Split-Channel Radio:

- ***The new frequencies and requirements for split-channel radio operation***
- ***Problems involved in the new operation***
- ***Suggested procedures to follow in changing to split-channel operation***

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EDITOR'S NOTE: This paper was presented by Mr. McCall at the Communications Section convention in Kansas City on May 13-15. The FCC has assigned a block of frequencies based on split-channels for railroad usage, and the Committee 4 of the Communications Section has sent a new frequency assignment plan for the new band to the railroads for review. Most railroads have approved the plan, although in some cases with changes in assignments. It is expected that the plan will be filed with the FCC by June 1. Therefore, because of the great interest in split-channel radio at this time and its importance, Mr. McCall's paper is presented below in practically complete form.

LET US SEE what we mean by split-channels. The present allocations in the railroad radio frequency band are based upon 60 kc spacings. In other words, primary frequencies of allocation have been set up 60 kc apart starting with channel 1 at 159.51 mc and continuing every 60 kc to channel 39 at 161.79 mc.

Based on the new FCC rules and regulations, the allocations will now be made on a 30 kc spacing instead of 60 kc. Hence the term "split-channel" since the old 60 kc spacing did not have a station interspersed at the 30 kc point. Obviously, this takes our original 39 channels and doubles the number of channels to 78. The total number of channels were more than the railroads were able to justify for their exclusive use. As a result, the railroads have been allocated 45 channels which were retained in one block and do not have other services interspersed. Perhaps you do not realize the advantage of this, since your interference problems, if any, are strictly of your own making and under your own control. If other services were interspersed within your block of frequencies as we find in other services, your interference problems could be of great magnitude.

Band on 30 Kc Spacing

The new frequency band on the basis of 30 kc spacing now begins at present channel 13, 160.23 mc and continues to present channel 35, 161.55 mc. As you will notice, frequencies at the low end of the original allocations and frequencies at the high end of the original allocations have been deleted. Obviously this calls for reallocation of railroads whose present operating frequencies fall outside the new band. It also requires changes in equipment of those railroads who do not change frequency to meet the new requirements of split-channel operation.

In order to better discuss the problems we will encounter, let us change our thinking from frequency allocation to terms of band width. Under the old system of 60 kc channel spacing, we were allowed a transmitter deviation of plus or minus 15 kc which determined our band width. This is a band width of 30 kc total. Since all deviation controls permit a certain amount of splatter beyond the point at which they are supposed to stop, the FCC have always had a guard band which is in addition to your 30 kc band width, to keep your transmitter from interfering with the station on the next 60 kc channel. This guard band we can ignore in our consideration of split-channel.

On the basis of the new 30 kc allocations we now have a deviation of plus or minus 5 kc or a total band width of 10 kc. A guard band is also set up by the FCC in this case, but as I said before, is not of concern in our discussion of split-channel.

Narrow Band Performance

What happens when you change a system from a 30 kc band width to a 10 kc band width; in other words from the present 60 kc allocation to the 30 kc allocation? This is commonly referred to as wide band for the 60 kc allocation and narrow band for the 30 kc allocation. Technically, tests indicate that the change from wide band to narrow band results in some degradation of performance. Actually this difference in performance is so slight that it cannot be noticed in normal operation. It was my original intention to have recordings of standard wide band operation and then the same recording of narrow band operation. The recordings were to be based upon a mobile unit in close proximity to a base station and then a mobile unit on the fringe. Actually there was so little difference in performance of the two systems that the difference caused by the location of the mobile unit was greater than the change between wide band and narrow band. Therefore the recording idea was dropped. Suffice it to say that in listening tests you would generally be unable to tell the difference between a wide band and a narrow band system.

