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The "Stenode"

Part II, Appendix

By J. ROBINSON, Dsc., PhD. MIEE, F. Inst. P.

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The first part of this paper is additional to the paper on the Stenode receiver, published in the Club Proceedings of December, 1930. Discussion of the main paper then follows.

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THE following analysis was obtained in discussions with Dr. Alexander Russell, F.R.S., principal of Faraday House, London.

Transmitting Waves

Let us suppose that the carrier wave has a frequency n and that $\omega_1 = 2\pi n$. Then the magnetic flux produced at a point in the receiver may be written $\Phi \text{ Sin } \omega_1 t$ where Φ is a constant which depends on the kind of transmitter used and its distance from the receiver, and t is the time in seconds. In practice Φ is modulated in various ways. Let us suppose that a pure note C Sin ω_2 t is sounding at the transmitter and is modulating the amplitude of the current producing the carrier wave. In this case the instantaneous value of the flux at the receiver with the modulated transmitting current is given by

$$\phi = \Phi (1 + m \text{ Sin } \omega_2 t) \text{ Sin } \omega_1 t \qquad (1)$$

where m is a constant independent of the frequency and the time. By trigonometry this may be written

$$\phi = \Phi \text{ Sin } \omega_1 t + m \frac{\Phi}{2} \left\{ \cos (\omega_1 - \omega_2) t - \cos (\omega_1 + \omega_2) t \right\}$$

Resonating Receiver

The impressed e.m.f. in the resonating circuit e is given by

$$e = \frac{\delta \phi}{\delta t} = \omega_1 \Phi \cos \omega_1 t + m \frac{\Phi}{2} \left\{ (\omega_1 + \omega_2) \text{ Sin } \overline{\omega_1 + \omega_2}\, t - (\omega_1 - \omega_2) \text{ Sin } \overline{\omega_1 - \omega_2}\, t \right\}$$

If the resonating receiver consists merely of an inductive coil of resistance r and inductance L and a condenser K in series with it we have

$$e = ri + L \frac{\delta i}{\delta t} + \frac{\int i\, \delta t}{c} \; \ldots\ldots\ldots \qquad (2)$$

where i is the current in the circuit where $\int i \delta t = q$ is the charge on the condenser at the time t. Writing for e its value from (1) and substituting in (2) and solving the equation we get

$$I = \frac{\omega_1 \Phi \cos (\omega_1 t + \alpha_o)}{\left\{ r^2 + \left(L \omega_1 - \frac{1}{c\, \omega_1} \right)^2 \right\}^{\frac{1}{2}}} + \frac{\Phi}{2} m \frac{(\omega_1 + \omega_2) \text{ Sin} \{ \overline{\omega_1 + \omega_2}\, t - \alpha_1 \}}{\left\{ r^2 + \left(L\, \overline{\omega_1 + \omega_2} - \frac{1}{C (\omega_1 + \omega_2)} \right)^2 \right\}^{\frac{1}{2}}} - \frac{\Phi}{2} m \frac{(\omega_1 - \omega_2) \text{ Sin} \{ \overline{\omega_1 - \omega_2}\, t - \alpha_2 \}}{\left\{ r^2 + \left(L\, \overline{\omega_1 - \omega_2} - \frac{1}{c (\omega_1 - \omega_2)} \right)^2 \right\}^{\frac{1}{2}}} \qquad (3)$$

Where $\tan \alpha_o = \dfrac{L \omega_1 - \frac{1}{c\, \omega_1}}{r}$

$$\tan \alpha_1 = \frac{L (\omega_1 + \omega_2) - \frac{1}{c (\omega_1 + \omega_2)}}{r}$$

$$\tan \alpha_2 = \frac{L (\omega_1 - \omega_2) - \frac{1}{c (\omega_1 - \omega_2)}}{r}$$

The formula (3) gives the complete solution when the steady oscillating state is attained. In practice the ratio $\frac{\omega_2}{\omega_1} = \frac{f_2}{f_1} = x$ is less than one in a hundred.

If the resonating receiver is adjusted to resonance with the carrier wave we have $L\, \omega_1 - \frac{1}{c\, \omega_1} = o$. Thus $\tan \alpha_o = o$, and consequently $\alpha_o = o$.

