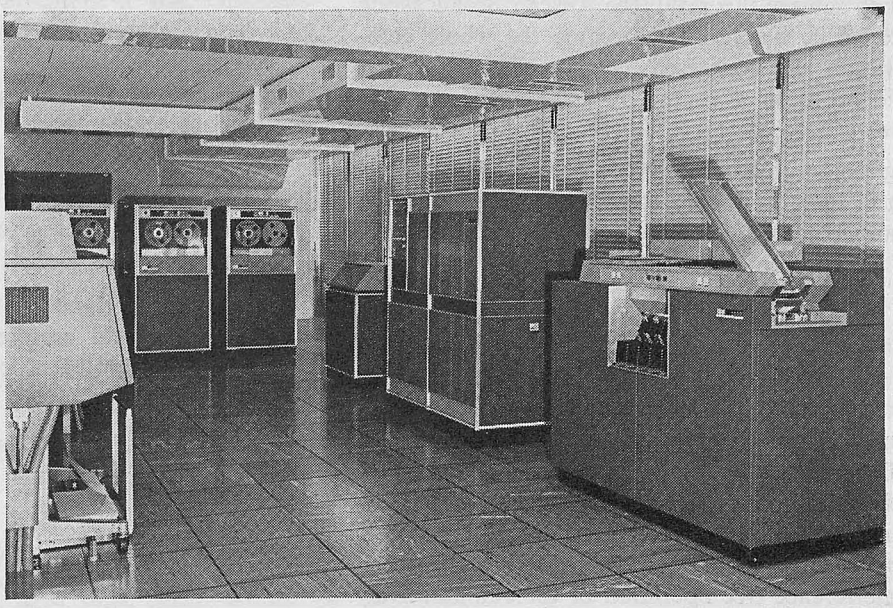
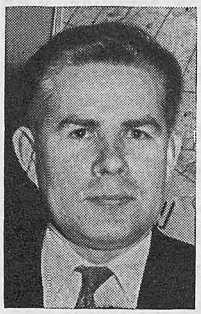
AN ELECTRONIC COMPUTER



in the service of African broadcasting planning

by



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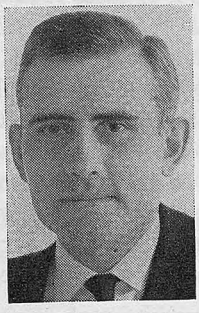


When it was agreed to hold the African VHF/UHF Broadcasting Conference there was little doubt that it would be necessary to use an electronic computer to do the many tedious and time-consuming calculations which would have to be made if frequency assignment plans were to be prepared for the entire African Continent for all the VHF and UHF broadcasting bands.

Nevertheless few could have foreseen the extent to which the use of the computer was instrumental in ensuring that the conference was able to keep to its time-table and finish all the work it had set out to do.

The African VHF/UHF Broadcasting Conference was the first international frequency assignment planning conference to use scientific planning methods for the preparation of the plans in all broadcasting bands allocated by Radio Regulations for television and FM broadcasting. The very considerable number of stations for which frequencies or channels can be assigned in a short time through the use of the channel distribution theoretical lattice concept, makes it imperative that the planners have at their disposal a tool with which to quickly and efficiently check their work. There would be little point in being able to determine the correct frequencies for several thousand stations in a few days, if it was going to take months of manual calculations to discover what adjustments had to be made to the plan in order to make it fully workable.

Without exaggeration it can be affirmed that the calculations made by the computer during the African Conference would have taken a large team of engineers many months to make and even then it would not have been certain that all the cases of harmful interference would have been found.

In order to achieve this result the African Broadcasting Conference broke new ground because the whole computer operation was conceived from the outset to meet the specific needs of a frequency assignment planning Conference.

Before going on to consider how this was achieved it is interesting to look back over the last decade to some of the first applications of electronic computers to VHF and UHF broadcasting planning problems.

Historical background

Electronic computers were first used in connexion with VHF broadcasting problems by the Institute of Broadcasting Technique *(Institut für Rundfunktechnik, IRT)*, Hamburg, when the need for improved methods of planning arose in the early 1950's. The problem then was the interference free operation of the comparatively large number of VHF sound broadcasting stations which were to be operated in the Federal Republic of Germany if the quality of service and number of programmes envisaged was to be attained. Only electronic computation methods were able to handle the volume of calculations required. Later on these methods were extended first to VHF television broadcasting and after that to the UHF bands.

