SINCLAIR

A DIVISION OF NORSAT INTERNATIONAL INC.

A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

Written by Michael Macki

Product Design Engineer, Sinclair Technologies

A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

Written by Michael Macki, Product Design Engineer
Sinclair Technologies, a Division of Norsat International

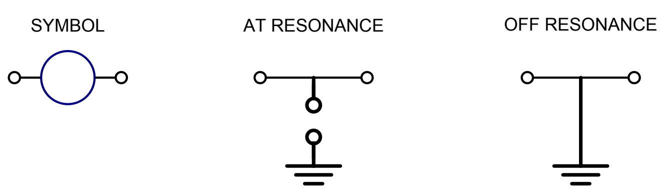
Introduction

The cavity combiner is an important tool for joining multiple signals onto a single path or for separating these signals onto individual paths. This paper will describe how resonant cavities are used to accomplish this.

First, in order to understand how these combiners operate, it is important to have an approximate idea of how cavities and transmission lines work.

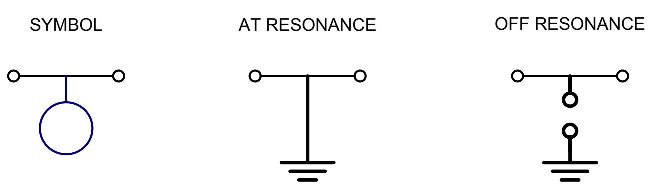
The Pass Band Cavity

The pass band cavity is a two-port device that acts like an impedance to ground. At its resonance frequency it behaves like a very large resistance which for our purposes we will treat as an open circuit. When the frequency is sufficiently far from the resonant frequency, the pass cavity can be approximated as a short circuit.



The Stop Band Cavity

The stop band cavity or notch cavity is the reverse of the pass band cavity. It is a short circuit at resonance and an open circuit away from resonance.



United States
1 800 236 3275
salesusa@sinctech.com

Canada
1 800 236 3275
salescan@sinctech.com

Asia Pacific
+1 905 726 7687
salesasia@sinctech.com

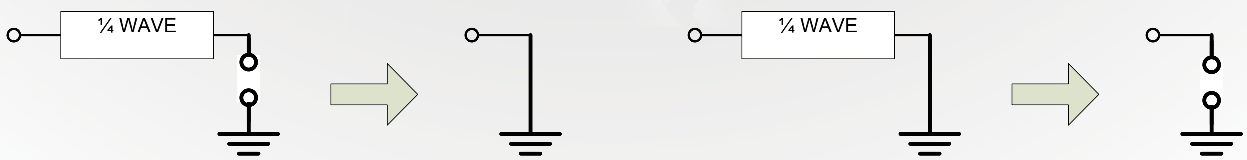
EMEA
+44 1487 842819
salesuk@sinctech.com

Latin America
+1 905 726 7676
salesla@sinctech.com

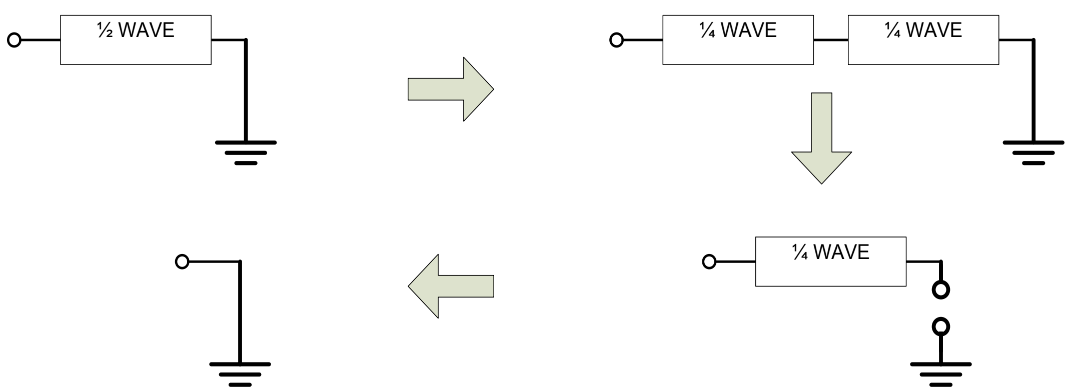
A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

