Elektronica en Telecommunicatie 12

Gemeenschappelijke publikatie van de
Sectie voor Telecommunicatietechniek van het K.I.v.I. en het
Nederlands Elektronica- en Radiogenootschap.
Redactie-adres: Prinsessegracht 23, Den Haag.

MOGA 70, Eighth International Conference on Microwave and Optical Generation and Amplification, Amsterdam, 7 ... 11 September 1970

Introduction

Every two years the MOGA-conferences bring those together who are interested in the generation and amplification of microwave and optical signals. In the 'old' days, when the conference started in Paris (1956), the participants were found mainly among microwave tube scientists. However, in the last decade many other devices for microwave and optical generation were invented which added solid-state physicists and engineers as well as laser specialists to the attendance of the conference.

The MOGA 70 can be split up into three major areas of interests. The first one deals with the highly developed microwave tube field. Although much of the fundamental research in this area seems to be terminated, many discussions and studies aimed at a further sophistication in the state of the art were presented. This fact was already skillfully anticipated in the survey paper of Prof. Döring.

The second area was that of the solid-state microwave devices. Although several reports on 'conventional' devices, such as varactors, transistors and tunnel diodes were heard, most contributions were devoted to transferred electron and avalanche transit time devices. Since these devices may be expected to be used in practical systems soon, a detailed knowledge of their behaviour becomes necessary. The output power is no longer the central property of the device but frequency and temperature stability and oscillator noise demand attention. The latter topic especially prompted animated discussions during the conference.

The fast-moving field of quantum electronics which includes laser techniques, non-linear optics and optical parametric conversion, formed the third area of interest. Although the present state of the art is still far from making full use of the promising potentialities, many interesting applications to radar and space communications were discussed during the conference. Some of the problems arising in practical systems were reviewed in an invited paper by Dr. Le Mézec.

In another invited paper Prof. Bordewijk described plans for broadcasting radio and T.V. programs from satellites, especially their social consequences and political difficulties.

Prof. dr. H. Groendijk.
Dr. ir. M. T. Vlaardingerbroek.
Prof. dr. ir. W. J. Witteman.

Opening address

by prof. dr. ir. J. Davidse, Chairman of the NERG

Gentlemen,
It is a great honour to me, in my quality of Chairman of the NERG, (Dutch Society of Electronic and Radio Engineers), to open this 8th MOGA-conference. As you will know, the NERG is the sponsor of this conference, in happy co-operation with two co-sponsors, viz. the Benelux Section of the IEEE and the Royal Institution of Engineers in the Netherlands, the Dutch general Engineering Society, covering all branches of engineering.

The NERG was founded in 1920, in the early days of the development of radio science, so this very year our Society celebrates its 50th anniversary. It may be true that the coincidence of our jubilee and our MOGA-sponsorship is purely accidental,

The proceedings of MOGA 70, containing all documents presented at the Conference, will be published in the course of January 1971 by KLUWER-Technical Books, P.O. Box 23, Deventer, The Netherlands. Apart from that, the invited papers are also published in 'Elektronica en Telecommunicatie', as incorporated in 'De Ingenieur'.

we consider it to be a happy coincidence. As a modest expression of its state of mind the NERG is glad to offer you a drink at the end of the opening session of this morning. Fourteen years of MOGA-conferences have provided full evidence of their fruitfulness and have established their value as a *rendezvous* for the microwave profession. Bearing in mind the tremendous expansion of the field the MOGA-conferences are devoted to, one needs not be surprised by the appreciation they enjoy.

The programmes of the successive conferences reflect the turbulent development of microwave techniques and their applications. The first conference, in 1956 in Paris, under the at that moment quite appropriate name of 'microwave tubes', was entirely devoted to microwave tubes, in particular TWT's, magnetrons and klystrons, research on which was then in full progress. In the second conference, in 1958 in London, tube research was still the chief element of the programme. Emphasis now was shifted to sophistication in development work, as e.g. the pursuit of low-noise properties and high efficiency. In the third conference, in 1960 in München, parametric amplification, the great fashion at that time, dominated.

The emphasis was still on vacuum devices, operating with cyclotron waves in electron beams; however, solid-state devices in the form of parametric amplifiers, made their entrance, so to say by the back-door, but soon gaining in preponderance. In 1962 for the first time Holland offered hospitality to the Conference, which was held in the well-known seaside resort of Scheveningen. The great tune now was beam-plasma interaction, flavoured however by a growing number of papers on solid-state devices.

The trend towards solid-state topics continued in the fifth conference, which renewed the relations, established in the first days, with the French capital. A new star appeared at the already well-populated microwave sky, soon to shine brightly in a very literal way: the *laser*.

The fast rise of this multicoloured star urged to a change of name of the Conference, so that the sixth meeting of the microwave brotherhood was for the first time announced under the name of MOGA (Microwave and Optical Generation and Amplification). This time the conference took place in Cambridge and it became apparent that lasers and solid-state devices now had reached the front seats. When the bell rang for the seventh time, the town of Hamburg welcomed a conference in which solid-state devices had definitely taken the lead.

So far for the history. The eighth conference is not yet history, though it will be within a week. Even a very superficial glance at the Conference Programme reveals the further progression of the trend already outlined.

Of the 130 working-session papers, announced in the Conference Programme, no less than 68 are concerned with solid-state devices and their applications, 22 are devoted to lasers and 40 to vacuum devices. Within the group of solid-state topics those having to do with the Gunn effect lead with 26, closely followed by 19 papers on ATT topics. Such bookkeeping exercises stimulate the temptation to futurological extrapolations. Unwise as such extrapolations in general may be, forecasting further growth of interest in ATT-effects seems so obvious that it hardly qualifies for the prophet's mantle.

That still about one third of the papers deals with vacuum devices may be slightly surprising, but it should certainly not be overlooked. Progress here centers on further sophistication; brand-new devices are rare in this field, where development dominates over research. This points to a definite advantage of vacuum techniques: they rest on a vast body of well-established knowledge and on a far-developed technology. This, added to some inherent advantages, in particular concerning their natural tendency to live on speaking terms with high power, gives them still a strong foothold in the field. That a lead in development, stemming from a monopoly in the past, can result in a very strong position in an area of technology, is demonstrated by very many common technical achievements, like the grammophone record in acoustical engineering and the combustion engine in automotive engineering.

At any rate, the expectation that vacuum devices will for a long time remain to play their role in certain special applications, seems well to be justified, be it that no longer they establish the general image of most microwave equipment.

A particularly interesting aspect of solid-state microwave devices is their potentiality to open the way for cheap low-power microwave gadgets, that may introduce microwaves in everyday applications like household and car appliances and even toys. So, unlike microwave tubes, solid-state devices seem to carry the capacity to a vast proliferation of microwaves in non-professional areas. At present, things have not yet taken that way. Microwaves is still a typically professional field, almost restricted in its applications to communications and measuring systems.

Football and scientific conferences certainly have not much in common, but one thing they have. In both usually the ball is kicked off by someone who is not a typical representative of the profession. This conference is not an exception to that rule. I have the honour to open this conference in my quality of chairman of the sponsoring NERG, though not being a typical microwave specialist myself.

Perhaps for one opening a conference, there is an advantage in not being personally and directly involved in one of the branches constituting the field of the conference, in that his views do not suffer from personal bindings, interests and emotions. Having had a period of intensive contacts with microwaves some 15 years ago, my interests shifted to somewhat lower frequencies. Comparing that time with contemporary microwave techniques, I am inclined to describe those early days as the 'steam century' of microwave techniques. Though being far from nostalgic feelings, I believe the old times had one advantage, viz. the relative simplicity of terminology. Who now is turning to the microwave field, is captured by a slight bewilderment, when confronted with the growing complexity of terminology with its numerous abbrevations and acronyms, as ATT, LSA, IMPATT, TRAPATT, and its highly specialized jargon. Let us, however, not be embarrassed by this trend and take a positive attitude towards it, interpreting it as a token of fertility and vitality of this field of human activity.

Gentlemen, it is my sincere hope that this conference will serve the furtherance of microwave science and will offer you much personal and professional satisfaction. Before leaving this place, I feel urged to express my gratitude to all who contributed to the organization; their task certainly was not an easy one. Of course it is virtually impossible to mention separately all the individual contributors to the fulfilment of this task. But I am sure that nobody will feel discriminated when I mention the name of *Mr. Sandberg*, who merits our special thanks as the pertinent organizer of this conference, bearing the burden of the numerous organizational problems. Mr. Sandberg, we all are much obliged to you: be convinced of our sincere thanks for your efforts.

And now, gentlemen, it is a great pleasure to me to call upon Prof. Casimir for delivering his lecture.

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Microwave and Optical Generation and Amplification

by prof. dr. H. B. G. Casimir, N.V. Philips' Gloeilampenfabrieken, Eindhoven

'The first experiments on microwaves were carried out about three quarters of a century ago by Heinrich Hertz.' Those were the words with which I started a similar talk as that I am supposed to give today at the meeting at Scheveningen. The Bible says: As a dog returneth to his vomit, so a fool returneth to his folly. But this is not going to stop me from starting my lecture in the same way. And having been put into the appropriate biblical mood I may continue by reading two passages from the major prophets, the major prophets of physics, that is. To begin with, a quotation from Maxwell's Treatise on Electricity and Magnetism: '*In several parts of this treatise an attempt has been made to explain electromagnetic phenomena by means of mechanical action transmitted from one body to another by means of a medium occupying the space between them. The undulatory theory of light also assumes the existence of a medium. We have now to shew that the properties of the electromagnetic medium are identical with those of the luminiferous medium. To fill all space with a new medium whenever any new phenomenon is to be explained is by no means philosophical, but if the study of two different branches of science has independently suggested the idea of a medium, and if the properties which must be attributed to the medium in order to account for electromagnetic phenomena are of the same kind as those which we attribute to the luminiferous medium in order to account for the phenomena of light, the evidence for the physical existence of the medium will be considerably strengthened*'. Today we will probably put it in a different way: instead of speaking about the properties which must be attributed to the medium in order to account for electromagnetic phenomena, we discuss the equations we have to postulate in order to describe electromagnetic phenomena, a more formalistic point of view.

My second quotation is from Heinrich Hertz, and it is at the end of the paper in which he describes his experiments with short waves, the focussing by mirrors, the diffraction by a large prism, and so on. He says: – I first give the original text – '*Wir haben die von uns untersuchten Gebilde als Strahlen elektrischer Kraft eingeführt. Nachträglich dürfen wir dieselben vielleicht auch als Lichtstrahlen von sehr grosser Wellenlänge bezeichnen. Mir wenigstens erscheinen die beschriebenen Versuche in hohem Grade geeignet, Zweifel an der Identität von Licht, strahlender Wärme und elektrodynamischer Wellenbewegung zu beseitigen. Ich glaube, dass man nunmehr getrost die Vortheile wird ausnutzen dürfen, welche sich aus der Annahme dieser Identität sowohl für das Gebiet der Optik, als das der Elektricitätslehre ziehen lassen.*' ('We have called the entities we have investigated rays of electric force. In retrospect we might perhaps also call them rays of light of very long wavelengths. To me at least the experiments described seem most suitable to remove any doubt concerning the identity of light, thermal radiation and electrodynamic wave motion. I believe that we may now safely start to use all the advantages which result from such a view for the field of optics as well as for the field of electricity'.)

We may ask whether this really happened and whether in the years afterwards really the development of optics and of electromagnetism went in parallel. Now this is undoubtedly the case if we look at *theory:* the theory of diffraction of waves, the theory of wave motion in general, the theory of dispersion, and so on, certainly developed in parallel for electromagnetism and optics. It were often the same scientists who were dealing with such phenomena as propagation of radiowaves on the one hand and the optical properties of colloidal solutions on the other hand. Also, the notion of a radiating dipole used and elaborated by Hertz has played an important role in describing optical and atomic systems. And as a matter of fact the idea of virtual dipoles associated with transitions of quantum states in atoms became the starting point of Heisenberg's formulation of new quantum mechanics, one of the great breakthroughs of modern physics.

If, however, we look at the *generation of waves* there is much less of a parallelism. The development from a simple oil lamp to a kerosene lamp and to a gas burner with an incandescent gas mantle, the development of incandescent lamps, arc lamps, mercury lamps and other gas-discharge lamps and so on, bears only little analogy to the development of high-frequency dynamos, the poulsen-arc source and the various types of vacuum tubes and valves that have been developed. When we look at the principle of generating microwaves by means of vacuum tubes, I think an essential characteristic of all such devices is that the radiating dipoles or multipoles are formed by currents circulating in metallic structures. There are a few cases where electron clouds themselves radiate, as in synchrotron radiation, or in experiments of Purcell where electrons are shot past a ruled grating, and perhaps in certain analogies to Cherenkov-radiation, but in general we may say it is the charge-current density on the metallic structure that is the source of the radiation. There, currents and charges are the result of a coupling to electron clouds which then by a feedback are kept in the proper state of movement. We might also say that there is always a metallic structure that acts as a kind of impedance-matching transformer between the moving electrons and empty space in which the radiation takes place. The moving electron clouds are different for different types of valves, spoked wheels in magnetrons, simple space-charge-controlled clouds of electrons in triodes and transit-time diodes, electrons bunched by velocity modulation in klystrons and more sophisticated density waves in travelling-wave tubes and backward-wave oscillators.

Characteristic of microwaves as distinguished from the much longer waves is, that the metallic structures I refer to are always of dimensions comparable to the wavelength we are dealing with, with the result that tubes get smaller when we get to higher frequencies. Now here we meet with a curious fact

Rede, uitgesproken bij de opening van het Congres MOGA 70, op maandag 7 september 1970 te Amsterdam.

and this was already referred to by the chairman: after all these years since the war, microwaves are still more or less professional things and in any case, as long as we are dealing with vacuum tubes, microwave tubes tend to be rather more expensive than normal types of tubes. There is something surprising in that, for *after all* they are getting smaller, therefore they should get cheaper. And if I look at generation of acoustical vibrations this is on the whole the case. If I am well informed a fine quality piccolo flute costs about a thousand guilders, whereas you have to pay down hfl. 3500 for a double bassoon of comparable quality. Now what is wrong with physics, that we don't have this same logical proportion between frequency and price that prevails in musical instruments? I don't see much reason for it really. It may be that tolerances get a bit more critical. I imagine that tolerances of a piccolo flute are slightly more critical than those of a double bassoon, but I don't think it is a very strong argument. Perhaps this may give some food for thought. But it may be that we do have to wait for solid-state devices in order to arrive at a real popularization of the electromagnetic waves.

Now, if we look at solid-state devices, we know it is a whole new field of physics and technology, but has it really changed the principles of generation I tried to outline, speaking about tubes? I don't think so. I think we are still dealing with cavities and similar structures with electrons in the solid state playing a role very similar to that of electrons in certain very simple types of tubes. Now what is the advantage? First of all it is clear that electrons in a solid are moving much more slowly than electrons in vacuum at the rather high voltages used in microwave tubes. Is that an advantage? At first sight it is not, for, since we must have transit times comparable with times of oscillation, it follows that distances in our semiconducting devices need to be smaller than those in tubes. But this is offset by the fact that it is rather more easy to prepare a layer of one micron or two microns of a semiconductor than it is to prepare a layer of two microns of vacuum; that is to say, two microns of vacuum don't give the trouble, but the *boundaries* do, which boundaries are difficult to keep apart at the distance of two microns. This advantage, that it is so much easier to make a stable construction with very small dimensions in the solid state, more than compensates the disadvantage that the structure is smaller because of the lower velocity of electrons. That is one feature. It has, however, at once an obvious consequence. Since efficiencies will never be really close to 100 %, we can say that the total power generated must roughly be dissipated in the devices themselves. To do this in a very small device is particularly difficult. Hence it is to be expected that for many years to come – and perhaps even for ever – the vacuum tube will hold the field when we are dealing with the generation of really high amounts of microwave power.

There is another feature of the solid-state devices, and that is that we can work with higher current densities because of a charge compensation that is inherent in a solid-state device. This is also true for gas-discharge tubes, but it seems that the use of gas-discharge tubes as microwave generators, which had its moment of high popularity when one was dealing with beam-plasma interactions, has faded away. Then of course, and that is one of the essential features of the Gunn-effect, electrons moving in a crystal lattice show a much more sophisticated dependency of energy on momentum. Then the fact that we don't have cathode heating may in itself be an advantageous feature when we are dealing with questions where noise is essential. All these things together explain the great promises of solid-state devices.

On the other hand one cannot help feeling that there is also an *element of fashion* entering into this field of technology. The preference of system designers for all solid-state devices is not in every case purely rational: they are to a certain extent influenced by a prevailing trend. I have suggested to my colleagues in the sales field not to speak about vacuum tubes, but to call them solid-state devices and to describe them as solid-state devices *with vacancies in a collective mode*. Collective phenomena are most popular these days and are the subject of many studies. Certainly you can have electrons in solids, you can have moving them through vacancies, one can try to arrange the vacancies in a way we desire: the best we can do is to make vacancies in a collective mode. And what have you: *a perfect vacuum tube with a glass envelope*. Well, I don't know whether it will work, but I think it is just as well to realize that the element of fashion enters into our preferences and prejudices which in itself is not saying anything against the most interesting field of microwave solid-state devices.

