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If this hypothesis can be accepted it seems to me therefore that graphs which may express the phase and frequency characteristics of a particular amplifier are capable of being combined to yield a resultant curve which expresses the over-all effective distortion (or the «goodness» factor). Such an assessment would be far more valuable to operating engineers than the separate curves of phase and frequency whose sum effect cannot readily be visualized. I would be interested to know if Mr. Nuttall can see any practical way of effecting a combination of this sort.

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Wide Band Systems for Television

By *E. Labin*, Nutley, USA

621.397.6.018.424

Introduction

The purpose of this lecture is to consider the bandwidth requirements of various components of television networks and to describe some results obtained in this field. I intend to handle this problem from the point-of-view of a transmission, rather than a television engineer. In transmission, we are interested in reproducing faithfully, at a distance, a message which is not exactly known. The message is generally defined as part of a certain category of signals; such as, television signals, speech signals, etc. The main characteristics of a group of signals of this kind are known only on a statistical basis. The importance of the concept of bandwidth of a given message is due to the experimental fact that messages of a given family have generally the same bandwidth in spite of possible large variations in wave shapes. The usefullness of the bandwidth concept has been often criticized by television engineers who prefer to study signals as time functions. These criticisms are not justified from the point-of-view of the transmission engineers because bandwidth is the most permanent characteristic of a series of messages of the same family.

What are the bandwidths we are likely to meet in television? Present American television standards call for a video bandwidth of 4,5 Mc./s. This is adequate for the screen sizes which are now popular, or which are likely to be used in the average home. It corresponds to a quality comparable to what 16 mm home movie projectors will supply.

Many years will elapse before, in a commercial network, including home receivers, full advantage will be taken of the existing standards. If television pictures shall compare with movie pictures as projected in ordinary theatres in size and quality, a more ambitious standard probably up to 12 Mc./s video will be necessary. If, in addition, color is desired we might arrive at a video standard of 30 Mc./s. The message so defined has to be transmitted from the camera to a distant broadcast transmitter and from there to the home receiver, or eventually to the theatre projector. This represents a complex series of transformations of the message which are outlined in Fig. 1.

We intend to follow the message through this complex network and to indicate how broad a band can now be achieved for the various components. The message at the output of the camera has to be amplified within suitable video amplifiers, from there it has to go either through a coaxial line or through a radio pick-up link to a fixed relay station.

From there, the signal might be transmitted through radio relays, or again through a coaxial line to a distant city. In that distant city, the signal will be restored to its video form, amplified again by video amplifiers and finally applied to an AM transmitter which will broadcast the message. The intermediary coaxial cable links will normally use the video spectrum directly, or the same spectrum translated into another frequency range, but essentially it will be the same bandwidth.

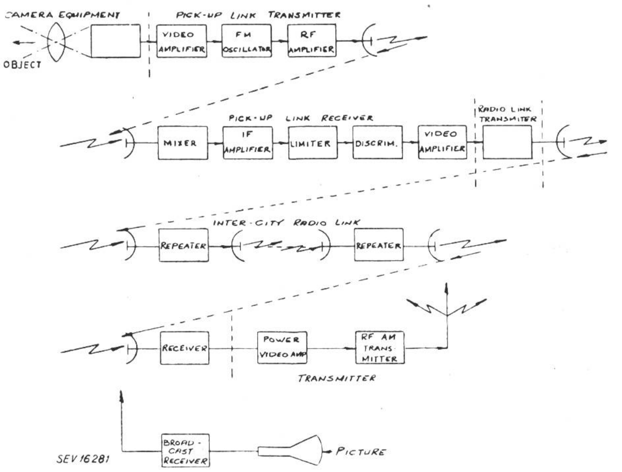

Fig. 1

The radio links will not normally use FM, meaning that the bandwidth at radio frequencies will be at least twice and normally three times the video bandwidth. It might be found useful in the future to transform the video signal before it is applied to the radio link. Such transformation could further increase the bandwidth. All this means that we need various tools; such as, frequency modulated oscillators, RF amplifiers, IF amplifiers, limiters, and discriminators with bandwidths which have to extend, depending upon the video standards referred to above, essentially from 10 to 100 Mc./s. The broadcast transmitters using vestigial side band AM modulation do not have to be that broad, but would still have to operate with a bandwidth of 6 to 60 Mc./s.

I do not intend to determine, on theoretical grounds, what the possible limits might be, but to describe briefly what has been done in our Laboratories in terms of independent components; such as, video amplifiers, IF amplifiers, limiters, discriminators, etc. I would like to stress before I start to show you the results obtained in these various fields that I do not claim any innovations in this art of broadband systems. As a matter of fact, all of the slides you will see describe circuits which are, in principle, well known for many years and I believe that it is the most interesting part of it because it proves that with existing tools and known principles, it is possible to design very broadband systems, indeed, if one is ready to pay the price for it.

Video Amplifiers

Methods for arriving at broadband video amplifiers have been extensively studied, and many examples are known. I would like to show you what can be obtained with two methods.

One, using a feedback principle from one stage to the preceding one and the other, using transmission lines.

