Shortwave broadcasting efficiency

A method of measuring the success of a broadcasting service in achieving its target coverage

by George Jackson, *Radio Canada International*

Before doing an analysis of how successful we can be in reaching our listeners, we must know what it is we are up against. We could go into great detail and list such factors as type of listener, his habits, his tastes and so forth, but these are parameters which we can assume are taken into consideration by those who are providing the programmes for the region involved. This analysis is based on the need to reach the target in the first place. If you do not reach your audience physically, it is impossible to stimulate them mentally, no matter how good your programmes are.

Considering this fact, then, we must ask ourselves three main questions about our shortwave service:

- How well do we overcome the inconsistent nature of shortwave eption?
- How successful are we in overcoming interference to our broadcasts caused by severe crowding of the high-frequency broadcasting bands?
- How well do we tailor our transmissions to the best possible listening periods in our target area?

These questions relate directly to the three major factors influencing shortwave broadcasting. These are: ionospheric propagation; band crowding; and programme timing. The degree to which a broadcaster can control these factors will determine the success or failure of his target service.

A broadcaster can successfully overcome, or at least diminish, the negative effects of the major influencing factors by carefully manipulating four variables. These parameters are completely within his power to control and, used correctly, can make a second-rate broadcaster into a dominating force on shortwave. The four variables are: programme timing; frequency diversity; transmitted power; and transmitter location. This article shows how to best combine these four parameters to achieve a ninety to one hundred percent *probability of success* which we shall call "efficiency".

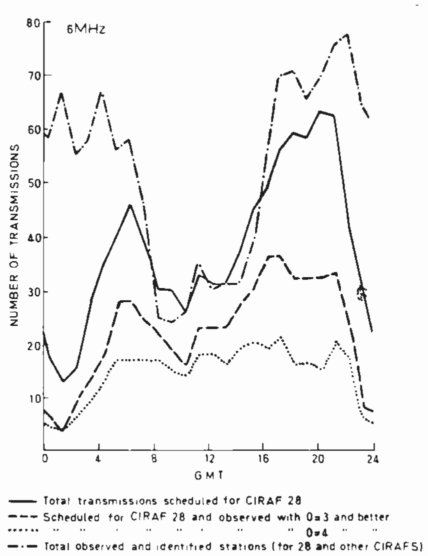

Fig. 1. Comparison of number of transmissions in the 6MHz band of scheduled and observed shortwave stations in CIRAF zone 28 (see footnote) over a twenty-four hour period.

Programme timing

We will define prime listening times as 0600-0900 and 1800-2400 hours local. Although, admittedly, these times vary for certain regions according to working hours and listening habits, audience research and current broadcasting practice* indicate that this definition is correct.

Outstanding programmes can draw listeners to periods outside the prime hours, but only if the other variables are combined in such a way as to produce a highly "receivable" programme. Such occurrences as this are quite rare and usually happen in conjunction with an event of special interest to a certain target area or group of areas.

Length of programmes within prime times is the next factor to consider. It has been generally established that a broadcaster's "presence" in a given target area need not be excessively long to be effective. Surveys have shown that a two-hour presence (not necessarily continuous) during prime time would be sufficient to either hold audience interest or to capture the greatest number of listeners†. Longer periods tend to become repetitive and tedious while shorter periods make it difficult to programme all available information. Also, the chances of losing an entire day's programmes due to interference or propagation become greater as presence is decreased.

Individual programme lengths can vary within the two hours according to the material to be aired and the policies of the broadcasting organization. Radio Canada International uses half an hour as its basic block because this time is manageable, because it best uses, and to a degree compensates for, staff limitations, and because it permits us to fit our multiplicity of languages into the desired prime time segment. On the other hand, Radio Netherlands uses an eighty-minute format which can be easily handled by an adequate technical plant and relatively few languages.