In addition we have $L (\omega_1 + \omega_2) - \frac{1}{c (\omega_1 - \omega_2)} = L\, \omega_1 (1 + x) - \frac{1}{c\, \omega_1 (1 + x)}$ $= L\, \omega_1 \left\{ 1 + x - \frac{1}{1 + x} \right\} = L\, \omega_1 \{ 1 + x - (1 - x + x^2 - x^3 \ldots) \} = L\, \omega_1 (2x - x^2)$ $= L\, \omega_2 (2 - x)$ very approximately.

Similarly

$L (\omega_1 - \omega_2) - \frac{1}{c (\omega_1 - \omega_2)} = L\, \omega_1 \{ 1 - x - (1 - x + x^2 \ldots) \} = - L\, \omega_2 (2 + x)$ very approximately.

When x can be neglected compared with (2) we can therefore write

$\tan \alpha_1 = \frac{2\, \omega_2 L}{r} = \tan \alpha_2$. Hence $\alpha_1 = - \alpha_2 = \alpha$ say.

Thus substituting in (3) the formula for the current I in the resonating circuit is

$$I = \frac{\omega_1 \Phi \cos \omega_1 t}{r} + \frac{m\, \omega_1 \Phi}{2 \{ r^2 + 4 L^2 \omega_2^2 \}^{\frac{1}{2}}} \left\{ \begin{array}{l} 1 + x \text{ Sin } \overline{\omega_1 t + \omega_2 t - \alpha} \\ - 1 - x \text{ Sin } \overline{\omega_1 t - \omega_2 t - \alpha} \end{array} \right\} \qquad (4)$$

Now the expression inside the large bracket equals

Sin $(\omega_1 + \omega_2 t - \alpha)$ — Sin $(\omega_1 t - \omega_2 t - \alpha)$ + x { Sin $(\omega_1 t - \omega_2 t - \alpha)$ + Sin $(\omega_1 t - \omega_2 t - \alpha)$ }

which equals $2 \cos \omega_1 + \text{Sin} (\omega_2 t - \alpha) + 2 \times \text{Sin } \omega_1 t \cos (\omega_2 t - \alpha)$.

If 2 L ω_2 is greater than 25 r the error made in assuming that $(r_2 + 4 L^2 \omega_2^2)^{1/2} = 2 L\, \omega_2$ is less than one in a thousand.

We see that (4) can be written

$$I = \frac{\omega_1 \Phi \cos \omega_1 t}{r} + \frac{m\, \omega_1 \Phi}{2 L\, \omega_2} \left\{ \begin{array}{l} \cos \omega_1 t \text{ Sin } (\omega_2 t - \alpha) \\ + x \text{ Sin } \omega_2 t \cos (\omega_2 t - \alpha) \end{array} \right\}$$

The second term in the bracket being multiplied by x the ratio of the frequencies can in practice be made negligibly small compared with the first. Neglecting it we get finally

$$I = \{ A + \frac{B}{f_2} \text{ Sin } (\omega_2 - \alpha) \} \cos \omega_1 t \qquad (5)$$

where

$$A = \frac{\omega_1 \Phi}{r} \quad B = \frac{m\, \omega_1 \Phi}{4 L \pi} \quad \tan \alpha = \frac{2 L\, \omega_2}{r}$$

Since we have supposed that $\frac{2 L\, \omega_2}{r}$ is 25 or greater than 25, $\alpha = 90°$ very approximately and thus (5) becomes

$$i = \{ A - \frac{B}{f_2} \cos \omega_2 t \} \cos \omega_1 t \qquad (6)$$

Comparing (6) with (1) we see that the current in the resonant circuit consists of a modulated carrier wave and would produce an audible note the frequency of which is f_2.

It is to be noticed, however, that the amplitude of this audible note is inversely proportional to the frequency, the higher the note, the smaller the amplitude.

If there are notes of several frequencies f_2 f_3 . . . sounding at the transmitting apparatus, the current would be given by

$$I = \{A^1 - \frac{B^1}{f_2} \cos \omega_2 t - \frac{B^{11}}{f_3} \cos \omega_3 t \ldots\} \cos \omega_1 t$$

where B^1 B^{11} are constants which depend on the amplitude of the pure tone sounding at the transmitter.