Now how about the generation of light waves? There we certainly meet an entirely different situation, because there we are dealing with radiating atoms or radiating molecules. Let us look at the case of atoms, at the sodium lamp for instance and what do we see? There, we have a very large number of atoms, millions, or billions even, and good Anglo-Dutch billions and not the skinny American ones, that are emitting light. If we look at an atom as a kind of antenna, it is a remarkable one, because its dimensions are very small compared with the wavelength, the wavelength being about 5000 Ångstrom units and the atomic dimension 0.5 Å. Now in general, if you would make a radio antenna, and you would give it a dimension of 1/10,000 of the wavelength, one would not expect such a radiating system to be particularly efficient. This, however, is quite different in the case of an atom because the poor thing has no other way of getting rid of its energy, at least not at low pressure and when there are no impurities that might lead to radiationless transitions. Therefore the system has a total resistance that is identical with its radiative resistance and if you have no ohmic and other losses, then of course even the smallest dipole will radiate all the energy it has got. And that is what an atom is doing. You might also say why radiate with such a very large number of individual systems? We would have great difficulty in making a billion of systems exactly identical, but atoms happen to be that way and every single sodium atom, if it is the same isotope, is identical with every other sodium atom. So all these little antennae may seem clumsy things, since they are so small, but in reality they are perfect since they have no other losses and since all of them are identical and all of them are emitting. But even though the individual dipole behaves electromagnetically speaking like the macroscopic dipoles of radio engineering, yet this mechanism of producing light is quite different from our way of producing electromagnetic waves. This has also an influence on the nature of the signal coming out. We can make a very pure monochromatic gas discharge. If we work at low pressures with pure separated isotopes we get extremely sharp spectral lines and if we carry out interference experiments with such sharp lines we arrive at a considerable coherence length. Yet this system is not quite comparable with an oscillator even if the frequency stability of that oscillator would be poor as compared with the sharpness of the wave coming out of our gas-discharge lamp. What is the difference? Let me cite the way in which my colleague Rinia used to describe it; he always said: 'a light source is not an oscillator, it is a *ruisfluit*'. Now the word 'ruisfluit' is a beautiful Dutch word and very difficult to pronounce for a foreigner, because of the curious diphthong 'ui'.

A *ruisfluit* means a 'noise whistle'. Suppose you start from white noise and then you filter that white noise through a very narrow band-pass filter, then you get a signal of a quite well-defined frequency, but it is different from a normal acoustical vibration. The difference appears at once if we look at the amplitude. If we have an acoustical generator that vibrates, we have an amplitude going periodically up and down between extremes that lie between narrow limits. The frequency of going up and down may vary a little bit if the frequency is unstable, there may be slight amplitude variations, but that is all. If you take a noise whistle, this is no longer true. You have a superposition of a number of Fourier components and there is a Gaussian distribution of probability of the amplitudes, and I have been told that the character of the sound of such a noise whistle is rather different from that of a tuning fork. Because of the special mechanism of light emission with all the atoms uncorrelatedly emitting light, even though it is always on exactly the same frequency, we get this character of a 'ruisfluit' and not of a real oscillator. It is there that the *laser* comes into the picture. By synchronizing the emission of the individual atoms through stimulated emission, stimulated by a signal emitted by the atoms themselves either by feedback in an optical cavity or possibly by a slowly increasing travelling wave, we arrive at a situation where all these atoms radiate not only with the same frequency, but they are also synchronized in phase; therefore the Gaussian spread or the amplitude of the signal is eliminated and the signal is much closer to that of a normal oscillator. This means that a laser, if it is working at an appropriate frequency, can be used in much the same way as any other microwave oscillator, but now we can use the molecules and the atoms *as we find them in nature* as a tuning system, which in a way is highly satisfactory. For after all it is attractive to base all kinds of standards, all kind of stability, not on the correctness of size of man-made objects but to base them on the properties of atoms which happen to be invariable and identical. We know already that we can base our units of lengths on the wavelength of certain spectral lines and this has now supplanted older standards. We can do the same with time, if we choose to do so, by means of atomic clocks. It is still a little bit difficult to do it for weight and to use, let us say, the mass of a hydrogen atom as unit of weight, but this will come sooner or later. It is certainly satisfactory to be aware that it is not only possible now to base measurements in a 'Bureau of Standards' on such things, but that we can expect also to find more and more oscillators the frequency of which will be controlled by the inherent properties of atoms and molecules. In my opinion this does remove the difference in the nature of a signal from a light source and from an oscillator, but it does not remove this curious sudden jump from objects of the order of magnitude of the wavelength as radiating systems to a very large number of objects much smaller than the wavelength. In my opinion this is and will remain an essential difference between optical generation and microwave generation, even if the optical method of generation produces microwaves that can also be produced by reflex klystrons or backward-wave oscillators, or frequency multipliers and so on, for we know that the gap has been amply closed between the two. Is there a possibility of making objects that would be intermediate between the two? I doubt it, because, although we are getting better and better at making small objects, in most cases the ohmic losses would be such that it would not be very profitable. They would not be able to compete with the atom which would also be a poor antenna if it were not that it cannot get rid of its energy in any other way.

On second thought one might perhaps say that microwave generators based on Josephson tunnelling, especially if they make use of a large number of small particles, are somewhat intermediate between the microwave and the optical type of generators.

Ladies and Gentlemen,

This has been a very short talk, but I believe this is about what I would like to say as a general introduction to the discussions of this meeting. I may have been slightly incoherent here and there. I do hope that all the same I may have been able to shed some slight amount of light, be it incoherent light, on the discussions you will have during this conference.

Thank you very much.

621.385

State of the Art and Research Trends of Microwave Tubes

by Prof. Dr.-Ing. Herbert Döring, Technische Hochschule, Aachen

Synopsis: A survey is given on the state of art of Microwave Tube Technology. By means of some characteristic examples the trends of this development are shown.

The European – especially the German – technology will be presented more in detail, because at that point the author is better informed. Furthermore some special types, for instance crossed-field devices, magnetrons, etc., shall not be discussed, since, according to their special applications, the number of publications has been reduced.

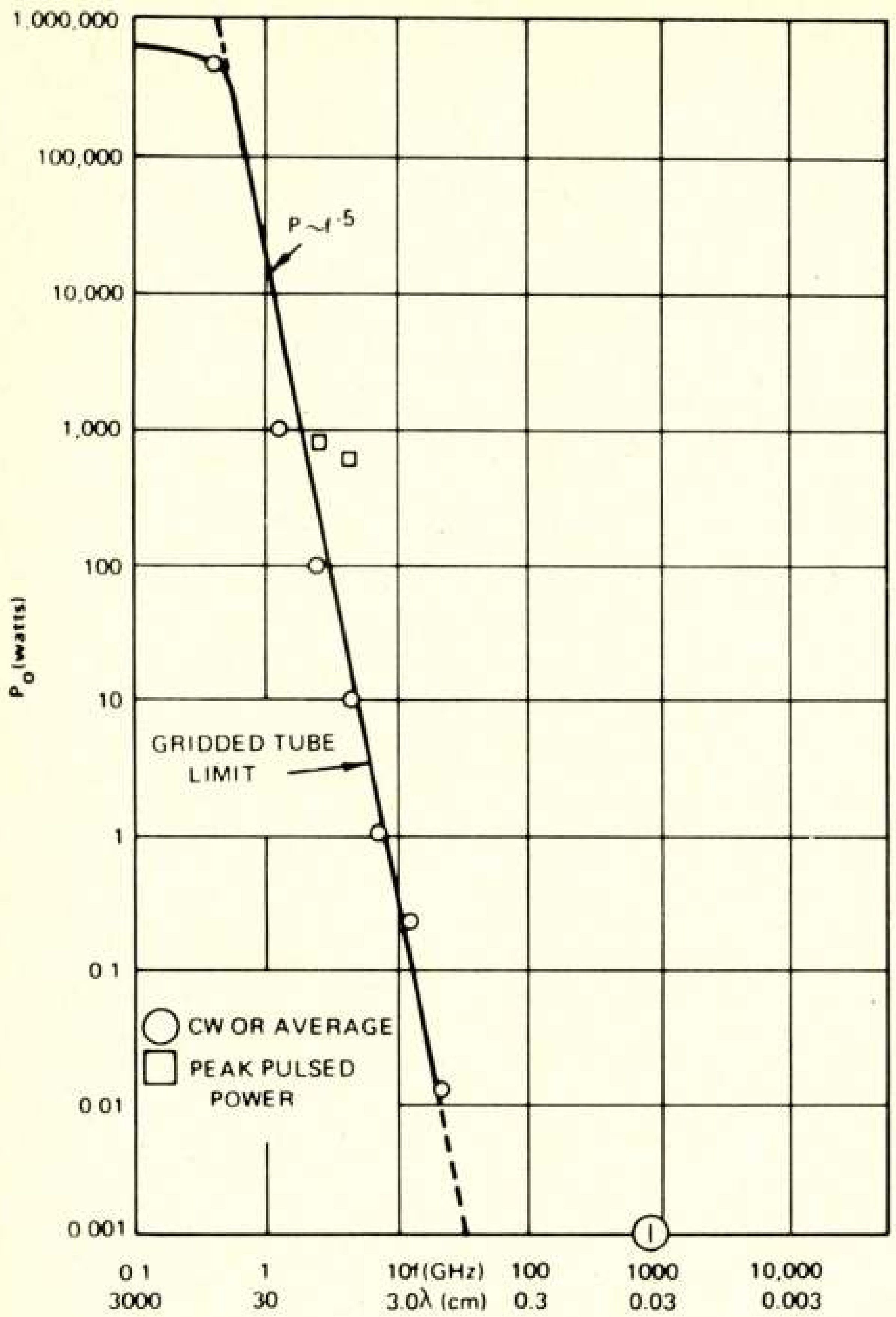
1. Introduction

First of all we have to make the statement, that in the last years no principally new ideas for microwave tubes have been found and realized. On the contrary, much interesting work was done in adapting the well-known types of tubes to different applications, as for instance to the new demands of astronautics, with regard to efficiency, weight, reliability, properties for communication, etc.

The question arises, whether it is worth talking today, in 1970, on research trends in the field of microwave tubes, and whether it is justified to speak on this subject at a conference like this,

Invited paper, read on 7 September 1970 for the audience at the Eighth International Conference on Microwave and Optical Generation and Amplification: MOGA 70, Amsterdam.

GRIDDED TUBES

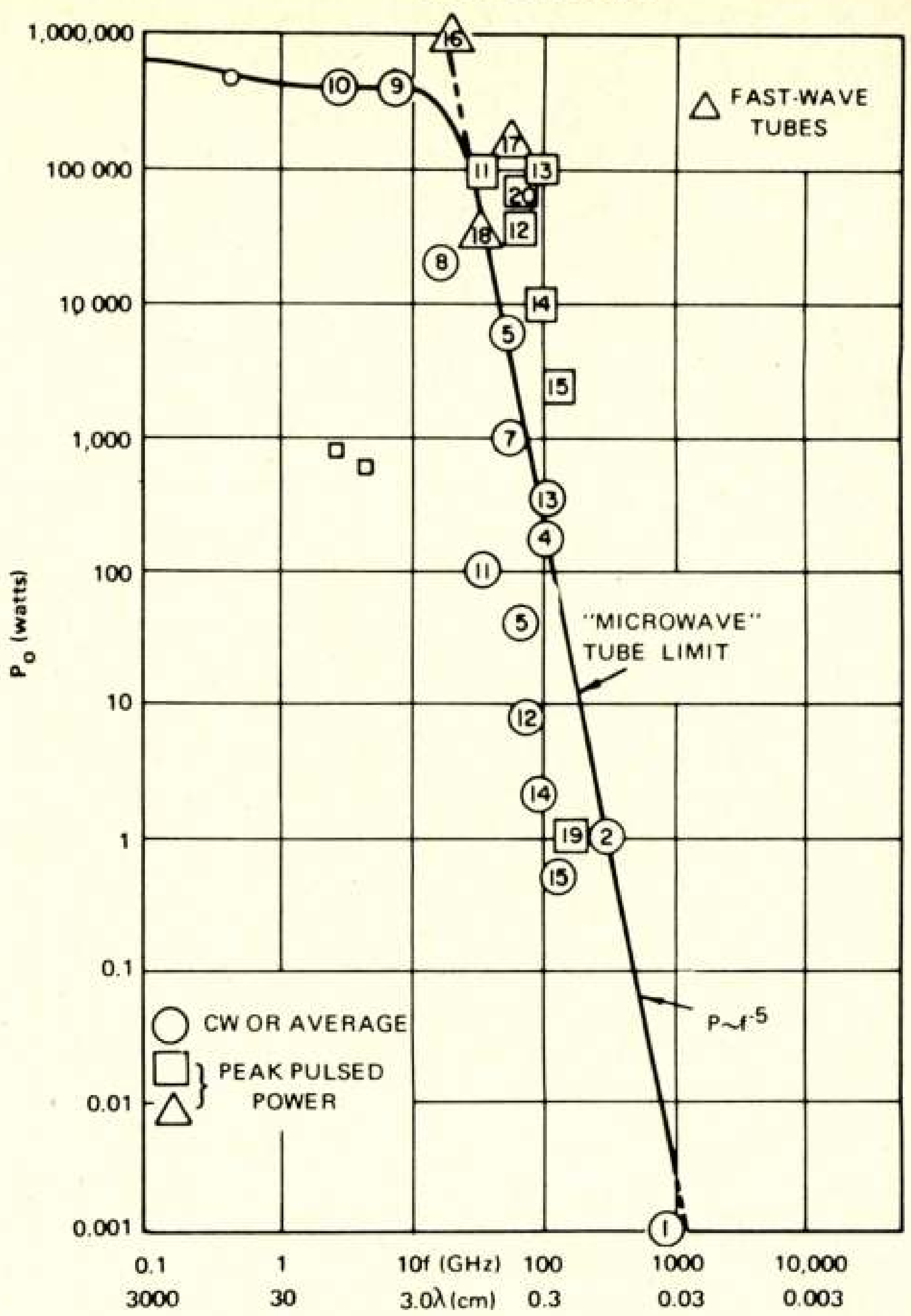


NOTE: 1: PEAK POWER UP TO 40 mw AVAILABLE BELOW UHF.

2: LIMIT PLOTTED FOR CW OR AVERAGE POWER.

3: DATA EXCLUDES INFORMATION ON CLASSIFIED TUBES

MICROWAVE TUBES



NOTE 1: PEAK POWER UP TO 30 mw AVAILABLE AT LOWER MICROWAVE FREQUENCIES

2: LIMIT PLOTTED FOR CW OR AVERAGE POWER.

3: DATA EXCLUDES INFORMATION ON CLASSIFIED TUBES

Fig. 1. Performance characteristics of principal frontier tubes 1969.

held every two years. With reference to the economic importance of electron tubes this question can be answered at once positively. At a turnover for active components, tubes and semiconductors growing rapidly all over the world, the value spent in 1969 to electron tubes was 55% of the total turnover. Besides, in the last years the applications for tubes have changed: tubes in entertainment electronics have virtually been replaced by semiconductor elements, such as diodes and transistors. Today tubes find their major application on the one hand in the field of optical indication, above all as picture tubes and in oscilloscopes; on the other hand in the microwave field, and here at high power and at highest frequencies.

As far as can be overlooked today the microwave semiconductor will be able to replace the microwave tube only at small power; but even in this field there exist some troublesome secondary effects, for the microwave semiconductor is not yet mature.

Another technological point of view supervenes: because in microwave tubes as for instance the klystron or the travelling-wave amplifier, high-frequency conducting parts are electrically and thermally separated from d.c. power-conducting parts, and the latter can be dimensioned nearly at any size. This is impossible at the solid-state devices known till now; for instance, the performance of the Gunn-element is based on a volume effect. Recently an experienced pioneer in the field of tube technology, *Dr. Leon S. Nergaard* of RCA, published his opinion [1] on the 'coexistence' of tubes and semiconductors in the 'Microwave Journal'. He showed that with regard to the product *HF-power times frequency to the power 'n'*

for frequencies below 30 GHz: $P \cdot f^2 = C_1$

for frequencies above 30 GHz: $P \cdot f^{\frac{9}{2}} = C_2$

Of course the values of these products differ for tubes and semiconductors by at least a factor one thousand (10^3). This will be evident if one looks at the range of applications of semiconductors and that of tubes.

In the summary of the paper referred to above *Nergaard* says furthermore: 'Tubes are mature; solid-state devices are at best 'teenagers'; maybe some of them will grow up'. And I add that elder tube engineers will help to educate them!

Dr. Osepchuk compiled the state of art of tube technology in 1969, and found similar exponents for the power-frequency product. Fig. 1 shows the limits of microwave tubes. As example we read for *continuous wave* powers of 350 W at 100 GHz and of 1 MW at 8 GHz; and by extending the dotted curve for *pulse operation* a peak power of 20 MW at nearly 3 GHz. In comparison

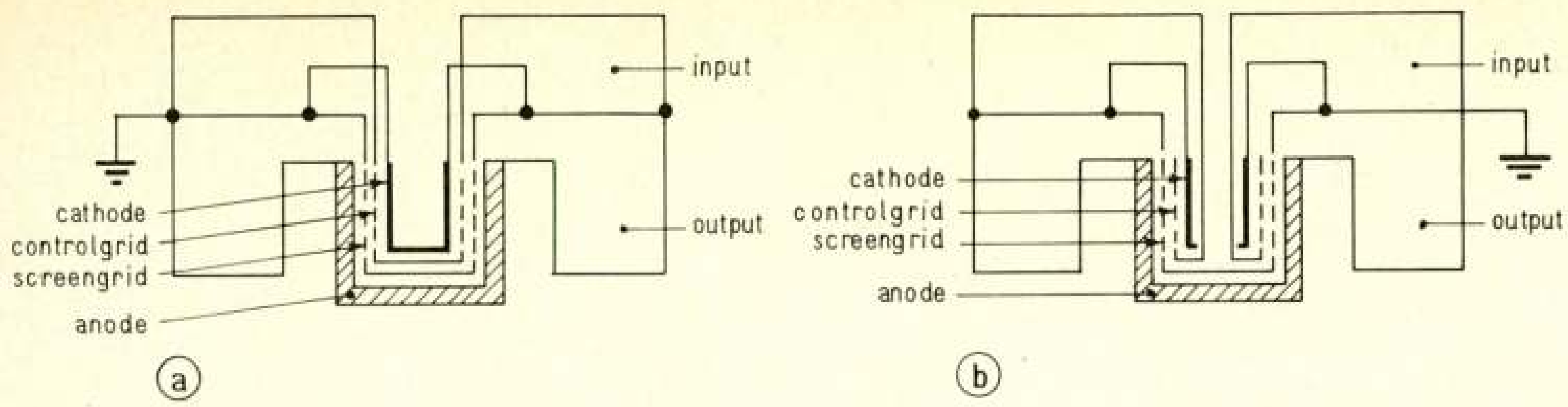


Fig. 2. Different tetrodes for common cathode circuits.

the limits for grid-controlled tubes are considerably lower, as can be seen on the left side of Fig. 1. As remarked before the separation of rf-conducting parts from d.c.-conducting parts is not possible and besides, in contrast with transit time tubes the electron transit time is here an undesirable effect. For additional numerical data on rf-power obtained with different types of tubes I refer to the comprehensive summaries which Dr. Osepchuk published in 'The Microwave Engineers Handbook and Buyers Guide' 1970 [2].

