TV-FM LEAD-IN:

How to select the right kind of lead-in for your antenna. Complete rundown of all the various types now available, performance, cost.

IN some localities, an indoor TV or FM antenna works fine. But in most locations, you need an outside antenna to get a clean TV picture or good FM sound. To use an outdoor antenna, you need lead-in wire, to carry the r.f. signal from the antenna to the receiver. But you cannot simply connect any type of wire between the antenna and receiver. You have to use the right kind, and there are several types on the market. Here's how to select the right one for your installation.

Lead-in Requirements

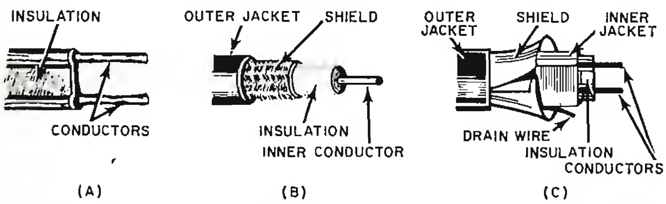
To do the job properly, lead-in wire must meet certain requirements.

1. The lead-in must match the impedance of the antenna, and that of the receiver's antenna-input circuit. Most TV and FM receiving antennas are 300-ohm types, and most TV and FM receivers similarly have 300-ohm inputs. You can get either 300- or 75-ohm lead-in, and you can get transformers to match 300 ohms to 75, and *vice versa.*

2. The lead-in should attenuate the r.f. signal as little as possible (or cause as little signal loss as possible), because if the signal is too weak when it reaches the receiver, you'll get a snowy picture or a noisy FM signal. If you live in a high-signal area near the broadcast stations, this may be no problem. But if you live in a near-fringe or fringe area, you may need lead-in with the lowest possible loss. And color-TV and stereo-FM are even more sensitive to signal attenuation.

3. The lead-in should not add anything to the signal it gets from the antenna, that is, the lead-in itself should not pick up any direct r.f. signal, whether from TV or FM stations, or other radio signals, or noise (ignition or otherwise). If the lead-in does pick up other signals, such signals cause interference in the TV picture or FM sound. Of course, no lead-in is perfect, and all pick up *some* spurious signals. But some pick up less than others. If you live in a sparsely settled area, you won't have to worry much about unwanted lead-in pick-up, for there won't be much r.f. around. But if you live in an urban area, spurious r.f. and noise may be heavy in your neighborhood. Even if spurious r.f. and noise are no problem, direct pick up of the TV signal by the lead-in causes ghosting to the picture or multipath distortion with FM.

Fig. 1. Common types of lead-in include (A) flat twin-lead, (B) coaxial cable, and (C) shielded twin-lead cable.



4. The lead-in should be durable, since it's outside the house and exposed to wind, snow, ice, sun, rain, soot, and salt. All of these elements deteriorate the plastic insulation or jacket of the lead-in eventually; some go bad sooner than others. Also, with some lead-in types, rain, snow, and ice make the TV picture or FM sound worse. Obviously, long life is a desirable lead-in characteristic, as you have to replace the lead-in less often, and it costs you less in the long run.

5. The lead-in should be easy to install. A lead-in which is sensitive to nearby metal objects (6" or closer) is more difficult to install than one which is not, because most houses have such metal objects as rain gutters and downspouts on the eaves and corners, and you have to avoid them when running the lead-in. The same consideration applies to lead-in types which are sensitive to nearby a.c. lines. With some lead-in types, also, the use of metal-ring stand-off insulators can be detrimental to signals; you have to use nonmetallic stand-offs.

6. The lead-in should be reasonably priced. You can buy very good lead-in which will do quite well in meeting all the preceding requirements. But it may cost several times what more common types do.

Stereo-FM, Color-TV, and U.h.f.

All lead-in types attenuate the signal somewhat. This attenuation increases as the length of the lead-in does, and it also increases with the signal frequency.

Since the noise level is generally constant at the receiver r.f. input, the greater the signal losses in the lead-in, the noisier the signal, or the snowier the picture.

