Vacuum Lamp Interference

R.F. Oscillations from Electric Light Bulbs

By "CATHODE RAY"

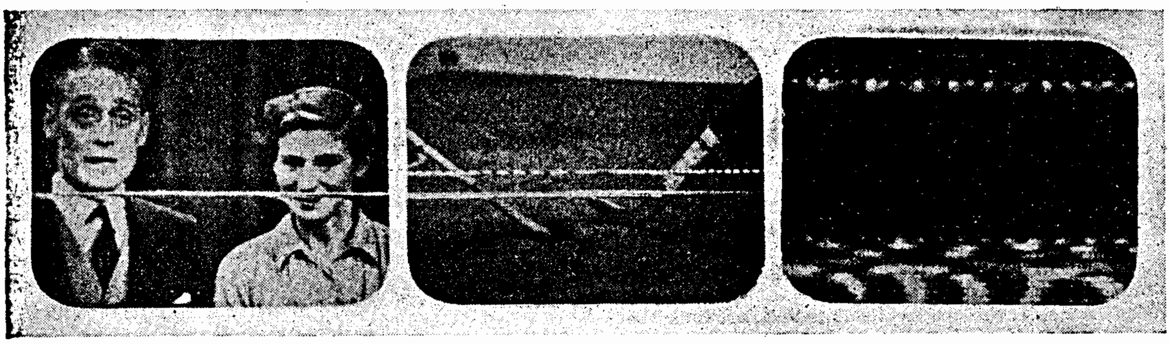


Fig. 1. Example of lamp interference on television pictures.

IF you think you have seen Fig. 1 before somewhere, you are quite right. It appeared as recently as the March issue, p. 102, to illustrate a short note summarizing the findings of 1953 *Wireless World* correspondence on lamps as sources of interference with television. The main point put on record was that gas-filled lamps may interfere when they are so near the end of their life that a microscopic break occurs in the filament, across which an arc is produced, but vacuum lamps can radiate interference throughout their life. No explanation was offered of how vacuum lamps managed to perform this remarkable but objectionable feat, so I have looked into the matter to see if it could be explained.

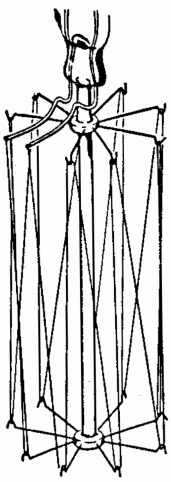


Fig. 2. Typical tungsten filament in vacuum lamp.

Not having actually experienced any of this particular brand of interference, I set about getting some. To do this it was necessary, as Mrs. Beeton might have said, to first catch one's lamp. Some of the younger readers not only may never have seen a specimen of the required type but may even be rather hazy about what a vacuum lamp is. It has long been displaced by the gas-filled lamp for domestic purposes, but apparently is used to this day for a few special applications, mostly connected with transport. As a matter of fact I had to poke around for some time in a dusty old junk box near the ceiling before I could find one. It was an authentic specimen of the kind that must be familiar to all in what I will tactfully refer to as the upper age groups; a long zig-zag filament suspended between two sets of glass-mounted spokes as in Fig. 2. In case it is of interest to anybody, here is the information it carried on the bulb:

3.1.18
Pope "Elasta"
British Made
200-32

The 200 presumably refers to the voltage, and the 32 takes one back to a still earlier era when the carbon-filament lamp reigned supreme, and as the less that was said about its consumption the better it was usually rated not in watts but in candle-power—8, 16, or 32.

Having found my vacuum lamp, I plugged it in and brought it near the television receiver; but with no effect on either picture or sound. The next thing was to dig out the v.h.f. super-regenerative receiver described in the January, 1947, issue, and put near it the lamp connected to a variable source of 50-c/s a.c. To give it a better chance I put a pair of r.f. chokes in the leads close to the holder, and a by-pass capacitor, as in Fig. 3. This worked right away, producing a broad band of interference. By varying the voltage, the centre of the band could be shifted, from about 75 Mc/s at 200V to 56 Mc/s at 145V, below which oscillation ceased altogether. The lack of TV interference in the preliminary test was thus explained, for the local station is Channel 1, 45 Mc/s.

