A Working Paper Draft

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SUPPLEMENT TO ISSUE No. 28-A:

SEMINAR: How Is Your Sociological Imagination?

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SUPPLEMENTARY NOTES FOR SEMINAR: "How Is Your Sociological Imagination?"

Fifth Session, References and Comments

I. References

5A. Colin Cherry, On Human Communication, N.Y.: (1957), pp. 1-51, 217-355. Wiley

5B. John R. Pierce, Electrons, Waves and Messages, Garden City: Hanover House (1956), pp. 243-274.

5C. James G. Miller, "Information Input Overload and Psychopathology," American Journal of Psychiatry, Vol. 116, No. 8, Feb. 1960, pp. 695-704.

5D. Gregory Bateson, Don D. Jackson, Jay Haley and John Weakland, "Toward A Theory of Schizophrenia," Behavioral Science, Oct., 1956, Vol. I, pp. 251-264.

The listing of the above material is useful to show one that there is a growing body of communication theory based primarily on the mathematical theory applicable to engineering problems (physical), but which have analogous phenomena in biological, psychological, and social phenomena.

These four references together form a potential synthesis of certain physical, biological, psychological, and social phenomena which are of relevance in developing cooperation between responsible individuals in our civilization. Understanding the limitations imposed by nature on our behavior should enable us to make a more rational choice of what steps to take to prevent World War III in pursuit of a basic ethical principle such as Albert Schweitzer's "Reverence for Life."

II. The Growing Field of Communication Science

From Ref. 5A, On Human Communication, the following quotations are significant to give us an introduction and outline:

> Leibnitz, it has sometime been said, was the last man to know everything. Though this is most certainly a gross exaggeration, it is an epigram with considerable point. For it is true that up to the last years of the eighteenth century our greatest mentors were able not only to compass the whole science of their day, perhaps together with mastery of several languages, but to absorb a broad culture as well. But as the fruits of scientific labor have increasingly been applied to our material betterment, fields of specialized interest have come to be cultivated, and the activities of an ever-increasing body of scientific workers have diverged. Today we are most of us content to carry out an intense cultivation of our own little scientific gardens (to continue the metaphor), deriving occasional pleasure from a chat with our neighbors over the fence, while with them we discuss, criticize, and exhibit our produce.
>
> Too many of us today are scientifically lonely; we tire of talking continually to ourselves, and seek companionship. We attend Symposia and Congresses, perhaps too many! From time to time since the growth of specialization, broad movements have arisen in reaction to this trend, seeking unity and attempting integration.—Some have lived and prospered; others were stillborn.
>
> There are signs of such a movement today; an awareness of a certain unity of a group of studies is growing, originally diverse and disconnected, but all related to our communicative activities. The movement is rapidly becoming "popular," so great is the desire for unification, and this popularity carries with it a certain danger. By all means let us encourage any tendency toward unity, any attempts to make common ground, but we must continually be critical. The concept of "communication" certainly arises in a number of disciplines; in sociology, linguistics, psychology, economics; in physiology of the nervous system, in the theory of signs, in communication engineering. Awareness of the universal nature of "communication" has existed for a very long time, in a somewhat vague and empirical way, but recently the mathematical developments which come under the heading of the 'theory of communication" have brought matters to a head, and many there are who regard this work as a panacea. True, it has very considerable relevance to these different disciplines, which we shall try to explain in these

pages; but it is not a cure-all. Perhaps, since we shall be discussing this relevance, we had better state a point of view, right at the start, and write it in italics: *At the time of writing, the various aspects of communication, as they are studied under the different disciplines, by no means form a unified study; there is a certain common ground which shows promise of fertility, nothing more.*

The contents of the first two chapters are listed below:

III. A Less Enthusiastic Outlook

The author of reference 5B, *Electrons, Waves and Messages*, in Chapter XIV explains the mathematical and physical aspects of communication theory. The author questions some of the recent attempts to apply information theory to other fields, such as psychology, philosophy, etc.

