# MICROWAVE & VHF RADIO INSTALLATION FOR THE UNION ELECTRIC SYSTEM

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## Introductory Remarks

### General Historical Background

The prime function of any electric utility is that of reliable and uninterrupted power flow to its customers. The direct relation between the growth of a utility and the expansion of its communication facilities often times do not parallel. This results in the communications facilities becoming so overburdened that they almost become ineffective. Figure 1 shows Union Electric's growth over the past few years.

A good communications system must not only meet the exacting demands placed on it by load dispatching and other vital operating functions; but it must also bring about the closest possible coordination between executive and administrative personnel and the field crews throughout the vast territory which it serves.

Union Electric's Management felt that the Company's existing communication facilities were falling far short of our requirements and just prior to World War II studies were initiated by the Engineering Department for the rehabilitation and enlargement of our communications systems. The huge impact of the war upon the manufacturers of electric equipment and the necessity for deferment of any new construction, which in the slightest manner might hamper the nation's war effort, prompted the postponement of any attempts to realize plans for improving our communication facilities.

## Reasons Leading to the Choice of a Microwave/VHF System

### Remarks Comparing Various Types of Communication Facilities

After the war, the Engineering Department again renewed its studies for the expansion of the Company's communication facilities. The means of accomplishing this task were not easy and were limited to few in number:

(1) The construction of wire lines or leasing of same.
(2) Augment existing power-line carrier current systems.
(3) Installation of a microwave and VHF space radio system.

The choice of any one method, or combination of methods, resolves itself into one of economics, desired reliability and future expansion. Figure 2 shows advantages and disadvantages of various types of communication facilities.

## Wire Facilities

The use of physical metallic circuits, either leased or constructed by ourselves, was first considered and then abandoned. New lines, if we were to construct them ourselves, would not only result in high first costs; but also would be high in subsequent maintenance costs.

Such lines would have to be constructed along our existing transmission line right-of-ways. In most cases the transmission line tower spacing is too great to accommodate telephone-type construction. High ambient noise levels and other undesirable factors result when placing telephone circuits in close proximity to high tension transmission lines.

Leasing the required circuits was studied and found to be uneconomical because of the high monthly rental charges. Past experience with open-wire telephone lines strung across the rugged Ozark countryside has not been too good. Even if the telephone circuits could be made reliable, our communication facilities would not be fully met. The rural areas, across which our major transmission lines traverse, would still be almost void of adequate communication coverage. The telephone circuits would have to more-or-less parallel the major transmission line right-of-ways and be equipped with numerous drop stations. Such fixed point-to-point telephone service is a very unsatisfactory method for contacting the outside field crews. Much valuable time is wasted as all contact is lost until the crews report in by telephone. During interim periods, contact is again lost. More often than not transmission line troubles do not occur at or near one of the wayside stations; so outages are greatly prolonged due to the travel time involved. Figure 3 shows Union Electric's major transmission line systems.

## Power-Line Carrier Current

The problem of enlarging our communication facilities was next approached from the standpoint of increasing our power-line carrier current installations. The high tension transmission circuits upon which the r-f carrier is superimposed are of rugged construction and are able to withstand most weather conditions. Since the carrier is confined primarily to these high tension circuits, the application problems concern themselves largely with coupling, trapping, frequency spectrum space availability and transmission attenuation.

Power-line carrier operates in the 50-200 kcs band. By utilizing the most modern carrier equipment available, this 150 kcs bandwidth allows for only a relatively few channels. If carrier is to do all the things required of a modern communication system -- such as handle voice communications, load control and telemetering functions, relaying, etc., it is soon found that spectrum space availability becomes a major consideration. This problem becomes further complicated when power systems are interconnected, as carrier frequencies must be staggered or shared amongst the several companies. Costly trapping schemes must be employed to keep unwanted signals out of various parts of the system.

Again, carrier-like wire line facilities lack versatility and flexibility. A carrier channel cannot be readily augmented to handle additional functions. The equipment associated with a carrier installation, such as coupling capacitors, line traps and tuner units are relatively large in physical size and their installation in transmission line get-a-way structures can prove to be very cumbersome and costly; notwithstanding the line outage time involved.

## Microwave/VHF Radio Facilities

With these thoughts in mind, it was determined that a microwave and VHF space radio installation came the closest to solving our communication requirements. It was planned that the microwave system would serve as a "backbone" to handle the bulk of the voice communication traffic and load control-telemetering information between the remote points of our System. VHF base radio stations, operating in conjunction with this microwave, would be strategically located so as to provide adequate coverage of the major transmission line systems.

Studies revealed that microwave though quite high in first cost was very competitive with other forms of communication when 3 or more channels are required. Microwave is very flexible in that additional channels can be readily added as future conditions dictate. The cost for adding or rearranging channel drops is very attractive. Microwave is entirely divorced from the transmission lines; so troubles on these lines do not effect the operation of microwave equipment.

## Factors Considered in Planning the Microwave/VHF System

Many factors required careful consideration in planning and laying out our microwave and VHF radio systems. Some of these were:

(1) Selection of a system which was low in first cost and subsequent maintenance and operating costs.

(2) Selection of a system which had a high ultimate channel capacity.

(3) In the interest of frequency spectrum space required, we desired a system which utilized as narrow a bandwidth as possible.

(4) Selection of a system that required as few frequencies as possible.

(5) At the time we considered the installation of microwave, our communications maintenance personnel were not conversant with ultra-high frequency techniques. We, therefore, desired a system which was more-or-less straightforward in its circuitry so that transition from power-line carrier and VHF radio techniques could be made smoothly.

(6) Points of termination, channel requirements, drops, extensions and interconnections with neighboring utilities' communications systems were carefully considered.

(7) Thought must be given to Company growth so that possible future expansion of the communication system could be planned.

(8) In order to determine optimum location for the unattended repeater stations, a knowledge of terrain characteristics, land values, power availability, access roads, etc., is very helpful.

## Description of the Microwave/VHF Radio Systems

After much study and careful consideration, it was decided to install Radio Corporation of America CW-20A microwave equipment, (operating at approximately 2000 mcs), for the long-haul, multi-channel backbone systems and RCA Type CWT/R-5A equipment, (operating at approximately 960 mcs), for one extension which would have light ultimate channel requirements. Frequency division type multiplex is used. Operating in conjunction with the microwave, VHF radio equipment was also installed to provide radio coverage for the transmission line systems. Where required certain voice channels are terminated in Bell Telephone Company PBX and PAX equipment.

Late in the year of 1951, RCA was contracted to handle the entire installation, with the exception of land acquisition, access road construction, power feeds to the sites, etc., on a "turn key" basis; i.e., they were to deliver a working communications installation consisting of the "Missouri Microwave System" and the "Illinois Microwave System".

### The Missouri Microwave System

As shown on Figure 4, the "Missouri Microwave System" extends generally westward from the Company's main headquarters and General Offices in St. Louis to the Osage Power Plant, 150 airline miles from St. Louis. In so doing, 3 drop repeaters, (at High Ridge, Sullivan and Belle, Missouri), and one through repeater, (Dixon, Missouri), are used. A "dog-leg" extension from this main system is dropped out at the Belle, Missouri repeater and goes generally northwestward to the Moberly Substation at Moberly, Missouri. This substation is the communication tie-point between the Union Electric and Kansas City Power & Light Companies. As this latter Company employs no microwave, our facilities were dropped to audio level and interconnected with their power-line carrier facilities extending from Moberly, Missouri to Kansas City, Missouri. Also, one voice channel was dropped out at the Holts Summit, Missouri repeater and extended approximately 8 miles over a leased physical telephone circuit to Missouri Power & Light Company's General Offices in Jefferson City, Missouri.

Another "dog-leg" extension was dropped out at the High Ridge, Missouri repeater station to our Rivermines Substation about 60 miles south of St. Louis. This particular link operates at approximately 960 megacycles and has an ultimate capacity of 6 voice channels. It was deemed that this would be adequate to handle present as well as future channel requirements.

