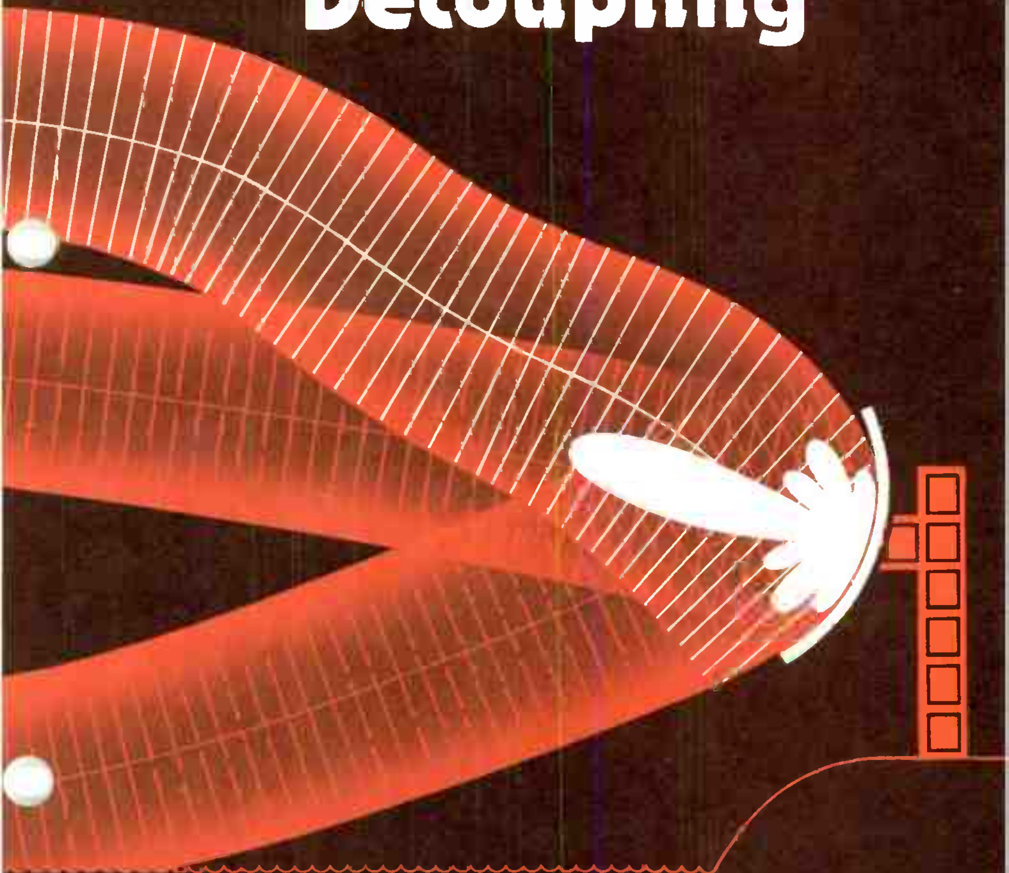
GTE LENKURT

DEMODULATOR

MARCH/APRIL 1978

Antenna Decoupling



Also in this issue: **Loop Pulsing**

The July/August, 1975 GTE Lenkurt Demodulator's discussion of anomalous microwave propagation briefly considers antenna decoupling as a type of non-selective power fading. Since that issue, a substantial amount of field experience has shown that antenna decoupling is a major cause of nocturnal fading on microwave links. This issue of the Demodulator reports on this experience.

In some geographic areas, nighttime multipath fading on long or low-clearance, line of sight microwave links is regarded as inevitable and not correctable except by diversity techniques. These areas usually have hot humid atmospheres supported by swamps, irrigated land or other nearby warm, shallow bodies of water. In these areas severe evening and morning fades occur which make some 6 to 13 GHz systems unusable.

Recordings and Analyses

The two recordings shown in figure 1 are typical of numerous rf receive signal level recordings which have been made on some of these unreliable paths. Analyses of these recordings show that fades sufficiently deep to cause outages most often occur when fast multipath fades are superimposed on slow power fades. These slow power fades are often caused by a change in the wavefront arrival angle at the receiving antenna.

The arrival angle change is usually upward and results from after sundown, superrefractive atmospheric conditions caused by the movement of cool air over warm, moist terrain. A similar change may occur when a weather front crosses or traverses the path. This angular change could cause antenna decoupling and a consequent increase in net path loss (Power Fading). One conclusion based on analyses is: The increase in selective multipath fades, to a severity which makes a path unusuable, is more often related to a depression in the desired receive signal level caused by antenna decoupling, than to any dramatic increase in the number or amplitude of multipath interferring signals.

Some skill is needed to distinguish between the slow power fades of interest here, and the slow multipath fades caused by a stable, multipath reflection. These latter fades occur on paths over reflection terrain or water during a time of relatively stable atmospheric conditions. A stable, deep reflection fade is seldom accompanied by additional multipath signals and has a slow, rolling characteristic rather than the random characteristic of a power fade.

Figure 2 shows recordings typical of reflection-only interference fading. The characteristic differences between multipath superimposed on power fading and interference only fading may be seen by comparing figure 1 to figure 2.

