

THE G-E

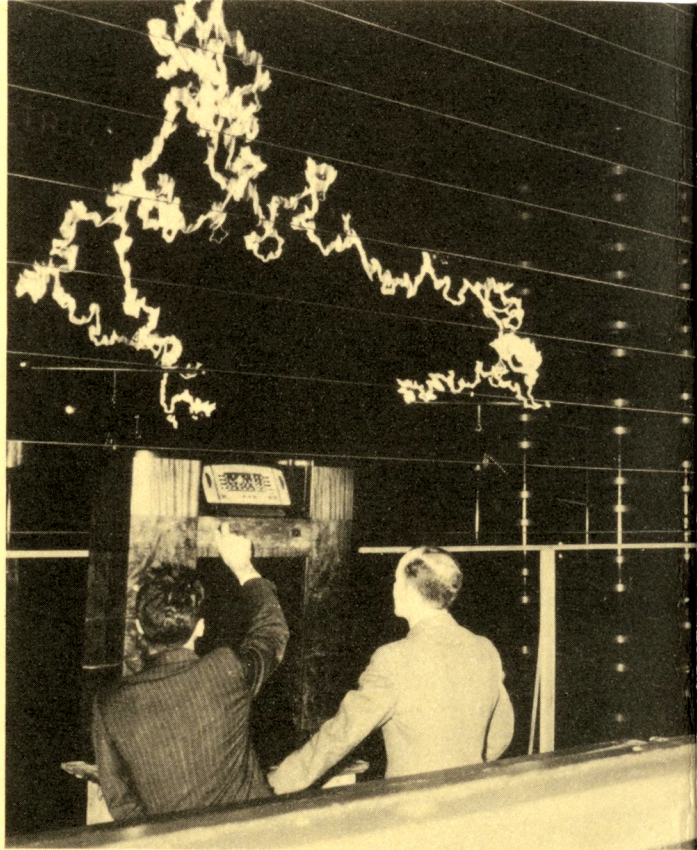
F*requency* **M***odulation*

PRIMER

GENERAL



ELECTRIC



PEOPLE visiting the General Electric exhibit at the New York World's Fair were amazed—not a crackle of static came from this G-E FM radio even though powerful bolts of man-made lightning were released just a few feet away!

THE G-E FM PRIMER

Since the beginning of radio, engineers have endeavored to improve broadcasting and reception so that you may have the program in your home with the same beauty and realism it has when you hear it in a concert hall.

People have become so accustomed to hearing music on the radio that they accept what they hear as realism. But, if you could listen to a concert in an auditorium one minute, and the next listen to the same concert on the radio in your home, you would realize that what you had come to accept as the real thing is only a fair imitation. Something is lacking.



Our purpose is to explain in a simple manner how Frequency Modulation—FM for short—a new system of radio broadcasting, comes very close to the ideal of giving you a seat in the broadcast studio without leaving your home.

Before we explain FM, let us see what sound is.

A SOUND WAVE COMES TO LIFE



When you pluck a string on a musical instrument, you can see the string vibrate. These vibrations set up air waves which travel in all directions, just like the ripples caused by dropping a stone in a pond.



When these air waves reach your ears, you hear the sound.

Now remember this: Sound is composed of: 1. Pitch, 2. Loudness, 3. Quality.

The number of times per second the string vibrates determines the *pitch* of the sound you hear.

For example, the string of middle “C” on the piano always vibrates 256 times per second, no matter how hard it is struck.

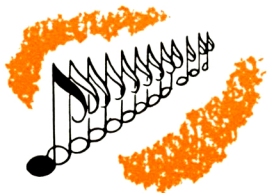
So when you hear middle “C” it means that air waves vibrating 256 times per second are striking the diaphragm of your ear.

When you hear notes below or above middle “C,” it simply means that the air waves striking the diaphragm of your ear are vibrating at rates less or more than 256 times per second.

The harder you strike middle “C” the greater the energy of the air waves and the *louder* the sound, but no matter how loud or soft, middle “C” keeps a *pitch* of 256 vibrations per second.



OVERTONES GIVE MUSIC ITS COLOR



Now let us see what is meant by the *quality* of a sound. Middle “C”—or any other note—is actually composed of a “fundamental” tone plus a series of “overtones,” which sound in harmony with it.