To sum up briefly, as shown on Figs. 5 & 6, the "Missouri Microwave System":

(1) Consists of 10 hops for a total of 283.8 path miles, or an average of 28.38 miles/link.

(2) Contains 7 repeaters; 5 of which are drop repeaters and 2 through repeaters.

(3) Handles 7 duplex voice channels, one VHF radio channel and 11 telemeter and automatic load frequency control functions.

(4) Guyed-type towers are used at all locations except the St. Louis terminal, where parabolae are affixed to the top of an advertising sign on the roof of our 11 story Office Building and at Rivermines Substation where the parabolae are mounted on top of a 50' self-supporting tower mounted on the Substation's Building roof. The highest tower, 300', is used at the Osage, (Lakeside), terminal. The shortest towers are 100' at the Halifax Repeater and 150' at the Dixon Repeater. All other towers are 200' or 250' in height.

The Illinois Microwave System

As shown on Figure 7, this system extends generally northward from St. Louis to Wood River Plant of the Illinois Power Company. At this point, the microwave is dropped to audio level and directly interconnected with this latter Company's microwave facilities.

The "Illinois Microwave System" also extends southwardly from St. Louis to our Meramec Plant, then southeastwardly through the State of Illinois to the Joppa Steam Plant of Electric Energy, Inc. This latter Plant is near the huge Atomic Energy Commission's installation at Paducah, Kentucky. The microwave is terminated in PBX-PAX equipment at Joppa, and can, by PBX patching, be interconnected with Central Illinois Public Service Company's microwave facilities. Thus, the microwave facilities of Union Electric, Illinois Power and Central Illinois Public Service comprise a 672 mile communication "loop".

As shown on Figs. 8 & 9 the "Illinois Microwave System":

(1) Consists of 6 hops for a total of 157.7 path miles or 26.28 miles/link. One link is 46.5 miles.

(2) Consists of 5 repeaters, 3 of which are drop repeaters and 2 through repeaters.

(3) Handles 8 duplex voice channels, one VHF radio channel and 9 telemeter and load control function.

(4) Guyed-type towers are used at only the outlying unattended repeater stations, (150' at Waterloo, Illinois, and 250' at Swanwick and Cobden, Illinois). A 200' self-supporting tower is used at Meramec Plant and the parabola is mounted at the 300' level on one of the 487' transmission line towers at Joppa.

## The VHF Space Radio System

Two channels have been set aside in each of the aforementioned microwave systems for VHF voice and control. At the St. Louis, Lakeside and Rivermines terminal points, control consoles, equipped with dual loudspeakers and dual handsets, have been provided. Briefly, the mode of operation is as follows:

(1) If one handset is used, only the local VHF transmitter is energized, for handling VHF traffic within the immediate area.

(2) If the other handset is used, all outlying VHF base stations are energized; thus blanketing our major transmission lines in the State of Missouri and Illinois.

When a vehicle in the outlying countryside replies, whichever VHF base station receives the capturing signal, causes a VHF lockout tone to be placed on the microwave channel, thereby silencing all other receivers for the duration of the mobile units broadcast. The various base stations are equipped with directive antenna arrays and carrier operated relays, so that when operated on a "Local System" basis they will not get into the "System VHF".

## Standby Equipment

All terminal microwave stations have been provided with full standby r-f equipment. All unattended repeater stations have been provided with "flip-flop" standby, (partial standby); i.e., one r-f unit which can replace an EW unit or a WE unit upon failure of same. Transfer time is approximately 30 seconds.

Muting relays are employed so as to prevent unintentional transfer to the standby equipment upon loss of signal due to fading. Subject muting relays are set slightly above the noise level. Should a receiver fail, however, the relay does not "hear" normal electron rush in the receiver and the equipment transfers to standby.

The unattended repeater stations have also been provided with standby Kohler engine-driven motor-generator sets. These units start automatically upon failure of normal power supply. Transfer time from normal to standby power takes approximately one minute. These units continue to run for 30 minutes after restoration of normal power. This added running time is a precautionary measure taken to assure that the normal power has actually been restored. As is often the case in rural areas, power will bump off or on several times before complete restoration.

The engine-driven motor-generator sets, though installed in the same building which houses the electronic equipment, are completely separated from same by a metal fire wall. Each building compartment is equipped with a separate filtered air intake ventilating system. The electronic compartment is provided with 2 ventilating systems, one a gravity type and the other a forced air system. The forced air system is automatic in that it is thermostatically controlled and operates during periods of hot weather to reduce the high ambient temperature within the building.

No heating is provided in the buildings. Immersion-type heaters are provided in the Kohler unit crankcase to keep the lubricant viscous during periods of low temperature. Anti-freeze is used in the radiators of the units to prevent coolant freezing.

Fault Alarm System

Fault indication units have been provided at all terminals and repeater stations. These units consist of a lamp bank containing 12 neon lamps which light up in various combinations when a fault occurs. "Scanning" for faults is accomplished by a small commutator-like device. When a fault occurs anywhere on the system a fault relay sets this distributor into motion. By means of a fault tone sent out over the microwave service channel, other companion distributors are set into motion and lock into step with the original. Scanning is continuous, taking into account any number of faults at any location or locations. Scanning automatically ceases once the trouble has been corrected. An audible alarm sounds once each $4\frac{1}{2}$ minutes to call the operator's attention to the fact that a fault exists.

At the St. Louis terminal the equipment fault panel has been extended from the Radio Room to the Load Dispatcher's Office, which is continuously manned. It was found that the fault alarm buzzer sounding every $4\frac{1}{2}$ minutes was objectionable from an operating standpoint because of the other duties performed by these personnel. The unit has since been modified so that the buzzer sounds once every 20 minutes for a 5 second period. The fault lights still continue to operate, independently of the alarm buzzer.

At the other terminals a fault indication light and audible alarm has been incorporated in the VHF radio console, (for lack of a better location). When faults occur this light and buzzer are energized. By a simple toggle switch arrangement the operator can determine whether the fault is at his terminal station or out on the system. In these cases, if it is desired to determine what type of fault exists and where it exists, it is necessary to go to the electronic equipment and inspect the fault indication panel. Such an arrangement provides for fault indication at all terminals; thereby making for "2-way supervision".

Union Electric alarms the following faults:

(1) Transfer from normal to standby r-f equipment.
(2) Transfer from normal to standby power.
(3) Top tower light failure.

(4) Side light failure.

## Survey Method Employed, Frequency Choice, Polarization, Frequency Staggering & Overshoot Prevention

### Survey Method Employed - Tower Height Determination

RCA used an aerial-radar type survey in laying out the microwave systems. In making such a survey the first step was to determine as well as possible from studies of topographical maps, suitable microwave paths. These maps, at best, are not completely up-to-date, data is missing or other inaccuracies exist. The next step was to actually fly out the paths using an aeroplane equipped with craft-to-earth type radar. From an air navigational safety standpoint this type of survey possesses several hazards in that the aircraft must fly at low altitudes, (generally in the neighborhood of 200 feet), at speeds slightly higher than stall-out. Special permission must be obtained from the local CAA authorities to make such a flight.

As the flight is made from point to point, a continuous record is taken of the path clearances. Notes are taken relative to the type of intervening terrain. Nearby obstructions and other factors of importance are noted. Aerial photographs together with a word description were later given to our Real Estate Department for the purpose of land acquisition.

We believe this type of survey to be superior to that of using field crews. The cost is certainly the lowest of any type. Our entire microwave system was flown out in $1\frac{1}{2}$ days. The plane's registry number is not readily traceable -- so the survey is conducted in utmost secrecy. This insures that land can be acquired at a reasonable cost. Accuracy is good. Each path was checked from known check points, (these were not revealed to the survey crew), and the accuracy was found to be well within 5 feet.

