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# Why No Receiver Can Eliminate Spark Interference

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WE ARE accustomed to thinking of a radio wave as having a single wavelength, or a single frequency. Such a wave would be produced by an unmodulated antenna current, as represented in Fig. 1a. The current here chosen for an example passes through a complete cycle in one millionth of a second, so its frequency is one million cycles per second, as represented by the single line in Fig. 1b; this frequency corresponds to a wavelength of 300 meters.

For signalling purposes, however, the radiating current must be modulated. In telephony, the modulation is by the voice; in continuous-wave telegraphy, it is by the sending key; while in other systems of telegraphy it is by some tone source in addition to the key.

### Why It Can't Be Done

Interference from spark stations is a subject that becomes of increasing importance with the sale of every broadcast receiver. Why the issue has been side-stepped so thoroughly is a matter of great conjecture. Some of the blame may be laid at several doors, but rather than place the blame, we find the Radio Club of America attempting to seek a solution.

At a recent meeting of the Club, Professor Hazeltine was asked to explain why even the most selective receiver would not eliminate this interference, even though it was receiving broadcasting on a frequency considerably above or below the code station. His most interesting and instructive analysis answers this question thoroughly.

We trust it may act as a stimulus to hasten some action whereby broadcasting and ship to shore radio service will be allotted waves sufficiently different to overcome this serious situation.—The Editor.

### HOW MODULATION OCCURS IN CONTINUOUS WAVES

THE simplest modulation would be that produced by a pure musical tone impressed on a telephone transmitter which controlled the radiating current. This current would then vary as represented in Fig. 2a, where the frequency of modulation is represented as 1,000 cycles per second. (In this figure and those that follow, it is not possible to represent all time intervals to the same scale, as the radio frequency and the modulation frequency differ so greatly.) The effect of the modulation is equivalent to the introduction of two new currents having different frequencies called "side frequencies." The side frequencies are respectively the sum and the difference of the original "carrier" frequency and the modulation frequency, and in the example chosen are therefore 999,000 and 1,001,000 cycles per second. The intensity of the radiation at the side frequencies is usually considerably less than the radiation at the carrier frequency, as represented by the three lines in Fig. 2b.

If the modulation is produced by a musical note which is not a pure tone, as for example the note of a violin, it will have a fundamental frequency and harmonics, which are multiple frequencies such as 1,000 cycles per second for the fundamental and 2,000, 3,000, etc. for the harmonics. In this case two side frequencies are radiated for each harmonic, as 998,000 and 1,002,000 for the second harmonic.

In the voice, or in musical instruments played for a considerable interval of time, musical tones will appear having all frequencies between certain ill-defined limits. Tones whose pitch or frequency is above about 5,000 cycles per second are not appreciable, and this

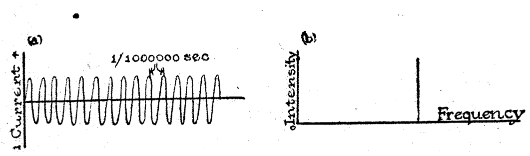


FIG. 1
Pure, unmodulated continuous wave

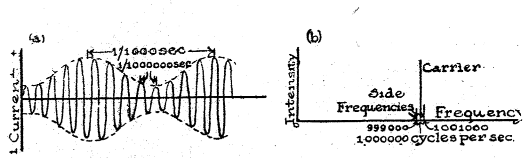


FIG. 2
Continuous wave modulated by pure tone

figure may be taken as a safe upper limit. Hence a 300-meter broadcasting station will radiate waves having frequencies confined between 995,000 and 1,005,000 cycles per second, these extreme values having little importance. Fig. 3a represents such a voice-modulated current; and Fig. 3b represents the relative intensities of the component waves, which consist of the "carrier" and the two "side bands." Broadcast stations whose carrier frequencies differ by 10,000 cycles per second evidently have no overlap in their frequency bands and can be distinguished by sufficiently selective receivers, provided that their signal intensities are not too different.

