S. S. SPRAGGS, B.Sc(Eng), C.ENG, M.I.E.E

TRANSMITTER RESERVE FACILITIES

INTRODUCTION

However reliable a broadcasting transmitter proves to be, in practice there will be occasions when it will fail, but these failures can be so widely spaced that a break in programme is a rare occurrence. Transmitter stations, staffed by qualified technicians and manned during programme hours, have operated successfully for years without reserve equipment and preventive maintenance; speedy fault finding and quick repairs have kept off-air time to a minimum. Unfortunately, the hazard of a fault requiring considerable time to repair cannot be removed. With a more critical public developing over the last two decades, many broadcasting organizations have decided to build some form of redundancy into their main stations to guard against the possibility of a long-term fault. With attended stations and modern equipment such faults, although possible, are rare. As services have extended the number of transmitter and translator sites have grown, throwing an added burden onto maintenance departments whose finances may not allow their staff to be increased, or who may have been unable to recruit technicians with the necessary expertise. The days of fully manned stations are numbered; already many stations are unattended, remotely controlled or automatically operated. Maintenance teams have been set up to tour the lower-powered stations and translator sites, while main stations, if still staffed, are often unattended during evening programme hours.

The best transmitting sites tend to be the most inaccessible, some being totally isolated for some months of the year. A simple fault may thus cause a protracted breakdown unless some form of reserve equipment is installed.

TYPES OF RESERVE EQUIPMENT

To obtain the highest insurance against long breaks in programme a transmitting station must have full redundancy built into the installation, namely, two programme sources, two transmitters, two aerial feeders, two aerial systems, and two electrical power supplies. Considering each in turn, many authorities provide a reserve programme source — though this may be only an off-air receiver tuned to another station. Reserve transmitters take a variety of forms (to be described later). It is common practice to install two aerial feeders to a split aerial system, each half being independent of the other. The supporting mast is considered reliable to the point where a failure would be a major catastrophe. Even so some authorities hold a light mast and lightweight aerial system in store that can be erected quickly should the need arise. The reserve power source is generally a diesel alternator set but can be a second power line.

Type of reserve transmitter

An authority, having decided to install a reserve transmitter, has to determine the answers to the following questions:

(a) Has the reserve transmitter to give the same output power as the main transmitter (i.e is the e.r.p from the aerial to remain unchanged?).

(b) Alternatively, can the e.r.p be lower without an unacceptable reduction in the service area coverage. (The reduction in field strength at translator sites is relevant here.)

(c) Can a break in programme, however short, be tolerated when switching from main to reserve transmitter and *vice-versa*.

(d) What financial limitations apply?

Parallel transmitters

Two television transmitters of equal power are shown in figure 1 and, when paralleled, all units of each transmitter are working with the exception of the f.m driver. Here one or other is selected to drive both sound chains. The vision oscillators, being c.w sources, can be phased locked together to avoid changeover switching in the vision chains. The output from each vision and sound combining unit is fed to a diplexer whose output is connected to the aerial splitter transformer. When monochrone television transmitters were first paralleled it was thought that both transmitting chains could be completely independent, paralleling being accomplished by the addition of the radiated signals from each half of the aerial. Provided the station was located some distance away from viewers this worked very well, but those receiving in the shadow of the antenna suffered from the addition of two fast changing vertical radiation patterns which, on

