SIGNAL-TO-STATIC-INTERFERENCE RATIO IN RADIO TELEPHONY*

By

JOHN R. CARSON

(DEPARTMENT OF DEVELOPMENT AND RESEARCH, AMERICAN TELEPHONE AND TELEGRAPH COMPANY, NEW YORK)

A criterion of fundamental importance in radio transmission is the ratio of the energy levels of the signal and of interference. The object of this note is to discuss the signal-to-*static*-interference[1] ratio in two systems of radio transmission described in a recent issue of these PROCEEDINGS.[2] The first system is known as single side-band transmission and is characterized by the transmission of only one side-band, the other side-band and the unmodulated carrier being suppressed. In the second system, both side-bands are transmitted, either with or without the carrier; both cases will be discussed.

In the propositions stated and discussed below, comparison is made on the basis of equal total energy transmitted or radiated from the sending stations.

I. *The signal-to-static-interference ratio in double side-band transmission with carrier suppression is equal to that in single side-band transmission, if and only if, in the double side-band system* (1) *over-all transmission is effected without appreciable phase distortion of the component frequencies, and* (2) *a local demodulating carrier or homodyne wave is provided at the receiving station which is exactly synchronous as regards both phase and frequency with the original carrier. Neither of these requirements is imposed on the single-side-band system.*

Both the requirements imposed on double side-band transmission in the foregoing proposition are necessitated by the fact that the equality of ratio presupposes that the two side-bands,

---

* Received by the Editor, May 4, 1923.

[1] The word *static* is used in a generic sense to cover random and irregular interference, such as atmospherics, as distinguished from the interference from another station.

[2] "Relations of Carrier and Side Bands in Radio Transmission," R. V. L. Hartley, PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, February, 1923. This paper should be consulted for a description of the systems of transmission dealt with in the present paper.

after demodulation, come into exact phase. Under these circumstances the low frequency energy in double side-band transmission is twice that in single side-band transmission on the basis of the same transmitted energy. The mean interference energy, however, in the former system is twice that in the latter owing to the fact that the receiving system must receive a frequency band of double width.[3] Consequently the ratio is the same in the two cases.

The foregoing statement may be explained as follows. In the *radio frequency* receiving circuits, the signal energy is the same in the two systems of transmission. The interference energy, however, in double side-band transmission is twice that in single side-band transmission on account of the necessity of receiving a frequency band of double width in the former case. Consequently the possibility of obtaining equality of signal-to-interference ratio in the *audio frequency* circuits depends on *demodulating the radio-frequency signal in double side-band transmission with double efficiency* as compared with the interference. At first glance this might seem impossible; however, an examination of the problem shows that this can be accomplished provided the corresponding frequencies in the two-side-bands and the local and original carrier are so related in phase that the corresponding frequencies coalesce into a single frequency of double amplitude in the audio frequency side of the demodulator. This result, however, depends strictly on the requirements stated in proposition I. With phase or frequency fluctuation of the local carrier, the signal and interference are demodulated, on the average, with the same efficiency, giving a signal-to-interference ratio in double side-band transmission just ½ that of single side-band transmission.[4]

A brief consideration, however, will serve to show that the requirements imposed on double side-band transmission with carrier suppression for equality of signal-to-interference ratio are unrealizable in present-day practice and that consequently the inferences to be drawn from the preceding proposition as regards the possibilities of double side-band transmission are erroneous in their practical implications. As regards the first requirement,

---

[3] This statement can be established in a very general way without any assumptions regarding the impulsive character of static. A theoretical investigation of the problem will be published shortly.

[4] To guard against possible misunderstanding on the part of the reader, it should be clearly understood that the requirements stated above have to do with energy relations. It is not implied that any such severe requirements are imposed on double side-band transmission in order to have satisfactory transmission of signal.

over-all transmission without appreciable phase distortion, no data are at hand to estimate the magnitude of this effect. Some rough calculations of wave transmission over sea water make it appear probable that the phase distortion would be small. On the other hand, it would seem probable that the over-all phase distortion, including that occurring in the terminal apparatus might be appreciable in long distance transmission. However, it is theoretically possible to introduce phase-correcting circuits at the receiving station, so that the first requirement, theoretically at least, can be satisfied.

As regards the second requirement, phase and frequency synchronism of the demodulating carrier, the case is different. The only known means of securing this synchronism is by transmitting some of the original carrier.[5] This, however, requires that some of the total transmitted power, in the case of double side-band transmission be assigned to the unmodulated carrier. This is not necessary in single side-band telephone transmission where, as discussed in the Hartley paper, phase distortion introduces no loss in signal energy and inappreciable loss in quality. In fact, an asynchronous homodyne can be employed.[6]

In view of these considerations the following propositions, rather than proposition I, correctly represent the actual possibilities of double vs. single side-band transmission.

II. *The signal-to-interference ratio in double side-band transmission with carrier suppressed is one-half the corresponding ratio in single side-band transmission, when account is taken of the phase and frequency variations from synchronism of the local carrier or homodyne wave.*

III, *The signal-to-interference ratio in double side-band transmission with carrier transmitted is* $1/(1+c)$ *times the corresponding ratio in single side-band transmission, where c is the ratio of the unmodulated carrier energy to the side-band energy in the former system.*

In the case considered in proposition II, account is taken of the fact that the local demodulating carrier or homodyne is inevitably subject to asynchronous variations, that is, departures as regards phase or frequency from the original carrier. This produces on the average a reduction of demodulated signal energy

---

[5] Whether energy is transmitted at the original carrier frequency or at some other frequency from which the carrier is derivable is immaterial to the present argument. The essential point is that energy must be transmitted in addition to the energy of the side-bands.

[6] As stated by Hartley, the case is different in *telegraph* transmission. The conclusions of this paper, as indicated by its title, are limited to telephonic transmission.

to $\frac{1}{2}$ that obtaining when exact phase and frequency synchronism exists. Aside from this loss of energy, it seems probable that this system of transmission is inferior in radio-telephony owing to the fluctuations of energy level as the local homodyne swings into and out of phase.

The case considered in proposition III, where the required synchronism in double side-band transmission is secured by carrier transmission, is the one of most practical importance. In practice, since the carrier should be fairly large compared with the side-bands a conservative figure for c is 2, which gives a relative signal-to-static-interference ratio of 3-to-1 in single versus double side-band transmission. It seems probable that this figure is rather low and that 4-to-1 would more correctly represent the condition actually obtaining in practice.

To summarize, in addition to the very important gain in economy of the frequency range, single side-band transmission enjoys the added advantage of a very substantial gain in the signal-to-static-interference ratio. It is interesting to note that this gain is made possible not only by the narrower transmission band required, but by the fact that it is possible to employ an asynchronous homodyne wave.

Department of Development and Research,
American Telephone and Telegraph Company,
May 1, 1923.

SUMMARY: Several general propositions are stated relative to the signal-to-static ratio, in single and double side band transmission, indicating a superiority in practice for the former system.