CANADIAN ELECTRICAL ASSOCIATION

BRIEF TO DEPARTMENT OF COMMUNICATIONS REGARDING EFFECTS OF PROPOSED BROADCAST SERVICE IN THE 115-190 KHZ BAND TO POWER LINE CARRIER SYSTEMS

SEPTEMBER 1977

checked Jan/84

Canadian Electrical Association

(1) Brief to Department of Communications

Regarding Effects of Proposed Broadcast Service in

the 115-190 kHz Band to Power Line Carrier Systems

September, 1977

Abstract:

Power line carrier systems are used throughout the world to protect and control large blocks of electric power. Power line carrier is used extensively in Canada; there are more than 2100 radio frequency terminals in operation, representing over 115,000 route miles. The capital invested in power line carrier equipment is enormous. The proposal to be presented by the United States to WARC79 to establish commerical broadcast service on a world-wide basis in the power line carrier frequency spectrum of 115-190 kHz, is viewed with dismay by the Canadian Electric Utilities. The probable interference to power line carrier systems from broadcast transmitters in this band could seriously impair the control and protection of power grids. The Brief describes the characteristics of power line carrier and presents several alternatives to power line carrier. However, owing to technical difficulties, the alternatives cannot be considered as viable solutions and a recommendation is made urging the Department of Communications to vigorously oppose the United States proposal at WARC79.

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1. Foreward

The Canadian Electrical Association, on behalf of the Electric Utilities in Canada, welcomes the opportunity to present this Brief to the Department of Communications on the effects of proposed broadcast service in the 115-190 kHz band to power line carrier systems.

Power line carrier (PLC) systems operate in a hostile electrical environment. Although the latest techniques are utilized to ensure reliable and secure operation, any additional external interference, such as radio, may make the PLC system unuseable. Unlike radio, PLC systems cannot rely on antenna discrimination to minimize interference.

In order to appreciate some of the problems faced in engineering a PLC system, this Brief describes the characteristics of PLC and shows some of the factors affecting its operation. From this description, CEA hopes the Department of Communications will have a better understanding of PLC equipment, and how easily external interference may affect its performance.

2. Introduction To Power Line Carrier Systems

The use of three-phase high voltage transmission lines as the propagation medium for carrier current is known as power line carrier. Carrier current is the method by which low frequency radio currents are propagated over metallic conductors. There is a similarity between PLC and two-wire transmission line systems, even though different propagation conditions are encountered.

Frequencies in the range of 30 to 200 kHz and 415 to 490 kHz are used for power line carrier systems. This frequency band is high enough that 60 Hz power frequency, can be ignored, and the power line noise is greatly reduced. At the same time, the carrier frequency line attenuation is still fairly low, so reasonable signal-to-noise figures can be obtained. Frequencies lower than 50 kHz can be used but it is difficult to efficiently couple them to the line by using coupling capacitors.

Power line carrier is used to connect major generating and transformer stations which in many areas of Canada, form the bulk 230 kV, 500 kV and 750 kV power grids. The prime function of the PLC network is for protection of transformers, remote control and automatic generation control (AGC) of power generating machinery, and acquisition of data for load control. PLC is also used to provide essential operating voice circuits.

Power line carrier is especially attractive for a number of reasons. First, it is most economical for providing a relatively small number of communication channels over long as well as short distances. Second, it is attractive in that the cost per station is relatively independent of the distance over which it must operate. However, the frequency and the length of the transmission line combined, dictate the transmitter power. Some other advantages of PLC are its capability to transmit economically to many scattered locations; it is not as susceptible to natural hazards as wire line or cable, and it is inherently rugged. Nor does PLC require repeaters for long distances as does microwave. PLC however, is susceptible to power line noise and must operate within a limited frequency spectrum.

The capital invested in PLC is enormous, and CEA views with dismay the proposed use of broadcast services on a world-wide basis in the PLC frequency band. The 115-190 kHz band represents 34% of the PLC frequency spectrum. The importance of PLC to the life of a community and to industry in ensuring a reliable power supply is clearly recognized by all countries. In protection schemes, PLC is especially useful since it is necessary to exchange signals at relatively high speed and with utmost reliability.

The Department of Communications is aware that several Electric Utilities in Canada rely solely on PLC to protect large blocks of electric power. The disruption of the power system due to radio interference to PLC stations will have great social and political implications. In addition, the Department should recognize the cost penalty that will be assessed to the Utilities involved if PLC systems must be relocated to other bands; this aspect is beyond the scope of this Brief. However, CEA is prepared to discuss this topic with the Department.

3. Statistics on Power Line Carrier Systems

There are about 40,000 PLC terminals in operation throughout the world. Canadian use of PLC is extensive. There are in operation more than 2100 RF terminals representing over 115,000 route miles. In the US, there is a total of 19,963 PLC terminals in operation of which 10,805 of these terminals operate in the 115-190 kHz band.

4. Characteristics of Power Line Carrier

In Canada, power line carrier operates in the frequency band of 30 to 200 kHz. Some assignments have been made above 200 kHz to Ontario Hydro (415 to 445 and 470 to 490 kHz bands). Frequencies generally are selected on the basis of line attenuation and co-ordination with other carriers in the crowded PLC spectrum. At carrier frequencies, the average power line represents a transmission circuit which is very long, compared to the wavelength of the carrier being transmitted. It is possible to calculate the characteristic impedance and loss over such a line if the values of the inductance, capacitance and resistance of the equivalent circuit are known. Parameters such as these are normally obtained from transmission line tests.

Line attenuation is affected by the method of coupling. Phase-to-ground coupling is often used. With this method, the signal goes out on one phase wire and returns through the ground and the other power line conductors, and will depend on ground resistance and the configuration of the power line. With phase-to-phase coupling, there is a definite return path over another phase wire and losses are usually lower than for phase-to-ground coupling. Within a distance of several miles, the signals are largely converted to the lowest loss mode, with a specific distribution of the signal between the various conductors. Power line transpositions, if used tend to disrupt this mode resulting in higher losses.

