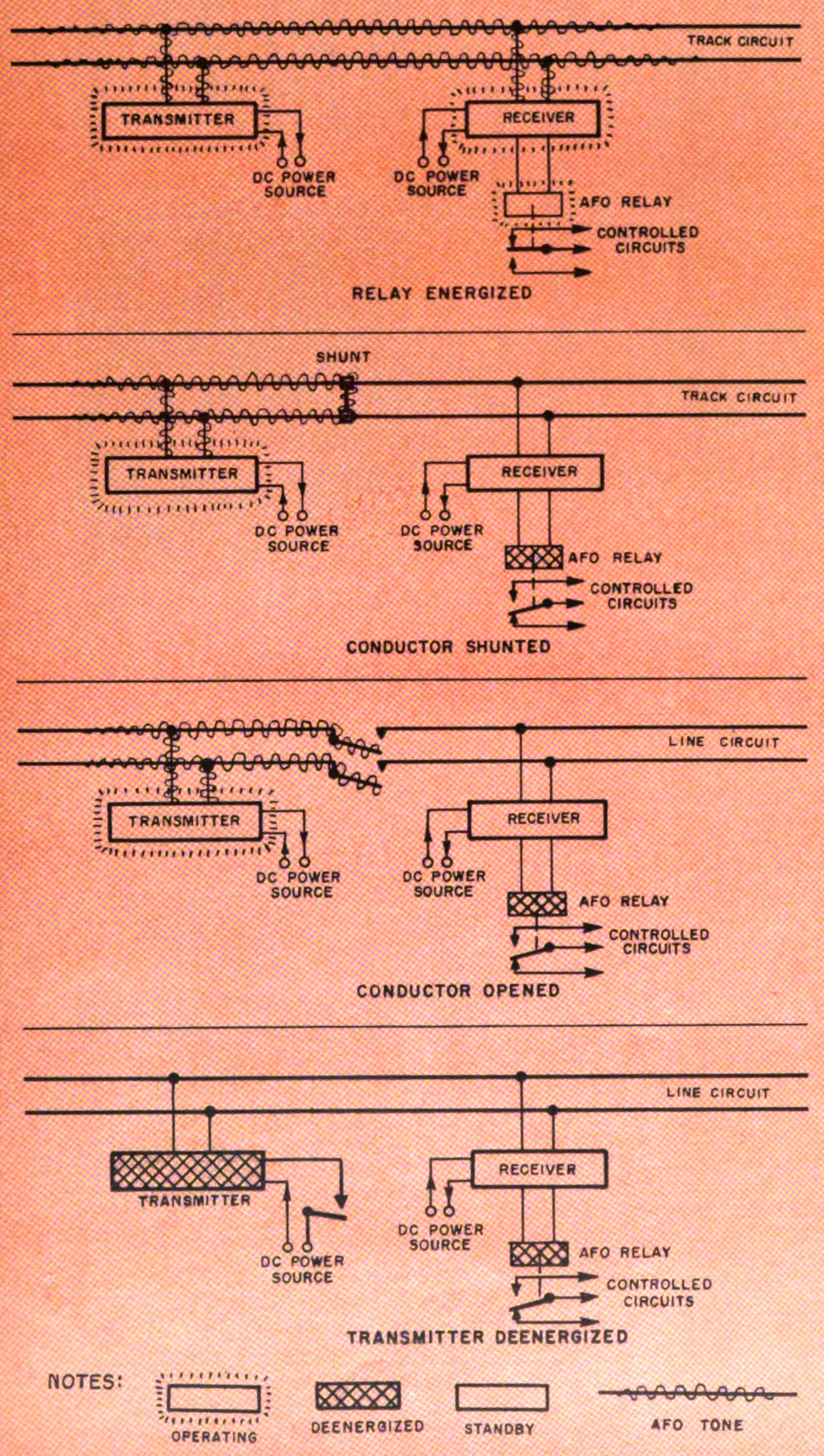
AFO can solve highway crossin



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As its name implies, the Audio Frequency Overlay circuit functions by applying a signal from a tone transmitter to a track or line circuit at one selected point and detecting this tone by a receiver connected to the circuit at another point. The receiver detects, amplifies, and rectifies the tone signal to energize a control relay. The tone signal may be interrupted, to deenergize the control relay, by opening the conductors (as in a line circuit), by opening the power leads and deenergizing the transmitter, or by shunting the conductors (as in a track circuit).

The overlay feature is independent of the limits of the principal circuit. It can be confined within a shorter length, or can be extended beyond the limits of the principal circuit. Thus, the AFO circuit limits can, but need not, coincide with the principal limits.

The more common problems of AFO track circuit installation and maintenance, particularly the overlap shunting area, adjustment, and frequency allocation for highway crossing applications will be dealt with in this article.

The AFO receiver has a potentiometer for adjusting its sensitivity, to provide proper energization of the relay. The vital track receiver has additional terminals with straps to increase the range. Typical receiver characteristics are shown in the tabulation, along with the frequencies available. Individual units may vary somewhat from the tabulated values.

All receivers are designed to operate a 400-ohm style PN-150 relay, but other types and resistances can be used which fall within the output curve limits, such as a 1,000-ohm relay with less than 7.5 volts working. The 500-ohm style DN-22BH relay is recommended for minimum overlap shunting distance.

The AFO line transmitter also has a potentiometer for adjusting the output level to prevent interference to other audio communication circuits, but no such adjustment is provided on track transmitters, since adequate adjustment is available on the receiver.

