TELEVISION by RESONANCE

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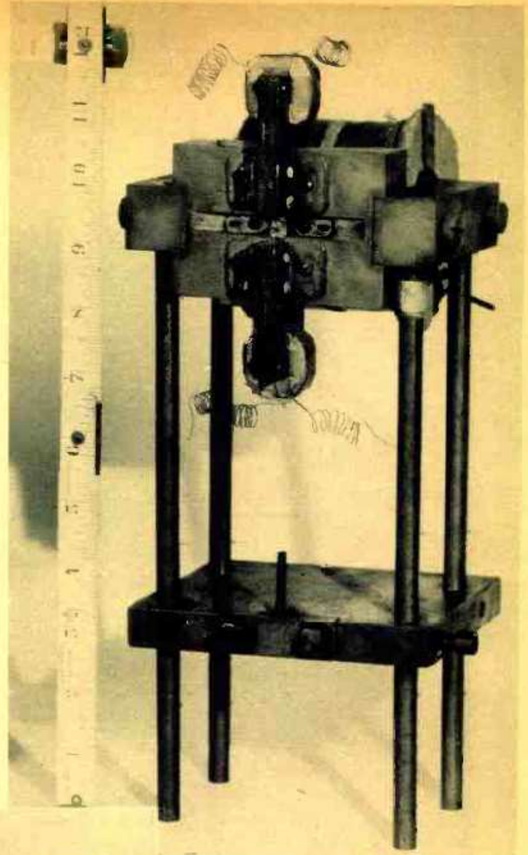
Whirling disks and Cathode Ray tubes are accepted methods of receiving television signals. Mr. Priess describes a new and unique method by which these may become antiquated because his system is capable of enlargement, and might be much cheaper.



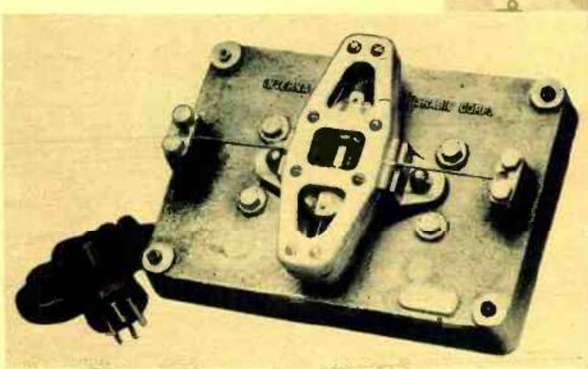
SCIENCE is pregnant with oddities that are spectacular. Innocuous observations that loom up to giant proportions with maturity. A mathematical inconsistency, and a new planet is added to our knowledge. A puzzling change in the resistance of selenium, and the photo cell is born. A persistent intelligent curiosity about the nature of the space in an incandescent lamp, and de Forest gave us the "audion," or vacuum tube, with its myriads of wonders which include the long distance telephone, radio broadcasting, talking motion pictures, surgical and therapy devices, and instruments that permit us to delve into the very essence of substance, force, life and time.

And so it is with the simple phenomena of resonance. Possibly it was first noted when a savage listened to the twang of his bow string. A twang that persisted, reproduced itself in successive plucking, and differed in character from the usual noises of nature.

The applications of the principles of resonance have taken long strides since that dawn era day. Electrical resonance is the cornerstone of the radio art. With the expansion of the understanding of the vagaries of resonance, the lonely beat of the crude jungle tom-tom has risen to the glorious majesty of the Wagnerian orchestra. The breath-taking exactness of each second ticked off by the millions of watches we carry with us to measure elusive time is weighed with an astonishing precision by a resonant device of utter simplicity, a device which in my watch makes over seventy million complete oscillations to tick off the thirty-one and a half million odd seconds that it takes the earth to swing about the sun. Resonance is often a most wicked unwanted customer. It may pile up potentials in power networks, working devastation upon insulators, transformers and generators. It may get into machinery and snap shafting, find its way into ships, automobiles, airplanes and railroads to the discomfort of the passengers, and the rapid deterioration of equipment.

