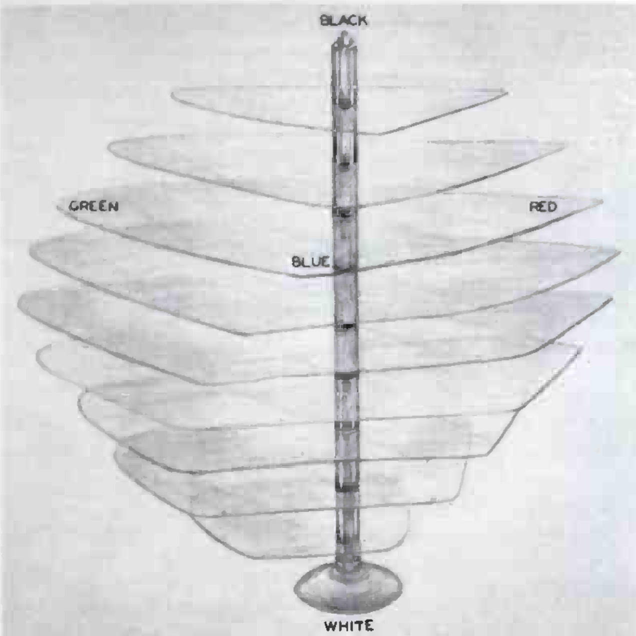


FIG. 2. A MODEL OF JUDD'S MODIFIED HUNTER ALPHA-BETA COLOR SYSTEM

The trichromatic coefficients are obtained by simply normalizing the tristimulus values as follows:

$$x = \frac{X}{W}, \quad y = \frac{Y}{W}, \quad \text{and} \quad z = \frac{Z}{W} \qquad (2)$$

$$\text{Since} \quad x + y + z = 1, \qquad (3)$$

it is customary to specify only x and y. In making additive color mixtures, a plot of colors on an x, y chromaticity diagram is very useful. By considering a weight proportional to the color weight W at each color, the resulting chromaticity of the mixture can be found by simply calculating the center of gravity of the system.

Response of the eye is not uniform in different parts of the diagram. Fig. 4A shows the Munsell colors plotted on the chromaticity diagram for Value 5. Both Hue and Chroma contours are close together in the blue region and are spread out in the green. This means that the eye is able to detect chromaticity changes in the blue more easily than in the green. Also, on the left side and bottom of the diagram the Munsell colors do not extend all the way to the spectral locus, but only as far as the maximum-demand contour.[11] At this specified brightness level, it is theoretically impossible to obtain a reflecting surface having a chromaticity outside this contour. As the luminosity becomes greater, the demand curve becomes smaller, Fig. 4B, until at white it is only a point.

At least a dozen different transformations of the ICE diagrams have been made in attempts to obtain spacings that more nearly correspond to the perceptibility of the eye.[6,12] These transformations are of all sorts and complexities; some are linear homogeneous transformations,[4,5] and others are not. Some almost succeed in making the Munsell Chroma loci concentric circles and in making the angular separation of the Munsell Hues uniform. Just how complicated a transformation is justified for a particular color problem depends on the way in which the transformed color solid is to be used. In color television, the optimum color solid depends primarily on two factors: the effect of noise, and the complexity of the receiver required to decode and present the color information.

Color Transmission: Consider now the problems of color television. Basic requirements are that the information be packaged in such a way that it can be transmitted in the available spectrum, that it can be received by present black-and-white receivers, that it undergoes a minimum of damage from noise in transmission, and that color receivers can use the received information. The color information to be transmitted is three-dimensional, so that three parameters are necessary. Some of the possible combinations that specify a color completely are:

X, Y, Z	Y, (X-Y), (Z-Y)
Y, x, y	$Y, \frac{x}{y}, \frac{z}{y}$
W, x, y	R, B, G
Y, S, Θ_H	

where S = saturation
Θ_H = hue angle
R, B, G = red, blue, and green primaries.

Since the only information required at black-and-white receivers is the luminosity signal Y, it would seem logical to modulate the black-and-white carrier with Y or some function of it. It has been found by experiment that a signal located 3.6 to 3.9 mc. above the picture carrier is not noticeable on most black-and-white receivers, particularly if the exact frequency is chosen such that the intensity modulation cancels out on successive pictures. Therefore, it has been proposed that chromaticity information be applied to this color subcarrier. If both sidebands of the subcarrier are transmitted, then the signal can be modulated in amplitude and phase simultaneously so that two independent types of information can be transmitted. By utilizing the oscillating color sequence[13] technique, one set of sidebands can be transmitted during one picture interval and the other set during the next picture interval.

Tests have been made[14] which indicate that sufficient chromaticity information can be conveyed if the color subcarrier is modulated only at frequencies up to 1 mc. Fig. 5A is a diagram of the video waveform as various colors are transmitted according to tentative NTSC standards. Gamma was set at 1.

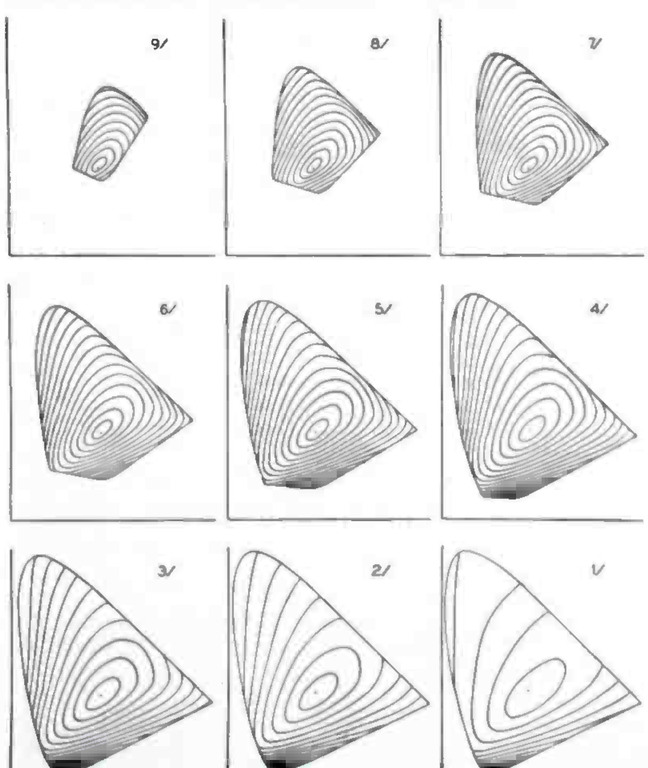


FIG. 4B. SCALED CHROMATICITY DIAGRAMS FOR MUNSELL VALUES 1 TO 9

[11] "Maximum Visual Efficiency of Colored Materials", by D. L. MacAdam, *J. Opt. Soc. Am.* 25, p. 361; 1935.

[12] "Comparison of Color Systems with Respect to Uniform Visual Spacing", by Robert W. Burnham, *J. Opt. Soc. Am.*, vol. 39, No. 5, pp. 387-392; May, 1949.

[13] "Color Television Systems with Oscillating Color Sequence", by B. D. Loughlin, Report No. 7116-2, Hazeltine Corporation; May 7, 1951.

[14] "Requisite Color Bandwidth for Simultaneous Color-Television Systems", by Knox McIlwain, *IRE Proceedings*, vol. 40, No. 8, pp. 909-912.

The corresponding colors are shown in Fig. 5B. All chromaticities are at maximum saturation.

All the color systems discussed in this paper employ phase modulation of the color subcarrier for hue transmission, and amplitude modulation of the subcarrier for saturation transmission. From the standpoint of noise, it is important to know in precisely what manner the phase varies with hue, the amplitude varies with saturation, and the DC level varies with luminosity.

The Brightness Signal: Brightness or luminosity transmission will be considered first. Let it be assumed that the transmitting equipment is capable of transmitting any function of Y, and that the receiver is capable of decoding this and reproducing the original Y values on the picture tube. If noise were not important, then it would be logical to transmit the function of Y that could be most easily decoded. For example, if receiver circuits were all linear, except for the picture tube which had a gamma of 2.75, then it would be sensible to transmit $Y^{1/2.75}$. Unfortunately, this is not the optimum characteristic for best performance with noise.

If it were desired to transmit ten brightness levels with noise noticeable equally at any level, ten brightnesses separated by intervals that are equally preceptible to the eye would be chosen. Those brightnesses should correspond to ten equally-spaced[15] modulation voltage levels. This assumes a large signal-to-noise ratio. The problem then, reduces to that of determining the function of luminosity, f(Y), which approximates the response curve of the normal eye in the range of brightnesses reproducible by a TV screen. Considerable study and experimentation[7,16] has been done in an effort to obtain an ideal value scale. The Munsell Value scale is one result. Value is defined as the brilliance of the colors of a series of standards, varying in reflectance from zero to unity, in such a way that all the visual intervals are uniform. Munsell Value, V, is shown in Fig. 6 plotted as a function of Y. The curve does not obey any simple exponential or logarithmic law. An approximation is:

$$Y = 1.2219V - 0.23111V^2 + .23951V^3 - 0.021009V^4 + 0.008404V^5 \qquad (4)$$

If it be assumed that a simple exponential relation is desirable for television, then it is obvious that $Y^{1/2.34}$, Fig. 6, gives a good approximation to the ideal straight line except at the lower end, near black. The curve $Y^{1/2.75}$ has been plotted also to show how well this approaches an ideal straight line. Since the slope of this curve is nearly constant from gray to white, noise should be noticeable equally well throughout this region. In the very dark region the slope of the curve is large, so that noise should be less noticeable in that range.

For any function of Y, a comparison of the effects of noise at two brightness levels A and B can be obtained by comparing the slopes of the curves at the two points.

$$\text{db difference} = 10 \log \left(\frac{\text{slope at A}}{\text{slope at B}} \right)^2 \qquad (5)$$

R. S. Hunter[6] gives an expression that approximates the ideal Value curve rather well:

$$\frac{V}{10} \sim Y \frac{.51\ (20 + 20Y)}{(1 + 20Y)} \qquad (6)$$

This is plotted in Fig. 6. Although it provides excellent correction, it might be more difficult to use in color receivers than a simple exponential gamma correction.

Even though a gamma of 2.75 is not as good as 2.34 from the standpoint of noise, it may be close enough to the ideal curve to be acceptable.

Munsell Chromaticity: The relative importance and frequency of occurrence of the different colors has a bearing on the best way to transmit the chromaticity signal. Probably the colors of skin complexions are of most importance. Colors of low saturation are more common than those of high saturation; in fact, some colors near the maximum demand contours occur very rarely. It is probably safe to assume that all Hues are equally important and that they occur with equal frequency.

If it is assumed that all the Munsell colors are equally important, that they all occur equally often, and that noise should be equally perceptible for all colors, then the Munsell color system could, theoretically, be transmitted. That is, the average video level over .25 microsecond or more would be proportional to Munsell Value, the phase angle of the color subcarrier at 3.9 mc. would be proportional to Munsell Hue, and the amplitude of the color subcarrier would be proportional to Munsell Chroma. The modulation voltage might then be

$$E_m = M_v + M_c \sin (\omega t + 3.6\ M_H) \qquad (7)$$

where E_m is the modulation potential
M_v is the Munsell Value
M_c is Munsell Chroma
M_H is Munsell Hue (1 to 100)

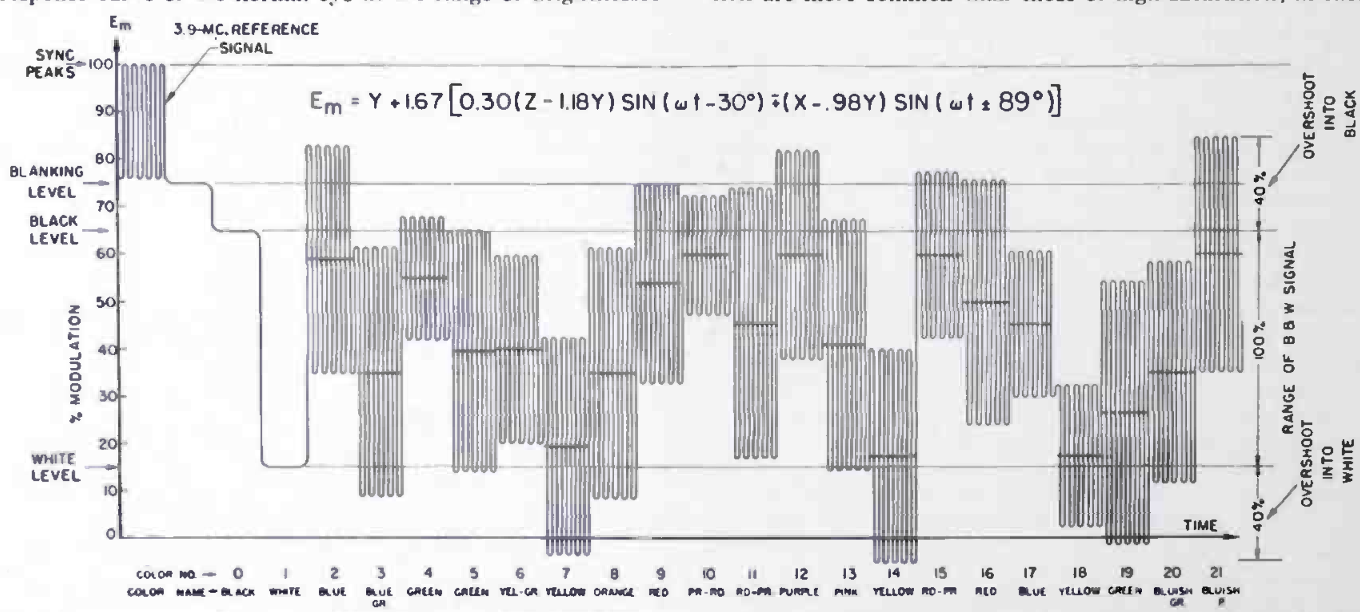
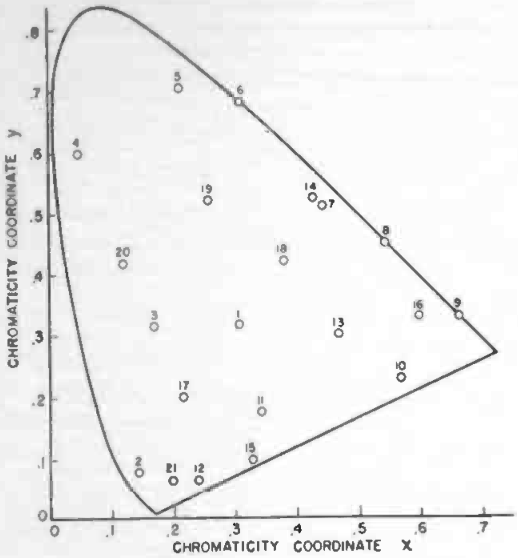


FIG. 5A. MODULATION ENVELOPE FOR VARIOUS COLORS WITH TENTATIVE NTSC STANDARDS. GAMMA IS 1. DC LEVEL, 3.9-MC. PHASE AND AMPLITUDE VARY

[15] *Frequency Analysis, Modulation, and Noise*, by S. F. Goldman, McGraw-Hill Book Company, Inc., New York, Chapter VI; 1948.

[16] "Neutral Value Scales I, Munsell Neutral Value Scale", by A. E. O. Munse=' L. L. Sloan, and I. H. Godlove, *J. Opt. Soc. Am.* 23, p. 394; 1933.



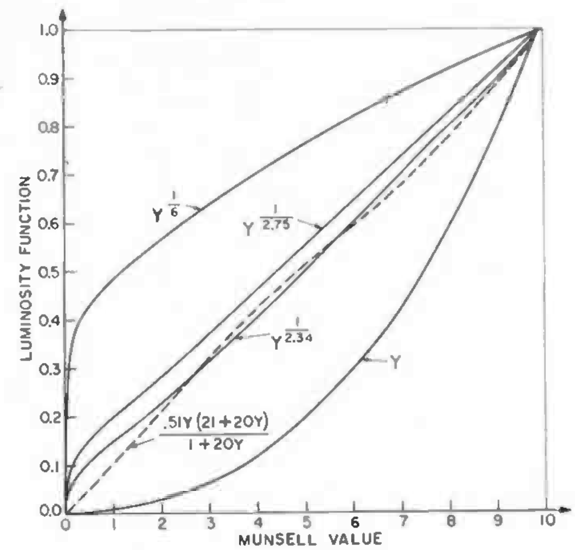


FIG. 5B, LEFT. THESE COLORS ARE TRANSMITTED BY CORRESPONDINGLY NUMBERED SECTIONS, AS SHOWN IN FIG. 5A

FIG. 6, RIGHT. HOW VARIOUS FUNCTIONS OF Y AFFECT THE LINEARITY OF THE LUMINOSITY SIGNAL-TO-NOISE RELATION

If the bandwidth of the chromaticity signal were a quarter of that of the luminosity signal, the RMS noise would be only half as much. Thus, the signal could be

$$E_m = M_v + .5\ M_c \sin(\omega t + 3.6\ M_H) \qquad (8)$$

With such a signal, the noise in hue and brightness would be about equally noticeable, and chroma noise would be slightly less[17,18], about 1 db. At all brightness levels, noise would be equally perceptible; at all hues, noise would be equally perceptible; and at all saturations, noise would be equally perceptible.

It would probably be rather difficult to code color information into this form at the transmitter and to decode it into a usable form at the receiver. Also, it would not be practical to use a color subcarrier of such large amplitude because the modulation would extend too far below the white level, producing negative modulation.

