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Tropospheric scatter – automatic power level control

Summary

This article highlights the problems associated with enhanced propagation caused by ducting conditions often encountered on tropospheric scatter links. The limits imposed by such conditions on receiver performance and on the acceptability of tropospheric systems as a whole are explored and measures to reduce these limitations are discussed. The operating parameters required for their implementation in the form of an automatic control system are outlined.

This new control system utilizes a closed loop over the link and is automatic in operation. The transmitted power is controlled in accordance with signal level measurements performed at the receiver, the control information being relayed over the link via normal supervisory channels. The hardware being developed to control the transmitted power is described.

Introduction

In the search for even higher availability and wider acceptance of tropospheric scatter systems, Marconi Communication Systems is at present developing a new range of equipment which will overcome many of the problems associated with enhanced propagation conditions. One of the features of the equipment is that it may be fitted retrospectively to systems already in service.

Enhanced propagation conditions are not a new phenomena as far as radio communication systems are concerned, but the range of enhancement encountered in tropospheric scatter systems can cause the received signal level to rise some 50dB or more above the median value. Such a large increase causes the receiver to become saturated, usually in the low noise amplifier stage, and the output is then distorted. More serious from many points of view are the interference effects which tropospheric scatter signals, subject to enhancement, can have on line-of-sight microwave systems many hundreds of miles beyond the receiving antenna. These latter effects hinder acceptance of tropospheric scatter systems in situations where they are otherwise eminently suitable and as such are of great concern to both the operating and planning authorities, and to the equipment manufacturers.

It is self evident that the only way to overcome the latter problem is to transmit the signal at a level which more or less matches the propagation conditions. This would also overcome the problem of excessive receiver level, although this could of course be equally well done by increasing the dynamic range of the receiver.

Basic system requirements

GENERAL CONSIDERATIONS

The requirement is thus to prevent the field strength at the receiving station from rising above a pre-determined level without affecting the low signal level condition. Obviously there is no direct knowledge at the transmit end of the link about the receiving end signal levels, and therefore measurements have to be made at the receiver and the information fed back to the transmitter if enhanced signal levels are detected. This information can then be used to adjust the transmitted power by an amount proportional to the propagation enhancement.

Manual intervention to carry out the adjustment is not feasible for several reasons: round the clock attendance would be required to carry out the 'fine tuning' nature of the corrections involved, an error could result in the loss of communications, tying up operating staff for this function over the lifetime of a system would be uneconomic, etc. The first requirement of the transmit power control system is, therefore, that it must be automatic in operation, with the control loop embracing both the transmitter and the receiver.

A link transmitting and receiving in both directions is thus implied although control may be unnecessary in both directions. Since the atmospheric conditions which produce signal enhancement have a reciprocal action, two-way control would normally be required. However, in some situations such as a link which transmits overland in one direction and out to sea in the other, control in the land direction only may be necessary to satisfy the P & T authorities of the country concerned because the 'overshoot' effect from the sea link may cause interference unless properly controlled.

TRANSMIT STATION CONSIDERATIONS

In determining a suitable specification for the control system, several factors relating to the transmitters and receivers have to be considered. Transmitter powers range from 20W on short hops, through 1kW on medium links rising to 10kW and above on long distance links. In addition, modern systems often have two transmitters, one transmitting using vertical polarization and the other horizontal or alternatively operating on two different frequencies. Attenuators which can handle the output powers involved are not available and even if they were would be very expensive. Therefore the power must be controlled at a convenient low power point in the transmit chain. Most transmit chains have a discrete drive stage followed by a power amplifier, with drive output powers in the range of 100–500mW. In choosing the attenuator to perform the actual power control it must be borne in mind that for the vast majority of the time, maximum transmitted power will be required in order to give an acceptable level of receive signal. Therefore the insertion loss, in the minimum attenuation setting, must be very small – 0.5dB or less – in order *not* to reduce the maximum available transmitted power by any marked degree.

Having accepted that it is necessary to effect control before the power amplifier stage, an additional factor must now be considered, namely the effect on the power amplifier performance when operating on lower than normal input signal levels. The magnitude of this factor will vary from one power amplifier design to another. Some will show a difference in their useful bandwidth and almost all will be bound to show relative increases of in-band spurious and thermal noise to wanted signal. The importance of these effects will also be related to the bandwidth necessary to carry the amount of traffic being handled by the link. In any case there is likely to be a lower limit of power beyond which the increase of in-band transmitted spurious and bandwidth reduction will swamp any improvement to be gained. Flexibility in setting a control range lower than the maximum possible is therefore essential.