Even after a timing format has been developed by a broadcaster, he cannot be sure the plan can be followed. Technically, a transmission may not be propagated from the transmitter location to the target at the desired time. Interference patterns may be such that programmes are not heard at the desired times due to inadequate technical facilities. This is why it is important that the second, third and fourth variables (above) be considered in conjunction with programme timing when one is considering a target service.

To summarize then, we have outlined prime time (0600-0900 and 1800-2400 local), language or broadcasting presence (two hours ideal), optimum programme length (15 minutes to two

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*A graph prepared by the Deutsche Welle (shortwave service of the Federal Republic of Germany) representing current use of the 6MHz band in CIRAF zone 28 is shown in Fig. 1 to illustrate current broadcasting practice. (CIRAF stands for Conferencia Internacional Radiodifusion por Altas Frequencias, an ITU conference for h.f. broadcasting at Mexico City during which the world was divided up into a number of zones).

†This, of course, does not apply in the case of a world service format such as that used by the BBC. Their programming is prepared with different ultimate goals from those of most other international shortwave broadcasters.

hours) and technical limitations to programme timing.

Frequency diversity

The factor which can be varied the most and which can have the greatest single effect on the success or failure of a transmission is that of frequency. In general, frequencies between 2 MHz and 30 MHz can carry, with varying degrees of success, voice or data transmissions over long distances. International broadcasting has been allotted bands of frequencies within the 2MHz to 30MHz spectrum. These areas occur in the 6, 9, 11, 15, 17, 21 and 26 MHz bands and comprise some 40 to 70 discrete frequencies in each band. The 7MHz band is also used, although not in the western hemisphere.

A shortwave transmitter can be tuned to any one of these discrete frequencies. The antenna system associated with the transmitters is, on the other hand, constructed on the basis of one or more antennas per shortwave band per target area. The number of discrete frequencies allotted to each programme is therefore directly related to the number of transmitters and antennas available for use at that particular time. The importance of this fact cannot be over-emphasized in that our analysis will define the optimum amounts of hardware and their ideal dispersion based on our overall priorities.

It is relatively easy to put a frequency on the air — but which one, or indeed, which ones? Ionospheric theory and past results have shown that the ability of a certain frequency to reach a given target depends on the time chosen for its operation. The ability of the ionosphere to support a given frequency depends on time of day, season of the year and period of time within the 11-year cycle of sunspot activity. (See, for example, H.F. Predictions in this journal.)

To determine correct frequency usage, a frequency manager will consult his charts for a certain time of day and season of the year and come up with a maximum usable frequency (m.u.f.) for a given path. He will check his records for a similar period in the preceding year and then select a frequency band which should allow transmission to the target area desired. Depending on available transmitters, he will then select one or two other bands below that m.u.f. band. The purpose in doing this is to allow for m.u.f. variation throughout the season he is planning. Once he has chosen the bands, he will begin the difficult task of choosing discrete frequencies within each band.

The frequency manager then goes to his transmitter plant and surveys his equipment. If he has enough transmitters and antennas he will assign a minimum of two and as many as five or six frequencies to that particular programme. Diagrams will show that the more frequencies you have, the better are your chances of being received.

To use Sackville to Western Europe as an example of a route, let us suppose we wish to broadcast a German programme at 1800 local time. All the data available show that 15MHz is the m.u.f. at that time. The frequency manager would then choose two 15MHz, two 11MHz and two 9MHz frequencies. Say these were 15.280, 15.325, 11.875, 11.860, 9.680 and 9.625 MHz. He would then look at his available transmitters and find, say, four were free at that time. Next, he would look at his antennas. There he would find one European antenna array capable of transmitting one frequency only in each of the 6, 9, 11, 15 and 17 MHz bands. His only option then is to use 15.280, 11.875 and 9.680 MHz even though six frequencies would have been ideal and four could have been used with the available transmitters. This time the limitation was antennas. Another time it could be transmitter or frequency availability.

One can easily see that management of frequencies goes far beyond choosing correct operating bands for a given programme. Propagation, interference patterns and equipment availability all play their roles in allowing frequency diversity. The next step is to consider the equipment requirement.