The Transmission Line

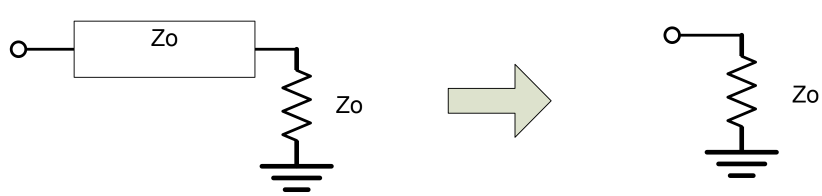
When terminated in an impedance, the transmission line transforms that impedance to a different value. The value of this new impedance depends on the length of the line compared to the wavelength of the signal in the line. An important case is where the transmission line is ¼ wavelength long. This transmission line inverts the value of the terminating impedance, i.e. a short circuit becomes an open and an open circuit becomes a short. The ¼ wave line is also referred to as an inverter.



From this we can deduce how the ½ wave line works. The ½ wave line is just 2 ¼ wave lines in series. The first ¼ wave inverts the impedance and the second ¼ wave inverts it again, bringing it back to its original value. The ½ wave cable acts as if it was not there.



The exception to this is when the terminating impedance is equal to the impedance of the cable. In this case, the cable / impedance combination acts as if the cable was not there irrespective of the length of the cable.



A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

The important points to remember are:

> A pass band cavity is an open circuit at resonance and a short circuit when away from resonance.

> A stop band cavity is a short at resonance and an open when away from resonance.

> A ¼ wave transmission line transforms an open circuit to a short and a short circuit to an open.

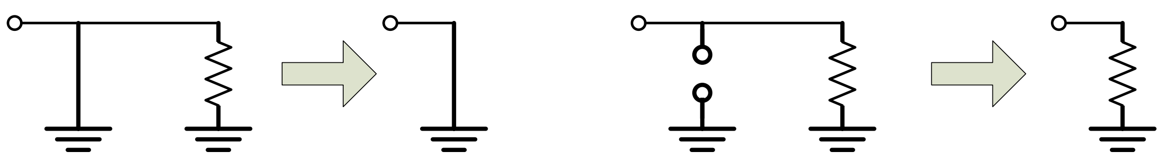
> A ½ wave transmission line acts as if it is not there.

> Any length of line acts as if it is not there if it is terminated in an impedance equal to the impedance of the transmission line.

Two other important rules are:

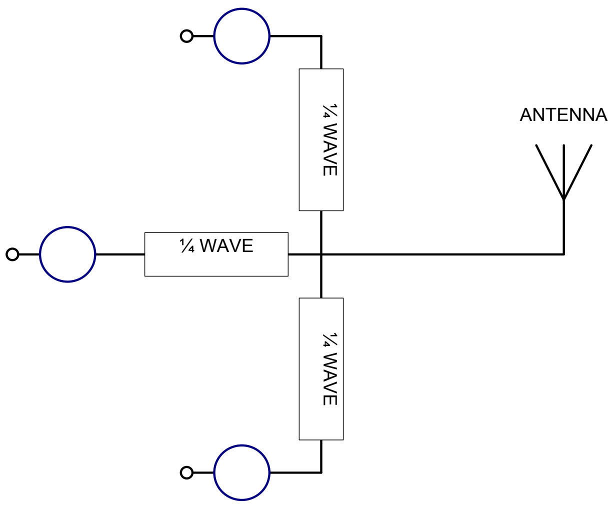
> If a short circuit is placed in parallel with any impedance then the result is a short circuit.

> If an open circuit placed in parallel with any impedance then the result acts as if the open circuit was not there.