Constraints when designing the control system in a manner which makes it suitable for use on single or dual drive/power amplifier systems are basically mechanical, e.g the use of modular construction to ensure that superfluous hardware is not included when control is required on a single drive system, and the avoidance of unnecessary duplication on a dual drive system.

RECEIVE STATION CONSIDERATION

At the receive end of the link a convenient point in the receive chain must be chosen to make a level measurement. Obviously this should be at a point where the signal level is linearly related to the incoming signal. This constraint restricts measurement to a point in front of the a.g.c, or pre-detection combiner, if the latter type of receive system is employed. Measurement at the incoming s.h.f after the parametric amplifier would be possible, but the signal at the 70MHz i.f is at a higher level and hence easier to detect and so is usually chosen. Fortunately, linearity of detection is not important since measurement of the absolute level of the signal is in itself irrelevant, it being necessary only to detect when the signal has exceeded a threshold value, this being the level above which receiver intermodulation distortion is likely to occur. To exercise the degree of close control over the transmitter output power necessary to keep the receiver input level at exactly the chosen threshold value would offer no real operational gain in terms of percentage availability: provided that the received field strength can be controlled to give a 5–15dB margin with respect to the signal level at which unacceptable distortion would occur, then the desired result will have been achieved. This fact can be used to advantage as it simplifies quite considerably the operation of the control system, the transmitted power being adjusted in a series of steps of pre-determined magnitude rather than in a proportional manner linearly related to the received level. Before leaving the subject of detectors, another factor has to be taken into account, this being the problem of interfering carriers. In future, systems with particularly difficult frequency planning problems may have to be fitted with narrowband filters in front of the low noise receivers in order to have a measure of protection against interfering carriers which might otherwise produce intermodulation products coincident with the wanted carrier. However, this will not always be the case and so far it has not been found necessary on existing systems. Nevertheless, provision should be made to include narrow band filtering in front of the level detector, otherwise there is the danger of the transmitter power being reduced because of the presence of a high level interfering signal putting the receiver at an even further disadvantage.

With the possibility of having up to four diversity chains per receiver, measurement of level has to be done in each chain since a high level in any one chain could result in distortion. However, before acting on the high level in any one chain, account must be taken of the levels in all the other chains.

The conditions which cause enhancement will affect the levels in each of the paths by the same amount. On quad diversity systems therefore a check that all levels are within 20dB of each other is made before a 'decrease power' command is sent to the transmitter. An excessive level in just one path while the others are at a normal or low level could be due to the spurious effects of a fault condition. As a further protection against spurious decrease or increase power commands being sent to the transmitter, a time delay is employed. Fortunately, experience of ducting and signal enhancement conditions indicates that the condition occurs slowly, and hence a time delay does not affect the response required to keep up with the signal changes.

The final part of the system at the receiver is concerned with the coding of the information derived from the processing of the signal levels into commands, with a format that can be easily sent back to the receiving site. As a natural consequence of the decision to control the transmitted power in steps rather than linearly, the commands sent back need only represent three conditions: 'decrease power', 'increase power' and 'hold power'. The signal processing logic is arranged with two output lines giving a possibility of four logic conditions of which only three are used. The two lines are encoded onto a single line and used to key a v.f.t channel with a steady mark for one condition; a steady space for the second and 'reversals' for the third. The reversal rate can be chosen to suit the v.f.t channel employed, normally 60 bauds for a 120Hz spaced channel with a $\pm$30Hz shift. Choice of the v.f.t channel can be left to the purchaser who can use one of his own sub-baseband supervisory channels or even one of his traffic telegraph channels. Alternatively the v.f.t

