As the SCTE celebrates its 75+1 year, we present this article on 'System Architecture' published in Vol. 15 no. 8 (Spring 1993) of Cable Television Engineering (CTE) magazine. Rien Baan is now Vice President of the SCTE Executive Committee and sits on various committees within the SCTE

New criteria for advanced CATV and data networks

by ING. RIEN BAAN

Based upon various user-defined controlling systems, a detailed prescription of new technologies applying to CATV and Local Area Networks (LAN's) is given. The more services being offered through coaxial networks, the more special requirements will be asked for by the end users. Security services and high speed DATA links via coaxial networks will demand special equipment and possibilities to ensure continuous operation.

The article covers several items such as advanced Status Monitoring, Failsafe Bypass with Redundancy amplifier, different frequency splits in amplifiers combined with Feedforward technology.

Coaxial Networks, offering multiple services

Wide band coaxial networks offer a variety of services to the end users. Historically these applications were mainly used for entertainment Cable TV services. Based upon common frequencies used in this field, a specific band plan was introduced. The industry produced equipment according to this frequency plan, known as the "sub-split", allowing the operators to distribute TV programs at frequencies suitable for the TV receivers.

When the need of distributing entertainment TV channels increased, the frequency range was extended at the higher end and right now there is equipment available up to 550MHz. At the lower end of the frequency range a limited area has been reserved for so called "up-stream" information. This can either be one or two video services with a 5MHz bandwidth or narrow band DATA information. Since the total available bandwidth is 5-25MHz there is only a limited amount of "up-stream" information possible in this sub-split configuration.

Today there is a need of additional services to be relayed by the coaxial network. Today's technology is making it possible to invest in suitable equipment. For the operators it brings additional revenues.

Looking to the present ratio of Video/Audio transmission and other services, the following table can be made:

	Video/Audio		Other services
95%	Broadcast and local TV and FM programs	5%	Up-stream video
	Videotext information		Data communication: —controlling network —security network
	Pay-TV services		—security combined with video (camera control system) —data transmission for computers —telemetry

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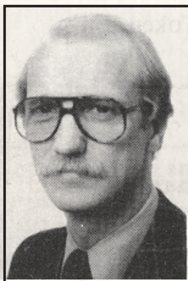

Rien Baan graduated in communication techniques from Higher Technical College in Dordrecht in 1972, and joined Oak Holland, a subsidiary of Oak Industries in the United States. As application engineer he was concerned with the development and production of set-top converters. He then moved to DeltaKabel, marketing CATV systems throughout the Netherlands, and after being involved in the development and sales of antenna equipment and satellite receiving stations he joined C-COR Europe BV towards the end of 1983. As a marketing manager he has direct contact with all European C-COR distributors, and assists them with engineering support demonstrations, seminars and lectures.

Recently the ratio tends to change in favour of other services which are going to be used in greater extent than before. This has led to a complete new demand of network frequency planning.

Various frequency splits

Besides the conventional entertainment sub-split with the different upper margins, new standards have been introduced providing a more symmetrical bandwidth capability in the forward and reverse direction (see Fig. 1).

SUB-SPLIT	5 __ 25	47 __	300--------	550
MID-SPLIT	5 ______ 108	156 ______	300-----	450
HIGH-SPLIT	5 ______ 186	222 ______		450

Fig. 1. Common frequency splits in broadband cable nets.

Sub-Split

Networks with this split are mainly used for entertainment video and audio. Occasionally the 5-25MHz band is used for data telemetry signals or a single video channel.

Mid-Split

These networks are used for DATA transmission combined with video signals. These services can be:

VIDEO;
- — Entertainment
- — Educational or Locally orginated programs
- — Teleconference
- — Surveillance

VOICE;
- — Point to point
- — Broadcast
- — Telephone
- — Trunk (T—1)

DATA;
- — Point to point, 300 to 19.2kB
- — High speed, 9.6, 56kB, 1.54MB
- — Networking, LAN, CSMA/CD, Token Ring

TELEMETRY;
- — Facility management
- — Status monitor
- — Municipal controls
- — Home services, meter reading, security

High-Split

Basically these networks handle the same services as the Mid-Split network but the amount of services going up-stream may require an almost equal frequency range in both splits. The High-Split is offering this.

Dual Cable

These networks are using the Sub-Split frequency plan per cable, offering a 5-450MHz bandpass in both directions. The system can be built either with complete separate cables or with one cable, looped at the end of the trunk line.

Each network concept has its own typical application and is selected by the amount and type of DATA traffic in both directions, the amount of video channels and the required security for the network.

Available equipment

Handling additional services and DATA channels results in increased amplifier loading. To maintain or even give improved signal quality, Feedforward techniques must be used. When, at the same time, higher security levels for the networks are required, a state-of-the-art Status Monitoring System brings the solution.

In order to keep, under all circumstances, a connection between each trunk amplifier, a Failsafe Bypass system must be used. With a connection cable fitted in a standard housing it is not necessary to make extra connections. The amplifier can be by-passed by means of high quality relays which will activate the By-pass system in case of power failure or amplifier exchange.

When using two cables that can be interconnected via A/B Switches, a double security is obtained. The A/B switch is activated either automatically in case of signal loss in one of the cables or it is controlled by the Status Monitoring System.