From figure 1, it is clear that: Had the direct signals remained stable at or near their unfaded level, the severe multipath fading and its accompanying "hits" or outages would not have occurred. Therefore, solutions to this kind of fading problem should be directed toward stabilizing the desired dish-to-dish received signal, to eliminate or minimize long-term power fluctuations, instead of trying to minimize the amplitude or number of secondary interference signals.

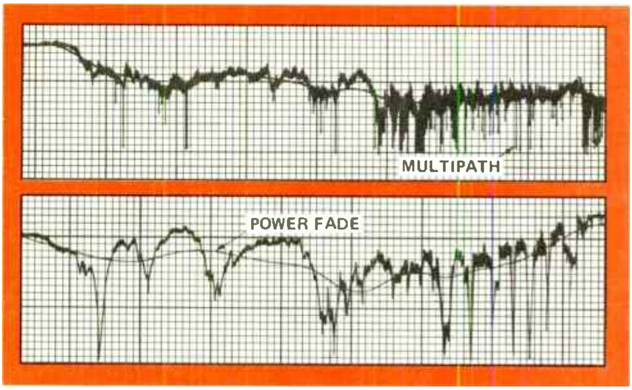


Figure 1. Two examples of multipath fades superimposed on power fades.

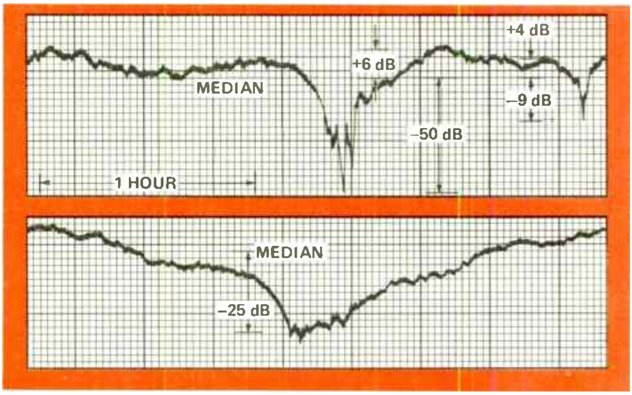


Figure 2. Two examples of reflection only interference.

As previously stated, the power fades under discussion result from antenna decoupling. Antenna decoupling refers to a partial or complete loss of signal that occurs when the direct ray moves vertically off the peak of the main lobe of either or both the transmit and receive antennas. The antennas are temporarily misaligned to the incoming wavefront.

Ray Tracing

A microwave wavefront traveling through the atmosphere may be represented as a single line or ray which is the centerline of the route taken by the expanding wavefront. The track taken by the ray is perpendicular to the wavefront at every point, as shown in figure 3.

Analysis of refraction, diffraction and reflection are simplified by using single-line ray techniques. All path profiles, whether plotted on flat or curved earth graphs, are smoothed ray tracings, as shown in figure 4.

Propagation Conditions

There may be many interference rays propagated along a microwave path, but there is only one direct ray to which the antennas should be aligned. This alignment should be accomplished during stable, non-fading radio propagation periods.

Stable propagation periods are not identified with a stable atmosphere. On the contrary, stable propagation periods are associated with an unstable, mixed, turbulent atmosphere

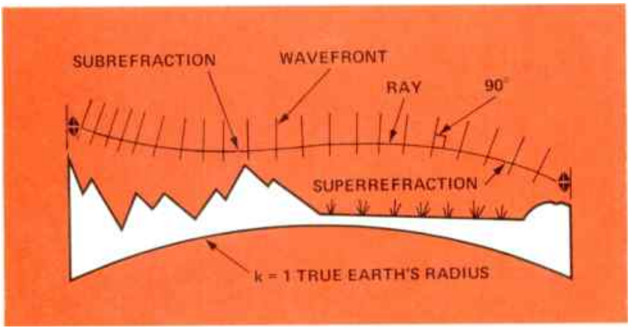


Figure 3. Ray tracing.

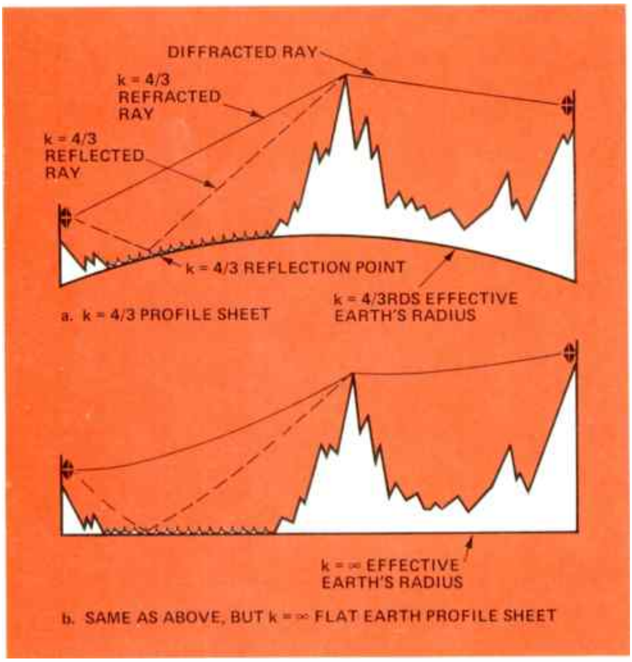


Figure 4. Ray tracings, flat and curved earth profile sheets.

which is most often present on cool, windy days when air temperature decreases as altitude increases. This causes the warm air near the ground to rise and mix with the cooler air aloft.

