SINGLE SIDEBAND RADIO-TELEPHONY

First Use of the System in Marine Communications

By **H. D. B. KIRBY**

(Standard Telephones and Cables)

THERE has been since the war a general extension of the use of single-sideband operation on long-distance point-to-point radio-telephone links throughout the world. Now the use of this system has been extended to the long-distance ship services with the installation of single-sideband equipment in the new Cunard White Star liner *Caronia*.

What exactly is this system, and what advantages can it offer over the normal double-sideband method of transmission? To answer these questions it is necessary to consider first what happens when a speech wave is used to modulate an r.f. carrier. This has been discussed at some length in previous issues of this journal,[1 2] so it will simply be stated here that the ordinary process of amplitude modulation produces a wave which may be analysed into three groups of sine waves, the upper sideband, the lower sideband and the carrier. If the carrier has a frequency f_c and the modulating signal consists of a number of frequencies between 100 and 5,000 c/s then the upper sideband will comprise a band of frequencies between $(f_c + 100)$ and $(f_c + 5{,}000)$ c/s and the lower sideband frequencies between $(f_c - 100)$ and $(f_c - 5{,}000)$ c/s.

The frequency, phase and amplitude of the carrier remain unaltered whatever the modulating signal, and it therefore contains no intelligence. Moreover, each sideband is, as it were, a mirror image of the other, so that each contains the same intelligence as the other. Consequently the only medium necessary to convey the modulating signal from the transmitter to the receiver is one of the sidebands. Unfortunately, however, although the intelligence is present in the sideband, it cannot be extracted at the receiver without the use of the carrier. In the ordinary d.s.b. system the carrier is transmitted together with both sidebands, and when these are applied to a non-linear impedance in the demodulator stage of the receiver a number of new frequencies are produced among which are the original signal frequencies. In the s.s.b. system the carrier is still necessary for the process of demodulation, but since it does not vary with modulation it can either be generated at the receiver or transmitted at a very low level and amplified separately.

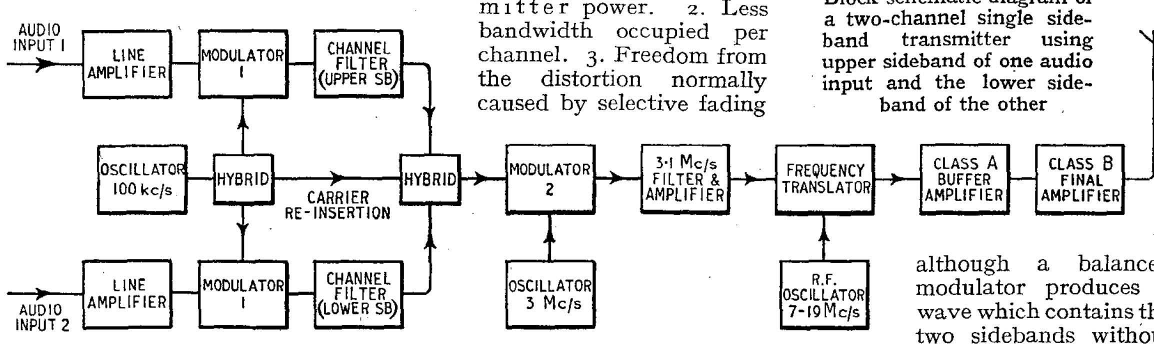
The advantages of the system may be summarized as follows: 1. Improved signal-to-noise ratio at the receiver for a given transmitter power. 2. Less bandwidth occupied per channel. 3. Freedom from the distortion normally caused by selective fading and multi-path propagation. What do these advantages mean in the field of marine radio-telephony?

Since the radio equipment carried on board ship is necessarily limited in size, weight and power consumption, it has been the practice in the past to attempt to improve communication between ship and shore by using more powerful transmitters and more sensitive receivers on land. This is not effective above a certain point, at least in the ship to shore direction, since noise then becomes the limiting factor. By the use of s.s.b., however, it is possible to concentrate the whole of the available output power in the one intelligence-bearing sideband. The effect of this is that the signal at the receiver is equivalent to that which would be received from a d.s.b. transmitter about four times as powerful. This will double the distance at which the level of the received signal will be satisfactory for public use.

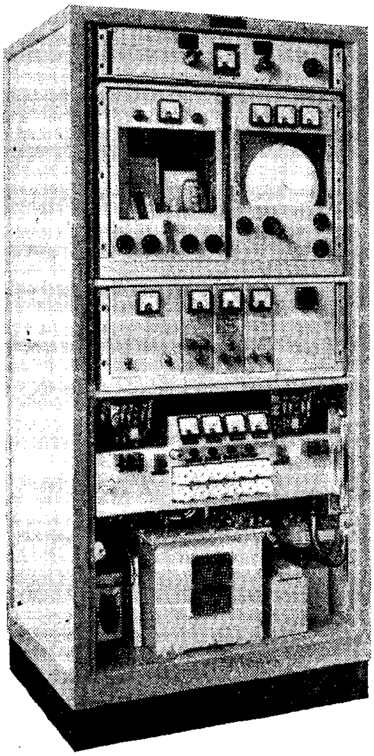
The decrease in bandwidth will reduce the noise picked up at the receiver since it will be possible to tune the filter circuit more sharply. This again will increase the useful range of the equipment.