It is the “overtones” that give realism and color to music. If the “fundamental” note of middle “C” for example was plucked on a banjo,



played on a violin, blown on a whistle, or struck on a piano, and *all the overtones were eliminated*, you could not tell which instrument made the sound.

We said that when middle "C" is struck on the piano, air waves strike the diaphragm of your ear at the rate of 256 times per second. Actually, you also hear overtones of middle "C" which are vibrating at rates of 2, 3, 4, 5 and more times 256 up to 8100 vibrations per second, the limit of the sound range of the piano.

But when middle "C" is played on an oboe, for example, a greater number of overtones are produced because the sound range of the oboe extends up to 16,800 vibrations per second.

The fact that the oboe produces more overtones of any note than a piano enables you to distinguish between the two. These overtones give music its quality.

YOUR EARS ARE BETTER THAN YOUR RADIO

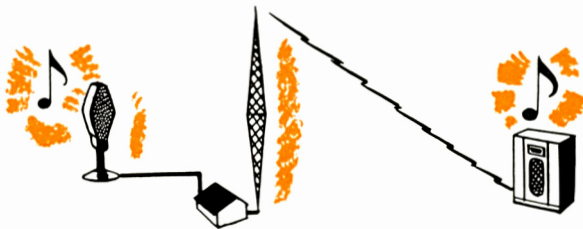
The human ear can hear sound ranging from 16 to 16,000 vibrations per second. This is usually referred to as the "frequency" of the sound waves.

So, you see that to bring you true realism, the radio would have to bring you *all* of the tones and overtones that you can hear. Because of the limitations in broadcasting as it exists today, even the best conventional radio brings you *less than half* the range of tone you can hear.



WHAT IS RADIO?

Radio is a system of wireless communication in which sound waves created in the studio are changed into electrical waves by the broadcasting transmitter radiated into space and picked up by your receiver, which changes the electrical waves back to sound.



Inside a microphone there is a diaphragm much the same as the diaphragm in your ear. When the sound waves of the program strike the diaphragm of the microphone, they are changed into electrical waves.



These electrical waves, if you could see them, would have exactly the same form as the sound waves. However, they can travel only a short distance. Therefore, it is

necessary to use some vehicle to carry the electrical sound waves to your receiver. This is called the "carrier" wave and it is an electrical wave of *much higher frequency*.



When you tune in a

station, say “810” on your dial, you are adjusting your radio set to receive a carrier having a frequency of 810,000 vibrations per second—usually called 810 kilocycles.

Conventional radio stations broadcast carrier waves ranging from 550 to 1600 kilocycles.

By itself the carrier wave cannot transmit any music or speech.

The transmitter places the electrical sound wave

from the microphone on the carrier. This is called modulation. It means that the carrier is moulded or shaped to conform with the sound.

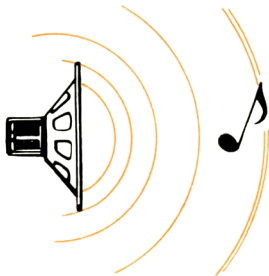
Your receiver discards the carrier which has served its purpose and admits only the electrical sound wave. This electrical sound wave causes the loud-speaker cone (which is similar to the microphone diaphragm) to vibrate and produce sounds which should correspond to those which entered the microphone.

We say “should correspond” because certain limitations of conventional radio make true realism impossible.

To achieve true realism it is necessary to —

1. Eliminate all noise and interference.
2. Transmit and reproduce all the sound you can hear.

When this is done, your receiver brings you pure music against a background of silence. Each note comes in as distinctly as if you



were sitting in the very studio with the orchestra. Every tone—and all the delicate overtones that bring music to life—reaches your ear in crisp realism!

HOW FM CREATES A BACKGROUND OF SILENCE

To create a background of silence, we must do away with static, station interference, and fading.

There are two kinds of static which cause noise in our radio reception, nature-made static, such as that produced by lightning and sun spots and man-made static, such as may be produced by electric razors, neon-signs, dial telephones, and electrical machines. Even with the best conventional radio it is impossible to enjoy a pro-



gram during a thunderstorm and the annoyances of man made static are all too familiar.