Varying C in Fig. 3 from 0 to 500 pF had only a minor effect; the less the capacitance the higher the frequency, but the whole variation was only a mega-

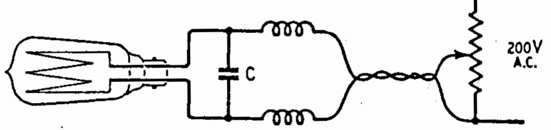


Fig. 3. First experimental lamp oscillator. This proved to be needlessly elaborate.

cycle or so. With 500pF, oscillation seemed a little less ready than with, say, 25 or 50. Removing the chokes made no noticeable difference. In other words, the lamp interfered at least as merrily when connected in the ordinary way at the end of a piece of flex as with any combination of tuning components. The only thing having a substantial effect on the frequency was the voltage. Remember, there is a good vacuum in this kind of lamp, so there is no question of gas discharge, as with the interference caused by neon lighting and a small proportion of fluorescent lamps. It is genuine v.h.f. oscillation, modulated in amplitude and frequency at 50 c/s.

Just to complicate the problem, oscillation ceased every time I drew my hand rapidly away from the bulb, and was stimulated by moving it towards the bulb. Let me emphasize that *holding* the hand at any point within this range of movement—about ½in to 6in from the bulb—did not produce the effects mentioned; they depended entirely on movement. An exception was that actually touching the bulb about its middle invariably stimulated oscillation, and in fact was the most certain way of reviving it when it had petered out, as it was apt to do on slight provocation, such as shifting the position of the lamp. Various arrangements of wires and metal plates, earthed, unearthed, or connected to either lamp terminal, produced sundry effects, but none so marked as with the hand.

Since the main factor controlling frequency was voltage, which with an a.c. supply is varying all the time, it was obviously going to simplify the situation somewhat if the lamp were fed with d.c. This was rigged up with the aid of a mercury rectifier and a smoother that left enough ripple to be heard on the receiver. The general results were very similar to those obtained with a.c., except that as expected there was less frequency modulation, so interference was confined to a narrower band. The tendency for oscillations to fade out was more marked, and it was difficult to keep them going at all unless the lamp holder was connected straight to the supply, without any chokes, etc. The voltage required to tune to a given frequency was nearly 30% higher than the r.m.s. voltage with a.c. (but somewhat lower than the peak voltage), and with 135V ceased altogether, the last measured frequency being 42 Mc/s.

One-Electrode "Valve"

Some months ago* I extolled the marvels of the magnetron, which, though a mere diode, oscillates to such intense effect in the centimetre wavebands. We might feel sure that two was the absolute minimum number of electrodes for true electronic oscillation. Yet here we have a "valve" consisting of filament only, so presumably classifiable as a monode, working as a complete v.h.f. transmitter, without the aid of anything except an ordinary domestic a.c. or d.c. supply. How does it do it?

The best clue was given by A. Q. Morton in a letter in the July, 1953, issue—his reference to an article by P. S. Rand in *CQ*, July, 1952. This article is worth reading not only for the information presented but for the ingeniously humorous manner of presentation. The vital essence, however, is a reference to Barkhausen and Kurz. Old hands will no doubt have their mental bells set ringing by the mere mention of those magical names, but the younger may experience no

* "Valves for Microwaves," Sept., 1953.

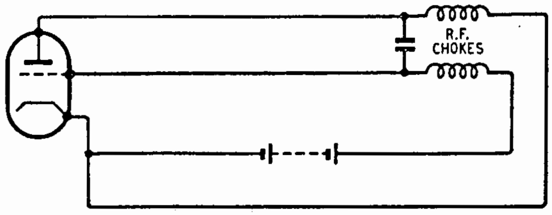


Fig. 4. Barkhausen-Kurz oscillator circuit.

reaction. Barkhausen and Kurz created a considerable stir in highbrow circles from 1920 onward by their disclosure of the type of oscillation named after them. It is obtained with a triode having a positive voltage applied to the grid, and zero or slightly negative anode. The oscillatory circuit consists of parallel Lecher wires, as in Fig. 4. The object of tuning these leads is not to vary the frequency—for their effect on it is slight—but to facilitate oscillation at the frequency set by the grid voltage.

