DECIBEL PRODUCTS, INC.
ANTENNAS • TRANSMISSION LINES • DUPLEXERS • CAVITIES
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about
SELECTIVE
CAVITIES

ABOUT SELECTIVE CAVITIES

As the present frequency jam in the land mobile radio services grows ever worse the problems caused by frequency congestion, receiver desensitization and intermodulation, grow apace. A help in solving these two problems is the selective cavity.

It is our purpose in these few pages to discuss selective cavities, how they work and how they can be used.

WHAT A SELECTIVE CAVITY IS, AND WHAT IT DOES

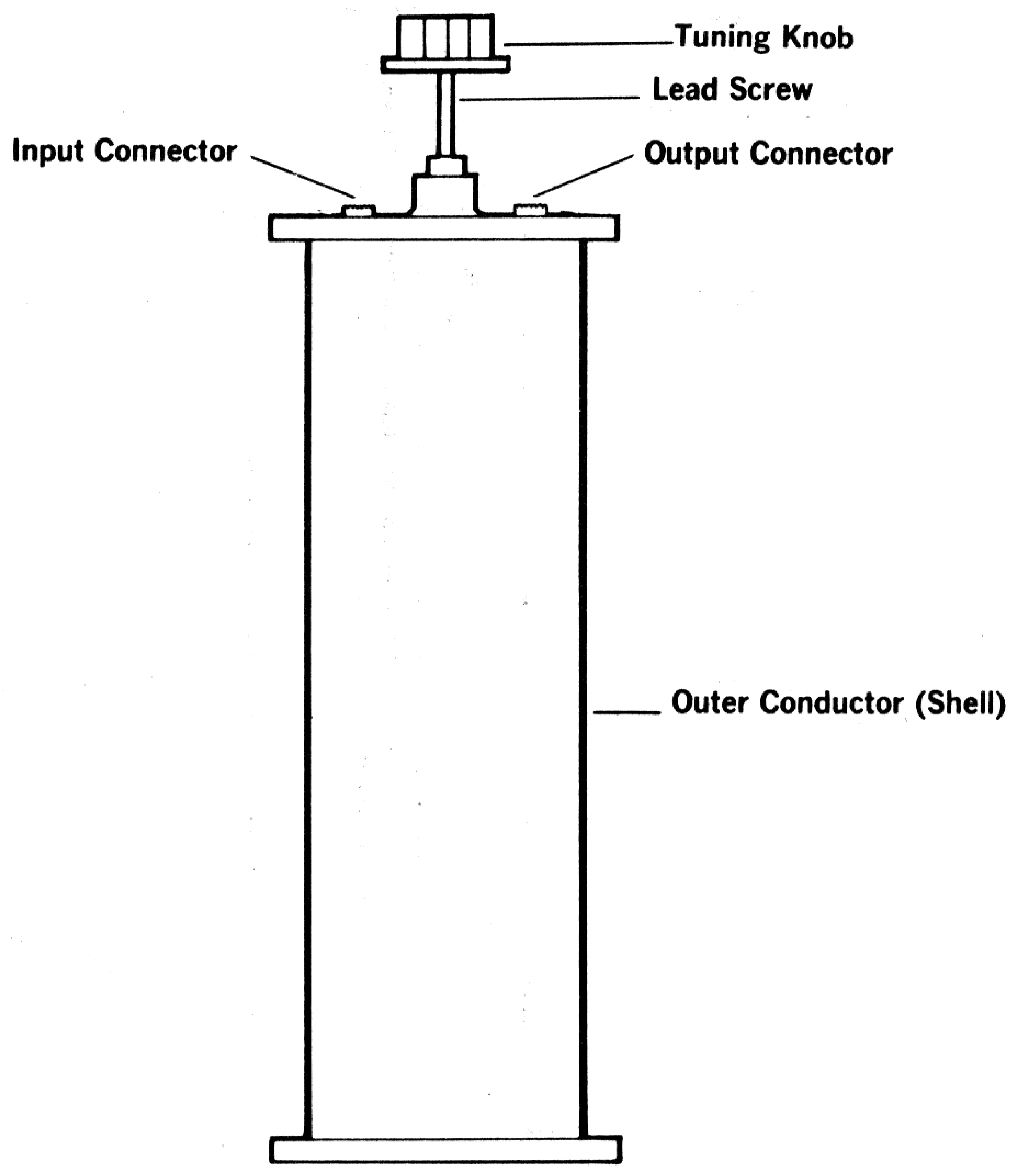
A selective cavity is a rather uncomplicated device that serves as a sort of filter of radio frequencies. It has the ability to let a narrow band of frequencies pass through while frequencies outside of this narrow band are attenuated. Stated differently, the unwanted, i.e., the unselected, frequencies are discriminated against and are filtered out while the desired frequency is passed through the cavity only slightly attenuated. The narrow band of frequencies that pass through are within a few thousand cycles of the resonant frequency of the cavity.

The selective cavity with this "filtering action" is becoming increasingly important in the land mobile radio services as more and more new stations are crowded into the same area. As new stations go on the air they can, and frequently do, cause interference to and receive interference from other stations in the area. The two most usual forms of interference are receiver desensitization and intermodulation. To avoid going into lengthy discussions of these problems let it suffice to say that receiver desensitization occurs when a nearby transmitter "overpowers" a receiver; the most usual form of intermodulation occurs when two or more transmitters in the area mix in the r.f. stages of a receiver and generate new frequencies, one of the new frequencies being the receiver frequency.