One word of caution might be mentioned in using this type of survey. That is the interpretation of the aerial photographs. Most people find it a little difficult to understand an aerial photograph -- especially real estate personnel or those not trained in aerial photography. In one case we acquired the wrong parcel of land using an aerial photograph. After the microwave system was placed in service improper operation, due to considerable fading, was experienced. After study it was found that we should have procured another parcel of land close by, which through coincidence appeared very similar on the photograph to the parcel we erroneously acquired. The elevation, however, was some 65 feet higher. This required "picking the station up bodily" and moving it to the new site.

From the data obtained in the aerial survey, tower heights were determined. The data is plotted on 4/3's earth's curvature paper, noting areas of foliage, bodies of water and high projections near the proposed line-of-sight path. In order to minimize the possibility of error, the profile paper should have a radius of curvature at least 10 times greater than the distance of a midpoint on the curve and a chord joining the two station locations. The 0 db and -2 db loss zone curves are constructed about the proposed line-of-sight. These loss zone curves are emperically derived and are very similar to Fresnel Zone clearance Curves.[1] Obstruction losses are taken into account by observing the projection of the obstruction into these clearance zone curves and suitable loss factors are applied.

The total losses, (comprised of free space transmission loss, fading loss, transmission line loss and obstruction losses), are then "balanced" against equipment gain and parabolic antenna gain. The difference between the summation of losses and gains is the path margin and reveals the merit of the path under consideration.

Frequency Choice, Frequency Staggering, Polarization, Etc.

From all the information available at the time we were planning our microwave system several years ago, it appeared that the lower frequencies were the most desirable because:

(1) Full first order Fresnel Zones were not required. Therefore, lower tower heights, (hence lower tower costs), could be used.

(2) Beam width at the half power points is wider for the lower frequencies. Therefore, the towers supporting the antennae need not possess an extremely high degree of torsional rigidity.

(3) The lower frequencies are less affected by rain, sleet, fog and other climatic conditions.

During the short time which we have had our microwave system in service, we still believe that our choice of lower frequencies was a correct one. On the 960 mcs leg, which falls far short of first order Fresnel Zone clearance, little or no fading has been experienced. On the 2000 mcs systems, slow fading has occurred during the early morning hours only during spells of very hot weather.

In order to prevent interference caused by possible overshoot, relay stations were laid out in a zig-zag manner from terminal point to terminal point. The frequencies were also staggered. The same frequency is used to transmit in both directions from a given repeater. Likewise, another frequency separated by 40 mcs, is used at that same station for reception from both directions. What was used as the transmitting frequency at one station would become the received frequency at the next station. This alternating of frequencies is employed from hop to hop. Alternate polarization of the transmitted signals is also employed; that is from any one given station the EW transmitted signal was polarized in the horizontal plane and the WE transmitted frequency is vertically polarized.

## Operating Experience

Although our microwave system has been in full operation only since June 1953, we believe that we learned much during its installation and subsequent operation. Some of these items are as follows:

### Method of Locking Building Doors

All exterior building doors are locked by what appears to be conventional night latches. However, these have been so modified that it is impossible to lock the door by merely slamming same. This eliminates the possibility of personnel, (often times one man by himself), accidentally leaving the keys inside the building and then closing the door. Exit from the building can always be made from the inside without the use of a key.

### Tower Light Failure and Relamping Procedure

No tower light failures have been caused by other than normal lamp failure. We were somewhat concerned about hunters, pranksters and the like, shooting at the tower lights, parabolae or building, (which are Butler sheet metal types). To date no such troubles have been experienced.

The cost of lamps is minor compared to the cost of replacing same. Therefore, it is not our policy to replace only a single burned out unit. When personnel report to the tower upon notification of a light burn-out, all lamps are replaced.

### Radio Interference Caused by Flasher Beacon

At the time our microwave system was being installed, radio interference was reported by people living in areas near towers equipped with flasher beacons. It was necessary to install "hash filters" in the flasher mechanisms to eliminate subject radio interference.

### CAA Reporting of Top Tower Light Failure

Two lamps are employed in the top tower light assembly. In case only one of these lights fail, we get a "top tower light failure alarm". Personnel at the attended terminal station report same to the nearest CAA Office. Aviators report that the top tower light is still burning, as the other unit is still operative. Studies are now underway to ascertain alarm methods for determining whether just one light has failed or whether the top beacon is totally obscured.

### Effect of Winds on Tower Stability

Our towers, although they appear light and flimsy when compared with transmission line towers, are in reality very stable. They are designed to withstand wind velocities up to 100 mph, (indicated), under heavy icing conditions.

Several strong blows were encountered during the installation period. No towers failed or distorted. One 6' parabola did, however, shift out of line. It was later found that this antenna had not been securely tightened on its mount.

## Lightning Protection

Microwave towers located on high points of ground make perfect lightning rods. As shown in Fig. 10, elaborate steps were taken to insure that the tower, its associated guying and the building were all securely grounded.

To date no damage has resulted from direct lightning strokes; although we feel sure that same has occurred. A power meter loop was lost at one location -- failure of same was attributed to lightning. No damage to the electronic equipment was noted.

## Kohler Unit Troubles

### Cathodic Protection

The fuel supply for the Kohler engine-driven motor-generator sets at the unattended repeater stations is contained in 55 gal. drums buried in the earth in close proximity to the building containing the electronic and motor-generator equipment. These fuel tanks are conventional steel drums coated with a mastic compound and wrapped with a burlap material.

Even though care was exercised in placing these containers in the earth and covering with backfill, it still was not possible to prevent minor damage to the exterior coating which later caused galvanic action.

We, therefore, applied cathodic protection to all such installations. The fuel lines were also broken where they entered the building by means of insulating couplings. In this way buried fuel tank is electrically separated from the remainder of the station equipment.

## Sticking and Sluggish Starting

During the initial check-out period considerable difficulty was experienced with Kohler units failing to start if not operated at frequent intervals.

After investigation it was found that sticking was caused by small traces of ethylene glycol, used for anti-freeze protection, had leaked into the oil through the head gaskets. The units were thoroughly flushed and the ethylene glycol was replaced with an alcohol type anti-freeze. This appears to have remedied the troubles.

Test switches for exercising the Kohler units have been incorporated. It is now standard procedure for our personnel to exercise the unit each time they visit a location.

## Overheating

During preliminary tests the Kohler units would overheat and often times cut out on thermal protection. As the engine room compartment in the buildings is small, it was determined that this cut-out was caused by high ambient temperature conditions. Overheating was corrected by installing oversize radiator fans.

## VHF Carrier-Operated Relays

As mentioned previously, the VHF base stations have been equipped with carrier-operated relays adjusted so that the VHF receiver opens up only upon receipt of a strong signal from a mobile unit and not some other base station. Antenna arrays are oriented so as to present a null toward the undesired receiver. We have found that these relays are difficult to keep in adjustment and are now considering the matter of eliminating them. At first it was felt that mushiness would result if more than one base station picked up a mobile unit's conversation. Recent tests indicate that in some instances a slight mushiness does occur; but that it is not objectionable.

## Tube Replacements & Component Failures

The RCA microwave systems use more tubes than in some other types of equipment. This gave us some cause for concern at first as it was felt that any electron tube was a potential source of trouble. Operating experience has not justified these fears. Many of the tubes including the 2C39A's have in excess of 10,000 hours operation to date. Tube replacements can be considered as normal, now that the shakedown is about completed.

Failures of other components such as capacitors, resistors, etc., have been low as was expected.

The item which has caused the most trouble is not electronic in nature; but rather electro-mechanical. This is the "distributor commutator mechanism" used in the fault alarm equipment. This device consists of a set of segments cast in a ceramic plate, across which a sweeping contactor arm rotates. We have found that dirt, copper particles, etc., tend to pile up between the contact segments causing faulty operation. Studies are now underway to eliminate this difficulty.

## Fading

As was mentioned previously, some fading has been experienced in the early morning hours, (1:00 A.M. to 8:00 A.M.), during spells of hot weather. Signal level drops off for several hours at a time -- in most cases not great enough to cause prolonged outages. The fading appears to be of the beam-bending type rather than multi-path reception. The only guard against beam bending is to engineer into each path an adequate amount of fading margin. On the longer paths in our system, 25 to 30 db fading margin was incorporated; in shorter paths a lesser figure was used. We have found that it is extremely important that all equipment be kept in excellent operating condition during fade seasons. Any deterioration in equipment performance manifests itself as an outage or serious fall-off in signal strength during periods of deep fade.