This pioneering work was done by Messrs. Eden, Fastert and Kaltbeizer of the IRT under the leadership of Dr. Stepp. Their work was not restricted to the establishment or checking of frequency assignment plans, but also dealt with such problems as determining the service area of transmitters, the effect of directive receiving antennas on protection and many others.

When it was decided to establish plans for bands IV and V at the European VHF/UHF Broadcasting Conference, Stockholm, 1961, it was felt that an electronic computer could considerably assist this work. In order to provide the same degree of coverage in bands IV and V as in the lower frequency bands many more stations were going to be required. The whole interference problem had now become more acute. Not only could strong interference be expected on the co-channel and adjacent channel but also on the second channel frequency and on the frequency of the local oscillator. The determination of harmful interference was no longer possible by manual means in a relatively short time and the use of the electronic computer was the only solution to this problem.

The preparation of the computer programme which was used at Stockholm was a joint IFRB/IRT venture in which the two organizations combined to produce a programme which would relieve delegates of having to do many of the time-consuming calculations necessary to find whether their assignments had adequate protection.

In the course of this work it became evident that computer programmes suitable for use by international conferences had to meet much more stringent requirements than those suitable for what might best be described as " home use." The calculations would have to be substantially speeded-up and there were other features which were to become very important.

Basic requirements for programmes to be used at international conferences

Four basic requirements have to be met by a computer programme if it is going to be of substantial assistance to a frequency assignment conference.

a) The work done by the computer should be that which would require the greatest effort and the incompletion of which would delay the conference most.

b) The calculations must be done by the fastest methods which can be evolved and this for the following reasons:

i) the per day cost of an international conference is very high, and every day gained on the duration of the conference is a substantial saving;

ii) the cost per hour of operating the computer is high, and although it is not significant in comparison to the overall cost of a conference quite an economy is possible if calculations have to be made for a large number of stations.

c) The results from the computer should be in a form which is usable by persons not familiar with electronic computers. The more easily understandable the results the less the chance of any confusion and the easier it is to apply the results to correcting the frequency assignment plans.

d) The data which are to be fed into the computer and for which the calculations are to be made should not require special preparation. Otherwise valuable time would be lost between the moment a frequency assignment plan is completed and the time the calculations can start. There is also the fact that the extensive coding of input data would require specialized staff.

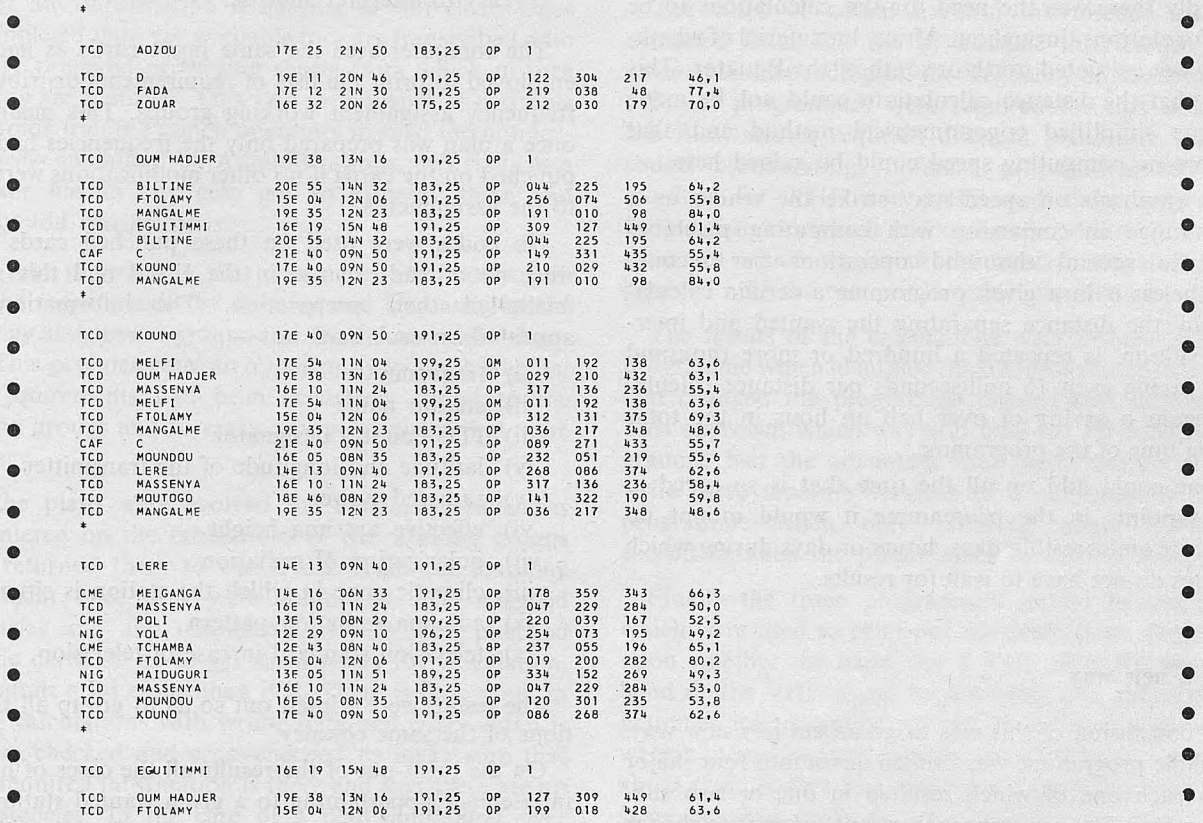
The first of these requirements is best met by using the computer to calculate the amount of interference each transmitter will receive. In VHF/UHF broadcasting planning the most suitable value for this purpose is the " interference field " calculated at the site of the wanted station. This value is given separately for each station causing harmful interference thereby enabling delegates to single out those for which serious conflicts exist and over which it is necessary to negotiate modifications in power or the use of directive antennas or even frequency changes.