> As far as I can see, the terms *communication theory* and *information theory* are synonymous. I prefer the former, because it seems to me to imply less. Under one title or the other more nonsense has been written about communication theory than about any other technical subject since the advent of relativity and quantum

theory. Everyone knows meanings of the words communication, information, and theory. When people hear that there is a theory about communication they immediately want to apply it to solve their problems. The problems may lie in philosophy, in linguistics, in psychiatry, in psychology, in chemistry, or in physics. The new theory may or may not be applicable to them. Whether or no, men will speak at conferences and men will write papers. Sometimes the gist of the talk or the text is that communication theory should be applied in some field. Sometimes the lofty strain is merely that communication theory is wonderful.

I know a competent engineer who, having been appointed to speak summarizing a particular conference, could in honesty only say at its end that he hadn't understood a great deal of what had been said. A competent mathematician who attended the same conference reported that many speakers wore rapt expressions and gazed out above the audience as they talked, apparently receiving from on high some inspiration which had not been communicated to him. I myself have read some papers on communication theory which were bewildering and some which were just plain confused.

It is doubly difficult to make sense of the field of communication theory, because it is difficult at this point to tell what does make sense or is the beginning of something that will in time make sense, and what is just wishful thinking. All I can hope to do here is to state some of the very simplest concepts and results of communication theory, and to try to relate them to some commonplaces of the world. Perhaps in doing so I shall indulge in my own particular form of nonsense, but I will try to warn the reader when I find myself on tricky ground.

We have seen that a transmission system is a tool used to transmit signals from one point to another. The signals we transmit are in a sense tools too, or perhaps patterns; they enable us to reconstruct at some distant point a replica of a sound or of a scene. In communication, then, we built apparatus which transmits patterns or descriptions of things that we wish to reproduce. . . . .

In the early days, signals were more or less taken for granted as facts of nature. They had certain band widths; they required a certain fidelity of reproduction, and these requirements were to be met by rather direct means. With the advent of broad-band frequency modulation, engineers were somewhat shaken. During and after World War II, several men began to speculate rather deeply on the nature of signals. What is it that communication systems are asked to send? How can we characterize and measure it, so that we can make valid,

quantitative comparisons between diverse sorts of signals? In 1948 Norbert Wiener published a book, Cybernetics, which had a good deal to say about communication theory. In the same year, Claude Shannon, another mathematician, published a paper, "A Mathematical Theory of Communication," which had even more to say. Shannon's paper, in fact, launched communication theory well on the way it has since taken.

Shannon found a way of characterizing signals by means of a quantity he called the amount of information. Sometimes merely the word information is used as a name for this quantity. The use of the word information in this sense is using an old word to express a very particular meaning, just as in physics force has a very particular meaning, completely excluding its meaning in such phrases as force of circumstance, or forceful delivery, and as, in engineering, stress has a particular narrow meaning which excludes the meanings of the word in he was under great stress or great mental stress. So, in information theory we must regard information as meaning no more than what we define it to mean. If we insist, for instance, that information so used must have or imply meaning, we are trying to carry into communication theory something of the useful but loose connotations of everyday language. In communication theory, amount of information, or more loosely, information, is a particular, quantitative technical term.

In communication theory, information can perhaps be best explained as choice or uncertainty. To understand this, let us consider a very simple case of communication. For instance, if you want to send a birthday greeting by telegraph, you may be offered a choice of sending one of a number of rather flowery messages, perhaps one from a list of sixteen. Thus, in this form of communication the sender has a certain definite limited choice as to what message he will send. If you receive such a birthday telegram, there is some uncertainty as to what it will say, but not much. If it was chosen from a list of sixteen standard messages, it must be one among the sixteen. The received message must enable the recipient to decide which among the sixteen was chosen by the sender.

IV. A Short, Oversimplified Explanation of Channel Capacity

Consider a telephone such as is sketched in Fig. 1. The telephone line together with the repeater circuits used with it has a bandwidth or maximum frequency that can be sent over the

line. The frequency is the number of cycles per second of the sound wave or electromagnetic waves. For example, middle C on the piano is 256 cycles per second. The human voice can be heard clearly if the telephone line passes frequencies between 300 cycles and 3300 cycles, giving a bandwidth of 3000 cycles. A sine wave representing one frequency of sound in air or electric voltage on a telephone line is shown in Fig. 3. If we are restricted to binary signals (two states such as Yes or No, + or -, "one" or "zero"), the "channel capacity" of the telephone line is twice the bandwidth. This is equivalent to opening a small slit window two times every cycle, as is shown in Fig. 3, to look at the telephone signal and then reconstruct the message from these samples.