Thirdly, much of the unpleasant distortion usually caused by selective fading is considerably reduced, so that a link which is quite unworkable on d.s.b. may well provide a reasonable speech circuit under similar conditions with s.s.b. operation.

We do not yet know of a satisfactory method of producing a single-sideband signal directly, although a balanced modulator produces a wave which contains the two sidebands without the carrier. Thus a very simple transmitter could be used to transmit such a suppressed carrier signal, but the receiver would have to be very complicated since for demodulation a locally generated carrier would be required not only of exactly the same frequency as the original carrier, but also of the same phase. Since this would



Block schematic diagram of a two-channel single sideband transmitter using upper sideband of one audio input and the lower sideband of the other be very difficult to produce it is necessary to suppress also one of the sidebands. This is normally done by means of crystal filters.



Single channel sideband transmitter rated at 300 watts as installed in the *Caronia*. It is made by Standard Telephones

The carrier frequencies normally used for long-distance telephone communication are between 2 and 30 Mc/s and the audio frequencies which must be reproduced are between 100 and 5,000 c/s. Thus it can be seen that each sideband is separated from the other by only 200 c/s and that with a carrier frequency of, say, 10 Mc/s the upper sideband filter would have to pass the band 10,005,000 - 10,000,100 c/s, but cut-off at 9,999,900 c/s. Since it would be practically impossible to design a filter to comply with these requirements it is necessary to generate the s.s.b. signal at a comparatively low frequency, convert it to the required frequency for transmission, and then feed it to the aerial through linear amplifiers.

The accompanying block diagram shows a low-power two-channel transmitter. Each audio input after amplification is fed together with the output of a 100-kc/s oscillator to a balanced modulator. Crystal filters select the upper sideband from the output of one modulator and the lower sideband from the output of the other. The two are then mixed, together with a very much reduced carrier, and applied to a second balanced modulator with the output of a 3-Mc/s oscillator. A 3.1-Mc/s filter selects the upper modulation product, which is then mixed with the output of a third oscillator, the frequency of which is variable between 7 and 19 Mc/s. This gives a signal frequency variable between 4 and 22 Mc/s. Three stages of linear amplification are provided at this frequency, negative envelope feedback being incorporated to increase the linearity.

A number of transmitters and receivers for single-sideband operation have been developed by Standard Telephones & Cables during the last few years. The transmitters have output powers ranging from 300W to 40kW, and the receivers vary in complexity according to the facilities required. The 300-W transmitter shown here is self-contained, but the larger ones have separate drive units, which contain all the stages shown in the block diagram up to the 3.1-Mc/s amplifier.

For land-stations diversity reception is normally used to give the best possible quality and freedom from fading effects. Such receivers are necessarily somewhat complex. Those designed for marine use do not include facilities for diversity reception and are therefore considerably simpler and easier to operate and maintain.

REFERENCES:

1 "Sidebands Again," by "Cathode Ray," *Wireless World*, December, 1947.

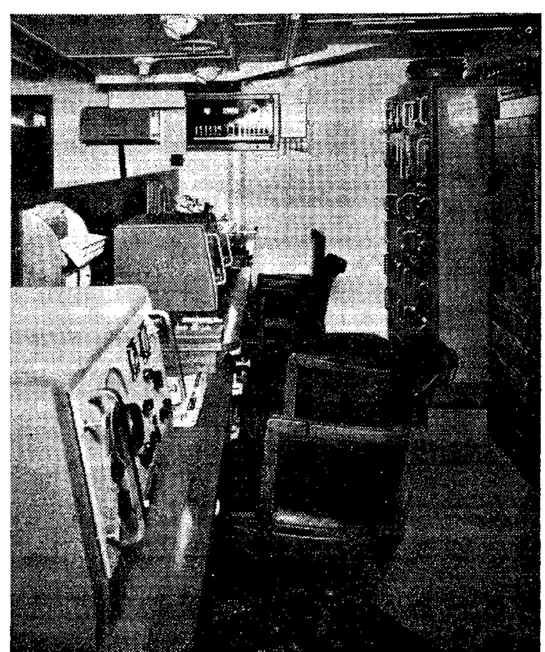
2 "Modulation," etc, by "Cathode Ray," *Wireless World*, July, 1948.

CARONIA RADIO EQUIPMENT

AMONG the other radio equipment which has been installed by the International Marine Radio Company in the *Caronia* is a double sideband high-power transmitter for r.t., c.w. or m.c.w. operation. It will be used for normal telegraph traffic and for supplementary telephone services with land stations not equipped for single sideband working.

This set, the ES4B, can operate on several spot frequencies in each of six separate pre-set channels in the band 1.76 to 22 Mc/s and delivers 300 watts to the aerial on r.t. or m.c.w. and 1 kW on c.w. telegraphy. It is remotely controlled from the receiving room, which adjoins the transmitting room.