Small delegations which have not enough delegates both to attend conference committee meetings and laboriously manually calculate the many hundreds of

interference cases that might give trouble, would without the use of the computer have the greatest difficulties in making sure that even their most important services were adequately protected.

The speed requirement is difficult to meet because the manual methods used by human beings are usually not the quickest, but the most convenient to use. Optimum programmes can only be arrived at by carefully analyzing the problem in terms of the computer at one's disposal and by then organizing the calculation accordingly. There is also the conflicting requirement that the faster after an assignment plan has been completed so that delegates do not have to wait longer than the actual time taken by the computer to produce the results.

The last aspect of the computer operation caused some difficulties during the Stockholm conference. This as well as other problems linked with the fact that the computer presently installed at the International Telecommunication Union (ITU) Headquarters was to be used, meant that the matter of making calculations for the African VHF/UHF Broadcasting Conference had to be studied from first principles.



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TCD   ZOUAR          16E 32  20N 26   175,25  OP   212  030  179   70,0
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TCD   FTOLAMY        15E 04  12N 06   191,25  OP   256  074  506   55,8
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TCD   EGUITIMMI      16E 19  15N 48   191,25  OP   309  127  449   61,4
TCD   BILTINE        20E 55  14N 32   183,25  OP   044  225  195   64,2
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An example of out-printing

and bigger the computer the higher the cost, but machines many times bigger and faster need not necessarily provide results sooner.

The way the results are presented is important if they are going to be really useful. If the information required to identify the station is heavily coded and if it is necessary to refer to special lists to identify the interfering transmitters and to determine their characteristics there is a considerable danger of confusion. On the other hand the more detail is provided in the results, the more difficult it is to achieve a high computation speed.

The last requirement, that of ensuring that the computer can readily use the same data as have been used for planning without much specialized preparation is a vital one. It is not possible to prepare such data without human intervention and if the coding process is complicated and requires a lot of checking much time can be spent on this. Ideally calculations should be able to start shortly

The task of the computer in the framework of the African VHF/UHF Broadcasting Conference

When the use of the electronic computer for the work of the African Broadcasting Conference was considered by the International Frequency Registration Board (IFRB) it became rapidly apparent that the requirements set out in the preceding section for programmes to be run at conferences, would have to be closely met. The short duration of the conference considered against the amount of work that would have to be accomplished, made it imperative that full use should be made of the computer and that the results of its calculations should be available to delegates with a minimum of delay.

Many of the delegations would be small consisting of one or at the most two persons and as all in all plans for five bands were to be established every effort had to be made to free delegates to attend frequency planning groups.