Electrons and Fields

A tremendous lot has been written and talked about Barkhausen-Kurz oscillations, and one can soon get tangled up in a confusion of complication; but there seems to be general agreement about the main essentials of the story. It has much in common with the one I told about magnetrons in "Valves for Microwaves." The underlying principle is that if an electron (or any other electrically charged body) moves *with* an electric field, it *receives* energy, and this energy is manifested as acceleration; if it moves *against* the field it *gives up* energy and consequently loses speed. In the magnetron, electrons are attracted by the h.t. from the cylindrical cathode to the surrounding anode, and this anode is divided into segments by resonant cavities, which have oscillatory voltages superimposed on the common h.t. Those electrons that happen to come under the influence of the oscillatory field in such a phase as to be moving with the field draw energy from it, but use it to their own destruction, or at least their speedy removal from the arena. Those that arrive against the field give up some of their energy (which has been given them by the h.t.) to help keep the oscillations going, and thanks to the subtle interplay of electric and magnetic fields they are able to continue doing this for some time as they dance around. So their contributions of energy far outweigh that taken away by the drone electrons in their much shorter lives.

Something of the same kind is responsible for B-K oscillations. The electrons leaving the cathode are attracted by the positive grid and accelerate violently towards it. But because it is a grid, there is plenty of space between its wires for electrons to go through, and most of them do this. They then find themselves confronted with a negative or at most zero-potential anode, and the positive attraction is now backward. So they are first retarded to a stop and then accelerated back to the grid. Again some go through, and the whole process is repeated until sooner or later they get caught. If you like the rolling-ball analogies we used recently, you can picture the zero-potential cathode and anode as ridges with the positive grid as a trough in between. The balls released at the cathode ridge gain speed as they roll down to the grid, and a few of them are collected there, but most go past and their momentum carries them nearly to the top of the anode ridge; then they roll back, and continue with a sort of to-and-fro pendulum movement. For a given weight of ball, the time for each to-and-fro cycle depends on the distance between the ridges and on the depth of the trough. Similarly the time for a cycle of electronic oscillation depends on the distances between the electrodes and on the grid voltage.

Assuming now, as we did with the magnetron, that the grid potential is oscillating above and below the steady h.t. voltage, at the same frequency as that of the electrons in and out of the grid wires, the electrons that leave the cathode just as the grid is becoming more positive are accelerated more than they would have been without the oscillatory potential. This extra acceleration is at the expense of that potential. And because of the synchronization of frequency, by the time the electron has gone beyond the grid the grid potential has reversed and so the electron is retarded less than it would have been. The net result of greater speed and less braking is that the electron fails to pull up before it reaches the anode, into which it crashes and is thereby removed from the event on the first lap. This, of course, is just what it deserves for stealing energy from the grid oscillation.

Electrons that start just as the grid is beginning its negative half-cycle are accelerated less than with the h.t. alone; and when they get beyond the grid they are retarded more. So all the time they are giving up their energy to the grid and their swing becomes less and less every half-cycle. There is consequently no risk of being collected by the anode, and they have a sporting chance of clearing the grid several times in succession (Fig 5). So, as in the magnetron, if conditions are favourable the energy-giving electrons are more effective than the one-lap energy-taking electrons, and the net result is a build-up of oscillation.

