It is questionable whether this additional increase in performance would be justified in light of additional equipment and maintenance costs.

It also appears feasible that return loss figures of 36 and 40 db may eventually be feasible. Present system requirements as established by major development groups in this field, have set a minimum return loss figure of 30 db for feeder and trunk cable, at the present time.

Because of the development of the aluminum sheathed coaxial cable with prevention of longitudinal vapor paths, it would appear that we have also approached optimum shielding efficiency and cable life. Cable life has been shown to be a very important factor in cable performance, coupled with the attenuation, cost, shielding and return loss factors.

MR. TAYLOR: Thank you very much, Mr. Kushner. Mr. Kushner mentioned the papers. We have gotten papers out of the boxes so that all of the papers that are available are here. Those papers that are not available will be available, however, through the transcription service which is taking down all of the presentations both in this room and the other room.

We're running right about on schedule. Unless somebody has an urgent question for Mr. Kushner, I would like to move on to the next speaker. You have the biographical sketch on your chairs so I will not take a particular time to introduce Dr. Theodore Hafner, who is going to speak on the "Breakthrough With Microwave by Wire". Dr. Hafner.

DR. THEODORE HAFNER (President, Surface Conduction, Inc.): I am somewhat embarrassed. I have to talk about something which is entirely different from what you have just seen. It is, in a way, fundamentally new. This has a certain advantage, but it also has a certain disadvantage. The disadvantage is in the difficulties of an explanation.

Now, if I may, I hope my predecessor here in speaking will forgive me if I use some of his figures. He's talking about improvements from 50 db per mile to 40 db per mile. And, I am going to speak about improvements from 40db per mile to 10 db per mile.

HISTORY AND THEORY

Wire or wireless. The surface wave, a third medium combining privacy of wire with the low loss of radiation. The surface wave, a fundamentally novel wave mode. Simple (though only theoretical) derivation of existence of surface wave; its low loss and wide applicability.

What is the G-Line? Where does it come from? Where does it go?

I am reminded of the famous Austrian General Radetzky. At one of the war games of the Austrian army, one of the participating army groups was commanded by an Archduke who was not too well known for his intelligence. After the battle, Radetzky surveyed the happenings

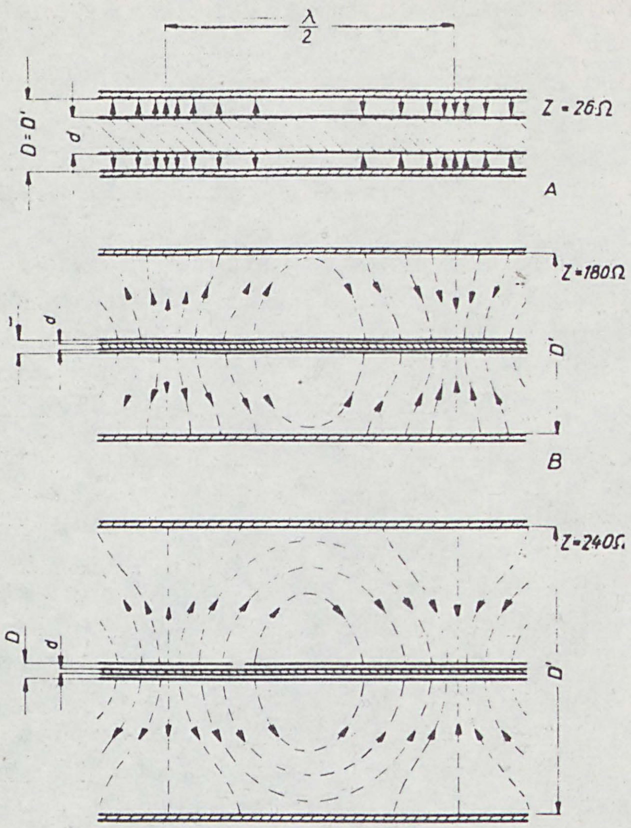

FIG. 1: From Coaxial to Surface Wave

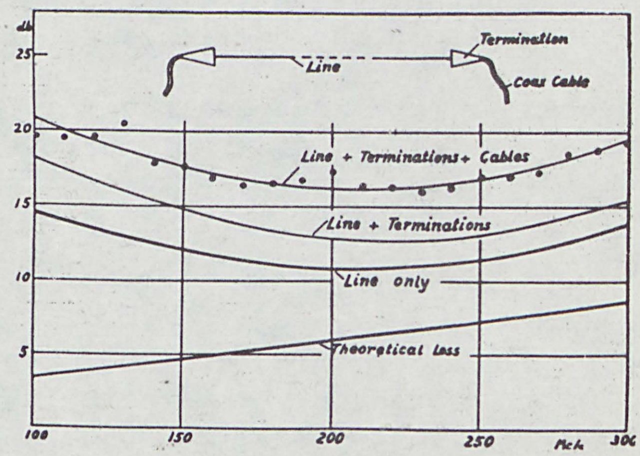

FIG. 2: Loss of 2-mile G-Line

and remarked to the Archduke: "The problem you faced had two solutions; Your Imperial Highness selected the third one."