In contrast to Stockholm the computer was to be used to make interference calculations for all the bands for which plans were to be established.

Three factors made the preparation of the computer programmes difficult. The first of these was that most of the initial design work on the programmes had to be done without a clear knowledge of the technical standards which were to be used for broadcasting planning in Africa.

Secondly there was the fact that the electronic computer used by the IFRB is substantially smaller and slower than the previously used computers, but on the other hand it has the advantage that it is very flexible and specifically designed to do data processing.

Thirdly there was the need for the calculations to be made for stations throughout Africa, immaterial of whether they were situated north or south of the Equator. This meant that the distance calculations could not be made by some simplified trigonometrical method and that therefore no computing speed could be gained here.

This emphasis on speed may strike the reader as a little strange in connexion with computing machines which do several thousand operations per second. Nevertheless if in a given programme a certain calculation, say the distance separating the wanted and interfering station, is repeated a hundred or more thousand times, saving even 15 milliseconds per distance calculation means a saving of over half an hour in the total running time of the programme.

If one could add up all the time that is so saved at various points in the programme it would mount up into hours and possibly days, hours or days during which delegates do not have to wait for results.

Going a new way

The conclusion of this was to go an entirely new way. The whole programme was broken down into four major phases each one of which resulted in one or two subprogrammes. The new approach meant a complete change from previous working methods. No longer was the computer being programmed to do the calculation very much like a human being would do it, but instead each major step of the calculations would be done for all the assignments before the next part of the work was started. Due to this it was possible to prepare the individual subprogrammes so that they were as near optimum as possible for the particular function they were to perform. The intermediate results of each operation were stored on tape.

Without going into detail the calculations were divided into the following four phases:

a) The loading into the computer of the information about the transmitters for which the interference was to be calculated. These data which were on punched cards were converted by this programme into a form suitable for use by the computer.

b) The selection of the interference cases. In this programme all the transmitters are noted from which interference could occur to a given " wanted " transmitter. This programme writes on a magnetic tape all the paths over which interference is anticipated.

c) For each of the " interference paths " which was noted by the previous programme the intensity of the interfering field is then calculated making due allowances for the power of the interfering transmitter, its frequency separation from the wanted station, its effective antenna height, the type of propagation prevalent in the area, the polarization of the wanted and the interfering transmitters, as well as in the case of television the standards used by the respective stations.

d) The printing out of the results in a form which was easy to interpret and use.

The computer used the same input cards as had been employed to print the lists of requirements distributed to frequency assignment working groups. This meant that once a plan was prepared only the frequencies had to be punched on the cards if no other modifications were made to the assignments.

No codes were used on these punched cards which were not already in use in the IFRB and this greatly facilitated their preparation. The information that appeared on each card was—

i) frequency
ii) station name
iii) ITU country designator
iv) latitude and longitude of the transmitter
v) radiated power
vi) effective antenna height
vii) polarization of radiation
viii) climatic zone in which the station is situated
ix) antenna radiation pattern
x) television standard in case of television.

The results were printed out so as to group all the stations of the same country.

On the print-out of the results all the cases of harmful interference appertaining to a given wanted station were listed below this station. The wanted station was identified by its name, its country designator, the frequency and geographical location. For each interfering station were given the name, the country designator, the frequency, the distance from the wanted station, its direction with respect to north seen from the wanted station, the direction of the wanted station seen from the interfering station and last but by no means least the interference field.

The availability of their respective directions from one another as well as the distance between the wanted and interfering stations is most useful in planning work. If the interfering station is not known by name, it is so much easier to locate if one knows in which direction to look and how far it is away. This is especially important if one is working in areas of the world for which sufficiently detailed or up-to-date maps may not be available. The azimuth of the wanted station seen from the interfering one is very useful when it comes to having to provide protection by means of directive antennas as one can see at a glance whether it is possible to provide such protection in the desired direction.

Fourteen programmes had to be written

All in all, fourteen programmes were required to do the work at the African VHF/UHF Broadcasting Conference. A brief description of how they were used will show the sequence of events from the preparation of the card on which the data concerning each transmitter were punched to the final printed draft plan which was approved by the conference.

It is never possible to ensure that the requirements submitted by Administrations are all presented in the same form and the first thing that must be done is to check whether any information is missing or not clear. Once the completed data are available they are transcribed onto specially prepared processing sheets from which in turn the cards are punched. This step in the work is desirable as it avoids training punch operators to read the notification forms submitted by Administrations, especially as a processor has in any case got to examine these and possibly add clarifications.

