The future of medium- and long-wave broadcasting

Problems facing the forthcoming planning conference

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The organization of broadcasting, in respect of transmitter frequencies and powers, requires a high degree of international co-operation if optimum coverage with minimum mutual interference is to be achieved. This applies particularly in the medium-frequency band, in which a transmitter having a service area radius of, say, 50km can produce interference by sky-wave propagation during the hours of darkness at fifty times that distance to other transmissions sharing its frequency channel. This co-operation is organized by the International Telecommunications Union and Fig. 1 shows the three regions into which the world is divided for radio planning purposes.

The present situation in Region 1 is based on the European Broadcasting Convention, concluded at Copenhagen in 1948, and the regional agreement for the African broadcasting area, drawn up in Geneva in 1966. However, the number of transmitters actually operating at the present time in the European area is some three times greater than the number for which provision was made in the plan. Region 3 has currently more than 1800 transmitters in operation but no overall formal plan. By common consent, comprehensive re-planning is well overdue. This conclusion will be endorsed by anyone in Britain that tunes a m.f. receiver, after dark, across the m.f. band.

It has now been agreed that a Regional Administrative Broadcasting Conference will convene this year in Geneva to commence the re-planning of frequency assignments in the m.f. and l.f. bands for Regions 1 and 3. The first session of this conference is scheduled for October 7th to 25th, 1974, and will, it is hoped, determine such technical parameters as the channel spacing, modulation system, protection ratios and propagation data to be used in the second session of the conference that will produce the final plan. The date for this second session will be some time in 1975 or 1976.

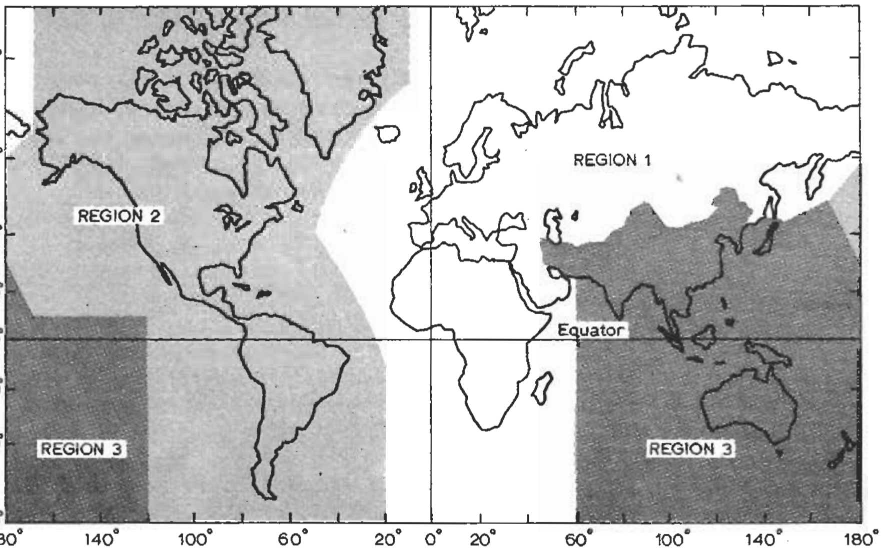

Fig. 1. ITU regions for radio planning purposes.

Propagation

Among the important factors in determining the optimum utilization of the m.f. and l.f. bands are the propagation characteristics of the medium. These are illustrated, for the range of distances of interest for a ground-wave service, in Fig. 2, which shows field strength as a function of distance for a base-fed vertical-mast radiator of the type commonly used at m.f. and l.f. transmitters. The curves labelled with frequency values represent the ground wave, while those labelled with values of mast height, h, represent the sky wave. Some features of this figure will bear explanation for readers unfamiliar with the subject.

(i) The curves are drawn for a constant cymomotive force of 300 volts. The cymomotive force is numerically the limiting value of the product of the field strength and the distance from the transmitter as this distance is reduced towards zero. This extrapolation ignores effects in very close proximity to the aerial (within about one wavelength). The product has the dimensions of voltage $(\frac{E}{d}\times d)$ and the term is usually abbreviated to c.m.f. or alternatively written as $E_o d_o$. The c.m.f. of 300V in these curves corresponds to a radiated power of 1 kW for a short aerial ($h \ll \lambda$), reducing to about 0.5 kW for $h = 0.575\lambda$. The magnitude of the radiated signal can alternatively be expressed in terms of the effective monopole radiated power (e.m.r.p.). This can be regarded as the signal produced when the stated power is fed into a perfect, lossless, vertical radiator of height much less than one quarter wavelength. As implied above, a c.m.f. of 300V corresponds to an e.m.r.p. of 1kW.