We are now entering the field of special devices and I will start with gridded tubes (triodes and tetrodes).

2. Gridded Tubes

The development of the approved construction with cylindrical or disc-shaped grids, respectively electrodes was continued. Such a device is especially qualified for an organic junction of the tube with a circuit consisting of a coaxial line or a cavity resonator.

We start with the former LD 9 ceramic *triode*, in 1942 manufactured by Telefunken, and with the American 2 C 39 family in glass and ceramic technology, types which today are to be considered as 'classical' dm-wave tubes. Special performance features as higher power, longer life, reliability, pulse operation, etc. were cultivated.

On the other hand also *tetrodes* were constructed in this shape. Fig. 2 shows a schematic cross-section of the Siemens tetrode RS 2032 CL in coaxial shape. In this tube the control-grid is led to the outside of the tube concentrically inside the cathode cylinder. Owing to this construction a cathode-base circuit in coaxial technique is possible, and crossing of the grid and cathode-leads is avoided. The two grids of this tube consist of seamless drawn tubes of molybdenum in which the gaps for the passage of the electron beam are stamped. This tetrode gives an output power of 12 kW at 110 MHz, working as B-amplifier. The input power is 25 W; the efficiency is 68%. Fig. 3 shows a view of this tetrode.

Disc-sealed triodes in metal-ceramic technology, delivering c.w.-powers up to 100 W, have been developed for the 3 GHz region. They satisfy the conditions necessary for space flights with regard to reliability, lifetime and acceleration. For this purpose above all, improvements in cathode and grid technology were necessary. Furthermore the possibility of pulsed operation is indicated.

Two advantages of grid-controlled tubes must be emphasized: they are working with low voltages instead of with kilovolts for transit time tubes. This is of interest in astronautics, especially for the phase of penetrating the atmosphere. Besides, higher bandwidths than by means of a klystron are obtained.

Fig. 3. View of the RS 2032 CL tetrode.

Altogether the future of triodes and tetrodes in the above named frequency bands and power ranges is seen to be absolutely advantageous.

3. Klystrons

With regard to klystrons some points of view are recognizable. The following improvements have been obtained at c.w. multicavity klystrons, that for instance are used in TV-transmitters:

1. higher power;
2. higher efficiencies, operating the collector at reduced potential and/or using multistage collectors;
3. higher amplification factors by using more than 4 cavities;
4. greater bandwidths by stagger-tuning the resonators and damping the intermediate circuits according to insight acquired from filter theory;
5. improvements in electron optics by using a digital computing technique for the electron gun design and by periodic permanent magnetic (ppm) focusing, with magnets directly fixed on the driftspaces.

As example we mention the Philips experimental klystron V 36 SK with a coaxial ppm-system for the beam focusing [3]. This 4-cavity klystron provides 45 kW with vapour-cooled collector and cooled catcher. This design of an external cavity

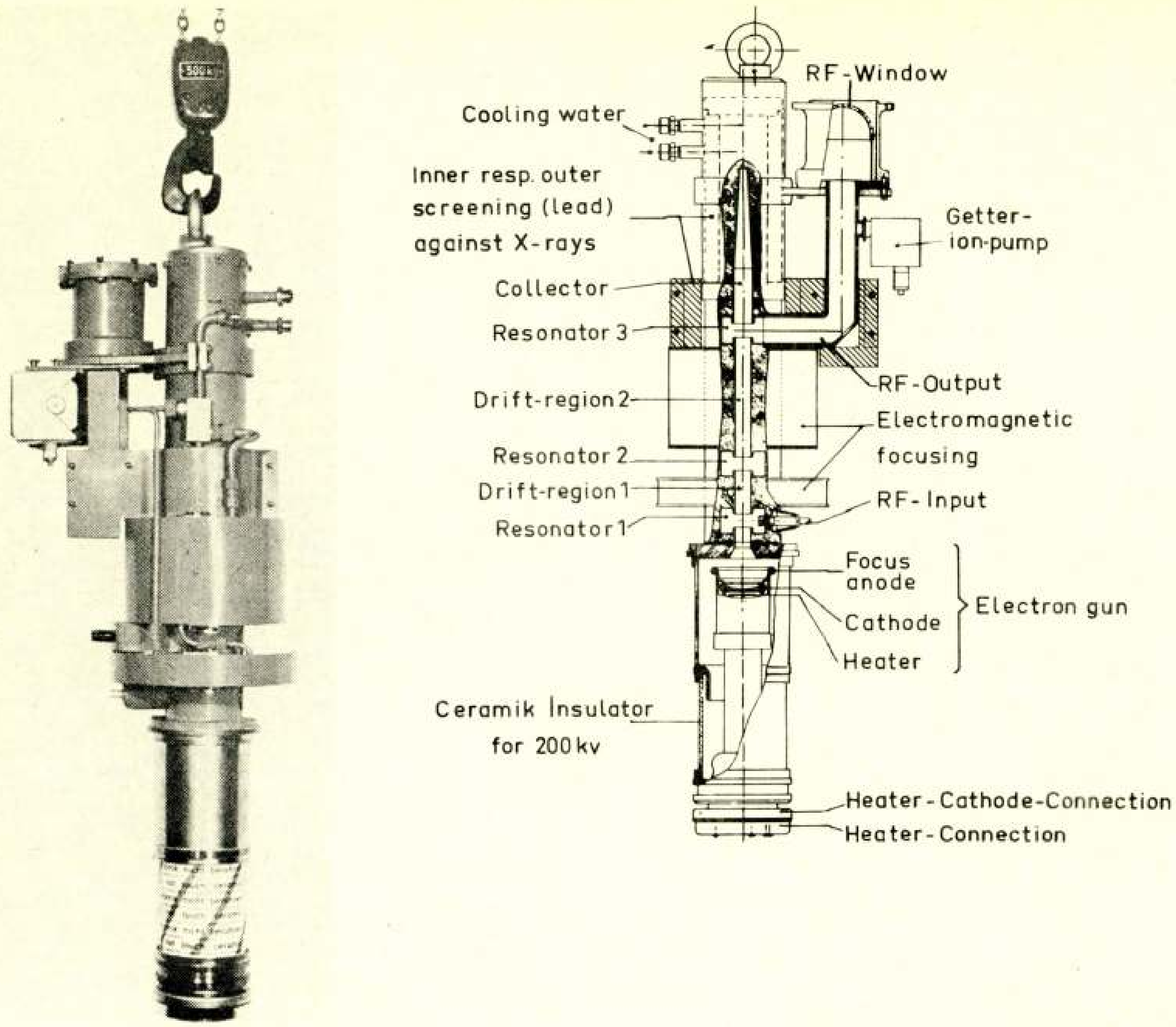


Fig. 4. The pulsed 5-MW klystron YK 1100.

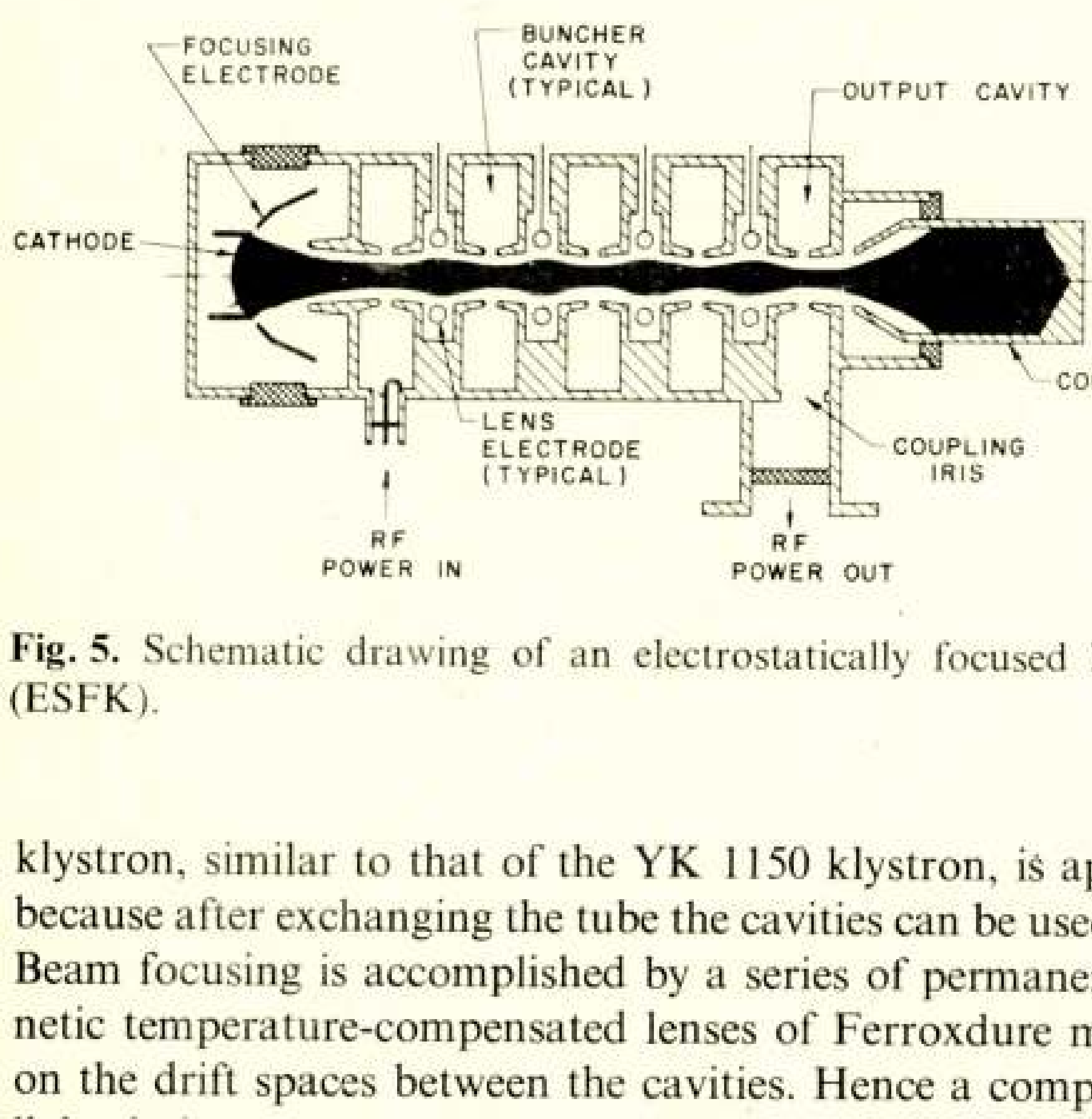


Fig. 5. Schematic drawing of an electrostatically focused klystron (ESFK).

klystron, similar to that of the YK 1150 klystron, is approved because after exchanging the tube the cavities can be used again. Beam focusing is accomplished by a series of permanent magnetic temperature-compensated lenses of Ferroxdure mounted on the drift spaces between the cavities. Hence a compact and light design results. It is the aim of this development to arrive at input powers that are low enough to be furnished by semiconductor preamplifiers. To get convenient operational parameters for the power stage within the operating bandwidth the pre-emphasis should be made within the preamplifier.

I am sure that high-frequency powers in the magnitude of 100 kW can be expected at TV bandwidths by this design, which combines high gain, ruggedness, simplicity and long life.

A pulsed three-cavity-klystron YK 1100 of the same firm for the application in particle accelerators [4] is shown in Fig. 4. The tube provides 5 MW peak power at approximately 3 GHz, working with an accelerating voltage of 200 kV. According to the high alternating voltage, internal fixed tuned cavities are used. Besides the X-radiation that is caused and the increased multipactor-effect, the relativistic mass-correction has to be taken into account.

In this type beamfocusing is performed by coils winded directly on the tube. The upper limit achieved with similar tubes for linear accelerators, for example at Varian, is approximately 25 MW in pulse operation.

For the in Germany proposed X-band television, Valvo developed the 5-cavity klystron V 42 SK. Characteristic data are:

frequency:	12 GHz
output power:	1 kW
gain:	45 dB

Other features are: air-pressed cooling, periodic permanent magnetic focusing and a beam voltage lower than 10 kV.

Multicavity-klystrons with electrostatically focused beam have been described by *I. Hechtel* [5]. These are manufactured for example at Litton's in the USA and at EMI in the United Kingdom. Modern computing techniques were used for calculating and plotting the path of the electrons from the cathode to the collector, the lens electrodes lying on cathode potential are arranged halfway the drift spaces. A longitudinal beam section is shown in Fig. 5 with a schematic drawing of an ElectroStatically Focused Klystron (ESFK) [6]. The Litton type L 5182 for instance delivers a c.w. power of 1 kW in the C-band at an amplification of 43 dB over a bandwidth of 10 MHz. Efficiencies in the magnitude of 40% were attained. For some applications also the weight of this tube being only 5 kg is of interest. This corresponds to 5 gram per watt c.w. power.

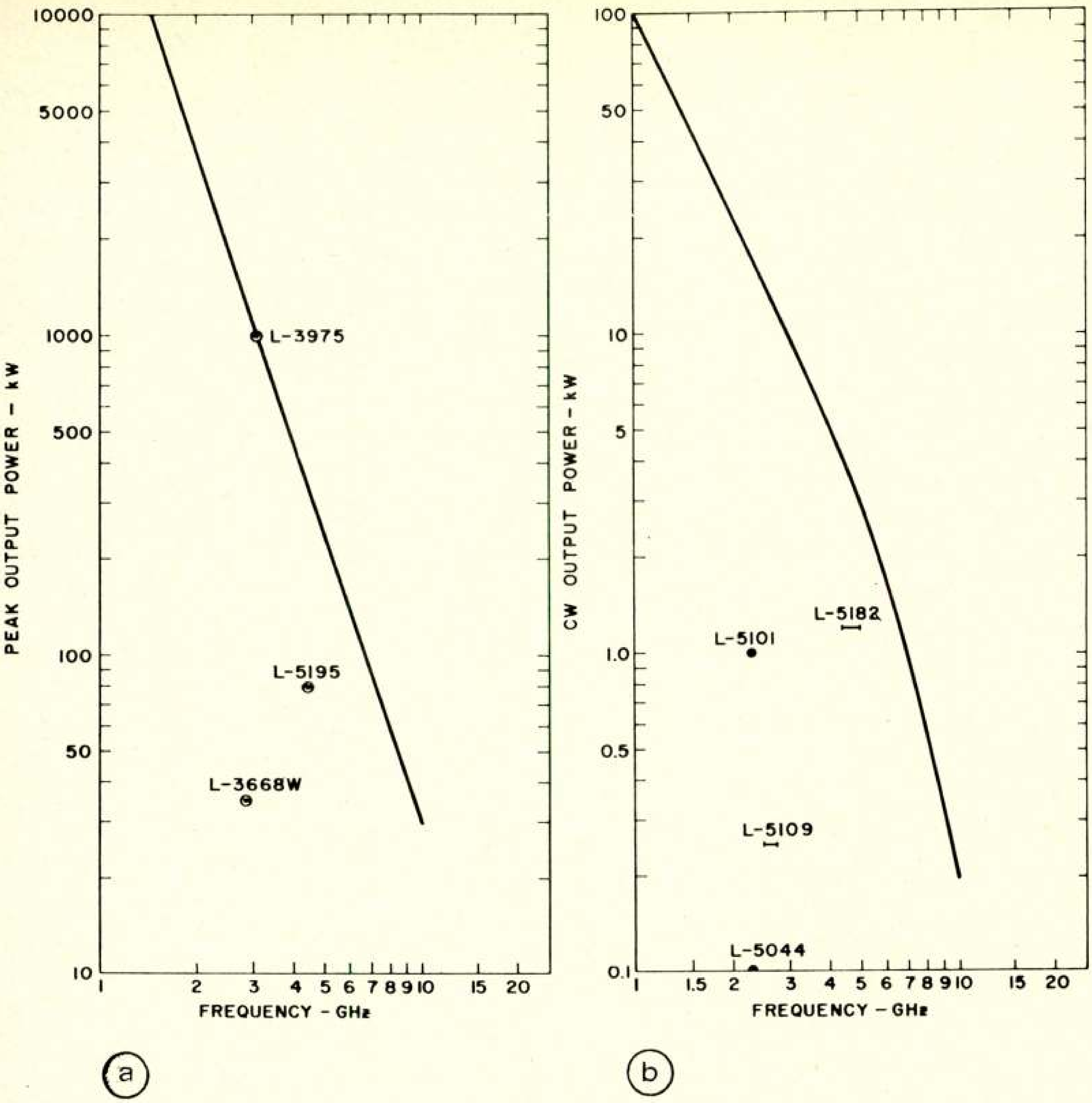


Fig. 6. Maximum peak power (a) and c. w. power (b) versus frequency for electrostatically focused klystrons.

Advantages of this concept are the light weight, the small volume and a reduced noise level. The latter results from the fact that these devices are free of spurious modulation due to ion-oscillations in the electron beam. Therefore applications are possible in airborne pulsed-doppler radars and in portable Troposcatter communication systems.