The first programme that was necessary was one to print the requirements by country and by band for the frequency assignment groups and for the national delegations. This gave delegates an opportunity to check whether their requirements had been accurately stated to the planning groups and to make any corrections that were necessary.

As the plans were evolved the assigned frequencies were entered on the tabulations of the working groups which returned them to the IFRB Technical Planning Department once they were completed. The assigned frequencies and any modifications were then punched onto the cards so as to get them ready for calculation. This sounds a lot easier than it is. There is little point in making calculations with wrong data and every detail is therefore checked and cross-checked to make sure that all the required information is there and that there are no inconsistencies. In the case of a plan containing over 4000 assignments the final checking task can take half a dozen persons something like eighteen hours of continuous work.

In order to make doubly sure that everything is right a special programme was prepared which checked whether any item of information is missing or not as it should be. Assuming that a television standard was punched onto a card which was not foreseen in the plan this would immediately be indicated by this programme. Similarly if the polarization had been left out this would show up.

The moment the cards show no more errors, they are put through the load programme which writes the information they contain, plus additional data required for fast computer operation, onto magnetic tape. This programme was prepared in such a way that it could identify the frequency band concerned and treat the data accordingly.

Once the data were on tape a special sorting programme created on magnetic tape two distinct files of the transmitters read in. One of these files was to represent the " wanted stations " and the other the " interfering stations." The same programme could be used for all bands.

In order to find the cases of possible interference these two files were compared. For every wanted station a list was established of all the transmitters which could interfere. Three distinct programmes were necessary at this stage. One for bands I and III, one for band II and the other for bands IV and V. The reason for this was that in band II interfering transmitters were selected plus or minus 450 kc/s from the wanted station whereas in the television bands the affected frequency range varied with the television standard.

The cases of actual harmful interference are then extracted from this list of possible interference cases. Once again depending on the frequency bands concerned different programmes were required for this task. The television service required different protection ratios to sound broadcasting, different propagation data were required for VHF and UHF and there were many little differences which had to be considered. These programmes which work out the actual interference field retained only the cases of harmful interference.

The results of the calculations were printed out by a programme which identified the frequency band concerned and changed the programme organization accordingly. This approach which was also used for the loading programme had the advantage that there was no need to write three separate versions of a substantially similar programme when only relatively slight differences existed between the programmes for the various bands.

Finally the three programmes should be mentioned which were used to print out the draft plans. Depending upon whether the band was a VHF or UHF television band or the VHF sound broadcasting one, different programmes were required for this task. These programmes were in themselves quite simple, but what is very important about them is that they printed the draft plans from the same punched cards as those used for the calculations.

This had two very substantial advantages. The first was that the data appearing in the draft plans were the same as those which were used for the calculations and there was therefore less likelihood of mistakes creeping into the draft plans. Secondly and this is very important, as except for the modifications made subsequently to the calculations all the data were already prepared, no time was lost in organizing the printing. Neither was additional staff required to type or otherwise materially prepare these draft plans.

Some special features of the programmes

A brief outline of some of the programming " tricks " which were used to obtain a high calculation speed may be of interest to some readers.

In the first place a number of quantities are used over and over again in the programme, and to avoid having to recalculate them every time, they are worked out during the loading programme. The most important of these were

the sine and cosine of the angular distance of the transmitter from the North Pole. By having these values available, finding the distance between two transmitters was reduced to finding one cosine and doing three multiplications and a subtraction. As the function routines always take valuable time a great saving results from this procedure. Among the other values which were converted during loading was the radiated power which was turned from kilowatts into decibels with respect to 1 kW.

A human being can tell at a glance by looking at a map whether two stations are too far removed from one another to warrant detailed examination for mutual interference.