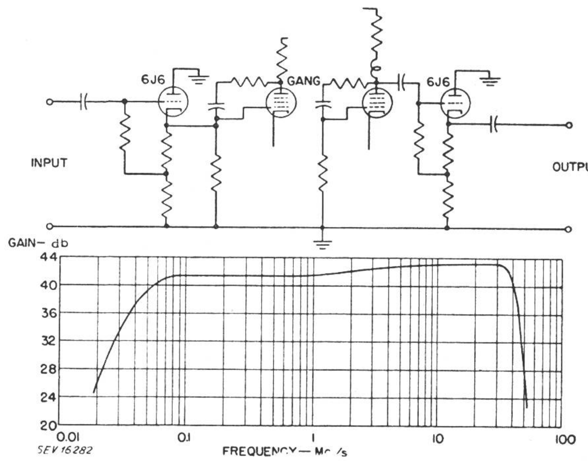

Fig. 2
Frequency Response 40 Mc./s Video Amplifier
Maximum Output before Limiting $\frac{1}{2}$ V

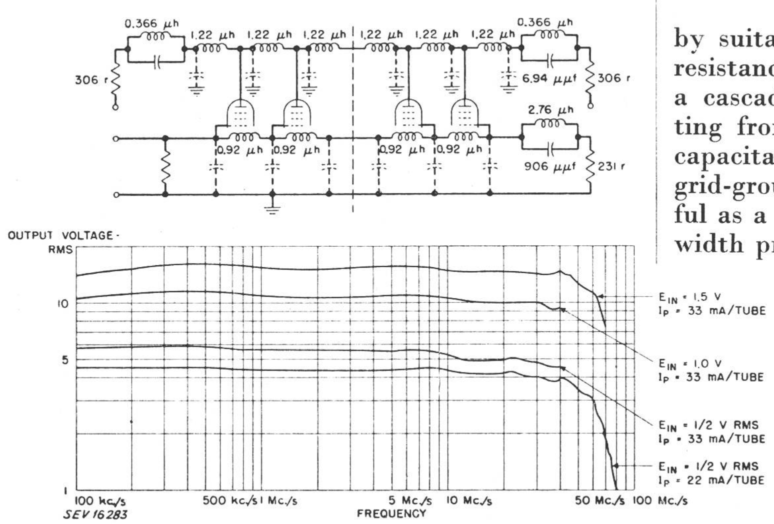

Fig. 3
Additive Amplifier, 6AN5 Tube
Maximum Variation = 1,0 db from 100 kc./s to 45 Mc./s
9 Tubes, Type 6AN5 Overall Gain = { 11 Ep = 200 V / Ip = 33 mA
Maximum Output Voltage = 28 V
Low Pass Filter Cutoff Frequency = 80 Mc./s

Fig. 2 shows the response curve of a feedback amplifier, flat within 2 db from 60 kc./s to 40 Mc./s [1]). It used eight 6AH6 tubes and two 6J6 miniature type tubes. The over-all voltage gain exceeds 40 db into 750 ohms. The maximum output voltage, before limiting, is 0,5 V.

by suitably connecting the grid and plate with a resistance, as the load for the preceding stage of a cascaded amplifier. The input admittance resulting from the grid-plate resistance has a negative capacitance component which subtracts from the grid-ground capacitance and thereby makes it useful as a video amplifier. Although the gain-bandwidth product of this amplifier is the same as the one of an ordinary type using peaking coils, it possesses a great advantage of simplicity. There is only one coil; there is no shielding and practically no decoupling; the values of the components are uncritical. The lining-up of such an amplifier is only a matter of minutes.

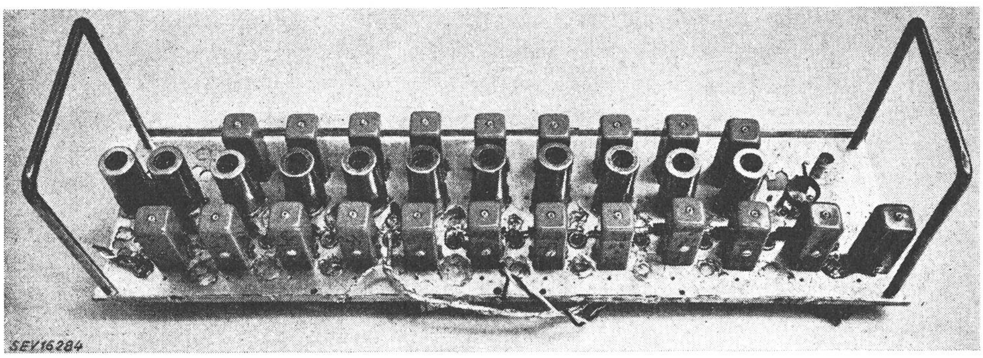

Fig. 4
40 Mc./s Wideband Additive Amplifier - Top View

The principle of this amplifier has been described several times. Essentially, it utilizes the resulting net input admittance of a vacuum tube produced

Fig. 3 is the frequency response of an amplifier of the additive type [1]). The frequency response is flat within 1 db from a few kc./s to 45 Mc./s.