A sample message in digital form from a computer is shown in Fig. 4. The letters LOVE are coded into a series of ones and zeros. In Figs. 5 and 6, where the message is sent at half and full maximum speed respectively, it can be seen that the message can be received correctly, with exception that errors could occur in Fig. 6 if the timing of the windows slipped out of place.

In Figs. 7 and 8 are examples of 3/2 maximum speed and twice maximum speed. Since the windows open less frequently than the occurence of new signals, many errors occur, except in rare messages where ones and zeros occur in special patterns such as double and triple sets, etc. In Fig. 8 it is shown that out of the 12 bits illustrated, the number of correct ones can vary between one and eight, depending upon the accuracy of the clock used to open and close the windows.

TELEPHONE WIRE

BINARY (YES-NO) CHANNEL CAPACITY

$C_{(bits/sec)} = 2 \cdot B$ (bandwidth in cycles / second)

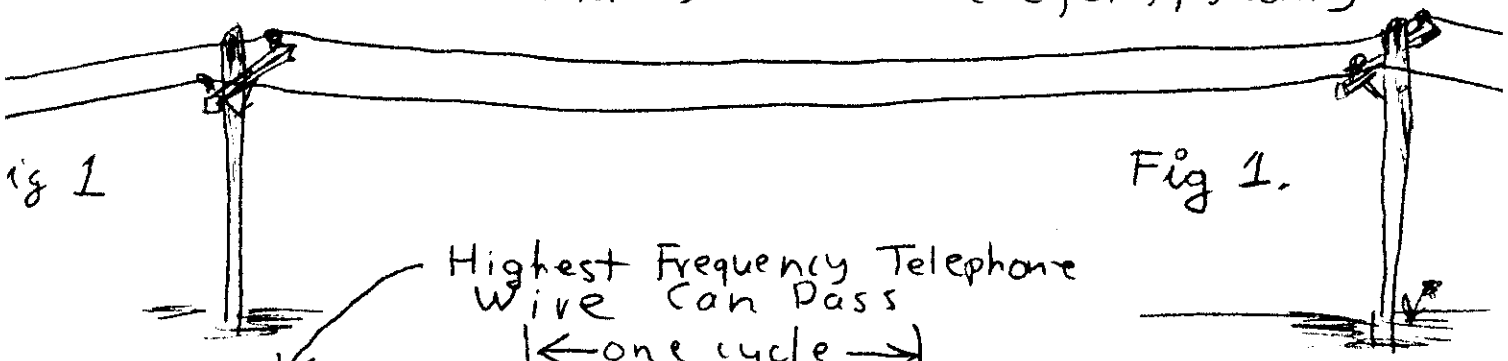

Fig 1.