Summarizing these items the following options are available:

Status Monitoring	*Failsafe Bypass*	*Two Cable System*
failure prevention system controlling	additional safety when using single cable	offering double security A/B switch

Each system may be used individually depending upon network requirements. Control and operation are such that when applicable they can be used in combination.

Each option will be discussed in detail in the next paragraph.

Status Monitoring System

The general purpose of such a system is to check continuously the critical characteristics of the amplifiers in order to prevent total failure. To scan all amplifiers on a regular base a computer controlled test program should be used. When a parameter deviates from a certain value within a given margin an "ok" signal must be given. An "error" signal will be generated when the deviation becomes too wide. When immediate action is required an "alarm" signal appears.

The computer terminal is situated in the service centre and the operator can direct a service crew to the specific amplifier station. Fig. 2 gives a block diagram of the system.

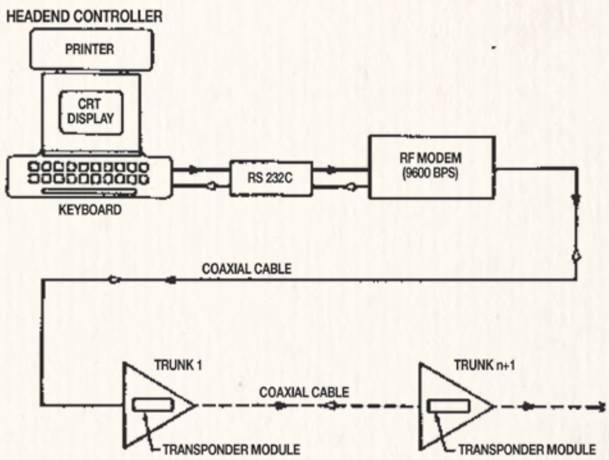

Fig. 2. Status Monitoring System block diagram.

Monitoring selected parameters with user-defined values enables the operator to perform preventive maintenance. Total system failures can be kept to a minimum when for instance extreme temperature changes or variations in power dissipation are discovered at the earliest moment that they occur.

In order to get all the information to the head-end or service centre, each amplifier has a Status Monitoring Transponder. All measured data, including a unique address for the specific amplifier station is sent up-stream as soon as the amplifier is polled by the head-end computer.

Trunk	Data RF dBmV	ALC RF dBmV	Rw DC volts	DC(B+) volts	Temp °C	DC amps	Trunk Lid	Rev Sw	Status
1	15.0	31.0	50.8	23.8	38	1.10		Off	ALARM!
2	15.0	31.0	40.0	24.1	38	1.10		Off	
3	15.0	31.0	43.3	23.8	41	1.10		Off	
4	15.0	31.0	48.6	23.9	43	1.00		Off	
5	15.0	31.0	43.8	23.8	39	1.10	Open	Off	ALARM!
6	15.0	31.0	40.0	24.1	42	1.20		Off	
7	14.9	31.1	49.7	24.1	40	1.20		Off	
8	15.0	31.0	49.3	24.0	42	1.00		Off	FAULT
9									
10	15.0	31.0	43.6	24.0	36	1.10		Off	

Fig. 3. Computer display of measured values.

Fig. 3 shows a table displayed by the computer terminal. In this table the measured parameters are visible as well as the status of the control functions. Each minute a maximum of 1024 amplifier stations can be monitored.

Per amplifier, the following critical operational parameters must be tested:

1. Output ALC pilot level
2. Output data carrier level
3. Raw d.c. voltage into the trunk station
4. B+ voltage of trunk station power supply
5. DC current of forward and reverse sections to
6. the trunk
7. Switching Feedforward hybrids
8. Temperature inside the trunk
9. Reverse switch status
10. Trunk lid status
11. Values of data via I/O port
12. Control of the Failsafe bypassing circuits
13. Control of the bridger Reverse switch

The signals mentioned under 1-10 are measured by the transponder with a unique digital address that can be programmed in the field. It is an intelligent device that incorporates a microcomputer with analogue to digital converter, MUX, and UART. It also incorporates sensors, receiver and transmitter.

The signals mentioned at parameter 12 and 13 are control functions. The status of the reverse switch is reported back to the Status Monitoring Controller.

Fig. 4 gives a transponder block diagram.

Recognizing possible failures

While measuring the level of the pilot carriers, the output level status of the amplifier is being checked. A failure due to humidity in combination with cable damage or loose connectors gradually result in a variation of the system bandpass. Before getting a Signal to Noise Ratio that is too high in certain channels resulting in a total loss of a data channel, the operator can check the cause.

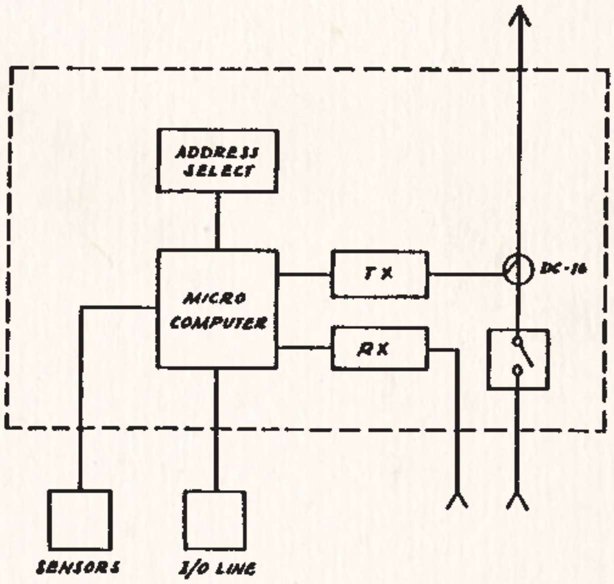

Fig. 4. Transponder module block diagram.