Maintenance Personnel Training

Thus far our microwave systems have required more maintenance attention than was at first believed would be necessary. As time goes on we look for improvement along these lines as the men become more familiar with the equipment and with u-h-f techniques. Also they are becoming more adept at locating and isolating cases of trouble by thinking on a "system performance" basis rather than isolated cases of trouble.

We attempted to train our personnel by having them work with the RCA field crews at the time the microwave installations were made. This procedure did not prove to be too satisfactory. It is believed that this "installation training" augmented by study and instruction in a training school at the manufacturer's plant offers the best solution for obtaining well qualified maintenance personnel.

## General Remarks

At the present state of the art it is our belief that an extensive microwave system involving a number of repeaters is not a suitable application for protective relaying of major transmission line systems. All microwave systems are subject to fade; then too, unless expensive steps are taken to eliminate the "dead times" which occur during transfer from normal equipment to r-f standby and normal to emergency standby power sources, the microwave is out of service. During such periods reliance must be placed upon slower type back-up relays. It is believed that less costly forms of protective relaying employing power-line carrier techniques is the more satisfactory.

For these same reasons the use of microwave is not advocated for remote supervisory control of circuit breakers, etc., nor integrating functions where extreme accuracy is required.

1. "Microwave & VHF Radio Installation on the Union Electric System", George W. Fox and M. G. Staton. A paper presented before the Joint Spring Meeting of the American Institute of Electrical Engineers and the Institute of Radio Engineers, St. Louis, Missouri, March 19, 1952.

GROWTH OF UNION ELECTRIC

| | 1930 | 1941 | 1945 | 1951 | % Increase |
|---|---|---|---|---|---|
| Total Generating Capacity, kw | 571,420 | 630,000 | 939,000 | 1,112,000 | 95 |
| Max. Demand, (System Peak), kw | 370,072 | 613,000 | 787,000 | 1,013,000 | 174 |
| Kwhr Output, Total | 1,954,460,028 | 3,315,099,677 | 4,491,575,076 | 5,489,560,158 | 181 |
| Number of Customers, Total | 319,334 | 369,785 | 428,719 | 504,845 | 58 |

Fig. 1 - Growth of Union Electric System during past decade.

ADVANTAGES & DISADVANTAGES OF CONVENTIONAL TYPES OF COMMUNICATION FACILITIES

| Physical Telephone Circuits | | Power-Line Carrier | |
|---|---|---|---|
| Advantages | Disadvantages | Advantages | Disadvantages |
| 1. If leased, maintenance is performed by owning company. | 1. High first cost.<br>2. High maintenance costs.<br>3. High leasing costs.<br>4. Derivation of additional channels over an existing circuit is very limited.<br>5. Susceptible to outages caused by inclement weather.<br>6. Does not fully meet requirements - no communication between terminal points. | 1. Well-known and reliable form of communication.<br>2. Unless distance between terminals is very great, no repeaters are required.<br>3. Maintenance costs are low.<br>4. All equipment located at terminal stations on Company's own property. | 1. Difficult to "crib" additional functions on an existing channel.<br>2. Susceptible to condition of transmission line:<br>(a) Sleet attenuates signal.<br>(b) Switching, grounded conductor results in loss of signal.<br>3. Addition of more carrier becomes difficult because:<br>(a) Frequency spectrum space may not be available.<br>(b) Physical space required in get-a-away structures for carrier appurtenances.<br>4. Change in configuration of transmission line can result in changes in the carrier system. |