The values shown on the receiver and transmitter tabulations are approxi-

roblems

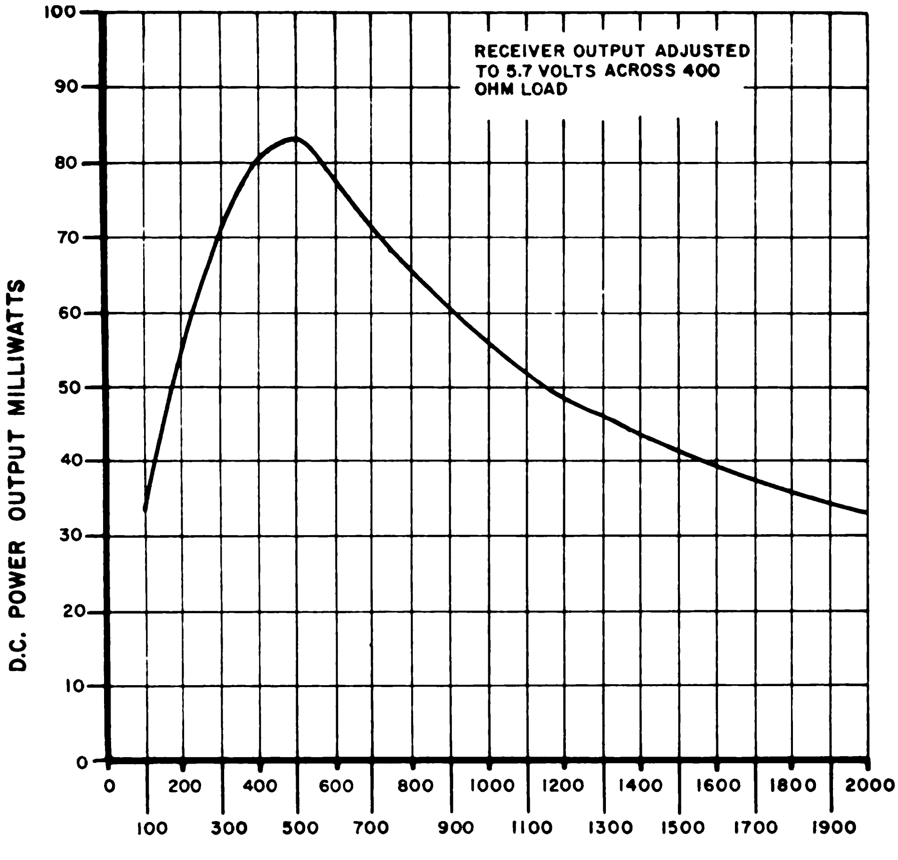
mate, and will vary with battery voltage and also due to manufacturing variations in the components. Limits are shown in the instruction pamphlets. A frequency tolerance of 5 cycles is permissible in the oscillators, although usually the units are tuned within one cycle.

A typical application, Figure 1, shows the AFO superimposed on the signal control lines to provide a block occupancy indication. Coupling units are used to pass the AFO signal from one line to another. Blocking reactors prevent the batteries from loading the AFO circuit. The AFO frequencies are low enough so that contacts can be used to interrupt the signal without fear of by-pass, so that AFO is superior to higher frequency carriers for such purposes. Several receivers can be operated from one transmitter to provide indications at different locations.

The idea of superimposing audio frequencies on other line or track circuits was conceived many years ago, but did not become economically practical until the invention of the transistor. AFO was developed shortly after transistors became commercially available, along with many other devices.

Lightning surges were responsible for considerable damage to transistors in the earlier installations. Use of the style LSS lightning surge suppressor and style USG arresters has greatly reduced this source of damage.

It is also now generally recognized that transistors and similar devices do have a random-failure rate, similar to the lamp curves. Early failures are usually due to aging, and can be



Curve of AFO receiver output characteristics.

Type	D. C. Input Power-Watts	Output Circuit Volts	Output Circuit Load-Ohms
Line			
Non-Vital	0.4	8.0*	600
Track			
Non-Vital	0.5	0.3	1.0
Vital Low Power	0.5	0.4	1.5
Vital High Power	3.0	1.2	1.5

* Adjustable from -10 to +20 dbm

AFO transmitter characteristics: DC input volts, 10 or 12 (nominal).

Type	A.C. Input Impedance Ohms	Maximum Sensitivity Millivolts	Frequencies Available KC
Line			
Non-Vital	600	100	1.0, 1.5, 1.95, 2.7
Track			
Non-Vital	10	20	1.0, 1.5, 1.95, 2.7
Vital	2	2	Class 1 1.0, 1.25, 1.5, 1.75, 2.3, 2.8 Class 2 1.125, 1.375, 1.64, 1.875, 2.175, 2.675

AFO receiver characteristics: DC input volts, 10 or 12 (nominal); DC input power, 0.3 watt.

minimized by conservative rating. The industry has not yet been able to develop methods for weeding out transistors likely to fail, but has been able to reduce the average rate to less than one per thousand. As more experience is gained, reliability will be improved.

Experience has also shown the necessity for training maintenance personnel and improving facilities. In repairing electronic equipment such as AFO, a qualified electronic technician should have adequate test equipment. Care should be used in handling, assembling, and soldering electronic components. Also, a supply of spare components and units should be available. While some of these testing devices are a little expensive, they are useful for many types of electronic equipment.

Fortunately, the many advantages and flexibility of AFO compensate for these growing pains. The AFO track circuit is an independent AC track circuit which can be superimposed upon a portion of one or more track circuits of another frequency. While the same fundamentals of power transmission apply, the AFO track circuit varies from other types because its boundaries are not precisely defined, resulting in an overlap shunting area.

Naturally, this brings up the question—how much will the overlap vary? To provide a precise answer is impractical, but an understanding of the variable factors involved will lead to some generalities, and will answer some other questions, too.