Transmitted power

It is said, and rightly so, that one or two watts of transmitted power on the correct high frequency, if it is completely clear, will permit communication between such far-flung regions as the Middle-East and North America, Europe and Australia, or South America and the Soviet Union. This type of communication was successfully used by both broadcasters and radio amateurs in the early days of short waves. As time passed however, and more institutions began using the h.f. spectrum, the possibility of finding a completely clear frequency became increasingly difficult. The only alternative, once one is sure one is using the correct frequency, to finding a clear channel, is to increase the radiated power of the transmissions. In this way, the communicator can out-muscle other users of his frequency and achieve his end.

This situation has been developing in h.f. broadcasting over the past three decades and has now reached crisis proportions. The broadcasting bands are now so crowded that there can be up to ten listings on any one shortwave frequency. This makes for fierce competition and, ultimately, a transmitted power race.

Transmitted power is, of course, the result of two variables, the output power of the transmitter and the gain of the antenna. The product of these variables is the effective radiated power of a transmitting location. For example, a broadcaster could be transmitting a programme with a 250kW transmitter and an antenna with gain of 12dB. Since 12dB is an amplification factor of approximately 16, this means that the effective radiated power of the transmission is 250,000×16=4MW. This is mentioned just to illustrate the point which broadcasters have now reached in the power struggle. Where 1 watt of power was effective in the early '30s, we now require power in the order of 10 megawatts just to compete.

Broadcasters today are using antennas whose gains vary anywhere from 16 to 23 dB with the average being around 18 or 19 dB (amplification factors of 63 to 80). Radio Canada International is in the process of constructing one antenna array for each target area which will be of this magnitude.

At the same time, broadcasters are, little by little, increasing their transmitter power. Whereas in the 1950s, transmitters of 50 and 100kW were adequate, the 1970s and '80s will require 250 and 500kW transmitters. Already, most broadcasters are using 250kW and 300kW for their long-haul circuits (BBC, Voice of America, Deutsche Welle and Radio Netherlands among others are in the 500kW club) and 100 to 200kW for their shorter distance circuits. In the case of RCI, we have been using our new 250kW transmitters for European programmes and the old 50kW transmitters for our North American, South American and African circuits. Ideally, 500kW with 20dB antennas are needed for Europe, Africa and South America, while 250kW with 16dB antennas would serve North America.

Transmitter location (programme source)

The last of the engineering considerations involves the source of the transmitted programme.

As already discussed, the aim of a shortwave broadcasting service is to put the strongest possible signal into a target area. Good frequency selection and powerful and diversified transmitting equipment are two ways of accomplishing the objective. The third and perhaps most significant way to "out-muscle" competitors is to be within one "hop" of your target. That is to say the strongest shortwave signal occurs in the area approximately 1500-3000 miles from the transmitter. Depending on antenna specifications and the frequency chosen, this distance represents the landing area of a wave which has been transmitted upwards and has been reflected once from one of three or four layers of the ionosphere. Obviously, the mixture of good frequency selection, high transmitted power and proximity to the target will allow for the optimum received signal strength.

Larger organisations such as Voice of America, BBC and Deutsche Welle have used the "one-hop" formula to advantage by installing relay stations around the world which are a distance of one hop from the transmitter or from each other. RCI is not in a position, financially, to provide such a relay system for its listeners, although over the years, co-operation with the BBC and DW has resulted in relay exchanges with those broadcasters. This has resulted in a viable service to the USSR for RCI which, even with high power and good frequency selection, would not otherwise have occurred from Sackville.

Efficiency calculation

The purpose of this analysis is first to determine the degree to which a broadcaster is successful in overcoming the largely uncontrollable factors of ionospheric inconsistencies and interference caused by overcrowding of the shortwave bands, and second to produce a plan by which this degree of success can be enhanced by intelligent manipulation of resources.