There is one other general-purpose transmitter, the type IMR29, which covers 3 to 17 Mc/s



Two of the receiving positions in the *Caronia*. The single sideband receiver is seen in the right rear alongside the telephone terminal equipment

Caronia Radio Equipment

in the h.f. band, 365 to 515 kc/s in the m.f. and 107 to 160 kc/s in the l.f. Radio-telephone facilities are available on reduced power of about 150 watts, the c.w. output being of the order of 400-500 watts.

A 400-watt h.f. telegraph transmitter covering 4 to 24 Mc/s and a complete battery-operated emergency transmitter and receiver, the former giving 50 watts output, and the single-sideband set completes the principal equipment in the transmitting room.

Four main operating positions are provided in the receiving room, two are primarily for radio-telephony and two are exclusively for radio-telephony. Each is fitted with two communications receivers which together cover all frequencies from 15 kc/s to 25 Mc/s. It is interesting to record that for long-wave reception, 14 kc/s to 500 kc/s, a t.r.f. set is used; the others are superhets.

There is some subsidiary radio equipment on the navigating bridge. It comprises a ship-to-shore r.t. set giving about 200 miles range and operating on 10 spot frequencies, switch selected, in the band 1.5 to 4 Mc/s. Here also is a loop direction finder and two radar sets, a Metropolitan-Vickers "Seascan," giving a coverage of about 30 miles radius, and an Admiralty type 268. All the radio equipment, except the emergency and the IMR29 transmitter, operate from the ship's 220-volt 3-phase a.c. supply.

ELECTRONIC CIRCUITRY

Selections from a Designer's Notebook

By J. McG. SOWERBY (*Cinema Television Ltd.*)

A GOOD deal of interest has been shown lately in the so-called "bootstrap" circuit[1] for the production of a saw-tooth waveform, for use in triggered and single-stroke time bases for pulse examination and photographic recording of high-speed transients. The circuit was widely used in American radar equipment[2] during the war, but has not been so much used in this country. The fundamental circuit is shown in Fig. 1.

The "Bootstrap" Circuit

The valve V_3 is normally kept conducting by the positive bias return of R*g*, and consequently the standing potential across C is only the few volts occasioned by current flowing through the h.t. supply V_1, R and V_3. If a negative pulse (as shown) of sufficient amplitude is applied to the grid of V_3, that valve is abruptly cut off. Immediately C begins to charge up positively taking with it the grid (and hence the cathode) of the cathode follower V_2. The time constant C_kR, is very long compared with RC, and so as the cathode of V_2 moves positively, V_1 is cut off and the charging current is transferred from V_1 to V_2. Thereafter a nearly constant potential is retained across R so that the charging current through it is also nearly constant; the potential at A is "pulled up by its own bootstrap." In fact if R_C is very large (and preferably returned to a negative source of supply) C will appear to be charged from a source of approximately μE volts through a resistance of approximately μR, where μ is the amplification factor of V_2.

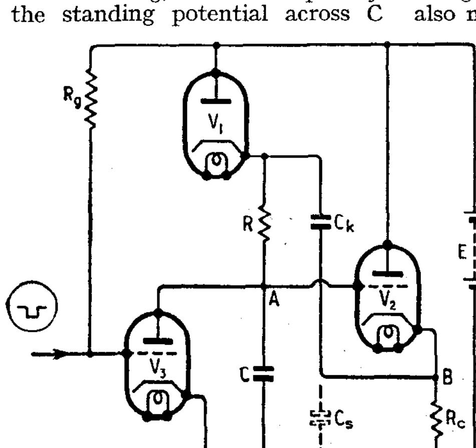


Fig. 1. Fundamental "bootstrap" circuit.

By way of example, suppose we allow C to charge up to 100 volts; let E = 400 volts and μ = 50. Then the apparent supply potential is about 20 kV, and the saw-tooth sweep potential across C will be linear within about 0.5 per cent.

It is obvious that the potential across C starts to rise immediately V_3 is cut off. The potential at the cathode of V_2 follows only after a short time lag needed to charge up the stray capacitance, C_s, between the cathode of V_2 and earth. This lag is determined by the time constant C_s/g_m, where g_m is the mutual conductance of V_2. From this, and the foregoing, we see that V_2 should have both a large μ and a high slope.

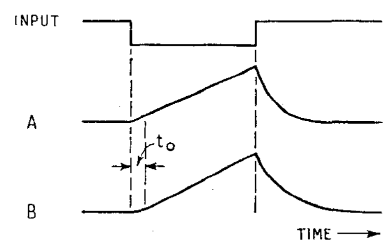


Fig. 2. Showing the potentials at A and B in Fig. 1 in response to a step input.

When V_3 is restored to conduction, C discharges through it, and the grid potential of V_3 falls, taking with it the cathode. However large C_k may be, it will have lost some charge during the sweep period, and this is restored through the diode and R_C in series.

Fig. 2 shows qualitatively the waveforms at A and B related to the input waveform.

The lag t_0 is generally of the order of 0.1 microsecond if V_2

[1] O. S. Puckle, "Time Bases." 1st Edn., p. 94. (Chapman & Hall.)
[2] Soller, Starr and Valley. "C.R.T. Displays," p. 137. (McGraw Hill.)