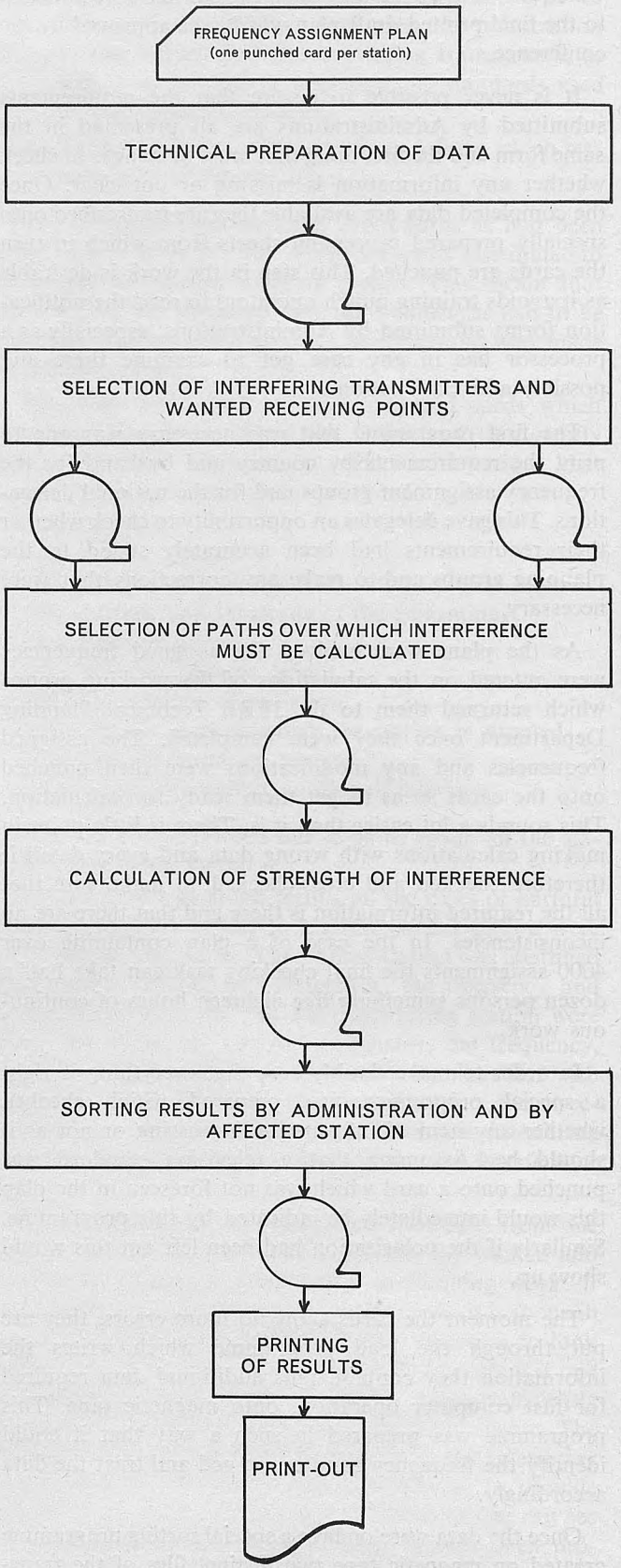
An electronic computer is unfortunately not equipped with perception and it is therefore necessary to provide it with some means of quickly telling when two stations are too far from one another. A special matrix was therefore included in the programmes to show countries too far from one another to warrant detailed calculations being made between their respective transmitters. This device considerably reduced the amount of calculations in a large continent like Africa.

A very important problem which was solved in connexion with the present series of programmes and which will certainly have repercussions on other programmes designed to determine harmful interference, is the rapid selection of the interference cases. To find all the interference cases it is necessary to compare the data of the wanted station with those of every possible interferer. Now of the latter there may be very many. For bands IV and V, for which it was necessary to examine all stations ranging from the fifth channel below that of the wanted station to the tenth channel above, this resulted in the need to examine an average of 1300 stations as possible interferers for each of the 4475 stations in the plan. If each interfering station had had to be read off magnetic tape separately every time it was needed the time taken would have been prohibitive.

Instead of this a method was developed which divided the interfering transmitters up in such a way that it was always possible to fully load the computer with a sample of the plan containing all possible interference cases. Then as the frequency of the wanted stations increases it was only necessary to insert into the computer those interfering stations which came into the frequency range affecting the wanted station. This programme works very fast as in practice something like 100 interfering stations can be examined against every wanted station without any " tape read " command being given. In terms of speed this means that on the computer used more than two hundred cases of interference were examined every second.

Another step which was taken to speed up the calculations was that the field intensity was not found from the distance, but instead from the cosine of the angular distance between the wanted and the interfering station. The distance routine gives this cosine value and this approach eliminated the need to find the actual distance for the many cases where the interference does not exceed the minimum field to be protected and which were therefore not retained as harmful interference.