We will use a system of weighting for the various factors over which we have some control in order to derive a formula which we can use to calculate a numerical efficiency which will indeed be a measure of our success in overcoming the odds. To put it more simply, how great a chance are we giving ourselves to place a competitive signal in our target areas? Further, how much greater can these chances be if we change a few things? These are the questions we hope to answer in this brief.

The controllable factors are those outlined in the preceding sections and can be listed as follows: programme timing (controllable, but constrained by operating finances, possible deployment of manpower and propagation); number of frequencies (controllable, but limited by equipment availability and band crowding); transmitted power (controllable, but limited by equipment availability, hence finances); and location of transmitters (programme source) (controllable, but subject to political and financial considerations).

We can assign points to these various factors in proper combination with one another. Programme timing can be measured against its "presence" within defined prime times locally. Number of frequencies and transmitter location in relation to target area must be considered together as they are directly related, as are transmitted power and transmitter location in relation to target area. The point system is constructed, then, as follows:

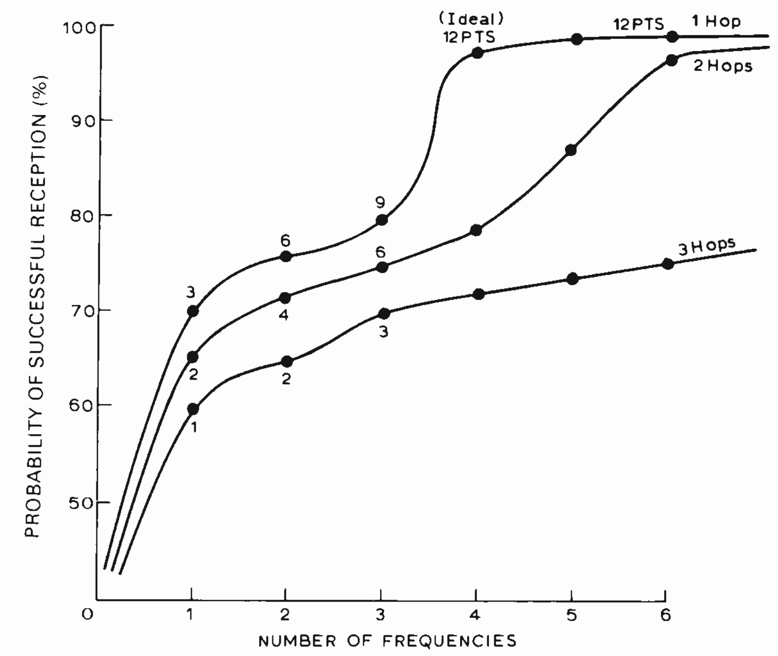

Fig. 2. Probability of successful reception vs. number of frequencies. (Power constant at 250kW).

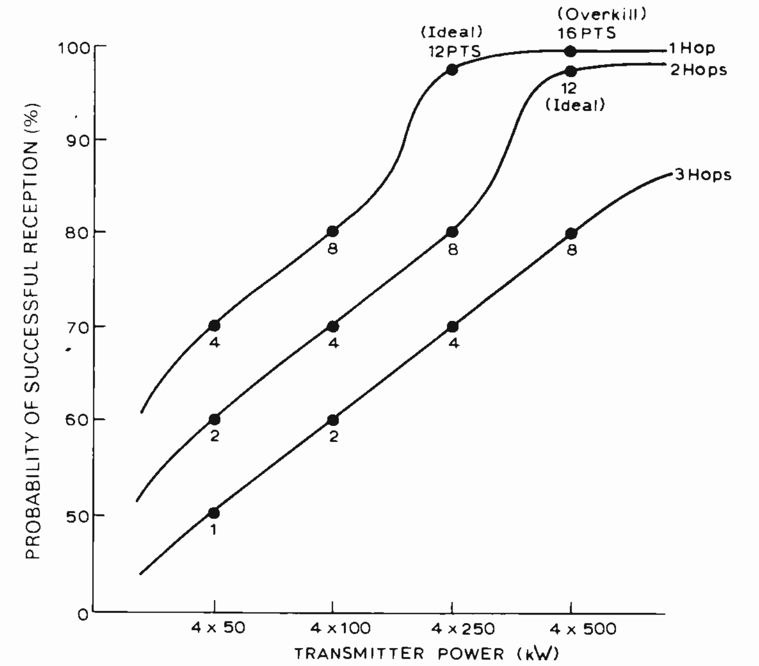

Fig. 3. Probability of successful reception vs. transmitter power. (Number of frequencies constant at 4.)