### HOW A "SPARK STATION" RADIATES ITS WAVE

A SPARK telegraph station, on the other hand, produces a radiating current in a succession of groups, each of which is of short duration, compared with the interval between groups, as represented in Fig. 4a. This is essentially equivalent to modulating a continuous wave by a variation in intensity which rises very rapidly to a maximum, then falls rapidly, and is sensibly zero for a large portion of the group cycle, as represented by the dotted envelope in Fig. 4a. Such a modulation curve is very rich in high harmonics. If the rate of building up of the oscillating current is very high and the decrement is at the legal limit of 0. 2, a wave which nominally has the frequency of one million cycles per second will actually consist of waves of almost uniform intensity ranging from about 970,000 to 1,030,000 cycles per second, and of waves of rather slowly decreasing intensity extending down to very low frequencies and up to a few million cycles per second, as represented in Fig. 4b. Such a wide band of frequencies will overlap a great many broadcasting bands and is the cause of the great amount of interference from spark stations.

### HOW THE RECEIVER RESPONDS TO VARIOUS WAVES

SO MUCH for the transmitted waves. Now let us see how the receiver responds. Selectivity is accomplished by *tuning* the receiver to a certain frequency. But the receiver will respond not only to that frequency but also to neighboring frequencies. The relation between response and frequency with a fixed tuning adjustment is represented by a "resonance curve," of which examples are given in Figs. 5 and 6. (As with the preceding figures, it has not been possible to draw these to scale.) For broadcast reception without sensible distortion of the music or speech, it is necessary that the resonance curve embrace a band of frequencies corresponding to that usefully radiated, as represented in Fig. 3b. On the other hand, the wider the band embraced, the greater will be the tendency to pick up interfering signals and atmospheric disturbances ("static"). For pure continuous-wave telegraph reception a very narrow band is best.

### WHAT MAKES RECEIVERS SELECTIVE

THE shape of a resonance curve and the effective width of the frequency band are controlled in two ways: first, by the ratio of the resistance to the reactance in each tuned circuit; and secondly, by the number of successive tuned circuits.

The effect of changing the resistance of a tuned circuit is illustrated in Fig. 5. The middle curve represents conditions when the resistance of the coil and the condenser are kept low by proper design and construction,

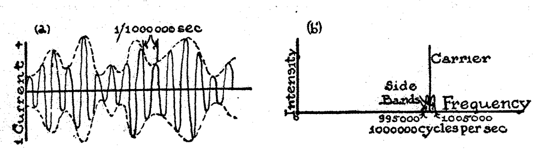


FIG. 3
Continuous wave modulated by voice

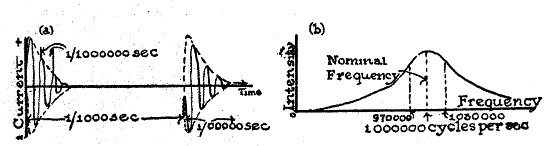


FIG. 4
"Spark" or damped wave

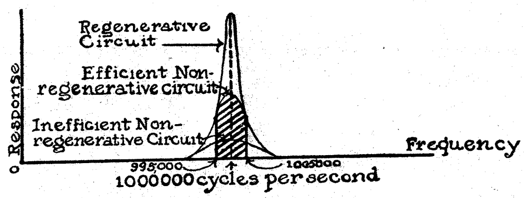


FIG. 5
Receiver selectivity with different resistances

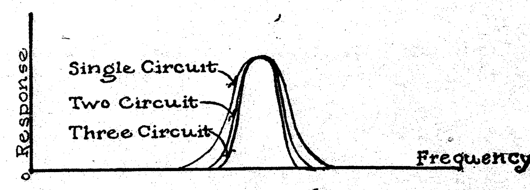


FIG. 6
Receiver selectivity with different numbers of successive tuned circuits

and gives a width of frequency band which covers the broadcast side bands satisfactorily. The moderate dropping off of the curve at the extreme frequencies is not important. The upper curve represents conditions in this tuned circuit when the effect of resistance has been artificially reduced by regeneration, and shows that distortion will thereby result. Here, the components of low audio frequencies (corresponding to radio frequencies very close to 1,000,000) are being amplified much more than those near the limiting frequency. The lower curve represents conditions when the coil and condenser have improperly high resistances. This arrangement gives a lower response to the broadcast music or speech, but the same response to interference as the other curves. It is a fortunate circumstance that for the allotted broadcasting frequencies it is feasible to design coils and condensers so as to nicely cover the frequency bands without the necessity of regeneration; for the use of regeneration is almost certain to be carried too far, resulting in distortion and finally in beat notes or "whistles" when the oscillating state is reached.