Normally, antennas are aligned for a maximum rf received signal level during quiescent, non-fading propagation periods, with k, the effective earth's radius between 1.25 and 1.6 in a standard atmosphere. The "k" factor is a measure of the refractive index gradient of the atmosphere. Complete definitions are presented in the references listed in the bibliography at the end of this article.

On paths in the areas discussed in this article, k could increase to infinity and beyond into negative values on the order of −1 to −½ during the nocturnal hours when superrefractive atmospheres exist. A major upward change in the ray departure angle from the transmit antenna and/or the ray arrival angle at the receive antenna results.

Antenna Beamwidths

If the antenna beamwidths are narrow and the path is long, the angular change causes an antenna decoupling "misalignment." The desired signal is reduced and the unwanted, multipath signals are often enhanced. Severe interference fading often results.

Narrow beamwidths are a characteristic of the larger antennas and reflectors used on long 6 and 12 GHz microwave systems. A ten foot diameter, parabolic antenna operating at 6.7 GHz has a beamwidth of ±0.50 degrees between half power points. Referring to figure 5, if such an antenna were aligned during a k = 1.2 standard propagation period, the upward change in arrival angle in a k = −1 superrefractive atmosphere would be 0.51 degrees, over a 38 mile path. A 6 dB power fade in received signal level would result. A k = −½ superrefractive atmosphere would cause a 0.79 degree upward change in arrival angle and a path outage could result. Ground based atmospheric conditions which produce a k = −½ factor are not uncommon in some areas.

Antenna Alignment

Antennas in the 12 GHz bands have a beamwidth about half of those in the 6 GHz bands. Since large passive reflectors have even narrower beamwidths than antennas their use may have to be avoided entirely in some areas.

Over the past several months, antenna decoupling was identified as the major cause of severe nighttime fading on several microwave paths. On most of these paths, the problem was corrected by first carefully aligning the antennas for maximum received rf signal, then elevating the orientation of each dish for a 1 to 2 dB loss of signal, to prevent nighttime, negative decoupling. The alignment were performed during stable, standard k propagation periods.

In summary, antenna decoupling has been identified as a major cause of severe nocturnal fading on many microwave links. Careful antenna alignment, following the procedure described, will correct most decoupling problems.

Checklist and Recommendations

The following paragraphs might be used as an antenna decoupling and alignment checklist:

1. Avoid narrow beamwidth antennas, such as large diameter parabolas or passive reflectors, on long or low clearance paths over:
   a. areas with basin-like characteristics capable of containing and supporting low-level atmospheres with steep refractive index grandients.
   b. areas with extensive irrigated lands, swamps or shallow bodies of warm water, especially those

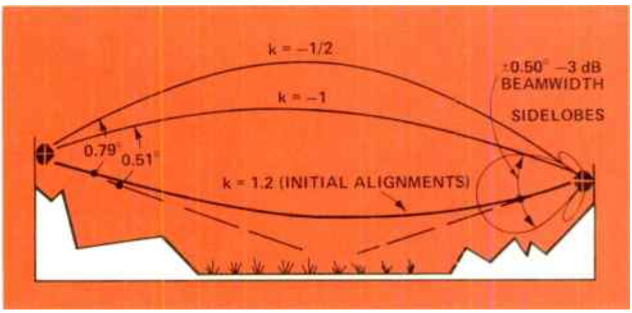


Figure 5. Antenna decoupling on a 38-mile 6.7 GHz path traversing a swamp.

which support steam or tule fog.

c. areas parallel to coastlines, rivers, lakes or other bodies of water which change temperature with the ambient air temperature or solar radiation.

2. If decoupling is predicted or suspected, antenna alignment must consist of more than simply orienting for maximum rf receive level. The antennas should be precisely aligned to the peak of the main lobe, then elevated slightly for a one or two dB loss. The alignment should be accomplished during a stable, nonfading, daytime period. This will provide two benefits:
   a. The main lobe will still be oriented to the incoming ray during superrefractive periods.
   b. The upward tilt will provide increased discrimination against ground reflections.

If antenna or passive reflector orientation is not completely effective the larger antenna, or the one nearest the atmospheric layer, could be reduced in size or defocused by changing the feed position or bowing the reflector to increase the beamwidth. However, these actions reduce the gain. There are indications that intentionally misaligning a few panels in a large passive reflector, to "fill in" the deep far field notches, may alleviate antenna decoupling problems for these devices. The antenna nearest the adverse terrain or lowest in elevation is usually the most critical.