High-voltage lines (500 kv and 750 kV) usually have lower loss due to the higher insulation level which reduces carrier leakage and dielectric loss. As the carrier frequency increases, losses go up due to increased conductor effective resistance and higher dielectric losses. The behaviour of a carrier current signal propagated along a multi-conductor power line is governed by the same physical laws that apply to isolated two-conductor communication lines. Figure 1 illustrates attenuation vs frequency for a typical PLC application.

Because the quality of the carrier current channel depends essentially on the signal-to-noise ratio at the receiving end, the attenuation of the signal and the level of interfering noise are important factors in designing PLC systems. Of the two characteristics, the noise on power lines is probably the most unpredictable.

The attenuation over a section of transmission line is also affected by the environment and the weather, and these factors must be considered in the design of PLC systems. Rain does not affect attenuation appreciably except where it moistens and makes a better conductor of deposits on transmission line insulators.

However, ice and hoar frost on the conductors can cause large increases in attenuation. More carrier channels fail or become noisy because of line noise than any other cause. Carrier systems which give ideal performance through high attenuation in the laboratory have failed to work in the field because line noise was excessive.

Noise generally falls into two categories; random noise, which has a continuous frequency spectrum, and impulse noise which consists of sharp, well separated impulses produced by specific electrical discharges. Power line noise is predominantly of the impulse type; the pulse peaks being well above the general level, but the space between the pulses is occupied by random noise.

Random noise can be caused by thermal agitation in the power line conductors and by the pick up of static or interfering signals, but the predominant continuous noise is produced by corona. This increases drastically in light snow or rain. Small discharges at many different points, although individually impulsive, together add up to random noise. Impulse noise can also be caused by lightning strokes, switching and line faults which produce impulses at a random rate.

The overall performance of any power line carrier system can best be determined by the signal-to-noise ratio (S/N) at the receiving end of the channel. The received signal level, of course, is a function of the transmitted level per channel and the carrier transmission losses.

The minimum S/N ratio at which various equipment will perform satisfactorily is dependent upon the characteristics of the particular equipment purchased. Most data is based on the radio frequency characteristics of the equipment. This is important to the co-ordination of various types of equipment in the frequency spectrum and to the propagation of signals with respect to performance and reliability.

The frequency spacing between operating frequencies of carrier equipment is of major importance when planning carrier systems. It is necessary for maximum utilization of the frequency spectrum and to prevent interference. The spacing used is a function of equipment combinations as well as equipment characteristics, such as receiver selectivity. While every effort is made to utilize the PLC spectrum, present day technology prevents closer frequency spacing.

To improve the equipment performance in the presence of noise, PLC equipment for voice and superimposed tones is almost exclusively single-sideband equipment. Often, the equipment is equipped with companders, and pre/de-emphasis is used. Protection channels are usually of the frequency shift type and have elaborate noise detection and squelch systems to prevent false operation. In the presence of interference, correct operations would be inhibited. Appendix 1 illustrates an example of an Ontario Hydro PLC system using SSB and how S/N ratios vary with different applications.

It is not possible to appreciably reduce the noise level present at any given receiving point in a carrier system. The only practical way to improve the S/N ratio is to raise the signal level at the receiving point. For instance, increasing a 10 watt amplifier to 100 watts will increase the S/N ratio 10 db. However, there are limits as to how much transmit power can be used; ie. interference to other PLC systems, limited battery power source capacity and availability of higher power carrier equipment and line coupling equipment.

5. Interference from Broadcast Service in the 115-190 kHz Band

(a) Europe

European electric utilities have reported that AM broadcast service in the PLC band does interfere with PLC service. Without exception, the European countries reported interference into power line carrier systems from high powered AM broadcast stations where they were established. In these cases, the electric utilities concerned had to abandon operation of their PLC systems in the operating area of the broadcast stations.

It should be recognized that there are not a large number of broadcast stations operating in the PLC spectrum in any one area in Europe. However, the experience and measurements taken by the European Utilities indicates that they cannot operate on the same frequency as a broadcast station without severe interference. Contrary to what has been reported in the US it appears that AM broadcast stations cannot be "engineered-in" with existing PLC systems.

(b) United States

PLC usage in the United States is similar to that in Canada. As indicated above, the 115-190 kHz band is heavily used by the US electric utilities. Based on a preliminary Utilities Telecommunications Council (UTC) review, and upon European experiences, it appears that the US electric utilities would have to abandon PLC operation in the 115-190 kHz band if the AM broadcast proposal is adopted.

UTC studies apparently indicate it is not possible to "engineer-in" AM broadcast stations without serious impact to PLC systems. UTC members have conducted preliminary studies on the effects of AM broadcast service on PLC systems and one multi-state utility reports that they would experience interference to 65 PLC terminals from one broadcast station located in the State of Ohio. The study was based on emissions from a 50 kW AM broadcast station. Of course, the actual impact on any one PLC station would depend on the final radiation pattern from the AM station in the particular area. The impact of the AM broadcast service would be substantially higher in the US, or in Canada, than in Europe because the broadcast industry proposes to establish many stations operating at both high and low powers.

The UTC have indicated that should the electric utilities be required to vacate the 115-190 kHz band, it will be difficult for many users to find other frequencies due to the congestion existing in the PLC spectrum. (This may also apply to Canadian users as well). If there is a need, at all, for the expansion of AM service, UTC in their submission to the FCC has recommended that it be achieved by expanding the standard broadcast bands, instead of using the 115-190 kHz PLC band; CEA concurrs with this statement.