In both cases a selective cavity can help solve the problem. In the receiver desensitization case it can be used at the transmitter to reduce transmitter noise sidebands; more usually it will be used to increase receiver selectivity and make it less sensitive to nearby transmitters. In cases of intermodulation the cavity is used to filter out the unwanted transmissions thus keeping them from reaching the receiver.

What happens is that r.f. energy is fed into the cavity by means of one coupling loop, which excites the resonant circuit formed by the inner and outer conductors, and the other loop couples energy from the resonant circuit to the output. The resonant circuit is formed by the inner conductor and an equal length (please note this) of the outer conductor. To change the resonant frequency of the cavity you change the length of the inner conductor. Usually this is done by making a portion of the inner conductor moveable and attaching it to a lead screw which is turned by the tuning knob. The coupling loops don't affect the resonant frequency; they do help determine the selectivity of the cavity.

A SELECTIVE CAVITY LOOKS SOMETHING LIKE THIS:



AND IF WE CUT AWAY HALF OF THE OUTSIDE WE WOULD SEE SOMETHING LIKE THIS:

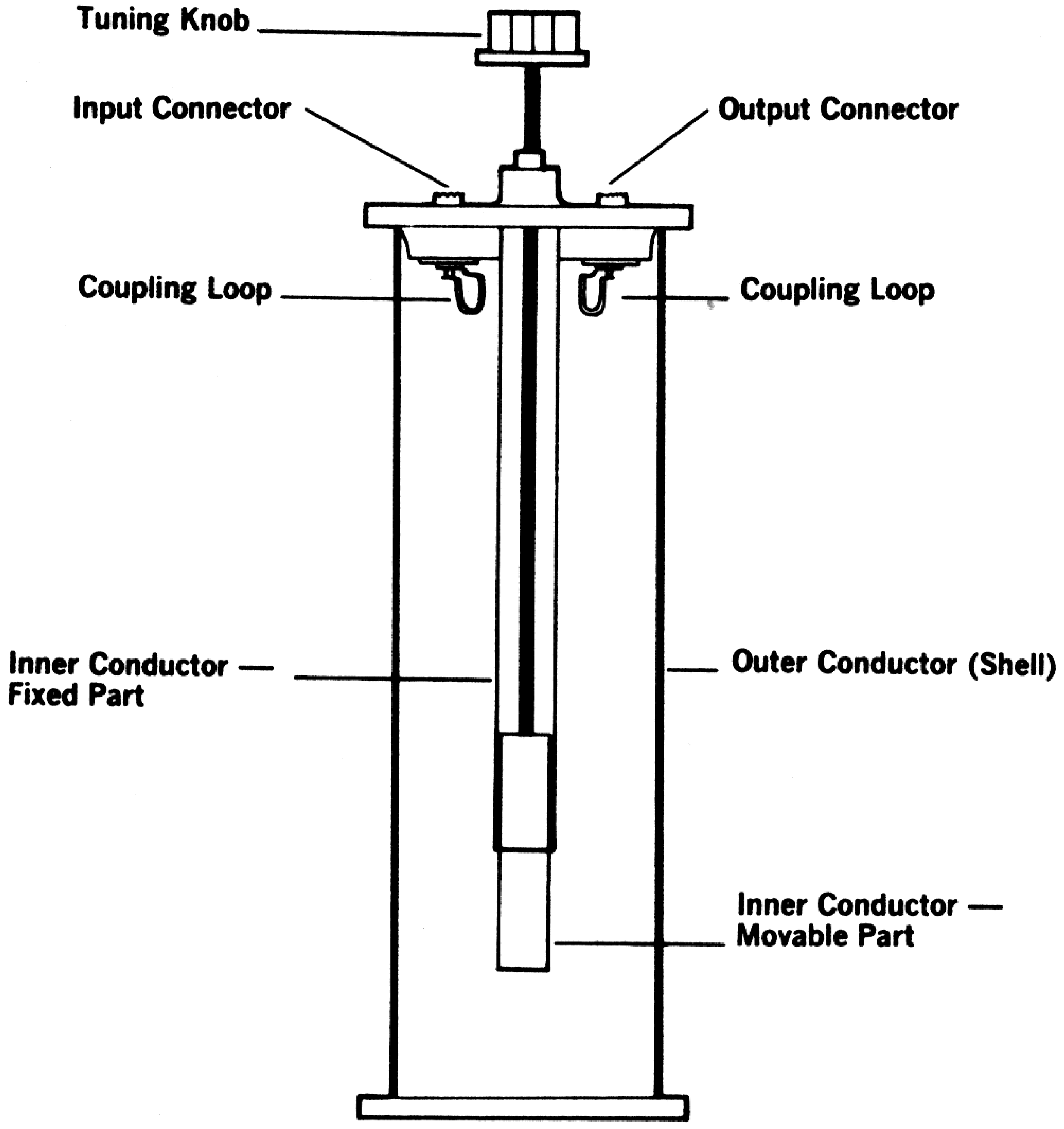
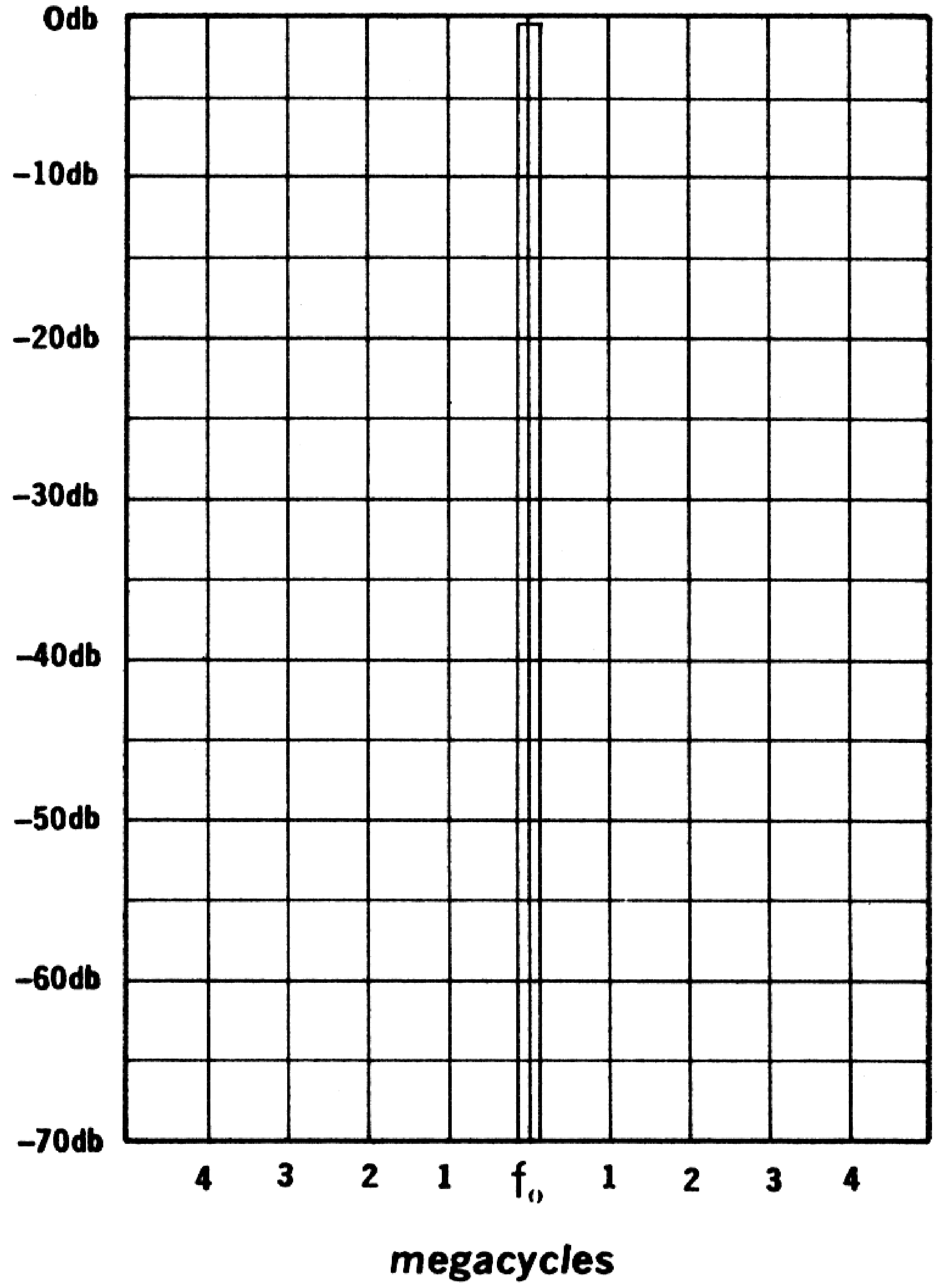


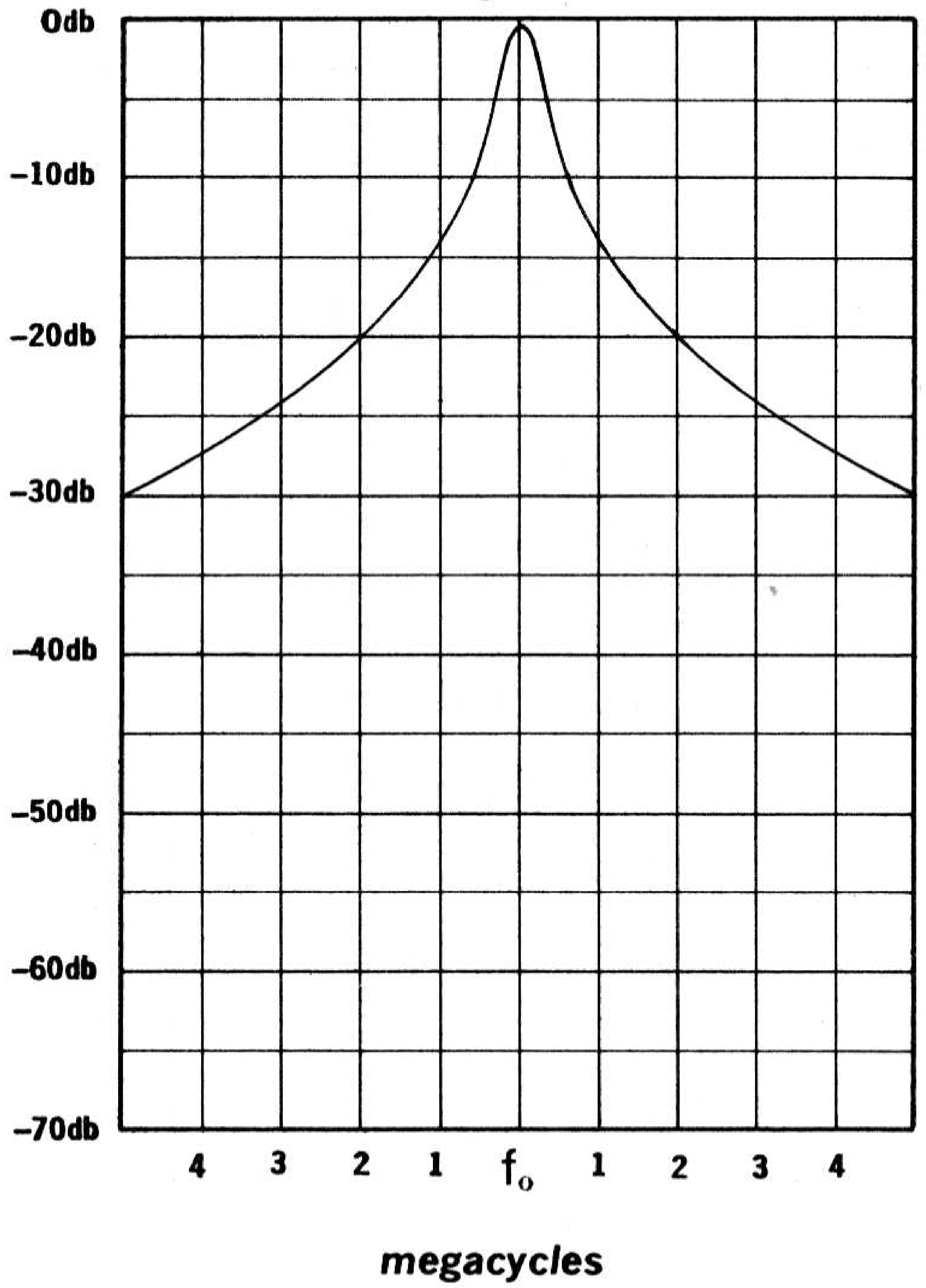
Figure 1



SELECTIVITY

Before discussing the coupling loops, however, let's discuss selectivity. Selectivity is the ability of a cavity to select one frequency and reject the rest. The ideal selective cavity would have a response curve like that in Figure 1. Along the horizontal axis of the chart are frequencies, along the vertical axis of the chart is the attenuation. According to Figure 1 a very narrow band of frequencies (actually we don't want the cavity to select just *one* frequency — we need a little more room for the modulation) gets through the cavity with very little attenuation. This narrow band of frequencies is centered on f_0 — that's the fre-

Figure 2

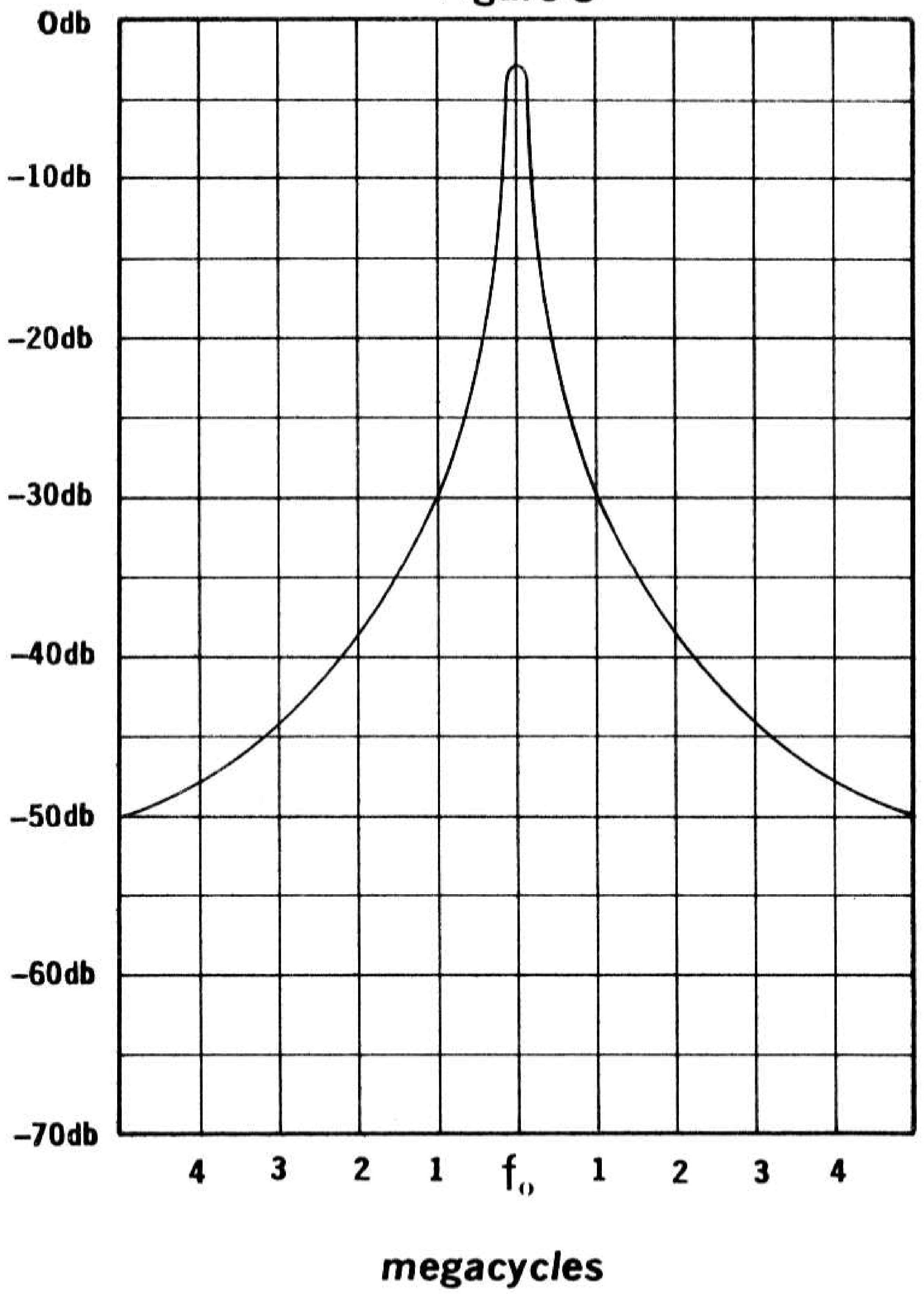


quency the cavity is tuned to, its resonant frequency. Everything else, all frequencies outside of this narrow band, doesn't get through at all. Just what we need for real selectivity.

But — and here's the rub — nobody has ever built the ideal cavity. We have to make do with something less perfect. Figure 2 shows the response curve for a typical cavity. The chart is laid out the same as before, frequencies are laid out along the horizontal axis f_0 in the middle) and attenuation in db along the vertical axis.

For the frequency to which the cavity is tuned, f_0, and for a little bit above and below this frequency, there is very little attenua-

Figure 3



tion, only about a half of a db. (A half of a db is a power reduction, or attenuation, of about 11 per cent.)

But for frequencies outside of the narrow band around f_0 things get more difficult. For frequencies 0.6 megacycle (600 kilocycles) above or below f_0 the attenuation is 10 db. An attenuation of 10 db is a reduction of 10 to 1. For frequencies 2 megacycles from f_0 the attenuation is 20 db, a reduction of 100 to 1. And at 5 mc from f_0 the attenuation is 30 db, or a reduction of 1000 to 1. To put it another way a signal 5 megacycles away from f_0 will be only 1/1000 as strong leaving the cavity as it was when it entered.

The attenuation of ½ db at the center frequency indicates a tightly coupled cavity. (More on "loose" and "tight" coupling later.) Figure 3 shows the response curve of a loosely coupled cavity. Here the f_o attenuation is 3 db (a 2 to 1 reduction), but notice how much steeper the sides of the response curve are, and how much lower they go before starting to flare out. Only 0.4 megacycles (400 kc) away from f_o the attenuation is 20 db at 1 megacycle away it's 30 db, at 5 megacycles away the attenuation is 50 db, a reduction of 100,000 to 1.

Comparing Figure 2 with Figure 3 we can say loosening the coupling increases the selectivity — but with increased attenuation of the desired frequency. This attenuation of f_o, the desired frequency, is referred to as insertion loss. Our objective when using a cavity should be to obtain the optimum combination of selectivity and insertion loss; only enough selectivity to solve the problem while keeping insertion loss at a minimum. Fortunately there is another way to improve selectivity without a sharp increase in insertion loss — we'll touch on this later.

HOW TO GET SELECTIVITY

The coupling loops, or the degree of coupling, are not all that govern the selectivity of a cavity, or that make one cavity design better than another. The other major factors are: (1) the volume of the cavity; (2) the internal r.f. losses; and, (3) the frequency of operation.

The volume of the cavity depends, of course, on its length and diameter. It must be a minimum of one-quarter wavelength long (electrically), or about 7 inches at 450 mc, about 20 inches at 150 mc and about 6 feet at 30 mc. (The statement just made is not completely accurate. There are ways for making cavities shorter, by using end loading or helical center conductors, for examples.) Or, the cavity can be ¾ wavelength long if we prefer. This is practical for a 450 mc cavity as it then becomes the same length as a 150 mc cavity.

Since the length is fixed we can increase the volume of the cavity only by increasing its diameter.

But, beyond a diameter of about one-fourth to one-third the length of the cavity we gain very little increase in performance, while the size, therefore the cost and inconvenience in handling, keep right on increasing. As you might guess, therefore, the diameter of most cavities is about ¼ to ⅓ their length.

