July 23, 1929. DE LOSS K. MARTIN 1,721,567

MULTIPLEX RADIO TRANSMITTING SYSTEM

Filed Feb. 7, 1928

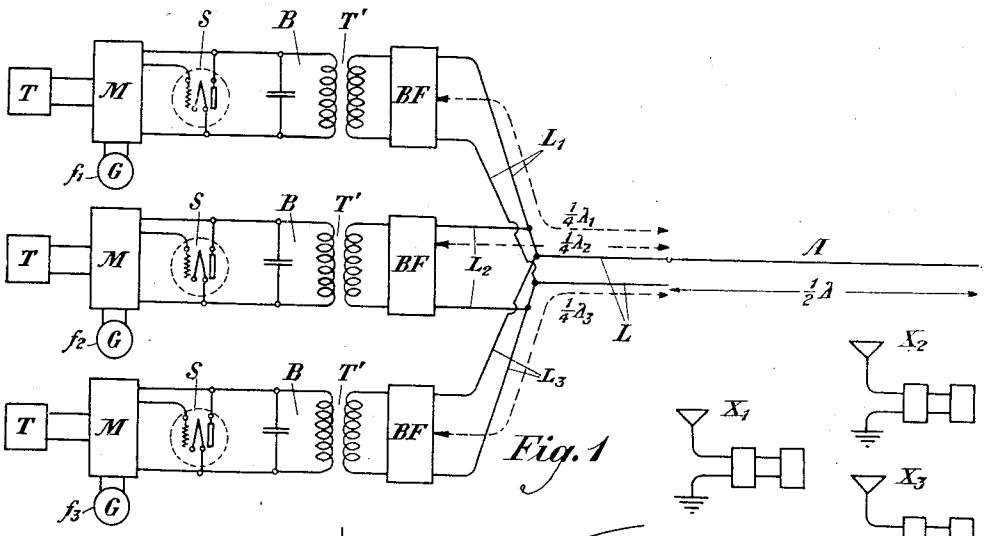


Fig. 1

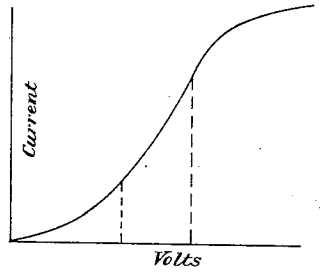


Fig. 2

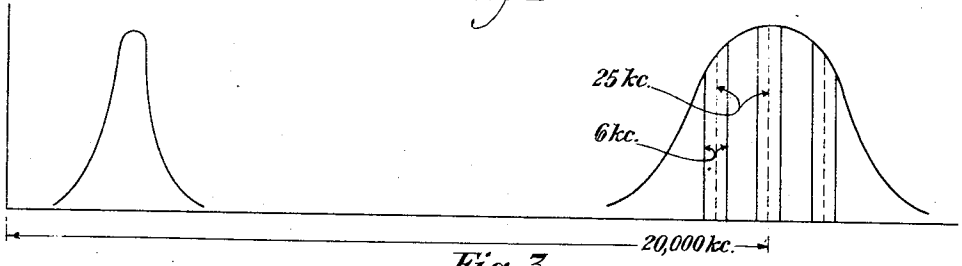


Fig. 3

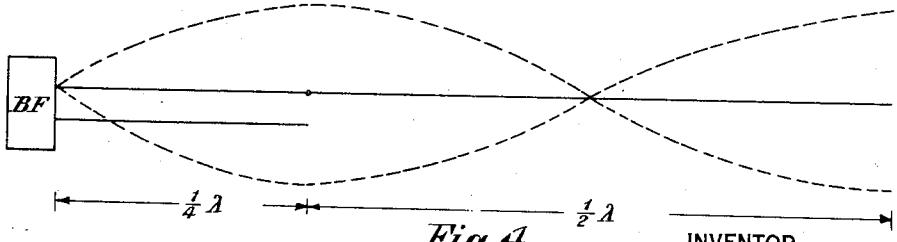


Fig. 4

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MULTIPLEX RADIO TRANSMITTING SYSTEM.

Application filed February 7, 1928. Serial No. 252,475.