These various sources of static are actually miniature broadcasting stations out of control. They send out radio waves similar to those broadcast by the conventional station.

With conventional radio, the only way to reduce static to the vanishing point is to increase the power of the station so that it will deliver a signal to your receiver 20 to 50 times greater than the static signal.

Such power increase would not only be expensive but it would also cause more interference between stations than already exists.

With FM, however, it is necessary for the signal at your receiver to be only twice as strong as the static signal to give you reception that is virtually static-free.

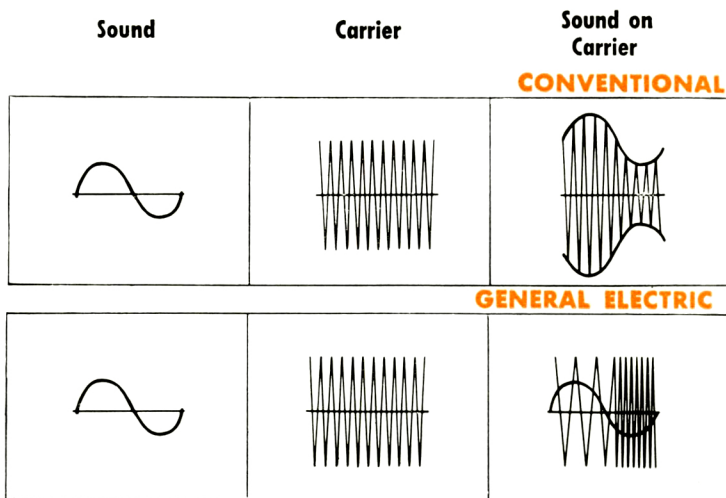
Now let's take a series of pictures to see what happens to a conventional radio wave and also an FM radio wave from the time the sound is picked up by the microphone until it reaches your loud-speaker.

These pictures are shown on the following pages.



FM brings you pure music against a background of silence

HOW FM REDUCES STATIC



SOUND At the left you see an electrical sound wave after it has left the microphone. It is the same for conventional radio as for FM.

CARRIER Next is the carrier wave before it has taken the sound wave aboard. It, too, is much the same for conventional radio as for FM.

SOUND ON CARRIER Next the sound wave has modulated the carrier. Notice that in conventional radio, the carrier increases and decreases in height in accordance with the sound wave while the frequency (shown as the distance between each wave) remains constant.

The sound wave modulates the FM carrier in an entirely different manner. Instead of causing the carrier to increase and decrease in height, the height remains the same and the frequency of the carrier changes in accordance with the sound. The modulated FM carrier bunches together in places and stretches out in others, like an accordion.

SOUND AND STATIC ON CARRIER As the wave travels through space to your receiver, it encounters static which attaches itself onto the modulated

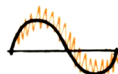
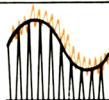
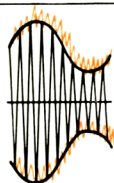
TO THE VANISHING POINT

Sound and Static
on Carrier

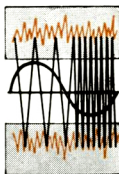
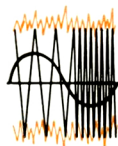
What the
Receiver Does

How Sound Looks
at Loudspeaker

RADIO



FM RADIO



carrier wave. Notice that in conventional radio the sound and carrier wave become jagged in appearance while in FM, only the carrier wave is affected the sound wave being nestled comfortably inside the carrier.

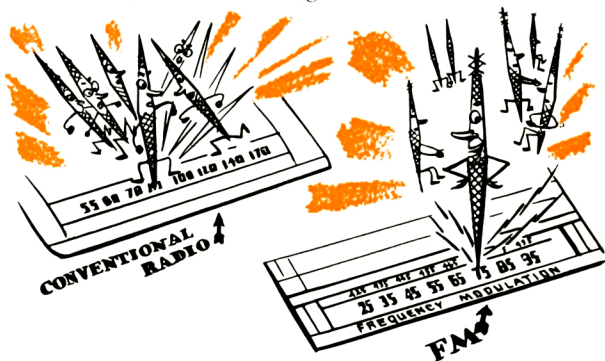
WHAT THE RECEIVER DOES For sound to be reproduced by your conventional radio, the *entire upper half of the modulated carrier wave must be used.*

But in the case of FM, it is *not necessary to use the entire height of the FM carrier wave* because sound is produced by a *change in frequency* not a change in height. The FM receiver is designed so that it shaves off the distorted top and bottom of the carrier wave as shown.