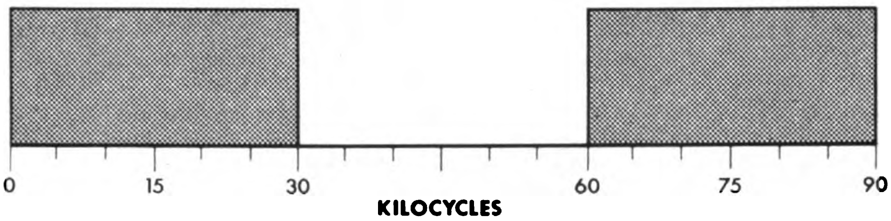
Transmitter Conversion

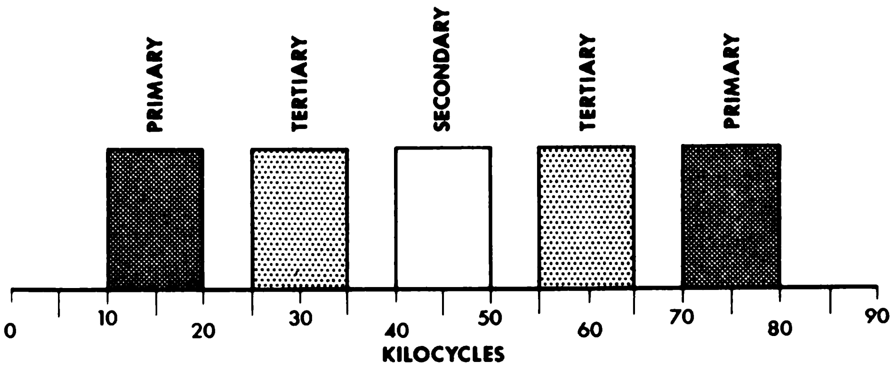
Now, what problems do we encounter when we go from a wide band to a narrow band system? Well, to analyze this let us look first at the transmitter. The first requirement we find on the transmitter is one of increased frequency stability. The present FCC allocations on the basis of 60 kc band width permitted a frequency devation from your assigned frequency of plus or minus .005 per cent. When you are required to change to 30 kc allocation, the frequency tolerance is much more stringent and has been set at plus or minus .0005 per cent. Obviously you must stay closer to your assigned frequency since the adjacent stations are closer to you and since your receiving equipment will now have a narrower band width. Such a change will necessitate improved crystals, in most cases heater crystals and possible improvement in the oscillator circuit of the transmitter, depending upon the manufacturer and age of the equipment.

Deviation Is Changed

It will be necessary to change deviation from plus or minus 15 kc to plus or minus 5 kc. In most transmitters this is simply a variable adjustment, since all transmitters of adjacent channel design have deviation controls. In some transmitters depending upon the manufacturer and vintage, it will be necessary to add a splatter choke. This is a cutoff filter required by the FCC to limit audio frequency splatter. It is usually an inexpensive item and easily installed. In the case of Motorola transmitters, this choke has been installed in all equipment manufactured since 1956.

EXISTING BAND WIDTH AND SEPARATION





BAND WIDTH AND SEPARATION FOR SPLIT-CHANNEL OPERATION

In the receiver we find similar problems. First of all, the question of receiver stability. Since the receiver is also crystal controlled, it is imperative that the receiver crystal oscillator circuit have frequency stability compatible with the transmitter. Although the FCC is not interested in the stability of the receiver oscillator, since it must work with a very stable transmitter, the drift characteristics of the receiver's oscillator circuit must be at least comparable to the transmitter. Again, heater type crystals are the order of the day and possibly some improvement in the oscillator circuit, depending upon the vintage of the set.

The second and equally as important phase of the receiver conversion is its band width. Receivers operating in the 160 mc range of frequencies in which the railroad bands are found, obtain the greater portion of their selectivity in the IF stages. Since they are double conversion units as a general rule, this IF stage is of a low frequency nature in the vicinity of 450 kc. Adjacent channel equipment in use today operating on the basis of the 60 kc spacings has a 30 kc band width. When we reduce our transmitter to plus or minus 5 kc deviation and obtain a 10 kc band width, in order to get proper operation of the receiver, the receiver band width should also be reduced. It is also necessary to reduce the receiver band width in order to keep your new neighbor who is now only 30 kc away instead of 60 kc from coming in equally as well on your system as your own transmitter. Therefore, some change in the IF circuits of the receiver must be made. The answer to this problem is dependent upon the make of the equipment you have and the age of the equipment. In Motorola's case, it is only necessary to remove the 30 kc filter and substitute the 10 kc filter in order to accomplish the change from wide band to narrow band.

Receiver Conversion

The third phase of the receiver change concerns the recovered audio or the audio volume level. When you reduce the band width of the IF system, the recovered audio from this smaller band pass is not as great as in the case of the wide band system. Therefore, it is necessary to change the discriminator circuit, generally requiring the change of a few resistors, in order to restore it to its original level of audio. This particular change is a simple one. For example, in the Motorola equipment it requires the replacement of five small resistors taking a total of perhaps 15 minutes time.

