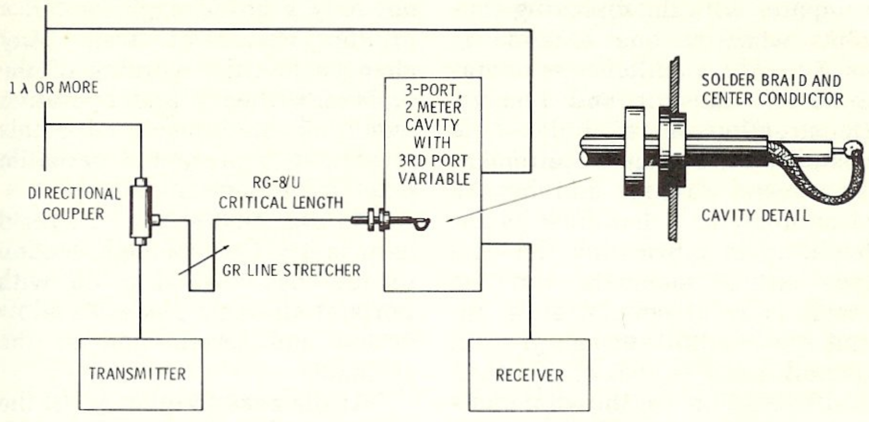

Fig. 4-27. Minimizing desensitization through feedback phasing.

his transmitted signal, emanating from the lower antenna, was being "picked up" by the upper (receiving) antenna. So he came up with the plan shown in Fig. 4-27.

The idea behind this scheme is to introduce the same transmit signal directly into the receiver at the same amplitude but **180 degrees out of phase** with the antenna-supplied signal. He did this by sampling the transmitted signal with a directional coupler, adjusting its phase with a line stretcher, and adjusting the critical length to the cavity. The cavity's loop was made variable so that attenuation without phase shift could be achieved.

To adjust, watch first-limiter current on a sensitive meter and turn adjustable cavity loop to about 45 degrees. Next, adjust the line stretcher. A dip should be noted on the meter at some point. If the dip comes at the end of the adjustment (and it always seems to), add a small section of coaxial cable. It pays to have several short random lengths of coax available (or you can cut each one a nanosecond longer than the last).

Once you have a dip, adjust the cavity loop for minimum limiter current. Once it is operating, the line stretcher can be replaced with a piece of coax of the proper length. Trimming can be accomplished by adding connectors or adapters.

The W2OQI approach represents a satisfactory and relatively simple solution to the problem of receiver desensitization, but it, too, has its limitations. Since effective cancellation depends on the critical phase separation, high winds or other unstable conditions at the site would be disastrous. It is necessary to keep the two antennas rigid so they will not move with the breezes. Also, the system must be moisture proof. If the VSWR shifts on a damp night, the phasing is out and so is the repeater.

Hybrid Loop Diplexing

Of all the methods for defeating desensitization, none quite compares with the **diplexing** concept, whereby one antenna is used for the simultaneous operations of transmit **and** receive. Construction of a diplexer is complicated by the requirement for several cavities and by the close tolerances that must be adhered to in fabricating the various critical elements. But the result is what counts, after all; and a good diplexer can give an overall insertion loss of less than 1 dB. Adding to the diplexer's appeal is the renewed purchasing power of the repeater's "antenna fund." Where two antennas might have been planned, a diplexer needs but one. So the repeater owner has the pleasant task of choosing to buy a better antenna than originally planned or to save the cash for other eventualities.

The diplexer of hybrid loops and cavities described herein was first publicized in the Toronto FM Communications Association Bulletin, of Canada, and later in FM Magazine. The designer, Gil Boelke (W2EUP) has earned the reputation of being not only a gifted engineer but a prolific writer as well. Any changes to Gil's wording of the diplexer's theory and operation would be an injustice; for this reason, it is presented verbatim (except for figure numbers):

"As Fig. 4-28 shows, a hybrid loop is a 1.5-wavelength section of low-loss coaxial cable with ports at strategic places to allow access and termination of the rf signals.