If all else fails, the path may have to be configured for space diversity. This provides close to 100% protection against multipath fading, even with the reduced fade margin caused by the long-term power fade. Space diversity also permits "angle diversity" where one receive antenna is pointed slightly up and the other slightly down to track arrival angle changes. In the reverse direction, the transmitters may have to be switched from one antenna to the other to track any long-term, non-selective variations in signal level.

An interesting correlation exists between microwave propagation conditions and smoke plumes. If a plume rises vertically at an accelerating or constant rate, propagation conditions are good. If the smoke plume bends and travels parallel to the earth or has a downward component, conditions conducive to an anamolous or decoupling propagation environment exist.

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Loop Pulsing

The first electro-mechanical calling devices installed in telephones were designed by watchmakers and the number plates were made by watch dial manufacturers so the device became known as a dial and the signaling method became known as dial pulsing. The first commercially successful automatic switch for telephone offices is named after its inventor, Almun B. Strowger. With the Strowger switch and the dial, recognizing the signaling address became strictly a matter of timing the interruptions in the subscriber's loop line-current. These interruptions cause the current to flow in a series of pulses, hence the term loop pulsing.

Today, dial pulsing is often originated by senders instead of dials and received in registers instead of directly controlling the Strowger step by step (S x S) switches. Electro-mechanical switches are being replaced by solid state devices. However, the basic timing requirements are still the same as those established for S x S switching years ago. In fact a large number, if not a majority, of telephone offices still use electro-mechanical switching.

The procedures and test equipment used for loop testing were also developed years ago. Except for a few evolutionary changes, they are the same today as they were then.

Recent experience indicates that these procedures and equipment are not completely adequate for testing all loop pulse applications. Also, as often happens with day to day operations that have been performed for a number of years, the tests have become so routine that little thought is given to what is actually being measured, the significance of the measurements, and the limitations of the test equipment.

This issue of the GTE Lenkurt Demodulator reviews the standard procedures with reference to what is being measured, under what conditions, and why certain test limits are specified. It also discusses the tests for which a signaling test set, using a selector type A relay as a pulsing standard, is suitable and the tests for which it is not. The characteristics of improved test sets, suitable for testing all the loops, are described.

In telephone systems employing loop pulsing, the local switches are controlled by the subscribers' dials directly, or through intervening pulse repeaters. The pulsing signals are connected to the office through a pulsing or type A relay which repeats the pulsing signals. The pulsing signals' characteristics and hence the relay performance are largely determined by the calling subscribers' dial characteristics and the line conditions.

Dial Characteristics

The subscribers' dial has a cam which, when a digit is dialed, provides a group of breaks separated by short makes. The number of breaks is determined by the numerical value of the digit dialed. A break is an open circuit or on-hook condition; a make is a closed circuit or off-hook condition.

The sum of break time and a make time gives the time of a pulse period. For example, if the break time is 56 milliseconds (ms) and the make time is 35 ms, a pulse period is 91 ms. Dividing 1000 by the pulse period gives the pulse rate (pps) in seconds—in this case 11 pps. Pulse rate is often referred to as dial speed. Dividing the break time by the period time and multiplying by 100 gives the break percentage of the pulse period, $\frac{56}{91} \times 100 = 61.5\%$. The requirement for dials in service is 8 to 11 pps which equates to pulse periods of 125 and 91 milliseconds respectively.

In our example, if the selector A relay repeated the dial pulses exactly it would close the circuit to the selector B relay 38.5 percent of each pulse period and during the remaining 61.5 percent of the period, it would close the circuit to the selector C relay and stepping magnets. Practically speaking, however, perfect repeat timing is rarely if ever achieved. There are several things which affect the pulses the A relay delivers. One of these is the dial itself. It may have a pulse ratio slightly higher or lower than 61.5 percent break. Variations in dial speed also affect the pulses.

Line Conditions, Loop and Leak

Another important factor, which affects the A relay's ability to repeat the dial pulses, is the subscriber's line. When the subscriber line is opened at the dial, there is a small time delay before the A relay releases. Similarly, when the dial closes the circuit, there is a small delay before the A relay operates. These time delays are known as "release time" and "operate time."

If the release time and operate time are equal the A relay will accurately reproduce the dial pulses. This seldom happens in practice. The release times and operate times are usually unequal and there is pulse distortion.

The resistance of the line loop in series with the A relay reduces the operating current and increases the operate time. This effect is aggravated by low battery voltage. If the line resistance is very high the operate time becomes much longer than the release time.

