MR. W. K. HEADLEY: The next subject to be treated here certainly well fits into the format of this session, "Looking Ahead". It is the subject of transistorized microwave for CATV. Delivering a discourse on this subject is Mr. Paul Hertel, Assistant Director of Engineering at Collins Radio Company.

MR. PAUL HERTEL: Two years ago I appeared before this group with comments about new devices and some new areas in which we were working at the time and attempted to make a guess as to what microwave equipment CATV people would be using a few years in the future. In looking back a few years and an equal number of "megabucks" of investment in engineering, I feel a little bit embarrassed, somewhat surprised, and I guess a little impressed at how slow new devices develop. However, over the years I think we have made substantial progress both in the area of performance and in the area of reliability. We are now manufacturing microwave equipment with a range of power outputs from 50 milliwatts through 10 kilowatts and frequencies from 4,000 megacycles through 13,000 megacycles. I might add that there is much more interest in the CATV market in the 50 milliwatt equipment than there is in the 10 kilowatt equipment. The 10 kilowatt microwave equipment, of course, is for tropospheric scatter systems. We have at our disposal today components which do allow us a wide range and type of operation, and by integrating these into numerous product lines, we are able to invest considerably more money in our development effort than one product line along would justify.

I would like to go through a rapid sequence of slides since we do not have a great deal of time. Our main effort in the past four or five years has been toward improvement of performance and reliability primarily by solid state design. Our first effort in transistorization was of the power systems. We have believed from the beginning of our efforts that the power supply reliability of a microwave system was predominant in determining the overall system reliability. Our first microwave systems offered battery powering as an option. This was accomplished with rotary machinery which was not veryattractive to us or to the user. As soon as the power transistor came along we applied the transistor approach to the powering system first. Our development effort in microwave transistorization was toward a series of improvements in specific areas rather than attempting in one big step to design a whole new product. This allowed us to do some of these things much faster than would have been possible if we had waited until, for example, we had transistors good enough to build wide band i-f amplifiers. The economical power transistors arrived in the market considerably earlier than the wide band type transistor which allowed us to design transistor i-f amplifiers. As I said previously, most of the equipment we are now delivering is transistorized with the exception of the r-f generation. We are doing considerable work in the solid state r-f generation area, but we feel it may be many years before we approach the performance of the klystron and TWT systems we are now manufacturing. We now have a number of five-watt TWT systems in operation. The first one was installed some 2 1/2 years ago in Venezuela. This system contains five-watt transmitters at each end of a two-way communication link. This link spans 175 miles between two mountain peaks. I have just received the record of propagation performance over a one-year period of time in which the reliability was 99.9927%. This performance over such an unusually long path was made possible by high power and by the use of both frequency and space diversity.

My first slide illustrates the direction taken to improve the power supplies. In this system 24 VDC battery voltage is converted to high voltage. This particular power supply operates a one-watt klystron and produces 750 volts and 1,200 volts DC. The technique used is to coarse regulate the input from a 24 volt system at 20 volts DC which operates most of the transistorized equipment including the klystron power supply. In some cases it is necessary to have considerably higher voltage, because of the voltage swing needed from some amplifier. In this case a converter is used for 130 volts or 60 volts. To operate from 48 volts we use the same basic system but substitute a regulating 48 to 24 volt converter for the coarse regulator. For 115 volts the same basic equipment is used, but the 20 VDC is supplied from a saturating transformer regulated power supply operating from 115 volts.

Next slide. The TWT system is slightly different in that we have somewhat higher power requirements. The TWT operates at about 2,000 volts on the collector and 3,000 or so on the helix and about 1500 volts on the anode. The helix and anode supplies are low current supplies and employ separate blocking oscillator type power supplies. The high current supply operates from an inverter, supplying 135 volts AC 500 cycles.

Next slide. In designing a transistorized product the object was to be as universal as possible in order to meet as many needs as possible and we came up with a packaging scheme we call our "Universal Microwave Group" in which we use many of the same components for system powers of 1/10 watt, 1 watt and 5 watts. The purpose of this slide is to attempt to show in a pictorial fashion the common use of equipment between systems. If amplifiers for example are used not only for video products, but also for 960 channel communication systems.

Next slide. In addition to improving reliability by solid state design, we also had to improve performance particularly for the message systems, and we have increased voice channel capacities to 600 and 960 channels. We have given a lot of effort to thermal design; for example, the low power klystrons employ a thermal control device which sometimes is called the "beer can" which controls the klystron temperature by its own heat. Hence, it does not require any additional power. More recently a thermal chamber has been designed for the one-watt klystron which employs vapor cycle cooling. This particularly has been helpful in stabilizing the differential gain on video systems and the intermodulation distortion on the message systems.