There you have the major portions of the problem, a change in the transmitter and a change in the receiver. These changes hold true whether we are talking about equipment for engines, cabooses, base stations, portables or automobiles.

Now what about the practical aspects of mixing split-channel equipment and standard equipment or shall we say narrow band equipment and wide band equipment. Suppose you have a wide band system in operation at the present time and you decide to purchase additional equipment. You are not ready, however, to go to split-channel for the whole system at this time. Well, we have customers who have been doing just that. They have been adding narrow band railroad equipment to wide band systems and have been able to operate with a fair compatibility. Now let me not mislead you that this is as good a system as all wide band equipment or all narrow band equipment. It is not, but it is usable and is indicative of some of the problems that you might encounter during a conversion from a wide band system to a narrow band system. Let us analyze what we have under these conditions. First of all, let us take the case of the wide band transmitter which is deviating plus or minus 15 kc or a total of 30 kc band width. This transmitter, received on the narrow band receiver which has an average 10 kc band pass, is bound to sound somewhat bassy and somewhat distorted though it will still be intelligible. As long as the units are in close proximity of each other, so they are not operating on fringe conditions, there should be no problem of intelligibility or volume. At the fringe, however, the wide band deviation would probably be so much greater than the band pass at the nose of the receiver selectivity curve that unintelligible conversation would probably result.

Narrow-Band Transmitter

Now let us take the opposite case, the narrow band transmitter deviating plus or minus 5 kc or a total of 10 kc band width into the wide band receiver. In this case, intelligibility would not be impaired and the only problem would be that the signal would not be loud enough. In fact, it is down about 10 db. In most cases, it is possible to turn up the volume of the receiver and overcome the difference in levels. In fringe cases, the noise level would probably be greater. In other words, the signal-to-noise would be much less than the signal-to-noise condition wherein you had a wide band transmitter. As I said before, however, in order to increase the system and still not buy equipment requiring further conversion this kind of operation can be used and the system not be too greatly impaired.

Recommended Procedures

It is rather difficult to recommend a procedure to make the change to split-channel because of the very great variations between the many systems and the many types of equipment. Therefore, any recommendations will be strictly on a general basis and more "food for thought," rather than actual procedure.

First of all, let us divide our thinking between yard and terminal systems and train or road radio systems. In the first case, most yard terminal systems are sufficiently isolated from the other portions of the radio systems that they can be handled on an individual case. Therefore, your thinking for conversion of any yard system can be confined to that particular system and the problems in converting those particular transmitters and receivers be so arranged materialwise and timewise to accomplish the conversion fairly easily. Of course, the total time for such conversion will be dependent upon the individual problems of the equipment involved and the number of units. I am sure no more time need be taken on systems of this type, since they are easily worked out for an individual case.

Car Inspection Radio

The second type of yard system would be that of a car inspection system. The car inspection system generally consists of portable transmitters and receivers which operate through a relay station consisting of a receiver to pick up the car inspection transmitter and a relay transmitter to rebroadcast this transmission. To give you some "food for thought," consider the fact that the FCC is only interested in the base transmitter and its frequency stability and deviation.

With this in mind, if you have no neighbors on either side of your portable frequency there is no reason why you cannot leave the portable transmitters as they are on a 30 kc band width or in other words, plus or minus 15 kc deviation. This is permissible if the transmitters of the portable units have less than 3 watts output. Since most portables in car inspection service meet this requirement, you can leave them as they are, leave the pick up receiver on a wide band basis, but change the relay transmitter as required by the FCC to narrow band plus or minus 5 kc deviation. Since you now will have less audio signal into your portables, it will be necessary to turn up the volume. To review this, you can operate under this method when the following conditions are met:

(1) There is no assignment on either 30 kc channel above or below your assignment for the portables.

(2) There is sufficient audio gain in the portable units to permit you to turn up the volume.

If these conditions cannot be met, then you must modify your receivers and transmitters in the portables and, of course, modify the receiver and transmitter in the relay station.

Biggest Challenge is Road-Train

The other consideration, that of the train or road radio system, represents the biggest challenge in the conversion problem. This is based primarily upon the number of units involved and the fact that they are generally spread over a large area. A further complication is the fact that an engine operating on one end of the system today may be operating on the other end of the system tomorrow. Where it is possible to sectionalize conversion of this type of system, the problem is reduced materially.