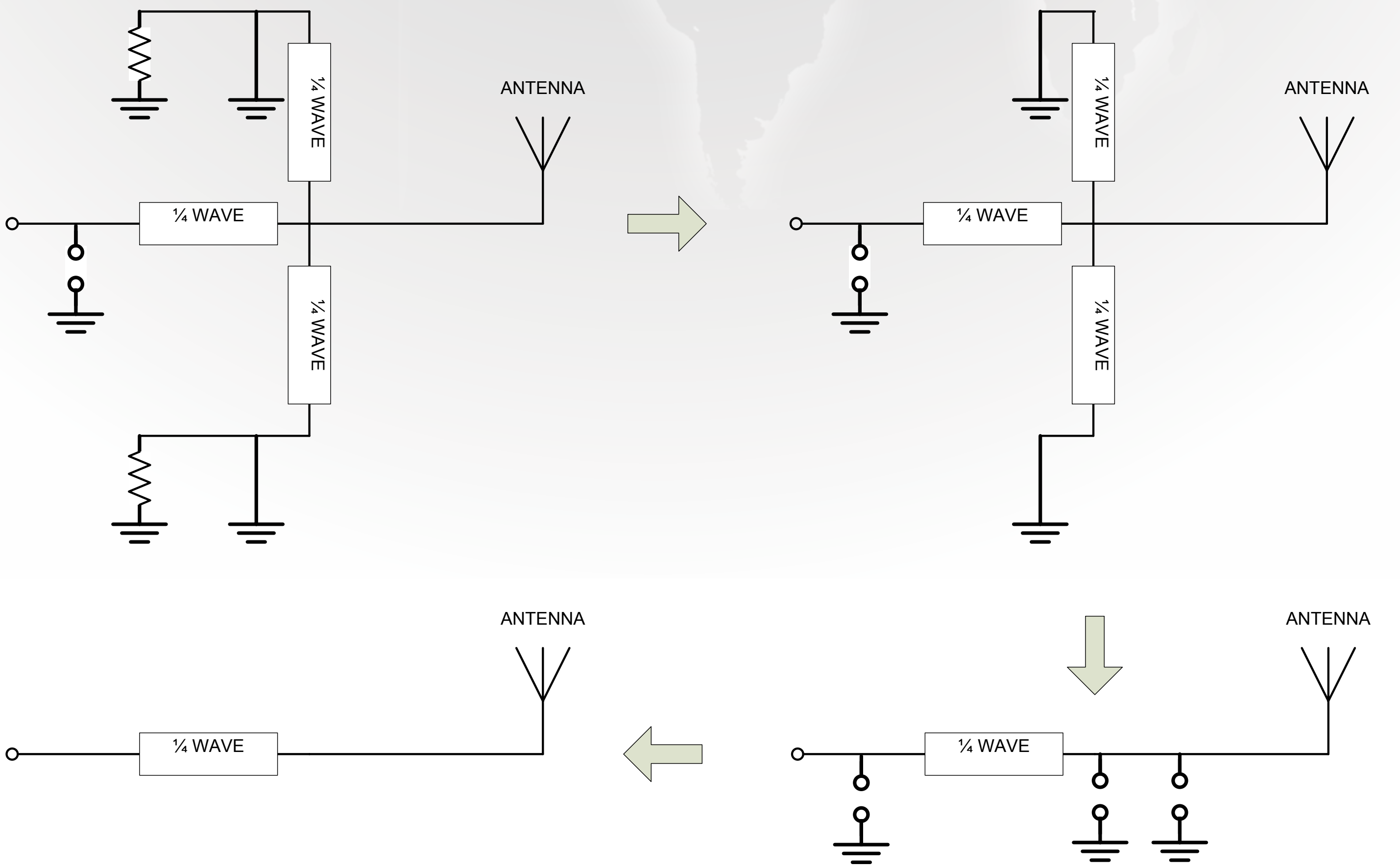
Star Junction Combiner

In a star junction combiner multiple signal paths come together at a single point or star. Each signal path has a pass band cavity tuned to the frequency of that path and this cavity is connected to the star by a ¼ wave transmission line. The Sinclair TJ, TN and CT combiners are star junction types.