Equation (6) can be written

$$I = A\,(1 - \frac{B}{A f_2} \cos \omega_2 t)\ \cos \omega_1 t = A \{1 - \frac{m\,\delta\,n}{2\,\pi\,f_2} \cos \omega_2 t\} \cos \omega_1 t \text{ where } \delta = \frac{r}{2\,n\,L}$$

Thus the modulation factor which for the input is m_1 becomes for the output

$$\frac{\delta}{3\,\pi}\,\frac{n}{f_2}\,m$$

and we have the result that a very selective receiver changes the modulation factor.

By the factor $\frac{\delta}{2\,\pi}\,\frac{n}{f_2}$ where δ is the logarithmic decrement, n is the carrier frequency and f_2 the modulation frequency.

▲

Discussions on the foregoing paper follow

ELLSWORTH D. COOK, PH.D*

THE radio profession has heard so many conflicting reports on the Stenode that we are indebted to Dr. Robinson for his explanation of what it is and how it is supposed to cperate.

A review of his paper shows that it does not question the existence of sidebands. Any suggestion that a difference would exist between the modulated wave and the three separate frequencies into which it can be resolved mathematically would be too naive to warrant discussion. Dr. Robinson, however, calls in question the need for such broad circuits in receiving. It will be essential, therefore, to discuss both the steady state and transient conditions. In the steady state case, a receiver designed so that a band lying (1000) cycles on either side of the carrier would be passed without attenuation while all frequencies outside of this band and extending up to 5000 cycles on either side of the carrier frequency, though still accepted by the receiver, are greatly attenuated, may be made to produce a uniform audio-frequency output by compensating the audio amplifier to properly accentuate the higher frequencies between (1000) and (5000) cycles. Outside of this range it is assumed that no signal can pass through the radio system. It is obvious that neglecting detector distortion, no audio frequencies in excess of 5000 cycles can now exist in the output of the set.

Detection is well understood to require at least one frequency separated from the carrier by the audio frequency in order to provide a beating note with the carrier which, after detection, yields the audio signal. Assuming single sideband transmission in the steady state, if this side-tone frequency is supplied from a separate oscillating system, the same audio output will be obtained. The manner of generation of this side-tone frequency is unknown to the detector. Thus in the steady state at least, there is no difference between the Stenode which is designed with a compensating audio-frequency amplifier and a receiver designed with a flat band-pass radio frequency characteristic for 5000 cycles width on either side of the carrier frequency having a perfect detector and audio-frequency amplifier. This has been freely granted by Dr. Robinson in the various discussions.

The flat band-pass radio-frequency characteristic would seem to be the more desirable since it does not require as careful tuning to give good audio quality as the Stenode does. Furthermore, the increase in high-frequency audio gain is contrary to the usual American design. It is becoming general commercial practice to decrease the amplification at high audio-frequencies in order to reduce the noise.

The paper, however, suggests a difference between a modulated and an unmodulated wave where the unmodulated wave existed at the identical frequency of one side-tone. This difference is ascribed to the transient condition, that is, the energy build up mentioned by Dr. Robinson. There is, however, no discernible difference in the radiation of a modulated wave where the modulation is by a single frequency tone, and the individual waves called for by the mathematical resolution of the modulated wave into its components. Phase difference between these three frequencies is meaningless unless the instant under consideration is given since all possible phases are successively taken on. The solution of the ordinary differential equation of a resonant circuit will show no difference in the results for the two cases even in the transient case. The additional phenomena of detection does not alter the situation since a difference in grid signal applied to the detector must be discernible before detection in order for the detector to differentiate between the two signals. The only possible conclusion left is that the fundamental theory of transients in resonant circuits is faulty and such a conclusion is untenable.

It then remains to find the advantage possessed by the Stenode. If the crystal used to provide the high degree of selectivity claimed, can be made as selective as claimed, it would seem that the advance made is in providing a receiver with this much selectivity without an array of resonant circuits which, to say the least, would be very imposing and certainly a trial to one assigned the problem of maintenance.

* *United Research Corporation.*

J. G. ACEVES*

THERE are several features pertaining to the "Stenode" which are worth discussing.

In the first place, it is my belief that in this type of receiver, the piezo-electric effect has been utilized for the first time in order to secure an extreme degree of selectivity in a broadcast radio set.

It is well known that no electrical vibratory system has a decrement as low as a mechanical system. If the latter could be employed as means of obtaining a high degree of selectivity, which is a consequence of low damping factor, the selectivity of a receiver could be considerably improved. A mechano-electric converter has to be secured, and this is precisely the function of the quartz crystal used in the Stenode.