Fig. 4 and 5 show views of this amplifier which is built with nine 6AN5 miniature type pentode tubes

[1]) Designed by A. Vallarino, Federal Telecommunication Laboratories, Inc.

and has an overall gain of 11 db for a plate current of 33 mA per tube. The maximum output voltage is approximately 28 V.

The principle of this amplifier has been proposed many years ago. It is radically different from other types because the total gain expressed in voltage ratios is not the product of individual gains, but the sum of the individual gains of each stage. It is essentially a „low frequency travelling-wave" amplifier using low pass filters to couple grids and plates in a parallel arrangement. The input signal travels from one grid to the next and the signal amplified by the first stage travels from one plate to the next. If grid and plate signals arrive at successive stages at the same time, they add all in phase. It is possible, using this principle, to go much further than indicated in the amplifier shown. Amplifiers flat up to 250 Mc./s and more have been designed using very large numbers of tubes. The usual limitation for the product of gain and bandwidth does not apply because even if the individual gain of each stage is smaller than one, the sum can be larger than one.

The amplifier shown has proved to be very stable and the alignment was not critical.

Fig. 6 and 7 show the view of an amplifier built by M. M. Newman at the Lightning and Transients Research Institute, University of Minnesota. It is one stage of an amplifier which has a voltage gain ratio of 2,5 and is flat within 3 db up to 250 Mc./s. Input and output impedances are 50 ohms. The stage actually consists of ten additive sub-stages, each one being composed of three 6AK5 type tubes. Actually, in each sub-stage, only one tube is active with two others being connected for balancing purposes. Cylinder-like elements are shown on the Bottom View of Fig. 7 and represents segments of concentric coupling line elements. When more gain is required, several stages of the same type are used in cascade. Newman informs us that he has under development, another bandwidth amplifier going up to 750 Mc./s of the same type using 4-X150 tubes.

In resumé, video amplifiers of output powers of the order of 1 W have been built, by using existing tubes and principles, up to 50 or 70 Mc./s. With a great expense in number of tubes, for additive amplifiers you can expand this frequency band still further and probably raise the power available up to 20 W.

Improvement in vacuum tubes would, of course, still further increase the possible bandwidths. Small power video amplification is not a limit to the use of most ambitious video standards.

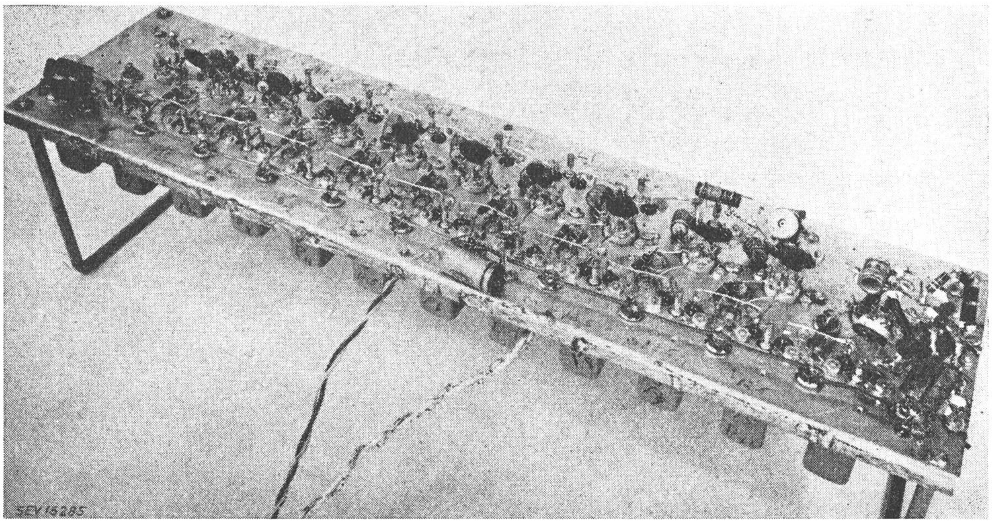

Fig. 5
40 Mc./s Wideband Additive Amplifier - Bottom View

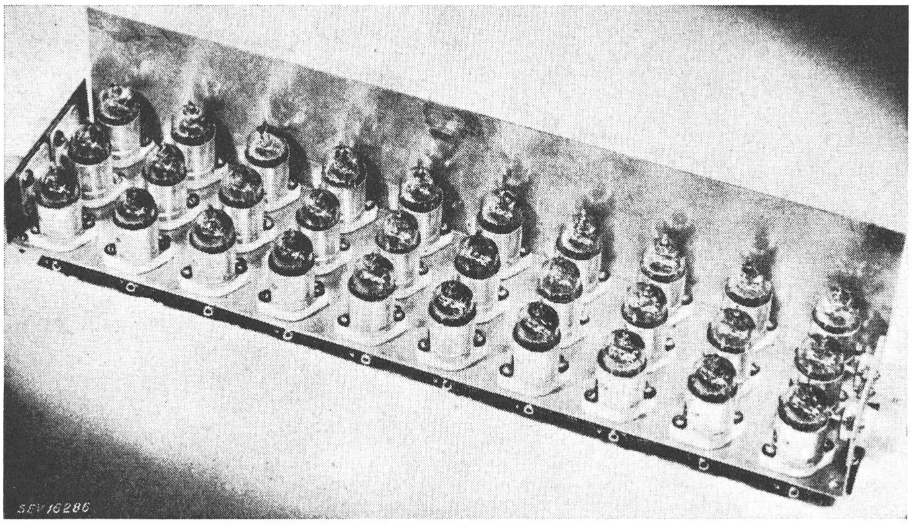

Fig. 6

RF Components

If we follow our hypothetical television link from the camera to the final receiver, after a video amplifier we will have to modulate an RF oscillator for transmission over the microwave link. This can easily be done with existing reflex klystrons.