Next slide. This is a simplified diagram of the receiver. We have been using eight-cell preselectors for a number of years to allow quite high density arrangements without interference between systems. The i-f amplifier is broken into four parts - preamplifier followed by a filter equalizer section, i-f amplifier and limiter discriminator.

Next slide. This is the five-watt transmitter which we drive with either 1/10 watt or 1 watt klystrons, depending on linearity requirements and drive. The TWT itself needs very little drive since it has a 35 to 40 db gain so a few milliwatts is quite adequate. Another device which has been added to this system to improve linearity has been the linearizer and this, of course, has been put in for improved intermodulation performance on message systems and better differential gain on TV systems.

Next slide. This is a picture of the TWT. We believe, like the designer of Telstar, that the TWT is going to be around for a while to come. We have picked this device because of its power capabilities, its high gain, and its efficiency. Where we need powers in excess of one watt, we feel that the TWT will be the tube we will have to use for quite some time. There are problems in the solid state devices which do become limiting at these power levels.

Next slide. This is the i-f amplifier, which consumed a good portion of our development effort. We have been helped in this task by the rapid improvement in technology and transistor manufacture. The IF contains considerable control in the bandpass and envelope delay characteristics which effect the differential gain and phase of TV systems and we have done a considerably better job even than we were able to do with similar tube systems. It certainly is a much less costly thing from the operation standpoint, compared to the 25 mc vacuum tube equivalent. Tube receivers with similar performance typically had 20 to 25 vacuum tubes of the frame grid type.

Next slide. This is a picture of the transistor preamplifier with a 3 db maximum noise figure. It is an example of the rapid change in the transistor technology. When we started the project we thought we might have to use nuvistors for the front end to meet our noise figure objective since the transistors available at that time could at best provide about 6 db noise figure. By the time we had finished the main i-f amplifier design portion, the transistors had developed to the point where we were able to obtain slightly better noise figures than were possible with our previous vacuum tube preamplifier.

In closing, I would like to say that I think considerable advancement has been made in the past two or three years. I think a lot will be accomplished in the future. We are now limited in power output only by our capabilities to pay the money and by FCC's limitations on licensing so power output is no longer a microwave systems design problem. Battery power and low power consumption microwave systems are expected to become increasingly more common in CATV's systems in the future, particularly as transistor designs become available for the head end equipment. (Applause)

MR. W. K. HEADLEY: Following along the growing trends of today and looking ahead to the requirements you will have to meet and the opportunities you will want to realize in the future, comes the subject of long line RF cable transmission. Here to deliver a paper on that subject is Mr. Dick Cullinane, TV Systems Engineer at Spencer-Kennedy Laboratories.

MR. RICHARD X. CULLINANE: Thank you very much Mr. Headley. I think we'd better start first of all with what our concept is of "long" in speaking of a long line cable transmission. The word "long" - like many other descriptive adjectives - denotes a condition or characteristic which is entirely relative in nature. Therefore, for the purposes of this discussion, we must seek a definition of what we mean when we speak of long line RF cable transmission.

Notwithstanding the advance through the years of developments in RF transmission equipment, coaxial cables and in the techniques of their application together in systems, it has heretofore been difficult to achieve and maintain acceptable signal quality in lines with amplifiers cascaded over 18 miles or so. Even in these cases, accumulative noise and distortion buildup at the end of the lines has been such that the installations have necessarily served a point-to-point function, without sufficient signal quality at the terminating end to feed a further distribution network satisfactorily. Probably the longest RF lines in operation today are in South Carolina, where Southern Bell Telephone Company has installed runs of nearly 30 miles in straight cascade, using SKL low band trunk line amplifiers. However, these lines (which are used to interconnect public schools for purposes of closed circuit instructional television on a point-to-point basis) carry only two or three channels, with no demands placed upon them for feeding a distribution network after the end of their runs.

It is therefore proper, I think to set the definition of long line RF cable transmission as a line of 15 miles or more in length. But we must demand of this line a capacity for carrying up to 8 television channels simultaneously and with a signal quality at the terminal end of an order to serve a wide band distribution network of more than 100 system miles throughout with pictures meeting entirely acceptable quality. Quite naturally, as the length of the long line is extended, its output into a distribution network will be such that limitations must be set on the length of such network. But even with a long line of 80 miles, for instance, carrying four channels simultaneously, we would demand from it a quality to serve from its output a wide band distribution system of 50 network miles.