Measuring the Raw-DC voltage will indicate any change of the incoming AC voltage via the coaxial cable. When because of a slowly changing resistance somewhere in the network the following amplifier stations get less and less input voltage, the stations power supply will not function normally. This results in bad amplifier performance.

When the amplifier hybrids do not operate properly, a change in power consumption is often noticeable. Therefore the DC current going into the trunk station is measured. In Feedforward technology 3 hybrids are used. If one of them should fail, the amplifier will stay in operation but under decreased quality conditions. The Feedforward operation should be checked in order to determine what is wrong.

By switching off the Feedforward "error amplifier" the difference in performance can be measured. This will give the operator an indication of the Feedforward operation. An important parameter for the MTBF

(Mean Time Between Failure) is the operating temperature. When problems with cooling occur, it will result in a slowly rising amplifier temperature which is decreasing the MTBF, or can even cause total failure.

The Reverse switch is situated in the Feeder-reverse line of the Trunk amplifier and should be activated when a problem in the feeder needs to be isolated. In case of system ingress it can be located by switching on a 6dB attenuator without interrupting the signal. The 3-position switch offers: ON, 6dB loss and OFF.

When the Trunk lid has been opened for service purposes, it will be indicated to the operator in the head-end or service centre.

With the I/0 port, data such as status of Stand-By power supply, Failsafe relay control, A/B switch control and 3 other options can be entered.

The status of the Failsafe Bypass switch indicates if the By-pass circuit is activated. This status can also be changed by the operator in the head-end or service centre when applicable.

System Controller

The IBM PC computer controls the system. With it the operator can monitor the system or make changes to the system. The RS 232 output is part of the IBM computer. It enables the computer to work with the RF modem. This modem encodes the information from the computer onto a data carrier which is injected into the forward system. Standard transmitting frequencies are 116.00MHz for sub-split systems and 223.25 for Mid/High split networks. The receiver frequency is 9.75MHz. Other frequencies can be used. A two-way filter provides a means of interfacing the modem with the system. Data from the transponder is encoded on a 9.75MHz carrier that is sent through the reverse system and separated from the forward signals and sent to the modem.

Software description

The Status Monitor software provides the means of interrogating the system and measuring and presenting the data received from the transponders. The system can monitor the entire network (all trunk stations containing a transponder) or a particular trunk station. Status reports can be generated on the network as well as on any possible changes.

In addition, a test on the Feedforward gain block in a Feedforward trunk station can be initiated, with the results printed for future reference.

The software consists of a Master Menu with ten functions; some of these bring up sub menus that contain additional functions. Each function contains prompt lines at the bottom of the screen requesting information from the operator. After each prompt the function is implemented or another prompt appears requesting further information.

The system as described before, applies to CATV and DATA networks requiring high reliability. Some other systems were mentioned when describing the various functions. Although these systems operate with the Status Monitoring System they can be used individually.

Stand Alone Status Monitoring

This system provides Status Monitoring at any point in an RF distribution network and may be used with any type of amplifiers or devices.

A transponder, operating with the same system as described before, has been built in a separate housing. When located at the end of feeder lines, measurement capability is provided for: up to 7 analogue parameters, monitoring of *TTL* input lines, control of *TTL* output lines and intelligent decision-making capability.

There is an optional Interface Bus to monitor and/or control devices external to the SSM. This option requires a special customer-written software package.

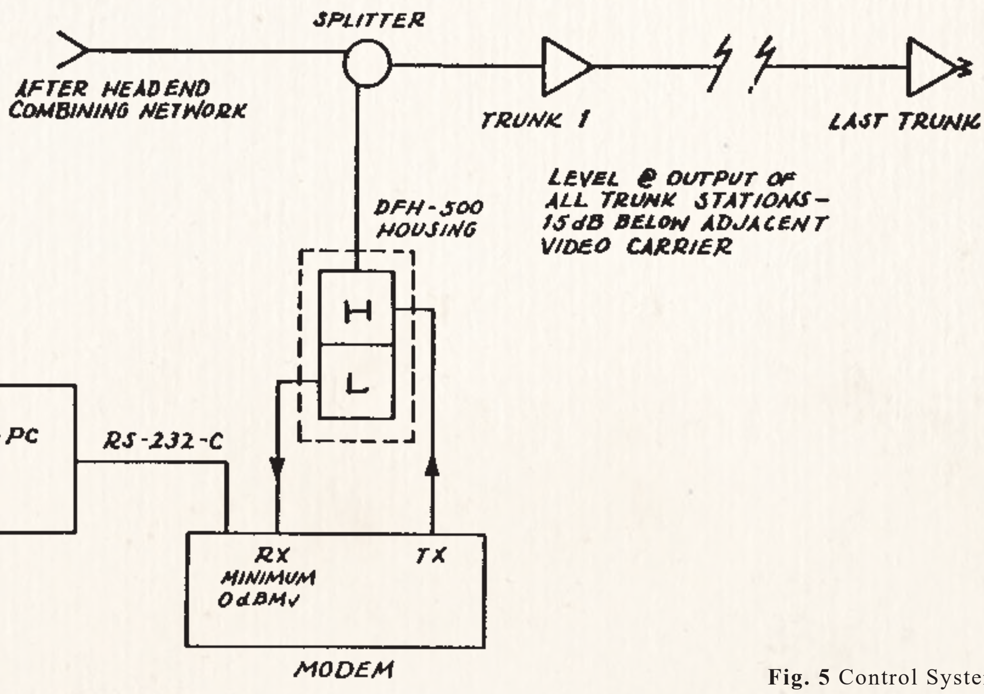

Fig. 5 Control System black

The following monitoring and control lines are available:

- 3 analogue to digital inputs, 8-bit resolution
- 2 input only lines, TTL
- 1 output only line, TTL
- 1 10 bidirectional input/output lines.

Failsafe Bypass

The Failsafe Trunk Bypass increases system reliability by providing trunk signal continuity during conditions which would otherwise produce a system outage. The system provides an alternate signal path around the trunk station's RF module for both forward and reverse trunk signals. This alternate RF-signal path will automatically bypass the RF Module during any loss of power or upon the removal or failure of a trunk forward or reverse module.

Although a portion of the system experiences lower signal levels when a trunk RF module is bypassed, each succeeding trunk station's automatic level control circuit will increase the trunk gain to return signal levels to normal. A reduced carrier-to-noise level signal is then provided to the subscriber instead of a complete system outage.

Fig. 6 shows a functional block diagram of the housing in the typical operating configuration. The components of the Failsafe Trunk housing include: the RF relays, a trunk bypass RF signal path which consists of a hard-wired coaxial cable between the input and output baseplates, a relay interface board and a Failsafe Control Module.

The Failsafe Control Module functions are taken over by the Status Monitoring Transponder module in case an SMS is used. Both modules provide an additional RF bypass mode by using current-sense circuits that activate the RF bypass if the trunk current changes from the nominal by 150mA. When used in combination with the Status Monitor System this current change can be set in the head end.

Redundancy amplifier

Redundant amplifier operation is achieved by duplicating all of the amplifier submodules.

Mounted in the standard trunk housing On the housing lid), a complete amplifier module takes over the main amplifier forward and reverse functions as well as the forward bridger function. Fig. 7 shows a functional block diagram.

Circuitry within the backup control module senses a failure of the main amplifier's forward or reverse trunk amplifier, or forward bridger amplifier, and switches to the backup amplifier. Within the backup amplifier there are only two hybrid amplifiers. Trunk and bridger functions are provided by using a directional coupler high loss path to feed the bridger output, and using the low loss path to feed the bridger output.

The Backup amplifier has a separate 60V.a.c. power supply that can be connected to a power source that does not have an a.c. fuse in series with it. Additional relays provide a passive failsafe trunk bypass around the backup amplifier, so that trunk signal continuity is provided in the event of a backup amplifier failure.

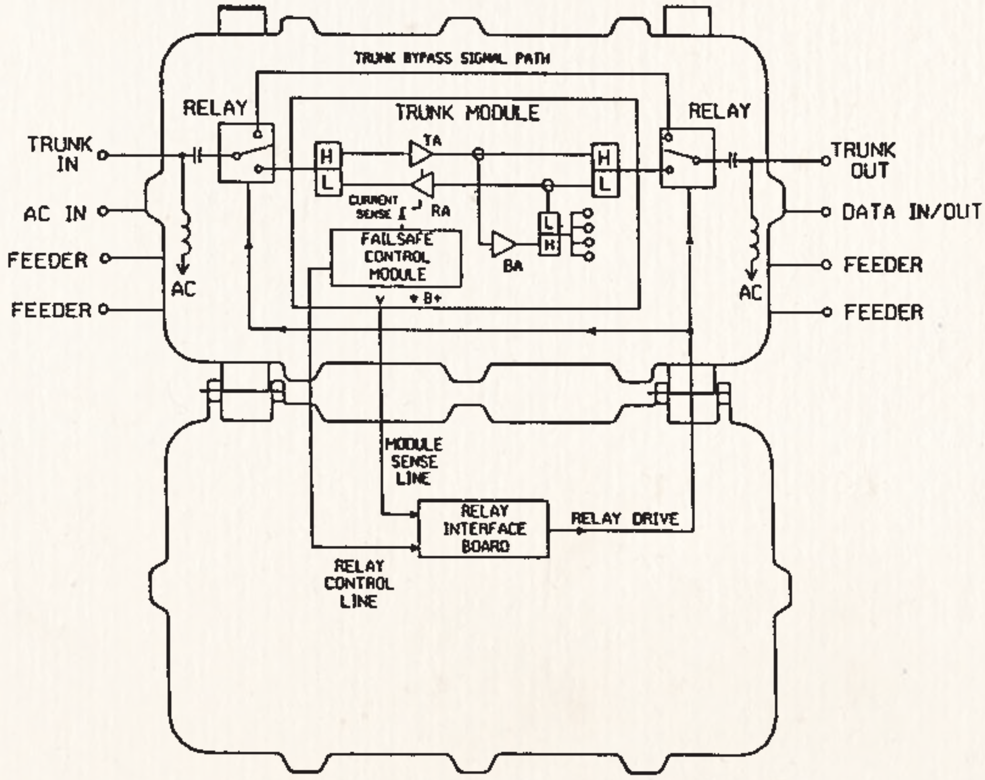

Fig. 6. Functional block diagram Failsafe Bypass System.