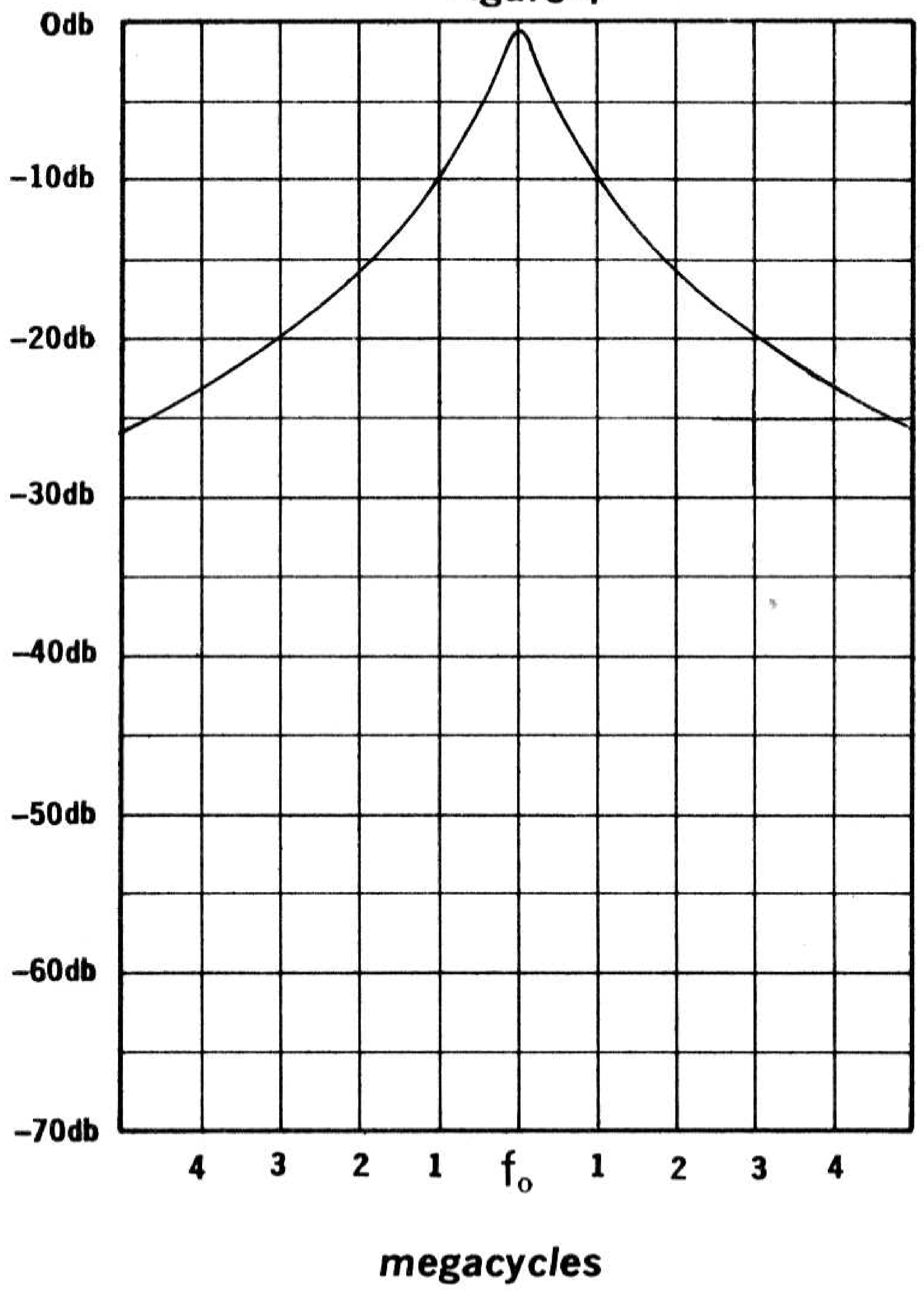
The internal losses are determined by the kind of materials used in the cavity, those materials that have the lowest resistance at the radio frequencies are preferred. Thus silver, copper and aluminum would be the most desirable materials, in that order. But, for practical purposes at the frequencies with which we're concerned (those below 500 mc) there is very little to choose from between the three, electrically that is. (The real requirement is that whether we use copper or aluminum we have to keep them from corroding. So, then, silver plating of copper, and/or laquer is used to prevent corrosion.)

The volume of the cavity and the internal losses determine the "Q" of the cavity. The greater the volume and/or the lower the internal losses the higher the "Q" of the cavity. A high "Q" is to be preferred over a low "Q" because the higher the "Q" the more selective the cavity.

(There are actually two "Q" figures: Unloaded "Q" and loaded "Q". These are not important for our discussion here but could be important if you're comparing cavity specifications.)