HOW SOUND LOOKS AT LOUD-SPEAKER After the receiver has discarded the carrier wave, the sound wave which the loud-speaker reproduces is a mixture of music and noise in the case of conventional radio, above, but in the case of FM, below, static has been eliminated and only clean cut sound is reproduced.

NO FIGHTS BETWEEN STATIONS WITH FM

Between 550 and 1600 on your dial there are 105 radio roadways or channels available. Yet there are at present more than 880 stations using these channels.



You can see that a crowded condition exists and stations *on the same frequency* or channel although many miles apart tend to interfere with each other, producing that familiar hum, whistle, or cross-talk that so often destroys radio enjoyment.

On the other hand when two FM stations broadcast on the same frequency, your FM radio will select the stronger of the two and reject the weaker one as if it did not exist. You will get no interference between two FM stations on the same frequency provided the stronger signal is twice as strong as the weaker one. With conventional radio you will get interference unless the stronger signal is at least 20 to 50 times as strong as the weaker one.

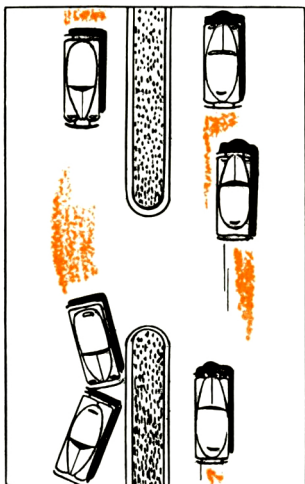
In addition, interference occurs because there is no clearance between channels and one station's program often overlaps its neighbors. For example, 800 and 810 on your dial.



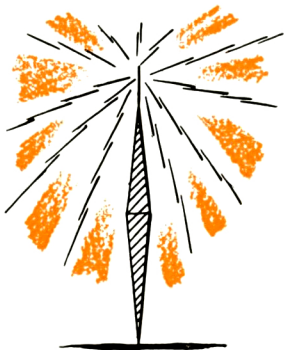
It is like a narrow two-lane highway where there is not enough clearance between opposing streams of traffic to prevent an occasional accident.

FM, on the other hand, is broadcast at much higher frequencies than conventional radio (42,000 to 50,000 kilocycles as compared with 550 to 1600). Up in this region wide enough channels have been assigned so that only 75 per cent of their width need be used for the program, leaving a safety zone between adjacent channels to guard against overlapping.

FM broadcasting can be compared to travel on a modern superhighway where a wide space separates opposing lines of traffic.



NO MORE PROGRAM FADING

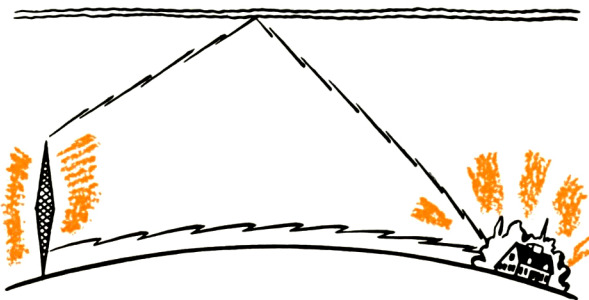


Broadcast stations send out waves in all directions. Some travel along near the earth. These are called ground waves. Others go shooting up into the sky. They are called sky waves.

These sky waves are reflected back to earth from an electrical ceiling called the Heaviside Layer.

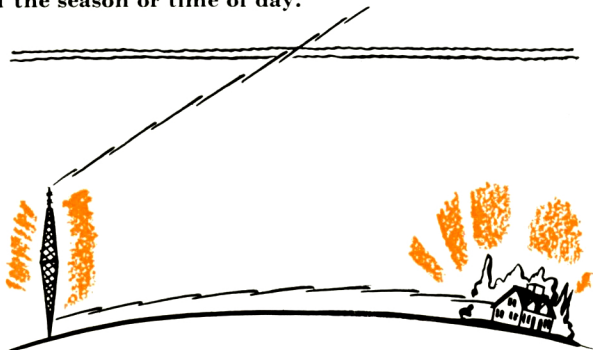
The height of this layer above the earth varies with the seasons and with the time of day or night.