(ii) The level and shape of the sky-wave curve depends on the vertical radiation pattern (v.r.p.) of the transmitting aerial and hence on the radiator height. For values of h approaching zero, the v.r.p. follows a cosine law relative to the angle of elevation above the horizontal. This produces the sky-wave curve for $h \ll \lambda$ and holds with reasonable accuracy up to about $h = 0.2\lambda$. As h is further increased, the radiation becomes more concentrated in the horizontal plane, and the high angle radiation illuminating the ionosphere is correspondingly reduced, until a value of $h = 0.475\lambda$ is reached. The corresponding sky-wave curves are omitted from Fig. 2 for the sake of clarity. Had they been shown, they would be of similar shape to those for $h \ll \lambda$ and $h = 0.475\lambda$ and would fall between them. As h is increased beyond 0.475λ, the main-lobe radiation above the horizontal is further reduced but a side lobe appears in the v.r.p. that produces a relatively rapid increase in high-angle radiation. This is manifested in the sky-wave curves by the characteristic double-humped shape. The progressive increase in the near-field sky-wave at distances up to some 100 to 200km is caused by the high-angle side-lobe radiation while the progressive fall in the sky-wave at greater distances results from the continuing reduction in the illumination of the ionosphere by the main lobe. With simple base-fed mast radiators, if *h* is increased beyond 0.575λ the proportion of the input power that is radiated in the horizontal plane falls and the proportion radiated at high angles increases. Both of these features are undesirable for a ground-wave service. Also, if *h* is reduced much below about 0.15λ, the radiation resistance falls sharply and the reactive component of the impedance rises. As a result, the losses in the earth resistance rise with consequent loss of efficiency and it may become difficult, particularly at l.f., to secure correct matching between transmitter and aerial over the required bandwidth.

(iii) Fig. 2 should not be regarded as universally valid. It represents one specific set of conditions. For example, the curves are drawn for good ground conductivity typical of that found over much of the U.K. If the propagation path were all over the sea, the ground-wave field strength at 1500kHz would be about an order higher and if it were over ground of poor conductivity it could be an order lower. The sky-wave field strength also depends to some extent on the ground conductivity in the vicinity of the aerial.

Fig. 2 illustrates very clearly one fundamental restriction on ground-wave services. A limit to the satisfactory service range at night is set by the minimum acceptable ratio of ground-wave to sky-wave. The sky-wave curves are plotted assuming unity reflection coefficient in the ionosphere. In fact, over the range of distances and diurnal periods of interest in planning, the sky-wave will suffer about 10dB ionospheric attenuation at m.f. and about 15dB at l.f. Thus, if we assume that a 10dB ratio of ground to sky-wave is the minimum to give a service acceptably free from fading and differential sideband distortion, the maximum service range is given in Fig. 2 for m.f. by the distance at which the sky-wave and ground-wave curves intersect, or, for l.f., at which the sky-wave is 5dB greater than the ground-wave. This limit is independent of transmitter power but is very dependent on transmitter frequency.

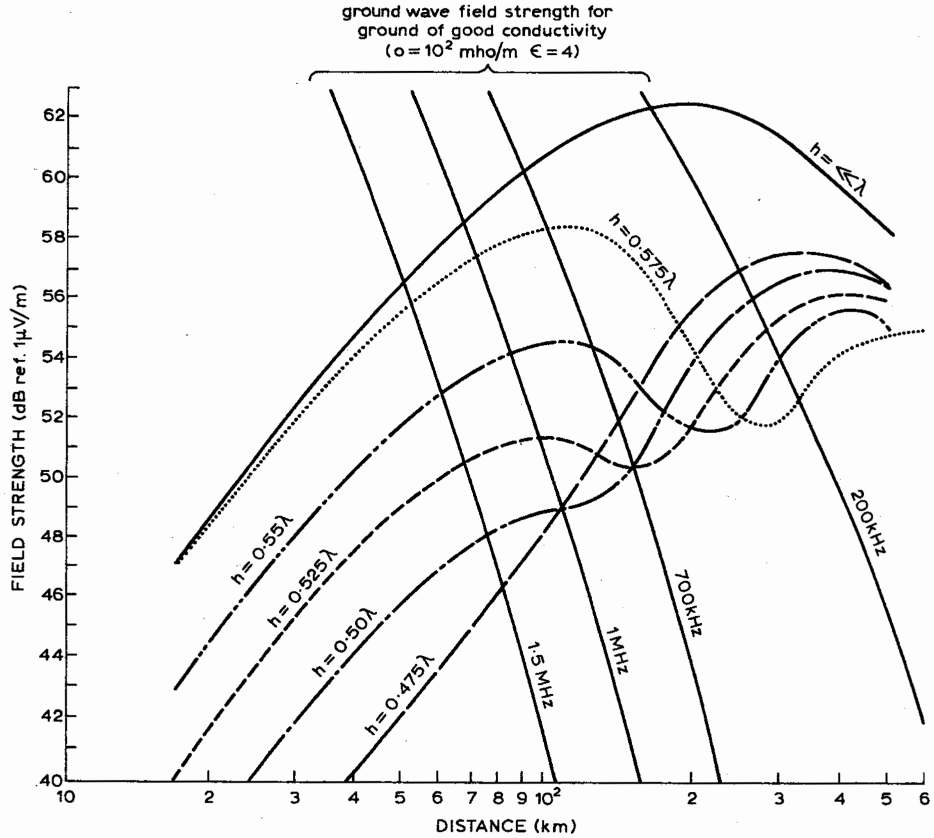

Fig. 2. Field strength from base-fed vertical aerial on ground of good conductivity. Layer height 100km, with unity reflection coefficient; c.m.f. = 300V; transmitting aerial velocity factor = 0.9, physical height = h; ground reflection factor = 1.9; loop receiving aerial.