The overlap shunting distance will vary with ballast resistance, battery voltage, proximity to insulated joints, frequency, adjustment, and direction of movement. Let us consider first a typical AFO track circuit of length L superimposed on a long track circuit. Let us assume that the receiver is adjusted with the track circuit dry for an overlap approaching shunting distance L_d, of say 24 ft. Actually, when you adjust the receiver sensitivity, you set its sensitivity at the voltage e_R which released the relay with the shunt; this also determines the rail voltage e_p, required for pickup, which is slightly higher. Since the receiver impedance is high compared to the shunt, the ratio of the rail voltage at the receiver e_R to that at the transmitter E_d is about the same as the ratio of the overlap shunting distance L_d to the circuit length L.

When the track circuit is wet, the ballast leakage increases the attenuation hyperbolically and also loads the transmitter, so that the transmitter rail voltage E_w is less than when the circuit is dry. Taking into account the higher receiver rail voltage e_p to pick up the relay on a receding move, and considering the battery voltage variations, the net result is a maximum receding distance which may be several times the minimum shunting distance. This ratio tends to increase with AFO frequency, track circuit length, and ballast leakage. The overlap distance is about the same at the transmitter end as at the receiver end of the AFO track circuit.

These curves, Figure 2, show how the maximum overlap receding distance varies with ballast resistance and length for a 1 kc circuit adjusted for 0.06-ohm minimum shunting sensitivity, which corresponds to a minimum overlap shunting distance of about 24 ft. since the rail impedance at 1 kc is about 2.4 ohms per thousand feet of track. As anticipated, the receding overlap distance does increase at lower ballast resistances or in longer track circuits. If you set an AFO track circuit for a longer shunting distance, the receding distance will be increased proportionately. On the other hand, if there are

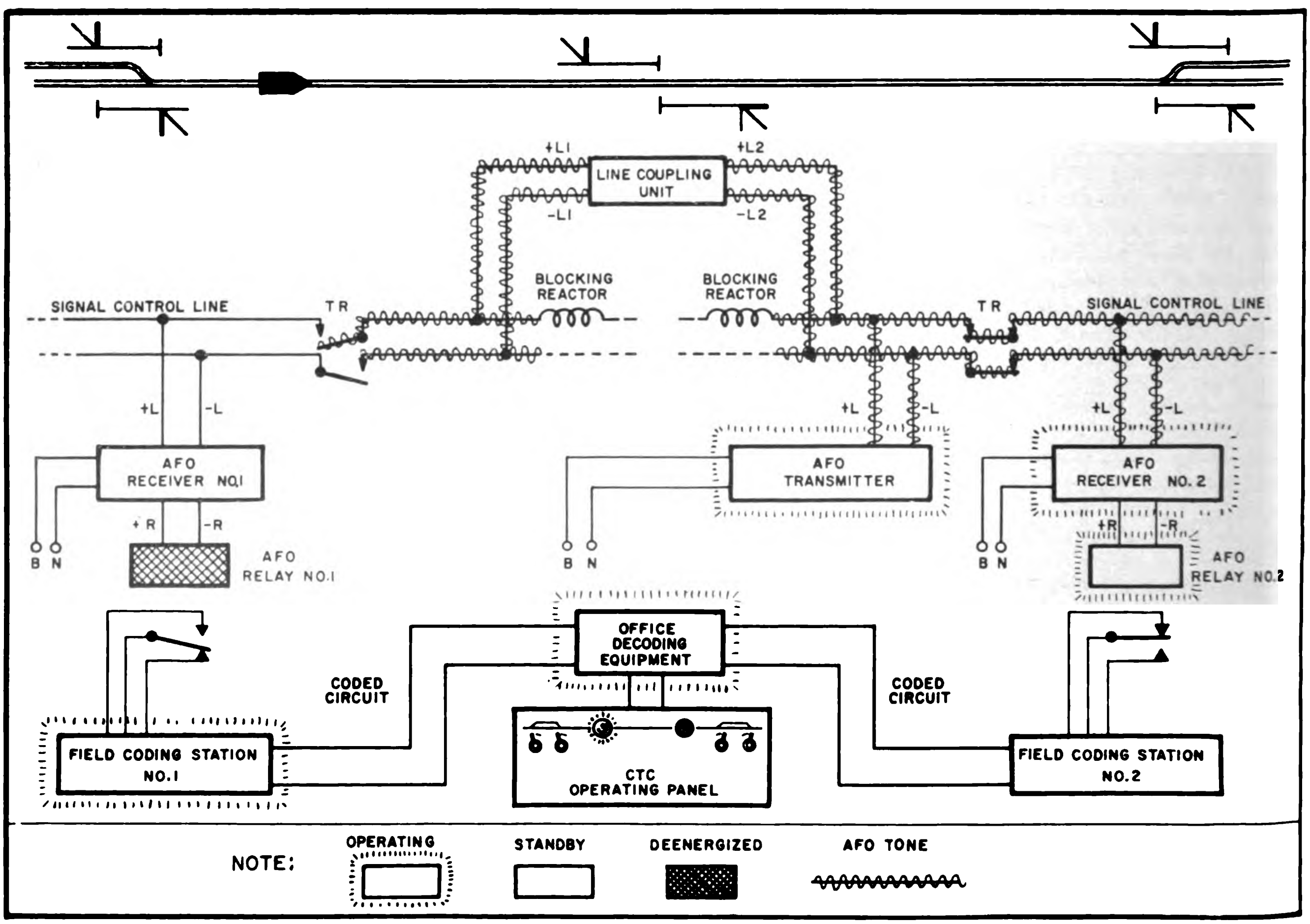


Fig. 1: two indication block occupancy provided by audio frequency overlay line circuits.