"At the pass frequency (f_1) the cavity is series-resonant, providing an effective short circuit at the cavity port (B). Counterclockwise-traveling rf power thus meets a short circuit after traveling one-quarter wavelength. The input end of this quarter-wave section then looks like an open circuit at this frequency.

"Power flow from port A is clockwise, then, since the counterclockwise path looks like an open circuit. The characteristic impedance of the input line is continued clockwise with negligible disturbance at port A.

"Assume for the moment that port C is unterminated and does

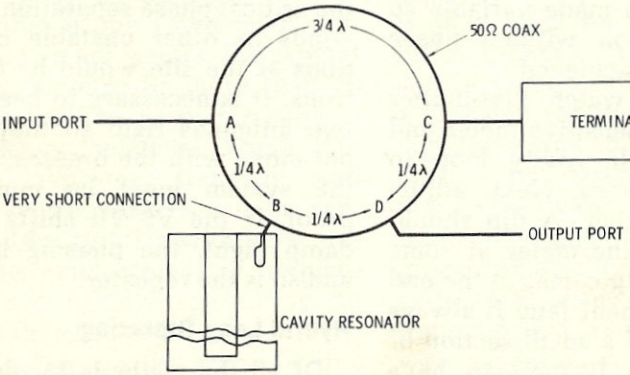

Fig. 4-28. Hybrid loop dimensions and terminations.

not have any effect on rf power traveling clockwise past it. Clockwise-moving power from the input then continues past port C to port D. The coax from port D to B is one-quarter wavelength and shorted by the cavity at B. Therefore, an open circuit appears to the left of port D, and power flow continues out of port D to the load at f_1. The power flow path from port A to port D is achieved without setting up a VSWR on the line at any point and, if the cavity loss is low, without appreciable attenuation.

"At the reject frequency (f_2) the cavity is no longer series-resonant, but it is detuned and presents a nearly pure reactance at port B. Radio-frequency power now flows past port B toward the output port. In so doing it traverses one-half wavelength of coax, with a resulting phase shift of 180 degrees.

"Note that the phase difference between these two waves is 360–180, or 180 degrees. If the power contributions are equal from opposite sides of the output port, power at f_2 is completely canceled.

"In practice, power passing port B is distributed by the cavity reactance. If port C is terminated in an equal reactance of the same sign as that of the off-resonance cavity at port B, the output contributions are again equalized and f_2 is canceled at the output. A useful analogy is to compare the loop with a bridge circuit. Anything seen at port B must be seen at port C to balance the output at port D.

"At f_1, in practice, port C is not open, but rather terminated in a reactance equal to the cavity reactance at f_2. This disturbs the wave traveling to port D, setting up a VSWR in the coax back toward the input port. The cavity is then detuned from exact series-resonance enough to produce an equal VSWR in the other leg of coax to the input termination, port A. The reactances appearing on opposite sides of port A are equal and opposite, so they cancel at the input. This adjustment in turn has an effect on the balance of the loop at f_2, and reactance at port C must be retrimmed.

"In the adjustment procedure the output power is maximized at f_1 by tuning the cavity, and the output power is minimized by adjusting the impedance at port C at f_2. Alternate adjustments will eventually result in a null at f_2 and a peak at f_1 if the cavity **Q** is high enough for the frequency spacing and the coupling is adjusted properly. If the insertion loss at f_1 is too high, it can be reduced by increasing the coupling in the cavity, and repeating the adjustment procedure. Too much coupling may prevent convergence of adjustment, and reduces the notch bandwidth.

"The value of impedance at port C depends upon the impedance of the cavity at f_2. The cavity, when coupled with an inductive coupling loop, varies roughly as in Fig. 4-29.

