An FM multiplex stereo tuner receives the sum signal in its regular FM section. In addition it has a special multiplex section which picks out changes in amplitude and rejects the carrier. The multiplex section receives the 38,000-cycle note which is getting louder and softer 440 times a second. The 38,000-cycle note is the carrier and is rejected, while the 440-cycle fluctuations in amplitude are picked off as a 440-cycle sound.

**To Sum Up Briefly...**

1. FM multiplex is achieved through transmission of two signals... the "sum" signal (L+R) and the "difference" signal (L−R).
2. The "sum" signal is transmitted by the FM station over its FM carrier, and is received by the regular FM section of the multiplex tuner.
3. The "difference" signal is superimposed on a 38,000 cps tone through Amplitude Modulation and is decoded by the multiplex section of the tuner.
   The "difference" signal starts out as AM, but through the magic of electronics it is received as FM. If you look back at our description of AM broadcasting you will note that the static and poor quality associated with AM occurs only in the carrier part of regular AM transmission.
4. You hear the full range of audible frequencies in thrilling stereo sound.
H. H. Scott explains how Multiplex Stereo works

1. AM radio station transmits left and right signals on a two-carrier basis.
2. Left and right signals contained in separate carriers, neither signal interferes with the other.
3. Multiplex FM receiver suppresses one carrier, left signal is heard in channel A.
4. Multiplex FM receiver suppresses one carrier, right signal is heard in channel B.
5. Stereo amplifier strengthens left and right channels.
6. Amplifier strengthens the weak signal.
7. Amplifier strengthens the signal.
8. Stereo amplifier strengthens the weak signal.
9. Amplifier strengthens the signal.
10. Listener hears the combined left and right signals.

Add, Subtract, and...

MULTIPLEX

On April 19, 1775, by the rude bridge in Concord, Mass., the shot heard 'round the world was fired. On April 19, 1961, from the marble halls of the FCC came another shot heard 'round the world — the world of high fidelity. A system of transmitting stereophonic programs by means of FM multiplex stereo had been approved.

Multiplex, like the weather, has been a topic of conversation for years, and the source of as much confusion and misinformation. This booklet will attempt to unravel the mystery of multiplex for you as painlessly as possible. All discussion will be simple and strictly in non-technical terms, so don't run for shelter at the first sign of an explanation. In the back of the booklet will be found a more technical analysis for the person who likes to understand how clocks and washing machines work. No electronics degree is needed.

Many helpful hints are included to help you obtain fine results. If you take the time to follow these simple suggestions, you will find FM multiplex stereo a source of limitless listening pleasure.
Chapter 1

What's it all about . . .

Multiplexing is a method of broadcasting two or more signals from one FM transmitter. This means that a single FM station can broadcast both the right and left channels of a stereophonic source from records, tapes, or live performances.

In your home you hear stereo . . . the sounds from the left side of the stage from a speaker placed on the left side of your room, the sounds from the right side of the stage from the right, where they belong. Stereo sound is really an aural version of 3-D photography . . . you hear two slightly different sound pictures . . . and get a realistic sound spread across your living room.

Before multiplex, a station transmitting stereophonic program material had to use an FM transmitter for the left channel and an AM transmitter for the right channel. Because of interference problems and limited frequency response found in present day AM broadcasting, this was not an ideal solution. An alternate method was to have two FM stations in a single community share the broadcast. This was feasible, but the listener needed two FM tuners, and the community to find friendly FM stations — two extremely unlikely possibilities. Multiplex eliminates these difficulties.

A single FM station can broadcast both stereo channels. The listener needs only an FM tuner equipped for multiplex plus the usual accoutrements of stereo (two speakers and a dual channel amplifier). Operation is not complex. You just tune to one station as you do now for regular FM broadcasts and you hear true stereophonic sound with all the advantages of FM: freedom from noise, interference, and distortion. At first glance FM multiplex stereo seems like a pretty remarkable feat — two separate signals from one station. Let us see how it is done.

In The Beginning . . .

When you listen to FM through your loudspeakers, you hear sounds, such as music, talk, or even (sigh!) commercials. These sounds result from waves (known as cycles) created by the motion of the loudspeaker cones. If the loudspeaker cone moves back and forth twenty times a second it creates 20 sound waves (or cycles) every second. A 20 cycle per second sound wave would be very deep or low in the bass region.

If the loudspeaker cone moves back and forth 20,000 times a second it creates 20,000 waves or cycles per second. Such a sound would be very high pitched and in the extreme treble region.

Humans are capable of hearing sounds between about 20 and 20,000 cycles per second. Any sound above 20,000 cycles per second is referred to as "supersonic" because it is above the range of human hearing.