A radio located at a distance from the station picks up both the ground wave and the reflected sky wave. At times these waves reach the set together, thus producing normal volume. At other times the sky wave is delayed so that it reaches the radio after the ground wave, thus causing fading and distortion.



While FM stations also send out waves in all directions, the sky waves are generally not reflected back to earth

but go right on through the Heaviside Layer because they travel at much higher frequencies than conventional waves. As a result, the receiver picks up only the ground waves from an FM station and fading is virtually eliminated. Your program always comes in clearly regardless of the season or time of day.



Thus you can see why FM—Frequency Modulation—by virtually eliminating static, station interference, and fading creates the velvety background of silence so necessary for faithful reproduction.

In fact, this is one of the amazing sensations to a person who first hears an FM radio—the utter silence of the radio in those moments when no music or speech is being broadcast.

The ability of FM radio “broadcast silence” adds to the effectiveness of such radio entertainment as symphonies and plays where the dramatic pause means so much.

HOW FM BRINGS YOU LIFE-LIKE REPRODUCTION

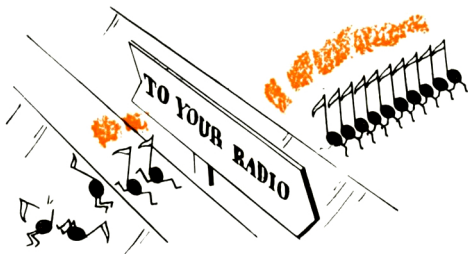
You will recall that we said the range of sounds our ears can hear run from approximately 16 to 16,000 cycles

per second. The sounds produced by the full range of instruments and symphony orchestra, together with their overtones, cover about this same range of frequencies. In a concert hall listening to an orchestra, you can enjoy the full range of frequencies; but in your home listening to this same orchestra over your conventional radio, the music lacks color.



This condition in conventional radio has come about because there are so many stations (approximately 880) and so little available air-lane space. As a result, it has been necessary to restrict the channel width or roadway for each station so that it is impossible to receive and reproduce sounds of more than 5000 cycles without getting interference from stations broadcasting on adjacent channels. Thus a conventional radio provides a highway 5000 cycles wide over which to transport sounds 15,000 cycles wide. As a result, you must sacrifice the life-like quality of the program.

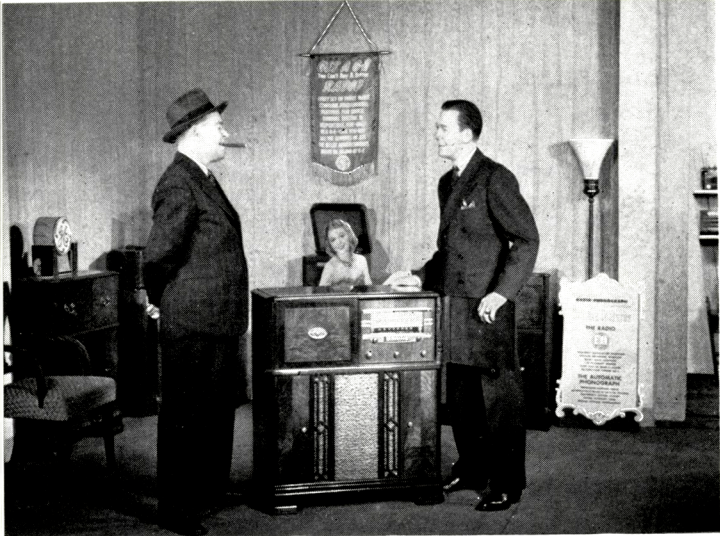
FM ROADWAY IS 20 TIMES WIDER



Frequency Modulation now makes it possible for you to enjoy the full range of frequencies produced by a symphony orchestra. FM is broadcast on much higher frequencies than conventional radio—and there is plenty of roadway space available in this ultra-high frequency region. Each FM station has been assigned a roadway 200 kilocycles wide or 20 times wider than a conventional one. There is ample room for each FM station to broadcast the full range of sound frequencies without creating any station interference problem.