"A parallel-resonant point occurs at a frequency (f_3), slightly below that of f_1. This frequency may be varied by changing the coupling or inductance of the link. It is possible, when f_2 is lower than f_1, to place f_3 at f_1. At

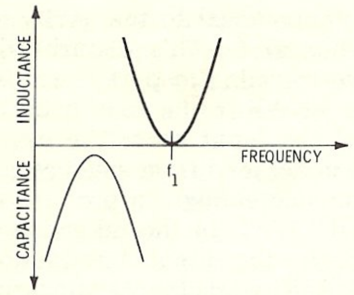

Fig. 4-29. Cavity characteristics with inductively coupled input.

this point it is possible to eliminate port C entirely, since the necessary impedance is near infinity.

"For f_2 above f_1, the reactance becomes inductive, and it becomes capacitive only below f_3. If a parallel-resonant tank is placed at port C, one sweep of the tuning capacitor wil lcause a swing from inductive, through infinity, to capacitive reactance. This technique is very convenient when the required value is inductive, because it allows variation of the inductive reactance with a variable C.

"In some cases it may be necessary to use some resistance at port C to achieve balance. This case occurs when there is some loss in the path past port B. A lossy cavity could cause it. With low-**Q** cavities, poorly cut loops, or close frequency spacing, this technique allows the system to balance at f_2, maintaining the full rejection of the cavity/loop combination, although compromising performance by resulting in a slightly higher insertion loss.

"The loop itself can be checked out by leaving ports B and C open, pumping power into the loop at port A. Very little power should come out at port D if it is cut properly. Remember that "end effects" on the coax joints can have a considerable effect upon the apparent electrical length of the lines. Shorting out either port B or port C should produce full output with little loss and a low-VSWR at the input. These checks should be made at some frequency between f_1 and f_2 preferably.

"There should be a negligible length of coax or lead lengths at ports B and C, especially when checking the loop. Port B should be mounted right at the cavity without unnecessary lead length. Port C is not as critical in this regard to the adjustable impedance.

"Two other important points: With rejections in the neighborhood of 50 to 60 dB in a cavity, lack of shielding at any point in the system can negate the effect of the cavity and loop system. Shield everything completely except the antenna itself. Also, when testing the cavity/loop, the average transmitter used as a signal source may have enough spurious radiation or even ordinary transmitter noise to limit the rejection as read on an rf indicator. It may be necessary to filter the transmitter output with another cavity to make final adjustments!

"Fig. 4-30 shows construction details for a two-meter cavity with sufficient **Q** to be used with the hybrid rings. Four each of the cavities and rings are required to produce a system by which a single antenna can be used for both receiving and transmitting simultaneously. Fig. 4-31 illustrates the