To attack this problem, let us consider first the simplest case:

(1) The system which will stay on the existing primary channel which is now assigned and is made up of equipment which is convertible to split-channel operation. The problems facing this type of system are:

(a) An improved crystal for the transmitter.

(b) Reduced deviation of the transmitter.

(c) The possible addition of the splatter choke.

(2) In the case of the receiver it would be:

(a) Improved oscillator stability if necessary.

(b) Improved IF selectivity through the replacement or modification of the IF portion of the receiver as for example, the replacement of the Permakay Filter in Motorola equipment.

(c) Improvement in the recovered audio by the replacing of a few resistors.

Just how this would be handled would be determined by the length of time required for these conversions. Since I am not as familiar with other manufacturers' equipment as our own, I can only say that in most cases the total time consumed for both conversions in the case of Motorola equipment would be no more than one hour on the bench.

Out-of-Service Procedure

There is the ever present problem of how to get the equipment on the bench and this perhaps is as great a problem as the actual conversion itself. To this end, I have talked to several users of large radio systems who have the following recommendations:

(1) Sectionalize the railroad, if possible, to reduce this problem to the smallest number of units.

(2) One group seemed to think it would be best to modify the transmitters to plus or minus 5 kc and then operate the system this way while a gradual modification of the receivers takes place. This is possible since the difference in volume level between the wide band and the narrow band transmission received on a wide band receiver can be compensated for by the volume control. True this system would not be as good as a total wide band system, but at least it is useable while in modification.

Modify Transmitters and Receivers At Same Time

(3) The other group feel it would be best to modify the transmitters and receivers at the same time taking the total one hour per unit, because it is so difficult to locate the units once they are returned to engines and cabooses. Here the modification would be total on each particular unit and system use would continue on the basis of mixing wide band and narrow band equipment. Here again, we have proved that you are not without communication even though it is impaired by some distortion and some bassy qualities of the voice.

System on Existing Frequency

The second system I would like to discuss would be that system which stays on its existing primary allocation, but has within it equipment which cannot be modified to split-channel operation. This type of system requires replacement of equipment and, therefore, becomes involved in more money and budgetary problems as well as conversion problems. It would seem the best approach to this would be to replace the obsolete equipment with narrow band units and add them into the existing wide band system. The degradation in overall performance is not too great to permit operation of the system for some considerable period of time. Modification of the balance of wide band equipment would then proceed as we mentioned in the first case either on the basis of total change one time or modifying the transmitters and then picking up the receivers later.

System in Deleted Frequencies

The third system presents an ever increasing problem. This concerns the existing railroad radio system operating today on frequencies which have been deleted, but having equipment which is convertible. The problem in this case is one of changing frequencies and converting to split-channel. I do not believe I can give any recommendation which would not be tempered by the individual conditions. Since any change in frequency takes that particular system and breaks it away from the other portions of the system, it is obviously necessary to change both transmitters and receivers at the same time and attempt to operate the system on two frequencies at the same time. The problems in connection with end-to-end, train-to-train, and train-to-wayside come into the picture very fast. One possible solution would be to put two types of equipment in the base station operating on the old frequency and the new frequency. This would always permit the mobile units to have contact with the base station and even an end-to-end conversation could be relayed by means of the base operator to maintain communication while conversion is taking place.

Another possible suggestion in this case is to take segments of the radio system out of operation and actually take time for the conversion. If this is done, it would seem best to change frequency and make the split-channel conversion at the same time.

Radio Outside New Allocation And Equipment Not Convertible

The fourth system would be one operating outside of the new allocation and in addition, having equipment which is not convertible. Obviously, this is the worst and most expensive condition. It would seem best to replace the equipment first before attempting to make any change in frequency. This would mean a double expense, however, since new crystals would have to be purchased when the move is made. Perhaps this idea could be modified by buying new equipment on the new frequency allocation and leaving the old equipment on the old allocation. Again, the cross-over would be made through the base station which would have both types of equipment and by sectionalizing the railroad as much as possible. I am very much afraid this particular solution would have to be worked out by the individual railroads.