CIE Chromaticity: The possibility of transmitting CIE chromaticity information alone on the color subcarrier has been suggested. Such a signal might be of the form

$$E_m = Y^{1/\gamma} + k\,(x \sin \omega t + y \cos \omega t) \qquad (9)$$

where γ is the gamma used for the brightness
k is a constant
x and y are trichromatic coefficients
ω is 2π times the frequency of the color subcarrier.

However, since x and y are always positive, the color subcarrier always lies in the first quadrant. A better system is obtained by translating the origin of the coordinate system to white, Illuminant C. The signal is then

$$E_m = Y^{1/\gamma} + k\,[\,(x - .310) \sin \omega t + (y - .316) \cos \omega t\,] \qquad (10)$$

Means for generating such a signal at the transmitter and using it at the receiver have been worked out.[19] A unique advantage of this method is that the luminosity and chromaticity components are completely independent. The signal disappears at white, and is relatively small at high luminosities because of the small area of the demand contour. At very low luminosities, on the other hand, the chromaticity signal for saturated colors is large, and the signal would extend into the blanking and sync regions. Chromaticity noise is less noticeable in dark regions than in light, because the eye is less able to detect chromaticity changes at low luminosities than at high luminosities. This is evident by comparing Munsell plots of low and high-Value colors, Fig. 4B.

The chromaticity signal can be made to decrease with decreasing luminosity by multiplying it by some function of luminosity. For example, suppose the signal

$$E_m = Y^{1/2.34} + 1.5Y^{1/2.34}\,[(x - .310) \sin \omega t + (y - 3.16) \cos \omega t] \qquad (11)$$

were transmitted. The constant in front of the chromaticity term was chosen such that the amplitude of the chromaticity signal is within reasonable limits. Fig. 7 shows how various Munsell colors are transmitted. All the colors at five dif-

[17] "Colorimetry", by Deane D. Judd, National Bureau of Standards Circular 478; March 1, 1950.

[18] "Color Television Specification", by D. Nickerson and K. F. Stultz, *J. Opt. Soc. Am.* 34, p. 550; 1944.

[19] *New Television Systems*, by C. H. Jones, thesis for M.S. degree, University of Pittsburgh; 1951.

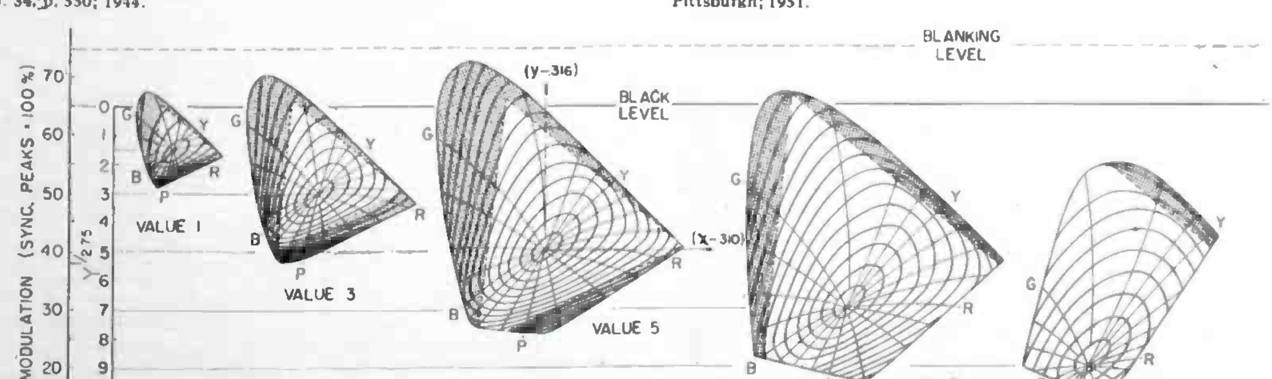
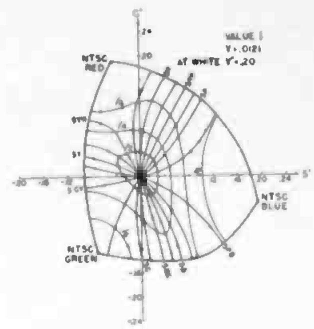
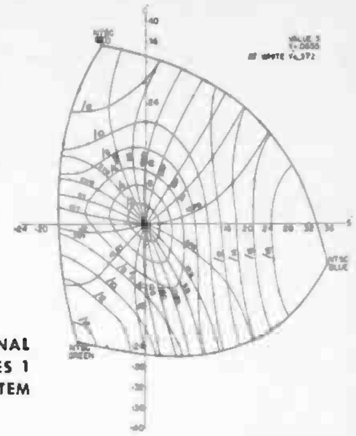


FIG. 7. DIAGRAMS OF COLOR SIGNALS TRANSMITTED IN ACCORDANCE WITH EQUATION 11. PLOTS ARE DRAWN FOR VALUES 1, 3, 5, 7, AND 9





FIGS. 9A AND 9B. SUBCARRIER SIGNAL PHASE AND AMPLITUDE FOR VALUES 1 AND 3, WITH TENTATIVE NTSC SYSTEM

ferent brightness levels are illustrated. The amplitude and phase of any color can be found simply by drawing a vector from the center of the appropriate diagram to the color. Swinging this vector downward, it is easy to determine if the 3.9-mc. modulation would extend below the white level and, if so, by how much. Similarly, swinging the vector so that it points upward reveals whether or not the modulation would extend above the black level, and by how much.

Hunter's Alpha-Beta Diagram: The possibility of transmitting a transformed version of the ICI system should be examined. The general aim of such transformation[12] is to make the Munsell Chroma loci approach more closely a set of concentric circles, and to make the Munsell Hues have equal angular separations.

Dr. D. B. Judd has developed a three-dimensional figure to represent colors and to serve as a guide for estimating the perceptibility of color differences.[5,17] A slightly modified form of this color solid could be used as a basis for transmitting a compatible color television signal. For a signal of the form

$$E_m = Y^{1/2.31} + 2.3\, Y^{1/4}\, (\alpha \sin \omega t + \beta \cos \omega t), \qquad (12)$$

the chromaticity portion inside the brackets is multiplied by the fourth root of Y. This has been done to make the diameter of the Munsell Chroma loci remain about constant as brightness varies from white to black.

The part of the signal inside the brackets represents the alpha-beta diagram developed by Hunter.[20,21,22] These co-

[20] "Multipurpose Photoelectric Reflectometer", by R. S. Hunter, *J. Research NBS* 25, p. 581; 1940, RP1345; also *J. Opt. Soc. Am.* 30, p. 536; 1940.

ordinates, Fig. 8, are related to the standard CIE chromaticity coordinates by the formulas:

$$\alpha = \frac{2.427x - 1.363y - 0.321}{1.000x + 2.236y + 1.105} \qquad (13)$$

$$\beta = \frac{0.571x + 1.245y - 0.571}{1.000x + 2.263y + 1.105} \qquad (14)$$

These signals could be obtained by using three color cameras with Hunter amber, green, and blue filters, and a matrix, since

$$\alpha \sim \frac{A - G}{A + 2G + B} \qquad (15)$$

$$\beta \sim \frac{0.4\,(G - B)}{A + 2G + B} \qquad (16)$$

where A, G, and B are the outputs of the amber, green, and blue cameras respectively.

NTSC Tentative Standards: Color field test specifications were released by the National Television Systems Committee on November 26, 1951.[23] The video voltage specified was

$$E_m = Y' + \frac{1}{1.14}\left[\frac{1}{1.78}(E'_B - Y')\sin \omega t + (E'_R - Y')\sin(\omega t \pm 90^\circ)\right] = Y' + S' \sin \omega t \pm C' \cos \omega t \qquad (17)$$

The symbols S′ and C′ are used to denote the coefficients of the sine and cosine portions of the signal.

The luminosity part is defined by the equation

$$Y' = 0.59E'_G + 0.30E'_R + 0.11E'_B. \qquad (18)$$

and the other terms are defined by these equations:

$$E'_G = E_G^{1/2.75} = (.212W_G)^{1/2.75} = (-0.985X + 2.00Y - 0.028Z)^{1/2.75} \qquad (19)$$

$$E'_R = E_R^{1/2.75} = (1.103W_R)^{1/2.75} = (1.908X - 0.531Y - 0.288Z)^{1/2.75} \qquad (20)$$

$$E'_B = E_B^{1/2.75} = (.699W_B)^{1/2.75} = (0.058X - 0.118Y + 0.896Z)^{1/2.75} \qquad (21)$$

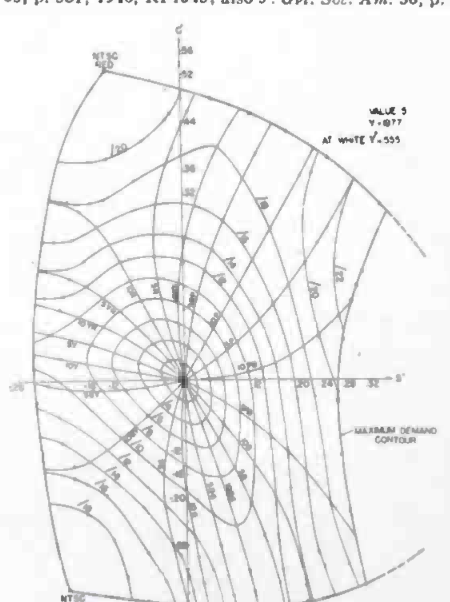
The chromaticities of the three primaries are plotted in Fig. 4A.

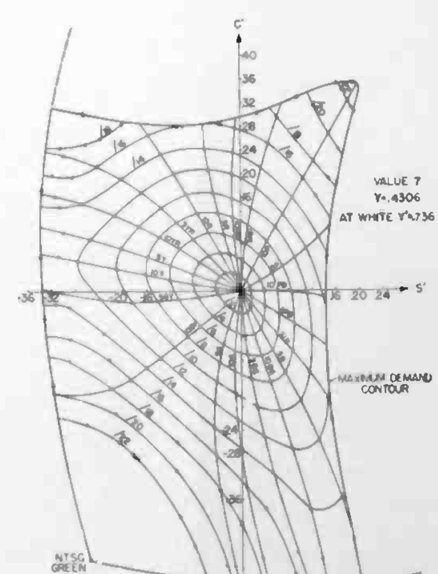
In order to examine more closely the transmitted signal, the

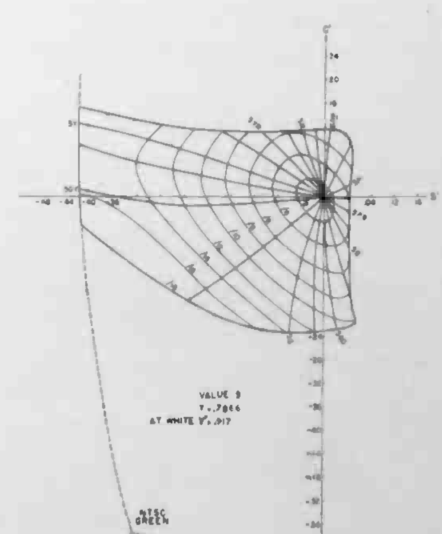
[21] "Photoelectric Tristimulus Colorimetry with Three Filters", by R. S. Hunter, NBS Circular C429; July 30, 1942.

[22] "A Proposed Method of Designating Color", by F. Scofield, D. B. Judd, and R. S. Hunter, *ASTM Bulletin*, p. 19; May 1941.

[23] National Television System Committee, Panel 13, Color Video Standards, "Report of Panel Actions"; 1951.







FIGS. 9C, 9D, AND 9E. AMPLITUDE AND PHASE OF COLOR SUBCARRIER FOR VARIOUS COLORS AT VALUES 5, 7, AND 9, UNDER TENTATIVE NTSC SPECS expression given in Equation 17 was evaluated for Munsell colors at various Values by taking X, Y, and Z values from a table,[7] and performing the indicated operations. The amplitude and phase of the color subcarrier are shown for Values 1, 3, 5, 7, and 9 in Figures 9A, 9B, 9C, 9D, and 9E. Constant Chroma and constant Hue loci have been plotted. The points marked were simply the calculated points, and have no special significance.

Equation 17 can be written in slightly different form:

$$E_m = Y' + .598E'_G \sin(\omega t \pm 119.4°) + .632E'_R \sin(\omega t \pm 103.6°) + .409E'_B \sin(\omega t \pm 12.4°) \quad (22)$$

which, in terms of color weights of the primaries, becomes

$$E_m = Y' + .635W_G^{1/2.75} \sin(\omega t \pm 119.4°) + .655W_R^{1/2.75} \sin(\omega t \pm 103.6°) + .394W_B^{1/2.75} \sin(\omega t \pm 12.4°) \quad (23)$$

If a color lies outside the triangle formed by the primaries, then W_G, W_R, or W_B will be negative. From Equation 23 it is evident that a negative quantity raised to the 1/2.75 power cannot be transmitted. A comparison of Figs. 4A and 9C illustrates this.

Since many colors near the maximum demand locus[11] seldom occur in practice, this limitation is not too serious. Examination of Fig. 9 reveals that the Chroma loci are not ideal circles, although at very low saturation levels they are reasonably round. As the saturation increases, the circles become more distorted until, near maximum saturation, many Chroma loci are almost parallel to the Hue loci. The diameters of Chroma[2] circles are about the same for all Values, and other Chroma loci also remain about the same size at different brightness levels.

TABLE 1

AMPLITUDE OF Y′ FOR SATURATED COLORS

COLOR	MUNSELL VALUE 1	MUNSELL VALUE 3	MUNSELL VALUE 5	MUNSELL VALUE 7	MUNSELL VALUE 9
White	.200	.370	.554	.736	.916
NTSC Blue	.048	.090	.134	—	—
Cyan	.159	.295	.440	.584	—
NTSC Green	.144	.265	.402	.527	—
Yellow	.188	.345	.516	.685	.848
NTSC Red	.094	.172	.258	—	—
Magenta	.122	.209	.312	—	—

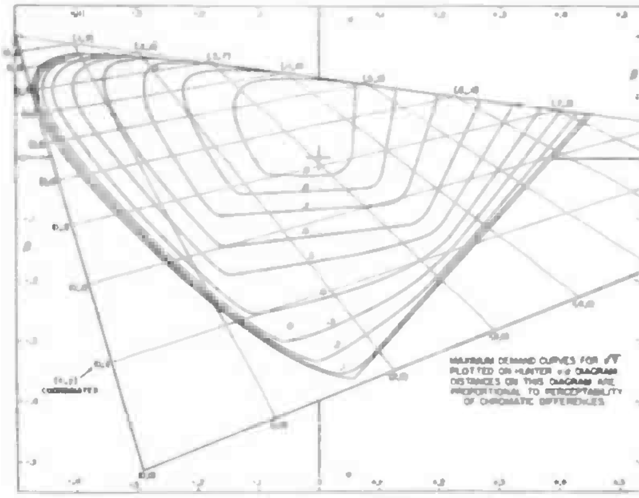


FIG. 8. DIAGRAM OF HUNTER'S ALPHA-BETA COLOR DESIGNATION SYSTEM

From the standpoint of noise performance, this is good. The spacing between Chroma circles is reasonably uniform, although it tends to become greater at high saturations. This is unfortunate, because high saturations are transmitted less frequently than low saturations.

For Hue loci, consider the Value 5 diagram in Fig. 9C. If the 20 Hues shown were spaced at equal angles, then the separation between adjacent Hues would be 18°. The angular separation between B5 and 10BG at Chromas up to 6 is about 9°. This means that the effect of noise is 6 db worse than it would be with uniform angular spacing. At high Chromas the angular separation is as low as 5.5° in some regions, so that noise is 10 db worse than ideal. Of course, there are regions where the angular separations are quite large, and noise in those regions has little effect on hue.

The equations shown in Fig. 9F indicate an average level of $Y^{1/2.75}$ rather than Y'. For all shades of gray along the neutral axis, the two quantities are equal. At all colors of low saturation the two are almost equal[24]; Y' is a little less than $Y^{1/2.75}$. At high saturations, however, there can be considerable differences between the two, as shown in Table 1.

Modified NTSC Signal: The distorted shape of the NTSC color solid is determined in considerable measure by the way in

[24] "Gamma Correction in Constant-Luminance Color Television Systems", by S. Applebaum, a paper presented at the 1953 IRE Convention, New York.