In Fig. 6 a plot is shown of the maximum peak- and c.w. output powers as a function of the frequency in the 1 to 10 GHz region. The curves have been calculated taking into account the physical restrictions of electrostatically focused klystrons. Measured values are noted. In principle the frequency and power limitations of this tube design are known.

Besides these 'classic' multicavity types, oscillators have been developed using the principle of distributed interaction, as for instance in the Japan 'Laddertron'. Reflex klystrons are manufactured especially for replacement today, which is at the moment a good job. Finally the possibility of reducing noise in the two-cavity oscillator by arranging a high-quality cavity in the feedbackline between the two resonators should be mentioned here. This design is for instance used at Telefunken.

4. Travelling-Wave Tubes

All over the world work has been continued on the design of travelling-wave tubes for different applications. Travelling-wave tubes are favourite due to their bandwidth and due to their improved efficiency. In the last years designers succeeded too in achieving higher powers, not only in c.w., but also in pulsed operation.

The major applications are with radio links, scatter communication and satellite communication. Applications just in this last field surely will increase. The expectations cherished for transistorized broadband amplifiers in the GHz frequency range have not yet been fulfilled.

Common to many types of travelling-wave tubes are:

1. operation at reduced collector voltage to enlarge the overall efficiency;
2. the collector is a hollow cylinder with a small hole for the entry of the beam in the front: slow secondary electrons emitted through this hole cannot be drawn into the interaction space;

3. irrespective whether the delay lines consist of a helix or of coupled cavities they are frequently subdivided, tapered or have different pitches.

Some types developed in Germany will now be discussed briefly, first the types for lower power and next those for high power.

The well-known Telefunken travelling-wave tube TL 4003 for the European Satellite 'Symphonie' has an available output power of 13 W (c.w.) at frequencies in the 4 GHz band with an efficiency of 38% [7]. A helix is used as delay line, the ppm-focusing system is integrated in the tube envelope. The light relative weight is remarkable: 40 grams per watt c.w. Special requirements with regard to linearity will have to be fulfilled in connection with the foreseen multicarrier operation, in order to reduce intermodulation effects so that an acceptable value for the signal-to-noise ratio can be secured. Furthermore the group-delay-time distortion must be held small enough. Here the interesting and characteristic quantities are the compression factor and the AM-PM-transformation.

In relation with the projected X-band TV in Germany, the Telefunken YH 1090 shown in Fig. 7 may be of interest: a TWT-amplifier providing 70 W at a beam voltage of 5 kV [8]. The beam focusing is performed by a ppm-system at 1200 Gauss in a similar way as in the system discussed before.

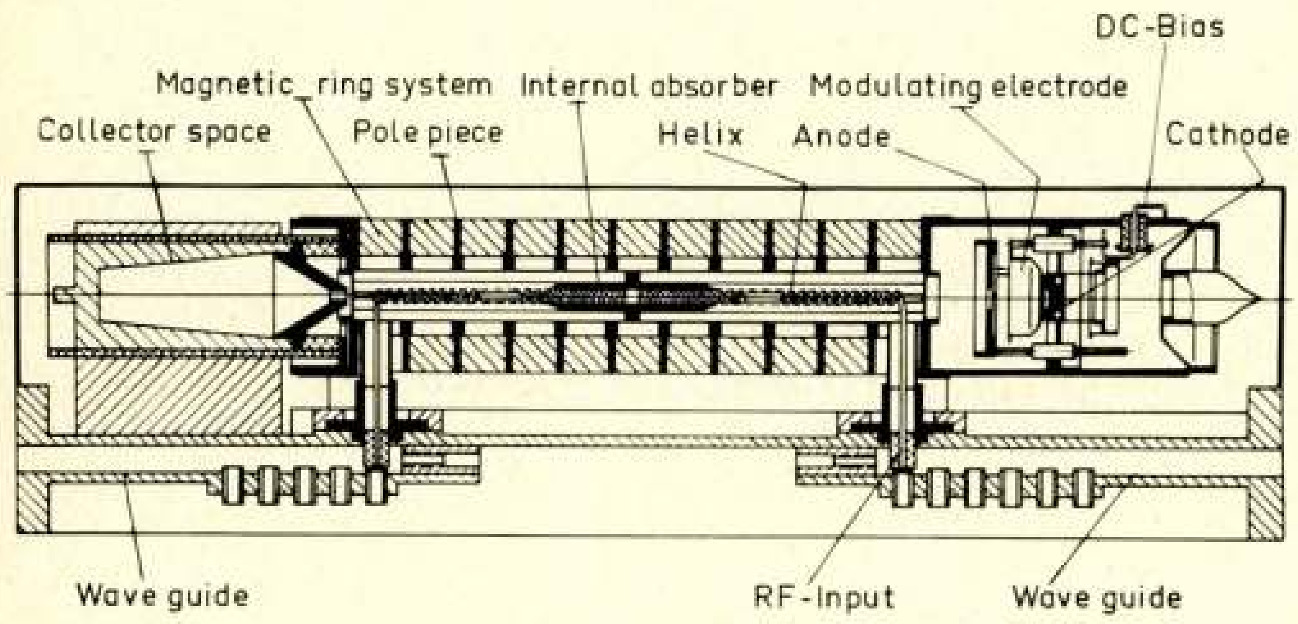


Fig. 7. Cross-section of the 70-W travelling-wave tube. YH 1190 for 11.7 ... 12.7 GHz.

A typical example of a power TWT is the Siemens YH 1043, Fig. 8, 9. In the 6-GHz frequency band a RF power of 1.5 kW is obtained at a beam voltage of 10 kV with an amplification of 30 dB. Electromagnetic beam focusing is used. In this tube a subdivided helix and a reduced collector voltage have been realized [9]. Similar types for a minimum saturation power of 8 kW with water-cooled collector and mixed electrostatic and electromagnetic focusing were developed at the same company. These types have been developed for satellite communication ground stations [10].

For comparison with the tubes, designed with a helix as delay line, three other types are emphasized in the following.

a. The Telefunken YH 1181 for the frequency band of 4.4 ... 5 GHz, with a bar-and-loop delay line (Fig. 10), a construction also used in the elder YH 1150 for the 2 GHz frequency band [11], a TWT employed many times in tropospheric scatter circuits, for instance between Berlin and West-Germany. The tube provides more than 1 kW output power and has a weight of 20 kg. The main characteristics are beam voltage: 10 kV, magnetic field: 820 Gauss, compressed-air cooling, an efficiency of up to 40% at depressed collector operation and an instantaneous bandwidth of 5% between the 1 dB-points [12].

b. The Hughes TWT with coupled cavities as delay line is quoted to deliver a c.w. power of 1 kW at 55 GHz (6 mm), at a beam voltage of 25 kV and a bandwidth of 2%.

c. Beside these c.w.-tubes, a TWT for pulsed operation is interesting, the Telefunken TL 16000, shown in Fig. 11. Working in the KU-band (16-17 GHz) the tube provides 5 kW at a duty cycle of 4%. The delay line consists of coupled cavities subdivided by attenuators (see Fig. 12). In this tube, as recently also in other American types, control grids are mounted before the cathode to reduce the pulsed-control voltage.

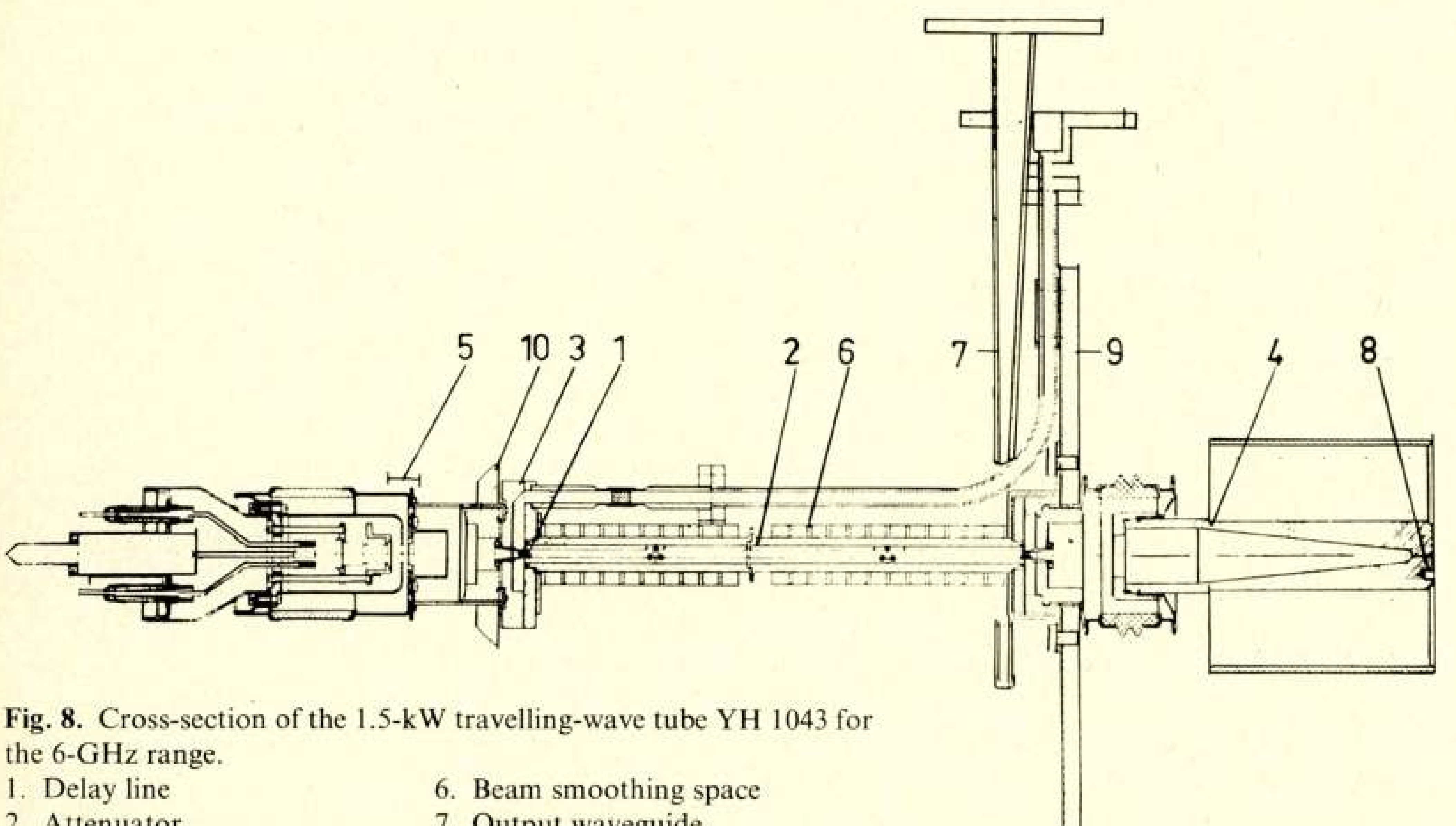


Fig. 8. Cross-section of the 1.5-kW travelling-wave tube YH 1043 for the 6-GHz range.

1. Delay line
2. Attenuator
3. Coupling wave-guide
4. Collector with cooling ribs
5. Electron gun
6. Beam smoothing space
7. Output waveguide
8. Collector terminal
9. Collector-ended pole piece
10. Gun-ended pole piece

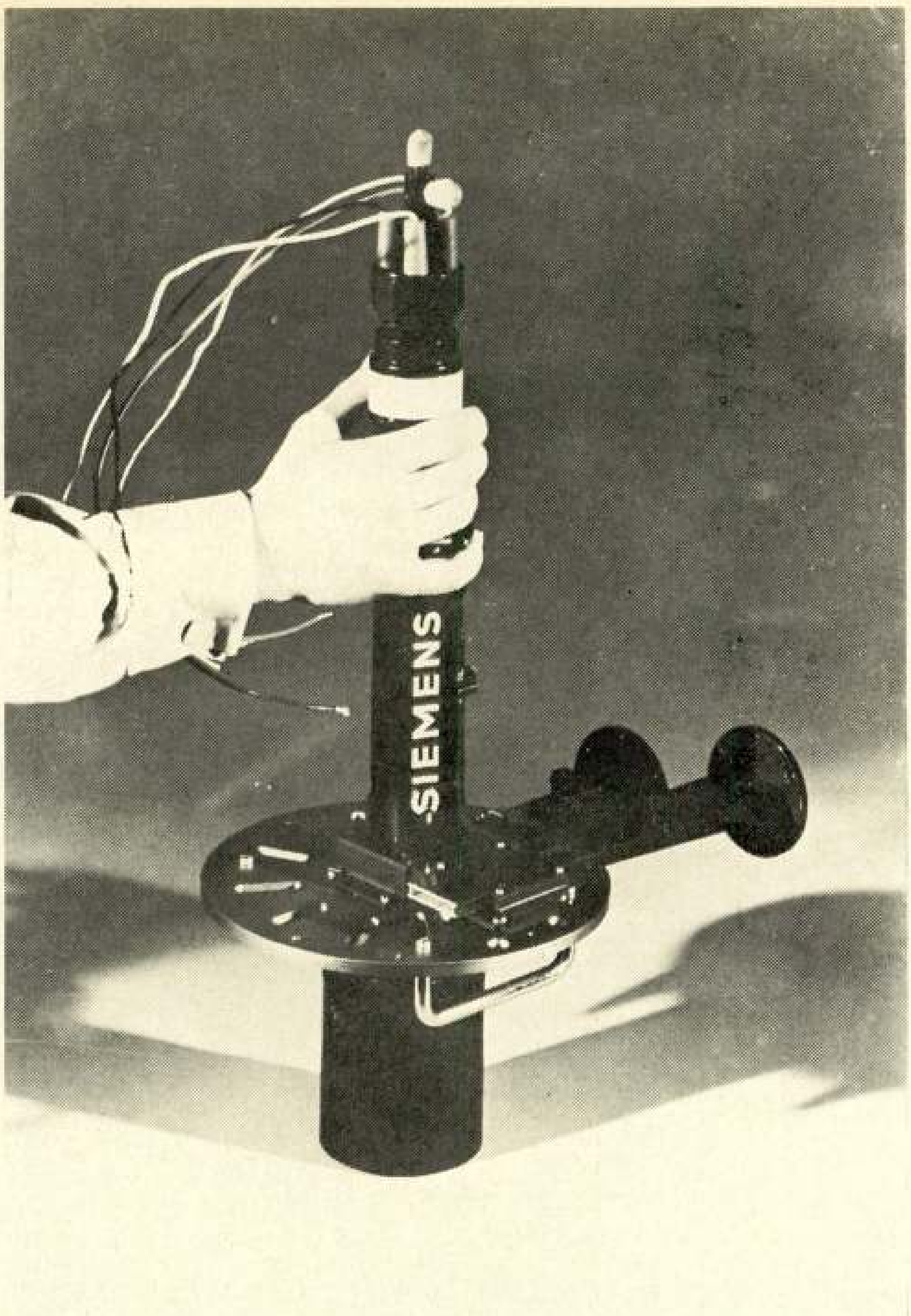


Fig. 9. View of the 1.5-kW travelling-wave tube YH 1043 for the 6-GHz range.

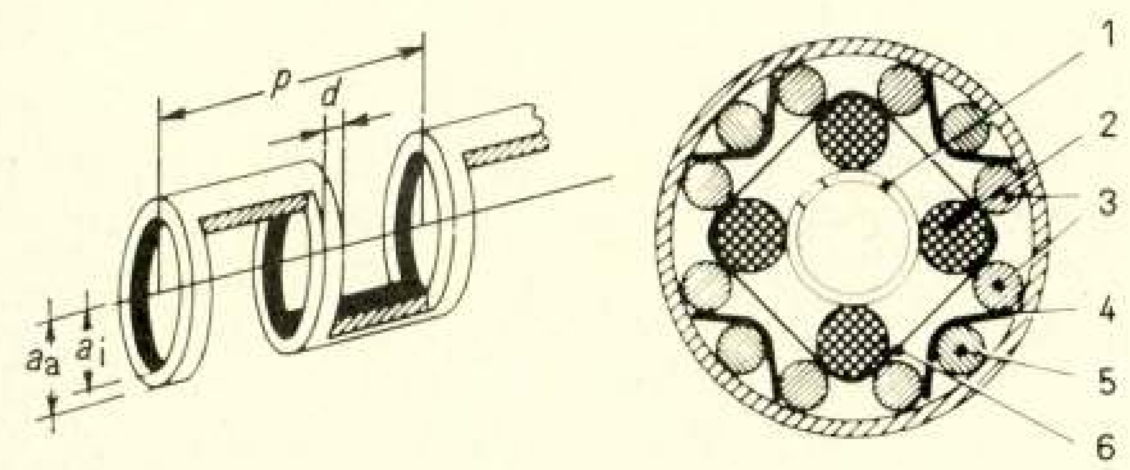


Fig. 10. Bar-and-loop delay line of the YH 1181.

a_i = Inner radius	1. Slow-wave structure	4. Cocking spring
a_a = Outer radius	2. Ceramic support (BeO)	5. Cocking rod
d = Width of the ring	3. Heat-conducting rods	6. Attenuation shaft for suppressing undesired wave-guide modes
p = Repeating length		

It should be mentioned supplementarily that modern tubes for pulsed operation have two grids before the cathode, one lying on cathode potential, the other lying in the shadow of the first one operating as nonintercepting control grid. This feature assures reliable grid pulsing at high peak and average power.

Apart from some exceptions I restricted myself in the preceding descriptions to types designed in Germany, as the principles used there are the same as in foreign designs. I mention two reasons for this. Firstly I am not sufficiently informed on foreign tubes and secondly I can imagine that it is interesting for this international audience to hear some details on tube research in Germany.