A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

When one cavity is at resonance then the other cavities are off resonance. The approximate circuit is shown below:



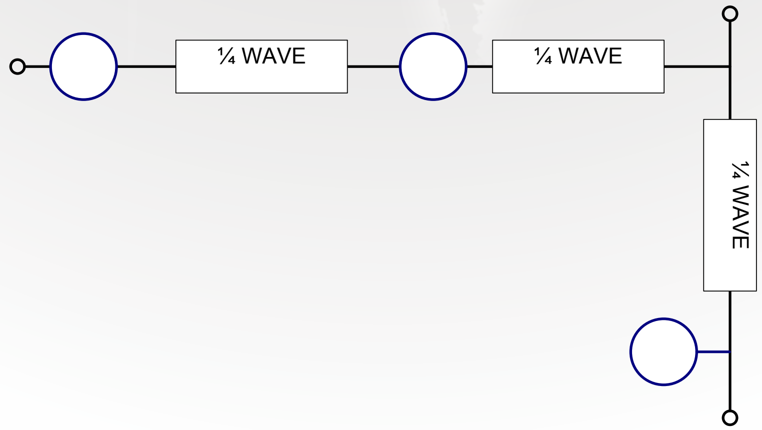
We can see how the rules we have established reduce the circuit to just the antenna and a ¼ wavelength transmission line. If the transmission line is the same impedance as the antenna then the line effectively vanishes and the transmitter only sees the antenna.

Star junctions work best when the frequencies in the combiner are relatively close together. If there is a large gap in the frequency list then it would be better to use two separate star junctions joined together with two half wave cables and a tee connector.

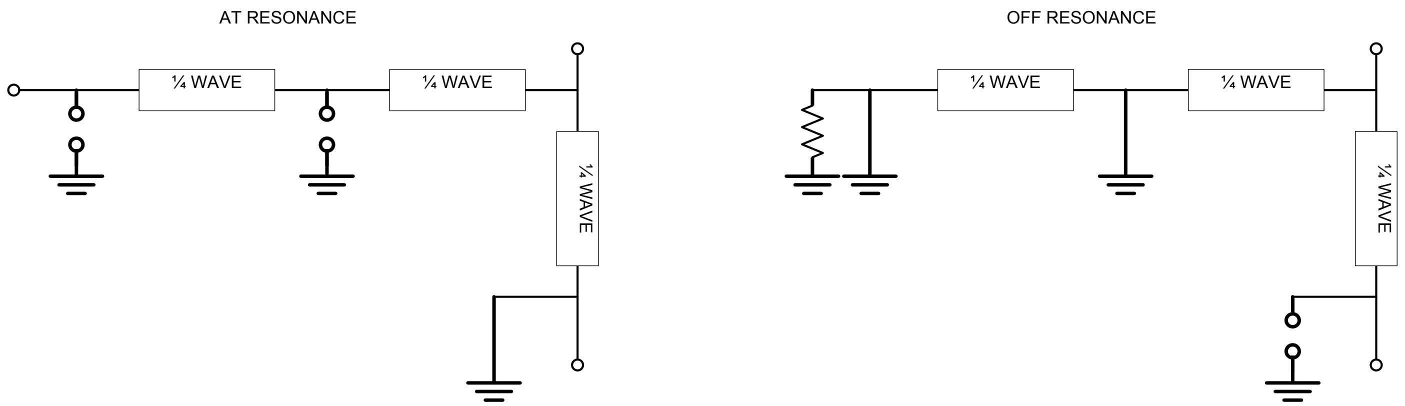
A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

Expandable Multi-coupler

This combiner type consists of individual modules that are chained together to form a common signal path which connects to the antenna. These modules form the Sinclair C-series product line. There would be one module for each input signal. Each module consists of one or more pass cavities along with a reject cavity. The arrangement is shown below:



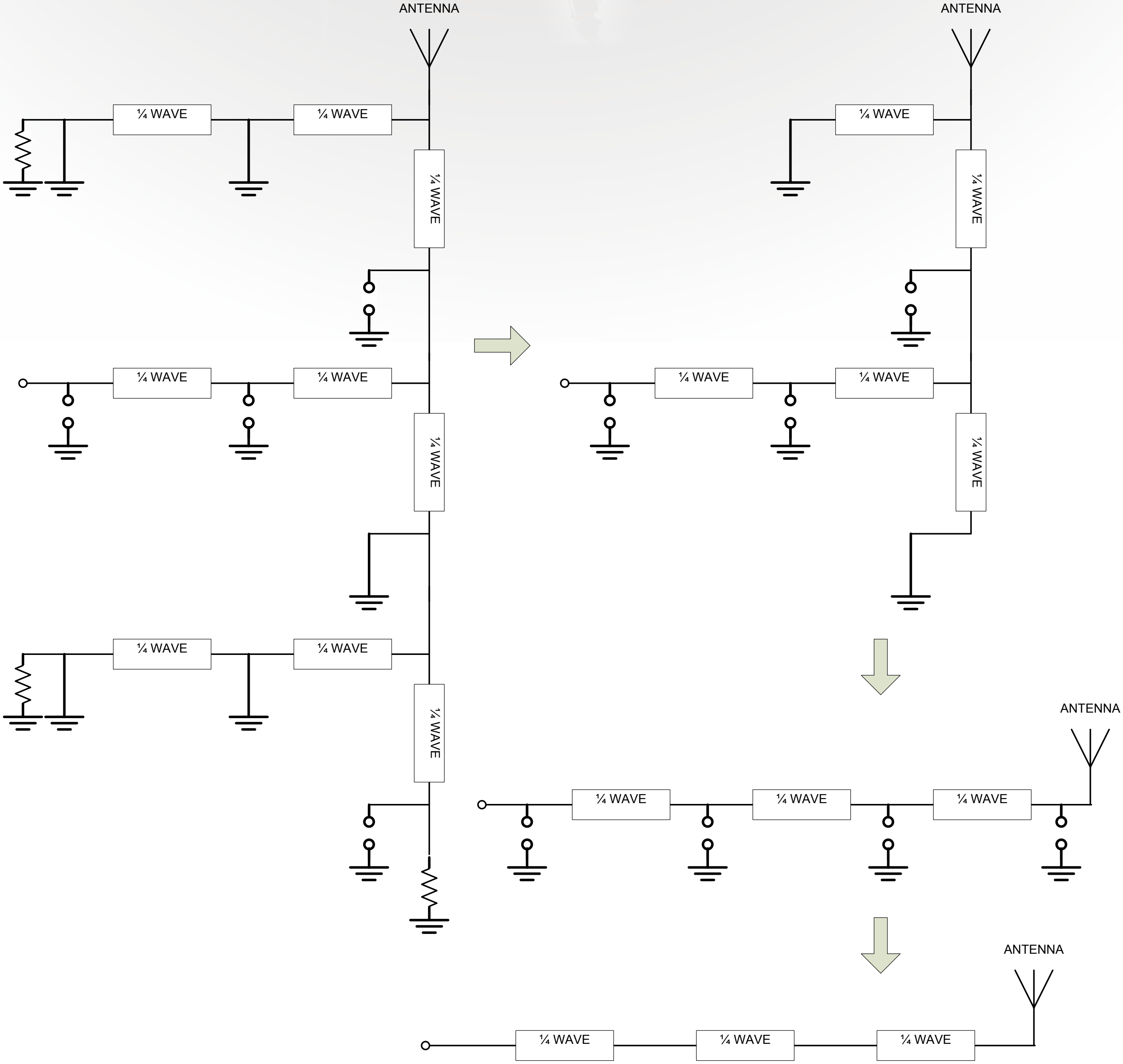
The approximate circuits for the module at resonance and off resonance are shown below:



On the next page, we see the equivalent circuit for a combiner made up of three C-series. The center channel is at resonance and the other ones are off resonance. The port near the notch cavity in the last module in the chain is terminated in 50 ohms. Again we see how the rules allow us to reduce the circuit to a length of transmission line going straight to the antenna.