One of the main factors limiting the total number of transmitters that can be accommodated in a given area and a given band is the interference between co-channel, and to a lesser extent adjacent-channel, transmitters that occurs after dark as a result of long-distance sky-wave propagation. Fig. 3 shows a sky-wave propagation curve applicable to the m.f. band. The level of the sky-wave signal can only be predicted statistically. It is subject to continuous fluctuation, varying from minute to minute due to turbulence in the ionosphere, with additional longer-term changes over periods of hours, days, seasons and years, the causes of which are not all fully understood. As a result, the sky-wave propagation information available to the planners is continually being up-dated as more measurement data are collected. Fig. 3 is a recently-proposed curve based on the continuing studies in this field carried out by the members of the International Radio Consultative Committee (CCIR) and the European Broadcasting Union (EBU). It shows the median field strength as a function of distance for a c.m.f. of 300V.

Co-channel and adjacent-channel interference and basic planning lattices

The essence of the planning problem is how to give listeners the maximum number of programmes consistent with an acceptable level of interference from other transmitters. The two important sources of interference are transmitters sharing the same channel and those in the two adjacent channels; transmissions at greater frequency spacings can be ignored in this context. It is first necessary to determine the channel frequency spacing. In Europe, this is at present 9kHz over most of the bands in question but this is not necessarily the optimum.

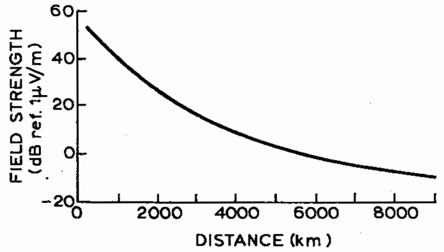

Fig. 3. Sky-wave propagation curve.

The protection ratio, i.e. the ratio of wanted to interfering signal for a given degree of impairment, is shown in Fig. 4 as a function of channel spacing. This is the curve recently adopted by the CCIR and is based on the performance of current receivers. It is plotted in terms of the relative protection ratio, that is the protection ratio at the stated frequency spacing, relative to that for co-channel interference, to give the same level of impairment of reception.

Suppose that we have to accommodate, in a fixed frequency band, a given number of transmitters within a finite area. If we adopt a large channel spacing, say 15kHz, adjacent-channel interference will be negligible but the number of channels available will be reduced; as a result the geographical separation between co-channel transmitters will have to be reduced, and co-channel interference will be greatly increased. On the other hand, if we reduce the channel spacing to, say, 5kHz, giving many more channels, co-channel interference will be reduced at the expense of a large increase in adjacent-channel interference. Somewhere between these limits there will be an optimum spacing, and this has been calculated on the basis of idealized transmitter location plans in the form of a regular geometrical lattice. The simplest form of elementary lattice is shown in Fig. 5. The transmitters sharing channel *n*

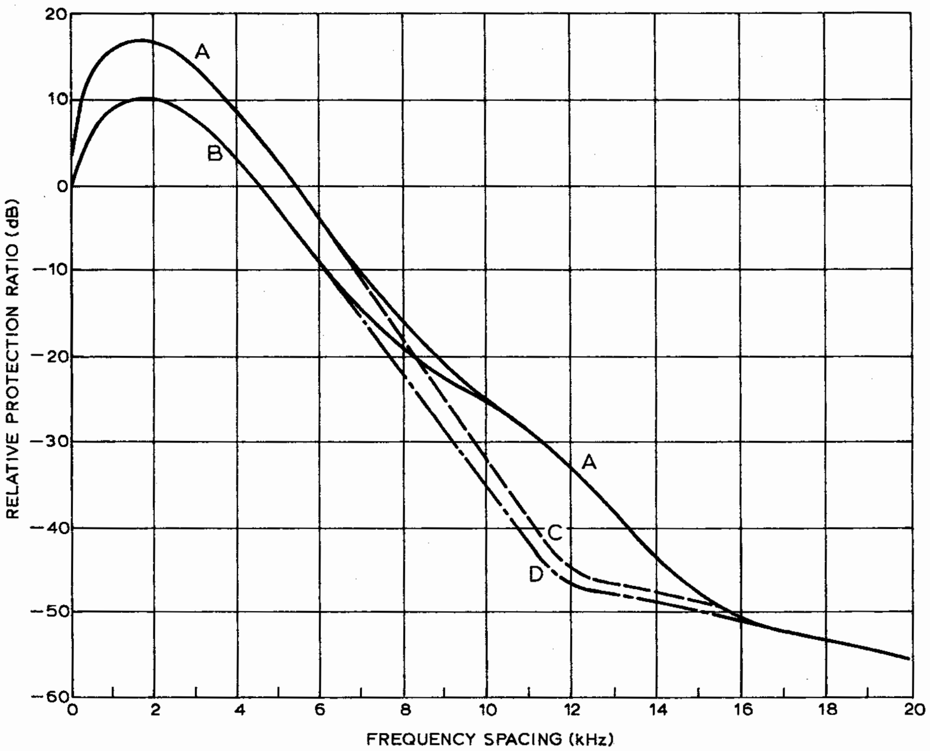

Fig. 4. Relative protection ratio. Curve A: limited degree of modulation compression at transmitter. Curve B: high degree of modulation compression at transmitter. Curve C: as Curve A but with a.f. bandwidth restricted to about 4.5kHz at transmitter. Curve D: as Curve B but with a.f. bandwidth restricted to about 4.5kHz at transmitter.

are disposed at the corners of an equilateral triangle of side D, which is repeated as necessary to fill the area being planned. Transmitters sharing channel $n+1$ and $n-1$ are similarly arranged, with the three individual channel lattices meshed so that each triangle of co-channel stations has one adjacent-channel station at its centre. With this arrangement, assuming that the layout of Fig. 5 is continuously repeated, each transmitter is surrounded by a ring of six co-channel transmitters at a distance d and six adjacent-channel transmitters at a distance $D/\sqrt{3}$.