Oscillator Components

What has all this to do with lamps? Well, the only major frequency-controlling factor in the B-K oscillator is the grid voltage. The only major frequency-controlling factor in the lamp oscillator is the applied voltage. This voltage is applied between one end of the filament and the other. Every part of the glowing filament emits electrons and is in a vacuum, so is potentially a valve cathode; and every part is likewise a grid because it is that shape. So when a suitable voltage is applied between one end and the other (either continuously or alternately) the negative end is a cathode and the positive end is a positive grid. The rest of the filament forms a zig-zag loop between the two, having distributed inductance and capacitance. So all the parts of the B-K oscillator seem to be present and correct except the anode. Another difference is that the "tuned circuit" is connected to the cathode instead. As far as potential is concerned there is nothing wrong with that. And the only purpose of the "anode" (it is really no such thing in this case) is to be at somewhere near cathode potential so as to ensure that the space between it and the grid has an electric field that is positive gridwards. P. S. Rand gets over the missing electrode problem by saying "The plate being negative does nothing and might as well be left out." That seems to me just a little too glib. My theory is that the bulb is the "anode."

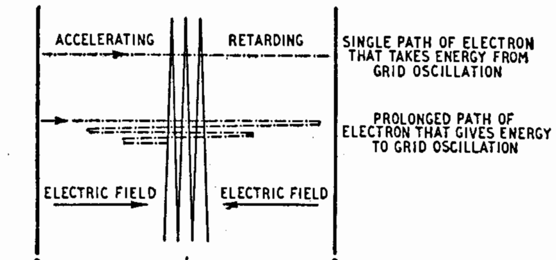


Fig. 5. In a B-K oscillator, electrons that come at the right moments to build up grid oscillation tend to have longer runs than those that damp it down, and so they prevail.

Unauthorized Anode

After all, it wouldn't be the first time. Quite a long while ago* an article appeared by K. A. Macfadyen entitled "A Form of Distortion Known as the 'Buzz Effect'." This showed very convincingly that a certain hitherto mysterious buzz superimposed on sound reproduced by some pentode output valves was caused by the getter—the metallic layer deposited on the inside of the bulb during manufacture—acting as the anode in a dynatron. Only last month, in 'Relaxation Oscillators," we had occasion to refer to an anode-current/anode-voltage diagram with the dynatron kink in it, and a load line cutting it at three possible working points, one of which we found to be impossible—at least for any period of time exceeding zero. Mr. Macfadyen uses exactly the same diagram to show that the unauthorized getter anode goes through sudden violent jumps up and down in potential as the real anode (which unbeknown is acting as the second grid in a dynatron) is trying to execute nice smooth ellipses to give nice smooth bass notes to the loud speaker but is frustrated therein by the said jumps working back via capacitance coupling to the control grid and injecting nasty spiky noises into the programme. Don't waste too much time puzzling this out—the details are not important just now. The main thing is the bulb acting as an electrode. (Incidentally, I usually back the British term "anode" against the American "plate," but with so many electrodes in disguise or playing the wrong roles it is becoming a little difficult!)

You may say that that is all very well, but lamps don't have metallic coatings on the insides of their bulbs—they would stop the light getting out. Certainly lamps wouldn't be very saleable if they were gettered like valves; but for our present purpose we are not looking for a dynatron anode but only for somewhere that can be at about zero potential, and I seem to remember that the whole subject of electronics is generally reckoned to have begun in 1883, when Edison, who had been trying to find a cure for the bulbs of his lamps blackening on the inside with use, discovered that an electric current could pass across the vacuum between filament and bulb. Presumably some trace of metallic coating accumulates, even in more modern lamps, and electrons shot against the bulb by the field we have already discussed tend to charge it negative and so establish a retarding field as required for B-K oscillations.

* *Wireless Engineer*, June, 1938, p. 310.

As it happened, looking up Macfadyen's article I found (what I had completely forgotten) that he goes on from buzz distortion to explain radio interference from vacuum lamps! But apparently the interference he explained was different from the kind we are trying to explain: first, because his interference occurred throughout the band 3 to 30 Mc/s; and secondly, because the dynatron effect was stopped by an earthed coating outside the bulb, whereas that invariably stimulated our kind of interference to greater achievements. No; the interest of this article for our present enquiry lies in its confirmation that the inner surface of a vacuum lamp bulb can act as an electrode. Incidentally, according to a formula quoted by F. E. Terman, giving the frequency of B-K oscillation in terms of voltage and electrode spacing, the spacing in my lamp works out at about 2 cm, which is just about what it is.