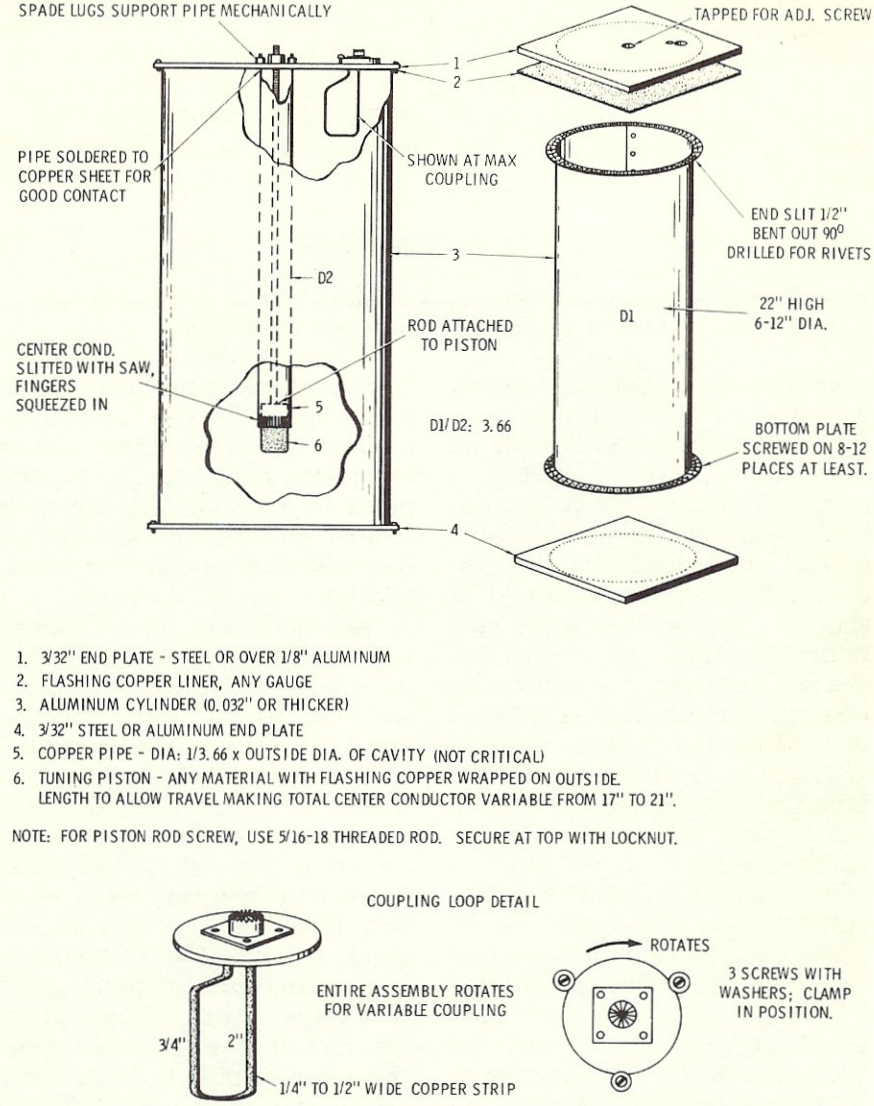

Fig. 4-30. Design details of the 144- to 148-MHz cavity.

interconnection of the elements for a 146.34-to-146.94 MHz repeater.

"A well designed preamplifier, such as a cascode FET type, can be placed at point B without getting overloaded. This placement is desirable because it reduces the diplexer loss on the receiver side to half. Similarly, it may be possible to install a power amplifier that isn't too noisy at point A, reducing the transmitter power loss in the diplexer. Experiment will tell which, if either, alternative connection is pos-

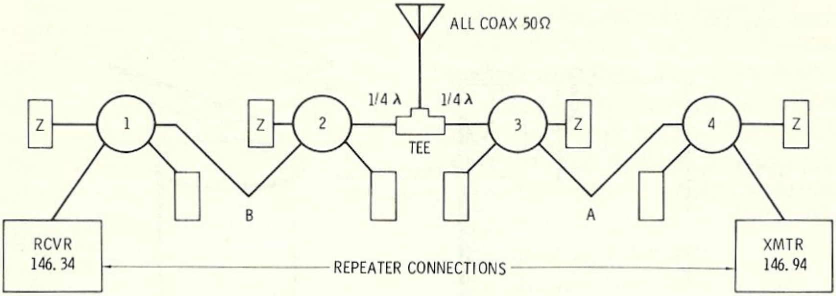

Fig. 4-31. Complete interconnection of loops and cavities for diplexing with transmit frequency of 146.94 MHz and receive frequency of 146.34 MHz.

sible for the particular system with which it is to be used.

"The terminations (**Z**) can be coax stubs or tuned circuits. I prefer the tuned circuits because they permit the attainment of a perfect null, whereas stubs produce a finite dip. Stubs should be shorted, because open stubs may radiate unless the ends are shielded. I found that a parallel-resonant circuit worked best on the transmitter cavities, and that a 3K shunt resistor across the tuned circuit produced a null in the 70- to 80-dB range. On the receive side, I found that a series-resonant circuit worked better. Again, the tuned circuit needed some loss to make a perfect null. However, an alternative method was used, which is equally applicable in either the receive or the transmit cavities.