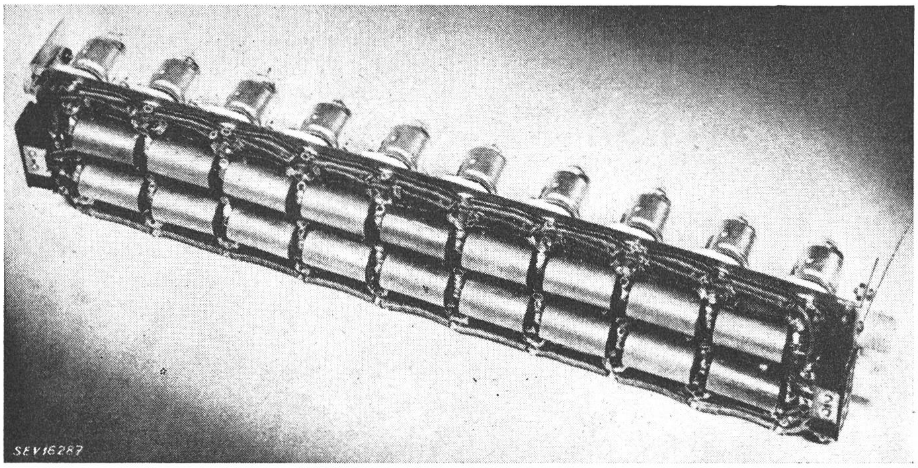

Fig. 7

Fig. 8 and 9 show the response curve of a reflex klystron, SCR-12, around 5000 Mc./s. A linear frequency displacement is obtained over an RF bandwidth of the order of 40 to 50 Mc./s. Similar

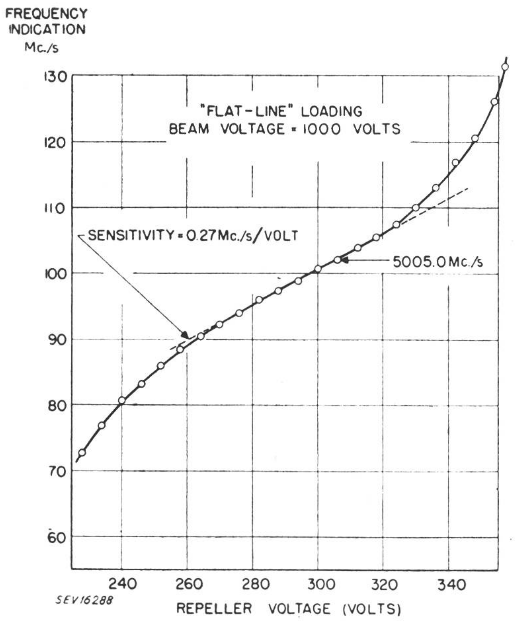

Fig. 8
Frequency VS Repeller Voltage

curves can be easily achieved at various radio frequencies. Output powers obtained in this manner are of the order of a few watts and they might be sufficient for many applications, nevertheless, more power is desirable even at very high frequencies when narrow beams can be obtained with reasonably sized antennas. The output power of broadband radio links should be of the order of 10 W to compensate for the increased noise generated in the very broadband and to achieve a sufficient margin against fades in propagation. RF power amplifiers in the microwave regions have been designed for many years in the form of velocity modulated tubes. Later efforts have been made to extend this principle somewhat to a design which is even better adapted to broadband operation, like the travelling wave tube.

The results obtained in our Paris Laboratory with velocity modulated tubes has already been published. Interesting results are expected soon from the travelling wave principle.

Antennas and Propagation

After our television message has been transformed in a frequency modulated signal and amplified, it will be transmitted at a distance to a set of suitable directive antenna. There is no practical limitation in bandwidth in this part of the system. The antennas are passive networks and their properties can be entirely counted for in terms of relative bandwidth, rather than absolute bandwidth, meaning by that, that the significant figure is expressed in percentages of the carrier frequency used, rather than in terms of an absolute number of megacycles.

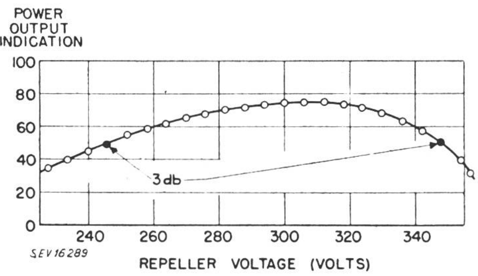

Fig. 9
Relative Power Output VS Repeller Voltage

Microwave antennas can easily cover frequency bands of the order of 1 octave when the input impedance of the antenna does not have to be rigorously constant. It is well known that when the distance between antenna and output stage of the transmitter becomes large, the impedance match required has to be quite accurate and the output bandwidth of the antenna structures is then reduced somewhere in the order of 5 to 10% of the carrier frequency; meaning that at 3000 or 5000 Mc./s a bandwidth of 150 to 300 Mc./s can be accommodated.