So now we have accounted for the whole B-K outfit. What is more, unless I am mistaken we have accounted for the Mystery of the Moving Hand. If an earthed body (mine, in this case) is suddenly moved to a charged body, the capacitance of the charged body to earth is increased, and in accordance with the relationship Q=VC the potential of the charged body is lowered. And vice versa when I move my body away. My theory is therefore as follows. The inner surface of the bulb, on the opposite side of the positive end of the filament ("grid") from the negative end ("cathode") is being bombarded with the electrons that miss the "grid." It therefore becomes negatively charged with respect to the "grid," until the charge is sufficient to keep away the retarded energy-contributing electrons and B-K oscillations can begin. The energy-receiving electrons that crash into it probably cause secondary emission that results in the potential becoming stabilized at a level that is still slightly more positive than "cathode." Bringing a hand quickly towards the bulb causes the potential to drop nearer zero ("cathode")—a condition that favours the oscillation. But when the hand somes to rest the newly increased value of capacitance charges up to the original potential and oscillation reverts to normal. Taking the hand rapidly away raises the potential enough to stop oscillation altogether, but when that incident is over the bulb comes back once more to normal. Holding the bulb firmly, on the other hand, keeps the inner surface at a lower potential by conduction through the warm glass as long as it is held.

If you have a better story, don't hesitate to send it in for general information.

CODES OF PRACTICE

ARRANGEMENTS have been concluded whereby with effect from April 1st, 1954, the preparation and publication of all Codes of Practice will in future be the responsibility of a council within the framework of the British Standards Institution. Hitherto such codes were prepared by the Ministry of Works or the professional institutions concerned, but they were often issued by the B.S.I.

Essentially, codes of practice are concerned with setting out tried and proved methods of operation, installation and maintenance of plant, machinery and equipment, etc., as opposed to manufacturing requirements and processes which take place before plant and equipment leaves the factory. Codes are thus closely related to, although quite distinct from, the standard specifications which form a large part of the work of the British Standards Institution.

The structure of the B.S.I.'s Council for Codes of Practice will be a broad one; its members will be drawn from the professional institutions and such Government departments that may be concerned. It will have a total of 51 members. Much of the work will be carried through by small specialist committees and panels with members drawn from institutions primarily concerned with the subjects to be considered.

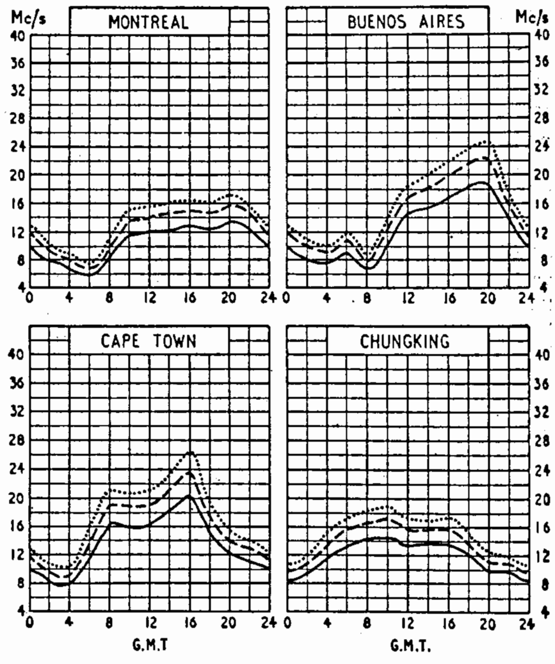
A recent example which has just appeared is a code of practice on "The Use of Electronic Valves," CP 1005: Parts 1 & 2: 1954. This has been prepared by a joint committee of the I.E.E. and the B.S.I. and covers receiving valves, cathode-ray tubes, rectifiers and thyratrons. It is issued as a small booklet of 38 pages by the British Standards Institution, 2, Park Street, London, W.1, and costs 6s.

Short-wave Conditions

Predictions for May

THE full-line curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during May.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.



——— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

– – – – PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

•••••••• FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME