Receiver Multicoupler & R.F. Preselectors

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Background Information

For more than twenty-five years the number of *multi-channel* wireless land mobile equipment sites has proliferated. To accommodate more and more systems on desirable communications sites the practice of coupling groups of receivers together and combining groups of transmitters together has increased. Improved Receiver Multicoupling systems grew out of these developments.

Receiver Multicoupler Systems are now commonplace at all established land mobile mountain top tower sites, stand alone tower sites and building top sites.

This bulletin is intended to update a bulletin prepared in 1988 with additional information gleaned from experiences since that time.

Receiver Multicoupler Essentials

Where a number of channels are to be coupled together using a Receiver Multicoupler the typical arrangement is shown in block diagram form in Figure 1. The components and their purposes are:

- The Preselector. A filter that defines a pass band that will encompass the desired range of receive frequencies and reject all other frequencies.
- The Pre-Amplifier. A solid state high performance amplifier having a low noise figure and high linearity with sufficient gain to overcome multicoupling losses.
- The Signal Power Divider. A balanced impedance divider circuit to divide the amplifier's output into the number of receiving channels required.
- A Power Supply. A regulated supply that will convert A. C. or other D. C. voltages set to the amplifier design operating voltage and current.

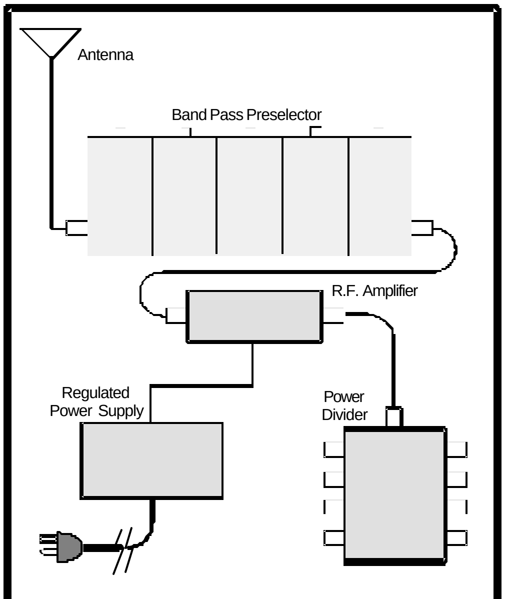


Figure 1 **Block Diagram of basic Receiver Multicoupler**

The band of frequencies determined by the preselector are amplified to overcome the combined losses of the coaxial feed lines, preselector and signal power divider.

Benefits Of Multicoupling

To review some of the benefits provided by a multicoupling system we list the following:

1. Receiving performance equal to or better than if each receiver were served by a separate antenna.

2. The preselector has flat response (within 0.5 dB) over the prescribed receiving range along with steep slope “roll off” responses above and below the desired pass band. The possibility of amplifier or receiver overload is minimized.

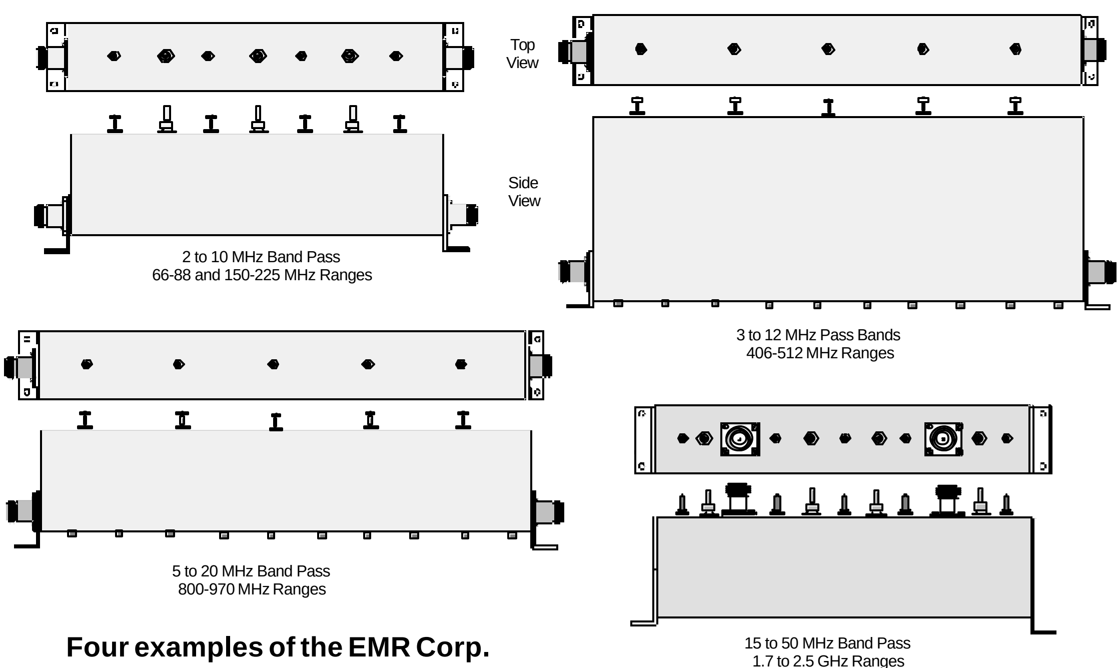
3. The low noise figure of the amplifier establishes a better system signal to noise ratio than a receiver connected directly to the receiving antenna.

4. The amplifier’s high linearity will preclude amplifier overload under strong multiple signal input levels within the preselector pass band range.

5. Sufficient additional amplifier gain is provided to overcome losses and to provide enhancement of weak signals from portables and low power mobiles.

6. In “Tower Top” models the preselector and amplifier are placed in a weather proof housing near the base of the antenna. A *D. C. Block or D. C. Line Tap* provides means to supply required power to the amplifier. Amplified signal levels are well above induced signals and noise from adjacent transmitter lines on a tower or other structure.

A number of EMR Corporation designed and built preselector types are portrayed in Figure 2. Note that various bandwidths can be provided in frequency ranges from 66 MHz through 2.5 GHz. Cavity filters are often added to provide needed special responses, notches, multiple ranges, etc. to suit system needs. All EMR preselectors are factory optimized for the desired frequency range, with



Four examples of the EMR Corp. Band Pass Preselector Filters for Receiver Multicoupling Application

Figure 2

lowest possible insertion loss and excellent VSWR's over the desired pass band.

Practical Preselector Responses

Figure 3 shows a plot of the response of an 800 MHz SMR plus NIPSPAC multicoupler preselector. Note that 18 MHz of flat response is provided with low loss in-band and that the selectivity curve shows about 70 dB of transmit carrier rejection at the lowest transmitter frequency. The dotted line curve suggests the level of wide band transmitter noise that can be passed through the transmitter combining system.

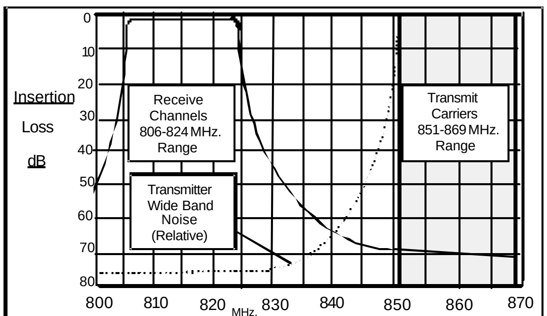


Figure 3

Response of a SMR system preselector

Showing relationships of system receiver and transmitter channel frequencies compared with the filter response..

Throughout the frequency bands covered by these filters various bandwidths can be provided, along with added notches to meet specific site needs. The models shown in Figure 2 have frequency ranges shown according to style of preselector housing.

A feature of these designs is that the coupling methods employed between resonator sections permits factory optimization to a broad range of frequencies and bandwidths, greatly expanding the utilization of each standard preselector assembly. Performance equals or exceeds traditional *comb filter* or *interdigital* filter expectations. Reliability is excellent, even under the rigors of tower top usage.

Preamplifier Characteristics

The first active stage of a receiving system will determine the system *signal to noise* performance. The noise figure of the preamplifier will, therefore, influence the effective sensitivity of all receivers in a multicoupled system.

EMR Corporation catalogs list twenty or more amplifiers that are manufactured to the highest standards possible. Although lower noise figures could be attained using GasFET devices, the low tolerance of these devices to overload by high signal strengths have led us to use carefully selected bi-polar R. F. transistor types. Frequency ranges covered include 66 MHz to 2.0 GHz.

These amplifiers have true noise figures from well under 2.0 dB to 3.5 dB, depending on model and frequency range. This is two to three times better than the average receiver noise figure. Most importantly, the 3rd Order Intercept Point (3 I/P) varies from +36 to +40 dBm with +19 to +24 dBm 1 dB compression points, according to frequency band and gain capabilities. Gains vary from 14 through 30 dB according to frequency range and intended application. Each model has been throughly field proven and each has demonstrated extremely low failure rates.

All amplifiers operate from a nominal 13.6 volt D. C. power source. Power supplies, power inverters and/or regulators provide operation from 108 – 250 V. D. C., 13.6, 24 or 48 volt D.C. either polarity primary power sources.

Basic models have the option of an added integral PIN diode attenuator, permitting setting gain as required in the receiving system.

Signal Power Dividers

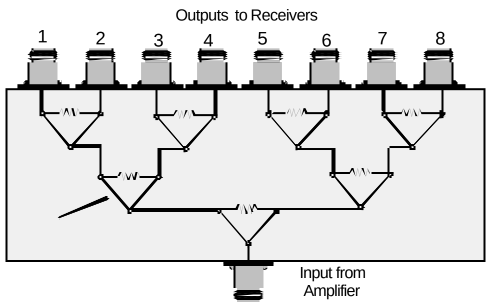


Figure 4 **8-way signal power divider for receiver multicoupling use.**

After the desired band of frequencies has been selected and amplified, signal power dividers are used to feed the individual receivers. Figure 4 suggests how Wilkinson Splitter hybrid circuits can divide the signal into 2, 4, 8 or more discrete feeds, according to the number of receivers in the system. A 0.5 to 1.0 watt termination must be placed on all unused ports to maintain circuit balance of the divider.

We have supplied multicouplers to serve up to 128 channels of 800 MHz SMR receiving, and as few as two channels at rural radio sites. For convenience in mechanical layout of multicoupler systems, we build 2, 4 and 8 port standard power dividers with choices of BNC or Type N connectors. Fifteen standard models cover the ranges of 30 – 512 MHz, 216 – 225 MHz, 806 – 960 MHz and 1.8 – 2.0 GHz. Where needed, we can also provide models to suit special applications.

Using this basic range of dividers and amplifiers, we can put together any combination from 2 to 128 receiver feeds. Often, a 2 or 4-way divider is mounted on the multicoupler chassis with separate divider panels. This approach saves cable runs, since a four-way split can serve up to 4 sixteen way splits if needed, for 128 receiver feeds.

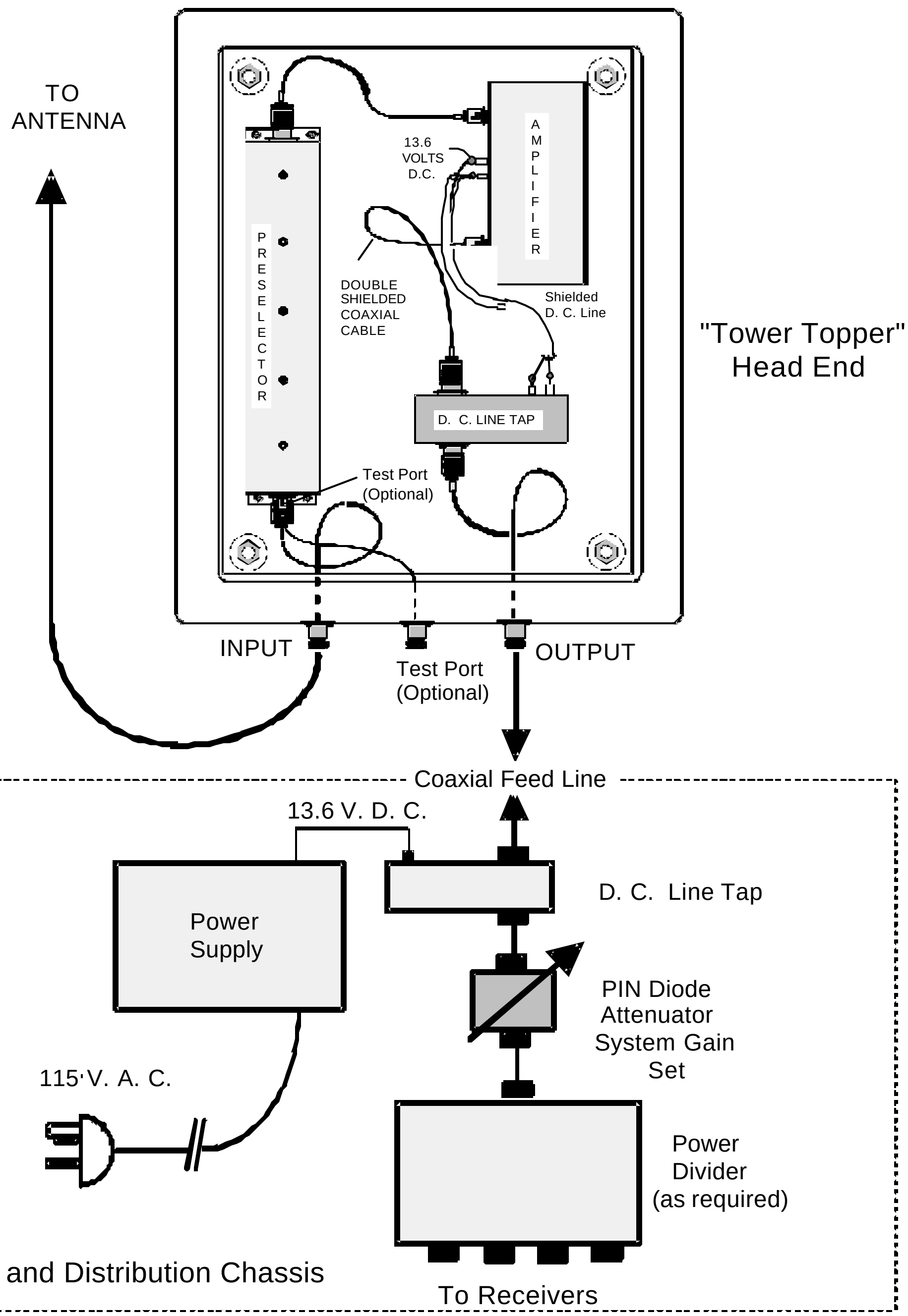
Each split can be expected to lose about 3.25 dB of signal power which, along with some cable and connector losses will amount to about 40 dB for 128 channels. For these systems we have used a 30 dB initial amplifier with PIN diode attenuator and a second, high 3rd order I/P rated, 16 dB gain amplifier in series. The first amplifier is adjusted to provide unity plus perhaps 3 dB of added gain, over unity according to system type and site R. F. environment.

Tower Top Systems

Losses between the signal source (the antenna) and the input of the preamplifier front end will reduce the system noise figure, dB for dB. For this reason it is very important that all circuits between the antenna and the amplifier input have losses as low as possible. Figure 5 provides a layout of a Tower Top multicoupler system.

Except for ultra narrow pass band versions, EMR preselectors have under 1.5 dB of insertion loss. Where added losses due to long runs of transmission line between the system receiving antenna and the input to the multicoupler are present the idea of placing the preselector and amplifier just after the antenna has proven to be most successful in improving system receiving range.

Testing, using the same receiving antenna and transmission line on a 350 foot tower with a 420 foot transmission line run, showed a *measured improvement of 9.6 dB* through tower top operation compared with a ground mounted multicoupler using the same components. Similar improvements have been verified at hundreds of sites, providing up to 12 dB of performance enhancement when significant lengths of line were present. The improvement factor is due to more than just overcoming line loss with amplifier gain. The added factors are:



Arrangement of components of a Tower Top Multicoupler System

Figure 5

1) Improvement in effective noise figure by minimizing loss between the source (antenna) and the amplifier input.

2) The weak signals are amplified such that they are well above the levels of noise induced in the form of extraneous transmitter signals and noise and random signals that could be coupled into the receiving coaxial line from other cables on a tower.

Reliability of Tower Top Systems

The Tower Top Multicoupler "head end" is subjected to a number of influences due to its position on a tower or other structure. Heat, cold, wind, ice, and vibration are all present in addition to lightning strike potential.

This is another reason for using rugged bi-polar high frequency transistor amplifiers as opposed to GasFET devices. To provide as secure a housing as possible we use heavy duty NEMA style enclosures. We recommend that these enclosures be stainless steel, particularly where installation will be in coastal or high rainfall locations.

The preselectors are shock tested prior to installation. Their construction has proven to be rugged enough to withstand tower top conditions. Of thousands shipped over the past 17 years, failures have been minimal; one or two due to lightning hits directly on the antenna. Due to the unique grounded loop coupling method used in our preselectors, lightning discharge short duration, high peak power pulses are by-passed and do not find their way through the preselector to the amplifier.

The "D. C. Block" or Tap-Off passes the R. F. signals with very little insertion loss and with lightning pulse protection. One of these is made a part of the tower top unit and another one, on the multicoupler distribution chassis permits applying D. C. voltage, using the coaxial center conductor to carry power to the amplifier.

We can express the in-service MTBF in terms of several hundred thousand hours on our tower top units. Due to the utter simplicity of the design and nature of components used the parts subject to failure are kept to a minimum.

Tower Top Redundant Systems

Various manufacturers provide considerable "gimmickry" either as options or designed into tower top systems. The validity of these various accessory items is reviewed here:

<u>Redundant Amplifiers</u>: The idea of providing a second amplifier with coaxial relays or solid state diode switching would seem to be a "good idea." But, is this still a good idea after looking at the ramifications of the matter? Consider that:

- Additional circuit losses are introduced by the switching devices, reducing effective noise figure and overall performance of all receivers.
- The switching devices add complexities that are, themselves, subject to failure. Moreover, suitable coaxial relays for up to 1 GHz are expensive and provide reduced isolations, further complicating designs.
- Solid state switching designs for this purpose involve some logic circuits that can be subject to failure or false operation arising from pulse energy such as that resulting from lightning hits on or near the site in question.
- If the active amplifier devices are damaged by a lightning strike, the odds are that the

redundant amplifier will also be damaged from high amplitude pulse energy arc-coupled through relays or solid state switch circuitry.

- The cost of adding this “feature” is considerable, due to the need for relays or switching circuits of high quality. Costs to manufacture are, accordingly, very high.
- In view of the fact that properly designed amplifiers are ultra reliable it seems to be somewhat ridiculous to reduce the system reliability with gadgetry to deal with completely unpredictable, random occurrences.
- What are the possibilities that the standby amplifier can fail from vibration or pulse activity and when switched in, will not operate?
- Some means of causing the switch over must be employed, such as pulsing the D. C. amplifier voltage or running a separate circuit up to the tower top unit. This, itself, can be damaged or lightning damaged and it simply brings more noise and unwanted signals into the multicoupler head end assembly.

It is noted that the added price for switched redundant amplifiers and their control circuitry is equal or greater than the cost of purchasing and holding a “head end” unit as a site spare.

With an EMR Corp. Tower Top system, we recommend an inner mounting plate assembly having a preselector, amplifier, D. C. Block and cables. One of these can be held as a *site spare* for each tower top system. <u>Since someone must climb the tower in any case</u>, the climber can carry this five pound assembly along with his normal tool belt kit and have the system back in full service in a few minutes. EMR Corp. recommends this approach in lieu of the uncertain value of redundant amplifiers, switching circuits current and voltage monitoring meters and other questionable approaches to amplifier failure monitoring and corrections.

The plate referred to is depicted at the inside of the “head end” assembly. It is held in place by four (4) nuts and all other connections are via Type N connectors.

If specific site conditions dictate the use of tower top “redundant amplifers”, EMR offers competitive receiver amplifier RF by-pass switching systems.

Other Multicoupler Considerations

<u>Adjustments</u>: Usually no adjustments are needed when installing your multicoupler with the possible exception of system gain setting.

Experience has shown that from 1 to 3 dB of gain over the calculated losses of transmission line loss is usually beneficial. It has also been determined that too much gain can be damaging. Excessive amounts of noise, and strong signals can be amplified to the degree that receiver front end desensitization will occur and receiver R. F. amplifier stages can be driven into saturation, causing “receiver intermod.”

We know of no other way to arrive at the “just right” amount of gain to use than through listening to the character of communications on the various receivers being multicoupled. We set the overall gain through each multicoupler to between 2 and 3 dB above unity during the final test phase of manufacture. This has proven to be quite satisfactory in most applications.

To adjust amplifier gain-set in systems with PIN-diode attenuators, we suggest the following:

First, it must be assumed that the responsible technician or engineer doing this work is familiar with the character and conduct of routine communications in the system(s) involved. If this a completely new system install, we recommend that our factory gain setting is not changed at time of installation.

Set up your service monitor or spectrum analyzer on the frequency of a strong control station signal. Use a spare port out of a signal power divider, monitor and record the signal strength level of that station as a reference.

Note the screwdriver slot in the potentiometer that controls gain. *It turns counter clockwise to increase gain.*

Now, increase the gain, relative to your reference station level, by 3 to 5 dB. Monitor signals and observe the receiving performance over some reasonable period of time to decide if things are better or worse.

Each site and each system has its own performance optimums. The quiet, relatively interference free site (quite rare, these days!) might tolerate more amplification, whereas, the dense, problem sites often perform better, overall, with less system gain.