Repairing AFO Units

Qualified Electronic Technician

1. Understands electronic components and circuits
2. Works carefully
3. Reads meters accurately
4. Solders well

Test Equipment

1. Electronic frequency counter
2. Variable frequency oscillator
3. Vacuum tube voltmeter
4. DC voltmeters and milliammeters
5. Oscilloscope
6. Battery or power supply

Caution

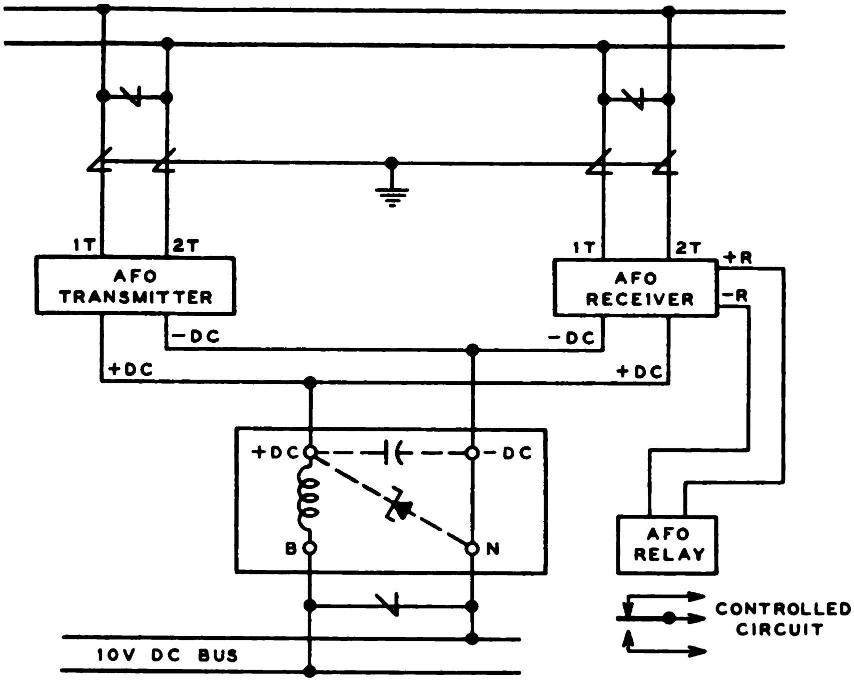
1. Handle components carefully
2. Do not stress leads
3. Use heat sinks when soldering
4. Apply proper polarity

insulated joints close to either end of the AFO circuit, the receding distance will be less.

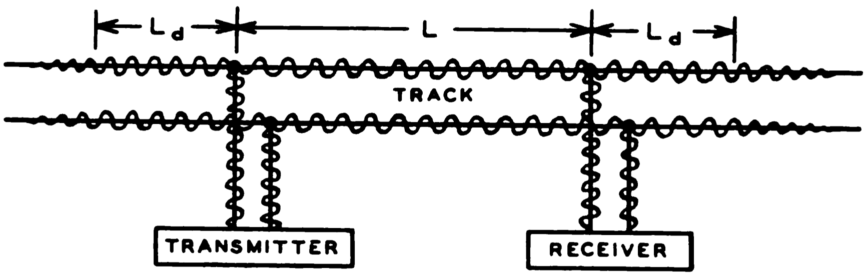
Since the rail impedance is nearly proportional to frequency, you might assume that a higher AFO frequency would have the same effect as a longer track circuit, increasing the receding overlap distance. Such would be the case if an AFO circuit of higher frequency is adjusted for the same approaching overlap distance, since the ratio of wet receding to dry approaching overlap distance does increase. However, if AFO circuits of various frequencies are adjusted for the same shunting sensitivity, results may be different. As these curves show, Figure 3, the minimum approaching overlap distance is reduced at higher frequencies, so that even with a greater ratio, the maximum receding overlap distance may be less. In general, it is desirable to use the lower frequencies for longer AFO track circuits and the higher frequencies for short AFO track circuits.

These curves show that AFO track circuits can be used for timing sections, for distinguishing between high and low speed trains, since variations are relatively small in the distance between shunting points of successive circuits.

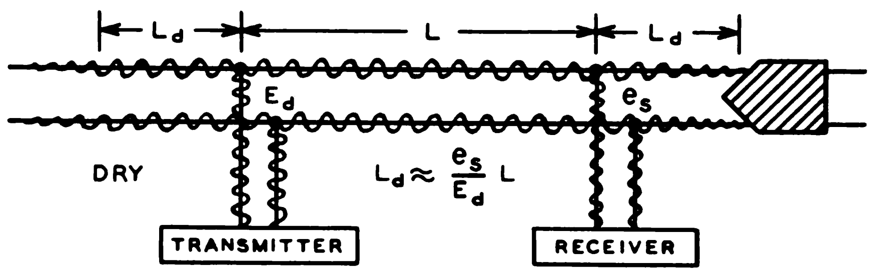
In non-signaled territory, it is not necessary to remove cross bonding or to insulate switches or gauge-rods farther than about 100 ft from an AFO circuit, provided ballast resistance is



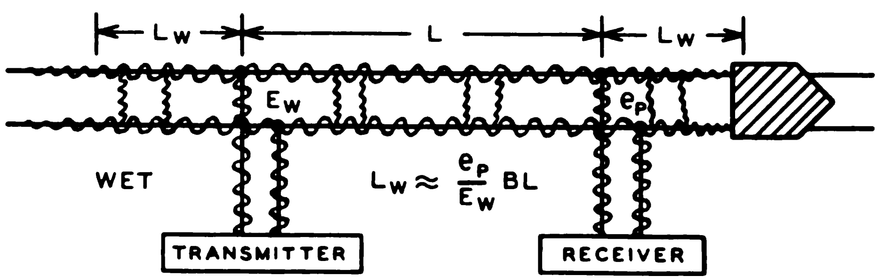
LIGHTNING SURGE PROTECTION



AFO TRACK CIRCUIT



APPROACH OVERLAP, DRY



$$\frac{L_W}{L_d} \approx \frac{E_d}{E_W} \cdot \frac{e_P}{e_S} \cdot B \qquad B = \frac{\cosh\left(L\sqrt{2.4f/b}\right)}{\left(L\sqrt{2.4f/b}\right)}$$