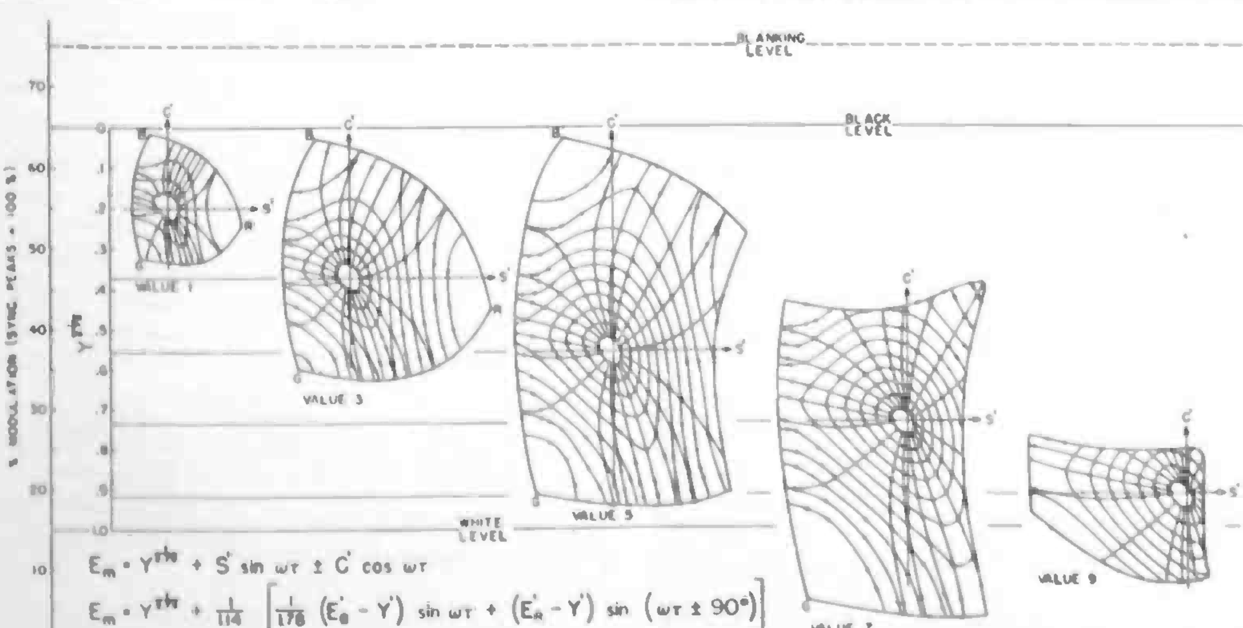


FIG. 9F. THE DIAGRAMS OF FIGS. 9A TO 9E TRANSFERRED TO A TRANSMITTER MODULATION CHART. NO OVERMODULATION IS POSSIBLE which the gamma is applied to the chromaticity portion of the signal. Suppose that Equation 17 is rewritten, assuming a gamma of 1 applied to the color part of the signal and a gamma of 2.34 applied to luminosity:

$$E_m = Y^{1/2.34} + \frac{1}{1.14}\left[\frac{1}{1.78}(E_B - Y)\sin\omega t + (E_R - Y)\sin(\omega t \pm 90^\circ)\right], \qquad (24)$$

which can be written as [13]

$$E_m = Y^{1/2.34} + 1.67\left[.030\,(Z - 1.18Y)\sin(\omega t \pm 30^\circ) + (X - .98Y)\sin(\omega t \pm 89^\circ)\right] \qquad (25)$$

or

$$E_m = Y^{1/2.34} + 1.67Y\left[.30\left(\frac{z}{y} - 1.18\right)\sin(\omega t \pm 30^\circ) + \left(\frac{x}{z} - .98\right)\sin(\omega t \pm 89^\circ)\right] \qquad (26)$$

Note that the terms inside the brackets contain only chromaticity information. A plot of the Munsell colors using this equation reveals that half the Hues are squeezed into two 60° sectors, while the other half are in the other two 120° sectors. Therefore, the phase of one term should be shifted 29° with respect to the other in order to improve the angular spacing of the Munsell Hues. The amplitude of the first terms are thereby slightly increased, also, which makes the Chroma circles more nearly round. This yields:

$$E_m = Y^{1/2.34} + kY\left[1/3\left(\frac{z}{y} - 1.18\right)\sin\omega t + \left(\frac{x}{y} - 0.98\right)\sin(\omega t \pm 90^\circ)\right], \qquad (27)$$

where k is an arbitrary constant.

Such signal is very similar to one suggested by F. J. Bingley[3] some time ago. If Munsell colors are plotted on a color solid based on this equation, it is found that the Chroma circles for low brightness are smaller than the same Chroma plots for high brightness. This situation can be remedied by applying an exponent to the Y coefficient of the term in brackets, which does not distort the chromaticity diagram at all. The modulation signal would then be

$$E_m = Y^{1/2.34} + .56Y^{1/2.34}\left[1/3\left(\frac{z}{y} - 1.18\right)\sin\omega t \pm \left(\frac{x}{y} - .98\right)\cos\omega t\right] = Y^{1/2.34} + S\sin\omega t \pm C\cos\omega t \quad (28)$$

where S and C are simply the coefficients of the sine and cosine portions of the signal. The constant 0.56 was chosen rather arbitrarily to make the diameter of the Chroma circles, Fig. 10, roughly the same as those in Fig. 9F. Provided that colors more saturated than the NTSC primaries need not be transmitted, this constant can be increased by 50%. Even then the modulation does not go as low as zero nor as high as blanking level. A 3.5-db improvement in chromaticity signal-to-noise ratio can be realized. Plots of the Munsell colors for transmitting this sort of a color system are shown in Fig. 10. It is evident that the spacing of the Hue angles is quite uniform.

As illustrated in Fig. 6,

$$Y^{1/2.34} \sim \frac{.51Y\,(21 + 20Y)}{(1 + 20Y)}, \qquad (29)$$

so that Equation 28 bears a close resemblance to the Hunter alpha-beta color solid.

Conclusions: The present NTSC proposed system is a fairly good one from the standpoint of noise effects on brightness and chromaticity. The signal-to-noise ratio for brightness would be improved slightly by employing a gamma a little lower than 2.75. The chromaticity signal-to-noise ratio can be improved appreciably by adjusting the amplitude and phase of the three color components, and by applying the gamma to the Y coefficient of the chromaticity part of the signal rather than to the individual parts of the chromaticity expression. This would also permit transmission of a wider range of colors, and would remove the limitation on primaries for use at the receivers.

The author wishes to thank L. Johnson and C. Carpenter for their calculations to obtain data for the figures and table.

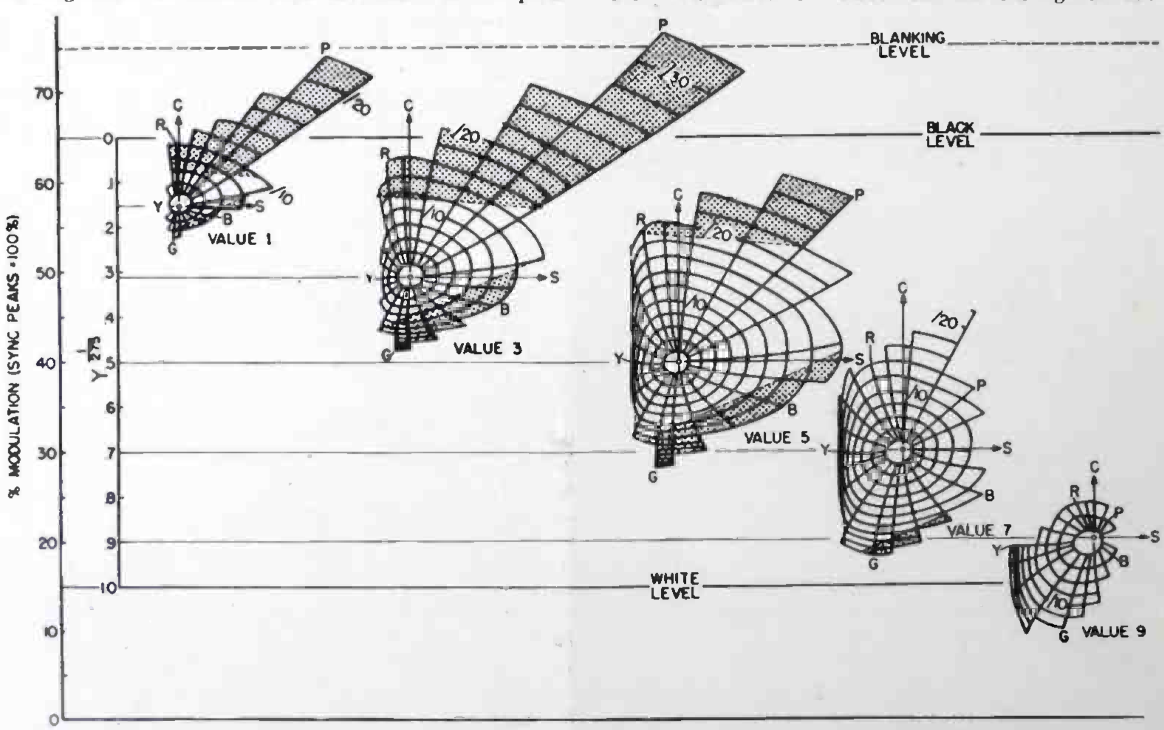


FIG. 10. PLOTS OF MUNSELL COLORS FOR 5 VALUES USING A MODIFIED VERSION OF THE NTSC COLOR SPECIFICATION

Report on Spurious Radiations

A RESUME OF INDUSTRY PROGRESS AND PROJECTED PLANS FOR REDUCTION OF SPURIOUS RADIATIONS FROM FM AND TV RECEIVERS AND TRANSMITTERS

An industry-wide meeting on the problems of spurious radiations from FM and TV receivers and transmitters was held at the Hotel Biltmore, New York City, on January 9, 1953. The meeting was called by Dr. W. R. G. Baker, director of RTMA's Engineering Department. Members and non-members of RTMA in the radio and television industry were invited, and the Joint Technical Advisory Committee.

Genesis of the meeting was a letter from the FCC to JTAC, requesting that body to study the problem of interference from spurious radiation, which information the FCC would use in determining methods and limiting values for its regulatory functions. Ralph Bown of JTAC then wrote to Dr. Baker, asking for information on RTMA views concerning the practical problems of the spurious-radiation situation, and any operating or proposed plans for establishing standards and performance limits to keep interference from spurious radiations within "sound engineering bounds." The January 9 meeting was called in order to review what has been done by the industry since initiation of the 41.25-mc. IF standard, determining the progress to date; to impress on the industry the seriousness of the problem and its own responsibility; and to appoint task forces on transmitters and receivers to guide future progress.

Standard IF Frequency: I. J. Kaar, chairman of RTMA Receiver Committee R4, gave a brief talk on the work of his committee with regard to the standard television IF. He reviewed the history of the old standard IF, 21.25 to 21.9 mc., which was not entirely satisfactory. When the FM band was moved to its present range, consideration was given to the 40-mc. band for a new television IF. In 1949, the RTMA adopted 41.25 mc. for the sound IF as a new standard. Experience has shown, said Mr. Kaar, that this is a better choice than the old standard. Manufacturing costs are about the same. Interference to TV receivers using the new IF, however, can be caused by high-power state police transmitters. This fact, in addition to natural reluctance to discard a debugged design, has prevented the adoption of the new IF by some manufacturers.

Oscillator radiation from sets using a 41.25-mc. IF can interfere with FM broadcasting, some air services, amateurs, and some government bands. However, no IF choice can eliminate all interference if local oscillators are permitted to radiate to an unreasonable extent, Mr. Kaar pointed out. The proper solution to the interference problem lies in 1) limiting oscillator radiation as much as is practical, and 2) insuring that services interferred with use reasonably adequate transmitter power.

Progress Since 1950: Chairman L. M. Clement of the RTMA Receiver Executive Committee reported on previous spurious-radiation recommendations and the degree to which they have been followed.

On Sept. 12 and Nov. 19, 1950, meetings of FCC and RTMA personnel were arranged as the result of a proven case of FM receiver radiation interference with an air VOR system in Indiana. A resolution was adopted which stipulated the following limits on radiation effective June 30, 1951:

FM — 50 microvolts/meter at 100 ft.
TV, Channels 2-6 — 50 microvolts/meter at 100 ft.
TV, Channels 7-13 — 150 microvolts/meter at 100 ft.

An IRE subcommittee has set up standards for such measurements.

Subsequent tests showed that these limits were adequate for protection to VOR systems, which operate sometimes with signal levels of 1 microvolt/meter.

A report of progress made by manufacturers toward meeting the RTMA recommendations, which was sent to the FCC on Oct. 7, 1952, showed the following figures:

	TV Channels 2-6		TV 7-13		FM	
	Within Limits	Outside Limits	In	Out	In	Out
1950 Sets	2	23	1	24		
1951 Sets	20	5	18	7	2	17
1952 Sets	23	4	19	8	12	2

At about the same time, the FCC sent a letter to RTMA expressing concern about increasing evidence of problems arising from oscillator and sweep-circuit radiation from VHF and UHF receivers and converters, and receiver spurious responses. The letter emphasized again the importance of adequate spurious-radiation suppression, and the use of the standard IF. UHF oscillator radiation was discussed at a meeting of the RTMA Committee on Radio Interference on Oct. 20, 1952, and limits of 500 microvolts/meter at 100 ft. were proposed for all UHF-TV equipments. Radiation from typical UHF units is considerably in excess of that value at the present time, as the following table shows:

UHF Oscillator Radiation,
Microvolts/Meter at 100 Ft.

		Average	Maximum
Converter	1	820	1,290
	2	550	980
	3	600	900
	4	1,180	1,400
	5	5,000	9,500
	6	500	820
	7	760	1,490
	8	2,180	4,400
	9	3,200	6,270
	10	1,900	2,560
Receiver	1	2,500	6,000
	2	360	615
	3	2,750	6,270
	4	1,310	2,260
Tuner	1	1,800	4,600

A continuous program of checking on performance is planned.

At the same meeting, interference from high-power state police transmitters was discussed. Interference is serious now in some areas, and it is expected that more trouble will be experienced as new TV stations begin operation. There are authorized presently some 46 five-kw. police transmitters, 5 ten-kw. transmitters, and 10 one-kw. transmitters, in 12 states. It is for this reason primarily that some manufacturers have been reluctant to employ the 41.25-mc. IF. Of 34 manufacturers replying to a questionnaire, 17 used the old IF in all 1952 receivers, 8 used the new IF in some 1952 receivers, and 9 used the new IF in all sets produced late in 1952.

Twenty-seven expect to use the new IF in 1953 sets. Of the 17 major manufacturers, 4 used the old IF in all 1952 sets.

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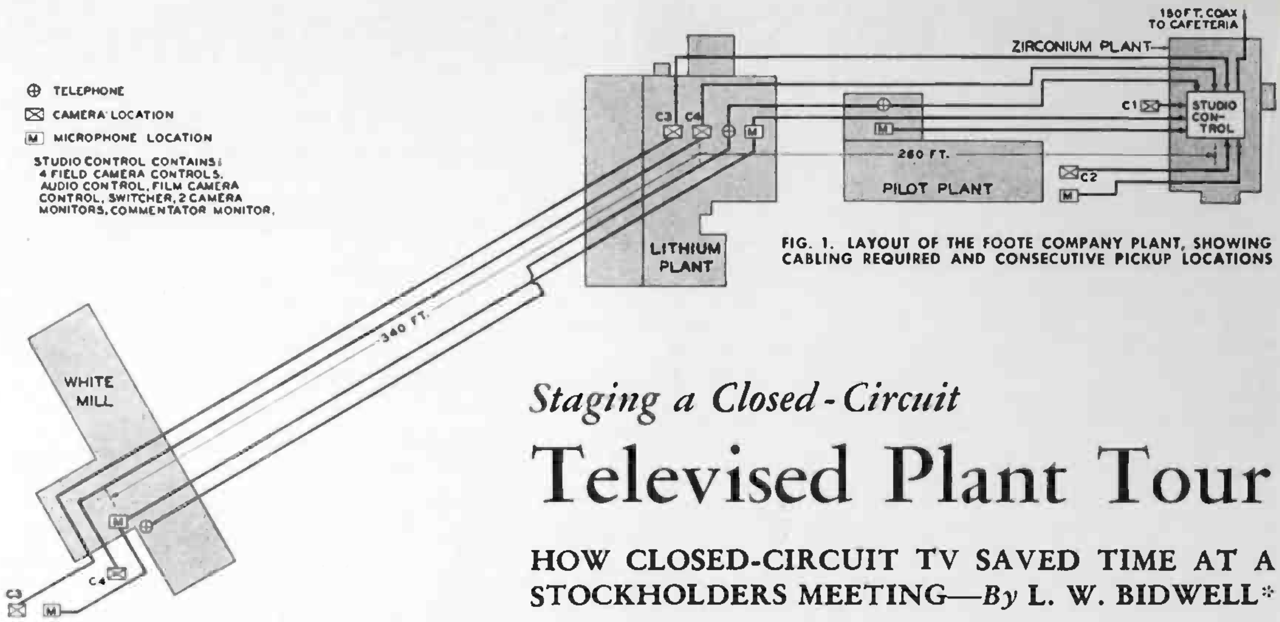


FIG. 1. LAYOUT OF THE FOOTE COMPANY PLANT, SHOWING CABLING REQUIRED AND CONSECUTIVE PICKUP LOCATIONS

Staging a Closed-Circuit

Televised Plant Tour

HOW CLOSED-CIRCUIT TV SAVED TIME AT A STOCKHOLDERS MEETING—*By* L. W. BIDWELL*

MOST owners of television receivers are quite aware of the great potentialities of TV broadcasting for entertainment and education. It is common knowledge also that this medium has affected profoundly the American living pattern. Less well-known, however, is the fact that non-broadcast or closed-circuit television can provide services just as valuable and significant to our way of life. The field of potential applications is so broad that it can be encompassed only by the most general descriptive terms, *i.e.*, wherever efficiency would be increased by some means to display a scene or event to many persons at one time, or to show an event occurring at some inconvenient or dangerous location. Closed-circuit systems are being used now in many industrial and research applications, and more uses are being found every day. A typical application of this equipment was the recent televised plant tour for a stockholders' meeting at the Foote Mineral Company in Exton, Pennsylvania. Because many unusual problems had to be solved for this project, it is described and shown in the photographs on these pages.

Plan of Operation: The physical layout of the Exton factory is diagrammed in Fig. 1. Four separate plants and the cafeteria, where the stockholders' meeting was held, stretch out over an area of 81 acres. Since there were over 250 at the meeting, it would have been a gigantic task to conduct the entire group on a tour through the factory. Instead, a closed-circuit TV system was set up to show the stockholders new facilities and key operations at widely-separated locations by means of television sets placed at strategic points in the cafeteria.