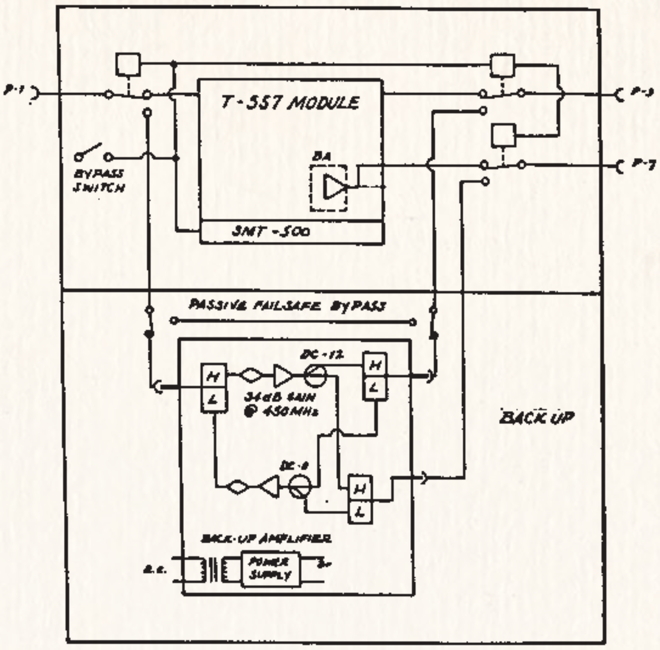

Fig. 7. Trunk and Bridger Backup amplifier.

The Backup amplifier gain and slope are fixed. Other automatic gain amplifiers will correct for any incorrect signal levels. All frequency selective components such as diplex filters, reverse equalizers and low or high pass filters are plug-in. Only one bridger output is available from the Backup amplifier, so multiple outputs can only be achieved with external splitters.

Two Cable System with A/B Switch

An A/B switch is usually configured to switch between two input sources over the entire 5 to 450/550MHz band, and so can be used to switch any combination of broadband frequencies in that frequency range.

A typical application is when duplicate cable systems using different routings are used to feed certain points in a system. Fig. 8 shows a functional block diagram of an intelligent A/B Switch, controlled by the Status Monitoring Transponder.

Résumé

We have seen a variety of solutions in order to secure continuous operation of CATV and DATA networks. For each type of network a specific system is applicable.

Using a Sub-split network, it can be upgraded via:

— Status Monitoring System in trunk amplifiers

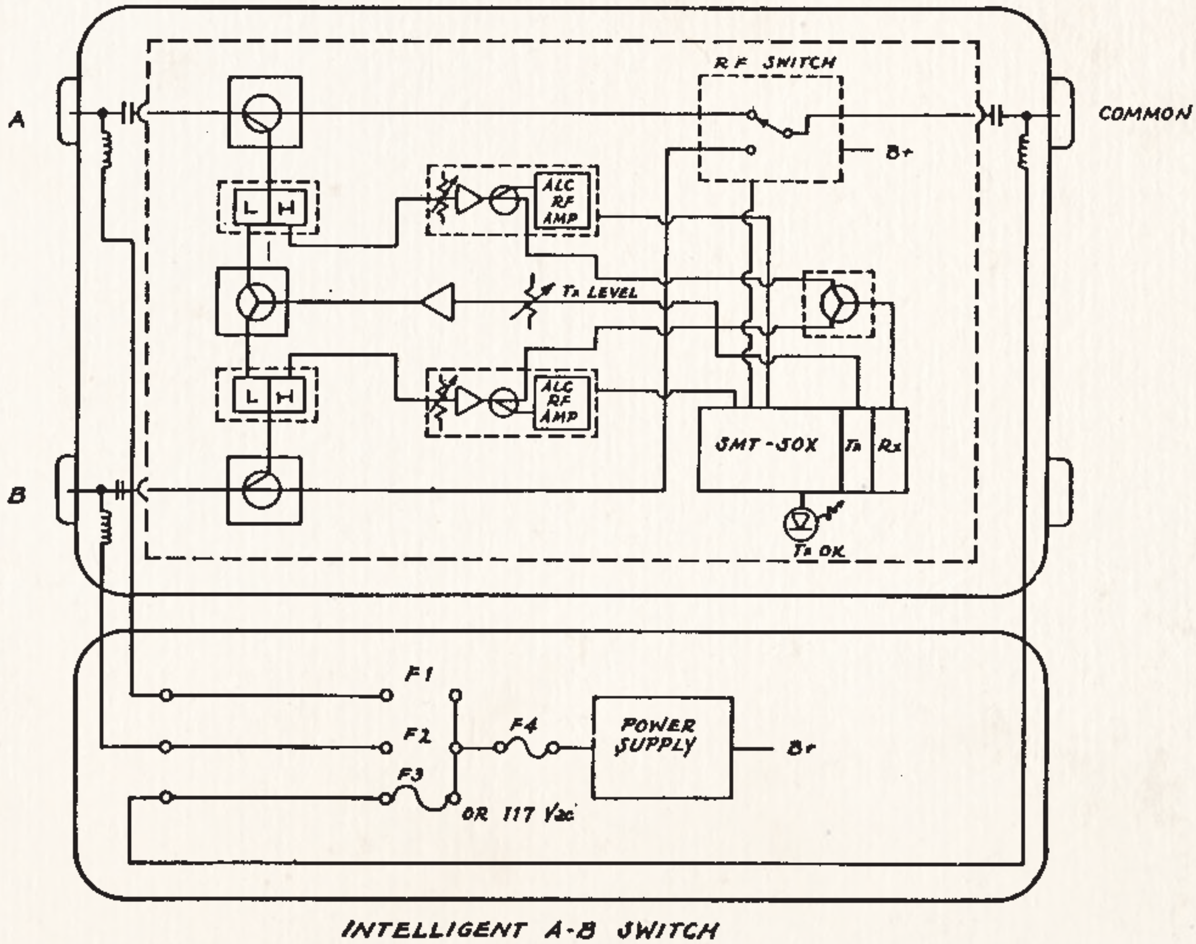

Fig. 8. A/B Switch functional block diagram.

— Stand Alone SMS at the end of major feeder lines
— Failsafe Bypass

Using a Mid/High Split network:
— Status Monitoring System
— Redundancy amplifier

Using a Dual Cable network:
— Status Monitoring System
— A/B switch

Coaxial networks are going to be used for additional services. Operators charging for these services must ensure a continuous data link. Upgrading the network with the aid of the technology mentioned in this paper will bring the required results.

Discussion

The President: Mr. Baan referred to the two-cable system and the A/B switch. Can I ask whether both cables carry the same information and programmes, and how far down the system do they normally go?

Mr. Baan: It is the intention that both cables should carry exactly the same amount of signals. The C-COR A/B switch is only constructed to get maximum security to a certain point - for instance a feeder - from the headend or position of computer. Similar signals are sent out on both cables which may follow different routings. Consequently, you will find a complete double set of amplifiers down the system, so it is 100 per cent double.

Mr. A. Burke (British Telecom): May I ask John Dahlquist to give us the latest information on the state of the art in terms of push-pull technology, and for that matter power-doubling and feed-forward in terms of the upper limit of the frequency spectrum. In other words, do we have in prospect the likelihood of devices of this sort going up to the top end of Band V, for example?

Mr. *Dahlquist* You will have to excuse me if I ask you one question in return. What is the upper limit on Band V?

Mr. Burke: I am talking about the spectrum up to about 860MHz.

Mr. Dahlquist The top of the UHF band. Over the last two years we at Jerrold have been working with all the major IC manufacturers to produce ICs with extended bandwidth capabilities. Currently - I guess for about the last year and so many months - we have been developing and testing amplifiers with capabilities of handling signals up to 550MHz, 77 NTSC-type channels. The basic bandwidth capability of the amplifiers of the IC modules themselves approximately 600MHz. However, we have been utilising them at 550MHz to provide us with the needed guard band which we typically figure at 5 per cent over the operating bandwidth at which we would use the devices. This is to ensure that we do not have excessive roll-off at the top end of the distribution spectrum.

Mr. Burke: Because of the problems that we have in this country with distributing signals simultaneously at VHF and UHF, one can get quite a number of second-order inter-modulation problems with using single ended amplifiers. Could you look forward a little and give us some indication as to whether we are likely to have the advantages of improved second-order performance in push-pull amplifiers up to 800MHz?

Mr. Dahlquist Certainly the ICs have the capability of achieving that type of bandwidth. However, the major constraint that the IC manufacturers have in dealing with that sort of frequency range is the output and input directional couplers. They have a hard time developing these to be flat over a full spectrum from 40MHz up to the top of the UHF band and keeping the phase relationship that is critical to provide the second order cancellation constant over the large a bandwidth. Some push-pull devices have been made. We have had samples from time to time that can provide this type of performance. However, we have notes a manufacturer in any way pushed the IC vendors really to supply it; it was more to look at out of interest rather than as an actual product development. I think you could probably make a good case for a manufacturer to develop this. If the volumes that would be needed were sufficient for him to go to the IC vendor, some product like this could be made. However, it would not be capable of handling the same kind of channel loading as the devices that are now working in the 50-450 or 50-550MHz range. They would probably change the actual amplifier circuit from a cascade circuit to a common emitter circuit to provide better high frequency performance. That will have the effect of reducing the performance as far as third order distortion is concerned at the lower frequencies and at those higher channel loadings.

Mr. R. J. Seacombe (British Telecom): Carrying on that sort of subject, I wonder whether you could give us some additional information as to the way in which the improvement that you would get due to feed forward relates to the frequency. In order words, do you get a constant improvement across the band or is it better at the top end or the bottom end, or is it a matter of design?

Mr. Dahlquist: It is a matter of design. It is not a perfectly fiat cancellation. It will move according to the resonances of the delay line which is really a strip filter so it has poles and zeros to it and you will see that across the band. What they say is that typically the cancellation will be 26dB in most hybrid feed forward ICs, and at certain frequency points it is going to be much better than that, but it should not be very much less.

Mr. Seacombe: It is a fairly well-known fact that as the upper frequency limit of these ICs is extended further, the intermodulation performance limit tends to be at those higher frequencies. I wonder whether it would be possible to design a feed-forward stage such that you got better cancellation at the top end so as to be able to reload the amplifiers to what they would have been had they not been extended to that high frequency.