So now you see that FM comes very close to the ideal of giving you a seat in the broadcast studio without leaving your home. A musician taps the triangle; its “ting” is a cool crystal of sound with a lingering after glow of uncanny clarity. Between selections the station is so quiet you can hardly believe your set is turned on. A trickle of water, the crackle of a match at the instant it bursts into flame, every subtlety of the piano—such reproduction by FM is exact, natural. Truly with FM you hear pure music against a background of silence.





WHY BUY AN FM RADIO NOW ?

If you live within listening range of an FM station, by all means *insist* that your new radio receive FM. A moderately-priced G-E radio with FM will bring you musical enjoyment which the most expensive radio without FM cannot bring you.

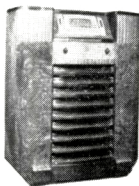
Even if you don't have FM broadcasting in your area now, you won't have to wait to begin enjoying your General Electric FM set. A radio or radio-phonograph designed and built to General Electric FM standards gives you unsurpassed reception not only of FM but of *all* programs!

New FM stations are going on the air regularly. Even if there isn't one in your area now, it's practically certain there will be before the time comes to retire the radio you buy today. So consider General Electric FM as protection for your radio investment.

1938
\$313



1939
\$200



1940
\$175



1941
\$140



**Lower Prices
and
Better Performance
Every Year!**

WHY BUY A G-E FM RADIO?

General Electric was selected by Major Armstrong, the inventor, to build the first group of FM receivers which he used in perfecting FM.

General Electric has produced a line of FM receivers every year since 1938. And every year performance has been improved and prices have been lowered.

General Electric builds not only FM receivers but complete FM transmitter equipment for commercial broadcasting and for police and military communications systems.

General Electric operates a complete "proving ground" FM station. Its doors are open to everyone interested in FM radio broadcasting.

General Electric is the only manufacturer building receivers with such a complete background of FM experience.



MODEL LFC-1228 RADIO-PHONOGRAPH

*Frequency Modulation
Standard Broadcasts*

*Automatic Record Changer
International Short-wave*

Plays twelve 10-inch or ten 12-inch records. Motor shuts off automatically when last record has finished playing. Permanent-point sapphire stylus. Featherweight crystal pick-up and tone arm. "Roll-out" phonograph drawer-front.

Dual cascade limiters for noise-free FM reception. FM interstation silencer. Double conversion FM circuit. Three built-in Beam-a-Scopes receive FM, Standard Broadcasts, and Foreign Short-wave. 10-inch dynamic speaker with enclosed acoustical tone chamber. Treble and bass tone selectors. Automatic tone compensation. Tuned R.F. on all bands. Three-gang condenser. 6 feathertouch tuning keys. Drift-proof station settings. De luxe visualux dial. Underwriters' approved. 12 tubes including rectifier. 12 watts output. Cabinet in figured mahogany veneers, in 18th Century Period. Size: H 36½ in., W 35 ⅜ in., D 16½ in.



MODEL LFC-1128 RADIO-PHONOGRAPH

Frequency Modulation

Automatic Record Changer

Standard Broadcasts

International Short-wave

Plays twelve 10-inch or ten 12-inch records. Permanent-point sapphire stylus. Light-weight crystal pick-up and tone arm. "Roll-out" phonograph drawer-front.

Dual cascade limiters for noise-free FM reception. FM inter-station silencer. Double conversion FM circuit. Separate built-in Beam-a-Scopes for FM, Standard Broadcasts, and Foreign Short-wave. 12-inch dynamic speaker. 6 feather-touch tuning keys. Drift-proof station settings. De luxe visualux dial. Treble and bass tone selectors. Automatic tone compensation. Tuned R.F. stage on all bands. Three-gang condenser for more efficient performance. 11 tubes including rectifier. 12 watts output. Underwriters' approved. Cabinet in charm of 18th Century in American walnut veneers. Size: H 35 ½ in., W 35 in., D 16 ⅝ in.



MODEL LFC-1118 RADIO-PHONOGRAPH

*Automatic Record Changer
Standard Broadcasts*

*Frequency Modulation
International Short-wave*

Changes twelve 10-inch or ten 12-inch records automatically. Permanent-point sapphire stylus. Light-weight crystal pick-up and tone arm.