This elementary model is obviously over-simplified, for example it gives us nowhere to locate the transmitters on channels $n+2$, so the next step is to distort the lattice to provide for a practicable number of channels. An example is illustrated in Fig. 6; the elementary cell of the lattice has become a rhomb, which again can be repeated as required to cover the area, with provision for 26 channels. The lattice gives the ratio of co-channel to adjacent-channel distance. From the sky-wave propagation curve, of which Fig. 3 is an example, this ratio of distances can be translated into a ratio of interfering signal levels. The relative impairment produced by co- and adjacent-channel interference is then obtained from Fig. 4. From studies of this type, based both on idealized lattice models and on actual transmitter site plans, it appears that the optimum channel spacing is very close to 8kHz and many broadcasting authorities, including the BBC, will urge that 8kHz should be adopted as the standard m.f./l.f. channel spacing in the forthcoming plan.

This lattice model is useful not only for channel spacing calculations, it is a powerful general-purpose tool for planning. It is quite feasible to construct a lattice for a hundred or more channels, the total number available in the m.f. band, but this would be of little practical use since in any one lattice it is assumed that all transmitters are of substantially identical powers, and we would not wish to be limited only to one size of transmitter. A practicable method of planning an area the size of an ITU region would be to decide how many categories of transmitter power are needed. Let us assume we require three, low power for purely local coverage, medium power for large conurbations and high power for regional areas. These three categories of transmitter could then each be allocated its own section of the m.f. band. Fig. 2 shows that the lower frequency channels are more suitable for large-area coverage and the higher frequencies for small areas. A separate lattice could then be prepared for each transmitter category, the co-channel distance (D in Fig. 6) being adjusted to suit the power, from about 1000km for the low-power lattice to about 4000km for the high power one. To avoid awkward adjacent-channel problems at the junction points in the spectrum where differing power bands adjoin, one or two channels could be allocated at each junction as international common-wave channels. These could be used by very-low-power transmitters on an unplanned basis but perhaps subject to an upper limit on the total power radiated by any one country on any one channel. Such a limit could be adjusted according to the area of the country concerned.

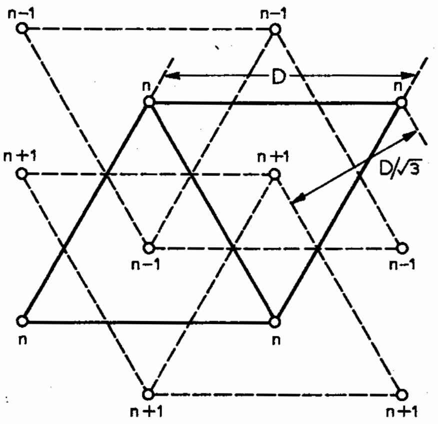

Fig. 5. Elementary planning lattice.

Strict adherence to a lattice-plan geographical distribution of transmitters would give, in an ideal situation, optimum area coverage. However, what we usually require is not optimum area coverage but optimum population coverage. Furthermore, we have also to take account of local terrain. Who wants a m.f. transmitter on top of a granite mountain of low ground conductivity in the middle of a desert where nobody lives? These factors can be allowed for. If a transmitter were required to be at a given specific location, it could be assigned the channel frequency appropriate to the nearest available lattice position but its permitted radiated power would be reduced by an amount sufficient to ensure that the interference caused to its co-channel and adjacent-channel neighbours would not exceed that produced by strict adherence to the theoretical lattice plan. It has been calculated that a displacement of 10% of the co-channel distance would entail a power reduction of between 2dB and 4dB but a higher power could be permitted if the displaced transmitter employed a directional aerial system.

One of the planning parameters that the Geneva conference will have to decide is the acceptable co-channel protection ratio. The EBU is recommending that this shall be 30dB. Nobody pretends that interference at this level is negligible but it should be remembered that it will, in the great majority of cases, occur only at night and will be suffered only by listeners at the fringe of a transmitter service area.

The value of this protection ratio determines the ratio of the radius of the transmitter service area to the co-channel distance. Thus, if the approach to planning is that a stipulated, fixed number of transmitters must be accommodated in a fixed number of channels in a given area, this determines the co-channel distance and the co-channel protection ratio then determines the interference-limited service area.

On the other hand, if the approach is that a given service area per transmitter is required with a given co-channel protection ratio at its limit, then the value of that protection ratio determines the co-channel distance, and hence the number of transmitters that can be accommodated in each channel.

The options: ground-wave or sky-wave, alternative modulation systems

Two assumptions have been implicit in the foregoing discussion, first that m.f. broadcasting, in Europe at least, will be planned mainly on the basis of ground-wave services and, second, that the modulation system used will continue to be double sideband a.m., as in the past. In the course of the wide-ranging discussions that have been going on among broadcasters during the run-up period to the forthcoming conference, both of these assumptions have been called into question. Let us consider first the question of ground-wave versus sky-wave.

There are three possible approaches to the planning of the m.f. band.

(i) To plan for two separate transmitter networks, one for sky-wave coverage at night, the other for ground-wave coverage by day.