This, of course, was facetious; there was no third solution.

In choosing between wire and wireless, is there a third solution?

Until recently, there were known only two ways of guiding a signal from point to point: either within a cable or without a cable. We have now a third way: a surface wave around a cable.

This evolution should place the use of surface waves by CATV in the proper perspective. It is part of a historic development and, as every real achievement, it affects every important field of communications, railroads, power distribution, broadcasting, and one day, perhaps all types of long distance transmission.

What is a Surface Wave? How is it produced?

At least mentally, it can be construed from a coaxial cable. (Figure 1.)

By increasing the outer conductor of a coaxial cable, we reduce the loss, as is well known, but something else happens: With increasing outer diameter some of the coaxial field lines between inner and outer conductor will not reach the outer, but since they have to end somewhere, return to the inner conductor.

By further increasing the radius of the outer conductor, more and more of these field lines will close on the inner conductor. Finally, if the

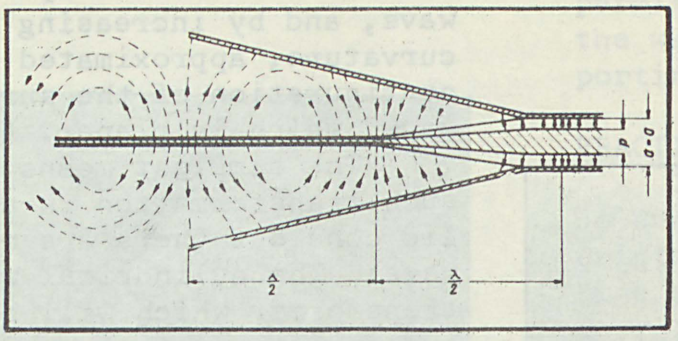

FIG. 3: Transforming Coaxial to Surface Wave

outer conductor is large enough, almost all of the field lines will terminate along the inner conductor. The wave, eventually, will be propagated substantially only by the inner conductor, sliding on its surface in an air channel of a diameter, as determined by Dr. Goubau, of wavelength dimension. Under these circumstances, of course, the outer conductor could be omitted with relatively little, if any, energy loss.

What remains is a single wire of a closed wave configuration.

In a similar way, one of the two wires of a twin line can be moved away and finally omitted.

It is obvious from a comparison with this twin line that the remaining single wire must have not more than half the loss of that of a twin line. Actually, the loss of the G-Line is much less: around 8 - 10 db per mile at VHF and UHF. (Figure 2.)

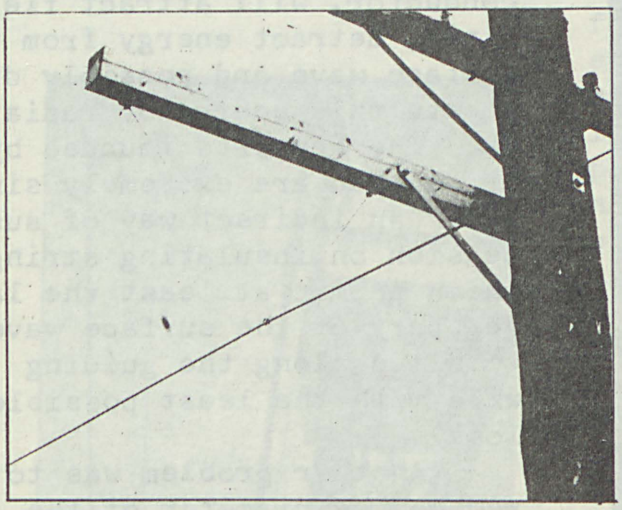

FIG. 4: V-Shaped Nylon Suspension: Helena, Montana

REALIZATION OF SURFACE WAVE IS DIFFERENT FROM VISUALIZATION

The launching of the surface wave. Indirect suspension. Concentration of the surface wave by special cable structure.

While this mode of creating a surface wave from a coaxial cable is easily understood, it does not present a practical way of producing a surface wave.

Dr. Goubau found such a way. He started out from a coaxial line section and then transformed the impedance of the coaxial line into the impedance of the surface wave - which is that of air. At the same time, he gradually transformed the coaxial wave into a spherical wave, and by increasing its curvature, approximated the configuration of the surface wave, which is planar. (Fig. 3)

The simplest means for such transformation is a metallic cone but there are other ways: The cylindrical wave transformer which will be discussed later on.