Since the readings taken are inclusive of the performance of antenna, lines and multicoupler the integrity of the entire system may be properly set in this way.

Test ports: For those who wish to provide a cross check on their multicoupler systems EMR Corp. and others can provide a test port to inject a test signal into the preselector. This provides a lightly coupled (30-40 dB down) coupling into the first stage of the preselector, permitting the introduction of a reference test signal with no appreciable de-tuning effect on normal preselector performance.

In lieu of the use of a reference on the air signal as a bench mark, which could vary somewhat in level over time, this permits a verification of performance of the multicoupler, however, the antenna system will not be a part of this consideration.

For a tower top system, it will be necessary to run a separate coaxial cable from the equipment building up to the tower top "head end" position. If system gain has not changed since last measured, poor performance can be diagnosed as antenna or antenna jumper cable problems.

Overall reliability; spares: The concept of having a tower top assembly spare on site was discussed earlier (See Figure 6). Remembering that a multicoupler is a common link to all receiving, it makes sense to keep a spare amplifier and a spare power supply on site.

Although the amplifiers and the high quality switching power supplies that we use are ultra reliable, no piece of electronics can be construed as failure proof. Having such spares is simply good insurance against revenue losses, customer inconvenience, *two trips to make one repair* and the other consequences of running without reasonable spares.

Installation Notes

We offer the following notes relating to the installation of multicouplers:

- Locate your multicoupler or distribution chassis in the case of a tower top system as central to the cabinet or relay rack positions as possible. This assures that cables to receivers are kept as short as they can be.
- Where receiver locations are split up between various locations, you can plan

for running a single feed line from the multicoupler with splitters to accommodate the number of receivers to be fed.

- Use only high quality double shielded or solid copper outer conductor low loss cable for receiver feeds. Avoid “bargain” connectors.
- If at all possible, use an A.C. circuit that is dedicated to the multicoupler or for powering non-transmitting equipment. This will insure that the failure of some other devices will not disable the multicoupler
- It is most important that the coaxial line from the antenna is separated from transmit lines. Despite the fact that most lines used have solid copper outer conductors, even slight mismatches result in standing waves on the outside conductor which can radiate unwanted signals.
- Be sure that the tower used is properly grounded and that the multicoupler tower top housing has a good solid ground to the tower.
- Don’t install the multicoupler, either an integral unit or a tower top distribution panel in a cabinet or rack immediately adjacent to any transmitter.

Conclusion

EMR Corporation’s sales and engineering staff will be pleased to assist you in any way with your applications of receiver multicoupling, for the very best of receiver performance in all of your systems.

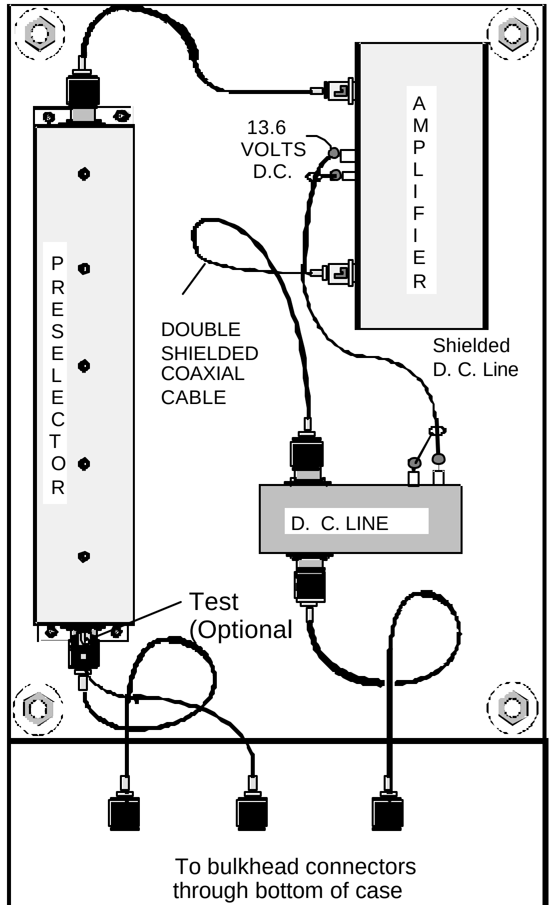


Figure 6
Recommended spare tower top system plate including preselector, amplifier and D.C. line tap as system spare.

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