(ii) To plan for maximum ground-wave coverage in daylight, considering only ground-wave interference and ignoring the incidence of sky-wave-propagated interference during dark hours.

(iii) To plan for maximum coverage by ground-wave services at night, regarding the increased coverage during daylight as a welcome bonus.

It has been argued that system (i), above, is technically the most efficient since it would give the listener the greatest choice of programmes both by day and by night, and this is undoubtedly true. However, it is subject to a number of disadvantages. Firstly, a sky-wave service is subject to fading and to the distortion resulting from selective sideband fading. Recent developments in technology may permit the production of inexpensive synchronous-detector receivers that eliminate the non-linear distortion produced by fading signals but no such receivers that are reasonable in price and easy to tune have yet appeared on the market. In any case the linear spectrum distortion will remain and, certainly with the envelope-detector receivers that are in universal use at present, sky-wave signals can only be regarded as providing a low-grade service. Secondly, sky-wave propagation is efficient because the signal attenuates only slowly with distance and a high-power transmitter can serve a very large area. The sky-wave network would therefore consist of relatively few high-power transmitters, spaced very widely apart. In Europe, where most countries are small compared to a sky-wave service area, this means that most if not all of the programmes available to listeners would originate outside their own countries. Language difficulties would severely limit the choice of programme material; indeed it is difficult to imagine what the programme could consist of apart from music, and this is not likely to have a wide appeal in view of the poor quality obtained from a sky-wave channel. In many countries also, the idea of providing access to extra-territorial broadcasting services may be politically unacceptable. Thirdly, we must consider the confusion produced in the minds of listeners by the twice-daily switchover from ground-wave to sky-wave network. These switching times would not be fixed but would cycle throughout the year with the changing seasons. The result would probably be that only the most dedicated radio enthusiasts would know what programmes to expect on what channels. To those lacking that degree of interest, the m.f. band would have all the characteristics of a lucky dip. Also, the performance of both networks would be sub-standard for a period around the switching time because the transition from day to night propagation conditions is gradual and not instantaneous. To summarize, although this proposal has features that appeal to engineers in so far as it is technically elegant and efficient, it does not appear on balance to have much to offer to the average listener that he would find of value.

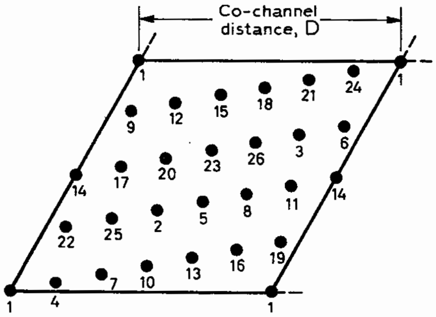

Fig. 6. A 26-channel lattice.

System (ii) is not really practicable. Sky-wave interference would be so heavy after dark that the services would be virtually unusable. In winter months in high latitudes, this condition would apply over most of every day.

We are thus left with alternative (iii), to base our planning on ground-wave services taking into account the night-time level of sky-wave interference, and this will probably be the decision of the conference for planning the greater part of the m.f. band. There are two important applications, however, for which a section of the m.f. band might be set aside for sky-wave services. One is for domestic broadcasting in countries covering very large areas (the USSR is an obvious example in Region 1). The other is if it is decided to permit part of the band to be used specifically for external or international services.

Turning now to the question of alternative modulation systems, the possibility of using some form of single-sideband (s.s.b) transmission system for broadcasting in the l.f. and m.f. bands has been extensively canvassed during the last few years. The advantage to be gained by such a system, compared to double-sideband (d.s.b.) modulation, is either a reduction of interference with the existing number of transmitters or an increase in the number of transmitters that could be accommodated with existing interference levels. The disadvantages are the heavy cost to the public of re-equipping with new and probably substantially more expensive receivers, and the difficulty of maintaining adequate broadcasting services during the interim period while the changeover is taking place. A further advantage frequently claimed for s.s.b. is that it reduces the non-linear distortion produced by selective-sideband fading in sky-wave propagation conditions. This is not strictly true; the reduction of this form of distortion is primarily due to the use of synchronous detection which is necessary in s.s.b. receivers, not to the modulation system itself.

Compatible single-sideband (c.s.s.b.) preserves the correct modulation envelope but confines the transmitted energy very largely to the carrier and one sideband. It is designed for receivers with conventional envelope detectors. As with the other s.s.b. systems discussed below, any overall improvement in the planning situation would rely on the use of new receivers with the appropriate narrower i.f. bandwidth. Recent international discussions have, however, tended to reject c.s.s.b. on the grounds of distortion in receivers with reasonably simple i.f. filters that are not phase corrected. Also, it would rule out the option of using synchronous-detector receivers to reduce non-linear distortion on fading signals.

Vestigial-sideband (v.s.b.) can be regarded as derived from a d.s.b. transmission by the use of an asymmetrical filter with 6dB attenuation at the carrier frequency. It gives full transmission of one sideband and full suppression of the other sideband beyond a certain distance from the carrier (e.g., 1kHz). Provided that the modulation depth is restricted to 70% or 80%, i.e., the carrier component has an amplitude 2dB or 3dB greater than the peak sum of the sidebands, this system has a substantial degree of compatibility with existing receivers. For a given carrier-to-sideband ratio the compatibility is slightly better than with s.s.b.-plus-carrier.