"By varying the LC ratio of these tuned circuits, the resistive portion of the resonant circuits can be varied. Thus, instead of physically inserting a resistor, I raised the effective **Q** of these circuits until they produced the appropriate amount of loss. Tuning is simply a matter of dipping the capacitor (piston type for smooth accurate adjustment), noting the amount of rejection, then squeezing or spreading the coil and redipping. The inductance value is readjusted until the signal disappears in the noise. Rejection is limited only by the stability of the adjustment and the bandwidth required of the notch.

"Notch bandwidth and insertion loss are the only limiting factors for frequency spacing. I was able to get 60-dB rejection and 1-dB loss at 300-kHz separation. However, the notch width is small, and rejection degrades rapidly with deviations from the center of the notch. The 60-dB figure only represents the rejection level easy to attain in a quick adjustment. It should be emphasized that the notch depth is always unlimited except by the fact that it becomes more and more critical to adjust as it gets deeper, and obviously harder to hold there.

"My insertion loss measurements are not as accurate as I would like and I hesitate to quote them, but the rejections are reasonably accurate. Here are some figures: Pass 146.34, reject 146-.94: Insertion loss less than 1 dB; rejections: at 146.940, 70 dB; at 146.928 and 146.952, 50 dB. Pass

146.94, reject 146.34: Insertion loss 0.6 dB, rejection at 146.34, over 80 dB (saw 100!); at 146.328 and 146.352; 50 dB.

"Miscellaneous facts: Low cavity **Q** results in high insertion loss for a given notch bandwidth. Rejection notch still unlimited theoretically; depends upon stability and accuracy of adjustment. Use low-loss coax for loop. I tried small **Teflon** coax and got very poor results. Solid shield better in system. Need double-shielded