Programme timing ● 6 points are allotted if the target area service (by language) occupies a "presence" of 2 hours within prime time. ◗ 5 points are allotted if this "presence" is 1½ hours. ◗ 4 points are allotted if it is 1 hour. ◗ 3 points are allotted if it is ½ hour.

Frequencies transmitted as a function of programme source (Fig 2). ◗ 3 points are allotted for each frequency transmitted, one "hop" from the target (1,500-3,000 miles). ◗ 2 points are allotted for each frequency transmitted, two "hops" from the target (2,500-4,000 miles). ◗ 1 point is allotted for each frequency transmitted, three "hops" from the target (3,500-5,000 miles).

Transmitted power as a function of programme source (Fig 3). ◗ 4 points are allotted for each 500kW transmitter, one "hop" from the target. ◗ 3 points are allotted for each 500kW transmitter, two "hops" from the target; also each 250kW transmitter, one "hop" from the target ◗ 2 points are allotted for each 500kW transmitter, three "hops" from the target; also each 250kW transmitter, two "hops" from the target; also each 100kW transmitter, one "hop" from the target. ◗ 1 point is allotted for each 250kW transmitter, three "hops" from the target; also each 100kW transmitter, two "hops" from the target; also each 50kW transmitter, one "hop" from the target.

We can now define three specific measurable categories for our transmissions. These are: (A) Evaluation of individual programmes. (B) Evaluation of a language service to a target area. (C) Evaluation of the overall service (several languages) to a target area.

In category (A) only "frequency/source and power/source points" can be assigned as "programme timing" is based on overall language presence during prime time and therefore is not applicable to individual programmes. In category (B) all factors can be assigned and a language efficiency calculated. In category (C) all factors can be averaged and a target area efficiency can be calculated.

Definition of the "ideal" point total. In order to determine the efficiencies for categories (B) and (C) above, we must define an "ideal situation" combination of factors and hence, an ideal point total for these categories.

For programme timing, it is quite obvious that the ideal score is 6 in that we wish to achieve the two-hour "presence" per language within prime target area time. Any less would compromise the overall objective. The ideal point total is 6.

For the frequency/source factor, an ideal situation would constitute a four frequency service no more than one hop away. Frequency diversity can be used to lessen the effects of the ionosphere and band congestion. The provision of two frequencies in each of the two optimum bands, or two frequencies in one band and one in each of two others will provide an "ideal" situation. Naturally more frequencies one "hop" away would better the situation still further, but overall efficiency would vary only slightly for each frequency added (see Fig. 2). The ideal point total is 4 × 3 = 12.

For the power/source factor, the best situation would occur if each of the frequencies mentioned above were powered by a 500kW transmitter one "hop" away. This situation, however, is considered overkill, as the best use of 500kW is in 2-3 "hop" situations, or for emergency use in congested bands. We will therefore define the ideal as four 250kW transmitters one "hop" away from the target (see Fig 3). The ideal point total is 4 × 3 = 12.

The result of an addition of the three factors (programme timing, frequency/source, power/source) gives us an ideal point total of 6 + 12 + 12 = 30 points. This total we will use as a base for the efficiency calculations which follow.

An example .....

Calculate the efficiency of a shortwave service to Argentina from a transmitter site in Los Angeles, California. The plant consists of two 500kW and two 250kW transmitters and broadcasts

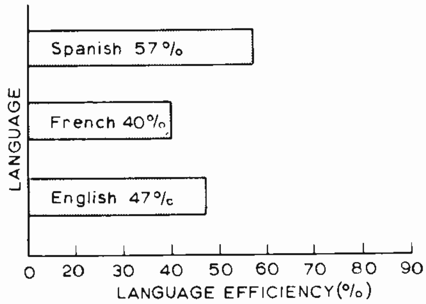

Fig. 4. Language efficiency target of Radio Canada International for North America.