Single-sideband (s.s.b.) with no carrier transmitted is widely used in commercial point-to-point communication networks. It has the advantages that it eliminates the carrier-beat component that is a significant part of adjacent-channel interference and also reduces the level of ionospheric intermodulation ("Luxembourg effect"). It has the disadvantages that there is no means for operating a satisfactory a.g.c. system and also that the receiver must synthesize the demodulating carrier with an accuracy of about 10^{-6} without a reference component in the transmission to assist it. It is also not compatible with existing receivers.

SSB with carrier component overcomes the two major drawbacks of the system referred to above by radiating a carrier component. If the peak sideband level were restricted to about 70% of the carrier amplitude, this system would have a reasonable measure of compatibility with existing envelope-detector receivers.

Independent-sideband (i.s.b.) with no carrier transmitted is similar to s.s.b. but uses the upper and lower sidebands to carry two different programmes. It has the same advantages and disadvantages as s.s.b. and, in addition, it makes very stringent demands on the receiver design if adequate rejection of the unwanted sideband is to be achieved. This latter point is considered further below.

ISB with carrier component is similar to i.s.b. but with the addition of a carrier component to provide a.g.c. and assist in the regeneration of the demodulating carrier. Two different methods of operating this system may be distinguished. In the first method, the two sideband signals are radiated from the same transmitter. In this case the field strengths and fading characteristics of the two signals are sensibly identical at the receiving site, the common carrier component provides adequate a.g.c. information for both, but the receiver is required to achieve a high degree of unwanted sideband suppression. With this method of operation, the system is not compatible. In the second method, the upper and lower sideband signals are radiated from two transmitting stations which are geographically separated. In this case the two signals would require protection ratios of about 20dB against mutual interference in order to prevent confusion of the receiver a.g.c. system by the carrier of the unwanted transmission. This method would require a lower degree of unwanted sideband suppression in the receiver and would also have a measure of compatibility with existing receivers if the carrier component were sufficiently large, say 3dB greater than the peak sideband.

CSSB is not regarded as a serious contender for the reasons outlined above. SSB and i.s.b. without carrier are thought to be impracticable, primarily because of the difficulty in providing satisfactory a.g.c. in the receiver. VSB is receiving support in some quarters in Europe but is not generally a preferred system. It offers, in comparison to s.s.b.-plus-carrier, slightly better compatibility but requires a larger channel spacing. Also, being a s.s.b. system at high modulation frequencies, it requires a synchronous-detector receiver for distortionless detection but, being d.s.b. at low modulation frequencies, the regenerated carrier must be phase-locked to the carrier component of the incoming signal. This phase-locking represents a further complication in the receiver that is not required for s.s.b. or i.s.b.

SSB and i.s.b., in both cases with a carrier component, are the two alternatives to d.s.b. that are currently receiving most attention in Europe.

Part of the argument in favour of s.s.b., in all its forms, is that the relatively complex receivers required will not prove to be unduly expensive in view of the rapid developments now taking place in technology. This may be true but, in the U.K. at least, the great majority of sound radio listening on the m.f. and l.f. bands is with battery portable receivers. It is therefore necessary, in order to make the new receivers acceptable to the public, that not only must the initial cost be reasonable but the battery drain must also not be excessive. This latter requirement may well be difficult to satisfy. One prime requirement in receivers for either v.s.b., s.s.b. or i.s.b. is to re-generate a demodulating carrier. For s.s.b. or i.s.b. this need not be phase-locked to the incoming carrier and can have a frequency error of up to 2Hz. It can therefore be produced either from the incoming carrier component by filtering and amplitude limiting or by locking a free-running oscillator, or by generating it locally in a synthesiser of high accuracy without reference to the incoming signal. For v.s.b. the demodulating carrier must be phase-locked to the incoming carrier and the option of using a locally-synthesised frequency without reference to the incoming signal is not practicable.

Of the various methods proposed, the local-synthesis method is the one most likely to give reasonable ease of tuning. In any method deriving the demodulating carrier directly from the received signal or locking a free-running oscillator to it, there is difficulty in reconciling the conflicting requirements of ease of tuning with those of immunity to fading and spurious locking to adjacent-channel signals or to sidebands of the wanted signal.

Receivers for i.s.b. would need to provide adequate rejection of the unwanted sideband. If the two separate sideband signals associated with each carrier were radiated from the same transmitter, a rejection of at least 40dB would be required. This would be impracticable by i.f. selectivity alone and would require the use of post-detector quadrature networks giving a constant 90° phase shift over the whole modulation-frequency band. For broadcasting use this bandwidth extends from, say, 50Hz to 5kHz and the problems of production of such networks to the required tolerances and at an economic price may be very difficult to solve. If the two sideband signals were radiated from geographically separated transmitters they would require protection, in their respective service areas, against mutual interference as discussed above. Assuming a protection ratio of about 20dB, this would ease the requirement for unwanted-sideband suppression. The quadrature-filter technique would still be necessary but the tolerances in the filters could be considerably relaxed.