A receiver equipped with such a sharp "filter"—after all, this is the way the crystal acts—must obviously pass the side frequencies, or for that matter any frequency in general departing from the resonance frequency, with a rapidly increasing attenuation.

It follows that for tolerably good overall fidelity response in the case of a broadcast receiver, some means must be resorted to in order to secure an adequate compensation. In the case of the Stenode, the audio-frequency amplifier is compensated. How far this compensation is feasible may be surmised from the following calculations.

Let us consider the effect of the crystal by analogy to an equivalent electrical circuit.

Let a constant voltage, variable frequency sine wave generator G, Fig. 1, impress an electromotive force E into a circuit formed by an inductance L, a capacity C and a resistance R. If we take the voltage drop across the coil, which may be connected to a valve V and call this drop e, the ratio between the impressed voltage E and the received electromotive force e will be the gain, which we shall call H, and it is given by the expression:

* *Chief engineer, Amy, Aceves & King, Inc.*

$$H = \frac{e}{E} = \frac{pL}{\sqrt{\left(pL - \frac{1}{pc}\right)^2 + R^2}} \qquad (1)$$

in which p stands for the frequency in radians (6.283 times the frequency in cycles).

Let us use frequency ratios and introduce the "efficiency" of the circuit, each one defined respectively as follows:

$p = np_o$ where $p_o = \frac{1}{\sqrt{LC}}$ or resonance frequency)

Let $Q = \frac{p_o L}{R} = \frac{\frac{1}{p_o C}}{R}$ or ratio of reactance to resistance at resonance

and by dividing both numerator and denominator of the fraction in the second member of expression (1) by R and substituting, we obtain:

$$H = \frac{n}{\sqrt{\left(n - \frac{1}{n}\right)^2 + 1/Q^2}} \qquad (2)$$

For values of n so close to unity that $(n-1/n)^2$ may be ignored in comparison with Q^{-2},

$H = nQ$ and as n is very close to 1, H will be constant and equal to the efficiency of the tuner. In the curve shown in Fig. 2, this portion lies between A and B.

As the frequency ratio n departs from unity, the quantity $(n-1/n)^2$ increases very rapidly and soon will be much larger than $1/Q^2$ and if we ignore the latter in comparison with the former, expression (2) will become

$$H = \pm \frac{n}{n - \frac{1}{n}} = \pm \frac{n^2}{n^2 + 1} \qquad (3)$$

Care should be taken to use the proper sign so that H will come out always positive.

For a frequency change within the range that we are interested in, which will correspond to values of n between say .98 and 1.02, (2 per cent away from resonance) we can write:

$n = 1 \pm \Delta n$

hence: $H = \frac{1 \pm 2\Delta n}{\pm 2\Delta n}$ (whenever $(n-1/n)^2$ is large compared to $1/Q^2$) (4)

and ignoring $2\Delta n$ in comparison with unity,

$$H = \frac{1}{2\,\Delta n} \qquad (5)$$

This expression means that the gain is inversely proportional to the percentage

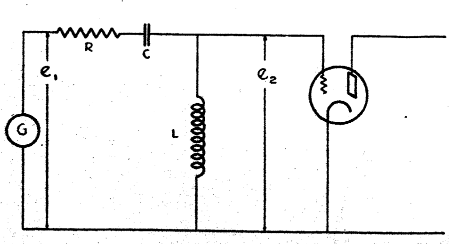

Fig. 1.

of frequency deviation from resonance and this deviation is proportional to the resultant audio frequency after demodulation. This proportionality holds beyond point C in Fig. 2 where the resonance curve approaches a hyperbola. Hence, for proper compensation, it is necessary to have an audio amplifier with a gain directly proportional to the audio frequency, as Dr. Robinson properly pointed out. But how far from unity must n be so that equation (5) will hold true, even approximately?

If we make $(n-1/n)^2$ at least four times $1/Q^2$, the error, committed by ignoring the second quantity in comparison with the first will be about 3 per cent in the calculation of H from expression (2) which thus simplified becomes expression (3) or (5).