The idea of the TV tour originated with Robert Drake, Foote's advertising manager, who saw RCA's see-yourself television demonstration at the 23rd Exposition of the Chemical Industries in New York. He discussed the possibilities with Richard Hooper, manager of the Shows and Exhibits Division of RCA Victor's Public Relations Department, and Douglas Deakins, of Mr. Hooper's staff. Detailed plans, charts, and script were then worked out by Messrs. Drake, Deakins, and Otto Renner, Jr., of Renner Advertisers, who handle the Foote account. Television, they reasoned, would obviate the expenditure of effort, the inevitable confusion, and the inconvenience involved in taking a large body of people over long treks through the plant from one key installation to another. As it turned out, it also afforded the stockholders a clearer and more concise picture of the operation of their company than they could have obtained by making a physical tour.

*Press Division, RCA Victor, Camden, New Jersey.

FIG. 4. L. G. BLISS, AT THE COMMENTATOR'S DESK, PROVIDED CONTINUITY

FIG. 2, BELOW: SOME OF THE EQUIPMENT IN THE STUDIO CONTROL SETUP

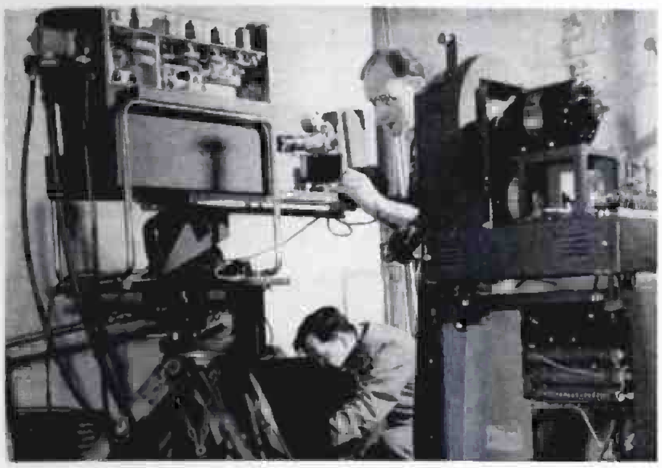


FIG. 3. FILM OF NORTH CAROLINA PLANT WAS INTEGRATED INTO PROGRAM

Four image orthicon field cameras, twelve 17-inch home-type receivers, 1,800 ft. of 24-conductor camera cable, 1,200 ft. of microphone line, a TV film camera chain consisting of a 16-mm. film projector and an iconoscope film-pickup TV camera, and field equipment required for a complete control and monitoring station, were used on the project. Total value of the installation was more than $80,000.

Ten receivers were mounted on stands about 6 ft. high and lined up around three sides of the meeting room, and the other two were placed in an adjoining coatroom to take care of the overflow audience. The field cameras were set up in four strategic locations. Fig. 1. and a carefully charted plan of movement, integrated with the script and bound to precision timing, permitted coverage of seven plant locations without interruption of the show.

The power supply, monitor and control units for each camera, a switcher and fader with its own power supply, and a sync generator were installed in the zirconium processing plant building, near the cafeteria. This is shown in Fig. 2. Also located in this building were the TV film camera chain, Fig. 3, and the narrator's desk, Fig. 4, which was covered by one of the field cameras. From this point L. G. Bliss, Foote's vice president in charge of sales, supplied the commentary and introductions that tied together the remote pickups making up the show.

The equipment installation and the staging were handled by a crew of eight, including six RCA Service Company engineers led by Frank Helgeson, and two members of the RCA Victor shows and exhibits group — Mr. Deakins, as producer, and G. E. Ryan, his assistant. Members of this group have pioneered new applications of television and demonstrated the medium throughout the United States and in many foreign countries.

FIG. 7. ONE OF THE OUTDOOR SCENES, BEING COVERED BY TWO CAMERAS

Special Problems: Chief problems encountered in the Foote project, Mr. Helgeson said, were the necessity for stringing a total of about 3,000 ft. of cable and microphone line, most of it overhead; split-second timing of camera movements, which meant shutting down a camera, moving it to a new location, and putting it back in operation without the customary allowance for warm-up time; and quick shifts from indoor to outdoor light levels, and vice versa, with little time for camera adjustment.

Nothing could be done about warm-up time, but the problem caused more worry than difficulty, since all four cameras performed extremely well without it. The problem of compensation for varying light levels was met by supplementing quick lens adjustments with electrical compensation. A camera operating in one of the plant buildings with the lens

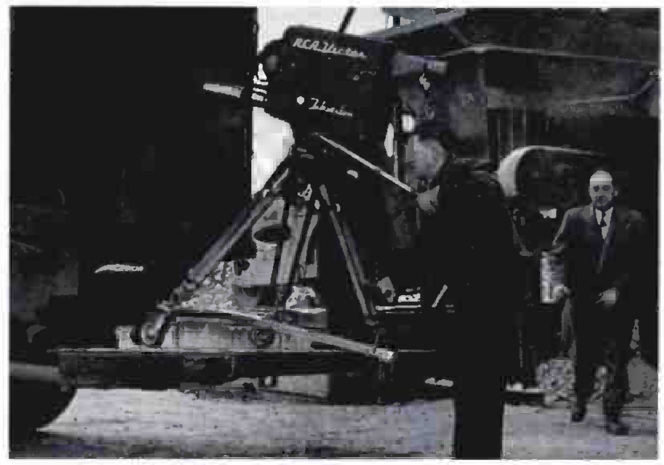
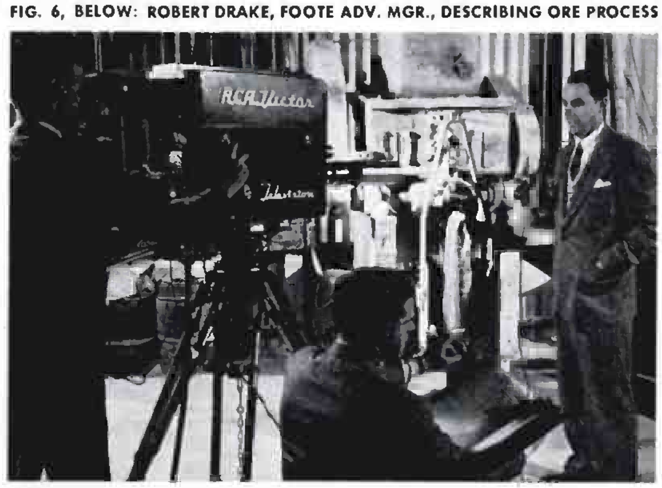


FIG. 5, ABOVE: CAMERAS WERE MOVED BY TRUCK WITH A HYDRAULIC LIFT

FIG. 6, BELOW: ROBERT DRAKE, FOOTE ADV. MGR., DESCRIBING ORE PROCESS



adjusted to f:5.6, for example, would be moved hastily to an outdoor location and stopped down to f:22. When this was found insufficient, the control operator would compensate for excessive highlights by adjusting the target voltage.

Target voltage adjustment was accomplished at the control station if it was observed that objectionable highlights persisted in the monitor image after the lens adjustment had been made. In such instances, the operator at the camera control would adjust the target voltage toward cutoff until the highlights were reduced satisfactorily. The effect of this measure was to reduce the flow of electrons away from the target in the pickup tube, thus reducing the intensity of the charge pattern on the target and, in turn, limiting the modulation of the beam which generates the signal.

It was pointed out that target voltage adjustment for such

Continued on page 38

PATTERN FOR TV PROFIT

PART 6—MICROWAVE EQUIPMENTS FOR NETWORK HOOKUPS, MOBILE PICKUPS, STUDIO-TRANSMITTER LINKS, AND OTHER POINT-TO-POINT APPLICATIONS

By **Roy F. Allison,** ***in collaboration with*** **A. B. Chamberlain, Rodney D. Chipp, Raymond F. Guy, Thomas E. Howard,** ***and*** **Frank L. Marx***

A TELEVISION station manager may be confronted with any or all of 4 operating problems which make necessary the transmission of program material over relatively long distances outside the studio or transmitter building. First, it is probable that interconnection is desired between the nearest network access point and the station master control. Second, where studios are located in widely-separated buildings, some special means must be provided to bring the remote studio originations to master control. Third, wherever mobile pickup units are used by the station, their program originations must be sent to the master-control point. Finally, if the transmitter is not at the same location as the master control, the two must be interconnected.

Facilities for such interconnections may be installed and operated by the station, the AT&T Long Lines Department, or the local telephone company, depending on a number of circumstances. Although the telephone companies may find it advisable to use either coaxial cable or point-to-point radio links, the private operator does not, in general, have this choice. He is restricted by practical considerations to microwave radio equipment. This fact, combined with the circumstances involved in each application, determines the best solution to each interconnection problem.

*Collaborators are, respectively; Chief Engineer, CBS Television, New York; Director of Engineering, DuMont Television Network, New York; Manager, Radio and Allocations Engineering, NBC, New York; Chief Engineer, WPIX, New York; and Vice President in charge of Engineering, ABC, New York.

Network Connections: Most connections to intercity network lines are installed and operated by the telephone company concerned, although some stations do operate private facilities. Cost is a major consideration here, particularly when the station is situated at some distance from an available AT&T terminal or relay station.

When making negotiations with a network (or networks) the station may decide to install its own link to the nearest city served by the AT&T system, which involves an appreciable expenditure on its part but which has long-term advantages. Alternatively, the network may arrange for the connection, dealing with the local telephone company or, if an intercity link is required, with AT&T. Terms of agreement between the network and the station may vary according to the market served by the station, by its competition, and other local factors.

Remote Studios: Especially at the larger stations, and those which originate network programs, one or more permanent studios may be required in addition to those available at the main studio and control building. In New York, for instance, the networks have taken over several theatres for large-scale TV productions. Such remote studios can be connected to the master-control headquarters by lines leased from the local telephone company or by private short-hop microwave circuits installed permanently. The choice is dependent on long-range plans for the remote studio, by the availability of line-of-sight paths between such studios and control-center buildings, by the time of availability of coaxial lines, and other economic factors.

Mobile Pickups: Remote pickups using field equipment are usually of great programming value, and are extremely important to the successful operation of even small stations. As was pointed out previously, however, extra operating personnel, equipment, and maintenance costs are involved.

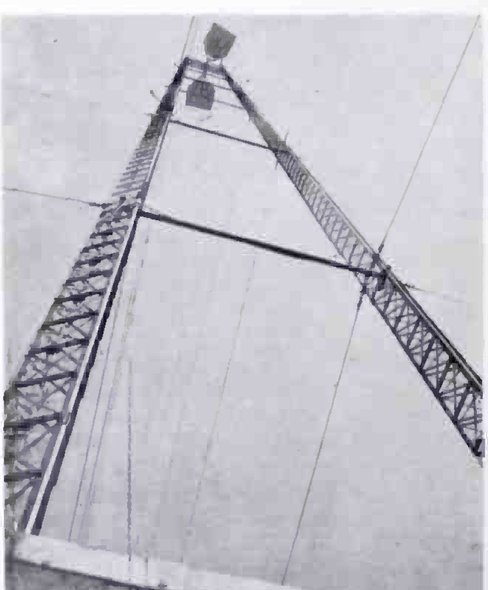


FIG. 1. MOTOROLA MICROWAVE REPEATER TOWER.

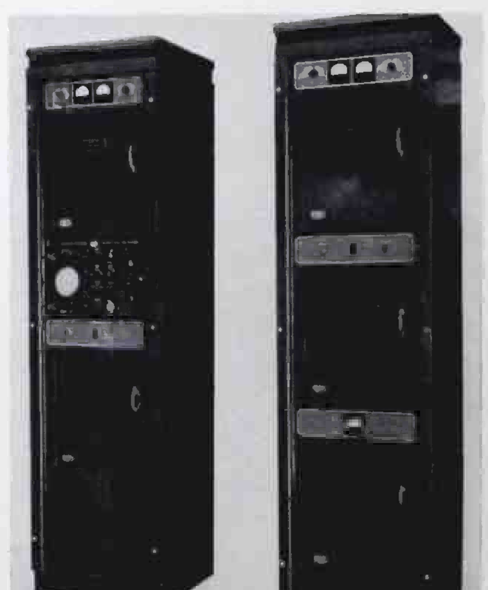


FIG. 2. DUMONT LINK EQUIPMENT FOR FIXED INSTALLATIONS.

FIG. 3. FEDERAL MICROWAVE RECEIVER

Many scheduled events of local interest can be covered by remote-pickup equipment without a mobile microwave link, since the telephone company can often provide the required facilities if they are requested far enough in advance. However, for on-the-spot news coverage, pickup of events requiring camera mobility, and for general flexibility and versatility, microwave equipment is invaluable. Probably the most important advantage of the portable radio link is the mobility it provides, permitting pickups from anywhere within its operating range that the TV field equipment can be carried on short notice.

Whenever it is possible to do so, the site of the proposed remote pickup should be tested before the broadcast to determine that satisfactory operation of the link can be obtained. Also, as will be explained later, relay link equipment may or may not be capable of handling the audio part of a pickup. If it is not, arrangements must be made with the telephone company to obtain a telephone line for the audio. This can usually be made available with much less delay than a coaxial line, of course. Preliminary planning and survey work is always advisable when the time is available for it, in order to avoid unforeseen difficulties.

Studio-Transmitter Links: As with other point-to-point connections, this service can be handled privately or by the local telephone company. Basis of the choice seems to consist primarily of the relative desirabilty of a large initial expenditure and the maintenance of a private link or a long term of line-charge payments.

Link Equipment: Because it is quite likely that a station will require at least one microwave link circuit in its daily operation, descriptions of the equipments available for these applications are given in the following section.

FCC frequency allocations which became effective July 1, 1949, provide 3 specific operating ranges for TV remote-pickup and studio-transmitter links. They consist of the following frequency bands:

1,990 to 2,110 mc.
6,875 to 7,125 mc.
12,700 to 13,200 mc.

Commercial equipments are available which operate in the lowest two bands. All utilize frequency modulation of the carrier, and klystron tubes in the transmitter output stage. All except one are designed for either mobile or fixed application, and all can be used in multi-hop applications; that is, where the distance to be covered is too great for a direct transmitter-to-receiver path, additional units can be used as intermediate repeater stations.

The links are used with parabolic reflector antennas which provide extremely high power gains. The actual power from the transmitter in the 2,000-mc. band may be from 5 to 10 watts. At these frequencies, the gain obtainable from a 4-ft. parabola is 25 db; from a 6-ft. parabola, 29 db. Since these antennas are normally used at both receiving and transmitting locations, the effective radiated power is at least 500,000 watts if the two antennas are aimed precisely at one another! Thus, distances up to 45 miles may be covered by these equipments.

There is a distinct disadvantage to such high power gains in that the antennas must be aimed with great accuracy, because the radiated beams are so narrow. For that reason, separate voice communication channels must be provided on remote pickups so that the operator at the transmitter end of the link can adjust his antenna for maximum signal strength at the receiver, in accord-

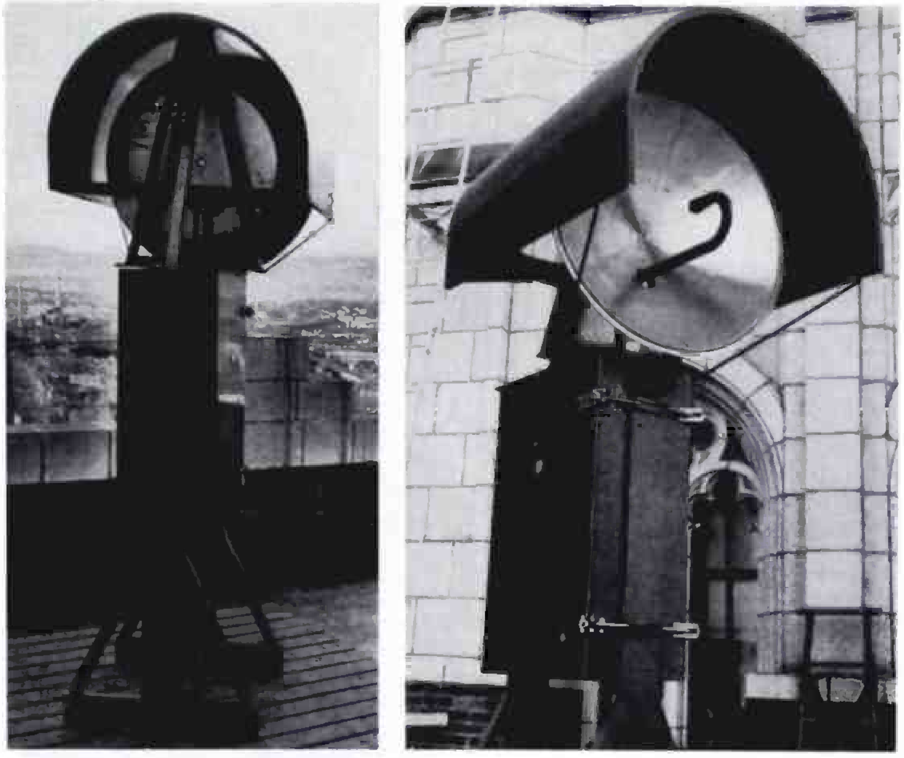


FIG. 5. TWO VIEWS OF A MOTOROLA 7,000-MC. TRANSMITTER-RECEIVER-ANTENNA COMBINATION UNIT

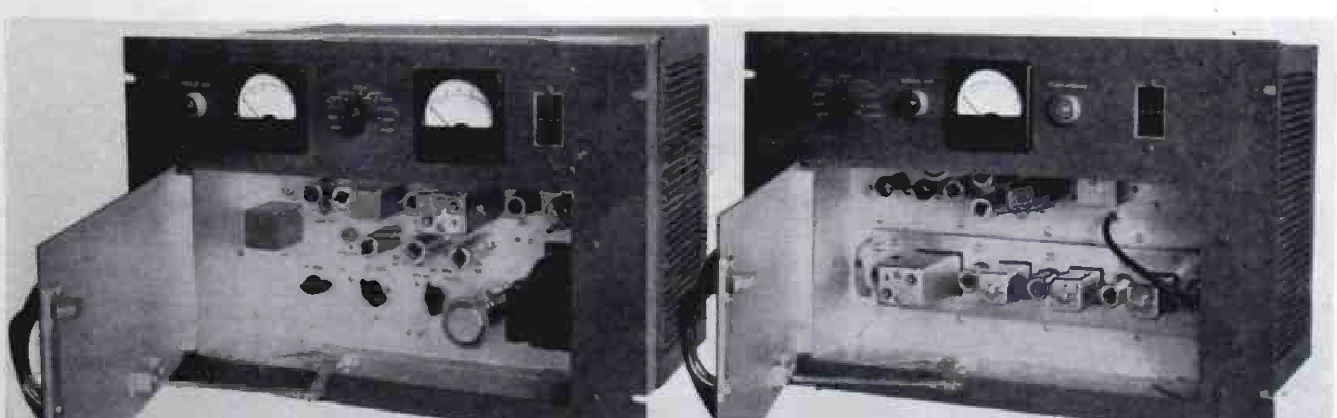


FIG. 4. SUBCARRIER TRANSMITTER AND RECEIVER UNITS PERMIT SUPERIMPOSITION OF AN AUDIO SIGNAL ON A STANDARD VIDEO MICROWAVE CHANNEL

ance with instructions from the receiver operator. Antenna mountings must be easily and precisely adjustable over wide ranges in order that aiming can be accomplished quickly and smoothly. When the receiving antenna is mounted in an inaccessible location, such as on the station transmitting antenna tower, a remote positioning device must be utilized. Four-ft. parabolas are ordinarily used on mobile installations. The 6-ft. models have considerably more gain, but are much heavier, more unwieldy, and have narrower beams, so that aiming is a good deal more difficult.