Line leakage has the opposite effect. Leakage is anything which permits current to flow after the dial opens the loop. It includes the steady current permitted by the line's insulation and the transient current due to the line capacitance. The capacity of the ringer condensers is usually the major item. Leakage increases the release time of the A relay. This effect is aggravated

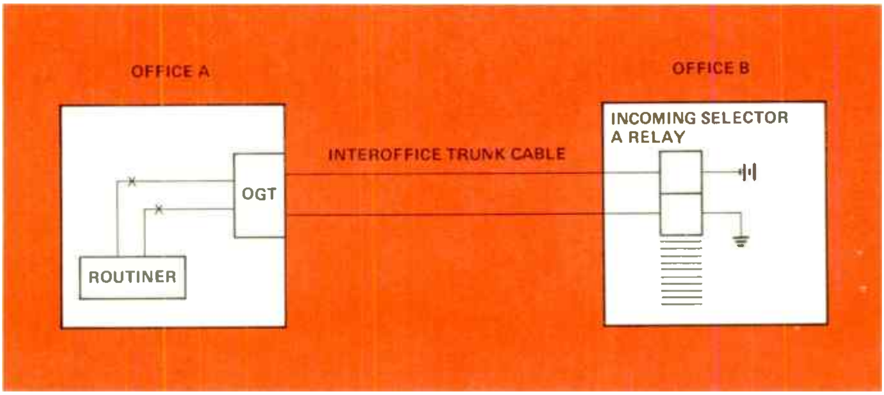


Figure 1. Outgoing Trunk Number Completing Test

by high battery voltage. If the leakage is very high, the release time becomes much longer than the operate time.

Subscriber loops are engineered so that the Strowger switches will operate under worst case leakage conditions and worst case loop conditions. Both of these conditions must be met under worst case dial speeds of 12 pps.

These worst case conditions are simply the minimum and maximum time limits required for proper stepping of the Strowgers. In other words, the engineering constraints for both the subscriber dial and line are established by the operational capabilities of the Strowger switches.

Local Selector and Connector Tests

The selector and connector switches are tested by pulsing their A relays under loop and leak conditions and observing the switches to see that they step correctly. The craftsman watches the mechanical operation of the switches while dialing a series of digits. A meter is not used for these tests. However, if the Strowger operates correctly, it is known that the pulse break percentages are within 42% to 84%, since these are the limits for proper switch operation, under leak and loop test conditions.

The loop test pulses the A relay through a simulated 1400 ohm line at a dial speed of 12 pps with a 68.5% break ratio. The leak test pulses the A relay at a dial speed of 12 pps with 60.5% break ratio and a Leak A condition. If the switches operate correctly, subscribers connected to this office can dial through to each other – intraoffice dialing can be accomplished.

Outgoing Trunk Test

Outgoing trunk tests may be accomplished end to end or on a single ended basis. Figure 1 shows the test setup for end to end tests. The Routiner is used at office A to dial pulse the outgoing trunk, with standard loop and leak test conditions, to a test number in office B. If the test number is reached, interoffice calls can be completed from office A to office B. Physical trunks that fail this number completing test must undergo additional testing and adjustments until satisfactory performance is exhibited. These tests are described next.

Local Pulse Repeating Tests

Local pulse repeating tests are per-

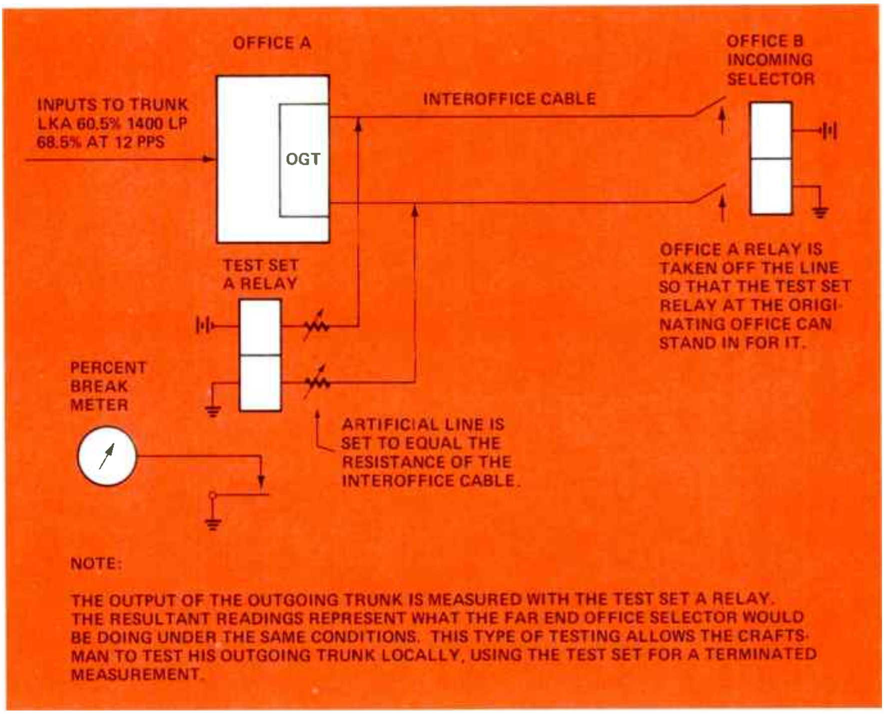


Figure 2. Local Pulse Repeating Test

formed by pulsing the outgoing trunk with standard leak and loop inputs. The dial pulses are sent over the trunk cable by an outgoing trunk (OGT) type A relay. Machine switch contacts are not available as visual indicators so the actual percentage of break ratios must be measured.