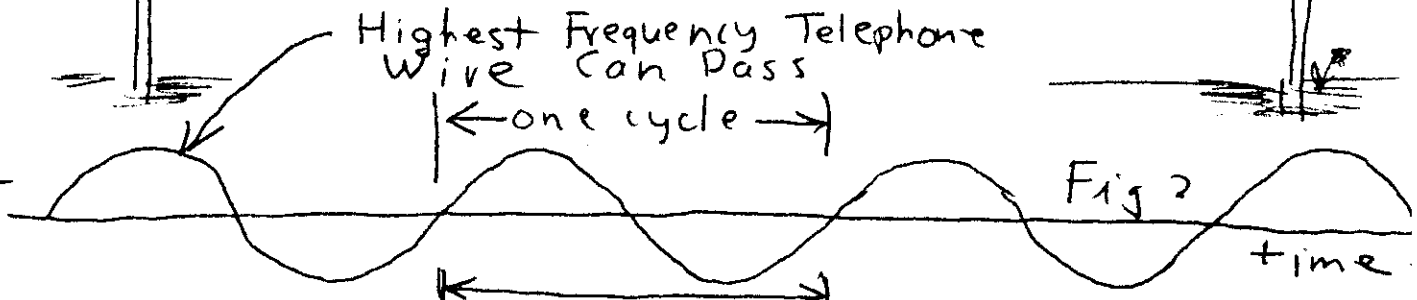

Fig 2

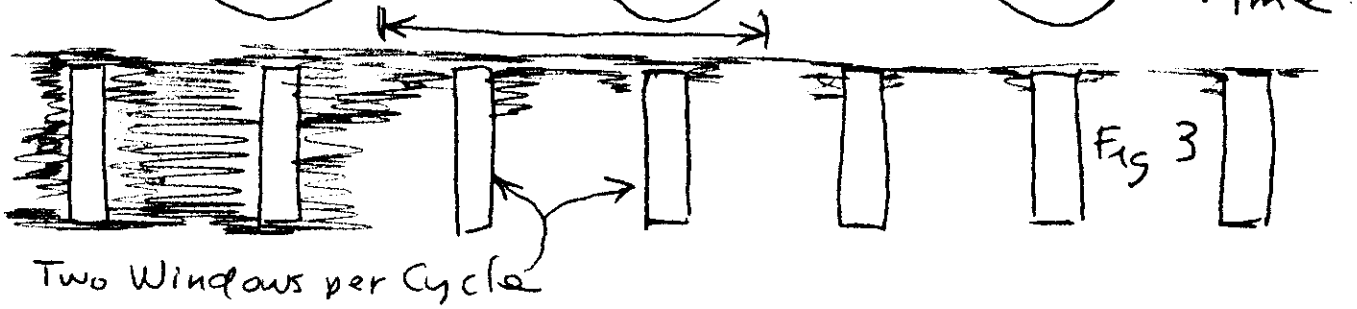

Fig 3

Fig 4
Sample Message

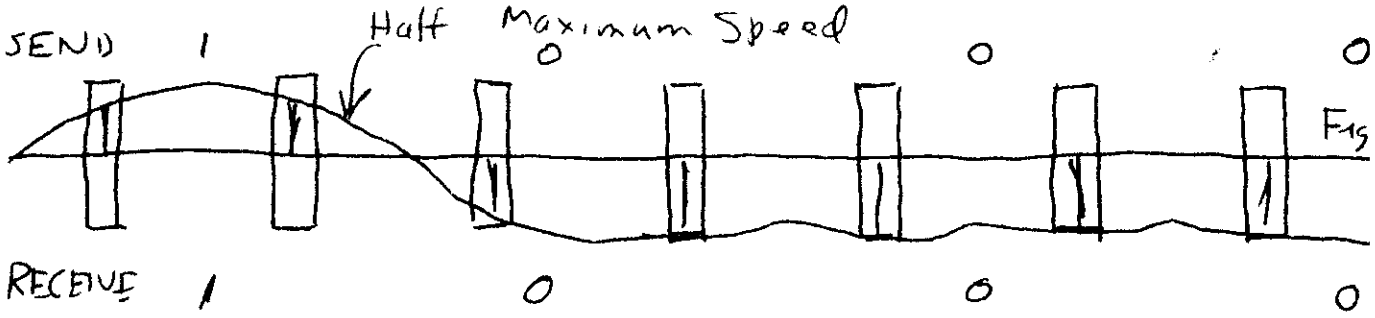