Dual cascade limiters for noise-free FM reception. FM interstation silencer. Double conversion FM circuit. Receives FM, Standard Broadcasts, and Foreign Short-wave. 12-inch dynamic speaker. 6 tuning keys. Separate treble and bass tone selectors. Automatic tone compensation. Tuned R.F. stage on all bands. Three-gang condenser. 11 tubes including rectifier. 12 watts output. Underwriters' approved. Full-size console grand cabinet of American walnut veneers. Size: H 37 in., W 32½ in., D 16⅔ in.



MODEL LF-116

*Frequency Modulation Standard Broadcasts
International Short-wave*

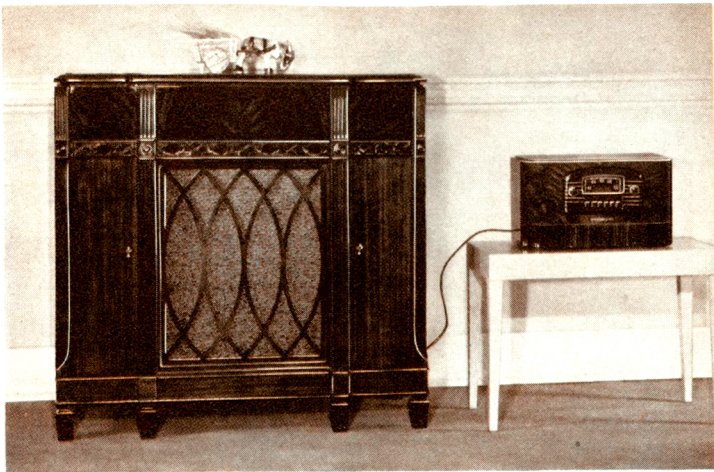
Dual cascade limiters for noise-free FM reception. FM inter-station silencer. Double conversion FM circuit. Built-in Beam-a-Scopes receive FM, Standard Broadcasts and Foreign Short-wave. Record player pick-up connection. 6 feathertouch tuning keys. Drift-proof station settings. 10-inch dynamic speaker with enclosed acoustical tone chamber gives full-depth clarity of tone. Separate treble and bass tone selectors. Automatic tone compensation. Tuned R.F. stage on all bands for finer, quieter reception. Three-gang condenser. 11 tubes including rectifier. 12 watts output. Underwriters' approved. Impressive cabinetry in beautifully figured American walnut veneers. Size: H 41 in., W 31 in., D 15½ in.



MODEL LF-115

Frequency Modulation Standard Broadcasts
International Short-wave

Dual cascade limiters for noise-free FM reception. FM inter-station silencer. Double conversion FM circuit. Built-in Beam-a-Scopes receive FM, Standard Broadcasts, and International Short-wave. Record player pick-up connection. 12-inch dynamic speaker. 6 feathertouch tuning keys. Drift-proof station settings. Separate treble and bass tone selectors. Automatic tone compensation. Tuned R.F. stage on all bands. Three-gang condenser. Tone monitor circuit. 11 tubes including rectifier. 12 watts output. Underwriters' approved. Charming "chest-on-stand" styled console in American walnut veneers. Size: H 40½ in., W 31 in., D 15¼ in.



YOU CAN ADD FM TO YOUR PRESENT RADIO

This General Electric FM Translator makes it easy and inexpensive to add FM to your present radio. Only one simple connection is required.

Do not confuse the G-E Translator with cheap FM table model receivers. It is a high quality FM pick-up and General Electric recommends that it be used only with a console radio or radio-phonograph known to have a high-quality amplifier and speaker system.

As far as the G-E FM Translator itself is concerned, you can depend on it to receive FM and transmit it to the sound system of your radio with unexcelled fidelity and freedom from static.

The G-E Translator (Model JFM-90) has feathertouch tuning keys for 6 stations, an easy-to-read illuminated dial, and 9 tubes including rectifier. The cabinet is of matched butt walnut and rosewood veneers. Dimensions 9 in. high, 15½ in. wide, 7¾ in. deep.

Only one simple connection is required between the G-E FM Translator and your radio.



Address inquiries to
Radio and Television Dept.
GENERAL ELECTRIC CO.
Bridgeport, Conn.