Figure 2 shows the test setup for local pulse repeating tests. *It is important to note that this is a terminating test.* The A relay in the test set simulates the A relay in the incoming selector switch at office B. To assure that calls will be successfully completed into office B, the break percentages must fall within the following limits:

Minimum	48% (Leak Test)
Maximum	78% (Loop Test)

The OGT type A relay is a better pulse repeater than the Selector A relay. The OGT break ratios are tighter than the selector break ratios. Therefore, the office B incoming selector should be pulsing well within its limits.

	Selector Limits	OGT Limits	Safety Margin
Minimum	42%	48%	6%
Maximum	84%	78%	6%

Satisfactory completion of the local selector and connector test and the local pulse repeating test assure that a subscriber can dial through office A and into office B, if the interoffice cable is within specifications. The same subsciber loops that adhered to the 42 to 84 percent break ratio limits to the selectors and connectors produce outgoing trunk A relay outputs in the 48 to 78 percent range.

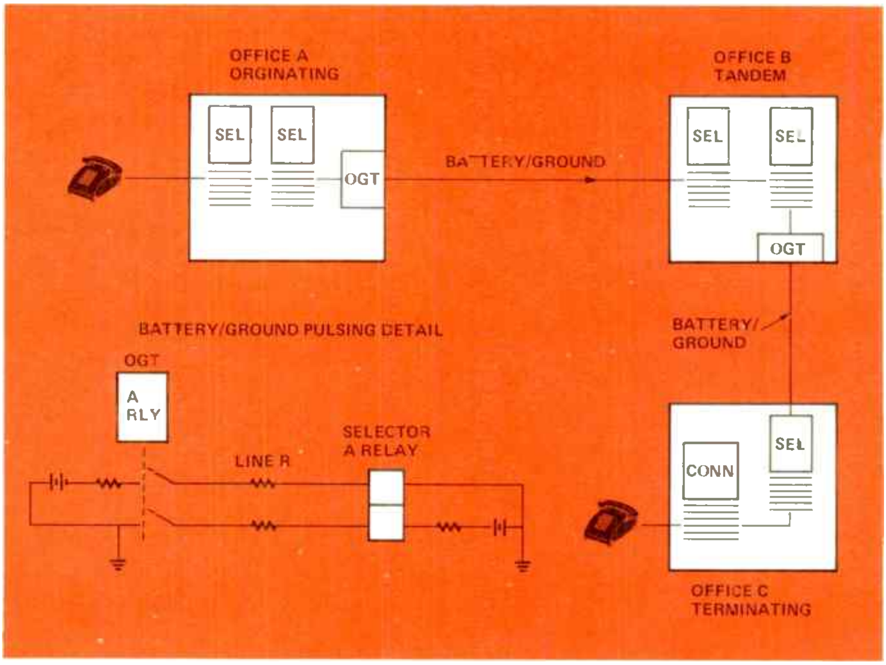


Figure 3. Tandem Physical Trunks

Tandem Physical Trunks

Physical type equipment such as selectors, connectors and loop outgoing trunks that are maintained within specifications, and pulsed with a recommended type of battery/ground input, will follow the pulsing source contacts with minimum distortion. Therefore, subscribers in office A will be able to reliably dial through office B to office C as shown in figure 3. Battery/ground pulsing is superior to loop pulsing because it reduces the effects of line length.

Subscriber Carrier Pulsing

Referring to figure 4, a subscriber carrier system must operate within the same constraints as a local subscriber loop. That is, under standard leak and loop tests, the carrier system must not produce outputs greater than 84% or less than 42% break while dialing into local selectors and connectors. However, the craftsman uses the meter and stand-in selector A relay for the measurements. The percentage requirements are established by local practice but must be within 42 - 84%. If they are satisfactory, local intraoffice dialing can be completed.

Also, the same constraints apply to subscriber carriers pulsing outgoing trunks as apply to local subscriber loops. That is, outputs greater than 78% or less than 48% break must not be produced while dialing into an outgoing trunk.

Trunk Carrier Pulsing

Referring to figure 5, the trunk carrier must operate within the same constraints as an outgoing, physical trunk circuit. That is, taking into account worst case dial and line conditions, the terminating end of the