It is among the objects of my invention to provide a new and improved system for transmitting several messages simultaneously by radio from one antenna. Another object of my invention is to provide for multi-channel transmission from one antenna with prevention of modulation of the currents originating in one channel by those originating in other channels. Another object of my invention is to provide an advantageous combination of an antenna and a transmission line thereto with branch circuits and filters for multiplex radio transmission. These objects and other objects of my invention will become apparent on consideration of a specific example of practice according to the invention which I have chosen for disclosure in the following specification. It will be understood that this specification relates principally to this particular example of the practice of the invention, and that the scope of the invention will be indicated in the appended claims.

Referring to the drawings, Figure 1 is a symbolic diagram of a transmitting station and a plurality of receiving stations adapted for the practice of my invention; Fig. 2 is a volt-ampere curve diagram for the output circuit of a certain 3-electrode vacuum tube of Fig. 1; Fig. 3 is a resonance-frequency diagram for the multiplex system of Fig. 1; and Fig. 4 is a diagram showing potentials on the transmission line and the antenna.

Referring to Fig. 1, this shows a multiplex signaling system in which the signaling is accomplished by one-way telephone conversations; three channels for respective messages of this character are shown. From each transmitter T, voice currents go to a respective modulating station M. Referring more particularly to the upper part of Fig. 1, the modulating station M has associated therewith a generator G of carrier current of frequency f_1, and this carrier current is modulated by the voice current. As a part of the modulating station M, or associated therewith, there will be one or more 3-electrode vacuum tubes. One or more of these may be ordinary amplifiers which may operate either before or after modulation occurs, and of course, the modulator per se will be one such tube. In any case there will be one 3-electrode vacuum tube which will be the last in sequence and whose output currents will be delivered to go to the antenna, as will be pointed out presently. This last tube of the sequence is represented at S, and it will be seen that its plate circuit comprises the resonant loop B tuned to the carrier frequency f_1. Of course, the tuning is flat enough so that the modulated carrier current will be passed. This current is transmitted through the transformer T to the input terminals of the shielded band filter BF, whose output terminals are connected by the branch line L_1 to the line L. The length of L_1 and L consecutively is $\frac{1}{4}\lambda_1$, where λ_1 is the wave length at the frequency f_1.

Of the two conductors that make the line L, one is left free and unconnected, and the other is connected with an antenna of length $\frac{1}{2}\lambda$, where λ has the value that will be pointed out presently.

The foregoing description has been more particularly for the uppermost of the three channels shown in Fig. 1. Whereas its carrier current frequency is f_1, the carrier current frequencies for the other channels will be f_2 and f_3, and in each case the branch line L_2 or L_3 will be of such length that taken with the line L it will be $\frac{1}{4}$ the wave length for the corresponding frequency. These three frequencies f_1, f_2 and f_3 will be separated at proper intervals along the frequency scale. For example, f_2 may be 20,000 kilocycles, and f_1 may be 25 kc. less and f_3 may be 25 kc. more, as indicated in Fig. 3. The length of the antenna A will be $\frac{1}{2}\lambda$, where λ is the average of the three wave lengths λ_1, λ_2 and λ_3. In the particular case supposed, $\lambda=\lambda_2$.

Each band filter BF will pass a frequency range lying on both sides of the corresponding carrier frequency, such as f_1. Thus, in the specific example heretofore suggested, each band filter may pass a range of 6 kc., with the corresponding carrier frequency lying at the middle of the range, as indicated in Fig. 3. At the high frequencies involved, the elements of these band filters, such as BF, must be shielded, as already suggested.

The resonance curve for an antenna will be broader at high frequency than at low frequency, as indicated in Fig. 3. At comparatively low frequency it might not be possible to get the required separation between three telephone channels without

greatly attenuating the transmission in the extreme channels, as compared with the intermediate channel. But at a frequency of 20,000 kc., for example, the resonance curve will be so broad or flat that the channels can be separated by 25 kc. between their centers and yet the transmission will be nearly equal in all three channels.

Three different receiving antennas X_1, X_2 and X_3 are shown in Fig. 1, adapted respectively to receive on the carrier currents f_1, f_2 and f_3.