Mr. Dahlquist: You can certainly adjust the delay line to provide different characteristics of cancellation. I have done it myself on our Century III product lines. It can be done and you can see the difference in cancellation. Whether it would be practical I do not know; whether we could do it on a repetitive basis to get amplifiers with the same characteristics so that we could use them in an amplifier cascade and utilise the typical calculations that we would in designing a system, I am not really sure. I have not looked into it or had other people look into it enough to be sure. You can tailor the cancellation line. Whether we could achieve the benefits you would be looking for, I am not sure.

Mr. G. Meek (Thorn EMI Cable TV): I would like to ask Rien Baan if he would explain the action of the fail-safe bypass and how it would affect the following amplifiers in systems that we use today. Obviously the levels are going to drop, etc.; how many repeaters later before level compensation is complete?

Mr. Baan: The fail-safe bypass system you are referring to, without an active redundant amplifier, will indeed mean that if an amplifier station fails you will have a drop in gain of 22dB. Supposing a 22dB spacing on the system. In this situation, which we can demonstrate, you see that all the following amplifiers are going at once to their maximum gain. Normally the amplifiers are spaced at 22dB or 26dB, whatever is applicable for normal or feed-forward operation, and they have a ±3dB reserve for the ALSC (automatic level slope control) operation.

So all of the amplifiers behind the defect station are going up 3dB in gain. That means if you lose 22dB about seven amplifiers later you are back to normal again. Of course, this will result at the end of the trunk line in increased signal-to-noise ratios because you will have one amplifier less, but the system level as it is remains for what it was after seven ALSC amplifiers.

Mr. C. Swires: Could I ask Mr. Baan to express some opinion on the relative reliability of the actual trunk system and the reliability of the status monitoring system. It seems we are getting more complex status monitoring, and I wonder if the factor is then going to be failure of the status monitoring rather than the failure of the system.

Mr. Baan: That is always a criterion: do I make my controlling amplifier more reliable than the system itself? What are you controlling? Please note that in a complete system we are just talking about amplifier failure: there can be external circumstances that cause an amplifier to fail. I have already mentioned that there may be a cooling problem if the amplifier is placed in the cabinet and the ventilation holes of the cabinet are not opened any more. After a year or so the temperature may rise slowly. Secondly, the power may drop somewhere in the trunk system. Therefore, it is not true that status monitoring as it was described is only added just to watch the amplifier action. It is indeed watching and securing the amplifier operation, including external parameters, and as such is as reliable or better than the amplifier itself. Do not forget that it is a microcomputer, and the system is as reliable as the microcomputer is. Basically the active components in the amplifier are being monitored. We all know that the active components get warm, especially high output hybrid modules. Those are the basis trouble-makers for many factories. Therefore, Jerrold and C-COR both select their own manufacturers to get reliable hybrids and those hybrids produce the heat and have to be monitored. The status monitoring system is a microprocessor and it is using sensors, and nowadays they can be made very reliable. It is true that the controlling system is more reliable than the RF hybrids module although they have a very good MTBF. Moreover, it has often appeared, and we have seen that applying our stand alone status monitoring system, used in a system with various kinds of amplifiers where system dropouts occur not because of amplifier failure but because of power drop, or if someone has left the lid of the trunk open or if there are ventilation and cooling problems. So it is often an external cause which made the system fail.

Mr. Burke: I wonder if Mr. Baan could tell us whether his company has considered the possibility of measuring the presence of moisture or water inside cabinets. It seems to me that there is a likelihood of securing screws being left loose rather than their being completely open and the presence of some sort of detector to indicate ingress of moisture would be of significant value.

Mr. Baan: That is a fact, but C-COR have chosen to watch and measure the consequences, the parameters which are caused by this moisture, because it is *very* complicated to make sensors for moisture in everything.

Then I come back to Mr. Swire's question: it is easier for us if we check the consequences of moisture, changes in amplifier behaviour or loss of AC power. It is not very important for an operator at a certain point to detect that there is moisture or anything in an amplifier housing; for him the first point that is important is that there is something wrong in that amplifier and that it may fail in future. The system as described works preventatively. You can see exactly what level it is within tenths of dBs. A change in that, caused by moisture or whatever, if it is within certain limits will result in a no problem" status; there is an "alert" status when it comes within certain limits and then the operator can take action, then the serviceman with his own eyes will see that there is moisture in it. The main message coming out of the system should be that there is something wrong, whatever it is. On the other hand, it keeps the system simpler if you omit those rather complicated sensors. Do not forget that everything is out in the open. It is an amplifier and you have to keep it practical.

The President: I would imagine that unless the lid was wide open the actual heat generated by the devices inside the amplifier would help to keep it dry inside anyhow. Is that so?

Mr. Baan: That is correct.

The President: What is the practical limit of feed forward as well as other trunk amplifiers in cascadability, in terms of both distance and number of amplifiers?

Mr. Baan: It depends, of course, on what criteria you use for the network as it is. I can give you a Dutch example from the top of my head. There is a criterion for the trunk system where they use 46dB signal-to-noise on the trunk line and 43dB overall, but for the trunk 46dB signal-to-noise there is an inter-modulation second and third order combined to 57dB. With C-COR trunk amplifiers, and 26dB of spacing we can go up to 35 amplifiers.

The President: That is feed forward amplifiers?