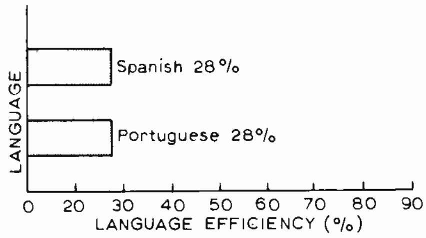

Fig. 5. Language efficiency target of Radio Canada International for South America and Caribbean area.

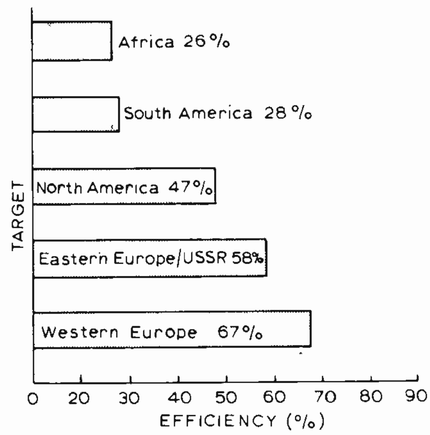

Fig. 6. Overall broadcasting efficiency of Radio Canada International by target area.

occur between 0730 and 0800 local time and between 1930 and 2000 local time.

..... and the solution —

Programme timing score: Both half-hour programmes are within the defined prime times so the total presence is ½ + ½ = 1 hour. Points for 1 hour presence are 4. (Ideal is 2 hours for 6 points.)

Frequency/source score: Argentina is two hops from Los Angeles. We will assume all four transmitters are used for both time periods. This would result in four frequencies, two hops away. Points then are 4 × 2 = 8. (Ideal is 4 frequencies, one hop away for 4 × 3 = 12 points.)

Power/source score: Argentina is two hops from Los Angeles. Assuming again that all four transmitters are used, we have two 500kW transmitters, two hops away for 2 × 3 = 6 points and two 250kW transmitters, two hops away for 2 × 2 = 4 points. Total power/source points then are 6 + 4 = 10. (Ideal is four 250kW transmitters, one hop away for 4 × 3 = 12 points.)

Totalling the points for each of the three factors gives us a grand total for the service of 4 + 8 + 10 = 22 points. The ideal total is 30 points. Thus the service efficiency is 22/30 × 100 = 73.3%.

Summing up

Many conclusions can be drawn from an analysis such as this. Once a level of efficiency has been calculated, a broadcast service can clearly see which of the four major parameters needs to be improved in order to reach the desired ninety to one hundred percent efficiency level.

Radio Canada International, for example, has found that the large number of languages (11) which it broadcasts, coupled with a relatively small number of transmitters (5 owned and operated) have combined to produce low scores in all but one of the key areas, programme timing, frequency diversity, transmitted power, and programme source. An overall efficiency level of forty-five percent was calculated for RCI. This factor, translated into equipment requirements means an additional seven 250kW transmitters are required at the Sackville plant together with associated antennas if current programme levels are to be maintained. These requirements, if maintained, would raise the overall efficiency level to the desired ninety per cent.

The calculation allowed RCI another means of increasing its efficiency. The number of languages broadcast or the number of target areas covered could be reduced, leaving the equipment at present levels. The overall effect would be that RCI would do a better job of broadcasting to fewer targets, thereby again achieving its ninety percent level.

A method, totally divorced from highly subjective audience surveys or inconclusive levels of audience mail, has been developed whereby a shortwave broadcasting organisation can measure itself. It is a device which has been sorely needed by broadcasters, whatever their size. How does your organisation rate?

George Jackson is head of the Engineering Department of Radio Canada International, a post he has occupied for three years.