How can such standards as these be achieved? Current practice in transmission line design is to set a minimum tolerable specification at the terminal end of the system, then to improve this minimum by an arbitrary safety factor - say 3 db. Using the more conservative resulting specification, the system designer would then go to curve charts and determine the maximum allowable gain of the repeater amplifier then available to him, consistent with factors of economy to meet system requirements. He would of course be further guided by factors of noise and cross-modulation inherent in his amplifier and their effect on system characteristics. He would know that these factors have been treated theoretically by asymptotically converging curves of noise and cross-modulation versus number of amplifiers in cascade. But he would also be aware that even theoretical cascaded limits have not been attainable. For one thing, the theoretical assumption is that both transmission equipment and coaxial cable are perfectly matched, both in characteristic impedance and in gain-loss relationship. In practice these conditions simply are not so, and a downward system design compromise must be made. Further, as the number of repeater amplifiers in cascade is increased, theory dictates a higher input and a lower output level for each repeater. Again, from a practical standpoint, what results is an uneconomically and unrealistically high number of relatively lower and lower gain amplifiers in cascade as the length of the trunk line is increased. These problems have combined in the past to limit severely the lengths of RF lines.

Again, how then can such greatly increased line lengths and performance standards as we previously described be achieved? The answer, of course, lies in the availability of a repeater amplifier so far superior to those which have been previously used that it can actually add a new dimension to RF transmission - the dimension of length - lengths of 20, 40, 50, 90, 100 miles and more. Its operating gain must be high enough to be economical - let us say 28 db - and its bandwidth broad enough to accommodate up to 8 channels. Its noise figure must be low - around 7 db. Its multi-channel output level must be reasonably high, again for reasons of economy. We will set the output level requirement at 40 db above a millivolt. And yet its distortion characteristics must be remarkable at this + 40 dbmv level - specifically we will ask that cross-modulation be down 100 db and second order beats down70 db. Then and only then can these line lengths, which have seemed way beyond practical consideration to us in the past, be used with assurance in various system design applications. We are happy to report that we have developed such an amplifier at our company, and feel confident that it will make a great number of useful contributions to the CATV industry where maximum cascaded lengths of point-to-point lines are desired with minimum distortion characteristics at their terminating outputs.

With our sights now reset, what practical uses do we find for greatly extended coaxial cable lines? We hasten to say that the long line amplifier does not appear on the scene as a direct replacement for microwave. It is obvious that microwave - widely used to serve CATV systems - is the logical technique for many extended signal delivery requirements. But there are many more situations where the use of microwave may prove impractical or uneconomical as against a coaxial line. And I am sure we are all aware of other situations where microwave is simply unobtainable by FCC permit.

Let us conceive of a city of 70,000 population, with two local TV stations and located 115 miles away from a major city having five TV stations, including an educational outlet and an independent station with highly desirable programming. Between the major city and our city of 70,000 people, and fifteen miles from the latter, lies another community of 20,000 population. A tall tower is erected 85 miles from the major city and a complete head end receiving station is installed at this location. The five major city stations are picked up and carried 15 miles via long line to the 20,000 population community, where a side trunk is derived to feed this town, using regular CATV distribution and associated system components. The long line continues on to transmit the five signals the additional 15 miles to the city of 70,000 which again is served by a standard distribution network. One head end serves both communities, and the two local stations are picked up at very little expense and put into the input of each distribution system. Because of the distance involved to the major city, the only alternative method of bringing its signals in would be via microwave. But, first, what do you feel would be the prospect of securing an FCC microwave permit in a case like this to serve areas with two local television stations already operating in them? And second, over a five-year amortization period, the cost of installing and maintaining the 30 mile long line would be less than a five-channel microwave service at typical common carrier tariff rates. Third, at no increase in cost, other than signal receiving or originating equipment at the head end, as many as three more signals could be added to the long line as the occasion might call for them and transmitted to the two communities.

As a second example of long line application, we will set up the hypothesis of two cities lying 20 miles apart, each with about 15,000 population. Along the highway between them lie two small communities, each with a population of approximately 2,000. The most distant signals desired for distribution originate from a city 80 airline miles to the north of the two 15,000 population towns and located more or less at the top point of an isosceles triangle encompassing the three communities. The problem here is how to reach the primary market of 30,000 people without a big cost in duplicated tall-tower antenna sites, and at the same time to pick up the market of 4,000 people in the two small interlying towns, which normally would be much too marginal even to consider service to them. A centrally located antenna site is the obvious answer, but with regular CATV trunk line amplifiers, the runs from the tower of ten miles each way to the larger communities, and wide band distribution systems involving perhaps another 8 or 9 miles each of trunk amplifiers in cascade, would cause signal levels to deteriorate to intolerably low quality toward the ends of the lines. Multi-channel microwave from the central tower to the small towns, then on to the communities of 15,000 population, would be absolutely inconceivable in cost for this application. But by long line cable, with the kind of transmission capabilities we have described, the entire market of 34,000 people is reached with real economy from one head end location.