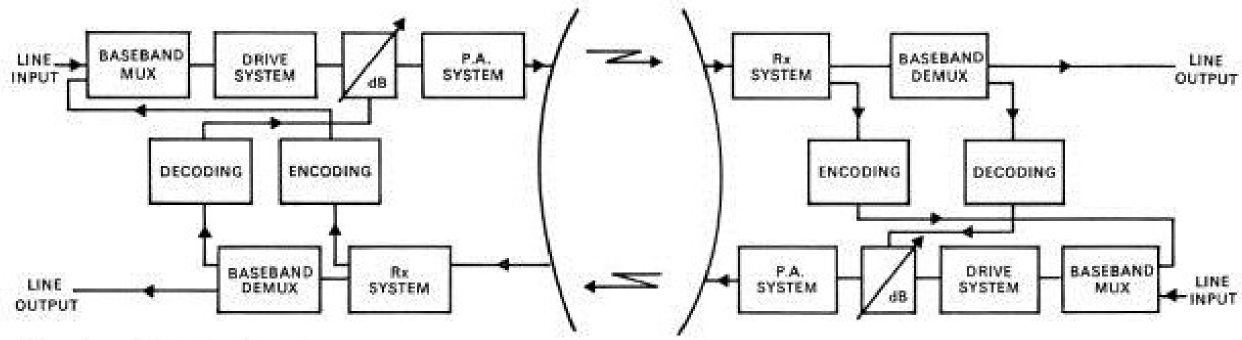

Figure 1. Bi-directional level control system

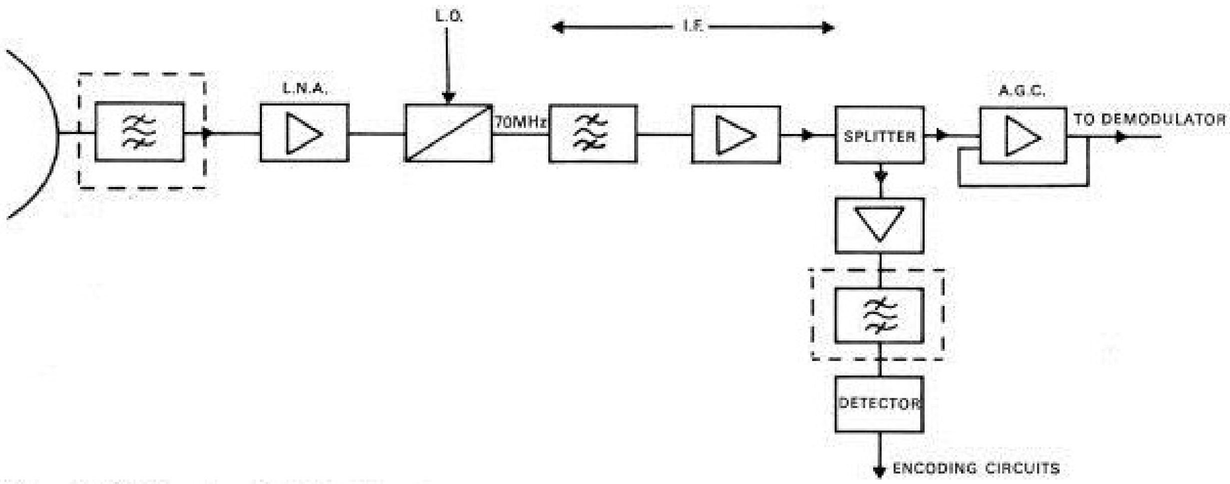

Figure 2. Single receive chain-level detection

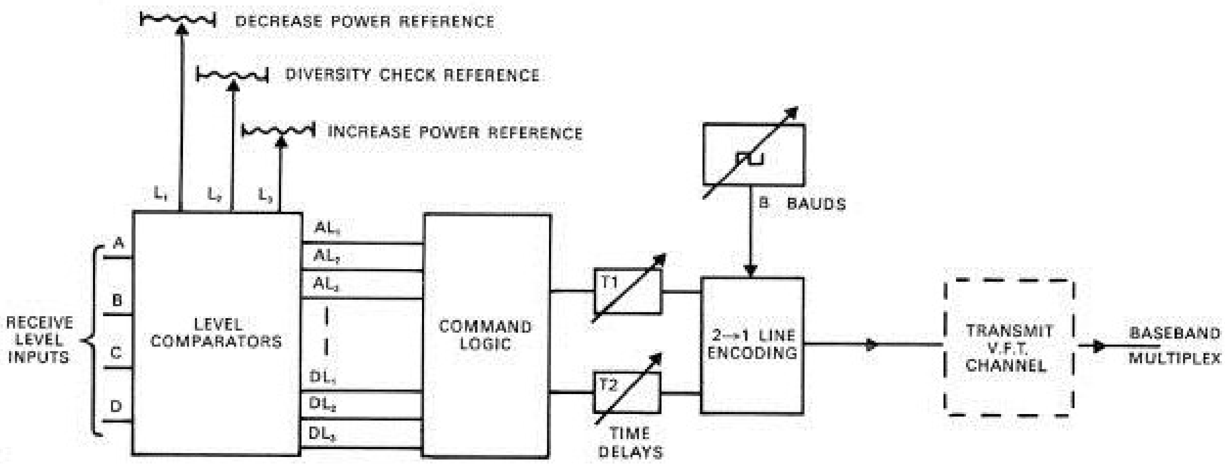

Figure 3. Receive processing and encoding

channel can be included as part of the level control equipment.