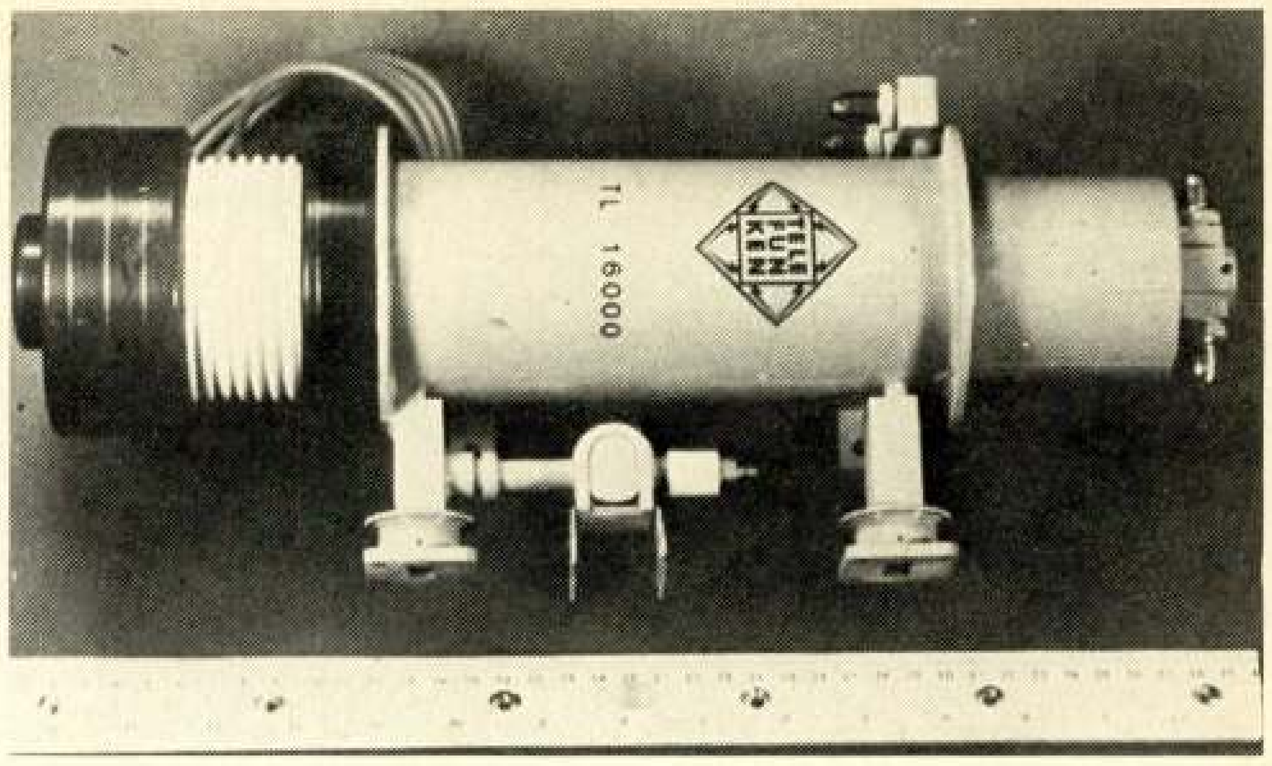


Fig. 11. 5-kW peak power travelling-wave tube TL 16 000 for 16 ... 17 GHz.

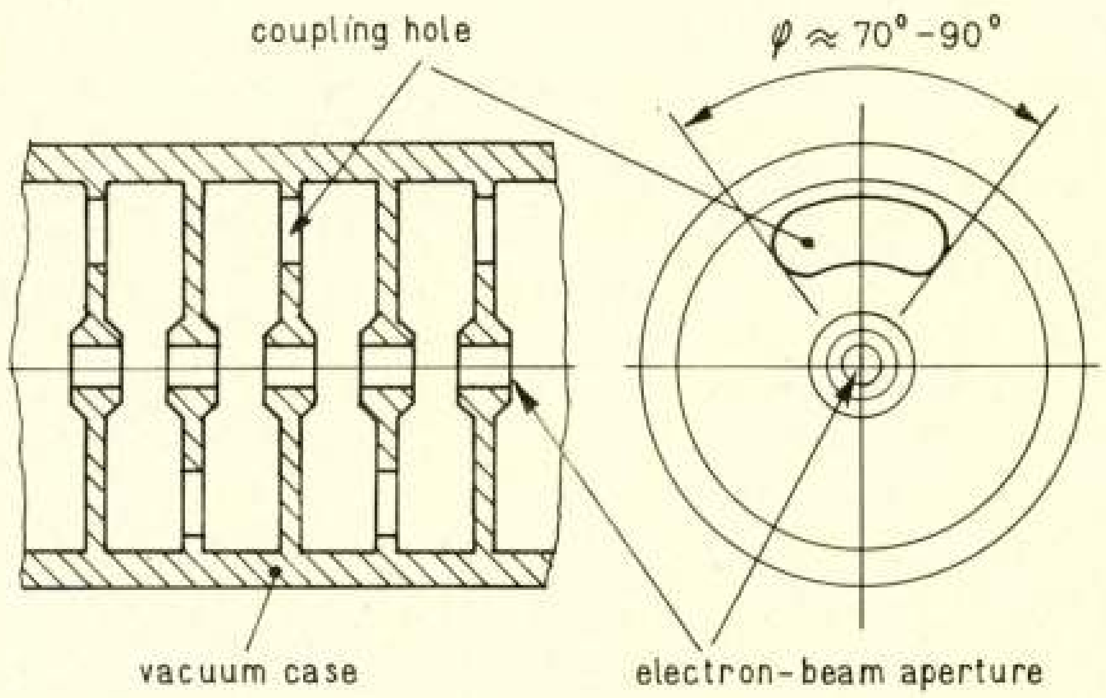


Fig. 12. Coupled-cavity delay line.

5. Hybrid Tubes

Next, some hybrid types of amplifiers shall be described. *Eshleman* and *Pickard* [13] give an account on the so-called *Coaxitron*, a double-stage broadband amplifier consisting of a triode and a pentode in one envelope. At 400 MHz this tube delivers 1,45 MW peak power at an efficiency of 45% with 10% bandwidth. Application of this tube: airborne radar sets.

The TWYSTRON, a hybrid tube composed of a klystron amplifier as buncher and a travelling-wave tube as catcher was treated in detail at the Hamburg-MOGA 1968 [14]. Since that report no more details were published according to a possible application in military electronics. Only *Richard Nelson* [13] describes an amplifier for applications at about 400 MHz with 15% bandwidth, delivering 5 MW peak power with an average power of 20 kW at 40% efficiency. The klystron cavities of this tube are staggertuned and are partly attenuated.

Siemens developed an UHF-travelling wave klystron, the MYK 1180. In this 5-cavity tube, shown in Fig. 13, the effective resonating elements in the cavities are short helix lines which too are staggertuned [15]. The aim was to realize an amplifier which is driven by a transistorized preamplifier. A beam voltage of 10 kV is used. The beam perveance is $5 \cdot 10^{-6}$ A/V$^{3/2}$, the

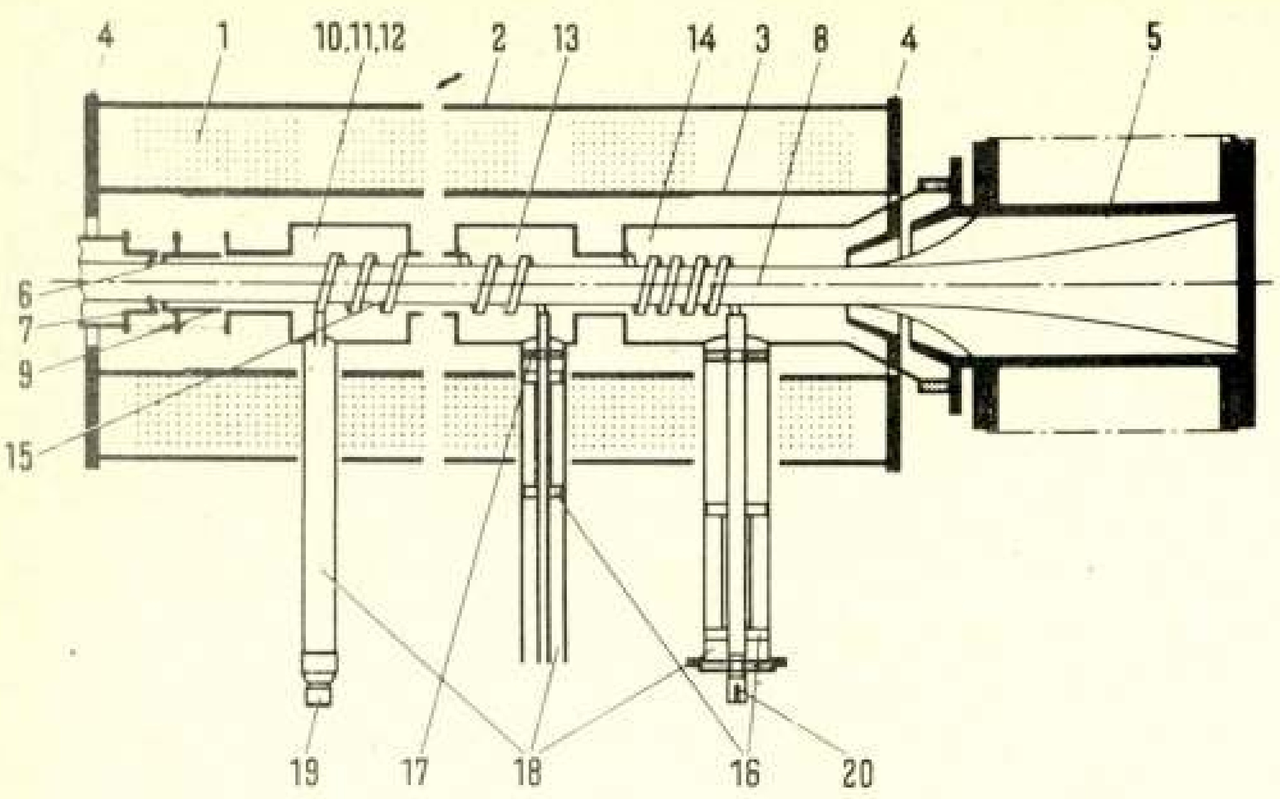


Fig. 13. Schematic drawing of the UHF travelling-wave klystron MYK 1180.

1. Winding of the electro-magnets
2. Magnetic screening
3. Magnetic guiding system
4. Pole pieces
5. Collector (catcher)
6. Cathode
7. Modulator electrode
8. Beam
9. Anode

10 ... 14. Resonators
15. Delay line
16. Shorting plunger
17. Ceramic window
18. Coaxial line
19. Coaxial plug: RF-Input
20. RF-Output

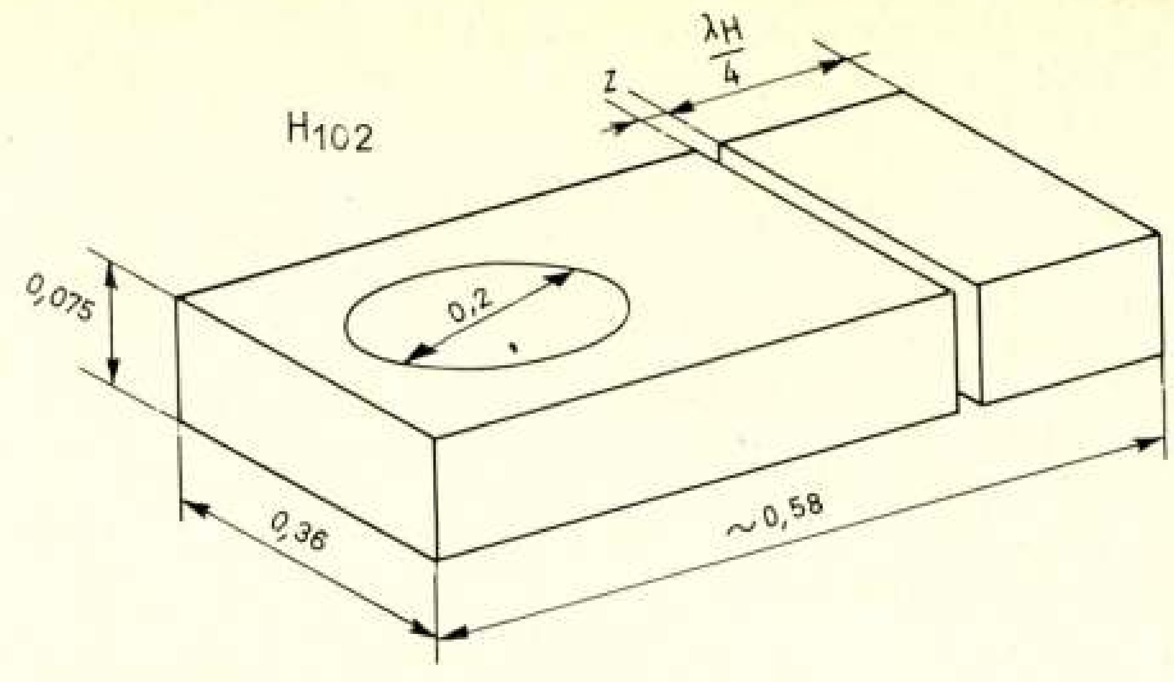


Fig. 15. Catcher-H_{102}-cavity for an experimental c.w. klystron for 0.4-mm waves.

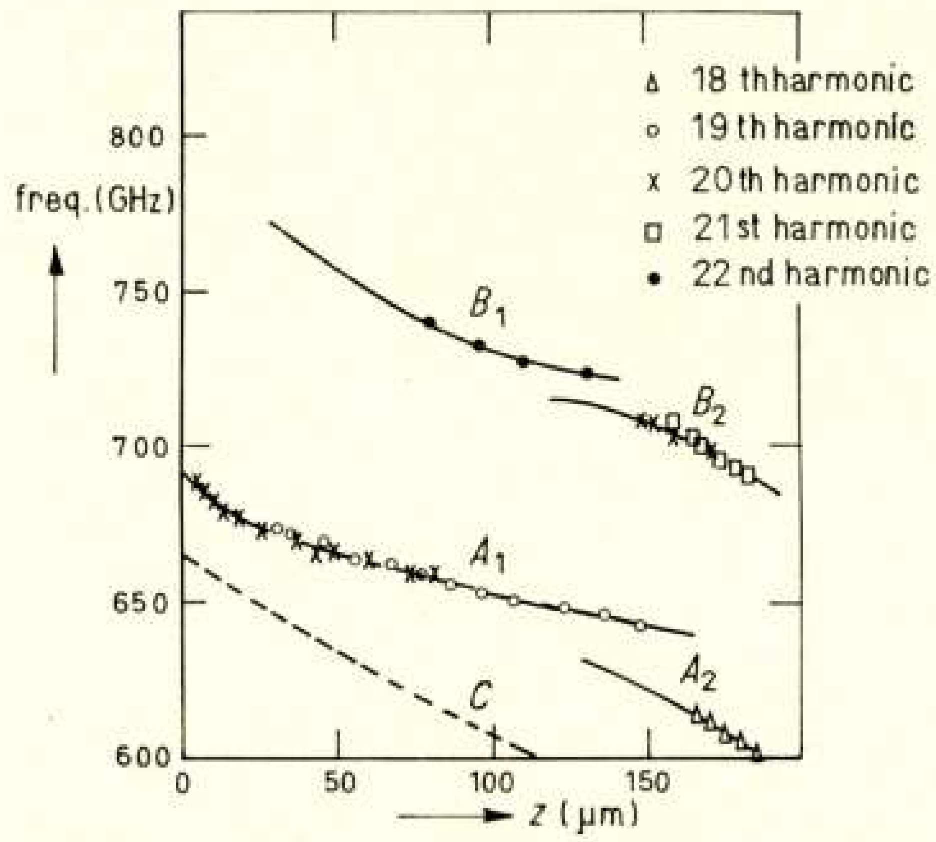


Fig. 16. Resonant frequencies of the catcher cavity as function of the width z of the tuning gap.

A_1 and A_2 : H_{102}-mode (TE_{012}-mode)
B_1 and B_2 : Cavity mode with electric fields at both sides of the tuning gap in antiphase.
C : Tuning curve of the cavity without beam hole or tuning gap.