Fig 5
1ST SAMPLE

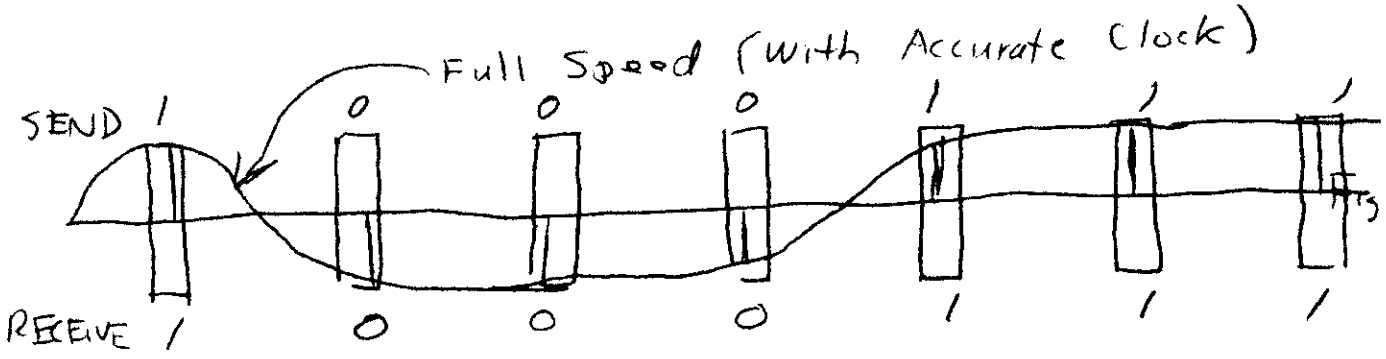

Fig 6
2ND SAMPLE

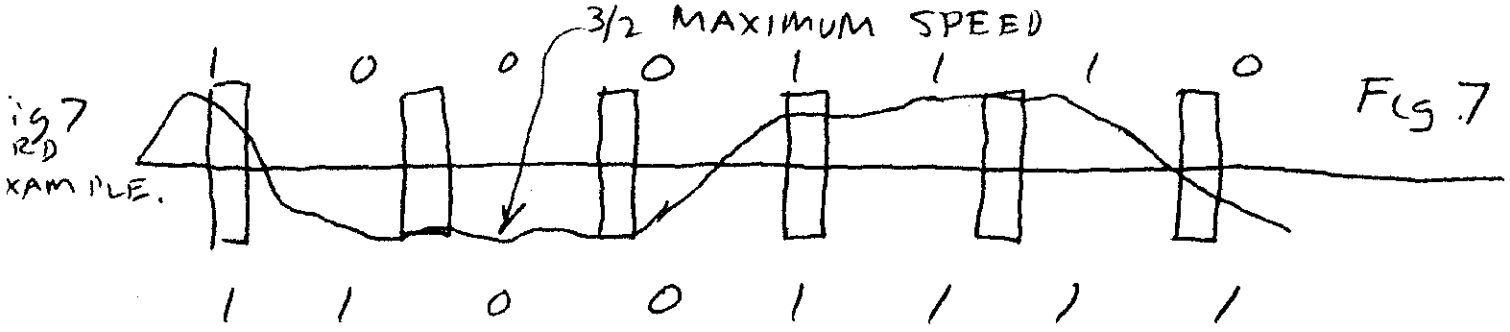

Fig 7

Fig 7
RD
XAMPLE.

