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REPORT

POWER DIVIDERS FOR DIRECTIONAL ANTENNA SYSTEM

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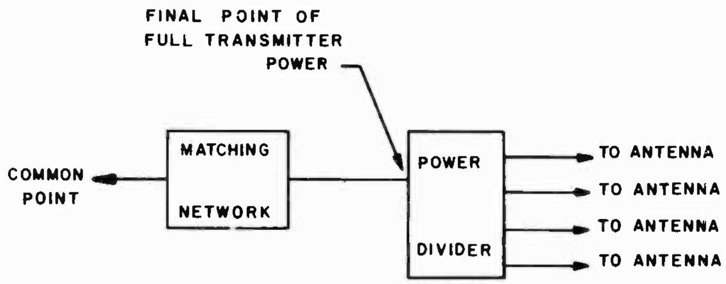
POWER DIVIDERS FOR DIRECTIONAL ANTENNA SYSTEMS

INTRODUCTION: Many engineers have often expressed a long felt need for better understanding of power divider systems, particularly as they are in use today. Available literature is very limited, and a survey of the problems encountered in power divider design and adjustment indicates that there are many areas where a more comprehensive understanding of present day power divider devices would lead to more economical designs and easier, more efficient adjustments.

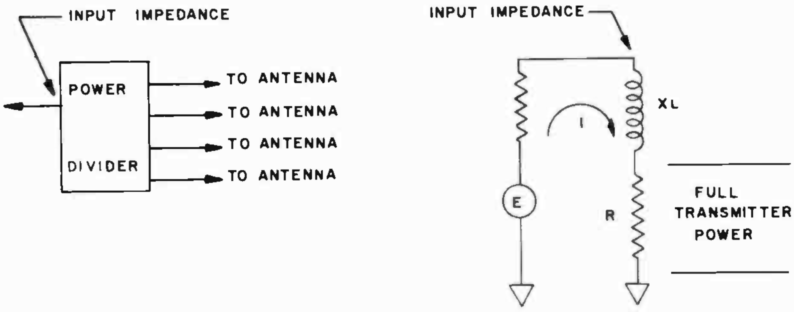
It is the purpose of this paper, therefore, to examine power divider systems and illustrate those factors which are of prime consideration. In this way, it is believed, that many designs can provide a somewhat more realistic approach, easier adjustments and a better contribution to more economical phasing systems.

THE GENERAL POWER DIVIDER: The power divider section of a directional antenna phasing system is, in reality, two separate and distinct devices as shown in Figure 1. Specifically, there is the power divider proper and a device for matching the impedance of the divider to the desired common point resistance. The point of separation between the two devices is always that point at which the full transmitter power exists for the last time.



BLOCK DIAGRAM GENERAL POWER DIVIDER
FIGURE 1

In Figure 2, a Thevenin equivalent circuit has replaced the power divider proper. The impedance of the divider is shown consisting of a real, or resistance part, and an imaginary, or reactive part. Except in rare instances, this reactance will always be inductive. The resistance shown here is the real load for the transmitter and if the full transmitter power is to be supplied to the antenna system, the full transmitter power must be dissipated in this resistance. For this reason, the value of this resistance is the all important parameter in the design and adjustment of any power divider. It completely determines the current flow in the circuit.



GENERAL POWER DIVIDER AND ITS EQUIVALENT CIRCUIT
FIGURE 2

Power dividers must first of all be capable of dividing power and this power division must be easily adjustable. However, in the final analysis, they must also operate efficiently and require as inexpensive components as is consistent with good engineering practice. And, since efficency and economy are a function of the currents flowing in the power dividing system, it can readily be seen that the higher this input resistance can be made, the more efficient and economical will be the divider.

This resistance also determines the requirements of the matching network; for, as will be shown later, it is this resistance that must be matched to the desired common point.

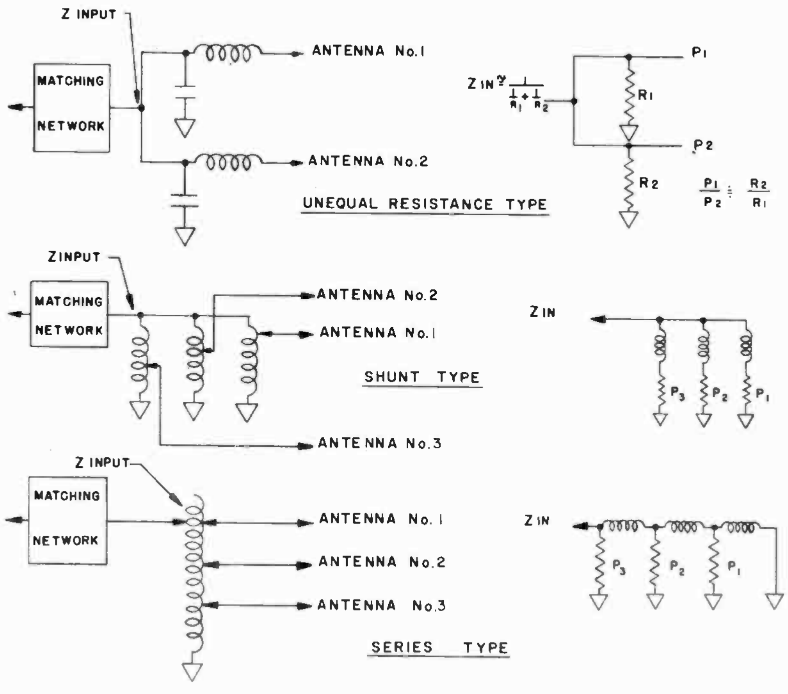
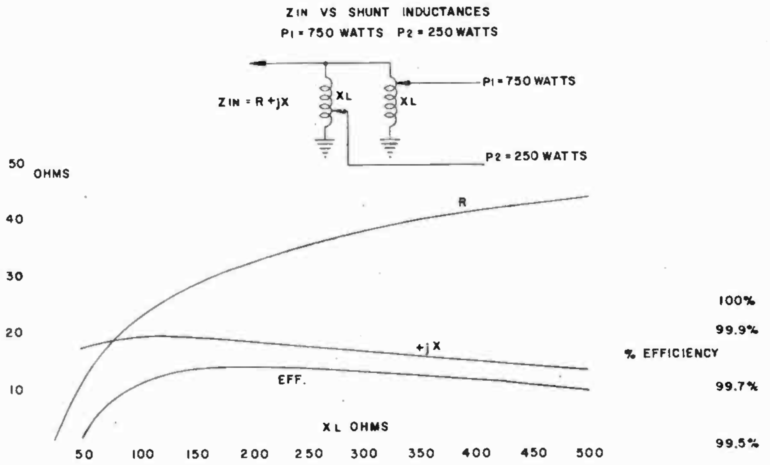


FIGURE 3

Currently, there are three basic types of power dividing circuits in use. For lack of better names, they have been called an "Unequal Resistance Type", a "Shunt Type", and a "Series Type". They are shown in Figure 3, together with their equivalent circuits.

THE "UNEQUAL RESISTANCE TYPE": The "Unequal Resistance Type", consists essentially of two "L" networks connected back to back, and power division is accomplished by making their input resistances inversely proportional to the two powers. It is not too easily adjusted, because it requires an adjustment of both the series inductances and the shunt capacities to effect the desired power division, and, every adjustment is always accompanied by a rather large change in phase shift added to the two lines. This type of power divider is not used very often and is not practical at all except for two tower arrays.

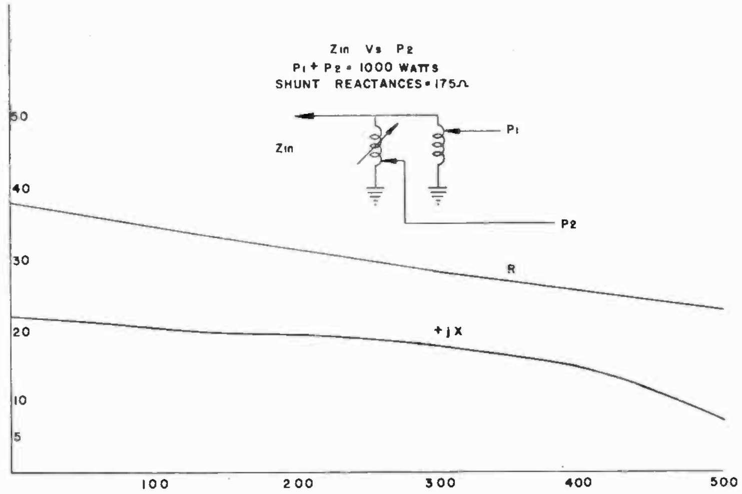
THE SHUNT POWER DIVIDER: The "Shunt Type" of power divider consists of a separate coil shunted to ground for each antenna feed. Full and complete control of the power division is possible if all but one of the shunt coils is made variable. Placing the tap for the highest power output from this divider at the top of one of the coils, always produces the highest possible input resistance for any given power division.



SHUNT POWER DIVIDER
FIGURE 4

In Figure 4, the variation of the input resistance and reactance of this type of divider is shown as a function of the reactance of the two shunt coils. The example is based on the assumption that the input to each of the transmission lines is 50 ohms. From these curves, it is readily seen that the input resistance of the divider increases as the reactance of these coils increase. However, the efficency curve definitely shows an optimum size for them--in this case, approximately 3 to 4 times the transmission line impedances. This is an important consideration in the design and adjustment of this type of divider.

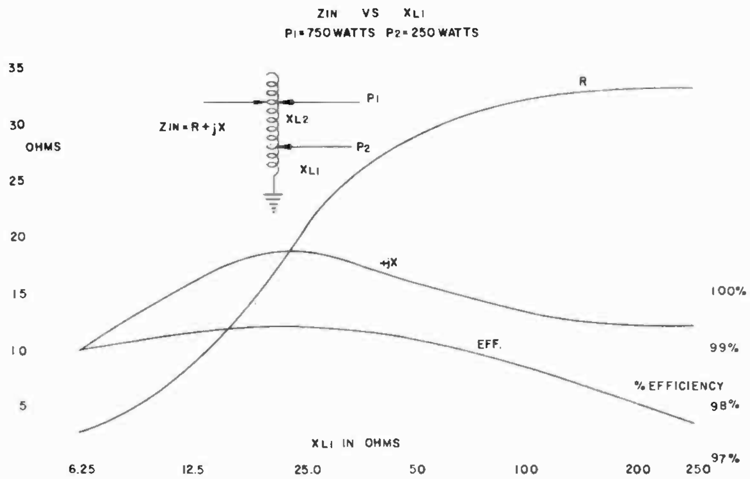
Figure 5 illustrates the variation of the impedance as a function of the power fed to the lowest power tower, with the transmitter power remaining constant at 1000 watts. The resistance curve, in this figure, is especially significant in that it shows only a small variation as the power division is adjusted from zero to equal powers in both towers. This fact is indicative of the relative ease of adjustment of this type of power divider over a very wide range of power division. This is, definitely, the main advantage of this type.



SHUNT POWER DIVIDER
FIGURE 5

The primary disadvantage for this divider lies in the fact that as more antennas are added, additional impedances are connected in parallel across the input of this divider. Consequently, from a practical viewpoint, if more than three towers are served with this type, the input resistance becomes very low and the resulting high currents make the shunt divider very inefficient and costly.

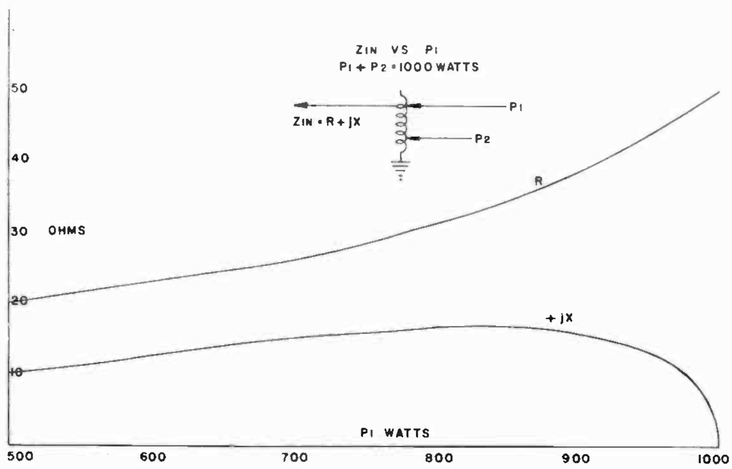
THE SERIES POWER DIVIDER: The series divider consists of a single coil on which the various antenna feeds are tapped. Practical adjustment of this divider is usually begun by locating the tap for the most power well up on the coil, and then adjusting the lower power feeds, as required, for the desired power division. The input of this divider always occurs at the position of the highest power tap.



SERIES POWER DIVIDER
FIGURE 6

For design purposes, however, it is more convenient to fix the lowest tap and adjust those for higher powers. So, in Figure 6, is shown the variation of the input resistance and reactance of this type of divider as the lowest tap is placed higher and higher on the coil. Here, again, an optimum position is indicated as far as efficiency is concerned, although it is not critical as long as this lowest tap is above a certain minimum value.

In Figure 7, the lowest tap is set at a point where the reactance of the coil below the tap is equal to the input to the transmission line feeding from it. The highest tap is then moved further and further up the coil to provide more power to the number one tower. Note the rather sizeable change in input resistance as the power division is changed. Obviously from this curve, this type of divider is a little more difficult to adjust than the shunt type. However, in general, the input resistance can be made higher. Also, as additional antennas are served with this type, the input resistance is not directly shunted by the additional impedances, so that the series divider can always provide a higher input resistance with a large number of towers that can the shunt divider. This fact gives this type of divider a decided advantage over the shunt type for greater than three towers or for systems involving high powers.



SERIES POWER DIVIDER
FIGURE 7

One of the most common errors made in power divider design occurs in the practice of making the assumption that the input impedance to the transmission lines is a pure resistance. This is done to simplify the mathematics. However, the design is often concluded with this assumption being considered as a statement of fact.

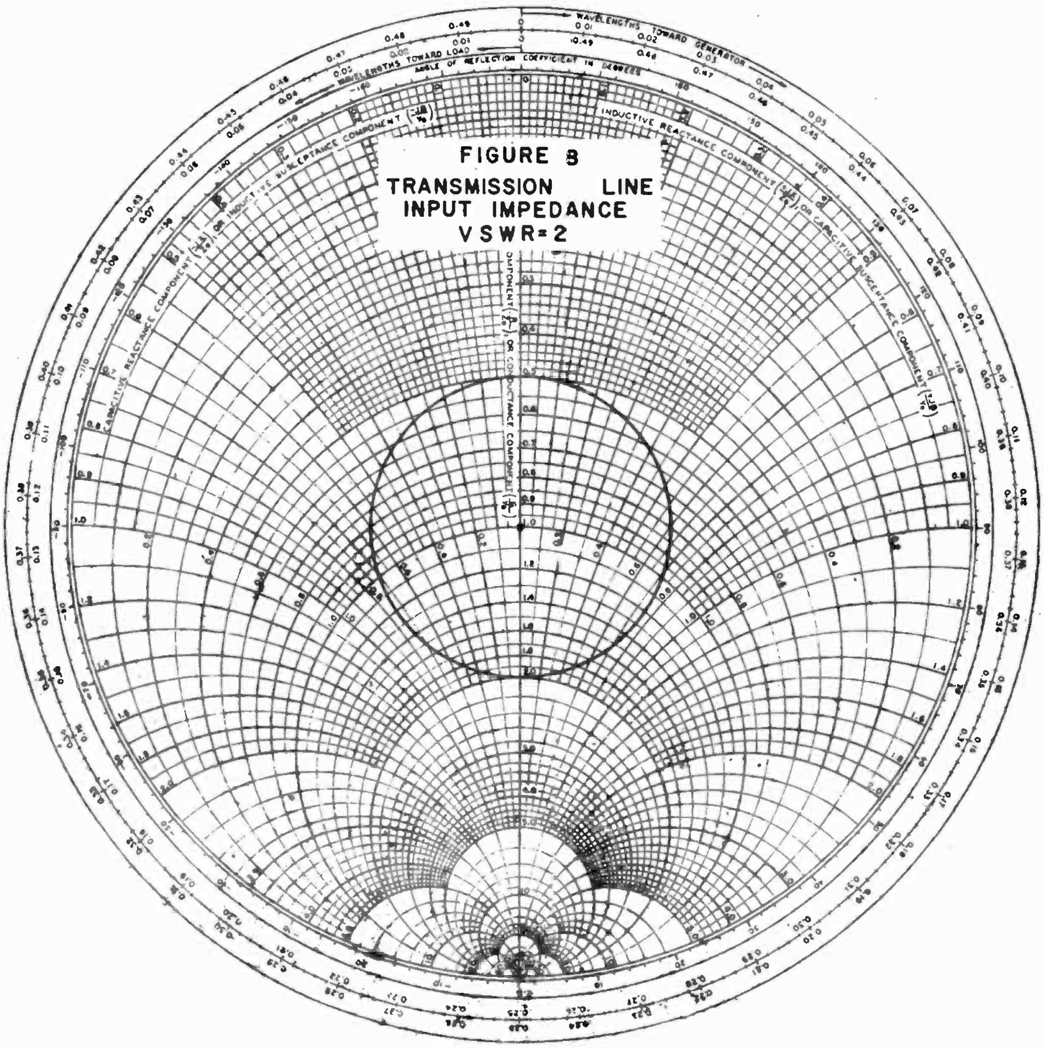


FIGURE 8

Now it is a well known fact, that, in most directional antenna systems, the transmission lines will be somewhat mismatched in the final adjustment. This mismatch materially affects the operation of the power divider, since the lines provide the load for the divider. To illustrate this, a specification has been chosen that the lines will have an input VSWR of 2 to 1, and the Smith chart in Figure 8 gives the range of input impedance that the lines may have if they fall within this specification.

In Figure 9, both the shunt and the series type of divider have been adjusted for the power division shown and so that they will have equal input resistances when the transmission line inputs show a VSWR of unity. This input resistance is represented by the horizontal line in the center of the figure. Now, by induction the maximum effect of the transmission line mismatch occurs when both transmission lines are mismatched an equal amount in the same direction. The two resistance curves represent the variation in the input resistance of each type of divider as the input to the lines varies around the VSWR circle of Figure 8.

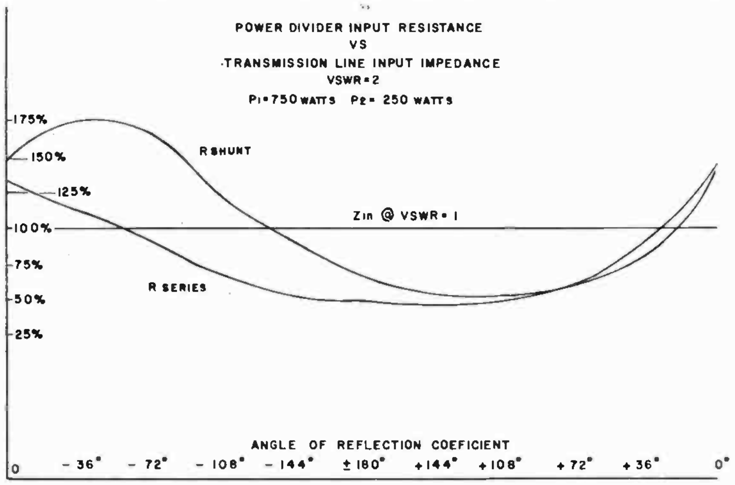


FIGURE 9

Evidently, there can be a considerable variation of the divider input depending upon the extent of the transmission line mismatch. Hence, no power divider design can ever be considered complete unless that design has been computed over a considerable range. It is likewise an important point that no power divider design should ever be submitted unless accompanied with a full and complete statement as to the extent of the range over which the power divider design has been considered. The range would be impossible to predict from a simple list of components, and the adjusting engineer could not possibly know within what limits the system was capable of satisfactory performance.

THE MATCHING NETWORK: Probably more variation occurs from one system to another in the matching network that in any other portion of phasing system design. However, as will be shown, all methods are basically the same and aside from requiring more or less components, all perform equally well.

In Figure 10, an "L" network is shown designed to match the given power divider input resistance to the common point. This is the simplest and most economical method, and, if designed with sufficient range, it is the easiest to adjust, since there are only two elements to adjust. Matching devices, no matter how elaborate, serve only the single purpose of matching the divider input to the common point. Consequently, the more simple this network can be made, the more efficient and economical will this portion of the system be. The "L" network will always suffice for this purpose if power is to be supplied to more than one tower; for with this stipulation, the input resistance of the power divider can never exceed the common point resistance.

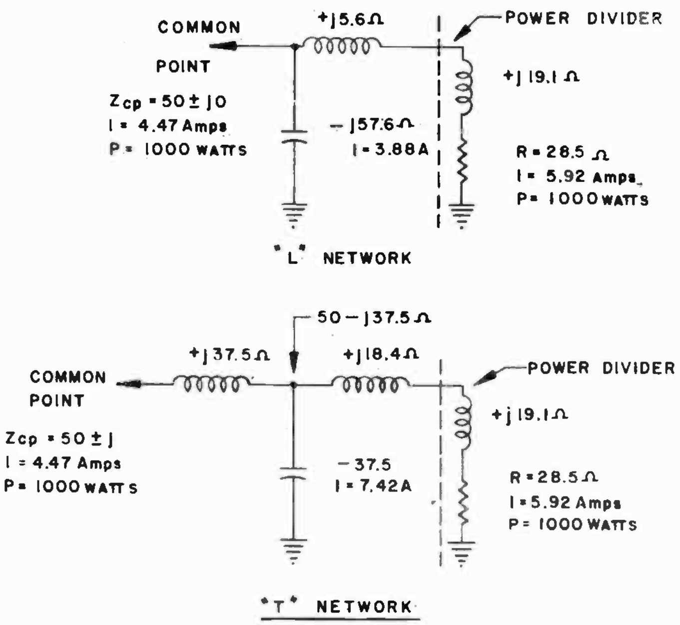
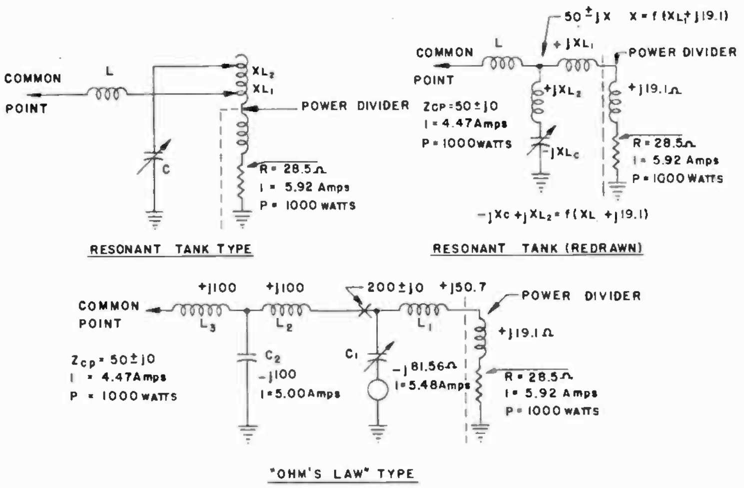


FIGURE 10 MATCHING NETWORK

The " T" network, shown in Figure 10, is nothing more than an " L" network with an additional reactance to aid in tuning out a reactance which appears at the junction of the capacitor and the series coils. The " T" network, therefore, provides a slight advantage in adjustment facility at the sacrifice of adding an additional element to adjust.



MATCHING NETWORKS
FIGURE 11

Probably the most common type of matching system used today is the resonant tank circuit type shown in Figure 11. Here the capacity " C" is tuned to resonance with an additional inductance added to that already supplied by the input impedance of the power divider. The actual operation of this type, however, is best illustrated in the re-arranged version shown at the right. Here it is easily seen that this type of network is really nothing more than the " T" type shown in Figure 10.

The fourth matching network, chosen for this discussion, is one that has come into frequent use in recent years. C is tuned to resonance with the power divider input and L, so that a pure resistance of some value higher than the common point appears at point X. This high resistance is then matched down to the desired common point value by an additional " T" network. A parallel resonant circuit with resistance in the inductive branch is exactly equivalent to an " L" network matching the resistance in the inductive branch to the higher resistance appearing across the capacitor. In the illustration shown here, exactly the same component values and the same currents and voltages are computed regardless of whether this circuit is designed as a resonant tank circuit on the basis of circuit " Q", or whether it is designed as an " L" network to match the 28.5 ohms to the 200 ohms. From this, then it follows, that in this type of matching network, we have nothing more than an " L" network preceded by a " T" network to perform exactly the same function as was performed by the simple " L" network shown in the first illustration.

Occasionally the term " bandwidth" has been used in connection with power divider systems and their associated matching networks. Bandwidth of any phasing systems is a function of the system as a whole. It is effected by the antennas, by the system parameters, and by the adjustment of the complete phasing system from transmitter to antennas. Generally, the greater the ratio of the dissipated energy in any part of the system to the stored energy, the broader will the bandwidth be. In connection with the power divider, the higher the input resistance of the divider the broader the bandwidth. When considering only the matching networks, however, no significant difference could be found from one type to another when all of the above types were considered on an equal basis.

CONCLUSION: It has been shown that two devices are involved in every divider design-the divider and a matching network. Of the two most generally used, the shunt type is easiest to adjust and most suitable for two or three tower systems, especially for lower powers. For more than three towers or for high power, the series divider is better suited because of its higher input resistance.

The necessity for designing power dividers over a wide range and for specifically stating over what range the design was considered, has been demonstrated as important, because of the wide variation the input resistance may assume with varying adjustment conditions.

And finally, the matching network should be as simple as possible, consistent with the ability to match the common point resistance over the full expected range of the power divider input.

Obviously, the subject of power dividers has been barely touched upon in this discussion. It is believed, however, that sufficient information has been given to stimulate further investigation and in this way much can be done to provide power dividing networks that are easier to adjust, more efficient to operate and contribute to more economical phasing systems.

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