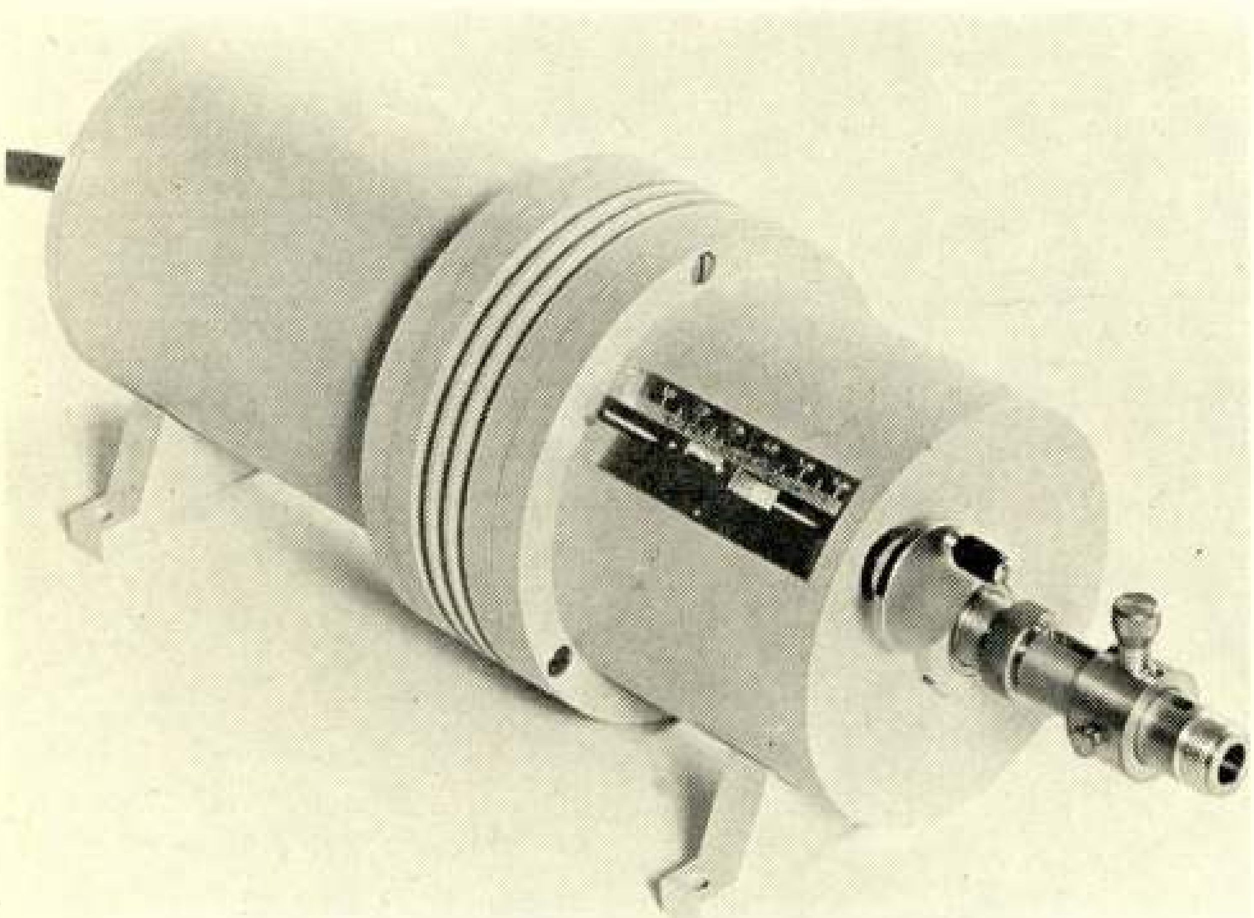


Fig. 14. Resonance backward-wave oscillator RRWO-10.

current density on the cathode surface is more than 1 A/cm^2. The homogeneous focusing field is produced by a solenoid demanding 2 kW d.c.-power. 10 kW output power was obtained at 630 MHz at an amplification of 30 dB. The magnetic field strength is 600 Gauss, the beam transmission more than 99%.

6. Millimeter and sub-mm Wave Tubes

In the region of mm-waves, beside the reflex klystrons for small band operation down to 1 mm wavelength, the backward wave oscillators are dominant. They are used according to their properties especially in sweep oscillators. Here the exceptional research work, performed at the French firm CSF since 1951, has to be emphasized. Three statements about their c.w. power characterize these devices:

at 4 mm wavelength: 40 W
at 2 mm wavelength: 10 W
at 1 mm wavelength: 1 W

Beside the design, the most difficult problem in fabricating these tubes, is a precise assembly technique for the various parts that have to be produced with extreme precision.

Siemens in Germany produces a resonance-backwardwave oscillator (see Fig. 14), providing in the almost one octave broad frequency band of 6,8 ... 12,7 GHz a medium power of 1 W. This oscillator, which is allowed to be frequency modulated or pulsed, is primarily used for measuring techniques.

Beside these broadband sweep oscillators Siemens delivers backward wave oscillators for the frequencies of 75 ... 115 GHz, delivering c.w. powers in the magnitude of 5 mW. The delay line has a length of 8 mm [10]. It consists of stamped copper discs with 0,15 mm diameter holes for the passage of the electron beam, which have been fixed by soldering under pressure. Perhaps these types are interesting for the coming H_{01}-technique. The shortest wavelength, attained with electron tubes, lies, as I am informed, in the region of 0,4 mm, not only at the CSF tubes, but also at an experimental klystron of Philips which I want to put forward at the end of this paragraph because of its originality. This tube is a c.w.-klystron, used as oscillator and frequency multiplier.

The oscillator is working at 35 GHz. It contains 6 mutually coupled re-entrant cavities. It is designed for oscillating in the 2π-mode and can be tuned by an outer cavity of high quality. The rectangular catcher designed for the TE_{102}-type as shown in Fig. 15 is excited by the 18th ... 22nd harmonic of the entering beam. The catcher is divided into two parts along a plane at about a quarter of a wavelength from one end of the cavity. Tuning is performed by varying the width z of the gap between the two parts of the resonator. The dimension of the resonator in mm and the diameter of the hole for the beam passage is indicated in Fig. 15. The catcher cavity that oscillates is tunable over a 15% band as shown in Fig. 16. The klystron operates at a beam voltage of 25 kV and a current of 20 mA; without oscillation the beam transmission is 99%, when oscillating 85% of the beam reaches the collector. The quality of the loaded catcher is 250. At a frequency of 637 GHz, corresponding to a wavelength of 0,47 mm, 1 mW c.w. power is delivered. Compared with a former experimental klystron delivering more c.w. power than this tube the tuning range is considerably enlarged.

7. Summary

I will summarize my above-mentioned considerations on the research trends of the state of microwave tube art as follows:

1. Since the last MOGA-conference, 1968, no important developments as a result of principally new trends in the field of microwave tubes can be reported.
2. Many improvements were made in existing types of tubes; above all in adapting them to special applications, for instance better linearity etc., or, if desired to a longer lifetime.
3. Operation at reduced collector potential and electrostatically beam-focusing delivered higher efficiencies.
4. At higher frequencies the efficiency of TWT's reaches and overtakes the efficiency of klystrons.
5. For special applications a fast warming up cathode of high reliability was developed.
6. In broadband multicavity klystrons the cavities are staggertuned and attenuated as known from high-frequency filter theory.
7. Pulsed tubes are designed with control grids to reduce the pulse-control power.
8. Modern high-power tubes contain ion-getter-pumps.
9. To a large extent computers are employed for designing the electron gun and the beam-focusing.
10. The use of new magnetic materials as for instance samarium-cobalt for beam-focusing will increase, in the form of a periodic permanent magnet integrated with the tube envelope to obtain a compact construction and light weight.

8. Acknowledgement

Finally I want to express my thanks to the firms: AEG-Telefunken; Philips-Valvo; Standard Elektrik Lorenz and Siemens, for providing me with data and figures and for many helpful discussions.

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Satellite Broadcasting in a Modern World

by prof. dr. ir. J. L. Bordewijk, Technological University, Delft

Synopsis: This paper presents a general discussion regarding some technical and social aspects of the use of communication satellites for purposes of broadcasting.

1. Satellite Broadcasting: 'a Panacea or a Box of Pandora'?

We all, living in the age of space technology, have witnessed the great achievements in the fields of space transportation and space communication, culminating in a live transmission of television pictures from the moon. And with this experience in mind none of us, I assume, was excessively shocked when some of our colleagues started to discuss the possibilities of *satellite television broadcasting*. In fact, satellite television broadcasting appears to be feasible in the next two or three years, at least from a technical point of view. At the closing of this MOGA-conference we will certainly know more about the potentialities of newly developed microwave devices that may play an important rôle in transmission as well as in reception of future space broadcasts.

Yet one should not be too optimistic. The step from the United States' Telstar, the Russian Molnya and even the international Intelsat IV towards satellite broadcasting is much more than a difficult technical step. The problems of a strictly technical nature may appear to be solved more or less. But financial and co-ordinational problems that accompany a future worldwide application of satellite broadcasting have not been solved at all. Co-ordination between countries with different political, economical and religious background, co-ordination with space communication services of all other kinds, such as long-distance telephony, satellite navigation, meteorology, earth-resource exploration, and even 'settlements' of industry in space, co-ordination also with the rapidly expanding terrestrial communication services, all this has still a long way to go. But do we have so much time?

It has to be recognized that satellite television broadcasting has the potency and the flexibility of an all-purpose medicine for our sick world, a *panacea* in the sense that every member of our world's population can benefit from it in one way or another, no matter where he lives, be it in the United States, in Russia, in India, in Indonesia, in Latin America, or in our 'below-sealevel countries', and no matter at what level of development his country has arrived. But the crucial question is how to obtain this benefit without colliding with existing social, political and economic structures.

Satellite broadcasting in fact presents a classical example of a technical development that – somewhat like atomic energy – can be used in a very constructive way, as a blessing from heaven, a *panacea* for all maladies, but also in a very destructive manner, much in the way of the ill-famed *box of Pandora* (see Fig. 1).

It could remodel the world into one peaceful village, the while avoiding the need to physically dislocate our villages and to make people city-dwellers. But if used in a wrong manner it could also lead to a worldwide uniformation or even a mental slavery that may be worse than physical destruction by the atomic bomb. The days of Hitler are still close behind us and there are numerous examples again in our days of information-manipulation. The free flow of unmanipulated information around the earth is the basis of all freedom. Because of its flexible potency in this respect, satellite broadcasting must be looked upon as one of the most central, but also as one of the most complex problems with which humanity is confronted today.

I estimate it a very good thought of the organizing committees of this conference to spend the precious time of the first day of the conference in the problem of satellite broadcasting. Especially because I firmly believe that it is our task as engineers and scientists to be aware of the non-technical consequences of our work, to discuss these consequences among ourselves and to inform our colleagues in neighbouring fields, to inform the leading authorities in governments and organizations, and not in the least to inform the general public of the promises that lie ahead of us if we were able to make our choices well. As M. Ponte [1] states in a recent publication in the IEEE Spectrum: '*In truth there is no longer any public affair that is entirely political, nor is there any that is entirely technical*'.

2. Growth and Shortcomings of Earthbound Telecommunication

For a good understanding of the perspectives of satellite broadcasting it is essential to be well aware of some characteristic properties of modern terrestrial telecommunication. I shall for that reason briefly survey the growth and shortcomings of earthbound transmission.

The information-carrying signals that are to be transmitted over telecommunication systems have shown a marked increase in complexity during telecommunication's short history. This increase in complexity makes itself among other things felt in the broadening of the frequency spectrum occupied by the signals.

The classical 50 baud telegraphy takes up approximately 40 Hz, telephony 3 100 Hz, the video signal 5 MHz, digitalized picture signals may need even 100 MHz and computer signals are in a fascinating process of growth and seem to beat all that was (Fig. 2). This increase in signal-bandwidth together with the steady growth in the amounts of signals that have to be transmitted have given a tremendous stimulus in the search for cheap wide-band transmission channels.

In the area of cable transmission, i.e. the class of all guided electromagnetic waves, it is possible and even common practice to arrange a number of channels in parallel along the same transmission path if needed. These channels can be formed over symmetrical pairs of wires, over coaxial pairs, in waveguides

Invited paper, read on 7 September 1970 for the audience at the Eighth International Conference on Microwave and Optical Generation and Amplification: MOGA 70, Amsterdam.

and so on and can all occupy the same frequency spectrum with the aim of thus extending the total bandwidth and hence the traffic capacity over the transmission path.

In the field of radio transmission such a solution consisting of the repeated use of the same frequency spectrum along one and the same communication route is technically impossible. As a consequence the point was pressed to utilize more and more the higher and higher frequencies for broadcasting, as well as for radio-relay links and other radio services.

Thus, although research on wave cables has confirmed the operationability of cable transmission in the millimeter waveband and even in the optical range, there is a large gap of almost three orders of magnitude between the highest frequencies that are in operational use in cable transmission and those in radio transmission. This is illustrated in Fig. 2, which makes also manifest that the three growth-curves given respectively signal bandwidth, for the highest operational cable frequency and for the highest operational radio frequency, follow the exponential law with astonishing accuracy and without showing any sign of saturation sofar.

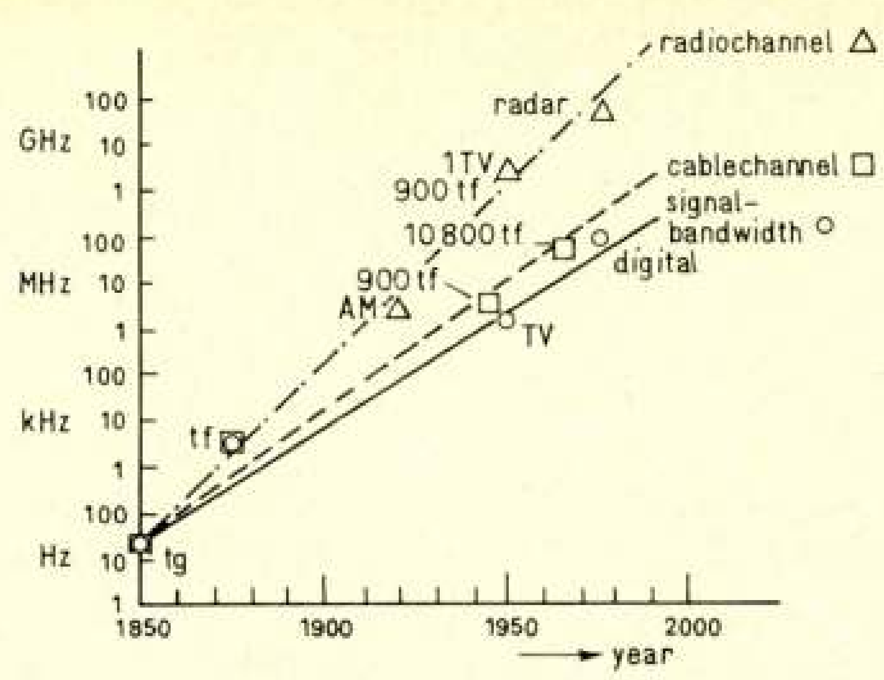

Fig. 2. Highest operational frequency in cable- and radio-transmission compared with growth of signal bandwidth.

Now as is well known, above approximately 30 MHz the ionospheric layers around the earth do not function any longer in securing long-distance transmission. As a consequence bandwidth usurpators such as FM-sound broadcast transmitters and television broadcast transmitters which by international agreement are allocated the spectrum in the VHF and UHF band from 40 MHz up to almost 1000 MHz, have a service area limited practically to within the 'horizon', and so the property of the long-, medium- and especially the short-wave sound broadcasting emissions to bridge great distances could not be preserved for our modern broadcasting networks. Within one country the problems raised by the limited coverage obtained with an FM-sound or television broadcast transmitter could be overcome by providing a number of transmitters with slightly overlapping coverage- or service-areas, all emitting the same program. Such a combination of transmitters is often called a transmitter network (Fig. 3).

And although at the frontiers between countries a certain '*overflow*' does occur – at times even of a long-range character due to incidental irregularities of the troposphere or the ionosphere – the international character of broadcasting was lost at the threshold of a new era in which the picture, that unique *languagefrontiers ignoring information carrier*, was ripe for electronic transportation and broadcasting. Only by means of special international arrangements some programs from foreign countries are relayed over national broadcasting transmitters after being transported over terrestrial radio-relay links or over coaxial cables. Examples are to be found in Eurovision, Mundivision and comparable mutual exchange schemes. These international relays, however, are up to now too incidental and too selective – with peaks in football and moontravelling – to give broadcasting back its international face.

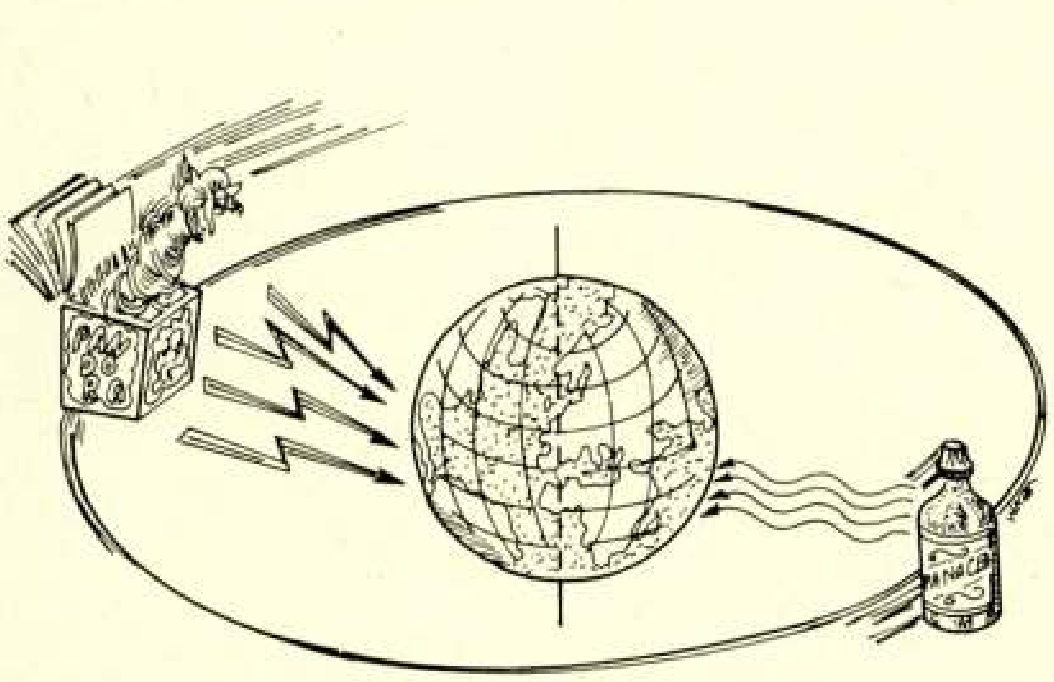

Fig. 1. Satellite broadcasting, a curse or a blessing for our world?

Now, if enough radio spectrum were available for broadcasting purposes, it would be possible to install television transmitter networks for permanent relay of wanted foreign television programs. Alas, – with a few exceptions holding for small isolated and very flat countries – in several developed countries in Europe the radio spectrum available today is in use for distribution of 2 to 3 programs of a national, public or commercial, nationwide character or is planned for use in instructional broadcasting.

If we restrict ourselves, at this point of the exposé to terrestrial transmission there happily appear to exist some possibilities for further expansion and re-internationalization of broadcasting, that in the course of our further discussion will have to be confronted with satellite solutions and therefore require some elucidation here.