For good stereo-FM, you need a fairly clean r.f. signal, for noise degrades stereo separation by interfering with the relatively weak 19-kHz pilot and the stereo-AM sidebands around 38 kHz. Similarly, for good color-TV you also need a fairly clean signal, for noise easily degrades the 3.58-MHz color subcarrier and the color-difference signals. In both stereo-FM and color-TV, the additional information is multiplexed on the main carrier at a lower level than main-channel information, making it more susceptible to interference. Also, stereo-FM and color-TV receiver bandwidths are usually greater than those of mono-FM and black-and-white TV. The greater the bandwidth of any system, the more susceptible to noise that system is.

In the days of only mono-FM and black-and-white TV considerable lead-in loss was tolerated. Ghosts and noise weren't so noticeable. Today, unless you don't plan to enjoy stereo or color, you should install lead-in to handle both.

What Kind to Use?

By THOMAS R. HASKETT

U.h.f.-TV signals also make stringent demands on lead-in. V.h.f.-TV signals range from 54 to 216 MHz, while the u.h.f. band runs from 570 to 890 MHz. Since lead-in losses increase with frequency, this means that some types will work satisfactorily at v.h.f., but not at u.h.f.

Nearly every part of the country has at least one u.h.f. station on the air, and more are coming on every month. By federal law, all new TV receivers sold in interstate commerce must be capable of receiving both v.h.f. and u.h.f. Therefore, any new antenna installation should be all-channel.

Basic Lead-in Types

The most common type of TV-FM lead-in for many years has been ordinary *flat twin-lead,* as shown in Fig. 1A. It has a characteristic impedance of 300 ohms, to match the impedances of most antennas and receivers. It is balanced to ground (that is, neither side is grounded) and unshielded.

Less popular until recently is *coaxial cable* (Fig. 1B). Its impedance is in the range of 72-75 ohms. Since few antennas and receivers can match this impedance, transformers are usually required at both ends of the cable, to match the 300-ohm terminals. Coax is unbalanced (the outside conductor is grounded) and shielded. (Since the matching transformer used with coax converts a *bal*anced line to *un*balanced, it's often called a *balun.*)

More recently, a lead-in has been developed which combines the best feature of both twin-lead and coax. Called *shielded twin-lead* (Fig. 1C), it has 300-ohm impedance, is balanced to ground, and is also shielded.

As Fig. 2 shows, there are differences between coax and the two types of twin-lead in the distribution of the electromagnetic and electrostatic lines of force which surround the conductors. These lines are produced by the current and voltage of the signal moving through the lead-in, and if the lines are disturbed, the signal may be impaired.

In ordinary twin-lead (Fig. 2A), many of the lines of force extend away from the conductors, which is why you cannot

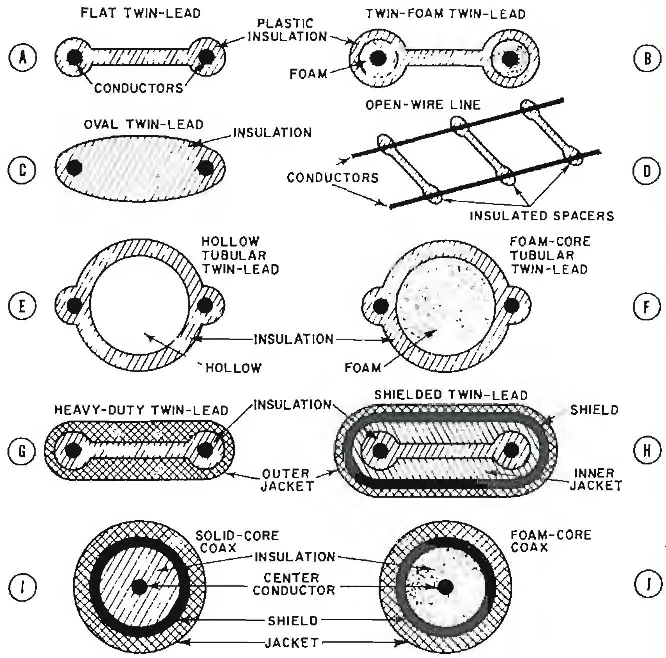
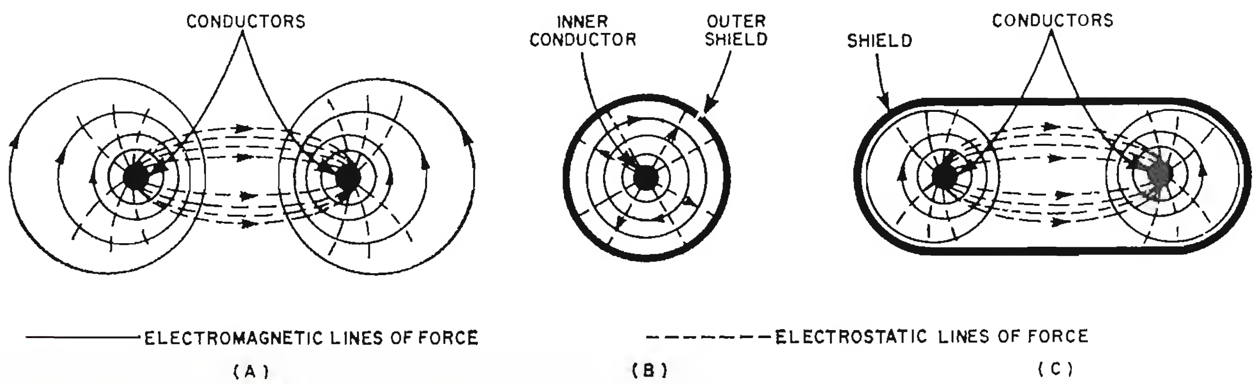