RECEDING OVERLAP, WET

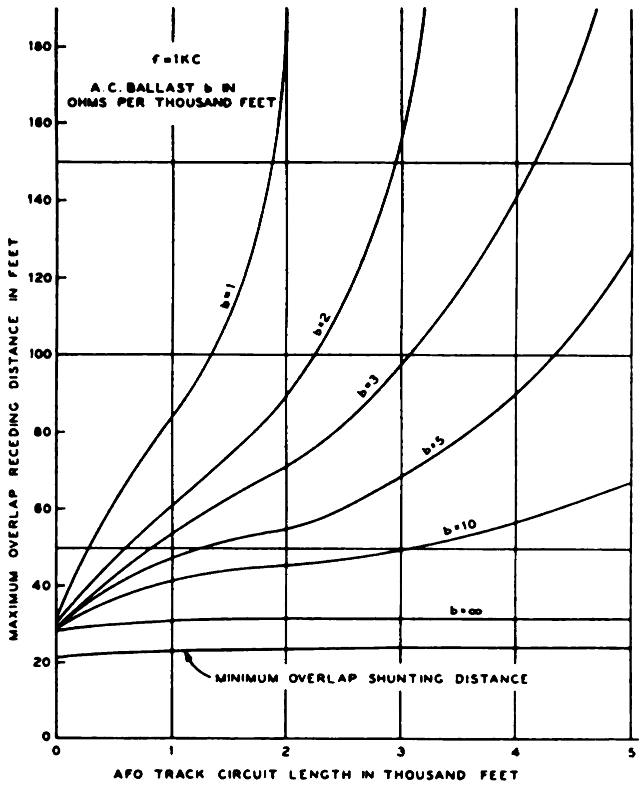


Fig. 2: curves of maximum overlap receding distance.

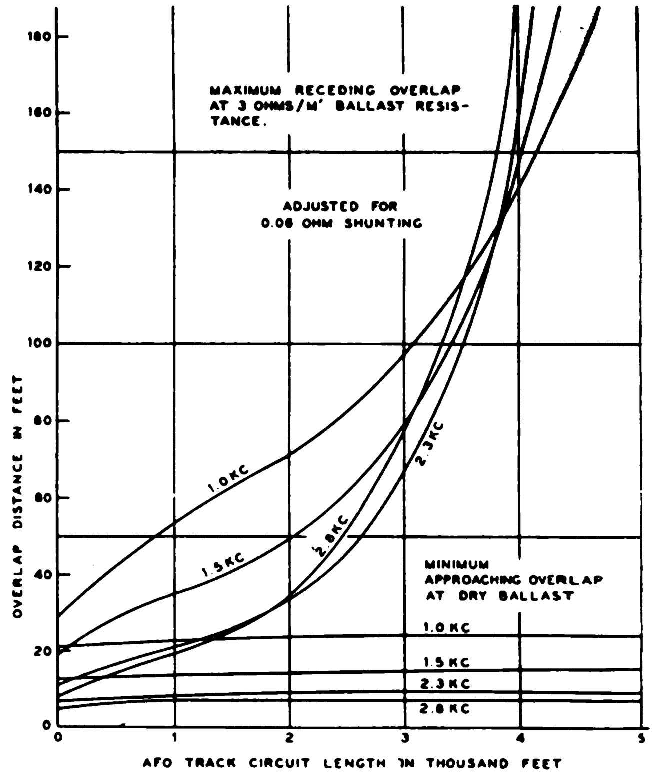


Fig. 3: curves of minimum approaching overlap distance.

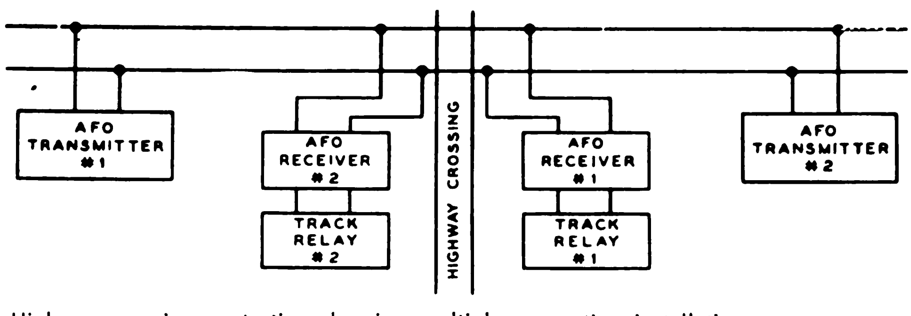
not too low, since the AFO track circuits would probably be short in nonsignaled territory. It should be noted that AFO may not provide good shunting on infrequently used track; in such cases it is preferable to use a higher power track circuit, such as the type C.

Except when the ballast resistance is low, these curves show that the receding overlap distance can be kept fairly short. Thus, the multiple rail connection can be used for the receiver in most cases. Loops need be used for receivers only where more precise cut-off is required and where ballast resistance is frequently low. We suggest that you try the multiple connection first, using a loop connection only where necessary.