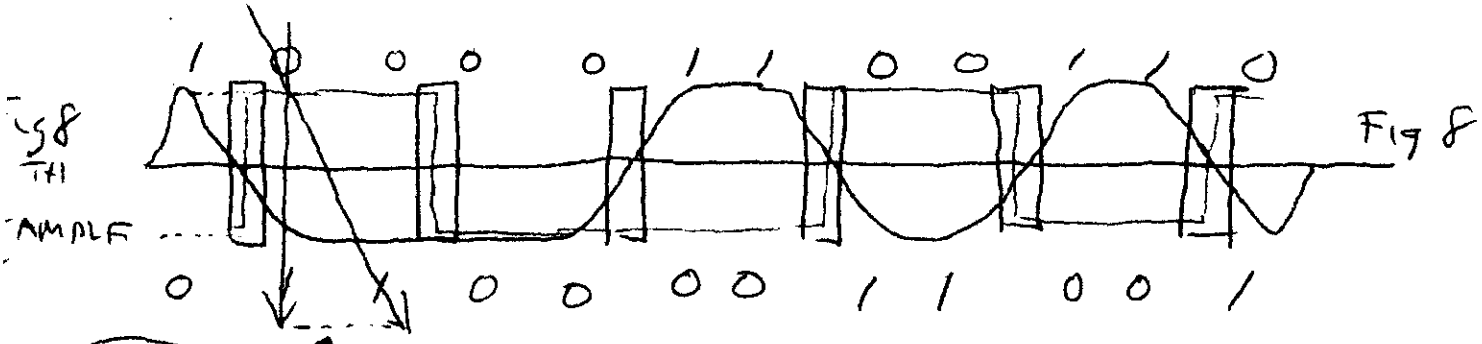

Fig 8

Fig 8
TH
AMPLE

DEPENDING UPON TIMING OF CLOCK
WE HAVE

1	BIT	OUT OF	12	CORRECT
6	BITS		12	
8	BITS		12	

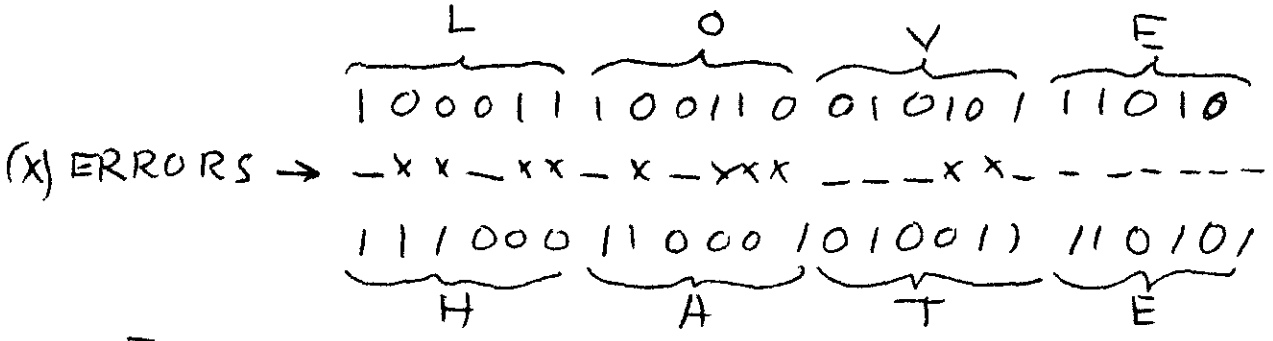

Fig 11

The results of these analyses are plotted in Fig. 9 for Line A, having an accurate clock, and Line B, having a drifting clock. These two curves of OUTPUT vs. INPUT approach the limiting curves.

V. Experimental Evidence of an Analogous Channel Capacity in Human Beings

Fig. 1 of Ref. 5C is replotted as Fig. 10 for comparison with the telephone line case. Examination of the curves shows a remarkable similarity. The similarity does not mean telephone engineers can do psychiatric work, nor does it mean psychiatrists can design telephone lines. The significance lies in two areas:

1. The philosophical significance is that individual engineers and scientists can understand more of science outside of their own special field by use of "information theoretical" concepts like "channel capacity." This should eventually lead to better cooperation between physical and social scientists in advancing our understanding of nature.

2. The impact of the understanding of human channel capacity is that people desiring to push society closer to the ideals of our civilization can make wiser plans which do not exceed the individual's channel capacity. In this way methods of social reform could be reviewed to determine whether they are socially realizable.

The approach to social problems using concepts of "channel capacity" can be described as "information theoretical," being analogous to "information theory" in physical communication circuits.