Fig. 3. Cross-sections of various types of lead-in.

Fig. 2. Magnetic fields (electromagnetic lines of force) and electric fields (electrostatic lines of force) in (A) flat twin-lead, (B) coax cable, and (C) shielded twin-lead.



Type of Lead-in	Signal losses in dB per 100 feet at:		
	100 MHz	500 MHz	900 MHz
Unshielded 300-ohm twin-lead			
Open-wire	0.5	—	—
Oval	0.9	2.6	3.9
Foam-core tubular	1.1	3.0	4.3
Flat	1.1	3.0	4.5
Twin-foam	1.1	3.5	4.5
Heavy-duty	1.2	3.5	5.1
Shielded			
300-ohm twin-lead	2.5	5.4	7.7
75-ohm foam coax	2.7	6.4	8.0
75-ohm RG-6/U coax	2.7	6.4	8.4
75-ohm RG-59/U coax	3.8	8.5	12.0

Table 1. Lead-in comparison by signal loss at the various frequencies indicated, under ideal conditions.

run twin-lead near metal objects. Coax overcomes this difficulty (Fig. 2B), as most of the lines are concentrated within the shield. The same is true of shielded twin-lead (Fig. 2C).

But there is a significant difference between coax and shielded twin-lead, regarding construction and performance. There are only *two* conductors in coax. In most types the outer conductor is a woven metallic braid; in others, it is a solid sheet of metal foil. The foil is slightly more effective as a shield. But since there are only two conductors, the shield carries current, which means that any interference is present in the signal circuit.

In shielded twin-lead, on the other hand, there are *three* conductors. The two inner conductors carry the signal and nothing more. The outer shield carries only interference. To install shielded twin-lead properly, you should tie the shield and drain wire to chassis or ground at the receiver only, and let it float at the antenna. Any interference picked up by the shield is thereby drained to ground at one end only, and doesn't get into the signal circuit.

Shielded twin-lead, then, is somewhat more immune to noise and spurious r.f. pickup than ordinary coax. This feature can be useful in high-noise locations.

Comparison of Lead-in Types

A number of different types of lead-in are available today. Fig. 3 shows cross-sections of these types.

Flat twin-lead (A) has been the most common type for many years because it's inexpensive. The conductors are surrounded by a polyethylene plastic insulator, which is available in either of two colors. Clear or white twin-lead is usable only indoors, where it blends with wall baseboards. It can't be used outdoors for the ultraviolet in sunlight rapidly deteriorates the poly. Brown twin-lead lasts longer outdoors, as the color keeps the ultraviolet light out. In *twin-foam twin-lead* (B), a core of foam poly surrounds each conductor. Foam poly is simply a mixture of polyethylene and air bubbles. Since air has lower dielectric losses than poly, foam twin-lead has less loss than solid poly.

Oval twin-lead (C) was designed to keep contaminating moisture, soot, etc., farther from the lines of force surrounding the conductors. *Open-wire line* (D) has insulating spacers which maintain the conductors at the proper distance and keep the line impedance constant. Since the dielectric is chiefly air (except for the spacers), open-wire line has the lowest losses of all—at least when the insulators are clean and dry.