Fig. 2

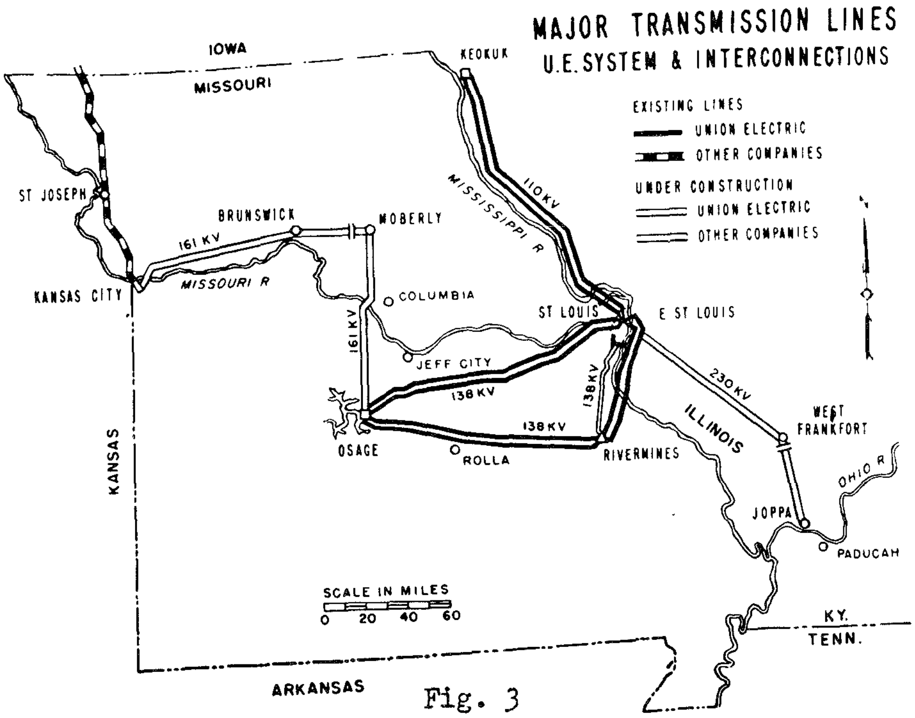



Fig. 3

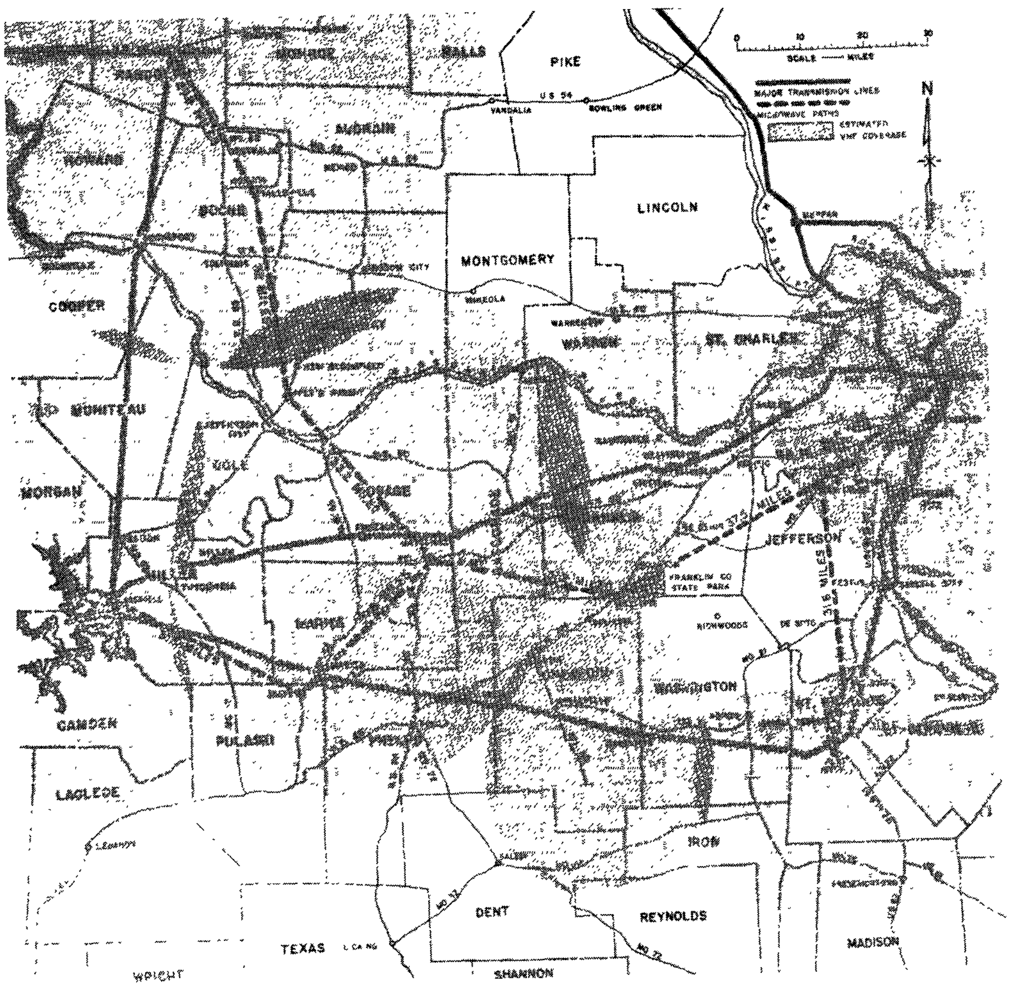



Fig. 4 - Missouri Microwave System and VHF radio coverage superimposed on major transmission line system.

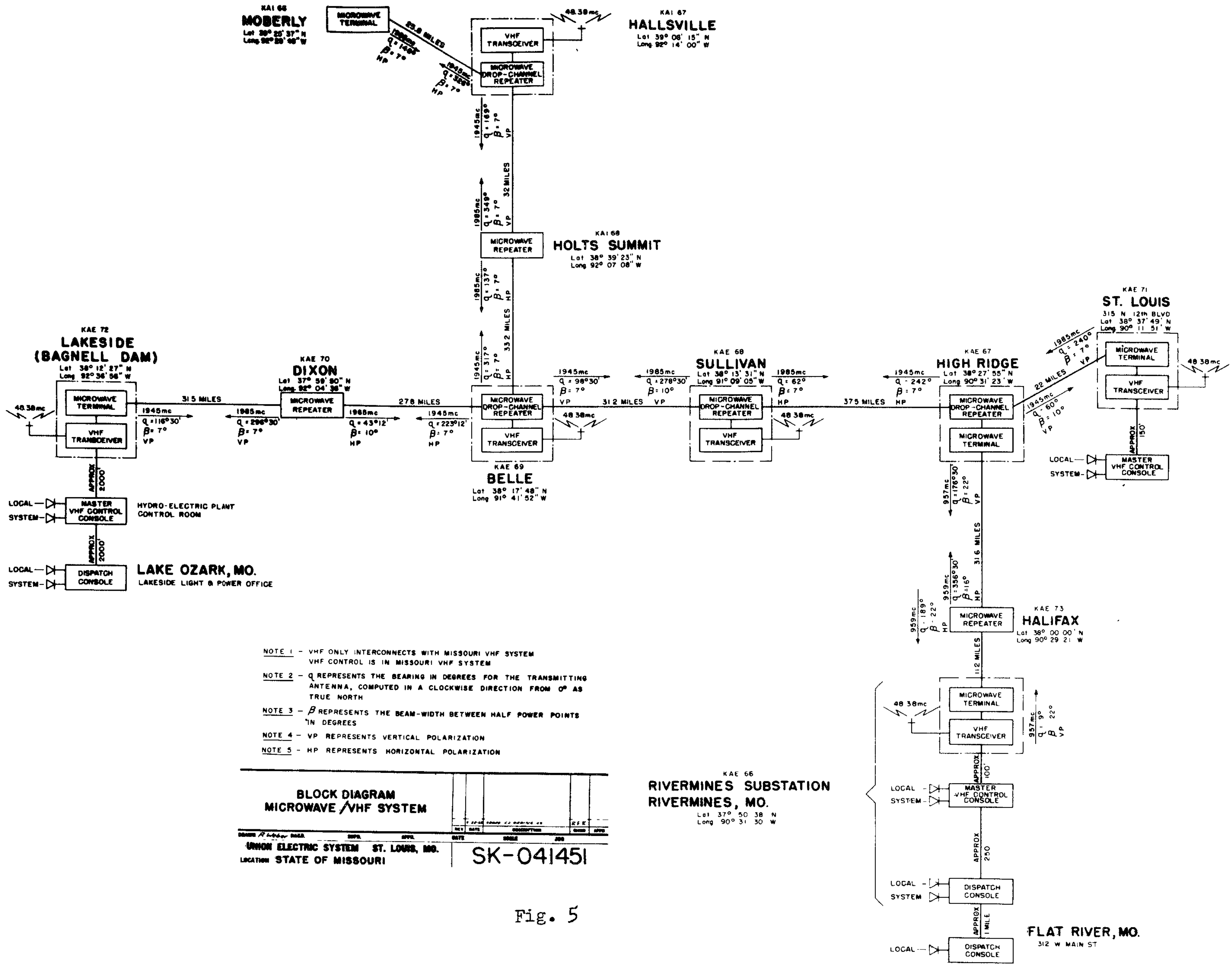

KAI 66 MOBERLY
Lat 39° 25' 37" N
Long 92° 25' 48" W
MICROWAVE TERMINAL
KAI 67 HALLSVILLE
Lat 39° 08' 15" N
Long 92° 14' 00" W
VHF TRANSCEIVER
MICROWAVE DROP-CHANNEL REPEATER
KAI 68 HOLTS SUMMIT
Lat 38° 39' 23" N
Long 92° 07' 08" W
MICROWAVE REPEATER
32 MILES
33.2 MILES
KAE 72 LAKESIDE (BAGNELL DAM)
Lat 38° 12' 27" N
Long 92° 36' 56" W
MICROWAVE TERMINAL
VHF TRANSCEIVER
48.38mc
315 MILES
KAE 70 DIXON
Lat 37° 59' 50" N
Long 92° 04' 38" W
MICROWAVE REPEATER
278 MILES
KAE 69 BELLE
Lat 38° 17' 48" N
Long 91° 41' 52" W
312 MILES
KAE 68 SULLIVAN
Lat 38° 13' 31" N
Long 91° 09' 05" W
375 MILES
KAE 67 HIGH RIDGE
Lat 38° 27' 55" N
Long 90° 31' 23" W
MICROWAVE TERMINAL
22 MILES
KAE 71 ST. LOUIS
315 N 12th BLVD
Lat 38° 37' 49" N
Long 90° 11' 51" W
MASTER VHF CONTROL CONSOLE
APPROX 150'
LOCAL
SYSTEM
31.6 MILES
KAE 73 HALIFAX
Lat 38° 00' 00" N
Long 90° 29' 21" W
11.2 MILES
KAE 66 RIVERMINES SUBSTATION
RIVERMINES, MO.
Lat 37° 50' 38" N
Long 90° 31' 30" W
APPROX 100'
APPROX 250
DISPATCH CONSOLE
APPROX 1 MILE
FLAT RIVER, MO.
312 W MAIN ST
APPROX 2000'
HYDRO-ELECTRIC PLANT CONTROL ROOM
LAKE OZARK, MO.
LAKESIDE LIGHT & POWER OFFICE
NOTE 1 - VHF ONLY INTERCONNECTS WITH MISSOURI VHF SYSTEM VHF CONTROL IS IN MISSOURI VHF SYSTEM
NOTE 2 - q REPRESENTS THE BEARING IN DEGREES FOR THE TRANSMITTING ANTENNA, COMPUTED IN A CLOCKWISE DIRECTION FROM 0° AS TRUE NORTH
NOTE 3 - β REPRESENTS THE BEAM-WIDTH BETWEEN HALF POWER POINTS IN DEGREES
NOTE 4 - VP REPRESENTS VERTICAL POLARIZATION
NOTE 5 - HP REPRESENTS HORIZONTAL POLARIZATION
BLOCK DIAGRAM
MICROWAVE /VHF SYSTEM
UNION ELECTRIC SYSTEM ST. LOUIS, MO.
LOCATION STATE OF MISSOURI
SK-041451