Mr. Baan: Yes, feed forward, 450MHz amplifiers. Then we have an operational cascade of 550 amplifiers, but we have not tested that according to European standards. But there you get more problems for the flatness as described before, but with the feed forward amplifier under these conditions - let us say Dutch PTT regulations - you can go up to approximately 45 depending on what your criterion is for the trunk line system. We run a simple computer programme for it.

There is the well-known scissor diagram which determines this. It is a combination of output level against signal-to-noise ratio and third and second order inter-modulation and the optimum between these parameters results in an amount of amplifiers with a certain optimum output level.

Mr. Dahlquist Certainly besides the design criteria the carrier-to-noise ratios, the carrier to distortion you want to achieve, the other thing is the channel loading at which you are going to operate the system. Typically in the States we have limited, or tried to limit, cascades to the mid-thirties as a practical, manageable, maintainable limit to amplifiers. Certainly, in some cases, we have some cascades that are 50-60 amplifiers deep, but they really cannot provide high quality, high performance signals to every subscriber, especially the ones at the end. It is really the practical limit that we have found *anyway* around 30 amplifiers for a sixty-channel system.

Mr. Baan: I know a trunk in Holland, partly Century, which has 62 amplifiers in cascade, but it is lower channel loading, and that is why it still gives an acceptable picture at the end. The one I was talking about is 40 channel loading.

Mr. Dahlquist: There is a system that we know where feed-forward was actually developed up in Canada, where they have actually gone over 120 miles of cascade distance. This was done from, I think, only about 100MHz at the top end, maybe 40 to 120MHz in the far reaches of Manitoba to serve all the outlying communities with 8, 10, 12 channels, something like that. Yes, you can go for ever if you limit the number of channels you want to carry.

Mr. Baan: There is a third criterion, the flatness, what you expect from the overall flatness of the system. In England there is a C-COR feed-forward system in Swindon. They reached ±½dB flatness with feed forward amplifiers. That is something which has been achieved after 10 amplifiers. So parameters are signal-to-noise channel loading, what do you accept from the flatness, and what is the intermodulation figure overall?

The President: Thank you very much. That was *a very* comprehensive answer.

Mr. R. J. Seacombe: I would like to continue on that theme for the moment. You were talking about the overall flatness of the system. You could make an amplifier that in effect corrected the errors in the same way as it corrects for the errors in its linearity.

The President: Obviously food for thought.

Mr. D. E. Kent (Jerrold): The feed-forward technique does correct for errors in amplitude response of the main amplifier, because you derive an error signal which is the difference between the output of the main amplifier and the straight through signal from the input. Therefore the error signal includes amplitude variations and cancels out when you add in the error signal at the output. You will obviously introduce some error if the response of the error amplifier is not perfect, but the majority of the error is cancelled.

May I just ask a question of Mr. Baan? On your fail-safe circuit, I may have missed a point, but could you explain again how you sense that there has been a failure on one of the amplifiers in order to switch over to fail safe?

Mr. Baan: The sense is made via a change current. When there is no status monitoring controlling, just the fail-safe bypass control module, that module senses a change in current dissipation of the hybrids. That is regrettable. That was 150 milliamps I mentioned. Once a change bigger than that occurs in that amplifier, then it is switched over automatically. So it is either the change, or if you say you want to replace that amplifier or take it out of service, the external power totally drops, then that is normal to zero change in current dissipation. Then it also switches off, so either the power drops totally externally or internally, or there is a change in current because one of the hybrids is defective and then that by-pass circuitry is activated.

Mr. Kent: That means that if there is a failure that is due to something other than the hybrid failing catastrophically, it will not switch over, and if the r f level at the output drops but the current does not change, does that mean the fail-safe does not work?

Mr. Baan: The fail-safe starts working if the power drops or if the current dissipation changes. Then it switches over. What are you referring to under "catastrophically"?

Mr. Kent: If there was a failure in some other part of the circuit that did not involve a failure of an integrated circuit.

Mr. Baan: A failure in an integrated circuit, I have said it but we have found a failure in an integrated circuit results in a 99 per cent change in DC current, so if an integrated circuit for any reason fails you can detect it because of its change in current. Therefore, that parameter has been selected as a yes- or no-go.

Mr. R. Terris (Wolsey): Back to your multiple trunk repeaters: assuming that the amplifiers have a similar frequency response by the time you go through 40 or 50 trunk repeaters, the overall frequency response would, I imagine, be fairly diabolical. Do you take steps to contract the dips and peaks in the frequency response of the system?

Mr. Dahlquist: Yes, we have that capability.

Mr. Baan: We do too.

Mr. Dahlquist: We have the capability to provide mop-up controls to account for certain inherent dips or peaks in the frequency response, and you can get on those in your system alignment to eliminate the peak normally caused by certain systematic signatures of the equipment, whether it be the passive equipment inside the amplifier or the active devices themselves.

Mr. Terris: Are these separate items apart from the amplifiers placed along the trunk route, or inherent built into the amplifiers themselves?

Mr. Dahlquist: They would be typically a plug-in circuit that goes right inside the amplifier module itself.

The President: All that now remains is for me to thank Mr. Dahlquist and Mr. Baan on behalf of us all for what has been a very interesting meeting. They were interesting talks and we have had a good discussion. Perhaps everyone would join with me in thanking our two speakers in the usual manner. *(Applause)*