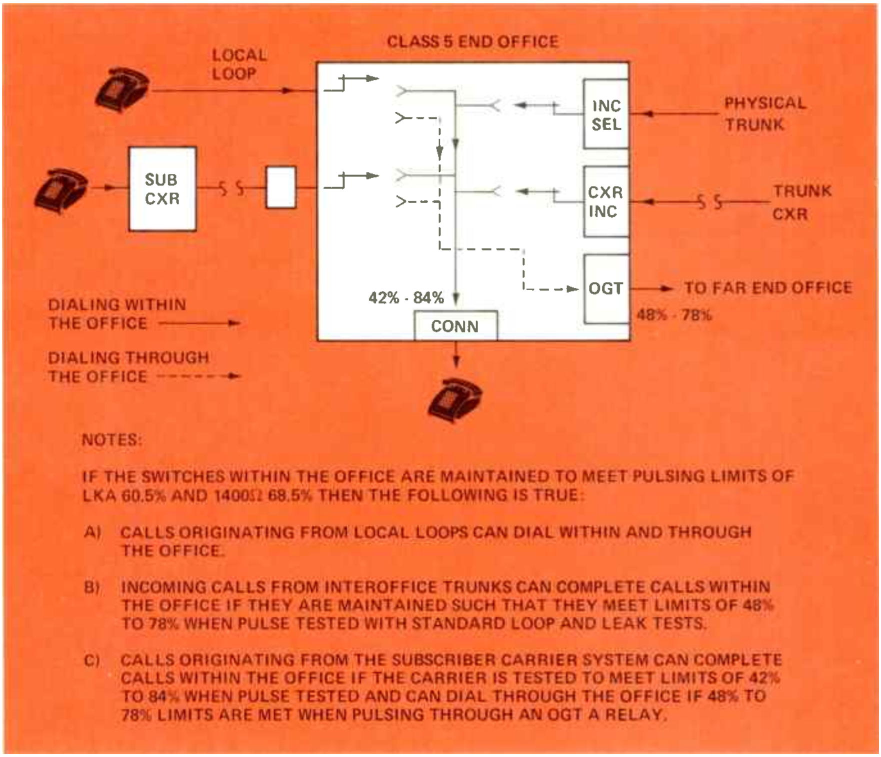


Figure 4. Subscriber Local Office Pulsing

trunk carrier must maintain outputs less than 78% maximum and more than 48% minimum break when pulsing into a selector type A relay.

Carrier Pulsing Tests

The original intent of Local Pulse Repeating Test Sets was to provide a convenient instrument for measuring the pulsing performance of loop outgoing pulse repeater trunks. Those test sets include a selector A relay to, "simulate the pulse receiving relay in a distant office." Signaling Test and Local Pulse Repeating Test Sets were developed to measure interoffice pulsing performance. As long as the interoffice trunk is a cable using battery and ground or dry loop pulsing, a selector A relay is a suitable device for measuring interoffice pulsing performance.

With the advent of subscriber carrier, PBX trunks, and other originating equipment working into a Class 5 office, a need arose to test the pulsing performance of these systems. The same test sets that were designed to measure the pulsing performance of interoffice trunks are now used to test local, intraoffice devices. The selector A relay in the test sets is used to indicate that subscriber carriers, etc. can connect into a local office. However, when this same equipment dials through the local office and accesses an outgoing trunk for an interoffice call, pulsing cannot be guaranteed because the same incoming line pulses that correctly pulse the selectors and

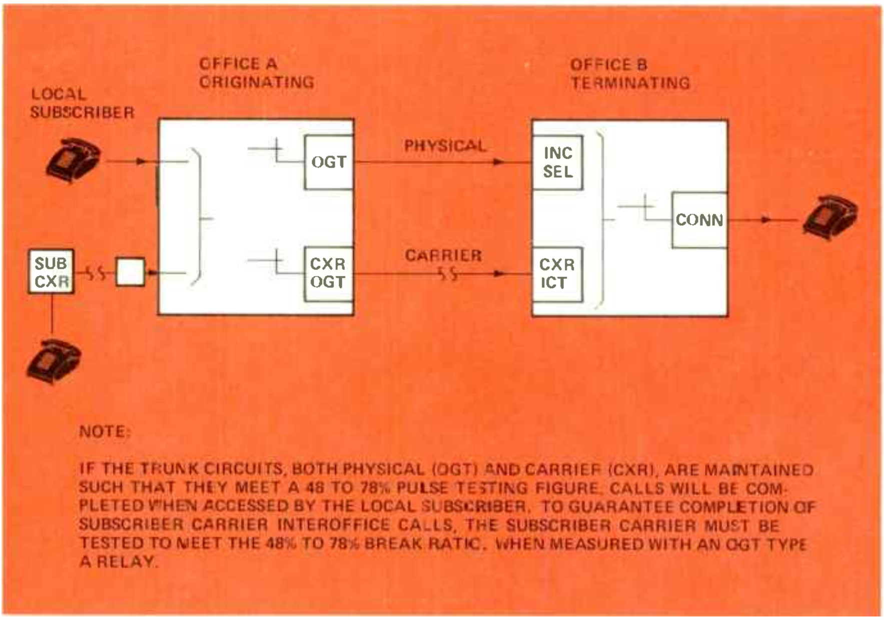


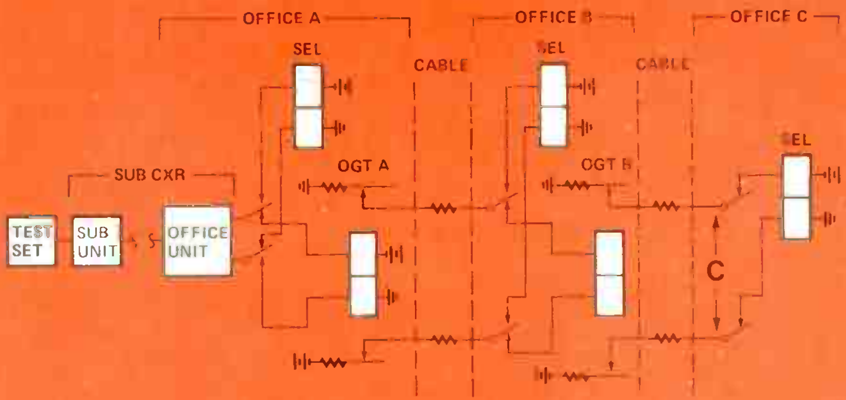
Figure 5. Interoffice Single Trunk Link Call

connectors will be "looking" at a different load when they pulse the OGT type A relay. In this case, tests which are based on a Selector A relay are not valid for outgoing trunks because the two relays react differently to the pulsing inputs. Tests based on the Selector A relay are valid only for a terminating measurement.