It is one thing to imagine the mere possibility of the existence of a surface wave. It is another thing to realize a surface wave and it is a third problem to apply a surface wave transmission line in a practical way.

Obviously, a surface wave sliding outside the cable must proceed unimpeded by anything which may affect its transmission. How then support the cable?

From the previous derivation of the surface wave from the coaxial wave, it is apparent that another conductor, arranged near the surface wave conductor, will attract field lines, detract energy from the surface wave and possibly dissipate this energy by radiation.

The supports founded by Dr. Goubau are extremely simple: an indirect way of suspension on insulating strings which permit at least the larger part of the surface wave to slide along the guiding wire with the least possible loss.

Another problem was to reduce the diameter of the airchannel. Obviously, the smaller its diameter, the smaller the launching devices

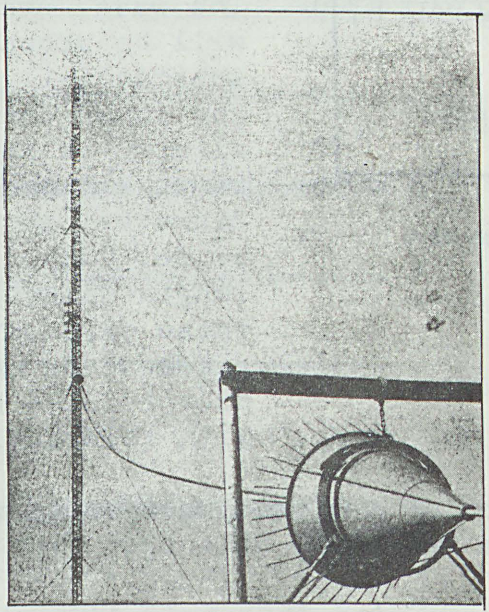

FIG. 5: G-Line for 10 kw 500mc
Federal Broadcasting System
Sigmanningen, Munich, West Germany

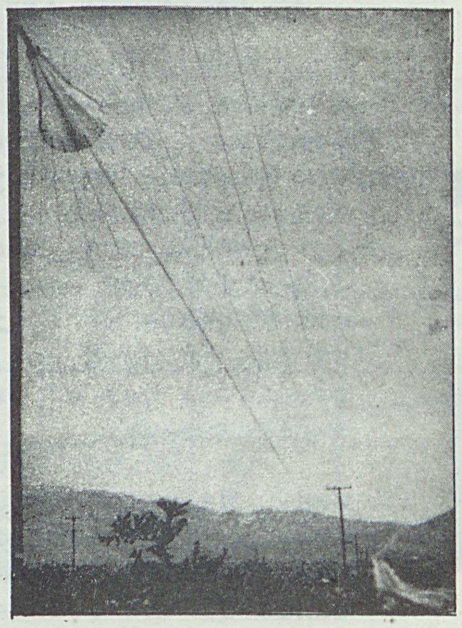

FIG. 6: Launching horn-Yucca Valley

for producing the surface wave to permit practical dimensioning of the wave producing and wire supporting devices.

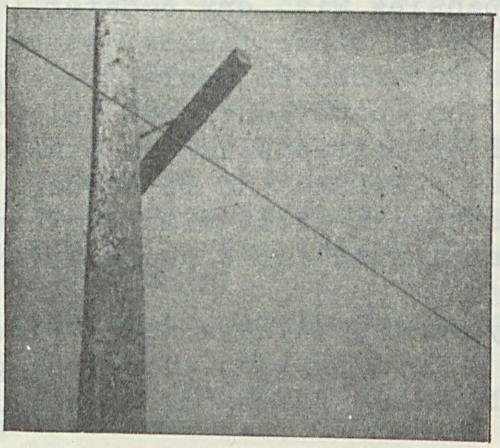

FIG. 7: V-Suspension - Yucca Valley

PRACTICAL APPLICATIONS

The Community G-Lines at Helena, Yucca Valley, Lewistown. Originally provisionally used, G-Line becomes permanent feeder line.

Thus we find, as a classical means of suspension, the V-shaped nylon string, which was applied in CATV, for the first time in the Helena (Montana) G-Line by Archie Taylor, which was constructed under our license. (Fig. 4)

The G-Line, therefore, as a wire line, can be important for CATV, as an industry substantially relying on wire techniques. It combines the good features of wire and wireless and produces a broad, low-loss transmission path which is essentially private and easily expandable.

In this respect, CATV is not alone. Other industries have similar requirements. You can profit from their experience.

Among the many uses the G-Line found in practice, was, at the outset, a quick substitute for a coaxial cable or a wave guide to a radio transmitter.