Between the transmitter and receiver antenna, the message travels in space and is affected by the topography and the state of the atmosphere. The propagation conditions for microwave is, in itself, a complicated subject which we will not handle here, but I would only call the attention to the fact that it might represent in final analysis, the most definite limitation in bandwidth and the only one against which little can be done.

We are now using frequency bands which are narrower than 1% of carrier frequency. Should we want to expand it to 10% of the carrier frequency, the propagation irregularities within the useful band might exceed the tolerances acceptable. Selective fadings which is the most important single factor limiting quality of short wave transmissions, is not an important practical factor now for microwave communications, but might become one if we had the ambition to extend our bandwidth to much more than 1% of the carrier frequency.

IF Amplifiers

When the message is received, it is normally transposed to a lower frequency in a microwave mixer. This operation can be done for very broad bands, because here again, the significant factor is the relative bandwidth. Quiet RF amplification has not been achieved yet to our knowledge and therefore most of the gain at the receiver or the repeater has to be obtained in the IF amplifier. The gain required is generally of the order of 80 to 100 db. The bandwidth required here depends upon the frequency deviation at the transmitter. For the type of problems we are dealing with and for normal specifications of linearity, the bandwidth will normally be approximately two to three times the video bandwidth.

Fig. 10 shows the response curve of an IF amplifier at 120 Mc./s with a bandwidth of 16 Mc./s [3]. Fig. 11 and 12 show the amplifier proper (Top View and Bottom View).

of the circuits show that it is possible to design accurately for much broader bandwidth than had been done in the past.

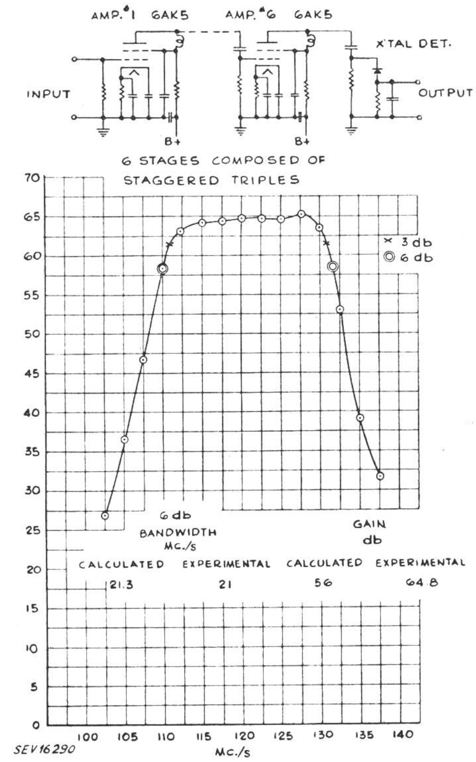

Fig. 10
Frequency Response of 120 Mc./s IF Amplifier

Another IF amplifier, with a bandwidth of 55 Mc./s within 3 db points and a gain of 80 db in 12 stages, is shown in Fig. 13 [4]).

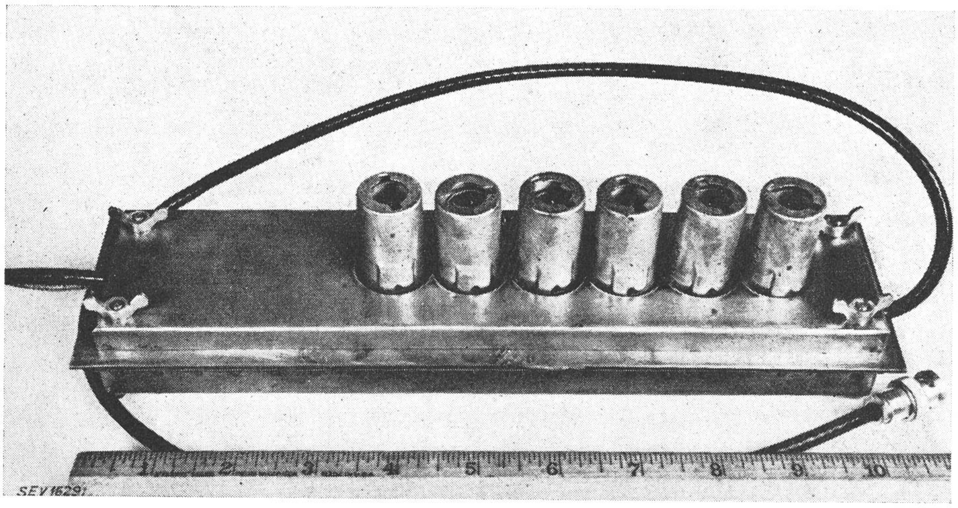

Fig. 11
6 Tube IF Amplifier
Top View

The amplifier consists of six 6AK5 tubes arranged in staggertriples mounted on a brass plate with top and bottom covers. The pictures show the simplicity of the electrical circuit and physical configuration. The principle of staggered stages used to be treated, pre-war, in a qualitative manner. A careful analysis

It uses the principle of staggered damping as opposed to staggered tuning. The input stage consists of a grounded grid amplifier in order to reduce the noise factor. The complete amplifier consists of four sets of triples making a total of twelve stages of amplification, each one of the stages

[3]) Designed by M. Silver, Federal Telecommunication Laboratories, Inc.