The first one is that experimental television broadcast transmitters and receiving equipment have been developed recently in the 11.7 ... 12.7 GHz microwave band, which band, according to existing international agreement, for a still to be settled part, may be used for broadcasting. Calculations and system considerations presented by Goes, Heinzelmann and Vogt [2] show that an additional coverage with up to 8 TV-programs is possible, especially in connection with the development of a second promising distribution-system: the so-called *community antenna television system*, usually abbreviated as CATV, or more general the cable television system that, anyhow, for urban areas will turn out to be a necessary facility for the future. For these 8 additional programs only 600 MHz needs to be available.

For a good understanding one should further realize that there are great differences in the organizational structure of television broadcasting in the different parts of the world. The preponderantly commercial stations in the United States are concentrated in areas that present the best 'market' for 'selling' their audience to advertisers. Especially in rural areas with a very weak or almost zero fieldstrength the desire to pick up some of the programs has led to the erection of a community antenna at a favourable site and the installation of a simple cable distribution network along the houses of the community. As soon as the quality of the wide-band amplifiers necessary in such a network improved, it was recognized that these systems were able to solve also the problem of quickly degrading reception in urban areas with tall buildings and an increasing radio spectrum pollution. Fetching distant programs by radio-relay links and thus being able to offer a rich assortment of up to 12 programs to their subscribers, community antenna operators have become firm competitors of the commercial television transmitter operators in the United States. Some people in the United States are of the opinion that such a competition leads to improved quality.

Others are aware of the need of a timely co-ordination with the telephone industry. For as soon as CATV-networks will be able to offer facilities of a kind that competes with extended future services of the common carriers in matters such as electronic mail, electronic papers, meter-reading and so on, there will occur a collision of interests that seems to be undesired in a field of such great national importance and with so obvious opportunities for technical combinations.

In fact, after a first confrontation between line- and radio-point-to-point communication around 1950, followed by a process of diffusion and integration that is still going on, and after a second confrontation of no minor importance between systems for distribution of television 'through the air' and cable distribution systems taking place now, the third and greatest '*bang*' in telecommunication is already announcing itself: *The meeting, collision and eventual integration of point-to-point and distribution systems belonging hitherto to rather different technical and industrial and even political disciplines* (Fig. 4).

In Europe, regional agreement has led to a much more homogeneous distribution of transmitters in order to obtain nationwide coverage for a maximum number of programs. Rural areas as well as urban areas were covered. And in hilly terrain so-called 'fill-in' transmitters were inserted in order to obtain a better coverage varying in Western Europe from a low 5 % in Greece up to 99 % in the very flat and densely populated country of the Netherlands.

Many developing countries have coverage figures that are considerably lower. Very often only the principal centers have available one television station. Geographical as well as financial circumstances retard or impede further expansion of a communication medium that especially in those countries could open the door towards freedom and prosperity if properly used with a correct dose of education and instruction.

Probably because of the relatively good coverage figures for rural areas in Europe, the need for improvement in the quality of reception is felt mainly in the large population centers. Having started with master antenna systems in apartment buildings, there is now a tendency in Europe of further expanding these simple systems towards cable distribution systems for entire city districts, especially the new suburbs.

Taking into account the actual as well as the potential increase in picture program-sources such as distant-programs, picturephone, television newspaper in its several phases of development, local-interest programs, etc. falling under the authority or the concession of often quite different organizations observing the need for technical co-ordination due to the difficult technical problems involved in delivering all these signals to the customer-viewer with sufficient *quality*, recognizing the dangers connected with the constitution of *monopolies* in the field of information supply, it is clear that careful studies of a multi-disciplinary nature have to be undertaken before the 'simple cable television systems' as a whole can be exchanged for the 'wired-city concept' [3] in the process of integration that will follow, as we hope, the third above-mentioned confrontation in the development of telecommunication.

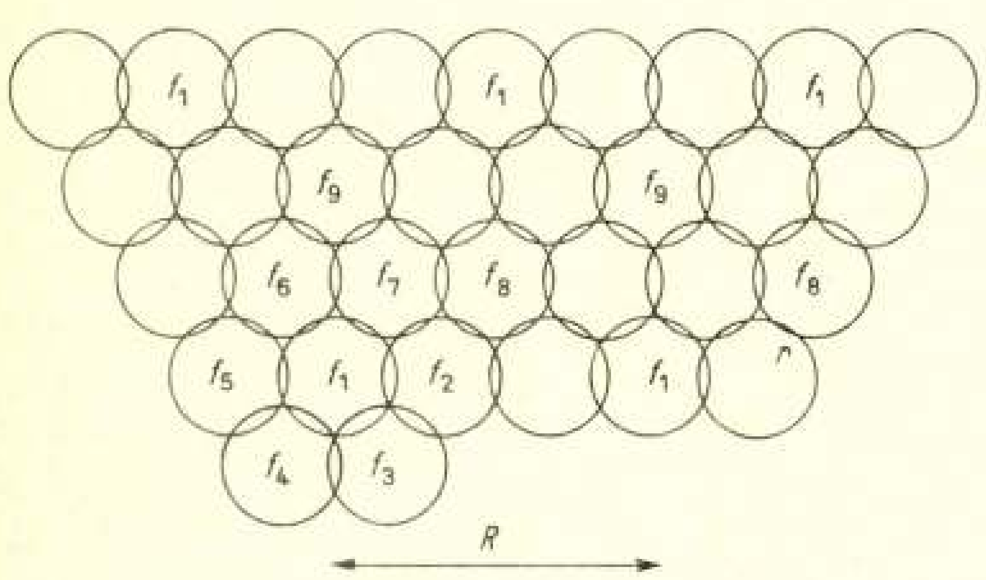

Fig. 3. Example, showing that for a terrestrial television transmitter network 9 frequency channels $f_1, f_2, \dots f_9$ are needed if the frequency-repetition-distance R is approximately 5 times the radius of the coverage area.

3. Improvements obtainable from Satellite Communication

Technically speaking, the only essential new feature of satellite communication that puts it apart from terrestrial radio communication is the unusual site occupied by some of the receivers and transmitters that play a rôle in a satellite communication system.

The enormous progress in space and aeronautics after the Second World War made it possible to bring small prefabricated radiostations complete with receiving and transmitting aerials

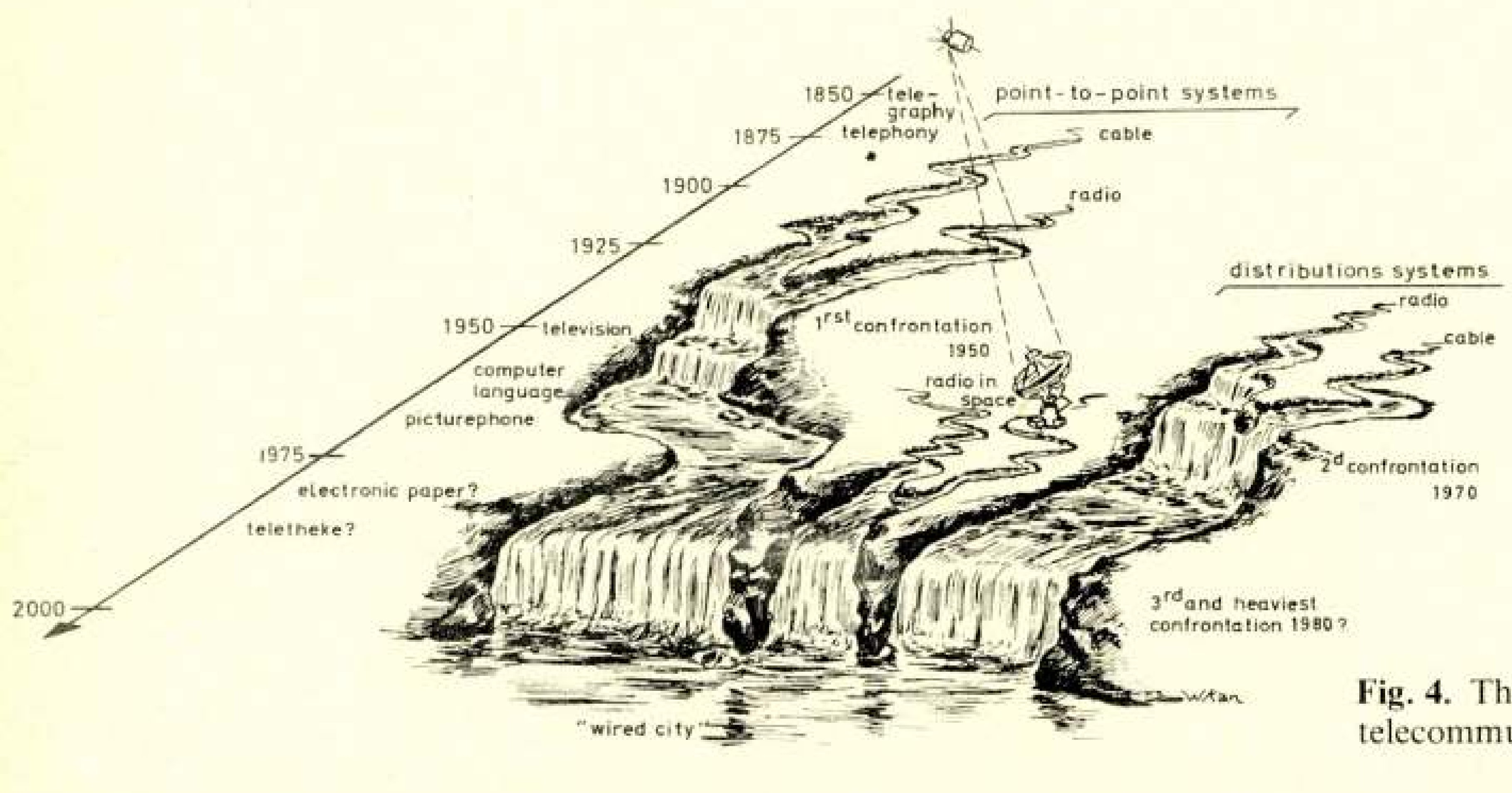

Fig. 4. The three confrontations in the development of telecommunication.

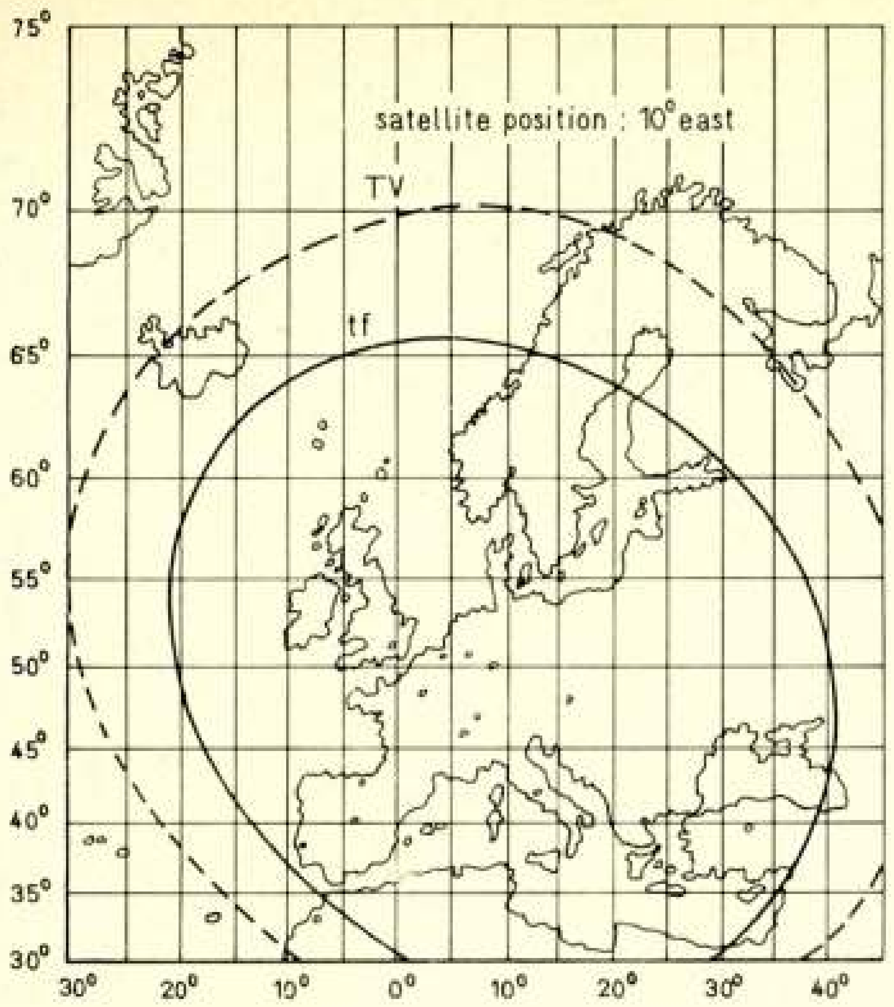

Fig. 5. Possible coverage areas for a European telecommunication satellite (courtesy of Ir. R. Viddeleer, Netherlands PTT).

and an individual power supply system into a circular or elliptical orbit around the earth. Launchers answering to euphonous names like Titan, Saturnus, Atlas-Centaur, etc. can in combination with a small apogeemotor today carry even a two-storey radiostation with a weight of some 3 000 pounds like the Intelsat IV satellites to a position in space fixed with respect to the earth where it is 'anchored' more or less like a lightship at sea, but behaving extremely more stable through the use of a sensitive stabilization system.

Such a radiostation is referred to as a 'geostationary communication satellite' because it moves along a circle concentric with the equator at such a distance and brought there with such a velocity that the gravitational force exercised on it by our earth makes it revolve around the earth's axis in exactly one sidereal day, thus keeping it in a fixed position relative to the earth's surface, at a height of approximately 36 000 km. Only small ejections of gas suffice to the satellite for its slight position and attitude corrections. It receives the required electrical power from the sun via solar cells with a yield of 100 W/m^2 and better.

A variety of other orbits is possible, and for certain purposes these are in use: asynchronous and subsynchronous (lower) orbits in the equatorial plane, and polar as well as skew elliptical orbits covering pole-neighbouring areas for considerable parts of their orbiting time. However, none of these variants has the advantage of being geostationary. Up to now, for communication purposes in the belt between $\pm 70°$ latitude the geostationary or synchronous orbit has turned out to be the most practicable [4]. Even the almost too large propagation time of 250 ms for telephony, with its bi-directional character, seems – against many professional expectations – to be accepted by the users.

For mass transportation of telephone signals the geostationary communication satellite has proven its use and has become a severe competitor of the transoceanic cables. It offers a much wider frequency band: 1200 circuits for Intelsat III now in service, and 6000 circuits for the Intelsat IV-series to be launched from 1971 onwards, against a few hundred over the cables. It shows a hitherto unknown flexibility. By applying *multiple access* and *demand assignment* methods of operation it becomes a real multisource-multidestination system almost acting as an automatic telephone exchange in space.

Intelsat's global system earns its money mainly from transoceanic commercial telephony. But especially in the Intelsat IV-series more space will be available for television relay purposes. The global system is characterized by the use of relatively small spacecraft using small, wide-beam antennas and expensive earthstations with a 27-meter diameter antenna. Improvements in the solar cell power supply system, use of larger satellite antennas with narrower beams will make it possible to concentrate the energy and reduce considerably the cost of earth terminals. This opens the way for a second system, a *regional television distribution satellite* that might replace and extend existing terrestrial radio-relay networks.

As an example the idea of a European distribution satellite may be mentioned. It has the aim of considerably expanding the facilities of Eurovision. Fig. 5 shows the result reached by a mixed CEPT/ESRO/EBU telephone-television studygroup that examined the desirability of a satellite system with accommodation for e.g. 7 × 1800 telephone circuits and 2 television circuits each with a satellite transmitter power of 7 watt and earthstation antennas with a diameter of 13 meter. In the United States and in Russia such a satellite would probably be called a 'domestic' satellite! As in Europe all frequency bands below 10 GHz are already in use or allocated, it is proposed to make use of 11.45 ... 11.95 GHz for the down-path and of 12.75 ... 13.25 GHz for the up-path.

A third system that requires still more satellite power is the *educational television satellite*. We might take as an example India, or one of the developing areas that makes great efforts in this field. The United States will make the use of their so-called Applications Technology Satellite ATS-F available for India for a period of one year starting in 1973. It rests solely under the responsibility of India for the television programming, and has the aim of bringing instructional television programs to some 5000 Indian villages. ATS-F will carry a 30-ft antenna with pointing accuracy of $\pm 0.1°$ and is provided with an UHF-80-watt-transmitter (800 ... 900 MHz) capable of transmitting one video and two audio signals. The village receivers will require a 2 to 3 meter diameter antenna. The satellite will get its program supply from the Indian earthstation Ahmedabad in the 4 ... 6-GHz band. It is questionable whether for instructional purposes under all circumstances a videochannel is required. Simple sketches and drawings can be transmitted over much narrower channels. As there are great advantages in using simple standard television sets in the village school, the problem of cheap binary memories arises. Among other things, work in this field is done at the Delft University of Technology in this country in collaboration with the Institut Teknologi Bandung of Indonesia.

A fourth system, that of direct or semi-direct satellite broadcasting in the 11.7 ... 12.7-GHz band, is more or less competitive with the plans of using this band for supplementary terrestrial broadcasting. In this band which is not yet definitely subdivided for broadcast purposes, the point of spectrum economy may become of some importance. Is it advantageous from the point of view of spectrum economy to put all broadcast transmitters in this band in a geostationary orbit instead of on earth? Both seem technically feasible for countries that are large enough. Although it is already considered feasible to erect in space, antennas with overall dimensions of 30 m for 12 GHz, the transmitting antenna suffices to measure only 2 m in diameter for a beamwidth of 1°. This is a major advantage of the use of higher frequencies for space broadcasting.