Hollow tubular twin-lead (E) is also designed to keep contaminating deposits away from the area between the conductors. The plastic insulator is formed in a tube, and since the core is hollow, the dielectric is mainly air. Unfortunately the hollow tube gathers moisture, which increases losses. In an effort to overcome this disadvantage, *foam-core tubular twin-lead* (F) was developed. The foam core gathers very little moisture.

Heavy-duty twin-lead (G), which is also called "jacketed" or "encapsulated," is surrounded by a tough, plastic, insulating jacket which resists the effects of weather and soot. *Shielded twin-lead* (H), as previously described, contains two conductors with insulation between, covered with a metal shield, and covered over-all with a tough, weather-resistant jacket.

Solid-core coax, at (I), as its name implies, has solid poly between the center conductor and the outer conductor (shield). Two types—RG-59/U and RG-6/U—are suitable for home installations; RG-6/U is slightly larger and has less loss. *Foam-core coax* (J) has an air-bubble-filled core which reduces losses. Most coax is covered with a weather-resistant, polyvinyl-chloride jacket.

Comparison by Signal Losses

Table 1 compares the various lead-in types by signal losses, at three frequencies. 100 MHz is roughly the middle

Type of Lead-in	Signal losses in dB at:		
	100 MHz	500 MHz	900 MHz
Shielded 300-ohm twin-lead	3	6	8
Heavy-duty 300-ohm twin-lead	5	8	9.5
Foam or RG-6/U coax, with two transformers	5	8.5	10
RG-59/U coax, with two transformers	7	11	16
Foam-core tubular 300-ohm twin-lead	10.5	16	20
Flat 300-ohm twin-lead	25	>35	>35

Table 2. Lead-in comparison by signal loss for a typical home installation. Naturally, these figures are only very approximate and will vary widely depending on the particular installation.

of the FM and the v.h.f. TV bands; 500 MHz is near the bottom, and 900 MHz near the top, of the u.h.f. TV band.

As mentioned before, open-wire lead-in has the lowest loss of any lead-in, roughly ⅐th of the lossiest type at 100 MHz, if it can be properly installed. Exact figures were not available at 500 and 900 MHz for open-wire, but average losses are around 2 dB for u.h.f. But open-wire lead-in is seldom used for TV or FM reception. It is difficult to install, not the least expensive, and highly susceptible to noise pickup, as well as losses if installed close to loss-inducing objects. It won't withstand weather conditions: you get a nice picture on a clear, dry day, but you may lose the signal when it rains or snows. Years ago, if the receiver were a great distance from the antenna, open-wire line was the only solution; any other type of lead-in would attenuate the signal too much. Today, you can use a mast-mounted preamplifier and conventional twin-lead or coax.

Losses for the other unshielded types are very similar. Unshielded-line losses increase roughly three times at 500 MHz, and roughly five times at 900 MHz. (Hollow tubular twin-lead isn't shown because it has been largely superseded by foam tubular type.)

Note that shielded lead-in losses are generally two to three times those of unshielded. But losses of shielded types don't increase as rapidly with frequency as those of the unshielded types. RG-59/U is the worst offender. With losses of 12 dB at 900 MHz, it is the least desirable in all-channel installations.

But the figures given in Table 1 were derived by measuring the various lead-in types under laboratory conditions, when the cables were dry and clean and removed from nearby objects. What happens to the various types at a typical home installation? The lead-in is run through stand-off insulators, perhaps routed through walls and near metal gutters or a.c. lines, and exposed to rain, snow, soot, and possibly salt spray. Inside the house, the lead-in may even be attached to walls with metal staples. All these factors cause greater losses in some types of lead-in than in others.

Table 2 compares the various types by losses in a typical installation. Shielded 300-ohm twin-lead has the least loss, followed by 300-ohm heavy-duty twin-lead. Foam-core coax isn't bad. All three are usable at u.h.f. Ordinary RG-59U 75-ohm coax works fairly well at 100 MHz, poorly at 500 MHz, and badly at 900 MHz. Foam-core tubular and flat 300-ohm twin-lead don't work as well at any frequency in this particular case, although foam-core tubular is better than regular flat twin-lead. Naturally, these figures will vary widely, depending on the kind of installation.

Coax suffers from an additional disadvantage in the typical installation. Very few antennas and receivers will work directly with 75-ohm coax. Thus you must use matching transformers, which add 2 or 3 dB of loss to the over-all cable figure. Table 2 coax-loss figures include approximately 2 dB of balun loss.

Noise Immunity and Durability

An unshielded line is more susceptible to interference pickup than a shielded one. Thus most coax picks up less interference than most twin-lead. But twin-lead is balanced to ground, avoiding hum pickup more than coax, which is unbalanced to ground. This disadvantage partially offsets the noise immunity of coax. Shielded twin-lead is both balanced to ground and shielded.

Some flat twin-lead isn't very durable, because the insulation deteriorates from the effects of the weather. When this happens, the insulation may fall apart, changing conductor spacing and line impedance. Standing waves are produced, causing ghosts on TV and loss of separation in stereo-FM. Oval and tubular twin-lead are a bit more immune than flat to such deterioration. The most immune types are heavy-duty and shielded twin-lead, and most coax. They are encapsulated in material impervious to weather and contamination.

Type of Lead-in	Approx. price per 100 ft
Unshielded 300-ohm twin-lead	
Flat	$1.70
Hollow tubular	2.50
Heavy-duty	2.63
Open-wire	3.27
Twin-foam	3.68
Foam-core tubular	4.65
Oval	5.35
Shielded	
75-ohm RG-59/U coax	5.58
75-ohm foam coax	6.07
300-ohm twin-lead	10.15
75-ohm RG-6/U coax	16.80

Table 3. Comparison of various lead-ins by price. The price varies somewhat depending on quality and source.

To run ordinary flat twin-lead from antenna to receiver, you have to use stand-off insulators every 5 feet or so, and pull the line taut. Flat twin-lead whips easily in the wind and this flexing may break the conductors, requiring you to replace the line. It is also a good idea to twist the twin-lead in order to minimize noise and signal pickup.

If you use an ordinary metal-ring stand-off, you bring metal near the twin-lead, possibly causing ghosts. It's better to use all-poly-head types, which don't surround the line with metal. Also, you must run twin-lead carefully to avoid gutters and rain downspouts, for the same reason. You must likewise be careful when running flat twin-lead through the house wall so that it does not come too close to pipes and electrical wiring.

Oval and tubular twin-lead aren't much better than flat in this respect.

All shielded lead-in types are inherently easy to install, simply because you can run them nearly anywhere with no deleterious effects. The shield prevents nearby metal objects from disturbing line impedance, and minimizes noise pickup. You can use any type of stand-off to hold the line, and you can even tape it to the antenna mast, or run it inside pipe or conduit, which you should not do with most twin-lead. You must not deform shielded line—or any other type, for that matter. When you deform the line you change conductor spacing and you may possibly reduce signals and create ghosts.

Comparison by Price

After comparing various lead-in types on the basis of how well they perform, there remains the matter of price. There isn't much point in paying more than you have to, for your particular installation.

Table 3 compares the various lead-in types by price. The least expensive is flat twin-lead. Since most of the other types perform better, they cost more. Shielded types generally cost more than unshielded. RG-6/U, the most expensive, costs nearly 10 times as much as flat twin-lead.

Just as you cannot buy lead-in solely for its loss figure, or for its noise immunity, you cannot simply buy for price. You should consider all the previous criteria before making a choice. Even with flat twin-lead there are various qualities of insulation, several conductor sizes, and several conductor types (copper or copper-coated steel, for high strength) to choose from.

Over-all Lead-in Comparison

Table 4 shows an over-all comparison of six lead-in types, assuming a 100-foot run from antenna to receiver, some snow or rain, soot or other contamination, and a few metal objects and wiring near the lead-in.

Type of Lead-in	dB Losses @ 900 MHz	Noise Immunity	Durability, Contamination Immunity	Approx. Total Cost
Shielded twin-lead	8.0	Excellent	Excellent	$10.15
Foam coax	8.5	Good	Excellent	12.25*
RG-6/U coax	10.0	Good	Excellent	22.98*
Heavy-duty twin-lead	9.5	Poor	Excellent	2.63
RG-59/U coax	16.0	Good	Excellent	11.76*
Foam tubular twin-lead	20.0	Poor	Good	4.65

*Includes cost of two matching transformers, average total price $6.18

Table 4. Over-all comparison of a number of lead-in types for a typical 100-foot installation.