FIG. 8: Cylindrical Pickup-Yucca Valley

The U.S. Signal Corps produced the first G-Lines in the form of antenna feeder lines for their mobile radio equipment. Here already, the remarkable simplicity of the G-Line, its lightweight, easy handling, were put to such use, or rather abuse, as no coaxial cable could ever have withstood.

The German government found it convenient to start TV broadcasting and testing immediately and prior to the permanent connection of the coaxial cable or the wave guide, which generally took several months to install; the G-Line took as many days. Some of these substitute G-Lines became permanent, as in Sigmanningen, Germany. (Fig. 5)

Another example of G-Line, in operation for almost 10 years, is

3000 ft., 2500 MC antenna feeder at Florence, Alabama; two 3000 ft. 2000 MC feeder lines for ITT, Brazil.

In this connection we may add our UHF home G-Line, indispensable for fringe area UHF reception; a #12 wire, with a loss of 1 db/100 ft. only over 400 to 1200 MC, therefore, dispensing with any booster.

Similar uses were found for the G-Line in other fields, where for one reason or another immediate connection by coaxial cable, wave guide or Air was not available. Among them is the above mentioned Helena G-Line, where due to the absence of channel allocations for an otherwise more convenient and more direct air route, a G-Line had to be used to bring a channel down a mountain, over a distance of 14 miles. This provisional installation, using a #8 wire, lasted for 8 years before the FCC channels were granted.

Another G-Line, at Lewistown, Pennsylvania, using a No. 6 wire, runs for 3 1/2 miles without an amplifier, at a loss of less than 9 db per mile, suspended on the poles of a power line and following a railroad track.

In this G-Line we applied a cylindrical pickup which permits branching off from the G-Line cable into a coaxial cable, without interfering with the surface wave.

Similarly, in Yucca Valley, Microwave channels were not available in time to assure the contractual TV service to a housing area. A 35-mile G-line was found economical, with amplifiers every 2 miles. (Figures 6, 7, 8)

All these installations, born from necessity rather than intrinsic planning, have now shown that there is more to the G-Line than just an occasional feeder to a coaxial cable or a short time substitute for a Microwave Relay. The G-Line is quite capable to replace and supersede both coaxial and Microwave Relays.

MICROWAVE BY WIRE vs. AIR AND SPACE

Comparison of economics, G-Line competitive and also indispensable because of independence from government channel allocations. Reliability to come with experience, and therefore no principal drawback. Convenience of Air and Space deceptive in view of expense and complexity involved. G-Line as wiring technique more fitting to private right of way users, such as CATV, railroads and power systems.

It is not my intention to disparage air or space technology, but we on this earth and in this country are guided by economics. And the G-Line fits economically into CATV more than Microwave by Air.

We need not defend the G-Line against coaxial cable which for long distance is at least four times as expensive. It may be worthwhile, however, to briefly compare cost of G-Line with that of Microwave by Air. Since the VHF G-Line with a bandwidth of 200 MC may carry 20 TV channels or more, we may assume cost of G-Line installed at $2,000.00/mile, regardless of number of channels; average cost of Microwave Relaying is given (See Paul McAdam, NCTA Bulletin, December 1, 1961) at $28,000.00 per hop per channel, plus $9,000.00 per additional channel.

For one TV channel, therefore, the G-Line will be competitive at any distance less than 14 miles; for seven TV channels, at any distance of less than 41 miles. Freedom from FCC channel allocations favors G-Line for any distance.

Admittedly, in favor of Microwave Relaying is its proven reliability. However, this is an advantage any old system has against any newcomer. There is no reason to assume non-radiating cylindrical surface waves to be less reliable than radiating spherical waves which, on the contrary, due to their very expansion, should be more exposed to atmospherics, reflection and fading.

Microwave through Air and Space, which seems so convenient for bridging large distances, depends on so fickle a matter as government control. Its transmitting equipment is complex. Admittedly, the G-Line requires a new wiring technique, but this is still a wiring technique, mastered more easily than the operation of a Microwave Relay.

The convenience of Microwave Relaying is, therefore, more apparent than real, as may be its reliability. The telephone company charges for their microwave as much as for their coaxial channels. ATT and Western Union provide several alternative microwave routes for every point-to-point connection.

While Microwave through Air and Space has now become sort of a fetish and the poor land wire somewhat neglected, we should not forget that this is accomplished at tremendous cost for which bear witthe common carrier rates of ATT, now also extended to transmission by satellite.

RAILROADS AND POWER DISTRIBUTION AS SPECIALIZED MARKETS

Essential interest in wiring technique. Historic autonomy on own right of way includes communications. Nature of operation requires flexibility in expansion and privacy of transmission medium.

And yet, important interests exist, which demand permanent communications by wire, foremost among them railroads and power systems.