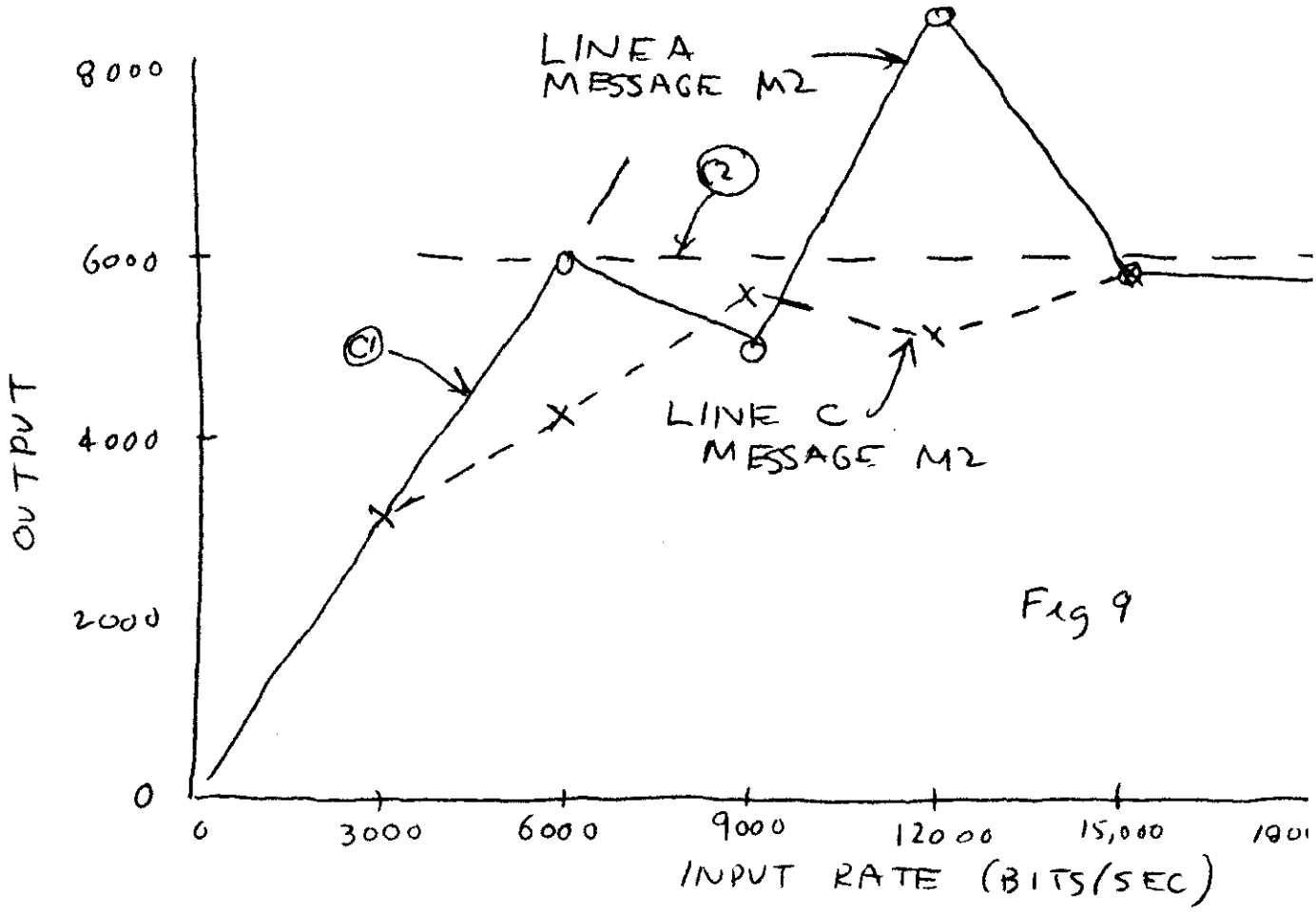
LINE A
MESSAGE M2
C2
C1
LINE C
MESSAGE M2
OUTPUT
8000
6000
4000
2000
0
0
3000
6000
9000
12000
15,000
INPUT RATE (BITS/SEC)