Each band filter BF is capable of operating either way as a filter. From left to right in Fig. 1 it will suppress or greatly attenuate currents lying outside the permissible range which we have assumed at 6 kc. Thus, harmonics of the carrier current which might otherwise get out of the transmitting antenna will be suppressed. Such harmonics if allowed to pass would lie in other frequency ranges than that permissible for the station here considered, and would, therefore, be objectionable.

But each band filter BF serves also to stop output currents from other band filters from getting back to the plate circuit of the 3-electrode vacuum tube S. In general, the current-voltage relation in such a plate circuit is not linear, but may be as represented in Fig. 2. Now, if two electromotive forces are superposed in a circuit having such a non-linear characteristic, the resultant currents will not be merely additive but there will be modulation of one current by the other. Hence, if the modulated carrier current of basic frequency f_2 could get around back into the plate circuit carrying the carrier current f_1, the effect would be to modulate the carrier current f_1 according to the message impressed on the carrier current f_2.

Of the three receiving antennæ shown in Fig. 1, that designated X_1 is intended to be non-receptive to messages on the carrier current f_2, but if, as suggested above, the modulated carrier current at basic frequency f_2 could get into the output circuit for the frequency f_1 and modulate the current of frequency f_1, then the receiving antenna X_1 would receive that modulated current; in other words, antenna X_1 would receive the message originally impressed on the carrier current f_2 and to which antenna X_1 is non-receptive directly. Hence, it will be seen that an important function of the band filters BF is in connection with the plate circuits of the 3-electrode vacuum tubes to which the said filters are adjacent, respectively. These filters prevent the message currents in other channels from getting back into the plate circuits and producing spurious modulation of the currents therein.

With the transmission line L_1 of length $\frac{1}{4}\lambda_1$ and the antenna A of length $\frac{1}{2}\lambda$, the combination of these two conductor systems consecutively will have the approximate length of $\frac{3}{4}\lambda$. For currents at the corresponding frequency f_1 there will be set up in this combination of transmission line and antenna a system of standing waves of potential values indicated by the dotted line curves of Fig. 4. There will be a potential node at the middle point of the antenna A and points of maximum potential where the transmission line joins the antenna and likewise at the extreme end of the antenna.

When an antenna is excited at a frequency for which the antenna length is a half-wave length, as in this case, its radiation resistance is about 80 ohms, and to this corresponds the radiation of energy from the antenna into surrounding space. The high impedance terminal of the antenna being connected to the open circuited end of the transmission line gives a proper matching of impedances at this point, and the relatively low impedance of the near-end terminal of the transmission line is matched by the termination of the combined filter unit, for it is an easy matter to design a filter for such a relatively low impedance connection.

I claim:

1. The method of multiplex radio signal transmission from a single antenna which consists in radiating at high frequency from an approximate half-wave length antenna, supplying the energy thereto through an approximate quarter-wave length transmission line, generating the modulated carrier currents of neighboring different frequencies in respective separate channels, and passing them to the transmission line through respective filters to prevent modulation in one channel by the currents of another channel.

2. The method of multiplex radio transmission which consists in generating modulated carrier currents of high frequency in respective separate channels, filtering to prevent modulation of the currents in one channel by the currents in another channel, transmitting the currents after filtering through approximate quarter-wave length transmission lines, and superposing and delivering these currents to an approximate half-wave length antenna.

3. In combination, a plurality of sets of apparatus to generate respective carrier currents of neighboring different frequencies and modulate them according to respective messages, each such set comprising a 3-electrode vacuum tube with a respective plate circuit for the output current from such set, respective band filters each with its input connected to a respective plate circuit, and a common antenna of average half-wave length, and a branch transmission line of quarter-wave length from each filter output to the said antenna.

4. In combination, a high frequency approximate half-wave length antenna, a

plurality of branching approximate quarter-wave length transmission lines thereto, and means respective to the branches to generate and deliver thereto signal modulated carrier currents of basic frequencies corresponding to the said wave lengths.

5. In combination, a high frequency approximate half-wave length antenna, a plurality of branching approximate quarter-wave length transmission lines thereto, means respective to the branches to generate and deliver thereto signal modulated carrier currents of basic frequencies corresponding to the said wave lengths and filters interposed between such means and the branches to prevent currents in one branch from getting back into another branch to modulate the currents therein.

In testimony whereof, I have signed my name to this specification this 6th day of February, 1928.

DE LOSS K. MARTIN.