The narrow beamwidth possible for the receiving antenna leads to an interesting new degree of freedom in the use of the frequency spectrum that is not offered by terrestrial distribution. This degree of freedom follows from the possibility to receive two or even more different televisionprograms on the *same* channel by pointing the receiving aerial in the direction of other satellite transmitters sufficiently far removed from each other to use the same channel (Fig. 6). Calculations and system considerations learn that on the average there will be a gain in spectrum economy by putting the transmitters in space. But obtaining a sufficient 'clearance' for the direct-to-home receiving antenna will be difficult for most city-dwellers and sufficient pointing accuracy will be costly in investment and maintenance. Moreover, if the public in highly developed areas only wants *supplementary programs* the question arises why one should not introduce cable television and keep the radio spectrum clean of broadcast signals, with the exception of some channels for portable receivers; or at most, feed the *head-ends* of the CATV-networks from a regional television distribution satellite?

However, how important these questions may be, the crux of the problem is largely of a non-technical nature.

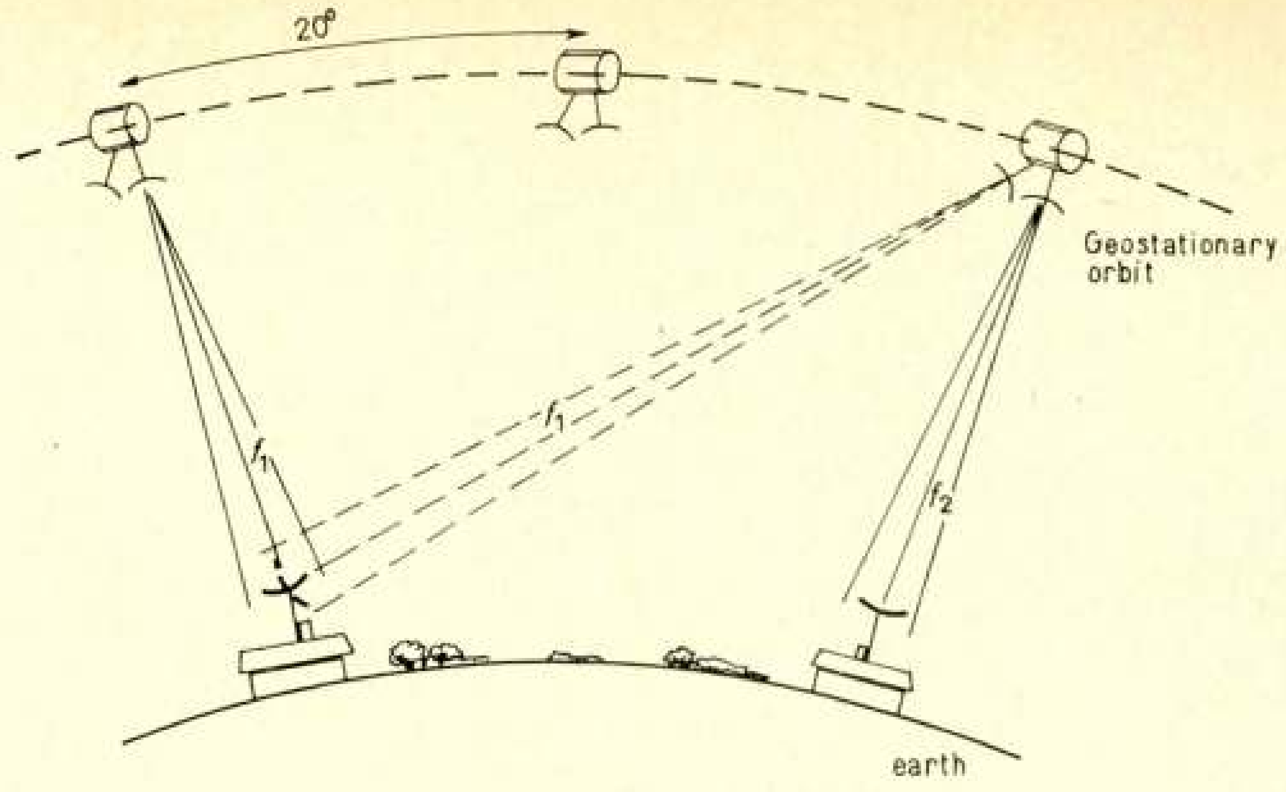

Fig. 6. Illustration of manifold reception on the same frequency channel in space broadcasting.

4. Satellite Broadcasting and Non-technical Criteria

In judging the desirability or the realizability of direct satellite broadcast on the basis of non-technical criteria we have to consider first that, because of the *limited range of a television emission*, in most countries television broadcasting has grown up as a purely national affair. That is to say: the enormous influence, that can be exercised by television with regard to social and cultural, religious and political thinking, was from the early beginning highly nationally coloured. Even the advertisements were! Only incidentally – and certainly not daily – programs from abroad were allowed to be included in the process of information flow. And that only if national organizations deemed it desirable.

As a consequence of this development the putting into operation of direct-to-home television broadcast satellites by one country shall evoke great *political*, *religious* and *commercial opposition*. I am strengthened in this opinion by what I read in the final report of the meeting of governmental experts on international arrangements in the space communication field in Paris last February under authority of the UNESCO. Among other things I read there:

'several experts called for a general declaration of policy asserting the right of each country to self-determination regarding what broadcasts should be received'.

It is surprising and very instructive too for the engineer to see what influence a passing technical restriction has had on social and political thinking, i.e. the temporary restriction on television reception to an area within the horizon of a terrestrial transmitter antenna, a restriction that can be eliminated today by the use of satellite broadcasting. Although in sound broadcasting such a thought never came up because of the very nature of the propagation properties of long, medium and short waves, in the same meeting of UNESCO-experts the possibility of 'broadcasting in a country without prior agreement of the governments concerned' was put forward as a serious problem.

The effect of such a passing restriction may be well compared with the temporary blocking up of a river for example by an ice-barrier in winter. Problems of this kind need a careful approach. A reckless blowing up of the barrier by one country could indeed provoke a complete space communication 'deluge'. Many years of careful international deliberations in the domain of telecommunication could thus lose their value in a fraction of time.

One has to realize that telecommunication is linked with, if not balanced against the economical, social and political situation in the respective countries. I believe that we have to be very careful in disturbing this balance by applying a communication-shock-therapy. A suddenly introduced daily-returning continuous confrontation of people in areas with poverty, undernourishment, lack of freedom or other shortcomings, with the situation in wealthy nations could do incalculable harm.

For that reason I do not judge it wise for the near future to apply (semi-)direct television broadcasting other than:

a. for educational purposes in developing countries in the UHF-band;

b. for fast introduction of a national television service in developing countries in the UHF-band, as long as they do not interfere with services in surrounding countries;

c. only for supplementary programs in the developed countries if these are able to guarantee a sufficiently weak fieldstrength in neighbouring countries.

This requirement will probably restrict satellite television in the developed countries for at least the next decade to semi-direct reception, i.e. via CATV-systems that can work economically with rather low fieldstrengths that are too weak for direct-to-home reception. And even this semi-direct broadcasting will probably be restricted to countries where the call for supplementary programs is extremely strong.

From these three possibilities a., b. and c. the first two can be classified as highly necessary medicaments of the 'panacea-type'. Only under the restrictions mentioned we may expect that possibility c. does not turn out to be equivalent to the opening of Pandora's Box.

Indeed too rude an overstepping of frontiers that have been closed for long might be equivalent to opening Pandora's Box. But let us not give up *hope*, when at some time in the coming years our satellites will show a little bit of the character of Pandora's Box and some evil will jump out, when 'the lid is opened'. For even at the bottom of Pandora's Box, according to the old Greek legend, '*Hope*' was left.

5. The Key-Position of the Microwave Engineer

The requirement of avoiding 'unwanted' unilateral radiation on other countries will in my opinion, for a long time to come, play an important rôle in the design of satellite broadcast systems.

An antenna with a beamwidth of 3 to 4°, mounted on a satellite in geostationary orbit can almost cover the whole of Western Europe as we may derive from Fig. 5. Such a beamwidth could be useful for a European TV-distribution satellite and perhaps for direct-to-home broadcasting of inter-European TV-programs, but it would be a waste of frequency spectrum to use it for the national programs of all the countries involved and moreover give 'unwanted' radiations in a number of countries. For the coverage of one of the larger countries in Western Europe the beamwidth should be less than one degree. At a frequency of 1 GHz a one-degree beamwidth already requires an antenna with overall dimensions of approximately 20 m. At 10 GHz the dimensions could be reduced to roughly 2 m.

These facts and the needs of existing services in the frequency bands below 10 GHz make it very probable that, although frequencies above 10 GHz suffer from increasing attenuation due to rain, fog and molecular absorption phenomena, the realization of satellite broadcasting will depend greatly on the success of microwave engineers in devising powerful and efficient transmitters as well as receivers with a sufficiently low operational temperature in the microwave region from 10 GHz upwards.

The remarkable conclusion must be that: *the very property that restricted the range of microwave transmission in terrestrial applications i.e. their short wavelength, leading to a pseudo-optical propagation behaviour – may be the key to a peaceful use of communication in space.*

I can imagine that you, microwave engineer, in spite of all your enthousiasm in the search for new devices do not feel fully satisfied with this conclusion. Neither do I. Therefor the principle of 'free flow of information' is too attractive.

Let us, however hope – utopic as the idea may seem – that it will be possible for the United Nations Organization to make available soon at least one global program – practically organized as a number of analogous but 'sun-time adapted' television programs – of sufficient interest for all, and 'unwanted' by none of the countries.

I think that everybody will be happy to sacrifice a little of his time, his energy and our common 'frequency spectrum' for such a panacea.

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[1] M. Ponte: The role of the engineer in public affairs. IEEE Spectrum, July 1970, Vol. 7, number 7.

[2] O. W. Goes, G. Heinzelmann and K. Vogt: Transmitter-network planning for terrestrial television broadcasting in the 11.7 to 12.7 GHz band. E.B.U. Review, October 1968, part A, technical, number 111.

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[4] C.C.I.R. Doc. XI/236, 17 September 1969.

Korte technische berichten

Opening computer terminal in Rotterdam

Op 27 november 1970 werd het semi-openbare eindstation van Logisterion officieel in gebruik genomen. Dit geeft het bedrijfsleven in de omgeving van Rotterdam directe toegang tot een CDC 6600 computer, opgesteld bij de 'C.D.C. data services' te Rijswijk.

Control Data Europe Inc. heeft drie CDC 6600 datacentra geïnstalleerd: een in Stockholm, een tweede in Rijswijk en een derde in Stuttgart. Drie semi-openbare eindstations zijn aangesloten op het datacentrum te Rijswijk: een in Rotterdam, bij Logisterion, een in Düsseldorf en een in Brussel, terwijl de aansluiting van een vierde eindstation, te Milaan, in voorbereiding is. Het ligt in de bedoeling, in de komende maanden nog een semi-openbaar eindstation te openen in Arnhem, Amsterdam en Utrecht.

Op het datacentrum in Stockholm zijn terminals aangesloten te Kopenhagen, Oslo en Helsinki.

Het eindstation te Rotterdam, geëxploiteerd door Logisterion, is uitgerust met een kaartenlezer, een ponsbandlezer en een regeldrukker. Het is via het PTT-net door middel van een 2400 baud verbinding verbonden met de computer te Rijswijk.

Logisterion is een dienstverlenend bedrijf; zij verzorgt onder andere de programmering van technische berekeningen voor bouwkundige en werktuigbouwkundige projecten. De rekenprogramma's, welke in de computer te Rijswijk worden opgeslagen, blijven het bezit van Logisterion. Via een codesleutel heeft men vanuit de terminal tot de eigen programma's en berekeningen toegang; anderen zijn van het gebruik van de gegevens dus uitgesloten.

Door C.D.C. is met de exploitanten van de terminals een regeling getroffen, waardoor men na onderling goedvinden elkanders programma's kan gebruiken. Voor het gebruik vindt met de eigenaar van het programma een verrekening plaats. De centra te Stockholm, Rijswijk en Stuttgart kunnen door deze regeling van elkanders programma's gebruik maken.

De samenwerking tussen de centra kan verder worden geïntensiveerd, wanneer zij onderling kunnen worden gekoppeld door een dataverbinding met grote snelheidscapaciteit. Een snelheid in de orde van 40 000 tekens/s zou daarvoor benodigd zijn.

Persbericht, Logisterion-Control Data Corporation.

Varia

1971 European Microwave Conference will be held in Stockholm, Sweden, August 23 ... 28, 1971

The 1971 European Microwave Conference will be held in Stockholm, Sweden, at the Royal Institute of Technology on August 23 ... 28, 1971.

This international conference is the second of its kind, succeeding the conference in London, September 1969, to deal comprehensively with the subject of microwaves. It is organized by the Royal Swedish Academy of Engineering Sciences in co-operation with IEE Electronics Division, IEEE Region 8 and the Group of Microwave Theory and Techniques, and the Swedish National Committee of URSI.

In addition to short contributed papers, all of which will be orally presented, there will also be invited review papers covering important subjects. Original papers in the following fields are invited:
Microwave solid state devices
Microwave components, and computer analysis
Microwave integrated techniques
Microwave antennas
Microwave acoustics
Microwave applications

Submission of short papers
The time for presentation and discussion will be 15 minutes. Authors are requested to submit 3 copies of a typed summary 300-500 words in length. The author's name, affiliation and complete return address should be clearly stated.

Since papers are selected on the basis of the summary, it must include a concise statement of what new results have been obtained, supported by illustrations where appropriate:

The summary should be forwarded to reach the organizing secretariat
1971 European Microwave Conference
Fack 23, 104 50 Stockholm 80, Sweden

at the latest by March 1, 1971.

The authors will be notified of the acceptance of the papers by March 30, 1971. They will be requested to submit a final one-page summary for publication in the Abstracts Handbook, on June 1, 1971, at the latest, and a complete manuscript for the Conference Proceedings on or before July 15, 1971. It is intended to have the printed proceedings available at the end of the conference. The subsequent submission of conference papers to technical journals for open publication is not precluded.

The submission and presentation of the papers should be in English. There will be no simultaneous translation planned for the conference.

A tentative conference program and information concerning accommodation will be mailed in April 1971 to those who have sent a request to the address given above.

Boekennieuws

E. SCHANDA, u.a.: **Theorie der elektromagnetische Wellen,** 128 blz., Birkhäuser Verlag, Basel und Stuttgart, 1969.

Dit boek bevat 11 voordrachten gehouden in een telecommunicatie-colloquium in 1966/67 aan de Universiteit van Bern. Het colloquium werd georganiseerd voor ingenieurs en fysici, werkzaam in de telecommunicatie-industrie. Na de inleidende voordracht van *Prof. G. Epprecht* (Zürich, ETH) volgt een recapitulatie van de mathematische hulpmiddelen (vectoranalyse) door *Prof. H. Carnal* (Bern). In de daarop volgende zes voordrachten van *Dr. E. Schanda* (Bern) wordt de basisstof van het colloquim systematisch behandeld. Hierbij komen aan de orde: de grondbeginselen van de elektriciteitsleer en de theorie van Maxwell, beschouwingen over oppervlaktegolven, golfgeleiders en gesloten resonatoren, de voortplanting van elektromagnetische golven in anisotrope media, waarbij aandacht wordt besteed aan toepassing van ferrieten in golfpijpen, antennestraling en tenslotte de voortplanting en versterking van elektromagnetische golven langs periodieke structuren, toegespitst op de lopende golfbuizen en de parametrische lopende golfversterker, terwijl de laatste voordracht wordt afgesloten met enige beschouwingen over masers en de toepassingsmogelijkheden van lasers in de telecommunicatietechniek. De behandeling van deze materie is helder en systematisch zonder dat daarbij al te diep wordt ingegaan op de mathematische aspecten. In de laatste drie voordrachten worden enige specialistische onderwerpen behandeld. *Prof. H. Severin* (Bochum) geeft een overzicht van cilindrische oppervlaktegolfgeleiders en hun toepassingen. Onder de aandacht worden gebracht de Sommerfeld leiding, de Goubau leiding en de diëlektrische golfgeleider. In de voordracht van *Prof. H. Bremmer* (Eindhoven) wordt ingegaan op de voortplanting van elektromagnetische golven met grote golflengte in de ionosfeer en exosfeer. De toenemende belangrijkheid van V.L.F.-propagatie (3-30 kHz) en E.L.F.-propagatie (< 3 kHz) maken dit overzicht zeer actueel. In de laatste voordracht van *Prof. D. J. R. Stock* (New York) worden nieuwe ontwikkelingen rond de 'minimal streuenden Antenne' behandeld. Al met al geeft dit boekje nuttige informatie voor diegenen die hun kennis van de aan de orde gestelde, toch wel min of meer klassieke, onderwerpen uit dit vakgebied willen opfrissen.

Dr. ir. H. Blok.

Uit het NERG

Administratie van het NERG: Postbus 39, Leidschendam. Giro 94746 t.n.v. penningmeester NERG, Leidschendam. Secretariaat van de Examencommissie-NERG: Von Geusaustraat 151, Voorburg.

Afscheid prof. dr. F. L. Stumpers

Prof. dr. F. L. Stumpers trok zich na het verschijnen van de vorige aflevering van de rubriek Elektronica en Telecommunicatie terug uit de Redactiecommissie. Hij is opgevolgd door ir. O. B. P. Rikkert de Koe.

In prof. Stumpers neemt de Redactiecommissie afscheid van een zeer gewaardeerde medewerker, die ruim 15 jaren een groot aandeel had in het voorbereiden van artikelen voor het Tijdschrift van het Nederlands Radio Genootschap en die sinds 3 jaar deze taak voortzette in de redactie van Elektronica en Telecommunicatie. *Redaktie.*

Ledenmutaties

Nieuwe adressen van leden
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