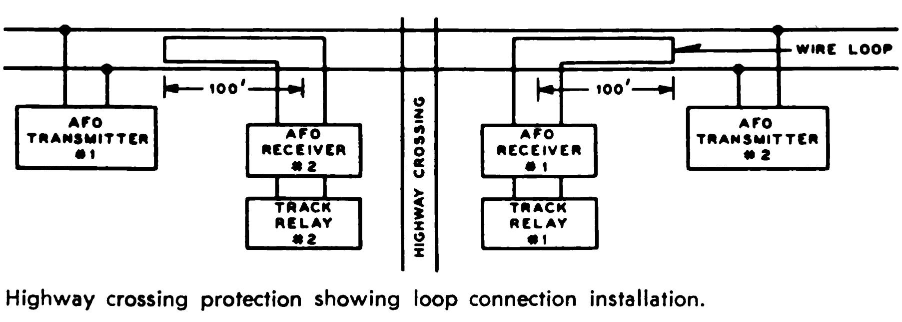
When the AFO receiver is adjusted for 0.06 ohm shunting sensitivity, its pickup sensitivity is approximately the value shown on the curves of Figure 4. Again, this shows the desirability of using lower frequencies for longer circuits, in order to provide a larger signal at the receiver. In short track circuits, 300 ft or less with the low power transmitter, it may be necessary to add a resistor in series with the receiver in order to reduce the receiver signal within the adjusting limits to obtain 0.06 ohm shunting sensitivity. On the other hand, in long track circuits, the low power transmitter may deliver less than 3 millivolts to the receiver, which is its maximum sensitivity, so that it is necessary to take on a higher shunting sensitivity, which results in a longer overlap distance.

The high power transmitter provides a higher receiver voltage, which permits adjustment of the receiver to provide shorter overlap distance. Figure 5 shows the maximum AFO track circuit length which can be operated with 0.06 ohm shunting sensitivity with the low power transmitter. The high power transmitter should be used for longer track circuits, in order to hold the overlap distance within the limits shown on the previous curves.

Sometimes it is necessary to use track coupling units, where the AFO extends beyond insulated joints. The coupling unit for each class can be connected for any one of the six AFO frequencies to reduce losses at that frequency. Each frequency requires its own coupling unit, if more than one AFO circuit extends past insulated joints. The losses depend upon the load, but for practical purposes, the reduction in track circuit length is about 300 ft at 1 kc and proportionately less at higher frequencies. While a coupling unit will attenuate other frequencies, it does not block them. Therefore, frequencies should not be repeated in adjacent cir-



Highway crossing protection showing multiple connection installation.

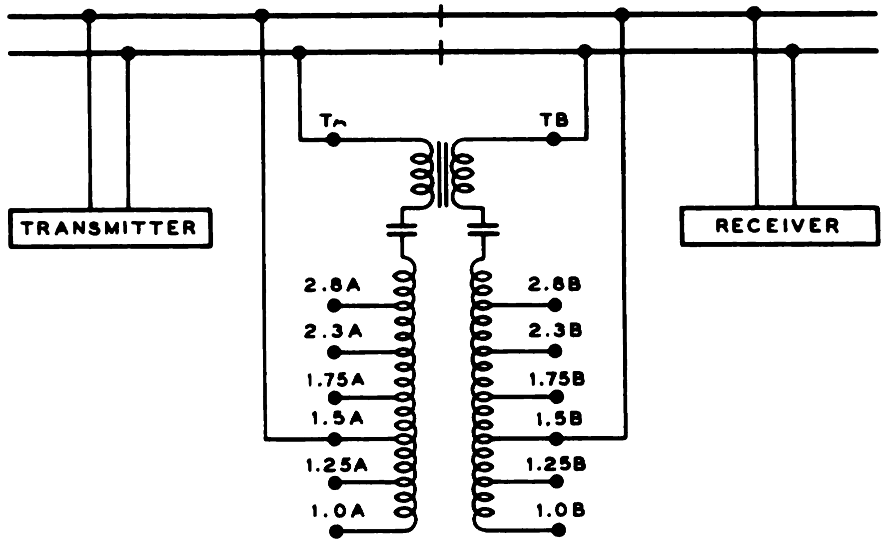


Highway crossing protection showing loop connection installation.

cuits joined by a coupling unit.

The curves, previously mentioned, are based on average conditions in welded rail territory, using 500-ohm style DN-22 BH relays. Naturally, there will be some variations in units. Sometimes you can stretch these limits and get away with it, but it is better to be prudent and allow some margin.

Remember that the AFO track circuit is, first of all, a track circuit. Even conventional track circuits must be properly adjusted to maintain adequate shunting sensitivity. You have qualified personnel to adjust conventional track circuits according to rules. Use the same safeguards for AFO track circuits. Sometimes the question is asked, "What is to prevent the maintainer from adjusting the receiver for maximum sensitivity?" The answer is—your rules. The adjustment is provided to allow for adequate margin. It should be used just as carefully as in conventional track circuits.



Track coupling units are where AFO extends beyond insulated joints.

Adjustment of AFO Track Circuits

1. Make final adjustment in dry weather with circuit unoccupied.
2. Connect all AFO units to rails in track section.
3. Place 0.06 ohm shunt across receiver leads at case terminals, or across rails.
4. Adjust receiver output control until relay just releases.
5. Add resistor, if necessary, in series with receiver.
6. Tighten the output control lock nut.
7. Remove 0.06 ohm shunt. Relay should pick up.

The accompanying chart shows the adjustment procedure. Make final shunting adjustment in dry weather with the circuit unoccupied, with battery voltage high or normal, after all AFO units in the circuit are connected to the rails, including reactors in series with leads to nearby track batteries. If a battery feed for a conventional track circuit is close to an AFO track circuit, enough reactance should be inserted in series with the battery to provide an impedance of 1.5 ohms at the lowest AFO frequency, to avoid shunting the circuit.

The shunting test may be made by applying an 0.06 ohm shunt across the rails at the receiver, using rail clamps to insure good contact. Another way is to apply a 0.06 ohm shunt across the track leads at the relay case terminals. This will produce practically the same results, and may be easier. Lower the receiver output control until the relay just releases. On short track circuits, it may be necessary to add a resistor of 5 or 10 ohms in series with the receiver. Tighten the output control lock nut and remove the shunt.