Resonance is the heart of the magnetostriction and piezo electric effects, where infinitesimal motions within the bodies of certain materials are used to control the frequency of substantial forces from ranges of a few cycles a second up to several millions a second.

There are, however, wide gaps that remain a blank in our knowledge of resonance. One gap is obvious, namely, the absence of wide amplitude mechanically resonant devices in the frequency range above one hundred cycles a second. The exploration of this uncharted territory was replete with surprise. Steel that acted like a gum under apparently small applied force. Rigid materials that disintegrated under the influence of high frequence mechanical stresses of a low order of magnitude. Glue, and cements for glass, quickly transformed into fluffy masses entirely devoid of adhesive property. This exploration came about in the perfectly logical search for a means to an end.



An early experimental model which destroyed mirrors and wire when it reached resonance.

Final Priess model by which large television pictures can be made possible. The mirror welded to the wire can be clearly seen.

Television had been demonstrated scientifically. Unfortunately the solutions possessed inherent features that rendered them non-commercial. The Nipkow rotor school was barred by the expense of the receiving set scanner whose cost rose as the cube of the lineage. A satisfactory 60 line scanner at $50 became a curiosity for 240 line scanning, because the $50 jumped to $3,200. The Cathode Ray school developed pictures measured in inches. And even an 8 by 10 inch picture cost about $600. If the pictures were enlarged by projection, the cost mounted about as the ratio of the areas, and the applied voltages reached the dizzy and dangerous heights of 20,000 volts in the home. The obvious conclusion from this state of facts was, that some other principle must be developed for television scanning. We undertook this search. One by one, promising principles were discarded on the results of a first order of magnitude inquiry. There finally remained the principle of the oscillating optical element using either a vibrating lens or mirror. But that element had to travel fast, say 10,000 half swings a second over a wide angle.

Since the driving force varies as the square of the frequency, it would require one hundred million times the force to move the mirror at this frequency, as it would to move it at a frequency of one-half swing a second. The mirror had to have a fair size, for the intensity of the illumination on the screen is directly proportional to the area of the mirror. A calculation showed that the power required to drive a satisfactory mirror over the required angle approximated ten kilowatts. This power would melt the mirror with explosive violence. A model was constructed and from the data obtained on tests at low frequency these calculations were confirmed. Little hope was held out for the helping hand of resonance, for the usual experience with electrical resonance circuits indicated that only an amplitude gain of about fifty to one might be expected. In other words, a power of 200 watts might be used instead of ten kilowatts. This amount of power would fuse the mirror. However, structures were designed, we might say, for the sole purpose of confirming failure, even with the application of the resonance principle.

Then the inexplicable began to happen, and happen fast. Steel wires that had withstood a load of a hundred pounds stretched and broke upon the application of a resonant force of a few ounces. Heavy steel mounting frames developed resonant fre-

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quencies in their structure that were harmonics of the applied driving frequencies, and vibrated in an odd jumble of ways to react upon the purity of the path of the mirror motion, producing elliptical motion, of varying shapes and frequencies. The life of the parts was measured in seconds, and it was a turbulent short life. There was no simplicity of cause and effect, for there were many interacting causes, and the effect was always destruction in many variations, and in a short interval. Two weeks of model building, for an active life of two or three seconds.

The job was now one of isolating all extraneous effects so that the resonant member could be studied in motion, free from all other influences. This resulted in a discovery of far-reaching importance, a property of materials that was so far unsuspected. The resonant build up of a system employing a metal rod in torsion as the elastic element, without pivots and bearings, was of the order of five thousand, or one hundred times as great as suspected. Now at last the reason for the destruction of known materials under apparently safe known applied forces was clear. The forces, instead of having to be multiplied by fifty, must be multiplied by five thousand to determine the peak stresses. For example, if a steel rod had an elastic limit of five thousand pounds, this rod could be destroyed with a resonating driving force of one pound. The energy of the applied force would be stored in the vibrating rod and summed up on each cycle, until at equilibrium the stored-up vibrating energy in the rod became five thousand times as great as the energy expended by each cycle of the driving force.