[4]) Designed by A. M. Levine, Federal Telecommunication Laboratories, Inc.

being tuned to the same center frequency and has the same coupling elements representing a double tuned transformer. This, makes construction quite simple since only one coil design and assembly is required for the amplifier proper. The only difference between individual stages is the damping resistor across the secondary coil. In the example shown, three values of resistances have been chosen; 650 ohms, 240 ohms and 180 ohms. After a triple of this type, values of the resistances repeat themselves. Fig. 14 shows the response curve obtained.

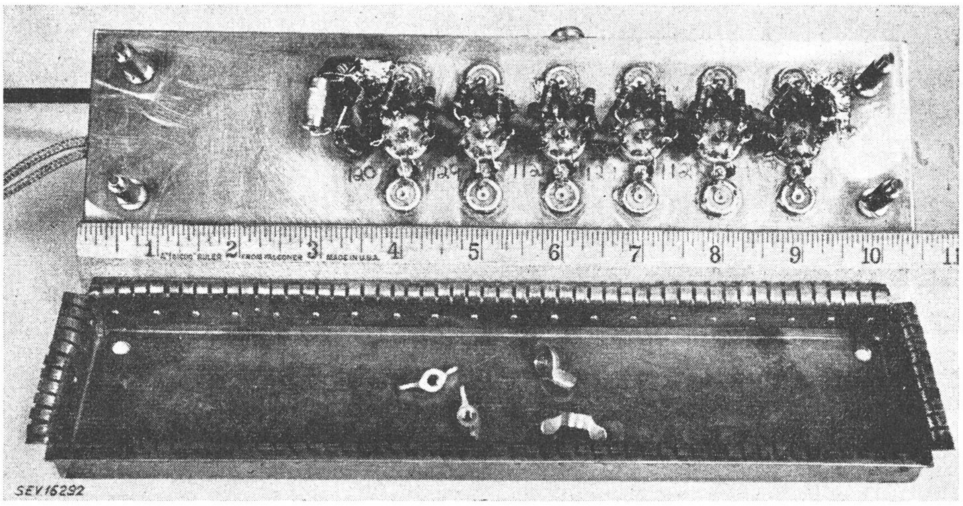

Fig. 12
6 Tube IF Amplifier
Bottom View

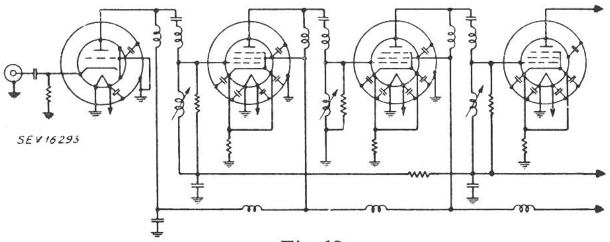

Fig. 13
Imput Plus Interstage Connections

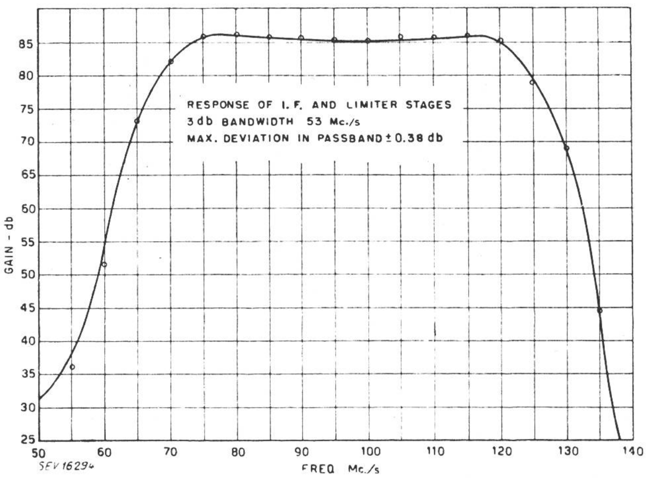

Fig. 14

Limiters and Discriminators

In order to take full advantage of the properties of FM, discriminators have to be proceeded by a limiter. Limiters for very broad bands become increasingly difficult because the clipping action of the limiters actually generate higher frequencies which have to be reproduced if the limiter is expected to perform correctly.