Giving numerical values to our data, let us make $Q = 1000$ which is a higher value than can be obtained electrically

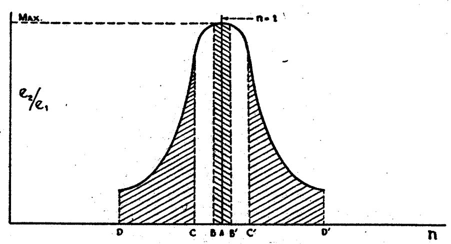

Fig. 2.

without regeneration. Let also, by hypothesis, as previously mentioned:

$$\frac{\left(n - \frac{1}{n}\right)^2}{1/Q^2} = 4$$

hence; $\pm\ (n-1/n)Q = 2$ and with $Q = 1000$, $n-1/n = .002$, or $n^2 - .002n - 1 = 0$ from which $n = 1.001$ and therefore, from a frequency 1/10% away from the carrier, and thereafter, equation (5) will hold true for values of n included between .9 and 1.1 at least. If we choose a value of resonance frequency of 50 kilocycles, then the expression will hold good for frequencies 50 cycles away from 50,000 and beyond. These will generate audio frequencies of 50 cycles and beyond after demodulation. It is clear that the inverse proportionality law in the audio response will hold for the entire audio frequency range. The same results that are obtainable with the sharply selective system involved in the Stenode with its highly compensated audio system could be secured without the crystal to more or less the same extent by substituting the "band-pass" type of intermediate frequency amplifier in a superheterodyne by a very sharply tuned regenerative stage, as has been done by E. V. Amy. The old fashioned audio-frequency transformers had a response curve which was approximately proportional to the audio frequency up to a value a little higher than 1000 cycles, after which the decline was very rapid due to the distributed capacity within the windings and also that due to internal capacity between anode and grid of the tubes.

I wonder how feasible it is to make an audio amplifier the gain of which is proportional to the frequency for a total range of from 50 to 5000 cycles?

Granted that we lower the gain at 50 cycles to as little as 40 db. or 100 to one, the amplification at 5000 cycles would have to be 10,000.

An alternate method would be to use a power detector with a gain of about 10 at 50 cycles from there to the loudspeaker. In that case the upper frequency (5000) would have to be amplified 1000 times and unless the detector was strictly linear at the low sound intensities the bass notes will be wiped out and a serious distortion may result in case of loud signals of very different frequency components, due to nonlinear relations in the characteristics of the tubes. A compromise would have to be secured, and this is precisely the impression that I gathered from the demonstration at the Radio Club meeting.

Being fortunate enough to be able to play the pipe-organ and the pianoforte, and being a lover of symphonic music, I may be able, perhaps, to detect the presence of all the frequencies present in a reproduction of music and my ears tell me—right or wrong (?)—that the bass notes below 200 cycles and the treble tones above 2000 were inaudible during the demonstrations.

There is another novel feature in the Stenode receiver; the use of an electronic "reversing switch" for the purpose of bringing the low decrement circuits or (crystal) to a standstill and cutting short the "tails" due to free vibrations. There is nothing in this that involves the same principle used in super-regeneration since the effective resistance in the latter case alternates from a positive to a negative value at every half-cycle of the intermediate supersonic frequency. In the super-regenerative circuits the r-f. tuned circuit having a negative decrement builds up with or without external impulse until the effective circuit resistance changes sign. The extent to which it will build up is governed by the amplitude of the signal at the time that the resistance is negative. Nothing of this sort happens in the Stenode since the resistance is always positive. It is true, however, that the maximum amplitude that the free vibrations will reach before the input signal is reversed will depend upon the amplitude of such signal at the beginning.

L. C. F. HORLE

I AM pleased that the committee on publications has given me this opportunity to add to the general discussion of Dr. Robinson's paper since my rather completely occupied position as mediator at the discussion following Dr. Robinson's paper did, quite obviously, preclude the possibility of my contributing any technical discussion at that time and I feel that some effort of summarizing the extended and, at times, highly controversial discussion is well worthwhile.

I am afraid that I must admit that neither the lengthy analysis of the action of the "Stenode" nor the demonstration of the device by any means convinced me of the validity of the broad claims of its deviser as made in the delivery of his paper. In so far as the analysis is concerned I must admit that my difficulty in following his explanation, disclosing as it did the action of the device only under transient conditions with the consequent need for constant interpretation in terms of the more familiar and commonly employed "sideband" basis may have caused me to miss such points in support of the alleged characteristics of the device as were made.