A number of other steps were also taken to reduce the number of redundant calculations and thereby increase the overall programme speed. Some measure of the extent to which these were effective can be gained from the fact that the bands IV and V calculations for the African



General organization of programmes used to check plans

Conference took about the same time as a similar volume of calculations at Stockholm and this although the computer used at Stockholm was some eight to ten times faster internally than the one used at Geneva.

Twenty-four hours round the clock

About the actual calculation work there is little that can be said. The data are fed into the computer, reels of tape have to be changed, new programmes loaded in and results have to be printed. If the plan is a small one the calculations may all be over in an hour or two, on the other hand if it is big and covers several thousand stations it may take twenty-four, thirty-six and more hours.

The first plans to be calculated were those for bands I and III and as they were not very substantial the results were available virtually the morning following the completion of the plans by the working groups. With more than four thousand stations the plan for band II took about twenty-four hours to calculate (eleven thousand cases of interference). Compared to the calculations for bands IV and V (twenty-nine thousand cases of interference) which took about forty hours it is interesting to note that the amount of time taken was related to the number of interference cases found. This shows that relatively little time is spent on the cases which are not retained as probable harmful interference.

It is usual to think of electronic computers as devices which look after themselves; once the data have been put in it is only a matter of waiting for the results. This is not so, the hundreds and thousands of calculations that are made in the course of the work on one band have got to be read off and written on tape. Reels have to be changed all the time, new sections of the programme have to be fed into the computer and an eye has got to be kept on anything which might go wrong.

Throughout one week there was staff on duty at the computer twenty-four hours a day. During this time all the plans were checked with the computer. The plans for bands I and III were also checked a second time in their revised version. The work of the calculations did not come to an end until early on the morning of 21 May when the over twenty-nine thousand cases of harmful interference found in the draft of the plan for bands IV and V had been printed out and were being prepared for distribution to the delegates.

Future developments

The IFRB is now in possession of series of computer programmes with which VHF and UHF frequency assignment plans can be examined for harmful interference. Further improvements can certainly be made on some minor aspects of their design, but it is doubtful whether they can be made to run sensibly faster. Developments will in the future most probably tend towards their simplified operation. So much so that in the perhaps not too distant future the IFRB would be able to supply Administrations with copies of programmes enabling them to do their own calculations.

The programmes used for band II would require very few modifications in order to make them suitable for checking frequency assignment plans for the VHF land mobile services. In this application Administrations with considerable land mobile operation might find it very convenient and economic to use an electronic computer. In some countries there is a distinct shortage of channels for the land mobile service and a lattice frequency distribution used in conjunction with an electronic computer to discover incompatibilities might be successfully applied to obtain a more efficient use of the spectrum.

Conclusions

The use of the electronic computer for the African VHF/UHF Broadcasting Conference has shown what can be achieved along these lines if the problem is studied in terms of the work that has to be done. At this conference the delegates were relieved of all the interference calculation work. The accuracy of the calculations was such that results never differed more than half a decibel from those calculated manually. The results were presented in a form that was easily readable. The computer had done what it had been asked to do and one cannot hazard a reasonable guess as to the duration of the conference if the plans were to have been checked by manual means.

The systematic way in which the computer works makes certain that even the most obscure cases of interference are found. Some of these might go unnoticed in hand calculations and it furthermore prints out the results so that there is a permanent record of the calculations.

Although the volume of the work was at least twice that which the computer had had to handle at the Stockholm Conference and that added to this the computer now printed both the lists of requirements and the draft plans, the whole task was accomplished without any additional staff being required. This meant that many members of staff worked long days, in fact some of them worked very long days, but added numbers would not have improved the situation much.

A considerable credit for the success of the operation must go to the staff which processed the requirements, to those which co-ordinated changes and modifications with the delegates, to the machine operating staff and to the punching staff. A special mention should also be made of Mr. Szorc, of the Mathematical Institute of Warsaw University, who prepared trigonometrical function routines specially optimized for the computer used.

Yet the real credit for success must go to the delegates themselves who recognized the computer for what it really was: a powerful modern tool allowing them to devote their efforts to the real planning aspect of the work, thereby enabling the conference to complete its work on time.

(Original language : English)