Railroads are used from their beginnings to communicate over their own property. Frequently they were the physical carriers of circuits for the telephone companies and Western Union. Gradually, our telephone and telegraph systems grew independent from the railroad's right of way. The increasing communication traffic forced them to establish wire and cable lines on their own land and later on to expand into the public space, using Microwave through Air.

Railroads and power companies, on the other side, also growing, were at first satisfied with what they had in the way of communications: the railroads with wires on their own tracks, and the power companies using carrier frequencies over their own high tension wires.

In the last few years, however, railroad and power systems alike had to expand communications and signaling; the railroads needed quick data transfer from one point to another, in accordance with increasing train speed and freight processing. The increased demand for electrical power forced the power companies to enlarge their systems and system controls. Both railroads and power companies are now at the point where they have to consider using either Microwave by

Air or Microwave by Wire.

RAILROADS' SPECIFIC REQUIREMENTS

G-Line for tunnel communications; data transmission; Japanese and English speed controls by G-Line; train automatization. Railroad radar and security fence.

As far as the railroads are concerned, their communication and signaling demands are complex.

In Tunnels, for instance, Radio transmission has been found impractical. Due to the shape of the expanding radio wave, the radiated wave suffers so many reflections that, after a few hundred feet, a voice or signal will become distorted. The non-radiating surface wave, with its essentially tubular shape, concentrated around a wire mounted in the tunnel, fits aptly into the more or less cylindrical shape of the tunnel. By means of suitable pickups, the surface wave can be picked up, without physical contact, from people or trains passing through the tunnel.

Such a tunnel G-Line has been built for the New York Central Railroad over a distance of 3 1/2 miles.

Tunnel communication is important. The railroad freight yard in question, which is now open, will soon be covered up to permit building construction to go up in the valuable air space above the yard. In order to conserve the function of the yard, personnel and engines in and outside the tunnel must be able to communicate with each other in the same manner as in open freight yards with the aid of normal walkie-talkies.

Especially important is the use of the G-Line in underwater tunnels. In Japan as well as in Great Britain, and recently in this country, attempts are made to increase the train speed to 150 miles/hour and more. At these high speeds, control of the train becomes difficult and cannot be made dependent upon visual observation alone. Therefore, the possibility has been considered of observing the track from the engine by means of a radar-type beacon.

FIG. 9: Curve Trolley – Yucca Valley

In the usual type of radar, a radiating beam reflected from any subject located in its path is used; for example, to locate aircraft. This type of radar is not readily applicable, due to the manifold reflections occuring near the ground, which distort the signal. In this type of application, surface wave conduction was used first by the Japanese and now by Ferranti in England. (Fig. 9)

Ferranti has built a G-Line mounted along the railroad track, which produces a surface wave field that envelops the train. When the train passes, the field is disturbed and the position of the train will be indicated at a distant station as a pip on a cathode ray tube.

Similarly, any obstacle ahead of the train can be indicated in the central station, as well as on the train itself. Naturally, this signal could not only be used for observation, but also to control speed, brakes, etc. to automatize the train. The same G-Line along the railroad track could also carry, because of its bandwidth, a great deal of other information, such as freight data, voice, tec.

Such a system is now under study by ourselves, our Belgian licensee, ELECTROBEL, and the British Railways Board for a 200 mile data transmission system, connecting Manchester and Glasgow, to carry 760 data channels. It is intended to be installed simultaneously with the electrification and speeding up of a vital portion of the British Railways System.

Similar radar-type G-Line installations have been used as security fences to observe from a remote position the entry of persons or objects into sensitive areas surrounded by such G-Line fence.

POWER DISTRIBUTION CONTROL

The ELECTROBEL study. The specific needs of power distribution systems. Rapid increase of consumption and equipment requires increase of controls, channels, and bandwidth of transmission medium, especially in highly industrialized areas in Belgium. Difficulty of planning ahead and obtaining government channels for expansion. The G-Line a flexible private transmission medium, fitting into operation of power distribution system operation.

A development of equal significance is taking place in the field of communications along electric power lines. As mentioned before, this is an industry which traditionally had a certain autonomy in communications.

Until now, these communications and signals were carried as high frequency currents superimposed on the high voltage lines. Here again with the increasing size and complexity of the power networks, and especially in the highly industrialized areas of Western Europe, the need arose to increase the number of channels: The various power stations of a network had to be inter-connected and controlled in such a way that any such station was in operation only when it would produce power at the cheapest price, compared to other stations of the network.

These operations, ever growing in number and in complexity, with increasing power demand, led to a progressive automatization and to the use of computers. This required an increase of the bandwidth of the communication medium and also an increased purity of signal which could not be found in the relatively low frequency range of the carrier currents superimposed on the high tension wires.