Incidentally, in regard to economy, it is important to remember that by the very nature of its point-to-point function over long distances, the long line in most cases will be running along the highway in rural areas, where direct burial of the cable is naturally indicated. With present ploughing techniques and spacing of the long line amplifiers nearly a mile apart, the installed long line cost per mile will be substantially less than the average cost per strand mile of a wide band distribution system.

I think it would be appropriate at this point also to make reference to another development which bears upon our discussion of RF transmission over long distances. The development as interesting as its possibilities may be, is not new, either as a concept or as an accomplished fact. Unlike open wire, with which most of you are probably familar, the mode of aerial transmission known as G-line, is not subject to climatic conditions, and its use therefore may be indicated under certain circumstances. However to reach a practical status in the art of long line transmission, greater flexibility in its application must be achieved.

Even though we are talking of long lines of 100 miles or more as fully feasible technically, present day applications will more often center around problems of extending 6, 7 or 8 signals perhaps 8, 12 or 18 miles. It is here that the long line technique has its most numerous possibilities currently. In this latter area I am sure many of you can think from your own experience of situations where profitable opportunities could be realized by extending runs substantially without having to make a self-defeating sacrifice in the quality of signals resulting thereafter for distribution. That suburb a few miles beyond the end of your present trunk, that little town 8 miles out from your community where 96% of the residents have been clamoring for service for years, perhaps that military base 16 1/2 miles each of your tower, for which you could get the contract to wire all 3200 dwelling units, but which has seemed as unreachable as the sun because of its distance and its large distribution area after that .. all of these opportunities can now be turned to money-making actualities with long line cable extensions carrying many channels many miles with such an extremely low build-up of noise and distortion that the quality of signals at the input and the output of the long line seem nearly identical.

As we have said, many of today's long line applications, under our new reference standards of length, are for situations involving relatively short "long runs". But let's take the theme of this panel this morning and see what might be on the horizon when we are "Looking Ahead". Chairman Henry of the Federal Communications Commission recently reminded an audience that "America is being wired for sight and sound". America is a very large country, ladies and gentlemen, and it is studded with thousands of sizeable communities. As television is itself extended as a many-faceted medium, its transmission will surely be extended in degree and to points which we can barely anticipate today. And just as surely, the unique advantages of multi-channel closed circuit cable transmission will be recognized and exploited to carry video and audio information at RF frequencies over greater and greater distances.

A number of you, after the close of this convention, will be visiting the World' Fair in New York, where you will be fascinated by exhibits which project your attention into the future of our world, our scientific achievements and our human society. If I may be permitted onesmall personal commercial reference, I would like to refer to our company's exhibit at this "World"s CATV Fair" here in Philadelphia. A 16-foot mural in our display depicts a long RF coaxial cable transmission line carrying the signals from New York, the World's Fair City to our hotel here in Philadelphia, our convention city. We had this mural made up in the spirit of good fun and of a colorful demonstration taking some artistic license. While the close circuiting of World's Fair events to the Bellevue-Stratford Hotel by this means would undoubtedly fall into the category of a simple tour de force with questionable practicality, the point I want to emphasize seriously is that this feat can be accomplished - now - with new transmission achievements that are available to you all and which may in the very near future open great new areas of opportunity, and profit to each of you.

Thank you very much. (Applause)

MR. W. K. HEADLEY: Since the session opened you may not believe it, but you have heard six speakers and are about to hear the seventh. So I think it's fitting now, remaining more or less in your places, to take a short seventh inning stretch. (Pause) We have talked about the growing need for longer and longer point-to-point transmission. Another facet, of course, which many of you are facing today is the requirement of the larger and larger distribution system. The next discourse you will hear on that subject is entitled, "Problems of Signal Distribution in Large Communities". Here to cover that subject for you in Heinz E. Blum, Vice President in charge of Engineering at Entron, Incorporated.

MR. HEINZ E. BLUM: Gentlemen, the excellent presentation of my co-panelists might have given you the impression that certain manufacturers have specialized in the work of individual system components. However from the association with my friends in the associate membership group I know that all of us have experience