Shielded twin-lead is preferred in most installations. Its only drawback is price, which is moderate compared to the least and most expensive shown in the table. Shielded twin-lead has the lowest loss at u.h.f. under poor outdoor conditions, has excellent noise immunity, durability, and contamination immunity. It is also easy to install.

Foam coax is also good. The cost figure shown in Table 4 is a bit higher than for shielded twin-lead because it includes the cost of two baluns.

RG-6/U has only fair performance and is more than twice as expensive as shielded twin-lead. Thus it doesn't seem very desirable for a home installation.

Heavy-duty twin-lead is very inexpensive and durable, with excellent contamination immunity and moderate losses at u.h.f. in a typical installation. But it has poor noise immunity. If station signals are strong and interference and noise minimal at your location, heavy-duty twin-lead is probably a very good bet.

RG-59/U coax costs about the same as shielded twin-lead and performs as well, except it has less noise immunity and greater losses at u.h.f.

Similarly, foam tubular twin-lead has higher u.h.f. loss and is also susceptible to noise pickup.

Table 4 doesn't show the other lead-in types previously discussed, because they do not usually perform quite as well in a stereo-FM, color-TV, all-channel installation. Oval, twin-foam, hollow-tubular, and flat twin-lead usually have higher u.h.f. losses in a typical installation, and are susceptible to interference pickup.

Although price is a factor in lead-in choice, don't forget one thing: The user has already invested $300 to $600 or more in a color-TV receiver, perhaps $30 to $60 in an antenna, and additional dollars for stereo-FM. Saving only a few dollars on lead-in cost may not be wise, for then the lead-in may be the weakest link in your equipment chain.

Antenna Preamplifiers and Multiset Couplers

In a fringe area, a high-gain antenna often picks up enough signal to provide a good picture or FM sound. But if the antenna is up on a tower, the downlead run may be long enough to negate the antenna advantage through line loss. And if you have noise and/or weather problems, the only solution is a mast-mounted preamplifier driving shielded line.

The preamplifier (or booster) is even more useful if you have more than one TV or FM receiver driven by the antenna, because to drive several sets you must connect them through multiset couplers which introduce additional signal losses. In this case, an amplified booster may be located at the point where the lead-in enters the house and individual lead-in runs made to the separate receivers. ▲

A listing of some representative lead-in types along with their manufacturers and catalogue designations.

Unshielded, 300-ohm, flat twin-lead
Alpha 5150
Amphenol 214-056
Belden 8225
Columbia 1010
Lafayette 32T8912
Winegard 8200

Unshielded, 300-ohm, twin-foam twin-lead
Allied 11C1657
Columbia 5790 Durafoam
Lafayette 32T3604

Unshielded, 300-ohm, oval twin-lead
Belden 8235

Unshielded, 300-ohm, hollow-core tubular twin-lead
Columbia 1555
Lafayette 32T3608

Unshielded, 300-ohm, foam-core tubular twin-lead
Belden 3275 Celluline

Unshielded, 300-ohm, heavy-duty twin-lead
Alpha 5153
Amphenol 214-103
Belden 8230 Weldohm
Belden 8285 Permohm
Columbia 5050 Permaline
Lafayette 32T3605

Unshielded, 300-ohm, open-wire lead-in
Allied 11C1473
Lafayette 32T3610

Shielded, 72-75-ohm coax, RG-59/U
Alpha 9810
Amphenol 21-025
Belden 8241
Columbia 5750
Dearborn 59/U
Lafayette 32T1715

Shielded, 72-75-ohm foam coax, RG-59/U
Alpha 9820
Amphenol 621-186
Belden 8228 Duofoil
Columbia 1112
Dearborn 59/U
Finco CX-283-100
Jerrold Coloraxial
Lafayette 32T3134
Winegard 2700

Shielded, 72-75-ohm foam coax, RG-6/U
Alpha 9006A
Amphenol 21-330
Belden 8215
Winegard 2800

Shielded, 300-ohm twin-lead
Belden 8290