### SELECTIVE TYPES OF RECEIVERS

THE effect of changing the number of successive tuned circuits is illustrated in Fig. 6. The single-circuit receiver gives a curve which drops off rather slowly outside the useful frequency band, and so is particularly subject to interference. The curves for the two-circuit receiver and particularly for the three-circuit receiver (which are drawn with the same maximum point, for convenience) drop off much more rapidly outside the useful frequency band, though they do not differ greatly inside. This applies to receivers in which the successive tuned circuits are very loosely coupled, or not reactively coupled at all as in the neutrodyne. When the coupling is close, there is little gain in selectivity over the single-circuit receiver. It should also be noted that "three-circuit" here refers to three successive tuned circuits preceding the detector and not to a receiver having two such tuned circuits, plus a tuned plate circuit for regeneration.

### ONE EXAMPLE OF INTERFERENCE EXPERIENCE

INTERFERENCE from a radio telephone broadcasting station is illustrated by the curves of Fig. 7, and is due to the fact that the response curve of the receiver overlaps the frequency band of the interfering station. This will occur only when the station is very powerful and near-by, or when its frequency is very near that being received, or when the receiver has little selectivity. To minimize this effect, the receiver should be made as selective as possible by employing more successively tuned circuits. In addition, it is frequently helpful to reduce the size of the receiving antenna or the amount of amplification.

Interference from a spark telegraph station is of a different sort and is illustrated by the curves of Fig. 8. It is not usually due to the nominal frequency of the station, but rather to those side frequencies which come within the response band of the receiver. It will be

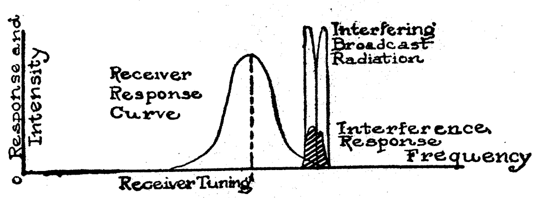


FIG. 7
Interference from telephone broadcasting station

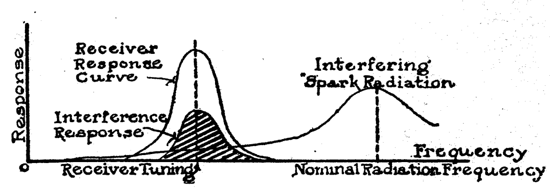


FIG. 8
Interference from spark telegraph station

reduced by narrowing the response band of the receiver as far as distortionless broadcast reception will permit; but this would be done anyhow in a properly designed receiver.

### WHY SPARK STATIONS CAN'T HELP INTERFERING

EVEN if one uses more successively tuned circuits, it won't avail, *because the interfering frequency is the same as the frequency being received*. Obviously we cannot select between two waves which have exactly the same frequency.

Those who have used neutrodyne receivers, which ordinarily employ three successively tuned circuits, have observed that a strong spark station can be tuned in almost anywhere on the dials, provided only that the three dials are set for the same frequency. When the dials are set for different frequencies, usually the spark stations (and also atmospherics) are no longer heard. This is a direct proof that the interference is not caused by the nominal frequency of a spark station, but rather by a portion of its side band.

It cannot be too strongly emphasized that the *interference from spark stations is scientifically impossible to eliminate at the receiving end*. It is also impossible to eliminate at the transmitting end unless the rates of building up and dying out of the spark oscillation can be slowed down so as to correspond with the rates of amplitude variation in modulated continuous waves. Such a result, however, has never been attained by any form of spark oscillator. The solution of the problem of interference from telegraph transmitting stations must therefore be the substitution of continuous-wave transmitters for spark transmitters. The pure continuous wave is by far the most preferable, as the modulation is at a low rate, corresponding to the keying. Modulated continuous waves, however, are not likely to be objectionable if the modulation is not abrupt.