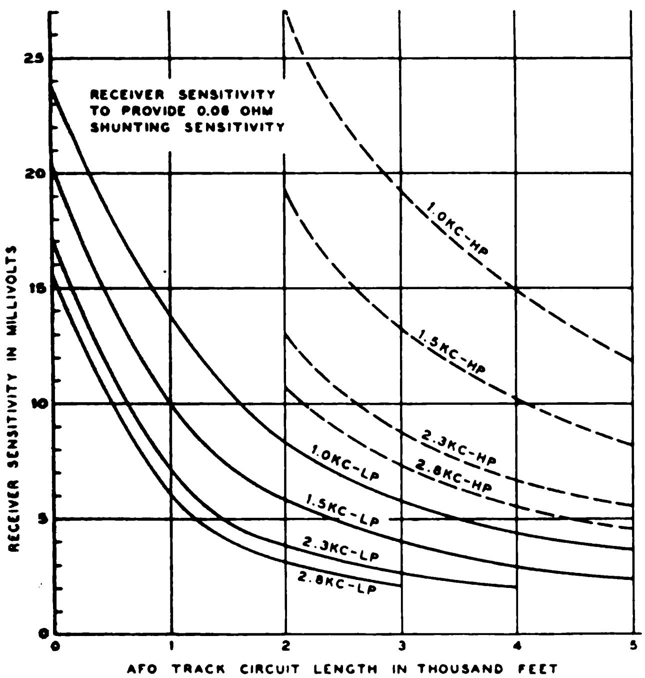


Fig. 4: curves of AFO receiver pickup sensitivity.

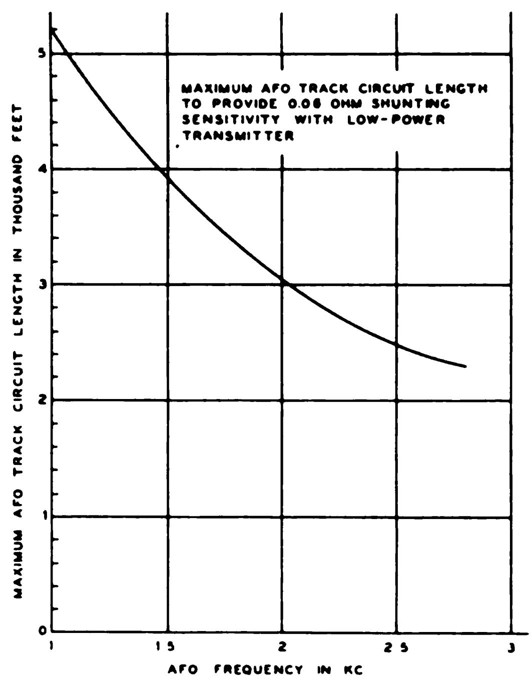


Fig. 5: AFO track circuit length with low power transmitter.

In no case should the receiver be adjusted for a shunt of less than 0.06 ohm. If a higher shunt is used, the overlap distance will be increased proportionately. It is not necessary to check the shunting at the transmitter, since it will be practically the same.

Multiple receivers are frequently used, to provide several AFO track circuits with one transmitter. The shunting of each receiver should be adjusted independently. Since the adjustment is in the amplification of the received signal, it does not affect the signal, so adjustment of one receiver will not affect another receiver.

We have recommended that track lead resistance be kept low. However, it is sometimes economical to house the equipment at the crossing, and take on greater receding distance. This shows the preferable arrangement. With No. 10 copper or equivalent for the transmitter track leads, and the receiver adjusted for 0.06 ohm shunting sensitivity at the receiver rail connections with high battery voltage and infinite ballast, the maximum receding distance L_W will be between 10% and 15% of the circuit length L, with maximum circuit lengths of 2,500 ft at 3 ohms per thousand feet minimum ballast, using low-power transmitters.

In order to meet requirements for complicated highway crossing installations, six more frequencies have been added making a total of 12 available. However, care must be used in allocating these frequencies, particularly where high power transmitters are involved, to prevent interference.

In general, Class 1 frequencies should be used for single track installations and for the first track of double track installations, with Class 2 frequencies being used for the second track. If more tracks are involved, the Classes should be alternated. This eliminates the possibility of interference due to inductive coupling between adjacent tracks.

These rules should be followed for most applications. At first glance, they may seem too restrictive. However, in practically every application, frequency allocations and transmitter and receiver locations can be made within the requirements.

Frequency Allocation Rules

1. Do not use the same frequency on adjacent parallel tracks.
2. Do not repeat the same frequency on the same track unless separated by two pairs of insulated joints.
3. If a high power transmitter is used, do not use another frequency with a separation of less than 500 cps on the same track unless separated by insulated joints.
4. If a low power transmitter is used, do not use another frequency with a separation of less than 235 cps on the same track unless separated by insulated joints.
5. If a coupling unit is used to by-pass insulated joints, do not consider the by-passed joints insulated in determining frequency separation.
6. Provide a ripple-free power source for low power transmitters located within 500 ft of a receiver of another frequency on the same track section.
7. Provide a ripple-free power source for high power transmitters located within 1,000 ft of a receiver of another frequency on the same track section.
8. Do not use frequencies which are close to harmonics of other track circuit frequencies.
9. Code in propulsion or high level coded AC track circuit territory.

The first five rules are designed to prevent mutual interference between different AFO track circuits, due to mutual coupling, leakage around insulated joints, or selectivity. While AFO receivers have good selectivity, it must be recognized that if you connect a transmitter of one frequency directly to a receiver of another frequency and adjust the receiver to maximum sensitivity, you may get some output. However, when properly connected to the rails and properly adjusted for at least 0.06 ohm shunting sensitivity, the output of a receiver should be negligible when energized from a transmitter of the specified frequency separation.