There's not much we can do about the frequency of operation since that depends on the system in which the cavity will be operating. Unfortunately the higher the frequency the more difficult it is to obtain selectivity. That's because of a rule that

Figure 4



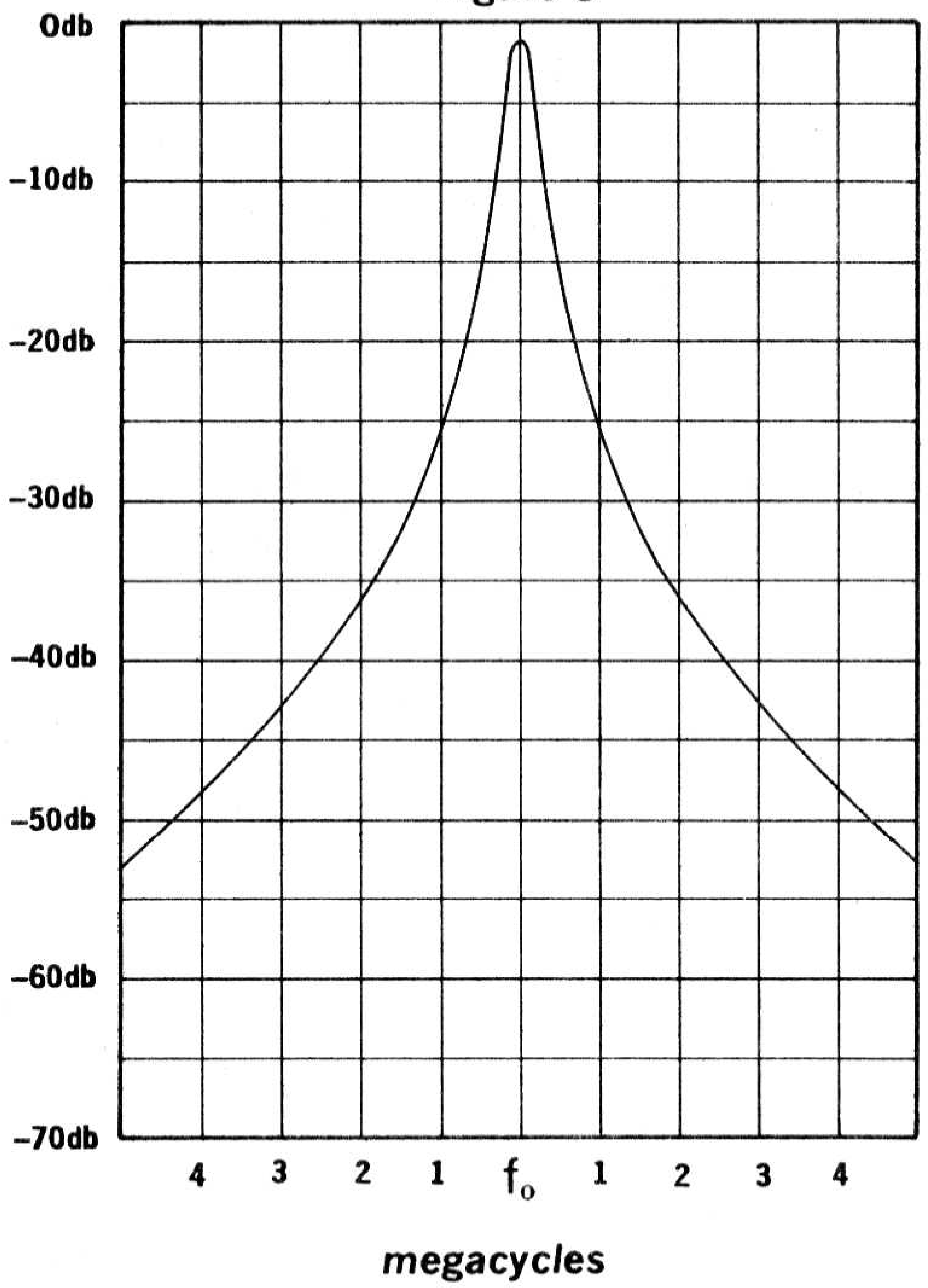
says that bandwidth, or selectivity, is directly proportional to frequency and inversely proportional to the "Q" of the cavity. (Algebraically: Bandwidth $= \frac{\text{Frequency}}{Q}$)

We can go up in frequency rather readily, but we can't increase the "Q" as quickly. Therefore it's more difficult to be selective at high frequencies than at low frequencies.

FOR MORE SELECTIVITY — ?

What can we do when a cavity will not provide enough selectivity without excessive insertion losses? For example, we might conclude that to solve an interference problem caused by a signal 2 megacycles off our receiver frequency it will have to be reduced by 32 db before it reaches our receiver. A glance at Figure 4 shows us that one cavity with ½ db loops (½ db insertion loss) will provide only 16 db of attenuation of the interfering signal. Figure 5 shows that the same cavity with 3 db loops (3 db insertion loss) will attenuate the interfering signal by 36 db. But a 3 db insertion loss means that we're losing about 50 per cent of our signal power — the one we want — in the cavity. A ½ db insertion loss means we're losing about 11 per cent of our signal power.

Figure 5



There is another way, however. If we put two cavities in series each with ½ db loops the unwanted signal will be attenuated by a total of 32 db; 16 db in each cavity. But the power of the wanted signal is attenuated by only 1 db, ½ db in each cavity. An insertion loss of 1 db means that we're giving up only 20 per cent of the desired signal power. And that's much better than losing 50 per cent.

The purpose of this example is to prove that it is better to obtain the desired attenuation by using several tightly coupled cavities instead of trying to get by with one loosely coupled cavity. There is a limit to this procedure, however, because of other factors, and it is usually not practical to use more than 3 cavities in series, and almost never practical to use more than 4 cavities in series.