The power companies were forced to seek other transmission media, and many of them started to use Microwave by Air.

As with the railroads, this was a policy not easily accepted, because it forced the power companies to abandon their autonomy in communication over their own ground. They had to apply to governmental authorities for public channels, buy new land for construction of antenna towers, incur further expenses to connect these towers to their high tension lines, etc., and what is more important, it also restricted their freedom and facility of expansion.

In CATV, also, once you have acquired a Microwave system for say seven TV channels, the bandwidth is fixed. If, years later, you need additional channels, you will have to apply and pay again, unless you had foreseen and built for such an expansion, and provided the government had given you sufficient bandwidth.

This, of course, is as difficult to foresee as it is to obtain. The expansion capability given by the G-Line is within your control.

The G-Line, running on the power company's own masts, gives it all the expansion it may ever want.

THE ELECTROBEL G-LINE

UHF G-Line, replacing UHF Microwave Relay. The same terminal equipment is connected by a G-Line, mounted on power masts. Surface wave transmission line adapted to stress and grounding regulations of high voltage line.

Such a power G-Line has been built by ELECTROBEL in Belgium.

The ELECTROBEL G-Line replaces an existing Microwave by Air system. The old Microwave Relay system consisted of a transmitter-receiver unit, at the station of Gouy operated at 450 to 460 mc, feeding an antenna located on top of the station.

A similar transmitter-receiver unit, located 8 miles away, fed another antenna located on a mast on Monceau.

Now, the two antennas have been disconnected and the transmitter-receiver units directly connected through a G-Line mounted on the masts of a 70 kv high tension line, connecting Gouy and Monceau (Fig. 10)

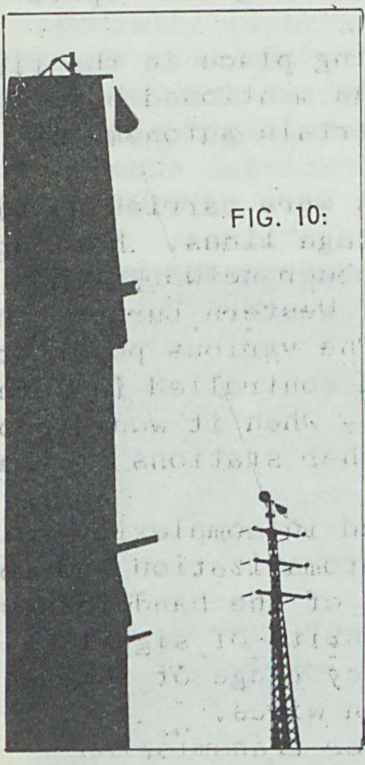

FIG. 10:

G-Line, Bi-Directional for Power Line ELECTRI BEL Brussels Terminal at Gouy

SPECIFIC DESIGN OF ELECTROBEL INSTALLATION

The G-Line, as a multi-conductor cable, with horns of extremely low loss, low-standing wave ratio, low overall loss safety against current increase. Mechanical requirements imposed by high power line regulations. Installation by power line crews; signals found not different from Microwave Relaying. No intermodulation; no additional noise. 8 db/mile at 450 mc.

This terminal equipment has a capacity of 24 channels of which, at present, 6 channels are utilized to transmit the following information: 1 telephone channel -- 6 telemeasuring channels -- 24 telecounter channels -- 3 telesignaling groups -- 2 teleprotection channels -- 2 transmissions of production data.

The cable utilized in this system consists of a galvanized steel core, imposed by the Belgian regulations for ground wire, covered by an insulation layer, which in turn is surrounded by a copper foil, forming the surface conductor proper. Then follows an uncolored plastic layer, coated by a black protection sheath, leading to an outer diameter of .64".

The attenuation expected was of the order of 8 db/mile at 450 to 460 mc.

Power line regulations imposed upon the installation of this cable certain stringent conditions which were mechanical as well as electrical.

Tensile strength had to be adjusted to hops of 800 to 1200 ft. length. The cable running parallel and rather close to the power conductors, is continuously subjected to the induction of very high voltages.

In order to protect the terminal equipment, these induced voltages must be led to the ground. It is necessary; therefore, to connect the surface wave conductor to a ground galvanically. Moreover, there must be assured around the surface wave conductor a free space of about one wavelength diameter. Since it was difficult to comply with this condition on the existing masts and in view of the necessity of grounding the induced charges, you will notice (Fig. 11) that on the top of each mast the G-Line is not supported by nylon V-shaped suspensions, but coming out of a horn on one side of a tower and connected by a coaxial cable to another horn on the other side of the tower.