For systems where carriers are involved, the only correct application for signaling test sets, with Selector type A relay indicators, is end to end tests. A suitable test set up for these tests is diagrammed in figure 6. There is an obvious disadvantage to this test method. It involves extensive coordination between offices. If the offices are owned by different telephone companies, this disadvantage is compounded. A better solution to the problem is a test set using an OGT type A relay as a pulsing standard. A short discussion outlining reasons why the "standard" test set is not suitable will help in understanding the features of an "ideal" test set.

The use of OGT pulsing relays as a pulsing standard would provide several benefits. The repeatability with OGT type A relays is better than the repeatability with Selector type A relays. OGT relays are designed to pulse better than selector relays. An OGT relay pulsing standard would relate to tandem loop pulsing networks. The readings one would expect to see would be in the range of 48 to 78% break. Readings within this range would guarantee tandem operations and also be ample to guarantee terminating connections.

Referring to figure 7, it would be possible to split up the tandem connection into separate pulsing links and make meaningful measurements on each link. If each link met the 48 to 78% break ratio with an OGT relay as the measuring device, the total tandem link should work. The signaling test set with the OGT A relay would

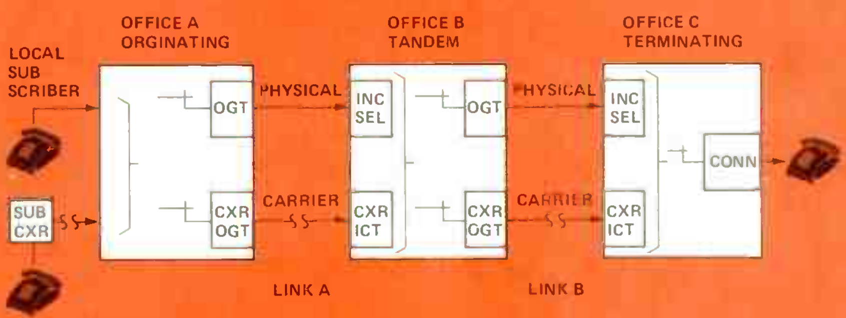


NOTES:

1) TO PULSE TEST THE ABOVE NETWORK A SELECTOR A RELAY WOULD BE PLACED AT POINT C ONLY. PULSES THEN WOULD ORIGINATE AT THE CXR INTERFACE AT THE WORST CASE LOOP AND LEAK CONDITIONS. THE SELECTOR A RELAY OUT PUT AT OFFICE C SHOULD THEN FALL WITHIN 42 TO 84% (THEORETICAL) OR 46 TO 80% ALLOWING FOR MARGIN.

2) TESTING THE INDIVIDUAL LINKS WITH A SELECTOR A RELAY WILL NOT INDICATE WHAT WILL HAPPEN WHEN THE INDIVIDUAL LINKS ARE SET UP IN TANDEM. THIS IS BECAUSE THE SELECTOR A RELAY DOES NOT BEHAVE LIKE THE OGT RELAYS.

Figure 6. End to End Pulsing Test



NOTE:

IF TESTING IS DONE WITH A SELECTOR A RELAY, TESTING OF LINKS A AND B DOES NOT GUARANTEE PULSING FROM A TO C. IF A TRUNK A RELAY IS USED FOR THE MEASUREMENTS TESTING A AND B WILL GUARANTEE PULSING FROM A TO C.

Figure 7. Interoffice Loop Tandem Call

indicate whether or not the subscriber carrier system pulsing performance is suitable enough to work on inter-office type calls.

Even if the new standard is adopted, the selector A relay is still useful for end to end terminating tests. Experience has shown that some subscriber pulsing loops may pulse an OGT type A relay within the 48 to 78% break limit when they directly access the outgoing trunk but may exceed the 42 to 84% limits when they are pulsing a Selector A relay for a local call. Therefore, the "ideal" test set should have two relays – a Selector type A relay for testing terminating connections and an OGT type A relay for testing tandem connections.

Electronic Sensor

One other feature should be incorporated in a complete signaling test set. An "electronic sensor" transistor circuit should be included so that the pulsing contact performance can be examined. This would make it easier for the craftsman to determine if a problem lies in the pulsing contacts or the circuit being pulsed.

To sum up, the "ideal" test set should incorporate two pulsing standards and an electronic sensor in addition to a dial, a percent break meter, an adjustable artificial line, and various selector switches and jacks to interconnect the internal test set devices to the circuits being tested.

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