Most good FM tuners are capable of reproducing these supersonic frequencies above 20,000 cycles per second ("cps" for short). Though you cannot hear them, these supersonic frequencies are used very effectively for multiplex. At a frequency of 38,000 cycles per second (cps), high above the sounds you can hear, the second (stereo information) signal is added on. While you can't hear this second signal, your FM tuner can, and, if equipped for multiplex, will convert this into sound you can hear — stereo sound.

How FM Multiplex Stereo Works

It would be possible for your regular FM tuner to pick up the left stereo channel of the stereo program, while the supersonic signal carries the right stereo channel. However, this method is not used because the person with a monophonic FM tuner would hear only the left channel, or half of the total material. Instead, a method is used that provides stereo for the listener with multiplex equipment and a full monophonic signal for the listener with a regular FM tuner. (See simplified diagram on inside front cover.)

Fasten seat belts and read carefully . . .

Visualize a symphony orchestra spread out before you on the stage. One microphone is positioned on the left side of the stage and another on the right. The left microphone
The FCC-approved stereo multiplex system permits broadcasters to continue this service. You will not be able to hear the background music with your equipment. This service will be transmitted at a higher frequency and will be added onto the main FM carrier by frequency modulating a separate subcarrier. There should be little or no interference between the stereo subcarrier and the background music subcarrier — a true case where you and the broadcasters can have your cake and stereo, too.

How to set up your FM Multiplex Stereo System...

A. If you already own a stereo console

Many stereo consoles come equipped with FM radios. Most console manufacturers are not recommending or manufacturing adapters to convert these consoles to multiplex stereo. In the few cases where the console manufacturer is providing a multiplex adapter for this purpose, they suggest that you follow his recommendations if you care to invest more money in your console. Remember, however, that the quality of multiplex reception with components will usually far exceed that obtainable with pre-packaged consoles. If you want truly outstanding multiplex stereo reception, you owe it to yourself to listen first to a component system before converting your console to multiplex. With components the value is concentrated in the electronic equipment rather than in the furniture. Specialized companies — like Scott — who manufacture fine components can maintain far higher standards of quality and performance and true dedication to their product. Before investing in any multiplex equipment we suggest that you investigate component multiplex tuners, like the Scott Model 350.

B. If you have a monophonic console

Probably it will not be worth the expense to convert a regular set to multiplex stereo. Here again you will be better off acquiring a component multiplex stereo system and using your present console in another room.
C. If you own a high fidelity component stereo system

If you do not have an FM tuner, add the H. H. Scott Model 350 multiplex stereo tuner, regardless of the manufacturer of the other components. If you have an H. H. Scott tuner, add the Model 335 Wide-Band Multiplex Adaptor (regardless of age or model). All connections are external and can be made in a matter of minutes. The conversion to multiplex stereo reception may be more difficult if you have another make of FM tuner. Other manufacturers will undoubtedly make sincere efforts to provide workable adaptors for the various tuners they have produced. However, for optimum performance, the adaptor must match the tuner exactly in sensitivity, impedance, and frequency response. It is the multiplex subcarrier which provides the stereo difference that creates the stereophonic effect. If the adaptor doesn’t match the tuner properly you will still get sound out of both speakers — but if there is no difference between the two sounds it will be almost pure monophonic sound and not stereo. Your best chance of avoiding this is to choose the adaptor made by the manufacturer of your tuner. If this manufacturer does not provide a good quality adaptor, then your best bet is to swap your tuner for a new FM multiplex stereo tuner.

D. If you do not have a stereo system at the present time

If you are starting from scratch, you will need a complete stereo system, consisting of three parts: the signal source (multiplex stereo tuner, record player, and/or tape recorder), a two-channel amplifier, and two loudspeakers. An H. H. Scott component stereo system is the ideal way to take full advantage of the high quality stereo records and stereo broadcasts that are available.

Why Wide-Band Design is Important in Receiving Multiplex

Even before multiplex, Wide-Band tuner design gave superior reception. The research on VHF FM receivers performed 25 years ago by Major Armstrong, inventor of FM, clearly demonstrated the inherent advantage of Wide-Band circuitry. H. H. Scott perfected the first commercially successful FM tuner employing these fundamentals. H. H. Scott’s Wide-Band tuners have always been capable of reproducing the full frequency range with very low distortion in both soft and loud passages. The exceptional sensitivity of these tuners permitted this performance even with very weak signals. H. H. Scott tuners have also exhibited complete freedom from drift and remarkable ease of tuning. Because of the subtleties of Wide-Band circuitry, most manufacturers continued to produce narrow-band tuners which could give adequate results with regular monophonic FM. It remained for the FCC to point up the superiority of Wide-Band design in receiving multiplex: The FCC-approved multiplex system “...like any multiplex transmission, will increase energy transmission at the edges of the channel involved. Accordingly, for optimum stereophonic reception, the (tuner’s) bandwidth...must be considerably greater than that of monophonic (tuners)...”* H. H. Scott tuners have always had the wider bandwidth needed, and H. H. Scott’s enormous experience with Wide-Band design gives its tuners a clear-cut advantage.