The preceding considerations point up the desirability of making preliminary surveys at sites of proposed mobile pickups, wherever possible. With equipment for the 7,000-mc. band, transmitter outputs are lower and antenna gains even higher.

Where direct line-of-sight paths are not available, it is often practical to use towers on permanent or semi-permanent installations for repeater or terminal stations. The towers may be large enough to mount the equipment at the top, or passive 45° reflector antennas can be employed, as in Fig. 1. The transmitter or receiver antenna, or both in the case of a repeater, are aimed directly upward at the reflector, which is then positioned so that the beam is reflected toward the remote antenna.

Low-Band Units: Links for the 2,000-mc. range is available from DuMont and Federal. Fig. 2 shows the DuMont fixed-station receiver on the left and the transmitter on the right. Both are equipped with metering facilities for all tubes. The transmitter has equipment for measurement of frequency and power output, and output waveform. A built-in test oscillograph can be provided on the receiver rack, and test signal sources for system lineup are included. The Federal receiver can be seen in Fig. 3. Both

FIG. 6. AN RCA MOBILE MICROWAVE LINK UNIT. THE TRANSMITTER IS IN CYLINDRICAL HOUSING

types of equipment can be furnished in mobile cabinets.

These units are designed basically for video transmission. Audio subcarrier modulator and demodulator sections can be added, however, as shown in Fig. 4. They can be obtained in portable carrying cases also.

7,000-Mc. Links: Motorola and RCA link equipments operate in the 7,000-mc. band. The Motorola transmitter-receivers, shown from two angles in Fig. 5, are designed for fixed installations only. The video signal is applied directly to the RF modulator. Separate subcarriers are used for the audio program signal and a 2-way service channel or order-wire channel.

RCA equipment is quite compact and portable, although it can be used at fixed locations, of course. The transmitter, as shown in Fig. 6, is located in a cylindrical enclosure directly behind the parabolic antenna. A small, portable control unit, Fig. 7, is connected to the transmitter and provides for the necessary operating adjustments. The receiver is similar in operation and appearance. Fig. 8 shows the receiver chassis removed from its cylindrical cover.

Costs: Total cost of microwave link equipment required for a single hop may range from $15,000 to $20,000. This includes transmitter, receiver, control and test units, antennas, cabinets, and transmission lines. If sound channel equipment is provided, those figures may be increased by about $5,000. Multi-hop systems will cost more, of course, although not in direct multiples of the single-hop cost. For mobile installations, the vehicle may cost from $3,000 to $10,000 or more, in addition. Camera chains, other video equipment, and audio pickup equipment are not included in these figures.

Microwave link equipment for TV applications can be obtained from the following sources:

Allen B. DuMont Laboratories, Inc., 1500 Main Avenue, Clifton, New Jersey.

Federal Telecommunication Laboratories, Inc., 500 Washington Avenue, Nutley, New Jersey.

Motorola, Inc., Communications & Electronics Division, 4545 Augusta Blvd., Chicago 51, Illinois.

RCA Victor, Engineering Products Division, Camden, New Jersey.

EDITOR'S NOTE: *This concludes the "Pattern for TV Profit" series, which will be published soon in revised and expanded form as a book.*

FIG. 7. RCA MICROWAVE TRANSMITTER CONTROL UNIT.

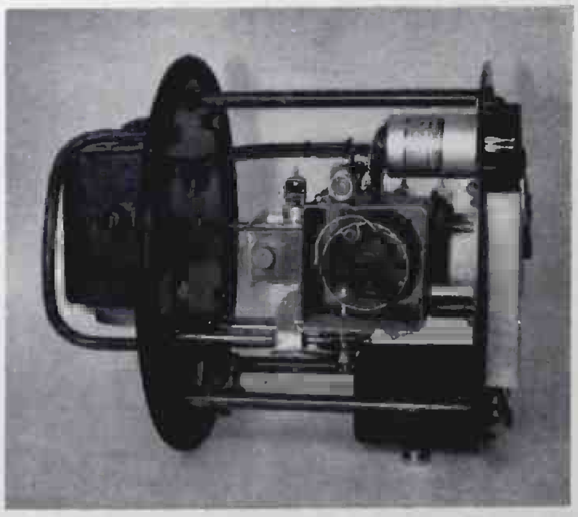


FIG. 8. RECEIVER CHASSIS, DESIGNED SAME WAY AS TRANSMITTER, WITH SIMILAR CONTROL UNIT

Head-End Design for FM Tuners*

A DETAILED ANALYSIS OF THE PROBLEMS ASSOCIATED WITH THE DESIGN OF FM TUNER HEAD-ENDS, WITH PRACTICAL SOLUTIONS — *By* H. H. CROSS**

This paper is based on a B.S. thesis in the Department of Electrical Engineering, M.I.T. 1952

Abstract

The design of signal-frequency and frequency-changing sections of narrow-band VHF superheterodyne receivers for the FM broadcast band is analyzed. It is shown that, since noise factor varies inversely as the power efficiency of the input network, any finite-Q input network must compromise between noise factor and selectivity. For a given number of tuned circuits, the best arrangement is one which utilizes one tuned circuit for the input network and the rest to obtain interstage selectivity.

Mixer operation is considered, and the optimum adjustment is found to be relatively low oscillator injection combined with RF gain sufficient to make the amplifier input noise one to ten times the power of the noise generated in the mixer tube.

Tuners built in accordance with these principles are described briefly. Experimental data show that their performances compare favorably with those of medium-frequency receivers.

Introduction: The fundamental task of any receiver is to receive one and only one station at a time. In superheterodyne receivers, the task of separating two signals differing by only a small increment of frequency is made easier by changing the desired signal, along with its interference, to lower fixed frequencies, for which fixed-tuned amplifiers and selective networks can be used. Most of the signal amplification occurs in this intermediate frequency (IF) amplifier.[1]

A major disadvantage of this system is that the converter circuits tend to change several discrete frequencies to the IF frequency, while only one is wanted. Selective circuits, therefore, are ordinarily used between the antenna and the converter. One or more RF amplifier stages may be used also. The selective circuits are supposed to pass the desired signal and attenuate the undesired signals which may appear on the spurious-response frequencies. In the usual case these spurious-response frequencies are separated from the desired signal by at least half the IF frequency so that, if the IF frequency is not too small a fraction of the signal frequency, several sharply-tuned circuits accomplish this separation fairly well.[2,3]

This paper describes the development and construction of a tuning head suitable for use in a high-performance receiver for reception of FM broadcasts. The rest of the receiver was designed by Roy Paananen. A discussion of the basic problems peculiar to the FM broadcast band in metropolitan areas will be found in his thesis.[4]

Design Considerations: Once the IF frequency and required performance are determined, the receiver design can be resolved into sections. For instance, the gain of the RF section is determined by the overload level of the mixer, not by the signal level the designer of the IF amplifier would prefer at its input; and the level of audio from the IF portion is determined by the limiter and detector circuitry, not by what is convenient in an audio system.

The plan of attack was to build the best receiver we could with components which were at least potentially adaptable to mass production or, better yet, used widely in present-day commercial equipment. In the event that the resulting performance was more than adequate, it should have been possible to effect economies in cutting back. On the other hand, if we had underestimated the problem, the extra performance would be available. The best justification for this procedure lies in experience in the communication field, where it is often found that only the over-designed unit is left when others have been rendered obsolete by ever-worsening channel congestion. It turned out that the best we could do was about right. Tests show that most commercial units are annoyingly deficient, by comparison, in one respect or another.

The intermediate frequency was fixed at 10.7 mc. Better control of selectivity in the IF amplifier can be obtained by using a lower frequency; however, spurious-response frequencies are separated more widely from the desired signal with a high-frequency IF. The RTMA standard frequency is quite suitable as a compromise.

It was decided to use an ordinary transformer-rectifier power supply, providing low-voltage AC for the tube heaters and 225 volts DC for the plate supply. Most low-level tubes give full performance with plate potentials of 100 volts or more, but there seemed to be no reason for conserving power and there were some advantages to be obtained from the higher B+ value.

For best receiver performance the limiters should limit well, but the selective circuits should be free from overload. This requires high maximum gain for weak signals and, in order to prevent overloading on very strong signals, some automatic gain control must be used. Provision for bias control of gain was made accordingly in this tuning head.

Some other tentative requirements were: Input suitable for unbalanced 75-ohm lines; less than 30 kc., or .03%, frequency drift during warm-up; FM noise 60 db below full program modulation, or about 50 cycles RMS; gain of tuning head as high as seems practicable; tuning range, 88 to 108 mc. with some to spare; little variation of gain as the receiver is tuned through the range; sensitivity at least as good as any commercial receiver; reasonably low oscillator radiation; low spurious responses, few in number; and reasonable size and cost. A tuning head meeting the spirit of these specifications should be quite satisfactory.

Tuned-circuit components of the best design can be expected to have warm-up drifts corresponding to the linear expansion coefficients of the materials. Compensating capacitors commercially available have temperature coefficients of the same order of magnitude. Permissible warm-up drift is 300 parts per million, however, so that a change of from 10 to 20°C. will be required to give this drift, if compensation is correct plus or minus the usual commercial tolerances. By individual adjustments, the compensation can be made much closer.

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*This work was supported in part by the Signal Corps, the Air Material Command, and the Office of Naval Research.

**Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass. Mr. Cross is now with Pickard and Burns, Needham, Mass.

[1]"General Superheterodyne Considerations at Ultra-High Frequencies," L. Malter, *IRE Proceedings*, Oct. 1943.

[2]*Radio Receiver Design*, K. R. Sturley, London, Chapman & Hall Ltd., 1943, Ch. 5.

[3]*Vacuum Tube Circuits*, L. B. Arguimbau, John Wiley & Sons, 1948, p. 422.

[4]M.I.T. Electrical Engineering Thesis, 1952, Roy Paananen. This will be published in TV & Radio Engineering in a forthcoming issue.

To keep oscillator noise at least 60 db below program level, the FM on the oscillator must be limited to 50 cycles RMS or 75 cycles peak. The way to obtain this performance is simple: build a good oscillator, make it mechanically and thermally stable, and supply it with well-filtered plate voltage. In some cases, filtered DC might be required for the heaters. Then the only source of noise would be the tube itself, as even a poor oscillator will be hum-free if supplied only from batteries.

The author has had some experience with oscillators in the VHF range which employ modern high-transconductance miniature triodes in Colpitts' circuits,[5] Fig. 1. The grid-cathode condenser, C2, is made as large as possible without stopping the oscillations at low line voltage, in order to adjust the feed-back to optimum and to keep the influence of the rather variable input capacitance on the tuned circuit as low as possible. The FM hum in such an oscillator at 100 mc. can be much less than ten cycles when AC is used to heat the cathode. F. B. Llewellyn[6] has shown that plate and grid lead inductances in a Colpitts oscillator can be arranged to reduce the shifts in frequency with changes in tube voltages. This may be considered a point in favor of this arrangement, as lead inductances are appreciable at VHF. Lea[7] has shown that it is not possible to neglect the resistance-temperature coefficient of copper if the tuned circuit is not operating at true resonance. Any measures which decrease the stray detuning effects of parasitic elements better the stability. Colpitts or ultra-audion circuits will oscillate at true resonance at VHF.

Gain obtained in the tuning head should be fairly high, so that less gain is required in the IF amplifier. But strong signals when amplified may overload the mixer stage, even though the receiver is not tuned to them. Thus, there should not be *too* much gain.[2,8] This is a true dilemma, and it will be considered in detail later.

The FM broadcast band is narrow in tuning ratio; its range of 1.23:1 in frequency requires only 1.5:1 variation in tuning inductance or capacitance. Because the mechanical action of a multisection variable capacitor is better and smoother than that of most inductance-tuning devices, capacitance tuning was used in this design.

Amplification should be kept as nearly constant as possible throughout the band, for the lowest gain may limit the sensitivity, while the point of highest gain will be more subject to overload on strong signals. Tracking errors vary the gain as a function of tuning frequency, but any single-range receiver can be made to track very well by bending the plates of the tuning capacitor slightly.

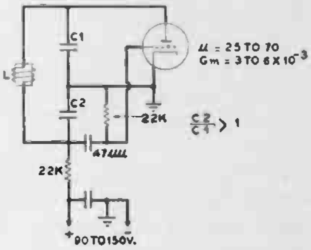
In some receivers, the gain is not sufficient for proper limiting action on weak signals; in others, capable of proper limiting, sensitivity is determined by the noise generated internally which is strong enough to mask signals below a certain strength. The average commercial receiver falls in the first group, as it is neither simple nor inexpensive to build a receiver having an overall power gain (in the absence of limiting) from antenna to detector of 130 db. 100 db must ordinarily be provided by the IF stages.

The experimental tuners were designed on the assumption that the receivers should have enough gain for proper limiting on input-circuit noise. In such a case, the weakest usable signal is determined by the signal-to-noise ratio of the first stage or stages of the receiver, and care should be taken to see that this section has the proper characteristics for good sensitivity. Practically, it is possible to build a receiver which, with a directive antenna of reasonable size, will provide good-quality reception of 1 to 5-microvolt-per-meter signals, in the absence of any local noise sources outside the receiver. This would be an ideal design for perhaps 5% of the people likely to buy FM receivers. But to obtain this sensitivity, almost everything else important to the other 95% would have to be sacrificed. Therefore, it is believed that special cases should be accommodated by adding some sort of low-noise preamplifier to a well-designed receiver.

Oscillator radiation from FM and television receivers has become a source of annoyance, and some effort has been made to reduce this effect in recent commercial products. One or two RF amplifiers with tuned interstage coupling circuits give attenuation of oscillator energy in the reverse direction sufficient so that, with proper shielding and filtering, the leakage is tolerable.

Oscillator radiation may affect the frequency stability also. It is found that those receivers which have excessive radiation

FIG. 1. A VHF OSCILLATOR DESIGNED FOR VERY STABLE OPERATION & LOW FM HUM



become detuned slightly when the antenna or antenna feeder is moved about, as by the wind, when the input circuits are adjusted, or even when a hand is put near them.

A dozen or more receivers of various makes were tried out for spurious responses. Some were tested in detail, and measured performances were compared with subjective ratings. The tests were made with a reference level of 10 microvolts RMS in 300 ohms, and a maximum generator output 92 to 98 db higher, roughly equivalent to a field strength of .25 volt per meter. One receiver was installed in an automobile; it was found that almost everywhere in the greater Boston area there is a possibility of spurious-response trouble from very strong signals, while the desired signal may be fairly weak on the average and may occasionally drop to zero because of destructive reflections.

Only one commercial receiver tested was judged to be adequate in this test. However, it still showed some repeat tuning points when tested in a private home which was two miles from the nearest transmitting station. Stations outside the FM band do not give the same degree of annoyance. They can be trapped or filtered out, if need be, and are not so powerful as the broadcast transmitters, so that lower limits can be put on the susceptibility of the tuner to out-of-band spurious pickup. The experimental units showed us what could be done.

Keeping costs down in commercial production is often accomplished at the expense of performance. This is more prevalent in the radio industry than, say, in the automobile business. The features immediately apparent to the customer are the logical place to spend development money. Since, in the case of a well-designed tuner the proof of performance is what is *not* heard, why bother? On the other hand, there is often room for improvement in the utilization of circuits already in the equipment. The rejection of spurious responses can sometimes be much improved by small changes, without appreciable degradation of either noise figure or net useful sensitivity.