Receivers for any new modulation system would need to be compatible with d.s.b. transmissions, which would still be radiated during the changeover period. VSB receivers, and i.s.b. receivers with 40dB unwanted-sideband suppression, would be automatically compatible since they would in effect treat an incoming d.s.b. signal as v.s.b. or i.s.b. and demodulate it normally. SSB receivers, and i.s.b. receivers with a lower order of unwanted-sideband suppression would require some additional circuit features in order to cope with d.s.b. The simplest method would probably be to provide a conventional envelope detector, with an appropriate adjustment of the i.f. bandwidth if necessary, brought into circuit by a manually-operated or automatic switch. If it were decided to change the system of modulation to v.s.b. or s.s.b.-plus-carrier, it is difficult to foresee precisely how the process of conversion would be organized. Two alternative methods might be possible. One would be to set aside a portion of the m.f. band for use by transmitters operating on the new system and expand this in successive stages as suitable receivers were purchased by an increasing proportion of the public. The alternative would be to convert transmitters, a few at a time, initially to a more-or-less compatible form of s.s.b. with an enhanced carrier component and preserving the original d.s.b. channel spacing and later, in the final stages of the transition, convert to full non-compatible s.s.b. with closer-spaced channels.

With either method, the successive stages of conversion would need to be implemented by all countries in the planned area proceeding in unison. Eventual completion of the changeover could only be realized when virtually all listeners had acquired receivers suitable for the new system. Unless the receivers were fully acceptable to the public in terms of first cost, running costs and operational convenience, there would be a danger of the conversion plan remaining in its interim stages for an indefinite period. During this period, owners of old-type receivers would suffer increased distortion, increased interference and possibly a restriction in their choice of programmes, with no compensating advantages.

If the new system were i.s.b.-plus-carrier, conversion would still have to be on a stage-by-stage basis as the new receivers came into use but international planning would be far simpler. It could be left to individual countries to convert their own channel assignments to i.s.b. operation with two programmes per channel, if and when they wished, or to continue indefinitely with d.s.b.

Thus, even if the decision of the Geneva conference is to aim for the ultimate conversion of the m.f. and l.f. bands to operation with some novel modulation system, this conversion would have to be spread over a considerable period of time. The immediate plan will have to be based on d.s.b. operation, at least over the greater part of the bands in question.

One cautionary note. Although the present situation on the m.f. and l.f. bands in Europe owes little to formal planning, it is the result of a great deal of empirical cut-and-try experience. It is, therefore, not to be expected that the outcome of the planning conference will be a staggering reduction in interference levels all round. The most we can hope for is a moderate improvement.

Channel frequencies and bandwidth

Apart from the fundamental requirements of good planning, i.e. ensuring that transmitters are put in the right places and on the right channels and that there are not too many of them, there are some other measures that can be adopted in order to minimize interference. If all transmitter carrier frequencies of receivers were made integral multiples of the channel spacing (i.e., with 8kHZ spacing, all carrier frequencies and i.fs would be on $8n$ kHz with n integral), the interference resulting from spurious responses in receivers (image channel and the like) would produce carrier beats either at zero frequency or at the channel spacing frequency. This would be much less troublesome than the present situation where such interference can produce whistles anywhere in the audio-frequency range. With present-day receiver designs this proposal would not give any great benefit because of the tolerances in i.f. values. With future improvements in receiver manufacturing techniques, particularly if simple types of frequency synthesizer are used as local oscillators, the potential benefit may be realizable. The conference may well decide that the proposal is worth implementing as far as frequencies are concerned.

Another operational measure that is being adopted by a number of broadcasters, including the BBC, is the limitation of the modulation-frequency bandwidth of m.f. and l.f. transmitters. The principle of this is that the sidebands corresponding to modulation frequencies above about 5kHz are so heavily attenuated in present-day receivers that they do not contribute significantly to the quality of the received programme but do contribute significantly to the interference produced in the adjacent channels. It has been suggested that the audio frequency bandwidth transmitted should be limited to no more than one half the channel frequency separation. Then, if the receiver i.f. bandwidth were similarly limited, adjacent-channel interference would not occur. If this suggestion were adopted, it would mean that the quality of reproduction for all listeners, at all times, would be limited for a benefit needed by only fringe area listeners after dark. The preferred BBC practice is to equip l.f. and m.f. transmitters with low-pass filters at the modulation input that have a slightly rising response between 1kHz and 4.5kHz and then a fairly rapid cut above 5kHz. This has been found to give a modest benefit in adjacent-channel interference with no perceptible degradation of quality on average receivers.

How do we make the best use of the m.f./l.f. bands?

When the Geneva conference has completed its task, the broadcasters have to decide how to make best use of the channels they have got.

In the U.K. we have hitherto tried as far as possible to duplicate our main programmes in the m.f./l.f. and the v.h.f. bands but, with Radio 1 and 2 sharing one v.h.f. channel and the Open University and schools transmissions taking over the Radio 3 and Radio 4 v.h.f. networks from time to time, this policy has become progressively harder to implement. With increasing demands for specialist programmes for language minorities, road information to motorists and so on, it may well be that duplication is a luxury that we shall have to abandon. Should this be so, it is obviously desirable that the allocation of services between the m.f./l.f. and v.h.f. bands should take account of the characteristics of the channel and the requirements of the programme and its audience.

Some types of specialist audience are easy to distinguish, for example motorists. The m.f. and l.f. bands offer many advantages for a programme intended primarily for car radio reception. The area of coverage of transmitters is greater, particularly at the lower carrier frequencies, than with v.h.f., hence the receiver requires less frequent re-tuning and the motorist is less frequently distracted from his primary duty of keeping himself and other road users alive. The signal level is more consistent and less liable to the extreme variations that occur close to ground level at v.h.f. The superior quality and signal-to-noise ratio possible with v.h.f. are less important in the unfavourable acoustic environment of a car and even the dynamic compression that we are compelled to use on the m.f. and l.f. bands, to improve the signal-to-noise ratio, can be a positive advantage for car reception where soft passages tend to become inaudible against the high acoustic noise level.