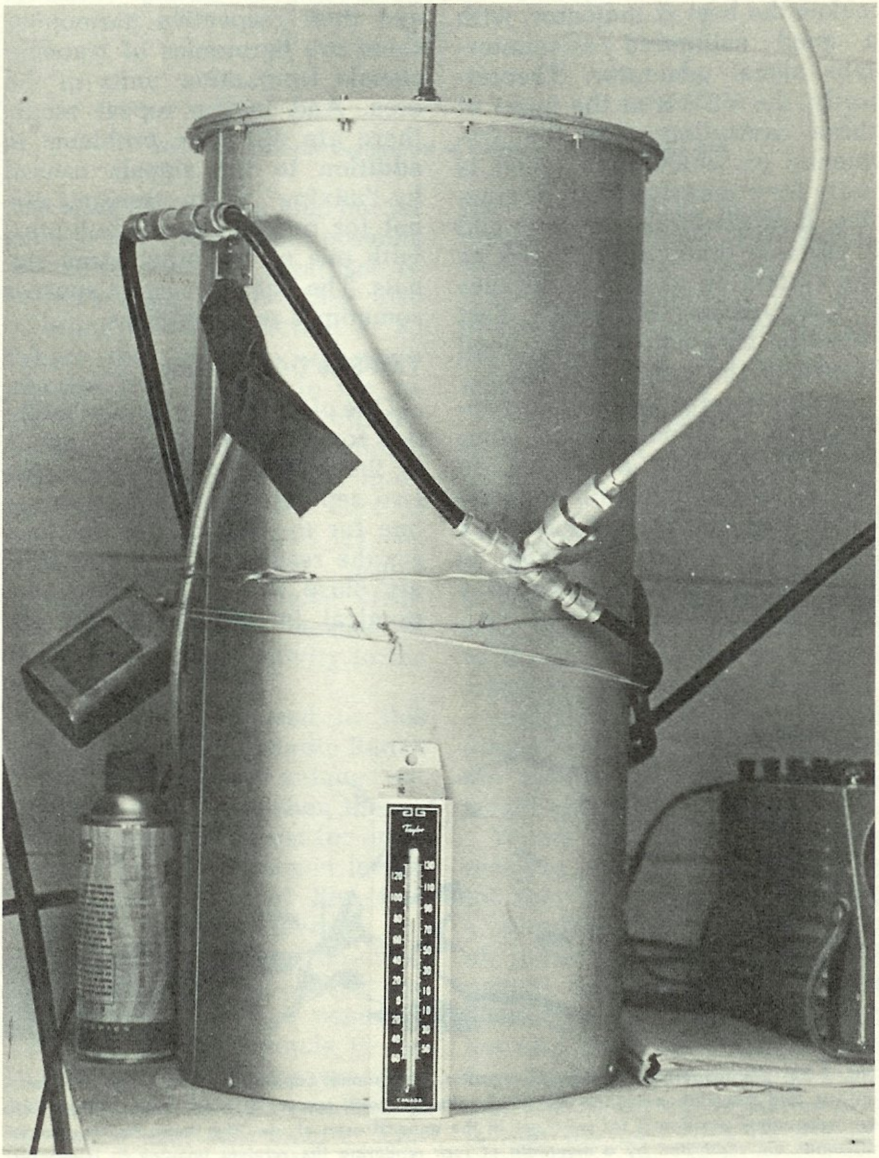

Fig. 4-32. This receiver cavity, in use by Ontario's VE3RPT repeater, uses Boelke's design.

coax at receiver output and transmitter input lines. Double-shielded cables also make good loops. Clamp loops down to prevent movement. Cavity coupling loops must be wide straps, not wire.

"For test purposes, a receiver makes the best rf indicator, with a good calibrated attenuator-type signal generator. Theoretically, the VSWR at the input of these cavity/loops at the frequency to which it is tuned is unity for a resistive load. In practice, it might be desirable to add a variable matching network to the system on each side because a cavity/loop tuned for best rejection may not exhibit a good VSWR at the pass frequency.

"With careful design and construction it is possible to combine all the best attributes, so that a single high-gain antenna and a lone run of low-loss coax will give results comparable to two such installations spaced a great distance apart."

As more and more equipment gets placed into service at a remote site, the chances of interference increase more than proportionately. Consider the possible signal sources: In the standby mode, there are local and i-f oscillators of nearby receivers and their respective harmonics, there are harmonics of transmit signals from other units in the area. And in the repeat mode, there are all these problems **in addition to** the signals caused by "mixing" of the transmit signal (or one of its submultiples) with one of the other stray signals. The list of possible sources sometimes seems endless.

Two-Site Deployment

One of the most effective methods for defeating desensitization is the passive method of using two separate remote locations—one for the transmitter and one for the receiver. If the two sites are close enough to allow economical interconnection of the

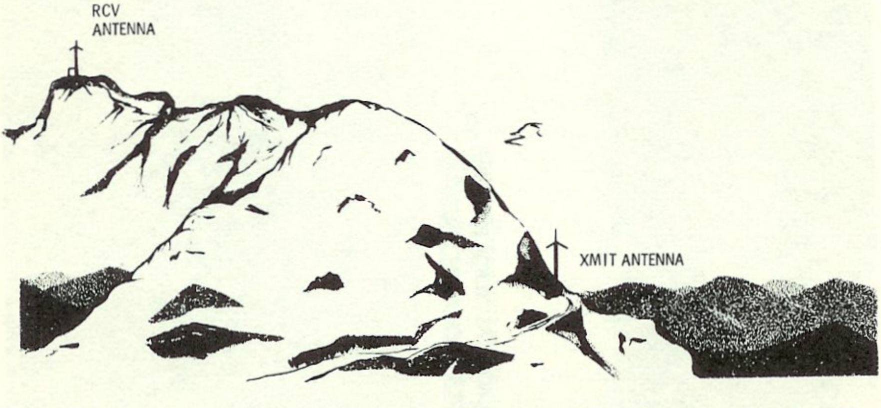

Fig. 4-33. Site layout for on-channel repeater. On-channel capability exists when the transmitting and receiving antennas are poorly situated with respect to each other, though both are adequately positioned for coverage in the general area of use. The Radio Ranch repeater antennas are separated by a mountain of rock rendering the receiver immune to low-power signals from the transmitter.