In this assembly, the horn proper transforms the surface wave into a wave which can be normally

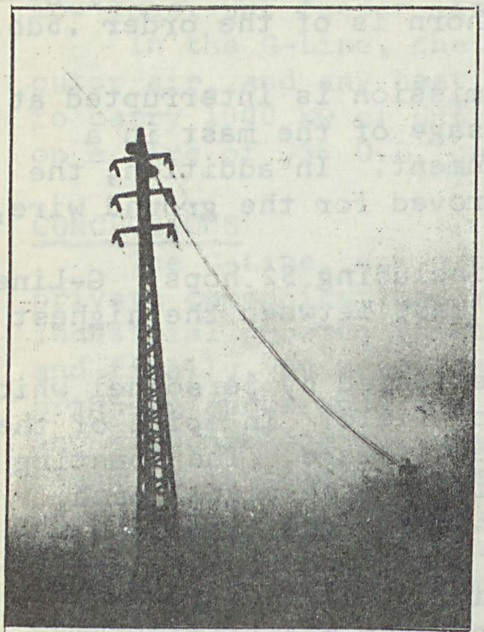

FIG. 11: G-Line on Power Masts: Gouy-Monceau

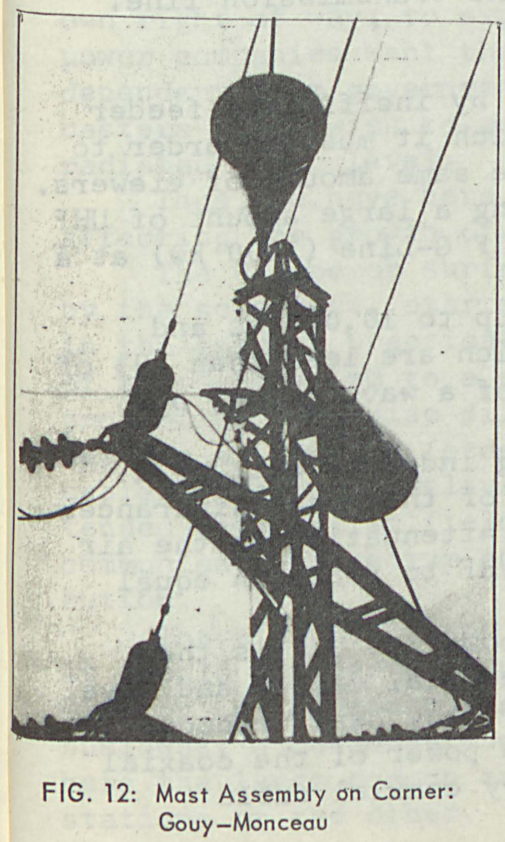

FIG. 12: Mast Assembly on Corner: Gouy-Monceau

propagated in a coaxial cable. The horn is connected to a transducer which adapts the impedance of the G-Line (about 230 ohms) to the impedance of the coaxial cable (50 ohms) and also assures the necessary galvanic ground connection. The attenuation per horn is of the order .5db. It can be reduced to .15 db per horn.

Due to this arrangement, the G-Line transmission is interrupted at each mast by a coaxial cable which permits passage of the mast in a manner not subjected to restrictions of environment. In addition, the cable can be fixed in a manner, officially approved for the ground wire, of high voltage power lines.

The Power G-Line has a length of 8 miles including 52 hops. G-Line cable and horns are attached to the top of the mast between the highest power conductors and the ground wire.

The installation of the power G-Line was effected by personnel which were in no way specialized in the high frequency field. In spite of the great number of connections, defects were extremely rare. The mounting personnel itself was able to check the continuity of the signal path.

After the terminal equipment had been connected, the line loss was measured (Fig. 12). A satisfactory regularity was found as a function of the distance; i.e., a good homogenity in quality of installation. In operation, until now, neither distortion nor inter-modulation was noticeable. It is planned to leave the G-Line in permanent service and add a bi-directional amplifier at the midpoint of the line, to demonstrate the possibility of extending the G-Line with the aid of conventional repeaters, to any desired distance.

Eventually, the G-Line will be raised in place of the ground wire, which is on the top of the high tension lines. There it will serve two functions: as a ground wire, and as a broad-band transmission line.

OTHER DEVELOPMENTS

TV broadcasting, at UHF frequency hampered by inefficient feeder lines, also incapable of carrying high power which it must in order to compete with existing VHF stations and reach the same amount of viewers. The G-Line, with surface wave capable of carrying a large amount of UHF power, without being overheated. A mega watt UHF G-Line (1000 kw) at a loss of .5 db/100 ft.

Further applications are in antenna lines up to 10,000 mc and which provide antenna transmission at losses which are less than 50% of that of a coaxial cable and comparable to that of a wave guide, but costing much less.

Of particular interest for the broadcasting industry will be a UHF antenna line of extremely large power. One of the great hindrances of UHF is the fact that UHF is subject to great attenuation in the air and, therefore, needs more radiated power than VHF to reach an equal number of viewers.