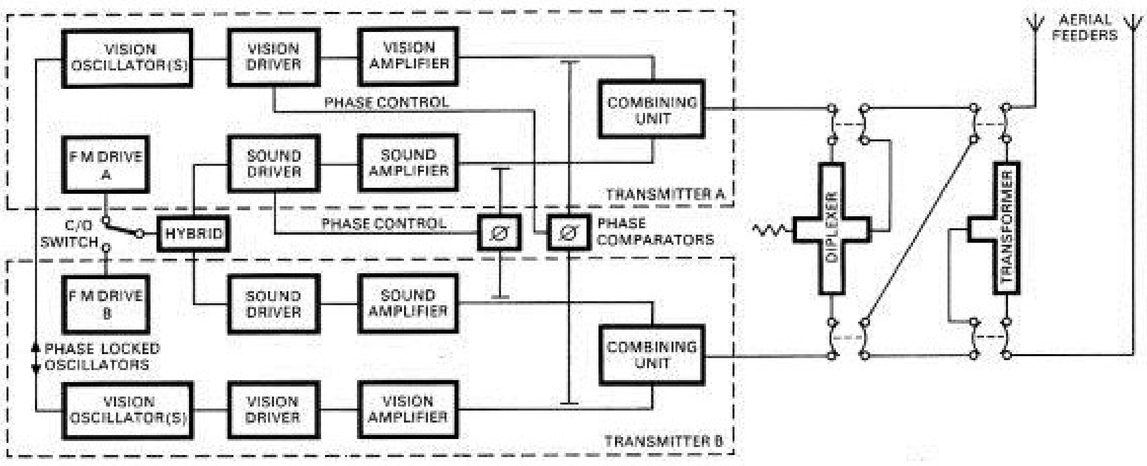

Fig.1 Parallel operation

occasion, resulted in a complete inversion producing negative pictures on the viewer's screen. When this fact became known most authorities fitted diplexers to combine the signals before transmission and this is now accepted practice when paralleling colour transmitters. Unfortunately, the diplexer is a common component in the system, but happily a passive one, and provided the design is conservatively rated the chance of a fault is very remote. However, special care has to be taken with the balancing load associated with the diplexer for this load normally takes close to zero power when both transmitters are in parallel. If one transmitter fails it absorbs half the power of the remaining transmitter. Should both transmitters become 180° out of phase the load takes the combined power. The latter would be a fault condition in a v.h.f system, but in a u.h.f system the transmitters can become in and out of phase very rapidly during initial warm-up before settling down to an in-phase condition. The load in this case must therefore be able to withstand short-term overload when cooling can become a problem. For low-power installations a naturally cooled load can be used but for higher powers most designs incorporate water-cooled or forced-air-cooled loads. A pump is used to circulate water through the water-cooled load and a water-to-air heat exchanger is generally also included. The diplexer load, with associated cooling system whether forced air or water cooled, becomes a vulnerable component. Failure would mean the loss of one transmitter, or operation on independent halves of the aerial with the hazard explained. The problem has been solved at u.h.f frequencies by using a vapour-phase load housed in a water tank. The load in effect radiates r.f power into the water which boils off to waste and is replaced from a header tank. The load does not incorporate a resistor element and the cooling system is free from moving parts. Loss of water will be small because the load only dissipates out-of-balance power. This load can also be used as a conventional transmitter test load.

The main advantage of a paralleled pair of transmitters is that, should either transmitter fail, the transmission from the station continues uninterrupted. However, when the fault occurs the transmitted power is reduced by 6dB. By switching the working transmitter direct to the aerial system at a convenient point in the programme schedule 3dB can be recovered.

Some transmitter designs include the possibility of switching h.t to a reduced value to obtain half the transmitter rated output power. If two such transmitters are paralleled, each at half power, and one fails in service, the remaining transmitter can be switched to full power and the normal station power restored. Changing the operational state of a television transmitter by h.t switching, or substitution of modulated drives, or change of feeder routing, will have an effect on the overall performance specification. The operator has to decide the normal operating condition, set up corrections to give optimum performance under this condition, and accept any deterioration in performance when operating in the alternative condition due to the corrections then being wrong. The reserve condition can be unacceptable in terms of linearity, differential gain and phase performance unless care is taken with the complete system design.

Each transmitter in a paralleled pair can be set up and corrected independently into a test load. When paralleled the combined performance tends to be better than that from either transmitter. However, difficulties can arise in meeting some performance parameters when the outputs are combined. It can

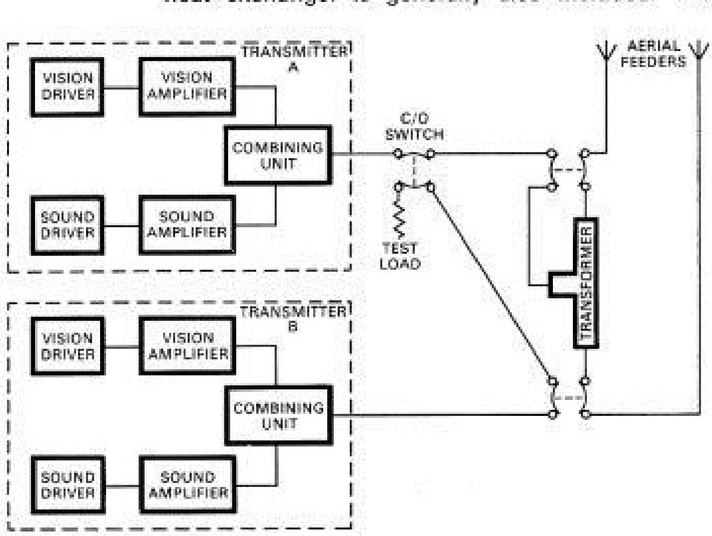

Fig.2 Working and standby

be said that there are three specifications to be maintained covering the performance of the individual and combined transmitters.

An added complication in a paralleled system is the phasing circuitry. Transmitters at v.h.f, having been phased manually, will stay in phase for many months and it is not necessary to fit automatic means of maintaining the in-phase condition. It is not so simple when phasing u.h.f transmitters. There are usually many multiplications of frequency in each transmitting chain and a small change of relative phase between transmitters at low frequency will result in a large phase change at output frequency. In such circumstances automatic phase correction must be applied but this can be overcome by using a common modulated driver with output at radiated frequency for two power amplifiers and having a second modulated driver in reserve. In this event the solution to one problem produces another in that a fault in the working modulated driver would mean complete loss of transmission until the reserve is switched into circuit. The main advantage of a paralleled system is then lost. Another less obvious problem, when using a common modulated driver for two power amplifiers, is that of correction. Correction set for two amplifiers working in parallel would be incorrect should one amplifier fail and have to be switched out.

Working and standby system

This system is illustrated in figure 2 where two television transmitters are fed through a changeover switch to a common aerial.

This is a more simple system than a paralleled arrangement but suffers the disadvantage of a break in transmission in the event of a fault. If two identical transmitters are used a fault does not result in a reduction of radiated power or a degradation in overall performance. Unlike the paralleled system where both transmitters are normally working, the reserve transmitter is not powered. Depending upon the type of design of transmitter it may be running with filaments on and delay interlocks made, or even with final h.t applied and producing low power into a test load. Or it may be completely shut down with only the drive ovens energized. Obviously, should a fault occur on the working transmitter, the reserve must be put into service with minimum delay, and it must be appreciated that the changeover cannot be instantaneous. When the working transmitter trips, the 3-shot recycling system will operate in an attempt to restore power, but if it fails to do so the equipment will lock out. At this point the changeover logic will register that the working transmitter has failed irretrievably but must wait, say another second before commanding the changeover switch to function. This is because a change from one transmitter to the other must be a positive function and the logic must not take notice of transients and short breaks in the mains supply. The changeover switch, depending on its size, can take anything up to five seconds to operate. A period of ten seconds could therefore elapse before the reserve transmitter is connected to the aerial and can be powered. Power must be applied as soon after that as possible.

It follows that the ideal transmitter for a working and standby system is one that can be on full power almost instantaneously after having initiated the start signal, but can remain completely unenergized until required. Modern transmitters have a high content of solid-state circuitry but some valves are still used. There may be three for a 15kW v.h.f equipment, or only one for a 1kW equipment, but whilst the filament is energized the guaranteed life is being expended. Filaments in a standby equipment should, if possible, be unenergized. High gain tetrodes are now available that only require a one second filament heating time before the application of anode and screen voltages. It is thus practical to design a v.h.f transmitter having a two to four second overall starting time. In fact, the starting time is mostly dictated by the time taken for the cooling fan to run up and the air interlock to operate.

Another relevant factor is the number of moving parts in an equipment for as this number is reduced the reliability of the equipment increases. Control relays have been replaced in modern designs by solid-state switches as transmitters using control relays have a habit of failing to start due to bad contacts. This could be disastrous in a working and standby system because there is no way of making certain that either the r.f changeover switch will operate, or the reserve transmitter start. Whilst the working and standby arrangement is simple this uncertainty is perhaps the biggest disadvantage of the system and the more moving parts that can be eliminated the less the uncertainty becomes. It has been established that the likelihood of a completely solid-state equipment failing to operate on application of the start signal is very low. Therefore a reserve transmitter of modern design can be left unenergized with some confidence that it will operate when required.

Every equipment has a reliability characteristic over its working life. Initially there tends to be a high fault incidence which rapidly falls as 'teething' problems and substandard components are located and replaced. Then follows a period of low fault

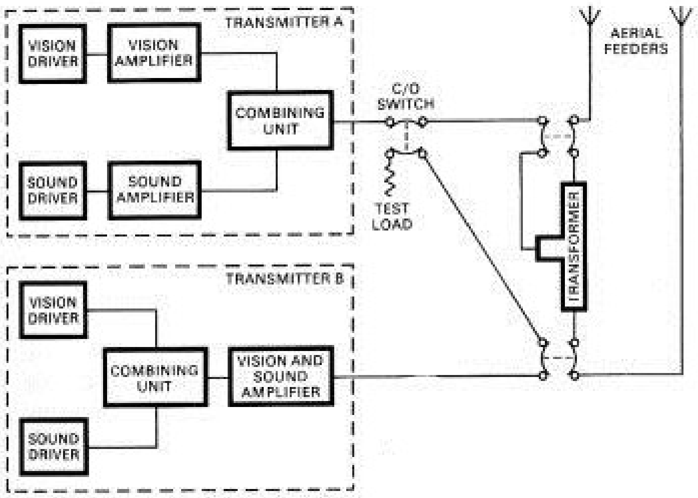

Fig.3 Working and low-power standby

incidence which remains during the working life of the equipment. Fault incidence will then increase rapidly to a point where equipment replacement becomes necessary. The 'bath tub' curve, as it is generally called, is the graph of faults against hours in operation, i.e, power applied and circuits energized. The calendar life of a standby equipment may therefore be lengthened if it is normally unenergized but well maintained.

There is no general rule regarding operation of a working and standby system. Some operators use a transmitter on alternate days to have recent knowledge that the standby equipment will work satisfactorily. Others take a different view – even to the extent of running one transmitter continuously for anything up to six months and then using the other as the main transmitter for the next six months. It was found in one case, where programme hours were 18 to 20 daily, that the cost of power to run continuously was more than offset by the saving obtained in increased valve life by avoiding switching filaments on and off every day.

When comparing running costs of a paralleled system to that of a working and standby system, for the same station output power, those of the working and standby will usually be slightly less. Also, when comparing capital equipment costs, there is little difference between the two systems with the working and standby again tending to be less. The same can also be said for valving costs but here, depending upon the type (v.h.f or u.h.f) and power of transmitters, the difference can be more marked.

Lower-power reserve transmitter

If in the opinion of the operating authority the cost of a paralleled pair of transmitters or two identical transmitters is not justified, but that some form of standby arrangement must be built into the system, it could well be decided to install a low-power transmitter as a reserve in a working and standby arrangement. With modern equipment design, where the trend is to have a low-power driver transmitter feeding a chain of amplifiers to obtain the required output powers, the advantage of having common components in the main and standby transmitters need not be lost. If television transmitters are involved, it is quite often possible to dispense with the sound amplifier and combining unit in the reserve transmitter and use the remaining amplifier for combined vision and sound signals. The linearity has to be very good to keep the intermodulation products low. This method is particularly attractive in u.h.f transmitters using klystron amplifiers where disposal of the sound klystron represents a significant cost saving. It is normal to expect that a vision klystron, which can produce say a 40kW peak vision signal, would give a combined signal of 8kW peak vision and 1·6kW f.m sound with 3-tone 'in band' intermodulation products being in the region of −50dB.

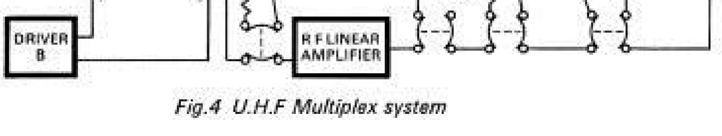

Fig.4 U.H.F Multiplex system

A u.h.f working and low-power standby system can therefore be arranged as shown in figure 3 while retaining the simplicity of the working and standby system. There are however three klystrons involved, but this number can be reduced to two for the same reserve facility if extra switching and control logic is incorporated – producing a system which has come to be known as 'multiplex'.

U.H.F multiplex system

This system is shown in figure 4 and comprises two drives, a logic and changeover unit, two klystron amplifiers (each complete with power supplies and cooling equipment) and a combining unit built into a switching frame. In the normal operating condition drive A feeds one amplifier with a vision signal and the other with a sound signal with the output of these amplifiers being fed to the combining unit. This mode of operation represents a conventional television transmitter and the corrections in drive A are set up to give the required performance. If a failure occurs, the system changes over to the reserve condition and the vision and sound outputs from drive B are combined at low level and fed into one of the klystron amplifiers. As the vision and sound signals are combined before amplification, the high-power combining unit is switched out of circuit. Drive B is always used in the reserve condition so that the corrections can be set up for combined vision and sound working. The combined output power is normally 7dB below the normal power. When comparing this system with that shown in figure 3, the capital cost is very much the same. Although there is a saving of one klystron, this is offset by the higher electrical power costs for the multiplex system. A comparison of running costs cannot be made until the price of power is determined and the klystrons replacement cost ascertained. While some uncertainty exists regarding the operation of the reserve transmitter when required, this uncertainty is largely with respect to the correct operation of the logic and feeder changeover switches, as the reserve drive is solid-state and the klystron amplifier was previously used in the normal condition. It follows that special care must be taken in the design of the feeder switches as they become the key item in determining the system reliability. Another important point is that, unlike a working and standby system, at u.h.f the reserve klystron does not have to run with filaments energized to ensure that the reserve condition can be put into operation with the minimum of delay. The klystron amplifiers in the multiplex system must have their own power supplies and cooling systems and be completely

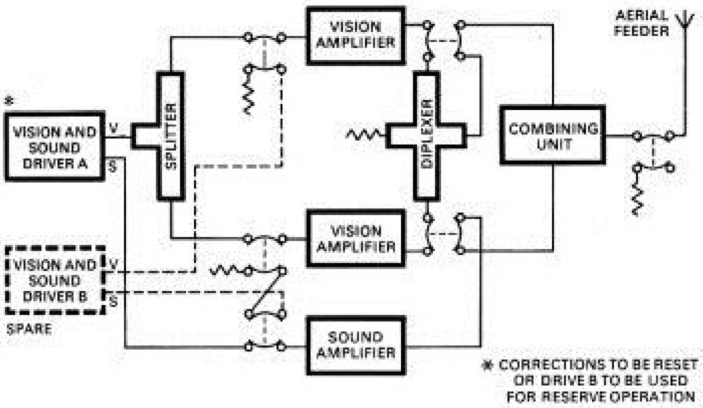

Fig.5 One sound and two vision amplifiers

independent of each other to obtain maximum reliability.

OTHER RESERVE SYSTEMS

If a broadcasting authority requires some form of reserve equipment in an installation, but funds for the reserve facility are low, a compromise has to be reached. A second independent transmitter is required to provide full redundancy and this will probably have to be sacrificed. The installation will take the form of a single transmitter incorporating reserve features, and there are many possibilities of providing such facilities including:

(a) **Power cutback**

Should the output amplifier fail the service can continue at low power by switching out the high-power amplifier. In some designs the output amplifier is made up by paralleling a number of smaller amplifiers using 3dB couplers. Failure of one amplifier results in a reduction of output power, but the output amplifier remains in service.

(b) **Television transmitter with one sound and two vision amplifiers**

The vision modulated driver feeds two amplifiers which are paralleled (Fig.5). The sound modulated driver feeds one amplifier and should the sound amplifier fail one of the vision amplifiers is switched for use as a sound amplifier. A spare modulated driver may also be incorporated in the system.

(c) **Combined sound and vision reserve**

The transmitter has a vision and sound chain fed into a combining unit. Both vision and sound final amplifiers are set up wideband although the sound chain normally operates narrow band. In the event of a failure in either amplifier the remaining amplifier is fed with combined sound and vision signals and the high-power combining unit switched out of circuit. This system is similar to multiplex and a spare modulated driver can be built in. The difference is that, unlike multiplex, the amplifier probably has a common cooling system and a common high-tension supply.

RELIABILITY AND PERFORMANCE OF AN INSTALLATION WITH RESERVE FACILITIES

The object of having a reserve facility is to increase the reliability of the installation above that of a single transmitter. Unless due care is taken it is quite possible to design a system which is less reliable than a single transmitter despite the reserve facilities provided. To avoid this hazard switching and change-over logic must be as simple as possible. Switches must be very robust and positive in action and the number of components using moving parts must be reduced to a minimum.

Care must also be taken to ensure that the best technical performance is obtained both in the normal and reserve conditions. Where corrections have to be applied to meet specification they will probably only be suitable for one operating condition. If full performance is required in the reserve condition a second set of corrections will be necessary.

CONCLUSION

This article has been written in general terms and applies to sound broadcasting and television transmitters. The suitability of a particular reserve system depends on the type of transmitters that are involved. Transmitters at u.h.f using high-gain klystron amplifiers and low-power modulated drivers have been designed into a variety of reserve systems. Transmitter installations at v.h.f are usually confined to paralleled, working and standby, and power cutback. However, some authorities have of late favoured the three-transmitter installations where at any one time two transmitters are paralleled with the third available to take the place of either working transmitter should a fault occur.

The author discusses the advantages and disadvantages of a number of reserve systems which a broadcasting authority will assess with their own requirements in mind. Their order of priorities and the compromise they are prepared to accept will lead them to a particular solution. It is therefore not possible to conclude that, in the general case, any one reserve system is preferable to all others.