A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

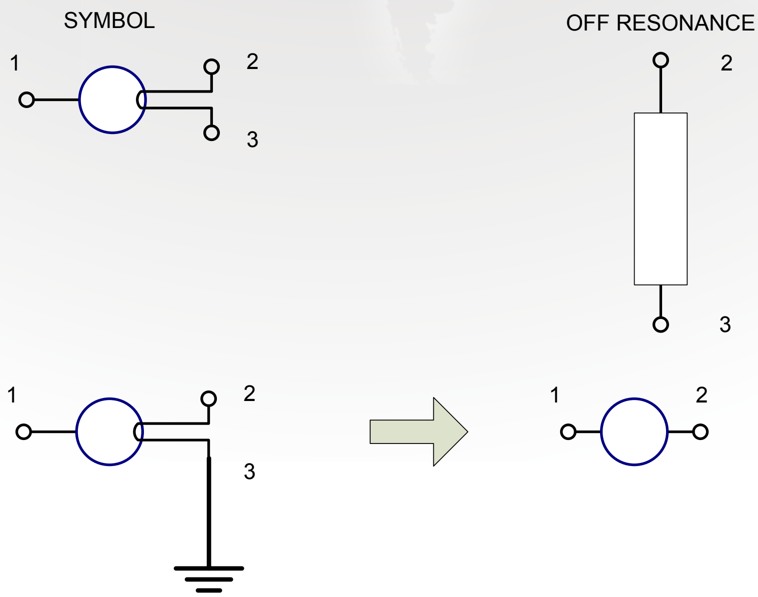
C-series are typically used when there is a mix of transmit and receive frequencies in the system. The extra pass cavities provide additional protection for the receivers. It should be noted that in the analysis of the C-series the length of the transmission line joining the individual modules was not mentioned. The length of this line does not affect the system's performance. This means that modules can be added or removed and frequencies can be changed without having to use specific lengths of cable. The main drawback for the C-series is the notch cavity which increases the size of the system and limits the closeness of the frequencies in the chain.