The limiters and discriminators used with the 55 Mc./s IF amplifier are shown on Fig. 15 and 16 [5]). The limiters consist of two cascade stages operated as very broad band amplifiers. The first limiter is a 6AK5 coupled by a series shunt video coupling network to two 6AK5 in parallel. This coupling network is used so that the DC restoring effect of the grids of the second limiter removes any changes due to averaging effect of noise. The grid current on the first limiter is used for the AVC voltage applied to the IF stages. The circuit impedances are so low

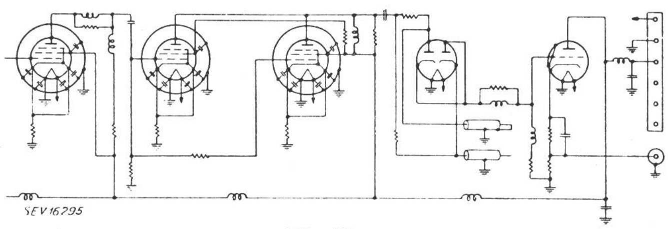

Fig. 15
Output Section Limiter, Discriminator and Cathode Follower

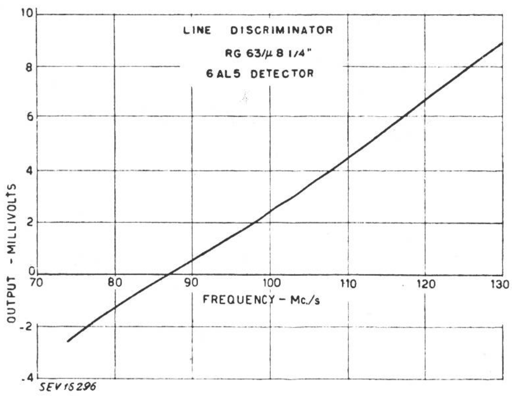

Fig. 16

5) Designed by A. M. Levine, Federal Telecommunication Laboratories, Inc.

in the broadband amplifier that the effect of the grid current is negligible on the limiting action. The output of the next limiter is fed into a line discriminator with an impedance of 120 ohms. Detectors are 6L5 tubes. Line discriminators are capable of extremely broad bands. This one shows quite a linear voltage output over more than a 50 Mc./s band (Fig. 16).

The distortion of line discriminators is especially small and from that point of view are useful, not only for television, but also for microwave links using frequency division multiplex.

At the output of the discriminator, we find again our video signal and the video amplifiers necessary to raise the signal at the desired level.

Repeaters

If the transmission is done by microwaves or by coaxial cables, the signal will have to be amplified several times before it reaches its final destination. The intermediary repeater stations will also introduce additional distortions and the final bandwidth of the system will result from the product of the individual bandwidth at each repeater. It is, therefore, necessary to be extremely severe with regard to the specifications of the individual repeaters, as the system has to be designed to cover long distances.

From this point of view, the usual specifications of bandwidth within 3 db points is not sufficient. It is more interesting to know the individual bandwidth within one-half a db because variations of this order usually can be compensated for by overall correcting networks at each repeater or after three or four repeaters. This over-all correcting network plays an important role in a long range television transmission.

There again, the fundamental principles are the ones which have been described in technical literature for many years. When these principles are applied with care, but without regard to cost, overall bandwidth up to 50 Mc./s can now be obtained in radio links.

Broadcast Transmitters

When the television reception finally arrives at the broadcast transmitter, it has to be amplified up to a power level sufficient for broadcasting. Video amplifiers, flat over a bandwidth of 12 Mc./s and supplying approximately 1 kW have been built and described previously in connection with the color television transmitter which has been in experimental operation in New York for the last two years.

I do not know of any actual design for broader bands at that power level, but I do not see any reasons why, if we wanted to, one could not design such an amplifier for bandwidth of the order of 30 or 40 Mc./s. 1 kW video power is probably sufficient for amplitude modulation of any broadcast transmitter likely to be built for television. The opinion about the power ratings for such a transmitter is still divided, but it is likely that powers larger than 5 kW will be required at any frequencies which have been considered so far for broadcasting. The color television transmitter I referred to previously, operates at 500 Mc./s, with a power of 1 kW.

If we consider video messages extending up to 12 or 30 Mc./s, we will probably want to operate at still higher carrier frequencies and with larger power. I do not know of any existing tubes which would permit you to do so at this time. The output stage of the television broadcast transmitter is probably the limiting factor now in possible bandwidth if one wants to talk of video messages in excess of 12 Mc./s. It is natural that improvements in this field should be slower than in others since developments are so expensive.

The possibility to improve the situation exists. Powerful magnetrons at frequencies within 500 and 1000 Mc./s have been built and while true amplitude modulation of a magnetron is a difficult problem, there does not seem to be any fundamental objection to modulate by absorption on the transmission line. Another promising possibility, is to adopt the principles of the travelling wave tube to large powers in these frequency ranges and therefore obtain all the advantages of travelling wave tubes for broadband operation.

Receiver

The problem of designing a very broadband television receiver is not so much a technical one, but an economical one. IF amplifiers, limiters, discriminators, and video amplifiers of the type shown could be combined into a broadband television receiver, but it would be an expensive receiver indeed.

Conclusion

We hope to have shown that the essential tools for television links with video standards up to 30 Mc./s are almost available. It is also obvious from the few slides which you have seen, that the corresponding equipment becomes expensive. The difficulties now encountered in the United States to take full advantage of the existing standards of 4,5 Mc./s only prove that while the technique for broader bands exist in the Laboratories, it will take many years before it could be made available to the public.