One of the main factors limiting radiated power at UHF is the antenna feeder line. At UHF even the heaviest coaxial cables and wave guides have excessive losses. In Coax, moreover, the heat produced by the power cannot be dissipated. This limits the power of the coaxial cable. In addition, cost of installing the heavy coaxial cable and wave guide structures are prohibitive.

With the G-Line, we expect to produce, at reasonable cost and low loss, UHF feeder lines, carrying from 100 to 1000 kw.

In the G-Line, the surface wave carries the energy through the outer air, and any heat produced is readily carried off. We expect to carry 1000 kw of UHF power at a loss of less than .5 db/100 ft., on a wire of .36 O.D. only.

CONCLUSIONS

The G-Line, now a practical tool for industries, requiring a private communications medium. The scientists directly affected industrial growth, first by mere speculation, then by experiment and finally, by practice. Practical application hampered by unorthodox appearance and lack of proof of reliability, inherent in any new development. G-Line should overcome prejudice, first because it is sometimes irreplaceable, has been demonsrated and is now being used as a permanent communication medium in the power industry. Why not in CATV to which it is well adapted as a wiring technique, independent from government handout, as well as old established communication carriers. In the power field fitting to its application, the simple wire wave guide has become a sophisticated multiconductor cable.

Summarizing, we see surface waves developing from an abstract concept into a practical tool capable of serving a number of industries, like CATV, which need low cost to reach into wide and low density areas.

Other industries like the railroads need better use of their own right of way, to expand speed and freight requirements: The power companies want the surface wave for communications, also independent from government, and finally, there are the UHF TV broadcasters which wish to compete with the VHF stations on the same radiated power level.

Thus, we have here the living proof of the scientist directly affecting the growth of an entire series of industries.

The G-Line or surface wave transmission line, as it is called by the scientist, started as a purely mathematical conception, and in the ensuing practical applications, the unorthodox appearance of the G-Line led to a slow, albeit progressing, recognition of properties otherwise difficult to believe. First, the line was used as an antenna feeder line, temporarily replacing coaxial cables, Microwave Relays and other media. Gradually, its use extended to specific fields, and now it is about to become a general communications medium for entire industries such as power distribution.

There is no reason why the G-Line should not go further, why it should not serve young industries like CATV which have so much difficulty to retain their rightful place in the communications business, a business dominated to a great extent by its senior members the large common carriers on one side and the broadcasting stations on the other. Is it not logical that the newcomer should turn to new techniques so well adapted to his operations and that the G-Line should become for long distance what coaxial cable is for short distance wiring: a permanent instrument in CATV installations? This tool, in spite of its unorthodox suspension methods, is much closer to the wiring techniques of CATV than microwave towers.

The new technique could give Community and Pay Television relative independence not only from the FCC, but also from the old communication carriers in possession of established rights.

It has become a transmission medium in its own right, usually superior and frequently irreplaceable. It has also become more sophisticated.

The development of the G-Line parallels the development of modern solid-state technique. This also started around 1950 with the introduction of germanium diodes used at the outset only as detectors, but gradually penetrating the entire amplifier technique in the form of multi-electrode transistors.

What was once a single wire G-Line has now become a multi-conductor cable, adding to the surface wave, the conduction of high tension currents, the grounding for safety, and the capability of coupling in transit.

It can combine the functions of several components into a single unit having all these functions.

This is progress.

MR. TAYLOR: Thank you very much, Dr. Hafner, for a very interesting talk on a very interesting subject, which I have had some opportunity to fool with myself, as you said. I think that we had best move along. We started a half hour late because of the very remarkable performance we had at noontime and we have two very interesting and important papers to hear this afternoon.

Mr. Rudy Riley, President of Systems Engineering, Inc. is sponsored in this paper by Phelps-Dodge Electronics Products Company and he is speaking on "Just Twelve Inches Away". Mr. Riley.

MR. RUDY RILEY (President, Systems Engineering Inc.): A casual glance at a well-constructed CATV plant reveals the striking similarity to its neighbor, just 12 inches away. Since the beginning of our industry, telephone research, techniques and equipment have contributed immeasurably to the success of CATV.

Historically, the basic problems experienced by the telephone companies have proved to be common to all cabled communication networks.

This paper will discuss the two factors that effect the economics of a cable system most: Cable and its maintainence.

<u>Cable</u>

The advent of color television and all band transmission has created a demand for CATV cable with minimum frequency and delay distortion.* An air-insulated rigid coaxial cable meets these requirements. In this cable the center conductor is supported with a minimum number of carefully spaced, low-loss insulators. However, this type of construction is not practical for use in strand supported CATV systems.