A GUIDE TO BASIC TYPES OF CAVITY COMBINERS

Pass Thru Combiner

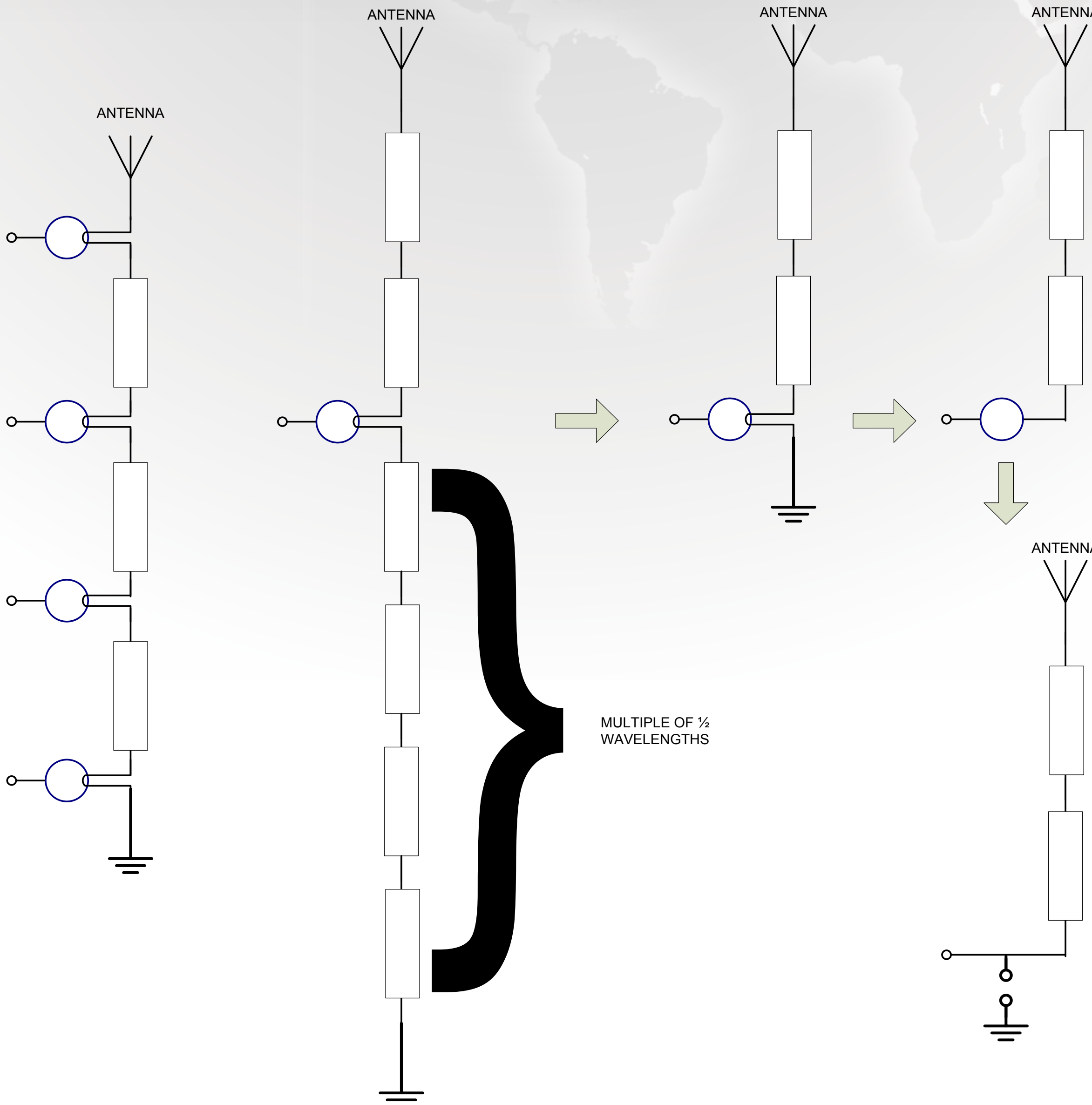
This type of combiner uses a specialized three port cavity with some interesting behaviors. If the third port is terminated in a short circuit then it acts as if it is a standard pass band cavity. When it is off resonance then port 1 becomes isolated from ports 2 and 3 and the path between ports 2 and 3 acts like a short piece of transmission line.



On the next page, the diagram is of a 4-channel pass thru combiner with one cavity at resonance. The electrical lengths of the lines between the short and the resonant cavity need to add up to a multiple of ½ of a wavelength. This effectively connects the short to the third port of the cavity, causing it to behave like a pass cavity. The circuit then becomes a resonant pass band cavity connected to the antenna through a length of transmission line.

Pass thru cavities perform a similar role to the C-series. The lack of a notch cavity between channels allows for much closer frequency spacing than the C-series. The main drawback for the pass thru is the transmission lines joining the different channels. These lengths not only depend on the frequency of the specific channel, but also on the frequencies of all the other channels between it and the short at the end of the chain. This means that it would be difficult to implement any future changes to the frequency plan.

A GUIDE TO BASIC TYPES OF CAVITY COMBINERS



Alternative Pass Thru

A pass thru like performance can be achieved using standard pass cavities. A ¼ wave transmission line is added to the standard cavity along with a tee junction. These tee connectors are then joined together with ½ wave transmission lines. A three-channel combiner is shown on the next page. As the ½ wave lines act as if they were not there, the circuit behaves just like the star junction combiner discussed previously.

This alternative structure is less sensitive to the lengths of the cables joining the individual channels so it provides more flexibility than the standard pass thru with respect to future changes. The internal structure of the cavity acts as the ¼ wave transmission line in the circuit when the frequency is high enough. For VHF frequencies and external cable would need to be added making the standard pass thru more practical in this frequency range.