System description

GENERAL CONFIGURATION

The generalized form of a tropo system with two-way level control is shown in figure 1. The symmetry of form of the control system enables identical equipment to be used at each end of the link. One-way control would require the level measuring and encoding circuits at the receive end only, the decoding and attenuator drive being at the transmit end. The hardware is being engineered in a manner which will ensure that the same basic building blocks can be used for one-way or two-way control, dual or quadruple diversity receive, and single, dual or quadruple transmit.

RECEIVE STATION EQUIPMENT ARRANGEMENT

A very simplified diagram of a typical receive chain is shown in figure 2. This illustrates the point at which the level is measured, at 70mHz, just before the a.g.c or predetection combiner, as the case may be. Note the optional narrowband filter in front of the detector to attenuate unwanted interfering signals should any be present. Each receive chain is being fitted with identical detectors. Amplification is included after detection as the detected signal has a very small amplitude and could not be used directly for further processing. As shown in figure 3, the signals are fed to a series of comparators, the outputs of which indicate whether the signals in each of the chains are above or below a number of preset reference levels. All the reference levels may be adjusted on site if required, although normally the operating signal levels will be known and the levels set when the equipment is being tested during manufacture. In addition to the high-level reference which determines the highest signal level permissible in the receiver and the low-level reference below which transmitted power would be stepped back towards its maximum value, there is a further reference which may be used as a check for faults or spurious levels. The comparator circuits are followed by a logic stage. These circuits take account of all comparator states simultaneously and determine which command is sent back to the transmitter. Distortion would result if the level in any one path were allowed to rise above its high reference. The logic is therefore arranged to allow 'decrease power' commands, if any level exceeds the high-level reference: however, if the level check facility is used the command is only sent if all other levels are above the check reference level. The time delay is adjustable, with a maximum time of approximately 1 minute, and ensures that only relatively long-term enhancements, result in a decrease power command being sent. Once the need for a reduction in power has been established the command is sent on a continuous basis and will only be cancelled when the outputs of the comparators indicate that the receive levels are no longer exceeding the high reference, *i.e* that power has been reduced or that the level of enhancement has dropped.

Similar reasoning applies to the generation of an 'increase power' command. Any level dropping below the increase power reference will produce an 'increase power' request from its own comparator. However, should this request be granted at a time when the level in one of the other paths lies at an intermediate position between the increase and decrease references, an increase in power could take the level in this second path above the decrease power' reference resulting in a 'decrease power' command, *i.e*, an unstable condition would ensue, with the transmitted power see-sawing up and down. This is prevented by arranging the command logic to give out an 'increase power' command only if all the levels are below their 'increase power' reference. Time delay T_2 has a similar function to T_1 in ensuring that only relatively long-term effects result in an 'increase power' command being sent. It will therefore be the case that under normal propagation conditions the 'quiescent' output will be an 'increase power' command. This will have no effect of course as the transmitter will already be operating at its maximum output power.

The 2–1 line encoder consists of simple gating which is either outputting a '1', a '0' or reversals, these representing the three possible command states.

TRANSMIT STATION EQUIPMENT ARRANGEMENT

Figure 4 shows a block diagram of part of the level control system at the transmit end of the link. The 1–2 line decoder interprets the output from the receive v.f.t and provides an input to either T_3 for 'decrease power' commands, or T_4 for 'increase power' commands. These time delays are of quite short duration, less than 10 seconds, and are included as a protection against noise on the v.f.t channel giving spurious commands.

The attenuation control logic contains an UP/DOWN counter which is driven from pulse circuits which act upon the change of state of T_3 and T_4. Each time the counter changes its count an inhibit is placed on the input to the attenuation control logic and time delay T_5 is initiated. This inhibit is maintained until T_5 times out. It is a further precaution against spurious operation which gives time for the system to react after a change of power and will exceed, by a few seconds, the total 'increase power' time delay (T_1+T_3) or the total 'decrease power' time delay (T_2+T_4), whichever is the greater.

The output of the UP/DOWN counter represents the number of attenuation steps required to be inserted at the transmitter in order to keep the received level below the maximum permissible, each step representing a specific number of dB's. A simple display of the attenuation is provided in the form of light-emitting diodes, by decoding the counter output. This display is presented on a panel, which also has the controls for enabling manual intervention of the automatic control system. By the operation of an Auto/Manual switch together with Increase and Decrease push-buttons, any desired transmit output power may be set manually.

Certain links may require less than the maximum available power under normal non-ducting conditions and more than the minimum possible even under enhanced conditions. Provision is made to preset these constraints into the attenuator control counter. The transmitted power will operate between these limits regardless of the demands on the inputs.

The 4-bit digital to analogue converter may be regarded as an output interface which may vary from system to system, depending upon the attenuator used. Present development has concentrated on the requirements of reasonably high output power systems, one kilowatt Class A amplifiers and above. Here the attenuator is situated between the drive and the power amplifier as shown in figure 1. Attenuators suitable for this application are of the electro-mechanical type and not only have a distinctly non-linear characteristic, but also vary from sample to sample. Therefore provision

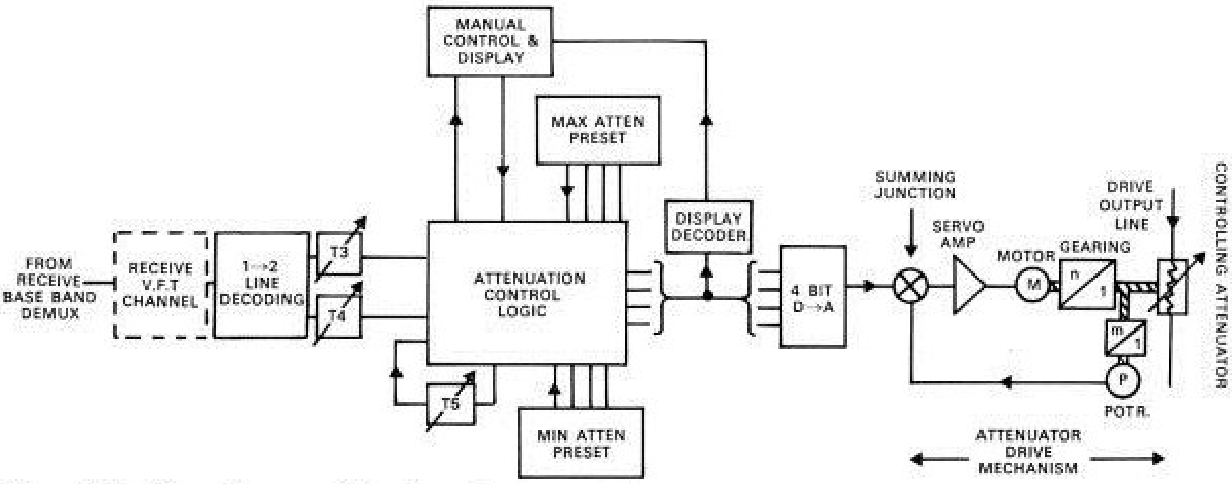

Figure 4. Level control command decoding and attenuator drive

is made to calibrate the digital-analogue converter to match the attenuator used. The high power amplifier gain is unlikely to be linear over the full control range. This non-linearity may also be counteracted by the D–A calibration.

The remainder of the control consists of a linear position control servo loop. The servo amplifier drives a motor which drives the attenuator via a step-down gearbox. A potentiometer driven from the drive-shaft of the attenuator provides a position feedback to the input of the servo amplifier to close the position loop. Obviously, short links require less power, and with the advance of present-day technology, output powers using Class C amplifiers providing 50W are economical. Control on the input to these amplifiers is not possible with the range of control required; up to 40dB's. Therefore attenuators with 50W capability have to be used to control the output of these amplifiers. Attenuators which can handle these powers, with less than 0·5dB insertion loss have yet a different attenuation characteristic which will require a different law from the D–A converter.

Conclusion

Automatic transmitter power control is a new departure in the design of tropospheric scatter communications systems. It can provide operators with higher system availability due to the prevention of distortion in the receiver which would otherwise occur under enhanced propagation conditions. It also provides system planners with a new facet to consider in situations where signal interference with other communication systems is a potential hazard.

Analysis of the required operating parameters has shown that effective control can be achieved by employing simple measuring, analogue/digital processing and servo control techniques. Furthermore, the use of modern modular construction and integrated circuits enables a highly flexible design to be achieved in terms of system size, configuration and operating parameters without incurring any great cost penalty.