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REPORT

DIPLEXING AM TRANSMITTERS WITH BUT 3 PERCENT FREQUENCY SEPARATION

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SUMMARY: A diplexing network to combine the output of two transmitters operating on 2522 and 2598 kilocycles is described. Many of the practical limits and considerations pertinent to all diplexing systems are discussed in connection with the description. A slightly different approach to the design of critical systems is taken pointing out the practical limitations of prior designs. Conclusions drawn show the definite need for regular attention to the operation of diplexing systems in general. More specifically, the combination of the outputs of transmitters operating simultaneously on the above two frequencies is shown to be both practical and possible, provided the system receives regular attention.

INTRODUCTION: The successful operation of two transmitters simultaneously into a single antenna with no more than 3 percent frequency separation requires a very thorough understanding of the many factors involved. Field conditions, optimum network responses, component reliability and control all enter the problem in a very positive way. This paper, then, has a two fold purpose. It is an attempt to point out some of the more important considerations with their practical limits. And, secondly, it is a description of a system, recently built and installed. In this way, it is hoped, that the ever growing field of medium frequency diplexing will be given a clearer, practical understanding.

Operating data available on a diplexing system similar to the one described, clearly points to at least three design areas that must be taken into account. First, component reliability is of paramount importance. Secondly, current and voltage ratings of practical components are more likely to provide design limits than are the usual network realizability conditions. This is true even at relatively low powers. Third, and at least as important, the system must be easily controlled. This will be discussed in greater detail, but for now it is well to remember that in any antenna system there is a continual change in field conditions. A network sufficiently complex to provide satisfactory operation of transmitters into a single antenna with only 3 percent frequency separation must be capable of being adjusted from time to time to compensate for this change.

DESIGN AND ADJUSTMENT: The units described in this article were designed and built to meet the following specifications. Two one kilowatt AM transmitters, operating on frequencies of 2522 and 2598 kilocycles, are to be fed to a single vertical radiator. A third transmitter simultaneously operating on 2566 kilocycles will be fed to a second radiator a short distance away. The required network for the first two transmitters shall provide suitable coupling to the antenna and sufficient attenuation that no combination of any of the three frequencies will be re-radiated at a higher level than 80 decibels below the desired field of the carrier frequencies. The networks shall have an insertion loss of less than 1.25 db at each operating frequency.

Because undesired radiation can originate from many sources other than through the coupling to the antenna, the specification for attenuation through the network was later revised. It was finally stated that each filter would have a one-way loss of at least 30 db for all undesired frequencies. This value is arrived at by assuming a conversion loss of 20 db. Thus a signal traversing the filter from the antenna and combining in the transmitter to produce an undesired signal would experience an attenuation of 30 plus 20 plus 30 or 80 db before the undesired signal is radiated.

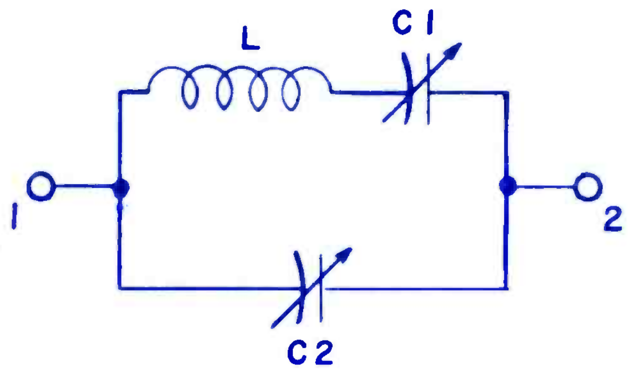

FIGURE 1

Figure 1 is a two terminal network configuration that provides the basis for most diplexing networks. When the two frequencies are fairly widely separated, L and C_1 are made series resonant at the operating frequency. C_2 is adjusted to make the whole circuit anti-resonant at the frequency of the second transmitter. Theoretically, it is an ideal circuit for this purpose. However, as the two operating frequencies approach each other, the value of the inductance increases. Assuming most of the circuit losses occur in L, these, too, increase. This fact together with a rapid increase in circulating current in this circuit as the difference in operating frequencies approach 3 percent, make the above adjustment of this network extremely impractical for the purposes of this design.

Despite these difficulties, however, the two terminal network of Figure 1 still seemed to offer the best solution provided it's synthesis could be made to furnish the desired characteristics and at the same time keep losses and currents within reasonable values. For the 2522 kc filter, the solution was accomplished by setting the series resonant frequency of L and C_1 at .9 of the operating frequency. The circuit was then made anti-resonant at 2598 kc and its impedance level at 2522 kc was set equal to the magnitude of the antenna impedance. In this adjustment, assuming a "Q" coil of 400, the circuit loss at 2522 kc was .5 db with an attenuation of 62.2 db at 2598 kc. Circulating current was computed as 21 amperes.

Due to the existance of the 2566 kc frequency and in order to provide additional control, the final filter arrangement was made to consist of two of these two terminal networks in series together with a mid shunt capacitive leg. In this manner, at 2522 kc the completed filter then formed a "T" network with the shunt capacity leg serving primarily as an impedance level setting device. The actual match of the antenna to the transmission line is accomplished with a second, straightforward "T" matching network, removing any matching requirements from the adjustment of the filters.

The opposite filter for the 2598 kc transmitter is simply the reciprocal of the 2522 filter. In this case, the series resonant frequency becomes 1.111 times the operating frequency, making the completed "T" network a high pass circuit at 2598 kc. A simplified schematic of both units is shown in Figure 2 as they appear in the final installation.

Selection of components for the networks involved two somewhat contradictory considerations. It was desired that all components be of sufficient size and rating that under no possible condition would there be any heating or excessive losses. It was also desired that all components be kept as small as possible in physical size. It was imperative that if design conditions were to be met, extraneous capacities and lead inductances would have to be held to very low values.

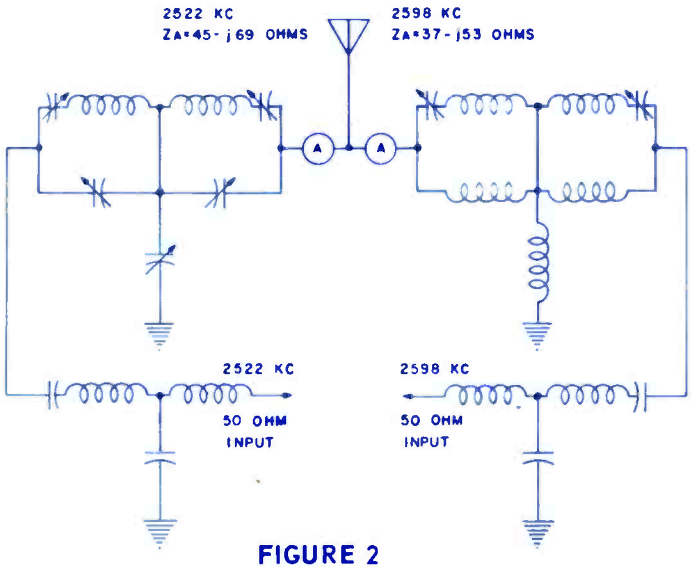

FIGURE 2

Vacuum capacitors are used throughout the filters proper because of their inherent stability and extremely low temperature coefficient. The types used are rated at 20,000 to 25,000 peak volts. This is a safety factor of better than 5 over the calculated circuit voltages, but as determined from a study of prior diplexers, transient voltages of this magnitude are possible.

The coils are silver-plated, 3/8 inch copper tubing, and known to have Q's in excess of 500 at these frequencies. All inter-connections are made with 1/2 inch silver plated copper tubing to minimize losses and lead inductances. Ground connections are carried through the cabinets with 4 inch copper strap.

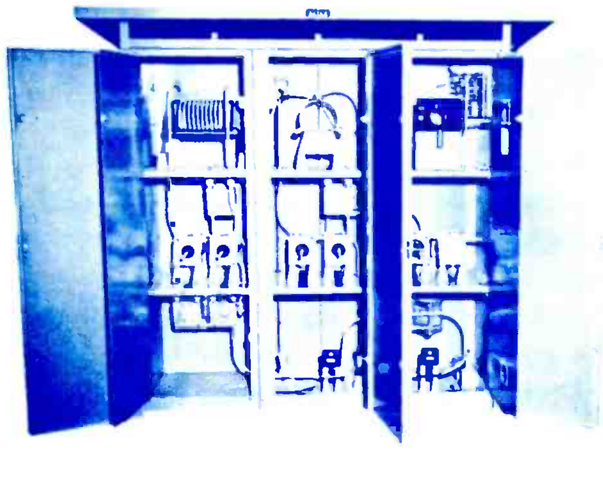

FIGURE 3

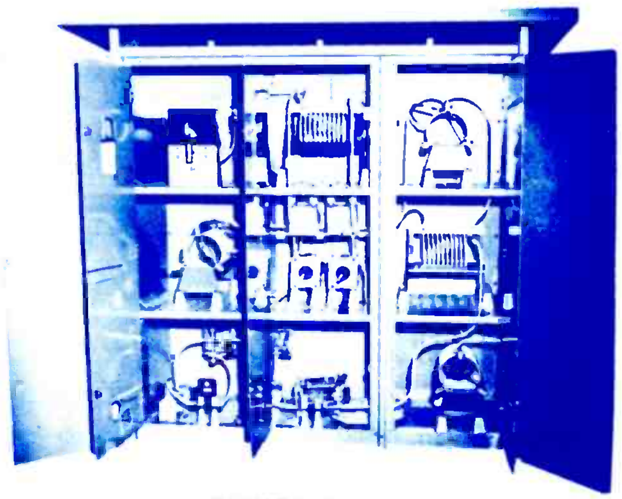

FIGURE 4

Figure 3 and Figure 4 show the interior arrangement of the 2522 and the 2598 kc filters, respectively. The compartments housing the individual sections of the filter are of such size that the coils at no point are closer than one diameter from their shields. Subsequent measurements of this construction revealed that the coil Q's remained very close to their free space value and well above the assumed 400 used in design calculations. The variable capacitors are tuned with a screwdriver fitting into the end of an insulated shaft. One inch holes appear in the inner doors opposite each capacitor making possible the complete adjustment of the filter with the doors closed.

FIGURE 5

In Figure 5 can be seen the two units as they appear in their final installation. Each of the two cabinets measures 72 inches high, overall. At the base they are 63 inches wide and 23 inches deep.

The roof has a 6 inch overhang all around. Each unit is made of an outer weatherproof cabinet and an inner cabinet separated by 1½ inches of spun glass insulation. The inner doors are interlocked with the transmitters and remain closed during operation. The outer doors may be locked and provide access to the controls and meters.

Ventilation for the units is provided by a free air space between the roof and the ceiling of the inner cabinet. The free flow of air through this space pulls air through three screened openings in the bottom of the unit and thus up through the cabinet and out three similar openings in the ceiling of the inner cabinet. This has long proven a very effective cooling method for antenna couplers.

Upon completion the units were tuned and adjusted at the factory under conditions as near similar to expected field conditions as possible. However, because of the many facets of field conditions, these factory adjustments can only be considered qualitatively and may or may not be indicative of actual results obtained in the field. It was extremely interesting to note the extent to which the actual units approached the calculated design performance. Attenuations of better than 60 db were measured at the opposite transmitter frequency in each filter while they exhibited less than 1 db of attenuation at their respective operating frequencies. With this adjustment, the final filters also each measured greater than 40 db of attenuation at 2566 kc.

Certainly by far the most interesting aspect arising from the factory adjustments was the degree of flexibility of control which the completed units exhibited. This was dramatically demonstrated in the manner in which the two series arms of each filter were adjusted.

Referring again to Figure 1, C_1 is the most critical of the three elements in the adjustment procedure. It was used to hold the anti-resonant frequency of the circuit at the main reject frequency of the filter. L and C^2 were then increased until the series resonant frequency of the circuit approached the design value. In so doing is was determined that over a relatively wide range, C^1 would vary the anti-resonant frequency but at the same time produce only a small change in the amount of attenuation at the operating frequency. Thus, once the units were in adjustment, actual control of the complete filters reduced to only two capacitors. Furthermore, each of the two series arms of either filter could be finally adjusted to produce maximum effect on two slightly different frequencies.

With this knowledge it was readily apparent that the two units were capable of wide latitude of adjustment depending upon particular field requirements at any one time.

CONCLUSIONS: In this diplexing system, as with others, the adjustment of each filter for maximum attenuation of the opposite transmitter frequency is not the same adjustment which allows each filter to see the antenna impedance at its operating frequency. In other words, the adjustment of the filters to produce maximum attenuation of the unwanted frequency results in a slight mismatch of impedance at the output of each filter. Also, as in this case, the fundamental frequency of the opposite transmitter may not be the cause of the most troublesome interfering signal appearing in the field. A harmonic of one of the transmitters may combine with the output of the other transmitter to cause more serious interference. Either of these conditions may be of concern at the time of the original adjustment, but at a later date with a change of transmitter tubes or a shifting of some field condition, some other set of conditions may be of more concern.

These conditions plus others peculiar to each individual installation preclude the possibility of considering diplexing networks as though they were single antenna couplers. They might more properly be considered as one would a directional antenna system which is kept under regular surveillance. Conversely, if a diplexing system is thoroughly understood, regularly monitored, and readjusted from time to time as is done with a well maintained directional antenna system, there appears no reason why satisfactory performance cannot be continually secured even though the system be highly complex.

The system described has demonstrated its ability to provide a high degree of attenuation at the specified frequencies with acceptable loss at the operating frequencies. It has demonstrated its flexibility of control so that it may be adjusted for satisfactory performance under a wide variety of possible field conditions. It is constructed of such components as to make it highly stable. If it is maintained over the years to come in the light of the points discussed above, it should prove conclusively that two transmitters separated by only 3 percent in frequency can be successfully combined into a single antenna.

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