Other Important Features in FM Multiplex Equipment

Whether you are buying a stereo multiplex tuner or just an adaptor, there are certain design features you should look for. The multiplex circuit should be able to separate out the right and left channel without crosstalk between channels. Crosstalk refers to the unwelcome phenomenon

*See paragraph 36, FCC Report and Order, Docket No. 13506, 4/19/61. Emphasis ours.
of having the sound from the right channel creep into the left channel signal and vice versa. If enough of this occurs, you will hear the sound monophonically. It takes elaborate filtering and careful design to avoid this. Sharp cutoff filters are also required to prevent interference between the background music channel and the stereo channel. You will probably want to use FM multiplex stereo as a source for good home tape recording. Unless your multiplex equipment includes special circuitry, your tape recording may produce a series of beats and whistles along with music. If you are interested in doing any recording, investigate thoroughly the equipment you buy to be sure that it has the necessary safeguards.

Noise is a more severe problem with multiplex than with ordinary monophonic reception. The multiplex subcarrier is more prone to pick up background interference when dealing with weak signals, than is the main carrier. A switchable subchannel noise filter is very useful in such cases. This kind of filter would have no effect on the main carrier which supplies the sum of the right and left stereo signals. It would merely act on the subcarrier where the stereo difference is being transmitted. As a result, the use of such a filter would have no effect on the overall frequency response of the stereo program material. This is unlike conventional noise filters which do attenuate the high frequencies of the audible music along with the noise.

It is perfectly possible to design multiplex receiving equipment without any of these features. Conceivably such units would give usable results and would probably sell for less money. The reason most people invest in high fidelity components in the first place is a desire for better quality than that found in conventional equipment. Be very careful where you decide to compromise. With H. H. Scott multiplex equipment, no compromises have been made.

When purchasing a complete FM multiplex stereo tuner, the tuner section itself must also be of the highest quality. One of the surest ways to determine this is to check the manufacturer's specifications for the unit. These should be given according to the test methods outlined by the IFHF (Institute of High Fidelity Manufacturers). These specifications, if honestly stated, will give a good indication of the worth of any product. Other test procedures are generally less accurate and often quite misleading.

Naturally, there is nothing to prevent a manufacturer from basing his published specifications on the hand-built, original engineering model rather than on the minimum guaranteed performance of the poorest production unit.

As in all things, it is always worthwhile to see what company has consistently distinguished itself over the years in advanced engineering, trouble-free production units, and outstanding service and customer relations.

**Antennas for Better Multiplex Reception**

The absence of an appropriate antenna for your particular installation may prevent you from realizing the true potential of stereo multiplex. This is true for two reasons:

1. **Insufficient signal strength.** In many installations a small piece of wire or rudimentary folded dipole will provide all the signal needed for satisfactory monophonic FM reception. This is particularly true when using a sensitive Wide-Band tuner. Unfortunately, a signal strong enough to produce good monophonic listening may not be adequate for stereo multiplex. The solution is to use a better antenna to supply additional signal. If you have been using a piece of wire, you may need a good folded dipole. If you have been using a folded dipole under your rug, you may improve reception remarkably by raising it off the floor. If you are over 30 miles from the transmitter you may need an outdoor roof FM antenna to receive FM multiplex.

![Folded Dipole](image)

2. **Reflections.** In areas with many tall buildings or hills, some of the signal from the transmitter will bounce off these obstructions before reaching your antenna. As a result the signal coming directly to the antenna will arrive a fraction of a second before the reflected signal arrives. In television the reflected signal is referred to as a "ghost"
because of its effect on the picture. In areas with many reflected signals, the solution is a directional antenna...one designed to pick up the signal from one direction only. A very popular directional FM antenna is the "yagi".

Such an antenna is readily available at most high fidelity dealers. With a proper antenna, fine H. H. Scott multiplex stereo equipment will give you years of the highest quality stereophonic reception.

A Promise Fulfilled

FM Multiplex is the missing link in the complete world of stereo entertainment. Records and tapes were first. Now, by adding a multiplex tuner to your system you will be able to hear stereo "off the air" by simply tuning to FM.

This new kind of broadcasting presents a tremendous challenge to the FM station since the quality of the signal they transmit directly affects what you hear. During this change-over period stations will have to obtain and install new equipment. Engineers will have to develop new broadcast techniques. No one expects that this complex procedure will go off without an occasional hitch.

Many of the first broadcasts will be gems...a few will be less than perfect. Over the next few months exploration of the full possibilities of multiplex broadcasting will begin. You will soon thrill to live stereo broadcasts of world-famous symphony orchestras and opera companies...intimate close-ups of jazz in stereo...dramatic presentations with life-like movement. You will hear the wonderful new sound of FM multiplex stereo in your home...and you will be able to tape it off the air for your stereo library.

At last the promise of stereo is fulfilled. Are you ready?

APPENDIX:

How Multiplex is Transmitted

Let's start with a broadcasting station assigned to the 100 megicycle (mc) band. In order to receive this station, you tune into 100 mc. on the dial. Whatever is being transmitted by the broadcasting station (music or talk) will be received. The 100 mc. band (properly called the "carrier frequency") is completely inaudible. What you eventually hear is the signal that has been superimposed on the 100 mc. carrier frequency.

Superimposing a signal is accomplished by making the carrier change in some manner. For example, we can make the carrier get louder and slower. Or we can make it go faster and slower. These various methods of changing the carrier (100 mc. in our example) are known as "modulation".

a) This is a visual representation of the 100 mc. carrier. Nothing is being done to it. It is simply moving along, wagging back and forth 100 million times a second (100 mc.)

b) Now it is being changed (or modulated) by making it louder and softer.

c) Now it is being changed (or modulated) by making it go faster and slower.

*This means that the broadcasting station transmits at an assigned frequency of 100 million cycles per second.
When you make something get louder or softer, you change the amplitude of its sound. Therefore, this type of modulation (see b above) is known as "Amplitude Modulation."

The frequency of the carrier in our example is 100 mc. (100 million cycles per second). If we make this carrier go faster and slower (see c above) we are changing (or modulating) its frequency. This is called "Frequency Modulation."

Let's see how this is done. A man is playing a piano in the broadcasting studio. He strikes a low note which happens to be a 50-cycle-per-second note. If this is an AM station, the 50 cps tone is used to vary the amplitude of the broadcasting station's 100 mc. carrier. The transmitted carrier gets louder and softer at a rate of 50 times per second.

Meanwhile, back at the tuner, the dial has been set to 100 mc. The tuner receives the modulated 100 mc carrier. The tuner is designed to pick out the modulation (information) and reject the carrier. Only the 50 cps tone comes out of the tuner.

Let's repeat the process, this time substituting an FM transmitter. The 50-cycle piano note will make the 100 mc carrier go a little faster and a little slower 50 times a second without varying the amplitude of the carrier at all. The tuner, set to 100 mc., receives the total signal and separates the 50-cycle tone from its carrier.

In both cases the musical tone comes out of the tuner, without its carrier, but on FM it sounds better than it does on AM. One reason for this better sound is that the FM band is not as crowded as the AM band. As a result, FM stations can transmit the full range of audible frequencies (from below 50 cycles to above 15,000 cycles) and not interfere with stations adjacent to them on the dial. Another reason, a true technical advantage, is that FM is much freer from noise and interference than AM. Most static-producing phenomena, like lightning, atmospheric conditions, and machines, mostly affect the amplitude of the carrier but have little affect on the frequency. Since AM works on amplitude, these interferences are heard over an AM radio as static. However, FM does not respond to variations in amplitude — only to changes in frequency. Since this bothersome interference is mainly an amplitude variation you barely hear it on FM.

Now we add multiplex. The signal from the left microphone is added to that from the right microphone (L + R) and transmitted as a regular FM broadcast. Suppose that the sum of the left and right microphones happens to be a 50-cycle note. This presents no problem. The FM station has its 100 mc. carrier go faster and slower 50 times a second, and a regular FM tuner readily receives this as a 50-cycle note.

This doesn't give us stereo. In order to have stereo we need a difference signal (L - R) as well. Suppose a 440-cycle note is the difference signal (L - R). If we superimpose this directly on the carrier along with the sum (L + R) signal we would have a jumble of sounds. What is needed is a way of superimposing this difference signal on the FM carrier without being audible and spoiling the sum signal (L + R). If we could somehow get this difference signal (440 cycles in our example) up in the supersonic range (above 20,000 cycles) it could be superimposed on the FM carrier without any audible effect on the sum signal. A very clever method has been evolved for doing this.

The broadcasting station supplies a 38,000 cycle note, which is high in the supersonic range, well beyond what we hear. The 440 cycle difference signal is used to modulate (change) the amplitude of the 38,000 cycle note by making it get louder and softer 440 times per second. This amplitude modulated 38,000-cycle note is added to the FM carrier along with the sum (L + R)*. The regular FM listener receives the sum signal, which he can hear, and a 38,000-cycle note fluctuating in amplitude 440 times a second which he cannot hear.

*This is a somewhat simplified explanation of what is actually a suppressed carrier system. For a complete technical description by one of the world's leading authorities on multiplex, Daniel von Recklinghausen, write to H. H. Scott, Inc., Technical Services Dept., 111 Powdermill Rd., Maynard, Mass.