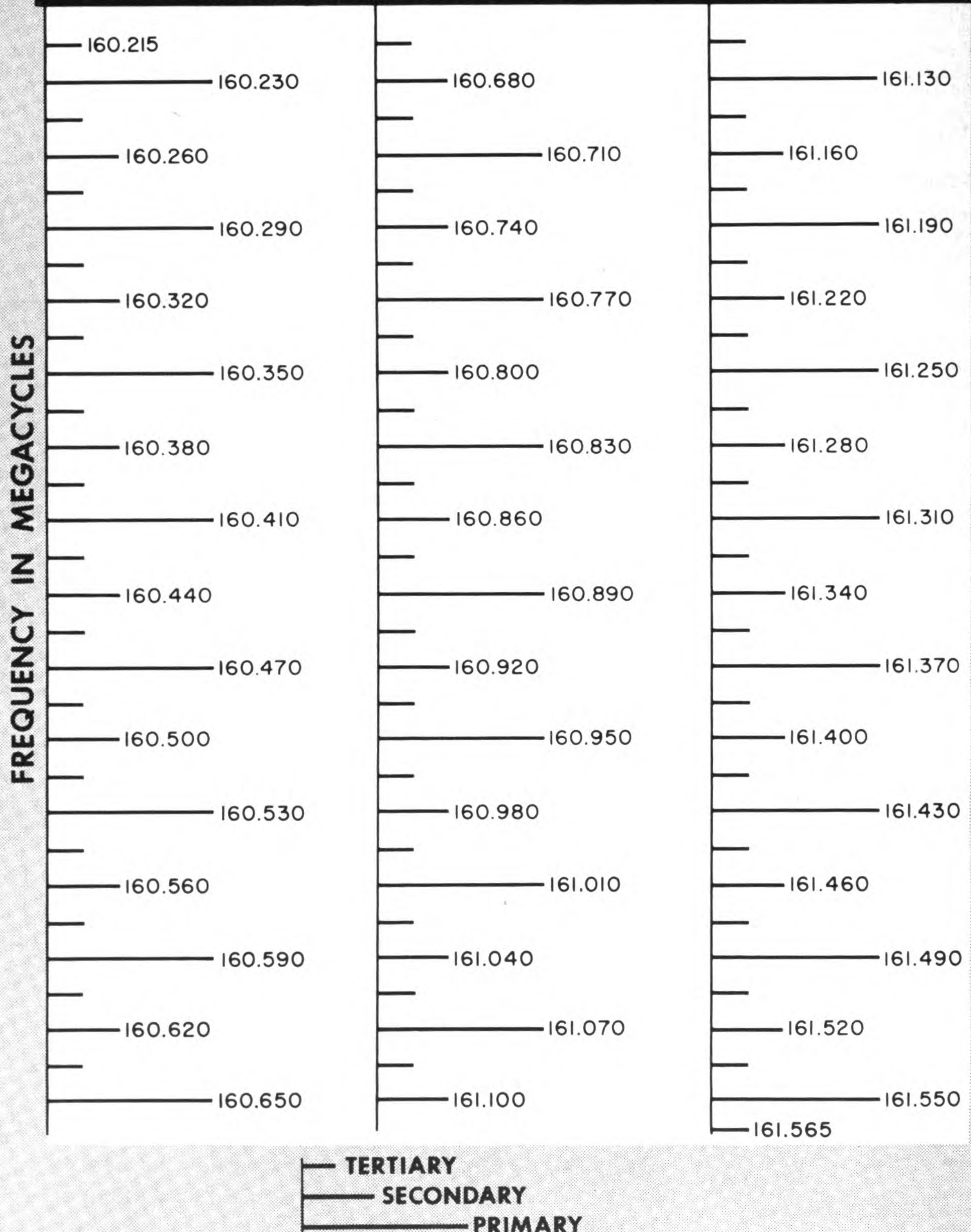
Turn Page for Chart of Railroad Frequencies

The chart on the next page shows the new split-channel frequency allocations as of April 1, 1958, as set up by the Federal Communications Commission.

Use this handy chart for marking down your road's allocations when you receive them. For radio maintainers this chart is an easy way of keeping track of frequencies in use in your area, your own road as well as your neighbor's. File, but don't forget.

File for Future Reference

RAILROAD RADIO BAND
Frequency Allocations April 1, 1958



NOTE:

PRIMARY, SECONDARY AND TERTIARY TERMS ARE FOR IDENTIFICATION PURPOSES ONLY. ALL THREE HAVE SAME BANDWIDTH (10 K.C.), SAME TOLERANCE (0.0005 %) AND SAME MODULATION DEVIATION (± 5 K.C.).