The Input Circuit: From the foregoing survey, the reduction of spurious tuning points seems to be the major problem in tuner design. This checks the observation that most commer-

[5] "A Cascode Converter for 144 Mc.", H. H. Cross, *QST*, Oct. 1949.
[6] *Bell System Technical Journal*, F. B. Llewellyn, Jan. 1932.
[7] "Notes on the Stability of LC Oscillators," Norman Lea, *Journal I.E.E.*, Vol. 92, pt. III, Dec. 1945.
[8] "Adjacent Channel Operation of Mobile Equipment," D. E. Noble, *Electronics*, June, 1949, p. 90. Also "Adjacent Channel Rejection Receiver," H. Magnusky, *Electronics*, Jan. 1951, p. 100.

cial receivers are deficient in this respect to some extent.

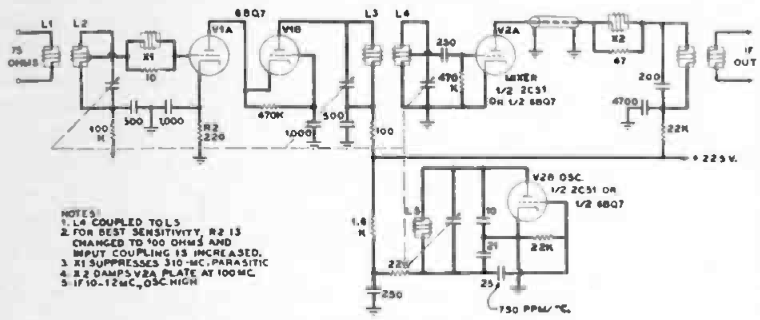
If cost were of no importance, almost any desired degree of protection could be obtained by preceding the first tubes in the receiver with some sort of tunable filter which would offer high attenuation to undesired signals, while passing the proper ones with much less attenuation. This is actually a possibility because, for the case of an IF frequency less than one-fourth the signal frequency, the first spurious response point of importance is separated from the desired signal by one-half the IF frequency or, in this case, 5.35 mc.[2,3] A filter at the signal frequency consisting of two loosely-coupled circuits, the Q of each being 100, provides about 40 db discrimination between desired and spurious responses, but the desired signal will be weakened also. As a practical matter, it is not possible to make such a filter in small size at reasonable cost without considerable attenuation of the desired signal.

Unfortunately, there is a limit to the attenuation that can be tolerated.[9,10] An FM signal contains many frequencies, so that a finite band of frequencies must be passed in its transmission and reception. For any band B cycles wide, a resistor at temperature T (degrees Kelvin) delivers a thermal noise power $P=E^2/R=kTB$ when suitably matched, or twice the square root of kTRB volts open-circuit for a resistance of R ohms. This is true also of any circuit components which introduce loss, and of antenna radiation resistance, where T is the temperature of the region with which the antenna is in thermal equilibrium. In these formulas, k is Boltzmann's constant, 1.38×10^{-23} watts per cycle-degree. If B is 2×10^5 as for an FM broadcast receiver, a 50-ohm resistor will produce about 0.4 microvolts RMS at ordinary temperatures. If the receiver were otherwise free of noise, a 2 microvolt or .02 microwatt signal would be received satisfactorily in the absence of any other noise interference. An actual receiver we have tested did as well with 6 microvolts open-circuit RMS.

Rather than microvolts sensitivity at some particular bandwidth and impedance level, it is convenient to use a dimensionless number, first proposed by D. O. North,[9] known as the noise factor. This is the ratio of the noise power from an actual receiver to that from an otherwise identical noise-free receiver, measured at a point in the system before any overloading or nonlinearity occurs. This noise factor, or noise figure, can be measured directly or indirectly by several methods.[11] It provides an absolute basis for comparing the performances of sensitive receivers.

Since any receiver has some noise originating in the first stages, a weak signal which is attenuated further by going through a lossy network will not be relatively so noise free after amplification. In general, if inserting the network, assumed to have rather more bandwidth than the receiver as a whole, does not disturb the impedance relationships but only adds attenuation, then the noise figure of the system will be the noise figure of the receiver times the reciprocal of the power efficiency of the network. A 6-db noise figure for the receiver alone is changed to 16 db when a 10-db attenuator is inserted ahead of the RF stage.

This suggests that a low-noise receiver should be designed for high tank and coupling-circuit power efficiencies. For best efficiency, high-Q selective circuits should be employed. They should be loaded by the antenna resistance until their working Q's are fractions of the unloaded values. Because typical ganged resonant circuits have unloaded Q values of 100 to 200, however, this procedure makes them tune so broadly as to be useless for discrimination against the spurious response frequencies.



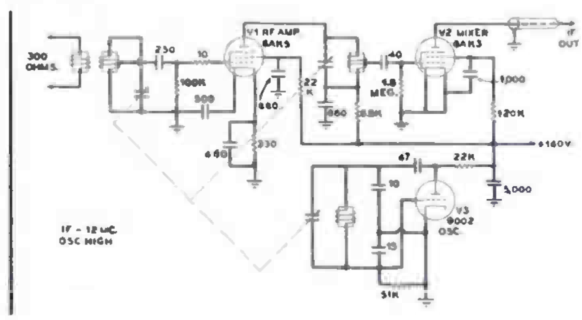


FIG. 2, LEFT: THE 4-GANG TUNING HEAD. FIG. 5, RIGHT: A 3-GANG EXPERIMENTAL TUNING HEAD. NOISE FIGURES ARE 12 AND 20 DB, RESPECTIVELY

If a Q of 100 per tuned circuit is assumed, with an interfering signal removed in frequency by 5%, the performances of a few simple input-circuit configurations are as shown in Table 1. The rest of the system is assumed not to load the network, and to be adjustable to a noise factor of 4 (6 db).

TABLE 1

Performances of Simple Input Networks

Circuit Arrangement	Overall NF	dNF	Atten. 5% Off Freq.
1 — Single-tuned, ideally mismatched	6 db	0 db	0 db
2 — Single-tuned, matched	9	3	14.2
3 — Double-tuned, both mismatched	6	0	0
4 — Double-tuned, pri. mismatched, sec. matched	9	3	14.2+
5 — Double-tuned, pri. loaded to half Q by ant., sec. coupled to half $Q\omega L$	12	6	27.4
6 — Single-tuned, loaded to ¾ Q	12	6	17.6
7 — Single-tuned, virtually unloaded	very poor	(do.)	20

For best signal-to-noise ratio, cases 1 and 3 are best. If both sensitivity and selectivity are desired, some compromise is necessary. For a given noise figure increment, 5 gives more selectivity than 6, though at greater cost. Economically, the choice is between 1, 2, and 5.

The figures in Table 1 suggest that, in order to obtain much selectivity from the antenna coupling circuits, some sensitivity must be sacrificed.

In calculating the table above, it was assumed that loading of the tuned circuits by the first tube could be neglected. This is not quite true, in general, and is particularly in error at frequencies around 100 mc. For grounded-grid operation of the

[9] "The Absolute Sensitivity of Radio Receivers" D. O. North, *RCA Review*, Jan. 1942.
Also *IRE Proceedings*, H. T. Friis, July, 1944.
[10] *Vacuum Tube Amplifiers*, E. I. Schremp, McGraw-Hill Book Co., 1948. Vol. 18 of the MIT Radiation Laboratory Series.
[11] *Vacuum Tube Amplifiers*, V. Beers, Ch. 14.

first tube, the optimum source impedance may be about 600 ohms, while the input impedance may be some 400 ohms. With a 6AK5 pentode, the input impedance will be 8,000 to 12,000 ohms at 96 mc.,[12,13] and the optimum source impedance for best noise figure, some 1,900 ohms.[12,14] In the first case, loading is severe, and in the second, it is about 20%. The cascode circuit, in which a 6AK5 might be used as a triode, would have an optimum source impedance on the order of 800 ohms. The loading effect would be around 10%.[14]

If a grounded-grid stage is not employed, then Table 1 is reasonably valid. The unloaded impedance of the tuned circuit would be around 5,000 ohms. If it were matched, as in the second case, the impedance across its terminals would be 2,500 ohms. A pentode RF stage, using a 6AK5, would have a grid connection to the top terminal. When the coupling is arranged so as to provide the maximum gain, the source impedance will be about optimum. If a triode stage or connection were utilized, the grid lead might be tapped down on the tuned circuit to obtain the desired grid-to-cathode impedance. The voltage applied to the grid would be reduced, of course, but the noise from the stage would decrease proportionally more than the signal.[15]

For a 3-db deterioration in noise figure, the single-tuned matched input circuit appears to be a reasonable compromise between cost and selectivity. This is the circuit most used at the input of VHF receivers. Two tuned circuits at the input do very little better in attenuating the response at 5% off-frequency, unless a further loss of sensitivity is permissible. For signals off-tune by 20% or more, however, this is not true. For cases in which circuit losses are so low that power efficiency is good at working Q values of 50 or 100, there may be an advantage in adding selective circuits between the antenna and the first tube, since the loss of sensitivity is not then appreciable; on the other hand, more benefit can invariably be derived by adding more resonant circuits to the interstage couplings.

Because the cost per gang-tuned circuit is fairly high, and for the same expense the extra tuned circuits might be used as interstage RF couplings, where they would contribute to the RF selectivity without degrading the sensitivity, a double-tuned input circuit is not ordinarily worthwhile. If signals far off the desired frequency are likely to overload the first tube, the most practical means of protecting a receiver with a narrow tuning range is passive wave filters inserted between the antenna and the receiver. Experimental data supports these conclusions, as will be shown later.

The Input Tube: The following points should be considered in the selection of a tube for the RF stage: First, if the input circuits are gang-tuned, tube loading lowers the selectivity at that point, and tends to handicap spurious-signal rejection. Second, the noise figure obtainable with low-cost tubes. Third, the tube screening, which not only limits the maximum stable gain[16] but controls oscillator radiation as well. Finally, the overload point, and the possibility of bias control of gain.

A grounded-grid triode is ruled out by the first consideration, as explained previously. The second restricts the choice to types developed for the television market. The third excludes neutralized triodes, other than the cascode, and the fourth suggests a direct-coupled cascode or a pentode with a screen-dropping resistor.

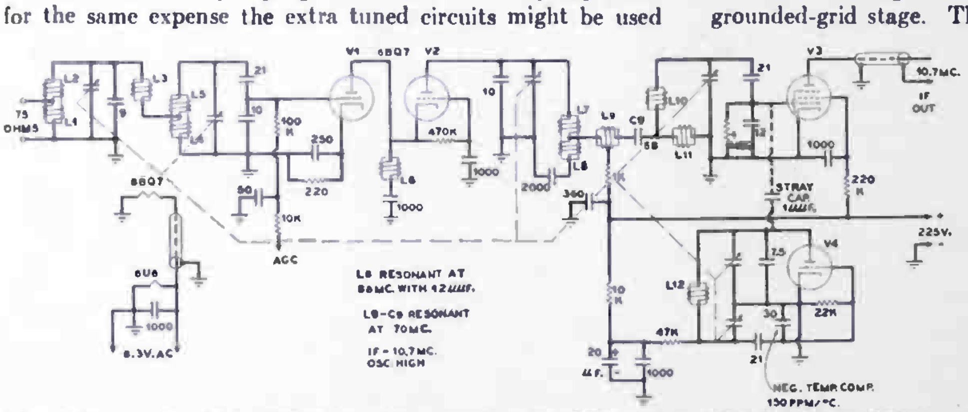
It is well known that a pentode tube is less noisy when connected as a triode amplifier than when operated as a pentode, if the plate current is the same in each case. Also, with low load impedances, a triode can handle the same grid swing as an equivalent pentode for a given amount of distortion. Because the noise generated by the triode is lower, and the overload point the same, the triode has a greater useful dynamic range.

If the noise figure is 10, there are about 1.2 microvolts equivalent open-circuit noise at a 50-ohm input. Transformed to a grid impedance of 800 ohms, this would be about 4.8 microvolts for a bandwidth of 200 kc. Signals weaker than this are masked by noise.

For grid-cathode structures similar to that of the 6AK5, including the 2C51, 6N4, and 6BQ7, the third-order characteristic curvature is tolerable over a grid range of 2 to 3 volts for 100 volts on the screen and plate. About 1 volt RMS is the overload point, then, if a bias slightly higher than normal is used. The dynamic range is then about 100 db. More plate voltage would increase the permissible bias and signal.

Because of the advantage with respect to noise and overloading, it was decided to use a triode in the RF stage. Other factors, as explained earlier, suggested some sort of cascode circuit, consisting of a grounded-cathode stage driving a grounded-grid stage. The arrangement described by Cohen[17] was tried initially. The neutralizing condenser had to be omitted, and it was found that adding an inductor to tune out the stray capacitance in shunt with the plate of the first section gave a slight improvement in sensitivity, about 1 db. Another db could probably be obtained by tuning out the grid-to-plate capacitance of the first triode,[18] but this inductor is less convenient to add in the series arrangement, and there is no room for it.

The 6BQ7 was considered to be nearly ideal for our purpose since it was reputedly designed on the basis of the grid-cathode structure employed in the 6AK5. Previous tests of various tube-types in the first stage of a cascode amplifier at 145 mc. showed that types 6AK5 and 6AS6, triode-connected, had no-



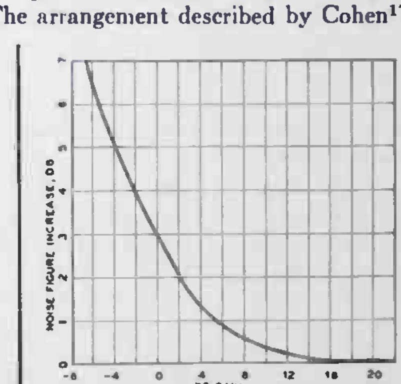


FIG. 3, LEFT: 6-GANG EXPERIMENTAL TUNING HEAD. FIG. 4, RIGHT: NOISE FIGURE INCREASES ABOVE INPUT STAGE NOISE WITH DECREASING RF GAIN

[12] "Characteristics of Vacuum Tubes for Radar Intermediate Frequency Amplifiers," G. T. Ford, *B.S.T.J.*, XXV. 1946. Also "The Radar Receiver," L. W. Morrison. *B.S.T.J.* Oct. 1947.

[13] *Introduction to Television Receiver Design*, Philco Corp., Vol. I, 1951, p. 100.

[14] *Vacuum Tube Amplifiers*, R. Q. Twiss and Y. Beers, Ch. 13, esp. p. 645.

[15] "An Analysis of the Signal-to-Noise Ratio of Ultra-High Frequency Receivers," E. W. Herold, *RCA Review*, Jan. 1942, esp. eq. 10.

[16] *Microwave Receivers*, A. B. MacNee, McGraw-Hill. 1948. Ch. 5, p. 126. Vol. 23 of MIT Radiation Laboratory Series

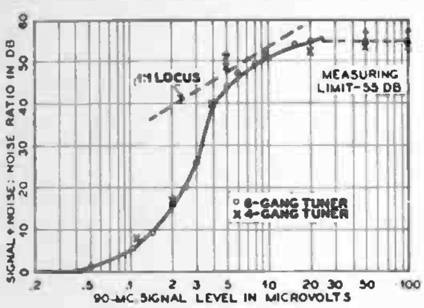
[17] "Use of New Low-Noise Twin Triode in Television Tuners," R. M. Cohen, *RCA Review*. March 1951.

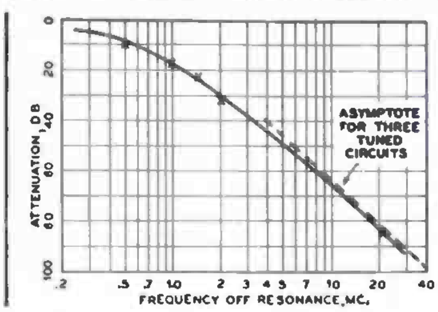
tably lower noise figures than those tubes having circular-cylinder elements such as the 6BH6 or 6AU6, or the wider-spaced 6AG5, 6CB6, or 6AH6, all circuit-connected as triodes. The 6BQ7 is rated for use in the Cohen series circuit, wherein relatively high voltage may appear across the heater-to-cathode insulation of the second triode section. Finally, in the series circuit, the 6BQ7 has reasonably good bias-control characteristics.

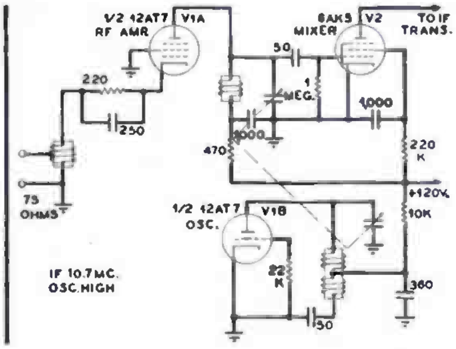
In the Paananen receiver[4] automatic gain control voltage is applied to the RF stage and to the 6AU6 first IF amplifier. A design precept for the IF system was that no overloading

Mixer Section: Design of the coupling network between the amplifier plate and mixer grid is not particularly involved. There should be two or more loosely-coupled circuits, for reasons given previously. Any amount of selectivity can be employed at this point, provided the overall bandwidth is not affected, without any basic effect on the noise figure. If the selective networks have excessive loss, it may be necessary to add a second stage of RF amplification in order to make up the gain, but there will not ordinarily be any need for this. The gain attainable from a single cascode amplifier is considerably in excess of that needed for good sensitivity,[22] and the

FIG. 6, LEFT: SENSITIVITIES OF THE 4 AND 6-GANG TUNERS WITH SAME IF AND DETECTOR. FIG. 7, CENTER: RF SELECTIVITY FOR 4 TUNED CIRCUITS. FIG. 8, RIGHT: TUNING HEAD FOR CAR RECEIVER







was to take place within the selective portion of the receiver. while the limiters were to have wide bandpass and very short time constants, so as to provide proper capture of a signal only slightly stronger than noise or interference.[19] The range of gain control required in these two stages is approximately the same as the voltage gain from RF grid to the grid of the last IF amplifier. This is on the order of 60 db. In practice, satisfactory operation as planned was achieved over the usual range of signals. The AGC voltage is not effective on weak signals, and tests showed no significant change in signal-to-noise ratio on weak or moderate-strength signals with AGC on or off.