Fig. 5

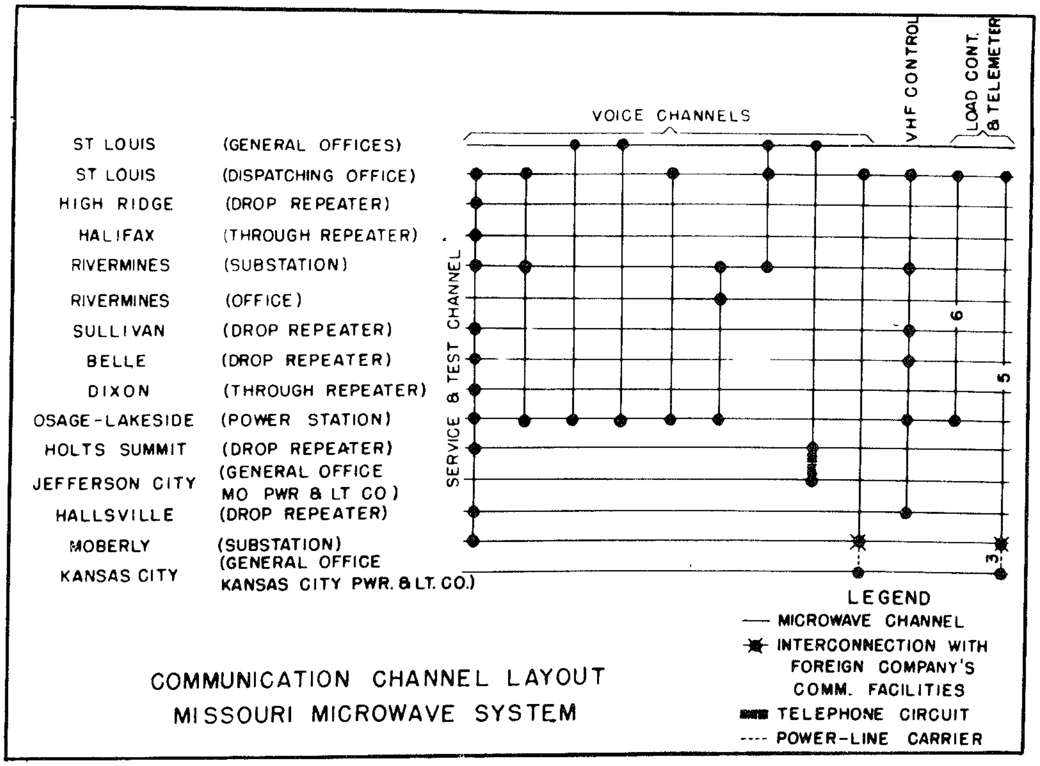



Fig. 6

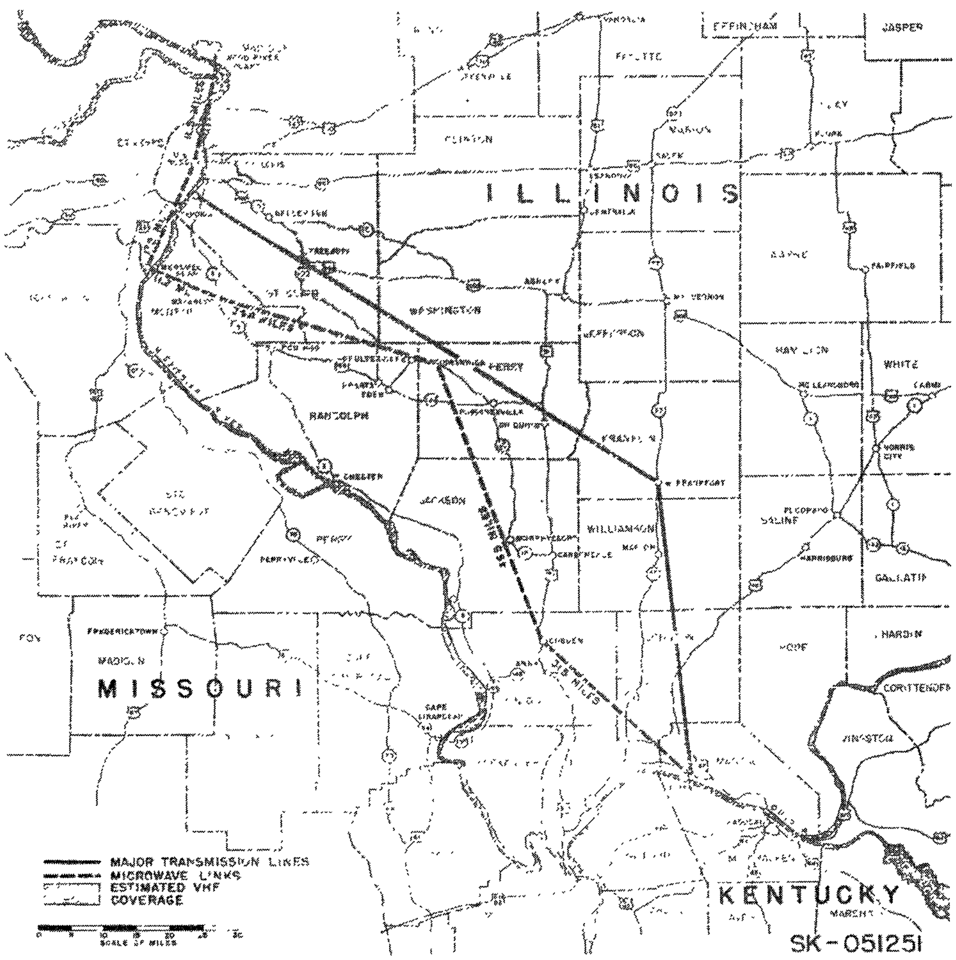
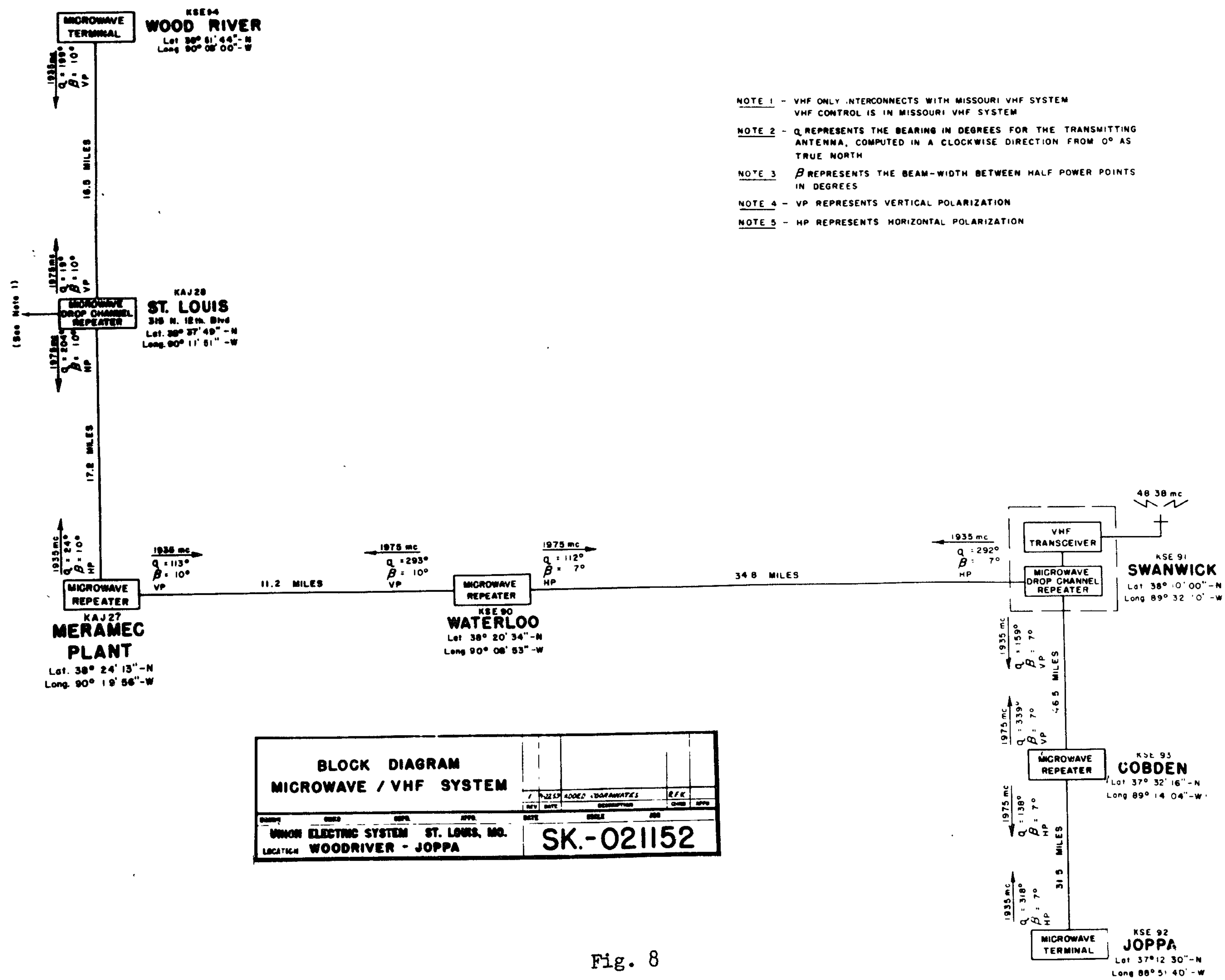