Similarly, I can, by no means accept the demonstration of the device as being indicative of the unusual, and to me, as yet unexplained characteristics claimed for the device. There was, of course, evidence of a high degree of selectivity and it may be assumed, similar evidence of compensation of the speech amplifying equipment to accommodate the frequency distortion of the high frequency amplifier. But, certainly, by no stretch of imagination could the quality of reproduction of the device be termed even "fair." There was of course, no suggestion of numerical values of any of the characteristics of the device either given in the paper or suggested by the demonstration. In the case of the latter much doubt was cast on its complete validity by the facts brought out in the discussion, namely, that, in addition to there being no actual demonstration of the frequency difference between the remote transmitter, and the local interfering transmitters no effort was directed at indicating to the membership the relative magnitude of the signal voltages induced in the antennas of the "Stenode" and the comparison receiver by either the remote or the local transmitters.

It is, however, to be noted especially that two significant points were brought out by the discussion and concurred in by Dr. Robinson. These were: First, the fact that the performance of the "Stenode," consisting as it does of a high frequency amplifying system of an unusually high degree of selectivity in connection with a low frequency amplifier properly compensated to accommodate the "sharpness" of the high frequency amplifier, would be duplicated by a combination of a high frequency amplifier of the conventional type having a selectivity of the order of that of the "Stenode" along with a similarly compensated low frequency amplifier.

Second: The only basis on which the "Stenode" might be expected to differentiate between sidebands of the carrier to which it was tuned and such potentially interfering sidebands of another and possible closely adjacent carrier lay in the simple and constant phase relationship between the carrier and the desired sidebands and the lack of this constancy and symmetry in the sidebands of the undesired signals with respect to themselves or to the desired carrier.

The significance of this second point escapes me in my efforts to understand its application to the circuits of the "Stenode" but the significance of the first point seems to me to be all important in that it brings within the range of my capacity for consideration the circuits and operating characteristics of the "Stenode." And since, in view of Dr. Robinson's repeated acquiescence to the former proposition, I feel that I need not concern myself with such claims as have been made by others for the Stenode.

I believe that all that was shown in the demonstration needs no other explanation other than the unquestionably high selectivity of the piezoelectric crystal included in the "Stenode" and I certainly feel that the ingenious inclusion of the extremely "sharply" tuned piezoelectric crystal within a high frequency amplifier so as to bring into play the extreme selectivity inherent in such a crystal with the resultant high degree of selectivity of the system as a whole is of utmost importance and must attract to itself further and successful efforts in the adaptation of this scheme to practical radio apparatus.

The use of the crystal in a bridge structure balanced for the non-resonant condition appeals to me because of its simplicity and economy but it is to be borne in mind that there are other arrangements that may be devised for the employment of the crystal as a selective coupling means and it is in the investigation of all of these means for the employment of the crystal and the adaptation of these means to their proper fields of usefulness that further work must be done.

It is my conviction, in contradistinction to the suggestions made by the deviser of the "Stenode," that neither the crystal coupling nor any even more markedly selective device—if such exist—will serve to greatly modify at any early date the broadcast frequency allocation under which the nation now operates—and suffers. Even though the impossible might be accomplished in apparatus design so that closer frequency assignment might be made without loss of fidelity of reproduction, or even though the audience to radio broadcasting might be further reconciled to the elimination of the higher tones in the reproduction of music and speech, the large number of radio receivers now in use and which are, so obviously, considered satisfactory by their users, makes quite impossible within less than ten to fifteen years any such revolutionary alteration of the broadcast pattern as would allow of materially increasing the number of channel assignments within the broadcasting band without more than proportionally increasing the resultant interference.

Dr. JAMES ROBINSON

THERE seems to be an impression from the discussion that the demonstration of the Stenode receiver was given in circumstances which were not accurately specified, and in consequence it is suggested that the demonstration was not entirely convincing to some members of the audience. It is difficult to understand how such a public demonstration can be completely satisfactory to everyone, and all that I hoped to do was to give a general idea of the performance of the Stenode. Had anything further been my intention, no demonstration whatever could have been given, it being impossible to test the apparatus adequately prior to the lecture as the room was occupied almost continuously.