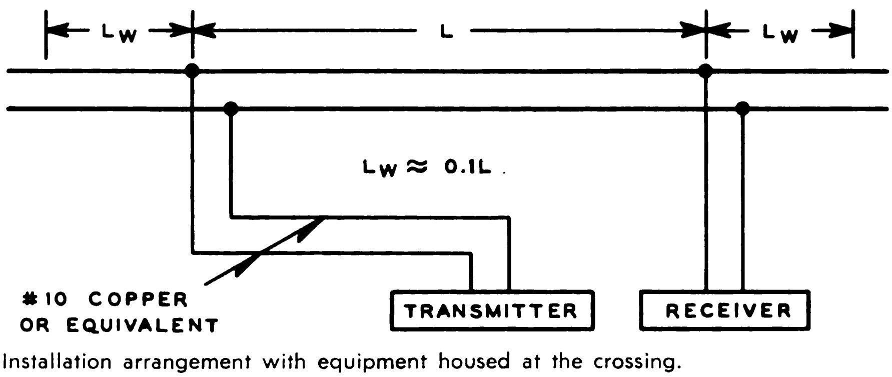
In most installations where multiple crossings are involved, the frequency separation is no handicap. Usually, in the more complicated applications, the low power transmitters provide adequate track circuit length.

The last four rules are designed to prevent interference from other sources. For instance, when an AFO transmitter is energized from a rectifier or a heavily overcharged battery, the AFO signal may be modulated by the ripple frequency or its harmonics, producing small signals at beat or ripple frequencies. The distance factor prevents interference with operation of receivers of other frequencies. This distance can be reduced where the receiver of another frequency is comparatively close to its own transmitter.

AFO track circuits have been successfully superimposed on 60 cps and 100 cps track circuits, but some care should be used in selecting AFO frequencies which are not close to harmonics of 60 cps or 100 cps. Good quality reactors in series with the AC track circuit feed will limit the harmonics fed to the track.

Generally, we have recommended coding AFO track circuits in propulsion or high level coded AC track circuit territory. However, some installations without coding have been successfully made in propulsion territory where the AFO track circuits are short, where the receiver signal is considerably above the propulsion interference. Even coding

(Please turn to page 52)



Installation arrangement with equipment housed at the crossing.

AFO Frequencies in CPS

Class 1 LP	Class 1 HP	Class 2 LP	Class 2 HP
1000	1000	1125	1125
1250	1250	1375	
1500	1500	1640	1640
1750		1875	
2300	2300	2175	2175
2800	2800	2675	2675

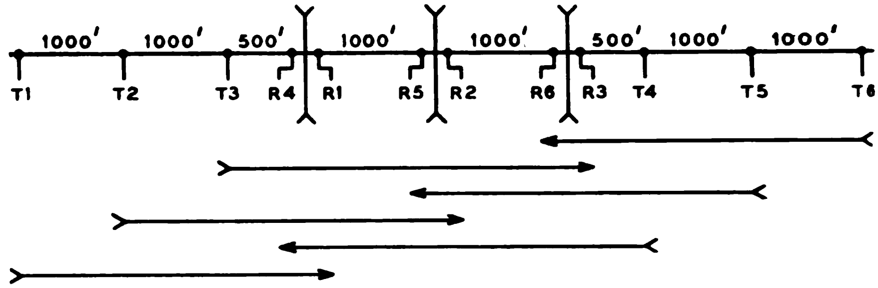
(Continued from page 26)

may not be unduly costly, because such installations usually involve multiple track, where one transmitter can be coded alternately to two tracks. In one double track installation, covering nine adjacent crossings with gates, in service over two years, by coding alternately to the two tracks, six transmitters operated 27 receivers.

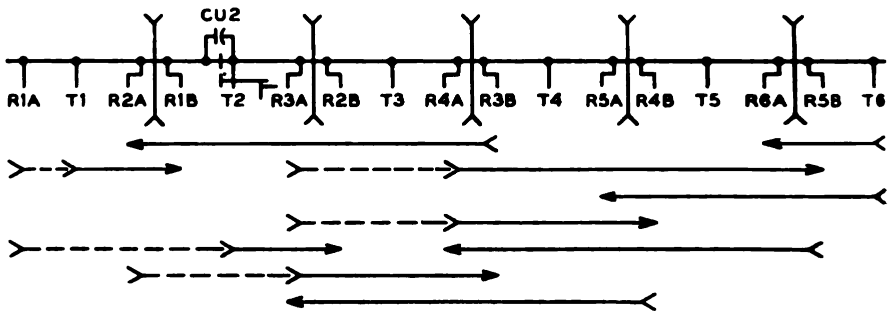
A number of railroads are now installing large stretches of welded rail. To save insulated joints, they are extending the signal track circuits by using style DN-22BH track relays or coded track circuits, and using AFO for highway crossing control. In some of the more complicated highway crossing applications, they are using some of the existing line wires to simplify the AFO application.

If only three or less highway crossings are involved in a space 500 ft less than the approach distance, and low power transmitters can be used, there is no problem in frequency allocation. Simply use the six frequencies in one Class on each track.

One railroad, in converting to welded rail, had many line wires available, and used this combination of AFO frequencies to eliminate insulated joints except at signal locations. Timing out control sections are dotted. Note that the use of two receivers fed from each transmitter provides twice the number of track sections and control points for the same number of frequencies. The comparatively short AFO track circuits provide short overlap sections, and this factor coupled with the spacing, eliminated the necessity of providing a ripple-free power supply.



AFO circuits used for three or less adjacent highway crossings.



How AFO may be used to eliminate insulated joints except at signals.

At least four receivers, two in each direction, can be fed from one transmitter to reduce equipment and frequencies. Another alternative in complicated layouts is to use a conventional island track circuit at one highway crossing; then the same frequencies can be used on either side of the island circuit, thus reducing the number of frequencies required.

Any complicated layout justifies study to determine the most economical arrangement of AFO equipment, insulated joints, and line wire. AFO is so flexible that it is impossible to cover all feasible arrangements. RS&C

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