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NORTH AMERICAN REGIONAL BROADCASTING

ENGINEERING COMMITTEE

SYNCHRONOUS OR COMMON FREQUENCY BROADCASTING

A U. S. NARBEC REPORT

FOREWORD

The following Report on common frequency broadcasting has recently come to the attention of the U. S. NARBEC Member. It is believed that the paper will be of interest to the countries of the North American Region and is submitted herewith as an information release.

Full credit for the Report is assignable to Mr. Glenn D. Gillett and Mr. Joseph Waldschmitt of Washington, D.C.

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SYNCHRONOUS OR COMMON FREQUENCY BROADCASTING

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I. INTRODUCTION:

Synchronous or common frequency broadcasting consists of the operation of many stations on the same frequency in such a manner as to minimize their mutual interference.

The term synchronous is taken to include all attempts at and methods of common frequency broadcasting in which the difference in carrier frequencies is held to a small value and the same program is transmitted. The ideal common frequency broadcasting system, and by ideal is meant the elimination of any distortion effects to the listener, must provide not only identical carrier frequency, but also must reduce the audio delay, relative audio phase shift and audio distortion values within limits that will satisfy the most critical listener.

II. HISTORY:

The history of synchronous broadcasting, which dates back to 1925, has shown continual progress towards obtaining the ideal system. In the United States synchronous operation has been employed for varying periods since this date by the following stations:

WBZ-WBZA	WWDC and Booster
WHO-WOC	WBT and Booster
KFAB-WBBM	WSAI and Booster
WLLH-WLLH	WINX and two Boosters

In Germany and Sweden common frequency broadcasting has been used commercially since 1929. In England common carrier operation, in use since 1929, reached its height during World War II. Nine groups of stations were in operation; each group transmitting on a separate frequency. The largest of these groups had 61 stations on a single frequency.

III. ADVANTAGES:

Some of the principal advantages which synchronous operation offers are as follows:

(1) The most important is that considerably fewer radio channels are required to provide a single radio program service to a large area or population.

(2) Synchronous or common frequency operation provides a simple and flexible method of meeting the demands of future expansion without the serious allocation problems and a disruption of frequency assignments.

(3) It permits optimum use of the best available frequencies. This means that not just one station, but many stations can benefit by the advantages of the most desirable frequencies. For instance, a low frequency channel with its resultant excellent groundwave coverage or a channel having low interference levels can be put to much more effective use.

(4) Synchronous operation provides a better secondary nighttime sky wave service with the signal relatively free from quality distortion and deep fade outs.

IV. BASIC COVERAGE PRINCIPLES:

The basic problem of synchronous broadcasting is that of making the radio frequency differences between the stations very small. Experience and reports show that the carrier frequency difference should be less than 0.1 and preferably 0.05 cycles per second in order to obtain the full potential benefits of synchronization.

The first detailed mathematical study of the percentage of time that the sum of a group of various numbers of radio signals would exceed any given values was given in the paper of Glenn D. Gillett on "Developments in Common Frequency Broadcasting", Proceedings of the IRE, Volume 19, Pages 1347-1369, August, 1931. This paper also included a brief study of the distortion that will result in the area where the signals from the two stations approach the same order of magnitude for varying degrees of modulation and audio phase differences, as well as experimental verification of these theoretical studies. This work was further expanded by Mr. C. B. Aiken in his own paper, "A Study of Reception from Synchronous Broadcast Stations", Proceedings of the IRE, Volume 21, Pages 1265-1301, 1933. This study indicates that a ratio of carrier field intensities of 6 db (2:1) would not result in objectionable interference even for relatively large audio delays, except where the phase of the two RF signals is nearly 180° (the most critical condition). This is to be compared to the accepted standard broadcast co-channel desired to undesired ratio of 20:1. The carrier field ratio can approach 1:1 as the audio delay becomes 0. With a carrier field intensity ratio of 2:1, the effect of audio delays is not important until the audio delay becomes sufficiently large to produce noticeable "echo effects".

It should be noted that when the audio delay is sufficient to provide a noticeable "echo", there is a marked difference in the amount that the average listener will tolerate between the case where the weaker signal or "echo" arrives after the dominant signal and where the weaker signal or "echo" arrives before the dominant signal. Experimental tests have indicated that the tolerance for the "echo" arriving after the dominant signal is some 20 to 25 db's higher than when the "echo" arrives before the dominant signal. This probably is due to the fact that we have no experience in nature with a situation where the "echo" arrives first. Hence, it is disturbing because it is to us unnatural.

Mr. Aiken reports that when there is no phase difference in the audio signal, that for the worst condition, that is when the carrier phase angle is equal to 180° plus or minus 1°, a "change of 0.5 decibels in one carrier amplitude resulted in a very great improvement in quality and 1.0 db reduced the distortion to a mere trace." A change of 1.0 db represents a field intensity ratio of about 1 to 1.1. These figures are likewise substantiated by the reports of WSAI Booster operation, wherein the conditions of synchronization were equally good and the distortion almost non-existent.