It is very interesting to note from the quick summary which we have made, that the weakest element in the chain we have examined are the output stage of powerful broadcast television transmitters and the home receiver. This would indicate that the true field for highly improved television standards might not be broadcast television, as we understood it for home reception, but that it should be considered for theatre television where broadcasting with large powers is not required and where the cost of the receiver is not as determining a factor.

A comparable situation exists in the film industry, where two standards are used; the 16 mm film for home projectors and the 35 mm film for theatres. It seems most likely that television will follow in the future this same example. Television standards as now used in the United States are probably adequate for home receivers but more ambitious standards will have to be adopted for theatre television.

It gives me a special satisfaction to conclude in favor of theatre television in this place where Prof. Fischer, during his lifetime, and his able successors since have done so much for the promotion of theatre television.

Acknowledgments

The equipment described in this paper have been developed at the Federal Telecommunication Laboratories, Inc. (a subsidiary of International Telephone and Telegraph Corporation) mostly under the sponsorship of Camp Coles, United States Army Signal Corps Laboratories.

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A Comparative Analysis of Certain Television Standards

By *L. H. Bedford*, Chelmsford, England

389.6 : 621.397.5

Introduction

The British and American television systems have been developed along strictly parallel lines of thought in which a two-way choice of standard presents itself at a number of stages. It is unfortunate that in most cases where the balance of advantage is not absolutely clear the opposite choice has been taken on the two sides of the Atlantic.

In the present paper it is proposed to discuss only two of these divergences, namely (*a*) The Polarity of Modulation, and (*b*) The significance of «Equalising Pulses».

Before going into detail we may pause to consider what results may be expected from a comparative analysis. In each case there would appear to be one of two possibilities.

(1) That one or other party has blundered.

(2) That the balance of advantage one way of the other is insignificantly small.

In the latter case one may perhaps still consider that a «blunder» has been committed, that of failure to standardise where standardisation was possible.

Polarity of Modulation

One reason for this point being selected for analysis is because it has been the subject of a good deal of loose reasoning. Thus it is argued that with negative modulation the transmitter occupance at peak power is only of the order of 10% whereas with a positive modulation it can be 85%; therefore a given output valve allows a higher rating of the transmitter with negative modulation. A closer study however reveals that the character of this «advantage» is strictly nominal, the word being used in its literal sense; that is it enables us to *name* a higher power, but not necessarily to put down a stronger useful signal in any given place.

To determine whether or not we get any advantage (at the transmitter) with negative modulation, we have to take into account two considerations which are conveniently left out in the above «argument». These are:

(a) What constitutes the «useful signal» in relation to peak radiated power?

(b) What parameter constitutes the limitation on the output valve rating, viz. peak current, peak voltage or (mean) anode or grid dissipation? Table 1 shows comparative conditions. We assume a peak carrier amplitude (expressed in amps, volts or field strength at a given place) of unity, and a corresponding carrier power also of unity (arbitrary units). The useful picture signal, E_u, namely the difference of field strength between black and white, is seen to be 0,7 for the case of positive modulation and 0,6 for the case of negative. These figures are not intrinsic to positive or negative modulation as such, but relate to the particular standards that have for good reasons been associated with them in the two Countries; the most significant point here being the low limit of 15% in the case of negative modulation.

For the rest of Table I the following approximations and assumptions have been made:

(1) The two systems have been reduced to comparative terms by the assumption of equal occupance for sync and equal occupance for blanking.

(2) The instantaneous efficiency at relative amplitude a has been taken as $a\eta_1$, where η_1 is the efficiency at peak amplitude. The relative anode dissipation D_α at amplitude a is $a^2\left(\frac{1}{\eta}-1\right)$ or $\frac{a}{\eta_1}-a^2$. (η_1 has been taken as 0,5).

Table I

	Rel. Carrier Amplitude	η	Rel. Inst. Watts			Occupance	Rel. Average Watts			Figures of Merit
			Output	Plate Dis.	Grid Dis.		Output	Plate Dis.	Grid Dis.	
White	1 0,15	0,5 0,075	1 0,022	1 0,27	1 0	0,85 0	0,85 0	0,85 0	0,85 0	
Black	0,3 0,75	0,15 0,375	0,09 0,562	0,50 0,94	0 0,32	0,05 0,90	0,005 0,506	0,025 0,845	0 0,29	
Sync.	0 1	— 0,5	0 1	0 1	0 1	0,10 0,10	0 0,10	0 0,10	0 0,10	
Useful picture Signal E_u	0,7 0,6									
Total relative Average watts							0,855 0,606 (W_a)	0,875 0,945 (D_a)	0,85 0,39 (G_a)	
$E_u/\sqrt{W_m}$										0,70 0,60
$E_u/\sqrt{W_a}$										0,76 0,77
$E_u/\sqrt{D_a}$										0,75 0,62
$E_u/\sqrt{G_a}$										0,76 0,96

Note: These Quantities calculated for the Highest Drain Picture, viz. All White or All Black for Positive or Negative Modulation Respectively.