The values in Table 1 were based on the assumption that the first amplifying tube together with the remainder of the receiver could be adjusted to a net noise figure of 6 db. Cohen. for instance, reports this value measured on a television tuning head which used a cascode circuit with a 6BQ7 dual triode.[17] There have been more sensitive receivers made for those frequencies.[5,9,18,20] Presently available tubes appear to limit the performance at 100 mc. to a noise figure of about 2.3, or 3.6 db.[18,21]

Two experimental tuners were built: a 4-gang unit, Fig. 2, and a 6-gang unit, Fig. 3. The sensitivity of each was poorer than would be expected from Table 1, for the following reasons: 1) tuned-circuit shunt loss from the fairly high-capacity input circuits lowered the efficiency; 2) the neutralizing circuits, and, in the 4-gang model, the plate coil, were omitted; 3) the gain of the RF section was kept low intentionally, so that the mixer noise was not negligible; 4) the plate supply voltage was lower than that of Cohen's circuit, and the 6BQ7 was operated at lower plate current, with resulting lower transconductance. The sensitivity could be improved by changing any of these factors, but this would involve a sacrifice in simplicity, spurious-signal rejection, or tube-life. Because tests show that the useful sensitivity is exceptionally good with the circuit as described, and better than most commercial receivers, no changes are planned.

[18] "A Low Noise Amplifier," Wallman, MacNee, and Gadsden, *IRE Proceedings*, June 1948.
[19] "Sky-Wave FM Receiver," L. B. Arguimbau and J. Granlund, *Electronics*, Dec. 1949.
[20] "Radar Echoes from the Moon," J. Mofenson, *Electronics*, April 1946, p. 92. Also "Detection of Radar Signals Reflected from the Moon," J. H. DeWitt and E. K. Stodola, *IRE Proceedings*, March 1949.
[21] *Microwave Receivers*, A. B. MacNee, McGraw-Hill, 1948, Ch. 5, p. 131.

insertion loss of the interstage coupling will not usually be more than 10 or 12 db.

For a direct-coupled 6BQ7 cascode stage, with no tuning inductor across the cathode-to-ground capacitance of the second triode, the effective output impedance will be about 9,500 ohms in shunt with .1 mmf. If the inductance is added, and the first section is coil-neutralized, the output appears as 250,000 ohms at midband; without the neutralizing coil, the output resistive term is around 100,000 ohms. With the self-shunt loss of the tuned circuits some 5,000 ohms at resonance, the loading effect will be moderate in the first case, and negligible in the last two. Tapping the plate terminal down on the tuned circuit might be desirable if the loading experienced in the first case was found to be excessive.

The RF input impedance of a silicon diode mixer may be as low as 50 ohms at microwaves. In the 100-mc. range, the triode or pentode mixers ordinarily used have some transit-time loading and, usually, feedback effects from cathode, plate. and screen impedances at signal frequency which may make the net input impedance either positive or negative. In some commercial television tuners, negative loading of a triode mixer with a plate circuit which was inductive at signal frequency was used to improve operation on the high channels. Experience shows that this sort of designing often makes for production trouble. as minor variations in lead lengths make large differences in tuning and loading of the mixer grid circuit.

In the six-gang experimental unit, the mixer was found to have an input impedance of only a few thousand ohms, probably because of the large grid-to-cathode loop inductance of the 6U8 pentode section. The grid was, therefore, fed from a capacitive voltage divider, so as to reduce the load on the tuned circuit and to maintain the selectivity of the interstage network.

It should be noted that with a loosely-coupled pair between RF stage and mixer there is a possibility of the mixer grid circuit impedance being *too* high, in which case thermal and induced grid noise terms might become excessive. The voltage gain between antenna and the mixer grid should be kept low; for a given gain, it is best to keep the mixer source impedance as low as possible. This is another reason for using a capacitive tap feed.

The gain over the tuning range may vary with changes in

[22] *Microwave Receivers*, A. B. MacNee, Ch. 16, p. 419.

circuit characteristics. Because of lead-inductance effects and stray couplings, the situation is complicated. Once the variations have been determined by observation, however, it is not difficult to compensate for them in part. In the six-gang experimental tuner the compensation consisted of inductive coupling so arranged that K increased considerably at the low-frequency end of the range, with a circuit resonant about 15% below the band. This can be seen in Fig. 3.

The gain from antenna to mixer is controlled easily by varying the coefficient of coupling and the voltage divider at the mixer grid. The proper amount of gain is a matter for experimental investigation. At 100 mc., 100 db of gain can be obtained easily, if there is need of it.[23] It is important to find out the variation of noise figure and spurious-response rejection with changing RF gain.

The noise figure of the combination can be calculated as described previously. Curves showing how the overall noise figure increases over RF stage noise with decreasing RF gain can be seen in Fig. 4.

Performance of a single-input mixer, in which both oscillator and signal voltages are applied to the same pair of terminals, is generally better than that of a multigrid tube at VHF. Also, less power is generally required from the oscillator.

Some extremely high responses to spurious signals were discovered in the exprimental work. This was traced to two mechanisms: 1) the presence of UHF resonance in the wiring, causing a single high-order term to be emphasized unduly, and 2) leakage of oscillator voltage and harmonics to the grid of the RF stage, and there mixing with strong signals in such a way as to give an output at the frequency of the desired signal. In the second case, no amount of selectivity subsequent to the mixing process will help, although RF selectivity at the plate of the amplifier may reduce the amount of oscillator energy leaking back. Both these effects are reduced by having two tuned circuits before the first tube.

Morgan[24] and Sturley[2] classify the possible ways a mixer can receive the wrong signal by the algebraic expression for the conversion process. A flaw is inherent in this neat system, however, since a signal at 2fo–IF passed into our experimental receiver by a process which was entirely different from the way that its algebraic counterpart at 2fo+IF was received. The design steps which reduced one actually made the other a little worse.

The requirements for image suppression have been mentioned briefly. If RF selectivity is adequate to protect the mixer from other interference, the image response, unless the situation changes, will be down far enough. A 60-db image ratio seems to be adequate. The response depends only on the number and Q of the tuner's selective circuits.

Intermediate frequency suppression is more important. This interference is not tunable, and there is no way to escape, short of realigning the IF section, should a strong station appear on 10.7 mc. Even the cheapest receiver should have 60 db of IF rejection, and 90 db is a minimum for good design. Fortunately, a 60-db high-pass 75 or 300-ohm filter can be constructed for about a half dollar, and adding such a device to an existing receiver should be very simple. Most of the IF attenuation should be obtained ahead of the first tube, since the IF frequency may beat with oscillator voltage at the RF amplifier. It could then pass through the interstage circuits, for it would be at signal frequency. This is the means by which IF interference most often enters a VHF receiver, probably because most VHF receivers have considerable leakage from the local oscillator.

The circuit of the mixer stage may take several forms. In general, what is shown in a schematic diagram is much less important than what is not shown, because the arrangement of the wiring is crucial. The mixer bias, ideally, should be set at the point where the second derivative of the mutual characteristic is a maximum; actually, it is set somewhere between the class A bias point and cutoff, for reasons given above. It may be obtained from a cathode resistor whose resistance is on the order of four times the proper value for an amplifier, or by means of a grid-leak and capacitor, with series resistance in the screen or plate circuits sufficient to limit the current to a safe value if oscillations should stop. In the latter case, the grid resistor must be of high value so that only a few microamperes of grid current can be drawn at the most positive excursion of the oscillator excitation, and the bias developed is governed mainly by the magnitude of that excitation. This tends to compensate in part for variations in oscillator voltage. The coupling capacitor should be fairly small, although if it is too small it may cause the mixer to oscillate at the intermediate frequency. This is not common in pentode mixers, but high-transconductance triodes may be unstable with grid coupling capacitors of less than 50 mmf.

Mixer plate lead configuration must be attended to carefully. Unless the first IF transformer is immediately adjacent to the mixer tube, this wire may be resonant at the signal or oscillator frequency. One way to remove the strong VHF currents flowing in this lead is to put the IF tuning capacitor at the socket of the mixer tube. A better solution, and one which avoids much leakage and feed-back, is to run the mixer plate lead to the first IF transformer through a shielded wire with the outside braid grounded at the socket. The shield provides an excellent bypass for signal-frequency components in the mixer plate current. Its capacitance is calculated as part of that in the tank circuit.

The proper oscillator injection is a compromise between poor signal-to-noise ratio on the one hand, and too many spurious responses or repeat points on the other. There is seldom a sharp line between the two, but a fairly safe rule is that the injection should be slightly less than the value

Continued on page 36

TABLE 2

Measured Performances of FM Receivers

Tuner	IF, Mc	Image Ratio	In-Band Sp. Resp.	Remarks
1 — 6-gang metal shaft	10.7	85 db	92 db	NF 11 db
2 — 4-gang, cer. shaft, adjusted for low sp. resp.	12	87	92	NF 12 db
3 — 4-gang, cer. shaft, adjusted for best sensitivity	10.7	72.5	90	N F 9 db
4 — 3-gang, cer. shaft	12	60	88	N F 20 db (est.)
5 — Comm. rcvr. 1 3-gang	10.7	54	82	Sp. resp. satisfctry
6 — Comm. rcvr. 2	10.7	41	69	S. R. poor
7 — Comm. rcvr. 3	10.7	49	73	S. R. poor
8 — Comm. rcvr. 4	10.4	42	65	S. R. bad
9 — Auto. rcvr.	10.8	33	69	S. R. bad

In each case, oscillator was above signal frequency, and worst in-band response was at signal frequency + ½ IF. Reference level for 75-ohm input receivers, 5 μv; for 300-ohm inputs, 10 μv. Units 5, 6, 7, and 8 are commercial models. Others built by author.

[23] *Vacuum Tube Amplifiers*, H. Wallman, p. 196.
[24] *IRE Proceedings*, H. M. Morgan, Oct. 1935, p. 1164.

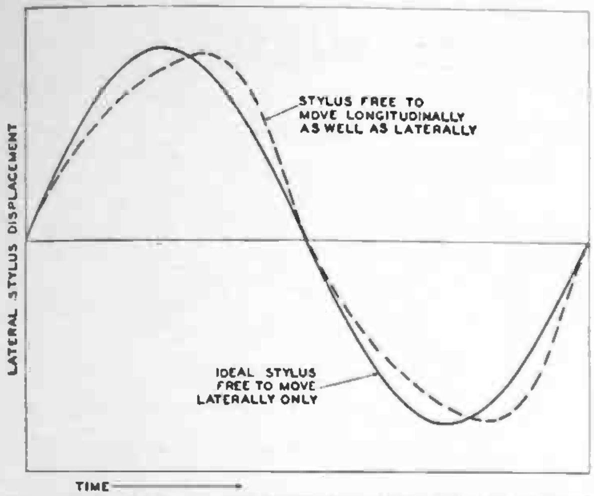


FIG. 1. DISTORTION OF SINE WAVE BY LONGITUDINALLY COMPLIANT STYLUS.

FIG. 2. APPARATUS FOR MEASURING LONGITUDINAL STYLUS EXCURSION

Phonograph Stylus Drag Distortion

HOW HARMONIC DISTORTION IN DISK RECORDING AND PLAYBACK CAN BE REDUCED SIGNIFICANTLY BY LIMITING LONGITUDINAL STYLUS MOVEMENT

A recent study by Jacob Rabinow and Ernest Codier, of the National Bureau of Standards, demonstrates the existence of a type of distortion often found in phonograph reproducers that has, apparently, not been treated in available literature. The Bureau's study discloses that if a phonograph stylus can move longitudinally with respect to the groove of an ordinary laterally-recorded disk, the needle will not follow perfectly the lateral excursions of the groove, and drag distortion will result. On playback of recorded music, this distortion can produce spurious tones of greater amplitude than the true ones.

Nature of Drag Distortion: The mechanism of drag distortion is not difficult to understand. The usual type of disk phonograph record is recorded laterally; that is, the audio-frequency motion of the recording stylus is at right angles to the record groove. For ideal distortion-free reproduction, the motion of the playback stylus tip should duplicate exactly the original lateral motion of the recording stylus. Provided the electrical output of the pickup is proportional to the lateral displacement of the stylus, there is then no distortion. However, if forces acting on the stylus cause longitudinal motion, its lateral motion does not follow exactly that of the recording stylus, and distortion is introduced. The two conditions are shown in Fig. 1.

Many possible causes for such longitudinal motion can be suggested. One is the well-known pinch effect caused by uneven width of the record groove. Another is the varying force which the sides of the record groove exert against the stylus. A third is the change in friction with changes in the pressure and velocity of the stylus within the groove.

The NBS study included both mathematical analysis and laboratory experimentation. Mathematical treatment indicates that if the recording consists of a pure tone of constant amplitude, drag distortion can produce only even harmonics, with the second harmonic predominating. A sudden transition from one amplitude to another will produce a large change in the longitudinal force on the stylus, and this can be expected to give rise to transient distortion if the stylus is not properly restrained longitudinally.

Test Results: A conventional crystal pickup with a replaceable steel stylus was used in experimental work. For some tests, a thin steel wire was spot-welded to the stylus near the tip; by tying the tip back with this wire, longitudinal motion could be minimized. A dual-beam oscilloscope was used to indicate simultaneously the waveform of the pickup output and the longitudinal displacement of the stylus tip.

Two methods of measuring the longitudinal motion were tried. The first consisted of a photoelectric arrangement in which spurious motion of the stylus modulated a beam of light. In the second, more satisfactory method, longitudinal motion of the stylus frequency-modulated a 50-mc. oscillator. Two small metal plates were mounted near the steel shank in such a way, Fig. 2, that the capacity between the plates varied with longitudinal motion of the stylus but not with lateral motion. The plates were connected across the tank coil of the oscillator,

Concluded on page 40

FIGS. 3, 4, 5. LONGITUDINAL MOTIONS (ABOVE) AND PICKUP OUTPUTS FOR 40, 50, AND 300-CYCLE GROOVES. FIG. 6. 300 CYCLES, STYLUS TIED BACK

Increased VTVM Sensitivity

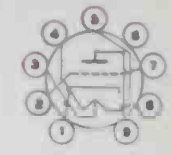


FIG. 2. THE 12A4

NEW VACUUM-TUBE VOLTMETER CIRCUIT EMPLOYING 12A4 TUBES INCREASES SENSITIVITY 15-20 TIMES — *By* JOSEPH GIUFFRIDA*

IN conventional vacuum-tube voltmeters, maximum sensitivity is hardly ever realized because the tubes employed exhibit imbalance, instability, and nonlinearity when operated at the large plate currents necessary for high sensitivity. However, by employing tubes designed for normal high-plate-current operation with low grid currents, the Commercial Engineering Department of CBS-Hytron has developed a simple VTVM circuit, described here, which has a sensitivity 15 to 20 times that of conventional circuits.

VTVM Bridge Operation: The elementary VTVM bridge circuit consists of four resistances arranged in series-parallel, as shown in Fig. 1. Resistances R1 are the plate load resistors for the two tubes in the bridge, and R2 represents the static impedances of the tubes. The meter is normally connected across the two tube plates. Delta E, then, is a measure of circuit sensitivity. The potential difference across the bridge is:

$$\Delta E = E_{IN}\left(\frac{R2+\Delta R}{R1+R2+\Delta R} - \frac{R1}{R1+R2}\right)$$

The curve at the right in Fig. 1 shows that delta E approaches zero asymptotically as R2 is increased, corresponding to the use of conventional vacuum tubes with low plate currents. Maximum delta E occurs when R2=0. This indicates that tubes used in a VTVM bridge circuit must have very low resistance at the operating point in order to achieve high sensitivity. As a corollary, they must have a dissipation rating sufficiently high to permit their use with low-resistance plate loads, and low bias voltages.

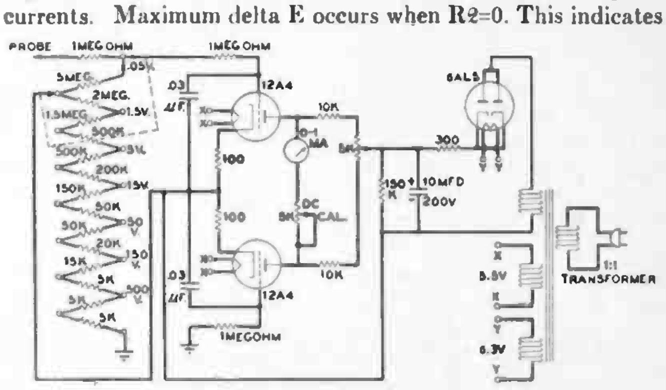


FIG. 4. COMPLETE BASIC CIRCUIT DIAGRAM OF THE NEW VTVM DESIGN

Use of the 12A4: The Hytron type 12A4 vacuum tube, while designed for use as a vertical output tube in television receivers, is virtually ideal for VTVM service because of its high perveance and uniformly small grid current. This 9-pin medium-mu miniature triode, with connections as shown in Fig. 2, has the following characteristics:

TYPICAL CHARACTERISTICS, 12A4

Heater volts	12.6 or 6.3
Heater current, ma.	300 or 600
Plate volts	250
Grid bias, volts	−9
Amplification factor	20
Transconductance, umhos	7800
Plate current, ma.	21
Grid cutoff, volts (Eb=500 v.)	−33

*Commercial Engineering Department, CBS-Hytron, Salem, Mass.