Fig 9

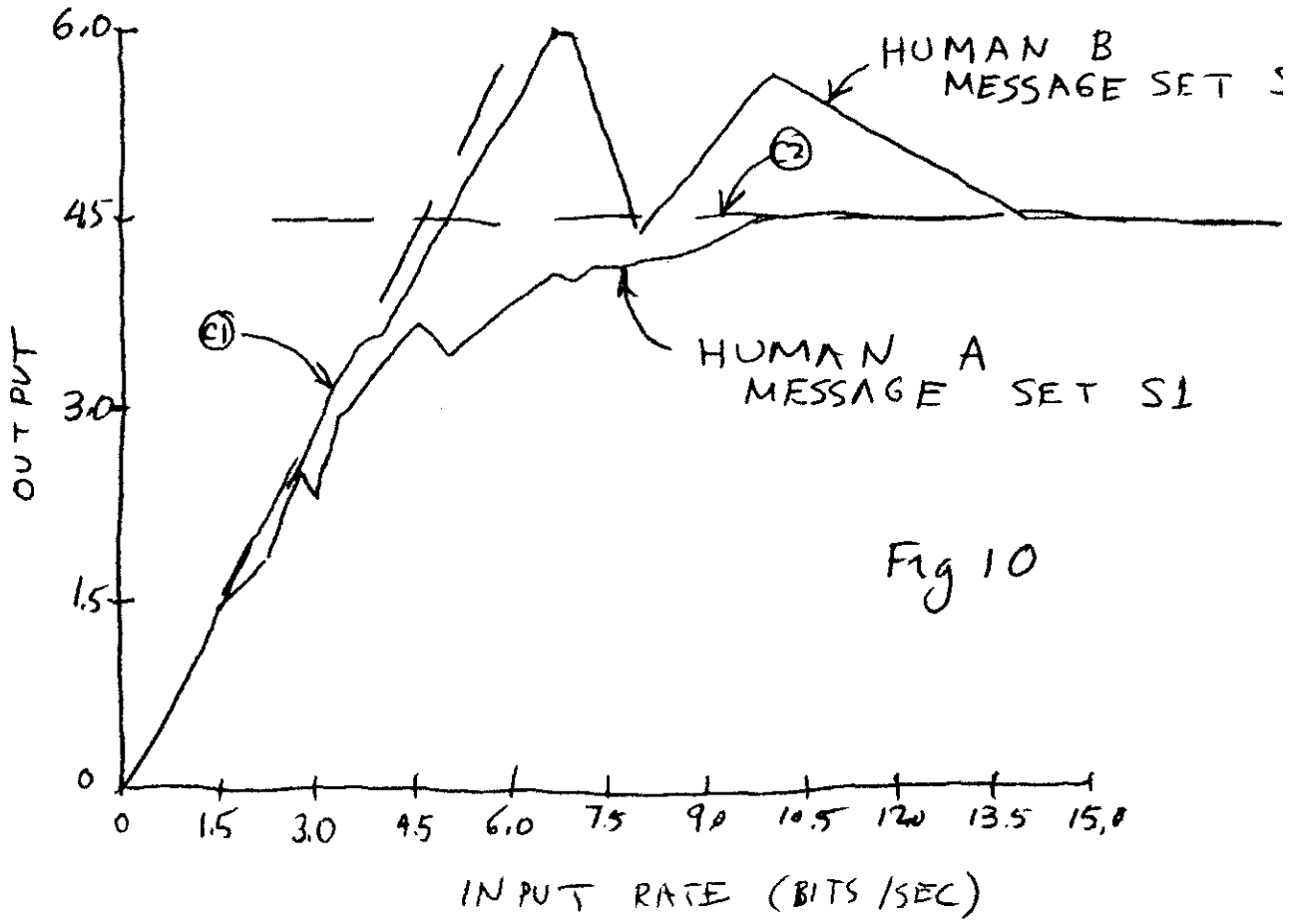
HUMAN B
MESSAGE SET S
C2
C1
HUMAN A
MESSAGE SET S1
OUTPUT
6.0
4.5
3.0
1.5
0
0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0
13.5
15.0
INPUT RATE (BITS/SEC)

Fig 10

VI. The "Cybernetic" or "Negative Feedback" Approach to Human Problems

Ref. 5C, "Toward a Theory of Schizophrenia," describes a "double-bind" situation which in some individuals may accelerate mental difficulties such as schizophrenia. This gives another set of phenomena we must be aware of in trying to do something to prevent World War III. It is suggested that Figs. 3-5 of Socio-Engineering Problems No. 7, Aug. 1959, be used to help visualize the "double-bind" situation described in Ref. 5C.

In emphasizing these "information-theoretical" and "cybernetic" approaches, it should not be forgotten that physical, chemical (drugs), biological (and genetic) phenomena could be very important influences in these mechanisms. The above-mentioned factors may affect the numerical value of the "channel capacity" in the "information-theoretical" approach, and the functioning of the "feedback loops" in the "cybernetic" approach.

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July 30, 1960