United States
1 800 236 3275
salesusa@sinctech.com

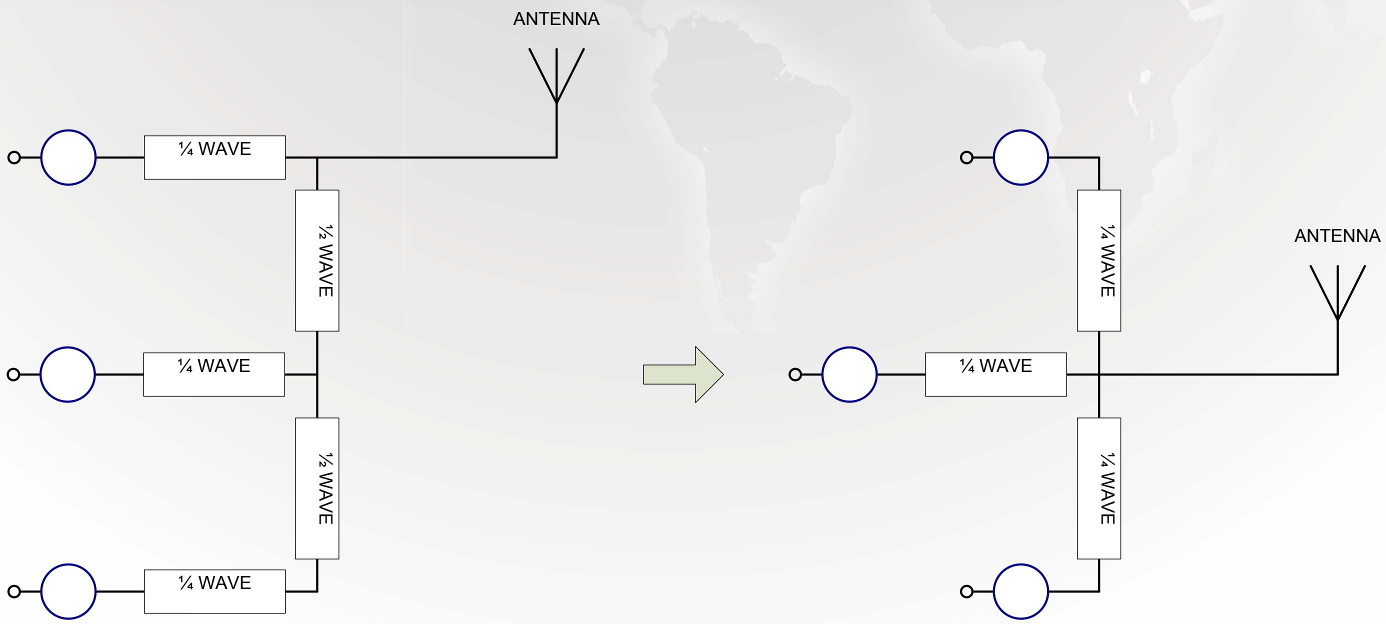
Canada
1 800 236 3275
salescan@sinctech.com

Asia Pacific
+1 905 726 7687
salesasia@sinctech.com

EMEA
+44 1487 842819
salesuk@sinctech.com

Latin America
+1 905 726 7676
salesla@sinctech.com

A GUIDE TO BASIC TYPES OF CAVITY COMBINERS



Final Thoughts

Throughout this paper, cavities have been treated as being either perfect open or short circuits, and transmission lines as being either ½ or ¼ wavelengths long. A cavity will never be able to achieve this ideal. It will always have a finite resistance and also it will have an inductive or capacitive component when it is off resonance. The transmission lines can also only be exactly ½ or ¼ wavelengths at specific frequencies which means that in many cases a compromise length is used. The consequence of this is that real world combiners will have finite losses and may require additional matching circuitry such as stubs. A portion of the signal can also feed back into the paths leading to the other radios, creating additional losses. This is why isolators or sometimes extra cavities, are added to increase the isolation between channels. Another important consideration is how far a frequency has to be away from the resonance of the cavity before the off resonance approximation is valid. This is the main consideration for determining the minimum frequency spacing between channels in a cavity combiner and is also the reason why the combiner performance improves as the channel spacing gets wider.

Even with the simplifications and approximations used, this paper provided a basic summary of how a cavity combiner creates a path for multiple signals to reach a single antenna with a minimum of interference between them.

For more information on cavity combiners, please refer to our website, www.sinctech.com.