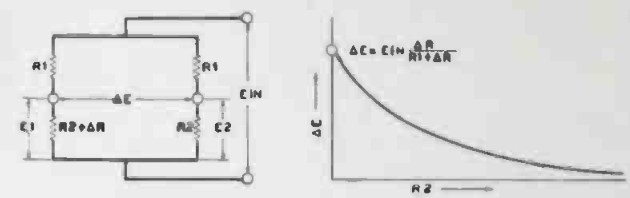


FIG. 1. OPERATING PRINCIPLE OF THE STANDARD VTVM BRIDGE CIRCUIT

By using cathode resistors of low value, the static operating point of each tube can be set at 5 milliamperes, which is a much higher current than is usual in VTVM circuits. The grid current that accompanies such operation can be balanced out by means of a center-tapped dividing network, as Fig. 3 shows. Resistance between the common cathode return and the two grids is kept constant by using an ordinary 2-wafer ganged switch for the voltage-divider network. The two functions of dividing input voltage correctly and maintaining equal grid-to-cathode resistances can be accomplished by substituting two resistors for each resistor in an ordinary divider. These two resistors have the same total resistance as the original, but are connected to the 2-gang switch, Fig. 3, so that the resistor connected to the high VTVM grid has a value half that of the total resistance in the divider below that particular tap. Resistor values shown in the diagram will make this clear. The range switch is in the 15-volt position.

Fig. 4 is a diagram of the complete basic circuit, with typical component values. This circuit has a sensitivity of .5 volts full-scale on a 0 to 1-milliampere meter, with stability comparable to conventional less-sensitive VTVM's. Input resistance is 10 megohms for any range, and the source resistance makes no practical difference in the reading obtained.

Heater voltage is limited to 5.5 volts, at which level operation is still quite satisfactory. However, tube life is extended significantly, and circuit stability is further improved by this reduced heater voltage. No difficulty was caused by operation of the power supply above ground potential. Ordinary power transformers have sufficient insulation resistance for this application.

Only the DC section of the circuit is shown, since this is the foundation of most VTVM's. Peak-to-peak or RMS diodes for AC scales, and an additional divider for ohmmeter scales, can be added easily.

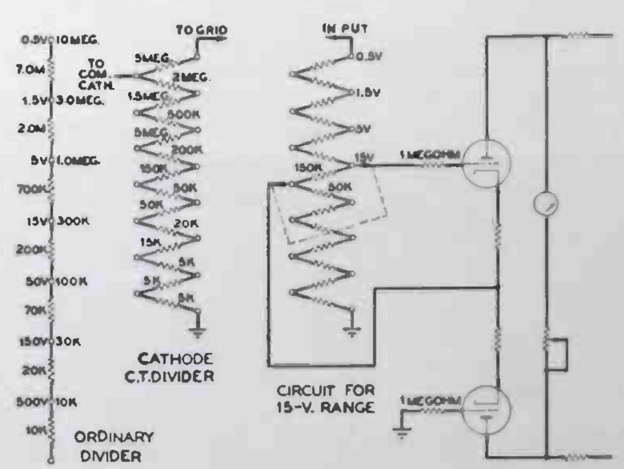


FIG. 3. STANDARD AND CONSTANT-RESISTANCE VOLTAGE-DIVIDERS

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SPURIOUS RADIATION

(Continued from page 21)

7 used the new IF in some 1952 sets, and 6 used the new IF in all late 1952 sets. All expect to use the 41.25-mc. IF in all 1953 models, although 2 stated that its use depends to some extent on interference experienced from the state-police transmitters. Means have been suggested to the FCC to eliminate or reduce such interference.

It was decided at the Oct. 20 meeting that recommendations on TV sweep circuit radiation would be postponed until the IRE subcommittee on sweep radiation completed its work on measurement standardization. Preliminary standards have been developed, and are now ready for distribution, it was stated.

Television Transmitters: J. E. Keister, Chairman of RTMA Transmitter Committee RT-4, spoke on the status of his committee's work on harmonic radiation from television transmitters. Because a typical single-ended TV output circuit provides about 30 db second-harmonic suppression without a harmonic filter, this figure was incorporated into TR-104B, RTMA Electrical Performance Standards for Television Broadcast Transmitters. Subsequently, it was decided to change this figure to 60 db. and the new figure is given in the C issue of TR-104.

For complete installations, the "radiation outside the assigned channel shall be as low as possible and in any case shall not disturb other services." This places the responsibility for suppressing spurious radiation on the industry, even when adjustments must be made in the field. All actual cases of TV transmitter interference have been corrected satisfactorily, Mr. Keister said.

On Nov. 28, 1952, the FCC published Docket No. 10353, in which 60-db harmonic suppression was proposed, and greater suppression where necessary to protect other services. RTMA filed a request that the effective date of such a Rule amendment be specified as at least a year after its formal adoption, because of the time necessary to prepare for production of the low-pass filters required. The following Schedule was estimated to represent the least possible times required for development, procurement, and manufacturing of such filters:

Filter Type	Channels	Time
2nd. harm. only	2-3	3 mos.
2nd. harm. only	4-6	4 mos.
Low-pass	2-6	8 mos.
Low-pass	7-13	11 mos.
Low-pass	14-83	1 year

UHF Receivers: Chairman of IRE Committee on Spurious Radiation R. F. Shea reported that the IRE standard method for measuring local oscillator radiation from FM and VHF-TV receivers has been used with good results for UHF receivers also. Such measurements are handicapped to some extent, Mr. Shea noted, by the commercial availability of only one type of UHF field-strength meter. Consequently, deliveries are slow. Others are in development, however, and should be in production by this fall.

Three task forces were then set up for further work on these problems. No. 1, under chairman K. A. Chittick, is to be concerned with determining the maximum practical reduction of receiver spurious radiations, and establishing a schedule for compliance by the industry. No. 2, under J. E. Keister, is charged with the same task on TV transmitters. No. 3, under chairman D. G. Fink, is to act as coordinator between RTMA and JTAC, FCC, and IRE.

FM TUNER HEAD

(Continued from page 32)

giving maximum conversion gain, if there is such a maximum. The IF output on the desired signal will be roughly proportional to both signal and to oscillator magnitude, for low oscillator injections, and the nearby beat responses increase as some higher power of each. Therefore, when the conversion gain is no longer proportional to the oscillator injection, it is more advantageous to increase the RF gain, if it is required for maximum sensitivity than to increase the injection.

For experimental adjustment, the RF gain should be held fixed while the oscillator injection is adjusted by setting the oscillator plate-supply voltage and the coupling to the mixer for the best operation, as explained above. Then the RF gain, which is most likely excessive, should be reduced until the measured noise figure is degraded by ½ to 3 db. This gives best rejection of the most annoying beat, $fo \pm \frac{1}{2}IF$, when referred to standard sensitivity rather than to an absolute level. The proper way to reduce the RF gain is not by changing the transconductance but by decreasing the coupling between tubes and resonant circuits, or between circuits, so that gain is traded for selectivity.

The method by which oscillator voltage can be supplied to the mixer is mostly a question of convenience. Ref. 8 describes a mixer using cathode injection; ref. 22, a low-impedance link; in ref. 5 and Fig. 3, the coupling is accomplished by circuit stray capacitances; and in Fig. 2, the oscillator and mixer grid inductors are coupled magnetically. In each instance, the amount of oscillator injection can be varied over a fairly wide range by one means or another.

Performance Checks: If the ultimate truth of a theory cannot be verified, experimental evidence is at least a consolation. The foregoing discussion is in part the result of experiment, so that the correlation between theory and practice should be fairly direct.

Three examples of FM broadcast tuning heads designed for low spurious responses are shown in Figs. 2, 3, and 5. Their measured performances are shown in Table 2, where they are numbered 2, 1, and 4, respectively. No. 3 is No. 2 modified for better sensitivity. The other receivers are representative of lower-priced equipment, and should be compared only among themselves.

Fig. 6 shows the performances of Nos. 1 and 2 (as complete receivers) for weak signals. It can be seen that a signal of 4 microvolts at 75 ohms is sufficient for a 40 db overall signal-to-noise ratio on either receiver. This exceeds the signal-to-noise ratio of the average living room, and should be considered noise-free enough for good listening.

If the same tuning heads were used with an AM receiver with a bandwidth of 10 kc. rather than 200 kc., the standard sensitivity would be on the order of two microvolts. This is typical of MHF

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FM TUNER HEAD

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communication receivers. The image ratios also compare favorably with good MHF receivers in the 5-mc. region.

No. 4 receiver, Fig. 5, is considered the best confirmation of the methods outlined here. When first checked, the sensitivity was excellent, but image and spurious-response ratios were 40 and 67 db respectively. As modified, the figures were increased to 60 and 88 db, at no cost for parts (none were added), and with no perceptible difference in sensitivity. Previously, interference from two nearby stations had been very annoying; now, there is no interference in the entire band. The RF gain was reduced 10 or 12 db, but the overall gain was still sufficient for adequate limiting, so the changes were an unqualified improvement.

RF selectivity for the 6-gang tuner is shown in Fig. 7. It can be seen that, for the region of interest, only 3 of the 4 tuned circuits contribute to selectivity. This confirms previous deductions.

Figure 8 is a diagram of the tuning head used in receiver No. 9, Table 2. Simplicity and maximum RF gain per milliampere of plate current were the design objectives. The noise figure of a similar tuner has been measured as 3 db at 30 mc. and 9 db at 150 mc. It is better than a straight mixer without an RF stage in this respect, but worse for spurious responses.

TV PLANT TOUR

(Continued from page 23)

a purpose is a compromise measure which is not recommended, except where adequate optical adjustment is impossible, since the reduction of peak signal strength may involve a sacrifice of signal-to-noise ratio. To be preferred is the use of lenses which can be stopped down to the desired value or, where this is impracticable, the use of a neutral-density filter which cuts down the overall light input without discriminating against any particular wavelengths.

Quick movement of the cameras was facilitated by using a special truck with a hydraulic lift on the rear end, shown in Fig. 5. This truck stood by with the lift lowered until a camera completed one sequence and a camera in another location took over. The first camera was then rolled onto the lift, tripod and all, hoisted to the truck floor, hauled to the next location, lowered, and rolled into position. Toughest haul was about 450 ft., with only 10 minutes available from the instant it was shut down to the time when it had to be putting out a signal from the next location.

The five tons of equipment, consisting of 49 separate units, was trucked to the plant from Camden in 38 large wooden boxes. Uncrating and setting up the equipment took about four hours. Only two hours were required after the show to knock it down and crate it, ready for the trip back to Camden.

Stringing the half-mile of cable, however, was another matter. That took about eight hours in itself. To protect the insulation from puddles and wet ground, in many cases bearing lithium salts and other chemicals, and to avoid blocking plant streets and drives or the risk of damage to the cable by passing vehicles, it was decided best to string most of it overhead. Where it crossed a spur of railroad track, the railroad required that it be suspended a minimum of 8 ft. above the tops of freight cars. This was accomplished without raising poles by stringing it from one to another of the plant buildings and tanks. For the longest run, a 100-ft. stretch from one support to another where the cable crossed the railroad, it was necessary to use a catenary steel support cable to prevent sagging.

Two 800-ft. lengths of camera cable were used to carry signals from the two most remote cameras to the control station, and 100-ft. lengths were required for each of the two remaining cameras. Four microphones were used, three in the field and one at the narrator's desk. These required microphone-line runs of 800, 200, 100, and 50 ft., respectively.

Six floods provided lighting for the indoor sequences. One special lighting problem was engendered by the presence of an open doorway and two windows near one side of the narrator's desk. This was solved by hanging white muslin over the openings to diffuse the outside light, and using a flood to balance lighting in the rest of the scene.

The floods employed Westinghouse lamps rated at 500 watts, with filaments adjusted to burn at about 2,800° Kelvin. This supplied the equivalent of 750 watts, and produced a very white light. In most instances, one or more floods were placed within a range of 10 to 15 feet of the subject or main objects in the scene, the distance depending on the nature of the shot and the effects desired.

Little in the way of special effects was attempted, but one measure that was tried proved quite effective. This consisted of fading in the opening frames of the film part of the program behind an image of Felix Shay, vice president in charge of production for Foote, as he sat at the narrator's desk after being introduced. Mr. Shay furnished the commentary for the film, which was concerned with the Kings Mountain, North

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Carolina plant of Foote. Here spodumene, a source of lithium salts, is quarried and processed. The film reproduction, incidentally, was unusually clear because the film camera had been modified with the latest laboratory improvements, and shading was not necessary.

Program: On the receiver screens in the cafeteria, the stockholders saw first the processing of lepidolite ores from Africa to obtain lithium products used for many industrial purposes, including the preparation of special types of glass for TV picture tubes. In Fig. 6, Mr. Drake explains the ore-bagging process.

Next, the Kings Mountain film was run, with commentary by Mr. Shay. More lithium processing operations were then shown, followed by the activities in progress at the pilot plant, Fig. 1, where a new process was being evaluated.

Detailed close-up action views were then presented of complex operations and equipment used in processing zirconium, a metal employed in radar and television manufacturing and for jet engines, atomic reactors, and the fabrication of vacuum tubes. The tour closed with a visit to the plant area, Fig. 7, where various minerals are processed to produce welding electrode coating materials.

Commenting on Foote's introduction of this new use of television, Mr. Bliss predicted that closed-circuit TV will become a valuable tool of business and industry for such purposes.

"It provides a unique means of showing stockholders what is being done with their money, and how their investments are being protected," he said, "without wasting their valuable time and energies and those of company officials in traveling from point to point.

"Further, it makes it possible to present a dramatic vignette of highlights in a company's operations that is more impressive and understandable than a physical tour of the plant. It presents the company's story with more realism and conviction than film can achieve, since it is recognized that there is no window-dressing in a TV presentation, and no opportunity for cutting and editing.

"It may even be found practicable for firms with plants in different cities to bring live TV pickups from various plants to a stockholders' meeting in one convenient location."

DRAG DISTORTION

(Continued from page 33)

and the resulting FM signal was picked up on a standard FM receiver a few feet away. With proper tuning, the instantaneous output of the receiver varied with the instantaneous longitudinal position of the stylus tip.

Various test records were reproduced with this experimental equipment. Tests were made with recordings of pure tones ranging from 20 to 10,000 cycles per second, of two different tones recorded simultaneously, and of music. The unrestrained stylus showed significant longitudinal motion, substantially verifying the original hypothesis. Figs. 3 and 4 show the results at 40 and 50 cycles respectively, with the upper waveforms representing longitudinal motion and the lower waveforms the pickup output. Longitudinal motion was not restrained. Figs. 5 and 6 are similar views of 300-cycle waveforms, with the stylus restrained longitudinally in Fig. 6.

With the equipment available, it was not possible to measure electrically the amount of distortion caused by this motion, because of the simultaneous presence of other forms of distortion. It was possible, however, to determine the magnitude of the longitudinal motion, and by computation to arrive at the character and amount of distortion attributable to this motion.

Although it was pointed out that the effects of drag distortion can be serious with some pickups, it was shown also that the styli in the better modern pickups have high longitudinal stiffness; with such pickups, drag distortion is probably negligible.

Conclusion: Both the mathematical analysis and the laboratory work were necessarily limited in scope. However, the NBS work may serve as the basis for more rigorous investigation elsewhere. Although no tests were made on vertical records and pickups, the same general considerations should apply as with lateral recordings and reproducers. It is probable also that a form of drag distortion can occur in the recording operation if the recording stylus is not sufficiently rigid longitudinally.

This investigation of phonograph drag distortion was a by-product of the Bureau's military research program. Telemetered information from experimental weapons is frequently recorded on disks in the NBS ordnance development laboratories, and the distortions introduced in the recording and reproducing processes are sufficiently serious at times to cast doubt on the significance of indicated measurements. Analysis of possible sources of error in these recorded measurements led to the study of distortion introduced by phonograph-stylus drag.

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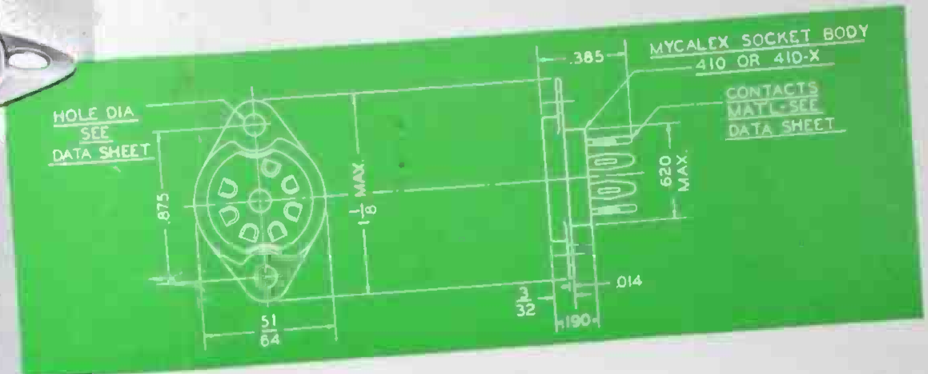

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