My object was to demonstrate the sharpness of tuning of the receiver and that all modulation frequencies were received without sacrifice. In order to determine precisely the type of response with the Stenode careful measurements which certainly could not be made at the demonstration are necessary. The accompanying curves taken by the Crosley Radio Corporation during their investigation of the Stenode, and reproduced by their kind permission, illustrate graphically the achievements of the invention and answer a number of questions that have been put to me. Fig. 1 shows the selectivity of the Stenode and Fig. 2 shows the overall fidelity. These curves show that with the very great selectivity of the Stenode

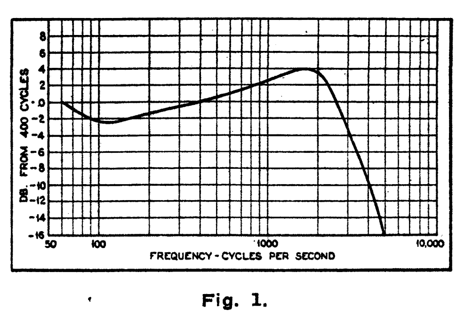

Fig. 1.

the high modulation frequencies are reproduced.

Another object was to show the greatly increased freedom from interference when the selectivity of a receiver is increased and that when the apparatus demonstrated is employed it is possible to receive broadcast stations five kilocycles apart without appreciable mutual interference. For this purpose two local modulated oscillators were employed with their carrier frequencies set five kilocycles on either side of WJZ. It was shown that the Stenode received these transmissions individually without interference whereas a present-day receiver considered to be of extremely good selectivity did not do so. Had conditions allowed it would certainly have been arranged to demonstrate that the field strengths were as nearly as possible identical for the two receivers.

During this experiment the variable balancing condenser in the quartz bridge circuit was first adjusted so that the resonance curve was exceedingly sharp. When the balance position has been correctly set the three simultaneous transmissions can each be received independently but by increasing or decreasing the value of the balancing capacity the mutual interference increases and the larger the deviation from the correct value the greater becomes the mutual interference.

This experiment demonstrates that the sharper the resonance curve the greater is the ability to overcome interference and with the Stenode in its present form it is possible to receive broadcasting stations five instead of ten kilocycles apart without sacrifice of fidelity.

In my paper I have indicated certain reasons which lead to an explanation of the great advance brought about by the Stenode—an advance which cannot be too strongly emphasized. Mr. Cook examines these reasons of mine and apparently comes to the conclusion that they do not yield a satisfactory explanation. He states that the transient nature of the effects cannot lead to any positive difference, and further proceeds to show that we cannot really discuss the phase difference of various components of any modulation when we are considering complicated modulations where many modulation frequencies may be present. If this is true the same remark surely applies to the actual components or sidebands themselves so that we could not really discuss sidebands on such conditions. I am sure Mr. Cook does not wish to draw this deduction. He further dismisses the question of rectification with a few words as having no possible influence at all, and apparently he has overlooked the fact that a strong carrier actually demodulates a weaker carrier. This phenomenon has been discussed in England by Butterworth. When he has taken these effects into account he will not so definitely draw the conclusion that the Stenode does not give better results against interference than a band-pass receiver.

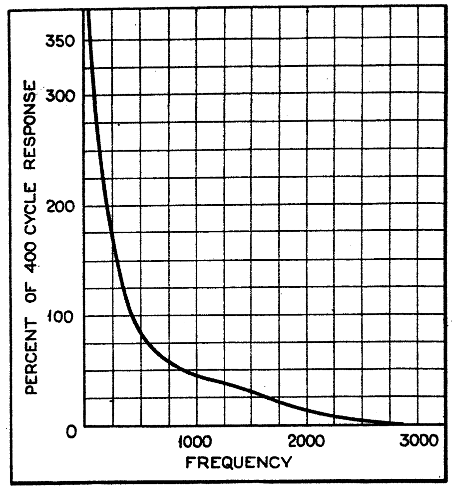

Fig. 2.

Certain other remarks in the discussion of more detail and less importance could be taken up, such as the fact that Mr. Horle states that I advanced the phase difference explanation as the only means of explaining distinguishing between the sidebands of the two stations. Answers to remarks of this type will be obvious from a perusal of my paper.

Mr. Horle states that it would be impossible to place broadcasting stations closer together today because there are so many million receivers which would be unable to separate them. This difficulty can be overcome by arranging that receivers supplied to the public in future provide such desired separation and in due course the stations could then be placed closer together.

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