Here at last was a principle that inherently possessed an activity that multiplied brute force by five thousand. A principle that provided harmonic motion in the purest form we have ever experienced, for the purity of the motion marches step by step with the gain of the motion with respect to the applied force. The track of the motion gave an ideal constancy for scanning.

The rate of decay or decrement could be controlled by merely varying the absolute values of the elasticity and the moment of inertia, while keeping the ratio constant for a given frequency. Vacuum enclosure would still further lower the decrement. Decrements could be exactly measured by the driving frequency-rod motion curves.

Many forms of resonant devices were constructed and tested. The ideal form is one where the elastic element is a rod, firmly embedded in an anchorage of substantial inertia at each end, and with the dynamic moment of inertia element affixed to the center of the rod.

The natural period of the system could be made independent of temperature, by proper choice of materials for the elastic element and the moment of inertia element, whose separate coefficients of expansion formed a compensating couple in such a way that the elasticity and moment of inertia each raised an equal percentage for a given raise in temperature. This cannot be done with either the piezo electric crystal or the magnetostriction rod, for their substance is both factors jointly, and not subject to the separation that is possible with structures such as the ones we devised.

Now our elementary scanner mechanism had been developed, but as yet the optical element had not been applied. This looked to be an easy task involving nothing more than cementing a mirror to the rod; so just that was done. The result was an average mirror life of a few seconds. The cement, under the action of an intense high frequency mechanical motion, turned to a fluffy dust. Bezeling a mirror somewhat in the manner of a jeweler's setting was tried. This likewise did not work, for the mirror developed an infinitesimal play in its mounting which prevented the vibrating motion from building up after the slightest play had developed. Other methods were tried without success. Ultimately a portion of the surface of metal welded to the rod was polished and plated and the surface plated with iridium or rhodium; and the problem was solved. There can be no joints, no possible relative sliding movement of parts, or the gains inherent in the system are lost. The final solution was operated steadily for a run of fifty billion swings without observable deterioration.

It was a simple matter to mount the high frequency vibrating mirror in a cross frame that vibrated slowly at right angles to the original motion, and thus produce a scanner capable of dissecting two or three million picture elements a second at the studio, and reassembling the same number of picture elements a second in the home. There, at last, was a scanner with no wearing parts, and costing about as much as an inexpensive radio speaker to build.

As actually constructed, the rod has an angular twist of 4 degrees on either side of neutral, or a total swing of 8 degrees, providing a scanning angle of 16 degrees. The mirror device optically doubles the mechanical angle, since the angles of incidence and reflection for a mirror are equal. Only one-half a watt of low voltage power is required to drive the mechanism. If a higher definition is desired it can be designed, and we have built scanners that exceed the allowable channel limitations determined by the rules of the Federal Communications Commission and our ability to construct such ultra high frequency amplifiers. The power to drive the low frequency motion is infinitesimal.

Here is a scanner that should bring television in the home with a set to retail at $200 initially, and provide a projected picture approximating the size, *quality and brilliancy of a home motion picture.* A blank in our knowledge of resonance has been sketched in. Other uses and devices will follow. This principle has already been applied to a clock mechanism that runs with microscopic power, and to relays sharply responsive to frequency for the operation of remote control devices. These relays have a valuable unique property of inherently preventing contacts from sticking, for the total summed up force required to cause the movable contact to finally reach the fixed contact is, in its full summation, the force available for breaking the contact.

Briefly, this excursion into the unknowns of resonance has sprouted mechanisms of importance. The ten kilowatt impossibility and monstrosity becomes a docile steady performer needing but a half watt to satisfy its requirements. Much more will be done by others in this new resonance field. There are always many who follow if even so little as a gleam of ultimate success shows.