Another listening situation in which m.f./l.f. would often be preferred to v.h.f. is for what might be termed the mobile audience; the housewife carrying a portable receiver round the house to provide a background to the daily chores or the picnicker with a portable receiver on the beach. The standing-wave pattern existing at v.h.f. inside houses can produce a situation in which either a v.h.f. portable will not work satisfactorily in some positions or the signal will fluctuate and periodically drop below a usable level as the listener moves about. In the open air, the receiver is usually standing on the ground, and the field strength at ground level of a v.h.f. signal horizontally polarized, as the great majority of Band II transmissions are, is theoretically zero and in practice often nearly so.

The audience to whom the characteristics of v.h.f. would appear to be most suitable are those listening at home on a fixed receiver, particularly those to whom sound radio is a major contributor to their home entertainment and who are prepared to acquire a receiver giving high-quality reproduction. Perhaps one could attempt a generalization, that m.f. and l.f. are better suited to casual listening and v.h.f. to serious listening. Having done this, we are not much further forward unless we can classify programmes into those intended for casual and for serious listening. That is a rather more difficult problem, bearing in mind that what is memorable to one listener is trivial to another. Perhaps we should be thankful that some problems in broadcasting do not fall to us, the engineers, to solve.

Acknowledgements. The author wishes to thank the Director of Engineering of the BBC for permission to publish this article and his colleagues in the BBC Research Department for assistance in preparing it.

Sixty Years Ago

From our August, 1914 issue . . .

"The efforts to solve for the vision the problem or problems of space which the telephone has solved for the ear bears a close enough resemblance to some of the problems in the wireless field to permit us to follow with sympathetic interest the endeavours which scientists are making to reach a practical solution. Hopeful results were foreshadowed in a communication made during the past month to the Academy of Sciences in Paris by Professor Lippmann on behalf of M. Georges Rignoux, who has devoted himself to this subject for many years. M. Rignoux has now devised an improved apparatus to which he has given the name of Telephote, and which is just a scale of shade and light. There is a transmitting and receiving apparatus connected by two wires. At the transmitting station a concave mirror throws the rays of a 200 candle-power Nernst lamp upon the object which is to be reproduced at the other end of the wire. Each point thus illuminated is shown through a magnifying glass upon a screen composed of cells of selenium metal, of which the electric resistance varies in accordance with the intensity of the light thrown upon it. An electric current is passed through this screen, and, thanks to the peculiar properties of selenium, is transmitted in varying strength according to the amount of light on each portion of the screen. The currents are transmitted over a wire to the receiver, which emits through a Nicol prism rays of light corresponding in intensity with the current received. These rays are cast through a lens upon a revolving mirror, which reflects upon a screen a picture of the light and shade of the object at the other end of the wire, drawn in small rays of light. M. Rignoux claims to have succeeded in his laboratory in thus producing letters of the alphabet, and he is hopeful of further progress."

wireless
world

Using channels efficiently

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An article in this issue referring to the forthcoming re-planning of the m.f. and l.f. broadcasting bands draws attention, once again, to the permanent problem of finding enough space in the frequency spectrum for all the radio systems we would like to set up. We tend to be so preoccupied with the frequency spectrum, thinking up ways of making the most efficient use of what bandwidth is available to us, that perhaps we do not pay enough attention to the other constituents of every communications system—time and signal-to-noise ratio. Do we in fact make the most efficient use of these also?

There is not much we can do with signal-to-noise ratio except to trade it for more information in a given channel, as in the stereo broadcasting system, but time seems to offer more possibilities. It is a sobering thought that every night we switch off for several hours hundreds of megahertz of broadcasting bandwidth and numerous communications channels. However, to make use of all this for day-time purposes we would have to devise systems with storage or recording facilities. But there are plenty of opportunities of making more efficient use of time during day-time operations, particularly in mobile communications where channels are not continuously loaded but tend to be used intermittently for separate messages. Of course with mobile radio the time gaps between messages are already utilized to some extent in systems where different users time-share a single channel—radio taxis, for example. But this is a haphazard process and does not make the best use of the available channel capacity.

One systematic method of utilizing a group of channels efficiently, called dynamic channel assignment, was proposed by J. F. Craine at the recent Communications 74 conference at Brighton. In this the use of a number of channels is controlled automatically by an exchange, rather as in the trunk telephone system. When a call is made from a station the exchange assigns it to a free channel in the same manner as an automatic line exchange would find a free trunk route. The receiving station must then be informed that a call is being made and that its equipment has to be tuned to the appropriate channel.

Another possible system, suggested by S. R. McConoughey of the American FCC, is based on the principle of trading signal-to-noise ratio for more information, as mentioned above. Each user has access to multiple channels and the system simultaneously shares the same radio spectrum with other users. Instead of experiencing channel blocking, a user would observe only a gradual degradation of signal-to-noise ratio as the loading increased.

Undoubtedly such systems would be very complicated, but should certainly be feasible with the present technology of digital processing and large-scale integrated circuits at our disposal. This complication is the price we would have to pay for more efficient utilization of channel capacity.