A carrier ratio of 2:1 as indicated by the Aiken article has been substantiated by numerous operational tests, and, therefore, is generally accepted as a conservative figure to indicate limits of a distortion zone.

The distortion zones as computed using the 2:1 ratio of field intensities and within which the two signals are very nearly equal do not by any means represent a total loss in service within this boundary. Within this zone, distortion occurs in narrow bands. These bands take the form of spherical hyperbolas which at 1000 kc will be spaced approximately every 500 feet or more. These zones represent locations wherein the RF phase of the two signals is very nearly 180° and equal in magnitude resulting in almost complete cancellation of the carrier. The width of these bands is reduced as the audio delay and distortion is reduced and as the field intensity ratio departs from 1:1. With reasonably good "synchronization" (of frequency and audio delay) the total area of these distortion bands is only a few percent of the area of the possible distortion zone.

It should also be noted that any listener located within the so-called distortion zone can recover either one or the other signal without objectionable distortion by the use of a receiving antenna with a directivity of not more than 6 db. Hence, the theoretical distortion zones are in fact of little significance or practical importance.

Thus, the above studies show that it is possible to reduce the distortion in the worst spots to substantially 0 if the phase angle of the audio programs is maintained identical in reference to the carriers at each of the transmitting stations. This can be done only by transmitting the modulated radio frequency carrier, by either high frequency relay or some other means, for amplification without de-modulation at each of the satellite or subsidiary transmitting stations in the synchronous network. However, the ideal condition can be substantially approached if adequate steps are taken to reduce to a minimum the audio delays at the various transmitters and to keep the phase and other distortion in each transmitter at a minimum.

At night beyond the limit of groundwave service where the secondary sky wave service becomes the controlling factor, the signal from a synchronized network is much steadier than that from an individual station. Thus the time lost through deep fades or drop-outs is markedly reduced and the resulting distortion largely eliminated when a group of stations are operated synchronously. This result has not only been predicted from theoretical probability studies but has also been confirmed by field tests and listener reports.

V. PRACTICAL SYNCHRONOUS SYSTEM:

Synchronous broadcasting involves two distinct problems: (a) the RF synchronization, and (b) the minimization or elimination of the audio delay, relative phase shift and distortion. It is now feasible to secure the necessary RF synchronization by the use of very highly stable, free-running oscillators which are periodically checked and corrected. The maintainance of synchronization by means of a control frequency transmitted by wire lines over long distances is subject to some difficulty on account of transient phase shifts. In such cases a large degree of filtering or storage of frequency control is required. As a result of World War II, oscillators of sufficiently high stability to provide satisfactory synchronization without correction over long periods have been made available commercially.

Where it is feasible the preferred method for providing carrier synchronization is the transmission of the modulated carrier by high frequency relay with its amplification and re-radiation without de-modulation at the secondary stations. This provides a perfectly synchronized carrier with side bands correctly phased in reference to the carrier with negligible distortion at any point in the area served.

Another method for providing carrier synchronization is by the transmission of the carrier or a submultiple thereof by high frequency radio relay, low frequency relay (England) or as a difference frequency, by wire line carrier.

The audio delay, relative phase shift, and distortion may become a problem if the program to be broadcast is carried from station to station by telephone facilities - particularly if cable is used. Mr. Plotts, reporting on the operation of WBBM-KFAB (Bib. ref. 11), states that audio delays of 0.005 seconds (5 milliseconds) were noticeable, that slightly longer delays affected the quality of the transmission, and still greater periods of delay appeared as echos. With regard to tolerable relative phase distortion, tests indicate that high frequencies in the range of 5000 to 8000 cycles should not suffer delays more than 5 to 10 milliseconds greater than the delay suffered by frequencies of about 1000 cycles. However, low frequencies, for example 50 cycles, may be delayed as much as 75 milliseconds more than those in the neighborhood of 1000 cycles without noticeable deterioration in quality.

The RF propagation method for maintaining the RF synchronization discussed above, using either the common frequency or high or low frequencies, eliminates the audio delay problem, and can be made to minimize the relative phase shift and distortion problem by virtue of the very high velocity of propagation, namely 186,000 miles per second.

Another method for reducing the audio problems is by the use of carrier telephone. The use of carrier telephone minimizes the audio delay and phase shift equalization problem due to the fact that the velocity of propagation on telephone lines approaches that of light at carrier frequencies. The delay equalization problem is not as severe due to the fact that audio modulation on the carrier represents only a small percentage frequency difference and the relative phase shift characteristic is small and is linear.

These audio problems can be compensated for by the use of the proper audio circuits or networks located as required in the system.

Practical receiving antennas tend to eliminate the distortion for two reasons: (a) They can be used to discriminate against one station over the other because of directional properties, hence changing the carrier ratio of 1:1; and (b) they will physically extend outside of the narrow distortion band sufficiently to greatly reduce carrier cancellation.

VI. CONCLUSIONS:

Synchronous or common broadcasting has been proven to be a simple and practical means of providing a single program to large areas by the use of one frequency channel. It, therefore, provides great economies in the use of the radio spectrum. The distortion zones can be reduced to a negligible amount by employing existing techniques and commercially available equipment.

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