(c) Canada

Owing to a lack of reliable technical data and field reports, probable interference to PLC systems in Canada from radio broadcast service cannot be accurately documented at this time. Some field tests have been conducted by Ontario Hydro in connection with Loran C emissions (90-110 kHz). The interference mechanism is a complex subject and without field tests results can be confusing. However, some progress has been made in interference studies relating to PLC systems; a brief review is presented.

As stated previously, the PLC signal is usually applied to the power line either between one phase conductor and ground or between two of the phase conductors. In either case the signal quickly couples onto all the conductors and travels along the line in several independent "modes". One mode propagates between all the conductors in parallel and ground. The others, the "line modes", propagate between groups of conductors. The ground mode has very high attenuation and represents a more or less fixed signal loss regardless of line length, whereas the line modes are the active modes for signal transmission and have losses of the order of 0.1 db per mile at 100 kHz. Attenuation increases with frequency so that use of much higher frequencies, for example the 415-490 kHz PLC band, is restricted to relatively short power lines. Typical attenuation for a 100-mile line at 100 kHz might be:

Initial loss due to ground mode		3 dB
Attenuation loss	0.1 x 100	10 dB
Total attenuation		13 dB

The power line is, thus, a relatively efficient radio frequency transmission line.

It is, however, a "noisy" line. All practical power lines of 230 kV and above produce some corona discharges, a partial breakdown of the air very close to the conductor surface. These discharges result in impulsive noise throughout the radio frequency spectrum, and are one of the causes of noise sometimes heard on a car radio when passing below a power line. The corona is more severe in foul weather, increasing as much as 26 dB above its relatively low fair weather value.

This type of noise is the limiting factor in power line carrier operation, especially in high-security applications which must operate reliably under all weather conditions. Foul weather noise levels in a PLC system may be as high as 0 dBm, quasi-peak, in a 3 kHz bandwidth. Thus, if a signal-to-noise ratio of 20 dB were required, the received signal level would have to be at least +20 dBm.

The characteristics of a power line as a radio receiving antenna have not been studied in much detail. It has been suggested by some that the line should be considered as a long-line or Beverage antenna. Others suggest that the line itself picks up little signal and that the drop-leads connecting the line to the coupling capacitor at the receiving station act as vertical receiving antennas. Measurements carried out in US and Canada in 1972 with reference to the American Decision Information Distribution System (DIDS) plus recent Ontario Hydro measurements of a Mini-Loran-C signal have provided some data, but it is not very reliable.

The most important factor which must be known in order to predict impact of a radio system on power line carrier operation is the ratio of interference voltage at the PLC receiver to the incident field strength near the line. This may be a function of such factors as power line length, orientation of the line with reference to the signal source, power line conductor configuration (double circuit vertical configuration or single-circuit flat configuration), etc. The DIDS tests, however, failed to determine any correlation. From the Ontario Hydro DIDS and Mini-Loran-C tests it is suggested that this ratio might be between 6 and 22 dB. Considerably more research is required in this area before reasonable predictions of interference to PLC from radio systems can be provided.

6. Alternatives to Power Line Carrier Systems

Although this Brief suggests alternatives to PLC in the 115-190 kHz spectrum, the implementation in Canada of any one of the alternatives may not be economical or technically feasible. Every kHz of available spectrum that is taken away becomes a direct cost to the Utility because other services must be purchased or rented. The alternatives listed have assumed that radio interference in the 115 to 190 kHz band from broadcast services is of sufficient levels to impair operation of PLC equipment in the areas concerned. Costs shown are estimated material costs only and are based on 1977 Canadian dollar value.

(a) Microwave Radio System

PLC systems can be replaced by microwave radio systems. The main advantages of microwave are that many more channels can be obtained than PLC, and microwave is independent of the power system and will not be affected by power system disturbances. However, replacing a PLC system by an exclusive microwave system can rarely, if ever be economically justified. As an example, a 200 mile transmission line can be protected by PLC at an estimated material cost of $100,000; depending on system requirements, to replace the PLC with microwave would require 9 microwave stations at an estimated material cost of 1.5 to $2.7 million. Land purchase for microwave repeater sites, access roads and ac power have not been included in the material costs; the cost of these items would be considerable. In addition, microwave frequency spectrum must be made available. The cost of replacing a significant portion of the PLC now in the 115-190 kHz band with microwave would be excessive, and the Electric Utilities do not recommend this alternative.

(b) Microwave and Power Line Carrier

Microwave and PLC can be used to complement each other. Where microwave is already available, or where microwave radio is being planned for multi-channel use and where the transmission line section requires additional security, a PLC system can also be installed. Each system operates as a back-up to the other. Normally, protection schemes use audio tone channels; the number of audio tone channels carried on a multiplex channel in the microwave system is duplicated in the PLC system. Figure 2 illustrates one such scheme. Note that any two protection audio tone channels will produce a trip when operated.

The combination of microwave and PLC can be adopted by Electric Utilities in areas where interference may be a problem. However, the cost comparison and comments for this alternative will be the same as listed in (a) above. From a Utility viewpoint, this alternative is also not recommended.

(c) Leased Facilities

Leased facilities may be used by Electric Utilities for protection purposes. Before discussing the use of leased facilities, a short description of a typical relay scheme is necessary.

In order to achieve reliable tripping, yet avoid false trips, conventional relay arrangements may be quite elaborate. Often two or three back-up relay arrangements are used to provide high speed and supplementary protection and to prevent false tripping for faults in adjacent transmission sections. In a typical two-terminal transmission line (two-ended), the relay scheme may use high speed distance relays at each end of the line to provide fast "first zone" protection. The relays are adjusted to respond to faults occurring within the 90% of the distance to the far end of the transmission line.

At the distant end, a similar arrangement is used. Thus, faults occurring within the centre 80% of the line will be detected at each end and quickly isolated by tripping the breakers at both ends. If a fault occurs within the far 10% of the line, the distant breaker will immediately trip, thus disconnecting its end of the line. However, because the fault is beyond the reach of the near-end relay, it cannot respond, leaving the generator at the near end still feeding the power to the fault. To prevent this from continuing, an "over-reach" relay is used. This is a sensitive distance relay that is adjusted to respond to faults occurring not only on the protected (80%) transmission section, but also in the first 20% of the adjacent section. Figure 3 illustrates the above arrangement.

To prevent the overreach relay from tripping the near-end circuit breakers for faults in the next section, a blocking signal is transmitted, which in effect, identifies the fault as lying in the next section and prevents breakers in the local section from operating. In order, to allow the blocking signals "first priority", the overreach relay is normally made slightly slower acting than the first zone relays and the blocking signal. This time delay also tends to prevent tripping in response to routine transients occurring at the far end.

Obviously, some sort of independent communications channel, or "pilot" circuit is required to link each end transmission line in order to trip the breakers at both ends of the line in case of a fault. Traditionally, these pilot channels have taken the form of physical wire or cable circuits. The disadvantage of physical circuits is that they are generally limited to short distances, usually 10 to 15 miles. The reason for this is that the shunt capacitance and series resistance of the line alter the currents which are put on the line to detect faults, and this effect becomes excessive as the distance increases. Power line carrier is of course, used extensively for blocking, transfer trip and permissive relay schemes; the terms "transfer-trip" and "permissive" are covered in Section (d) Audio Protection Tones on Leased Facilities.

The currents placed on the physical circuit is supplied by the Utility station battery (125 V or 250 V dc). The battery operates as a floating supply and additional caution is required to prevent grounding either pole of the battery. Elaborate monitoring schemes are required to verify integrity of the physical circuit. In addition, because of ground faults, all leased facilities must pass through neutralizing transformers. The cost to Utilities of providing neutralizing transformers and cable duct systems is approximately $1500.00 per cable pair. Figure 4 shows a typical dc remote trip arrangement using leased cable pairs.

In order to provide security, in many instances the dc remote trip is duplicated using a separate geographic leased cable route and a separate entrance into the power station. However, even with alternate routing, leased cable facilities are of marginal value for protection purposes. Standard protection devices placed on cable facilities outside a power station often function during power faults, thus temporarily disconnecting the cable circuit when it is required for protection.

It can be seen that where distances are short between stations (10 to 15 miles) pilot or dc remote trip may be used by Electric Utilities. It is obvious however, that PLC systems of any length cannot be replaced by leased cable facilities; therefore this alternative cannot be considered as a viable replacement to PLC.

(d) <u>Audio Protection Tones on Leased Facilities</u>

It is becoming more difficult to obtain metallic pairs for pilot or dc remote trip functions from local Telephone Companies. Derived carrier circuits are being proposed. Consideration therefore has been given to using audio protection tone channels operating from approximately 1100 Hz to 3000 Hz, on leased circuits for protection of transmission line sections. The technical problems associated with the use of audio tones on leased circuits are considerable. The leased facility may be partially metallic, loaded cable and carrier.

Carrier equipment can only be as good as the cable over which it transmits. The decision by Common Carriers to install carrier on existing cable facilities must take into account the serviceability of the cable, which is an important item from a Utility viewpoint. The maximum operating length, without repeaters, will depend on the gauge of wire used. One Utility (Ontario Hydro), who is faced with this problem of obtaining metallic pairs for dc remote trip, has conducted extensive tests to determine if audio protection type tone equipment can be used on leased facilities.

Before discussing some of the major technical problems encountered, a description of the operation of protection tone equipment would be helpful in understanding this alternative to PLC. (The following description refers to an Ontario Hydro application; other utilities may use a slightly different approach).

One solution to dc remote trip is the use of transferred trip. The principle of transferred trip is directly opposite to that of conventional blocking schemes. With transferred trip, distant breakers are tripped on command of a signal transmitted from a terminal where the fault has been identified. Generally two modes of tripping are used with protection tone equipment; one mode is a transfer trip arrangement, and the other a permissive arrangement. Transfer trip implies a command sent by the transmitting end to the receive end to trip the breaker without delay. Permissive trip on the other hand implies a trip permission sent by the transmitting end with tripping the breaker occurring only after the local equipment at the receive end confirms the legitimacy of the tripping information, thus permitting the circuit breaker to be opened. Of course, the protection tone equipment can be used as a blocking scheme as well.

Generally two or four protection tone channels are used in a particular protection scheme (the number of channels used depends on line security). The tone channels operate either 85 Hz above or 85 Hz below their nominal centre frequencies and are in the band 1105 to 2975 Hz. Tone channels are combined together before they are connected to the leased facility. Also with the above tones, a pilot is used to verify system continuity and to prevent a false trip if the frequency of the leased carrier channel shifts from its operating frequency due to malfunction of the frequency generation equipment; the pilot shifts into a noise sensing band, which clamps the protection tone receivers. A noise detector supervisory unit is also provided with each receiver, and this unit will prevent a trip condition should the noise in the transmission facility become high enough to cause a trip. Logic is also provided in the tone equipment to detect voltage failure and signal amplitude variations.

Protection tone equipment is capable of providing transmit levels up to +13 dbm, and the tone receiver will operate approximately from 0 dbm to -40 dbm. These levels coordinate with all anticipated transmission levels. However, when protection tone equipment is connected to leased facilities, constraints are placed on transmission levels by the Telephone Company.

The present practices of Telephone Companies require that the composite (RMS) signal level be somewhat below test tone level on the voice channel. Values in the range of 0 to -8 dbm0 are generally used. The telephone company might allow a composite level as high as 0 dbm; however, if two or more protection tones are used, the individual tone level is much lower than reference. The telephone transmission system, including pads, might provide up to 16 db of loss at the 1000 Hz reference frequency. This loss, combined with a low transmit level of the protection tone transmitter, makes this type of application susceptable to impulse and random noise. Impulse noise, caused by the telephone switching network has placed severe limitations on the use of protection tone equipment on leased facilities.

Tests conducted on a 28-mile cable facility produced the following results: Over a period of 71 days, there were 131 clamps, that is, the protection tone receivers were disabled with loss of protection. Metallic pairs will not be available indefinitely and steps have been taken to implement protection schemes using protection tone equipment operating over leased facilities. However, with present day equipment this type of operation can only be used over relatively short distances, 20 to 30 miles, and with a reduction in reliability and security. Again, this alternative cannot be used entirely as a replacement for PLC. Figure 5 shows the arrangement for this alternative.

(e) Coaxial Cable

Studies have been carried out in Europe on the use of the overhead ground wire of the power line to support a communications cable. This is in effect using the power line as the bearer for a land-line communication system. Both coaxial cables and quad-cables have been used. In some cases the cable is suspended below the ground wire and in some cases it is embedded inside the ground wire. To our knowledge this form of communication has not been considered in North America. The advantages of such a system are wide bandwidth, 200 kHz or more, and the great strength of the power line towers as bearers. Disadvantages might be cost if the wide bandwidth is not required and reliability. The latter is most important when protective relaying information is being transmitted. If a power system fault should be initiated by breaking of the overhead ground wire, then the communication channel would also be lost just when it was required to function. For this reason, use of coaxial or quad-cables on the overhead ground wire is not considered to be useful if interruptions are of any length.

(f) <u>Fiber Optics</u>

Optical transmission systems promise bandwidths of approximately 1000 GHZ and bit rates from 100 to 500 Mb/s, or more. Such large capacity transmission systems are presently under development and trial optical transmission systems are undergoing field tests by some Telephone Companies.

In a fiber optical transmission system of any great length, repeaters are needed for regenerating the optical signals that have become attenuated and distorted in transmission. The apparent present goal of fiber manufacturers is to produce fiber losses of about 10 db/km, with repeaters located 5 to 10 kilometers. Fiber optic systems of any length are unproven and costs unknown. In addition, primary attention in this field is being devoted to developing systems for common carriers. Fiber optics requires a great deal of development before it can be considered as a replacement to PLC.

Fiber optic techniques may have a place within a power station where fault conditions create large voltage transients on metallic cable pairs. However, it appears that this new technology will not be extensively used by the Electric Utilities for at least 5 to 10 years.

(g) <u>Frequency Assignments above 200 kHz</u>

Depending on the number of PLC channels being displaced, in some areas of Canada, it may be possible to relocate some short PLC systems above 200 kHz. However, some Electric Utilities who have long transmission line sections, cannot consider frequencies above 200 kHz because of increased line attenuation. An extensive study would be required to ensure that other established users are not interferred with by this relocation. Engineering considerations such as line length, attenuation and transmit power would have to be investigated before assignments above 200 kHz are made. In general, it appears that some Utilities could relocate above 200 kHz if frequencies are available. Factors such as whom will assume the cost for relocating PLC systems to a new band must be determined; as indicated previously, this Brief will not discuss this topic, but the Department of Communications must recognize the ramifications of such relocation. Provided sufficient frequencies are made available (to be determined on a case by case basis) some Electric Utilities may accept this alternative. It should be noted that a lead time of 2 1/2 to 3 years is required by Utilities for any relocation schemes, and that higher line losses at the higher frequencies generally will result in reduced channel margins.

The reduced channel margins may not be acceptable to all Electric Utilities in Canada.

(h) Co-Existence

This alternative is attractive to all parties since in essence, the status quo is maintained. It is possible that with proper engineering and carefully selected frequencies, the broadcasters can establish a system which does not interfere with PLC systems. Theroretical studies which show no probable interference from broadcast services to PLC cannot be accepted on face value by the Electric Utilities. Extensive and costly field testing would be required to verify interference levels before final broadcast service is sanctioned. Depending on resolution of technical matters, co-existence may be acceptable.

7. Conclusion

Reviewing the technical data available to date indicates probable interference from broadcast service in the 115-190 kHz band to power line carrier systems.

As mentioned earlier, no attempt has been made to assess the cost to the Utilities in the event relocation must take place. The Electric Utilities are constantly investigating new technology in an effort to improve or expand PLC systems in the frequency band allotted by the Department of Communications. Techniques such as SSB, FSK and digital, have been investigated and implemented where technically and economically feasible. However, it must be recognized that the prime function of the Electric Utilities is to provide secure and dependable electric power to the Canadian people. With this thought in mind, Utilities insist that new communications equipment must be proven and field tested for a minimum of two years before it is incorporated into a system used for protection and control of the power grid.

By permitting broadcast service in this band, the adverse impact on power line carrier operations in Canada would be immense. The ability of Utilities to deliver reliable electric power to their customers would be affected, if this portion of the PLC spectrum is abandoned. It is evident from the alternatives listed, that at this time there is no viable alternative to power line carrier.

8. Recommendation

CEA urges the Department of Communications to support the Electric Utilities resolution of assigning primary status to PLC systems. CEA further urges the Department to vigorously oppose the Broadcasters proposal of using the 115-190 kHz band for broadcast service. If additional frequency spectrum is necessary to expand public broadcast service, CEA is confident that spectrum above the present broadcast band can be made available.

230kv 100 mi. STEEL GROUND WIRES =4db
CENTRE TO OUTER COUPLING = 3db COUPLING
EACH END.

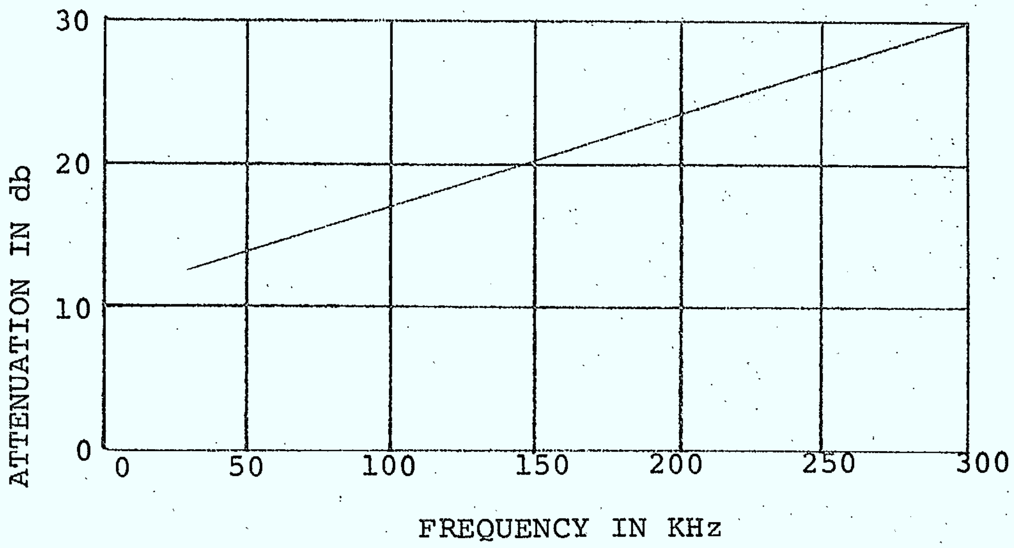

FIGURE 1

LOSS VS FREQUENCY FOR A TYPICAL 230KV LINE
LENGTH = 100 mi., UNTRANSPOSED, PHASE-TO-PHASE
COUPLING. INCLUDES LINE COULPING LOSSES.

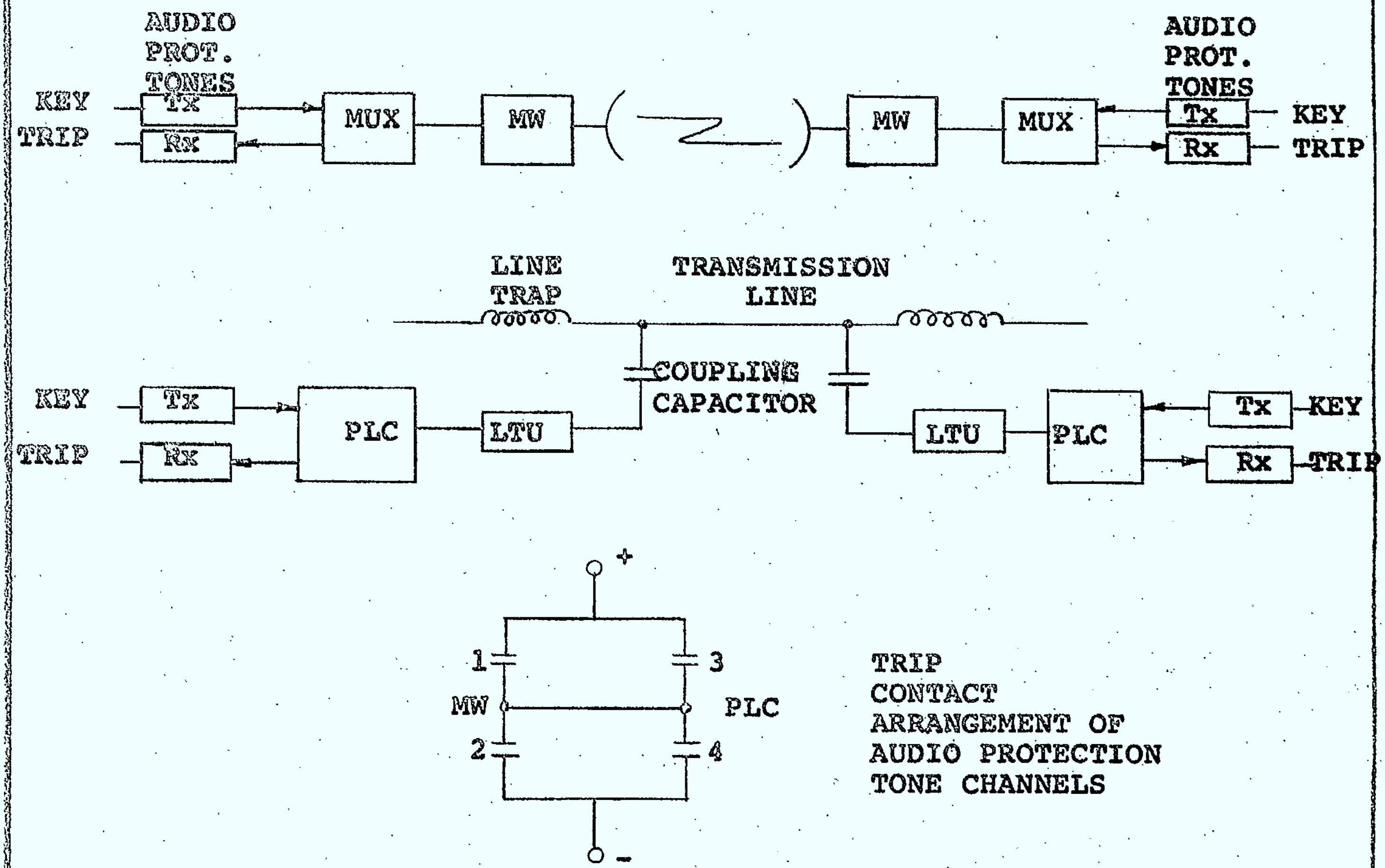

FIGURE 2

PROTECTION SYSTEM USING MICROWAVE AND PLC. TRIP CONTACT ARRANGEMENT FOR AUDIO PROTECTION TONE CHANNELS. AUDIO TONES 1 AND 2 ARE CARRIED BY THE MICROWAVE SYSTEM AND AUDIO TONES 3 AND 4 ARE CARRIED BY THE PLC SYSTEM.

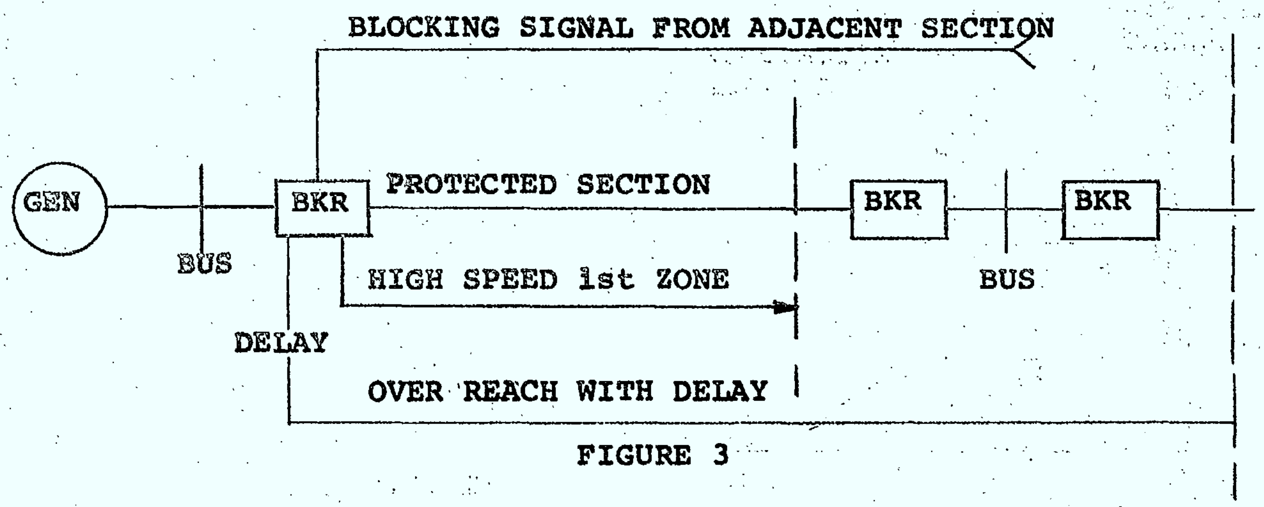

FIGURE 3

TYPICAL "OVERREACH ARRANGEMENT WITH THIRD ZONE BLOCKING. HIGH SPEED DISTANCE RELAYS AT BOTH ENDS DETECT FIRST ZONE FAULTS. SENSITIVE OVERREACH RELAY DETECTS 2nd ZONE FAULTS, BUT IS BLOCKED BY SIGNAL FROM FAR END WHICH INDICATES WHEN FAULT COMES FROM ADJACENT SECTION. A SLIGHT DELAY IS BUILT INTO OVERREACH CIRCUIT TO ALLOW THE BLOCKING SIGNAL TO HAVE "FIRST PRIORITY" IN ACTING.