HOW MUCH POWER

As mentioned earlier, we can use cavities to add selectivity ahead of the receiver or we can use them to sharpen up the output of a transmitter. (A transmitter does not emit on one frequency only; it also has low power noise sidebands.) But when the cavity is in series with the transmitter we need to be concerned with the amount of power the cavity can handle. With ½ db loops in the cavity about 11 per cent of the power will be "lost" in the cavity; this power must be dissipated by the cavity. With a 100-watt transmitter the cavity will have to dissipate 11 watts, with a 250-watt transmitter it will have to dissipate 28 watts. This does not present much of a problem to a typical cavity with its large metal conducting surface. But consider a 3 db loop cavity being used with a 350-watt transmitter. A 3 db insertion loss means that 50 per cent of the transmitter power must be dissipated by the cavity. And 50 per cent of 350 watts is 175 watts. This is more than most cavities, even with their large metal conducting surface, will handle. Thus, power handling limitations of the cavities must be observed. This is another good reason for using a series of cavities, each with a low insertion loss, letting each cavity dissipate a portion of the power.

MORE ABOUT COUPLING LOOPS

So far we have discussed using cavities with various insertion losses. And we have previously stated that insertion losses, or coupling loop losses, and selectivity vary with the degree of coupling. Loose or tight coupling can be obtained in several different ways.

Some cavities have permanent coupling loops, and the only way we could get a different selectivity characteristic and a different insertion loss for the job at hand would be simply to change cavities. Or, other cavity designs have replaceable coupling loops. To change from 1 db loops to 3 db loops, for example, we merely have to remove some screws, take out the old loops, put in the new ones, and replace the screws. These replaceable loops ordinarily come in several "sizes": ½ db, 1 db, 2 db, or 3 db. It is very handy to have a pocketful of them when trying to solve a particular interference problem. That's because it is usually very difficult to figure out in advance precisely how much selectivity will be required to solve the problem and, therefore, what "size" loops will be required. The objective should be, of course, to use the minimum insertion loss possible and still solve the problem by rejecting the interfering signal.

The next alternative is to use cavities with variable coupling loops. In this type of cavity the loops are not changed, rather they are moved closer to or further away from the center conductor. This movement is usually accomplished by rotating the loops. For tighter coupling they are moved close to the center conductor; for looser coupling they are moved away from the center conductor. With this method it is possible to obtain the minimum insertion loss and still obtain the required selectivity to solve the problem. And it's not necessary to have a pocketful of loops, either.

We should add that the coupling loops must be of a right size and shape to match the impedence of the connecting coaxial cables. The cavity manufacturer takes care of this detail, however.

STABILITY

To really be a help to us the cavity must have frequency stability. If it is going to shift resonant frequency and require retuning with changes in temperature, or with mechanical shock, it is going to be more of a hindrance than a help. When tuned to a particular frequency the cavity *must* stay tuned to that frequency. Mechanical stability requires only an application of sound mechanical engineering principles with regard to sizes, shapes, and materials. Stability in spite of temperature change requires that the length of the inner conductor remain constant, or very nearly so, when the temperature varies. Expansion or contraction of the outer conductor doesn't affect anything. That's because only that part of the outer conductor equal in length to the inner conductor is in the resonant circuit. The "excess" part of the outer conductor is actually not being used electrically. And if the diameter of the cavity changes because of expansion or contraction it changes only the volume of the cavity, and only very slightly at that, so that only the "Q" of the cavity changes, not the resonant frequency.

To keep the length of the inner conductor constant we need a metal that doesn't expand or contract when the temperature varies. If we use this metal for the lead screw that the moveable part of the center conductor is attached to then the problem is solved — the inner conductor cannot change length when the temperature changes. Fortunately there is Invar, a metal with a nearly zero temperature coefficient; or that changes practically not at all with temperature. (To be precise a 2 foot length of Invar will change 0.00145 inches in length with a change of 100 degrees Fahrenheit.)

CAVITY INSTALLATION

What about the installation and tune up of cavities? The installation is simplicity itself since the cavity can be mounted in any position; just leave room to get to the tuning knob. The cavity is placed in the circuit by means of coaxial cable and appropriate connctors. Since there's no difference in the coupling loops either one can be used for the input, the other for the output.

. . . AND TUNE UP

If the cavity is to be used with a transmitter a wattmeter should be used on the output side of the cavity and the cavity tuned for maximum power reading.

In tuning the cavity when it is in series with a transmitter it is necessary that there be a load of some kind, antenna or dummy load, connected to the output. Otherwise, the cavity will have to dissipate all of the transmitter power, which will probably damage the cavity. You should, of course, have the transmitter in "tune" power position for the initial cavity adjustments.

If the cavity is being used in series with a receiver the easiest way to tune up is to have a low level, on-frequency signal from the antenna. Then adjust both the cavity and the receiver antenna coil for maximum limiter current. You could start with a signal generator but if so be sure to touch up the cavity and receiver antenna coil after the antenna has been connected.

A selective cavity is both highly useful and easy-to-use; it is the solution to many troublesome interference problems.

AND NOW A WORD FROM OUR SPONSOR

Decibel Products makes selective cavities in the frequency ranges 30 - 50 mc, 148 - 174 mc, 406 - 420 mc, and 450 - 470 mc.