Fig. 7 - Illinois Microwave System and VHF coverage superimposed on major transmission line system.



MICROWAVE TERMINAL
KSE94
WOOD RIVER
Lat 38° 51' 44"-N
Long 90° 08' 00"-W
16.8 MILES
KAJ28
ST. LOUIS
315 N. 12th. Blvd
Lat. 38° 37' 49" -N
Long. 90° 11' 51" -W
MICROWAVE DROP CHANNEL REPEATER
(See Note 1)
17.2 MILES
MICROWAVE REPEATER
KAJ27
MERAMEC PLANT
Lat. 38° 24' 13"-N
Long. 90° 19' 56"-W
11.2 MILES
MICROWAVE REPEATER
KSE90
WATERLOO
Lat 38° 20' 34"-N
Long 90° 08' 53"-W
34.8 MILES
48.38 mc
VHF TRANSCEIVER
MICROWAVE DROP CHANNEL REPEATER
KSE 91
SWANWICK
Lat 38° 10' 00"-N
Long 89° 32' 10'-W
46.5 MILES
MICROWAVE REPEATER
KSE 93
COBDEN
Lat 37° 32' 16"-N
Long 89° 14' 04"-W
31.5 MILES
MICROWAVE TERMINAL
KSE 92
JOPPA
Lat 37°12' 30"-N
Long 88°51' 40'-W
NOTE 1 - VHF ONLY INTERCONNECTS WITH MISSOURI VHF SYSTEM VHF CONTROL IS IN MISSOURI VHF SYSTEM
NOTE 2 - α REPRESENTS THE BEARING IN DEGREES FOR THE TRANSMITTING ANTENNA, COMPUTED IN A CLOCKWISE DIRECTION FROM 0° AS TRUE NORTH
NOTE 3 β REPRESENTS THE BEAM-WIDTH BETWEEN HALF POWER POINTS IN DEGREES
NOTE 4 - VP REPRESENTS VERTICAL POLARIZATION
NOTE 5 - HP REPRESENTS HORIZONTAL POLARIZATION
BLOCK DIAGRAM
MICROWAVE / VHF SYSTEM
UNION ELECTRIC SYSTEM ST. LOUIS, MO.
LOCATION WOODRIVER - JOPPA
SK.-021152


Fig. 8

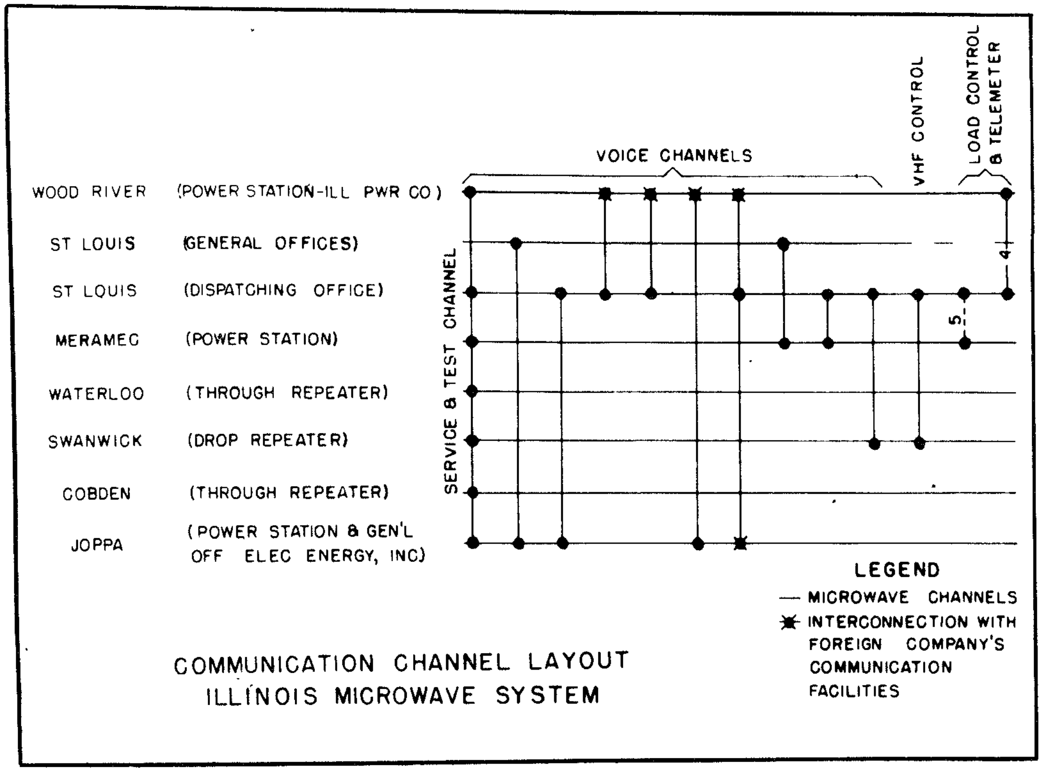
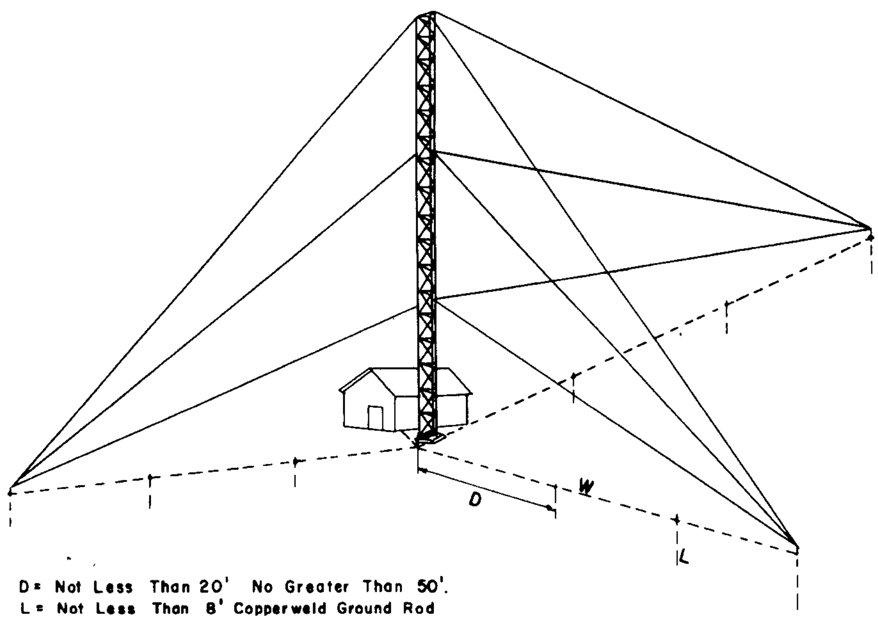



Fig. 9

GROUNDING DETAILS




D = Not Less Than 20' No Greater Than 50'.
L = Not Less Than 8' Copperweld Ground Rod
W = Not Less Than 2 AWG. Conductor.

Fig. 10

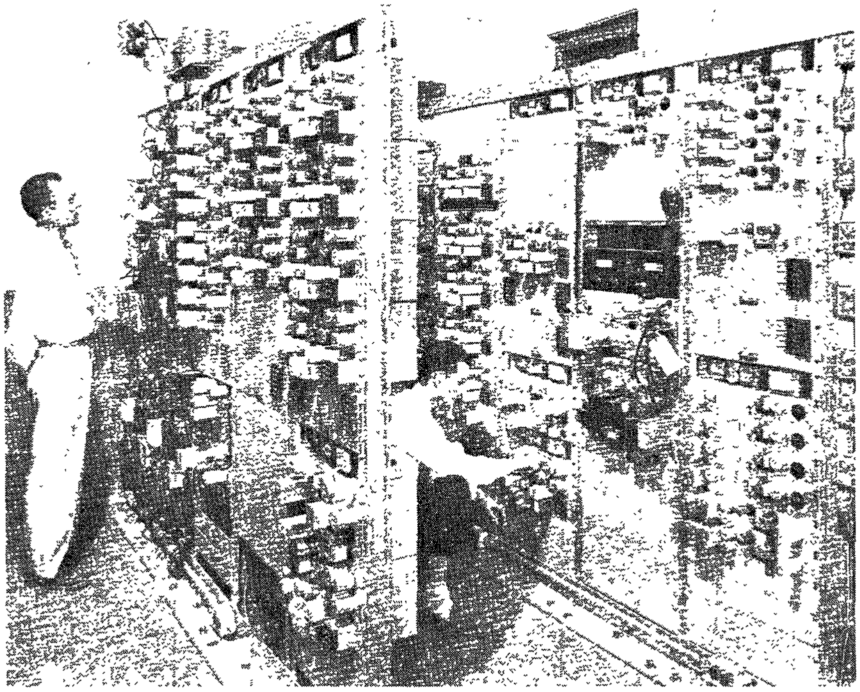


Fig. 11 - View of the terminal equipment - St. Louis.

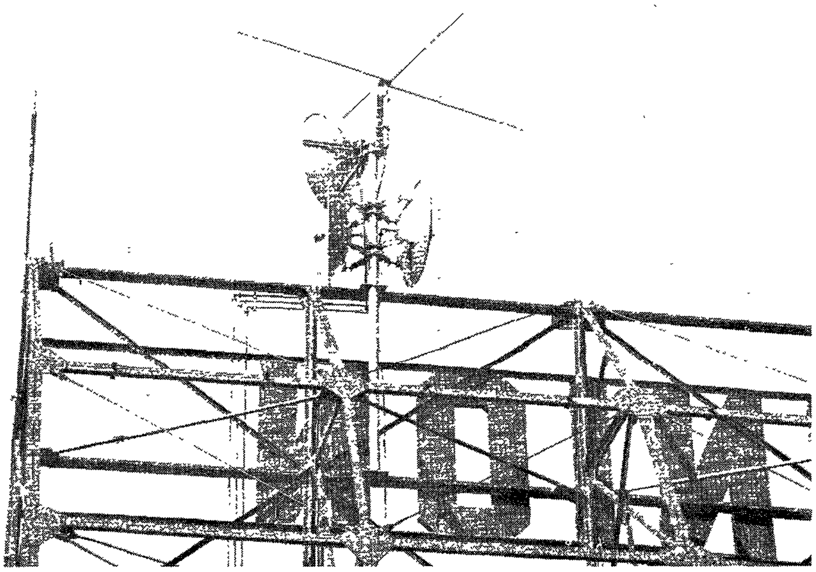


Fig. 12 - View of the microwave parabolae and VHF antenna mounted on sign atop Union Electric Building - St. Louis.

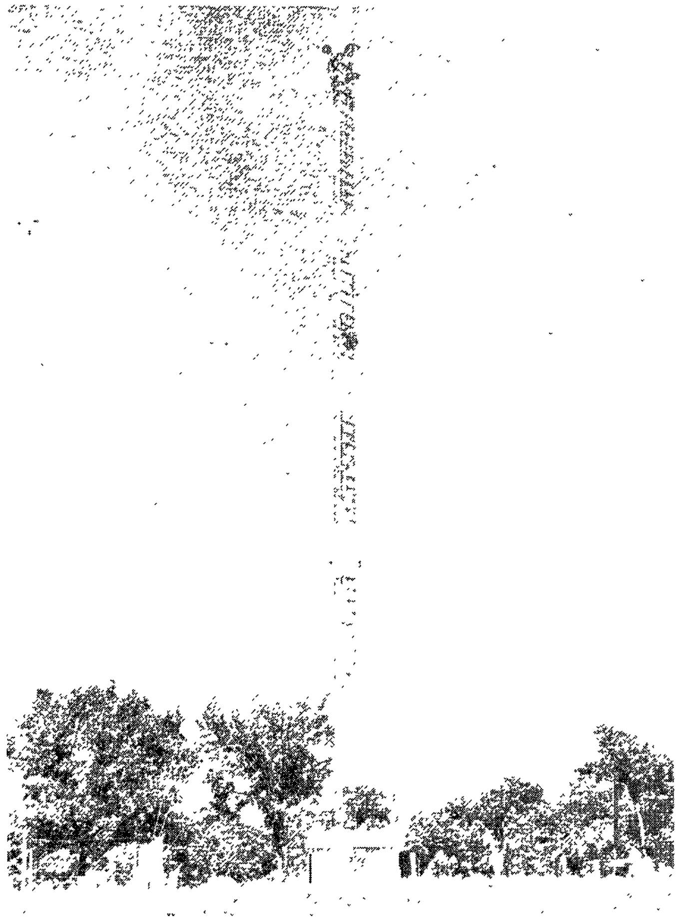


Fig. 13 - View of the High Ridge Repeater sight.

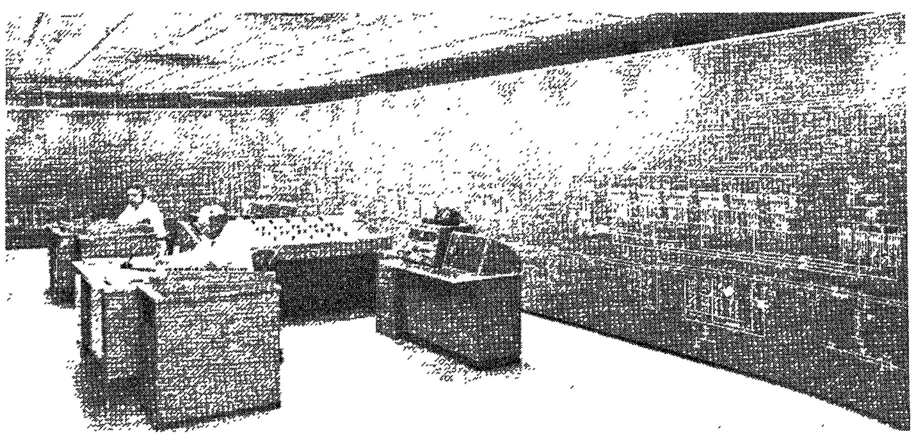


Fig. 14 - Panoramic view of the Load Dispatcher's office, St. Louis, showing the VHF radio console in the foreground and Leeds and Northrup automatic load control console between the two dispatchers.