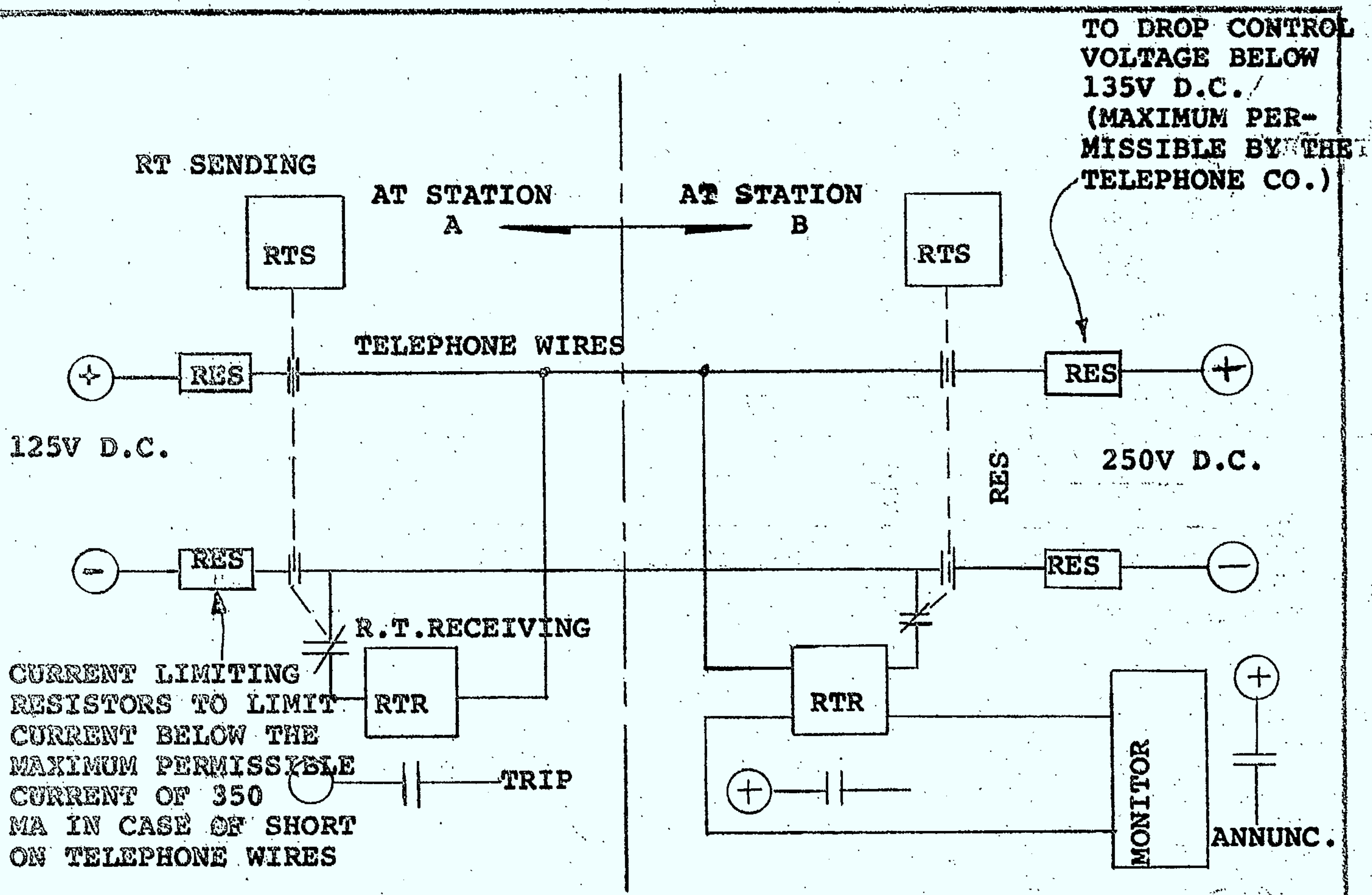

FIGURE 4

DC REMOTE TRIP ARRANGEMENT

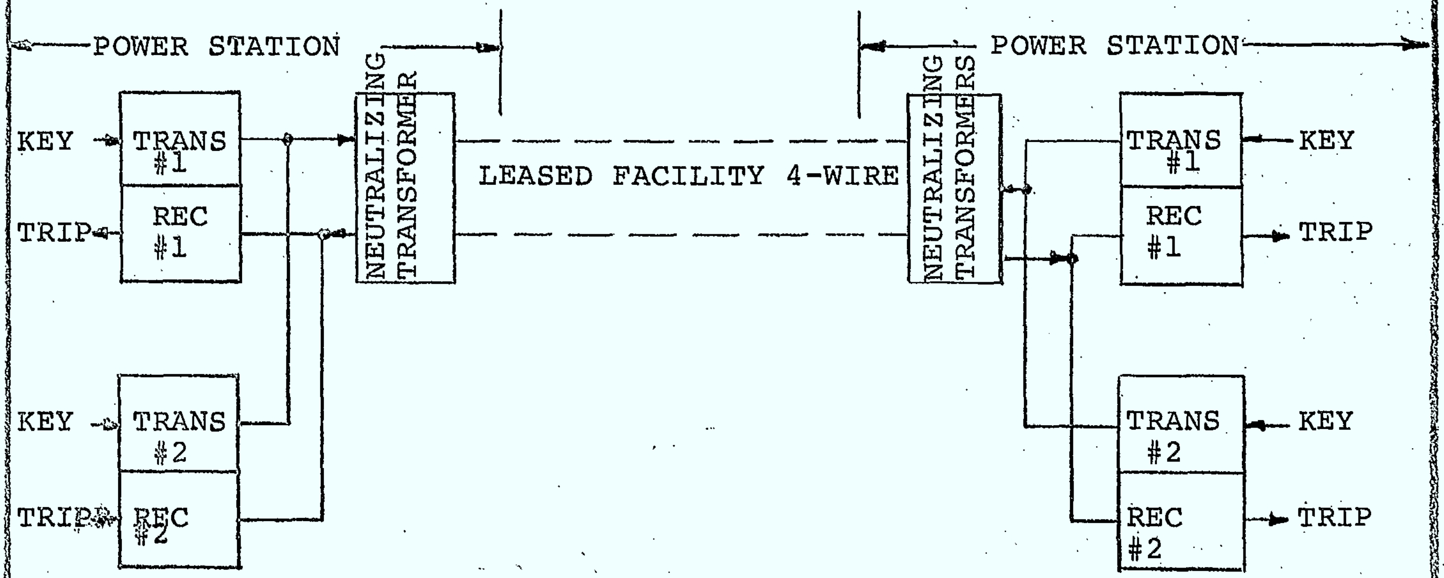

FIGURE 5

PROTECTION AUDIO TONE CHANNELS ON LEASED FACILITIES

BRIEF TO DEPARTMENT OF COMMUNICATIONS REGARDING EFFECTS OF PROPOSED BROADCAST SERVICE IN THE 115-119 kHz BAND TO POWER LINE CARRIER SYSTEMS

SERVICE	MODULATION ASSIGNED	BANDWIDTH	TRANSMITTED POWER	RECEIVED LEVEL db *	NOISE LEVEL* (MAX)db	S/N RATIO db	REQUIRED MIN. S/N RATIO dB
Voice	50%	1900 Hz	20	+14.75	-7.21db	21.96 note 1	25
DACS TONE	20%	±120 Hz	3.20	+6.79	-16.2	22.99	10
TELEM. TONE	10%	±30 Hz	0.80	+0.77	-22.2	22.99	10
PROT. TONE GUARD	20%	±60Hz	3.20	+6.79	-19.21	26	18
TRIP	40%		12.80	+12.81	-19.21	32.02 note 2	18

Worst Case Performance Data for a Typical SSB Carrier Installation

Two horizontal untransposed lines on same right-of-way, 91 miles long, 230 kv nominal. Inter-circuit coupling. Steel sky wires.
SSB carrier, 80 watt available sideband power, 140 kHz, upper sideband.
Line attenuation 19.23 db (calculated).
Corona noise at maximum due to adverse weather.

Note 1: Does not include improvement due to compander and pre-emphasis.

Note 2: This figure could be reduced to approx. 22 db during a simultaneous line fault on one of the lines, because of additional attenuation.

* The received level and noise level figures are given in db relative to 0.775 volts across 75 ohms.